Welcome to the digital edition of the June 2013 issue of CERN Courier.

While collisions at the LHC can directly produce heavy particles – like the one recently identified as a Higgs boson – they can also cast light on the existence of new particles that have masses beyond the energy limit of the machine. Such particles can be observed indirectly through their “virtual” participation in rare decay processes, which are described by penguin-like diagrams. Searches for these processes are important for the LHCb experiment, specialized in studying the transitions of b quarks. It is one area in which LHCb can compete with the huge, general-purpose experiments, ATLAS and CMS, which received the provisional go-ahead exactly 20 years ago. In the same month – June 1993 – the CERN School of High-Energy Physics evolved into the European School of High-Energy Physics. Organized jointly by CERN and JINR in Dubna, the school continues to exemplify how interest in science brings together people from different nations to work in harmony.

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The SLAC National Accelerator Laboratory, at Stanford University, is seeking applications for the position of the Director of its Linac Coherent Light Source, LCLS. As Associate Laboratory Director (ALD) for LCLS, the candidate will report to the SLAC Laboratory Director and is expected to develop the vision and mission objectives to keep LCLS at the international forefront of cutting edge x-ray science while representing LCLS on SLAC’s Executive Council.

Tools for Discovery

SLAC, one of the world’s leading research laboratories, is a U.S. Department of Energy Office of Science multi-program laboratory operated by Stanford University. For 50 years, SLAC’s linac has produced high-energy electrons for cutting-edge physics experiments. Now, scientists continue this tradition of discovery by using the linac to drive a new kind of laser: creating X-rays using unprecedented brilliance.

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- X-ray laser offers new tool in fight against diseases
- X-ray laser takes aim at cosmic mystery
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- X-ray laser takes aim at cosmic mystery
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Extraordinary results from LCLS science has led to DOE approval of LCLS II.

The LCLS Director is expected to be an internationally recognized scientist with established leadership credentials; significant reputation in scientific research; strategic thinking and execution skills; excellent communication skills; commitment to excellence with ability to expand capabilities and capacities of the world’s foremost x-ray laser. The successful candidate is expected to assume a tenured position on the SLAC Faculty.

For additional information or to be considered for candidacy please contact/send application materials to: Lisa Mongetta, Manager, SLAC Staffing Services 2575 Sand Hill Road, Menlo Park, CA 94025 650-926-2733 email: mongetta@slac.stanford.edu

The SLAC National Accelerator Laboratory values diversity and is an Affirmative Action, Equal Opportunity Employer.

The Linac Coherent Light Source at SLAC National Accelerator Laboratory is an Office of Science user facility sponsored by the Department of Energy at Stanford University.
Are some atomic nuclei pear shaped?

Most atomic nuclei that exist naturally are not spherical but have the shape of a rugby ball. While state-of-the-art theories are able to predict this behaviour, the same theories have predicted that for some particular combinations of protons and neutrons, nuclei can also assume an asymmetrical shape like a pear, with more mass at one end of the nucleus than the other. Now an international team studying antimatter is affected by gravity. The ALPHA experiment at CERN’s ISOLDE facility has found that some atomic nuclei can indeed take on this unusual shape.

Most nuclear isotopes predicted to have pear shapes have for a long time been out of reach of experimental techniques. In recent years, however, the ISOLDE facility has demonstrated that heavy, radioactive nuclei, produced in high-energy proton collisions with a uranium-carbide target, can be selectively extracted before being accelerated to 8% of the speed of light. The beam of nuclei is directed onto a foil of isotopically pure nickel, cadmium or tin where the relative motion of the heavy accelerated nuclei and the target nucleus creates an electromagnetic impulse that excites the nuclei. By studying the details of this excitation process it is possible to infer the nuclear shape of 224Ra as deduced from the experiments at ISOLDE.

The new measurements will help to direct the searches for EDMs currently being carried out in North America and in Europe, where new techniques are being developed to exploit the special properties of radon and radium isotopes. The expectation is that the data from the nuclear-physics experiment at ISOLDE can be combined with results from atomic-trapping experiments that measure EDMs to make the most stringent tests of the Standard Model of particle physics. EDMs to make the most stringent tests of the

F, that is, on antigravity. Refinements of the technique, coupled with larger numbers of short-lived isotopes 220Rn and 224Ra, the data show that while 220Rn is pear shaped, 224Ra does not assume the fixed shape of a pear but rather vibrates about this shape. The findings from the teams at ISOLDE are in contradiction with some nuclear theories and will help others to be refined.

The experimental observation of nuclear pear shapes is also important because it can help in experimental searches for atomic electric-dipole moments (EDMs). The Standard Model of particle physics predicts that the value of the atomic EDM is so small that it will lie well below the current observational limit. However, many theories that try to refine the model predict values of EDMs that should be measurable. Testing these theories requires improved measurements, the most sensitive being to use exotic atoms whose nuclei are pear shaped.

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CERN presents novel investigation of the effect of gravity on antimatter

The ALPHA collaboration at CERN has made the first direct analysis of how antimatter is affected by gravity. The ALPHA experiment was the first to trap atoms of antihydrogen, held in place with a strong magnetic field for up to 1000 s (CERN Courier July/August 2011 p6). Although the main process it is possible to infer the nuclear mass of antimatter, \( F = M \), on the ratio of the gravitational to inertial mass. This allowed them to measure limits directly on the gravitational to inertial mass of antimatter, \( F/M \).

Measuring a total of 434 atoms, they found that in the absence of systematic errors, \( F/M \) must be < 7.5 at a statistical significance level of 5%; the worst-case systematic errors increase this limit to < 110. A similar search places somewhat tighter bounds on a negative \( F/M \), that is, on antigravity. Refinements of the technique, coupled with larger numbers of cold-trapped antinuclei, should allow future measurements to place tighter bounds on \( F/M \) and approach the interesting region around 1.

Meanwhile, the antimatter programme at CERN is expanding. AEgIS and GBAR, two experiments currently under construction, will focus on measuring how gravity affects antimatter.


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Astronomical observations—such as the rotation velocities of galaxies and gravitational lensing—show that more than 80% of the matter in the universe remains invisible. Deciphering the nature of this “dark matter” remains one of the most interesting questions in particle physics and astronomy. The CMS collaboration recently conducted a search for the direct production of dark-matter particles (χ), with especially good sensitivity in the low-mass region that has generated much interest among scientists studying dark matter.

Possible hints of a particle that may be a candidate for dark matter have already begun to appear in the direct-detection experiments; most recently the CDMS-II collaboration reported the observation of three candidate events in its silicon detectors with an estimated background of 0.7 events. This result points to low masses, below 10 GeV, as a region that should be particularly interesting to search. This mass region is where the direct-detection experiments start to lose sensitivity because they rely on measuring the recoil energy imparted to a nucleus by collisions with the dark-matter particles. For a low-mass χ, the kinetic energy transferred to the nucleus in the collision is small, and the detection sensitivity drops as a result.

The CMS collaboration has searched for hints of these elusive particles in “monopole” events, where the dark-matter particles escape undetected, yielding only “missing momentum” in the event. A jet of initial state radiation can accompany the production of the dark-matter particles. A search is conducted for an excess of these visible companions compared with the expectation from Standard Model processes. The results are then interpreted within the framework of a simple “effective” theory for their production, where the particle mediating the interaction is assumed to have high mass. An important aspect of the search by CMS is that there is no fall in sensitivity for low masses.

In March 2012, the LHCb collaboration reported an observation of CP violation in charged B-meson decays, B→DK+. Now, just over a year later, the collaboration has announced a similar observation in the decays in another B meson, in this case the B0 meson composed of a beauty antiquark b bound with a strange quark s. This first observation of CP violation in the decays B0→KS→π+π− has a significance of more than 50 marks the first time that CP violation has been found in the decays of B0 mesons—only the fourth type of meson where this effect has been seen. It is an important milestone for LHCb because the precise study of B0 decays is sensitive to physics beyond the Standard Model.

The study of CP violation in charmless two-body decays provides stringent tests of the Cabibbo-Kobayashi-Maskawa picture of CP violation in the Standard Model. However, the presence of hadronic contributions means that several measurements from these decays are needed to exploit flavour symmetries and disentangle the different contributions. In 2004, the BaBar and Belle collaborations at SLAC and KEK, respectively, discovered CP violation in the decay B→KS using a model-independent test was proposed to check the consistency of the observed size of the effect with the Standard Model. The test consists of checking CP violation in B→KS with that in B0→KS. The B factories at KEK and SLAC did not have the possibility of accumulating large enough samples of B0 decays and, despite much effort by the CDF collaboration at Fermilab’s Tevatron, CP violation had until now not been seen in B0→KS with a significance exceeding 5σ.

Using a data sample corresponding to an integrated luminosity of 1.0 fb−1 collected by the experiment in 2011, the LHCb collaboration measured the direct CP-violating asymmetry for B0→KS decays, ACP(B0→KS) = 0.13 ± 0.03 (stat.) ± 0.01 (syst.), with a significance of more than 5σ. In addition, the collaboration improved the determination of direct CP violation in B0→KS decays, ACP(B0→KS) = 0.080 ± 0.007 (stat.) ± 0.033 (syst.), which is the most precise measurement of this quantity to date.

