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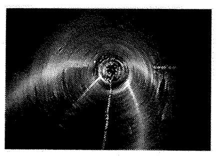

Cover photograph:
A full-length (10-metre) pre-prototype superconducting magnet designed with CERN's proposed LHC hadron collider in mind slides into its cryostat at the FBM factory, Bergamo, Italy (Photo CERN AC54.10.90).

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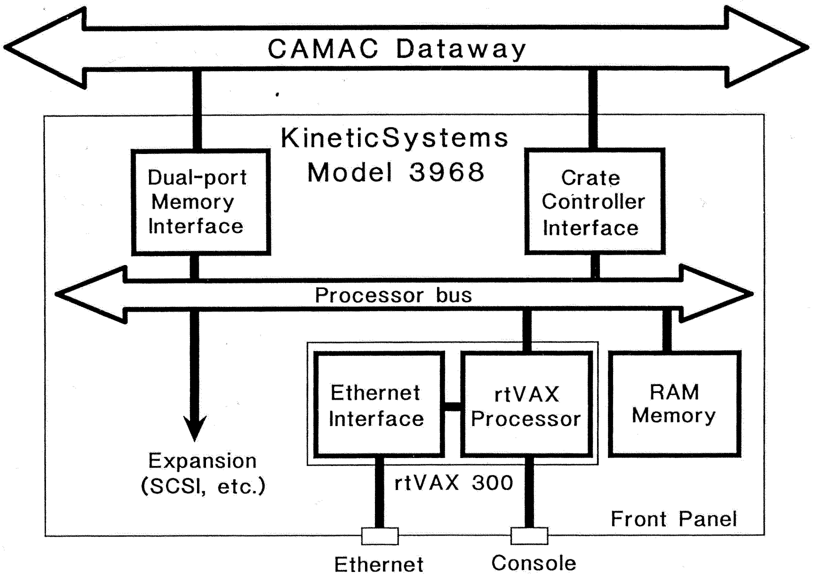

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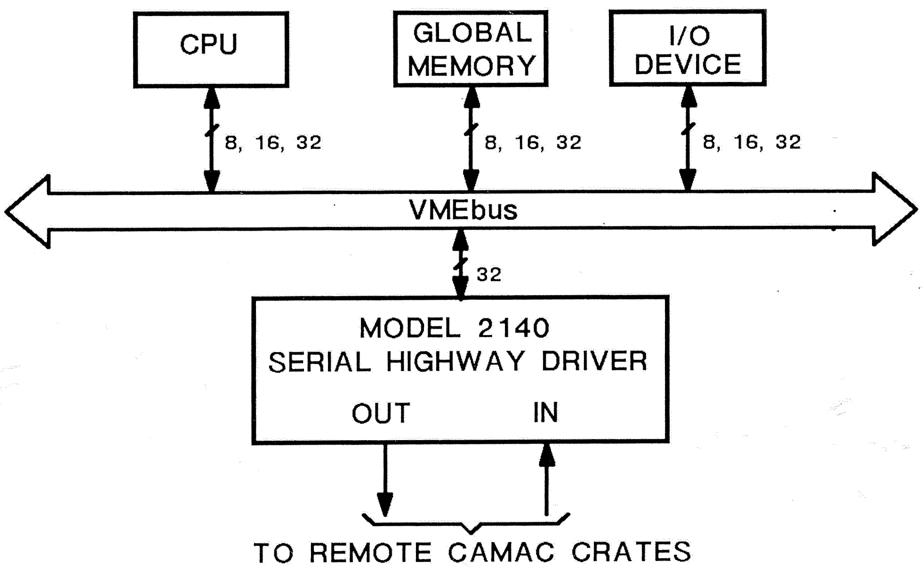

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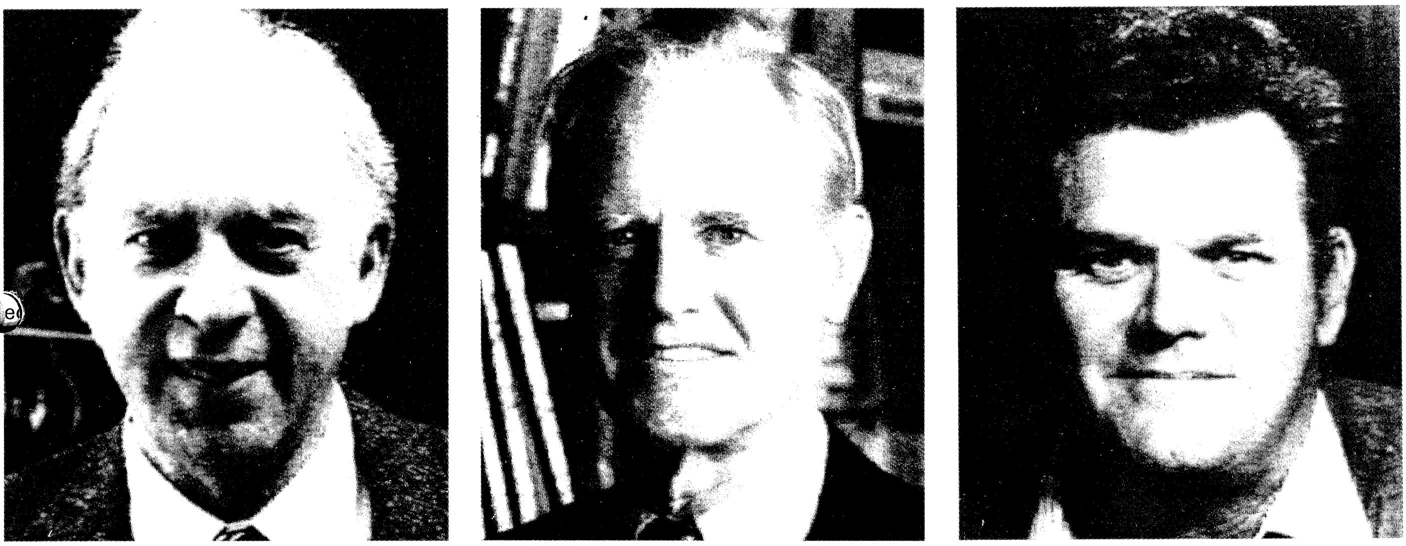
Nobel Prize 1990



1990 Physics Nobel Prize people – left to right, Jerome I. Friedman and Henry W. Kendall of MIT, and Richard Taylor of Stanford.

(Photos Keystone)

The most prestigious award in physics went this year to Jerome I. Friedman and Henry W. Kendall, both of the Massachusetts Institute of Technology (MIT), and Richard E. Taylor of Stanford 'for their pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics'.

Their experiments, carried out from 1967 at the then new two-mile linac at the Stanford Linear Accelerator Center (SLAC) showed that deep inside the proton there are hard grains, initially called 'partons' by Feynman and later identified with the quarks, mathematical quirks which since 1964 had been known to play an important role in understanding the observed variety of subatomic particles.

These initial forays into high energy electron scattering discovered that a surprisingly large number of the electrons are severely deflected inside the proton targets. Just as the classic alpha particle results of Rutherford earlier this century showed that the atom is largely empty space with a compact nucleus at its centre, so the SLAC-MIT experiments showed that hard scattering centres lurked deep inside the proton.

Writing on the wall for this year's Nobel Prize was the award last year of the Wolfgang Panofsky Prize (sponsored by the Division of Particles and Fields of the American Physical Society) to the same trio for their leadership in the first deep-inelastic electron scattering experiments to explore the deep interior of nuclear particles.

In the early 1960s when construction of the SLAC linac was getting underway, the 1990 Nobel trio, who had first met in the 1950s as young researchers at Stanford's High Energy Physics Laboratory, came together in a collaboration preparing the detectors and experimental areas to exploit the new high energy electron beams.

The outcome was described in an article (October 1987, page 9) by Michael Riordan, subsequently a member of the experimental collaboration and now SLAC's Science Information Officer, for the 20th anniversary of SLAC's electron beams.

In October 1967, MIT and SLAC physicists started shaking down their new 20 GeV spectrometer; by mid-December they were logging electron-proton scattering in the so-called deep inelastic region where the electrons probed deep inside the protons. The huge excess of scattered electrons they encountered there - about ten times the expected rate - was later interpreted as evidence for pointlike, fractionally charged objects inside the proton.

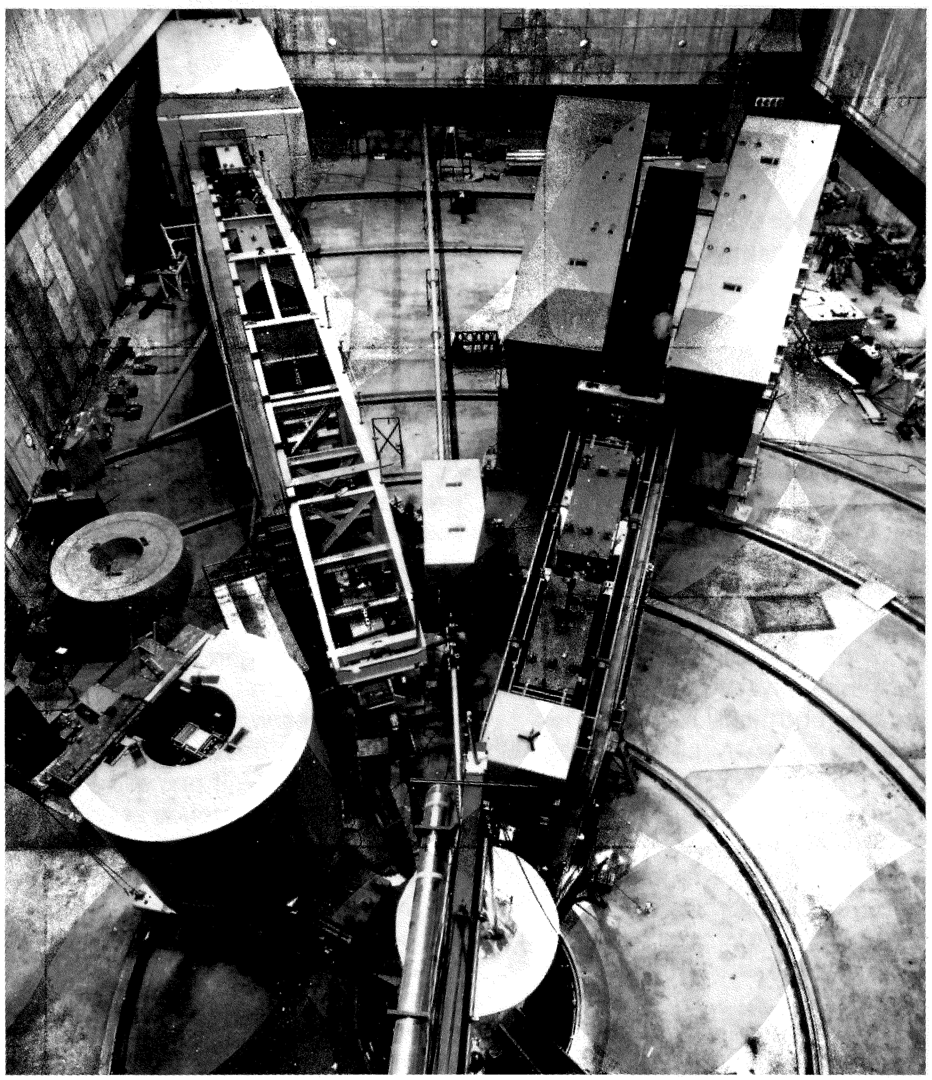
The quarks we take for granted today were at best 'mathematical' entities in 1967 - if one allowed them any true existence at all. The majority of physicists did not. Their failure to turn up in a large number of intentional searches had convinced most of us that Murray Gell-Mann's whimsical entities could not possibly be 'real' particles in the usual sense, just as he had insisted from the very first.

Jerome Friedman, Henry Kendall, Richard Taylor and the other MIT-SLAC physicists were not looking for quarks that year. SLAC Experiment 4B had originally been designed to study the electroproduction of resonances. But the proddings of a young SLAC theorist, James Bjorken, who had been working in current algebra (then an esoteric field none of the experimenters really understood), helped convince them to make additional measurements in the deep inelastic region, too.

Over the next six years, as first the 20 GeV spectrometer and then its 8 GeV counterpart swung out to larger angles and cycled up and down in momentum, mapping out this deep inelastic region in excruciating detail, the new quark-parton picture of a nucleon's innards gradually took a firmer and firmer hold upon the particle physics community. These two massive spectrometers were our principal 'eyes' into the new realm, by far the best ones we had until more powerful muon and neutrino beams became available at Fermilab and CERN. They were our Geiger and Marsden, reporting back to Rutherford the detailed patterns of ricocheting projectiles. Through their magnetic lenses we 'observed' quarks for the very first time, hard 'pits' inside hadrons.

These two goliaths stood resolutely at the front as a scientific revolution erupted all about them during the late 1960 s and early 1970s. The harbingers of a new age in particle physics, they helped pioneer the previously radical idea that leptons, weakly interacting particles, of all things, could be used to plumb the mysteries of the strong force. Who would have guessed, in 1967, that such spindly particles would eventually ferret out their more robust cousins, the quarks? Nobody, except perhaps Bjorken - and he wasn't too sure himself.

