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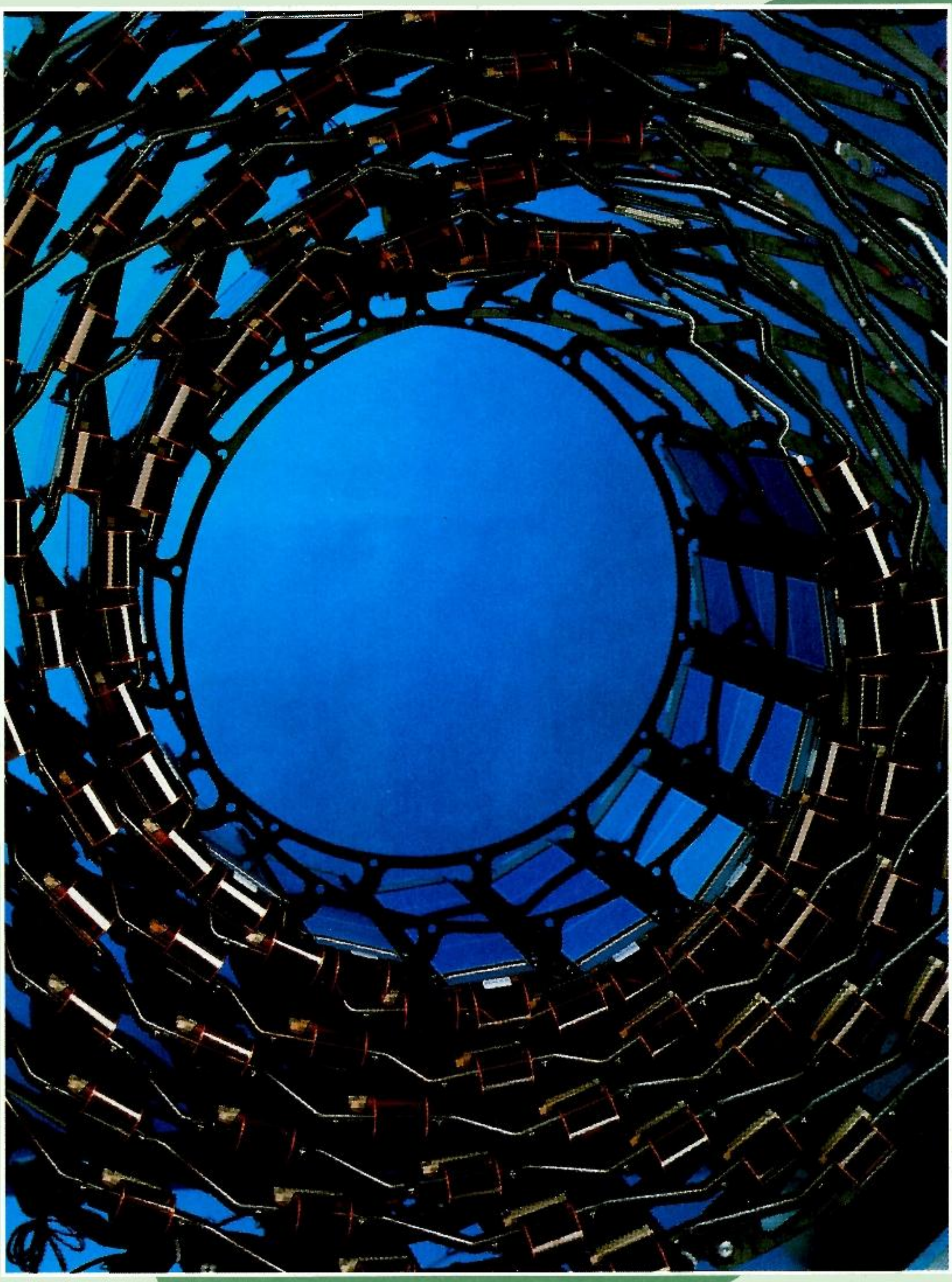

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*Editor:* Gordon Fraser
CERN.COURIER@ CERN.CH
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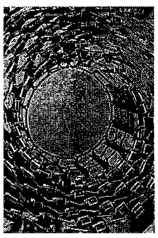

*Cover photograph: "The Silicon Wheel" prototype for the barrel of the silicon tracker deep inside the CMS detector at CERN's future LHC proton collider. Elements on a specially designed structure will track the emerging particles close to the beam pipe. The supporting structure is made out of special carbon fibre discs holding 112 detector modules (448 individual silicon detectors). The modules are arranged to provide three detection points per track and are distributed in seven layers on a spiral geometry to leave enough room for cables, cooling tubes, etc. The inner radius of the wheel is 20.5 cm; the overall diameter is 80 cm. The prototype is a combined CMS silicon community effort; the main participating institutions were: Aachen (Germany), Bari (Italy), CERN, Florence (Italy), Imperial College (UK), Oulu (Finland), Padova, Perugia, Pisa (Italy), Rutherford Laboratory (UK), Seft (Finland), ETH-Zurich ( Switzerland), and Vienna (Austria), with final assembly in INFN Pisa. (Photo CERN EX6.8.97/2).*

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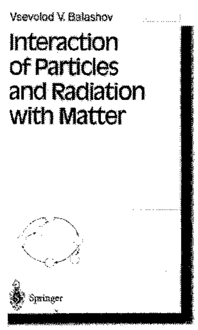


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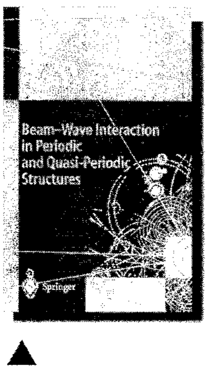


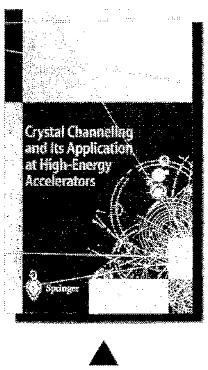


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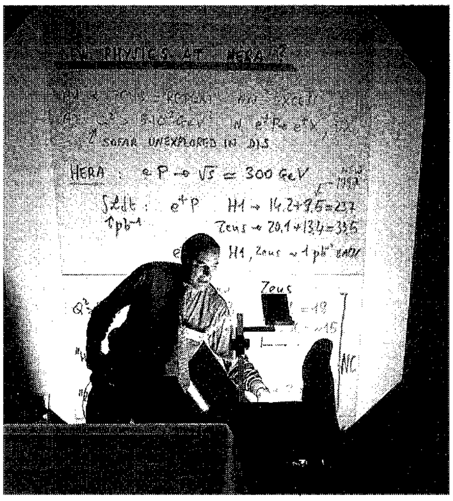
# Trying to peer behind the Standard Model



*Hamburg Standard Model reviewer Guido Altarelli viewed with caution the excess of backscattered positrons seen by the HERA collider at DESY, Hamburg.*

When will the Standard Model crack? Earlier this year (April, page 1), the Zeus and H1 experiments at the HERA electron-proton collider at DESY, Hamburg, reported an intriguing handful of excess of positrons recoiling backwards from collisions between 27.5 GeV positrons and 820 GeV protons. The violent backscattering suggested interactions with a new, hard layer of matter deep inside the protons, deeper than the quarks themselves, at a scale of $10^{-16}$ cm.

It had long been a safe bet that major physics meetings would continue to revere the conventional picture of six quarks and leptons grouped pairwise into three families interacting via electroweak and inter-quark forces. From time to time unorthodox physics has been sighted, but nothing had stood the test of time. However the HERA data had been more suggestive than most and delegates at the International Symposium on Lepton and Photon Interactions, held in Hamburg from 28 July - 1 August, were eager to hear whether the HERA signal had become stronger.

Zeus and H1 experiments carefully kept their cards close to their chest until the last minute. In a carefully stage-managed talk, Bruce Straub of Columbia covered recent HERA results from an integrated luminosity (a measure of the number of collisions collected) up by 67%.

The earlier results had concentrated on neutral current interactions (with the positron emerging unscathed) for both experiments, with 2 and 12 backscattered events, compared to an expected signal of a fraction of an event and five events from Zeus and H1 respectively. Only H1 had reported similar charged current interactions, where the incident positron does not survive intact.

At Hamburg both experiments reported charged current effects, Zeus and H1 together seeing 28 backscattered events in a kinematical zone where $18 \pm 4$ are expected.

The new neutral current data from the two experiments is enigmatic. Zeus does not add to its anomalous score of 2, while the 12 events from H1 have been supplemented by 6 more. The two superimposed signals moreover have little overlap and cannot be explained by a single resonance.

In the neutral current data, it depends where one looks. In one area H1 sees in total 8 backscattered events where 1.5 are expected, while Zeus observes 3 and expects 3. In another area Zeus sees 5 where 1.5 are expected, while H1 sees 1 and expects 1. Data taking continues.

## *Standard model*

Hamburg Standard Model reviewer Guido Altarelli viewed the HERA results with caution, and, while leaving a door open to fresh physics interpretation, suggested that a statistical fluctuation is the most likely explanation. 'I could win the lottery,' he surmised, 'but this would not be new physics.'

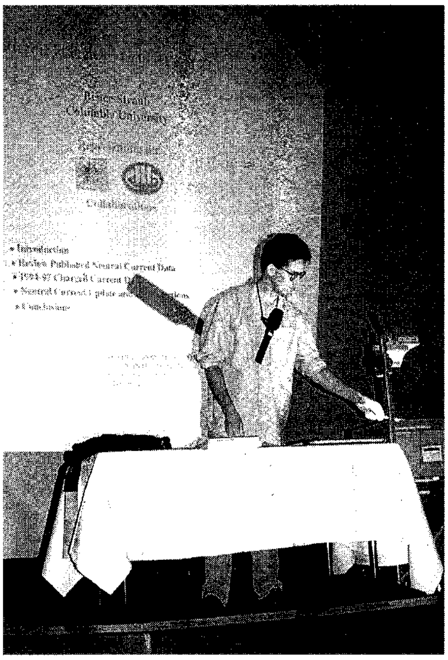
The higgs particle, responsible for symmetry breaking in the electroweak sector, is the missing link in the Standard Model and remains the major objective. But even if the higgs were to be found, the Standard Model would still be too empirical for comfort. A deeper understanding of the three quark/lepton generations and the widely disparate strengths of the different forces of nature is needed.

Doubling the number of elementary particles and pairing each Standard Model lepton, photon or force carrier with a supersymmetric partner gives a beautifully balanced picture and has become the conventionally accepted dogma. 'SUSY (Supersymmetry) has many virtues,' declared Altarelli.

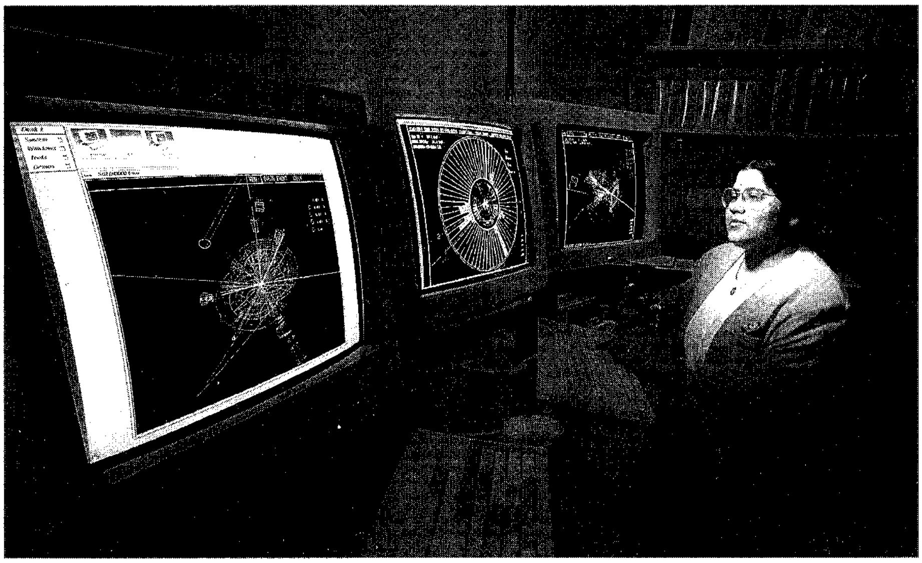
Reviewer R. Barbieri of Pisa covered the wider unified theories encompassing the Standard Model, and tried to absorb the new HERA events at face value. Earlier, reviewing searches for SUSY and 'new' (unseen) particles, Carlo Dionisi of Rome had only negative results to report within the limits given by the regions scrutinized so far. With supersymmetry being touted as the way to go, but no signs of such particles seen, limits on where they could be found are loaded with implications. With the anomalous HERA data, leptoquark limits from Fermilab's Tevatron proton-antiproton collider were of more than usual interest (September, page 14).

High on the list of unseen particles is the higgs, almost ruled out below 72 GeV, while Standard Model consistency points to a likely mass of 121 + 119 - 68 GeV. With the higgs possibly a light particle, at least by top quark standards, ongoing physics at higher LEP energies and at the

*Bruce Straub of Columbia presented the latest HERA data at Hamburg.*



*Monitoring proton-antiproton collision events at the D0 detector at Fermilab's Tevatron. D0 and the companion CDF detector have now intercepted about 60 examples of the production of particles containing the sixth 'top' quark in channels producing weakly interacting particles (leptons), and several hundred in all channels combined.*



Tevatron could yet reveal higgs information prior to the debut of CERN's LHC proton collider in 2005.

However with the higgs particle still in hiding, the sixth - 'top' - quark assures the Standard Model interregnum. At the Tevatron, where the top quark was discovered in 1995, the CDF and D0 experiments have now intercepted about 60 examples in channels producing weakly interacting particles (leptons), and several hundred in all channels combined.

Summarizing the top sector, Paolo Giromini of Frascati likened top production at Fermilab to the Ferrari factory, where it takes a lot of people and a lot of time to carefully make each example. Top quark physics had begun by cautiously tasting small slices of easy-to-digest decay channels, said Giromini, but with increased confidence customers were turning to larger slices of the top decay cake. The measured value for the all-important top quark mass depends on the decay channel under scrutiny, but CDF centres on 178 GeV and D0 on 172 GeV.