The four plots in figure 2 show different combinations of the KS0 invariant mass. The upper plots indicate the well-established difference in the decay rates of B0 mesons. The enlargements in the lower plots reveal that a difference is also visible around the mass of the B0 meson. The measured values are in good agreement with the Standard Model expectation.

Hence the data sample collected in 2011 was used to obtain these results, so LHCb will improve the precision further with the total data set now available, which more than trebled with the excellent performance of the LHC during 2012.

The CMS collaboration searches for W and Z boson decays, which are the most likely to be detected with CMS. The CMS collaboration also searches for signal events in which the decay products of a W or Z boson are not observed. These signal events are then interpreted within the framework of a simple “effective” theory for their production, where the particle mediating the interaction is assumed to have high mass. An important aspect of the search by CMS is that there is no fall in sensitivity for low masses.

The model search requires at least one jet with more than 100 GeV of energy and has the best sensitivity if there is more than 400 GeV of missing momentum. Events with additional leptons or multiple jets are vetoed. After event selection, 307 events were found in the recent analysis, with an expectation from Standard Model processes of 363 ± 190 events. The contribution from electroweak processes dominate this expectation, either from pp→Wγ with the Z decaying to two neutrinos or from pp→Wγ+jets, where the W decays to an electron or a muon and the lepton escapes detection.

With no significant deviation from the expectation found in the analysis, CMS has set limits on the production of dark matter, as shown in the figures of the γ→νν lepton and γ→νν neutrino. The limits show that CMS has good sensitivity to the low-mass region of interest, for both spin-dependent and spin-independent interactions.
**First jet measurements with ALICE**

When quarks and gluons (partons) in opposing beams at high-energy hadron colliders meet they can scatter violently to produce correlated showers of particles, or “jets”. In proton–proton (pp) collisions, the rate of such events can be predicted using state-of-the-art QCD calculations and compared with the measurements. However, in heavy-ion collisions, jets are expected to be modified by the interaction of the scattered partons with the surrounding excited nuclear matter – the quark–gluon plasma, or QGP. Jets and this phenomenon of “jet quenching” thus provide important diagnostic probes of the QGP.

ALICE, which is devoted to a broad study of the QGP at the LHC, first observed jet quenching in lead–lead (ppb) collisions through the suppressed production rate of high-momentum single hadrons (CERN Courier June 2011 p77). Fully reconstructed jets are measured using the high-precision tracking of charged particles in the ALICE central barrel, together with a measurement of the energy of neutral particles in the EMCal (figure 1). The EMCal is a lead–scintillator calorimeter that has a minimum ħ/2p energy of 0.014 TeV in azimuth, which consists of 11,520 separate towers, each subtending Δφ × Δη = 0.014 × 0.014. A late addition, its installation was completed in January 2011. This “dual calorimeter” was expected to reconstruct jets from the more traditional approach with hadronic plus electromagnetic calorimetry and provide a systematically different way to study jets. The first step for ALICE in the study of fully reconstructed jets in heavy-ion collisions is to measure the ratio of the inclusive differential jet cross-section for R = 0.1 and R = 0.4, together with the predictions from QCD. This cross-section ratio is sensitive to the distribution of energy within jets and is of particular interest in the study of jets in heavy-ion collisions. The theoretical approach used here has a good agreement with the measured ratio if “hadronization” effects, which arise because the experiment measured hadrons and not partons, are taken fully into account.

These results demonstrate that ALICE can measure jets well with the advantage of precise determination of the jet structure, which is of crucial importance for studies of jets produced in PbPb collisions.

**Further reading**


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**NOvA detector records first 3D tracks**

The NOvA neutrino detector that is currently under construction in northern Minnesota has recorded its first 3D images of particle tracks. Researchers started up the electronics for the first block of the NOvA detector in March and the experiment was soon catching more than 1000 cosmic rays a sec.

Once completed in 2014, the NOvA detector will consist of 28 blocks with a total mass of 14,000 tonnes. The blocks are made of PVC tubes filled with scintillating liquid. It will be the largest free-standing plastic structure in the world.

Fermilab, located 35 km south-east of the NOvA site, will start sending neutrinos to Minnesota in the summer. The laboratory is finalizing the upgrades to its Main Injctor accelerator, which will provide the protons that produce the neutrino beam. The upgraded accelerator will produce a pulse of muon neutrinos every 1.3 seconds and the goal is to achieve a proton-beam power of 500 kW. A smaller, 330-tonne version of the far detector for NOvA will be built on the Fermilab site to measure the cosmic neutrinos that leave the laboratory.

The neutrino beam will provide particles for three experiments: MINOS, located 735 km from Fermilab in the Soudan Underground Research Facility, right in the centre of the neutrino beam; NOvA, which is located off axis to probe a specific part of the neutrino energy spectrum; and MINEBEA, a neutrino experiment located on the Fermilab site.

The NOvA collaboration aims to discover or confirm the mass hierarchy of the three known types of neutrino – which type of neutrino is the heaviest and which is the lightest. The answer will shed light on the theoretical framework that has been proposed to describe the behaviour of neutrinos. Their interactions could help to explain the imbalance of matter and antimatter in today’s universe; there is even the possibility that there might be still more types of neutrino.

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**VELA: the small accelerator with a big potential**

A new particle accelerator in the UK has achieved a significant electron acceleration milestone. On 5 April, the Versatile Electron Linear Accelerator (VELA) produced its first electron beam, an important step on the way to being ready for commercial and research use this summer.

VELA, which is situated at the Daresbury Laboratory’s Science and Technology Facilities Council, is designed to be one of the most flexible particle accelerators of its type. The medium-term aim is to develop a 6 MeV injector with additional linac sections in order to achieve 250 MeV beams at 400 Hz with bunch charges in the range 50–250 pC. At present, the beam pulses are generated by targeting a copper photo-cathode with a UV laser.

With stable, reliable beams over a broad range of energies, VELA will provide interesting new opportunities for users and collaborators. The facility is exceptional in offering access on “both sides of the wall”, allowing users not only to perform conventional studies on samples but also to access the accelerator itself. This opens up the possibility of testing a variety of accelerator components or items for beam diagnostics. One of the primary collaborating institutes currently working on VELA is Strathclyde University. The team from Strathclyde has provided a significant level of hardware that will allow a demonstration of the capability of RF injectors for use with laser-driven plasma wakefield accelerators (CERN Courier June 2007 p28).

The researchers plan to install an RF injector for Strathclyde’s project Advanced Laser-plasma High-energy Accelerators towards X-rays (ALPHA-X), but to date they have not been able to demonstrate a suitable performance capability. Working with VELA, however, they have developed a system that is directly suited to their application and its design is being qualified, enabling its use at the university’s facility.

The plan for VELA is to continue collaborations with other leading institutions and with industry. The aim is that the facility will allow the development of technological advances in accelerator design, for use not only in research but also in industry.  

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**Daresbury**

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A new technique called CLARITY promises to revolutionize biology by making normally opaque tissue clear. It has already been used to make a brain transparent, so that its detailed structure and connections between cells can be seen in 3D without having to slice it up.

Karl Deisseroth and colleagues at Stanford University soaked tissue of a mouse brain in acrylamide, formaldehyde and a heat-activated initiator that forms a hydrogel mesh to support the tissue. Adding a negatively charged detergent and applying an electric field allows all of the lipids to be pulled out. What then remains is an optically transparent but macromolecule permeable structure, which permits multiple staining and destaining to highlight features—in particular in 3D imaging and analysis. With this technique an optical microscope reveals individual neurons and their connections as if they were embedded in glass.

**Ion propulsion for efficient travel**

Normal aircraft achieve thrust by pushing air from the back end. However, the use of ions, electrically accelerated before being shot out, has usually been considered suitable only for space flight. But now, argue Kento Masuyama and Steven R H Barrett of Massachusetts Institute of Technology, based on experimental work, they show that ionic wind could provide a higher thrust per kilowatt—which is a staggering improvement over the 2 N/kW for a jet engine. In addition to offering higher efficiency, ion propulsion is also silent and gives off no heat signature. Interestingly, lower-velocity ion jets are more efficient, wasting less kinetic energy in the wake.

**Seeing dreams by reading minds**

It sounds like science fiction but Y Kamitani and colleagues at the National Institute of Science and Technology in Kyoto and colleagues can read your mind while you dream. Volunteers slept while their brains were imaged by functional MRI but were woken up when EEG signals indicated that they were “seeing” something. By asking the volunteers what was in their dreams and correlating it with brain activity, the researchers could learn to predict what people were dreaming about within about 20 broad categories. The accuracy is about 60%, which is much more than chance. There is some discussion as to whether the team is really seeing dreams or just perceiving hallucinations that appear as people drop off to sleep. Nevertheless, it mounts up to dreaming someone’s thoughts from brain activity patterns.

**Coelacanth sequenced**

The African coelacanth is a “living fossil” – a creature 1.5 m long that was assumed to be extinct until one was accidentally caught by a fisherman in 1938. It represents a type of fish previously thought to have died out by a fisherman in 70 million years ago and now its genome has been sequenced. Analyses of the genome are expected to hold clues as to how fins became limbs. Early work shows that non-coding parts of the genome seem to have changed quickly over time, suggesting that these pieces, which play a role in gene expression, may be significant in evolutionary change. Also, it seems that the lungfish – not the coelacanth – is the closest living relative of the first four-legged vertebrates.

