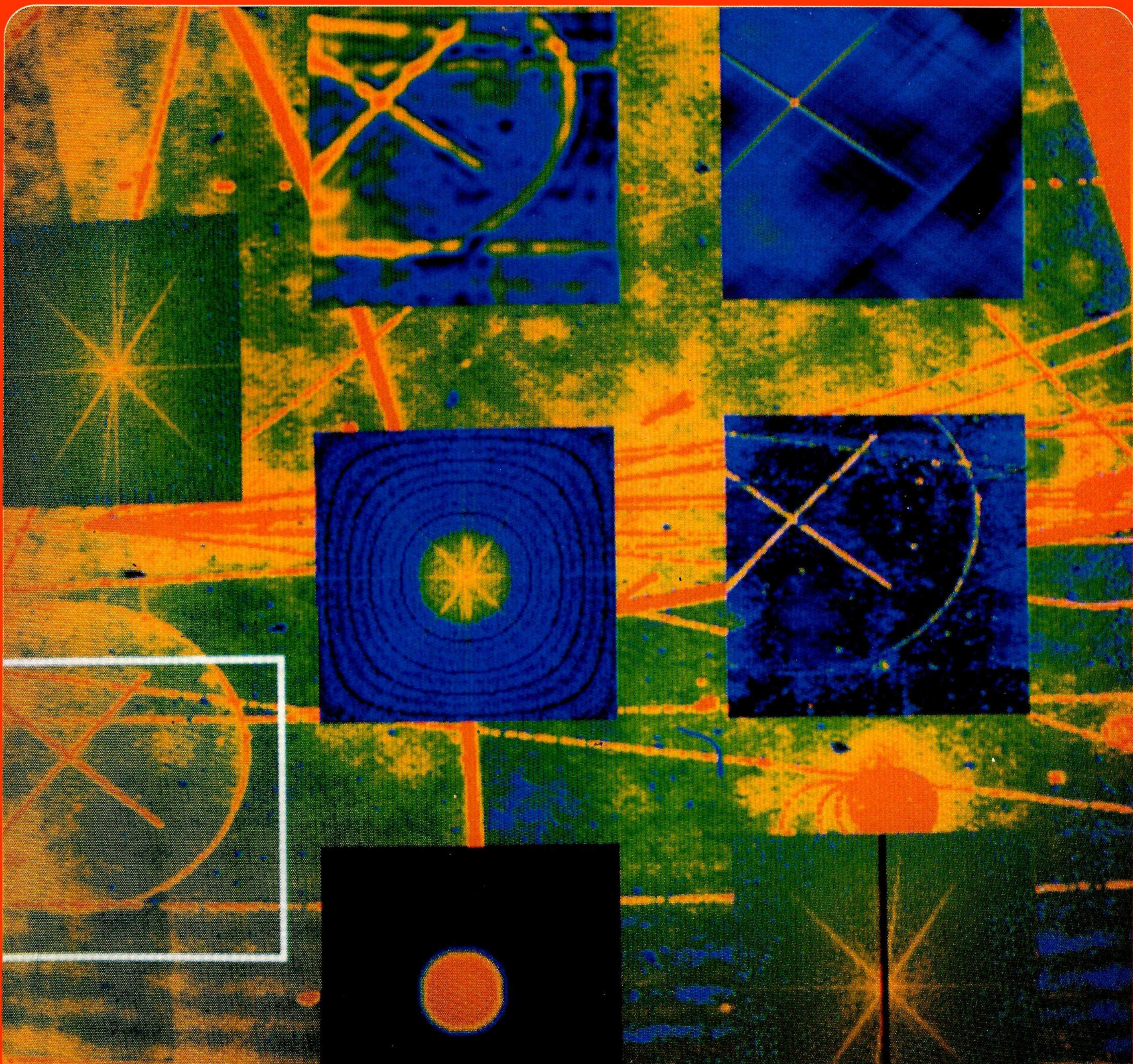
# CERN COURIER

International Journal of High Energy Physics



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# CERN COURIER

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*Cover photograph: Image processing at work at CERN. Superimposed on a digitized bubble chamber picture are the results of interposing various digital filters. (Photo CERN X503.3.84)*

# DELPHI

## A LEP forward

*At CERN, 1984 is a LEP year. Construction of the 27-kilometre circumference LEP electron-positron collider is well underway, following the official groundbreaking ceremony last year attended by President Mitterrand of France and Pierre Aubert, then President of Switzerland.*

*The sinking of the vertical access shafts, some of which have to go down 140 metres, is now well advanced, and boring of the tunnel proper will begin later this year. All is proceeding according to schedule for the machine to provide its first 50 GeV beams in 1988 (also a LEP year).*

*In parallel with the civil engineering work around CERN, a vast effort is being mounted across Europe, and even further afield, to prepare the four big experiments (DELPHI, OPAL, ALEPH and L3—see October 1982 issue, page 322), and have them ready to intercept the first LEP electron-positron collisions.*

*In the CERN COURIER this year, a series of articles will cover the preparations for these experiments and the progress of the LEP construction work, starting this month with the DELPHI experiment.*

Like all the experiments for the giant LEP electron-positron collider now under construction at CERN, DELPHI, short for Detector with Lepton, Photon and Hadron Identification, is big. It involves a collaboration of some three hundred physicists from over thirty research institutes in seventeen countries.

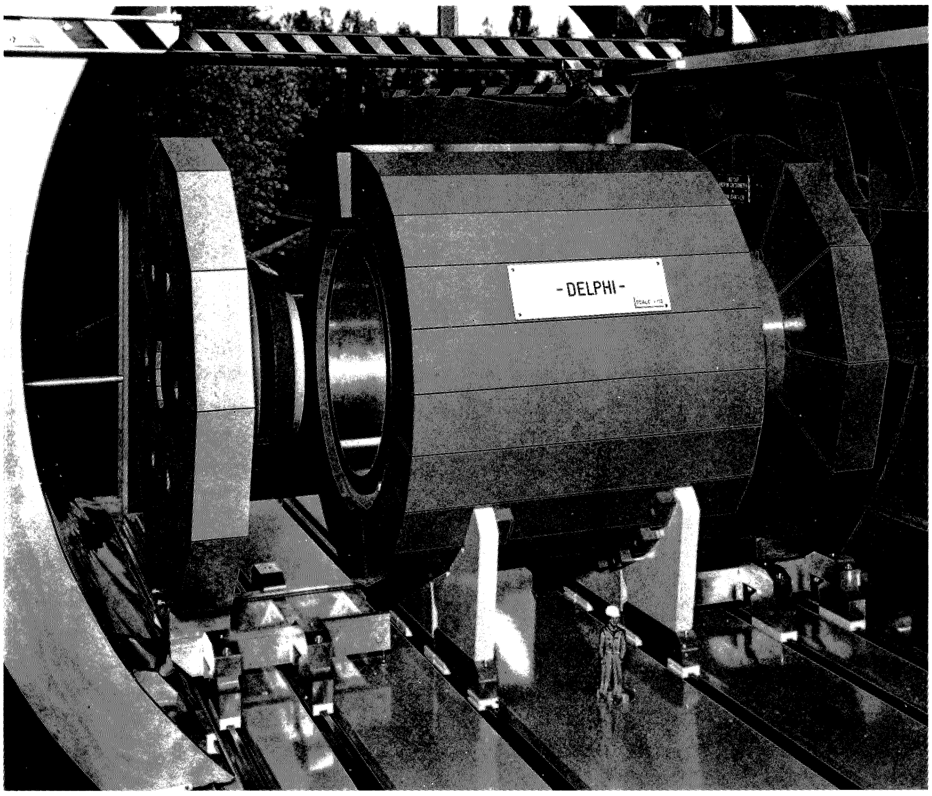
Its total cost is estimated at some 70 million Swiss francs, and its construction will involve over 500 man-years. It will contain well over 100 000 electronics channels distributed over more than a dozen main detector components.

