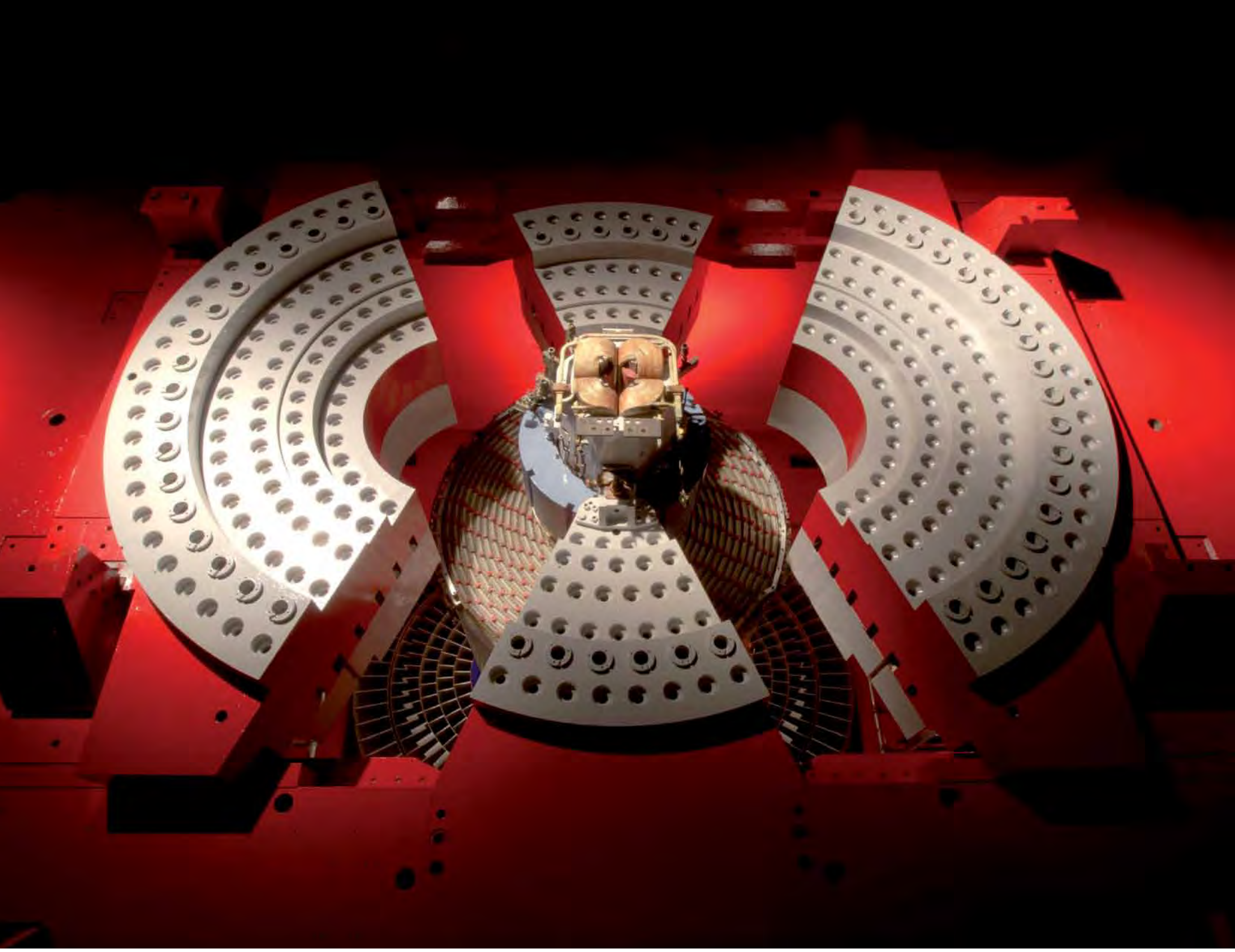


PARTICLE PHYSICS 2011.

Highlights and Annual Report

Accelerators | Photon Science | Particle Physics

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

Cover

The particle physics detector ARGUS (Photo: DESY)

PARTICLE PHYSICS 2011.

Highlights and Annual Report

Contents.

The year 2011 at DESY.

Chairman's foreword

The year 2011 has seen much progress at DESY in all relevant scientific fields. The present annual report highlights the remarkable achievements in particle and astroparticle physics throughout 2011. These achievements clearly demonstrate that DESY is a premium partner in international collaborations, and will continue to be so in the future. Our involvement in the two major LHC experiments, ATLAS and CMS, has begun to pay off with the harvesting of stunning physics results. We are now eagerly awaiting future data and exciting results on Higgs and supersymmetry searches. Our strong commitment to the LHC and to future detector upgrades is an important element of the DESY strategy.

As an integral part of our mission, DESY in Zeuthen has a strong astroparticle physics profile and gained international reputation in this field. IceCube, the world's largest particle detector, which fills a cubic kilometre of deep Antarctic ice, and the Cherenkov Telescope Array (CTA), which is currently in the preparatory phase, will allow us to retrieve information about distant galaxies from neutrinos and high-energy gamma rays. With Christian Stegmann, we attracted an international renowned astroparticle physics expert as the successor to Ulrich Gensch. Stegmann will further strengthen astroparticle physics in Zeuthen and expand DESY as a national centre in this field of research.

At its core, DESY is an accelerator laboratory. It is very gratifying to see how the smooth operation of our accelerator facilities DORIS III, PETRA III and FLASH is pushing DESY at the international forefront of photon science to become the world-best laboratory in this field. DESY's scientific output is impressive and openly acknowledged by our colleagues in the USA and Japan.

The construction of the European XFEL X-ray laser has made enormous progress. The 2.1-km-long accelerator tunnel was successfully completed in August 2011. All necessary preparations are currently being made to allow installation of the technical infrastructure to begin in May 2012. Around this time, we also expect the first production and testing of the 100 superconducting accelerator modules, the core elements of the linear accelerator, which were originally developed for the TESLA linear collider project. Moreover, FLASH II and the PETRA III extensions are already under construction and will soon offer additional and novel possibilities for research with superbrilliant X-ray light. To fully explore the potential of the superconducting technology for free-electron laser science, DESY must engage in the development of continuous-wave operation. This will take up a substantial part of our accelerator resources.

On a regional and national level, we have launched the Partnership for Innovation, Education and Research (PIER) together with the University of Hamburg. Four research fields (particle and astroparticle physics, photon science, nano-


Work on superconducting cavities in the clean room

At the symposium "Solar Energy for Science", from left: Prof. Gretchen Kalonji (UNESCO), Prof. Klaus Töpfer (Executive Director IASS), Dr. Gerhard Knies (DESERTEC Foundation), Prof. Khaled Toukan (Minister for Energy and Mineral Resources, Jordan), Prof. Maget Al-Sherbiny (President of ASRT), Prof. Robert Pitz-Paal (DLR) and Prof. Helmut Dosch (DESY).

sciences and structural biology) have been defined, enabling us to join forces in fostering common research projects and promoting young students through a joint graduate school.

Under the guidance of DESY, three novel Helmholtz R&D areas were identified and successfully implemented in the research field “Structure of Matter”:

- Accelerator Research and Development (ARD), an initiative that bundles the accelerator competences of the Helmholtz centres and integrates the accelerator activities carried out at the universities,
- a detector technology and systems platform, which strives for a new and enhanced collaboration across disciplines to develop better detection systems for current and future challenges, and
- the large-scale data management and analysis project, which is dealing with the rapidly increasing demand in handling large data sets harvested at ever shorter time scales.

Joining all forces within the Helmholtz centres – but also beyond the Helmholtz Association with the university groups – will strongly impact other disciplines, such as health and key technologies. The successful implementation and transformation of these portfolio topics into dedicated research topics under the new Helmholtz main programme “Matter and Technologies” in the upcoming third Helmholtz framework funding period (2015–2019) has been of highest relevance for DESY.

A unique event that DESY hosted in May 2011 was the international symposium “Solar Energy for Science” under the auspices of UNESCO. International key authorities from science met with policy makers from Europe and the Middle East and North Africa (MENA) region to discuss a novel energy and science partnership which aims to stimulate scientific cooperation and promote renewable energies for a sustainable development around the Mediterranean basin. As a top-class international research laboratory, DESY was an ideal host and moderator for this event.

I warmly thank all our colleagues and collaborators at DESY for their impressive work in 2011. ●

Helmut Dosch
Chairman of the DESY Board of Directors

Particle physics at DESY.

Introduction

Computer farm for the National Analysis Facility (NAF) and the Tier-2 facility

The year 2011 marks a record year for the Large Hadron Collider (LHC) at CERN in Geneva. The accelerator crew increased the luminosity beyond even the most optimistic expectations, by a factor of approximately 100 compared to 2010. The collected luminosity provides the basis for a multitude of very interesting scientific results obtained and published by the collaborations. Narrowing down the allowed mass range of the Standard Model Higgs particle to a small window around 125 GeV, in which both the ATLAS and CMS experiment observe intriguing events, is just the most prominent example.

The DESY groups provided numerous important contributions to the LHC experiments. We participated both in the very successful operation of the detectors, which coped well with the tremendous increase in collision rates, and in the scientific harvest of the data. We are also strengthening our efforts to prepare improvements of the detectors, in particular in view of the LHC high-luminosity phase after 2020. These projects, which focus on the replacements of silicon tracking detectors in ATLAS and CMS, will become a major activity at DESY.

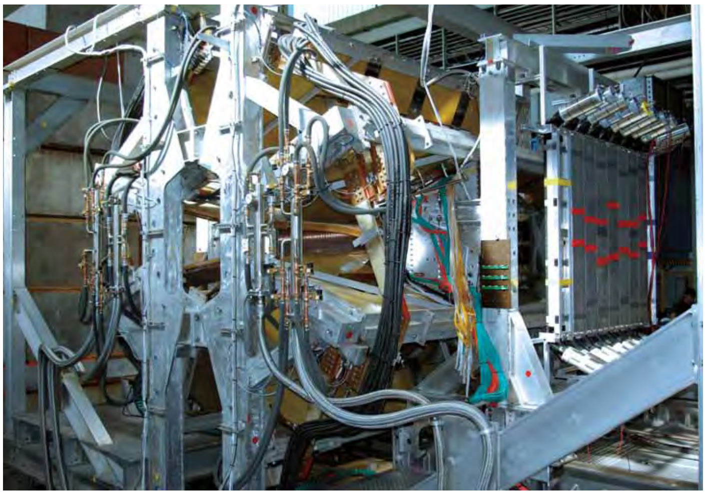
In our engagement for the LHC experiments, we closely collaborate with our international partners and in particular with German institutes, effectively fostering the role of DESY as the German centre for particle physics. DESY itself contributes with its infrastructure, such as the Tier-2 centre and the National Analysis Facility (NAF), to the common scientific effort. The Helmholtz Alliance “Physics at the Terascale” continues to be an important anchor in coordinating particle physics in Germany. It remains a challenge, however, to arrange that the services and the role of the Alliance be continued beyond the end of dedicated funding for the Alliance at the end of 2012.

The HERA collaborations continue to finalize and publish their data analyses at a high rate. The relevance of these experimental results on the structure of the proton is more and more appreciated as input for LHC analyses.

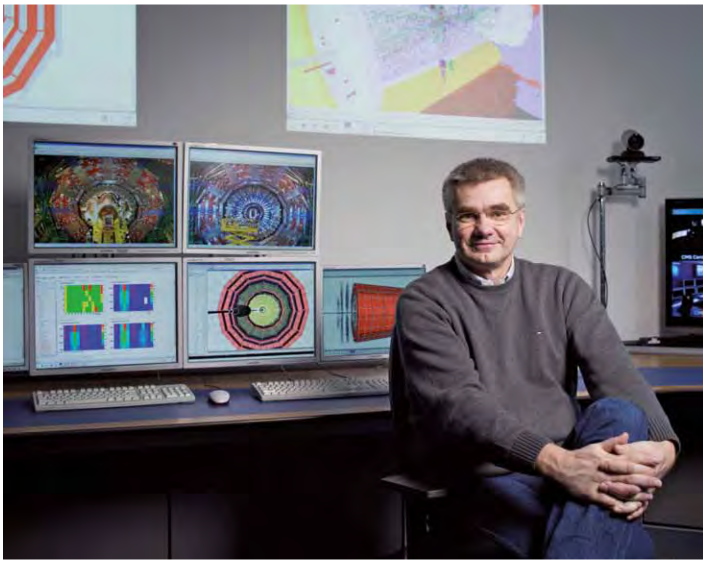
2011 was a crucial year in the preparation of the OLYMPUS experiment at DORIS III, whose goal is to precisely measure electron– and positron–proton scattering at low energies in order to resolve an experimental puzzle in the elastic form factors of the proton. Accelerator and detector were successfully modified and set up so that everything is prepared for the dedicated data-taking runs scheduled in 2012 before DORIS III will be shut down.

The technical design reports (TDRs) for the International Linear Collider (ILC), both for the accelerator and for the experiments, are due to be published in 2012. Work on these reports is in full swing, and significant progress on many key items has been made in a truly worldwide collaborative effort. DESY contributed significantly in many areas, for example through work to establish the required yield of high-gradient cavities, which profits from the mass production for the European XFEL, and by performing experiments at FLASH with operating parameters close to those of the ILC. We continue to play an important role in the preparation of the experimental programme at such a collider. We are very pleased to learn about efforts in Japan to host the ILC, which include the political level and are suited to create an extra stimulus for this project in the near future, when the TDRs and possibly interesting results from the LHC will be available.

We also played a central part in a Helmholtz-wide effort to strengthen the role of detector science. Particle physics at DESY, with its long tradition of cutting-edge detector development, is an important element of this strategy. We contribute to these efforts through concrete projects, such as the upgrades of the LHC experiments, but also through long-range research as exemplified by the DESY contributions to the development of experimental techniques for a future linear collider. In close cooperation with the detector development effort in photon science, we have made good progress in enhancing our capabilities and improving our infrastructure for this important topic.



The OLYMPUS experiment



DESY has extended its long-standing collaboration with Japan in particle physics by joining the Belle II experiment at the planned Super B factory at KEK. As part of a German consortium consisting of nine universities and other institutes, we are contributing to the design and construction of the vertex detector using a technology that is a spin-off from the ILC detector R&D.

In astroparticle physics, we made progress in the data analyses of the IceCube detector and the preparation for the Cherenkov Telescope Array (CTA). With Christian Stegmann, who became the new head of DESY in Zeuthen in October 2011, we have a renowned expert in high-energy gamma-ray astronomy who will push forward the DESY involvement in the planned CTA experiment. With the support of the Helmholtz Association, a new Alliance for Astroparticle Physics was founded in Germany with strong DESY participation.

With this brochure, we look back at a very interesting and eventful year in particle and astroparticle physics at DESY. The outlook for 2012 is no less promising, and results will be timely to support an in-depth discussion of the European Strategy for Particle Physics, which is planned to take place during the year. DESY is well positioned to assume an important role in the new European particle physics landscape.

Joachim Mnich

Joachim Mnich
Director in charge of High-Energy Physics
and Astroparticle Physics

Helmholtz Alliance.

Physics at the Terascale

The Helmholtz Alliance "Physics at the Terascale" is coming close to the end of its first five-year funding cycle. Over the last four years, it has become an important element in the particle physics community in Germany. The scientific reasons for the existence of the Alliance are as valid as ever: the physics at the terascale can only be explored in collaboration and by joining forces. In this respect, the Terascale Alliance has become an example that is recognized worldwide for its efficiency and effectiveness for the German particle physics community.

2011 was the first year in which significant amounts of data from the LHC were available. At the yearly meeting of the Alliance in Bonn, which took place in December 2011, the excitement in the community was very tangible. Though no final results were available, talk about the Higgs boson and possible first discoveries was ever present. The broad participation and contributions by high-profile speakers illustrate that the main aim of the Alliance – to bring the community together with the common goal of doing physics at the terascale – has been met. A multitude of results were shown and discussed, many of which with strong involvement of Alliance members. The investment in cross-experiment projects starts to pay off, with a very visible role played, for example, by the working group on the interpretation of LHC data. Tools developed in this group allow the interpretation of LHC data in view of physics within and beyond the Standard Model.

The Helmholtz Alliance was formed in 2007 to support the German high-energy physics community beyond the actual involvement in specific experiments. It brings together physicists from DESY, KIT, MPI Munich and 18 German universities. It provides a platform for collaboration and common infrastructures to all partners. The training of young physicists is an essential component of the Alliance.

The Alliance brings a new quality of cooperation to the German high-energy physics community. It was designed to make German particle physics even more visible internationally and to optimize the impact German contributions have in major international projects. The Alliance has also enabled a new level of cooperation between the German universities and the Helmholtz research centres. The funding during the first five years allowed the partners to hire strategically placed

Participants at the 5th annual workshop of the Helmholtz Alliance in Bonn, Germany, on 7–9 December 2011 experts, bring missing expertise to Germany and invest in infrastructure and common activities, which are open to all partners.

The activities of the Alliance, in particular in the area of detector and accelerator development, were important elements to start new initiatives within the Helmholtz Association. Both initiatives are complementary to the structures of the Alliance and bring the idea of the Alliance – a common and community-wide coordinated programme – into the Helmholtz Association. Strong relationships between the Alliance activities and the new Helmholtz initiatives are being established.

The Alliance is organized in four working areas: analysis, computing, detectors and accelerators. Over the first years of the Alliance, the large infrastructure projects in the detector area have been installed and are now available to all partner institutions. The accelerator project bundles the involvement of the German groups in the preparations for the next big project in particle physics, a linear electron–positron collider. In addition, it has established a new group working on novel accelerator technologies, namely plasma accelerators.

The analysis project was clearly dominated by the high number of publications of the LHC experiments. Many studies are ongoing to combine the results from different experiments and interpret the data in the context of different theoretical models. The Alliance was also very active in the preparations for projects beyond the LHC, in particular a linear collider. Progress has also been made in profiting from the legacy of HERA and optimizing the input from HERA on the LHC. One major challenge has been to provide adequate computing resources to the German LHC community. The Alliance was central to the establishment of a distributed system of Tier-2 centres in Germany with a significant and very important participation of the universities. In addition, the physics analysis is supported by the National Analysis Facility (NAF) at DESY.

Education plays a big role in all of the research areas of the Alliance. In 2011, the Alliance organized 20 schools and workshops with over 1000 participants. The schools and workshops allow young researchers to gain experience in different areas (e.g. simulation and data analysis tools, statistics), learn about accelerator and detector techniques and exchange ideas with colleagues from other institutions.

The Alliance triggered a process by which the community as a whole agreed on the areas to support, where to invest and where to place resources. The Alliance thus gave a strong boost towards a common German particle physics infrastructure and a closely cooperating, united community.

One of the big successes of the Alliance is that a significant part of these activities – and many of the people – will remain available after the end of the current funding period. In 2011, the Helmholtz Association decided to provide additional funding for the years 2013 and 2014. The Alliance will use these funds to start a process to re-orient its activities and align them with the challenges ahead, namely the analysis of the LHC data and the preparation for the future of particle physics.

Contact:

Ties Behnke, ties.behnke@desy.de
Klaus Desch, klaus.desch@desy.de
Christian Zeitnitz, christian.zeitnitz@desy.de

Reference:

http://www.terascale.de/

News and events.

News and events.

A busy year 2011

January

Gay-Lussac Humboldt Prize for Volker Schomerus

Professor Volker Schomerus, head of the DESY theory department, was awarded the Gay-Lussac Humboldt Prize. The French research minister Valérie Pécresse announced the nomination on 22 January in Paris on the occasion of the anniversary of the Franco–German Elysée Treaty.

Volker Schomerus, who received the prize together with four German and four French academics, works mainly in the field of string theory. The CEA institute in Saclay nominated the 45-year-old physicist for the award, which is worth 25 000 euro, to highlight his commitment in Franco–German collaboration on so-called scale-invariant sigma models.

Professor
Volker Schomerus

February

LHCPhenoNet

The kick-off meeting for LHCPhenoNet, a new EU network that aims to strengthen the theoretical research field at the LHC, took place in February 2011 in Valencia. This network, which is funded by the EU with 4.5 million euro, comprises groups from 28 European universities and research institutes, the University of Buenos Aires, CERN and three industrial partners. The network's research goal is to improve and enhance theoretical predictions, which are of considerable importance to experiments at the LHC.

Within the funding framework, new research and training possibilities dedicated to particle theory are being developed for young physicists from all over Europe. In Germany, DESY, the Max Planck Institute for Physics in Munich, the Humboldt University in Berlin, the University of Wuppertal and the Karlsruhe Institute of Technology (KIT) are participating in the network.

PIER sets sails

Since its foundation more than 50 years ago, DESY has been collaborating closely with the University of Hamburg. This cooperation was now put on a new basis: on 8 February, the Partnership for Innovation, Education and Research (PIER) was launched in the Hamburg city hall with the signing of a formal agreement by University president Dieter Lenzen and DESY director Helmut Dosch in the presence of Hamburg's science senator Herlind Gundelach.

PIER will become a point of crystallization for excellent research in Northern Germany, where it will serve to intensify cooperation in four research fields: particle and astroparticle physics, the nanosciences, photon science, and infection and structural biology. A PIER office on the DESY campus in Hamburg-Bahrenfeld will coordinate the collaboration in several fields of action.

From left: Prof. Helmut Dosch, Dr. Herlind Gundelach, Prof. Dieter Lenzen

March

German Physical Society awarded dissertation prize

The German Physical Society's (DPG) divisions of gravitation and theory of relativity, hadronic and nuclear physics, and particle physics awarded the 2011 dissertation prize to Dr. Sebastian Klein. The prize was awarded for his PhD thesis on the calculation of three-loop quantum chromodynamics corrections for massive quark production in deep-inelastic scattering.

The thesis includes substantial contributions to the understanding of the proton's quark and gluon substructure, which are important for the analysis of precision measurements in deep-inelastic scattering by several experiments around the world and which will also be important for interpreting the data of experiments at the Large Hadron Collider (LHC) at CERN.

Sebastian Klein carried out his research activities at DESY. During his time as a PhD student, he was supported with grants from the German National Academic Foundation and DESY.

Centre: Dr. Sebastion Klein

April

New video: “Into the Microcosm”

DESY unveils a new video which, in twelve minutes, summarizes the research centre’s activities in particle and astroparticle physics.

Watch the new video on the DESY website in English at:
http://www.desy.de/about_desy/desy_videos/particle_and_astroparticle_physics/index_eng.html

or in German at:
http://www.desy.de/ueber_desy/desy_im_film/teilchen__und_astroteilchenphysik/index_ger.html

Physics Olympiad at DESY

The German national finals for the 42nd International Physics Olympiad took place at DESY from 26 to 29 April. Germany’s 15 best junior physicists put their skills to the test in two written exams and in practical tasks. The crowning final was the presentation ceremony on 1 May. In July, the five winners packed their bags and left for Thailand, where the German delegation of five students accompanied by their team leaders competed for Olympic medals with participants from all over the world.

The International Physics Olympiad advances the interests and knowledge in physics of particularly talented high-school students and, at an early stage, offers them the possibility to establish professional contacts on the national and international level.

May

Humboldt Research Award for Richard Milner

Professor Richard Gerard Milner from the Massachusetts Institute of Technology (MIT) was honoured with a Humboldt Research Award, granted by the Alexander von Humboldt Foundation. The award, valued at 60 000 euro, offers him the opportunity to stay at DESY during the preparations and data taking of the OLYMPUS experiment at the DORIS III accelerator.

Milner is currently the director of the Laboratory for Nuclear Science at MIT as well as the initiator and spokesman of the OLYMPUS collaboration. OLYMPUS is designed to determine the so-called proton form factors with high precision. For this purpose, MIT’s BLAST detector was brought to Hamburg and modified to cope with the collisions, in rapid alternation, of electrons and positrons from the DORIS III accelerator with protons from a hydrogen gas target.

Earlier in his career, DESY was also important: Milner is considered to be one of the fathers of the HERMES experiment, whose principle activity is the investigation of the spin structure of the nucleon.

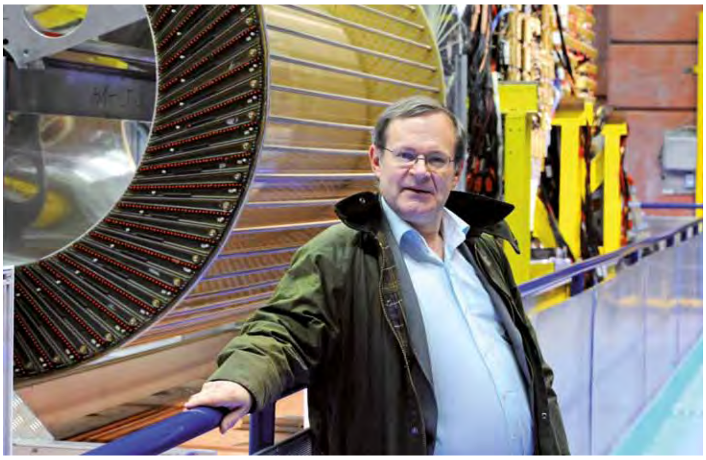
Professor Richard Milner

New Humboldt professor Brian Foster takes office at DESY

On 12 May, Brian Foster was awarded the Alexander von Humboldt professorship. Foster was thereby invited to DESY to do research on the future of particle acceleration and, as a professor, to lecture at the University of Hamburg.

In June, Foster took up his work at DESY and the University of Hamburg as a joint professor for experimental physics with a focus on accelerators for very high energies. He is one of eight professors to have won a Humboldt professorship in 2011. The Humboldt professorship is the most outstanding research prize programme in Germany and is endowed with 5 million euro for five years.

Foster will engage in several research fields, covering the present, the future and perhaps the science fiction of accelerator physics. The most concrete project is the analysis of data on deep-inelastic scattering processes at DESY's HERA accelerator. Also well-defined is a programme whose main goal is the optimization of the accelerating gradient of cavities for the International Linear Collider (ILC), a programme which explores several promising directions such as surface treatment and thin films. Foster's third field sounds a little more like science fiction: the use of wakefields in a plasma to accelerate particles. Foster and his colleagues plan to investigate the feasibility of further accelerating the electron beam of the FLASH free-electron laser with wakefield techniques while maintaining its usability for physics measurements.



Professor Brian Foster in the HERA hall

CMS tracker alignment workshop at DESY

On 30–31 May, the CMS tracker alignment group convened for a workshop at DESY in Hamburg. The agenda focused on the review and refinement of the alignment strategy of CMS's silicon detector, the largest silicon detector ever built, for the 2011 LHC run. Items discussed include the subtle effects of curvatures in the almost 17 000 silicon modules and their treatment with the Millepede-II algorithm, as well as the control of systematic effects by including cosmic muons and Z boson decays.

For attendants from many European and non-European countries, it was a rare but welcome opportunity to meet with colleagues in person, since the majority of the regular alignment group meetings are video conferences.

Participants of the CMS tracker alignment workshop at DESY

June

All aboard the long bunch train

Learning to stabilize a particle beam with long pulses such as those needed for the ILC requires diligence, patience and practice. ILC and FLASH scientists shared the fruits of all three at a workshop on long bunch trains held at DESY from 6 to 8 June.

At the "Workshop on linac operation with long bunch trains", researchers reviewed their progress in the quest to make high-quality particle beams. The workshop, the second in a series, covered beam studies performed for the ILC and FLASH. It also afforded collaborators a chance to examine the issues involved in making stable beams composed of roughly millisecond-long pulses (the "long" in "long bunch trains").

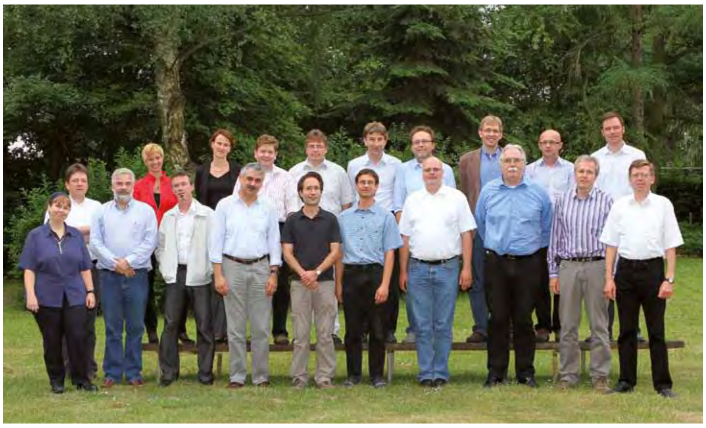
Participants of the "Workshop on linac operation with long bunch trains"

Many topics were covered, including the results of beam tests performed in February, a detailed look at how cavities might be tuned for smooth timing and acceleration of the beam, methods to mitigate cavity quenching under the burden of high power and ways to modify quality factors of cavities in order to achieve the highest possible gradients. Workshop participants included scientists from KEK in Japan, Rutherford Appleton Laboratory in the UK, Argonne National Laboratory and Fermilab in the USA and DESY. ILC Global Design Effort project managers were also in attendance.

Kick-off meeting of the Helmholtz Accelerator Initiative

Modern accelerator facilities embody a decisive future technology which is vital for a successful attack on many of the major challenges of our time, particularly in the fields of energy, medicine and information. Today and in the future, the development of cutting-edge accelerators is a driving force for the development of new high-technology fields. Accordingly, the Helmholtz Initiative for Accelerator Research & Development (ARD) was established with the goal of creating a close collaboration of universities, national and international partners to strengthen future-oriented R&D into accelerator physics and technology, and thereby ensure competitiveness in the international arena. The purview of the Helmholtz ARD programme includes superconducting technologies, new concepts for particle sources and ring accelerators, femtosecond electron and laser beams, and plasma acceleration with very high gradients.

The ARD kick-off meeting took place at DESY on 7 June with representatives of the six participating Helmholtz centres.



Participants of the Helmholtz ARD initiative kick-off meeting at DESY

Royal visit to DESY

On her two-day stay in Hamburg, Princess Maha Chakri Sirindhorn from Thailand took the opportunity to visit DESY. Her Royal Highness was welcomed by Helmut Dosch, chairman of the DESY Board of Directors.

Helmut Dosch offers the model of a superconducting cavity to Princess Maha Chakri Sirindhorn.

Princess Sirindhorn is very interested in science and technology, and DESY is well known to her. At her last visit to the research centre nine years ago, an agreement was made on Thailand's participation in the DESY summer student programme. Since that time, 15 Thai summer students have taken part in the two-month training programme, with excellent results.

July

Helmholtz Alliance for Astroparticle Physics

On 1 July, the Senate of the Helmholtz Association gave its approval for the new Helmholtz Alliance for Astroparticle Physics (HAP). In this alliance, scientists from KIT and DESY are joining forces with working groups from 15 German universities, three Max Planck Institutes, APC Paris and KICP Chicago. The five-year funding period started on 1 July 2011; the funds amount to 10 million euro.

German astroparticle physics has an internationally outstanding position in many areas, with the Helmholtz centres being active in the fields of cosmic radiation, neutrino astronomy, gamma astronomy, the search for dark matter and the determination of neutrino mass. At first, HAP will focus on the evaluation of the results obtained from the current flagship facilities IceCube, Auger, H.E.S.S. and MAGIC. Parallel to this, the facilities will be further developed, innovative methods will be tested, and new facilities like CTA will be planned.

Summer students 2011

DESY's summer student programme is an opportunity for young students to experience life and work at a large accelerator laboratory. During their stay at DESY in Hamburg or Zeuthen, the students become involved in the daily work of the research groups. Lectures in research fields such as accelerators, particle physics in experiment and theory, photon science or computing, together with visits of experimental facilities, help to prepare the physics students for their future lives as scientists.

In 2011, the eight-week programme attracted 99 students from 23 countries (Belgium, Canada, China, Colombia, France, Greece, Germany, Hungary, Ireland, Israel, Italy, Mexico, Netherlands, Oman, Poland, Romania, Russia, Slovakia, Spain, Thailand, Ukraine, UK, USA).

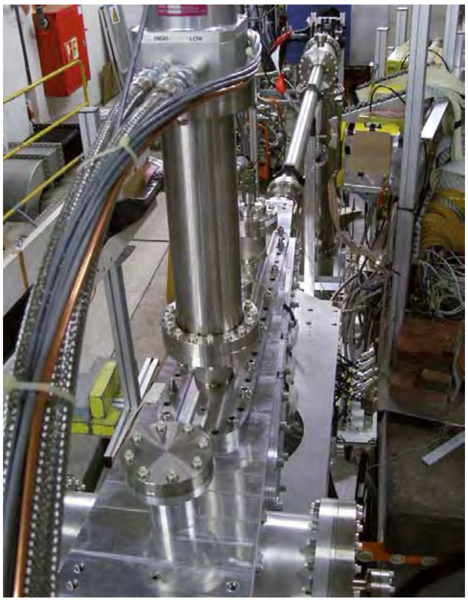
Summer students 2011

August

OLYMPUS in beam position

The summer break 2011 was a very busy time at the OLYMPUS experiment: the collaboration and a team of DESY technicians and engineers used the shutdown days of the DORIS III accelerator to bring the pre-assembled experiment into beam position for the first time and carry out extensive tests. As of recently, OLYMPUS is under new management, with spokesman Michael Kohl (Hampton University) and deputy Alexander Winnebeck (MIT).

Punctually, on 5 August, the complete experiment was ready for operation. OLYMPUS will deliver precise information on the nature of lepton–proton scattering and evidence on the proportion of the electric and magnetic charge distribution in the proton. The first beam test at DORIS III started with a beam energy of 2 GeV and, for the first time, the positrons collided with the new, extremely sensitive internal hydrogen target.



Assembly of the OLYMPUS experiment

Boring of European XFEL accelerator tunnel completed

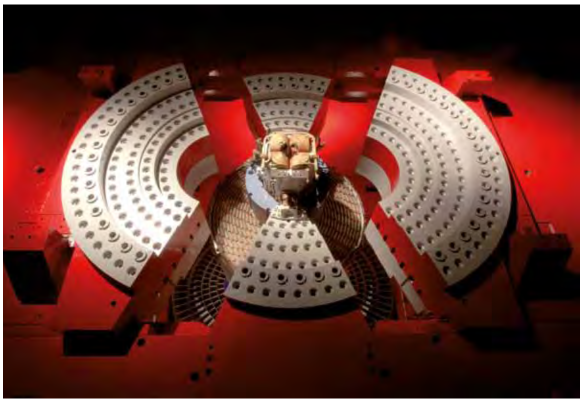
On 27 July, the European XFEL tunnel boring machine TULA (“tunnel for laser”) stood outside the wall of its reception shaft on the DESY-Bahrenfeld site. It then slowly drilled through the 1.50-metre-thick diaphragm wall of the construction pit and passed through the round “TULA window” in the adjoining wall. With a landing precision of one millimetre, TULA arrived in its travel-out panel on the western wall of the injector building.

A few days later, the tunnel builders installed the last concrete ring of the accelerator tunnel. On 6 August, the boring of the 2010-metre-long tunnel for the accelerator of the European XFEL X-ray laser was finally completed.

The cutterhead of TULA

ARGUS becomes outdoor exhibit

The ARGUS particle detector has started its third stage of life. Initially a detector at the DORIS storage ring, it opened up exceptional insights into particle physics and, among other things, was the first to verify the transformation of so-called B mesons into their antiparticles. Then, for many years, ARGUS was a visitors’ attraction in the DORIS hall. In 2010, it had to make way for the OLYMPUS experiment. A group of technicians and workshop staff have newly conserved the 500-tonne colossus and installed it as an outdoor exhibit near the DESY main gate. It will spend the next stage of its life there and tell DESY visitors about its discoveries.



The ARGUS detector

September

In memoriam: Gustav Weber

DESY mourns for its former research director, Professor Gustav Weber, who died on 2 September 2011 at the age of 85.

From 1973 until 1978, Weber was director of research at DESY. During this time, he shaped the research programme at the double storage ring DORIS and ensured the timely completion of the experiments at the electron–positron storage ring PETRA. He was a member of the JADE experiment, which made far-reaching contributions to our understanding of the Standard Model of particle physics. In the 1980s, Gustav Weber was the founding father of the international H1 collaboration at the electron–proton storage ring HERA. He gave priority to the integration of institutes from the former GDR and Eastern Europe, thus creating the basis for many years of successful scientific cooperation with Eastern Europe, from which DESY still benefits today.

With his great commitment, Gustav Weber achieved and induced a lot at DESY.

Dieter Haidt wins Enrico Fermi Prize

The Italian Physical Society awarded DESY physicist Dieter Haidt with the Enrico Fermi Prize 2011. Haidt and Antonino Pullia from the University of Milano shared the renowned research prize for their contributions to the discovery of weak neutral currents in the Gargamelle neutrino experiment at CERN. On 26 September, the Enrico Fermi Prize was awarded to both scientists at the annual meeting of the Italian Physical Society in L’Aquila.

Weak neutral currents, which were discovered in 1973 in the Gargamelle bubble chamber at CERN, provided important fundaments for today’s Standard Model of particle physics. Haidt’s calculations for the Gargamelle experiment proved that the observed events were not interactions between the long-known neutrons but a new kind of process.

Enrico Fermi Prize winner

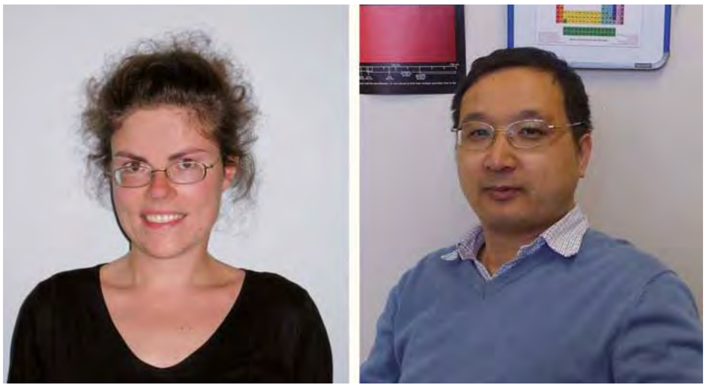
Dieter Haidt

Two new Helmholtz Young Investigators Groups at DESY

On 26 September, the Helmholtz Association announced its support for a new series of Young Investigators Groups. Again, DESY takes part in this programme with two young scientists.

Yvonne Peters will come to DESY from Fermilab to build up a working group aimed at the exploration of top-quark physics. This elementary particle has a surprisingly large mass and thus plays a special role in the search for physics beyond the Standard Model. As a member of the ATLAS collaboration, the group of Yvonne Peters will analyse data from the LHC detector to better determine the properties of the top quark and thereby explore new territory in the search for new physics. The working group of Gouqing (Noah) Chang will be active in the field of photon science. Their research goal is the development of optical technologies that allow for very compact extreme-ultraviolet and X-ray sources.

Both Young Investigators Groups are funded with 250 000 euro, half from the Helmholtz Association and the other half from DESY, for a period of five years.



Yvonne Peters and Noah Chung head the new Young Investigators Groups at DESY.

October

Christian Stegmann new head of DESY in Zeuthen

On 1 October, Professor Christian Stegmann took office as the new head of DESY in Zeuthen. Stegmann follows the nomination of both the University of Potsdam and DESY. Stegmann will take over the management of the Zeuthen institute from Hans-Jürgen Grabosch, who was the provisional manager after the retirement of the long-term Zeuthen head Ulrich Gensch.

Professor Christian Stegmann

Stegmann has already been associated with DESY for many years. He earned his diploma at the University of Bonn with his study of data from the ZEUS experiment in Hamburg. In 1995, after his doctorate at the University of Freiburg, Stegmann came to DESY in Zeuthen and carried out research with the HERA-B collaboration for five years. After this, he focused on earthbound astroparticle physics. He was professor at the University of Erlangen-Nürnberg and was engaged in the H.E.S.S. experiment (High Energy Spectroscopic System), a system of Cherenkov detectors in Namibia.

German–Japanese Workshop on modern trends in QCD

Intensive science and high-technology relationships between Germany and Japan have existed for decades. Indeed, Japanese scientists are working in several research projects at DESY. In October, a DFG-funded German–Japanese workshop on current research in the field of theoretical physics, “Modern Trends in Quantum Chromodynamics”, was held at DESY in Zeuthen with the goal of further intensifying the relations between research groups in the two countries in the field of strong interactions.

Honouring 150 years of diplomatic relations between Japan and Germany, Satoshi Odoi, First Embassy Secretary for science and technology, opened the conference.

Participants of the “Workshop on Modern Trends in Quantum Chromodynamics”

More than 13 000 visitors at DESY Open Day and Science Night

A science festival at DESY: until midnight on 29 October, thousands of curious people flocked to the DESY campus in Hamburg-Bahrenfeld. The DESY Open Day and Science Night census counted a total of 13 621 visitors. Thus, two out of three participants of the 4th Hamburg Science Night also came to DESY.

Visitors gained insights into the workings of DESY by visiting more than 60 attractions. They were fascinated by numerous highlights including the tunnel of Germany's largest accelerator, HERA, the the FLASH X-ray laser and the huge experimental hall of PETRA III.

The first visitors came even before the official opening at noon and the last ones arrived at a quarter to midnight.

It is not only the top-level research that interests many people, the DESY workshops and the school lab were also very popular among both young and old. About 850 helpers explained DESY to guests, distributed 21 600 gummi bear bags, 4400 balloons and 3000 apples with DESY logos. More than 1000 young scientists took a trip through the FLASH hall and won PIXI books – a special edition which describes DESY for young minds.

The enormous response to this wide range of attractions demonstrates the great interest of citizens in science and research. “I am especially pleased about the large number of children and young people who made use of this opportunity together with their parents,” said Hamburg's science senator Dorothee Stapelfeldt, who also visited DESY.

November

Award for outstanding PhD theses

Two outstanding PhD theses were honoured with the 2011 PhD thesis award of the Association of the Friends and Sponsors of DESY (VFFD). The prize was shared by Dr. Martin Beye and Dr. Roman Kogler. Martin Beye earned his doctoral degree at the free-electron laser FLASH, Roman Kogler in the H1 collaboration at HERA.

New X-ray lasers such as FLASH facilitate a completely new approach to the investigation of natural processes. The very intense and ultrashort X-ray pulses allow snapshots of the movement of electrons and atoms to be taken with exceptionally high time resolution. Among other things, Martin Beye experimentally observed a new liquid phase of silicon for the first time. His observation is a highly significant contribution to the understanding of the properties of liquids.

In his thesis, Roman Kogler presented precision measurements of 2-jet and 3-jet events at H1. A substantial part of Kogler's thesis deals with the development of a new and efficient method to evaluate particle jets. With his method, the precision of jet measurements can be significantly improved compared to previous analyses.

From left: Dr. Martin Beye, VFFD chairman Prof. Friedrich-Wilhelm Büßer, Prof. Helmut Dosch and Dr. Roman Kogler

New Helmholtz–Russia research group hunts for cosmic radiation

Using innovative technologies, a German–Russian research group is on the hunt in Siberia for high-energy cosmic gamma rays and cosmic rays – high-energy atomic nuclei from outer space whose origin, even a hundred years after their discovery, is still largely mysterious. The project is funded within the framework of the Helmholtz–Russia Joint Research Groups (HRJRG), with an annual sum of about 150 000 euro for a period of three years.

Entrance to the Tunka National Park (Courtesy: Tunka collaboration)

In the Tunka valley, not far from Lake Baikal, physicists are installing a test array of Cherenkov detectors to identify extremely high-energy (from 10 TeV up to PeV) cosmic gamma rays. Because gamma rays, unlike electrically charged atomic nuclei, are not deflected by cosmic magnetic fields on their way to Earth, this gamma radiation may reveal the sources of cosmic particle radiation. The planned detectors will record the Cherenkov light of fast secondary particles produced by cosmic particles and gamma radiation in the Earth's upper atmosphere.

Cooperating partners of the new group are the Institute for Nuclear Research of the Russian Academy of Sciences in Moscow, the Universities of Moscow (MSU), Irkutsk and Hamburg, the Karlsruhe Institute of Technology (KIT) and DESY. The location was chosen because it already runs another air shower Cherenkov detector array named Tunka-133. With its precise shower energy measurements, Tunka-133 provides a perfect basis for a test of new experimental technologies.

DESY engages in Belle II

On 18 November, the laying of the foundation stone for the SuperKEKB accelerator took place at the Japanese accelerator laboratory KEK in Tsukuba. Along with the associated particle detector, Belle II, this accelerator will become a so-called Super B factory. Seven German universities, the Max Planck Institute for Physics in Munich and DESY will join to build the pixel vertex detector for this ambitious experiment. The DEPFET technology, originally designed for the ILC, will be used for this purpose for the first time. On the occasion of the ceremony, an agreement with KEK on the participation of the German research institutes in the construction of Belle II and subsequent data taking and analysis was made.

“The Belle II engagement is a logical continuation of our detector development work for the ILC. Our participation in the construction of the pixel detector perfectly matches the corresponding DESY activities at the LHC experiments,” DESY research director Joachim Mnich declared. “With the current cooperation agreement, we continue the tradition of 40 years of very fruitful cooperation with Japanese particle physics institutes.”

SuperKEKB will produce a 40-fold increase in data rate over its predecessor KEKB.

A day devoted to the LHC

Two years of proton–proton collisions at the LHC – on this occasion, universities and research centres in 15 cities in Germany celebrated the “Weltmaschine Day”.

On 23 November, DESY presented two science slams, one in the Urania event hall in Berlin and the other in the DESY auditorium in Hamburg. At the science slams, scientists competed against each other with 10-minute talks, trying to persuade and, of course, to entertain the audience which, in the end, chooses the winning speaker. In Hamburg, the Science Café and the particle physics exhibition were also well attended.

Particle physics exhibition at the “Weltmaschine Day” on 23 November at DESY

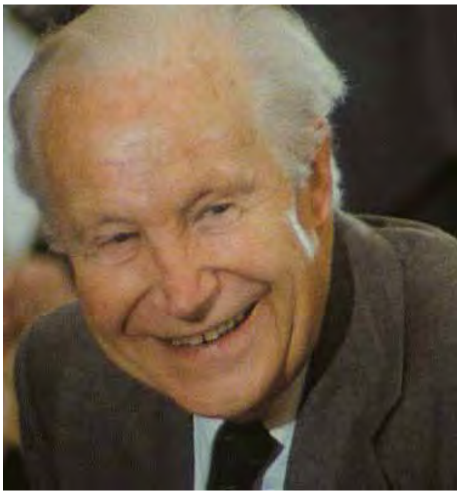
December

DESY recalls its founding father

The founding of DESY in 1959 was, above all, realized thanks to the vision, charisma, persistence and negotiating skills of this man: Prof. Dr. Dr. h.c. Willibald Jentschke. On 6 December 2011, the physicist whose appointment to the University of Hamburg brought about the research centre DESY, would have turned 100 years.

Jentschke was the founding father of DESY and chairman of the DESY Board of Directors from 1959 to 1970. Afterwards, as director-general of CERN, but also after his retirement and into old age, he was actively involved in particle physics and always very interested in “his” DESY developing into one of the world’s leading accelerator laboratories.

Willibald Jentschke passed away in 2002, only a few months after his 90th birthday.



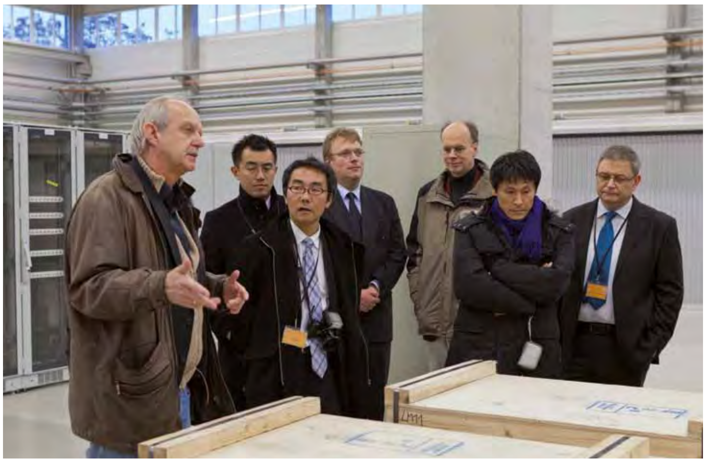
Professor
Willibald Jentschke

Japanese ILC delegation explores European labs

Two Japanese regions are possible candidates for the home of the next big accelerator, the International Linear Collider (ILC). A delegation from one of the regions, the prefectures Fukuoka and Saga on the Japanese island Kyushu, visited DESY and CERN to learn about existing research infrastructures and the labs' experiences with management, administration, local communication and a whole lot more.

Even though a site for the proposed next-generation particle accelerator will not be chosen before first results from CERN’s LHC determine the future of the field of particle physics, Japan is a strong contender for hosting the project. The delegation, consisting of four members of the Fukuoka/Saga ILC planning committee, wanted to establish a dialogue with the European labs to exchange ideas and information.

At DESY, they heard about DESY regional cooperation, socio-economic impacts, innovation and technology transfer, outreach with local communities and of course DESY and the ILC. They also visited the cavity preparation and testing facilities on campus, including the new accelerator module test hall for the European XFEL, as well as FLASH and PETRA III.



The Japanese ILC delegation at DESY

Humboldt Research Award for Vladimir Fateev

The Russian physicist Professor Vladimir Fateev was honoured with a Humboldt Research Award, granted by the Alexander von Humboldt Foundation. Professor Fateev is an internationally renowned mathematical physicist, with non-perturbative quantum field theory as his main research field. For years, he has enjoyed good contacts with the DESY theory group based on numerous joint research interests. The Humboldt Research Award is valued at 60 000 euro and offers Vladimir Fateev the possibility to stay at DESY for a period of up to one year.

Professor
Vladimir Fateev

New Emmy Noether research group at DESY

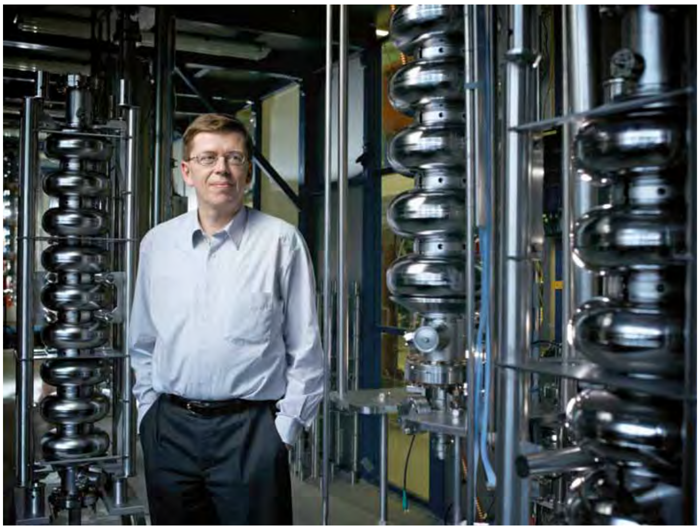
DESY theorist Frank Tackmann has been accepted to the Emmy Noether programme of Germany's research funding organization DFG. This programme allows outstanding young scientists to qualify for scientific leadership roles by managing their own junior research groups. Frank Tackmann's group is working on the topic of "Precision theory predictions for Higgs and new-physics measurements at the LHC". The research will be funded for five years with a total of 940 000 euro.

Higgs particles and other heavy particles produced in proton–proton collisions at the LHC are identified by their decay products, which typically produce a characteristic signature of collimated jets of particles in the detector. The precise experimental measurement of masses and couplings of the Higgs and new particles requires theoretical predictions for signal and background processes containing a specific number of such jets. The goal of the Emmy Noether group is the precise theoretical calculation of the required probabilities for such processes with the help of new field-theoretic methods and their combination with numerical simulations.

Reinhard Brinkmann confirmed in office

In its session on 14 December, the DESY Administrative Council appointed Reinhard Brinkmann for another five-year term as director of the accelerator division. His second term will begin on 1 July 2012.

Since 2007, Reinhard Brinkmann has been the director of the accelerator division, the largest of the three research sectors at DESY. He started working at DESY in 1984 and has always been directly involved in the developments of accelerator physics at DESY – as HERA machine coordinator, participating in the draft for the TESLA linear collider, or at the European XFEL project. In his second term, he will not only direct the extension of the comprehensive activities in the construction and operation of particle accelerators, but also see to the advancement of the accelerator research field.



Reinhard Brinkmann

Research topics.

HERA takes farewell walk at the energy frontier.

Searches for new physics in highest-energy ep collisions

The final results of the H1 and ZEUS collaborations on searches for the subtle effects that would arise from as yet undiscovered physical phenomena have recently been published. The publications describe the analysis of the complete data set of violent collisions of point-like electrons and positrons with quarks from protons, amassed in over 15 years of data taking at HERA. They are a testament to the unique abilities of an electron–proton collider to explore for unknown physics processes. With these publications, HERA passes the baton to the LHC for further searches.

ep scattering at large momentum transfer

By studying electron– or positron–proton (ep) collisions at unprecedented energies up to 319 GeV, the HERA experiments explored a unique phase space where the momentum transfer squared reached values as high as 30 000 GeV^2. The proton was thus probed with spatial resolutions down to 10^{-18} m. The high interaction energy was sufficient to create particles with high masses such as the top quark which, if observed, would have suggested new physics. The recent results described here show the final reach of HERA. They are the product of many years of improvements in data precision and analysis techniques.

Search for single top production in ep collisions

According to the Standard Model, top quarks are produced in ep collisions when a W boson is radiated from an incident electron and converts a bottom quark from the proton into a top quark. However, the predicted rate is too low to be detectable in the HERA data sample. An observation of top quarks would thus signal the existence of an anomalous production mechanism and point to new physics. One possible mechanism would result from a finite coupling between an up quark, a top quark and either a photon or a Z boson, in other words, a so-called flavour-changing neutral current (FCNC). The effect could also be interpreted in terms of the anomalous decay of a top quark into an up quark and a photon, or an up quark and a Z boson, as shown below.

A recent ZEUS publication reports on a search for top quarks produced in ep collisions. The top quark nearly always decays into a b quark and a W boson, which may subsequently decay into a lepton (an electron or muon) and a neutrino. This sequence would show up in the final state of the collision as an isolated lepton, an energetic jet and missing transverse energy. An excess of such events over the Standard Model prediction was previously observed by the H1 collaboration, but it nonetheless agreed, within measurement uncertainties, with a ZEUS analysis showing no excess. (These two measurements were subsequently combined to extract a measurement of W boson production at HERA.) Analysis of the full ZEUS data set still shows no signal. The resulting limits on the anomalous decay branching ratios are shown in Fig. 1. The excluded domain for the decay of a top quark into an up quark and a photon from the present analysis extends well beyond the previous limits from LEP, the Tevatron and the H1 collaboration. The H1 limit is weaker due to the excess of events mentioned above.

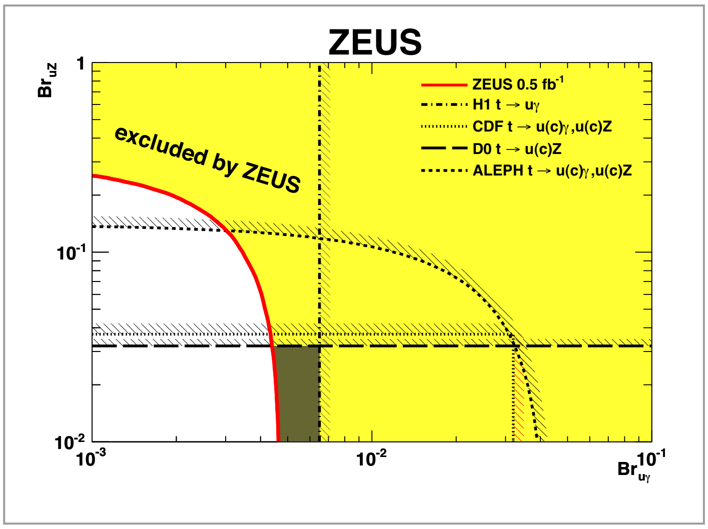


Figure 1

The exclusion domain shown in the plane of the two anomalous branching ratios of the top quark

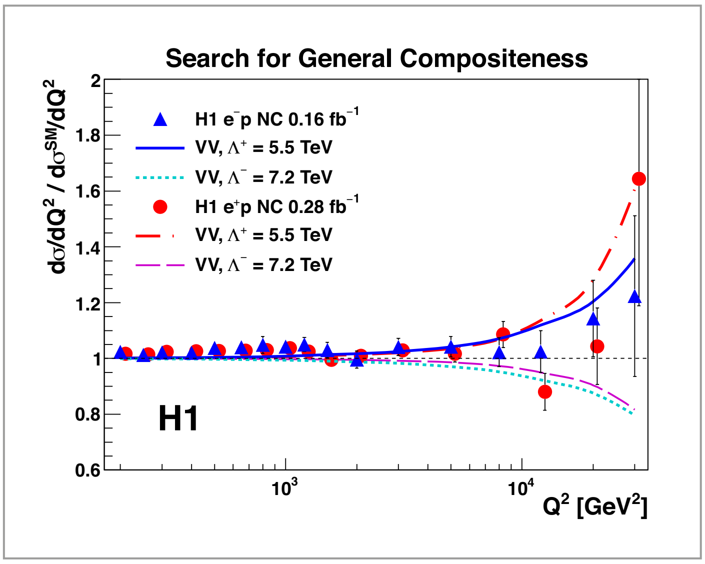


Figure 2

Ratio of the measured deep-inelastic cross section to the Standard Model prediction

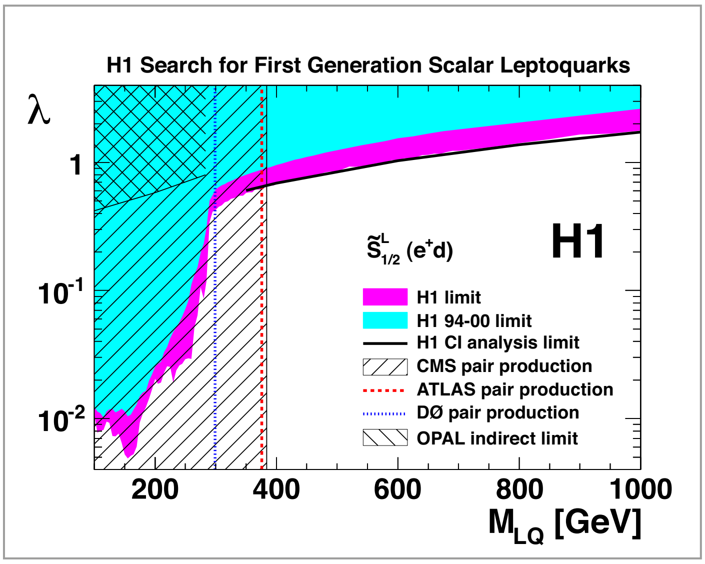


Figure 3

The exclusion domain in the plane of the leptoquark mass and the coupling λ. Recent result from the ATLAS and CMS experiments are also indicated.

Contact interactions and leptoquarks

One hundred years after Rutherford discovered the nucleus by bombarding composite atoms with “point-like” probes, the HERA experiments searched for quark compositeness by bombarding composite protons with point-like electrons and positrons. A deviation in the distribution of the scattered lepton at large scattering angles, or equivalently, large momentum transfer squared (Q^2) from the prediction of the Standard Model would indicate that the quark is composed of more fundamental particles. The effect of quark substructure on the Q^2 distribution is parameterized by the so-called compositeness scale Λ, which gives an indication of the Q^2 value at which deviations become apparent.

The full potential of HERA to probe the large Q^2 domain is demonstrated in a recent publication, based on the full data sample, by the H1 collaboration [2]. As illustrated in Fig. 2, the H1 data probes a compositeness scale of a few TeV (depending on the chiral structure of the compositeness model). As shown, the ratio of the observed deep-inelastic scattering cross section to the Standard Model prediction shows no significant deviation from expectations, in agreement with LEP and Tevatron measurements as well as previous observations from ZEUS. Pushing the lower limit on Λ to even higher values is now the job of the LHC experiments. Given the simplicity of the experimental setup, the data is sensitive to many models of compositeness, such as leptoquark exchanges and multidimensional interactions, and is able to constrain the quark radius to less than a few times 10^{-19} m.

The same deep-inelastic scattering final-state topology can be used to search for resonant production of new particles such as leptoquarks (LQs). Indeed, HERA was ideal for this purpose since the full electron–quark collision energy was available for s-channel leptoquark production. Many searches by H1 and ZEUS failed to find leptoquark signals and thereby established limits on the allowed range of the lepton–quark coupling (λ) and its mass (M_{LQ}). As illustrated in a recent publication by the H1 collaboration [3] (Fig. 3), leptoquark masses up to nearly the HERA kinematic limit are excluded for large values of the coupling λ. Thus, a new domain beyond the sensitivity of previous colliders and in the region where the coupling is important has been explored. The explored domain will soon be substantially extended by the LHC experiments.

As demonstrated by the results presented here, HERA, the world’s unique high-energy ep collider, enabled a measurement programme that complemented all other experimental programmes at the energy frontier. If new measurements at the LHC or elsewhere reveal unexpected physics, an interest for new analyses of HERA data for cross checks, confirmation or possibly as a means to further the understanding of the future experimental landscape may well emerge.

Contact:

Cristinel Diaconu, diaconu@cppm.in2p3.fr
Achim Geiser, achim.geiser@desy.de

References:

[1] H. Abramowicz et al. [ZEUS Collaboration], Phys. Lett. B708 (2012) 27-36
[2] F.D. Aaron et al. [H1 Collaboration], Phys. Lett. B705 (2011) 52-58
[3] F.D. Aaron et al. [H1 Collaboration], Phys. Lett. B704 (2011) 388-396

Electrons and jets at HERA.

A strong view of the proton

The detection and analysis of final-state electrons scattered off high-energy protons is a very effective way to reveal the secrets of the proton's structure. The corresponding complete data sets from the H1 and ZEUS collaborations, the result of 15 years of successful data taking at DESY's HERA accelerator, have been combined and used to obtain a very precise "electromagnetic" view of the charged constituents of the proton, the quarks. In addition, measurements of jets, i.e. collimated bundles of strongly interacting particles, provide direct sensitivity to the carriers of the strong interactions, the gluons, which are exchanged between these quarks and thus offer a complementary "strong" view of the proton. A combined fit to both kinds of data from both experiments allows the measurement of the coupling constant of the strong force (α_s) and yields additional constraints for cross section predictions at the LHC.

