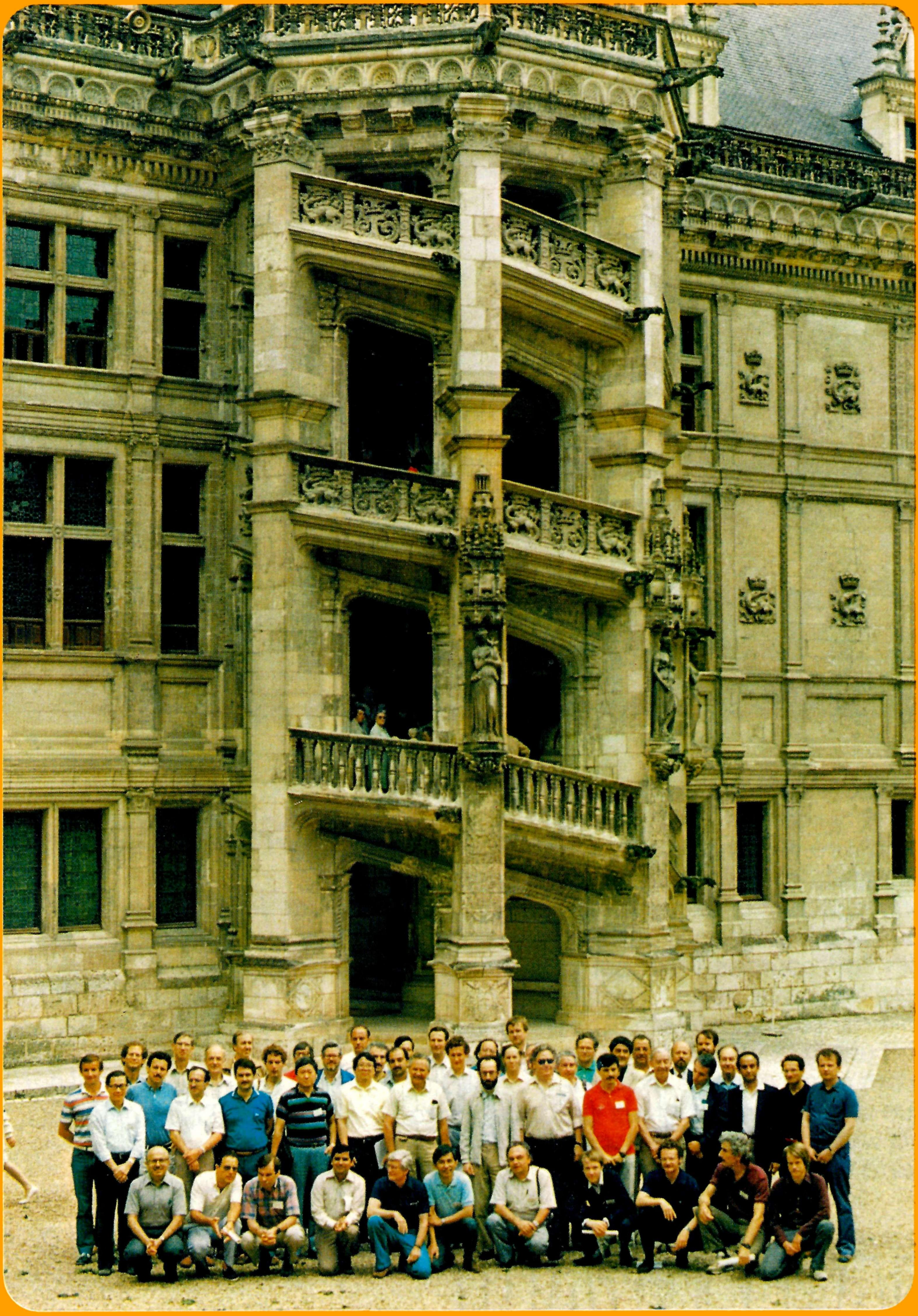
CERN COURIER

International Journal of High Energy Physics



VOLUME 26 **2** MARCH 1986

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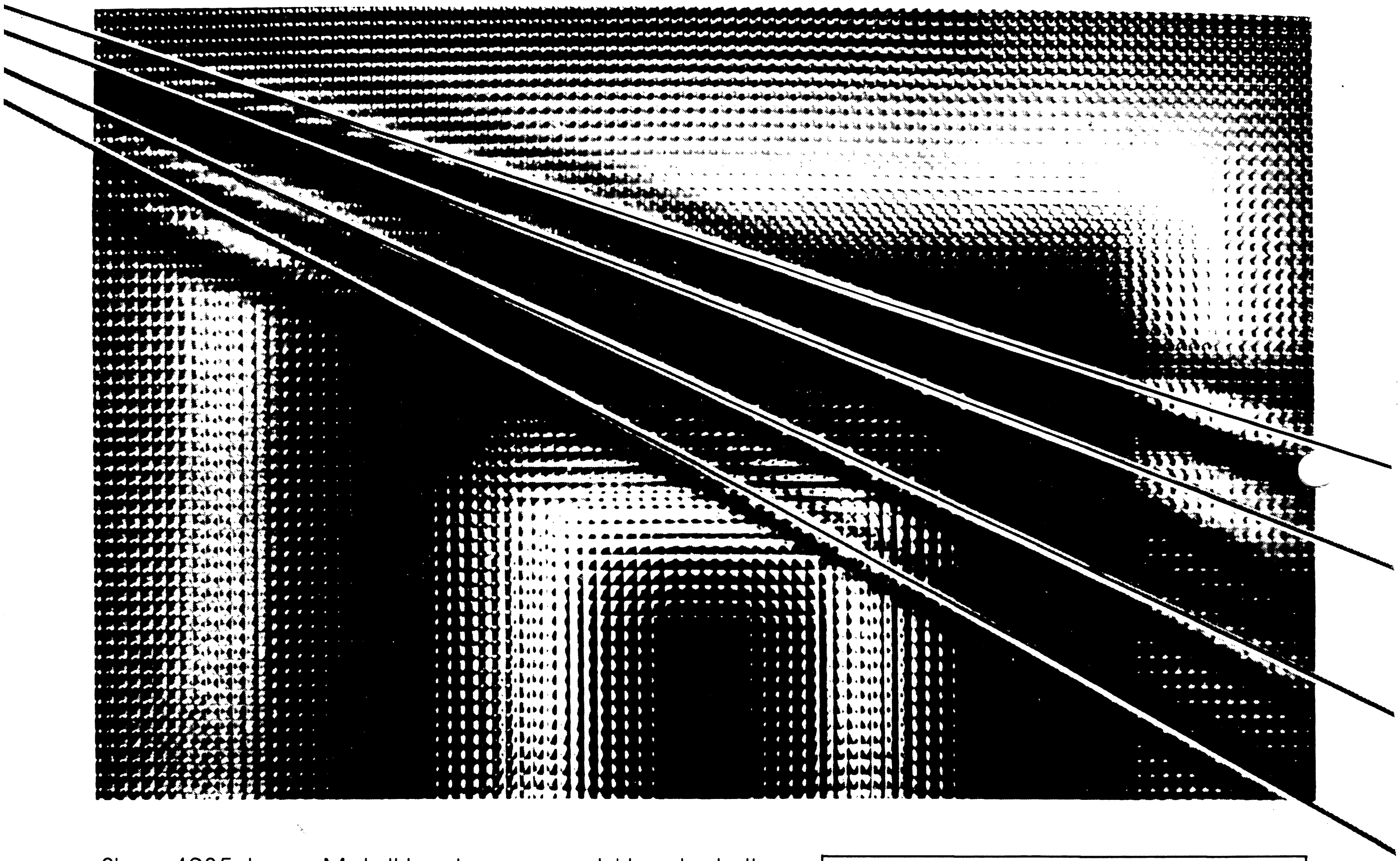

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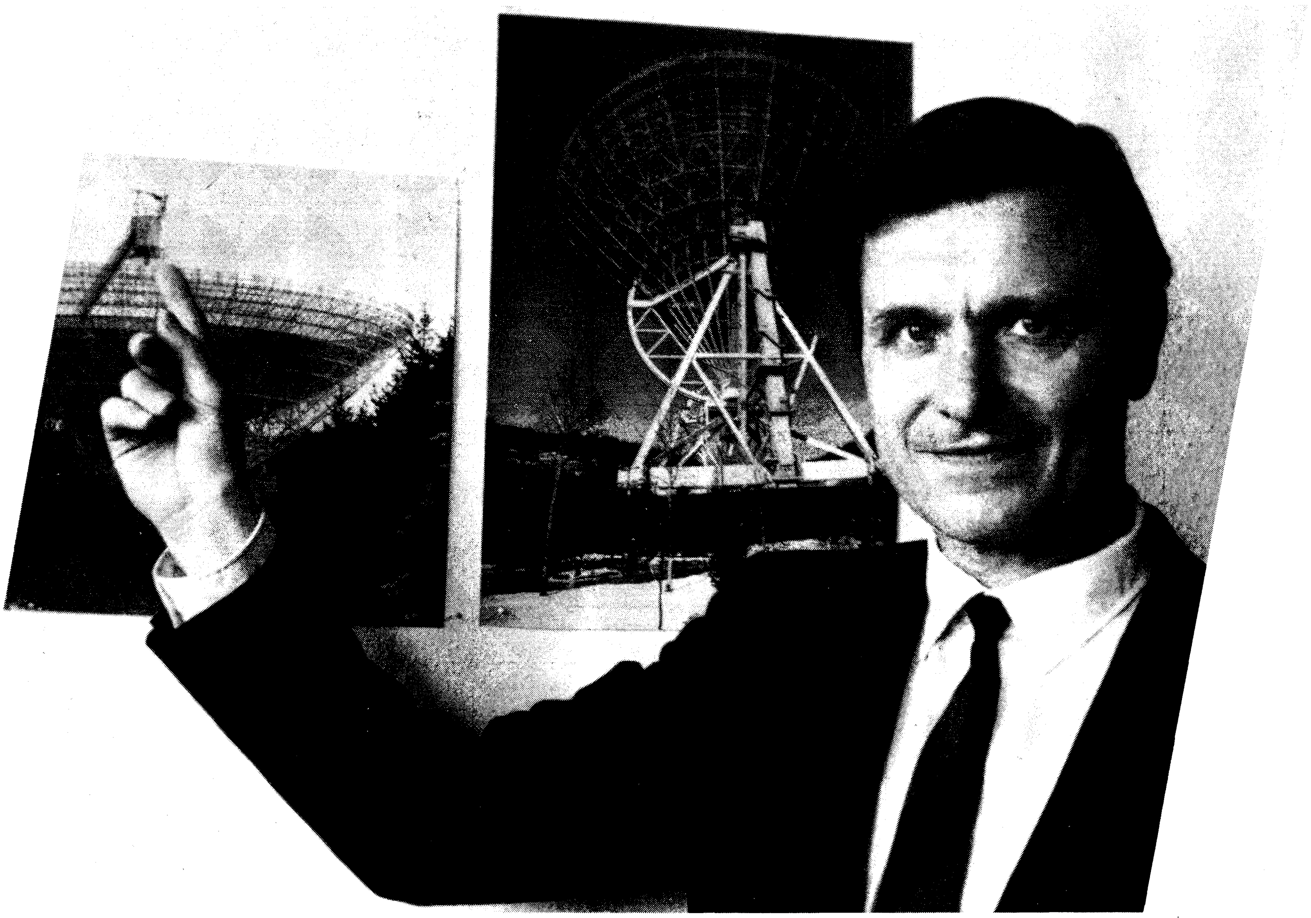

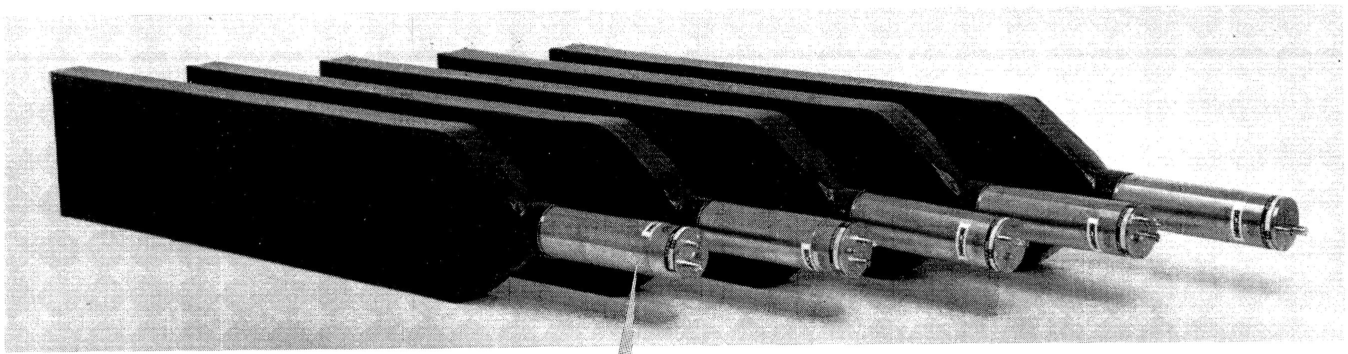

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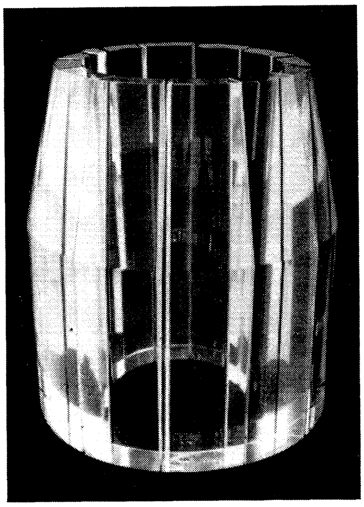

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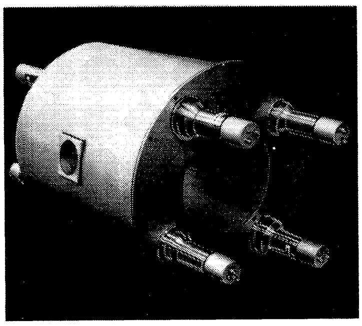

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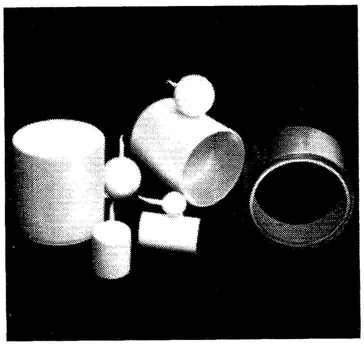

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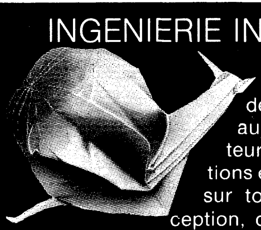

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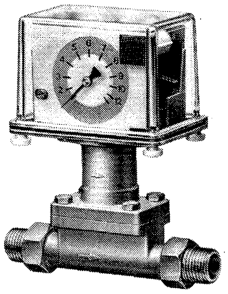

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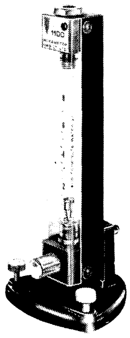

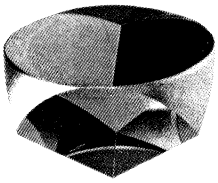

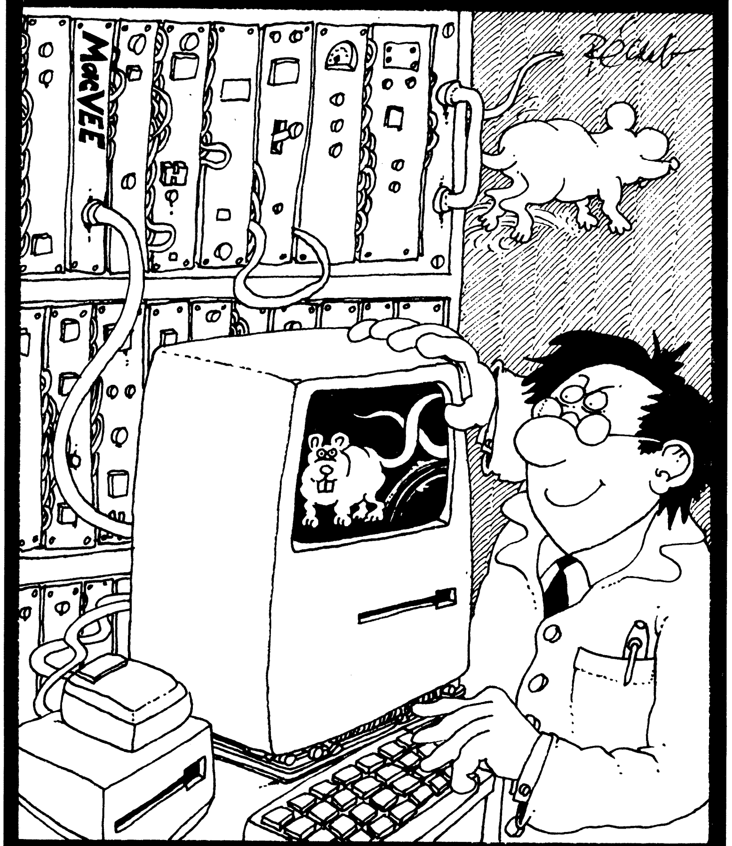
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CERN COURIER

International Journal of High Energy Physics

Editors: Gordon Fraser, Brian Southworth, Henri-Luc Felder (French edition)/
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VOLUME 26 Nº 2 MARCH 1986

Around the Laboratories

Physics monitor

Cover photograph: The famous 16th-century spiral staircase of the château at Blois, France, forms the backdrop for a group photograph of the participants at a recent workshop on Elastic and Diffractive Scattering (for report, see page 25). As well as being negotiable on horseback, the famous staircase also served as a grandstand overlooking the courtyard.

