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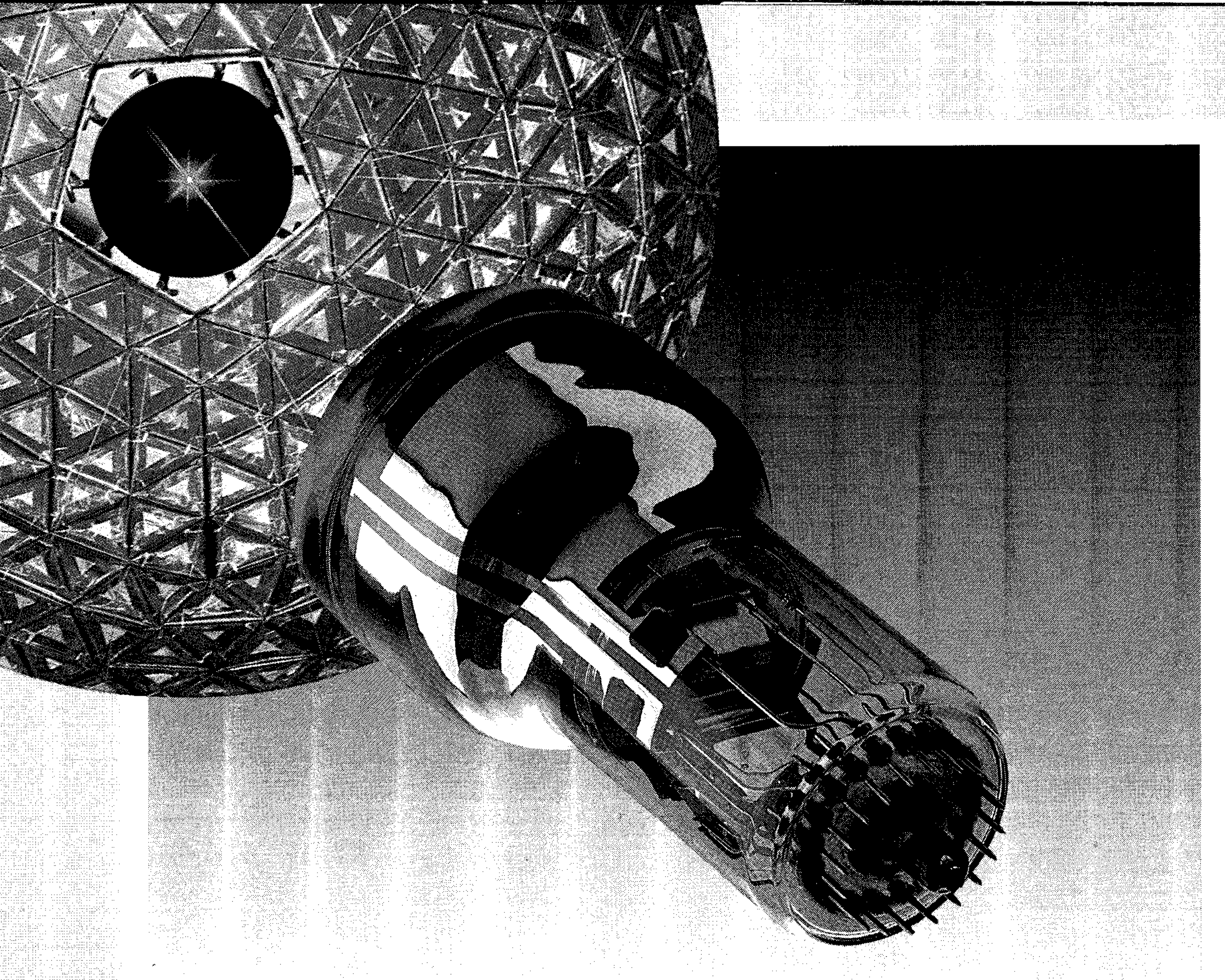

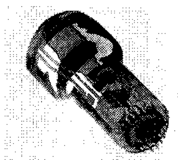

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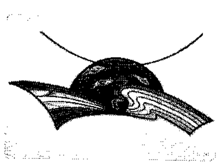

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On view recently at CERN was this stained glass composition by Dolors Guixa which contrasts 'containment', represented by the blue circular segment, with simultaneous 'expansion', symbolized by the traversing wave-like form, with its colour evolution around a constant yellow centre (Photo Gilbert Cachin).

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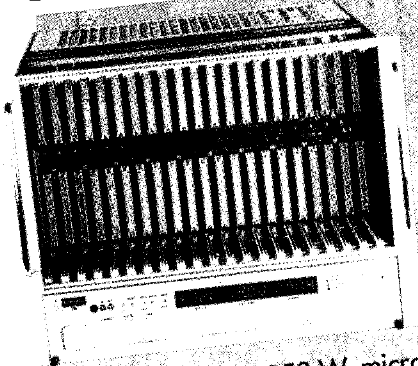

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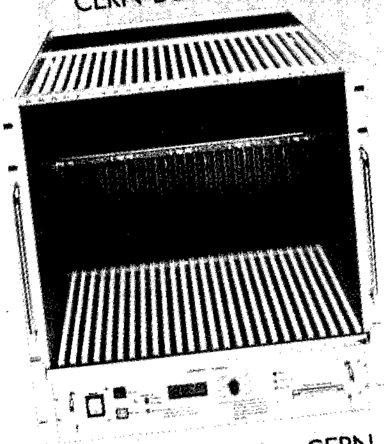

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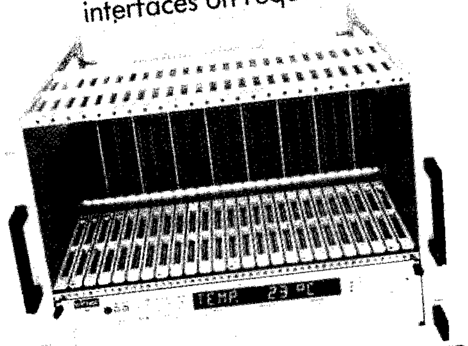

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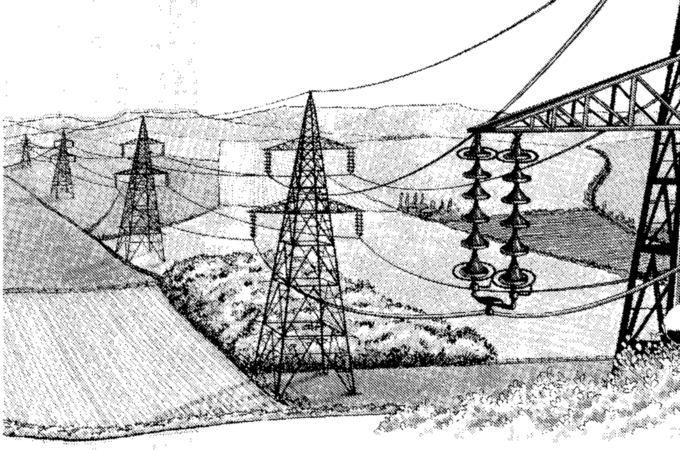

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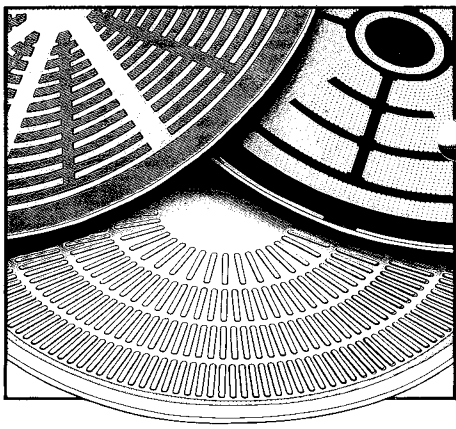

