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1 US Supercollider approved
Initial green light for mammoth new machine

3 Long range physics
How to use the big new machines

Around the Laboratories

4 CERN: Cast your ion first results/Crystal clear/LEP progress/Latest muon results/Many rods make light work
Hints from nuclear beams/New uses for particle detectors/Big machine takes shape/Many years of data/Detector soldiers on

15 COSMIC RAYS: New Soviet installation/International symposium
Giant detector under construction/Conference report

19 DESY: The weak get stronger
Electroweak effects show up well

21 SERPUKHOV: UNK underway
Big Soviet machine takes shape

22 ARGONNE: Accelerator research
Keeping alive a strong tradition

25 European medical accelerator initiative
Plans for multinational project

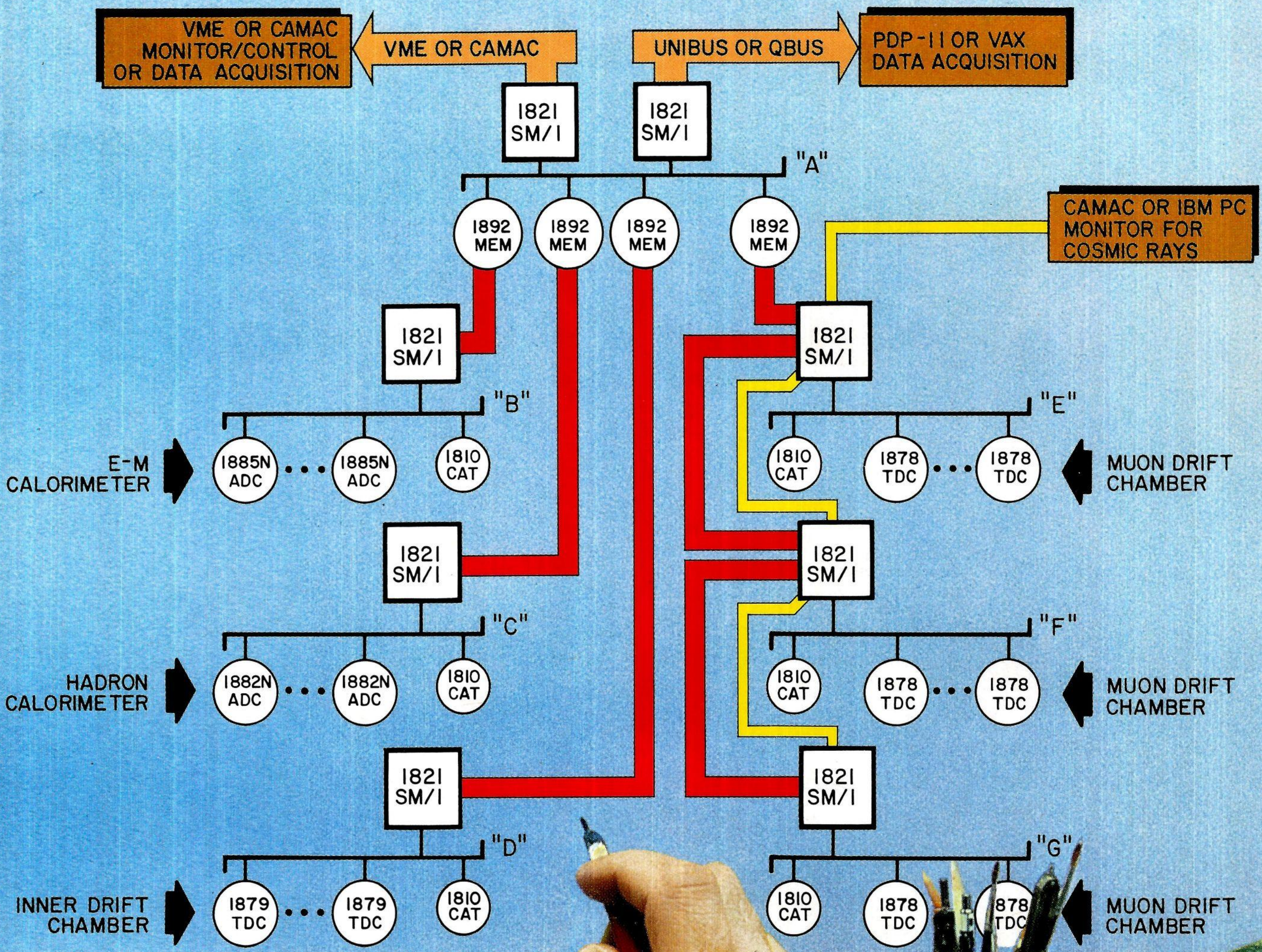
27 DATA COMPILATION: Protocol signed
International agreement

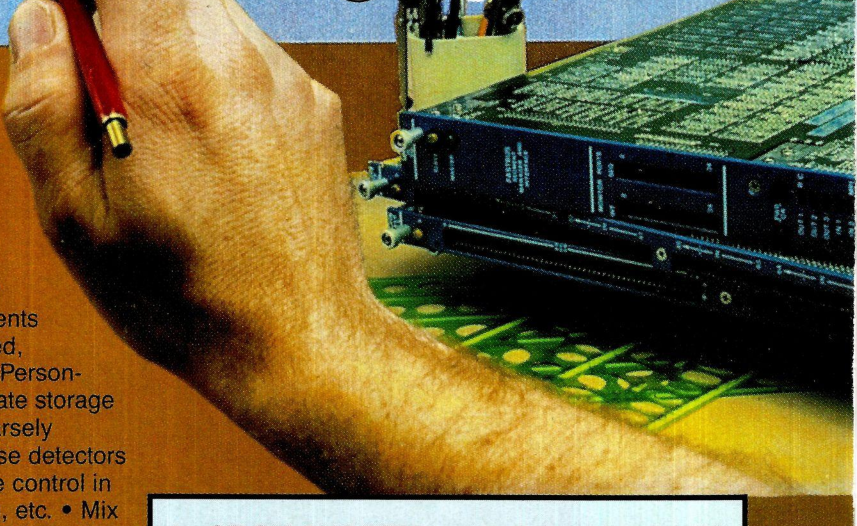
27 CERN makes history
First volume of the early story

31 **People and things**

39 Stanford Collider gets ready

Cover photograph:
The flowering fibre optics readout from the fibre calorimeter measuring transverse electromagnetic energy accompanying muon pairs produced in high energy oxygen-uranium interactions at CERN in the NA38 experiment (Photo Jack Arnold – LPC Clermont-Ferrand).





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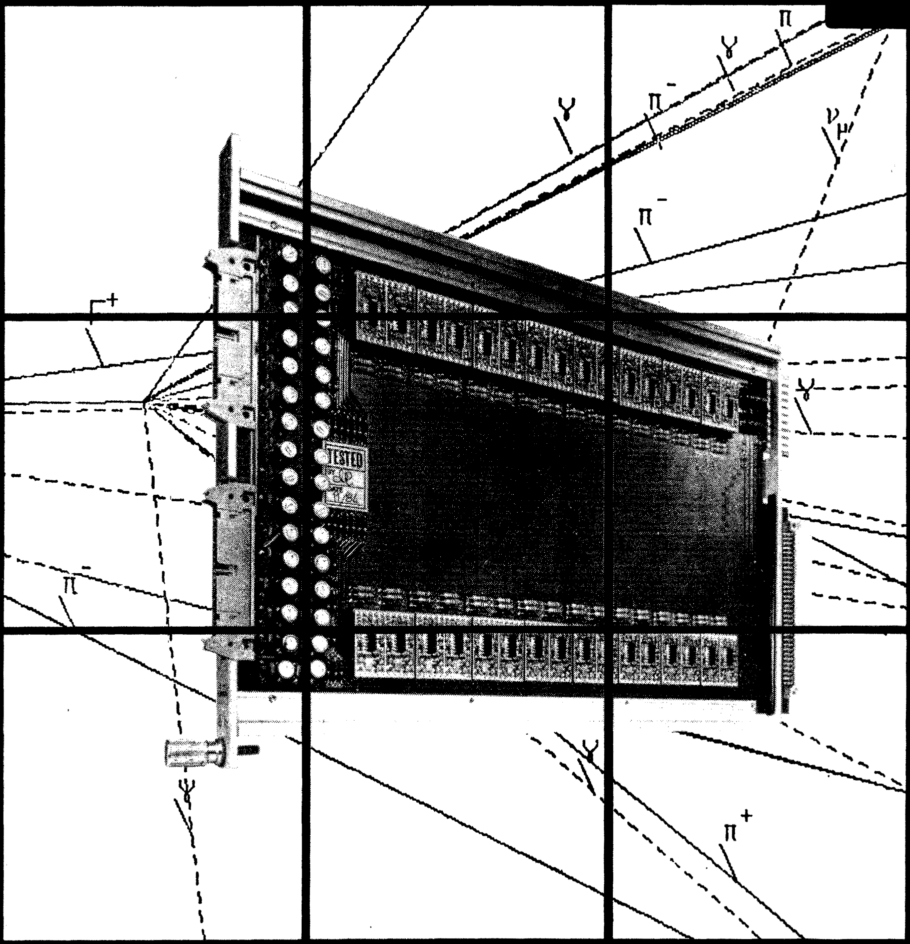
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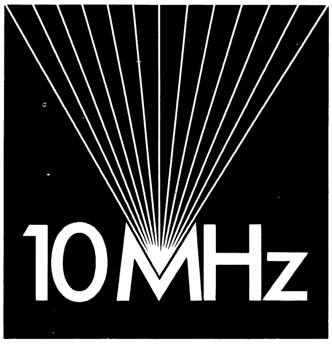
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US Supercollider approved

In a bold move to boost US high energy physics, President Reagan has approved construction of the world's largest particle accelerator, the Superconducting Supercollider, SSC. With the requested start in Financial Year 1988, the Supercollider could be completed in 1996. The actual timetable depends on Congressional approval and actual levels of funding.

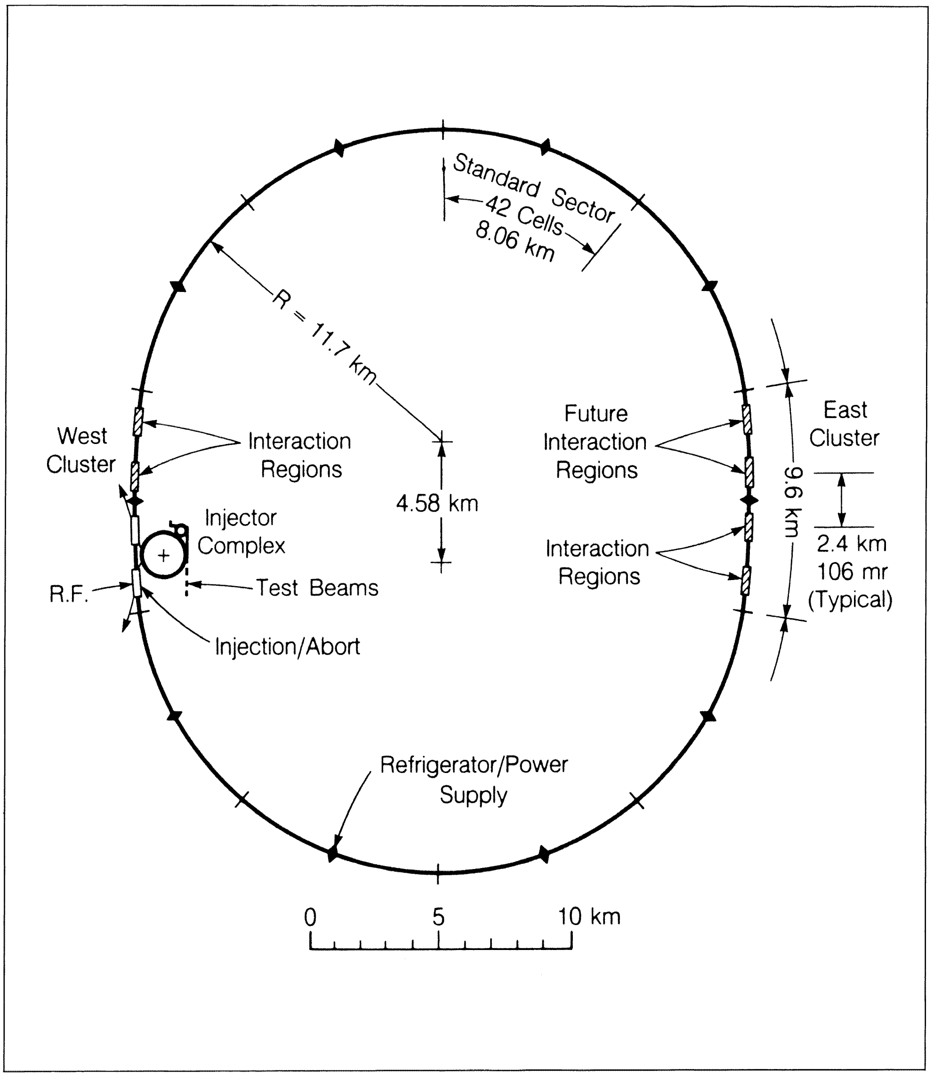
Ideas for this mammoth machine emerged several years ago in the context of thinking on the future of US high energy physics, where confidence had been shaken following the unanticipated success of CERN's proton-antiproton collider scheme.

A specially formed Central Design Group produced a farsighted plan for an 84 kilometre racetrack-shaped ring with a string of 10 000 superconducting magnets in a 3 metre diameter tunnel to contain two contrarotating 20 TeV (20 000 GeV) proton beams. A detailed design report was published last year.

Cost of the project is estimated at $3.2 Gigadollars in 1988 prices, with an additional $1.2 Gigadollars for detectors, computers, research and development work and pre-operations. As yet no decision has been taken for a site, but many states are clamouring for selection.

Another motivation for building the SSC is the conviction that it will reveal new physics. In the summer of 1982, participants at a workshop organized by the American Physical Society's Division of Particles and Fields agreed that exploration of quark physics at TeV energies was essential to answer fundamental questions in high energy physics. It was at this workshop that the concept of a 20 TeV accelerator, the SSC, was first studied in detail.

Design for the US Superconducting Supercollider, SSC, showing the 84 kilometre racetrack tunnel where proton beams would be taken to 20 TeV (20 000 GeV). The gigantic machine could be complete by 1996.



The feasibility of the SSC was examined in detail at a workshop in the spring of 1983. The conclusion was that, just as developments in physics made evident the need for a machine like the SSC, so developments in technology, especially in superconductivity, made the building of such a machine possible.

Enthusiasm soon turned to action. In July 1983, the High Energy Physics Advisory Panel of the US Department of Energy unanimously endorsed detailed research into the feasibility of the SSC. With Congressional approval, funds were reallocated to support research and development on the new accelerator, especially on the superconducting magnets.

Early in 1984, the Reference Design Study Group met at Berkeley to review the technological needs of the SSC. There an initial price tag, based on proven technology, was put on the machine.

At the same time, a management structure for the R&D programme was also established. The broad national scope of the SSC effort was emphasized by the choice of the Universities Research Association, a consortium of 56 major universities, as the contractor for R&D. Primary responsibility was delegated to an appointed Board of Overseers, which chose Maury Tigner of Cornell to direct the Central Design Group (CDG), responsible for coordinating the R&D activities. Berkeley was selected as the host Laboratory for the CDG. Work has been carried out in industry and at several universities and national Laboratories, especially Brookhaven, Fermilab, and the Texas Accelerator Center, as well as Berkeley.

The first two years of SSC work saw the preparation of a siting parameters document, the selection of a specific magnet type and, more recently, the publication of the Conceptual Design Report, a detailed account of all the systems needed for operation of the SSC as a fully functioning research facility. Cost estimates and a proposed construction schedule are also included.

The future of the project now hinges on Congressional authorization and subsequent appropriation. If Congressional response is positive, there will be a national competition for the SSC site, with proposals judged against detailed requirements drawn up by the Department of Energy. It is planned that these proposals will be reviewed by a distinguished panel appointed by the Presidents of the National Academies of Sciences and of Engineering. The panel will select a small number of proposals that best satisfy the site requirements, and will submit them unranked to the Department of Energy for final site selection.

Full-length turnout for the first full-length (17 metre) dipole of the preferred design for the proposed US Superconducting Supercollider (SSC) at Brookhaven, ready for its transfer to Fermilab for cryogenic testing.

(Photo Mort Rosen, Brookhaven)

Elsewhere

In Europe, the news of the initial approval for the US Superconducting Supercollider was received enthusiastically as it showed that the future of high energy physics is regarded as being of paramount importance at the highest levels. While the US plans gather momentum, the possibility of a hadron ring in the LEP tunnel at CERN is still attractive. Although restricted in energy by the 'modest' dimensions of the LEP tunnel compared to the SSC (27 kilometres circumference against 84), this Large Hadron Collider (LHC) scheme scores points for the magnificent beam injection systems already in place at CERN, a complete tunnel, and several collision options. Once the LEP electron-positron collider has become routinely operational at about 60 GeV per beam, the high field superconducting magnets required for LHC to reach about 8 TeV (8000 GeV) per proton beam could be installed in parallel with the superconducting cavities required to attain design energy (about 100 GeV per electron/positron beam) in the LEP ring.

In the Soviet Union, the big UNK project (see page 21) also pushes ahead.

Long range physics

John Mulvey, chairman of the physics subpanel set up under the CERN Long Range Planning Committee.

To push forward the frontiers of knowledge, far-sighted specialists are planning and designing new particle physics machines. Their size and complexity means that such projects can no longer be attacked by a bunch of local enthusiasts, and have grown instead to involve an international community. In parallel with this effort, researchers are looking in detail at the physics conditions these machines are likely to generate, and the types of experiment and detection equipment needed to exploit them.

In the US, the Superconducting Supercollider (SSC) project for handling 20 TeV (20 000 GeV) proton beams has spawned a series of workshops to discuss physics issues and detector ideas (see previous story).

At CERN, Council set up in 1985 a Long Range Planning Committee, chaired by Carlo Rubbia, to explore various options for the long term future of the Laboratory. This Committee issued an interim report last year (see September 1986 issue, page 17), and is scheduled to produce final recommendations later this year.

The Committee set up three specialist subpanels; one chaired by Giorgio Brianti to investigate the feasibility of a hadron collider in the tunnel now being built for the LEP electron-positron collider, a second, chaired by Kjell Johnsen, to look into the possibility of a large electron-positron collider in the 1 TeV range (in its initial version, LEP will attain about 60 GeV per beam), and a third, chaired by John Mulvey, to examine the underlying physics issues.

Of the two major machine ideas, thinking on the so-called Large Hadron Collider (LHC) in the LEP tunnel is more advanced (see, for example, July/August 1986 issue, page 5), as it would benefit naturally from the superb chain of hadron machines already at work at CERN, and from the LEP tunnel, now almost complete. In addition it offers the possibility of electron-proton collisions. With the goal of high luminosity (particle collision rate), LHC opinion favours a proton-proton option rather than proton-antiproton. Assuming the necessary superconducting magnets can be developed, LHC would provide beams around 8 TeV.