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CERN COURIER is published ten times yearly in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management

Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland

Published by:
European Laboratory for Particle Physics
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11, Telex 419 000
(CERN COURIER only Tel. (022) 83 41 03)

USA: Controlled Circulation
Postage paid at Batavia, Illinois

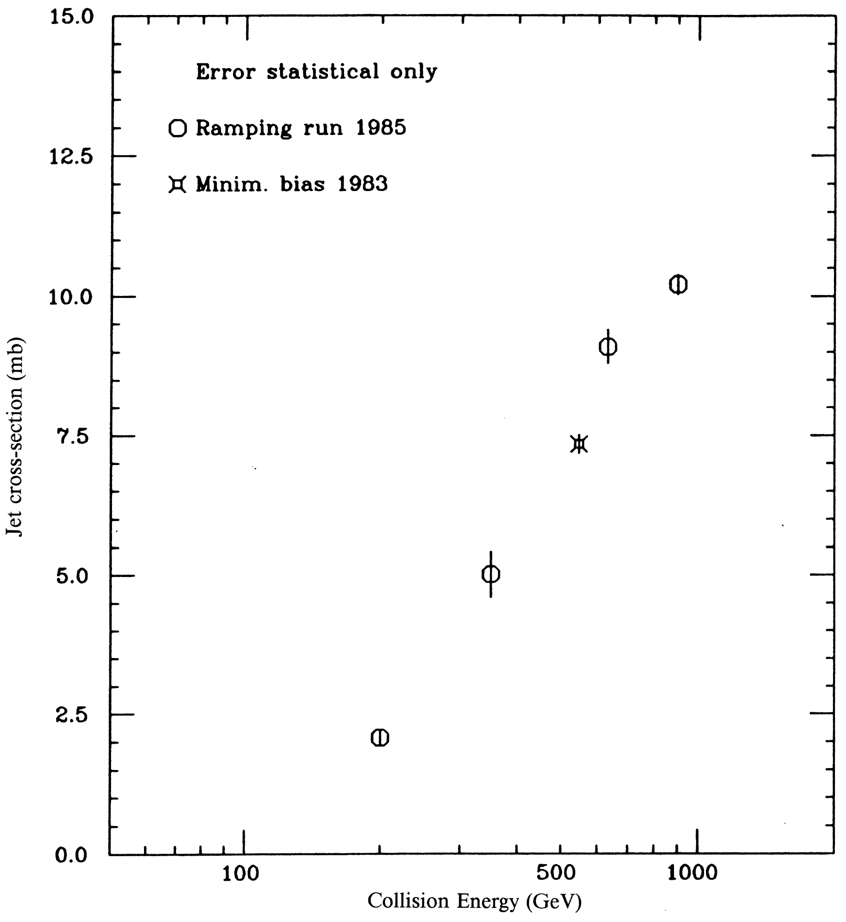
Around the Laboratories

CERN
Antiprotons 1985

Although the new Fermilab Tevatron took the world collision energy record, 1985 was still a vintage year for CERN antiprotons.

The scene was set last March when the ambitious attempt to ramp protons and antiprotons up and down between 100 and 450 GeV in the SPS was immediately successful, providing the first glimpse of physics at collision energies of 900 GeV. In June came a short special run for the UA4 elastic scattering experiment. The main 1985 run got underway at the beginning of September, and when the 315 GeV beams were finally dumped on 23 December, the accumulated luminosity (a measure of the number of proton-antiproton collisions achieved) had reached a record figure of 655 inverse nanobarns, surpassing even the total number of collisions om all previous runs (0.2 inverse nanobarns in 1981, 28 in 1982, 153 in 1983 and 395 in 1984). Another great success last year was the smooth parallel running of the SPS Collider and the LEAR Low Energy Antiproton Ring.

The main 1985 Collider run progressed in grand style with up to 70 nb^{-1} being recorded in a single week, while the superb Antiproton Accumulator scaled new heights of reliability, running at one stage for 999 hours (42 days) without the slightest mishap, notching up on the way a new stacking record of 4.2 x 10^{11} antiprotons. Later in the run, electrostatic separators ensured that the Collider's three circulating bunches of protons and of antiprotons collided only where needed, thus reducing beam instabilities. Tests were also carried out using one bunch of antiprotons against six bunches of circulating protons. All this bodes well for next year, when the new ACOL Antiproton Collector will hopefully boost CERN's antiproton intensity tenfold.



Results from the UA1 experiment at the CERN proton-antiproton Collider show that the production of clusters or 'jets' of hadrons increases significantly over the energy range 200-900 GeV.

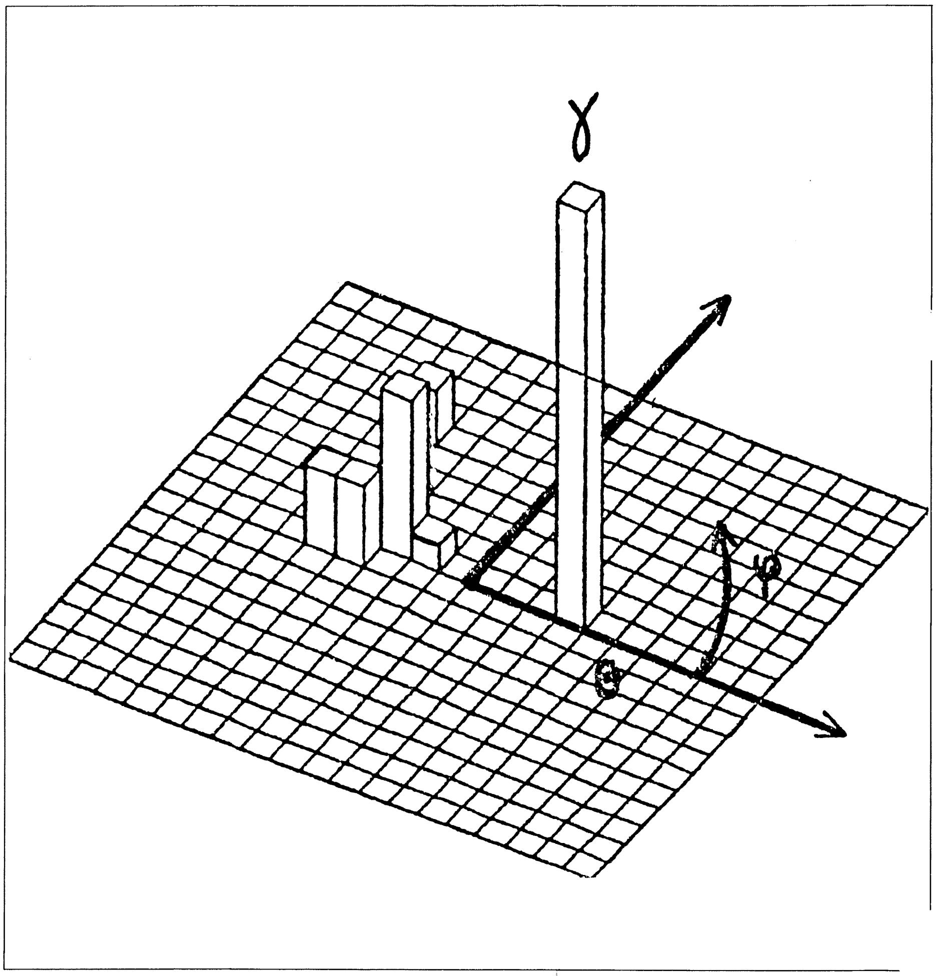
Plenty of particles

In March last year, packets of 450 GeV antiprotons orbiting in the seven-kilometre SPS ring at CERN smashed into 450 GeV packets of protons travelling in the other direction. This set up a world record collision energy, surpassed seven months later when 800 GeV particles collided in the new Fermilab Tevatron ring (see December 1985 issue, page 419).

Scanning the 450 + 450 GeV collisions at CERN were the big UA1 experiment led by Carlo Rubbia and the UA5 streamer chamber team (Bonn/Brussels/Cambridge/CERN/Stockholm). UA5's results pointed to a new description of the number of produced particles (multiplicity), covering a much wider range than at lower energies (see October 1985 issue, page 335). UA1's results from this new energy range also point to new behaviour, and together the results have significant implications for the higher energy studies soon to get underway at Fermilab's Tevatron Collider.

UA1 finds that the fraction of 'hard' scatterings producing a cluster or 'jet' of hadrons (strongly interacting particles) increases significantly, tripling over the collision energy range (200-900 GeV) covered in the March 1985 run, and accounting for almost 20 per cent of the activity as the energy approaches 1 TeV.

The big experiments now setting up at the Tevatron can look forward to plenty of particles!



Compton scattering off a quark, showing the emerging photon (gamma) and the recoiling jet of particles from the struck quark.

Bouncing photons

As well as sticking tightly together through the strong nuclear force, the quark constituents of nucleons are electrically charged and behave electromagnetically.

One of the textbook examples of modern electromagnetism is the Compton Effect where photons bounce off individual electrons whose recoil shifts the photon wavelength. However a similar effect should be seen when photons bounce off any other charged particles carrying half a unit of spin, like quarks.

An Athens / CERN / Collège de France / Ecole Polytechnique / Imperial College London / Orsay / Saclay / Southampton / Strasbourg / Warsaw group (NA14 experiment) using the high intensity photon beam in the North Experimental Area of the CERN 450 GeV SPS synchrotron has looked at the (prompt) photons which emerge with large transverse momenta directly from a target.

The average energy of the incident photons is about 90 GeV, corresponding to a wavelength 10^8 smaller than the X-rays used in the original measurements of the Compton Effect over sixty years ago. Making allowance for background processes which provide spurious prompt photons, the NA14 team has isolated the signal due to photons which bounce off the quarks within the target nucleons.

Such events are rare — one in ten million. The structure of the emerging particles clearly shows an isolated photon and a recoiling 'jet' of hadrons from the struck quark. This is the first time that Compton scattering on quarks has been observed and measured.

The scattering can be calculated

using the nucleon quark structure measured in other experiments. Like the classic Klein-Nishina formula for Compton scattering, it depends on the fourth power of the electric charge of the target particle.

While standard quark theory proposes fractional electric charges, there was still room for models with quarks carrying integer electric charge. The CERN experiment strongly favours the fractional charges.

Another effect studied with this high energy photon beam is the prompt photoproduction of gluons, seen through the production of neutral pions (identified through their decay into photon pairs). This effect, called QCD Compton scattering (QCD — quantum chromodynamics — is the theory describing quark interactions), is the inverse of the process, discovered in the late 1970s, where quarks radiate electromagnetic energy (photons) when sharply struck.

The observed effect agrees with theoretical predictions, including delicate correction terms, providing an accurate check of QCD theory.

Low energy US antiprotons

Now that Fermilab has demonstrated that the ability to handle high energy antimatter is not restricted to Europe, thoughts are turning also to the construction in the US of a low energy source of antiproton beams. The LEAR Low Energy Antiproton Ring at CERN, which began operation in 1983, continues to be a great success, attracting hundreds of users, many of them new, to CERN. The availability of the new ACOL Antiproton Collector next year should considerably increase LEAR's potential.

Last October, a workshop was held at the University of Wisconsin, Madison, to look at the possibility of a dedicated low energy antimatter source in the US. The Madison workshop attracted about 60 participants from the US and Europe. There were extensive discussions of the present LEAR programme and the physics goals of low energy antiproton interactions as well as the properties of antiprotons, including the intriguing possibility of measuring the pull of gravity on these particles (do they fall down or up ?).

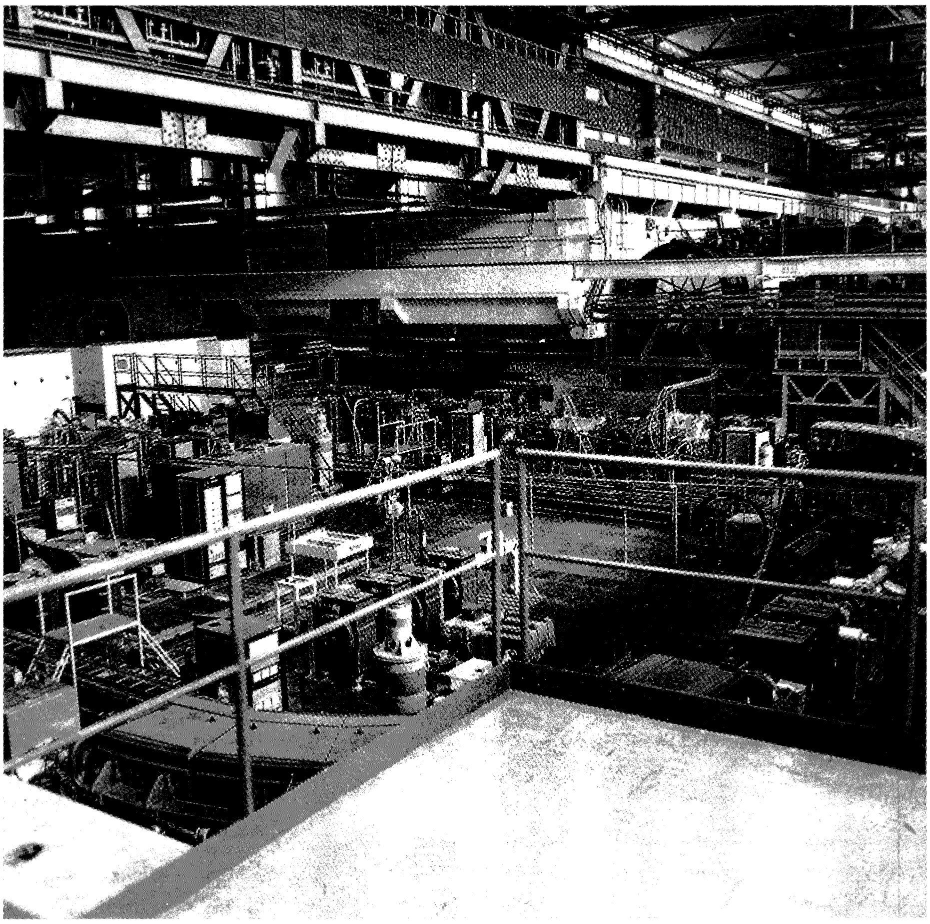
Carl Dover of Brookhaven gave an extensive summary of what theory expects to happen in low energy proton-antiproton collisions. At the end of the meeting Fred Mills (Fermilab) summarized the new techniques which could be used to collect more low energy antiparticles.