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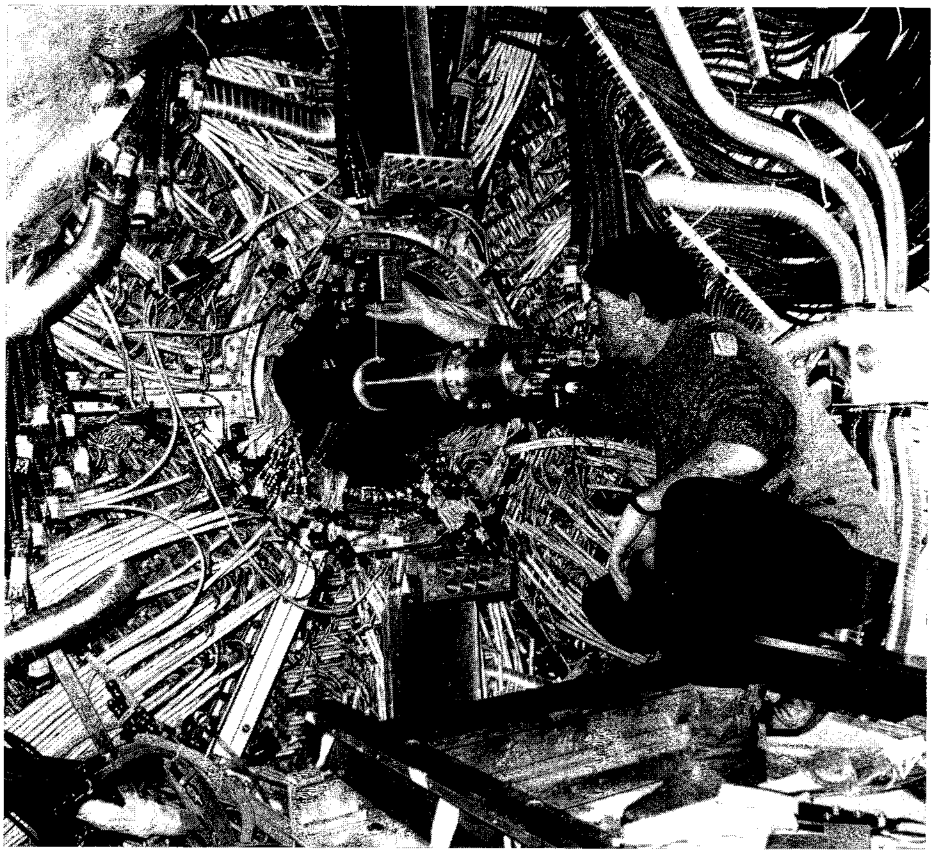
CONTROL THE ACTION IN HIGH POWERED INDUSTRY

LEP from London

All four experiments – Aleph (seen here), Delphi, L3 and Opal – at CERN's LEP electron-positron collider have been fitted with narrower beam pipes to allow them to get nearer to the collisions.



A flood of physics from CERN's LEP electron-positron collider so soon after its commissioning underlines the wisdom of the project and bodes well for the machine's continued success. With only just over a year of data-taking behind them, the four big experiments – Aleph, Delphi, L3 and Opal – have supplied comprehensive results whose implications and precision could only have been dreamed when the giant 27-kilometre collider hesitantly produced its first beams in July 1989.

The major UK interest in LEP had programmed a discussion meeting on LEP in the august surroundings of the Royal Society in London in January. With physics rapporteurs pulling together results from the four experiments, the meeting provided a useful focus of attention on the premier research tool of European particle physics for the 1990s.

Concentrating on conventional physics (the Standard Model), James Stirling of Durham pointed out how much LEP was now contributing to the strong interaction sector. While precision determinations of electroweak numbers had always been seen as a major priority, LEP research was giving new insights into quantum chromodynamics, the candidate field theory of inter-quark forces and, with the electroweak picture, one of the twin columns supporting the Standard Model.

The inter-quark coupling (known in the trade as 'alpha-s'), has been fixed to within about ten per cent, with good information in particular from events producing three well-defined 'jets' of particles, said Stirling. Initial indications of this number had come from comparing the weak and strong decays of the Z particles mass-produced at LEP. More analysis and theoretical calculations would be needed to improve on this alpha-s precision, remarked Stirling.

Amidst all this new precision knowledge, two things have yet to be seen at all – the sixth ('top') quark stubbornly refuses to come out into the open, and the 'Higgs' mechanism which provides the delicate symmetry breaking at the heart of the electroweak picture remains a complete mystery.

But enough is known about the rest of physics for even these numbers to be assigned limits. The top quark looks like it lives in the mass range 90 –160 GeV, while a Higgs particle has been ruled out below 40 GeV. Stirling reported predictions that if the top quark were to turn up at 120 GeV, then the Higgs could not go higher than 600 GeV. LEP's energy upgrade (March, page 1) should open up more room to look for the Higgs.

CERN Theory Division Leader John Ellis examined the implications of LEP beyond the Standard Model. The conventionality of LEP results so far, with no surprises and no new particles, can be put to good use. A long list of unseen particles had been proposed for possible explanations for the invisible 'Dark Matter' of the Universe (June 1990, page 1), but the non-appearance of new particles at LEP restricts the form this Dark Matter can take.

The most conventional unconventional picture of particle physics is 'supersymmetry', where the number of available particles is doubled – every half-integer spin ('fermion') quark or lepton having an integer spin (boson) counterpart 'squark' or 'slepton', and existing bosons having half-integer spin partners.

Boldly extrapolating today's results out over 15 powers of ten in energy, intrepid theorists can look for signs of a 'Grand Unification', with the two halves of the Standard Model welded into a single picture, and with all interactions becoming equal at some cataclysmic energy.

At the Z resonance, the LEP results complement data from lower energies and give such extrapolations their first firm foothold towards the Grand Unification scale (March, page 1). This is 'encouraging' for supersymmetry, commented Ellis (see page 3). With new heavy particle territory yet to be entered, the big question, he said, is not why the top quark is so heavy, but why its five companions are so light.

Janet Carter of Cambridge surveyed the shape and position of the Z as measured by the four experiments. Here precision is gradually improving, although LEP's energy is still unknown to within 20 MeV. The four measurements are consistent, and summing together different leptonic channels avoids problems of lepton identification and possible overlap.

Howard Stone of Geneva looked at the electroweak information coming from Zs decaying into leptons. Here special channels, such as spin effects associated with the tau leptons, could provide additional insights. Walter Venus of the Rutherford Appleton Laboratory described the jet and heavy quark physics which provide LEP's powerful capacity as a testing ground of strong interactions.

The meeting included detailed progress reports from the four experiments, while former CERN Director General Herwig Schopper looked back at LEP's convoluted history. Reliving the decisions to embark on four major detectors which set the scale for the future of particle physics, Schopper likened such big experimental efforts to a convoy of diverse shipping headed for a common destination, rather than a 'supertanker' under tight central control.

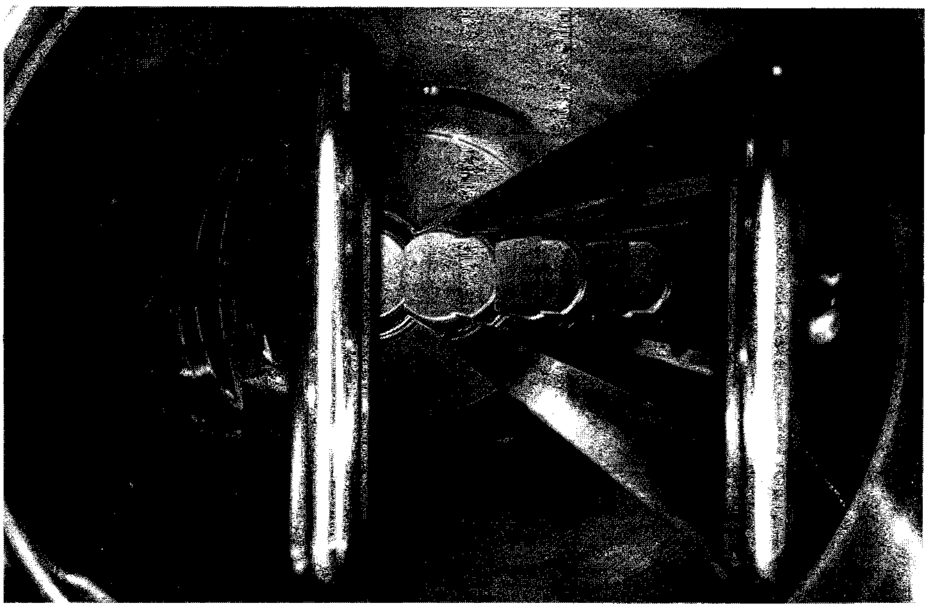
Steve Myers of CERN spoke for the machine specialists, describing LEP's progress so far and the plans for the future. Unforeseen beam-beam coupling has offset attempts to goad the machine to higher collision rates, but a better understanding of the machine's current limitations should lead to improved performance, running at an optimal difference (split) between the vertical and horizontal tunes, while improved beam instrumentation should also pay dividends. Further compression of the beams is a natural way of increasing the collision rate, while a longer-term aim is to go from four to eight bunches per beam, using additional electrostatic beam separators.

Polarization (spin orientation) was a big bonus for LEP last year (November 1990, page 3), and in principle opens up a new era of precision measurements. However these initial polarization levels were seen in single beam operation, and the hope this year is that spin orientation can be achieved in collider mode with the solenoids of the four experiments switched on.

In conclusion, CERN Scientific Policy Committee Chairman Chris Llewellyn-Smith of Oxford stressed that LEP's physics contributions were only just beginning.

