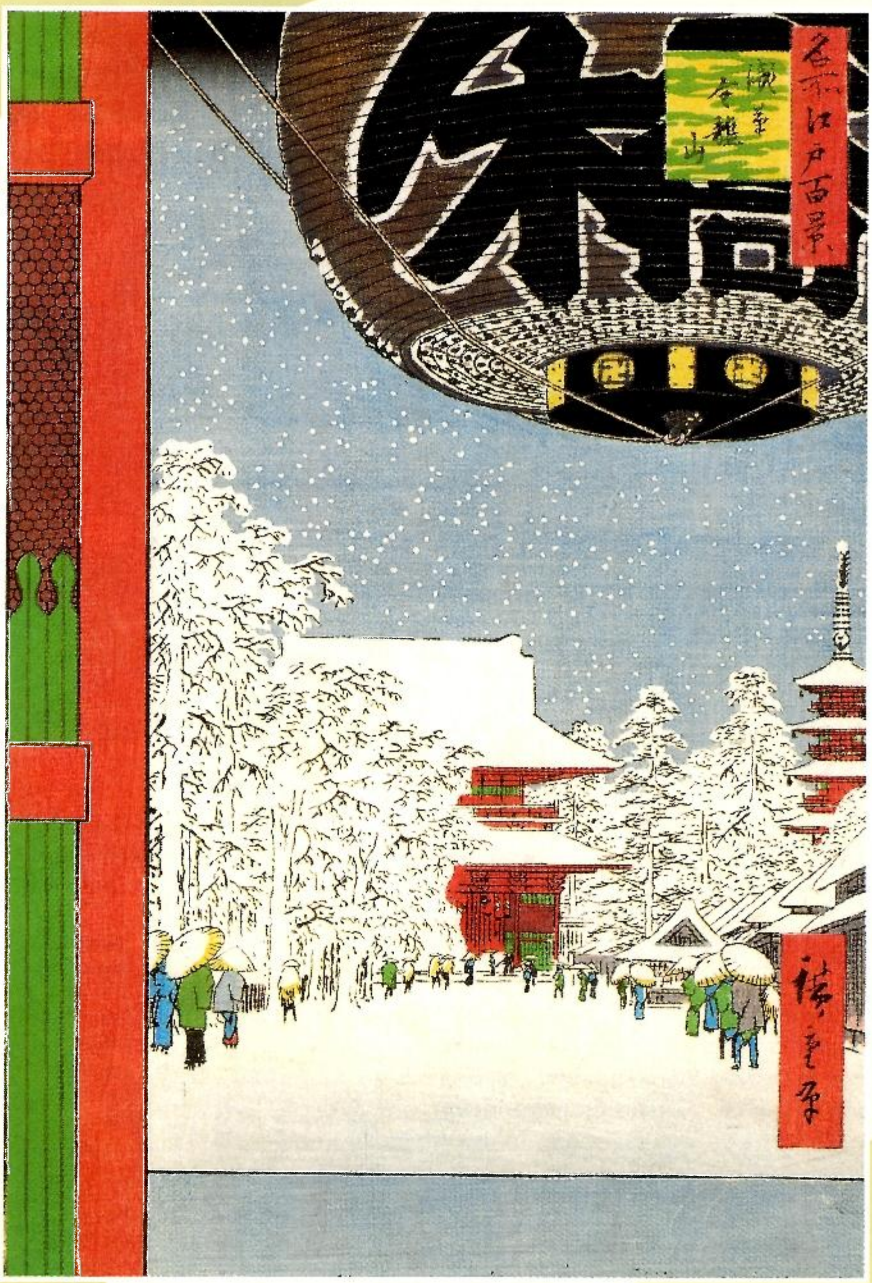
CERN COURIER

International journal of high energy physics

VOLUME 38 3 APRIL 1998



From Winding to Cryostating:

Your partner for magnet engineering


Winding of the superconductor at the coil end

Complete dipole prototype

Noell has been developing, manufacturing and supplying superconducting prototype dipole magnets for the LHC particle accelerator in Geneva since 1990. Several prototypes, with a length of 10 m, have already been supplied which fulfilled the expectations of the design in tests performed by CERN.

Further developments in this field include 15 m prototypes. The construction of production lines for these is currently in preparation. At the end of 1997 Noell was able to prove its competence in the manufacture of complete dipole magnets for the LHC, with the assembly of a cold mass to form a complete 15 m test magnet - a process known as cryostating.

Noell is designing and manufacturing the tools required for production, e.g. a numerically controlled winding machine, itself. In the winding process shown, specially trained staff are positioning the superconductor on the geometrically complex coil end.

In addition to complete dipoles for the LHC, Noell is also developing magnetic components for nuclear fusion experiments, e.g. the Joint European Torus, Wendelstein 7X and ITER.

This is just one more reason for you to contact us for a discussion on magnet systems of the future. Give us a call.

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Distributed to Member State governments, institutes and laboratories affiliated with CERN, and to their personnel.

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CERN COURIER is published monthly except January and August in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management.

Printed by: Drukkerij Lannoo nv
8700 Tielt, Belgium

Published by:

European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
tel.: +41 (22) 767 61 11,
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telefax: +41 (22) 767 65 55

CERN COURIER only:
tel. +41 (22) 767 41 03,
telefax +41 (22) 782 19 06

USA: Controlled Circulation
Periodicals postage paid at St. Charles, Illinois

ISSN 0304-288X

Volume 38
No. 3
April 1998

Covering current developments in high energy physics and related fields worldwide

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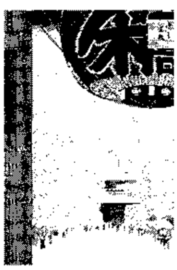
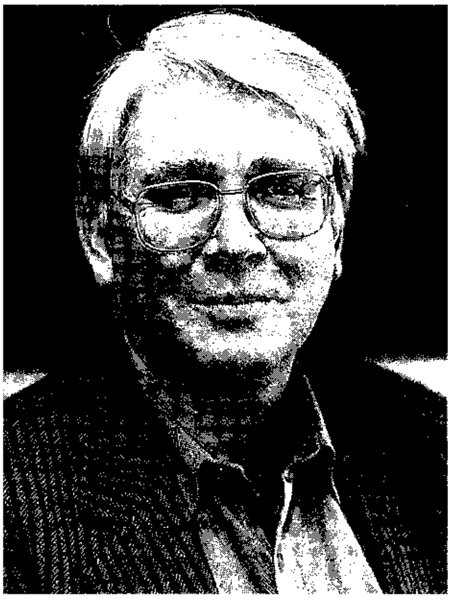


Cover picture: Kinryuzan at Asakusa by Utagawa Hiroshige (1797-1858), from One Hundred Famous Views of Yedo (Meisho Edo Hyakkei). This Floating World style woodcut depicts Asakusa through the Kaminari-mon gate. ASACUSA – Atomic Spectroscopy and Collisions Using Slow Antiprotons – is also a new experiment at CERN to study antiprotonic helium atoms (see page 9).

Forward vision at DESY

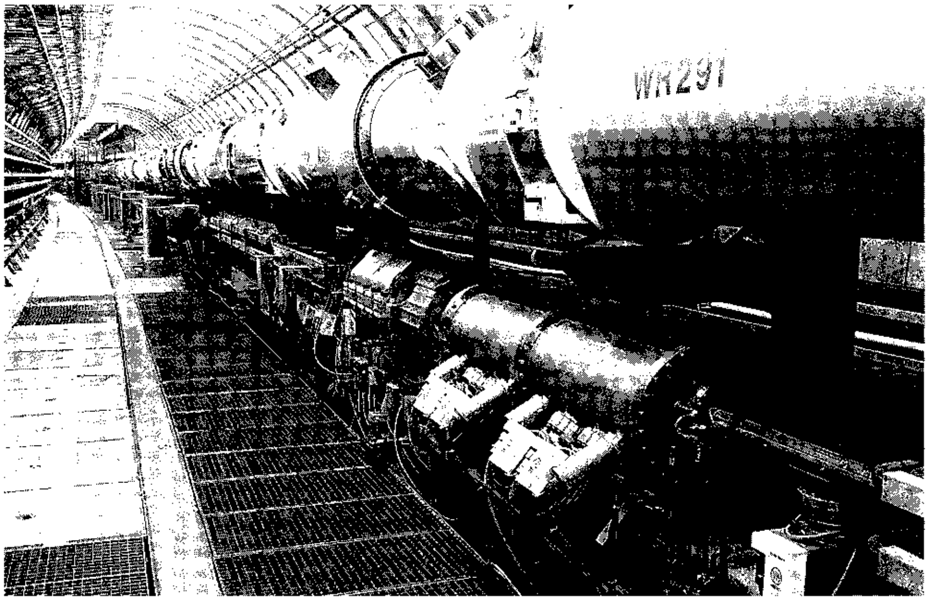
ICFA Chairman and DESY Director Bjørn Wiik - bright future for particle physics

(Photo Patrick Piel)



At the DESY Laboratory in Hamburg, particle physics at the unique HERA 6.3 kilometre electron-proton collider alone has 1200 researchers from 114 institutes in 25 countries. Some 800 of these come from outside Germany.

(Photo P. Waloschek)



With inter-regional collaboration increasingly becoming a reality, the role of the International Committee for Future Accelerators - ICFA, a unique forum for objective international exchange, becomes correspondingly more important. ICFA Chairman and DESY Director Bjørn Wiik points out that the indefatigable push for innovation which has always been such a strong feature of particle physics shows no signs of abating, despite economic pressures and changed physics horizons. A series of CERN Courier articles under ICFA patronage will project this forward vision as seen from major laboratories throughout the world. The first article looks at the DESY Laboratory in Hamburg.

DESY, the Deutsches Elektronen Synchrotron centre in Hamburg, has come a long way since the original 6 GeV electron machine began operation in 1964. Providing synchrotron radiation as well as high energy beams, DESY now attracts more than 3000 users from 35 countries. Particle physics at the unique HERA 6.3 kilometre electron-proton collider alone has 1200 researchers from 114 institutes in 25 countries. Some 800 of these come from outside Germany.

1997 has been a very successful year for HERA. The collider, which began operation in 1992, reached a peak luminosity of 1.4×10^{31} per sq cm per s, and an integrated luminosity of some 36 inverse picobarns (September 1997, page 18) compared to the design values of 1.5×10^{31} and 35 respectively.

The major H1 and Zeus experiments began 1997 in a blaze of publicity with their unexpected yield of wide-angle scatterings (April, page 1). Thanks to a record number of HERA collisions, these experiments collected more data in 1997 than in all previous years combined. Physicists are eager to see whether this harvest continues to reflect the initial abnormal trend for wide angle scatterings. However results reported last summer did not suggest that this would be the case.

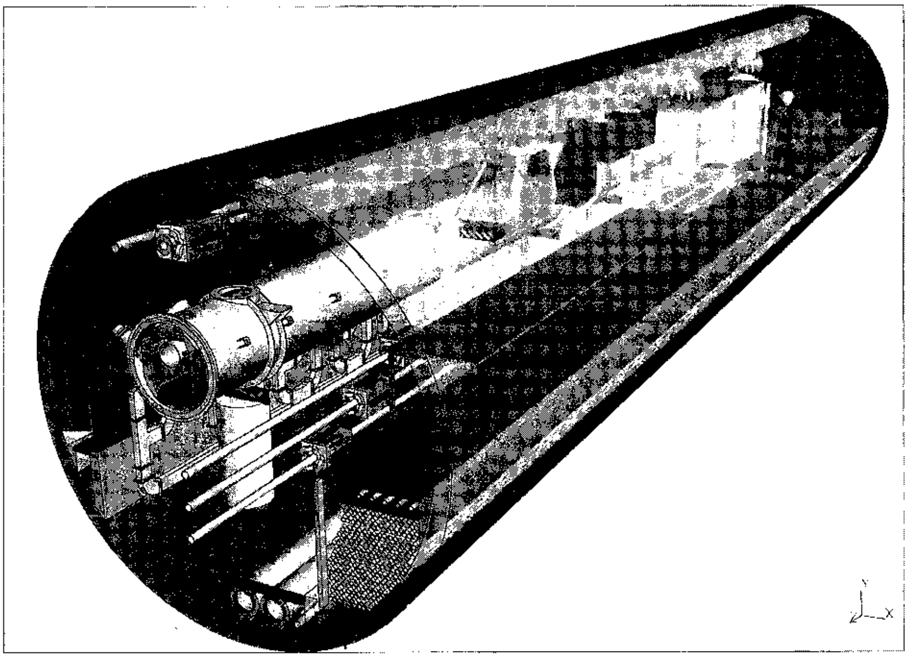
To settle this question, however, would require more luminosity, and an upgrade is now underway to increase the HERA peak luminosity to 7×10^{31}, five times its design value. This requires a redesign of the interaction region to move the final focus proton quadrupole magnet closer to the interaction regio and involves rather exotic magnets. If funding can be secured this upgrade will take place in the 1999/2000 shutdown.

The new HERMES experiment, using longitudinally polarized electrons and a polarized gas jet target, has benefited from polarization levels reaching 60%, giving also a record annual data yield.

The other major HERA experiment, HERA-B, using the HERA proton beam to produce B particles (containing the fifth - beauty, or b, quark) is in its final stages of installation and should begin commissioning this year with data taking in 1999. Machine physicists' worries that HERA-B would perturb

DESY project planning agreement signed

On 19 March, representatives of the city of Hamburg and the neighbouring German state of Schleswig-Holstein signed an agreement covering planning requirements for the construction and operation of a TESLA electron-positron linear collider for the DESY laboratory in Hamburg. The TESLA collider (October 1997, page 12) would need a 33-kilometre tunnel to house two 15-kilometre accelerators, one for electrons, the other for positrons.



Research and development work for electron-positron linear colliders at DESY now focuses on the superconducting radiofrequency cavities (TESLA) approach, using L-band (1.3 GHz) niobium cavities cooled by superfluid helium to 2 K. This shows a sketch of the 5 m diameter TESLA linac tunnel infrastructure.

HERA's electron-proton collision performance have turned out to be unfounded.

For the future, the HERA electron vacuum system is being improved to permit electron-proton collisions (all physics so far has been with positrons, due to electron beam lifetime problems). Additional radiofrequency power and an improved proton supply will also boost the collision rate, while running the superconducting magnets at 4K rather than 4.7K will allow the proton beam to attain 900 GeV rather than the 820 GeV energy used so far. Indeed the HERA magnets have already been ramped to slightly above 1 TeV (1000 GeV).