The HERA electron–proton collider, which was operated at DESY until 2007, was in some sense a giant electron microscope studying the structure of the proton. The virtuality of the exchanged photon (Q^2) is the resolution variable of this microscope, reaching down to 1/1000 of the proton size.

With such a resolution, it is possible to detect not only the three valence quarks which formally make up the proton, but also many so-called sea quarks arising from the creation of virtual quark–antiquark pairs. Another important variable is x, the fraction of the proton's momentum carried by the constituent (a.k.a. parton) on which an individual scattering process takes place. The result of many such scattering processes can be parameterized in the form of so-called parton density functions (PDFs) or parton distributions, which describe the probability of encountering a constituent parton (quark or gluon) with a momentum fraction x at a given resolution Q^2. One of the striking initial results of HERA was the confirmation that, contrary to intuition but as predicted by the Standard Model of particle physics, this probability is highly resolution-dependent, and that the strength of this dependence strongly increases for very "soft" partons, i.e. small x.

To study the quark constituents of the proton, it is sufficient to detect the energy and direction of the scattered electron in the final state (inclusive data, dominated by the first diagram in Fig. 1), since quarks are electrically charged and directly sensitive to photon exchange. The neutral gluons which are exchanged between these quarks, and among each other, can only be accessed indirectly in such data through the resolution dependence of the quark distributions. This induces a strong correlation between the gluon distribution and the

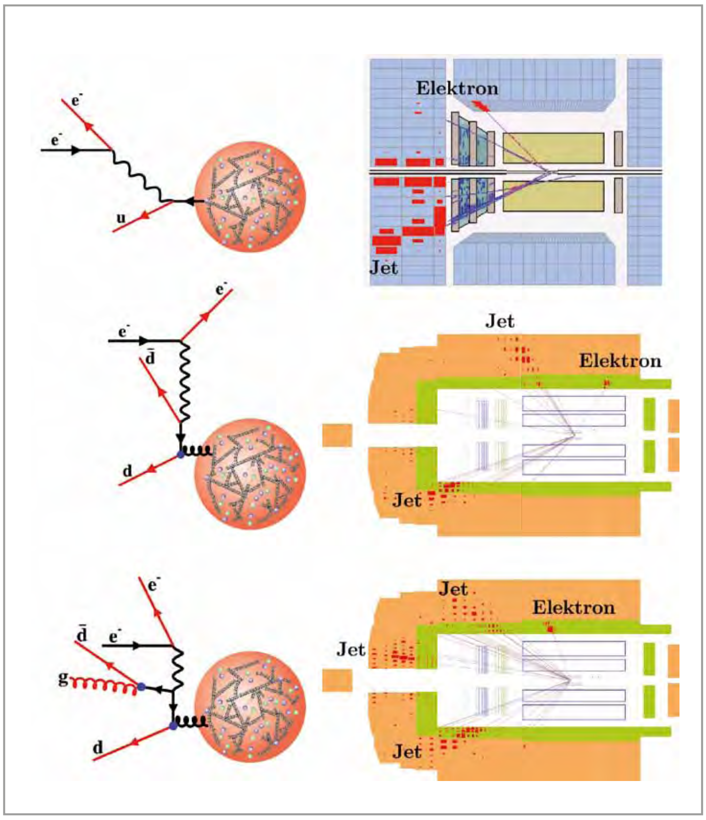


Figure 1

Examples for electron–proton scattering events with 1-jet, 2-jet, and 3-jet final states. The left diagrams show these processes in terms of quarks and gluons, while the event displays on the right show how they appear when measured in the ZEUS or H1 detector.

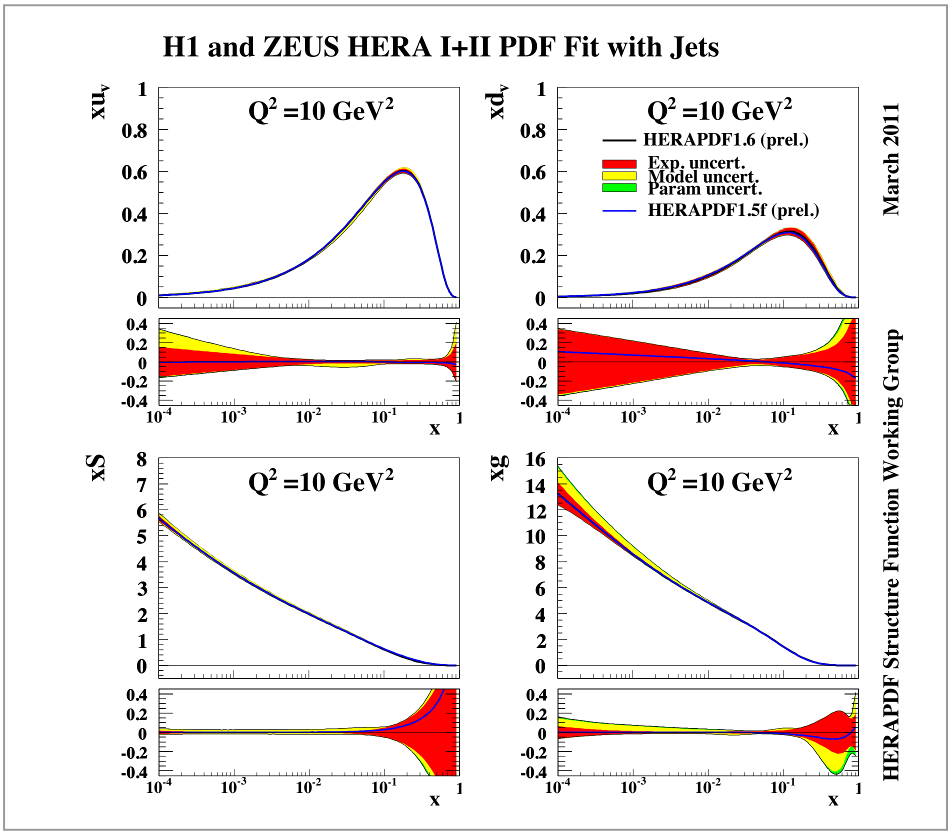


Figure 2

Valence (xu_v, xd_v), sea (xS) and gluon (xg) distributions for the combined fit including jet data (HERAPDF1.6) and comparison to the result without jet data (HERAPDF1,5f), for fixed α_s. The lower boxes illustrate the fractional differences to the central value.

value of the strong coupling constant α_s, the strong equivalent of the electromagnetic fine-structure constant α. The corresponding complete data sets from both collider experiments, H1 and ZEUS, have been successfully combined and used to extract the experimentally most precise parameterization of the PDFs. Apart from increasing the basic understanding of the proton, these PDFs are an essential input for the prediction of processes in proton–proton collisions, such as those being studied by the ATLAS and CMS experiments at the Large Hadron Collider (LHC). The particular parameterizations obtained by the joint efforts of the H1 and ZEUS collaborations are known as “HERAPDF”. A theoretically more precise next-to-next-to-leading order (NNLO) version of HERAPDF has recently been released and is being intensively used for the interpretation of LHC measurements.

When the electron scatters off the proton, it usually destroys the proton and produces a final state of many strongly interacting particles, called hadrons. Of particular interest are final states in which these hadrons are collimated into narrow bundles, or jets, which result from the emergence of individual high-energy quarks or gluons from the proton fragments. Because their properties are strongly shaped by the strong interactions, detecting and studying final states with up to three such jets (Fig. 1) gives a largely complementary view of the proton, directly sensitive to its gluon content and to the strong coupling constant α_s. Several such data sets have been used in conjunction with the inclusive data described above to obtain a simultaneous fit of all these quantities. For the first time, jet data from both H1 and ZEUS have been used simultaneously for this purpose, thereby significantly reducing the related uncertainties. The resulting parton distributions shown in Fig. 2 are consistent with earlier results, but favour a softer sea quark contribution at large momentum fraction. This affects cross-section predictions, e.g. for very heavy new particles being searched for in proton–proton interactions at the LHC.

Another important impact of the jet data is a large reduction of the correlation between the gluon distribution and α_s, which allows both to be determined simultaneously. The value of the strong coupling constant at the scale of the Z boson mass is measured to be $\alpha_s(m_Z) = 0.1202 \pm 0.0013(\text{exp}) \pm 0.0040(\text{th})$, where the first uncertainty is experimental and the second is the symmetrized theory and model uncertainty. The very good agreement with values obtained from other unrelated measurements and with the world average confirms the validity of the Standard Model description of the proton structure.

Contact:

Achim Geiser, achim.geiser@desy.de
Cristinel Diaconu, cristinel.diaconu@desy.de

Authors and reference:

H1 and ZEUS Collaborations
http://www-h1.desy.de/psfiles/confpap/DIS011/H1prelim-11-034.ps

Diffraction.

Combination of diffractive cross sections determined from proton tagging from H1 and ZEUS

Over the time of HERA operation, the H1 and ZEUS collaborations measured diffraction in electron–proton (ep) scattering using several different methods. One of these methods is to detect the diffractively scattered protons in special proton spectrometers in addition to measuring the reaction products in the central detectors. After the end of HERA operation, data sets of inclusive diffractive cross sections obtained by the H1 and ZEUS collaborations using this method have been combined into a single set of cross sections with improved precision.

Diffractive scattering in hadron–hadron interactions at high energy has been well known for a long time. It is mostly a soft, non-perturbative process, which can be described in Regge theory by the exchange of a hypothetical particle without quantum numbers, the pomeron. Already at a very early stage of HERA operation, events due both to diffractive ep scattering from soft processes and to hard processes with high four-momentum transfer squared at the electron vertex (Q^2) were observed. High Q^2 in hard diffractive processes provides a large scale which enables an approach based on perturbative QCD. Thus, the study of diffractive ep scattering offers the opportunity to test perturbative QCD and gain an understanding of the transition from the non-perturbative to the perturbative regime.

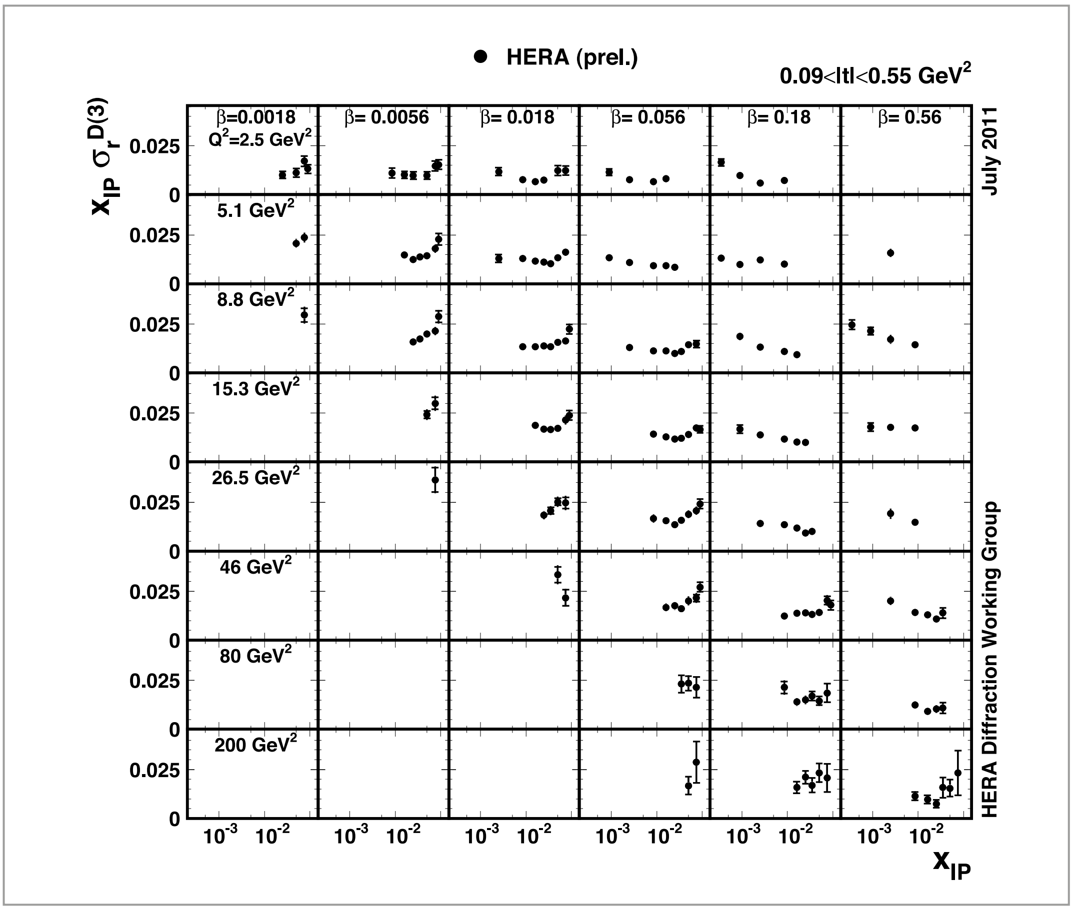


Figure 1

The combined cross section for inclusive diffraction at HERA as a function of x_{IP} in different bins of Q^2 and β as indicated in the figure. The cross sections are given for the range $0.09 < |t| < 0.55$ GeV^2.

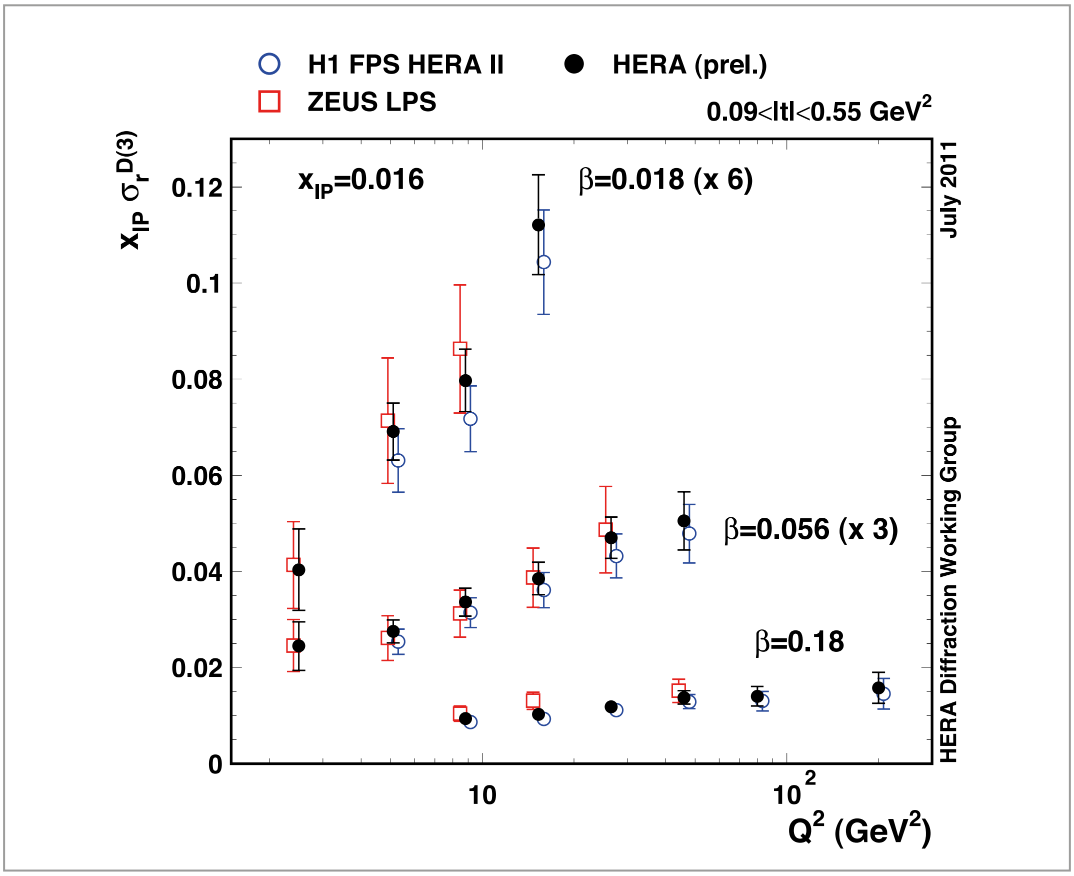


Figure 2

The figure shows $x_{IP}\sigma_r$ as a function of Q^2 for fixed x_{IP} = 0.016 and three values of β. The individual measurements are plotted in blue for H1 and in red for ZEUS. The combined cross sections in black have smaller errors than the individual measurements if both experiments contribute to the combination.

Diffractive ep scattering events are characterized by the incoming proton losing little energy and leaving the interaction intact, at very small angles to the beam direction, with small four-momentum transfer squared to the proton (t). Both the H1 and ZEUS detectors had spectrometers to measure diffractively scattered protons close to the proton beam about 90 m downstream from the interaction point. These were the forward proton spectrometer (FPS) in H1 and the leading proton spectrometer (LPS) in ZEUS. The particles produced in the diffractive process were measured in the central detectors. Over the years, the data have been used to perform several analyses, which resulted in sets of inclusive diffractive cross sections. In 2010, both experiments worked on combining the individual measurements into one single dataset and a unique set of cross sections with improved precision.

The differential inclusive diffractive cross section depends on four kinematical variables: the four-momentum transfer squared at the electron vertex (Q^2) and at the proton vertex (t), the Bjorken scaling variable x at the electron vertex and the fractional longitudinal momentum loss of the proton (x_{IP}). Often the variable $\beta = x_{IP}/x$ is used. The variables Q^2, x, x_{IP} are determined from the final state measured in the central detectors, while t can only be measured from the scattered proton. For most datasets, t was either not measured at all or only in two or three bins over the accepted t range. Therefore the cross sections for the combined dataset were integrated over the range $0.09 < |t| < 0.55$ GeV^2. The formula for the inclusive diffractive cross section is made up of a part which contains the dynamics of the reaction, the reduced cross section σ_r and kinematical factors. As a result of the combination, the reduced cross section multiplied by x_{IP} is quoted. Figure 1 shows the reduced cross sections times x_{IP} as a function of x_{IP} in different Q^2 bins.

The combination of the individual cross section measurements into a single dataset leads to improved precision for the whole dataset. As an example, Fig. 2 shows $x_{IP}\sigma_r$ for fixed x_{IP} and three different values of β. Plotted are the combined cross section values plus the corresponding H1 and ZEUS measurements. The errors of the combined cross sections are smaller than the individual ones if both experiments contribute to the combined value.

Contact:

Bernd Loehr, bernd.loehr@desy.de
Cristinel Diaconu, cristinel.diaconu@desy.de

Authors and references:

H1 Collaboration
H1 Coll., A. Aktas et al., Eur. Phys. J. C 48, 749 (2006)
H1 Coll., A. Aktas et al., Eur. Phys. J. C 71, 1578 (2011)

ZEUS Collaboration
ZEUS Coll., S. Chekanov et al., Eur. Phys. J. C 38, 3 (2004)
ZEUS Coll., S. Chekanov et al., Nucl. Phys. B 816, 1 (2009)

Shedding light on hadron formation.

Hadronization in the nuclear environment

The HERMES experiment is best known for its extensive nucleon spin programme. However, thanks to its superb particle identification capabilities, it was also able to investigate another fascinating facet of the Standard Model: the formation of stable, colourless particles from quarks. Hadron multiplicities in semi-inclusive deep-inelastic scattering were measured on neon, krypton and xenon targets relative to deuterium at an electron (positron) beam energy of 27.6 GeV. The nucleus to deuterium ratios were measured as a function of the virtual-photon energy, its virtuality, the fractional hadron energy and the hadron momentum transverse to the virtual-photon direction. These dependences were analysed separately for positively and negatively charged pions and kaons as well as for protons and antiprotons in a two-dimensional representation. These data will contribute to the understanding of how colour-neutral hadrons are formed from quarks and gluons, the basic building blocks of quantum chromodynamics.

Confinement and hadron formation

One of the remaining mysteries of the strong interaction is confinement, i.e. the lack of free coloured particles. This is intimately related to the question of how, from initially coloured states, colourless hadrons, e.g. protons, neutrons, pions, kaons, etc., are formed in the so-called “hadronization” process. An answer to this question will deepen the understanding of the structure of hadrons and thus of how quarks and gluons conspire to build up the majority of the visible universe.

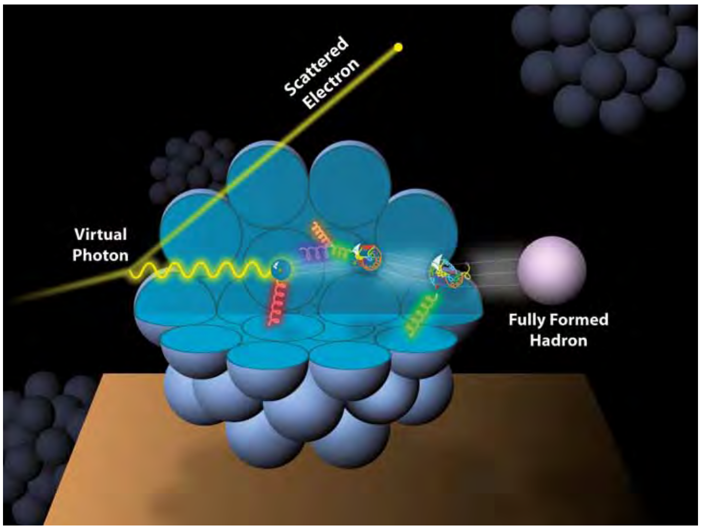


Figure 1

Illustration of hadronization in deep-inelastic scattering of leptons by nuclei

Hadronizaton has usually been studied at e^+e^- colliders where, in the annihilation process, pairs of quarks and antiquarks are produced which subsequently fragment into several hadrons (i.e. they “hadronize”). On the theoretical side, hadronization is described in terms of fragmentation functions. In e^+e^- collisions, hadronization occurs in the vacuum. For this reason, while e^+e^- studies can provide quantitative, flavour-dependent (i.e. up, down, strange, etc.) information on the multiplicity and energy distribution of the hadronization products, little can be learned about the space-time evolution of hadron formation.

A different experimental approach is to compare yields of hadrons produced by deep-inelastic scattering of electrons or positrons on target nuclei. By varying the size of the target nucleus, one can study the length and time dependence of hadronization for the various hadron types separately. This is enabled by the facts that the distance over which hadronization occurs can be comparable to the size of a nucleus, and that hadron yields depend on whether the hadronization occurs inside or outside of the nuclear matter. This latter fact comes about because, as the coloured quark traverses the nucleus, it is subject to the strong force of the coloured remnants, while hadronization products, pions, kaons and protons are subject to relatively weaker forces.

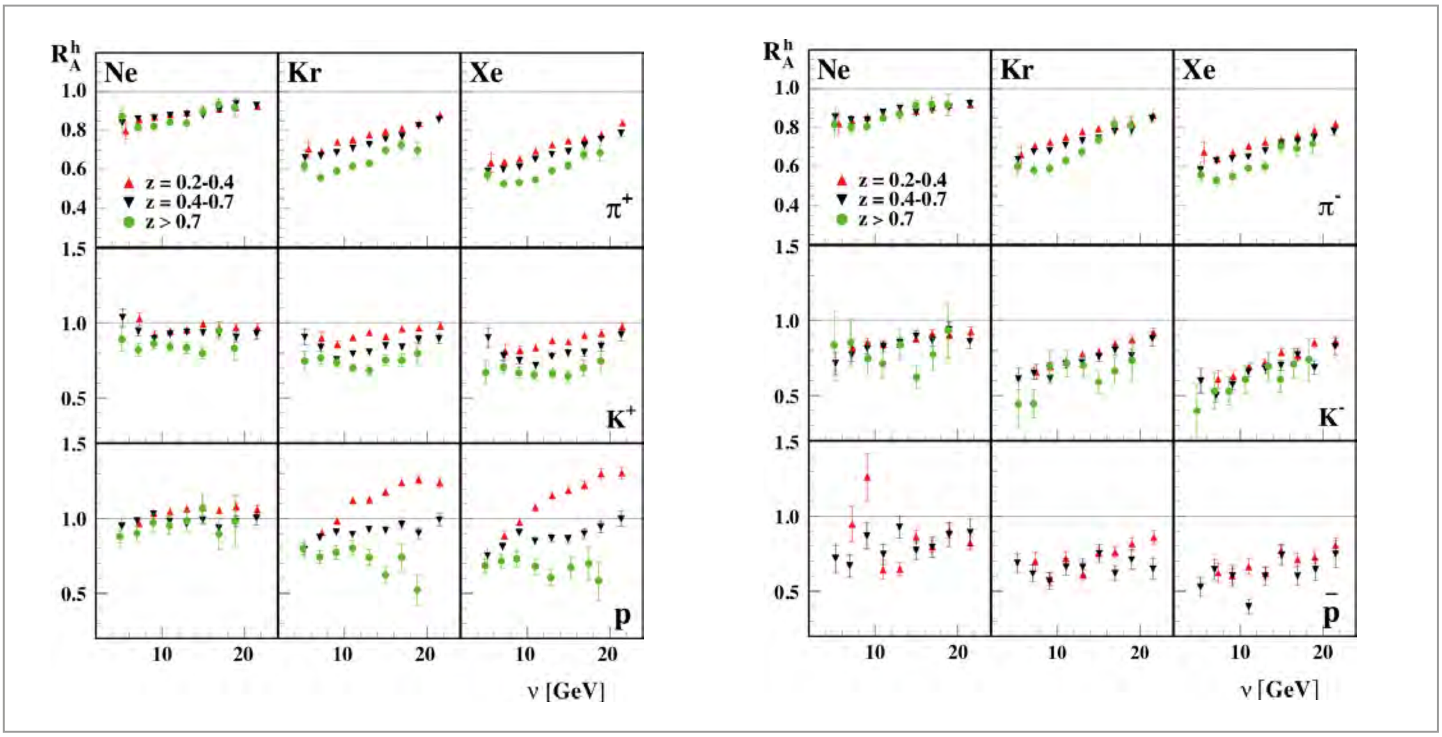


Figure 2

Multiplicity ratios of hadrons (from top to bottom: pions, kaons, protons and antiprotons) produced in deep-inelastic scattering by neon, krypton or xenon relative to deuterium as a function of the energy of the virtual photon and in slices of the energy fraction carried by the hadrons

For these reasons, and also because the kinematics of the process is well constrained by the observation of the scattered lepton, deep-inelastic scattering is a powerful complement to the study of hadronization in e^+e^- annihilation and hadron collisions.

Multiplicity ratios

The ratios of the normalized yields of identified hadrons produced in deep-inelastic scattering of leptons on neon (Ne), krypton (Kr) and xenon (Xe) targets to the same quantity on a deuterium (D) target were measured by the HERMES experiment at DESY's HERA accelerator. HERMES studied electrons and positrons, accelerated to 26.7 GeV, impinging on nuclei in a narrow gas-filled tube. The scattered electron (positron) and produced pions, kaons, protons and antiprotons were detected and identified in an eight-metre-long array of dedicated detectors positioned before and after a large dipole magnet, which deflected charged particles.

The various hadron types, i.e. positively and negatively charged pions ($\pi^{+/-}$), kaons ($K^{+/-}$), protons and antiprotons were measured separately. For the first time, a two-dimensional analysis was performed for all hadrons separately, thus allowing the observation of otherwise hidden features of the hadronization process.

The results show, for example (Fig. 2), that the behaviours of the π^+ and the π^- are very similar. However, the dependence of the ratios on the virtual-photon energy (ν) changes with the fraction (z) of the virtual-photon energy carried by the hadron. In contrast, for kaons, K^+ mesons show different features compared to K^-. This could be due to their different quark content, as the K^- meson has no valence quarks in common with the nucleons in nuclei. Particularly striking is the behaviour of protons, which depends strongly on *z*. Presumably, this is due to a sizable contribution of final-state interactions, such as knock-out processes which eject protons from the nuclear matter where they are abundant, in addition to the fragmentation process. In general, a clear dependence on nuclear size is observed. All of the mentioned features are amplified when going from neon to the heavier krypton or xenon nuclei, which are also bigger in size.

In conclusion, the two-dimensional distributions of the multiplicity ratios on heavy nuclei compared to deuterium for identified π^+, π^-, K^+, K^-, protons and antiprotons provide detailed information which in general cannot be extracted from studies of one-dimensional distributions (in which all kinematic variables except one are integrated over, as has been traditionally done). These new detailed studies are expected to be an essential ingredient for constraining models of hadronization and thereby for improving our understanding of hadron formation and structure.

Contact:

Gunar Schnell, gunar.schnell@desy.de

Reference:

HERMES Collaboration, Multidimensional study of hadronization in nuclei, Eur. Phys. J. A 47, 113 (2011)

Broken records and UFOs.

LHC operation and beam conditions monitors

The 2011 LHC operation with beams ended on 7 December after a very good year. Following an energy world record set in 2010, in spring 2011 the LHC set a new world record in a key parameter for hadron colliders – the luminosity. Apart from the success of several improvements, such as the reduction of the beam size, a surprising phenomenon – localized beam losses called UFOs – was observed, which induced occasional beam dumps.
Beam halo monitors are essential tools to ensure a safe and high-performance operation of the LHC detectors. Since 2011, fast beam conditions monitors of the BCM1F type used in the CMS experiment, which were developed and are operated by DESY physicists together with colleagues from CERN, have also been installed at several positions along the LHC ring to measure the beam halo.

Chronicle of LHC operation

After the winter break, first beams were back in the LHC on 19 February, and circulating beams were rapidly established. In the weeks before, intense tests of magnets, power supplies and protection systems were completed in record time. First stable beams, containing three proton bunches each, were delivered to the experiments on 13 March. After checks of critical systems (beam dumps and interlock systems), fills with an increasing number of bunches were delivered, culminating in a fill with 200 bunches on 22 March. With the reduced beam size at the interaction points in ATLAS and CMS, this resulted in a peak luminosity of 2.5x10^{32} cm^{-2}s^{-1}, comfortably beating the 2010 record established with 368 bunches.

Figure 1

The new record in the number of bunches and a stored energy of 70 MJ on 23 May 2011

The luminosity determines the number of events produced in a certain process. For a light Higgs boson, for example, a few events per hour are expected at this luminosity. Because only a small fraction of these events will be seen in the detectors, this rate is much too low to discover the Higgs boson in a reasonable amount of time.

Hence, the LHC crew focused on several measures to enhance the luminosity. The bunch spacing was reduced from 75 to 50 ns, and more bunches were injected into the machine. During the first attempts, beam conditions were spoilt by the electron cloud effect (see below). After a few "scrubbing" runs, however, the number of bunches was rapidly increased. On 21 April, with 480 bunches in each ring, a luminosity of about 4.4x10^{32}cm^{-2}s^{-1} was reached – a new world record for luminosity at a hadron collider, which superseded the previous record of around 4x10^{32}cm^{-2}s^{-1} set by the Tevatron at Fermilab.

At the beginning of May, the LHC underwent a machine study period, which ended with a low-intensity setup to allow special detectors at very low polar angles, TOTEM and ALFA, to take data for commissioning. Then, special fills were used for Van der Meer scans – moving the beams in a controlled manner around the nominal position to allow the experiments to calibrate their precision luminosity measurement devices.

Before the summer conferences, the number of bunches was increased to 1092, breaking a record again (Fig. 1). The milestone for the integrated luminosity of 1 fb^{-1}, the goal for 2011, was passed already in June.

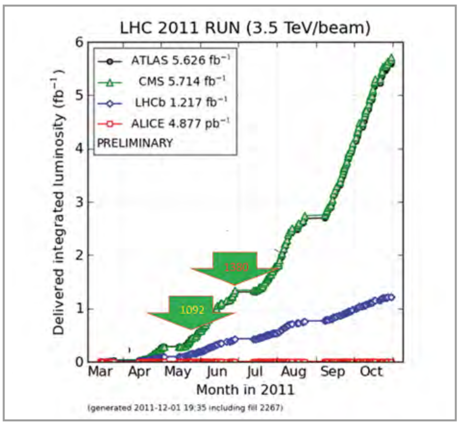


Figure 2

Integrated luminosity delivered to the LHC experiments in 2011 as a function of time. The numbers in the arrows indicate the number of bunches.

Before the next stop at the end of June, the number of bunches was increased to the maximum of 1380, corresponding to 1.6×10^{14} protons per beam and a combined energy of around 89 MJ at 3.5 TeV. Keeping the number of bunches at the maximum for the remaining run time, efforts were made to reduce the transverse bunch size, first by injecting smaller bunches into the LHC. This brought an increase in the peak luminosity of about 50% to 2×10^{33} $cm^{-2}s^{-1}$. Increasing in addition the bunch intensity to 1.35×10^{11} protons per bunch resulted in a formidable integrated luminosity of 90 pb^{-1} in one day.

The machine development in the second half of August was used to squeeze the bunches even harder with the quadrupole magnets situated on either side of the experiments. The crucial machine parameter is the so-called β^*. The smaller it is, the stronger the squeezing. For ATLAS and CMS, β^* was reduced from 1.5 m to 1 m. Overcoming some trouble with the collimators in fills after 9 September, a new luminosity record of 3.3×10^{33} $cm^{-2}s^{-1}$ was obtained. This number corresponds to one third of the design luminosity, delivered at half the design energy with half the design number of bunches.

Up to 30 October, more than 5 fb^{-1} were delivered to both ATLAS and CMS, five times more than promised at the beginning of the year. The development of the performance of the LHC is nicely illustrated in Fig. 2, which shows the integrated luminosity as a function of time.

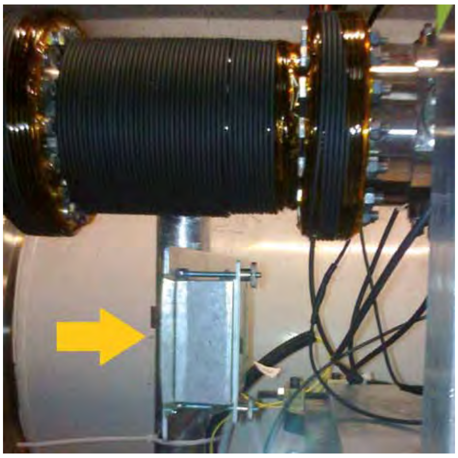


Figure 3

A BCM1F module, containing a single-crystal diamond sensor and front-end electronics, installed below the LHC beam pipe

After a machine development period, a four-week run with lead ions began on 12 November. The step-wise increase of the number of bunches to 358 resulted in a peak luminosity of 3.5×10^{26} $cm^{-2}s^{-1}$, 10 times more than in 2010.

Electron clouds, scrubbing and UFOs

When the LHC is filled with a large number of proton bunches, electrons accumulate in the beam pipe and are accelerated by the bunches. They hit the beam pipe and generate more electrons. To avoid this electron cloud effect, “scrubbing” runs with high beam current at low energy are performed. Gas molecules trapped on and inside the metal of the beam pipe are released and pumped out, leading to a drop of secondary electron emission. Such runs were successfully performed at the beginning of April. To further reduce the effect, solenoid coils were installed around the beam pipe.

Occasionally, strong local beam losses, called “unidentified falling objects” (UFOs), were observed. UFOs induced signals in nearby beam loss monitors, initiating beam dumps which led to a reduced efficiency of the collider. More studies will be needed in the future to avoid such beam losses.

Fast beam conditions monitors

Fast beam conditions monitors using single-crystal diamond sensors (BCM1F) are successfully operated by DESY physicists in the CMS experiment to protect the tracking detectors from adverse beam conditions. Two similar devices (Fig. 3) have been installed along the LHC near the ALICE and LHCb experiments.

Single-particle count rates and arrival time distributions as shown in Fig. 4 are delivered by a dedicated data acquisition. In 2012, this information will be displayed in the main LHC control room to support a smooth operation of the machine.

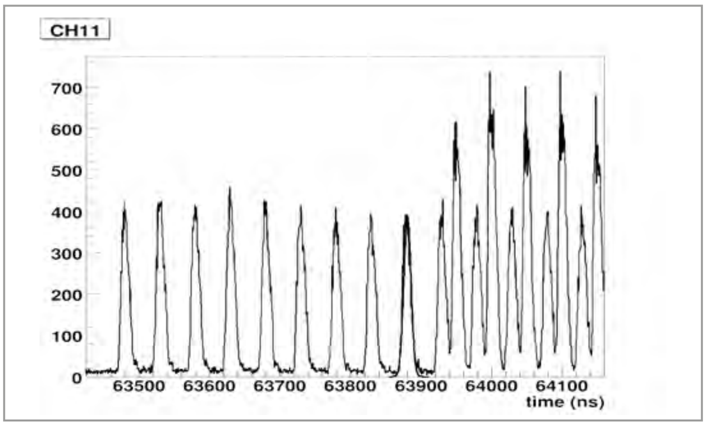


Figure 4

Arrival time distribution of particles detected outside the beam pipe near LHCb. The larger peaks are caused by collision products from LHCb.

Contact:
Wolfgang Lohmann, wolfgang.lohmann@desy.de

The quest for the Higgs particle.

Unravelling the mystery of mass

In the first year of high-luminosity LHC operation, the ATLAS and CMS experiments took bold strides in the 45-year pursuit of one of the biggest questions in particle physics today: the nature and origin of mass. In a tremendous concerted effort involving thousands of physicists, a large part of the territory in which the elusive Higgs particle could still be hiding is being explored. Since the end of 2011, the Standard Model-compliant Higgs boson, if it exists, is cornered in a very narrow mass range.

The opportunity

For the highly successful Standard Model of particle physics, the Higgs particle is the last missing link. The Higgs mechanism provides a way to explain why elementary particles have mass – a fundamental property of nature and our own existence. A prime goal of today's particle physics experiments is to verify the existence of this particle and measure its properties, or to rule it out. Strong groups from DESY take part in the Higgs search in both the ATLAS and CMS experiments at the Large Hadron Collider (LHC).

Before the LHC entered high-luminosity operation in early 2011, searches at the electron–positron collider LEP had set a lower mass bound for the Standard Model Higgs boson at 114 GeV. Measurements of the W boson and top-quark masses, combined with electroweak precision measurements at the Z pole, provided an indirect constraint for the Higgs boson mass to be below 158 GeV. Estimates showed that with ~5 fb^{-1} of integrated luminosity, the LHC experiments should have a fair chance to obtain sensitivity to the Standard Model Higgs in a large part of the mass range up to 600 GeV. This required, however, a subtle combination of many different decay channels and thus a very broad and well-organized approach in the collaborations. At low masses, the range of Higgs decay channels is dominated by pairs of b quarks and τ leptons, while the regime at large masses is governed by W and Z boson pair final states. The cleanest, although by no means most copious decay modes are those into two photons, which are only relevant at low Higgs masses, and into four leptons, the latter mediated by a pair of Z bosons, one of which is virtual at low Higgs masses.

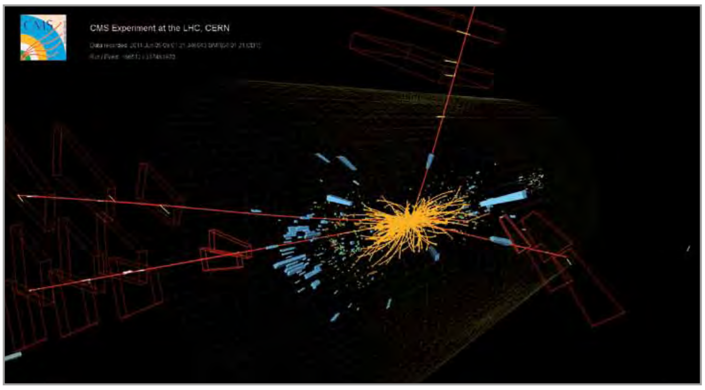


Figure 1

Display of a CMS proton–proton collision event in which four high-energy muons (red lines) are observed. The event shows characteristics expected from the decay of a Higgs boson but is also consistent with background Standard Model physics processes.

The chase

The flawless operation of the LHC collider in 2011 led to a rapid growth of the data samples. The first point of harvest was reached for the 2011 summer conferences, in particular the EPS conference in Strasbourg and the Lepton Photon conference in Mumbai, for which about 1.2 fb^{-1} of data per experiment were available and analysed. The Tevatron experiments CDF and D0 presented their updated results obtained with up to 8.6 fb^{-1}. Their combined measurements excluded the Higgs boson in the mass ranges between 100 and 109 GeV and between 156 and 177 GeV. The combined ATLAS and CMS results were already able to exclude the Standard Model Higgs boson in the mass range between 141 and 476 GeV at a confidence level of 95%.

In the meantime, the instantaneous luminosity of the LHC steadily increased, together with the number of interactions per bunch crossing. In the autumn of 2011, more than ten proton–proton interactions typically occurred simultaneously, with tails even exceeding 20 interactions. This pile-up constituted a significant challenge for the trigger, reconstruction and analysis techniques of the experiments. Figure 1 shows the display of an event recorded by the CMS detector in June 2011, featuring four muons of large transverse momentum. Additional activity appearing in the display includes particles from the pile-up interactions.

The Higgs sector as of December 2011

The 2011 run was concluded with about 5 fb^{-1} of data recorded per experiment. The events were analysed very quickly and first results presented to the public in an eagerly awaited seminar at CERN on 13 December 2011. The press all over the world widely covered the occasion to report on what could be the first glimpse of the Higgs boson. The bottom line is that neither of the experiments observes a significant signal of the Higgs in any of the channels or kinematic ranges studied.

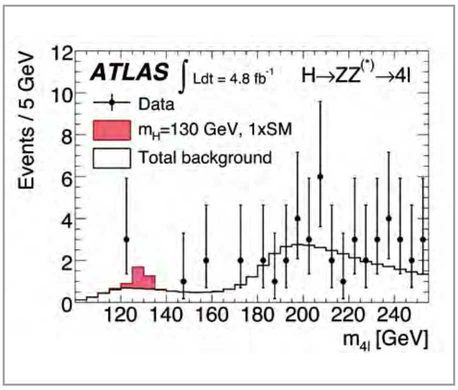


Figure 2

Four-lepton invariant-mass spectrum from ATLAS. The unshaded histogram shows the expected background. The red-shaded histogram indicates the contribution expected from a Higgs signal at a mass of 130 GeV.

As an example, Fig. 2 shows the invariant-mass spectrum in the “golden decay channel” with four charged leptons from the ATLAS experiment, a channel with excellent mass resolution and very low background. No sharp peak is observed within statistics, but the result does not contradict the existence of a Standard Model Higgs boson below 134 GeV. Figure 3 shows the diphoton invariant-mass spectrum measured by the CMS experiment. The spectrum shows a mild excess near 125 GeV which is, however, compatible with a statistical fluctuation. Similar levels of excess in the same mass range are present in the corresponding spectrum from ATLAS.

Currently, the combined results of the 2011 run from each experiment exclude the Standard Model Higgs at the 95% confidence level in the ranges of 112.7–115.5 GeV and 131–453 (except 237–251) GeV for ATLAS, and in the range of 127–600 GeV for CMS. The detailed mass-dependent confidence limits in the low-mass region are shown in Fig. 4 for both experiments. It is interesting to note that the actually observed upper limits are “worse” than they would be expected by the experiments from the integrated luminosity, the combined efficiency and the background estimate, if no Higgs boson existed. Such a behaviour can be surmised if a signal is gradually coming into statistical reach. More data are needed to clarify whether these effects are caused by an actual particle or just statistical fluctuations.

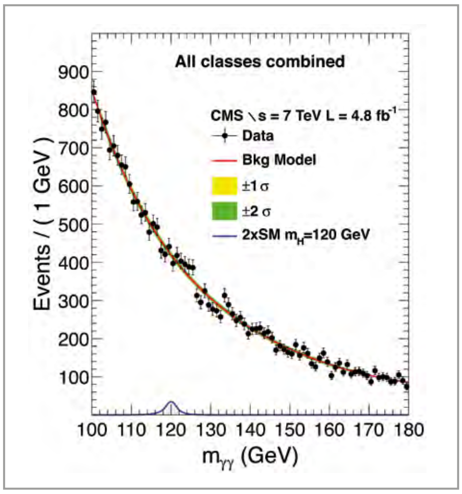


Figure 3

Two-photon invariant-mass spectrum from CMS. The solid red line corresponds to the fitted background model; the blue line indicates the expected shape of a Higgs signal at m = 120 GeV, at twice the Standard Model cross section.

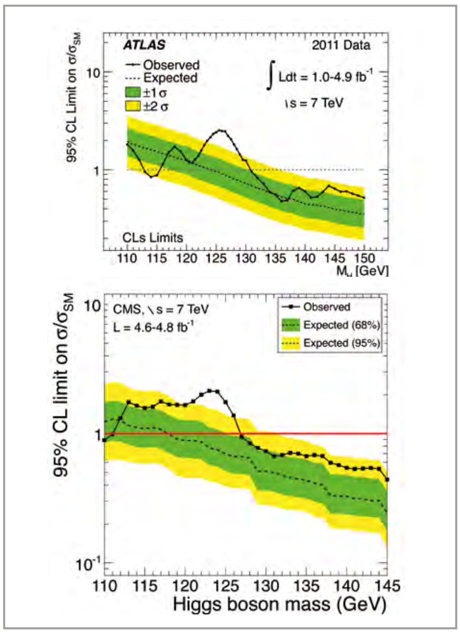


Figure 4

Confidence limit on the Higgs cross section in the low-mass region as determined by the ATLAS (top) and CMS experiments (bottom)

Exciting times ahead

After one year of LHC high-luminosity running, the electroweak landscape has changed remarkably. The experiments performed superbly. A wide range for the Higgs mass allowed by the Standard Model has already been excluded, and the search is now focusing on the low-mass region around 120–125 GeV just above the LEP limit. The explicit goal of the 2012 run is to provide both ATLAS and CMS with sufficient data to either verify or disprove, independently, the existence of a Standard Model-type Higgs boson.

In either case, the impact on our vision of the world will be enormous. The discovery of the Higgs boson will initiate a rich programme to measure its precise properties and uncover the full structure of the Higgs sector. Its exclusion would imply that the Standard Model of particle physics is fundamentally incomplete and thus, that either the Higgs mechanism is part of an extension of the Standard Model, or that entirely new explanations for the existence of mass must be searched for.

Contact:

Rainer Mankel, rainer.mankel@desy.de
Michael Medinnis, michael.medinnis@desy.de
Kerstin Tackmann, kerstin.tackmann@desy.de
Roberval Walsh, roberval.walsh@desy.de

Search for new physics.

Hunting for supersymmetric events in the ATLAS data

One of the main aims of the LHC is the search for as yet unobserved phenomena, i.e. “new physics”. Supersymmetry is a very appealing extension of the Standard Model of particle physics, which predicts new particles while addressing some of the experimental and theoretical shortcomings of the Standard Model. Common features of supersymmetric events are multiple jets and large missing transverse momentum. Other particles such as light leptons, taus and photons might also be produced. The ATLAS/DESY group is making prominent contributions to the search of supersymmetry in different final states. We report here on two of them: the search for events with missing transverse momentum and either two photons or two taus.

Over the last decades, the predictions of the Standard Model have been confirmed in great detail by many experiments. Only the detection of the elusive Higgs boson is needed to complete the picture. Nevertheless, the Standard Model has some shortcomings. For example, it does not predict a dark matter candidate which could explain the measured amount of dark matter in the universe. There are also theoretical arguments which hint that the Standard Model is not the final theory of particle physics.

Supersymmetry, or SUSY, predicts a new SUSY particle for every Standard Model particle with the same properties except for its spin. The SUSY particles must be heavier than their Standard Model partners. Assuming R-parity conservation, SUSY particles are produced in pairs and decay through cascades into the lightest SUSY particle (LSP). The LSP is stable and weakly interacting and hence a candidate for dark matter. It is neutral and therefore escapes direct detection, but can still be seen indirectly because it carries a large momentum transverse to the beam direction. The total momentum in the transverse plane must be conserved. The missing transverse momentum due to the two LSPs can thus be deduced from the measurement of the transverse momentum of all other particles.

The main production process of SUSY particles at the LHC is through gluino and squark pairs, the SUSY partners of the gluon and quark. The gluinos and squarks decay into jets and lighter SUSY particles. Common to all SUSY events are multiple jets from these decays and missing transverse momentum from the escaping LSPs.

The search for supersymmetric events is divided into different final states based on the number of light leptons, taus and photons in the event. The ATLAS/DESY group contributes to the search for SUSY in the dilepton, ditau and diphoton final states. Here, we report on the latter two.

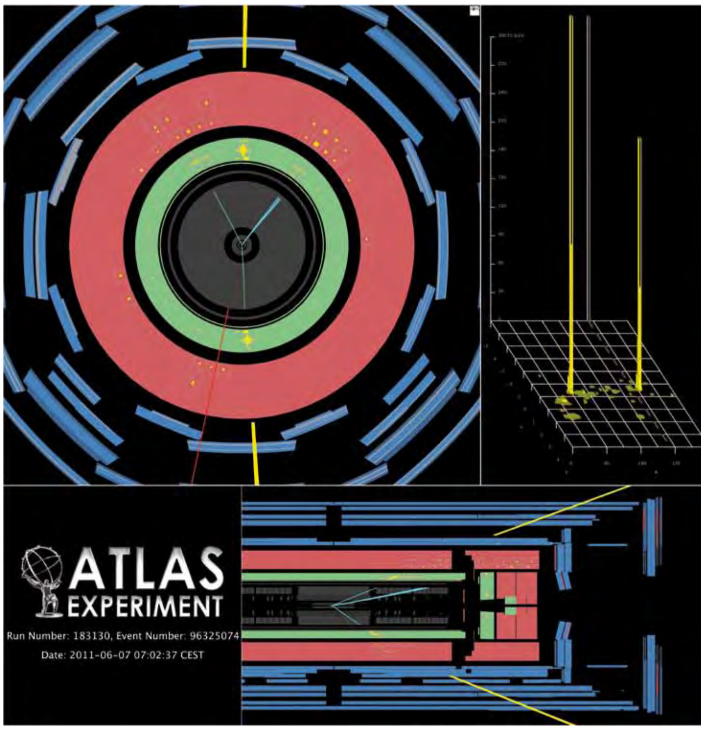


Figure 1

Display of a SUSY candidate event with a diphoton plus missing transverse momentum in the ATLAS detector.

Top left and bottom: Tracks are shown in blue. The direction and momentum of reconstructed and identified photons are shown in yellow. The direction of the missing momentum is indicated by the red line.

Top right: Reconstructed calorimeter energy, showing two large yellow peaks where the photons deposit their energy. The position and size of the missing transverse momentum are indicated by the grey line.

Diphoton final states

In some SUSY models, a significant rate of events with two photons with high transverse momentum is predicted. The presence of photons makes the online selection of these events easy. The final event sample is selected by requiring large missing transverse momentum and two photons. A typical candidate event is shown in Fig. 1.

The expected background from real diphoton production in the Standard Model is small. The contribution from events in which one or two photons are erroneously reconstructed from jets or electrons is significant, however, and not modelled in all its detail in the Monte Carlo simulation. The ATLAS/DESY group contributed significantly to the overall analysis and the estimation of such fake photons arising from jets using only the data, without recourse to Monte Carlo simulations.

For the 2011 summer conferences, 20% of the 2011 data set had been analysed. The data are well described by the background estimate. Therefore, the ATLAS/DESY group derived model-independent limits on the contribution from SUSY production using advanced statistical methods in order to take the relevant experimental and theoretical uncertainties into account. This statistical analysis was repeated to derive limits on model parameters in various SUSY models that predict final states with two photons.

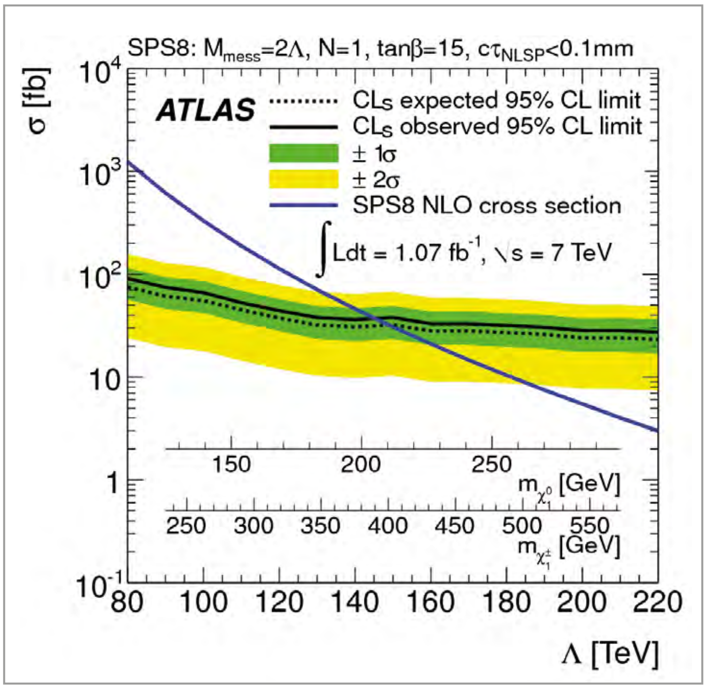


Figure 2

Observed and expected limit at 95% confidence level using the CLs method on the SPS8 model parameter Λ and the lightest neutralino (χ_1^0) and chargino ($\chi_1^\pm$) masses. The blue line shows the expected cross section in this model at next-to-leading order (NLO).

Figure 2 shows the expected and observed limits on the SPS8 model parameter Λ and the masses of the lightest neutralino and chargino, the SUSY partners of the neutral and charged gauge bosons, respectively. Λ values up to 145 TeV are excluded, which improves significantly on the limits from the D0 and CDF experiments. This is the first time that an LHC experiment is considering this model. The paper has been accepted for publication, and the analysis of the full 2011 dataset is well underway. The paper is expected to be published in spring 2012.

Ditau final states

Tau leptons in supersymmetric events are produced in stau decays, the SUSY partner of the tau. Investigating final states with taus is one way to study the third generation of SUSY particles. In some regions of the SUSY parameter space, the production of third-generation particles is expected to be enhanced compared to the first and second generation.

After requiring multiple jets, two taus and large missing transverse momentum, the main Standard Model background is from W, Z and top-pair production. The Monte Carlo simulation describes events with two real taus quite well, but overestimates the contribution of events with one real tau and one mis-reconstructed tau.

The ATLAS/DESY group made prominent contributions to the estimate of the tau mis-reconstruction rate for these processes using data in control regions. No hint of supersymmetric events with two taus has been found in the data. Therefore, the ATLAS/DESY group has derived model-independent limits on the contribution from new physics and model-dependent limits in a gauge-mediated supersymmetric breaking model, which extend previous limits set in this model by the four LEP experiments. The results are approved to be shown at the winter conferences 2012, and the final publication is expected for early 2012.

Perspectives

There are many reasons to believe that the Standard Model needs to be extended. The search for new physics, especially SUSY, shows no signals yet. The ATLAS/DESY group will continue to contribute to the search of SUSY within ATLAS. The group will use its acquired expertise to finish the analysis of the full 2011 dataset and the data to be taken in 2012, to either discover new physics or to push the exclusion limits as far as possible.

Contact:
Wolfgang Ehrenfeld, wolfgang.ehrenfeld@desy.de
Klaus Moenig, klaus.moenig@desy.de

ATLAS inner detector upgrade for High-Luminosity LHC.

Simulation studies for a next-generation tracking detector

An upgrade of the LHC is planned for 2022. The upgrade will provide very high collision rates, which will enhance the possibilities for new physics measurements, but also pose very significant experimental challenges. The current ATLAS inner detector will not be suitable for operation in such an environment and so must be replaced; an all-silicon tracker is considered to be the best solution for such conditions. To arrive at the optimum design, detailed simulation studies are needed to predict the tracking performance of candidate layouts.

High-Luminosity LHC and ATLAS

In 2011, the LHC ran spectacularly well, at a centre-of-mass energy of $\sqrt{s} = 7$ TeV with a peak instantaneous luminosity of $L = 4\text{x}10^{33}\ \text{cm}^{-2}\text{s}^{-1}$. The luminosity determines the rate at which particles collide. It is a measure of the beam intensity and is proportional to the number of proton–proton collisions that occur at the interaction region every second.

In the events recorded by the ATLAS detector, all collisions from a single bunch crossing are superimposed on each other. Therefore, while higher luminosity increases the yield of low-cross-section processes, extending the discovery reach of the experiment, it also presents a challenge to both the detector and the reconstruction software to identify processes of interest amidst a large number of so-called “pile-up” interactions.

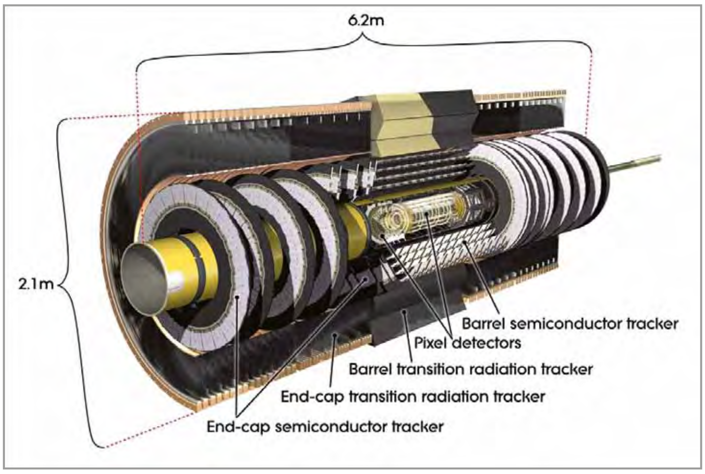


Figure 1

The current ATLAS inner detector, composed of a pixel detector (silicon pixels), semiconductor tracker (SCT, silicon microstrips) and transition radiation tracker (TRT, gaseous straw tubes).

In 2022–2023, a long shutdown of the LHC is planned, during which the accelerator will be upgraded to run at about 12 times its current peak luminosity (High-Luminosity LHC, HL-LHC). This will result in an estimated 140 proton–proton collisions per bunch crossing, every 25 ns, greatly increasing the complexity of event reconstruction. The radiation damage sustained by the ATLAS inner detector (ID) (Fig. 1) up to this point and the increased occupancy in the transition radiation tracker (TRT) will render the ID ineffective under HL-LHC conditions, and so a completely new inner tracker system will be needed.

ATLAS inner tracker for HL-LHC

A general requirement for the new ATLAS inner tracker (ITk) at the HL-LHC is to maintain at least the same level of performance as the current ID. To achieve this, the ITk will be built solely from layers of silicon pixels and microstrips; the TRT will be removed completely because of its insufficient granularity. The current benchmark layout for the ITk (Fig. 2) consists of four cylindrical barrel layers (in the central region) and six end-cap disks (at either end) of silicon pixels, surrounded by five barrel layers and five end-cap disks of double-sided microstrip detectors. The final number and position of each type of sensor layer is one of the questions that will be answered by simulation studies; the potential benefits of extra tracking points are offset by the extra material along the path of the particle. Possible performance improvements through the addition of extra layers must also be weighed against the cost.

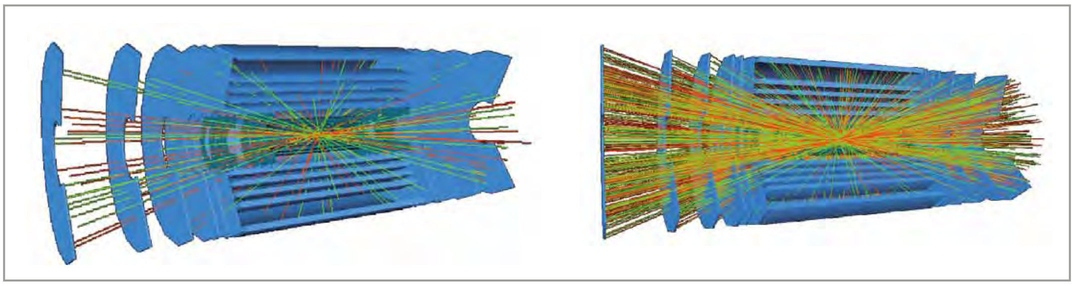


Figure 2

The benchmark layout of the ATLAS inner tracker for HL-LHC, traversed by an event containing 28 (left) and 200 (right) pile-up collisions.

The simulation of the candidate inner tracker layouts is performed within the ATLAS software framework "ATHENA", using Geant4 to model the interaction of particles with the detector material, a digitization package which mimics the detector readout electronics, and the full ATLAS offline reconstruction, which takes as input the resulting space point information from the digitization step, to form particle tracks. In this way, a wide variety of tracking performance parameters can be estimated, from simple tracking resolutions and efficiencies to more complex quantities, such as the power to distinguish between particle jets originating from b quarks and those originating from light-flavour quarks.

Pile-up collisions are overlaid onto the interaction containing a simulated signal process during the digitization stage at two levels: 140 and 200 collisions per event, corresponding to nominal and extreme HL-LHC conditions, respectively. This represents a very significant increase on the 28 collisions per event expected at the LHC's design luminosity (Fig. 2). The number of fake tracks (i.e. tracks that cannot be associated to any single physical particle) rises steeply with increasing pile-up, especially in regions of the detector with a large amount of material, where multiple scattering smears the particle trajectory and secondary particles can confuse the reconstruction code. This is a particular problem in the transition region between the barrel and end-caps, and so, keeping the amount of material in this region as low as possible is a high priority. Several ITk layout alternatives in addition to the benchmark just described have been proposed with this aim in mind.

Other inner tracker layouts under study

An alternative "conical" layout dispenses with traditional end-cap disks in the pixel detector. It relies instead on tilted sensors at the ends of the pixel layers to provide tracking coverage at small angles to the beam direction. Small "diskettes" can be added where necessary to recover hit coverage in specific regions. Another proposed alternative, the "Alpine" layout, also uses sensors at an angle to the *z* axis to replace end-cap disks, but in this case the tilted elements are placed at various positions along the length of the barrel, not just at the ends. Both of these options are under consideration for use in the upgraded ATLAS inner detector, and their implementation in simulation is underway.