This article is confined to a broad overview of the project and cannot do justice to the many man-years of painstaking work which have to go into the development, assembly, testing and installation of the separate components, each of which involves a large team.

For the record, the DELPHI collaboration involves Ames (Iowa State), Amsterdam (NIKHEF), Athens (University and Technical University), a Belgian contingent, Bergen, Bologna, CERN, Copenhagen (Niels Bohr Institute), Cracow, Dubna, Genoa, Helsinki, Karlsruhe, Liverpool, Lund, Milan, Orsay, Oslo, Oxford, Padua, Paris (Collège de France), Paris (P. et M. Curie University), Rome, Rutherford, Saclay, Santander, Serpukhov, Stockholm, Strasbourg, Trieste, Turin, Uppsala, Valencia, Vienna, Warsaw and Wuppertal!

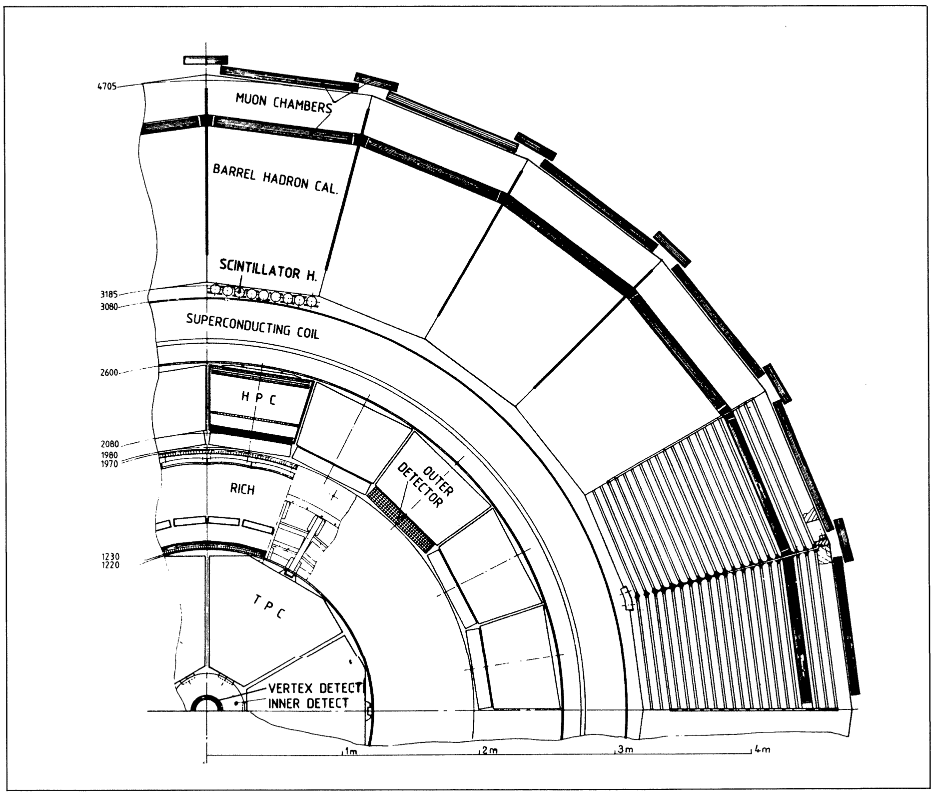
The detector, which spans 10 m of LEP beam pipe, has broad physics aims, and is designed to provide three-dimensional measurements, fine grain energy deposition and particle identification over the complete available solid angle surrounding the beam intersection.

A superconducting coil will provide a highly uniform 1.2 T magnetic field. Construction of this mighty so-




*Scale mock-up of the DELPHI detector. The real thing will represent 500 man-years of effort.*

*(Photo CERN 252.10.82)*




*Transverse view of one quadrant of the 'barrel' of the DELPHI detector for LEP. The detector is completed by end-caps.*

lenoid, one of the world's largest—6.2 m across and 7.4 m long—has been contracted to the Rutherford Appleton Laboratory in the UK.

The coil will be wound with niobium-titanium/copper superconductor embedded in a 24 mm by 4.5 mm aluminium matrix cooled by a forced flow of liquid helium at 4.5 K. The aluminium stabilizes the conductor and provides protection if the 100 MJ of stored energy are released in a quench. Using a 500 watt refrigerator, cooldown from ambient temperature to 4.5 K should take nine days.

Around the beam pipe will be a silicon microstrip vertex detector (CERN / Milan / Saclay / Rutherford), followed by a 150 cm-long inner detector (Cracow / Amsterdam) containing several thousand wires installed with 20 micron precision. It will provide good positional accuracy and, with the 'outer' detector, help with the trigger decision.

Around the inner vertex detector, the central part of the main tracking detector will be a Time Projection Chamber (TPC — CERN / Paris / Lund / Orsay / Saclay), similar to that used by a Berkeley team at Stanford, but with its argon-methane filling at atmospheric pressure. About 25 000 separate connections have to pass from this 3.4 m-long vessel to the outside of the detector.

Energy loss measurements in this central detector will aid particle identification, while charged hadrons will be identified in a barrel RICH (Ring Imaging CHerenkov Counter—Amsterdam / Athens / CERN / Orsay / Paris / Strasbourg / Uppsala / Wuppertal) containing both liquid and gaseous freon radiators and which surrounds the TPC.

Outside the RICH barrel will be the outer tracking detector (Paris/Liverpool) — a 4 m diameter barrel containing 2500 5 m-long drift tubes, fixing the position of particle tracks to a fraction of a millimetre.

Also inside the coil will be the electromagnetic calorimeter, a novel 5 m-long High Density Projection Chamber (Ames / Bologna / CERN / Genoa / Karlsruhe / Milan / Rome / Stockholm / Warsaw), which will drift electrons over long distances in narrow slots. Its high granularity promises better pattern recognition than more conventional electromagnetic calorimeter designs. Prototype modules have been assembled and tested at Rutherford and CERN.

The whole DELPHI barrel, between the solenoid and the magnet yoke, will be covered with scintillation counters for time-of-flight measurements (Santander / Valencia).

