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CERNCOURIER

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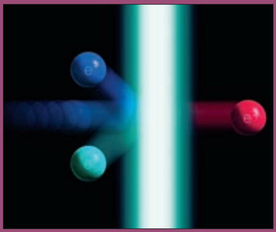
Rutherford and the nuclear atom



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PHYSICS IN THE ALPS

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

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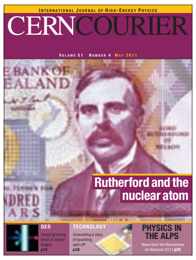

On the cover: May 1911 saw Ernest Rutherford's publication of the paper that contained his description of an atom with a tiny nucleus at its heart (p20). Originally from New Zealand, he became honoured around the world for his many discoveries. This image is from a NZ$100 note.
(Image credit: Bank of New Zealand/John Campbell.)

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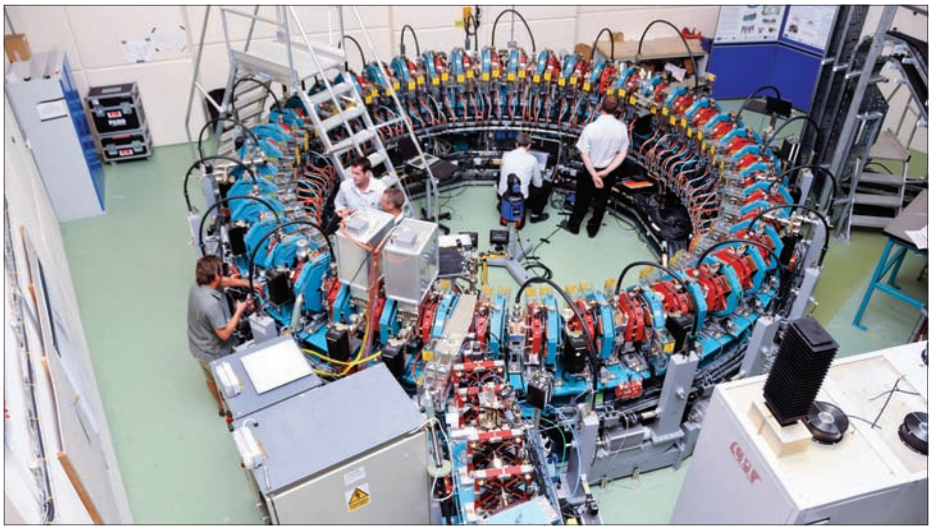
ACCELERATORS

A world first for EMMA

At the end of March, an electron beam was steered round the ring of a new type of particle accelerator and successfully accelerated to 18 MeV for the first time. EMMA (Electron Model for Many Applications) is a proof-of-principle prototype built at the UK Science and Technology Facilities Council's Daresbury Laboratory to test the concept of the non-scaling fixed-field alternating gradient accelerator (FFAG). The technique should allow the construction of a new generation of more powerful, yet more compact and economical accelerators.

The successful acceleration – a "world first" – confirms not only that the design of the most technically demanding aspects of EMMA is sound but it also demonstrates the feasibility of the technology used. The next steps will be to move towards full acceleration, from 10 to 20 MeV, and commence the detailed characterization of the accelerator.

The basic concept underlying EMMA is that of the FFAG, in which a ring of fixed-field magnets simultaneously steers and focuses the electron beam round the machine (*CERN Courier* September 2008 p21). The focusing is as strong as in an alternating-gradient synchrotron but the beam spirals outwards while it is accelerated, as in a cyclotron. However, with sufficiently strong magnetic focusing the displacement of the beam as it accelerates and spirals can be kept much smaller than in other types of accelerator. This makes the FFAG concept attractive for a range of applications, from treating cancer to powering safer nuclear reactors that produce less hazardous waste.



The proof-of-principle prototype EMMA accelerator. (Image credit: STFC.)

The design of EMMA's magnet ring presented several challenges. The focusing magnets have a standard quadrupole geometry but they are used to steer the beam by offsetting it horizontally. The magnets are short, so "end effects" become important, and pairs of magnets are closely spaced around the ring, so the interaction between magnets is non-trivial.

● EMMA is a major part of the British Accelerator Science and Radiation Oncology Consortium CONFORM project and is funded by the Research Councils UK (RCUK) Basic Technology programme.

Earthquake in Japan

People around the world were deeply saddened to learn of the devastation caused by the major earthquake and the related tsunami on Friday 11 March in northern Japan. The 8.9-magnitude earthquake had its epicentre some 130 km off the eastern coast, and gave rise to unprecedented damage that extended far and wide.

The KEK high-energy physics laboratory and the Japan Proton Accelerator Research Complex (J-PARC) are the two particle accelerator facilities closest to the epicentre. In both case there were fortunately no reported injuries, nor was there any resulting radiation hazard. J-PARC lies on the eastern coast at Tokai and was the most heavily affected of the two facilities. Designed to withstand a tsunami of up to 10 m, on this occasion there was little effect. Although surrounding roads and some buildings were severely damaged, the accelerators at the facility appear to be in relatively good shape. KEK, at Tsukuba some 50 km north-east of Tokyo, suffered significant disruption to services and some damage to buildings and facilities.

The thoughts of the particle-physics community are with friends and colleagues at partner institutes in Japan, as well as those at laboratories and institutes elsewhere who have family and friends in Japan. The latest information about KEK and J-PARC is available on the websites: www.kek.jp/quake/en/index.html and http://j-parc.jp/index-e.html.

Sommaire en français

LHC PHYSICS

ALICE collaboration measures the size of the fireball in heavy-ion collisions

The ALICE collaboration has measured the size of the pion-emitting system in central lead–ion collisions at the LHC at a centre-of-mass energy of 2.76 TeV per nucleon pair. The radii of the pion source were deduced from the shape of the Bose-Einstein peak in the two-pion correlation functions.

In hadron and ion collisions, Bose-Einstein quantum statistics leads to enhanced production of bosons that are close together in phase space, and thus to an excess of pairs at low relative momentum. The width of the excess region is inversely proportional to the system size at decoupling, i.e. at the point when the majority of the particles stop interacting.

An important finding at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven was that the QCD matter created there behaved like a fluid, with strong collective motions that are well described by hydrodynamic equations. The collective flow makes the size of the system appear smaller with increasing momentum of the pair. This behaviour is also clearly visible for the radii measured at the LHC in the ALICE experiment. Figure 1 shows the results for measurements of the radius of the pion source in three dimensions: along the beam axis, R_{long}; along the transverse momentum ($\mathbf{k}_T$) of the pair, R_{out}; and in a direction perpendicular to these two, R_{side}.

The similarity between the values for R_{out} and R_{side} indicates a short duration for the emission, hence an "explosive" emission. The time when the emission reaches its maximum – measured with respect to the first encounter – can be derived from the dependence of the longitudinal radius on the transverse momentum, $R_{\mathrm{long}}(k_T)$. ALICE has found this to be 10–11 fm/c, which is significantly longer than it is at RHIC. Moreover, the product of the three radii at low pair-momentum – the best estimate of the homogeneity volume of the system at decoupling – is twice as large as at RHIC (figure 2).

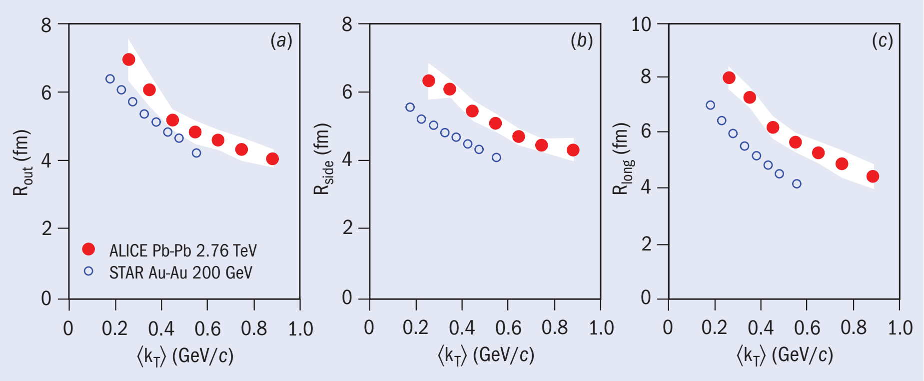


Fig. 1. Pion source-radii for the 5% most central Pb–Pb collisions at 2.76 TeV per nucleon-pair in the centre-of-mass, as a function of the transverse momentum. The white bands represent the systematic errors. For comparison, radii from the STAR experiment at RHIC are also shown.

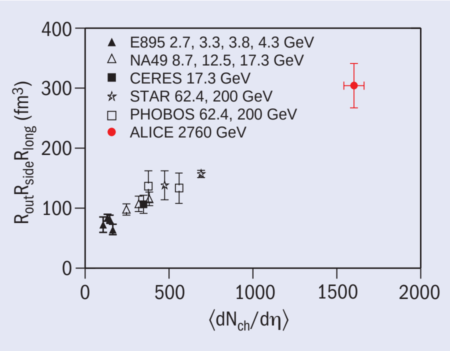


Fig. 2. Product of the three pion source-radii (homogeneity volume) at $k_T = 0.3$ GeV/c. The ALICE result (red-filled dot) is compared with those obtained for central gold and lead collisions at lower energies.

These results, taken together with those obtained from the study of the multiplicity and the azimuthal anisotropy, indicate that the fireball formed in nuclear collisions at the LHC is hotter, lives longer and expands to a larger size than at lower energies. Further analyses, in particular including the full dependence of these observables on centrality, will provide more insights into the properties of the system – such as initial velocities, the equation of state and the fluid viscosity – and strongly constrain the theoretical modelling of heavy-ion collisions.

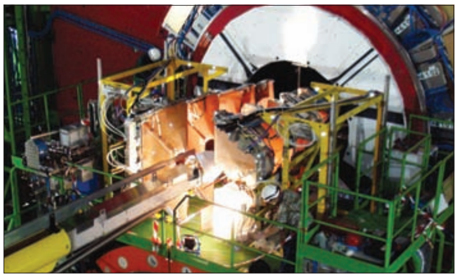
● Further reading

K Aamodt *et al.* ALICE collaboration 2011 *Phys. Lett. B* **696** 328.

TOTEM construction complete

The winter technical stop saw the final steps of the installation of the TOTEM experiment at the LHC (*CERN Courier* September 2009 p19). After 8 years of development, the two arms of the inelastic telescope T1 were successfully installed inside the CMS endcap at about 10.5 m on either side of the interaction point. This detector joins the previously installed telescope T2 (at 13.5 m), as well as detectors in two sets of Roman Pots at 147 m and 220 m. Additional detectors at 147 m were also installed in the shutdown.

TOTEM is designed to make precise measurements of the total proton–proton cross-section and to perform detailed studies of elastic and diffractive proton–proton scattering. It requires dedicated runs of the LHC at low luminosities to allow the movable Roman Pots to bring detectors as close to the beam as possible.



The two half-arms of the inelastic telescope under test on the installation platform, before insertion ("+" side).

CMS experiment makes use of the tau

Measurements with leptons are an important tool for physics studies at the LHC. While electrons and muons – being the easiest to detect and identify – are used for many analyses, studies that include τ leptons are important for searches and for electroweak measurements in particular. It is a sign that experimental analyses are reaching maturity when physics results on τ leptons become available, as they are now doing with CMS.

The lifetime of the τ is of the order of 10^{-13} s, so it decays shortly after production, complicating its identification and use in physics analyses. It decays most often leptonically, into an electron or muon plus two neutrinos, or hadronically to either one or three charged particles together with neutral hadrons and a neutrino. The hadronic decays of the τ thus contain collimated low-multiplicity jets, a feature that is used experimentally to select τ decays, while reducing background from QCD jets.

CMS recently published two physics papers studying decays into τ leptons. The first presents a study of the decay of Z bosons into τ pairs, using both leptonic and hadronic decays of the τ (CMS collaboration 2011a). The τ leptons are identified via isolated groups of particles, found through the CMS particle-flow event reconstruction, that are compatible with the possible τ decays. Figure 1 shows the visible invariant mass of the two τ candidates for a τ pair, where one decays leptonically to a muon and the other decays hadronically. Because of the escaping neutrinos in the τ decays the reconstructed Z boson mass is not at its known value, but the result of the measurement agrees well with the expectation from the Monte Carlo simulation.

This yields a cross-section for $Z\rightarrow\tau\bar{\tau}$, in proton–proton collisions at 7 TeV, of 1.00 ± 0.05 (stat.) ± 0.08 (syst.) ± 0.04 (lumi.) nb. This agrees well with similar cross-sections measured in the electron and muon decay modes of the Z – as is expected from the lepton universality in Z decays that was established in precision measurements by experiments in the 1990s at the Large Electron Positron collider.

More interestingly, the τ can be used to search for new particles, for the Higgs boson in particular. Higgs particles in the minimal supersymmetric extension of the Standard Model (MSSM) are expected to show a large decay-rate to τ pairs, especially for large values of the parameter $\tan\beta$, which is the ratio of the vacuum expectation values of the two members of the Higgs doublet.

CMS has carried out such an analysis with the full data sample of 2010 and found no excess of τ pair production above the expected background (CMS collaboration 2011b). The resulting excluded region in the plane of $\tan\beta$ and the mass of pseudoscalar Higgs boson in the MSSM, for a benchmark scenario called m_h^{max}, is shown in figure 2.

The surprise is that the search already goes well beyond the reach of the searches at the Tevatron, in part thanks to the high efficiency and high quality of the detection and reconstruction of the τ leptons in CMS. Clearly, the τ has now become an important tool for the collaborations in exploring the new energy region at the LHC.

● Further reading

CMS collaboration 2011a arXiv:1104.1617. Submitted to *JHEP*.
CMS Collaboration 2011b arXiv:1104.1619. Submitted to *Phys. Rev. Letts*.

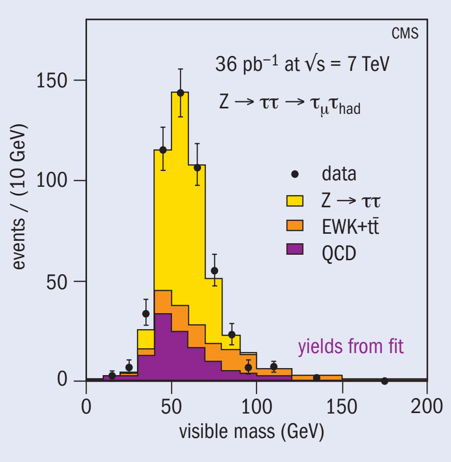


Fig. 1. The visible invariant mass of the two τ candidates for a τ pair where one τ decays leptonically to a muon and the other τ decays hadronically.

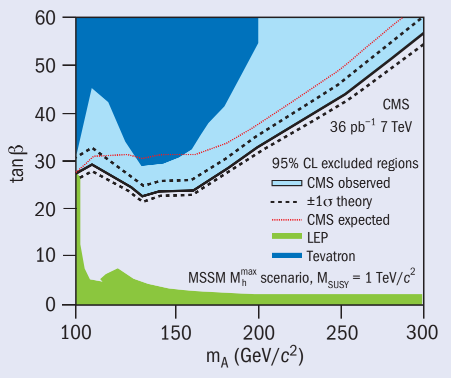


Fig. 2. The excluded region in the plane of $\tan\beta$ and the mass of pseudoscalar Higgs boson in the MSSM, for a benchmark scenario called m_h^{max}.

LHC News

New records at the LHC

A month after restarting in February, the LHC was once again breaking records. Following a period of commissioning, the first run with stable beams for physics at 7 TeV in the centre-of-mass began on 13 March, with a modest three bunches per beam and a luminosity of 1.6×10^{30} cm^{-2}s^{-1}. Then, after further machine-protection tests, the way was opened for increasing numbers of bunches to be introduced in "fills" for physics, culminating with 200 bunches per beam on the evening of 22 March. This gave a peak luminosity at ATLAS and CMS of 2.5×10^{30} cm^{-2}s^{-1}, comfortably beating last year's record made with 368 bunches. By 25 March, the LHC had delivered an integrated luminosity of 28 pb^{-1}, more than half of the total delivered in 2010.

The next challenge was to have not only more bunches but also at a closer spacing; 2010 saw running with 368 bunches with 150 ns spacing, while the run with 200 bunches this March was with 75 ns spacing. However, combining small bunch spacing with a high number of bunches leads to an effect known as "electron cloud": synchrotron radiation from the protons releases electrons at the beam-screen, which are pulled towards the protons and knock out more electrons on hitting the opposite wall.

After a brief technical stop for maintenance, the operating team began a period of "scrubbing runs", in which a high beam current is injected at low energy to induce electron clouds under controlled conditions. The aim is to release gas molecules trapped inside the metal, to be pumped out later, and decrease the yield of electrons at the surface. These runs had already paid off by 10 April when the number of bunches per beam reached 1020, with a total of 10^{14} protons per beam – another record for the LHC.

LHC PHYSICS

CDF announces intriguing results

The CDF collaboration at Fermilab's Tevatron has published two measurements that hint at the existence of physics beyond the well tested Standard Model of particles and their interactions. The first measurement revealed an unexpected asymmetry in the production of top/anti-top ($t\bar{t}$) quark pairs. The second analysis unveiled surprising evidence for an excess of events that contain a W boson accompanied by two hadronic jets. The excess cannot be due to the long sought-after Higgs boson but could perhaps be explained by new physics ideas.

While both measurements rely on the Tevatron's unique ability to produce proton–antiproton collisions, if the new physics hinted at in these results does exist, it will manifest itself in some other form in the particle collisions at the LHC at CERN.