For the long range future two options are now being explored, storing polarized protons and heavy ions in the HERA proton ring. A conceptual design study has shown the feasibility of using polarized protons in HERA, and an international working group led by polarization specialist Alan Krisch of Michigan in collaboration with the polarization experts at DESY headed by D. Barber is looking into the suppression of depolarizing resonances using 'Siberian snake' magnets. The physics possibilities of polarized electron-proton collisions at HERA collider energies were examined in a recent workshop held at Zeuthen (Berlin).

A DESY/GSI (Darmstadt)/ Novosibirsk collaboration is looking at the possibilities of storing nuclei in the HERA superconducting ring. A forthcoming physics workshop will explore the research potential.

On DESY's traditional electron-positron front, higher energies call for linear colliders to avoid the problems of massive synchrotron radiation losses. DESY, with the support of a large international collaboration, has been pushing design work for a 500 GeV collider and a first Conceptual Design Report was published in the spring of 1997. After promising results last year with superconducting radiofrequency cavities (July 1997, page 1), the R&D effort now focuses on this (TESLA) route, using L-band (1.3 GHz) niobium cavities cooled by superfluid helium to 2 K.

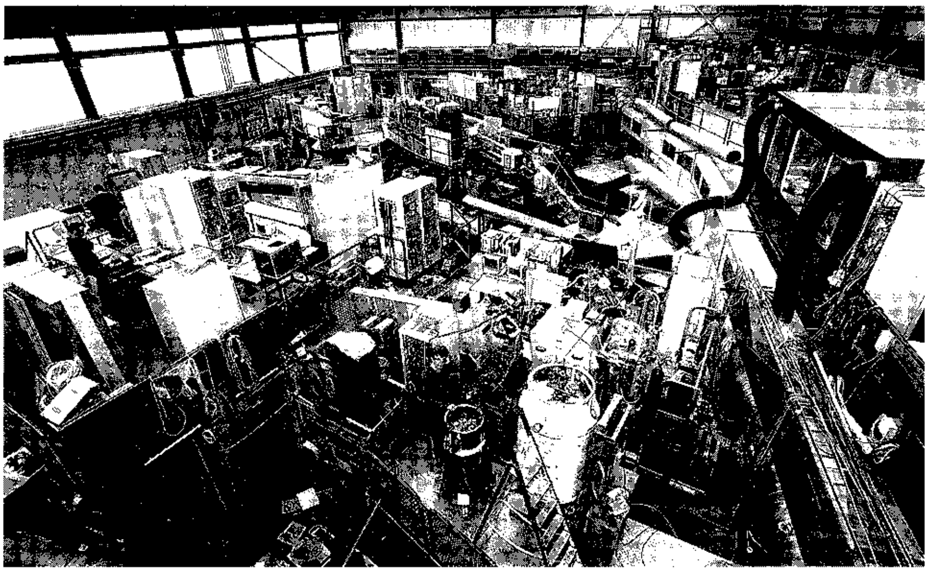
New manufacturing techniques will look at the possibilities of using cavities spun or hydroformed from a single piece of niobium, thereby avoiding the performance problems from welds. A welcome benefit of this technology is a substantial reduction in cost. Palmieri and his coworkers at the INFN nuclear physics laboratory in Legnaro have already produced 4 and 5 cell chamber cavities by spinning.

At the test linac now under construction electrons have been accelerated to 125 MeV corresponding to an accelerating gradient of 16.7 MV/m. Two further modules will be installed by late autumn raising the electron energy to 400 MeV. This linac, augmented by an radiofrequency photoinjector, two longitudinal bunch compression systems and a high precision undulator will also be used to demonstrate the production of intense bursts of light by the SASE (Self Amplified Spontaneous Emission) method.

In a second stage the accelerator will be upgraded to energies above 1 GeV by adding further modules incorporating the experience from the first study. This linac will then act as the driver of a SASE free electron laser undulator yielding light in the vacuum ultraviolet region with unprecedented properties.

As well as providing beams for high energy physics, this linear machine, eventually up to 33 kilometres long,

More than 1900 experimenters now use synchrotron radiation facilities at DESY's HASYLAB. Synchrotron radiation is well suited to determine the electronic and geometrical structures of atoms and molecules, and has widespread applications.



could also drive an X-ray free electron laser and deliver electrons to a pulse stretcher ring for nuclear physics experiments (the ELFE project). DESY's linear collider development programme was summarized in a previous article (October 1997, page 12).

As well as particle physics, DESY has acquired other strings to its bow. Early in its history, DESY soon capitalized on the trend towards electron-positron colliders, first with the 9 GeV (4.5 GeV per beam) DORIS, commissioned in 1974 and subsequently upgraded to 11 GeV, and then PETRA, operating up to 47 GeV. Experiments exploiting synchrotron radiation started at DESY in 1964 in parallel with particle physics experiments and it was hence natural to exploit these storage rings for their spinoff synchrotron radiation.

This burgeoned into a full research programme, and more than 1900 experimenters now using synchrotron radiation facilities at DESY's HASYLAB (using DORIS, and in a parasitic mode PETRA) complement the laboratory's traditional particle physics activity. Synchrotron radiation is well suited to determine the electronic and geometrical structures of atoms and molecules, with widespread applications in medicine, solid state physics, chemistry, crystallography, geoscience, materials science and molecular biology.

Work at DESY in this latter sphere is in close collaboration with the European Molecular Biology Centre (EMBL), where DESY technology and infrastructure has played a vital role. In total some 700 biologists from all over Europe, including three Max Planck groups, use DESY facilities. Major advances using this synchrotron radiation have come in non-invasive coronary angiography, enzyme and semiconductor structure, etc. As well as being scientific advances in their own right, these studies provide DESY with a useful multi-disciplinary atmosphere and outlook.

DESY is poised for a graceful entry into the next century.

US forward look

To guide thinking, every few years the High Energy Physics Advisory Panel (HEPAP) of the US Department of Energy commissions a subpanel to help plan the emerging scenario for US high energy physics. The latest such report is by a subpanel chaired by Fred Gilman of Carnegie Mellon.

The previous such report, in 1994 by a subpanel chaired by Sid Drell of SLAC, had to face the situation in the US following the demise of the US Superconducting Supercollider in 1993. The Drell report recommended that the US join the LHC project at CERN to build a proton collider in the 27 kilometre LEP tunnel.

US involvement in this project is now assured, and was formally recognized by the signing of an agreement in Washington last December (January, page 1).

'The financial and intellectual scale of future facilities means that international collaboration in their design and construction is increasingly necessary,' says the Gilman report. 'This trend is exemplified by US participation in the LHC collider at CERN.'

Meanwhile the Subpanel places highest priority on optimum utilization of the forefront facilities nearing completion and recommends that funding for operation of the Fermilab Tevatron collider, the PEP-II electron-positron collider at SLAC, Stanford, and the CESR electron-positron collider at Cornell, and for the physics groups using them, be at a level that ensures they fulfil their physics potential.

In particular, the Tevatron will remain the world's highest energy collider until commissioning of the LHC in 2005, and, following the closure of CERN's LEP electron-positron collider, from 2001-5 will be the only place where the key question of electroweak symmetry breaking (Higgs mechanism) can be investigated. The report advocates boosting the Tevatron collision rate to ensure maximum physics reach during this period.

In the short-term, the fixed-target programme at the Fermilab Tevatron and SLAC's SLC linear electron-positron collider will soon cease operation.

The Subpanel 'strongly endorses' the physics goals of the LHC and US participation in the accelerator and in the ATLAS and CMS experiments.

For the longer-term future, the Subpanel recommends that a new facility at the energy frontier be an integral part of the US national programme. R and D collaboration between SLAC and the Japanese KEK Laboratory should continue towards a common design for an electron-positron linear collider with a luminosity of at least 10^{34} per sq cm per s and an initial collision energy of 1 TeV, eventually augmented to 1.5 TeV. The Subpanel recommends a Conceptual Design Report. Any construction decision would be taken by a future Subpanel.

Elsewhere, R and D towards a muon collider and on a 'very large' hadron collider should continue, and at an increased level. While CERN's LHC is targeted for a collision energy of 14 TeV, the 'VLHC' looks towards 100 TeV in a ring of circumference 100 - 600 km (depending on the strength of the magnetic field in the bending magnets). Likewise progress in these sectors should be reviewed in about two years.

The Subpanel rues the erosion of US university particle physics, both in terms of the numbers of students involved and the support available. To safeguard the vitality of the national programme, the Subpanel stresses than over a two-year period, the available funding should be ramped to 10% above inflation to 'partially restore the losses of the last five years and better prepare university groups to use the new facilities'. In particular, the Subpanel recommends the establishment of new funding, at an annual level of $2 million, for generic detector R and D to seed the ground for future experiments.

The recommendations come in the context of recent US proposals to drastically increase the nation's research budget over the next decade, a move the Subpanel strongly supports.

Fred Gilman of Carnegie Mellon chairs the latest HEPAP subpanel to recommend future scenarios for US high energy physics.

Around the Laboratories

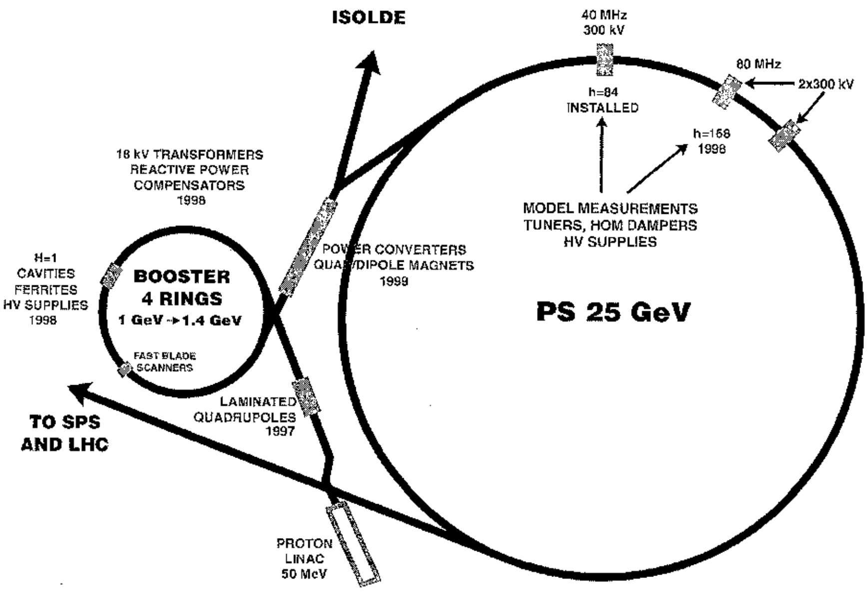
TRIUMF
Canadian contribution to the LHC

Since 1995 the TRIUMF Laboratory in Vancouver has been collaborating with CERN staff to provide a five-year $30-million Canadian contribution to CERN's LHC collider complex. This is in addition to contributions to the LHC detectors, and has involved activities in a variety of areas, not only on the LHC itself, but, especially in this initial phase, on the machines in the injector chain. In particular, the Proton Synchrotron (PS) and its Booster require major modifications to deliver proton beams with much higher brightness, more strictly controlled emittance, and a different bunch spacing.

The beam brightness required to achieve the LHC luminosity specifications is a severe challenge at low energies because of space-charge defocusing. To counter this the whole beam filling system is being changed to allow two Booster cycles, instead of one, to feed each PS cycle (with both machines operating at lower radiofrequency harmonics), and the Booster energy is being raised from 1.0 to 1.4 GeV to facilitate injection into the PS.

The Canadian contribution here has been the ferrite rings and the tuning and high-voltage power supplies for the four new first-harmonic r.f. cavities for the Booster, most of the magnets and power supplies for the upgraded 1.4 GeV transfer line between Booster and PS, new transformers for the Booster main magnet supply, and a reactive power compensator to reduce Booster-

CERN's PS complex, showing the equipment (shaded blocks) contributed by Ca[illegible] TRIUMF.



induced transients on the electrical grid. The magnets (3 dipoles, 7 quadrupoles and 5 steering dipoles), which differ from those they replace by being laminated for pulsed operation, were designed and fabricated by industry, but mapped and shimmed at TRIUMF.

The 36 transfer-line power supplies were built by Inverpower Controls, the 5 large rectifier transformers by Ferranti-Packard, and the 20 MVAR compensator by GEC-Alsthom with TRIUMF acting as contract manager in each case. TRIUMF has also produced 15 Timing Surveillance Modules for the PS controls group, with a further 30 to follow.

The measures taken to restrict emittance growth as the beam progresses through the injector chain, in which there has been Canadian involvement, include improving the accuracy of beam profile measurement and shortening kicker rise-times. A fast blade profile monitor for the Booster has been designed and a prototype is under construction. A possible technique for shortening the PS kicker rise-times is to improve the pulse shape by the use of saturating ferrite inductors; simulations and full-scale tests at TRIUMF have confirmed that significantly shorter rise-times can be obtained by placing inductors at the kicker input.