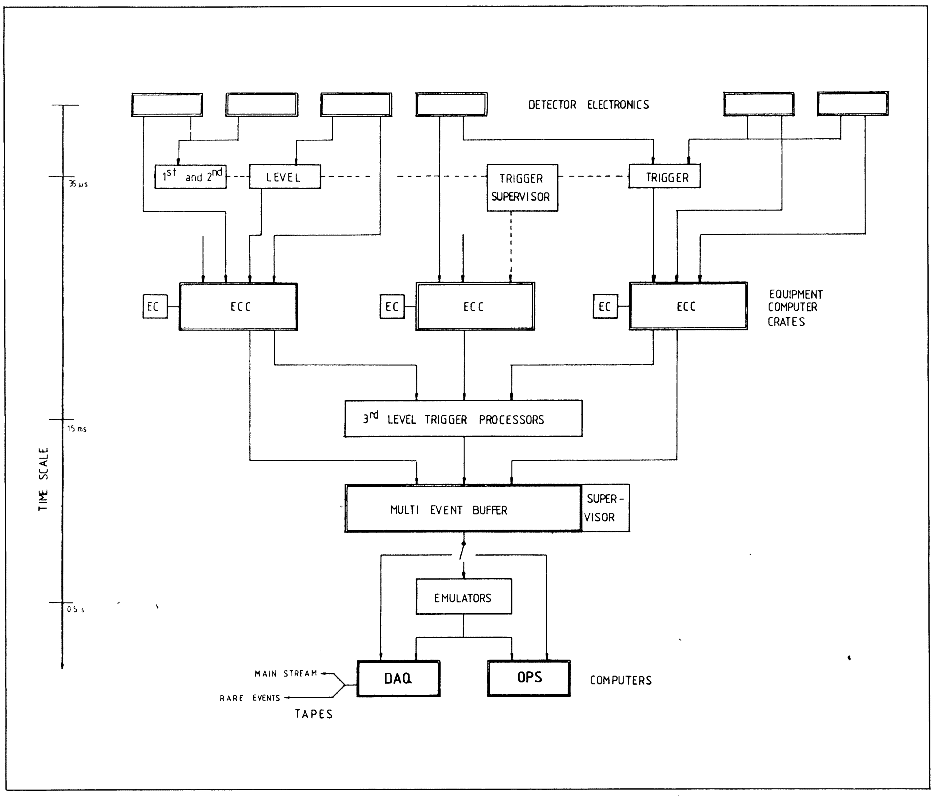
The two ends of the detector will be equipped with forward drift chambers (Vienna / Wuppertal) to improve momentum resolution at small angles, to provide particle tracking and to extend the triggering down to small angles.

The end-cap regions will also be covered by integrated gas/liquid RICH counters (Amsterdam / Copenhagen / Cracow / Uppsala / Wuppertal), while the electromagnetic calorimeter end-caps (Padua / Santander / Trieste / Turin / Valencia) will use lead glass counters.

Outside the solenoid will be the big hadron calorimeter (Dubna / Helsinki / Serpukhov / Rome) consisting of a barrel calorimeter (100 cm of iron) together with end-caps. The iron plates of the return yoke will be interleaved with gaps for plastic streamer tubes. The barrel elements will be grouped sequentially into 'towers', 'supertowers' and 'hypertowers'.

The outside of the detector will be covered by muon chambers (Oxford / Belgium), involving a total of 2000 drift chambers in multiple layers.

*Schematic of the DELPHI data acquisition and filtering system. These systems play a vital role in all the LEP experiments and were the subject of a special study.*




In the extreme forward directions, next to the low beta quadrupoles which squeeze the colliding beams, will be a small-angle tagging system (Bergen / Oslo) which will also serve as an on-line luminosity monitor.

## *Data handling*

With LEP's high collision rates, efficient and flexible data handling is required if valuable information is not to be lost through saturation of the data acquisition system, and to ensure fast extraction of interesting physics. Thus data acquisition and analysis play a vital role in all the LEP experiments and were the subject of special study.

The raw electron-positron crossing rate inside all LEP experiments will be about 50 kHz. For DELPHI, an initial fast trigger will decide whether candidate events recorded in coincidence with the beam-crossing signal are worth retaining. This information from the inner and outer detectors and the forward chambers will be available within a few microseconds—a fraction of the time for particles to drift in the central TPC.

The second level trigger, using extra information coming in meanwhile from the TPC and the electromagnetic calorimeter, will be available within about 35 microseconds, minimizing 'lost' collisions which occur while the experiment's telemetry is dead. This second level will use fast processors (microcomputers) integrated into the electronics.

This should accommodate an event rate of 20 Hz (average trigger spacing 50 msec). To keep dead time down to the one per cent level, digitized data will be passed to local buffers after the second level trigger is satisfied, thus freeing all inputs within 500 microseconds.

To further reduce deadtime, these distributed (local) buffers will be able to store up to five events at a time. Full readout of an event will take about 20 msec.

Computer crates located in the electronics racks will control the readout into a main multievent buffer, ready for the third level of selection (5 Hz). Data will be passed to on-line computers and/or magnetic tape (or other storage media) at the rate of a few events per second.

In addition to the local data handling system, physicists will be able to make use of CERN-wide and international computer networks.

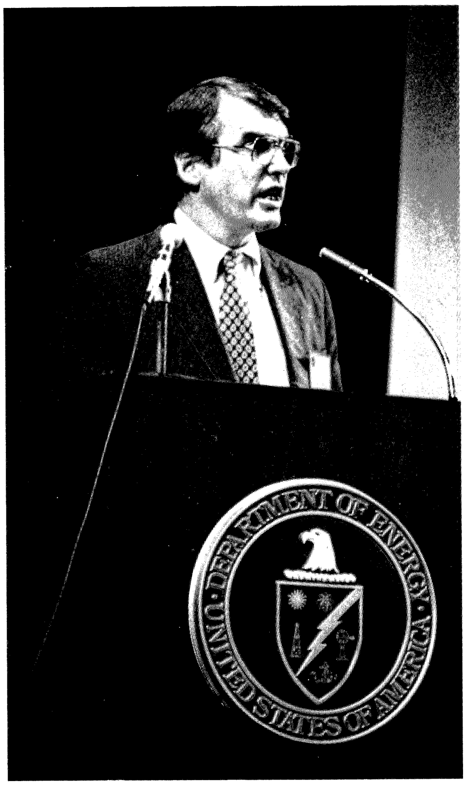
The DELPHI collaboration was formed around common physics interests and a desire to build a high performance detector. While being ideally suited to the study of $Z^0$ particles (the carriers of the weak neutral current which LEP will provide in quantity) the intention with DELPHI is also to scan closely for signs of new and unexpected behaviour. With LEP accessing a new physics region, the potential rewards are great.

# Savouring the Saver

Last year, the new superconducting Energy Saver/Doubler ring at Fermilab came into action for the first time, and quickly established a new world record, accelerating protons to 512 GeV. The energy was subsequently increased and earlier this year saw the start of an experimental programme using 800 GeV beams. The machine's eventual target energy is 1000 GeV, or 1 TeV, hence the alternative name Tevatron.

The new machine was formally dedicated on 28 April in conjunction with the annual Fermilab users' meeting. Some 300 visitors and an equal number of users attended the event. They had come to christen a machine that, as well as accelerating protons to a record energy, has, in the process, brought superconductivity from the laboratory to the threshold of an industry.

*President Reagan's Science Adviser George Keyworth: 'The spectacular debut of the Fermilab Energy Saver marks the beginning of what we expect to be an incredibly productive period of physics.'*



Visitors numbered prominent congressmen, important officers of the US federal executive branch, representatives of companies that had worked on accelerator components, and a host of others who had contributed to the construction. The Dedication was an opportunity to thank these people, layman and scientist alike, for their help.

