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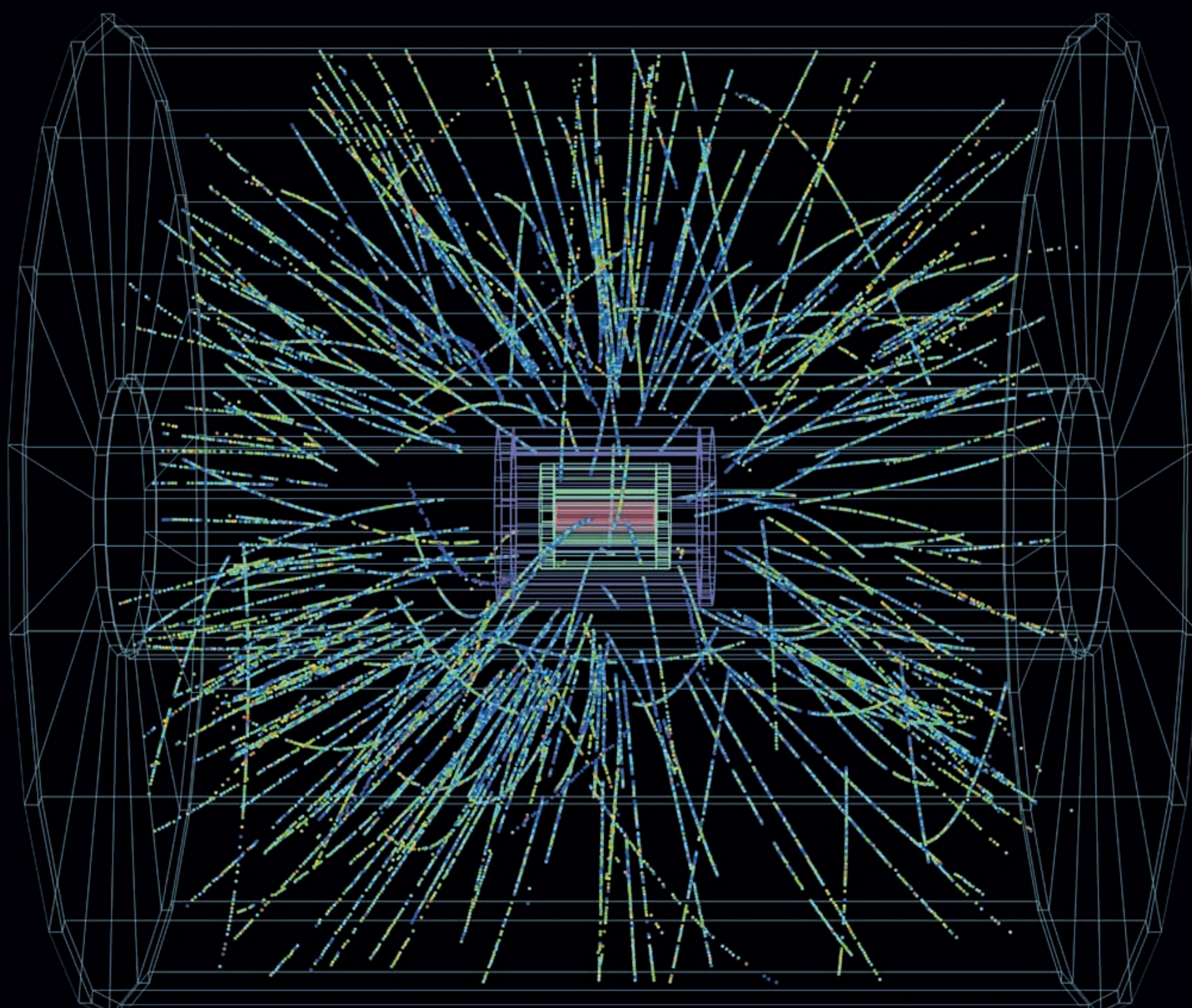

Proton–ion collisions at the LHC

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SLAC

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Europe's future in particle physics **p50**

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Covering current developments in high-energy physics and related fields worldwide

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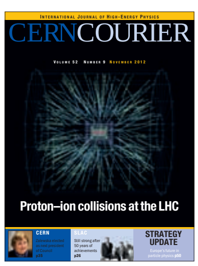


On the cover: Collisions between protons and lead ions in the LHC, recorded by the ALICE experiment. This new mode of running the LHC (p6) will provide benchmarks for studies with lead–lead collisions and also access other physics (p8).

News

CERN

Linac4 parts arrive from near and far

After a journey from Siberia of more than 13,000 km, a special delivery arrived at CERN on 14 September, bringing modules for Linac4, the new four-stage injector being built for the laboratory's accelerator complex. A month earlier, the first major accelerating stage had made a shorter journey. Built entirely at CERN and designed in collaboration with CEA Saclay, the radio-frequency quadrupole (RFQ) was installed at the accelerator test stand in Building 152.

Linac4, which is the fourth hadron linac to be built at CERN, is set to replace Linac2 in 2017/2018 as the new first link in the acceleration chain for the LHC. Its four accelerating structures will increase the beam energy successively to 3 MeV, 50 MeV and 102 MeV before finally reaching 160 MeV. By accelerating hydrogen ions (H^-) instead of protons, Linac4 will bring several advantages. The use of H^- will enable injection into the PS Booster with essentially no losses and the increase in beam energy will allow a doubling of the maximum intensity from the Booster for the same emittance (*CERN Courier* September 2012 p33).

The 3-m-long RFQ will accelerate the beam from 45 keV to 3 MeV, directly from the source. The RF field not only accelerates the particles but also bunches them and provides longitudinal and transverse focusing, thereby defining the beam characteristics and the quality for the entire accelerator chain. The Linac4 team is currently performing the RF tuning of the RFQ cavity, while the ion source, which will provide protons for the tests, is being installed and connected. Once both of these steps have been completed, the team will begin testing the RFQ with beam.

The delivery from Siberia consisted of the first two of seven modules for a cell-coupled drift-tube linac (CCDTL). The first of its kind to be used in an accelerator, it will provide the energy increase from 50 MeV to 102 MeV. Weighing 2 tonnes each, the modules were disassembled into six components for transportation. Once at CERN, a visiting Russian team reassembled the modules before carrying out a series of tests. They repeated vacuum tests performed before the modules began their journey and made checks of radio-frequency properties and the alignment of the modules on their supports. Two further modules are due for delivery to CERN in December, while the final three will follow early next year.

Top: Final module assembly of the RQF takes place (left) before delivery to the new Linac4 test stand (right). Bottom: After arrival from Siberia, components for the CCDTL modules are inspected (left) before reassembly (right).

The seven CCDTL modules took two and a half years to produce and were made entirely by a team outside CERN. The modules are the result of six years of close collaboration between two Russian research institutes: the All-Russian Institute of Technical Physics in Snezhinsk and the Budker Institute of Nuclear Physics in Novosibirsk, located in south-western and central Siberia. The collaboration was made possible by support from the International Science and Technology Centre, an intergovernmental organization set up in 1992 to help former weapons scientists redirect their skills towards peaceful activities.

● To keep up to date with news on the LHC, Linac4 and other developments, see *The Bulletin*, http://bulletin.cern.ch.

Sommaire en français

News

LHC NEWS

Celebrations, challenges and business as usual

Some of the members of the ion team celebrate proton–ion collisions in the CERN control centre, but the road to success is not always easy.

Champagne corks popped on 13 September as the LHC confirmed its potential as a multipurpose machine and successfully switched to a new running mode with proton–ion collisions. This achievement marked the first test with colliding beams in this mode, in preparation for the planned four-week proton–ion run in 2013.

Even though the LHC does not change magnetically, proton–ion operation is a challenge for the LHC RF system and its synchronization with the Super Proton Synchrotron. The proton and ion beams are injected and ramped with different RF frequencies; they then need to be re-phased and locked to provide a stable collision point. Despite a 36-hour break to repair a vacuum leak on one of the LHC wire scanners, the tests went well and the first 4 TeV proton–lead collisions were successfully recorded by the LHC experiments – an outstanding achievement for all of the teams involved (see cover and p8).

A day later, the machine's repertoire was extended further to collide "unsqueezed" proton beams at a β^* of 1000 m (a measure of the envelope of the beam oscillations) at Points 1 and 5. This is to allow the ALFA and TOTEM experiments, co-located with ATLAS and CMS respectively, to probe proton–proton scattering at low angles (p7). The tests were followed by a return to routine proton–proton collisions, with the integrated luminosity for the year passing 15 fb^{-1} in both ATLAS and CMS.

A five-day technical stop – the third this year – began on 17 September for scheduled maintenance and consolidation of systems, but with two out-of-the-ordinary interventions. These involved the replacement of the mirrors and supports of the beam synchrotron light monitors (BSRTs) and the replacement of one of the fast-pulsed kicker magnets used to inject the beam. The BSRTs had been put out of operation because of deformations caused by beam-induced heating. The injection magnets have also suffered from this heating, and waiting for them to cool down can delay the injection process by hours.

In total there are eight injection magnets in the machine. The "hottest" of these was replaced during the technical stop with a new version of the magnet with improved measures to reduce impedance. The LHC will gain some running time from this intervention, which will also allow the new design to be checked under operational conditions. The replacement of the injection magnet was carefully planned and executed successfully in four and a half days, requiring round-the-clock work from all of the teams involved.

It is always challenging to restart after a technical stop, with debugging, testing and requalification of all critical systems. A number of technical problems affected this recovery, which was further slowed down by the need to re-establish good vacuum conditions in the newly installed injection magnet. Once the so-called vacuum "scrubbing" was complete, the normal ramp-up in the number of bunches in the machine took place and nominal conditions were re-established on 30 September.

Despite the rocky restart, the LHC made a good recovery. On 6 October, an integrated luminosity of 286 pb^{-1} was delivered to the ATLAS and CMS experiments in the space of only 24 hours – a new record.

PUBLISHING

Peer-reviewed particle physics for all

A new initiative to provide open access to peer-reviewed particle physics research literature was launched at CERN on 1 October by the Sponsoring Consortium for Open Access Publishing in Particle Physics – SCOAP^3. Open dissemination of preprints has been the norm in particle physics for two decades but this initiative now brings the peer-review service provided by journals into the open-access domain.

In the SCOAP^3 model, funding agencies, research institutions, libraries and library consortia pool resources that are currently used to subscribe to journal content and they use them to support the peer-review system directly. Publishers then make electronic versions of their journals open access. Articles funded by SCOAP^3 will be available under a Creative Commons, CC BY licence, meaning that they can be copied, distributed, transmitted and adapted as needed, with proper attribution.

Representatives from the science-funding agencies and library communities of 29 countries were present at the launch. The publishers of 12 journals, accounting for the vast majority of articles in particle physics, have been identified for participation in SCOAP^3 through an open and competitive process. With a projected SCOAP^3 budget of SwFr36 million over three years, more partnerships with key institutions in Europe, America and Asia are foreseen as the initiative moves through the technical steps of organizing the re-direction of funds from the current subscription model towards a common internationally co-ordinated fund. SCOAP^3 expects to be operational for articles published as of 2014.

● For more information, see http://scoap3.org/.

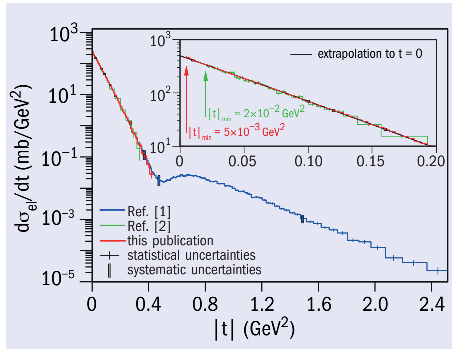
LHC PHYSICS

TOTEM extends study of elastic scattering

A year after publishing first results on proton–proton elastic scattering at a centre-of-mass energy of 7 TeV at the LHC, the TOTEM collaboration now has new measurements based on the analysis of data collected in October 2011. These latest results extend the measurement of the differential elastic cross-section to smaller values of |t|, the four-momentum transfer squared. They also allow a new determination of the elastic and total proton–proton (pp) cross-sections.

TOTEM, which stands for "TOTal cross-section, Elastic scattering and diffraction dissociation Measurement", is optimized for making precise measurements of particles that emerge from collisions in the forward direction, close to the direction of the LHC beams. This allows it to probe physics that is not easily accessed by other LHC experiments, in particular elastic pp scattering down to small values of |t|. It detects protons scattered at small angles by using silicon detectors in Roman Pots – movable insertions in the beam pipe that allow the detectors to be brought closer to the beam (*CERN Courier* September 2009 p19).

The first measurement of the differential elastic cross-section dσ/dt by TOTEM covered a range $0.36 < |t| < 2.5\,GeV^2$, revealing features similar to those first observed at CERN's Intersecting Storage Rings in the 1970s: a peak at low |t| with an exponential decrease leading to a pronounced dip, followed by a rounded peak that falls away as a power law (*CERN Courier* October 2011 p37). With the data taken in 2011, the collaboration has now extended the measurements down to $0.005\,GeV^2$ – corresponding to scattering angles of some 20 μrad – enabling



The elastic differential cross-section measurements by TOTEM. Each measurement is shown in a different colour. The insert enlarges the region used for extrapolation to t = 0, showing the lowest |t| values accessible in a previous analysis (green) and the latest analysis (red).

the observation of 91% of the elastic cross-section and further exploration of the exponential slope of dσ/dt at small |t|.

For these measurements, the Roman Pot detectors had to approach close to the beam centre – to a distance of around five times the transverse size of the beam – during a dedicated run in which the LHC beams were deliberately left relatively wide and straight as they collided, rather than being "squeezed" for maximum luminosity. This involved running the LHC with magnet settings such that the β function, which describes the envelope of the beam oscillations, had a value of β^* – the distance to the point where the beam is twice as wide as at the interaction point – of 90 m.

The results show that the slope of dσ/dt remains constant down to $0.005\,GeV^2$, so that an exponential fit with only one constant $B = (19.9\pm0.3)\,GeV^{-2}$ describes all of the range $0.005 < |t| < 0.2\,GeV^2$ (TOTEM collaboration 2012). The small error on B – a result of the high precision of the measurement and the large range of the fit – allows a precise extrapolation over the non-visible cross-section (the remaining 9%) to t = 0. Taken with the luminosity measured by the CMS experiment at the same interaction point, this gives an elastic pp cross-section of 25.4±1.1 mb at a centre-of-mass energy of 7 TeV and, using the optical theorem, yields a value for the total pp cross-section of 98.6±2.2 mb. In addition, the difference between the total and elastic cross-sections gives a precise indirect measurement of the fully inclusive inelastic cross-section, with no dependence on Monte Carlo models, notably in the low-mass extrapolation region.

The measurements are being repeated this year at a centre-of-mass energy of 8 TeV. In addition, the machine optics for a still larger β^* of 500–1000 m is being developed, which will enable TOTEM to reach a value of |t| as small as $0.0005\,GeV^2$. This is where the Coulomb and hadronic contributions to the differential cross-sections are about equal, allowing the study of Coulomb-hadronic interference and the determination of the ρ parameter (the ratio of the real to imaginary part of the forward hadronic scattering amplitude). The collaboration is also studying the possibilities for measurements of pp elastic scattering at high values of |t| because these could reveal further diffractive minima, as predicted by some models.

● Further reading

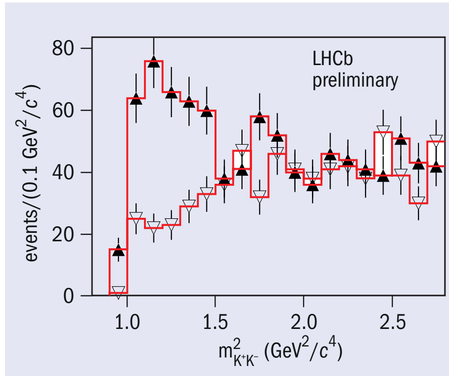
The TOTEM collaboration 2011a *EPL* **95** 41001.
The TOTEM collaboration 2011b *EPL* **96** 21002.
The TOTEM collaboration 2012 CERN-PH-EP-2012–239.

Large CP-violation effects appear in three-body B decays

One of the interesting ways to search for CP violation in B-meson decays is by using three-body decays of charged B mesons, i.e. $B^+ \to K^+K^-K^+$, $K^+\pi^-\pi^+$, $K^+K^-\pi^+$ and $\pi^+\pi^-\pi^+$ (and the charge-conjugated modes). In the 1.0 fb^{-1} of data accumulated in 2011, LHCb already recorded samples of these decays that are an order of magnitude larger than those available to previous experiments. The first studies of the $K^+K^-K^+$ and $K^+\pi^-\pi^+$ decays were presented by the collaboration at the 2012 International Conference on High-Energy Physics in July, revealing evidence of large CP-violation effects (LHCb 2012a). Now, at the 7th International Workshop on the CKM Unitarity Triangle, held at the end of September, LHCb has complemented these with results from the rarer decays to $K^+K^-\pi^+$ and $\pi^+\pi^-\pi^+$, finding evidence of even larger CP violation (LHCb 2012b).

While the inclusive CP asymmetries (which are integrated over the entire phase space, or the Dalitz plots, of the three-body decays) show evidence of CP violation, more pronounced effects are visible when looking at the variation of the effect in different regions. The LHCb analyses have used model-independent approaches – based on binning the Dalitz plot – to explore the local asymmetries.

A remarkable feature of the new results is that the CP-violation effects appear to arise in regions of the Dalitz plots that are not dominated by contributions from narrow resonances. For example, previously the BaBar collaboration observed a broad feature at low values of the K^+K^- invariant mass in $B^\pm \to K^+K^-\pi^\pm$ decays (Aubert *et al.* 2007); in the LHCb data, this appears to be present only in B^+ decays, as the figure shows, indicating direct CP violation in these decays.



B^+ (filled triangles) and B^- (open triangles) event-yields for $B^\pm \to K^+K^-\pi^\pm$ candidates, including both signal and background, as a function of the K^+K^- invariant-mass squared.

This points to some interesting hadronic dynamics that must generate the strong (CP conserving) phase difference that is necessary for direct CP violation to emerge.

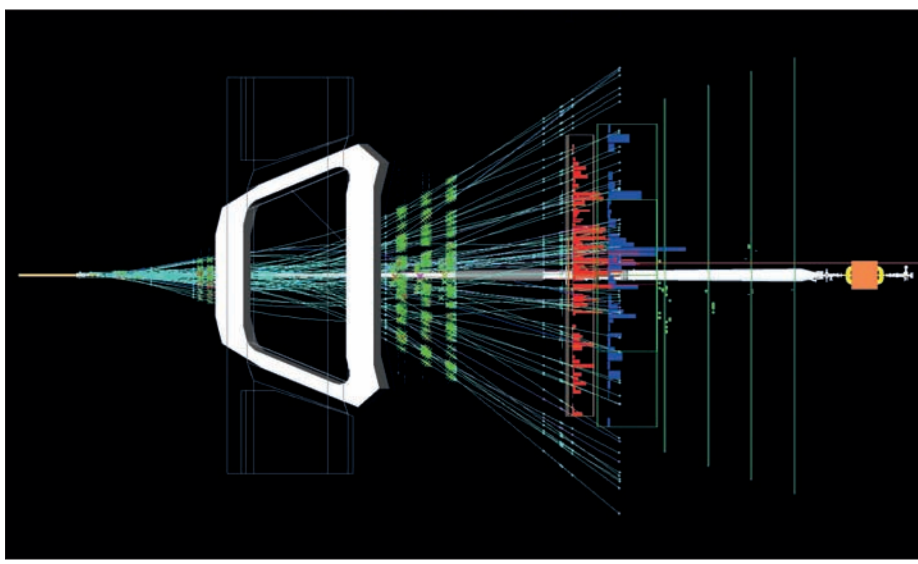
To understand these effects further, the LHCb collaboration is now starting detailed studies of these channels and will also exploit the larger data sample that will be available after the 2012 running. The results from these analyses will also establish whether the observed CP violation is consistent with the expectations of the Standard Model or whether it has a more exotic origin.

Further reading

B Aubert *et al.* BaBar collaboration 2007 *Phys. Rev. Lett.* **99** 221801.
LHCb 2012a LHCb-CONF-2012–018.
LHCb 2012b LHCb-CONF-2012–028.

Successful test of proton–ion collisions in LHCb

Unlike the other three large experiments at the LHC, LHCb did not participate in heavy-ion runs in 2010 and 2011. This was because the forward region covered by the experiment, which corresponds to angles below 20° with respect to the beam axis, has been optimized for the study of heavy quarks in the proton–proton (pp) collisions that the LHC provides for most of the year. In the usual heavy-ion environment, i.e. the collisions of two lead-ion beams (PbPb), the density of tracks in this region would be so high that LHCb's tracking detectors would be saturated with hits. However, the decision to run with proton–lead-ion (pPb) collisions for the next heavy-ion run opened the door for LHCb to participate, as the track occupancies would to be more similar to the usual pp running.



Event display of a proton–lead event in the LHCb detector, showing the reconstructed tracks of particles produced in the collision. The proton beam travels from left to right.

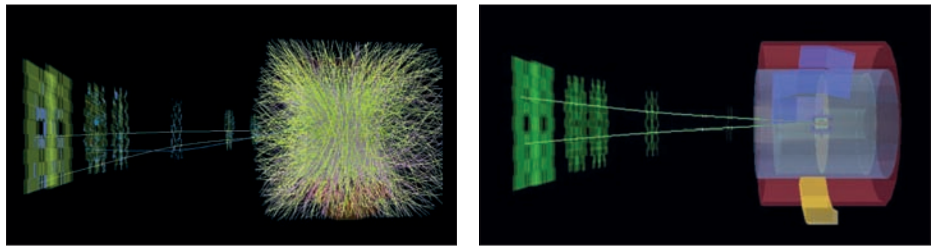
In the recent test of this mode of operating the LHC, collisions were provided for a few hours in the early morning of 13 September (p6). The LHCb detector worked perfectly during the test, as the figure shows, and it was exciting for the LHCb team to see this new category of events being recorded. The data were analysed quickly and clean signals were reconstructed for decays of K_S and Λ decays (long-lived particles containing the strange quark). The signals were found to be even cleaner than equivalent ones extracted from pp data. This was to some extent expected, because the luminosity was low during the test run, so there were only single primary pPb interactions, whereas in pp running there may be four or more primary interactions in the same event in LHCb. However, once the signals had been normalized to the number of primary vertices, there still remained a factor of three or so enhancement in the pPb data compared with pp.