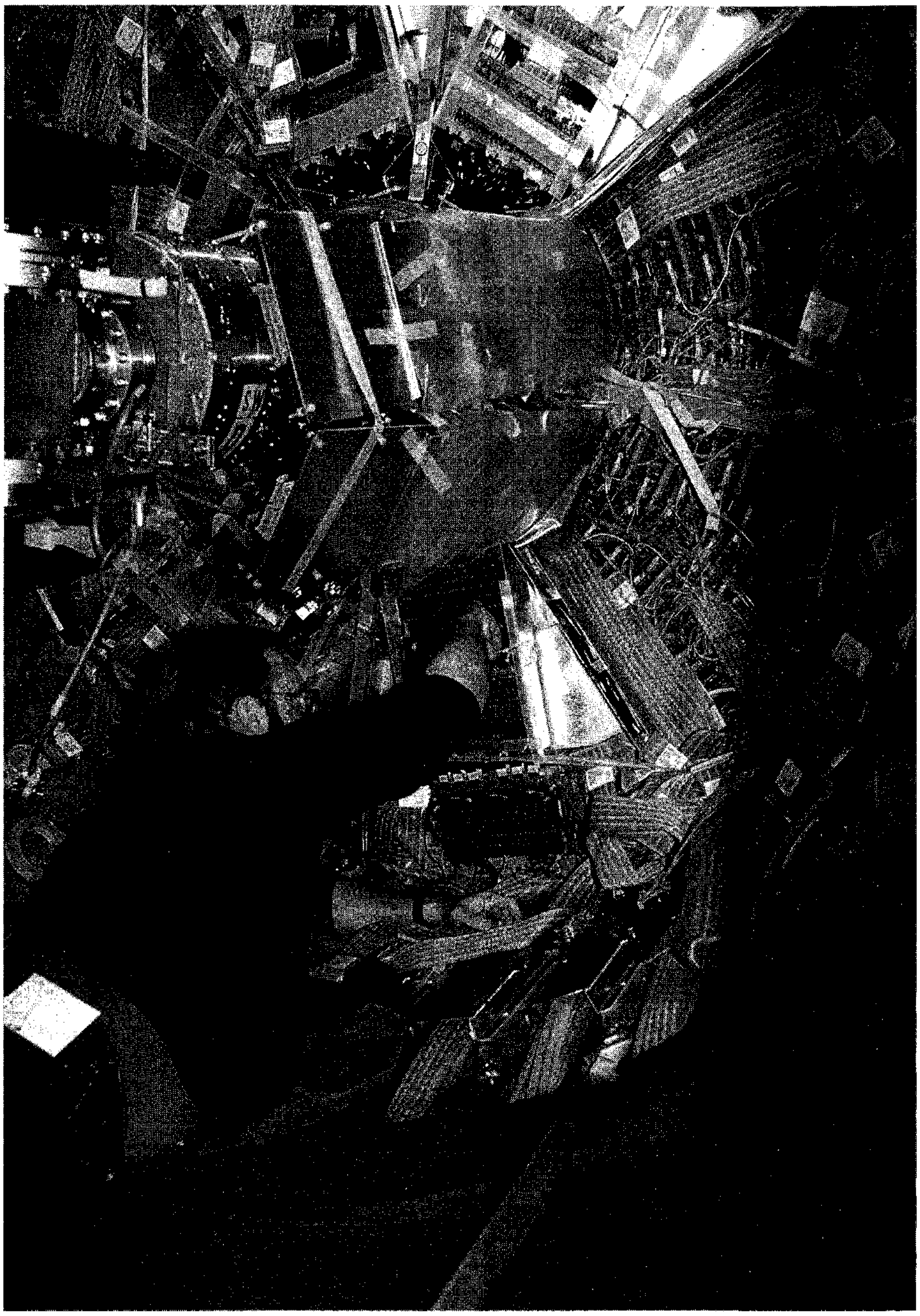
With the heaviest quark well established and its mass firming up, physicists are beginning to look at its weak decays. Like deep sea trawlers, top quark experiments sometimes bring to the surface weird examples from the subnuclear deep, always the object of much curiosity, although physics conclusions from such rare sightings are difficult.

The other Standard Model sector which benefits from Tevatron input is the mass of the W particles, the electrically charged carrier of the weak force (covered at Hamburg by Y.K. Kim of Berkeley). The Tevatron value is now accurate to 90 MeV, compared to LEP's 140 MeV.

Precision contributions to the Standard Model from the electron-positron sector were covered by Jan Timmermans from NIKHEF, Amsterdam, with input from the LEP and SLC colliders at CERN and Stanford respectively. The Z mass, object of much heroic work at LEP with a sample of 4.4 million Zs and scene of perturbations from such unexpected sectors as earth tides and nearby railways, has been fixed with a precision of just 1.5 MeV.

While LEP dominates the world Z count, the SLC works with polarized (spin oriented) beams and its asymmetry results are particularly valuable. However asymmetry effects measured in at LEP and the SLC still do not agree. Standard Model reviewer Altarelli pointed to the discrepancy between the two results, especially in view of the SLC's number pulling the higgs mass very low.

In several remarks, Stanford Linear Accelerator Centre Director Burt



*Servicing the electronics of the Cleo detector at Cornell's CESR electron-positron collider. With more than three million examples of the production of B particles, containing the fifth - 'beauty' or 'b' - quark, Cleo has made its mark on this physics.*

Richter doubted the advertised precision of the LEP Z mass, and wondered how the Standard Model fix can be considered so precise when results still shift or differ by more than their ascribed error ranges. In reply, Altarelli underlined the compelling consistency of the current picture, pointing out that taking some results at face value pull the fit way out of line.

## *Heavy flavours*

With the better-known light quarks and leptons appearing to be so well behaved, the spotlight has fallen in recent years on the physics of the heavier quarks and the tau lepton. However, as Altarelli warned in his summary talk, these sectors are the most difficult to measure and it is hardly surprising that deviations occur from time to time.

W. Li of Beijing presented tau lepton information dominated by results from the Cleo detector at Cornell's CESR electron-positron ring, with four million events, three million of which have been able to profit from a silicon vertex detector. The tau sector is becoming better explored and physicists more adventurous, and will benefit from future mass production of B particles containing the fifth - beauty, or 'b' - quark.

Covering B decays, Persis Drell of Cornell first showed that basic processes appear to be well understood and are good material for heavy quark effective theory, with a hydrogen-atom-like picture of a light quark orbiting round the central heavy b quark.

Much information has been compiled since the first sighting of B particles twenty years ago. But to study them properly needs special conditions, and dedicated experiments, such as HERA-B at DESY and new B 'factory' colliders are under construction at KEK, Japan, and at SLAC, Stanford.

In the meantime more than 3 million B pairs have been collected at Cornell, also the scene of much activity to optimize the conditions for B production.

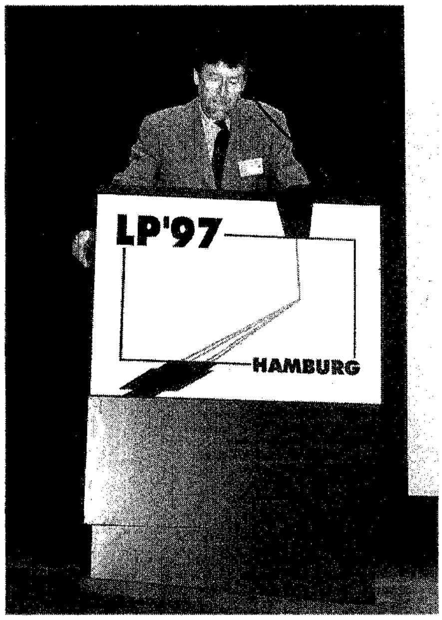
B particles prefer to decay into charmed particles, however the decays can also follow other routes which sidestep charm and produce light quarks instead. These charmless decays were once a rarity, but with so many Bs available now provide a useful physics window.

Cleo has used its large B sample to search for decays into two pions, two kaons, and a pion and a kaon. Aleph and Delphi at LEP are also beginning to contribute to this sector. Drell described as 'stunning' the B decay rate into a kaon and an eta prime, implying a complicated production mechanism. This result has been attracting special interest this year (see page 20).

However further progress in this

*The Hamburg Lepton-Photon Symposium was impressively orchestrated by a DESY committee chaired by Albrecht Wagner. Beeindruckend organisiert! (The conference logo shows the sort of thing which happens when 27.5 GeV positrons collide with 820 GeV protons.)*

*(DESY photos by Ilka Flegel and Daniela Friebel)*




sector has to await the new projects, providing more copious supplies of Bs than are currently available. The lead time needed for these facilities and experiments to get underway means that new results could be at least four years off, said Drell. In his summary talk, Barbieri warned that B physics may follow an unfamiliar path by the standards of experience with lighter quarks.

A particular route for B production is via the Z particles manufactured at LEP and SLC. D. Su of SLAC summarized the accumulated results from LEP (4.4 million Zs per experiment) and the SLC (200,000). In 1995 there had been a 'crisis' when the fraction of Zs seen to decays into Bs was judged to be slightly too high for the Standard Model's comfort. However this crisis has now passed, particularly thanks to a precise new measurement from the Delphi experiment at LEP, with the world average branching fraction of 21.69% now in accord with the Standard Model.

With this now in order, attention in B decays has turned to the marked asymmetry effects due to the marked left-handedness of the b quark. Here too the data has yet to settle down.

Olivier Schneider of CERN looked at the spectroscopy of heavy quarks. These exotic particle families are now the subject of detailed study, interpreted usually in terms of the now fruitful approach of heavy quark effective theory. Even radially excited B states have now been seen, while subtle differences in the lifetimes of particles containing heavy quarks but with different charge can usually be explained by the heavy quark mechanism.

Although effects have yet to be measured under all conditions, a high level of directly produced ('prompt') heavy quark-antiquark bound states (upsilons and J/psis) produced in high energy collisions looks to require explanation. It was once considered a major achievement to even see particle-antiparticle oscillations in the B sector, however these effects are now beginning to give useful constraints on inter-quark transitions.

Turning to a full quantum chromodynamics picture of quark interactions rather than simplistic approaches, Chris Sachrajda of Southampton underlined the theoretical difficulties of B physics.

In his Standard Model summary talk, Altarelli commented that while tau and B physics were the most difficult to bring into line with the Standard Model, these were also the most difficult sectors to measure and therefore were likely to show the largest deviations.

## *Hadron structure and quark dynamics*

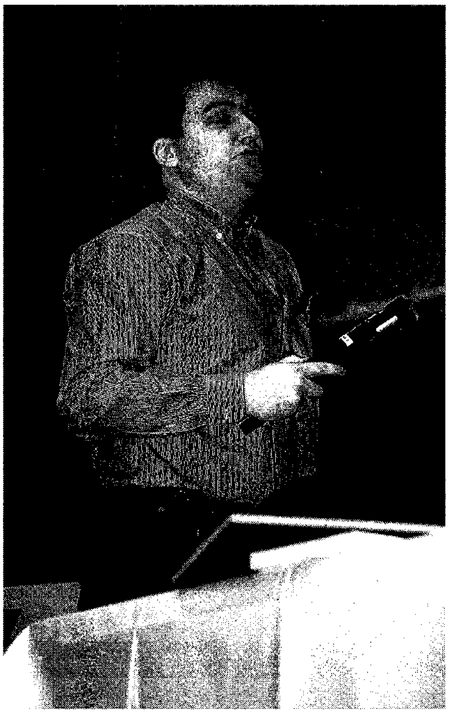
Following the initial controversy around the new HERA results, the programme offered the now well explored territory of hadron structure, where Vladimir Chekelian of Moscow showed that the quark and gluon content seen by a wide range of experiments is in agreement. A highlight is the low momentum fraction contribution pioneered by HERA, where a steep rise is attributed to gluon effects deep inside the proton.

Also on hadron structure, Antje Brüll of Heidelberg turned to the spin dependence, where a decade of accumulated results now show that the spin of the nucleon is not entirely carried by its quarks. 'The spin decomposition of the nucleon spin is still not resolved,' declared Brüll. New experiments are gearing up to study this question, with Hermes at HERA an important player and reporting its first results at Hamburg.

Quark-gluon structure is explored in exchange mechanisms as well as strongly interacting particles. Elisabetta Gallo looked at the mechanism of elastic scattering (the 'Pomeron'), which has both hard and soft components, depending on the kinematical domain.

Stefan Söldner-Remboldt looked at results on the quark-gluon structure of the photon. While the photon is the carrier of the electromagnetic force, its quantum fluctuations also mean that it contributes in other ways, and is being studied by an increasing number of experiments.

Quantum chromodynamics (QCD), the field theory of quarks and gluons, is becoming a very technical field. Not satisfied with explaining the production of confined clusters ('jets') of strongly interacting particles over many orders of magnitude of transverse energy, Heidi Schellman explained how attention is turning to the problem of differentiating be-



*André Rubbia covered the very active field of neutrino experiments at accelerators.*

tween jets of quark and gluon origin.

Even the complex 'fragmentation' mechanism which governs the production of visible particles from invisible quarks and gluons is less impenetrable.

Also highlighting QCD was Stefano Catani of Florence, who described attempts to break out of the straitjacket of perturbative QCD (which works very well in the limited areas where it is valid) and attack a wider range of problems.

An alternative route is the computer-hungry lattice approach (described by Martin Lüscher of DESY) which continues to provide encouraging results and act as a valuable pointer.

## *Neutrinos*

Neutrino effects are notoriously difficult to measure. This physics thus has always been in evolution, and this evolution now looks distinctly oscillatory. The big question now is whether the three neutrino types - electron, muon and tau - are immutable, or whether they gently oscillate, gradually changing from one variety to another as the neutrinos propagate over long distances.

After a brief pause while new experiments were prepared, the accelerator neutrino field is booming again, with major programmes at CERN and Fermilab and with complementary results from lower energy studies at Los Alamos and the Rutherford Appleton Laboratory (Karmen). At Hamburg, André Rubbia surveyed the accelerator neutrino scene.

The LSND experiment at Los Alamos continues to see an excess of events suggestive of neutrino oscillations. The initial signal came from muon decays at rest, but the experiment now also looks at muon decays in flight. The results are consistent with each other. However some of the LSND-allowed region for neutrino oscillations has been covered by other experiments, which exclude oscillations. The surviving LSND region could be further eroded when the Karmen study at RAL installs additional veto counters to further improve its sensitivity.

Strong suggestions of oscillating neutrinos from passive experiments (reported in the subsequent talk by Yoji Totsuka of Tokyo), coupled with the obstinate Los Alamos signal, requires further investigation by long- and medium-baseline neutrino studies, comparing neutrino signals at two widely-spaced detectors.

Such experiments are in the pipeline in Japan, with the K2K project linking the KEK laboratory and the Kamiokande underground facility, 250 kilometres away, and in the US, with the Minos project spanning Fermilab and the Soudan mine 730 kilometres distant. There are also plans to link CERN with the Italian Gran Sasso laboratory, another 730 kilometre footprint. 'A very active field,' concluded Rubbia.