The Tevatron has been producing $t\bar{t}$ pairs since the early 1990s. In first-order Standard Model calculations, the direction of flight of $t\bar{t}$ pairs produced in proton–antiproton collisions should be independent of the colliding particles' charge, thus there should be equal numbers of t and $\bar{t}$ quarks emitted along either beam direction. More detailed, next-to-leading-order calculations predict an asymmetry of 9 ± 1% at large rapidity, favouring the proton beam's direction.

CDF announced in March that it measured a $t\bar{t}$ production asymmetry of 48 ±11% for an invariant mass of the $t\bar{t}$ pair ($M_{t\bar{t}}$) larger than 450 GeV/c^2, which is three standard deviations above the Standard Model expectation. The result is based on the analysis of 5.3 fb^{-1} of collision data, about half of the number of collisions that CDF has recorded to date. The asymmetries were observed in both the laboratory frame of reference and the $t\bar{t}$ rest frame. A number of theoretical models predict such asymmetries, including models with a Z' or large extra dimensions.

The analysis was repeated more recently on events where the t and $\bar{t}$ quarks decay to a different final state. The asymmetry was again measured at close to a 3 σ level with a value of 0.42 ± 0.15 ± 0.05, averaged over all masses, compared with a 6% Standard Model expectation (T Aaltonen *et al*. 2011a). This confirms the earlier result with a completely independent data sample.

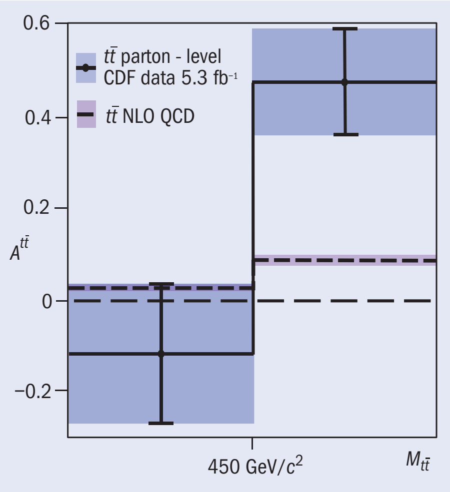


Fig. 1. Top forwards/backwards asymmetry as a function of the mass of the $t\bar{t}$ mass system. The points show the CDF data corrected to the parton level while the pink dashed line represents the next-to-leading-order theoretical calculation. At low $M_{t\bar{t}}$, the data agree with expectation but there is significant deviation at high values of $M_{t\bar{t}}$.

The second surprising result from CDF started out as a routine Standard Model measurement of collisions, where a W boson was detected in coincidence with two hadronic jets. The team found an unexpected peak in the spectrum of the invariant mass of the pair of jets. The excess of approximately 250 events appeared as a bump around 144 GeV/c^2 (T Aaltonen *et al*. 2011b).

The analysis required the presence of a high-transverse-momentum, isolated lepton; a significant amount of missing energy; and two hadronic jets. The invariant mass spectrum of the jet pair shows a clear peak at 80–90 GeV from a W or Z boson decaying into a jet pair. The surprising peak shows up at a higher mass (figure 2). It has a width compatible with the CDF detector resolution and its significance is 3.2 σ, which takes into account systematics and trial factors. If the peak is from a single particle, the particle would have a production cross-section of approximately 4 pb^{-1}.

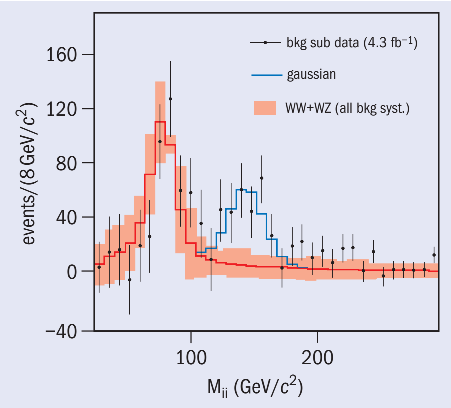


Fig. 2. The di-jet invariant mass distribution for candidates selected in an analysis of W+2 jet events. The black points represent the data. The red line plots the expected Standard Model background shape based on Monte Carlo modelling. The red shading shows the systematic and statistical uncertainty on this background shape. The blue histogram is the Gaussian fit to the unexpected peak centred at 144 GeV/c^2.

The peak cannot result from the Higgs boson predicted by the Standard Model. If a Higgs boson had a mass of 140 GeV/c^2 and such a large production rate, both the CDF and DØ experiments at the Tevatron would have seen its decay into pairs of W bosons a long time ago. Furthermore, such a Higgs would decay mainly into bottom-quark jets, which are not observed in an appreciable amount in the CDF data peak. There are, however, new physics ideas that predict the appearance of resonances with the observed features, such as technicolour-based models. If the peak does not originate from a new particle, particle physicists will need to reconsider how the Standard Model is used to make precise predictions for the production of a W boson and two jets.

Physicists from CDF and DØ are in the process of analysing larger data samples, up to 10 fb^{-1}, to either refute or confirm these two results. At the same time, they may find even more interesting signals.

● Further reading

T Aaltonen *et al.* The CDF collaboration 2011a arxiv:1101.0034. Submitted to *Phys. Rev. D.*

T Aaltonen et al. The CDF collaboration 2011b arxiv:1104.0699. Submitted to *Phys. Rev. Letts.*

***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.

NEUTRINOS

ICARUS starts to fly

The experiment for Imaging Cosmic and Rare Underground Signals (ICARUS) was officially inaugurated on 29 March at the Gran Sasso National Laboratory (LNGS) of the INFN. The ceremony was attended not only by members of the ICARUS collaboration, but also by representatives from national and local authorities and companies involved in construction, as well as colleagues from other universities and institutes.

ICARUS started operating gradually from 27 May 2010 onwards. It has collected data from the start, recording the tracks of the rare cosmic rays that reach the laboratory, about 1400 m below the Gran Sasso massif and, above all, capturing interactions of the neutrino beam that travels some 700 km through the Earth's crust from the CERN Neutrinos to Gran Sasso facility. The experiment will use the muon-neutrinos produced at CERN to study the phenomenon of neutrino oscillation, together with the OPERA experiment (*CERN Courier* July/August 2010 p5). In addition, ICARUS will study atmospheric neutrinos and those produced by the Sun, as well as events in the cosmos, such as supernovae explosions and the collapse of neutron stars. Another ambitious objective is the observation of nucleon decay.

Alberto Guglielmi of the University of Padova, left, with Carlo Rubbia, spokesperson and "father" of ICARUS.

ICARUS is the largest liquid-argon detector in the world, the culmination of 20 years of R&D in a project led by the Nobel laureate Carlo Rubbia, the spokesperson and "father" of the experiment. By using liquid argon to detect ionizing particles, the experiment can reconstruct charged-particle tracks and produce high-resolution images of interaction events in real time. Essentially a wire detector immersed in 600 tonnes of liquid argon, it records the passage of charged particles electronically, with the spatial and energy resolution of a bubble chamber, but more quickly.

Participants at the inauguration in the cavern that houses the ICARUS experiment, (Image credits: Robert Sulej.)

The ICARUS collaboration comprises physicists from several sections of INFN and Italian university departments (L'Aquila, LNGS, Milan, Naples, Padua, Pavia) as well as groups of physicists from Poland, Russia and the US. The experiment was built in close collaboration with national industries. Cinel Strumenti Scientifici was responsible for the extremely refined mechanics of the detector, which has some 54 000 steel wires strung on huge frames of approximately 4 m × 18 m; the electronics were designed and constructed in collaboration with the CAEN Spa; and the cryostat and cryogenic systems were constructed in co-operation with Air Liquide Italia and Stirling, in the Netherlands.

NEUTRINOS

Experiments in Soudan mine seem fine after shaft fire

Research teams think that there is little damage, if any, to the two large particle-physics experiments in the Soudan mine in Minnesota, following a fire in the access shaft on 17 March, which shut down both the mine and the experiments located 800 m underground.

When the fire was detected at around 9 p.m., the fire-protection system shut down the power to the Soudan Underground Laboratory, as designed. No personnel were in the mine at the time. The cause of the fire is believed to be linked to shaft-maintenance work earlier in the day.

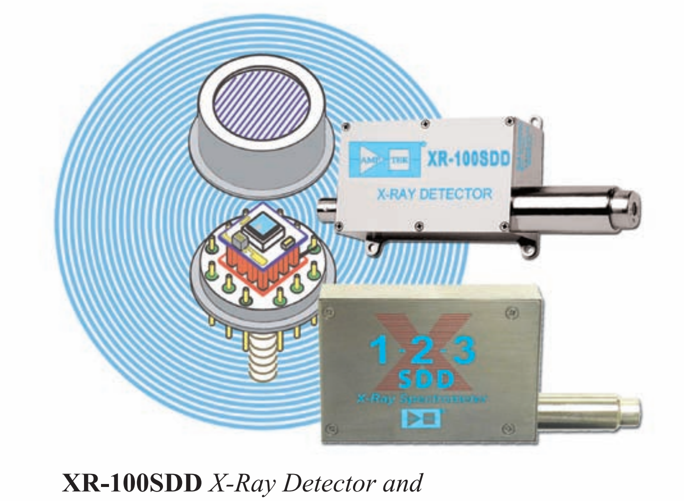
Fire fighters extinguished the fire by pumping some 265 000 litres of water and fire-extinguishing foam down the access shaft. Some of the foam entered the caverns of the underground laboratory, which is managed by the University of Minnesota. The laboratory houses the 5000-tonne far detector of the Main Injector Neutrino Oscillation Search (MINOS) experiment, the Cryogenic Dark Matter Search (CDMS) experiment, managed by Fermilab, and several other smaller experiments.

Ten days after the fire, the first crew of scientists returned to the laboratory as electricians began restoring power. Residue of fire-fighting foam was found across large parts of the laboratory, however, researchers from CDMS found no apparent damage to their experiment. During the 10-day power outage, the experiment, which operates ultra-sensitive particle detectors at a temperature of about 50 mk, warmed to room temperature without losing vacuum. When the team turned the power back on, all cryogenic systems functioned as normal.

No water or foam was found on the electronics for MINOS. The experiment's large electromagnetic coil was partially immersed in water and will be carefully dried out before being used once more. The coil provides the neutrino detector with a magnetic field for charged-particle identification.

There are several smaller experiments in the mine, including the CoGeNT dark-matter search. An assessment of these experiments will be made when full access to the underground laboratory is available.

Complete clean-up, final assessment and restart of the experiments will occur once a new power cable has been installed in the shaft, allowing full power to be restored to the laboratory.



XR-100SDD
X-RAY DETECTOR
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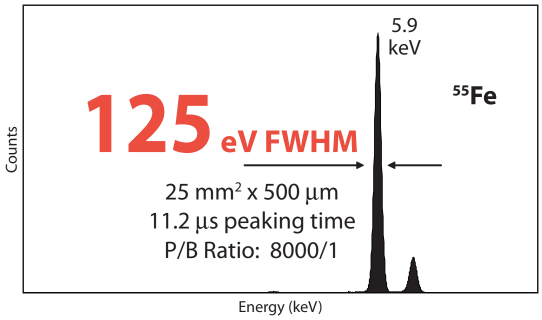
X-Ray Spectrometer



5.9
keV
55Fe
125 eV FWHM
25 mm² x 500 µm
11.2 µs peaking time
P/B Ratio: 8000/1
Counts
Energy (keV)

1 2 3
X-Ray Spectrometer
XR-100CR
Si X-RAY DETECTOR
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Sciencewatch

Compiled by John Swain, Northeastern University

Sulphur could help to deliver Earth's precious metals

Though known and used for millennia, the lapis lazuli gemstone is found only in a few places worldwide, such as the Sar-e-Sang mines in Afghanistan. Its blue colour is a result of charge transfer involving a little-known form of sulphur, the trisulphur anion S_3^-, which may be more common than anyone had imagined. Gleb Pokrovski of Paul Sabatier University in Toulouse and Leonid Dubrovinsky of Bayreuth University used the diamond-anvil technique to look at how sulphur behaves in aqueous solutions at temperatures above 250 °C and pressures above 0.5 GPa.

It turns out that in these conditions trisulphur dominates over the well known – and until now thought to be most common – forms of sulphate SO_4^{2+} and sulphide S^{2-}. Amazingly, deep geological fluids may well be deep ultramarine blue and, more importantly, a major revision of sulphur geochemistry could be required. The results may affect understanding of how sulphur-containing gases are released by volcanic eruptions and how precious metals such as gold and platinum – which are expected to have high affinities for trisulphur – are transported towards the Earth's surface.

Further reading

G B Pokrovski and L S Dubrovinsky 2011 *Science* **331** 1052.

Lapis lazuli's beautiful blue colour comes from a trisulphur anion, which could be much more common deep in the Earth. (Image credit: Hsandler/dreamstime.com.)

The skin's own memristors

In 1971 Leon Chua of the University of California, Berkeley, invented the idea of a memristor, to complete a symmetric set of four elements with the capacitor, inductor, and resistor. It then took until 2008 for Stanley Williams of Hewlett Packard's Information and Quantum Systems Lab in Palo Alto, California, to make one out of titanium dioxide (*CERN Courier* July/August 2008 p10). However, Gorm Johnsen and colleagues of the University of Oslo have found that nature was way ahead of everyone, showing that sweat pores in skin are essentially biological memristors.

A negative potential applied to skin draws sweat, which contains many positive ions such as sodium, into a pore. With the pore filled with sweat, the resistance of the skin is lower and it stays that way until the sweat drains out or a positive potential helps to push the sweat out. In other words, the pore has a memory and acts just as a memristor is supposed to. While skin is unlikely to be involved in future electronics and it is not clear how useful this will be to people who need to model skin, it is nevertheless an amazing example of how nature can be well ahead of even the most recent ideas, right before our eyes.

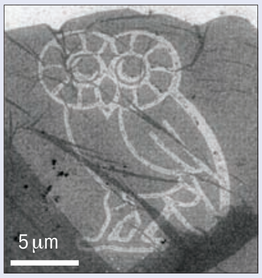
Further reading

G K Johnsen *et al.* 2011 *Phys. Rev. E.* **83** 031916.

Making patterns in graphene

A new and simple means to create patterns with graphene could lead to its wider use as an electronics material. James Tour and colleagues of Rice University sputtered zinc onto graphene and then dissolved it off with dilute hydrochloric acid. Remarkably, the process removes just one layer – no more and no fewer. So, by repeatedly sputtering zinc in various patterns and taking it off with acid, graphene can be shaped all of the way down to the substrate on which it is deposited.

This is significant because the electronic properties of single and double layers of graphene are quite different: bilayers can be made into transistors while monolayers make good conductors. In this way, the elements of all sorts of electronic devices have the potential to be made out of – as well as connected by – carbon.



This graphene owl measures only 10 μm across.

Further reading

A Dimiev *et al.* 2011 *Science* **331** 1168.

Waveform synthesis works for optical frequencies

Every physicist or engineer has used, or at least seen, a waveform generator, which is capable of making not just sine waves but also square waves, sawtooth waves etc. Until now, there seemed little hope of one that could work up to optical frequencies but this has all changed with work by Han-Sung Chan of the Institute of Atomic and Molecular Sciences and the National Tsing Hua University and colleagues. They manipulated phases and amplitudes of five discrete frequencies from mid-infrared to blue to produce square, sawtooth and subcycle sine and cosine pulses with repetition rates up to 125 THz.

The team sent one initial laser pulse into a lithium niobate crystal to generate its second harmonic. Both frequencies were then used to pump hydrogen gas to generate five frequencies via Raman scattering. These were then attenuated and phase-shifted as required so that they could be recombined to the desired form – essentially by simple Fourier synthesis, only at optical frequencies. Cross correlations were used to verify that the correct shapes were, indeed, achieved and there seems no fundamental problem to scaling this up to synthesize from far more than five frequencies.

Further reading

Han-Sung Chan *et al.* 2011 *Science* **331** 1165.

Astrowatch

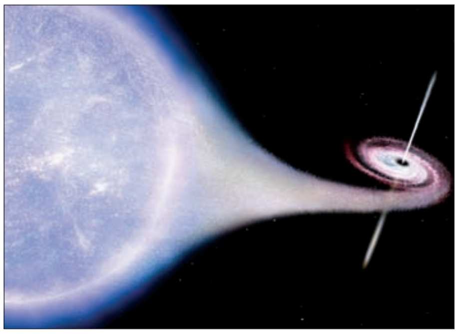
COMPILED BY MARC TÜRLER, ISDC AND OBSERVATORY OF THE UNIVERSITY OF GENEVA

INTEGRAL sees gamma rays from black-hole jets

A detailed analysis of observations of Cygnus X-1 by ESA's International Gamma-ray Astronomical Laboratory (INTEGRAL) has found strongly polarized gamma-ray emission. The polarization suggests that the highest-energy emission from this famous galactic binary is emitted by the jets ejected by the black hole.

Discovered in 1964 with an X-ray sensitive rocket, Cygnus X-1 is the first Galactic binary system for which strong evidence for a black hole was found in the early 1970s. About 7000 light-years away in the Cygnus constellation, the black hole of about 10 solar-masses orbits a blue supergiant star of 35 times the mass of the Sun. This heavy stellar couple is tightly bound. Its separation is five times smaller than the Sun–Earth distance – close enough for the black hole to strip away some of the gas from the outer layers of the star.