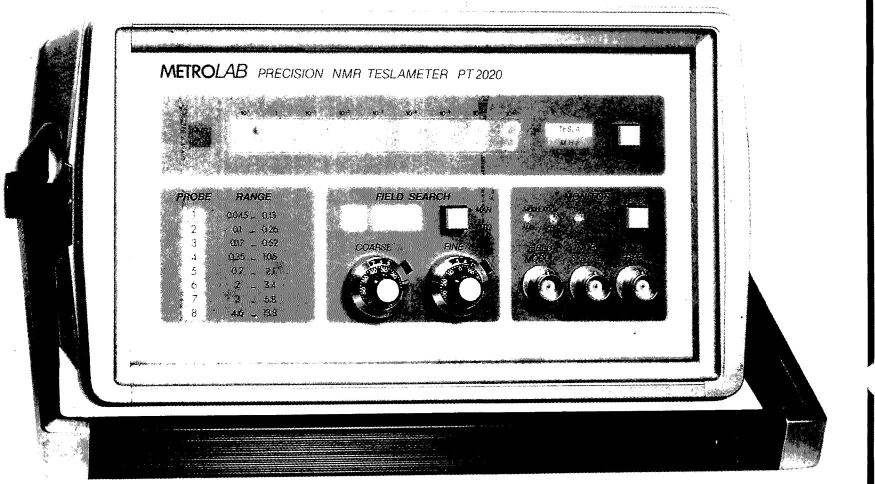
With antiprotons already on tap for the Tevatron, Fermilab is one possible site for the new US antiproton source. These ideas will be aired at another workshop, to be held at Fermilab in April.

From David Cline

The LEAR Low Energy Antiproton Ring at CERN - a great success. Ideas are being put forward for a low energy antimatter source in the US.

(Photo CERN 437.4.85)

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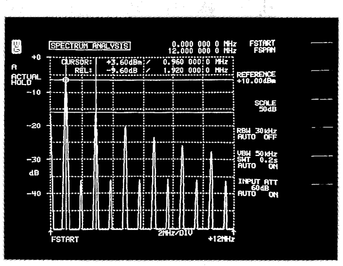
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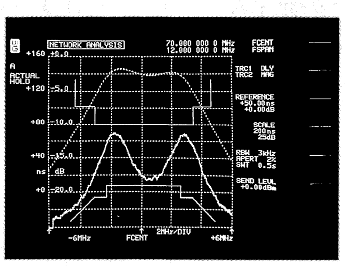
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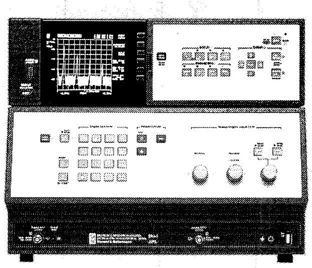
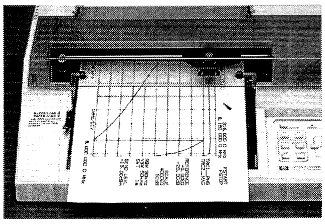




FERMILAB
New beams

Last summer, the world's highest energy electron/photon beam was commissioned at Fermilab. This beam in the Proton East area is capable of producing electrons of energies in excess of 650 GeV. It is called 'Wideband' because it collects electrons over a large momentum range, resulting in a high intensity. The first experiments with this beam use the high energy electrons to create the highest energy photon beam in the world. Because of its unique design, the beam can also operate as a high intensity pion beam, a primary proton beam, or a neutron beam.

In the past, Fermilab's efforts to study high energy photoproduction have been constrained by having two alternative photon beams sharing the same primary proton beam. For the Tevatron, a new beam splitting station has been installed in the Proton Area so that the new Wideband Beam and the existing Tagged Photon Beam can now run at the same time.

To make the new beam, a primary proton beam is focused onto a beryllium target. Magnets just downstream of the target sweep charged secondaries and remaining protons into a dump while forward photons (and neutral hadrons) emerge through a small hole. A thin piece of lead converts the photons into electron-positron pairs. The electrons are captured by a 1200-foot charged particle beam transport consisting of 14 quadrupoles and 8 dipoles. Positrons, neutral hadrons, and unconverted photons are absorbed in a dump about halfway down the beam. Just before the experimental hall the electron beam is passed through a lead radiator to produce photons and the electrons are then swept away by magnets.

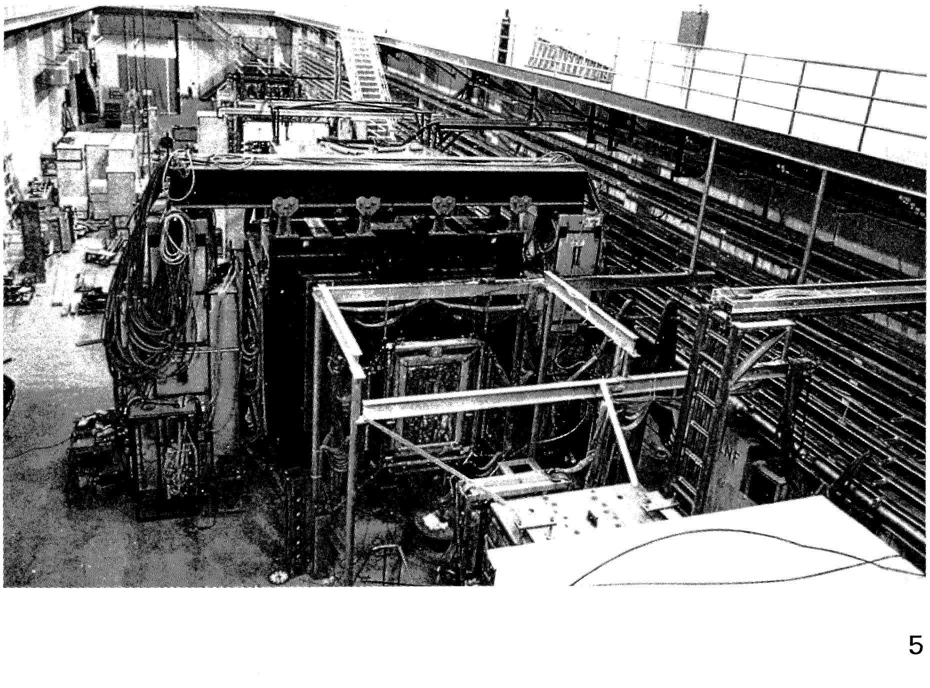
This classic approach of going from photons to electrons to photons is necessary to separate the photons from the unwanted neutrons which would otherwise obscure the photon interactions. However each stage costs energy and intensity, so it is necessary to collect the electrons over the widest possible range of angles and momenta.

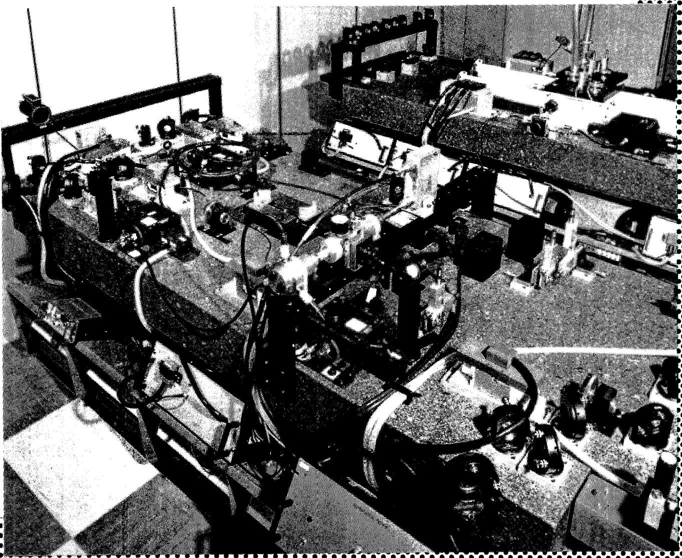
One unique feature of this wideband beam is that it is bent through very small angles (3 milliradians), just large enough for removal of the neutral beam. The dipoles are arranged in an achromatic double dog-leg so that the beam returns to the line of the original protons. These features give the beam its large momentum acceptance and permit, with suitable rearrangement of components, the creation of neutral hadron beams. A series of angle-varying magnets upstream of the production target allows the primary beam to be targeted so as to produce high intensity charged beams. The beam transport can operate at momenta up to 800 GeV as presently installed and can go up to 1000 GeV with slight rearrangements of elements.

The beam was operated in the electron/photon mode last summer at momenta ranging from 650 GeV down to 15 GeV (for calibration purposes). The beam behaved as expected with pion contamination of only a few percent. The neutral hadron background appears to be less than 10^{-4} at all energies and will therefore not interfere with experiments.

The first experiment scheduled to use this beam is a study of the photoproduction of charm and bottom quarks, expected to begin next winter. It is a collaboration of Colorado, Fermilab, Illinois, Frascati (INFN), Milan (INFN), Northwestern and Notre Dame.

View of the Wideband Experimental Hall at Fermilab with components of the E687 photoproduction experiment, dominated by the electromagnetic calorimeter built by Frascati.



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nur spannungslos stecken/umpolen
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0-3,5 kV 0-40 mA

Muon beam

Leptons — weakly interacting particles — have long been a favourite probe for studying nucleon structure. At Fermilab early emphasis was placed on neutrino beams. The muon beam was obtained by redirecting the secondaries from the neutrino target without attempting to refine the resulting muons. This non-dedicated muon beam presented several problems, among them being relatively low beam intensity and a large halo of particles outside the central beam.

Planning for experiments at the Tevatron showed that a dedicated muon beam would be needed. In particular Experiment 665, a study of muon scattering with hadron detection (a collaboration of Argonne, California – San Diego, Cracow, Fermilab, Freiburg, Harvard, Illinois – Chicago Circle, Maryland, MIT, Munich, Washington, and Wuppertal) would require high intensity (more than three million muons per spill second) at the highest possible energy with low halo and limited spatial and momentum spread.

The final design uses 26 separate enclosures over a total beamline length of 2.5 km, making it the longest beamline at Fermilab and one of the longest in the world.

In the first 800 metres the primary protons are directed toward the target hall using, among other elements, a string of six superconducting Doubler dipole magnets. After the production target the resulting pion and kaon secondaries are steered into a 1.2 km decay channel which mainly consists of alternately focusing and defocusing large gap quadrupoles positioned every 60 metres. The net effect is a strong-focusing muon channel.

The New Muon Laboratory at Fermilab with Wilson Hall (the Laboratory's main building) in the distance.

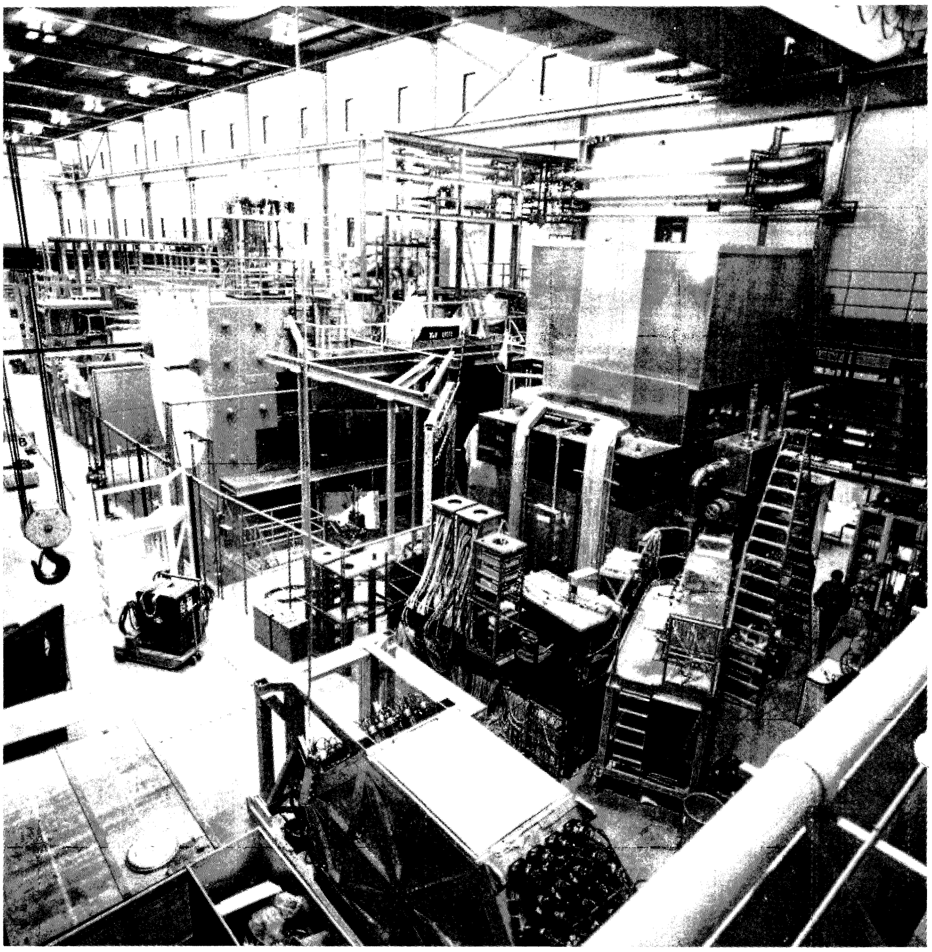
After filtering out the remaining hadrons with 11 metres of beryllium, the last 500 metres of beamline is used to purge the unwanted halo muons. To this end 34 m of magnetized thick-walled pipe ('mupipe') and 15 m of large diameter toroid will ultimately be employed.

Conventional construction began in 1984 and installation of the myriad components was started by Fermilab Research Division personnel last March. As a result of their diligence the entire beamline, except for part of the halo purging toroid system, was installed by July 1985. Less than a month later this mammoth investment of time, effort and money came to fruition as an intense beam of well focussed muons entered the New Muon Laboratory.

During the subsequent three weeks of the fixed target run the beam was used to bring up various detectors in the E665 spectrometer which in turn were used to measure the performance of the beam. The agreement between measurement and prediction is excellent. The distribution of the halo is not quite what was expected, but a more careful alignment of the magnetic elements and tunable toroids should remedy this.

While the muon beam was being prepared, the E665 team was busy installing the components of the open geometry spectrometer. The main thrust of the experiment, particulary in the first data run, will be a detailed investigation of muoproduced hadrons out to masses of 1200 GeV^2. Also of great interest will be the study of nucleon quark structure in a kinematical domain of interest to theorists. At the other end of the kinematical spectrum concentrated effort is going into the development of an efficient trigger to study nuclear shadowing.

A test run with partial instrumentation was highly successful and paved the way for the data run later this year. The experiment uses the old Chicago Cyclotron Magnet, now superconducting, but the upstream superconducting vertex magnet (from the European Muon Collaboration at CERN) awaited its refrigeration plant.



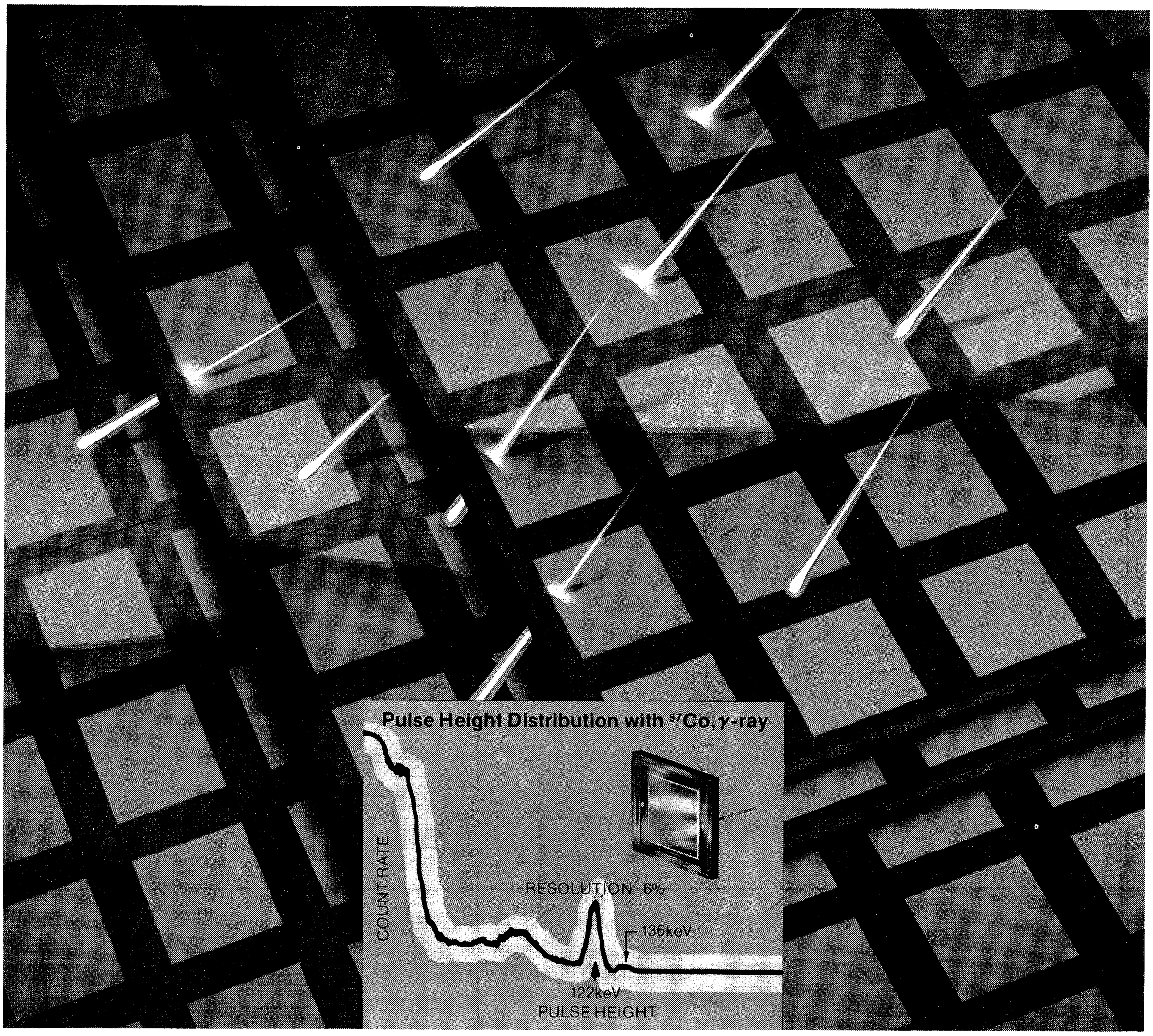
▲
The spectrometer of the E665 experiment using the Tevatron muon beam which enters from the bottom right. The first major component is superconducting vertex magnet from the European Muon Collaboration experiment at CERN, with further back the superconducting spectrometer magnet using steel from the old Chicago Cyclotron.