This is a first indication of the interesting physics that can be studied in the full pPb run, currently scheduled for early in 2013. With its high-precision vertex reconstruction and powerful particle-identification capabilities, the LHCb experiment should provide extra information to complement the measurements from the other experiments. In particular, the production rates of heavy-flavour states such as the J/ψ and Υ, or charmed particles, will be of interest in the forward region.

Using the LHC as a photon collider

The protons and nuclei accelerated by the LHC are surrounded by strong electric and magnetic fields. These fields can be treated as an equivalent flux of photons, making the LHC the world's most powerful collider not only for protons and lead ions but also for photon–photon and photon–hadron collisions (*CERN Courier* October 2007). This is particularly so for beams of multiply charged heavy-ions, where the number of photons is enhanced by almost four orders of magnitude compared with the singly charged protons (the photon flux is proportional to the square of the ion charge).

The ALICE collaboration has recently taken advantage of this effect in a study of coherent photoproduction of J/ψ mesons in lead–lead (PbPb) collisions. The J/ψ is detected through its dimuon decay in the muon arm of the ALICE detector, which also provides the trigger for these events. The relevant collisions typically occur at impact parameters of several tens of femtometres, which is well beyond the range of the strong force, so the nuclei usually remain intact and continue down the beam pipe. The photonuclear origin of the J/ψ is therefore ensured by requiring that the detector is void of other particles, that there is only one positive and one negative muon candidate, and that the J/ψ has very low transverse momentum, etc. The appearance of these events (see figure) stands in sharp contrast to central heavy-ion collisions, where thousands of particles are produced.



J/ψ candidates in a central PbPb collision (left) and in an ultra-peripheral collision (right).

These interactions carry an interesting message about the partonic substructure of heavy nuclei. Exclusive photoproduction of heavy vector mesons is believed to be a good probe of the nuclear gluon distribution. The cross-section measured in a heavy-ion collision Pb+Pb → Pb+Pb+J/ψ is a convolution of the equivalent photon spectrum with the photonuclear cross-section for γ+Pb → J/ψ+Pb. The latter process can be modelled as the colourless exchange of two gluons.

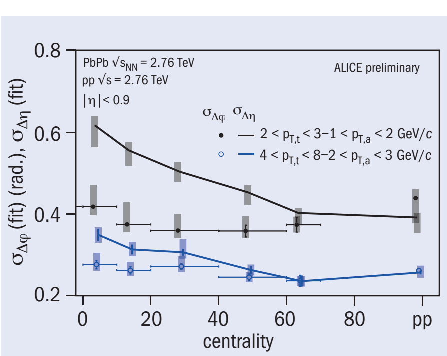
At the rapidities (y around 3) studied in ALICE, J/ψ photoproduction is sensitive mainly to the gluon distribution at values of Bjorken-x of about 10^{-2}. Although the experimental error is rather large, the conclusion from ALICE is that the data favour models that include strong modifications to the nuclear gluon distribution, known as nuclear shadowing.

● Further reading

B Abelev *et al.* (ALICE collaboration) 2012 arXiv:1209.3715, submitted to *Phys. Lett. B*.

Correction

In the article "Heavy-ion jets go with the flow" (*CERN Courier* September p7), figure 2 was misprinted. The correct figure is reproduced below.



σ of the near-side peak in Δφ (data points) and Δη (lines) as a function of centrality for two different p_T bins (the rightmost point shows the result for pp collisions).

ALICE takes a first look at diffraction

Diffractive processes represent more than 25% of the cross-section for inelastic proton–proton collisions at the LHC. So, it is only natural that the ALICE collaboration is interested in a field that started with optical phenomena but which today provides access to non-perturbative QCD processes, at the heart of ALICE's scientific programme. There are also practical reasons that diffraction cannot be ignored, for instance, when normalizing data to specific event classes such as non-single diffractive (NSD) or inelastic (INEL), or when measuring precisely the proton–proton inelastic cross-section, which is used by ALICE as input for model calculations to determine the number of nucleon–nucleon binary collisions in heavy-ion collisions.

Diffractive reactions in particle physics are characterized by an exchange that has the quantum numbers of the vacuum – the pomeron – and leaves a "rapidity gap", devoid of particles. Experimentally, there is no possibility to distinguish large rapidity gaps caused by pomeron exchange from those caused by other colour-neutral exchanges (e.g. secondary Reggeons). The ALICE collaboration therefore used the occurrence of large rapidity gaps as definition of diffraction (figure 1). Single Diffraction (SD) processes are those that have a large gap in rapidity from the leading proton, limited by the value of the diffracted mass $M_X < 200\,GeV/c^2$ on the other side; other inelastic events are considered NSD events. Double diffraction (DD) processes are defined as NSD events with a gap in pseudorapidity, $\Delta\eta > 3$.

ALICE profited from particularly favourable circumstances in its study of diffraction: a detector sensitive to particles with low transverse-momentum, down to about 20 MeV/*c*; data taken with low luminosity so that corrections for event overlap in the same proton bunch-crossing are small; and above all, the presence in the collaboration of Martin Poghosyan, a developer of diffraction models and a former co-worker of the late Aleksei Kaidalov, which gave ALICE privileged access to the details of the Kaidalov-Poghosyan (KP) model.

The challenge was to study diffraction while being unable to observe either the non-diffracted proton or events in which the diffracted system escapes the acceptance of the detector. Nevertheless, the ALICE detectors cover a sufficient range in pseudorapidity (8.8 units, from –3.7 to 5.1, for collisions at the origin of the co-ordinate system) to have ample sensitivity to the SD and DD processes. Two independent observables were identified that are sensitive to diffraction: the ratio of the numbers of SD-like (activity on one side of the detector only) to NSD-like (activity on both sides of the detector) events; and the width distribution of the pseudorapidity gap for events of NSD type.

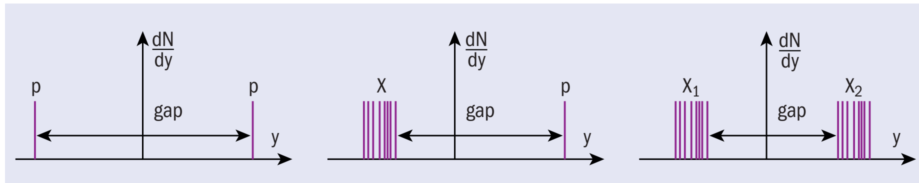


Fig. 1. Schematic rapidity (y) distribution of outgoing particles in elastic (left), single-diffraction (middle) and double-diffraction (right) events, illustrating the typical rapidity-gap topology.

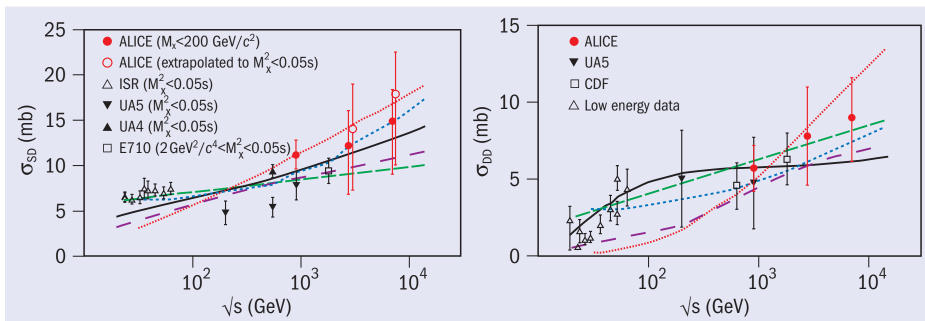


Fig. 2. Single- and double-diffraction ($\Delta\eta > 3$) proton–proton and proton–antiproton cross-sections, left and right, respectively, as a function of centre-of-mass energy, compared with current models: Gotsman et al. *(short, dot-dashed blue line), Goulianos (dashed green line), Kaidalov-Poghosyan (solid black line), Ostapchenko (long, dot-dashed pink line) and Ryskin* et al. *(dotted red line).*

Obtaining the relative rates of diffractive processes from these two observables required the use of a model, so ALICE chose the KP model to estimate the fraction of unseen events. In practice, the diffracted-mass distribution is the sole relatively unknown parameter – the kinematics of diffractive collisions and the fragmentation of the diffracted system are known with sufficient precision. Experimental data and recent models that include higher-order pomeron terms show that the variation of the diffracted-mass distribution with centre-of-mass energy is slow, which gives confidence that extrapolation to LHC energies does not add a large uncertainty.

The sensitivity to models was studied by considering different models for the diffracted-mass distribution. The systematic error was obtained from extreme cases, varying the KP model by a factor of ±50% at the low-mass threshold and using the Donnachie-Landshoff model as the other limit. A van der Meer scan of the transverse profiles of the beams provided the luminosity L. The simulation needed to be adjusted using the KP model and the observed relative rate of diffraction to determine the acceptance and efficiency factor, A, in the measurement of the trigger rate, R(t), so that the inelastic cross-section, σ_{INEL}, could be determined, using $R(t) = A \times \sigma_{INEL} \times L$. Combining the relative rates of diffractive processes with inelastic cross-sections, ALICE obtained the SD and DD cross-sections at three centre-of-mass energies, $\sqrt{s} = 0.9$, 2.76 and 7 TeV, as shown in figure 2. (σ_{INEL} at $\sqrt{s} = 0.9$ TeV was not measured by ALICE, instead, $\sigma_{INEL} = 52.5{+}2.0/{-}3.3$ was used.)

This first measurement of SD and DD cross-sections at the LHC confirms that these processes evolve only slowly from the centre-of-mass energies of the Intersecting Storage Rings to 7 TeV at the LHC. The analysis by ALICE also shows the importance of including diffraction correctly to describe precisely the acceptance and efficiency of the detector for minimum bias triggers.

Further reading

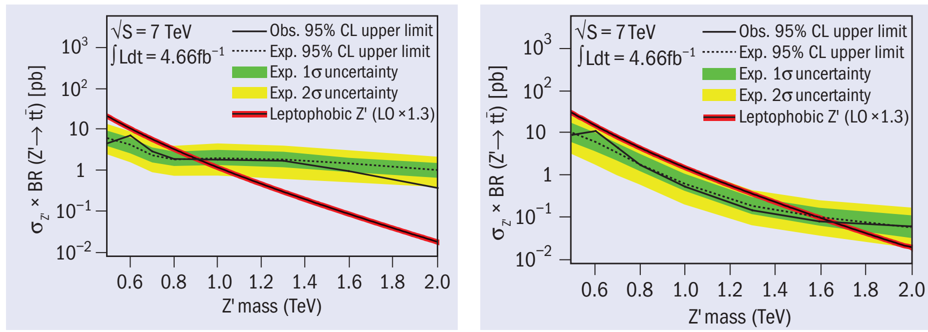
ALICE collaboration, arXiv:1208.4968, submitted to *EPJC*.

Top-quark production gets a boost

Top quarks are especially interesting at the LHC because they are the most massive fundamental particle known, suggesting an intimate association with electroweak symmetry breaking and possible new-physics scenarios.

The top quark decays via two channels: $t \to Wb \to l\nu b$ or $t \to Wb \to qqb$. When a $t\bar{t}$ pair is created in an experiment with energy roughly equal to the quark–antiquark rest mass, the decay products appear well separated in the detector. With the higher energies at the LHC, however, particles are often given a "boost" in momentum when produced so the decay products of a $t\bar{t}$ pair have extra momentum along the directions of the top and antitop, and are found in opposite hemispheres of the detector.

While higher energies allow the experiments at the LHC to probe for new physics as never before, they also bring new challenges. For example, what if the top quark is so boosted that the three jets from the decay $t \to Wb \to qqb$ merge to a point where they are indistinguishable from each other and appear as one large jet? With the high energy at the LHC, this boosted situation happens quite often and must be accounted for when



Upper limit on the production cross-section of the benchmark model $Z' \to t\bar{t}$ in the final state with one lepton with "resolvable" jets only (left) and also including boosted techniques (right), as a function of the mass of the hypothetical Z' boson. The solid red line corresponds to the predicted cross-section of the Z' boson. The solid black line traces the observed 95% CL upper limit on production of $Z' \to t\bar{t}$. Mass points where the solid black line falls under the red one are excluded by this study, i.e. if the Z' exists, it has another mass. The lower limit on the new particle's mass, where the red and the black lines cross, increases from 0.91 TeV to 1.66 TeV when using boosted techniques (ATLAS collaboration 2012c.)

reconstructing top-quark decays. Analyses involving top quarks or other "boosted objects" at the LHC, now include approaches that allow for these effects (*CERN Courier* September 2012 p35).

The special techniques for measuring boosted top quarks are particularly important when searching for new resonances, where a new heavy particle decaying primarily into $t\bar{t}$ pairs could be observed as a bump in the relevant invariant mass spectrum. The higher the mass of the new particle, the more likely it is that the top-quark decay products will merge in the detector.

ATLAS recently performed searches for $t\bar{t}$ resonances in final states with one or no leptons. In the former case, the lepton is allowed to be much closer to the b quark than in non-boosted analyses. In the other hemisphere of the detector, a wide massive jet with underlying structure is required. Using these boosted techniques, the sensitivity to a new heavy-gauge boson increased by nearly 700 GeV.

With the expected energy upgrade of the LHC the frequency of boosted final states will increase and even more sophisticated methods will be needed to search for physics beyond the Standard Model. The future, is certainly boosted.

● Further reading

ATLAS collaboration 2012a arXiv:1207.2409, accepted by *JHEP*.
ATLAS collaboration 2012b ATLAS-CONF-2012–102
ATLAS collaboration 2012c ATLAS-CONF-2012–136.

EUROPE

Updating the strategy for particle physics

On 10–12 September, some 500 physicists attended an open symposium in Krakow for the purpose of updating the European Strategy for Particle Physics, which was adopted by CERN Council in 2006. The meeting provided an opportunity for the global particle-physics community to express views on the scientific objectives of the strategy in light of developments over the past six years. With the aid of a local organizing committee, it was arranged by a preparatory group chaired by Tatsuya Nakada (see Viewpoint p50).

NUCLEAR PHYSICS

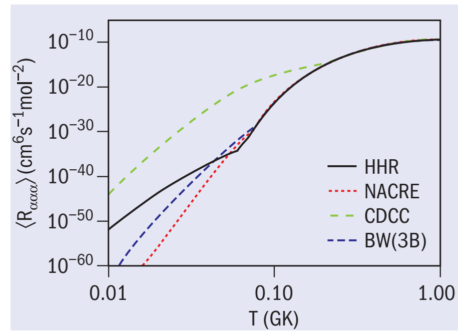
Theorists calculate the route to carbon-12

The triple-alpha reaction rate that produces carbon-12 in stars and other energetic astronomical phenomena has been a tricky subject for nuclear theorists for some time. Initially, Fred Hoyle proposed that there should be a 0^+ resonance close to the 3α threshold to justify the observed abundances of carbon-12 in stars, a theory that was later confirmed experimentally. However, if there is not enough energy in the stellar environment to reach the narrow resonances involved, then a direct three-body capture becomes the favoured path.

In the Nuclear Astrophysics Compilation of Reaction Rates (NACRE), the direct triple-alpha capture rate has been extrapolated from the two-step resonant capture to temperatures well below 10^8 K, where the resonant capture dominates (C Angulo *et al.* 1999). However, this estimation has proved inadequate and nuclear theorists began trying to solve the problem more directly.

Recently, a team at Kyushu University in Japan made use of the continuum-discretized coupled-channel (CDCC) method, which expands the full three-body wave function in terms of the continuum states of the two-body subsystem – in this case beryllium-8 (Ogata *et al* 2009). This method is challenging in the case of the triple-alpha reaction problem because the charged-particle reaction occurs at large distances and is dominated by Coulomb interactions. The results reflected these challenges, as the predicted rates showed an increase of 20 orders of magnitude when compared with NACRE, and caused the red-giant phase in low- and intermediate-mass stars to disappear in theoretical models of stellar evolution. Additionally, studies of helium ignition in accreting white dwarfs and accreting neutron stars showed that the CDCC rate is barely consistent with observations of Type Ia supernovae and type I X-ray bursts, respectively.

To skirt some of these difficulties, the nuclear theory group at the National Superconducting Cyclotron Laboratory at Michigan State University combined the Faddeev hyperspherical harmonics and the R-matrix method (HHR) to obtain a full solution to the three-body triple-alpha continuum (Nguyen *et al.* 2012). The researchers find that the HHR method agrees well with NACRE above 7×10^7 K. However, below that temperature the calculations revealed a pronounced increase of the rate accompanied by a completely different temperature dependence. Though the results do show a strong enhancement at these low energies, it is not as strong as that seen in the CDCC result.



The triple-alpha reaction rate calculated by the hyperspherical harmonic R-matrix method (solid), compared with the NACRE, CDCC and the three-body Breit-Wigner methods.

This finding turns out to have crucial repercussions for astrophysics. When the new results are used in stellar evolution simulations within the MESA (Modules for Experiments in Stellar Astrophysics) code, the red-giant phase in the stellar evolution of low- and intermediate-mass stars survives. The team plans to carry out further astrophysical studies to understand the implications of the new rate in explosive scenarios in the near future.

● Further reading

C Angulo *et al.* 1999 *Nucl. Phys. A* **656** 3.
N B Nguyen *et al.* 2012 *Phys. Rev. Lett.* **109** 141101.
K Ogata *et al*. 2009 *Prog. Theor. Phys.* **122** 1055.

***Les physiciens des particules du monde entier sont invités** à apporter leurs contributions aux CERN Courier, en français ou en anglais. Les articles retenus seront publiés dans la langue d'origine. Si vous souhaitez proposer un article, faites part de vos suggestions à la rédaction à l'adresse cern.courier@cern.ch.*

CERN Courier welcomes contributions from the international particle-physics community. These can be written in English or French, and will be published in the same language. If you have a suggestion for an article, please send proposals to the editor at cern.courier@cern.ch.

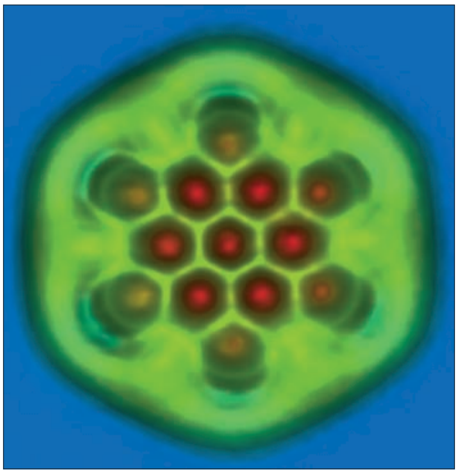
Sciencewatch

Compiled by John Swain, Northeastern University

Molecular bonds seen for first time

We all learn at school that atoms can form bonds to other atoms. Now these bonds have been seen in individual molecules for the first time. Leo Gross of IBM Research in Zurich and colleagues used non-contact atomic-force microscopy (AFM) to see directly the numbers, or "orders", of bonds between carbon atoms in polycyclic aromatic hydrocarbons and fullerenes.

Higher bond-orders correspond to higher electron densities and hence greater Pauli repulsion from a carbon-monoxide functionalized AFM tip. This brightens these bonds in the AFM images. However, the team was surprised to discover a second mechanism for distinguishing bonds. It turns out that tilting of the carbon-monoxide molecule at the apex of the tip occurs during imaging and has the effect of decreasing the apparent bond length with increasing bond order, as demonstrated by first-principles density-functional theory calculations.



A nanographene molecule exhibiting carbon–carbon bonds of different length and bond order imaged by non-contact atomic-force microscopy using a carbon-monoxide functionalized tip. The molecule was synthesized at the Centre National de la Recherche Scientifique in Toulouse. (Image credit: IBM Research Zurich.)

● **Further reading**
L Gross *et al.* 2012 *Science* **337** 1326.

Separating oil and water

It is an old adage that oil and water don't mix but neither is it that easy to separate the two, for example, when oil spills occur or emulsions form. Now, Anish Tuteja of the University of Michigan and colleagues have made a new type of membrane that can achieve bulk separation through simple gravity-driven filtration.

The idea is to coat a fabric or mesh with a mixture of hydrophilic cross-linked polyethylene glycol diarylate and oleophobic fluorodecyl polyhedral oligomeric silsesquioxane. Water is pulled through while oil is held back. The researchers have shown that a continuous-flow system based on this can work for more than 100 hours without the membrane fouling or slowing down the process. This looks like a major breakthrough of great simplicity, with wide applications.

● **Further reading**
A K Kota *et al.* 2012 *Nature Communications* **3** 1025.

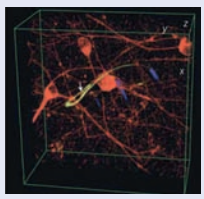
Light-gathering insects

Photosynthesis is usually thought of as something that plants do but it turns out that some insects may also use light directly. Some aphids have carotenoids, which play a role in photosynthesis in plants and some bacteria and fungi. Jean Christophe Valmalette of the Université du Sud Toulon and colleagues have found that aphids with carotenoids have an increased production of ATP – an energy-storage molecule – when exposed to light. This does not happen in aphids that are bred not to have the carotenoids and suggests that some aphids can gather energy directly from light. This would be the first example of the direct utilization of light energy by an animal.

● **Further reading**
J C Valmalette *et al.* 2012 *Scientific Reports*, doi:10.1038/srep00579.

Electrical scaffolding for biological tissues

For some time it has been possible to grow cells on 3D scaffoldings of synthetic biomaterials. Now, Charles Lieber of Harvard University and colleagues have gone one step further by making the scaffolding electrically active. They have made 3D networks of conductive nanowires using silicon sensors covered with biological materials such as collagen, on which cells can grow.



A 3D rendering of rat hippocampal neurons after a two-week culture on a nanoelectrical scaffold. The metal interconnects are shown in blue.

Rat neurons, heart cells and muscle were grown on this scaffolding, producing a collection of real beating heart cells threaded with electronics. The researchers also grew a 1.5-cm-long blood vessel made of human cells, which was similarly threaded with wires. This opens up a vast range of possibilities combining electronic and biological materials.

● **Further reading**
B Tian *et al.* 2012 *Nature Materials*, doi:10.1038/NMAT3404.

Video clips of molecules

A new approach to making images of molecules could lead to video clips of them instead of traditional still photographs. Electron diffraction can take images of molecules in the gas phase but, unless the molecules are aligned, all that results is a blurry average over orientations. Christopher Hensley and colleagues of the University of Nebraska and colleagues have now shown how to get round this problem.

Taking trifluoroiodomethane gas as an example, they use a 300 fs laser pulse to align the molecules. This distorts them, but a few picoseconds later the molecules return to their undistorted states and a 500 fs electron pulse reveals their shape by diffraction. This is the first such measurement done with sub-picosecond resolution and can be thought of as the first frame in a future film that could track the shapes of molecules such as chlorophyll or retinal (which is involved in vision) as they do their jobs.

