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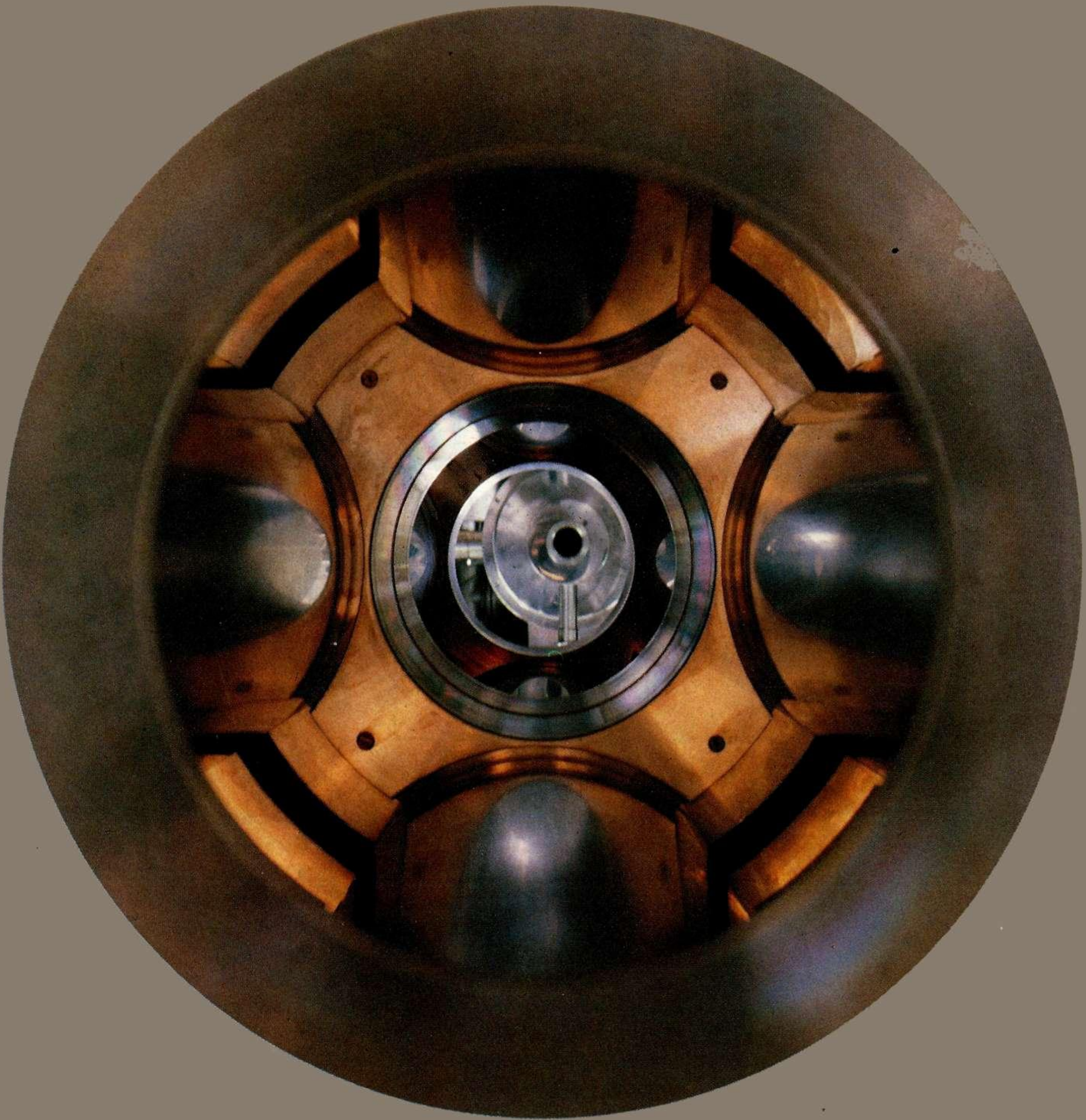
International Journal of High Energy Physics



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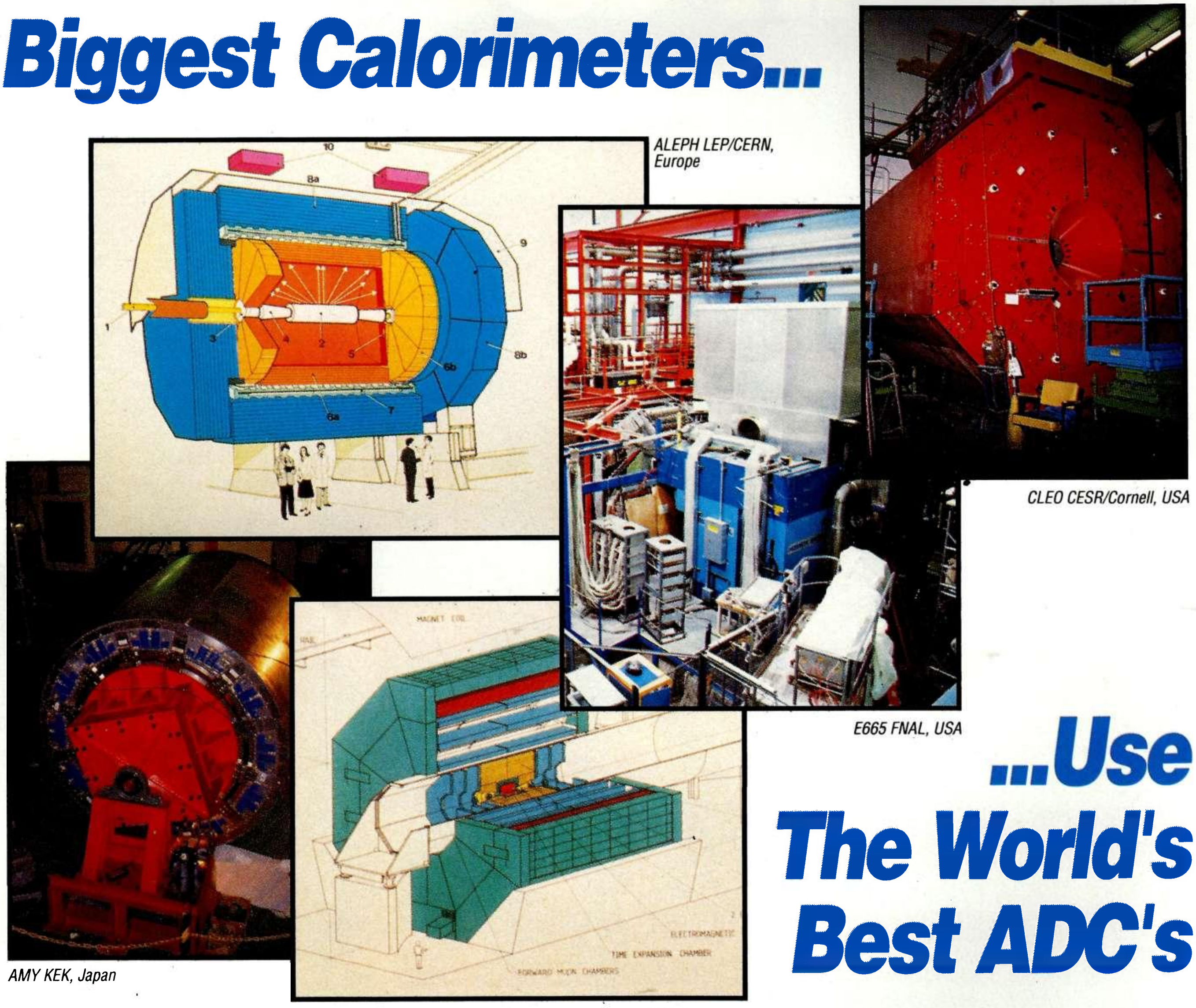

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Looking down an electrostatic quadrupole lens at CERN's ISOLDE-3 on-line isotope separator towards the target of the NICOL nuclear orientation apparatus, cooled to below 5 millidegrees kelvin by helium dilution refrigeration. (Photo CERN 0016.4.88).

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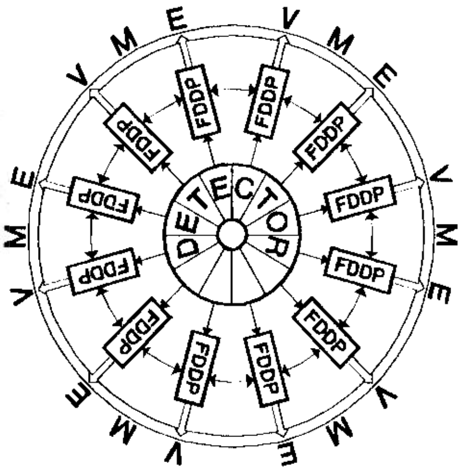

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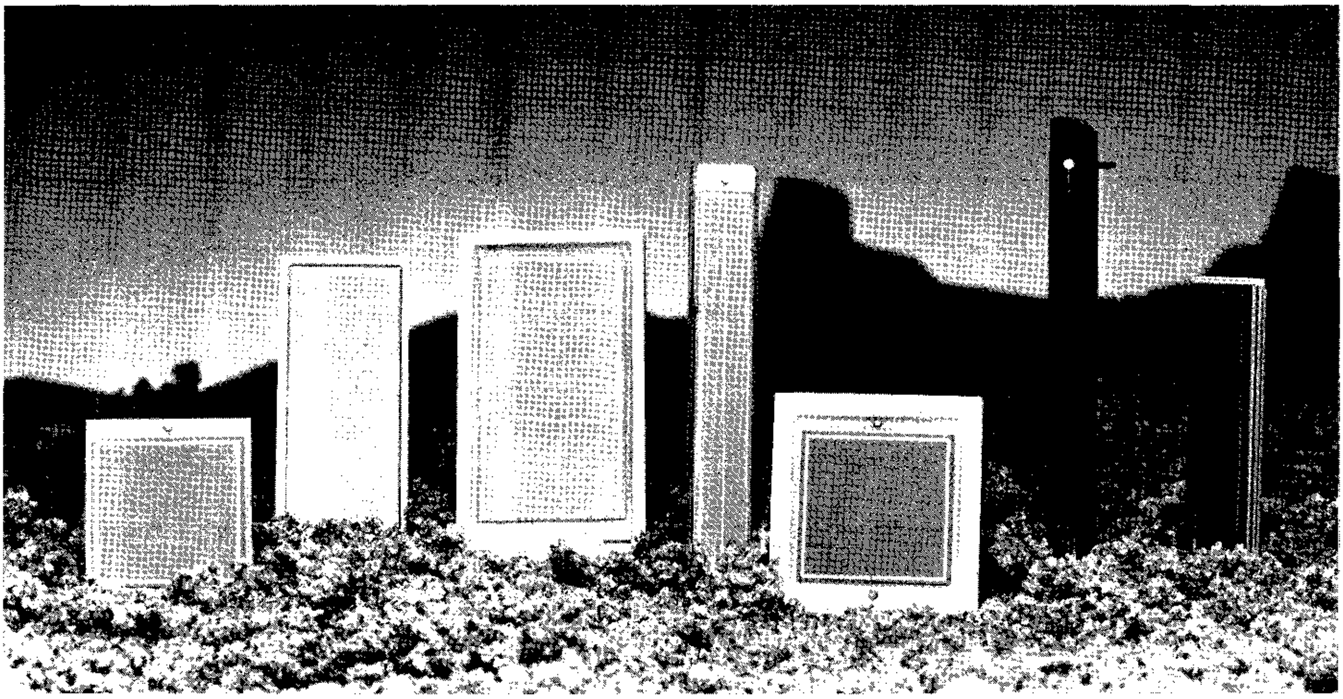

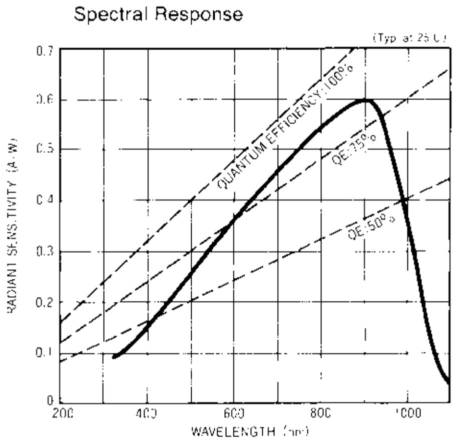

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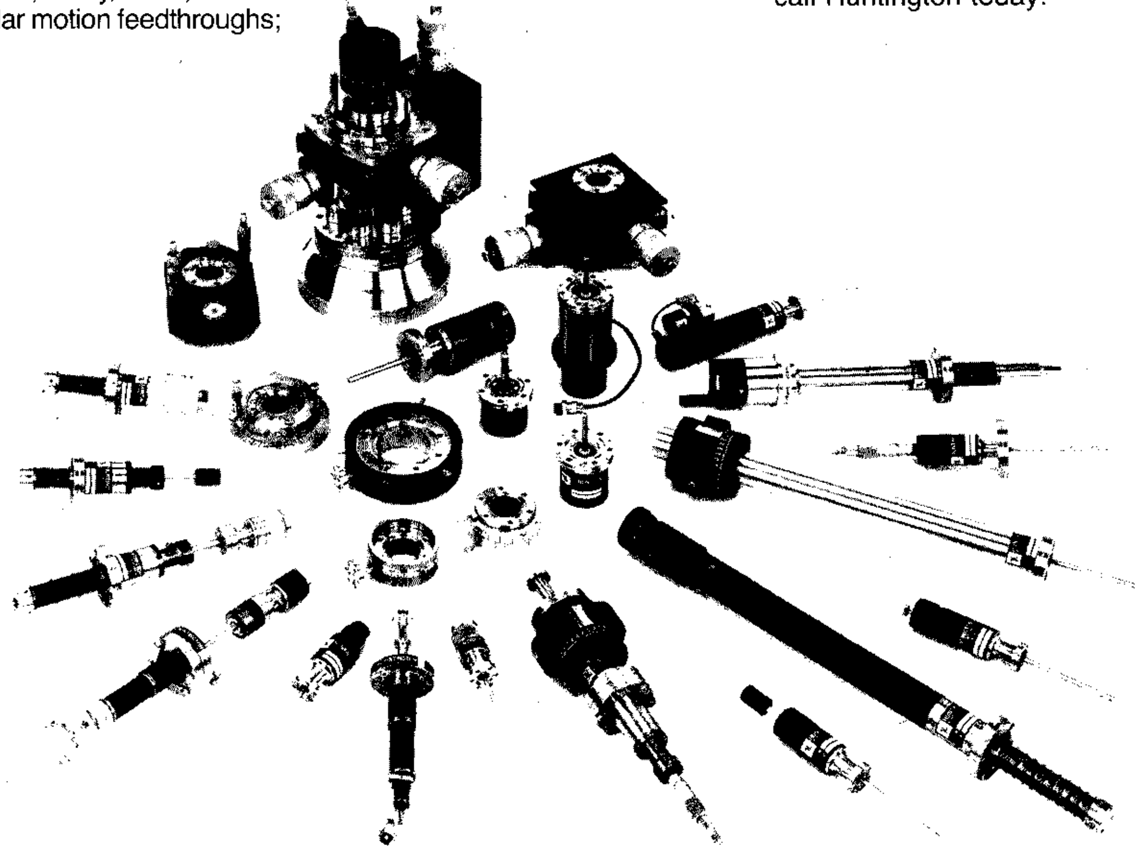

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1.4 million cubic metres of achievement

After five years of civil engineering work, the accent at CERN's 26.7 kilometre LEP electron-positron collider is now on installation. The first 2.8 kilometre section is now virtually complete and awaits the first positron test beam this summer, while the preparations for the four big detectors enter their final phase.

It was more than a decade ago that the idea of a large electron-positron ring at CERN first emerged to spearhead European high energy physics effort in the years to come.

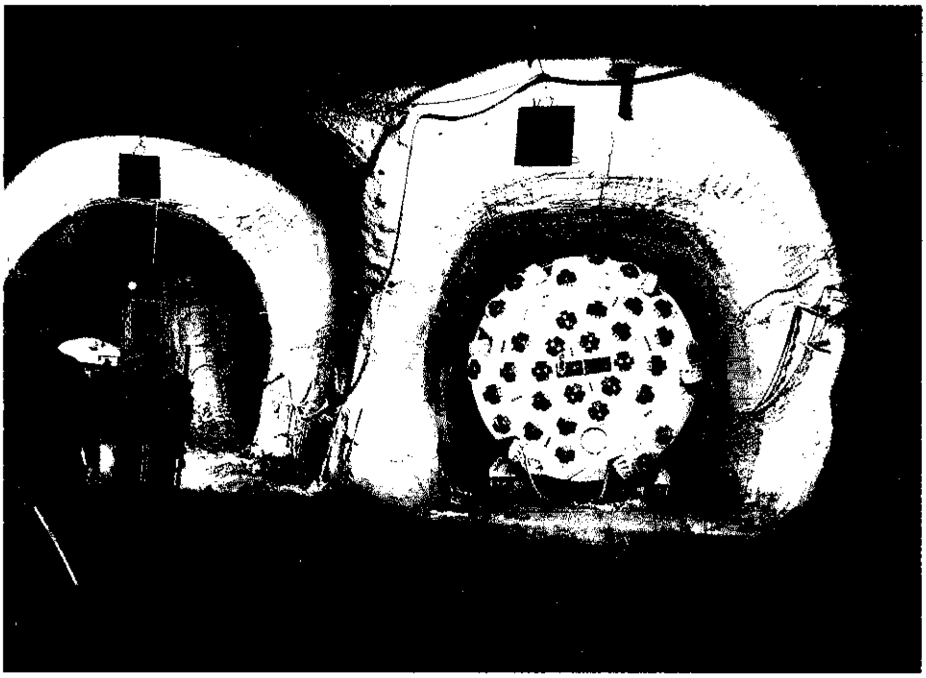
LEP's dimensions are a compromise between capital cost and energy losses. As a beam of electrons is bent by a magnetic field, it loses energy ('synchrotron radiation'), which has to be compensated by bursts of radio-frequency energy. The larger the ring, the less the electron beams have to be bent, and the smaller the energy losses. On the other hand, a larger machine costs more.

The siting of the ring was critical. The existing CERN accelerator network has to be used to give the LEP electrons and positrons their initial burst of energy. The stringent requirements for stable beams also require the machine to be built in firm bedrock. Moreover the terrain around CERN is far from flat – the Jura range with peaks of 1700 metres is only a few kilometres away.

Between the Jura and CERN, the underlying rock is 'molasse' - alternate layers of sandstone and marl with all intermediate compositions. Although requiring some special measures, this material is relatively

Waiting to cut the ribbon marking the end of LEP tunnelling. Left to right, M. Meloni, works director of the Jura tunnelling consortium; M. Masson (wearing coat), mayor of Crozet (under whose territory the LEP ring passes); project leader Emilio Picasso; CERN engineer Bruno Bianchi; and Henri Laporte, head of CERN civil engineering.

(Photo CERN X143.2.88)



Most of the excavation work for LEP used roadheaders (left) and full-face tunnelling machines (right).