Less dramatic variations of the layout are also under study, for example, the extent to which a small "stereo" angle between the two sides of the microstrip layers is necessary. Removing the stereo angle in several microstrip layers would allow fast measurements of a track p_T to be made, which can then be used at the first level of the ATLAS trigger. The consequences for tracking performance of losing the stereo information must be determined and weighed against the advantages of a level-1 track trigger for overall physics performance.

The advantages of increased pixel granularity are also under study. This factor may be particularly important for the tracking performance within high-p_T jets, especially in the case where two jets merge, in which the local track density is very high. Accurate reconstruction of such objects will be critical for the ATLAS HL-LHC physics programme.

Further important work is ongoing to describe the so-called "petal" design for the microstrip end-cap disks (Fig. 3) properly in simulation. DESY has made very significant contributions to the development of the petals and will be one of the institutes responsible for their eventual construction.

The outcomes of these studies will have a significant impact on the design of the upgraded ATLAS inner detector and thus far-reaching consequences for the future of the ATLAS experiment.

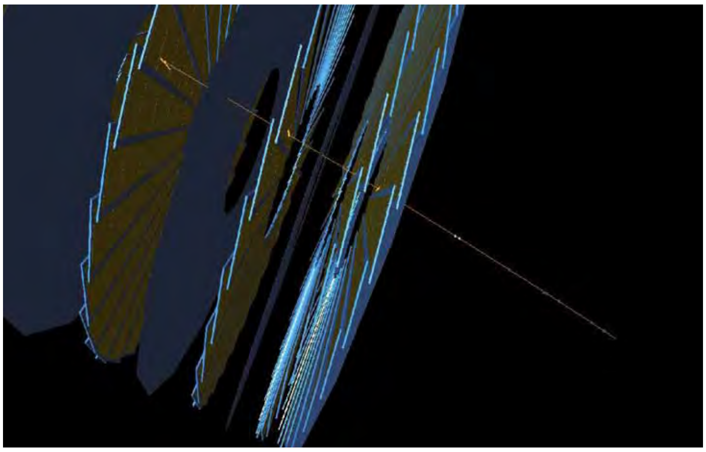


Figure 3

Simulation of a petal-like end-cap for the ATLAS inner tracker at HL-LHC

Contact:
Nicholas Styles, nicholas.styles@desy.de
Peter Vankov, peter.vankov@desy.de

Strange sea quarks in the proton at the LHC.

A novel sensitivity to the composition and magnitude of the light quark sea from ATLAS data

The LHC collider can not only be used to search for elusive physics beyond the Standard Model; ATLAS physicists have shown that precise W and Z boson production data can provide new information on proton structure and, in particular, on the poorly determined strange sea quark density.

The physics of the structure of the proton has been an active subject of detailed theoretical and experimental investigations since the proton's finite radius was established in elastic electron–proton experiments in 1956. The proton has a highly complex structure, which consists of interacting particles such as quarks and gluons. Its main components are two up quarks and one down quark, collectively referred to as "valence quarks", because they carry the electric charge of the proton. Valence quarks interact with each other through the strong interaction mediated by gluons, as prescribed by quantum chromodynamics (QCD), the theory of the strong force.

In QCD, the apparent structure of the proton becomes richer as smaller distances are resolved. Gluons not only interact with valence quarks, but also split into quark–antiquark pairs, so-called "sea" quarks. There are different flavours of sea quark: up (u), down (d), strange (s), charm (c), bottom (b) and top (t).

Little is known about the s sea quarks. Although they are significantly heavier than u or d quarks, they are still much lighter than the proton itself. Some models assume the s quark mass is so high that s quark production by gluon splitting is suppressed relative to the lighter u and d quarks, as is certainly the case for the heavier quarks such as c, b and t.

The basic constituents of the proton are determined from the global modelling of data sets obtained at various high-energy accelerator facilities. Crucial information came from the world's only electron–proton collider, HERA, which was in operation at DESY for 15 years, until 2007. Amazingly sensitive measurements of gluons and all of the sea quarks, including c and b quarks, were performed at HERA. Nonetheless, the light sea quark composition could not be resolved well, because the measurements relied mainly on photon exchanges between the initial-state electrons and protons. As u quarks have twice the electric charge of other light quarks, the photon couples more strongly to them. Consequently, the structure of the u quark sea is relatively well known, while the s sea remains elusive and poorly known.

Since 2010, the Large Hadron Collider (LHC), the world's largest particle accelerator, has been colliding beams of protons with unprecedentedly high energy and thereby opened the window to new information on proton structure. Several processes have the potential to contribute, including the production of the carrier particles of the weak force: the Z and W bosons. The strength of the coupling of these bosons to quarks depends both on quark flavour and on the boson. The pattern of these couplings also differs from that of the photon-mediated electron–quark coupling of the processes observed at HERA. The Z boson couples more strongly to d and s quarks than to the other quarks. The Z boson production process is also more sensitive to the s quark content of the proton than processes involving W or photon production. Therefore, a judicious combination of the HERA data with the W and Z measurements at LHC has the potential to disentangle the various quark contributions to the sea and thereby introduce an unprecedented sensitivity to the s sea quark density.

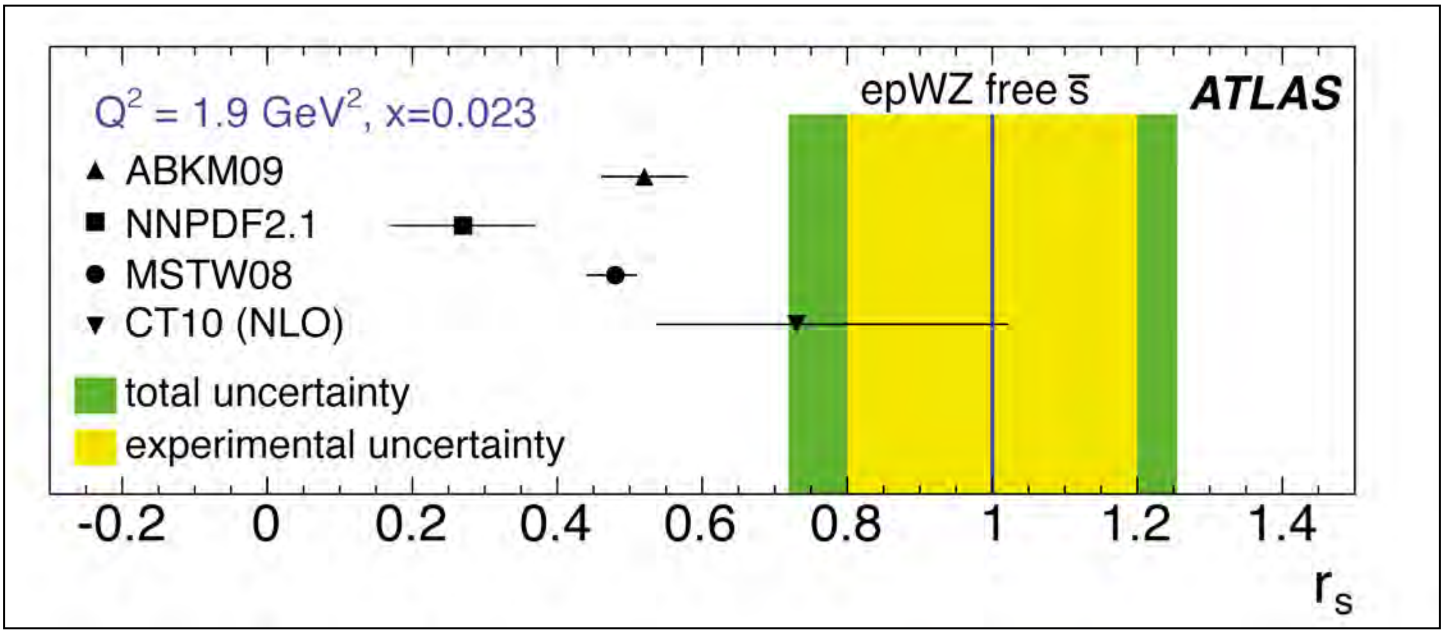


Figure 1

Comparison of the ATLAS determination of the ratio of the strange to down sea quark densities r_s compared to various model predictions from theory groups which use different strategies to analyse the available data (prior to LHC)

The Z and W bosons are abundantly produced at the LHC, and their experimental signatures in the ATLAS detector are uniquely clear. Already with the data taken during the first year, very high experimental accuracy has been achieved due, in part, to the excellent performance of the ATLAS detector. The ATLAS collaboration analysed the precise ATLAS measurements together with HERA data using a QCD analysis package for proton structure developed mainly at DESY by HERA physicists.

The results of the analysis are expressed in terms of the ratio of s to d sea quark densities (r_s). The ATLAS collaboration found that the ratio is consistent with unity (Fig. 1), which implies that the s quark sea is not suppressed. Figure 1 also shows predictions from phenomenological models, which use the pre-LHC era data sets used to determine proton structure. The predictions typically favour lower r_s and tend to disagree with each other. However, to model the s sea structure, they are forced to rely mainly on neutrino measurements, which are subject to model-dependent nuclear corrections.

The ATLAS observation is consistent with the prediction that the light quark sea is flavour symmetric. A consequence is that, since the s quark contribution to the sea is not suppressed by a factor of two as had been generally assumed, the total sea quark content must also be considerably larger than was previously thought.

Contact:
Alexander Glazov, alexander.glazov@desy.de
Voica Radescu, voica.radescu@desy.de

The Higgs and the photon.

Using massless particles to explore the origin of mass

The Higgs boson is the only undiscovered particle of the Standard Model (SM) of particle physics and also part of many extensions of the SM. If it exists, it provides a natural explanation of electroweak symmetry breaking and the masses of the gauge bosons and fermions. The Helmholtz Young Investigators Group (YIG) "Higgs Physics with Photons at the ATLAS Experiment" takes part in the search for the Higgs boson at the Large Hadron Collider (LHC).

2011 marks the year in which Higgs searches at the LHC started in earnest. With the data taken up to summer 2011, the LHC experiments narrowed down the possible mass range for the Higgs boson and extended the excluded regions set by the LEP and Tevatron experiments. With the 5 fb^{-1} taken during all of 2011, only little space is left for the SM Higgs boson to hide. A prominent Higgs decay channel for the exploration of the still-open mass range is the decay into two photons, which also contributes significantly to the present exclusions limits.

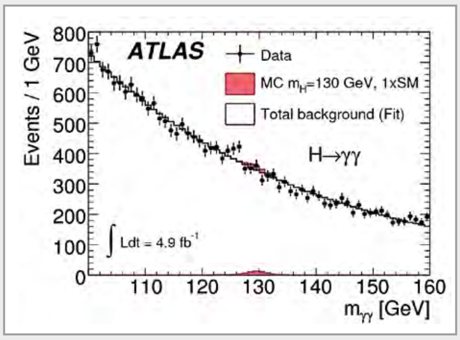


Figure 1

The diphoton spectrum measured by ATLAS using the data taken in 2011. The pink area shows what a Higgs signal at a mass of 130 GeV would look like.

Searching for the SM Higgs boson in the diphoton decay channel at the ATLAS experiment is the primary focus of the YIG. For the results published in summer 2011, the group contributed to the classification of diphoton events according to their invariant-mass resolution, which improved the sensitivity of the analysis by 15%. For the analysis of the full data set taken in 2011, the YIG focused on the measurement of the photon identification efficiency using electrons from Z boson decays, which have a similar signature in the electromagnetic calorimeter to photons.

In addition, the group is involved in an effort to improve the precise knowledge of the material budget in the ATLAS tracking detectors, which is essential to reduce the uncertainties on the photon energy measurement. It is also one ingredient for a good mass measurement of the Higgs boson, should it be found in the still-open mass range. The YIG is also contributing to the adaptation of the photon reconstruction software needed to cope with the increasing event complexity due to the higher luminosity expected for the 2012 data taking period.

To further improve the performance of the detector and cope with the large particle multiplicities and the harsh radiation environment expected after the luminosity upgrade of the LHC in 2022, ATLAS will be replacing the current tracking detectors with an all-silicon system, which will also have a lower material budget. The YIG has started to prepare a study of radiation damage in silicon microstrip detectors, which will be used for the upgraded detector.

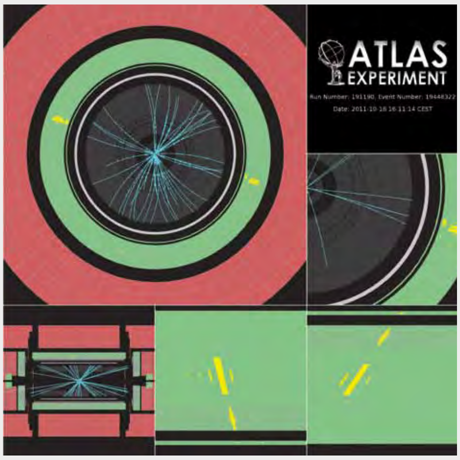


Figure 2

A diphoton event recorded in October 2011 with the ATLAS detector. The measured invariant diphoton mass is 125.8 GeV. One of the two photons is converted to electrons in the middle layer of the pixel detector and is reconstructed in the tracking system.

Reference: http://hgf.desy.de/ivf/projekte/vh_ng_701

HELMHOLTZ
| ASSOCIATION

Helmholtz Young Investigators Group

"Higgs Physics with Photons at the ATLAS Experiment" (VH-NG-701)

Contact:

Kerstin Tackmann, kerstin.tackmann@desy.de

Precision theory for Higgs with and without jets.

Sharpening our theory tools for the Higgs hunt

The search for the Higgs and other new heavy particles at the LHC is in full swing. Precise theoretical predictions for the measured cross sections including experimental selections, such as the number of observed jets, are essential to interpret the experimental results. The Emmy Noether Junior Research Group "Precision Theory Predictions for Higgs and New-Physics Measurements at the LHC" is developing and applying new field-theoretic methods to perform the required precise calculations.

Higgs bosons and other heavy particles created in proton–proton collisions at the LHC are typically produced in conjunction with a characteristic signature of hadronic jets. The experimental Higgs searches divide the data into several categories based on the number of observed jets in the event, which allows for a better background discrimination and a significant increase in the signal sensitivity. Examples are the searches in the H → WW, H → $\gamma\gamma$, H → $\tau\tau$ and H → $b\bar{b}$ decay channels. Precise predictions for the experimentally measured Higgs cross sections and the relevant background processes will be essential to interpret any observed excess and identify it as either a Standard Model(-like) Higgs particle or some other Higgs-like particle with non-Standard-Model couplings.

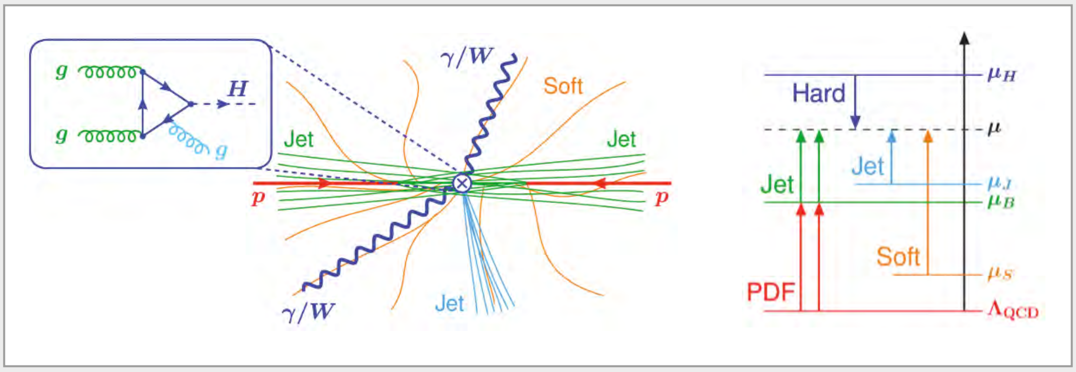


Figure 1

Left: Illustration of the different components contributing to the exclusive Higgs + 1-jet cross section, with the Higgs decaying into a pair of photons or W bosons.

Right: The natural energy scales for each of the different contributions together with their renormalization group evolution to a common renormalization scale μ.

In contrast to inclusive production cross sections, the prediction of such exclusive cross sections is more complicated, because they typically involve several different contributions that are all sensitive to different energy scales.

By employing an effective field theory description of jets and their interactions, one can break up the full cross section into smaller and more manageable pieces, each describing the physics at a specific energy scale. This is referred to as factorization and requires a detailed investigation of the theoretical properties of the employed jet observables. By performing a renormalization group evolution between the different scales, the dominant set of terms in the perturbative series for the cross section can be resummed to all orders in the strong coupling constant. This allows for precise predictions along with a detailed investigation of theoretical uncertainties. The same field-theoretic methods are also used to improve our understanding of other important aspects of hadronic collisions, such as parton distribution functions (PDFs) and the underlying event.

To enable experimentalists to directly benefit from these results, the group is also developing a Monte Carlo framework called "GenEvA" that can utilize such advanced resummed predictions including the systematic estimation of the corresponding theoretical uncertainties.

Reference: http://www.desy.de/~frank/emmy.html

DFG

Emmy Noether Junior Research Group
"Precision Theory Predictions for Higgs and
New-Physics Measurements at the LHC"

Contact:
Frank Tackmann, frank.tackmann@desy.de

CMS: Physics of the top quark.

Measurements of the quark at the LHC are starting to constrain theory

In the first two years of operation, the LHC has proven to be a true top-quark factory. During the 2011 run, LHC collisions produced more than 600 000 top-quark pairs, a multiple of the number of events created at the Tevatron. Recent measurements are challenging or even exceeding the precision of theoretical calculations. The DESY CMS group has pioneered measurements of differential cross sections of top-quark pairs and the extraction of the top-quark mass from the measured cross section.

In recent years, measurements of top-quark production cross sections and properties have played a major role in testing the Standard Model (SM) and in searches for new physics. For the first time at the LHC, the top-quark pair production rate is sufficiently high to measure differential cross sections as a function of top-quark-related quantities with high precision. These measurements provide key ingredients to verify the production mechanism in this new energy regime within the scope of the SM and perturbative quantum chromodynamics (QCD). Further, many scenarios beyond the SM, for example decays of massive Z-like bosons, could be uncovered in such measurements, most prominently as narrow resonances in the top-quark pair invariant-mass spectrum.

In 2011, the DESY CMS group performed the first measurement of differential top-quark pair cross sections in the dilepton channel, in which the top-quark pairs decay into a final state with two isolated leptons (muons or electrons) of opposite charge and two jets. The momenta of the top quarks are reconstructed using a kinematic algorithm, and the differential cross section is measured as a function of

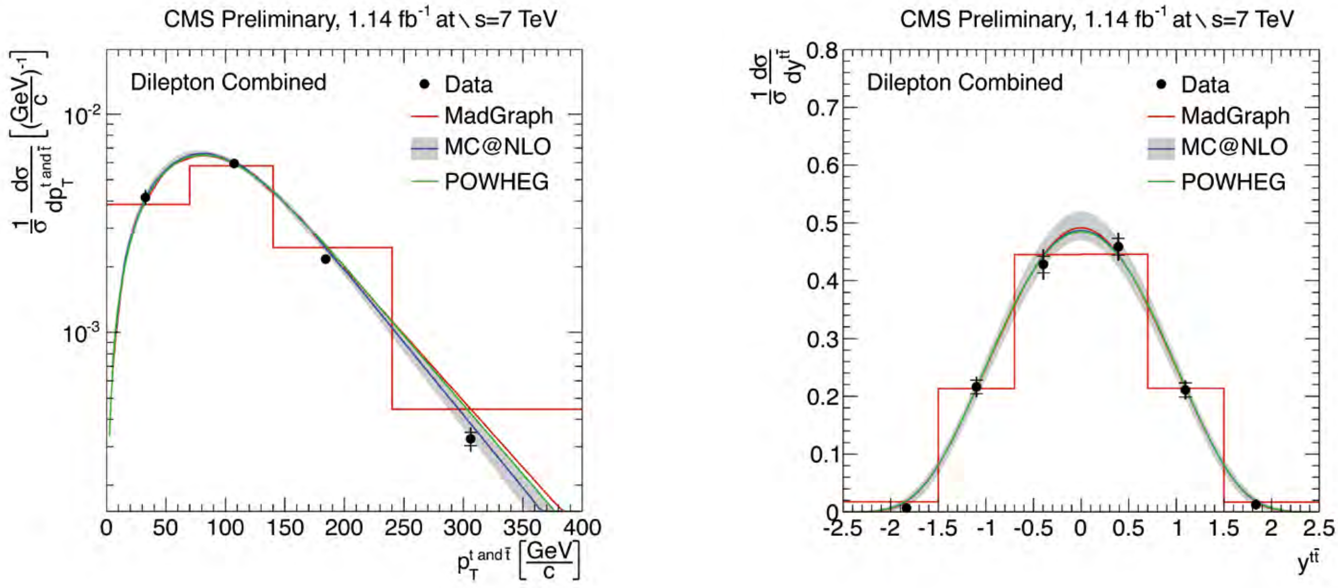


Figure 1

Differential cross section of top-quark pair production at 7 TeV as a function of the transverse momentum of the top quark (left) and the rapidity of the top-quark pair (right)

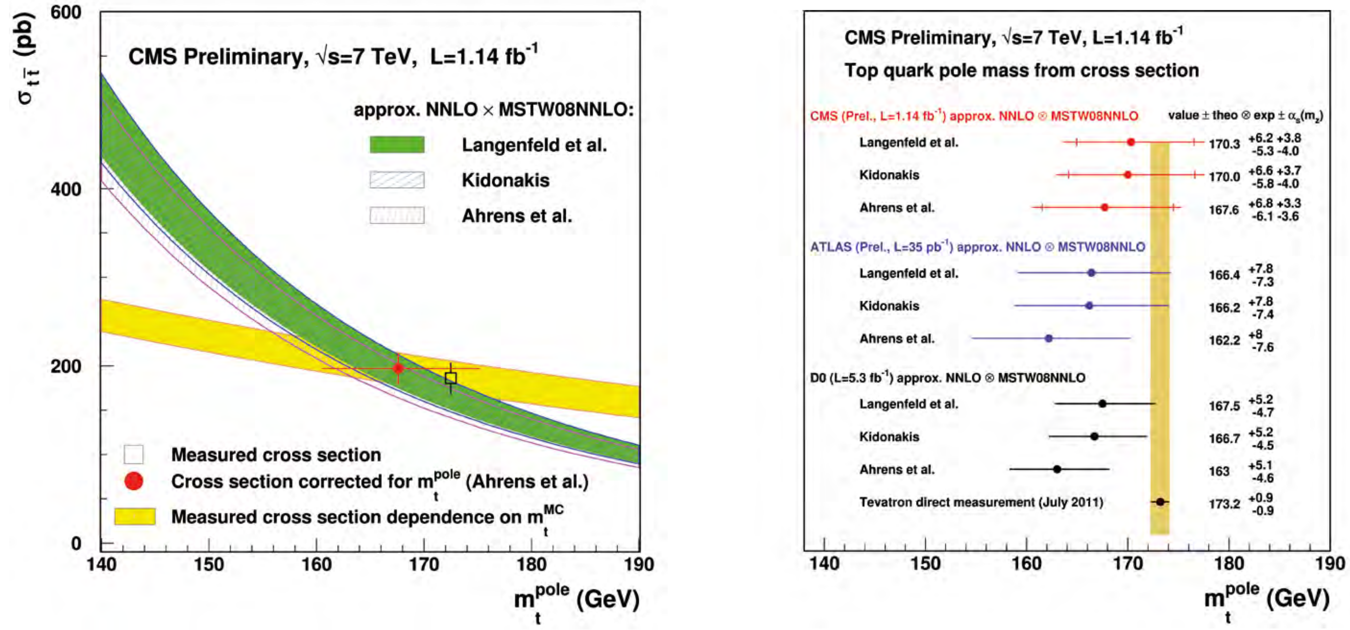


Figure 2

Left: Top-quark pair cross section as a function of the top-quark mass. The closed circle represents the cross section measured by the CMS experiment. The experimental dependence of the measured cross section on the top-quark mass is shown as a yellow band. Different higher-order QCD predictions are shown as hatched bands.
Right: Top-quark pole mass, as extracted from the measured cross section, compared to results from the D0 and ATLAS collaborations. The direct top-quark mass world average is also shown.

several variables from the number of events in each bin, correcting for detector acceptances, efficiencies and resolutions (Fig. 1).

The top-quark mass (m_t) is a crucial parameter of the SM. A precise measurement of this quantity is one of the most important inputs to global electroweak fits that provide constraints on the properties of the Higgs boson, as well as on models for physics beyond the SM.

In higher-order QCD calculations, the mass of the top quark depends on the renormalization scheme and its value can differ considerably, e.g. for pole mass or $\overline{\mathrm{MS}}$ mass definitions. Therefore, it is important to understand how to interpret the experimental result in terms of the renormalization conventions. Direct measurements of m_t rely on the reconstruction of kinematic observables sensitive to m_t. These measurements depend highly on the detailed description of the corresponding signal and top-quark mass m_t^{MC} in Monte Carlo (MC) simulations.

Alternatively, the top-quark mass can be derived indirectly from the cross section measurement. The group at DESY used the inclusive top-quark pair production cross section measured by CMS in the dilepton channel to extract the top-quark mass through its comparison to three different fully inclusive calculations at higher-order perturbative QCD, which provide an unambiguous definition of m_t. The extraction provides an important test of the mass scheme as applied in MC simulations and gives complementary information, with different sensitivity to theoretical and experimental uncertainties than direct measurements of the top-quark mass m_t^{MC}, which rely on the kinematic details of the mass reconstruction. The results, both for the pole mass (Fig. 2) and the $\overline{\mathrm{MS}}$ mass definitions, are in very good agreement with similar measurements at the Tevatron and from ATLAS, and provide, for the first time, the determination of the $\overline{\mathrm{MS}}$ mass at the LHC.

Contact:

Maria Aldaya Martin, maria.aldaya@desy.de

References:

http://cms.desy.de/e53612/e90820/
[1] CMS Collaboration, TOP-11-013,
http://cdsweb.cern.ch/record/1422425/files/TOP-11-013-pas.pdf
[2] CMS Collaboration, TOP-11-008,
http://cdsweb.cern.ch/record/1387001/files/TOP-11-008-pas.pdf

The CMS pixel detector upgrade.

Production, test and calibration of a 17-million-pixel detector at DESY

To ensure that the superb physics performance of the CMS detector is maintained as the LHC luminosity increases in the coming years, the detector will be improved and refurbished in a staged programme in parallel with data collection. The first stage is foreseen for 2016, when the LHC will have reached design luminosity and the CMS vertex detector will be operating close to its performance limit and nearing the end of its expected lifetime. After 2016, the luminosity will continue to increase. If the detector were left in place, it would be forced to operate outside of its specifications and in a radiation-damaged state. It will therefore be replaced with an improved version currently under design, during a four- to five-month-long LHC technical stop planned for the end of 2016. DESY, together with the German universities involved in the CMS barrel pixel upgrade, will contribute by building the outermost layer. This article describes the preparation for the production, quality control and calibration of the planned detector.

The CMS pixel detector

The current CMS pixel detector consists of three barrel layers placed concentrically around the beam pipe and two end-cap disks which extend the detector coverage along the beamline on either side. The pixel detector is the innermost detector of CMS and the first to measure particles emerging from the interaction point. It was designed to operate with collision rates up to the LHC design luminosity of 10^{34} $cm^{-2}s^{-1}$, which, according to expectations, will be achieved in 2016. Afterwards, the luminosity is expected to grow by an additional factor of two. As the luminosity increases, the detector will suffer from performance limitations and radiation damage, particularly as the luminosity increases beyond the design value. It is therefore planned to replace the current system with a newly designed pixel detector comprising four barrel layers and three end-cap disks on either side. Figure 1 shows the old and the new barrel pixel detector in a radial view.

Thanks to a smaller beam pipe, the first measurement point of the new pixel detector will be closer to the beam than in the present detector. The detector will also extend to a larger

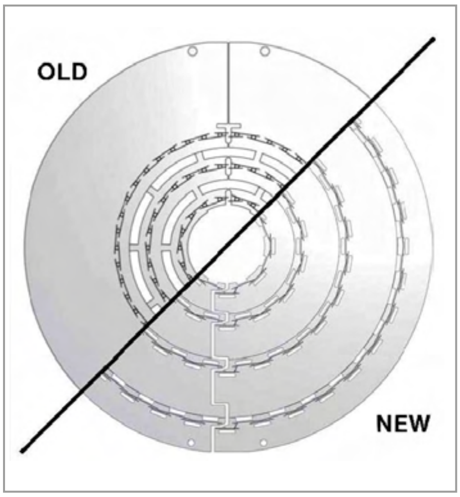


Figure 1

Radial view of the current and new barrel pixel detector

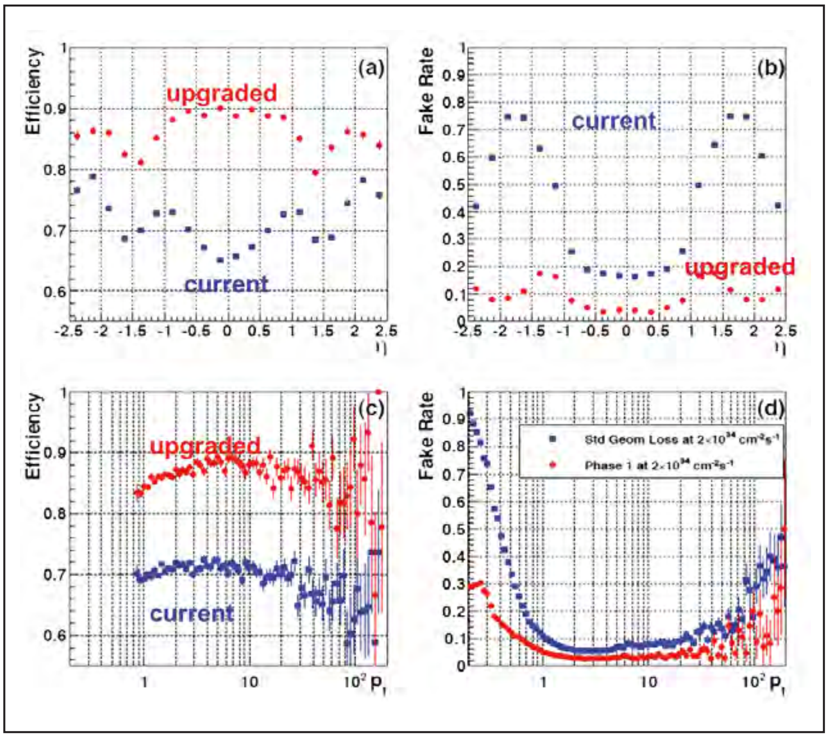


Figure 2

Comparison of the track efficiency and fake rate of the new and current pixel detector for $t\bar{t}$ events at $2\text{x}10^{34}$ $cm^{-2}s^{-1}$

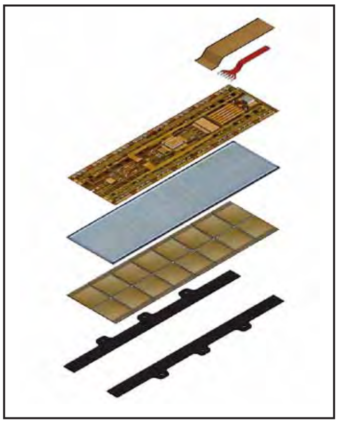


Figure 3

Exploded view of the current barrel pixel module

Figure 4

CMS pixel sensor in the DESY test beam

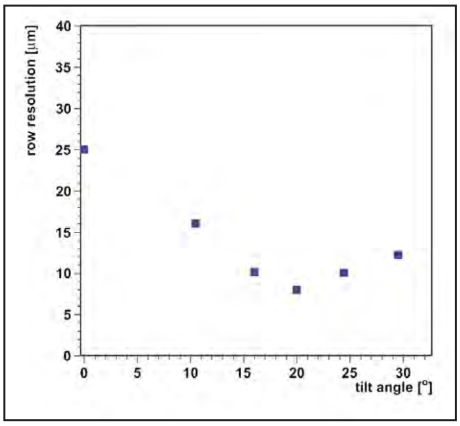


Figure 5

Resolution of a CMS pixel sensor measured in the DESY test beam as a function of the incident angle of the incoming beam

radius because of the additional fourth layer. Despite this additional layer, a substantial net reduction in the material budget will be realized thanks to new support materials, a lightweight cooling system and improved readout cables. In total, the new pixel detector will achieve a substantially improved track parameter precision. Figure 2 compares the track efficiency and fake rates of the current and the upgraded pixel detector at twice the LHC design luminosity.

Figure 3 shows the basic element of the pixel detector, the pixel module with its three major components, in an exploded view: the sensor in the middle, the readout chips at the bottom and the readout hybrid, called “high-density interconnect” (HDI), on top.

A sensor consists of 52x80 pixel cells. The 2x8 pixel sensors of the module are connected to the corresponding readout chips by way of solder bumps on the bottom side. The HDI is glued to the sensor on the top and has wire bond connections at the edge to the readout pads of the readout chips. Eight of these modules are then connected in a row to form a part of a barrel layer. Depending on radius, a barrel layer will be built from 12, 28, 44 or 64 such rows. The new barrel pixel detector will be composed of nearly 1200 modules with about 79 million pixels, of which 512 modules with 34 million pixels will be located in the outer layer. To reduce the material budget, the support structures for the new pixel detector will be made from lightweight carbon structures and cooled by a highly efficient evaporative CO_2 cooling system. The readout capability of the new readout chip will be improved to allow for higher LHC collisions rates with no increase in dead time.

Building, testing and calibration of modules

In cooperation with the German universities of Aachen, Hamburg and Karlsruhe, DESY will contribute to the new barrel pixel detector by building the outermost layer, consisting of 512 modules with 2x8 sensors each. One half of the modules will be built, tested and calibrated in close cooperation by DESY and the University of Hamburg; the other half will be done in Aachen and Karlsruhe. The assembly of the fourth layer will be carried out at DESY.

The first step in the module production will be the testing and characterization of the delivered sensors. This will be followed by the bump bonding of the readout chips to the sensor module (with the help of the DESY-FE group). (For a detailed description of the process and the preparations for production, see page 102.) The resulting bare modules will then be tested and quality-controlled. Next, the HDI will be glued to the sensor and wire-bonded to the readout chips in the DESY electronics service centre. The completed module will then undergo several tests, including thermal cycling stress tests, and a full calibration of its readout parameters before assembly into the half-shell.

The test and calibration procedures are presently being commissioned at DESY with the current pixel sensors, and the module test infrastructure is being installed. As an example of the tests performed, Fig. 4 shows the test board and a current pixel chip in the DESY 6-GeV electron test beam. The test board is mounted between the EUDET telescope planes on a rotating frame which allows tilting of the sensors by up to 30° with respect to the beam axis. Figure 5 shows the measured resolution versus the tilt angle of the module to the incident beam.

The test and calibration procedures will be ready for testing the first prototype of the new readout chip when it arrives in the summer of 2012. The full module production line must be ready by the end of 2013 to allow for module production in 2014 and 2015. The fully tested, calibrated and assembled half-shells will then be transported to CERN for system integration and extensive full system tests prior to installation in CMS, which is currently foreseen for the LHC technical stop starting at the end of 2016.

Contact:

Günter Eckerlin, guenter.eckerlin@desy.de
Daniel Pitzl, daniel.pitzl@desy.de

Target tailoring.

Design, fabrication and characterization of plasma targets for plasma wakefield optimization

The creation of GV/m electric fields for particle acceleration in strong wakefields requires the development of centimetre-scale plasma structures. Currently, plasma media are employed to generate femtosecond-duration electron bunches with GeV energies. To control this process, precise knowledge and tailoring of the plasma density distribution is crucial. The upcoming plasma accelerator experiments at FLASH and REGAE, performed as part of the LAOLA collaboration [1] programme, represent a challenge in this respect owing to the necessity of operating their plasmas in low-density regimes.

Relativistic particle acceleration in plasmas

Plasma-based acceleration of charged particles is a novel concept that has shown remarkable progress in recent years, as demonstrated by the acceleration of high-quality electron beams to GeV energies [2]. Electric-field gradients that can be realized exceed 10 GV/m, which is two to three orders of magnitude higher than those achievable with RF accelerators. These enormous accelerating fields are generated by either high-intensity laser pulses or high-current-density particle beams propagating through a plasma, where they push away the plasma electrons, causing a strong charge separation in the tail of the drive beam. This results in a co-propagating plasma wave, known as a wakefield. Achieving controlled particle insertion and efficient acceleration requires control over and precise knowledge of the background plasma density, which determines the plasma wavelength.

Our group focuses on modelling, fabrication and characterization of suitable plasma targets. These targets typically consist of a cylindrical capillary with a diameter of a few hundred micrometres and a length of a few centimetres.

Modelling of design ideas

The open-source, 3D fluid simulation code OpenFOAM is employed for initial modelling of the gas flow through the targets. Capillary shapes with multiple gas in- and outlets can be designed and the time dependence of the resulting gas density profile along the driver beam propagation axis can be modelled.

An example of such a target with a horizontal driver beam direction, a free-flow gas jet and two gas inlets in the vertical axis is shown in Fig. 1. The free-flow jet is implemented to act as an electron injection stage. It increases the gas density at a specific location, which allows for controlled electron trapping at the location of the generated steep density down-gradient. The constant-density region further downstream between the two main gas inlets fulfils the role of a booster stage, increasing the energy of the injected electrons.

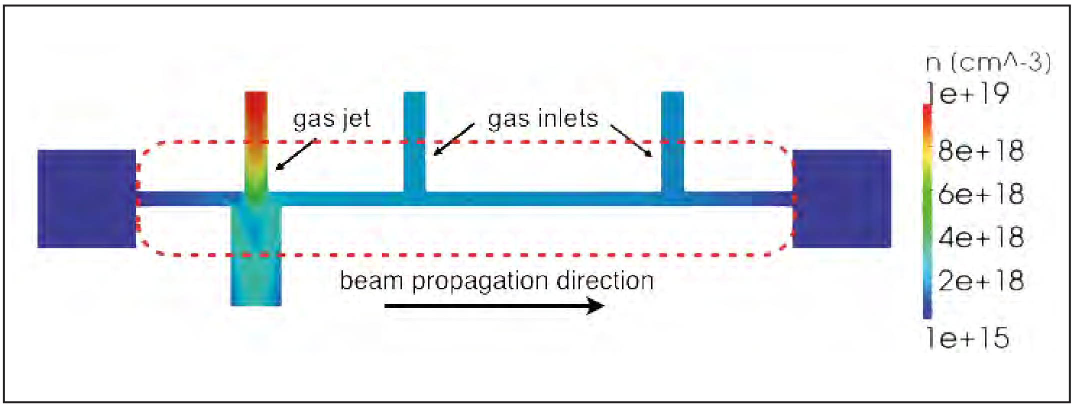


Figure 1

Simulated gas density profile (colour-coded) inside a capillary (horizontal direction) with two gas inlets, a free-flow gas jet (vertical direction) and vacuum on both capillary ends (blue boxes at capillary ends). Physical capillary dimensions are indicated by the red dashed box. The driver and generated electron beam are propagating along the horizontal direction (from left to right).

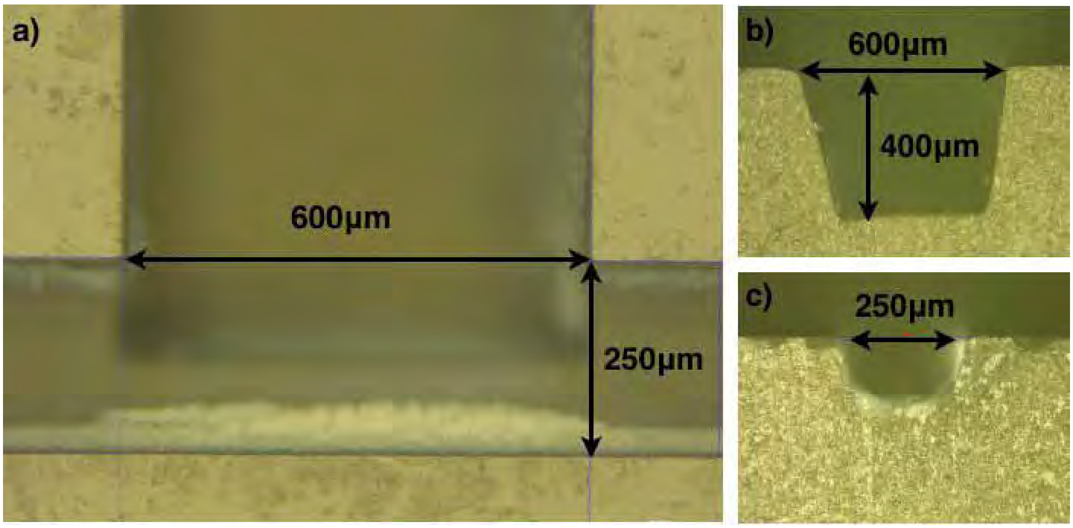


Figure 2

a) Side view of a small section of a machined sapphire capillary in horizontal direction and a gas inlet from the top, b) cross section of a gas inlet and c) capillary

Laser machining of sapphire capillaries

After the design has been simulated and refined, capillary shapes are machined into blocks of sapphire using ablative femtosecond laser machining. To allow for easier access with the machining laser, the capillary is split in two halves along the main channel, so each half can be fabricated independently. Afterwards, both halves are put together to form the final plasma container. Thus, quasi-three-dimensional capillary and gas inlet shapes, profiles and configurations can be realized.

A magnified gas inlet section of the modelled capillary from Fig. 1 is shown in Fig. 2a. The bright parts depict the non-machined surfaces, the darker regions are the machined channels, which are slightly out of focus. The white residue in the lower part of the image is produced by leftovers from the ablation process and can easily be removed. The gas inlet (Fig. 2b) joining from the top has a different depth (about 400 µm) and profile from the main capillary, which is a semicircle with a diameter of 250 µm (Fig. 2c).

Absolute density at a new level of sensitivity

Characterization of the machined capillaries and benchmarking of the OpenFOAM simulation is performed with a combination of two independent detection techniques: interferometry and Raman side scattering, as illustrated in Fig. 3. These methods are established diagnostic schemes in the plasma density regime above 10^{18} cm^{-3}, in which current plasma accelerators operate [3]. However, next-generation plasma accelerators and also the planned accelerator experiments at REGAE and FLASH at DESY will require the detection of plasma and thus gas densities of 10^{17} cm^{-3} and lower, a regime in which established diagnostics must operate at hitherto unachieved sensitivity.

We are utilizing longitudinal interferometry to measure laser fringe shifts (Fig. 3b) resulting from the change of the refractive index along the capillary, which can be converted to an average gas density. The second diagnostic technique, Raman scattering, is a non-resonant method in which the scattering signal is proportional to the gas density. Hence, a spatially resolved density distribution along the capillary can be obtained through observation in transverse direction, as shown in Fig. 3a. By combining both measurements, a high-sensitivity absolute calibrated spatial gas density map can be obtained.

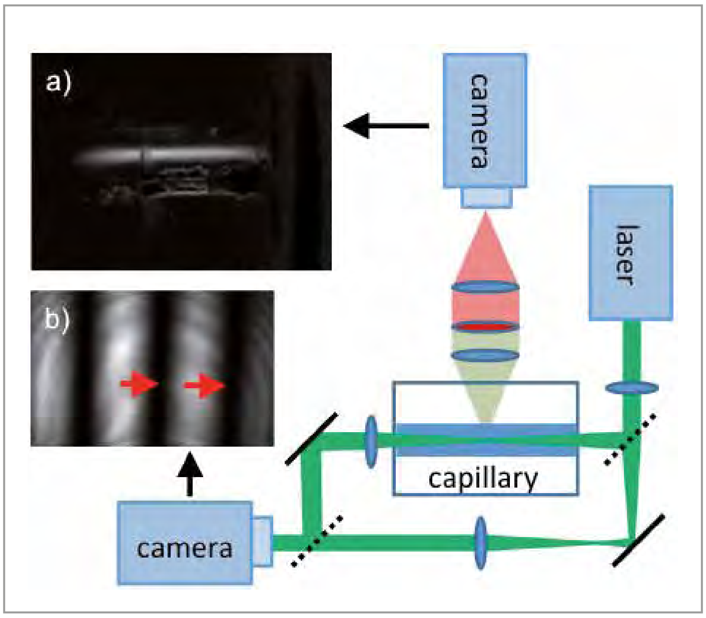


Figure 3

Experimental diagnostic setup with a) Raman and b) interferometry data. In a) a typical raw signal obtained in the constant-density region of a capillary is shown. b) depicts an example of interference fringes, which shift (indicated by red arrows) with changing gas density inside the capillary.

Contact:

Lucas Schaper, Lucas.Schaper@desy.de
Jens Osterhoff, Jens.Osterhoff@desy.

References:

[1] See “DESY Accelerators 2011 Highlights and Annual Report” for more details
[2] W.P. Leemans et al., Nat. Phys. 2 (2006), 696
[3] S. Kneip et al., Phys. Rev. Lett.103 (2009) 035002

Simulating strong wakes in plasma.

Preparing for unique plasma wakefield experiments at DESY

The acceleration of charged particles in plasma wakes has seen tremendous progress in the last ten years, which led to the recent inclusion of this emerging field into the DESY research programme with experiments planned by the LAOLA collaboration [1] in Hamburg and Zeuthen. These unique laser- and beam-driven plasma wakefield acceleration experiments require extensive simulations to understand the large variety of effects that will be accessible for experimental studies for the first time. Among these investigations will be the controlled injection of an electron bunch into a laser-driven wake at REGAE and the study of plasma wakefield-induced electron beam self-modulation effects at PITZ.

Laser-driven wakefield acceleration

Laser plasma wakefield acceleration (LPA) exploits the fact that short, intense laser pulses focused onto a gas target excite wakes with electric gradients that are orders of magnitude higher than in conventional accelerators. These fields can be used to accelerate charged particles.

One of the key issues in LPA is to control the injection process of electrons into a wake, which in the common wave-breaking regime might be unstable and difficult to manipulate. Our aim is to inject externally accelerated and tailored beams from a conventional accelerator into a laser-driven wake for full control of the electron trapping process. These experiments will open numerous opportunities for probing wakefields and exploring fundamental properties of laser plasma interaction and electron acceleration. Moreover, external injection experiments are of crucial importance for exploring the “staging” principle, in which several LPA modules will be used in serial configuration to reach higher electron energies.

Particle-in-cell simulations of a laser-driven wake with external bunch injection were performed (Fig. 1a), with parameters matched to the future experimental setup of the Relativistic Electron Gun for Atomic Exploration (REGAE), delivering ~5 MeV bunches of ~10 fs length. With laser pulses of 1.2 J energy, 25 fs pulse duration, and a normalized vector potential of $a_0 = 1.8$, the bunch can be accelerated to about 22 MeV over 8 mm distance, with a relative energy spread not exceeding 5%, as shown in Fig. 1b.

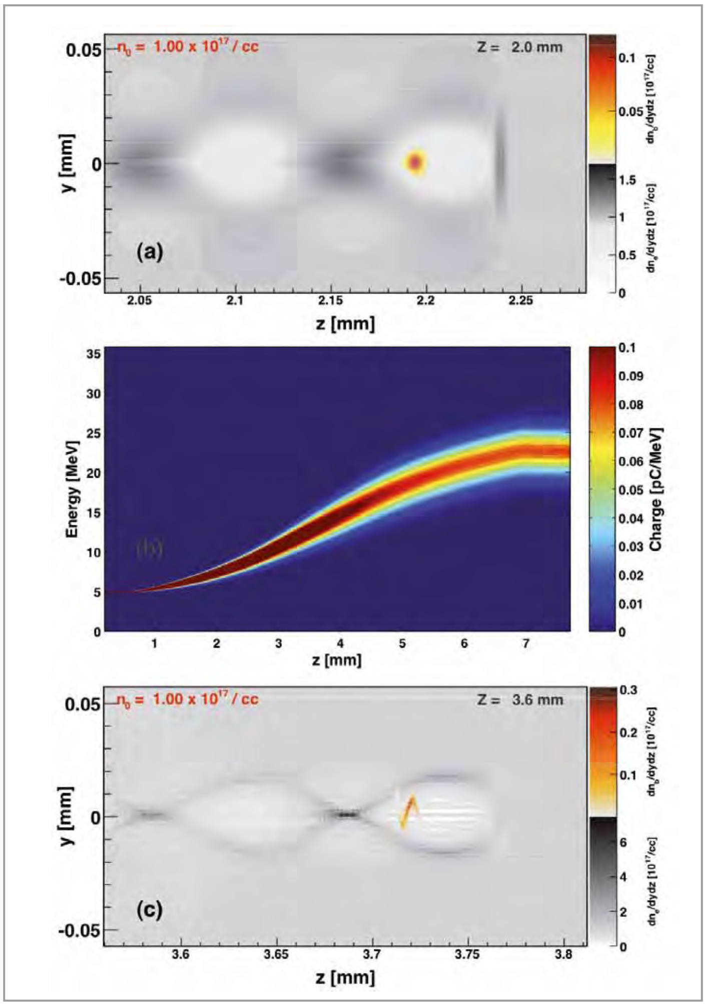


Figure 1

OSIRIS 2.0 particle-in-cell simulations of an electron bunch, externally injected into a laser-driven wakefield (a). The trapped electron bunch can be accelerated to about 22 MeV over 8 mm distance (b). In case of off-axis bunch placement, it can undergo collective betatron oscillations (c). The parameters of the simulations are matched to reproduce future experiments at REGAE.

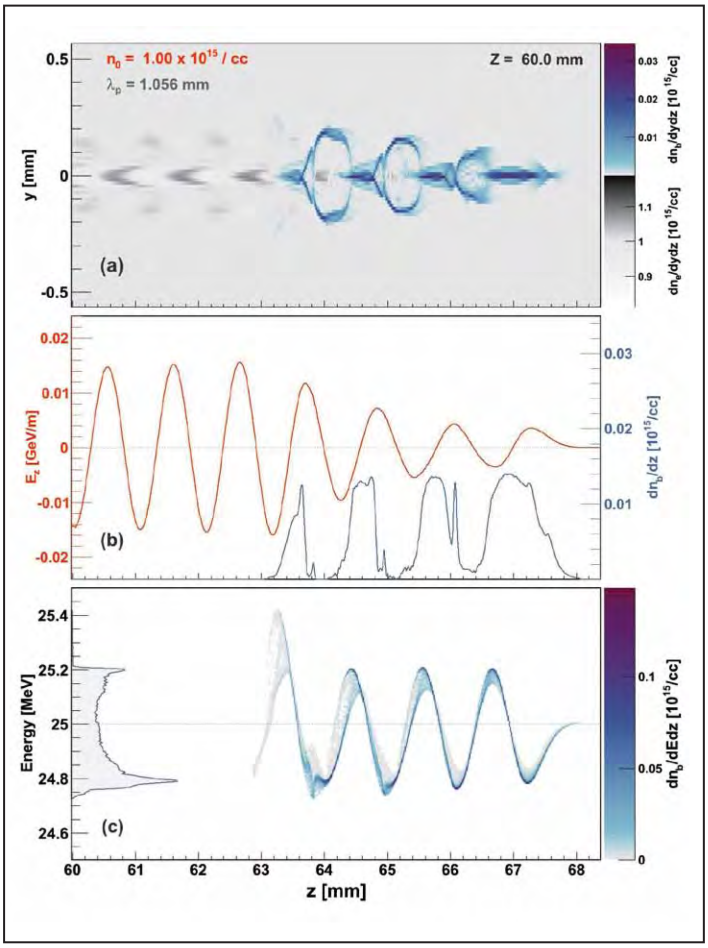


Figure 2

OSIRIS 2.0 particle-in-cell simulation of the PITZ flat-top electron beam self-modulated after 6 cm of propagation in plasma (a). Longitudinal wakefields and charge density of the bunch on the propagation axis (b). Energy spectrum of the bunch (c).

External injection enables the selection of a dedicated phase in the wake and thus, by measuring the electron beam quantities at the exit of the LPA module, allows for probing of the wakefield itself. Furthermore, the external injection scheme allows accurate bunch off-axis placement into the wakefield. Such a bunch can then undergo controlled collective betatron oscillations inside the transversally focusing phase (Fig. 1c), which results in the emission of intense synchrotron radiation. The accessible degrees of freedom for phase-space population provide extensive control over betatron trajectories and thus the precise shaping of the emitted radiation spectrum. This may open up the door for tailored, small-scale, high-peak-brightness light sources up to the multi-keV range.

Another crucial topic for LPA is the evolution of the bunch emittance, e.g. for high luminosity in particle colliders. Minimum emittance is a prerequisite for LPA staging. Initial simulations showed that a large fraction of the time-projected emittance growth was due to rotation of the sliced phase-space ellipses with respect to each other. Further studies and future external injection experiments will help to obtain a fundamentally better understanding of the reasons and contributions towards beam emittance growth.

Self-modulation of long electron beams in plasma

Intense wakefields in plasma can also be excited by charged particle beams. In this process, the energy gain of a trailing witness bunch riding the wakefield directly depends on the energy of the driving bunch. This led to speculations to use current accelerator facilities with proton beam energies close to a TeV for the acceleration of electrons up to TeV energies in just one single plasma stage. However, the available high-energy bunches are much longer than the wavelength of the accelerating plasmas (λ_p). The creation of strong accelerating gradients relies on the fact that the beam becomes self-modulated along the plasma, splitting into ultrashort sub-bunches separated by ~λ_p, which can then resonantly build up the high-amplitude plasma wave.

The Photo Injector Test Facility at DESY in Zeuthen (PITZ) offers the possibility to study and demonstrate the self-modulation of comparatively long electron bunches in plasma. PITZ can generate high-quality electron beams with 25 MeV energy and a few millimetres length with a constant peak charge density of 10^{13} cm^{-3} and low emittance. The use of particle-in-cell techniques allows the simulation of the actual conditions of the PITZ beam propagating through a plasma electron channel of 10^{15} cm^{-3} (λ_p = 1 mm).

The effect of the self-modulation can be clearly seen in Fig. 2a, in which the initially uniform (flat-top) electron bunch is modulated after 6 cm of propagation in the plasma due to the combined effect of focusing and defocusing wakefields. Accordingly, Fig. 2b depicts how the beam charge density on the propagation axis splits into several sub-bunches (blue line), which resonantly create a wake of longitudinal electric fields with peak values of around 0.02 GeV/m (red line). These wakefields are strong enough to induce in the electron beam a sizable and measurable modulation in energy, which exactly follows the longitudinal wakefield structure (Fig. 2c).

First measurements of the self-modulation of long flat-top beams at PITZ are foreseen by the end of 2012. They will provide, for the first time, an experimental proof of principle for future beam-driven wakefield acceleration experiments with long particle beams.

Contact:

Jens Osterhoff, jens.osterhoff@desy.de

Authors and reference:

Julia Grebenyuk, julia.grebenyuk@desy.de
Alberto Martínez de la Ossa, alberto.martinez.de.la.ossa@desy.de
Timon Mehrling, timon.mehrling@desy.de

[1] See “DESY Accelerators 2011 Highlights and Annual Report” for more details

Gauging ultrabright electron beams.

Exploring the afterglow

Electron beams driving X-ray free-electron lasers need to be of exceptional quality in terms of charge density, energy spread and emittance. The same features which are mandatory for the lasing process cause trouble for one of the most widespread and universal beam diagnostic techniques: imaging the beam profile using optical (visible) transition radiation. The highly compressed electron bunches tend to develop self-sustaining microstructures which in turn lead to coherent radiation emission. The coherent optical transition radiation outshines the normal incoherent image by orders of magnitude but does not reveal important information on the bunch profile. We present a powerful method to mask out the coherent radiation flash by delayed imaging and demonstrate that beam diagnostics can be successfully restored using this technique.

The operation of short-wavelength free-electron lasers (FEL), such as FLASH at DESY, LCLS at SLAC (USA) and SACLA in Japan, or the many other facilities under construction, such as the European XFEL or the SwissFEL, rely on electron beams with extremely high brightness. At high energies, the electrons are compressed into small packets (bunches) with micrometre dimensions, low divergence and small energy spread. The extremely dense swarm of charged particles in these bunches acts as the laser medium for the FEL process.

The same distinguishing properties of the bunches create severe problems for one of the most widespread and universal methods of beam diagnostics: imaging using optical transition radiation (OTR). Transition radiation (TR) is produced whenever a highly relativistic particle beam traverses the boundary between two media with different dielectric constants. The spectrum of the TR extends from microwaves into the ultraviolet region. The radiation in the visible wavelength range (OTR) can easily be observed using conventional CCD cameras. It offers a quite simple but nevertheless powerful tool to gauge the transverse profile of the beam. A thin metal screen oriented at 45° to the path of the bunches acts as an optical boundary, emitting the OTR light perpendicular to the beam direction. Under "normal" conditions, the luminous spot on the screen perfectly reveals the charge distribution of the electron beam, because the "point spread function" of OTR at high beam energies is small and the local intensity is proportional to the local charge density. OTR imaging can be used not only to observe the transverse profile of single bunches, but also, in combination with dispersive magnets and transverse streaking resonators, to measure the energy distribution and longitudinal profile of single bunches.

COTR: the problem

As first observed at LCLS and soon confirmed at many other FEL facilities, the "brilliant" properties of the highly compressed electron bunches lead to effects rendering all OTR-based measurements impossible. Instead of reliably imaging the bunches, the OTR light is suddenly observed as enormously bright flashes which not only blind the camera systems, but flicker and are extremely irregular in nature. As shown in Fig. 1, the observed images exhibit typical interference structures and warped doughnut-like shapes that have nothing in common with the actual bunch profile.

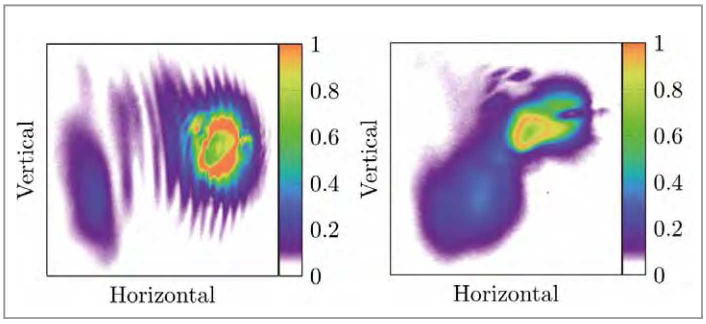


Figure 1

Typical examples of beam "images" in the presence of coherent visible-light (COTR) emission

The reason behind this is a phenomenon called "microbunching instability". The extreme Coulomb field inside the dense bunches, together with the magnetic compression schemes employed by FELs, causes self-amplifying micromodulations inside the bunch [1]. The distribution of the electrons is no longer purely random, but starts to exhibit "patterns" with a broad spectrum of periods. If this happens, the TR starts to comprise a coherent component that exceeds the normal incoherent part by a factor equal to the number of particles involved in the microbunching patterns. Since the total number of particles in a bunch is typically a few times 10^9, even a tiny self-modulation of the bunch creates dramatic effects.

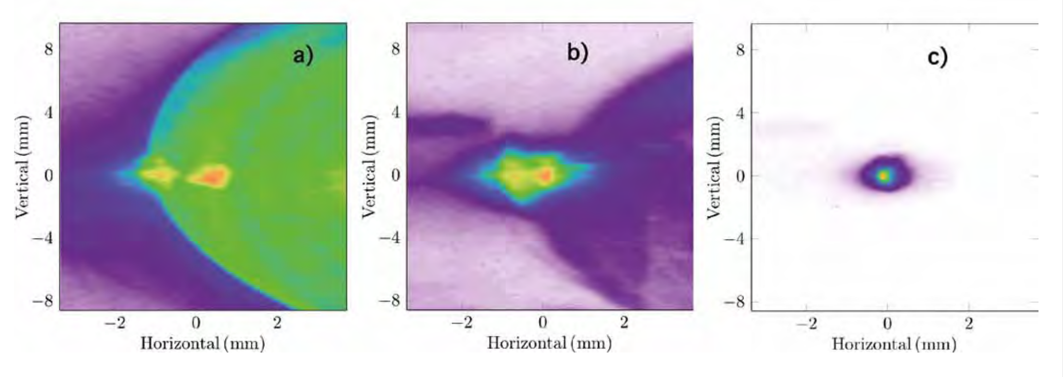


Figure 2

Images of electron bunches in the presence of strong coherent emission: a) normal metallic OTR screen, b) scintillator screen and c) scintillator screen and image delayed by 200 ns after the passing of the bunch. While a) and b) are clearly spoiled by coherent radiation flares, the delayed image c) shows the undisturbed charge profile of the electron bunch.

COTR: remedies

A variety of methods to mitigate or even completely avoid the problem of coherent optical transition radiation (COTR) emission have been discussed and explored during the past years. A special one which proved to be exceptionally successful will be outlined here.

At LCLS, a so-called laser heater is used to deliberately increase the uncorrelated energy spread (the “temperature”) of the bunches. As a consequence, microstructures at short wavelengths are smeared out and the emission of COTR is strongly suppressed. Despite the effectiveness of the method, it does not completely erase the coherent effects which render image-based diagnostics impossible.

Since the excitation of scintillation light is a purely statistical process completely unaffected by the internal structure of the bunch, the use of scintillation screens replacing the metallic OTR targets promises undisturbed imaging. Unfortunately, OTR light is produced at any dielectric boundary and thus at the surface of the scintillator, and because of its extreme intensity, it can easily outshine the scintillation light.
One way to separate COTR and scintillation light is to exploit their very different geometrical emission characteristics. While scintillation light is emitted isotropically, COTR light is concentrated in a cone around the specular direction of the screen with respect to the incident electron beam. Thus, imaging the screen from well outside this cone or blocking the cone by appropriate masks strongly suppresses the COTR light reaching the imaging system. But because the COTR intensity can exceed the incoherent light by many orders of magnitude, even weak tails of the radiation distribution cause severe problems.

At DESY, we explored another, rigorous method to completely block the COTR flash by temporal separation. COTR emission is an instantaneous process, and the duration of the COTR light pulse corresponds to the length of the electron bunches, typically less than a few picoseconds. Scintillation light, on the other hand, originates from excited atoms with a decay time of several hundred nanoseconds. If a high-speed camera that can be gated at the nanosecond level is used instead of conventional CCD cameras, the scintillator image can be observed after a delay when the COTR flash has died out completely.

