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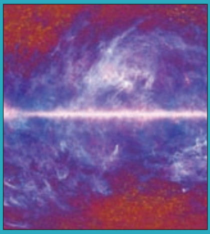
CERN COURIER

VOLUME 51 NUMBER 1 JANUARY/FEBRUARY 2011

Forty years on: the legacy of the ISR



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CELEBRATION

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COSMIC RAYS

New evidence supports origin in remnants of supernovae **p21**

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

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CERN

CERNCOURIER

VOLUME 51 NUMBER 1 JANUARY/FEBRUARY 2011

On the cover: On 27 January 1971, Kjell Johnsen, who led the team that built the Intersecting Storage Rings, announced that the first ever interactions from colliding protons had been recorded. On the left are Franco Bonaudi, who was responsible for the civil engineering, and Dirk Neet, who later took charge of ISR operations.

News

CERN

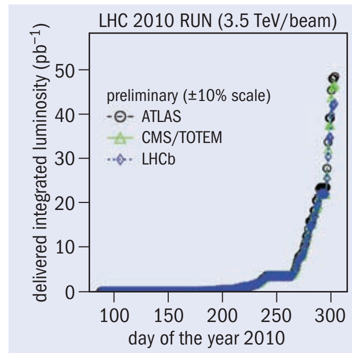
Council looks forward to new members and new physics

The opening of CERN to new members was top of the agenda when delegates met in December for the 157th session of the CERN Council. Formal discussions can now begin with Cyprus, Israel, Serbia, Slovenia and Turkey for accession to membership, while Brazil's candidature for associate membership was also warmly received.

"It is very pleasing to see the increasing global support for basic science that these applications for CERN membership indicate," said CERN's director-general, Rolf Heuer. "Basic science responds to our quest to understand nature and provides the very foundations of future innovation."

Established in 1954 by 12 European states, CERN had grown to have 20 member states by the end of the 1990s, with many countries from beyond the European region also playing an active role. Discussions on opening CERN to membership from outside Europe – while at the same time allowing CERN to participate in future projects beyond Europe – reached a conclusion at the Council's session in June 2010.

Under the scheme agreed on in June, associate membership is an essential prerequisite for membership. Countries may therefore apply for associate membership alone, or associate membership as a route to membership. At the recent meeting in December, Council formally endorsed model agreements for both cases. These will serve as the basis for negotiations with candidates, which could lead to CERN welcoming its first associate members as early as later this year. Currently, any country may apply for membership or associate membership of CERN, and if CERN wishes to participate in projects outside Europe, mechanisms are also now in place to make that possible.



Left: First proton collisions in the LHC led to smiles in the CERN Control Centre on 30 March 2010. Right: By the end of proton running, the integrated luminosity had risen to nearly 50 pb^{-1}, allowing for a range of physics studies in the new energy region.

The other highlight of the December Council meeting was the success of the LHC in 2010. The LHC experiments have already published dozens of scientific papers on the basis of the data collected during the year. The results not only re-establish the physics of the Standard Model, but also take the first steps into new territory.

"The performance of the LHC this year has by far exceeded our expectations," said Michel Spiro, president of the CERN Council. "This bodes extremely well for the coming years."

The LHC switched off for 2010 on 6 December. Details of the 2011 LHC run and plans for 2012 will be set following a special workshop to be held in Chamonix on 24–28 January, while the first beams of 2011 are scheduled for mid-February.

Redesign

CERN Courier has a new look

CERN Courier has changed several times during its 50 years of existence, most noticeably with different cover designs and variations in layout. Now, for the first time in a decade, its look has changed once again.

The previous design dated back to 1998, when IOP Publishing took over the production work on the magazine and introduced a more dynamic layout and distinct pages for News and Features, as well as regular sections, such as Astrowatch and Bookshelf, which have since grown to include Sciencewatch, Archive and the back page Viewpoint or Inside Story.

The new design by Andrew Giaquinto and Jesse Karjalainen of IOP Publishing retains this structure but brings a cleaner, more contemporary appearance. At the same time it maintains the authoritative style appropriate to the magazine that will continue to serve the worldwide particle-physics community, in particular as CERN extends geographically. We hope that you, the reader, enjoy the new look.

Sommaire en français

LHC PHYSICS

ATLAS observes striking imbalance of jet energies in heavy ion collisions

The ATLAS experiment has made the first observation of an unexpectedly large imbalance of energy in pairs of jets created in lead-ion collisions at the LHC (G Aad *et al*. 2010). This striking effect, which is not seen in proton–proton collisions, may be a sign of strong interactions between jets and a hot, dense medium (quark-gluon plasma) formed by the colliding ions.

Concentrated jets of particles are formed in the head-on (central) collisions of lead ions at the LHC. The jets materialize from the hadronization of quarks and gluons scattered from the protons and neutrons in the colliding ions. If a quark-gluon plasma is formed in the collisions of the high-energy ions, then as the jets materialize they will traverse this hot, dense medium. In so doing they should lose energy to the medium through multiple interactions, in a process called jet quenching (*CERN Courier* September 2003 p17).

The jets are most often produced in pairs (dijets) travelling in opposite directions with equal transverse energies, but if the jets travel different distances before escaping the medium, then their energies will no longer be equal. Experiments at the Relativistic Heavy Ion Collider at Brookhaven observed signs of this effect in single-particle distributions; however, the result from ATLAS represents the first direct observation of energy loss by jets, and the first in which the effect is visible on an event-by-event basis (figure 1).

The excellent angular coverage, segmentation and energy resolution of its calorimeters make ATLAS well suited to measuring jets. For this analysis, the collaboration looked at a sample of 1693 events with at least one jet having transverse energy greater than 100 GeV. They then characterized the difference in energy in the dijets by the ratio of the difference of the jet energies to the sum of the energies. In studying this dijet asymmetry ratio they found that it varies as a function of the centrality of the colliding nuclei, as figure 2 shows, where the fraction of events with a given asymmetry is plotted versus the measured asymmetry for four different ranges of centrality, the most central events in the plot at the right and the least central at the left.

The plots show the asymmetry for lead-ion collisions at 2.76 TeV/nucleon in the centre-of-mass and for 7 TeV proton–proton collisions together with the prediction from a Monte Carlo simulation that does not include interactions between the jets and the medium. The measured asymmetry clearly increases with centrality: the distribution broadens and the mean shifts to higher values. To confirm the effect, the collaboration performed numerous studies to verify that events with large asymmetry are not produced by energy fluctuations, background, or detector effects.

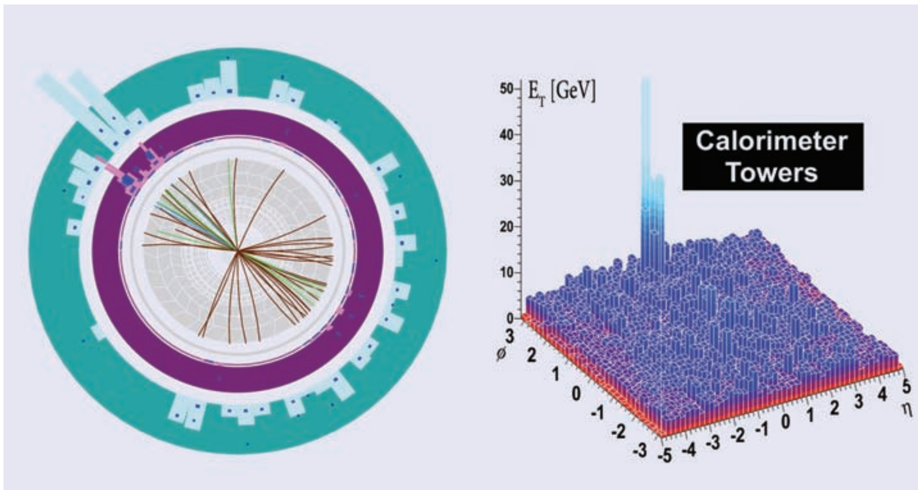


Fig. 1. Event display of a highly asymmetric dijet event, selecting charged particle tracks with p_T>2.6 GeV and calorimeter cell energies E_T>700 MeV (electromagnetic calorimeter) and E_T>1 GeV (hadronic calorimeter).

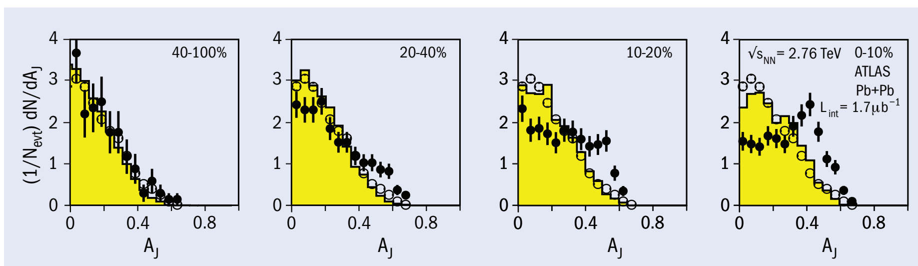
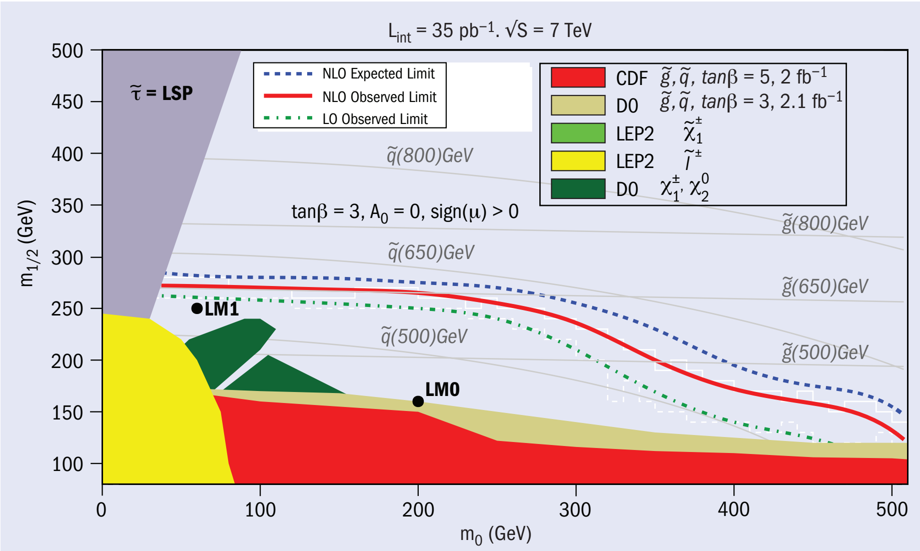


Fig. 2: Dijet asymmetry distributions for lead–lead data at E_{CM}=2.76 TeV/nucleon (solid points), proton–proton data at E_{CM}=7 TeV (open circles), and simulated lead–lead collisions with superimposed dijets (solid yellow). Error bars are statistical only.

The observation of this centrality-dependent dijet asymmetry by ATLAS has a natural interpretation in terms of QCD energy loss and may point to a strong energy loss by the jets in the quark-gluon plasma. The asymmetry has also been reported by the CMS collaboration and a related effect in single particle distributions has been reported by the ALICE collaboration, at a seminar at CERN together with ATLAS on 2 December. The result, together with others presented at the seminar, marks the beginning of a broad and exciting programme of heavy-ion physics at the LHC.

● Further reading

For all the presentations at the LPCC seminar on 2 December see http://indico.cern.ch/conferenceDisplay.py?confId=3D114939=20.
G Aad *et al.* (ATLAS Collaboration) 2010 *Phys. Rev. Lett.* **105** 252303.
K Aamodt *et al.* (ALICE Collaboration) *Phys. Rev. Lett.* **105** 252301 and 252302.



Results of the search for supersymmetry by CMS: the area below the curves is excluded by this new measurement. Exclusion limits obtained from previous experiments are presented as filled areas in the plot. Grey lines indicate constant squark and gluino masses.

CMS announces first results of search for SUSY

At the "LHC end-of-year jamboree" at CERN on 17 December, the CMS collaboration announced the first results of its search for supersymmetry (SUSY) at the LHC.

SUSY is one of the strong candidates for physics beyond the Standard Model that could be detected in proton–proton collisions at the LHC. If it exists in nature, it could solve many of the outstanding issues in particle physics, such as the gauge hierarchy problem. SUSY can reveal itself through the production of new heavy particles and so could deliver a natural candidate particle to explain the large density of dark matter in the universe.

This first result is based on proton–proton collision events with multiple jets and missing transverse energy. The dataset corresponded to an integrated luminosity of 35 pb^{-1} collected between March and October 2010 at a centre-of-mass energy of 7 TeV. Large, missing transverse energy is a key characteristic of SUSY event candidates, reflecting the supposition that the lightest SUSY particle is expected to be neutral, stable, and weakly interacting – thereby escaping detection.

After stringent cuts to reduce the background arising from Standard Model processes that can fake missing transverse energy or that may contain escaping neutrinos, 13 events remained. The collision data also allowed estimates of the expected numbers of background events from Standard Model processes and these are consistent with the number of observed events. As a consequence, the present data do not yet show evidence for SUSY; however, they significantly extend previous search results.

The figure illustrates the reach of the CMS analysis with respect to other experiments in the plane of the universal scalar and gaugino masses (m_0 and $m_{1/2}$, respectively) at the grand unified theory scale of the constrained minimal supersymmetric extension of the Standard Model (CMSSM), after just one year of LHC data-taking. The observed limit significantly improves those set previously by other experiments, thus further constraining the masses of SUSY particles.

Physicists are now looking forward to the 2011 physics run at the LHC, which is expected to bring a data sample that could be as much as two orders of magnitude larger than the present one.

Further reading

For all of the presentations at the LHC end-of-year jamboree, see http://indico.cern.ch/conferenceDisplay.py?confId=113139.

CMS Collaboration 2010 CERN-PH-EP-2010-084, submitted to *Phys. Lett. B*.

CERN

Antihydrogen scoops award for breakthroughs

Research at CERN's Antiproton Decelerator (AD) has made important breakthroughs in experimental techniques for studying antihydrogen in the laboratory. On 17 November, in a paper published in *Nature*, the ALPHA collaboration announced that it had successfully trapped atoms of antihydrogen for the first time. Then, on 6 December, the ASACUSA collaboration published results in *Physical Review Letters* on a technique that should allow the production of a beam of antihydrogen. Recognition of these achievements soon followed in the scientific media, with the award of *Physics World*'s "2010 Breakthrough of the Year" on 20 December.

Both ALPHA and ASACUSA aim to measure precisely the spectrum of antihydrogen and compare it with that of hydrogen. Any small difference would cast light on the imbalance between matter and antimatter in the universe today. The first nine atoms of antihydrogen were produced at CERN in 1995. Then, in 2002, the ATHENA and ATRAP experiments at the AD showed that it was possible to produce large quantities of cold (i.e. very low velocity) antihydrogen, thus opening up the possibility of conducting detailed studies (*CERN Courier* November 2002 p5 and December 2002 p5). However, the challenge remained of producing the antihydrogen in such a way that its spectrum could be analysed.

The strategy being pursued in the ALPHA experiment, which evolved from ATHENA, is to make cold antihydrogen and then hold the neutral antiatoms in a superconducting magnetic trap similar to those used for high-precision atomic spectroscopy. The ultimate aim is to measure 1s–2s transitions for comparison with the latest results in hydrogen. The ALPHA trap consists of an octupole and two solenoidal "mirrors", which together create a magnetic field that confines the antiatoms by interacting with their magnetic moments. Silicon detectors surrounding the trap record the annihilations of any trapped antihydrogen once it is released. In the studies reported in November, the collaboration observed 38 annihilations (Andreson *et al*. 2010).

The ASACUSA experiment is following a different approach aimed at studying hyperfine transitions in antihydrogen, which

News

involve much smaller energy differences and hence microwave rather than laser spectroscopy. The technique does not require the antiatoms to be trapped, so the collaboration is taking steps towards extracting a beam of antihydrogen in a field-free region for high-resolution spectroscopy. The December paper reports success in producing cold antihydrogen in a so-called "cusp" trap, an essential precursor to making a beam. This trap consists of a superconducting anti-Helmholtz coil and a stack of multiple ring electrodes (Enomoto *et al*. 2010). The next step will involve extracting a spin-polarized antihydrogen beam along the axis of the trap.

Further reading

G B Andreson *et al.* 2010 *Nature* **468** 673.
Y Enomoto *et al.* 2010 *Phys. Rev. Lett.* **105** 243401.

Members of the ALPHA (right) and ASACUSA teams in the AD hall at CERN, which also accommodates the ATRAP experiment that pioneered trapping techniques in the 1990s.

FACILITIES

Italian government approves SuperB

The Italian government has selected the SuperB project as one of its "flagship projects" in Italy for the coming years and has delivered initial funding as a part of a multiyear programme. Proposed by INFN, the project has already attracted interest from many other countries, with physicists from Canada, Germany, France, Israel, Norway, Poland, Russia, Spain, the UK and the US already taking part in the design effort (*CERN Courier* December 2010 p8).

SuperB will be an asymmetric electron–positron collider with a peak luminosity of 10^{36} cm^{-2} s^{-1}. Such a high luminosity will allow the indirect exploration of new effects in the physics of heavy quarks and flavours at energy scales up to 10–100 TeV, through the studies at only 10 GeV in the centre-of-mass of large samples of B, D and τ decays. At full power, SuperB should be able to produce 1000 pairs of B mesons, the same number of τ pairs and several thousands of D mesons every second.

The key advances in the collider design come from recent successes at the DAΦNE collider at INFN/Frascati, at PEP-II at SLAC and at KEKB at KEK. These include new concepts in beam manipulation at the interaction region known as the "crab waist" scheme, which has been tested at DAΦNE (*CERN Courier* January/February 2009 p17).

The aim of the SuperB project is to conduct top-level basic research, while developing innovative techniques with an important impact for technology and other research areas. In this respect, the Istituto Italiano di Tecnologia is co-operating on SuperB with INFN. The accelerator will also be used as a high-brilliance light source, equipped with several photon channels, allowing the scientific programme to include the physics of matter and biotechnology.

On 18 November 2010, CERN signed an agreement with the Facility for Antiproton and Ion Research (FAIR) GmbH, the company that is co-ordinating the construction of the accelerator and experiment facilities for the FAIR project in Germany. The agreement, which was signed by CERN's director-general, Rolf Heuer (left) and FAIR's scientific director Boris Sharkov, concerns collaboration in accelerator sciences and technologies and other scientific domains of mutual interest.

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

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

Sciencewatch

Compiled by John Swain, Northeastern University

Photons form a Bose-Einstein condensation

At first glance, the idea of a Bose-Einstein condensate of photons seems ridiculous: photons have zero chemical potential, which is to say that their numbers are not conserved as temperature varies. Indeed, there is no Bose-Einstein condensation of photons in blackbody radiation. Remarkably, Martin Weitz of the University of Bonn in Germany and colleagues have found a way round this.

The idea is to confine light between two closely spaced mirrors, with a laser-pumped dye between them. By making the energy of photons confined between the mirrors higher than the thermal energy of the dye, they created a situation in which the thermal energy of the dye and the energy of photons are conserved separately. This allowed for the condensation of the trapped photons into a sort of "superphoton".

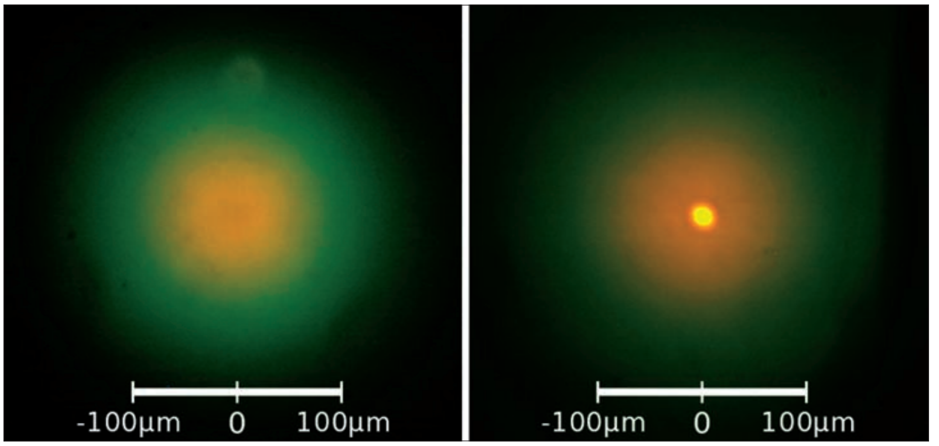


Image of the radiation transmitted through one cavity mirror with the photon density between the mirrors below (left) and above (right) the critical photon number (and hence energy). In the latter, a macroscopically occupied ground-state mode is visible.

The phenomenon is essentially an experimental realization of a 2D weakly coupled Bose gas of confined photons – a brand-new form of matter. It is also in many ways a new sort of laser and this exciting discovery could lead to novel ways of generating very short wavelength coherent light – an appropriate find, coming in the same year as the laser's 50th anniversary (*CERN Courier* December 2011 p6).

● Further reading

Jan Klaers *et al.* 2010 *Nature* **468** 545.

Bacteria that live off arsenic

They are as close to being a fundamentally different form of life as one could hope for: organisms that can use arsenic instead of phosphorus. Typically, living things are made mostly of carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus. Arsenic is chemically similar to phosphorus in many ways but is generally toxic. So it came as a surprise to Felisa Wolfe-Simon of the NASA Astrobiology Institute and the US Geological Survey in Menlo Park to find bacteria in California's arsenic-rich Mono Lake that not only thrive in the presence of arsenic, but are actually able to use it in place of phosphorus. The details of where exactly arsenic is incorporated into the biochemistry of these bacteria have yet to be worked out, as does how the arsenic-substituted molecules work.

● Further reading

Felisa Wolfe-Simon *et al.* 2010 *Science* published online 2 Dec 2010, DOI: 10.1126/science.1197258

Blood from skin

Researchers at McMaster University in Hamilton, Canada, have made a major breakthrough in chemically reprogramming adult human skin cells to become blood cells. Typically, attempts to produce new tissues have involved trying to get a cell to turn into a pluripotent stem cell with the capacity subsequently to turn into any other type of cell. In this research, Mickie Bhatia and colleagues managed the transformation directly. The details of the process are complicated but the work holds great promise, not only for the production of potentially limitless quantities of blood for transfusions but also for the production of other tissue types without the need for stem cells and without the associated legal and ethical issues.

● Further reading

E Szabo *et al.* 2010 *Nature* **468** 521.

Time before the Big Bang

The end of the first decade of the 21st century is proving to be an interesting time for controversy in cosmology. V G Gurzadyan of Yerevan State University and Roger Penrose of Oxford have recently proposed that the extreme uniformity of the very early universe could result from its having emerged from the end of a previous universe that had expanded out to be flat and smooth. The process could have repeated any number of times leading to a sort of cyclic cosmology for which these authors say there is observational evidence. This is in the form of rings in the cosmic microwave background radiation resulting from gravitational radiation from the violent collisions of supermassive black holes that occurred before what is called the Big Bang.

Three recent papers by Ingunn Wehus and Hans Kristian Eriksen of the University of Oslo, Adam Moss, Douglas Scott and James Zibin of the University of British Columbia in Vancouver and Amir Hajian of the Canadian Institute for Theoretical Astrophysics in Toronto all confirm the presence of the circles but argue against their significance and interpretation. No matter how this story turns out, it is exciting to see fresh ideas in cosmology with experimentally testable consequences.

● Further reading

For a review, see E Cartlidge 2010 *Nature* DOI:10.1038/news/2010.665.
V G Gurzadyan and R Penrose 2010 arxiv.org/abs/1011.3706; arxiv.org/abs/1012.1486.
A Hajian 2010 arxiv.org/abs/1012.1656.
I K Wehus and H K Eriksen 2010 arxiv.org/abs/1012.1268.
A Moss, D Scott and J P Zibin 2010 arxiv.org/abs/1012.1305.

Astrowatch

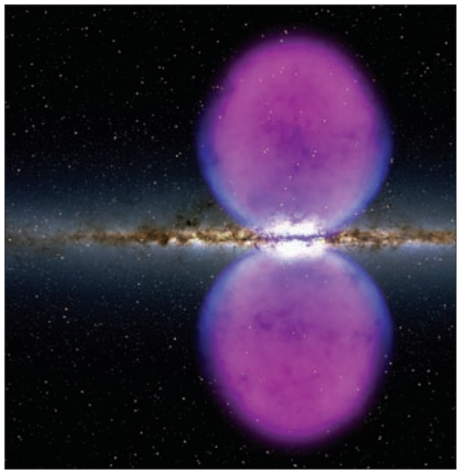
Compiled by Marc Türler, ISDC and Observatory of the University of Geneva

Fermi sees giant bubbles in the Milky Way

The Fermi gamma-ray space telescope has detected high-energy emission from two giant lobes on both sides of the plane of the Galaxy. This unexpected finding suggests that the Milky Way was more active in the past, either through a phase of intense stellar formation or of much higher activity of the central black hole.

The launch of a new facility with much higher sensitivity than its predecessor always raises the hope of finding something unexpected. The Fermi satellite, observing in the relatively unexplored area of giga-electron-volt photons, is especially suited for such discoveries (*CERN Courier* November 2008 p13). Having already found pulsars emitting pulsed radiation only in gamma-rays (*CERN Courier* December 2008 p9) and evidence for intergalactic magnetic fields (*CERN Courier* June 2010 p10), it has now detected mysterious gamma-ray bubbles in the Milky Way.

The two gamma-ray-emitting bubbles extend 50° above and below the Galactic plane with a width of about 40°. They have been revealed by Meng Su and two colleagues from the Harvard-Smithsonian Center for Astrophysics. The features were hidden in the diffuse galactic gamma-ray emission that arises mainly from inverse-Compton radiation of relativistic electrons and from π decay induced by cosmic-ray interactions with interstellar gas. The distinct characteristic of the bubbles is their hard spectrum, i.e. with more high-energy gamma-rays, which allows them to be disentangled more easily from the other diffuse emission features. Su and colleagues use different ways to remove the latter from the all-sky Fermi images to reveal the faint glow of the two bubbles.



The two giant bubbles detected by the Fermi satellite are illustrated here in purple on an infrared view of the disc of the Milky Way. Associated X-ray emission observed by ROSAT in blue. (Image credit: NASA.)

The emission of the gamma-ray bubbles is remarkably uniform, with no significant change of intensity over their 25 000 light-years extent or between the north and south bubbles. They must therefore have been produced by a powerful process near the Galactic centre. Further indications as to the origin of the giant features comes from apparently associated X-ray emission from the rim of the bubbles, which has been identified in all-sky maps from the early 1990s by the Germany-led Roentgen Satellite (ROSAT), and from a spatially consistent haze of radio emission detected by the Wilkinson Microwave Anisotropy Probe (WMAP). The presence of these lower-energy counterparts disfavours the annihilation or decay of dark matter as the origin for the gamma-ray emission. The association of the radio signal with the high-energy gamma-ray emission suggests instead emission by relativistic electrons. The WMAP signal would then come from synchrotron radiation in the Galactic magnetic field, while Fermi would have recorded the inverse-Compton gamma-rays from electrons scattering off photons from the Galaxy or the cosmic microwave background. The X-ray signal from the edge of the bubbles further suggests a shock-wave interaction of expanding gas with the surrounding medium.