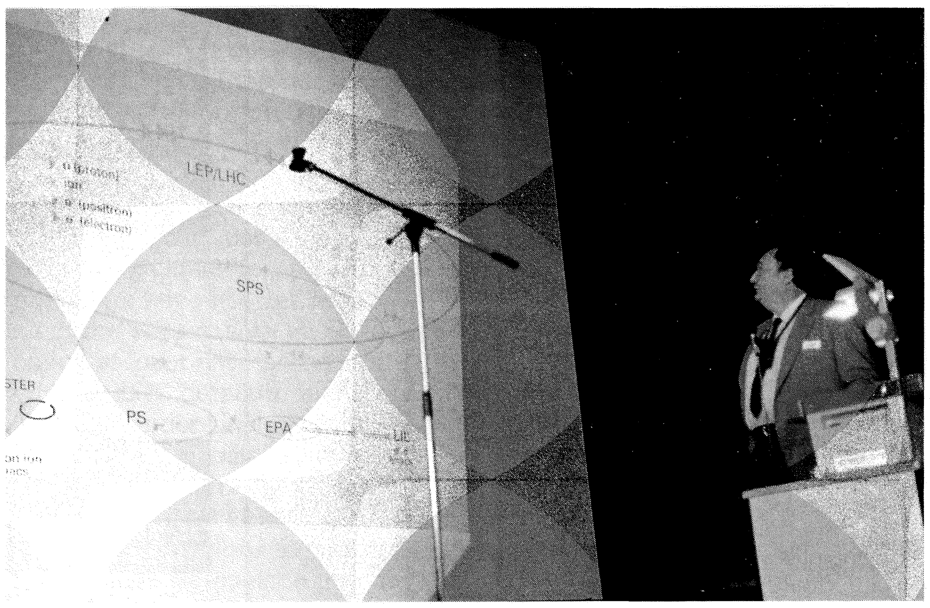
(The saga is recounted in every detail in Riordan's book 'The Hunting of the Quark', published by Simon and Schuster.)



1990 Physics Nobel Prize apparatus – the big spectrometers at End Station A of the Stanford Linear Accelerator Center (SLAC) in 1967: right, the 8 GeV spectrometer, and left, its 20 GeV and (extreme left) 1.6 GeV counterparts.

Big meeting puts the case for LHC

At the Aachen workshop on the proposed LHC proton-proton collider at CERN, CERN Director General Carlo Rubbia displays the complementarity of the existing LEP electron-positron collider and LHC.



It was a workshop on a scale to match the ultimate goal. When some 500 physicists met in Aachen, Germany, in October to put the research case for the proposed Large Hadron Collider (LHC) at CERN, the turnout was among the biggest attendances of the year.

Organized by ECFA, the European Committee for Future Accelerators, the meeting, by its attendance and by the depth of its scientific content, clearly displayed the enthusiasm for LHC in the research community, and provided valuable additional impetus for the already compelling idea of a proton collider using superconducting magnets in the 27-kilometre tunnel built for LEP.

Introducing the plenary sessions at Aachen, CERN Director General Carlo Rubbia underlined the complementarity of a dual LEP-LHC complex with its electron and proton beams, providing a balanced two-pronged attack on the physics research frontier while at the same time making the most of CERN's versatile beam handling systems, both existing and potential.

With CERN already serving a varied menu of particles, LHC physics would be well-endowed with beam options. As well as providing proton-proton collisions at about 8 TeV per beam, LHC could follow the tradition of CERN's other proton machines and handle heavy ions as well. With LEP and LHC sharing the same tunnel, electron-proton collisions would become a natural extension of the research programme.

With basic (dimensional) arguments saying that reaction rates have to decrease with collision energy, then high luminosity (related to the collision rate) is a basic collider requirement which is expected to become even more important at higher energies. Thus a main aim of the LHC design is to attain the highest possible luminosities.

The Aachen meeting mirrored on one hand the physics potential opened up by such a high luminosity approach, and on the other the challenges for the detector systems which will have to handle bunches of 10^{11} protons crossing every 15 nanoseconds or so, resulting in billions of secondary particles each second.

In addition to coping with this flood of data, the potentially delicate detector components will have to withstand long exposure to this harsh radiation environment.

The presentations at Aachen summarized the work of the hundreds of physicists in LHC working groups set up by ECFA earlier this year. Three groups looked at the physics potential of the three collision options (proton-proton, electron-proton, and ion-ion), while others studied detector aspects (simulation and software engineering; signal processing, trigger and data acquisition; vertex detection and tracking; calorimetry; electron identification; muon identification; radiation hardness; experimental areas).

The first half of the Aachen meeting was given over to parallel sessions covering the findings of the different working groups. While this resulted in a mass of material and a sometimes baffling choice, many participants reported hearing valuable progress.

After a brief Saturday afternoon's leisure, the participants met early on Sunday (!) morning for the start of the plenary sessions. In his opening address, Josef Rembser, representing at Aachen the German Ministry of Research and Technology, pointed to the growing support for the LHC project. Dr. Rembser is also President of CERN Council.

After Carlo Rubbia's rallying introduction, the scene was set by Giorgio Brianti of CERN who described the status of LHC development and planning, where some very detailed work is being done. The spotlight then briefly moved away from LHC, with summaries of the status and physics programme of other major projects in varying

stages of completion – the HERA electron-proton collider nearing readiness at DESY, the RHIC heavy ion collider soon to be built at the US Brookhaven Laboratory, and the US Superconducting Supercollider (SSC) being prepared in Ellis County, Texas (see page 12).

For proton-proton collision physics, Daniel Denegri of Saclay looked at the implications of the current Standard Model, while Felicitas Pauss of CERN attempted to look at the uncharted territory beyond.

Putting the physics case for LHC proton-proton studies, Guido Altarelli of CERN was confident that new physics would turn up at the mass scales covered by this machine and provide a natural explanation for some of the apparently arbitrary numbers of today's Standard Model (the unification of the weak nuclear force and electromagnetism loosely tied to the quark-gluon field theory of strong nuclear forces). While no cracks have yet appeared in this structure, Altarelli thought that with LHC the betting would be against the Standard Model, and its continued survival would be a turnup for the book.

Major goals include the clarification of the electroweak symmetry breaking mechanism (Higgs Particle), where Altarelli remarked there was room for contributions from LEP a well as from the proton-proton sector. However with its proposed high luminosity of 10^{34} per sq cm per s, LHC has the discovery potential to attack the main outstanding questions of particle physics.

Subsequent talks outlined the additional potential opened up by LHC's electron-proton and ion-ion collision options.

Summarizing the work on the interaction regions where LHC experiments would be housed, Lars Leistam of CERN pointed out that if construction work on big new underground caverns is to begin in 1993, then the plans for the experimental areas should be ready by the end of next year.

Although ideas for individual experiments have not yet been tabled, the sessions on muon identification at least gave some idea of what an LHC detector might look like. Contenders included toroids, solenoids, and their variants, and an idea to convert the L3 setup currently used at LEP.

Detector sessions explored the broad range of research and development work currently underway, including the Italian-funded LAA project at CERN, specifically launched to look into the requirements of the next generation of hadron colliders. Promising new techniques are emerging from all this effort, particularly for calorimetry, summarized by Jacques Colas of Annecy.

The potential of alternative approaches was explored in depth. David Saxon of Glasgow, talking on vertex detection and tracking, put the question 'To B or not to B?' – should the central detector have a magnetic field or not?

Data acquisition and triggering at LHC's high interaction rates have long been looked at apprehensively. In the summary sessions Livio Mapelli suspected that the most difficult problem would be in the electron sector, where 100,000 candidates or even more could be released each second, with in the muon sector a first level trigger taking the edge off the raw signal of about a million particles each second.

Analog pipeline techniques are looking promising, while the industrial effort behind high-definition TV could produce useful spinoff for physics research. A representative from Thomson (France) described some of the work currently in progress.

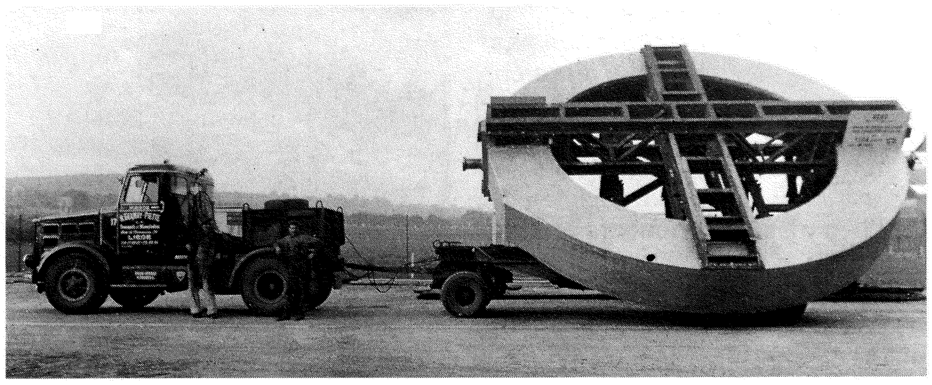
Concluding the mammoth workshop, George Kalmus of the UK Rutherford Appleton Laboratory described the valuable progress being made en route to LHC detectors. However he emphasized the problems of radiation tolerance for the detectors, calling also for cost estimates to guide the design of experimental areas and a global strategy for the experiments.

Finally ECFA Chairman J.-E. Augustin reminded participants of the role of ECFA in pushing LHC as the best possible course for Europe, exploiting CERN's existing investment and facilities.

Although the instrumentation will not be easy, the idea of LHC as Europe's major goal in this area of science was firmly launched at Aachen.

The organization of the mammoth meeting at the Rheinische-Westfälische Technische Hochschule was led by Günther Flügge.

Goodbye Synchro-Cyclotron



The magnet coil for CERN's first accelerator, the 600 MeV Synchro-Cyclotron, arrives in 1955. This machine is being shut down in December after an illustrious 33-year career.

On 17 December, after having seen many other physics machines come and go during its 33-year career, CERN's 600 MeV Synchro-Cyclotron (SC) is being shut down.

Judged simply by its length (to say nothing of its quality), the research career of this machine testifies to the wisdom and imagination of the CERN pioneers who proposed it in the early 1950s.

When the idea for what was to become CERN was being discussed in 1950, imaginations were captured by the concept of a Laboratory built around a giant accelerator rivalling those being planned in the US. By 1951, with experience and know-how in Europe (with the exception of the UK) still thin on the ground, a note of pessimistic reality began to creep in, led notably by Niels Bohr and Hendrik Kramers, calling for an initial, more modest machine to pave the way for the later giant.

In a 'classical' fixed frequency cyclotron, the output energy is limited by the relativistic increase in the effective mass of the circulating particles as they approach the velocity of light. The synchro-cyclotron technique, invented by Edwin McMillan in the US and, independently, by V.I. Veksler in the Soviet Union, overcomes this by modulating the radiofrequency and was demonstrated at the Berkeley 37-inch machine in 1946. Almost immediately its companion 184-inch cyclotron was converted, yielding initially 195 MeV deuterons and 390 MeV alpha particles, subsequently being modified to produce 350 MeV protons.

In the UK, which had inherited a lot of nuclear physics know-how and investment in the wake of the big World War II projects, the Harwell 110-inch SC supplied 175 MeV protons from December 1949 and the Liverpool 156-inch machine attained 400 MeV in 1954.

The first CERN Council meeting, held in Paris on 5 May 1952, appointed Cornelis Bakker to lead an SC study group. At the second Council session, held the following month in Copenhagen, Werner Heisenberg, fresh from a physics meeting, advised that the SC should provide 600 MeV protons. With no central site, SC work soon became dispersed all over Western Europe – vacuum chamber at Harwell and Liverpool, magnet at Uppsala (Sweden), shielding and control in Paris, and radiofrequency in Holland by a group working in close collaboration with Philips at Eindhoven.

By November 1953 the machine design was practically complete, and after construction got underway at the new Meyrin site in 1954 the SC soon lived up to its promise of a machine that would be 'quick and easy to build'.

When CERN's first Director-General, Felix Bloch, resigned in 1955, his place was taken by Bakker. Wolfgang Gentner, previously a consultant for CERN's big machine – to become the 28 GeV Proton Synchrotron – was invited to CERN to become Director of SC Division.

Under his leadership, the SC project came to fruition, and first beams were accelerated on 1 August 1957, practically on the date foreseen, thereby establishing an important CERN tradition.

With the field to itself pending completion of CERN's larger machine, the SC lost no time in attacking new physics. Early successes included the discovery of the decay of a charged pion into an electron (and a neutrino), and into a neutral pion and an electron (together with a neutrino). The first 'g-2' group was formed to make precision measurements of the magnetic moment of the muon, and showed for the first time that this particle behaved like a heavier version of the electron.

Naturally these early SC studies provided valuable experience for young researchers who would go on to make their mark on the physics scene.

As research at the neighbouring PS machine got underway in the early 1960s, it was inevitable that some physicists were attracted by the lure of higher energies, and a group was formed to look into future SC options to maintain its research appeal. Various possibilities were discussed, but the option which emerged in 1964 and went on to be adopted was for an on-line isotope separator, an idea which had grown out of the early SC nuclear chemistry studies. The idea had been demonstrated in a

1951 Copenhagen experiment, and a strong Scandinavian tradition has remained a feature of this research.

In such a separator, radioactive isotopes produced by the primary proton beam hitting a target are magnetically separated to isolate different mass components and electrostatically steered towards various experiments. With continuous beams available, experiments can study the properties of nuclei which live only for a brief fraction of a second and would otherwise be inaccessible. A new underground experimental area was constructed in 1965-6, and the new facility, called ISOLDE, received its first beam in October 1967. (For a long time a French/German/Scandinavian collaboration, ISOLDE has gone on to attract researchers from many other countries.)

In 1973, the SC was shut down for major modifications, and when it came on line again in 1975, little remained of the original machine other than its big magnet. ISOLDE also underwent a facelift, emerging as ISOLDE-2, and offering a 50-fold increase in extracted beam intensity. Subsequent work on new ISOLDE beams has steadily increased both the range of elements available (to cover about half the Periodic Table) and the mass range covered for each element. Even for a middleweight element like rubidium, ISOLDE can supply some 30 isotope variations.