The success of this technique is demonstrated in Fig. 2. While the instantaneous pictures from both the OTR screen (a) and the scintillator (b) exhibit strong COTR flares which completely overwhelm the incoherent image, the scintillator image (c) taken 200 ns after the passage of the electron bunch reveals the true beam image. Using this delayed technique, image-based diagnostics, for instance, for measuring the longitudinal profile of the bunches using a transverse streaking resonator, becomes possible again. As an example, Fig. 3 shows the bunch length as a function of the “compressor phase”, measured with three imaging screens. While the delayed-image technique is in perfect agreement with the reference method (called ES-CCD), non-delayed scintillator images are completely useless for bunch lengths below about 250 fs.

After the delayed-image technique has shown its effectiveness in these groundbreaking experiments, it will now be refined and optimized to be used at FLASH and the European XFEL.

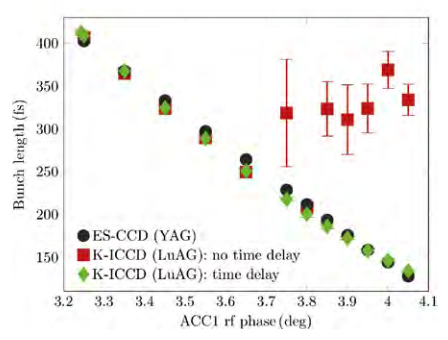


Figure 3

Electron bunch length measured with three different imaging methods. ES-CCD is a reference method using a dispersive energy spectrometer with no coherence effects present. K-ICCD is a screen in the normal beamline. The non-delayed method is spoiled by strong coherent radiation emission for bunches shorter than 250 fs.

Contact:

Bernhard Schmidt, bernhard.schmidt@desy.de

Authors and references:

Minjie Yan, Christopher Behrens

[1] E.L. Saldin, E.A. Schneidmiller and M.V. Yurkov, Nucl. Instr. Methods A 398, 373 (1997)
[2] M. Yan, C. Behrens, Ch. Gerth, G. Kube, B. Schmidt and S. Wesch, Proc. 10th DIPAC, Hamburg, Germany, TUPD59 (2011)

Optical inspection.

A closer look at superconducting cavities

The International Linear Collider (ILC) is entering the final phase of the Global Design Effort, which will culminate in the technical design report slated for publication in 2012/13. The ILC will be an e^+e^- collider with centre-of-mass energies of initially 500 GeV and upgradeable to 1 TeV. Electrons and positrons will be accelerated by superconducting RF cavities operating at 1.3 GHz using the same technology that is employed for the European XFEL, which is under construction at DESY in Hamburg. As the mass production of cavities for the European XFEL begins, the ILC team is commissioning an optical inspection tool, called OBACHT, which has been developed in the European Framework Programme ILC-HiGrade. Supplemented by 24 ILC-HiGrade cavities, the inventory of 800 cavities for the European XFEL will contribute to an increase of the accelerating field of niobium cavities to values well exceeding the 31.5 MV/m foreseen for the ILC and almost 50% above the requirement for the European XFEL.

Start of cavity production

Over the past few years, the European XFEL team has elaborated and refined the production procedure of the TESLA collaboration [1] for superconducting RF cavities. 800 cavities will be manufactured by industrial partners and eventually serve to accelerate electrons to energies of up to 17.5 GeV. DESY will perform RF tests of the cavities in a vertical cryostat, while the Saclay partner institute will assemble the cavities into cryomodules. These cryomodules will then be lowered into the tunnel of the European XFEL. Figure 1 shows a string of cavities during assembly.

International Linear Collider

Based on the support grant ILC-HiGrade [2] of the Framework Programme 7 of the European Commission, 24 additional cavities will be produced in the same fashion to allow for detailed investigation of their performance limitations and to explore ways to increase the accelerating field for the ILC. The ILC is completing its R&D phase for the design of a 500-GeV centre-of-mass e^+e^- collider, which will be extendable to 1 TeV. The findings will be compiled in the technical design report, scheduled for release in early 2013. An interim progress report [3] was issued in 2011, documenting the tremendous progress achieved in the understanding of the gradient limitations of superconducting RF cavities: the yield of high-performance cavities has been boosted considerably; it is now conceivable that gradients of 45 MV/m can be achieved – a value that was adopted as the baseline for the studies of a 1-TeV collider. The cavities and cryomodules are the biggest cost drivers for the ILC and naturally in the focus of R&D efforts.

Limitations in superconducting RF cavities

The very high quality factor ($>10^{10}$) of superconducting RF cavities leads to high power efficiency for long pulses. The axial accelerating electric fields can be increased to the maximum value of the associated magnetic field (critical field) on the surface of the superconductor, which sets the fundamental performance limit for the technology. Small surface irregularities may cause these fields to locally exceed the critical value and cause a quench, i.e. the loss of the superconducting state, or conversely lead to field emission of electrons which may be trapped in the resonator.

Figure 1

Assembly of a string of cavities together with the ancillary support lines for helium and the large-diameter gas return pipe. The cavities can be seen at the bottom. (Courtesy: Heiner Müller-Elsner)

Figure 2

The automated cavity inspection tool OBACHT. A cavity is placed on a sledge driven by a linear motor; the camera is housed at the end of the rod in the background and can be rotated by 360° using the torque motor drive. (Courtesy: Heiner Müller-Elsner)

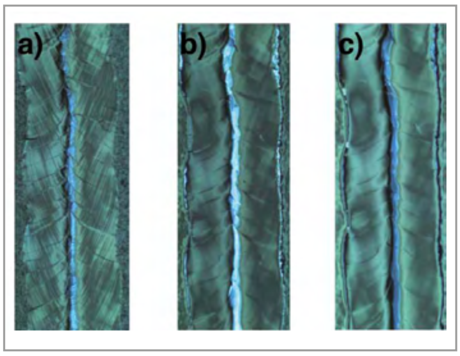


Figure 3

The surface of a cavity and the electron beam welding seam during processing steps: a) before, b) after first and c) after second electropolishing. The welding seam has a typical width of 5 mm.

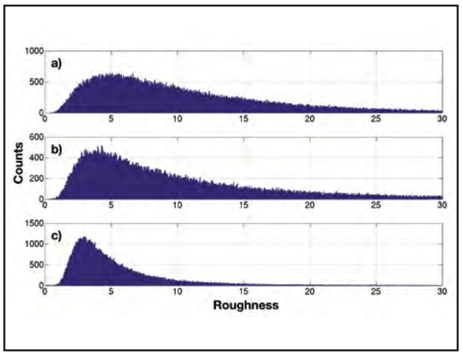


Figure 4

The roughness of objects during electropolishing: a) before, b) after first and c) after second electropolishing. The roughness is a measure of the variation of greyscale values of an object in arbitrary units.

OBACHT – cavity inspection tool at DESY

Utmost care for cleanliness and process control is taken in the assembly of cavity cells at the manufacturer, since a single defect in only one cell of a nine-cell cavity will limit the performance of the entire cavity. DESY has built an automated cavity inspection tool, OBACHT, which enables the quality survey of an assembled cavity. Figure 2 displays how a linear drive and a torque drive are used to orient the camera head towards an arbitrary position on the axis of the cavity under investigation. The camera [4] covers an angle of 4° in azimuth so that on the equator the pixel resolution corresponds to 3.5 x 3.5 μm^2. At the start of the cavity series production, all cavities are fully examined to verify the quality of the welding seam between the two half-cells and to search for defects remaining on the surface.

Image processing

Sample images taken with the optical inspection camera are shown in Fig. 3. The area of the welding seam of two half-cells is monitored during processing: while before electropolishing (a) many features can be recognized, the surface appears considerably smoother after the initial electropolishing procedure (b) and even smoother after the second polishing step (c). Evidently, the processing significantly decreases the number of objects as well as the roughness.

These properties can be measured: an image-processing algorithm has been implemented which identifies objects as contiguous areas of pixels with a greyscale value above threshold that itself depends on the illumination. An impression of the roughness of an object can be obtained from the mean intensity variation (greyscale variation) across the area of the object. Figure 4 displays the frequency of objects against the roughness for the samples of Fig. 3. The number of recognized objects visibly decreases during electropolishing. Even after the first electropolishing step, the number of objects with high values of roughness is appreciable. Ridges on the surface (recognized as sharp variations of contrast for extended objects) still contribute at high values of roughness. After the second electropolishing, the number of high-contrast objects is largely reduced.

This is but one example of the power of optical inspection: a 3D impression of a given surface area can be obtained by recording images at various focal depths. Post-processing of the images of the area of interest provides a nearly 3D impression of the surface area. Such investigations of the surface are important since sudden profile changes lead to local field enhancements and hence to an increased likelihood of field emission or super-critical fields of the niobium superconductor.

Another genuine goal of the inspection evidently is to scan the surface for local defects, i.e. rare impurities in the smooth surface that originate from faults in the material or during production.

The ILC-HiGrade efforts will continue during mass production of cavities with the goal of obtaining a complete understanding of field-limiting defects for superconducting cavities in order to boost the maximum accelerating field and quality factor of the cavities.

Contact:

Eckhard Elsen, eckhard.elsen@desy.de
Lea Steder, lea.steder@desy.de

Authors and references:

Sebastian Aderhold, Eckhard Elsen, Detlef Reschke, Felix Schlander, Marc Wenskat

[1] R. Brinkmann et al. (eds.), TESLA: The superconducting electron positron linear collider with an integrated X-ray laser laboratory. Technical design report. Pt. 2: The accelerator, DESY-01-011

[2] For more information on the ILC-HiGrade programme see: ilc-higrade.eu

[3] N. Walker, N. Phinney, N. Toge, editor. International Linear Collider Reference Design Report, Volume 3: ACCELERATOR. International Linear Collider Collaboration, 2007 and E. Elsen et al., editors. International Linear Collider, a technical progress report, DESY-11-041

[4] Y. Iwashita et. al., "Development of high resolution camera for observations of superconducting Cavities", Phys. Rev. ST. Accel. Beams 11, 093501 (2008)

Detector science at DESY.

The detector technology and systems platform

Detectors are important tools for science. Basic science in particular does not function without detectors. The Helmholtz Association in general and DESY in particular will face major detector challenges in the next years. Experiments at large particle colliders, such as the LHC or, in the future, the ILC, become increasingly complex. New and extremely powerful light sources, like PETRA III, FLASH or the European XFEL, require detectors of a completely new quality. Together with seven other Helmholtz centres, an initiative has been started to strengthen detector science and provide a platform for basic detector technology.

The Helmholtz detector technology platform will bring together the diverse and very strong detector development activities existing within the different centres and the different programmes. The platform will be the place to identify new promising developments, contribute to these developments and make sure that the Helmholtz centres participate in and shape emerging technologies. The platform will also be the place to make this innovative and vibrant field of science more visible, both within the Helmholtz Association and to a broader community.

In close collaboration with universities and other centres active in the field, the platform will be a central point of contact for a broader cooperation on detector technologies in Europe and worldwide. It will also contribute to the education and training of the next generation of instrumentation scientists.

The members of the platform have identified a number of key areas where immediate action is deemed important.

Solid-state detectors play a central role within the platform. These technologies are increasingly important in many fields of science. In particle physics in particular, the technology of solid-state detectors is broadly accepted. The LHC detector collaborations have installed and operate huge footage of high-precision silicon-based tracking detectors. The anticipated upgrades of these detectors, in which DESY intends to participate in a central way, are mostly concerned with the upgrades of these solid-state tracking systems. In photon science, solid-state photon detectors are a central part of the instrumentation of the beamlines, e.g. at PETRA III and the European XFEL. In many cases, these detectors are based on the same technologies as particle physics detectors.

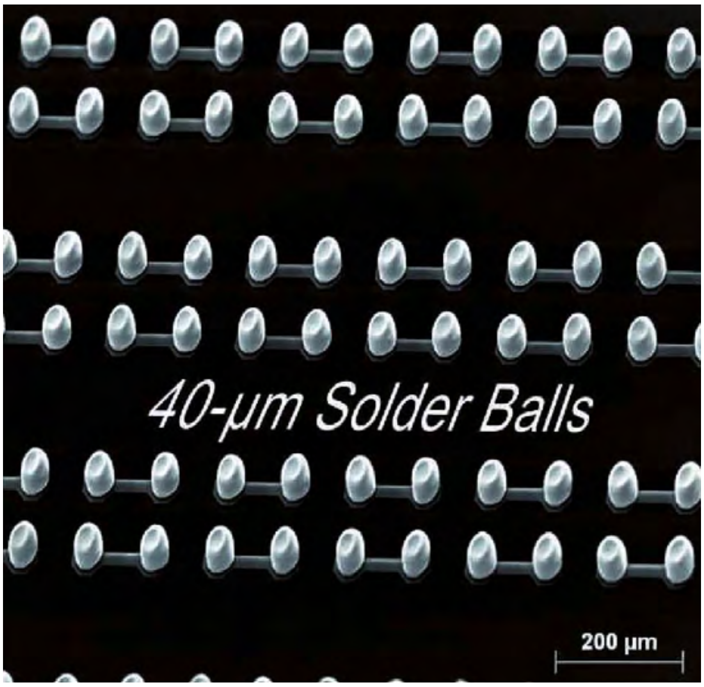


Figure 1

Example of a grid of solder balls on a 40-µm grid realized by the DESY FE group

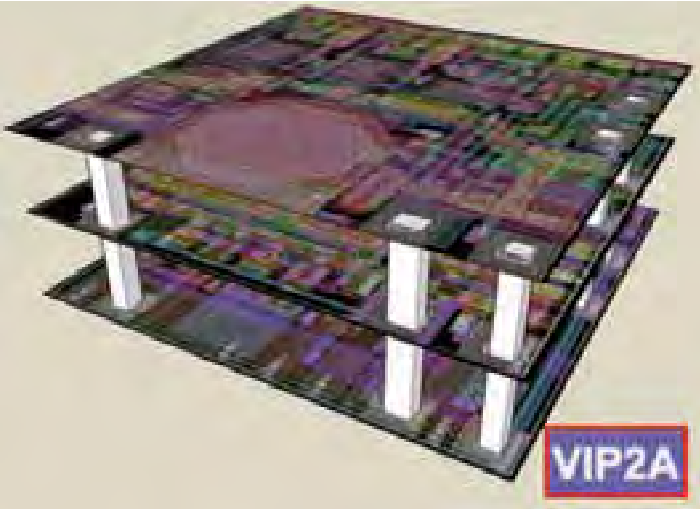


Figure 2

Example of a silicon pixel detector realized with three-dimensional functionality. This particular example was developed at Fermilab, a partner of the platform, for a vertex detector at the ILC, and has triggered significant developments in this area.
(Courtesy: Fermilab)

A major step in these detectors is the move from planar to three-dimensional systems. By using the third dimension, more functionality can be put into a smaller space, which will help to answer the demands for ever more granularity and resolution in modern detector systems. This area plays a central role in the detector platform.

In the first and biggest work package, the development of three-dimensional interconnect technologies is the central topic. The main goal of this part is to develop a functioning and fairly generic pixel detector prototype, the so-called Helmholtz cube. This system will provide a specially developed readout ASIC for a pixel detector, integrated into a package so that sensors realized in different technologies can be connected to the system. It will be realized using three-dimensional techniques, features no exposed wire bonds and can thus be a test bed to develop and demonstrate the relevant technologies needed to build up the readout. The system will be used to demonstrate the bump bonding technique required to connect the readout to the sensor. And, last but not least, it will be a self-contained easy-to-use test system to test different sensor prototypes under controlled and understood conditions.

The second work package is concerned with the development of fast data transfer and processing technologies. The modern highly pixelated detectors produce huge amounts of data, which need to be transferred away from the detector and processed. Handling these data requires putting more intelligence into the sensor – something that is addressed in the first work package – but also the development of large-bandwidth data transfer and acquisition systems.

The third work package will then take the developments from the first and second work package and put them to use in prototypes. A number of specific systems are to be developed, which will explore and demonstrate the power of the new technologies. Examples are silicon photomultipliers of the second generation, read out by the chip developed for the Helmholtz cube, or compact gas detectors, realized utilizing the three-dimensional processing and post-processing technologies to construct compact detectors. In addition, the detection of neutrons is an important topic, in particular in view of the worldwide scarcity of ^{3}He.

The final work package is special. It is lateral in construction, connecting the different work packages together and reaching out to other areas within and outside of science. It is meant to provide a forum through which the results (products) from the platform are disseminated and connections to other areas are developed. Examples are ties into the medical community, where detectors are needed, or into areas like Earth science or biology.

The detector technology platform is a new element within the Helmholtz Association. It has the potential to strengthen the role the Helmholtz Association will play in detector science.

Contact:

Ties Behnke, ties.behnke@desy.de
Heinz Graafsma, heinz.graafsma@desy.de

Time projection chambers.

Developing high-precision tracking detectors

Tracking detectors are a central part of any modern particle physics experiment. Gaseous detectors offer a number of unique properties, which make them interesting alternatives to the widely used solid-state detectors for some applications. A new compact time projection chamber readout to be used at a time projection chamber at the ILC has been developed and tested at DESY.

For a detector at a future linear collider, highly efficient tracking in a high-multiplicity environment is a key challenge. In some ways, efficiency is more important than ultimate precision. This is particularly true for the so-called “particle flow” ansatz. Here, every single particle in the event should be reconstructed individually. Loosing even a small number of particles will significantly impact the achievable resolution, thus stressing the necessity of an extremely efficient tracking device.

A gaseous detector such as a time projection chamber (TPC) is a candidate for the central tracker in the ILD detector, one of the experiments proposed for the International Linear Collider (ILC). Such a detector provides a large number of truly three-dimensional measurement points (up to 200 for ILD). Even though the achievable individual point resolution is somewhat worse than the one possible with solid-state detectors, in total, by combining all 200 hits, a very precise reconstruction of a charged particle is possible.

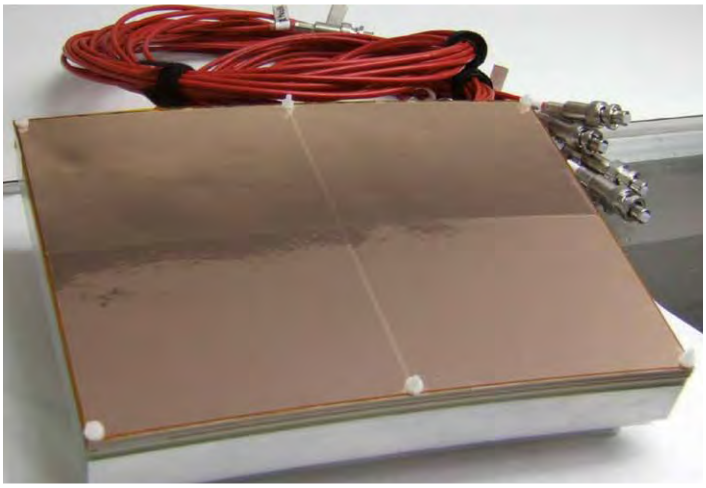


Figure 1

Photograph of the finished readout module. Visible is the excellent coverage of the area, with very little dead space. Also visible through the GEM foils is the ceramic support structure.

The recording of the charge in a TPC for the ILD is proposed to be done with micropattern gas detectors. They are compact, robust and provide gas amplification with structures that are of a similar length scale than the resolution, thus minimizing the systematic effects connected to the amplification stage.

Initially provided in the context of the EUDET programme and partially funded by the European Commission, a test TPC has been developed, which is being operated at DESY for the community. The TPC can be equipped with up to seven readout modules and, if operated within a magnetic field, can provide meaningful tests of the tracking at a linear collider.

At DESY, a module is being developed based on gas electron multipliers (GEMs) as gas amplification devices. The GEMs, which are produced by CERN especially for the requirements of this module, are mounted with ceramic frames and spacers to provide a mechanically stable and compact system.

A prototype module was assembled and tested during 2011. The module consists of three stacked GEM foils, mounted in a ceramic frame. It is read out by small pads 1 x 6 mm^2. Because the number of available readout electronics is limited, only a strip in the centre of the module is instrumented. A view of the module is shown in Fig. 1.

The module was constructed during the first half of 2011 and exposed to electron beam during the summer. Around two million events were recorded.

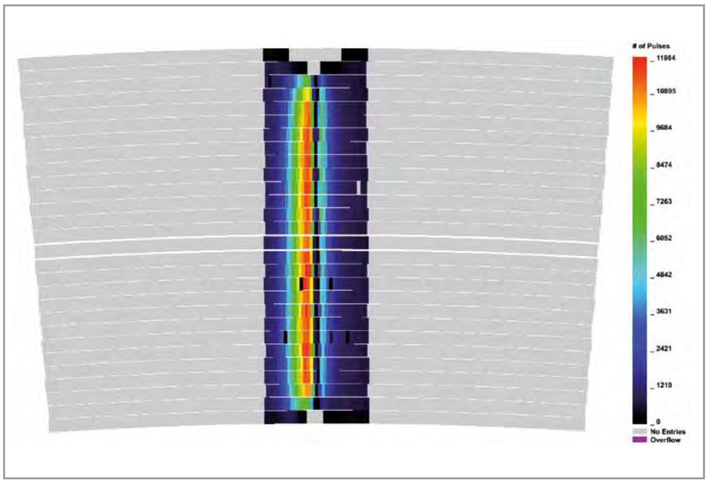


Figure 2

Plot of the distribution of pulses recorded with the module in a test beam experiment. As described in the text, areas of inefficiency are visible at the top and bottom of the module.

Figure 2 shows the average pulse height recorded on each pad. The illuminated area is clearly visible. Towards the edges of the active area, a significant decrease in pulse height can be seen. Detailed simulations of the electrostatic conditions of the module were performed to study the expected pulse behaviour. It was found that an unexpectedly large impact of the gap surrounding the module was responsible for the drop in pulse height.

Figure 3 shows the simulated field strength parallel to the readout plane in the area surrounding the gap. From this, it can be seen that a strong transverse field is present extending around two pads, which will tend to push electrons away from the pad into the gap, thus reducing the overall efficiency. By controlling the potential of a guard ring surrounding the module, this effect can be largely eliminated. This feature will be included in the next iteration of the module.

During the operation of the system, a number of problems with the module high-voltage supply were encountered. In particular, it was found that the charge stored in the system under some conditions was sufficiently large to destroy sections of the GEM. To protect the system against such events, a system of protecting resistors has been integrated into the module, minimizing the danger of a catastrophic discharge. Compared to the previous system, the resistors are mounted closer to the GEM. This will result in a slight dependence of the operating conditions of the GEM on the rate, but it is considered acceptable for the expected range of operating conditions.

A first look at the data collected with the module shows that the system as a whole is functioning well. The overall behaviour is as expected. Apart from the problem in close proximity to the edges, the response of the module is uniform and stable over time.

The next iteration of the module is expected to be ready in time for the summer 2012 test beam campaign. At least three modules will be installed, allowing the measurement of a long track segment with up to 78 hits. Operating three modules at once will provide a powerful test of the overall system. A first study of the anticipated momentum resolution might also be possible, depending on the availability of a precise external reference detector.

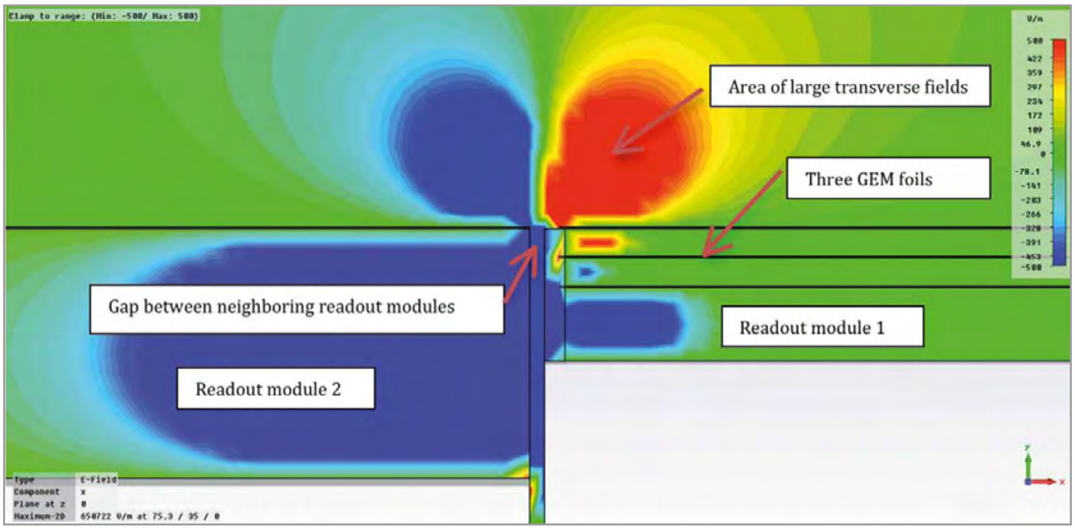


Figure 3

Two-dimensional map of the transverse component of the electrical field in the module. The gap between the two modules induces a significant transverse field. This is responsible for the area of inefficiency observed in the data, at the top and bottom of the module.

Contact:

Ties Behnke, ties.behnke@desy.de

Proof of concept.

FCAL prepares prototype calorimeter

When a detector concept based on novel technologies has been developed and the major components are available and have been tested, the crunch question arises – does it work as a full system? This is the current situation in the FCAL collaboration. The key components for highly compact and fine-grained calorimeters in the very forward region of future electron–positron collider detectors have been developed. Now physicists and engineers are working to bring them together for a full system test.

Sensors and ASICs

Sensors to instrument two of the calorimeters – BeamCal and LumiCal – are available and have been tested. For the LumiCal, the choice is fine-structured silicon pad sensors and for the BeamCal radiation-hard gallium arsenide (GaAs) pad sensors. Before assembly, all sensors are qualified using a probe station (Fig. 1). Important characteristics are the leakage current as a function of voltage and temperature.

Only sensors matching high quality criteria are used in the assembly. For the readout, dedicated front-end and ADC ASICs have been prepared by collaborators from the University of Science and Technology (UST) in Cracow and from Stanford University.

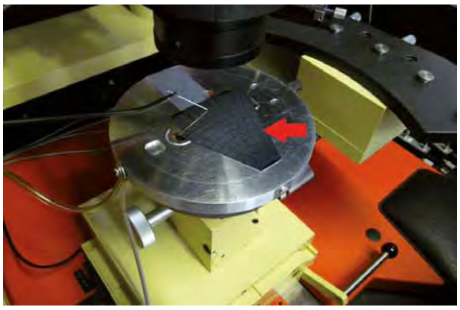


Figure 1

GaAs sensor (arrow) on the probe station

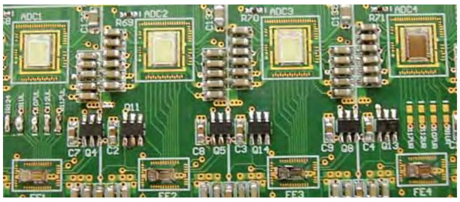


Figure 2

Four fast 10-bit ADC ASICs with eight channels from UST Cracow mounted on the readout board

Beam test of a fully assembled sensor plane

Sensor planes were assembled with both front-end and ADC ASICs (Fig. 2) and then installed in the 4-GeV electron beam at DESY. Several million single-particle triggers were recorded for different areas of a silicon and a GaAs sensor. The data analysis is still ongoing. Preliminary measurements of the signal-to-noise ratio reveal values around 20 – better than required for the application.

Using a sensor plane installed behind a tungsten absorber block, a profile of an electromagnetic shower was reconstructed (Fig. 3).

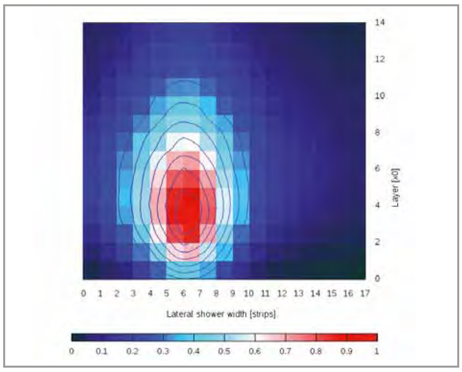


Figure 3

Profile of an electromagnetic shower, measured using a silicon sensor plane behind a tungsten absorber block

Preparing a prototype

Within the European-Community-supported AIDA project, the laboratories CERN, DESY, UST and Tel Aviv University will prepare a fully functional calorimeter prototype. The mechanical structure (Fig. 4) will be manufactured at CERN. ASICs will be delivered by UST. Tel Aviv and IFJ-PAN Cracow took over the responsibility for the data acquisition. The integration and preparation of the beam test will be done at DESY.

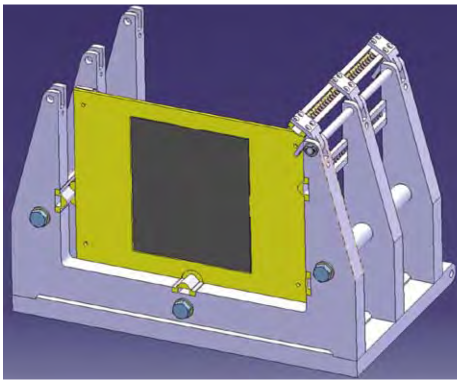


Figure 4

Mechanical frame to hold sensor and absorber planes for beam tests

Contact:

Wolfgang Lohmann, wolfgang.lohmann@desy.de

Hot targets: material at the limit.

Positron generation for intense beams

Positron production in solid targets for future linear colliders is a challenge. Target and source components must survive the long-term bombardment with particles without undergoing significant changes of material properties.

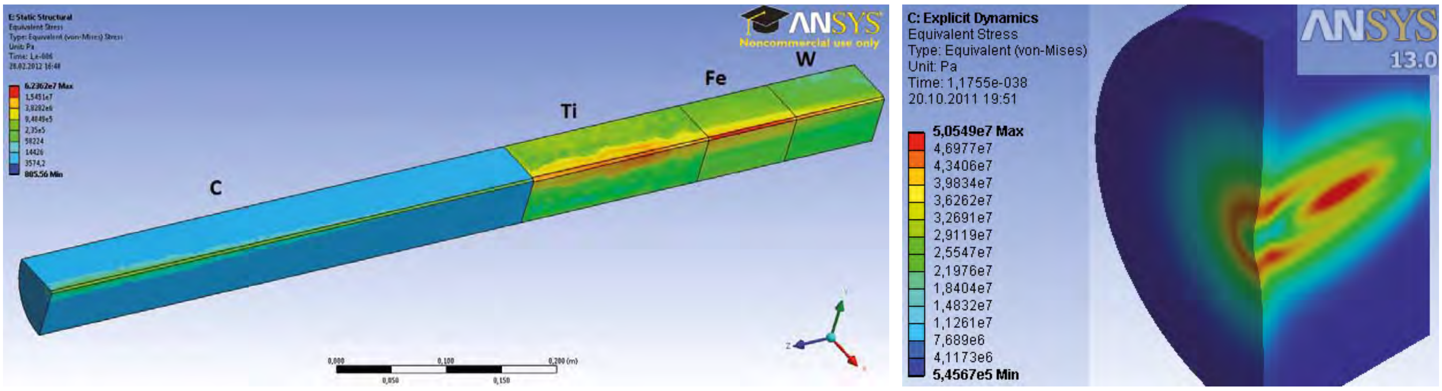


Figure 1

Left: Simulated pressure distribution in the photon collimator after one photon bunch train. The collimator consists of hollow cylinders of different materials. Shown is a cut through the collimator along the *z* direction. The photon beam goes from left to right. Right: Simulation of the pressure wave development in the target due to energy deposition by the photon beam (snapshot, target is cut along *z*). The photon beam enters the centre of the target from the right and escapes at the surface shown in the front.

A future electron–positron linear collider like the ILC will require intense positron beams, which in addition need to be polarized – a challenge regarding the procedure to create such beams.

In the current ILC design, polarized photons are created in a helical undulator, collimated and steered onto a thin target – a rotating wheel – to generate electron–positron pairs. Within a very short time, a huge amount of energy is deposited in the target, which rotates at 2000 rpm to distribute the energy deposition, and in the collimator material. The fast temperature rise and the repeated deposition of high energy density result in pressure waves in the material, which could easily exceed the elasticity limits. Through a clever design, it must be avoided that the source components fail.

The ANSYS simulation system is used to study the dynamic stress in the bulk materials of the target and the collimator. But before constructing the collider, it must be tested experimentally whether the simulation of high-stress creation and propagation is properly understood and reflects the true conditions.

In close contact with the ILC/CLIC positron source group, teams at DESY in Zeuthen and Hamburg University started the development of models to describe the behaviour of materials in intense beams. Two approaches are being followed concurrently: the improvement of hydrodynamical models to describe these material effects and the use of programs like ANSYS for simulation. The results are compared and adjusted with data from targets already used in colliders.

For the ILC design, the stress expected in the target as well as in the photon collimator has been studied. Figure 1 presents a snapshot of the stress distribution in the target hit after one bunch train. The design of the collimator allows the absorption of at least 50% of the photon beam power without exceeding the elasticity limits. This success enables a high degree of positron polarization as is desired for physics measurements.

Furthermore, simulations are being performed to experimentally test the agreement of simulation with reality. Both the FLASH and the PITZ facilities are well suited for these tests.

Contact:

Sabine Riemann, sabine.riemann@desy.de

CALICE
Calorimeters à la carte.

Data taking with ILC calorimeter prototypes

Highly granular electromagnetic and hadronic calorimeter prototypes have been constructed with major contributions from DESY to evaluate technologies for use in detector systems at a future linear collider. In 2011, these calorimeters have been extensively used for physics data taking in test beam facilities at CERN and Fermilab. The unprecedented granularity of the detectors provides detailed information about the properties of hadronic showers, which helps to constrain hadronic-shower models through comparisons with model calculations.

The CALICE collaboration is developing new technologies for calorimeters for a future linear-collider (LC) experiment. The physics goals at an LC require a high jet energy resolution that can only be achieved with new ideas for the design of calorimeters. With the particle flow approach, every particle in a jet can be reconstructed. By combining the calorimeter information with the measurements from the tracking detectors, an unprecedented jet energy resolution can be achieved. Therefore, calorimeters with very high spatial segmentation are needed to allow for the separation of individual particle showers.

The CALICE collaboration constructed several prototypes to test different materials and readout techniques and compare data with simulations. Since 2006, several detectors have been operated in test beams. Especially, in 2011, detectors with analogue as well as digital readout took data at CERN and Fermilab. The analogue hadron calorimeter (AHCAL), which was constructed mainly by DESY groups, was operated in June, July and September 2011 at the CERN SPS test beam facility. A new absorber structure built at CERN consists of 39 plates of 10-mm tungsten alloy. The 38 active layers from DESY, which are interleaved between the

Figure 1

The CALICE analogue hadron calorimeter (right) and the tail catcher (left) as installed at the CERN test beam facility

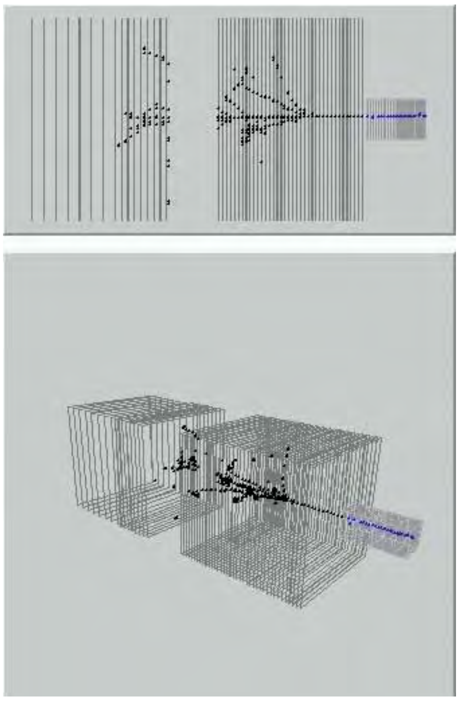


Figure 2

Event display of a 20-GeV pion shower in the CALICE digital hadron calorimeter

absorber plates, serving in steel since 2006, consist of small plastic-scintillator tiles with sizes ranging from 3x3 cm^2 to 12x12 cm^2, read out by silicon photomultipliers. The total depth of the calorimeter is large enough to contain complete hadron showers with energies up to 10 GeV. For the beam tests with energies above 10 GeV, a tail catcher system was installed behind the AHCAL for a better shower containment and better control of the energy leaking out of the detector. Figure 1 shows a photo of the complete setup.

The full setup was exposed to particle beams of different type and in total, 33 million pion, electron and muon events were recorded at energies between 10 and 300 GeV. The low energies are particularly interesting for the comparison with Geant4 simulations, which often have to interpolate between different phenomenological models at these energies. The high energies are interesting for the performance of the hadron calorimeter at single-particle energies relevant at very high-energy linear colliders, such as CLIC.

During the data taking periods, the photo sensors of the detector can be calibrated with LED light, which also allows for the monitoring of the electronics channels. Overall, the number of dead channels is very low, and it turns out that during the past six years of operation, the detector technology has been incredibly robust. This is remarkable, since the AHCAL has been operated at DESY, CERN and Fermilab and had to be dismantled, shipped and re-assembled several times. Nevertheless, each data-taking period has proved to be very successful.

One of the advantages of the collaboration is that different readout technologies can be combined with different absorber structures, so that a variety of calorimeter systems can be tested. In 2011, the CALICE collaboration was thus also able to test hadron calorimeters at Fermilab with digital readout, based on gaseous detectors (DHCAL). 38 layers of resistive plate chambers (RPCs) were interleaved with the 16-mm steel absorber plate structure that was built at DESY, and used in beam tests of the AHCAL between 2006 and 2009. The detector was mounted together with the silicon-tungsten electromagnetic calorimeter and a tail catcher on a movable stage, which was also constructed at DESY. In total, 25 million events were measured with a granularity of 1x1 cm^2, providing the world record channel count in calorimetry of almost 480 000 channels – a figure that exceeds the channel count of all LHC calorimeters together! Figure 2 shows the event display of a 20-GeV pion event recorded with the combined setup of CALICE calorimeters.

While millions of events have been recorded with several calorimeter prototypes during the last years, the analyses are still ongoing. After establishing the calibration chain and cleaning the event samples, the data can be compared to Monte Carlo simulations with unprecedented precision. For example, the shower starting point can be reconstructed in space. Detailed investigations of shower shapes (Fig. 3) and substructures ultimately allow current Geant4 predictions to be tested and improved.

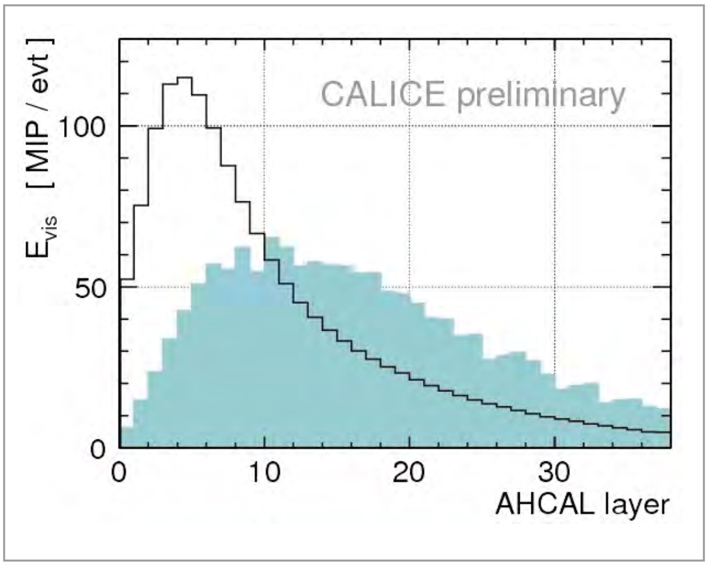


Figure 3

Longitudinal profile of 45-GeV pions, measured in the analogue hadron calorimeter, relative to the calorimeter front face (filled) and to the first hard interaction (black line)

Contact:
Felix Sefkow, felix.sefkow@desy.de

OLYMPUS.

Preparing the detector

The goal of the OLYMPUS experiment at the DORIS III storage ring is to precisely measure the ratio of the positron–proton and electron–proton elastic scattering cross sections to quantify the effect of two-photon exchange. The experiment will use intense beams of electrons and positrons stored in the DORIS ring, an unpolarized internal hydrogen target and the former BLAST detector from the MIT Bates Linear Accelerator Center. The detector parts arrived at DESY in the summer of 2010. Significant progress was made over the following 18 months. The detector assembly was completed in the DORIS hall, the interaction region was modified in January 2011, and during the 2011 summer shutdown, the detector was moved into beam position to start commissioning and preparing for the data taking in 2012.

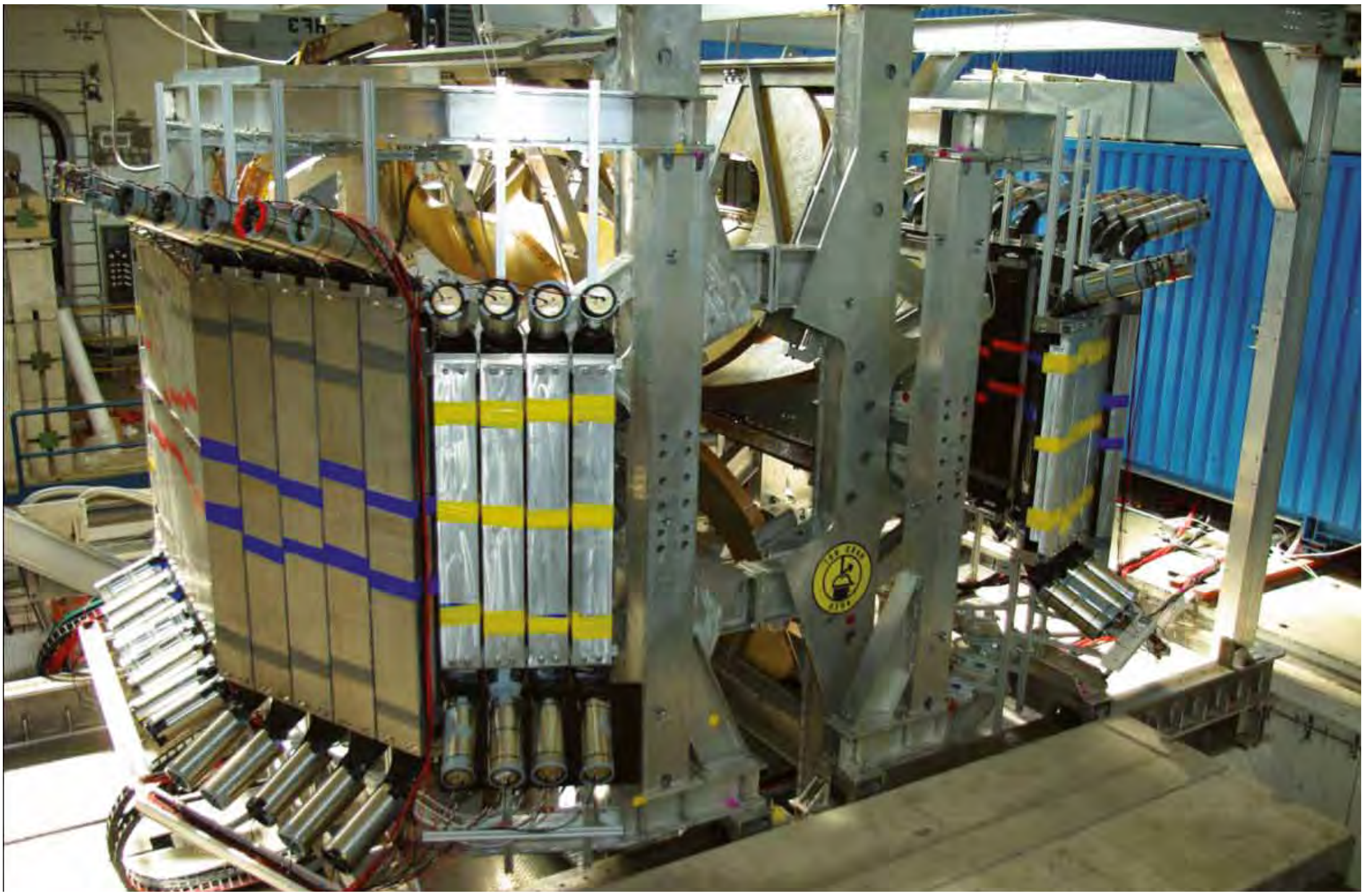


Figure 1

Assembled OLYMPUS detector in the parking position shortly before being moved into beam position

Figure 2

Beamline components and detector in the beam position

The OLYMPUS experiment aims to measure the ratio of the positron–proton to electron–proton elastic scattering cross sections in order to determine the contribution of multi-photon exchange to electron–proton scattering. The motivation for this measurement came from an observed deviation from unity in the electric to magnetic form factor ratio of the proton determined in polarization transfer measurements performed at Jefferson Lab, in contrast to measurements using the Rosenbluth separation technique. Since the Rosenbluth formula assumes a one-photon exchange between the electron and proton, higher-order radiative corrections, in particular multi-photon exchange, are expected to be the source of this discrepancy. The measurement at DORIS will be performed using the former MIT BLAST detector, which was transferred from MIT to DESY in the summer of 2010 and reassembled in the DORIS hall. Significant progress was made in 2011.

During the 2010–2011 DORIS winter shutdown, the interaction region was prepared for the OLYMPUS detector, including installation of the OLYMPUS vacuum system with the target chamber and a small test experiment. Several DORIS shifts were spent studying beam operation at 2 GeV, commissioning the target system and taking the first data with the test experiment. The operation was very successful and elastic positron–proton events were recorded with the test experiment. The only problem was some heating of the target cell at large beam currents, which required the removal of the target before the start of synchrotron radiation running.

In the following months, improvements to the target cell design and wakefield shielding were made, new detector components were tested using the DESY test beam, and the assembly of the detector was completed in the parking position in the DORIS hall.

The fully assembled detector was then moved into beam position in July 2011, during the four-week summer shutdown. The target chamber was reinstalled with a modified target cell and wakefield suppressors. Heating was no longer observed even at maximum beam current. The complete detector was commissioned using some dedicated beam time during the regular service weeks. Several improvements of the detector components were prepared and installed during the maintenance period in January 2012. The first data-taking period of four weeks of dedicated beam operation at 2 GeV started at the end of January 2012. Another two months of running in autumn will complete the data taking by the end of 2012.

Contact:

Uwe Schneekloth, uwe.schneekloth@desy.de

Reference:

http://web.mit.edu/OLYMPUS/

DESY @ Belle II.

Joining the hunt for flavour at the terascale

For the last 40 years, DESY has been enjoying a very fruitful partnership with research institutions in Japan. The close cooperation began with Masatoshi Koshiba at the DORIS experiment DASP. The collaboration then developed further with Japanese participation in JADE, ZEUS and HERMES and within the combined efforts for the ILC. Since last year, DESY has been engaging in preparations for the very ambitious Belle II experiment which will be operated at the Japanese High-Energy Accelerator Research Organization KEK in Tsukuba close to Tokyo. This "intensity frontier" experiment will address some of today's fundamental questions in particle physics by exploiting properties of B mesons, which were first measured in 1987 at the DORIS experiment ARGUS.

From 1998 to 2010, KEK, the Japanese High-Energy Accelerator Research Organization, operated KEKB, a 3-km circumference asymmetric electron–positron collider. Over this period, the instantaneous luminosity continuously increased, eventually attaining the world record of 2.11 x 10^{34} cm^{-2} s^{-1}. The beam energies were chosen such that the collisions mainly produced B mesons, thus its designation as a "B factory". The Belle experiment precisely analysed the characteristics of pairs of B and anti-B mesons and thereby confirmed the effect of CP violation as described by the theory of Makoto Kobayashi and Toshihide Maskawa, who both received the Nobel Prize in Physics in 2008. CP violation is believed to be one of the origins for the observed dominance of matter over antimatter in our present universe. The level of CP violation measured, however, turned out to be by far insufficient to quantitatively explain the actual asymmetry. Therefore, a much deeper understanding of the related phenomena is required.

SuperKEKB (Fig. 1, left) is an upgrade project at KEK designed to increase the instantaneous luminosity by about a factor of 40 to 8 x 10^{35} cm^{-2} s^{-1}. The next-generation B factory will complement the exploration of new physics beyond the Standard Model currently being carried out at the energy frontier by the experiments at the Large Hadron Collider (LHC). While the LHC experiments provide a direct probe of the TeV mass scale, high-precision measurements of rare decays and CP violation in heavy quarks and leptons provide a unique probe of new physics at these and even higher mass scales through the effects of new particles in higher-order processes. In the past, measurements of processes involving internal loops have given access to high mass scales before accelerators were available to directly probe these scales.

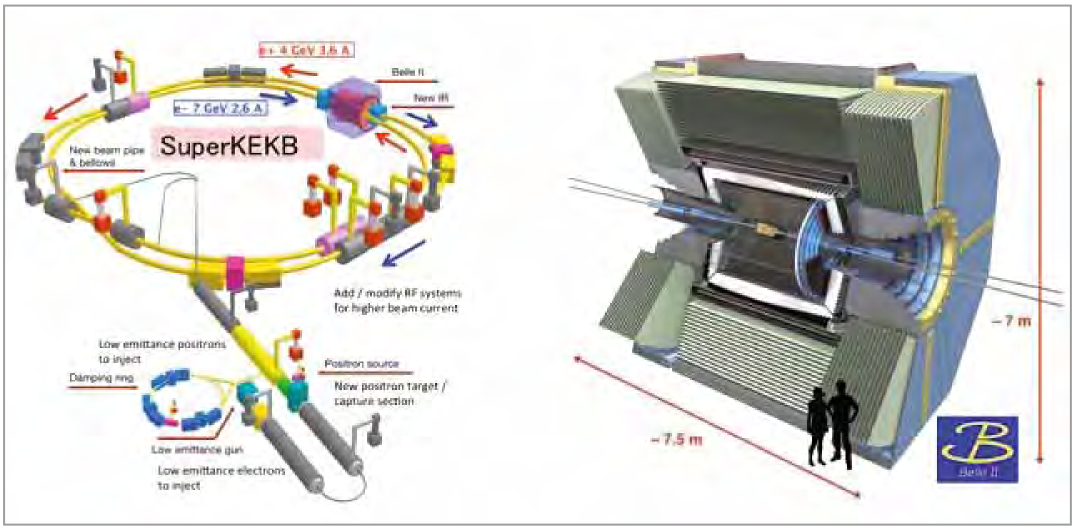


Figure 1

KEK is upgrading its B factory to the SuperKEKB facility (left) to provide a 40-fold increase in instantaneous luminosity by exploiting higher beam currents, a large crossing angle and squeezing the beams down to nanometre scales. The former Belle detector will be upgraded to Belle II (right) to cope with the enormous increase in intensity.

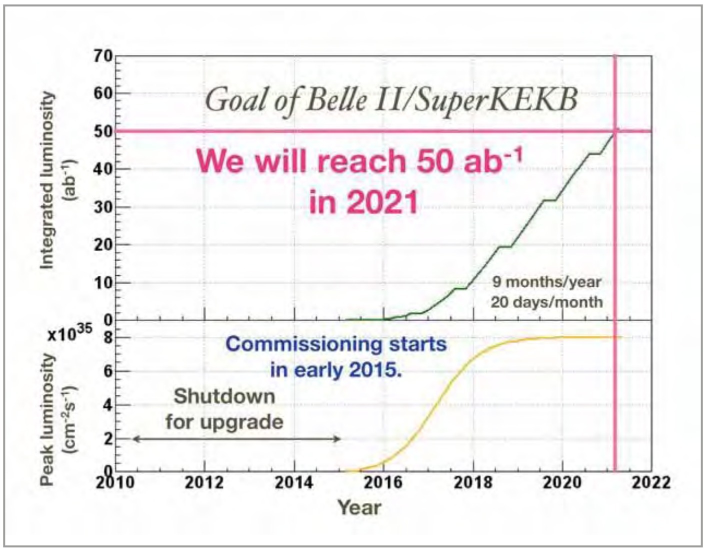


Figure 2

Projected luminosity profile at Belle II/SuperKEKB resulting in a 50-fold increase of accumulated luminosity at the beginning of the next decade

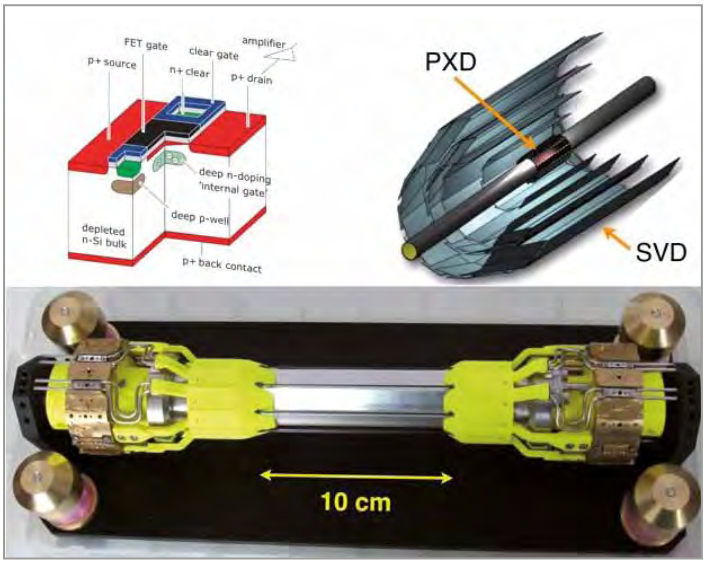


Figure 3

DEPFET (Depleted p-channel FET) principle (upper left). Schematics of the Belle II vertex detector, consisting of the pixel detector (PXD) surrounded by the strip detector (SVD) (upper right). Mechanical PXD mock-up (below).

Figure 4

Representatives of German institutes participating in Belle II and members of the KEK directorate after signing a memorandum of understanding on 18 November 2011

Reaching higher luminosity in a collider usually involves both increasing the beam current and reducing the beam size at the interaction point. The original approach for the SuperKEKB upgrade focussed on an increase of the beam currents and the beam–beam parameter – the high-current option. However, in March 2009, the SuperKEKB design changed course based on ideas of Pantaleo Raimondi from the Italian SuperB project. Raimondi proposed to use a large crossing angle at the interaction point and to squeeze the beams to nanometre-scale to increase luminosity – the *nano-beam* option. The ambitious goal is to accumulate an integrated luminosity of 50 ab^{-1} by 2021, which is 50 times more than that acquired by the previous Belle detector.

Because the SuperKEKB accelerator will produce electron–positron collisions at a much higher rate, the detector also needs to be upgraded (Fig. 1, right). The data acquisition system will be redesigned to use a network of optical fibres. Trigger electronics will be replaced with a new system. A pixel detector will be added to provide better resolution for particle tracking and a new silicon vertex detector will cover a larger solid angle. A central tracking chamber, a time-of-propagation chamber and an aerogel ring-imaging Cherenkov detector are also being newly built. The first beam of SuperKEKB is expected in 2014 and the physics run will start in 2015 (Fig. 2). The design of the new pixel detector is based on the DEPFET technology (Fig. 3, upper left) that was originally developed for the International Linear Collider (ILC). It allows the fabrication of very thin sensors and thereby helps to minimize the effect of multiple scattering of the relatively low-energy decay particles produced in the collisions.

In summer 2011, DESY joined a consortium of several German institutes (universities of Bonn, Heidelberg, Göttingen, Gießen, Karlsruhe, TU Munich, LMU Munich and MPI Munich) which is responsible for designing, building, installing and operating the pixel detector as part of the Belle II experiment. Since November 2011, DESY has also been an official member of the Belle II collaboration. On the occasion of the ground-breaking ceremony for the SuperKEKB project at KEK on 18 November 2011, representatives of KEK, DESY and the other German institutes signed a corresponding memorandum of understanding (Fig. 4).

The DESY group is in charge of building a thermal mock-up to study and optimize the complex cooling system for the entire vertex detector (Fig. 3, upper right). The mock-up consists of the central beam pipe, the two-layer pixel detector and four layers of silicon strip detectors, the latter being built by the HEPHY institute in Vienna and by KEK. Other areas where experience available at DESY is highly welcome are alignment and calibration of tracking detectors and background simulation studies.

Contact:

Carsten Niebuhr, carsten.niebuhr@desy.de

LEXI moves on.

Collaborative efforts of the Cluster of Excellence bear fruit

Starting in summer 2009, the scientific collaboration between particle physicists, astrophysicists, astronomers and mathematicians from Hamburg University and DESY has been strengthened thanks to additional support from the Hamburg excellence initiative "Landesexzellenzinitiative" (LEXI). The significant funds provided by the city-state of Hamburg to the Cluster of Excellence "Connecting Particles with the Cosmos" are, for example, being used to start new and innovative research initiatives and to invest into strategic interdisciplinary projects.

The broad scientific spectrum covered by the cluster centres around the common subject of particle physics is organized in seven research areas: accelerator physics, detector physics, collider experiments, particle phenomenology, astronomy and astroparticle physics, particle cosmology, and mathematical physics and string theory.

Figure 1

Artist's view illustrating the links between topics covered by the Cluster of Excellence (Courtesy: Patrick Schell, Hamburg University)

One of the main goals of the cluster is to intensify the collaboration between these different fields. Recently, a number of professorships at Hamburg University became vacant in several of the relevant research areas, offering the unique opportunity to create a coherent research network. One of the important initial goals of the cluster was therefore to help to attract the most suitable and outstanding candidates by offering supplemental appointment funds. Meanwhile, all those positions were filled by excellent scientists, and the entire research field has been strengthened as a result.

Another essential element of the cluster has been the establishment of several young investigators groups working at the interface between several of the research areas covered by the cluster. The high scientific quality of the appointed group leaders as well as the relevance of their research fields are demonstrated by the fact that, in the meantime, two of these young investigators have accepted offers for external permanent positions. A very good example for the strategic use of the LEXI funds is the start-up grant awarded to another young researcher, who then successfully applied to the German Research Foundation (DFG) for an Emmy Noether research group on "Precision theory predictions for Higgs and new-physics measurements at the LHC". This research will be funded for five years and thus extend well beyond the presently anticipated duration of the cluster of 3.5 years.

Education and training play another important role in the research areas of the cluster. As an example, several educational activities of the graduate school (International Research Training Group, IRTG) are supported with the aim to widen the scientific perspective of the participants by stimulating discussion and collaboration between the students of the different projects. Other examples are the well-attended interdisciplinary seminars in the field of astrophysics and instrumentation, where many high-level speakers could be invited thanks to the financial support granted by the cluster.

As in previous years, a certain fraction of the funds was distributed in a competitive manner by launching a call for new initiatives. From several very good proposals, a few innovative projects, like for example the development of instrumentation for a hidden-photon search, were selected for funding.

At the annual LEXI cluster meeting in October 2011, an excellent overview was given of the entire research spectrum, with first-rate presentations ranging from mathematical physics to recent results on dark-matter physics, the latest tantalizing experimental results in neutrino and LHC physics, and an outline of future perspectives of the field emphasizing the potential in the Hamburg area.

Contact:
Carsten Niebuhr, carsten.niebuhr@desy.de

SFB 676: Particles, strings and the early universe.

Collaboration to unravel the structure of matter and space-time

The main research focus of the SFB 676 project is the interface of particle physics, string theory and cosmology. In particular, it includes activities in astroparticle physics, which cover a wide range of subjects, from searches for relics from the early universe, such as dark matter or primordial magnetic fields, to using radiation from the cosmos as test beams for new particle physics. Here, the interplay between theorists, experimentalists and astronomical observatories is of particular importance, as several highlights in 2011 have shown.

Selected scientific highlights

A new line of low-energy neutrino astrophysics has recently flourished, which investigates the flavour conversions of neutrinos emitted during the gravitational collapses of supernovae. Supernovae represent a unique laboratory to probe the flavour mixing in high-density conditions, where neutrino oscillations exhibit unusual collective behaviours associated with their self-interactions. The characterization of these fascinating effects is the subject of many ongoing investigations and is also relevant for the astrophysics of supernova explosions. In July 2011, DESY hosted the “Hamburg Neutrinos from Supernova Explosions HAνSE” workshop, which attracted more than 50 researchers working on different aspects of supernova physics.

A topic in which DESY and university groups are actively involved is the characterization of possible signatures of new light particles (e.g. axion-like particles, hidden photons) predicted in many extensions of the Standard Model. These particles interact too weakly to be produced at colliders but could play an important role in astrophysical and cosmological observations. In this context, oscillations between very-high-energy photons and axion-like particles in large-scale cosmic magnetic fields have been studied as an intriguing possibility to explain the unexpected transparency of the universe to TeV gamma rays recently observed by imaging air Cherenkov telescopes such as H.E.S.S. (Fig. 1). Solar hidden photons are now also being searched for with the Solar Hidden Photon Search (SHIPS) experiment at the Hamburg observatory in collaboration with DESY. The modified astronomical telescope is sensitive to oscillations between ordinary solar photons and putative hidden photons.

Figure 1

The High Energy Stereoscopic System (H.E.S.S.) in Namibia is currently being extended to include a large (28 m) telescope to search for gamma rays from cosmic accelerators as well as from self-annihilating dark matter. The telescope will see first gamma rays in 2012. (Courtesy: Björn Opitz, Univ. Hamburg)

New collaborations in astroparticle physics

In 2011, the activities in astroparticle physics within the SFB have gained national and international impact with new collaborations. In July 2011, a new Helmholtz Alliance for Astroparticle Physics (HAP) was established in which both the University of Hamburg and DESY are involved. The theoretical astroparticle group at the University of Hamburg coordinates the theory work package within this Alliance. Both the theoretical and experimental neutrino groups at the University of Hamburg joined the European design study LAGUNA-LBNO (Large Apparatus for Grand Unification and Neutrino Astrophysics – Long Baseline Neutrino Observations) whose main goal is to assess the feasibility of a new pan-European research infrastructure able to host the next-generation, very-large-volume, underground neutrino observatory. This observatory will probe proton decay, use long-baseline neutrino beams to measure neutrino properties and detect low-energy extraterrestrial neutrinos with unprecedented sensitivities. The Hamburg groups are actively involved in the study of the physics potential of the large liquid-scintillator detector LENA for low-energy neutrino physics and astrophysics, and the theoretical neutrino group leads the work package on low-energy neutrino astrophysics.