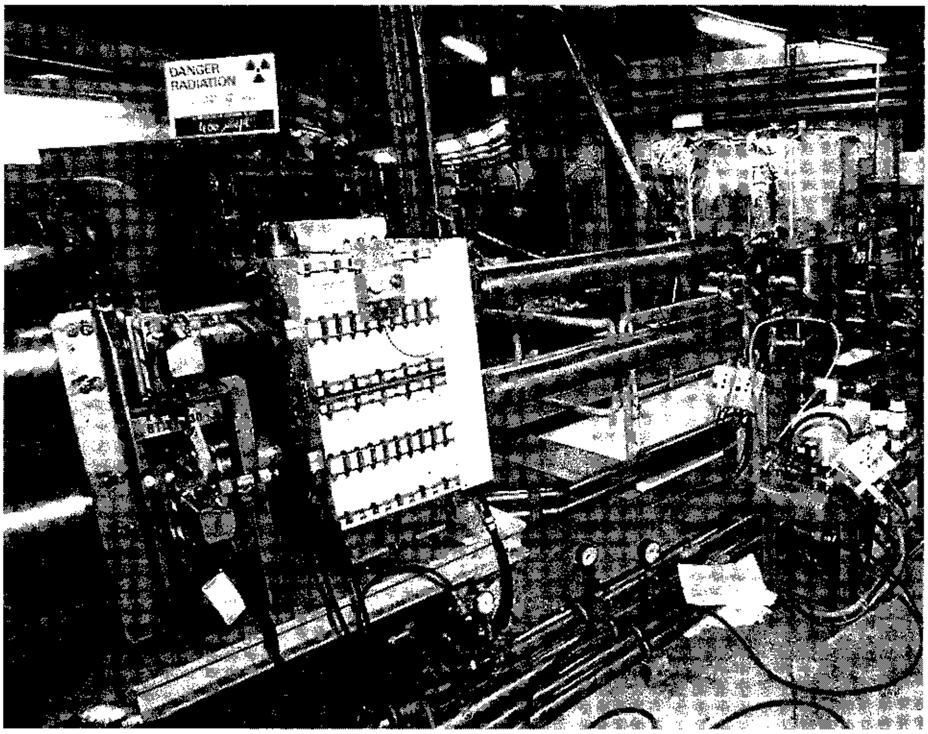
To produce the 25 ns bunch spacing required in the LHC, the beam in the PS will be allowed to debunch at top energy and will then be recaptured using new 40 MHz and 80 MHz r.f. cavities. Canada has contributed the high-voltage power supplies, the tuner designs, and the higher-order-mode dampers for these five cavities. Seven different damper designs and 6 filter assemblies were needed, requiring extensive computer simulations and model studies (September 1995, page 15).

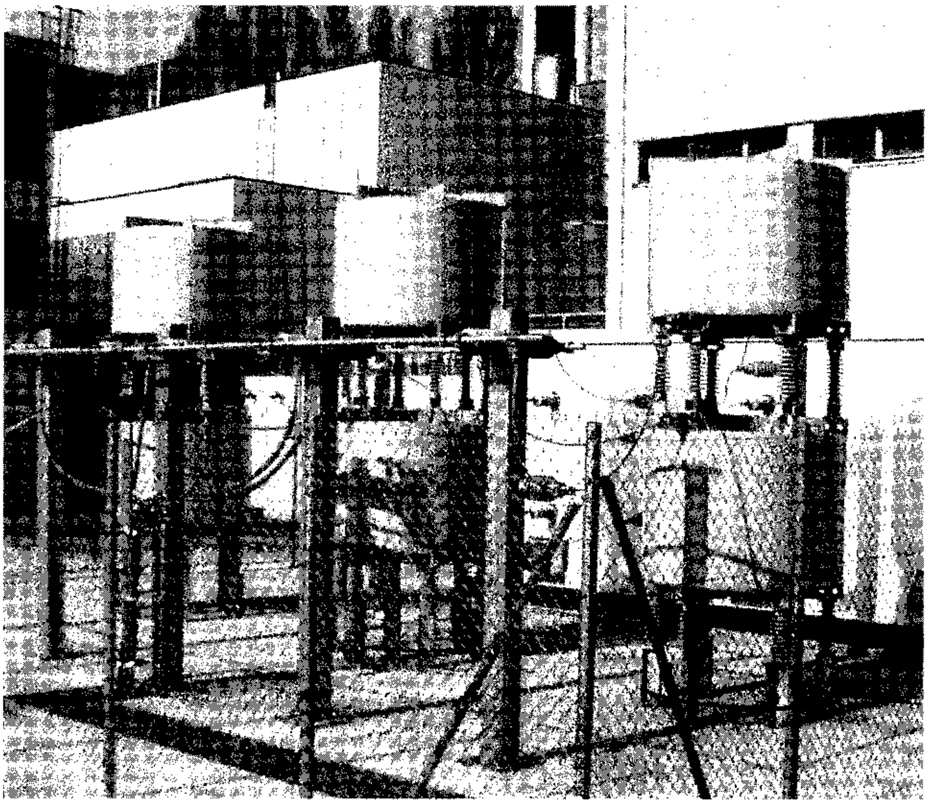
As most of the equipment required for the PS and Booster had to be installed during the 1997-8 winter shutdown, last year was an especially challenging period for TRIUMF staff and for the many companies manufacturing the components. Happily, the commitments were all met, although not without special efforts and some use of air freight! Although the majority of the Canadian contributions have been directed to the PS complex, others have involved the SPS and LHC. Thus, for the SPS orbit monitor electronics upgrade, TRIUMF has built, tested and sent to CERN fifty 200 MHz and four 47.5 MHz calibrator modules, with a further 250 of the 200 MHz modules to be delivered during 1998.

For the LHC itself, Canada is contributing to the injection kickers, the cleaning-insertion quadrupoles, and the current calibration equipment. For the kickers, a prototype 60 kV resonant charging power supply has been designed, built and tested, nine pulse forming networks will be built based on a CERN prototype, and computer simulations of the entire kicker circuit are under way to optimize the design and reduce the ripple below ± 0.1%. GEC Alsthom in Quebec has built a prototype of the novel twin-aperture warm quadrupoles to be used in the beam cleaning insertions at LHC Points 3 and 7. Measurements International in Ontario has supplied a 20 kA 1 ppm current comparator and other calibration equipment.

Besides all these hardware contributions, CERN and TRIUMF staff have been collaborating on a variety of beam dynamics studies. For the LHC this includes optimization of the beam optics and of the collimator locations and orientations in the betatron and momentum cleaning insertions; calculation of hardware impedances potentially affecting beam stability; and development of a simulation tool

Part of CERN's PS proton synchrotron complex, showing equipment contributed by Canada via the TRIUMF Laboratory in Vancouver. Two of the seven new quadrupoles from Canada are installed in the double 1.4 GeV Booster-PS transfer line. Further upstream (left), the four transfer lines from the four-ring Booster (one line per ring) merge into the two lines seen here. Downstream these two lines in turn merge into a single pipe before injecting into the PS.





More Canadian contributions: chokes for the 20 MVAR static compensator (in the cabin behind) for the Booster main power supply.

for testing online control of betatron tune and chromaticity. The latter two studies are also being carried out for the SPS, and indeed the tune control scheme will be first tested there. For the PS complex, there has been collaboration in the development of low-energy orbjt simulation codes, and in experimental and theoretical studies of second harmonic r.f. in the Booster, where a longstanding instability has finally been identified as a sextupole mode, rather than a beam-loading or space-charge effect.

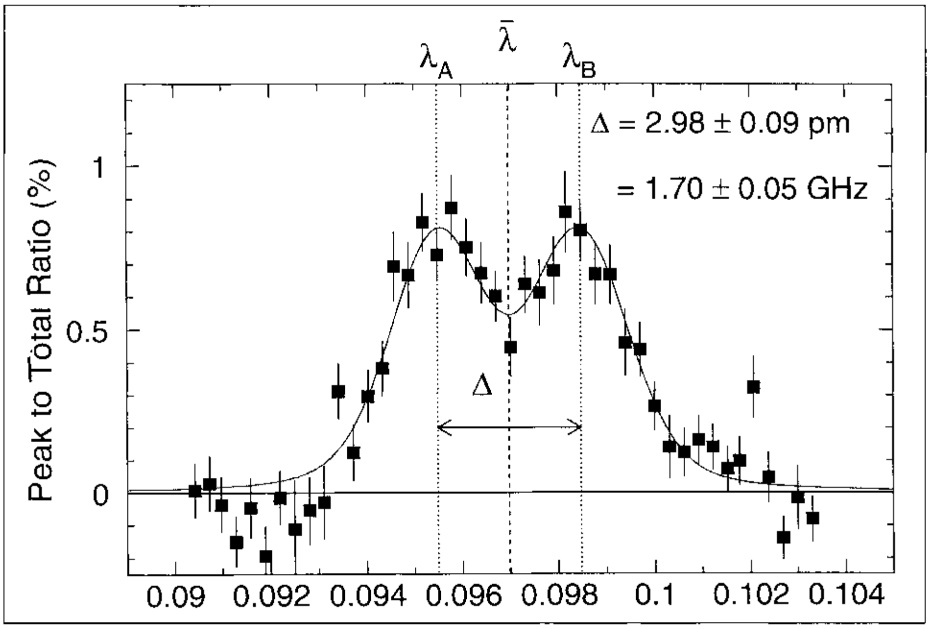
With this collaboration approaching its completion in 2000, planning has now begun on the preparation of a proposal to the Canadian government for the inclusion of a contribution of similar value in TRIUMF's next Five Year Plan for the years 2000-5.

The spotlight is now switching from installation to commissioning the upgraded systems. Low intensity beams have been taken to the PS top energy on the new r.f. harmonics and the new equipment, most of which is of Canadian origin, has performed well. Higher intensities are the next goal.

CERN
Stealing a march on the millennium

To add further confusion to current arguments as to whether the third millennium starts in the year 2000 or 2001, a number of physicists in Japan and Europe are working to a

Figure 1: Hyperfine splitting of the (n, l) = (37,35) to (38,34) transition in antiprotonic helium. The wavelength splitting of 2.98 pm (1.7 GHz) corresponds to the tiny energy difference (7 x 10^{-6} eV) between states with the electron spin magnetic moment up and down relative to the antiproton orbital magnetic moment (E. Widmann et al. 1997, Physics Letters B404, 15).



calendar in which 1 AD corresponds to 1999.

This odd millennial convention is related to the closure of CERN's Low Energy Antiproton Ring (LEAR) which, although it ceased operation in December 1996, did so in a blaze of glory. Among its late successes were the historic first synthesis of antihydrogen atoms (March 1996, page 1) and the opening up of a new research field of laser spectroscopy of antiprotonic helium atoms (November 1996, page 13), in which both an antiproton and a residual electron 'orbit' the helium nucleus. The AD (Antiproton Decelerator - May 1997, page 1), a less complex but more economical replacement for LEAR, is the phoenix rising from the ashes of this conflagration, and should begin operation in 1999.

In November, CERN's Research Board, which had already approved two AD experiments (ATHENA and ATRAP) to investigate the antiworld through the antihydrogen atom, gave the go-ahead for a new programme of research on antiprotonic helium, largely funded by the Japanese Ministry of Education, Science, Sports and Culture (Monbusho), and to be done by a Japanese-European collaboration bearing the name ASACUSA. This stands for Atomic Spectroscopy and Collisions Using Slow Antiprotons, but it is also the namesake of the famous Asakusa temple district, familiar to every visitor to central Tokyo and located just a few kilometres from the Tokyo university campus. The collaboration has chosen for its logo the giant lantern of the Kaminari-mon, the ceremonial gate leading into Asakusa (see cover picture).

The ASACUSA programme is an outgrowth of the LEAR work on antiprotonic helium, which traces its origins to 1990 when a Tokyo group working at the Japanese KEK Laboratory showed that about 3% of atoms (created when antiprotons stop in a helium target) consisting of a helium nucleus together with an antiproton and an orbital electron survive for some microseconds before the antiproton falls into the nucleus and annihilates.

This metastability was quite contrary to expectations and is apparently connected with the presence of the electron; by shielding the atom from the destructive effects of collisions with normal helium atoms in the target, the electron gives it a kind of insurance cover. As the antiproton's principal (n) and angular momentum (l) quantum numbers are both about 40, its de Broglie wavelength in the atom is therefore some 40 times smaller than that of the ground state electron. This means that its atomic orbit is almost classical, while that of the electron is fully quantum-mechanical.

Were this hybrid characteristic the only interesting feature of the antiprotonic helium atom, it might have remained nothing more than an excessively rare item in the atomic physicists' stamp collection. Much more important is the fact that its microsecond lifetime against annihilation is long enough to permit laser beams to be fired at it. Near n=40, the antiproton energy level spacing should be about 2 eV, or about 600 nanometres; this was confirmed in 1993 by the LEAR group, who stimulated a quantum jump between its (n, l) = (39,35) and (38,34) levels with a 597.259(2) nm laser pulse. The experimenters have so far published some 250 journal pages of results and demonstrated ever-increasing accuracy in the laser technique. These measurements cover both helium-4 and helium-3.

On the theoretical side, calculations are now detailed enough to take into account relativistic corrections to the electron's motion, and give transition wavelengths within a few parts per million of the measured ones for all

13 transitions now known. From these developments, the antiproton's Rydberg constant - the fundamental energy 'ruler' of its quantum electrodynamics - can be deduced with commensurate precision.

A final parting shot from LEAR was the revelation of hyperfine structure in the transition (n, l) = (37,35) to (38,34) (see figure), arising from the tiny interaction energy of the electron's spin with the angular momentum of the antiproton.

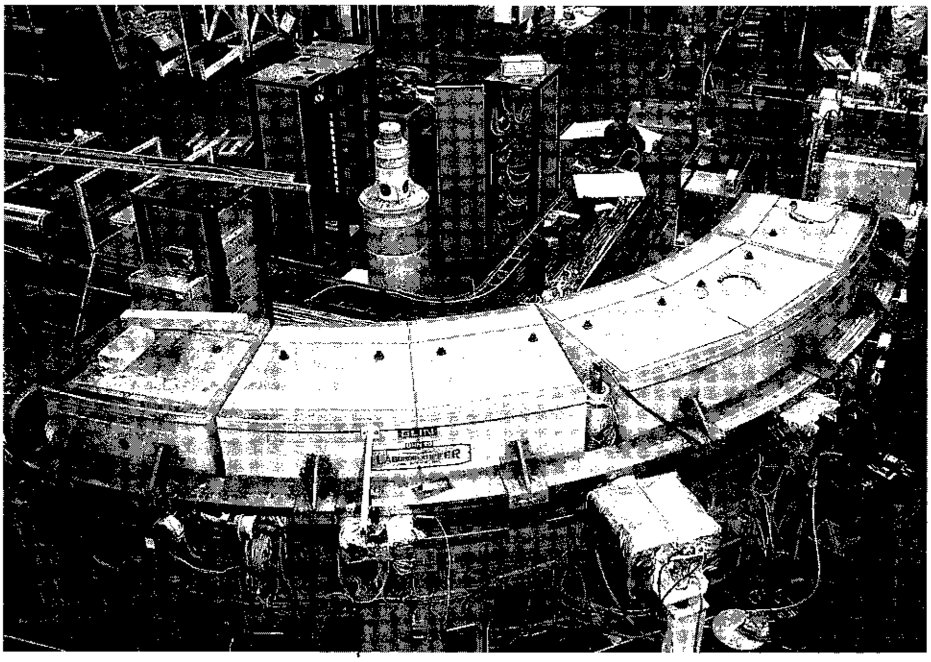
What is happening here is familiar from the history of the hydrogen atom, which for at least a century has had the status of a physical benchmark. Antiprotonic helium is in turn becoming the first laboratory benchmark for the quantum electrodynamics of the antiproton, and therefore of the antiworld in general. In this respect, it complements the antihydrogen atom, and is much easier to synthesize.