According to the authors of the paper, published in the *Astrophysical Journal*, the most likely origin of the bubbles is a large episode of energy injection from the Galactic centre. This could consist either of past accretion events on the now quiescent supermassive black hole at the centre of the Milky Way or a nuclear starburst event in the past 10 million years or so. However, both explanations have some difficulties in accounting for the observations. While a simple jet explanation would not easily produce the smooth surface brightness and north–south symmetry, an intense and prolonged star formation period is not suggested by recent observations of radioactive decay of aluminium-26 (*CERN Courier* January/February 2006 p10).

Further reading

M Su *et al.* 2010 *ApJ* **724** 1044.

Picture of the month

Serenely floating in space, this delicate shell is reminiscent of the “soap bubble” planetary nebula (*CERN Courier* September 2009 p11). However, its calm is only illusory because the shell is lit up by a blast wave that is smashing into the interstellar medium at more than 5000 km/s. Called SNR 0509, the bubble is the remnant of a stellar explosion that should have been visible in the Large Magellanic Cloud to observers in the southern hemisphere around 1600 AD. This neighbouring galaxy – only 160 000 light-years away – was also the site of the most recent naked-eye supernova, SN 1987A (*CERN Courier* February 2007 p11 and p23). The image is a composite of visible light (red shell) and X-rays (blue-green glow) from the Hubble and Chandra Space Telescopes, respectively. (Image credits: NASA, ESA, the Hubble Heritage Team (STScI/AURA), and NASA/CXC/SAO/J Hughes.)

CERN Courier Archive: 1968

A look back to CERN Courier vol. 8, January/February 1968, compiled by Peggie Rimmer

News from abroad

ADONE commissioning

The elegant building that houses the ADONE storage ring at the Frascati Laboratory. (Image credit: CNEN.)

Commissioning of the electron–positron e^-e^+ storage ring ADONE is under way at the Frascati Laboratory in Italy. Electrons and positrons have been successfully injected into the ring and some acceleration of the beams has been achieved. The ADONE project was first proposed in 1962 by the Italian National Institute for Nuclear Physics (INFN) and has been financed mainly by the National Committee for Nuclear Energy (CNEN).

A wide experimental programme has already been proposed. The approved experiments, now in an advanced state of preparation, are:

- Single boson production (Naples University/Frascati);
- e^-e^+ annihilation into two bosons (Padua University/Frascati);
- e^-e^+ annihilation into two gammas, neutral pion plus gamma, or eta plus gamma (Rome University/Frascati);
- Muon pair production (Rome University/Frascati);
- A study of the phi resonance through its charged kaon, muon and neutral decays (Instituto Superiore di Sanità);
- Nucleon pair production (Naples University/Frascati);
- Search for leptonic quarks and heavy leptons (Bologna University/Frascati).

Parents unknown

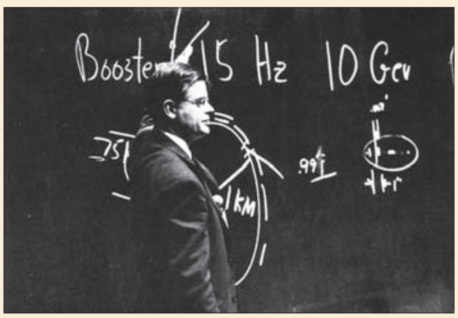
In *Physics Review Letters*, 25 December 1967, news emerged from a group of University of Utah physicists down a mine in search of neutrinos, led by J W Keuffel. The Utah Park City lead mine is different from others being used for research on cosmic and solar neutrinos in that it is only about 600 metres deep and it is possible for very high energy muons in cosmic rays to penetrate to this comparatively modest depth.

The team has looked at the variation in intensity of the muon flux in the energy range 1000 to 10 000 GeV, with depth and with angle. The variation with depth was in excellent agreement with what was expected but the variation with angle produced an unexpected result.

It is generally assumed that the high-energy muons result from the decays of pions and kaons, making it possible to say something about the muon intensity expected at different angles. If the muon parents are in fact pions and kaons, one would expect to detect more muons at large angles to the vertical and progressively less at closer and closer angles to the vertical. This is because pions and kaons produced in denser regions of the atmosphere are more likely to interact with other particles than to decay. Pions and kaons coming from "inclined primaries" are produced at higher altitudes and so are more likely to decay than to interact. The Utah team, however, observed hardly any variation in high-energy muon flux as they looked through a wide range of angles.

Their conclusion is that the majority of muons in cosmic rays with energies greater than 1000 GeV are either produced directly in some interaction or are the decay product of some unknown parent, which decays copiously into muons with a much shorter average lifetime than the kaon. An obvious candidate is the intermediate boson, the postulated mediator of the weak interaction, which has been searched for without success in neutrino experiments at CERN and elsewhere. They suggest looking in nuclear emulsions for high-energy muons (though the energies involved are at the upper limit for direct detection in nuclear emulsion) and for high-energy electrons which would be expected if the intermediate boson were being produced.

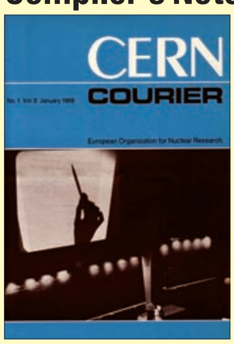
● Compiled from texts on pp12–13.



On 9 February, Professor R R Wilson, Director of the National Accelerator Laboratory [Fermilab] at Weston, Illinois, USA, was at CERN to discuss the American 200–400 GeV accelerator project with ECFA, the European Committee for Future Accelerators. In the afternoon, he gave a talk to a packed Main Auditorium on the design of the Weston machine.

● Compiled from texts on p31 (photo p34).

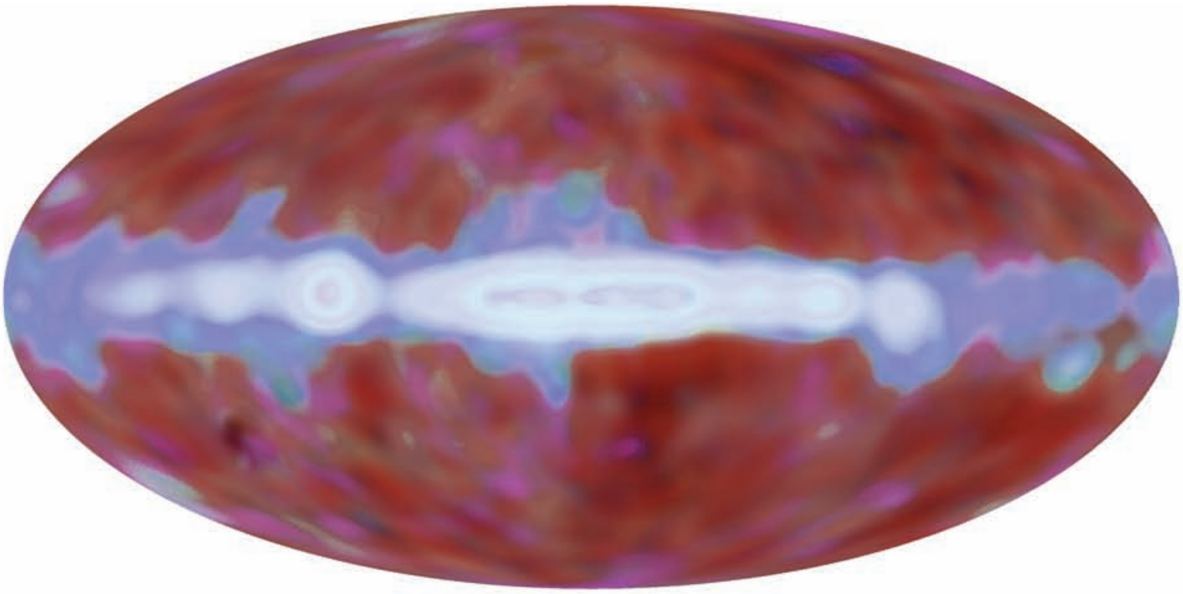
Compiler's Note

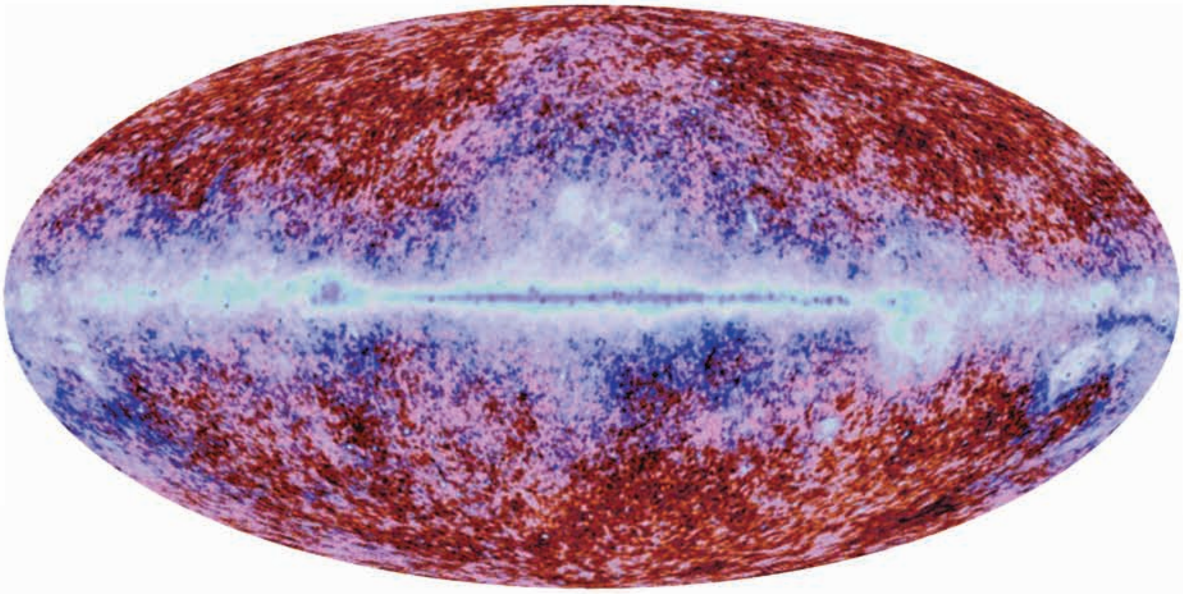


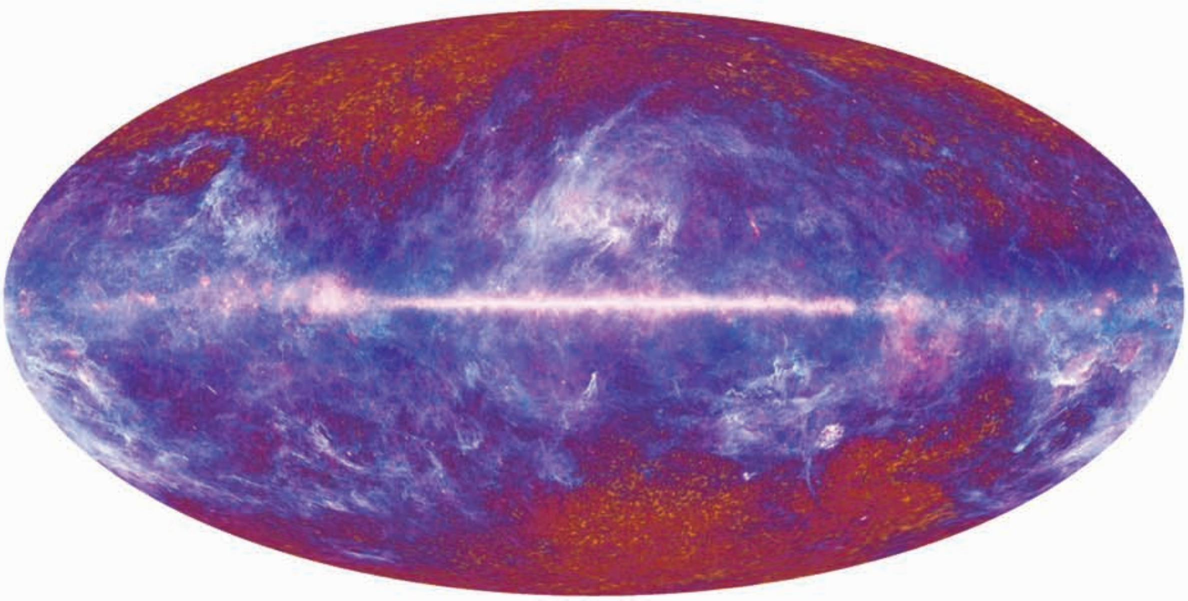
ADONE was the successor to the first e^-e^+ collider AdA (Anello di Accumulazione), which ran at Frascati from 1961 to 1964 with 2×250 MeV collision energy. Results from the ADONE experiments, Italian for "big AdA", were immediately exciting and by 1971 it was clear from production rates in e^-e^+ collisions that hadrons are not elementary. This supported the nascent theory of quarks as the point-like components of hadrons, and boosted interest in e^-e^+ physics. Since the early 1970s, a series of high-energy e^-e^+ colliders have been built around the world, the latest being the Beijing Electron–Positron Collider, BEPC II, with 2×3.7 GeV collision energy.

As for the weak force bosons, the Utah miners were not in fact on their trail. At the time, Leon Lederman described theoretical speculation that their expected mass range was 3–20 GeV/c^2 as having reached hysterical proportions. When the bosons finally weighed in at CERN in 1983 they had masses in excess of 80 GeV/c^2 (charged Ws) and 91 GeV/c^2 (neutral Z). The jury is still out on the mass of the next big boson.

Astroparticle physics







Planck reveals a stellar first year

The first results from the Planck mission, released on 11 January, are already providing new insights into astrophysics and augur well for the future, with plenty more contributions to cosmology still to come.

The cosmic microwave background (CMB) is one of the most powerful resources that cosmologists have to investigate the evolution of the universe since its earliest moments. Like a "fabric" that permeates the cosmos, it holds information about the temperature distribution, keeping a permanent memory of all of the events that the universe has gone through. In particular, its anisotropies – deviations from the isotropic distribution that characterizes the universe – contain the signatures of the primordial perturbations that gave birth to the large-scale structure of the universe observed today.

Reading among these ripples in the CMB is by no means easy because they appear as tenuous fluctuations (1 part in 100 000) in a cold background at 3 K. In May 2009, ESA's Planck spacecraft was launched into space to prise out the secrets hidden there (*CERN Courier* July/August 2009 p8). The result of about 20 years of work by the international Planck collaboration, it is a third-generation satellite that follows on from the Cosmic Background Explorer (COBE) and the Wilkinson Microwave Anisotropy Probe (WMAP). Since mid-July 2009, Planck has been orbiting at the second Lagrangian point (L2) of the Earth–Sun system, 1.5 million kilometres from Earth. It carries on board a Low Frequency Instrument (LFI), consisting of an array of 22 radiometers, and a High Frequency Instrument (HFI), which has 48 bolometric detectors (*CERN Courier* April 2009 p26). Since its launch, Planck has performed extremely well. The two instruments have so far scanned the whole sky almost three times in nine different frequency channels, with a sensitivity that is up to 10 times better and an angular resolution up to 3 times better than that of its most recent predecessor, WMAP (figure 1).

On 11 January, the Planck collaboration released its first catalogue of compact astrophysical sources. This is the first full-sky source catalogue to cover the frequency range 30–857 GHz at nine different frequencies. It includes a variety of different types of sources, from nearby objects in the galaxy to various classes of radio galaxies, and dusty galaxies to distant clusters of galaxies.

Because Planck is optimized to measure the CMB, the catalogue turns out to be an extremely powerful tool for identifying the cold objects that populate the interstellar medium (ISM) and measuring their temperature accurately. In this task Planck is allied with the Herschel space observatory, which was launched by ESA on board the same spacecraft. Herschel, designed to study cold objects, is not a survey telescope; rather, its purpose is to look closely at one part of the sky at a time. Planck and Herschel are thus good companions, whereby Planck provides the whole-sky survey and points Herschel to interesting locations that it can focus on.

Among the sources detected by Planck are "protostellar objects", that is, clusters of matter that could give rise to a star. The complex processes at the origin of stars are among the hottest topics for astronomers, who carefully investigate the properties of the ISM to identify the trigger factors for star formation. Researchers at many Earth-based observatories will be able to use data from Planck to improve our understanding of these processes.

After only a few months of observation, Planck is also shedding light on another component of the ISM: namely, spinning dust grains. These are tiny aggregates of matter that appear to be slightly bigger than molecules such as CO_2. They spin and radiate with a particular spectrum. Planck has for the first time been able to reconstruct this spectrum at high frequencies and so confirm that the spinning dust grains really do exist. This opens up a completely new field of study for astronomers, who will now have to understand the exact nature and behaviour of this intriguing component of the ISM.

Moving away from the interior of the Galaxy, one of the major contributions of the first part of Planck's scientific programme is the identification of clusters of galaxies and the study of their properties through the signature that they leave in the CMB when its photons travel through the hot gas of the cluster. This is the Sunyaev-Zel'dovich effect, in which photons in the CMB increase in energy through inverse Compton scattering off hot electrons in the galaxy clusters. As a consequence, along the cluster direction, the CMB temperature increases at high frequency (>217 GHz) and decreases at ▷

Left: Fig. 1. The cosmic microwave background radiation over the full sky as seen by three generations of satellites: COBE, with 4 years of data (top); WMAP, with 7 years of data (centre); and Planck, after just one year. The instruments on Planck are up to 10 times more sensitive than those on WMAP and have an angular resolution that is up to three times better. (Image credit: Planck.)

Astroparticle physics

low frequency (<217 GHz) with a well defined frequency spectrum, observable by Planck thanks to its wide frequency coverage.

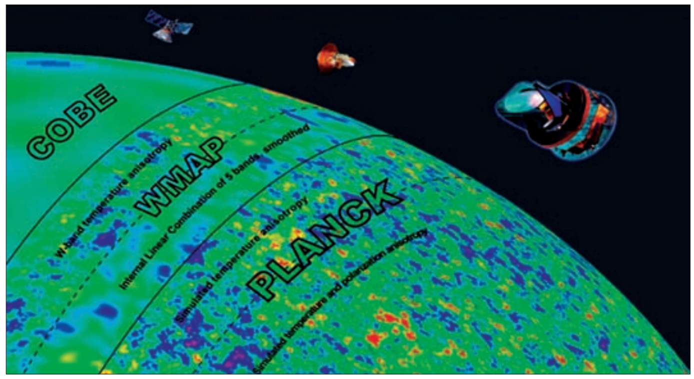
Matter in the universe is grouped in enormous clusters surrounded by vast, empty spaces. These clusters can contain hundreds of galaxies and large amounts of dark matter. Dark matter consists of particles observed so far only through their gravitational effect; their exact nature remains unknown. Observing clusters of galaxies is crucial to understanding why matter of any kind aggregates in this fashion. The Sunyaev-Zel'dovich effect can be used to estimate the total mass of the cluster, which, when combined with X-ray observations, can in turn provide evaluations of the proportion of dark matter. The list of sources of this type that Planck has identified through the Sunyaev-Zel'dovich effect is 2–3 times larger than those published so far by the best observatories on Earth.

Planck has also been able to extend the spectrum of conventional radio sources. Previously this was known up to about 100 GHz but Planck has now pushed this to 857 GHz, giving new insight into the behaviour of these sources and the physical processes involved.

This first set of results is just the beginning of the Planck adventure. There will be more accurate catalogues and further findings in astrophysics, followed in early 2013 by Planck's crucial contributions to cosmology. While the theoretical models used at present in cosmology seem to fit the current observations well, they require important components whose nature is not yet known – dark matter and dark energy. A major aim of the Planck mission is to cast light on both of these enigmatic components.

Dark energy is yet another contribution to the energy density of the universe, being different from dark and ordinary matter. It is presumed to provide the current acceleration to the expansion of the universe and its existence is inferred from observations of Type Ia supernovae, of the CMB and of the baryon acoustic oscillations that are determined by surveying galaxies at different cosmic epochs. The equation-of-state of dark energy characterizes the late and future evolution of the universe. Planck will be able to measure the parameters ρ (energy density) and w (ratio of pressure to ρ) of the equation-of-state with an accuracy that is expected to be an order of magnitude greater than for the previous data from WMAP. Moreover, studies of CMB anisotropies will allow the Planck collaboration to distinguish between various theoretical models that do not consider new ingredients in the energy-budget of the universe (such as dark energy and dark matter) but, rather, change the Einstein equations (as for example in "modified gravity" models).

As far as gravity is concerned, Planck's contribution will depend on which theoretical model best describes the evolution of the universe. Among the many models that try to explain the initial conditions of the Big Bang, two have gained particular prominence: one is the inflationary model, in which the early universe underwent a period of exponential expansion; the other is the "bouncing model", where the universe is described as something that was contracting and then "bounced" at the time when quantum gravity was important and began to re-expand. Inflationary models generally generate gravitational waves that can in principle be detected by Planck, depending on their amplitude, the value of which is a feature of the specific inflationary model. By contrast, the bouncing models do not predict gravitational waves. Planck will also constrain the expected deviation from the Gaussian distribution



Planck follows on from COBE and WMAP in mapping the CMB in ever increasing detail. (Image credit: ESA.)

of the primordial fluctuations that are imprinted in the CMB. This feature characterizes more the bouncing models than the inflationary ones. While Planck will not have the final say in this field, it will indeed have the opportunity to rule out several models.

In addition to questions directly related to cosmology and astrophysics, Planck will also address a number of problems that are linked to particle physics and the Standard Model. It will increase by at least a factor three the accuracy of limits on the mass and number of neutrino species that WMAP currently sets at 0.56 eV and 4.3+/–0.8, respectively. Planck may also provide limits on the mass of the Higgs boson in certain theoretical models for a non-minimally coupled Higgs-inflation field with gravity.

According to current theories, the conditions of the universe today were set at the time of inflation, about 10^{-35} s after the Big Bang. The LHC below ground and Planck in deep space are allies in probing these first moments of the universe's evolution. While the physicists at CERN are seeking to reproduce the conditions of the early universe, with Planck we observe the first light that came out of this "soup" of matter and radiation. Particle physicists, as well as astrophysicists and cosmologists, must work towards a concordant description of this early epoch in which data from the different sources fit together to give a consistent picture of the universe that we all inhabit.

Résumé

Planck : une année dans les étoiles

En mai 2009, le satellite Planck, de l'Agence spatiale européenne, a été lancé dans l'espace avec pour mission d'explorer le rayonnement cosmique diffus. Les premiers résultats donnent déjà de nouvelles perspectives sur l'astrophysique. Le 11 janvier, la collaboration a publié son premier catalogue de sources astrophysiques. Ce catalogue, le plus complet jamais produit, inclut des sources très diverses : des objets proches de la galaxie, différents types de radiogalaxies et de galaxies poussiéreuses, ou encore des amas distants de galaxies. Planck étudie les propriétés des amas de galaxies au moyen de la signature qu'elles laissent dans le fonds commun cosmologique.

Reno Mandolesi, INAF IASF Bologna, **Jean-Loup Puget**, IAS Orsay, and **Jan Tauber**, ESA.

Warwick hosts a feast of flavour

CKM2010, the latest in the series of international workshops on the physics of quark flavour, provided an opportunity to look forwards to a new generation of experiments.

In September 2010, the University of Warwick played host to CKM2010, the 6th International Workshop on the CKM Unitarity Triangle. The CKM workshops, named after the Cabibbo-Kobayashi-Maskawa matrix that describes quark mixing in the Standard Model, date from 2002 when the first meeting took place at CERN (*CERN Courier* May 2002 p33). The workshop has since established itself as one of the most important meetings in the field.

With a two-year gap since the previous meeting, there was much at CKM2010 for theorists and experimentalists alike to discuss. This was the first time since the inauguration of the series that the workshop occurred with neither of the B-factory experiments – BaBar and Belle – being operational. A generation of experiments in charm and kaon physics have also completed data-taking. While much is being done to archive the knowledge that has been accumulated from this era, the organizers of CKM2010 chose instead to look to the future.

Uncharted territory

Only by looking forwards is it possible to address the many open questions in flavour physics, which Paride Paradisi of the Technische Universität München presented in the first of the opening plenary sessions. The biggest issue, perhaps, concerns the fact that there is still no real understanding of the underlying reason for the flavour structure of the Standard Model. More pressing, however, is the so-called "new-physics flavour puzzle": how is the need for physics beyond the Standard Model at the tera-electron-volt scale – to resolve the hierarchy problem – to be reconciled with the absence of such new physics in precision flavour measurements? The most popular solution is the "minimal flavour violation" hypothesis, which can be tested by observables that are either highly suppressed or precisely predicted in the Standard Model.

Two sectors where the experimental measurements do not yet reach the desired sensitivity are those of the D^0 and B_s mesons. Guy Wilkinson of the University of Oxford described the progress made at Fermilab's Tevatron over the past few years, emphasizing the potential of the LHC experiments at CERN – particularly LHCb – to explore uncharted territory. It will be interesting to see if the datasets with larger statistics confirm the hints of contributions from new physics to B_s mixing that have been seen by the CDF and DØ experiments at the Tevatron. The large yields of D, J/ψ, B and Υ mesons already observed by the LHC experiments augur well for exciting results in the near future.

However, the LHC will not be the only player in flavour physics in the next decade. Yangheng Zheng of the Graduate University of Chinese Academy of Sciences and Marco Sozzi of the Università di Pisa and INFN described the new facilities and experiments that are coming online in the charm and kaon sectors, respectively. The BEPCII collider in Beijing has achieved an instantaneous luminosity above $3\times10^{32}\,cm^{-2}s^{-1}$, and the BES III collaboration has already published the first results from its world's largest datasets of electron–positron collisions in the charmonium resonance region. The kaon experiments NA62 at CERN and K0T0 at J-PARC are well on the way towards studies of the ultra-rare decays $K^+\rightarrow\pi^+\nu\bar{\nu}$ and $K_L\rightarrow\pi^0\nu\bar{\nu}$.

Meanwhile, there are plans for a new generation of B factories, which Peter Križan of the University of Ljubljana and J Stefan Institute described. The clean environment of electron–positron colliders provides a unique capability for various measurements, such as $B^+\rightarrow\tau\nu_\tau$. The upgrade of the KEKB facility and the Belle detector to allow operation with a peak luminosity of $8\times10^{35}\,cm^{-2}s^{-1}$ (40 times higher than achieved to date) has been approved and construction is now ongoing, with commissioning due to start in 2014. The design shares many common features – most notably the "crab-waist" collision scheme – with the SuperB project, recently approved by the Italian government (p8).