Contact:

Günter Sigl, guenter.sigl@desy.de

Improved neutrino limits, patterned muon sky.

Neutrinos and charged cosmic rays

IceCube, the first neutrino telescope on the cubic-kilometre scale, was completed in December 2010. The detector records about 100 neutrinos per day, most of which were generated in the Earth's atmosphere. Sources of extraterrestrial neutrinos have not yet been identified, but the upper limits on the corresponding neutrino fluxes were improved by one order of magnitude. This challenges basic models on the generation of cosmic rays. Contrary to the neutrino sky, the sky of cosmic rays charted with downward-flying muons in IceCube shows highly significant patterns. IceCube's surface detector IceTop and the Siberian Tunka detector delivered interesting data on the energy spectrum of galactic cosmic rays.

IceCube

With IceCube, a dream older than 30 years became reality: a neutrino detector with a volume of one cubic kilometre. This is the order of magnitude that is considered to be necessary to detect the extremely small neutrino fluxes from extraterrestrial sources in the TeV energy range.

The IceCube Neutrino Observatory consists of two components: the neutrino telescope IceCube in the deep Antarctic ice and the surface detector IceTop. IceCube comprises 5160 light sensors (or digital optical modules, DOMs) on 86 strings. The DOMs are arranged at depths between 1.4 und 2.4 km and record the Cherenkov light emitted by charged particles – among them particles generated in neutrino interactions. In the lower central part, the distance between the strings and between the DOMs along the strings is smaller, resulting in an improved efficiency of light collection and a much reduced energy threshold. This inner sub-detector was dubbed DeepCore. IceTop consists of 81 ice tanks, which also detect Cherenkov light – in this case from charged particles in air showers initiated by primary cosmic-ray particles.

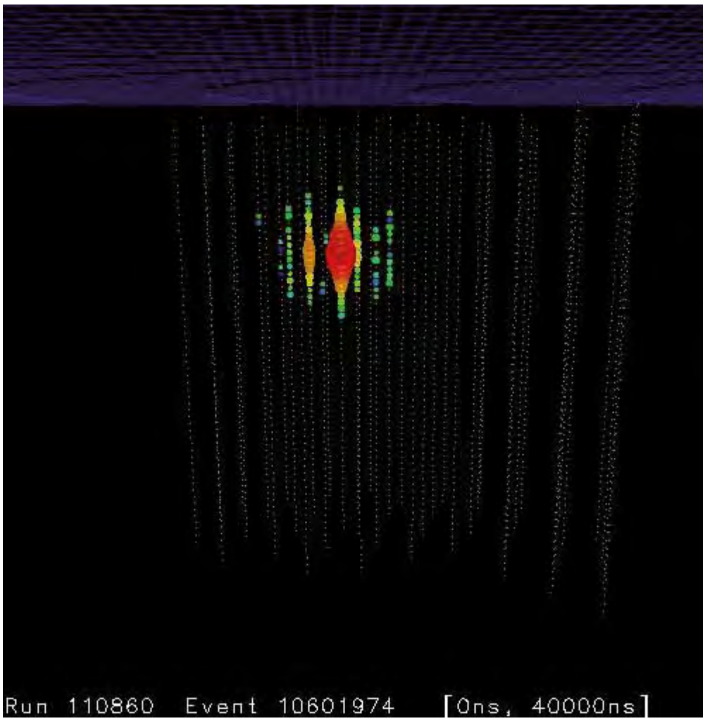


Figure 1

An isolated particle shower ("cascade") corresponding to an electron neutrino with an energy of approximately 130 TeV

A current R&D programme addresses the possibility to further increase the instrumentation density of DeepCore and lower the energy threshold down to 1 GeV (PINGU project). PINGU would enable us to measure matter-induced neutrino oscillations and possibly determine the mass hierarchy of neutrinos.

A quarter of the DOMs was assembled and tested at DESY. DESY also designed and built the electronic board for the communication between IceCube and the data centre at the surface. IceCube was completed on 18 December 2010, within the planned cost budget and at the planned time. However, data have been taken already since 2005 using the partial configurations installed in the corresponding years. The data volume amounts to about 80 TB per year. Similar to the LHC, the data are accessible within a worldwide Grid structure. Here, DESY with its Zeuthen location plays an important role as European Tier-1 centre.

In 2011, the IceCube collaboration published 14 papers in refereed journals, seven of them including a leading author from DESY.

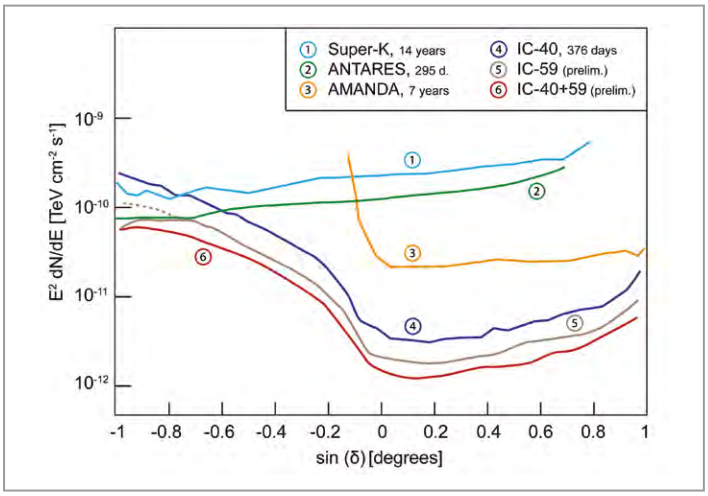


Figure 2

Limits to the flux of extraterrestrial point sources of high-energy neutrinos as a function of declination. The left part of the figure covers the southern sky, the right part the northern sky. The AMANDA limit of the year 2000 was at $E^2 \times dN/dE \sim 6 \times 10^{-10}$ TeV cm^{-2} s^{-1}, resulting in a factor 500 improvement in less than 12 years.

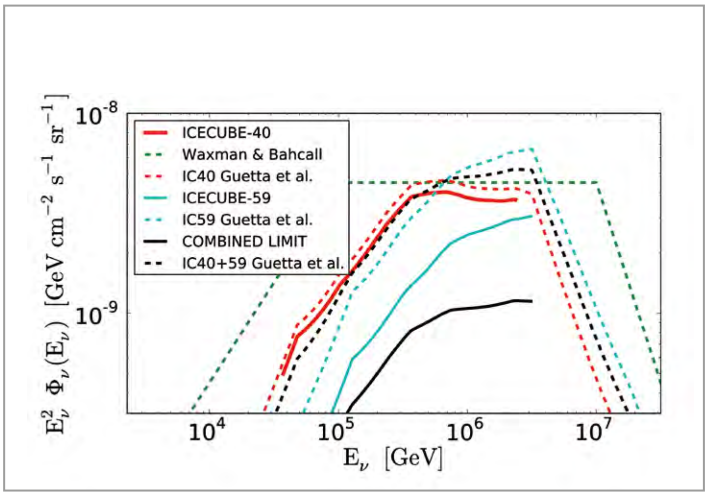


Figure 3

Limits to the flux of neutrinos from gamma-ray bursts (full lines) compared to model predictions (dashed lines). The limit derived from the 59-string data is a factor three below the model prediction of Guetta.

Neutrinos: spectra and limits

In 2011, the results from the data taken in 2009 were published and the analysis of the 2010 data was started. In the meantime, the energy spectrum from about 10^5 atmospheric neutrinos has been obtained. It extends up to 400 TeV und follows the prediction for “standard neutrinos”. For neutrinos moving faster than light – a speculation suggested in 2011 by results for neutrinos sent from CERN to the OPERA experiment – the flux should have been substantially suppressed at high energies.

Combining the data from the years 2008 (40 strings) and 2009 (59 strings), one obtains a cumulative exposure of 1 km^2 × year. However, the sky map based on this data set does not show any indications of point sources. Also, the energy spectrum of neutrinos from the whole sky did not show signals of an excess at high energies, as would be expected for a strong diffuse flux of extraterrestrial neutrinos. In both cases, the upper limits on the flux compared to those from twelve years ago have been improved by three orders of magnitude (by one order of magnitude compared to the first IceCube results) and exclude several model predictions.

The most important upper limit is that for a neutrino flux from gamma-ray bursts (GRBs). These cataclysmic events are considered as a possible source of cosmic rays above 10^{19} eV. The IceCube results exclude models that assume GRBs are the only source of such particles. The corresponding paper was accepted by the journal *Nature*.

The standard signature for neutrino reactions is muons emerging from muon neutrino interactions and passing through the detector from below. In 2011, the collaboration succeeded in clearly identifying another signature that is much harder to recognize. It consists of isolated particle showers (“cascades”), which mostly emerge from electron and tau neutrino interactions. Due to neutrino oscillations, 2/3 of the extraterrestrial neutrinos arrive as electron or tau neutrinos. The identification of this pattern is an important methodological progress.

Cosmic rays at the South Pole and in Siberia

The IceCube sky map of the downward-flying muons recorded in 2007 (22 strings) and 2008 (40 strings) showed significant anisotropies. The observed patterns have now also been confirmed by the data taken in 2009. These muons stem from air showers with energies in the range of several TeV to 100 TeV. Although the effect is only of the order of 0.1%, the pattern is highly significant. It is a combination of a dipole and a quadrupole pattern with small-scale patterns in the range of 10 to 20 degrees. A convincing explanation is still missing. The results of three years of data collection were published in *The Astrophysical Journal*.

IceTop records air showers from primary particles in the PeV range. The same range is covered by the Tunka experiment in Siberia, not far from Lake Baikal. Tunka consists of 175 wide-angle light sensors, which record the Cherenkov light from air showers. For DESY, the parallel participation in Tunka and IceTop provides very good control possibilities of the results against each other, as the two experiments use completely different registration methods. It turns out that the spectra of cosmic rays, which in both cases extend to almost 10^{18} eV, agree within errors. The same applies to the mass composition of cosmic rays, which in both cases indicates a trend towards heavier nuclei with increasing energy.

Contact:

Christian Spiering, christian.spiering@desy.de

CTA.

The Cherenkov Telescope Array

High-energy photons with energies above a few GeV trace the high-energy cosmic accelerators that are found in a variety of sources such as supernova remnants, binary systems, active galactic nuclei and gamma-ray bursts. The measurement of very low fluxes of such gamma rays is a key to understanding not only the cosmic accelerators, but also the origin of cosmic rays and the nature of dark matter. The measurement of low fluxes, in turn, requires a detection area of several square kilometres. The Cherenkov Telescope Array (CTA) will offer just that: the two CTA instruments, with their extended energy range and improved angular resolution, will be an order of magnitude more sensitive than current-generation instruments. A preparatory study that includes the building of prototypes is currently underway with strong participation of DESY. The start of construction is planned for 2014.

Ground-based gamma-ray astronomers specialize in the observation of photons with energies above a few tens of GeVs. When a gamma ray interacts in the upper atmosphere, a cascade of high-energy particles produces a short, faint Cherenkov light flash, which can be collected by telescopes on the ground and imaged onto a photomultiplier camera. An array of such imaging atmospheric Cherenkov telescopes can image the development of a shower from several angles and thereby reconstruct the direction, energy and type of the incoming high-energy particle. The CTA will bring the field of gamma-ray astronomy to a new level of sensitivity by using a much larger number of telescopes with improved optical properties and high-sensitivity focal plane instruments coupled with a sophisticated trigger concept.

The field of gamma-ray astronomy addresses a wide range of topics in physics, including the origin of cosmic rays, the acceleration of particles in the jets of active galactic nuclei and the determination of the particle nature of dark matter. The technical requirements of the CTA are currently being determined, in part by using these and other physics questions as starting points for detailed performance studies. The DESY CTA group is contributing to the evaluation of several such physics scenarios with detailed Monte Carlo simulations.

Figure 1

Prototype of a quarter of a mid-size telescope dish

The CTA is promoted by about 150 groups in Europe, Africa, Asia and the Americas and endorsed by all groups currently participating in gamma-ray astronomy. The CTA is on the list of projects on the roadmap of the European Strategy Forum for Research Infrastructures (ESFRI) and has the support of the European committees of the astroparticle and astronomy communities. It is also given top priority on national roadmaps in Europe and the Americas.

For full sky coverage, two CTA arrays will be built, one in each hemisphere. The Southern CTA array will consist of telescopes of three types, while the Northern array will be constructed of two types. To obtain sensitivity over an extended energy range, the Southern array will include:

- a few very large telescopes with 23 m mirror diameter to detect the faintest showers,

Figure 2

Digital trigger board developed at DESY

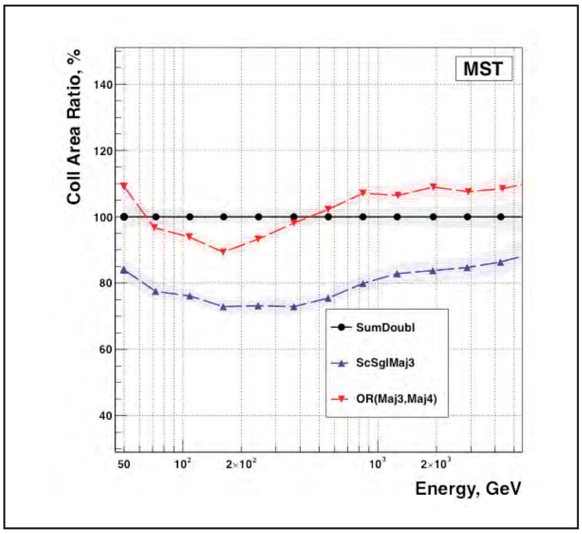


Figure 3

Trigger collection area ratios for the mid-size telescope

- a few tens of mid-size telescopes (MSTs) with a 12 m mirror diameter (100 m^2 mirror area) for high sensitivity in the energy range from 200 GeV to 10 TeV and
- a large number of small telescopes with a mirror of diameter below 7 m to achieve a high collection area for photon energies well beyond 10 TeV.

The DESY CTA group has system responsibility for the design and production of the MSTs. It is leading the development and mechanical construction of the MSTs and collaborating with design teams from Argonne, Saclay and Zürich. First prototypes for the structure, the drive system and the safety system were built and are being used as test facilities. Figure 1 shows a prototype of a quarter of the dish of one MST. It is being used for production studies, surveys, mirror mounting and alignment, and aspects of array control.

A full MST prototype is currently in production and will be built in Berlin in the summer of 2012. Its construction will help to refine the understanding of the construction process and give an opportunity to check the production quality of the components produced by the industrial partners of the project. The completed prototype will be used for detailed tests of the drive and safety system, the mirror mounting mechanics and procedure, the core calibration system and aspects of telescope control.

Controlling a large number of telescopes and subsystems at a remote site is a major challenge, which is being addressed by an array operation control system developed by DESY in collaboration with partners in Erlangen and Berlin as well as Annecy and Barcelona. The MST prototype in Berlin will also serve as a realistic test bed for these developments.

In addition, the group is developing a new type of digital trigger system that will strongly suppress the night sky background with no significant loss of signal. The performance of test boards of this system (Fig. 2) is being compared with that of more conventional trigger boards. The design of the telescope and the electronics development are done in close collaboration between physicists and engineers. Figure 3 shows a result of this collaboration: the ratio of the collection areas for complex digital trigger information (red) to the above-mentioned conventional analogue trigger (black). The result demonstrates the potential of high-performance FPGA-based trigger schemes for MSTs and small telescopes.

The CTA will be an order of magnitude larger than current instruments and measure each event with much higher precision. New analysis methods are necessary to exploit the full potential of the instrument. Together with the Helmholtz Young Investigators Group VH-NG-602 (“Towards the Next-Generation Gamma-Ray Observatory”), the DESY CTA group is developing methods that emphasize background suppression and low-energy photon reconstruction.

The site characterization procedure is underway to prepare for a site selection in 2013. About ten candidate sites in the Americas, Africa, Asia and Europe have been proposed. Installation of the first CTA array is planned to start in 2014, and first data will be taken soon thereafter.

In addition to its CTA activities, the group participates in the operation of telescopes such as H.E.S.S., MAGIC and VERITAS, and is also active in the FERMI-LAT collaboration. Members of the Helmholtz Young Investigators Group VH-NG-602 have produced interesting physics results from analysis of VERITAS data, including the detection of pulsed emission above 100 GeV from the Crab pulsar.

Contact:

Stefan Schlenstedt, stefan.schlenstedt@desy.de

Reference:

http://www.cta-observatory.org

The Fermi scale under the zeptoscope.

Why and how we expect the LHC to uncover the origin of the weak scale

The Standard Model Higgs boson is cornered. In 2012, we will either find it or exclude its existence. This, however, marks just the beginning of the search for the theory of the weak scale. The Standard Model is a beautifully simple theory with a beautiful theoretical problem – the weak scale is not stable under quantum corrections. We expect signatures of a stabilization mechanism like supersymmetry or strong dynamics to emerge at the TeV scale. The LHC had a spectacularly successful start. With the data coming in, our understanding of physics beyond the Standard Model is improving. Three questions pose themselves: What can we hope to see? How we will see it? How can we test the implications for our candidate theories of the weak scale?

In 1933, Fermi proposed the first theory to describe a weak interaction phenomenon, the beta decay of nucleons. The interaction he wrote down contained an explicit scale, the weak scale or "Fermi scale". By measuring the lifetime of the neutron, we can calculate it to be about 290 GeV, roughly 290 times the mass of the proton. We believe it to be one of the two fundamental scales in particle physics, the other being the scale of strong interactions. This scale is also the energy above which Fermi's original theory is expected to start to break down. Early on, it was conjectured (also by Fermi) and discovered in 1983 at CERN that the force carriers of this interaction are in fact vector bosons (the $W^{\pm}$ bosons), like the photon in electromagnetism or the gluon of strong interactions. The reason why the interaction is weak at energies much lower than this scale is that the $W^{\pm}$ bosons, other than the photon and gluon, are massive.

Including these force carriers together with the Higgs, which is responsible for their masses and intimately related to the weak scale, to form the Standard Model (SM) drastically changes the nature of the theory. Two remarkable and related properties result:

- its validity now extends to arbitrarily high energies and
- all theories with the same particle content and symmetries (with additional particles characterized by a mass above the weak scale) will be indistinguishable from the SM at sufficiently low energies.

This latter property is one of the main difficulties in trying to anticipate physics beyond the SM. The SM has passed all collider tests with flying colours. Why do we then not expect the SM to hold up to arbitrarily high energies? The reason is that the SM does not explain observations like e.g. dark matter, or the matter antimatter asymmetry, or why the electron is more than 100 000 times lighter than the top quark. And the list goes on.

It is easy to imagine solutions to these shortcomings, which will remain at such high energies that they will be forever untestable. So what makes us so bold to think that the LHC might tell us more? We are optimistic because of a peculiarity of the weak scale.

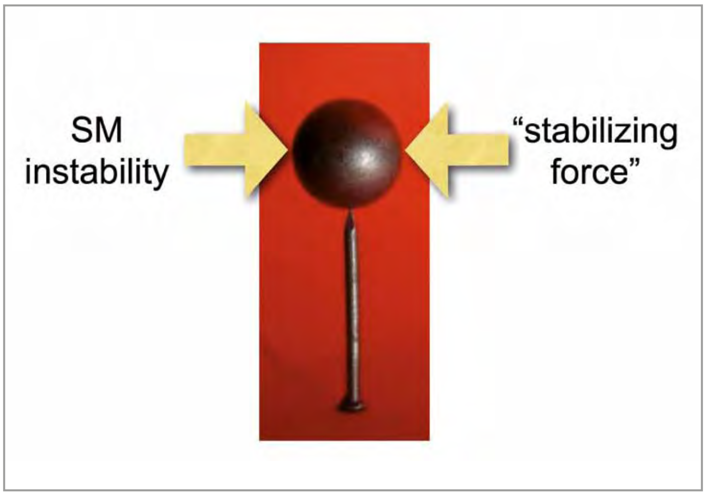


Figure 1

An illustration of the fine-tuning problem of the Standard Model

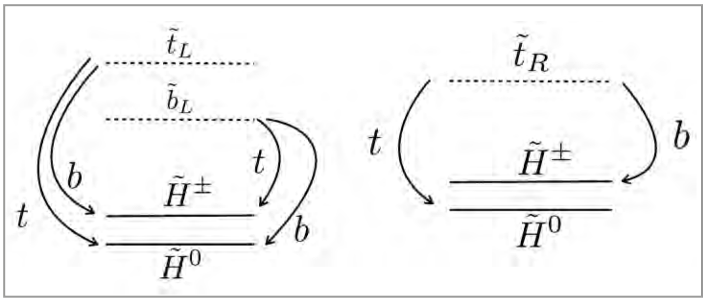


Figure 2

Possible decay modes in the simplified model consisting only of a left-handed stop/sbottom, or a right-handed stop, decaying to a higgsino lightest supersymmetric particle

Since the days of Heisenberg, we have known that nature is fundamentally quantum mechanical. Everything we observe is affected by fluctuating quanta – even the vacuum is a very busy place, particles are constantly created and destroyed. Almost all quantities in the SM are only slightly affected by these fluctuations, except the one that determines the scale of weak interactions. Any heavier particle interacting with the Higgs will tend to forcefully pull the weak scale up to its mass. Keeping the weak scale at its measured value requires considerable theoretical preparation, a fine-tuning of fundamental parameters to a tantalizing number of decimals: this is the naturalness problem of the SM.

A solution to this puzzle is found if the SM is embedded in a theory that contains a "stabilizing principle". The most successful proposals use the fact that fermion masses are not destabilized by quantum fluctuations. The two most studied paradigms then relate the Higgs boson to new fermions:

- supersymmetry, a symmetry that forces the Higgs to behave approximately like its fermionic mirror image and
- the composite Higgs, where the Higgs emerges as a bound state of more fundamental fermions.

Finding a fully satisfactory model based on these paradigms is one of the goals of our group.

Most of our guidance in the following years will be provided by the data from the LHC experiments. A first glance at the probing power can be seen from a recent analysis of the implications of di-jet searches for a particularly simple composite Higgs model [arXiv:1106.6357], which we proposed.

With the searches for new physics in full swing, a timely and important task is to ensure that the results from the LHC are as generally useful as possible and that "no stone is left unturned", meaning that the search coverage should be as large as possible. Together with groups at Berkeley Lab and Tel Aviv University, we are continuing to develop and validate a tool that replicates almost all of the new physics searches of ATLAS and CMS and allows the automatic test of any model, in particular models that have not been targeted by the experiments. The aim is to give a reliable test of new physics versus existing data while remaining self-contained and automatic. It is less powerful and precise than a full simulation by the experimental collaborations, but there is a big payoff in ease of use and applicability.

In a recent work, we used this setup to determine limits that all of the 1 fb^{-1} searches pose on a Minimal Supersymmetric Standard Model (MSSM) spectrum motivated by bottom-up naturalness. We find limits on higgsinos, stops and the gluino, including the first limit on directly produced stops [arxiv:1110.6926].

In the coming years, the LHC will explore distances measured in units of zeptometres (10^{-21} m), a billionth of a billionth of a millimetre! We believe that once we examine the Fermi scale under the "zeptoscope" LHC, there is a good chance we will learn about its origin and the dynamics responsible for electroweak symmetry breaking.

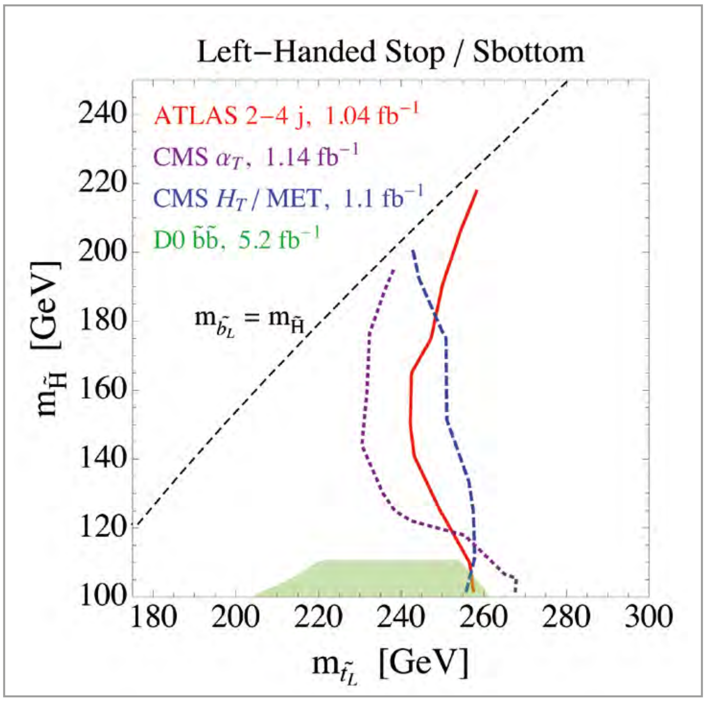


Figure 3

Estimating the allowed masses of directly produced top superpartners re-using results from ATLAS and CMS

Contact:

Andreas Weiler, andreas.weiler@desy.de

Dynamics of the electroweak phase transition.

At the interface between cosmology and particle physics

Current collider experiments – first and foremost at the Large Hadron Collider (LHC) at CERN – investigate how the electroweak symmetry is broken in nature. In the Standard Model, this amounts to finding and studying the elusive Higgs particle. At the same time, the breaking of the electroweak symmetry also has implications in cosmology. In particular, the observation of gravitational waves can provide information on electroweak symmetry breaking that is complementary to collider experiments.

The big bang theory constitutes today's concordance model of cosmology: the universe is observed to be expanding and cooling. Accordingly, at an early stage the universe was filled with a hot and dense medium of elementary particles. Because of the cooling, the medium filling the universe passed through different phases with characteristic properties, which has observable consequences.

The most prominent example for this is the generation of the cosmic microwave background (CMB). At very large temperatures, the plasma in the universe was ionized and photons interacted strongly with the medium. Once the temperature dropped below a certain threshold (corresponding to energies in the electronvolt range), nuclei and electrons combined to form electrically neutral atoms and the universe became transparent to light. The photons that were present at the time are still observable as a stochastic background with a thermal spectrum and a temperature of about 2.7 K.

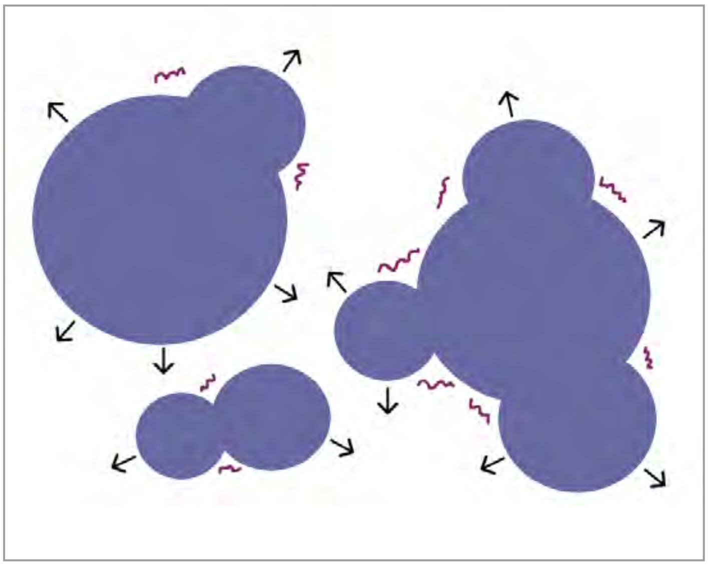


Figure 1

First-order phase transitions proceed by bubble nucleation. In the case of the electroweak phase transition, domains of broken electroweak symmetry expand into regions of unbroken electroweak symmetry. Collisions of these bubbles at the end of the phase transition produce gravitational waves.

Likewise, the breaking of electroweak symmetry drastically changed the properties of the medium filling the early universe. Once the electroweak symmetry was broken, the fermions and W and Z bosons of the Standard Model became massive, while they had been massless before.

Depending on the model under consideration, the electroweak symmetry breaking proceeds by a crossover or a phase transition of second or first order. The latter case of a first-order phase transition is particularly interesting, as it can lead to a variety of observable phenomena.

First-order phase transitions proceed by bubble nucleation – as seen in the case of boiling water – which in the context of cosmology is a quite violent process. The latent heat drives the expansion of the bubbles and accelerates the bubble walls, which easily achieve velocities of the order of the speed of light.

One immediate consequence is that at the end of the phase transition, when the bubbles percolate and collide, gravitational waves are produced. Observing a spectrum of gravitational waves, as expected from a phase transition, would give important insights about the temperature at which the phase transition happened and the corresponding latent heat. In the case of the electroweak phase transition, this information can be used to constrain the Higgs sector in the Standard Model and its extensions.

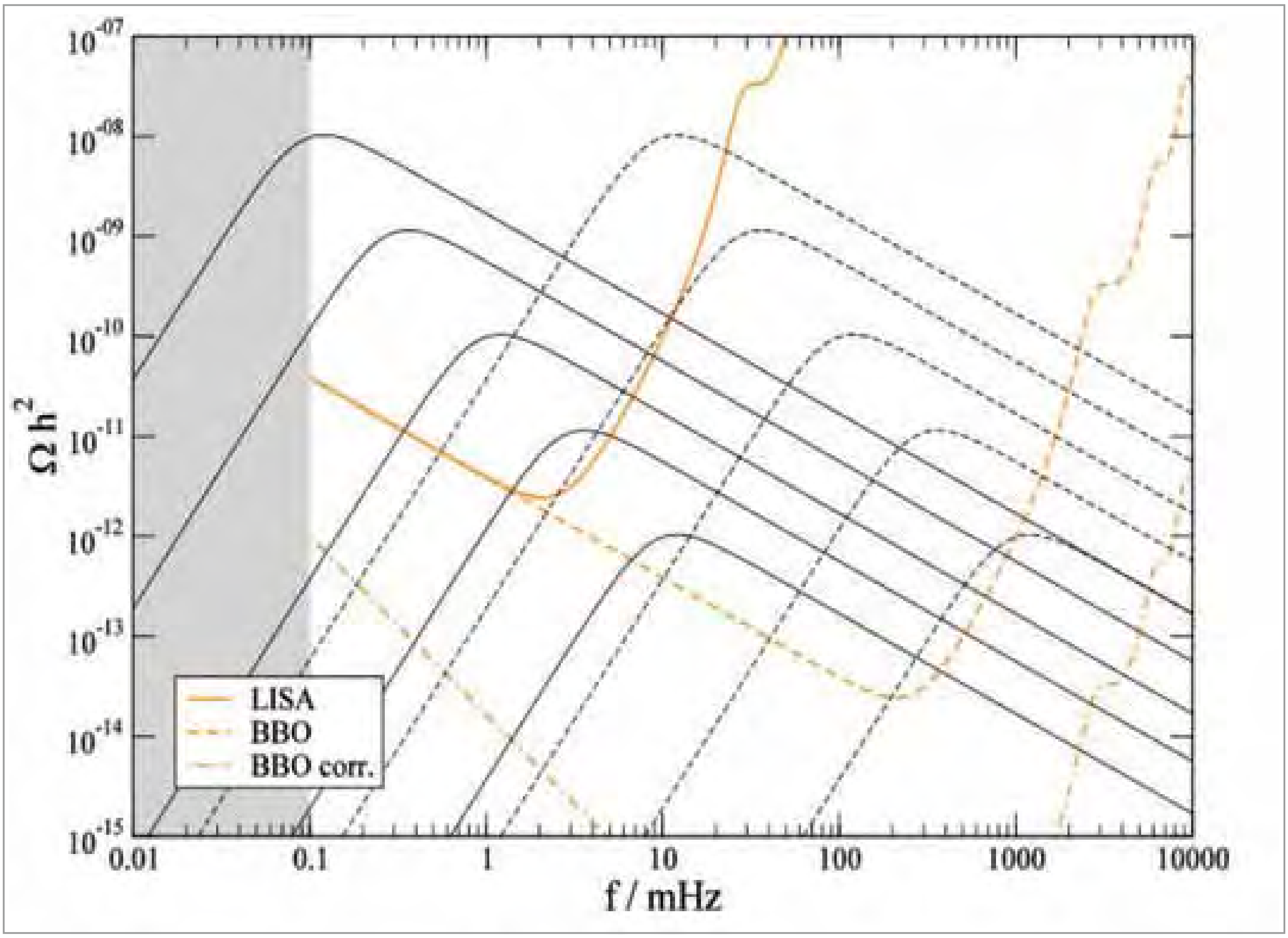


Figure 2

Some example spectra of gravitational waves produced in a model with a warped extra dimension. The yellow lines show the expected sensitivity of various satellite interferometers that are under consideration.

Ultimately, if and when these phenomena are observed depends on the mechanism that breaks the electroweak symmetry in nature. Quite generally, mechanisms that involve strong coupling of some sorts lead to stronger phase transitions and better prospects in terms of cosmological observations than weakly coupled frameworks. Examples for the former class are Technicolor, composite Higgs models and models with warped extra dimensions, while representatives of the latter class are the Standard Model, two Higgs doublet models and their supersymmetric companions.

Other interesting occurrences that can be linked to the electroweak phase transition are the production of primordial magnetic fields or the origin of the matter–antimatter asymmetry. Combining these phenomena with other laboratory probes (e.g. measurements of CP violation in electric dipole moments) will be essential to develop a unifying picture of particle physics and cosmology on electroweak scales.

Contact:

Thomas Konstandin, thomas.konstandin@desy.de

Supersymmetry, string theory and geometry.

A fruitful interplay

Supersymmetric field theories are of considerable interest in particle physics – mainly as an extension of the Standard Model. Supersymmetry also plays an essential role in consistently formulating string theory. The geometrization of particle physics in string theory establishes a further connection between supersymmetry and mathematics, which has led to a fruitful and sometimes surprising interplay.

Introduction

For many years, string theory has been developed as a candidate for a consistent quantum theory of gravity. This has indeed been achieved, but so far only in a perturbative expansion around flat Minkowski space. However, it is also possible to unify all known forces of nature within string theory at the same time. Being a theory of gravity, the characteristic scale of string theory is the Planck scale, and at energies far below that scale the theory looks like a (non-Abelian) gauge theory coupled to Einstein's gravity. Specific string backgrounds exist which resemble the Standard Model of particle physics or generalizations thereof. In particular, supersymmetry appears to play an essential role in the consistency of string theory, and therefore one generically encounters supersymmetric versions of the Standard Model.

String backgrounds can be described geometrically by specifying a ten-dimensional space-time. To make contact with our visible world, one assumes that four of these ten dimensions are infinitely extended, while the other six are curled up in a compact manifold. Consistency and supersymmetry demand that these six-dimensional manifolds are special manifolds termed Calabi-Yau manifolds (Fig. 1). This setup can be considered as a generalization of the original ideas of T. Kaluza and O. Klein, who viewed electromagnetism as a geometrical property of an extended space-time geometry (Fig. 2).

In string theory, a similar "geometrization" of particle physics occurs where properties of non-Abelian gauge theories can be related to geometrical properties of the Calabi-Yau manifolds. These manifolds are also of considerable interest from a mathematical point of view; in their study, methods of differential geometry and methods of supersymmetry nicely complement each other.

Figure 1

Model of a Calabi-Yau manifold

In recent years, string theory has also been used as a technical tool for other branches of physics and mathematics. For example, the structure of (higher-loop) scattering amplitudes in supersymmetric and non-supersymmetric quantum field theories has been successfully reconsidered with string theoretic tools. Also, in various branches of mathematics, string theoretic and/or supersymmetric considerations have led to significant advances.

The more supersymmetry a field theory has, the easier it becomes as a quantum field theory. The reason is that the quantum fluctuations are constrained by supersymmetry and, as a consequence, considerably simplify the quantum theory. Theories with two supercharges ($N = 2$ supersymmetry) are of particular interest. On the one hand, the two supersymmetries significantly constrain the quantum theory, on the other hand, such theories do display interesting (quantum) phenomena. In the following, we will describe some of the recent research activities in $N = 2$ theories carried out at DESY and the University of Hamburg.

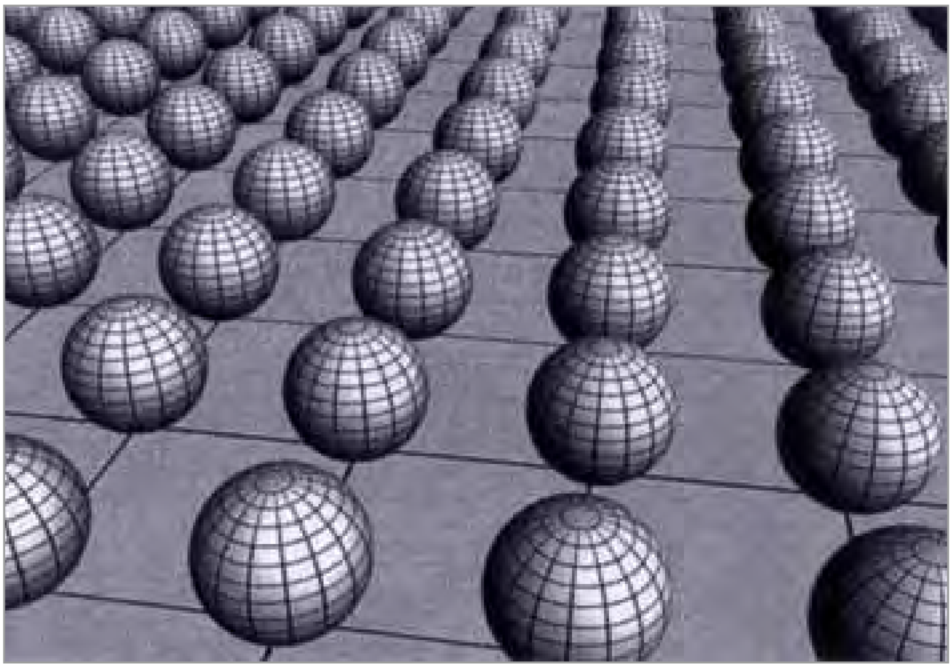


Figure 2

Space-times with extra dimensions

Supersymmetric $N = 2$ theories

Embedding the Standard Model of particle physics in string theory is an interesting field of current research. In particular, one would like to identify promising generalizations of the Standard Model that will hopefully become visible at the LHC.

Grand unified models are attractive because of the "observed" gauge coupling unification in the supersymmetric Standard Model and the non-vanishing neutrino masses. However, these theories are notoriously plagued by a somewhat contrived Higgs sector. This can be eased if one chooses to consider field theories with extra space dimensions where the full GUT symmetry is never visible in four space-time dimensions. Such theories can be naturally embedded in string theory. Particularly promising are backgrounds with an intermediate six-dimensional space-time. This theory has $N = 2$ supersymmetry, which is explicitly broken to $N = 1$ by the compactification to four space-time dimensions. However, as a consequence of the intermediate $N = 2$, the possible couplings in the $N = 1$ theory are constrained. The corresponding effective action has recently been computed, and an appropriate smooth Calabi-Yau manifold has been identified.

Alternatively, one can study spontaneous supersymmetry breaking from $N = 2$ to $N = 1$ theories. Below the scale of this breaking, an effective $N = 1$ theory can be derived by integrating out all states that become massive in the process of supersymmetry breaking. However, the couplings of this effective $N = 1$ theory again "remember" the original $N = 2$ input data.

Consistency of this procedure also relates the respective field spaces to each other. In $N = 2$ theories, the matter fields can be viewed as the coordinates of a quaternionic-Kähler manifold. Such manifolds are characterized, for example, by its holonomy group Sp(n)xSp(1). In $N = 1$ theories, the corresponding field space is a simple Kähler manifold, and the spontaneous supersymmetry breaking implies a connection between these two classes of manifolds. It turns out that the symmetry breaking needs two Goldstone bosons eaten by two Abelian vector fields. Integrating out these vector fields amounts to taking a particular quotient of the $N = 2$ field space. It was possible to show that for a quaternionic-Kähler manifold this quotient is always Kähler. This property, which was unknown in the mathematical literature, followed immediately from the consistency of the two supersymmetric field theories. This is an example of the fruitful interplay between supersymmetric field theories and differential geometry.

Contact:

Jan Louis, jan.louis@desy.de

References:

Schasny, Valandro, arXiv:1112.5106 [hep-th]
Cortes, Louis, Smyth, Triendl, arXiv:1111.0679 [math.DG]

The muon anomalous magnetic moment from lattice QCD.

Testing the Standard Model

In this article, the John von Neumann Institute for Computing (NIC) group at DESY in Zeuthen discusses a lattice QCD calculation of the leading-order hadronic contribution to the muon anomalous magnetic moment. The group shows that by using improved definitions of the lattice observables, the accuracy of the computation can be significantly improved, leading to a promising prospect for future determinations of this important quantity to test the Standard Model of particle physics.

In Dirac's theory, the electron is described as a spin 1/2 particle with the positron as its antiparticle. Like the angular momentum in the classical theory, the spin $\vec{S}$ leads to a magnetic moment of the electron

$$\vec{\mu}_{\mathrm{m}} = -g_{\mathrm{e}}\mu_0\vec{S} \qquad (1)$$

with $\mu_0 = e/4m_{\mathrm{e}}$, e being the electric charge and m_{e} the mass of the electron. The quantity g_{e} is the gyromagnetic ratio of the electron which, in Dirac's theory, equals 2. In quantum field theory, deviations from $g_{\mathrm{e}} = 2$ originate from virtual photon exchange and give rise to an anomalous magnetic moment, $a_{\mathrm{e}} = (g_{\mathrm{e}} - 2)/2$.The simplest correction to g_{e} was already computed by Schwinger in 1948 directly from quantum electrodynamics (QED), the relativistic theory of electromagnetic interactions. Experimental measurements found a value for $g_{\mathrm{e}} = 2.00238(10)$ compared to Schwinger's calculation of $g_{\mathrm{e}} = 2.00232$.

Today, the electron magnetic moment is one of the most precisely tested quantities in nature: the agreement between experiment and theory has achieved the amazing accuracy of ten significant digits. It has thereby become a cornerstone result and makes us confident that quantum field theory is indeed the correct method to describe particle interactions.

For another lepton, the muon, the comparison of theoretical and experimental determinations of the anomalous magnetic moment (a_μ^{th} and a_μ^{exp}, respectively) is much less satisfactory: one finds $a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{th}} = 2.90(91)\cdot 10^{-9}$. The values disagree by more than 3σ. This is a very interesting result. It means that either something has been neglected or not properly included in the theoretical calculation. A more exciting alternative is that the discrepancy indicates a breakdown of the Standard Model of particle interactions and that the inconsistency stems from effects of some yet unknown new physics beyond the Standard Model.

Indeed, calculations show that a new physics effect would lead to a correction to the anomalous magnetic moment of size $\delta(a_\mu^{\mathrm{newphysics}}) = m_\mu^2/M_{\mathrm{newphysics}}^2$. Here m_μ is the mass of the muon and $M_{newphysics}$ represents the mass (or scale) of a particle originating from the (unknown) new physics beyond the Standard Model.

There are several contributions to a_μ. In particular, the strong interaction of quarks and gluons in quantum chromodynamics (QCD) leads to the so-called hadronic contributions a_μ^{had} which have an intrinsically non-perturbative nature. It is exactly at this point where lattice field theory methods applied to QCD can help – at least in principle. In lattice QCD, the theory is formulated on a discrete four-dimensional Euclidean space-time lattice, and the theory is approached by means of numerical simulations. In this way, calculations from first principles can be performed without the need of any modelling.

It turned out, however, that the value of a_μ^{had} computed from lattice calculations had a 10 times larger error than that obtained from the phenomenological calculation. The lattice community has therefore been rather sceptical that lattice QCD could provide a relevant contribution to our understanding of the $g_\mu - 2$ discrepancy.

In 2011, a significant step forward was made by members of the DESY NIC group. They observed that by a suitable redefinition of the lattice observable needed to compute a_μ^{had}, a much smoother and better extrapolation of a_μ^{had} from the value calculated at unphysical pseudoscalar masses to the physical pion mass can be achieved. To illustrate the idea, let us give the definition of a_μ^{had},

$$a_\mu^{\mathrm{had}} = \alpha^2 \int_0^\infty dQ^2 \frac{1}{Q^2}\omega(r)\Pi_R(Q^2) \qquad (2)$$

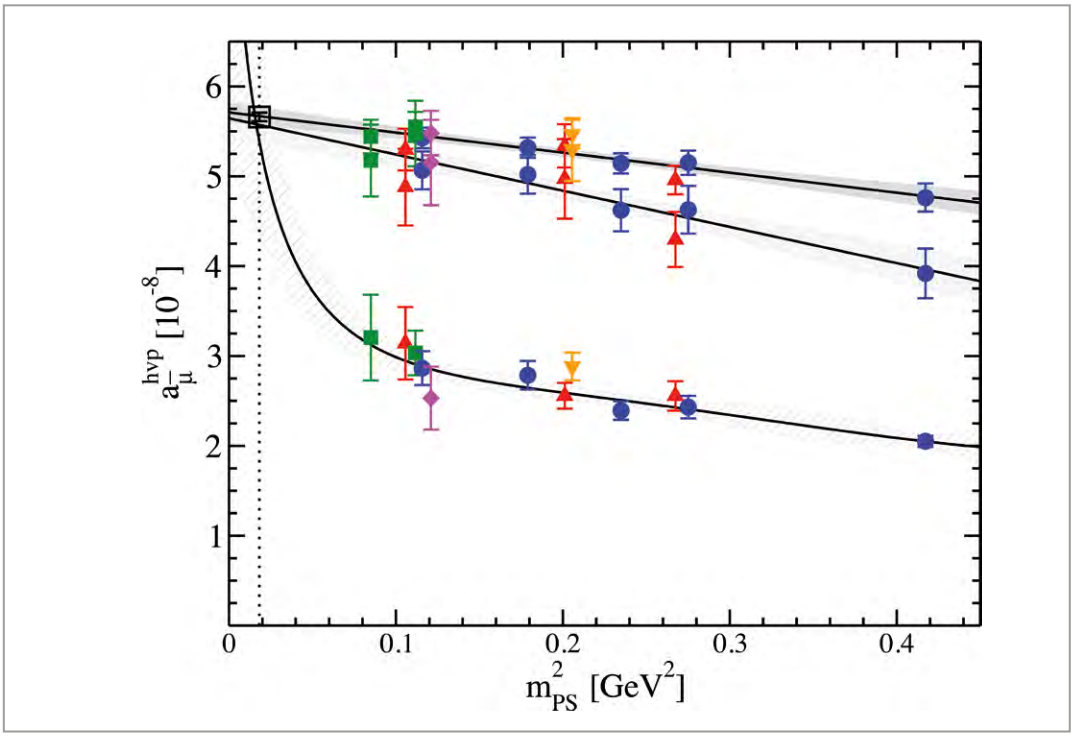


Figure 1

The hadronic contribution to the muon anomalous magnetic moment computed on the lattice using the improved observables introduced by members of the NIC group. The curves correspond to the definitions r_1, r_2 and r_3 in eqs. (3) from bottom to top.

Here, α is the electromagnetic coupling and $\Pi_R(Q^2)$ is the renormalized vacuum polarization function: $\Pi_R(Q^2) = \Pi(Q^2) - \Pi(0)$. The functional form of $\omega(r)$ is analytically known, and the argument r is given by $r = Q^2/m_\mu^2$ where Q denotes a generic momentum. The key observation is that, on the lattice, there is a large freedom to choose a definition of r. The only requirement is that in the limit of reaching a physical pion mass, the continuum definition of $r = Q^2/m_\mu^2$ is recovered. Hence, one may define $r_{\text{latt}} = Q^2 \cdot H^{\text{phys}}/H$ with possible choices for H

$$r_1\colon H = 1,\ H^{\text{phys}} = 1/m_\mu^2$$
$$r_2\colon H = m_V^2(m_{PS}),\ H^{\text{phys}} = m_\rho^2/m_\mu^2$$
$$r_3\colon H = f_V^2(m_{PS}),\ H^{\text{phys}} = f_\rho^2/m_\mu^2 \qquad (3)$$

Here, $m_V(m_{PS})$ is the mass of the ρ meson and $f_V(m_{PS})$ the ρ meson decay constant as determined on the lattice at unphysical pion masses m_{PS}. Furthermore, m_ρ and f_ρ denote the corresponding ρ meson mass and decay constant at the physical point. All the definitions in eqs. (3) guarantee that the desired definition of r is indeed recovered in the limit of a physical pion mass, since then by definition $m_V(m_{PS})$ and $f_V(m_{PS})$ assume their physical values.

In Fig. 1, we show the results for a_μ^{had} for all three definitions of r. Clearly, for the definitions r_2 and r_3 the behaviour of the lattice data towards physical pion masses is much more linear and allows for a controlled extrapolation to the physical point. As a result, when using r_2 in eq. (3), the lattice computation yields $a_{\mu, N_f=2}^{\text{had, latt}} = 5.72\,(16) \cdot 10^{-8}$, while the experimental value from e^+e^- cross sections is $a_{\mu, N_f=2}^{\text{had, exp}} = 5.660\,(47) \cdot 10^{-8}$. The index $N_f = 2$ indicates that the lattice QCD calculations only used a mass-degenerate pair of up and down quarks.

In conclusion, by using the modified and improved definitions of a_μ^{had} on the lattice, it is first of all possible to recover the experimental result. In addition, it is also possible to come significantly closer to the experimental accuracy. Before a direct comparison to the experimental results can be made, the strange quark must be included. Furthermore, since newly planned experiments at Fermilab and J-PARC are aiming at an accuracy of better than 0.5% for the hadronic contribution to the muon anomalous magnetic moment, even more accuracy from theory will be needed. To accomplish this, lattice simulations will possibly have to include explicit effects of isospin breaking and electromagnetism. All this is in principle reachable within lattice QCD, but constitutes a real challenge for the lattice community.

Contact:

DESY NIC group
Karl Jansen, karl.jansen@desy.de
Hubert Simma, hubert.simma@desy.de
Rainer Sommer, rainer.sommer@desy.de

Precision tools for LHC physics.

From mathematics to open-source software and predictions

For precise predictions of LHC physics, we have to go far beyond textbook mathematics. This is due to higher-order loop corrections as well as multi-particle final states. The problems stem from the growing number of variables arising from the masses and energies of the heavy particles and from more integration variables in the multi-loop integrals. In one-loop perturbation theory, the underlying mathematics is known in all details, but must be applied in a sufficiently efficient way. The reason is that many contributions to the calculations, sometimes tens or hundreds of thousands, must be combined into a precise and stable theoretical prediction. The resulting software should be easy to use and accessible to everybody. The last years brought impressive progress in all steps of the calculational chain. In this article, we describe a few recent milestones with examples from the open-source projects PJFry and GoSam.

The Large Hadron Collider (LHC) at CERN started regular operation in March 2010 and is now producing an enormous amount of data. The hope is that their analysis will not be in accordance with the known particles of the Standard Model – quarks, leptons, gluon, photon, $W^{\pm}$ bosons and Z boson. To complete the Standard Model, the Higgs boson is needed as its last building block, which has not been discovered so far. Even more exciting would be to see anything else – something that cannot be really predicted, but the signatures of which may be described, even quantitatively, if a certain elementary particle model is assumed. The most prominent case is supersymmetry.

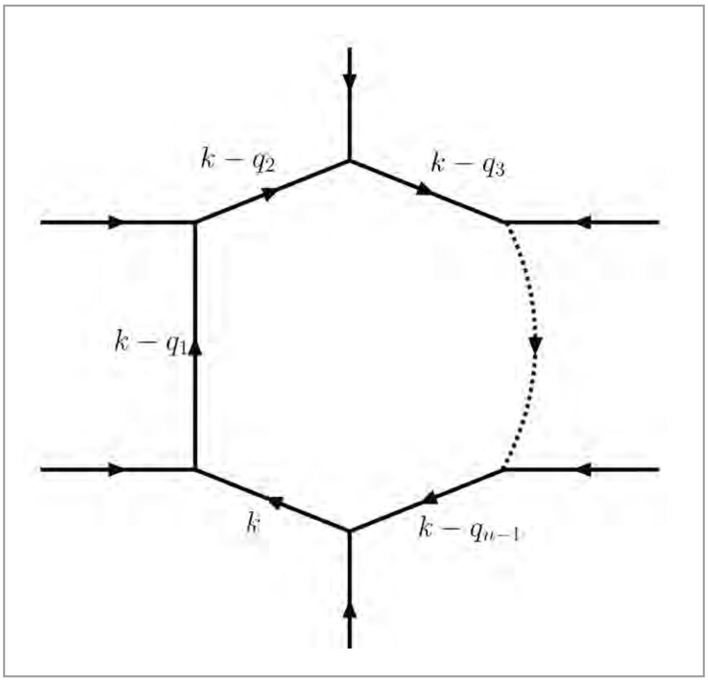


Figure 1

Feynman graph with one loop for *N* particle production. Internal and external particles may have arbitrary masses. The corresponding Feynman integral has to be evaluated as a part of the complete calculation, summing over all Feynman diagrams that are allowed in a specific theory.

We cannot foresee what will happen in the future at the LHC, but what is sure is that one or the other new phenomenon must show up – a “predicted” one or something unexpected. The reason is that the predictive power of the Standard Model breaks down at the terascale, the energy scale of the LHC. We must be prepared for truly small deviations of observations from predictions – if any. In many scenarios, deviations are expected to be as small as the quantum fluctuations of the Standard Model reactions. The reason is deeply rooted in quantum field theory. We may observe incoming and outgoing particles, but the contribution of a variety of possible intermediate states makes a distinction on an event-by-event basis impossible. Furthermore, most of the predicted or just expected new particles in the discovery range of the LHC should decay nearly instantly into other, more stable particles. These “other particles” come from Standard Model interactions, and here the circle closes: a very precise understanding of the Standard model is needed to properly “subtract” the signatures; the “rest”, if there is any, is what we are seeking. In particle physics terms: calculate the background, calculate the quantum corrections, and calculate one- or multi-loop corrections!

A one-loop example is shown in Fig. 1. The basic algorithms to evaluate all its so-called tensor integrals have been well known since the seminal paper by Passarino and Veltman in

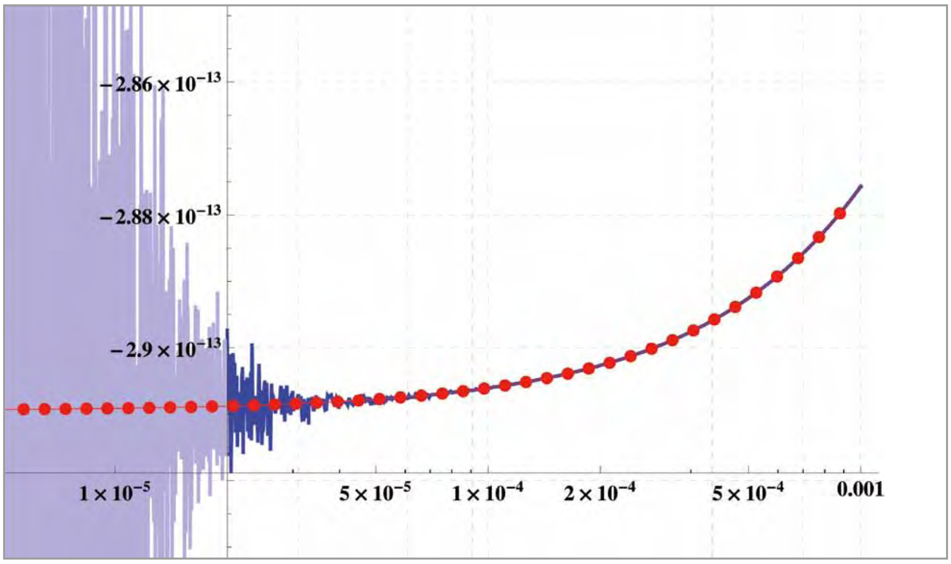


Figure 2

Accuracy of tensor Feynman integral evaluation in the neighbourhood of a singular point.
Blue: Passarino-Veltman method, red: improvement by use of higher-dimensional integrals and Pade approximation. (Courtesy: V. Yundin)

1978, plus a few extensions for more than four external particles. A major problem is stability, and the appearance of inverse powers of determinants built from masses and momenta has to be treated with care.

In the PJFry project, we do so by intensively using Feynman integrals defined not only in four, or $4-2\varepsilon$, dimensions, but in dimensions $N-2\varepsilon$, for $N = 4, 6, 8$, etc. (Fig. 2). For the tensor of rank 7 of a 7-point function, for example, conventionally one must perform multiple sums with about $6^7 = 279\,936$ terms. Alternatively, we found a way to perform sums algebraically, e.g. for $n = 7$:

$$\Sigma_{ab}^{4,stu} = \sum_{i,j=1}^{n-1} (q_a\cdot q_i)(q_b\cdot q_j)\begin{pmatrix} stui \\ stuj \end{pmatrix}_n ,$$

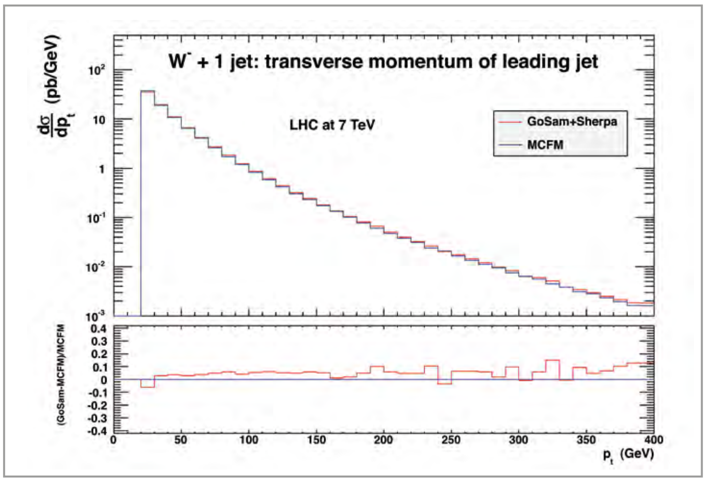


Figure 3

Transverse momentum of the leading jet for W^- + jet production at the LHC with $\sqrt{s} = 7$ TeV. (Courtesy: GoSam)

where $(q_a \cdot q_i)$ are scalar products of momenta and the $\begin{pmatrix} stui \\ stuj \end{pmatrix}_n$ are signed minors – kinematical determinants. The sums depend on a few simple combinations of the momenta involved. This marks a breakthrough: instead of multiple sums, one handles only a multiple product of a few terms.

Modern software packages for the evaluation of cross sections for the LHC integrate all kinds of such improvements. No wonder that the authoring teams get larger, and that they interlink not only their own developments, but also packages of others; as an example, GoSam integrated the PJFry package.

The GoSam collaboration is a joint effort of colleagues from Durham, Edinburgh, Geneva, Munich, New York, Urbana, and DESY in Zeuthen. A sample prediction is shown in Fig. 3. GoSam is an example of true open-source software with dedicated support, so that other researchers have a realistic chance to run the package for their projects.

Contact:

Tord Riemann, tord.riemann@desy.de
Jochem Fleischer, jochem.fleischer@desy.de
Sven-Olaf Moch, sven-olaf.moch@desy.de

References:

http://theorie-zeuthen.desy.de
https://github.com/Vayu/PJFry
http://projects.hepforge.org/gosam

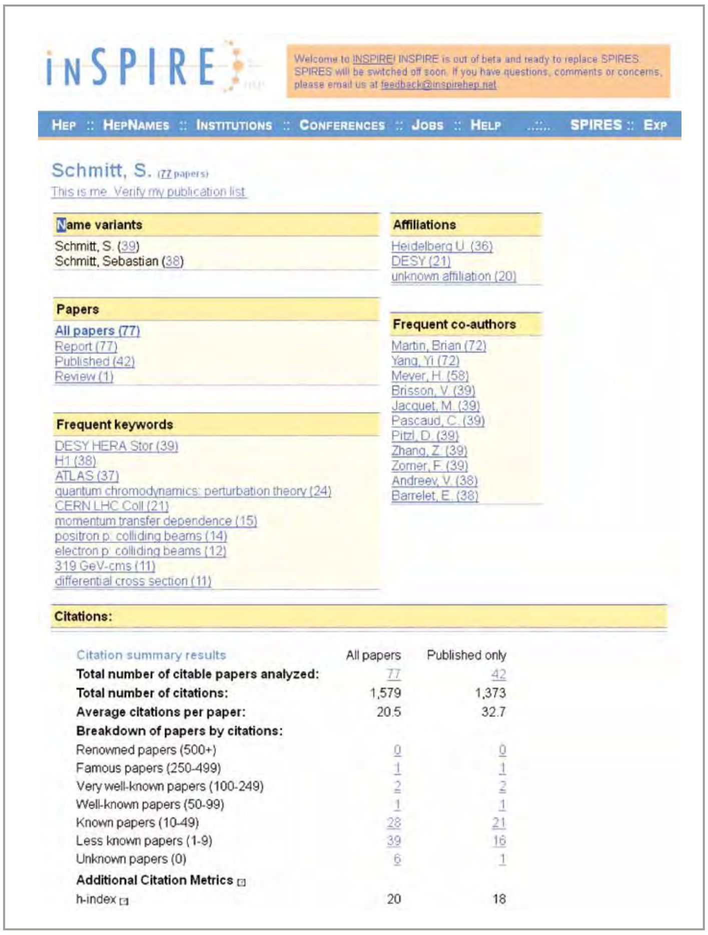
INSPIRE.

The new HEP database and the date preservation project

In mid-2011, INSPIRE replaced SPIRES as the database for high-energy physics (HEP) publications. Soon afterwards, satellite databases, such as those containing information on institutes, conferences and jobs as well as the HepNames database, were incorporated into the new system. Among other features, INSPIRE boasts a modern interface and a blazingly fast and flexible search engine.

More features

HepNames, the database of people working in HEP, benefits greatly from the new service of author identification. The service uses a smart clustering algorithm to match authors to entries in HepNames based on affiliations and subjects of publications and also provides for the assignment of a unique author ID. This feature helps to resolve identities of authors with common names (e.g. Schmitt, Kim) or authors with name variants on various publications.