● **Further reading**
C J Hensley *et al.* 2012 *Phys. Rev. Lett.* **109** 133202.

Astrowatch

Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

Closer to the Milky Way's supermassive black hole

The two W M Keck Telescopes on Mauna Kea, Hawaii, observing the centre of the Galaxy. The lasers create an artificial star in the Earth's upper atmosphere that is used to correct in real time the blurring effects of atmospheric turbulence. (Image credit: Ethan Tweedie Photography.)

Astronomers have been tracking the motion of stars at the very centre of the Galaxy for the past 20 years. One star in particular has attracted a great deal of attention by completing a full orbit round the supermassive black hole at the centre with a period of about 16 years. Now a team using the two Keck telescopes in Hawaii has detected another much fainter star with an even shorter period of only 11.5 years. This second star will help test Albert Einstein's theory of general relativity in the strong gravitational field of the back hole.

The Sun is located at the periphery of a disc-shaped spiral galaxy, commonly known as the Galaxy. Seen from Earth, the lights from thousands of millions of stars in this galaxy form a bright stripe across the night sky. This is the Milky Way. However, most of the stars remain hidden behind an inhomogeneous web of gas and dust, forming the interstellar medium. While this absorbing material obscures the view of the galactic centre in visible light, at infrared wavelengths, dust becomes much more transparent. The advent of infrared cameras in the 1990s therefore allowed the detection of the Galaxy's most centrally located stars for the first time.

Europeans and Americans competed to follow the motion of these stars with the goal of ascertaining the existence of a supermassive black hole in the Galaxy. The Europeans started in 1992 by using the New Technology Telescope and then the Very Large Telescope of the European Southern Observatory (ESO) in Chile, and since 1995 the Americans have used the Keck Observatory in Hawaii. Both groups used a star, S0-2, that orbits the radio source Sagittarius A* in 15.9 years to derive the mass and the distance of the black hole coinciding with this source. Around four years ago, they obtained a result of about 4 million solar masses located some 27,000 light-years away.

Now a group of astronomers, led by Leo Meyer and Andrea Ghez from the University of California, Los Angeles, has found a second star that is even closer to the supermassive black hole, with a period of only 11.5 years. Being 16 times fainter than S0-2, this new source, S0-102, was difficult to detect by the twin Keck telescopes in the crowded central region of the Galaxy. It is mainly thanks to adaptive optics that this star could be identified and tracked. Adaptive optics, first employed in 2004 at the Keck Observatory, is a technique used to correct in real time the deformation of the image induced by turbulence in the atmosphere. The wave-front deformation is measured by observing a bright star or an artificial "guide star", generated in the upper atmosphere by a powerful sodium laser. The correction is implemented by changing the inclination and the shape of the deformable secondary mirror on time scales of a few milliseconds.

The detection of a second star orbiting closely the supermassive black hole of the Galaxy will enable tests of general relativity in a gravitational potential that is two orders of magnitude stronger than at the surface of the Sun. The effect of curved space–time manifests itself by a deviation from the Keplerian orbit of the stars and a relativistic red shift of their emission. The gravitational red shift could become measurable at the next closest approach to the black hole, in 2018 for S0-2 and three years later for S0-102. The deformation of the elliptical orbits induced by curved space–time will be more difficult to identify and might await the next generation of 30-m class telescopes. The presence of the second star will anyway be instrumental in breaking the degeneracy inherent in the measurement of curved space–time with a single star.

Further reading

L Meyer *et al.* 2012 *Science* **338** 84.

Picture of the month

On 15 January 1996, the Hubble Deep Field (HDF) made a sensation by revealing for the first time the tapestry of background galaxies that can be detected in a small, apparently completely dark region of the sky. This new image, released on 25 September 2012, is called the Hubble eXtreme Deep Field (XDF). With more than two million seconds of total exposure time, it is the deepest image of the universe ever made, combining data from previous images including the Hubble Ultra Deep Field (taken in 2002 and 2003) and its infrared view of 2009. The image covers an area in the constellation of Fornax, less than a tenth of the width of the full Moon, making it just a 30 millionth of the whole sky. Yet it reveals about 5500 galaxies, some of them so distant that they are seen when the universe was less than 5% of its current age. (Image credits: NASA, ESA, G Illingworth, D Magee, and P Oesch (University of California, Santa Cruz), R Bouwens (Leiden University) and the HUDF09 Team).

CERN Courier Archive: 1969

A look back to CERN Courier vol. 8, November 1969, compiled by Peggie Rimmer

CERN

Ten years ago: the PS starts up …

On the night of 24 November 1959, a Polaroid picture similar to the one on the cover [see thumbnail in Compiler's Note, below] was pushed into an empty vodka bottle and parcelled off to Moscow. The vodka had been given to John Adams a few months earlier by Vladimir Nikitin labelled "Not to be opened until 10.1 GeV" – surpassing the 10 GeV peak of the synchro-phasotron at the Dubna Laboratory, then the highest-energy machine in the world. The picture showed an oscilloscope trace of the CERN proton synchrotron PS beam stretching out to 24 GeV for the first time.

Discussion of a European Laboratory built around a large particle accelerator began about 1950. By 1952, the Provisional Council of CERN came into being and a PS Group was set up to study a 10 GeV scaled-up version of the 3 GeV Cosmotron in the USA. Late that year, the new idea of alternating gradient focusing was carried back from Brookhaven and the study switched abruptly to a higher-energy machine. In October 1953, a design for a machine of about 30 GeV (later pruned to 25 GeV) based on the alternating gradient principle was successfully presented at a meeting in Geneva.

Thus began a great adventure in technical accomplishment and a great adventure in European collaboration, adventures because no-one really knew whether either the machine or the collaboration could work.

Adams replied to a question at a CERN Council Meeting in 1959: "Machines such as the PS consist of an enormous number of parts, and there are therefore several million reasons why they might not work." All problems were in the hands of a brilliant but inexperienced team and they were solved on schedule (within six years of the signing of the CERN Convention) and at a cost (120 million Swiss francs) reasonably close to the 1955 estimate.

On 24 November 1969, there was a celebration for the tenth anniversary of first operation of the CERN PS. Assisting in the traditional blowing out of candles are, left to right, P Germain, Hildred Blewett and P H Standley. [Image from the cover of CERN Courier *December 1969.]*

The success of the collaboration was perhaps even more impressive. To propose that Belgians, British, Dutch, French, Germans, Greeks, Italians, Scandinavians, Swiss and Yugoslavs could work successfully together on a huge project – demanding the highest technical skills, production of a million components by manufacturers scattered throughout Europe, very careful planning and the closest co-operation – was idealistic. But it worked.

● Compiled from texts on pp330–331.

… some personal reminiscences by Hildred Blewett

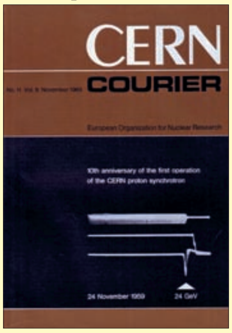
Remember the night of 24 November 1959? Of course I do. I was sitting in the canteen eating supper with John Adams. There was not a wide choice of food in those days – spaghetti or ravioli or, occasionally, fried eggs – but our thoughts were not on the meal. We had hardly spoken, our spirits were low, then John lit his pipe and said, "Well, now that we've finished eating, we might as well walk over and see if anything is happening." As we went in the direction of the PS buildings, I asked him, "Shall we go to the Main Control Room or the Central Building? Chris Schmelzer said that Wolfgang Schnell has that radial phase-control thing working." John pulled on his pipe, "Probably doesn't matter, it may not do much good." Then he added, "Let's go to the Central Building and see what they're up to." It was about quarter to seven.

[…]

Many things were in my thoughts as Adams and I approached the Central Building. I was depressed at having to leave the next day. I had wanted so much to see this machine operate successfully. John interrupted my thoughts with, "Well, Hildred, we haven't done much during your stay. It's hardly been worthwhile ..." I broke in, "Wolfgang thinks this radial phase-control will really work, he's very optimistic, and maybe ..." But I knew that no one else had great hopes for any improvement. The idea was to use the radial-position signal from the beam to control the r.f. phase. With this system, the sign of the phase had to be reversed at transition and, in his haste, Schnell had built this part into a Nescafé tin, the only thing of the right size. But could Nescafé tins help?

● Compiled from texts on p331 and p334.

Compiler's Note



Well, Nescafé tins could help and the rest is history. Those inexperienced PS pioneers built a machine that is still going strong today in the chain of accelerators that feed the LHC and, thanks to the *esprit de corps* that they established, CERN is now global. Only countries with a name beginning with O, W, X, Y or Z are missing from the programme, and there isn't actually a country beginning with X.

Space does not permit a longer extract from the late Hildred Blewett's memoir, packed with technical facts and engaging anecdotes. A fuller text was reprinted in the *Courier* for the 50th birthday of the PS and is highly recommended reading (*CERN Courier* November 2009 p19).

Quark Matter goes to Washington

The physics of the quark–gluon plasma took centre stage at the Quark Matter 2012 international conference in Washington DC.

The Quark Matter conferences, held roughly every 18 months, form the most important series of meetings in relativistic heavy-ion physics. The latest and 23rd in the series took place on 13–18 August at the Omni Shoreham hotel, a historic landmark in downtown Washington, DC. The meeting attracted around 700 participants from all around the world who discussed an unprecedented amount of new heavy-ion data from experiments at both Brookhaven National Laboratory (BNL) and CERN. This rich harvest of high-quality experimental results from the PHENIX and STAR collaborations at BNL's Relativistic Heavy-Ion Collider (RHIC) and the ALICE, ATLAS and CMS collaborations at CERN's LHC is providing a deep insight into the behaviour of quarks and gluons under the extreme conditions of high temperature and density.

The opening ceremony included presentations by Bart Gordon, former chair of the US House of Representatives Committee on Science and Technology, Timothy Hallman, associate director of Science for Nuclear Physics of the US Department of Energy, and Samuel Aronson, director of BNL. Urs Wiedemann of CERN provided an overview of the current status of relativistic heavy-ion physics, followed by highlights from the experiments presented by Takao Sakaguchi of PHENIX, Xin Dong of STAR, Karel Safarik of ALICE, Barbara Wosiek of ATLAS and Gunther Roland of CMS. The welcome reception was held at the spectacular Smithsonian Institute's National Portrait Gallery.

Understanding the quark–gluon plasma

Quantum chromodynamics (QCD) – the theory describing the interactions of quarks and gluons – is believed to be responsible for 99% of the mass of the visible universe, with the Higgs boson responsible for the remaining 1%. It has become clear that this mass originates mainly from the self-interaction of gluons, which at short distances is governed by asymptotic freedom. Yet the dynamics of gluon interactions in the large-distance, strong-coupling regime, which is responsible for quark confinement and the existence of atomic nuclei, remains mysterious. It is intimately linked to the complicated and poorly understood structure of the QCD vacuum.

The understanding of matter is often advanced by the study of phase transitions in macroscopic systems; thus heavy-ion physics aims towards a better understanding of QCD by creating a "macroscopic" domain of excited vacuum populated by a hot quark–gluon fireball. Advancing the understanding of the quark–gluon plasma also helps in better understanding the origins of the universe – this is because the conditions created in heavy-ion collisions, albeit fleetingly, are similar to the conditions that existed a few microseconds after the Big Bang. In addition, because both QCD and the electroweak sector of the Standard Model are described by non-Abelian gauge theories, understanding the QCD plasma will therefore provide valuable insight into the dynamics of matter at temperatures above the electroweak phase transition that are not accessible in the laboratory. This is important because, for example, the topological "sphaleron" transitions in the electroweak plasma could be responsible for the baryon asymmetry of the present-day universe.

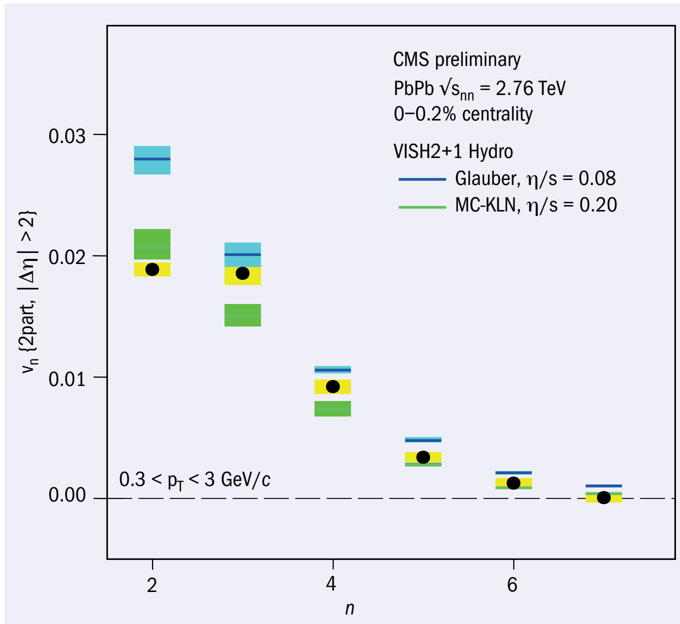


Fig. 1. Measurements by CMS of the Fourier coefficients v_n for the most central lead–lead collisions at the LHC, compared with hydrodynamical calculations for various harmonics, n.

A major advance in the physics of the QCD plasma made possible by the data from RHIC – and now also from the LHC – was the realization that at experimentally accessible temperatures the plasma behaves as a liquid with small dissipation, quantified by ▷

small values of shear and bulk viscosities. This implies that there exists a range of temperatures above the deconfinement phase transition in which the plasma does not at all resemble the quasi-ideal gas of quarks and gluons that is expected at high temperatures as a result of asymptotic freedom. At strong coupling, the non-Abelian plasma possesses small shear viscosity as exemplified by the supersymmetric plasma that is amenable to the studies by holographic methods based on string theory. In the latter case, the ratio of shear viscosity to entropy at strong coupling reaches the value of $1/(4\pi)$, a value that was conjectured to be the universal lower bound for any fluid. The physics underlying this bound is of a quantum nature because at strong coupling the mean free path approaches the de Broglie wavelength of the constituents, making the quasi-particle picture inapplicable.

The new data presented at Quark Matter 2012 have strengthened the case for the "perfect liquid" and made the physical picture more detailed. The data on hadron spectra and azimuthal correlations from RHIC and the LHC point towards the presence of well localized quantum fluctuations at the early stage of the collision that induce excitations in the quark–gluon liquid. The azimuthal distributions of hadrons are conveniently parameterized by their Fourier coefficients v_n. For large n, these coefficients signal the presence of localized fluctuations at the early stage of the collision; their values should be sensitive to the shear viscosity of the liquid.

Ordinarily, the "elliptic flow" v_2 dominates over higher harmonics because it reflects decompression of the elliptical shape of the produced fireball. However, all harmonics in the most-central heavy-ion collisions become similar, as illustrated in figure 1 by data from the CMS collaboration in the 0.2% most-central lead–lead (PbPb) collisions at the LHC. A comparison of the data with hydrodynamical calculations shows that the shear viscosity of the liquid is quite close to the conjectured quantum bound, although its precise value depends on the choice of initial conditions.

The initial conditions in heavy-ion collisions are determined by the structure of nuclear wave-functions at small Bjorken-x and the dynamics of their interaction. Significant progress in the understanding of QCD at small x has been made in recent years, triggered by the data from RHIC and the LHC. The quantum evolution in QCD and the high density of partons in Lorentz-contracted nuclei (which can be described as the "colour glass condensate") lead to the emergence of strong colour fields that dominate the early moments of heavy-ion collisions. The data on the collective flow and other observables suggest that thermalization occurs very early on – within 1 fm/c of the beginning of the collision. The dynamics of this "early thermalization" is not yet entirely understood but several promising theoretical developments were reported at the conference.

One of the proposed signatures of the colour glass condensate is the disappearance of quantum back-to-back di-jet correlations in the forward rapidity region of deuterium–gold collisions at RHIC, owing to the emergence of a semi-classical gluon field at small Bjorken-x. Both the PHENIX and STAR collaborations reported on observations of this effect at RHIC.

The QCD medium can be studied using hard probes to investigate its response to external localized perturbations. The RHIC experiments observed the strong quenching of high-transverse-momentum hadrons and jets that had been proposed as a signature of hot and dense quark–gluon matter. The LHC has significantly extended the kinematic reach in the studies of jets. All LHC experiments found that the strong suppression of jets persists up to high jet energies.

The mechanism behind the jet-energy loss is still not clear: does it depend on the colour charge of the leading parton (quark

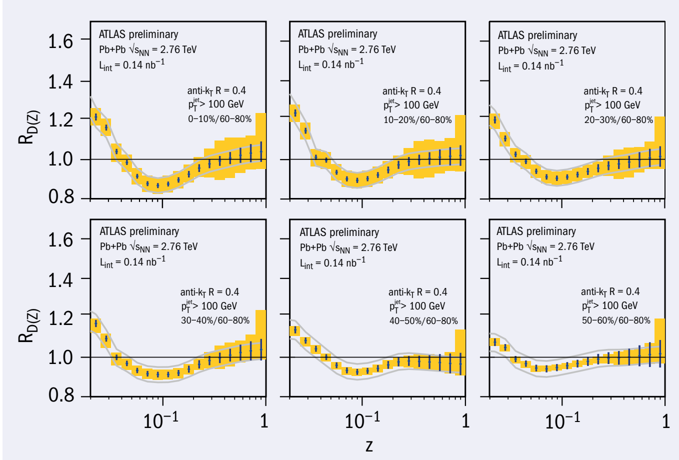


Fig. 2. The ratio $R_{D(z)}$ measured by ATLAS of D(z) for each of six bins in collision centrality to that in peripheral (60–80%) collisions. The results reveal a slight enhancement of hadron production at low z and a suppression at intermediate values.

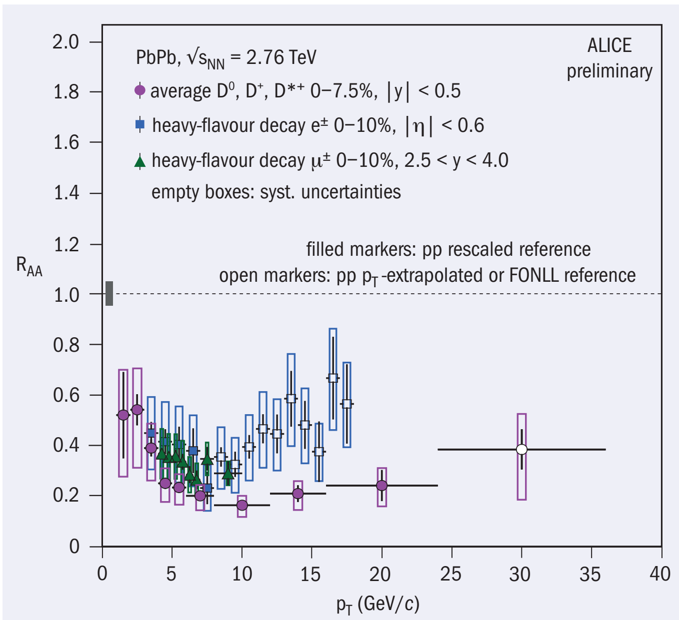
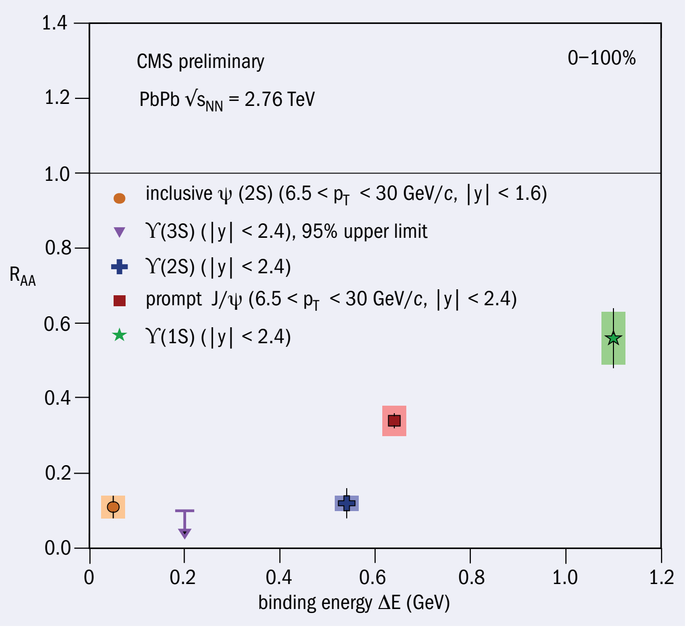


Fig. 3. The nuclear-modification factor, R_{AA} (basically, the ratio of particle production in nucleus–nucleus (AA) interactions to that expected from the proton–proton spectrum) measured by ALICE for charm. Shown are measurements from direct detection of charm mesons via hadronic decays as well as indirect measurements through semileptonic decays where only the decay lepton is reconstructed. Results suggest that heavy flavour decays are not as quenched as charm decays alone.



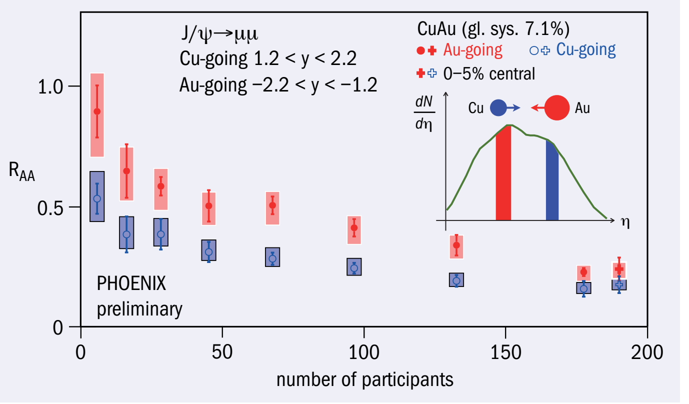


Fig. 4. (a) Left: The nuclear-modification factor, R_{AA}, measured by CMS shows the expected suppression hierarchy for quarkonium states. The states with higher binding energy are less suppressed as they are more difficult to dissolve. (b) Above: Data from PHENIX on J/Ψ production in asymmetrical copper–gold (CuAu) collisions shows stronger suppression in the Cu fragmentation region.

or gluon)? Is it suppressed for heavy quark jets, as expected for the medium-induced gluon radiation as a result of the "dead cone" effect? Are the dynamics of energy loss adequately described by perturbative QCD, or does it call for new strong-coupling methods? These questions can be answered only after more detailed data are acquired on jet shapes and flavour-tagged jets.