Fermilab Director Leon Lederman captured his Laboratory's aim. 'To look in a place where no one has ever looked before, to observe deeper into the core of the atomic nucleus than has ever been probed; to measure in a domain more remote from human experience—much more remote than the surface of the Moon and Venus—to be able to recreate, in microcosm the conditions which existed in the earliest instant after creation. This is the exalted privilege that has been given to us by our guests and the public they represent. And for this we thank them!'

Danny Boggs, Deputy Secretary of the US Department of Energy and principal speaker, reminded the audience of the quickening pace of scientific development: 'The concepts of the Greeks endured for 2000 years. The building of modern science took 200 years, the development of nuclear science forty years. This has accompanied a remarkable transformation of human existence. The pace of change during the lifetimes of E. O. Lawrence and Enrico Fermi was phenomenal... They were, in a true sense, founders of the age of nuclear science, not only the art and science of building accelerators and using them for discovery, but also the style of work that is needed for success. The Energy Saver here at Fermilab is the latest, but by no means the last, creative step to draw upon their example.'

President Reagan's Science Adviser George Keyworth stirred the audience with an encomium to the Saver: 'The spectacular debut of the Energy Saver last July marks the beginning of what we expect to be an incredibly productive period for physics in this country and indeed throughout the world. Fermilab has demonstrated the feasibility of a powerful new technology, one destined to play an important role in the development of accelerators in the future. This accomplishment is important for broader reasons. These frontier experimental facilities are creative hubs—places that draw the very best minds to them. The existence of such places sends out strong messages of inspiration.'

With Boggs, Keyworth and Lederman on the Dedication platform were James Thompson, Governor of Illinois; Charles Percy, Senator from Illinois; John Myers, Congressman from Indiana; Alvin Trivelpiece, Director of Energy Research for the US Department of Energy; Edward Knapp, Director of the US National Science Foundation; Hilary Rauch, Manager of the Department of Energy's Chicago Operations Office; H. Guyford Stever, President of Universities' Research Association; David Saxon, Chairman of the Corporation of MIT; Robert Wilson, Fermilab Director Emeritus; Rich Orr, Head of the Accelerator Division; Helen Edwards, Deputy Head of the Accelerator Division; and Richard Lundy, Head of the Technical Support Section.

The Fermilab User Organization held its Annual Meeting in conjunction with the Dedication. Stewart Loken of Berkeley, chairman of the Users Executive Committee, presided.

George Keyworth spoke on 'SSC

Left to right: H. Guyford Stever, President of Universities' Research Association; Hilary Rauch, Head of US Department of Energy Chicago Operations Office; Danny Boggs, Deputy Secretary of the US Department of Energy; George Keyworth, President Reagan's Science Adviser; Helen Edwards, Deputy Head of Fermilab's Accelerator Division; Jim Thompson, Governor of Illinois; and Charles Percy, Senator from Illinois at the Fermilab Doubler/Saver Dedication.

(Superconducting Super Collider), The Next Big Step.' Keyworth emphasized the importance of maintaining a competitive programme of basic research. He indicated that the SSC is important, not only as an instrument of high energy physics, but also as a sign of our recognition of the value of new knowledge and of our commitment to excellence in what we choose to do.

Alvin Trivelpiece discussed the recent US funding trends and the increased support for basic research. While the possibility of a large US Federal deficit makes future prospects uncertain, he remained optimistic about continued support for high energy physics and for the SSC.

Leon Lederman reported on the state of the Laboratory, recalling that during the users' meeting one year earlier the Saver ring was just getting cold. In a series of successes, Fermilab commissioned the Saver and completed the first round of experiments. He noted that progress continues on colliding beam facilities, with a full scale test of beam storage scheduled for next year. The Physics Advisory Committee has approved a new major detector for the DO interaction region (see May issue, page 147). Meanwhile, the fixed target programme is moving vigorously ahead.

Rich Orr described the commissioning of the machine, and reviewed the milestones of the past year. Efforts are now underway to further improve machine performance and reliability. A new compressor will be added to the central plant and additional r.f. will be installed.

Two perspectives on the performance of the Saver came from Bob McCarthy of Stony Book describing life at the end of a beamline and Bob Mau of Fermilab reviewing machine statistics and work to improve reliability. Tom Kirk then gave a status report on the fixed target programme construction effort. The project is on schedule and will soon provide twelve beamlines for a broad range of fixed target physics at 1 TeV.

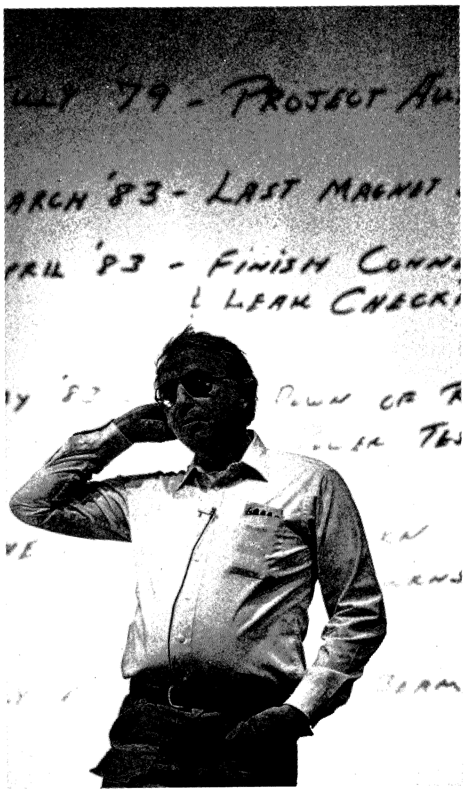
The colliding beam experiments were reviewed by Paul Grannis of Stony Brook. Of six possible interaction regions, five are now committed to experiments.

Al Brenner discussed the computing situation at Fermilab and described the developing computer network. A major concern for the future is the large data rate from the colliding beam experiments, and plans are now being developed to meet these demands.

The meeting ended with a look at the short term future. In his talk 'The Next Three Years', J. D. Bjorken surveyed the rich physics potential of the Tevatron fixed target programme. The broad range of beams, targets, and detectors permits a detailed study of fundamental physics. He expressed his concern that the enthusiasm for colliding beams and limited funds may reduce the vitality of the fixed target programme and concluded by urging experimentalists to maintain a commitment to a healthy programme of fixed target experiments.

*At the Saver/Doubler dedication, Fermilab's Accelerator Division Head Rich Orr reviewed the progress of the superconducting ring's commissioning.*

*(Photos Fermilab)*



# Homage to Sir John

CERN's Main Auditorium was packed on 27 April when tributes were paid to the memory of Sir John Adams, former Director General of CERN, one of the main architects of CERN's big machines and a key figure in the development of the Laboratory, who died on 3 March.

Introducing the proceedings, CERN Council President Sir Alec Merrison, a former colleague, recalled his early days with Adams at the Harwell Laboratory in the UK just after the Second World War, under the guidance of Cockcroft. Here Adams was introduced to the field of particle accelerators which was to become a major portion of his life's work.

Anselm Citron of Karlsruhe described John Adams' first contributions to CERN. Former CERN Directorate member Hans-Otto Wüster, now Director of the JET fusion experiment joint undertaking at Culham in the UK, took over to cover Adams' work after he left CERN in 1961 to establish the Culham Laboratory.