The 1 TeV electron-positron collider is further away in the sense that a determined research and development programme is needed for the technology to get the idea off the ground.

The long range physics subpanel set up working groups to attack special topics, and findings were aired at a recent workshop at La Thuile in the Alps, with summary sessions at CERN.

Particle physicists have always loved to peer into their crystal balls and foretell what might happen with future machines, but these latest sessions had the unusual slant of making direct comparisons of the three different colliding beam scenarios offered by the long term options — proton-proton, electron-proton and electron-positron.

For each of these scenarios the physics preoccupations include additions to the present 'Standard Model', notably the continuing quest for the elusive 'Higgs mechanism' responsible for the different ranges of the electromagnetic and weak nuclear forces, and a search for additional leptons and quarks, heavier than those currently known.

Going beyond the Standard Model, there are many ideas on the market with considerable intuitive appeal but as yet no experimental evidence to back them up — supersymmetry, superstrings, etc., as well as a search for structure inside the so far indivisible leptons and quarks. There is no shortage of new physics to probe or ideas to test.

The working groups' prolific output reflects both the high degree of confidence and skill in the underlying theories and the wide experience gained from work at existing colliding beam machines. It shows the three colliding beam avenues to be highly complementary, with each scoring marks for different physics objectives.

With their continual search for rarer and rarer processes, physicists are ever-hungry for raw collisions, driving the machine designers to push for more intense beams and higher luminosity levels. This challenge is being bravely taken up, so that on paper LHC

Ugo Amaldi — underlining the complementarity of different collision options.

could inch towards 10^{34} cm^{-2} s^{-1}.

There are classic examples of new machines finding that the theorists were right — the discovery of the antiproton at the Berkeley Bevatron in 1956 and the sighting of the W and Z carriers of the weak force at the CERN Collider in 1983. Summarizing the physics findings, Ugo Amaldi warned that these landmark discoveries are rare. However this is no reason not to build new machines and reveal our ignorance.

Amaldi deftly underlined the complementarity of the proton-proton, electron-proton and electron-positron colliding beam options, and pointed out the detector innovations needed to cope with the new physics. For example data acquisition at the advocated energies and collision rates poses considerable technological (and financial) problems using present-day solutions.

A theme continually stressed throughout the sessions was continued research and development — to produce the superconducting magnets for LHC, to provide the power for the 12.5 kilometre linacs of the 1 TeV electron-positron collider, to perfect the necessary detection and data handling techniques, etc.

This was hammered home by Carlo Rubbia in his concluding remarks, who reiterated the interim recommendations of the Long Range Planning Committee for a vigorous European research and development programme. 'The time has come to get our hands dirty,' he stated.

One of the items agreed by the CERN Council during the course of its December meeting was a new programme financed by the Italian government to develop new technologies for detectors to study the physics emerging from future large hadron colliders. Amounting to some 37 million Swiss francs over five years, the programme is open to the entire physics community and is completely selfsupporting. Antonino Zichichi will be Project Leader. The introduction of additional programmes financed by one or more Member States outside the normal CERN budget is not new. The big BEBC bubble chamber, which came into action in 1973 and involved the design and construction of the world's largest superconducting magnet, was financed by France and Germany.

Around the Laboratories

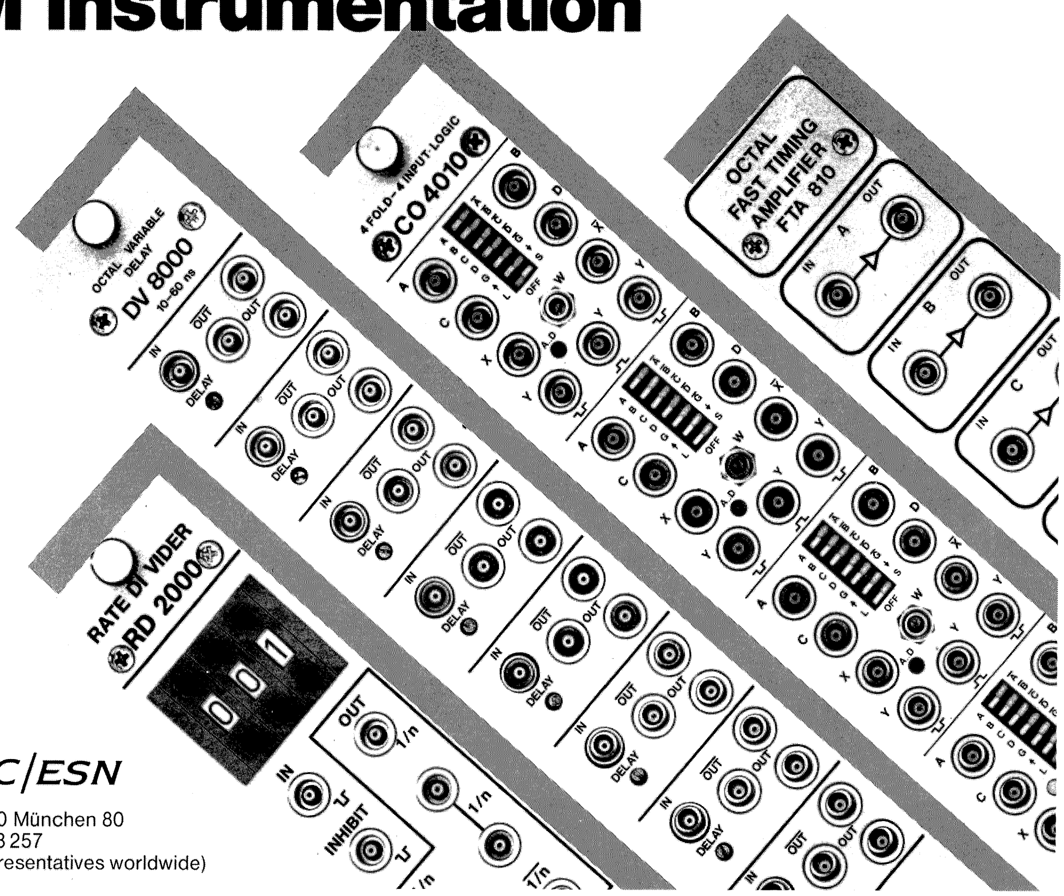
CERN
Cast your ion first results

CERN's 450 GeV Super 'Proton' Synchrotron (SPS) finished 1986 with several weeks supplying beams of oxygen ions (first at 200 GeV/nucleon, later at 60 GeV). Coming after a very smooth commissioning run with oxygen ions in September (see October 1986 issue, page 37) which gave several experiments a foretaste of nuclear beams, this unique research programme is already providing tantalizing hints of interesting behaviour.

The ultimate goal is to find the long-awaited quark-gluon plasma, when quarks and gluons become 'hot' enough to break loose from their nucleon 'bags'.

Lined up to receive these oxygen ion beams are a number of experiments, much of whose equipment has been recycled or converted from other studies (see December 1985 issue, page 428), complemented by seven investigations using nuclear emulsions and/or plastic detectors.

Together, these detectors showed their remarkable ability to cope with the large numbers of secondary particles released — up to several hundred per collision. Initial results suggest that the target nuclei do not always break up, and the oxygen ion projectiles are



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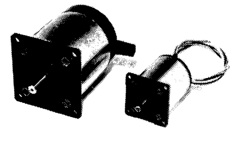

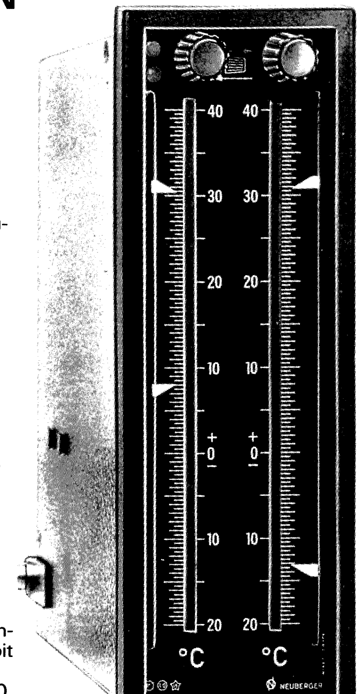

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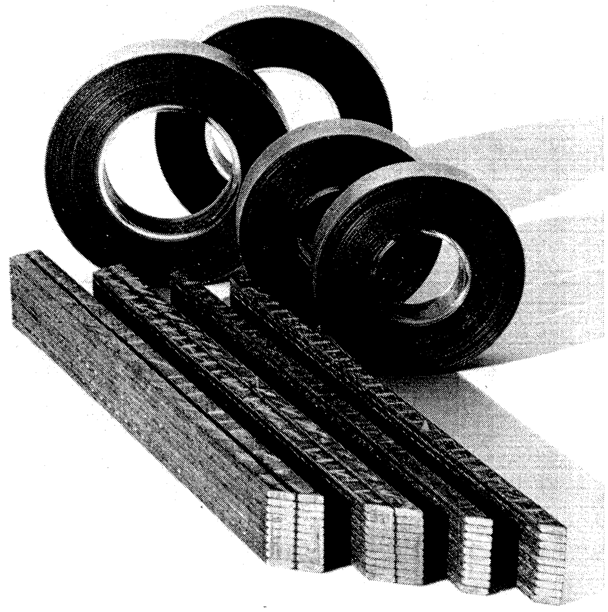

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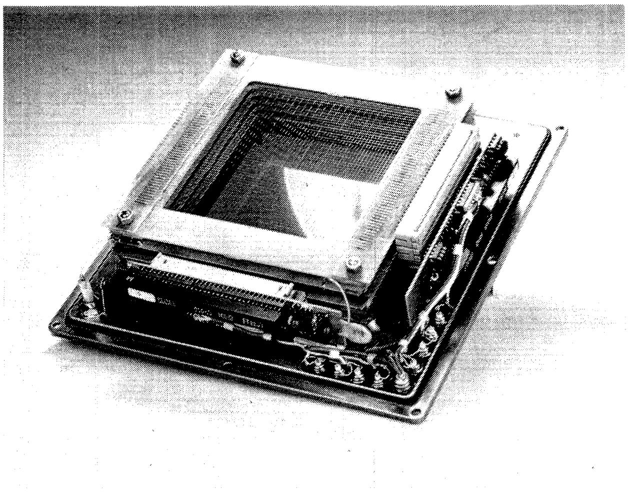

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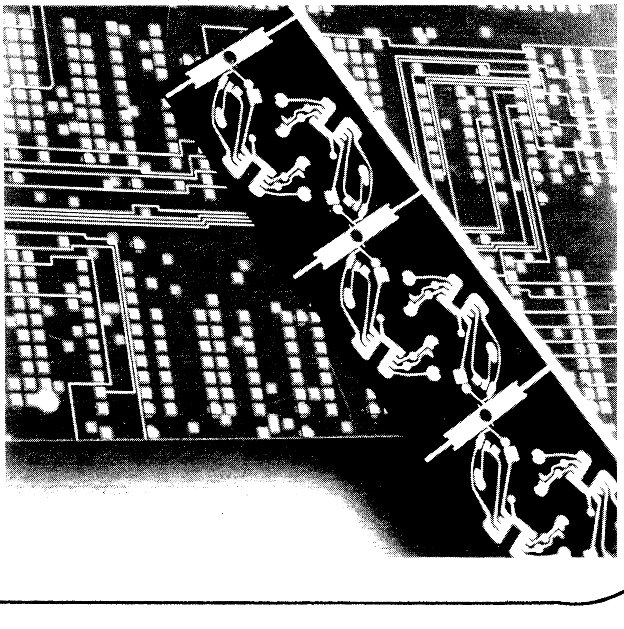
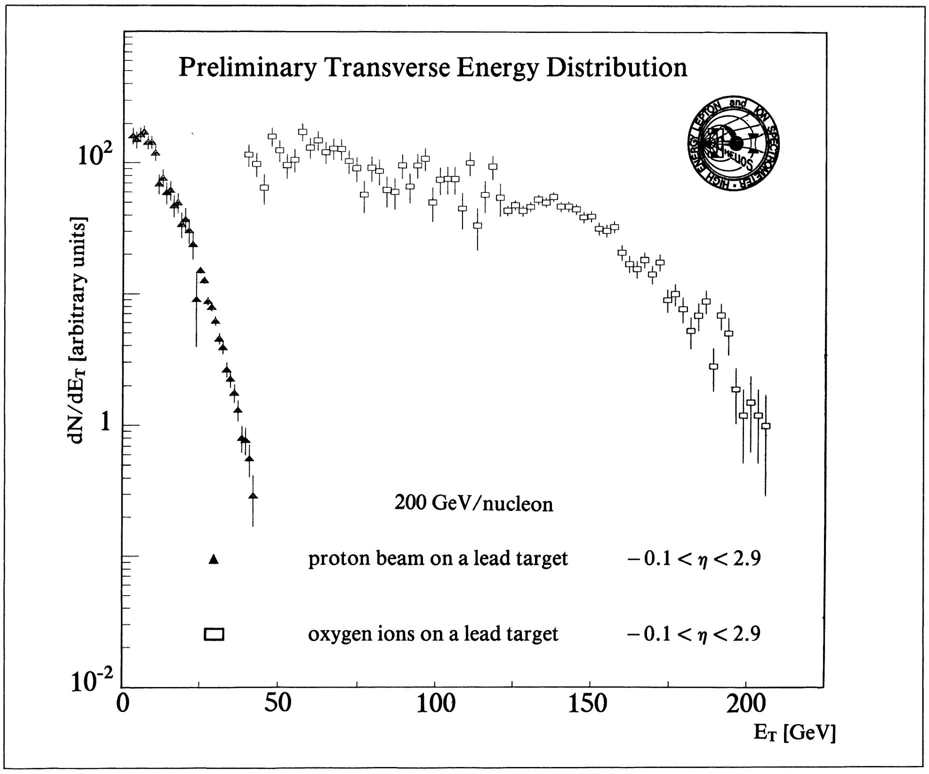


Intriguing preliminary results from the HELIOS experiment at CERN show the much larger amounts of transverse momentum produced by oxygen ions than by protons.



absorbed at an unexpectedly high rate. Even at the higher energies, there is lots of 'stopping power' — the ions do not pass easily through the nuclei. The resultant 'heating' of the target nuclei is demonstrated by the large amount of energy released sideways through 'evaporation'.

The ion researchers are eagerly looking forward to their next run, scheduled for September-October.

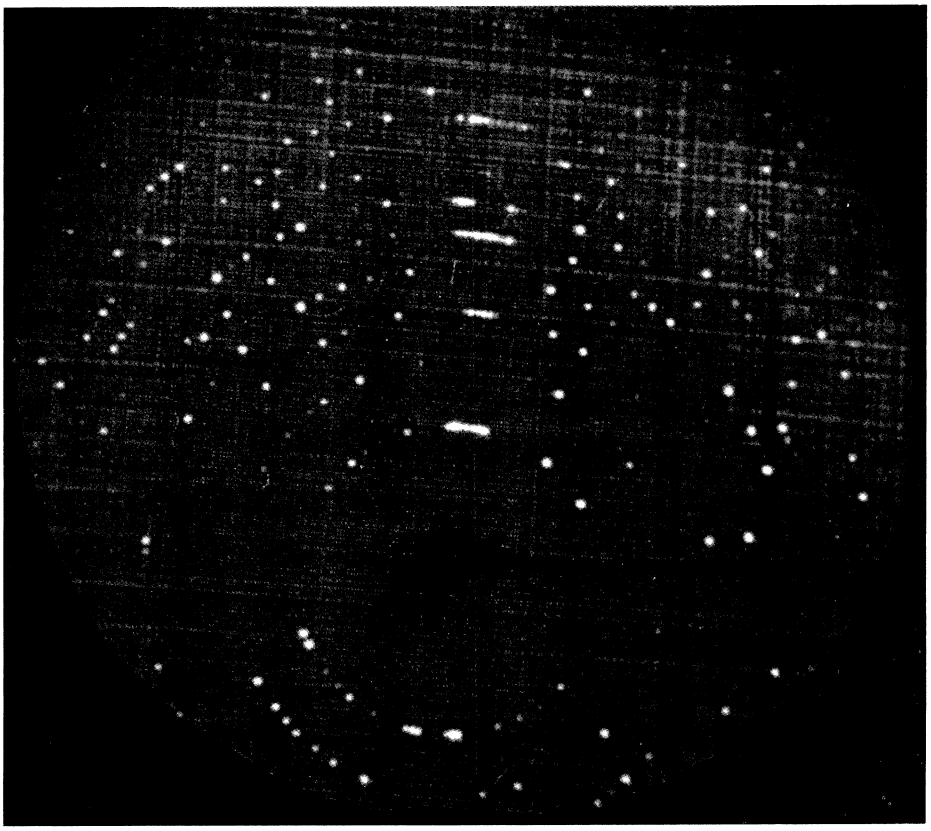
Crystal clear

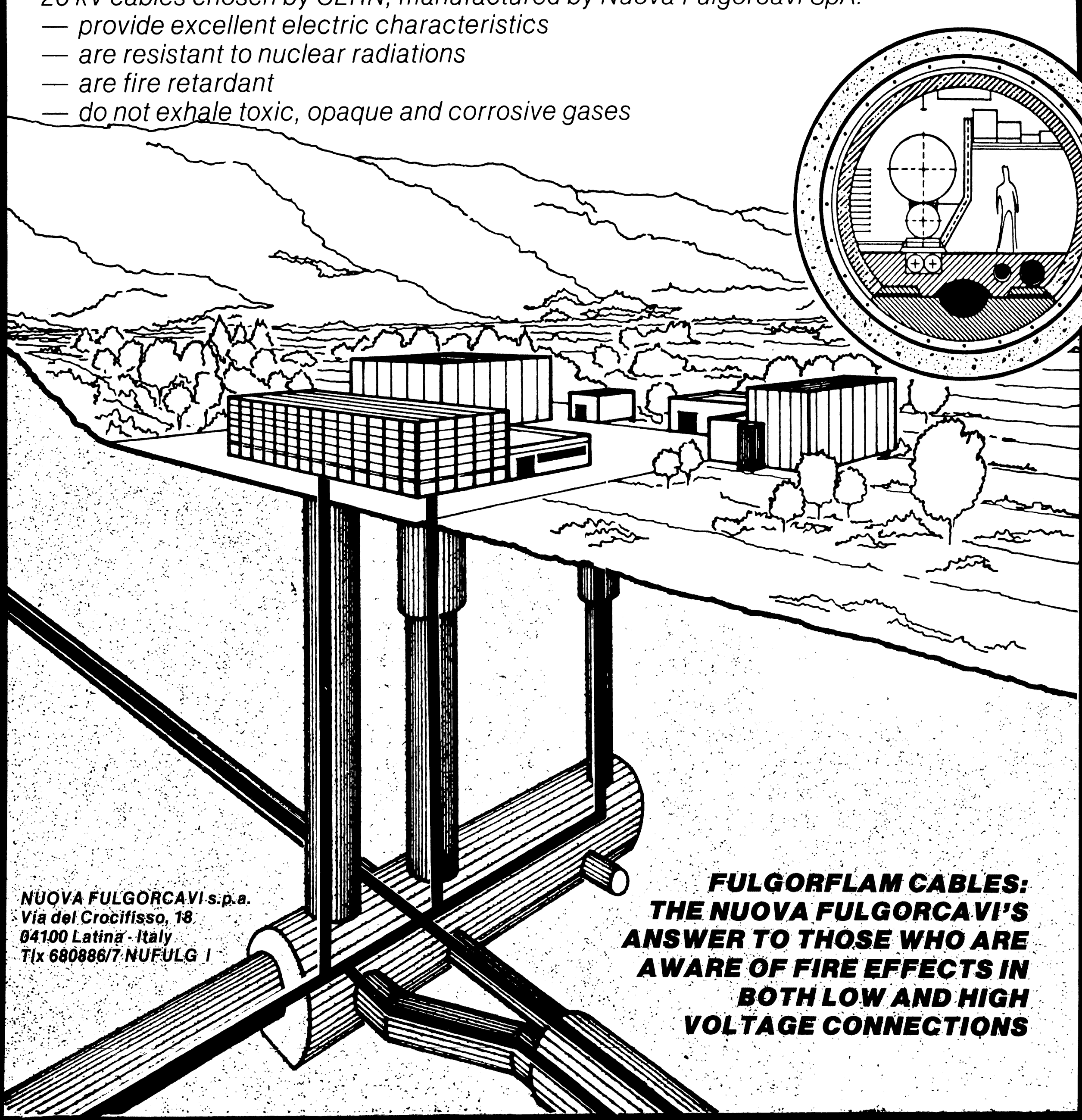
The so-called 'drift chamber' is already widely used in particle physics experiments for localizing interaction signals. Accurate to a few tens of microns, its advantages also include high counting rates and good energy resolution.