Only by looking forwards is it possible to address the many open questions in flavour physics

Maximizing the impact of these new experiments will require progress in lattice QCD calculations. Junko Shigemitsu of Ohio State University described recent developments in this field, showing that accuracy below a per cent has been reached for several parameters in the kaon sector, with calculations using different lattice actions giving consistent results. In the charm sector, determinations of constants are approaching the per cent level of ▷

From William Shakespeare to Nicola Cabibbo

The packed agenda of CKM2010 was interrupted only by an excursion to gain inspiration from William Shakespeare's birthplace in Stratford-upon-Avon and for the conference dinner, which was held in the magnificent medieval surroundings of St Mary's Guildhall in Coventry. There were also two special events. Frank Close of the University of Oxford presented a public lecture entitled, "Antimatter: Fact, Fiction or Fancy?", in which he contrasted the drama of Dan Brown's *Angels&Demons* with the exciting reality of research into antimatter. A dedicated session paid tribute to Nicola Cabibbo, who sadly passed away just a few weeks before the workshop (*CERN Courier* November 2010 p39). Guido Martinelli of Università di Roma "La Sapienza" and INFN, who was Cabibbo's student, described the scientific legacy of the "father of flavour physics" with many moving personal reflections.

Guido Martinelli pays tribute to Nicola Cabibbo. (Image credit: Tagir Aushev.)

Conference participants at CKM2010 pose for the traditional group photo before the conference dinner in St Mary's Guildhall in Coventry. (Image credit: Tagir Aushev.)

precision; this advance, when combined with new measurements, appears to have resolved the apparent discrepancy in the value of the D_s decay constant. Further work is needed to reach the desired level of precision in B physics but excellent progress is being made by several groups around the world.

The main body of the workshop consisted of parallel meetings of six working groups, which provided opportunities for detailed discussions between experts. The summaries from these working groups were presented in two plenary sessions on the final day.

Working group I, convened by Federico Mescia of the Universitat de Barcelona, Albert Young of the University of North Carolina and Tommaso Spadaro of INFN Frascati, focused on the precise determination of $|V_{ud}|$ and $|V_{us}|$. A measurement of the muon lifetime at a precision of one part per million by the MuLAN collaboration determines the reference value of the Fermi coupling. Improved measurements of $|V_{ud}|$ and $|V_{us}|$, mainly from nuclear β-decay and (semi-)leptonic kaon decay, respectively, set constraints on the unitarity of the first row of the CKM matrix at better than 1 permille. Interesting discrepancies in the measurements of the neutron lifetime and of $|V_{us}|$ demand further studies.

Hint of new physics?

Working group II, convened by Jack Laiho of the University of Glasgow, Ben Pecjak of the University of Mainz and Christoph Schwanda of the Institute of High Energy Physics in Vienna, had as its subject the determination of $|V_{ub}|$, $|V_{cb}|$, $|V_{cs}|$ and $|V_{cd}|$. This is an area where dialogue between theorists and experimentalists has been extremely fruitful in driving down the uncertainties. Lively discussions continue, stimulated in part by the apparent discrepancies between inclusive and exclusive determinations of both $|V_{cb}|$ and $|V_{ub}|$. The latest data on the leptonic decay $B^+\rightarrow\tau\nu_\tau$, which is sensitive to contributions from charged Higgs bosons, show an interesting discrepancy that may prove to be a first hint of new physics.

Working group III, convened by Martin Gorbahn of the Technische Universität München, Mitesh Patel of Imperial College London and Steven Robertson of the Canadian Institute for Particle Physics, at McGill University and SLAC, tackled rare B, D and K decays. One particularly interesting decay is $B\rightarrow K^*l^+l^-$, where first measurements of the forward-backward asymmetry by BaBar, Belle and CDF hint at non-standard contributions. This is exciting for LHCb, where additional kinematic variables will be studied. Inclusive rare decays, such as $b\rightarrow s\gamma$, and those with missing energy in the final state are better studied in electron–positron collisions and help to motivate the next generation of B factories. Among other golden modes, improved results on $B_s\rightarrow\mu^+\mu^-$ and $K\rightarrow\pi\nu\bar{\nu}$ remain eagerly anticipated by theorists, who continue to refine the expectations for these decays in various models.

A common feature of all working groups was the strong emphasis on the sensitivity to new physics

The fourth working group, convened by Alexander Lenz of the Technische Universität Dortmund and Universität Regensburg, Olivier Leroy of the Centre de Physique des Particules de Marseille and Michal Kreps of the University of Warwick, was concerned with the determination of the magnitudes and relative phases of V_{td}, V_{ts} and V_{tb}. While the Tevatron experiments have started to set constraints on these quantities from direct top production, with further improvement anticipated at the LHC, the strongest tests at present come from studies of the oscillations of charm and beauty mesons. Hints for new physics contributions in the B_s sector provided the main talking point, but the potential for and the importance of improved searches for CP violation in charm oscillations was also noted.

Measurements of the angles of the unitarity triangle were the subject of the remaining two working groups. Working group V, convened by Robert Fleischer of NIKHEF and Stefania Ricciardi of the Rutherford Appleton Laboratory, focused on determinations of the angle γ using $B \to DK$ decays, while working group VI, convened by Matt Graham of SLAC, Diego Tonelli of Fermilab and Jure Zupan of the University of Ljubljana and the J Stefan Institute, covered measurements using charmless B decays. The angle γ plays a special role because it is has negligible theoretical uncertainty. The precision of the measurements is not yet below 10°, leaving room for results from LHCb – combined with measurements from charm decays – to have a big impact on the unitarity triangle fits. The measurements based on charmless decays, which are dominated by loop ("penguin") amplitudes, tend to have significant theoretical uncertainties that must be tamed to isolate any new physics contribution. The main issue concerns developing methods to understand whether existing anomalous results (such as the pattern of CP asymmetries in $B \to K\pi$ decays) are caused by QCD corrections or by something more exotic.

A common feature of all working groups was the strong emphasis on the sensitivity to new physics and the utility of flavour observables to distinguish different extensions of the Standard Model. Less than two years after the award of the Nobel prize to Kobayashi and Maskawa "for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature", their greatest legacy – and that of Nicola Cabibbo (see box) – will perhaps be a discovery that finally goes beyond the paradigm of the Standard Model.

● CKM2010 was generously supported by the University of Warwick, the Science and Technology Facilities Council, the Institute for Particle Physics Phenomenology and the Institute of Physics.

● Further reading

For details on the workshop, see http://ckm2010.warwick.ac.uk.

Résumé

Warwick : 6e édition de la conférence CKM

En septembre 2010, l'Université de Warwick a accueilli CKM2010, le 6e atelier international sur le triangle d'unitarité CKM. Après un intervalle de deux ans depuis la dernière réunion, il y avait matière à discussion pour les théoriciens comme pour les expérimentateurs. C'est la première édition de cet atelier après la fin de l'exploitation des expériences d'usines à B - BaBar et Belle. Une génération d'expériences en physique des charmés et des kaons a également achevé l'acquisition de données. Les expériences s'emploient à archiver les connaissances accumulées jusqu'à présent, mais l'attention de CKM2010 s'est portée plutôt sur la prochaine génération d'expériences.

Tim Gershon, University of Warwick.

The origin of cosmic rays

Where do cosmic rays come from? **Anatoly Erlykin, Romen Martirosov** and **Arnold Wolfendale** present the case that fine structure in the energy spectrum provides vital confirmation that the nuclear component of cosmic rays below about 100 PeV originates in the remnants of supernovae.

As 2012 approaches, and with it the centenary of Victor Hess's famous discovery, it really is time that we found out where cosmic rays originate. Gamma-ray astronomy has shown that most of the particles come from the Galaxy, but even this discovery was 63 years in coming (Dodds *et al*. 1975). Supernova remnants (SNR) have long been suspected to be the source of cosmic rays below about 100 PeV, the production mechanism being Fermi acceleration in shock-borne magnetic fields. The energies involved are reasonable: about 10^{43} J into cosmic rays per SNR per century. However, there are doubts, with pulsars or extended sources being other possibilities.

The origin problem arises because magnetic fields on a variety of scales in the Galaxy cause particles at these energies to pursue tortuous paths, so that their arrival directions at Earth bear virtually no relationship to the directions of the sources. Solving the problem therefore requires other approaches. Structure in the energy spectrum could provide such a possibility.

Clues from the energy spectrum

The only feature of the cosmic-ray energy spectrum that researchers currently agree on is a steepening that starts in the region of 3–5 PeV. First observed by German Kulikov and George Khristiansen at Moscow University around 50 years ago (Kulikov and Khristiansen 1958), this so-called "knee" has been confirmed time and again from the 1960s onwards. It was not until 13 years ago, however, that we pointed out that the "knee" is too sharp for a conventional explanation in which the galactic magnetic field gradually "loses its grip" on the particles (Erlykin and Wolfendale 1997). We argued instead that it results from a dominant contribution from a single, nearby source. The idea is that particles from the single source provide a component that pokes through the background arising from an amalgam of many differing sources (figure 1).

The single-source model has had a rough ride, with most researchers being unwilling to accept that there could be "fine structure" in the spectrum caused by nuclei heavier than protons from this source. Our early analysis was based on extensive air-shower (EAS) data from a variety of EAS arrays. While these results are still valid, we have recently analysed new data from some 10 arrays, thus extending the reach to higher energies than before. Remarkably, and importantly, a new feature has appeared at about 70 PeV.

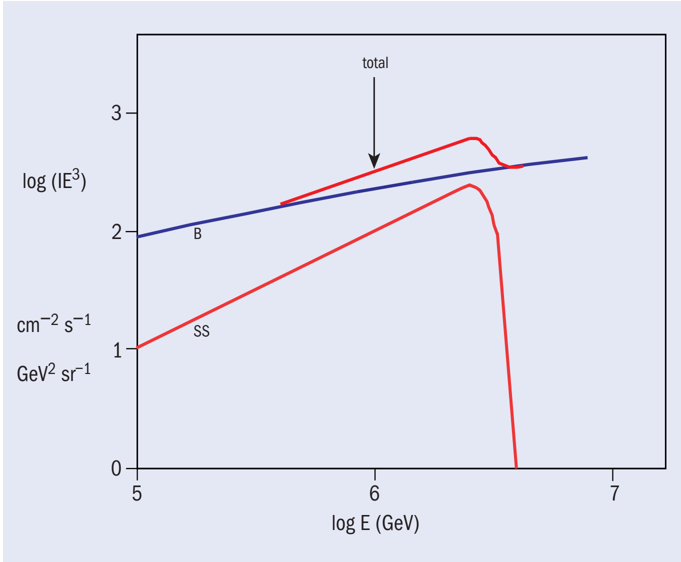


Fig. 1. Cosmic-ray spectra from the single-source model (Erlykin and Wolfendale 1997). SS denotes the single-source contribution, B the background from all but the nearest, most recent, source. The relative heights of SS and B were chosen such that the "total" matches the observed spectrum (the mean of the measurements at the time). The plot is schematic.

Remarkably, and importantly, a new feature has appeared at about 70 PeV.

When the energy spectrum is plotted as $\log(E^3I(E))$ versus $\log E$, a "knee" will appear as a peak and it is a new peak in the spectrum plotted in this way that is of interest (figure 2, px). It was first reported by the GAMMA collaboration led by Romen Martirosov, using the GAMMA EAS array of the A I Alikhanyan National Science Laboratory at Mount Aragats in Armenia (Garyaka *et al*. 2008). Our own survey shows that it is also present in most of the other reported spectra (Erlykin and Wolfendale 2010). It is ▷

Origins

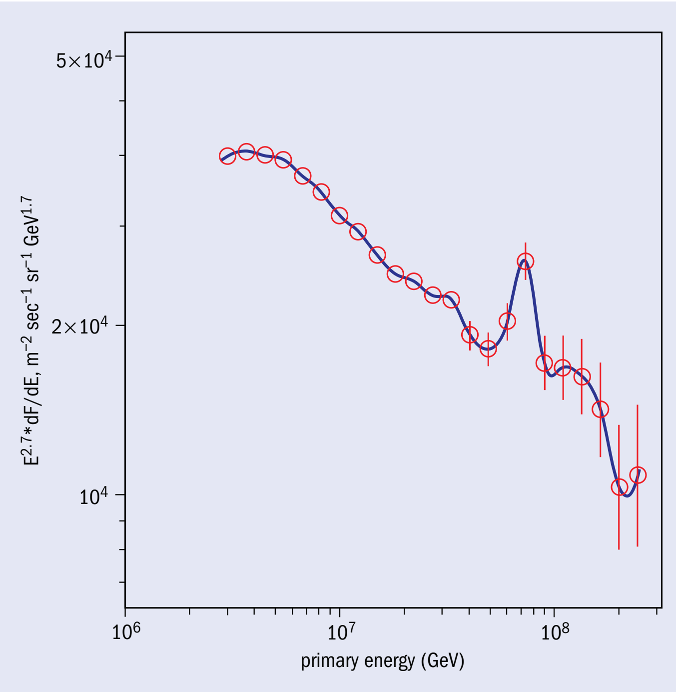


Fig. 2. The all-particle energy spectrum from the GAMMA experiment (Garyaka et al. *2008).*

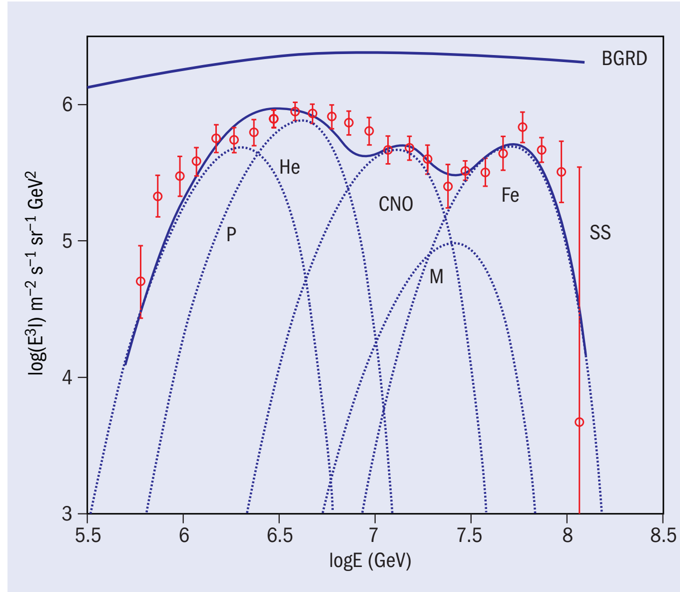


Fig. 3. The energy spectrum of the single source and its interpretation. The full line denoted as BGRD is the background spectrum. Dotted lines are best-fit contributions from five cosmic-ray mass groups: P, He, CNO, M and Fe. The full line denoted as SS is the sum of these five components.

interesting to note that our first paper on the single-source model showed a small excess at the level of 2.6σ just where the GAMMA collaboration finds its 70 PeV peak. However, we did not claim that this small peak was significant at the time.

We have now used these recent spectra to investigate the case for SNRs in general as the source of cosmic rays at energies below 100 PeV. The model for the acceleration of the cosmic rays predicts that those with charge Z should have a differential energy spectrum, with a negative slope of about 2, up to a maximum energy proportional to Z. Nuclei are conventionally grouped into the following nuclear bands: P, He, CNO, M(Ne, Mg, Si) and Fe (actually Fe and Ni). The spectrum expected at some distance from the single source differs from that at the SNR itself because of propagation effects, but these can be calculated. This is what we have done, assuming that the single source is Monogem, a "recent" SNR with an age of 85–115 ky, at a "local" distance of 250–400 pc (Erlykin and Wolfendale 2003).

We interpret this as showing that the majority of the galactic sources are SNR, like Monogem, but of course with different ages and distances.

Figure 3 shows a synthesis of the 10 reported spectra from the EAS arrays from which the (predicted) smooth background, also shown, has been subtracted. The resulting "spectrum" is thus our estimate of the extra contribution from the single source. The figure also shows our fits of the individual single-source spectra in the different nuclear bands to the observations. Inevitably, there is no question of a perfect fit: although the He and Fe peaks seem well founded, those for CNO and P are less well so. Peaks for P and He have been seen in other experiments, however. The whole range is thus reasonably well represented.

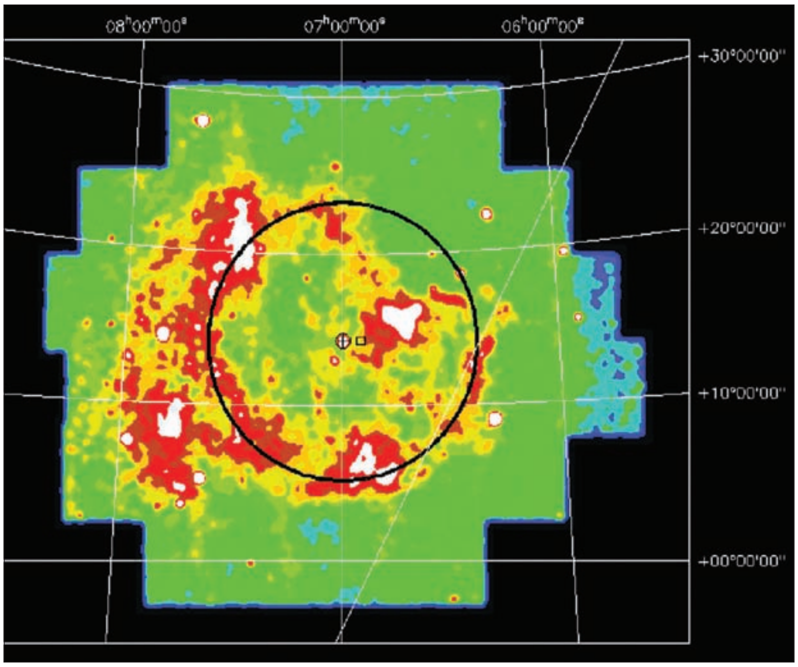
Our calculations give the relative abundances at a fixed energy per particle of the various nuclear groups on ejection from the single source as: P(0.477), He(0.406), CNO(0.081), M(0.010) and Fe(0.026). Remarkably, with the exception of the M group, these abundances are close to those inferred for the ambient cosmic radiation at 10^3 GeV, an energy where direct measurements are available. We interpret this as showing that the majority of the galactic sources are SNR, like Monogem, but of course with different ages and distances.

The search for confirmation

The identification of the peaks in figure 3 could be confirmed by searching for discontinuities in those entities that have given rise to estimates of the mean mass of the ambient cosmic radiation. However, such a search is bedevilled by two facts. First, it is in the nature of things that at any energy the mean mass of the single-source particles should be close to that of those injected for the ambient cosmic radiation. Second, the different analyses of the variety of EAS parameters used in deriving the mean masses give, notoriously, different results. Our conclusion, however, is that there is no evidence against our identifications.

These differences provide a happy hunting ground for searches for changes with increasing energy in the nature of the interactions between cosmic rays and nuclei in the atmosphere. It must also be said, however, as we have pointed out, that recent results from CERN show no significant change in at least some of the interaction characteristics over the range 0.4–26 PeV (*CERN Courier* June

Origins



Monogem Ring, a supernova remnant with the pulsar B0656+14 at its centre, is probably the "single source" responsible for the "knee" in the cosmic-ray energy (Thorsett et al. *2003).*

2010 p29). This is just where the cosmic-ray energy spectrum has its knee; LHC data on forward physics are eagerly awaited.

● Further reading

D Dodds, A W Strong and A W Wolfendale 1975 *Mon. Not. Roy. Astr. Soc.* **171** 569.
A D Erlykin and A W Wolfendale 1997 *J. Phys. G* **23** 979.
A D Erlykin and A W Wolfendale 2003 *J. Phys. G* **29** 709.
A D Erlykin and A W Wolfendale 2010 *Proc.22 ECRS Turku* (to be published in *ASTRA*).
A P Garyaka, R M Martirosov, S V Ter-Antonyan *et al.* 2008 *J. Phys. G.* **35** 115201.
G V Kulikov and G B Khristiansen 1958 *JETP* **35** 63.
S E Thorsett *et al.* 2003 *Ast. J.* **593** L71.

Résumé

L'origine des rayons cosmiques

D'où viennent les rayons cosmiques ? À l'approche du centenaire de la découverte par Victor Hess des rayons cosmiques en 1912, la question, posée de longue date, de leur origine se fait plus pressante. Dans cet article, Anatoly Erlykin, Romen Martirosov et Arnold Wolfendale expliquent que la structure fine dans le spectre d'énergie apporte une confirmation cruciale du fait que le composant nucléaire des rayons cosmiques de moins de 100 PeV trouve son origine dans les résidus des supernovas. En particulier, ils supposent une source unique proche, en s'appuyant sur des données provenant de gerbes atmosphériques.

Anatoly Erlykin, P N Lebedev Physical Institute, **Romen Martirosov**, A I Alikhanyan National Science Laboratory, and **Arnold Wolfendale**, Durham University.

TWEPP-2010

Electronics experts connect in Aachen

Topics from chip design to power provision and high-speed data transmission came under scrutiny at the TWEPP-2010 workshop, as hardware physicists and engineers looked to R&D for future projects in high-energy particle physics. **Katja Klein** reports.

Each year, the Topical Workshop on Electronics for Particle Physics (TWEPP) provides the opportunity for experts to come together to discuss electronics for particle-physics experiments and accelerator instrumentation. Established in 2007, it succeeds the workshops initiated in 1994 to focus on electronics for LHC experiments, but with a much broader scope (*CERN Courier* January/February 2008 p13). As the LHC experiments have now reached stable operating conditions, the emphasis is shifting further towards R&D for future projects, such as the LHC upgrades, the studies for the Compact Linear Collider and the International Linear Collider, as well as neutrino facilities and other experiments in particle- and astroparticle physics.

The latest workshop in the series, TWEPP-2010, took place on 20–24 September at RWTH Aachen University and attracted 190 participants, mainly from Europe but also from the US and Japan. It covered a wide variety of topics, including electronics developments for particle detection, triggering and data acquisition; custom analogue and digital circuits; optoelectronics; programmable digital logic applications; electronics for accelerator and beam instrumentation; and packaging and interconnect technology. The programme of plenary and parallel sessions featured 16 invited talks together with 63 oral presentations and 66 poster presentations selected from a total of 150 submissions – an indication of the attractiveness of the workshop concept. The legacy of the meeting as a platform for the discussion of common LHC electronics developments is reflected in several electronics working groups for the super-LHC (sLHC) project holding their bi-annual meeting during the workshop, namely the Working Groups for Power Developments and for Optoelectronics, as well as the Microelectronics User Group. In addition, two new working groups on Single Event Upsets and on development of electronics in the emerging xTCA standard had "kick-off" meetings during TWEPP-2010.

After a welcome and introduction to particle physics in the host country and the host institute (see box), the opening session continued with "Physics for pedestrians", a talk by Patrick Michel Puzo of the Laboratoire de l'Accélérateur Linéaire, Orsay, in which he explained the Standard Model of particle physics, as well as experimental measurement techniques, to the audience of hardware physicists and engineers. DESY's Peter Göttlicher went on to present the European X-ray Free Electron Laser project (XFEL) currently under construction at DESY. This fourth-generation light source will provide ultra-short flashes of intense and coherent X-ray light for the exploration of the structure and dynamics of complex systems, such as biological molecules. Dedicated two-dimensional camera systems, such as the Adaptive Gain Integrating Pixel Detector (AGIPD), are being developed to record up to 5000 images a second with a resolution of 1 megapixel. The session closed with a summary of the status of the LHC by CERN's Ralph Assmann, who also discussed the expected and observed limitations and prospects for further increases in intensity, luminosity and beam energy at the LHC, as well as short- and long-term planning.

From ASICs to optical links

For the next three days, morning and afternoon sessions began with plenary talks, after which the audience separated into two parallel sessions. With 20 presentations, the session on application-specific integrated circuits (ASICs) was again by far the most popular, demonstrating the demand of chip designers for a forum to present and discuss their work. One increasingly important aspect in the next generation of experiments with high radiation levels is the mitigation of single-event effects (SEE), such as single event upsets (SEU), which are caused by the interaction of particles with the semiconductor material. Deep-submicron integrated circuit technologies with low power consumption are becoming increasingly sensitive to SEEs and this must be carefully taken into account at both the system level and the ASIC design level. Invited speaker Roland Weigand of the European Space Agency gave insight into the various approaches of SEE mitigation that are employed in space applications, where integrated circuits are exposed to solar and cosmic radiation.

A relatively new development is the 3D integration of circuits

Host highlights

Following the welcome from the vice-rector of RWTH Aachen University, the workshop began with the traditional "local" plenary session, which aims to make the participants familiar with both the host institution and the high-energy physics landscape of the host country.

Bernhard Spaan, chair of the Komitee für Elementarteilchenphysik, presented the activities and perspectives of particle physics in Germany. He stressed the role of the Helmholtz Alliance "Physics at the Terascale", which was founded in 2007 as a structured research network comprising 18 German universities, 2 Helmholtz centres (DESY and the Karlsruhe Institute of Technology) and the Max Planck Institute for Physics in Munich (*CERN Courier* May 2008 p11). The Alliance engenders more effective collaboration, in particular between experimentalists and theorists, and creates and maintains common infrastructures. Its role was highlighted in the talk by Karlheinz Meier of the Kirchhoff Institute for Physics at Heidelberg University. He introduced the concept of "virtual ASIC laboratories" (Heidelberg University and Bonn University) that provide laboratory equipment, assembly facilities and support for layout and simulation software, for example, to the German particle-physics community.

Lutz Feld, chair of the Local Organizing Committee, introduced the particle-physics programme at RWTH Aachen University. Here the focus is on hardware development, physics analysis and Grid computing for the CMS experiment at the LHC. In addition, the RWTH's three experimental institutes participate mainly in experiments in astroparticle physics, in particular in the Alpha Magnetic Spectrometer, Ice Cube and the Pierre Auger Observatory.

Left to right: Philippe Farthouat and Francois Vasey, co-chairs of the Scientific Organizing Committee, Heather Hofmeister, vice-rector of RWTH Aachen University, and Lutz Feld, chair of the Local Organizing committee, at the welcome session. (Image credit: Martin Lux/RWTH Aachen.)

A relatively new development is the 3D integration of circuits, where several circuit layers are stacked on each other and interconnected, for example by through-silicon-vias. The advantages include the reduction of the chip area, reduced power consumption, a high interconnection density and the possibility to combine different processes in one device. Within particle physics, a possible future application is in the upgrades of the large silicon trackers of the LHC experiments. Kholdoun Torki from Circuits Multi-Projets, Grenoble, presented the plans for a 3D multiproject wafer run for high-energy physics, which allows several developers to share the cost of low-volume production by dividing up the reticle area.

The parallel session on "Power, grounding and shielding" focused mainly on novel power-provision schemes for upgrades of the LHC experiments, namely serial powering and DC–DC conversion. An increase in the number of readout channels and the possible implementation of additional functionality, such as a track trigger, in the tracker upgrades of ATLAS and CMS will lead to higher front-end power consumption and consequently larger power losses in the supply cables (already installed) and to an excessive increase in the material budget of power services. New ways to deliver the power therefore need to be devised. Both of the new schemes discussed solve this problem by lowering the current to be delivered. In serial powering, this is done by daisy-chaining many detector modules, while DC–DC conversion schemes provide the power at a higher voltage and lower current, with on-detector voltage conversion. These topics were further expanded in the session of the Working Group for Power Developments.