The stolen gas falls onto the black hole and forms an accretion disc. Swirling up to relativistic velocities, the plasma in the inner disc is frictionally heated to millions of degrees, thus emitting X-rays. While some of the material will fall inside the event horizon of the black hole, a significant part may escape by following the lines of magnetic field generated by the accretion disc. Evidence of this process comes from the observation of two opposite radio jets, which are presumably ejected on both sides of the disc. This property makes Cygnus X-1 a "microquasar", which is a Galactic scaled-down version of the massive black holes that power the nuclei of active galaxies.



An artist's impression of the Cygnus X-1 binary system. Gas from the blue giant star spirals into the black hole but a small fraction is diverted by magnetic fields into two opposite jets. (Image credit: ESA.)

Cygnus X-1 was the target of INTEGRAL's first-light observation in November 2002. It has since been the subject of several studies, adding up to about two months of exposure time. Philippe Laurent of the Astroparticles and Cosmology (APC) centre in Paris and colleagues from Europe and the US searched for a polarized signal in this huge dataset.

The study of gamma-ray polarization requires non-standard analysis of the data. A successful technique was developed for the spectrometer of INTEGRAL, allowing the polarized radiation from the Crab Nebula to be measured (*CERN Courier* November 2008 p11). The current study instead uses the main imaging instrument and selects photons that happen to interact with both of its detector layers. Indeed, gamma rays with energies above around 250 keV can Compton-scatter on electrons in the upper layer and be deflected towards the second layer below. Because the Compton scattering angle depends on the polarization direction of the incident photon, it is therefore possible to measure the polarization properties of the incoming radiation.

Laurent and his team found a strong polarization fraction of 67 ± 30% for gamma rays at the highest detected energies in the 400–2000 keV range. The polarization is much lower in the 250–400 keV band, with an upper-limit of 20%. Spectroscopically, the polarized signal can be attributed to a power-law emission that starts to dominate a thermal-emission component just around 400 keV. A coherent magnetic field is needed to account for the observed polarization and this suggests a jet origin for the high-energy gamma rays.

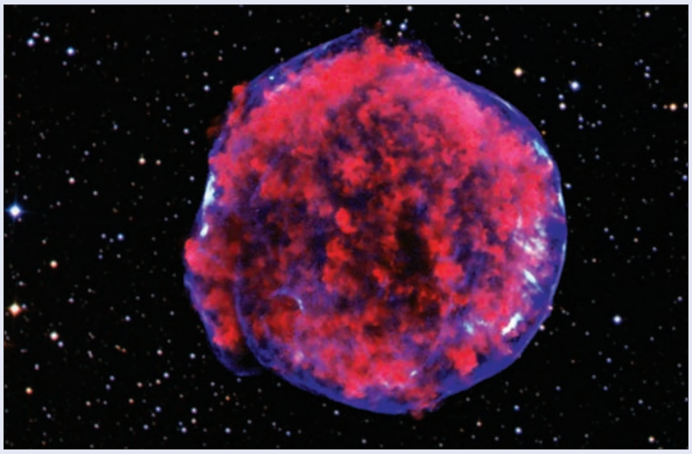
The authors of the paper published by *Science* cannot distinguish between a synchrotron or an inverse-Compton origin for this polarized emission component. Synchrotron emission would imply electrons with energies around a few tera-electron-volts, which could then also account – via inverse-Compton scattering – for the tera-electron-volt photons detected from Cygnus X-1 by the MAGIC Cherenkov telescope in September 2006. An alternative, inverse-Compton scenario would correspond to the gamma-ray emission process in the neighbouring microquasar, Cygnus X-3 (*CERN Courier* January/February 2010 p11).

● Further reading

P Laurent *et al.* 2011 *Science Express*, doi: 10.1126/science.1200848.

Picture of the month

No, this is not a virus or a jellyfish. Instead it is an amazing image of Tycho's supernova remnant (SNR). The very deep view by NASA's Chandra X-ray Telescope shows the detailed structure of gas, glowing in X-rays, from the supernova witnessed in 1572 by the famous Danish astronomer Tycho Brahe. This explosion of a white-dwarf star was so bright that it could even be seen during the day. In this image, lower- and higher-energy X-rays are colour coded in red and blue, respectively, and are shown on a starry background from the Digital Sky Survey. The blue-coded image contains a pattern of stripes never seen before in other SNRs (*CERN Courier* October 2004 p19, December 2004 p15 and January/February 2011 p11). The spacing of two stripes was found to correspond to a gyromagnetic-radius of a proton of 10^{15} eV, the "knee" energy of the cosmic-ray spectrum. (Image credit: X-ray, NASA/CXC/Rutgers/K Eriksen *et al.*; optical, DSS.)



CERN Courier Archive: 1968

A look back to CERN Courier vol. 8, May 1968, compiled by Peggie Rimmer

DARESBURY

Symposium on intensity measurement

A symposium on beam intensity measurement was held at Daresbury on 22–26 April bringing together about 45 specialists from accelerator laboratories throughout the world. (V Agoritsas, C D Johnson and H Wachsmuth attended from CERN.)

The most reliable method of measuring beam intensity is still the long-established ‘Faraday cup’, though it has become more sophisticated with advancing years. The beam is fired into the thick base of a cup-shaped block of metal. A small magnetic field is applied to bend any electrons scattered from the base into the walls of the cup. The cup sits in a vacuum box with a protruding snout, at the end of which is the window through which the beam passes. A magnet around the snout prevents any secondary electrons from the window reaching the cup. Measuring the charge collected and knowing the unit of charge carried by the particles gives the number of particles in the beam directly; simple but effective. People believe in the accuracy of these devices to be considerably better than 1%.

Calorimeters could also give a direct measurement by recording the rise in temperature produced when the beam strikes the calorimeter, but they have proved rather cumbersome. A large block of metal is needed to absorb all of the beam and it takes many beam pulses to give a reasonable rise in temperature.

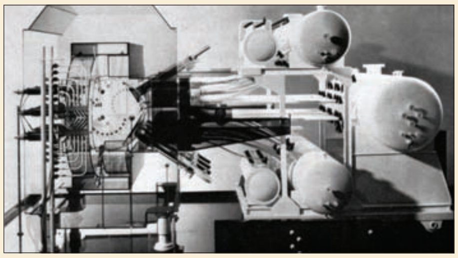
All other devices measure the intensity indirectly with the readings converted into absolute measurements by calibration against a Faraday cup. “Quantameters” are used to measure the intensity of photon beams. They consist of thick metal plates where the photons produce showers of electrons. Twelve to twenty plates sit in a gas such as argon with the spacing between the plates specially arranged so that the read-out of the charge they receive gives a Simpson integration of the beam intensity. The conventional gas-filled quantameter is not, however, suitable for high intensities.

Another method using electron emission from a metal, which is suitable for high intensities, is the “secondary emission chamber”. Here, very thin foils are set up in vacuum and the number of electrons knocked out of the foils is recorded. These devices are used for proton as well as electron beams – for example, to monitor the ejected proton beams at the CERN synchrotron. They are, however, very sensitive to contamination of the foil surface.

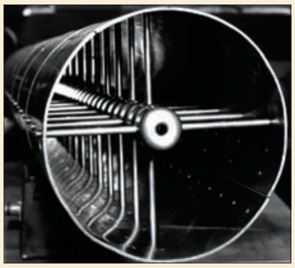
All of the above devices destroy or interfere with the beam they are measuring. Two types which are transparent to the beam are toroid and cavity monitors. Toroids use the beam as a single turn of a transformer, passing it through a ferrite ring with windings to tap off the current induced as a pulse of particles goes through. Cavity monitors are tuned to a harmonic of the beam radio frequency structure and the voltage induced on the cavity can be measured as the beam passes through. Both of these methods are very useful for setting up beams and for rough measurements but are not accurate beyond about 10%.

- Compiled from p105.

Modelling at CERN



A 1/8 scale model of Gargamelle [above] constructed of transparent coloured Plexiglas is used to show the way in which the different components fit together. On the right are the pressure system units culminating in the diaphragms in the chamber (they look like two pistons pointing in directions almost along the diagonals of the photograph). The optical system views the chamber through fish-eyes lenses set in the diaphragms. The chamber, magnet and coils can be picked out and on the left is the illumination system.



[Right] A scale model linear accelerator cavity (15 cm in diameter) is being used in the Intersecting Storage Rings ISR Department to optimize future cavity design. It has a “cross-bar” structure – the stems supporting alternate drift-tubes are at right angles (for the first drift-tube they are horizontal, for the second vertical and so on). By changing the orientation and size of the stems it is possible to considerably improve cavity performance compared with the conventional Alvarez structure. Advantages include making it easier to cope with beam loading, more uniform accelerating fields and less stringent mechanical tolerances.

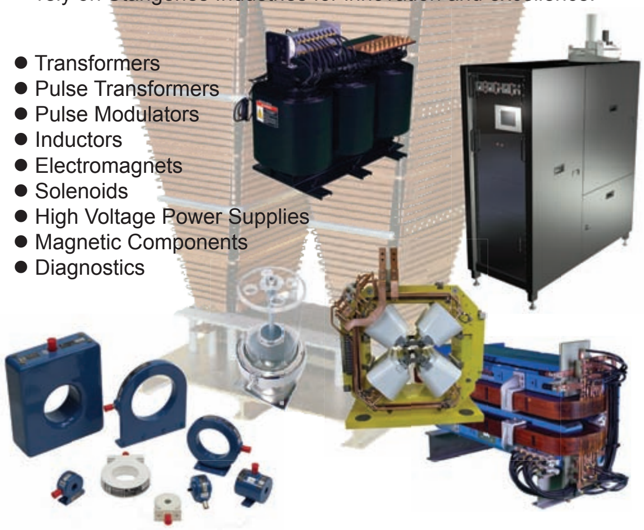
- Compiled from pp96 and 100.

Compiler’s Note

The chamber of the real Gargamelle, which famously detected neutral currents in 1973 is on show in the garden next to the Microcosm exhibition at CERN. Inside Microcosm is the real first cavity of Linac 1, used at the Proton Synchrotron from 1958 to 1992. As well as protons, this linac accelerated deuterons and alpha particles for the Intersecting Storage Rings and oxygen and sulphur ions for the Super Proton Synchrotron.

At the LHC, thousands of sophisticated instruments monitor the size and position of the counter-rotating beams around the ring but they cannot be placed in the most critical locations, namely the collision points deep within the experimental detectors. This has led to some novel interactions between the experiments and machine operators, with high-precision inner detectors being used online to generate 3D profiles of the beam-crossing spots that are sent to the LHC control room in real time.


Cremat, Inc.
CR-111



NA63's enlightening experiments

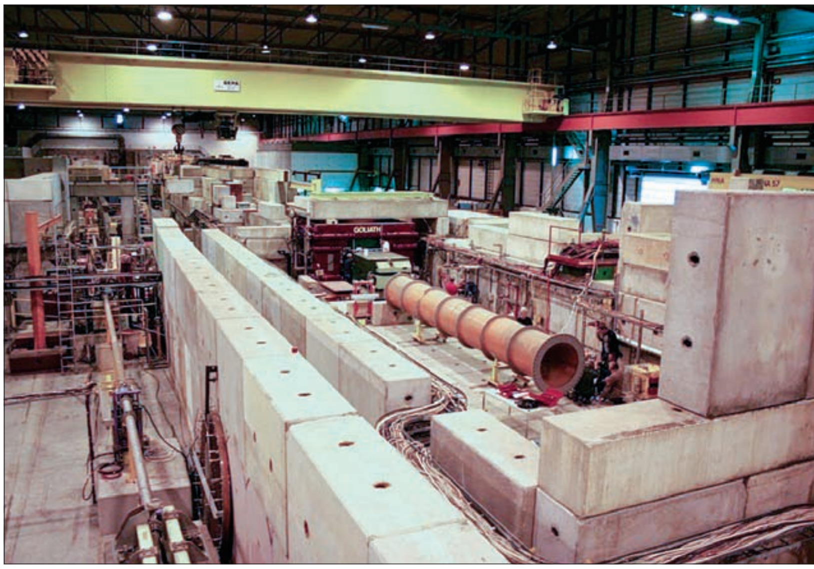
Using crystal targets, the NA63 experiment at CERN is investigating interaction processes in strong electromagnetic fields, with results that are relevant for a range of physics, including beam–beam effects in a future linear collider.

"Why still do experimental quantum electrodynamics, isn't everything known?" This provocative question is often heard by the collaborators at one of the smaller CERN experiments, NA63. Their answer is almost as short as the question: it is precisely the fact that everything is supposed to be known that makes it interesting. This understanding enables the exploration of physics in regimes of strong electromagnetic fields, for example as a function of interaction times or in studies of scattering. The results cast light on phenomena in various branches of physics.

Take, as an example, the emission of beamstrahlung, which is expected in the next generation of electron–positron linear colliders, such as the Compact Linear Collider (CLIC) currently under conceptual design at CERN. Particles in a bunch of particles in one beam "see" the electric field in the opposing bunch as boosted by $2\gamma^2-1$, where γ is the Lorentz factor. This appears as a strong electric field in the bunch's rest frame and leads to the emission of intense synchrotron-like radiation, which is known as beamstrahlung. The electric field seen by the particles is comparable to the so-called critical field, which depends only on the reduced Planck's constant, $\hbar$, the speed of light, c, and the mass, m, and charge, e, of the electron – $m^2c^3/\hbar e$ – and is equivalent to 1.32×10^{16} V/cm and a corresponding magnetic field of 4.41×10^9 T. In such fields, quantum corrections to the emission of synchrotron radiation become important in determining the emission spectrum. They lead to a strong suppression when compared with the classical calculations that are applicable in most other contexts for synchrotron radiation emission.

Into the laboratory

The effects of strong fields are also relevant in many other branches, ranging from the so-called "bubble-regime" in plasma wakefields used for extremely high-gradient particle acceleration, through astrophysical objects such as magnetars, to intense lasers and heavy-ion collisions. The concept even applies in a gravitational analogue – Hawking radiation. Therefore, further investigation of the underlying phenomena is of broad interest.



A photograph of the experimental area of NA63, seen in the right half of the figure, at the North Area at CERN. The long orange tube is a helium vessel through which the beams of hundred giga-electron-volt electrons and photons pass from the target to the detectors. (Image credit: Mikkel D Lund/NA63.)

Clearly, electric fields of the order the critical field are inaccessible in the laboratory. However, by replacing the opposing bunch in the example of a linear collider by a crystalline target, processes linked to the critical field can be studied with relative ease because the crystalline electric fields are orders of magnitude higher. At small angles of incidence to a crystallographic axis or plane, the strong electric fields of the nuclear constituents add coherently to form a macroscopic, continuous field with a peak value around 10^{11} V/cm. In the rest frame of an ultra-relativistic electron with γ around 10^5, the field encountered by the incident particle thus becomes comparable to the critical field.

It is precisely the fact that everything is supposed to be known that makes it interesting

▷

Applications of these strong crystalline electric fields are widely known, in particular in "channelling", where a beam of charged particles is steered by the fields within a crystal (*CERN Courier* January/February 2006 p37). This has been used, for example in the NA48 experiment at CERN, to deflect a well defined fraction of the main proton beam for the generation of kaons.

The NA63 experiment, following on from its predecessor, NA43, focuses on fundamental investigations of the strong fields themselves. The results have already shown that the emission of synchrotron radiation in the quantum regime is, indeed, well understood, being strongly suppressed as expected. These results mean that reliable estimates based on QED of beamstrahlung in future machines can now be made. In addition, the spin-flip component of the synchrotron-like radiation that is emitted as the beam passes through the crystal is many orders of magnitude higher in energy and intensity than that of a storage ring, with corresponding polarization times of femtoseconds instead of hours.

Strong scattering effects

The suppression in the emission of radiation arises loosely speaking because the field becomes so strong that the particle is deviated out of the formation zone necessary for the generation of the photon – in effect before it has time to generate the radiation. It is equivalent to a shortening of the formation zone. Although the concept of the formation zone was introduced more than 50 years ago by the Armenian physicist Mikhail Ter-Mikaelian, it is still a surprise to many that it can take time corresponding to macroscopic travel distances for a relativistic electron to emit a photon. This is the basis of the Landau-Pomeranchuk-Migdal (LPM) effect, where multiple scattering within the formation length leads to a reduction in radiation emission.

Figure 1 illustrates the suppression mechanism at play. It depicts the electric field from a particle, incident along the dashed line, that has scattered twice (at locations marked by crosses). Outside a radius given by the time since the scattering event, the field points towards the location that the particle would have had if it had not scattered. This is a result of the finite propagation time of information; inside the corresponding sphere, the field follows the particle. The transverse components correspond to radiation and, because of the short time between the scattering events, they are closely spaced and pointing in opposite directions. A distant observer looking at low frequencies will see two electric field lines that mutually cancel – and, therefore, less radiation. It is as if a "semi-bare" electron is interacting.

However, as the NA63 collaboration has recently shown, if a particle impinges on a target that is so thin that the formation zone extends beyond the target, then the LPM suppression is alleviated. To study this effect the collaboration measured the radiation emission from ultra-relativistic electrons in targets consisting of a number of thin foils of tantalum corresponding to 0.03%–5% radiation lengths. They found that, for the thinnest targets, the radiation emission agrees with expectations from the Bethe-Heitler formulation of bremsstrahlung, with the target acting as a single scatterer. Only as the thickness increases does the distorted Coulomb field resulting from the first scattering lead to a suppression of radiation emission in subsequent scattering such that the radiation yield becomes a logarithmic function of the thickness, eventually to become LPM suppression (Thomsen *et al.* 2010).