However a development of this chamber at CERN looks like providing a powerful new instrument capable of probing distances hundreds of times smaller. It is used for studying the crystal structure of complex and/or rapidly evolving structures, such as organic molecules, using intense X-ray sources.

Ionization electrons produced in a gas by the passage of charged particles drift and diffuse under an electric field. If the initial interaction time is known, measuring the delay of the drifted electrons arriving at the anodes gives the distance the

X-ray diffraction picture of a protein crystal ▶ recorded using the spherical drift chamber developed at CERN. The closeness of the spots follows from the large crystal cell size — 230 angstroms (23 nanometres). A development of this chamber could open up a way for studying the structure of viruses.





LEP progress

As tunnelling work for the 27 kilometre ring of CERN's LEP electron-positron collider nears completion, installation in the completed sections of the tunnel gathers momentum. The photograph shows infrastructure being readied in a klystron tunnel.

(Photo R. Lewis)

At the end of January, the last tunnelling machine at work for the LEP ring at CERN made its final breakthrough. Only a few hundred metres of the 26.7 kilometer ring now remain to be cut by careful excavation in the limestone under the Jura mountains.

◄ ionization has travelled and enables the initial interaction to be localized. This is the basis of the drift chamber technique.

It is seldom possible to use this drift time measurement when localizing X-rays because the X-ray emission time is generally unknown. However the properties of electrons drifting in a gas have substantially increased the precision of X-ray images.

Since their discovery, multiwire chambers have been used to localize X-rays. To ensure satisfactory performance they must be operated with pressurized xenon. Precision is limited by the distance between the anode wires and parallax caused by the thickness of the chamber. One of the main applications of this technique is the study of giant organic molecular structures such as proteins by measuring the intensity of the diffraction spots produced by their crystals.

The main defects of wire chambers have been eliminated by coupling a spherical drift chamber to a wire chamber. A 15 cm drift space is enclosed by a spherical entry segment made of beryllium and a spherical grid, both centred on the crystal to be studied. The electric field is radial, with the crystal at its centre, so that there is no parallax effect. The electrons freed by the X-rays leave the drift space and are localized in a wire chamber. The long drift distance causes the cloud of electrons to diffuse and spread over a width greater than the distance between the anode wires, so that interpolation methods allow continuous and more accurate localization than the distance between the wires.

The group of Georges Charpak and Fabio Sauli at CERN, working in close association with a group from the LURE Electromagnetic Radiation Laboratory in Orsay, has developed a chamber of this type and demonstrated its currently unrivalled capacity for studying protein crystals.

Data can be collected at a rate of 3 x 10^5 per second and within a few weeks results can be obtained which would take over a year by conventional photographic methods. At CERN R. Bouclier, G. Million and J. C. Santiard have developed production techniques for these chambers.

Georges Charpak believes that by continuing moderate research efforts in this field and by making the most of new developments in wire chambers, it should be possible to develop techniques for easily investigating the structure of viruses. The cover of our December issue gave a striking example of results achieved by this technique.

Latest muon results

The two big experiments built to exploit CERN's high energy muon beams from 1978 stopped taking data in August 1985, but more high quality results have recently emerged from analysis of the huge amounts of data accumulated during the final years of running.

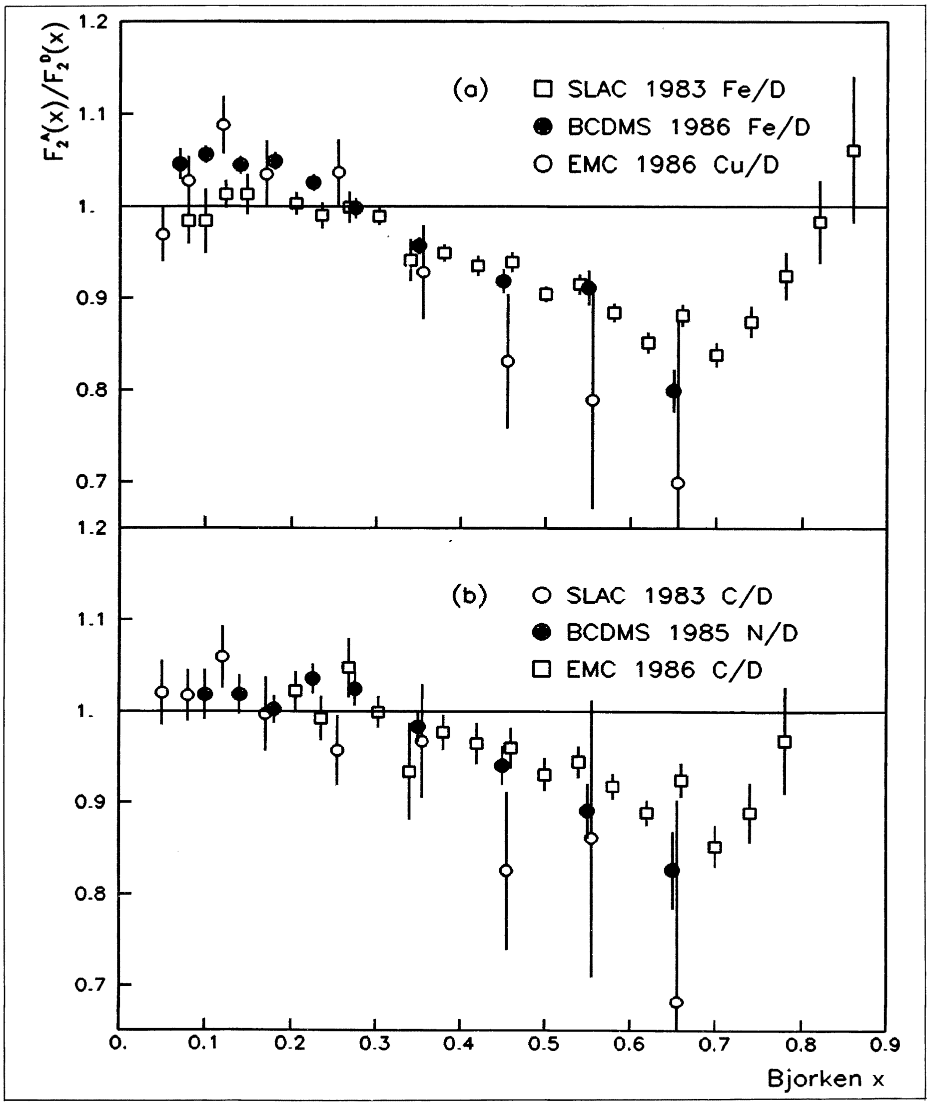
The Bologna / CERN / Dubna / Munich /Saclay collaboration (BCDMS — NA4 experiment) recently completed the analysis of the quark structure of the nucleon (F_2 structure function) measured using a carbon target in the 50m toroidal iron spectrometer.

The measured quark distribution looks very much independent of momentum transfer (Q^2) at fixed values of the 'scaling variable' x, (the fraction of nucleon momentum carried by the struck quark).

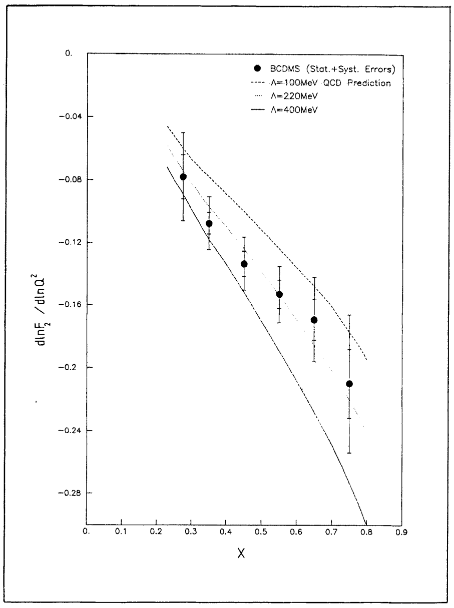
This shows that the interaction probability of the (virtual) photon (carrying the electromagnetic force between the incoming muon and the target quark deep inside the nucleon) does not depend very much on its wavelength.

This behaviour (known as 'scaling') was first seen in 1968 using the electron beams from the big Stanford linac and showed that the quarks hidden deep inside nucleons are pointlike.

It is one thing to know that nucleons contain pointlike quarks, but quite another to account for the quarks' detailed behaviour.



A compilation of recent measurements of nuclear effects in the quark structure of nucleons using electron beams at Stanford (SLAC) and muons at CERN (BCDMS and EMC). Results above (a) are for heavy targets (iron and copper) while those below (b) are for light targets (carbon and nitrogen). If there were no nuclear effects, quark structure measurements (F_2 structure function) would be the same for all nuclei.



The kinematic dependence of the quark structure of nucleons (F_2 structure function) as measured by the BCDMS experiment at CERN. This 'scaling violation' is described by the underlying theory, and enables the quantum chromodynamics (QCD) mass scale parameter to be determined.

The quantum chromodynamics (QCD) picture of quark interactions predicts that scaling is only approximate, and the observed deviations from scaling provide an important test of the theory.

This is one of the few areas where confident QCD calculations confront high statistics data. Using the latest results from the high energy muon beam studies at CERN, the agreement is very good, boding well for the new theory. More such results are expected soon from similar measurements using hydrogen and deuterium targets.

Another major physics result to emerge from these experiments was the so-called 'EMC Effect' — the quark structure of nucleons depends on the surrounding nuclear environment.

The initial 1983 findings by the European Muon Collaboration (EMC) at CERN showed that the quark content of bound nucleons in iron differs from quasi-free nucleons in deuterium. This was subsequently underlined by data from Stanford using high energy electrons, and from the BCDMS collaboration.

This discovery set the theoreticians thinking (see the excellent article by Richard Roberts in the September 1985 issue, page 270), and, together with the search for the quark/gluon plasma, was the starting point for a whole series of experiments which might be described as high energy nuclear physics.

The original EMC data were obtained from separate measurements of the absolute values of nucleon structure parameters with iron and deuterium targets, taken under different experimental conditions (beam energy, intensity, target length, etc.) and at different times. As a result the systematic errors were rather large. Other (normalization) effects could also have caused inaccuracies.

Comparing the behaviour seen by EMC and by the BCDMS experiment and the electron data from Stanford, there was broad agreement across the range of kinematical conditions studied, except where x is small. The original EMC data showed the ratio of the nucleon quark structures (structure functions) rising as x got smaller, while the other data showed the ratio falling.

To clarify the situation and decrease the intrinsic measurement errors, both muon experiments at CERN took new data. The EMC experiment used nuclear targets with similar geometries and interchanged them every few hours to average out time dependent effects.

The target vessels in the 40 m magnetized iron solenoid of the BCDMS experiment were filled with liquid deuterium for the latest data run. External targets in front of the magnet extended the kinematical range of the collected data. For part of the run, the first of the external targets was replaced by an iron target.

After the necessary corrections, the new EMC data shows the ratio of structure functions turning over as x decreases.

The latest BCDMS measurements now provide precise information in the interesting region of small x, although the range is not wide enough to confirm the turnover seen by EMC. Heavy target results (iron and copper) are slightly different to the low Q^2 Stanford data.

Thus one of the more puzzling aspects of the original EMC findings has largely evaporated, but the basic message remains unchanged — the quark structure of nucleons depends strongly on the surrounding nuclear environment.

The observed behaviour may now turn out to be easier to explain in terms of conventional quark physics.

However it seems unlikely that such models can explain the EMC Effect entirely. For example some approaches use as a parameter the nuclear separation energy, which saturates when nuclear masses reach about 50. This implies that the effect should be the same for these heavier nuclei, in contrast to the Stanford measurements. Thus more exotic explanations may still be required to provide the full story. As one high energy nuclear physicist remarked 'it was the EMC Effect which got us thinking about the role of quarks in nuclei'.

Many rods make light work

Continuing a distinguished career at the 450 GeV Super Proton Synchrotron is the big calorimeter built by Bari and the Max Planck Institute, Munich, now in the NA35 streamer chamber-based experiment looking at the collisions of high energy nuclear beams with nuclei and previously used in a series of landmark SPS experiments.

When it came into action in 1978 it was one of the first detectors capable of picking up the energy released in all directions when a high energy beam slammed into a target. Among the techniques used are plastic scintillators to pick up the energy of produced photons and hadrons. The scintillator light is collected in acrylic rods, so that the output from many scintillators can be funnelled into a single photomultiplier. An ingenious system of colour-doped light guides gives the signals from the photon and hadron parts of the calorimeter a characteristic colour, fed along a single rod but picked up by separate photomultipliers after discrimination by light filters.

The first team to use the calorimeter was the Bari / Cracow / Liverpool / Munich (MPI) / Nijmegen collaboration (NA5 experiment) looking at the detailed distribution of the energy released in hadron reactions under SPS conditions, and for the first time over a large solid angle, intercepting as many of the produced particles as possible.

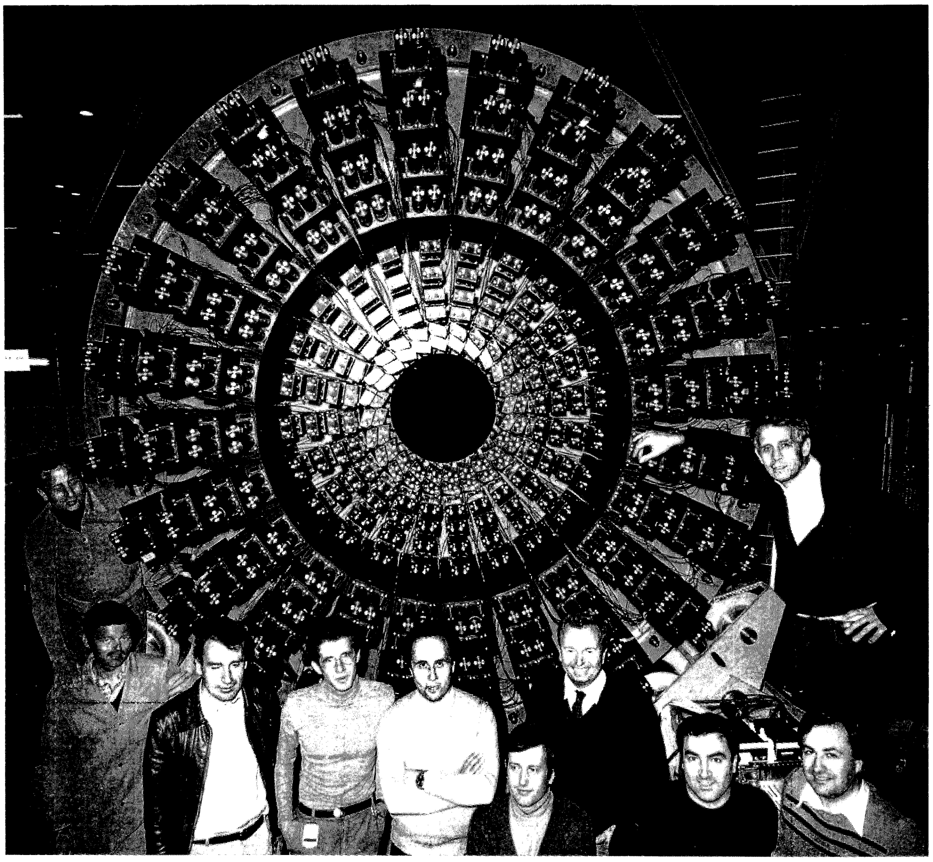
After setting the calorimeter to select events with a high proportion of energy released sideways, the experiment found this energy to result from large numbers of secondary particles, each carrying a relatively low transverse energy. Similar behaviour was seen subsequently by studies at higher collision energies at the Intersecting Storage Rings, at the proton-antiproton Collider, and at the SPS using nuclear beams, where prolifically produced secondary particles (high multiplicity) result in large amounts of transverse energy.

At the time, physicists were eagerly searching for well-defined 'jets' of produced hadrons carrying high transverse energy, indicative of violent quark interactions deep inside the target nucleons. These were not easy to spot under SPS conditions. Jet searches at the higher collision energies available at the Intersecting Storage Rings and subsequently at the proton-antiproton Collider were highly successful.

With its work done for NA5, the calorimeter was transferred to a new study by a Bari / Freiburg / Moscow (ITEP) / Munich (MPI) team (NA24 experiment) looking at the single photons released through the electromagnetic interactions of quarks.

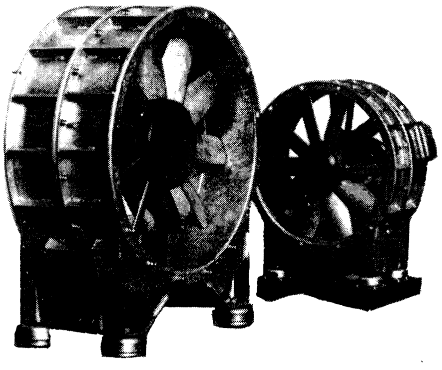
Although the separation of these rare single photons from the large background (due to neutral pion decay) is difficult, the interaction is a particularly clean one to follow in terms of the underlying theory and gives a valuable check on our understanding of quark dynamics. The results show that the theory is in good shape.

With the nuclear beam programme at CERN poised to provide interesting results (see page 4), the Bari/MPI Munich calorimeter continues to pay good research dividends.



End-on view of the Bari/Max Planck Institute Munich calorimeter, now in use in its third experiment at the CERN SPS Super Proton Synchrotron. When it came into operation in 1978, it was one of the first detectors to cover a large solid angle and intercept as many of the produced particles as possible.