The next innovation was the acceleration of ions, and by 1980 the SC handled helium-3, carbon-12, nitrogen-15 and neon-20 in various charge modes. This research gave a first look at ion reactions at intermediate energies (close to 100 MeV/nucleon) and helped to prepare the ground for a new generation of experiments at dedicated heavy-ion accelerators such as GANIL (Caen, France) and those at the Germany GSI Laboratory in Darmstadt.

1966 – excavations underway for the ISOLDE on-line isotope separator at CERN's Synchro-Cyclotron.

(Photo CERN 178.4.66)

By this time, ISOLDE requirements, with hundreds of regular users, were dominating SC operations, and the ISOLDE-3 high resolution separator arrived in 1985.

As well as making many valuable contributions to nuclear physics, ISOLDE also opened up new research techniques, notably the elegant optical pumping method proposed in 1968 by Ernst Otten, then at Heidelberg, for measuring the spin and magnetic moments of short-lived nuclei. (For this work Otten received in 1987 the Gentner-Kastler Prize awarded by the French and German Physical Societies.)

An enthusiastic (and highly multidisciplinary) user group that grew in stature during the 1980s exploited muon spin rotation to study the structure of a wide range of materials, including macromolecules, metals and semiconductors.

While remaining SC research has been redirected to other Laboratories, on-line isotope studies will live on at CERN. After three incarnations at the SC, ISOLDE will reappear in 1992 after modifications have been completed at CERN's 1 GeV Booster synchrotron. Conceived as a link in the CERN accelerator chain, the Booster has never had its own experimental area, but has capacity to handle additional particles. Construction work began last year.

A symposium to mark the SC's contributions to physics is being planned for the Spring.

Spin 1990

The idea of the intrinsic angular momentum, or 'spin', of a particle has played an essential part in fundamental physics for more than 60 years, and its continuing importance was underlined at the 9th International Symposium on High Energy Spin Physics, held in September in Bonn.

The opening historical lecture ..as given by C. D. Jeffries (Berkeley) who pioneered the development of polarized targets along with A. Abragam. Back in the 1950s when this work was done spin was expected to be a trivial complication in high energy reactions.

However it is now clear that this is far from true. A. D. Krisch (Michigan) from the experimental side and N. E. Tyurin (Protvino) from the theoretical side discussed the surprising new data in violent proton-proton scattering. In particular the new AGS data on the single spin asymmetry show a clear growth of polarization effects (September/October, page 34) difficult to ;commodate in standard perturbative quark-gluon field theory.

Looking for possible explanations, P. Kroll (Wuppertal) introduced a diquark model. The standard picture often fails in connection with spin phenomena, and the strong relation between spin, chirality (handedness) and anomalies and the resulting implications for high energy interactions was described by R. Peccei (Los Angeles).

Polarization data with the highest available proton energies at Fermilab and Protvino (USSR) were presented by A. Yokosawa (Argonne) and S. B. Nurushev (Protvino) and recent measurements of baryon magnetic moments and hyperon polarization by J. Lach (Fermilab) and K. J. Heller (Minnesota). Hyperon polarization is astonishing, appearing to be due completely to the 'sea' of virtual quarks surrounding the three valence quarks.

V. Hughes (Yale) explained the new muon magnetic moment experiment planned at Brookhaven (April 1989, page 7). The extreme precision of experimental and theoretical determinations of the anomalous magnetic moment of the muon test for possible quark substructure and allow a lower bound measurement of the mass of the Higgs particle responsible for electroweak symmetry breaking.

Another hangup is the so-called 'proton spin crisis', where data from the European Muon Collaboration at CERN (June 1988, page 9) showed that quarks carry almost none of the proton spin. H. Rollnik (Bonn) discussed models presented in a parallel session by B. Ioffe (Moscow) and A. Efremov (Dubna) and others, offering ways out of the crisis, but only new experimental information can resolve the problem. A comprehensive list of experiments planning to probe the spin structure of protons and neutrons was outlined by K. Rith (Heidelberg).

A highlight of the symposium was the important progress towards polarized beams, with reports by A. Blondel (CERN-LEP), D. P. Barber (DESY-HERA), K. Moffeit (Stanford-SLC) and N. Horikawa (Nagoya-TRISTAN). LEP saw about 10% electron polarization at 50 GeV (see November, page 3) while TRISTAN reported an unexpected 40% electron polarization at 29 GeV (see page 11).

This was followed by discussion of experimental proof of the 'Siberian Snake' concept pioneered in 1974 at Novosibirsk and recently demonstrated at Indiana (January/February, page 20), described at Bonn by T. Roser (Michigan).

C. Y. Prescott (Stanford) summarized the recent spin symposium in Bonn.

For the first time, intermediate energy spin physics with electron machines was comprehensively reported at this symposium. Recent results from Kharkov and Yerevan were discussed by P. Sorokin and H. Hakopian. The physics programme for the new stretcher accelerator ELSA at Bonn was presented by G. Anton (Bonn), W. Heil (Mainz) explained the future plans at MAMI (Mainz), while S. Kowalski (MIT) illustrated the Bates plans and S. Nanda covered the CEBAF (Newport News, Virginia) spin programme.

Using the electron as a probe, the fundamental properties of particles – sometimes embedded in a nuclear medium – will be investigated. Examples are the neutron electric form factor and detailed study of the excited or polarized nucleon-nucleon interaction. This research is closely related to that of the intermediate energy hadron machines, described by M. Locher for PSI (Villigen, Switzerland), by F. Lehar (Saclay) for Saturne, by W. van Oers (Manitoba) for KAON, proposed at TRIUMF, and D. Rapin

(Geneva) for the LEAR ring at CERN.

Summarized by C. Y. Prescott (Stanford), the symposium attracted 280 participants and was organized by the Physikalisches Institut der Universitaet Bonn under the leadership of K.-H. Althoff and W. Meyer.

kom Gisela Anton

KEK
TRISTAN polarization

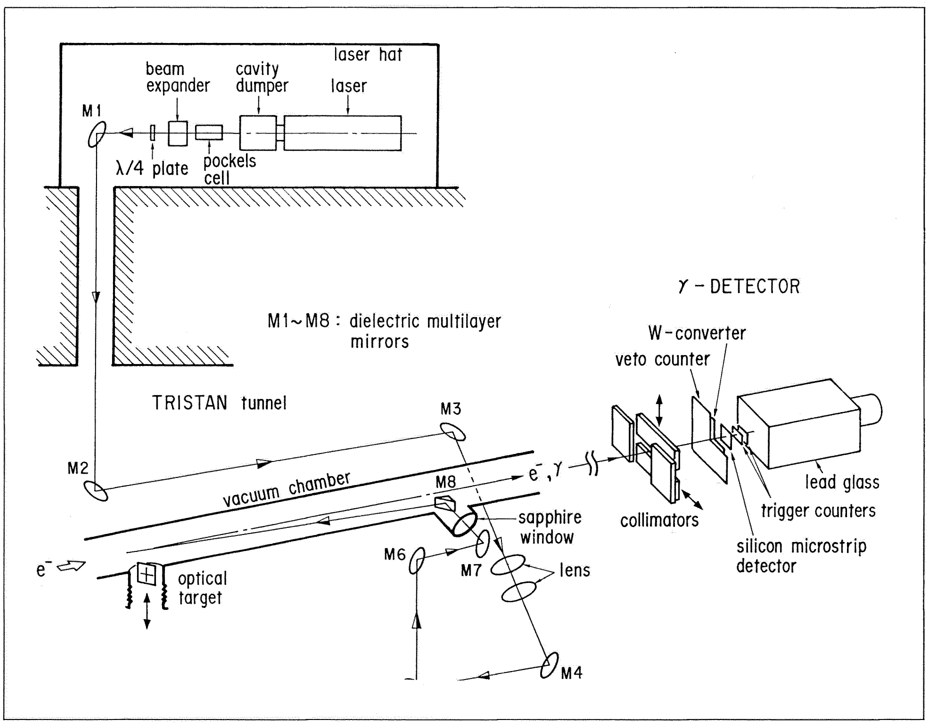
Following the observation of high energy polarized (spin-oriented) electrons in CERN's LEP electron-positron collider (November, page 3), comes news of polarized beams in the TRISTAN electron-positron collider at the Japanese KEK Laboratory.

In electron-positron storage rings, the electrons and positrons are transversely polarized (respectively antiparallel and parallel to the guiding magnetic field) through the Sokolov-Ternov synchrotron radiation effect. This radiative spin polarization has been observed in many storage rings, although generally lower than the theoretical limit of 92 per cent, due to depolarization effects in a real system.

For example at the PETRA ring at the German DESY Laboratory, polarization levels around 80 per cent were achieved in the early 1980s around 16 GeV beam energy by depolarization compensation. However for higher energy rings such as TRISTAN, HERA and LEP, theoretical calculations predicted a pessimistic level of radiative polarization.

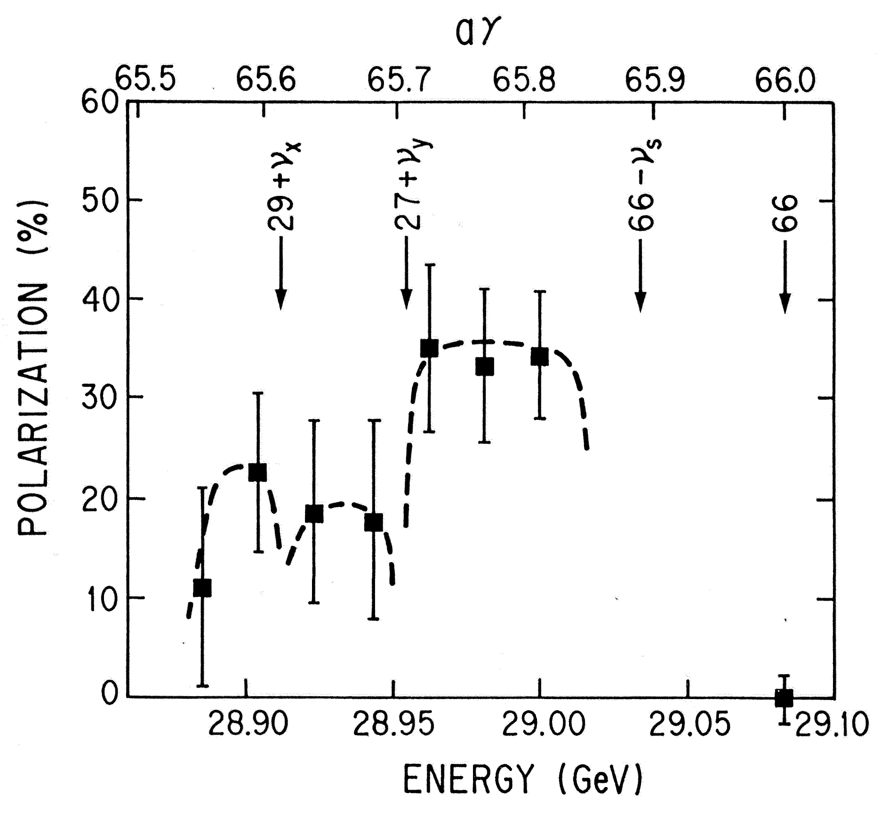
To investigate the natural radiative polarization at TRISTAN, a Compton polarimeter was installed during the 1989 autumn shutdown, and during the May-July run this year polarization of about 40 per cent was observed at 29 GeV beam energy.

The present polarimeter detects circularly polarized laser photons which are Compton scattered by beam electrons, and allows simultaneous measurement of both transverse and longitudinal components. Vertically polarized electrons give an asymmetry in the vertical distribution of backscattered photons, while an asymmetry in pho-



A schematic of the apparatus used for measuring beam spin orientation (polarization) at the TRISTAN electron-positron ring at the Japanese KEK Laboratory.

Transverse polarization of the TRISTAN electron beam from an energy scan (bottom axis) around 29 GeV. The top axis shows spin tune, and the arrows denote expected depolarization resonances. The results, with polarization levels up to some 40 per cent, suggest the energy dependence shown dotted.



ton energy distribution results from longitudinal electron polarization.

The polarimeter consists of an argon ion laser with 100W peak power and photon detectors followed by a fast data processor, and is installed at the end of a long straight section. The vertical position and the energy of converted photons are measured by a silicon microstrip detector and a lead-glass calorimeter respectively.

An intrinsic asymmetry of the experimental system was examined at an integer spin resonance energy and verified to be zero. The figure shows the transverse polarization measured at several energy points. The arrows indicate where strong depolarization resonances are expected from betatron and synchrotron tunes, and the results suggest the energy dependence shown dotted.

Since the polarization builds up in less than a minute at these TRISTAN energies, it was difficult to measure the time dependence. Thus the absolute degree of polarization was derived using the analyzing power calculated for the polarimeter acceptance.

Another interesting observation, made at 28.9 GeV in normal colliding beam operation, showed a 33 per cent transverse and 18 per cent longitudinal component, implying 37 per cent polarization of electron spin, inclined by 28 degrees. A quick glance at annihilation data from the Venus detector is not conclusive, but does not contradict this observation.

The large superconducting solenoids of the three major experiments did not depolarize the electron spin, but rather rotated it to some extent. It is not yet understood why an inclined spin vector still maintains a significant polarization with these solenoid fields. Further studies are planned to begin early next year.

SUPERCOLLIDER
Detector progress

More than 500 people interested in detector research and development for the planned US Superconducting Super Collider (SSC) met in Fort Worth, Texas, from 15-18 October. Although confined in windowless meeting rooms, what they said about how to do experiments at the SSC may open a big window on physics, for progress in this area has been very substantial.

After SSC Director Roy Schwitters opened with an SSC progress report (November, page 15), Fred Gilman, Associate Director for Physics Research, described plans for the experimental programme. Two big, complementary detectors are planned initially, along with a number of smaller experiments. Fifteen 'expressions of interest' were submitted in May and letters of intent for the big experiments were due at the end of November. Almost 2000 physicists have expressed interest in experiments at the SSC.