Bubbling away

Although extinct at CERN, bubble chambers continue to make useful contributions to physics. In a CERN/Fermilab collaboration, the small (20 cm diameter) LEBC lexan bubble chamber which was used at CERN from 1979 to 1984 recently completed a fruitful period of data taking during the initial run of the new Fermilab Tevatron using the full power of the primary 800 GeV proton beams. Physicists from East and West Europe, India and the US last year amassed 1.3 million triggers on film and tape. The experiment also used a reconfigured Fermilab Multiparticle Spectrometer.

Small bubble chamber for a big machine — group photograph of the team which used the LEBC bubble chamber from CERN in the initial run of the Fermilab Tevatron. Holding the 20-cm chamber are Joy Perington (right) and Phyllis Hale of the Fermilab Users' Office.

(Photos Fermilab) ▼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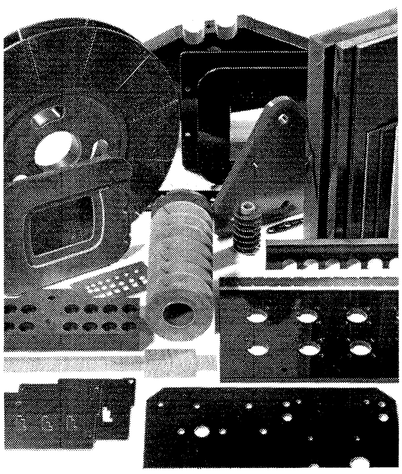

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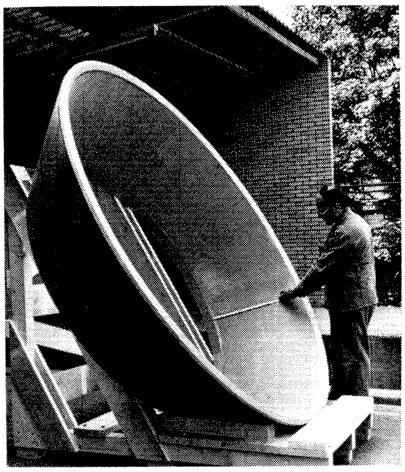

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Japanese KEK Laboratory Photon Factory staff in the storage ring control room watch the first scope traces indicating successful storage of positrons on 20 December. From left to right in the front row are Director Junichi Chikawa, Motohiro Kihara, Jiro Tanaka, Tatsuya Yamakawa and Toshiuki Mitsuhashi. Kazuo Huke is spreading the good news on the telephone.

(Photo Herman Winick)

KEK
First positrons

The 2.5 GeV linac at the Japanese KEK Laboratory is now producing positrons as well as electrons. This is the culmination of plans which began more than ten years ago for a powerful injector to serve the needs of both the TRISTAN electron-positron storage ring and the Photon Factory (the latter for synchrotron radiation experiments).

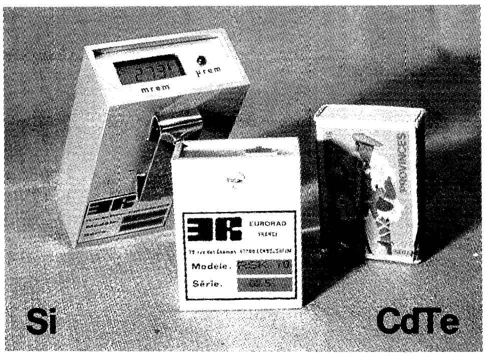
As well as being part of the particle diet for TRISTAN, positrons are of considerable benefit to a synchrotron radiation facility such as the Photon Factory. Although individual positrons produce the same synchrotron radiation as electrons at the same energy in the same magnetic field, positron beams do not trap positive ions or positively charged particles as do electron beams. Such trapping can be a pernicious problem because of the scattering and focusing effects of the trapped particles. For example, at the Photon Factory, bremsstrahlung measurements carried out by the Light Source group under the direction of Kazuo Huke have shown a clear correlation with abrupt decreases in lifetime due to trapping in the electron beam.

(Similar problems have led the Orsay group to use positrons routinely when operating the DCI ring for synchrotron radiation experiments. At Stanford these effects have been observed during single electron beam operation of the SPEAR electron-positron ring, and the synchrotron radiation group would like to use positrons during these runs. However much of synchrotron radiation operation on SPEAR uses a new Nuclear Physics Injector (NPI gun) installed at the 80 per cent point of the Stanford linac. The NPI gun provides high current, low energy electron beams for nuclear physics at Stanford and also makes it possible for synchrotron radiation studies using SPEAR during the summer months when power costs make full linac operation prohibitive. The gun provides only electrons at present.)

The KEK electron linac was built under the direction of Jiro Tanaka. It produced its first accelerated beams in February 1982 and one month later the linac reached its design goal of 50 mA 2.5 GeV electrons. Injection of electrons at 2.5 GeV into the 6 GeV TRISTAN Accumulator Ring was achieved in November 1983 (see March 1984 issue, page 51).

Construction of the positron generator began in April 1982. It consists of an upstream 200 MeV high intensity electron linac, an electron-positron conversion target and a 250 MeV positron linac. The 250 MeV positron beam is transported to the 250 MeV point of the 2.5 GeV linac, and the first positron beam was successfully accelerated to 250 MeV in July. In the initial operation a primary 1.6 A electron beam at 200 MeV was used to produce a 3 mA, 250 MeV positron beam. Successful injection and storage of a low current positron beam in the TRISTAN Accumulator Ring was achieved in October, so that Japanese hopes are still high for first colliding beams in TRISTAN later this year.

The first injection of positrons into the Photon Factory ring took place on 20 December. A current of 5.5 mA was accumulated, about what was expected in this initial test. Improvements over the next few months (such as an increase of injection repetition rate from the 2 Hz used in the first test to the full 50 Hz capability of the linac) should result in a much higher accumulation rate. This will allow the use of stored positron beams of 100 to 200 mA so that direct comparisons can be made with the intense electron beams routinely used in the Photon Factory.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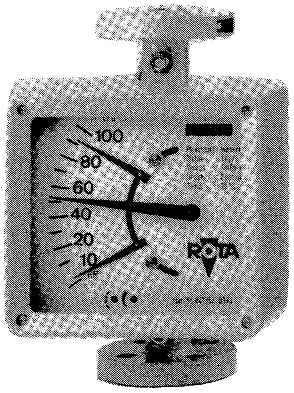
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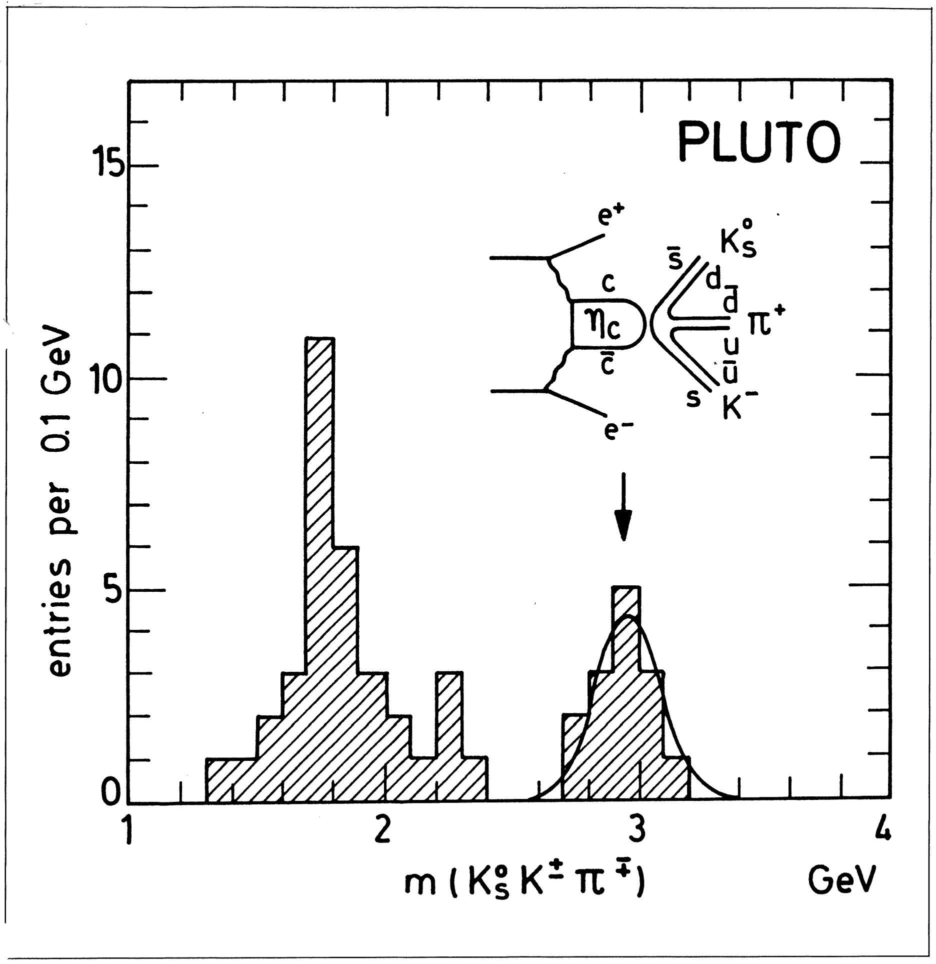


Mass distribution of a short-lived neutral kaon plus a charged kaon and a pion showing a clear eta-c peak around 3 GeV. The results come from the analysis of photon-photon interactions recorded by the PLUTO group at DESY's PETRA electron-positron collider back in 1980-81.

DESY
The charm of two photons

As well as their basic fare of electron-positron collisions, high energy electron-positron colliders also provide the luxury of photon-photon interactions.

In these reactions, the approaching electron and positron each emit a (virtual) photon, and it is then these two photons, rather than the electron and positron, which interact. The PLUTO detector, removed from the PETRA electron-positron collider ring at the German DESY Laboratory four years ago, made some pioneer contributions to this branch of physics.

This 'light-light' scattering has different selection rules to electron-positron annihilation and enables other particle states to be seen.

Two photon production of the eta-c has now been seen in data taken back in 1980-81 by the PLUTO team at a beam energy of 17.34 GeV. The eta-c is composed of a charmed quark bound to its antiquark partner, with the quark spins antiparallel, rather than parallel as in the famous J/psi formed in electron-positron annihilation and is lighter. After initial evidence from the Crystal Ball and Mark II detectors at Stanford's SPEAR electron-positron ring, the eta-c was pinned down at SPEAR by the Mark III detector studying the radiative decays of J/psis (see April 1984 issue, page 99).

Other mesons were found earlier in photon-photon collisions, starting at the SPEAR (Stanford) and DORIS (DESY) rings with the eta-prime, followed by the f, the A2, the f prime, the normal eta and the delta (980). Also the neutral pion was recently observed in photon-photon collisions by the Crystal Ball Group working at the DORIS ring. The possibility of such a measurement had been pointed out as early as 1960 by Francis Low.

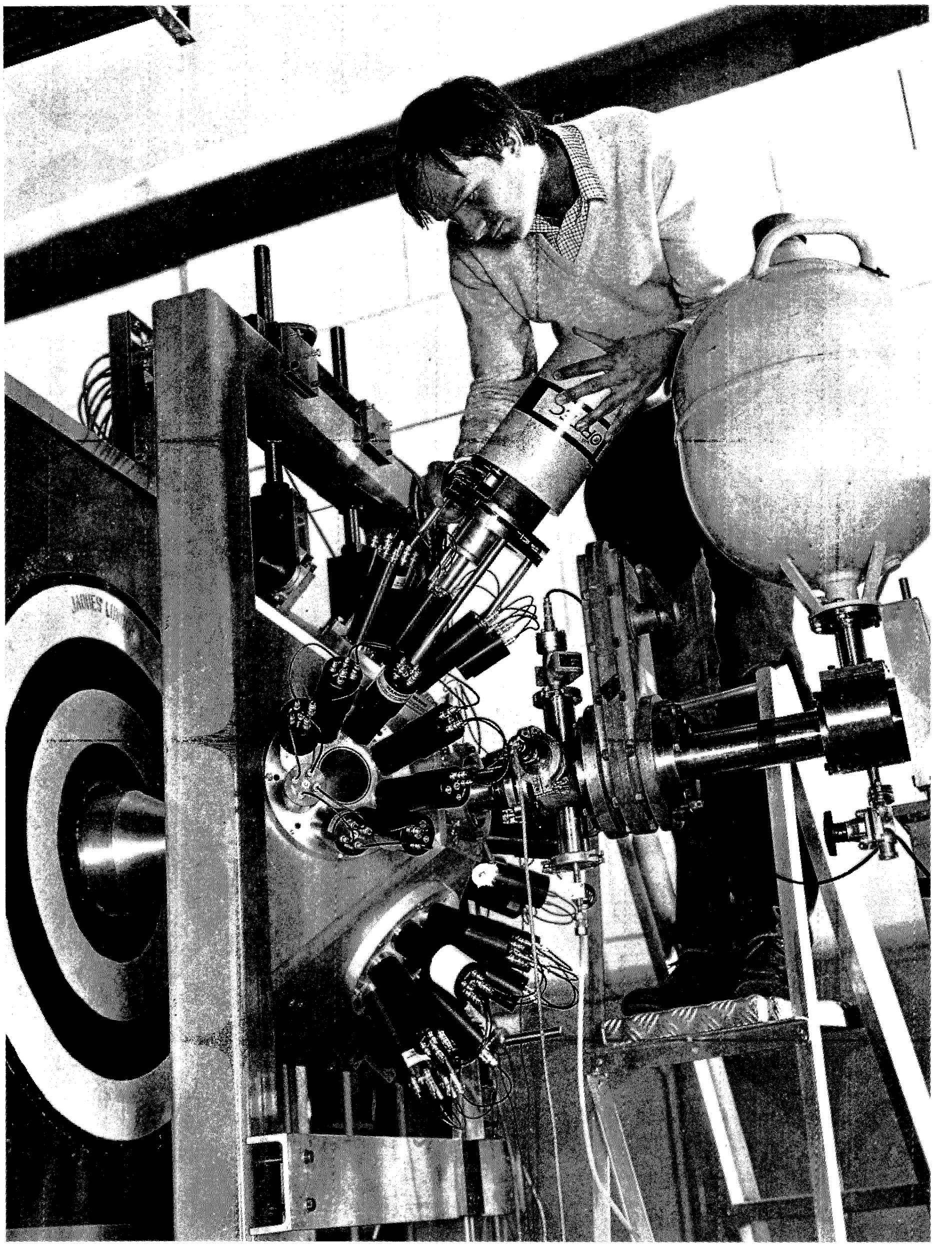
PLUTO's seven eta-c events were found after a painstaking analysis of four-track events.

