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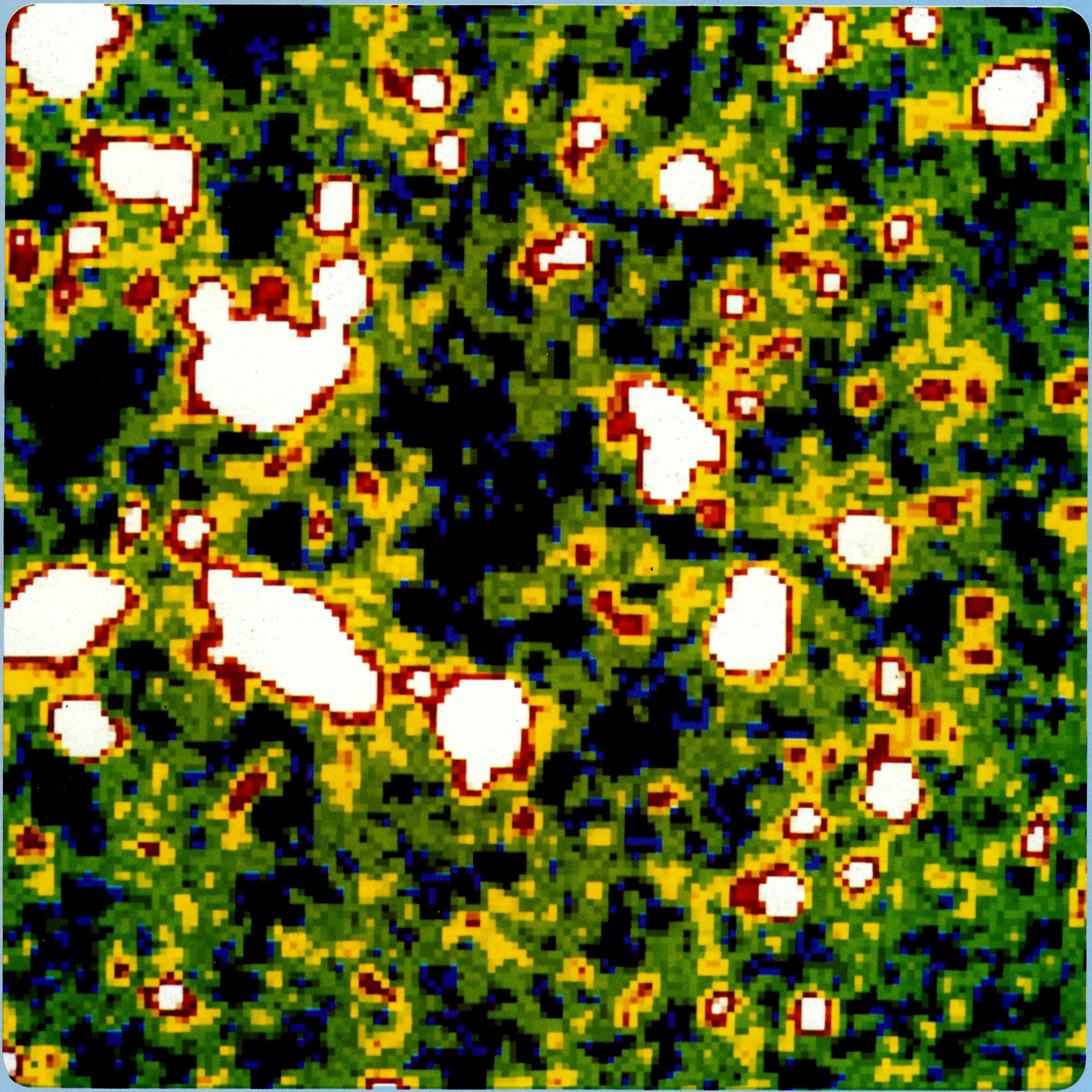

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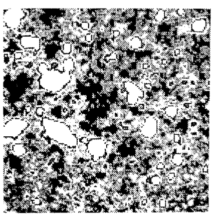

Cover photograph:
These distant galaxies seen by the European Southern Observatory's New Technology Telescope are the faintest objects yet seen by an optical telescope anywhere (see page 33).

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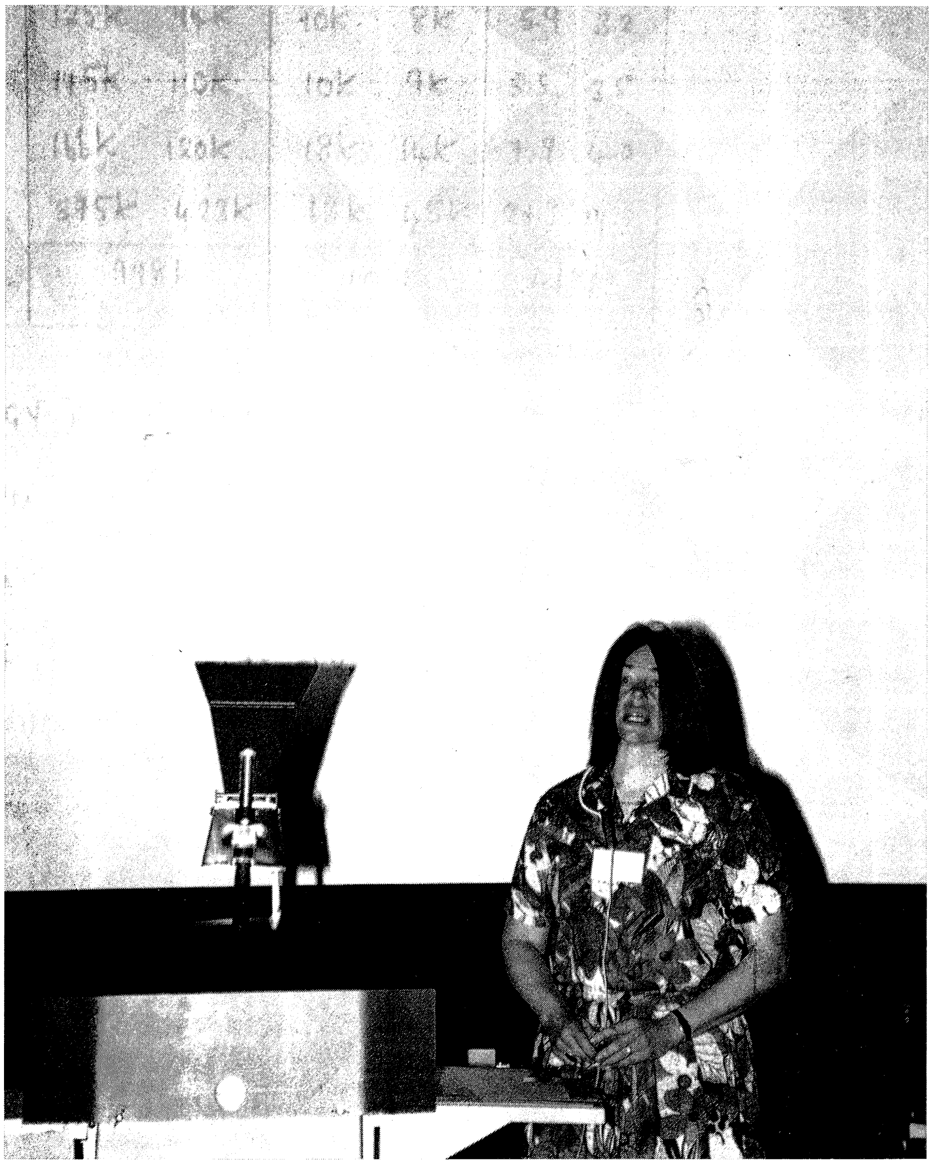
LEP dominates LP-HEP

Janet Carter of Cambridge and Opal – Precision tests of the Standard Model with LEP.



CERN's LEP electron-positron collider was the star of this year's major physics meeting – the Joint International Lepton-Photon Symposium and Europhysics Conference on High Energy Physics (LP-HEP) – held in Geneva from 25 July – 1 August.

All major results so far from LEP, and there are plenty of them, are in accord with the Standard Model of physics – a dual picture with the electroweak unification of the electromagnetic and weak nuclear forces on one hand coupled with the quantum chromodynamics (QCD) field theory of inter-quark forces on the other.

Summarizing the meeting, CERN Director General Carlo Rubbia pointed out the need to probe this picture in as much detail as possible. Far from being a closed book, the Standard Model covers a lot of uncharted territory, with the long-awaited sixth ('top') quark and the neutrino sector still being 'terra incognita', while the spontaneous symmetry breaking ('Higgs') mechanism at the heart of the electroweak unification, and the details of QCD dynamics, are still far from clear.

LEP apart, the meeting reflected the continuing reluctance of the neutrino to give up all its secrets. The long-standing difficulty of pinning down the delicate violation of combined particle/antiparticle left/right switching (CP) symmetry, known for more than a quarter of a century but still not understood, was also a talking point. For both neutrino and CP-violation physics, insights from new areas are eagerly awaited.

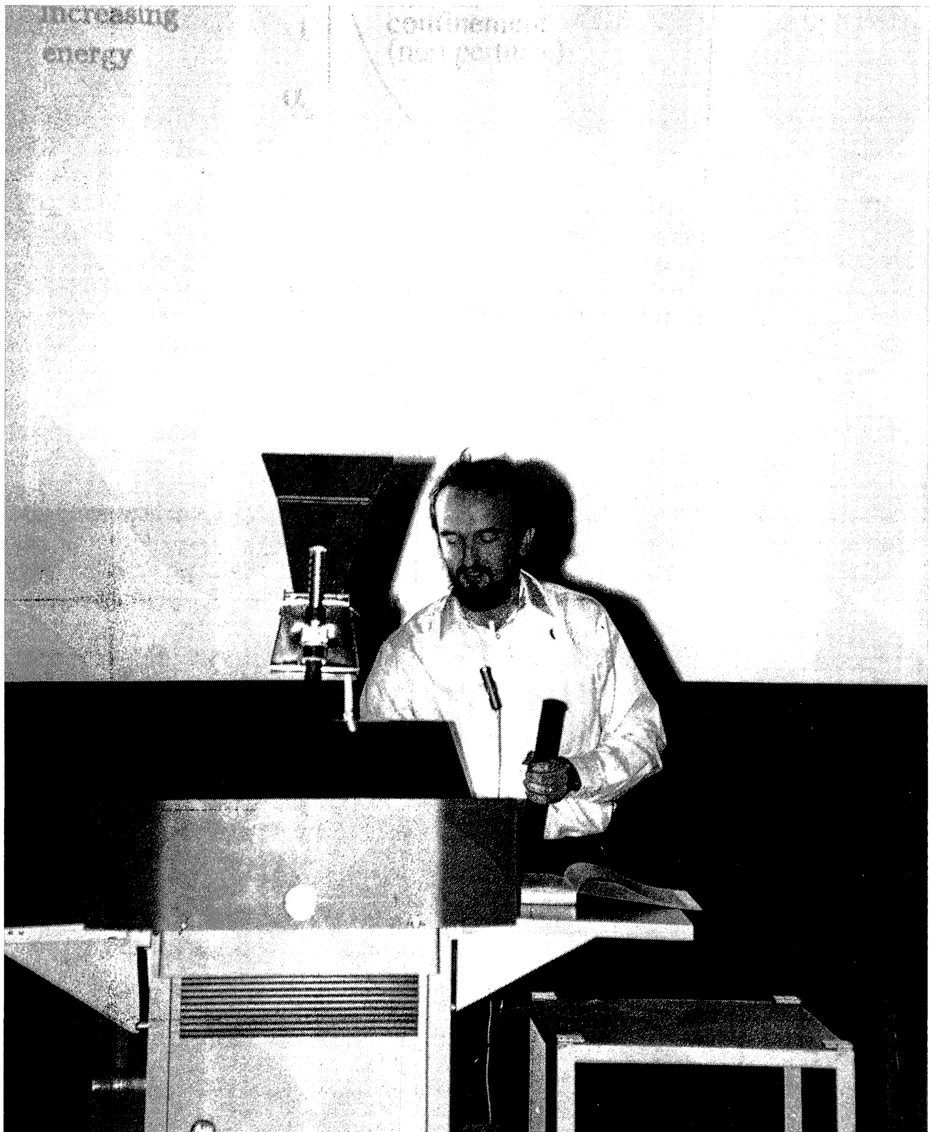
With CP violation effects so far confined to the neutral kaon sector, Rubbia pointed out the need for additional CP violation investigations using B mesons (carrying the fifth 'beauty') quark, and the contributions which could be made with the next generation of proton colliders.

In their keynote talks on the final day, Rubbia and neutrino summarizer Rudolf Mössbauer surmised that the lower energy region, relying on reactors and the Sun, would supply the bulk of new neutrino information. Mössbauer also looked forward to the advent of cryogenic detectors to open up new neutrino fields of study.

Closing the meeting, Sheldon Glashow of Harvard highlighted the changing face of physics. For a century, researchers had been used to a steady stream of surprises to keep them on their toes and stimulate thinking. According to Glashow, the last major particle physics surprise dates back to 1977, with the discovery of the fifth quark through the upsilon particle at Fermilab.

The proposed big proton collid-

Thomas Hebbeker of Aachen and L3 – QCD studies with LEP



ers – LHC at CERN and the US Superconducting Supercollider (SSC) – will surely reach beyond the Standard Model, declared Glashow, but until then the task is to exploit and test the existing picture.

Nowhere is this happening better than at LEP. The four big experiments – Aleph, Delphi, L3 and Opal – at CERN's big ring were deftly treated at the meeting, with parallel session speakers using their own results as pointers but being careful to summarize results from all around the ring.