**Storage rings in the sky**

The Van Allen belts are two realistic electron storage rings in space around the Earth—but sometimes they are joined by a third. D N Baker and colleagues found that on 2 September 2012 a third ring of high energy (> 2 MeV) electrons appeared between the usual two belts and persisted for more than four weeks before an interplanetary shock wave from the Sun blew them away. The third belt was detected by the two NASA Radiation Belt Storm Probe spacecraft that loop between the known belts. It seems that even 50 years after the original belts were discovered, this natural particle accelerator system is not yet fully understood.
Why do some gamma-ray bursts last hours?

Three unusually long-lasting stellar explosions discovered by NASA’s Swift satellite represent a new class of gamma-ray bursts (GRBs). Astrophysicists conclude that they probably arose from the catastrophic death of supergiant stars, hundreds of times larger than the Sun. GRBs are extremely powerful flashes of gamma rays observed from a random direction on the sky about once a day. They are traditionally classified as short- and long-duration events. Short bursts last 2 s or less and are thought to represent a merger of compact objects (neutron stars or black holes) in a binary system. Long GRBs last up to several minutes and are probably associated with the birth of a black hole during the supernova explosion of a massive star (CERN Courier September 2003 p5). Both scenarios give rise to powerful jets that propel matter at nearly the speed of light in opposite directions. As they interact with matter in and around the star, the jets produce a spike of high-energy radiation. (CERN Courier December 2005 p20.)

While most of the thousands of GRBs observed so far fall into these two categories, there are also peculiar sub-energetic bursts (CERN Courier September 2004 p3) and ultra-long duration events. GRBs that arise from the tidal disruption of a star by a supermassive black hole (CERN Courier July/August 2011 p6). Now, three recent long GRBs with sizes much larger than the star create a much longer-lived jet. (Image credit: Mark A Garlick, used with permission by the University of Warwick.)

An artist’s impression of two stars of very different size creating gamma-ray bursts (GRBs). In both cases, the GRB is produced by a jet punching through the star, but in the case of the ultralong GRBs the much larger size of the star creates a much longer-lived jet. (Image credit: Mark A Garlick, used with permission by the University of Warwick.)

GRB 111209A, which erupted on December 9, 2011 and remained active for 7 hours as observed by NASA’s Swift spacecraft and several other gamma-ray, X-ray and optical instruments. The detailed study, led by Bruce Gendre while at the Italian Space Agency’s Science Data Centre, shows that the burst is a genuine GRB at a redshift of z = 0.677 but with an outstandingly long duration and a high total flux.

An earlier event, GRB 101225A, exploded on Christmas Day 2010 and produced high-energy emission lasting at least two hours. Because the distance to this atypical GRB was unknown, astronomers thought that this so-called “Christmas burst” could be a radiusally different nature. One group suggested an asteroid or comet falling onto a neutron star within the Galaxy, while another team suspected a merger of a neutron star with an evolved giant star to be at the origin of the burst. Both scenarios are disproved by the recent measurement of the redshift of the host galaxy by Andrew Levan of the University of Warwick and his team. They place the Christmas burst 7000 million light-years away (z = 0.687), implying that the burst was far more powerful than first thought. Levan and colleagues link it with the similar GRB 111209A and another recent burst, GRB 121027A, all of extremely long duration.

Both studies propose that the ultralong duration of such atypical bursts is related to the size of the collapsing star. The duration of the event would be proportional to the time that it takes for matter to fall towards the new-born black hole at the stellar core or for the particle jets to drill their way through the star. In either case, the bigger the star the longer the duration. The likely candidates for ultralong GRBs would thus be supergiant stars with a size of hundreds of times the Sun’s diameter. Gendre’s team goes further, suggesting that GRB 111209A reflects the death of a blue supergiant containing modest amounts of elements heavier than helium. This would make ultralong-duration GRBs would have been much more common in the distant past of the universe, when matter was not yet enriched in the heavy elements produced by massive stars.

Further reading

Preparing for a third ‘g-2’

Preparations are well advanced for a third experiment to measure the “g-2” of the muon (2 e the anomalous magnetic moment). The search for an unexpected effect improved the experimental accuracy of this parameter by a factor of 20 over its predecessor, giving a value of (1166.03 ± 10) × 10−9 compared with the theoretical prediction of (1165.88 ± 11) × 10−9. The third hopes to improve the accuracy by a factor of 10.

The interest in further decimal places is a search for a difference between the muon and the electron (seemingly identical particles whose mass difference could be due to a force felt by muons but not by electrons) and a test of the validity of quantum electrodynamics QED down to extremely small distances.

To achieve greater accuracy, the experiment will use new apparatus, a 14 m diameter muon storage ring consisting of forty bending magnets and an electromagnetic quadrupole, to be installed in the West Experimental Hall. The main differences are:

1) Unlike the previous storage ring, the magnetic field in the ring will be constant to eliminate the effect of radial variations in the muon orbits.
2) Vertical focusing will be achieved by using a quadrupole electrostatic quadrupole. Normally the muon magnetic moment is sensitive to the electric field, but there is a “magic” energy (3.1 GeV) at which it is no longer sensitive. This energy has therefore been selected for the stored muons.
3) Previously, protons ejected from the PS were directed onto a target inside the muon storage ring, giving a current of charge spread to the pions produced (which decay to give the muons). In the new experiment, pions will be generated in a target outside the ring and only those with accurately measured momentum will be injected, by means of a pulsed injector.
4) A higher intensity muon beam, several hundred times greater than that with a few tens of muons, will be stored, partly due to increased PS intensity.
5) Operating at 3.1 GeV (rather than 1.3 GeV) will make it possible to observe the muons for about two and a half times as long, due to the relativistic effect of time dilution. The experiment is unusually complex.

Half-scale model of a set of two magnets for the muon storage ring of the new g-2 experiment. The model is equipped with a device for measuring the magnetic field. year’s running is anticipated to get to know the apparatus, and actual data-taking will also require about a year. It should finish in 1974 and final analysis of the results may then take until 1975. It is a long haul for a few decimal places but they are very important places.

Compiled from texts on pp158–186.

43rd session of CERN Council: collaboration with ESO

The possibility of collaboration between the European Southern Observatory organization and CERN was first brought to the attention of the Council last December. At the June meeting, the text of a formal Agreement was presented and Council was unanimously in favour of implementation. The General Director [Bernard Gregory] was authorized to finalize the text with the Director General of ESO, Prof. A Blaauw, to be sent to delegations for comments before being signed.

ESO are constructing a large (3.6 m) optical telescope to be installed at La Silla in Chile. Under the terms of the Agreement, a Division of ESO will come to CERN where the final design, construction and testing will be carried out. The Division, comprising about 50 astronomers, engineers and technicians, will be able draw on CERN’s experience in the engineering and administrative aspects of implementing large projects.

Compiled from texts on pp146–147.
Chasing new physics with electroweak penguins

The recent identification of the new particle discovered at the LHC as a Higgs boson with a mass of 125 GeV/c² completes the picture of particles and forces described by the Standard Model (CERN Courier May 2013 p21). However, it does not mark the end of the story as, unfortunately, the Standard Model is an incomplete description of nature. Puzzles still remain, for example, in explaining the existence of dark matter and the matter–antimatter asymmetry. The answers to these puzzles may lie in the existence of as yet undiscovered particles that would have played a key role in the early, high-energy, phase of the universe and whose existence would help to complete the description of nature in particle physics. The question then is: at what energy scale would these new particles appear?

Particle physics provides no certain knowledge about this scale but the hope is that the new particles might be produced directly in the high-energy proton–proton collisions of the LHC. However, new particles could also be observed indirectly through the effects of their participation as virtual particles in rare decay processes. By studying such processes, experiments can probe mass scales that are much higher than those accessible directly through the energy available at the LHC. This is because quantum mechanics and Heisenberg’s uncertainty principle allow virtual particles to have masses that are not constrained by the energy of the system. Searches based on virtual particles are limited by the precision of the measurements, rather than the energy of the collider.

Rare transitions of b quarks could cast light on heavy new particles beyond the direct reach of the LHC.

One promising place to look for contributions from new virtual particles is in the rare transitions of b quarks to s quarks in which a W boson is emitted. Described by the Feynman man diagrams shown in figure 1 (overleaf), these involve what are known as “flavour-changing neutral currents” because the initial quark changes flavour without changing charge. In the Standard Model, transitions of this type are forbidden at the lowest perturbative order — that is, at “tree-level”, where the diagrams have only two vertices. Instead, they are mediated as shown in figure 1 (p16) by higher-order diagrams known as “electroweak penguin” and “box” diagrams. For this reason the Standard Model process is rare, which enhances the potential to discover new high-mass particles.

Rudaz and I immediately started running searches at LHCb for discoveries in particle physics in the past, specifically in the decays of K mesons, where s quarks change to d quarks. Investigations of mixing between the mass eigenstates of the neutral kaon system and of rare K-meson decays led to the prediction of the existence of a second u-like quark (the charm quark, c), at a time when only three quarks were known (u, d and s). It was 10 years before the existence of the c quark was confirmed directly. Similarly, the observation of CP violation in neutral kaons led to the prediction of the third generation of quarks (b and t). Now, the study of flavour-changing neutral-current processes related to the third generation...
of quarks—in particular the rare $b \to s\mu\mu$ transitions—could soon provide similar evidence for the existence of new particles.