Welcome to INSPIRE! INSPIRE is out of beta and ready to replace SPIRES. SPIRES will be switched off soon. If you have questions, comments or concerns, please email us at feedback@inspirehep.net

Schmitt, S. (77 papers)

This is me. Verify my publication list

Name variants

Schmitt, S. (39)
Schmitt, Sebastian (38)

Affiliations

Heidelberg U. (36)
DESY (21)
unknown affiliation (20)

Papers

All papers (77)
Report (77)
Published (42)
Review (1)

Frequent co-authors

Martin, Brian (72)
Yang, Yi (72)
Meyer, H. (58)
Brisson, V. (39)
Jacquet, M. (39)
Pascaud, C. (39)
Pitzl, D. (39)
Zhang, Z. (39)
Zomer, F. (39)
Andreev, V. (38)
Barrelet, E. (38)

Frequent keywords

DESY HERA Stor (39)
H1 (38)
ATLAS (37)
quantum chromodynamics: perturbation theory (24)
CERN LHC Coll (21)
momentum transfer dependence (15)
positron p: colliding beams (14)
electron p: colliding beams (12)
319 GeV-cms (11)
differential cross section (11)

Citations:

Citation summary results	All papers	Published only
Total number of citable papers analyzed:	77	42
Total number of citations:	1,579	1,373
Average citations per paper:	20.5	32.7
Breakdown of papers by citations:		
Renowned papers (500+)	0	0
Famous papers (250-499)	1	1
Very well-known papers (100-249)	2	2
Well-known papers (50-99)	1	1
Known papers (10-49)	28	21
Less known papers (1-9)	39	16
Unknown papers (0)	6	1
Additional Citation Metrics		
h-index	20	18

Figure 1

The INSPIRE author page

In addition to the standard bibliographic metadata, INSPIRE offers information that either enriches the records or allows for more powerful selection and searches, including full-text searches, thumbnails of figures and supplementary materials like data files for figures and tables.

Data preservation and INSPIRE

The above-mentioned features have been successfully exploited by an ongoing project aimed at integrating more of the publication process of working groups and collaborations into INSPIRE. This includes the storage of collaboration-internal documents, such as notes and preliminary papers, in such a way that only the members of the owning collaboration can access them. This project is being carried out in collaboration with DPHEP, a working group for Data Preservation in HEP. When completed, the system will serve as a reliable and sustainable long-term preservation service for all of the documentation and supplementary data needed for any further re-use of experimental data. It will thus provide an essential new service to the HEP community.

Plans for 2012

The front end of SPIRES was already successfully replaced by INSPIRE several months ago, and the old web pages will soon be shut down. More exciting new features are being developed and implemented to make the usage of the INSPIRE interface as efficient and pleasant as possible and to cater to all of the possible search requests and reference listings.

The back end of SPIRES, which contains all of the various workflows for document harvesting, metadata assignment, classification and consistency checks, will also be faded out so that, by the end of 2012, all of the workflow will be done within INSPIRE.

Contact:
Zaven Akopov, zaven.akopov@desy.de
Kirsten Sachs, kirsten.sachs@desy.de

The DESY picture library.

Preserving history

At the end of 2010, the DESY Library, in collaboration with the DESY Information Technology and Public Relations groups, started working on a project to restore the existing, rudimentary picture library. The restoration involved the sorting, classification, documentation and digitization of the existing images (negatives, positives and slides) from the years 1955–2004.

Project start

Initially, the images were stored randomly in four large cabinets belonging to the Administration group (Fig. 1). There was no documentation of the data, and it was almost impossible to quickly find a picture. In December 2010, the picture library was moved to the DESY Library, where a detailed examination of approximately 750 000 images began. The chronological image meta information allowed us to start rearranging the negatives. There were some surprise finds, among them an early negative of the library, dated 15 July 1968 (Fig. 2).

Figure 1

Picture library at V1

(Courtesy: R. Baus)

Figure 2

The DESY Library in 1968

Progress in 2011

During 2011, the negatives were sorted and rearranged, and photos with particular motifs were digitized. These included DESY events concerning employees (birthdays, etc.), buildings and facilities (construction and aerial photos), and special events (visits of state representatives, open days, etc.). Altogether, data from approximately 300 000 images in 140 folders remained in the archive, as well as a considerable quantity of slide storage equipment.

The challenge

The most complex and important part of the project is still to come: adding meta information like image number, the date the picture was taken and, especially, what can be seen on it and why it was taken. To store this information, the DESY Library uses the Cumulus database software, which enables picture metadata to be included and allows fast searches on particular search terms.

Figure 3

Online access to the new DESY media database

An initial set of 250 out of 60 000 digitized images were added to the database. Another 1000 photos were removed because of duplication or lack of suitability. Additional tasks were performed, such as setting up the topology of the database and image identification. Image identification proved to be difficult for the older photos. Valuable assistance was provided by former and current DESY colleagues. Erich Lohrmann, in particular, turned out to be a virtual gold mine for knowledge on DESY history and provided outstanding help.

The future

Initially, approximately 10 000 out of about 60 000 digitized images will be uploaded to the Cumulus database. The remaining images will be listed with as much information as is known. Images still to be digitized will also be registered and entered into the database. The remainder of the image data, including, for example, measurements and layouts of printed circuit boards, construction components, devices and machinery, will be processed later. Certainly, there are still some hidden treasures of DESY history to be discovered.

Contact:
Renate Baus, renate.baus@desy.de

From design documentation to design integration.

How the technical design documentation for the ILC helps to achieve a better design

Nobody likes to write documentations. Designing a new accelerator is interesting, challenging and sometimes fun, whereas documenting the design is tedious. But when designing and documenting go hand in hand, both the design and its documentation improve in the end.

Design documentation: More than a glossy report

By the end of 2012, the technical design report (TDR) of the International Linear Collider (ILC) will be completed, in time for publication in early 2013. Delivering a TDR is a pivotal moment in a large project such as the ILC: it marks the completion of a long and successful R&D effort and the beginning of a review and decision process that will hopefully turn into the start of a construction project. At this point, new groups enter and old groups sometimes leave the project. Documenting the result of this R&D effort is of utmost importance to avoid having to reinvent the wheel at a later project stage. Equally important is that only a solid documentation will convince the review committees that the ILC is indeed technically feasible and that it can be built at the estimated cost.

While writing the TDR itself is already a considerable task, such a document cannot in any way reflect all the work that went into the design it describes. Tonnes of internal notes, memos, calculations captured in spreadsheets, lattice design files, technical drawings and CAD models have been produced and need to be kept available for a successful continuance of the project.

That an electronic database is used for this purpose is self-evident today. However, employing an engineering data management system (EDMS) to store the documentation is only the first decision. More important, and more difficult, is the definition of a suitable process to compile this body, which is termed the technical design documentation (TDD), to define the nature of the documents that need to be provided and to embed the documentation process into the design process itself, so that the design (and the designer) profits from the documentation.

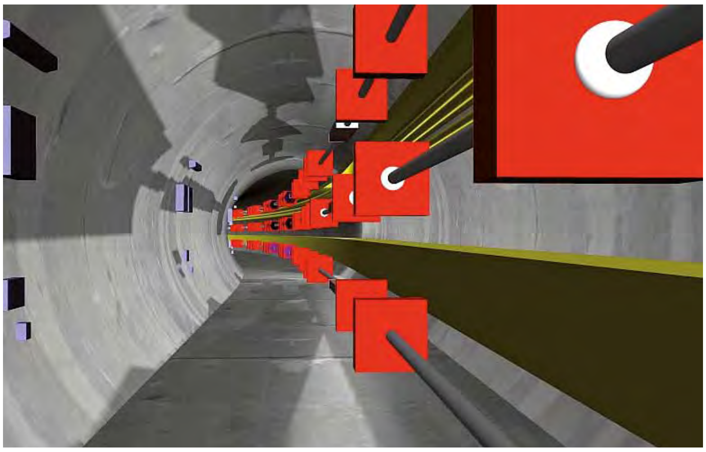


Figure 1

A visualization of the three damping rings (for electrons in the middle, and positrons at bottom and top) in the ILC tunnel. This model combines a fast visualization of the accelerator, based on the lattice design, with a conceptual CAD model for the tunnel and some of its infrastructure.

Documentation drives design

So what makes the TDD special compared to the ubiquitous web-based documentation systems we encounter daily, be it traditional, centrally maintained web pages or self-organizing Wiki sites? For one: reliability and accountability. The TDD is organized more formally than a Wiki-style information platform: a work breakdown structure (WBS) of the design project organizes the topics, a set of mandatory documents defines the deliverables, and these documents are reviewed by the stakeholders and approved by the management before they are released. Thus, the TDD becomes the single point of information on relevant data within the project. Numbers, layouts and specifications become valid when they enter the TDD, before that they are just rumours.

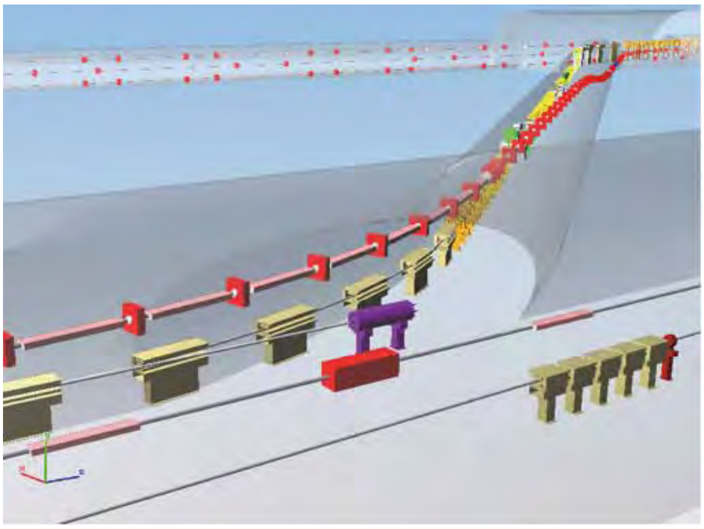


Figure 2

A view of the branch-off of the transfer tunnel between the ILC main linac and damping rings, one of the most crowded regions where five beamlines belonging to three accelerator systems come together.

By developing a WBS early in the project, it is ensured that responsibilities are clearly defined and that everybody knows where to look for information: the cryomodule group defines the length of the cryomodules, the cryogenics group specifies the number of modules that form a cryo string, and the main linac integration group bases the lattice design on these numbers. If pieces of design are missing, it is clear who must them and whether they are official. Equally important: later on in the design, it is documented where a number came from, because not only documents are versioned, but also their relationships. If document A, version 3, is based on document B, version 8, and no later version of B exists, document A is probably up-to-date. In a project that evolves over years, information about which parts of a design or a calculation are up-to-date and which are not is crucial; without that information, a calculation may become so unreliable that it has to be completely redone from scratch, possibly several times, wasting precious time and money.

Next to the WBS comes the definition of a set of mandatory documents – such as a system overview, a parameter list, a lattice file, to name just a few – that are required to be prepared for each WBS element (where it makes sense). Specifying the deliverables of the design work in this way is a good way not to overlook anything in the design. If the management provides templates (e.g. for parameter tables) which list values expected to be given, the documentation turns from a passive, obnoxious task that needs to be done after the “real” work (i.e. the design) has been completed, into an active steering instrument for the management. The documentation asks the questions, rather than just collecting answers, and thus starts to drive, or at least steer, the design work.

From documentation integration to design integration

The TDD aims to achieve the three C’s: completeness, correctness, and consistency. A structured documentation, which allows everyone involved to keep track whether the information about the various parts of the design is present, is a prerequisite to making sure that the design itself is complete, correct, and consistent. In a project such as the ILC, whose contributors are scattered around the whole globe and all time zones, it is even harder than usual to keep everyone on the same page. The fact that virtually all researchers working on the ILC can devote only part of their time to that project is an additional obstacle.

Thus, a central group that collects, edits and disseminates the documentation is important. This service is provided by the DESY-IPP group. Of course, the place where all of the information flows together is ideally suited to go one step further, i.e. to integrate the design itself. For instance, designing the tunnel that houses the accelerator requires, on the one hand, that the accelerator geometry information derived from the lattices is provided to the tunnel designers in a form that is suitable as input for CAD programs. On the other hand, this requires not only an accelerator layout that has been adjusted such that all parts fit together seamlessly, but also an optimization in which the beamlines of different systems are adjusted such that they fit into a reasonably sized tunnel. This is achieved by bringing the designs of different groups together, overlaying them with the existing tunnel designs and making proposals for further adjustments.

Making it visible

A proverb says “seeing is believing,” and this is also true for the design of future accelerators. By applying tools and techniques that are employed successfully in the design of the European XFEL, it is possible to combine 3D models from different CAD programs with rapidly generated visualizations of the ILC accelerator lattice in the design process.

A virtual-reality room even makes it possible to take a virtual tour of the ILC. This helps to review issues such as installation space, accessibility of components, or escape routes, especially in crowded regions that are difficult to depict in 2D drawings. It also conveys a feeling for the size of some of the planned installations. And in the end, the motivation a lattice designer or an engineer experiences when “walking” through her or his own design should never be underestimated!

Contact:

Lars Hagge, lars.hagge@desy.de

The DESY Grid Centre.

A common computing infrastructure for many experiments

In 2011, the operation of the DESY Grid infrastructure and the National Analysis Facility (NAF), together called the "DESY Grid Centre", successfully continued. With almost 6000 job slots in the Grid, the two sites at DESY in Hamburg and DESY in Zeuthen participated in the data processing of the LHC experiments ATLAS, CMS and LHCb and provided computing resources for the HERA experiments, ILC and astroparticle physics (IceCube, CTA). Support for the OLYMPUS and Belle experiments was added. With approximately 3000 job slots and 400 TB of analysis disk space, the NAF was heavily used and provided computing resources for data analysis of LHC and ILC experiments in Germany.

Introduction

Grid computing is the key technology to meet the vast computing demands of the LHC experiments. It is realized as the Worldwide LHC Computing Grid (WLCG) [1], which was set up and brought to operation in the six-year course of the EU project Enabling Grid for E-science (EGEE) as the major part of a global multidisciplinary Grid infrastructure. In the last two years, this Grid infrastructure has been run by the EU project European Grid Infrastructure (EGI) [2], the successor of EGEE. DESY participates as a member of the National Grid Initiative (NGI-DE). In 2011, the middleware, produced by the European Middleware Initiative (EMI) [3], was introduced and deployed in many Grid services. Complementary to the batch-oriented Grid infrastructure, the NAF is being operated in its fourth year to meet the special needs of data analysis for the LHC and ILC.

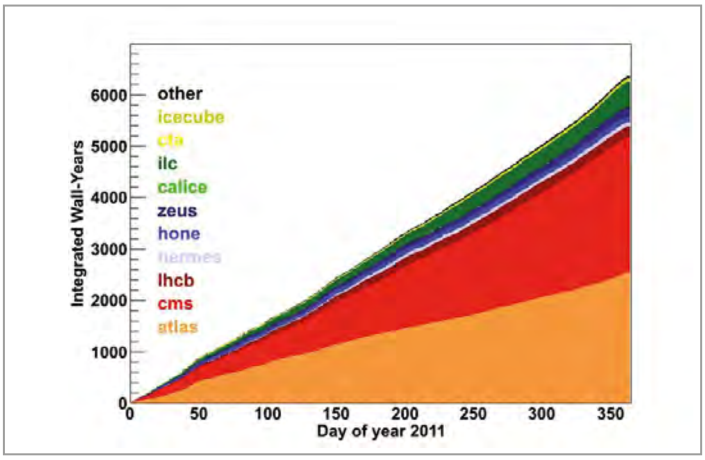


Figure 1

Accumulated time spent on DESY Grid and NAF resources in 2011, detailed for the different virtual organizations. Although ATLAS and CMS consumed most of the resources, other communities like HERA, ILC and astroparticle physics also used substantial parts of the resources.

Grid infrastructure

DESY operates one Grid infrastructure for all supported virtual organizations (VO). It contains all node types to make it a complete Grid infrastructure with all mandatory services, such as VO-specific unique core services to manage VO members (VOMS) and file catalogue services (LFC). Core services with multiple instances are the workload management (WMS), proxy server (PX) and information services (BDII). Resources are provided by computing elements (CE) and storage elements (SE). The SEs are based on dCache. Many of the services run multiple instances to ensure performance and reliability. Virtualization technologies are exploited for most of the Grid services to increase the reliability, scalability and flexibility even more.

DESY is the home for the HERA VOs (HONE, ZEUS, HERMES), the linear collider community (ILC, CALICE), astroparticle physics (ICECUBE), lattice QCD (ILDG) and photon science (XFEL.EU). DESY supports the LHC VOs hosted at CERN (ATLAS, CMS and LHCb), astroparticle physics (CTA) and bioinformatics (BIOMED). In 2011, support for the VO "BELLE" hosted by KEK in Japan was added to reflect DESY's activities with the Belle collaboration, and a VO for the OLYMPUS experiment at DESY was founded. The commitment to provide computing and storage resources for ATLAS, CMS and LHCb as a Tier-2 centre is based on the memorandum of understanding with WLCG. Furthermore, DESY operates VO-specific Grid services such as VOBoxes, PhEDEx for the CMS data transfer system, an Oracle-based tag database for ATLAS and various Squid servers to cache conditions data for ATLAS and CMS.

The DESY Grid resources are located at the two DESY sites in Hamburg (DESY-HH) and Zeuthen (DESY-ZN). Per job slot, 2 GB to 4 GB of memory and 15 GB to 20 GB of local disk space are provided on the computer nodes, called "worker nodes" (WN). The resource distribution is listed in Table 1.

Table 1: Overview of the resources at both DESY sites

Site	Physical cores	Job slots	Hosts	Disk space
DESY- HH	3504	4784	370	3.5 PB dCache (w/o HERA data)
DESY-ZN	960	960	96	1 PB dCache
NAF	3008	3008	288	150 TB Lustre

In 2011, the two Grid sites (DESY-HH and DESY-ZN) and the NAF delivered in total 56 million CPU hours or 17 CPU years every day. Although a multi-VO site, DESY was the biggest Tier-2 site for CMS in Europe with respect to the delivered CPU time.

Operations

The HERA experiments massively used Grid resources to produce Monte Carlo events worldwide. Their VOs are constantly utilizing a sizable fraction of the resources at DESY. For the ILC, event simulation campaigns for detector studies were carried out on the Grid. Comparable resources would not be available on local resources. The CALICE collaboration as well as the AIDA pixel telescope group are using DESY as a Tier-0 centre to store test beam data from DESY, CERN and Fermilab, which allows for seamless access from all over the world. The Zeuthen site operates as a Tier-1 centre for the IceCube project. It hosts half of the Monte Carlo data and all of the second-level data. In addition, it acts as a backup for the Tier-0 site in Madison, USA. CTA is already running large-scale Monte Carlo simulations on the Grid. This can be considered as a proof for the CTA collaboration that the Grid is ready to be used also for this new project (Fig. 1).

In EGI, the Grid infrastructure is monitored and managed nationally by the NGIs. DESY, as a part of the NGI-DE, which is located at FZ Karlsruhe, regularly participates in on-duty shifts.

The National Analysis Facility

The NAF was set up in the context of the Helmholtz Alliance "Physics at the Terascale" with the goal of offering the best possible data analysis infrastructure for German high-energy physicists by complementing the DESY Grid Infrastructure. In 2011, the NAF was an important platform for many LHC analyses. The NAF has proved to be an important link in the LHC analysis chain, augmenting the GRID infrastructure at DESY and in Germany.

Usage of the NAF in 2011

The most prominent cases of analysis use of the NAF are:

- The NAF provides tools for the experiment administrators to boost analyses with higher priority.
- The NAF enables users to use the PROOF facility for their data analysis. This tool spreads one analysis task over many different worker nodes while maintaining interactivity for users. Many users have adopted PROOF for their analysis and are using it extensively.
- In the NAF context, the dCache storage space for ATLAS and CMS has been enlarged by 1 PB to host additional data necessary for analysis, ranging from user n-tuples to ESDs.

The NAF has attracted hardware contributions from outside. In 2011, hardware purchased by the University of Hamburg was put into service as an integral part of the NAF, using the same operational model that was already chosen for their purchase in 2010. This model allows the university group to profit from the NAF services. It also demonstrates that pooling resources into one common infrastructure, the NAF, is more economic than building separate dedicated entities.

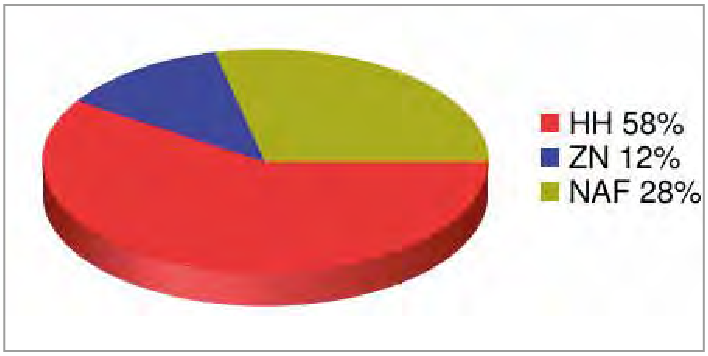


Figure 2

Distribution of CPU consumption between the Grid sites of Hamburg and Zeuthen, and the NAF

Contact:

Andreas Gellrich, andreas.gellrich@desy.de
Andreas Haupt, andreas.haupt@desy.de
Yves Kemp, yves.kemp@desy.de
Peter Wegner, peter.wegner@desy.de

Reference:

[1] http://lcg.web.cern.ch/lcg/
[2] http://www.egi.eu/
[3] http://www.eu-emi.eu/
[4] http://naf.desy.de/

dCache storage technology.

Storing large amounts of data for LHC, ILC and photon science

With the start of the Large Hadron Collider (LHC) physics programme at the end of March 2010, the dCache technology has proven that it can easily cope with the requirements imposed by heavy LHC data production. Several tens of petabytes of data have been transferred and stored by the various Tier-1 and Tier-2 centres around the world. dCache manages at least 50% of the total amount of LHC data.

With the adaption of more industry standards, especially WebDAV and NFSv4.1, more scientific communities, as well as storage consultant companies, are evaluating dCache for their members or customers. To simplify collaboration with those new groups and funding bodies, the dCache team moved away from its special license model towards the more standard GNU Affero General Public License (AGPL) for general purpose and extensions on request.

Throughout 2011, as in the past, dCache.org has been offering an extremely stable software release following strict quality criteria, as well as releases with experimental features for partners and advanced sites for evaluation and testing.

dCache's participation in the European Middleware Initiative (EMI) as part of the seventh European Framework Programme (FP7) did not only provide dCache with additional funding, but helped us to reach out to new communities and industry.

Figure 1

dCache technology at the core, adapting to storage protocols for different user communities

The dCache software enhancements

As required by the EMI work description, dCache focused even more on industry standards and interoperability with other Grid and Web components.

Particularly challenging are the ongoing development of an automatic synchronization of the dCache namespace with the distributed metadata catalogues of the LHC experiments, the integration of a common policy-based authorization system (ARGUS) and the migration from GSI to standard SSL/X509 authentication for the storage resource manager (SRM).

In 2011, dCache finalized the work on WebDAV and NFSv4.1/pNFS. With the availability of pNFS in Linux kernels provided by most Linux distributions, the goal of mounting a dCache data repository into the file namespace of worker nodes, desktops and laptops without additional client software was finally achieved. Both WebDAV and NFSv4.1 have been an essential prerequisite to incite non-high-energy physics communities to use dCache storage elements.

The collaboration, the support model and dCache.org

Before 2011, the dCache collaboration was composed of a fixed number of sites committed to developing and supporting parts of the dCache software stack. At the end of 2011, dCache had to face a change in concept. Individuals have been joining the team, which cannot easily be associated to a particular laboratory or organization. In consequence, the way of communication and the license model had to be adjusted. More effort is being put on documentation, and instead of imposing a proprietary license, the dCache software is now available under AGPL, which does not exclude other license agreements on request.

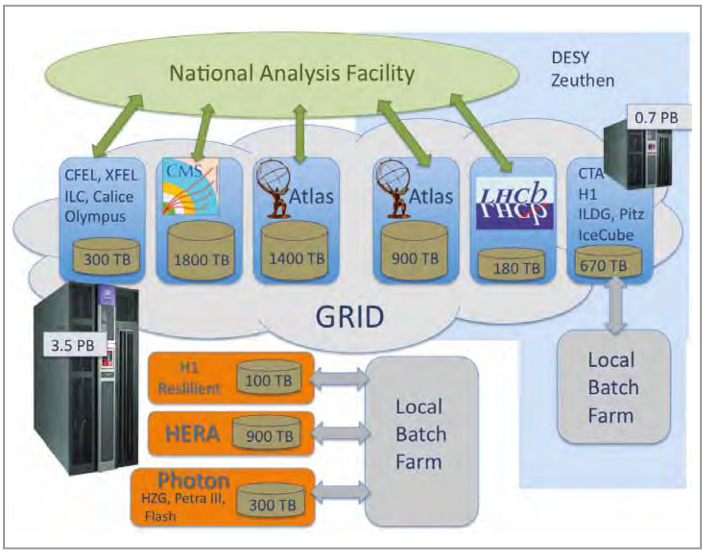


Figure 2

dCache installations at DESY

In addition to the core developer team, other groups and organizations support dCache in different ways. In Germany, the D-Grid Integration Project and the Helmholtz Alliance “Physics at the Terascale” are supporting dCache development at DESY and dCache system administration at the various German data centres. The latter builds the “German dCache Support Group”, which coordinates activities such as regular information exchanges, tutorials and workshops, e.g. the dCache session during the GridKa School of Computing and the annual dCache users’ workshop. In the USA, the Open Science Grid (OSG) initiative deploys dCache through the virtual data toolkit (VDT), their data management base system. Throughout 2011, the first-level support for the Northern European countries was completely covered by the Nordic Data Grid Facility. As partner in EMI, dCache participates in the EMI professional deployment and software quality control.

The link between the distributed code development and the networking activities described above is dCache.org. The group is primarily funded by DESY and provides standard interfaces to developers and customers. It covers the overall project management, which includes representing dCache in various forums, e.g. the Grid Deployment Board, the OSG External Software Group, the German DGI-II and “Physics at the Terascale”, as well as in EMI. In the context of the Worldwide LHC Computing Grid (WLCG), dCache.org offers weekly phone conferences to all LHC Tier-1 centres. Finally, dCache.org collects requirements of potential customers and presents solutions.

Deployment

At the time being, dCache is primarily used in the context of the LHC and high-energy physics data storage. Eight out of the eleven LHC Tier-1 sites in the USA, France, Spain, Canada, Northern Europe, the Netherlands and Germany continue to run dCache, as well as about 40 Tier-2 centres around the world. In total, about 100 petabytes of data are already stored in dCache installations, which is more than 50% of the entire LHC data.

To allow those sites to plan their software upgrades properly and still comply with the WLCG requirement of not applying new software during the run periods, in 2009 dCache.org introduced the concept of golden releases. A golden release is guaranteed to be supported for at least a year and no new feature will be added. The next golden release will be identical to the second production release of EMI *Matterhorn*.

At DESY, PETRA III and CFEL are using dCache to access the back-end tape system. The European XFEL computing technical design report (TDR) describes dCache as the preferred storage system. LOFAR, the Low Frequency Array antenna project based in the Netherlands, is using dCache at sites in Amsterdam and Jülich (Germany). The Swedish National Infrastructure for Computing recently decided to build a nation-wide dCache infrastructure for data-intensive communities.

dCache at DESY

Figure 2 gives an overview of the dCache installations at DESY. The DESY Hamburg dCache operations team manages six dCache instances. Three are Grid-enabled storage elements (SE), two of which are dedicated to LHC experiments and their virtual organizations (ATLAS, CMS). The third one mainly served ILC and photon science experiments. In 2011, the latter SE was split into two separate SEs to give the photon science community its own storage home. The two remaining SEs are utilized by the local HERA experiments and do not need to be accessible from within the Grid.

The three Grid-enabled SEs are configured for the same type of access but from different computing infrastructures, such as the LHC Tier-2 centre and the National Analysis Facility (NAF) at DESY. At the end of 2011, the three SEs reached a total disk capacity of 3.5 PB, which is an increase by a factor of two compared to 2010.

In the data model of the LHC experiments, Tier-2 centres only store replicas of files, with the obvious consequence that archiving data to tape is not required. That is completely different for ILC and photon science data, which are unique data from test beams for detector development and experiments from photon beamlines like PETRA III and FLASH.

Contact:
Patrick Fuhrmann, patrick.fuhrmann@desy.de

Reference:
http://www.dcache.org

Weltmaschine.

Facilitating CERN and LHC communication with the German public

The German name for the Large Hadron Collider (LHC) is “Weltmaschine” – a popular neologism that was coined by the DESY-based CERN and LHC communication coordinator for Germany. The coordinator is responsible for a mobile exhibit about the LHC, the maintenance of a website dedicated to the LHC, and the organization of LHC-related events. These activities are substantially raising the public’s awareness and interest in the LHC and in particle physics in Germany.

2011 was a highly successful year not only for the LHC, but also for the communication of its activities to the general public. In 2008, a position specifically aimed at facilitating CERN and LHC communication with the German public was set up under the auspices of the DESY public relations department, with funding from the German Federal Ministry of Education and Research (BMBF) and the Helmholtz Alliance “Physics at the Terascale”. The main task of this “LHC communication coordinator” is the promotion of CERN and the LHC and especially of the German participants in this global project. Together with the German Executive LHC Outreach Group (GELOG), with delegates of the four LHC experiments, German institutions and CERN, the communication coordinator began setting up a project with the twin goals of making people aware of the cutting-edge research performed at the LHC and maintaining the visibility of the German institutions involved. The catchy label “Weltmaschine” was developed for the communication of the project within Germany.

Figure 1

The mobile exhibition “Weltmaschine” at DESY’s Open Day on 29 October 2011

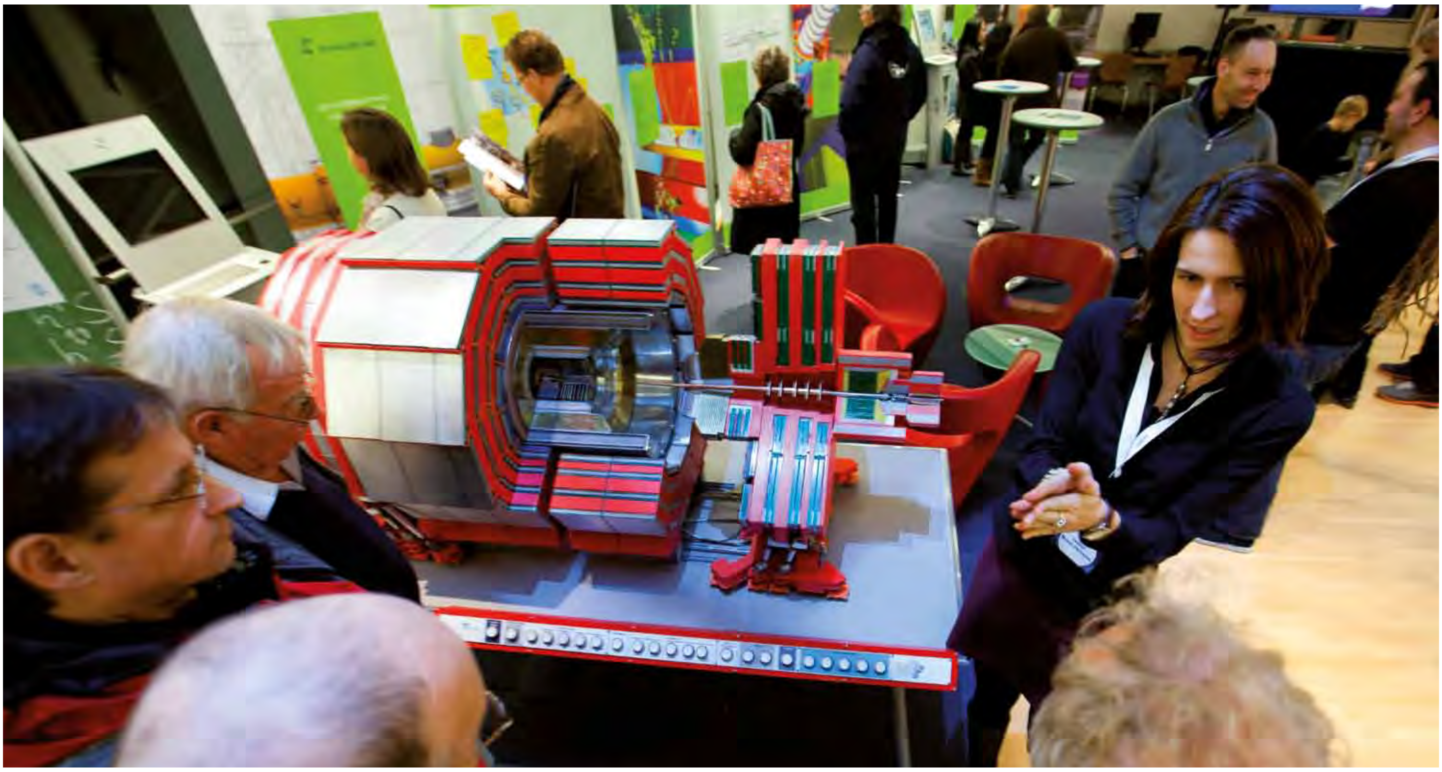


Figure 2

The "Weltmaschine Day" at DESY on 23 November 2011 featured two science slams, a science café and an exhibition.

The start-up of the LHC in 2008 was accompanied by an exhibition in the subway station "Bundestag" in Berlin. After a resounding success – with more than 30 000 visitors in five weeks and a great deal of press attention to particle physics and the LHC – the exhibit was transformed into a mobile version. Since its first appearance at the Hamburg harbour festival "Hamburger Hafengeburtstag" in spring 2009, the mobile exhibit has travelled to more than 25 universities and research centres throughout Germany and attracted more than 130 000 visitors so far. With its hands-on exhibits and explanatory displays, the exhibit gives visitors an insight into the world of particle physics – from physics to technology and even cultural aspects. Dedicated scientists serve as guides, and people are always pleased to get in close contact with them and ask questions. The guides give a face to the abstract field of particle physics and communicate their genuine passion for particle research. In 2011, the exhibit was shown in nine German cities – from the Open Day at DESY in Hamburg to Tübingen, from Bonn to Dresden. The high demand for the exhibit together with the large number of visitors convincingly demonstrate the high interest of the general public in the field of particle physics and the LHC.

In parallel with the start-up exhibition in Berlin, the website www.weltmaschine.de was launched. While focussed on German LHC research activities, this central tool also enables people to learn the latest LHC news, gives access to a wealth of background material and offers the opportunity to pose questions to scientists. Since its launch in 2008, the website evolved into the central starting point for the general public and particularly for journalists interested in developments at CERN and the LHC.

The second anniversary of proton–proton collisions at the LHC on 23 November 2011 was celebrated as the "Weltmaschine Day" by universities and research centres in 15 cities in Germany. Overseen by the LHC communication coordinator, the various institutes organized exhibitions, "science slams", public lectures and an open day. The central and connecting element was a live interview with CERN Director General Rolf-Dieter Heuer, which was streamed to all participating institutions. DESY presented two science slams, one in the Urania event hall in Berlin and one in the DESY auditorium in Hamburg. At the science slams, scientists compete against each other with 10-minute talks, trying to persuade and, of course, entertain the audience which, in the end, chooses the winning speaker.

Since 2008, the German CERN and LHC communication coordinator has helped to raise an ever-increasing awareness of the LHC and has generated keen interest by the public to keep abreast of all the latest news concerning the LHC; the latest example being the high level of interest in the news of the Higgs boson in December 2011. Not only is the media coverage huge, the events and exhibitions have also brought particle physics to the public and established a sound basis for direct communication between the scientific world and society.

Contact:

Gerrit Hörentrup, gerrit.hoerentrup@desy.de

Reference:

http://www.weltmaschine.de

School lab.

physik.begreifen grows up

The school lab "physik.begreifen" at DESY in Hamburg was launched in 1997. The idea behind the project is to spark the interest and fascination of young people in the natural sciences, especially in physics. The school lab programme provides hands-on experience to students from the elementary level up to 11th to 13th grade high school. In age-appropriate laboratory programmes, the students become researchers for one day. They have the opportunity to find out more about vacuum, radioactivity and quantum physics and to carry out eLab experiments. In 2011, the number of one-day laboratories for school classes was increased, and different offers, such as holiday camps, cosmic-ray masterclasses and the German contest for the International Physics Olympiad, became possible. In November 2011, the 50 000th student was welcomed to physik.begreifen.

New rooms

Up to now, the school laboratory for vacuum experiments has been located in a pavilion provided by the Hamburg school authority. Over the last years, the offer of the school lab was expanded with a few more topics – also for students of the 11th and 12th grade – and, as a consequence, some major space shortages became apparent. Thanks to the German Economic Stimulus Package II, funds were granted by the Hamburg science authority, which allowed the expansion of the pavilion by two more laboratory facilities and one multifunctional seminar room. Besides the laboratories for vacuum (4th to 6th grade) and radioactivity (9th and 10th grade), physik.begreifen now offers attractive experiments for the 11th to 13th grades in two new laboratories, with topics of quantum physics and physics of the electron.

Figure 2

The quantum physics laboratory

Figure 1

Building extension of the physik.begreifen pavilion

New formats and experimental possibilities, such as a holiday camp in which students from all over Germany can participate, are now possible after the building expansion. Students are housed at the DESY hostel for one week, during which they can carry out research experiments at the school lab in the morning and get to know DESY in the afternoon. In this way, students learn how big science works and what it takes to accomplish it. Furthermore, the new facilities provide enough room for external science events, such as the national preliminaries to the International Physics Olympiad. In this context, 15 students experimented in the physik.begreifen laboratories in 2011. The five best students were then sent to Bangkok to represent Germany in the International Physics Olympiad. Thanks to the additional space, 320 school classes attended one-day labs in 2011. In addition, many extracurricular activities were held.

eLab

The “eLab – experiments about the electron” was supported by the Hamburg school authority and inaugurated in 2010, with visits starting in 2011. About 400 senior students used the opportunity to carry out experiments in the new laboratory. The student workbenches are equipped with notebooks, electron tubes, oscilloscopes, Helmholtz coils and measuring instruments. Under these perfect conditions, students are highly motivated to do basic natural scientific research. They investigate various physical properties of the prominent elementary particle – the electron. The behaviour of electrons in fields is a very important issue to understand the operation of the DESY accelerators.

The students work on their one initiative. For this reason, workbooks containing the primary information are conceived for each experiment. In addition, DESY engages PhD student assistants to cautiously guide the pupils in the lab. In this way, not only the experiments, but also academic research skills are conveyed. The students are guided to deal with data, to prepare the results and to eventually present it.

Cosmic-ray detector

The project “Measuring cosmic rays in the classroom” has been expanded. A new detector was constructed at DESY in Zeuthen in the context of the particle physics network “Netzwerk Teilchenwelt”. The compact small detector can easily be operated by students at school. After a further training of the teachers, the detector can be borrowed for five to six weeks for project work. In this way, students can design their own experiments.

Moreover, a new format – a cosmic-ray masterclass – was organized at physik.begreifen. Together with a PhD student, a group of 10 students investigated cosmic muons using the cosmic-ray detector. The students get in contact with real scientists and learn more about the state of the art in astrophysics.

Contact:

Karen Ong, karen.ong@desy.de

Reference:

http://physik-begreifen.desy.de

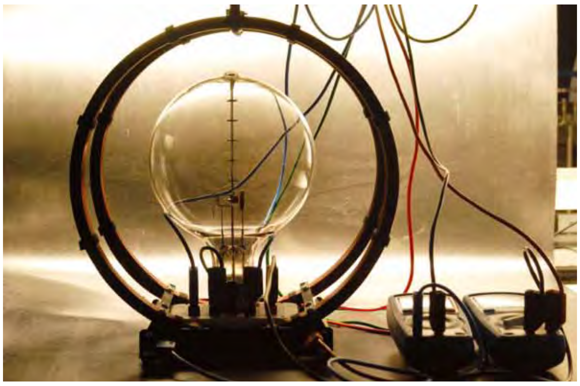


Figure 3

Electron tube with Helmholtz coils

Figure 4

Young researchers in the eLab

Figure 5

Cosmic-ray detector

The DESY II test beam facility.

A unique facility for the internatinal detector R&D community

DESY continues to operate and improve its DESY II test beam facility for detector R&D projects. In 2011, users from the LHC detector upgrade community, the Linear Collider Detector R&D programme, the upcoming experiments at FAIR (GSI) and many more made extensive use of the DESY II test beam. Because of its ease of use, it remains a highly popular facility for testing detector prototypes.

DESY operates a test beam facility at its Hamburg site using the DESY II synchrotron. Besides being the pre-accelerator for DORIS III and PETRA III, it delivers electron and positron beams from 1 to 6 GeV to three test beamlines via a fixed target. The energy spread is less than 5%, and the maximum flux is up to 5000 particles/cm^2/s, depending on the choice of secondary target. Each test beam is controlled by the user and provides additional infrastructure as well.

World-class infrastructure

Each test beam area provides basic infrastructure such as *xy* platforms, pre-installed patch panels for cabling and network connectivity. In one of the three test beam areas, a high-precision pixel telescope is installed and available to the users. The telescope is predominantly used to provide accurate tracking of test beam particles and thereby facilitate the study of the tracking efficiency and resolution of the detectors under study. This telescope can provide a pointing resolution of better than 3 µm even with the relatively low-momentum beam available from DESY II. Recently, this infrastructure has been enhanced with a faster data acquisition system to increase the maximum event rate from 700 Hz to 4 kHz, thereby significantly reducing the time required to collect high-statistics test beam data sets.

The infrastructure in one of the three test beam areas includes a large-bore, Japanese-made superconducting magnet with a field of up to 1 Tesla. This magnet has been extensively used for the development of a lightweight time projection chamber (TPC), which is a central element of the Linear Collider Detector R&D programme. In July 2011, the magnet was returned to Japan for a major upgrade funded by the EU-FP7 project AIDA, the KEK research centre and DESY. Before the upgrade, the magnet needed to be refilled regularly with liquid helium to maintain superconductivity. In the ongoing upgrade, the built-in helium reservoir has been

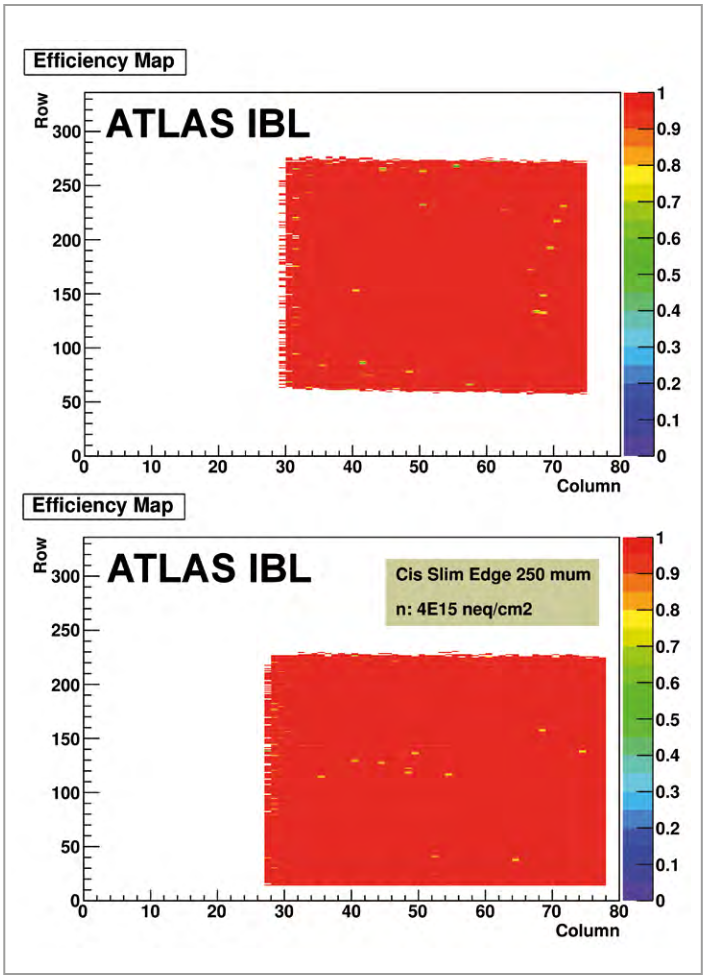


Figure 1

Pixel efficiency map for irradiated planar pixel sensors at two different particle incident angles, 0° (top) and 15° (bottom). The overall pixel efficiencies are almost equal for both particle incident angles.

removed and a closed-circuit cryogenic cooling system is being installed. By rendering the complex filling procedure obsolete, this modification allows for a safer and more efficient magnet operation by the research groups. The magnet will return to DESY at the end of March 2012 and be operational again in May. The initial funding for both the pixel telescope and the magnet was provided by the EU-FP6 EUDET project.

Its infrastructure makes DESY one of the few sites in Europe where particle detectors can be tested with high-energy beams. The test beam facility has been extensively used in the past by the HERA experiments and now plays an important role for both the LHC upgrades and the Linear Collider Detector R&D programme. It attractiveness has also attracted users from beyond these communities.

Test beam activities in 2011

In 2011, a total of 14 groups were allocated 35 weeks of beam time at the test beam facilities at DESY. A few selected highlights from the 2011 test beam users are briefly summarized.

ATLAS

The upgrade of the ATLAS detector for the High-Luminosity LHC (HL-LHC) will take place in steps, the first of which will consist in the construction of a new pixel layer. This pixel layer will be installed during the first shutdown of the LHC, foreseen for 2013–2014. The new detector, the Insertable B-Layer (IBL), will be located between the existing pixel detector and a new (smaller-radius) beam pipe at a radius of 33 mm. The IBL requires the development of several new technologies to cope with the higher anticipated radiation fluence and pixel occupancy and also to improve the tracking performance, which will be achieved by reducing the pixel size and the detector mass. Two different promising silicon sensor technologies, planar pixel sensors (PPS) and 3D pixels, are currently under investigation for the IBL.

The ATLAS test beam sensor qualification programme for the IBL made extensive use of the EUDET pixel telescope. The track pointing resolution of the telescope is better than 3 μm, which allows for many detailed studies of detector parameters, such as pixel efficiency, charge collection efficiency, intrinsic sensor resolution and the dependence of charge sharing on particle incident angle. The pixel efficiency maps for PPS after irradiation to the maximum expected HL-LHC fluence are shown in Fig. 1. During the beam test, sensors were held at -15°C and tested at two different incident angles, 0° (Fig. 1, top) and 15° (Fig. 1, bottom). These maps were important inputs for the decision of which sensor type would be used for the IBL.

CMS

For the CMS pixel detector upgrade, the pixel resolution and efficiency were measured in the test beam. The high resolution of the telescope provides an ideal reference frame and allows scans of the efficiency across each pixel. Data with the present CMS pixel readout chip were taken at several incident angles. They will be used as reference for the new chip available in 2012.

Quartz radiators

A group from the University of Gießen did several test beam measurements for a prototype of the ATLAS forward physics (ATLAS AFP) upgrade programme. This prototype consists of quartz radiators that are read out by digital silicon photon multipliers. In the same test beam, a prototype of a future detection of internally reflected Cherenkov light (DIRC) detector for the PANDA experiment at FAIR was tested.
A picture of the prototype is shown in Fig. 2.

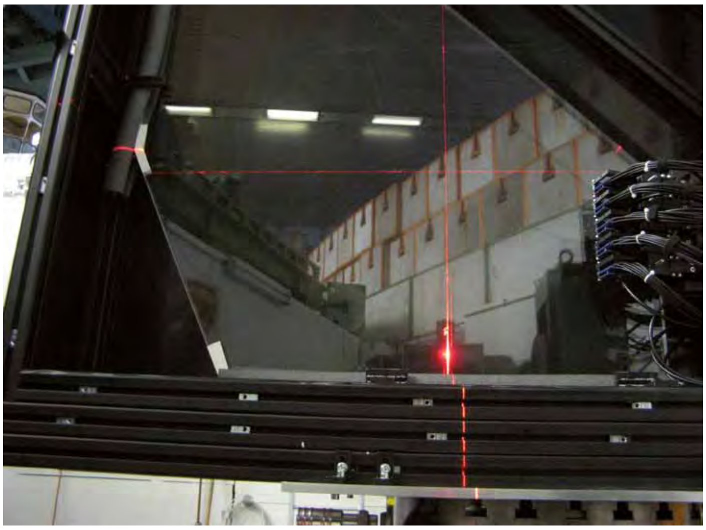


Figure 2

The quartz radiator plate during a laser alignment procedure. The plate acts as a Cherenkov radiator. The photons produced are internally reflected and then detected by photomultiplier tubes at the edge of the quartz plate.

Contact:
Ingrid-Maria Gregor, ingrid.gregor@desy.de
Norbert Meyners, norbert.meyners@desy.de
testbeam-coor@desy.de

Reference:
http://testbeam.desy.de

Laser-assisted assembly techniques for silicon pixel detectors.

Upgrade of DESY bonding facilites

With the LHC going beyond its initial design performance, the current barrel pixel detector (BPIX) of the CMS experiment at CERN will reach its performance limits and suffer more and more from radiation damage. Therefore, it is planned to install a new detector with better performance, to which DESY will contribute. A central part of this contribution is the production of silicon-bare modules for the outermost layer using bump bonding interconnection techniques. To achieve a precise and reliable production, DESY is investing in corresponding onsite assembly and test facilities.

BPIX upgrade

As the innermost part of the CMS detector, the BPIX measures up to three space points of a particle track within the first 16 cm from the interaction point. The BPIX is thus essential to precisely determine the origin of the particle tracks. Figure 1 shows a photograph of the present three-layer BPIX. With increasing LHC performance, the current BPIX will suffer from readout inefficiencies and increasing radiation damage. Hence, it is planned to replace the current version with a four-layer BPIX with better performance in terms of data throughput, resolution and redundancy.

In collaboration with German universities, DESY will contribute to the new BPIX by building the outermost layer, which corresponds to 43% of the total BPIX. DESY and the University of Hamburg will build one half-shell of the fourth layer, consisting of 256 modules with 17 million pixels in total. The present detector is planned to be replaced during the LHC technical stop 2016–2017. The production of modules is due to be finished at the end of 2015 to allow time for sufficient commissioning and testing.

Figure 2 shows the components of a single bare module with 16 readout chips (ROCs). The electrical connections between sensors and ROC pixels will be realized by an array of solder bumps. Both devices are fabricated by external foundries. A service provider processes an under-bump metallization (UBM) on all contact pads of the sensors and ROCs to improve their wetting behaviour and protect both devices from diffusion of the solder alloy elements.

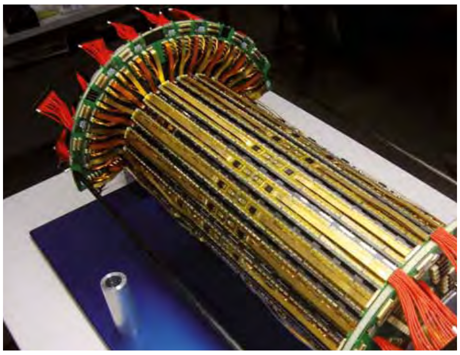


Figure 1

The present three-layer BPIX consists of 672 modules with 66 560 pixels each and 96 half-modules. (Courtesy: PSI)

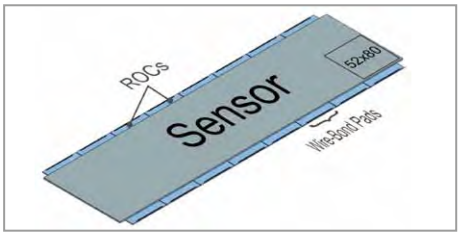


Figure 2

A bare module consists of a sensor chip mounted on top of 16 ROCs. Each ROC handles 52-by-80 pixels and has a prominent pad row for wire bond connections to the subsequent electronics, which will later be located on top of the sensor (Fig. 1).

Process technologies and inspection methods

Common mass production processes for solder application onto wafers involve several photolithographic and chemistry-assisted steps. These techniques are rather complex and expensive, especially for smaller wafer quantities. An alternative maskless process is based on the sequential jetting of solder balls. Spheres of diameters down to 30 µm can be singulated from a reservoir and forced onto pads through a capillary by N_2 gas flow. A short and intense near-infrared (NIR) laser pulse targets the falling sphere and causes its reflow during the flight through the capillary. Jetting rates of up to eight balls per second could be achieved, making this technique also very attractive for sensor applications. Furthermore, jetting at non-perpendicular incidence and multiball placement is possible. State-of-the-art flip chip (FC) equipment can place dies within seconds

Figure 3

Four-inch wafer (left) with two dummy sensors and forty dummy ROCs. Both sensors are assembled with 66 560 solder balls each (SEM images, middle). Micrograph of a bump in pre-reflow state and micrograph of a flip chip after tacking and final in-situ reflow (right).

with micrometre accuracy. Some of the new machines provide in-situ and fluxless reflow processes, eliminating the need for conventional reflow ovens.

Apart from the introduction of cost-efficient in-house processes, the most important requirement for bumping is to achieve high yields. To reach and preserve a high-quality level, visual and mechanical inspection methods are applied. Precision equipment for cutting, molding, grinding and final polishing allows the preparation of cross sections of bonded samples (Fig. 3, right). Shear testers are commonly used to determine the mechanical stability of soldered devices. Finally, all sub-modules will undergo an ROC electrical test via the prominent pad row (Fig. 2). For that purpose, special probe cards mounted on an automatic probe station connect an entire ROC pad row and perform the module tests automatically with high positioning accuracy.

The equipment needed for the mentioned inspection methods has recently been installed in the laboratory of the DESY-FEC group. The new techniques of solder ball jetting and FC bonding are under study in cooperation with external vendors.

First achievements

Figure 3 illustrates the latest results utilizing the whole process flow. Four-inch test wafers (left) with a large number of sensors and ROC dummies were produced. Both devices imitate their real counterparts regarding pad size and count. An UBM layer was electrolessly deposited on the pads through passivation openings. This process is purely chemically assisted and does not require any masking steps. Lead-free solder balls (Fig. 3, middle) were successfully placed onto the pads and a NIR laser-assisted heating process was executed to obtain a ball-like shape of the deposited solder bumps (Fig. 3, upper right: pre-reflow). As a next step, a flipped ROC die without bumps was accurately placed with minimized force for tacking. The final reflow process was carried out again using the fast laser-induced heating scheme. The micrograph in the lower right corner of Fig. 3 shows a cross-sectional view of a single bump, applying the sample preparation technique to two ROC dummies. To succeed in bonding the larger sensor dummies, process optimizations as well as the development of improved FC tooling are underway.

In preparation of the electrical characterization of the bumping process, an epoxy probe card with 104 tungsten probes was designed and cable-connected to a programmable switching system. This device switches quickly through the connections per dummy ROC and routes the signals to an integrated high-accuracy digital multimeter. Short metal traces on sensor as well as ROC dummy samples alternately connect two neighbouring bumps (Fig. 3, middle) so that, when bonded together, the electrical path is closed. The series resistance of this daisy chain allows the extraction of the mean bump bond resistivity. Figure 4 shows the probe station equipped with the probe card. Dummy-bare modules can be placed on the 300-mm chuck. Altogether, 16 contact steps per module are needed for full characterization. These tests are prepared for future samples and planned for final process optimization.

The experimental results demonstrate the feasibility of using laser-assisted techniques for a maskless lead-free solder ball placement as well as for a low-force tacking and a fluxless reflow process. The underlying technologies satisfy the demands for cost-efficient in-house processes.

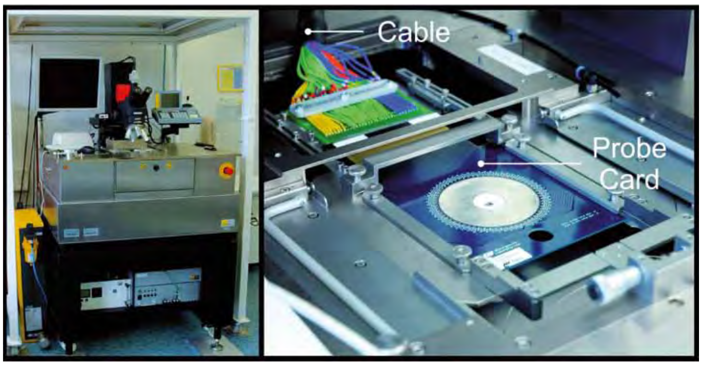


Figure 4

Automatic probe station with 300-mm thermo chuck (left). Inside its shielding box, a probe card (right) simultaneously connects all wire bond pads of an ROC. The external test electronics is connected through a cable visible in the back.

Contact:

Jan Hampe, jan.hampe@desy.de
Karsten Hansen, karsten.hansen@desy.de

References.

Committees.

DESY Administrative Council

Representatives of the Federal Republic of Germany:

Dr.-Ing. **B. Vierkorn-Rudolph** (Chair)
(Federal Ministry of Education and Research)

MinR'in **O. Keppler**
(Federal Ministry of Education and Research)

MinR **H. J. Hardt**
(Federal Ministry of Finance)

Representatives of the Free and Hanseatic City of Hamburg:

LRD Dr. **R. Greve**
(Ministry of Education and Research)

ORR Dr. **M. Brüser**
(Ministry of Finance)

Representatives of the Federal State of Brandenburg:

MinDirig Dr. **J. Glombik**
(Ministry of Science, Research and Culture)

Dr. **C. Menzel**
(Ministry of Finance)

DESY Board of Directors

Dr. **R. Brinkmann**
(Accelerator division)

Prof. Dr. **H. Dosch**
(Chairman of the DESY Board of Directors)

Prof. Dr. **J. Mnich**
(High-energy physics and astroparticle physics)

C. Scherf
(Administrative division)

Prof. Dr. **E. Weckert**
(Photon science division)

Prof. Dr. **C. Stegmann**
(Representative of the directorate in Zeuthen)

DESY Scientific Council

Dr. **U. Bassler**
CEA-DSM Gif sur Yvette (FR)

Dr. **E. Chapochonikova**
CERN, Geneva (CH)

Prof. Dr. **S. Chattopadhyay**
Daresbury Laboratory (UK)

Prof. Dr. **M. Danilov**
ITEP, Moscow (RU)

Prof. **J. Hastings**
SLAC National Accelerator Laboratory (USA)

Dr. **N. Holtkamp**
SLAC National Accelerator Laboratory (USA)

Prof. **E. Iarocci**
INFN Frascati (IT)

Prof. Dr. **J. Kirz**
Lawrence Berkeley National Lab (USA)

Prof. Dr. **S. Larsen**
MAX IV Laboratory (SE)

Dr. **G. Long**
Argonne National Laboratory (USA)

Prof. Dr. **J. Nordgren**
University of Uppsala (SE)

Dr. **P. Wells**
CERN, Geneva (CH)

Prof. **G. Wormser**
LAL, Orsay (FR)

Prof. Dr. **L. Young**
Argonne National Laboratory (USA)

and the chairs of:

ECFA: Dr. **M. Krammer**
(Institut für Hochenergiephysik, Wien, AU)

MAC: Prof. Dr. **R. Walker**
(Diamond Light Source, UK)

PRC: Prof. Dr. **A. White**
(University Texas at Arlington, USA)

PSC: Prof. Dr. **C. Norris**
(Diamond, CCLRC Rutherford Appleton Laboratory, USA)

WA: Dr. **T. Behnke**
(DESY, Hamburg)

European XFEL: Prof. **M. Altarelli**
(European XFEL GmbH)

DESY Scientific Board

K. Balewski (DESY)
F. Beckmann (GKSS)
T. Behnke (DESY) (Chair)
M. Bieler (DESY)
K. Borras (DESY)
W. Buchmüller (DESY)
H. Chapman (DESY)
W. Drube (DESY)
G. Eckerlin (DESY)
E. Elsen (DESY)
T. Finnern (DESY)
K. Flöttmann (DESY)
H. Franz (DESY)
H. Graafsma (DESY)
I.-M. Gregor (DESY)
G. Grübel (DESY)
V. Gülzow (DESY)
J. Haller (Univ. Hamburg)
A. Hayrapetyan (Univ. Gießen)
K. Honkavaara (DESY)
J. Jung (DESY)
J. Kaminski (Univ. Bonn)
F. Kärtner (DESY)
M. Kasemann (DESY)
O. Kind (Humboldt-Univ. Berlin)
K. Krüger (Univ. Heidelberg)
M. Martins (Univ. Hamburg)
K. Mönig (DESY)
T. Naumann (DESY)
D. Nölle (DESY)
K. Rehlich (DESY)
B. Reisert (MPI München)
A. Ringwald (DESY)
K. Rith (Univ. Erlangen-Nürnberg)
M. Roessle (EMBL)
R. Santra (DESY)
F.-P. Schilling (Univ. Karlsruhe)
S. Schlenstedt (DESY)
M. Schmitz (DESY)
V. Schomerus (DESY)
S. Schreiber (DESY)
H. Schulte-Schrepping (DESY)
A. Schwarz (DESY)
J. Spengler (DESY)
M. Tischer (DESY)
T. Tschentscher (European XFEL)
U. Vainio (DESY)
J. Viefhaus (DESY)
M. Vogt (DESY)
D. Wegener (Univ. Dortmund)
P. Wegner (DESY)
G. Weiglein (DESY)
H. Weise (DESY)
K. Wittenburg (DESY)

Machine Advisory Committee (MAC)

Dr. **M. Borland** (ANL, USA)
Dr. **H. Braun** (PSI, CH)
Dr. **M. Eriksson** (Univ. Lund, SE)
Dr. **J. Filhol** (Soleil, FR)
Prof. Dr. **A. Jankowiak** (BESSY II)
Dr. **K. Oide** (KEK, JP)
Dr. **M. Ross** (Fermilab, USA)
Dr. **R. Schmidt** (CERN, CH)
Dr. **R. Walker** (Diamond, UK)

Physics Research Committee (PRC)

Prof. Dr. **G. Anton** (Univ. Erlangen)
Dr. **E. Aschenauer** (BNL, USA)
Prof. Dr. **M. Beneke** (RWTH Achen)
Prof. Dr. **P. Buchholz** (Univ. Siegen)
Dr. **M. Carena** (Fermilab, USA)
Prof. Dr. **H. Enyo** (RIKEN, JP)
Prof. Dr. **J. Haba** (KEK, JP)
Prof. Dr. **L. Köpke** (Univ. Mainz)
Dr. **E. Perez** (CERN, CH)
Prof. Dr. **G. Quast** (Univ. Karlsruhe)
Dr. **A. White** (Univ. Texas, USA) (Chair)
Dr. **R. Yoshida** (ANL, USA)

Photon Science Committee (PSC)

Prof. Dr. **M. Drescher** (Univ. Hamburg)
Prof. Dr. **M. Fröba** (Univ. Hamburg)
Dr. **R. Horisberger** (PSI Villigen, CH)
Prof. Dr. **C.-C. Kao** (SLAC. USA)
Prof. Dr. **C. Norris** (Diamond, UK) (Chair)
Prof. Dr. **F. Pfeiffer** (TU München)
Dr. **H. Reichert** (MPI Stuttgart)
Prof. Dr. **J.-P. Samama** (Soleil, FR)
Dr. **S. Techert** (MPI Göttingen)
Prof. Dr. **E. Weckert** (DESY)
Prof. Dr. **P. Withers** (Univ. Manchester, UK)

Landesexzellenzinitiative Hamburg, Research Board

Connecting Particles with the Cosmos

M. Baumgartl (Univ. Hamburg)
T. Behnke (DESY)
W. Buchmüller (DESY)
E. Elsen (DESY)
C. Hagner (Univ. Hamburg)
T. Kneiske (Univ. Hamburg)
B. Andreas Kniehl (Univ. Hamburg)
J. Louis (Univ. Hamburg)
J. Mnich (DESY)
C. Niebuhr (DESY)
A. Ringwald (DESY)
P. Schleper (Univ. Hamburg) (Chair)
C. Schweigert (Univ. Hamburg)
G. Weiglein (DESY)
G. Wiedemann (Univ. Hamburg)

Helmholtz Alliance International Advisory Board

Physics at the Terascale

Dr. **J. Brau** (Univ. of Oregon, USA)
Dr. **N. Geddes** (Rutherford Appleton Lab, UK)
Dr. **P. Jenni** (CERN, CH)
Dr. **D. Schlatter** (CERN, CH)
Prof. Dr. **B. Spaan** (Univ. Dortmund)
Prof. Dr. **J. Stirling** (Univ. of Cambridge, UK)
Prof. Dr. **T. Virdee** (Imperial College, London, UK)
Prof. Dr. **S. Yamada** (Univ. of Tokyo, Japan)

German Committee for Particle Physics (KET)

Prof. Dr. **S. Bethke** (MPI München)
Prof. Dr. **K. Desch** (Univ. Bonn)
Prof. Dr. **S. Dittmaier** (MPI München)
Dr. **M. Hauschild** (CERN, CH)
Prof. Dr. **W. Hollik** (MPI München)
Prof. Dr. **K. Jakobs** (Univ. Freiburg)
Prof. Dr. **T. Lohse** (HU Berlin)
Prof. Dr. **T. Mannel** (Univ. Siegen)
Prof. Dr. **J. Mnich** (DESY)
Prof. Dr. **K. Mönig** (DESY)
Prof. Dr. **T. Müller** (KIT, Karlsruhe)
Prof. Dr. **R. Rückl** (Univ. Würzburg)
Prof. Dr. **D. Schaile** (LMU München)
Prof. Dr. **B. Spaan** (TU Dortmund) (Chair)
Prof. Dr. **U. Uwer** (Univ. Heidelberg)

John von Neumann Institute for Computing (NIC): Scientific Council

Prof. Dr. **K. Albe** (TU Darmstadt)
Prof. Dr. **K. Binder** (Univ. Mainz)
Prof. Dr. **J. C. Cuevas** (Univ. Madrid, ES)
Prof. Dr. **D. di Vincenzo** (FZJ Jülich)
Dr. **St. Güsken** (Postbank Systems AG)
Prof. Dr. **E. Laermann** (Univ. Bielefeld)
Prof. Dr. **R. Lasser** (GSF, Helmholtz Zentrum München)
Prof. Dr. **V. Lindenstruth** (Univ. Frankfurt)
Prof. Dr. **M. Müller** (Univ. Göttingen)
Prof. Dr. **G. Münster** (Univ. Münster) (Chair)
Dr. **H. Simma** (DESY)
Dr. **H. Weiß** (BASF AG)
Dr. **W. Wenzel** (KIT Karlsruhe)
Prof. Dr. **U.-J. Wiese** (Univ. Bern, CH)

Memberships.