RUTHERFORD APPLETON
International ISIS

The ISIS spallation neutron source recently inaugurated by UK Prime Minister Margaret Thatcher (see December 1985 issue, page 435) has officially become an international research centre.

On 10 December a Memorandum of Understanding was signed by George Walden, junior Minister at the UK Department of Education and Science, Hubert Curien, French Research and Development Minister, and Luigi Granelli, Italian Minister for Co-ordination of Scientific and Technological Research.

Under the Memorandum, three bodies will be established: a Council, with members from the UK, France and Italy and observers from other countries, whose main task over the next year will be to make arrangements for ISIS to be jointly funded by European coun-



Gamma ray detectors with a neutron detector array used in the study of exotic nuclei at the Daresbury Nuclear Structure Facility. The neutron detectors are behind a lead shield to the left.

(Photo Daresbury)

tries and operated for the benefit of European scientists; a Project Group of UK, French and Italian experts which will prepare costed plans for additional technical developments to maintain the international standing of ISIS; and an international Science Advisory Committee with members from several countries to provide a forum for wider consultation and discussion on developments at ISIS.

DARESBURY
Gamma rays and nuclear structure

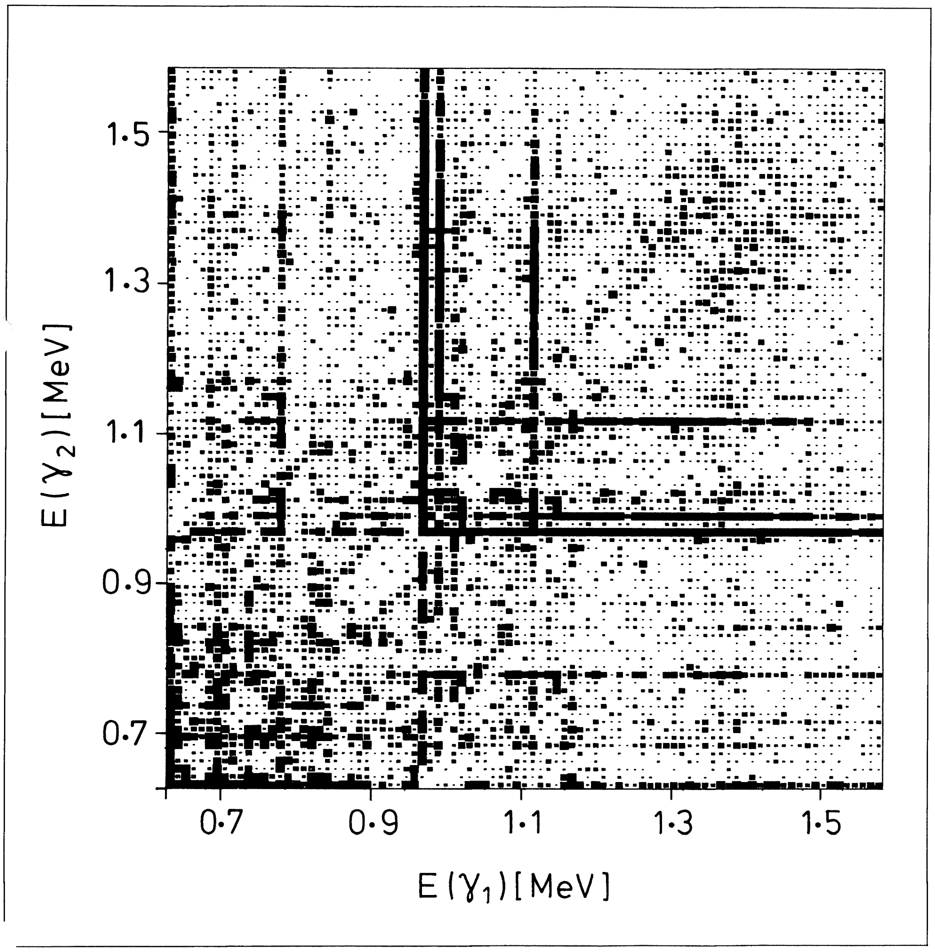
At the Daresbury Laboratory (UK) Nuclear Structure Facility (NSF), the 20 MV tandem Van de Graaff accelerator has had three years of full operation. During this time it has produced a range of high quality heavy ion beams for gamma ray studies including high spin states, superdeformations and exotic nuclei. The development of sophisticated detectors has played an important role in the research; spectrometers to analyse slow recoil nuclei, apparatus to record multiple neutron events, and a complex array of gamma ray detectors known as TESSA (Total Energy Suppression Shield Array) are just some examples.

There has been a rewarding study of nuclei with high angular momentum. Since the early days of nuclear physics the liquid drop model, refined to include shell effects arising from individual nucleons, has been used to predict how the nucleus behaves as its angular momentum increases; for example how its shape changes until fission through internal stress. At high enough spin, a nucleus with an initially prolate (rugby ball) shape should change to an oblate (discus) shape, and at even higher spin to a superdeformed prolate with a major-to-minor axis ratio of 2:1. Seeing these long sought-for phase changes was one of the early successes of the NSF.

One piece of evidence was the onset of irregularities in the usually regular spacing of energy levels of the rotating deformed prolate nucleus erbium 158 which occurred at high spin on excitation by a calcium 48 beam. This indicated a prolate to oblate shape change — quantum mechanically, an oblate nucleus cannot rotate macroscopically about its symmetry axis and any such angular momentum must come from the internal motion of its individual nucleons, which results in an irregular distribution of energy levels. A second clue was the transition in the spherical nucleus dysprosium 152 from irregularly spaced levels at low spin to a band structure at very high angular momentum. The moment of inertia of the nucleus at this high excitation, and later its rate of de-excitation, were deduced from gamma ray emission experiments and confirmed that the nucleus had indeed changed from a spherical to a superdeformed shape. Work is still underway to examine in detail how the initially hot rotating nucleus formed in a heavy ion collision cools and slows by emitting gamma rays.

Another example of work based on gamma rays emitted in heavy ion collisions is the study of sub-barrier fusion. When two heavy nuclei approach they initially feel a strong electrostatic repulsion

Energy correlations between gamma rays from a rapidly rotating nucleus, as observed at the Daresbury Nuclear Structure Facility. The diagonal ridges indicate a superdeformed shape.



due to the positively charged protons in each nucleus. If the incident beam energy is below this barrier, fusion takes place by quantum mechanical tunnelling. From the height and shape of the barrier the probability of fusion can be easily calculated. However recent results indicate that this is underestimated by at least an order of magnitude. NSF studies of the gamma rays emitted by the fused system showed that this enhanced effect was linked to a very large imparted angular momentum. The reason is that during their close approach the two nuclei excite each other and even transfer particles prior to actually fusing, thereby altering the barrier between them.

The study of nuclei far from stability has also been rewarding. Much of our present understanding of nuclear structure is based on nuclei close to stability. The most stringent tests of this understanding come from comparisons of predicted and experimentally determined structures of nuclei which are either very deficient or very rich in neutrons. Such tests are difficult, requiring versatile heavy ion beams and sensitive detectors. They have been carried out at CERN for many years using the ISOLDE isotope separator to study the beta decay of exotic nuclei and the structure of their daughter products. Work at the NSF has concentrated mainly on so-called in-beam studies, in which the structure of the parent nucleus is examined. This means observating gamma ray emission from a nucleus within a very short time (10^{-15} s) of its formation. The gamma rays of interest must then be distinguished from the background of gamma rays resulting from other, more prolific reactions. This work, which involves the use of an array of neutron detectors, has resulted in the discovery in very neutron-deficient strontium nuclei of the most deformed nuclear ground states known. Similarly, another region of deformation was found in neutron-deficient light rare-earth nuclei. These regions of deformation were predicted by some theories and not by others.

These examples give a flavour of the gamma ray work in progress at the NSF. The experiments are part of a wide-ranging nuclear structure programme which also covers nuclear collisions, moments of short-lived radioactive nuclei, laser studies and nuclear breakup phenomena.

BERKELEY
Around the Bevalac

The high energy heavy ions from the Superhilac linac/Bevatron synchrotron combination, the Bevalac, at Berkeley have for many years been feeding a programme for both biomedicine and nuclear science. The two subjects are not easy bedfellows. The Biomedical Facility has been treating some fifteen patients a day and each requires a half-hour beam set-up to give a few minutes of radiation. Since it is difficult to switch between the heavy ion species in the old synchrotron, the biomed requirements obviously eat into the time available for the nuclear science research in a way which does not allow efficient running.

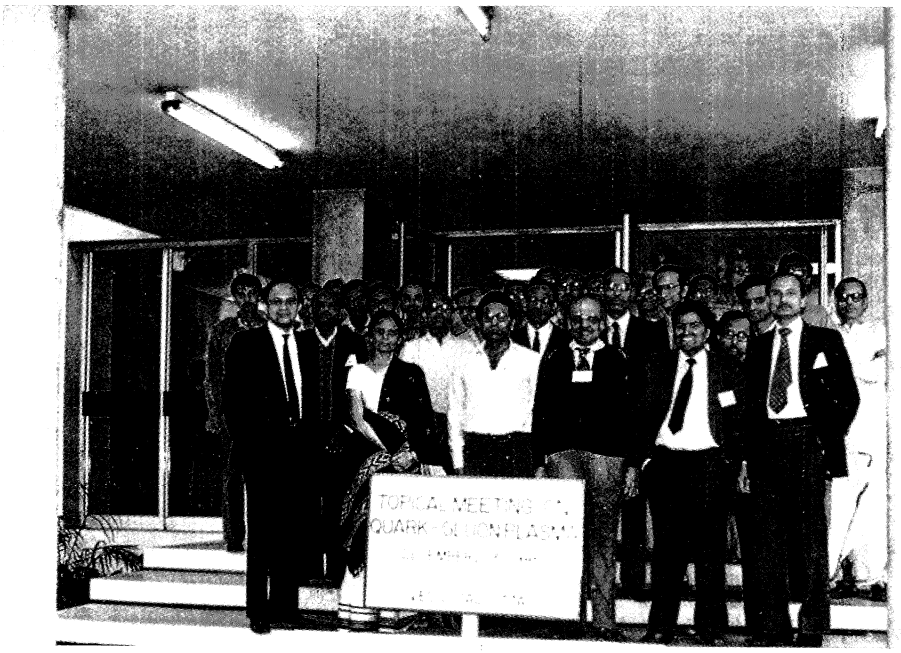
For the past two years there has been work to modify the Bevatron's local 20 MeV proton injector to allow injection of ions up to silicon. This has come to fruition and it is now possible to switch readily between ions from the Superhilac and ions from the injector. The injector uses a PIG ion source yielding some 100 microamps of silicon ions into a radiofrequency quadrupole, RFQ, which takes the ions to 200 keV per nucleon. Both on RFQs and ion sources there have been advances at Berkeley in recent years.

It was the successful completion of the RFQ in August 1983 which launched the injector modifications. Since then another RFQ has been completed which is the main contribution to the Berkeley/CERN/Darmstadt collaboration to achieve oxygen 16 ions in the CERN accelerator (see December 1985 issue, page 427).

The interest in more intense beams of ions led to work on metal vapour vacuum arcs (from which the new sources have garnered the name MEVVA) as the source of the plasma from which the beams are drawn. These arcs can establish a current of a few hundred amps and the discharge kicks out material from the cathode which plumes away to the anode. Beams of the cathode material (many metals from lithium to uranium have been tried) are then pulled through a hole in the anode by high extraction voltages. Emerging beams of as much as 1 A of uranium ions of good quality have been obtained. This compares with tens of milliamps with previous sources and there is more development which can be done to improve the MEVVA sources. It is intended to use these sources on the Superhilac, aiming initially for at least a fivefold increase in beam intensities.

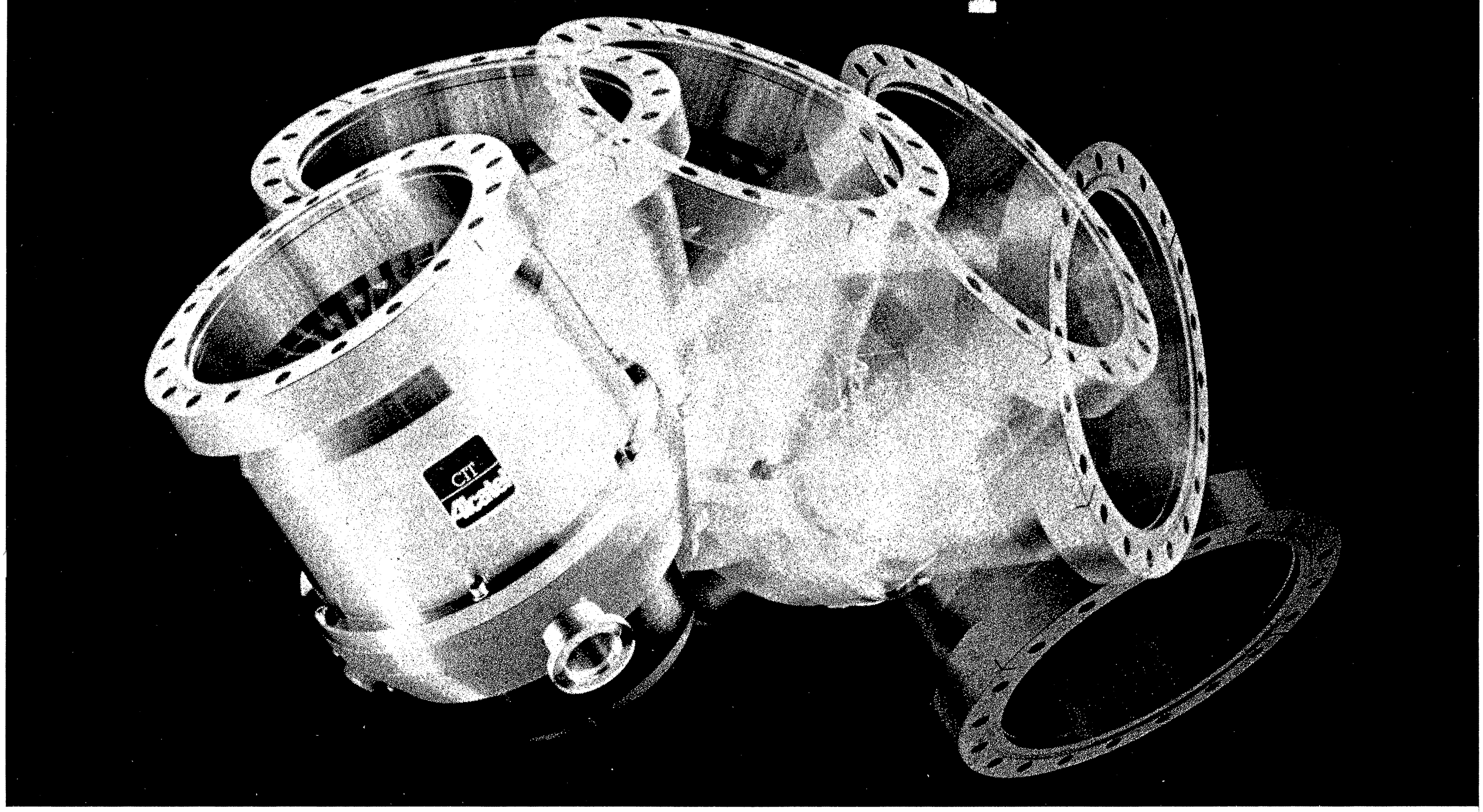
The Bevalac heavy ion programme will also benefit from the implementation of 'radioactive beams'. At multi-GeV energies, short-lived ions emerging from targets can retain properties of the primary beam and for many radioactive ions high energy beams of some 10^4 particles can survive. Such beams can help in radiotherapy since their penetration depth can be pin pointed when they decay. Beams of carbon 11 and neon 19 have already been used. They are also a prolific source of 'exotic' isotopes (some 24 new isotopes were identified from only a few hours running). They have made possible the study of helium isotopes up to helium 8 which is giving new information in nuclear radii studies.

For the longer range future there are still hopes that a heavy ion collider could be constructed at Berkeley. Having abandoned the more ambitious plans of yesteryear, efforts are now concentrating on a 'mini-collider' ring, which could just be squeezed into an existing experimental hall, for 4 GeV on 4 GeV ion collisions.