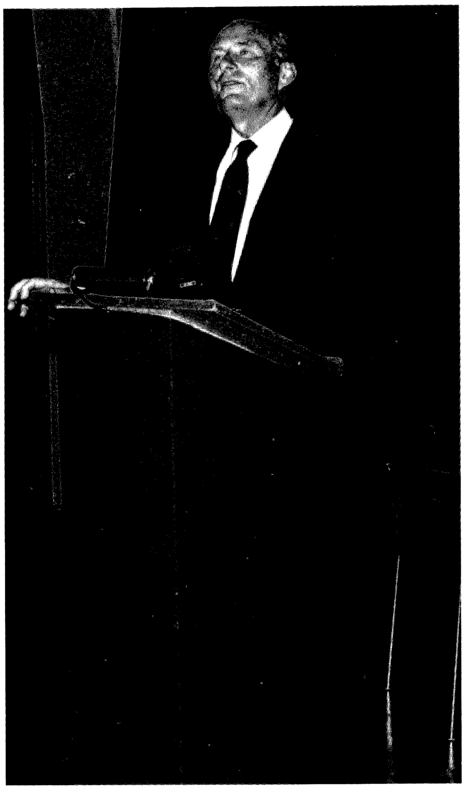
Then it was the turn of Paul Levaux, President of CERN Council from 1975-1977, to recollect Adams' return to CERN in 1969, his role in the construction of the big SPS machine and in the enlargement of CERN. Carlo Rubbia underlined the success of the SPS, emphasizing how its careful design facilitated subsequent operation as a storage ring for protons and antiprotons.

Before Sir Alec Merrison paid his final tributes, CERN Director General Herwig Schpopper recalled Adams' concern for the environment and surroundings of the new CERN site on French territory, and proudly displayed photographs of the new features around the site's entrance. These now provide lasting memorials to one of CERN's great personalities.

Together, the speeches at the memorial gathering provided a fitting tribute to one of CERN's founders and key figures. Here we concentrate on extracts from the presentations by Anselm Citron and Paul Levaux, which had most to do with Adams' work at CERN.

*Sir Alec Merrison: early days with Adams at Harwell, under Cockcroft.*

*(Photo CERN 761.4.84)*



'It was in the building of the PS (Proton Synchrotron) machine that John Adams built up his reputation and the technical reputation of CERN from scratch under unusual circumstances,' said Citron.

'In October 1952 the CERN Council approved a switch to the exploration of the newly discovered alternating gradient principle with the aim of building a much higher energy machine for the same money. Also Geneva was selected as the site for CERN. The name of John Adams appears first on an invitation to a meeting of the PS group in Brussels in January 1953.

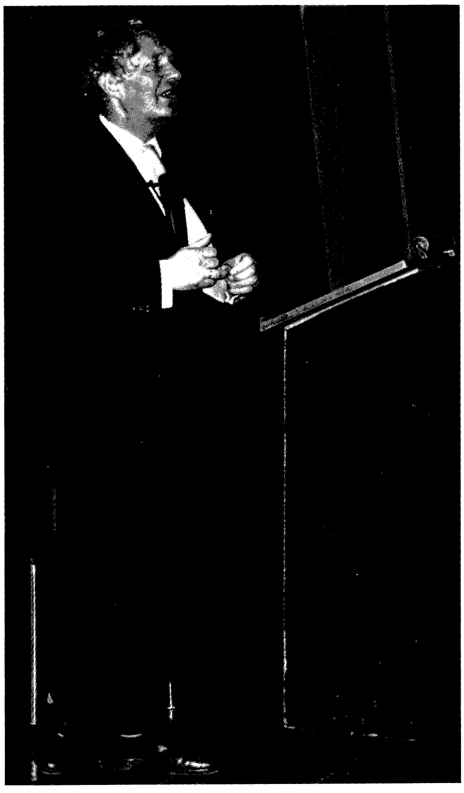
In October 1953 the group presented a set of parameters to an international accelerator conference in Geneva. The Council endorsed these parameters. New staff members, amongst them John Adams, were appointed and the group, consisting initially of 12 persons, including two visitors from Brookhaven, took up their work at the Institut de Physique of the University of Geneva.

In the following year, after the sudden death of Frank Goward, Adams became deputy. Later in the year, when PS Director Odd Dahl had to go back to Norway, Adams was appointed as his successor.

By 1959 the PS was operating on schedule, about one year ahead of the Brookhaven Alternating Gradient Synchrotron. The cost was within 15 per cent of that budgeted originally. One year as a Director General terminated this decisive span in the life of John Adams and of CERN.

*Anselm Citron: how John Adams moved from an interested spectator to project leader in barely two years.*

*(Photo CERN 737.4.84)*



What is immediately apparent from the time schedule of the initial meetings is the enormous drive with which the founders of CERN, the senior scientists and politicians, pushed the realization of a European Laboratory. This speed would have been impossible without a corresponding enthusiasm of the builders of CERN who devoted themselves wholeheartedly to this noble challenge.

What is not apparent from the record is the way John Adams came into the picture and how he moved up from an interested spectator to the leader of the project in barely two years.

After working on radar projects during the war, John Adams had joined Harwell in 1945 and had built a synchro-cyclotron. There he was joined by Mervyn Hine who had a Cambridge nuclear physics background. The two listened to the discussion about the alternating gradient principle and soon started working on it in addition to their normal duties. Before long it became evident that the field index had to come down. But even then it was by no means clear whether a machine based on the principle would work. Today one would tend to simulate the whole accelerating process on a big computer. In 1952 computers were in their infancy but John Adams tried to run at least an oversimplified version of the process on a computer. But as an annual report note says: 'It is easy to show that a (complete) computer program would cost about twice the total budget of the PS machine'.

There were other difficulties. People coming from different countries that had been at war only seven years before had to work together. German group members still needed a visa for every European country.

John Adams came from a background of industry and Government projects and he had now to work with people from academia where only professors count! Finally, the contracts CERN could offer were of questionable legal value.

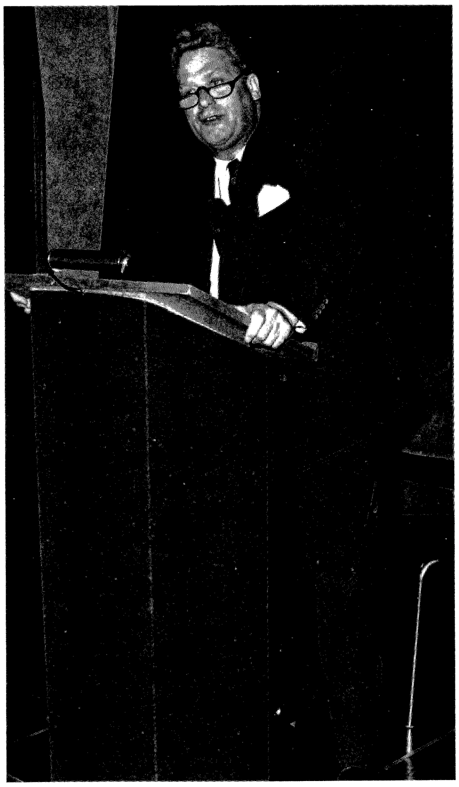
All these difficulties were just swept away by everybody's enthusiasm. John Adams used to say that he found people much the same everywhere.