(Photo CERN 40.5.79)



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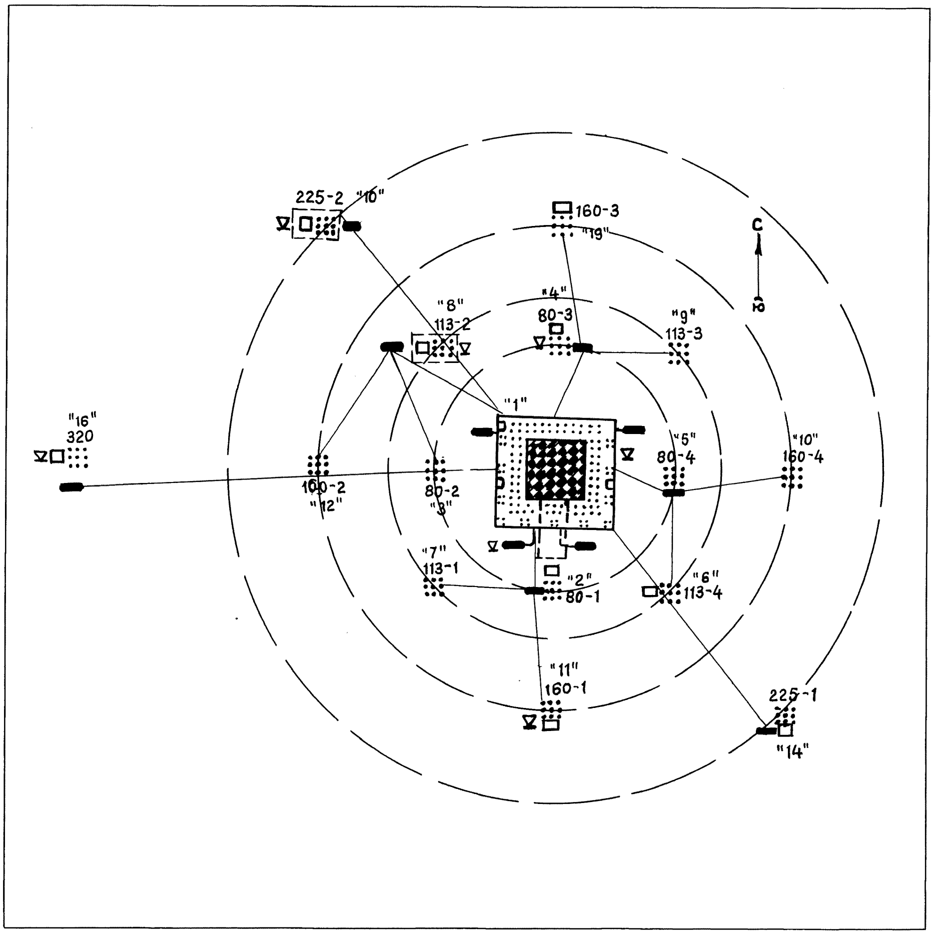
COSMIC RAYS
New Soviet installation

With advances in particle physics highly dependent on input from studies at energies beyond those currently attainable with laboratory machines, the extreme energy clues provided by cosmic ray investigations continue to provide useful pointers.

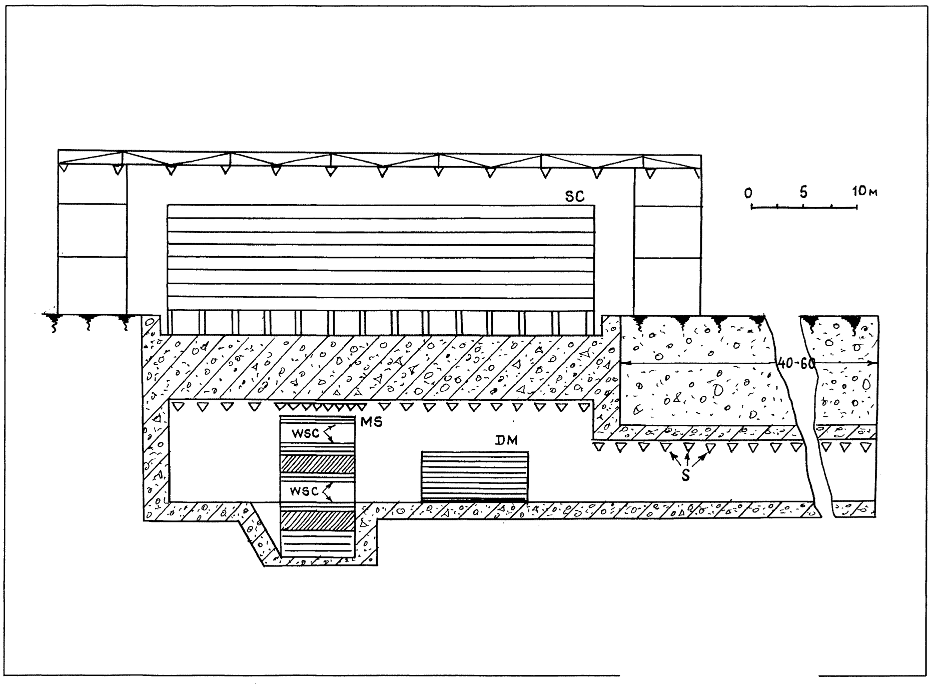
ANI (Russian acronym for near-ground hadron investigation) will be an impressive experimental complex for studying the interactions of cosmic ray particles and nuclei with primary energies between 10^3 and 10^6 TeV (1 TeV = 1000 GeV). It is under construction by the Yerevan Physics Institute together with the Lebedev Physics Institute (Moscow) at the Aragats high altitude (3250 metres) station 65 km north-west of Yerevan in Soviet Armenia.

The upper energy limit is governed by the abruptly falling energy spectrum of primary cosmic rays and the feasible size of terrestrial detectors. Satellite-borne detectors provide another research window but their size is even more restricted.

The aim of the new detector is to compile as complete information as possible on multiple production processes over a wide energy range using X-ray emulsion chambers combined with a 1600 m^2 ionization calorimeter at the centre of the installation, complemented by a large array of instrumentation



Layout of the ground and underground detectors at the 'ANI' high altitude installation now under construction in Soviet Armenia. Dots represent scintillators, open squares show gas discharge hodoscopes, hatched areas ionization calorimetry, dashed areas underground muon laboratories, triangles Cherenkov detectors and solid ovals computers with their communications lines.



Sketch of the ground and underground portions of the central part of ANI. MS stands for magnetic spectrometer, S for scintillators, DM for muon pair-meter, SC for spark chambers and WSC for wide-gap spark chambers.

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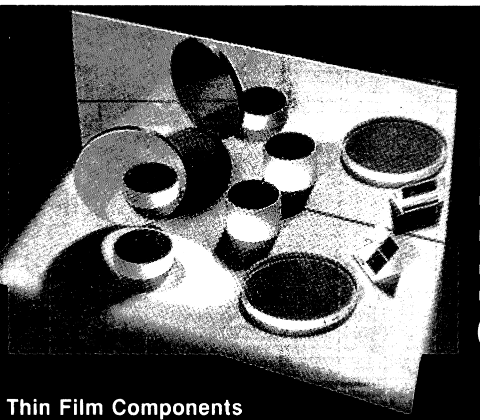

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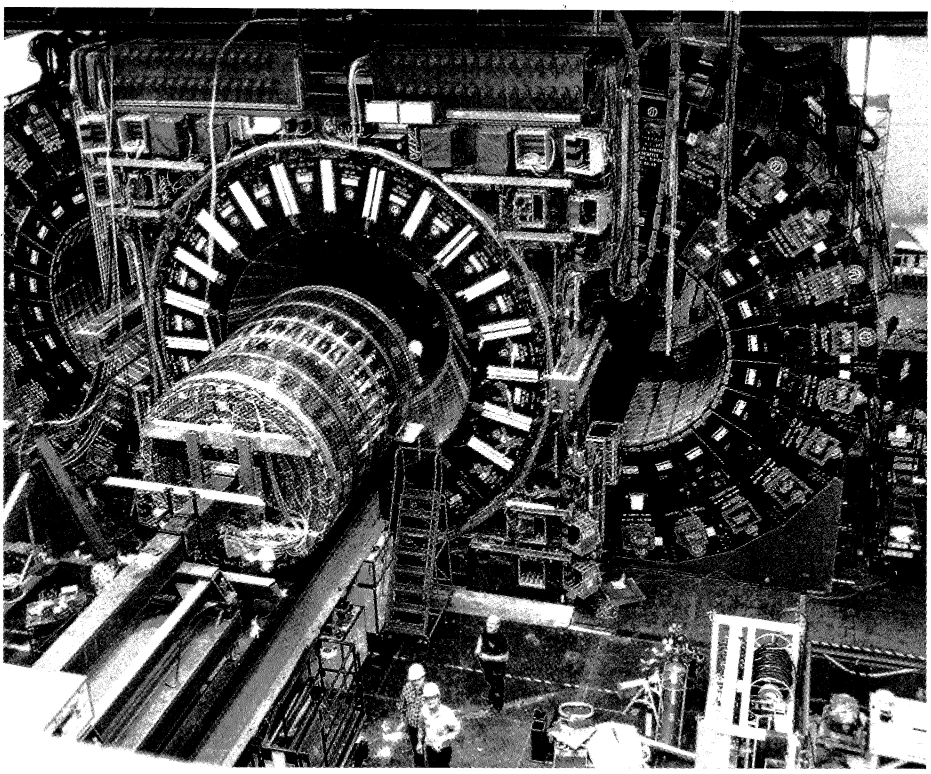
OPTISA

After an initial run in 1985 at a collision energy of 1.6 TeV (1600 GeV), the Fermilab Tevatron proton-antiproton collider began physics operation in January with 900 GeV proton and antiproton beams (1.8 TeV collision energy, the world's highest). Monitoring the results is the 4500 ton CDF Collider Detector at Fermilab, seen here in assembly position with the cylindrical central tracker and calorimeter arches clearly visible. Progress of the run will be covered in a forthcoming issue.

(Photo Fermilab)



spread over hundreds of metres to detect photons, electrons, hadrons and muons.

All clusters of photons and of electrons or hadrons with a total energy of 10^3 TeV could be detected. High energy muons deriving from collisions above 10^3 TeV could be picked up through a magnetic spectrometer, 'pair-meter' and scintillation hodoscopes, together with simultaneous information from the whole atmospheric nuclear cascade.

This way the big detector will be able to intercept a lot of information. Data acquisition will be computer controlled, allowing special criteria to be applied in the search for particular events. The list of physics topics for scrutiny with ANI is long and impressive, covering such areas as the production and decay of heavy quarks and the search for more exotic cosmic ray phenomena, as well as particle astronomy.

Construction work is well underway, and excavation for the underground muon laboratory is complete.

From E. Mamidjanyan

International symposium

Latest in the series of biennial international conferences on cosmic ray interactions at superhigh energies was held in Beijing late last year. As well as providing a wealth of new data, it made for a careful examination of the overlap between cosmic ray results recorded in emulsion chambers and the energy range accessible in the laboratory using particle beams.

The CERN proton-antiproton collider has achieved up to 900 GeV collision energies (equivalent to a 4×10^{14} eV beam hitting a fixed target), while the Fermilab Tevatron should eventually reach about 10^{15} eV. The main interest at the Beijing meeting centred on the consistency (or otherwise) of cosmic ray results and accelerator data, and speculation on what will be seen beyond presently available accelerator energies.

Cosmic ray data will be the only source of input until higher energy projects such as the UNK (USSR) Collider, the US Superconducting Supercollider (SSC), or CERN's LHC in the LEP tunnel come to fruition. Away from the emulsion chamber sector, extensive air shower measurements using detectors such as the Fly's Eye in Utah provide additional information.

Results from the CERN Collider show that the production level of 'jets' of hadrons carrying relatively low transverse energies (above about 5 GeV) increases significantly over the scanned collision energy range. This trend has implications for the Tevatron and beyond, so that mini-jets could eventually make up quite a large fraction of the total particle production.

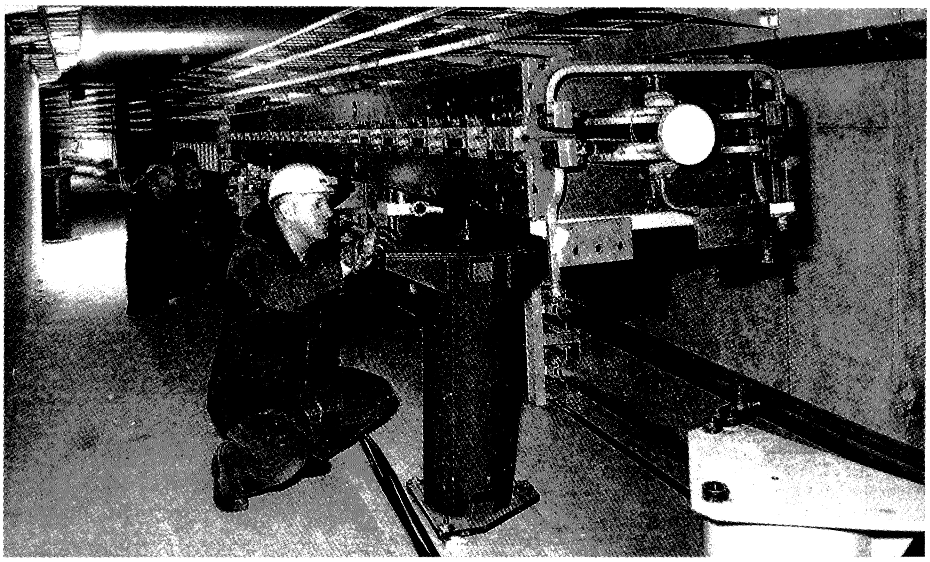
Cosmic ray results certainly show consistencies with accelerator data, such as the prominence of large transverse momentum events with a multicore structure seen in both mountain emulsion chamber studies and in extensive air shower measurements.

Significant violation of kinematical scaling behaviour in multiple particle production was noticed several years ago in emulsion chamber studies. The Pamir and Mt. Fuji collaborations both report a similar change in the multiplicity rate between 10^7 GeV and 100 GeV.

Big news at the meeting was a new 'Centauro' event, found in the Pamir chamber operated by a Japan/USSR collaboration. Events of this type, where most of the incoming energy goes into producing long-lived secondary hadrons with few of the neutral pions normally seen in high energy collisions, had been found previously by the Japan/Brazil collaboration at Mt. Chacaltaya in the Andes, but a careful search up to 900 GeV collision energy at the CERN Collider failed to find anything. Centauros, then, are something new, beyond the present horizon of laboratory energies. At the meeting, the Mt. Chacaltaya team gave a status report on their Centauro sample.

The ongoing study of cosmic ray phenomena will surely complement results from future hadron collider experiments.

From D. Cline and S. Slavatinsky



Mounting a magnet in the proton injection tunnel for the HERA electron-proton collider now being built at the German DESY Laboratory in Hamburg.

(Photo DESY)

DESY
The weak get stronger

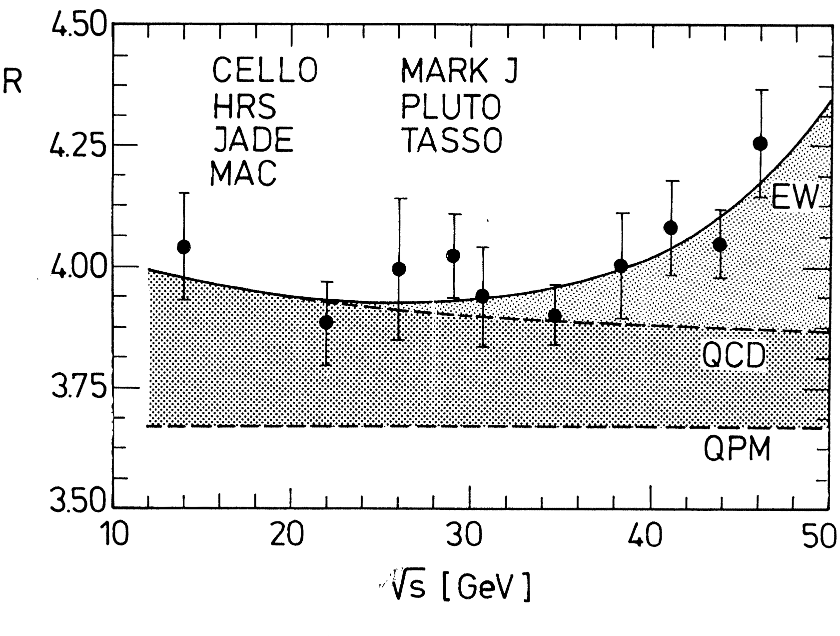
Physics at the PETRA electron-positron storage ring has finished, but the results obtained in eight years of data taking remain as landmark contributions to modern physics.

The textbooks already cite the initial evidence for gluons in 1979. In addition, measurements of the relative production rate of hadrons (strongly interacting particles) from electron-positron annihilation provided a valuable testbed for the two underlying theories — the quantum chromodynamics (QCD) picture of quark interactions and the electroweak unification scheme.

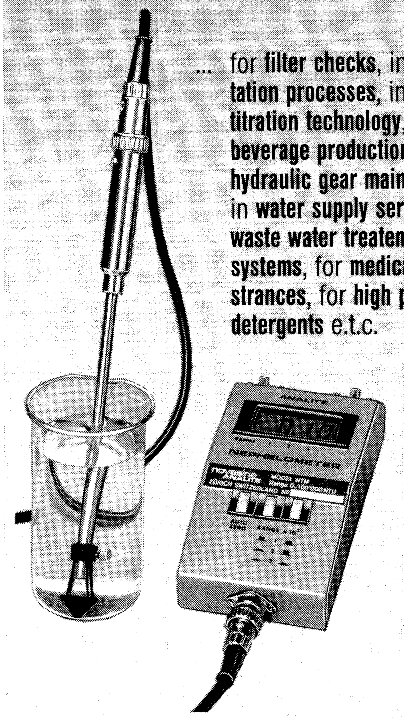
The total hadron production rate in this case, including effects due to gluon emission, is a particularly clean quantity to calculate in QCD, where predictions are often difficult due to uncertainties in the theory.

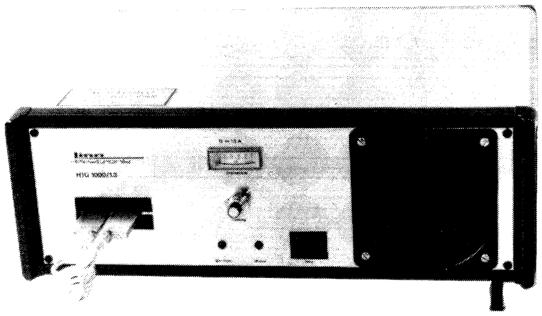
A compilation of results from studies both at PETRA (up to 46.6 GeV collision energy) and the PEP ring (up to 29 GeV) at Stanford now provides solid values for underlying parameters in the theories — the strong coupling constant of QCD and the electroweak mixing angle.