A topical meeting on quark-gluon plasma held recently at the Variable Energy Cyclotron Centre of the Bhabha Atomic Research Centre, Calcutta, sparked a healthy interest among researchers from all parts of India.

(Photo M. D. Trivedi)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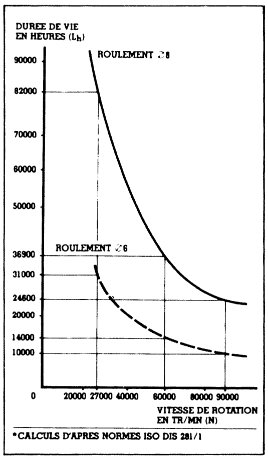
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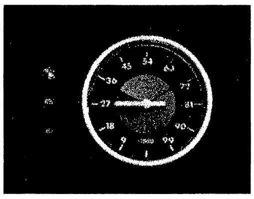
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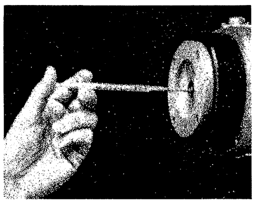

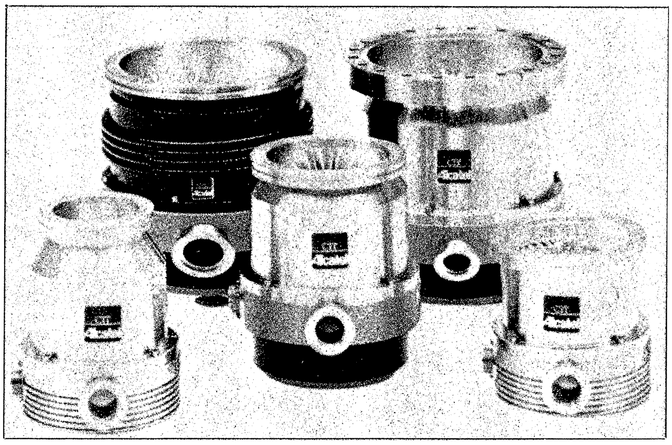

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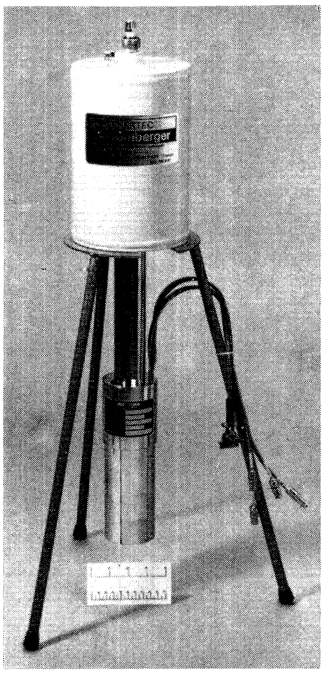

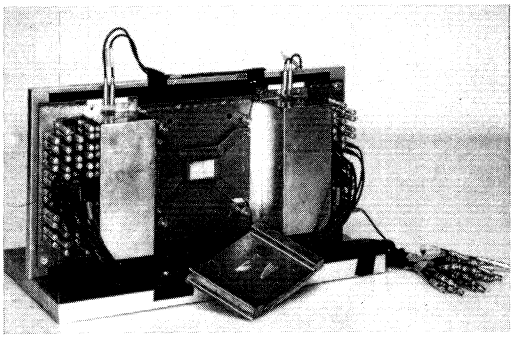

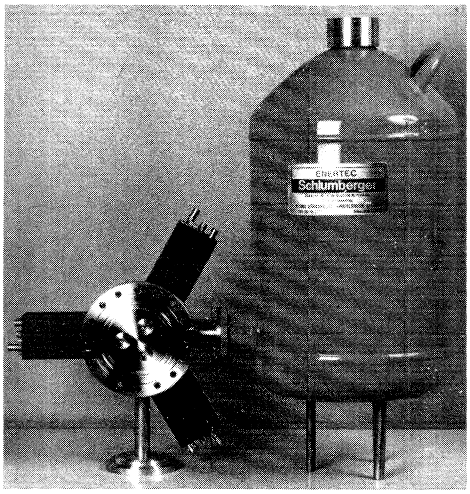

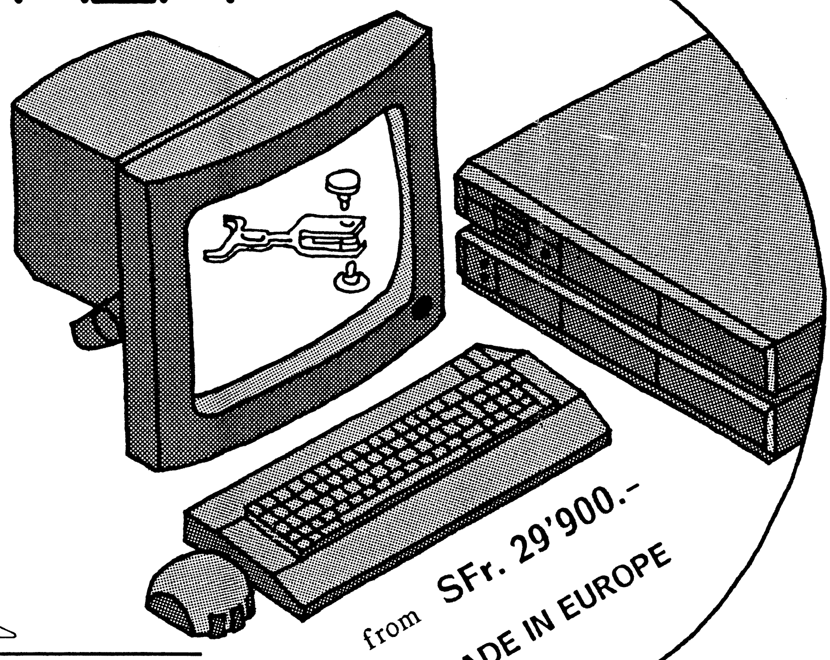

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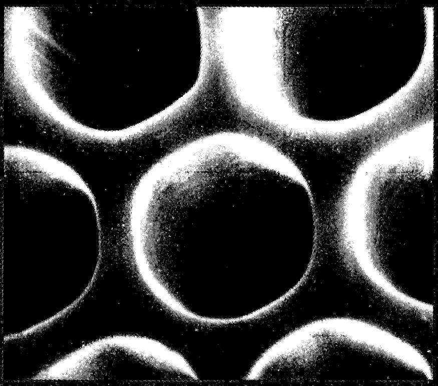

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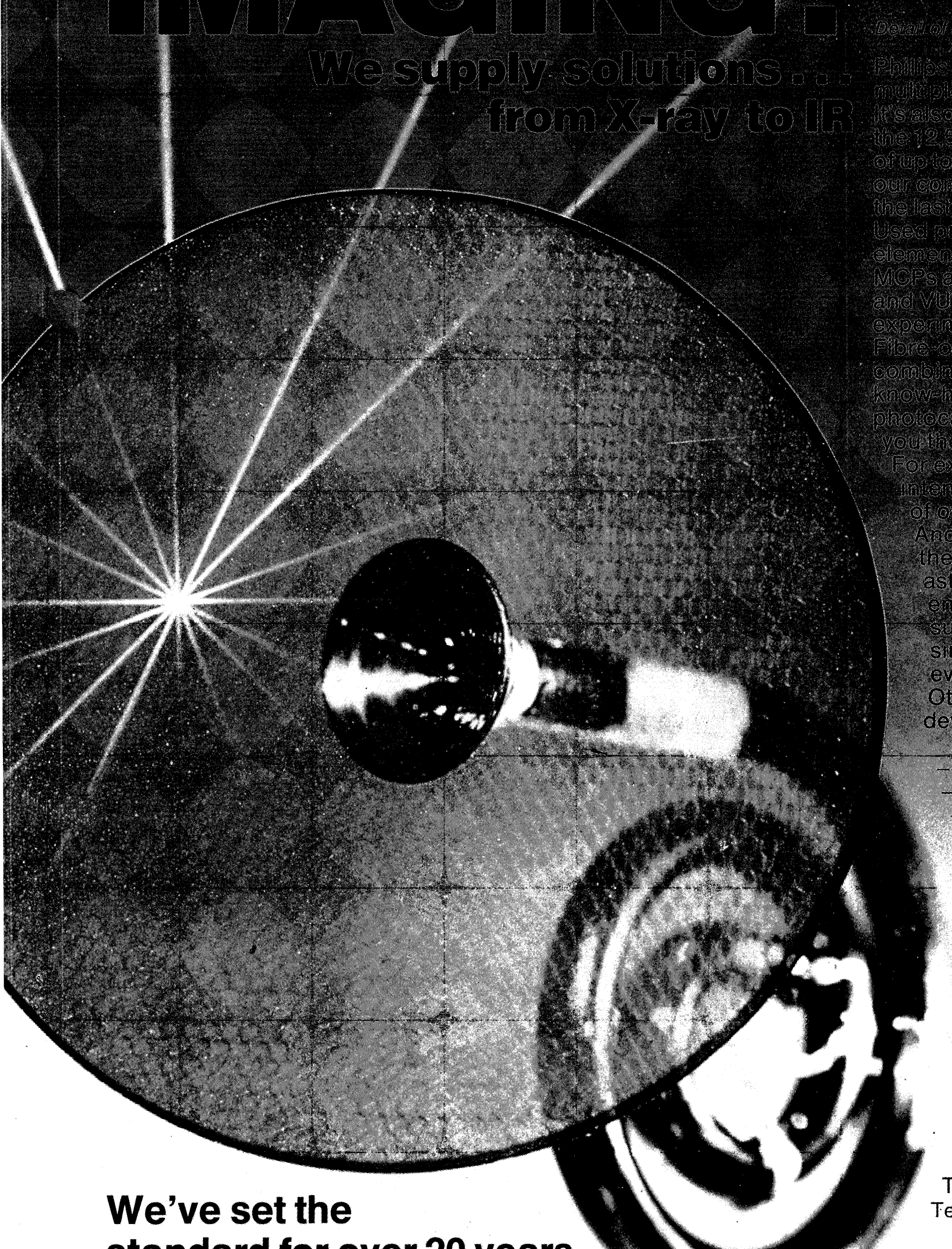

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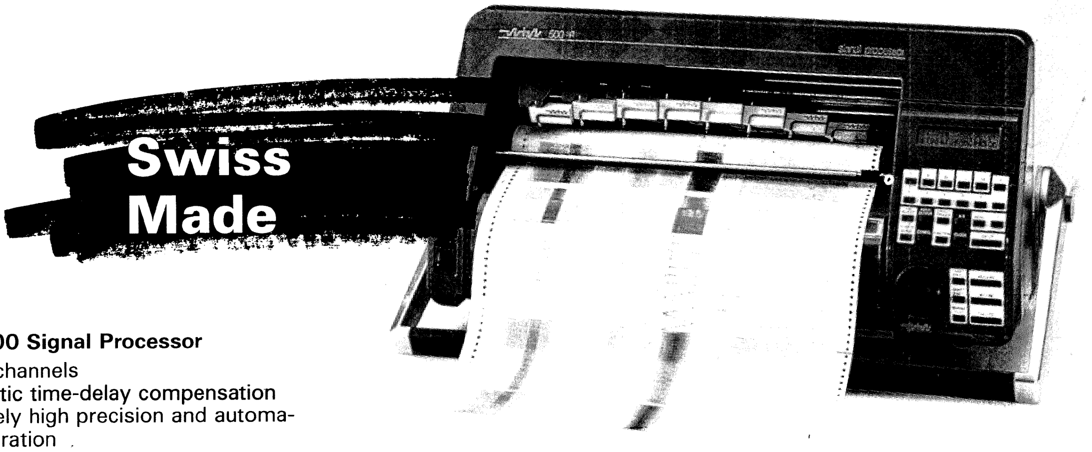

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Physics monitor

Diffraction attraction

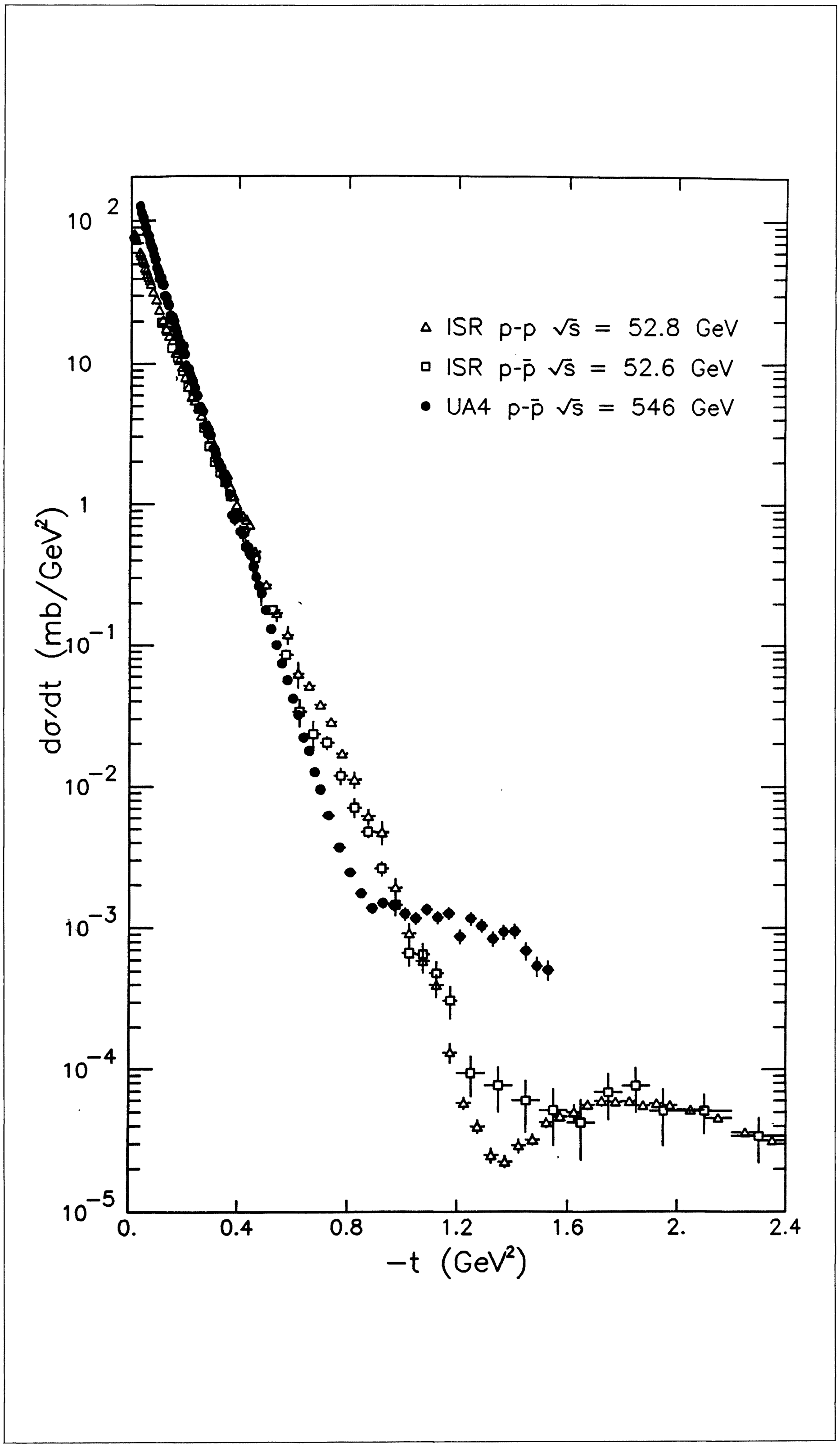
Elastic scattering — when colliding particles 'bounce' off each other like billiard balls — has always had a special interest for high energy physicists. While its simplicity makes for deep analogies with classical ideas like diffraction, its ubtle details also test our understanding of the intricate inner mechanisms which drive particle interactions.

With a new stock of elastic scattering data now available thanks to experiments at the CERN proton-antiproton Collider, and with studies at higher energies imminent or planned, some seventy physicists gathered in the magnificent château at Blois, France, for a 'Workshop on Elastic and Diffractive Scattering at the Collider and Beyond'.