Overviewing the SSC-sponsored detector R&D programme, Brig Williams was very impressed at the progress of the past few years. As chairman of the committee that reviews SSC detector R&D proposals, he has been closely following

More than 500 researchers attended the recent symposium on detector research and development for the planned US Superconducting Supercollider, SSC, held at Fort Worth, Texas, from 15-18 October.

this research, which began as a 'generic' detector R&D programme in 1986. The generic effort continued until 1990, overlapping by one year with a new programme for major subsystems for potential SSC experiments. Major subsystems work is expected to continue for another year, overlapping with development of specific proposals in 1991.

Parallel session topics discussed at Fort Worth ranged from radiation-hardened microelectronics to massive superconducting magnets. Industrial exhibits were a feature and there were numerous speakers from industry, underlining the close connection between advanced SSC detector technology and the interests of many industries.

The State of Texas is a major SSC supporter, and Mort Myerson, head of the Texas National Research Laboratory Commission, gave an energetic presentation of the very substantial state support expected in the next years. About $10M for detector-related research and development is expected next year, with more to follow.

Plenary talks covered the major areas of detector technology. Although much more detailed development work remains to be done, there was a general consensus that the technology is in hand for the big, general purpose experiments at a luminosity of at least 10^{33} per sq cm per s.

Concluding, M.G.D. Gilchriese presented the SSC accelerator designers' expectations that even higher luminosities, above 10^{34}, can be reached 'rather easily' with limitations coming rather from the detectors!

Responding to this challenge, he looked at limitations to tracking, calorimetry and muon detection at these intensities. However it was clear that the R&D programme has led people to seriously consider operation at higher luminosities, but much more work will be required to make this a reality. For luminosities beyond a few times 10^{34}, completely new approaches will be needed.

DESY
Half HERA at 4.4K

After a cooldown lasting eleven days, on 30 October the north half of the 6.3-kilometre superconducting proton ring for the HERA electron-proton collider at the German DESY Laboratory in Hamburg reached liquid helium temperature. No problems were encountered, promising well for the commissioning of the full ring next year.*

About 1680 tons of material, including 208 nine-metre dipoles and 108 shorter quadrupoles, were

**** A ceremony on 8 November marked the official completion of HERA (see page 30).***

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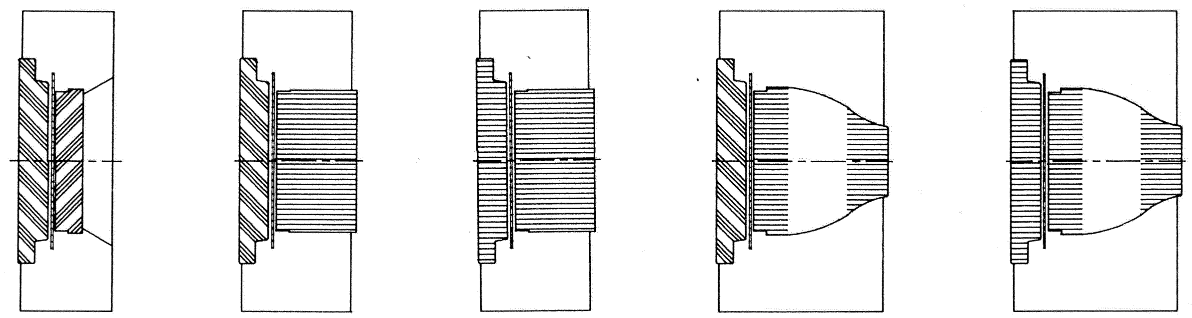

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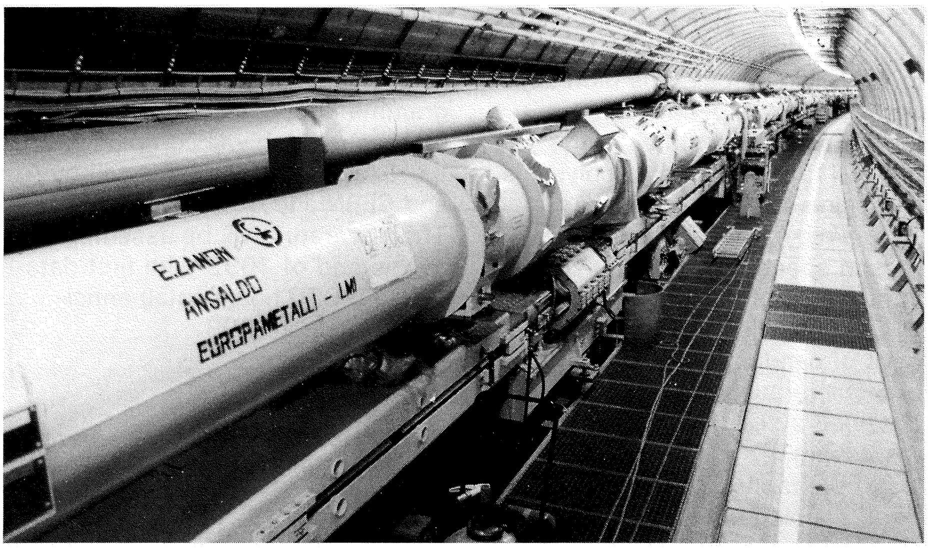
Half the 6.3-kilometre superconducting proton ring (top) of the HERA electron-proton collider at the German DESY Laboratory in Hamburg has now been cooled to liquid helium temperatures. Underneath are the conventional magnets of the HERA electron ring.

(Photo P. Waloschek)



cooled to 4.4K, making it one of the world's major cryogenic installations.

In the cooldown, supercritical helium at a pressure of 4 bar and 4.8K (it cannot boil under these conditions) is first passed through a heat exchanger in a pre-cooler box and enters the magnet chain at 2.4 bar and 4.35K. The supercritical helium is in contact with practically all parts of the magnet to be kept cold.

The helium is expanded to 1.05 bar through a Joule-Thomson valve, when a mixture with about 95 per cent liquid results. This is returned to the pre-cooler box through a tube passing through all the magnets. The heat loads of the magnets slightly increase the vapour content and the helium boils as heat leaks in. Its temperature depends only on the pressure, corresponding to 1.1 bar at 4.35K.

Cooldown time aimed to minimize mechanical stresses due to temperature gradients, and with more experience the process could probably be speeded up.

Earlier this year a smaller portion (octant) of the ring was cooled down and in a test of the quench protection system was powered to 6000 ampere, corresponding to a proton energy of 980 GeV. The nominal value is 5027 ampère for 820 GeV. In June, beam position monitors were tested with a 7 GeV positron beam.

BROOKHAVEN Hunting for unusual mesons

In the late 1960s, meson spectroscopy was providing crucial evidence for what was to become the naive quark model – mesons with electric charge and strangeness values of ± 1 or 0 are grouped in nonets whose spin, parity and charge conjugation quantum numbers corresponding to a nonrelativistic bound state of a quark and an antiquark, each carrying half a unit of spin angular momentum.

A number of experiments searched for, but did not find, mesons that were doubly charged or carried two units of strangeness (exotics of the first kind). Other searches looked for more exotic mesons, whose spin, parity and charge conjugation quantum numbers were inconsistent with the naive quark model (exotics of the second kind, e.g. 0--, 0+-,1-+, or 2+-).

After the overwhelming experimental evidence for the quark model came the notions of colour and confinement which explained why quarks should prefer to bind in 'colourless' systems – quark-antiquark (mesons) and three quarks (baryons).

But these are only the minimal colourless systems. Also possible are multiquark states such as two quarks and two antiquarks – quark molecules made up of colourless mesons. Quantum chromodynamics (QCD), the field theory of quarks and the coloured gluons (which carry the inter-quark force) predicts 'glueballs' – gluons bound by the same attractive forces that bind quarks. 'Hybrid' combinations are also possible – bound states of quarks and gluons.

The plethora of mesons predicted by QCD should include exotics both of the first and second kind. Frank Close made a pointed observation, referring to the latter – 'had such a state been found in 1968, it would have undermined the naive quark model. If one is found tomorrow, it will be greeted with enthusiasm as proof for the quark-gluon theory of hadronic particles. This interesting turnabout is the stuff of theses on the philosophy of science'.

A number of experiments in the last decade examined hadronic production, proton-antiproton annihilations and J/psi radiative decays for signs of states not made of quark-antiquark pairs. There are no completely unambiguous glueball or hybrid states but there are several tantalizing candidates. The GAMS detector operated by a CERN/USSR collaboration (May 1988, page 21) has seen signs of a 1405 MeV meson decaying into an eta and a neutral pion whose exotic quantum numbers (1-+) and unit isospin imply that it cannot be a glueball, suggesting rather a bound state of two quarks and two antiquarks or a hybrid.

Frank Close and Harry Lipkin have noted that if it is the former then its decay into an eta and a pion should dominate over decay into eta prime and a pion, while if it is a hybrid, the reverse should be true. The same group has reported a scalar G(1590) decaying into two etas or an eta and an eta prime. The measured branching ratios for the G(1590) into similar particles are not those of a conventional quark-antiquark meson. Other studies have explored the gluon-rich J/psi radiative decay for non-quark-antiquark candidates such as the eta(1440) and the f_2(1750) (formerly the iota(1440) and theta(1750) respectively).

There is still much work to be done in light meson spectroscopy to carefully map out the conventional quark-antiquark sector. In trying to identify the eta(1440) as a glueball candidate, several quark-antiquark states could also inhabit this mass region and obscure the view. There are also missing meson nonets, and a clear map of all these particles is needed so that other states can be definitively labelled.

In the past decade, there have been a number of experiments in meson spectroscopy at Brookhaven's Alternating Gradient Synchrotron (AGS) using the Multiparticle Spectrometer (MPS). One observed the 2++ f_2 (formerly g_T) meson at 2240 MeV decaying into a pair of phis. Another made a close study of the confusing 1440 MeV region in neutral kaon pair plus pion spectra. A recent experiment has looked for hybrid states in the pion-f_1(1285) channel. Analysis is in progress.

The recent advances in light-meson spectroscopy point to the importance of being able to detect all the possible pseudoscalar decays of candidate states and find branching ratios. The rich results obtained by GAMS demonstrate the advantage of studying systems with constrained quantum numbers, coupled with excellent detection of photons and charged particles.

A new Brookhaven experiment, by a Brookhaven/Indiana/Louisville/Moscow State/Notre Dame/Serpukhov/Southeastern Mass/Washington collaboration, has been approved at the AGS to use the MPS with extensive upgrades. These are motivated by recent developments in experimental meson spectroscopy and include the addition of a 3000-element lead glass calorimeter, a cesium iodide barrel surrounding the target placed inside the MPS magnet, improved tracking and a segmented Cherenkov counter.

Initial running will use a 21 GeV negative pion beam and a liquid hydrogen target. The upgrades will permit simultaneous detection of neutral and charged modes and help establish branching ratios. A key feature is the ability to reconstruct photons in the trigger and, for example, to require the presence of an eta decaying into two photons. The excellent coverage in decay angles, coupled with high statistics, will permit a complete angular momentum analysis, crucial in the search for missing nonets or states not composed of a quark-antiquark pair.

These MPS upgrades are seen as the beginning of a lively programme in precision meson spectroscopy which will complement the GAMS studies at Serpukhov and CERN and other approaches. The apparatus will be assembled by the end of 1992 with first data-taking (2000 hours total) anticipated in early 1993.

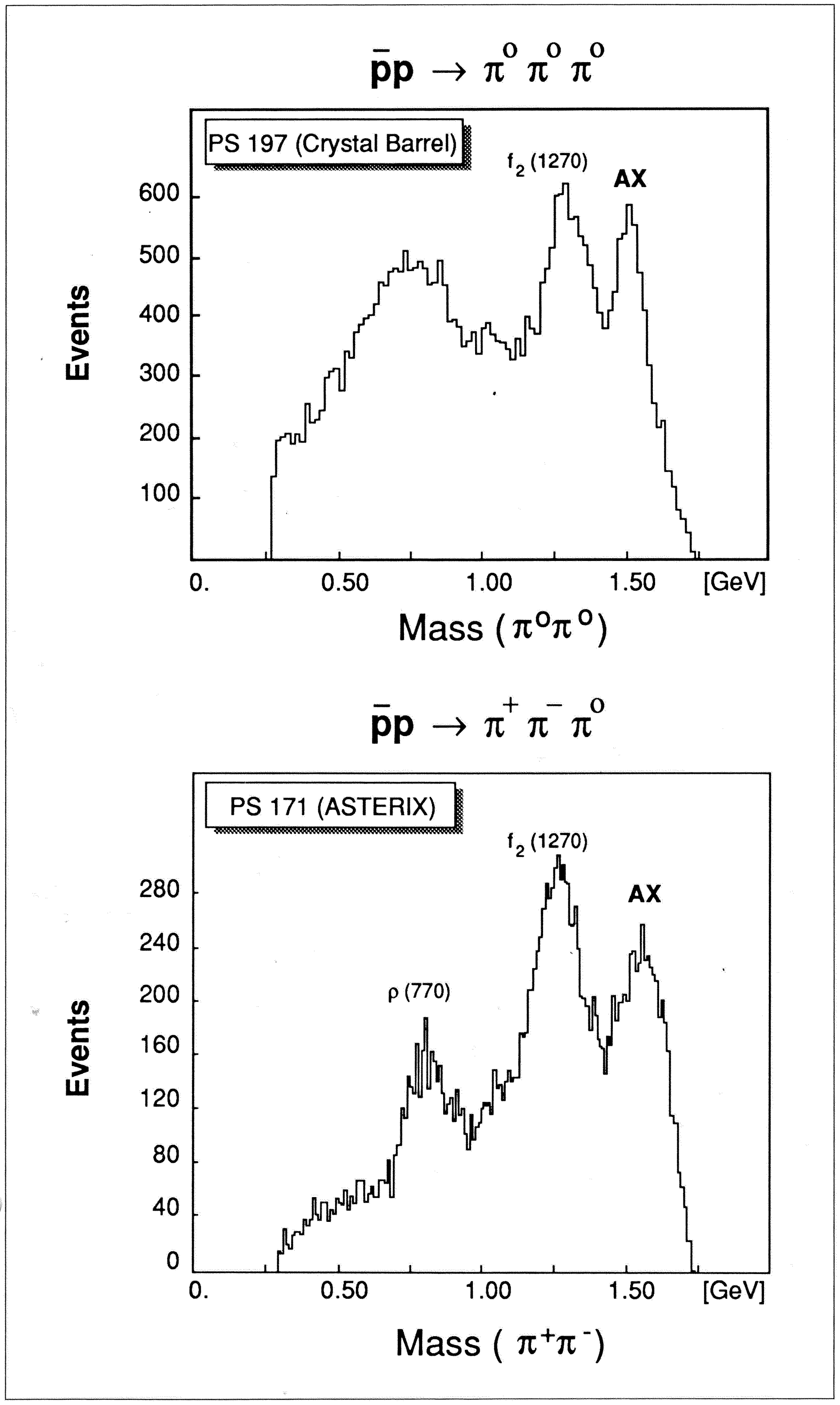
From Alex R. Dzierba

(Important contributions to particle spectroscopy also come from other areas, for example experiments at CERN's LEAR low energy antiproton ring – see page 17, two-photon physics and radiative J/psi decays at electron-positron colliders, charm spectroscopy at colliders and in fixed target experiments, and fixed target central particle production.)