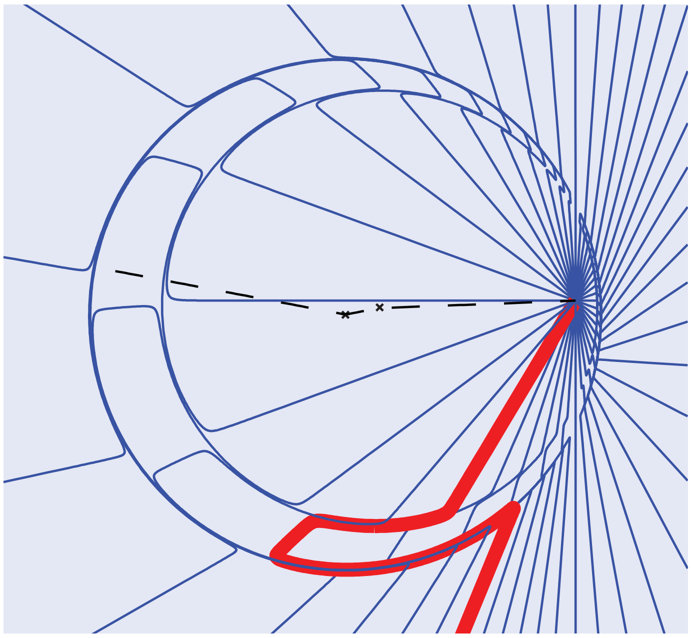


Fig. 1. An illustration of the electric field from a particle, incident along the dashed line, that has scattered twice at the locations of the crosses. Field lines are shown in blue, with one line emphasized in red. The transverse components correspond to radiation; a distant observer looking at low frequencies would see two field lines mutually cancelling, and therefore less radiation. (Image credit: K K Andersen/NA63.)

The NA63 collaboration has also studied higher-order processes, such as "trident production", in which an electron impinging on an electromagnetic field produces a positron–electron pair directly through the emission of a virtual photon. The process is illustrated in figure 2 in a reference frame close to the rest frame of the incident electron, in which the field has the critical value. In the laboratory frame, the original particle plus the pair are all directed forwards in a three-prong pattern, giving rise to the name "trident". The effect is reminiscent of a phenomenon studied by Oskar Klein and Fritz Sauter 80 years ago – the so-called Klein paradox. Klein was one of the first to do calculations using the celebrated equation of Paul Dirac. In 1929 Klein looked at the probability of reflection of an electron from the steep potential barrier provided by an electric field and found that the probability for transmission into a potential of infinite height approached the velocity of the incident electron in units of the speed of light, i.e. that transmission into a "forbidden" region approaches certainty. Soon after, Sauter found that the process takes place for electric fields beyond the critical field, i.e. when the field is so high that an electron transported over a Compton wavelength produces its rest mass, mc^2. Today, this process is understood in terms of pair production at the boundary, but without knowledge of the positron this was an impossible conclusion for Klein, hence the name "Klein paradox".

Studies by NA63 of trident production, with crystals of germanium a few hundred micrometres thick, have shown a similar phenomenon: that when the crystal is turned to an axial direction

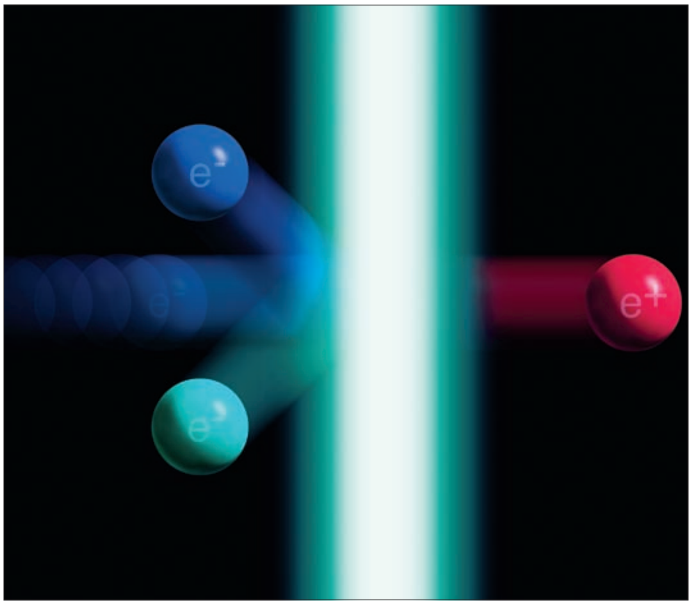


Fig. 2. Trident production in a strong field, where an electron impinging from the left on an electromagnetic field produces a positron–electron pair directly through the emission of a virtual photon. (Image credit: Bent A Lomholt.)

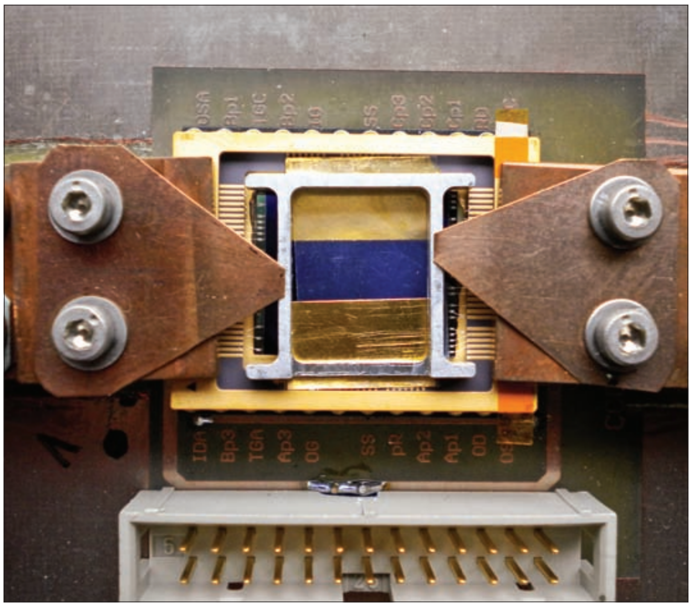


Fig. 3. The CCD used for experimental investigations of the King-Perkins-Chudakov effect. The detector is partly covered by thin foils of gold, installed at well defined distances from the CCD surface. (Image credit: NA63 collaboration.)

along the beam, giving rise to a critical field in the particle's rest frame, the trident process increases significantly (Esberg *et al.* 2010). Recent calculations have shown that trident production is an important factor in the design of the collision zone at CLIC, underlining the relevance of these experimental investigations.

A suppression mechanism also occurs in the case of pair production. In this case mutual screening of the charges in the pair substantially reduces the energy deposition in matter in the vicinity of the creation vertex. Because of the directionality of the pair, at high energies this internal screening – the King-Perkins-Chudakov effect – takes place over a distance of several tens of micrometres. This is a distance comparable to the sensitive layers in a CCD or a silicon vertex detector (figure 3), which can be used to study the effect.

Finally, as Allan Sørensen of Aarhus University has recently calculated, bremsstrahlung from relativistic heavy ions is expected to show a peak-structure connected to the finite size of the nucleus. The detection of this effect is among the future plans of NA63.

So QED still presents challenges, even for the otherwise well known case of radiation emission. In the words of one of the originators of the quantum theory of beamstrahlung, Richard Blankenbecler: "It is surprising that there is so much more to learn about such a well understood process."

Further reading

J Esberg *et al.* 2010 *Phys. Rev. D* **82** 072002.
H D Thomsen *et al.* 2010 *Phys. Rev. D* **81** 052003.

For more about the interaction of relativistic particles with strong crystalline fields, see:

U I Uggerhøj 2005 *Rev. Mod. Phys.* **77** 1131.

Résumé

NA63 : des expériences éclairantes

« Pourquoi faire encore des expériences sur l'électrodynamique quantique, puisqu'on sait déjà tout ? » Voilà une question provocante, adressée parfois aux collaborateurs de NA63, l'une des plus petites expériences du CERN. La réponse est simple : c'est justement parce que, normalement, on connaît tout, que c'est intéressant. Cela permet d'explorer la physique dans des régimes de champs électromagnétiques élevés. Au moyen de cibles en cristal, l'expérience NA63 étudie les processus d'interaction dans des champs électromagnétiques élevés, avec des résultats qui sont importants pour différents domaines de la physique, y compris les effets faisceau-faisceau dans un futur collisionneur linéaire.

Ulrik I Uggerhøj, Aarhus University.

Technology transfer

A sparkling tale of spin-off

Philip Bryant unravels some of the interwoven strands that link research at CERN with a hi-tech company in Austria.

Stories about how technology giants like Hewlett Packard started in a wooden garage appeal to everyone. Private venture capital is constantly searching for the right spin-off or newly founded company to emulate such success stories. Likewise, politicians try to create the right atmosphere for technology-driven projects in the hope of creating jobs and driving economic growth. Institutes like CERN are expected to stimulate this process of rejuvenation by generating new ideas and supporting a high turnover of students and staff to spread those ideas. Most institutes duly hold open days, run technology fairs, compile lists of their in-house technologies, apply for patents and support technology transfer in general.

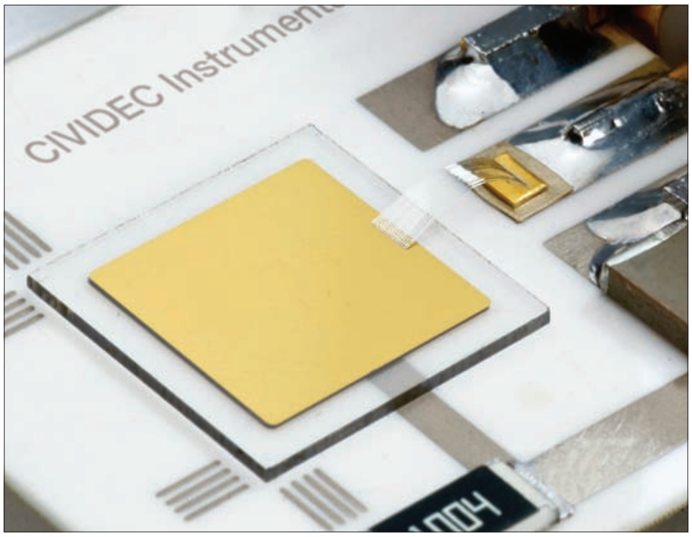
However, much of technology transfer is possibly more subtle and incremental in nature. It is as if ideas have a life of their own and are working away steadily for years, often through seemingly unconnected events, while the different elements are being assembled. One example that has weaved its way through the activities of CERN and its member states concerns a particle detector using artificial diamond, which is finding an expanding role in the LHC experiments and machine, as well as in other applications.

Following the tracks

The advanced-technology landscape is constantly evolving and there is no absolute beginning or end to any particular development. The action moves from one field to another and is driven forward by different goals at different times. Here, the quest to produce artificial diamond provides an appropriate starting point. This was akin to the search for the philosopher's stone – recorded efforts date back a hundred years – but the first person to succeed was William G Eversole of the Union Carbide Corporation in the US in 1952. Contrary to intuition and the bulk of earlier work, he used a low-pressure process called chemical vapour deposition (CVD).

The CVD technology made it possible to manufacture diamond coatings, films and precise shapes. Prior to this time, natural diamonds had been demonstrated as UV detectors in the 1920s and as ionizing radiation detectors in the 1940s. The advent of CVD diamond removed limitations arising from size, shape and uncertainty in material characteristics and provided a rich potential for the development of sophisticated particle detectors.

The transition from fixed-target physics to colliding-beam physics during the 1970s stimulated a tremendous growth in the technology of particle detectors, and the requirements for speed and radiation hardness increased with each new collider project. In 1989 the DIAMAS collaboration of the Superconducting Super Collider (SSC) project in the US was the first to propose diamond for its particle trackers. With the closure of the SSC the focus moved to CERN, where the RD42 collaboration for the Development of Diamond Tracking Detectors for High Luminosity Experiments at the LHC was founded in 1994. This collaboration looked into CVD diamond technologies under the leadership of Peter Weilhammer of CERN, Harris Kagan of Ohio State University (and formerly of the DIAMAS collaboration) and William Trischuk, who was a founding member of RD42 and co-spokesperson in the early days.



Single-pad pCVD diamond detectors with a size of 10 mm × 10 mm and gold electrodes of 8 mm × 8 mm on top and bottom are used at LHC as fast beam-loss monitors (BLMs). The diamond BLMs have a time resolution below 1 ns, are sensitive to single particles and have a high dynamic range. They are produced by CIVIDEC Instrumentation, Austria. (Image credit: Hikade.)

It is as if ideas have a life of their own and are working away steadily for years

One important activity in this group was the development of a beam condition monitor (BCM) for ATLAS, under the project leadership of Marko Mikuz. In fact, the first diamond BCM had been proposed and constructed some time earlier by Patricia Burchat of SLAC and Harris Kagan of the BaBar experiment at SLAC. The CMS, ALICE and LHCb experiments quickly followed the lead from ATLAS and installed diamond beam monitors.

Just before RD42 got going, in 1993 Erich Griesmayer, a postdoc working for the AUSTRON study in CERN, nurtured the idea of building a gigahertz particle counter for medical applications and wrote a proposal for its use in hadron therapy. (AUSTRON was an initiative in technology transfer funded by the Austrian government and hosted by CERN to lend its expertise in machine design. It later metamorphosed into MedAustron, which was recently funded for construction in Wiener Neustadt, Austria, but that is another story.) At that time, Griesmayer used silicon for his base calculations, although the material was too slow for what he had in mind.

In 1995, he returned to Austria to head the Department of Electrical Engineering of the Technische Fachhochschule in Wiener Neustadt and later its spin-off company FOTEC. There he pursued his ideas for a counter capable of resolving 10^9 particles a second, still with hadron therapy in mind. Meanwhile, a fellow postdoc, Heinz Pernegger, was working at MIT in the Laboratory for Nuclear Science for the PHOBOS collaboration, building a silicon detector for the Relativistic Heavy Ion Collider at Brookhaven. Griesmayer and Pernegger found that they had a common interest and Griesmayer and his engineer Helmut Frais-Kölbl built the calibration electronics for PHOBOS. This was the start of a long and fruitful collaboration that continued within the RD42 collaboration. In particular, the pre-amplifiers for the ATLAS BCM were built for CERN by FOTEC.

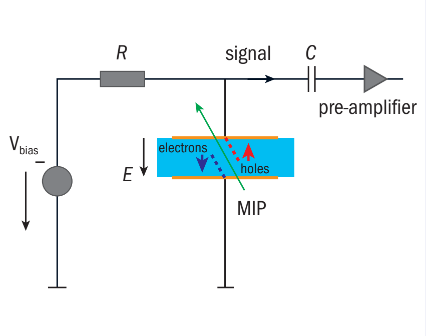
This was already a successful spin-off story for Austria and CERN, demonstrating how CERN could stimulate hi-tech projects in member states, but history was to be made when the Wiener Neustadt Technische Fachhochschule became a full member of the ATLAS collaboration, supplying electronic components for the readout system of the new diamond BCM. This was an unprecedented move and an inspiration to educational institutions across Europe.

Diamond benefits

Compared with silicon, diamond produces a lower linear density of electron-hole pairs along the incident particle track, but this is more than balanced by the positive effects of much higher electron and hole mobilities and a quasi-zero noise contribution from the diamond (see box). The leading edge of a single-particle pulse can be resolved in tens of picoseconds and individual pulses can be resolved on a nanosecond scale. Diamond is also an extraordinary material for radiation resistance. This is not only from the point of view of damage; diamond also responds linearly to the incident flux and its range is limited by the attached electronics rather than the material of the detector. According to the application, a diamond detector can be configured as a particle-counting ionization chamber or an energy-measuring calorimeter.

The potential of the diamond detector was clear to Griesmayer, who conducted many tests on prototypes with different particles and particle energies at accelerators in Europe and the US. Eventually, he founded his own company, CIVIDEC Instrumentation GmbH, in December 2009, creating a second-generation spin-off. The company now produces beam-monitoring systems based on diamond detectors with ultra-fast, low-noise electronics. It also specializes in the R&D aspects of tailoring the systems to particular problems. CIVIDEC recently collaborated with CERN to instrument the LHC machine with diamond beam-loss monitors.

Diamond detectors



The diamond detector works as an ionization chamber. The detector comprises a uniform diamond plate of the order of 500 μm thick with gold electrodes bonded on the two opposing faces and a constant voltage applied across the electrodes. The transverse dimensions are typically of the order of 10 mm. The passage of a high-energy charged particle through the semiconducting detector leaves a trail of "free" ionization electrons and matching holes. For a minimum ionizing particle (MIP) in diamond, the ionization channel would be formed with about 36 electron-hole pairs/μm in the order of one picosecond. Under the influence of the applied bias field, the "free" electrons and holes are attracted to their respective electrodes with a speed of about 10^5 m/s. Thus, the transit time in the diode will be of the order of nanoseconds. The external detection circuit registers the displacement and conduction currents, indicating the passage of the particle.

Many crystals behave in this way and can be used as the detector element. Silicon is the most widely used because it is cheap to produce and the ionization density for a MIP is much higher at 89 electron-hole pairs/μm. Why, then, go to the significantly higher expense of diamond? Diamond may deliver a smaller signal but its wider band gap (5.5 eV compared with 1.1 eV for silicon) means that it has effectively zero noise from electrons spontaneously jumping into the conduction band and does not require the PIN diode configuration that is used for silicon. Furthermore, the velocities of the "free" electrons and holes are much higher in diamond, giving shorter and higher pulses. Last, but not least, diamond is remarkably radiation tolerant, as indicated by the displacement energy of 43 eV for diamond compared with 13 eV for silicon.