Another parallel session was devoted to the topic of optoelectronics and optical links. Data transmission via optical links is already standard in the LHC experiments because such links do not suffer from noise pick-up and contribute less material than the classic copper wires. In the session and in the following working-group meeting, presentations focused on experience with installed systems as well as on new developments, in particular for the Versatile Link project, which will develop high-speed optical-link architectures and components suitable for deployment at the sLHC. In an inspiring talk, invited speaker Mark Ritter of IBM expanded on optical technologies for data communication in large parallel systems. He explained that scaling in chip performance is now constrained by limitations on electrical communication bandwidth and power dissipation and he described how optical technologies can help overcome these constraints. The combination of silicon nanophotonic transceivers and 3D integration technologies might be the way forwards, with a photonic layer integrated directly into the chip such that on-board data transmission between the individual circuit layers is performed optically.

First LHC experience

A highlight of this year's workshop was the topical session devoted to the performance of LHC detectors and electronics under the first beam conditions. Gianluca Aglieri Rinella of CERN presented the experience with ALICE, a detector designed specifically for the reconstruction of heavy-ion collisions, where high particle-multiplicities and large event sizes are expected. He showed that more than 90% of the channels are alive for most of the ALICE detector subsystems, with the data-taking efficiency being around 80%. The ALICE collaboration's goal for proton–proton collisions is ▷

TWEPP-2010

A majority of the 190 participants line up in front of the conference venue. (Image credit: Martin Lux/RWTH Aachen.)

TWEPP-10 participants reading and discussing during the lively poster session. (Image credit: Lutz Feld/RWTH Aachen.)

to collect a high-quality, minimum-bias sample with low pile-up in the time projection chamber, corresponding to an interaction rate of 10 kHz. For this reason, the peak luminosity at ALICE is deliberately reduced during proton–proton running.

Thilo Pauly of CERN presented the ATLAS report. He showed that more than 97% of the channels are operational for all detector systems and that 94% of the delivered data are good for physics analysis. The ATLAS momentum scale for tracks at low transverse momentum is measured with a precision of a few per mille, while the energy scale for electromagnetic showers is known from the reconstruction of neutral pions to better than 2%. The experience of CMS, presented by Anders Ryd of Cornell University, is similarly positive, with all subsystems being 98% functional with a data-taking efficiency of 90%. He explained that the collaboration struggled for a while with the readout of high-occupancy beam-induced events in the pixel detector – the main reason for detector downtime – but managed to solve the problem.

Last but not least, Karol Hennessy of the University of Liverpool reported on LHCb, which is optimized to detect decays of beauty and charm hadrons for the study of CP violation and rare decays. This experiment has had a detector uptime of 91% and a fraction of working channels above 99% in most subdetectors. One specialty is the Vertex Locator – a silicon-strip detector consisting of retractable half-disks whose innermost region is only 8 mm away from the beam. This detector reaches an impressive peak spatial resolution of 4 μm.

Posters and more

The well attended poster session took place in the main lecture hall and featured 66 posters. Discussions were so lively that the participants had to be reminded to stop because they would otherwise miss the guided city tour. The workshop dinner took place in the coronation hall of the town hall, where participants were welcomed by the mayor of Aachen. The dinner saw the last speech by CERN's François Vasey as Chair of the Scientific Organizing committee. He became Workshop Chair in 2007, shaping the transition to TWEPP and after four successful workshops he now passes the baton to Philippe Farthouat, also of CERN. The next workshop in the series will take place on 26–30 September 2011 in Vienna.

TWEPP-10 was organized by the Physikalisches Institut 1B, RWTH Aachen University, with support from Aachen University, CERN and ACEOLE, a Marie Curie Action at CERN funded by the European Commission under the 7th Framework Programme.

● Further reading

For all presentations and posters from TWEPP-10, see http://twepp10.physik.rwth-aachen.de and http://indico.cern.ch/event/twepp10. The proceedings, including a summary, are published in *J. Inst.* at http://iopscience.iop.org/1748-0221/focus/extra.proc9. For more about TWEPP-11, see http://twepp11.hephy.at/.

Résumé

Des experts en électronique réunis à Aix-la-Chapelle

Chaque année, l'atelier thématique sur l'électronique pour la physique des particules (TWEPP) est l'occasion pour les experts de discuter de l'électronique pour les expériences de physique des particules et l'instrumentation des accélérateurs. À l'heure où les expériences LHC ont atteint des conditions de fonctionnement stables, l'intérêt se porte sur la R&D pour les projets futurs. Le dernier atelier dans la série, TWEPP-2010, a couvert une grande variété de sujets : nouveautés électroniques pour la détection de particules, déclenchement et acquisition de données, circuits analogiques et numériques sur mesure, optoélectronique, applications logiques numériques programmables, électroniques pour l'instrumentation des accélérateurs et des faisceaux, et enfin technologie de conditionnement et d'interconnexion

Katja Klein, RWTH Aachen.

CERN's ISR: the world's first hadron collider

On 27 January 1971, two beams of protons collided in the ISR for the first time. This machine was a true pioneer and paved the way for the operation of the SPS as the first proton–antiproton collider in the 1980s, and subsequently for the development of the LHC.

The concept of a particle collider was first laid down by Rolf Widerøe in a German patent that was registered in 1943 but not published until 1952. It proposed storing beams and allowing them to collide repeatedly so as to attain a high energy in the centre-of-mass. By 1956, the first ideas for a realistic proton–proton collider were being publicly discussed, in particular by Donald Kerst and Gerard O'Neill. At the end of the same year, while CERN's Proton Synchrotron (PS) was still under construction, the CERN Council set up the Accelerator Research Group, which from 1960 onwards focused on a proton–proton collider. By 1962, the group had chosen an intersecting ring layout for the collider over the original concept of two tangential rings because it offered more collision points. Meanwhile, in 1961, CERN had been asked by Council to include a 300 GeV proton synchrotron in the study.

In 1960 construction began on a small proof-of-principle 1.9 MeV electron storage ring, the CERN Electron Storage and Accumulation Ring (CESAR). This was for experimental studies of particle accumulation (stacking). This concept, which had been proposed by the Midwestern Universities Research Association (MURA) in the US in 1956, would be essential for obtaining sufficient beam current and, in turn, luminosity. The design study for the Intersecting Storage Rings (ISR) was published in 1964 – involving two interlaced proton-synchrotron rings that crossed at eight points.

After an intense and sometimes heated debate, Council approved the principle of a supplementary programme for the ISR at its meeting in June 1965. The debate was between those who favoured a facility to peep at interactions at the highest energies and those who preferred intense secondary beams with energies higher than that provided by the PS. Those who were against the ISR were also afraid of the leap in accelerator physics and technology required by this venture, which appeared to them as a shot into the dark.

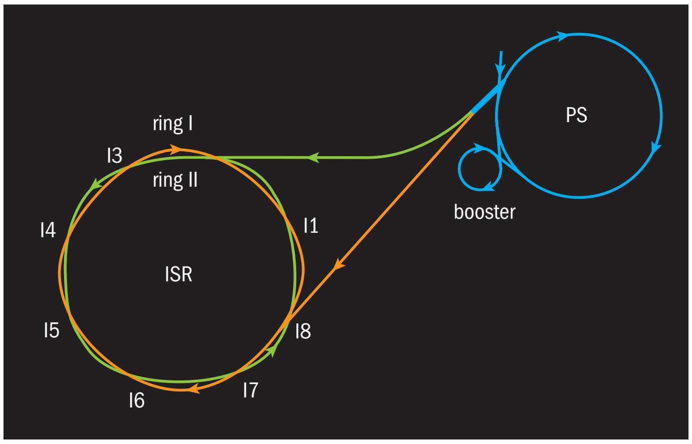


Fig. 1. The ISR consisted of two interlaced proton-synchrotron rings, both 300 m in diameter, which received protons from the PS.

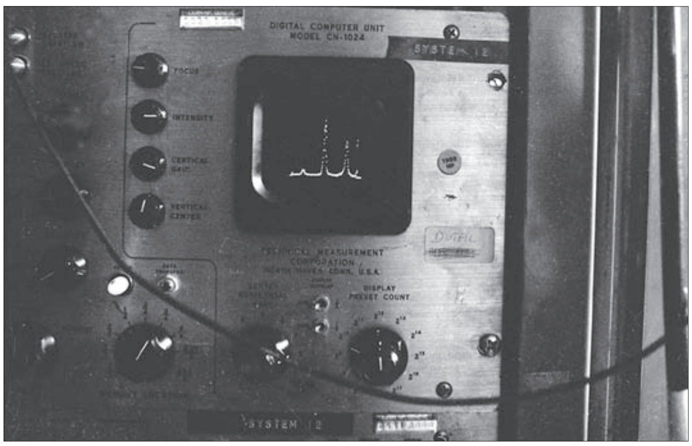


Fig. 2. The first interactions between the two beams in the ISR in January 1971. The trace shows time differences between pulses from detectors on the two sides of the intersection region. The central peak is from beam–beam collisions, those at either side from beam–gas or beam–wall collisions (Johnsen 1984).

France made land available for the necessary extension to the CERN laboratory and the relevant agreement was signed in September 1965. The funds for the ISR were allocated at the Council meeting in December of the same year and Kjell Johnsen was appointed project leader. Finally, Greece was the only country out of the 14 member states whose budget did not allow it to participate in the construction. In parallel, the study of a 300 GeV proton synchrotron was to be continued; this would eventually lead to ▷

ISR 40 years

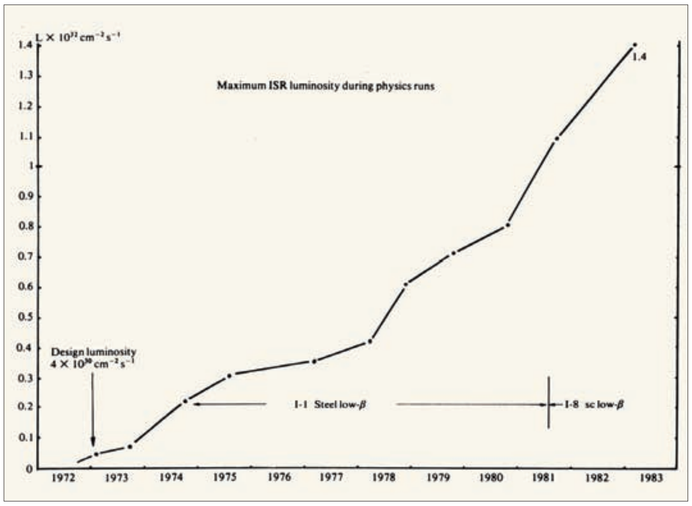


Fig. 3. Peak luminosity for physics at the ISR as a function of time. The first experiment to be completed (R101) received a maximum of 1.3×10^{29} cm^{-2} s^{-1}, while R807 achieved the highest ever, 1.4×10^{32} cm^{-2} s^{-1}, in December 1982 (Johnsen 1984).

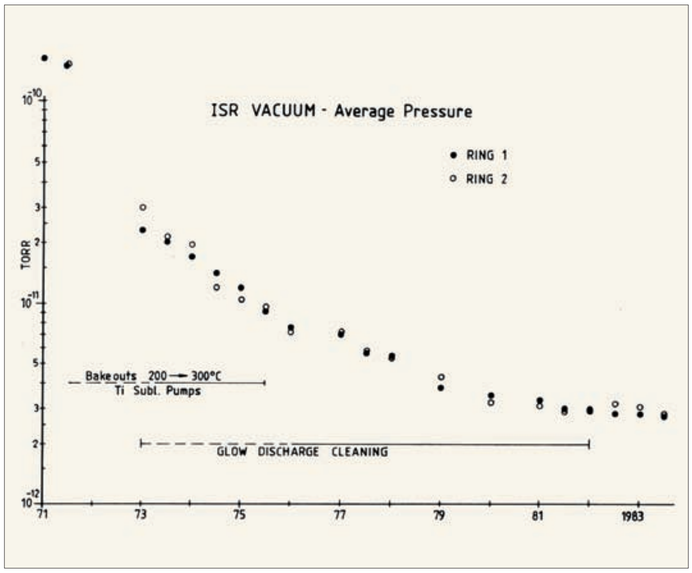


Fig. 4. Evolution of the average pressure in the ISR showing how it improved thanks to continuous upgrading (Johnsen 1984).

the construction of the Super Proton Synchrotron (SPS) at CERN.

Figure 1 shows the ISR layout with the two rings intersecting at eight points at an angle of 15°. To create space for straight sections and to keep the intersection regions free of bulky accelerator equipment, the circumference of each ring was set at 943 m, or 1.5 times that of the PS. Out of the eight intersection regions (I1–I8) six were available for experiments and two were reserved for operation (I3 for beam dumping and I5 for luminosity monitoring).

The ISR construction schedule benefited from the fact that the project had already been studied for several years and many of the leading staff had been involved in the construction of the PS. The ground-breaking ceremony took place in autumn 1966 and civil engineering started for the 15-m wide and 6.5-m high tunnel, using the cut-and-fill method at a level 12 m above the PS to minimize excavation. The construction work also included two large experimental halls (I1 and I4) and two transfer tunnels from the PS to inject the counter-rotating beams. In parallel, the West Hall was built for fixed-target physics with PS beams; ready in July 1968, it was used for assembling the ISR magnets. The civil engineering for the ISR rings was completed in July 1970, including the earth shielding. The production of the magnet steel started in May 1967 and all of the major components for the rings had been ordered by the end of 1967. The first series magnets arrived in summer 1968 and the last magnet unit was installed in May 1970.

Pioneering performance

The first proton beam was injected and immediately circulated in October 1970 in Ring 1. Once Ring 2 was available, the first collisions occurred on 27 January 1971 at a beam momentum of 15 GeV/*c* (figure 2, p27). By May, collisions had taken place at 26.5 GeV/*c* per beam – the maximum momentum provided by the PS – which was equivalent to protons of 1500 GeV hitting a fixed target.

In the first year of operation, the maximum circulating current was already 10 A, the luminosity was as high as 3×10^{29} cm^{-2} s^{-1} and the loss-rates at beam currents of up to 6 A were less then 1% per hour (compared with a design loss-rate of 50% in 12 h). Happily, potentially catastrophic predictions that the beams would grow inexorably and be lost – because, unlike in electron machines, the stabilizing influence of synchrotron radiation would be absent – proved to be unfounded.

The stacking in momentum space, pioneered by MURA, was an essential technique for accumulating the intense beams. In this scheme, the beam from the PS was slightly accelerated by the RF system in the ISR and the first pulse deposited at the highest acceptable momentum on an outer orbit in the relatively wide vacuum chamber. Subsequent pulses were added until the vacuum chamber was filled up to an orbit close to the injection orbit, which was on the inside of the chamber. This technique was essential for the ISR and had been proved experimentally to work efficiently in CESAR.

".. the most important discovery in the field of accelerator physics was that of Schottky noise in the beams."

The design luminosity was achieved within two years of start-up and then increased steadily, as figure 3 shows. It was particularly boosted in I1 (originally for one year in I7) and later in I8 by low-beta insertions that decreased the vertical size of the colliding beams. The first low-beta insertion, which consisted largely of borrowed quadrupoles from the PS, DESY and the Rutherford Appleton Laboratory, increased the luminosity by a factor of 2.3. Later, for the second intersection, more powerful superconducting quadrupoles were developed at CERN but built by industry. This increased the luminosity by a factor of 6.5, resulting in a maximum luminosity of 1.4×10^{32} cm^{-2} s^{-1}. This remained a world record until 1991, when it was broken by the Cornell electron–positron storage ring.

The stored currents in physics runs were 30–40 A (compared with 20 A nominal); the maximum proton current that was ever stored was 57 A. Despite these high currents, the loss rates during physics runs were typically kept to one part per million per minute, which provided the desired low background environment for the experiments. Beams of physics quality could last 40–50 hours.

Because the ISR's magnet system had a significant reserve, the beams in the two rings could be accelerated to 31.4 GeV/*c* by phase displacement, a technique that was also proposed by MURA. This consisted of moving empty buckets repeatedly through the stacked beam. The buckets were created at an energy higher than the most energetic stored particles and moved through the stack to the injection orbit. In accordance with longitudinal phase-space conservation, the whole stack was accelerated and the magnet field was simultaneously increased to keep the stack centred in the vacuum chamber. This novel acceleration technique required the development of a low-noise RF system operating at a low voltage with a fine control of the high-stability, magnet power supplies.

The ISR was also able to store deuterons and alpha particles as soon as they became available from the PS, leading to a number of runs with p–d, d–d, p–α and α–α collisions from 1976 onwards. For CERN's antiproton programme, a new beamline was built from the PS to Ring 2 for antiproton injection and the first p-$\bar{\text{p}}$ runs took place in 1981. During the ISR's final year, 1984, the machine was dedicated to single-ring operation with a 3.5 GeV/*c* antiproton beam.

The low loss-rates observed for the gradually rising operational currents were only achievable through a continuous upgrading of the ultra-high vacuum system, which led to a steady decrease in the average pressure (figure 4). The design values for the vacuum pressure were 10^{-9} torr outside the intersection regions and 10^{-11} torr in these regions to keep the background under control. The initial choice of a stainless-steel vacuum chamber bakeable to 300°C turned out to be the right one but nevertheless a painstaking and lengthy programme of vacuum improvement had to be launched. The vacuum chambers were initially baked to only 200°C and had to be re-baked at 300°C and, later, at 350°C. Hundreds of titanium sublimation pumps needed to be added and all vacuum components had to be glow-discharge cleaned in a staged programme. These measures limited the amount of residual gas, and hence the production of ions from beam–gas collisions, as well as the out-gassing that occurred when positive ions impinged on the vacuum chamber walls after acceleration through the electrostatic beam potential.

The electrons created by ionization of the residual gas were often trapped in the potential well of the coasting proton beam. This produced an undesirable focusing and coupling between the electron cloud and the beam, which led to "e–p" oscillations. The effect was countered by mounting clearing electrodes in the vacuum chambers and applying a DC voltage to suppress potential wells in the beam.

By 1973 the ISR had suffered two catastrophic events in which the beam burnt holes in the vacuum chamber. Collimation rings were then inserted into the flanges to protect the bellows. The vacuum and engineering groups also designed and produced large, thin-walled vacuum chambers for the intersection regions. The occasional collapse of such a chamber would leave a spectacular twisted sculpture and require weeks of work to clean the contaminated arcs.

While the ISR broke new ground in many ways, the most important discovery in the field of accelerator physics was that of Schottky noise in the beams – a statistical signal generated by the

This view of Intersection 5 (I5) in 1974 clearly shows the layout of the magnets and the crossing of the two beam pipes.

finite number of particles, which is well known to designers of electronic tubes. This shot noise not only has a longitudinal component but also a transverse component in the betatron oscillations (the natural transverse oscillations of the beam). This discovery opened new vistas for non-invasive beam diagnostics and active systems for reducing the size and momentum-spread of a beam.

The longitudinal Schottky signal made it possible to measure the current density in the stack as a function of the momentum (transverse position) without perturbing it. These scans clearly showed the beam edges and any markers (figure 5, p30). A marker could be created during stacking by making a narrow region of low current-density or by losses on resonances.

The transverse Schottky signals gave information about how the density of the stack varied with the betatron frequency, or "tune", which meant that stacking could be monitored in the tune diagram and non-linear resonances could be avoided. During stacking, space–charge forces increase and change the focusing experienced by the beam. Using the Schottky scans as input, the magnet system could be trimmed to compensate the space–charge load. A non-invasive means to verify the effect of space charge and to guide its compensation had suddenly become available. ▷

ISR 40 years

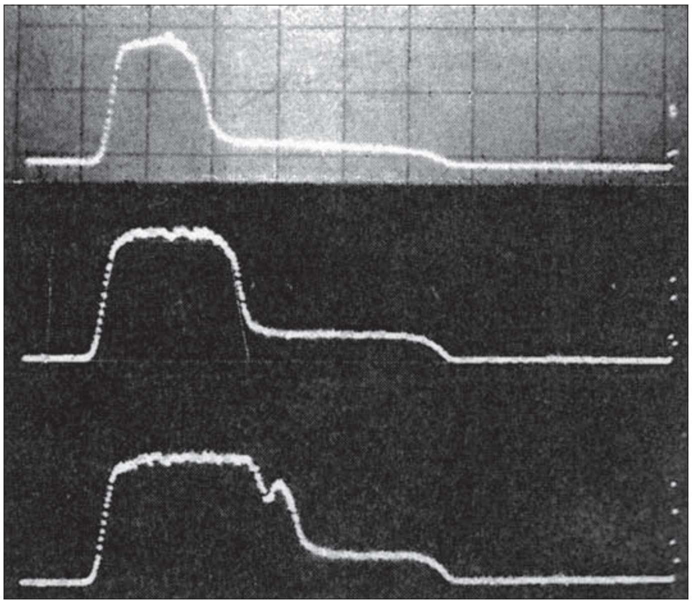


Fig. 5. Longitudinal Schottky scans taken at different intensity levels during the build-up of a stack (10 A, 15 A and 19 A). (J Borer et al. *1974 CERN-ISR-DI/RF/74-23.)*

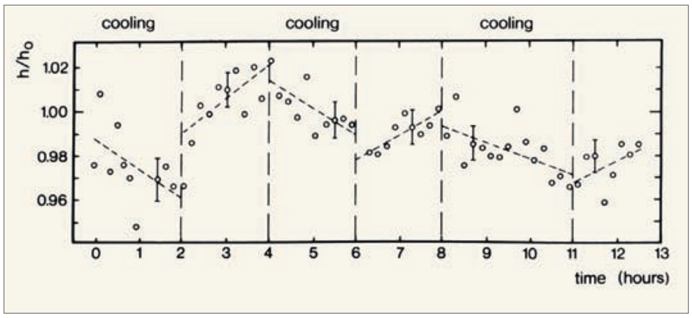


Fig. 6. The measurement of the relative beam height (h/h_0) as a function of time, decreasing with stochastic cooling on and increasing with it off. The luminosity was inversely proportional to beam height. (P Bramham et al. *1975* NIM **125** *201.)*

The discovery of the transverse Schottky signals had another, and arguably more important impact, namely the experimental verification of stochastic cooling of particle beams. This type of cooling was invented in 1972 by Simon van der Meer at CERN. Written up in an internal note, it was first considered as a curiosity without any practical application. However, Wolfgang Schnell realized its vast potential and actively looked for the transverse Schottky signals at the ISR. This was decisive for the resurrection of van der Meer's idea from near oblivion and its experimental proof at the ISR (figure 6). Towards the end of ISR's life, stochastic cooling was routinely used on antiproton beams to increase the luminosity in antiproton–proton collisions by counteracting the gradual blow-up of the antiproton beam through scattering with residual gas as well as resonances.

Stochastic cooling was the decisive factor in the conversion of the SPS to a p$\bar{\text{p}}$ collider and in the discovery there in 1983 of the long-sought W and Z bosons. This led to the awarding of the Nobel Prize in Physics to Carlo Rubbia and van der Meer, the following year. The technique also became the cornerstone for the success of the more powerful Tevatron proton–antiproton collider at Fermilab. In addition, CERN's low-energy antiproton programmes in the Low Energy Antiproton Ring and the Antiproton Decelerator, as well as similar programmes at GSI in Germany and at Brookhaven in the US, owe their existence to stochastic cooling. The extension to bunched beams and to optical frequencies makes stochastic cooling a basic accelerator technology today.

A lasting impact

With its exceptional performance, the ISR dispelled the fears that colliding beams were impractical and dissolved the reluctance of physicists to accept the concept as viable for physics. In addition to stochastic cooling, the machine pioneered and demonstrated large-scale, ultra-high vacuum systems as well as ultra-stable and reliable power converters, low-noise RF systems, superconducting quadrupoles and diagnostic devices such as a precise DC current transformer and techniques such as vertically sweeping colliding beams through each other to measure luminosity – another of van der Meer's ideas.

The ISR had been conceived of in 1964 in an atmosphere of growing resentment against the high costs of particle physics and it was in a similar climate in the early 1980s that the rings were closed down to provide financial relief for the new Large Electron–Positron collider at CERN. The political pressures in the 1960s had fought and accepted the ISR as a cost-efficient gap-filler because the financial and political climates were not ready for a 300 GeV machine. However, had CERN built the 300 GeV accelerator instead of the ISR, then the technology of hadron colliders would have been seriously delayed. Instead, the decision to build the ISR opened the door to collider physics and allowed an important expansion in accelerator technology that would affect everyone for the better, including the 300 GeV project, the p$\bar{\text{p}}$ project and eventually the LHC.

● Further reading

Maurice Jacob and Kjell Johnsen 1984 CERN 84-13.

Résumé

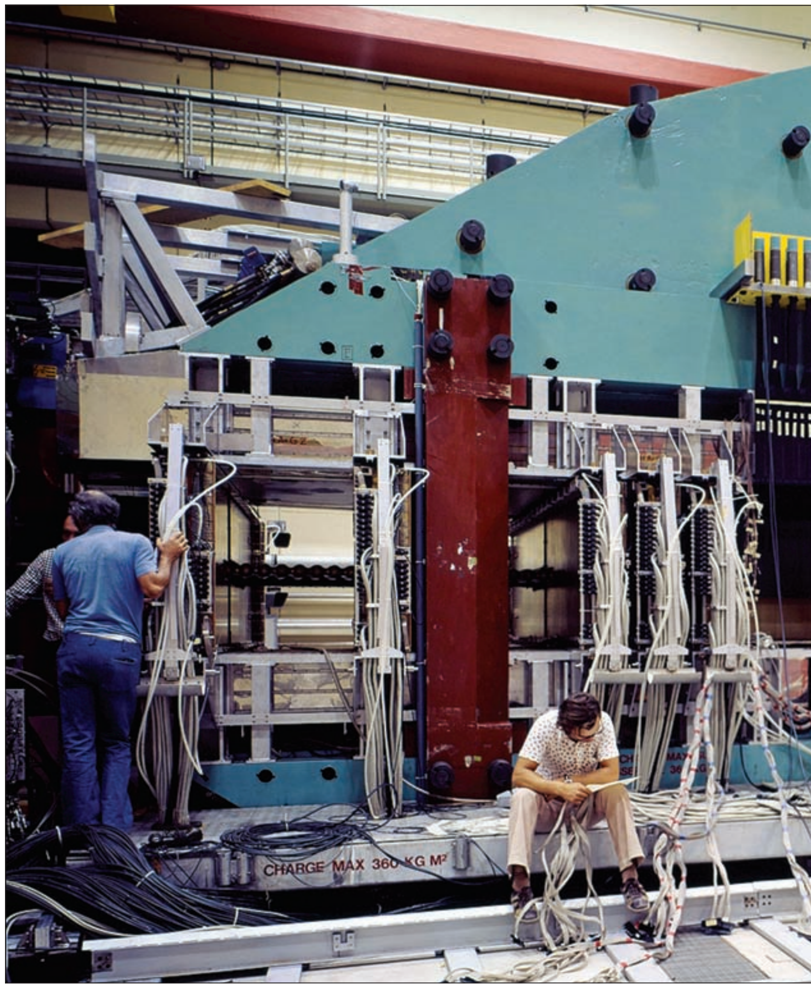
Les ISR du CERN : le premier collisionneur de hadrons du monde

Le 27 janvier 1971, des faisceaux de protons entraient en collision pour la première fois dans les anneaux de stockage à intersections (ISR) du CERN. La luminosité atteinte a finalement été supérieure à la valeur nominale, avec un courant de protons stocké maximum de 57 A. Les faisceaux de protons pouvaient durer 40 à 50 heures. La machine, qui a fonctionné également avec des deutérons et des particules alpha à partir de 1976, a été à l'avant-garde des techniques dans beaucoup de domaines : systèmes d'ultravide, convertisseurs de puissance ultrastables, quadripôles supraconducteurs et surtout le fameux refroidissement stochastique. La machine a ainsi ouvert la voie au Supersynchrotron à protons, premier collisionneur proton–antiproton, et au LHC.