(Photo CERN 170.7.85)

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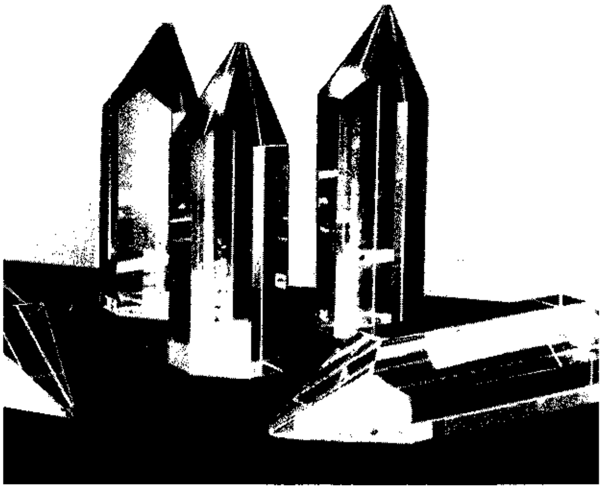

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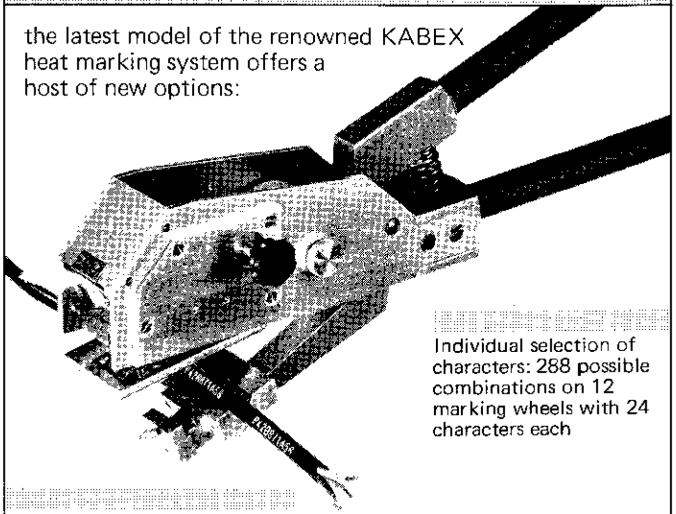

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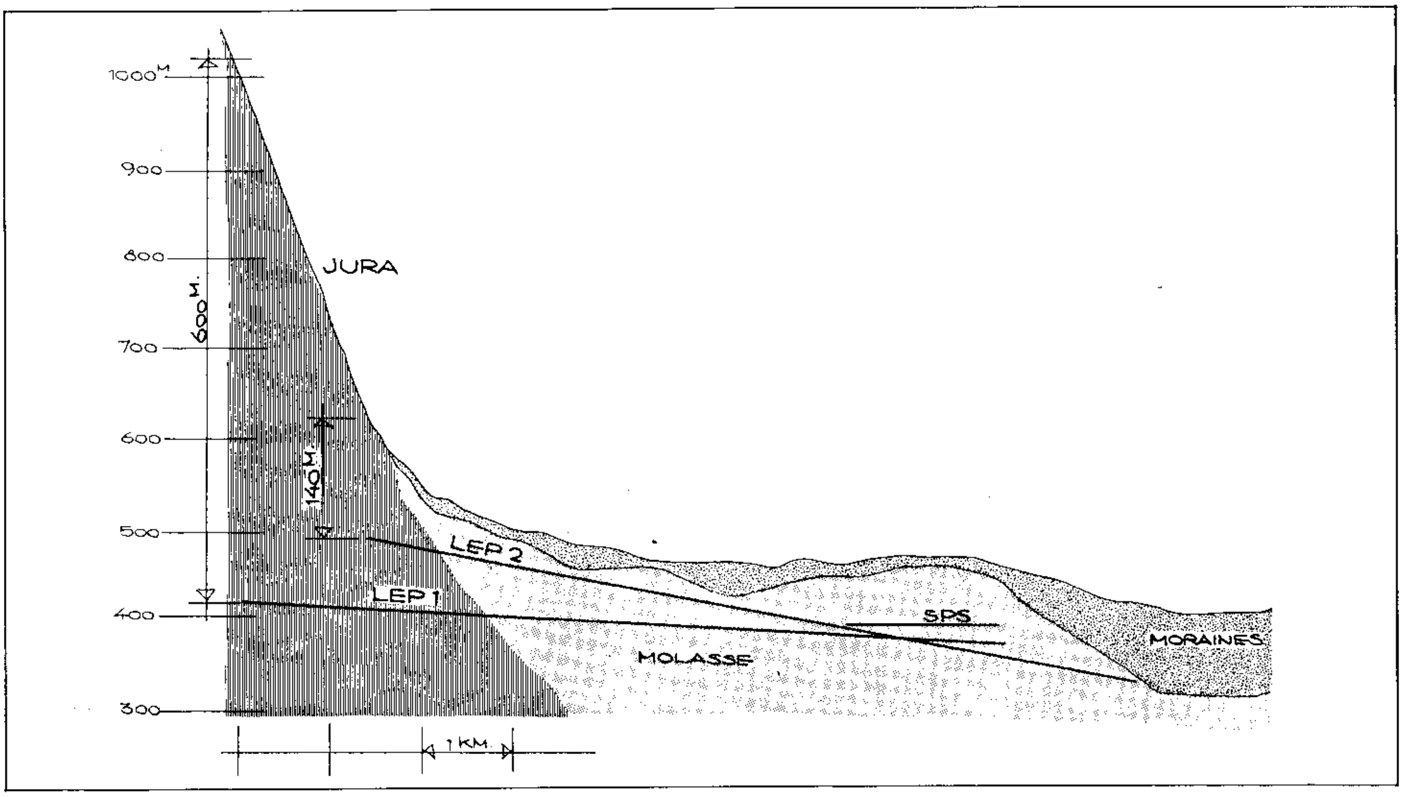
Built on a tilt. Schematic cross-section of the terrain around CERN, showing how the location of the LEP ring was swung away from the Jura mountains and tilted. This minimized risky tunnelling under the Jura and benefited from the 'molasse' (sandstone and marl) in the plain, good for tunnelling.



good to excavate using roadheaders and boring machines. Its characteristics were well charted at CERN after experience in building the 7 kilometre SPS Super Proton Synchrotron ring in the early seventies.

The older Jura range was severely fractured when the neighbouring Alps appeared, so that geological faults and folds in the Jura limestone are common, and sometimes large.

The first LEP design envisaged a 31 kilometre ring, tangential to the existing SPS ring (to facilitate injection), but penetrating deep under the Jura, with rock overburdens of over 1,000 metres at some points.

To reduce the penetration under the Jura, a second solution reduced the ring to its present size of 26.7 kilometres, but maintaining a position tangential to the SPS ring still called for 8 kilometres of tunnel under the mountains at depths of up to 600 metres.

Between 1980 and 1982, numerous geological, geophysical and hydrological studies were carried out. A 3.6 metre diameter reconnaissance gallery cut one kilometre into the Jura from the bottom of a 60 metre shaft, while boreholes were drilled, one over 1000 metres deep.

This careful work revealed potential difficulties due to geological faults and/or underground water, possibly at high pressure. To minimize these risks, known from the outset, the position of the LEP ring was swung away from the Jura to reduce the amount of tunnel under the mountains. Inclining the LEP ring slightly (1.4 per cent) also cut the depth under the Jura to less than 200 metres.

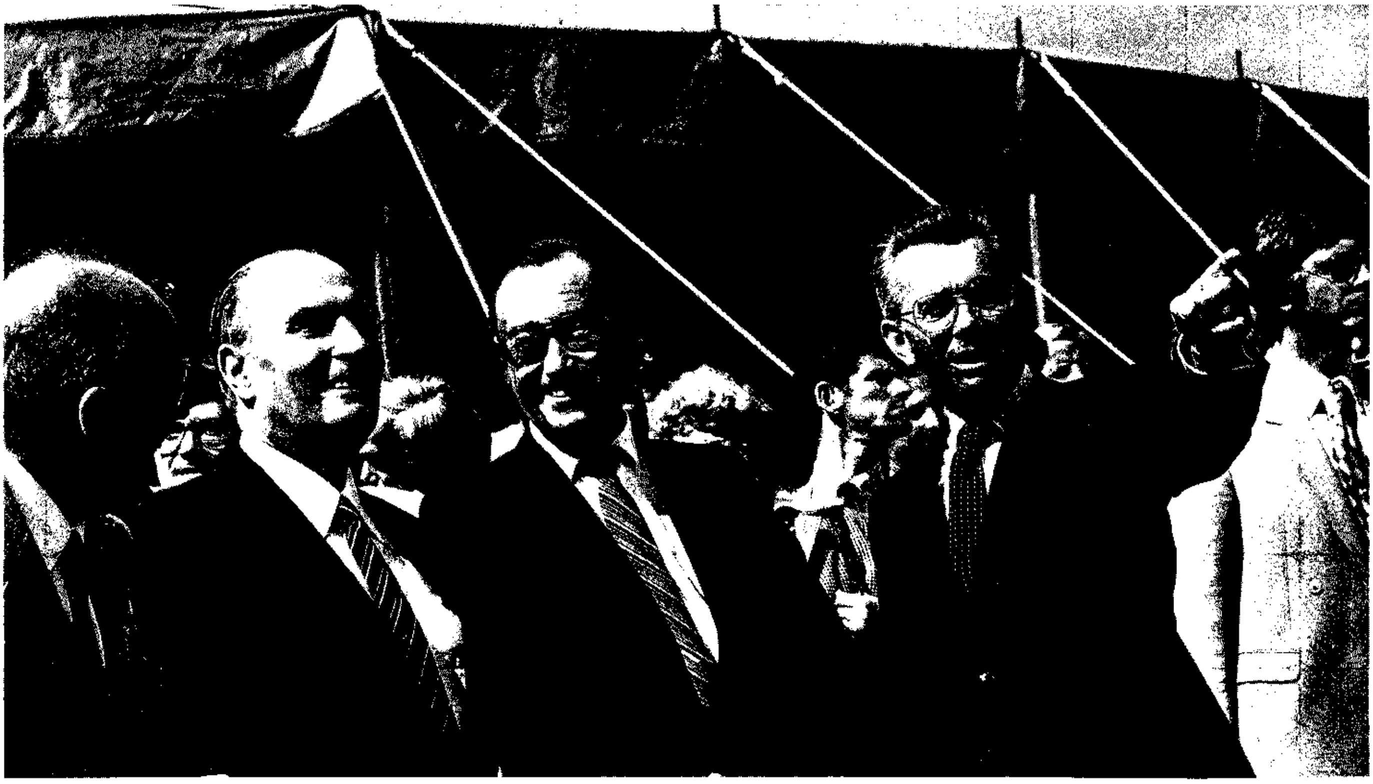
This bold decision – the first time a major particle accelerator has been built on a tilt – added to the already complex tasks of design and machine assembly, but reduced the total length of access shafts, and ensured that in populated areas the machine passes deep underground.

With the position of the ring known, legislative procedures got underway, complicated by having to negotiate with authorities in two countries – Switzerland and France, each with special requirements. In France, for example, land ownership extends in principle to the centre of the Earth, so that tunnelling required individual agreements with private landowners. The implications of the huge machine for its environment were detailed in an in-depth study ('etude d'impact').

With the Swiss authorization received in June 1982 and the French 'Déclaration d'utilité publi-

LEP Project Director Emilio Picasso (left) and CERN Director General Herwig Schopper (right) accompany French President François Mitterrand and Swiss President Pierre Aubert as groundbreaking for LEP starts on 13 September 1983.

(Photo CERN 195.9.83)



que' issued in May of the following year, work could begin.

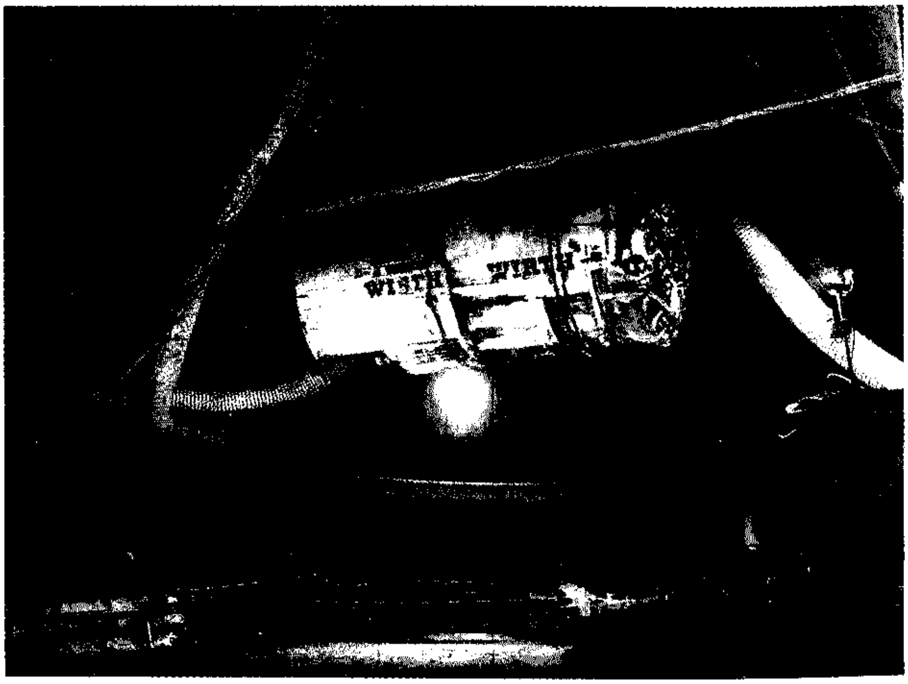
On 13 September 1983, the start of LEP construction was marked by a formal groundbreaking ceremony with French President François Mitterrand and Swiss President Pierre Aubert as guests of honour.

Before attacking the tunnel, access shafts had to be dug, with depths varying from 40 to 150 metres. At some points, special equipment was brought in to freeze the ground so that work could penetrate the water tables unhindered. The 19 access shafts plus the four huge underground caverns to house the LEP experiments represent about half of the total excavation volume.

With the tunnel being built to house a particle accelerator handling beams to micron precision, there was never any question of

Specially built by Wirth of West Germany, the LEP tunnelling machines pushed ahead at an overall average daily rate of 25 metres.

(Photo CERN 67.10.85)



A LEP tunnelling breakthrough. Project leader Emilio Picasso with (centre) tunnelling team leader M. Bacuzzi and (right) LEP Division Leader Gunther Plass.

(Photo CERN 312.7.86)

moving its path to avoid obstacles encountered on the way – the ring as designed on paper had to be faithfully cut through rock and stone.

Tunnelling work was dividing into two separate projects. The 24 kilometres through sandstone and marl were attacked by the 'Eurolep' consortium (led by Fougerolle of France, with Astaldi of Italy, Entrecanales Y Tavora of Spain, Philip Holzmann of West Germany and Rothpletz, Lienhard of Switzerland) using three full-face tunnel boring machines specially built by Wirth of West Germany. Built to cut at up to 5.4 metres per hour, these machines and their crews performed magnificently, with a record eight-hour shift advance of 23 metres, a record daily push of almost 60 metres, over 200 metres in one five-day week, and 760 metres in one month, and an overall average of 25 metres per day.

To complement the sterling work of CERN's own survey specialists (see April 1984 issue, page 103), tunnelling was guided by a laser/computer system from the UK, ensuring that deviations averaged only a few centimetres.

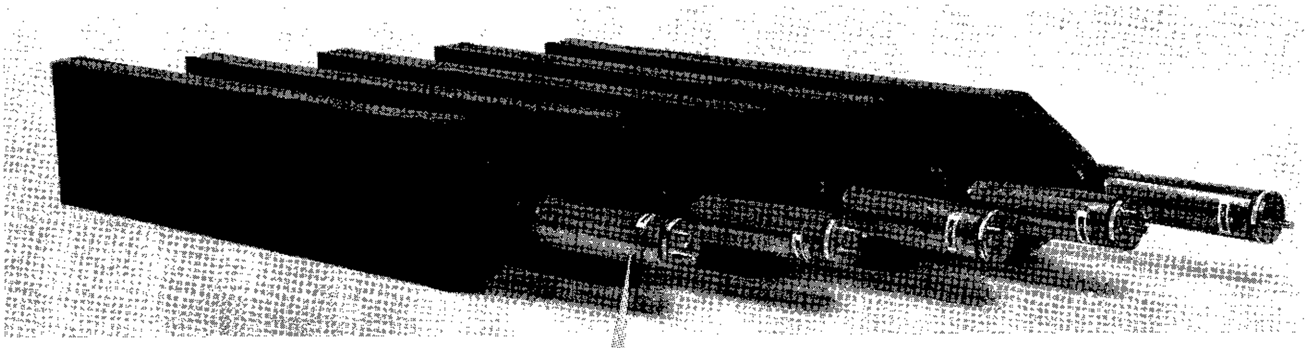
The double-shield support system allowed an initial prefabricated concrete lining to go up as the rams progressed, making for rapid progress and continuous tunnel support. The final tunnel lining was poured later with the tunnel floor. To feed LEP, two mighty plants can provide over a hundred cubic metres of concrete per hour.

Despite inevitable delays and hitches in a project of these dimensions (petrol deposits were twice encountered, requiring removal of 250 tonnes of hydrocarbon-bearing material), this portion of the tunnel was completed in January 1987, just two years after the first 170 ton boring machine was lowered into position.

Auxiliary galleries, shafts and caverns were handled by an army of roadheaders, with temporary support provided by shotcrete, wire mesh and rockbolting ('New Austrian tunnelling method').

The potentially problematic 3.5 kilometre stretch under the Jura was tackled by a second consortium (led by Locher of Switzerland, with Les Chantiers modernes and Intrafor-Cofor of France, CSC Impresa Costruzioni of Italy, and C. Baresel and Wayss and Freitag of West Germany).