One prediction of the electroweak theory is that the 'weak' nuclear force starts to get stronger with energy. At PETRA, radio-frequency accelerating power was crammed into the ring to boost the collision energy. While the increasing electroweak contribution was clearly seen, the Z particle (the neutral carrier of the weak force) responsible for the effect could not come out into the open. It needed the higher collision energies of the CERN proton-antiproton ring to isolate the Z near 93 GeV in 1983.



Variation of the relative production level of hadrons in electron-positron annihilation (R) with collision energy (horizontal axis) from experiments at both the PETRA (DESY, Hamburg, up to 46.6 GeV collision energy) and PEP (Stanford, up to 29 GeV) colliders. The results clearly show the increasing electroweak effects (EW), together with the calculated contribution from the field theory of quark and gluon interactions (QCD), including effects due to gluon emission, and the prediction of simple quark parton model (QPM). The agreement of the combined EW + QCD predictions with the data shows that our understanding is in good shape.





A section of the tunnel for the UNK machine being built at the Soviet Serpukhov Laboratory. The 21 km tunnel is expected to be complete in 1990.

SERPUKHOV
UNK underway

The 'Accelerator and Storage Complex' (better known by its Russian initials, UNK) at Serpukhov, USSR, advanced with some 3 km of tunnelling completed in 1986 and a number of superconductiong magnets successfully tested.

The initial plans for UNK are to build a conventional magnet ring to reach 600 GeV (400 GeV in the storage ring mode) and a superconducting magnet ring to reach 3 TeV. This complex will be fed by the existing 76 GeV proton synchrotron currently providing 10^{13} protons per pulse and being upgraded to 5×10^{13}.

The two rings will be located in the same tunnel, with the conventional ring above the superconducting, so that collisions between vertically crossing proton beams can be obtained. Alternatively the storage of antiprotons also in the 3 TeV ring (space has been left available in the site design specifically for the possible addition of an antiproton accumulator) would obviously allow proton-antiproton collisions up to a combined energy of 6 TeV.

Several 6 m superconducting magnets of the warm-iron Fermilab Tevatron type have been built and tested. They trained rapidly to 6.2 T with good field quality; this is comfortably above the design value of 5 T. The cold-iron solution, such as is being used at DESY for HERA, is being considered with the particular aim of reducing the heat load. This could enable the

Superconducting magnets for UNK under test.

(Photos Serpukhov)

refrigeration system (consisting of a central plant and 24 2 kW satellite stations) being installed for the initial stage of the project, to cater also for a second 3 TeV ring. There is room to install this additional ring in the same tunnel.

Superconducting magnet construction and testing will be done at Serpukhov, while the conventional magnets will be built in Leningrad. It is intended to install 100 superconducting magnets in the machine tunnel for tests of the refrigeration and quench system before carrying on with the production of the 2000 magnets needed for the full ring.

Civil engineering work has included a lot of site clearance and it is hoped to complete a further 6 km of the tunnel this year. The completion of the tunnel, 21 km in circumference, is scheduled for 1990 and first beams are expected in 1993.

Some control equipment for UNK magnets has been developed by the French Saclay Laboratory, and negotiations are underway to extend this collaboration.

ARGONNE
Accelerator research

As a large multipurpose research organization, one notable achievement of the Argonne National Laboratory in its 40 year history has been the development and construction of prototypes of most of the major fission reactor types now used for power generation in the United States and throughout the world.

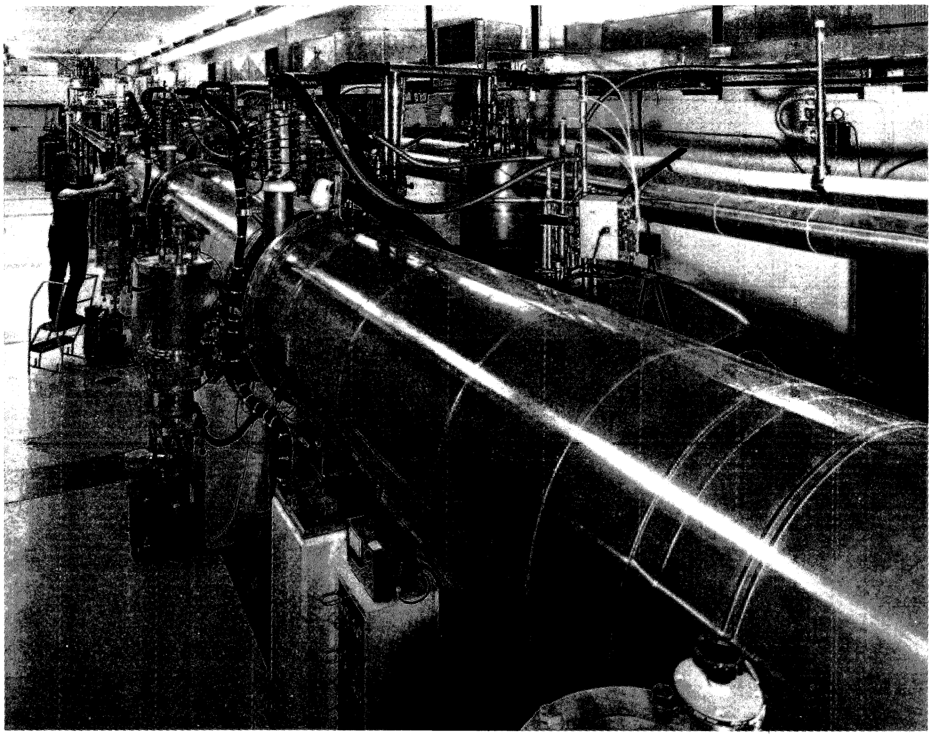
In nuclear physics, the outstanding accelerator activity for the last decade has been the development of the superconducting heavy ion facility, ATLAS (Argonne Tandem Linear Accelerator System), the first stage of which came into operation in 1982. It consists of a 9 MV electrostatic tandem followed by two stages of superconducting linac. Heavy ion beams ranging from lithium-7 to iodine-127 are accelerated, with energies up to 25 MeV per nucleon. The first beam was produced through the full system in April 1985.

The group under Lowell Bollinger that developed and built the machine are now embarked on an upgrade project to be built in phases over the next four or five years. It will increase the beam intensity for the present ions by two orders of magnitude and will also allow the acceleration of heavier nuclei, up to uranium.

Another operating accelerator that supports a major user community is the 500 MeV rapid cycling proton synchrotron at the heart of the Intense Pulsed Neutron Source (IPNS). This recently celebrated its fifth year of operation. The synchrotron was originally built as an injector to the 12 GeV Zero Gradient Synchrotron, closed in 1979.

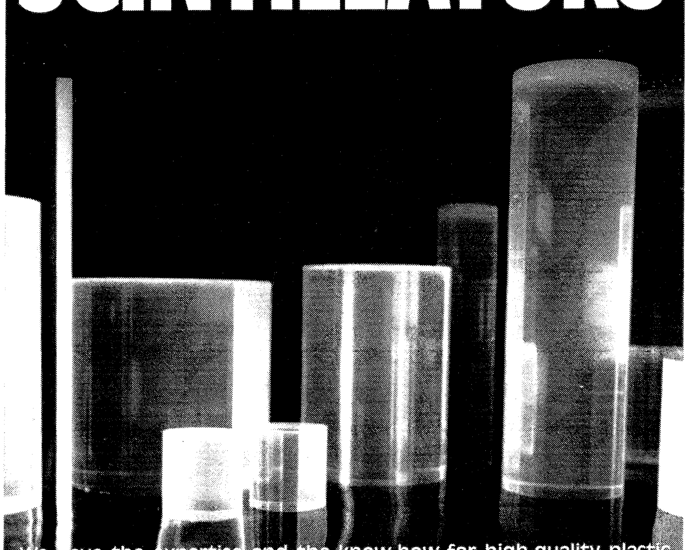
Until the ISIS machine at the Rutherford Appleton Laboratory (UK) and the PSR (Proton Storage Ring) at Los Alamos National Laboratory come into full operation, the IPNS system will remain the world's workhorse producer of proton-generated spallation neutrons. Since May 1981, it has delivered 1.8 x 10^9 beam pulses to a uranium neutron generation target with very high reliability.

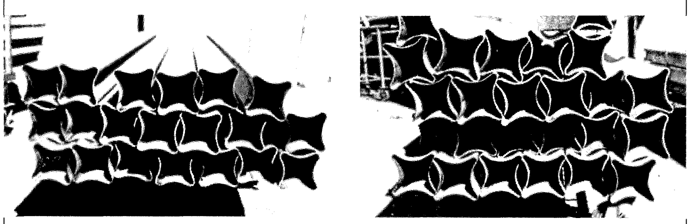
In the High Energy Physics Division a group, led by Jim Simpson and Sandro Ruggiero, is in the early commissioning stage of an experimental wake field accelerator using both solid linac structures and

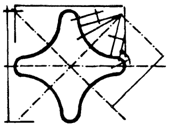


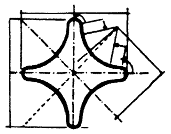
The superconducting ATLAS — Argonne Tandem Linear Accelerator System — now supplying a wide range of ions at energies up to 25 MeV per nucleon.

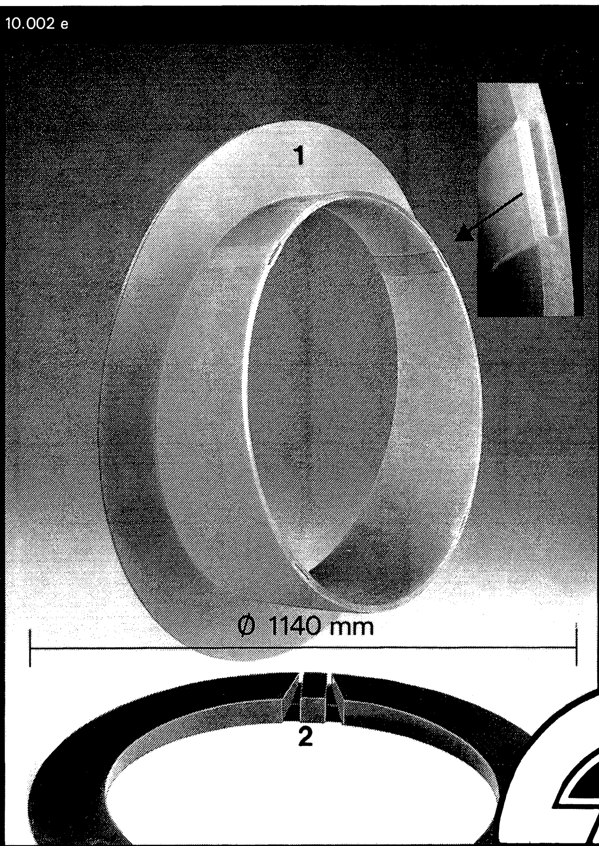
(Photo Argonne)







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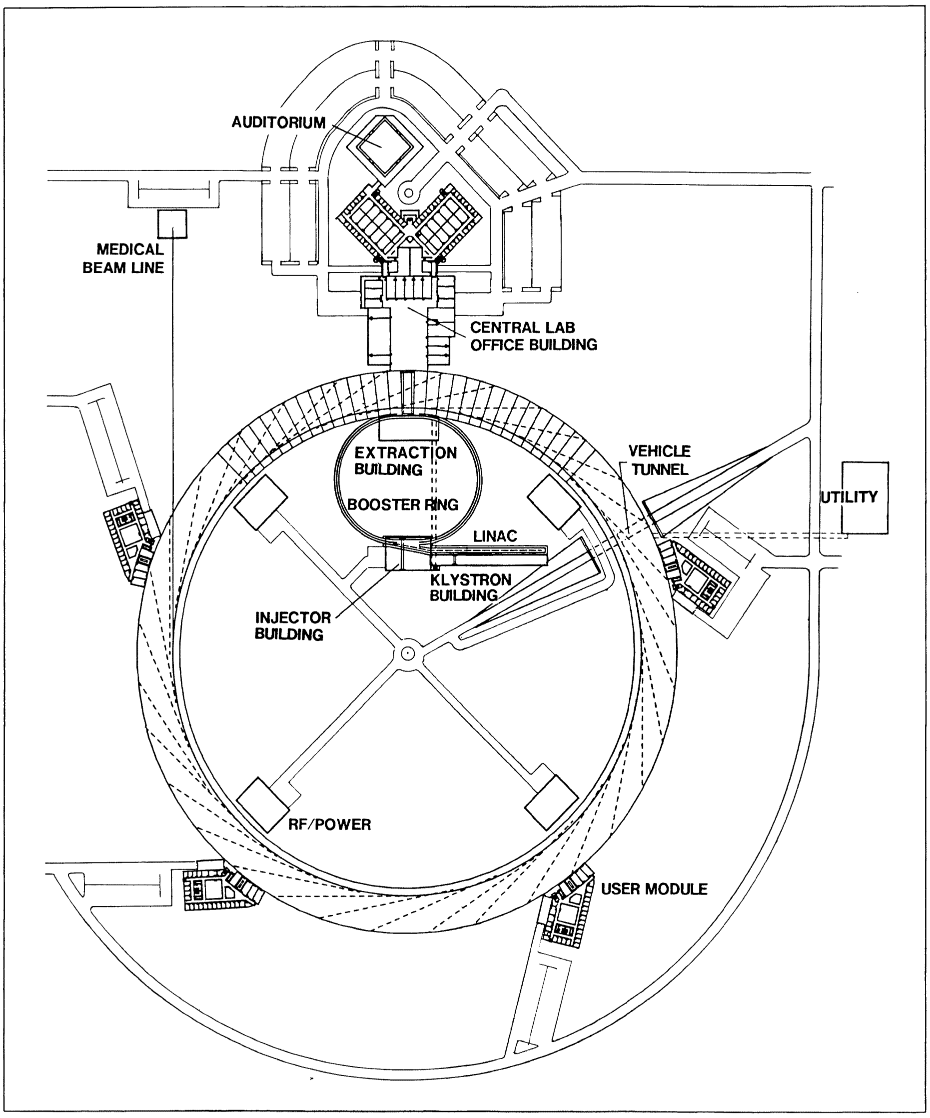
The Advanced Photon Source, a 7 GeV positron storage ring project at Argonne to provide for future synchrotron radiation requirements.



plasmas. It is based on a 20 MeV electron linac operated by the Chemistry Division, currently producing very short (30 psec) pulses of electrons, each containing 10 nanocoulombs of charge with a repetition rate up to 800 Hz. After the intense 20 MeV pulse excites the cavity or plasma, a following lower energy (15 MeV) beam will be accelerated by the fields set up by the primary pulse. Commissioning of the system began in November 1986, with the first experiments imminent.

A major new project centres on the design and construction of a unique synchrotron radiation source. A dedicated positron storage ring with a nominal energy of 7 GeV has been designed by a group under the leadership of Yang Cho. Designed solely for research using synchrotron light, the Advanced Photon Source will provide optimized beams of X-rays with spectra extending up to tens of keV.

It starts with a high current 200 MeV electron linac to produce positrons from a target. The positrons are then accelerated to 450 MeV and injected into a synchrotron to take the positron beam to full energy for transfer to the storage ring. This ring is designed to store about 100 mA of positrons with a beam lifetime of 15 hours. Positrons rather than electrons are used since the stored beam will then not trap positive ions from the residual gas in the vacuum chamber. The storage ring has a circumference of 1000 m and can provide up to 60 secondary beams. 28 of the 32 straight sections can be equipped with insertion devices and all 32 bending magnets will give useful fluxes of X-rays.

The storage ring optics are designed for a low emittance positron beam which will meet the requirements of the undulators and beam wigglers. As a result, the brilliance is much higher than is possible when the insertion device is retrofitted into an existing ring.

A modification of the Chasman-Green magnet lattice has been chosen. The dynamic aperture can be kept large by proper adjustment of the sextupoles in the dispersion-free straight sections. A similar lattice is used in the lower energy National Synchrotron Light Source at Brookhaven, and has the advantage that it can be initially operated detuned to give less sensitivity to magnet errors, but at the expense of emittance. As the machine optics are better understood, the tune can be tightened.

The design of the $375 M facility is being completed and detailed engineering work is also underway. Construction could start in 1988 with completion in 1992, providing a vigorous research programme at Argonne well into the next century.

From Malcom Derrick

European medical accelerator initiative

Last November CERN played host to a group of medical practitioners, radiobiologists and accelerator engineers meeting to institute a feasibility study of the *EU*ropean *L*ight *I*on *M*edical *A*ccelerator project (EULIMA). The project will bring together the joint resources of several European teams from Belgium, France, Germany, Italy and the United Kingdom to design and build a particle accelerator for cancer treatment.

The project proposal was the outcome of a meeting in October 1985 of the European Organization for Research and Treatment of Cancer at Nice. A preliminary EULIMA meeting at CERN in March 1986 defined the project aims and examined the possibility of carrying out a feasibility study. A request for funding has been made to the European Communities.

EULIMA's key concept consists of introducing the advantages of light ion treatment into an operational medical facility. The accelerator incorporates an existing compact cyclotron used for neutron and proton therapy in the 60 MeV energy range (like MEDICYC at the Centre Antoine Lacassagne in Nice, or CYCLONE at the Centre de Recherches du Cyclotron in Louvain-la-Neuve, Belgium) and a booster to raise the energy of the particles injected from the cyclotron to the energy needed for radiotherapy, of the order of several hundred MeV/nucleon. It will be fitted with an external ion source, like OCTOPUS developed at Louvain-la-Neuve, capable of producing fully stripped light ions.

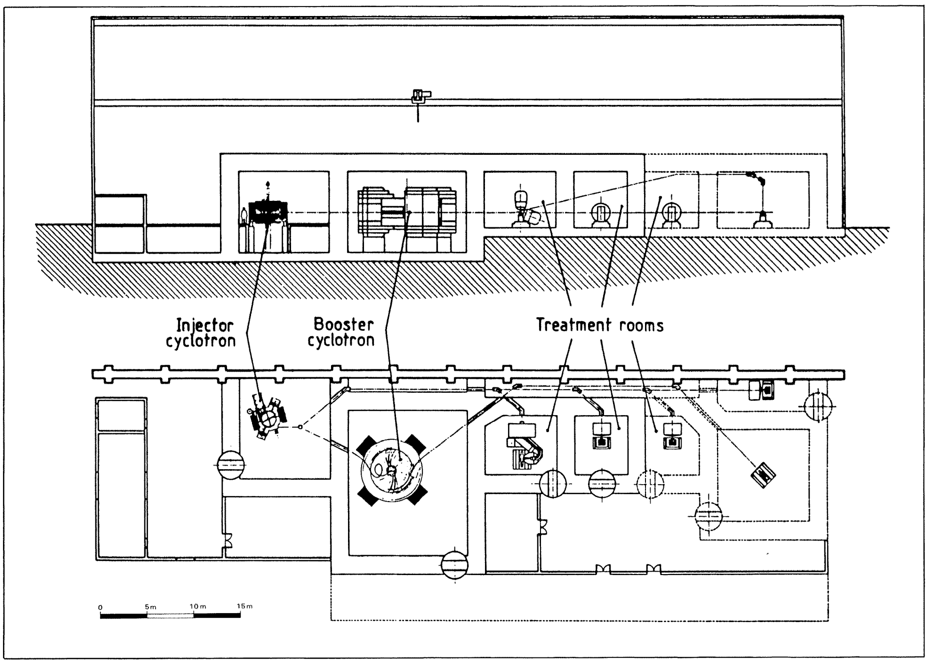
The performance of the post-accelerator has been specified with neon ions as the reference particles at about 500 MeV per nucleon.