CERN
Important summer for LEAR physics

An integral part of CERN's comprehensive antiproton facilities is the LEAR low energy antiproton ring which came into action for physics in 1983 and has gone on to host many experiments looking at a wide range of physics topics.

With CERN's big SPS proton-antiproton collider now in what could be its final production physics run after an illustrious career which began in 1981, the face of antiproton physics at CERN will change over the next few years. However LEAR runs independently of high energy antiproton operations, and any phasing out of collider operations has no direct impact on LEAR.



The Crystal Barrel experiment at CERN's LEAR low energy antiproton ring has confirmed (in neutral pion spectra) the A_X state at 1565 MeV reported several years ago in charged pion spectra by the Asterix experiment, also at LEAR.

This summer several meetings looked at current progress and future possibilities for low energy antiproton physics at CERN. The LEAP meeting at Stockholm in July gave an overview of the many interesting results to emerge from the first round of LEAR experiments. A workshop at CERN in June examined new ideas for future experiments with low and medium energy antiprotons, providing important input to a special meeting in the alpine resort of Cogne in September, where the objectives were to review in-depth the present programme and look towards a long range future for LEAR.

Among the most important results presented at Stockholm was a new meson, the A_x state at 1565 MeV seen (in charged pion spectra) several years ago at the old Asterix experiment at LEAR and now confirmed (in neutral pion spectra) by the new Crystal Barrel detector (January/February, page 17). The 2^+ spin-parity assignment suggests a four-quark state (two quarks paired with two antiquarks), but more work is needed to pin this down.

In annihilations producing a hyperon-antihyperon pair close to threshold, the PS185 group looks at the production of strange particles. They find that almost every lambda-antilambda particle pair (and so presumably every strange quark-antiquark pair) is produced with the two component spins aligned (triplet state), independent of energy from 200 MeV down to threshold.

The Franco/Italian PS170 collaboration has the as yet most precise data on the electromagnetic form factor of the proton in the time-like region from studies of proton-antiproton annihilation into an electron-positron pair at rest and in flight up to 900 MeV. Instead of being smooth, the result is surprisingly bumpy, raising questions about the conventional (vector meson dominance) model or suggesting a new resonance.

Two experiments using polarized hydrogen targets see marked left-right asymmetries. PS 172, looking at charged pion and kaon pairs, sees asymmetries varying rapidly with momentum and often reaching 100 per cent. This behaviour, as well that seen by PS 199 looking at the production of neutron-antineutron pairs, cannot be explained easily by the conventional picture of meson exchange.

At ultra-low energies, the PS 196 Harvard/Mainz collaboration has taken 5 MeV antiprotons down to even lower energies, using a Penning trap and electron cooling to attain cryogenic temperatures (a fraction of a millielectronvolt – March, page 3), measuring the mass of the antiproton down to a few parts in a hundred million. These techniques have considerable potential for new precision measurements.

At the Cogne meeting, both the current LEAR programme and future ideas were examined. The machine was thought to have an interesting physics potential for the next three years at least, with three broad avenues of interest – meson spectroscopy (with the Crystal Barrel, Jetset and Obelix second-generation experiments prominent); the violation of CP symmetry (where the CP-LEAR study is set to make valuable contributions); and the unique high precision experiments at ultra-low energies. Continuation into and beyond 1994 will depend on the results of the ongoing programme, and the situation should be reconsidered in about two years.

Recent measurements from CERN and Fermilab on CP symmetry violation in the neutral kaon sector have revived interest in this physics and the lambda polarization from the PS 185 experiment offers a prospect of studying CP violation in lambda decays. However the feasibility of such an experiment, which would need to amass several billion proton-antiproton annihilations into lambda-antilambda pairs, needs to be looked at.

Another appealing option for the medium-term future is construction of an inexpensive facility dedicated to producing very slow antiprotons for high precision atomic physics experiments, such as the manufacture and spectroscopy of antihydrogen atoms.

SuperLEAR, a new idea with superconducting bending magnets and gas-jet targets, has attractions for extending meson spectroscopy beyond the current LEAR and Fermilab ceilings. In particular, the search for charmed 'hybrid' states (containing a charmed quark-antiquark pair and a gluon) looks promising because the charm spectrum is already well understood and any additional state will be easy to identify. However the physics case for such a machine is premature and the situation will be reviewed in two years when more spectroscopy data has appeared from LEAR and Fermilab.

ARGONNE/ NOVOSIBIRSK Storing polarized deuterons

Promising new results come from a collaboration between the Institute of Physics, Novosibirsk, and the US Argonne Laboratory, initiated in 1988 to look at the possibilities for using polarized (spin oriented) gas targets in high current electron storage rings, the object being to maximize target polarization levels.

Using a polarized deuterium gas target in the 2 GeV VEPP-3 electron ring at Novosibirsk, the tensor analysing power (a measure of the electron-deuteron scattering for deuterons with the appropriate spin-orientation) up to momentum transfers of 3 inverse fermis has been measured by the two groups, led by S. Popov at INP and R. Holt at Argonne.

The success of this experiment shows the feasibility of using a storage cell – an open-ended tube coaxial with the electron beam – for getting more polarized deuterium atoms in an electron storage ring.

The storage cell, manufactured at Argonne, increased the effective total target thickness fifteenfold compared with a conventional polarized jet target. The target polarization was 60 per cent.

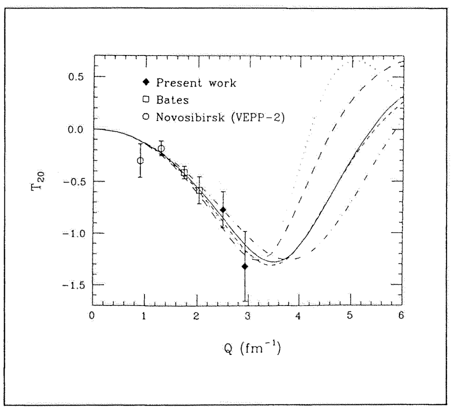
A depolarizing effect arising from the intense time-dependent magnetic field created by the electron beam pulses was minimized by placing the target in a 1-kgauss magnetic field.

Following this success, a new target cell is being constructed which should increase effective thickness by a factor of 90 over a conventional polarized jet target, and extend the results to higher momentum transfers.

Apart from advancing the techniques of spin physics, this work probes the electromagnetic structure of the deuteron, the simplest nucleus, where polarization measurements provide deeper insights.

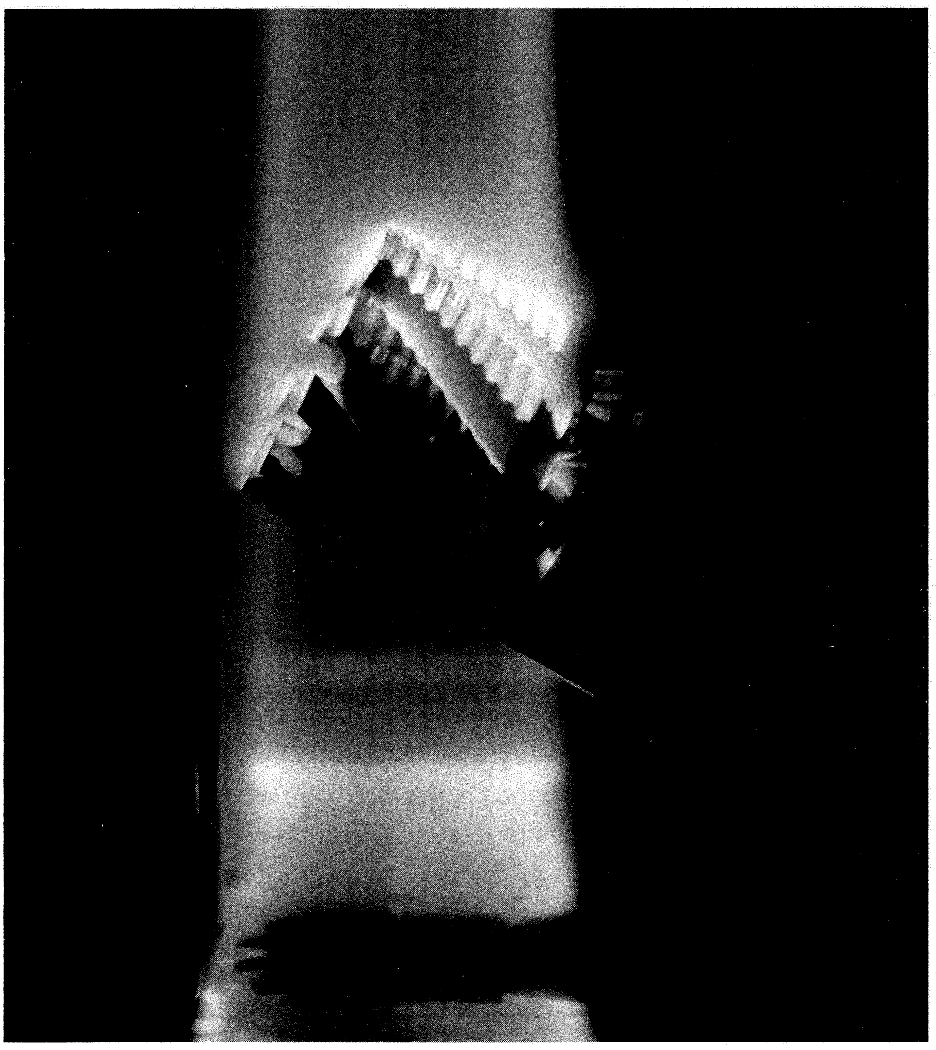
Polarized hydrogen atoms have been stored in cells before, but this work exploits the technique for experiments at a storage ring. New ideas have also been tabled for internal polarized targets in storage rings at DESY and at CERN.

Elastic electron scattering from (tensor-)polarized deuterons against momentum transfer (horizontal axis), with new results from a Novosibirsk/Argonne collaboration reaching out towards the dip suggested by theoretical models (curves).



Ion beams bring important benefits to material processing

(Photo Leybold AG)



APPLICATIONS
Accelerators for new materials

Ion beams bring important benefits to material processing, and the Seventh International Conference on Ion Beam Modification of Materials (IBMM 90), held in Knoxville, Tennessee, in September showed the promising progress being made.

The biannual IBMM conferences were originally created through a unification of international conferences on ion implantation in semiconductors and ion implantation in metals. These two materials are still important targets for ion beam treatment, but today's most important results come from insulators.

Today's ion beam modification techniques use mechanisms other than strict ion implantation. From the use of heavy ion beams of 100 keV and a few microamps for standard implantations in semiconductors twenty years ago, the use of accelerators for materials modification has come a long way. Multi-MeV beams are being used for creating buried oxide and nitride layers in semiconductors with an eye on creating three-dimensional integrated-circuit structures. Beams of many milliamps are being used for surface treatment of large and complicated stainless-steel machine parts aiming at better corrosion, friction and wear resistance.

The most exciting results in semiconductors presented at the conference came from attempts to push miniaturization, using extremely fine-focused ion beams, obtained from a liquid-metal ion source. A.J. Steckl (Cincinatti) told about focal spots of 600 nm with beam densities of the order of a milliamp per sq mm. As well as being used for mask repair in LSI circuit fabrication, these beams may be used more profitably for producing miniature optical structures in III-V semiconductor sandwiches like GaAs/GaAlAs.

M.Bode (AT&T Bell Laboratories) described perhaps the ultimate miniaturization – imaging the tracks of single ions passing through a multilayer GaAs/AlAs sandwich. The chemical changes caused by the passage may be imaged with a lateral resolution of one interatomic distance or 0.2 nm – perhaps also the ultimate resolution for vertex detectors!

The electrochemical processes induced by the radiation damage in the multilayer stack appear at one type of surface only. As Bode put it, it is like firing a bullet through a telephone book, and opening the book to find holes only on the odd- and not the even-numbered pages!

III-V semiconductors are generally not well suited for ion implantation because any accompanying damage to the crystal lattice may not be entirely removed by a rapid thermal anneal and give a group III atom on a group V site or vice ver-

sa. Such mixups are not possible in silicon, which may be why silicon appears to be coming back strongly as the favourite semiconductor for treatment by ion implantation. The creation of buried nitride or oxide layers for SIMOX structures was discussed by Peter Hemment (Guildford).