Philip Bryant and **Kurt Hübner**, formerly CERN and ISR (now retired).

Evolution and revolutio

The challenges presented by a changing scene in particle physics, as well as by the environment of colliding beams, led to many innovations in experimentation at the ISR. **Christian Fabjan** describes how they underpinned a rich harvest of physics.



The Split-Field Magnet (SFM) at I4 had an unconventional topology, consist
first general facility at the ISR. It had a useful magnetic field volume of 28 m³
length of 10.5 m, the magnet weighed about 1000 t. The SFM spectrometer fe
which filled the main magnet, visible here in 1974, and the two large compens

The committee for the ISR experimental programme – the ISRC – started its work in early 1969, with the collider start-up planned for mid-1971. Two major lines of experimental programmes emerged: "survey experiments" would aim to understand known features (in effect, the Standard Model of the time) in the new energy regime, while other experiments would aim at discoveries. This was surprisingly similar to the strategy 40 years later for the LHC. But in reality the two approaches are worlds apart.

Hadronic physics in the late 1960s was couched in terms of thermodynamical models and Regge poles. The elements of today's Standard Model were just starting to take shape; the intermediate vector bosons (W^+, W^- and W^0, as the Z^0 was called then) were thought to have masses in the range of a few giga-electron-volts. The incipient revolution that was to establish the Standard Model was accompanied by another revolution in experimentation. Georges Charpak and collaborators had demonstrated the concept of the multiwire proportional chamber (MWPC) just one year earlier, propelling the community from a photographic-analogue into the digital age with his stroke of genius (*CERN Courier* December 2009 p33). Nor should the sociological factor be forgotten: small groups, beam exposures of a few days to a few weeks, as well as quick and easy access to the experimental apparatuses – all characterized the style of experimentation of the time.

These three elements – limited physics understanding, collaboration sociology and old and new experimental methods – put their stamp on the early programme. From today's perspective, particle physics was at the dawn of a "New Age". I will show how experimentation at the ISR contributed to the "New Enlightenment".

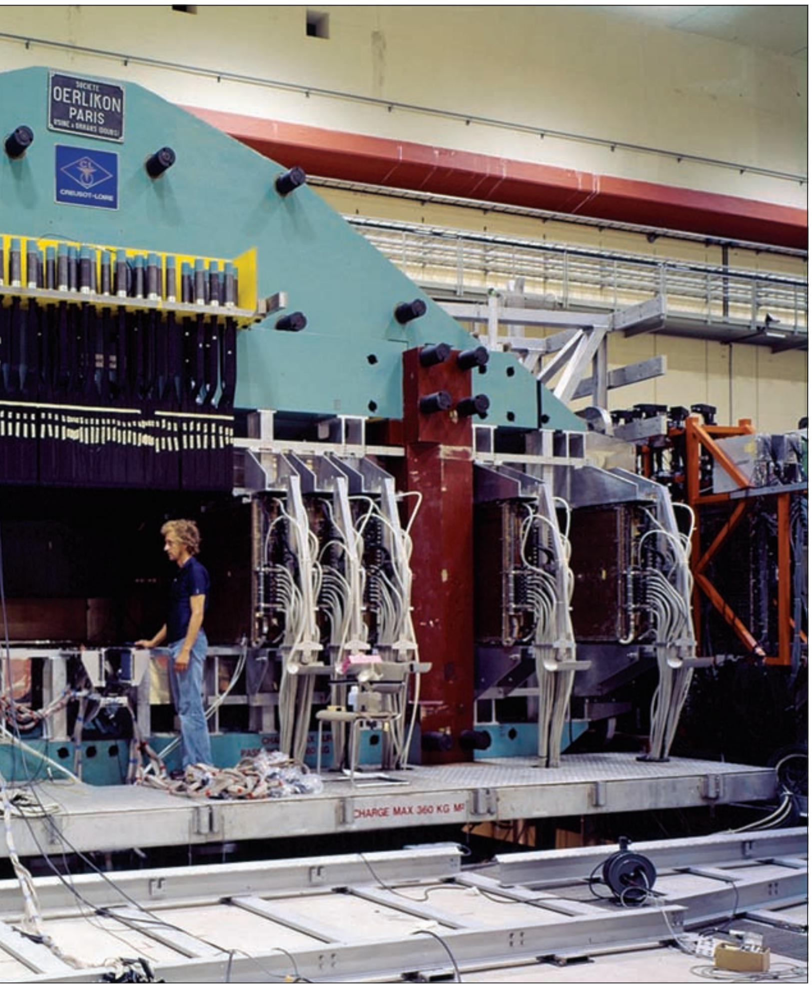
1971–1974: the 'brilliant, early phase'

Maurice Jacob, arguably one of the most influential guiding lights of the ISR programme, called this first period the "brilliant, early phase", in reference to its rich physics harvest (Jacob 1983). The lasting contributions include: the observation of the rising total-cross section; measurements of elastic scattering; inclusive particle production and evidence for scaling; observation of high-p_T production; and the non-observation of free quarks. Several experimental issues of the period deserve particular mention.

The experimental approach matched the "survey" character of this first period. The ISR machine allowed tempting flexibility, with operation at three – later four – collider and asymmetric beam energies. Requests for low- or high-luminosity running and special beam conditions could all be accommodated. A rapid switch-over from one experimental set-up to another at the same interaction point was also one of the guiding design principles. Notwithstanding this survey character, this early period saw several imaginative contributions to experimentation – some with a lasting influence.

The devices known today as "Roman pots" were invented at the ISR with the aim to place detectors close to the circulating beams, which was a requirement for elastic-scattering experiments in the Coulomb interference region. During beam injection and set up these detectors had to be protected from high radiation doses by

on: detectors at the ISR



sisting of two dipole magnets of opposite polarity. It formed the heart of the m^3 and a field in the median plane of 1.14 T. With a gap height of 1.1 m and r featured the first large-scale application of MWPCs (about 70 000 wires), pensator magnets.

retracting them into a "stand-by" position. The CERN-Rome group (R601, for experiment 1 at intersection 6 (I6)) in collaboration with the world-famous ISR Vacuum group developed the solution: the detectors were housed in "pots" made from thin stainless-steel sheets, which could be remotely moved into stand-by mode or one of several operating positions. This technique has been used at every hadron collider since, including at the LHC (*CERN Courier* September 2009 p19).

The first 4π-detector was installed by the R801 Pisa-Stony-Brook collaboration. It used elaborate scintillator hodoscopes, providing 4π-coverage with high azimuthal and polar-angle granularity, well adapted to the measurement of the rising total cross-section and short-range particle correlations. The Split-Field Magnet (SFM), ultimately installed at interaction 4 (I4), was the first general ISR facility. The SFM was groundbreaking in many ways and was proposed by Jack Steinberger in 1969 as the strategy for exploring *terra incognita* at the ISR with an almost 4π magnetic facility.

The SFM's unconventional magnet topology – two dipole magnets of opposite polarity – addressed dual issues: minimizing the magnetic interference with the two ISR proton beams; and providing magnetic analysis preferentially in the forward region, the place of physics interest according to prevailing understanding. It made daring use of the new MWPC technology for tracking, propelling this technique within a few years from 10×10 cm^2 prototypes to instrumentation of hundreds of MWPCs with hundreds of square metres and almost 100 000 electronic read-out channels. The SFM became operational towards the end of 1973 – a fine example of what CERN can accomplish with a meeting of minds and the right leadership. True to its mission this facility was used by many collaborations, changing the detector configuration or adding detection equipment as necessary, throughout the whole life of the ISR. The usefulness of a dipole magnetic field at a hadron collider was later to be beautifully vindicated by the magnetic spectrometer of the UA1 experiment in the 1980s.

The Impactometer was the name given by Bill Willis to a visionary 4π detector, proposed in 1972 (Willis 1972). It anticipated many physics issues and detection features that would become "household" concepts in later years. The 4π-coverage, complete particle measurements and high-rate capabilities were emphasized as the road to new physics. One novel feature was high-quality electromagnetic and hadronic calorimetry, thanks to a futuristic concept: liquid-argon calorimetry. In a similar spirit, an Aachen-CERN-Harvard-Genoa collaboration, with Carlo Rubbia and others, proposed a 4π-detector using total-absorption calorimetry but based on more conventional techniques: among the three options evaluated were iron/scintillator, water Cherenkovs and liquid-scintillator instrumentation. However, the ISRC swiftly disposed of both this proposal and the Impactometer.

The discovery of high-p_T π^0-production at rates much higher than anticipated was one of the most significant early discoveries at the ISR, which profoundly advanced the understanding of strong interactions. Unfortunately, this physics "sensation" proved also to be an unexpected, ferocious background to other new physics. Discovered by the CERN-Columbia-Rockefeller (CCR, R103) collaboration in 1972, the high rate of π^0s masked the search for electrons in the region of a few giga-electron-volts as a possible signal for new physics – as in, for example, the decay of an intermediate vector boson into e^+e^- pairs – and ultimately prevented this collaboration from discovering the J/ψ.

The reaction to this "sensation plus dilemma" was immediate, resulting in several proposals for experiments, all of which were capable of discoveries – as their later results demonstrated. These more evolved experimental approaches brought a new level of complexity and longer lead-times from proposal to data-taking. ▷

ISR 40 years

However, the fruition of these efforts came a few years too late to make the potentially grand impact that was expected from and deserved by the ISR.

In 1973, the CCOR collaboration (CCR plus Oxford) proposed the use of a superconducting solenoid, equipped with cylindrical drift chambers for tracking and lead-glass walls for photon and electron measurements (R108). The Frascati-Harvard-MIT-Naples-Pisa collaboration proposed an instrumented magnetized iron toroid for muon-pair studies and associated hadrons. Originally intended for installation in I8 (R804), it was finally installed because of scheduling reasons in I2 (R209). The SFM facility was complemented with instrumentation (Cherenkov counters and electromagnetic calorimetry) for electron studies, and later for charm and beauty studies.

The 1972 Impactometer proposal was followed with a reduced-scale modular proposal concentrating on e^+e^- and γ-detection, submitted in November 1973 by a collaboration of Brookhaven, CERN, Saclay, Syracuse and Yale. It combined the liquid-argon technology for electromagnetic calorimetry with novel transition-radiation detectors for electron/hadron discrimination. (These latter consisted of lithium-foil radiators and xenon-filled MWPCs, with two-dimensional read-out, as the X-ray detectors.) The advanced technologies proposed led to the cautious approval of the detector as R806T (T for test) in June 1974 with a gradual, less than optimal build-up.

1974-1977: learning the lessons

The first "brilliant period" ended with a Clarion call for the particle-physics community at large and sobering soul-searching for the ISR teams: the discovery of the J/ψ in November 1974. The subsequent period brought a flurry of activities, with the initial priority to rediscover the J/ψ at the ISR.

First was R105 (CCR plus Saclay), which employed threshold Cherenkovs and electromagnetic calorimeters, permitting electron identification at the trigger level. Second, an overwhelmingly clear physics justification for a new magnetic facility with an emphasis on high-p_T phenomena, including lepton detection, emerged. Several groups, including teams from the UK and Scandinavia, were studying a facility based on a large superconducting solenoid, while a team around Antonino Zichichi explored the potential of a toroidal magnetic facility. The inevitable working group, constituted by the ISRC and chaired by Zichichi, received the remit to motivate and conceptualize a possible new magnetic facility.

With exemplary speed – January to March 1976 – the working group documented the physics case and explored magnets and instrumentation, but shied away from making a recommendation, leaving the choice between toroid and solenoid to other committees. It is a tribute to the ISRC that it made a clear recommendation for a solenoid facility with large, open structures in the return yoke for additional instrumentation (particle identification and calorimetry). The toroidal magnet geometry, while recognized as an attractively suitable magnet topology for proton–proton collider physics, was considered too experimental a concept for rapid realization. It would take another 30 years before a major toroid magnet would be built for particle physics, namely the ATLAS Muon Spectrometer Toroid (*CERN Courier* October 2008 p39).

The CERN Research Board did not endorse the ISRC recommendation, possibly being concerned – I am speculating – about the constraints on the long-term impact on the ISR schedule and adequate support among the user community. Despite this negative outcome, the working group had a significant influence on CERN's research agenda. It provided an assessment of state-of-the-art collider experimentation and many members of the working group would use their work to shape the UA1 and UA2 facilities at the Sp$\bar{p}$S programme, which was proposed at about the same time.

Within weeks following the negative decision from the Research Board, some key members of the working group banded together and submitted a new proposal for a fully instrumented facility, building around Tom Taylor's innovative Open Axial Field Magnet (warm Helmholtz coils with conical poles), as a base for the Axial Field Spectrometer (AFS). The time was just right: it took only three months from the submission of the proposal by the CERN-Copenhagen-Lund collaboration in January 1977 to ISRC recommendation and Research Board approval as R807 in April, thanks to the strong and courageous support from the then Research Director, Paul Falk-Vairant, and the committees.

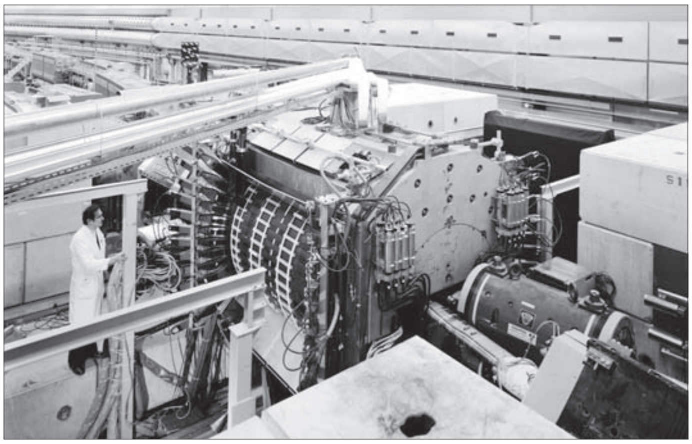
The end of this period also coincided with a turning point in our understanding of hadronic interactions. The early view of "soft" hadronic interactions, limited to low-p_T phenomena, shaped the initial programme. Ten years later, hadrons were still complicated objects but the point-like substructure had been ascertained. Hard scattering became the new probe and simplicity was found at large p_T with jets, photons and leptons. This marked a remarkable "about-turn" in our approach towards hadron physics, which found its expression in the second half of the ISR experimentation and exploitation.

The shock of 1974, followed by the debates on physics and detector facilities in 1976 focused the minds of the various players.

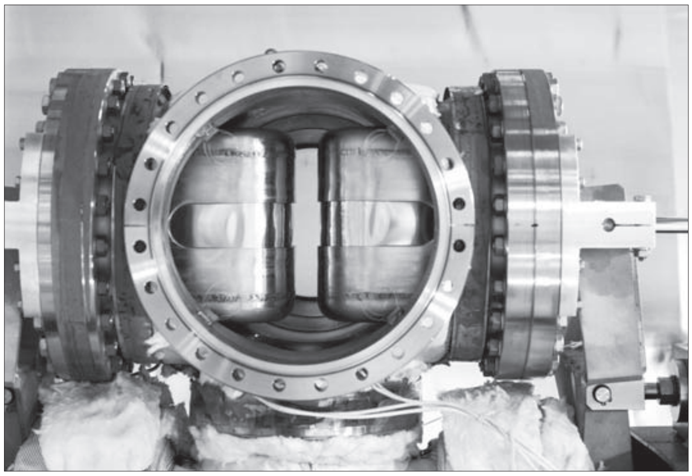
1977–1983: maturity

The shock of 1974, followed by the debates on physics and detector facilities in 1976 focused the minds of the various players. Experimental programmes were being prepared for (relatively) rare, high-p_T phenomena, in a variety of manifestations: leptons, photons, charmed particles, intermediate vector bosons with a sensitivity reaching beyond 30 GeV/c^2 and jets. This strategy was vindicated by the discovery at Fermilab of the Υ in July 1977. This was yet another cruel blow to the ISR, particularly considering that the R806 collaboration saw the first evidence for the Υ at the ISR in November 1977 (Cobb *et al*. 1977).

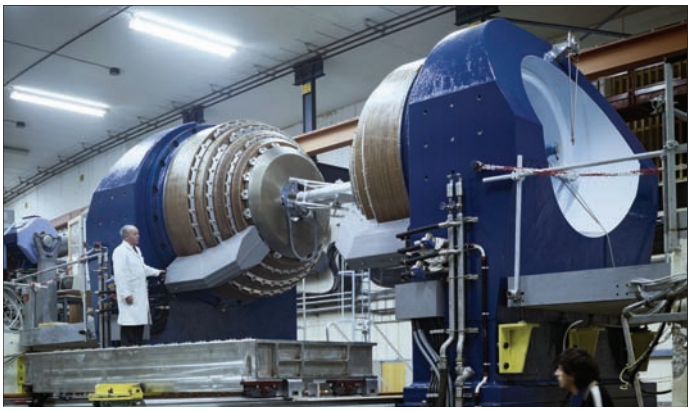
The versatility of the ISR and the incipient Sp$\bar{p}$S development brought also proton–antiproton collisions and light-ion (d, α) physics to the fore. A multifaceted and promising programme – confirmed by the 2nd ISR Physics Workshop in September 1977 – was being put in place. By early 1978 the efforts that were started in 1973 and 1974 brought their first fruits: the R108 collaboration reported their first results at the 1978 Tokyo Conference; the R209



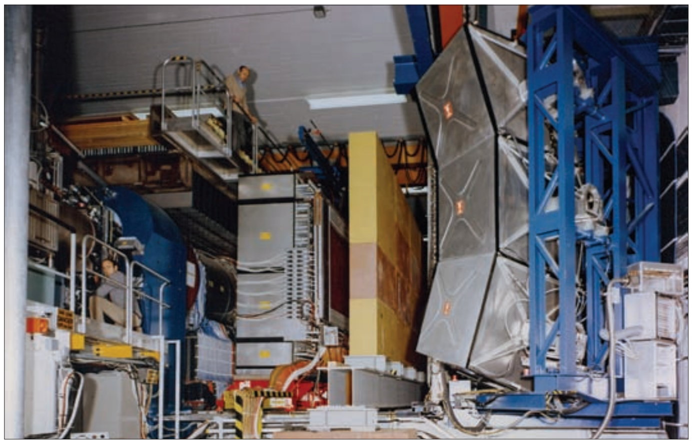
The R108 detector designed by the CERN-Columbia-Oxford-Rockfeller collaboration consisted of a superconducting solenoidal magnet, planes of cylindrical drift chambers, scintillation counters and two arrays, each composed of lead-glass Cherenkov counters



"Roman pots" were invented for the ISR to place detectors close to the circulating beams. They consisted of remotely controlled re-entrant vacuum vessels with thin central windows.



The innovative Open Axial Field Magnet at I8 left the central collision region unobstructed to ease analysis of secondary particles emitted at large angles. The ISR circulating beams passed through a hole in the magnet poles. Weighing in at 300 t, it was brought into operation early in 1979.



In this view of the Axial Field Spectrometer at I8, the vertical uranium/scintillator hadron calorimeter (just left of centre) is retracted to give access to the cylindrical central drift chamber. The yellow iron structure served as a filter to identify muons, with MWPCs and the array of Cherenkov counters to the right.

collaboration had their experiment completed by the end of 1977; R806 was completed by early 1976; and R807 was building up to a first complete configuration towards the end of 1979. A walk round the ISR-ring would have shown the diversity of approaches that were being adopted:

- I1 was home for the R108 collaboration using an advanced, thin (1 radiation length) 1.5 T superconducting solenoid, which would become its workhorse for the subsequent six years. This was instrumented with novel – at the time – cylindrical drift chambers inside and lead-glass electromagnetic-shower detectors outside. Several upgrades brought higher sensitivity through the addition of shower counters inside the solenoid, which resulted in full azimuthal coverage both for charged particles and for photons, as well as higher collision rates, as provided by the inventive ISR teams in the form of warm, low-beta quadrupoles for stronger beam focusing (p27).
- I2 was truly complementary to I1, with the R209 (CERN-Frascati-Harvard-MIT-Napoli-Pisa) collaboration betting on muons and magnetized steel toroids and aiming at dimuon mass sensitivity beyond 30 GeV/c^2. This was combined with a large-acceptance hadron detector, based on scintillator hodoscopes for hadron correlation studies.
- I4 was where the SFM showed its strength as a "user facility", accommodating the 22nd ISR experiment, R422, at the end of the ISR. The open magnet structure invited many groups to add equipment for dedicated low- to high-p_T physics, with remarkable contributions to charm physics and candidates for Λ_b.
- I6 explored physics in the forward region with an unusual magnet, known as the "Lamp Shade". It also had considerable emphasis on charm particles.
- I7 was reserved for "exotica". In the late 1970s, a group operated a streamer chamber as a rehearsal for what later would become UA5 at the Sp$\bar{\text{p}}$S. The last experiment to take data – after the official closure of the ISR on 23 December 1983 – was R704, which used 3.75 GeV/c antiprotons colliding with an internal ▷

ISR 40 years

A view of the Axial Field Spectrometer – the last large experiment at the ISR. The horizontal top and vertical outer arrays of the uranium-scintillator hadron calorimeter are clear to be seen, with the blue cylindrical pole piece of the magnet just visible. The pipes that are visible in front of the pole piece are cryogenic feed pipes for the superconducting low-beta quadrupoles.

gas-jet of H_2 to perform charmonium spectroscopy.

- I8 became the home of R806, with its finest hour being the discovery of prompt γ production, the golden test-channel for perturbative QCD. It entered into a rich symbiotic relation with the nascent AFS (R807) between the end of 1979 and late 1981, when all of R807 was installed except for the uranium/scintillator calorimeter. After a considerable struggle to obtain the uranium plates, this advanced (and adventurous) hadron calorimeter was finally completed by early 1982. One of the significant results obtained with the calorimeter was the first measurement of the jet production cross-section at ISR energies in 1982, consistent with QCD predictions. With the closure of 2π calorimeter coverage, R806 finally had to yield its place, morphing into two novel photon detectors (NaI crystals with photodiode read-out). The Athens-Brookhaven-CERN-Moscow collaboration (R808) provided these detectors, which were placed on opposite walls of the uranium/scintillator calorimeter. In its final years, the ISR machine teams integrated superconducting low-beta quadrupoles, providing peak luminosities in excess of $10^{32}\,cm^{-2}\,s^{-1}$ – a superb rehearsal for the LHC.

The final year, 1983, saw a valiant struggle between the physics communities, hell-bent on extracting the most physics from this unique machine – proton–proton, light ions, proton–antiproton operation with a total of almost 5000 hours of physics delivered – and a sympathetic, yet firm director-general, Herwig Schopper, who presided over the demise of the ISR. In the last session of the ISRC he not only paid tribute to the rich physics harvest but also emphasized the important and lasting contribution of the ISR to experimentation at colliders – or, in the words of one of today's most brilliant theorists, Freeman Dyson: "New directions in science are launched by new tools more often than by new concepts. The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained!"

- I am grateful to M Albrow, G Belletini, L Camilleri and W Willis for discussions and careful reading.

Further reading

J H Cobb *et al.* 1977 *Phys. Lett. B* **72** 273.
M Jacob 1983 *CERN Yellow Report* **83**-1.
W J Willis 1973 *CERN/ISRC/* **73**-1.

Résumé

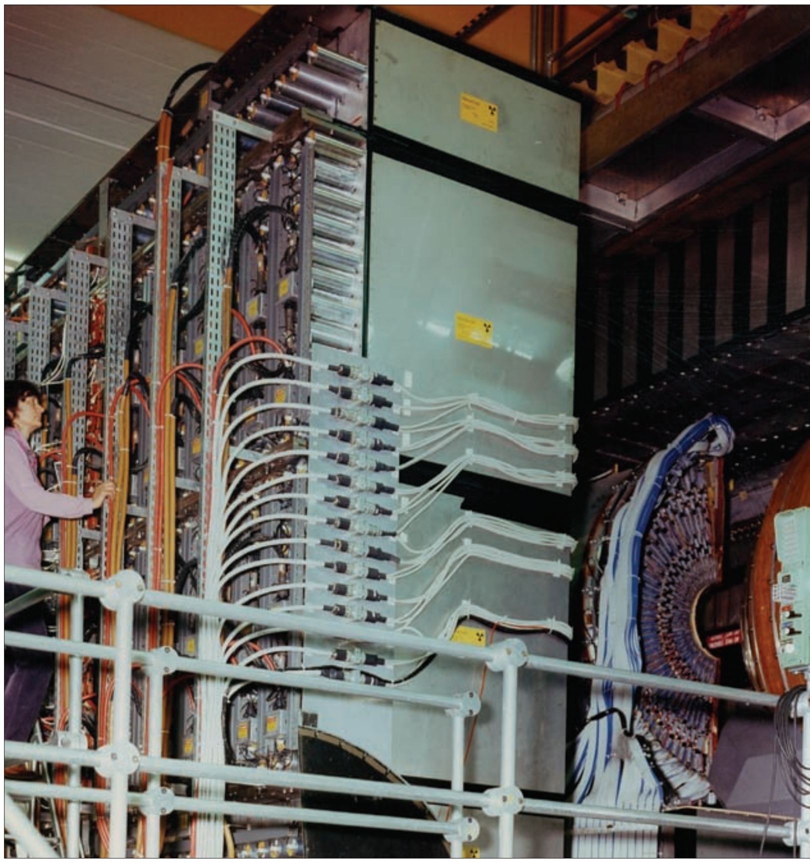
Évolution et révolution : les détecteurs auprès des ISR

Du fait des défis représentés par l'environnement des faisceaux de protons en collision, ainsi que de l'évolution de la physique des particules, il y a eu de nombreuses innovations en matière d'expérimentation aux ISR. Il faut citer en particulier les «pots romains» permettant de placer les détecteurs tout près des faisceaux en circulation ; l'utilisation à grande échelle des chambres proportionnelles multi-fils ; les chambres à dérive cylindriques ; l'utilisation d'argon liquide pour les calorimètres électromagnétiques et d'uranium pour les calorimètres hadroniques. Chris Fabjan décrit comment ces nouveautés ont abouti à de nombreux résultats de physique, malgré le virage à 180° pris dans l'approche de la physique hadronique qui a suivi la «révolution» de novembre 1974.