In 1 AD, ASACUSA therefore expects to continue studying antiprotonic helium atoms where its predecessor collaboration at LEAR left off, using microwave and optical beams in triple resonance with the atoms to make a precision measurement of hyperfine splitting.

In 2 AD, a decelerating Radio Frequency Quadrupole (RFQ) will be added to the AD beam to reduce the antiproton energy from MeV to keV values. This will permit the (n, l) distribution of the atoms to be studied at the instant of their birth, and allow investigations of the atomic interactions of antiprotons at extremely low energies.

The year 3 AD should see the further addition of a Penning trap from which antiprotons at rest will be reaccelerated to eV and keV energies. The resulting monochromatic ultra-low energy beams will permit tighter control of the conditions under which the metastable atoms are formed. They should also make it possible to study protonium (proton-antiproton) atoms in vacuum or near vacuum conditions.

Protonium is easier to handle theoretically than antiprotonic helium and can readily be formed by introducing antiprotons into hydrogen targets. Unlike antiprotonic helium, it has no electron, and therefore does not possess fully comprehensive collision insurance. However, in vacuo, with no other vehicles in sight, this should no longer be a hindrance against the metastability necessary for carrying out laser spectroscopy.



After having completed its antiproton programme, CERN's LEAR Low Energy Antiproton Ring has been rechristened the Low Energy Ion Ring (LEIR). Its job will be to accumulating lead ions for CERN's LHC collider.
(Photo CERN AC97.11.016)

From LEAR to LEIR

CERN's LEAR Low Energy Antiproton Ring, which has now completed its antiproton programme (May 1997, page 1) has been rechristened the Low Energy Ion Ring (LEIR) and has turned its attention to accumulating lead ions for CERN's LHC collider.

The current Electron Cyclotron Resonance (ECR) sources, used in conjunction with the Booster to supply lead ions for the SPS synchrotron, are fifty times too weak to provide the beam intensity needed for the LHC. LEIR has therefore stepped into the chain of injector machines to boost ion levels. The final scheme calls for LEIR batches of up to 1.2 x 10^9 ions (four LHC bunches) every 3.6 seconds.

For LHC ions, LEIR can take over the role currently played by the Booster, which in the LHC era can then be dedicated to handling

protons. The feasibility tests were done last year using injection from the ion Linac 3, which could be pushed to a cycling rate of 2.5 Hz. This rate allowed up to 7 x 10^8 ions to be accumulated. The ions are fed into the accumulator as a series of pulses, each containing about 8 x 10^7 ions.

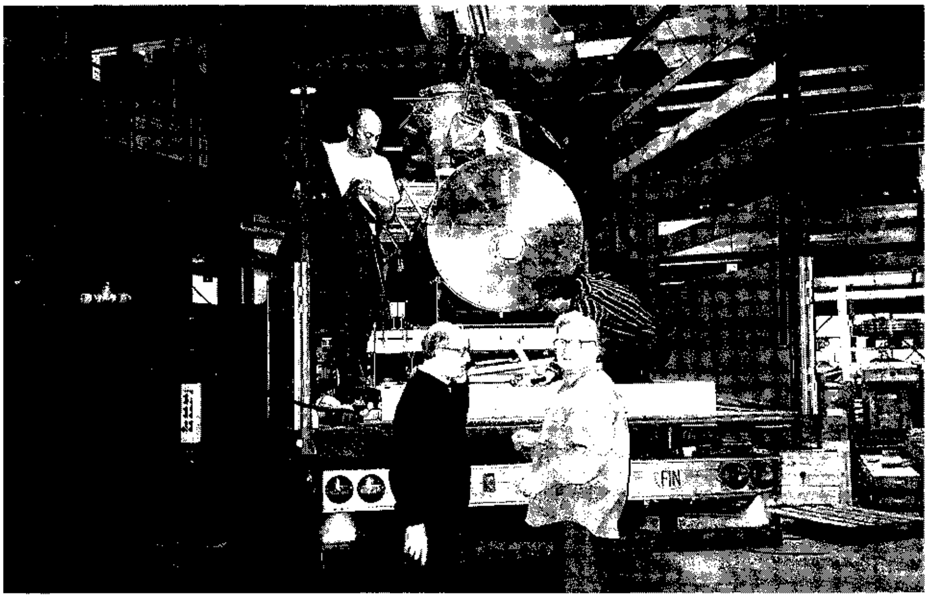
When ion pulses are transferred in single-turn injection, only the fraction of the Linac beam corresponding to one turn in the circular machine is captured. However, LEIR has adopted a new combined transverse and longitudinal multiturn injection technique which allowed to "catch" up to 20 turns at each injection. This injection technique exploits the ability of the ring to contain a large spread of circulating particle momenta in addition to their transverse oscillations.

In this scheme, the closed orbit is deformed by a "bump" which is made to change as the energy of the injection linac is increased in such a way that the resultant closed orbit for the incoming particles remains (more or less) fixed. In the usual transverse multiturn injection, the linac energy is constant and the bump shifts the closed orbit, so the momentum spread of the circulating beam remains as small as that of the incoming beam. Ramping the momentum of the injected beam creates room for more turns. Electron cooling then "compresses" the pulse and drags it to the stacking orbit in the corner of the aperture, before a new injection arrives (after 400 ms in the tests).

Earlier runs in 1995 with lead ions of charge state 53+ (53 of the 82 electrons stripped off) revealed an anomalous fast loss with electron cooling, due to ions recombining with the cooling electrons. LEIR side-stepped the problem by switching to lead 54^+, which paradoxically does much less recombine in this way.

High performance levels require a good vacuum, and some components that induce a large pressure rise with the ion beam had to be removed. Further improving the vacuum is one way in which the machine physicists hope to reach the LHC specifications. They are also looking at ways of speeding up the electron cooling to make space for incoming pulses more quickly, and will eventually run the Linac at 10 Hz, as opposed to the current 2.5 Hz. Already half the required 1.2 x 10^9 lead ions have been attained; the experts are confident that the rest will follow.

The LEIR electron cooling system was originally part of CERN's Initial Cooling Experiment (ICE) in 1977, and is now being re-installed for a new role on CERN's Antiproton Decelerator.



Herbert Lengeler (left) and Boris Prosin in front of a superconducting radiofrequency beam separator being prepared for transport from CERN to the Institute for High Energy Physics (IHEP), Serpukhov (Protvino), near Moscow. Built at Karlsruhe by a team under Lengeler's direction, the separator operated at CERN until 1980 before being mothballed.

CERN/SERPUKHOV Superconducting separator emerges from sleep

After being mothballed for 18 years, in January a large superconducting radiofrequency beam separator was transported from CERN to the Institute for High Energy Physics (IHEP), Serpukhov (Protvino), near Moscow.

The separator, a pioneering instrument in radiofrequency superconductivity, was developed and constructed from 1971-77 at the Institute für Kernphysik of the Kernforschungszentrum Karlsruhe under the leadership of Herbert Lengeler from CERN.

From 1977 it was operated in conjunction with a 1.8K refrigerator from British Oxygen in a counter beam for the Omega spectrometer at the SPS synchrotron.

The separator provided high

intensity secondary beams of positive and negative kaons, antiprotons, positive pions and deuterons between 3 and 37 GeV. Around 1980, detector response and the limitation of proton intensities at the SPS allowed experiments to handle the range of interactions without prior beam separation, and the detector was put into vacuum storage.

Meanwhile the intensities at major proton accelerators has been boosted by another order of magnitude and has raised again the need for separated secondary beams.

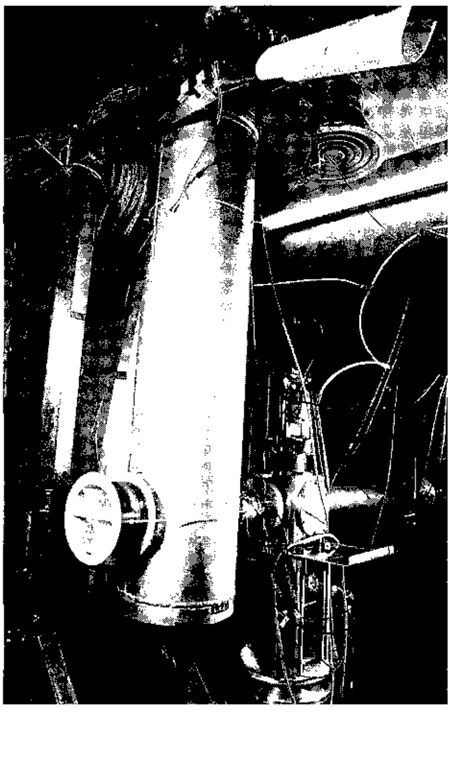
In 1997, other laboratories expressed interest in acquiring the superconducting separator stored at CERN, and it was decided to transfer the two superconducting deflectors and their cryostats to IHEP Serpukhov. After careful testing at CERN with generous support from the laboratory's LHC, SL and ST Divisions, they were prepared for shipment to Russia using the support systems used for the superconducting cavities for CERN's LEP electron-positron collider (December 1997, page 8).

At IHEP, the separator will be installed in a beamline providing more than 10^9 particles per extraction cycle, suppressing unwanted particles by a factor of a hundred. It will be interesting to see how well the separator performs after its long sleep in vacuum.

FRANCE
Neutron irradiation at cryogenic temperatures for the LHC project

Cryogenic devices are frequently encountered at high-energy accelerators and are expected to become even more familiar in the coming decade. A good example is provided by CERN's LHC project, in which the very high proton beam energy calls for the use of high-field magnets both in the accelerator and in the detectors. In order to satisfy technical and economical requirements, the high-field magnets are superconducting coils operated at liquid helium temperature.

For the LHC, low temperatures are not reserved for the operation of magnets. Because of the intrinsic radiation hardness of noble liquids, the ATLAS collaboration has decided to use liquid argon calorimetry in a region of the detector where the radiation levels are high.



Cryogenic test assembly for neutron irradiation testing for LHC components.

As well as creating strong levels of radiation in the detectors, the high luminosity of the LHC collider (10^{34} per sq cm per s) will also give rise to high radiation levels in the machine, whose effects on the performance and ageing of instrumentation need to be seriously tested.

For this, a neutron irradiation station was built and operated over the past few years at the SARA heavy ion facility in Grenoble by a collaboration of three laboratories: ISN Grenoble, IPN Orsay and LAL Orsay. It consists of a cylindrical cryostat which can contain up to 10 litres of liquid argon (87.6 K) or liquid helium in a normal or superfluid state (1.8 - 4.2 K).

A thick beryllium target, in which a 5 microamp deuteron beam of 20 MeV is stopped, is installed in front of the cryostat. The beryllium-9/deuteron reaction, producing boron-10 plus a neutron, has been known for years in neutron therapy or nuclear fusion research to be extremely effective in producing high intensity neutron beams. At SARA, neutron fluences of 2 x 10^{14} per sq cm may be attained in one day of operation over an exposed sample area of 25 cm^2.

Among the numerous topics studied so far, two specific irradiation questions have received special attention, as SARA is presently the only site in the world where they can be experimentally investigated. These are: the stability and ageing of the LHC magnet thermometers; and the pollution of liquid argon under neutron radiation of the polymeric components of the ATLAS calorimeter.

Simulations have shown that in the electromagnetic barrel calorimeter,

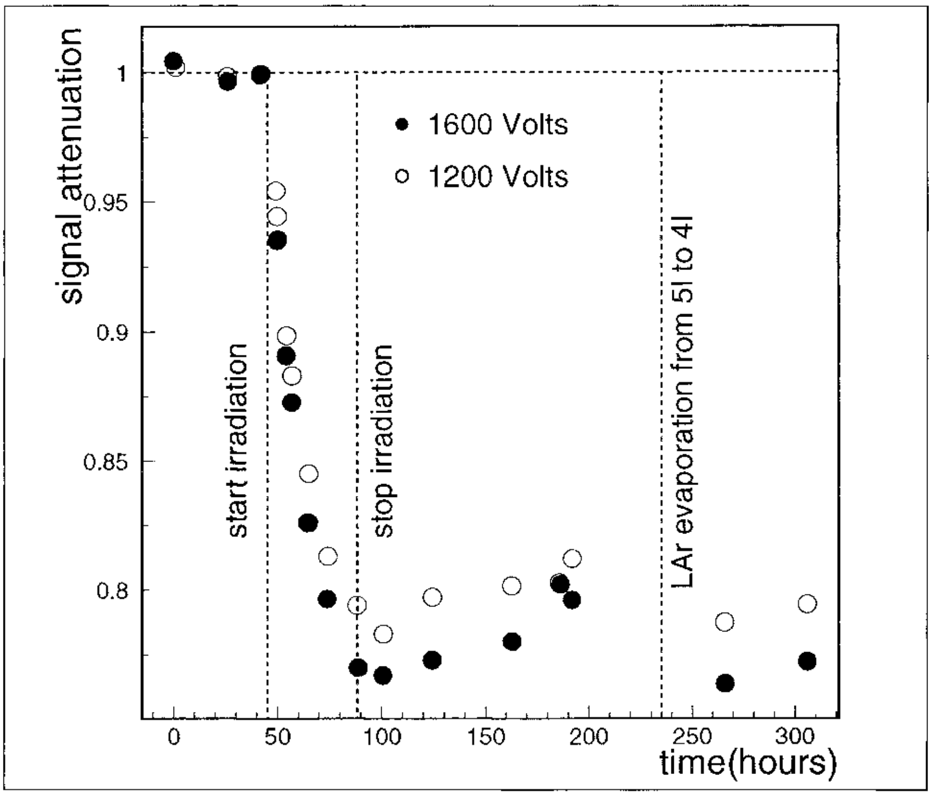


Figure 1: Testing detector components under high radiation conditions: Alpha particle charge attenuation as a function of time when irradiating pre-impregnated foils in liquid argon with a material-to-liquid proportion enhanced by 22. The open and the full circles correspond to different high voltage values applied to the ionization chamber. The impurity causing the signal attenuation seems to remain in the cryostat even after part of the liquid has evaporated.

fast neutron fluxes up to 10^{14} per sq cm will be obtained in 10 years of operation at full luminosity. Under fast neutron irradiation, some parts of the calorimeter, especially those made of polymers, could undergo radiolysis and release undesirable elements, compounds or radicals which represent a potential pollution danger.