Several $b \to s\mu\mu$ transitions have already been observed by the Belle, BaBar and CDF experiments at KEK, SLAC and Fermilab respectively. So far, the results have been limited by the small size of the data sets but with the LHC, a new era of precision has begun. The collider is the world’s largest “factory” for producing particles that contain b quarks: in one year, it produced about $10^{35}$ b-hadrons in the LHCb experiment, while running at a centre-of-mass energy of 7 TeV with an instantaneous luminosity in the experiment of $4 \times 10^{33}$cm$^{-2}$s$^{-1}$. ATLAS and CMS have also recently joined the game, showing their first results on the $b \to s\mu\mu$ decay at the BEAUTY conference (ATLAS collaboration 2013 and CMS collaboration 2013).

The LHCb detector is characterized by excellent vertex and momentum resolution (coming from its tracking systems) and impressive particle-identification capabilities (from its two ring-imaging Cherenkov detectors). Combined with the large b-hadron production rate, these features allow LHCb to reconstruct clean signals of rare b-hadron decays (figure 2). These processes have branching fractions below 10$^{-5}$ and at most occur once in every 100 million collisions.

The branching fractions of these decays are sensitive to new physics but their interpretation is unfortunately complicated. The b quark has hadronized, so the observations relate to hadronic physics but their interpretation is unfortunately complicated. The $b$ quark has hadronized, so the observations relate to hadronic physics but their interpretation is unfortunately complicated. The $b$ quark has hadronized, so the observations relate to hadronic physics but their interpretation is unfortunately complicated.

Angles and asymmetries

Fortunately, the branching fractions of these decays are not the only handles for investigating new particle contributions. It is often much more instructive to look at the angular distribution of the particles coming from the decay. However, such angular analyses are experimentally challenging because they require a detailed understanding of how both the geometry of the detector and the reconstruction of the event bias the angular distribution of the particles. The decays $B \to K\mu\mu$ and $B \to \pi\mu\mu$ have been shown to be highly sensitive to a variety of new physics scenarios (LHCb collaboration 2013a and 2013b). These decays are characterized by three angles, $\Theta$ which describes the $K_0^*\bar{K}_0$, and the dimuon decay planes.

The angular distribution of the particles depends on the properties of the underlying theory. For instance, two features of the Standard Model drive the angular distribution: the photon exchanged in the penguin diagram of figure 1 is tranversely polarized, while the charged-current interaction (the W-exchange) is parity left-handed. The angle in the dimuon system also has an intrinsic forward-backward asymmetry that arises from interference between the different diagrams. The forward-backward asymmetry can be studied as a function of the mass of the dimuon system, which can be anywhere between twice the muon mass and the difference between the mass of the B and the mass of the $K^*0$.

In the Standard Model, the forward-backward asymmetry has a characteristic behaviour, changing sign at a dimuon mass of around 2 GeV/c$^2$. It turns out that this point can be predicted with only a small theoretical uncertainty. Figure 3 shows LHCb’s measurement of the forward-backward asymmetry in the decay $B^+ \to K^{*+}\mu^+\bar{\mu}$. In addition, the angle $\Phi$ can be used to test nature’s left-handedness, through an observable called $A_{FB}$. So far, both the forward-backward asymmetry and $A_{FB}$ show good agreement with the predictions of the Standard Model. While there is no evidence for any disagreement, it is nevertheless important to emphasize that the room for new physics is still large given the statistical uncertainty of the present measurements.

Another way to decrease the theoretical uncertainty associated with the hadronic transitions is to form asymmetries between specific decay modes—for example, CP asymmetries between particle and antiparticle decays. In the Standard Model, the decay $B^+ \to K^{*+}\mu^+\bar{\mu}$ and its CP conjugate are expected to have the same branching fraction to about 1 part in 1000. With the large LHCb data samples, LHCb has verified this at the level of 95% (LHCb collaboration 2013a).

Isospin asymmetries

Another example concerns so-called isospin asymmetries between decays that differ only in the type of spectator quark (u or d), labelled q in figure 1. The isospin asymmetry between $B^+u\mu^+\bar{\mu}$ and $B^-d\mu^+\bar{\mu}$ is defined as:

$$A_{FB} = \frac{B(B^+ \to K^{*+}\mu^+\bar{\mu}) - B(B^- \to K^{-}\mu^+\bar{\mu})}{B(B^+ \to K^{*+}\mu^+\bar{\mu}) + B(B^- \to K^{-}\mu^+\bar{\mu})}$$

This is formed using the branching fractions of the $B^+$ and $B^-$ decays and the ratio $\tau_{B^+}/\tau_{B^-}$ of the lifetimes of the $B^+$ and the $B^-$. In the Standard Model, the spectator quark is expected to play only a limited role in the dynamics of the system, so isospin asymmetries are predicted to be tiny. Experimentally, $A_{FB}$ is measured as a double ratio with respect to the decay channels $B^+ \to K_{s}^0 \mu^+\bar{\mu}$ and $B^- \to K_{s}^0 \mu^+\bar{\mu}$, which give the same final states 4$q$ decays to $\mu^+\bar{\mu}$ and are well known from previous measurements.

Isospin asymmetries have been measured for both $B^+ \to K^{*+}\mu^+\bar{\mu}$ and $B^- \to K^{-}\mu^+\bar{\mu}$ by the BaBar, Belle, CDF and LHCb experiments. All of these measurements are in good agreement with each other and favour a value for $A_{FB}$ that is close to zero and a negative value for $A_{FB}$. The LHCb experiment observes a negative isospin asymmetry in this channel at the level of four standard deviations (from zero) (LHCb collaboration 2012). This unexpected result is yet to be explained. Indeed, most extensions of the Standard Model do not predict a significant dependence on the charge or flavour of the spectator quark.

Looking to the future

The LHCb experiment has already on tape a data set that is roughly three times larger than that used in its results published so far. Even with only 1 fb$^{-1}$ of integrated luminosity currently analysed, LHCb has larger samples than these decay modes combined in most of the channels shown in figure 2. Furthermore, while the selected current data sets contain hundreds of events, the samples will be of the order of tens of thousands of events once the experiment has been upgraded. With these larger data sets the LHCb collaboration will be able to chase progressively smaller and smaller deviations from the Standard Model. This will allow them to probe over higher mass scales, far beyond those that can be accessed by searching directly for the production of new particles at the LHC. A new era in precision measurements of flavour-changing neutral currents is now opening.

Further reading


Résumé

Rechercher la nouvelle physique avec des pionniers électrofaibles

Les transitions rares quarks $b$–quarks à lors desquelles est produite une paire de muons sont propices à la recherche des effets de nouvelles particules ayant des masses supérieures à celles qu’il est possible d’obtenir par des recherches directes. Ces processus, dans lesquels le quark initial change de saveur sans changer de charge, sont décrits par les “diagrammes en piongous”. Plusieurs transitions de ce type ont été observées par les expériences auprès d’autres machines, mais les résultats ont été limités par la petite taille des échantillons de données. À présent, le LHC ouvre une nouvelle ère de précision, et l’expérience LHCb analyse les données à la recherche de ces désintégrations rares.
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Nuclotron tests out stochastic cooling in Dubna

Recent runs of JINR’s Nuclotron have tested the stochastic-cooling system being prepared for the future NICA facility.

The Nuclotron-based Ion Collider Facility (NICA) is the future flagship project of the Joint Institute for Nuclear Research in Dubna. In addition to the existing Nuclotron, this accelerator-collider complex will include a new heavy-ion linear accelerator, a superconducting 25 Tm booster synchrotron and two rings for a superconducting collider (CERN Courier January/February 2012 p5). The new facility will ultimately provide a range of different ion beams for a variety of experiments with both colliding beam and fixed targets (see box, overleaf).

Construction of the 3 MeVu heavy-ion linear accelerator is now under way in co-operation with the BEVATECH Company in Germany; its commissioning in Dubna is scheduled for the end of 2013. Serial production of superconducting magnets for the booster is expected to start in early 2014. The Technical Design Report for the collider complex has meanwhile been approved. As the first step in the realization of the NICA heavy-ion programme, Baryonic Matter at Nuclotron (BM@N) – a new fixed-target experiment developed in co-operation with GSI, Darmstadt – has been approved by JINR’s Programme Advisory Committee and Scientific Council and is now under construction.

In the meantime, the modernized Nuclotron, which will be a key element of the future facility, is being used for basic research in accelerator physics and techniques, the development of modern diagnostics and the testing of prototypes for the collider and booster systems. This is in addition to the implementation of the current physics programme at the superconducting 45 Tm synchrotron. Development work for NICA performed during recent Nuclotron runs includes the testing of elements and prototypes for the Multipurpose Detector using extracted deuteron beams; the transportation of the extracted beam (C10+ ions at 3.5 GeV/u and deuterons at 4 GeV/u) to the point where the BM@N detector is under construction; tests of the Nuclotron operating with a long flat-top of the high magnetic field (up to 1000 s, 1.5 T) to simulate the operating conditions of the magnetic system for the collider; and operational tests of the automatic control system based on the TANGO platform, which has been chosen for the NICA facility. A particularly important step concerned the construction, installation and testing at the Nuclotron of the prototype for the collider’s stochastic cooling system. This is of major importance for NICA’s heavy-ion programme because beam cooling during collisions is essential for providing maximal luminosity across the whole energy range of 1–4.5 GeV/u. Operational experience of stochastic cooling and experimental investigations of the beam-cooling process at the Nuclotron are therefore a necessity.