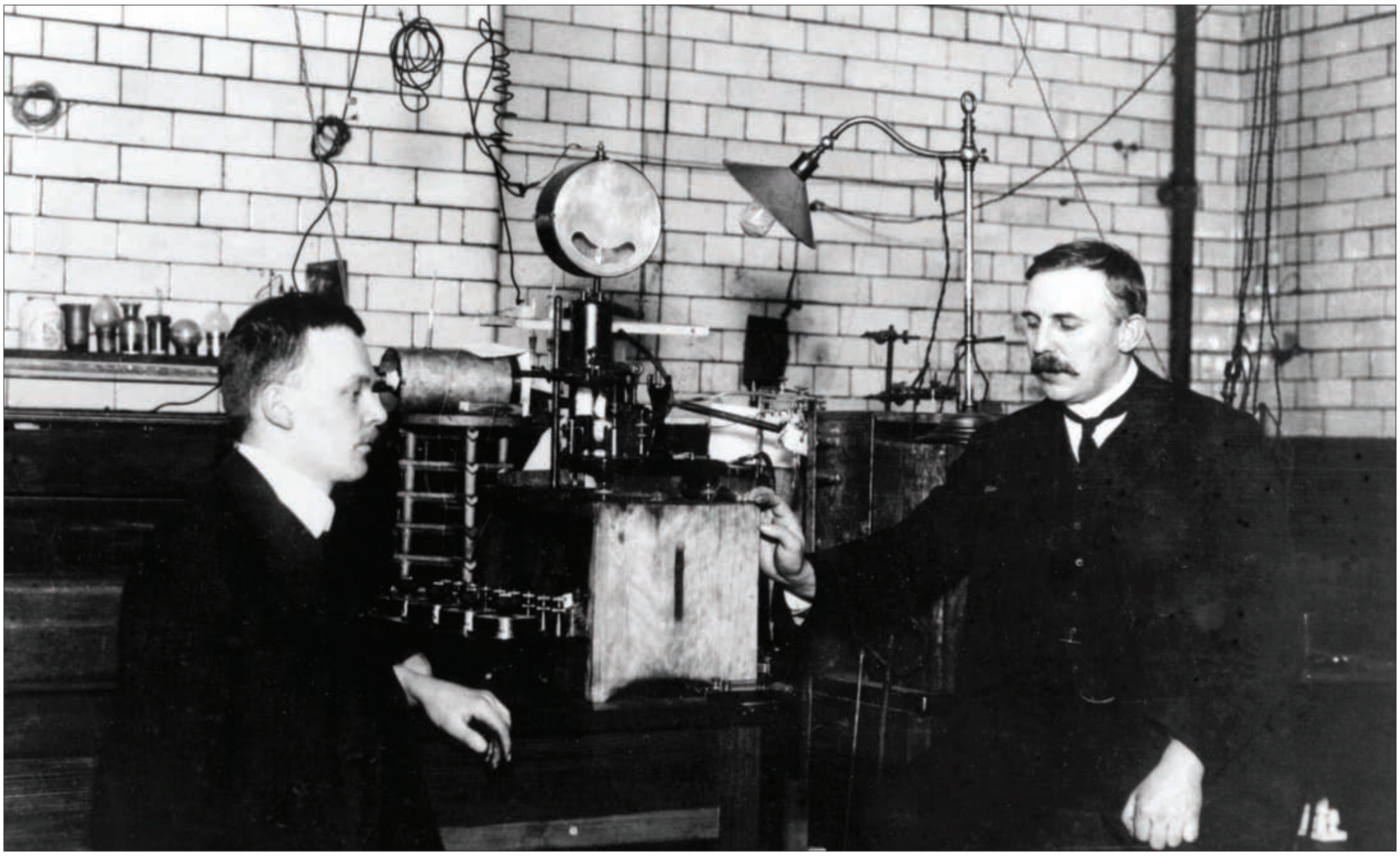
Résumé

Un transfert étincelant

Le transfert de technologies est une notion très importante aujourd'hui pour de nombreux instituts de recherche, à l'heure où les pouvoirs publics s'efforcent d'encourager les projets technologiques susceptibles de créer des emplois et de favoriser la croissance économique. Les instituts ont un rôle dans ce processus, dans la mesure où ils produisent des idées nouvelles et voient passer un grand nombre d'étudiants et de chercheurs, à même de diffuser les idées. Toutefois, explique Philip Bryant, une grande partie du transfert de technologies se produit de façon plus subtile. Dans cet article, consacré aux détecteurs à diamant artificiel, il décrit les liens étroits qui se sont tissés entre la recherche menée au CERN et une société high-tech en Autriche.

Philip Bryant, CERN (retired).

Rutherford – the road



Rutherford, right, in the laboratory at Manchester University with Hans Geiger, around 1908. (Image credit: Rutherford family.)

Serendipity plays a larger than recognized role in major discoveries. Ernest Rutherford's discovery of the nuclear atom – published in a famous paper in May 1911 – is a prime example, as **John Campbell** explains.

After three degrees and two years of research at the forefront of the electrical technology of the day, Ernest Rutherford left New Zealand in 1895 on a Exhibition of 1851 Science Scholarship, which he could have taken anywhere in the world. He chose the Cavendish Laboratory at the University of Cambridge because its director, J J Thomson, had written one of the books about advanced electricity that Rutherford had used as a guide in his research. This put the right man in the right place at the right time.

Initially, Rutherford continued his work on the high-frequency magnetization of iron, developing his detector of fast-current pulses to measure the dielectric properties of materials at high frequencies and hold briefly the world record for the distance over which electric "wireless" waves were detected. "JJ" appreciated Rutherford's experimental and analytical skills, so he invited Rutherford to participate in his own research into the nature of electrical conduction in gases at low pressures.

Within five months of Rutherford's arrival at the Cavendish Laboratory, the age of new physics had commenced. Wilhelm Röntgen's discovery of X-rays was swiftly followed by Henri Becquerel's announcement on radioactivity in January 1896. Rutherford capitalized on the new forms of ionizing radiation in his attempts to learn what it was that was conducting electricity in an ionized gas. He soon changed to trying to understand radioactivity itself and with his research determined that two types of rays were emitted, which he called "alpha" and "beta" rays.

Thomson continued mainly studying the ionization of gases. Less than two years after Rutherford's arrival he had carried out a definitive experiment demonstrating that cathode rays were objects a thousand times less massive than the lightest atom. The electronic age and the age of subatomic particles had begun, though mostly unheralded. Rutherford was a close observer of all of this and became an immediate convert to – and champion of – subatomic

d to the nuclear atom

objects. Beta rays were quickly shown to be high-energy cathode rays, i.e. high-speed electrons.

For Rutherford, however, there was no future at Cambridge. After only three years there he – as a non-Cambridge graduate – was not yet eligible to apply for a six-year fellowship, so in 1898 he took the Macdonald Chair of Physics at McGill University in Canada. (Cambridge changed its rules the following year.) From then on, the world centre of radioactivity and particle research was wherever Rutherford was based.

At McGill, he showed that radioactivity was the spontaneous transmutation of certain atoms. For this he received the 1908 Nobel Prize in Chemistry (*CERN Courier* December 2008 p19 and March 2009 p46). He also demonstrated that alpha particles were most likely helium atoms minus two electrons, and he dated the age of the Earth using radioactive techniques. In studying the nature of alpha particles and by being the first to deflect them in magnetic and electric fields in beautifully conceived experiments, Rutherford observed that a narrow beam of alphas in a vacuum became fuzzy either when air was introduced into the beam or when it was passed through a thin window of mica.

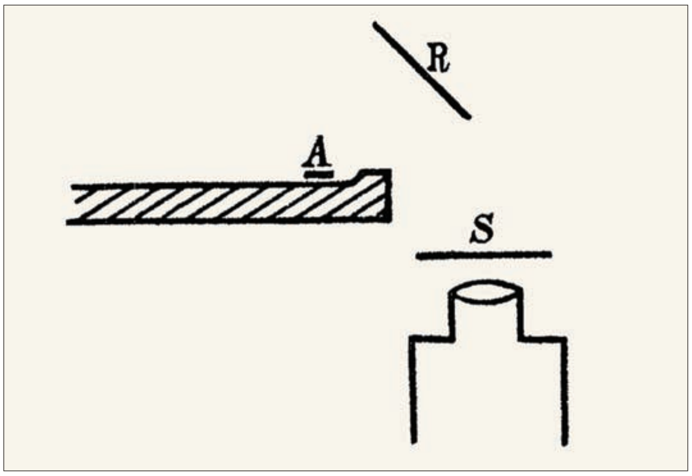


Fig. 1. Marsden's arrangement for studying scattering had the alpha source, A, on the same side of the metal, R, as the fluorescent screen, S, with a lead shield (hatched) to prevent the alpha particles from going directly to the screen. (Geiger and Marsden 1909.)

Return to England

With blossoming international scientific fame, Rutherford was regularly offered posts in America and elsewhere. He accepted none because McGill had superb laboratories and support for research, but he was wise enough to let the McGill authorities know of each approach; they increased his salary each time. However, Rutherford also wished to be nearer the centre of science, which was England, where he would have access to excellent research students and closer contact with notable scientists. His desire was noted. Arthur Schuster, being from a wealthy family, said he would step down from his chair at Manchester University provided that it was offered to Rutherford, and in 1907 Rutherford moved to Manchester

At Manchester University Rutherford first needed a method of recording individual alpha particles. He was an expert in ionized gases and had been told by John Townsend, an old friend from Cambridge, that one alpha particle ionized tens of thousands of atoms in a gas. So, with the assistant he had inherited, Hans Geiger, the Rutherford-Geiger tube was developed.

Many labs at the time were studying the scattering of beta particles from atoms. People at the Cavendish Laboratory claimed that the large scattering angles were the result of many consecutive, small-angle scatterings inside Thomson's "plum pudding" model of the atom – the electrons being the fruit scattered throughout the solid sphere of positive electrification. Rutherford did not believe that the scattering was multiple, so once again he had to quantify science to undo the mistaken interpretations of others.

Geiger was given the task of measuring the relative numbers of alpha particles scattered as a function of angle over the few degrees that Rutherford had measured photographically at McGill. However, photography could not register single particles. Nor was the Rutherford-Geiger detector suitable for "quickly" measuring particles scattered over small angles; it was not sensitive to the direction of entry of the alpha particle and all that they observed was the "kick" of a spot of light from a galvanometer. Yet one of the reasons for developing the Rutherford-Geiger tube had been to determine whether or not the spinthariscope invented by William Crookes did, indeed, register one flash of light for every alpha particle that struck a fluorescing screen.

So, Geiger allowed monochromatic alpha particles in a vacuum tube to pass through a metal foil and onto a fluorescing plate that formed the end of the tube. A low-power microscope, looking at about a square millimetre of the plate, allowed the alphas to be counted. It was tiring work, waiting half an hour for the eye to dark adapt, then staring at the screen unblinking for a minute before resting the eye. It is said that Rutherford often cursed and left the counting to the younger Geiger.

Another of Geiger's duties was to train students in radioactivity techniques and it was Rutherford's policy to involve undergraduates in simple research. So, when Geiger reported to Rutherford that a young Mancunian undergraduate was ready to undertake an investigation, Rutherford set Ernest Marsden the task of seeing if he could observe alpha particles reflected from metal surfaces. This seemed unlikely, but, on the other hand, beta rays did reflect.

Marsden used the same counting system as Geiger, but had the alpha source on the same side of the metal as the fluorescing screen, with a lead shield to prevent alphas from going directly to the screen (figure 1). When he reported that he did see about 1 in 10 000 alphas scattered at large angles, Rutherford was astonished. As he later ▷

Left, lower centre and right: stamps with the nuclear atom, the symbol most associated with Rutherford. Upper centre: a Soviet stamp showing the diagram from Rutherford's paper of May 1911, illustrating what is now known as Rutherford scattering.

famously recalled: "It was as if a 15-inch naval shell had been fired at a piece of tissue paper and it bounced back."

Geiger and Marsden published their measurements in the May 1909 issue of the *Proceedings of the Royal Society*, but the study laid fallow for more than a year, while Geiger continued obtaining more accurate results for his small-angle scattering from different materials and various thicknesses of foils. It is said that one day Rutherford went in to Geiger's room to announce that he knew what the atom looked like. In January 1911 Rutherford was able to write to Arthur Eve in Canada: "Among other things, I have been interesting myself in devising a new atom to explain some of the scattering results. It looks promising and we are now comparing the theory with experiments." .

The nuclear atom

On 7 March 1911 Rutherford spoke at the Manchester Literary and Philosophical Society. Two other speakers followed him: one spoke on "Can the parts of a heavy body be supported by elastic reactions only?", the other showed a cast of the "Gibraltar Skull". A reporter from *The Manchester Guardian* was present and in the edition of 9 March (p3) succinctly paraphrased Rutherford: "It involved a penetration of the atomic structure, and might be expected to throw some light thereon." Rutherford had asked Geiger to test experimentally his theory that the alpha scattering through large angles varied as $\mathrm{cosec}^4(\phi/2)$. He concluded that the central charge for gold was about 100 units, that for different materials the number was proportional to NA^2 (where N was the number of atoms per unit volume and A the atomic weight), and that large-angle scattering (hyperbolic paths) was independent of whether the central charge is positive or negative. The reporter concluded: "… we were on the threshold of an enquiry which might lead to a more definite knowledge of atomic structure."

Rutherford's talk was published in the *Proceedings of the Manchester Literary and Philosophical Society* (Rutherford 1911a) and more fully in the *Philosophical Magazine* for May (Rutherford 1911b). In the latter, he acknowledged Hantaro Nagaoka's mathematical consideration of a "Saturnian" disc model of the atom (Nagoaka 1904), stating that essentially it made no difference to the scattering if the atom was a disc rather than a sphere.

The nuclear atom created no great stir among scientists and the public at the time. Three nights after his announcement, Rutherford addressed the Society of Industrial Chemists on "Radium". The nuclear atom was not mentioned by Sir William Ramsay in his opening address to that year's meeting of the British Association, although his reported claims of various discoveries caused Schuster – who had stepped down to attract Rutherford to Manchester – to write a letter to *The Manchester Guardian* stating which of those were discovered by Rutherford.

Rutherford's busy life continued as normal: accepting a Corresponding Membership of the Munich Academy of Sciences; giving talks on all manner of subjects but the nuclear atom; refuting several claims of cold fusion that came from Ramsay's laboratory; motoring in the car recently purchased with the money that had accompanied his Nobel prize; and being involved with many organizations, including being a vice-president of both the Manchester Society for Women's Suffrage and the Manchester Branch of the Men's League for Women's Suffrage. (At Canterbury College in New Zealand, his landlady and future mother-in-law was one of the stalwarts who in 1893 had obtained the vote for women in New Zealand.)

Rutherford's Nobel Prize in Chemistry of 1908 was too recent for physicists to nominate him again for a prize. It was to be 1922 before he was next nominated, unsuccessfully. There have been 27 Nobel prizes awarded for the discovery of, or theories linking, subatomic particles but there was never one for the nuclear atom (*CERN Courier* March 2009 p46). However there was a related one. At the end of 1911 Rutherford was the guest of honour at the Cavendish Annual Dinner, at which he was, not surprisingly, in fine form. The chairman, in introducing him, stated that Rutherford had another distinction: of all of the young physicists who had worked at the Cavendish, none could match him in swearing at apparatus.

Rutherford's jovial laugh boomed round the room. A young Dane, visiting the Cavendish for a year to continue his work on electrons in metals, took an immense liking to the hearty New

Geiger and Marsden

Hans Geiger returned to Germany in 1912, to the Physical-Technical Reichsanstalt in Berlin. During the Great War he was an artillery officer, serving opposite Marsden at the front. However, he was able, via Neils Bohr in neutral Denmark, to congratulate Marsden on his chair in Wellington. In 1925 Geiger became professor in Kiel, in 1929 in Tübingen and from 1936 in Berlin. He helped to develop coincidence-counting and studied cosmic rays. In 1928 he and Walther Müller modified the Rutherford-Geiger detector and today it is called the Geiger-Müller tube. Geiger died in 1945, not long after the Second World War. In 1927 he named one of sons Roland Ernst Arthur, in honour of his time at Manchester.

Ernest Marsden graduated BSc with First Class Honours in 1909 and became a lecturer at the University of London before returning to Manchester in 1912 to succeed Geiger. In 1914 he was appointed professor at Victoria University College at Wellington, New Zealand. He served in the Great War, in sound-ranging of enemy guns, and was awarded the Military Cross. From 1922 his career was in administration in New Zealand: assistant director of education (1922–1926); secretary of the new Department of Scientific and Industrial Research (1926–1944); scientific advisor to the New Zealand government during the Second World War (1941–46); scientific liaison officer in London (1947 until retirement in 1954). He died in New Zealand in 1970.

Zealander and resolved to move to Manchester to work with him. And so it was that Niels Bohr received the 1922 Nobel Prize in Physics for "his services in the investigation of the structure of atoms and of the radiation emanating from them". He had placed the electrons in stable orbits around Rutherford's nuclear atom.