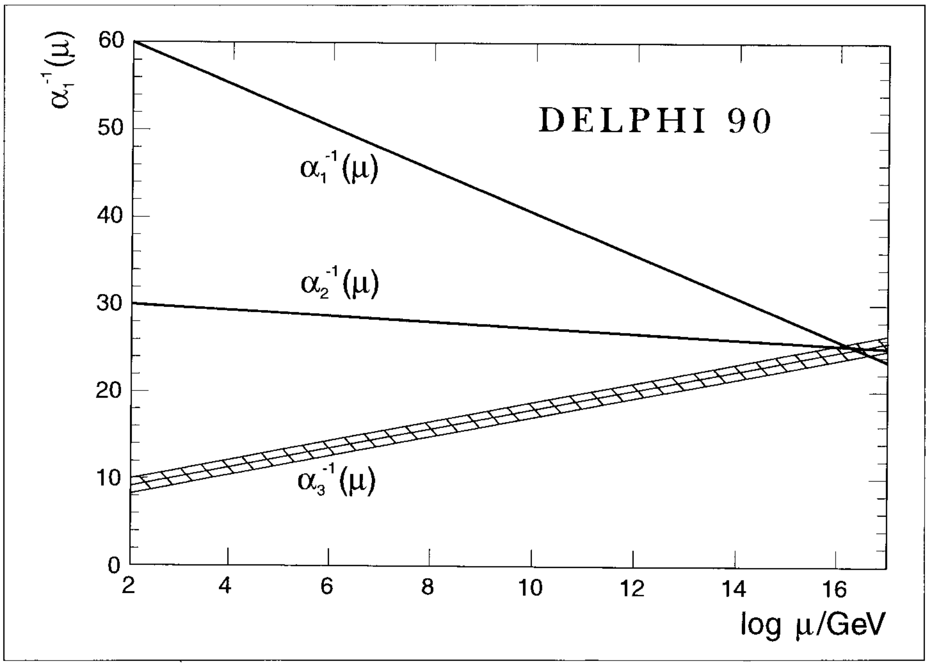
A 3-m long electrostatic separator of the type designed to upgrade operations at CERN's LEP electron-positron collider from four to eight bunches per beam. The patterns on the right are reflections from the device's illuminated aperture.

(Photo CERN 98.2.91)



Physics monitor

Supersymmetry on the horizon. A 'Grand Unified Theory' synthesizing weak, electromagnetic and strong interactions and invoking the idea of 'supersymmetry' can chart the coupling strengths of the different interactions in terms of one free parameter (vertical axis). Using 'low energy' input from experiments at CERN's LEP electron-positron collider, the coupling strengths become equal at 10^{16} GeV, from where their histories diverged after the Big Bang. The hunt for supersymmetric particles is now on in earnest.



SUPERSYMMETRY Precision LEP data point the way

Accurate measurements from CERN's new LEP electron-positron collider are hinting at a new global picture of fundamental forces.

Today's Standard Model of particle physics uses the electroweak unification of electromagnetic and weak nuclear forces loosely coupled with quantum chromodynamics (QCD), the candidate field theory of inter-quark forces.

Other than the neutrino sector (see page 9), no experimental data has appeared to question this Standard Model, which has dominated the physics scene for the past decade. However despite its success most physicists are convinced that this cannot be the whole picture, as a substantial list of fundamental parameters has to be input by hand, severely limiting predictive power.

The hope is that the two halves of the Standard Model – QCD and the electroweak picture – combine naturally in a larger Grand Unified Theory (GUT) with just two basic parameters – a grand unification scale where the strengths of all the forces become equal, and their common value at this energy.

While electromagnetism and the weak nuclear force strengths become comparable at about 100 GeV, strong nuclear effects are still very different, and only blend in at the GUT unification scale of about 10^{15} GeV – a temperature perhaps only attained in the Big Bang itself.

GUTs predicted that the proton is unstable, with a lifetime of some 10^{31} years according to the simplest models, and a wave of experiments got underway to look for signs of proton decay. In ten years, no consistent evidence has emerged. Moreover initial measurements of the electroweak mixing parameter (relating electromagnetic and weak nuclear couplings) were also difficult to reconcile with minimalist GUT ideas.

To attack the awkward scale disparity between the electroweak interactions – characterized by the masses of the W and Z particles, near 100 GeV – and the remote GUT unification point came the idea of 'supersymmetry'. In conventional physics, the basic particles (quarks and leptons) are 'fermions', carrying half-integer units of spin and obeying the Pauli Exclusion Principle, which limits each available energy state to one particle, while force carriers (e.g. photons) are 'bosons', carrying integer spin and not subject to Pauli restrictions.

Supersymmetry assigns counterpart 'squark and slepton' bosons to the existing fermion particles, and, for example, 'photino' fermions to partner the field bosons, thus doubling the particle spectrum.

The extrapolation to GUT energies works much better if supersymmetry is included in the picture. Other candidate explanations of scale disparity, such as 'technicolour' – the introduction of a new layer of substructure to explain the 'Higgs' symmetry breaking mechanism at the heart of the electroweak unification – have a more difficult time.

The picture is widened even further by bringing in the concept of 'superstrings' – a supersymmetric theory where particles are described by two-dimensional strings in an abstract multidimensional space, which can be 'compactified' to the physics we know in four-dimensional space-time. Many theorists feel that this contains all the ingredients to eventually build a unified picture of Nature, including gravity.

These theories predict a value for the energy when all forces, now

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described by a single parameter, should become equal. This is in fair agreement with extrapolations from the precision values of electroweak and strong force couplings deduced from the experiments at CERN's LEP electron-positron collider. (The GUT proton lifetime is beyond the reach of any search so far, but the hunt continues.)

There are other encouraging hints. A major triumph from the first electron-positron studies at the Z resonance (December 1989, page 18) was reliable confirmation that there are no more than three kinds of neutrino in Nature. This limits the Standard Model to six varieties of quark, five of which are known so far.

The hunt for the sixth 'top' quark has drawn a blank all the way up to about 90 GeV. However this is not the only limit. The sum total of all Standard Model data is only consistent if the top quark lies in the range 90-160 GeV. Plugging these limits into the supersymmetric picture give the effective mass of the fifth ('beauty') quark at about 5 GeV, in excellent agreement with studies on the spectroscopy of particles containing this type of quark. This prediction only works if there are three kinds of neutrinos.

Together, these arguments suggest that supersymmetry is on the right track, and that the theory looks comfortable without having to await the onset of unknown, radically different processes, other than supersymmetry, at higher energy.

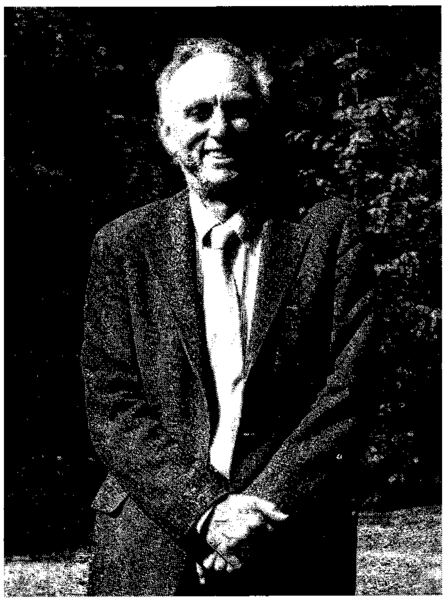
However no sign of supersymmetric matter has yet been seen. The lightest such particle, the photino, should be stable, and the search for it is now on in earnest.

Perl's of wisdom

Physics moves fast, and what was once a major discovery quickly becomes bread and butter for a subsequent generation of experiments. Nowhere is this more true that with the Z particle – the electrically neutral carrier of the weak nuclear force. Long expected following the revelation at CERN in 1973 that the weak nuclear force does not necessarily permute electric charge, the Z was discovered by Carlo Rubbia's UA1 team at CERN's proton-antiproton collider in 1983.

In 1983, the total world stock of Z information was a handful of events from CERN. By 1989, with the proton-antiproton colliders at CERN and at Fermilab attaining record antiproton levels, about a thousand had been catalogued.

Even before the 1983 Z discovery, CERN's LEP electron-positron collider project was well underway. Here the idea was not just to snare rare Zs, but to mass-produce them. LEP came into operation in the summer of 1989, and by the end of the following summer, some three-quarters of a million had been recorded.



Tau lepton pioneer Martin Perl.

(The first major discovery at the CERN collider was not the Z but its more commonly produced electrically-charged counterpart, the W. However the W, which has to be produced in pairs in electron-positron annihilation, cannot appear at LEP until its energy is considerably boosted – March, page 1.)

One of the major pieces of physics to emerge from LEP's initial data has been the conclusive evidence that only three kinds of leptons (weakly interacting particles) can exist (December 1989, page 18). The three electrically-charged leptons are – the light (0.5 MeV) electron, the substance of the atomic exterior and responsible for chemistry; at 106 MeV, some 200 times heavier than the electron, is the muon, the penetrating particle discovered in cosmic rays, where it was initially thought to be the carrier of the nuclear force; and at 1784 MeV, almost twice as heavy as even the proton, is the tau, discovered by Martin Perl's team at Stanford only about a year after the same detector (used by a another team) had seen the J/psi particle that heralded an additional type of quark, charm.

As a major by-product of Z decays, taus have become a bread-and-butter particle for the LEP experiments. Speaking at a workshop on tau lepton physics held in Orsay in September (December, page 22), Martin Perl of Stanford looked back to the particle's discovery in 1975. The history of the tau, whose role in the spectrum of elementary particles is still not understood, is in sharp contrast to that of the Z, long expected and rapidly discovered once the stage had been set.