For the subsequent plenaries, the LEP presentations featured a speaker from each of the four experiments – Janet Carter of Cambridge and Opal (Precision tests of the Standard Model), Thomas Hebbeker of Aachen and L3 (QCD studies), Michel Davier of Orsay and Aleph (Searches for new particles), and Patrick Roudeau of Orsay and Delphi (Heavy flavour physics).

The presented LEP data included more than a million hadronic Z decays seen by the four experiments combined. Janet Carter opened the plenary sessions, setting the tone with a mass of precision data on the Z resonance, together with directional effects in lepton pair production, tau spin orientation, charged hadron production in general and B meson production in particular all supporting the Standard Model and sharpening knowledge of specific parameters.

The consistency of this information, combined with precision measurements from other experiments, provides powerful limits on the top quark, now confidently predicted to live somewhere between 120 and 160 GeV.

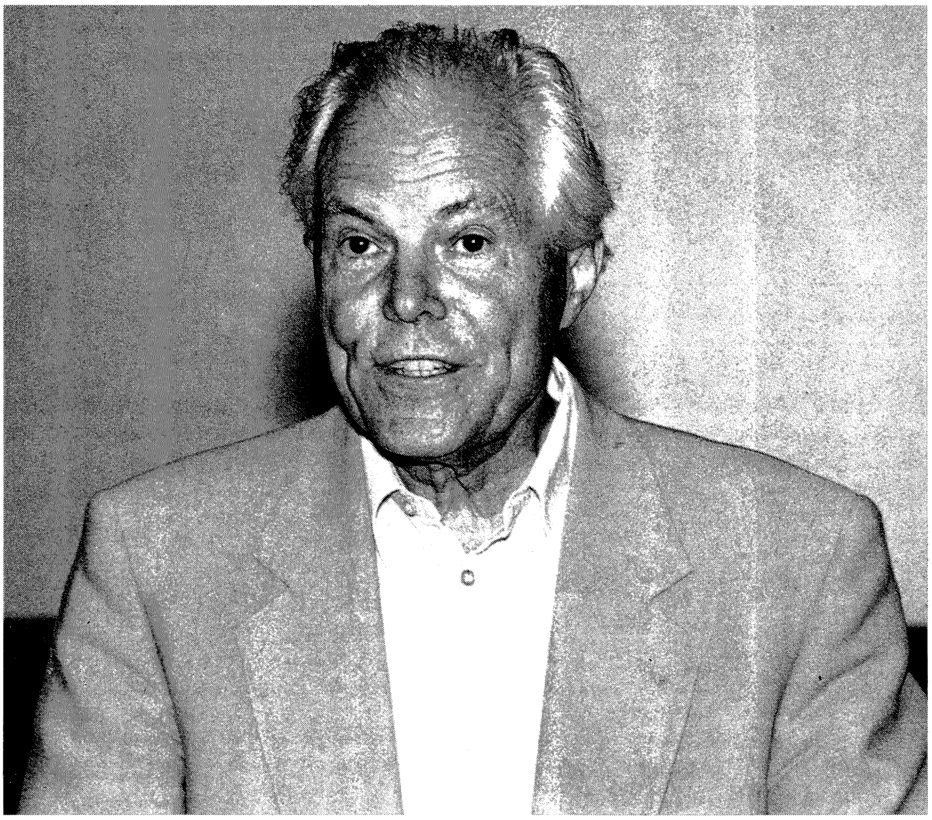
One suggestion of a non-standard effect had come recently from Aleph, where the level of electron-positron annihilations into two tau leptons accompanied by a pair of charged particles was significantly higher than the analogous channels with two muons and with two electrons.

In a parallel session, Sau-Lan Wu of Aleph revealed that the latest data do not continue this trend, which moreover is not seen by Aleph and Opal at LEP, nor by the Mark II detector at Stanford's SLC Linear Collider (S. Wagner).

Another non-standard hint had come from L3 (Juan Alcaraz) in the parallels, where high energy photons accompanying an electron-positron pair invited an explanation. Standard Model theorists were unconvinced.

Speaking on LEP QCD results, Hebbeker pointed out the advantages of LEP for QCD measurements – high energy, high precision and relative freedom from hadronic masking (fragmentation) effects. The coupling strength of quark in-

Rudolf Mössbauer – 15 major neutrino questions still to be answered.



teractions (alpha-s) is measured in both Z hadronic decays and in the production of collimated 'jets' of hadrons. Comparison of the production rates of particles containing heavy and light quarks shows that alpha-s is independent of quark flavour, while the variation of jet production shows how alpha-s is 'running' with energy.

The experiments are beginning to probe many detailed hadronic effects, including the production of hyperons, etc. The average number of charged hadrons produced is just above 20. Initial surveys indicate that hadron jets arising from gluons are softer and broader than those from quarks.

With no new particles yet to report from LEP, Michel Davier concentrated on the Higgs sector, where LEP is at last beginning to shed some light on this obscure, but highly important, mechanism. Whatever it might be, and there is precious little indication, LEP experiments have now ruled out a lot of lower energy territory, and the Higgs must be heavier than 57 GeV. 'The Higgs hunt is now on in earnest,' affirmed Davier.

When the top quark is finally seen (all the smart money is on the CDF experiment at Fermilab's proton-antiproton collider) it might clarify the Higgs, but several speakers emphasized that this was not necessarily the case.

Guido Altarelli had updated a new parametrization method to analyse detailed behaviour and help correlate Standard Model and non-SM effects. This sort of evidence, according to Davier, needs to be monitored closely. On the evidence so far, Rubbia did not rule out a Higgs sighting at LEP after its energy upgrade. Also preoccupied with Higgs were John Ellis of CERN and Graham Ross of Oxford, investigating possible Higgs dynamics in talks on the Status of the Electroweak Sector and Beyond the Standard Model respectively.

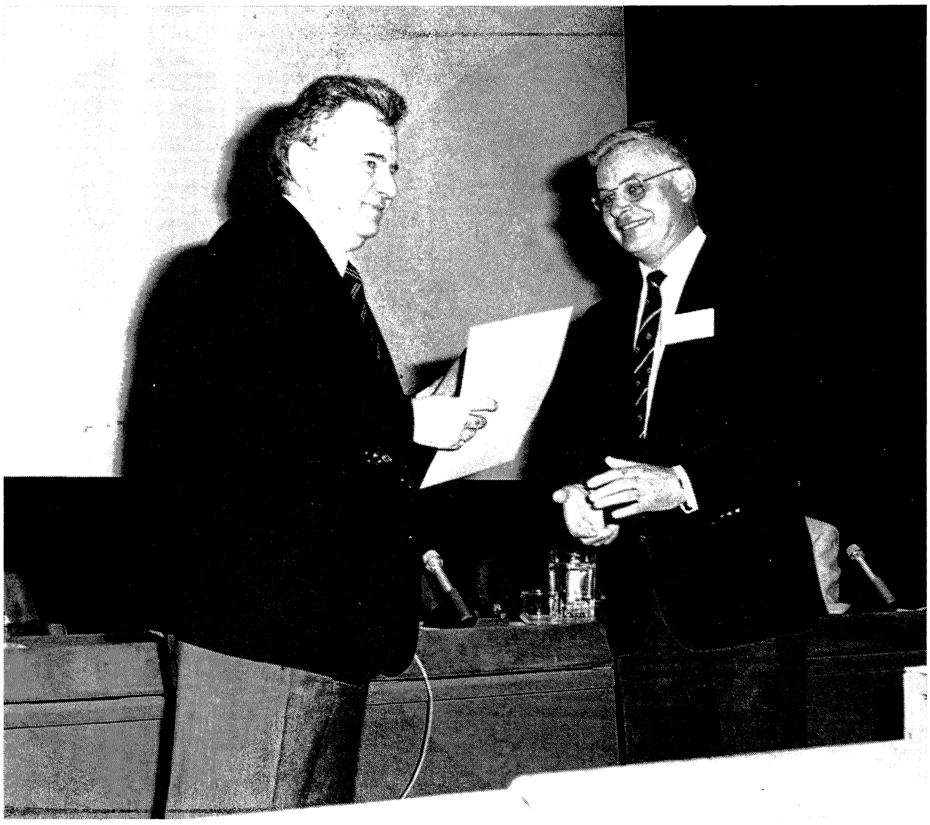
Looking at heavy quark production at LEP, Roudeau showed how b quarks are a powerful probe of directional effects (forward-backward asymmetry), although account has to be taken of B particle mixing. Charmed particles too are also a good source of Standard Model information and are beginning to be studied, while the parameters of B mesons and tau leptons now benefit from LEP data.

Guido Martinelli of Rome described the status of QCD, showing how precision is improving and how more and more processes are becoming amenable to calculation. In this difficult work, approximations are always attractive, but Martinelli remarked that perhaps only the unseen sixth quark is heavy enough to use this approximation confidently.

Neutrino sessions can always be counted on for controversy. With reports of 17 keV neutrinos from several experiments (John Simpson, Guelph) in conflict with a range of null results, the neutrino sector was in relative disarray.

Speaking on cosmology and particle physics, M. Turner of Fermilab was also worried about the 17 keV neutrino. 'It fits nothing, so if it exists it has to be important,' he remarked. Neutrino summarizer Mössbauer called for careful neutrino experimentation in a sector so vital to physics progress. Remarkably little is known about such an important particle, he admitted, displaying a list of no less than 15 major neutrino questions still awaiting an answer.

During the Joint International Lepton-Photon Symposium and Europhysics Conference on High Energy Physics in Geneva in July, distinguished Italian theorist Nicola Cabibbo (left), who is President of the Istituto Nazionale di Fisica Nucleare, was awarded this year's High Energy and Particle Physics Prize of the European Physical Society in recognition of his many outstanding contributions to the subject. July. The prize was first awarded in 1989, when the recipient was Georges Charpak of CERN. Right is European Physical Society President Maurice Jacob.



Merging conferences

This year's big physics meeting in Geneva was, as its convoluted name suggests, a one-off merger between two traditional series of biennial international conferences on high energy physics – the Lepton-Photon Symposium sponsored by the International Union of Pure and Applied Physics (IUPAP), and the Europhysics meeting organized by the European Physical Society.

These meetings take place in odd-numbered years, with the Lepton-Photon event preferring a venue associated with an electron machine. With LEP now marking CERN's debut as an electron Laboratory, this year's merger in Geneva was particularly apt.

Even-numbered years see the traditional IUPAP 'Rochester' meetings, whose worldwide venues aim to reflect the growing geographical spread of high energy physics activity (Singapore in 1990, Munich in 1988, Berkeley in 1986, Leipzig in 1984, Paris in 1982.) Next year's event had originally been scheduled for Moscow, but Geneva IUPAP Particles and Fields Commission Chairman T. Fujii announced that Moscow had backed down, and the 1992 meeting would instead be held in Dallas, Texas, from 5-12 August.

In 1993, the Lepton-Photon and Europhysics events once more go their separate ways, in Cornell (US) and Marseille respectively.

In the coming year, the IUPAP commission will review the rotation of venues for the Rochester and Lepton-Photon series, including the definitions of the world regions on which the rotations are based.

Prominent among them is the solar neutrino puzzle, where the flux of particles coming from the sun is considerably less than the expected value. New experiments – Gallex in the Italian Gran Sasso Laboratory and SAGE in the USSR – use gallium to get a more typical picture of the particles emerging from the deep solar interior, but it is still too early for these new studies to contribute. Barry Barish, summarizing non-accelerator experiments, looked forward to a first crop of gallium solar neutrino data next year.

Another outstanding neutrino question is neutrino masses. Mössbauer thought the improvement expected from traditional measurements is now limited, and that neutrino oscillations – cyclic variations in neutrino type – would be more sensitive.

With mixing well known and fairly accurately measured in the quark sector, it is interesting to speculate on what physics would look like if neutrinos behave in a similar way.

Rubbia pointed out that the big passive experiments needed to look at neutrino effects would also be well suited to search for signs of proton decay, where the longest lifetime from minimal grand unification schemes has long been ruled out, but where other schemes could still allow a tiny hole for basic nuclear instability.

A relatively new feature of the neutrino sector is limitations on neutrino parameters from cosmology – reflecting the important role these particles play in basic physics. Graham Ross showed how the 17 keV neutrino candidate is tightly constrained by cosmology. Turner, in his cosmology talk, des-

cribed how nucleosynthesis following the Big Bang excludes the tau neutrino mass from the range between 0.5 and 25 MeV. With the ARGUS experiment at DESY indicating it to be lighter than 35 MeV anyway, the tau neutrino does not have a lot of room left.

CP-violation can be accommodated in, but not explained by, the Standard Model. Two major high precision experiments, one (NA31) at CERN and the other (E731) at Fermilab, have for several years been patiently accumulating and analysing data on the decay of neutral kaons into pairs of charged and neutral pions.

Over the years, batches of data from these two experiments have come in with different values for a parameter related to the 'ratio of ratios' – the relative decay rates of long- and short-lived neutral kaons into neutral and charged pion pairs. Now each with samples of more than two million neutral kaon decays, the experiments do not necessarily disagree, but the agreement could be better, making any precise interpretation difficult.

A fresh CP violation feature was a preliminary result from the CP LEAR experiment at CERN's low energy antiproton ring, where evidence has been seen for different decay properties of particle and antiparticle.

In the plenary session, J.-M. Gerard of Louvain looked hard at the framework of CP violation, where the limited room for CP violation appears to hinge on limitations on quark transitions, and on empirical isospin selection rules long known but still not understood.

Looking to the future, with plans for complementary particle physics machines to attack the high energy and high precision frontiers, Carlo Rubbia was optimistic. 'Nature has put the answer to many questions within our reach,' he concluded.