The design and construction of the stochastic-cooling channel at the Nuclotron began in mid-2010 in close collaboration with the Forschungszentrum Jülich (FZJ). All stages of the work have been strongly supported by the director of the FZJ’s Institute for Nuclear Physics (IKP), Rudolph Mayer. This R&D is also important to IKP FZJ for testing elements of the stochastic-cooling system designed for the High-Energy Storage Ring (HESR), which will form part of the future international Facility for Antiproton and Ion Research in Darmstadt.

The main task of beam cooling at the HESR will be to accumulate a beam with 1010 antiprotons above 3 GeV at a momentum resolution down to 10–4 for the PA N DA experiment. To enhance beam-cooling performance, new ring slot couplers have been developed at FZJ for the pick-up and kicker structures. The pick-ups were tested successfully at the Cooler Synchrotron at FZJ in experiments with the internal target of the Wide-Angle Shower Apparatus.

A pick-up and kicker, each assembled from 16 rings designed for a 2.4 GHz bandwidth, were produced at FZJ for testing at JINR, as the institutes joined forces to prepare for an experiment on stochastic cooling at the Nuclotron. The kicker structure was installed in the room-temperature section of the Nuclotron, with the pick-up
The NICA facility will provide experiments with:
- extracted ion beams (from protons up to gold or uranium nuclei) at kinetic energies up to 13.8 GeV/u for protons, 6 GeV/u for deuterons, and 4.5 GeV/u for heavy nuclei. The fixed-target experimental BM@N is under construction by a JINR-GSI collaboration;
- colliding heavy-ion beams with a kinetic energy in the range 1–4.5 GeV/u at a luminosity of $10^{28}$ cm$^{-2}$ s$^{-1}$;
- colliding heavy and light ions with the same energy range and luminosity;
- colliding polarized beams of light ions in the kinetic energy range 5–12.5 GeV/u for protons and 2–5.8 GeV/u for deuterons, at a luminosity level not less than $10^{29}$ cm$^{-2}$ s$^{-1}$.

NICA’s beams will be available to these experimental areas and facilities:
- 10,000 m$^2$ experimental hall for fixed-target experiments, using slow, extracted beams from the Nuclotron;
- the dedicated experimental hall for applied research on extracted ion beams from the booster;
- the collider of heavy and light polarized ions, equipped with the Multipurpose Detector and the Spin Physics Detector for fundamental research;
- an internal target station in the Nuclotron cryomagnetic system for research, including relativistic atomic physics and spin physics.

NICA’s objectives

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The experimental investigation of stochastic cooling was a component of the recent run. The detectors for this new method and their automatic control systems were developed at the Nuclotron and have been chosen for manufacture and installation on the NICA booster. The system provides monitoring of the statuses of all of its components, as well as signal testing of external systems, and also indicates malfunctions.

These tests were the result of an international team effort: A Sidoren, N Shukhno, G Trubnikov (JINR, Dubna) and R Stassen (IKP FZJ) supervised all stages of the system design and participated in the Nuclotron shifts dedicated to testing and adjusting the equipment. T Katayauma and H Stockhorst (GSI and IKP FZJ) performed simulations of the cooling-process dynamics and experimental measurements. L Thorndahl and P Coqes (CERN) contributed to the design and simulation of RF structures.

Résumé

Le Nuclotron teste le refroidissement stochastique à Doubna

Le projet NICA collabore avec le Nuclotron et le futur projet de l’Institut de recherche nucléaire de Doubna. Outre le Nuclotron actuel, ce complexe accelerateur-collisions inclura un nouvel accelerateur limite d’ions lourds, un synchrocyclotron booster supraconducteur et deux anneaux constituant un collisier supraconducteur. Ainsi que la conception et la construction de ces nouveaux éléments sont en cours, le Nuclotron modernisé est testé, entre autres, pour tester les prototypes des systèmes du collisier et du booster. Une étape particulièrement importante a été la construction, l’installation et l’essai du prototype de système de refroidissement stochastique pour le collisier.

Grigory V Trubnikov, Laboratory of High-Energy Physics, JINR.
Towards a Higgs boson: first steps in an incredible journey

Twenty years ago, in June 1993, ATLAS and CMS received the provisional go-ahead to submit technical proposals. Thus began a difficult but amazing path to last year’s major discovery.

The idea that the tunnel for the future Large Electron–Positron (LEP) collider should be able to house at some time even further in the future a Large Hadron Collider (LHC) was already in the air in the late 1970s. Moreover – thankfully – those leading CERN at the time had the vision to plan for a tunnel with a big enough diameter to allow the eventual installation of such an accelerator. In the broader community, however, enthusiasm for an LHC surfaced for the first time in 1984, promoted in part by members of CERN’s successful proton–antiproton collider experiments and their discovery of the W and Z bosons the previous year (CERN Courier, May 2013 p27). A workshop in Lausanne on the “Large Hadron Collider in the LEP ‘Tunnel’” organized jointly by the European Committee for Future Accelerators (ECFA) and CERN brought together working groups that comprised machine experts, theorists and experimentalists.

With the realization of the great physics potential of an LHC, several motivating workshops and conferences followed where the formidable experimental challenges started to appear manageable, provided that enough R&D work on detectors could be carried out. Highlights of these “LHC experiment preliminaries” were the 1987 Workshop in La Thuile for the so-called “Rubbia Long-Range Planning Committee” and the large Aachen ECFA-LHC Workshop in 1990. Last, in March 1992 the famous conference “Towards the LHC Experimental Programme” took place in Evian-les-Bains, where several proto-collaborations presented their designs in “expressions of interest”. Moreover, CERN’s LHC Detector R&D Committee (DRDC), which reviewed and steered R&D collaborations, greatly stimulated innovative developments in detector technology from the early 1990s.

Designs for a Higgs

The detection of the Standard Model Higgs boson played a particularly important role in the design of the general-purpose experiments. In the region of low mass (114 < m < 150 GeV), the two channels considered particularly suited for unambiguous discovery were the decay to two photons and the decay to two Z bosons, where one or both of the Z bosons could be virtual. Because the natural width of the putative Higgs boson is < 10 MeV, the width of any observable peaks from supersymmetry drove the need for good resolution for jets and missing transverse energy, as well as for almost full 4π calorimetry coverage.

The choice of the field configuration determined the overall design. It was well understood that to stand the best chance of making discoveries at the new “magic” energy scale of the LHC – and in the harsh conditions generated by about a billion pairs of protons interacting every second – would require the invention of new technologies while at the same time pushing existing ones to their limits. In fact, a prevalent saying was: “We know how to build a high-energy, high-luminosity hadron collider – but we don’t have the technology to build a detector for it.” That the general-purpose experiments have worked so marvellously well since the start-up of the LHC is a testament to the difficult technology choices made by the conceivers and the critical decisions made during the construction of these experiments. It is noteworthy that the very same elements mentioned above were crucial in the recent discovery of a Higgs boson.

At the Aachen meeting in 1990, much discussion took place on which detector technologies and field configurations to deploy. At the Evian meeting two years later, four experiment designs were presented: two using toroids and two using high-field solenoids. In the aftermath of this meeting, lively discussions took place in the community on how to continue and possibly join forces. The time remaining was short because the newly formed peer-review committee, the LHC Committee (LHCC), had set a deadline for the submission of the letters of intent (LoI) of 1 October 1992. The designs based on the toroidal configurations merged to form the ATLAS experiment, deploying a superconducting air-core toroid for the measurement of muons, supplemented by a superconducting 2T solenoid to provide the magnetic field for inner tracking and a liquid-argon/lead electromagnetic calorimeter with a novel “accordion” geometry. The two solenoid-based concepts were eventually submitted separately. Although not spelled out explicitly, it was clear to everyone that resources would permit only two general-purpose experiments. It took seven rounds of intense encounters between the experiment teams and the LHCC referees before the committee decided at its 7th meeting on 8–9 June 1993 to recommend provisionally that ATLAS and CMS should proceed to technical proposals, with agreed milestones for further review in November 1993. The CMS design centred on a single large bore, long, high-field superconducting solenoid, together with powerful microstrip-based inner tracking and an electromagnetic calorimeter of novel scintillating crystals.

So, the two general-purpose experiments were launched but the teams could not have foreseen the enormous technical, financial, industrial and human challenges that lay ahead. For the technical proposals, many difficult technology choices now had to be made “for real” for all of the detector components, whereas the LoI had just presented options for many items. This meant, for example, that several large R&D collaborations sometimes had to give up on excellent developments in instrumentation that had been carried out over many years and to find their new place working on the technologies that the experimental collaborations considered best able to deliver the physics. Costs and resources were everywhere constrained, they were recalculated by many years by an expert costs-review committee (called CORE) of the LHCC. It was not easy for many bright physicists to accept that...
LHC experiments

the chosen technology also had to remain affordable.