However the main evidence for oscillations comes from non-accelerator experiments, with interactions of neutrinos from the decay of particles produced by cosmic ray interactions in the atmosphere.

In principle this signal should show twice as many muon-neutrinos as electron-neutrinos, but for some time underground experiments have been reporting a lack of muon neutrinos, which is now underlined by initial results from the new Super-kamiokande detector in Japan (September, page 18).

In addition, these detectors also monitor angular dependence, where there is a smaller signal from neutrinos coming from below - particles which have traversed the Earth before entering the detector, possibly affecting their oscillation pattern.

Neutrinos from the Sun can also be used as pointers to an oscillation phenomenon, with the signals from different solar reactions having to be reconciled with each other and with theoretical predictions.

As well as major new solar neutrino observatories at Sudbury, Canada, scheduled to begin operations next year, and Borexino at Grand Sasso, Totsuka also looked forward to new results from neutrino experiments at nuclear reactors.

Neutrino oscillations look to be 'here to stay', commented Altarelli in his review.

*Elsewhere*

Temporarily on hold, as far as new data is concerned, is the CP violation sector, where data from a previous generation of major experiments at CERN and Fermilab gave an inconclusive result. Following the overthrow of parity (the symmetry of space reflection) in weak interactions in 1956, a combined symmetry of parity and particle-antiparticle interchange was thought to be good, until that too fell in 1964.

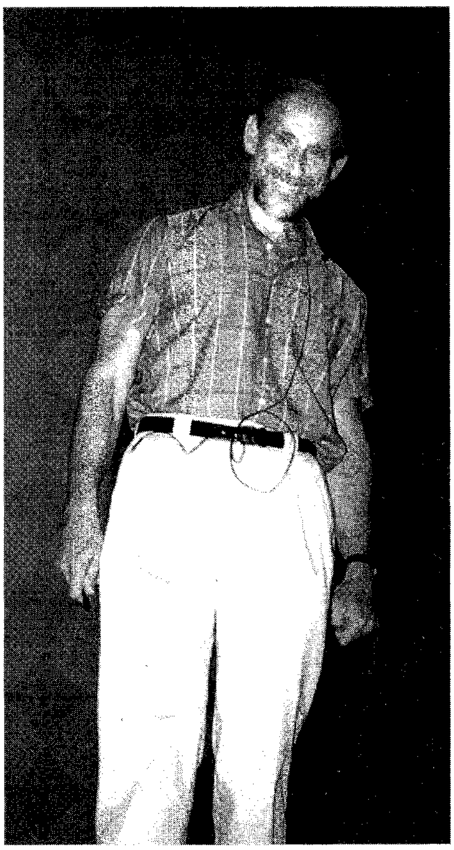
Ever since, physicists have been striving to pin down the detailed parameters of this mechanism, which so far has only been seen in the decays of neutral kaons. Speaking on the theory of CP violation, Yosef Nir of the Weizmann Institute rejected the conventional view that CP violation is the least understood Standard Model mechanism. Instead, he said, it was the 'least tested'.

Surveying the experimental CP violation scene, A.J. Stewart Smith of Princeton looked forward to fresh results, this time from the major NA48 and KTeV studies at CERN and Fermilab respectively, and from KLOE at Frascati, while a little further distant is the promise of the B sector, where CP violation is expected to be larger.

Temporarily reconciling themselves to the deficiencies of the Standard Model, delegates enjoyed a talk on astrophysics and cosmology from Neil Torok of Cambridge. 'We live inside the highest energy experiment ever conducted,' he observed, looking forward to more data being taken.

On the machine side, Eberhard Keil of CERN looked to the future of hadron machines, to CERN's LHC and well beyond, with machines of up to 100 TeV per beam, while Alban Mosnier of Saclay surveyed lepton collider prospects.

In a historical interlude, Jost Lemmerich sketched the background behind the discovery of the electron by J.J. Thomson at Cambridge one hundred years ago, recalling how this discovery was the outcome of a long series of investigations by many investigators.



*Leonard Susskind of Stanford in a memorable final outlook at the Hamburg Lepton-Photon Symposium tried to convince the Standard Model congregation that an understanding of the whole of physics was within reach.*

*Brane power*

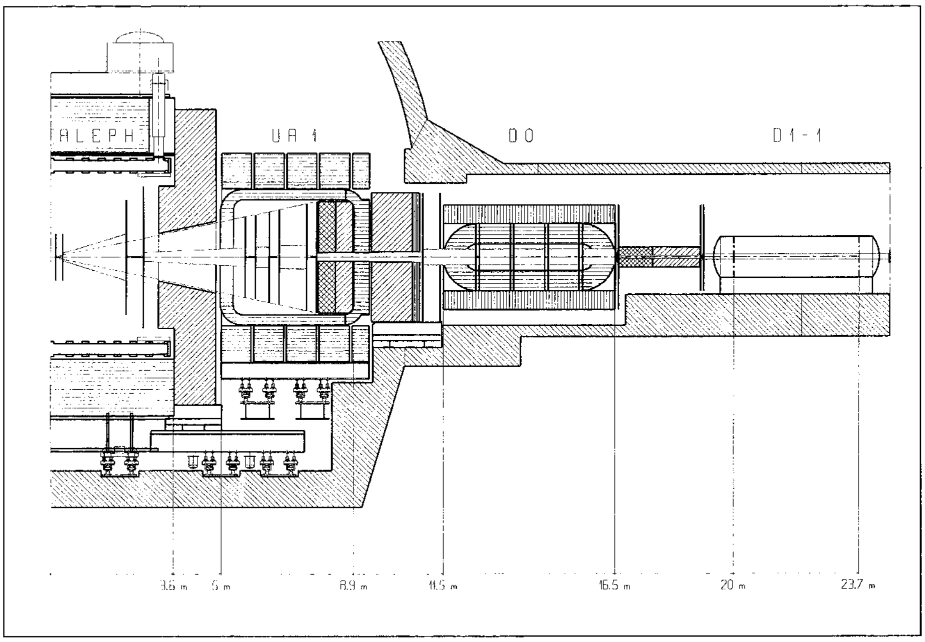
And so to outright speculation, where theorists are getting excited about descriptions of physics in terms of multi-dimensional 'branes' in abstract spaces (a particle, with no dimensions, is a 0-brane, while a one-dimensional string is a 1-brane). Wolfgang Lerche of CERN stressed the compelling demonstrations of the power of these pictures, which can account for the entropy of black holes.

However it was left to Leonard Susskind of Stanford in a memorable final outlook to make these arguments even more compelling, telling the Standard Model congregation that an understanding of the whole of physics was within reach.

*by Gordon Fraser*
*(who would like to thank Olivier Schneider for his help)*

# Around the Laboratories

*One half of the FELIX project proposed for CERN's LHC collider. Together with a similar setup in the other direction, the complete detector resembles two fixed target detectors back-to-back. By concentrating on these forward and backward regions around the beam pipe, FELIX hopes to uncover valuable new information on quark-gluon effects.*




## CERN
## Physics FELIX

The experimental programme for CERN's LHC collider continues to take shape en route to commissioning in 2005. The major landmarks are the big ATLAS and CMS general purpose detectors, ALICE for the LHC ion beam option, and LHC-B for the copiously produced B particles containing the fifth - 'beauty' or 'b' - quark.

Now a new arrival on the LHC scene is a letter of intent for a fifth experiment, FELIX, a major international collaboration to build a 'full acceptance' detector to catch as many as possible of the particles produced in the 14 TeV proton-proton collisions.

Because at these energies so many high energy secondary particles graze the direction of the colliding proton beams, emerging close to the beam pipe, traditional 'full solid angle' detectors in fact do not see most of the emerging energy. FELIX thus concentrates on the highly tapered conical zones close to the beam pipe on either side of the collision point.

Traditional major colliding proton beam detectors concentrate on high transverse momentum particles flying out at large angles to the beam and use a central barrel closed by more or less flat end caps. Instead, FELIX resembles two fixed-target detectors placed back-to-back, giving the overall appearance of a high technology cigar 33 metres long and some 8 metres in diameter. This is complemented by smaller detector modules extending out to 430 metres from the collision point, picking up relative momentum transfers as small as 2 parts in a thousand!

The central part of FELIX would be the existing superconducting magnet of the Aleph experiment at CERN's LEP electron-positron collider, and the plan is that FELIX would succeed Aleph as tenant of Point 4 under the Jura mountains in the 27 kilometre LEP/LHC tunnel. This old Aleph magnet, largely uninstrumented, would be sandwiched on either side by calorimetry housed in two halves of the old UA1 magnet, now undergoing a second lease of life for the Nomad neutrino experiment at CERN and which would be reconfigured for a third incarnation for FELIX.

A full-acceptance detector like FELIX cannot afford overlapping collisions and has to work event by event. Thus the luminosity (a measure of the collision rate) is limited to $10^{32}$ per sq cm per s. Unlike other LHC intersection regions, where the colliding beams will be squeezed tighter to boost this collision rate as high as possible, FELIX will work with focusing quadrupoles more than 120 m from the collision point.

Inside this region, the beams will meet exactly head-on in a 'kissing scheme' profiting from large aperture superconducting dipoles developed at Brookhaven for the RHIC heavy ion collider. Further from the detector, these would be supplemented by more superconducting dipoles.

Calorimetry on either side of the collision point would make use of sampling techniques using plastic scintillator and wavelength shifting readout. Further forward, calorimetry would use 'spaghetti' techniques with thin capillaries filled with scintillator or with quartz fibres.

Tracking tries to get as close to the beam direction as possible, with some 50 tracking stations extending 430 metres down the beam pipe. Fixed radius tracking using silicon pixels will reach to within 2.5 cm of the beams. To get closer still, FELIX will use so-called 'Roman pots', a technique pioneered in the early 1970s at CERN's Intersecting Storage Rings in which detector modules slide into vacuum-sealed keyholes in the beam pipe and probe the particles inside. These pots will probably employ silicon strip detectors.

Rather than hunting for new particles, the physics aims of FELIX are to explore in detail the quark-gluon (quantum chromodynamics - QCD) processes at work at ultra-high energy, to map the inner structure of the proton on more detail, and work towards a better understanding of everyday mechanisms such as jet production and diffraction. In particular, the momentum fraction explored will extend down to $10^{-7}$, compared to the $10^{-4}$ explored at the HERA electron-proton collider at DESY, Hamburg, and where an intriguing increase in gluon content shows up.

These goals had also been identified at the US Superconducting Supercollider (SSC) project, unfortunately cancelled in 1993, where J.D. Bjorken of SLAC, Stanford, had masterminded a scheme for a general-purpose detector. He is now a key member of the FELIX team, whose spokespersons are Karsten Eggert of CERN and Cyrus Taylor of Case Western Reserve.

The unusual configuration, with a central barrel magnet largely uninstrumented except for the inner tracker, means that FELIX would cost only a fraction of the outlay for a more traditional collider detector. FELIX proponents point out that no such experiment has ever been mounted at a proton collider. The project welcomes additional collaborators.

## FERMILAB/CERN Scintillating collaboration

As well as preparing to construct the LHC proton collider itself in CERN's 27-kilometre LEP tunnel, scientists worldwide are also turning their attention towards preparations for the big experiments which will exploit the new machine.

The CMS - Compact Muon Solenoid - detector (June 1995, page 5) will use a 4 tesla superconducting electromagnet 13m long and 5.9m diameter. (Although it will occupy more than half the length and almost all the width of a singles tennis court, the detector nevertheless merits the adjective 'compact' on this scale of physics.)

Inside this detector, a major component will be the hadron calorimetry system and associated technology to measure the energies and directions of all colliding proton constituents - quarks and gluons - by picking up the particle jets released by these reactions, and inferring the release of otherwise invisible neutrinos through any energy imbalance of the visible particles. The tracker, the electromagnetic calorimeter and the inner hadron calorimeter all reside inside the superconducting solenoid.

The electromagnetic part, surrounding the central tracker, will be of lead tungstate crystals. Surrounding it, the hadron calorimeter will have a central barrel of inner diameter 1.8m, extending over a distance of 1.1m, with endcaps 1.8m thick, supplemented by additional instrumentation (the outer calorimeter) interleaved with the surrounding muon detection system. Closing the ends of the barrel are two hadron calorimeter endcaps, also inside the superconducting solenoid.

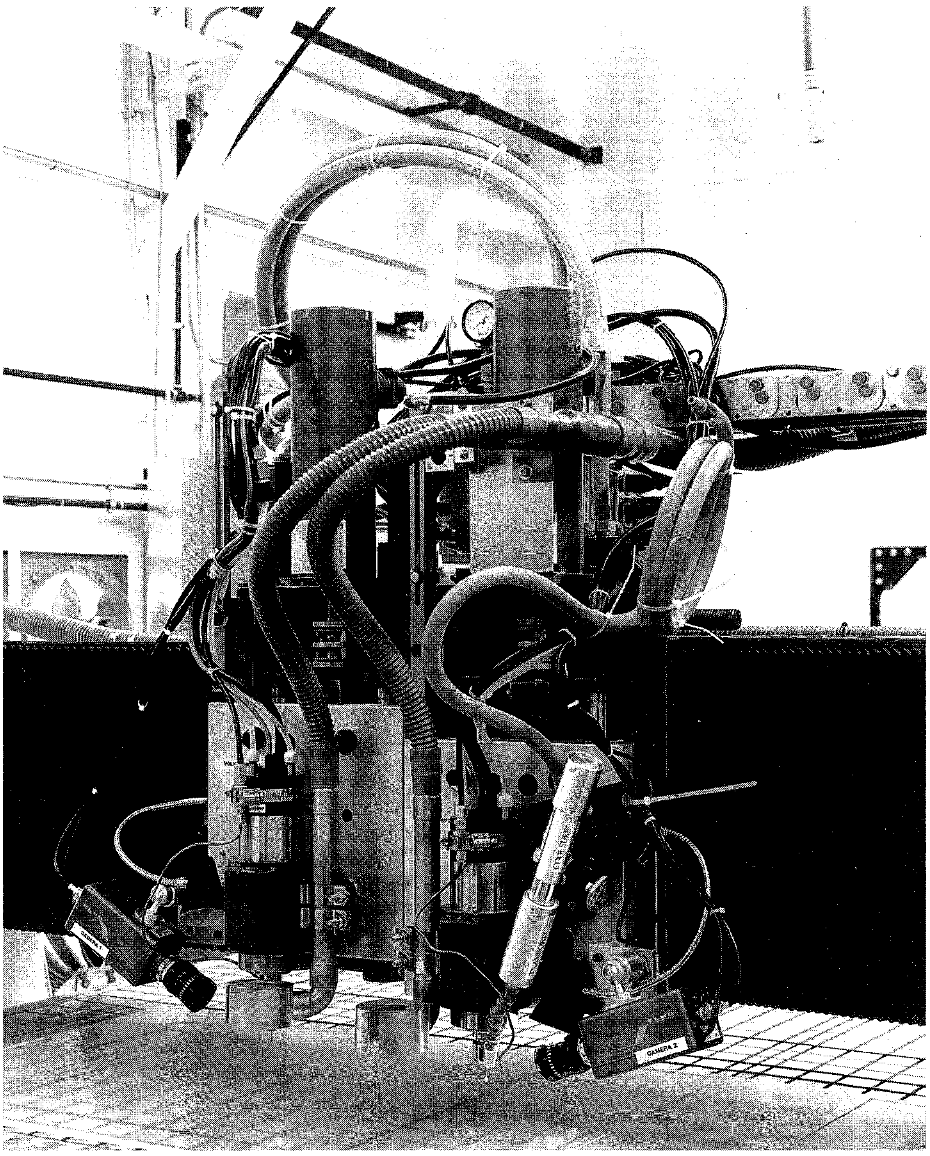
The CMS central hadron calorimeters use tiles of scintillator plastic as their active elements. Scintillation light produced in the tiles is captured in wavelength-shifting optical fibres placed in grooves in the tiles. The light is then carried to the photodetectors to be converted into electrical pulses. This technique is similar to that used in the upgrade for the CDF detector at Fermilab's Tevatron.