An interesting effect of the modification of the jet-fragmentation function in PbPb collisions was reported at the conference by the ATLAS and CMS collaborations. Figure 2 shows the ATLAS result. In addition to the enhancement of hadron production at a small fraction of the jet energy z, there is also a sizable dip for the intermediate values of z, which has yet to be understood.

As for the flavour-tagged jets, high-energy b- and c-tagged jets are seen by the LHC experiments to be quenched similarly to the inclusive jets, which are dominated by gluons. At present there is no clear sign of the dependence of jet-energy loss on the colour charge of the parton. At transverse momenta below 8 GeV, there is a hint of weaker quenching for D mesons than for light hadrons, as reported by the ALICE collaboration. The electrons from heavy-flavour decays that receive a significant contribution from beauty decays at high transverse momenta have been found by ALICE to be quenched less than the charm decays of D mesons, as figure 3 shows. This suggests that the quenching of bottom quarks is weaker than that of charm quarks.

The PHENIX collaboration presented the first data on heavy-meson quenching from decay electrons obtained by using their new silicon vertex detector. In accord with the expectations from theory, D mesons are observed to be suppressed less than light hadrons. However, the PHENIX collaboration found surprising hints of a significantly stronger suppression of B-mesons.

An important baseline for jet quenching is provided by the colourless probes – the photons, Z and W bosons. Indeed, the ATLAS and CMS collaborations reported the production of Z bosons with no sign of suppression up to transverse momenta of about 100 GeV. This implies that the observed suppression of jets is, indeed, a result of the colour dynamics.

Heavy quarkonium has been proposed as a probe of deconfinement – the Debye screening in the quark–gluon plasma (QGP) is expected to make quarkonium formation impossible. Strong suppression of J/ψ production was observed at CERN's Super Proton Synchrotron – and then at RHIC and at the LHC. Studies of heavy quarkonium have now been extended to the bottomonium family, with the expected hierarchy of suppression, as shown in figure 4a from the CMS collaboration: it is more difficult to dissolve states with larger binding energies and smaller radii.

Nevertheless, the observed suppression stems from a complicated interplay of final- and initial-state effects, as suggested by the recent PHENIX data on J/ψ production in asymmetrical copper–gold (CuAu) collisions presented at the conference (figure 4b). The J/ψ suppression at rapidities in the Cu fragmentation region is found to be stronger than in the Au-fragmentation region. This is inconsistent with a final-state effect alone because the density of produced particles is larger in the Au-fragmentation region. On the other hand, J/ψ production in central CuAu collisions in the Cu-fragmentation region selects a high-density region in the wave function at small x of the Au nucleus. The rescattering of heavy quarks in this dense gluon system before the formation of the QGP is expected to reduce the probability for J/ψ formation.

Fluctuations, broken symmetries and the critical point

An important goal of heavy-ion physics is to map the QCD phase diagram. A prominent feature of this phase diagram is the possible existence of a critical point at finite baryon density at the end of the first-order phase-transition curve. The signature of the critical point is the enhancement of fluctuations, including the fluctuations of net baryon number. Experimental access to the high baryon-density in heavy-ion collisions requires decreasing the energy of the collisions at RHIC. The search for the critical point, and thus for the disappearance of signatures of deconfined matter, was the goal of the recent scan of the beam energy at RHIC. ▷

QM2012

Both the STAR and PHENIX collaborations reported results from the RHIC Beam Energy Scan at the conference. The STAR experiment sees an intriguing deviation of the higher moments of net proton-fluctuations from the Poisson baseline and from the expectations based on Monte-Carlo models at centre-of-mass energies below 20 GeV. A measurement at higher statistics with a finer step in collision energy will be needed to tell whether this observation does point to the existence of the critical point. As the energy of the collision was decreased, several signatures of the plasma phase were found to disappear, as reported by STAR. These include the suppression of the high-transverse momentum hadrons, the scaling in constituent number of the elliptic flow and the fluctuations of charge separation, which is a consequence of the chiral magnetic effect.

Theoreticians have proposed the existence of quantum fluctuations of topological origin in the early stage of heavy-ion collisions, which generate chirality similarly to the electroweak sphalerons that generate baryon number at much higher temperatures. In the presence of the strong magnetic field generated by the colliding heavy ions, the fluctuations in net chirality can lead to fluctuations in the electric-charge separation because of the "chiral magnetic effect". The resulting observable is the event-by-event fluctuation in the electric-charge separation relative to the reaction plane, signalling the fluctuating electric dipole moment of the plasma. The effect can be accessed experimentally by measuring the difference in the fluctuations of the parity-odd harmonics of azimuthal distributions for hadrons of the same and opposite charge. The effect has been seen at RHIC by the STAR and PHENIX experiments; an effect of similar strength was also reported by the ALICE collaboration.

However, because the observable is parity-even it can receive contributions from more mundane effects. An alternative conventional explanation has been put forward based on the combination of correlations between opposite electric charges and the elliptic flow. Usually, the elliptic flow is correlated with the magnetic field by the geometry of the collision and both vanish in central collisions. However, the new RHIC data on uranium–uranium (UU) collisions allow separation of the two effects. Because of the deformed shape of the uranium nucleus, the central collisions produce a deformed fireball leading to a sizeable elliptic flow; yet, the number of spectators detected by the Zero Degree Calorimeter is small, so the magnetic field must be greatly suppressed. Thus, it should be possible to establish whether the observed fluctuations in charge asymmetries are driven by the elliptic flow or by the magnetic field.

Preliminary data from STAR presented at the conference indicate that the difference in the fluctuations of the asymmetry for the same- and opposite-charge hadrons vanishes in central UU collisions (figure 5), suggesting that these fluctuations are driven by the magnetic field. Another important result on this topic reported by STAR was the difference between the elliptic flows of positive and negative pions in AuAu collisions at 200 GeV, which is found to be linearly dependent on the charge asymmetry in the event, as expected on the basis of the chiral magnetic effect. New refined data are necessary to reach a definitive conclusion on this issue. Topological transitions in QCD generating chirality are analogous to the electroweak sphaleron transitions that generated the baryon asymmetry of the universe shortly after the Big Bang. Therefore, understanding them better is important.

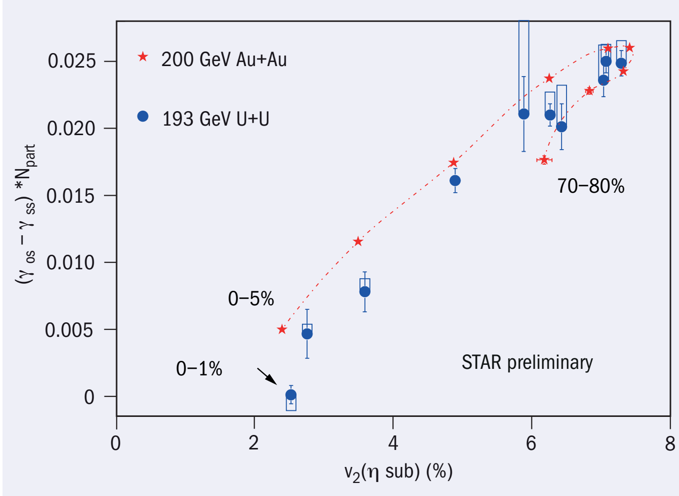


Fig. 5. Data from STAR on fluctuations in the asymmetry between same-charge and opposite-charge hadrons, measured as a function of elliptic flow (v_2), indicate that it vanishes in central uranium (UU) collisions, as seen by the per cent centrality dependence shown.

Broad connections

The conference highlighted the broad connections of relativistic heavy-ion physics to condensed-matter physics, string theory, cosmology and astrophysics. For example, the small viscosity of the QGP makes it similar to such seemingly distant objects as ultracold atoms and graphene, where the charge carriers are chiral and the effective coupling is large. The non-dissipative chiral magnetic current appears to exist also in Weyl semimetals and opens possibilities for the creation of a new generation of electronic devices.

The conference made clear the need for dedicated future facilities, several of which were discussed, including: the Electron–Ion Collider needed for a precision study of small-x gluon wave-functions of nuclei and of the spin structure of the proton; the Large Hadron–Electron Collider at CERN, which would advance the high-energy, high-momentum-transfer frontier of deep-inelastic scattering; the Facility for Antiproton and Ion Research under construction at GSI in Darmstadt; and the Nuclotron-based Ion

Reaching out

Quark Matter 2012 played an important role in communicating the results of research to the general public, as well as in the education of the next generation of scientists. The programme featured a special half-day event for high-school science teachers. The entire day of 12 August was dedicated to pedagogical lectures for graduate students given by some of the experts in the field, including Javier Albacete of IPN/ IN2P3/ CNRS, Néstor Armesto of the University of Santiago de Compostela, Paul Sorensen of BNL, Mikhail Stephanov of the University of Illinois and William Zajc of Columbia University.

A new film about nuclear science for the general public was shot during the conference by Agnes Mocsy, a heavy-ion theorist from Pratt Institute, and her team of graduate students. The conference programme also included two talks directed towards the general public: "Death from the Skies!", by the popular author and astronomer Philip Plait, and "Energy for the 21st Century World Economy" by Wolfgang Bauer of Michigan State University.

Collider facility, currently under construction in Dubna. The case for the latter two facilities was advanced by the first results from the beam-energy scan at RHIC that were reported at the conference.

Summaries of the results presented were provided by three pairs of rapporteurs, each pair composed of a theorist and experimentalist: Boris Hippolyte of the Institut Pluridisciplinaire Hubert Curien and Dirk Rischke of the University of Frankfurt on global variables and correlations; Jorge Casalderrey-Solana of the University of Barcelona and Alexander Milov of the Weizmann Institute of Science on high-transverse-momenta and jets; and Charles Gale of McGill University and Lijuan Ruan of BNL on heavy flavours, quarkonia and electroweak probes. The wealth of new data and the resulting leap in the theoretical understanding of QCD matter were possible only because of the successes of the two complementary experimental programmes at RHIC and the LHC.

● For the full programme, slides, photos and videos of the presentations at Quark Matter 2012, see http://qm2012.bnl.gov.

Résumé

La matière quarkonique à l'honneur à Washington

L'édition 2012 de la conférence Quark Matter a réuni à Washington, en août dernier, environ 700 participants venus du monde entier. Cette conférence a été l'occasion de regarder la très grande quantité de données sur les ions lourds venant des expériences du laboratoire national Brookhaven (BNL) et du CERN. Cette abondance de résultats expérimentaux de grande qualité venant, pour ce qui concerne le Collisionneur d'ions lourds relativistes du BNL, des collaborations PHENIX et STAR, et, pour ce qui concerne le LHC, au CERN, des collaborations ALICE, ATLAS et CMS, donne des éléments très riches sur le comportement des quarks et des gluons dans des conditions extrêmes de température et de densité.

John W Harris, Yale University, **Dmitri Kharzeev**, Stony Brook University and BNL, and **Thomas Ullrich**, BNL.

Deep-inelastic scattering enters the LHC era

Results from the LHC complemented those from other colliders at the recent DIS 2012 workshop in Bonn.

The unusually early date for the 20th International Workshop on Deep-Inelastic Scattering and Related Subjects proved not to be a problem. The trees were all in blossom in Bonn during DIS 2012, which was held there on 26–30 March, and the sun shone for most of the week. As is the tradition for these workshops, the first day consisted of plenary talks, with the ensuing three days devoted to parallel sessions, followed by a final day of summary talks from the seven working groups. Almost all of the 300 participants also gave talks: there were as many as 275 contributions, not including the summaries. For the first time, the number of results from the LHC experiments at CERN was larger than from DESY's HERA collider, which shut down in 2007. Given such a large number of contributions, it is not possible to do justice to them all, so the following report presents only a few rather subjective highlights.

With the move from dominantly electron–proton collisions to more and more results coming from hadron colliders, the workshop started with an "Introduction to deep-inelastic scattering: past and present" by Joël Feltesse of IRFU/CEA/Saclay. Talks on theory and on experiment followed, which covered the full breadth of the topics presented in more detail in the parallel sessions. With running at Fermilab's Tevatron coming to an end in 2011, results with the complete data set are now being released by the CDF and DØ collaborations. There were also several results from the LHC experiments based on the complete data set for 2011. The emphasis in many of the theory presentations was on calculating processes to higher orders and on parton density function (PDF) and scale uncertainties.

Structure functions and PDFs

Measurements that are relevant to the determination of the PDFs in the nucleon, were reported on combined data from the HERA experiments, H1 and ZEUS, the LHC experiments, ATLAS, CMS and LHCb, as well as from the Tevatron experiments, CDF and DØ. New experimental results have come – in particular from the LHC – on Drell-Yan production, including W and Z bosons, and from HERA and the LHC on jet production, including jets with heavy flavour. In addition, analyses of deep-inelastic scattering

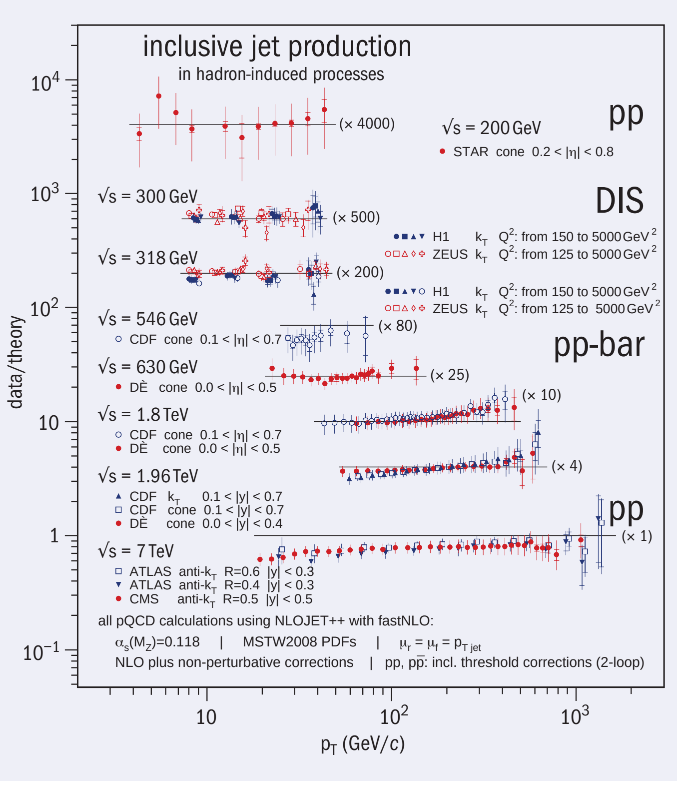


Fig. 1. An overview of data-to-theory ratios for inclusive jet cross-sections measured in different processes at different centre-of-mass energies.

(DIS) data on nuclei were presented at the workshop.

There has been substantial progress in the development of tools for PDF fitting, including the so-called HERAfitter package. This package is designed to include all types of data in a global fit and can be used by both experimentalists and theorists to compare different theoretical approaches within a single framework. The FastNLO package can calculate next-to-leading-order (NLO) jet cross-sections on grids that can then be used for comparisons of data and theory, as well as in PDF fitting. Figure 1 shows a comparison of data and theory for many different ▷

For the first time, the number of results from the LHC was larger than from HERA.

energies and processes.

Looking at the current status of fit results, the conclusion is that the determination of the PDFs still gives rise to some controversy but that there is progress in understanding the differences, as Amanda Cooper-Sarkar of Oxford University explained. All of the groups presented PDFs up to next-to-next-to-leading order (NNLO) in the Dokshitzer-Gribov-Lipatov-Altarelli-Parisi formalism. Extensions of the formalism into the Balitsky-Fadin-Kuraev-Lipatov regime and into the high-density regime of nuclei are in progress. The H1 and ZEUS collaborations have also measured the longitudinal structure function, F_L. However, the precision is still not good enough to discriminate between predictions of the gluon density and different models.

Measurements of cross-sections of diffractive processes in DIS open the opportunity to probe the parton content in the colourless nucleon, the goal being to determine diffractive PDFs of the nucleon. The H1 and ZEUS collaborations selected diffractive processes in DIS either by requiring the detection of a scattered proton in dedicated proton spectrometers (ZEUS-LPS or H1-FPS) at small angles to the direction of the proton beam, or without proton detection but instead requiring a large rapidity gap between the production of a jet or vector-meson and the proton beam direction. Figure 2 shows reduced cross-sections obtained from LPS and FPS data (and also combined), which were presented at the workshop. The LHC experiments have also started to contribute to diffraction studies. The ATLAS collaboration reported on an analysis of diffractive events selected by a rapidity gap.

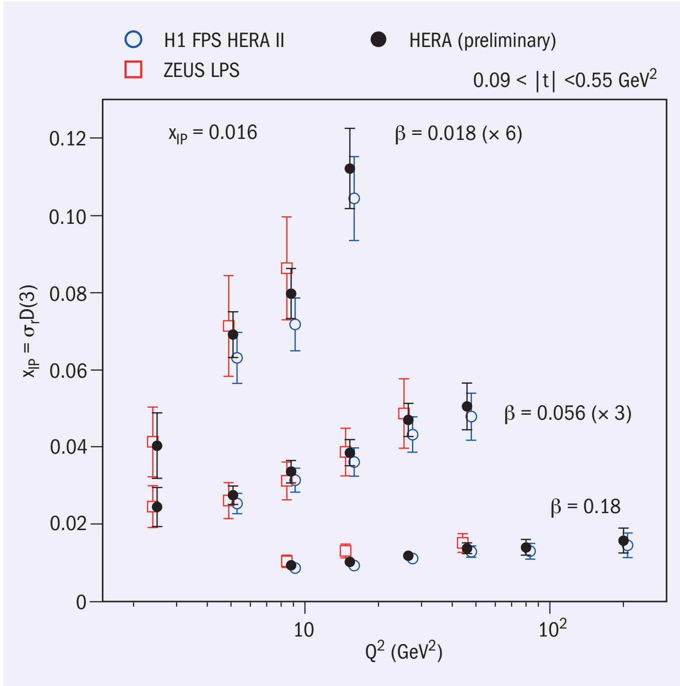


Fig. 2. The reduced inclusive diffractive cross-section from the preliminary combined FPS/LPS data from HERA (black points) compared with the uncombined data (open symbols). (Image credit: HERA Diffraction Working Group.)

Searches and tests

At the time of the conference, the LHC experiments had only tantalizing hints of an excess in the mass region around 125 GeV using the data from 2011. It was nevertheless impressive that many results could be shown using the full 5 fb^{-1} of data that had been collected that year. The Higgs searches were the only ones to show any real sign of new particles. All others saw no significant indications and could only set upper limits. Experiments at both the LHC and the Tevatron have now measured WW, ZZ and WZ production with cross-sections that are consistent with Standard Model expectations, calculated to NLO and higher.

As Feltesse reminded participants in his talk, measurements of hadronic final states in DIS were the cradle for the development of the theory of strong interactions, QCD. Such measurements remain key for testing QCD predictions. New results were presented from HERA and the LHC, in which the QCD analyses have reached an impressive level of precision. While leading-order-plus-parton-shower Monte Carlos provide a good description of the data in general, a number of areas can be identified where the description is not good enough. Higher-order generators are needed here and it is important that appropriate tunes are used.

In general, NLO QCD predictions give a good description of the data. However, the uncertainty in the theory because of missing higher-order calculations is almost everywhere much larger than the experimental errors. Moreover, it was shown that in several cases the fragmentation process of partons into hadrons is not well described by NLO QCD calculations.

A central issue is the value and precision of the strong coupling constant, α_S, and its running as a function of the energy scale. Many results were presented that improve the precision and show that the energy dependence is well described by QCD calculations.

There has been a great deal of progress in calculations of heavy-quark production. A particular highlight is the first complete NNLO QCD prediction for the pair-production of top quarks in the quark–antiquark annihilation channel. There is also a wealth of data from HERA, the LHC, the Tevatron and the Relativistic Heavy-Ion Collider (RHIC) on the production both of quarkonia and of open charm and beauty. The precision with which the Tevatron experiments can measure the masses of both the top quark and the W boson is particularly impressive. Although the LHC experiments have more events of both sorts by now, it will still take

DIS 2012

some time before the systematic uncertainties are understood well enough to achieve similar levels of precision.

The X,Y,Z states discovered in recent years have been studied by the experiments at B factories, the LHC and the Tevatron. Their theoretical interpretations are still a challenge. The LHCb experiment has performed the world's best measurements of the properties of the B_c meson and b baryons and has made important contributions in other areas where its ability to measure particles in the forward direction is important.

Experiments that use polarized beams in DIS on polarized targets are relevant for studying the spin structure of nucleons. New results were presented from HERMES at HERA and COMPASS at CERN's Super Proton Synchrotron, as well as from experiments at RHIC and Jefferson Lab. A tremendous amount of data has been collected and is now being analysed. Current results confirm that neither the quarks nor the gluons carry much of the nucleon spin. This leaves angular momentum. However, a picture describing the nucleon as a spatial object carrying angular momentum has yet to be settled.

The conceptual design report for a future electron–proton collider using the LHC together with a new electron accelerator, known as the LHeC, was released a couple of months after DIS 2012 (*CERN Courier* May 2012 p25). This was the main topic of the last plenary talk at the workshop. In the parallel sessions, a broad spectrum of options for the future was discussed, covering the upgrades of the LHC machine and detectors, the upgrade plans at Jefferson Lab and RHIC, as well as proposed new accelerators such as an electron–ion collider, the EIC. One of the central aims is to understand better the 3D structure of the proton in terms of generalized parton distribution functions.

DIS 2012 participants once again profited from lively and intense discussions. The conveners of the working groups worked hard to put together informative and interesting parallel sessions. They also organized combined sessions for topics that were relevant for more than one working group. For relaxation, the workshop held the conference dinner in the mediaeval castle "Burg Satzvey", which was a big success. Many of the participants also went on one of several excursions on offer. Next year, DIS moves south and will take place on 22–26 April in Marseilles.

Résumé

La diffusion profondément inélastique à l'ère du LHC

Le 20e atelier international sur la diffusion profondément inélastique et les sujets connexes s'est tenu fin mars à Bonn. Sept groupes de travail ont planché sur des sujets allant de la mesure des fonctions de structure aux installations futures possibles. Pour la première fois, le nombre de résultats issus du LHC a été supérieur à la production du collisionneur électron proton HERA, à DESY, dont l'exploitation a été terminée en 2007, certains des résultats issus du LHC s'appuyant déjà sur l'ensemble complet des données 2011. De plus, les collaborations CDF et DØ à Fermilab communiquent maintenant des résultats tirés de leurs données complètes, à la suite de la fermeture du Tevatron en 2011.

Ian Brock and **Ewald Paul**, University of Bonn.