What qualities singled out John Adams as a leader? I shall try and approach this question by commenting on another one. Was Adams an optimist or a pessimist? As usual, the answer depends to the meaning you are giving to the terms. If an optimist is a person who ignores the difficulties, hoping that with some luck he will get away with it, then Adams was certainly not an optimist. If a pessimist is a person who sees all the difficulties and gets paralyzed by them, then Adams was certainly not a pessimist. He would not only see the difficulties, but he would go out of his way to spot them. Then he would set his mind to work to find ways to solve the difficulties, minimize the risks, or build up a second line of defence. After this process, he would go ahead without hesitation and without having to rely on the advice of many people.

One of his first acts as a director of the PS group was to thank all the consultants and to concentrate the process of defining the parameters of the machine in a weekly parameter meeting. I still remember the careful and transparent way in which decisions were reached under his chairmanship and the atmosphere of calm assurance that emanated from him.

Paul Levaux: how Adams brought 'Project B' (subsequently known as the Super Proton Synchrotron) to fruition at CERN.

(Photo CERN 748.4.84)



This style of John Adams has become, to a large extent, the style of CERN. It has sometimes been criticized, but it has made possible the great achievements which came later.'

Paul Levaux covered the period after John Adams was invited by CERN Council, in December 1968, to return to CERN to lead the building of a '300 GeV' machine at a second European particle physics Laboratory, geographically separate from the existing one in Geneva. The CERN Convention had been amended to allow two Laboratories to run at the same time, and Member States had been invited to propose sites.

'From the very beginning, John Adams had been aware of the uselessness of the operation and the risk it posed to the future of European collaboration in the high energy field. Technically, the projects were complete by 1969, but the spirit of competition which had gradually arisen between the various sites and the Member States concerned deadlocked the final decision.

From the time of his appointment, John Adams had anticipated such a setback and his pragmatic approach had brought him to imagine an alternative to the various projects. Abandoning the basic idea, the setting up of a second, geographically separate Laboratory, he propounded the concentration of all CERN's future activities in Geneva.

This change of direction made it possible to avoid the reef represented by the choice of sites, and was subsequently to afford a solid basis for European collaboration.

Although one problem had been overcome, there remained the other: the lack of enthusiasm on the part of some governments to support the project financially. John Adams then took up his pilgrim's staff and set out to defend his project before every competend national authority. He invited the United Kingdom Minister of Education to visit CERN and see for herself the worth and interest of its work. Fully persuaded, Mrs. Thatcher obtained the British cabinet's agreement to take part in this new scheme and soon all the Member States agreed on the principle of building this new tool for the elementary particle physicists.

At the end of 1970 John Adams put the new project before the Council, which accepted it. Nevertheless, its acceptance did not automatically mean that the programme was to start, although it had obtained the conditional support of seven Member States. The Council session was therefore adjourned until 19 February 1971, when ten countries decided to take part in the building of the SPS and John Adams was appointed Director General of CERN II.

The bringing into being of what was later to become the 400 GeV SPS was no easy task, and required all Adams' diplomatic talent and powers of persuasion. While he had succeeded in convincing political and administrative circles of the importance of creating this new scientific potential, he still had to persuade the scientific community that it was possible to build in Geneva a machine large enough to satisfy physicists' future needs. He decided to fix the diameter of the machine at its maximum, taking the risks with the molasse surrounding the Geneva site.

Thus, on 19 February 1971, CERN found itself running two Laboratories, CERN I, administered by Jentschke, and CERN II, administered by John Adams. Having amended its Convention to meet the need to operate two geographically separate Laboratories, CERN now had to face the long procedure required to unite two neighbouring establishments.

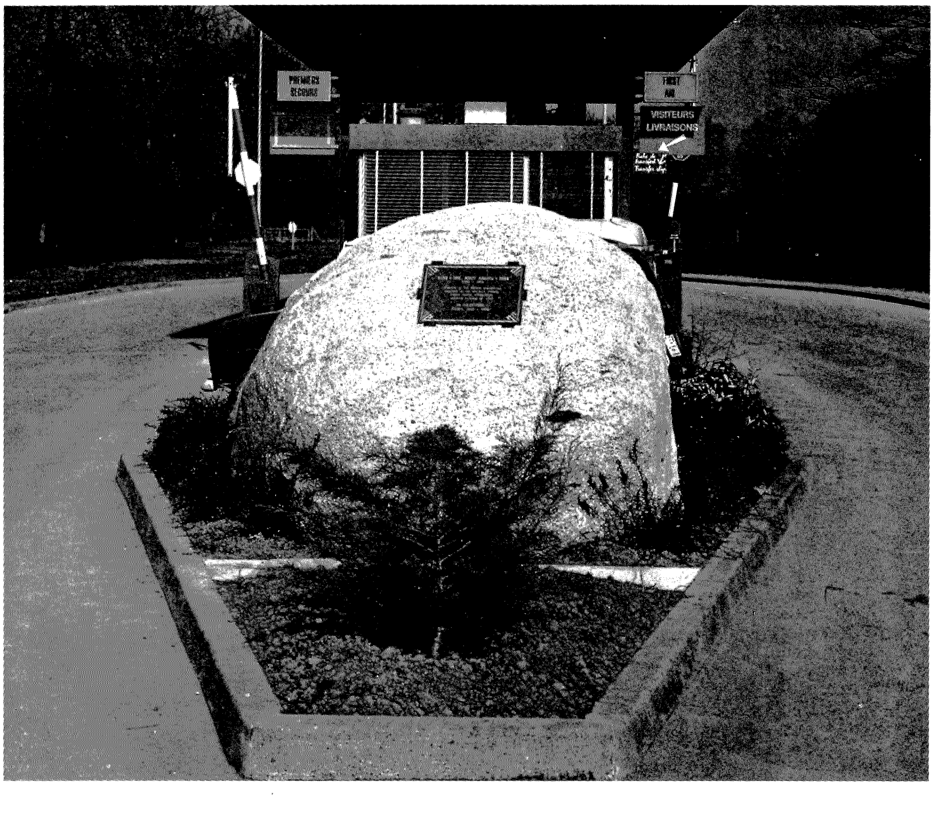
Laboratory II was soon to expand under John Adams' leadership. The tiny initial team was gradually to be joined by the most highly qualified specialists from the European Laboratories, including some of the old brigade from the first PS team who had just completed the Intersecting Storage Rings.

In 1975 CERN still bore traces of the ideas of the sixties — there were two Laboratories. However they were no longer geographically separated but joined together like Siamese twins on either side of the Franco-Swiss border. The final merger took place when the building of the SPS was completed, and the united Laboratories were placed under the joint tutelage of John Adams and Léon Van Hove.

It is with considerable emotion that the members of the Council re-

The memorial plaque at the entrance to CERN's Prévessin site (below).