The calorimetry coverage will be completed by forward units 11 metres either side of the interaction point. Because of the extremely high radiation levels in the forward region, they require a different, radiation-resistant readout technique. These devices will measure Cerenkov light generated in quartz fibres.

In this mighty array of calorimeter instrumentation, the barrel alone will weigh over 1000 tonnes. Operating inside the solenoid, the calorimeter absorber will be made of layers of non-magnetic metal, predominantly brass (90% copper, 10% zinc) plates, 5cm thick in the barrel (8 cm in the endcaps). Brass is chosen because it is mechanically stronger than copper and easier to machine than stainless steel.

The barrel is made up of two halves, each containing 18 wedges, each weighing 28 tonnes. The endcaps are constructed as monoliths, each weighing about 300 tonnes. The barrel and endcap absorber structures will be built and assembled in commercial factories and shipped directly to CERN.

The central calorimeter wedges are instrumented with scintillator, typically 4mm thick, fitted with grooves to carry the readout wavelength-shifter fibres. The tiles are arranged in trays, fitted with fibre and



*As well as being the headquarters of the major US involvement in the CMS detector for the LHC proton collider at CERN, Fermilab will play a major supply role for the detector's hadron calorimeter. Some 3000 square metres of scintillator are needed for the barrel calorimeter, enough to cover several Olympic swimming pools. Here a machine is cutting scintillation 'tiles' for a prototype calorimeter.*

*(Photo Fermilab)*

optical connector assemblies, called 'pigtails'. The tile arrays - 'megatiles' - are cut from large sheets of scintillator (2 x 1m) of closely monitored properties. The inner barrel alone needs some 43,000 tiles. Fabrication must be closely controlled, with special attention paid to mechanical tolerances and fibre grooving. A collaboration of 16 US groups is responsible for the central calorimeter.

Some 3000 square metres of scintillator are needed for the barrel calorimeter, enough to cover several Olympic swimming pools. Even just cutting this material at Fermilab will take several years of work.

In addition, some 1000 square metres of scintillator are needed for the outer barrel, underneath the muon chambers. The outer calorimeter scintillators will be fabricated by a consortium of Indian groups, led by the Tata Institute.

One of the challenges of building a calorimeter that will live in a 4T environment was to find a photodetector insensitive to magnetic fields. The proximity-focused hybrid photodiode (HPD) was adopted. This device, developed at CERN, consists of a photocathode, a high accelerating voltage, and a silicon diode. When the electric and magnetic fields are aligned, this device can perform in very strong magnetic fields.

The endcap calorimeters are based on the same technology as the barrel. Here 27,500 4mm-thick tiles are required, with a total surface area of scintillator of about 1000 sq m. Russia and Dubna Member States are responsible for supplying large parts of the endcap calorimeters, with US groups supplying HPDs and the front-end electronics.

As well as being the headquarters of US CMS involvement, Fermilab will play a major supply role for the detector's hadron calorimeter. A large factory is being set up at Fermilab to assemble the scintillators for the CMS barrel. The scintillators for each CMS barrel wedge will arrive at CERN in sea containers, where they will be mated with the absorber wedges.

Activity at CERN will quicken in 1998, with the arrival of full-size calorimeter prototypes.

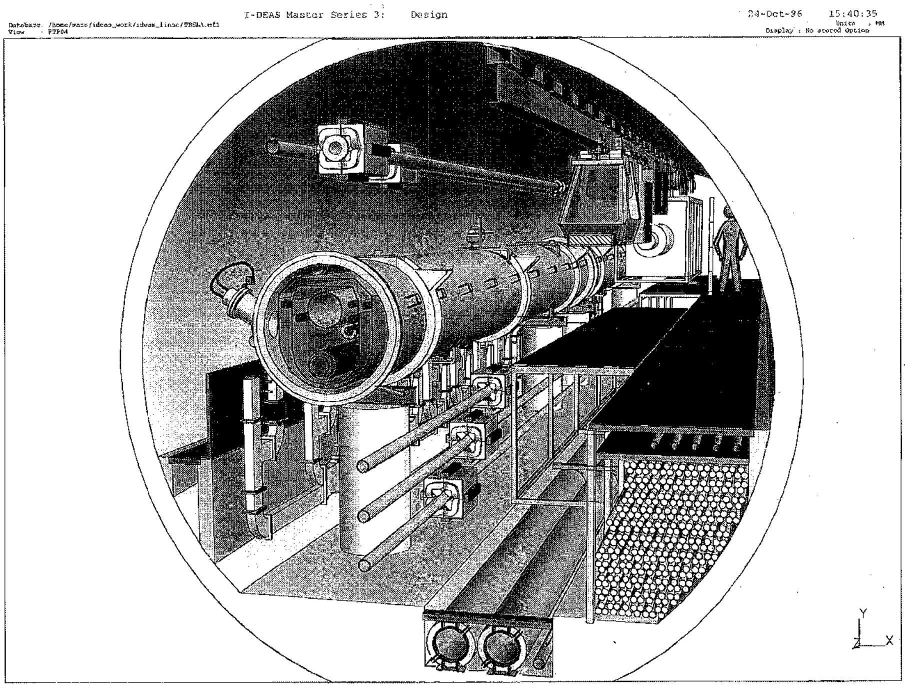
## DESY
## Collision course

Proton and electron beams have provided complementary approaches to solving the big problems in physics, and this looks set to continue. While CERN's LHC proton collider pushes ahead en route to its scheduled commissioning in 2005, elsewhere plans are being prepared for the complementary electron scenario.

With electron synchrotrons hamstrung by synchrotron radiation losses at higher energies, CERN's 27-kilometre LEP ring will surely be the largest electron synchrotron to be built, and ongoing plans focus on linear electron-positron colliders to attain the new energy horizons.

The feasibility of such a collider was demonstrated in 1989 when the SLC linear collider at the Stanford Linear Accelerator Centre provided its first physics results. After accelerating electrons and positrons down the same 2-mile pipe, the SLC separates the beams, bending them round 180°

*DESY uses the superconducting TESLA (TeV Superconducting Linear Accelerator) approach as the prime contender technology for its next generation electron-positron collider.*




in opposite directions to eventually collide.

In a true linear collider, separate electron and positron 'cannons' would fire their beams into each other head-on.

The DESY Laboratory in Hamburg has been preparing electron-positron collider scenarios for some time and has now published the conceptual design of a 500 GeV collider. To maintain DESY's tradition of providing synchrotron radiation for materials science, the design also incorporates an integrated X-ray laser.

After promising results with superconducting cavities (July, page 1), recently DESY focused on the superconducting TESLA (TeV Superconducting Linear Accelerator) approach as the prime contender technology.

DESY's TESLA uses 9-cell niobium cavities cooled by superfluid helium to 2K and operating at 1.3 GHz (L-band). For a 500 GeV collider, the accelerating field should attain 25 MV/m and a resonance Q of 5 x $10^9$. Recent results show that the difficult quality control needed to ensure flaw-free cavities to attain the design field is well in hand.

Unlike other linear collider approaches (April, page 16) , TESLA uses low r.f. peak power (0.2 MW/m) but long pulses (800 microsec), which with low power dissipation in the cavity gives high efficiency conversion of AC power to beam power. With high average beam power, the required collision rate ($10^{33}$ per sq cm per s luminosity) can be achieved with a 19-nanometre beam spot, only three times smaller than what has already been achieved at the SLAC Final Focus Test Beam experiment at lower energy.

The long r.f. pulse makes for large bunch spacing (708 nanoseconds) so that physicists can resolve single crossings of particle bunches, while fast bunch-to-bunch feedback can stabilize the beams within a few bunch collisions and keep the tiny beams locked onto each other.

Following the encouraging cavity performance, the next stage is for a 24-cavity test linac to attain 400 MeV. As well as providing valuable operating experience, it will also provide a sound basis for final cost analysis.

The high beam quality of the TESLA machine would also make it an ideal driver for an X-ray Free Electron Laser (FEL). However, like the linear collider itself, such an FEL would be a significant extrapolation of present technology, but would open up a wide range of studies.

If the linear collider is constructed at DESY, the 6.3-kilometre HERA ring would provide additional flexibility, opening the door to electron-proton collisions, and/or acting as a pulse stretcher to deliver an electron beam for nuclear physics experiments - the ELFE Electron Laboratory For Europe (December 1995, page 6).

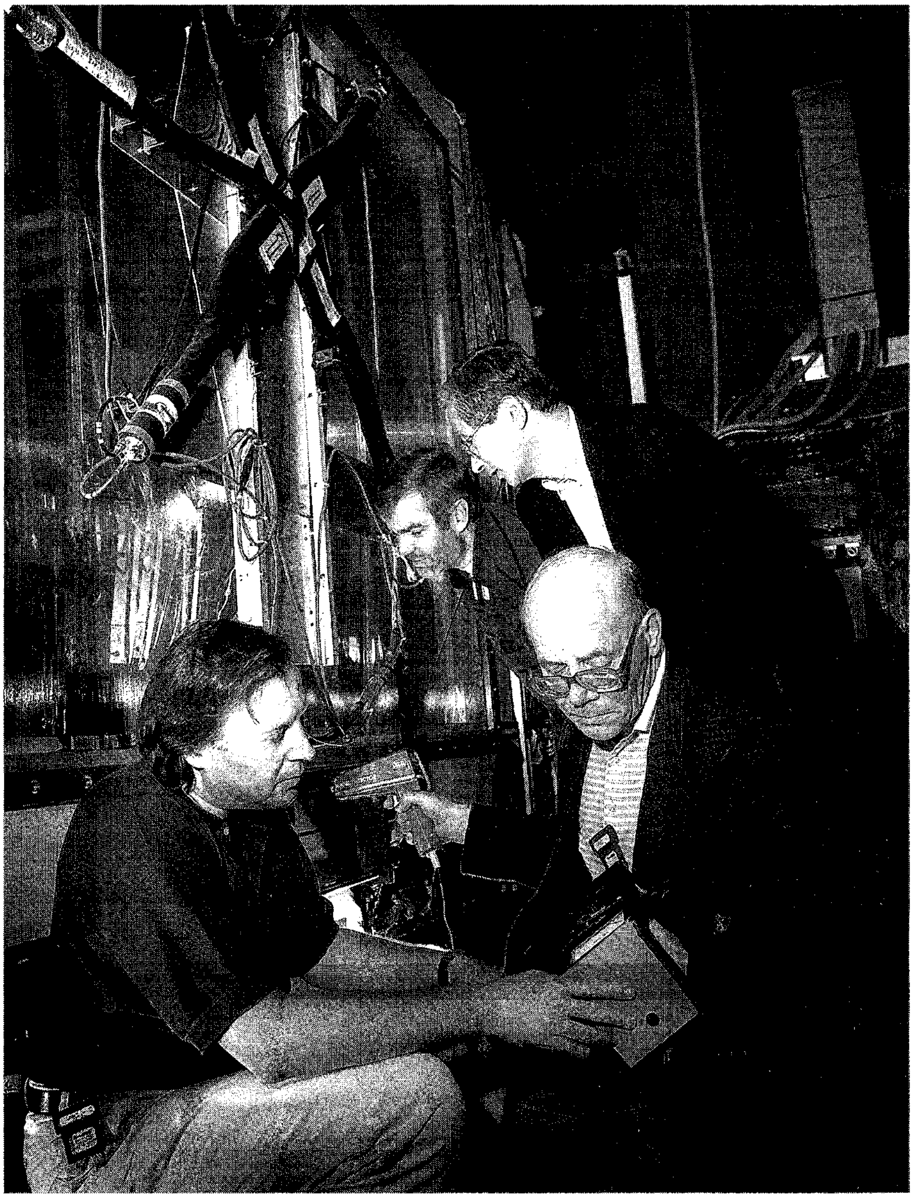
As well as TESLA, DESY also has a fallback design based on more conventional S-band (3 GHz) radiofrequency technology. Together the DESY-coordinated TESLA and S-band development work involves 30 institutes in nine countries.

The S-band approach would require an accelerating gradient of 17 MV/m with 12 MV/m peak power, 2 microsecond pulse length and 6 nanosecond punch spacing

## *Physics objectives*

The detailed case for an electron-positron linear collider has been studied by a specially-convened DESY/ECFA (European Committee for Future Accelerators) committee which sponsored working groups looking at physics, detectors con-cepts, detector subsystems, and the

*The E852 experiment at Brookhaven has found evidence for an exotic 1370 MeV meson. Left to right: Dennis Weygand and Hans Willutzki (foreground), and Robert Hackenburg and Suh-Urk Chung (background).*



collider-experiment interface.

Physics-wise, the collider would be able to make a precision survey of the sixth 'top' quark and pin down masses to within 200 MeV. While the physics of the top quark is totally consistent with current 'Standard Model' wisdom, the heaviness of this quark remains a puzzle.

The collider would also extend the study of the W and Z weak interaction carriers, and provide a canvas for higgs physics, the unknown symmetry breaking mechanism at the heart of the electroweak unification.

To attack these physics questions, the optimal detector scenario would need a large and powerful solenoid to bend the high energy tracks, with calorimetry inside the coil for jet resolution. Compared to conventional installations at colliding beam machines, the detector surrounds a much smaller beam pipe, making for a smaller inner radius for the central tracker and requiring much higher resolution.