Protected by probe borings to gauge the rock ahead, careful drilling and blasting by the 'Canadian cut' technique went remarkably well until September 1986, when, with some three kilometres of tunnel already accomplished, the



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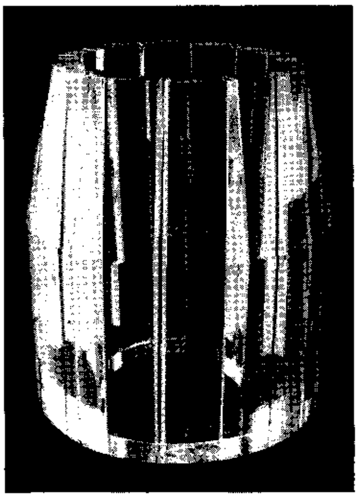

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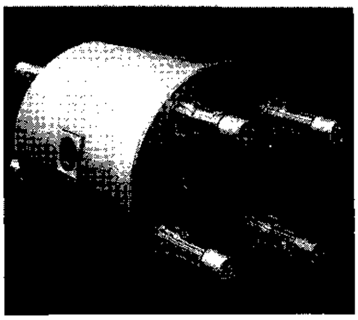

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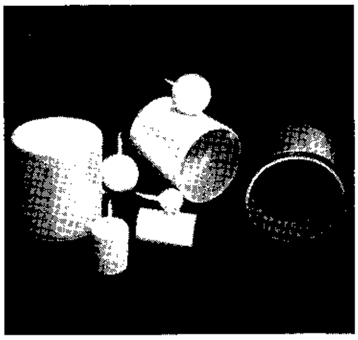

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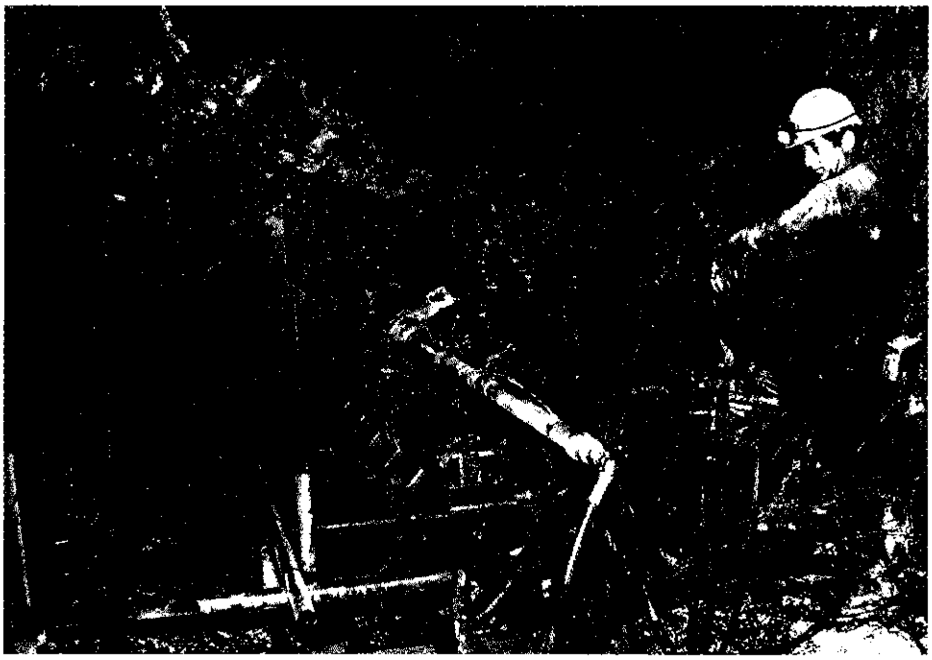


▲ *Under the Jura mountains, careful probing tested the rock ahead.*

teams were stopped by a 100 litre/second inrush of water from behind!

Progress was halted for several months while the tunnel lining and the surrounding rock were solidly reinforced and delicate probing tried to ascertain the extent of the problem ahead. After the resumption of tunnelling last year, a second water problem resulted in further delays before work could begin again last autumn.

At a poignant moment earlier this year, the clearing of the last few metres of rock was screened to an audience of several hundred people in the huge experimental hall at Point 4, 150 metres below ground.

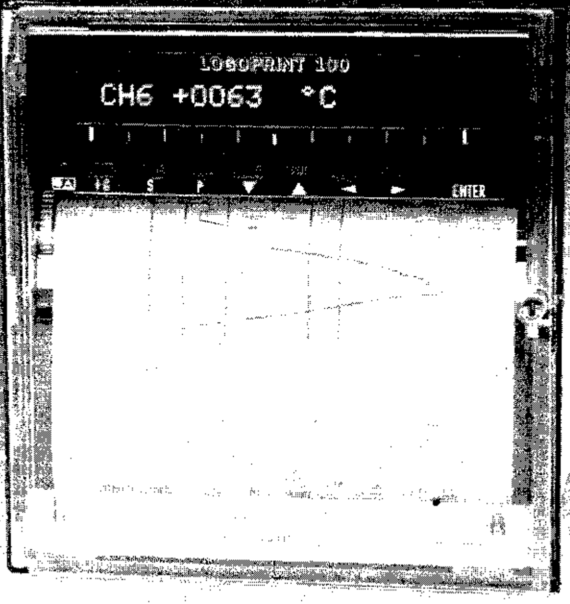
Despite the delays, the progress of the overall project continues relatively unperturbed, thanks to some highly flexible planning and resource control gymnastics behind the scenes. By the end of the year, the tunnel lining will be complete, providing the final insulation against all natural eventualities.

In total, the LEP tunnel, shafts and pits required the removal of 1.4 million cubic metres. Despite being equivalent to about a third of the Great Pyramid, this spoil is now almost invisible, having been discharged close at hand (making also for minimal intrusion by heavy road transport), thanks to excellent cooperation with local authorities. In addition, the road system in France was substantially improved, funded by local and central French government and by CERN.

Although civil engineering work is not yet complete, the LEP tunnel is a great achievement, especially for the teams of Henri Laporte (civil engineering) and Michel Mayoud (surveying) and all their advisors and contractors.

Despite a big safety drive, three fatal accidents occurred underground and two more (not connected with the tunnelling and which could have happened anywhere, anytime) on the surface. A plaque will be mounted to commemorate these five men who lost their lives in this gruelling endeavour.

▼ *3 kilometres into the Jura mountains, LEP tunnelling was temporarily stopped by an inrush of water from behind the rock face.*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Ready for the Z

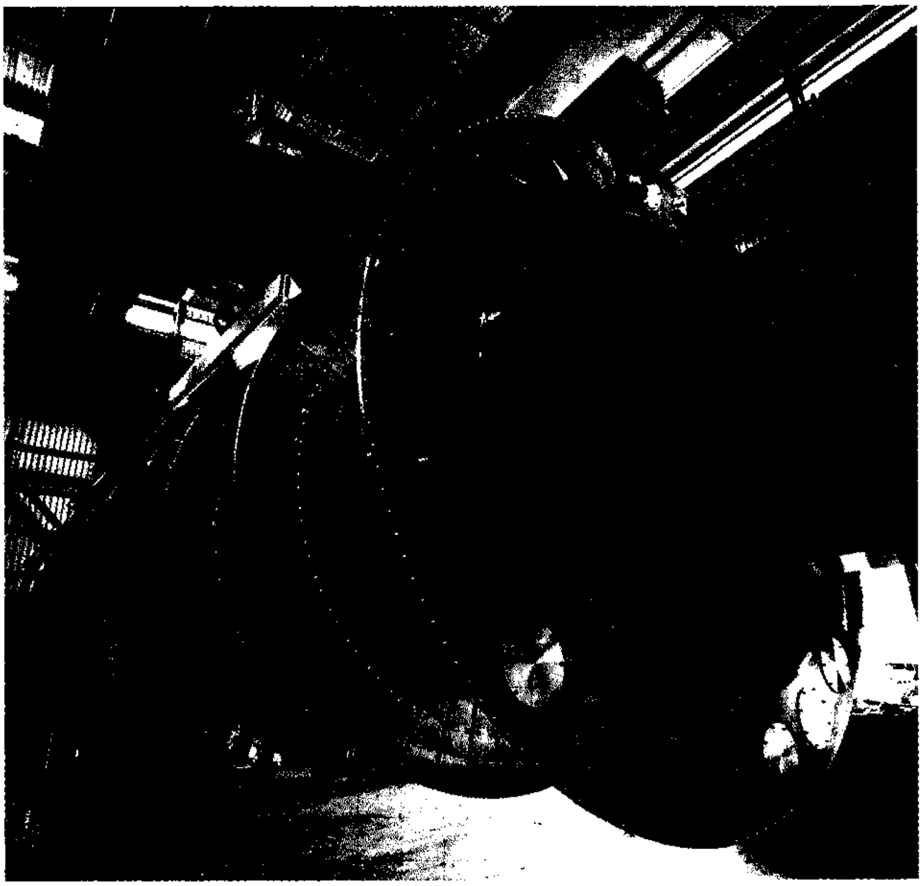
April was an encouraging month of solid progress at the Stanford Linear Collider (SLC). Aided by cool, cloudy weather, which settled upon the San Francisco Bay Area and helped promote stable running conditions, the collider commissioning team finally brought electron and positron beams into collision at the interaction point. It was a major milestone in the SLC commissioning effort. For the rest of the month, the two beams ran fairly routinely at 10 Hz, with both spots smaller than 10 microns.

Just after Easter weekend the positron beam had been transported right through the final focus and into its dump for the very first time. But blistering temperatures and a host of hardware problems limited the beam time available for physicists to work on focussing the positron bunches down to the 4 micron size needed to begin research at the Z^o particle, the electrically neutral carrier of the weak neutral force.

The weather turned more favourable over the weekend of April 16-17, and spot sizes of 7-8 microns were achieved on Sunday afternoon. At 7.00 the following morning, the two beams passed through one another with simultaneous small spots, as indicated by beam position monitors near the interaction point.

This advance came with 2 x 10^9 particles in each bunch, operating at a total collision energy of 92 GeV. During the remainder of April, the currents were pushed to 10^{10} electrons per bunch and 5 x 10^9 positrons per bunch, while small spots (5-7 microns) were maintained and the beams were kept in collision. Attempts to measure the deflection of one beam by the other, which should begin to be detectable under these conditions, were not successful by month's end.

As May began, Mark II physicists were switching their detector back on to study backgrounds from the positron beam. These are thought to be less serious than the worrisome muon backgrounds from the electron beam scraping metal in the final focus area (see April issue, page 12). Positron level rose to 7 x 10^9 per bunch while the detector was promisingly free of background. After a shutdown to install new collimators, the SLC should be ready, at long last, to begin making Z^os.



The inner dewar for the liquid argon calorimeter of the big SLD detector. After the revamped Mark II detector has had a first look at the physics at the new SLC Stanford Linear Collider, SLD will roll in.

(Photo Joe Faust)

CERN
Probing the proton spin

At the end of the 1960s, classic electron beam experiments at the Stanford Linear Accelerator Center (SLAC) penetrated deep inside the proton and discovered tiny grains hidden inside. Subsequent work with neutrino beams, especially at CERN using the Gargamelle bubble chamber, identified these tiny grains ('partons') with quarks, showing that the proton contained three principal ('valence') quarks.

Further Stanford studies with electron beams probed the spin

(intrinsic angular momentum) of the struck quarks, showing clearly that they carry half a unit of spin, and the advent of polarized (spin oriented) electron beams and targets probed deeper into the quark spin structure of the proton.

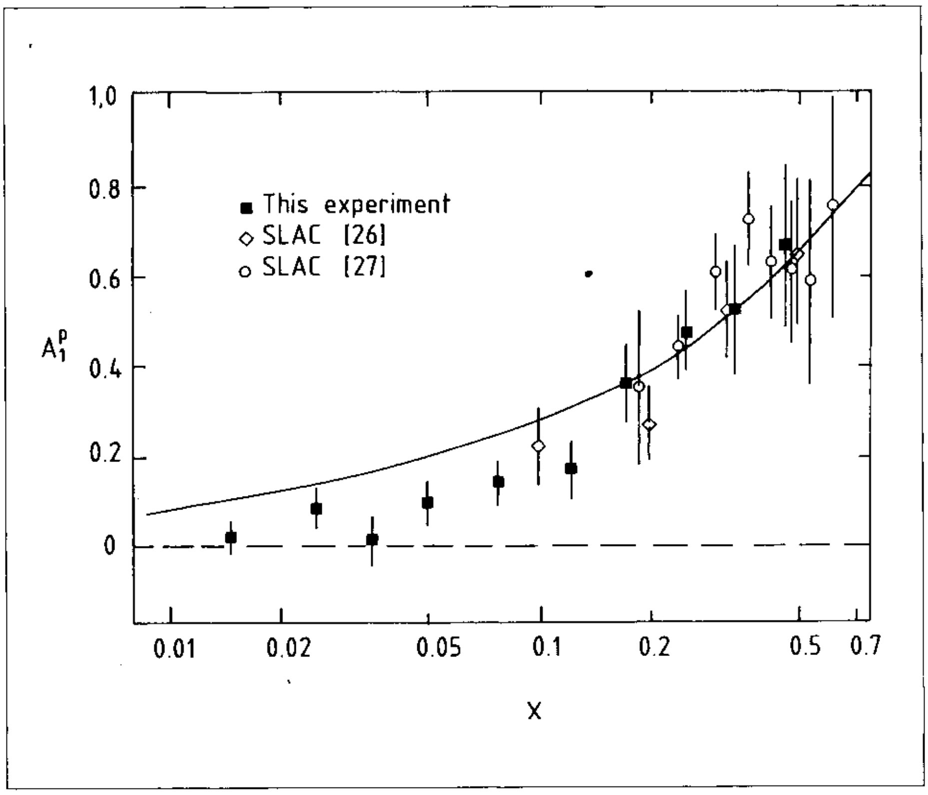
In a series of eleven separate runs using a range of energies, the European Muon Collaboration (EMC) at CERN recently used a polarized muon beam and a specially constructed polarized target to take a closer look at the spin content of the proton, extending the kinematic range studied in the earlier Stanford experiments.

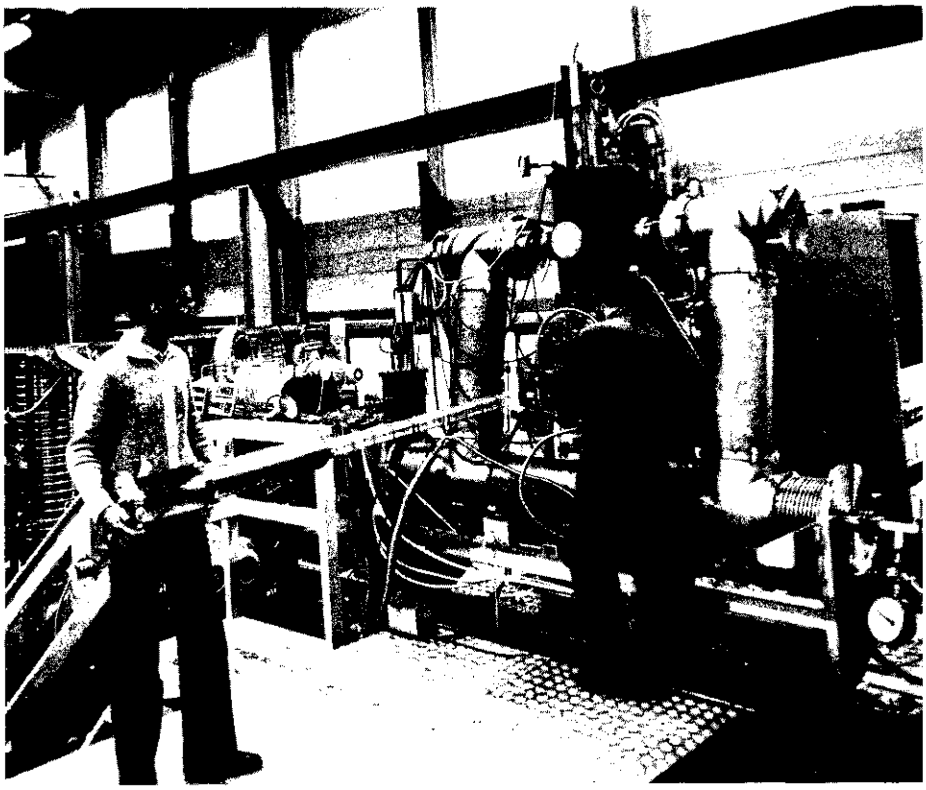
The target had two sections, polarized simultaneously in opposite directions, and the data from the two halves was carefully compared to disentangle the contributions coming from different quark spin alignments.

The measured quark-spin content (structure function) is remarkable. While the individual quark spin contributions show definite directional preferences, the overall contribution to the proton spin from the quarks adds up to almost zero! This means that under these conditions (the incoming muon penetrating deep inside the struck proton and the quarks recoiling violently) the vast majority of the proton's spin comes from the gluons holding the quarks together, and/or from orbital angular momentum of the proton constituents relative to each other.

At face value, this result implies that the quark structure of the proton (which depends on kinematics) is under these conditions more complex than the simple quark

Variation of asymmetry (vertical axis) with kinematics as seen by the European Muon Collaboration (EMC) at CERN using spin-oriented beams and targets, compared with earlier results from Stanford (SLAC) using electron beams. The solid line gives the theoretical prediction, in line with experiment in one region (x is the fraction of momentum carried by the struck quark) but seriously awry in the small x region probed by EMC.

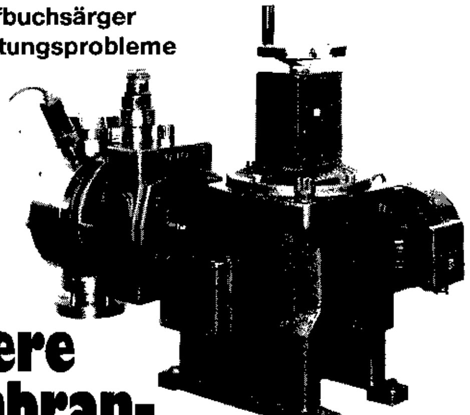


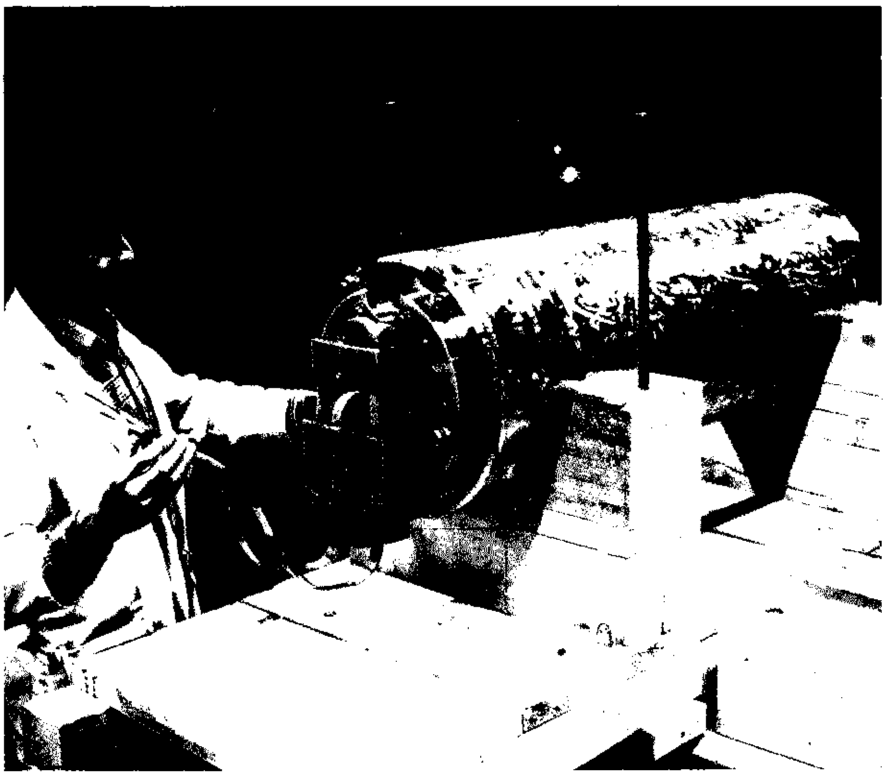


The EMC experiment used the world's largest polarized target.