The years just after the LoI were also the time when the two collaborations grew most rapidly in terms of people and institutes. Finding new collaborators was a high priority on the “to do” list of the spokespersons, who became real frequent flyers, conducting global “grand tours”. These included many trips to far-flung, non-European countries to motivate and invite participation and contributions to the experiments, in parallel (and sometimes even in competition) with CERN’s effort to get non-member state contributions to enable the timely construction of the accelerator. It is during this period that the currently healthy mix of wealthy and less-wealthy countries was established in the two collaborations, clearly placing a value on not only material contributions but also intellectual ones. One important event was the integration of a strong US community after the discontinuation of the Superconducting Super Collider in 1993, which had a notable impact on both ATLAS and CMS in terms of the final capabilities of these experiments.

The submissions of the technical proposals followed in December 1994 and these were approved in 1996. The formal approval for construction was given on 1 July 1997 by the then director-general, Chris Llewellyn Smith, based on the recommendations of the Research Board and the LHCC (by then at meeting number 27) after the first of a long series of Technical Design Reports and the imposing of a material cost ceiling of SwFr475 million. These were also the years when the formal framework was set up by CERN and all of the funding agencies, first in interim and finally via a detailed Construction Memorandum of Understanding, agreed on in the new, biannual Resources Review Boards.

Further reading

For more about this journey in search of a Higgs boson, see “Journey in the Search for the Higgs Boson: The ATLAS and CMS Experiments at the Large Hadron Collider”, M Della Negra, Tejinder Virdee, University of Freiburg and CERN, and Jürgen Herold, Imperial College London, have been involved in the LHC adventure from the beginning, together with many colleagues. They served respectively as spokesperson of ATLAS and deputy-spokesperson then spokesperson of CMS, in the early years of the experiments until 2009.
The original CERN Schools of High-Energy Physics were established in the early 1960s at the initiative of Owen Lock, who played a leading role in their development over the next three decades. The first schools in 1962 and 1963 were one-week events organized at St Cergue in Switzerland, near CERN. However, from 1964 onwards the annual events – by then lasting two weeks – took place in other countries, generally in member states of CERN.

Starting in 1970, every second school was organized jointly with the Joint Institute for Nuclear Research (JINR), CERN’s sister organization in the Soviet Union. This collaboration between East and West, even during the Cold War, exemplified how a common interest in science could bring together people from different nations working in harmony with the common goal of advancing human knowledge.

With the changes in the political scene in Europe, and after discussions and an exchange of letters in 1991 between the directors-general of CERN and JINR, it was agreed that future schools would be organized jointly every year and that the title should change to the European School of High-Energy Physics. In each four-year period, three schools would take place in a CERN member state and the fourth in a JINR member state.

In 1993, a new series of physics schools began in Europe. Organized jointly by CERN and JINR, they have inspired similar ventures in Latin America and Asia.

The target audience for the European Schools is students in experimental high-energy physics who are in the final years of working towards their PhDs. Most of the courses teach theory and phenomenology, concentrating on the physics concepts rather than the details of calculations. This training is highly relevant for the students who will use it in interpreting the results of physics data analysis, e.g. as they complete the work for their PhD theses. Even if experimental physicists do not usually perform advanced theory calculations, it is of great benefit to have a good understanding of the theoretical framework.
European Schools

importance that they can follow and appreciate the published work of their theory colleagues and also have the necessary background to discuss the phenomenology. This last aspect is addressed particularly through the discussion sessions at the schools.

The scientific programme of the European Schools consists of typically four and a half hours of lectures each day (three lectures, each 90 minutes in duration, including questions), complemented by discussion sessions in groups of about 15–20 students with a discussion leader. The programme includes a poster session where many of the students present their own research work to the other participants, including the teachers and organizers. This way, students get to discuss their own work with some of the leading experts in the field.

A new development in the programme since the 2011 school is the inclusion of projects in which the students from each discussion group collaborate as a team to study in detail an experimental data analysis. With this, on top of the rest of the programme, the students say that they have to work really hard; nevertheless they still seem to enjoy the schools a great deal.

The focus of the schools is mainly on subjects closely related to experimental high-energy physics, so there are always core courses on topics such as field-theory and the electroweak Standard Model, quantum chromodynamics, flavour physics and CP violation, neutrino physics, heavy-ion physics and physics beyond the Standard Model. Since 2009 there have also been lectures on practical statistics for particle physicists, which are particularly relevant to the day-to-day work of many of the students.

The core courses are complemented by some more topical lectures, including in recent years the latest results from the LHC and their implications. The programme generally also includes lectures related to cosmology, given the important interplay with particle physics, e.g. in connection with dark matter. But not least the scientific general of CERN and JINR often attend in person and give lectures on the scientific programmes of their respective organizations and their outlook for the coming years; this also gives them an opportunity to meet and discuss informally with some of the most promising young physicists in the field.

The scientific programme, including the choice of subjects to be studied; they then have to organize themselves to share the work with different individuals or sub-groups addressing distinct aspects of the analysis; they have to work as a team to prepare and rehearse a short talk summarizing what they have learnt; and they have to select a speaker to represent them. All of these skills are important for young physicists working in large international collaborations such as those that run the LHC experiments.

Geographical enlargement

The European Schools have served as a model for similar series that are now organized in other parts of the world. Since 2005 there have been schools every two years in Latin America, catering for the growing high-energy-physics community there. The most recent event was held on 6–19 March this year in Arequipa, Peru.

A second new series of schools – the Asia–Europe-Pacific School of High-Energy Physics – started last year (CERN Courier January/February 2013 p45). The first event was held in Japan and the next one is planned for India in 2014. As with the Latin-American Schools, these events will be held every second year, with a programme that is similar to the model of the European Schools.

Thus, the European Schools have inspired other series catering for the needs of young physicists in other parts of the world. This is part of CERN’s policy of geographical enlargement and its mission to support scientists from other parts of the world to increase their participation in high-energy physics in general and their collaboration with CERN in particular.

The European Schools continue to attract a large number of applications from highly qualified candidates, despite the emergence of many other excellent schools that offer alternative training. For example, the 2013 school, which takes place on 5–18 June in Hungary, was oversubscribed by more than a factor of two compared with the target of around 100 students. This implies a rigorous and highly competitive selection process, focusing on students with the most promise for an outstanding career in high-energy physics and who are at the optimum stage in their studies to benefit from the school.

Critical to the success of the schools are the lecturers and discussion leaders who teach there, selected for their qualities as first-class researchers and also as teachers. They come from institutes in many countries, including ones that are not member states of either CERN or JINR. The European Schools have benefited from the strong support, and often the presence as lecturers, of successful directors-general of both CERN and JINR. The organizers are extremely grateful to the many people from the worldwide high-energy-physics community who every year contribute to the success of the schools, a success that can be judged from the positive feedback received from the students who participate.

Further reading

For more about all of the schools, see: http://physicschool.web.cern.ch/PhysicSchool/

Résumé

Formation des jeunes physiciens : 20 ans de succès


Nick Ellis, CERN, current director of CERN Schools of Physics.
Awards

ACFA and IPAC announce accelerator prizes

The Asian Committee for Future Accelerators (ACFA) and the fourth International Particle Accelerator Conference, IPAC’13, have awarded the ACFA/IPAC’13 Accelerator Prizes for outstanding and original contributions to the field. The awards, decided by the Prizes Selection Committee, chaired by Jia-er Chen of the National Natural Science Foundation of China, are to be presented at the conference in Shanghai on 13–17 May. Shouxian Fang of the Institute for High-Energy Physics, Beijing, receives the prize with no age limit for outstanding work in the accelerator field. He led the team that constructed the Beijing Electron–Positron Collider (BEPC), China’s first high-energy accelerator, and has contributed to the Shanghai Synchrotron Radiation Facility, the China Spallation Neutron Source and the Chinese Accelerator-Driven Subcritical System for nuclear-waste transmutation, as well as to proton therapy accelerators and to initiating the major upgrade of BEPC (BEPCII). He has also promoted accelerator-based science in China through extensive international collaboration and built up a solid bridge between China and other parts of the world in the accelerator field.

The prize for an individual with no age limit having made a recent significant, original contribution to the accelerator field, goes to Michael Borland of the Advanced Photon Source, Argonne, for his original contributions in creating the ELEGANT programme and its self-describing data-sets platform. These are widely applied in the design, simulation and analysis of circular accelerators, energy-recovery linacs and free-electron lasers. His algorithms, methods and software have been adopted at many accelerator facilities around the world, and for numerous developments in the field of beam dynamics and non-linear optimizations.

The third prize, for an individual in the early part of his or her career, having made a recent, significant and original contribution to the field, goes to Hiroshi Imao of RIKEN for his realization of the next-generation charge-state stripper using recirculating helium gas. This stripper makes it possible to increase the intensity of uranium-ion beams by an order of magnitude at RIKEN’s Radioactive Isotope Beam Factory and has had immense, worldwide impact on the field of heavy-ion accelerators. He also developed a compact and efficient position accumulator that has led to the successful production of antihydrogen atoms in the ASACUSA experiment at CERN.