If, for example, oxygen were released in the liquid argon with a concentration of 10 ppm, the calorimeter signal could be reduced by 10% by capture of electrons in the argon gaps. To investigate this, a purity monitor with an americium-241 alpha source mounted in a liquid argon ionization cell was installed in the irradiation cryostat. Each alpha particle creates a known number of drifting electrons in the liquid which may get captured if pollution develops during the irradiation. A decrease of the collected electron charge before, during and after the irradiation is the external signature of liquid pollution.

Eight different polymer-containing materials have been tested so far. To amplify the phenomenon, and to prove the correct operation of the purity monitor, some tests used proportions much higher than expected for the final calorimeter.

An example is given in Figure 1. Here, the pre-impregnated foils used for gluing the electromagnetic presampler modules were tested with a material-to-liquid proportion enhanced by a factor of 22 with respect to the final ATLAS calorimeter. The pollution following irradiation is clearly visible.

Further tests have shown that pollution is proportional to the quantity of material in the cryostat. When properly counting the contributions of all tested materials, the total calorimeter signal attenuation expected after 10 years of operation, without any replacement or any purification of the liquid, remains lower than a very satisfactory 1.5%.

The LHC accelerator will need a large number of superconducting coils operating in superfluid helium at a temperature ranging from 1.8 to 1.9K which will be monitored with a precision of 5mK. To meet this challenge, nearly 10000 temperature sensors (thermoresistors) will be installed at different critical points of the superconducting magnets where the proton beam losses could induce high radiation doses: 10^2 -10^3 Gy for 10 years of operation. In the beam interaction sections, these radiation doses could even be ten times higher.

Adopting a safety margin of 2, it was decided to test the candidate sensors at a neutron fluence of 10^{15} per sq cm (corresponding to 2 x 10^4 Gy).

Four irradiation experiments were performed in 1997 and another campaign of the same type will be conducted this year. In each experiment, about 50 sensors of different types (carbon resistors, thin film oxide resistors, pure metal or alloy resistors in wires or thin films)

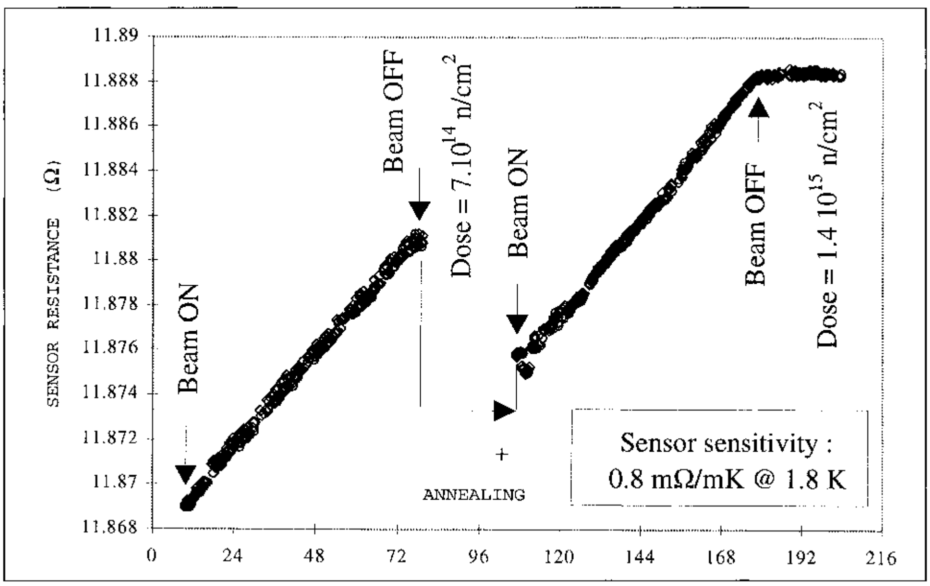


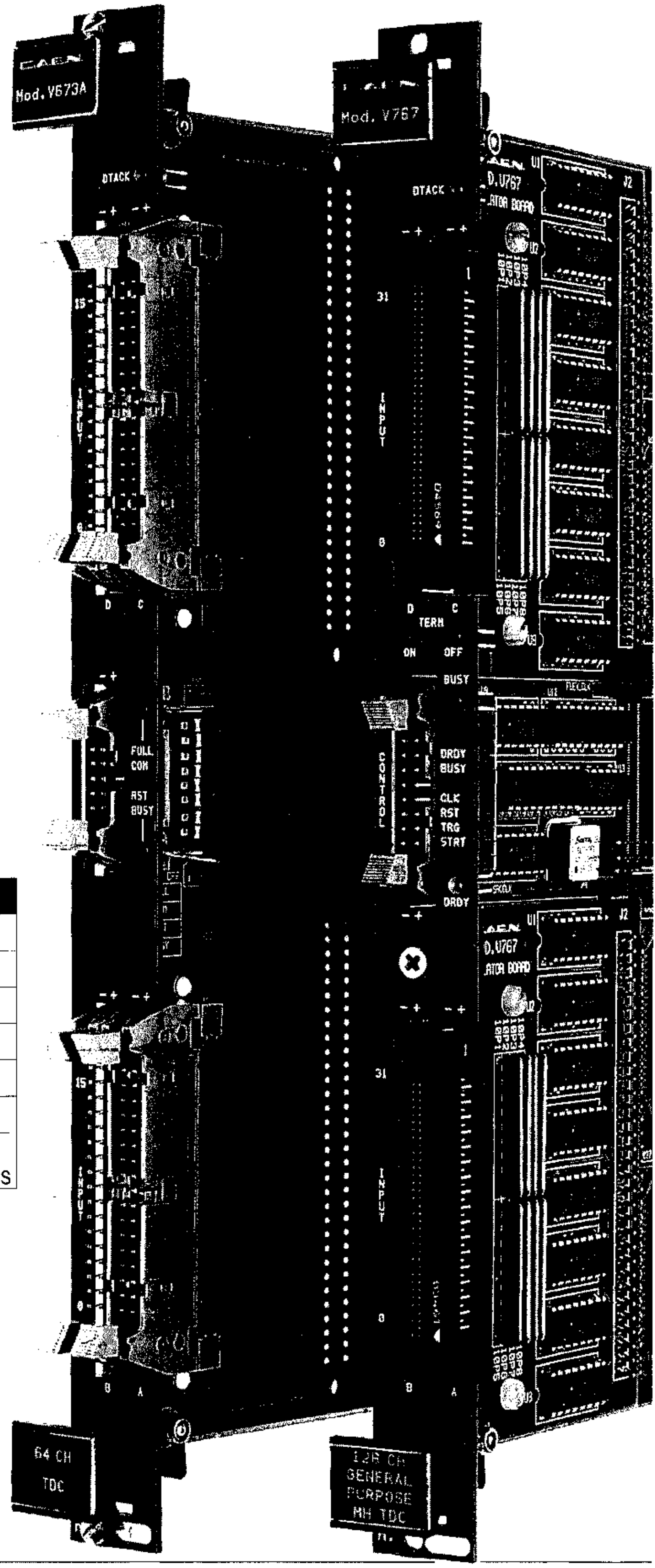
Figure 2: Testing accelerator components under high radiation conditions. Rhfe thin film thermometer resistance measured during neutron irradiation at 1.8 K. The sensor shift is 15 mK for 7 x 10^{14} neutrons per sq cm

21st Century's TDCs

To meet the requirements of the next generation HEP Experiments, two leading European Physics Research Institutes have developed two ASIC **Multihit Time-to-Digital Converters** in VLSI technology.

By integrating them in two single-width, 6U VME modules we have created two modular TDCs featuring an **unprecedented density** and the **lowest price per channel** achieved to this date.

They are available now to allow today's experiments to take advantage of **next century's' technology.**



Type*	V667	V673A	V767	V693
Width	1 slot	1 slot	1 slot	1 slot
Channels	64	64	128	128
Bits	21	16	20	16
LSB	780 psec**	1 nsec	780 psec**	1 nsec
DPR	10 nsec	5 nsec	10 nsec	5 nsec
Conv. Time	Nil	Nil	Nil	Nil
Output Buffer	2KWords	4 events 6KWords	32KWords	4 events 12KWords

*VME 6U Units ** 520 psec with speed graded ICs and 60 MHz Clock

The V667 and V767 are based on an IC developed at CERN by the ECP-MIC Group
The V673A and V693 are based on an IC developed for the KLOE experiment by INFN-Roma

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are irradiated. The evolution of their resistances is measured on line and compared to accurate temperature references provided by vapour pressure bulbs in the range of 1.8 to 4.2K. Moreover, different temperature and annealing cycles are performed to study the influence of the operating cryogenic conditions.

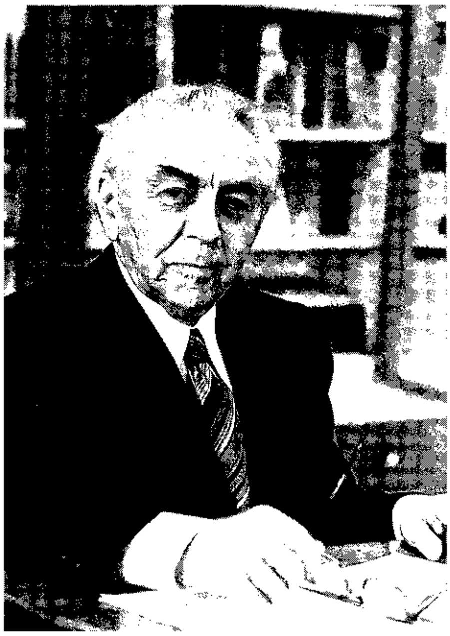
The resistance evolution of a typical sensor as a function of the neutron fluence is presented in Figure 2. These experiments showed that each sensor family, when irradiated, evolves with a typical behaviour. Based on these results and the data to come in 1998, a comparative study will select the final temperature probes for the LHC superconducting coils and cryogenic equipment.

Since SARA will cease activities this year, the extension of this programme for the years 1999-2000 at another site in western Europe is presently under examination. For tests of liquid argon calorimeter components, a second site will soon be operational in Russia at Dubna by the IBR-2 reactor. With fluxes which may attain 10^{16} neutrons per sq cm in a few days of exposure, this offers the possibility of tackling the question of a pollution in the ATLAS endcap calorimeters (in particular in the very forward section) where expected radiation levels may be a hundred times higher than in the central barrel section.

By. B. Merkel (Orsay)

DUBNA Honours

The Joint Institute for Nuclear Research (JINR), Dubna, near Moscow, is honouring two of its distinguished senior scientists.



Venedikt P. Dzhelepov - 85

Dmitri V. Shirkov - 70

On 12 April Venedikt P. Dzhelepov celebrates his 85th birthday. Among the major founders of the Institute of Nuclear Problems of the USSR Academy of Sciences (1949) and later of JINR (1956), he was Director of JINR's Laboratory of Nuclear Problems from 1956-88 and has been its honorary director since 1989.

Before coming to Dubna, he was involved in uranium work at I.V. Kurchatov's institute. Milestones in his scientific career of more than 60 years include the construction of the then (1949) world's largest 680 MeV proton synchrocyclotron, later (1984) upgraded to a high-current phasotron with a spirally varying magnetic field allowing a 20-fold increase of extracted 680 MeV proton intensity.

His experimental researches of nucleon-nucleon and pion-nucleon interactions, nuclear capture of negative muons by protons in gaseous hydrogen, negative pion electron decay, pion production of normal and strange neutral particles, hypercharge-exchange reactions and other processes at the accelerators of JINR and IHEP (Protvino) together made a substantial contribution to particle and nuclear physics.

V.P. Dzhelepov is also known for his work on high-current accelerator complexes in the range 0.8 - 1.5 GeV based on isochronous cyclotrons. It was under his supervision that Russia's first clinico-physical complex was constructed at the synchrocyclotron of the Laboratory of Nuclear Problems for proton treatment of cancer and for radiobiological investigations for space medicine.

He is a corresponding member of the Russian Academy of Sciences, for many decades one of the leaders of the Nuclear Physics Division of the Russian Academy of Sciences, and a winner of the State Prizes of Russia and of the I.V.Kurchatov Gold Medal of the Russian Academy of Sciences. As a member of IUPAP commissions, ICFA, and editorial boards of highly authoritative scientific journals he has made a substantial contribution to development of international scientific cooperation.

3 March marked the 70th birthday of Dmitri V. Shirkov. The first years of his scientific career were devoted to nuclear reactors, neutron diffusion and moderation. In the mid 50s he began working with N.N. Bogoliubov in quantum field theory, making a fundamental contribution to the axiomatic formulation of perturbation theory for the scattering matrix and to the establishment of the renormalization group. These results became a part of their famous monograph "Introduction to the Theory of Quantized Fields" first published in 1957 and later translated into English and French.

In the late 50s D.V. Shirkov suggested a method of taking the Coulomb effect into account in the microscopic theory of superconductivity. In 1960 he moved to Novosibirsk to found the Theoretical Physics Department of the Mathematical Institute and the chair of Theoretical Physics at Novosibirsk University. He and his colleagues elaborated dispersion theories of strong interactions at low energy. In 1970/71 he lectured at Lund as Nobel guest professor.

He returned to JINR in 1971 and continued his research into the application of the renormalization group and formulated the hypothesis of finite renormalization. He initiated a well-known series of Dubna papers on multi-loop calculations in QCD and elaborated the method of summing the asymptotic series which was effectively used in critical phenomena.

He also developed general methods for renormalization group transformations in various fields of physics and introduced a notion of functional self-similarity generalizing the scaling laws. From 1993-97 he was Director of the Bogoliubov Laboratory of Theoretical Physics.

He devoted much effort to the training of young scientists, for more than a quarter of a century teaching first at Novosibirsk and then Moscow State University. He is a member of the Russian Academy of Sciences, the Physiographic Society of Lund (Sweden) and the Saxon Academy of Science in Leipzig (Germany).