(Photo CERN 393.3.81)

25 KG
KG





The 1 metre long superconducting high field model dipole, designed at CERN for the LHC Large Hadron Collider scheme in the LEP tunnel and manufactured by Ansaldo Componenti, Genova, attained fields of up to 9.1 Tesla in initial tests.

(Photo CERN 144.3.88)

model which attempts to explain proton properties by adding up quark effects. For example the proton could have a complicated structure, such as the lump-like soliton or 'Skyrme' model.

In 1982, the EMC collaboration's discovery that the quark structure of nucleons depends on the nuclear environment (the 'EMC Effect'), also set people thinking. This result came from the initial EMC configuration comparing results from different nuclear targets. A second phase used a vertex spectrometer to look at the way struck quarks emerged as visible hadrons ('quark fragmentation'), and a third phase used the world's largest polarized target to study detailed spin effects.

CORNELL
New detector and more collisions

On March 14 the CLEO detector finished its successful career in electron-positron physics at the Cornell Electron Storage Ring (CESR). CLEO is one of a class of solenoid-based magnetic detectors popular at electron-positron colliders. Active since CESR first started operating in 1979, it made the first observation of the B meson (containing the 'beauty' – b – quark) as well as other important contributions to the physics of beauty and charm, and of the tau lepton.

The CLEO collaboration now includes physicists from Albany, Carnegie-Mellon, Cornell, Florida, Harvard, Ohio State, Maryland, Minnesota, Purdue, Syracuse and Vanderbilt Universities, and in earlier years also from Rochester and Rutgers. Last year CLEO recorded 230,000 decays of the fourth upsi-

CERN
Magnet success

Technical preparations for a possible proton-proton collider (Large Hadron Collider – LHC) in the LEP tunnel at CERN have made substantial progress with the successful testing of the first LHC superconducting high-field 1 metre long model magnet.

The single aperture niobium-titanium wound dipole was designed by R. Perin and his LHC magnet study team, and manufactured by Ansaldo Componenti, Genova, Italy. Operating at 2K, it reached and passed its 8 Tesla nominal field without any quench, the first three quenches occurring at central fields of 8.55, 8.9 and 9.0 Tesla respectively. It then attained 9.1 Tesla without quenching and operated at this level for some time before the initial series of tests was voluntarily stopped.

At these high fields, electromagnetic forces are very strong, nearly three times those of the superconducting dipoles now being manufactured for the proton ring of the HERA electron-proton collider at the German DESY Laboratory. A special clamping technique was devised using aluminium alloy collars around the coils, surrounded by the rigid iron yoke split into two halves and closed around the collars during cooldown by the thermal contraction of an overall shrink-fitted stainless steel cover.

This is the first time a high field 'accelerator quality' superconducting dipole model has been designed and built as a joint venture between a scientific laboratory and industry. CERN provided most of the know-how and the superconductor, while manufacture was taken over by Ansaldo.

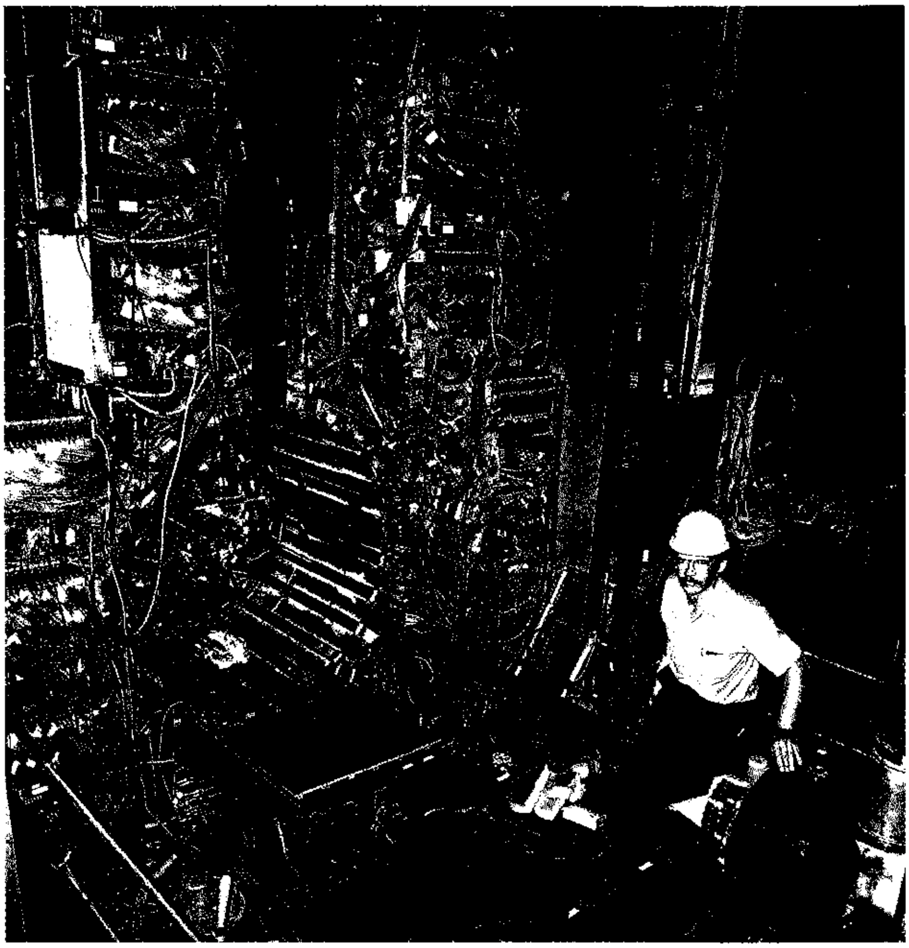
The LHC design foresees a single yoke enclosing a double aperture 'two-in-one' magnet to handle the contra-rotating proton beams. Fields of 10 Tesla would provide proton beams of about 8 TeV (8000 GeV), with 16 TeV collision energies.

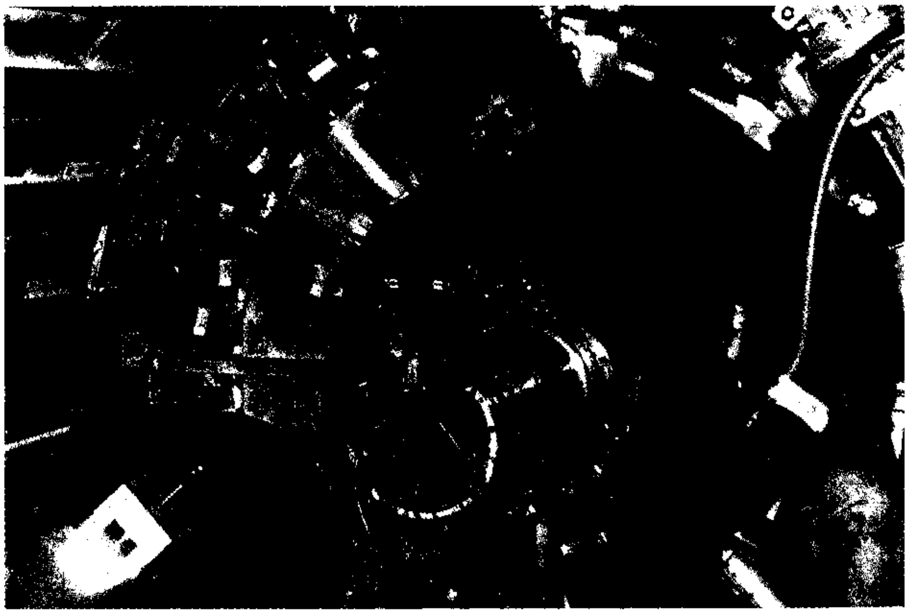
lon (4S) resonance into B-meson pairs, more than doubling the world's supply, and in the first few months of this year collected a unique sample of 40,000 decays of the next upsilon (5S), a potential source of strange B mesons. These data samples, now undergoing analysis, should provide more accurate measurements of oscillations of B mesons and of charmless weak decays of the B, topics which aroused much interest last year.

Before being dismantled and replaced by the new CLEO-II, the old CLEO detector is serving briefly as a testbed for a prototype high resolution vertex drift chamber. To intercept very short-lived particles, any tracking device intended for heavy quark physics has to get very close to the event vertex. In electron storage rings the radius of the beam pipe in the interaction region has been about 6 cm, because of the difficulty of protecting tracking chambers from synchrotron radiation and beam spill background from the circulating beams. The new CLEO prototype drift chamber has an inner radius of 2.3 cm. If the tests of the chamber and the radiation masking are successful, the decays of charmed mesons produced in B decays will be seen more clearly, simplifying the reconstruction of complicated events.

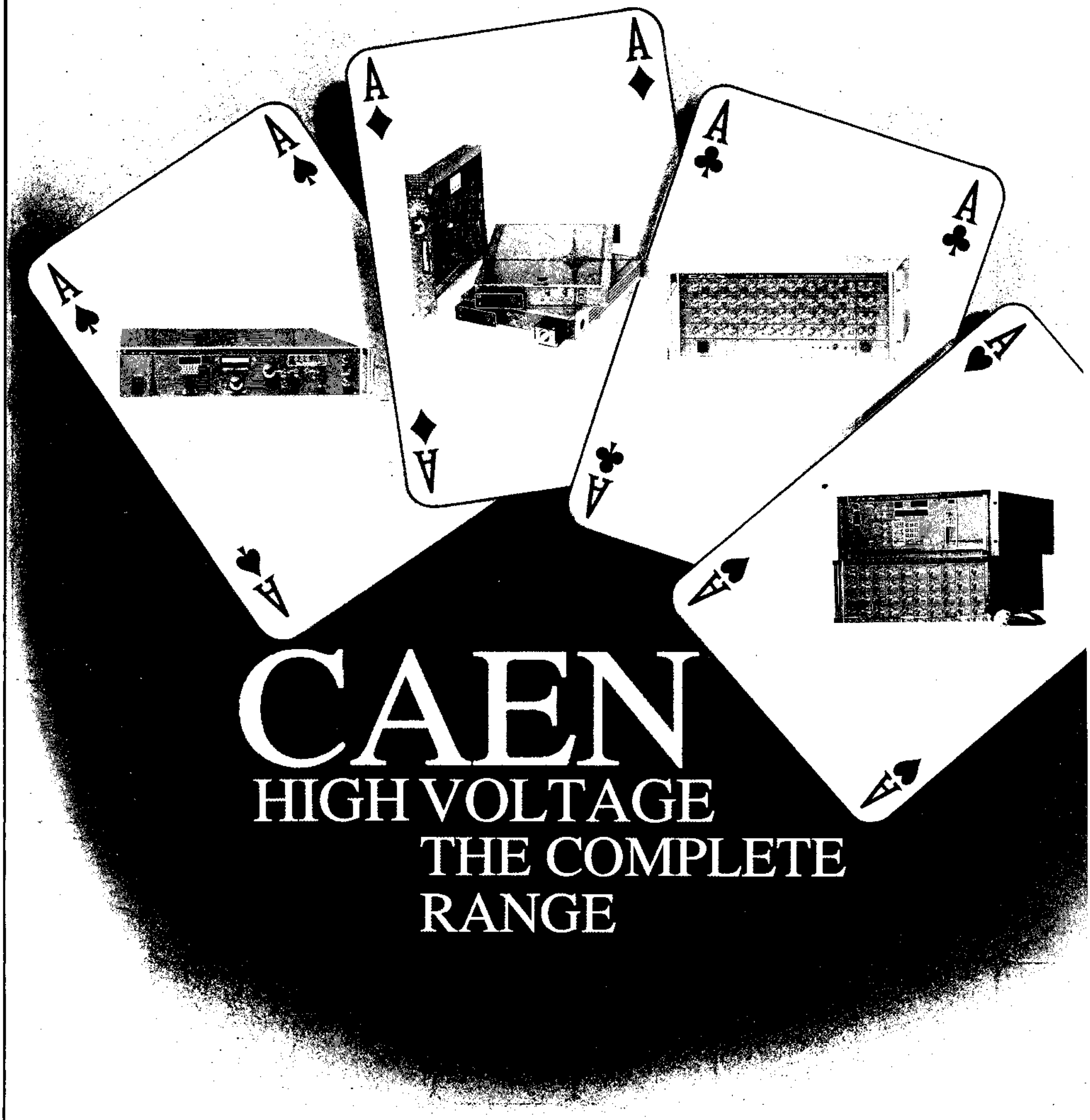
The successor detector, CLEO-II, will differ in having a main cylindrical drift chamber considerably improved in momentum and ionization resolution (this was already installed in CLEO in 1986), a 30-ton caesium iodide scintillator array for very high resolution electromagnet-

End face of the CLEO detector at the CESR electron-positron collider at Cornell, prior to installation of a prototype vertex chamber and 2.3 cm inside radius beam pipe.





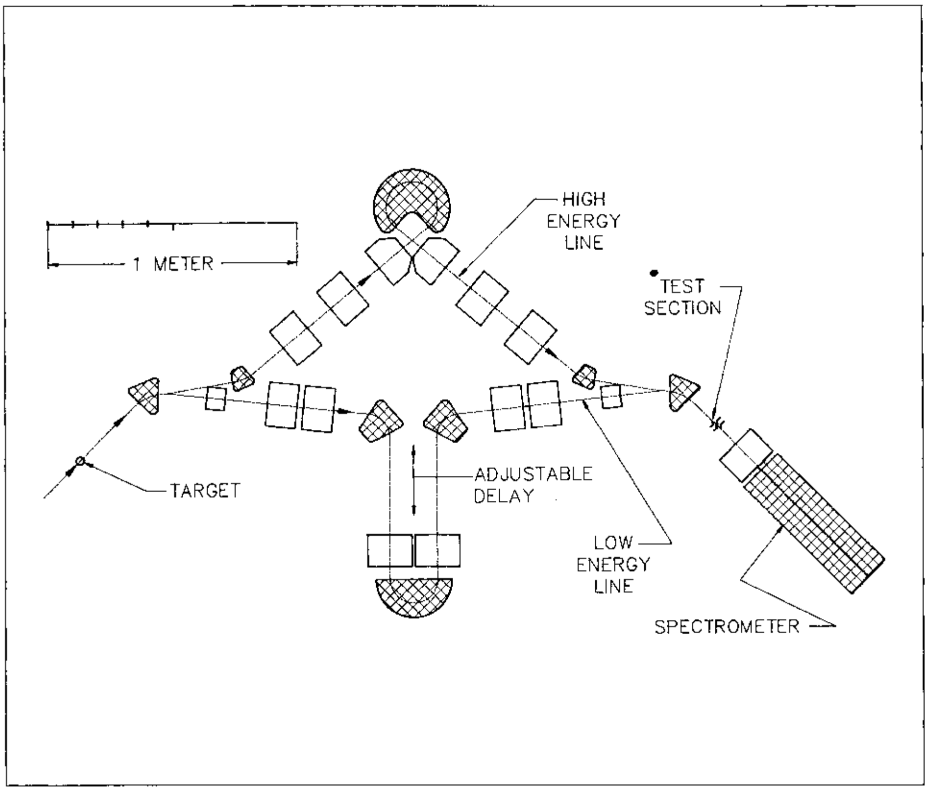
Riccardo DeSalvo prepares readout cables for the CLEO prototype vertex chamber test. The large cylinder under his arm is the rare-earth/cobalt quadrupole magnet for 'micro-beta' beam focusing.


CAEN
HIGH VOLTAGE
THE COMPLETE
RANGE

ic calorimetry, a 3 m diameter 1.5 Tesla superconducting solenoid coil, new time-of-flight scintillators and muon detection chambers, and a new magnet yoke. Installation should be complete early in 1989. For the first time it will be possible to have in one detector both the charged particle capability of a large magnetic detector and the neutral particle capability of a calorimetric detector like the Crystal Ball.

The transition from CLEO to CLEO-II was also an occasion to celebrate the recent successes of the CESR machine. The accelerator physicists and operations crew have succeeded in increasing the circulating current to 11 mA per bunch in 7 bunches per beam, tightening the focus at the interaction point and shortening the bunch length to 1.75 cm. As a result, the peak luminosity per interaction region at CESR has now exceeded 10^{32} $cm^{-2}sec^{-1}$, a new record for electron-positron colliders. The final month of running logged an integrated luminosity of 90 inverse picobarns in each interaction region. This impressive performance, along with the increased efficiency and resolution of the new CLEO-II detector, will boost b-quark physics in the coming years.

Schematic of the Argonne Wakefield Test Facility. An intense electron beam strikes a carbon target. The spectrometer system transports the full energy beam through the upper path while a low intensity beam follows the lower.



ARGONNE Plasma wakefields work

A unique tool for investigating plasma 'wakefields' has yielded the first direct observations of particle acceleration using this technique.

The wakefield accelerator idea is one of the approaches being investigated to attain high accelerating fields for the next generation of particle accelerators. Bunches of charged particles passing through certain geometric structures can leave behind them (in their wake) higher field gradients than they themselves have experienced.

Initial collinear schemes were tested experimentally in the early 1970s, and although reproposed many times, physics reasons exclude their use for a new accelerator scheme.

In a version initiated by Tom Weiland and Gus Voss at DESY, a hollow circular beam running along the outside rim of a cavity produces electromagnetic waves travelling through slots to the cavity axis. The cavity structure acts as a transformer, and another beam, travelling along the axis, sees very high accelerating fields.

Last year, a DESY 'Wakefield Transformer' experiment showed the principle worked (see September 1987 issue, page 8), with a successful acceleration of electrons (accelerating gradient higher than 8 MeV per metre) in a 'Stage 1' experiment without final bunch compression.

The 'Stage 2' set-up is still under construction and will be completed soon. It will include a hollow beam rotation, giving significantly improved drive beam homogeneity, already observed in a first run in December with an almost complete set-up.

The wakefield transformer concept has been modified into the 'resonant wakefield transformer', now being looked at in the context of future machine studies, and a new experiment is being planned.