● Further reading

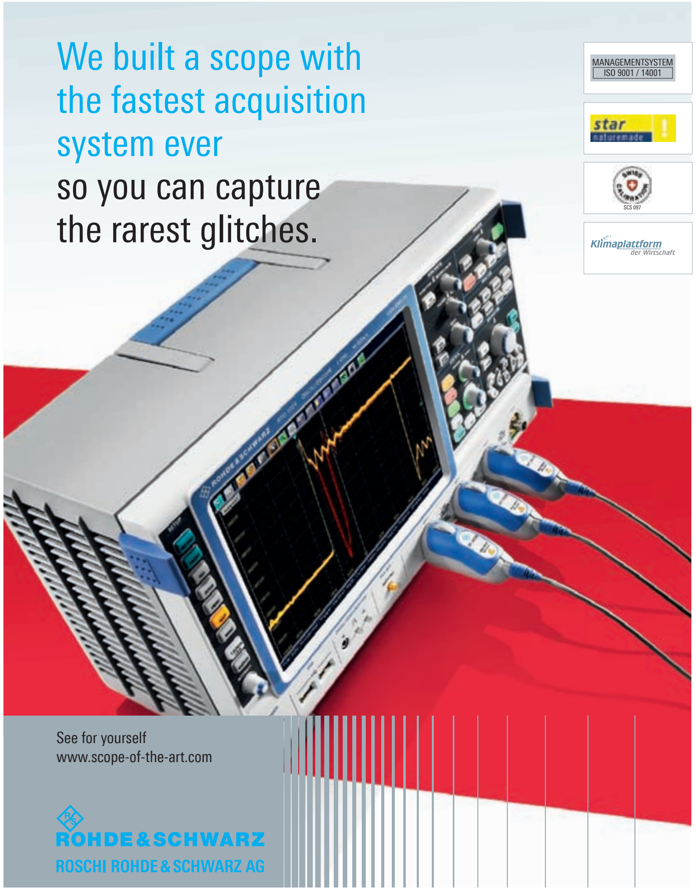
H Geiger and E Marsden 1909 *Proc. Roy. Soc.* A **82** 495.
E Rutherford 1911a *Proc. Manc. Lit. & Phil. Soc. IV* **55** 18.
E Rutherford 1911b *Phil. Mag.* **21** 669.
H Nagaoka 1904 *Phil. Mag.* **7** 445.

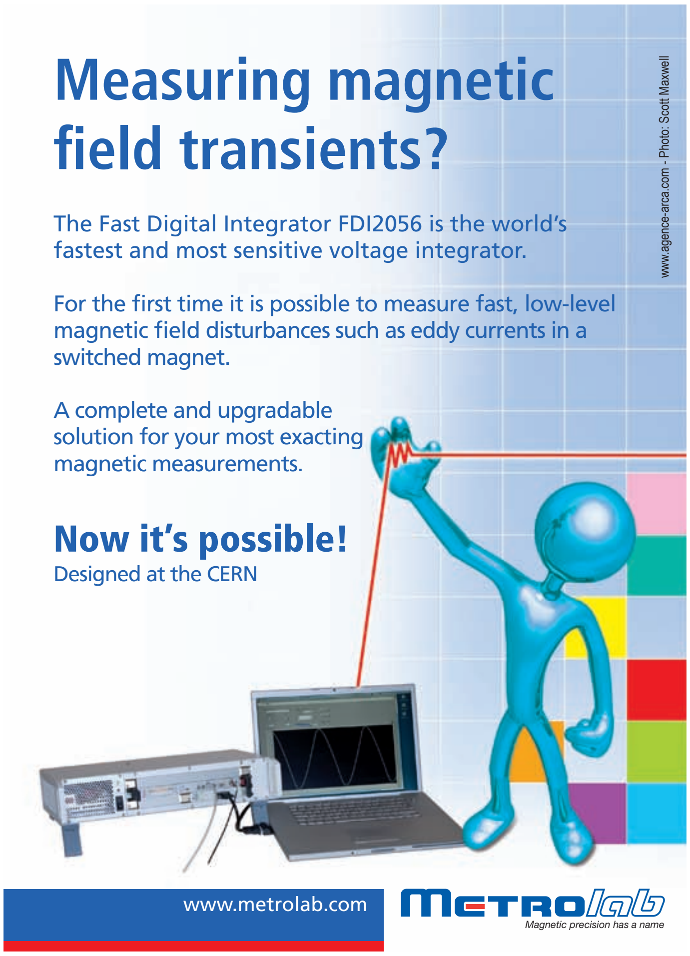
Résumé

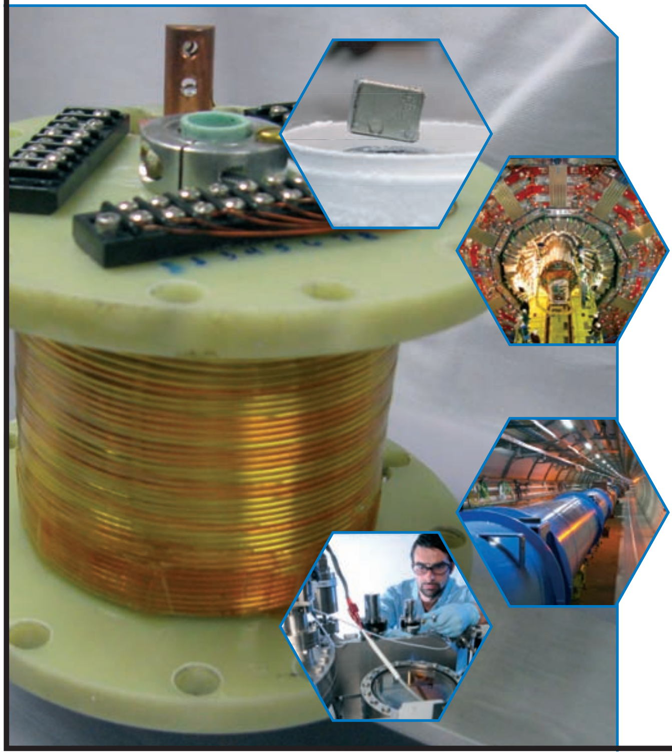
Rutherford – la découverte du noyau atomique

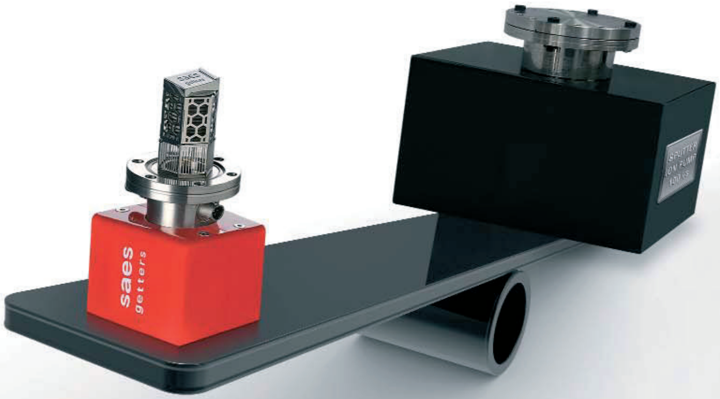
Il y a un siècle, en mai 1911, la Royal Society *de Londres publiait un article d'Ernest Rutherford considéré maintenant comme historique. Rutherford avait analysé les résultats de la diffusion de particules alpha, obtenus deux ans auparavant par ses collègues de l'Université de Manchester, Hans Geiger et Ernest Marsden. Rutherford avait compris que les grands angles de diffusion mesurés signifiaient que la totalité de la charge positive de l'atome devait nécessairement se concentrer en un noyau central minuscule. Comme l'explique John Campbell, le hasard a joué un grand rôle dans cette découverte.*

John Campbell, University of Canterbury, New Zealand, is the author of *Rutherford Scientist Supreme* (AAS Publications 1999) and an online compendium of information about Rutherford: www.rutherford.org.nz.





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High-energy interactions in the Alps

A major winter conference confirms how the baton of discovery in the field of high-energy physics is passing to the LHC experiments.

Participants listen attentively during a presentation in the session on QCD and High-Energy Interactions at this year's Rencontres de Moriond. (Image credit: Christian Bareille.)

Held in the picturesque mountain setting of La Thuile in the Italian Alps, the international Rencontres de Moriond is one of the most important winter conferences for particle physics (*CERN Courier* July/August 2005 p21). Composed of meetings spread over two weeks, it covers the main themes of electroweak interactions, QCD and high-energy interactions, cosmology, gravitation, astroparticle physics and nanophysics. This article reviews some selected results from the approximately 90 talks presented at the 2011 QCD and high-energy interactions session on 20–27 March.

In the well known spirit of the Moriond meetings, the conference provided an important platform for young physicists to present their latest results. In particular, the sessions this year covered the search for the Higgs boson, the physics of heavy flavours and the top quark, the search for new objects and the first results from the heavy-ion run at the LHC. Lively discussions between theorists and experimentalists followed the presentations and were particularly motivating for the young physicists present.

The LHC had an outstanding first year of operation in 2010, with beam intensity rising systematically over the course of the year. The LHC experiments collected 35–40 pb^{-1} of proton–proton collision data, of which around 50% were taken during one of the last weeks of proton running. Lead–ion collisions were observed for the first time in November. In 2011 and 2012, most of the run time is planned for physics data-taking, with the aim of collecting 1–3 fb^{-1} of proton collisions per experiment in 2011.

In the quest for the highest collision energies, the LHC was preceded by the Tevatron at Fermilab in the US. In La Thuile, the collaborations for the CDF and DØ experiments at the Tevatron presented new, combined results, confirming that there is no Standard Model Higgs boson in the mass region between 159 GeV and 173 GeV (95% confidence level). This year, both collaborations also presented exclusion limits within this Higgs-mass region. The Tevatron will end its successful period of data-taking in September. With all of the collected data and improved analyses, the CDF and DØ teams expect to exclude the existence of the Higgs boson in the whole mass region between 114 GeV and 200 GeV – if it does not exist. On the other hand, the experiments will not have enough data to prove discovery if a Higgs does, indeed, exist in this mass region.

The CMS and ATLAS experiments at the LHC cannot yet reach the Tevatron experiments' level of sensitivity in the search for the Higgs boson. However, within a year and if all goes well and the LHC delivers the expected number of collisions then both CMS and ATLAS will be able to explore the full range between 130 GeV and 460 GeV. If the teams do not see evidence of the Higgs in this wide mass region then they can conclude that no new particle exists with the properties of the Higgs boson and that mass. If a new signal does appear in the data, they will need to wait for more data and improved statistics before confirming any new discovery – but this will happen only in 2012.

The region for a low-mass Higgs, between the 114 GeV limit set by the experiments at the Large Electron–Positron collider and 130 GeV, is more difficult at the LHC. More data time will be needed to exclude or discover the Higgs in this region. The exclusion limits depend on the theoretical calculations of Higgs boson production. The theoretical uncertainties of these calculations formed the subject of a long and interesting discussion between experimentalists and theorists during the Moriond meeting.

One important area of the LHC programme relates to direct searches for new phenomena. The ATLAS and CMS collaborations presented results from the 2010 data-taking period, which show that new physics has not (yet?) been found. However, in many cases the exclusion limits have already surpassed the ones from the Tevatron. The search for new phenomena has always played an important role at the Moriond meetings and is set to become even more so ▷

following the increase in luminosity and energy at the LHC.

The LHC experiments are also searching indirectly for new physics. LHCb is doing so through the lens of rare decays of the B particle. This requires high sensitivity of the experimental apparatus and extremely high accuracy in the data analysis. At La Thuile, the LHCb collaboration showed that – after just a few months of operation – their detector has reached a sensitivity that in some cases is already comparable to other detectors that have run for years. These include the measurements of the rare decay of the B_s meson to pairs of muons, where the Standard Model branching ratio is precisely calculated (*CERN Courier* April 2011 p9), as well as the mixing frequency in the B_s system. By the end of 2011, LHCb may be able to measure, among other things, the production rate of like-sign muon pairs in B decay. This is important to complement the measurement by DØ, which showed an unexpectedly high matter–antimatter asymmetry in the number of pairs from B^0 decay (*CERN Courier* July/August 2010 p6). LHCb should confirm whether or not the observed phenomenon can be associated with new physics.

In early December last year, the first ion–ion collisions at the LHC confirmed the astonishing jet-quenching phenomenon (*CERN Courier* January/February 2011 p6), one of the possible signatures of quark–gluon plasma. For the first time, the LHC experiments could actually see the disappearance of the energy of the recoiling jet that is interacting with the produced medium, providing new insights into the strong interaction through quantitative studies of the dynamics of jet quenching. The Moriond conference provided a good opportunity to discuss the redistribution of the jet energy, which happens over an unexpectedly wide angle, as observed recently by CMS and ATLAS. This is an important step towards understanding jet quenching, as well as the behaviour of the medium in heavy-ion collisions. In another highlight, the ALICE collaboration has found that the effects of the strongly interacting medium at lower particle momenta are stronger than those observed at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven. These recent findings will give valuable input to theorists and improve understanding of the jet-quenching phenomenon, and the LHC will allow the effects of the medium to be studied at high particle momenta.

The search for new phenomena has always played an important role at the Moriond meetings

The top quark was discovered at the Tevatron in 1995 but it has yet to be explored fully because – with its high mass – it sits astride the border between Standard Model physics and new physics. At La Thuile, the CMS and ATLAS collaborations presented for the first time results of their analyses of the whole 2010 dataset. Their sensitivity in measurements of the top cross-section is approaching that of the Tevatron experiments and they are now ready to study other properties of the particle, for example making a precise measurement of the mass. For the time being, the most precise measurements of the properties come from DØ and CDF, but the LHC experiments have already seen the production of single top quarks, something that it took 14 years to observe at the Tevatron.

CDF and DØ have observed significant forwards–backwards $t\bar{t}$ asymmetries in the proton–antiproton collisions at the Tevatron, particularly at a $t\bar{t}$ mass above 450 GeV. This could be interpreted as a sign of new physics. The size of the effect is expected to be smaller in the proton–proton collisions of the LHC, so interesting comparisons with the Tevatron are not expected until the end of 2011.

The search for new physics requires an excellent understanding of Standard Model processes. In this respect, the LHC experiments have shown important progress in jet reconstruction and calibration, while theorists have made improvements in higher-order QCD corrections, discussed in detail at La Thuile. The agreement now achieved between experimental measurements and theoretical calculations is setting an important baseline in the search for new phenomena.

Meanwhile, far from the LHC, the Pierre Auger Observatory (PAO) in South America has opened the window to the study of interactions at far higher energies in the cosmic radiation. The PAO collaboration presented evidence of an unexpected effect: the highest-energy cosmic rays may have an important contribution from iron ions (*CERN Courier* October 2010 p9). This observation was possible because protons and iron nuclei generate showers of different shapes but confirmation of the effect will require a better understanding of these shower shapes.

During their long history the Rencontres de Moriond meetings have followed advances at the frontier of energy at the Tevatron, the frontier of flavour at the BaBar and BELLE experiments, the frontier in heavy-ions at RHIC and the detailed measurements of structure functions at the HERA electron–proton collider at DESY. This year, the evidence at La Thuile is that these excellent research programmes will all be continued at the LHC and its experiments.

Further reading

For more about the sessions described in this article, see the QCD and High-Energy Interactions webpage, http://moriond.in2p3.fr/QCD/2011/qcd.html.

Résumé

Interactions à hautes énergies dans les Alpes

Organisées dans la pittoresque station de La Thuile, dans les Alpes italiennes, les « Rencontres de Moriond » désignent l'une des principales conférences d'hiver dans le domaine de la physique des particules. Sous la forme d'une série de séminaires répartis sur deux semaines, il y est question d'interactions électrofaibles, de chromodynamique quantique et d'interactions hautes énergies, de cosmologie, de gravitation, d'astrophysique des particules et de nanophysique. L'article évoque certains résultats présentés lors des quelque 90 conférences données à la session 2011 sur le thème de la chromodynamique quantique et des interactions à hautes énergies, du 20 au 27 mars. La conférence a confirmé que ce sont les expériences LHC qui prennent le relais s'agissant des découvertes en physique des hautes énergies.

Bolek Pietrzyk, Laboratoire d'Annecy-le-Vieux de Physique des Particules. Based on the article in *CERN Bulletin*, with contributions from **Boaz Klima**, **Rob Lambert**, **Greg Landsberg**, **Frank Ma** and **Meenakshi Narain**, see http://cdsweb.cern.ch/record/1339911.

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Alan Jackson, former Technical Director of the Project (ASP)

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Gianluca Chiozzi, Head of the Control and Instrumentation Software Department (ESO)

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Faces & Places

AWARDS

Nobel laureates receive the Science for Peace Erice Prize

Werner Arber, Yuan T Lee, Gerardus ’t Hooft and Samuel Ting are the 2010 laureates of the Science for Peace Erice Prize.

This prize was instituted in 1988 by the Sicilian parliament at the request of the World Federation of Scientists (WFS) on the occasion of the 25th anniversary of the Ettore Majorana Foundation and Centre for Scientific Culture (EMFCSC). It is awarded to world leaders in science and scientific culture, and to those who have played an essential role in promoting and implementing the goals outlined in the Erice Statement: Science for Peace, written in 1982 by Paul Dirac, Pyotr Kapitza and Antonino Zichichi, the current president of the EMFCSC.

Werner Arber receives the prize for “his fundamental contributions to unravel the mechanisms which promote and limit the spontaneous variation of genetic information in micro-organisms; for his theory of molecular evolution which puts on a scientific basis the fact that nature cares actively for biological evolution, thus allowing us to understand and evaluate the risks of genetic engineering”. Arber received the 1978 Nobel Prize in Physiology or Medicine together with Daniel Nathans and Hamilton O Smith for the discovery of restriction enzymes and their application to problems of molecular genetics.