In addition to the new data and the prospects for the future, the remarkable 'posthumous' results from the now-closed CERN Intercting Storage Rings (ISR) still provide valuable benchmarks.

The most important experimental message at the meeting was that 'asymptopia' is still very far away. More than a decade ago the initial results from the ISR upset any naive idea that particle behaviour in this newly-accessible energy range would settle down to a constant (asymptotic) level. Instead, reaction rates were seen to be growing with collision energy.

Experiments at the CERN proton-antiproton Collider have probed elastic scattering at still higher energies and show that the total reaction rate continues to grow (see October 1984 issue, page 336). The Collider has also given new insights into multiparticle production, where a new description



What makes proton-proton and proton-antiproton scattering so different? The marked diffractive dip seen in proton-proton elastic scattering at the Intersecting Storage Rings (ISR) becomes a gentle 'shoulder' in the proton-antiproton case. This shoulder also lifts dramatically at the higher energies (UA4) of the CERN proton-antiproton Collider.

of the number of produced particles is now required (see October 1985 issue, page 335).

High energy elastic scattering is understood by the exchange of a 'Pomeron' between the colliding particles (Soviet physicist Y. Pomeranchuk developed important theorems on high energy scattering). Many years after its appearance on the physics scene, the Pomeron remains very much a mystery. In his summary talk at Blois, A. Donnachie emphasized the continual challenge to understand it.

Is the Pomeron made up of gluons, the carriers of inter-quark forces? Does it have any quark constituents? Does it interact with gluons? Why does a Pomeron-photon analogy work so well?

As well as playing a key role in true elastic scattering, where the colliding particles do not change their form, the Pomeron is also responsible for 'diffractive' reactions where the incident particle flies off forwards, leaving in its wake a cluster of produced particles. New experiments will be able to study such clusters up to masses of 200 GeV (see July/August 1985 issue, page 237), thus providing important new Pomeron clues.

Toward the end of its career the ISR came up with another surprise — proton-proton and proton-antiproton behaviour are remarkably different. The marked diffractive 'dip' seen in proton elastic scattering becomes a gentle 'shoulder' in the proton-antiproton case. This shoulder also rises dramatically at the energies of the CERN Collider (see December 1985 issue, page 433). Speakers at Blois stressed the need to understand the different proton-antiproton behaviour.

One candidate is exchange of three gluons, each coupled to a different valence quark. Another idea is the so-called 'odderon', which unlike the Pomeron couples differently to particles and antiparticles.

With plans for further studies at higher energies, both imminent and still on the drawing board, there is great promise for the future. The rich ISR results and the first fruits of the Collider studies have shown that mundane diffraction is full of rich structure and unexpected behaviour. Although asymptopia may still be very far away, the way there is not through a desert but through a flourishing region of exciting physics.

The successful Blois meeting — thanks to the tireless efforts of B. Nicolescu and J. Tran Thanh Van — seems likely to become a regular event.

From Elliot Leader

Higgs for the masses

The unified theory of electromagnetism and the weak nuclear force, crowned with the discovery at CERN in 1983 of the W and Z bosons which carry the weak nuclear force, is one of the great triumphs of modern physics.

But the picture is not yet complete. An essential but still elusive ingredient is the so-called 'Higgs boson' (after Edinburgh theorist Peter Higgs), responsible for the vital symmetry breaking in the theory. This gives the carriers of the weak force mass, while the photon, the carrier of electromagnetism, is massless.

For some, the theory of Higgs particles is shrouded in mystery. With several experiments embarking on fresh Higgs searches, Richard Dalitz and Louis Lyons at Oxford organized last November a series of talks cleverly entitled 'Higgs for the masses', to cover both the theory and experimental status of the particles.

Douglas Ross introduced the subject, pointing out that the unified electroweak theory with massive Ws and Zs is not well-behaved (renormalizable), but this is remedied if the masses of the weak carriers arise through a Higgs mechanism. This also patches up other deficiencies (unitarity). Of course it may be that Nature is perverse and does not require a theory which is well behaved!

Another oddity is that unless it is very light (less than 10^{-17} eV), the Higgs should make the Universe curved, contributing more to the Cosmological Constant than the known limit permits. Since most theories need to have their parameters finely tuned to produce a suitably small value of the Cosmological Constant, this is not considered too much of a problem.

Lower limits (spontaneous symmetry breaking) and higher limits (unitarity) open up a wide range of masses for the Higgs to manoeuvre — between 7 and 1000 GeV (1 TeV).

If there is only a single, electrically neutral Higgs, its coupling to each particle is proportional to that particle's mass, so that it would prefer to decay into the heaviest possible pair of particles. Other Higgs constraints follow from the apparent success of the standard electroweak picture.

Turning to Grand Unified Theories (GUT) which attempt to extend the electroweak sector to include the strong nuclear force, couplings to very heavy GUT particles would take Higgs masses over the 1 TeV limit. GUT followers have to look for clever mechanisms to rectify this.

At the Oxford meeting, Sudhir Chadha showed that models without Higgs quickly became complicated, underlining the attractiveness of the Higgs approach.

Louis Lyons turned to the experimental situation. He pointed out that in electron-positron collisions it is easier to look for electrically charged Higgs particles, unfortuate when the neutral Higgs is the most basic requirement.

Neglecting the puzzle of the Cosmological Constant, low energy nuclear, atomic and macroscopic physics now set a lower limit of about 10 MeV for the neutral Higgs mass. Further limits come from particle decays. Higgs of up to 10 GeV mass, for example, could be produced in upsilon decays. The CUSB group at Cornell have scanned almost half a million upsilons, but the production rate is predicted to be so low anyway that even more events are required before this possibility can be ruled out.

Electrically charged Higgs should be heavier than the tau lepton (1784 MeV), otherwise a Higgs mode would dominate tau decays. Similarly if the mass of the top quark is confirmed from the initial indications around 40 GeV, and if no unusual decays are seen, an additional mass range can be excluded.

Direct searches for charged Higgs have been carried out at the PETRA (DESY, Hamburg) and PEP (Stanford) electron-positron colliders, but Higgs pair production under these conditions would be difficult to spot explicitly. Studies of states that might be characteristic of Higgs pairs show that most of the mass range up to 13 GeV can be excluded.

From time to time, new 'bumps' and effects are tentatively put forward as candidate Higgs, but so far none are convincing. Rather than closing on a pessimistic note, the meeting concluded that the search for the neutral Higgs has yet to attain the region where the particle is to be expected. Prospects for future searches were covered by Roger Cashmore.

The Higgs could be hiding in some mass range that is either out of reach or makes its detection very difficult. This makes the chance of experimentalists proving that the Higgs does not exist and that their theoretical colleagues have been persuing the wrong option look remote. However new experiments will probe an interesting mass region, giving hope that the Higgs could be discovered in the not too distant future.

From Louis Lyons

Portugal has become CERN's fourteenth Member State. Heavy rain failed to dampen the enthusiasm of CERN's Portuguese community as their national flag was raised on the site for the first time on 24 January.

(Photo CERN 312.1.86)

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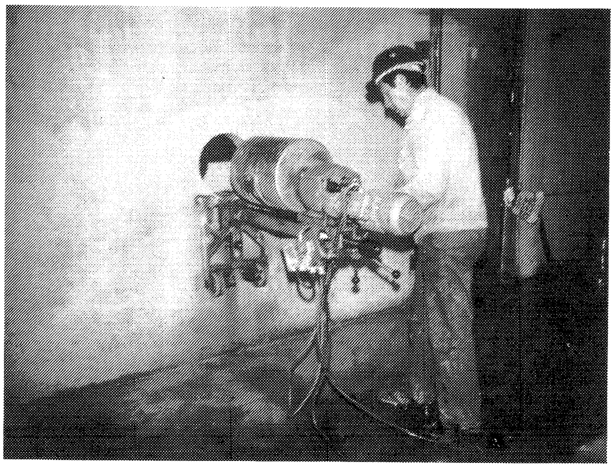

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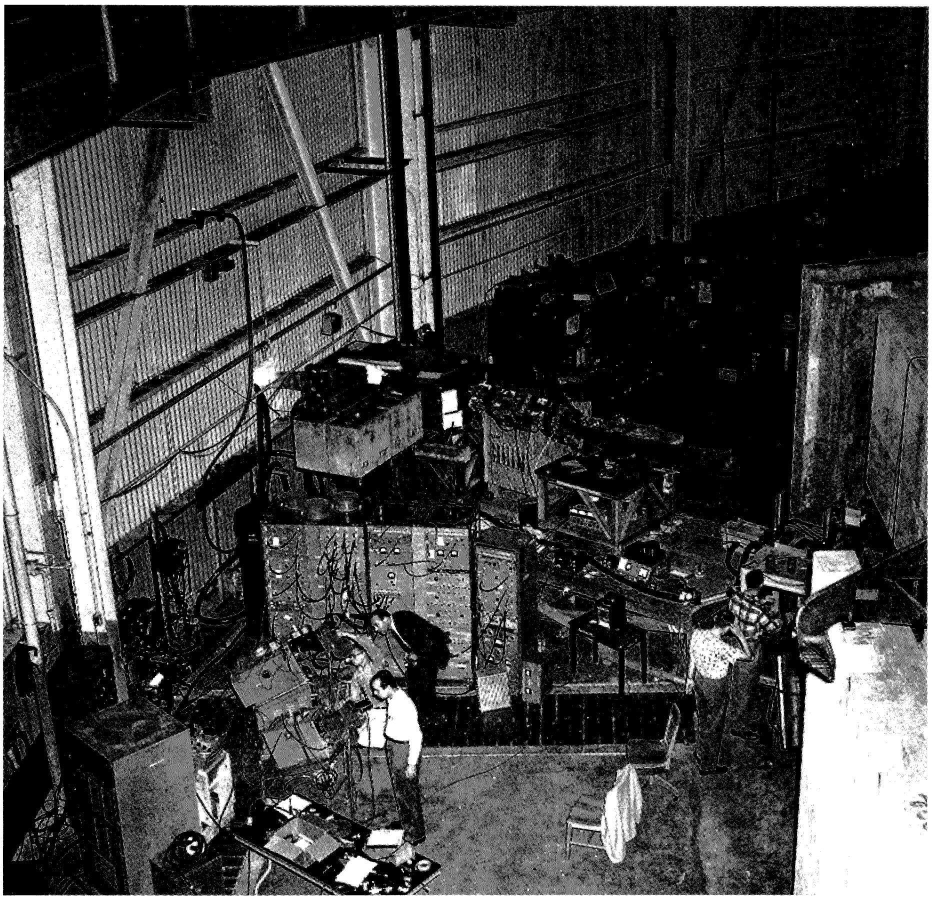
A plea for unity

by Leon Lederman

Last November saw the 30th anniversary of the discovery of the antiproton using the Bevatron at the University of California's Lawrence Berkeley Laboratory (then called the Radiation Laboratory). Fermilab Director Leon Lederman was in sparkling form at the banquet, where in his inimitable way he made an impassioned plea for scientific unity in these difficult times.

30 years ago last November, the antiproton was discovered at the Berkeley Bevatron using this apparatus — modest by the standards of today. To mark the event, antiproton personalities past and present met at Berkeley for a two day jamboree.

(Photo LBL)



Today we have the 30th anniversary of the antiproton. Whereas everything that could be said about antiprotons is on the daytime schedule, I would like to comment on the institution in which antiprotons were discovered. Growing up scientifically in the East, in New York, you can't imagine how large this Institution looked to us amateurs in a field whose pace and whose style had been invented ere.

We felt very much like the famous New Yorker cartoon: looking west one saw 6th Avenue, 7th Avenue, 8th then Los Angeles! Berkeley's Radiation Laboratory was the cauldron which cooked and disseminated so many of our results, practitioners and so many of our traditions. It is historically fascinating that here is now housed the unborn infant we call SSC or the Superconducting Super Collider for short. Today the care and nurturing of this is your greatest responsibility and you are doing very well.

Let me turn to the status of high energy physics, with my shaky credentials as a practitioner, for thirty years of more or less robust activity not only in experimental physics but also in the rough and tumble suburbs of science policy.

The good news is that our subject vibrates with vitality. Anyone who reviews the period 1950-1985 must feel the enormous achievement of the synthesis we call the Standard Model and which Ian Hinchliffe elegantly reviewed for us this afternoon. This is the notion that the world is made of quarks and leptons.

This achievement out of a splendid collaboration between experiment and theory suggests the potential for progress. Theorists, in crafting the SM have suggested where to look. At this stage, I'm reluctant to admit that Theory is ahead — you have only to open your Physical Review and theory papers spill all over the floor. As you sweep them up you notice the familiar titles — technicolour, hypercolour, supersymmetry, compositeness,... these speculative SM extensions create challenges we can rise to but there are more and more practitioners of a new cult — Superstrings — abstract theory that is so far out that we are tempted to call for help.

There is today a pause in the progress of experimental physics. Since the spectacular discovery of the W and Z and the similarly spectacular materialization of quarks in the CERN Collider's jets, the most pressing information is the refusal of the proton to decay and the continuing incorporation of astrophysical data into an evolving Standard Model of Cosmology. This has led to a rejoining of two subjects that were born together at the dawn of science. I see, increasingly, our theorists talking and thinking in terms of temperature instead of energy and talking of accelerators as time machines.

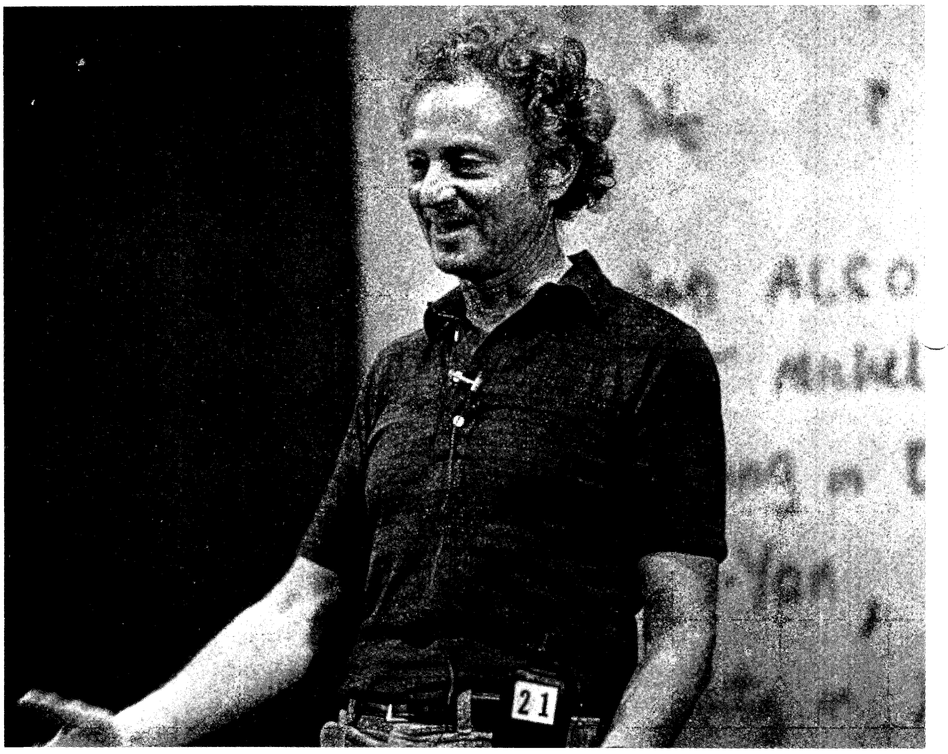
There is more good news. The US HEP community — and indeed the world community — has now three new facilities which can break new ground — enable us to look where no one has ever looked, measure well where one could only see dimly. I refer to the Linear Collider nearing completion at Stanford, to the proton-antiproton collider nearing completion at Fermilab and to the Fermilab 800-1000 GeV fixed target programme which is beginning to hit its stride.

These will be joined by sister projects at CERN (LEP), in Japan (TRISTAN), in Germany (HERA) and in the Soviet Union (UNK) by 1990 or so. Together these will constitute a powerful arsenal to deepen the foundations of the SM and search for clues to the simpler, more symmetrical and deeper theory which must be there.

I certainly agree with Ian Hinchliffe, and in fact the entire HEP community, that this powerful arsenal will not be enough to resolve what might be called the agreed objectives of Particle Physics and Cosmology: a unified theory which can account for the creation and evolution of the physical universe from time zero. To do this, we need the SSC.