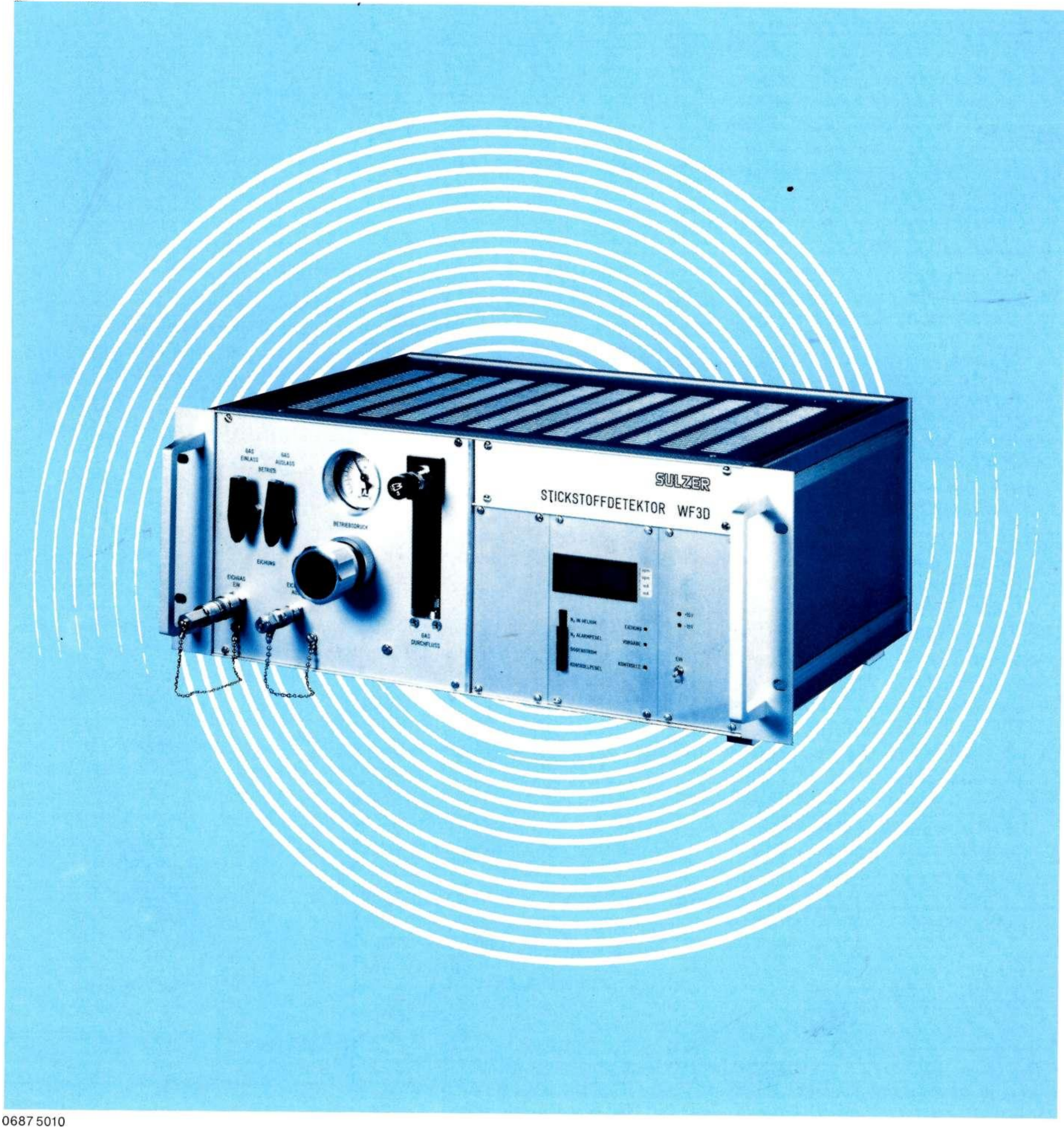
Plasma wakefield accelerators are collinear schemes using a plasma instead of a resonator.

At Argonne, an intense 21.4

SULZER

Cryogenics

Nitrogen in Helium Detector



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Sulzer Nitrogen in Helium Detector Type WF 3D

- Measures the concentration of nitrogen in helium (ppm range)
- Measurement and indication both continuous
- No dead time
- Remote indication, relais output
- Easy to operate – connect and measure
- No carrier gas required
- High degree of stability
- Inlet pressure 1–20 bar gauge

1. Application

Measurement of nitrogen (N_2) in helium (He).

2. Measurement principle

Optical emission spectroscopy. Excitation of the gas is obtained by use of an electrical discharge between two metal electrodes. Analytical line emission is selected by an interference filter. Measurement of radiation is by means of an Si photo-diode.

3. Data of gas to be measured

- Inlet pressure 1–20 bar gauge
- Outlet pressure 0.05–0.3 bar gauge
- Rate of gas flow 0.03 Nm^3/h

4. Range and accuracy of measurement

- Standard range of measurement 2–50 vpm N_2
- Indicated range 0–199.9 vpm N_2
- Resolving power 0.1 vpm
- Reproducibility ±0.1 vpm, typical value for range 2–30 vpm
- Accuracy without re-calibration ±2 vpm

5. Indication, outputs

- 3½ position liquid crystal indication (LCD)
- Analogue signal 4 to 20 mA, corresponding to a measurement of 0 to 50 vpm N_2. Resistance load min. 250 Ω, max. 500 Ω
- Relais output adjustable over the whole measurement range. Maximum loading:
  DC 30 W, 50 V, 1 A
  AC 250 VA, 250 V, 1 A

6. Dimensions, weight

Equipment size suitable for fitting into 19″ rack to IEC 297/DIN 41494.

- Height 177.8 mm (4 units ≙ 7″)
- Casing depth 305 mm
- Weight ca. 13 kg

7. Power supply, ambient temperature

- Supply voltage 220 V, 50/60 Hz
- Permissible variation in supply voltage ±10%
- Power input max. 150 W
- Permissible ambient temperature range 0 to 40 °C

Cryogenics

SULZER

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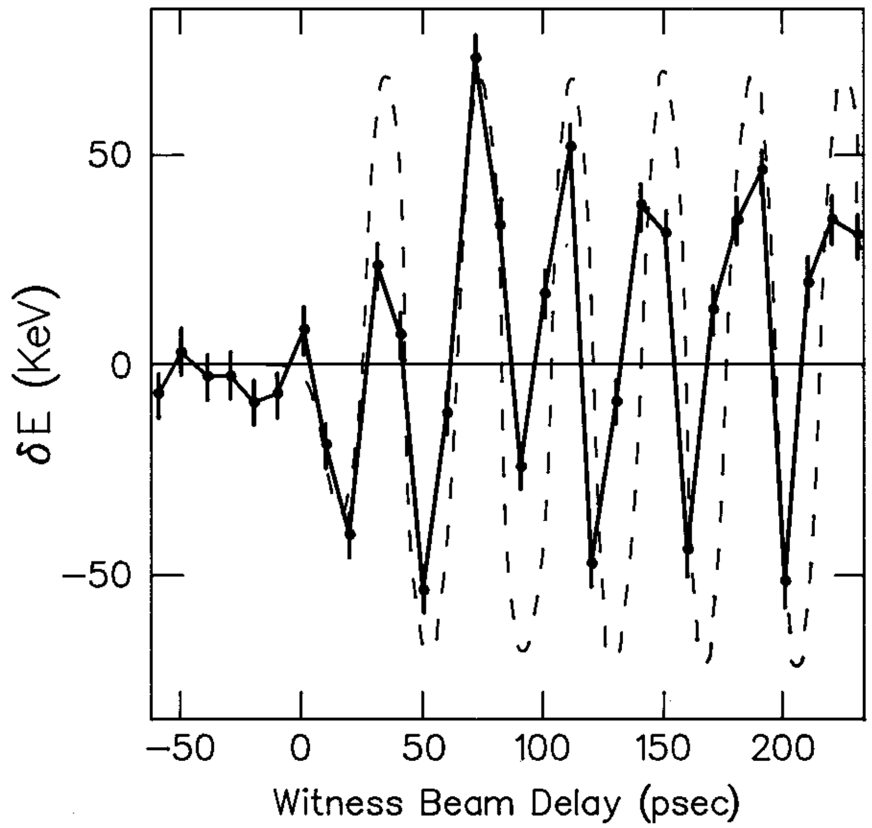


Acceleration of a 'witness beam' by a plasma wakefield at Argonne. The dashed line shows the predictions of a simple model for the experimental conditions – driver beam charge of 2.1 nC, a 33 cm long plasma, plasma electron density of 2.3 x 10^{13} cm^{-3}. The corresponding accelerating gradient is about 1 MeV/m.

MeV electron beam from an L-band linac (operated by the Chemistry Division) strikes a small carbon target. The spectrometer system transports the full energy beam, which excites the wakefields, through one path while a low intensity 15 MeV beam follows another. The two beams are recombined and passed through a test section. The 15 MeV 'witness' beam can be placed at a variable distance behind the intense driving beam by means of a trombone section. The energy and angle of both beams emerging from the test cavity or plasma are analyzed by a spectrometer. Several test cavity sections were looked at, and in a second series of measurements acceleration of the witness beam by a plasma wakefield was observed.

A workshop to discuss these results and to plan future experiments with the facility was held at Argonne on April 6-7. W. Gai reported on current status and on the initial measurements of wakefields in structures. Three iris-loaded cavities were tested at Argonne, and the results for both longitudinal and transverse wakes are in reasonable agreement with expectations.

J. Rosenzweig presented the data from the plasma wakefield experiment. The peak gradient observed was 1.6 MeV/m. Transverse deflections were also observed when the two beams were offset. With the shorter beam pulses available from the recently commissioned pulse compression system, gradients of 10 MeV/m should be attainable.

P. Schoessow talked about possible future experiments. Wakefields in dielectric-loaded and elliptical cavities will be measured as part of the experimental program. To measure impedances in conventional accelerator components with the facility, an improved sensitivity is needed.

In an invited overview talk, C. Joshi discussed some of the advanced accelerator work at UCLA, a new technique for generating ultrashort optical pulses by Compton scattering of a CO_2 laser pulse from an electron bunch. He also discussed plasma wiggler and plasma lens research.

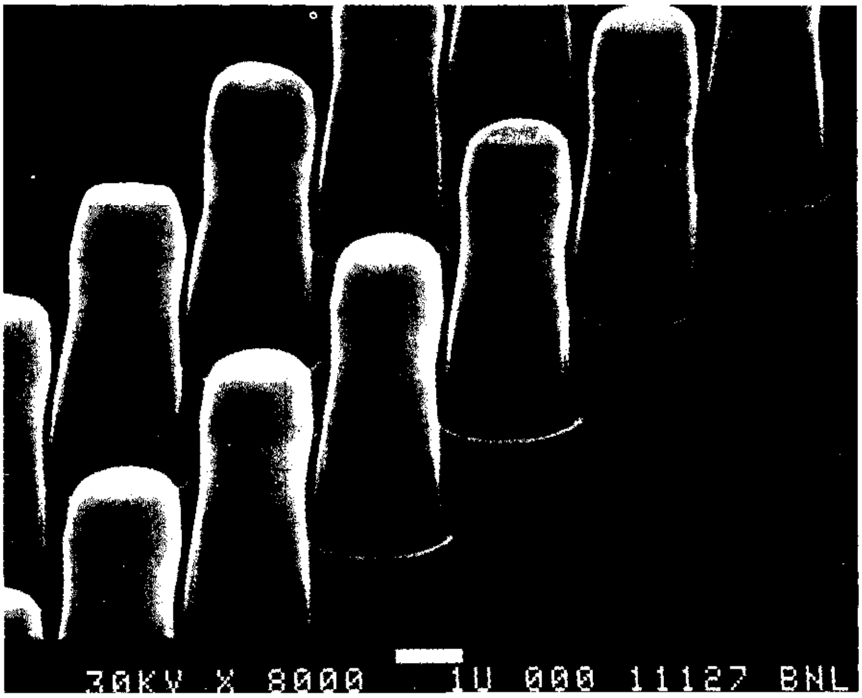
Y. Yan (Los Alamos) presented his work on the counter streaming beam plasma wakefield accelerator. A. Ruggiero (Brookhaven) discussed impedances and wakes in conventional storage ring components, and R. Keinigs (Los Alamos) described his calculations of wakefields in dielectric structures. P. Chen (Stanford) talked about his work on the plasma lens as a final focus device for linear colliders.

The participants then split up into two working groups: structures, impedances, and single-beam experiments, chaired by Ruggiero, and plasma accelerators and lenses, headed by T. Katsouleas (UCLA).

The plasma group discussed plans for an experiment on a focusing plasma lens using the facility. J. Norem (Argonne) presented various possibilities. It appears that the plasma density required for good luminosity enhancement at the Stanford Linear Collider may result in severe background problems. This may not be a problem for future linear colliders where effects of the lens could be accommodated in the design of the detector.

Anybody interested in using the facility or in collaborating with the Argonne group on specific experiments was invited to contact J. Simpson at Argonne.

BROOKHAVEN
Gratings for laser linac



Scanning electron microscope image of an etched 'colonnade' grating of the type used at Brookhaven. The intense electric field generated by high power laser will accelerate an electron beam skimming across the grating.

After much work by Bob Palmer and co-workers at Brookhaven to study laser-driven grating accelerators, an experiment to test this concept, a bold attempt to provide a new technique to accelerate particle beams to ultra-high energies, is being assembled at the Accelerator Test Facility now under construction at Brookhaven.

When the experiment is ready in 1990, a narrow (low emittance) electron beam, accelerated to 50 MeV by a conventional linac, will skim a few microns above a grating irradiated by a high-power, picosecond-pulse CO_2 laser. The intense electric field generated in the vicinity of the grating will further accelerate the electrons, which will then pass through a spectrometer for analysis.

At first, it was thought that Lawson's criterion would prevent 'grating accelerators' from accelerating relativistic particles, but Palmer has shown that for appropriate grating geometries and orientations of the laser and electron beams, accelerating gradients of several GeV/m can be achieved.

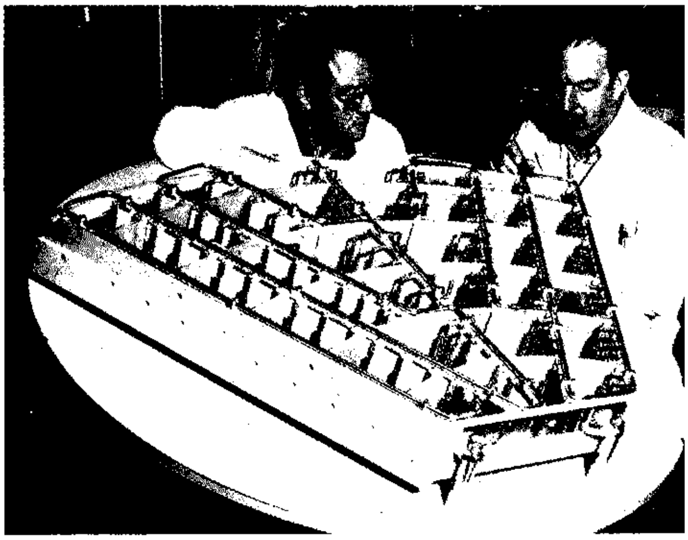
Brookhaven physicist Rick Fernow has studied several types of grating structure, using computer simulations of the interaction between the field near the grating and the electron beam. He found that acceptable structures with appropriate radiation patterns could be devised by varying the size and location of the grating sub-units by a few percent from the mean value. The periodicity of the grating is determined by the laser's wavelength of 10.6 microns. Fernow's calculations thus imply that the dimensions of the grating sub-units must be defined with sub-micron accuracy, otherwise energy from the laser will not couple efficiently to the electron beam. One kind of grating being considered is the 'colonnade' – a double row of truncated cylinders. The electron beam would travel between the rows, near the top plane of the cylinders.

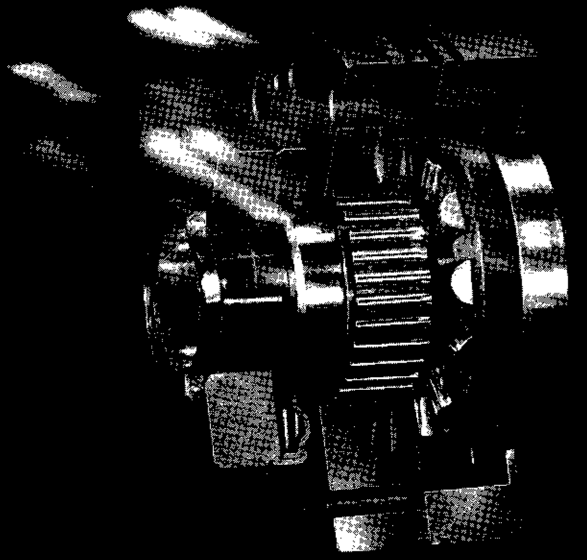
John Warren, a materials scientist in Brookhaven's Instrumentation Division, has made a few of these gratings by plasma-etching patterns defined by contact lithography. Most of the production methods for these microstructures are being used in the semiconductor industry, but dimensional requirements in this case are even more stringent. The gratings must be quite conductive to reduce resistive losses, resistant to damage from the laser and very smooth, to minimize field emission problems. Microfabrication is only the first step in the process. The grating must be precisely measured using such tools as scanning electron microscopy or scanning tunneling microscopy. Methods must also be devised to fine-tune individual sections, using laser-induced chemical vapour deposition of a few monolayers of material exactly where required.

Although the problems are formidable, much progress has already been made. Completed grating sections of a few millimetres should be ready in another year, sufficient to test the grating accelerator concept.

Rare kaon decays

In his pioneer investigations of the weak nuclear interaction, Enrico Fermi made the first attempts to describe the W particle – the carrier of the beta decay force, finally





discovered at CERN in 1983 – by looking at rare beta decays.

Half a century later, at Brookhaven, physicists are using the same techniques to look for another new area of physics. They are looking for rare decays of kaons, forbidden by today's 'Standard Model' but which might be mediated by additional intermediate bosons, a thousand times heavier than the W and Z carriers of the weak nuclear force.

Releasing a lot of decay energy, the kaon is an excellent testbed for these searches. With about a microamp of proton current at 24.5 and 29 GeV, well above the kaon production threshold, the Brookhaven Alternating Gradient Synchrotron produces lots of kaons, and with energies in the laboratory of about 5 GeV they are travelling slowly enough to give lots of decays. Many positively-charged kaons are brought to rest.