Sam Ting, left, one of four Nobel laureates who received the Science for Peace Erice Prize from Antonino Zichichi, right, at the end of January. (Image credit: WFS.)

Yuan T Lee is recognized for “his discoveries to determine the structure and chemical behaviour of highly reactive polyatomic radicals and unusual transient species; for his achievements in the basic chemical reactions and primary photo-dissociation processes; for his studies to modify chemical reactivity; for his contributions to the development of methods to detect, directly, the transient intermediates that are critical in combustion and atmospheric processes”. In 1986 he was awarded the Nobel Prize in Chemistry jointly with Dudley R Herschbach and John C Polanyi for their work on the dynamics of chemical elementary processes.

Better known in the particle-physics community are ’t Hooft and Ting, who received the Nobel in physics in 1989 and 1976, respectively. ’t Hooft’s Nobel-prize work is reflected in his citation for the Erice prize, awarded for “his discovery of the negative sign of the β-function in the most critical period of crisis for relativistic quantum field theory, which he brought to new life with his fundamental contributions to understand the renormalization processes, thus paving the road to quantum gravity, supergravity, superstring theories, including the nature of black holes”. The citation for Ting similarly recognizes his early work that earned him the Nobel prize as well as his more recent contributions. He receives the Erice prize for “his discovery of the J-particle, the first ‘narrow’ state in subnuclear physics, which gave rise to the so-called ‘November revolution’, from where a great step forward came in the understanding of the logic of nature, whose most recent frontier is the search for antimatter in space”.

In the ceremony at the Vatican, each laureate was invited to present current projects, followed by discussions with members of the WFS. The ceremony continued with a visit to the Galileo Galilei exhibition inside the Renaissance church Santa Maria degli Angeli and ended with a midnight concert in the church.

Indian Nuclear Society honours Kakodkar

Anil Kakodkar, former chair of the Indian Atomic Energy Commission and secretary to the Department of Atomic Energy has been awarded the Indian Nuclear Society’s Homi Bhabha Lifetime Achievement Award 2009. The award was presented at the 21st Annual Conference of the Indian Nuclear Society, held in Mumbai in January. The award is given in recognition of outstanding lifetime achievement in research, technology development, management, operation and maintenance and, safety or education in fields related to nuclear sciences and technology. Kakodkar has strong links with CERN, for example leading the Indian delegation at its first time as an Observer at CERN Council in June 2003 (*CERN Courier* September 2003 p43).

Anil Kakodkar, left, receives the award from Yukiya Amano, director-general of the IAEA. (Image credit: INS.)

Michel Davier. (Image credit: IN2P3.)

Michel Davier receives André Lagarrigue Prize

Michel Davier, physics professor at the University of Paris-Sud 11, has been awarded the 2010 André Lagarrigue Prize. A worldwide authority in particle physics, Davier is recognized for his deep understanding of physics and of experimental devices of great complexity as well as his passion and talent for teaching and for educational outreach.

The prize, instituted by the Linear Accelerator Laboratory (LAL) at Orsay, under the aegis of the French Physical Society, is awarded to front-line researchers who have had responsibility for machine and detector construction and derived maximum scientific benefit from such projects, performed in a French laboratory or in close collaboration with French groups.

Davier has played a leading role in particle physics, especially within the CELLO (DESY), ALEPH (CERN) and BaBar (SLAC) collaborations, and is a former leader of the French-Italian Virgo project for a laser interferometer to detect gravitational waves. He was director of LAL from 1985 to 1994 and – under his mandate – LAL built the LEP Injector Linac for CERN and the linear accelerator for the CLIO free-electron laser facility in Orsay.

Devoting himself to both theoretical and experimental studies of the strong interaction, Davier has become one of the world's leading experts in this field. His work on the muon magnetic moment suggests new physics that may soon be confirmed at the LHC, while his measurements of the τ, among others, have led to the most accurate measurement of the strong interaction coupling and contributed to indirect constraints on the mass of the Higgs boson. Davier also excels in explaining the mysteries of the subatomic world to a large audience, a talent that is revealed in numerous courses, books, radio programmes and public presentations

The prize is awarded every other year in honour of Lagarrigue, who was director of LAL from 1969 until his untimely death in 1975. It is sponsored jointly by CNRS/IN2P3, CEA, CERN, the Ecole Polytechnique, LAL and Paris-Sud 11 University.

VISITS

Italian president, **Giorgio Napolitano**, far left, spent time in the ATLAS control room, as part of a visit to CERN on 4 March. Here he is sitting with CERN's director-general, **Rolf Heuer**, while ATLAS spokesperson, **Fabiola Gianotti**, and CERN's director for research and scientific computing, **Sergio Bertolucci**, look on from the right. The president also viewed CERN's permanent exhibition, the *Universe of Particles*, located in the Globe of Science and Innovation, and addressed the Italian community at CERN.

OUTREACH

ALICE physicist features in book about Mexico

The recently published book *Uno + Uno: 32 líderes sumando por México* (32 Leaders Stand Up for Mexico) contains reflections about the future of Mexico by 32 people born in the 1970s or early 1980s, from different walks of life. Representing science is Daniel Tapia Takaki of the ALICE collaboration, who presents his views on the role of public education in Mexico and how knowledge can be a focus for change in many areas, such as politics, culture, sport, science and technology.

The book was written by two journalists, Paula Odorica and Carlos Mota. Other contributors include the international football player Rafael Márquez, pop star Paulina Rubio, actress Kate del Castillo and photographer Pablo López Luz.

Daniel Tapia Takaki at his degree ceremony in Birmingham in 2008. (Image credit: Orlando Villalobos Baillie.)

Manuel Eduardo Baldeón, national secretary of higher education, science, technology and innovation for the Republic of Ecuador, right, came to CERN on 1 March. He is seen here in the LHC superconducting magnet test hall with **Frédérick Bordry**, head of the technology department at CERN. Baldeón also visited the CMS control centre and the CERN computing centre.

On 2 March, **Catharina Håkansson Boman**, Swedish state secretary to the minister for enterprise and energy, right, was welcomed to CERN by **Felicitas Pauss**, head of international relations. The visit included a presentation about the LHC Computing Grid project and a tour of the LHC superconducting magnet test hall and the ATLAS visitor centre.

Maciej Banach, Polish under secretary of state, ministry of science and higher education, right, was at CERN on 8 March to open an exhibition to celebrate the 100th anniversary of the awarding of the Nobel Prize in Chemistry to Maria Sklodowska-Curie, together with CERN's director-general, **Rolf Heuer**. The visit also included the opportunity to meet Polish scientists working at CERN.

Australian senator, minister for innovation, industry, science and research, **Kim Carr**, second from right, visited CERN on 14 March. His tour included the ATLAS visitor centre, where he was accompanied by, from left to right, **Emmanuel Tsesmelis**, adviser for Australia, **Fabiola Gianotti**, ATLAS spokesperson, and **Geoffrey Taylor**, team leader for the University of Melbourne in the ATLAS collaboration. The minister also met Australian scientists working at CERN.

NEW PRODUCTS

Aitech Defense Systems Inc has announced a 3U VPX product family that is based on the low-power Intel Core i7 processor that enables extremely high computing within very compact environments. The new family includes the C870 SBC with a Core i7 dual-core processor and incorporates an on-board Intel Gen 5.75 high-performance graphics controller. The C870 offers all-soldered memory to meet high-shock and vibration conditions. For more information, tel +1 888 248 3248, e-mail sales@rugged.com or see www.rugged.com.

Cobham Technical Services has introduced an addition to the Vector Fields Software product line, Opera. Opera is a complete design-simulate-analyze-optimize tool chain that is available in several variants with finite element analysis (FEA) solvers for static and time-varying electromagnetic fields, or with application-specific solvers for design work. The latest Version 14 of the software increases the range of FEA meshing to simplify numerical solutions. For more information, tel +44 1865 370 151, fax +44 1865 370 0277, e-mail vectorfields.info@cobham.com, or visit www.cobham.com/technicalservices.

Elma Electronic Systems has released a new ½ ATR conduction-convection cooled enclosure with an airflow design that distributes air across external fins in sidewalks. This new configuration helps to ensure fast removal of dissipated heat yet maintains a low profile design. It comes with a 6-slot 3U OpenVPX backplane and is also available with either a 3U cPCI backplane or a single-width MicroTCA backplane. For more information, contact Valerie Andrew, tel +1 510 656 3400, e-mail sales@elma.com, or visit www.elma.com.

Hiden Analytical has announced a new purpose-designed HPR-90 precision gas analyser for measurement of the static fill-gas and of the residual gases within diverse vessel types, ranging from multi-litre electric lamps and florescent tubes to electronic devices with volumes of 10 microlitres. Hiden has also introduced a range of quadrupole residual gas analysers for pressures ranging from millibar through to extreme high vacuum. The single-step mass filters are for general applications, with the 3F-series triple-stage mass filter being for the most demanding of applications. For more information, contact Jessica Neale, tel +44 1925 445 225, fax +44 1925 416 518, e-mail jneale@hiden.co.uk, or see www.hidenanalytical.com.

OBITUARY

Stewart Christian Loken 1943–2011

Stewart Loken, an accomplished experimental physicist and scientific computing leader, passed away on 19 February after an 18-year battle with cancer.

Stewart, or "Stu", was born in Montreal on 16 February 1943. He received his BSc from McMaster in 1965 and earned a PhD in physics at Caltech in 1972 under Barry Barish. After a postdoctoral appointment at Cornell, Stu spent the next 37 years at Lawrence Berkeley National Laboratory (LBNL), where he became senior scientist in 1981. He became a US citizen in 1991.

As a postdoc in the first muon-scattering experiment at Fermilab (E-26), Stu built one of the earliest data-acquisition systems managed by a powerful byte-oriented minicomputer. He made major contributions to analysis of the experiment's surprising result – the first observation of logarithmic violation of Bjorken scaling in deep-inelastic lepton-nucleon scattering. This was early evidence for the theory of QCD. Subsequently, during 1976–1979 he oversaw much of the construction of Fermilab's E-203/391 multimuon spectrometer and co-ordinated collection of the data, which extended the E-26 discovery. In 1980 Stu initiated and secured approval for an additional run (E-640) of the spectrometer in the new muon beam from Fermilab's Tevatron.

Remarkably, while amassing these accomplishments at Fermilab, Stu found time to contribute centrally to LBNL's time-projection chamber experiment (PEP-4) at SLAC. He designed the data-acquisition architecture for both the prototype and the main experiment, which introduced the large-scale use of CCDs as analog delay lines, and he also supervised several PEP-4 students.

Stu Loken. (Image credit: LBNL.)

In 1984, after reports of anomalies in proton–antiproton collisions at CERN, Stu persuaded his E-640 collaborators to suspend preparation for their experiment in order to join the nascent DØ collaboration at the Tevatron proton–antiproton collider. There he represented a large group of LBNL participants, helped to build DØ's first vertex chamber, and pushed strongly for coherent design of its software.

As director of LBNL's Information and Computing Sciences Division (1988–2000), Stu created the forerunners of today's Computing Sciences, Creative Services, and Information Technology organizations there. He helped create the US Department of Energy's high-speed network (ESnet) and attract the National Energy Research Scientific Computing Center (NERSC) to LBNL. There, Stu worked effectively to develop NERSC into a resource used by a vibrant, nationwide community. During this period he retained his enduring interest in particle-physics computing, strongly influencing choices of networking and software tools and methodologies in that field. He was elected a Fellow of the American Physical Society in 1990.

After returning to LBNL's Physics Division as its deputy-director (2000–2010), Stu touched every aspect of its programme. He developed a special interest in ATLAS computing and in the Nearby Supernova Factory, where as project manager he played a key role in securing funding and organizing the data processing. With characteristic optimism, during the past year Stu took on new responsibilities in the LUX dark matter search planned for the Homestake mine. Committed to outreach, he was an enthusiastic leader in QuarkNet, which trains and supports physics teachers.

Stu's passion extended equally to his personal life. He was a skier, sea kayaker, scuba diver and a lover of classical music, as well as lifelong recreational cyclist, twice circling Lake Tahoe as a leukaemia survivor. Stu is survived by Geanie, his close companion and wife of 40 years, daughter Kristen, son Scott, and two sisters. All those who have known him treasure his memory and admire his courage.

● *Mark Strovink and Ronald Madaras, LBNL.*

Megatech has introduced the Simplicity Solutions 830 VQM System, an ultra-fast mass spectrometer for measuring vacuum quality. The system combines high-performance gas-analysis technology with the ability to transform complex measurements into instantly usable information. Much smaller than existing residual-gas analysis instruments, it incorporates the state of the art in mass separation based on patented electrostatic ion-trap technology. For more information, contact Peter White, tel +44 1543 500044 or e-mail peter@megatechlimitied.co.uk.

Southern Scientific has launched the SS300 and SS330 high quality, general-purpose gamma probes designed to be used with Radhound, a new digital radiation monitor. The SS300 has an uncompensated (900 V) pancake Geiger detector for beta and gamma contamination measurements, while the SS330 model has a compensated pancake Geiger counter for dose-rate measurement. Both the SS300 and SS330 models have dimensions of 254 mm × 70 mm × 64 mm, and weigh 280 g and 300 g respectively. For more information, see www.ssl.gb.com.

Trek Inc has announced a new high-frequency amplifier, Model 2100HF, which is designed to deliver high-frequency, high-speed, wide-bandwidth performance in a variety of applications. The Model 2100HF provides precise control of output voltages from 0 to +/–150 V DC or peak AC, with output currents of 0 to +/–300 mA, large-signal bandwidth capabilities to 2.6 MHz (-3 dB), and typical slew rates of 2000 V/μs. For more information, tel +1 585 798 3140, e-mail sales@trekinc.com, or visit the website at www.trekinc.com/pdf/2100HF_Sales.pdf.

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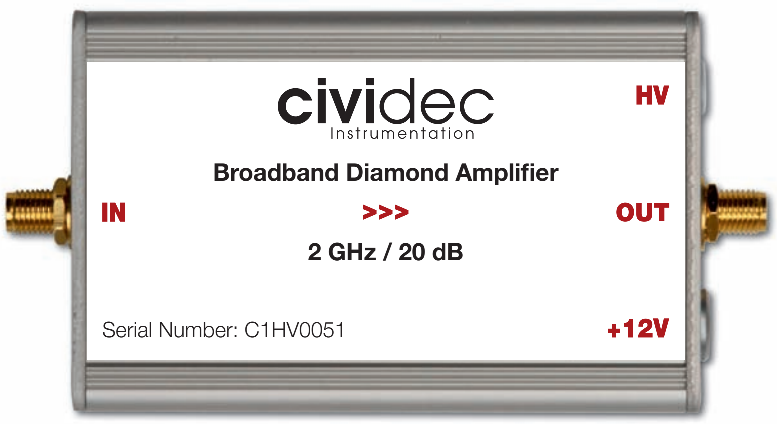

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ALBA

Consortium for Construction, Equipment and Exploitation of the Synchrotron Light Laboratory

Director position at the ALBA light source

The Consortium CELLS - jointly owned by the Spanish and Catalan Administrations – is responsible for the operation and future development of ALBA, a 3 GeV third generation synchrotron light facility. At present, the construction is finished and the accelerator complex is being commissioned. Seven state of the art beamlines covering a variety of research fields are already installed and expected to be commissioned with photons by mid 2011 and fully open to external users in 2012. Details may be found at www.cells.es.

ALBA is located in Cerdanyola del Vallès, at some 20 km from Barcelona, in a metropolitan region of about 4.5 million people, a zone of improving scientific and technological level, with several international schools, universities and scientific and technological parks and with very good international communications.

The Consortium is looking for a new Director of the facility. The Director is responsible for the scientific and technical exploitation of ALBA, for the definition of short and long term development strategies and must report to the Governing Bodies of the Consortium (an Executive Commission and a Rector Council whose delegates are appointed by the Owner Administrations).

Candidates must have experience in research institutes or similar facilities, a solid experience with synchrotron light research and have qualifications for Directorship. The working language at Alba is English. Knowledge of Spanish and or Catalan is an asset.

The Director will be offered a full time contract according to the Spanish law. Employment conditions and salaries can take into account the needs of professionals and their families. The incorporation date to the position is expected in January 2012.

Applications should be sent to the Chairman of the Executive Commission of ALBA; Carretera BP 1413 de Cerdanyola a Sant Cugat, km 3.3; E 08290 Cerdanyola del Vallès; Spain. Candidates should send a letter of motivation and their CV to the Chairman of the Executive Commission of ALBA Prof. Ramon Pascual (pascual@cells.es).

Deadline for receiving applications: 15th May 2011.

POSTDOCTORAL RESEARCH POSITION – MUON ACCELERATOR PROGRAM

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Postdoctoral research position on simulation for the Muon Accelerator Program (MAP). Collaboration with MAP members on design and simulation of six-dimensional cooling for a muon collider, possibilities for demonstration of 6D cooling in Muon Ionization Cooling Experiment (MICE) at the Rutherford Laboratory, and cooling for International Design Study for a neutrino factory.

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Letter of application, curriculum vitae, list of publications, and three reference letters should be directed to:

Gail.Hanson@ucr.edu subject line MAP-Postdoc.

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Postdoctoral Research Associate - Muon Cooling

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Prof. Daniel Kaplan, Physics Division, Illinois Institute of Technology,
3101 S. Dearborn St., Chicago, IL 60616, USA

or (preferably) by email to kaplan@iit.edu. Further information on the activities of our group may be found at http://capp.iit.edu on the World-Wide Web.