Perl said – 'Our first publication

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(in 1975) was followed by several years of confusion and uncertainty about the validity of our data and its interpretation. It is hard to explain this confusion a decade later when we know that tau pair production is twenty per cent of electron-positron annihilation below the Z, and when tau pairs stand out so clearly at the Z.'

'There were several reasons for the uncertainties of that period. It was hard to believe that both a new quark, charm, and a new lepton, tau, would be found in the same range of energies. And, while the existence of a fourth quark was required by the theory, there was no such requirement for a third charged lepton.'

Rare decays

With the Standard Model of particle physics currently looking impregnable, physicists are eager to look inside it to see what makes it work.

(The Standard Model uses the electroweak synthesis of electromagnetism and the weak nuclear force, loosely coupled with quantum chromodynamics – QCD – the contender field theory of quark interactions.)

One way of finding a crack to peer inside the Standard Model is to look for 'rare' decays (by rare, physicists mean processes forbidden or highly suppressed by well-known selection rules). This approach was highlighted in the recent Europhysics Nuclear Physics Conference in Bratislava, Czechoslovakia.

Searching for rare decays needs special detectors, and Nobel Laureate R. Mössbauer opened the meeting with a talk on low temperature radiation detectors, a theme taken up by K. Pretzl, A. Guiliani and L. Gonzales-Mestres (September 1988, page 23). These devices will go on to play a major role in the search for the invisible 'dark matter' thought to make up much of the Universe.

The meeting was a convenient shop window for the new 17 keV neutrino results (see page 9). Also in the neutrino sector, several speakers reported new results from attempts to measure the mass of the electron-type neutrino in the beta decay of tritium. The lowest limit, 9.4 eV, came from experiments using free molecules, reported by T. Bowles from Los Alamos, while a solid tritium source, reported by S. Shibata from INS Tokyo, gave a 13 eV limit.

Double beta decay accompanied by two neutrinos, first reported in selenium-82 several years ago (January/February 1988, page 32), is now well established, and measurements were reported at Bratislava from germanium-76 (F. Avignone, S. Carolina, and I. Kirpichnikov, ITEP Moscow) and for molybdenum-100 (M. Moe, UC Irvine, and H. Ejiri, Osaka). With half-lives between 10^{19} and 10^{21} years, these are the slowest processes seen in Nature.

The search continues for neutrinoless beta decay, the best limits so far coming from germanium-76, reported by D. Caldwell, Santa Barbara, and F. Avignone.

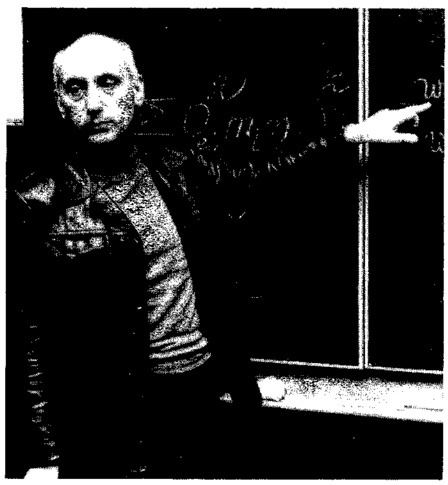
Possibilities for neutrino mixing, which could help explain existing neutrino puzzles, were reviewed by S. M. Bilenky, pointing out that existing data cannot exclude the possibility of visible neutrinos being superpositions of three light varieties and one heavy one.

The relative probability of a pion decaying into an electron, rather than a muon, was reported as $1.223 \pm 0.004 \times 10^{-4}$, slightly different to the calculated value, according to G. Czapek of Berne. A search for muon-electron conversion at the SINDRUM detector at the Swiss PSI Laboratory gave an upper limit relative to muon capture of 4.4×10^{-12}, said W. Bertl of PSI.

The meeting was organized by the Board of the Nuclear Physics Division of the European Physical Society (EPS), by the Union of Slovak Mathematicians and Physicists and by Bratislava University. It was the first time that an EPS Nuclear Physics Division Conference had been organized in a former socialist country. The proceedings will be published as a special issue of Journal of Physics G: Nuclear and Particle Physics.

From Pavel Povinec

At the recent Bratislava meeting on Rare Decays, S.M. Bilenky of Dubna talked about the implications of neutrino mixing.



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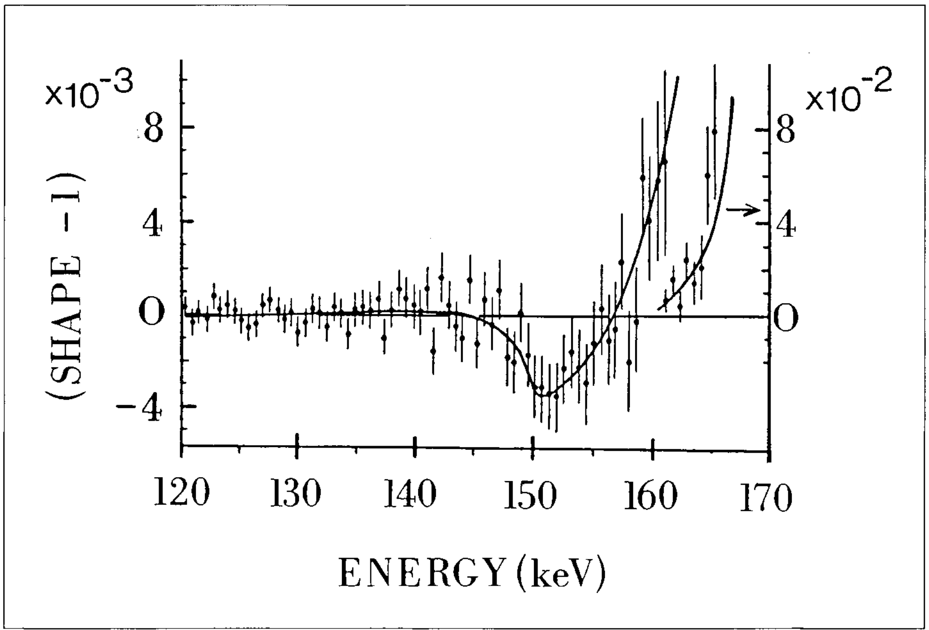


Sulphur-35 beta decay data measured by an Oxford group compared with what would be expected from a single massless neutrino (deviation from zero), showing a distortion 17 keV below the endpoint, attributed to a heavy neutrino. The smooth curve shows the result of including a 17 keV neutrino emitted about one per cent of the time. (The data above 161 keV go off the scale and should be read off against the right-hand axis.)

Evidence for a heavy neutrino at 17 keV is building up to another crescendo. First news of such a particle came from John Simpson in Guelph, Canada, in 1985 (July/August 1985, page 241), who saw a distortion in the beta decay spectrum of tritium 17 keV below the limiting energy.

Neutrinos are difficult to catch and most data comes from summing all visible weak decay products and looking for an imbalance. It was an apparent mismatch in beta decay momenta which more than 50 years ago led Wolfgang Pauli to postulate the existence of the neutrino.

Neutrinos were long thought to be massless. While this makes for a neat underlying theory, it is not necessary and a small mass can make for some interesting physics. However 17 keV, although lightweight even by the standards of the electron, is enormous by neutrino standards and difficult to put into perspective.

Thus quite a few physicists breathed a sigh of relief when the initial Guelph report came under heavy fire, with other experimenters pointing out that solid-state and atomic physics effects in the tritium-implanted silicon-lithium detector could undermine the delicate effect.

The original result came under intense scrutiny, and to sidestep many of its inherent complications, a new study got underway at Guelph using tritiated but otherwise pure germanium. The 17 keV signal remained, albeit clouded by incomplete knowledge of how tritium fits into the surrounding crystal lattice.

However the observed distortion in the tritium spectrum attributed to the heavy neutrino should also turn up in other beta decays. While other experiments continued to disfavour the heavy neutrino, the Guelph team persevered, going on to find a positive effect in the beta decay of sulphur-35. Meanwhile a study at Berkeley (March issue, page 7) has reported a 17 keV neutrino from the beta decay of carbon-14.

At Oxford, Andrew Hime, who collaborated in the Guelph studies, and Nick Jelley have carried out a new experiment which improves on the earlier Guelph technique by using an improved collimation between the sulphur-35 source and the cooled Si(Li) detector.

The data comes from two separate runs, the second using a smaller source to reduce the number of decay electrons hitting the edges of the detector (200 sq mm and 5 mm thick), giving a total of some 200 million events. Both spectra favour a heavy neutrino produced in about one per cent of the decays.

A 17 keV neutrino, while interesting, is not very useful. Neutrino mass is a candidate for the 'Dark Matter' needed to understand cosmological dynamics. However the condition that the Big Bang expansion of the Universe has one day to be halted by its gravitational stiffness gives limits on the required neutrino masses. These are remote from 17 keV, so the heavy neutrino can only be tolerable for cosmology if it is highly unstable.