Physics monitor

The physics window at LEP

Over the next two years or so, CERN's LEP electron-positron collider will take data at energies up to about 10% larger than those achieved so far, and take several times more data than the currently accumulated amounts at energies above the Z. While those increases may seem to be opening the window onto new physics only a little, our present understanding of the physics opportunities suggests it is a window with a great view.

How can we judge the value of small increases in energy or luminosity (the luminosity is a measure of the number of collisions per second)? To make a discovery from an increase in energy it is necessary that the new particle(s) or interaction(s) occur just in the small region of the increase. Similarly, there is a luminosity threshold where one goes from too few events to be seen to a possible observable signal.

One way to judge whether we are entering such a region is to take a model of the new physics that incorporates the successful physics of the Standard Model, that includes the known motivations for possible new physics, and does not predict any phenomena that are inconsistent with existing data. Then we ask if the model suggests there will be new physics in the region accessible to LEP.

Luckily we have such a model, one which adds a new symmetry called "supersymmetry" to those we already know. All particles have a property called spin. Some (photons, Z, etc.) have spin that is an integer multiple of a basic unit; they are called bosons. The others (electrons, quarks, etc.) have spin that is a half-integer multiple and are called fermions. Under the rules of quantum theory bosons and fermions behave very differently. Supersymmetry is the hypothesis that the fundamental theory incorporates bosons and fermions equally.

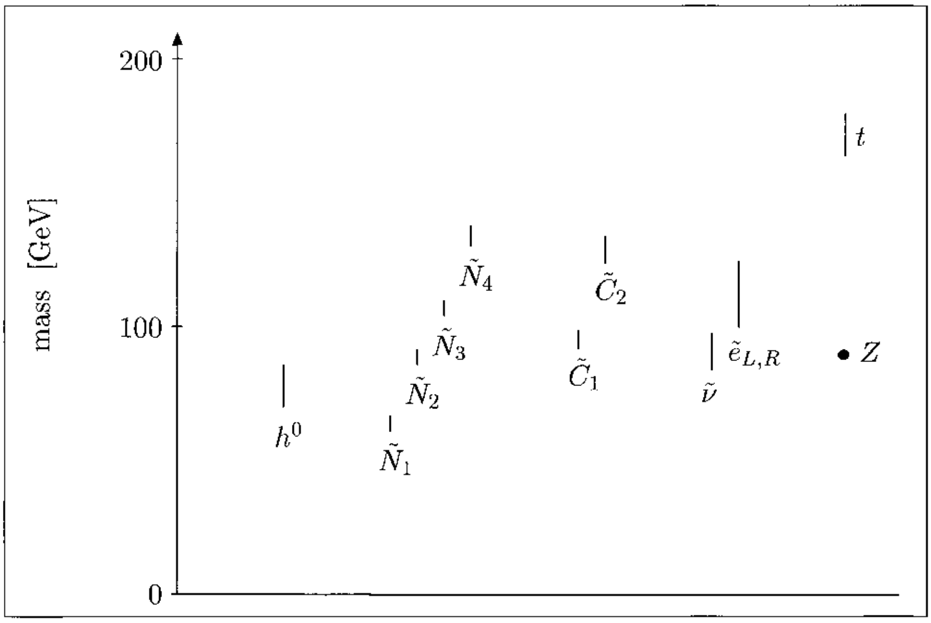
Since the Standard Model does not treat them similarly, supersymmetry predicts new particles should exist. In the following we will use supersymmetry as a guide to evaluate the promise of LEP. There are good reasons to be optimistic that nature will indeed have this new symmetry, so that its implications will be meaningful; if not, perhaps the right answer will share implications with this model. One successful prediction of supersymmetry was that all of its effects on Standard Model observables must occur only through virtual particles, so the effects must be less than a per cent, similar to the effects of the top quark, as LEP indeed found (see the article of Daniel Treille in the April 1995 issue, page 10).

Supersymmetry not only predicts new particles, it offers an explanation of why Higgs bosons should exist, and most importantly, why the Higgs boson is likely to be light enough to be detected at LEP. (In order to incorporate a description of the mass of particles into the Standard Model it was necessary to postulate the existence of a new field, the "Higgs" field, analogous to the electromagnetic field. Interactions with the Higgs field then led to mass. Just as the photon is the quantum of the electromagnetic field, the Higgs boson is the quantum of the Higgs field. The existence of the Higgs boson is the test of the correctness of this approach.)

The logic proceeds as follows. The Standard Model of particle physics, the theory of quarks and leptons interacting via the exchange of "gauge bosons" (the photon, gluons, W and Z), describes phenomena well on the scale of collider energies. Alternatively we can think of distance or size scales from distances smaller than a proton (about 10^{-13} cm down to about 10^{-16} cm) the Standard Model works well. In physics it is very useful to think in terms of "effective theories". For example, the physics of the atom is an effective theory. Given the properties of electrons and of nuclei one can study and understand the properties of atoms. We do not need to understand whether there are quarks in a proton, or the structure of nuclei, or the origin of the electron's mass, to understand atoms.

The Standard Model can be thought of as an effective theory, but it is not a complete effective theory, surprisingly, because the mass of the Higgs boson must be within a few times the mass of the Z for the theory to be consistent, but if there are any scales in nature that are much larger than this the Higgs boson mass is unstable and will exceed the consistency limit.

There are at least two strong indications for such larger mass scales. One is the Planck scale, first studied by Max Planck a century ago, the scale formed by taking Planck's constant (h), Einstein's speed of light (c), and Newton's force constant (G) and constructing from them a mass scale. That scale turns out to be large, near where gravitational forces are about the same strength as the other forces. Equivalently one can



A possible spectrum of superpartners and a Higgs particle. Although none of these have yet been observed, some could be in forth-coming runs at CERN's LEP electron-positron collider. The $\tilde{N}_i$ are the 'neutralinos', states of definite mass formed from the superpartners of the neutral carrier particles (photon, Z,...). The $\tilde{c}_i$ are the equivalent 'charginos', superpartners of the W. ν_i is probably lighter than C_i for this spectrum. The 'squark' and 'gluino' states are not shown as they are less relevant for LEP. The 'stop' superpartner of the top quark could also be in this mass region. The Z and top quark are shown for comparison.

think of the Planck distance, about 10^{-33} cm. The second is the apparent unification of the strong, weak, and electromagnetic forces of the Standard Model. If the two-century-old hope to simplify our understanding of the forces could work, then they must have the same strength in some sense.

Starting from the LEP measurements of the force strengths, and using quantum theory to extrapolate them to smaller distances, it has been found that the strengths could be the same at distances near the Planck distance. Although supersymmetry was not invented to make an effective theory that could be consistent with joining such higher mass scales with the Standard Model, it turned out to allow that problem to be solved. There is an associated prediction: the symmetry requires a doubling of the number of particles, one very analogous to the doubling when antiparticles were introduced by Dirac about 70 years ago.

If the supersymmetric Standard Model is to be a consistent effective theory, the new particles ("superpartners") must be near the Standard Model particles in mass, with masses not much larger than those of the W and Z which have been studied at LEP. Supersymmetry has additional attractive features and consistency requirements that reinforce the idea that the new particles will be in this mass region. More specifically, the arguments suggest that the superpartners of W, the photon, and the Higgs boson are likely to have masses accessible at LEP. They should be heavy enough that few, if any, have been produced so far, but some should be produced in the next two LEP runs. It is not a theorem - supersymmetry is not excluded from being true if they are not found at LEP, but there is a suggestion that we understand supersymmetry less well than we think if they are not found.

There are also arguments that the superpartner of the top quark is likely to be light enough to be found at LEP, though they are not as strong as the arguments for the partners of the W, the photon, and the Higgs. The actual particles detected should be quantum mechanical mixtures of those mentioned above that have definite mass rather than definite symmetry properties. They are called "neutralinos" and "charginos".

Even better, supersymmetry suggests that the Higgs boson itself should be observable at LEP. In a supersymmetric world there are very general arguments that the mass of the Higgs boson should be less than about twice the W mass, but that is still too large for LEP, which will be sensitive up to at most about 5/4 the W mass. But when detailed supersymmetric models incorporating as much information as possible are made, they usually lead to Higgs boson masses that are within the range of LEP. Again, it is not a theorem, but it is what comes out of the best present analyses.

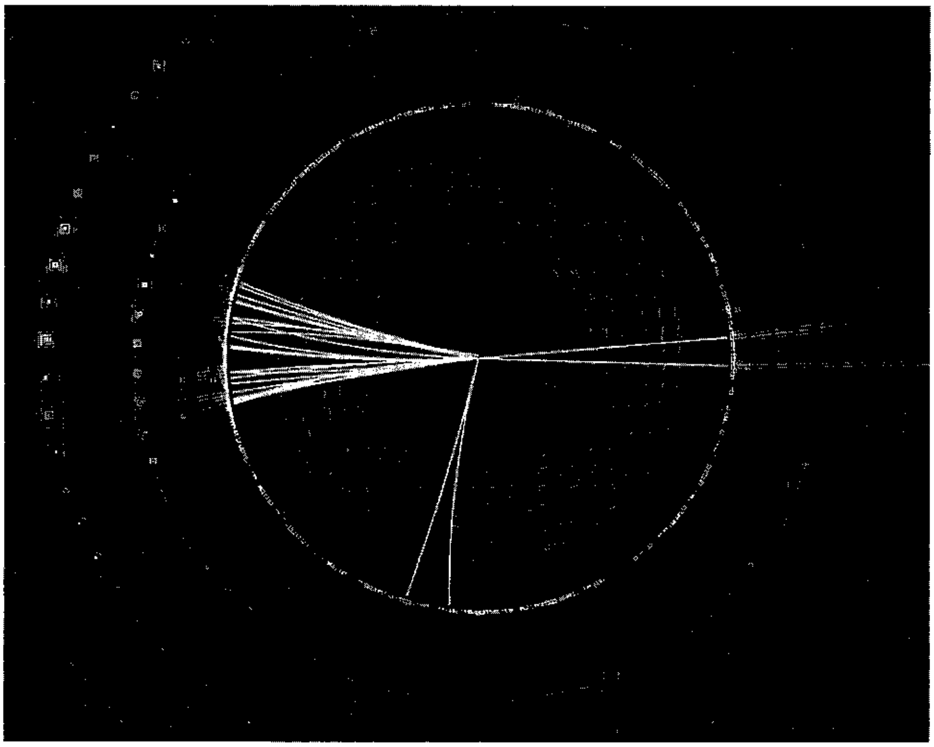
Basically, in supersymmetry the mass of the Higgs boson is calculable, but the value depends on some parameters of the theory that are not yet themselves calculable or measured. Using constraints from other information and good assumptions implies the Higgs boson should be observed at LEP.

Ideally a few superpartners and a Higgs boson will be found at LEP. However the most important result will of course be the basic discovery of the new physics. We will have landed on the shore of a new world to be explored. Even though only tens of events of each can be collected, it is possible to deduce significant information from limited data when they fit into a theory. Then more information will be obtained from the Fermilab collider when it takes data after its luminosity upgrade, in about two years, and then from CERN's LHC.

Fermilab and LHC provide rather complementary information, being mainly sensitive to different superpartners. The LHC will be a superpartner and Higgs boson factory. A higher energy lepton collider with polarized beams will probably also be necessary to learn what is needed to fully understand the structure of the supersymmetric theory.

Sometimes people suggest that what is most likely to emerge from higher energy or intensity facilities is a surprise, as happened so often in the past before the establishment of the Standard Model. Because the Standard Model is a full quantum field theory that is now well established and tested experimentally, it allows us to formulate questions and to think through expectations in new ways that were not possible historically before the Standard Model. Based on that thinking, it is now fair to say that the discovery of superpartners and a Higgs boson have in a sense become the default. For many workers in the field, it would be more surprising if they were not found at LEP than if they were.

by Gordon Kane, Randall Lab of Physics, University of Michigan



Synthetic Higgs. Simulation of what the CMS detector at CERN's LHC proton collider might see from 2005. This shows a Higgs decaying into (left) two sprays ('jets') of hadrons (strongly interacting particles), and (right) two electrons, together with a few accessory particles.

LHC physics vision

When CERN's LHC collider begins operation in 2005, it will open a wide new window on physics. However the view is expected to be so panoramic that the physics community is already busy getting its vision tested so as to be able to appreciate every detail of the view when the curtain goes up.

Thus to review current knowledge and to organize and stimulate further theoretical studies, a week-long Workshop on "The Theory of LHC Processes" was held at CERN from 9 - 13 February, organized and sponsored by CERN's Theory Division.

Strong encouragement for the Workshop had come from the large physics community which has much to gain by maintaining active physics discussion during the long years of LHC machine and detector construction. The LHC Committee warmly endorsed the initiative and prompted collaboration from the experimental groups.

The Theory Division organizes a few Workshops every year on specialized topics, and in this framework the idea of a Workshop on theoretical aspects of LHC physics was enthusiastically adopted.

The response was impressive, with some 120 participants from outside CERN, conspicuous among them being some 20 distinguished visitors from the United States, many contributing invited talks.

The first day focused on input from experiments. Joey Huston (Michigan State) summarized the experiments at Fermilab's Tevatron which will be active before the LHC startup. After this appetizer, the main course of theoretical demands from the LHC's ATLAS, CMS and LHC-B experiments were a natural focus of attention, with presentations by Daniel Froidevaux, Daniel Denegri and Tatsuya Nakada. (The heavy ion part of the LHC programme will be covered at a more specialized meeting.)

James Stirling of Durham (UK) presented a comprehensive review on quark/gluon structure functions in connection with the LHC programme, and this discussion continued on Tuesday morning. The afternoon session was devoted to review talks on jets by Walter Giele (Fermilab), on W and Z Production by Keith Ellis (Fermilab) and on QCD in Dense Matter by Yuri Dokshitser (Milan).

The Wednesday session opened with a thorough overview of the status of theoretical calculations on the production of Higgs and supersymmetric particles by Michael Spira (DESY), followed by shorter presentations on special topics on Higgs production and detection. Supersymmetry (SUSY) is high on the LHC agenda, and in the afternoon came three review talks: the Minimal Supersymmetric Standard Model by Howard Baer (Florida State), on more general approaches by Gordon Kane (Michigan) and on gauge mediated SUSY models by Sandro Ambrosanio (DESY). An open discussion on SUSY searches at the LHC was chaired by Howard Haber (Santa Cruz).