Anniversary

Stanford University trustees sign the construction contract for SLAC on 30 April 1962, while future director Wolfgang Panofsky, centre, looks on. (Image credit: Stanford News Service.)

Panofsky, left, gestures at a control-room monitor on 21 May 1966 as the linear accelerator delivers its first electron beam. (All subsequent photos, image credit: SLAC National Accelerator Laboratory.)

The End Station A fixed-target area and spe used in the late 1960s in the SLAC–MIT exp that found the first direct evidence of quarks

SLAC at 50: honouring the p

Founded in 1962, as construction work began on its famous linac, the SLAC laboratory went on to make ground-breaking discoveries that changed particle physics, and to evolve in the face of a changing scientific landscape.

In the early 1960s, a 4-km-long strip of land in the rolling hills west of Stanford University was transformed into the longest, straightest structure in the world – a linear particle accelerator. It was first dubbed Project M and affectionately known as "the Monster" by the scientists at the time. Its purpose was to explore the mysterious subatomic realm.

Fifty years later, more than 1000 people gathered at SLAC National Accelerator Laboratory to celebrate the scientific successes generated by that accelerator and the ones that followed, and the scientists who developed and used them. The two-day event on 24–25 August, for employees, science luminaries and government and university leaders, was more than a tribute to the momentous discoveries and Nobel prizes made possible by the minds and machines at SLAC. It also provided a look ahead at the lab's continuing evolution and growth into new frontiers of scientific research, which will keep it at the forefront of discovery for decades to come.

A history of discovery

The original linear-accelerator project, approved by Congress in 1961, was a supersized version of a succession of smaller accelerators, dubbed Mark I to Mark IV, which were built and operated at Stanford University and reached energies of up to 730 MeV. The "Monster" would accelerate electrons to much higher energies – ultimately to 50 GeV – for ground-breaking experiments in creating, identifying and studying subatomic particles. Stanford University leased the land to the federal government for the new Stanford Linear Accelerator Center (SLAC) and provided the brainpower for the project. This set the stage for a productive and unique scientific partnership that continues today, supported and overseen by the US Department of Energy.

Soon after the new accelerator reached full operation, a research team that included physicists from SLAC and Massachusetts Institute of Technology (MIT) used the electron beam in a series of experiments starting in 1967 that provided evidence for hard scattering centres within the proton – in effect, the first direct dynamical evidence for quarks. That research led to the awarding of the 1990 Nobel Prize in Physics to Richard Taylor and Jerome Friedman of SLAC and Henry Kendall of MIT.

SLAC soon struck gold again with discoveries that were made possible by another major technical feat – the Stanford Positron Electron Asymmetric Ring, SPEAR (*CERN Courier* June 2003 p16). Rather than aiming the electron beam at a fixed target, the SPEAR ring stored beams of electrons and positrons from the linear accelerator and brought them into steady head-on collisions.

These discoveries that reshaped understanding of matter were empowered by a series of colliders and detectors.

In 1974, the Mark I detector at SPEAR, run by a collaboration from SLAC and Lawrence Berkeley National Laboratory, found clear signs of a new particle – but so had an experiment on the other side of the US. In

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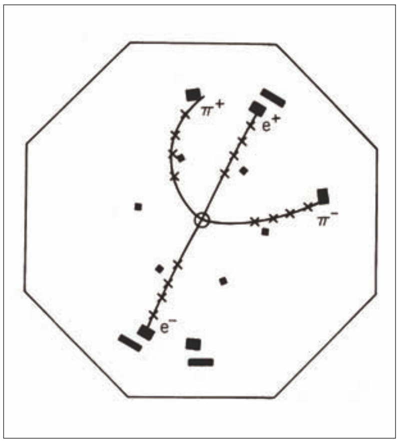
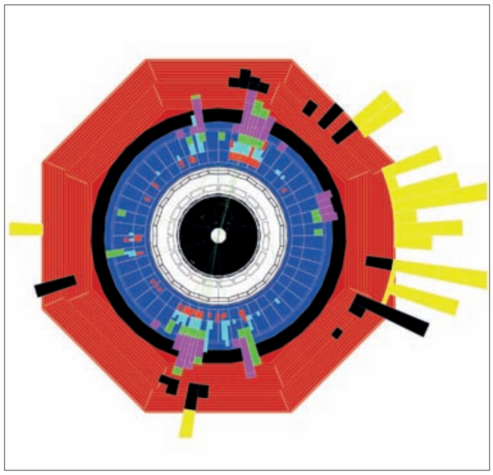
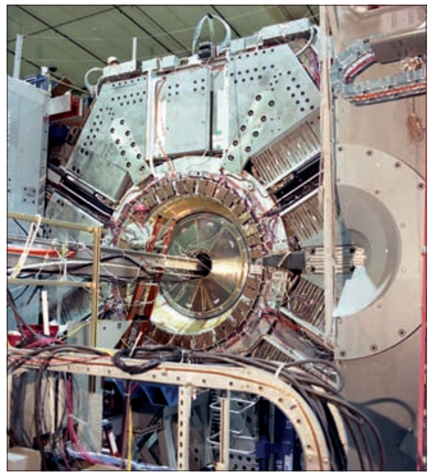


Reconstruction of a ψ' decay in the Mark I detector, making a near-perfect image of the Greek letter ψ.



The Stanford Linear Detector records its fifty-thousandth Z particle in 1993.



End view of the calorimeter of the BaBar detector in 1999.

past and creating the future

what became known as the "November Revolution" in particle physics, Burton Richter of SLAC and Samuel Ting of Brookhaven National Laboratory announced their independent discoveries of the J/ψ particle, which consists of a paired charm quark and anticharm quark. They received the Nobel Prize in Physics for this work in 1976. Only a year after the J/ψ discovery, SLAC physicist Martin Perl announced the discovery of the τ lepton, a heavy relative of the electron and the first of a new family of fundamental building blocks. He went on to share the Nobel Prize in Physics in 1995 for this work.

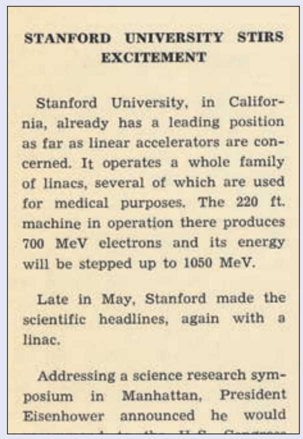
These and other discoveries that reshaped understanding of matter were empowered by a series of colliders and detectors. The Positron–Electron Project (PEP), a collider ring with a diameter almost 10 times larger than SPEAR, ran during the years 1980–1990. The Stanford Linear Collider (SLC), completed in 1987, focused electron and positron beams from the original linac into micron-sized spots for collisions at a total energy of 100 GeV. Making thousands of Z bosons in its lifetime, the SLC hosted a decade of seminal experiments (*CERN Courier* October 1998 p29). It also pioneered the concepts behind the current studies for a linear electron–positron collider to reach energies in the region of 1 TeV.

PEP was followed by the PEP-II project, which included a set of two storage rings and operated in the years 1998–2008. PEP-II featured the BaBar experiment, which created huge numbers of B mesons and their antimatter counterparts. In 2001 and 2004, BaBar researchers and their Japanese colleagues at KEK's Belle experiment announced evidence supporting the idea that matter and antimatter behave in slightly different ways, confirming theoretical predictions of charge-parity violation.

Synchrotron research and an X-ray laser

Notably, new research areas and projects at SLAC have often evolved as the offspring of the original linear accelerator and storage rings. ▷

From the archives



STANFORD UNIVERSITY STIRS EXCITEMENT

Stanford University, in California, already has a leading position as far as linear accelerators are concerned. It operates a whole family of linacs, several of which are used for medical purposes. The 220 ft. machine in operation there produces 700 MeV electrons and its energy will be stepped up to 1050 MeV.

Late in May, Stanford made the scientific headlines, again with a linac.

Addressing a science research symposium in Manhattan, President Eisenhower announced he would

Stanford University, in California, already has a leading position as far as linear accelerators are concerned. It operates a whole family of linacs, several of which are used for medical purposes. The 200 ft machine [Mark III] in operation there produces 700 MeV electrons and its energy will be stepped up to 1050 MeV.

Late in May, Stanford made the scientific headlines – again with a linac.

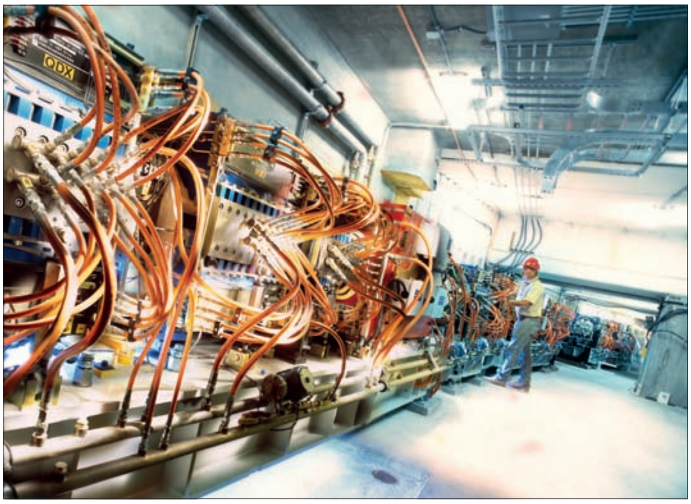
Addressing a science research symposium in Manhattan, President Eisenhower announced that he would recommend to the US Congress the financing of a "large new electron linear accelerator … a machine two miles long, by far the largest ever built".

This machine, intended for Stanford University, would be one of the most spectacular atom smashers ever devised. Two parallel tunnels would have to be driven for two miles into the rock of a small mountain in the vicinity of Palo Alto. Such natural cover would, of course, stop any dangerous radiation. One of the tunnels, the smaller in diameter, would house the accelerator proper, while the bigger one would be used for maintenance purposes.

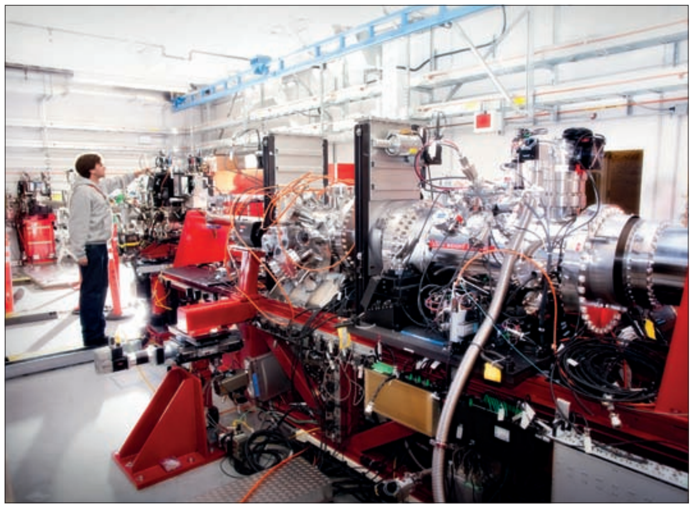
The proposed new linac for Stanford would initially produce 15 BeV (GeV) electrons; it is announced that this energy could later be raised to 40 BeV. It is believed that the machine would take six years to build, at a cost of 100 million dollars. Approval of the project, now only taken after Congressional hearings, depends on the decision to be held in July.

● From the first issue of *CERN Courier* August 1959 p7. (See also *CERN Courier* July/August 2009 p37).

Anniversary



View inside the accelerator tunnel of the Stanford Synchrotron Radiation Lightsource in 2004.



The Coherent X-Ray Imaging instrument received its first X-rays from the Linac Coherent Light Source in 2010.

Researchers at Stanford and SLAC quickly recognized that electromagnetic radiation generated by particles circling in SPEAR, while considered a nuisance to the particle collision experiments, could be extracted from the ring and used for other types of research. They developed this synchrotron radiation – in the form of beams of X-ray and ultraviolet light – as a powerful scientific tool for exploring samples at a molecular scale. This early research blossomed as the Stanford Synchrotron Radiation Project (SSRP), a set of five experimental stations that opened to visiting researchers in 1974.

Its modern descendant, the Stanford Synchrotron Radiation Lightsource (SSRL), now supports 30 experimental stations and about 2000 visiting researchers a year. SPEAR – or more precisely, SPEAR3 following a series of upgrades – became dedicated to SSRL operations 20 years ago. This machine, too, has allowed Nobel-prize winning research. Roger Kornberg, professor of structural biology at Stanford, received the Nobel Prize in Chemistry in 2006 for work detailing how the genetic code in DNA is read and converted into a message that directs protein synthesis. Key aspects of that research were carried out at the SSRL.

Cutting-edge facilities

Meanwhile, sections of the linear accelerator that defined the lab and its mission in its formative years are still driving electron beams today as the high-energy backbone of two cutting-edge facilities: the world's most powerful X-ray free-electron laser, the Linac Coherent Light Source (LCLS), which began operating in 2009 (*CERN Courier* December 2010 p13); and FACET, a test bed for next-generation accelerator technologies (*CERN Courier* March 2011 p23). LCLS-II, an expansion of the LCLS, should begin construction next year. It will draw electrons from the middle section of the original linear accelerator and use them to generate X-rays for probing matter with high resolution at the atomic scale.

The late Wolfgang "Pief" Panofsky, who served as the first director of SLAC from 1961 until 1984, often noted that big science is powered by a ready supply of good ideas. He referred to this as the "innovate or die" syndrome. In 1983, Panofsky wrote that he had been asked since the formation of the lab, "How long will SLAC live?" The answer was and still is: "about 10 to 15 years, unless somebody has a good idea. As it turns out, somebody always has had a good idea which was exploited and which has led to a new lease on life for the laboratory."

Under the leadership of its past two directors – Jonathan Dorfan, who helped launch the BaBar experiment and the astrophysics programme, and Persis Drell, who presided over the opening of the LCLS – SLAC's scientific mission has grown and diversified. In addition to its original focus on particle physics and accelerator science, SLAC researchers now delve into astrophysics, cosmology, materials and environmental sciences, biology, chemistry and alternative energy research. Visiting scientists still come by the thousands to use lab facilities for an even broader spectrum of research, from drug design and industrial applications to the archaeological analysis of fossils and cultural objects. Much of this diversity in world-class experiments is based on continuing modernizations at the SSRL and the unique capabilities of the LCLS.

SLAC's scientists and engineers continue to collaborate actively in international projects – designing machines and building components, running experiments and sharing data with other accelerator laboratories in the US and countries around the globe, including China, France, Germany, Italy, Japan, Korea, Latin America, Russia, Spain and the UK. The lab's long-standing collaboration with CERN provided an important spark in the formative years of the World Wide Web and led to SLAC's launch of the first web server in the US. SLAC is also playing an important role in the ATLAS experiment at CERN's LHC. In the area of synchrotron science, collaborations with US national laboratories and with overseas labs such as DESY in Germany and KEK in Japan have contributed greatly to the development of advanced tools and methodologies, with enormous scientific impact.

Somebody always has had a good idea which has led to a new lease on life for the laboratory.

Anniversary

US Energy Secretary Steven Chu delivers the keynote address during the 50th-anniversary celebration's scientific symposium at SLAC on 24 August.

Expertise in particle detectors has even elevated the lab's research into outer space. SLAC managed the development of the Large Area Telescope, the main instrument on board the Fermi Gamma-ray Space Telescope, which was launched into orbit in 2008 and continues to make numerous discoveries. The lab has also earned a role in building the world's largest digital camera for an Earth-based observatory, the Large Synoptic Survey Telescope, with construction scheduled to begin in 2014 for eventual operation on a mountaintop in Chile.

Richter, who served as SLAC director from 1984 to 1999, has said that the fast-evolving nature of science necessitates a changing path and pace of research. "Labs can remain on the frontiers of science only if they keep up with the evolution of those frontiers," remarks Richter. "SLAC has evolved over its first 50 years and is still a world leader in areas beyond what was thought of when it was first built. It is up to the scientists of today to keep it moving and keep it on some perhaps newly discovered frontiers for the next 50."

● This article is based on the one published on the *SLAC News Centre*, https://news.slac.stanford.edu/features/slac-50-honoring-past-and-creating-future.

Résumé

Le SLAC a 50 ans : honorer le passé et construire l'avenir

En 1962 ont commencé des travaux sur une bande de terrain de 4 km de long située à l'ouest de l'Université de Stanford, aux États-Unis, pour construire le plus long accélérateur linéaire du monde. Cette machine, surnommée affectueusement « le Monstre », avait pour but d'explorer l'univers subatomique. Grâce à elle, le Centre de l'accélérateur linéaire Stanford, devenu par la suite Laboratoire national de l'accélérateur Stanford (SLAC), a pu réaliser des découvertes fondamentales qui ont changé la physique des particules dans les années 1970. Depuis lors, le laboratoire a évolué, dans un paysage scientifique changeant, et il abrite désormais le laser à électrons libres le plus puissant du monde.

Glenn Roberts Jr, SLAC.

Accelerators

CEBAF: a fruitful past and a promising future

After many productive years, Jefferson Lab's 6 GeV electron beams recently turned off for the last time to make way for an upgraded 12 GeV facility.

On 18 May, the US Department of Energy's Jefferson Lab shut down its Continuous Electron Beam Accelerator Facility (CEBAF) after a long and highly successful 17-year run, which saw the completion of more than 175 experiments in the exploration of the nature of matter. At 8.17 a.m., Jefferson Lab's director, Hugh Montgomery, terminated the last 6 GeV beam and Accelerator Division associate director, Andrew Hutton, and director of operations, Arne Freyberger, threw the switches on the superconducting RF zones that power CEBAF's two linear accelerators. Coming up next – the return of CEBAF, with double the energy and a host of other enhancements designed to delve even deeper into the structure of matter.

Jefferson Lab has been preparing for its 12 GeV upgrade of CEBAF for more than a decade (*CERN Courier* April 2009 p15). In fact, discussions of CEBAF's upgrade potential began soon after it became the first large-scale accelerator built with superconducting RF technology. Its unique design features two sections of superconducting linear accelerator, which are joined by magnetic arcs to enable acceleration of a continuous-wave electron beam by multiple passes through the linacs. The final layout took account of CEBAF's future, allowing extra space for an expansion.

Designed originally as a 4 GeV machine, CEBAF exceeded that target by half as much again to deliver high-luminosity, continuous-wave electron beams at more than 6 GeV to targets in three experimental halls simultaneously. Each beam was fully independent in current, with a dynamic range from picoamps to hundreds of microamps. Exploiting the new technology of gallium-arsenide strained-layer photocathodes provided beam polarizations topping 85%, with sufficient quality for parity-violation experiments.

Jefferson Lab's director, Hugh Montgomery, clicks a button to terminate 6 GeV electron beams and watches a video screen confirming the shutdown. With him, from left to right, Arne Freyberger, former Jefferson Lab director Christoph Leemann and Andrew Hutton. (All image credits: Jefferson Lab.)

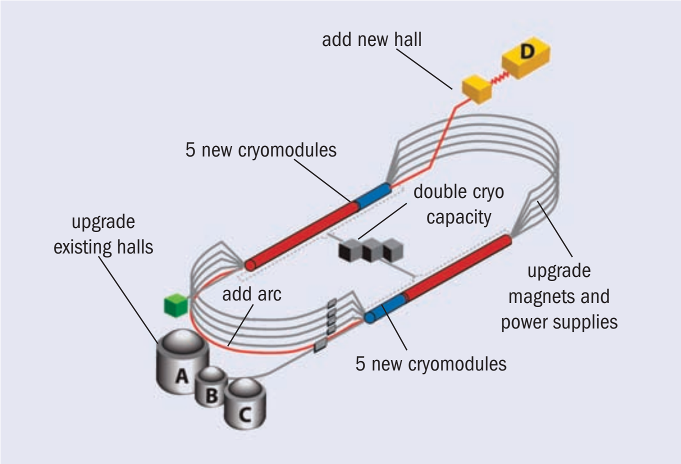
Inside the nucleon

CEBAF began serving experiments in 1995, bombarding nuclei with the 4 GeV electron beam. Its physics reach soon far outstripped the initial planned experimental programme, which was historically classified in three broad categories: the structure of the nuclear building blocks; the structure of nuclei; and tests of fundamental symmetry.

Experiments exploring the structure of the proton led to the discovery that its magnetic distribution is more compact than its charge. This surprising result, which contradicted previous data, generated many spin-off experiments and caused a renewed interest in the basic structure of the proton. Other studies confirmed the concept of quark–hadron duality, reinforcing the predicted relationship between these two descriptions of nucleon structure. Other measurements found that the contribution of strange quarks to the properties of the proton is small, which was also something of a surprise.

Designed as a 4 GeV machine, CEBAF exceeded that target by half as much again.

Turning to the neutron, CEBAF's experiments made



Schematic illustration of the CEBAF configuration at Jefferson Lab, illustrating components of the 12 GeV upgrade.

groundbreaking measurements of the distribution of electric charge, which revealed that up quarks congregate towards the centre, with down quarks converging along the periphery. Precision measurements were also made of the neutron's spin structure for the first time, as Jefferson Lab demonstrated the power of its highly polarized deuteron target and polarized helium-3 target.

Studies conducted with CEBAF revealed new information about the structure of the nucleon in terms of quark flavour, while others measured the excited states of the nucleon and found new states that were long predicted in quark models of the nucleon. High-precision data on the Δ resonance – the first excited state of the proton – demonstrated that its formation is not described by perturbative QCD, as some theorists had proposed. Researchers also used CEBAF to make precise measurements of the charged pion form-factor to probe its distribution of electric charge. New measurements of the lifetime of the neutral pion were also performed to test the low-energy effective field theory of QCD.

Following the development of generalized parton distributions (GPDs), a novel framework for studying nucleon structure, CEBAF provided an early experimental demonstration that they can be measured using high-luminosity electron beams. Following the upgrade, it will be possible to make measurements that can combine GPDs with transverse momentum distribution functions to provide 3D representations of nucleon structure.

From nucleons to nuclei

In its explorations of the structure of nuclei, research with CEBAF bridges the descriptions of nuclear structure from experiments that show the nucleus built of protons and neutrons to those that show the nucleus as being built of quarks. The first high-precision determination of the distribution of charge inside the deuteron (built of one proton and one neutron) at short distances revealed information about how the deuteron's charge and magnetization – terms related to its quark structure – are arranged.

Systematic deep-inelastic experiments with CEBAF have shed light on the EMC effect. Discovered by the European Muon collaboration at CERN, this is an unexpected dip in per-nucleon cross-section ratios of heavy-to-light nuclei, which indicates that the quark distributions in heavy nuclei are not simply the sum of those of the constituent protons and neutrons. The CEBAF studies indicated that the effect could be generated by high-density local clusters of nucleons in the nucleus, rather than by the average density.