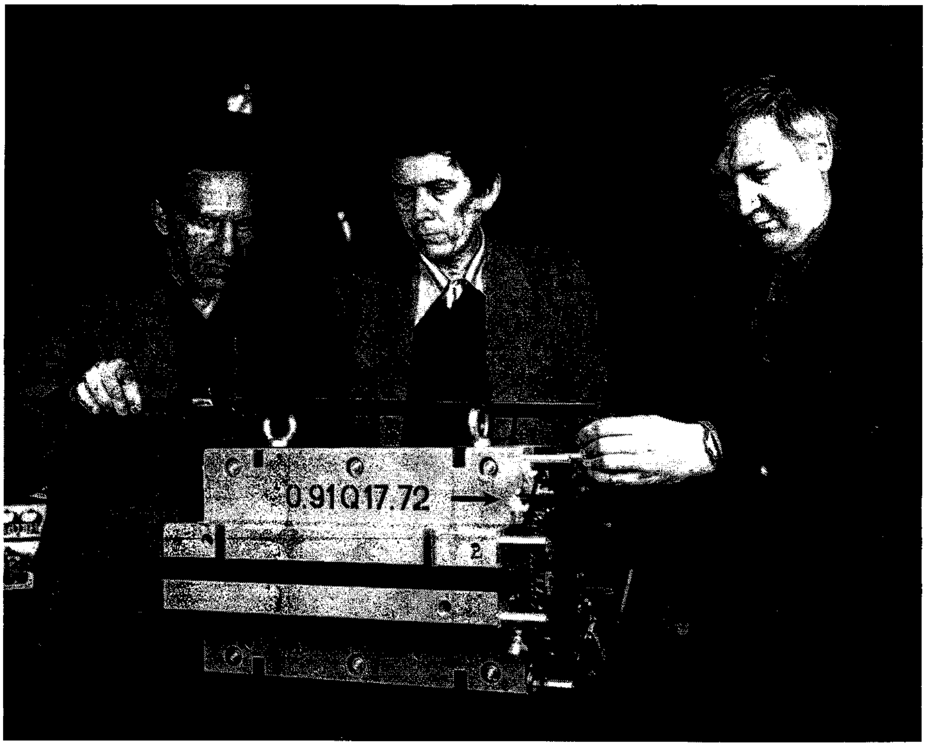
Conventional neutrinos, like electrons, are Dirac-type particles – having recognizably distinct antiparticles. However there is another possibility – that the particle and its 'antiparticle' are different spin states of the same 'Majorana' particle.

Sheldon Glashow invokes this possibility in an extended neutrino picture to accommodate the 17 keV finding and the possibility of matter-induced neutrino oscillations. This mechanism has been put forward to explain the 'solar neutrino problem' – the number of neutrinos detected on the Earth is only a fraction of those expected to be emitted by the sun (January/February, page 11).

According to Glashow, this latest neutrino finding 'proves that Nature's bag of tricks is not empty and demonstrates the virtue of consulting her, not her prophets'.

Zagreb neutrino

At the Ruder Boskovic Institute in Zagreb, Yugoslavia, an experiment has reported evidence for a 17 keV neutrino in the radiation spectrum (internal bremsstrahlung) emitted from electron capture (from atomic shells) in a germanium-71 source.



Left to right, V. Kamenov, V. Medjidzade, and A. Mikhailichenko of the Institute of Nuclear Physics at Novosibirsk, USSR, examine one of the first quadrupole magnets delivered from Siberia to Stanford for use in the new Final Focus Test Beam facility to study the focussing of submicron beam spots of electrons and positrons. (Not pictured are V. Alexandrov and A. Chernyshov).

STANFORD
First magnets for Test Beam Facility

The first quadrupole magnets for the Final Focus Test Beam (FFTB) were delivered to the Stanford Linear Accelerator Facility (SLAC) in February.

The task of the international FFTB effort is to investigate the magnetic focusing systems needed to handle submicron beam spots for the next generation of electron-positron linear colliders (November 1990, page 11).

As part of this international collaboration, the FFTB high precision lenses have been designed and fabricated by the Institute for Nuclear Physics, Novosibirsk (INP), where a group has taken responsibility for delivery of the main quadrupole, dipole, and sextupole elements of the FFTB beamline.

These first magnets will soon be followed in early spring by 30 identical units, and the entire complement will arrive at SLAC in the summer.

Extensive tests and measurements made in the Soviet Union and SLAC testify to the care and exactness with which this hardware has been fabricated and assembled. The goal of the FFTB project to produce nanometre beam spots requires careful control and compensation of the magnetic fields in the beamline.

Quadrupole fields accurate to one part in a thousand must be generated in lenses with centimetre apertures and focusing strengths as large as a half a tesla. This has been achieved by machining special contours into the poletips of the lenses, and by maintaining fabrication and assembly tolerances to within a few microns.

On schedule, the Final Focus Test Beam is planned to begin operations in the fall of 1992 and will provide valuable feedback for the design and construction of the next linear collider.

DESY
H1 detector ready for tests

Finishing touches are now being made to the two big detectors – H1 and Zeus – to exploit the new HERA electron-proton collider soon to be commissioned at the German DESY Laboratory, Hamburg.

A collaboration of more than 30 groups from ten countries, H1 is now nearly complete in HERA Hall

South and ready for tests with cosmic rays. (A progress report on the Zeus detector will appear in a forthcoming issue.)

The main parts of the H1 detector – tracking chambers, the liquid argon calorimeter, other calorimetry and the superconducting solenoid with its iron yoke – were completed in February.

After completion of installation and final welding, the calorimeter cryostat was carefully cooled. Filling with 50 cu m of liquid argon began on 10 February and lasted three days. At the same time, the inner central and forward tracking and proportional chamber systems have been installed and are undergoing high voltage tests.

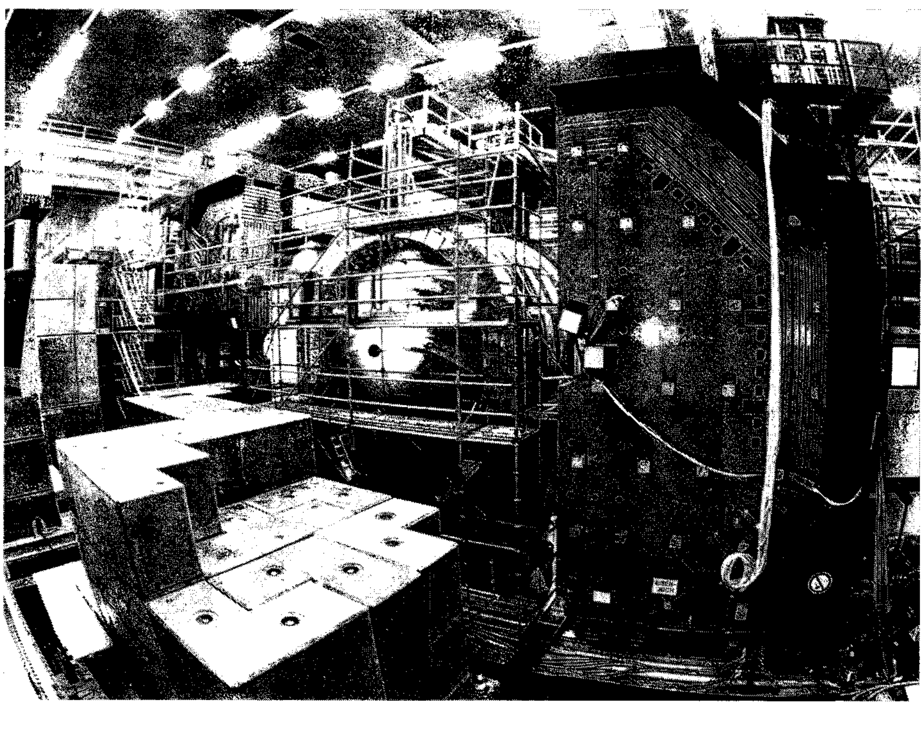
All cabling for both the calorimeter (45,000 channels) and the tracker (15,000 channels) was prepared in advance and the detectors are connected to supply and control electronics. Data readout under control of the central trigger and central data acquisition systems has been tested for all subsystems.

First tested in 1989, the 6-m diameter H1 superconducting coil is now cold again and tests with cosmic rays to check out calorimetry and tracking are imminent.

The forward muon spectrometer with its toroid and six double layers of drift chambers is, unlike the main detector, installed directly on the HERA beamline. With four out of the planned six double layers of drift chambers fitted, the spectrometer, together with large scintillators eventually to be used as veto counters, will study background around the beam.

From F. Brasse

The H1 detector – getting ready to exploit the HERA electron-proton collider soon to be commissioned at the German DESY Laboratory in Hamburg.



MAINZ MAMI microtron

Officially inaugurated at the end of January was the new Mainz Microtron – MAMI – which became fully operational last summer after a final three-year construction phase at Johannes Gutenberg University.

A continuous wave (c.w.) machine, MAMI delivers electrons up to 855 MeV and 100 microamps. Mainz has had a lot of experience with polarized electron sources, and the unit prepared for installation on MAMI gives today a 20 microamp beam with 20 hours of 40 per cent spin alignment.