Supersymmetry searches continued into Thursday morning with a number of specialized contributions, while in the afternoon it was the turn of heavy flavour physics to come under the spotlight. Yossi Nir (Weizmann) presented the projected status of B physics at the startup of LHC, after the commissioning of the new generation of B factories; Michelangelo Mangano (CERN) discussed the production properties of heavy quarks, and finally Scott Willenbrock (Illinois) presented a very complete overview on top quark physics at the LHC.

With simulation an increasingly important aspect of experimental work, an informal discussion on event generators and analytical calculations and their implications for experimental simulation, led by Mangano, began the last day. A session on short contributions on physics beyond the Standard Model followed. Finally, the final afternoon session was devoted to event generators with a comprehensive introduction by Brian Webber (Cambridge) and more specific presentations by Torbjorn Sjostrand (CERN) and Michael Seymour (Rutherford Appleton).

Despite the remoteness of the year 2005, the LHC physics Workshop was very positive and similar meetings are foreseen to keep the flame of LHC physics burning brightly.

Bookshelf

Homage to Tomonaga. Last year was the 50th anniversary of the renormalization procedure which opened the route to modern quantum electrodynamics and led to the 1965 Nobel prize for Richard Feynman, Julian Schwinger and Sin-Itiro Tomonaga for their independent contributions. In Japan this anniversary was marked by a special meeting at the Tanashi branch of the KEK Laboratory (formerly Tokyo University Institute for Nuclear Study), where the speakers included Tomonaga collaborators Gyo Takeda (left) and Daisuke Ito. Tomonaga, who died in 1979, proposed his new approach to electrodynamics during his regular Friday Tokyo seminars.

The Story of Spin, by Sin-itiro Tomonaga, translated by Takeshi Oka, University of Chicago Press, ISBN 0 226 80793 2, $50

Spin has always been a physics enigma. Emerging ghostlike from the fog of atomic spectroscopy in the early 20th century, it found its explanation ('acrobatically', according to Pauli) in Dirac's monumental formulation of relativistic quantum mechanics.

However even the name 'spin' is a misnomer. As Landau and Lifshitz point out in their standard quantum mechanics textbook - 'this property of elementary particles is peculiar to quantum theory and therefore has in principle no classical interpretation. It would be wholly meaningless to imagine the "intrinsic" angular momentum of an elementary particle as being the result of rotation around its own axis.'

To compound the spin enigma, the deceptively simple relation between spin and quantum statistics which emerges from the intricacies of relativistic quantum mechanics still awaits a simple explanation.

This delightful book, originally published in Japanese in 1974 (Tomonaga died in 1979), is, with some justification, claimed to be the most complete and accessible treatment of spin. Presented as a series of lectures, it begins with the efforts of Sommerfeld, Landé and Pauli to disentangle the details of atomic spectroscopy, and goes on to cover the emergence of the quantum mechanical explanation of electron spin, first by Pauli and then by Dirac, the discovery of proton spin, the relation between spin and quantum statistics, and the emergence of isopin in nuclear physics. Lovingly translated, the incisive formalism is interspersed with anecdotes, and the book's evocative final chapter abandons formalism to survey Japanese physics from 1925-40, where the figure of Yukawa looms large.

Tomonaga's personality is evident despite the physics rigour. A classmate of Yukawa at Kyoto, he settled at Tokyo after initial spells at the RIKEN research centre and two years with Heisenberg at Leipzig. In 1947 he independently developed a modern form of quantum electrodynamics in complete ignorance of the measurement of the Lamb shift which stimulated Schwinger and Feynman in the US. For their quantum electrodynamics work, Feynman, Schwinger and Tomonaga shared the 1965 Nobel prize.

As the book originally appeared some time ago, there is nothing on quark/gluon spins and the new enigma of how constituents carry the spin of the proton. Spin continues to be enigmatic.

Paul Dirac: The Man and his Work, by Abraham Pais, Maurice Jacob, David I. Olive and Michael F. Atiyah, edited by Peter Goddard, Cambridge University Press, ISBN 0 521 58382 9 (hbk £12.95/$19.950

On 13 November 1995, a plaque in London's Westminster Abbey was dedicated to the memory of Paul Dirac. This slim (120-page) volume contains four lectures on Dirac's life and work given at London's Royal Society prior to the ceremonies in the Abbey, together with an introduction by Stephen Hawking.

Despite his legendary taciturnity and reticence, Dirac was an avid traveller and a frequent visitor to scientific meetings, drawing on this contact, Pais summarizes Dirac's personal qualities and their impact on his approach to physics. Maurice Jacob of CERN describes Dirac's classic work on antimatter and its implications for modern physics and cosmology.

One of Dirac's special preoccupations was magnetic

monopoles. Although this work was not initially fruitful, magnetic monopoles now play a special role in revolutionary new physics thinking, as described by Olive, a pioneer of this new approach. Atiyah displays the significance of the Dirac equation in modern geometry, again touching on the new developments.

Edwin Hubble - Mariner of the Nebulae, by Gale E. Christianson, Institute of Physics Publishing, 0 7503 0423 5

In the 1920s, Edwin Hubble used the mighty 100-inch telescope on Mount Wilson to spearhead another Copernican revolution, showing that the visible Universe is much larger than the Milky Way, and that distant galaxies recede with velocities proportional to their remoteness - the 'Hubble expansion'. Hubble's multifarious talents as a sportsman, soldier and lawyer have over the years been embellished by fertile imaginations. Christianson's book, using hitherto untapped sources, rounds out the story of Hubble the man and burnishes the legend.

Books received

Mathematical Methods for Physics and Engineering, by K.F. Riley, M.P. Hobson and S.J. Bence, Cambridge University Press, 0 521 55506 X (hbk £59/$110) 0 521 55529 9 (pbk £17.95/$49.95)

A 1,000-page volume with worked examples and exercises

Group Theory in Subnuclear Physics, by Fl. Stancu, Oxford Science Publications, 0 19 851742 4 (£75)

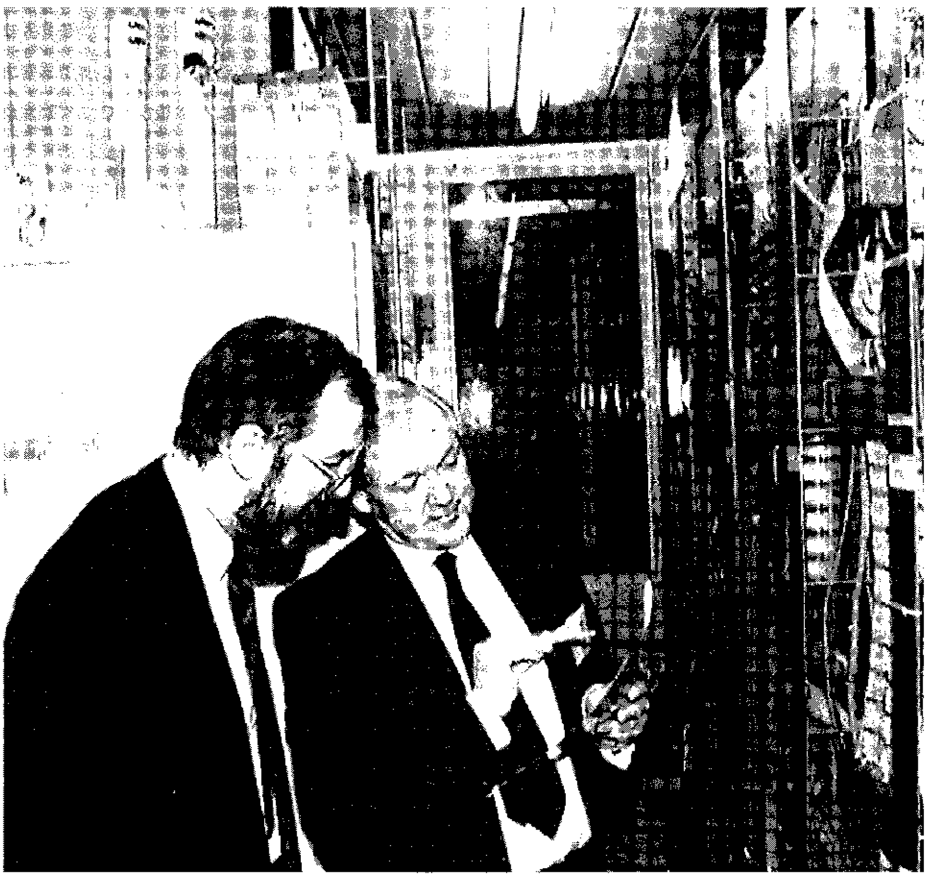
Elements of Group theory; permutation, Lie, orthogonal, Lorentz and unitary groups, gauge groups, and quark applications.

People and things

First collisions in DAFNE

Very soon after the completion of construction of the DAFNE electron-positron collider at the INFN National Laboratory in Frascati and injection of its first electrons (December 1997 page 12), comes the first single bunch electron-positron collisions with luminosities of the order of a few times 10^{28} per sq cm per s, which is already ten times that achieved at the same energy with Frascati's pioneer ADONE ring. In these early collisions, the DAFNE beam current was a few milliamps - more than 40 milliamps have been achieved with single beams. DAFNE has a design luminosity of 5×10^{32} at the phi resonance (1.02 GeV).

UK Minister of Science, Energy and Industry John Battle (left) with Aleph experiment spokesman Peter Dornan of London's Imperial College at CERN on 23 February.



Scientists and representatives from the German Federal Ministry of Education, Science, Research and Technology (BMBF) attended a colloquium to mark the retirement of distinguished DESY scientist Paul Söding (centre), Head of DESY's branch institute in Zeuthen, Brandenburg (Berlin). Among them were DESY Director Bjørn Wiik (left) and CERN Council President Hans Eschelbacher (right).

(Photo Petra Folkerts)

On people

Hermann Grunder, Director of the Jefferson Laboratory, Newport News, Virginia, (formerly known as the Continuous Electron Beam Accelerator Facility - CEBAF) has been named 1998 Outstanding Scientist in the state of Virginia.

Paul Söding retires

Distinguished scientist Paul Söding, Head of DESY's branch institute in Zeuthen, Brandenburg (Berlin), and professor of experimental physics at Hamburg and at Humboldt University, Berlin, retired on 1 March. As a long-standing DESY Research Director and as a scientist, Söding has contributed significantly both to physics and to science administration.

Born in 1933 in Dresden, Söding studied at Hamburg and Munich. When high energy physics research was initiated in Hamburg, he joined pioneer bubble chamber experiments. After several periods at CERN, Berkeley and Cornell, he became a Leading Scientist at DESY.

With the advent of the PETRA electron-positron accelerator, Söding played a key role in the construction and exploitation of the TASSO detector, where the first direct evidence for gluons was seen in 1979. For this historic discovery, he was one of the four 1995 recipients of the European Physical Society's prestigious High Energy and Particle Physics Prize.

As DESY Research Director from 1982 - 91, Söding led preparations for and construction of the HERA electron-proton storage ring and its collision experiments H1 and ZEUS, surmounting many obstacles.

When the former Institute for High Energy Physics of the East German Academy of Sciences in Zeuthen became a branch institute of DESY in 1992, he played an important role in its integration into DESY. An independent programme of elementary particle physics is now carried out in Zeuthen in close collaboration with DESY, CERN and other research institutes in Germany and further afield.

Ulrich Gensch (53), a leading scientist at Zeuthen since 1972, takes over as the institute's director. Until 1987, he worked at Serpukhov and Dubna and at CERN. In 1987 he became a member of the Zeuthen group which joined the international H1 collaboration. He has been a member of the DESY Directorate since 1995, responsible for the Central Technical Research and Computing department.

Gertrude Scharff Goldhaber 1911 - 98

Gertrude Scharff Goldhaber, eminent physicist and wife of former Brookhaven Director Maurice Goldhaber, died on 2 February.

She began her physics career in 1935 in antiferromagnetism with a PhD from Munich, moving on to London's Imperial College, Illinois and Brookhaven. As well as pioneer work on beta decay and nuclear fission, her contributions also spanned neutron and nuclear physics. She was a fellow of the American Physical Society, the US National Academy of Sciences and the American Association for the Advancement in Science. At Brookhaven, she promoted scientific awareness and was a founding member of the active Brookhaven Women in Science organization.

Richard Slansky (1940-98)

Richard Slansky, Director of the Theoretical Division of Los Alamos National Laboratory, died on 16 January following a brain aneurysm. Initial studies at Harvard and Berkeley were followed by a postdoctoral fellowship at Caltech and five years at Yale. Slansky came to Los Alamos in 1974 to join the

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please see page III

Richard Slansky (1940-98)

newly-formed elementary particle physics theory group set up by Peter Carruthers (who died last year). He worked on the phenomenology of particle production and moved on to the symmetries and problems of the unification of the forces of nature, including neutrino masses. In 1989 he was named division leader.
A fellow of the American Physical Society and the American Association for the Advancement of Science, he was also an adjunct professor of physics at UC Irvine. Dick was a great believer in the quality of science and worked hard to build a strong workforce in his division through a consistent series of outstanding postdoctoral and Oppenheimer fellowship appointments. His dedication to and deep interest in fundamental scientific questions was characterized by a boyish sense of enthusiasm and wonderment about science. He also strived to improve communication and collaboration that cut across scientific boundaries. He was also a regular visitor to CERN's Theory Division.