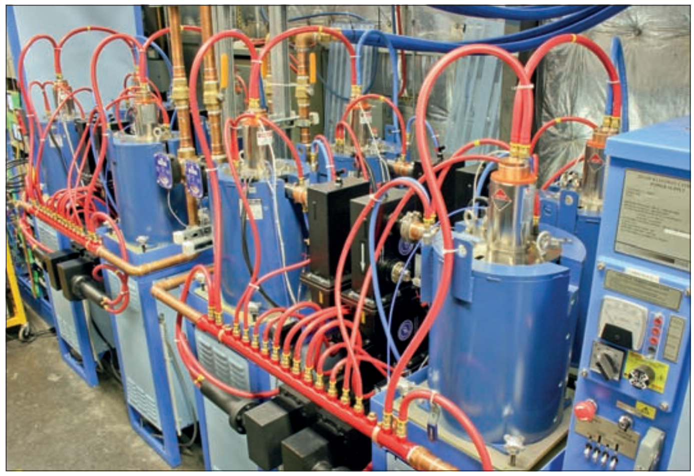
The CEBAF accelerator site is fully visible in this aerial photo, taken in May 2012. The outline of the racetrack-shaped accelerator is at the centre, with the circular experimental halls A, B and C in the bottom right corner and the rectangular Hall D just beyond the racetrack at the top left.

Related studies provided experimental evidence of nucleons that move so close together in the nucleus that they overlap, with their quarks and gluons interacting with each other in nucleon short-range correlations. Further explorations revealed that neutron–proton short-range correlations are 20 times more common than proton–proton short-range correlations (*CERN Courier* January 2009 p22). New experiments planned for the upgraded CEBAF will further probe the interactions of protons, neutrons, quarks and gluons to improve understanding of the origin of the nucleon–nucleon force.

High-precision data from CEBAF are also helping researchers to probe nuclei in other ways. Hypernuclear spectroscopy, which exploits the "strangeness" degree of freedom by introducing a strange quark into nucleons and nuclei, is being used to study the structure and properties of baryons in the nucleus, as well as the ▷

Accelerators

A cryomodule for the 12 GeV upgrade installed in the CEBAF accelerator tunnel.



Eight new klystrons recently installed as part of the 12 GeV upgrade. A total of 80 new klystrons are required to provide the RF power for the complete upgrade.

structure of nuclei. Also, the recent measurement of the "neutron skin" of lead using parity-violation techniques will be used to constrain the calculations of the fate of neutron stars.

CEBAF's highly polarized, high-luminosity, highly stable electron beams have exhibited excellent quality in energy and position. Coupled with the state-of-the-art cryotargets and large-acceptance precision detectors, this has allowed exploration of physics beyond the Standard Model through parity-violating electron-scattering experiments. Currently, the teams are eagerly awaiting the results of analysis of the experimental determination of the weak charge of the proton.

A bright future

Although the era of CEBAF at 6 GeV is over, the future is still bright. Jefferson Lab's Users Group has swelled to more than 1350 physicists. They are eager to take advantage of the upgraded CEBAF when it comes back online, with 52 experiments – totalling some six years of beam time – already approved by the laboratory's Program Advisory Committee (Dudek *et al.* 2012).

Jefferson Lab is now shut down for installation of the new and upgraded components that are needed to finish the 12 GeV project. At a cost of $310 million, this will enhance the research capabilities of the CEBAF accelerator by doubling its energy and adding an additional experimental hall, as well as by improving the existing halls along with other upgrades and additions.

Preliminary commissioning of an upgrade cryomodule has demonstrated good results. The unit was installed in 2011 and commissioned with a new RF system during CEBAF's final months of running at 6 GeV. The cryomodule successfully ran at its full specification gradient, 108 MeV, for more than an hour while delivering beam to two experimental halls. Commissioning of the 12 GeV machine is scheduled to commence in November 2013. Beam will be directed first to Hall A and its existing spectrometers, followed by the new experimental facility, Hall D.

Further reading

For details of many of these results, and others, see "New Insights into the Structure of Matter: The First Decade of Science at Jefferson Lab", *J. Phys.: Conf. Ser.* **299**.

J Dudek *et al.* 2012 arXiv:1208.1244v2 [hep-ex].

Résumé

CEBAF : un passé riche et un futur prometteur

Le 18 mai, l'accélérateur CEBAF (accélérateur d'électrons à faisceau continu) du laboratoire Jefferson a été arrêté, après 17 ans d'exploitation très fructueuse. L'accélérateur a servi à développer des éléments sur la structure des protons et des neutrons et sur la structure des noyaux, et à réaliser des études sur la symétrie fondamentale. Les faisceaux d'électrons à 6 GeV de la machine ont été arrêtés pour la dernière fois pour permettre l'installation d'éléments permettant un relèvement d'énergie à 12 GeV. Cette amélioration renforcera les capacités de recherche : non seulement l'énergie de l'accélérateur CEBAF sera doublée, mais un hall d'expérimentation supplémentaire sera ajouté et les halls existants seront améliorés.

Kandice Carter, Jefferson Lab.

Berkeley welcomes real-time enthusiasts

Specialists in real-time techniques from a variety of fields had the opportunity to share experiences at a conference in June.

Berkeley's Shattuck Plaza Hotel was the setting for RT2012. (Image credit: Stefan Ritt.)

The IEEE-NPSS Real-Time Conference is devoted to the latest developments in real-time techniques in particle physics, nuclear and astrophysics, plasma physics and nuclear fusion, medical physics, space science, accelerators and general nuclear power and radiation instrumentation. Taking place every second year, it is sponsored by the Computer Application in Nuclear and Plasma Sciences technical committee of the IEEE Nuclear and Plasma Sciences Society (NPSS). This year, the 18th conference in the series, RT2012, was organized by the Lawrence Berkeley National Laboratory (LBNL) under the chair of Sergio Zimmermann and took place on 11–15 June at the Shattuck Plaza Hotel in downtown Berkeley, California.

The conference returned to the US after being held in Lisbon for RT2010 and in Beijing in 2009, when the first Asian conference of this series was held at the Institute for High-Energy Physics. RT2012 attracted 207 registrants, with a large proportion of young researchers and engineers. Following the meetings in Beijing and Lisbon, there is now a significant attendance from Asia, as well as from the fusion and medical communities, making the conference an excellent place to meet real-time specialists with diverse interests from around the world.

Presentations and posters

As in the past, the 2012 conference consisted of plenary oral sessions. This format encourages participants to look at real-time developments in different sectors other than their own and greatly fosters the necessary interdisciplinary exchange of ideas in the various fields. Following a long tradition, each poster session is associated with a "mini-oral" presentation session. Presenters can opt for a two-minute talk, which helps them to emphasize the highlights of their posters. It is also an excellent educational opportunity for young participants to present and promote their work. With a mini-oral presentation still fresh in mind, delegates can then seek out the appropriate author during the following poster session, an approach that stimulates lively and intensive discussions.

The conference began as usual with an opening session with five invited speakers who surveyed hot topics from physics or innovative technical developments. First, David Schlegel of LBNL gave an introduction to the physics of learning about dark energy from the largest galaxy maps. Christopher Marshall of Lawrence Livermore National Laboratory introduced the National Ignition Facility and its integrated computer system. CERN's Niko Neufeld gave an overview talk on the trigger and data acquisition (DAQ) at the LHC, which provided an introduction to the large number of detailed presentations that followed during the week. Henry Frisch of the University of Chicago presented news from the Large Area Photodetectors project, which aims for submillimetre and subnanosecond resolution in space and time, respectively. Last, Fermilab's Ted Liu spoke about triggering in high-energy physics, with selected topics for young experimentalists.

The format fosters the necessary interdisciplinary exchange of ideas in the various fields.

The technical programme, organized by Réjean Fontaine of the University of Sherbrook, Canada, brought together various areas of real-time computing applications and DAQ covering a range of topics in various fields. About half of the topics ▷

came from high-energy physics, the rest mainly from astrophysics and nuclear fusion, medical applications and accelerators.

Some important sessions, such as that on Data Acquisition and Intelligent Signal Processing, started with an invited introductory or review talk. Ealgoo Kim of Stanford University reviewed the trend of data-path structures for DAQ in positron-emission tomography systems, showing how the electronics and DAQ are similar to those for detectors in high-energy physics. Bruno Gonçalves of the Instituto Superior Técnico Lisbon spoke about trends in controls and DAQ in fusion devices, such as ITER, particularly towards reaching the necessary high availability. Riccardo Paoletti of the University of Siena and INFN Pisa presented the status and perspectives on fast waveform digitizers, with many examples being given in following presentations.

Rapid evolution

This year the conference saw the rapid and systematic evolution of intelligent signal processing as it moves further towards front-end signal processing at the start of the DAQ chain. This incorporates ultrafast analogue and timing converters that use the waveform analysis concept together with powerful digital signal-processing architectures, which are necessary to compress and extract data in real time in a quasi "deadtime-less" process. Read-out systems are now made of programmable devices that include hardware and software techniques and tools for programming the reconfigurable hardware, such as field-programmable gate arrays, graphic processing units (GPUs) and digital signal processors.

Participants saw the evolution of many new projects that include architectures dealing with fully real-time signal processing, digital data extraction, compression and storage at the front-end, such as the PANDA antiproton-annihilation experiment for the Facility for Antiproton and Ion Research being built at Darmstadt. For the read-out and data-collection systems, the conceptual model is based on fast data transfer, now with multigigabit parallel links from the front-end data buffers up to terabit networks with their associated hardware (routers, switches, etc.). Low-level trigger systems are becoming fully programmable and in some experiments, such as LHCb at CERN, challenging upgrades of the level-0 selection scheme are planned, with trigger processing taking place in real time at large computer farms. There is an ongoing integration of processing farms for high-level triggers and filter farms for online selection of interesting events at the LHC. Experiences with real data were reported at the conference, providing feedback on the improvement of the event selection process.

A survey of control, monitoring and test systems for small and large instruments, as well as new machines – such as the X-ray Free-Electron Laser at DESY – was presented, showing the increasing similarities and possibilities for integration with standard DAQ systems of these instruments. A new track at the conference this year dealt with upgrades of existing systems, mainly related to LHC experiments at CERN and to Belle II at KEK and the SuperB project.

The conference saw an increasing number of applications and projects using new standards, emerging technologies such as Advance Telecommunications Computing Architecture (ATCA), as well as feedback on the experience and lessons learnt from successes and failures. This last topic, in particular, was new at this conference. Rather than showing only great achievements in glossy presentations, it can also be helpful to learn from other people's difficulties, problems and even mistakes.

A highlight of the Real-Time conference is the presentation of the CANPS prize, which is given to individuals who have made outstanding contributions in the application of computers in nuclear and plasma sciences. This year the award went to Christopher Parkman, now retired from CERN, for the "outstanding development and user support of modular electronics for the instrumentation in physics applications" (*CERN Courier* September 2012 p64). Special efforts were also made to stimulate student contributions and awards were given for the three best student papers, selected by a committee chaired by Michael Levine of Brookhaven National Laboratory.

Last, an industrial exhibit by a few relevant companies ran through the week (CAEN, National Instruments, Schroff, Struck, Wiener and ZNYX). There was also the traditional two-day workshop on ATCA and MicroTCA, which is the latest DAQ standard, following CAMAC, Fastbus and VME, from the telecommunications industry. This workshop with tutorials, organized by Ray Larsen and Zheqiao Geng of SLAC and Sergio Zimmermann of LBNL, took place during the weekend before the conference. Two short courses were also held that same weekend, one by Mariano Ruiz of the Technical University of Madrid on DAQ systems and one by Hemant Shukla of LBNL on data analysis with fast graphic cards (GPUs).

The 19th Real-Time Conference will take place in May 2014 in the deer park inside the city of Nara, Japan. It will be organized jointly by KEK, the University of Osaka and RIKEN under the chair of Masaharu Nomachi. A one-week Asian Summer school on advanced techniques on electronics, trigger, DAQ and read-out systems will also be organized jointly with the conference.

● For details about the Real-Time Conference, see http://rt2012.lbl.gov. A special edition of *IEEE Transactions on Nuclear Sciences* will include all eligible contributions from the RT2012 conference, with Sascha Schmeling of CERN as senior editor.

Résumé

Berkeley accueille des enthousiastes du temps réel

Des spécialistes des techniques de temps réels issus de différentes disciplines ont eu l'occasion de mettre en commun leurs expériences à la 18e Conférence sur le temps réel IEEE-NPSS, organisée en juin par le Laboratoire national Lawrence de Berkeley. Cette conférence biennale est consacrée aux dernières avancées des techniques de temps réel en physique des particules, en physique nucléaire et en astrophysique, en physique des plasmas et de la fusion nucléaire, en physique médicale, en sciences de l'espace et enfin dans les technologies de l'énergie nucléaire et de l'instrumentation en matière de radiations. Le programme a permis de confronter différents domaines d'application du calcul en temps réel, puisque la moitié environ des sujets présentés concernaient la physique des particules, le reste portant essentiellement sur l'astrophysique et la fusion nucléaire, les applications médicales et les accélérateurs.

Patrick Le Dû, IPN Lyon, and **Stefan Ritt**, PSI.

Faces & Places

CERN

Agnieszka Zalewska is elected president of CERN Council

The CERN Council has elected Agnieszka Zalewska to be its 21st president from 1 January 2013. She takes over from Michel Spiro, whose three-year term finishes at the end of December. Zalewska has been a member of several CERN committees and has been the Polish scientific delegate to the CERN Council since January 2010.

Zalewska, who is currently a professor at the H Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences in Krakow, has a distinguished career in particle physics and a long association with CERN. She received her doctorate in 1975 from the Jagellonian University in Krakow for work on the data from the 2-m bubble chamber at CERN. She later worked on the DELPHI experiment at the Large Electron–Positron collider, where she played an important role in the development of silicon tracking detectors.

Agnieszka Zalewska will be not only the first woman but also the first Polish physicist to be president of CERN Council.

Since 2000, she has worked primarily in neutrino physics through the ICARUS experiment at Italy's Gran Sasso National Laboratory, which studies a neutrino beam sent from CERN, and at the T2K (Tokai-to-Kamioka) experiment in Japan. She has also been involved in feasibility studies for an underground laboratory in Poland.

"The coming years will be fascinating but demanding, as we prepare the LHC for running at higher energies and implement the updated European Strategy for Particle Physics," said Zalewska. "CERN and its Council will become my only priority, and I would like to thank the council members and outgoing president for the confidence they have placed in me."

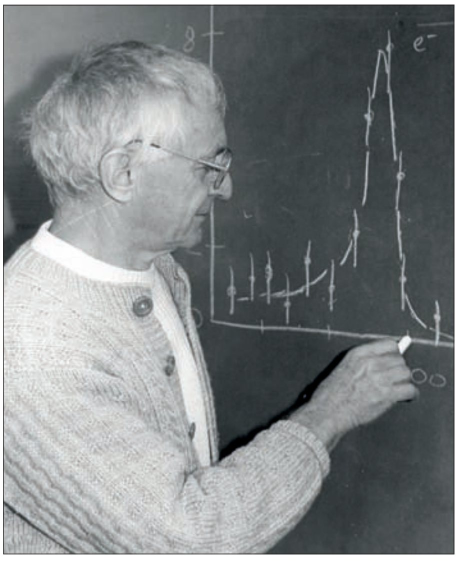
● For an interview with Agnieszka Zalewska, see *The Bulletin* https://cdsweb.cern.ch/record/1479361?ln=en.

CELEBRATION

Slovenian particle-physics pioneer reaches his 80th

Friends and colleagues gathered at the Jozef Stefan Institute in Ljubljana on 13 September to celebrate the 80th birthday of Gabrijel ("Elko") Kernel. Speakers there outlined his contributions to experimental particle physics, recognizing him as the "founding father" of the field in his home country, Slovenia.

Kernel's involvement in experiments at CERN dates from the mid-1970s, when he joined an international group of physicists, led by the late Neil Tanner of Oxford University, who were building the Omicron spectrometer at the 600 MeV Synchrocyclotron. As spokesperson of a series of experiments on pion production near threshold, Kernel established a small group of young and capable Slovenian particle physicists. His later research included experiments at DESY with the ARGUS spectrometer and at CERN's Large Electron–Positron collider with DELPHI. During this time, he supervised the PhD theses of many young colleagues, several of whom now lead Slovenian groups in large international collaborations such as ATLAS, Belle II and the Pierre Auger Observatory.



Kernel's contribution to science in general and Slovenian particle physics in particular is appreciated by not only the 40 or so members of the particle physics department at the Jozef Stefan Institute and particle physics groups at the Universities of Ljubljana, Maribor and Nova Gorica but also by national institutions that have recognized his work through many honours and awards.

Gabrijel ("Elko") Kernel. (Image credit: Janez Zrnec.)

Faces & Places

CONFERENCE

QCD 12 and Higgs-like happiness

Participants pose in the Montpellier sunshine. (Image credit: Alize Photo.)

Amid the beauty of Montpellier in France, the 16th International Conference in Quantum ChromoDynamics, QCD 12, took place on 2–6 July. It brought together theorists and experimentalists from laboratories around the world, all working actively within QCD. Mid-way through the conference, a live webcast from CERN thrilled participants with the news of the discovery of a Higgs-like boson.

The new boson was just one of the discussion topics at QCD 12. This biannual conference featured LHC physics alongside heavy-flavour spectroscopy, light flavours and glueballs, tau, kaon and B-decays, CP-violations and the QCD plasma.

Participants discussed several questions – including the hadron spectrum – suggesting approaches to manage the non-perturbative problems in a way similar to the weak coupling limit. Talks also dealt with the use of perturbation theory at high-energy in QCD to evaluate the production rate of pairs of top quarks, and presented the different determinations of the QCD coupling α_s.

The current work by Stephan Narison, the conference organiser, on heavy flavours with QCD spectral-sum rules could be a reference for experiments in much the same way as lattice computations. Elsewhere, researchers are now actively pursuing anti-deSitter models to map gravity and QCD.

Measuring the g factor of the muon could give a clue to new physics, although the critical point is determining the hadronic contributions. There is currently a 3.6 σ discrepancy between the theoretical computed value and the one measured. The programme concluded with talks on behalf of the ATLAS and CMS collaborations – a fitting end that allowed the participants to hear about the achievement announced on 4 July directly from some of the very people involved at CERN.

● For more information, visit www.lpta.univ-montp2.fr/users/qcd/qcd2012/ and Marco Frasca's blog at: http://marcofrasca.wordpress.com/2012/07/08/qcd-12-and-higgs-tears/.

ASP2012

Ghana hosts 2nd African physics school

Students and lecturers at the physics school in Kumasi. (Image credit: ASP2012.)

On 15 July – 4 August, the Kwame Nkrumah University of Science of Technology (KNUST) in Kumasi, Ghana, played host to the African School of Fundamental Physics and its Applications 2012 (ASP2012), which was attended by 50 students, nearly all of whom were from African nations. This was the second such school, following the highly successful first edition, ASP2010, which took place two years ago in Stellenbosch, South Africa (*CERN Courier* November 2010 p26). One new feature for 2012 was an extension of the school with three extra days dedicated to the Grid, taking place on 6–8 August.

The goal of the school is to help advance basic science and its applications throughout Africa by increasing the number of students acquiring higher education and improving proficiency in applications and technologies related to research at particle accelerators. To this end, it is based on a close interplay between theoretical, experimental, applied physics and computing, with a duration that allows for student-to-student interactions, as well as between students and lecturers. This year, the 32 lecturers – spread across the three-and-a-half-week period – came from Belgium, France, Ghana, Italy, South Africa, Sweden, Switzerland, the UK and the US, as well as from CERN.

The success of ASP2010 had encouraged the organizers to work hard towards the original aim of holding the school every two years. By exploring the option to hold the school in a different host country, the international organizing committee (IOC) – which consists of members from the International Centre for Theoretical Physics (ICTP), Brookhaven National Laboratory, the European Spallation Source (ESS), King's College London and the Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) of the Centre National de la Recherche Scientifique (CNRS) – selected Ghana for ASP2012. The local organizing committee (LOC) consisted of KNUST, the University of Ghana at Legon, the Ghanaian Atomic Energy Commission, the University of Cape Coast and the National Institute for Mathematical Sciences.

ASP2012 proved as successful as ASP2010, thanks to the dedication of the IOC, the organization by the LOC, the quality of the selected students and financial support from 23 institutions in Africa, Europe and the US, including ICTP, INFN, CERN and other major particle-physics laboratories, as well as governmental institutions in Africa, Europe and the US – all of whom foster the goals of the school. As Fernando Quevedo, the director of ICTP, commented: "The success of ASP2012 is a wonderful example of international scientific collaboration contributing to the development of fundamental science in Africa and the ICTP is proud to provide strong support to these schools." The IOC is now preparing a report of activities for the sponsoring institutes, before the preparation for the next school in 2014 begins in earnest.

● ASP2012 was sponsored by AIMS-NEI (SA), BNL (US), CEA-IRFU (France), CERN, CNRS/IN2P3 (France), DESY (Germany), EPFL (Switzerland), ESS (Sweden), FNAL (US), ICTP, INFN (Italy), JLAB (US), JSA (US), Louisiana Tech University (US), NITheP (SA), PSI (Switzerland), Université Catholique de Louvain (Belgium), University of Texas Arlington (US), Uppsala University (Sweden); by the networks ARDENT and DITANET; by the American Physical Society (US), the Department of Science and Technology (SA), the French Embassy Ghana, the NRF (SA) and the NSF (US); and by private donation (M Lindroos).

● For more about the school, visit http://cern.ch/africanschoolofphysics.

OUTREACH

ATLAS virtual visits awarded best online event

The ATLAS virtual visit project was awarded "best online event" at the recent Digital Communication Awards in Berlin, for excellence in online communication. More than 500 international communication projects competed for 36 awards and the project was shortlisted alongside major corporations as well as professional advertising agencies.

During a virtual visit, online participants can use web-based video-conferencing tools to talk to an ATLAS physicist, receive a tour of the control room and get answers to their questions. Visits have included students from Brazil and Palestine, as well as links with the UK, Poland and Italy during the recent EU Researchers' Night in September. In one event, CERN directors were able to link remotely with ATLAS from a town square in Krakow.

With the number of requests for visits increasing steadily, virtual visits look set to continue and bring the excitement of research at the LHC to students and the general public. The virtual visits are organized by the ATLAS outreach and education team and are hosted by members of the collaboration.

● For more details, see http://cern.ch/atlas-virtual-visit/.