ACOT-Advisory Committee for TRIUMF (Canada)
Kerstin Borras

AIDA Management Board / Steering Committee
Ties Behnke / Ingrid-Maria Gregor

Akademie der Wissenschaften Hamburg
Wilfried Buchmüller

Astroparticle Physics European Coordination (ApPEC), PRC
Christian Spiering (Chair)

ATLAS-Canada Review Committee of NSERC, Canada
Eckhard Elsen

ATLAS Executive Board
Klaus Mönig

BMBF, Gutachterausschuss Hadronen udn Kernphysik
Hans Weise

BMBF, Gutachterausschuss Teilchenphysik
Ties Behnke, Eckard Elsen, Joachim Mnich

CALICE Steering Board
Felix Sefkow (Spokesperson)

CERN Machine Advisory Committee
Reinhard Brinkmann

CERN Science Policy Committee
Christian Spiering

CLIC Steering / Advisory Committee
Brian Foster / Markus Hüning

Cluster of Excellence for Fundamental Physics, Munich: Scientific Advisory Committee
Wilfried Buchmüller (Chair)

CMS Collaboration Board, Executive Board and Management Board
Matthias Kasemann

CMS Collaboration Board, Conference Board and Finance Board
Kerstin Borras

Common Task Group Detector R&D
Wolfgang Lohmann

Computer Applications in Nuclear and Plasma Sciences (CANPS), Technical Committee
Günter Eckerlin

Computing Resource Review Board, CERN
Volker Gülzow

Data Preservation and Long Term Analysis in High Energy Physics (DPHEP) International Steering Committee
Zaven Akopov, Cristinel Diaconu, Achim Geiser, Volker Gülzow, David South

Deutsches Komitee für Astroteilchenphysik (KAT)
Christian Spiering

DFG Allianz "Digitale Information"
Martin Köhler

Deutsches Forschungsnetz DFN Verwaltungsrat / Betriebsausschuss
Joachim Mnich / Volker Gülzow

DKE Deutsche Kommission Elektrotechnik, Elektronik und Informationstechnik im DIN und VDE, Kommission K967
Peter Göttlicher

DPG Vorstandsrat
Thomas Naumann

DPG, Beirat der Sektion Teilchenphysik
Ties Behnke

DPG, Wissenschaftlicher Beirat des Physikzentrums
Wilfried Buchmüller

European Committee for Future Accelerators (ECFA)
Eckhard Elsen, Joachim Mnich, Klaus Mönig

European Particle Physics Communication Network (EPPCN)
Thomas Naumann

European Physics Journal C
Georg Weiglein (Editor in Chief)

European Strategy Group for Accelerator R&D (ESGARD)
Eckhard Elsen

European Studies on Norms for Electronics (ESONE)
Dieter Notz

FAIR, Machine Advisory Committee
Kay Wittenburg

Finance & Investments Board and Governance Review Group, UK Institute of Physics
Brian Foster

FP7-health EndoTOFPET-US work package
Erika Garutti (Leader)

FZ Karlsruhe, Nachwuchsbeirat
Rolf Nahnhauer

Gauss Allianz, Mitgliederversammlung und Grid-Koordinationsausschuss
Volker Gülzow

German Executive LHC Outreach Group (GELOG)
Ulrike Behrens, Klaus Ehret, Gerrit Hörentrup, Matthias Kasemann, Christian Mrotzek, Thomas Naumann, Thomas Zoufal

Global Design Effort (GDE)
Wilhelm Bialowons, Brian Foster (European Director), Nicholas John Walker (Project Manager)

GridKa, Technical Advisory Board
Martin Gasthuber, Birgit Lewendel, Knut Woller

GridKa, Overview Board
Volker Gülow

Helmholtz Alliance, Institute Assembly
Ingrid-Maria Gregor, Sven Moch

Helmholtz Alliance, Management Board
Ties Behnke (Scientific Coordinator), Karsten Büßer, Eckhard Elsen, Matthias Kasemann, Joachim Mnich, Thomas Schörner-Sadenius

Helmholtz Alliance, Project Boards
Doris Eckstein, Eckhard Elsen, Volker Gülzow, Matthias Kasemann, Klaus Mönig, Thomas Schörner-Sadenius, Felix Sefkow, Georg Weiglein

Helmholtz Lenkungsausschuss Struktur der Materie
Ties Behnke

Helmholtz-Programmsprecher für Elementarteilchenphysik
Joachim Mnich

HGF, Arbeitskreis Bibliotheks- und Informationsmanagement
Martin Köhler

HGF, Versammlung der wissenschaftlich-technischen Räte
Ties Behnke

Helsinki Physics Institute, Scientific Advisory Board
Wilfried Buchmüller

IEEE Radiation Instrumentation Steering Committee
Ingrid-Maria Gregor

ILC Accelerator Advisory Panel (AAP) and International Detector Advisory Group (IDAG)
Eckhard Elsen

ILC and High Gradient Superconducting RF-Cavities (ILC-HiGrade)
Eckhard Elsen (Project Coordinator)

ILC CLIC Physics and Detector Working Group
Felix Sefkow

ILC MDI Common Task Group
Karsten Büßer (Chair)

ILC Physics and Experiment Board
Ties Behnke, Karsten Büßer

ILC Programme Advisory Committee
Hans Weise

ILC Steering Committee (ILCSC)
Joachim Mnich

ILC Top Level Change Control Evaluation Panel
Karsten Büßer

ILD Executive Board
Ties Behnke, Karsten Büßer, Wolfgang Lohmann, Felix Sefkow

ILD Steering Boards
Felix Sefkow, Ties Behnke

INSPIRE Steuerungsgremium
Kirsten Sachs

Institut Pluridisciplinaire Hubert Curien, Advisory Board
Joachim Mnich

International Committee for Future Accelerators (ICFA)
Joachim Mnich

International Committee for Future Accelerators (ICFA), Panel on Advanced and Novel Accelerators
Siegfried Schreiber, Rainer Wanzenberg

International Lattice Data Grid
Karl Jansen

John von Neumann Institute for Computing (NIC), Director
Joachim Mnich

John von Neumann Institute for Computing (NIC), Scientific Council
Hubert Simma

Joint Institute of Nuclear Research JINR, Physics Advisory Committee
Joachim Mnich

KEKB2/BELLE2 Advisory Board
Wulfrin Bartel

KIT Center Elementary Particle and Astroparticle Physics (KCETA), Advisory Board
Joachim Mnich

Koordinierungsausschuss Datenverarbeitung der Helmholtz-Gemeinschaft (KODA)
Volker Gülzow

Komitee für Beschleunigerphysik
Hans Weise

Komitee für Elementarteilchenphysik (KET)
Joachim Mnich, Klaus Mönig

Laboratoire Souterraine Modane, Advisory Board
Christian Spiering

L'Agence d'Evaluation de la Recherche et de l'Enseignement Superieur (AERES)
Eckhard Elsen

Landesexzellenzinitiative Connecting Particles with the Cosmos, Research Board
Ties Behnke, Kerstin Borras, Wilfried Buchmüller, Eckhard Elsen,
Joachim Mnich, Carsten Niebuhr (Vorstandsmitglied),
Andreas Ringwald, Volker Schomerus, Felix Sefkow, Georg Weiglein,
Hans Weise

Large Hadron Electron Collider (LHeC), Scientific Advisory Committee
Joachim Mnich

LHC Experiments Committee (LHCC)
Eckhard Elsen, Daniel Pitzl

LHC Resources Review Boards (LHC-RRB)
Manfred Fleischer

LHC-RRB, Computing Resource Scrutiny Group
Martin Gasthuber

LHC-RRB, Scrutiny Group
Bernd Löhr (Chair)

LHC-US Accelerator Research Program Advisory Committee
Kay Wittenburg

LPNHE, Wissenschaftlicher Rat
Klaus Mönig

MPI-München, Scientific Advisory Board
Joachim Mnich (Chair)

Particle Data Group
Klaus Mönig, Georg Weiglein

Peta QCD Scientific Advisor
Karl Jansen

Rat Deutscher Sternwarten
Martin Pohl

Romanian CERN Project Funding Program of the Romanian Ministry of Education and Research, Scientific Advisory Board
Eckard Elsen

SFB676 Vorstand
Jenny List

Sponsoring Consortium for Open Access Publishing in Particle Physics ($SCOAP^3$)
Florian Schwennsen

STFC Oversight Committee for ATLAS UK
Bernd Löhr, Marcel Stanitzki

TTC Technical Board
Wolf-Dietrich Möller, Detlef Reschke, Hans Weise (Chair)

Collaborations.

H1

I. Physikalisches Institut, RWTH Aachen

Universiteit Antwerpen (BE)

VINCA Institute of Nuclear Sciences, Belgrade (CS)

School of Physics and Space Research,
University of Birmingham (GB)

Inter-University Institute for High Energies ULB-VUB,
Brussels (BE)

National Institute for Physics and Nuclear Engineering,
Bucharest (RO)

Rutherford Appleton Laboratory, Chilton, Didcot (GB)

The Hendryk Niewodniczanski Institute of Nuclear Physics,
Cracow (PL)

Institut für Physik, Technische Universität Dortmund

Joint Institute for Nuclear Research (JINR), Dubna (RU)

CEA, DSM-DAPNIA, CE Saclay, Gif-sur-Yvette (FR)

Deutsches Elektronen-Synchrotron DESY

Institut für Experimentalphysik, Universität Hamburg

Max-Planck-Institut für Kernphysik, Heidelberg

Kirchhoff Institut für Physik, Universität Heidelberg

Physikalisches Institut, Universität Heidelberg

Institute of Experimental Physics,
Slovak Academy of Sciences, Košice (SK)

School of Physics and Chemistry,
University of Lancaster (GB)

Oliver Lodge Laboratory, University of Liverpool (GB)

Queen Mary and Westfield College, London (GB)

Physics Department, University of Lund (SE)

Physics Department, University of Manchester (GB)

CPPM, Université de la Méditerranée,
IN2P3-CNRS, Marseille (FR)

Departamento de Fisica Aplicada, CINVESTAV, Mérida (MX)

Departamento de Fisica, CINVESTAV, México (MX)

Institute for Theoretical and Experimental Physics (ITEP),
Moscow (RU)

Russian Academy of Sciences, Lebedev Physical Institute,
Moscow (RU)

Max-Planck-Institut für Physik,Werner-Heisenberg-Institut,
München

LAL, Université Paris-Sud, IN2P3-CNRS, Orsay (FR)

Laboratoire Louis Leprince Ringuet, LLR,
IN2P3-CNRS, Palaiseau (FR)

LPNHE, Université Paris VI et VII, IN2P3-CNRS, Paris (FR)

Faculty of Natural Sciences and Mathematics,
University of Montenegro, Podgorica (YU)

Institute of Physics, Academy of Sciences of the Czech
Republic, Prague (CZ)

Institute of Particle and Nuclear Physics,
Charles University, Prague (CZ)

Dipartimento di Fisica, Università Roma 3 and INFN Roma 3,
Rome (IT)

Institute for Nuclear Research and Nuclear Energy, Sofia (BG)

Institute of Physics and Technology,
Mongolian Academy of Sciences, Ulaanbaatar (MN)

Paul Scherrer Institut, Villigen (CH)

Fachbereich Physik, Bergische Universität-GH Wuppertal

Yerevan Physics Institute, Yerevan (AM)

Institut für Teilchenphysik, ETH Zürich (CH)

Physik Institut, Universität Zürich (CH)

ZEUS

Department of Engineering in Management and Finance, University of the Aegean (GR)

Institute of Physics and Technology, Ministry of Education and Science of Kazakhstan, Almaty (KZ)

National Institute for Nuclear and High Energy Physics (NIKHEF), Amsterdam (NL)

Argonne National Laboratory (ANL), Argonne IL (USA)

Andrews University, Berrien Springs MI (USA)

University and INFN, Bologna (IT)

Physikalisches Institut, Universität Bonn

H.H. Wills Physics Laboratory, University of Bristol (GB)

Panjab University, Chandigarh (IN)

Rutherford Appleton Laboratory, Chilton, Didcot (GB)

Physics Department, Ohio State University, Columbus OH (USA)

Physics Department, Calabria University and INFN, Cosenza (IT)

The Henryk Niewodniczanski Institute of Nuclear Physics, Cracow (PL)

Department of Physics, Jagellonian University, Cracow (PL)

Faculty of Physics and Nuclear Techniques, AGH-University of Science and Technology, Cracow (PL)

University and INFN, Florence (IT)

Fakultät für Physik, Universität Freiburg

Department of Physics and Astronomy, University of Glasgow (GB)

Deutsches Elektronen-Synchrotron DESY

Institut für Experimentalphysik, Universität Hamburg

Nevis Laboratories, Columbia University, Irvington on Hudson NY (USA)

Institute for Nuclear Research, National Academy of Science and Kiew National University, Kiew (UA)

Department of Physics, Malaya University, Kuala Lumpur (MY)

Department of Physics, Chonnam National University, Kwangju (KR)

High Energy Nuclear Physics Group, Imperial College, London (GB)

Physics and Astronomy Department, University College, London (GB)

Institute de Physique Nucléaire, Université Catholique de Louvain, Louvain-la-Neuve (BE)

Department of Physics, University of Wisconsin, Madison WI (USA)

Departamento de Fisica Teórica, Universidad Autónoma Madrid (ES)

Department of Physics, McGill University, Montreal (CA)

Moskau Engineering und Physics Institute, Moskau (RU)

Institute of Nuclear Physics, Moskau State University, Moskau (RU)

Max-Planck Institut für Physik, München

Department of Physics, York University, North York (CA)

Department of Physics, University of Oxford (GB)

Dipartimento di Fisica, University and INFN, Padova (IT)

Department of Particle Physics, Weizmann Institute, Rehovot (IL)

Dipartimento di Fisica, Università La Sapienza and INFN, Roma (IT)

Polytechnic University, Sagamihara (JP)

Kyungpook National University, Taegu (KR)

School of Physics, University of Tel Aviv (IL)

Department of Physics, Tokyo Institute of Technology, Tokyo (JP)

Department of Physics, Tokyo Metropolitan University, Tokyo (JP)

Department of Physics, University of Tokyo (JP)

Università di and INFN, Torino (IT)

Università del Piemonte Orientale, Novara and INFN, Torino (IT)

Department of Physics, University of Toronto (CA)

Institute for Particle and Nuclear Study, KEK, Tsukuba (JP)

Department of Physics, Pennsylvania State University, University Park PA (USA)

Institute for Nuclear Studies, Warschau (PL)

Institut of Experimental Physics, University of Warschau (PL)

Faculty of General Education, Meiji Gakuin University, Yokohama (JP)

HERMES

National Institute for Subatomic Physics (NIKHEF), Amsterdam (NL)
Department of Physics and Astronomy, Vrije Universiteit, Amsterdam (NL)
Randall Laboratory of Physics, University of Michigan, Ann Arbor MI (USA)
Physics Division, Argonne National Laboratory, Argonne IL (USA)
Dipartimento di Fisica dell'Università and INFN, Bari (IT)
School of Physics, Peking University, Beijing (CN)
Nuclear Physics Laboratory, University of Colorado, Boulder CO (USA)
Joint Institute for Nuclear Research (JINR), Dubna (RU)
Physikalisches Institut, Universität Erlangen-Nürnberg
Dipartimento di Fisica dell'Università and INFN, Ferrara (IT)
Laboratori Nazionali di Frascati, INFN, Frascati (IT)
Petersburg Nuclear Physics Institute (PNPI), Gatchina (RU)
Department of Subatomic and Radiation Physics, University of Gent (BE)
Physikalisches Institut, Universität Gießen
School of Physics and Astronomy (SUPA), University of Glasgow (GB)
Deutsches Elektronen-Synchrotron DESY
P. N. Lebedev Physical Institute, Moscow (RU)
Institute for High Energy Physics (IHEP), Protvino (RU)
Institut für Theoretische Physik, Universität Regensburg
Gruppo Sanità, INFN and Physics Laboratory, Istituto Superiore di Sanità, Rome (IT)
Department of Physics, Tokyo Institute of Technology, Tokyo (JP)
Department of Physics, University of Illinois, Urbana IL (USA)
TRIUMF, Vancouver (CA)
Andrzeij Soltan Institute for Nuclear Studies, Warsaw (PL)
Yerevan Physics Institute, Yerevan (AM)

OLYMPUS

INFN, Bari (IT)
Universität Bonn
Massachusetts Institute of Technology, Cambridge (USA)
University of New Hampshire, Durham (USA)
INFN, Ferrara (IT)
Petersburg Nuclear Physics Institute, Gatchina (RU)
University of Glasgow (UK)
Deutsches Elektronen-Synchrotron DESY
Hampton University, Hampton (USA)
Universität Mainz
MIT-Bates Linear Accelerator Center, Middleton (MA)
INFN, Rome (IT)
Arizona State University, Tempe (USA)
Yerevan Physics Institute, Yerevan (AM)

TESLA Technology Collaboration

Argonne National Laboratory (ANL), Argonne IL (USA)
Fermi National Accelerator Laboratory (FNAL), Batavia Il (USA)
Beijing University, Beijing (CN)
Institute for High Energy Physics (IHEP), Academia Sinica, Beijing (CN)
Tsinghua University, Beijing (CN)
Lawrence Berkeley National Lab, Berkeley (USA)
BESSY Berlin
Hahn-Meitner Institut Berlin
AGH-University of Science and Technology, Cracow (PL)
Henryk Niewodnizanski Institute of Nuclear Physics, Polish Academy of Science, Cracow (PL)
Technische Universität Darmstadt
CCLRC, Daresbury & Rutherford Appleton Laboratory, Chilton, Didcot (GB)
Forschungszentrum Rossendorf, Dresden
Joint Institute for Nuclear Research (JINR), Dubna (RU)
Universität Frankfurt/Main
Laboratori Nazionali di Frascati, INFN, Frascati (IT)
GKSS-Forschungszentrum Geesthacht
CERN, Geneva (CH)
CEA/DSM DAPNIA, CE-Saclay, Gif-sur-Yvette (FR)
Deutsches Elektronen-Synchrotron DESY
Universität Hamburg
Raja Ramanna Centre of Advanced Technology (RRCAT), Indore (IN)
Cornell University, Ithaca NY (USA)
Variable Energy Cyclotron Centre VECC, Kolkata (IN)
Istituto Nazionale di Fisica Nucleare (INFN), Legnaro (IT)
Technical University of Lodz (PL)
Royal Holloway University of London (RHUL/JAI), London (GB)
University College London (UCL), London (GB)
Stanford Linear Accelerator Center (SLAC), Menlo Park CA (USA)
Istituto Nazionale di Fisica Nculeare (INFN), Milan (IT)
Institute for Nuclear Research (INR), Moscow (RU)
Moscow Engineering and Physics Institute (MEPhI), Moscow (RU)
Bhabha Atomic Research Centre (BARC), Mumbai (IN)
Jefferson Lab, Newport News VA (USA)
Budker Institute for Nuclear Physics (BINP), Novosibirsk (RU)
LAL, Université Paris-Sud, IN2P3-CNRS, Orsay (FR)
The Andrzej Soltan Institute for Nuclear Studies, Otwock-Swierk (PL)
University of Oxford (JAI), Oxford (GB)
Institute for High Energy Physics (IHEP), Protvino (RU)
Istituto Nazionale di Fisica Nucleare (INFN), Rome II (IT)
Universität Rostock
Sincrotrone Trieste (IT)
Institute for Particle and Nuclear Study, KEK, Tsukuba (JP)
Canada's National Laboratory for Particle and Nuclear Physics (TRIUMF), Vancouver (CA)
Institute of High Pressure Physics, Polish Academy of Sciences, Warsaw (PL)
Warsaw University of Technology (WUT), Warsaw (PL)
Warsaw University, Department of Physics, Warsaw (PL)
Bergische Universität-GH Wuppertal
CANDLE, Yerevan (AM)
Yerevan Physics Institute, Yerevan (AM)

Physics at the Terascale, Helmholtz Alliance

Rheinisch-Westfälische Technische Hochschule Aachen
Humboldt-Universität zu Berlin
Rheinische Friedrich-Wilhelms-Universität Bonn
Deutsches Elektronen-Synchrotron DESY
Universität Dortmund
Technische Universität Dresden
Albert-Ludwigs-Universität Freiburg
Justus-Liebig-Universität Giessen
Georg-August-Universität Göttingen
Universität Hamburg
Ruprecht-Karls-Universität Heidelberg
Karlsruher Institut für Technologie - Großforschungsbereich
Karlsruher Institut für Technologie - Universitätsbereich
Johannes Gutenberg-Universität Mainz
Ludwig-Maximilians-Universität München
Max-Planck Institut für Physik München
Universität Rostock
Universität Siegen
Julius-Maximilians-Universität Würzburg
Bergische Universität Wuppertal

Adjunct Partner
Universität Regensburg

ALPS

Deutsches Elektronen-Synchrotron DESY
Universität Hamburg
Albert Einstein Institut Hannover
Laser Zentrum Hannover

Publications.

H1-Experiment

H1 Collaboration, F.D. Aaron et al.
Measurement of Charm and Beauty Jets in Deep Inelastic Scattering at HERA.
Eur. Phys. J. C 71 (2011) 1509 and DESY 10-083; arXiv:1008.1731

Measurement of the Diffractive Deep-Inelastic Scattering Cross Section with a Leading Proton at HERA.
Eur. Phys. J. C 71 (2011) 1578 and DESY 10-095

Search for Squarks in R-parity Violating Supersymmetry in ep Collisions at HERA.
Eur. Phys. J. C 71 (2011) 1572 and DESY 10-181

Measurement of the Inclusive $e\pm p$ Scattering Cross Section at High Inelasticity y and of the Structure Function FL.
Eur. Phys. J. C 71 (2011) 1579 and DESY 10-228

Measurement of D$^{*\pm}$ Meson Production and Determination of $F_2^{c\bar{c}}$ at low Q^2 in Deep-Inelastic Scattering at HERA.
Eur. Phys. J. C 71 (2011) 1769 and DESY 11-066; arxiv:1106.1028

Measurement of Photon Production in the Very Forward Direction in Deep-Inelastic Scattering at HERA.
Eur. Phys. J. C 71 (2011) 1771 and DESY 11-093; arxiv:1106.5944

Search for Contact Interactions in e$^{\pm}$p Collisions at HERA.
Phys. Lett. B 705 (2011) 52 and DESY 11-114; arxiv:1107.2478

Search for First Generation Leptoquarks in ep Collisions at HERA.
Phys. Lett. B 704 (2011) 388 and DESY 11-123

M. Jacquet
Precise Measurement of the Longitudinal Polarisation at HERA with a Fabry-Perot Cavity Polarimeter.
J. Phys., Conf. Ser. 298 (2011)

K. Nowak
Particle Production and Fragmentation at HERA.
Nucl. Phys. B, Proc. Suppl. 210-211 (2011) 101

A. Valakárová
Particle Production in ep Collisions at HERA.
Nucl. Phys. B, Proc. Suppl. 219-220 (2011) 74

ZEUS-Experiment

ZEUS Collaboration, H. Abramowicz et al.
Measurement of the Energy Dependence of the Total Photon-Proton Cross Section at HERA.
Phys. Lett. B 697 (2011) 184 and DESY 10-178; arXiv:1011.1652
`http://dx.doi.org/10.1016/j.physletb.2011.01.051`

Study of tau-Pair Production at HERA.
JHEP 2 (2011) 117 and DESY 10-250, arXiv:1101.1390
`http://dx.doi.org/10.1007/JHEP02(2011)117`

Measurement of Beauty Production in Deep Inelastic Scattering at HERA Using Decays into Electrons.
Eur. Phys. J. C 71 (2011) 1753 and DESY 11-005; arXiv: 1101.3692
`http://dx.doi.org/10.1140/epjc/s10052-011-1573-x`

Measurement of Heavy-Qark Jet Photoproduction at HERA.
Eur. Phys. J. C 71 (2011) 1659 and DESY 11-067; arXiv:1104.5444
`http://dx.doi.org/10.1140/epjc/s10052-011-1659-5`

J. Figiel
Results on meson production at HERA.
Int. J. Mod. Phys. A 26 (2011) 365
`http://dx.doi.org/10.1142/S0217751X11051676`

W. Perlanski
Production of heavy flavors in ep collisions at HERA.
Nucl. Phys. B, Proc. Suppl. 210-211 (2011)
`http://dx.doi.org/10.1016/S0920-5632(11)00097-1`

J. Szuba, D. South
HERA Data Preservation Plans and Activities.
J. Phys., Conf. Ser. 331 (2011) 072032
`http://dx.doi.org/10.1088/1742-6596/331/7/072032`

HERMES-Experiment

A. Airapetian et al.
Ratios of helicity amplitudes for exclusive ρ^0 electroproduction.
Eur. Phys. J. C 71 (2011) 1609 and DESY 10-229 and arXiv:1012.3676
`http://dx.doi.org/10.1140/epjc/s10052-011-1609-2`

Inclusive Measurements of Inelastic Electron and Positron Scattering from Unpolarized Hydrogen and Deuterium Targets.
JHEP 05 (2011) 126 and DESY 11-048; arXiv:1103.5704
`http://dx.doi.org/10.1007/JHEP05(2011)126`

Measurement of double-spin asymmetries associated with deeply virtual Compton scattering on a transversely polarized hydrogen target.
Phys. Lett. B 704 (2011) 15 and DESY 11-100; arXiv:1106.2990
`http://dx.doi.org/10.1016/j.physletb.2011.08.067`

Multidimensional study of hadronization in nuclei.
Eur. Phys. J. A 47 (2011) 8 and DESY 11-120; arXiv:1107.3496
`http://dx.doi.org/10.1140/epja/i2011-11113-5`

W. Augustyniak
Single-Spin Azimuthal Asymmetry in Exclusive Electroproduction of ϕ and ω Vector Mesons on Transversely Polarized Protons.
Int. J. Mod. Phys. A 26 (2011) 763
`http://dx.doi.org/10.1142/S0217751X11052773`

S. Belostotski, D. Veretennikov, Y. Naryshkin
Spin transfer coefficient D_{LL}^{Λ} to Lambda hyperon in semi-inclusive DIS at HERMES.
J. Phys., Conf. Ser. 295 (2011) 012114
`http://dx.doi.org/10.1088/1742-6596/295/1/012114`

S. Belostotski, Y. Naryshkin, D. Veretennikov
Measurement of the nuclear-mass dependence of spontaneous (transverse) Lambda polarisation in quasi-real photoproduction at HERMES.
J. Phys., Conf. Ser. 295 (2011) 012116
`http://dx.doi.org/10.1088/1742-6596/295/1/012116`

M. Düren
Deeply Virtual Compton Scattering off Polarized and Unpolarized Protons at HERMES.
J. Phys., Conf. Ser. 295 (2011) 012036
`http://dx.doi.org/10.1088/1742-6596/295/1/012036`

F. Giordano, R. Lamb
Flavor-dependent azimuthal modulations in unpolarized SIDIS cross section at HERMES.
J. Phys., Conf. Ser. 295 (2011) 012092
`http://dx.doi.org/10.1088/1742-6596/295/1/012092`

S. Gliske
Tranverse Target Moments of SIDIS Vector Meson Production at HERMES.
J. Phys., Conf. Ser. 295 (2011) 012044
`http://dx.doi.org/10.1088/1742-6596/295/1/012044`

B. Marianski
Helicity Amplitude Ratios in Exclusive Electroproduction of the rho-0 Meson at HERMES.
J. Phys., Conf. Ser. 295 (2011) 012111
`http://dx.doi.org/10.1088/1742-6596/295/1/012111`

K. Rith
Transverse single-spin asymmetries in inclusive hadron electroproduction at HERMES.
J. Phys., Conf. Ser. 295 (2011) 012056
`http://dx.doi.org/10.1088/1742-6596/295/1/012056`

Search for a two-photon exchange contribution to inclusive deep-inelastic scattering.
J. Phys., Conf. Ser. 295 (2011) 012107
`http://dx.doi.org/10.1088/1742-6596/295/1/012107`

E. Steffens
Closing Remarks.
J. Phys., Conf. Ser. 295 (2011) 012030
`http://dx.doi.org/10.1088/1742-6596/295/1/012030`

S. Yaschenko
Overview of recent HERMES results.
J. Phys., Conf. Ser. 295 (2011) 012024
`http://dx.doi.org/10.1088/1742-6596/295/1/012024`

ATLAS-Experiment

A. Abdesselam et al.
Boosted objects: a probe of beyond the Standard Model physics.
Eur. Phys. J. C 71 (2011) 1661 and arXiv:1012.5412
`http://dx.doi.org/10.1140/epjc/s10052-011-1661-y`

J. Alasia et al.
Search for Diphoton Events with Large Missing Transverse Energy with 36 pb^{-1} of 7 TeV Proton-Proton Collision Data with the ATLAS Detector.
Eur. Phys. J. C 71 (2011) 1744 and CERN-PH-EP-2011-091; arXiv:1107.0561
`http://dx.doi.org/10.1140/epjc/s10052-011-1744-9`

ATLAS Collaboration
Search for Quark Contact Interactions in Dijet Angular Distributions in pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$ Measured with the ATLAS Detector.
Phys. Lett. B 694 (2011) 327 and CERN-PH-EP-2010-033; arXiv:1009.5069
`http://dx.doi.org/10.1016/j.physletb.2010.10.021`

Measurement of inclusive jet and dijet cross sections in proton-proton collisions at 7 TeV centre-of-mass energy with the ATLAS detector.
Eur. Phys. J. C 71 (2011) 1512 and CERN-PH-EP-2010-034; arXiv:1009.5908
`http://dx.doi.org/10.1140/epjc/s10052-010-1512-2`

Studies of the performance of the ATLAS detector using cosmic-ray muons.
Eur. Phys. J. C 71 (2011) 1593 and CERN-PH-EP-2010-070; arXiv:1011.6665
`http://dx.doi.org/10.1140/epjc/s10052-011-1593-6`

Measurement of underlying event characteristics using charged particles in pp collisions at $\sqrt{s} = 900\mathrm{GeV}$ and 7 TeV with the ATLAS Detector.
Phys. Rev. D 83 (2011) 112001 and CERN-PH-EP-2010-063; arXiv:1012.0791
`http://dx.doi.org/10.1103/PhysRevD.83.112001`

Measurement of the top quark pair production cross-section with ATLAS in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$.
Eur. Phys. J. C 71 (2011) 1577 and CERN-PH-EP-2010-064; arXiv:1012.1792
`http://dx.doi.org/10.1140/epjc/s10052-011-1577-6`

Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Rev. D 83 (2011) 052005 and CERN-PH-EP-2010-068; arXiv:1012.4389
`http://dx.doi.org/10.1103/PhysRevD.83.052005`

Charged particle multiplicities in pp interactions measured with the ATLAS detector at the LHC.
New J. Phys. 13 (2011) 053033 and CERN-PH-EP-2010-079; arXiv:1012.5104
`http://dx.doi.org/10.1088/1367-2630/13/5/053033`

Measurement of the centrality dependence of J/ψ yields and observation of Z production in lead-lead collisions with the ATLAS detector at the LHC.
Phys. Lett. B 697 (2011) 294 and CERN-PH-EP-2010-090; arXiv:1012.5419
http://dx.doi.org/10.1016/j.physletb.2011.02.006

Study of Jet Shapes in Inclusive Jet Production in pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$ using the ATLAS Detector.
Phys. Rev. D 83 (2011) 052003 and CERN-PH-EP-2010-077; arXiv:1101.0070
http://dx.doi.org/10.1103/PhysRevD.83.052003

Search for Diphoton Events with Large Missing Transverse Energy in 7 TeV Proton-Proton Collisions with the ATLAS Detector.
Phys. Rev. Lett. 106 (2011) 121803 and CERN-PH-EP-2010-076; arXiv:1012.4272
http://dx.doi.org/10.1103/PhysRevLett.106.121803

Measurement of the production cross section for W-bosons in association with jets in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Lett. B 698 (2011) 325 and CERN-PH-EP-2010-081;arXiv:1012.5382
http://dx.doi.org/10.1016/j.physletb.2011.03.012

Luminosity Determination in pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$ using the ATLAS Detector at the LHC.
Eur. Phys. J. C 71 (2011) 1630 and CERN-PH-EP-2010-069; arXiv:1101.2185
http://dx.doi.org/10.1140/epjc/s10052-011-1630-5

Search for Massive Long-lived Highly Ionising Particles with the ATLAS Detector at the LHC.
Phys. Lett. B 698 (2011) 353 and CERN-PH-EP-2011-010; arXiv:1102.0459
http://dx.doi.org/10.1016/j.physletb.2011.03.033

Search for supersymmetry using final states with one lepton, jets, and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7\mathrm{TeV}$ pp collisions.
Phys. Rev. Lett. 106 (2011) 131802 and CERN-PH-EP-2011-013; arXiv:1102.2357
http://dx.doi.org/10.1103/PhysRevLett.106.131802

Measurement of Dijet Azimuthal Decorrelations in pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$.
Phys. Rev. Lett. 106 (2011) 172002 and CERN-PH-EP-2011-014; arXiv:1102.2696
http://dx.doi.org/10.1103/PhysRevLett.106.172002

Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7\mathrm{TeV}$ proton proton collisions.
Phys. Lett. B 701 (2011) 186 and CERN-PH-EP-2011-022; arXiv:1102.5290
http://dx.doi.org/10.1016/j.physletb.2011.05.061

Search for high-mass states with one lepton plus missing transverse momentum in proton-proton collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Lett. B 701 (2011) 50 and CERN-PH-EP-2011-023;arXiv:1103.1391
http://dx.doi.org/10.1016/j.physletb.2011.05.043

Measurements of underlying-event properties using neutral and charged particles in pp collisions at 900 GeV and 7 TeV with the ATLAS detector at the LHC.
Eur. Phys. J. C 71 (2011) 1636 and CERN-PH-EP-2011-017; arXiv:1103.1816
http://dx.doi.org/10.1140/epjc/s10052-011-1636-z

Search for Stable Hadronising Squarks and Gluinos with the ATLAS Experiment at the LHC.
Phys. Lett. B 701 (2011) 1 and CERN-PH-EP-2011-026; arXiv:1103.1984
http://dx.doi.org/10.1016/j.physletb.2011.05.010

Measurement of the Muon Charge Asymmetry from W Bosons Produced in pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Lett. B 701 (2011) 31 and CERN-PH-EP-2011-036; arXiv:1103.2929
http://dx.doi.org/10.1016/j.physletb.2011.05.024

Search for New Physics in Dijet Mass and Angular Distributions in pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$ Measured with the ATLAS Detector.
New J. Phys. 13 (2011) 053044 and CERN-PH-EP-2011-030; arXiv:1103.3864
http://dx.doi.org/10.1088/1367-2630/13/5/053044

Search for supersymmetry in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ in final states with missing transverse momentum and b-jets.
Phys. Lett. B 701 (2011) 398 and CERN-PH-EP-2011-038; arXiv:1103.4344
http://dx.doi.org/10.1016/j.physletb.2011.06.015

Search for a heavy particle decaying into an electron and a muon with the ATLAS detector in $\sqrt{s} = 7\mathrm{TeV}$ pp collisions at the LHC.
Phys. Rev. Lett. 106 (2011) 251801 and CERN-PH-EP-2011-031; arXiv:1103.5559
http://dx.doi.org/10.1103/PhysRevLett.106.251801

Search for high mass dilepton resonances in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS experiment.
Phys. Lett. B 700 (2011) 163 and CERN-PH-EP-2011-037; arXiv:1103.6218
http://dx.doi.org/10.1016/j.physletb.2011.04.044

Search for supersymmetric particles in events with lepton pairs and large missing transverse momentum in $\sqrt{s} = 7\mathrm{TeV}$ proton-proton collisions with the ATLAS experiment.
Eur. Phys. J. C 71 (2011) 1682 and CERN-PH-EP-2011-040; arXiv:1103.6214
http://dx.doi.org/10.1140/epjc/s10052-011-1682-6

Measurement of the Inelastic Proton-Proton Cross-Section at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS Detector.
Nat. Comm. 2 (2011) 463 and CERN-PH-EP-2011-047; arXiv:1104.0326
http://dx.doi.org/10.1038/ncomms1472

Measurement of the differential cross-sections of inclusive, prompt and non-prompt J/psi production in proton-proton collisions at $\sqrt{s} = 7\mathrm{TeV}$.
Nucl. Phys. B 850 (2011) 387 and CERN-PH-EP-2011-041; arXiv:1104.3038
http://dx.doi.org/10.1016/j.nuclphysb.2011.05.015

Search for Contact Interactions in Dimuon Events from pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS Detector.
Phys. Rev. D 84 (2011) 011101 and CERN-PH-EP-2011-052; arXiv:1104.4398
`http://dx.doi.org/10.1103/PhysRevD.84.011101`

Search for pair production of first or second generation leptoquarks in proton-proton collisions at $\sqrt{s} = 7\mathrm{TeV}$ using the ATLAS detector at the LHC.
Phys. Rev. D 83 (2011) 112006 and CERN-PH-EP-2011-050; arXiv:1104.4481
`http://dx.doi.org/10.1103/PhysRevD.83.112006`

Measurement of the WW production cross section in proton-proton collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Rev. Lett. 107 (2011) 041802 and CERN-PH-EP-2011-054; arXiv:1104.5225
`http://dx.doi.org/10.1103/PhysRevLett.107.041802`

Search for massive colored scalars in four-jet final states in $\sqrt{s} = 7$ TeV proton-proton collisions with the ATLAS detector.
Eur. Phys. J. C 71 (2011) 1828 and CERN-PH-EP-2011-154; arXiv:1110.2693
`http://dx.doi.org/10.1140/epjc/s10052-011-1828-6`

Measurement of Wγ and Zγ production in proton-proton collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS Detector.
JHEP 09 (2011) 072 and CERN-PH-EP-2011-079; arXiv:1106.1592
`http://dx.doi.org/10.1007/JHEP09(2011)072`

Search for Heavy Long-Lived Charged Particles with the ATLAS detector in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$.
Phys. Lett. B 703 (2011) 428 and CERN-PH-EP-2011-077; arXiv:1106.4495
`http://dx.doi.org/10.1016/j.physletb.2011.08.042`

Measurement of the $\Upsilon(1S)$ Production Cross-Section in pp Collisions at $\sqrt{s} = 7\mathrm{TeV}$ in ATLAS.
Phys. Lett. B 705 (2011) 9 and CERN-PH-EP-2011-083; arXiv:1106.5325
`http://dx.doi.org/10.1016/j.physletb.2011.09.092`

Search for new phenomena with the monojet and missing transverse momentum signature using the ATLAS detector in $\sqrt{s} = 7\mathrm{TeV}$ proton-proton collisions.
Phys. Lett. B 705 (2011) 294 and CERN-PH-EP-2011-090; arXiv:1106.5327
`http://dx.doi.org/10.1016/j.physletb.2011.10.006`

Search for new phenomena in final states with large jet multiplicities and missing transverse momentum using $\sqrt{s} = 7$ TeV pp collisions with the ATLAS detector.
JHEP 1111 (2011) 099 and CERN-PH-EP-2011-155; arXiv:1110.2299
`http://dx.doi.org/10.1007/JHEP11(2011)099`

Measurement of the inclusive and dijet cross-sections of b-jets in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector.
Eur. Phys. J. C 71 (2011) 1846 and CERN-PH-EP-2011-146; arXiv:1109.6833
`http://dx.doi.org/10.1140/epjc/s10052-011-1846-4`

Search for Diphoton Events with Large Missing Transverse Energy with 36 pb of 7 TeV Proton-Proton Collision Data with the ATLAS Detector.
Eur. Phys. J. C 71 (2011) 1744 and CERN-PH-EP-2011-091; arXiv:1107.0561
`http://dx.doi.org/10.1140/epjc/s10052-011-1744-9`

Search for the Standard Model Higgs boson in the decay channel $H \rightarrow ZZ^{(*)} \rightarrow 4l$ with the ATLAS detector.
Phys. Lett. B 705 (2011) 435 and CERN-PH-EP-2011-144; arXiv:1109.5945
`http://dx.doi.org/10.1016/j.physletb.2011.10.034`

Measurement of dijet production with a veto on additional central jet activity in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ using the ATLAS detector.
JHEP 1109 (2011) 053 and CERN-PH-EP-2011-100; arXiv:1107.1641
`http://dx.doi.org/10.1007/JHEP09(2011)053`

Measurement of multi-jet cross-sections in proton-proton collisions at 7 TeV center-of-mass energy.
Eur. Phys. J. C 71 (2011) 1763 and CERN-PH-EP-2011-098; arXiv:1107.2092
`http://dx.doi.org/10.1140/epjc/s10052-011-1763-6`

Measurement of the transverse momentum distribution of Z/γ^* bosons in proton-proton collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Lett. B 705 (2011) 415 and CERN-PH-EP-2011-095; arXiv:1107.2381
`http://dx.doi.org/10.1016/j.physletb.2011.10.018`

Properties of jets measured from tracks in proton-proton collisions at center-of-mass energy $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Rev. D 84 (2011) 054001 and CERN-PH-EP-2011-110; arXiv:1107.3311
`http://dx.doi.org/10.1103/PhysRevD.84.054001`

Search for neutral MSSM Higgs boson decaying to $\tau^+\tau^-$ pairs in proton-proton collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS experiment.
Phys. Lett. B 705 (2011) 174 and CERN-PH-EP-2011-104; arXiv:1107.5003
`http://dx.doi.org/10.1016/j.physletb.2011.10.001`

Inclusive search for same-sign dilepton signatures in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
JHEP 1110 (2011) 107 and CERN-PH-EP-2011-094; arXiv:1108.0366
`http://dx.doi.org/10.1007/JHEP10(2011)107`

Search for a heavy gauge boson decaying to a charged lepton and a neutrino in 1 fb-1 of pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ using the ATLAS detector.
Phys. Lett. B 705 (2011) 28 and CERN-PH-EP-2011-121; arXiv:1108.1316
`http://dx.doi.org/10.1016/j.physletb.2011.09.093`

Search for dilepton resonances in pp collisions at $\sqrt{s} = 7\mathrm{TeV}$ with the ATLAS detector.
Phys. Rev. Lett. 107 (2011) 272002 and CERN-PH-EP-2011-123; arXiv:1108.1582
`http://dx.doi.org/10.1103/PhysRevLett.107.272002`

Measurement of the $Z \rightarrow \tau\tau$ cross section with the ATLAS detector.
Phys. Rev. D 84 (2011) 112006 and CERN-PH-EP-2011-097
`http://dx.doi.org/10.1103/PhysRevD.84.112006`

Search for a heavy neutral particle decaying into an electron and a muon using 1 fb-1 of ATLAS data.
Eur. Phys. J. C 71 (2011) 1809 and CERN-PH-EP-2011-140; arXiv:1109.3089
`http://dx.doi.org/10.1140/epjc/s10052-011-1809-9`

Search for a Standard Model Higgs boson in the $H \rightarrow ZZ \rightarrow l^+l^-\nu\bar{\nu}$ decay channel with the ATLAS detector.
Phys. Rev. Lett. 107 (2011) 221802 and CERN-PH-EP-2011-142; arXiv:1109.3357
`http://dx.doi.org/10.1103/PhysRevLett.107.221802`

Search for the Higgs boson in the $H \rightarrow WW \rightarrow l\nu jj$ decay channel in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector.
Phys. Rev. Lett. 107 (2011) 231801 and CERN-PH-EP-2011-130; arXiv:1109.3615
`http://dx.doi.org/10.1103/PhysRevLett.107.231801`

Measurement of the jet fragmentation function and transverse profile in proton-proton collisions at a center-of-mass energy of 7 TeV with the ATLAS detector at the LHC.
Eur. Phys. J. C 71 (2011) 1795 and CERN-PH-EP-2011-148; arXiv:1109.5816
`http://dx.doi.org/10.1140/epjc/s10052-011-1795-y`

Search for Quark Contact Interactions in Dijet Angular Distributions in pp Collisions at $sqrts = 7$ TeV Measured with the ATLAS Detector.
Phys. Lett. B 694 (2011) 327 and arXiv:1009.5069
`http://dx.doi.org/10.1016/j.physletb.2010.10.021`

Search for an excess of events with an identical flavour lepton pair and significant missing transverse momentum in $\sqrt{s} = 7$ TeV proton-proton collisions with the ATLAS detector.
Eur. Phys. J. C 71 (2011) 1647 and CERN-PH-EP-2011-039; arXiv:1103.6208

Measurement of multi-jet cross sections in proton-proton collisions at a 7 TeV center-of-mass energy.
Eur. Phys. J. C 71 (2011) 1763 and CERN-PH-EP-2011-098; arXiv:1107.2092
`http://dx.doi.org/10.1140/epjc/s10052-011-1763-6`

Search for the Standard Model Higgs boson in the two photon decay channel with the ATLAS detector at the LHC.
Phys. Lett. B 705 (2011) 23 and CERN-PH-EP-2011-129; arXiv:1106.2748
`http://dx.doi.org/10.1016/j.physletb.2011.10.051`

Limits on the production of the Standard Model Higgs Boson in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector.
Eur. Phys. J. C 71 (2011) 1728 and CERN-PH-EP-2011-076; arXiv:1106.2748
`http://dx.doi.org/10.1140/epjc/s10052-011-1728-9`

Measurement of the inclusive isolated prompt photon cross-section in pp collisions at $sqrts = 7$ TeV using 35 pb^{-1} of ATLAS data.
Phys. Lett. B 706 (2011) 150 and CERN-PH-EP-2011-115; arXiv:1108.0253

CMS-Experiment

V. Blobel, C. Kleinwort, F. Meier
Fast alignment of a complex tracking detector using advances track models.
Comput. Phys. Commun. 182 (2011) 1760
`http://dx.doi.org/10.1016/j.cpc.2011.03.017`

CMS Collaboration
Search for Microscopic Black Hole Signatures at the Large Hadron Collider.
Phys. Lett. B B697 (2011) 434 and arXiv:1012.3375; CERN-PH-EP-2010-073

Measurements of Inclusive W and Z Cross Sections in pp Collisions at sqrt(s)=7 TeV.
JHEP 1101 (2011) 080 and arXiv:1012.2466; CERN-PH-EP-2010-050

Measurement of the Isolated Prompt Photon Production Cross section in pp Collisions at sqrt(s)=7 TeV.
Phys. Rev. Lett. 106 (2011) 082001 and arXiv:1012.0799

Charged Particle multiplicities in pp Interactions at sqrt(s)= 0.9, 2.36, and 7 TeV.
JHEP 1101 (2011) 079 and arXiv:1011.5531

Search for Stopped Gluinos in pp Collisions at sqrt(s)=7TeV.
Phys. Rev. Lett. 106 (2011) 011801 and arXiv:1011.5861; CMS-EXO-10-003

First Measurement of the Cross Section for Top-Quark-Production in ProtonProton Collisions at $\sqrt{s}$=7TeV.
Phys. Lett. B 695 (2011) 424 and arXiv:1010.5994

Measurement of the inclusive Z cross section via decays to tau pairs in pp collisions at $\sqrt{(s)} = 7$ TeV.
JHEP 1108 (2011) 1108

Search for Supersymmetry in pp Collisions at 7 TeV in Events with Jets and Missing Transverse Energy.
Phys. Lett. B 689 (2011) 196 and CMS-SUS-10-003; CERN-PH-EP-2010-084; arXiv:1101.1628

Search for Heavy Stable Charged Particles in pp collisions at $\sqrt{s} = 7$ TeV.
JHEP 03 (2011) 024 and arXiv:1101.1645; CMS-EXO-10-011; CERN-PH-EP-2010-067

Inclusive b-hadron production cross section with muons in pp collisions at sqrt (s) = 7 TeV / CMS Collaboration.
JHEP 03 (2011) 090 and arXiv:1101.3512; CMS-BPH-10-007; CERN-PH-EP-2010-088

Measurement of Bose-Einstein Correlations in pp Collisions at $\sqrt{s} = 0.9$ and 7 TeV.
JHEP 05 (2011) 029 and arXiv:1101.3518; CMS-QCD-10-023; CERN-PH-EP-2010-091

Dijet Azimuthal Decorrelations in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 106 (2011) 122003 and arXiv:1101.5029; CMS-QCD-10-026; CERN-PH-EP-2010-086.-

First Measurement of Hadronic Event Shapes in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 699 (2011) 48 and arXiv:1102.0068; CMS-QCD-10-013; CERN-PH-EP-2010-072

Observation and studies of jet quenching in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.
Phys. Rev. C 84 (2011) 024906 and arXiv:1102.1957;
CMS-HIN-10-004; CERN-PH-EP-2011-001.

Measurement of Dijet Angular Distributions and Search for Quark Compositeness in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 106 (2011) 201804 and arXiv:1102.2020;
CMS-QCD-10-016; CERN-PH-EP-2010-092

Measurement of B$\bar{B}$ angular correlations based on secondary vertex reconstruction at $\sqrt{s} = 7$ TeV.
JHEP 03 (2011) 136 and arXiv:1102.3194; CMS-BPH-10-010;
CERN-PH-EP-2010-093

Measurement of the weak mixing angle with the Drell-Yan process in proton-proton collisions at the LHC.
Phys. Rev. D 84 (2011) 112002

Search for a Vectorlike Quark with Charge 2/3 in t + Z Events from pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 107 (2011) 271802

Search for Supersymmetry at the LHC in Events with Jets and Missing Transverse Energy.
Phys. Rev. Lett. 107 (2011) 221804

Measurement of the Differential Cross Section for Isolated Prompt Photon Production in pp Collisions at 7 TeV.
Phys. Rev. D 84 (2011) 052011

Measurement of the Drell-Yan Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV.
JHEP 10 (2011) 007

Search for Resonances in the Dijet Mass Spectrum from 7 TeV pp Collisions at CMS.
Phys. Lett. B 704 (2011) 123

Measurement of the Inclusive W and Z Production Cross Sections in pp Collisions at $\sqrt{s} = 7$ TeV with the CMS experiment.
JHEP 10 (2011) 132

Determination of Jet Energy Calibration and Transverse Momentum Resolution in CMS.
J. Instrum. 6 (2011) P11002

Search for Three-Jet Resonances in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 107 (2011) 101801

Search for supersymmetry in pp collisions at $\sqrt{s} = 7$ TeV in events with a single lepton, jets, and missing transverse momentum.
JHEP 08 (2011) 156

A search for excited leptons in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 704 (2011) 143

Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 7$ TeV and Comparison with $\sqrt{s} = 0.9$ TeV.
JHEP 09 (2011) 109

Missing transverse energy performance of the CMS detector.
J. Instrum. 6 (2011) P09001

Search for New Physics with a Monojet and Missing Transverse Energy in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 107 (2011) 201804

Search for New Physics with Jets and Missing Transverse Momentum in pp collisions at $\sqrt{s} = 7$ TeV.
JHEP 08 (2011) 155

Search for Supersymmetry in Events with b Jets and Missing Transverse Momentum at the LHC.
JHEP 07 (2011) 113

Measurement of the t-channel single top quark production cross section in pp collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 107 (2011) 091802

Search for Light Resonances Decaying into Pairs of Muons as a Signal of New Physics.
JHEP 07 (2011) 098

Search for Same-Sign Top-Quark Pair Production at $\sqrt{s} = 7$ TeV and Limits on Flavour Changing Neutral Currents in the Top Sector.
Phys. Lett. B 704 (2011) 411

Measurement of the Ratio of the 3-jet to 2-jet Cross Sections in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 702 (2011) 336

Measurement of the Inclusive Jet Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 107 (2011) 132001

Search for supersymmetry in events with a lepton, a photon, and large missing transverse energy in pp collisions at $\sqrt{s} = 7$ TeV.
JHEP 06 (2011) 093

Measurement of the Polarization of W Bosons with Large Transverse Momenta in W+Jets Events at the LHC.
Phys. Rev. Lett. 107 (2011) 021802

Charged particle transverse momentum spectra in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV.
JHEP 08 (2011) 086

Search for new physics with same-sign isolated dilepton events with jets and missing transverse energy at the LHC.
JHEP 06 (2011) 077

Measurement of the differential dijet production cross section in proton-proton collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 700 (2011) 187

Search for Neutral Minimal Supersymmetric Standard Model Higgs Bosons Decaying to Tau Pairs in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 106 (2011) 231801

Measurement of the Inclusive Z Cross Section via Decays to Tau Pairs in pp Collisions at $\sqrt{s} = 7$ TeV.
JHEP 08 (2011) 117

Search for Large Extra Dimensions in the Diphoton Final State at the Large Hadron Collider.
JHEP 05 (2011) 085

Measurement of the lepton charge asymmetry in inclusive W production in pp collisions at $\sqrt{s} = 7$ TeV.
JHEP 04 (2011) 050

Search for Physics Beyond the Standard Model in Opposite-sign Dilepton Events in pp Collisions at $\sqrt{s} = 7$ TeV.
JHEP 06 (2011) 026

Search for Resonances in the Dilepton Mass Distribution in pp Collisions at $\sqrt{s} = 7$ TeV.
JHEP 05 (2011) 093

Search for Supersymmetry in pp Collisions at $\sqrt{s} = 7$ TeV in Events with Two Photons and Missing Transverse Energy.
Phys. Rev. Lett. 106 (2011) 211802

Search for a W' boson decaying to a muon and a neutrino in pp collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 701 (2011) 160

Search for a Heavy Bottom-like Quark in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 701 (2011) 204

Strange Particle Production in pp collisions at $\sqrt{s} = 0.9$ and 7 TeV.
JHEP 05 (2011) 064

Measurement of the $t\bar{t}$ Production Cross Section in pp Collisions at 7 TeV in Lepton + Jets Events Using b-quark Jet Identification.
Phys. Rev. D 84 (2011) 092004 and arXiv:1108.3773;
CMS-TOP-10-003; CERN-PH-EP-2011-085

Search for B_s^o -¿ $\mu^+\mu^-$ and B^o -¿ $\mu^+\mu^-$ decays in pp collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 107 (2011) 191802 and arXiv:1107.5834;
CMS-BPH-11-002; CERN-PH-EP-2011-120

Dependence on pseudorapidity and on centrality of charged hadron production in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.
JHEP 08 (2011) 141 and arXiv:1107.4800; CMS-HIN-10-001;
CERN-PH-EP-2011-092

Measurement of the B_s^o Production Cross Section with B_s^o -¿ $J/\psi\phi$ Decays in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. D 84 (2011) 052008 and arXiv:1106.4048;
CMS-BPH-10-013; CERN-PH-EP-2011-063

Search for Physics Beyond the Standard Model Using Multilepton Signatures in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 704 (2011) 411 and arXiv:1106.0933;
CMS-SUS-10-008; CERN-PH-EP-2011-046

Measurement of the $t\bar{t}$ Production Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV using the Kinematic Properties of Events with Leptons and Jets.
Eur. Phys. J. C 712 (2011) 1721 and arXiv:1106.0902;
CMS-TOP-10-002; CERN-PH-EP-2011-060.

Measurement of the Inclusive Jet Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV.
JHEP 07 (2011) 049 and arXiv:1105.5661; CMS-TOP-11-002;
CERN-PH-EP-2011-055

Search for First Generation Scalar Leptoquarks in the $e\nu jj$ Channel in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 703 (2011) 246 and arXiv:1105.5237;
CMS-EXO-10-006; CERN-PH-EP-2011-062.

Indications of Suppression of Excited Υ States in Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV.
Phys. Rev. Lett. 107 (2011) 052302 and arXiv:1105.4894;
CMS-HIN-11-007; CERN-PH-EP-2011-074

Measurement of $W\gamma$ and $Z\gamma$ production in pp collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 701 (2011) 535 and arXiv:1105.2758;
CMS-EWK-10-008; CERN-PH-EP-2011-045

Long-range and short-range dihadron angular correlations in central PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.
JHEP 07 (2011) 076 and arXiv:1105.2438; CMS-HIN-11-001;
CERN-PH-EP-2011-056.

Measurement of the B^o Production Cross Section in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Rev. Lett. 106 (2011) 252001 and arXiv:1104.2892;
CMS-BPH-10-005; CERN-PH-EP-2011-034

Study of Z boson production in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.
Phys. Rev. Lett. 106 (2011) 212301 and arXiv:1102.5435;
CMS-HIN-10-003; CERN-PH-EP-2011-003.

Measurement of W^+W^- Production and Search for the Higgs Boson in pp Collisions at $\sqrt{s} = 7$ TeV.
Phys. Lett. B 699 (2011) 25 and arXiv:1102.5429;
CMS-EWK-10-009; CMS-HIG-10-003;
CERN-PH-EP-2011-015.