By Gordon Fraser

Computing in high energy physics

The increasingly important role played by computing and computers in high energy physics is displayed in the 'Computing in High Energy Physics' series of conferences, bringing together experts in different aspects of computing - physicists, computer scientists, and vendors.

The meetings have been held every one or two years since 1980 when the series was initiated in Bologna, and are traditionally organized under the initiative of the local organizing committee. For the recent conference in Tsukuba, Japan, the local organizing committee was chaired by Shinkichi Shibata of the Japanese KEK Laboratory with an international advisory committee through the LISTSERV electronic conference system.

The sessions began with John Thresher (CERN) who raised various questions on the computing environment of the 1990s - the major factors being evolution of computing environments due to appearance of high-performance microprocessor-based workstations and world-wide large collaborations for experiments at the planned big hadron colliders (SSC/LHC). K. Amako (KEK), M. Delfino (Barcelona,CERN), D. Notz (DESY), and T.Nash (Fermilab) reported on the current status of HEP computing in their respective laboratories, each facing the transition from mainframe-based centralized computing to a distributed or collective computing environment with various types of machine – mainframe, supercomputer, computer farm, and workstations, linked by networks. The transition appears to be coherent.

David Williams (CERN) asked 'Is the role of the mainframe terminated ?', anticipating a rundown of the mainframe emphasis in the next five years. But he is still worried about performance of the distributed system in data I/O and software and operational stability without the mainframe.

L.R. Cormell (SSCL) reported on the recent installation of the computer facilities at the US Superconducting Supercollider (SSC) Laboratory, where a 'farm' has been installed for batch jobs and interactive front-end workstations for physics/detector simulation of SSC experiments. There is no mainframe-like system.

A feature of this year's Computing in High Energy Physics Conference in Tsukuba, Japan, was a panel discussion chaired by Terry Schalk (UCIPP) on the worldwide computing environment, featuring ten in-person panelists plus Harald Johnstad from the Texas SSC Laboratory on the TV screen a video conferencing link.

Architecture

Many presentations looked at the problem of architecture. There has been considerable progress in special-purpose chips for the requirements of SSC/LHC experiments (R. Bock – CERN). Data acquisition is also architecture-related in large and complicated time-critical systems (P. Le Du – Saclay). Real time processing for event filtering in the second or third level trigger is a field for which various modern technologies are applicable. At higher levels, neural networks are beginning to be used as part of trigger systems (M. Campbell – Michigan). Trigger simulation to separate signals from background events in the Fermilab CDF experiment promises well for the application of neural net triggering.

Although high energy physics has traditionally used scalar computer systems, there is now some effort to utilize more complex architectures such as vector supercomputers and massively parallel systems. Y.Iwasaki (Tsukuba) described recent progress for a special computer system for lattice gauge simulation. Several large projects of this kind are underway in Japan, the US, and Europe.

Software engineering

Software engineering is the biggest challenge facing high energy physics today. The most significant factors are the number of people who contribute to the software, the fact that they work in many different institutions around the world and that few of them are trained in computer science or programming. These factors would make most programming experts give up before they start. For some time, there was a belief that the engineering problem was simply one of choosing the right design tools. Some groups adopted Structured Analysis/Structured Design (SA/SD) in the hope that they would be able to generate correct and maintainable code without doing any extra work. In many cases, they were disappointed and dropped the idea.

K. Hashimoto (Fujitsu) and J. Knobloch (CERN) looked at recent software engineering experience in the business world and HEP, respectively. In general, Hashimoto suggested, large scale software developments should be broken up into small independent elements as much as possible to reduce coupling overhead. Software productivity is inversely proportional to the size of these elements. J. Knobloch talked on the 'Reality of software engineering in HEP', where there are sceptics. Some recent advanced tools are fulfilling HEP requirements, but it is not yet standard practice everywhere.

Database management is one aspect of software engineering to deal with large volumes of data, including calibration, run conditions, and analysis parameters. The database must be maintained and updated automatically, advocated L.M. Barone (Rome).

In the near future new approaches such as object-oriented or extensible databases may make it easier to add relationships among data elements as the understanding of the database improves. As groups begin to look at the expected needs of the SSC/LHC experiments there are likely to be dramatic changes in data management.

R.Grossman (Illinois) explained ideas of database computing for future HEP data analysis, using built-in database functions without a need for FORTRAN programming, or FORTRAN can be mixed with a query language such as SQL.

D. Shirkov (Dubna) introduced computer algebra and recent techniques such as REDUCE, MACSYMA, MAPLE, Mathematica, and Scratchpad, used to calculate observables to compare with experimental results. This provides a bridge between physics and mathematics as well as between experiment and theory.

UNIX operating system

The conference perhaps marked the emergence of UNIX as a part of the high energy physics vocabulary. Even those who hoped, or believed, that UNIX would disappear now agree that it will continue to be important.

This results from the use of UNIX on virtually every major workstation and computer server. With the rapid evolution of computing technology, vendors have had to adopt a (nearly) standard portable operating system to avoid significant delays in bringing new products to market. This will continue in the foreseeable future.

The proliferation of workstations presents a new set of management challenges. The systems need to be updated and maintained on a regular basis, and the community is only beginning to address these issues.

While UNIX will have an important role in HEP, the VMS and VM systems are still used by a majority of the community. At most laboratories, these systems are saturated while the UNIX workstations are idle much of the time. Physicists like productive systems, and the situation will evolve only slowly unless the UNIX environment can provide the same productivity. Efforts to make the UNIX environment more familiar to the VM or VMS users may help but more likely new, high-level interfaces will change the way physicists work with their computers.

J.N. Butler (Fermilab) described the impact of UNIX for HEP and prospects for the future. Undesirable UNIX features include inadequate security, system management tools, resource management, and tape support, and nowhere to go for problems with commands and features. HEP will adapt and learn to love it, he said, by developing suitable environments and using a language physicists can understand, such as PAW.

F. Etienne (Marseille) spoke on graphics in the network environment.

L. Robertson (CERN) described a 'shift' project at CERN which aims to build a scalable heterogeneous integrated facility with CPU server, tape servers, disk servers and Cray connected by ULTRANET HUB. This includes functions such as a disk pool, tape-disk copy scheduler, portable UNIX tape control system, and batch system. The pilot project started last year.

On the other hand, C. Eades reported on the Berkeley central UNIX facility, stressing that the central facility must play an important role as a centre of expertise, training and information. The management service for workstations is also a function of the central facilities, but does not need to provide CPU for individuals.

User interface/graphics

One of the keys to enhanced physicist productivity is the user interface. Improvement is due largely to the ease with which the interfaces and visualization systems can be developed.

Many computer systems now have interface builders or visualization systems, facilitating the creation of applications by letting the user define an interface graphically rather than by writing code. Examples are NeXT's Interface Builder, UIMX and TeleUSE for X Window and SuperCard for the Macintosh.

The Application Visualization System (AVS) from Stardent has been used to develop powerful visualization programs. Many of the interface building programs are associated with Object Oriented Programming systems (OOPs).

Paul Kunz (SLAC) reviewed various analysis tools – LUND, GEANT, PAW, KAL, Cheetah, CABS, LUND++, Gismo, Reason, pointing out that although many tools are highly developed, their integration with each other remains poor. The use of C or an object-oriented language may lead to a revolution in physics analysis tools.

Graphics is also an important user interface, particularly in a network environment. F. Etienne (Marseille) talked on graphics for networks and graphical user interfaces. For a standard for graphics, the X Window system with MOTIF is a good compromise to optimize manpower resources for building and maintaining distributed graphics applications on a very wide range of hardware.

Networking

Networking has become more important as the size and geographical extent of collaborations has increased and has become vital to the success of most experiments and even much theoretical work. On the basis of L3 experience, R. Mount (Caltech) stated that the network is a lifeline of high energy physics.

F. Fluckiger (CERN) and W. Lidinsky (FNAL) reviewed the current status of networking in Europe and the US respectively and its future prospects. In the last few years, the speed of network links has increased significantly. In 1987, the typical link operated at 9.6 kbps. Today, the principal links operate at 1.5 or 2 Mbps within the US and Europe, with a 1.5 Mbps link between the US and CERN. Other international lines typically operate at 64 kbps.

Even so, many local and wide area networks are approaching saturation, with workstations doing local data analysis and with data samples becoming larger

At the same time new capabilities are being added. An example is video conferencing. Speaking from Texas, G. Chartrand (SSC) described video-teleconferencing in the US and recent developments using a teleconference system installed for the conference.

Current technology permits conferencing over links operating at 128 kbps using video compression and decompression units (CODEC) to provide quasi-full-motion video. Industry and research groups are now working on ways to include video into the same packets that now transmit data. When these systems are operational, video conferencing and multi-media messages will be as ubiquitous as electronic mail is today.

V. Schegelsky (Leningrad) spoke on computing for high energy physics in the USSR.

International collaboration

The last day of the conference featured a panel discussion on collaboration for the unified environment of the computing in HEP. The ten panellists in situ were joined by H. Johnstad (SSC) and L. Price (Argonne) via video conferencing links from the SSC and Fermilab, respectively.

The meeting contributed significantly to ongoing world-wide collaboration. The next CHEP meeting will be in Annecy, France, from 21-26 September 1992, organized by Annecy and CERN.

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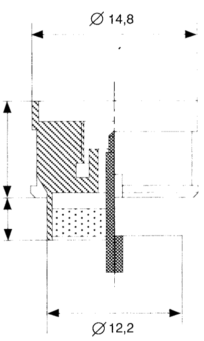

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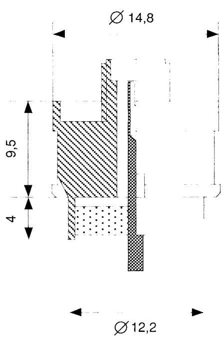

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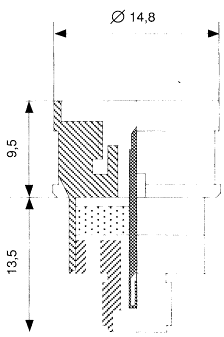

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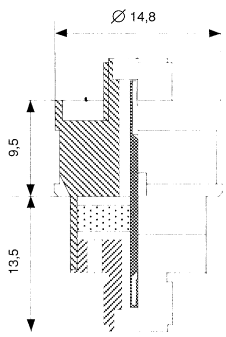

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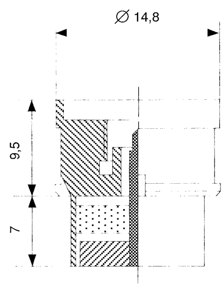

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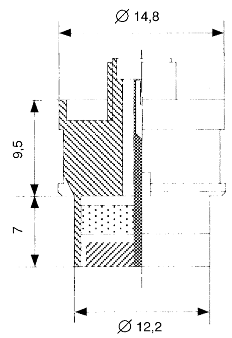

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Around the Laboratories

With Poland becoming CERN's 16th Member State, the Polish flag is symbolically hoisted outside the Laboratory's main entrance.

(Photo CERN H1 30-6-91/13A)

CERN
Widening horizons

At its June meeting, CERN Council, the governing body of the Organization, voted to accord Observer status to the Soviet Union and to Israel, who join Turkey and Yugoslavia as states able to send delegations to Council meetings and to receive official documents.

Observer status can be used as a springboard to increased involvement in CERN, a good example being Poland, long an Observer State, but which recently became CERN's 16th Member State.

CERN/USSR
Closer collaboration

The decision of CERN Council to grant Observer status to the Soviet Union is a new milestone in a long history of collaboration between European and Soviet particle physicists which bodes well for the continued success of their research programmes.

CERN/USSR collaboration dates back to the early 1960s, when the world front-line machines were the 10 GeV Synchrophasotron at the Joint Institute for Nuclear Research, Dubna, near Moscow, CERN's 26 GeV Proton Synchrotron, and the 30 GeV Alternating Gradient Synchrotron at Brookhaven in the US.

The next important step was when the Soviet Union decided to build a 76 GeV proton machine, to become the world's highest energy particle accelerator, at a new Institute of High Energy Physics at Serpukhov, near Moscow.

Under an agreement between CERN and the Soviet State Committee for Atomic Energy, signed in July 1967, CERN provided special equipment for the new accelerator (a fast beam extraction system and a radiofrequency separator), in return for which scientists from CERN and its Member States could participate in the Serpukhov experimental programme.

This was the first example of a physics mutual aid approach often called these days the 'HERA Model', underlining the major international contributions to the electron-proton collider now being commissioned at the German DESY Laboratory in Hamburg.

The 1967 agreement led to a series of joint European – USSR physics studies at both the Serpukhov and CERN machines, which continue to this day, while the Delphi and L3 experiments at CERN's LEP electron-positron collider include strong Soviet contingents.