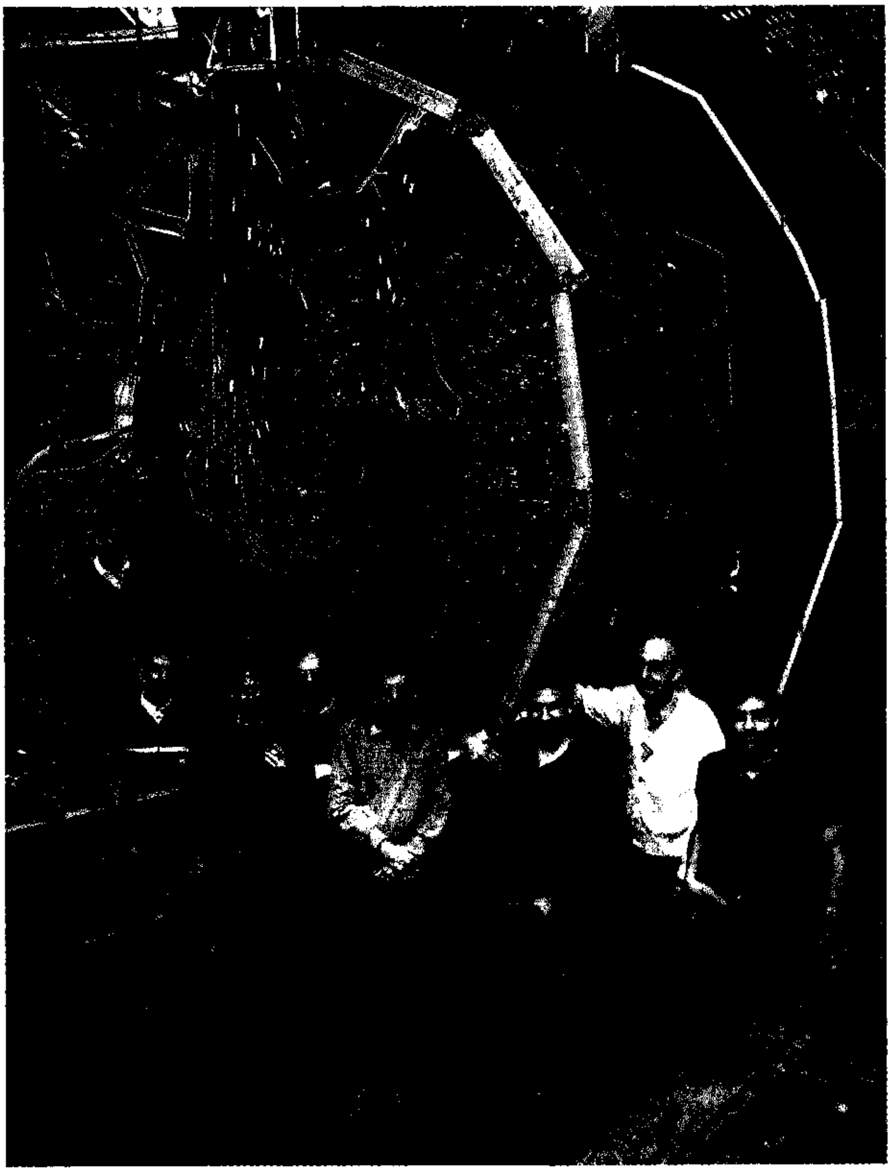
Four kaon decay searches are underway, between them looking for violations of several sacrosanct selection rules. Experiment 777 (Brookhaven/SIN (Switzerland)/Washington/Yale) is looking for the decay of a positively charged kaon into a positively charged pion, a muon and an electron, while E780 (Brookhaven/Yale) and E791 (UCLA/Los Alamos/Pennsylvania/Stanford/Temple/William and Mary) are interested in decays of the long-lived neutral kaon into a muon plus an electron, or into an electron-positron pair. E787 (cover picture, October 1987 issue) searches for positive kaons decaying into positive pions together with 'invisible' particles, such as neutrinos. A neutrino-antineutrino pair is expected in a few decays in every ten billion.

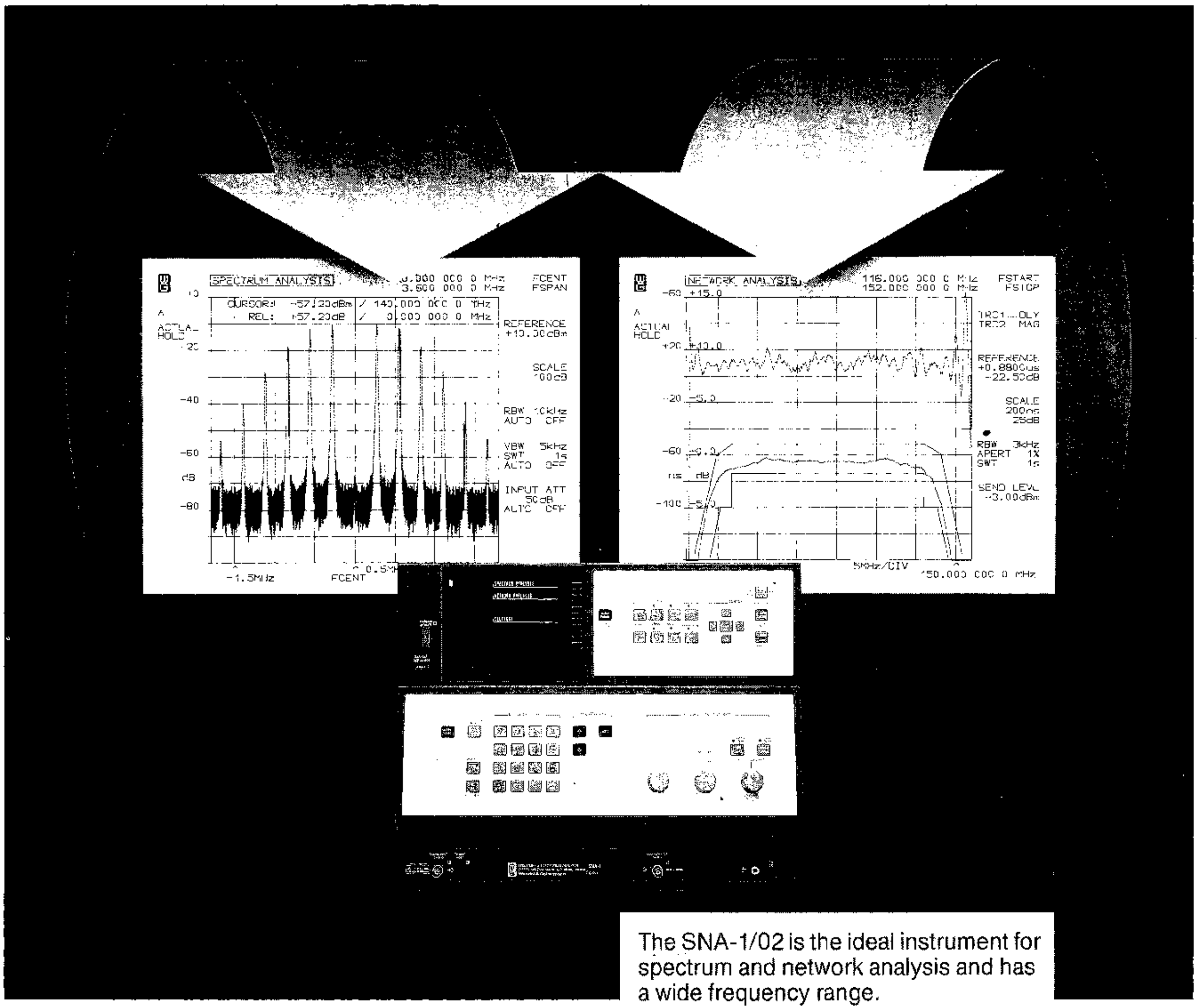
So far E777 has established that the pion/muon/electron combination is ruled out to the level of less than one decay per billion, implying that any particle mediating such a decay would have to be heavier than 15 TeV (15,000 GeV)! This year's run should push the limit back to one decay or less per ten billion, and another run is planned for next spring.

A fire at the start of the 1986-87 run set back E780 seriously. Recovering with makeshift instrumentation, the experiment was able to establish limits for the muon/electron (less than 6.7 x 10^{-9}) and electron/positron (less than 4.5 x 10^{-9}) decays. (The latter decay is not absolutely forbidden, expected through delicate (unitarity) effects at a rate of about 2.5 x 10^{-12}).

With all equipment in order, E780 hopes to collect ten times more data this year, which, if no

The detector of the E787 experiment at Brookhaven, one of a series looking for new decays of neutral kaons. The central cables read out photomultiplier signals from the active scintillating fibre target, where the incoming kaons stop and decay.

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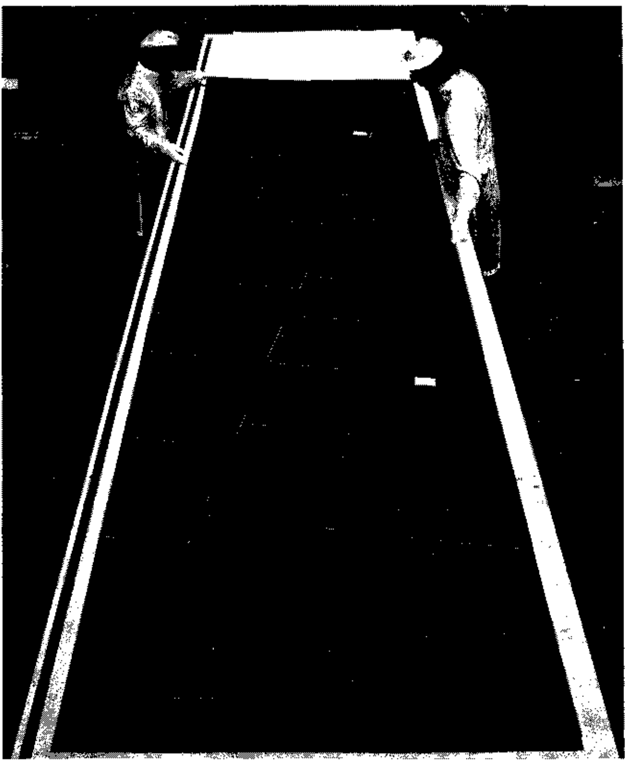


events are seen, will push the mass limit for any new carrier particle up to 100 TeV. Next year the plan is to look for the decay of the long-lived neutral kaon into a neutral pion plus an electron-positron pair, using a different detector configuration.

E777 is a 'signal' experiment with little background to obscure the three-particle signature, so that sensitivity is limited only by the size of the data sample. However E780 physicists consider their muon/electron search to be limited by background, more important at higher intensities, so they have deliberately stayed within the limits set by the beam or their data handling capacity.

With the Yale/Brookhaven E780 group going on to fresh physics after this year, Brookhaven is supporting E791 in an ultimate search for the muon/electron signal. The E791 design is not radically different to E780 but can handle more intense kaon beams. The study is running with a substantial part of its full configuration and should have results this year. It is expected to continue until Spring 1990.

The key to E787's search for positive kaon decays into positive pions and 'nothing' to a level approaching one decay per ten billion is the ability to reject kaons decaying into positive muons and neutrinos by clear separation of stopped muons and pions. This requires rapid measurement of decay particle momentum, range and energy, with full 'seamless' angular coverage of the decay region.

The start of the present run was concerned with fine tuning and triggering, with first data following later to probe down to one decay per billion. To attain the required sensitivity, the study will run for another two years.

Even if this ambitious programme of rare decay searches fails to find new physics, it will have demonstrated that our present picture of physics rests on a solid foundation. The carrier particle masses indirectly explored in these studies are well beyond the reach of direct production at any present accelerator.

The Fifteen Foot Bubble Chamber in its last run at Fermilab.

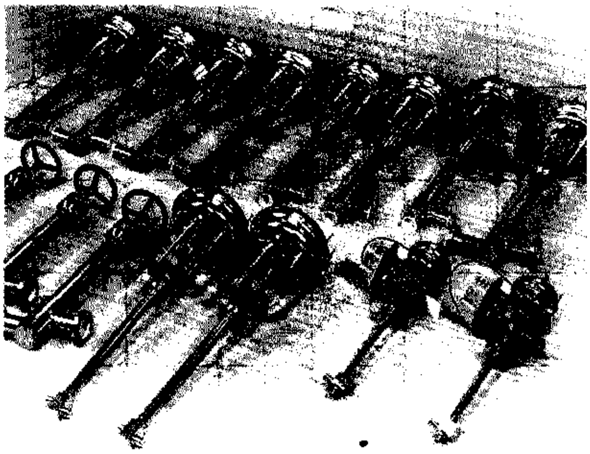
FERMILAB
Fifteen Foot last step

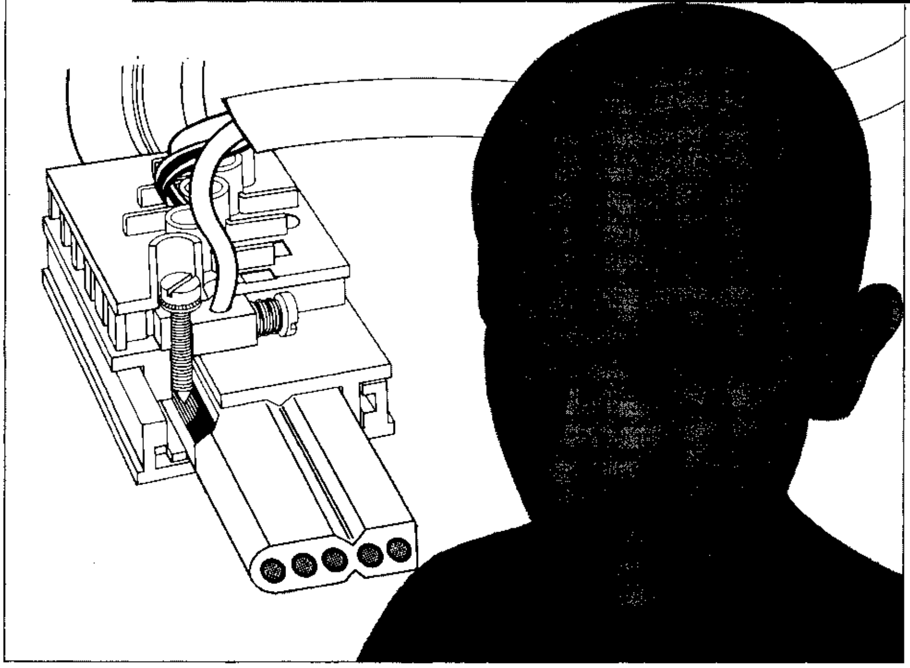
Fermilab's 15 Foot Bubble Chamber recently completed its last physics run and to mark the occasion a '15 Foot Fest' on 8 April highlighted the 19 year and 2,991,103 picture career of the huge detector.

Long the workhorse of particle physics experiments, the bubble chamber technique was developed by Donald A. Glaser in 1952 at the University of Michigan. Glaser's original bubble chamber was a transparent glass device only a few inches across. He knew that if he placed a pure liquid in a sealed container, he could superheat the liquid beyond its normal boiling point. Once superheated, boiling could be triggered by dropping something in.

Glaser calculated that the energy deposited by charged particles in the superheated liquid was enough to trigger boiling along the trajectory of the particle and these events could be observed and recorded photographically.

Shortly after this first design proved successful, bubble chambers were constructed from metal-glass combinations with photography via optical glass windows.





Comparison of baryon magnetic moment measurements with theoretical (broken SU(6)) predictions. The units are nuclear magnetons.

	experiment	broken SU(6)
p	2.794	input
n	-1.913	input
Λ	-0.613±0.005	input
Σ^+	2.38±0.02 2.479±0.025	2.67
Σ^0	?	0.79
Σ^-	-1.166±0.017	-1.09
$\Sigma \rightarrow \Lambda$	-1.59±0.09	-1.63
Ξ^0	-1.250±0.014	-1.44
Ξ^-	-0.69±0.04	-0.49
Ω^-	?	-1.84

Subsequently a Berkeley group headed by Luis Alvarez extended chamber diameters from inches to 6 feet.

The Fermilab 15 Foot Chamber was the last in a long and distinguished line of 'visual' detectors. In Europe, the French-built Gargamelle bubble chamber installed at CERN in 1969 probed the nucleus with neutrino beams, going on in 1973 to see for the first time the neutral currents of the weak interaction. The French bubble chamber tradition continued with Mirabelle, designed at Saclay for use at the Soviet 70 GeV accelerator at Serpukhov.

In the United States, Tom Fields and his Northwestern University Group developed the first bubble chamber in a superconducting magnet at Argonne, leading the way for Gale Pewitt and his colleagues who developed the 12 Foot Bubble Chamber at Argonne. The largest superconducting magnet chamber was BEBC at CERN, closed in 1985.

Fermilab's 15 Foot Chamber was the last large cryogenic bubble chamber to operate anywhere in the world. It recorded its first tracks on September 29, 1973 for Fermilab Experiment 28 and its last on February 1, 1988 for Experiment 632. In all, there were 17 approved and completed experiments performed with the chamber, covering a wide variety of physics topics.

Omega minus magnetic moment

Fermilab Experiment 756 (a collaboration of Fermilab, Michigan, Minnesota, and Rutgers) is looking at the magnetic properties of the omega minus, the particle whose dramatic discovery at Brookhaven in 1963 confirmed the SU3/quark classification of strongly interacting particles.

Measurements of magnetic moments provide an additional insight into the quark structure of particles. The most simple quark model baryon magnetic moment predictions are about ten per cent off the experiment values, (see table) and exact explanation of these differences provide a tough testing ground for refined models.

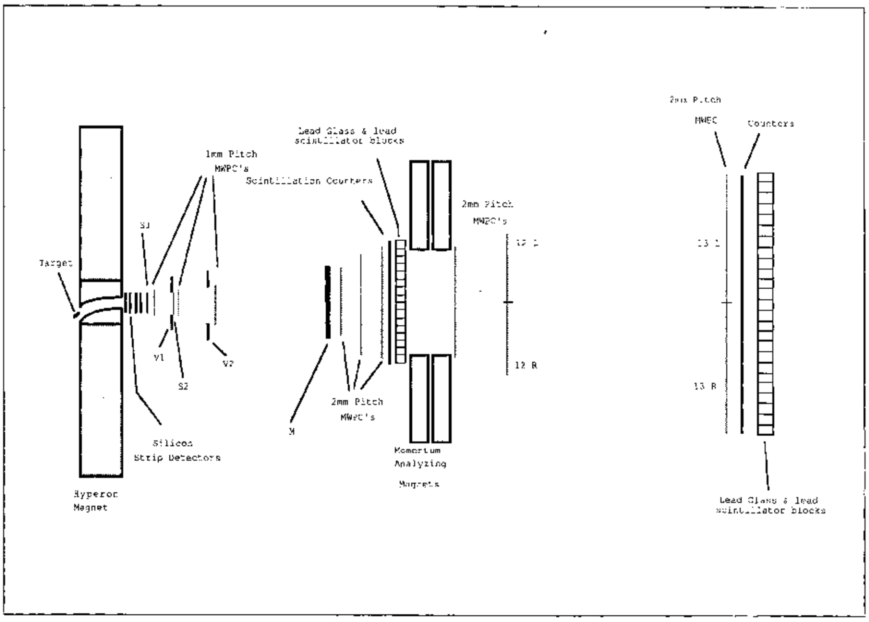
The omega minus is a simple and unique system made up of three identical strange quarks with their spins aligned in parallel.

Fermilab experiments have contributed significantly in determining the magnetic moments of the hyperons. Beginning with Experiment 8's discovery that lambda particles produced by protons were polarized (spin aligned), a series of studies subsequently found that other hyperons – 'cascades' (xis) and sigmas – were similarly polarized. At Fermilab energies, hyperons are copiously produced and typically travel several metres before they decay (due to the relativistic time dilatation effect), so that their magnetic moments can be measured by precessing their spin in a magnetic field.

The first goal for E-756 in the 1987-8 fixed-target run (using an 800 GeV primary proton beam) was to produce polarized omega minuses. Much effort went into the design of the incoming beam system to ensure that equal and opposite targeting angles could be achieved to better than 0.1 mrad, vital for systematic cancellation in the polarization measurement.

Downstream of the production target, a curved charged hyperon

Schematic of the 67m long and 1.3m wide Fermilab hyperon beam spectrometer. Most of the space between detectors is filled with helium bags. M is a multiplicity counter. The last two MWPCs (multiwire proportional chambers) are electronically divided into left and right halves for triggering purposes.



channel magnetically selected the momentum of the negatively-charged secondary particles. The magnetic field was also used to precess the hyperon spins.