Christian W Fabjan, Institute of High-Energy Physics, Austrian Academy of Sciences and Vienna University of Technology.

Physics in collision

Michael Albrow takes a personal walk through the physics legacy of the ISR, describing a period that witnessed dramatic shifts in the understanding of hadron interactions.



The Axial Field Spectrometer, with the vertical uranium/scintillator calorimeter and the central drift chamber retracted for service. One coil of the Open Axial Field Magnet is just visible to the right.

It is difficult to imagine a greater contrast than that between the particle detectors installed at the ISR, when the first proton–proton collisions took place 40 years ago, and those ready for the first collisions at the LHC in 2009. Several experiments were waiting in the wings, but in January 1971 just a few simple scintillation counters were in place to detect the first collisions at the ISR, while an oscilloscope trace showed left-moving and right-moving beam halo and some left–right coincidence signals from collisions.

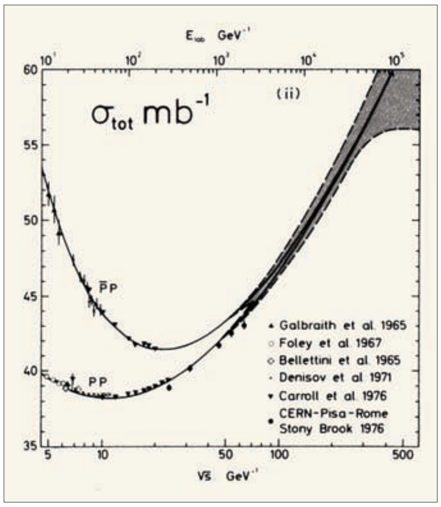
The ISR was in many ways a "transitional machine", a bridge between relatively low-energy, fixed-target accelerators and today's extremely high-energy colliders, as well as between detectors based largely on scintillation and Cherenkov counters, spark chambers or bubble chambers and today's (almost) full-solid-angle trackers, calorimeters and muon detectors that record gigabytes of data per second. For example, the last large ISR experiment, the Axial Field Spectrometer (AFS), pictured right, with its full-azimuth drift chamber and uranium-scintillator calorimeter, bore no resemblance to any of the first-generation experiments but had much in common with the detectors found in later colliders. Also, from the theoretical point of view, the decade of the ISR saw the transition from confusion to today's Standard Model, even though other machines made some dramatic key discoveries – charm, the W and Z bosons, and the third family of quarks and leptons.

Before the start of the ISR, the idea that fractionally charged quarks could be produced there led to a special session of the ISR Committee (ISRC-70-34) that reviewed eight quark-search proposals, of which three were "encouraged". It was later established that fewer than one charged particle in 10^{10} has a charge 1/3 or 2/3. It would be a stretch to claim that this was "observation of quark confinement", but being at a higher energy than other accelerator experiments and with much greater sensitivity than cosmic-ray studies, the ISR played a role in our current belief that free quarks do not exist outside hadronic matter. However, quarks can still be "seen" confined inside hadrons – as the deep-inelastic, electron-scattering experiments at SLAC discovered in 1968.

In 1971, today's theory of strong interactions, QCD, was also "waiting in the wings"; theorists were groping towards the light. Simple (experimentally, not theoretically) two-body reactions such as proton–proton (pp) elastic scattering or $\pi^- + p \rightarrow \pi^0 + n$ were described by Regge theory, which was based on the sound principles of unitarity (no probabilities higher than 1.0), analyticity (no instantaneous changes) and the crossing symmetry ("what goes in can come out") of scattering amplitudes. While Regge theory is still a more useful approach than QCD for those reactions, calculations became difficult because the strong interaction between hadrons is strong and the calculations do not converge. It was also clear that at the higher ISR collision energies – jumping from the 28 GeV beams of the Proton Synchrotron (PS) at CERN and the Alternating Gradient Synchrotron (AGS) at Brookhaven to an equivalent beam energy of 2000 GeV – many hadrons could be created and that Regge theory had little to say about it except for certain "inclusive" reactions, discussed below.

At the first ISRC meetings in 1968 and 1969 the decision was taken to devote one of the eight intersection regions to a "large, general-purpose magnet system". Three systems had been proposed and ▷

ISR 40 years



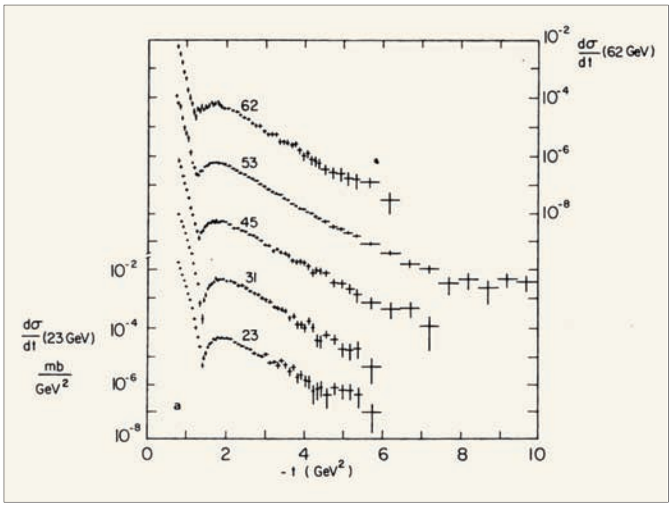


Fig. 1 (far left). The total p̄p and pp cross-sections as a function of centre-of-mass-energy in 1976, with a higher energy extrapolation using dispersion relations. Pre-ISR data extended only to 10 GeV.

Fig. 2. Differential cross-sections as a function of four-momentum-transfer-squared (-t) showing the diffraction minimum.

a working group was asked to make a rapid decision. The choice fell on the Split Field Magnet (SFM) – primarily because its field was strong and simple (a dipole) in the forward directions, where most particles would be produced. Unfortunately, the field was zero at 90° and, with pole pieces above and below the beams, it was unsuitable for physics at high-transverse momentum, p_T. By 1978 the SFM had been upgraded with greatly improved detectors, but it remained focused on forward and diffractive particle production.

Hadronic diffraction at high energies, the simplest example being elastic scattering, is described in Regge theory as arising mainly from the exchange of a pomeron between the scattering protons. This has quite different properties from other, virtual meson (or "Reggeon") exchanges. Before the ISR, the total pp cross-section was known to decrease with energy, as it did for πp (but not for K^+p). The early discovery that it rises (as in figure 1), which was a surprise to many, had been predicted if, and only if, the pomeron is an allowed exchange. Today we take it for granted that the total pp cross-section rises with energy but at the time the rise led to much experimental and theoretical activity: does the proton become more opaque? Or larger? Or both? Beautiful experiments, for example by the CERN-Rome group that developed "Roman pots" to place detectors very close to the circulating beam, showed that the slope (in momentum transfer, t) of elastic scattering increases with energy. Thus protons in effect become larger but they also become more opaque. Roman pots have been used at all subsequent hadron colliders, including the LHC.

The first ISR experiments were mostly concerned with strong interactions at large distances, or small momentum transfers. On the menu, in addition to searches for free quarks, monopoles and weak vector-bosons, were elastic scattering and low- and high-multiplicity final states. How could such complicated final states be handled experimentally? A popular approach, still common today, was to measure the angular and momentum distributions of a single particle from each collision and ignore all of the others – the so-called "inclusive single particle" spectra. As mentioned, Regge theory could be adapted to describe such data, but only at low p_T. Experiment R101 (intersection 1, experiment 1) was simplicity itself: literally a toy train with photographic emulsions in each wagon. When colliding beams were established it was shunted alongside the collision region, and left there to measure the angular distribution of produced particles. The first physics publication from the LHC was of the same distribution, although not measured with a toy train set!

Pre-ISR experiments at the PS typically installed detectors for a few weeks or months and then moved on. It was (jokingly?) said that you should not have more photomultipliers than physicists. That mindset persisted in the early ISR days. Four experiments shared Intersection 2 (I2). Three single-arm spectrometers measured inclusive particle spectra at small and large angles. They discovered Feynman scaling – in which forward particle spectra are proportional to the beam energy – at small (but not at large) p_T, high-mass diffraction and co-discovered high p_T particles. Feynman scaling was shown to be approximate only; indeed, scaling violations are a key feature of QCD. Two of these spectrometers were combined in 1975 to look for hadrons with open charm but, in retrospect, the acceptance was far too small. The fourth experiment at I2 was a large, steel-plate spark chamber designed to look for muons from the decay of the then-hypothetical W boson, supposing its mass might be only a few giga-electron-volts. (It was later found to have a mass of 81 GeV, much too high for the ISR.) Unfortunately, with hindsight, the muon detector was not made in two halves on opposite sides so as to have more acceptance for muon pairs; had the collaboration persevered as the luminosity increased they might have seen $J/\psi \rightarrow \mu^+\mu^-$. One reason they gave for not persisting was that the background from charged $\pi \rightarrow \mu$ decays was much larger than they had expected.

The observation of unexpectedly high rates of high-p_T hadron production at the ISR was a major discovery

The reputation of the ISR as a physics-discovery machine suffered greatly from missing the discovery of the J/ψ particle, which made its dramatic entrance in November 1974 at Brookhaven's AGS and the e^+e^- collider at SLAC. The "November Revolution" convinced remaining doubters of the reality of quarks, with important implications for electroweak interactions. How did the ISR miss it? There is no single answer. Today's intense interaction between theorists and experimenters hardly existed in the early 1970s – but even if it had, there would have been few, if any, voices insisting on a search for narrow states in lepton pairs.

R103, one of the early experiments designed to measure electron (and π^0) pairs by the CERN-Columbia-Rockefeller collaboration (CCR), already had two large lead-glass arrays on opposite sides of the collision region in 1972–1973 and found an unexpectedly high rate of events. This was the important discovery of high-p_T hadron production from quark and gluon scattering, but it had the unfortunate consequence that the team had to turn their trigger threshold (with 10 Hz rate-limited spark chambers) up to 1.5 GeV, just too high to accept $J/\psi \rightarrow e^+e^-$. This was followed in 1974 by R105 (by CCR plus Saclay), which included a gas Cherenkov counter. There were about a dozen J/ψ events on tape at the end of 1974 but not clear enough and not in time for a discovery. However, before November 1974, R105 (together with Fermilab experiments) had already discovered direct lepton production, in a proportion e/π of 10^{-4}, which was later described by a "cocktail" of processes (J/ψ, open charm and Drell-Yan $q\bar{q}$ annihilation).

High-p_T particle production was not promoted by theorists until after the ISR started up. In December 1971, Sam Berman, James Bjorken and John Kogut (BBK) used Richard Feynman's parton model, which was supported by deep-inelastic electron scattering, to predict a much higher production rate of hadrons and photons at high p_T than expected from a simple extrapolation of the then-known exponentially falling spectra (Berman *et al.* 1971). The rates that they calculated were for electromagnetic scattering of the charged partons, but they noted that these were lower bounds and strong scattering (the exchange of a spin-1 gluon) would give much larger cross sections. They also suggested that scattered partons (now known to be quarks and gluons) would fragment into jets ("cores") of hadrons along the direction of the parent parton. Feynman had similar ideas.

The observation of unexpectedly high rates of high-p_T hadron production at the ISR was a major discovery (figure 3); it showed that parton–parton scattering indeed occurred through the strong interaction, but with a weaker coupling than between two protons. This behaviour was later understood in QCD in terms of a decreasing strong coupling at smaller distances – the phenomenon of asymptotic freedom for which David Gross, David Politzer and Frank Wilczek received the Nobel Prize in Physics in 2004. Unfortunately, the high p_T discovery – made by the CCR collaboration (for π^0) and the British–Scandinavian and Saclay-Strasbourg collaborations (for charged hadrons) – masked the J/ψ in the e^+e^- channel. As noted earlier, high-p_T pions produced an unexpected large background also to muon measurements, so the muon pairs were not pursued.

The high-p_T jets predicted by BBK took another decade to be discovered in hadron–hadron collisions, almost 10 years after jets had been seen in e^+e^- collisions. One needed to select events with large, total transverse energy in an area much greater than the jets themselves, and with a hadron calorimeter with excellent energy resolution as in the AFS (see photo p39). After a long struggle, the collaborations of the AFS (R807) at the ISR and UA2 at the Super Proton Synchrotron (SPS) running in proton–antiproton ($p\bar{p}$) collider mode ($Sp\bar{p}S$), submitted papers on the same day to *Physics Letters* with convincing evidence for jets. The ISR data extended to a jet-transverse energy, E_T = 14 GeV, but the $Sp\bar{p}S$ data reached 50 GeV with 1/1000 the luminosity of the ISR. At all post-ISR colliders, high-E_T jets are considered as "objects" that are almost as clear as electrons, muons and photons. The experiments at the LHC are already studying the 2-jet mass spectrum for evidence of new particles with masses of up to 2 TeV.

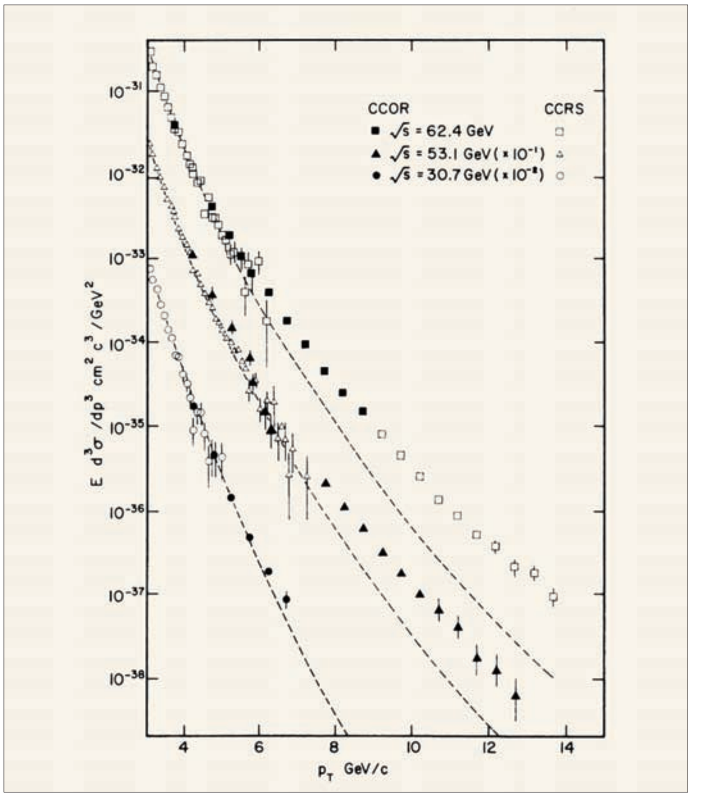
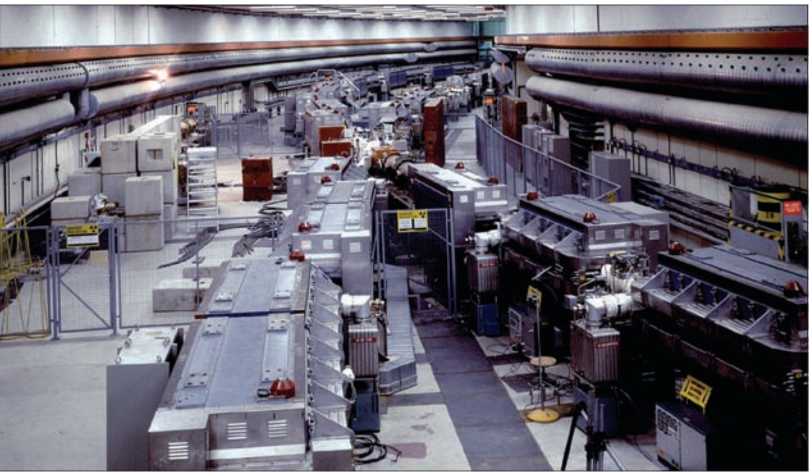


Fig. 3. The inclusive π^0 distribution from the CERN-Columbia-Oxford-Rockefeller and CERN Columbia-Rockefeller-Saclay collaborations shows how the data at large transverse momentum are orders of magnitude above expectations at the time (not shown).

The scattering of two quarks is described in QCD by the exchange of a gluon – the strong-force equivalent of the photon. Gluons must also be present as constituents of protons, being continuously emitted and absorbed by quarks. The "discovery of the gluon" is credited to the observation at DESY of e^+e^- annihilation to three jets, which showed clearly that outgoing q and $\bar{q}$ jets could be accompanied by gluon radiation. Although not as dramatic, it was clear at the ISR that the high-p_T particle production required more scattering partons in the proton than just the three valence quarks, and that the inclusion of gluons gave sensible fits to the data.

A related ISR discovery was the production of high-p_T photons, produced directly rather than coming from the decay of hadrons (such as π^0); these are direct probes of the processes $q + \bar{q} \rightarrow g + \gamma$ and $q + g \rightarrow q + \gamma$. Direct high-$p_T$ $\gamma\gamma$ production was later observed. Now, at the LHC, direct $\gamma\gamma$ production is a promising search channel for the Higgs boson.

With the advent of the parton model most physicists – theorists and experimenters – were happy to be able to leave the ▷



Thanks to a design that incorporated two independent rings, the ISR, seen here in 1983, proved to be a truly versatile machine.

complicated, difficult world of hadrons at the femtometre scale and dive down to the next, partonic, layer, which was both simpler theoretically and experimentally exciting. But what they left behind is still unfinished business. While QCD is frequently said to be *the* theory of strong interactions it still can not calculate hadron processes. Every hadronic collision involves large-distance processes, which we are not yet able to calculate using QCD. The problem is that the strong interaction becomes too strong when distances become as large as the size of hadrons (about 1 fm); indeed, this is responsible for the permanent confinement of quarks and gluons inside hadrons. Calculations that work well on smaller distance scales (or larger momentum transfers), do not converge; they blow up and become intractable.

So, while QCD cannot be used to calculate small-angle elastic scattering, Regge theory with pomeron exchange can describe it, although we recognize that it is less fundamental. High-mass diffraction provided a new tool for studying pomeron exchange and eventually double-pomeron reactions such as pomeron + pomeron $\rightarrow \pi^+\pi^-$ (and to other hadron states) were found. We now understand that the pomeron is, to leading order, a colourless pair of gluons. The idea that there could be quarkless hadrons, or "glueballs", also motivated these studies. Not finding them implied that if they exist they must be heavy (at least about 1 GeV) and so short-lived that they could not emerge from the collision as free hadrons.

The pomeron itself is not a particle, but an exchanged "entity" with Regge properties (complex angular momentum, negative mass-squared). Heroic attempts have been made to calculate its properties in QCD. Perhaps one day Regge theory will be proved to be a large-distance limit of QCD. While at the ISR, central masses in double-pomeron reactions were limited to less than about 3 GeV, at the LHC they extend to masses a hundred times greater, allowing Higgs bosons – if they exist – to be produced in the simple, final state p + H + p, with no other particles produced. Both the ATLAS and CMS collaborations have groups proposing to search for this process, which can be called "diffractive excitation of the vacuum" because the Higgs field fills (in some sense "is") the vacuum.

A string theory of hadrons was briefly in vogue in the 1970s, with $q\bar{q}$ mesons as open strings and pomerons as closed strings. Regge theory is compatible with this idea and can explain the relationship between the mass and spin of mesons. Thirty years later, string theory is in vogue once again but on a much smaller, near-Planck scale, with electrons and quarks as open strings and gravitons being closed strings. Despite the enormous progress in collider technology, no one can imagine a collider that could see such superstrings, unless extra dimensions exist on an LHC scale.

Many other studies of strong interaction physics were made at the ISR. These included particle correlations, short-range order in rapidity, resonance production etc. Multiparticle forward spectrometers also made systematic studies of diffraction, including the production of charmed baryons and mesons.

With its two independent rings, the ISR was more versatile than any other collider – then or since. Not only were pp collisions studied, but antiprotons and deuterons and α-particles were also made to collide with each other and with protons. For the last run, an antiproton beam was stored in the ISR for more than 350 hours, colliding with a hydrogen gas-jet target to form charmonium. So the swansong of the ISR was a fixed-target experiment measuring the very particle that it had missed because high p_T physics got in the way!

The ISR machine was outstanding and the detectors eventually caught up and led the way to the modern collider physics programme. When it was closed in 1984, there was still plenty to do, despite the higher energy $Sp\bar{p}S$ collider, whose UA1 and UA2 detectors owed so much to the ISR experience. However, the ISR had to make way for the Large Electron–Positron collider, which in turn made way for the LHC, so that proton–proton collisions are once again exciting.

• This has been a personal, and far from comprehensive, view of the physics that we learnt at the ISR. I thank Leslie Camilleri, Luigi Di Lella and Norman McCubbin for careful reading and redressing some balance. I also pay homage to Maurice Jacob, who did so much to bridge the gap between theorists and experimenters.

• Further reading

S M Berman, J D Bjorken and J B Kogut 1971 *Phys. Rev.* **D4** 3388.
C W Fabjan and N McCubbin 2004 *Phys. Rep.* **403-404** 165.
G Giacomelli and M Jacob 1979 *Phys. Rep.* **55** 1.

Résumé

La physique en collision

À bien des égards, les anneaux de stockage à intersections (ISR) ont constitué une machine de transition, une passerelle entre des accélérateurs à cible fixe aux énergies relativement faibles et les collisionneurs aux énergies extrêmement élevées d'aujourd'hui. Cette machine a également connu une période marquée par une véritable révolution dans la compréhension des interactions hadroniques, la théorie se transformant pour passer au modèle standard d'aujourd'hui. Même si sa réputation a souffert du fait que certaines découvertes lui ont échappé, cette machine a apporté une contribution importante à la physique hadronique. Dans cet article, Michael Albrow passe en revue la physique issue du premier collisionneur de protons, et l'héritage laissé à son successeur, le LHC.

Michael Albrow, Fermi National Accelerator Laboratory.

Faces & Places

CELEBRATION

A century for François de Rose

François de Rose, one of the founder fathers of CERN, turned 100 on 3 November 2010. Three weeks later he was at the CERN Control Centre to hear for himself about the progress made since CERN was formally established in 1954.

In the early 1950s, de Rose, a French diplomat, worked with some of the greatest physicists of the time to establish CERN (*CERN Courier* October 2010 p26). Returning to CERN on 24 November, he was able to marvel at how far the laboratory has advanced since then. Surrounded by the hive of activity of the operations teams – including those from the PS, an accelerator he inaugurated as president of the Council in 1960 – de Rose shared his emotions: "I feel a great sense of pride and admiration when I see that the ideals of peace, progress and universality that created CERN have been preserved after so many years. That the spirit of the founders has endured over the years confirms that their ideals were right. Their wildest dreams have been exceeded."

François de Rose in expressive mood in the CERN Control Centre.

CERN also organized a birthday celebration for the diplomat, where de Rose reiterated his sense of pride for CERN with a touch of humour: "You know, it is not an achievement to reach 100 years. With a little patience, you can get there eventually. On the other hand, every day there are real achievements here at CERN." He left with a promise to return for the discovery of the Higgs boson, which he estimates will be "in two years".

PRIZES

Medals for Kinoshita and Wolf

The Gian-Carlo Wick medal has been awarded to Toichiro Kinoshita, emeritus professor in physics at Cornell University. Antonino Zichichi, president of the World Federation of Scientists (WFS), presented the medal at the opening of the 43rd International Seminar on Planetary Emergencies at the Ettore Majorana Centre of Scientific Culture in Erice. Kinoshita is awarded the prize "for his fundamental and very careful calculations in quantum electrodynamics with deep consequences for physics of fundamental particles". The gold medal is awarded annually in memory of Gian-Carlo Wick by a scientific committee of the WFS, chaired by Tsung Dao Lee.

Toichiro Kinoshita (left) receives the Gian-Carlo Wick medal from Antonino Zichichi, president of the World Federation of Scientists, as Tsung Dao Lee looks on. (Image credit: EMFSCS.) Right: Günther Wolf. (Image credit: DESY.)

Günter Wolf of DESY is honoured with the 2011 Stern-Gerlach Medal, which is the highest award of the German Physical Society, for achievements in experimental physics. In outlining its award decision, the society stated: "With his important work and discoveries, he has significantly influenced both the development of this field and the establishment of the Standard Model of elementary particles." The medal will be presented in the coming year at the society's annual conference.

Meetings

The **PAC'11 conference** will take place at the Marriott Marquis Hotel, New York on 28 March – 1 April. The scientific programme includes invited talks, contributed oral presentations, poster sessions and an industrial forum. A special session on 27 March is devoted to highlighting the participation and contribution being made by young student researchers. The conference includes many satellite meetings; it is also an excellent opportunity for industrial representatives to interact with the accelerator community. For more details about this conference, see www.bnl.gov/pac11.

The **11th International Conference on Applications of Nuclear Techniques** will take place on 12–18 June in Crete. This series of meetings has provided a forum for scientists from many countries to present their research and development in a broad spectrum of applications of nuclear techniques, including unique and novel developments for particle accelerators. Papers presented at the conference will be published in refereed conference proceedings. The event will take place at the Rithymna Beach Hotel, which has been the location of the last four conferences, situated near the historic city of Rethymnon and 78 km west of Heraklion. The deadline for the submission of abstracts is 15 February. For more details about the conference topics, abstract submission or the venue, see the website www.crete11.org.

The second **International Particle Accelerator Conference**, **IPAC'11**, will take place at the Kursaal, San Sebastian, in Spain, on 4–9 September. This will be the second conference of the new IPAC series, which has evolved from the three regional conferences APAC, EPAC and PAC. The programme includes plenary sessions and parallel sessions with invited and contributed presentations. There will also be poster sessions, including a special poster session for students, held during conference registration on 4 September. An industrial exhibition will also take place on 5–7 September, with a special session for industry on 7 September. The EPS-AG Accelerator Prizes will be awarded on 8 September and the recipients will give talks on their prizewinning work. Interested participants should take careful note of the deadlines for registration and reservation of accommodation, and in particular for abstract submission by 13 April. For more details, see the website www.ipac2011.org.

Appointments

ATLAS physicist heads Colombian university

Marta Losada has been elected president of the University Antonio Narino in Colombia for the period 2010–2013.

After receiving a PhD from Rutgers University, she was a post-doc at CERN and has led the Colombian research group working in the ATLAS experiment. She has also participated in the Science, Technology and Innovation Policy Program of the Kennedy School of Government of Harvard University.

The University Antonio Narino has some 14 000 students and 1500 professors. One of the most important universities in Colombia, it was the first from the country to take part in the ATLAS experiment and it actively participates in CERN's research programme.