(Photos CERN 406/7.4.84)

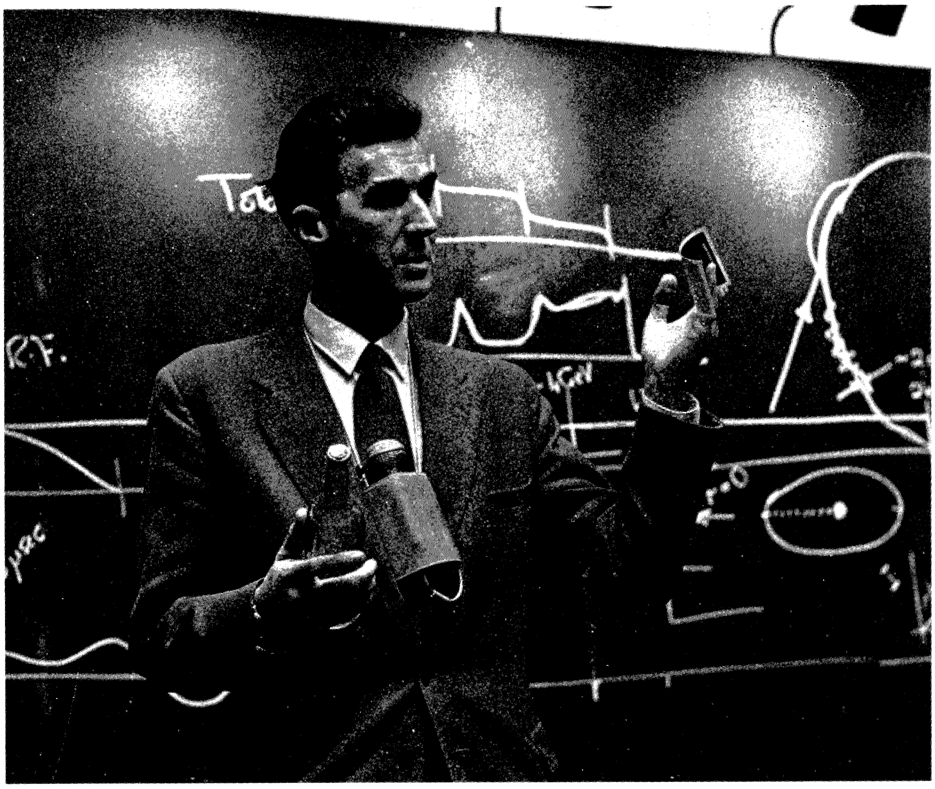

member the announcement made by John Adams at noon on 17 June 1976 that the SPS had reached its nominal energy of 300 GeV. The same day, at half past three in the afternoon, the SPS accelerated protons to 400 GeV. The physics world was unable to conceal its delight. Congratulations flowed in from all sides. This was the culmination of the efforts of John Adams and his team. The building of the SPS was a great success, and it is still one of the high points in the construction of equipment at the forefront of technology. It certainly rivals other technological achievements in sometimes more spectacular scientific fields.

CERN's management after the commissioning of the SPS in 1976 was to be mainly dominated by the proton-antiproton project and the design studies coming to fruition in the LEP project. In his report to Council in 1980, John Adams proudly reviewed the progress towards the proton-antiproton project, and stressed that the Council should approve the LEP project.

LEP is in fact the final result of a number of design studies made at CERN between 1970 and 1980. In the latest development of the project, it is proposed to use the PS and SPS as the injector for LEP, thus once again demonstrating the ingenuity of CERN's machine builders and the wisdom of the decision to keep all the machines in the same place.

Apart from the leading part which he took in the technical preparations for the project, one of John Adams' great achievements was the patient and highly detailed mapping out of the legal and administrative path for the Member States to take in approving it.

In 1980 Council gave John Adams its warmest thanks for the tremendous amount of work done and his




essential part. in developing this science of the future. Back in November 1978 Adams had said: 'For me it's clear that most of what I've been able to do is just luck—being in the right place at the right time.' Let me complement this self-judgement. He was in the right place at the right time by selecting the correct options through analysis and through intelligence. He had the skill to lead them through to their conclusion and the steadfastness not to be distracted by convenience.

He has left his indelible imprint on European science and has made a major contribution towards setting up the high energy physics infrastructure for the remainder of this century.

The friend to whom we are paying tribute as a great builder and leader has left us much more. He has, often unbeknown to us, surrounded us with a friendship and warmth which has made no small contribution towards the good name of our Laboratory.'

*November 1959. CERN Proton Synchrotron Director John Adams holds in one hand an empty vodka bottle, in the other a photograph of one of the first 24 GeV pulses supplied by the newly completed machine. The vodka had been supplied by Dubna (USSR) for consumption if CERN succeeded in surpassing the Dubna synchro-phasotron's world energy record of 10 GeV. The empty bottle served to send the photo to the USSR as proof of CERN's achievement. Twenty-five years later, the PS is still the kingpin of CERN's high energy particle beam supply system.*

*(Photo CERN 14F.11.59)*

## TOKYO
## Successful stochastic cooling tests

Successful tests of stochastic cooling have been carried out in the small TARN ion storage ring at the Institute for Nuclear Study (INS), Tokyo. TARN (Test Accumulation Ring for Numatron) is a low energy (around 10 MeV/nucleon) ion storage ring built for technical development for the Numatron high energy ion accelerator project. The aim is to develop the techniques of stacking and cooling to achieve intense ion beams of good quality.

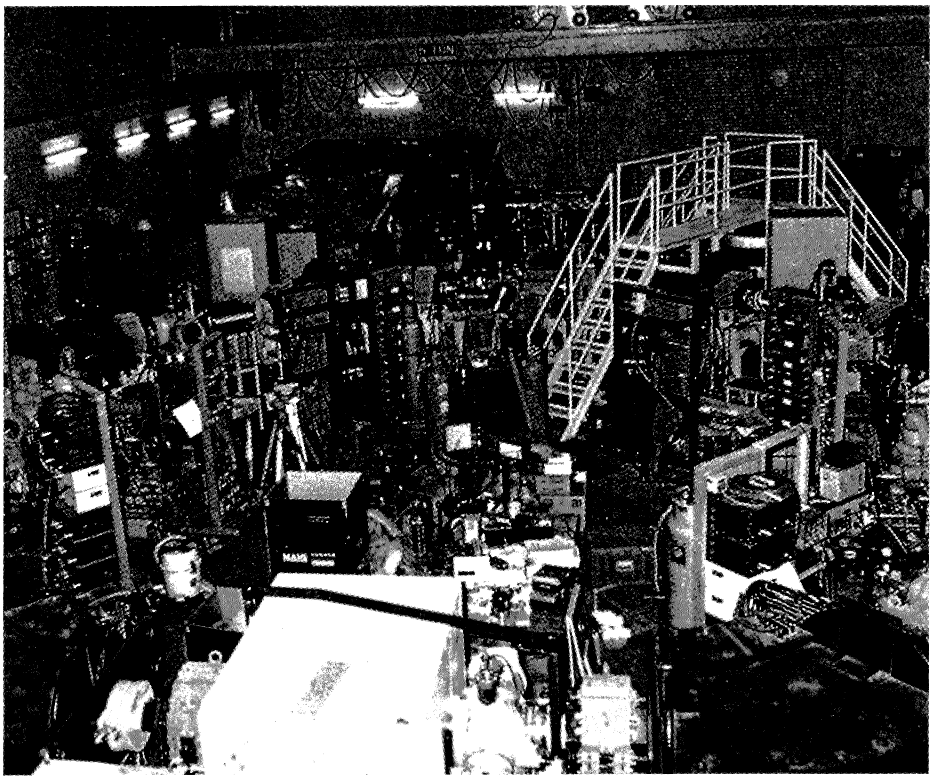
For these initial tests, proton beams injected from a sector focused cyclotron at 7 MeV were accumulated in horizontal and longitudinal phase spaces to obtain as high a current as possible in the 14 cm by 5 cm vacuum chamber. R.f. stacking was performed at 30 Hz and the intensity increased linearly up to 15 stackings, resulting in a momentum spread of 2.2 per cent.