A downstream spectrometer, consisting of six 2 mm spacing wire chambers and three 1 mm pitch chambers with 8 planes of silicon strip detectors and scintillators for triggering, picked up hyperon decay products. Photons from the decays were detected by two electromagnetic calorimeters made up of lead glass and lead-scintillator blocks.

Data taking began last August, and by the end of September a sample of more than 20,000 omega minuses showed that the polarization of the particle was too small for a precise measurement of its magnetic moment in the amount of time allotted for the run.

The targeting scheme was quickly changed to give a high energy polarized neutral hyperon beam from primary protons incident at 2 mrad. After collimation, the polarized neutral beam was directed straight at the charged hyperon production target. It took approximately one month to design and install this second stage of the experiment and the data accumulated showed that the technique of passing the spin orientation from the secondary neutral beam to the tertiary charged hyperon beam worked well.

The data will yield high precision measurements of the cascade minus and omega minus polarizations, magnetic moments, decay parameters, and lifetimes. In a preliminary analysis from the first targeting scheme, about 70 million three-track triggers will provide some 10 million cascades and 100,000 omega minuses. Preliminary analysis of the cascade minus polarization is in good agreement with the results recorded by Experiment 620 using 400 GeV beams. Full analysis should give the magnetic moment of the cascade minus to a precision of 1%.

The quality of the data collected in the spin transfer method is similarly high. Approximately 1.5 million cascade minuses and 22,000 omega minuses were produced by the polarized neutral beam, and preliminary analysis shows the particles to be polarized. This will give an initial value for the omega minus magnetic moment. The experiment has been approved to run again, with the goal of measuring the omega minus magnetic moment to higher precision.

CONFERENCE
Neutrino mass

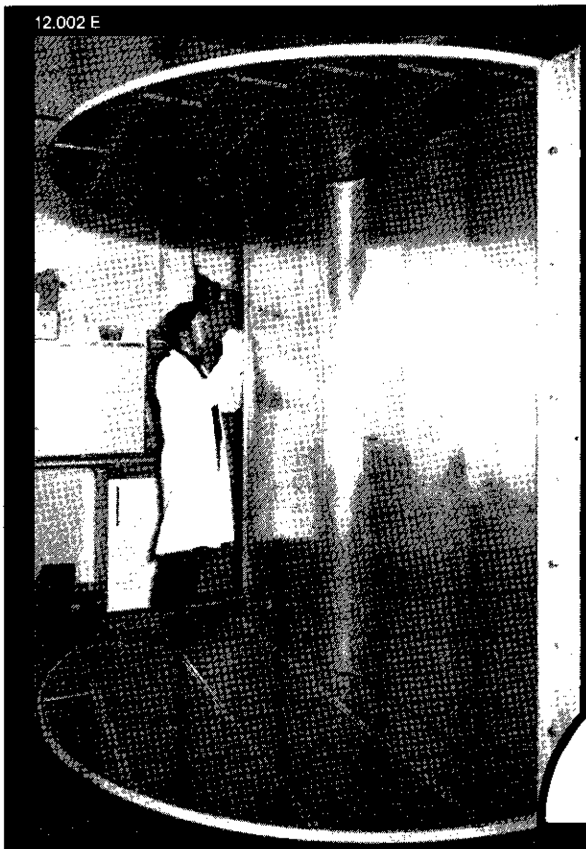
Introduced by Pauli more than fifty years ago as the energy-stealing culprit in nuclear beta decay, the neutrino is the joker in the particle physics pack. Pauli wagered that nobody would ever be able to see it, but lost the bet in Reines' and Cowan's epic feat of detection in the 1950s.

More than thirty years after the first sighting of a neutrino, nobody knows for sure what its mass is. Some cling to the idea of a massless electron-type neutrino (the lightest variant of the particle), others hold out for a small vestigial mass, which makes for some interesting physics.

Interest focused in March on a small international symposium on neutrino mass held at Tokyo University's Hongo campus and organized by Tokyo's Institute for Nuclear Study (Organizing Committee Chairman Sadayuki Kato).

After an introduction by neutrino pioneer Fred Reines of Irvine, the first day of the meeting was given over to reports on precision measurements of the electron-type

12.002 E



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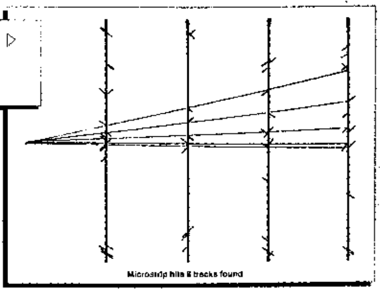

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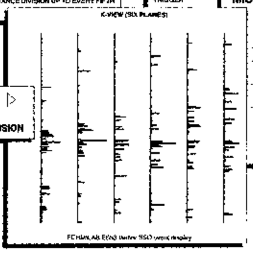

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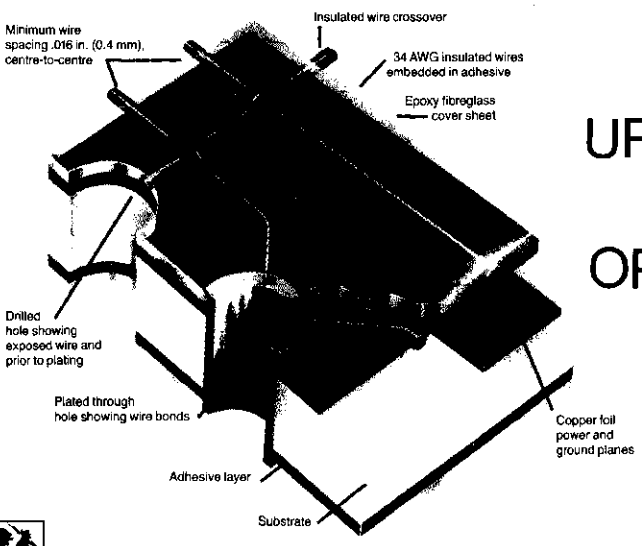

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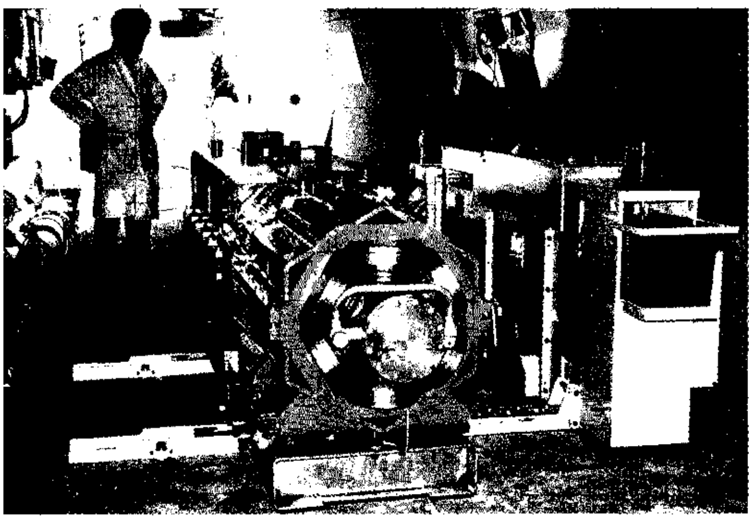


(anti)neutrino mass in the beta decay of tritium. ITEP Moscow still hold to 26 electron volts (plus or minus about 20 per cent), while Tokyo INS prefer less than 28 eV, SIN Switzerland less than 18 eV, Los Alamos less than 27 eV, and Munich say 15 (+52-15) eV. Further improvements in accuracy are eagerly awaited.

One neutrino question mark was removed last year with the discovery of double beta decay, where the daughter nucleus is two Periodic Table slots higher than its parent, following emission of two neutrinos (see January/February issue, page 32). Several speakers reviewed progress. A neutrino mass upper limit of about one electron volt coming from double beta decay data is not yet watertight because of insufficient knowledge of detailed mechanisms.

The Japanese Kamiokande underground experiment was able to report its first results on solar neutrinos with energies above 7.5 MeV (see also May issue, page 25), where the signal is a fraction of what is expected from confident predictions of solar neutrino fluxes. This confirms the long-standing results of Ray Davis and underlines the 'solar neutrino puzzle'.

New studies are in the pipeline, including a joint US/USSR effort at the Soviet Baksan neutrino observatory to use gallium, better suited to solar neutrino detection, and two experiments at the Italian Gran Sasso underground Laboratory (see May 1987 issue, page 26).

Yoshio Yamaguchi of Tokai closed the meeting, putting the new results into the chequered context of neutrino history.

From Sadayuki Kato

At the recent International Symposium of Neutrino Mass and Related Topics held at Tokyo's Institute for Nuclear Study, neutrino mass specialists W. Kundig (Zurich) and T. Ohshima (INS Tokyo) compare notes.

NEUTRINOS
Underwater detector

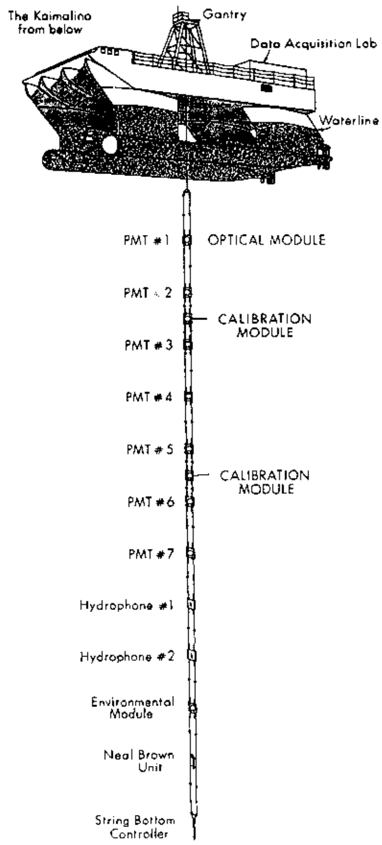
The successes in capturing neutrinos from last year's supernova underlined the usefulness of large underground detectors for this sort of physics, and ambitious new projects are now in the pipeline.

Meanwhile another approach to cosmic neutrino detection, carefully prepared during the past decade, has now taken its first experimental steps. DUMAND – Deep Underwater Muon and Neutrino Detector – aims to use the ocean as the active medium, tracking particles with arrays of photomultipliers picking up the tiny nanosecond flashes of blue Cherenkov light emitted by cosmic particles as they pass through seawater.

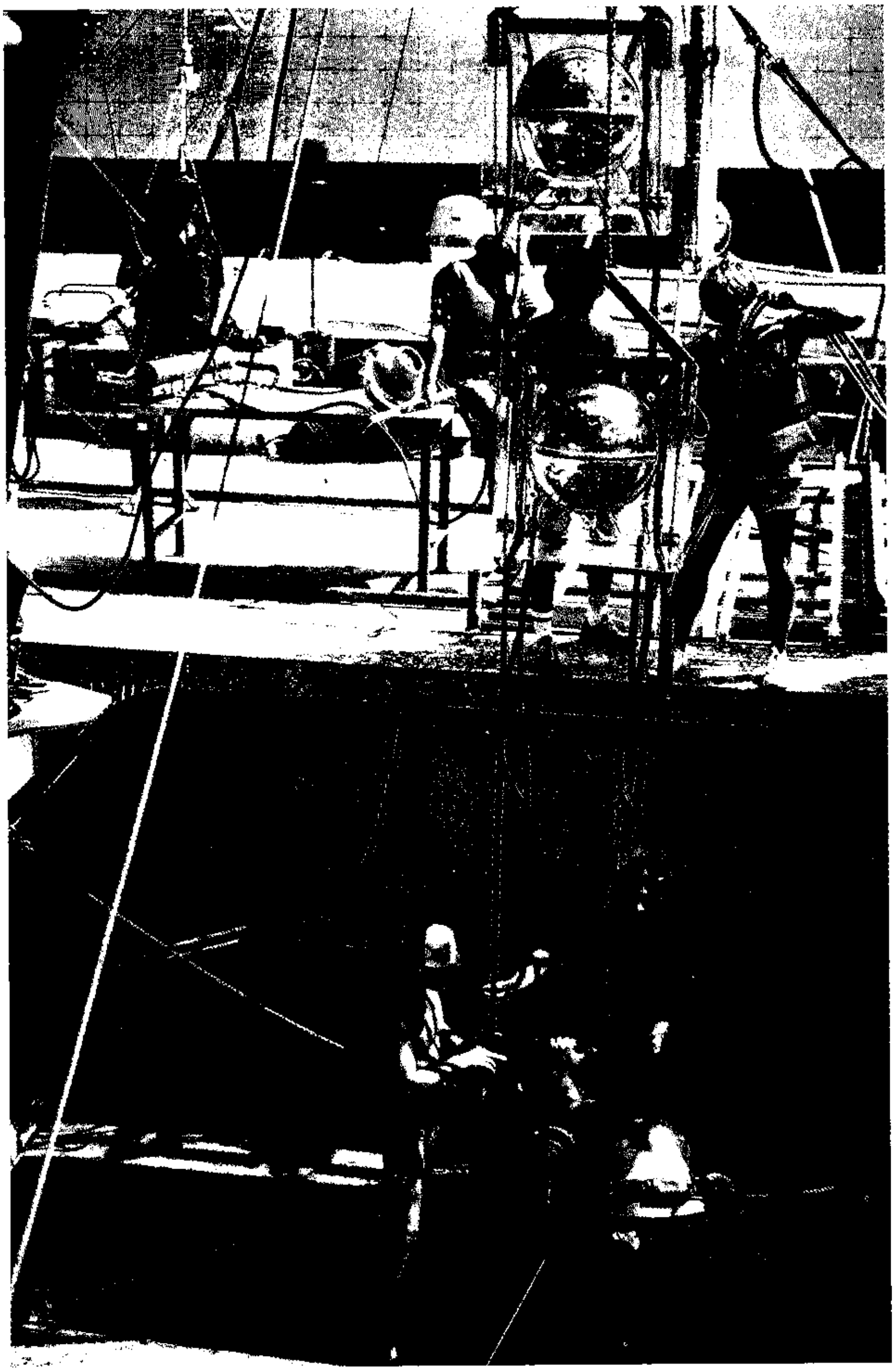
Based in Hawaii, the US/Japan/West Germany/Switzerland DUMAND collaboration has successfully deployed its 'Stage I' detector, consisting of a 60 metre string of seven photomultipliers, at depths of up to 4 kilometres in the Pacific west of Hawaii.

About 24,000 cosmic ray muons were recorded, the event rate displaying how the detector string is sensitive out to about 17 metres. In the final detector, neutrinos would be picked up through secondary muons released after collision with a seawater nucleon.

Stage II DUMAND envisages a 20,000 square metre array of nine 330-metre-deep strings each containing 24 sensitive modules. A 4.8 km-deep basin west of Hawaii provides enough depth to screen out most cosmic ray muons (provided the zenith quadrant is excluded), with clear water to ensure good light transmission and minimal biological activity to disturb



◀ *Sketch of the 60 metre-long Stage I DUMAND detector with its array of seven photomultipliers.*



▼ *Deployment of the photosensitive detector module for Stage I of the DUMAND – Deep Underwater Muon and Neutrino Detector – in the Pacific Ocean west of Hawaii.*

operation.

DUMAND uses 16-inch Hamamatsu phototubes with hemispherical cathodes, enclosed in oceanographic research glass spheres capable of resisting the accumulated pressure of 100 atmospheres per kilometre of depth. Data is read out through optical fibres.

In addition to cosmic ray detection, the highly sensitive photomultipliers discovered a new form of deep ocean bioluminescence, subsequently confirmed by Soviet researchers.

For the full detector, formidable challenges lie ahead, including the development of deploying machinery, detector-to-shore links, and methods for accurate string interlocation. However solutions for all these problems are known, and will be presented in the Stage II proposal.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ν_μ

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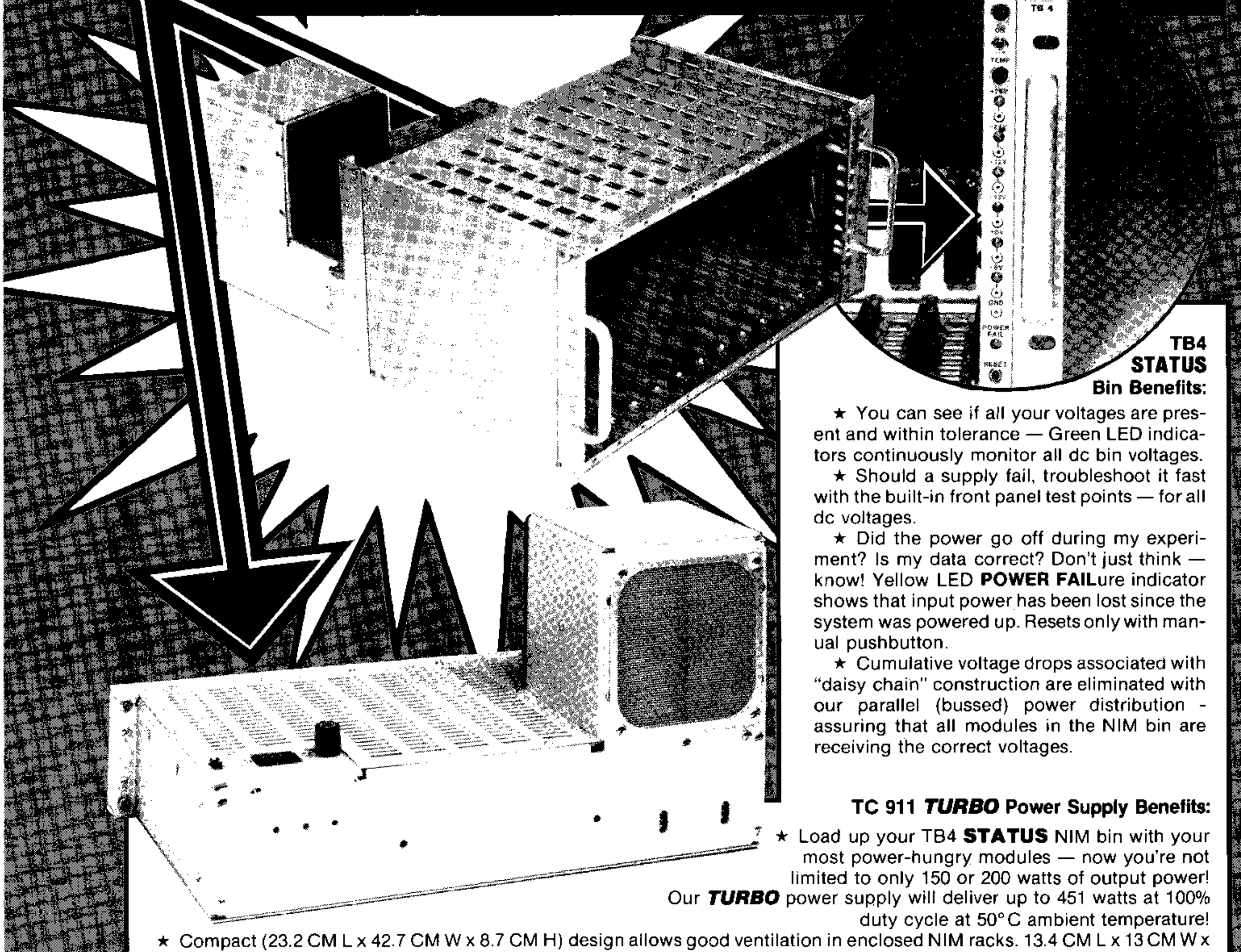