Electron beams probe deep inside nucleons, so that physicists can look for subtle variations in nucleon behaviour due to the surrounding nuclear environment. However this requires 'coincidence experiments' which look for simultaneously emitted secondary particles produced by the same incident electron.

In such studies, a continuous electron beam gives maximum performance. One approach is to use a 'pulse stretcher' ring to make the electron beam less like the series of spikes delivered by conventional linear accelerators. This principle is being used in several projects, including the AmPS project at Amsterdam and at the Bates Laboratory at MIT, with about the same energy. The ELSA machine at Bonn (January/February 1988, page 26) gives energies between 2.5 and 3.5 GeV with very long, smooth pulses at relatively low intensity.

On the other hand a c.w. machine, like MAMI, provides from the outset a smooth stream of electrons. While the CEBAF machine currently under construction at Newport News, Virginia, will use

*** The April issue will include a report on the S-DALINAC superconducting machine now coming into operation at Darmstadt.**

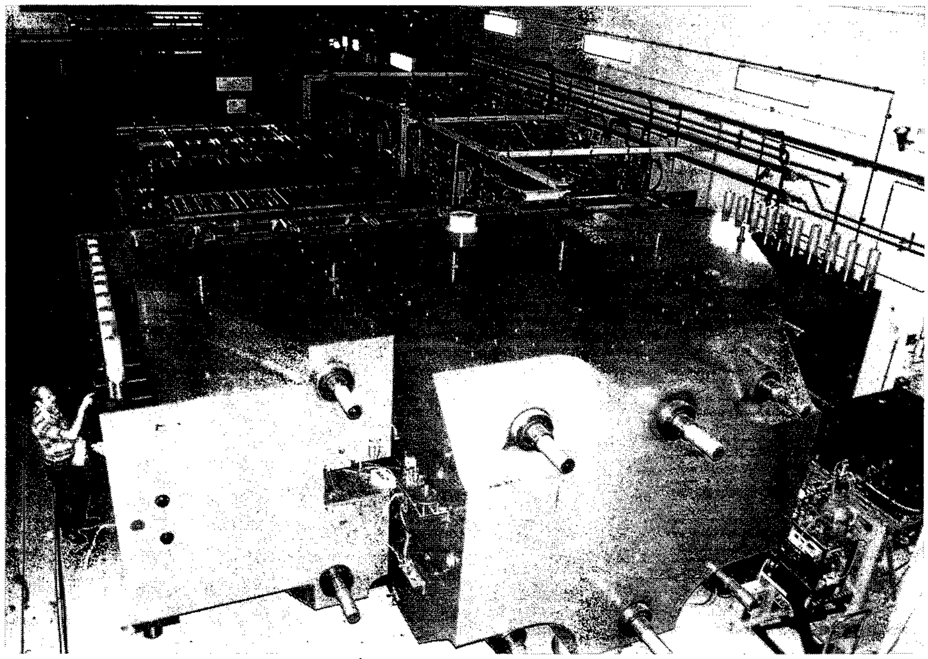
superconducting radiofrequency technology to provide a continuous electron beam of several GeV*, the MAMI project was based from its inception in the mid-1970s on conventional radiofrequency using the racetrack microtron idea – a linear accelerator where the beam is continuously recycled by 180° bending magnets at both ends.

MAMI's 3.5 MeV linear accelerator injector feeds a chain of three racetrack microtrons attaining respectively 14, 180 and the final 855 MeV. However the output energy can be varied from 180 to 855 MeV in 15 MeV steps. Typical energy spread is 60 keV. MAMI is the first c.w. accelerator using conventional r.f. (2.45 GHz) to attain the multi-MeV region.

The initial 14 MeV microtron was completed in 1979, and the second stage four years later. The 180 MeV facility was used for a range of nuclear structure investigations.

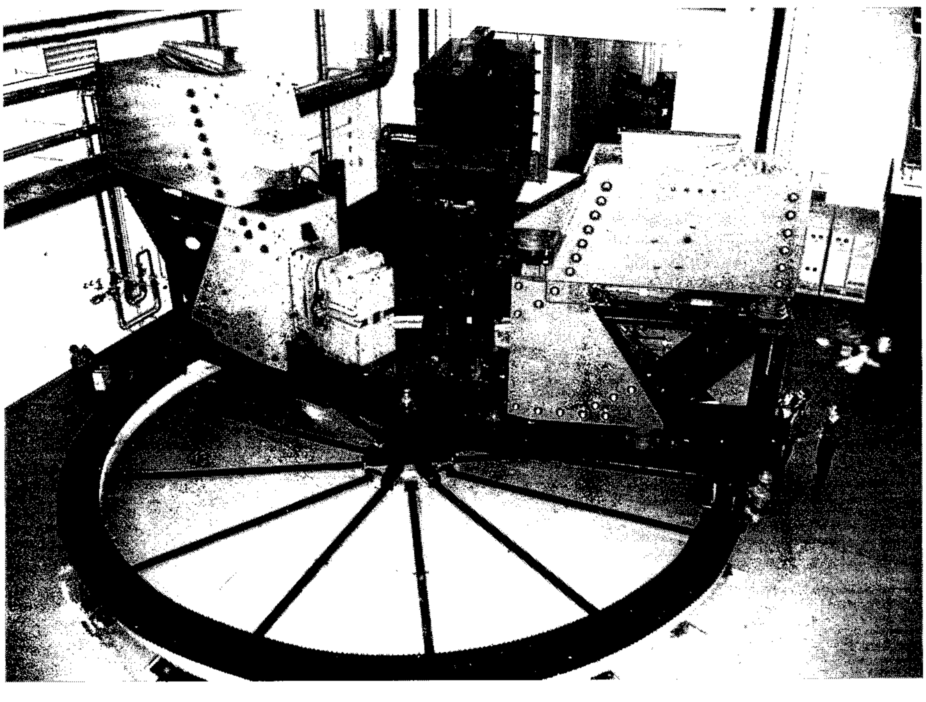
The project is funded by the federal and regional German governments, but also benefits from external sponsorship, notably from the UK Science and Engineering Research Council (SERC) and the French Saclay Laboratory.

The goal of the experimental programme at 855 MeV is the study of hadrons and nuclei through electromagnetic interactions. While MAMI's energy and consequent resolution of 0.2 fermi cannot discern quarks, its intense beams do allow precision measurements which may serve as sensitive tests of models inspired by quark field theories. Examples are the neutron's electric form factor (spatial charge distribution), and the high momentum components of bound nucleons which reveal details of internucleon interactions at very small distances. The idea is



▲ *The third microtron of the MAMI continuous electron beam machine at Mainz which came into operation recently can attain energies up to 855 MeV. Foreground and background are the two 450-ton deflecting magnets which turn the electron beams through 180° and recirculate them in the linear accelerator.*

▼ *One of MAMI's three major experimental stations – three magnetic spectrometers mounted on a turntable.*



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comparable to the study of nuclear composition in terms of nucleons and pions through precision measurements of global nuclear properties such as magnetic moments, gyromagnetic ratios, charge distributions, giant resonances etc..

MAMI's experimental programme is built around three major facilities.

- Three large high-resolution spectrometers rotating around a target will permit a range of studies of reactions mediated by (virtual) photon exchange – release of quasi-free nucleons, resonance and meson production, etc.
- A large broad-band photon energy tagger covering the range 50-800 MeV studies reactions induced by (bremsstrahlung) photons emitted by the electrons. Reactions include photodisintegration, photoproduction and Compton scattering.
- The third facility incorporates the polarized electron source, where an initial aim is to study the neutron's electric form factor, avoiding the need to first look at deuterium and then subtract the effects of the proton.

As well as these well-defined physics aims, MAMI's intention is to carry out front-line fundamental research with sophisticated technology in a university environment, with its concomitant limitations of infrastructure and manpower. Dedicated commitment by university staff and youthful enthusiasm from students ensured the success of the initial programme, and bodes well for the continued research at higher energies.

COLLIDERS
Preparing the way

A major international effort is underway to study the ongoing problems of building the next generation of electron-positron linear colliders.

A trail has been blazed by Stanford's SLC Linear Collider, based on the Laboratory's existing 2-mile linac, but many technical challenges have to be met before new machines can be proposed. As well as improved acceleration techniques to propel electron and positron beams economically to higher energies, a major task is to shrink the beam profiles into tiny spots to get sizable collision rates (luminosities).

Not that long ago the linear collider goal was to attain TeV collision energies, equivalent to those of the planned proton colliders (LHC at CERN and the SSC Superconducting Supercollider in the US), for a two-pronged attack on new physics frontiers.