Compared to the big detectors being prepared for CERN's LHC proton collider which will have to contend with an avalanche of physics information, the linear collider will have lower collision rates to contend with and will be able to sip their data more leisurely.

## BROOKHAVEN
## New exotic particle

Physicists working at Brookhaven have found evidence of a new "exotic" meson. The 51-strong team found the evidence after five years of diligent searching through the reaction products of billions of particle collisions at Brookhaven's Alternating Gradient Synchrotron (AGS) accelerator. Their paper was published in the September 1 issue of Physical Review Letters.

The E852 experiment closely examined the particles produced when an 18 GeV negative pion beam hit a liquid hydrogen target in the Multi-Particle Spectrometer. Led by physicists from Notre Dame, the collaboration also included Brookhaven, Northwestern, Rensselaer Polytechnic, the University of Massachusetts Dartmouth, and Russia's Institute for High Energy Physics and Moscow State University. The collaboration is funded by DOE and the National Science Foundation.

Subnuclear particles come in two types, baryons and mesons. Baryons (such as the familiar proton and neutron) contain three quarks, while mesons (such as the pion) are made up of a quark bound to an antiquark. The quarks in both baryons and mesons are bound together by gluons. In a meson, the gluon bond can be pictured as a string stretched between the quark and the antiquark. In normal mesons, this gluon string is stretched tight, but does not vibrate. However in a high energy collision the gluon string could be 'plucked' and oscillate, giving the meson extra energy. Theorists have predicted the existence of exotic 'hybrid' mesons since the late 1970s, but E852 may have found the first trace of their existence.

The new state, at 1370 MeV, has a width of 385 MeV with unit spin and negative parity, and had to be disen-

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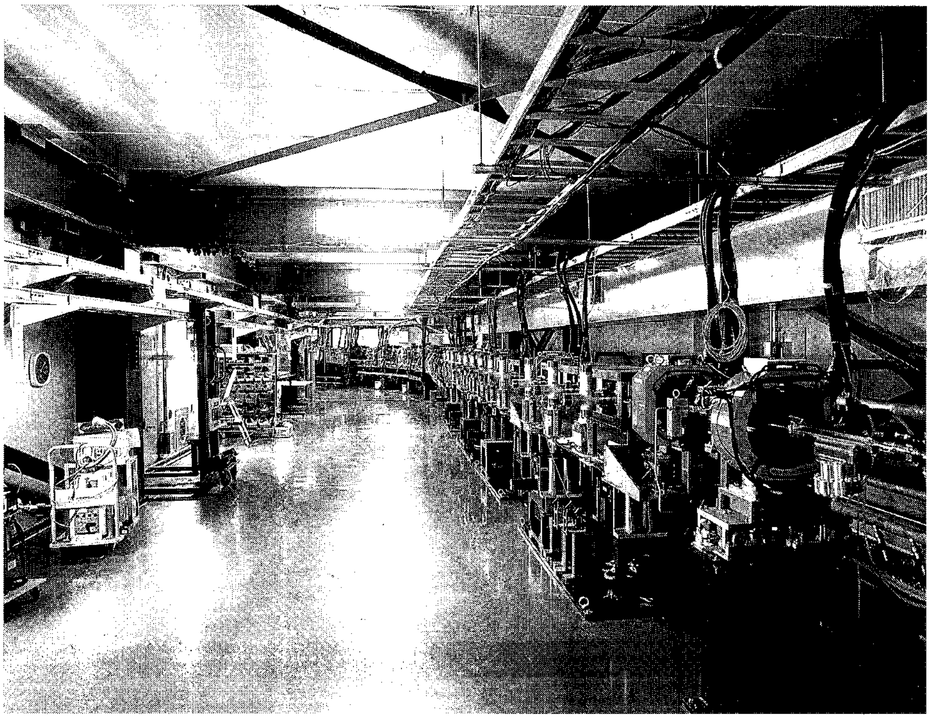


*The damping ring for the Accelerator Test Facility (ATF) project at the Japanese KEK Laboratory, currently being commissioned.*

tangled from the nearby $a_2$ at 1320 MeV. It cannot be explained as a quark and an antiquark with a quiet gluon string. It must be either a quark and an antiquark connected by a "plucked" string, or a four-quark system.

The findings were presented at the biennial International Conference on Hadron Spectroscopy, held at Brookhaven in late August.

## KEK
## New damping ring

The Accelerator Test Facility (ATF) project at the Japanese KEK Laboratory recently reached a new stage of development, with beam commissioning work for its damping ring to fine-tune the beams before they are finally injected into the accelerating linacs.

An absolutely essential requirement for obtaining the desired collision rate (luminosity) in next-generation electron-positron linear colliders is very slim multi-bunch trains of electrons and positrons. For instance, the JLC linear collider design currently considered at KEK calls for emittance parameters of $10^{-6}$ m and 3 x $10^{-8}$ m in the x and y directions respectively and a bunch length of 0.1 mm.

The ATF program was launched at KEK in 1990 as a test facility for investigating the technical feasibility of the low-energy portion of such a linear collider to produce multi-bunch beams with extremely low emittance.

The first subsystem to be built was a multi-bunch train thermionic gun capable of producing up to 20 bunches spaced by 2.8 ns with a maximum intensity 5 x $10^{10}$ per pulse. It was followed by a 1.54 GeV S-band injector linac. A variety of beam diagnostic instruments were tested in a multi-bunch environment. In 1993 an important proof-of-principle had been demonstrated using a multi-bunch beam-loading compensation system.

Construction of the 1.54 GeV ATF damping ring and associated beam lines started in early 1996. The race-track ring has a circumference of 138.6m. The two arc sections implement a special design of a strong-focusing (FOBO) lattice, where combined-function bending magnets are used for reducing the equilibrium beam emittance.

The straight sections accommodate injection and extraction septa, damped radiofrequency cavities operated at 714 MHz, and 20.4m-long damping wigglers. The design horizontal emittance is 4.3 - 6.6 x $10^{-6}$ m, and the damping time 9.1ms when operated at 1.54 GeV.

The damping ring is designed to eventually store 5 bunch trains, each of 20 bunches separated by 2.8ns.

Prior to beam commissioning, a new international collaboration in accelerator development at the ATF was formed late last year. This loose worldwide grouping of accelerator scientists includes KEK, SLAC (Stanford, US), DESY (Germany), CERN (Europe), SEFT (Finland), the Budker Institute (Novosibirsk/ Protvino, Russia), PAL (Korea), IHEP (China) as well as a number of universities in Japan, including Nagoya, Kyoto, Tohoku, Tohoku Gakuin, and Tokyo Metropolitan. Many members of the ATF collaboration helped in the beam commissioning and around-the-clock shift work. Colleagues from SLAC brought and installed the injection kicker system and also built a set of line ion chambers that continuously monitor beam loss along the ring.

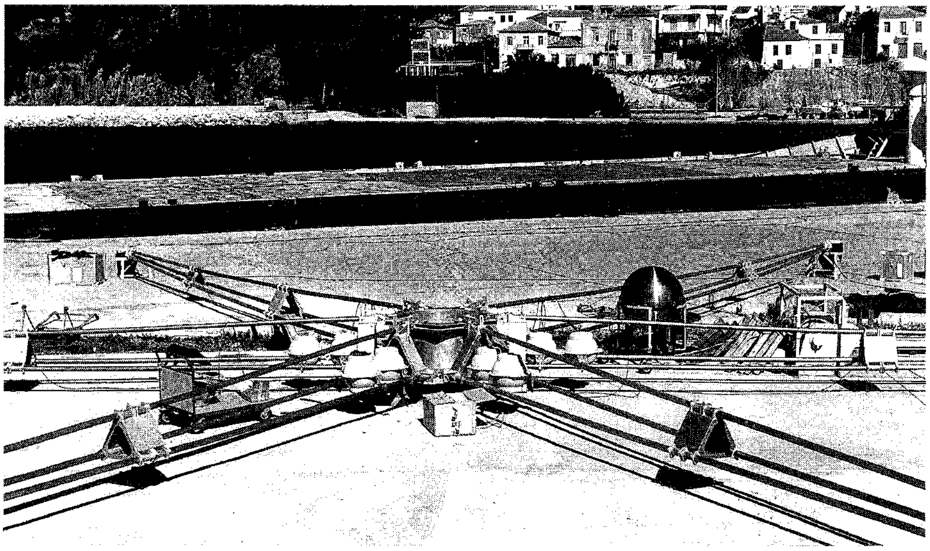
A longitudinal bunch oscillation monitor system was built by a member from DESY. Beam studies and data analyses have been conducted by members from all collaborating institutes.

The damping ring was initially operated at 1.3 GeV in a single-bunch mode at a repetition rate of 0.78 Hz with 7 x$10^9$ electrons per bunch, and a measured lifetime of 46s, consistent with the estimated lifetime. The x, y and z damping times have been measured to be 17.7 ±4.6 17.2 ± 6.5 and 18.5 ± 1.9 ms with the wigglers turned on, compared to the theoretically predicted values of 11.9, 16.5 and 10.2 ms. The measured bunch sizes are 88.5 ± 20 microns and 10.5 ± 1.5 mm in x and z directions respectively, within a factor of 2 of the predicted values of 36 microns and 6.6 mm.

However the vertical beam size measurement disagrees with the calculation and is a factor 10 or more too large. A number of possible causes have been considered, and studies are continuing.

The present focus is on correcting misalignment of damping ring components, errors in the damping ring beam optics (particularly the vertical dispersion), and possible systematic errors in the synchrotron radiation monitor system with which the beam sizes are measured.

In the next stage, beam energy will be increased to 1.5 GeV. A series of precise measurements on the image size, bunch length, possible field errors etc will continue in single-bunch operation until next spring, after which hardware upgrades for the radiofrequency system and multi-bunch operation are scheduled. Many aspects of stored beam behaviour remain to be investigated. Experiments with an extracted beam are also under consideration,



*A 'floor' of the NESTOR underwater neutrino detector, prior to deployment off the Greek coast.*

## NEUTRINOS
## Test of NESTOR

Recent neutrino results from the new Japanese Superkamiokande detector (September, page 25) underline the ongoing importance of passive neutrino studies. As well as underground detectors, studies using water and ice as neutrino targets are also geared to make contributions.

AMANDA at the South Pole (January 1996, page 7) uses Antarctic ice and the Lake Baikal detector in Siberia (September 1996, page 25). Also in the underwater neutrino stakes is NESTOR, to be deployed at Pylos just off the Greek coast.

A Greek/Russian/German/Italian collaboration, NESTOR continues to test detector modules prior to the start of data taking. A series of mechanical and deployment tests successfully deployed two aluminium 'floors' 34 m in diameter, each containing 12 photomultipliers, at a depth of 2600 m. Robustness was demonstrated by towing the assemblies submerged over considerable distances.

For the final detector, the basic unit will be a 'tower' of 12 six-legged floors stacked 30 m apart, taller than the Eiffel tower. These will then be put together to form a cubic kilometre detector which for neutrino physics will be deployed at a depth of 4000 m.

To support this new physics effort, the Greek government has now established a dedicated national laboratory, the Nestor Institute for Deep Sea Research, Technology and Neutrino Astroparticle Physics.

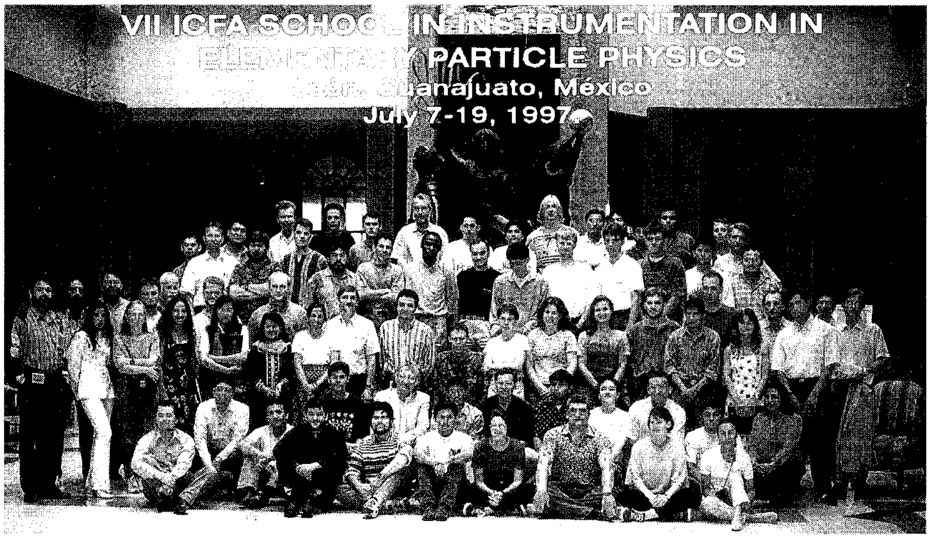
## BERKELEY
## New dipole record

On March 13, a 1-metre niobium-tin dipole magnet, designed and built at Berkeley, reached a new record field of 13.3 tesla; not long thereafter it reached 13.5 T at 1.8 K. These values surpass the record set in 1995 of 11.03 T for a similar type of 50 mm bore, 1 m long model dipole that was build by Twente University in the Netherlands and tested at CERN.

These figures may be compared to the field strengths used in existing and planned superconducting accelerators: Fermilab's Tevatron operates at about 4.5 T, HERA at DESY operates at 4.6 T, CERN's LHC plans to operate at 8.36 T, and the SSC would have operated at 6.6 T. Superconducting magnets conventionally employ ductile niobium-titanium conductor.

Although it can carry higher currents and therefore higher fields, niobium-tin suffers from the drawback of not being ductile. The niobium-tin superconductor composite can withstand only about 0.6% strain before permanent degradation in the current density is observed. The fabrication process requires that the cable be wound into the magnet before the brittle niobium-tin compound is formed, and then the niobium-tin phase is obtained by heating the coils to 950 K for about ten days. The coils are then cooled to ambient temperature, assembled into the dipole magnet, and then cooled to 4.3 K.

The strain state of the conductor must be calculated for each step after the material is reacted and the strain must be kept below some low threshold, usually less than about 0.5%. This is challenging, because from a reaction temperature of 970 K to a test temperature of 4.3 K, differential thermal contraction effects are large and can lead to unacceptably large strains. In addition, the magnet fabrication procedures must be thoroughly developed so that the conductor is not strained in the critical steps after reaction and before the coils are epoxy impregnated. Finally, the magnet pre-stressing approach must be chosen carefully so that the coils are not damaged.