I am committed to the concept of the SSC and so I talk about it a lot, and this means trying to explain the scientific needs to colleagues in other fields. Selling SSC (and HEP to the paying public) is a necessary and backbreaking activity. Time and again I found myself trudging down a long airport corridor, weighed down with two suitcases of SSC transparencies and my toothbrush.

Leon Lederman — our subject vibrates with vitality.



So what is the bad news?

The bad news is that science is in deep trouble. The average age of science and math faculties has risen alarmingly in recent years, obviously bad in subjects where creativity peaks early. The percentage of science and math graduate students that are US-born is decreasing — Americans are shunning graduate study in science and math. The very best small science professors survive by dint of several separate contracts with funding agencies to support their research. Equipment in university labs is archaic and federal support for science has not kept pace with the urgent needs for forefront research.

Studies show a projected shortage of qualified candidates for university openings in 1990. This is already felt in condensed matter physics where faculty openings go unfilled. If there are no teachers there will be no students.

Now for the small science/big science debate. We in HEP have indeed been somewhat sheltered but we share the precipitous decline — starting in 1968 — of the support of science. In spite of fairly dramatic improvements in 1982-83-84, we are still not back to the fraction of GNP enjoyed in the late 60s. Big Science is that group of university-based scientists who gave up their campus labs and pooled their claims for support so that their science can advance. This involves an increasing number of disciplines: Nuclear, Oceanography, Materials Science, Space Science, etc. Small scientists collectively spend many hundreds of millions too — there is good science there with the disadvantage of not having a vociferous, aggressive and organized community.

But we all share the base of the

university. Big laboratories are managed by universities for universities. As such we are all in the same boat and I can't see one subject, because of its visibility, succeeding in a climate in which colleagues, sharing courses, sharing heritage, and sharing an intrinsic unity will decline.

When the implications of a national deficit are superimposed on this bad situation it poses a terrible threat not only to our own vision of the SSC but to all science in universities.

The selling of the SSC, which must be pursued on all fronts for its scientific importance, must not be viewed as rivalry with the rest of science. Traditionally, each science made its own case but there are some precedents for coherent action. Sciences are interdependent — key ideas and key technologies have come to HEP from other branches of physics and they in turn depend on HEP-type equipment. But the common reliance on our university base for training and research underlines my point. If ever there was a time to pull together — this is it.

My tentative proposal for the physical sciences is a yearly increment of a few thousand million dollars in federal support of basic research over the next five or so years.

I believe the US public expects scientific leadership to be essential to achieve our goals in such areas as energy, medical care, the environment and a better life for an increasing number of people.

Scientific vigour is essential for economic strength. We cannot hope to generate the advanced technologies needed to stay industrially competitive if science, university science, is less than absolutely excellent.

People and things

On people

New members of the prestigious Pontifical Academy of Sciences include Carlo Rubbia of CERN, spectrocopist Kai Siegbahn of Uppsala and cosmologist Stephen Hawking of Cambridge, UK. This body draws its origin from the Academy of the Lincei, founded in 1603, and is composed of seventy members nominated by the Pope. Its purpose is to promote the progress of mathematical, physical and natural sciences.

Rutherford Appleton Laboratory Director Geoff Manning has been awarded Britain's CBE in the Queen's traditional New Year's Honours List.

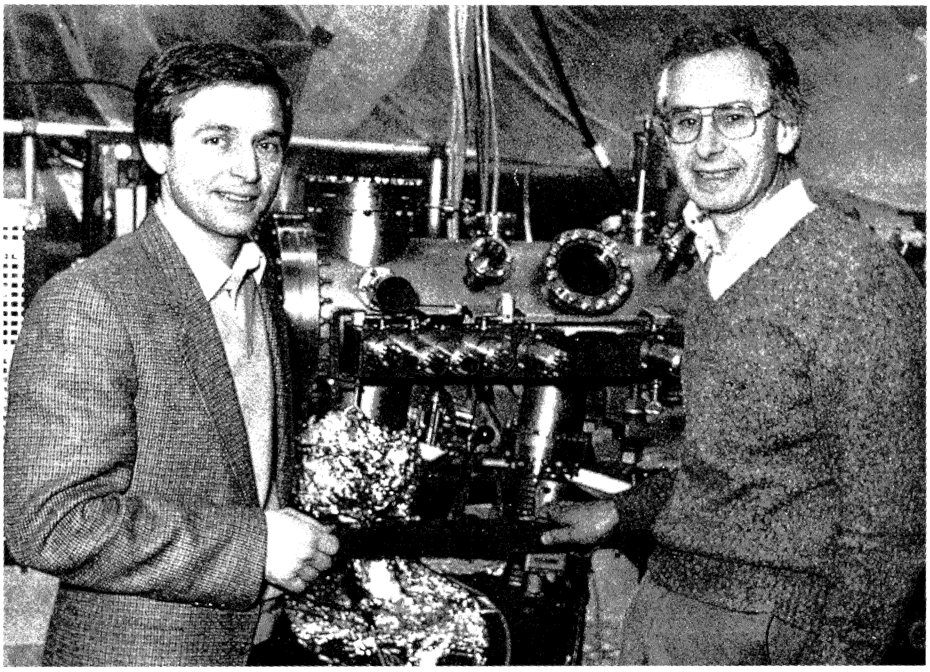
David Nygren of Berkeley was one of the six US scientists to receive a 1985 US Ernest Orlando Lawrence Memorial Award for outstanding contributions in the field of atomic energy.

René Turlay of Saclay has succeeded Günter Wolf of DESY as Chairman of the LEP Experiments Committee at CERN.

Bruno Zumino of Berkeley was the speaker at the traditional Shulamit Goldhaber Memorial Lecture at Tel Aviv University in January. His subject — Gravity and Supersymmetry.

Meetings

The second Conference on the Intersections between Particle and Nuclear Physics will be held from 26-31 May at Lake Louise, Canada. Further information from Lorraine King, TRIUMF, 4004 Wesbrook Mall, Vancouver BC, Canada V6T 2A3.



Change in directorship for the HASYLAB synchrotron radiation centre at the German DESY Laboratory in Hamburg – Gerhard Materlik (left) takes over from Christof Kunz (right).

(Photo DESY)

An international workshop on Constraint Theory and Relativistic Mechanics will be held in the Physics Department of the University of Florence from 28-30 May. Those interested should contact L. Lusanna, Sezione INFN di Firenze, Largo E. Fermi 2 (Arcetri), 50125 Florence, Italy.

A NATO Advanced Research Workshop on Super Field Theories will be held from 25 July to 6 August at Simon Fraser University, Vancouver, Canada. Attendance is limited. Further information from H. C. Lee, Theoretical Physics, Chalk River Nuclear Laboratories, Ontario, Canada KOJ 1JO.

Twenty years ago

For entertainment as well as interest, this new regular feature dips into the CERN COURIER archives, recalling the milestones and preoccupations of twenty years ago.

CERN started 1966 with a budget of 149.7 million Swiss francs plus 21.7 million for the start of a supplementary programme — the construction of the Intersecting Storage Rings. Another 4 million kept the proposal to build a 300 GeV accelerator alive. Bernard Gregory took over from Viki Weisskopf as Director General. In February, the PS protested at the advent of the ISR by blowing up its main magnet power supply putting itself out of action for three months. Before this happened, the first experiment at CERN to use wire spark chambers had taken its first data on the hot topic of CP violating neutral kaon decay... still hot today!

1986 CERN Schools

The 1986 CERN School of Physics will be held from 8-21 June at Sandhamn, an island east of Stockholm, and organized in collaboration with the University of Stockholm. The traditional and highly successful CERN School of Physics aims to cover aspects of high energy physics, especially theory, for young experimentalists, giving a current survey rather than a training course. Participants should have at least one year's research experience. After an introductory course on field theory, topics covered will include quark and gluon dynamics, tests of gauge theories, physics at LEP and a review of proton-antiproton collider work. Further information from the Organizing Secretary, Miss D. A. Caton, CERN, 1211 Geneva 23, Switzerland.

The 1986 CERN School of Computing, organized this year in collaboration with NIKHEF-H, Amsterdam, and Nijmegen, will be held from 31 August to 13 September at Renesse, Netherlands. As in previous years, the School is intended for postgraduate students or research workers in physics or computing, and the programme will cover a wide range of topics. Further information from the Organizing Secretary, Ingrid Barnett, CERN, 1211 Geneva 23, Switzerland. These computing schools have been held biennially since their inception in 1970, but it is intended to hold them annually from this year.

Advising the CERN Courier

At the beginning of 1981, a CERN Courier Advisory Panel was set up to widen the contact between the journal's editors and the high energy physics community, and to help maintain a good balance of information. The Panel has done an excellent job in carrying out these aims.

Under the Chairmanship of Maurice Jacob, the initial members were physicist Ugo Amaldi and machine specialist Kurt Hübner of CERN, and visiting physicist Egil Lillest0l from Bergen.

In 1983, the Chairmanship passed from Jacob to Jacques Prentki, another eminent CERN theoretician, and Ugo Amaldi's place was taken by Jim Allaby. US visitor James Cronin joined the Panel for a while. The following year Kurt Hübner was succeeded by Herbert Lengeler.

Last year saw a break with tradition with the appointment of Robert Klapisch of the CERN Directorate as Panel Chairman, the first time the job has gone outside CERN's Theory Division. After five years of sterling service, Egil Lillest0l was succeeded by another Scandinavian visitor, Hans B0ggild of Copenhagen's Niels Bohr Institute. CERN theorist André Martin took over from Jim Allaby.

The Editors have greatly appreciated the Panel's knowledge, ideas and constructive criticism, which have been a constant source of stimulation. The Panel members (listed on the masthead on page VIII) are there to help communication between the high energy physics community and the Editors, and we look forward to a continued fruitful collaboration.

G. F.

Some heated arguments for using the thermal specialists

If you have a thermal design problem, or are looking for ways of optimising your existing heat exchange equipment, here are arguments for using Alfa-Laval, the Thermal Specialists.

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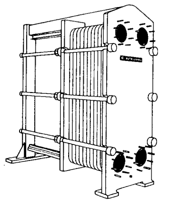

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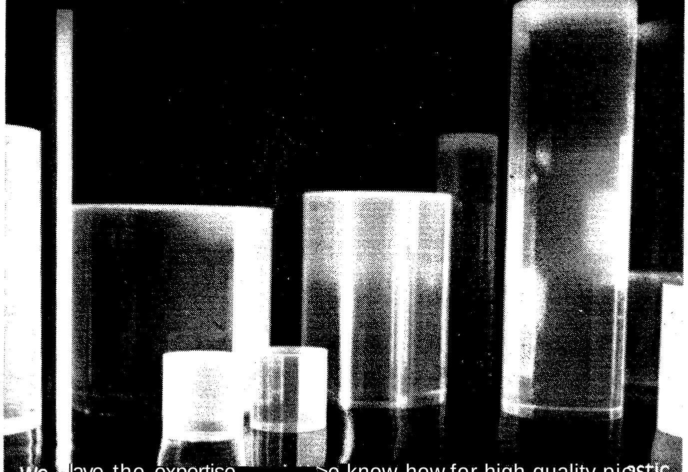

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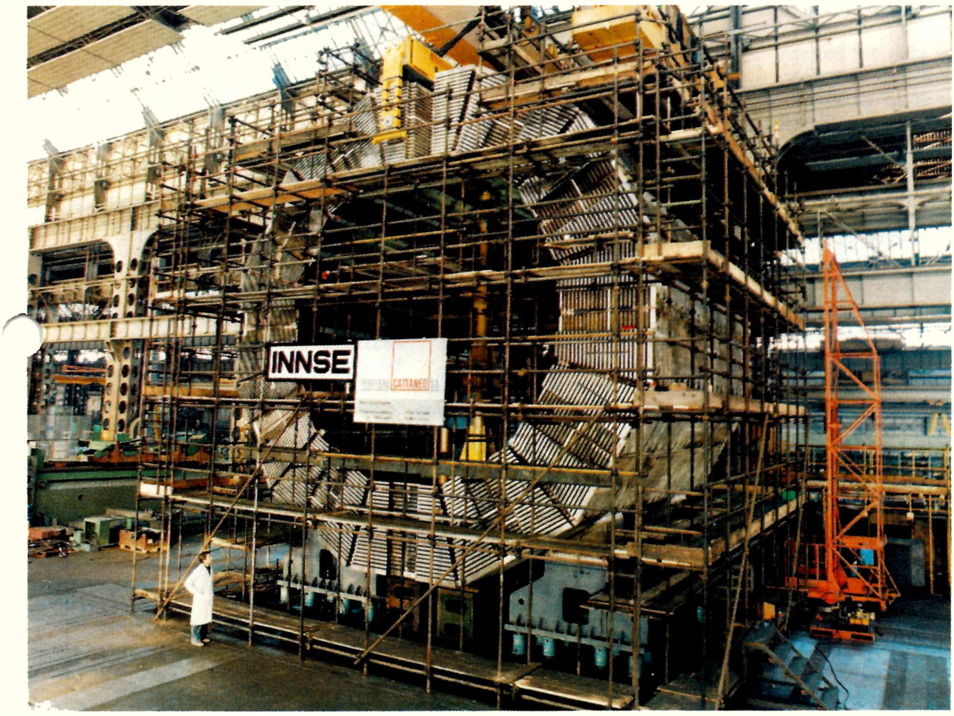
Physics 85 in Paris

The latest in the regular series of physics exhibitions in Paris organized by the French Physical Society was a great success, demonstrating to a large number of visitors the close interplay between progress in physics and advances in technology. The exhibition featured for the first time a CERN stand (above) where the emphasis was entirely in the new technologies developed for the LEP electron-positron collider, now under construction at CERN. A five-cell superconducting cavity is in the foreground. Below, CERN theoretician Maurice Jacob (left), last year's President of the French Physical Society, welcomes French Minister for Research and Technology Hubert Curien to the official inauguration of the exhibition. In his speech the Minister underlined his country's support for CERN.

LEP progress



◀
The four big experiments for the LEP electron-positron collider at CERN — ALEPH, DELPHI, L3 and OPAL — continue to make good progress. The end of 1985 saw the completion of the first major component for ALEPH, with 24 modules, seven metres long, assembled in the barrel-shaped return yoke of the detector's superconducting solenoid. The 1700 ton 10 m-high structure is a highly successful collaboration between Swiss (Ferriere Cattaneo) and Italian (INNSE) industry. The barrel will be dismantled and shipped to CERN to equip each module with the streamer tubes for hadron calorimetry and reassembled for the magnetic tests and field mapping.

Tunnelling for LEP continues to make good progress with three mole-like tunnellers burrowing round the 27 km ring. About 12 km of tunnel have been excavated to date. Here a machine head makes its final approach to landing in the operational zone prior to beginning tunnelling. Excavation of experimental areas and access points at two of the eight points around LEP is almost complete. The first experimental areas should be ready for installation of equipment by mid-1987.

(Photo CERN) ▼

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Send resume and names of three references by April 30, 1986 to:

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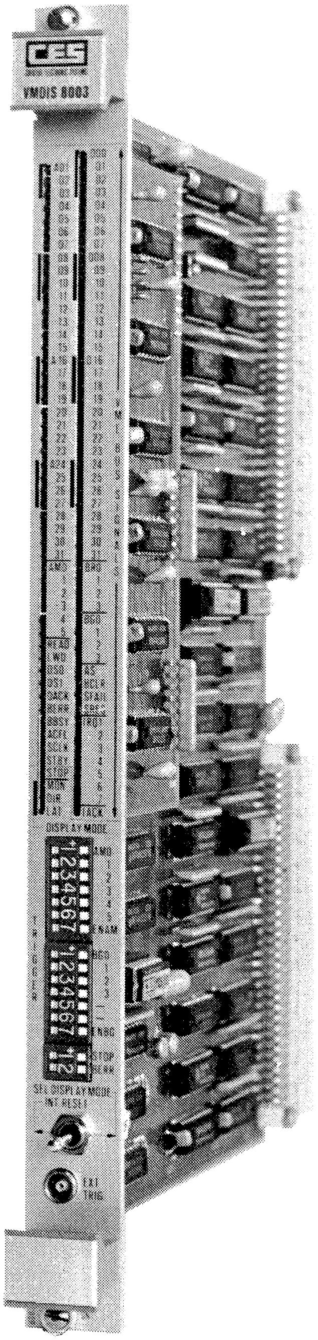
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