Preliminary studies have shown that a machine of suitable size for use in a hospital should have four separate treatment rooms, with a single circular superconducting coil to reach the required energy.

Following the pioneering work of the Bevalac biomedical group at Berkeley, it is now recognized that high energy light ions have two advantages for therapeutic purposes over the more conventional types of radiation: by using the Bragg peak it is possible to concentrate the dose very accurately in the tumour volume; and the biological efficiency is higher and the radiosensitivity of the irradiated cells is less dependent on their oxygen concentration. Thus EULIMA will give priority to local healing in the treatment of cancer tumours by working on the initial tumour and its satellite ganglions.

On recognizing these advantages a series of biomedical experiments was carried out at the Bevalac. Proposals for light ion biomedical accelerators designed for clinical treatment have been made by the National Institute of Radiological Sciences at Shiba in Japan (this proposal has received funding) and at Berkeley (LIBRA, the Light Ion Biomedical Research Accelerator). A proposal for adding a medical facility to the Heavy Ion Synchrotron at GSI (Darmstadt) is in preparation.

The Antoine-Lacassagne Centre in Nice and the Cyclotron Research Centre at Louvain-la-Neuve are already committed to the EULIMA project. Other European research centres and laboratories have expressed their interest. It is thus the aim of the EULIMA project to provide a powerful new weapon to continue the fight against cancer. (Other projects are underway in the US, see December 1986 issue, page 5.)



Proposed layout of the EULIMA European Light Ion Medical Accelerator project.

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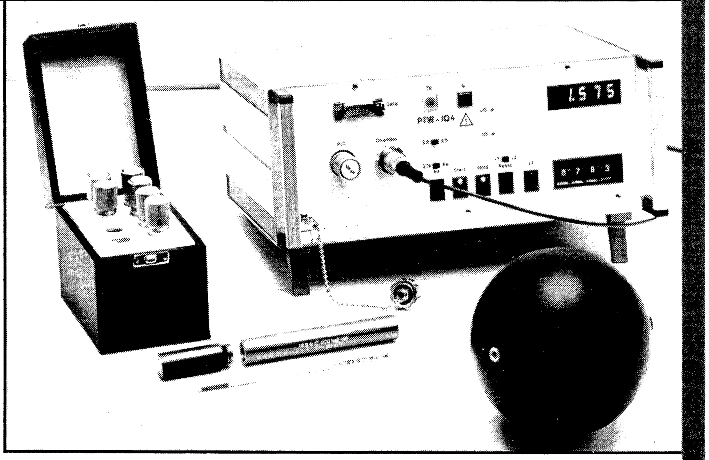

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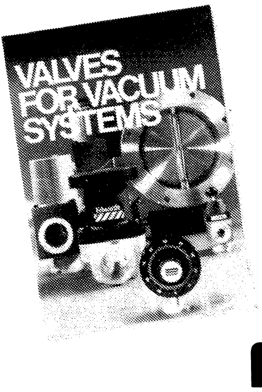

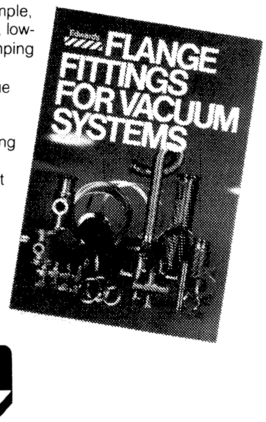

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DATA COMPILATION Protocol signed

CERN and other high energy Laboratories produce enormous quantities of data and results. The main results are written up and published; reviewers, conference rapporteurs and textbook authors compile them and present them in a digested form. But much experimental data is so voluminous and indigestible that it escapes this process.

Even though they are very important, specific reaction rates (cross-sections) are of this type. Recognizing the need to present as many results as possible, an informal international organization has gradually evolved and has been recognized officially by a protocol signed in 1986 between CERN, representing Western European groups, and the Soviet Union.

Compilations of many interaction cross-sections started in 1966 when Douglas Morrison made a study of two-body cross-sections for a conference in Stony Brook. The aim was to derive physics insight from the data (the cross-sections decreased with momentum by a power law and the power was dependent on the quantum numbers exchanged). So as not to waste this data compilation, other physicists were invited to join and an organization to compile cross-section data was set up in 1967. It was named HERA for High Energy Reaction Analysis. Several people agreed to compile different types of reaction. To allow easy access, the compilations have been issued in book form as CERN-HERA reports, and about a dozen reports plus updates have been issued. An agreement was made with the Particle Data Group, set up by Art Rosenfeld and based in Berkeley, to share the publication of HERA cross-section compilations and PDG compilations of other data. Postal costs are reduced by Berkeley being responsible for distribution in North and South America, Australasia and the Far East while CERN serves all other areas.

The HERA group has regular meetings with other European groups and reports are given at the CODATA conferences (a UN associated organization). In the UK, differential as well as total cross-sections are compiled and with the much greater volume of data, the compilation is made available to the community through a computer network — further information and details on how to access the data can be obtained from Mike Whalley at Rutherford or Durham. At Serpukhov (USSR) a strong theory group began collecting cross-section data and has set up the COMPAS organization. For some time tapes have been exchanged between the HERA, COMPAS and UK organizations and in 1986 this was formalized in a protocol signed by CERN and by the USSR. The coordinator of the work of this joint organization is Vicenzo Flaminio of Pisa. Groups at Bologna, CERN, Durham, ITEP (Moscow), Pisa, Rutherford and Serpukhov are members.

By Douglas Morrison

CERN makes history

A thriving international Laboratory with over thirty years of history and tradition behind it can look to the past as well as to the future. The first volume of an authoritative two-volume history about the creation and early years of CERN, published in February, traces the events leading to the coming into force of the Convention establishing the Laboratory in 1954.

A team of European historians began work on the CERN History towards the end of 1982 following the initiative of Gunther Lehr, Federal Germany's delegate in the CERN Committee of Council. The historians are led by Armin Hermann, Professor of the History of Science and Technology at Stuttgart, and included John Krige from the UK, Ulrike Mersits from Austria, and Dominique Pestre from France, helped part-time by Lanfranco Belloni from Italy and Laura Weiss from Switzerland. At CERN, Alfred Gunther helped the study along while Roswitha Rahmy and Yves Felt provided invaluable help from the CERN archives. The project also benefited from input from an Advisory Committee chaired by P. Levaux.

The two main threads in the lead-up to the creation of CERN — the physics and the politics — are reflected in the first volume of the CERN History, with a wealth of information.

Preparing the way

The historians outline the formative years: 'Towards the very end of 1949, in the aftermath of President Truman's announcement of the explosion of the first Soviet atomic bomb, several personalities associated with nuclear matters in Europe began to think seriously about the possibilities for multinational co-operation in this area. The most important of the first initiatives was that of Raoul Dautry, Administrator-General of the French Commissariat à l'Energie Atomique. At the European Cultural Conference in Lausanne in December 1949 he had a resolution passed recommending that studies be undertaken for the creation of a European institute for nuclear science 'directed towards applications in everyday life'. Six months later Isidor I. Rabi, American Nobel prizewinner and co-founder of the Brookhaven National Laboratory, put a resolution to the annual conference of UNESCO. It invited the states who so wished to create one or more regional European laboratories, including one in nuclear science. This was adopted by the General Assembly on 7 June 1950.

Two small groups took up these proposals in the following months. One comprised a handful of specialists in classical nuclear physics (people like Kowarski in France or Preiswerk in Switzerland), or in cosmic rays (most notably, of course, Amaldi in Italy and Auger in France, the latter also being Director of UNESCO's Department of Exact and Natural Sciences). The other group was composed of three important administrators of science — Raoul Dautry, Gustavo Colonnetti (who was President of the Italian Consiglio Nazionale delle Ricerche), and Jean Willems (Director of the Belgian Fonds National de la Recherche Scientifique). In December 1950 a first gathering of scientists and administrators organized by Auger and Dautry at the seat of the Centre Européen de la Culture in Geneva proposed that the biggest accelerator in the world (i.e. about 6 GeV) be constructed. A reactor was ruled out for political reasons, notably the problems posed by industrial applications and military interests.

In May, October, and November of the following year (1951) Auger, along with a number of scientific consultants, further refined the project advocated in Geneva. In December 1951 their recommendations were submitted to a European intergovernmental conference officially called by UNESCO, but in fact orchestrated by Auger himself. After lengthy discussions which reflected serious differences of opinion among scientists, the conference proposed that a provisional organization be established. It was endowed with $200 000 and given 18 months to present potential member states with worked out technical, organizational, and financial plans. The formal Agreement embodying these proposals was signed on 15 February 1952 by all those present, with the exception of the United Kingdom. Early in May, with the $200 000 guaranteed, and five signatures ratified, the Agreement entered into force.

On 5 May 1952 the provisional Council met for the first time. The technical groups to design the accelerators and plan the laboratory were set up. In October Geneva was adopted as the site for the laboratory, and it was decided to construct a 25-30 GeV proton synchrotron embodying the new alternating-gradient principle. This meant that a research and development effort — with its associated risks — was needed, and that the machine would take some five or six years to build. In January 1953 the British government was represented officially in the Council for the first time, and the

Previously unpublished photographs showing many of CERN's founders gathered for the Third Session of the provisional CERN Council in Amsterdam on 4 October 1952. (Photos Lindeman, Amsterdam)

discussion of the text of the Convention establishing the permanent organization began in earnest. On 1 July 1953 this Convention was signed by eight of the eleven member states of the provisional CERN and by the United Kingdom.

A period of waiting ensued. The last two ratifications needed for the Convention to enter into force were deposited some 15 months later on 29 September 1954. During the hiatus much was done: around October 1953 the group designing the big accelerator was installed in Geneva, and an embryonic administrative structure was set up; from January to March 1954 protracted and complex negotiations around the top post of Director-General led to the nomination of Felix Bloch in April; in May excavation work began on the site at Meyrin. In summary, during the 15-month interim period, the organization asked for, and got, 9.2 million Swiss francs from the member states, the scientific groups expanded steadily (numbering some 120 people gathered from all over Europe in September 1954), and the work proceeded to such an extent that, when the Council of the permanent organization first met on 7 October 1954, it was asked to approve the award of major building and technical contracts.'

Interpreting the motivation for CERN

The 'standard model' of the motivations behind these events is that the physics community's requirements for fundamental research outstripped national financing, and that, in consort, receptive politicians were looking for ways to rebuild war-torn Europe.

The historians agree that, as a first approximation, these motivations were widely at work in the creation of CERN. They illustrate, however, that the physicists were far from unanimous in their vision of the best path to follow, and the pro-European spirit amongst politicians was not as widespread as has been maintained. There were 'several groups of actors, several forces at work, each having its own interests' and there was an 'element of conjunctural coincidence involved in the birth of the Organization'.

The concluding chapter summarizes how these diverse interests were gradually reconciled so that the viewpoint of Edoardo Amaldi and Pierre Auger amongst the scientists, and of Gustavo Colonnetti, Raoul Dautry and Jean Willems amongst the politicians, eventually prevailed. The authors also deal with the aims of the American support for the new European Laboratory and discuss some early perceptions of CERN as a potential source of directly exploitable discoveries.

This first volume is a scholarly study comprising some 550 pages. A second volume, on the years of the Proton Synchrotron construction and operation, through to the authorization for the Intersecting Storage Rings, will be published in about a year. A condensed 'popular' edition will also be prepared. 'Launching the European Organization for Nuclear Research' is published by North Holland Physics Publishing, a division of Elsevier Science Publishers, P.O. Box 103, 1000 AC Amsterdam, The Netherlands. The sole distributor for the USA and Canada is Elsevier Science Publishing Company, 52 Vanderbilt Avenue, New York, NY 10017, USA.

The CERN history project has been supported financially by the Austrian Foundation for the Advancement of Scientific Research; Centre National de la Recherche Scientifique, France; Consiglio Nazionale delle Ricerche, Italy; Danish Natural Science Research Council; Federal Ministry for Science and Research, Austria; Istituto Nazionale di Fisica Nucleare, Italy; Joint Committee of the Science and En-

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Applications must be returned by 27th March 1987

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The facilities, like in the past, are operated primarily to develop new radiation source characteristics leading to new research findings and methods. These goals provide a dedicated and experienced accelerator physicist with exciting opportunities to develop state-of-the-art synchrotron radiation sources in a combination of theoretical as well as experimental activity.

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Associate Director
Stanford Synchrotron Radiation Laboratory
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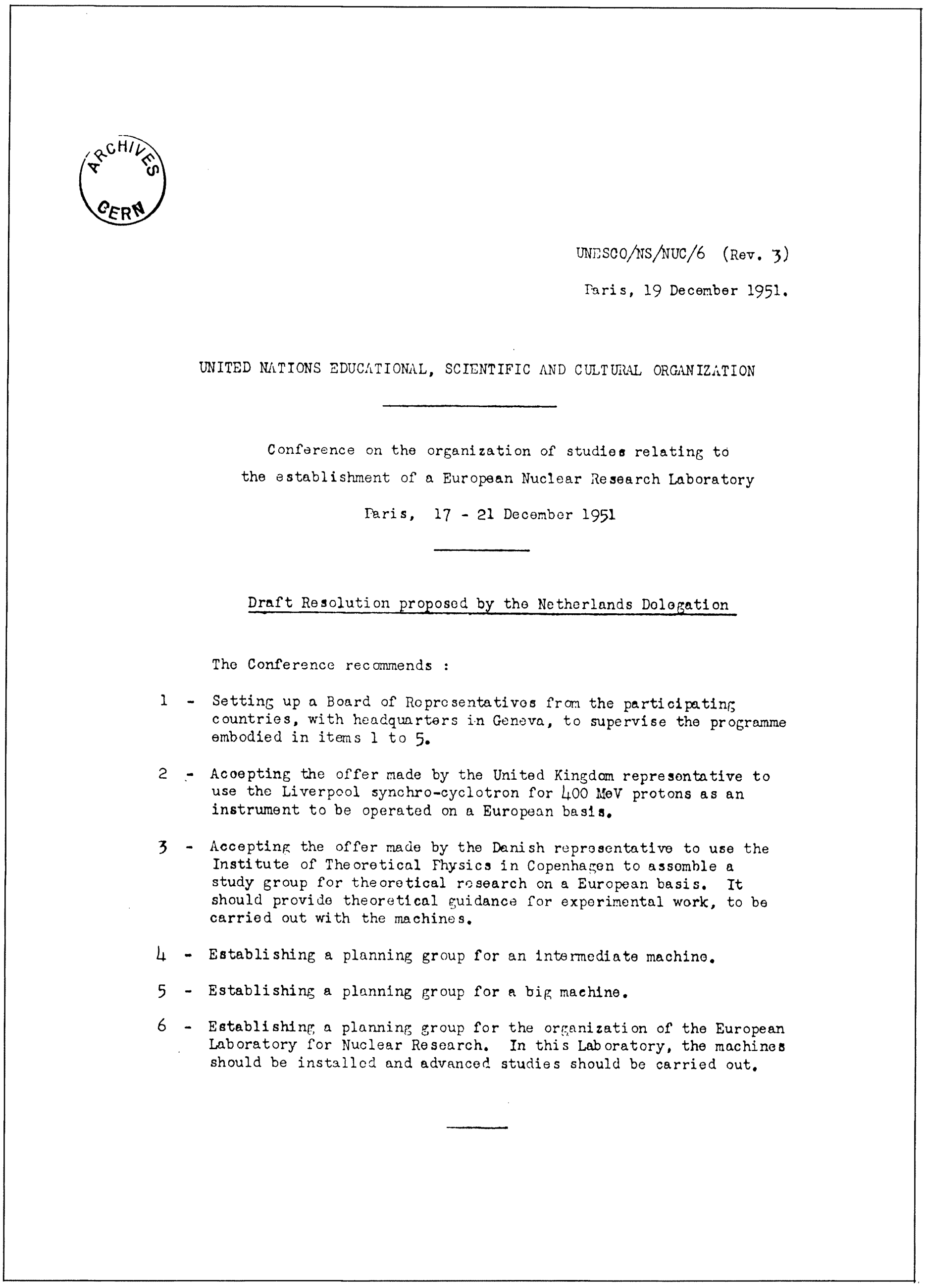
FRANCE

Opposing points of view amongst scientists gathered at the intergovernmental conference in Paris in December 1951 risked undermining the progress towards a European Laboratory. It was this Resolution, proposed by the Dutch delegation, which saved the day by offering something to all parties.



UNESCO/NS/NUC/6 (Rev. 3)

Paris, 19 December 1951.

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

Conference on the organization of studies relating to
the establishment of a European Nuclear Research Laboratory

Paris, 17 - 21 December 1951

Draft Resolution proposed by the Netherlands Delegation

The Conference recommends :

1 - Setting up a Board of Representatives from the participating countries, with headquarters in Geneva, to supervise the programme embodied in items 1 to 5.

2 - Accepting the offer made by the United Kingdom representative to use the Liverpool synchro-cyclotron for 400 MeV protons as an instrument to be operated on a European basis.

3 - Accepting the offer made by the Danish representative to use the Institute of Theoretical Physics in Copenhagen to assemble a study group for theoretical research on a European basis. It should provide theoretical guidance for experimental work, to be carried out with the machines.

4 - Establishing a planning group for an intermediate machine.

5 - Establishing a planning group for a big machine.

6 - Establishing a planning group for the organization of the European Laboratory for Nuclear Research. In this Laboratory, the machines should be installed and advanced studies should be carried out.

gineering Research Council and the Social Science Research Council, United Kingdom; LK-NES Foundation, Denmark (private industry); Netherlands Organization for the Advancement of Pure Research (Z.W.O.); Norwegian Research Council; République et Canton de Genève, Département de l'Instruction Publique; University of Milan, Italy; Volkswagen Foundation, Federal Republic of Germany.

People and things

On people

Theoretician Julius Wess of Karlsruhe has been awarded a Leibnitz Prize and the prestigious Max Planck Medal of the German Physical Society. This is partly in recognition of work on supersymmetry carried out at CERN in collaboration with Bruno Zumino.

Another Leibnitz Prize recipient is Albert Walenta of Siegen for his landmark contributions to the development of particle detectors, especially the drift chamber. The Leibnitz prizes are awarded by the Deutsche Forschungsgemeinschaft to stimulate and encourage frontier research.

Gerson Goldhaber of the University of California and the Lawrence Berkeley Laboratory has been presented with an honorary doctorate by the University of Stockholm. Goldhaber is currently visiting CERN, where he is collaborating in the UA1 experiment at the proton-antiproton Collider.