The absolute highlight of the conference was the presentation by Chris Buchal (Jülich) of doping and damage patterning of electro-optical materials like potassium- or lithium niobate. Although describing some of his perspectives as 'speculative' and 'science fiction', he nevertheless managed to persuade the audience that rare-earth implantations in these materials could provide miniature integrated optical amplifiers, lasers, mixers and switches. These ideas will surely be important for both communication techniques and computer development in the coming decade.

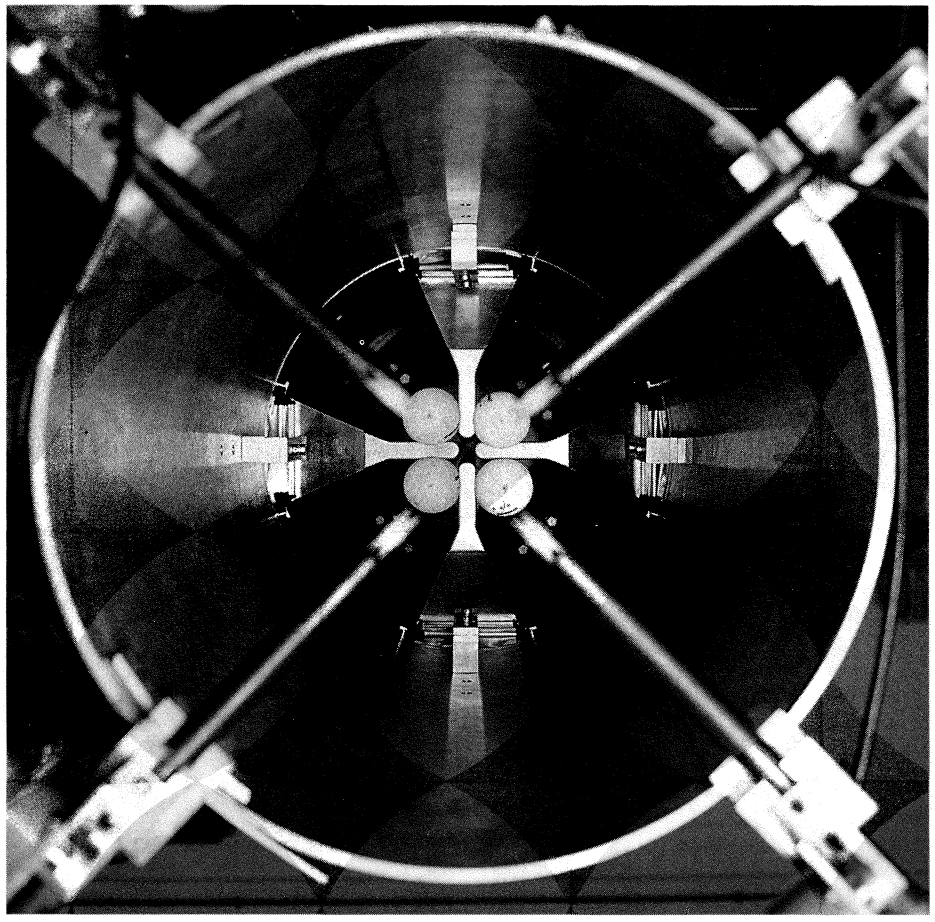
For a number of years it has been known that many vacuum-deposited films can be improved by bombardment with eV ions during deposition, presumably due to increased mobility of the deposited atoms which helps anneal out defects.

Another claim is that bombardment with large clusters (hundreds of atoms) further improves the quality of deposited films. Walther Brown (AT&T Bell Laboratories) showed that the commonly used source for these beams does not produce any large clusters and that the undeniably beneficial effects must come from single atom bombardment or bombardment with small clusters. This may be quite fortunate as Bob Averback (Urbana) showed in a series of very illuminating computer simulations that bombardment with large clusters does not promote the formation of atomically flat surfaces, giving instead meteor-like craters.

Energetic beams also play a role in the creation of high-temperature superconductors with improved current carrying capacity. Wei-Kan Chu (Texas Center for Superconductivity) described radiation effects induced by ion, neutron, electron, x-ray and gamma-ray beams. For the moment only neutron irradiation appears to give a beneficial effect. With an eye on future applications of these materials for large accelerator magnets, it is interesting to note that the extreme radiation sensitivity originally reported for these materials is found only in poor-quality samples.

(The proceedings of the conference will appear in the May 1991 issue of Nuclear Instruments and Methods B.)

From H.H.Andersen, Copenhagen



The radiofrequency quadrupole (RFQ), fast becoming the standard compact linear accelerator.

(Photo CERN 46.11.89)

WORKSHOP
Linac90

In 1960 the first linear accelerator (linac) conference was organized at Brookhaven by John Blewett. In the few years following, linear accelerator energies jumped from 50 MeV (at Brookhaven and CERN) to 2 GeV at Stanford. With the realization that, at least for electrons, circular accelerators have reached their practical limits, linacs are once more in the spotlight.

At this year's linac conference (the 15th), held in Albuquerque, New Mexico, present-day machines described covered the spectrum from industrial and medical x-ray linacs to Stanford's SLC 50 GeV linear collider, while on the drawing boards are linacs pushing all frontiers of operation including energies to 1 TeV for a vast variety of applications in and outside of the research laboratory.

One of the most popular topics at the meeting, with about 25 papers and posters, was the radiofrequency quadrupole (RFQ), a small linear accelerator suitable for low-velocity ion beams (June 1987, page 3). The RFQ has superseded the large high-voltage systems previously necessary in ion accelerator injection systems and makes compact linacs possible, even for a space-based system. Exhibited at the conference was the 1 MeV RFQ successfully tested aboard a rocket in a Los Alamos defence technology project.

Among many other advanced RFQ projects heard at Linac90 were the 250 mA unit at CERN reported by M. Weiss; the 100% duty-factor 75 mA RFQ at Chalk River, reported by G. McMichael; and a variable-energy RFQ for heavy ions described by A. Schempp from Frankfurt. An innovative feature which J. Watson said will be tried in front of the RFQ for the proposed US Superconducting Supercollider (SSC) is a helical quadrupole. At Argonne, work is underway towards a superconducting RFQ.

Large future accelerator projects will also lean towards superconducting radiofrequency cavities as a design option. The largest scale application to date is the ATLAS heavy-ion machine at Argonne, described by K. Shepard, but of course the real showpiece will be the CEBAF machine with recirculating linacs now being built at Newport News, Virginia, where cavities have achieved high fields (September/October, page 43). Summarizing the field, H. Padamsee (Cornell) reported that about 70 metres of superconducting cavities have been built so far at various institutions, either for development or real use (November, page 20).

To reach accelerating gradients ten times higher may require some other technological development such as r.f. pulse compression (November, page 5). New ideas such as this play a key role in the 1 TeV linear collider ideas aired in reports from SLAC (Stanford), CERN, KEK (Japan), and Novosibirsk.

The larger, more exotic and more expensive these machines become, the more the engineering must depart from cut-and-try to accurate design. Thus another technological advance is in computer design codes. The newer codes can handle r.f. cavities, beam optics elements, and beam dynamics with greater accuracy. This has been important for RFQ and superconducting cavity development, and design of any high performance machine. R. Cooper (Los Alamos) reported on the new and specialized field of accelerator design codes, which recently had its second conference.

Several papers, such as J. Warner's from CERN or Y. Yamazaki's from KEK, indicated that new linac structures could be on the way. Since a big advance may be necessary for TeV linear colliders, people at some major Laboratories are thinking about entirely new microwave structures. Linear collider projects at CERN (CLIC – November, page 5) and in Japan (JLC) are looking in this direction, as reported by G. Guignard and H. Matsumoto respectively, with the latter having achieved accelerating gradients of 85 MV/m in a 0.6 m tank. T. Weiland reported that DESY and Darmstadt are thinking about a 500 GeV (total) electron-positron linear collider using refinements of existing technology.

Apparently closer to realization is the Japanese Hadron Project, the subject of several reports at the conference. The linac stage of this machine will deliver a 1 GeV beam; among the advanced design features will probably be permanent magnet quadrupoles in the drift-tube section and possibly use of the annular coupled structure, a new coupled-cell configuration. Prototyping and construction of some parts of the JHP linac is underway at KEK.

Linac technology has taken root in several fields outside of the particle physics laboratories. One new community with more than 16 projects represented at Linac90 and surveyed by C. Pellegrini (UCLA) is developing the free electron laser, requiring a high intensity electron linac. One example, reported by P. O'Shea (Los Alamos), will run 300 A at 40 MeV.

In possible futuristic applications, for example the accelerator transmutation of radioactive waste or tritium production schemes sketched by G. Lawrence (Los Alamos), a high premium is placed on linac power efficiency. I. Hofmann from GSI (Darmstadt) and R. Bangerter from Berkeley, among others, reported on current development of r.f. and induction linacs to drive fusion reactors. In his summary P. Grand (Brookhaven) speculated whether civilization's need for energy might eventually become the prime force for development of linac technology.

The main organizers of Linac90 were Stan Schriber and Bob Hardekopf from Los Alamos.

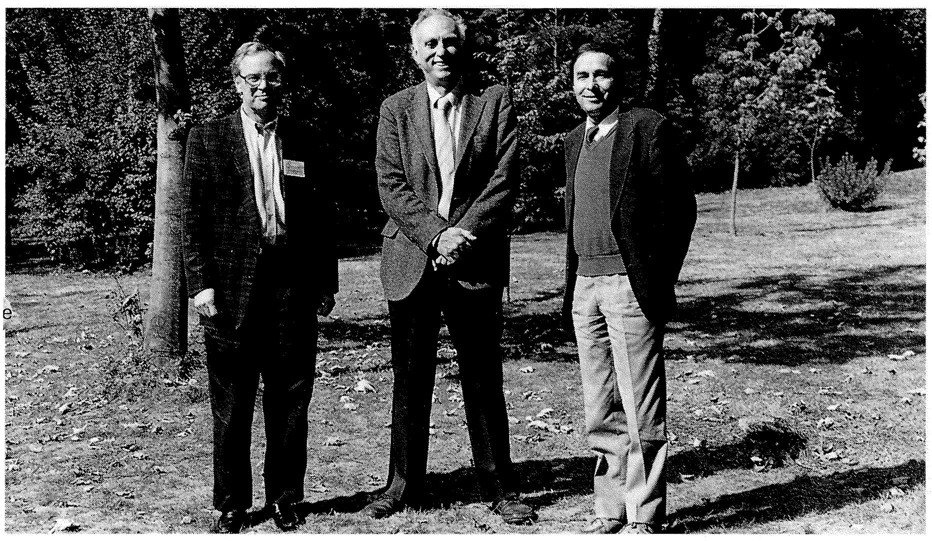
From Olin van Dyck

ORSAY
Tau workshop

From 24-27 September 120 physicists met at the French Orsay Laboratory for a meeting devoted to the tau lepton and its associated neutrino.

The tau was discovered in 1975 by Martin Perl and his collaborators

Tau lepton pioneer Martin Perl (centre) at the recent tau physics workshop at the French Orsay Laboratory, flanked by workshop organizers Michel Davier (Orsay Director, right) and Bernard Jean-Marie.



working with the Mark I detector at the SPEAR electron-positron ring at Stanford. This unexpected discovery heralded a scenario of three families of leptons and quarks, subsequently confirmed by the discovery of the fifth kind of quark at Fermilab in 1977.

The existence of a third family allows the violation of CP symmetry to be accommodated in (but not explained by) the Standard Model. While the sixth ('top') quark has yet to show itself, experiments at high energy electron-positron colliders have shown that there is room in Nature for only three quark-lepton families.

The Orsay meeting was the first to concentrate exclusively on tau physics, covering from the early days at SPEAR and at the DORIS ring at DESY through to the latest results from LEP.

After an introduction from tau pioneer Martin Perl, the meeting surveyed tau decays, where the situation is far from clear. Missing decays could be due to systematic experimental underestimations, or to new physics, so clarification is important.

A global analysis by the Cello collaboration at DESY succeeds in arriving at a coherent description without any problems, and a preliminary appraisal by the Aleph experiment at LEP, looking at the decays of Z particles into tau pairs and exploiting the detector's photon reconstruction and identification capabilities, confirms these results. Continuation of these studies and new information from the Cleo II detector at Cornell's CESR ring should tidy up the tau decay picture.

In this area, two results were presented by the Argus experiment at DESY – a high precision measurement of the Michel parameter for leptonic tau decays in accord with theory, and the first observation of parity violation in the decay of a tau into three pions and a neutrino, providing another incisive probe of the underlying theory. Despite these new results, tau information is still meagre compared with, say, the wealth of data in the muon sector.

The meeting went on to look at the coupling of the tau to the neutral current of weak interactions. The four LEP experiments – Aleph, Delphi, L3 and Opal – presented their Z profiles from tau pairs and their forward-backward production asymmetries, all measurements in accord with the Standard Model.

Aleph and Delphi have looked at tau polarization, with Aleph data suggesting parity violation in both tau production and decay. Together, the LEP results test the 'universality' (family independence) of lepton coupling to the neutral current with ten times better precision than before.

For the future, the Beijing BEPC ring should provide a better measurement of the tau mass, but LEP and lower energy machines should provide the bulk of new tau data. High luminosity electron-positron rings are being proposed to provide bulk data in relatively unprobed corners. B-factories geared to look at CP violation are not optimized for tau physics, although they should open up some new reaction channels. A tau-charm factory would be better adapted for tau physics and a design is on the drawing board at CERN (but not necessarily for construction on the CERN site).