Marta Losada. (Image credit: M Losada.)

New spokespersons for the ALICE and LHCb experiments at CERN

Changes at the helm of both the ALICE and LHCb collaborations are taking place this year. Paolo Giubellino is the new spokesperson for ALICE from 1 January and Pierluigi Campana will become spokesperson for LHCb in May.

Giubellino, of Turin university and INFN, takes over from Jürgen Schukraft who has been at the helm of the ALICE experiment since its inception in 1991 (*CERN Courier* October 2008 p51). As deputy spokesperson since 2004, he has overseen the ALICE detector largely completed and witnessed the exciting first collisions of protons and subsequently heavy ions in the LHC.

Campana, from INFN and the Laboratori Nazionali Frascati, was the national INFN spokesperson for LHCb from 2005–2009, and now succeeds Andrei Golutvin (*CERN Courier* October 2008 p4). He will hold the position for three years, as LHCb makes rapid progress with its studies, in particular of rare decay processes of B mesons at the LHC.

With Fabiola Gianotti and Guido Tonelli already in place as the spokespersons for ATLAS and CMS, respectively, these recent appointments mean that in May the four large LHC experiments will all be spearheaded by Italians.

EPS-HEPP calls for nominations

The High Energy and Particle Physics Board of the European Physical Society (EPS-HEPP) is calling for nominations for the following prizes in 2011: the Giuseppe and Vanna Cocconi Prize; the Gribov Medal; the Young Physicist Prize; and the Outreach Prize. The prizes will be awarded in a ceremony at the international Europhysics Conference on High Energy Physics on 21–27 July, in Grenoble.

Information about these prizes can be found on the HEPP Board website (http://eps-hepp.web.cern.ch/eps-hepp/prizes.php) together with a list of former prizewinners.

Nominations should be sent to Fabio Zwirner (fabio.zwirner@pd.infn.it) for the Cocconi Prize and the Gribov Medal, to Paris Sphicas (paris.sphicas@cern.ch) for the Young Physicist Prize and to Daniel Wyler (wyler@physik.uzh.ch) for the Outreach Prize.

All nominations must be received by 15 March 2011.

WORKSHOP

Nuclear strangeness comes to Trento

The Strangeness in Nuclei workshop, which took place at the ECT* in Trento on 4–8 October, brought together some 50 international experts and young researchers to discuss recent results and exchange ideas about future studies in low-energy QCD and particle astrophysics. The workshop showed that the field continues to have a promising future, with an ideal mix of young and expert theoreticians and experimentalists, understood items and deep puzzles in a range of topics.

One of the subjects discussed was hyper-nuclear spectroscopy, including strangeness $S = -2$ hyper-nuclei and their weak decays, with recent results from the FINUDA experiment at the DAΦNE collider at INFN's Laboratori Nazionali di Frascati. This is a topic that will also be addressed in next-generation experiments proposed for J-PARC in Japan and the Facility for Antiproton and Ion Research (FAIR) in Germany. These will search for double-Λ nuclei and the synthesis of cascade (Ξ) nuclei. Heroic theoretical efforts were also presented for solving the four- and even five-body nuclear structure of double-Λ nuclei for studying Λ–Λ interaction in nuclei.

In the area of antikaon–nucleon/nucleus interactions at low energy, the workshop heard of new results from the analysis of kaonic hydrogen, as well as the first kaonic ^{3}He spectra from the SIDDHARTA experiment at DAΦNE. The data on kaonic hydrogen agree well with the results of chiral dynamics, with coupled-channel techniques taking care of the complex nature of the antikaon–nucleon interaction that is governed by hyperon resonances close to threshold. In future, the SIDDHARTA2 experiment will measure kaonic deuterium for the determination of isospin-dependent scattering lengths. In addition, the E17 experiment, a precision study of kaonic X-ray spectroscopy of kaonic ^{3}He and ^{4}He, will take data in the near future at J-PARC.

Excited hyperons and their interactions with nuclei, in particular the double-pole property of the Λ(1405/1420) resonance, are crucial for understanding strangeness in nuclei. New data from the HADES and FOPI experiments at GSI, provide key information for theoretical understanding of the low-energy antikaon–nucleon interaction and led to much discussion.

The search for strongly bound, dense antikaonic light nuclei has reached a new phase with the results on the reaction $pp \rightarrow K^+\Lambda p$ at 2.85 and 2.50 GeV presented by the DISTO experiment at Laboratiore National Saturne. They see a resonance X(2265) in the two-body channel $pp \rightarrow K^+X$ at high-transverse momentum transfer; it is deeply bound, with a binding energy of 103 MeV and a width of $\Gamma_X = 118$ MeV. Its large width, mainly in the Λp channel, and production at high momentum but low angular-momentum transfer, is evidence that the X(2265) is a compact system – a gateway to dense, cold hadronic matter. There were many debates about its structure, together with presentations of various theoretical predictions. The FOPI experiment also presented preliminary data from proton–proton reactions at an energy of 3.1 GeV.

Final results were reported on Λ–n and Λ–p correlations following the absorption of stopped K^- in ^{4}He. These have been measured in the E549 experiment at KEK and give indications of deeply bound tri-baryon systems. E15 at J-PARC is going to search for the K^-pp state using the in-flight $K^-(^3\mathrm{He}, n)$ reaction with a kinematically complete experimental set-up. The AMADEUS experiment, with its 4π coverage of all charged and neutral particles, will complement this type of study at DAΦNE. The theoretical community is extremely keen to solve the di-baryon $S = -1$ puzzle, which is of astrophysical relevance in the context of the structure of the high-density phase within a neutron star.

Exploratory results on antiproton annihilation at rest in H, D and ^{4}He targets with the OBELIX experiment at CERN showed double-K^+ reaction-yields in ^{4}He of about 10^{-4} in certain channels. It has proposed to study antiproton annihilation at rest in ^{3}He to produce the doubly-strange di-proton, K^-K^-pp, with the E15 at J-PARC.

A session dedicated to the LEANNIS Network in HadronPhysics2 in EU Framework Programme 7 focused on low-energy antikaon–nucleon/nucleus interaction studies. The perspectives in the field were discussed in the context of future EU programmes.

● ECT* was organized by Tullio Bressani (University and INFN Torino), Catalina Curceanu (LNF-INFN), Paul Kienle (TU München), Toshimitsu Yamazaki (University of Tokyo and RIKEN), and Johann Zmeskal (SMI-Vienna). For details, see www.smi.oeaw.ac.at/ect_star_2010/.

Birthdays

Alexander Skrinsky turns 75...

Alexander ("Sasha") Skrinsky, director of the Budker Institute of Nuclear Physics turned 75 years on 15 January.

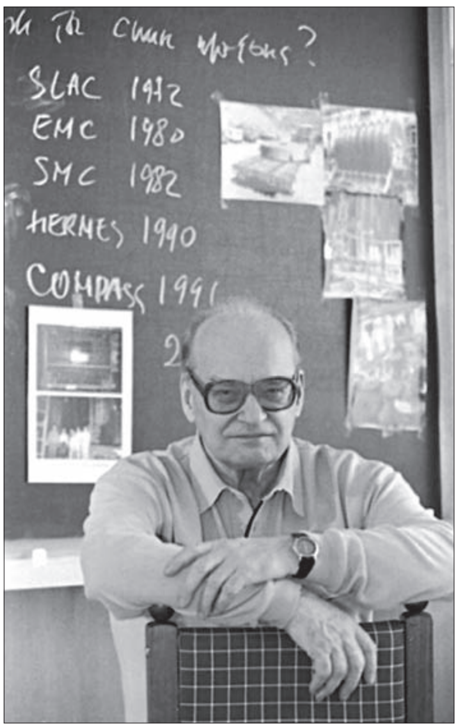
An outstanding physicist and member of Gersch Budker's Siberian school, Skrinsky went to Novosibirsk after graduating from Moscow University in 1959 and progressed to become director. There, he led the team pioneering the design and construction of the world's first electron–electron and electron–positron colliders. Their successful commissioning brought him the Lenin Prize in 1967. In the 1970s, together with Gersch Budker and Vladimir Balakin, he suggested the conceptual design of a linear collider. At about the same time he was among those who worked on the development of electron cooling, exploited today all over the world to arrange collisions of heavy particles.

Skrinsky has always had broad physics interests, bringing many new ideas that were successfully realized: resonance depolarization for high-precision determination of the absolute beam energy (the State Prize of the USSR in 1989), pioneering studies of beam–beam effects in electron colliders, the optical klystron, industrial applications of synchrotron radiation and radiation technologies, a concept for a muon collider etc. For his numerous achievements in accelerator physics and its applications he was twice awarded the State Prize of the Russian Federation (2001, 2005). Recently he has supported the design of the Super-tau-charm factory in Novosibirsk, a unique facility for high statistics studies of tau-lepton and charmed-quark interactions.

An active member of several international committees, Skrinsky has always played an important role in the development of accelerator laboratories and their scientific programmes in Russia. His activity and well balanced ideas about international co-operation proved to be extremely useful in the turbulent 1990s, in particular, during the construction of the LHC and its detectors at CERN. Skrinsky has supervised numerous students, many of whom are now members of the Russian Academy of Science and university professors; some play a key role in accelerator centres the world over.

Skrinsky. (Image credit: M Kupina.)

...while Igor Savin reaches 80



Igor Savin. (Image credit: JINR.)

Igor Alekseevich Savin, well known for pioneering work in experimental particle physics, celebrated his 80th birthday on 7 December. One of the rare specialists in structure functions of nucleons, he established a new research trend at JINR, namely experimental studies of nucleon and nuclear structure

Savin's scientific carrier has been closely connected with JINR in Dubna, where he started work in 1955 at the Laboratory of V I Veksler, later becoming head of the department where particle-physics research was conducted. He then founded the Laboratory of Particle Physics at JINR and served as its director from 1989 to 1997.

Since 1965 he has taken part in experimental programmes at CERN, first in studies of CP violation and then on the partonic structure of the nucleon and nuclei. He led experiments with neutral kaons at Serpukhov, demonstrating that the total cross-sections of neutral kaon and antikaon scattering on protons become equal as the energy rises – in agreement with the Pomeranchuk theorem.

During the 1980s, Savin worked with the BCDMS collaboration at CERN. The Dubna team that he led made important contributions to hardware for the NA4 experiment in the SPS muon beam. His group initiated the experiment's measurement in 1982 of the interference of electromagnetic and weak currents arising from the exchange of the Z boson, which was still undetected. This was the first evidence of electroweak asymmetry in the muon channel.

In the 1990s, Savin instigated JINR's participation in the HERMES experiment at DESY's HERA collider and in the Spin Muon Collaboration at CERN. The studies of the hadron structure that began at CERN in the late 1970s now continue with the COMPASS experiment. He was one of the first leaders of the JINR team involved in the project. Savin is the author of 250 scientific publications, including papers on modern problems of experimental particle physics, physics experiment methodology, reviews in prestigious journals and interesting lectures. His zeal and creativity, highest professionalism and leadership qualities have won him international respect and acknowledgement.

'Diffraction' reaches its first decade

The charming Italian resort of Lecce, on the coast overlooking both the Adriatic and Ionian seas near Otranto, was host to Diffraction 2010, the International Workshop on Diffraction in High-Energy Physics. The sixth meeting in the series of biennial workshops, it was also the 10th anniversary of the first meeting in Cetraro in 2000. The event confirmed the continuing success of the Diffraction series, with 92 participants from 17 countries, many of them PhD students and young post-docs. The scientific programme benefited much from talks by classic experts in the field, including Victor Fadin and Lev Lipatov, as well as by many young researchers. The meeting was dedicated to the memory of Alexei Kaidalov, who pioneered the field of diffractive processes and was an irreplaceable friend of the workshop (*CERN Courier* October 2010 p39). His outstanding scientific contributions and the gentle personality were recalled in two touching speeches by Eugene Levin and Alan Martin.

In a nutshell, diffraction in particle physics refers to high-energy scattering processes dominated by the exchange of vacuum quantum numbers between colliding objects, the experimental signature for that being a "rapidity gap" between particles or systems of particles in the final state. Such processes can be described in terms of a Regge trajectory, called the pomeron (after the Russian physicist Pomeranchuk), whose nature and properties still remain the subject of heated debates. What is special about diffraction is the opportunity that it allows to scan the "hardness" of the interaction in a broad region, which makes it a unique tool for studying the interplay between "soft" and "hard" phenomena of strong interactions. This is also reflected in the variety of theoretical approaches: it can be convenient to work with perturbative quarks and gluons, or to take the Regge-theory inspired approach towards pomeron exchange, or to introduce new degrees of freedom characteristic of strongly coupled theories.

The experimental study of diffraction was dominated over the past decade by DESY's electron–proton collider HERA and although data-taking there has stopped, new results continue to appear. The ZEUS, H1 and HERMES collaborations presented new results on inclusive and various exclusive reactions, in particular deeply virtual Compton scattering, which is being actively studied by theorists and gives access to a broader understanding of proton structure, through generalized parton densities (GPDs).

More recently, with data from the Tevatron, Fermilab's proton–antiproton collider, on the proton–proton total cross-section and single or double diffractive events, the focus has shifted towards diffractive phenomena at hadronic colliders. Konstantin Goulianos presented new diffraction results from the Tevatron, as well as an intriguing phenomenological analysis based on the dynamics of rapidity gaps.

The LHC will soon lead the way in diffraction physics. This drift was already visible in the presentations, with the keywords "prospect" and "perspectives" changing to "results". One of the hottest topics for the near future of the LHC was the discussion on the central exclusive production of systems separated from the protons by large rapidity gaps, the major goal being the double-diffractive Higgs boson production at the LHC, promoted by Valentin Khoze.

The session on spin physics included new results from the COMPASS, PHENIX, STAR and HERMES experiments, new data and future plans from Jefferson Lab, as well as theoretical approaches to spin asymmetries in hadronic reactions. The current situation in this field was well covered by Vincenzo Barone, Alexei Prokudin and Jacques Soffer.

The theoretical side was dominated by perturbative QCD approaches based on the Dokshitzer-Gribov-Lipatov-Altarelli-Parisi (DGLAP) and the Balitsky-Fadin-Kuraev-Lipatov (BFKL) equations. They govern the evolution of the nucleon structure as the process gets "harder", or more energetic. New results on the conformal properties of the BFKL equation were presented by Lev Lipatov and Victor Fadin, while younger theorists discussed applications to various processes. Saturation effects at high energy, which are expected to tame the growth of the cross-section and are particularly relevant in heavy-ion collisions, were the subject of a dedicated session, which included a contribution by Boris Kopeliovich.

The beautiful environment of the Salento peninsula's sandy beaches and clean sea, the relaxed elegance of Lecce with its baroque churches and palazzi, together with the delicious cuisine and the irresistible rhythm of the "pizzica" folk dance, provided an exceptional setting for this scientifically active event. For the next meeting, in 2012, Diffraction now feels mature enough to pass the pillars of Hercules, the venue being in Tenerife (Canary Islands), with the "local" organization by Agustin Sabio Vera of the Universidad Autonoma de Madrid.

The workshop was arranged and sponsored by the Physics Department of the University of Calabria, INFN, Temple University in Philadelphia, CERN and DESY-Hamburg. It also received valuable patronage from the Province of Lecce.

● This quick survey gives only a taste of the many subjects presented. For more details, see the Diffraction 2010 website at www.cs.infn.it/diff2010.

Diffraction 2010 participants enjoy the sunshine in Lecce. (Image credit: Diffraction 2010.)

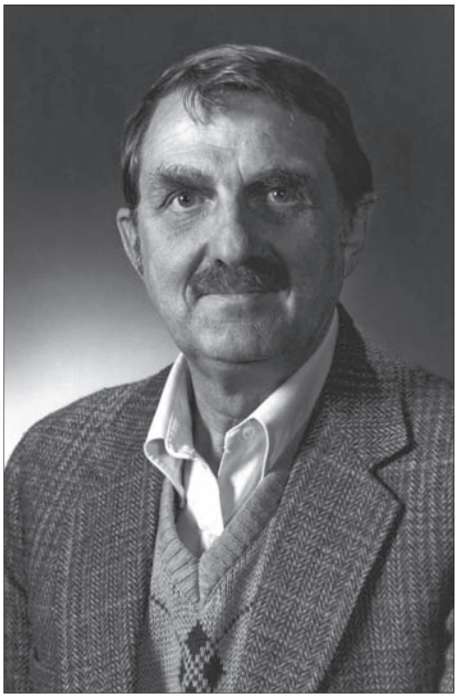
OBITUARY

Richard Allen Arndt 1933–2010

Richard Allen Arndt, a gifted and dedicated nuclear theorist and phenomenologist, passed away on 10 April 2010 at his residence in Blacksburg, Virginia, after a decades-long battle with carcinoid syndrome.

Born in Cleveland, Ohio, on 3 January 1933, Dick's studies in physics began in 1953 at Case Institute of Technology after two years in the Naval Reserve Officer Training Corps. He received a bachelor's degree in 1957 and took a position in an engineering group at Northrop Aviation in California, developing a climate-control system for guided missiles. Two years later he was appointed junior physicist with the Lawrence Radiation Laboratory in Livermore and started graduate studies at the University of California at Berkeley while working full time at the lab. He quickly gained remarkable facility at coding and this caught the attention of H Pierre Noyes, who solicited his interest in "doing some partial wave analysis". Working with Noyes, Henry Stapp and Michael Moravcsik, he gained valuable experience with numerical methods to perform phase-shift analyses of proton–proton scattering.

He began thesis research under Geoffrey Chew at Berkeley and Malcolm MacGregor at Livermore, developing a number of algorithms to solve the phase-shift analysis problem. The field of phase-shift analysis was, at that time, in a state of confusion regarding the uniqueness and stability of the solutions. Dick made a crucial contribution to the field by employing the well known but previously not applied observation that, at small scattering energies, only partial waves with low-orbital angular momentum contribute to any observable. This groundbreaking work led to a method of solving the phase-shift analysis problem in an essentially unique and smooth fashion. Codes that were developed at this time are still in use today.



Arndt. (Image credit: VPI & SU.)

So began Dick's nearly 45-year productive life as a self-proclaimed, if exceedingly humble, "phenomenologist". He published a series of 10 highly cited papers on the determination of the elastic nucleon–nucleon scattering matrix with adviser MacGregor and other collaborators, including Noyes and Robert Wright at Livermore in the period immediately following the completion of his dissertation in 1965.

Dick subsequently accepted a position at Virginia Polytechnic Institute and State University (VPI&SU) as an assistant professor of physics attaining the rank of full professor by the middle of the 1970s. He was elected as a fellow of the American Physical Society on 27 January 1973. During this time he had an academically profitable collaboration with many, including L David Roper with whom he published upwards of 50 papers in just over two decades; four of these have been cited more than 100 times. Much of the research in these papers resulted in the Scattering Analysis Interactive Dial-in (SAID) suite of analysis and database codes for which Dick is recognized across many fields of physics. The SAID facility, one of the earliest applications of network technology, is accessed through its online interface, to this day, by hundreds of scientists from around the world on a monthly basis.

Dick retired from VPI&SU in 1996 but remained a highly productive adjunct member of the faculty of the George Washington University (GWU) and professor emeritus of VPI&SU. His impact on the field of hadron spectroscopy, much of it made while at GWU after retirement, is singular. Many of the discoveries of the non-strange nucleon resonances were identified through Dick's analyses and can today be found in the *Review of Particle Properties*.

Dick's friends and colleagues alike remember him for his rapier wit, a nimble mind and an invariably kind and selfless generosity – a true gentleman and scholar. His humility precluded true boasting of any sort but his sense of humour permitted such conceits as stating that he had "written more programs than anyone east of the Mississippi". He was a dedicated husband and true partner to his beloved wife Donna, a devoted father and an avid fisherman. Despite a difficult childhood and challenging familial losses throughout life he always maintained a cheerful and convivial disposition. He asked us, at the latter stages of hospice care, to think of him as, "Not gone. Just gone fishing".

● *William B Briscoe, Mark W Paris, L David Roper, Igor Strakovsky and Ron L Workman.*

NEW PRODUCTS

X P Power has announced the VCS series of chassis-mount, single-output AC-DC power supplies aimed at cost sensitive industrial applications. The series comprises 50 W, 70 W and 100 W models, which are available with +5, +12, +15, +24 and +48 VDC outputs. A user accessible voltage-trim control provides a +/– 10% adjustment of the output voltage, allowing for the use of non-standard voltages or to compensate for cable losses. XP Power has also introduced the single-output AFM series of 48 and 60 W external AC-DC power supplies, with output voltages of 12, 15, 18 and 24 VDC. Offering a typical efficiency of up to 88%, these units meet the latest stringent energy-efficiency standards. For details, contact Steve Head, tel +44 118 984 5515,or e-mail shead@xppower.com.

Micromech has released the TMCM-078 stepper motor-drive module. This compact and rugged unit for bipolar two-phase stepper motors can operate with motor-coil currents of 0.7 A up to 7 A RMS (9.8 A peak) and voltages of 15 to 75 V. In addition, Micromech has announced the TMCM-1180 stepper motor, single-axis controller/driver module using the new coolStep

Faces & Places

technology for sensorless load-dependent current control. The module is designed to be mounted directly on an 86 mm flange (NEMA34) QMot stepper motor. For details, contact Stirling Morley, tel +44 13 76 333 333 or e-mail stirling@micromech.co.uk.

Kepco Inc has introduced four quadrant power supplies for solar cells/panels and piezo-electric applications with 200 W and 400 W BOP modules, which are optimized for driving capacitive loads, as an option to the standard line of BOP power supplies. This option makes the BOP suitable for many applications, including driving and testing piezo-electric devices, as well as capacitor testing. For further details, tel +1 718 461 7000, fax +1 718 767 1102, e-mail hq@kepcopower.com or visit www.kepcopower.com.

Resolve Optics Ltd has announced the Model 305 Fixed Focus Non-Browning Lens, designed to perform with large-image-format cameras and sensors in radiation environments. Only 30 mm in diameter, the f2 lens delivers high image resolution and minimum geometric distortion over 400–750 nm. It is manufactured from cerium-doped glass or synthetic silica and can withstand radiation exposure of up to 53 kGy (108 rads) and temperatures of up to 55°C without discolouration. For more information, tel +44 14 94 777 100, e-mail sales@resolveoptics.com or visit www.resolveoptics.com.

Yokogawa Test and Measurement Division has announced the Yokogawa AQ6370C, an optical spectrum analyser that covers the wavelength range from 600 to 1700 nm. Applicable to both single-mode and multimode fibres, the AQ6370C provides high wavelength accuracy of ±0.01 nm, high wavelength resolution of 0.02 nm, and an ultra-high dynamic range of 78 dB. For more information, contact Terry Marrinan, tel +31 88 464 1811, fax +31 88 464 1111, e-mail terry.marrinan@nl.yokogawa.com or see www.tmi.yokogawa.com/ea.

Trio Motion Technology has launched a range of modular DIN-rail mounted CAN I/O expansion modules featuring switchable TrioCAN I/O and CANopen DS401 protocols for use across its motion- and machine-control families. These include a variety of input/output modules with standard industrial signal levels and certified EMC emission and immunity ratings. For further details, e-mail mkennelly@triomotion.com or see www.triomotion.com.

VISITS

On 16 November, the Chinese vice-minister of science and technology, **Cao Jianlin**, right, visited CERN. His tour included the CERN Control Centre, the computer centre, the ATLAS visitor centre and the CMS control room, where **Guido Tonelli**, CMS spokesperson, introduced the experiment. The minister also met Chinese scientists working at CERN.

Neelie Kroes, vice president of the European Commission and European Digital Agenda commissioner, left, was at CERN on 24 November for a visit that included a tour of the computing centre with **Frédérick Hemmer**, head of the Information Technology Department. She also heard about CERN's involvement in open-access publishing and EU ICT projects.

On 30 November the Norwegian State Secretary for the Ministry of Government Administration, Reform and Church Affairs, **Raimo Valle**, was welcomed to CERN by **Felicitas Pauss**, CERN's head of international relations (here demonstrating a gift of CERN's special temperature-sensitive coffee mug that depicts the history of the universe). During the visit, the minister toured the computing centre and heard about the LHC Computing Grid.

The director-general of the World Intellectual Property Organization, **Francis Gurry**, left, visited CERN on 15 December. After meeting CERN's director-general, Rolf Heuer, his tour included the underground experimental area of CMS, as well as a visit to the experiment's control room and part of the LHC tunnel.

Recruitment

For advertising enquiries, contact *CERN Courier* recruitment/classified, IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.
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Applicants are requested send a curriculum vitae, an application form, a list of all university courses taken and transcripts of grades obtained, brief statements of research interests and experience, and the contact information for at least two referees. Applications received by the deadline of February 28, 2011 will receive full consideration.

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Application Procedure: Applications must include a CV and statements describing research, teaching and overall goals. At least three reference letters should also be submitted. Applications should be sent to Professor William Briscoe, Chair, Search Committee, Department of Physics, The George Washington University, Washington, DC, 20052, USA. Review will begin on Feb 1, 2011. Only complete applications will be considered. Applications from women and underrepresented minorities are strongly encouraged.

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TEXAS A&M UNIVERSITY

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Department of Physics and Astronomy

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The successful candidate for this position will assume a tenured position at the full professor level in the Department of Physics and Astronomy, with a joint appointment in the Cyclotron Institute and the Nuclear Solutions Institute. He/she will be expected to lead a vigorous basic research program based at the Cyclotron Institute and employing the facilities there, which include two cyclotrons – a newly refurbished K150 and a superconducting K500 – together with a wide variety of modern experimental equipment. An upgrade project, now underway and planned to be completed in 2012, will utilize the two accelerators to make radioactive beams available to all target locations.

Interested parties with a Ph.D. or equivalent in nuclear science or a related field should send a CV and a statement of research accomplishments via e-mail to **seniorsearch@comp.tamu.edu**. We also encourage informal enquiries, which can be addressed to the head of the search committee, John Hardy, at hardy@comp.tamu.edu or at +1 (979) 845-1411.

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Applicants should send a letter of application, a résumé, including a list of publications, and the names and addresses of at least three references to **Prof. Michael Syphers, NSCL, Michigan State University, East Lansing, MI 48824-1321 or jobs@nscl.msu.edu**.