*The seventh biennial School on Instrumentation in Elementary Particle Physics, organized under the auspices of ICFA, the International Committee for Future Accelerators, was held in León, Guanajuato, México, from July 7 - 19.*

## ICFA Instrumentation school in Mexico

The biennial School on Instrumentation in Elementary Particle Physics, organized under the auspices of ICFA, the International Committee for Future Accelerators, is devoted to the physics and technologies of instrumentation in elementary particle physics and applications of such techniques to medicine and nuclear sciences as well as to research and development in industry. The school is one of the activities of the efficacious ICFA Instrumentation Panel, chaired by Tord Ekelof of Uppsala.

The most recent such school (the seventh) was held in León, Guanajuato, México, from July 7 - 19, organized by the panel on Instrumentation Innovation and Development of ICFA, the University of Guanajuato at León, the Centro de Investigación y de Estudios Avanzados (CINVESTAV) and the Division of Particles and Fields of the Mexican Physical Society.

Topics covered include particle detection, gaseous detectors, particle identification, calorimetry, semiconductor detectors, signal processing and data acquisition. In addition, review talks include new techniques as well as applications in medical physics, astrophysics and particle physics.

An important feature of these schools are laboratory courses, in which students work in small groups on multiwire proportional chambers, silicon detectors, microstrip gas chambers, scintillating fibre, analog and digital circuits, and data acquisition.

The school gives the participants an opportunity to meet experts whose names they would otherwise know only from the pages of journals. Participants, especially those from third-world countries, have unique opportunities to review their objectives and techniques.

# Director Computing Division

**Fermi National Accelerator Laboratory,** dedicated to fundamental research in particle physics and related fields, and home to the world's highest energy accelerator, has an exceptional professional opportunity available to lead one of its four major scientific divisions.

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The demands of our experimental program on computing technologies, both for CPU capacity and data handling, are among the most intense of any activity in the world and include operating some of the world's largest workstation clusters for reconstruction of data, a 50 GFlop supercomputer for theoretical calculations, disk capacity exceeding 2 TBytes, and robotic storage of 40 TBytes. The next run of our colliding beam program, which is expected to commence in early 2000, will produce nearly a PetaByte of data per year requiring expansion of our computing capacity to nearly 300,000 MIPS for reconstruction and analysis, as well as some 40 TBytes of disk, and 400 TBytes of robotic storage for the first two years.

Reporting to the Laboratory's Director and Associate Director for Information and Technology, the qualified candidate will possess extensive knowledge of present computing technologies and trends relating to both the commercial and academic computer science sectors. Project management and organizational expertise in a highly technical environment is also essential, as is experience in large scientific facilities, with dispersed experimental collaborations. High energy physics experience is a plus.

Located 40 miles west of downtown Chicago, we offer a competitive salary and excellent benefits package. For consideration, please forward a curriculum vitae, three references and a letter of interest to: **Dr. Thomas Nash, Associate Director, M.S. 200, Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, IL 60510-0500, U.S.A.** To access Employment Opportunities at Fermilab and a complete description of this position, our URL is [http://fnalpubs.fnal.gov/employ/jobs.html]. EOE M/F/D/V.

**Fermilab**

## FACULTY POSITIONS IN PHYSICS

**University of California, Berkeley**

The Physics Department of the University of California, Berkeley intends to make one or more faculty appointments effective July 1, 1998. Candidates from all fields of physics are encouraged to apply. Appointments at both tenure-track assistant professor and tenured levels will be considered.

Please send a curriculum vitae, bibliography, statement of research interests, and a list of references to:

**Professor Roger W. Falcone, Chairman**
**Department of Physics**
**366 LeConte Hall #7300**
**University of California**
**Berkeley, CA 94720-7300**

by Tuesday, November 25, 1997. E-mail applications will not be accepted. Applications submitted after the deadline will not be considered. The University of California is an Equal Opportunity, Affirmative Action Employer.

## FACULTY POSITION

Southern Methodist University

The Department of Physics at the Southern Methodist University in Dallas invites applications for a tenure track faculty position in experimental high energy physics. Subject to budgetary approval, the position will be open at the Assistant Professor level although in exceptional circumstance a higher level appointment may be considered. The successful candidate will be expected to teach at the undergraduate and graduate levels and to conduct an active research program. Currently, the SMU group is involved in the CLEO and ATLAS experiments. Applicants should submit a detailed curriculum vitae, list of publications and a statement describing their research and teaching interest and should arrange for at least three letters of references sent directly to: Faculty Search, c/o Ms. Carol Carroll, Department of Physics, Southern Methodist University, Dallas, TX 75275-0175. Position begins in the fall semester, 1998. To ensure full consideration for the position, the application must be postmarked on or before December 1, 1997 but the committee will continue to accept applications until the position is filled. The committee will notify applicants of its employment decision after the position is filled.

*Southern Methodist University is an Equal Opportunity, Affirmative Action employer.*

# Physics monitor

Informal discussions present opportunities for the development of research projects between students and their lecturers, and strong links are formed among participants from all the continents.

ICFA schools are thus encouraging a network and accessible community of experts in instrumentation for elementary particle physics throughout the world.

With nearby Guanajuato considered by many to be the most beautiful city in America, León proved an excellent site for the school. China and Turkey are being considered as candidate sites for the eighth ICFA School in 1999.

*by Gerardo Herrera Corral, CINVESTAV*

## B and CP Heavy emphasis on heavy quarks

The physics of B particles (containing the fifth - beauty, 'b' - quark) and CP violation is now one of the major growth areas in high energy physics. Nearly every major high energy physics laboratory has a project underway to observe the large CP asymmetries expected in the B sector and test the consistency of the underlying physics. CP violation, one of the most subtle effects in today's Standard Model orthodoxy, may be the first clue to the physics which lies beyond.

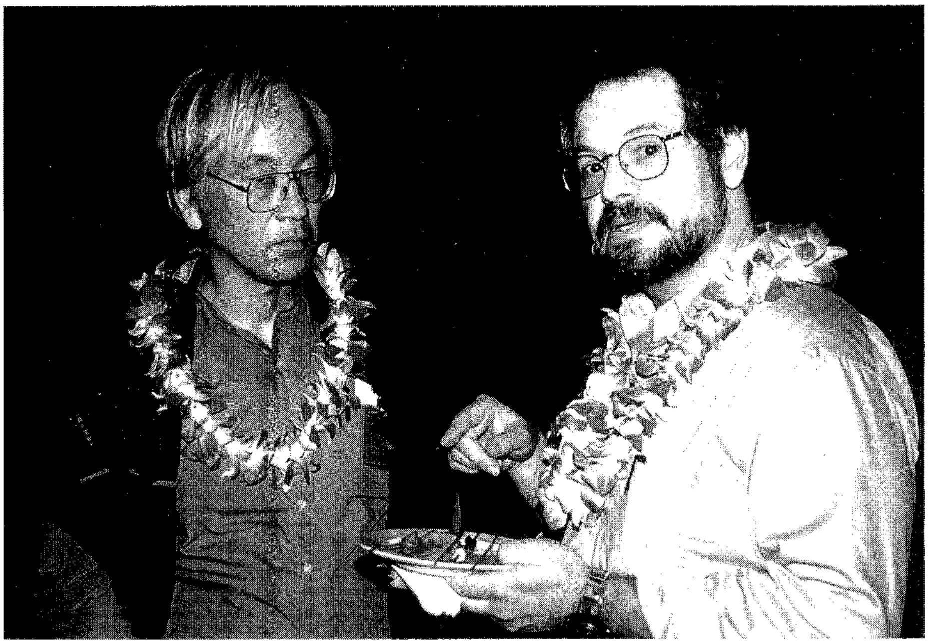
Although B physics was touched on in the major summer meetings, it was overshadowed by more traditional physics sector. A clearer view came when about 200 participants gathered earlier this year in Honolulu, Hawaii, to review B progress.

Charge conjugation, C, and parity, P, are candidate symmetries of particle interactions. C means replacing a particle by its antiparticle, while P is the operation of mirror reflection. Before 1956, it was believed that both these symmetries were separately respected.

After evidence for P violation was observed in weak interactions in 1956, theorists proposed that the combination of CP would be a symmetry of the weak interaction. Then in 1964 physicists found the first evidence for the violation of CP symmetry in the decays of kaons.

Although Kobayashi and Maskawa in 1972 showed how the Standard Model can accommodate such CP violation, its origin is still not explained. To distinguish between various possibilities requires the observation of a different type of asymmetry called direct CP violation, calling for very precise measurements of ratios of kaon decay rates.

However in B decays, where a



*F. Takasaki of KEK, Japan, (left) with W. Kozanecki of CERN at a major meeting on the physics of B particles (containing the fifth - beauty, 'b' - quark) at Hawaii.*

second order weak process whimsically named "penguin" interferes with another suppressed first order effect, it may be possible to observe these direct CP violating effects more readily.

At the Honolulu meeting, the status of the three major electron-positron B factory accelerator projects - KEK-B in Japan, PEP-II at Stanford, and CESR PHASE III at Cornell - was covered by S-I. Kurokawa of KEK. The new detectors under construction (BELLE at KEK, BABAR at Stanford, and CLEO-III at Cornell) and the challenges for precision vertex detection and high momentum particle identification were summarized by P. Harrison of London's Queen Mary and Westfield College.

There were also status reports on the complementary efforts underway at hadron machines, with reports by A. Maciel (Rio de Janiero) on the CDF and D0 detector and trigger upgrades at Fermilab, K. Ehret (DESY) on HERA-B at DESY, B. Cox (Virginia) on LHC-B at CERN, and S. Stone (Syracuse) on the BTEV proposal at Fermilab.

Interesting new results on rare B decays were reported from CLEO at Cornell. For the last two years, CLEO, and the Aleph, Delphi, and Opal detectors at CERN's LEP electron-positron collider have reported signals in the rare decays of neutral B mesons which are of great interest to the B factory projects.

With more data, Jim Alexander (Cornell) reported that CLEO has now isolated a signal in B decay into a negative kaon and a positive pion, with a branching fraction at the 1.5 x $10^{-5}$ level. This mode is expected to be dominated by the gluonic penguin diagram. (The photonic penguin was observed by CLEO in 1994.)

The complementary neutral B decay to a pair of charged pions, required to isolate one of the angles of the unitarity triangle of the KM matrix is not yet observed and a tight upper limit of 1.5 x$10^{-5}$ has been set.

B. Behrens (Colorado) also reported on CLEO's surprisingly large branching fractions for inclusive and exclusive B decays producing eta prime mesons. On a related note, H. Yamamoto (Harvard), I. Dunietz (Fermilab), and A. Kagan (Cincinnati) discussed puzzles associated with both experimental and theoretical accounting of the charm yield in B decays and the semileptonic B branching fraction. The possibility of either a major systematic flaw in the measurements, or an enhancement of gluonic penguin processes in which a b quark produces an s quark and a gluon remains unresolved and a challenge to experimenters at current electron-positron machines.

The experimental properties of exclusive hadronic B decays were described by J. Rodriguez (Hawaii) and the accompanying theoretical puzzles related to the strength of colour suppression by B. Stech (Heidelberg).

M. Feindt (DESY) surveyed latest B spectroscopy results from LEP. T. Junk (CERN) discussed the measurements of the anomalously low lifetime of the lambda-b baryon which, as M. Neubert (CERN) noted, cannot easily be accommodated by theory.

R. Forty (CERN) and A. Ouraou (Saclay) emphasized the beautiful time-dependent LEP measurements of $B_d$ mixing and the stringent limits on $B_s$ mixing. Important contributions are also expected soon from SLD and CDF.

Forty and C. Kreuter (CERN) showed the progress on measurements of exclusive semileptonic B decays from Aleph, Delphi, and Opal. R. Poling (Minnesota) also showed the CLEO results on exclusive semileptonic b/u quark transitions such as B decaying to rho mesons. A number of theoretical reviewers suggested paths to a better determination of CKM matrix elements.

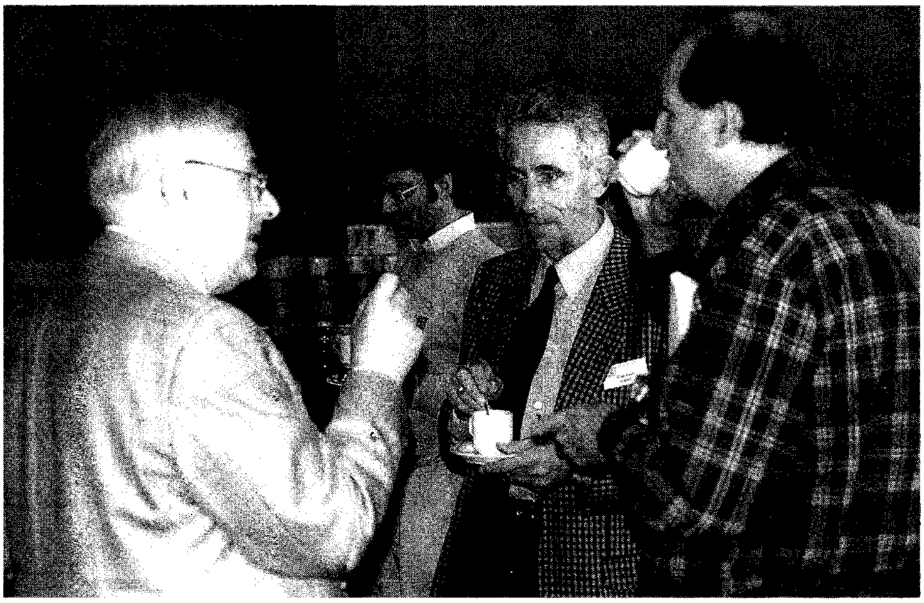
On the theoretical side, L. Wolfenstein (Carnegie-Mellon) emphasized the difficulty in ruling out a superweak model of CP violation even when the first measurements of the KM unitarity angles become available. N.G. Deshpande (Oregon), R. Enomoto (KEK), and R. Fleischer (Karlsruhe) discussed new theoretical approaches to the determination of the three angles of the unitary triangle.

Summarizing, J.D. Bjorken (SLAC) attributed much of the dramatic progress in B physics in the last ten years to technological progress in both vertex detection and accelerator physics in particular as well as experimental and theoretical progress in general. He also drew attention to emerging key questions and new approaches in observing CP violation.

The conference proceedings will be published by World Scientific. The meeting was the second in a series of such conferences which were begun by Tony Sanda at Nagoya in November 1994, and the third is tentatively scheduled for Taipei, Taiwan in March 1998, with Hai-Yang Cheng, George Hou and Darwin Chang as organisers.