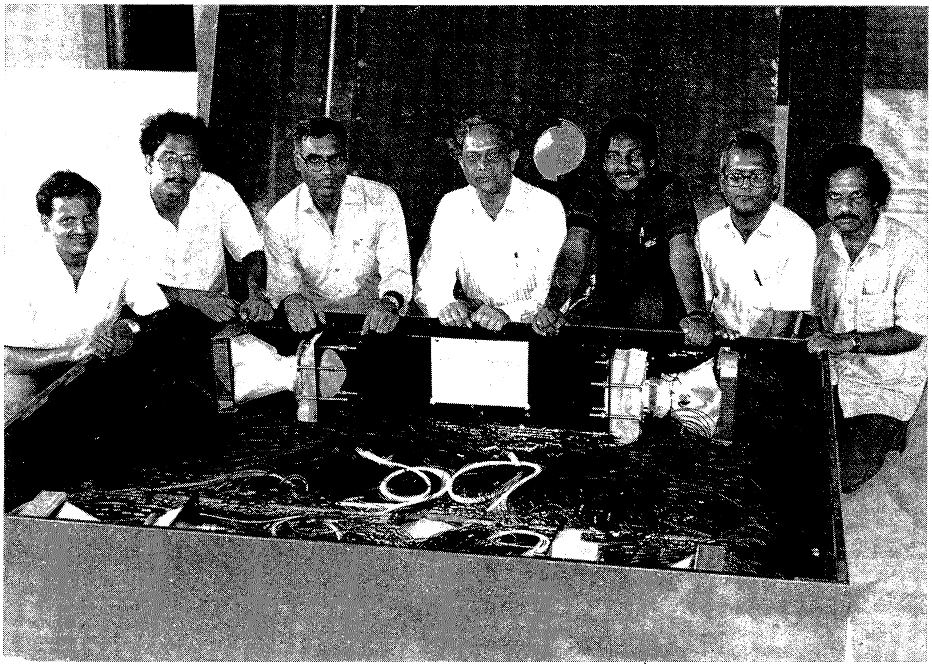
Subsequent protocols, dated 1975 and 1983, extended the CERN-USSR collaboration framework, and 1988 discussions looked specifically at mutual aid for major new projects – the proposed LHC proton-proton collider at CERN, the UNK proton machine under construction at Serpukhov and the VLEPP electron-positron linear collider proposed for Serpukhov with specialist assistance from the Novosibirsk Institute of Nuclear Physics.

In Moscow in May, CERN Director General Carlo Rubbia and Soviet Minister of Atomic Power and Industry V.F. Konovalov signed a new General Cooperation Agreement. This initially covers three items: USSR contributions to the project to increase the LEP energy and for the upgrading of external beams at CERN's SPS synchrotron; CERN contributions to the UNK control system and to its beam diagnostics; and a collaboration framework for the research and development programme for LHC detectors. A fourth protocol, yet to be finalized, would cover major USSR participation in LHC construction.

Soviet equipment earmarked for the LEP energy upgrade includes distribution transformers, high pressure helium storage, cryogenic transfer lines and power converter transformers. Initial shipments arrive this year. Likewise the first CERN high technology for the UNK control system should make its appearance at Serpukhov this year.

Soviet contributions to LHC detector development will concentrate on vertex detection, tracking, calorimetry, electron and muon identification, radiation resistance, and data acquisition.

The Cyclotron Centre at Calcutta, India, in collaboration with the Universities of Jammu, Chandigarh and Jaipur, has developed and assembled the photon multiplicity detector for the WA93 heavy ion experiment at CERN. Signals from the detector's plastic scintillation pads are transmitted using wavelength-shifting optical fibres, and read out using the image intensifier and CCD camera system from the UA2 experiment at CERN's proton-antiproton collider. The plastic scintillator and optical fibres were supplied by GSI, Darmstadt, Germany. All fabrication and assembly has been done at the Calcutta Cyclotron Centre.



CERN
Multiplicity detector from India

A highly granular pre-shower detector for measuring the number of photons produced in high energy heavy ion collisions has been designed and fabricated for the WA93 experiment at CERN by a Calcutta/Chandigarh/Darmstadt/Jaipur/Jammu collaboration.

The motivation for detailed photon multiplicity measurements over a wide solid angle comes when the large numbers of secondary particles in collisions of very heavy ions like lead are expected to produce only small variations in the ratio of photons to charged particles. However collisions producing quark-gluon plasma – the long-awaited state of matter where quarks break loose from their conventional confinement in nucleons – may produce an appreciable excess of photons.

The detector consists of a matrix of 7600 plastic scintillator pads, each 20 x 20 x 30mm, behind thick lead converter plates, and covers the forward hemisphere for 200 GeV/nucleon sulphur on gold collisions. Light from the pads is collected and transported by wavelength-shifting optical fibres read out using a 3-stage image intensifier and CCD camera system developed and used by the UA2 experiment at CERN's proton-antiproton collider.

The design, fabrication and assembly of the detector has been carried out at the Variable Energy Cyclotron Centre, Calcutta, with students and faculty from the three other collaborating Indian institutes.

The detector has recently been tested at CERN using electron, pion and muon beams in preparation for data-taking with a 200 GeV/nucleon sulphur beam in October. For heavier ions, a much larger detector, covering some 20 sq m, is planned.

CERN/NOVOSIBIRSK
Electron cooling improvements

A collaboration between CERN and Novosibirsk's Institute for Nuclear Physics (INP) has developed improved techniques for electron cooling in CERN's LEAR low energy antiproton ring.

Novosibirsk is the birthplace of electron cooling. It was there in 1974 that the team of G. Budker and A. Skrinsky first demonstrated the technique, using the small NAP-M storage ring.

Electron cooling, in which an unruly beam is 'tamed' by coming in contact with an electron beam of well-defined momentum, was overshadowed by Simon van der Meer's subsequent invention of stochastic cooling, which played a vital role in the big proton-antiproton collider projects at CERN and Fermilab in the 1980s.

The importance of electron cooling reemerged with the requirement for ultra-cold beams in low energy storage rings such as LEAR. Whereas stochastic cooling works well for relatively large beams of rare particles, electron cooling is very efficient to 'post-freeze' beams already reasonably cool. The LEAR electron cooling system was developed by CERN and KfK Karlsruhe using equipment taken over from CERN's early ICE (Initial Cooling Experiment) project.

In electron cooling, the accelerated electrons are picked up by high voltage collector electrodes, and the particles flow back to the cathode via a conductor, forming in effect a sort of subsidiary storage ring.

The LEAR collector must operate with electron beams of several amperes and energies of several tens of keV. Under these conditions, the primary electron beam hitting the collector produces many secondary particles, which in turn sputter material from the walls of the vacuum chamber and degrade the vacuum.

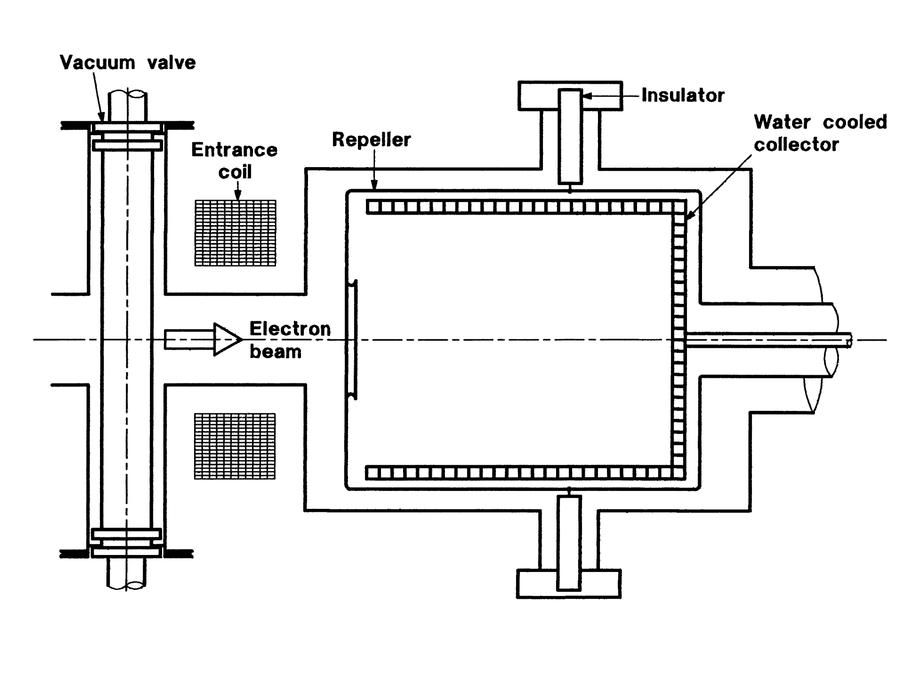
To suppress these unwanted secondaries, the collector systems use a special arrangement of electric and magnetic fields . The original LEAR collector consisted of a series of elaborate electrodes, but proved to be unreliable at high voltages and inefficient for routine operation at LEAR. CERN invited the Novosibirsk electron cooling pioneers to design, build and test a new unit. This was entrusted to INP's new Centre of Applied Physics and Technology at Lipetsk CAPT INP (January/February 1989, page 23). The collaboration was headed by J.Bosser (CERN) and I.Meshkov (CAPT INP).

After more than a year of hard work and frequent exchanges between CERN and CAPT INP specialists, the new collector has recently been installed and tested in the LEAR electron cooler. The device consists of a Faraday cup with a suppressor (repeller) electrode at the entrance. It is connected to the main cooler via a vacuum valve to allow repairs without disturbing the main LEAR vacuum. Another important constraint was the need to keep the existing power supplies.

First results are in accord with the original CERN specifications, with a tenfold improvement in collection efficiency which is now 99.95%. Tests are continuing.

The CERN/CAPT INP collaboration is continuing to investigate replacing the present source for the LEAR electron cooling with a new variable current gun.

Schematic of the new electron cooling collector for CERN's LEAR Low Energy Antiproton Ring, developed by a collaboration between CERN and Novosibirsk's Institute for Nuclear Physics.



GRAN SASSO
Roman lead for physics experiments

On June 15 at Oristano (Sardinia) a formal ceremony marked the start of an underwater archaeological campaign sponsored by the Istituto Nazionale di Fisica Nucleare (INFN) to recover the load of a Roman freighter (*navis oneraria*) which sank off Sardinia carrying an exceptionally large load of lead.

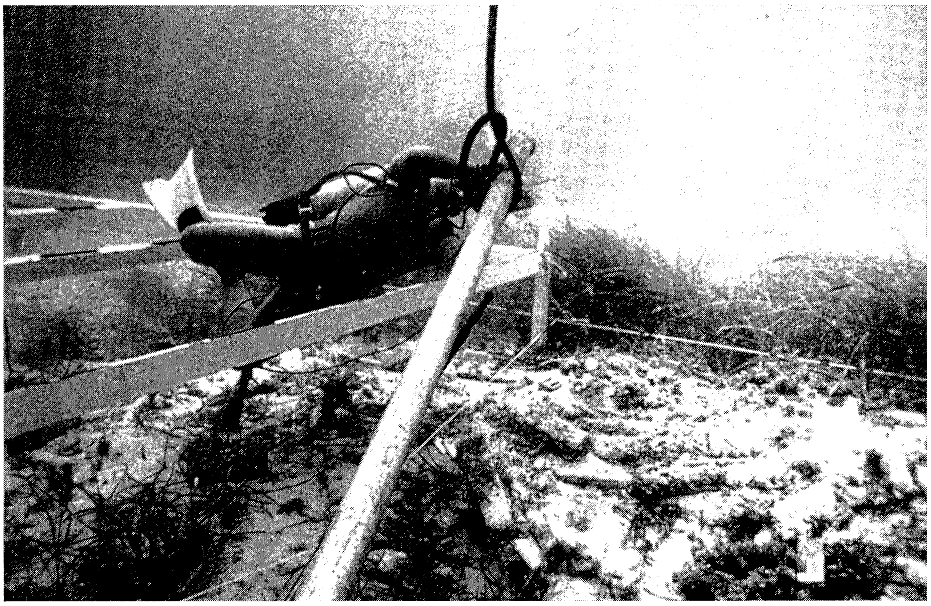
INFN's interest in obtaining part of this lead comes from the metal's particularly high value as a shielding material in delicate experiments, such as the interactions of solar neutrinos, or rare decay processes. These studies require strong suppression of background counts from charged cosmic rays, neutrons and gamma rays.

The charged cosmic ray background is greatly reduced deep underground. In the Laboratori Nazionali del Gran Sasso, under 1400 metres of rock, the intensity of charged cosmic rays is reduced by about 10^{-6} compared to the surface signal.

Neutrons are also considerably reduced, but less effectively since they are only partly produced by cosmic rays, some being generated by spontaneous fission in the rocks. In the Gran Sasso Laboratory the radioactivity of the rocks is rather low and therefore the fluxes of thermal and fast neutrons are three to four orders of magnitude smaller than in any low background laboratory on the surface.

But underground gamma ray background is similar to that on the surface, due to the radioactivity of surrounding rocks or construction

A diver at the wreck of a Roman freighter which sank off the Sardinian coast some 2,000 years ago carrying a load of lead. Protected from environmental radiation by some 30 metres of water, this lead will provide valuable low-background shielding for precision physics experiments.



materials. Reduction of gamma rays, essential for sensitive experiments, can only be accomplished by shielding the detector with suitable materials of high atomic number and low intrinsic activity.

Its reasonable cost, special mechanical properties, low neutron yield and high atomic number make lead an ideal material for shielding gamma rays. While for radiation protection purposes its intrinsic radioactivity is negligible, for highly sensitive low radioactivity experiments residual activity (due to lead-210 and its daughter nuclides bismuth-210 and polonium-210) may limit its usefulness.

Certified low-radioactivity lead is mainly produced for the electronics industry and is far too expensive to be used in large quantities. An alternative is old lead produced several half-lives (22 years) of lead-210 ago. However such lead is rare, since sources like water pipes, sunken shiploads, or sailing ship ballast are not frequently found.

The recent discovery of this Roman wreck loaded with lead has therefore triggered the interest of physicists Gianni Fiorentini and Ettore Fiorini, who have promoted, together with archaeologist Donatella Salvi, the rescue collaboration between INFN and the Italian authorities for artistic and historical heritage.