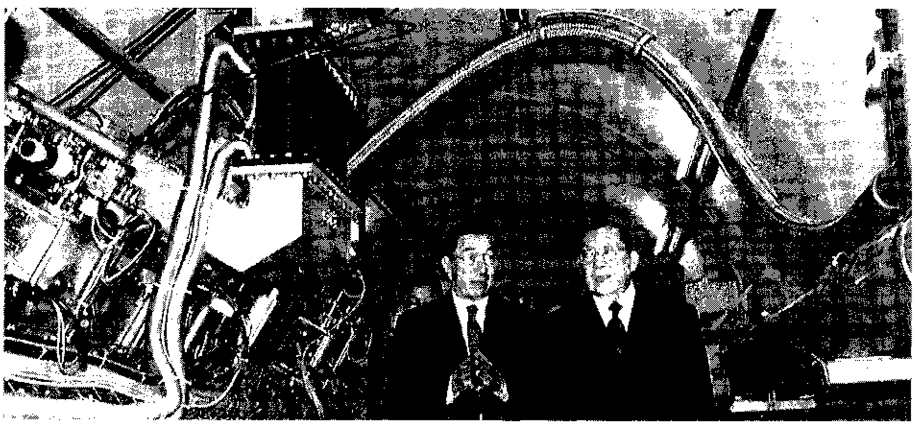
XVII International Conference on High Energy Accelerators

The Joint Institute for Nuclear Research (JINR), Dubna, near Moscow, will host the 17th International Conference on High Energy Accelerators - HEACC'98. These conferences are held every three years and traditionally involve about 600 specialists. The Conference will be held in Dubna, Moscow Region, Russia, on 7-12 September. It is supported by the Russian Academy of Sciences and the International Committee for Future Accelerators (ICFA). The scientific programme includes invited reports, mini-rapporteur talks and poster contributions. Leading specialists from major accelerator centres will present status reports. The programme will also include round-table discussions on the current status of accelerator science. An industrial exhibition will attract firms and specialists in the fields of accelerator, vacuum, cryogenic and high-frequency technologies. Measuring and control instruments as well as power supplies will also be exhibited. The social programme will include excursions to Sergiev Posad (former Zagorsk) and Moscow, as well as concerts by Dubna artistic groups and professionals from Moscow. Detailed conference information via http://www.jinr.ru/HEACC'98/ or contact the organizers fax (+7 09621) 65767 or phone (+7 09621) 65136

Bob Jaffe was one of the lecturers at a recent meeting 'Deep Inelastic Scattering off Polarized Targets - Theory meets Experiment' held at DESY-Zeuthen.

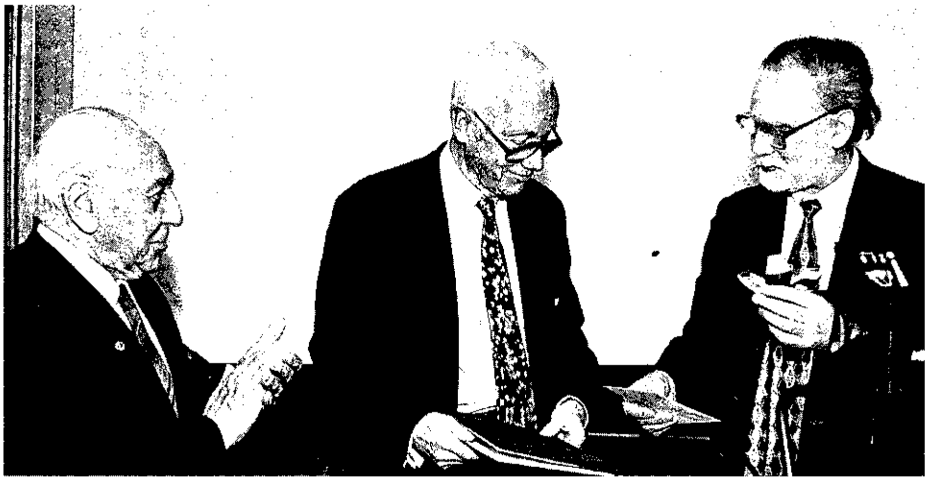
SLAC Summer Institute

The XXVI SLAC Summer Institute on Particle Physics will be on 'Gravity - From the Hubble Length to the Planck Length' and will be held from August 3-14 at the Stanford Linear



Chinese Deputy Prime Minister Li Lanqing (right) with eminent physicist Sam Ting during a visit to CERN on 4 February. The party included 60 Chinese dignitaries including 10 ministers.

Klaus Winter (centre) receives the prestigious 1997 Bruno Pontecorvo Prize of the Joint Institute for Nuclear Research (JINR), Dubna, near Moscow. He is flanked by JINR Director Vladimir Kadyshevsky (right) and Venedikt Dzhelepov, Honorary Director of JINR's Laboratory of Nuclear Problems.



Accelerator Center, Stanford, California.

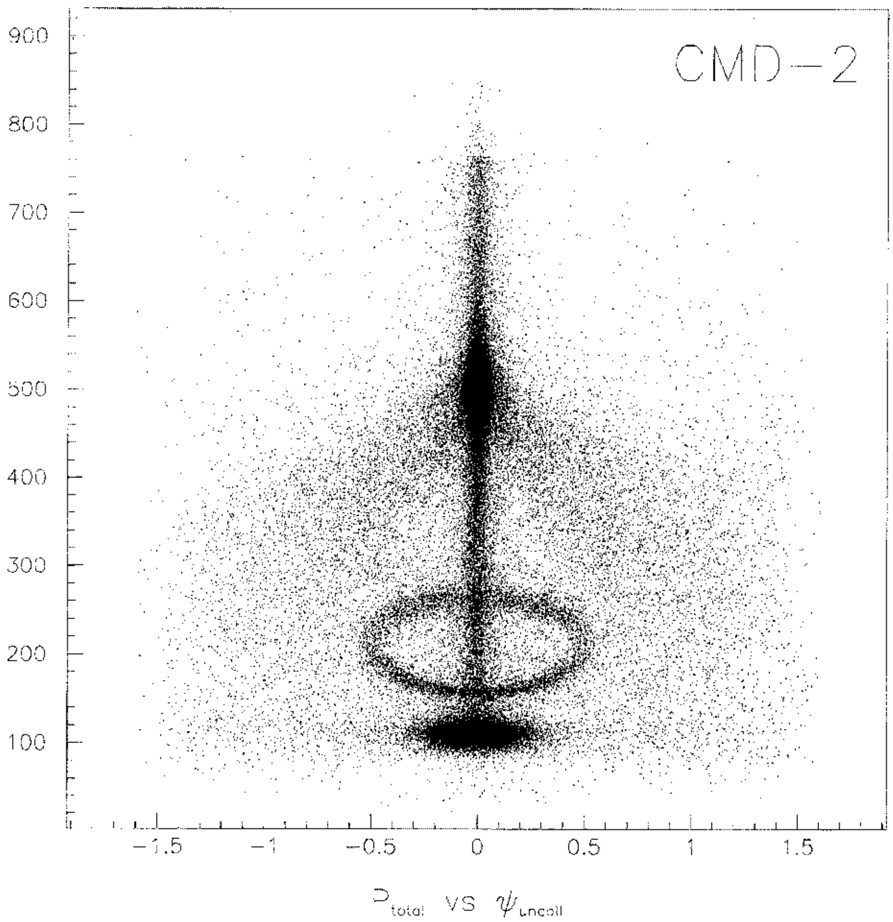
The Institute will consist of a seven-day school followed by a three-day topical conference and is designed primarily, but not exclusively, for postdoctoral experimentalists and theorists. Advanced graduate students are welcome.

Further Information - Lilian DePorcel, Conference Coordinator, SLAC, PO Box 4349, MS 62, Stanford, CA 94309, U.S.A. Phone: (650) 926-2710. Fax: (650) 926-3587. Electronic Mail: ssi@slac.stanford.edu.

http://www.slac.stanford.edu/gen/meeting/ssi/next/

DESY Theory Workshop

The next DESY Theory Workshop will be on "Directions beyond the Standard Model" and will be held at DESY from 30 September to 2 October. The Chairman is Hans-Peter Nilles of Bonn, e-mail: bsm98@physik.uni-bonn.de It will cover theoretical ideas such as supersymmetry, baryon and lepton number violation, dynamical symmetry breaking etc. with



Hi-phi: Raw data from the CMD-2 detector at Novosibirsk's VEPP-2M electron-positron collider, showing events with two charged tracks and an arbitrary number of photons selected at the energy corresponding to the phi (f) meson at 10^{19} MeV. The vertical axis is the total momentum of two tracks in MeV, while the horizontal axis gives the angle between the tracks, with the x=0 line corresponding to collinear events. The grouping of events around 500 MeV comes from electron-positron, muon and pion pairs. The cluster near 100 MeV is due to charged kaon pairs. The ring is due to neutral kaon pairs, with the (short-lived) kaon decaying into two pions. The cone below 500 MeV is due to events producing an electron-positron pair and a gamma.

emphasis on implications in particle physics, astrophysics and cosmology.

Fermilab meetings

May 7-9, PIXEL98 - International Pixel Detector Workshop. http://www-ppd.fnal.gov/epp_www/PIXEL98/PixelWorkshop.html

May 14-16, "Physics at Run II" - Workshop on Supersymmetry/Higgs: First General Meeting, M. Carena and J. Lykken, Co-Chairs; http://fnth37.fnal.gov/may_meeting.html

September 24-26, 4th Workshop on Small-x and Diffractive Physics; Michael Albrow (Fermilab) and Alan White (Argonne) Co-Chairs; http://www.hep.anl.gov/Theory/smxdf.html

Around 60 physicists, including many former colleagues and collaborators, came to Durham, UK, last December for a meeting to mark the 60th birthday of Alan Martin (sweater, centre front) and his many contributions to theoretical particle physics - ranging from pion scattering phase shift analyses to precision electroweak results from LEP.

CERN Courier contributions

The Editor welcomes contributions. These should be sent via electronic mail to cern.courier@cern.ch

Plain text (ASCII) is preferred. Illustrations should follow by mail (CERN Courier, 1211 Geneva 23, Switzerland).

Contributors, particularly conference organizers, contemplating lengthy efforts (more than about 500 words) should contact the Editor (by e-mail, or fax +41 22 782 1906) beforehand.

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Associate Scientists
Beams Division

The Fermi National Accelerator Laboratory (Fermilab) Beams Division has two excellent opportunities for Associate Scientists. These are initial three-year term appointments with a possible extension and consideration for a regular position on the Fermilab scientific staff. Both positions require a Ph.D. in physics (or equivalent) and two or three years of relevant post-doctoral experience. Excellent communication skills and leadership potential are also required.

Accelerator Physics

The Associate Scientist in this position will focus on applications of accelerator physics that are required by the Fermilab research program, but will also have some opportunity for self-directed research. The beam physics applications include opportunities to understand, operate and improve the performance of the Tevatron, Main Injector, Recycler or Antiproton Source, and to participate in the design of future accelerators and facilities. An excellence demonstrated by significant post-graduate work in accelerator physics, accelerator technology, particle physics or some related field is required for consideration.

NuMI Project

In this position, the Associate Scientist will assume a lead role in the Fermilab NuMI (Neutrinos at the Main Injector) Project, a search for neutrino oscillations. The NuMI Project includes the design, construction, operation and management of a high flux neutrino facility and detectors that will be used by both short and long baseline experiments.The successful candidate will be expected to make significant contributions to both the design and construction of the facility as well as to the experimental program. Additionally, the incumbent will make analytical and numerical calculations necessary for the design, fabrication and testing of technical components required for the neutrino beam and detectors. Experience and demonstrated excellence in both technical design and project management are required as is a strong interest in neutrino oscillations.

Located 40 miles west of downtown Chicago on a campus-like setting, Fermilab provides its employees with opportunities for personal and professional growth, competitive salaries, and an attractive benefits package. Applicants are requested to forward their curriculum vitae and a list of *at least* three references to: **Dr. Stephen Holmes, Fermi National Accelerator Laboratory, P.O. Box 500, M.S. 306, Batavia, IL 60510-0500, U.S.A.** To access Employment Opportunities at Fermilab, our URL is **<http://fnalpubs.fnal.gov/employ/jobs.html>.** EOE M/F/D/V.

Fermilab

Johann Wolfgang Goethe-Universität
Frankfurt am Main

The Physics Department of the Johann Wolfgang Goethe University at Frankfurt / Main invites applications for a

Full Professorship (C4) of Applied Physics

The appointment is to begin in April 1999.

Research in the group focuses on physical principles and applications of particle accelerators. Applications are solicited from scientists with an outstanding record in research areas such as the physics of intense particle beams, ultrahigh-frequency physics, and the development of modern particle accelerator systems. The prospective appointee is expected to participate actively in international large-scale projects.

Teaching obligations for undergraduate students cover the entire field of experimental physics. Willingness to participate in the autonomous academic administrative system is required.

The University is seeking to raise the percentage of female members of the scientific staff and thus specifically encourages applications from women.

The formal requirements to be fulfilled by the appointee are given by § 39a HUG (Hessian University Law). The regulations are available upon request. At the time of appointment, the appointee must not be older than 52. The law requires handicapped applicants to be given preference.

Please send your resume within six weeks after appearance of this announcement to: **Dekan des Fachbereichs Physik, Johann Wolfgang Goethe-Universität, Postfach 11 19 32, D-60054 Frankfurt am Main (Postal address for parcels: Senckenberganlage 31, D-60325 Frankfurt)**

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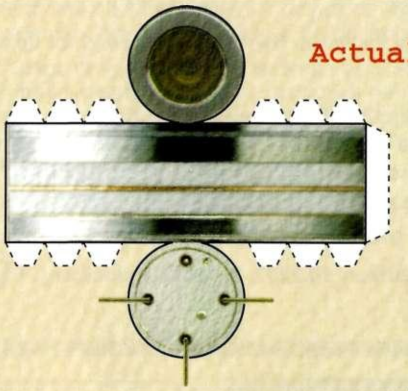

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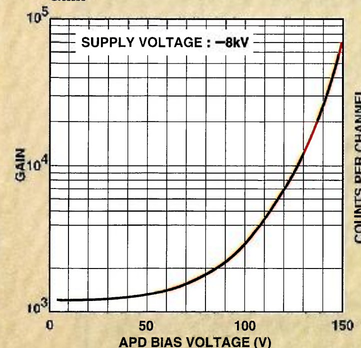

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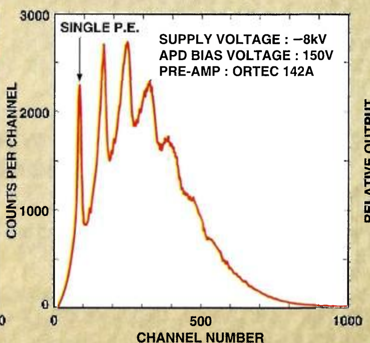

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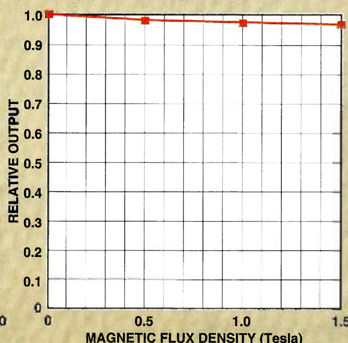

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