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The Cockcroft Institute in the UK is a unique international centre specifically responsible for research and development in particle accelerators, colliders and light sources for advancing the frontier of particle and nuclear physics, photon and neutron sciences and various applications to society in the areas of health, medicine, energy and security. The University of Manchester is a major stakeholder and one of the founding members, of The Cockcroft Institute - a partnership of the Universities of Liverpool, Manchester and Lancaster, the Science and Technology Facilities Council including its Daresbury and Rutherford Appleton Laboratories, UK industry and economic development agencies.

As part of this important, internationally-leading activity at The Cockcroft Institute, candidates will also have the opportunity to take advantage of the unique research centres provided at the University of Manchester, including the Dalton Nuclear Institute, Photon Science Institute and the Jodrell Bank Centre for Astrophysics. Applications are invited from Physical and Applied Scientists and Engineers with a PhD degree at the top of their profession seeking an academic career specialising in Particle Accelerator Science and Engineering with a focus on applications to any of the disciplines of Physics, Energy, Optoelectronics, Photonics, Material, Quantum Electronics, Quantum Optics and various electrical engineering disciplines of sensors, instrumentation and ultrafast signal processing, and electromagnetic modelling. Significant start-up laboratory equipment and infrastructure is expected to be made available to the appointed faculty from the Cockcroft and Photon Science Institutes. The successful candidate will be expected to work synergistically with existing Cockcroft faculty at the University of Manchester.

Candidates are sought with interest in areas such as conception and design of particle colliders, novel light sources and free electron lasers , for fundamental research as well as for developing cost- and energy-efficient photo-voltaic nano-structures towards solar energy, conception and design of high current proton accelerators for fundamental research and towards accelerator-driven subcritical reactors and various applications of proton and photon beams for health, medicine and security. These represent exciting and challenging opportunities for someone wishing to excel and lead a significant contribution to world-wide development of tomorrow’s particle accelerator systems for science and society.

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Active involvement and collaboration with the existing Cockcroft faculty and specialist research areas within the University of Manchester, along with relevant activities particularly with the other partners in the Cockcroft Institute will be encouraged.

Application forms and further particulars are available from our website http://www.manchester.ac.uk/jobs.

If you are unable to go online you can request a hard copy of the details from EPS HR Office, The University of Manchester, Sackville Street Building, Manchester, M60 1QD, Tel: 0161 275 8837; Fax: 0161 306 4037 or email: eps-hr@manchester.ac.uk.

The closing date for applications is: Tuesday 17 May 2011

For further information about the Cockcroft Institute, visit http://www.cockcroft.ac.uk or contact Prof. Swapan Chattopadhyay (swapan@cockcroft.ac.uk)

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Mathematical, Physical and Life Sciences Division

Department of Physics

University Lectureship in Accelerator Science

University of Oxford & STFC Rutherford Appleton Laboratory in association with Wolfson College Oxford

and a

Departmental Lectureship in Accelerator Science

University of Oxford

The John Adams Institute for Accelerator Science (JAI) in Oxford wants to appoint a University Lecturer in Accelerator Science (permanent academic post) on a joint appointment with STFC's Rutherford Appleton Laboratory, and a Departmental Lecturer in Accelerator Science (a 5-year fixed term appointment). Current projects include novel compact light sources and FELs based on laser-plasma acceleration, linear collider, neutrino factory, the Muon Ionisation Cooling Experiment (MICE), non-scaling Fixed-Field Alternating Gradient accelerators and plasma accelerator diagnostics. Applications are welcome in any area of accelerator science, especially those aligned with the strategic interests of the JAI, for example the development of compact light sources, areas of synergy between laser and plasma physics and accelerator physics, and areas where accelerator science may prove beneficial in technology, energy and medicine. This work involves close international collaboration. Details about the JAI can be found at http://www.adams-institute.ac.uk.

University Lectureship in Accelerator Science, jointly with the STFC Rutherford Appleton Laboratory

Salary on the scale £42,733 - £57,431

The appointee will undertake lecturing, research and administration within the JAI and the Department of Physics in Oxford, and will undertake research at the Rutherford Appleton Laboratory. The successful candidate will be offered a supernumerary Fellowship at Wolfson College Oxford; upon completion of a satisfactory review after an initial period of employment (normally five years), a University Lecturer is eligible for reappointment until retiring age.

Departmental Lectureship in Accelerator Science

Salary on the scale £29,099 - £39,107

This is a 5-year fixed-term appointment. The Appointee will undertake lecturing, research and administration within the JAI and the Department of Physics in Oxford.

Informal enquiries about either post may be made to Professor Andrei Seryi, email: Andrei.Seryi@adams-institute.ac.uk, and further particulars are available at http://www.physics.ox.ac.uk/pp/jobs/JAI-UL-DL-fp.htm. The deadline for applications is 1st June 2011. Interviews will be held in mid June to early July; candidates should consult the web-site for the exact date and keep this date free in case they are called for interview.

Applicants should submit before the deadline a letter of application setting out how they meet the criteria set out in the further particulars, supported by a curriculum vitae, list of publications, a statement of research interests to Mrs. Sue Geddes, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH, UK, email: s.geddes@physics.ox.ac.uk, FAX 0044-1865-273417. In addition, candidates should arrange for the three letters of reference to be sent to Mrs. Sue Geddes by the closing date. Applicants should state whether they wish to be considered for the University Lectureship, Departmental Lectureship or both.

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臺灣大學 National Taiwan University

Postdoctoral Fellow Positions at NTU

The experimental high energy physics group at National Taiwan University invites applications for three postdoctoral fellow positions in experimental particle physics. A Ph.D. in particle physics is required. Qualified candidates will be considered immediately, but applications will be considered until positions are filled, with possibilities to start in 2012. Well qualified applicants can be considered for research assistant fellow positions or higher.

The experimental HEP group at NTU has five faculty, five senior researchers, several postdocs plus graduate students, and contributes heavily to CMS, Belle, Daya Bay and E391a/KOTO experiments. This advert focuses on the CMS experiment at CERN.

The NTU-CMS team has been involved in ECAL preshower detector design, construction, commissioning and operation. The group has recently joined the CMS Phase 1 Upgrade Pixel project, and will play a major role in the detector construction and commissioning in the coming years. Other than hardware projects, the group is also involved in various physics analyses with CMS data. These include underlying events, QCD and Higgs related photon physics, and high-pT new physics searches such as 4th generation quarks.

The successful fellows are expected to spend half of the time on the Pixel upgrade project, with the other half on physics analysis. Candidates with detector hardware construction or commissioning experience are preferred. S/he will spend the majority of the time at CERN. Interested candidates should send a cover letter, curriculum vitae, short statement of research interests (1 page), and arrange to have three reference letters sent (by direct email in PDF format) to

Prof. George W.-S. Hou, Department of Physics,
National Taiwan University, Taipei, Taiwan 10617

E-mail: wshou [at] phys.ntu.edu.tw,
Phone: +886-2-3366-5145 (lab), 33665096 (office)
Fax: +886-2-2369-3472

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The focus of this position will be on electromagnetic design, analytical and numerical modelling and requires strong skills in mathematics and linear systems theory. Further skills in engineering mechanics, cryogenics, superconductor technology can be advantageous.

Fluency in English is mandatory.

The role requires strong analytical skills, a creative approach to problem-solving, and the ability to work effectively within multi-disciplinary teams. Applications are encouraged from individuals with recent graduate or post-graduate degrees in Physics or Electrical Engineering, as well as those with a professional background in a relevant industry or science.

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Contact : drh@bruker.fr

think forward

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Associate Director

The MIT Laboratory for Nuclear Science has an opening for the position of Associate Director. The responsibilities for this position include the following: broad, comprehensive responsibility for independently directing all administrative functions of the organization; assisting the Director and senior research management in implementing the goals of the laboratory, which supports a large program of research and educational activities in particle and nuclear physics with ~ 25 M$ annual research volume and with about 250 faculty, staff, researchers, and students; on behalf of the Director acting as key administrative liaison both inside and outside MIT; assisting in the development of long-range plans for research and staffing levels; analyzing the fiscal status of the Laboratory, assisting faculty and staff in developing grant or contract proposals and in meeting reporting requirements; assisting the MIT Office of Sponsored Programs in contract negotiations; providing interface and promoting effective relationships with sponsors, MIT administration, affiliated organizations, and national and international collaborative efforts; overseeing all administrative elements within the Laboratory, including budgets, service centers, personnel, public relations and other outreach programs, and resource allocation; initiating and coordinating the preparation of special reports, such as reports to sponsor, five-year plans, reports to the MIT President, and public relations documents.

A Ph.D. in a science-related field, or equivalent combination of education and experience, and significant experience in research administration are highly desirable. Familiarity with a scientific research environment is necessary, as is the proven ability to interact effectively with sponsors and other offices in an MIT-like administrative environment.

Please send CV to: **Kennneth L. Hewitt, 26-516, Massachusetts Institute of Technology, 77 Massachusetts Ave. Cambridge, MA 02139-4307**
Email: **khewitt@mit.edu**

http://web.mit.edu

Cornell Laboratory for
Accelerator-based Sciences
and Education (CLASSE)

Senior Research Associate

Cornell Laboratory for Accelerator-based Sciences and Education

The Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE) seeks an individual to take a lead role in the management and development of major accelerator systems. The specific research and development activities will be in one of the accelerator-associated fields that are part of the mission of CLASSE (x-ray science, accelerator science, or elementary particle physics). These activities will be determined in consultation with the CLASSE Director, to whom this position reports. Duties will also include: overseeing accelerator radiation protection and safety systems; performing radiation shielding calculations using Monte Carlo codes such as MARS, FLUKA, EGS5, or MCNPX; calculating radioactivity induced in materials by stray radiation fields around electron accelerators; assessing radiation damage in electronics; making measurements of photon and neutron spectra over a wide energy range; reviewing and approving safety analysis documents for laboratory operations, working with staff at all levels to analyze and set procedures for unusual or new safety issues.

Requirements: A PhD in one of the physical sciences or engineering, and several years of experience in experimental high-energy accelerator physics or nuclear science and engineering. Must be familiar with: biological effects from natural and man-made sources of environmental radioactivity; federal, state, and local laws governing radiation; photon and neutron dosimetry; and occupational, chemical, biological, and laser safety. A high level of people skills and mature judgment are essential.

Please send a cover letter, including curriculum vitae and a publications list to Dr. Maury Tigner, Newman Laboratory, Cornell University, Ithaca, NY 14853, and arrange for three letters of recommendation to be sent. Correspondence may be directed to search-classe@cornell.edu.

Cornell University is an equal opportunity, affirmative action educator and employer.

Inside Story

"Little wisps and threads of cloud"

In the spring of 1911, C T R Wilson made the first observation of particle tracks in a cloud chamber.

Contrails – an analogy to cloud chamber tracks. (Image credit: Cardiae/Dreamstime.com.)

"My choice of a subject to work upon was not due to any forethought on my own part nor to any good advice received, but just to the fact that in the autumn of 1894 I spent a few weeks on a cloudy Scottish hill-top – the top of Ben Nevis. Morning after morning I saw the sun rise above a sea of clouds and the shadow of the hill on the clouds below surrounded by gorgeous coloured rings. The beauty of what I saw made me fall in love with clouds…"

This love of clouds was to lead Charles T R Wilson to receive the Nobel prize in Physics in December 1927, when he spoke these words at the Nobel banquet in Stockholm. However, he received the ultimate accolade for research not for studies in atmospheric physics but for his development of the cloud chamber as a device to make visible the tracks of charged subatomic particles.

The journey from the top of Ben Nevis to Stockholm had taken more than 30 years and in this time physics had seen some remarkable developments. In particular, a new world of subatomic physics had opened up after Ernest Rutherford, while at Manchester University, had discovered "what the atom looked like" (p20).

Rutherford published his findings on the nuclear atom in May 1911 in what was not only a good year for physics, but a good few weeks. On 8 April, Heike Kamerlingh Onnes and his staff at the Leiden Cryogenic Laboratory were the first to observe superconductivity (*CERN Courier* April 2011 p46) and in the same month Wilson, at the Cavendish Laboratory of Cambridge University, included some of his first "rough" photographs of tracks in a communication to the Royal Society in London. His paper was published on 9 June (Wilson 1911).

Nowadays, many a particle physicist seeking to engage non-specialists will remind them of how the passage of aeroplanes is made clearly visible, in the right atmospheric conditions, through the trails of condensation – contrails – associated with the exhaust of the engines. When Wilson talked in his Nobel speech of, "little wisps and threads of clouds", he could easily have been referring to this phenomenon, but this was the 1920s. Instead, he was describing what he had seen in the first tests of his cloud chamber in the spring of 1911.

"I was delighted to see the cloud chamber filled with little wisps and threads of clouds – the tracks of electrons ejected by the action of the [X-] rays", he said. He then explained that on introducing some radium inside the cloud chamber, "the very beautiful sight of the clouds condensed along the tracks of the α particles was seen for the first time"; the "long thread-like tracks of fast β particles were also seen" with a suitable source.

Even in 1895, when Wilson began to make his own clouds back at Cambridge in order to study the optical effects he had admired on Ben Nevis, he soon became absorbed in studying the formation of the droplets themselves in apparatus of the kind already used by the Scot John Aitken and Pierre-Jean Coulier in France to form clouds in moist air supersaturated by expansion. By the autumn of that year, following Wilhelm Röntgen's announcement of the discovery of X-rays, Wilson (like Rutherford, who was also at the Cavendish Laboratory at the time) was following J J Thomson's lead in bringing the new radiation to bear on his research and he found that X-rays produced large numbers of the condensation nuclei in the cloud chamber.

There followed a few years of studying the role of ionization in condensation, but from around 1900 Wilson did not continue this line of research until about 1910. By, then, thanks in large measure to the work of Rutherford, the particle nature of the α and β radiation had become much more apparent. So Wilson began to pursue the idea of making the tracks visible, with notable results in 1911–1913. After the First World War, he resumed this work only in 1921, leading to the publication of two classic papers on investigations with the cloud chamber of X-rays and β rays (Wilson 1923).

By this time, Patrick Blackett at the Cavendish Laboratory had developed a cloud chamber that expanded automatically every 10–15 s and used cine film to record pictures. Among some 23 000 photographs of α particles shooting through nitrogen were a few that revealed the first visual evidence for nuclear transmutations. The α particles could occasionally penetrate the atomic nucleus that Rutherford had discovered in 1911. The frontier was about to change from subatomic to subnuclear – but that's another story.

● Further reading

For Wilson speeches at the Nobel prize ceremony in 1927, see: http://nobelprize.org/nobel_prizes/physics/laureates/1927/wilson.html.

C T R Wilson 1911 *Proc. Roy. Soc. Lond.* **A 85** 285.
C T R Wilson 1911 *Proc. Roy. Soc. Lond.* **A 104** 1 and 195.

● *Christine Sutton, CERN.*

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Digitizers Selection Table

Model (1)	Form Factor	N. of ch. (4)	Max. Sampling Frequency (MS/s)	N. of Bits	Input Dynamic Range (Vpp) (4)	Single Ended / Differential Input	Bandwidth (MHz)	Memory (MS/ch) (4)	DPP firmware (5)
x724	VME	8	100	14	0.5 / 2.25 / 10	SE / D	40	0.5 / 4	TF
	Desktop/NIM	4 / 2				SE			
	PCIe	2				SE			
x720	VME	8	250	12	2	SE / D	125	1.25 / 10	CI, NG
	Desktop/NIM	4 / 2				SE			
	PCIe	2				SE			
x721	VME	8	500	8	2	SE / D	250	2	no
x731	VME	8 - 4	500 - 1000	8	2	SE / D	250/500	2/4	no
	PCIe	2				SE			
x751	VME	8 - 4	1000 - 2000	10	1	SE / D	500	1.8 / 14.4 - 3.6 / 28.8	NG
	Desktop/NIM	4 - 2				SE			
x761	VME	2	4000	10	1	SE / D	TBD	7.2 / 57.6	no
	Desktop/NIM	1				SE			
x740	VME	64	65	12	2 / 10	SE	30	0.19 / 1.5	no
	Desktop/NIM	32							
x742	VME	32+2	5000 (2)	12	1	SE	500	0.128 (3)	no
	Desktop/NIM	16+1							

(1) The x in the model name is V1 for VME, VX1 for VME64X, DT5 for Desktop and N6 for NIM

(2) Sampling frequency of the analog memory (switched capacitor array); A/D conversion takes place at lower speed (dead-time)

(3) The memory size for the x742 is 128/1024 events of 1024 samples each

(4) The indication *"size 1/ size 2"* denotes different options

(5) DPP-TF: Pulse Height analysis (Trapezoidal Filters), DPP-CI: Charge Integration (digital QDC), DPP-NG: γ-n Discrimination

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DIPAC2011 *- 10th European Workshop on Beam Diagnostics and Instrumentation for Particle Accelerators*
May 16 - 18, 2011

NSTAR2011 *- The 8th International Workshop on the Physics of Excited Nucleons*
May 17 - 20, 2011

RICAP 2011 *- 3rd Roma International Conference on Astro-Particle physics*
May 25 - 27, 2011

GLA2011 *- 2nd International Workshop towards the Giant Liquid Argon Charge Imaging Experiment*
June 05 - 10, 2011

ANIMMA 2011 *- Advancements in Nuclear Instrumentation, Measurement Methods and their Applications*
June 06 - 09, 2011