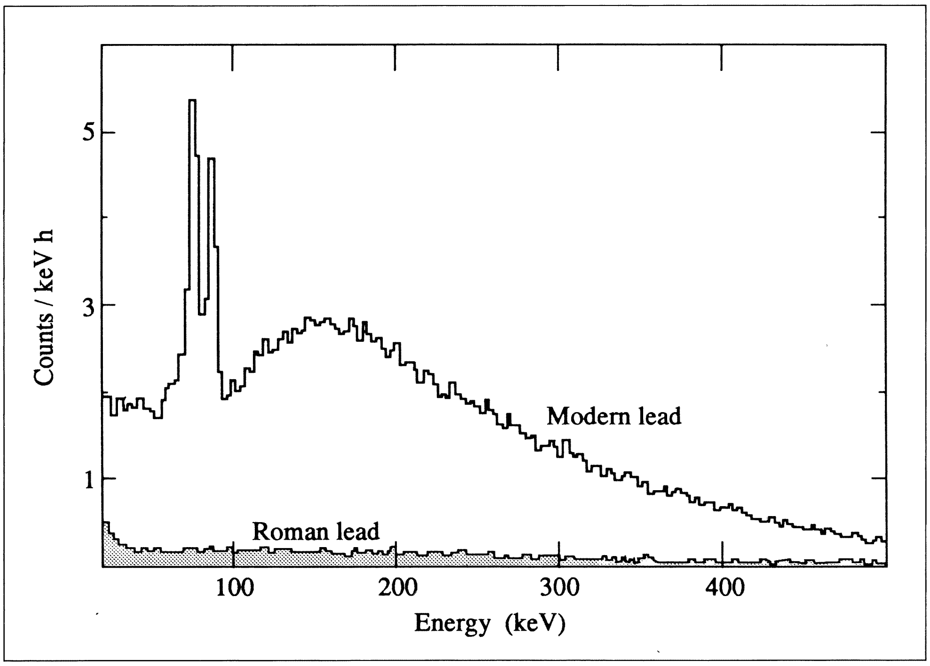
The agreement foresees financial support from INFN, use of part of the lead for researches at the Gran Sasso laboratory, and the creation of a database of all recovered material for archaeological studies. Several physicists and archaeologists are cooperating in the project.

The age of the Roman lead and the protection afforded by the water prevent visible contamination not only from lead-210 but also possibly of other long-lived naturally-produced radioactivity. For more than two thousand years the ship has lain on the sea bed at a depth of about 30 m, well shielded against environmental neutrons and radioactive remnants of the Chernobyl accident.

A sizable amount of this lead has been analysed by a Milan group, who have carried out measurements of X-ray fluorescence and diffraction, neutron activation and alpha, X-ray and gamma ray spectroscopy. Alpha, X-ray and gamma ray spectrosco-

One of the lead ingots found in a Roman ship sunk near Sardinia, with the manufacturer's mark. This lead turned out to be of extremely low radioactivity and will be used for delicate physics experiments at the underground Gran Sasso laboratory.

Comparison of the residual low energy radioactivity in modern and Roman lead.



py was also carried out for comparison on samples of modern lead, on specially-produced low radioactivity lead and on a sample of lead about 500 years old.

The intrinsic radioactivity of the Roman lead was found to be extremely low, showing its potential usefulness in low activity experiments on rare decays and in low level gamma spectroscopy.

The wreck is located near 'Mal di ventre' island off the south-west coast of Sardinia, where strong winds and small protruding rocks have made this area of sea notorious. The lead ingots lie on a flat, sand-covered sea bottom over an area 36 x 12 metres, delimited by the position of the anchors: one iron anchor lies on the prow, and three lead anchors on the stern, with two symmetrically arranged lead counterbalances. The size of the ship and the large quantity of lead ingot cargo indicates an *oneraria magna* adapted for carrying heavy loads of metals – the keel is reinforced by iron nails more than 70 cm long.

The estimated 1500 ingots each weigh about 33 kg (about 100 Roman pounds). Their shape and weight dates them to the first half of the first century BC, which ties in with accompanying pottery and the names of the ingot manufacturers, familiar from previous discoveries. The most frequent name is that of the Pontilieni family (*Societas* of Caius and Marcus, sons of Marcus), a family of the Fabia tribe active in the middle of the first century BC. Other ingots bear the mark of Caius Hispalius of the Menenia tribe.

The Spanish mining activity of these families of Italian origin is well known. On the other hand the discoveries of a considerable number of ingots in the Mediterranean sea demonstrate that such metals were widely spread. Lead was used in large quantities for a variety of purposes such as water pipes, anchors, net sinkers and lead clamps used in the construction of stone buildings. The large quantity of this metal found as a part of the shipload near Mal di Ventre island proves that specific ships were used to carry ingots to markets.

Identification of the source of this consignment is of considerable archaeological interest. In principle, it should be possible by comparing trace elements and lead isotope ratios of the ingots with ore from possible source regions, mainly on Sardinia itself and in southern Spain. Although these regions are geologically rather similar they may be geochemically differentiated. In addition, it would be interesting to see if all the ingots have a similar composition and therefore derive from a single ore deposit.

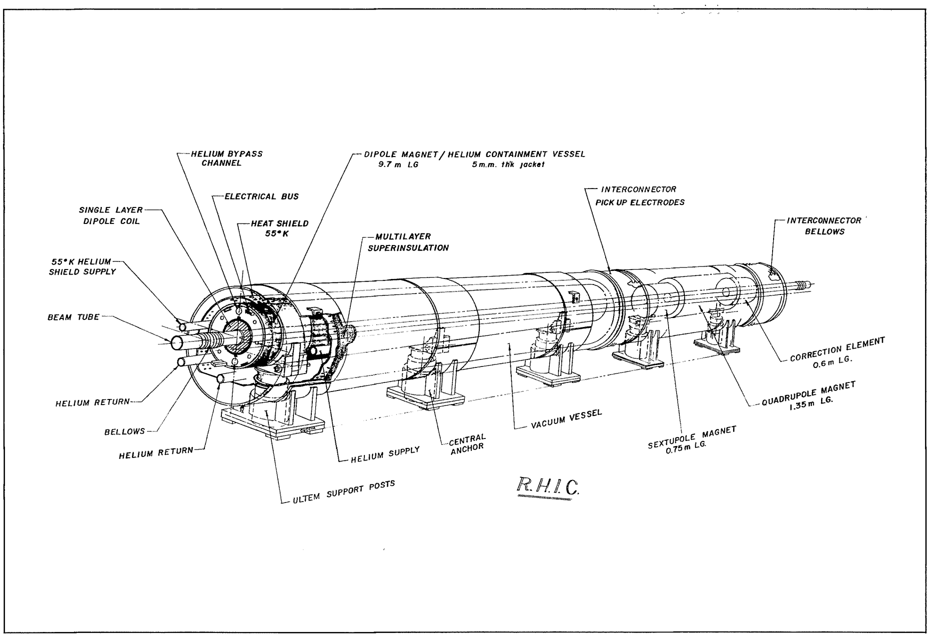
Thus, after an interval of two thousand years, the products of the once flourishing Roman metallurgical industry and the Pontilieni multinational concern are again in demand!

By Alessandro Pascolini

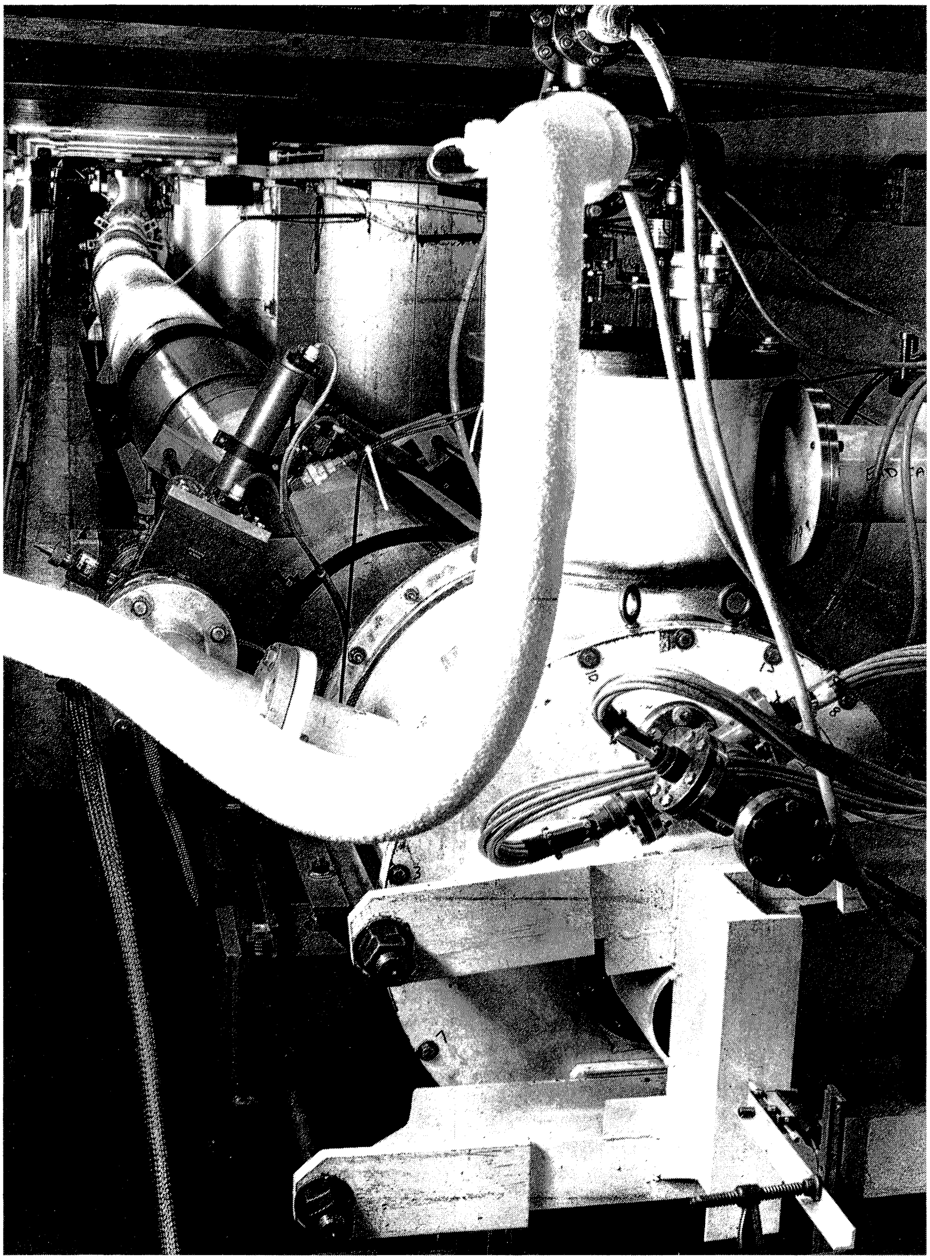
BROOKHAVEN RHIC magnets: industrial procurement and first system tests

Brookhaven's Relativistic Heavy Ion Collider (RHIC) project is now nearing the end of its first full year of construction – a year in which the major emphasis has been on groundwork for industrial production of the machine's superconducting magnets.

About three-quarters of the 1600 superconducting magnets for RHIC are expected to be produced in industry, using designs developed and tested at Brookhaven. These include all of the dipole, qua-



◀ *A half-cell of the RHIC magnet lattice.*



▼ *Superconducting magnets for the RHIC ion collider at Brookhaven under test.*

drupole, sextupole and corrector magnets with the machine's standard 80 mm bore.

Commercial studies of these designs have found the technology well suited for transfer to industry, and an Industrial Technology Orientation session held in October 1990 was attended by about 80 participants representing 34 interested industrial firms. A request for proposals for commercial manufacture of the arc dipoles, the largest RHIC magnets, is in the final stages of preparation, with bids on the other magnet types soon to follow.

In the meantime, the first tests of an interconnected Full Cell system were begun last November and have now been successfully completed. These tests have shown that the RHIC magnets, which had performed according to expectations when tested individually, also show no surprises when operated as a system.

After a major R&D effort, prototype tests were first carried out on each type of magnets for the arcs of the machine – the dipoles and quadrupoles are the largest components, for bending and focusing the beams; the sextupole magnets and corrector coils eliminate unwanted field components and fine-tune the particle orbits.

Within the 12 arcs of the two RHIC rings the magnets are arranged in a lattice, with a basic cell repeated 12 times in each arc, each cell consisting of two dipoles and two quadrupole-sextupole-corrector packages.

The first Full Cell tests aimed to validate the design of the electrical and mechanical interconnections and to operate the Full Cell as a system and monitor its thermal and electrical performance.

During the tests the Full Cell was taken through several cooldowns and was electrically ramped through 375 power cycles, taking the dipoles from 580 to 5000 amperes at a ramp rate of 80 amperes per second, corresponding to the acceleration cycle of the collider. A current of 5000 amperes in the dipole magnets corresponds to the top design energy (100 GeV/nucleon for gold beams), with a field of 3.45 Tesla.

In addition the Full Cell was subjected to 26 quench tests, with the current in the dipoles and quadrupoles increased until some portion of the conductor ceased being superconducting. This current sets the upper limit for magnet operation. As expected, all quenches occurred in the dipole magnets – the first at 6168 amperes, well above the operating value for the machine. Subsequent quenches occurred above 7000 amperes, a full 40% above the operating value.