*From Tom Browder and Sandip Pakvasa*

*Photon structure enthusiasts at the Photon'97 conference held recently in Egmond aan Zee, The Netherlands. Left to right - Joop Konijn, Alex Finch, Frits Erné and David Miller.*



## Photons under the microscope

Because of its tiny vacuum fluctuations, the photon, the carrier of electromagnetism, has 'structure' which is more than electromagnetic. This extra-electromagnetic component of the photon was again under scrutiny at the Photon'97 conference held recently in Egmond aan Zee, The Netherlands.

The conference, organized by NIKHEF, Amsterdam, was the eleventh in a series of photon-photon workshops which began with the emergence of high-energy electron-positron colliders. Two years ago, at the Sheffield conference, the HERA electron-proton collider made a debut appearance on the scene.

Hadronic particle production shows that the photon behaves partly like a strongly-interacting hadron and partly like a force-carrying gauge boson. The transitions between these two types of manifestation are now studied in detail.

The topics of the conference ranged from the photon-photon total cross section, the photon structure function, diffraction, jet and resonance production to future photon-photon colliders and interactions of cosmic photons.

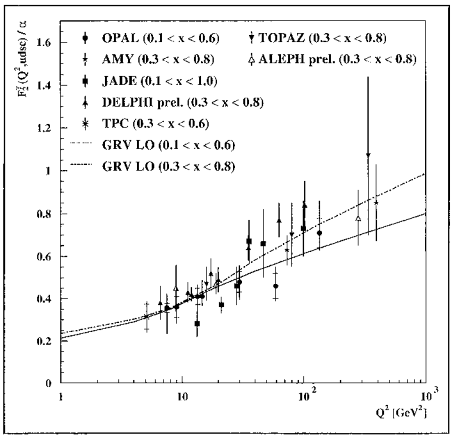
The physics of photon-induced hard processes was discussed by Patrick Aurenche (ENSLAPP, Annecy). It is similar to that of purely hadronic interactions, but the dynamics is more complex because of the dual nature of the photon. There is a wealth of data on jet production, single particle production, open heavy flavour and quarkonium production, both from HERA and from the LEP2 collider at CERN. Patrick Aurenche also emphasized that the HERA data on inelastic J/psi production could shed some light on possible mechanisms for charmonium production at the Tevatron. The current Tevatron production rate is higher than predicted by colour singlet production alone.

At LEP, Aleph, Delphi and Opal reported considerable progress on the dependence of the photon structure on the squared momentum transfer, $Q^2$. This dependence is now well established up to a few hundred $GeV^2$ and confirms theoretical predictions. An intriguing question is whether the photon structure function shows a similar rise at small momentum fraction (x) values as was observed for the proton at HERA. At present, for values as low as 2.5 x $10^{-3}$, no rise is seen. In his introductory talk Andreas Vogt (Wuerzburg) suggested that the rise may be just around the corner at the lower x-values obtained at LEP2.

Measurements of the collision rates of nearly real photons by L3 and Delphi yield results which resemble total hadron-hadron collision rates. Cleo (Cornell) and L3 reported new measurements of form factors in photon-photon reactions producing a pseudoscalar meson. The measurements, now more precise, cover a $Q^2$ range up to 30 $GeV^2$. and include the effects of strong interactions. Stan Brodsky (SLAC) showed that the results are in good agreement with a prediction by Lapage (Cornell) and himself which connects the result at large $Q^2$ to the decay of the light meson.

Diffraction phenomena, which can be clearly identified at HERA, were introduced by Michele Arneodo (Torino/Cosenza). This elastic production of light vector mesons is studied in the context of the exchange of a particle-like pomeron and reggeon while a perturbative description can probably be applied at higher $Q^2$ and to production of heavy vector mesons. All present indications point towards a dominant gluonic content of the pomeron exchange.

Valery Telnov (Novosibirsk) and




*Data from a range of experiments at electron-positron colliders show that the hadronic structure of the photon increases with the squared momentum transfer, $Q^2$. The data are compared with the theoretical prediction of M. Glück, E. Reya and A. Vogt.*

George Jikia (Freiburg, Protvino) reported on future photon-photon colliders and the experiments that could be performed with them. At present photon-photon collisions are generated via radiation in electron-positron collisions which yields mostly photons at low energies and relatively low luminosities.

At linear electron-positron colliders real photons could be obtained by backscattering powerful laser beams from the electron and positron beams. In this case the photon energy spectrum peaks close to the primary electron energy while the photon-photon luminosities approach the electron-positron level. At high energies this would for example allow detailed investigations of direct higgs-boson production.

Very different sources of photons were discussed by Hinrich Meyer (Wuppertal) in his enthusiastic talk on "photons from the universe, new frontiers in astronomy". Although these sources come for free, the variety of phenomena is bewildering and a good grasp of photon interactions helps in the interpretation.

The conference was summarized by David Miller (University College London) and Jeff Forshaw (Manchester), who remembered John Storrow (Manchester), a driving force in the field and who died last year. The conference proceedings will be dedicated to his memory.

*By Frits Erne, NIKHEF*

## NONCONFORMISTS Beyond the Standard Model

While major physics meetings have largely become festivals of the Standard Model (see page 1), the devotees, mainly theorists, of the meetings in the 'Beyond the Standard Model' series, which began in Iowa State in 1988 and has now reached a fifth iteration, think otherwise.

The latest such meeting was held earlier this year in Balholm, Norway, and was the first time the conference had been organized outside the US. Representatives from major experiments reported the status of their searches for new physics.

The ultimate physics experiment is the Big Bang, and M. Turner of Fermilab looked 'Beyond the Big Bang'. A more modest but still exciting physics scenario was described by DESY Research Director Albrecht Wagner, covering DESY's linear collider plans.

Balholm is at the Sognefjord, the longest fjord in Norway, and can be reached from Bergen by boat or bus in about three hours.

*DESY Research Director Albrecht Wagner describes DESY's linear collider plans at the recent 'Beyond the Standard Model' meeting at Balholm, Norway.*

# People and things

Associate Director for High Energy and Nuclear Physics of the US Department of Energy Peter Rosen (second from left) at CERN with (left to right) ATLAS muon project leader Chris Fabjan, CERN Non-Member-State affairs coordinator Jim Allaby, Sau-Lan Wu of the Aleph experiment, and ATLAS US coordinator Bill Willis.

(Photo CERN 3.8.97)

## On people

DESY Director General Bjoern Wiik has received an honorary doctorate from the University of Oslo.

## European Physical Society Prize

The prestigious 1997 High Energy and Particle Physics Prize of the European Physical Society has been awarded to theorists Robert Brout and Francois Englert of Brussels and Peter Higgs of Edinburgh for their milestone work in the formulation of the spontaneous symmetry breaking mechanism in quantum field theory which subsequently enabled electromagnetism and the weak nuclear force to be unified in a single 'electroweak' picture. The experimental observation of this symmetry breaking effect, now commonly known as the 'Higgs mechanism', is the major particle physics goal at the turn of the millennium. The prize was awarded on 24 August during the Europhysics Conference on High Energy Physics in Jerusalem.

## ICTP Dirac medal

Peter Goddard of Cambridge and David Ian Olive of Swansea (UK), share the prestigious 1997 Dirac Medal awarded by International Centre for Theoretical Physics (ICTP), Trieste, for their pioneer research in string theory.

Goddard's work on the quantization of the relativistic string (with J. Goldstone, C. Rebbi, and C. Thorn) showed definitively that dual resonance models should be understood as string theories. Olive's work on spacetime supersymmetry of the spinning string theory (with F. Gliozzi and J. Scherk) made possible the whole idea of superstrings, which we now understand as the most natural framework for supersymmetry and string theory.

The recent 'second superstring revolution' has also depended on pioneering insights on magnetic monopoles by Goddard, Olive, and J. Nuyts, and further extended by Olive and C. Montonen. Their revolutionary ideas for a dual interpretation of magnetic charge and electric-magnetic duality in non-abelian gauge theory have been of far-reaching importance.

Each year, ICTP announces the winners of the Dirac Medal on 8 August, the birthday of Paul A.M. Dirac who died in 1984 at the age of 82. The most recent winners have included Martinus Veltman, Tullio Regge, Michael Berry and Frank Wilczek.

## Vladimir Naumovich Gribov (1930-97)

The eminent Russian theorist Vladimir Naumovich Gribov died in Budapest on August 13 following a stroke during a lecture tour in Spain.

Born in Leningrad, he graduated from Leningrad State University in 1952 and joined the Leningrad Physical Institute. He became famous for his pioneer work on the theory of complex angular momenta and the theorem on the shrinking of the diffraction cone in high energy elastic scattering. During his first visit to the West, at the 1962 conference at CERN, he made a strong impression. Later, first with I. Pomeranchuk and later with other co-workers, Gribov made landmark contributions to 'reggeization' in quantum field theory and multiple scattering. The asymptotic behaviour of high energy processes continued to be a major theme. At the begin-

*Vladimir Naumovich Gribov (1930-97)*

*ning of the 1970s, Gribov and Lipatov set up their famous scattering evolution equations. He also made important contributions to non-abelian gauge theories (the Gribov 'horizon'). Latterly he turned to quantum chromodynamics.*

*Gribov led the Leningrad (Gatchina) school of theoretical physics for 25 years, and his pupils went on to become renowned in Russia, in Europe and in the US. His published lectures on Regge theory and quantum electrodynamics were basic texts for generations of Soviet theoretical physicists. From 1980 he worked in Moscow's Landau Institute. In 1991 he joined the Research Institute for Particle and Nuclear Physics in Budapest.*

*He was a member of the Academy of Sciences of the Soviet Union (later Russia), honorary member of the American Academy of Arts and Sciences and the Hungarian Academy of Sciences. Among his awards were the Landau prize of the USSR Academy of Sciences (the first recipient), the Sakurai prize of the American Physical Society and the Alexander von Humboldt prize. During the cold war, his frequent absence from Western meetings testified to an independent spirit. An exceptionally warm and cheerful personality, Vladimir Gribov generously shared his ideas and erudition with his students and colleagues, and was universally revered as an indefatigable discussion leader. He is widely missed.*

## Herb Chen memorial

*On 15 August, a memorial to Herb Chen was unveiled at the Sudbury Neutrino Observatory, the new underground laboratory soon to become operational. Herb Chen, born in China in 1942, died in 1987. After training as a theorist in the US, he switched to the challenge of neutrino observations. His keen awareness of the physics potential of a heavy water detector helped make SNO a reality.*

## Max Planck anniversary

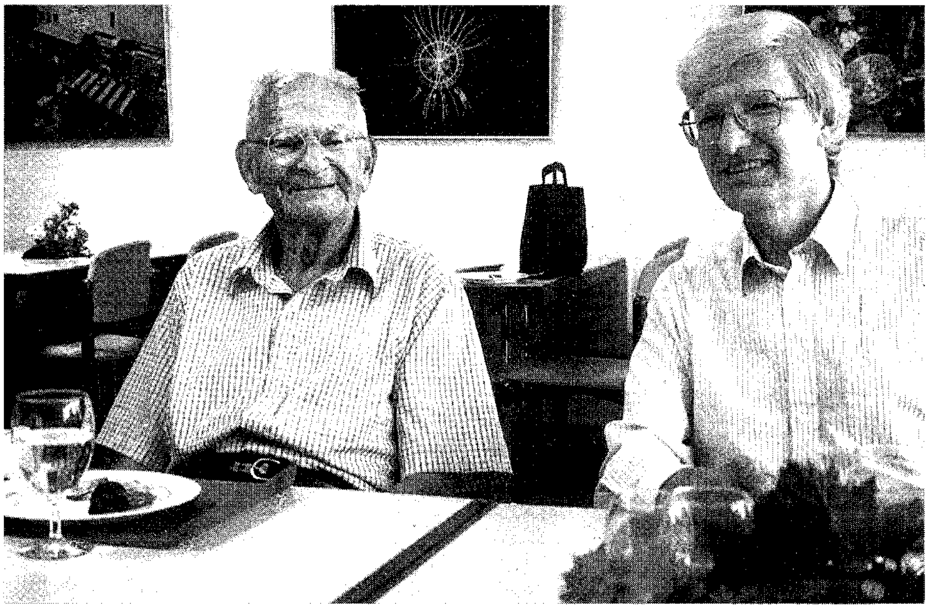
*This year marks the 50th anniversary of the death of quantum theory pioneer Max Planck in Göttingen, aged 89. From 1939-43 Planck spent his holidays in the Austrian Tyrol mountain resort of St. Jakob, which recently organized a small event in his memory. The photograph shows him, at the age of 82, on the 3014 metre-high Seespitze summit.*

*The courageous Planck resisted as best he could Nazi efforts to polarize German science, but in the final years of the war his spirit was broken by a series of personal disasters. However he lived to see the recreation of the illustrious German national scientific research organization, renamed in his honour.*

*As well as his own contributions to physics, Planck's name is also synonymous with fundamental*