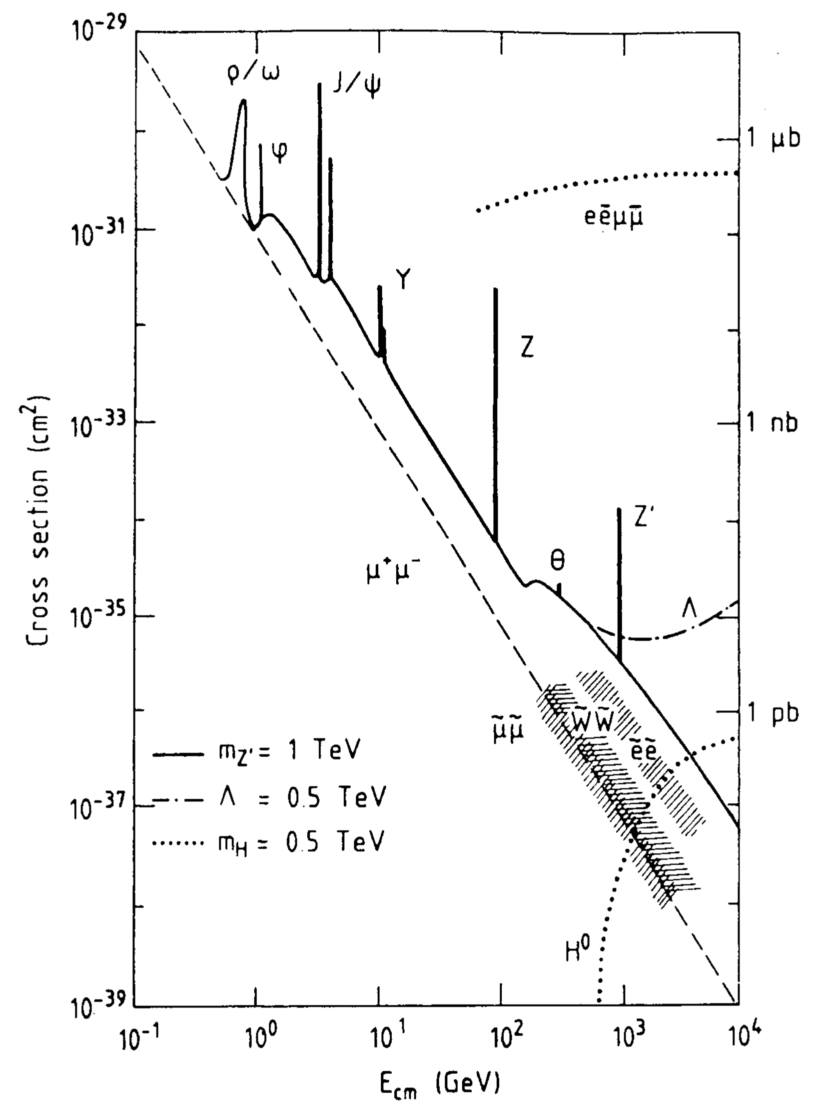
However achieving the necessary accelerating forces and the desired tiny beams needs more work. In the meantime new physics objectives have emerged at the sub-TeV level – the spectroscopy of the sixth ('top') quark and the hunt for the 'Higgs' symmetry breaking mechanism at the heart of electroweak physics. This has motivated a fresh effort for electron-positron collisions around several hundred GeV.

Thus at electron-positron Laboratories all over the world, research and development work is progressing on a number of fronts – new or improved radiofrequency acceleration techniques and production and dynamics of controlled (low emittance) beams, as well as final focus design (see page 10). Several Laboratories now view a few hundred GeV electron-positron collision energies as a realistic next step.

In Germany, electron beam experts Gus Voss and Tom Weiland are looking to push conventional technology with a multibunch machine using a standard radiofrequency (3 GHz) and accelerating

At a meeting in Munich in February to look at the physics potential of 500 GeV electron-positron collisions – left, European Committee for Future Accelerators (ECFA) Chairman J.-E. Augustin with Munich meeting Organization Committee Co-Chairman P. Zerwas of Aachen. (Photo Maurice Jacob)

An electron-positron annihilation spectrum covering both known behaviour at lower collision energies and possible new phenomena at higher energies, including the production of supersymmetric particles. Collision energies of several hundred GeV are not a technological dream and could reveal some interesting physics.



gradient (17 MV/m) to reach a collision energy of 500 GeV.

In the USSR, a Novosibirsk group is working at the Institute for High Energy Physics at Protvino, near Moscow, to develop new electron facilities to complement the UNK proton ring now under construction. Here a 500 GeV collision energy is the objective, with a design aiming for 100 MV/m accelerating fields with a gridded klystron working at 14 GHz.

At Stanford, and at KEK in Japan, specialists are also looking towards new power sources, with klystrons operating in the 7-14 GHz frequency range and around 100 MW, augmented by pulse compression units. Here the goal is to reach for 500 GeV – 1 TeV collisions, with accelerating field gradients of 90-100 MV/m.

Elsewhere in California and at CERN, the preferred option is a two-beam accelerator with a drive beam reducing the need for kilometres of expensive power tubes. This approach is widely accepted as the best way towards the very high frequency acceleration techniques which could open the way to a few TeV.

CERN's CLIC scheme foresees 30 GHz r.f. power generated by a drive beam of short (millimetre) intense (10^{12}) electron bunches powered by 0.35 GHz superconducting cavities developed for LEP (November 1990, page 5).

In California, a group from the Lawrence Berkeley and Livermore Laboratories is investigating a multi-stage free-electron laser at 17 GHz driven by an induction linac.

Another approach is a fully superconducting linear accelerator, long advocated by pioneers Ugo Amaldi at CERN and Maury Tigner at Cornell. At a meeting at Cornell last year the TESLA (TeV Energy Superconducting Linear Accelerator) international study group was launched (November 1990, page 20). TESLA is being actively pursued at Cornell and CEBAF in the US, and CERN, DESY, Saclay, Genoa and Wuppertal in Europe, and a new meeting is scheduled for end-August in Hamburg. Possible TESLA scenarios include a series of fully superconducting linear colliders of increasing length and accelerating gradient covering collision energies from a few hundred GeV up to 2 TeV. At a meeting in Munich in February, Bjorn Wiik of DESY suggested that the fully superconducting approach would be the optimal choice, provided production costs could be significantly reduced by vigorous R and D work over the next few years.

Another possibility which has attracted attention would be to make use of existing or planned rings. While the beam energy attainable with such conventional circular machines is necessarily limited by synchrotron radiation, electron-positron collisions in the few hundred GeV range could be obtained by firing an electron linac into a positron storage ring. Electron-proton collisions (with a proton ring) could also be achieved via this route.

Meanwhile physics groups are looking at the research potential of a 500 GeV electron-positron collider. Following the meeting at Munich in February, discussions will continue at Annecy, France, in June, and in Hamburg in August. A major discussion is being organized by the International Committee for Future Accelerators (ICFA), scheduled for Finland in September.

From Paul Grosse Wiesmann

People and things

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N. V. Baggett

TRIUMF Laboratory, Canada
M. K. Craddock

On people

Among the recipients of this year's UK Institute of Physics Awards are Sir Rudolf Peierls, who receives the Paul Dirac Prize for his major contributions to many and varied areas of particle physics, and Dennis Sciama, who receives the Guthrie Prize for his contributions to astrophysics.

Mel Schwartz at Brookhaven

Mel Schwartz, who shared the 1988 Nobel Physics Prize with Leon Lederman and Jack Steinberger, becomes Associated Director for High Energy and Nuclear Physics at Brookhaven, replacing Larry Trueman, who returns to theory research. The 1962 experiment which showed that neutrinos come in several distinct kinds and ultimately earned the Nobel was carried out at Brookhaven.

Mel Schwartz becomes Associate Director at Brookhaven.

Shadows of Creation

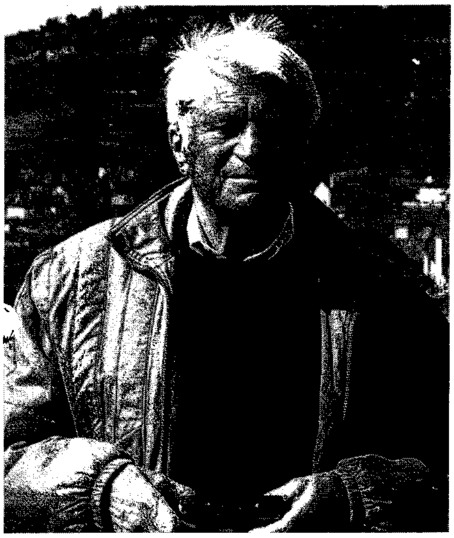
Published by W.H. Freeman is the book 'Shadows of Creation' by Michael Riordan and David Schramm, with a foreword by Stephen Hawking. Subtitled 'Dark Matter and the Structure of the Universe', the book looks at the need for dark matter and its major role in cosmology, and the search for it. Formerly Science Information Officer at the Stanford Linear Accelerator Center and currently assisting the President of the Universities' Research Association in Washington, Riordan is author of 'The Hunting of the Quark', which won the 1988 American Institute of Physics Science Writing Award. Louis Block Professor in Physical Sciences at Chicago, Schramm is co-author with Leon Lederman of 'From Quarks to the Cosmos'. Both Riordan and Schramm have been major contributors to the CERN Courier.