American Physical Society Awards

After being attributed the Enrico Fermi Award (together with the late Stanley Livingston) by the US Department of Energy, Ernest Courant of Brookhaven has been nominated as the first recipient of the new Robert R. Wilson Prize of the American Physical Society. The award comes in recognition of Courant's role in the invention of the strong focusing technique, and for his work in beam dynamics. It will be presented at the APS Spring Meeting.

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Professor Alex Dzierba
Chairperson,
Search and Screen Committee
Indiana University,
Bloomington,
IN 47405.

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An error was made in last month's advertisement. This position is not associated with the Indiana University Cyclotron Facility.

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Send applications and requests for further information to:

Prof. Nicola CABIBBO,
President National Institute
of Nuclear Physics (INFN)
Casella Postale, 56
00044 FRASCATI (Roma) ITALY.

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We seek an individual with technical expertise and aptitude, good judgment, and good management skills. Two (2) years of experience in management at a large-scale accelerator or similar highly technical facility is highly desirable. Minimum qualifications include an undergraduate degree in engineering or physical science. This is a full-time position on the UIUC academic professional staff. Salary will be competitive, depending on training and experience. The starting date is Spring of 1987. For full consideration, applications should be received by April 1, 1987. Interviews may take place prior to the applications deadline; no final decision, however, will be made until after that date.

For technical information, contact Prof. Robert A. Eisenstein, Nuclear Physics Laboratory, University of Illinois at Urbana-Champaign, 23 Stadium Drive, Champaign, Illinois 61820. Telephone # 217 / 333-3190.

To apply, please send resumes and the names of three references to: **Mr. Raymond F. Borelli (NFOM).**
Department of Physics,
University of Illinois at Urbana-Champaign,
1110 West Green Street,
Urbana, Illinois 61801.
Telephone # 217 / 333-0570.

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Bernard Frois of the Centre d'Etudes Nucléaires de Saclay and Ingo Sick of Basle have been named recipients of the 1987 Tom W. Bonner Prize 'For their elegant studies of nuclei using high energy electron scattering. In particular, their precision measurements of nuclear charge and current densities have offered novel perspectives on ground states and valence orbitals. Their studies of few-nucleon systems have demonstrated the need for subnucleon degrees of freedom in a complete description of the nucleus. This body of work has provided firm benchmarks against which to test our understanding of the nuclear many-body problem.'

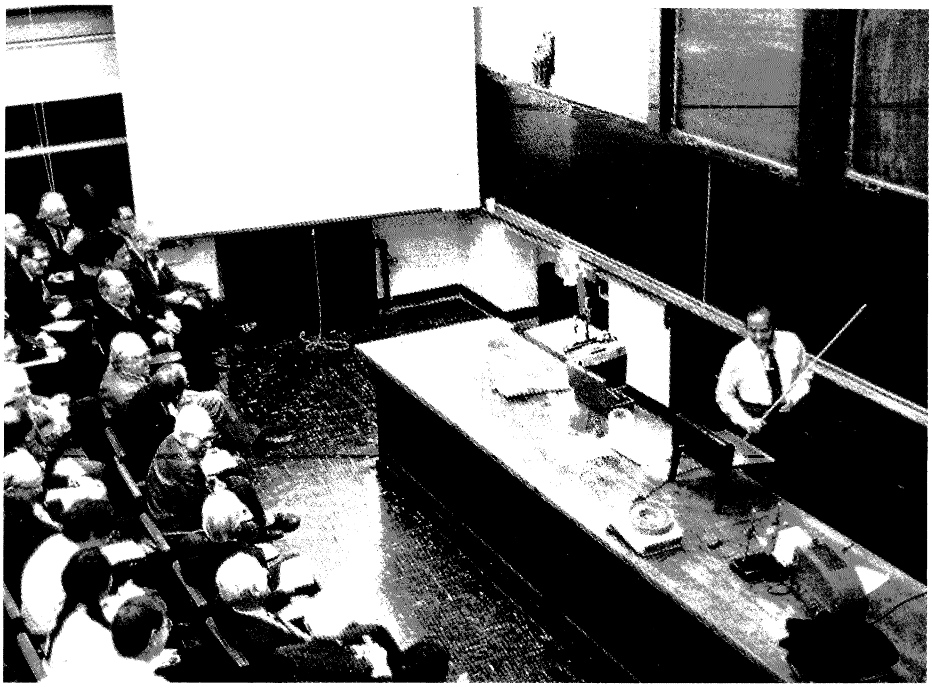
R. Baxter of the Australian National University has been named recipient of the 1987 Dannie Heineman Prize for Mathematical Physics 'For his novel use of mathematical analysis to solve in exact analytical form problems of fundamental importance in statistical mechanics relating directly to cooperative phenomena, phase transitions and quantum field theory.'

John Iliopoulos of Ecole Normale Supérieure and Luciano Maiani of Rome have been named recipients of the 1987 J. J. Sakurai Prize 'For their work on the weak interactions of charmed particles, a crucial step in the development of the modern theory of the fundamental interactions.'

Louise Dolan of Rockefeller University has been named recipient of the 1987 Maria Goeppert-Mayer Award 'For her work on the theory of elementary particles, particularly for the identification and study of Kac-Moody algebras and their applications to Yang-Mills fields and relativistic string theory.'

T. D. Lee - 'Happiness is when old friends come from far away'.

(Photo M. Jacob)



T. D. Lee Symposium

A symposium to celebrate the sixtieth birthday of T. D. Lee and to commemorate the thirtieth anniversary of the discovery of parity (left-right symmetry) nonconservation was held at Columbia in November. A distinguished lineup of speakers and chairpersons reflected T. D. Lee's physics interests and background. His own speech was poignantly entitled 'Happiness is when old friends come from far away'.

Protvino workshop

Last year's traditional annual summer Workshop on High Energy Physics and Field Theory was held in Protvino near Serpukhov, USSR, under the sponsorship of the Institute for High Energy Physics.

The wide range of items and highly informal atmosphere at the summer Protvino workshops always attract participants not only from Soviet institutions but also from abroad.

This time the Workshop started with the superstring theories (Bonora, Perelomov, Pron'ko, Isaev et al.), then proceeded through classical (Logunov et al.) and quantum gravity cosmological aspects of the field theory (Abbott, Tkachev et al.), theory and phenomenology of supersymmetry (Volkov, Zinoviev et al.), composite models (Pirogov, Farhi, Andrianov et al.) and finished with numerous discussions in soft and hard quantum chromodynamics, including nuclear aspects and quark-gluon plasma (Arbuzov, Matveev, Petrov, McLerran, Levin, Smirnov et al.). In total more than 50 talks were presented.

Future Protvino summer meetings hope to retain the fortunate combination of theoretical ideas and front line phenomenology.

(From V. A. Petrov)

UNIVERSITY OF OXFORD

Department of Nuclear Physics

Appointment of Research Officer and Postdoctoral Research Associates

Applications are invited for the above posts from experimental physicists who hold a Ph D degree. The research programme of the Department includes:

- Experiments at the Nuclear Structure Facility, Daresbury
- Determination of neutrino mass using tritium beta-decay
- Solar neutrino detection
- Proton decay (Soudan II)
- Preparation for the DELPHI experiment at LEP (CERN) and the ZEUS experiment at HERA (DESY)
- Development of cryogenic detectors for dark matter searches
- Development of precision proton microprobe and applications in material sciences, medicine, earth and biological sciences

The appointments will be for three years in the first instance, and salary will be on the University Lecturer scale for the Research Officer (£8,020 to £16,760) and the Research Support Grade 1 A scale (£8,020 to £12,780) for the Research Associates. Both scales are currently under review, and starting salaries will be according to age and experience.

Applications with a Curriculum Vitae, statement of research interests and the names and addresses of two referees should be sent to:

Mr. A. Jones,
General Administrator,
Department of Nuclear Physics,
Keble Road,
Oxford OX1 3RH

by 28 March 1987.

Continuous Electron Beam Accelerator Facility

ACCELERATOR SCIENTISTS

Located in Newport News, Virginia, the CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY (CEBAF) is building a 4 GeV high intensity, continuous beam electron accelerator for nuclear physics research. This machine will be a 4-pass recirculating electron linac utilizing superconducting RF technology and will provide a beam of exceptionally low emittance and energy spread. Acceleration will be provided by 418 five-cell, 1.5 GHz superconducting cavities, each fed with $\leq$ 5 kW average RF power. The Accelerator Physics Division of CEBAF has staff positions at various levels for accelerator scientists with expertise in the following:

- **accelerator operations**
- **magnet design**
- **injector design**
- **transport optics and beam dynamics**
- **RF and feedback**
- **instrumentation and control**
- **collective effects**
- **E&M calculations and cavity design**
- **computer simulation**

Interested applicants should submit a curriculum vitae, list of publications and three professional references to:

Personnel Director
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18-year old Janne Wallenius wins the 48 000 Swedish kronor (about 12 000 Swiss francs) jackpot in the Swedish TV programme 'Quits or Doubles' answering questions on particle physics.

(Photo Pressens Bild AB)

Saturday night physics fever

Towards the end of last year, over four million Swedes sat glued to their TV sets four Saturday nights in a row to follow the progress of 18-year old Janne Wallenius who eventually walked off with the 48 000 Swedish kronor (about 12 000 Swiss francs) jackpot in 'Quits or Doubles', the nation's most popular TV series, after bravely battling with questions on particle physics.

On his way to the big money Janne had to negotiate a tricky sequence of questions, compiled by Sverker Fredriksson of Stockholm's Royal Institute of Technology, concluding with a six-part grilling on the discovery of the W and Z carriers of the weak nuclear force (not yet in most of the textbooks).

Janne's performance and the courage of Swedish TV in taking up such a 'difficult' topic were widely applauded in both the press and in the universities. In addition to the cash came invitations to visit CERN and other major world Laboratories.

Meetings

The 1987 International Cryogenic Materials Conference and Cryogenic Engineering Conference will be held from 14-18 June at St. Charles, Illinois, hosted by nearby Fermilab. The seventh joint meeting of its kind, it is a multidisciplinary event with contributions from materials scientists, metallurgists, physicists and engineers. Further information from W.B. Fowler, Fermi National Accelerator Laboratory, PO Box 500, MS 347, Batavia IL 60510, USA.

UNIVERSITY
OF
GENEVA

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

RESEARCH ASSOCIATE

(maître-assistant)

to join a group participating in the L3 experiment at LEP. The candidate must have a Ph. D. or equivalent experience in high energy physics.

This is a non permanent position limited to a maximum of 6 years.

Applications should be sent before April 15 to:

Prof. E. Heer, Director
of Département de physique
nucléaire et corpusculaire
24, quai Ernest-Ansermet
CH - 1211 Geneva 4
Switzerland

UNIVERSITY
OF TORONTO

The Department of Physics plans to make

several tenure-stream appointments

in the next few years, of which at least one will be in Experimental High Energy Physics.

In anticipation, the Department invites applications for this position from qualified candidates for NSERC University Research Fellowships, which could begin July 1, 1988. NSERC University Research Fellows must be Canadian citizens or permanent residents. Fellows carry out research, supervise graduate students and have teaching loads comparable to starting assistant professors.

Successful candidates may in special circumstances be considered directly for a tenure-stream position as assistant professors.

Applications, consisting of a CV, list of publications, summary of research interests, a detailed research proposal, and the names of three (3) referees should be sent before June 1, 1987 to:

Professor R.E. Azuma
Chairman, Department of Physics
University of Toronto
Toronto, Ontario, Canada M5S 1A7.

CONTINUOUS ELECTRON BEAM
ACCELERATOR FACILITY
Newport News, Virginia

SUPERCONDUCTING RF TECHNOLOGY

The Continuous Electron Beam Accelerator Facility (CEBAF) is building a superconducting 4-GeV, high-intensity, continuous beam electron accelerator for nuclear physics research. This four-pass recirculating linac, the largest-scale application to date of superconducting rf technology, will produce a beam of exceptionally low emittance and energy spread. Acceleration will be provided by 418 five-cell, 1.5-GHz superconducting cavities, each fed with < 5 kW average rf power.

The Superconducting RF Technology division of CEBAF will also be engaging in an active research and development program to advance the state of the art.

The Superconducting RF Technology division has staff positions for scientists, technical associates, and engineers with expertise in the following:

- SRF technology
- superconducting cavities and cryostats- i.e. design, development, operation, and maintenance
- recirculating electron linear acceleration
- quality assurance
- designing electrical, electronic, computer, mechanical, vacuum, cryogenic, chemical, RF, and/or other new equipment

Applicants should submit a curriculum vitae, three professional references, and a five year salary history to:

Joyce Donald
Employment Manager
CEBAF
12070 Jefferson Avenue
Newport News, VA 23606

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All enquiries to:
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CH-1211 Geneva 23 Switzerland
Tel. (022) 83 41 03 Telex 2 36 98

A Topical Seminal on Heavy Flavours will be held in San Miniato, Tuscany, from 25-29 May, following a successful meeting on 'Few and Many Quark Systems' held there two years ago. Further information from Topical Seminar Secretary, Dipartimento di Fisica, Università di Bologna, Via Irnerio 46, 40126 Bologna, Italy.

An international conference marking the 40th anniversary of the discovery of the pion is being held in Bristol, UK, from 22-24 July. Further information from B. Foster, University of Bristol, H. H. Wills Physics Laboratory, Royal Fort, Tyndall Avenue, Bristol, BS8 1TL, UK.

The fifth Conference on Real-Time Computer Applications in Nuclear, Particle and Plasma Physics will be held from 11-15 May in San Francisco, preceded by a short course on Laboratory Network Systems. The Conference programme concentrates on laboratory experimental systems. Further information from Dennis W. O'Brien, Electronics Engineering Department, Lawrence Livermore National Laboratory, PO Box 5504, Livermore, CA 94550, USA.

Proca Jubilee

A special symposium at the University of Timisoara, Roumania, in November marked the 50th anniversary of the landmark contributions to the physics of vector fields by the Roumanian theoretician Alexandru Proca (1897-1955). At the meeting, prominent physicists from Timisoara, Bucharest, Brasov and Jassy described Proca's work and its implications for modern field theory.

New award

The Computer Applications in Nuclear and Plasma Sciences Technical Committee of the Nuclear and Plasma Physics Society, US Institute of Electrical and Electronics Engineers, has set up a new individual award 'for outstanding professional contributions to the profession of using computers in nuclear and/or plasma scientific research', regardless of nationality. Those interested in making a nomination can get further information from Dr. Lester Welch, Argonne National Laboratory, Physics Division 203/G-125, Argonne, Illinois 60439-4843 USA.

The Birth of Particle Physics

In May 1980, an International Symposium on the History of Particle Physics held at Fermilab traced the evolution of elementary particle physics from cosmic ray and nuclear physics during the years 1930-50, and the parallel development of relativistic quantum field theory which underpins its interpretation. This material has been carefully and imaginatively edited into a book 'The Birth of Particle Physics' by the organizers of the Symposium, Laurie M. Brown of Northwestern and Lillian Hoddeson of Urbana-Champaign and Fermilab. It is published by Cambridge University Press.

X-ray microprobe

A resolution of better than 10 microns, with a high enough intensity to measure trace concentrations of atomic elements, has been obtained using a new X-ray microprobe designed at Berkeley.

In tests at Brookhaven the new microprobe measured the concentration and spatial distribution of many elements quickly and simultaneously in a sample area of less than 100 square microns. An even higher resolution appears possible in the near future. In a 300 second counting time, picogram quantities of elements from potassium to zinc were measured.

Working at Brookhaven's National Synchrotron Light Source, the research team obtained a 10 micron by 10 micron focal spot of 10 keV X-rays, with an intensity of 100 million photons per second.The beam was focused by a pair of multilayer-coated mirrors and the characteristic spectral lines from elements in the sample were recorded by a lithium-drifted silicon detector.

The mirrors to focus the X-rays consist of standard fused-silica mirrors with alternate layers of sputtered tungsten and carbon.

Unlike electron microprobes, the new probe does not require that samples be placed in a vacuum. Consequently it permits a wider variety of samples, including living biological specimens, to be studied.

So far it has been used in a medical study to reveal the distribution of toxic concentrations of trace elements in biological tissue, and to locate internal cracks and flaws in ceramics. An experiment using the new microprobe to reveal the geological history of rocks is scheduled to get under way soon.

A spectacular illustrated journey into the subatomic world

T·H·E · P·A·R·T·I·C·L·E
E·X·P·L·O·S·I·O·N

by Frank Close · Michael Marten
and Christine Sutton

- The first major illustrated book on particle physics
- A unique collection of pictures, both historical and from the latest experiments
- A collaboration of distinguished authors
- Lengthy captions provide a detailed historical account of the course of experimental particle physics
- Comprehensible to the general reader – no mathematics is used

The Particle Explosion is a lavishly illustrated guide to the subatomic world discovered by physicists during the last hundred years. In lucid, straightforward language, the authors describe the fundamental discoveries and the developments in equipment which have led to our current understanding of the nature of matter in the Universe and the forces which govern its behaviour. And they give detailed, non-technical 'portraits' of all the major subatomic particles, from the electron, proton, and neutron, through to quarks.

The book contains almost 300 photographs of the leading personalities in the field, the increasingly vast and complex machines they use, and the striking images of tracks produced by the particles themselves. It is the first book to bring together, and to present in the style they deserve, the classic images of particle tracks produced with cloud chambers, photographic emulsions, bubble chambers, and modern electronic detectors.

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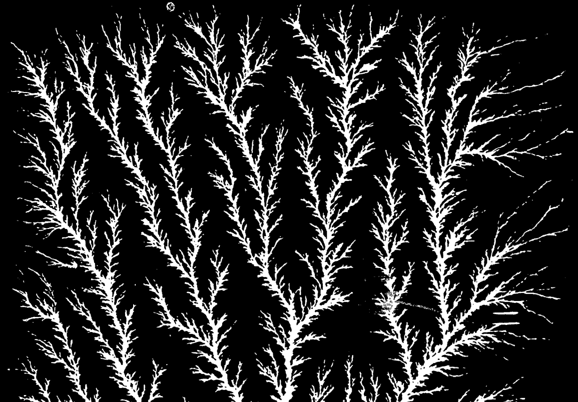
January 1987 £15



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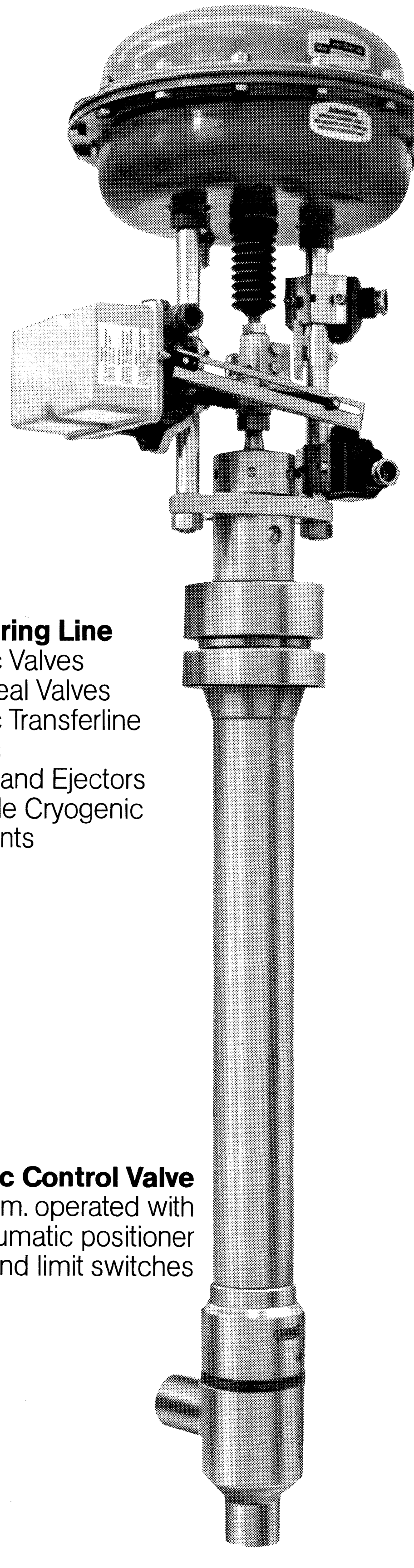

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One of the illustrations from 'The Particle Explosion' — an event from the UA1 detector at CERN's proton-antiproton Collider, showing the decay of a Z^0 into two electrons (yellow tracks).