Astroparticle Physics

Dark matter on the menu in Münster

The first meeting dedicated exclusively to dark-matter theory and experiment in Germany was held earlier this year at the University of Münster. Made possible through the generous financial support of the Helmholtz Alliance for Astroparticle Physics (HAP), the conference – HAP Dark Matter 2013 – was co-organized by Michael Klauen of Münster and Klaus Eitel of the Karlsruhe Institute of Technology (KIT). The 100 participants included senior German dark-matter scientists, many postdocs and students, as well as experts from neighbouring countries such as Belgium, Denmark, France, the Netherlands, Spain, Sweden, Switzerland and the UK.

The scientific programme aimed at a complete coverage of all aspects related to dark matter and ranged from astronomical observations through experimental searches to theoretical interpretations and tools. As the first speaker, Jürg Diemand of Zurich presented fascinating numerical simulations of galactic structures by the Via Lactea collaboration. Thomas Reiprich of Bonn and Justin Read of Surrey followed up with the prospects for galaxy-cluster cosmology using X-ray telescopes, with determinations of the local dark-matter density from stellar kinematics, while Eva Grebel of Heidelberg gave an overview of dark-matter-dominated dwarf galaxies.

Experimental results were reported from direct searches, for example, with the XENON experiment, described by Christian Weinheimer of Münster; indirect searches with the Fermi Gamma-ray Space Telescope, by Johann Cohen-Tannoudji of Montpellier; and the LHC experiments, by CERN’s Daviderge, CERN. While none of these searches can yet conclusively provide positive evidence, some, as Thomas Schwetz-Marrung of Heidelberg explained, do leave room for speculation on relatively light dark-matter particles. Participants were also curious to see the preparations for the XENON1T experiment, visible during several laboratory tours offered by Ethan Brown of Münster.

With increasing experimental sensitivity and precision, the need for precise theoretical and numerical tools is now evident. This was addressed in talks by Manuel Drees of Bonn and Andreas Hrycyna of Munich on the so-called Sommerfeld enhancement. Full next-to-leading order calculations, presented by Karol Kovarik of KIT, are integrated into programmes such as MEGAGAS and DarkSUSY, described by Geneviève Belanger of Ansercy and Torsten Brügmann of Hamburg, respectively. Whether dark matter is supersymmetric, as discussed by Laura Covi of Göteborg and Béa Brunner of Grenoble, or not, as Steen Haansnaes of Aarhus, Andreas Ringwald of DESY, and many others argued, still has to be decided. This might be possible at a second HAP Dark Matter meeting, which many of the participants eagerly demanded.

For more about HAP Dark Matter 2013, see https://indico.desy.de/event/hap-DM. For more about the Helmholtz Alliance for Astroparticle Physics (HAP), see www.hap-astroparticle.org.

Publishing

Progress bridges experimental and theoretical physics

In 1946, three years before he was to receive the Nobel Prize in Physics for “his prediction of the existence of mesons”, Hideki Yukawa founded the journal Progress of Theoretical Physics. Over the years it published many important articles, mainly in theoretical physics, including several that led to the Nobel prize. Now the journal has taken on a new life, by incorporating experimental physics under the title Progress of Theoretical and Experimental Physics (PTEP).

The new journal, which is a joint venture between Oxford University Press and the Physiological Society of Japan, is fully open access and available only online. Its coverage continues on from its predecessor by including high-energy physics, nuclear physics, astrophysics and cosmology, together with mathematical physics and condensed-matter physics. Now, it also welcomes papers in experimental particle physics, nuclear physics and astrophysics, as well as beam physics, instrumentation and technology. Regular monthly issues began in January 2013, following on from a number of special issues published in 2012. PTEP is an international journal and welcomes the submission of papers from authors around the world, and as a new initiative places strong emphasis on the Letters section. It participates in the Sponsoring Consortium for Open Access Publishing in Particle Physics (SCOAP³) initiative, launched at CERN last October (CERN Courier November 2012). As a result, high-energy physics articles in PTEP will from 2014 be published open access in perpetuity and free of charge.

For more about Progress of Theoretical and Experimental Physics, see http://ptep.oxfordjournals.org.
Henri Cornille 1929–2013

The French theoretical physicist, Henri Cornille, passed away on 23 February, aged 83.

Henri is a typical product of the French education system before 1968, i.e. an elitist system in which someone of modest origin could climb the ladder provided that he was good and courageous. Henri followed the rigorous cycle organized by Maurice Lévy at the École Normale but it was Roger Nataf (who, like Lévy, was from North Africa) at the Institut de Physique Nucléaire, Orsay, who realized that he had real talents. Nataf sent Henri to work with me at CERN, where we had a fruitful collaboration in the fields of potential scattering and high-energy scattering. Our best result, I believe, was the proof that the ratio of the widths of the diffraction peaks for particle–particle scattering and for particle–antiparticle scattering was approaching unity asymptotically. He was also the inventor of the “Cornille plot”, which gives the allowed domain for total and elastic cross-sections when they behave like powers of log s for large energies.

Peter Norton 1945–2013

Peter Norton, a physicist at the Rutherford Appleton Laboratory (RAL) in the UK, passed away on 2 February.

Peter graduated from Jesus College, Oxford, in 1966 and joined Arthur Clegg’s group at Oxford University working at the Rutherford Laboratory (later RAL) to study elementary particle physics for his DPhil. He then joined the Daresbury Laboratory, where he worked on the PEP experiment to study the details of electroproduction experiments done at SLAC in the late 1960s.

In the 1970s, Peter was a founder member of the European Muon Collaboration (EMC) formed to extend the studies of deep-inelastic scattering to the higher energies available at CERN. The purpose of EMC was to probe the quark structure of the nucleon. Peter was responsible for the development of the EMC chambers, which at that time were among the largest chambers ever made. His sharp intellect and ability to spot confused thinking made invaluable contributions to the experiment’s major discoveries of the EMC effect and the spin deficit in the proton.

In the 1980s, he joined the ALEPH collaboration and played a significant role in cementing together a larger UK university involvement in the experiment. This consortium constructed the endcaps of the electromagnetic calorimeter. Peter’s calm approach to the design and testing of the huge modules with his colleague Mike Edwards proved invaluable. Their insistence on maintaining a strict testing regime during construction – despite the enormous time pressures – led to an excellent apparatus that worked flawlessly throughout ALEPH’s lifetime.

Following ALEPH, Peter was involved in the creation of one of the embryonic groups keen to do experiments at the LHC. Realizing the value of naming the experiment with the first letter of the alphabet, he invented “ASCOT”, which later joined “EAGLE” to become the ATLAS collaboration. He was deeply involved in the conception of the experiment and played a significant role in the design of the superconducting toroid-magnet system. Here, he played a pivotal role linking the
The Karlsruhe Institute of Technology (KIT) is the result of a merger of the University Karlsruhe (TH) and the Forschungszentrum Karlsruhe. It is a unique institution in Germany, which combines the missions of a university with those of an internationally renowned research association. With 9,000 employees KIT is one of the largest research and education institutions worldwide.

In the Department of Electrical Engineering and Information Technology of the Karlsruhe Institute of Technology the Professorship (W3) for Detector Technology and ASIC Design combined with the position of a Founding Director of the KIT ASIC and Detector Laboratory is to be filled as soon as possible. The position is located at the Institute for Data Processing and Electronics.

We are looking for distinguished scientists with outstanding scientific credentials, experience in leading scientific groups and excellent didactical skills. Experience in the instrumentation of large-scale research experiments is an advantage.

Applicants should have experience in several of the following fields:

- Highly integrated mixed-signal CMOS technologies
- Monolithic Active Pixel Sensors (MAPS) or alternative sensor concepts
- 3D integration and packaging and interconnect technologies for detector instrumentation
- Applications of the aforementioned technologies in large-scale experiments of particle astrophysics, particle physics, in the research with photons, neutrons and ions as well as in optics and photonics, medical imaging etc.

The appointee will build-up the ASIC and Detector Laboratory and boost the development of innovative detector technologies. He/She will also be asked to draw on the infrastructure of the institute, in particular the clean-room with its technological facilities, workshops and the CAD-design office. The position offers an excellent research environment with many cooperation opportunities for collaboration within the department and other structures of KIT. This includes the KIT Center of Elementary Particle Physics and Astroparticle Physics (KCEPA) and the DFG graduate school KSEFA, participation in the programs of the Helmholtz Association and committed collaboration with the partners of the Helmholtz Portfolio “Detector Technologies and Systems Platform” (Helmholtz Centers, Universities and international institutions). Participation in the lecture courses of the department is expected. The appointee is responsible for the design and implementation of new detector systems as well as for the supervision and development of master’s and doctoral students.

Applicants must have the degree of habilitation or demonstrate equivalent scientific qualifications as well as experience in management.

KIT aims to increase the number of female professors and especially welcomes applications from women. Handicapped persons with equal qualifications will be preferred.

Applications including CV, list of publications, summary of scientific credentials, experience in leading scientific groups and detailed information about the appointment should be sent to the Director of the Department of Electrical Engineering and Information Technology, Karlsruhe Institute of Technology (KIT), Campus South, 76128 Karlsruhe.

Please contact Jürgen Weise at +49 721 608-3413, e-mail: jweise@kit.edu or visit www.kit.edu for further information.