An ATLAS virtual visit for students at Al-Quds University, a Palestinian university with campuses in Abu Dis and al-Bireh. Top: The scene from the ATLAS control room transmitted to the students, who can also be seen asking their questions, below.

*Si-Chen Lee (front right), president of the National Taiwan University (NTU), shakes hands with Chee-Chen Leung, vice-president and co-founder of Quanta Computer Inc, after signing the contract on 21 June for a donation of NT$570 million (US$19 million) to support the permanent operation of the Leung Center for Cosmology and Particle Astrophysics (LeCosPA), including the building of a dedicated building. The centre was made possible through an earlier donation from Leung in 2007 (*CERN Courier *July/August 2008 p38). (Image credit: LeCosPA.)*

Faces & Places

Visits

The president of the Slovak Republic, **Ivan Gašparovič**, centre left, shakes hands with CERN's director-general, **Rolf Heuer**, flanked by **Silvia Gašparovič**, left, and **Karel Safarik**, physics and computing group leader at CERN for the ALICE experiment. The president and his wife visited CERN on 11 September, where they toured the LHC tunnel and the ALICE experiment, and spoke to members of the CERN Slovak community.

The German Chancellor, **Angela Merkel**, centre right, visited the DESY laboratory in Hamburg on 20 September. Together with Hamburg's First Mayor, **Olaf Scholz**, centre left, Nobel laureate, **Ada Yonath**, right, and DESY's director, **Helmut Dosch**, left, she participated in the ceremony to name the PETRA III experimental hall after Max von Laue, who discovered the diffraction of X-rays by crystals exactly 100 years ago.

New products

CUI Inc has released its second-generation digital point-of-load DC-DC modules for distributed-power architecture applications. The NDM2P series is the latest addition to CUI's Novum Advanced Power product line. The modules offer true cycle-by-cycle compensation, autonomously balancing the trade-offs between dynamic performance and system stability. With efficiencies above 93% at half load, the series comes in three compact DIP configurations. For further details, contact Maggie Lefor, tel +1 503 612 2391, e-mail mlefor@cui.com or visit www.cui.com.

Essex X-Ray and **Medical Equipment Ltd** have extended the range of spring-loaded flanges manufactured for use with their high-voltage cable assemblies, covering voltages up to 300 kV. The constant tension created by these multi-spring flanges ensures that an even pressure is exerted on the contacts and all round the seals, regardless of external conditions. Detailed drawings and data sheets are available from www.essex-X-ray.com/dadasheets.html. For further details, contact Ray Wood, tel +44 1371 875 665, e-mail rwood@essex-X-ray.com or see www.essex-X-ray.com.

Keithley Instruments Inc has introduced three new economical source measurement unit (SMU) instruments to its Series 2600B System SourceMeter line. The 2604B, 2614B and 2634B are optimized for bench-top research, product development and student labs. Series 2600B offers single- and dual-channel models that combine the capabilities of a precision power supply, true current source, 6 $^1/_2$-digit multimeter, arbitrary waveform generator, pulse generator and electronic load in one instrument. Keithley has also announced the Model 2110 5 $^1/_2$-digit Dual-Display Digital Multimeter, which is optimized for general-purpose systems and bench-top design applications. System features such as external triggering and a built-in reading buffer to enhance ease of use. Its capabilities include DC voltage (up to 1000 V) and current (up to 10 A), AC voltage (up to 750 V) and current (up to 10 A) measurements. For further details, tel +49 89 84 93 07 40, e-mail info@keithley.de or visit www.keithley.com.

Kurt J Lesker Company has introduced the Chamber Builder, for designing and ordering custom vacuum chambers. Combined with the online drawing service, VacuCAD, the Chamber Builder programme allows a customer to take a standard KJLC chamber, customize it to fit their application and generate a 3D model in both PDF and STP formats. It is possible to add up to 20 ports per chamber. For further details, tel +1 412 387 9200, e-mail chambers@lesker.com or see www.lesker.com.

Siemens Industry Automation Division has extended its range of single-phase power supplies, Sitop, with three 24 V power supplies with rated output voltages of 2.5 A, 5 A and 10 A, as well as two 12 V power supplies with 7 A and 14 A. The output voltage is adjustable for 24–28 V for the 24 V power supplies and for 12–15.5 V for the 12 V models. The units can be used at ambient temperatures between –10 °C and 70 °C and are characterized by up to 90% efficiency, ensuring minimal heat generation. For further details, contact Peter Jefimiec, tel+49 911 895 7975, e-mail peter.jefimiec@siemens.com or visit www.siemens.com/sitop.

Unitemp has launched a range of energy efficient compact vacuum chambers manufactured by **Japan ESPEC Corporation**. The range, primarily for testing electronic/electrical components, materials, small assemblies and adhesives under low pressure, consists of three models, VAC-101P/-201P/-301P. A 20–40% energy saving is claimed by advanced manufacturing processes giving improved air tightness and sealing capacity. The pressure pull-down range is from atmospheric to less than 133 Pa, which can be obtained in 4 to 15 minutes, depending on the model. For further details, contact Paul Brown, tel +44 1628 850611 or e-mail paul@unitemp.co.uk.

COSMIC RAYS

Hess and his scientific legacy

There have been many meetings to celebrate the centenary this year of the discovery of cosmic rays but only one took place close to the site where Victor Hess landed after his historic balloon flight of 7 August 1912 (*CERN Courier* September 2012 p14). Not only did this conference bring together historians and key people in the ongoing study of cosmic rays, Hess's two grandsons from the US were also present and for, added flavour, participants had the opportunity to see the area themselves from a balloon.

The meeting on "100 Years of Cosmic Rays – Anniversary of Their Discovery by V F Hess" took place in the small town Bad Saarow-Pieskow, some 50 km south-east of Berlin, on 5–8 August. It was organized by the University of Potsdam, the Max Planck Institute for the History of Science and members of the DESY institute at nearby Zeuthen, which has a large involvement in the appropriately named HESS (High Energy Stereoscopic System) in Namibia, as well as with the IceCube experiment at the South Pole.

As with many important advances, the discovery of cosmic rays was "of its time". Hess was not alone in studying the conductivity of air. His ground-breaking measurements owed much to Theodor Wulf, for instance, who had invented a sensitive electroscope. Examples of this and other early instruments were on display at the meeting and presentations on the first day reminded the audience of other pioneers who refined instrumentation or took to the skies in hydrogen balloons – both before and after Hess. As an appropriate start, William "Bill" Breisky, an American writer and former editor of the *Cap Cod Times*, recalled his childhood visits to "Grandpa" Hess in New York (to where Hess had fled from the Nazis), providing a tangible link with the man whose work was being celebrated.

Hess's work led directly to further research on cosmic rays and the discovery of extensive air showers of secondary particles generated by very-high-energy cosmic rays. It also led to high-energy particle physics: Brookhaven's 3.3 GeV Cosmotron was so named in the early 1950s because it would accelerate protons to energies similar to those of cosmic rays. Jim Cronin, who epitomizes the links between the two fields, set the scientific scene for the conference with an overview of the developments that followed Hess's discovery up until around 1950. Awarded the Nobel prize for the discovery in 1964 of CP violation in neutral kaons, Cronin was later one of the instigators of the Pierre Auger Observatory in Argentina, which currently detects extensive air showers from the highest-energy cosmic rays.

Some conference participants fly over the area of Bad Saarow-Pieskow, a century after Hess landed in the region.

Arthur (left) and Bill Breisky unveil the plaque dedicated to Hess and his achievement, in the village of Pieskow. (Image credits: T Pritchard.)

Several speakers cast more light on the different techniques for detecting cosmic rays developed during the first part of the 20th century, from the cloud chamber, which made cosmic rays visible, to the discovery of Cherenkov radiation emitted by air showers. Claus Grupen carefully detailed the many "elementary" particles observed in cosmic rays during this period, from the positron of 1932 to the Σ particles and even maybe the Ω^- of the early 1950s. More of Hess the scientist and his work was the subject of Peter Schuster, who together with a group of other physicists set up the Victor Franz Hess Society in Graz, in 2007.

A move towards the present day began on the second day, with an overview by Alan Watson, who with Cronin led the construction of the Auger Observatory. Watson laid out the path from the late 1940s to the present, "chasing the highest-energy cosmic rays". Understanding where cosmic rays of the highest energies originate and the mechanisms that could accelerate them are still unknown – and the subject of debate, as some lively discussions demonstrated. Back to Earth, Ralph Engel reminded the audience of the essential role that current particles physics plays in understanding hadronic interactions, a crucial matter for simulating the production of showers in the atmosphere. Experiments at CERN, especially by LHCf and TOTEM at the LHC, as well as by NA61 and HARP, are making valuable contributions in this respect.

Cosmic-ray physics is now a part of the broader field of astroparticle physics and is advancing knowledge of the universe in a number of ways. Imaging air-Cherenkov telescopes, such as HESS, detect γ-ray sources through the air showers that high-energy γ-rays generate, providing a complementary view to that obtained by satellites. The age of neutrino astronomy began with the detection of neutrinos from the supernova SN1978a and continues today with IceCube, which aims to detect cosmic-neutrino sources. Closer to home, there still remain questions about the interactions of cosmic rays with the charged particles of the heliosphere that surrounds the Solar System. Last but not least, links between cosmic rays and climate and life on Earth remain fascinating areas of research, as the closing talks revealed.

While the meeting provided a broad, up-to-date look at cosmic-ray research, history was never far away. On 7 August – 100 years to the day after Hess landed close by – Bill and Arthur Breisky unveiled a plaque on a geological "erratic", a stone deposited after having been carried from afar by a glacier during the last ice age. It was a fitting tribute to their grandfather, who had found himself near the same place after making a long journey to study an intriguing natural phenomenon – and setting researchers onto a road that would lead to modern particle physics.

● For more about the conference, see https://indico.desy.de/conferenceDisplay.py?confId=4213. For Bill Breisky's article about Hess in *The New York Times* of 7 August, see http://www.nytimes.com/2012/08/07/science/space/when-victor-hess-discovered-cosmic-rays-in-a-hydrogen-balloon.html?_r=0.

OBITUARY

Michael Edwards 1939–2011

Mike Edwards, who made valuable contributions to several generations of particle-physics detectors, passed away on 23 November 2011.

Mike began his scientific career in 1960 when he joined John Holt's group working on pion scattering experiments at the synchrocyclotron at Liverpool University. There he developed spark chambers with automatic acoustic read-out, which kindled his interest in the techniques of particle physics, a career path that he was to follow.

Following his PhD at Liverpool University, he went to the US to work on the Carnegie-Mellon synchrocyclotron in Pittsburgh. From there he moved back to the UK, where he had been invited to the Daresbury Laboratory to develop automatic film-scanning systems. He then went to CERN to work on the Omega Spectrometer with the Liverpool University group. After this, he joined the Experimental Physics Group at Daresbury, playing a pivotal role in the construction and testing of multiwire proportional chambers (MWPCs) and their on-board electronics for the LAMP group.

When high-energy physics moved from Daresbury to the Rutherford Appleton Laboratory (RAL) attempts were made to keep Mike at Daresbury to help with the detector needs of the new synchrotron radiation facility. However, he wished to remain in high-energy physics and joined the RAL team working in the European Muon Collaboration (EMC) at CERN. He was responsible for the development and testing of even larger MWPCs inside the EMC forward magnet spectrometer and with the huge EMC muon drift chambers.

Mike Edwards. (Image credit: Edwards.)

Mike then became involved in the design and construction of the endcap electromagnetic calorimeters for the ALEPH experiment at CERN's Large–Electron Positron collider. Here his "down-to-earth" approach gave him a central role throughout. That the detectors worked perfectly during the 11 years of ALEPH data taking is a fitting memorial to him. He ended his career working first on the design of apparatus for experiments at the aborted Superconducting Supercollider in Texas and finally on the cooling system for the barrel and endcap silicon detectors for the ATLAS experiment at the LHC.

Much of the success of the LAMP, EMC and ALEPH detectors was built on the dedicated efforts of Mike and his team, working behind the scenes to make them operate. He did not take the accolades for the successes of the experiments on which he worked, but they would not have produced the same results without him. He was a genial man who would move mountains to make sure that the detectors worked.

Mike always smiled, was kind and fair to everyone and was a good source of humour while pushing back the frontiers of detector technology. He became a much respected colleague on all of the projects in which he was involved. He is sorely missed by all of us and by his family for whom he was a much loved husband, father and grandfather.

● *His friends and colleagues.*

LETTER

Boosting the Booster

Congratulations to the Booster team for achieving such impressive progress and thank you to the authors of the recent article for letting readers of *CERN Courier* participate (September 2012 p27). Having been the co-ordinator of the Booster Study Group 1966/67 (and the leader of Booster Group 1973–1983), I would like to add a few comments.

When I participated in a session of the Tevatron design group, I learnt that one of Robert Wilson's aims was to build a machine as compact and inexpensive as possible compatible with the performance aims. If that had been a design criterion for the Booster, the improvements described in the article would have required much deeper changes, such as the replacement of the complete magnet system. As it happened, the Booster improvements were able to benefit from the original implied design aims of: (i) flexibility of operation; (ii) keeping sources of beam instabilities as small as possible, with early provision of means to combat remaining ones; and (iii) ensuring machine reliability.

After intensive studies of possible alternatives, the consequences were: a slow-cycling separate-function synchrotron with triplet focusing and an even number of superposed rings (as against five rings preferred by some); the achievement of magnet characteristics as uniform as possible plus plenty of correction magnets; the maximum possible reduction of the beam-equipment coupling impedance; low magnetic, electric and thermal stress of machine components; radiation hardening and protection against stray protons; safety margins of 10–20% with respect to nominal electric currents and voltages; standardization of components wherever possible; an extension of the theory of various beam instabilities and their reduction by appropriate feedback systems (F J Sacherer and F Peterson 1977 *IEEE Trans. Nucl. Sci.* **NS-24** 1396).

More details on these and more can be found in the original Booster proposal, MPS/Int.DL/B 67-19, and later CERN documents MPS/Int.BR/74-10 and PS/BR/77-1 as well as *CERN Courier* July/August 1973 p219 and July/August 1997 p4.

To conclude, I take my hat off again to all who have achieved so many great improvements on those potentially fruitful foundations, which are still considered good enough for the upgrade to CERN's accelerator complex.

● *Helmut Reich, Glion, Vaud.*

CORRECTION

An unfortunate error crept into the article on the discovery of air-Cherenkov radiation in the September issue of *CERN Courier*. On p36, it states that Trevor Weekes "had worked with Jelley in a collaboration between AERE and the University of Dublin". The correct attribution should be to University College Dublin. Many apologies to all concerned.

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Temple Circus, Temple Way, Bristol BS1 6HG, UK.
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THEORETICAL CONDENSED MATTER AND STATISTICAL PHYSICS (CM&SP) POST-DOCTORAL POSITIONS AT THE ABDUS SALAM INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS (ICTP) TRIESTE, ITALY (ACADEMIC YEAR 2013-2014)

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A limited number of post-doctoral positions for young CM&SP theoreticians will be available starting Fall 2013.

Appointments will be made for two years, with the possibility of renewal for one more year.

Applicants should be no more than 35 years of age at the time of application and should have obtained their Ph.D. after 2008. The application form can be accessed at the website: **https://onlineapps.ictp.it/ENTER/APPLICANT/CP12.mhtml**

Additional detailed curriculum vitae, list of publications and at least three recommendation letters (sent separately after submission of application) must all be appended on-line.

Deadline for receipt of applications: 13th January 2013.

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For further information you may also contact Prof. Dr. Martin Pohl
Tel.: +49 33762-77484, martin.pohl@desy.de.

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Application documents including cover letter, CV, PhD certificate, list of publications, statement of research accomplishments and research plan should be uploaded at http://www.universe-cluster.de/about-us/jobs/. Please have three letters of recommendation sent to Dr. Andreas Müller at **job@universe-cluster.de**. Applications from female scientists and candidates with disabilities are especially encouraged. The salary is according to the German public service pay agreement (TV-L E14). Appointments end on 31st October 2017. **Application deadline is 30th November 2012.**

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The INFN Fellowship Programme 2012/2013 offers 16 (sixteen) positions for research activity in Experimental Physics.

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Online applications are to be sent to INFN not later than **November 20th, 2012** applying at the website **http://www.ac.infn.it/personale/exp_fellowships/**. The applications should include the research topic(s) of interest, the preferred INFN site(s) - two at the most, chosen among those listed in Annex 1 - and:

- a statement of research interests;
- a curriculum vitae;
- a publication list;
- at least three reference letters (specifying name, last name and e-mail of each referee).

At the end of the selection process the candidates will be informed by e-mail about the result of their application. Successful candidates will then receive an official communication from the INFN administration offices. The appointed fellows should start their fellowships not later than November 1st, 2013; special requests to defer the starting date can be considered.

ISTITUTO NAZIONALE DI FISICA NUCLEARE
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(*Prof. Fernando Ferroni*)

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Ms. Yen-Ling Lee ntulecospa@ntu.edu.tw
For more information about LeCosPA, please visit its website at
http://lecospa.ntu.edu.tw/

Three letters of recommendation should be addressed to
Prof. Pisin Chen, Director
Leung Center for Cosmology and Particle Astrophysics
National Taiwan University

INFN Istituto Nazionale di Fisica Nucleare

POST-DOCTORAL FELLOWSHIPS IN THEORETICAL PHYSICS

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The annual gross salary is € 40.000,00. Each fellowship is initially granted for one year and may be extended for a second year. Travel tickets to and from INFN sites will be reimbursed at the beginning and at the end of the fellowship; also lunch tickets will be provided for working days.

Applications, in electronic form, must be sent to INFN no later than **November 20, 2012** through the website **http://www.ac.infn.it/personale/theo_fellowships/**.
The applications must specify the research topic(s) and the corresponding INFN site(s) (up to a maximum of three) among those listed in Annex 1, and must include:

- a curriculum vitae;
- a publication list;
- at least three reference letters (specifying name, surname and e-mail of each referee).

For each fellowship primary consideration will be given to candidates working in the corresponding specific research topic; however candidates working in other subjects may be also considered.

At the end of the selection process the candidates will be informed by e-mail about the result of their application. Successful candidates will then receive an official communication from the INFN Administation Offices. The appointed fellows should start their fellowships no later than November 1, 2013; special requests to defer the starting date can be considered.

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Candidates are requested to submit a curriculum vitae, a publication list, a statement of research interests and accomplishments, and a research and teaching plan to: Professor Frank T. Avignone, Chair of the Particle Astrophysics Search Committee, USC Physics and Astronomy, 712 Main St., Columbia, SC 29208 (E-mail: avignone@sc.edu).
Candidates are also requested to ask at least three references to mail letters of recommendation directly to the above address. Inquiries may be directed to Professor Avignone at avignone@sc.edu.
For full consideration, applications must be received by November 30, 2012.
Further information is available at http://www.physics.sc.edu.

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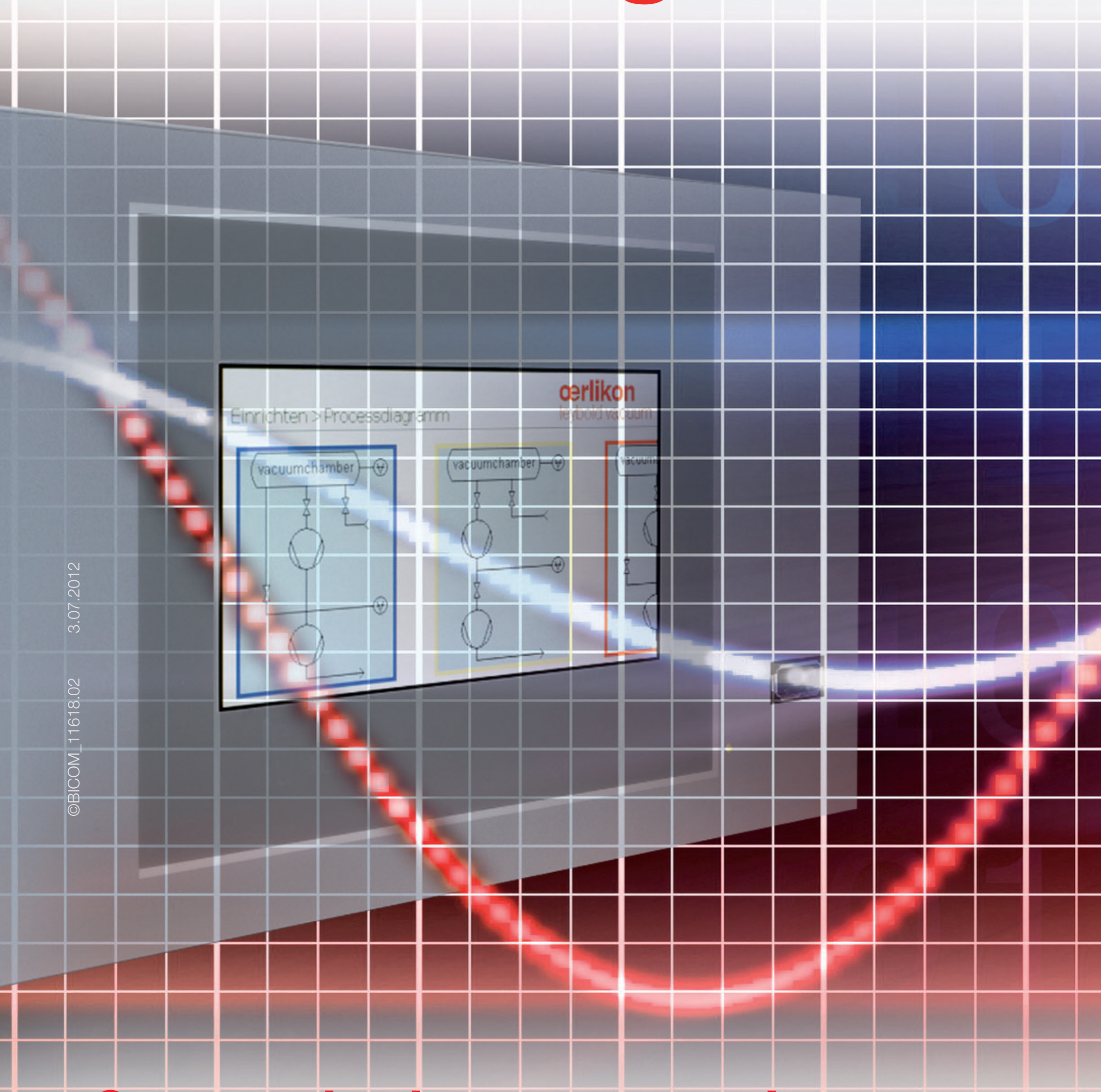

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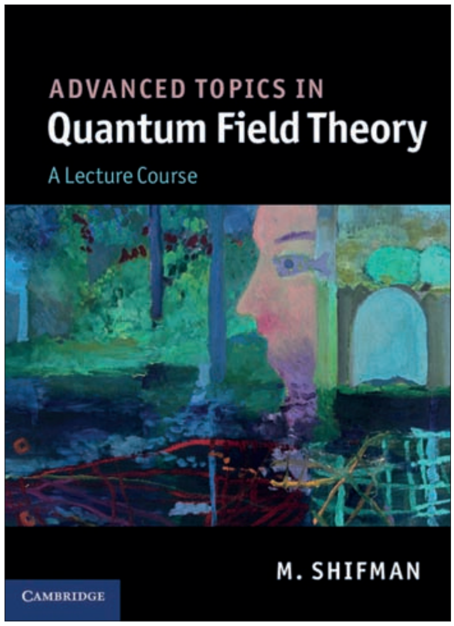
Advanced Topics in Quantum Field Theory: A Lecture Course

By M Shifman
Cambridge University Press
Hardback: £45 $80
E-book: $64



Many interesting developments have taken place in quantum field theory (QFT) since the 1970s, and there is no better place to learn about them than this book. The author has been an active contributor to the field over the past four decades and he has produced a personal book based on his lectures over the years. Reading the table of contents virtually gives you vertigo because the depth and breath of the topics covered is simply staggering.