Arkadii Benediktovich Migdal 1911-1991

Leading Soviet theoretician Academician Arkadii Benediktovich Migdal died on 9 February. With wide interests ranging over nuclear and many-body physics, he solved a number of crucial problems and opened new physics frontiers. Quick to see the potential interplay between advances in different areas of physics, his characteristic interdisciplinary approach led to new insights, and his ingenious use of qualitative methods was highly successful.

After initial studies in Leningrad, he moved in 1940 to Moscow's Institute of Physical Problems, headed by Lev Landau, for a docto-

Arkadii Benediktovich Migdal 1911-1991.



rate investigation of processes accompanying nuclear reactions. In 1945 he transferred to the Institute for Atomic Energy, where he made important contributions to early reactor design, and in the early 1950s turned his attention to the problems of radiation in controlled thermonuclear fusion.

During this time he continued to follow quantum and nuclear physics. His pioneer applications of dispersion theory to nuclear reactions led to new understanding of final state interactions (the Migdal-Watson Effect). In the late 1950s he turned to the implications of quantum field theory for the many-body problem and for nuclear physics, invoking a particularly effective quasi-particle approach.

Moving back to Moscow in the early 1970s, he turned his attention to the behaviour of particle systems in strong external fields, using non-perturbative techniques. This showed that nuclei are on the verge of producing pion condensates, and hinted at the possible existence of superdense nuclei and other extreme nuclear states, with interesting implications for astrophysics.

A gifted teacher, he lectured for 35 years at Moscow's Engineering Physics Institute, and was a prolific producer of influential monographs. He was awarded the Order of Lenin and several other Soviet distinctions.

Aside from science, he was a talented sculptor and jeweller as well as an inveterate sportsman – mountain climber, skier, skater and diver. He was the first Chairman of the Presidium of the Soviet Federation of Underwater Sports, holder of Underwater Sportsman's Card No. 1. He produced three well-known underwater films and was an appreciated TV popularizer of science.

In addition to his stature as a scientist, his sociability, wit and charm won him many friends throughout the world.

Igor Kobzarev 1932-1991

Igor Kobzarev, who died unexpectedly in Moscow on 20 January, was remarkable for being both an outstanding physicist and a real philosopher, concerned with the deepest problems of mind and knowledge, culture and history. In addition to well-known results on the physics of kaons, on cosmological implications of spontaneous symmetry breaking, on general relativity and on hadron structure, his philosophical and historical work was also influential, including a book, in English, with Yu.I. Manin – 'Elementary Particles. Mathematics, Physics and Philosophy'. His charm and erudition attracted young and old alike, and his talents were highly appreciated by many, including I. Pomeranchuk, I. Tamm, Ya. Zeldovich and A. Sakharov. Despite this high esteem of his colleagues, he gained little formal recognition.

Igor Kobzarev 1932-1991.

1992 Accelerator Conference

In 1992 the XVth International Conference on High Energy Accelerators will be held from 20-24 July at the Congress Centrum, Hamburg, Germany. Further information from the Conference secretariat at DESY, Notkestr. 85, D-2000 Hamburg, Germany; phone (49) 40 8998-2636, telex 215124 desyd, fax 40 8969-7305, e-mail HEAC92 at DHHDESY3.BITNET

School report

The 100 or so places for the CERN Accelerator School's 'Radiofrequency Engineering for Particle Accelerators' course in Oxford from 3-10 April were sold out well in advance. The next course, 'Advanced Accelerator Physics', is to be held from 16-27 September at Noordwijkerhout in the Netherlands. Further information from Mrs. S. von Wartburg, CERN Accelerator School, CERN, 1211 Geneva 23, Switzerland.

Another recent success was the Joint US-CERN School on Intensity

Limitations, held on Hilton Head Island, South Carolina, last November, at the invitation of the CEBAF Laboratory.

No 17 keV neutrino

(see page 9)

A new result from a Caltech group looking at the beta decay of sulphur-35 finds no evidence for a 17 keV neutrino. In their findings, the group point out that experiments giving negative results used magnetic spectrometers, while 17 keV neutrino claims derive from semiconductor detectors.

▲ A good turnout at the Joint US-CERN Accelerator School on Intensity Limitations held last November on Hilton Head Island, South Carolina, at the invitation of the CEBAF Laboratory

▼ Ugo Amaldi, spokesman of the Delphi experiment at CERN's LEP electron-positron collider, gave a talk at the recent 69th session of the Scientific Council of the Joint Institute for Nuclear Research, Dubna, near Moscow.

CERN 'Yellow' reports 1990 / 1991

The following reports have been issued in the official CERN Reports series, since the last list in CERN Courier in November 1990:

CERN 90-08
CERN. Genève
Kuiper, B *[ed]*
Proceedings, Europhysics conference on control systems for experimental physics, Villars-sur-Ollon, Switzerland, 28 Sep – 2 Oct 1987
CERN, 12 Oct 1990. – 592 p

CERN 90-09
Telegdi, V L
Mind over matter ; The intellectual content of experimental physics
CERN, 2 Nov 1990. – 20 p

CERN 90-10 v.1; ECFA 90/133 v.1
CERN, Genève
Jarlskog, G; *[eds]*
Proceedings, v.1, Large Hadron Collider Workshop, Aachen, 4–9 Oct 1990
CERN, 3 Dec 1990. – 634 p

CERN 90-10 v.2; ECFA 90/133 v.2
CERN, Genève
Jarlskog, G; *[eds]*
Proceedings, v.2, Large Hadron Collider Workshop, Aachen, 4–9 Oct 1990
CERN, 3 Dec 1990. – 1306 p

CERN 90-10 v.3; ECFA 90/133 v.3
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Jarlskog, G; *[ed]*
Proceedings, v.3, Large Hadron Collider Workshop, Aachen, 4–9 Oct 1990
CERN, 3 Dec 1990. – 853 p

CERN 91-01
CERN. Genève
Proceedings, CERN School of Physics, Lefkada, Greece, 8 Sep–1 Oct 1988
CERN, 10 Jan 1991. – 384 p

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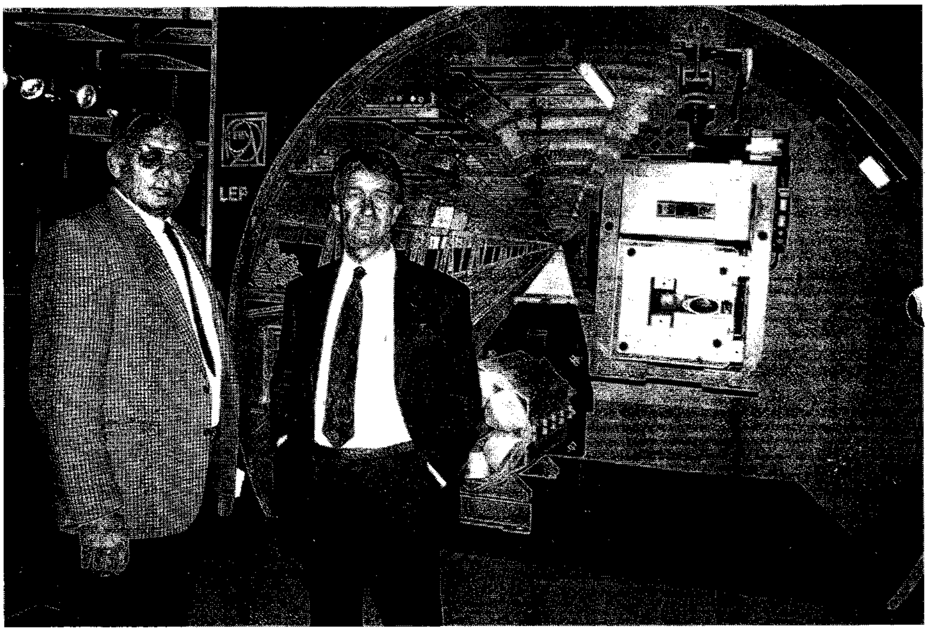

The 'Intertech Bodensee' fair held recently in Dornbirn, Austria, aimed to promote high technology in the Bodensee (Lake Constance) area at the common frontier of Austria, Germany and Switzerland. CERN was guest of honour at the expo, and was presented by Ernest Kaufmann (left) of PS Division, seen here in front of a mock-up of CERN's LEP tunnel with exhibition chairman Klaus Ulmer. CERN's work in high technology was much admired by visitors to the expo.

(Photo Heinz Lanz)

John Bell Symposium

A Symposium on Quantum Physics, in memory of John Stewart Bell who died on 1 October 1990, will be held at CERN on 2-3 May. The scientific programme includes talks by A. Aspect, H. Rauch, A.J. Leggett, K. Gottfried, A. Shimony, G.C. Ghirardi, J. Leinaas and R. Jackiw. Further information from Jeanne Rostant, Theory Division, CERN, 1211 Geneva 23, Switzerland, phone (+41) 22 767 4222, fax (+41) 22 782 3914, bitnet rostant at cernvm.cern.ch

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