(P. Loïez, CERN)

The Particle Explosion

Many people, even some of those involved in the field, think that particle physics is a difficult subject that delves into an invisible subatomic world, where quantum theory rules and cherished notions from everyday experience no longer hold. Some 'popularizers' of the subject even seem to encourage the idea that particle physicists are somehow losing touch with reality. Yet anyone who works at CERN, or any of the other labs, knows that particle physics is immensely practical. It involves large experiments in which physicists go to great lengths to study the reality of particle physics. A recently published book attempts to bring this reality to a wider audience.

In January, Oxford University Press published 'The Particle Explosion', *a highly illustrated account of the development of particle physics, from the work of Thomson and Rutherford in the late 19th century, to the present day. It is written by theoretician and popular lecturer and broadcaster Frank Close; Christine Sutton, well known for her physics writing, especially in* New Scientist; *and Michael Marten who runs the Science Photo Library in London.*

The book contains almost 300 photographs, many in colour, of the leading personalities in the field, the machines and apparatus they use, and many specially prepared images of particle tracks.

Electronic Mail

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

GFR. DB@GEN. BITNET

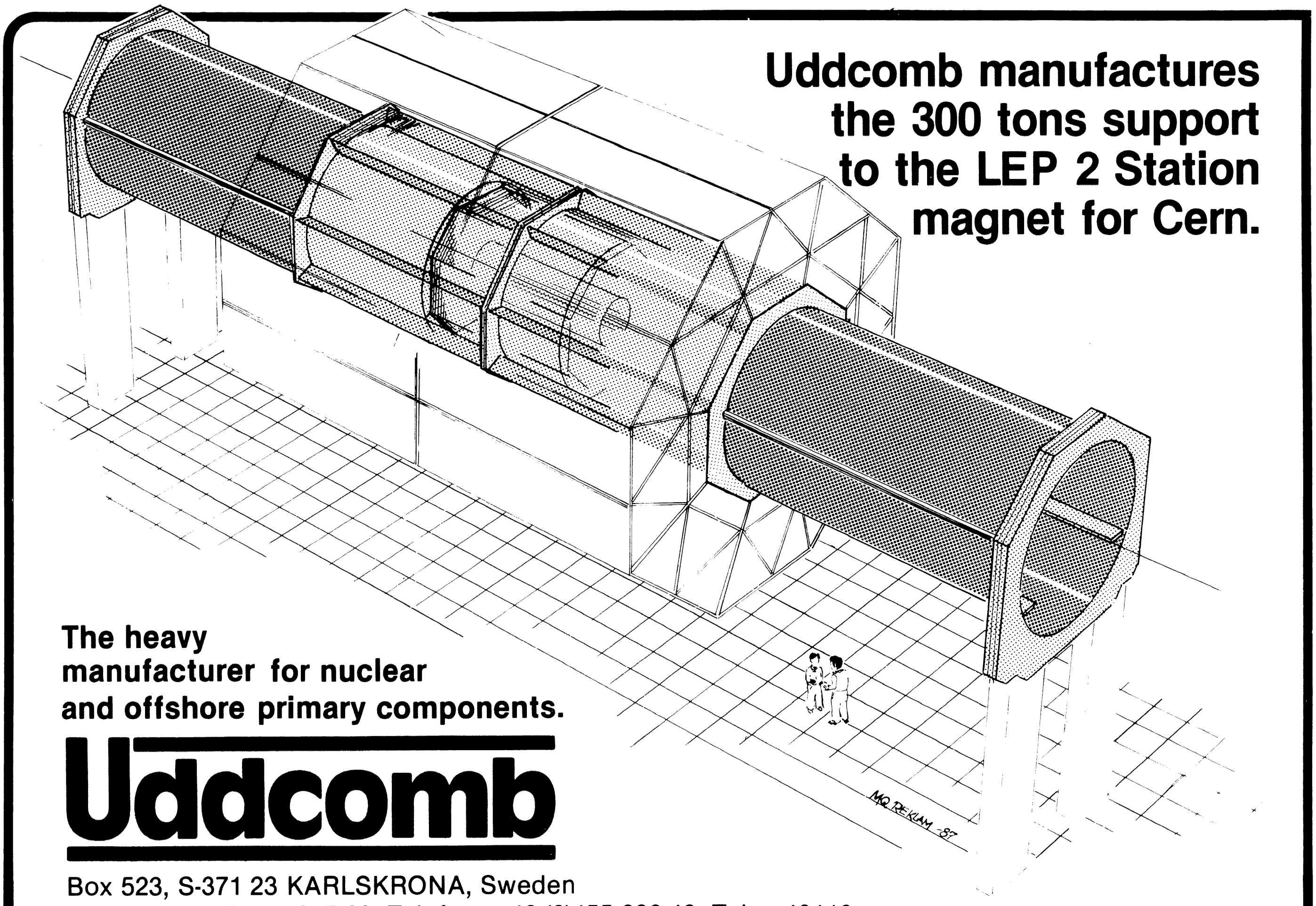
Stanford Collider gets ready

At the end of January, electrons were accelerated in the two mile Stanford linear accelerator to 50 GeV, the energy required for the Stanford Linear Collider (SLC) project.

This was achieved with some 24 of the 30 accelerator sectors equipped with new high power klystrons; the rest of the sectors were still operating with 'old' klystrons. The remaining sectors will soon be converted to the new tubes, and there should be little difficulty in producing Zs (mass 93 GeV) in electron-positron collisions at the SLC. The plan is now to run the big linac routinely at 47 GeV. Running at 43 GeV, the linac produced single bunches of 1.5×10^{10} electrons whose behaviour conformed with design values.

Beam has been transmitted from the end of the linac through the north arc of the collider as far as the reverse bend section (⅓ of north arc) with total transmission.

The north (electron) damping ring is in routine operation and the south ring is being prepared for positrons. Positron production has been measured and the beam sent back to the linac, and accelerated in sector 1.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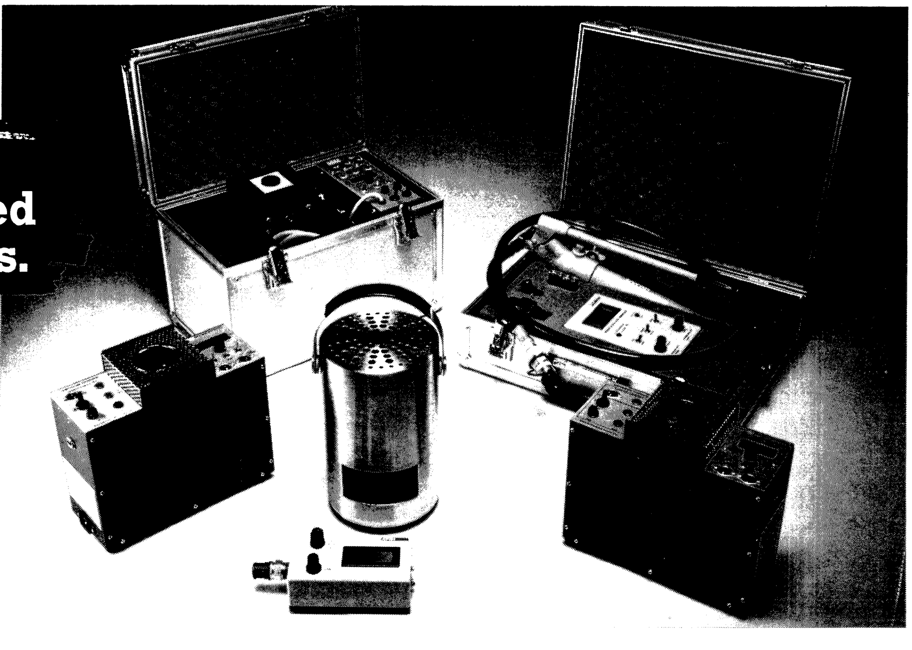

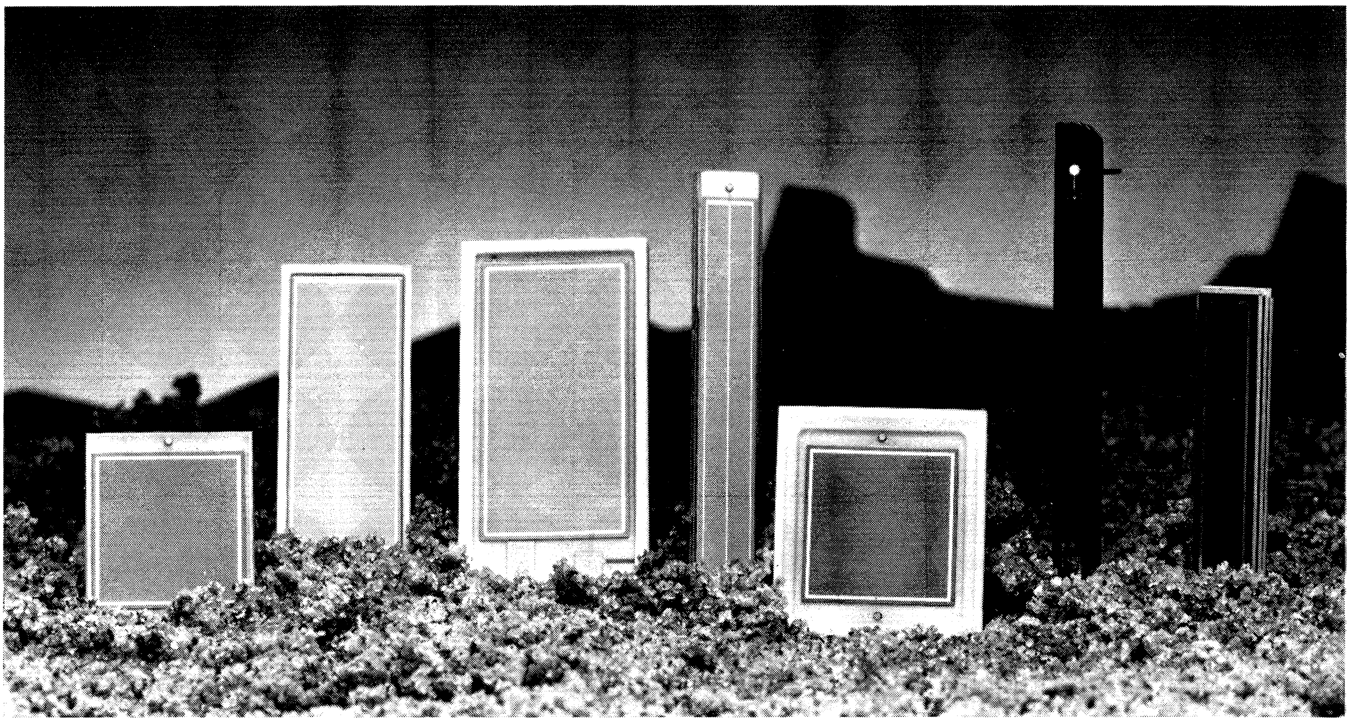

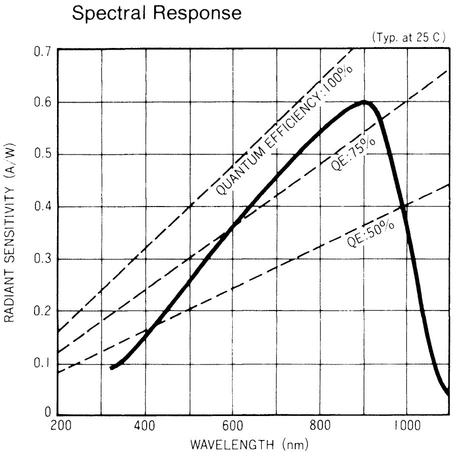
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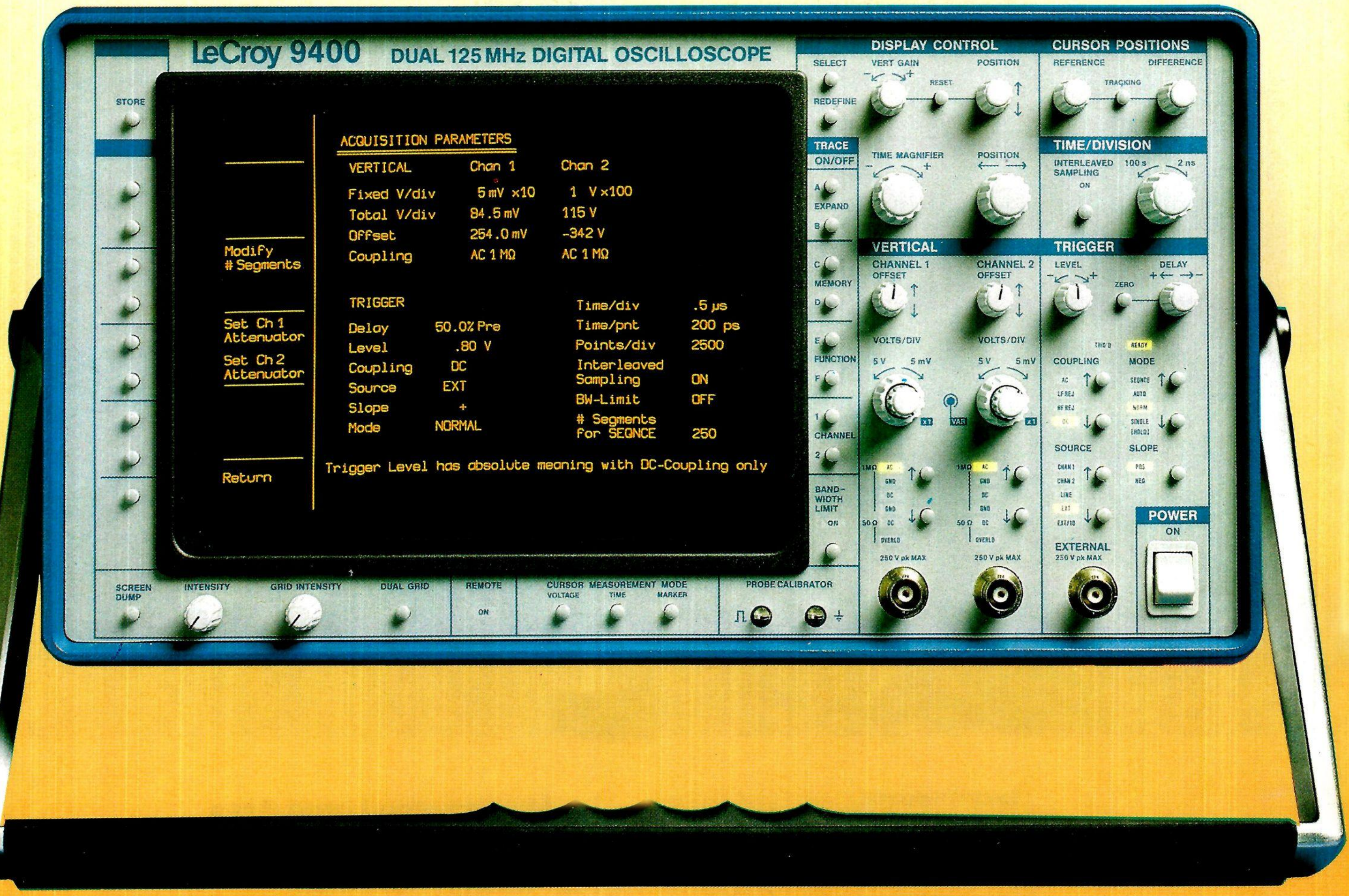

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ACQUISITION PARAMETERS
VERTICAL          Chan 1        Chan 2
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Total V/div       84.5 mV       115 V
Offset            254.0 mV      -342 V
Coupling          AC 1 MΩ       AC 1 MΩ

TRIGGER                         Time/div        .5 µs
Delay        50.0% Pre          Time/pnt        200 ps
Level        .80 V              Points/div      2500
Coupling     DC                 Interleaved
Source       EXT                Sampling        ON
Slope        +                  BW-Limit        OFF
Mode         NORMAL             # Segments
                                for SEQNCE      250

Trigger Level has absolute meaning with DC-Coupling only
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Modify
# Segments

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Attenuator
Set Ch 2
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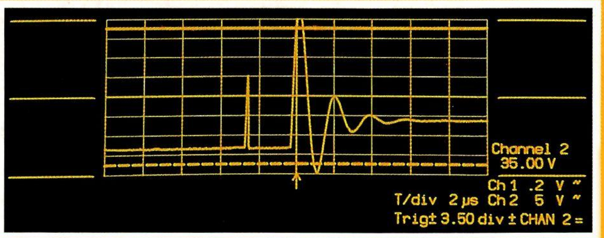

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T/div  2 µs       Ch 2   5  V ~
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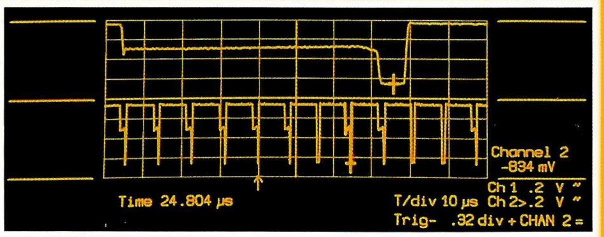

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Time 24.804 µs        T/div 10 µs  Ch 2>.2   V ~
                      Trig-  .32 div + CHAN 2 =
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Scope: Acquisition Parameters listing enables the 9400 user to precisely set and check front panel settings, all of which can be remotely controlled.

Upper inset: Window mode trigger set at ± 3,5 divs from center grid captures switching transient. 50% pre-trigger shows contact bounce prior to trigger moment.

Lower inset: Crosshair marker, acting as a precise timer and DVM, gives time from trigger (arrow) and absolute voltage.

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