The book is structured as two parts: before and after supersymmetry – although many of the concepts introduced in the first part have an extension in the supersymmetric context, with interesting conceptual variations. All subjects are treated thoroughly and with great clarity. The opening chapter deals with the important subject of the phases of gauge theories and it continues with the many exotic objects that populate QFT, namely kinks, domain walls, strings, vortices, monopoles, skyrmions, instantons, chiral anomalies, confinement, chiral-symmetry breaking and a quick overview of lower-dimensional models related to the theory of phase transitions. The treatment of each subject is rather complete, and many difficult subjects are explained with exemplary clarity, for example the use of collective co-ordinates and their importance in the quantization of semiclassical states, as well as the interplay between chiral-symmetry breaking in QCD-like theories and confinement.

The author provides one of the most elegant and concise presentations of the use of instantons in gauge theories that I have ever seen. This is a notoriously complex subject, with important physical implications, such as the vacuum angle in QCD and the strong CP problem. The computations are carried out in detail and the reader is led by a safe hand through all of the delicate aspects of rather complex calculations. This is a great service to anyone trying to learn advanced QFT after a grounding in the standard courses in the subject.

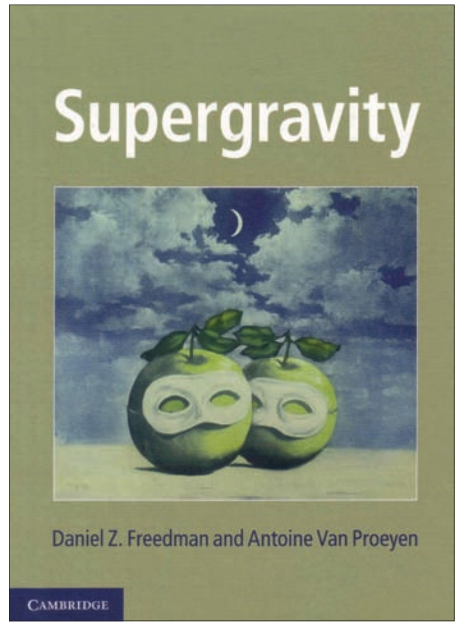
In the second part of the book, the author provides a remarkably lucid and complete presentation of supersymmetry, supersymmetric gauge theories and all of their associated phenomenology. It is difficult to pack more information in the 150 pages dedicated to the subject. The phase diagram of supersymmetric gauge theories is rather complex and subtle. There is no one better suited than the author to introduce the subject; he has been one of its main contributors over the years. Subjects such as supersymmetry anomalies, the Witten index, the implications and uses of instantons within supersymmetry, the super-Higgs mechanism and the Russian beta-function are but a few of the subjects featured in this part of the volume.

This book is a must for anyone interested in learning about the developments in advanced field theory over the past few decades. It is a pedagogical and deeply insightful presentation by one of the masters in the field.

● *Luis Álvarez-Gaumé, CERN.*

Supergravity

By Daniel Z Freedman and Antoine Van Proeyen
Cambridge University Press
Hardback: £45
E-book: $64



Since the work of Emmy Noether nearly a century ago, the idea of symmetry has played an increasingly important role in physics, resulting in spectacular successes such as Yang-Mills gauge theory along the way. Albert Einstein, in particular, realized that symmetry could be a foundational principle; his understanding that the space–time dependent ("local") symmetry of general co-ordinate invariance could be used to build general relativity had an enormous impact on the development of 20th-century physics.

The current zenith of the local symmetry principle is the theory of supergravity, which combines general relativity with the spin-intermingling theory of supersymmetry to construct the richest and deepest symmetry-based theory yet discovered. Supergravity also lies at the foundation of string theory – a theory whose own symmetry principle has not yet been uncovered – and so is one of the central ideas of modern high-energy theoretical physics.

Unfortunately, since its invention in the 1970s, supergravity has been an infamously difficult subject to learn. Now, two of the inventors and masters of supergravity – Dan Freedman and Antoine Van Proeyen – have produced a superb, pedagogical textbook that covers the classical theory in considerable depth.

The book is notably self-contained, with substantial and readable introductory material on the ideas and techniques that combine to make up supergravity, such as global supersymmetry, gauge theory, the mathematics of spinors and general relativity. There are many well chosen problems for the student along the way, together with compact discussions of complex geometry. After the backbone of the book on N=1 and N=2 supergravities, there is an excellent and especially clear chapter on the anti-deSitter supergravity/conformal field theory correspondence as an application.

Naturally, any finite book has to cut

Bookshelf

short some deserving topics. I hope that any second edition has an expanded discussion on superspace to complement the current, clear treatment based on the component multiplet calculus, as well as a greater discussion on supergravity and supersymmetry in the quantum regime.

Overall, this is a masterful introduction to supergravity for students and researchers alike, which I strongly recommend.

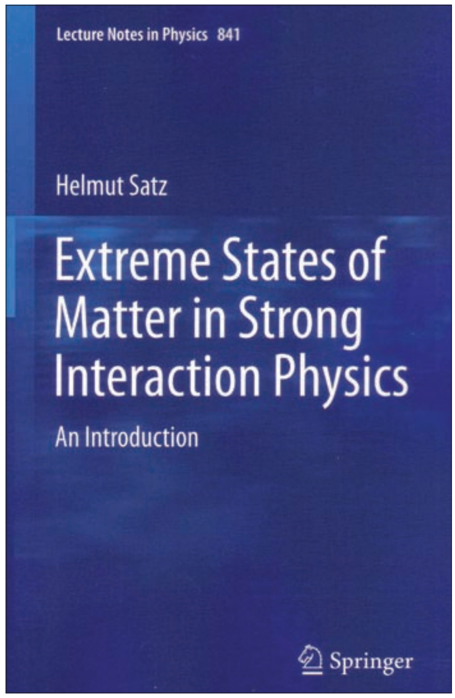
● *John March-Russell, University of Oxford.*

Extreme States of Matter in Strong Interaction Physics: An Introduction
By Helmut Satz
Springer
Paperback: £40.99 $59.95 €44.95
E-book: £38.99

Helmut Satz is a leading figure in the field of strong interactions in extreme conditions, having provided many original ideas that played a crucial role in the design of various experiments studying high-energy heavy-ion collisions. His most famous paper (with Tetsuo Matsui), proposing that quarkonium suppression should signal quark–gluon plasma formation in high-energy nuclear collisions, has acquired an exceptional status in this area of physics and accumulated more than 1600 citations since its publication in 1986 – surely an impressive achievement. However, the status of Satz in the heavy-ion community extends far beyond the impact of that one paper. His contributions are many, varied and often thought-provoking (sometimes, simply "provocative" would be a suitable qualifier). In particular, he often brings to discussions on "quark–gluon plasma physics" interesting concepts borrowed from other branches of physics (and mathematics). These trigger new ways of looking at old puzzles, with the important by-product of attracting new and creative minds to the field.

Another outstanding facet of Satz's personality is his brilliance as a speaker and writer. Over the past 25 years, I have attended tens of talks and lectures by him and I am amazed every time by the quality of his communication skills. The topics are always presented in crystal-clear and pedagogical ways that grab the attention of the audience. He always seems to have something new to say, making each talk worth attending. Discussions over a glass of wine are also truly captivating, even if it can be daunting to convince him of something that does not fit with his convictions.

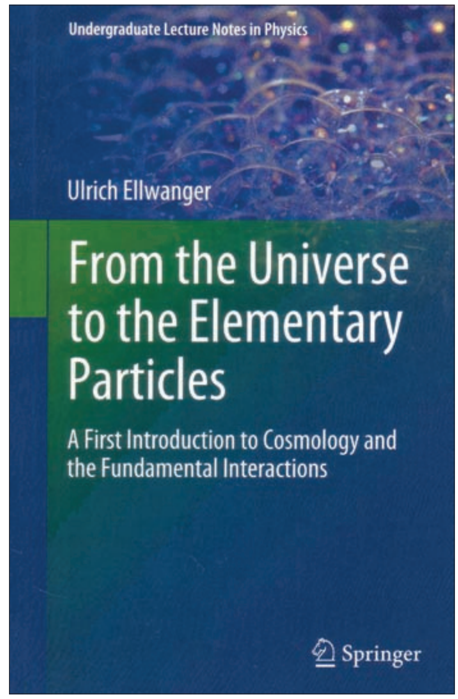
In publishing *Extreme States of Matter in Strong Interaction Physics*, in Springer's series "Lecture Notes in Physics", Satz has done a wonderful service to the community of people working on QCD



thermodynamics. The book presents a range of concepts, from statistical physics to particle and nuclear physics, covering critical behaviour and phase transitions, lattice QCD at nonzero temperatures or large baryon densities, deconfinement and chiral symmetry restoration, etc. It provides the reader with the background knowledge needed to understand the main properties of the quark–gluon plasma, a new state of strongly interacting matter, the study of which currently drives several thousands of physicists, engineers, technicians and students at CERN, Brookhaven and elsewhere.

These lecture notes have been prepared over a period of many years and "tested" in front of a multitude of audiences, in physics schools organized on several continents. The students in Bielefeld and Lisbon, where Satz lectured over long periods, must have been particularly helpful in shaping the arguments, which are presented in a clear and pedagogical style. Reflecting the author's multifaceted culture and broad interests, the book also includes well justified digressions, such as the one through black holes and Hawking-Unruh radiation, and its relation to thermal multihadron production in high-energy collisions.

I wonder if the book warrants the subtitle "An Introduction", given the detail of the exposition; Satz is not shy when it comes to filling pages and pages with non-trivial equations. Nevertheless, it is true that the field commonly known by the (unfortunate) label "heavy-ion physics" has become so



diversified and complex that it cannot be covered fully in a single book. This justifies the author's choice of concentrating on concepts and theory – the experimental side being mentioned only at a rather cursory level. Given the recent burst of results from the LHC experiments, of surprisingly high quality after only two lead-ion runs, he may soon need to begin writing a sequel. He certainly has the necessary energy and his pencil remains as sharp as ever.

In conclusion, this is a remarkable book, which I highly recommend to whomever wants to study "QCD matter" and related topics. I will keep it right next to another excellent textbook, *Ultrarelativistic Heavy-Ion Collisions* (Elsevier 2007), also written by a leading expert in the field, Ramona Vogt, who shares with Satz the talent of writing in exceptionally clear and proficient English. Apart from the pleasure of learning about interesting physics, it is a delight to read well written books such as these.

● *Carlos Lourenço, CERN.*

From the Universe to the Elementary Particles: A First Introduction to Cosmology and the Fundamental Interactions
By Ulrich Ellwanger
Springer
Paperback: £40.99 $59.95 €44.95
E-book: £38.99

This is an ambitious book, reaching out to a broad readership on the topics of cosmology and elementary-particle physics.

Bookshelf

In appearance and style it comes across as a textbook, including equations and simple exercises after each chapter. The level of mathematics required includes vector calculus and simple differential equations. In Germany, at least, there is no course in the university curriculum that it could correspond to, although I understand that in France there is.

It can also be considered a popular book including equations. This is supposedly an oxymoron – like "jumbo shrimp" – but more recently several blogs on particle physics that include a significant amount of maths have become quite popular with a non-professional audience. I also have non-physicist friends who want to get beyond the words and more into the (mathematical) details, although vector calculus might be pushing it a little too far.

All the same, I found parts of this book to be most inspiring and many of the latest developments are covered, including dark energy, inflation, gravitational waves, extra dimensions and quantum gravity. I believe that a "popular" audience will enjoy this; I know my friends will. With only 189 pages, the book is pleasantly concise, although it is a little uneven. I think that sometimes too much is assumed or that things are not explained explicitly enough. A good editor could probably push it that extra step, to make it an even better book.

(This book was first published in German as *Vom Universum zu den Elementarteilchen. Eine erste Einführung in die Kosmologie und die fundamentalen Wechselwirkungen*, Springer 2011.)

● *Herbert Dreiner, University of Bonn.*

Books received

Scientific Writing 2.0: A Reader and Writer's Guide
By Jean-Luc LeBrun
World Scientific
Hardback: £51
Paperback: £23
E-book: £67

This guide aims to help scientists write papers for scientific journals. Using the key parts of typical scientific papers (title, abstract, introduction, visuals, structure and conclusions), it shows through numerous examples how to achieve the essential qualities required in scientific writing. To enable writers to assess their writing from a reader's perspective, it also offers practical metrics in the form of six checklists, as well as an original Java application to assist in the evaluation.

Hamiltonian Mechanics of Gauge Systems
By Lev V Prokhorov and Sergei V Shabanov
Cambridge University Press
Hardback: £80 $130
E-book: $104

This book provides a systematic introduction to the Hamiltonian mechanics of systems with gauge symmetry and reveals how gauge symmetry may lead to a non-trivial geometry of the physical phase space and studies its effect on quantum dynamics using path-integral methods. It covers aspects of Hamiltonian path-integral formalism in detail, together with a number of related topics, such as the theory of canonical transformations on phase space supermanifolds, non-commutativity of canonical quantization and elimination of non-physical variables. The discussion is accompanied by detailed examples of dynamical models with gauge symmetries, clearly illustrating the key concepts.

Viewpoint

Charting the future of European particle physics

Tatsuya Nakada considers what the updated European Strategy for Particle Physics needs to address.

Tatsuya Nakada.

The original CERN convention, which was drafted nearly 60 years ago, foresaw that the organization should have a role as co-ordinator for European particle physics, as well as operating international accelerator laboratories. Today, this role is more appropriate than ever: the long lead times usually required to prepare and construct facilities and experiments for modern high-energy physics, together with the increased costs for these activities, underlie the need for a general European strategy in the field. So it was natural for CERN Council to initiate the creation of a European Strategy for Particle Physics in June 2005 and to establish dedicated groups for reviewing the scientific status and producing a proposal. They consulted widely with the community, funding agencies and policy makers in preparing the strategy document, which was adopted by Council in July 2006 during a dedicated session in Lisbon.

The strategy consists of 17 concise descriptions, with action statements (*CERN Courier* September 2006 p29). It addresses not only scientific issues but also subjects such as the organization and social relevance of high-energy physics. The highest priority on the scientific programme was given to the LHC, followed by accelerator R&D for possible future high-energy machines, including the luminosity and energy upgrades of the LHC, linear e^+e^- colliders and neutrino facilities.

CERN Council adopted this strategy in 2006 with an understanding that it be brought up to date at intervals of typically five years. The first update is now being prepared for presentation to Council in 2013, the process having been postponed for two years to wait for data from the LHC at energies of 7 and 8 TeV in the centre of mass. As a result, in addition to the recent discovery at the LHC of a new boson that is compatible with the Standard Model Higgs particle, the third mixing angle of the neutrino mass-matrix has become known through experiments elsewhere.

These new results generate more scientific questions compared with 2006, such as:

- How far can the properties of the Higgs(-like) particle be explored at the LHC, with the 300 fb^{-1} of data expected for Phase 1, and with the 1000–3000 fb^{-1} (1–3 ab^{-1}) that the high-luminosity upgrade should yield? Do we need other machines to study the particle's properties? If so, after taking into account factors such as the technical maturity, energy expandability, cost and location, what is the optimal machine: a linear or circular e^+e^- collider, a photon collider or a muon collider? As a more concrete question, what should the European reaction be towards the linear collider that is being considered in Japan?
- The European neutrino community is putting forward a short-baseline neutrino programme to search for sterile neutrinos, as well as a long-baseline one to measure neutrino-mass mixing parameters, to take place in Europe. In addition, R&D studies are underway for a "neutrino factory" as an eventual facility. But, what should the European neutrino programme be, and where does the global aspect start to play a role?
- What are the options for a future machine in Europe after the LHC? Will this be a machine to address physics at the 10 TeV energy scale? Will data from the LHC at the full design energy provide enough justification for this? When will be the right moment to take a decision, and what kind of R&D must be done to be ready for such a decision in the future?

Breakthroughs in science can emerge from unexpected corners. Therefore, the strategy must also have some flexibility to allow the fostering of unconventional ideas.

The process of updating the European strategy began formally in the summer of 2011 when Council set up a new European Strategy Group, which is assisted by the European Strategy Preparatory Group for scientific matters in preparing the proposal for the update. As with the process that led to the original strategy, the proposal will be based on the maximum input from the particle-physics community, as well as from other stakeholders – both inside and outside Europe. An important part of this consultation process was the Open Symposium recently held in Krakow, where the community expressed their opinions on the subjects outlined above, as well as on flavour physics, strong-interaction physics, non-accelerator-based particle physics and theoretical physics. Issues important for carrying out the research programme, such as accelerator science, detector R&D, computing and infrastructure for large detector construction, were also addressed. The meeting demonstrated that there is an emerging consensus that new physics must be studied both by direct searches at the highest-energy accelerator possible, as well as by precision experiments with and without accelerators.

The Preparatory Group is in the process of producing a summary document on the scientific status. The European Strategy Group will meet in January 2013 in Erice to draft the updated strategy – which must also take global aspects into account – for discussion by CERN Council in March. The aim is that Council will adopt the updated strategy during a special session to be held in Brussels in May.

- Further information on the update of the European Strategy of Particle Physics may be found at https://europeanstrategygroup.web.cern.ch/EuropeanStrategyGroup/.

- *Tatsuya Nakada, École Polytechnique Fédérale de Lausanne, is scientific secretary for the European Strategy Session of the CERN Council and chair of the European Strategy and Preparatory Groups.*

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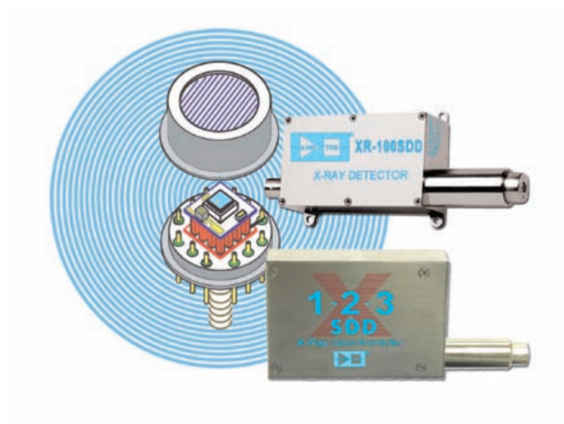

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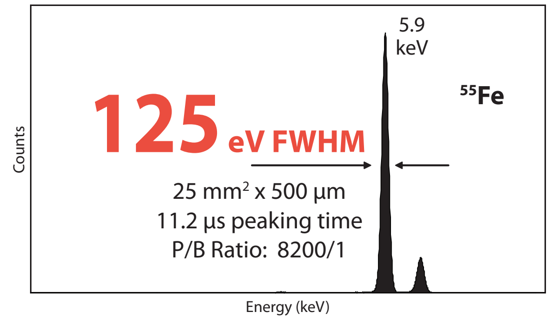

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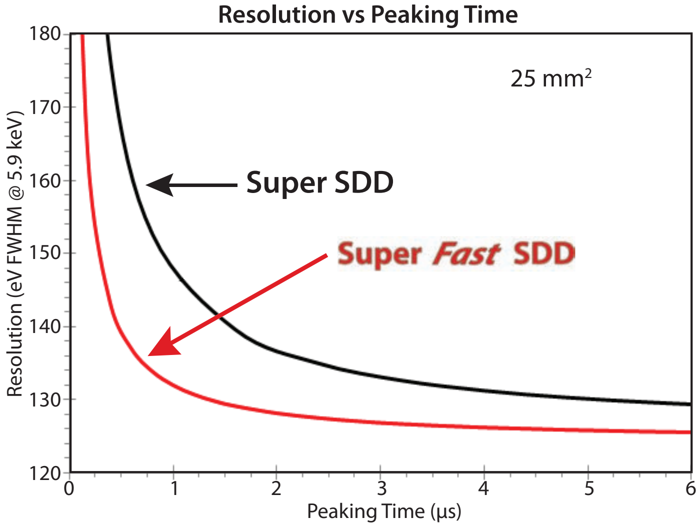

Resolution	Peaking Time
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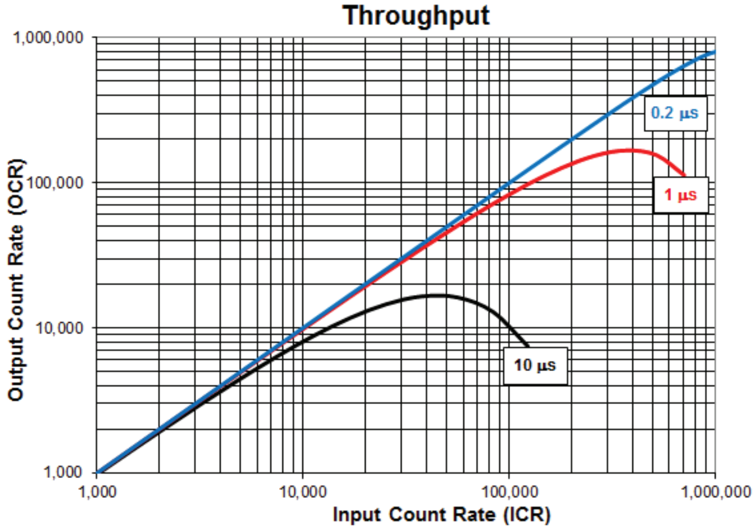
135 eV FWHM	1 µs
155 eV FWHM	0.2 µs

Throughput



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