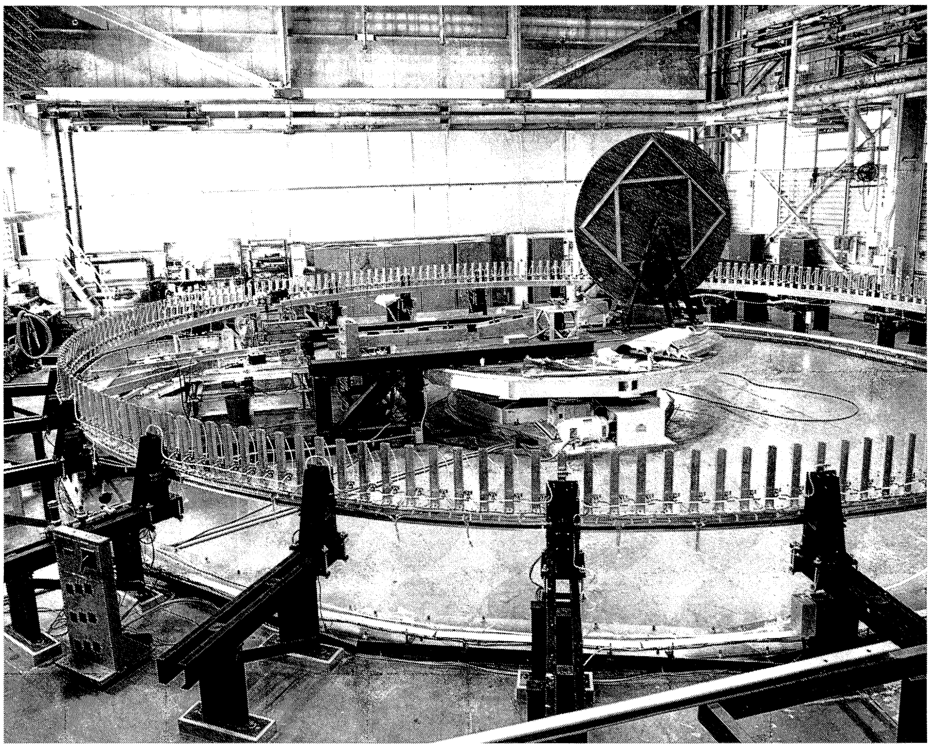
Readings taken during cooldown, power and quench cycles, and warmup showed that the forces on the magnets are well within expectations, showing no evidence of creep in the coil structures after many power cycles.

g-2 revisited

An experiment at Brookhaven's Alternating Gradient Synchrotron (AGS) to measure the anomalous magnetic moment (g-2) of the muon with new precision (April 1989, page 7) has completed winding the first of its four 14-metre diameter superconducting coils.

This is a major initial milestone in an effort to improve by a factor of 20 on an already remarkable CERN measurement of muon magnetism 15 years ago.

Winding the first of four 14 metre-diameter superconducting coils for an experiment at Brookhaven to measure the magnetism of the muon with unprecedented precision.



The extra precision will uncover the tiny effect due to vacuum fluctuations of the W and Z particles, carriers of the weak force. The anomalous muon magnetism due to various vacuum fluctuations is only 0.1%, and was measured at CERN to 7 parts per million (ppm). The W and Z particles contribute about 2 ppm, and the Brookhaven goal is to get down to 1/3 ppm.

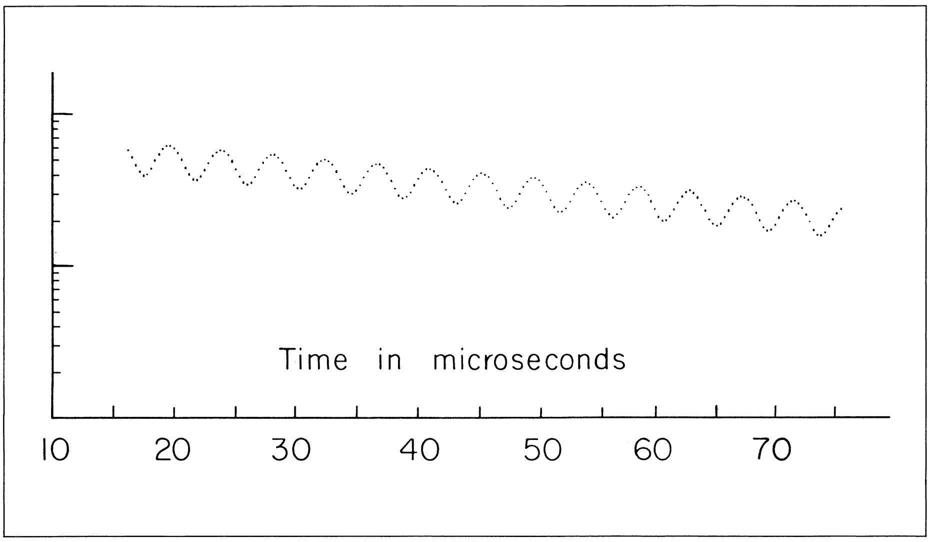
The W and Z contributions are predicted by the electroweak unification of electromagnetism and the weak nuclear force, and the new experiment will probe the delicate interaction between the weak force, carried by W and Z particles, and electromagnetism, carried by the photon.

When a muon is born in the decay of a pion, its spin points along its direction of motion, itself a significant piece of physics (the weak force is very careful about direction). Going through a magnetic field, the muon's path is bent, and the spin direction follows almost, but not quite. There is a tiny difference (proportional to g-2) between the spin direction and the muon's trajectory after passing through the magnetic field, seen as a rotation (precession) of the spin direction around the direction of motion.

The Brookhaven experiment will set out to measure 50 billion muons. These eventually decay into electrons, which point in the direction of the parent muon spin. The 3 GeV time-dilated muons will have an average lifetime of 64 microseconds (approximately 2/3 decay during this time) and the experiment will collect decay electrons over one millisecond for each pulse of muons.

The experiment will look for the decreased muon signal following the 64-microsecond lifetime, modulated by the cyclic precession of the muon spin around the muon

Results from a previous experiment at CERN, showing the slowly decreasing electron signal as the parent muons decay, modulated by the characteristic wave pattern due to the spin direction precessing round the muons' trajectory.



trajectory, which takes about 4 microseconds. It is this modulation period which must be measured very precisely, to 1.3 picosecond.

This sensitivity will be achieved by refinements on the CERN experiment, and taking advantage of a more effective muon gun – the AGS/Booster combination. One refinement is the use of a continuous 14-metre-diameter superconducting magnet as the muon storage ring, ensuring a more uniform magnetic field. The CERN ring used 40 discrete magnets and the field was known to 1 ppm over the 44-metre circumference storage region. The Brookhaven experiment will need to know the field to 0.1 ppm.

Other refinements include using superconducting coils (less cycling and heat) and a trolley carrying NMR probes to measure the field inside the storage ring without needing to turn the field off.

The muons, from pion decay, will follow an external beamline, from where they will be magnetically kicked into the storage ring. At CERN, pions were fed into the muon storage ring, where some decayed to give trapped muons. Muon injection improves the collection efficiency by a factor of seven.

The new experiment plans to run in late 1993. Targets include completion of three more coils by late fall, construction of the magnet and powering it next fall, and an extensive period of shimming to obtain a magnetic field uniform to 1 ppm and known to 0.1 ppm. Brookhaven and the Japanese KEK Laboratory are responsible for the magnet.

Other systems include a superconducting inflector magnet being built at KEK, the NMR system being built at Heidelberg and Yale, electrostatic quadrupoles (Brookhaven and Boston), a kicker (Brookhaven), the detector system (Boston and Yale), and the beamline (Brookhaven). Los Alamos contributed tracking studies on muon injection. The Soviet Novosibirsk Laboratory is contributing to the beamline and doing an important companion experiment to compare the production rates of hadrons and muons in electron-positron collisions.

From Gerry Bunce

DESY
ARGUS looks at the tau neutrino

As well as contributing important results on B mesons (particles carrying the fifth – 'beauty' – quark), the ARGUS detector at DESY's DORIS II electron-positron storage ring also specializes in the third generation of weakly interacting particles (leptons), with data on about half a million examples of electron-positron collisions producing pairs of tau particles.

Associated with the tau is the tau neutrino, and while the electron- and muon-type neutrinos have been shown to behave as expected, it is important to check out the third neutrino type as well.

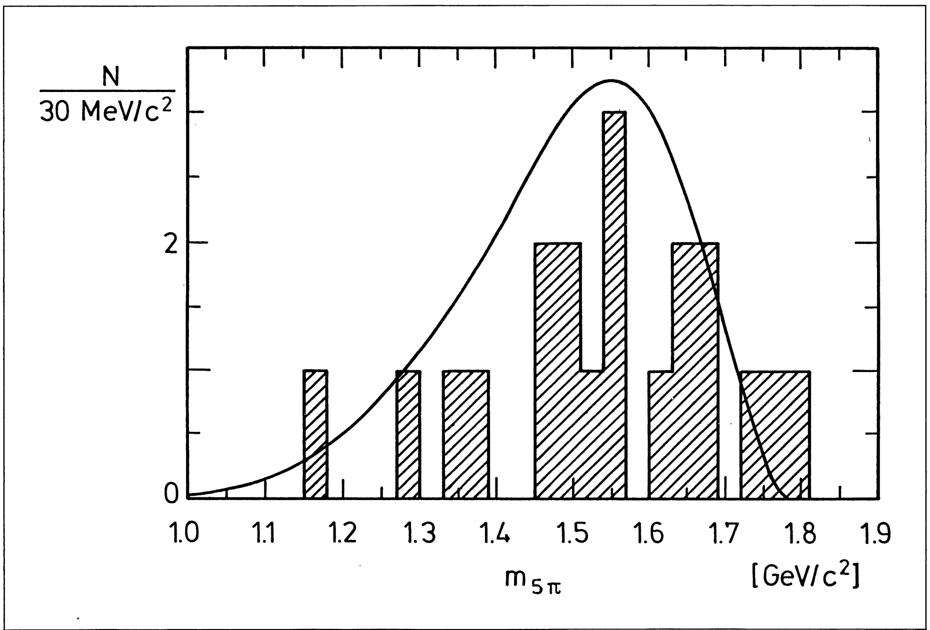
The mass of the tau is particularly important – neutrino masses are interesting for cosmologists because of the 'dark matter' (cosmological missing mass) problem. Neutrinos are widely expected to have no mass, but on the other hand the existence of a small mass opens up the possibility of 'oscillations', with neutrinos cyclically switching their electron, muon and tau allegiance.

Measuring a zero value gives experimenters a hard job – normally they have to rely on limits, currently single figure electronvolts for the electron neutrino mass and 250 keV for that of the muon neutrino.

ARGUS has used two techniques to measure the tau neutrino mass – analysis of the energy spectrum of tau decays, where the end point is sensitive to the mass of the accompanying tau neutrino; and measurements of the mass spectrum of tau decays into many particles.

Using the first method in 1986

Mass spectrum of tau decay into five pions, as measured by the ARGUS group at DESY's DORIS-II electron-positron collider. The curve is the prediction for a massless tau neutrino. From this data, the neutrino has to weigh less than 35 MeV.



demonstrated last year by ARGUS in the decay of taus into the a_1 (1260 MeV) particle, produced in a well-defined (spin/parity) state and subsequently decaying into pions through strong interactions, which conserve parity (left/right invariance).

Using 1937 decays of negatively-charged and 1950 of positively-charged taus, ARGUS has measured for the first time the helicity of the tau neutrino and antineutrino. As expected, they are −1 (left-handed) and +1 (right-handed) respectively, underlining the validity of the current picture of particle physics.

with a sample of taus producing three pions, ARGUS initially obtained a 70 MeV limit on the tau neutrino mass.

Decays of taus into five pions are especially good for tau neutrino information – the mass spectrum from only a few events can already produce significant results. Enlarging 1987's 12-event sample of these decays to 20 shows that the mass spectrum extends right out to the tau mass, so that the most probable tau neutrino mass is zero. Including known uncertainties in the mass of the five pions, the upper limit of the neutrino mass is 35 MeV, in accord with the value deduced from the 1987 data and the most sensitive bound on the tau neutrino mass yet established.

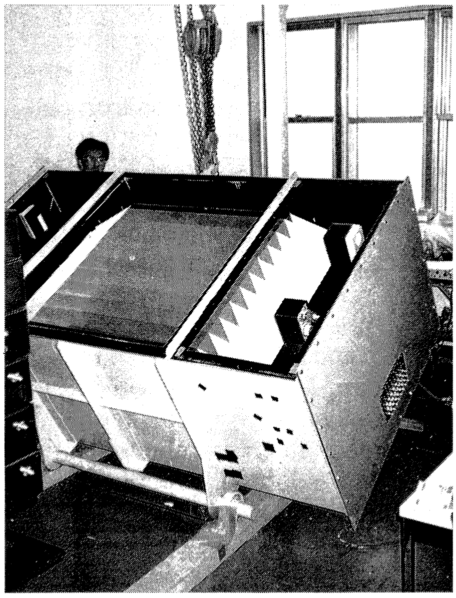
Using Gell-Mann's 'see-saw' model, which says the ratio of the neutrino masses goes as the square of the masses of the corresponding leptons, this tau neutrino limit implies a 3 eV limit on the electron neutrino mass, where the best experimental limit is some 9 eV.