C. Kleinwort, F. Meier
Alignment of the CMS silicon tracker - and how to improve detectors in the future.
Nucl. Instrum. Methods A 650 (2011) 240
`http://dx.doi.org/10.1016/j.nima.2010.11.187`

R. Mankel
Alignment and calibration experience under LHC data-taking conditions in the CMS experiment.
J. Phys., Conf. Ser. 331 (2011) 8
`http://dx.doi.org/10.1088/1742-6596/331/3/032022`

J. Olzem
Performance of the upgraded CMS pixel detector for the LHC Phase 1.
J. Instrum. 6 (2011) C12039 and CMS CR-2011/220
`http://dx.doi.org/10.1088/1748-0221/6/12/C12039`

OLYMPUS-Experiment

M. Kohl
Status of the OLYMPUS Experiment at DESY.
AIP Conf. Proc. 1374 (2011) 527

Astroparticle Physics

V. Acciari et al.
Multiwavelength Observations of the Very High Energy Blazar 1ES 2344+514.
Astrophys. J. 738 (2011) 169 and arXiv:1106.4594

V.A. Acciari et al.
TeV and Multi-wavelength Observations of Mrk 421 in 2006-2008.
Astrophys. J. 738 (2011) 25 and arXiv:1106.1210
`http://dx.doi.org/10.1088/0004-637X/738/1/25`

VERITAS Observations of the TeV Binary LS I +61 303 During 2008-2010.
Astrophys. J. 738 (2011) 3 and arXiv:1105.0449
`http://dx.doi.org/10.1088/0004-637X/738/1/3`

Discovery of TeV Gamma Ray Emission from Tycho's Supernova Remnant.
Astrophys. J. Lett. 730 (2011) L20 and arXiv:1102.3871
`http://dx.doi.org/10.1088/2041-8205/730/2/L20`

ANTARES Collaboration
A fast algorithm for muon track reconstruction and its application to the ANTARES neutrino telescope.
Astropart. Phys. 34 (2011) 652
`http://dx.doi.org/10.1016/j.astropartphys.2011.01.003`

First search for point sources of high energy cosmic neutrinos with the ANTARES neutrino telescope.
Astrophys. J. Lett. 743 (2011) L14
`http://dx.doi.org/10.1088/2041-8205/743/1/L14`

The ANTARES neutrino telescope: Status and first results.
Nucl. Instrum. Methods A 626-627 (2011) S19
`http://dx.doi.org/10.1016/j.nima.2010.06.232`

Baikal Collaboration
Search for neutrinos from gamma-ray bursts with the Baikal neutrino telescope NT200.
Astro. Lett. 37 (2011) 692
`http://dx.doi.org/10.1134/S106377371110001X`

The Baikal neutrino experiment.
Nucl. Instrum. Methods A 626-627 (2011) 13
`http://dx.doi.org/10.1016/j.nima.2010.06.209`

The Baikal Neutrino Project: Present and perspective.
Nucl. Instrum. Methods A 628 (2011) 115
`http://dx.doi.org/10.1016/j.nima.2010.06.298`

The Baikal neutrino telescope: Results and plans.
Nucl. Instrum. Methods A 630 (2011) 115
`http://dx.doi.org/10.1016/j.nima.2010.06.041`

The Gigaton Volume Detector in Lake Baikal.
Nucl. Instrum. Methods A 639 (2011) 30
`http://dx.doi.org/10.1016/j.nima.2010.09.137`

Status of the BAIKAL neutrino experiment.
Bull. Russ. Acad. Sci. Phys. 75 (2011) 414

An experimental string of the NT1000 Baikal neutrino telescope.
Instrum. Exp. Tech. 54 (2011) 649
`http://dx.doi.org/10.1134/S0020441211040178`

A. Baushev
Principal properties of the velocity distribution of dark matter particles on the outskirts of the Solar System.
Mon. Not. R. Astron. Soc. 417 (2011) L83-L87 and arXiv:1103.3828
`http://dx.doi.org/10.1111/j.1745-3933.2011.01125.x`

D.B. Blaschke, J. Berdermann, J. Cleymans, K. Redlich
Chiral condensate and chemical freeze-out.
Phys. Part. Nucl. 8 (2011) 811
`http://dx.doi.org/10.1134/S154747711108005X`

CTA Collaboration
Design Concepts for the Cherenkov Telescope Array.
Exp. Astron. 32 (2011) 193
`http://dx.doi.org/10.1007/s10686-011-9247-0`

G. Decerprit, D. Allard
Constraints on the origin of ultra-high-energy cosmic rays from cosmogenic neutrinos and photons.
Astron. Astrophys. 535 (2011) A66
`http://dx.doi.org/10.1051/0004-6361/201117673`

T. Delahaye, A. Fiasson, M. Pohl, P. Salati
The GeV-TeV Galactic gamma-ray diffuse emission I. Uncertainties in the predictions of the hadronic component.
Astron. Astrophys. 531 (2011) A37 and arXiv:1102.0744
`http://dx.doi.org/10.1051/0004-6361/201116647`

D. Eichler, M. Pohl
Can Ultrahigh Energy Cosmic Rays Come from Gamma-Ray Bursts? II: Cosmic Rays Below the Ankle and Galactic GRB.
Astrophys. J. Lett. 738 (2011) L21 and arXiv:1104.1796
`http://dx.doi.org/10.1088/2041-8205/738/2/L21`

Fermi-LAT Collaboration
A Cocoon of Freshly Accelerated Cosmic Rays Detected by Fermi in the Cygnus Superbubble.
Science 334 (2011) 1103
`http://dx.doi.org/DOI:10.1126/science.1210311`

Observations of the young supernova remnant RX J1713.7-3946 with the Fermi Large Area Telescope.
Astrophys. J. 734 (2011) 28
`http://dx.doi.org/10.1088/0004-637X/734/1/28`

Insights Into the High-Energy Gamma-ray Emission of Markarian 501 from Extensive Multifrequency Observations in the Fermi Era.
Astrophys. J. 727 (2011) 129 and arXiv:1011.5260
`http://dx.doi.org/10.1088/0004-637X/727/2/129`

Multi-wavelength Observations of the Flaring Gamma-ray Blazar 3C 66A in 2008 October.
Astrophys. J. 726 (2011) 43
`http://dx.doi.org/10.1088/0004-637X/726/1/43`

D. Gora, E. Bernardini, A.H. Cruz Silva
A method for untriggered time-dependent searches for multiple flares from neutrino point sources.
Astropart. Phys. 35 (2011) 201 and DESY 11-059; arXiv:1103.2644
`http://dx.doi.org/10.1016/j.astropartphys.2011.07.007`

IceCube Collaboration
Measurement of Acoustic Attenuation in South Pole Ice.
Astropart. Phys. 34 (2011) 382 and arXiv:1004.1694
`http://dx.doi.org/10.1016/j.astropartphys.2010.10.003`

Search for Neutrino-Induced Cascades with Five Years of AMANDA Data.
Astropart. Phys. 34 (2011) 420
`http://dx.doi.org/10.1016/j.astropartphys.2010.10.007`

Measurement of the atmospheric neutrino energy spectrum from 100 GeV to 400 TeV with IceCube.
Phys. Rev. D 83 (2011) 012001
`http://dx.doi.org/10.1103/PhysRevD.83.012001`

Constraints on the extremely-high energy cosmic neutrino flux with the IceCube 2008-2009 data.
Phys. Rev. D 83 (2011) 092003 and arXiv:1103.4250
`http://dx.doi.org/10.1103/PhysRevD.83.092003`

Search for dark matter from the Galactic halo with the IceCube Neutrino Telescope.
Phys. Rev. D 84 (2011) 022004
`http://dx.doi.org/10.1103/PhysRevD.84.022004`

Search for a diffuse flux of astrophysical muon neutrinos with the IceCube 40-string detector.
Phys. Rev. D 84 (2011) 082001
`http://dx.doi.org/10.1103/PhysRevD.84.082001`

First search for atmospheric and extraterrestrial neutrino-induced cascades with the IceCube detector.
Phys. Rev. D 84 (2011) 072001
`http://dx.doi.org/10.1103/PhysRevD.84.072001`

Constraints on high-energy neutrino emission from SN 2008D.
Astron. Astrophys. 527 (2011) A28 and arXiv:1101.3942
`http://dx.doi.org/10.1051/0004-6361/201015770`

IceCube sensitivity for low-energy neutrinos from nearby supernovae.
Astron. Astrophys. 535 (2011) A109 and arXiv:1108.0171
`http://dx.doi.org/10.1051/0004-6361/201117810`

Limits on Neutrino Emission from Gamma-Ray Bursts with the 40 String IceCube Detector.
Phys. Rev. Lett. 106 (2011) 141101
`http://dx.doi.org/10.1103/PhysRevLett.106.141101`

Time-Integrated Searches for Point-like Sources of Neutrinos with the 40-String IceCube Detector.
Astrophys. J. 732 (2011) 18
`http://dx.doi.org/10.1088/0004-637X/732/1/18`

Observation of Anisotropy in the Arrival Directions of Galactic Cosmic Rays at Multiple Angular Scales with IceCube.
Astrophys. J. 740 (2011) 16 and arXiv:1105.2326
`http://dx.doi.org/10.1088/0004-637X/740/1/16`

Y. Mizuno, M. Pohl, J. Niemiec, B. Zhang, K. Nishikawa, P. Hardee
Magnetic Field Amplification by Turbulence in A Relativistic Shock Propagating through An Inhomogeneous Medium.
Astrophys. J. 726 (2011) 62 and arXiv:1011.2171
`http://dx.doi.org/10.1088/0004-637X/726/2/62`

K.-I. Nishikawa et al.
Radiation from relativistic shocks with turbulent magnetic fields.
Int. J. Mod. Phys. D 19 (2011) 715 and arXiv:0906.5018
`http://dx.doi.org/10.1142/S0218271810016865`

M. Pohl, D. Eichler
Origin of Ultra-High-Energy Galactic Cosmic Rays: The Isotropy Problem.
Astrophys. J. 742 (2011) 114 and arXive:1108.2135
`http://dx.doi.org/10.1088/0004-637X/742/2/114`

The Fermi-LAT Collaboration et al.
Fermi-LAT Observations of Markarian 421: the Missing Piece of its Spectral Energy Distribution.
Astrophys. J. 736 (2011) 131
`http://dx.doi.org/10.1088/0004-637X/736/2/131`

The MAGIC Collaboration
Observations of the Crab pulsar between 25 GeV and 100 GeV with the MAGIC I telescope.
Astrophys. J. 742 (2011) 43
`http://dx.doi.org/10.1088/0004-637X/742/1/43`

A search for Very High Energy gamma-ray emission from Scorpius X-1 with the MAGIC telescopes.
Astrophys. J. Lett. 735 (2011) L5
`http://dx.doi.org/10.1088/2041-8205/735/1/L5`

Searches for Dark Matter annihilation signatures in the Segue 1 satellite galaxy with the MAGIC-I telescope.
JCAP 06 (2011) 035
`http://dx.doi.org/10.1088/1475-7516/2011/06/035`

MAGIC discovery of Very High Energy Emission from the FSRQ PKS 1222+21.
Astrophys. J. Lett. 730 (2011) L8
`http://dx.doi.org/10.1088/2041-8205/730/1/L8`

MAGIC observations and multiwavelength properties of the quasar 3C279 in 2007 and 2009.
Astron. Astrophys. 530 (2011) A4
`http://dx.doi.org/10.1051/0004-6361/201116497`

Tunka Collaboration
The new Tunka-133 EAS Cherenkov array: Status of 2009.
Nucl. Instrum. Methods A 628 (2011) 124
`http://dx.doi.org/10.1016/j.nima.2010.11.027`

A new 1 km2 EAS Cherenkov array in the Tunka Valley.
Nucl. Instrum. Methods A 639 (2011) 42
`http://dx.doi.org/10.1016/j.nima.2010.09.142`

TUNKA-133: A new array for the study of ultra-high energy cosmic rays.
Bull. Russ. Acad. Sci. Phys. 75 (2011) 367

Tunka-133: Preliminary results from the first year of operation.
Nucl. Phys. B, Proc. Suppl. 212-213 (2011) 53
`http://dx.doi.org/10.1016/j.nuclphysbps.2011.03.007`

VERITAS Collaboration
Spectral Energy Distribution of Markarian 501: Quiescent State Versus Extreme Outburst.
Astrophys. J. 729 (2011) 2
`http://dx.doi.org/10.1088/0004-637X/729/1/2`

VERITAS Observations of Gamma-Ray Bursts Detected by Swift.
Astrophys. J. 743 (2011) 62 and arXiv:1109.0050
`http://dx.doi.org/10.1088/0004-637X/743/1/62`

Multiwavelength Observations of the Previously Unidentified Blazar RX J0648.7+1516.
Astrophys. J. 742 (2011) 127
`http://dx.doi.org/10.1088/0004-637X/742/2/127`

Gamma-ray observations of the Be/pulsar binary 1A 0535+262 during a giant X-ray outburst.
Astrophys. J. 733 (2011) 96 and arXiv:1103.3250
`http://dx.doi.org/10.1088/0004-637X/733/2/96`

Spectral Energy Distribution of Markarian 501: Quiescent State vs. Extreme Outburst.
Astrophys. J. 729 (2011) 2 and arXiv:1012.2200
`http://dx.doi.org/10.1088/0004-637X/729/1/2`

Detection of Pulsed Gamma Rays Above 100 GeV from the Crab Pulsar.
Astrophys. J. Lett. 334 (2011) 69 and arXiv:1108.3797
`http://dx.doi.org/10.1126/science.1208192`

Multiwavelength Observations of the Very High Energy Blazar 1ES 2344+514.
Astrophys. J. 738 (2011) 169
`http://dx.doi.org/10.1088/0004-637X/738/2/169`

TeV and Multi Wavelength Observations of Mrk 421 IN 2006 - 2008.
Astrophys. J. 738 (2011) 25
`http://dx.doi.org/10.1088/0004-637X/738/1/25`

VERITAS Observations of the TeV Binary LSI +61 Grad 303 During 2008 - 2010.
Astrophys. J. 738 (2011) 3
`http://dx.doi.org/10.1088/0004-637X/738/1/3`

Insights into the High-Energy gamma-Ray Emission of Markarian 501 from Extensive Multifrequency Obsersations in the Fermi Era.
Astrophys. J. 727 (2011) 129
`http://dx.doi.org/10.1088/0004-637X/727/2/129`

Multi-Wavelength Observations of the Flaring Gamma-Ray Blazar 3C 66A in 2008 October.
Astrophys. J. 726 (2011) 43
`http://dx.doi.org/10.1088/0004-637X/726/1/43`

VERITAS Observations of the Unusual Extragalactic Transient Swift J164449.3+573451.
Astrophys. J. 738 (2011) L30
`http://dx.doi.org/10.1088/2041-8205/738/2/L30`

Discovery of TeV Gamma-Ray Emission from Tycho's Supernova Remnant.
Astrophys. J. Lett. 730 (2011) L20
`http://dx.doi.org/10.1088/2041-8205/730/2/L20`

Detection of Pulsed Gamma Rays Above 100 GeV from the Crab Pulsar.
Science 334 (2011) 69
`http://dx.doi.org/10.1126/science.1208192`

Theory

S. Abel, M. Goodsell
Easy Dirac Gauginos.
JHEP 1106 (2011) 064 and DESY 11-010

J. Ablinger, J. Blümlein, S. Klein, C. Schneider, F. Wissbrock
The $O(\alpha_s^3)$ Massive Operator Matrix Elements of $O(n_f)$ for the Structure Function $F_2(x,Q^2)$ and Transversity.
Nucl. Phys. B 844 (2011) 26 and DESY 10-109; TTK-10-46; SFB-CPP-10-077; arXiv:1008.3347
`http://dx.doi.org/10.1016/j.nuclphysb.2010.10.021`

J. Ablinger, J. Blümlein, C. Schneider
Harmonic Sums and Polylogarithms Generated by Cyclotomic Polynomials.
J. Math. Phys. 52 (2011) 102301 and DESY 11–033; DO–TH 11–12; SFB/CPP-11-24; LPN 11/24; arXiv:1105.6063
`http://dx.doi.org/10.1063/1.3629472`

P. Achard et al.
Test of the τ-Model of Bose-Einstein Correlations and Reconstruction of the Source Function in Hadronic Z-boson Decay at LEP.
Eur. Phys. J. C 71 (2011) 1648

Y. Aisaka
Operator space of pure spinors.
Prog. Theor. Phys. 188 (2011) 227

S. Alekhin, J. Blümlein, P. Jimenez-Delgado, S. Moch, E. Reya
NNLO Benchmarks for Gauge and Higgs Boson Production at TeV Hadron Colliders.
Phys. Lett. B 697 (2011) 127 and DESY 10-184; DO–TH 10/20; ZU-TH-17/10; SFB-CPP/10–118; arXiv:1011.6259
`http://dx.doi.org/10.1016/j.physletb.2011.01.034`

S. Alekhin, J. Blümlein, S. Moch
Higher order constraints on the Higgs production rate from fixed-target DIS data.
Eur. Phys. J. C 71 (2011) 1723 and DESY 11-001; SFB/CPP-11-01; LPN 11-01; arXiv:1101.5261
`http://dx.doi.org/10.1140/epjc/s10052-011-1723-1`

S. Alekhin, S. Moch
Heavy-quark deep-inelastic scattering with a running mass.
Phys. Lett. B 699 (2011) 345 and DESY 10-212; arXiv:1011.5790

C. Alexandrou, J. Carbonell, M. Constantinou, P.A. Harraud, P. Guichon, K. Jansen, C. Kallidonis, T. Korzec, M. Papinutto
Moments of nucleon generalized parton distributions from lattice QCD.
Phys. Rev. D 83 (2011) 114513 and DESY 11-056; arXiv:1104.1600
`http://dx.doi.org/10.1103/PhysRevD.83.114513`

C. Alexandrou, M. Brinet, J. Carbonell, M. Constantinou, P. Harraud, P. Guichon, K. Jansen, T. Korzec, M. Papinutto
Nucleon electromagnetic form factors in twisted mass lattice QCD.
Phys. Rev. D 83 (2011) 094502 and DESY 10-216; arXiv:1102.2208
`http://dx.doi.org/10.1103/PhysRevD.83.094502`

Axial Nucleon form factors from lattice QCD.
Phys. Rev. D 83 (2011) 045010 and arXiv:1012.0857
`http://dx.doi.org/10.1103/PhysRevD.83.045010`

A. Ali, C. Hambrock, S. Mishima
Tetraquark-based analysis and predictions of the cross sections and distributions for the processes $e^+e^- \to \Upsilon(1S)(\pi^+\pi^-, K^+K^-, \eta\pi^0)$ near $\Upsilon(5S)$.
Phys. Rev. Lett. 106 (2011) 092002 and DESY 10-076; arXiv:10114856
`http://dx.doi.org/10.1103/PhysRevLett.106.092002`

A. Ali, W. Wang
Production of the exotic 1^{--} hadrons $\phi(2170)$, $X(4260)$ and $Y_b(10890)$ at the LHC and Tevatron via the Drell-Yan mechanism.
Phys. Rev. Lett. 106 (2011) 1 and DESY 11-029
`http://dx.doi.org/10.1103/PhysRevLett.106.192001`

A. Ali, G. Kramer
Jets and QCD: A Historical Review of the Discovery of the Quark and Gluon Jets and its Impact on QCD.
Eur. Phys. J. H. 36 (2011) 245 and DESY 10-215; arXiv:1012.2288
`http://dx.doi.org/10.1140/epjh/e2011-10047-1`

A. Ali, F. Barreiro, J. Llorente
Improved sensitivity to charged Higgs searches in top quark decays $t \to bH^+ \to b(\tau^+\nu_\tau)$ at the LHC using τ polarisation and multivariate techniques.
Eur. Phys. J. C 71 (2011) 1737 and DESY 11-003; arXiv:1103.1827
`http://dx.doi.org/10.1140/epjc/s10052-011-1737-8`

A. Ali, W. Wang
Production of the exotic 1^{--} hadrons $\phi(2170)$, $X(4260)$ and $Y_b(10890)$ at the LHC and Tevatron via the Drell-Yan mechanism.
Phys. Rev. Lett. 106 (2011) 192001 and DESY 11-029; arXiv:1103.4587
`http://dx.doi.org/10.1103/PhysRevLett.106.192001`

M. Aliev, H. Lacker, U. Langenfeld, S. Moch, P. Uwer, M. Wiedermann
HATHOR: HAdronic Top and Heavy quarks crOss section calculatoR.
Comput. Phys. Commun. 182 (2011) 1034 and DESY 10-091; HU-EP-10-33; SFB/CPP-10-60; arXiv:1007.1327
`http://dx.doi.org/10.1016/j.cpc.2010.12.040`

S. Alioli, K. Hamilton, P. Nason, C. Oleari, E. Re
Jet pair production in POWHEG.
JHEP 1104 (2011) 081 and DESY-10-233; SFB/CPP-10-128; IPPP/10/100; DCPT/10/200; MCnet/10/23; arXiv:1012.3380
`http://dx.doi.org/10.1007/JHEP04(2011)081`

S. Alioli, P. Nason, C. Oleari, E. Re
Vector boson plus one jet production in POWHEG.
JHEP 01 (2011) 095 and IPPP/10/78; DCPT/10/156; DESY 10-158; SFB/CPP-10-85; arXiv:1009.5594
`http://dx.doi.org/10.1007/JHEP01(2011)095`

A.A. Almasy, A. Vogt, S. Moch
On the Next-to-Next-to-Leading Order Evolution of Flavour-Singlet Fragmentation Functions.
Nucl. Phys. B 854 (2011) 133 and LTH 916; DESY 11-108; SFB/CPP-11-33; LPN11-34; arXiv:1107.2263

P. Anastasopoulos, I. Antoniadis, K. Benakli, M.D. Goodsell, A. Vichi
One-loop adjoint masses for non-supersymmetric intersecting branes.
JHEP 1108 (2011) 120 and DESY-11-069

S. Antusch, K. Dutta, J. Erdmenger, S. Halter
Towards Matter Inflation in Heterotic String Theory.
JHEP 2011 (2011) 65 and DESY 11-015
`http://dx.doi.org/10.1007/JHEP04(2011)065`

A. Athenodorou, R. Sommer
One-loop lattice artifacts of a dynamical charm quark.
Phys. Lett. B 705 (2011) 393 and DESY-11-156; SFB-CPP-11-51; arXiv:1109.2303
`http://dx.doi.org/10.1016/j.physletb.2011.10.030`

A. Athenodorou, B. Bringoltz, M. Teper
Closed flux tubes and their string description in D=2+1 SU(N) gauge theories.
JHEP 1105 (2011) 042 and DESY 11-045; arXiv:1103.5854
`http://dx.doi.org/10.1007/JHEP05(2011)042`

Closed flux tubes and their string description in D=3+1 SU(N) gauge theories.
JHEP 1102 (2011) 030 and DESY-10-116; arXiv:1007.4720
`http://dx.doi.org/10.1007/JHEP02(2011)030`

S. Badger, R. Sattler, V. Yundin
One-Loop Helicity Amplitudes for tt^- Production at Hadron Colliders.
Phys. Rev. D 83 (2011) 074020
`http://dx.doi.org/10.1103/PhysRevD.83.074020`

R. Baños et al.
Sample-to-sample fluctuations of the overlap distributions in the three-dimensional Edwards-Anderson spin glass.
Phys. Rev. B 84 (2011) 174209
`http://dx.doi.org/10.1103/PhysRevB.84.174209`

J. Bartels, J. Kotanski, V. Schomerus
Excited Hexagon Wilson Loops for Strongly Coupled N=4 SYM.
JHEP 1101 (2011) 096 and DESY 10-157

A. Bartl, H. Eberl, B. Herrmann, K. Hidaka, W. Majerotto, W. Porod
Impact of squark generation mixing on the search for squarks decaying into fermions at LHC.
Phys. Lett. B 698 (2011) 380 and DESY 10-059

A. Bartl, H. Eberl, E. Ginina, B. Herrmann, K. Hidaka, W. Majerotto, W. Porod
Impact of Squark Generation Mixing on the Search for Squarks Decaying into Fermions at LHC.
Phys. Rev. D 84 (2011) 115026 and DESY 10-059

Flavour violating gluino three-body decays at LHC.
Phys. Rev. D 84 (2011) 115026 and DESY 11-098

P. Bechtle, O. Brein, S. Heinemeyer, G. Weiglein, K.E. Williams
HiggsBounds 2.0.0: Confronting Neutral and Charged Higgs Sector Predictions with Exclusion Bounds from LEP and the Tevatron.
Comput. Phys. Commun. 182 (2011) 2605 and DESY 11-016

W. Beenakker, S. Brensing, M. Kramer, A. Kulesza, E. Laenen, L. Motyka, I. Niessen
Squark and gluino hadroproduction.
Int. J. Mod. Phys. A 26 (2011) 2637 and DESY 11-060

K. Benakli, M.D. Goodsell, A.-K. Maier
Generating mu and Bmu in models with Dirac Gauginos.
Nucl. Phys. B B851 (2011) 445 and DESY-11-061

W. Bietenholz et al.
Flavor blindness and patterns of flavor symmetry breaking in lattice simulations of up, down, and strange quarks.
Phys. Rev. D 84 (2011) 43 and DESY 11-030
`http://dx.doi.org/10.1103/PhysRevD.84.054509`

L. Biferale, F. Mantovani, M. Sbragaglia, A. Scagliarini, F. Toschiand, R. Tripiccione
Reactive Rayleigh-Taylor systems: Front propagation and non-stationarity.
Europhys. Lett. 94 (2011) 54004
`http://dx.doi.org/10.1209/0295-5075/94/54004`

L. Biferale, F. Mantovani, M. Sbragaglia, A. Scagliarini, F. Toschi, R. Tripiccione
Second-order closure in stratified turbulence: Simulations and modeling of bulk and entrainment regions.
Phys. Rev. E 84 (2011) 016305
`http://dx.doi.org/10.1103/PhysRevE.84.016305`

L. Biferale, F. Mantovani, F. Pozzati, M. Sbragaglia, A. Scagliarini, F. Schifano, F. Toschi, R. Tripiccione
Numerical simulations of Rayleigh / Taylor front evolution in turbulent stratified fluids.
Phil. Trans. R. Soc. A 369 (2011) 2448
`http://dx.doi.org/10.1098/rsta.2011.0048`

J. Blümlein, A. De Freitas, W. van Neerven
Two-loop QED Operator Matrix Elements with Massive External Fermion Lines.
Nucl. Phys. B 855 (2011) 508 and DESY 10–220; DO-TH 11/13; SFB/CPP-11/42; LPN 11/41; arXiv:1107.4638
`http://dx.doi.org/10.1016/j.nuclphysb.2011.10.009`

J. Blümlein, A. Hasselhuhn, P. Kovacikova, S. Moch
$O(\alpha_s)$ Heavy Flavor Corrections to Charged Current Deep-Inelastic Scattering in Mellin Space.
Phys. Lett. B 700 (2011) 294 and DESY 11–032; DO–TH 11/06; SFB-CPP/11–19; LPN 11–19; arXiv:1104.3449
`http://dx.doi.org/10.1016/j.physletb.2011.05.007`

J. Blümlein, J. Brunner
New Exclusion Limits for Dark Gauge Forces from Beam-Dump Data.
Phys. Lett. B 701 (2011) 155

J. Blümlein, H. Böttcher
QCD Analysis of the Polarized Deep-Inelastic World Data.
AIP Conf. Proc. 1369 (2011) 159
`http://dx.doi.org/10.1063/1.3631532`

S. Bobrovskyi, W. Buchmuller, J. Hajer, J. Schmidt
Quasi-stable neutralinos at the LHC.
JHEP 1109 (2011) 119 and DESY-11-077

P. Bolzoni, G. Somogyi, Z. Trocsanyi
A subtraction scheme for computing QCD jet cross sections at NNLO: integrating the iterated singly-unresolved subtraction terms.
JHEP 2011 (2011) 1
`http://dx.doi.org/10.1007/JHEP01(2011)059`

P. Brax, C. Burrage, A.-C. Davis, D. Seery, A. Weltman
Anomalous coupling of scalars to gauge fields.
Phys. Rev. D 699 (2011) 5 and DESY 10-167

P. Brax, C. Burrage
Atomic Precision Tests and Light Scalar Couplings.
Phys. Rev. D 83 (2011) 035020 and DESY 10-156

T. Bringmann, F. Calore, G. Vertongen, C. Weniger
On the Relevance of Sharp Gamma-Ray Features for Indirect Dark Matter Searches.
Phys. Rev. D 84 (2011) 103525 and DESY 11-097

T.W. Brown
Complex matrix model duality.
Phys. Rev. D 83 (2011) 085002 and DESY 10-140

F. Brummer, W. Buchmuller
Light Higgsinos as Heralds of Higher-Dimensional Unification.
JHEP 1107 (2011) 010 and DESY 11-070

F. Brümmer, S. Fichet, S. Kraml
The Supersymmetric flavour problem in 5D GUTs and its consequences for LHC phenomenology.
JHEP 1112 (2011) 47 and DESY 11-151; arXiv:1109.1226

O. Buchmueller et al.
Frequentist Analysis of the Parameter Space of Minimal Supergravity.
Eur. Phys. J. C 71 (2011) 1583 and DESY 10-211

Supersymmetry and Dark Matter in Light of LHC 2010 and Xenon100 Data.
Eur. Phys. J. C 71 (2011) 1722 and CERN-PH-TH-2011-129

Implications of Initial LHC Searches for Supersymmetry.
Eur. Phys. J. C 71 (2011) 1634 and DESY-10-249

W. Buchmuller, K. Schmitz, G. Vertongen
Entropy, Baryon Asymmetry and Dark Matter from Heavy Neutrino Decays.
Nucl. Phys. B 851 (2011) 481 and DESY 11-002

C. Burrage, C. De Rham, D. Seery, A.J. Tolley
Galileon inflation.
JCAP 1101 (2011) 014 and DESY 10-132

C.C. Calame, H. Czyz, J. Gluza, M. Gunia, G. Montagna, O. Nicrosini, F. Piccinini, T. Riemann, M. Worek
NNLO leptonic and hadronic corrections to Bhabha scattering and luminosity monitoring at meson factories.
JHEP 1107 (2011) 126 and DESY 11-080; FNT/T 2011/01; LPN-11-25; SFB-CPP-11-26; WUB/11-05; arXiv:1106.3178
`http://dx.doi.org/10.1007/JHEP07(2011)126`

C. Candu
Continuum Limit of gl(M/N) Spin Chains.
JHEP 1107 (2011) 069 and DESY 11-031

C. Candu, V. Schomerus
Exactly marginal parafermions.
Phys. Rev. D 84 (2011) 051704 and DESY 11-058

C.A. Cardona, I. Kirsch
Worldsheet four-point functions in $\mathrm{AdS}_3/\mathrm{CFT}_2$.
JHEP 1101 (2011) 015 and DESY 10-105

M. Carena, P. Draper, S. Heinemeyer, T. Liu, C.E.M. Wagner, G. Weiglein
Probing the Higgs Sector of High-Scale SUSY-Breaking Models at the Tevatron.
Phys. Rev. D 83 (2011) 055007 and DESY 10-155

S.Y. Choi, D. Choudhury, A. Freitas, J. Kalinowski, P.M. Zerwas
The Extended Higgs System in R-symmetric Supersymmetry Theories.
Phys. Lett. B 697 (2011) 215 and arXiv:1012.2688
`http://dx.doi.org/10.1016/j.physletb.2011.01.059`

K. Cichy, G. Herdoiza, K. Jansen
Continuum Limit of Overlap Valence Quarks on a Twisted Mass Sea.
Nucl. Phys. B 847 (2011) 179 and DESY 10-240; FTUAM-10-35; SFB/CPP-10-130; arXiv:1012.4412
`http://dx.doi.org/10.1016/j.nuclphysb.2011.01.021`

M. Cicoli, A. Mazumdar
Inflation in string theory: A Graceful exit to the real world.
Phys. Rev. D 83 (2011) 063527 and DESY 10-166

M. Cicoli, M. Goodsell, J. Jaeckel, A. Ringwald
Testing String Vacua in the Lab: From a Hidden CMB to Dark Forces in Flux Compactifications.
JHEP 1107 (2011) 114 and DESY 11-042

M. Cicoli, C.P. Burgess, F. Quevedo
Anisotropic Modulus Stabilisation: Strings at LHC Scales with Micron-sized Extra Dimensions.
JHEP 1110 (2011) 119 and DESY 11-073

M. Cicoli, F. Quevedo
String moduli inflation: An overview.
Class. Quantum Grav. 28 (2011) 204001 and DESY 11-088

S. Collins et al.
Dirac and Pauli form factors from lattice QCD.
Phys. Rev. D 84 (2011) 074507 and DESY 11-102

L. Covi, M. Olechowski, S. Pokorski, K. Turzynski, J.D. Wells
Supersymmetric mass spectra for gravitino dark matter with a high reheating temperature.
JHEP 1101 (2011) 033 and DESY 10-143

G. Cullen, N. Greiner, G. Heinrich, G. Luisoni, P. Mastrolia, G. Ossola, T. Reiter, F. Tramontano
Automation of One-Loop Calculations with GoSam: Present Status and Future Outlook.
Acta Phys. Pol. B 42 (2011) 2351
`http://dx.doi.org/10.5506/APhysPolB.42.2351`

G. Di Bernardo, C. Evoli, D. Gaggero, D. Grasso, L. Maccione, M.N. Mazziotta
Implications of the cosmic ray electron spectrum and anisotropy measured with Fermi-LAT.
Astropart. Phys. 34 (2011) 10 and DESY 10-159
`http://dx.doi.org/10.1016/j.astropartphys.2010.11.005`

M. Diehl, A. Schafer
Theoretical considerations on multiparton interactions in QCD.
Phys. Lett. B 698 (2011) 389 and DESY 11-021

S. Dinter, C. Alexandrou, M. Constantinou, V. Drach, K. Jansen, D. Renner
Precision Study of Excited State Effects in Nucleon Matrix Elements.
Phys. Lett. B 704 (2011) 89 and DESY 11-129; JLAB-THY-11-1389; SFB/CPP-11-44; arXiv:1108.1076
`http://dx.doi.org/10.1016/j.physletb.2011.09.002`

X. Dong, B. Horn, E. Silverstein, A. Westphal
Simple exercises to flatten your potential.
Phys. Rev. D 84 (2011) 9
`http://dx.doi.org/10.1103/PhysRevD.84.026011`

M. Donnellan, F. Knechtli, B. Leder, R. Sommer
Determination of the Static Potential with Dynamical Fermions.
Nucl. Phys. B 849 (2011) 45 and arXiv:1012.3037; DESY 10-172; SFB/CPP-10-90; WUB/10-24; BUW-SC 2010/5
`http://dx.doi.org/10.1016/j.nuclphysb.2011.03.013`

C. Englert, T. Plehn, D. Zerwas, P.M. Zerwas
Exploring the Higgs portal.
Phys. Lett. B 703 (2011) 298 and arXiv:1106.3097
`http://dx.doi.org/10.1016/j.physletb.2011.08.002`

ETM Collaboration et al.
BK-parameter from $\mathrm{N_f} = 2$ twisted mass lattice QCD.
Phys. Rev. D 83 (2011) 014505 and ROM2F-2010-15; RM3-TH-10-8; DESY-10-138; ICCUB-10-052; UB-ECM-PF-10-028; IFIC-10-33; LPSC10137; arXiv:1009.5606
`http://dx.doi.org/10.1103/PhysRevD.83.014505`

Computing K and D meson masses with $\mathrm{N_f} = 2{+}1{+}1$ twisted mass lattice QCD.
Comput. Phys. Commun. 182 (2011) 299 and SFB/CPP-09-31; LPSC1049; MS-TP-10-10; DESY 10-055; LTH874; LPT-Orsay 10-30; HU-EP-10/19; arXiv:1005.2042
`http://dx.doi.org/10.1016/j.cpc.2010.10.004`

N. Evans, T. Kalaydzhyan, K.-Y. Kim, I. Kirsch
Non-equilibrium physics at a holographic chiral phase transition.
JHEP 1101 (2011) 1 and DESY 10-196, SHEP-10-38; arXiv:1011.2519

A. Falkowski, C. Grojean, A. Kaminska, S. Pokorski, A. Weiler
If no Higgs then what?
JHEP 1111 (2011) 028 and DESY 11-132

X. Feng, K. Jansen, D. Renner
Resonance Parameters of the rho-Meson from Lattice QCD.
Phys. Rev. D 83 (2011) 094505 and DESY 10-176; SFB/CPP-10-117; MS-TP-10-14; KEK-CP-242; JLAB-THY-10-1289; arXiv:1011.5288
`http://dx.doi.org/10.1103/PhysRevD.83.094505`

J. Fleischer, T. Riemann
Calculating contracted tensor Feynman integrals.
Phys. Lett. B 701 (2011) 646 and DESY 11-063; BI-TP 2011/12; SFB/CPP-11-25; LPN 11-26; arXiv:1104.4067
`http://dx.doi.org/10.1016/j.physletb.2011.06.033`

A complete algebraic reduction of one-loop tensor Feynman integrals.
Phys. Rev. D 83 (2011) 073004 and DESY 10-145; BI-TP 2010/31; HEPTOOLS 10-025; SFB/CPP-10-86; arXiv:1009.4436
`http://dx.doi.org/10.1103/PhysRevD.83.073004`

Simplifying 5-point tensor reduction.
Acta Phys. Pol. B 42 (2011) 2371
`http://dx.doi.org/10.5506/APhysPolB.42.2371`

P. Gerhold, K. Jansen, J. Kallarackal
Higgs boson mass bounds in the presence of a very heavy fourth quark generation.
JHEP 1101 (2011) 143 and HU-EP-10/66; DESY 10-180; arXiv:1011.1648
`http://dx.doi.org/10.1007/JHEP01(2011)143`

A. Glazov, S. Moch, V. Radescu
Parton Distribution Uncertainties using Smoothness Prior.
Phys. Lett. B 695 (2011) 238 and DESY 10-164; arXiv:1009.6170
`http://dx.doi.org/10.1016/j.physletb.2010.11.025`

J. Gluza, K. Kajda, T. Riemann, V. Yundin
Numerical Evaluation of Tensor Feynman Integrals in Euclidean Kinematics.
Eur. Phys. J. C 71 (2011) 1516 and DESY 10-144; HEPTOOLS-10-024; SFB-CPP-10-79; arXiv:1010.1667
`http://dx.doi.org/10.1140/epjc/s10052-010-1516-y`

N. Greiner, A. Guffanti, T. Reiter, J.R. Reuter
Next-to-Leading Order QCD Corrections to the Production of Two Bottom-Antibottom Pairs at the LHC.
Phys. Rev. Lett. 107 (2011) 102002 and DESY 11-079
`http://dx.doi.org/10.1103/PhysRevLett.107.102002`

S. Heinemeyer, V.A. Khoze, M.G. Ryskin, M. Tasevsky, G. Weiglein
BSM Higgs Physics in the Exclusive Forward Proton Mode at the LHC.
Eur. Phys. J. C 71 (2011) 1649 and DESY 10-217

B. Herrmann, M. Klasen, Q. Le Boulc'h
Impact of squark flavour violation on neutralino dark matter.
Phys. Rev. D 84 (2011) 095007 and DESY 11-099

T. Higaki, T. Kobayashi
Note on moduli stabilization, supersymmetry breaking and axiverse.
Phys. Rev. D 84 (2011) 045021 and DESY 11-094
`http://dx.doi.org/10.1103/PhysRevD.84.045021`

C. Horst, J.R. Reuter
CleGo: A package for automated computation of Clebsch-Gordan coefficients in tensor product representations for Lie algebras.
Comput. Phys. Commun. 182 (2011) 1543
`http://dx.doi.org/10.1016/j.cpc.2011.03.025`

V. Ivanchenko et al.
Recent Improvements in Geant4 Electromagnetic Physics Models and Interfaces.
Prog. Nucl. Sci. Technol. 2 (2011) 898

K. Jansen
The First Two Fermion Generations in Twisted Mass Lattice QCD.
AIP Conf. Proc. 1354 (2011) 51
`http://dx.doi.org/10.1063/1.3587585`

T. Kalaydzhyan, I. Kirsch
Fluid-Gravity Model for the Chiral Magnetic Effect.
Phys. Rev. Lett. 106 (2011) 4
`http://dx.doi.org/10.1103/PhysRevLett.106.211601`

Holographic dual of a boost-invariant plasma with chemical potential.
JHEP 1102 (2011) 1 and DESY 10-232; arXiv:1012.1966

W. Kilian, T. Ohl, J.R. Reuter
WHIZARD – simulating multi-particle processes at LHC and ILC.
Eur. Phys. J. C 71 (2011) 1742 and DESY 11-126
`http://dx.doi.org/10.1140/epjc/s10052-011-1742-y`

I. Kirsch, T. Wirtz
Worldsheet operator product expansions and p-point functions in $\mathrm{AdS}_3/\mathrm{CFT}_2$.
JHEP 1110 (2011) 049 and DESY 11-111

N. Kitanine, K.K. Kozlowski, J.M. Maillet, N.A. Slavnov, V. Terras
Thermodynamic limit of particle-hole form factors in the massless XXZ Heisenberg chain.
J. Stat. Mech.: Theory and Experiment 1088 (2011) P05028 and DESY 11-037; arXiv:1003.4557
`http://dx.doi.org/10.1088/1742-5468/2011/05/P05028`

K.K. Kozlowski, J.M. Maillet, N.A. Slavnov
Long-distance behavior of temperature correlation functions in the one-dimensional Bose gas.
J. Stat. Mech.: Theory and Experiment 2011 (2011) P03018 and DESY 10-226; arxiv:1011.3149
`http://dx.doi.org/10.1088/1742-5468/2011/03/P03018`

Correlation functions of one-dimensional bosons at low temperature.
J. Stat. Mech.: Theory and Experiment 1103 (2011) P03019 and DESY 10-254; arXiv:1102.1858
`http://dx.doi.org/10.1088/1742-5468/2011/03/P03019`

O. Lebedev
CP violation with Higgs-dependent Yukawa couplings.
Phys. Lett. B 697 (2011) 58 and DESY 10-198

O. Lebedev, H.M. Lee
Higgs Portal Inflation.
JHEP C71 (2011) 1821 and DESY 11-075

H.N. Li, S. Mishima
Possible resolution of the $\mathrm{B} \to \pi\pi$, $\pi\mathrm{K}$ puzzles.
Phys. Rev. D 83 (2011) 034023 and DESY 09-013, arXiv:0901.1272
`http://dx.doi.org/10.1103/PhysRevD.83.034023`

R.H. Li, C.D. Lü, W. Wang
Branching ratios, forward-backward asymmetries and angular distributions of $\mathrm{B} \to \mathrm{K}_2^* \mathrm{l}^+ \mathrm{l}^-$ in the standard model and two new physics scenarios.
Phys. Rev. D 83 (2011) 034034 and DESY 10-234
`http://dx.doi.org/10.1103/PhysRevD.83.034034`

S. Liberati, L. Maccione
Quantum Gravity phenomenology: achievements and challenges.
J. Phys., Conf. Ser. 314 (2011) 012007 and DESY 11-091

A. Linde, M. Noorbala, A. Westphal
Observational consequences of chaotic inflation with nonminimal coupling to gravity.
JCAP 1103 (2011) 013 and DESY 11-013

F. Mahmoudi, J. Rathsman, O. Stal, L. Zeune
Light Higgs bosons in phenomenological NMSSM.
Eur. Phys. J. C 71 (2011) 1608 and DESY 10-246

F. Mahmoudi et al.
Flavour Les Houches Accord: Interfacing flavour related codes.
Comput. Phys. Commun. 183 (2011) 285
`http://dx.doi.org/10.1016/j.cpc.2011.10.006`

D. Mesterhazy, K. Jansen
Anomalous scaling in the random-force-driven Burgers equation: A Monte Carlo study.
New J. Phys. 13 (2011) 103028 and arXiv:1104.1435; DESY 11-057
`http://dx.doi.org/10.1088/1367-2630/13/10/103028`

G. Moortgat-Pick, K. Rolbiecki, J. Tattersall
Early spin determination at the LHC?
Phys. Lett. B 699 (2011) 158 and DESY 11-017

H.P. Nilles, S. Ramos-Sanchez, P.K.S. Vaudrevange, A. Wingerter
The Orbifolder: A Tool to study the Low Energy Effective Theory of Heterotic Orbifolds.
Comput. Phys. Commun. 183 (2011) 1363 and DESY 11-187

S.L. Parameswaran, J. Schmidt
Coupling brane fields to bulk supergravity.
Phys. Lett. B 696 (2011) 131 and DESY 10-123
`http://dx.doi.org/10.1016/j.physletb.2010.11.069`

S.L. Parameswaran, S. Ramos-Sanchez, I. Zavala
On moduli stabilisation and de Sitter vacua in MSSM heterotic orbifolds.
JHEP 2011 (2011) 1 and DESY 10-148
`http://dx.doi.org/10.1007/JHEP01(2011)071`

Jh. Park
Constrained potential method for false vacuum decays.
JCAP 1102 (2011) 023 and DESY 10-213
`http://dx.doi.org/10.1088/1475-7516/2011/02/023`

Metastability bounds on flavour-violating trilinear soft terms in the MSSM.
Phys. Rev. D 83 (2011) 055015 and DESY 10-214
`http://dx.doi.org/10.1103/PhysRevD.83.055015`

M.I. Polikarpov, O.V. Larina, P.V. Buividovich, M.N. Chernodub, T.K. Kalaydzhyan, D.E. Kharzeev, E.V. Luschevskaya
Conductivity of SU(2) gluodynamics vacuum induced by magnetic field.
AIP Conf. Proc. 1343 (2011) 630

J. Redondo, A. Ringwald
Light shining through walls.
Contemp. Phys. 52 (2011) 211 and DESY 10-175

J. Reuter, D. Wiesler
Distorted Mass Edges from Supersymmetric Leptoquarks at LHC.
Phys. Rev. D 84 (2011) 8 and DESY 11-082
`http://dx.doi.org/10.1103/PhysRevD.84.015012`

D. Ridout, J. Teschner
Integrability of a family of quantum field theories related to sigma models.
Nucl. Phys. B 853 (2011) 327 and DESY 11-036

A. Saveliev, L. Maccione, G. Sigl
Lorentz invariance violation and chemical composition of ultra high energy cosmic rays.
JCAP 03 (2011) 046 and DESY 10-224
`http://dx.doi.org/10.1088/1475-7516/2011/03/046`

S. Schaefer, R. Sommer, F. Virotta
Critical slowing down and error analysis in lattice QCD simulations.
Nucl. Phys. B 845 (2011) 93 and DESY 10-151; SFB-CPP-10-81; arXiv:1009.5228
`http://dx.doi.org/10.1016/j.nuclphysb.2010.11.020`

G. Schierholz et al.
Flavour blindness and patterns of flavour symmetry breaking in lattice simulations of up, down and strange quarks.
Phys. Rev. D 84 (2011) 054509 and DESY 11-030

Charge Symmetry Breaking in Parton Distribution Functions from Lattice QCD.
Phys. Rev. D 83 (2011) 051501 and DESY 10-219

G. Somogyi
Angular integrals in d dimensions.
J. Math. Phys. 52 (2011) 083501 and DESY 11-004; SFB/CPP-11-02; LPN11-03; arXiv:1101.3557
`http://dx.doi.org/10.1063/1.3615515`

The L3 Collaboration
Test of the Tau-Model of Bose-Einstein Correlations and Reconstruction of the Source Function in Hadronic Z-boson Decay at LEP.
Eur. Phys. J. C 71 (2011) 1648 and CERN-PH-EP-2011-080; arXiv:1105.4788
`http://dx.doi.org/10.1140/epjc/s10052-011-1648-8`

G. Vertongen, C. Weniger
Hunting Dark Matter Gamma-Ray Lines with the Fermi LAT.
JCAP 1105 (2011) 027 and DESY 10-237

B. Vicedo
Splitting strings on integrable backgrounds.
JHEP 1111 (2011) 017 and DESY 11-078

K.E. Williams, H. Rzehak, G. Weiglein
Higher order corrections to Higgs boson decays in the MSSM with complex parameters.
Eur. Phys. J. C 71 (2011) 1669 and DESY 10-168

A. Glazov, S. Moch, V. Radescu
Parton Distribution Uncertainties using Smoothness Prior.
Phys. Lett. B 695 (2011) 238 and DESY 10-164;
arXiv:1009.6170

International Linear Collider

C. Adloff et al.
Effects of high-energy particle showers on the embedded front-end electronics of an electromagnetic calorimeter for a future lepton collider.
Nucl. Instrum. Methods A 654 (2011) 97 and LAL-11-19

M. Beckmann, J. List
Spin Tracking Studies for Polarimetry at the ILC.
J. Phys., Conf. Ser. 295 (2011)
`http://dx.doi.org/10.1088/1742-6596/295/1/012134`

T. Behnke
Detector concepts at the International Linear Collider.
Nucl. Instrum. Methods A 628 (2011) 19

E. Garutti
Silicon Photomultipliers for High Energy Physics Detectors.
J. Instrum. 6 (2011) C10003 and arXiv:1108.3166

Overview on calorimetry.
Nucl. Instrum. Methods B 628 (2011) 31

Engineering prototype of the CALICE analog hadron calorimeter.
J. Phys., Conf. Ser. 293 (2011) 012072

A. Hartin, G. Moortgat-Pick
High Intensity Compton Scattering in a strong plane wave field of general form.
Eur. Phys. J. C 71 (2011) 7 and DESY 11-092;
arXiv:1106.1671
`http://dx.doi.org/10.1140/epjc/s10052-011-1729-8`

A. Hartin
Full quantum treatment of spin-dependent beam-beam processes at linear colliders.
J. Phys., Conf. Ser. 295 (2011) 012158

OPAL Collaboration, G. Abbiendi et al.
Determination of alpha(s) using OPAL hadronic event shapes at sqrt(s) = 91 - 209 GeV and resummed NNLO calculations.
Eur. Phys. J. C 71 (2011) 1733 and arXiv:1101.1470

S. Riemann, A. Schälicke, A. Ushakov
Design and optimization of a polarized positron source for future linear collider using Geant4.
J. Phys., Conf. Ser. 295 (2011) 012154
`http://dx.doi.org/10.1088/1742-6596/295/1/012154`

Polarized positrons for future linear colliders.
J. Phys., Conf. Ser. 298 (2011) 012020
`http://dx.doi.org/10.1088/1742-6596/298/1/012020`

P. Schade, J. Kaminski
A Large TPC Prototype for a Linear Collider Detector.
Nucl. Instrum. Methods A 628 (2011) 128
`http://dx.doi.org/10.1016/j.nima.2010.06.300`

F. Sefkow et al., CALICE Collaboration
Tests of a particle flow algorithm with CALICE test beam data.
J. Instrum. 6 (2011) P07005

A. Ushakov, A. Schälicke, S. Riemann
Simulation of polarized positron sources for linear colliders.
J. Phys., Conf. Ser. 298 (2011) 012021
`http://dx.doi.org/10.1088/1742-6596/298/1/012021`

Linear Accelerator Technologies

M.C. Hoffmann, A. Cavalleri, B. Schmidt, S. Schulz, S. Wesch, S. Wunderlich
Coherent Single Cycle Pulses with MV/cm Field Strengths from a Relativistic Transition Radiation Light Source.
Opt. Lett. 33 (2011) 4473
`http://dx.doi.org/10.1364/OL.36.004473`

S. Wesch, B. Schmidt, C. Behrens, H. Delsim-Hashemi, P. Schmüser
A Multi-Channel THz and Infrared Spectrometer for Femtosecond Electron Bunch Diagnostics by Single-Shot Spectroscopy of Coherent Radiation.
Nucl. Instrum. Methods A 665 (2011) 40 and DESY 11-141
`http://dx.doi.org/10.1016/j.nima.2011.11.037`

Theses.

Habilitation

M. Pandurović
Physics Background in Luminosity Measurement at ILC and Measurement of the Proton b-Content at H1 Using Multivariate Method.
Univ. of Belgrade (2011)

PhD theses

C. Bartels
WIMP Search and a Cherenkov Detector Prototype for ILC Polarimetry.
Universität Hamburg (2011)
DESY-THESIS-2011-034

D. Bot
Measurement of Beauty Quark Production from Dimuon Events with the ZEUS Detector at HERA II.
Universität Hamburg, Department Physik (2011)
DESY-THESIS-2011-032

A. Cholewa
$D*\pm$ Meson Production at low Q^2 with the H1 Detector and Determination of Unintegrated Gluon Densities.
University Hamburg (2011)
DESY-THESIS-2011-005; h1th-585

D. Dammann
Production Cross Section Measurement of Top–Antitop Pairs in the Dimuon Decay Channel at $\sqrt{s} = 7$ TeV with the CMS Experiment.
Uni Hamburg (2011)
DESY-THESIS-2011-016

J. Draeger
Track Based Alignment of the CMS Silicon Tracker and its Implication on Physics Performance.
University of Hamburg (2011)
DESY-THESIS-2011-026

N. Feege
Low-energetic Hadron Interactions in a Highly Granular Calorimeter.
Universität Hamburg (2011)
DESY-THESIS-2011-048

D.-J. Fischer
Inclusive Neutral Current ep Cross Sections with HERA II and Two-dimensional Unfolding.
Univ. Hamburg (2011)
DESY-THESIS-2011-020; h1th-632

G. Fischer
Determination of the τ-Lepton Reconstruction and Identification Efficiency Using $Z \to \tau\tau$ Events in First Data at ATLAS.
Universität Hamburg (2011)
DESY-THESIS-2011-036

S.V. Gliske
Transverse Target Moments of Dihadron Production in Semi-inclusive Deep Inelastic Scattering at HERMES.
The University of Michigan (2011)
DESY-THESIS-2011-027

M. Goebel
Precision Test of the Electroweak Standard Model and Measurement of the Weak Mixing Angle at ATLAS.
Universität Hamburg (2011)
DESY-THESIS-2011-029

B. Gosdzik
Identification of Hadronic τ Decays and Observation Potential of CP-violating effects in SUSY at ATLAS.
Hamburg Universität (2011)
DESY-THESIS-2011-007

M. Grefe
Unstable Gravitino Dark Matter – Prospects for Indirect and Direct Detection.
Universität Hamburg (2011)
DESY-THESIS-2011-039

C. Hambrock
b-baryon light-cone distribution amplitudes and a dynamical theory for [bq][b-bar q-bar]-tetraquarks.
Universität Hamburg (2011)
DESY-THESIS-2011-012

E. Hennepemper
Simulation and Calibration of the Specific Energy Loss of the Central Jet Chambers of the H1 Detector and Measurement of the Inclusive D*± Meson Cross Section in Photoproduction at HERA.
Univ. Heidelberg (2011)
DESY-THESIS-2011-042; HD-KIP-11-68; h1th-536

M.C. Herbst
A Search for R-parity Violating Squark Production with the H1 Experiment at HERA.
Univ. Heidelberg (2011)
DESY-THESIS-2011-046; h1th-675

F.M. Idris
Long Lived Neutral Hadrons in the Calorimeter of the Zeus Detector.
University of Malaya, Kuala Lumpur (2011)

A. Junkes
Influence of radiation induced defect clusters on silicon particle detectors.
Hamburg University (2011)
DESY-THESIS-2011-031

K. Kaschube
Search for Stable Stau Production at the LHC.
Uni Hamburg (2011)
DESY-THESIS-2011-030

F. Kislat
Measurement of the Energy Spectrum of Cosmic Rays with the 26 Station Configuration of the IceTop Detector.
Humboldt-Universität zu Berlin (2011)

R. Kogler
Measurement of Jet Production in Deep-Inelastic *ep*
Scattering at HERA.
Uni Hamburg (2011)
DESY-THESIS-2011-003, h1th-590

M. Lisovyi
Measurement of Charm Production in Deep Inelastic
Scattering Using Lifetime Tagging for $D^{\pm}$ Meson Decays with
the ZEUS Detector at HERA.
Universität Hamburg, Department Physik (2011)
DESY-THESIS-2011-033

M. Marienfeld
Measurement of the Top Quark Pair Production Cross Section
in the Muon-Electron Decay Channel in Proton-Proton
Collisions at $\sqrt{s} = 7$ TeV with the CMS Experiment.
Universität Hamburg (2011)
DESY-THESIS-2011-023

I. Marchesini
Triple Gauge Couplings and Polarization at the ILC
and Leakage in a Highly Granular Calorimeter.
Hamburg University (2011)
DESY-THESIS-2011-044

S. Naumann-Emme
Simultaneous Measurement of Top Quark Mass and Jet
Energy Scale Using Template Fits at the CMS Experiment.
Universität Hamburg (2011)
DESY-THESIS-2011-022

H. Perrey
Jets at Low Q^2 at HERA and Radiation Damage Studies for
Silicon Sensors for the XFEL.
Universität Hamburg (2011)
DESY-THESIS-2011-021

R. Polifka
Analysis of Dijet Events in Diffractive *ep* Interactions with
Tagged Leading Proton at the H1 Experiment.
Charles Univ. of Prague (2011)
DESY-THESIS-2011-025; h1th-655

P. Roloff
Measurement of Charm and Beauty Production in Deep
Inelastic Scattering at HERA.
Universität Hamburg, Department Physik (2011)
DESY-THESIS-2011-049

R. Shehzadi
Measurement of beauty production in deep inelastic scattering
at HERA using decays into electrons.
Universität Bonn, Physikalisches Institut (2011)

Z. Staykova
Measurement of D^* Meson with Two Jets in Photoproduction
with the H1 Detector at HERA.
Univ. Hamburg (2011)
DESY-THESIS-2011-002; h1th-584

D. Šálek
Measurement of the Longitudinal Proton Structure Function
in Diffraction at the H1 Experiment and Prospects for
Diffraction at LHC.
Charles University in Prague and University Paris XI in Orsay
(2011)
DESY-THESIS-2011-013; h1th-617

N. Sen
Measurement of the Energy Flow at Large Pseudorapidities for
$\sqrt{s} = 0.9$ TeV and $\sqrt{s} = 7$ TeV at the Large Hadron Collider
using the Compact Muon Solenoid.
Uni HH (2011)
DESY-THESIS-2011-040

E. Shcherbakova
Quantum Corrections to Drell-Yan Production of Z Bosons.
Hamburg University (2011)
DESY-THESIS-2011-024

Diploma theses

J. Breunlin
Commissioning of an Electro-Optic Electron Bunch Length
Monitor at FLASH.
Universität Hamburg (2011)

J. Franck
Experimental Study of the Higgs-b/c Couplings in
Photon-Proton Collisions.
Hamburg (2011)
DESY-THESIS-2011-018

J. Haase
Study of the electron to photon misidentification rate in the
ATLAS detector.
Universität Hamburg (2011)

K. Heine
Trigger performance studies with the ATLAS detector using
$J/\Psi \rightarrow e^+e^-$ events.
Universität Hamburg (2011)

H. Kirschenmann
Exploitation of Jet Properties for Energy Scale Corrections for
the CMS Calorimeters.
Universität Hamburg (2011)
DESY-THESIS-2011-006

S. Kollowa
Aufbau und Test einer Detektorebene mit
Galliumarsenidsensor.
BTU Cottbus (2011)

B. Sarrazin
Parameterbestimmung supersymmetrischer Modelle am LHC
unter Einbeziehung systematischer Unsicherheiten.
Universität Hamburg (2011)

C. Schwerdt
Die Erforschung kosmischer Strahlung und ihre Darstellung im
Unterricht - Untersuchung der Breitenabhängigkeit der
Intensität kosmischer Strahlung.
Universität Potsdam (2011)

L. Zeune
Precise predictions for the W boson mass in models beyond
the Standard Model.
Uni Göttingen (2011)

Master thesis

T. Melzig
Verbesserung der IceTop-Detektorsimulation unter Verwendung von Geant4.
Humboldt-Universität zu Berlin (2011)

Bachelor theses

M. Grönke
Verteilung atomaren Wasserstoffs in der Milchstraße.
FU Berlin, Universität Potsdam (2011)

D. Jakobeit
Kalibration der Kaskadenrekonstruktion in IceCube mithilfe künstlicher Lichtquellen.
Humboldt-Universität zu Berlin (2011)

M. Hempel
Study of the Performance of the Data Acquisition Chain for BCM1F Software Upgrade.
BTU Cottbus (2011)
DESY-THESIS-2011-014

A. Kleinschmidt
Verteilung der Quellen kosmischer Strahlung in der Milchstraße.
Universität Potsdam (2011)

C. Krause
The Impact of Different Monte Carlo Models on the Cross Section Measurement of Top-Pair Production at 7 TeV Proton-Proton Collisions.
BTU Cottbus (2011)

M. Krause
Studies of the Influence of the Geomagnetic Field on the Sensitivity of Gamma-Ray Observatories.
BTU Cottbus (2011)
DESY-THESIS-2011-011

C. Martens
Eichmessungen und systematische Untersuchngen zum Nachweis kosmische Teilchen im IceTop-Tank.
BTU Cottbus (2011)

W. Rehmann
Construction of a LED System for the OLYMPUS Experiment.
Univ. Mainz (2011)
DESY-THESIS-2011-047

S. Uhlig
Flat Spectrum Radio Quasars with the MAGIC telescopes.
Brandenburg University of Technology (2011)

Photographs and graphics
CERN
DESY
Lars Berg, Münster
Heiner Müller-Elsner, Agentur-Focus.de
Rüdiger Nehmzow, Düsseldorf

The figures were reproduced by permission of authors or journals.

Acknowledgement

We would like to thank all authors and everyone who helped in the creation of this annual report. ●

Imprint

Publishing and contact
Deutsches Elektronen-Synchrotron DESY
A Research Centre of the Helmholtz Association

Hamburg location:
Notkestr. 85, 22607 Hamburg, Germany
Tel.: +49 40 8998-0, Fax: +49 40 8998-3282
desyinfo@desy.de

Zeuthen location:
Platanenallee 6, 15738 Zeuthen, Germany
Tel.: +49 33762 7-70, Fax: +49 33762 7-7413
desyinfo.zeuthen@desy.de

www.desy.de
ISBN 978-3-935702-64-5

Editing
Manfred Fleischer, Matthias Kasemann
Textlabor Ilka Flegel

Layout
Heike Becker

Printing
Druckerei Heigener Europrint, Hamburg

Copy deadline
24 February 2012

Editorial Note
The authors of the individual scientific contributions published in this report are fully responsible for the contents.

Reproduction including extracts is permitted subject to crediting the source.
This report is neither for sale nor may be resold.

HELMHOLTZ
ASSOCIATION

Deutsches Elektronen-Synchrotron
A Research Centre of the Helmholtz Association

The Helmholtz Association is a community of 18 scientific-technical and biological-medical research centres. These centres have been commissioned with pursuing long-term research goals on behalf of the state and society. The Association strives to gain insights and knowledge so that it can help to preserve and improve the foundations of human life. It does this by identifying and working on the grand challenges faced by society, science and industry. Helmholtz Centres perform top-class research in strategic programmes in six core fields: Energy, Earth and Environment, Health, Key Technologies, Structure of Matter, Aeronautics, Space and Transport.

www.helmholtz.de