The final topic at the workshop was the tau neutrino. Mass measurements of this elusive particle are difficult and are attempting to go below the present limit of 35 MeV. Tau neutrino interactions are difficult to catch, and drive ideas for new precision detectors.

Overall, the tau is an excellent testbed for the Standard Model, and could be the scene of important new revelations in the coming years.

The Orsay tau workshop was organized by Michel Davier, Director of Orsay's Linear Accelerator Laboratory, and Bernard Jean-Marie.

From Michel Davier

The Foundation for Fundamental Research on Matter

The foundation FOM is an organisation for research in the area of physics with some 1100 employees. Research is executed by task-forces at university laboratories and institutes. The National Institute for Nuclear Physics and High Energy Physics (NIKHEF) in Amsterdam is one of these institutes, a cooperation of FOM, the Free University (VU) in Amsterdam, the University of Amsterdam (UvA) and Catholic University of Nijmegen (KUN). The NIKHEF staff counts about 350 people spread over two sections. Most experiments of the Nuclear Physics section (K) use their own electron accelerator MEA. For the experimental program of the High Energy Physics section (H) the facilities of CERN and Desy are used.

FOM

Experimental high energy psysicists m/f

Applications are invited for post-doctoral and tenure-track positions in Particle Physics Research at the section High Energy Physics of the National Institute for Nuclear Physics and High Energy Physics (NIKHEF) in Amsterdam. The institute is involved in experiments at CERN (UA1, Delphi and L3) and DESY (ZEUS); it also has a theory group.
In view of the LCH project at CERN R&D projects have started on several aspects of detector technology.
The academic staff, including PhD students, consists of about 60 physicists. Technical support is provided by well equipped mechnical and electronic workshops. The institute has its own, up to date, computing facilities.

Requirements
Candidates should have a PhD degree, preferably in Experimental Particle Physics. Applicants may be considered for a tenured position when they have at least several years of post-doctoral experience with a strong record of accomplishment. It is assumed that successful applicants will join one of the present experimental teams.
They should demonstrate originality and initiative in their research activities and possibly help initiating future research directions of the laboraty.

Information
Further information can be obtained from the Scientific Director, prof. dr. K.J.F. Gaemers, telephone xx31.20.5925001.

Applications
Letters of application, including curriculum vitae, list of publications and the names of at least three references are to be sent within three weeks after publication of the advertisement to the personnel officer mr. T. van Egdom, P.O. Box 41882, 1009 DB Amsterdam, the Netherlands.

NIKHEF

Experimental Nuclear Physicist

There is a vacancy for a nuclear physicist at our Chalk River Laboratories in a research group that studies nuclei far from stability and weak interactions in nuclei. The group centers its activities about the TASCC accelerator facilities (a coupled Tandem Accelerator and Superconducting Cyclotron which produces heavy ion beams from lithium at 50 MeV/u to uranium at 10 MeV/u) and the Chalk River on-line isotope separator. The successful candidate will be expected to collaborate in the activities of the existing group and to assume a leadership role in related experimental research.

Candidates with several years of relevant post-doctoral research experience will be preferred. In that case, appointment will be to a position that is directly convertible to a permanent one after two years of satisfactory service. More junior candidates would be considered initially for a Research Associate position. Salary will be commensurate with experience.

Application forms may be obtained from the **Employment Office, Chalk River Laboratories, CHALK RIVER, Ontario, Canada, K0J 1J0** and completed forms, curriculum vitae and publication list should be sent, no later than **January 15, 1991** to **Dr. J.C. Hardy, Director of TASCC**, at the same address, quoting **File No. PPHS-9088.** Candidates should arrange for three letters of reference to be sent to Dr. Hardy.

This advertisement is directed in the first instance to Canadian citizens or permanent residents, but all qualified candidates are encouraged to apply.

AECL has an active Employment Equity Program and encourages applications from women, aboriginals, visible minorities and persons with disabilities.

AECL EACL

AECL Research **EACL Recherche**

EUROPEAN SYNCHROTRON RADIATION FACILITY
GRENOBLE – FRANCE

The Survey & Alignment Group in the Technical Services is looking for :

A TECHNICIAN (M/F)
specialized in Geodesic measurements

This group has the task of installing, measuring and adjusting all sensitive equipment of the Synchrotron Accelerator. Later, it will be in charge of the positioning of all equipment in the large Experimental Hall round the beam-lines.

QUALIFICATION & EXPERIENCE : He/she must have a sound basic education (HNC) or equivalent, at least 5 years experience in topometrics and micro-geodesy. Good knowledge in acceleration & micro-informatics would be appreciated.

The working language in ESRF is English : knowledge of French is desirable.

Please state your name, address and the reference number, and we shall provide you with an 'Application Form' to be sent back to us before **15 December 1990 to**

ESRF
Recruitment Office – Ref : 6523
BP 220
F – 38043 GRENOBLE CEDEX
France

People and things

On people

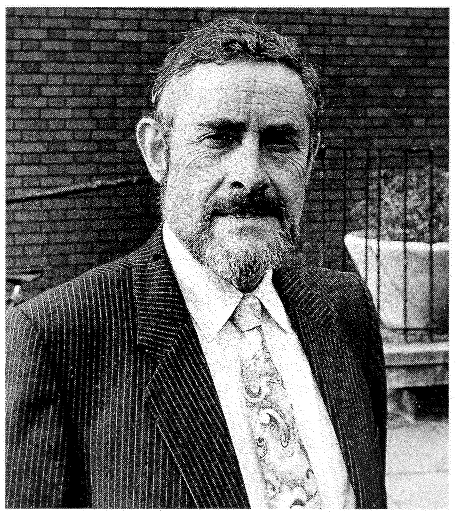
Maury Tigner of Cornell is one of the six recipients of this year's E.O. Lawrence Awards in the US for his contributions to high energy accelerator technology, including design for Cornell's CESR Electron Storage Ring, the development of superconducting radiofrequency cavities and his direction of the conceptual design of the planned US Superconducting Supercollider (SSC).

Walter E. Massey of Chicago, former Director of the Argonne Laboratory becomes Director of the US National Science Foundation, succeeding Erich Bloch. Massey leaves his position as Vice-President of the American Physical Society, where Ernest M. Henley now becomes President-Elect.

Peter Higgs of Edinburgh receives the 1990 Scottish Science Award for his work in theoretical physics, particularly in the unification of fundamental forces. This Award was attributed for the first time in 1989.

Michael Riordan, Science Information Officer at the Stanford Linear Accelerator Center (SLAC) and author of the book 'The Hunting of the Quark', moves to Washington to become Assistant to John S. Toll, President of the Universities' Research Association, the governing body of both Fermilab and the planned US Superconducting Supercollider (SSC). Michael is also SLAC's CERN Courier correspondent.

Mark Sakitt becomes Assistant Director of Planning and Policy at Brookhaven.



Paul Murphy recently retired as head of the particle physics group at Manchester.

Roger Blin-Stoyle, Honorary Professor of Theoretical Physics at Sussex, becomes President of the UK Institute of Physics for 1990-92.

Herbert Lengeler of CERN's Accelerator Technology Division, and a member of the CERN Courier Advisory Panel, been nominated Honorary Professor of Physics at the Technische Hochschule, Darmstadt, Germany.

Paul Murphy retires

Paul Murphy retired recently as head of the particle physics group at Manchester. Involved in many early experiments at then new accelerators – the Liverpool 400 MeV synchrocyclotron, the Bevatron at Berkeley and the UK Nimrod proton synchrotron, he became Professor of Experimental Physics at Manchester in 1965 and moved his attention to another new machine, the NINA electron synchrotron at nearby Daresbury. He has turned his attention in more recent years to experiments at colliders – first the ISR at CERN, then with the JADE experiment at the PETRA ring at DESY, and most recently

Imperial College of Science, Technology & Medicine
Blackett Laboratory

Lectureship in Theoretical and/or High Energy Physics

Applications are invited for the post of lecturer in the Blackett Laboratory. The appointee will join either the High Energy Physics or Theoretical Physics Groups (or possibly both, jointly, if appropriate).

The interests of the Theoretical Physics Group centre on unified theories of elementary particles and their forces, for example, superstring theory, theories with gauge symmetry and/or supersymmetry, QCD and quantum gravity. Current applications of these ideas include cosmology and the theory of phase transitions.

The present experimental programme is based on ALEPH (principally analysis in heavy flavour physics and QCD) and ZEUS, also a search for Dark Matter. Long-term development of detectors for LHC/SSC is underway and in the shorter term a new experiment on b quark physics is planned at CERN. The group is a world centre for the development of silicon-based microdetectors.

Salary according to experience in the range £12,086 – £22,311 plus £1,767 London allowance.

Applications comprising a c.v., a list of publications and the names and addresses of three referees should be sent to :

The Head of Department
Professor T.W.B. Kibble, FRS
Blackett Laboratory
Imperial College
Prince Concosrt Road
London SW 7 2BZ

*to arrive not later than **Monday, 21 January 1991.***

UNIVERSITY OF CALIFORNIA, RIVERSIDE
Faculty Position in Experimental High Energy Physics

The Department of Physics at the University of California, Riverside expects to make a faculty appointment in the area of experimental high energy physics on or after 1 July 1991. This tenure-track appointment will be at the level of Assistant Professor. The department is seeking candidates with outstanding research records and strong commitment to teaching. The individual appointed will be expected to join , for the near term, the ongoing Riverside research program in high energy electron-positron collisions. Please send a resumé and arrange to have at least three letters of recommendation sent to

Chair, Search Committee
Experimental High Energy Physics
Department of Physics
University of California, Riverside
Riverside,
California 92 521
USA

The deadline for receiving applications will be 15 February 1991. Any applications received after this date will be considered only if an appointment is not made from the original pool.

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Minority & women candidates are encouraged to apply

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Nuclear Research Centre
Dept. of Physics

The Subatomic Physics group at the University of Alberta has 3 openings for experimental and theoretical Research Associates. The group's interests include rare kaon decay tests of the Standard Model at Brookhaven, the spin structure function of the nucleon at HERA, parity violation and charge symmetry breaking at TRIUMF, elastic and inelastic NN scattering at TRIUMF, and photonuclear studies at the Saskatoon CW electron accelerator.

Of the successful candidates who have received their Ph.D. degrees in physics within the last two years, two experimentalists and one theorist will be appointed. The successful applicants will be expected to make major contributions to the projects in which they choose to participate, and will be based accordingly at either Edmonton or Vancouver. Salary will be commensurate with experience.

Candidates should send their resume and three letters of reference as soon as possible to: **Research Associate Search Committee, Nuclear Research Centre, The University of Alberta, Edmonton, Alberta, CANADA T6G 2N5.**

Closing date for applications is **April 1, 1991** and the positions will be filled as soon as possible thereafter.

We offer equal employment opportunities to qualified male and female applicants.

Postdoctoral Positions
Nuclear and High Energy Physics

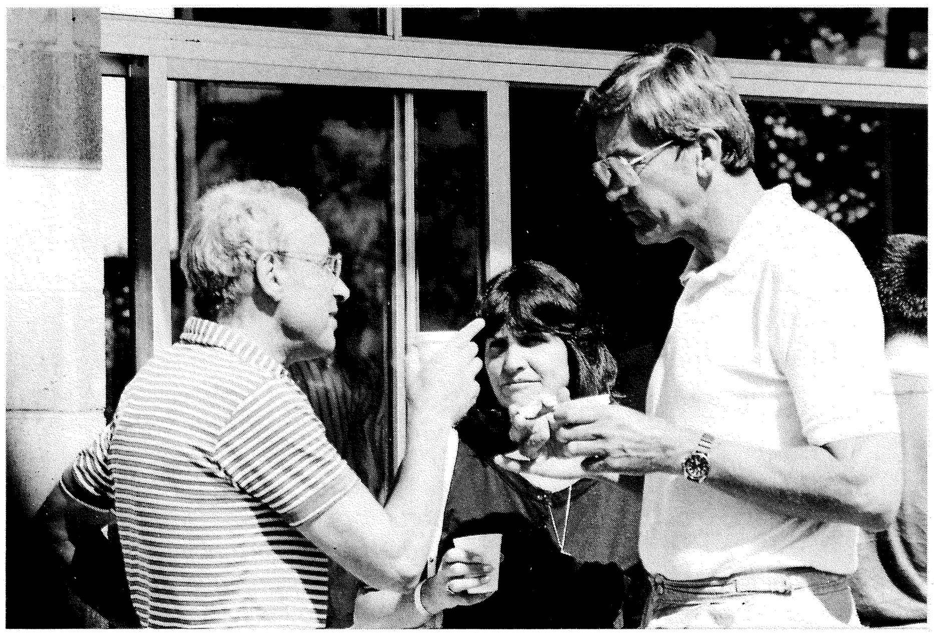
The Physics Department at Lawrence Livermore National Laboratory has challenging openings at the postdoctoral level in several of its new programs in experimental and theoretical nuclear physics and experimental particle physics. Included are opportunities to participate in new research areas ranging from particle physics at the Superconducting Super Collider, to relativistic heavy ion collisions at Brookhaven National Laboratory, to electronuclear studies at Stanford Linear Accelerator Center. There are also many opportunities to contribute to theoretical studies of nuclear many-body physics and to participate in experiments to search for shape isomers and superdeformed nuclei. In all of these areas, exceptional candidates will have wide latitude to pursue independent research directions supported by LLNL research groups within major international collaborations.

Successful applicants will be encouraged to initiate their own creative research programs in addition to participating in ongoing projects. Applications for outstanding recent PhD graduates in theoretical and experimental nuclear and high energy physics will be welcome. U.S. citizenship is preferred.

Salary and fringe benefits are very competitive. To apply, please send a resume, a brief statement of research interests and three letters of reference to: **Barbara Tuck, Lawrence Livermore National Laboratory, P.O. Box 5510, L-725, Dept. A90444, Livermore, CA 94550.** An equal opportunity employer.