As a weakly interacting particle, the neutrino is very sensitive to direction. Like its electron and muon counterparts, the helicity (spin direction) of the tau neutrino is expected to be −1 (a left-handed particle, with its spin pointing against the direction of motion). This was

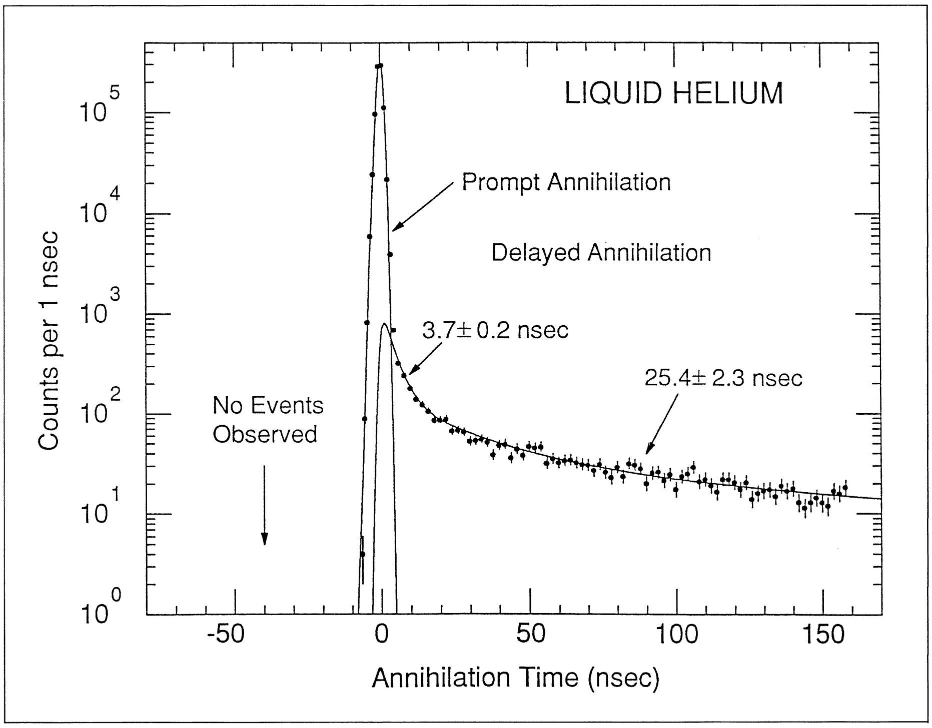
Linear accelerator pioneer Rolf Wideröe (left) in the HERA electron-proton collider tunnel, DESY, Hamburg, with HERA electron ring chief Gus Voss. In July the HERA electron ring was recommissioned, reaching 30.3 GeV with the help of superconducting radiofrequency cavities.

(Photo P. Waloschek)

Originally built to search for neutron-antineutron oscillations, the solar neutron telescope at the Japanese Mount Norikura Cosmic Ray laboratory saw clear evidence for neutrons accompanying a strong solar flare on 4 June.



Annihilation of antiprotons in liquid helium, as measured by a Tokyo group, showing clearly a component where lifetimes are measured in many nanoseconds.



JAPAN
Solar neutron sighting

In June, Japanese scientists saw clear signs of solar neutrons from a large solar flare. As these particles arrive at the Earth's surface relatively unperturbed by magnetic fields, they could provide especially clear insights into solar mechanisms.

Evidence for solar neutrons has been rare, although a report from scientists using the neutron monitor at the Jungfraujoch mountain station in Switzerland, published in 1987, was underlined by gamma-ray spectrometer data from the Solar Max spacecraft.

On 4 June this year, clean solar neutron events were picked up by the three detectors of the Mount Norikura (2770m) cosmic ray laboratory, by the Nagoya University 36 sq m scintillator array, and by the Riken 12 sq m neutron monitor. These were in coincidence with solar flare X-ray and radio signals. The energy of the particles was greater than 390 MeV. After the initial flare, several more pulses of particles were seen, but with different properties.

KEK
Catching antiprotons

When negatively charged hadrons (strongly interacting particles) are brought to rest, they can briefly form exotic atoms, with the negative hadron 'orbiting' close to the target nucleus, before being swallowed up by nuclear effects.

A few years ago, an experiment at the PS proton synchrotron at the Japanese KEK Laboratory found that negative kaons could be held in liquid helium for about ten nanoseconds. Following this up, a group from Tokyo University and Institute for Nuclear Study working at KEK have found that antiprotons can survive in this way for a relatively long time (many microseconds).

This abnormal at-rest stability of negative hadrons in liquid helium had been explained by the formation of metastable exotic atoms, with the negative hadron accompanying an electron around the helium nucleus. However unlike pions and kaons, antiprotons are themselves stable, and provide a good test particle.

The KEK experiment took care to remove fake events, the timing of the 'delayed events' with respect to the incident particle beam and their energy deposition being carefully monitored.

The results clearly show the prompt absorption of antiprotons, but in addition, about 3.6 per cent of the particles survive for a much longer time in liquid helium. In liquid nitrogen, where comparable exotic atoms are more difficult to form, no delayed annihilation was seen.

An immediate question is to look

Physics monitor

what happens in gaseous helium, and the Tokyo group, together with researchers from CERN and Munich's Technical University, are planning an experiment at CERN's LEAR Low Energy Antiproton Ring.

Other experiments at LEAR (September 1989, page 24) have used Penning traps and complementary cooling techniques to store antiprotons, the record being 60 days.

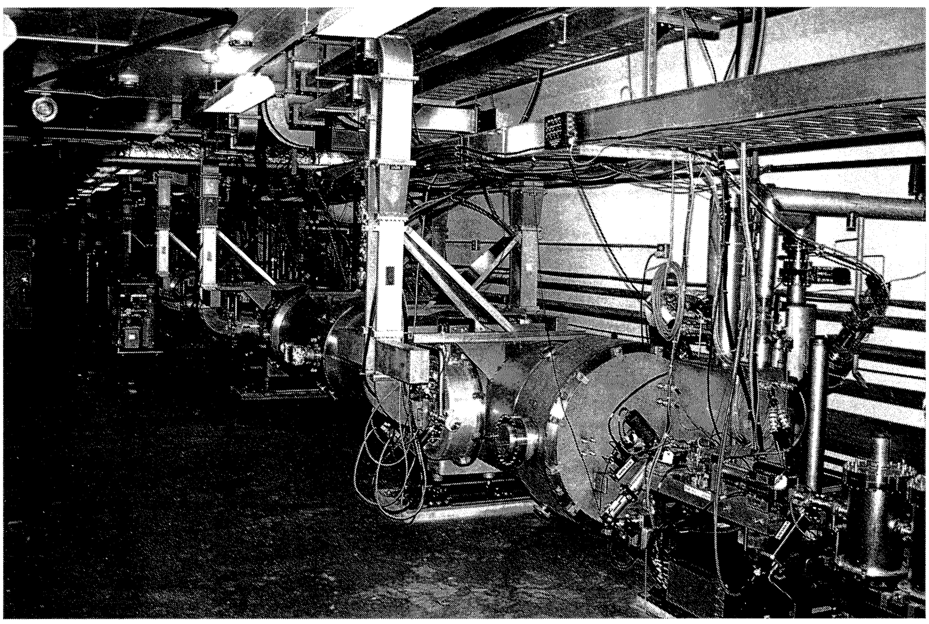
CEBAF Superconducting injector reaches design energy

On 11 June the superconducting injector at the Continuous Electron Beam Accelerator Facility (CEBAF) accelerated an electron beam to 45 MeV – design injection energy for the 4 GeV superconducting accelerator under construction in Newport News, Virginia.

Earlier, a partial injector configuration had reached 5 MeV using the injector's initial two-superconducting-cavity quarter-cryomodule to begin CEBAF's Front End Test (FET) of permanently installed components. In April, with 1 1/4 cryomodules, the FET reached 25 MeV (June, page 10). The injector's second full cryomodule was installed in May. The 20 MeV (nominal) cryomodules are identical to those being prepared for the main CEBAF accelerator.

Supplying FET liquid helium is CEBAF's central refrigeration plant, which is in commissioning and had operated for some 2100 hours for the test when 45 MeV was reached.

The superconducting injector at the Continuous Electron Beam Accelerator Facility (CEBAF) has accelerated electrons to 45 MeV – design injection energy for the 4 GeV superconducting accelerator under construction in Newport News, Virginia.



GUT feeling

CERN's LEP electron-positron collider is going full blast, with each of the four big experiments – Aleph, Delphi, L3 and Opal – now able to see thousands of Z particles (the electrically neutral carrier of the weak nuclear force) in a day.

For the moment, these physics results line up solidly behind the 'Standard Model', the twin picture of the electroweak unification of electromagnetism and the weak nuclear force on one hand, and the field theory of quark dynamics on the other.

Unfortunately as a physics theory the Standard Model is transparent, being riddled with unresolved questions. But its very solidity now means that physicists can use it as a springboard in their quest for the deeper theory which will finally answer these questions.

The main trouble with the Standard Model is its lack of predictive power – too many things have to be measured in experiments, and the values put into the theory by hand.

A classic example came in 1989 with initial results from Stanford's SLC Linear Collider and from LEP. These showed that there is room for only three kinds of lepton (weakly interacting particle). In the Standard Model each lepton - electron, muon and tau – is paired with its respective neutrino and two kinds of quark, but there is no limit on the number of allowed leptons. What did this evidence for a closed scenario of six leptons and six quarks tell physicists?

As well as not explaining its own spectrum of particles, the Standard Model cannot account for the mysterious charge-parity (CP – combined particle/antiparticle and

The Standard Model includes six leptons – the electron, the muon and the tau, each with its associated neutrino – and six quarks – 'up', 'down', 'strange', 'charm', 'bottom' and the long-awaited 'top'.

GENERATION / FAMILY	1	2	3	Electric Charge
1	ν_e	ν_μ	ν_τ	0
2	e^-	μ^-	τ^-	-1
3	u	c	t	$+ 2/3$
4	d	s	b	$- 1/3$

left/right reversal) symmetry violation known for more than 25 years in the decays of neutral kaons.

CP violation can be accommodated, but not explained, by a matrix of the various inter-quark couplings. As this (Cabibbo/Kobayashi/Maskawa) matrix has simple symmetry properties, not all the inter-quark couplings need to be known, and some uninformed predictions are possible. For CP violation to happen, at least six types of quark are needed, but more than six are not ruled out.

In the 1970s, when the Standard Model first started looking good, ambitious theorists looked for a wider 'Grand Unified Theory' (GUT). In the same way that the electroweak picture synthesized electromagnetism and the weak nuclear force, so GUT would encompass both electroweak and quark effects, and hopefully pointing to the origins of the quark-lepton spectrum and CP violation.

One encouraging early GUT prediction was for the vital mixing parameter ('Weinberg angle') linking the two electrically neutral carrier particles of the electroweak picture – the photon of electromagnetism and the Z of the weak force. The Standard Model cannot predict this mixing angle.

Another GUT prediction was that the proton has to be slightly unstable, with a lifetime of some 10^{32} years. With the proton, like the electron, previously considered absolutely stable, physicists had to backtrack, but with the age of the Universe 'only' about 10^{10} years, there is plenty of room for proton instability on this scale!

A wave of proton decay searches got underway, but with no positive sightings yet reported, the simplest GUT theory, proposed by Howard Georgi and Sheldon Glashow in 1974, has had to be abandoned. With many more elaborate GUT theories still on the market, experiments with higher sensitivity test for still longer proton lifetimes.

Another early GUT result, developed by a rolling collaboration at CERN's Theory Division, gave interesting interrelations between the quark and lepton masses, and suggested strongly that there was room only for six types of quark.

GUT dynamics would have ruled the first tiny fraction (10^{-30}) of a second of the Universe after the Big Bang, until it cooled to the stage where the quark and electroweak sectors separated out.

Looking at the implications of these dynamics for the early history of the Universe, astrophysicists calculated the amount of helium formed a few minutes after the Big Bang. This limited the number of lepton types to four (and thus eight quarks), a limit subsequently improved with better helium abundance data.

High energy experiments allow physicists to look back towards this GUT era. Confident measurements of the coupling strength of inter-quark forces in the energy range opened up by LEP (April, page 3) give a first tiny lever arm pointing back towards the GUT limit around 10^{14-16} GeV. These first extrapolations suggest that if electroweak and quark effects are to merge smoothly together, some new physics, such as 'supersymmetry', will have to make an appearance.

In the meantime the precision of Standard Model results improves steadily. Sooner or later the strain will begin to tell.

People and things

EUROPEAN SOUTHERN OBSERVATORY
Looking deep into space

The European Southern Observatory's New Technology Telescope (NTT) at La Silla, Chile, looking deep into an 'empty' part of the sky, has found it filled with many faint and remote galaxies. The limit images are at least 2.5 times fainter than any previously obtained by optical telescope, the signal being equivalent to the glow of a cigarette seen from the distance of the Moon!

ESO's NTT instrument produced its first images in 1989. Pictures are recorded by a CCD camera, with mirror shape and alignment under computer control. Air turbulence around the instrument is minimized by active thermal control, while precision pointing and tracking virtually eliminates smearing.

Having found this new rich pattern, the next step is to study the colours of these faint objects for an indication of their age. Spectral measurements will give their wavelength shifts a measure of their velocity and distance.

Established in 1962, ESO, like CERN, pools resources from Member States to provide a comprehensive international research programme. In the 1970s, many ESO staff used CERN as a base pending completion of the headquarters building in Garching, near Munich.

On people

Emilio Picasso of CERN, Director of the LEP Project during its entire construction phase, Leader of what became Experimental Physics Division from 1972-77, and who also played a major role in the famous precision g-2 experiment, received this year's Prix Mondial Nessim Habif of Geneva University.

Chairman of CERN Finance Committee Arnfinn Graue of Bergen has been awarded the Order of St. Olaf Commander for his contributions to science in Norway.

Giuseppe Fidecaro 65

Recently passing a career milestone at CERN was Giuseppe Fidecaro, whose characteristically careful and imaginative work spans almost the whole epoch of modern particle physics, with its evolving techniques and interests.

This year's JINR-CERN School of Physics was held in Alushta, Crimea, from 5-6 May. The twelfth in a series of joint schools organized by CERN and JINR, the Joint Institute for Nuclear Research at Dubna, near Moscow, it attracted more than 100 physicists from 15 countries. Its aim was to teach aspects of high energy physics, especially theory, to young experimentalists.