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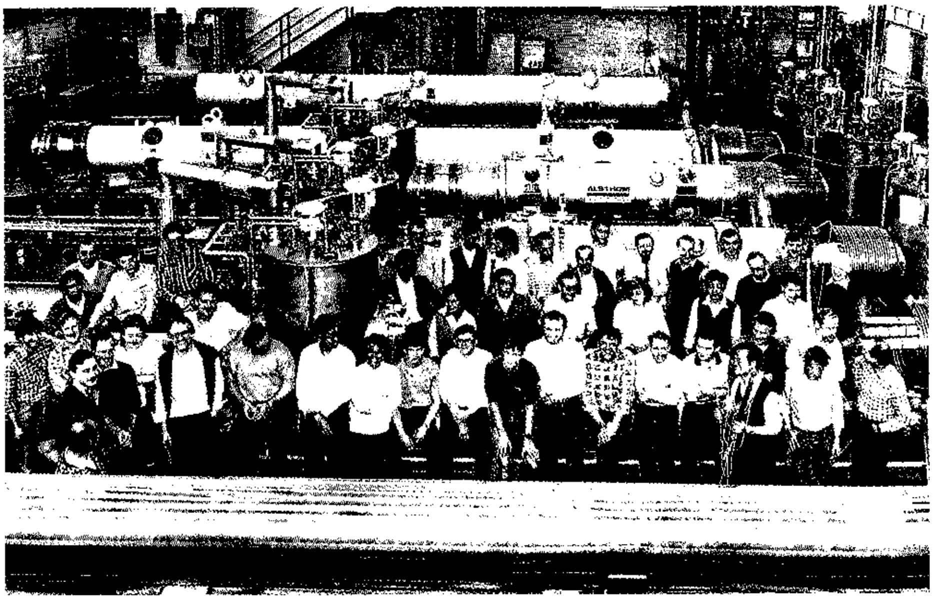
People and things

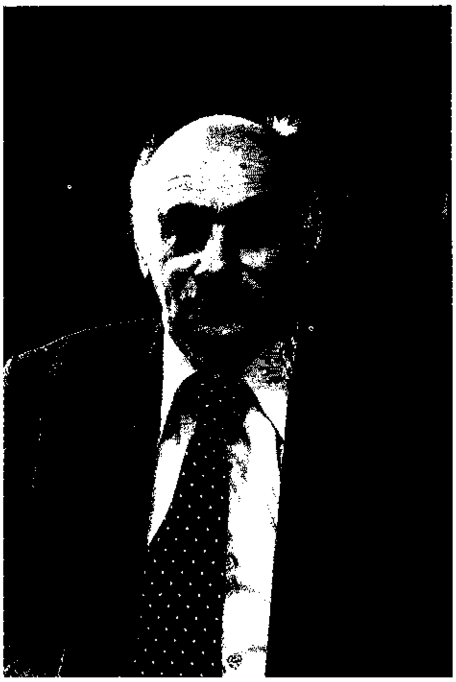


The team testing the superconducting magnets for the proton ring at the HERA electron-proton collider being built at DESY. At the rear is the first of ten pre-series 9-metre dipoles for the HERA bending magnet consignment supplied by Italian industry. All three 9-metre magnets tested previously were made at DESY and put into cryostats at Brown-Boveri Co. (BBC) Mannheim. Brown-Boveri are making the second consignment of dipoles, and the first pre-series magnet should be ready soon.

On people

The prestigious Max Planck Medal of the German Physical Society goes this year to theorist Valentine Bargmann of Karlsruhe. Hans Gutbrod of GSI Darmstadt and CERN and Reinhard Stock of Frankfurt and CERN receive the Robert Wichard Pohl Prize for their work on nuclear matter at high densities and temperatures, while CERN theorist Andre Neveu is the recipient of the Franco-German Gentner-Kastler prize, awarded in alternate years to French and German researchers. Alfred Petersen received the 1988 'Physik Preis' (see April issue, page 32).

Erich Vogt, Director of the TRIUMF Laboratory in Vancouver, is to receive the 1988 Medal for Achievement in Physics, the leading annual award of the Canadian Association of Physicists. He will also be receiving an honorary Doctor of Science degree from Carleton University in Ottawa this year.



In March, the scientific community of the Joint Institute for Nuclear Research, Dubna, near Moscow, celebrated the 75th birthday of Academician Georgi Nikolaevich Flerov, Director of Dubna's Laboratory for Nuclear Reactions. As well as making landmark contributions to fission physics, he has supervised the construction of Dubna's basic facilities for heavy ion acceleration and the Laboratory's physics discoveries with heavy nuclei.

George Kalmus of the UK Rutherford Appleton Laboratory has been elected Fellow of the Royal Society.

Daniel Froidevaux of Orsay and the UA2 experiment at CERN's proton-antiproton collider has been awarded the Thibaud Prize of the Academie des Sciences et Lettres of Lyon, France, in recognition of his contributions to UA2's achievements. The Prize is awarded every two years, having gone in 1985 to Michel Spiro of Saclay and the UA1 experiment at the CERN collider.

Academician Georgi Nikolaevich Flerov, Director of the Laboratory of Nuclear Reactions at the Joint Institute for Nuclear Research, Dubna, near Moscow, recently celebrated his 75th birthday.

Rodney Cool

Rodney L. Cool died on 16 April. A distinguished career at Brookhaven culminated in his being the Laboratory's Associate Director for High Energy Physics from 1966-70. Subsequently he established an experimental physics group at Rockefeller University. At CERN, where he did research for the last 18 years, he contributed to important studies at the Intersecting Storage Rings, including the CERN/Columbia/Rockefeller collaboration's observation of constituent effects in proton-proton collisions, and later to the UA6 gas jet target experiment at the SPS.

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The Department of Physics of The Pennsylvania State University invites applications for a tenure-track faculty position in theoretical particle physics/field theory. The current research interests of the theory group include gravitation and cosmology, superstring theory and supergravity, and many areas of phenomenology. The department also has a very active experimental high energy physics group. The successful applicant should have a Ph.D. and postdoctoral experience and is expected to teach at both the undergraduate and graduate levels and conduct an active research program. Candidates should submit a letter of application, a curriculum vitae, a brief description of research plans, and the names of at least three references to

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HEP Research Positions
Visiting Faculty at Stony Brook

The State University of New York at Stony Brook has several positions available for work on the DO Detector, which will have its initial running data run at the Fermilab 2 TeV pp Collider in late 1989. The Positions include Research Associate and/or research faculty appointments at levels commensurate with experience. Also available is a visiting faculty position for a term of 1-2 years. Stony Brook is involved in the construction of the central tracking detector and in the development and installation of the liquid argon-uranium absorber calorimetry. The group presently consists of 9 faculty and 9 research staff. Opportunities exist for hardware and software activities in support of both projects.
Applications, including vitae and three letters of reference, should be sent to:

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The Department of Nuclear and Particle Physics has an opening for a position of

RESEARCH ASSOCIATE

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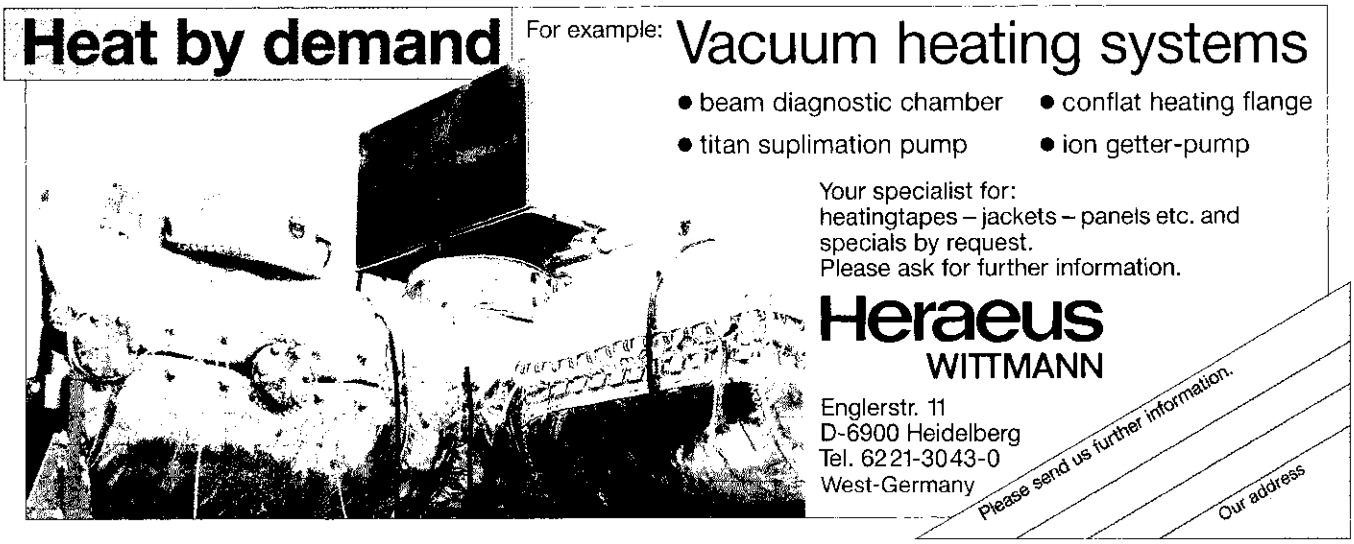

Supercomputer designer Seymour Cray (left) inspects the LEP tunnel at CERN with Robert R. Levy, President of Cray Research's South European Region. At CERN, Cray enthusiastically extolled the potential of gallium arsenide semiconductors for tomorrow's supercomputers, claiming that although the first machines exploiting this fast technology are ten times more powerful than their predecessors, the technology is still in its infancy, at the same state of advancement as silicon was twenty years ago.

(Photo CERN 0354.4.88)

Electronic Mail

The CERN Courier editorial desk can be contacted through electronic mail using the EARN/BITNET communications network. The Editor's address is

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Contributions coming in through electronic mail are edited on the screen, and are now coded for typesetting before being sent to the printer through a telephone modem link, making for increased flexibility.

For subscriptions (free!), changes of address, etc. the contact is

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Distribution in the USA, West Germany, Italy, the UK and China is handled from regional centres (see page III).

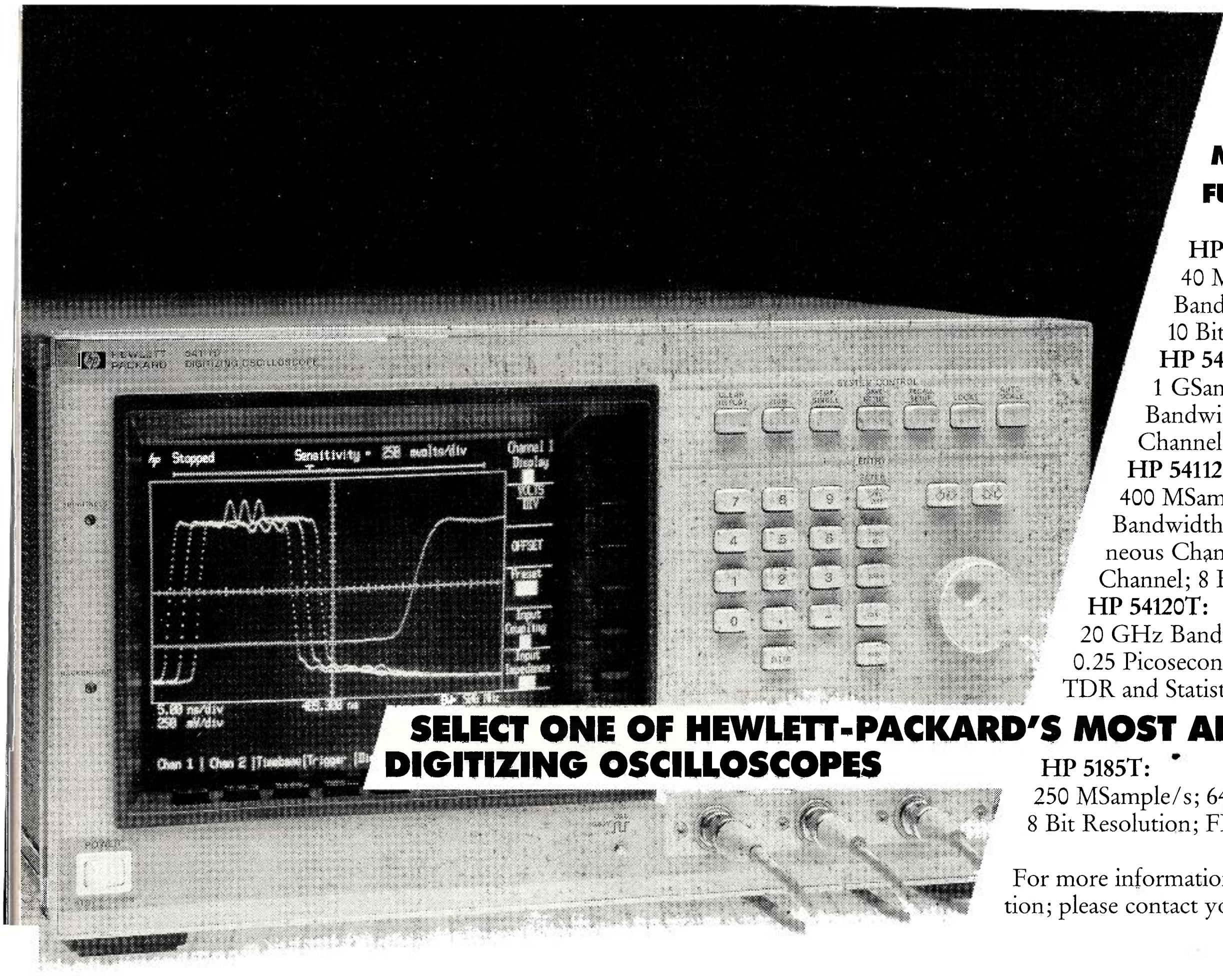
Superconducting offer

A free A2-size wallchart tracing the history of superconductivity and featuring the new high temperature 1:2:3 superconductors is available from Goodfellow Advanced Materials, The Science Park, Cambridge, CB4 4DJ, UK. Goodfellow also supplies a kit of essential materials for those who want to make their own 1:2:3 superconductors.

Meeting

The Rare Decay Symposium at TRIUMF, Vancouver, Canada, from 30 November to 3 December will focus on the rare decays of kaons and B mesons. Participation is limited to 125. Further information from Organizing Committee Chairman J.-M. Poutissou at TRIUMF, 4004 Wesbrook Mall, Vancouver B.C., Canada V6T 2A3, bitnet JMP at TRIUMFCL.

Among the items being air-dropped this month to Nigel Smith, manning single-handed the South Polar Air Shower Experiment (Bartol/Leeds collaboration) throughout the Antarctic winter, is a copy of the April issue of the CERN Courier, where Nigel made the front cover.



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For more information; or a demonstration; please contact your local HP office.

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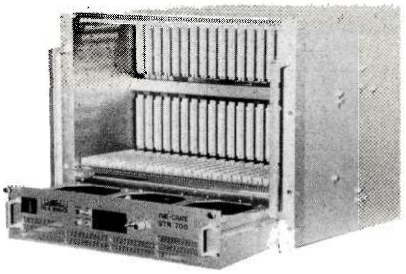

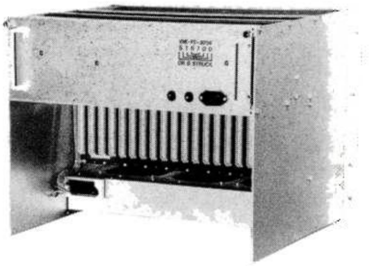

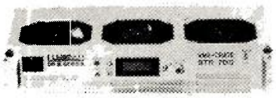

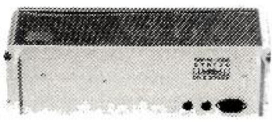

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- * Easy service

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- * Independent bin
- * Rigid mechanics
- * Direct access to J2/P2
- * 19" width, 8U, 400mm depth; incl. power supply tray and fan tray
- * 21 slots
- * 1 VME backplane with up to 21 slots
- * 2 active or passive terminators
- * Power supply 300W
  +5V/60A, +12V/4A, -12V/4A

Option:

- * +5V/100A, +12V/8A, -12V/8A or other high power versions
- * VME I/O backplane
- * Benchtop case 9U

- * Display for all voltages and currents
- * Status and fan fail display
- * Fan control
- * A.C. fail signal output
- * Fan fail and power fail disable power supply
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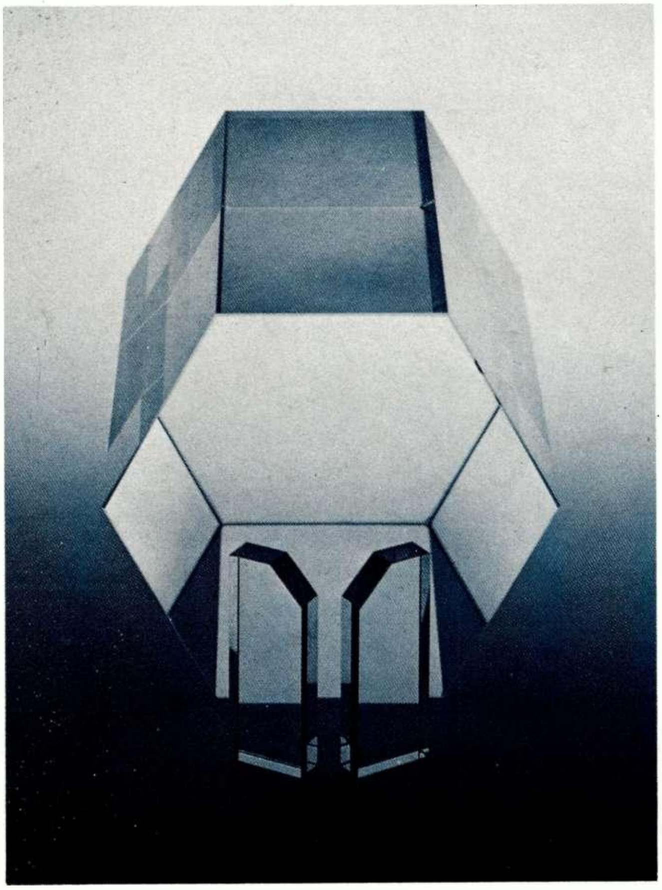


fug
12.50 kV
30.0 mA
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Hochspannungs-Kondensator-Ladegerät
0-12,5 kV 0-30 mA 200 J/s