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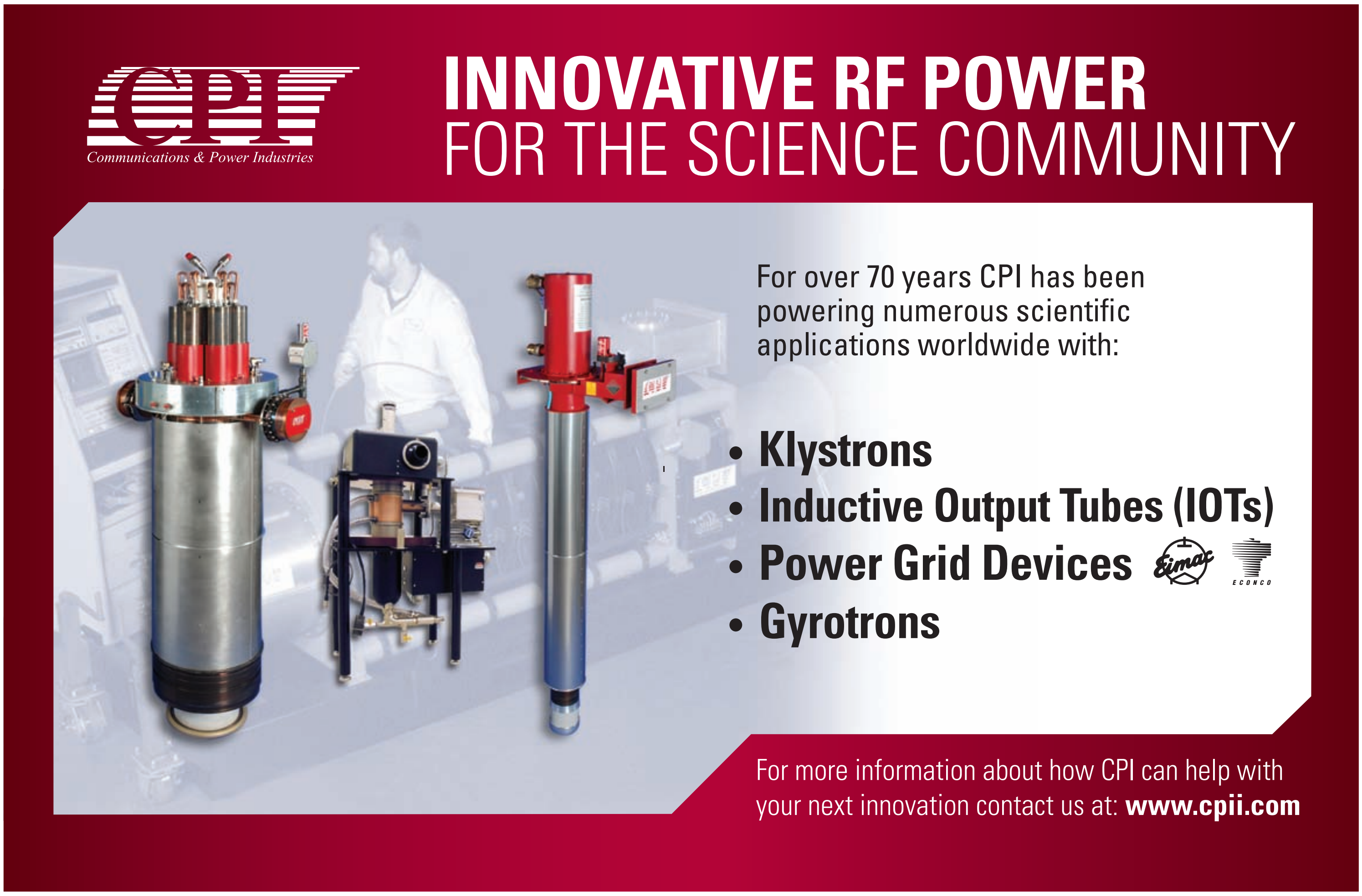
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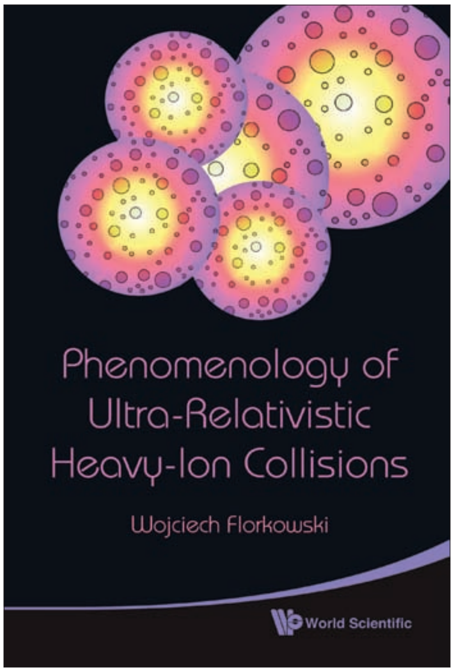
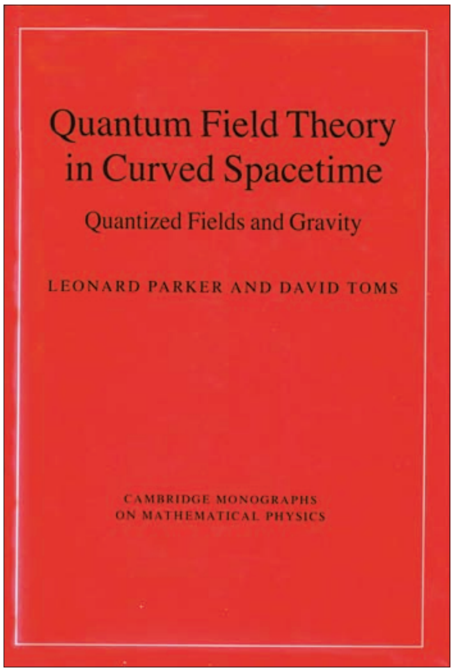
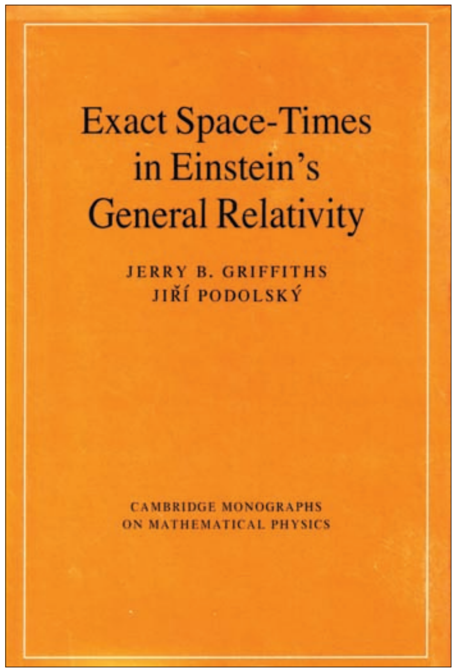






Phenomenology of Ultra-Relativistic Heavy-Ion Collisions
By Wojciech Florkowski
World Scientific
Hardback: £66 $96

Wojciech Florkowski's book on ultra-relativistic heavy-ion collisions appears right at the beginning of a new era in the field. In 2010, two new experimental heavy-ion programmes started at CERN. First, lead nuclei were accelerated to the highest ever energy – 1.38 TeV per nucleon – at the LHC and rich experimental results were released by the ALICE, ATLAS and CMS collaborations, even during the first data-taking period in November/December 2010. Second, in parallel, a new fixed-target heavy-ion programme at CERN's Super Proton Synchrotron (SPS) was launched with the acceleration of lead beams to the lowest-ever energy in the SPS, namely 13.9 GeV per nucleon. This was to study the use of the fragment separator in producing secondary light-ion beams for the NA61/SHINE experiment. These two research programmes are perfectly complementary. The one at the LHC aims at a systematic investigation of hot and dense quark-gluon plasma. The one at the SPS, on the other hand, will search for the critical point of strongly interacting matter and study the properties of the onset of deconfinement.

This book by Florkowski is highly relevant for all participants in the new programmes at CERN. I am convinced that it may also help all non-heavy-ion physicists involved in experiments at CERN to understand the language and excitement of their heavy-ion colleagues.

Furthermore, it gives an excellent introduction to and an in-depth review of the standard theoretical framework that is used to interpret the heavy-ion data. It provides a clear, logical and unified description of statistical, hydrodynamical and kinetic models. All this is illustrated by a selection of the most relevant experimental results of the past programmes at Brookhaven's Alternating Gradient Synchrotron and Relativistic Heavy Ion Collider, as well as at the SPS. Finally, there are various exercises in each chapter for use as a textbook in a graduate course.

All in all, this book is highly recommendable both for heavy-ion and non-heavy-ion physicists.

● *Marek Gazdzicki, Universities of Frankfurt and Kielce.*

Quantum Field Theory in Curved Spacetime: Quantized Fields and Gravity
By Leonard Parker and David Toms
Cambridge University Press
Hardback: £48 $83 E-book: $64

Exact Space–Times in Einstein's General Relativity
By Jerry B Griffiths and Jiří Podolský
Cambridge University Press
Hardback: £80 $129 E-book: $100

Long ago, more or less immediately after Einstein's formulation of general relativity, one of the dreams of physics was to understand why flat space–time is so special. Why are quantum mechanics and field theory formulated in flat space while their curved-space analogues are sometimes ill defined, at least conceptually? Can we hope, as Richard Feynman speculated, to quantize gravity in flat space–times and then construct all of the most complicated geometries as coherent states of gravitons?

The dreams of a more coherent picture of gravity and of gauge interactions in flat space are probably still there, but nowadays theorists invest a great deal of effort in understanding the subtleties of the quantization of fields, particles, strings and (mem)branes in geometries that are curved both in space and in time. Cambridge University Press was one of the first publishers to voice these attempts with the classic *Quantum Fields in Curved Space* by N B Birrel and P C W Davies, which is now well known to many students since its first edition in 1982. Leonard Parker (distinguished professor emeritus at the University of Wisconsin) and David Toms (reader in mathematical physics and statistics at the University of Newcastle) were both abundantly quoted in the book by Birrel and Davies and they have now published *Quantum Field Theory in Curved Spacetime*, also with Cambridge. While

Bookshelf

readers of Birrel and Davies will certainly like this new book, newcomers and students will appreciate the breadth and the style of a treatise written by two well known scientists who have dedicated their lives to the understanding of the treatment of quantum fields in a fixed gravitational background.

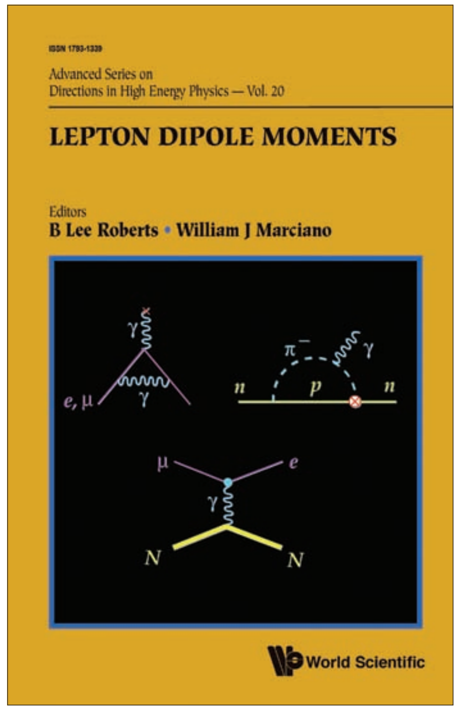
The book consists of seven chapters spread evenly between pure theory and applications. One of its features is the attention to the introductory aspects of a problem: students and teachers will like this aspect. The introductory chapter reminds the reader of various concepts arising in field theory in flat space–time, while the second chapter introduces the basic aspects of quantum field theory in curved backgrounds. After the central chapters dealing with useful applications (including the discussion of pair creation in black-hole space–times) the derivation of effective actions of fields of various spins is presented, always by emphasizing the curved-space aspects.

A rather appropriate companion volume is *Exact Space-Times in Einstein's General Relativity* by Jerry Griffiths and Jiří Podolský, published by Cambridge in late 2009. Here, the interested reader is led through a review of the monumental work performed by general relativists over the past 50 years. The book also complements (and partially extends) the famous work by Dietrich Kramer, Hans Stephani, Malcolm MacCallum and Eduard Herlt, *Exact Solutions of Einstein's Field Equations*, first published, again by Cambridge, in 1980.

Like its famous ancestor, the book by Griffiths and Podolský will probably be used as a collection of exact solutions by practitioners. However this risk is moderated to some extent by a presentation in the style of an advanced manual of general relativity (GR). The 22 chapters cover in more than 500 pages all of the most important solutions of GR. After two introductory chapters the reader is guided on a tour of the most important spatially homogeneous and spatially inhomogeneous, four-dimensional background geometries, starting from de Sitter and anti-de Sitter space–times but quickly moving to a whole zoo of geometries that are familiar to theorists but which may sound rather arcane to scientists who are not directly working with GR.

Both books reviewed here can also be recommended because they tell of the achievements of a generation of theorists whose only instruments were, for a good part of their lives, a pad of paper and a few pencils.

● *Massimo Giovannini, CERN and INFN (Milan-Bicocca).*



Lepton Dipole Moments

By B Lee Roberts and William J Marciano (eds.)

World Scientific

Hardback: £113 $164 E-book: $213

In December 1947, Julian Schwinger wrote a letter to the editor of *Physical Review*, wherein he reports in a mere five paragraphs that he has found "an additional magnetic moment associated with the electron spin". He gives the value as $\alpha/2\pi=0.00116$ and states that it is "the simplest example of a radiative correction" in the new theory of QED.

We have come a long way since Schwinger's letter. Toichiro Kinoshita has computed the anomalous magnetic moment of the electron up to the tenth order. Nature has revealed further mysteries in the intervening years, including the existence of the muon, with which to test our theories. Famously, the Brookhaven measurement of the anomalous magnetic moment of the muon shows an approximately 3σ deviation from the theoretical prediction of the Standard Model. Experiments have been searching for the CP-violating electric dipole moment as well, with many more experiments coming.

Lepton Dipole Moments, a review volume edited by Lee Roberts and William Marciano, begins with a historical perspective by Roberts and is followed by many excellent review articles. Articles are written by leaders of the field: Andrzej Czarnecki and Marciano on new physics and dipole moments, Michel Davier on g-2 vacuum polarization issues, Dominik Stoeckinger on new physics in g-2, Yasuhiro Okada on models of lepton-flavour violation, Eugene Commins and David DeMille on the electric dipole moment of the electron, and many more.

One reason that lepton moments are interesting to pursue, even during these heady times of high-energy LHC collisions, is their sensitivity to "chirality enhanced" contributions from new physics. In the case of supersymmetry, some large-tanβ theories can yield parametrically larger supersymmetric contributions than Standard Model contributions, increasing sensitivity to higher scales than usual electroweak precision tests allow. An analogous situation occurs for theories with large, new flavour- or CP-violating effects. Lepton dipole moment experiments are reaching levels of sensitivity that will make or break theories. For example, even theories of baryogenesis, which seem far remote at first thought from the vagaries of lepton dipole moments, "will be put to the ultimate test with the next generation of experiments", as Maxim Pospelov and Adam Ritz rightly explain.

The energy frontier is not the only place to put fundamental physics under extreme test, as this volume attests. Roberts and Marciano have put together an excellent survey of lepton dipole moments and their certain power to change our world view whatever may come.

● *James Wells, CERN.*

Fundamental Interactions: A Memorial Volume for Wolfgang Kummer

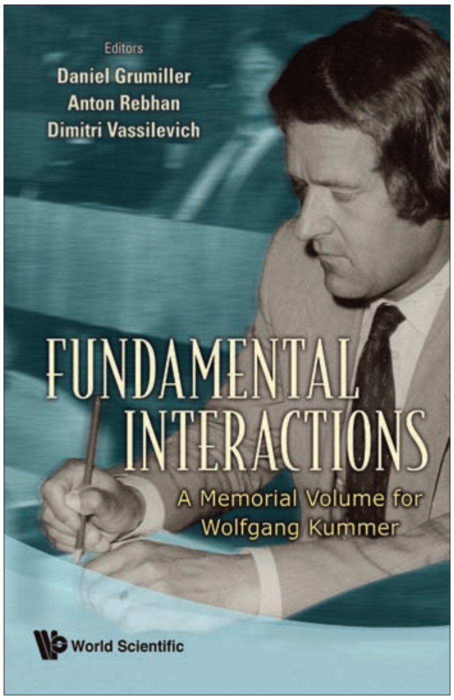
By Daniel Grumiller, Anton Rebhan and Dimitri Vassilevich (eds.)

World Scientific

Hardback: £76 $111 E-book: $144

It is nice that through this book homage is rendered to Wolfgang Kummer – a great physicist, a great administrator of European science, a warm personality and an excellent pianist, singer and skier. It is impossible for me to review in detail all of the contributions. I may know the field of quarkonium relatively well but it is not the case for gauge fixing or supergravity. However, I can see that the contributors all have a high reputation, which in turn proves the high level of Kummer's research work.

I was particularly interested by Herwig Schopper's contribution, which shows the important role that Kummer played at CERN, in particular when he was president of the CERN Council. It also helps to understand why the proposals of the Abragam commission that were followed by the CERN Council only in



part, i.e. early retirement but not additional funding to compensate it, have contributed to the current difficult situation with the CERN pension fund. I also appreciated Jack Steinberger's contribution, which summarizes the problems of global warming and energy resources, a subject that was dear to Kummer.

I would like to add just one remark: if, like me, you are satisfied by the CERN health insurance, Uniqa (formerly Austria), you can be thankful to Wolfgang Kummer.

I can only recommend reading this book.

● *André Martin, CERN.*

Books received

Particle Dark Matter: Observations, Models and Searches

By Gianfranco Bertone (ed.)

Cambridge University Press

Hardback: £70 $115 E-book: $92

Aimed at graduate students and researchers, this book describes the theoretical and experimental aspects of the dark matter problem in particle physics, astrophysics and cosmology. Featuring contributions from 48 leading theorists and experimentalists, it starts with an introduction to the observational evidence for dark matter together with a detailed discussion of the state-of-the-art in numerical simulations and alternative explanations in terms of modified gravity. It then moves on to the candidates arising from theories beyond the Standard Model and the prospects for detection at accelerators. It concludes by looking at direct and indirect searches and the prospects for detecting the particle nature of dark matter with astrophysical experiments.

Supersymmetric Solitons

By M Shifman and A Yung

Cambridge University Press

Hardback £64 $116 E-book $96

In the past decade methods and techniques based on supersymmetry have provided deep insights into QCD and other non-supersymmetric gauge theories at strong coupling. This book summarizes major advances in critical solitons in supersymmetric theories and their implications for understanding basic dynamical regularities of non-supersymmetric theories. The authors focus on three topics: non-Abelian strings and confined monopoles, reducing the level of supersymmetry, and domain walls as D-brane prototypes. They also provide a thorough review of issues at the cutting edge, such as non-Abelian flux tubes.

Quantum Mechanics Using Computer Algebra: Includes Sample Programs in C++, SymbolicC++, Maxima, Maple, and Mathematica (2nd edition)

By Willi-Hans Steeb and Yorick Hardy

World Scientific

Hardback £43 $62

In this book, the authors implement methods in quantum mechanics using two popular computer algebra packages, SymbolicC++ and Maxima. The programs and outputs are accompanied with text that explains the underlying mathematics and physics in detail. Selected problems have also been implemented using two other popular packages – Mathematica and Maple – while some problems are implemented in C++. Modern developments in quantum theory are covered extensively and new research topics added to this second edition include entanglement, teleportation, coupled Bose–Fermi systems and super-Lie algebras.

Non-Perturbative Field Theory: From Two-Dimensional Conformal Field Theory to QCD in Four Dimensions

By Yitzhak Frishman and Jacob Sonnenschein

Cambridge University Press

Hardback £75 $130 E-book $104

Providing a new perspective on quantum field theory, Yitzhak Frishman and Jacob Sonnenschein give a pedagogical and up-to-date exposition of non-perturbative methods in relativistic quantum field theory, introducing the reader to modern research work in theoretical physics. They describe in detail non-perturbative methods in quantum field theory and explore two- and four-dimensional gauge dynamics using those methods. The book concludes with a summary emphasizing the interplay between two- and four-dimensional gauge theories. Aimed at graduate students and researchers, it covers topics such as affine Lie algebras, solitons, integrable models, bosonization, four-dimensional conformal invariance, large N expansion, Skyrme model, monopoles and instantons.

Quantum Electronics for Atomic Physics

By Warren Nagourney

Oxford University Press

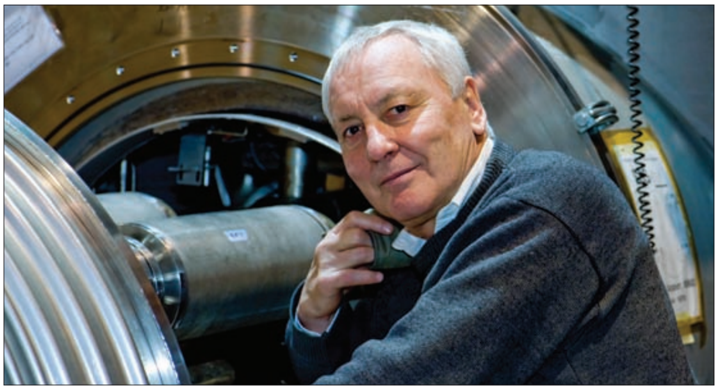
Hardback £45 $85

While this book covers the usual topics, such as Gaussian beams, cavities, lasers, nonlinear optics and modulation techniques, it extends to areas not usually found in a textbook on quantum electronics. It includes such practical matters as the enhancement of nonlinear processes in a build-up cavity, impedance matching into a cavity, laser frequency-stabilization (including servomechanism theory), astigmatism in ring cavities and atomic/molecular spectroscopic techniques for the generation of a discriminant for laser frequency-locking. A number of very recent developments are also discussed, such as fibre lasers and frequency metrology using femtosecond lasers. Graduate students and researchers in atomic physics, as well as university lecturers, will find this a useful resource.

Inside Story

Without the ISR...

Lyn Evans talks of the legacy of the ISR for the LHC project, which he led until start-up.



Lyn Evans admires the guts of the people who designed and built the ISR. "They took a real step into unknown," he says.

When Lyn Evans came to work at CERN in October 1969, construction of the Intersecting Storage Rings (ISR) was in full swing. It was to be the world's first proton–proton collider. Little did Evans realize that he would eventually lead the project to build the second proton–proton collider, the LHC – a project that would consume some 20 years of his life. Starting up almost four decades after the ISR, the LHC is in many ways a "super" ISR and in Evans' mind, a true successor: "Without the ISR there would be no LHC."

Back in 1969, Evans joined the linac group under Colin Taylor. Although not involved in the construction of the ISR, he witnessed the era of the naysayers, who doubted that it would ever work. Electron–positron colliders based on storage rings were already working successfully but, as Evans explains, "In these colliders, synchrotron radiation fixes all of the sins, making them stable and relatively easy to operate." The ISR was designed to produce collisions between stored protons, which with 2000 times the mass would not emit the synchrotron radiation that fortuitously damped excessive swings in the circulating electron beams.

"It was history repeating itself," says Evans. "When the PS was built, the prophets of doom said that resonances would kill it but they were proved wrong. With the ISR there was a well respected lobby that thought it wouldn't work. What the ISR did was show that you can make a proton storage ring work." Of course, it was not easy. With no damping, the machine had to operate with much tighter controls, for example on the stability of the power supplies. For its successor, the LHC, the power supplies are stable to 1 part in 10^6.

One significant difference between the ISR and the LHC is that the first collider was not designed to accelerate the beams. Some acceleration was later achieved through the ingenious method of phase displacement but in normal operation there was no RF acceleration; the beams simply coasted, unbunched. Moreover, the beams crossed at quite a large angle (about 15°) in the ISR, which meant that beam–beam effects were weak. This would be quite different, not only nearly 40 years later at the LHC, but at CERN's second hadron collider in the early 1980s, when the Super Proton Synchrotron (SPS) ran as a proton–antiproton collider, with bunches of protons and antiprotons travelling in opposite directions round the existing synchrotron ring.

The Sp$\bar{p}$S project was, in Evans' view, the second major step on the road to the LHC. However, a vital key to its operation was developed at the ISR – the technique of stochastic cooling, which was essential for taming the unruly beams of antiprotons created at the production target. While Simon van der Meer had written down the original idea – which he himself referred to as "far-fetched" – in a paper in 1972, it was Wolfgang Schnell who put it into practice with some real engineering at the ISR. "Simon's idea seemed mainly of academic interest," recalls Evans. "It was Schnell's practical genius to realize that you could make it work." Without the ISR there would have been no Sp$\bar{p}$S.

The Sp$\bar{p}$S, with its oppositely directed beams of protons and antiprotons in the same vacuum chamber, would have a much smaller crossing angle and a larger beam–beam tune shift. When the bunches passed through each other, the Coulomb interactions between them would be strong enough to shift the tune – the number of betatron oscillations per revolution of the beam – and cast doubt once again on the feasibility of another innovative machine. "There were real worries here," says Evans. "There are intrinsic nonlinearities in the magnetic field in these machines but the nonlinearity of the beam–beam interaction is much stronger". The Sp$\bar{p}$S thus represented yet another step into the unknown: not only would it have large beam–beam effects and bunched beams, there would be no synchrotron radiation damping to help redress the balance. Indeed, a test at SLAC in which the small electron–positron storage ring, SPEAR, ran at lower energy to reduce the damping, suggested that the Sp$\bar{p}$S would never work. However, Evans and others performed an experiment at the ISR, keeping the beam bunched rather than spread out around the ring so as to simulate the stronger beam–beam interactions that would be experienced at the Sp$\bar{p}$S. Although the beam–beam tune shift was considerably smaller than what would be needed in the SPS, the results were encouraging.

The manifest success of the Sp$\bar{p}$S threw open the door to the LHC. There, the teams could probe the limits in the beam–beam effects that would later be used in designing the LHC. The LHC's superb performance shows just how effective this experience proved to be. As the project leader of the LHC, Evans is keen to emphasize the machine's ancestry. "I've always thought of the pathway to the LHC as having two steps," he says, "ISR to Sp$\bar{p}$S to LHC." He also has great admiration for the guts of the people who designed and built the ISR. "They took a real step into unknown," he says. Without the ISR, there would be no LHC.

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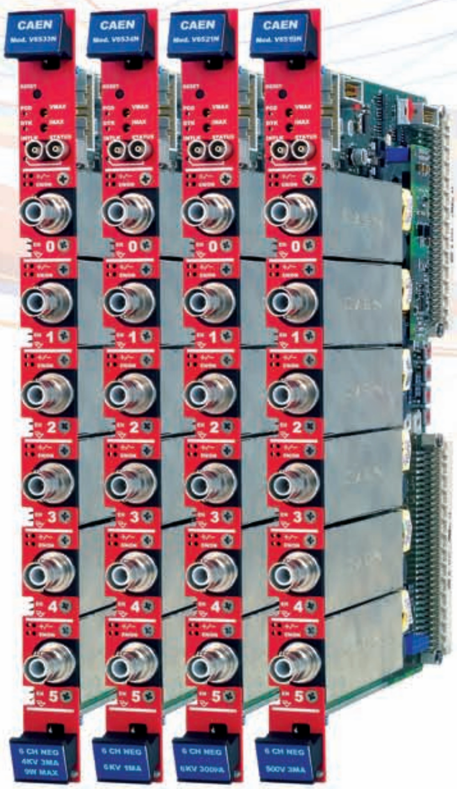

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