(Photo Yu. Tumanov)

Hard at work at the official inauguration of the ISA (Institute for Synchrotron Radiation), Aarhus, Denmark, earlier this year are (left to right) – J. Rostrup-Nielsen, Research Director of major synchrotron radiation users Haldor Topsoe A/S, CERN Director General Carlo Rubbia, ESRF (European Synchrotron Radiation Facility) Director Ruprecht Haensel and ISA Director Erik Uggerhoj. ISA uses the ASTRID electron/ion storage ring, modelled on CERN's LEAR low energy antiproton ring (July/August 1990, page 16).

After studies at Rome, his first published work, with Edoardo Amaldi in 1950, on muon scattering gained rapid recognition. A brief period in the US introduced him to new techniques, and returning to Europe, he joined the Cervinia-Testa Grigia cosmic ray laboratory, where he met Maria Cervasi (subsequently Maria Fidecaro), and went on to become Vice-Director of the Laboratory.

With the establishment of CERN on the horizon in 1954, he went to Liverpool, looking at the results of pion capture, one of the first experiments to use lead-glass. Coming to Geneva in 1956, he helped introduce new experimental techniques and played a leading role in early experiments at the Synchro-Cyclotron, notably the observation of the electron decay of the pion, making weak interaction physics eminently respectable, a position from which it has never looked back.

Subsequent major contributions included classic work on polarization in pion-nucleon scattering, and a search for neutron-antineutron oscillations motivated by predictions of Grand Unified Theories.

Away from physics, he played a vital role as coordinator of the USSR-CERN collaboration for ten years. With a firm eye on the future he now helps organize B-physics interest for studies at CERN's proposed LHC proton-proton collider, where his enthusiasm matches, and sometimes exceeds, that of researchers many years his junior!

At a meeting 'The Universe' at the Espace européen des Sciences et des Arts, Strasbourg, in July, Abdus Salam (left) spoke on Chirality and the Origin of Life, and Andre Linde on cosmic inflation.

▼ In May the first International A.D. Sakharov Conference on Physics took place in Moscow's Lebedev Institute, covering a wide range of topics, especially those in which the late Andrei Dimitrievitch took a special interest – plasma physics, quarks, gravitation, cosmology, baryogenesis, etc. J.A. Wheeler proposes a toast to Sakharov's widow Elena Bonner (standing). Joining the applause (left to right) are Tatiana Fabergé, V. Man'ko and H. Ito.

(Photo A. Martin)

▼ On 20 June French Minister of Research ▼ and Technology Hubert Curien inaugurated the new 'Refuge des cosmiques' in the French Alps, where much early cosmic ray research took place in the late 40s and early 50s. Oblivious to the view are Louis Leprince-Ringuet (left) who directed the early cosmic ray research there, and Jacques Dupin of CERN.

Reinhard Budde

Also passing a career milestone this summer was Reinhard Budde, one of CERN's earliest staff members, appointed by Lew Kowarski.

After a spell at Columbia under Jack Steinberger to learn the art of bubble chambers, he returned to CERN to construct and exploit the early CERN 10cm and 30cm hydrogen bubble chambers. From this he went on to become one of CERN's key experts on film handling, helping to develop and run the sophisticated scanning and measuring systems needed to process the many millions of physics photographs churned out by several generations of successively larger and more sophisticated bubble chambers.

He has played another pivotal role in the research programme, having served as Secretary of three generations of CERN Experiments Committees – first for track chambers, then for the SPS, and most recently for LEP.

Away from physics, he is a lover of fine taste, being both an accomplished musician and oenologist.

Klaus Goebel retires

Klaus Goebel retired from CERN at the end of June after 35 years.

During his early years at the Laboratory, he measured isotope concentrations in meteorites and used the Synchrocyclotron to measure isotope production by protons. This interest in trace measurements carried over to his work in CERN's Health Physics Group, which he joined in 1962.

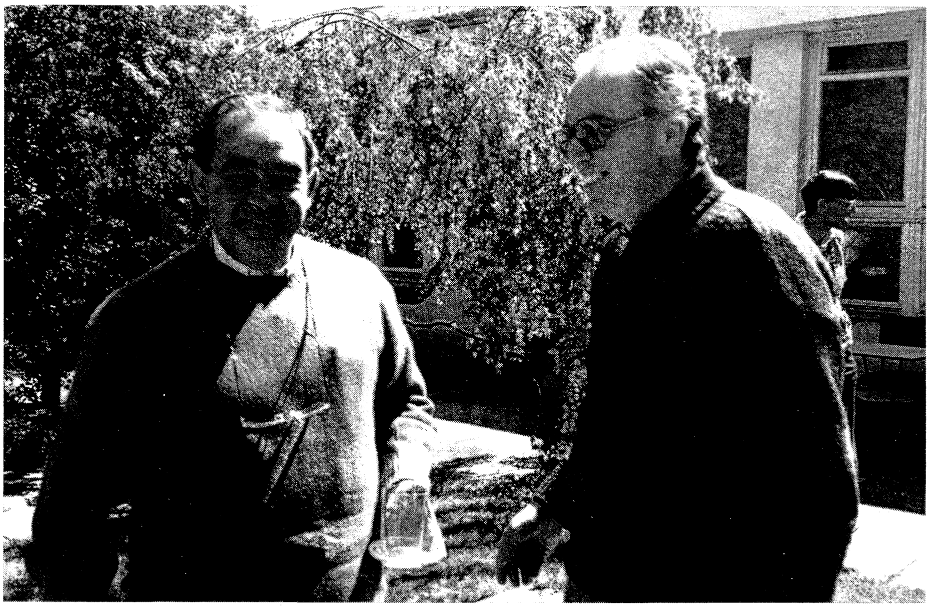
His main contribution to radiation safety at CERN began in 1971 when he was appointed head of the Radiation Group to advise on radiation for the SPS project under John Adams. With the completion of the SPS in 1976 he took over responsibility for radiation safety for the whole CERN site. Increasing awareness of radiation risks called for frequent reviews of procedures, and for availability of full information both inside and outside the Laboratory.

He has developed widespread contacts and his contribution to the field was recognized when in 1988 he became President of the Fachverband für Strahlenschutz (The Swiss/German Radiation Protection Society). His colleagues wish him an enjoyable and merited retirement.

Brookhaven NSLS reveals structure of carbon supermolecule

X-ray powder diffraction studies at the US National Synchrotron Light Source at Brookhaven have enabled US chemists to unravel the crystal structure of K_3C_{60} – one of the football-shaped 'buckminsterfullerene' supermolecules whose discovery was announced last

The XIV International Warsaw Meeting on Elementary Particle Physics held in Warsaw-Miedzeszyn from 27-31 May attracted 120 participants, mainly from abroad. Meeting Organizer and Director of Warsaw's Institute of Theoretical Physics S. Pokanski (right) talks with A. Tiemblo, President of the Spanish Physical Society.



year. The material is chemically a metal and is superconducting up to 19.3K.

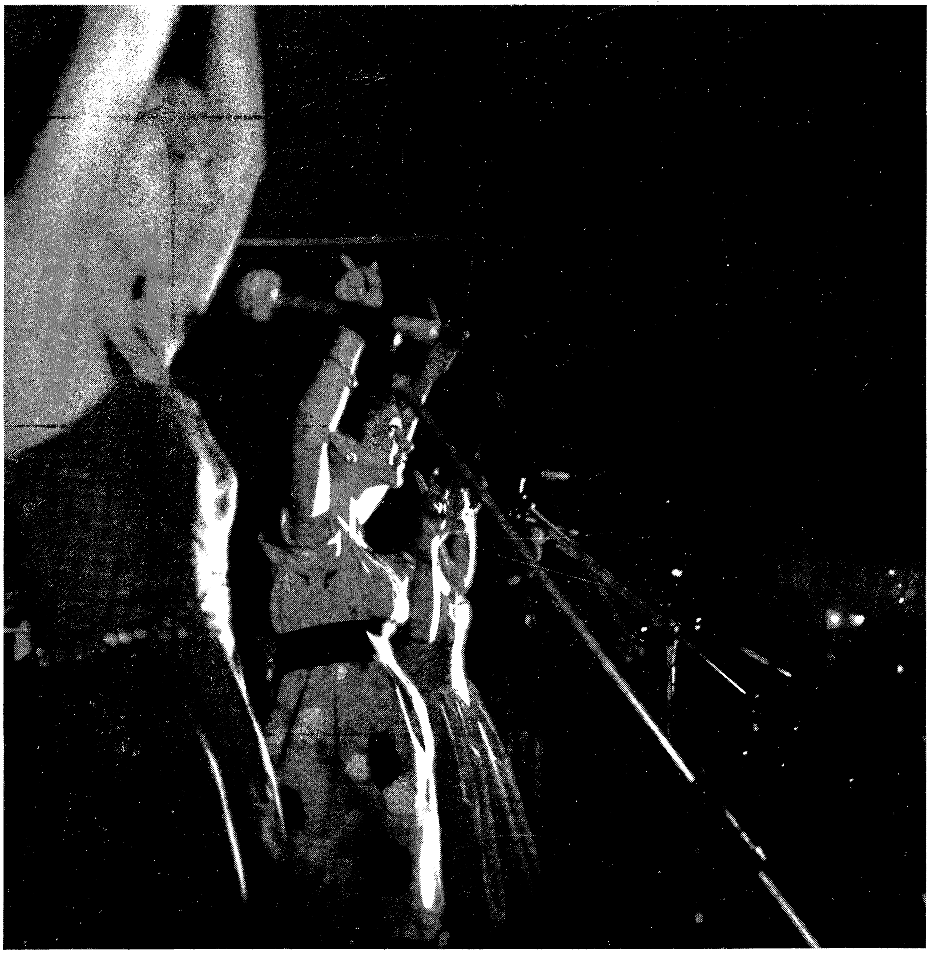
These giant (nanometer) molecules are named after architect Buckminster Fuller, whose geodesic dome for the US Pavilion at the 1967 Montreal Expo greatly impressed the molecules' future discoverers.

Meetings

In 1992 the International Symposium on Weak and Electromagnetic Interactions in Nuclei (WEIN-92) will be held from 16-22 June at JINR, Dubna, USSR. Its goal is to examine the status of the Standard Model and its applications to low and medium energy physics. Further information from the Conference Secretary, A.A. Osipov, JINR, LNP, 141980 Dubna, Moscow Region, USSR; telex 911621 dubna su, fax (7095) 200 22 83, e-mail osipov at ljap7.jinr.dubna.su

Following the first such workshop, held in Lyon in March 1990, the Second International Workshop on Software Engineering, Artificial Intelligence and Expert Systems for High Energy and Nuclear Physics will be held from 13-18 January in Agelonde La Londe Les Maures, Provence, France. Information from Michele Jouhet, CERN, PPE-ADM, 1211 Geneva 23, Switzerland, tel (+41 22) 767 2123, fax (+41 22) 767 6555, e-mail jouhet at cernvm.cern.ch

CERN theorist and President of the European Physical Society Maurice Jacob with his daughter Irène at Geneva airport on her return from the Cannes Film Festival, where she won this year's Best Actress Award for her intriguing dual role in Krzystof Kieslowski's French-Polish Film 'Two Lives of Veronique'.



Round, round, round, round, ye-ye – 'Les Horribles Cernettes', stars of the CERN Courier-sponsored entertainment evening for the recent International Lepton-Photon Symposium and Europhysics Conference on High Energy Physics (see page 1).

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W. Kirk

Superconducting Super Collider, USA
N. V. Baggett

TRIUMF Laboratory, Canada
M. K. Craddock

The 2nd Symposium on Swift Heavy Ions in Matter (SHIM 92) will be held in Bensheim/Bergstrasse, Germany, from 19-22 May 1992. Information from N. Angert, GSI Darmstadt, Postfach 110552, D-6100 Darmstadt 11. The first SHIM meeting was held in Caen, France, in 1989, covering the interaction of swift heavy ions with gaseous, plasma and condensed matter.

Gomal University, Dera Ismail Khan, Pakistan, is organizing an International Conference and Workshop on Quark Matter and Heavy Ion Collisions (QMATHIC) from 13-20 January 1992. Contact Prof. Abdul Waheed, c/o Dept. of Physics, Gomal University, Dera Ismail Khan, Pakistan.

Scientific Europe

Under the title 'Scientific Europe', a mighty tome of some 500 pages has been published by the Foundation Scientific Europe describing research and technological achievements in some twenty European countries. Articles highlight European collaborative efforts in space research, molecular biology, nuclear technology, robotics, aviation, supercomputers, etc.

In particle physics, a general introduction by the late Leon Van Hove traces the rapid ascendancy of European laboratories in several pure research areas. Carlo Rubbia writes on CERN's role in the advances in particle physics in recent years, Egil Lillestol traces the implications of 'science in the big league' and Giorgio Brianti covers the underlying high technology for accelerators.

Announcing itself as 'the most authoritative reference to European scientific and technical progress', the book is being launched under special terms (see facing page).

LHC News

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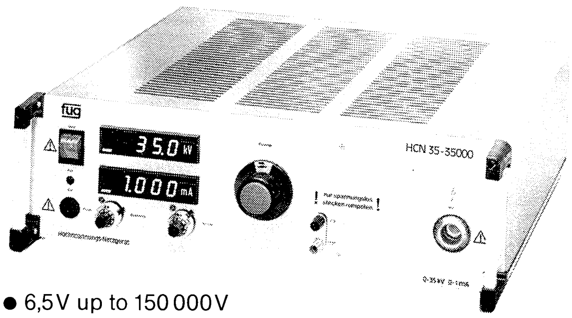

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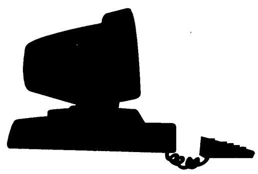

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