University of California
Lawrence Livermore National Laboratory

The annual Summer Institute at the Stanford Linear Accelerator Center (SLAC) always brings out the best of this lively Laboratory. This year's event attracted 269 participants. Here visiting Russian theorist Vladimir Gribov (left), with support from Mrs. Gribov, interacts with James Bjorken.



with the Opal collaboration at CERN's LEP. At CERN he has also served on several Experiments Committees.

ICFA Chairman

The Chairman of ICFA, the International Committee for Future Accelerators, is A.N. Skrinsky, Director of Novosibirsk's Nuclear Physics Laboratory, and no longer Yoshio Yamaguchi, who stepped down at the end of last year. We regret the error which appeared in November issue, and our apologies to all concerned.

A forthcoming issue will report on the important ICFA seminar on Future Perspectives in High Energy Physics, held at the Institute for High Energy Physics, Protvino, near Moscow, from 9-14 October.

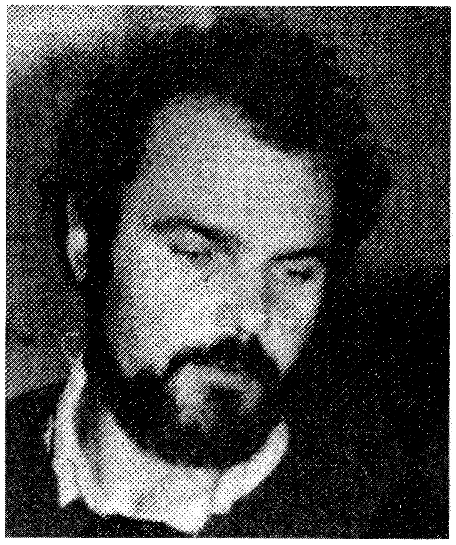
American Physical Society elections

New officers of the Division of Particles and Fields of the American Physical Society were elected recently. DPF officers now are Ed Berger (Chairman), A.J.Stewart Smith (Vice-Chairman), Bruce Barnett (Secretary-Treasurer), Fred Gilman (Past-chairman), Stan Wojcicki (Division Councillor), William Bardeen, Lowell Brown, Richard Field, Mary K. Gaillard, Paul Langacker, and Michael Witherell.

On 24 October CERN Director General Carlo Rubbia (left) and DESY Director Volker Soergel cut the ribbon to open the DESY exhibition at CERN's Microcosm expo centre. The exhibition, which lasts until February, includes full-scale components of the 6.3 kilometre HERA electron-proton collider with its superconducting proton ring, soon to become operational at the Hamburg Laboratory.

(Photo CERN EM464.10.90)

Res Jost.



Helmut Poth.

Res Jost 1918-1990

Eminent Swiss theoretician Res Jost, Honorary Professor at ETH Zurich, died on 3 October at the age of 72. His fundamental and frequently elegant contributions have become an integral part of modern quantum mechanical scattering theory and relativistic field theory. One-time assistant to Wolfgang Pauli in Zurich and member of Princeton's Advanced Study Institute, he became Professor of Theoretical Physics at ETH Zurich in 1955. His teaching in Zurich and elsewhere, notably the 'Les Houches' summer schools, was very influential. Recipient of the prestigious Max Planck Medal, he was also a member of both the US and Austrian Academies of Science. He will be remembered for his kindness, his sense of humour and his great culture.

Sir Ben Lockspeiser 1891-1990

UK scientist and scientific administrator Sir Ben Lockspeiser died on 18 October at the age of 99. In the early 1950s he helped convince an initially dubious UK Government of the importance of establishing CERN, and his signature appears for the UK on the 1953 CERN Convention document. His enthusiasm for CERN resulted in the UK being the first Member State to ratify this document, in December of the same year. As Permanent Secretary of the UK's Department of Scientific and Industrial Research, his administrative skills were much in demand. He chaired the Interim Finance Committee which helped prepare the administrative foundations for the future Organization, and after the formal establishment of the Organization went on to become its Council Chairman, from October 1954 to December 1957.

Harry Palevsky

Harry Palevsky died on 17 September at the age of 71 in California, where he had lived after retiring from Brookhaven. Working from 1942 to 1945 in the Manhattan Project prior to joining Brookhaven, he was first known through his experimental verification of the Landau theory of protons. He made pioneer studies of nuclear structure in an experiment crucial to the verification of Glauber theory, using the Cosmotron's 1 GeV proton beam. This brought him in closer contact with CERN, where he spent a sabbatical year in the mid-60s. His participation in the development of nuclear weapons led him join the Pugwash movement. Harry has left a deep impression on all those who had the privilege to meet and to work with him. He was a man of culture with a high sense for scientific knowledge and for its role in society. He also loved life, family and friendship.

Helmut Poth 1948-1990

Talented German experimentalist Helmut Poth of Darmstadt died on 8 October at the age of 42, after a paragliding accident. After thesis work on x-ray spectra of light antiprotonic atoms, he went on to take an important part in the LEAR low energy antiproton ring project at CERN, representing Karlsruhe's KfK laboratory. As well as coining the acronym LEAR, he helped shape the LEAR community by organizing an initial workshop at Karlsruhe in 1979. He took a particular interest in the technique of electron cooling, having visited its birthplace at the Soviet Novosibirsk Laboratory in 1981, and was co-leader (with CERN's Helmut Haseroth) of the electron cooling project at LEAR from 1980-1988, as well as being spokesman of the LEAR PS176 collaboration studying x-ray spectra of antiprotonic atoms. Most recently he was preparing for experiments at the new ESR heavy ion storage ring at GSI Darmstadt. He was a prime mover in both beam cooling methods and in the experiments which exploit them, and his untimely death is deeply regretted by both communities.

SPEAR leaves particle physics

In October, the SPEAR electron ring at Stanford became fully dedicated to research for Stanford's Synchrotron Radiation Laboratory. Conceived by Burton Richter in the late 1960s, the 80-metre diameter ring was built on a vacant lot at the

Mrs. Birte Toepfer presents theorist Lev Okun of Moscow with the 1990 Karpinski Prize, one of a series of prizes awarded by the Toepfer Foundation in Hamburg. It acknowledges important contributions to improving contacts between the Soviet Union and Germany as well as scientific achievement.

Stanford Linear Accelerator Center (SLAC) using money eked out of the Laboratory's operating budget. It came into operation in 1973, and in November of the following year produced the first psi particles, the sharp 3.1 GeV peak also seen by Sam Ting's experiment at Brookhaven (where it was called the J), heralding the quantum number charm and a new era in particle physics. From 1979, SPEAR became increasingly in demand as a source of synchrotron radiation.

Boost for TRIUMF KAON project

Prospects for approval of the proposed KAON Factory at the Canadian TRIUMF Laboratory in Vancouver took a further step forward in September when Premier Vander Zalm of British Columbia announced that his government would double their financial commitment to 236 million Canadian dollars. This represents one-third of the total $708 million for a six-year construction period. Another one-third is to be raised from international sources and from other Canadian provinces. A two-year $11-million preconstruction study completed earlier this year (July/August, page 19) concluded 'on the basis of extensive international consultations, it is reasonable to expect that the total foreign participation which can be negotiated could be close to the $200 million target'. The remaining one-third of the construction cost would be provided by the Canadian federal government.

British Columbia also announced its willingness to discuss contributions to the operating costs. A decision by the Canadian cabinet on the federal funding component is expected shortly.

CERN Accelerator School

The CERN Accelerator School (CAS) and the UK Rutherford Appleton Laboratory are organizing a course on R.F. Engineering for Particle Accelerators, to be held from 3-10 April 1991 at Exeter College, Oxford, aimed at staff in accelerator laboratories, universities and manufacturing companies specializing in r.f. and microwave equipment. Further information from Mrs. S. Wartburg, CERN Accelerator School, SL Division, CERN, 1211 Geneva 23, Switzerland, bitnet casral at cernvm.cern.ch

Later next year CAS, this time with NIKHEF-H, Amsterdam, will be organizing a course on Advanced Accelerator Physics from 16-27 September at Noordwijkerhout, Netherlands. Further information as above, but bitnet casnik at cernvm.cern.ch

The most recent CAS meeting was the General Accelerator Physics course, organized jointly with KFA, Jülich, Germany, in September. This attracted a two-day industrial exhibition mounted by Alcatel Hochvakuumtechnik, Balzers Hochvakuum, Interatom, Leybold, NTG Neue Technologien and VG instruments.

Heavy matter in cosmic rays

Reexamination of cosmic ray data from a detector flown from a Japanese balloon centre in 1981 has unearthed two events with multiple coincidences whose behaviour is consistent, using some extrapolations of current accelerator data, with fragments carrying a nuclear charge of about 14, and a mass 370 times that of the proton. Several authors have suggested the possibility of heavy nuclear matter, containing heavier quarks than the conventional 'up' and 'down' varieties, as a relic of the Big Bang.

LEP experiments

After first featuring Delphi (November, page 1) our series on the four experiments at CERN's LEP electron-positron collider continues in January with Aleph.

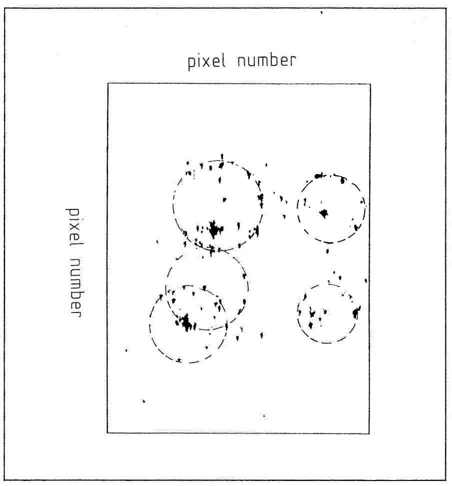
SSC people and initial contracts

The Superconducting Supercollider (SSC) Laboratory, Ellis County, Texas, has considerably reinforced its management team. Edward J. Siskin, formerly executive vice-president of Stone and Webster Engineering Corp, becomes general manager. Paul Reardon, acting head of SSC accelerator systems division, becomes project manager. George Robertson, formerly Major General commanding the North Pacific Division of the US Army Corps of Engineers, becomes deputy project manager. Jon Ives, formerly Rear Admiral commanding the Pacific division of the Naval Facilities Engineering Command, is appointed head of SSC's conventional construction division. Don Edwards, formerly head of SSC accelerator systems integration, becomes head of the new accelerator design and operations division. Theodore A. Kozman, formerly SSC acting project manager, is appointed head of accelerator systems division.

A $27-million contract for the first SSC cryogenic system has been awarded to Koch Process Systems Inc of Westborough, Massachusetts, in association with Sulzer Chemtech of Switzerland, Cryogenics Consultants Inc of Allentown, Pennsylvania, and Cryogenic Technology Services Inc of Denver.

In addition, industrial giants General Dynamics Corp and Westinghouse Electric Corp have been selected to enter into negotiations for a $200-million contract for design and initial production of superconducting magnets for the SSC.

8 November – German Research Minister Heinz Riesenhuber (left) presses the button to start cooling of the second half of the now complete superconducting proton ring of the HERA electron-proton collider at the DESY, Hamburg, Laboratory, watched by Laboratory Director Volker Sorgel. Cooling of the first half of the 6.3-kilometre ring was already complete (page 13).



Five charged particles picked up by the Ring Imaging Cherenkov counter (RICH) of the NA35 experiment at CERN. During its recent run with heavy ion beams, the NA35 streamer chamber experiment used a 50x50cm RICH as well as its Time Projection Chamber (TPC – see November, page 7). This RICH, the first such large-area device operating with CCD readout, and filled with liquid C_6F_{14} intercepted about 11 photons for each ring, permitting good separation of pions and kaons. (The dotted lines are drawn to guide the eye, since the detailed reconstruction is linked to streamer chamber analysis.) Together the TPC and RICH provide NA35 with the potential to exploit beams of heavier ions (lead). This RICH development was unfortunately omitted from the November article.

Assistant Professor Position
Experimental High Energy Physics
University of Illinois at Urbana-Champaign

The Department of Physics at the University of Illinois at Urbana-Champaign anticipates making a tenure-track faculty appointment in the area of Experimental High Energy Physics. Salary is commensurate with experience; the appointment would begin in the Fall of 1991. Our principal interest is in the candidate's ability to teach effectively at both undergraduate and graduate levels and to lead a vigorous and significant research program.

The high energy physics group in Urbana is involved in a number of experiments including studies of CP and CPT in the K meson system (E773,E799), charm and bottom physics (E687), hadron collider physics (CDF and SSC), Z physics (SLD), and high energy astrophysics (Fly's Eye). The group consists of ten faculty, several postdocs, and a number of graduate students. Our preference would be for the new faculty member to join one of the existing collaborations. The application deadline for full consideration is 15 January 1991.

Applicants should submit a cu… the names of three references to

A. C. Anderson
Head, Department of Physics
University of Illinois
Urbana
Illinois 61801

Tel. (217)333-3760

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Associate Professor

At the Stanford Linear Accelerator Center (SLAC), we're devoted to pursuing experimental and theoretical research in elementary particle physics. As one of the leading high-energy physics research facilities in the world, we're continuously developing new techniques in accelerators and elementary particle detectors.

We're currently seeking candidates for a tenured faculty appointment in theoretical accelerator physics. This appointment will be at the rank of Associate Professor. Applications from qualified applicants are solicited, and applicants should submit a curriculum vitae along with the names of three referees.

Applications should be submitted before January 15, 1991 to: Professor J.M. Paterson, Chairman, Faculty Search Committee, Stanford Linear Accelerator Center, P.O. Box 4349, Mail Bin 24, Stanford, CA 94309.

Stanford University is an equal opportunity employer and welcomes applications from women and members of minority groups.

Stanford Linear Accelerator Center

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