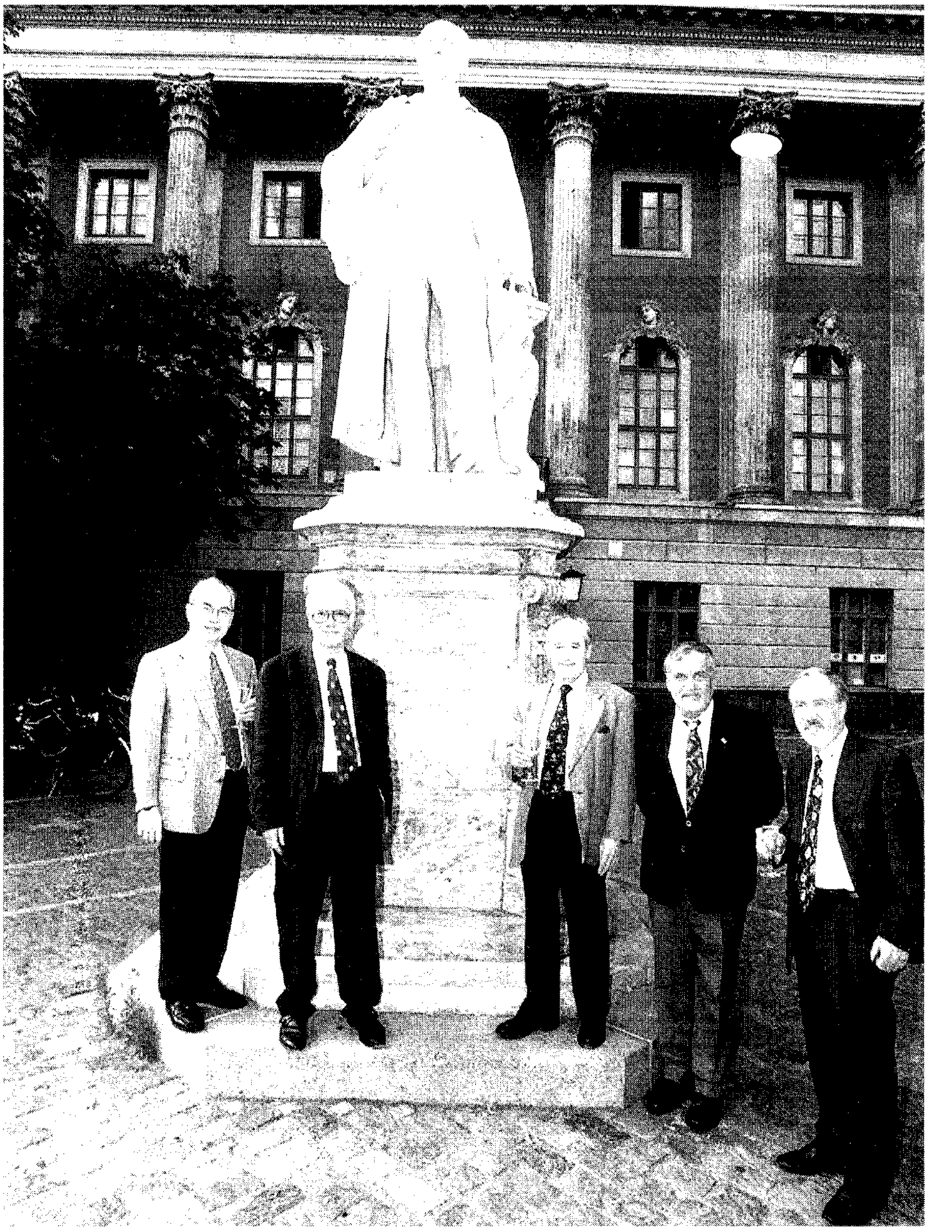
*A still agile 82-year-old Max Planck on the summit of the Austrian Seespitze (3014 m). This year marks the 50th anniversary of Planck's death.*

*Former CERN Council President Wolfgang Kummer at the recent "Fundamental Physics in Space' summer school organized by the Austrian Space Agency in association with the European Space Agency and held in the Tyrol village of Alpbach, where Erwin Schrödinger is buried.*

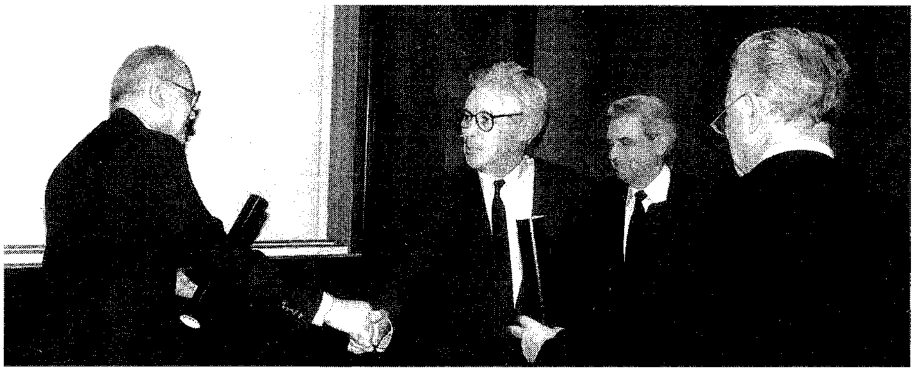


*Spanning 30 years of CERN history. Victor Weisskopf, CERN's Director General from 1961-65, and current Director General Chris Llewellyn Smith. Weisskopf, who will be 90 next year, was at CERN recently for a meeting of the Pauli Committee (October 1996, page 14).*

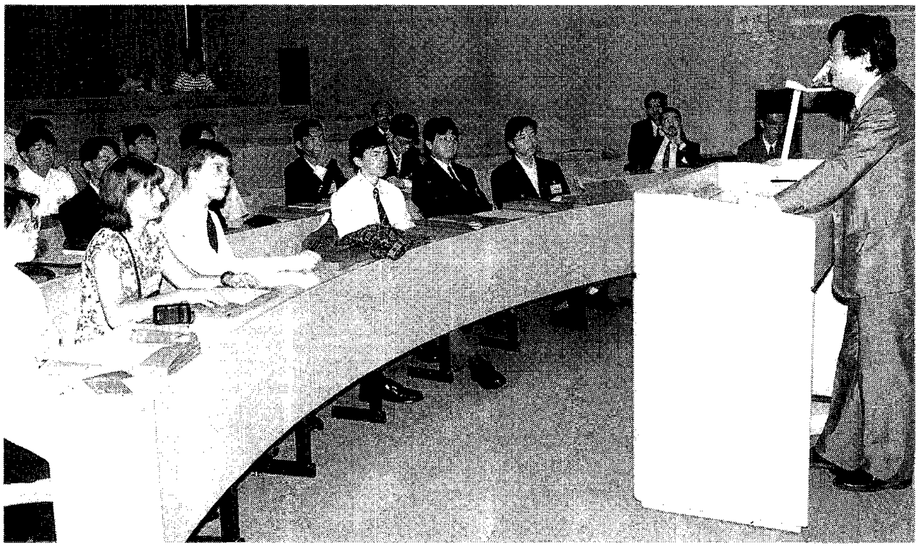
*physics concepts, such as the Planck mass. Now the European Space Agency's Horizon 2000 programme prestige experiment to measure the cosmic microwave background radiation, formerly COBRAS/SAMBA, has been appropriately renamed Planck.*



*At the opening of the CERN exhibition on medical applications of physics at Berlin's Humboldt University, left to right, M.H. Foster of the Benjamin Franklin Clinic of the Free University of Berlin, K. Winter of Humboldt University and ex-CERN, exhibition organizer W. Kienzle of CERN, and H. Homeyer of Berlin's Hahn-Meitner Institute under Hermann von Helmholtz's stern gaze in Unter den Linden.*



*Belgian Royal Academy President André Delmer presents the Academy's prestigious Adolphe Wetrems Prize for mathematical and physical science to Belgian physicists Jean-Pierre Stroot (shaking hands) and Freddy Binon for their driving roles in the GAMS experiments. On the right is the Academy's Permanent Secretary, Baron Roberts-Jones. The long-lasting GAMS international collaboration has several claims to fame. For physics, it has made important contributions to particle spectroscopy and the search for glueballs, particles composed of gluons rather than quarks. GAMS was also one of the pioneer collaborations between CERN and the former Soviet Union and has done much to catalyse and cement these important ties.*



*Hirotaka Sugawara, Director-General of the Japanese KEK Laboratory, opens a special international school for promising young students from 12 Asia-Pacific countries held this summer at KEK. The fourth session in a series sponsored by the Japanese Association of International Education with KEK as the host institute, its main theme was 'Exploring the World of Elementary Particles by Computer'.*

*Riverboat shuffle. New Orleans jazz on a trip down the Elbe during the recent Lepton-Photon symposium in Hamburg (see page 1), featuring DESY Accelerator Head Dieter Trines on banjo and Roy Rubinstein of Fermilab on trombone.*

*(Photo Albrecht Wagner)*

# Bookshelf

## External correspondents

Argonne National Laboratory, (USA)
**D. Ayres**

Brookhaven, National Laboratory, (USA)
**P. Yamin**

CEBAF Laboratory, (USA)
**S. Corneliussen**

Cornell University, (USA)
**D. G. Cassel**

DESY Laboratory, (Germany)
**Ilka Flegel, P. Waloschek**

Fermi National Accelerator Laboratory, (USA)
**Judy Jackson**

GSI Darmstadt, (Germany)
**G. Siegert**

INFN, (Italy)
**A. Pascolini**

IHEP, Beijing, (China)
**Qi Nading**

JINR Dubna, (Russia)
**B. Starchenko**

KEK National Laboratory, (Japan)
**A. Maki**

Lawrence Berkeley Laboratory, (USA)
**B. Feinberg**

Los Alamos National Laboratory, (USA)
**C. Hoffmann**

NIKHEF Laboratory, (Netherlands)
**Margriet van der Heijden**

Novosibirsk Institute, (Russia)
**S. Eidelman**

Orsay Laboratory, (France)
**Anne-Marie Lutz**

PSI Laboratory, (Switzerland)
**P.-R. Kettle**

Rutherford Appleton Laboratory, (UK)
**Jacky Hutchinson**

Saclay Laboratory, (France)
**Elisabeth Locci**

IHEP, Serpukhov, (Russia)
**Yu. Ryabov**

Stanford Linear Accelerator Center, (USA)
**M. Riordan**

TRIUMF Laboratory, (Canada)
**M. K. Craddock**

## Quark machines

*The Quark Machines - How Europe Fought the Particle Physics War by Gordon Fraser, Institute of Physics Publishing, ISBN 0 7503 0447 2*

In attempting to write books about the history of particle physics, authors have to choose a narrative focus. There is simply too much ground to cover. So far most have concentrated on the theoretical insights and breakthroughs achieved, while a few of us have delved into the messier business of performing experiments and extracting meaningful data from complicated detectors. Now CERN Courier Editor Gordon Fraser presents the history of particle physics from a refreshingly new perspective - that of the machine builders, or accelerator physicists, who generate the high-energy particles without which most of us would still be doing experiments on frosty mountain tops.

He also tells his tale from a Western European perspective. The war-torn continent found itself at a decided disadvantage in particle physics when Americans and Soviets began building powerful accelerators during the early 1950s. All its considerable expertise in cosmic-ray physics seemed about to be overwhelmed by the big new machines, which supplied intense, uniform, easily controlled beams of high-energy particles to experiments. This is the story of how European physicists abandoned old national animosities, joined forces, and fought back against the odds, eventually reaching parity - and perhaps even leadership - in the field.

I especially liked the chapter on the origins of CERN, entitled "All We Want Is the World's Biggest Machine!" It relates the postwar story of how Pierre Auger, Edoardo Amaldi, and others, working under the aegis of UNESCO and egged on by Isidor Rabi, maneuvered the radical idea of a pan-European accelerator laboratory into reality. A key encounter came in August 1952, when Odd Dahl, Frank Goward and Rolf Wideröe visited Brookhaven, where they learned about the newly minted idea of strong focusing. CERN physicists then gambled that they could build a 20 GeV proton synchrotron using this promising but untried technique, succeeding in November 1959 before the Alternating Gradient Synchrotron was commissioned. This is a fairly well-known tale in the particle physics community, of course, but it's a pleasure to have the story all together in one place, well written, and laced with amusing anecdotes.

But building first-class accelerators was not enough, as Fraser recounts. Time and again, US physicists beat their European and Soviet counterparts to the most important discoveries - such as CP violation and the J/psi particle - through a combination of imagination, daring and superior detectors. Finally, Carlo Rubbia brought these qualities back to Europe in the building of the proton-antiproton collider (with Simon van der Meer) and the UA1 detector, which in 1983 gave CERN its first Nobel-prizewinning discovery, of the massive W and Z particles.

If I have one major quarrel with this book, it is with its subtitle - which I understand was imposed by the publisher in hopes of boosting book sales. If this was a "war," then it's the first war in history where the combatants shared weapons designs, crack troops, and even a few commanding

officers. I worry that copies of The Quark Machines will fall into the hands of LHC opponents in the United States, confirming their worst suspicions about European intentions and aiding them in their efforts to eliminate U.S. contributions to this project. In such an event, I can only hope that they will not judge this book solely by its cover.

*Reviewed by Michael Riordan*

## The triumph of the transistor

*Crystal Fire - The Birth of the Information Age, by Michael Riordan and Lillian Hoddeson, Norton (New York) ISBN 0 393 04124 7*

As well as the centenary of the discovery of the electron and the half-centenary of that of the pion, this year also marks the fiftieth anniversary of a physics discovery which went on to revolutionize technology. On 16 December 1947 at Bell Laboratories, New Jersey, physicists John Bardeen and Walter Brattain, working in a team led by William Shockley, made a piece of germanium amplify a tiny electric current. The transistor was born.

Over the next few years, as semiconductor technology gradually matured, the transistor replaced the thermionic valve as the building block of electronic circuits. Freed of the need to have heating currents to power valves, transistor-driven circuits were easier to operate. The tiny transistor also brought a new era of miniaturization. Consumer electronics was born in the 1950s as teenagers listened to the new rock-and-roll music on miniature radios. In parallel, the Cold War opened up a vast new range of electronic logic applications, and digital computer technology changed course.

Michael Riordan of SLAC and Santa Cruz is well known to particle physicists through his books, notably the 'The Hunting of the Quark' which won the 1988 American Institute of Physics Science Writing Prize. He is also the CERN Courier's official correspondent at SLAC. Science historian Lillian Hoddeson of Illinois has produced many books on the history of both particle and solid state physics. In this fascinating and carefully documented book, in parts vividly written, Riordan and Hoddeson trace the evolution of the underlying science, the fortunes of the industrial concerns and the careers of the scientists involved.

This account of the invention and subsequent development of the transistor displays well how scientists, with no adequate map of where they are going, frequently have to grope their way through the unknown. With delicate semiconductor effects, initial results were often not very consistent. Only when reliable manufacturing techniques were developed could real progress be made. Also with the underlying physics initially not well understood, it was often difficult for the researchers to understand and interpret what they were seeing.

The breakthrough had been the result of a visionary reappraisal of research goals at Bell Labs immediately following the end of World War II. Ironically, despite their 1956 Nobel Prize, the main players, Bardeen, Brattain and Shockley, were left stranded. In 1955 Shockley set up his own company in the San Francisco Bay Area. This outfit, although the forerunner of today's 'Silicon Valley', was never successful. Bardeen turned to university research and eventually earned a second Nobel Prize, this time for superconductivity. Only Brattain remained at Bell Labs, although in a relatively peripheral position. As new specialized firms came into being, eventually even Bell Labs could not maintain the furious pace.

The book describes well the remorseless ebb and flow of science and how even dedicated and talented scientists can be buffeted by the waves and dragged along by the tides of fortune.

*Reviewed by Gordon Fraser*

## Books received

*Quarks Bound by Chiral Fields - The Quark Structure of the Vacuum and of Light Mesons and Baryons, by Georges Ripka, Oxford Science Publications*

In the Oxford series of Studies on Nuclear Physics, this book describes dynamical models which account for the spontaneous breaking of vacuum chiral symmetry, giving rise to mesons appearing as vibrational modes of the vacuum and baryons as bound states of quarks (solitons).