CERN Courier June 2013
Callach’s High Energy Physics group has a long-standing involvement in the design and development of the computing models in use in the LHC community. In parallel, the group has been pioneering the use of high-speed optical networks for HEP data analysis. Today, we have an opening for an experienced software development engineer to work on integration of advanced networking concepts with the scientific data and workflow management. The new team member will contribute to the development of software related to the use of dynamic circuit networks and pervasive monitoring systems in the software stack of the CMS experiment.

The project is being carried out in collaboration with partner institutes in the CMS and ATLAS experiments; this position is based at CERN, Switzerland.

**Job Duties:**
- Software development in the framework of the CMS data/workflow management
- Development of algorithms leveraging dynamic circuit APIs work enhancing workflow efficiency
- Integration of network monitoring services (pHSCONAR, MonALISA) into data management
- Active participation in collaborations with partner institutes and networks worldwide
- Other duties as assigned.

For full details please go to: www. Jobs.caltech.edu and search for position number 130173

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, Minorities, Veterans and Disabled Persons are encouraged to apply.
Consortium for Construction, Equipment and Exploitation of the Synchrotron Light Laboratory

Head of the Engineering Division of Alba

INSTITUTION
CELLS, the consortium for Construction, Equipment and Exploitation of the Synchrotron Light Laboratory ALBA, is jointly funded by the Spanish State Government and the Generalitat de Catalunya (Catalan Autonomous Government).

ALBA is a 3 GeV low emittance state-of-the-art third generation Synchrotron Light Facility located in Cerdanyola del Vallès near Barcelona. The facility is open to external users with seven Beam Lines. Alba is organized in five Divisions one of them devoted to engineering aspects of the facility.

FUNCTIONS
The successful candidate will take responsibility for the Engineering Division, which provides technical support in design, construction and operation activities of the Consortium. At present the areas of expertise in the facility are civil and mechanical engineering, vacuum, cryogenics, survey and alignment, maintenance and energy supplies.

The Head of Engineering Division reports to the Director of the facility and is a member of the CELLS Management Board. As such is strongly involved in running the laboratory and formulate proposals for the Division annual budgets and staffing plans.

QUALIFICATIONS
• Education: High level university degree in engineering, physics or equivalent.
• 10 years minimum experience in project management in large scientific or technological infrastructures. Experience in accelerator laboratories will be appreciated.
• 5 years minimum experience in the management of human resources teams on the fields mentioned above.
• Recognized leadership, communication and interpersonal skills.
• Adaptability to an international and multidisciplinary environment.
• Sense of responsibility and demonstrated ability to work independently or as a member of a team.
• Good knowledge of English.
• Basic knowledge of Spanish or Catalan or an undertaking to acquire it rapidly.

Contact
Applications shall be submitted by CELLS web application before June 15th 2013, 24:00 local time to:
http://www.cells.es/jobs/InfoOfficer/ViewJob/Division/Engineering

Associate Laboratory Director
Stanford Synchrotron Radiation Lightsource

The SLAC National Accelerator Laboratory, at Stanford University, is seeking applications for the position of Director of Stanford Synchrotron Radiation Lightsource (SSRL).

Reporting to the Laboratory Director, the Associate Laboratory Director (ALD) will lead a world renowned laboratory, producing extremely bright X-rays used to study our world at the atomic and molecular level. SSRL enables research that benefits every sector of the American economy and leads to major advances in energy production, environmental remediation, nanotechnology, new materials and medicine. SSRL also provides unique educational experiences and serves as a vital training ground for students in the sciences. Partnering with companies in industry, SSRL instruments help bring discoveries and innovations from theory to reality. Nobel prizes have been awarded for research carried out, in part, at SLAC’s SSRRL.

The SSRL ALD will be an internationally recognized Scientist with established leadership credentials, strategic thinking and execution skills, excellent communication skills, commitment to excellence and capability to expand the capacities of SLAC’s pioneering synchrotron facilities. The Director will serve on SLAC’s Executive Council, lead a directorate of accomplished scientists and administrators, serve as advisor to the Lab Director, as well as to national and international committees, represent SLAC and the Lab Director in communications with congress, DOE, private industry, local government and citizen groups and Stanford University. The successful candidate is expected to assume a tenured position on the SLAC Faculty.

SLAC, one of the world’s leading research laboratories, is a U.S. Department of Energy, Office of Science multi-program laboratory operated by Stanford University for 50 years.

For additional information or to be considered for candidacy please contact/send application materials to: Lisa Mongetta, Manager, SLAC Staffing Services 2575 Sand Hill Road, Menlo Park, CA 94025 650-926-2733 email: mongetta@slac.stanford.edu

The SLAC National Accelerator Laboratory values diversity and is an Affirmative Action, Equal Opportunity Employer.
Lectures on Quantum Mechanics
By Steven Weinberg
Cambridge University Press
This is a beautifully written book that is crafted with precision and is full of insight. However, this is for most people not the book from which to learn quantum mechanics for the first time. The cover notes acknowledge this and the book is advertised as being “ideally suited to a one-year graduate course” and “is useful for reference for researchers.” That is not to say that it deals only with advanced material – the theory is built up from scratch and the logical structure is quite traditional.

The book starts with a careful exposition of the early history and the Schrödinger-equation analysis of the hydrogen atom and the harmonic oscillator, before moving on to cover the general principles, angular momentum and symmetries. The middle part of the book is concerned with approximate methods and develops the theory starting from time-independent perturbations and ending with the general theory of scattering. The final part deals mainly with the canonical formalism and the behaviour of a charged particle in an electromagnetic field, including the quantization of the field and the emergence of photons. The final chapter covers the Zeeman effect and in atomic selection rules, the role of the Wigner-Eckhart theorem in a proper appreciation of the spectrum, the role of the Wigner-Eckhart theorem in a proper appreciation of the spectrum, the role of the Wigner-Eckhart theorem in a proper appreciation of the spectrum, the role of the Wigner-Eckhart theorem in a proper appreciation of the spectrum, the role of the Wigner-Eckhart theorem in a proper appreciation of the spectrum, the role of the Wigner-Eckhart theorem in a proper appreciation of the spectrum.

The book offers a refreshing mix of basic facts and up-to-date research, and avoids giving too much space to formal and relatively boring subjects such as the quantization of the bosonic string. Rather, the main focus is on the construction and properties of the various string theories in 10 dimensions and their compactifications to lower dimensions; it also includes thorough discussions of D-branes, fluxes and dualities. A particular emphasis is given to the two-dimensional world-sheet, or conformal field-theoretical point of view, which is more “stringy” than the popular supergravity approach. Filling this important gap is one of the strengths of this book, which sets it apart from other recent, similar books.

This is in line with the general focus of the book, namely the unification aspect of string theory, whose main aim is to explain, or at least describe, all known particles and interactions in one consistent framework. In recent years, additional aspects of string theory have been become increasingly popular and important lines of research, including the anti-de-Sitter/conformal-field-theory (AdS/CFT) correspondence and the quantum properties of black holes. The book barely touches on these subjects, which is wise because even the basic material would be more than enough for the whole book. For these subjects, a second volume may be in order.

In all, this book is a perfect guide for someone with some moderate prior exposure to field and string theory, who gets to like the principles and technical details of string model construction. It is a valuable addition to the literature.
Inside (photo)story

Pictures from a laboratory

In September, amateur and professional photographers had the opportunity to explore particle-physics laboratories around the world in the second Particle Physics Photowalk.

For the second Global Particle Physics Photowalk, 10 of the world’s leading particle-physics laboratories offered rare, behind-the-scenes access to their scientific facilities to hundreds of photographers. The participating laboratories then made their selections, nominating 10 photographs to be judged separately by an international jury – photographers Stanley Greenberg from the US, Roy Robertson from the UK, Andrew Haw from Canada and Luca Casonato from Italy – as well as by a “people’s choice” of more than 1250 photography enthusiasts who voted online.

The photographs shown here are the winners of the two competitions: one chosen by the jury (bottom) and one by the “people’s choice” (top). Italy took top honours in both competitions among a strong field. The top 39 photographs, including the six winners of both competitions, are now available online at www.flickr.com/photos/interactions_photos/set/721576271515630871.

This second Particle Physics Photowalk was organized by the InterActions Collaboration, whose members represent particle-physics laboratories in Asia, North America and Europe. The first such event was organized in 2010 (CERN Courier December 2010 p28).

The participating Particle Physics Photowalk laboratories were: Brookhaven National Laboratory (US), Catania National Laboratory (Italy), Chilbolton Observatory (UK), Daresbury Laboratory (UK), Fermi National Accelerator Laboratory (US), Frascati National Laboratory (Italy), Gran Sasso National Laboratory (Italy), Rutherford Appleton Laboratory (UK), TRIUMF (Canada) and the UK Astronomy Technology Centre.

Winner of the People's Choice Competition, this image shows an access tunnel connecting the experiment caverns of the Gran Sasso National Laboratory of the Italian Institute for Nuclear Physics (INFN). (Image credit: Nino Bruno.)

Winner of the Jury Competition, this image shows colourful close-up detail of the KLOE detector at INFN’s Frascati National Laboratory. (Image credit: Joseph Paul Boccio.)
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