Stochastic momentum cooling was then applied on the stacked protons with fairly simple systems, since the ring was not originally designed with such cooling in mind. The pickup and kicker are 75 cm travelling wave couplers with the inner conductors having helical pitch equal to the proton velocity. For the tests, the initial momentum spread of the beam was set at about 1 per cent.

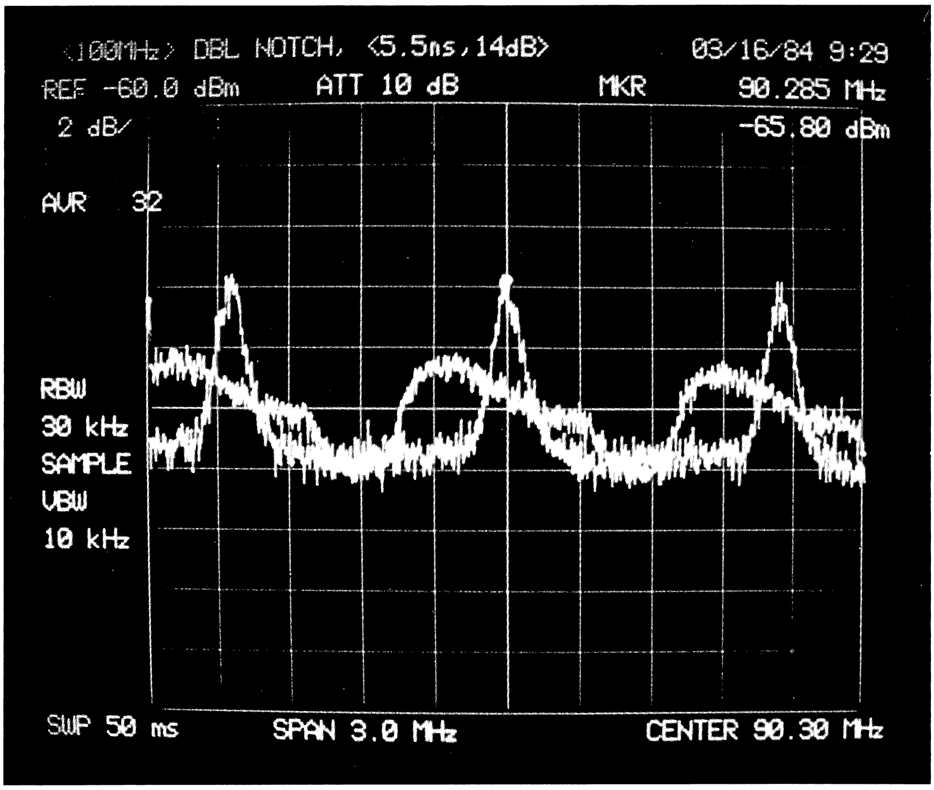
The measurement of stochastic acceleration rate with the notch filter gave precise information on the time delay for the protons to travel from the pickup to the kicker, and the propagation time of the Schottky signals through the electronic system. Fine adjustment of the delay time (within 2 ns) was necessary for successful cooling.

# the Laboratories

*The TARN (Test Accumulation Ring for Numatron) at the Tokyo Institute for Nuclear Physics. The 5 m radius ring has recently been the scene of successful stochastic cooling tests.*



*Below, typical result of stochastic cooling in TARN. Longitudinal Schottky scans were taken before and after cooling was applied to a 12 microamp 7 MeV proton beam. The initial momentum spead of 1.3 per cent (broad peaks) is reduced to 0.2 per cent (narrow peaks) in 20 s.*




As an example of the results obtained with an active gain of 107 dB for a beam current of 12 microamps, the initial momentum spread of 1.3 per cent was reduced to 0.2 per cent with 0.5 watts of power into the kicker. Cooling time was around 20 s. More sophisticated cooling systems (both stochastic and electron beam type), are planned in a newly built ring, TARN II, scheduled for operation in 1986.

## DESY
## CELLO solo

The CELLO detector at the German DESY Laboratory's PETRA electron-positron collider has provided one example of the annihilation of an electron-positron pair into two isolated high energy muon tracks plus two distinct showers ('jets') of hadrons, and which is proving difficult to explain on the basis of known physics.

Late last year, the collision energy in the PETRA ring was gradually increased from 43.2 GeV to just over 45 GeV, and the four detectors (TASSO, Mark-J, CELLO and JADE) anxiously searched for signs of new phenomena at these hitherto unexplored electron-positron annihilation energies.

A quick scan of the overall production rate of hadrons revealed no threshold effects indicating that the long-awaited sixth ('top') quark was being produced. At these energies, physics is topless!

However in subsequent analysis the CELLO detector has unearthed one event with two clear muon tracks (carrying opposite electric charges, and with energies of 11 and 12.6 GeV) and two accompanying hadron jets (10.1 and 9.1 GeV). Conventionally, these muons are explained as coming from the decay of highly unstable heavy particles

*At a symposium at the German DESY Laboratory in memory of the late Kurt Symanzik: (left to right) Gerard 't Hooft, Raymond Stora and Harry Lehmann.*

*(Photo J. Schmidt, DESY)*

(carrying charm and beauty), or from meson decays in flight. Another possibility is that isolated single hadrons could squeeze through the filters and fake muon signals.

Calculations on the expected level of such processes indicate that a thousand times more data would have to be collected before there should be a good chance of just one event from either source, making these conventional explanations look unconvincing.

With these mundane explanations pushed out of the way, the more interesting possibilities include new heavy quarks, Higgs particles, new heavy leptons, heavy neutrinos... But it is difficult to make physics out of just one event, and corroboration by the other three detectors working at PETRA is needed before the speculators can move in.

# Homage to Kurt Symanzik

Earlier this year, theoretical physicists from several countries met at the German DESY Laboratory to pay tribute to the scientific work of Kurt Symanzik who died on 25 October last year (see January/February issue, page 25). In lectures by prominent theoreticians, the contributions of Symanzik to several different fields of physics were sketched.

After a short introduction to the late theorist's life and scientific career by DESY Director Volker Soergel, Gerhard Mack (Hamburg) described those papers which can be summarized under the heading 'From S-matrix to Greens' functions'. Already Symanzik's 1954 thesis 'Ueber das Schwinger'sche Funktional in der Quantenfeldtheorie' shows something rather typical of the man: the use of Feynman's path integral (including the saddle point method) a full twenty years before it became popular. Many of these papers have one central topic: How can the basic equations of quantum field theory be formulated in a convergent way? Among them there are investigations on structural analysis on conformal bootstrap and of course the series of famous Lehmann-Symanzik-Zimmermann publications which are cornerstones of axiomatic field theory.

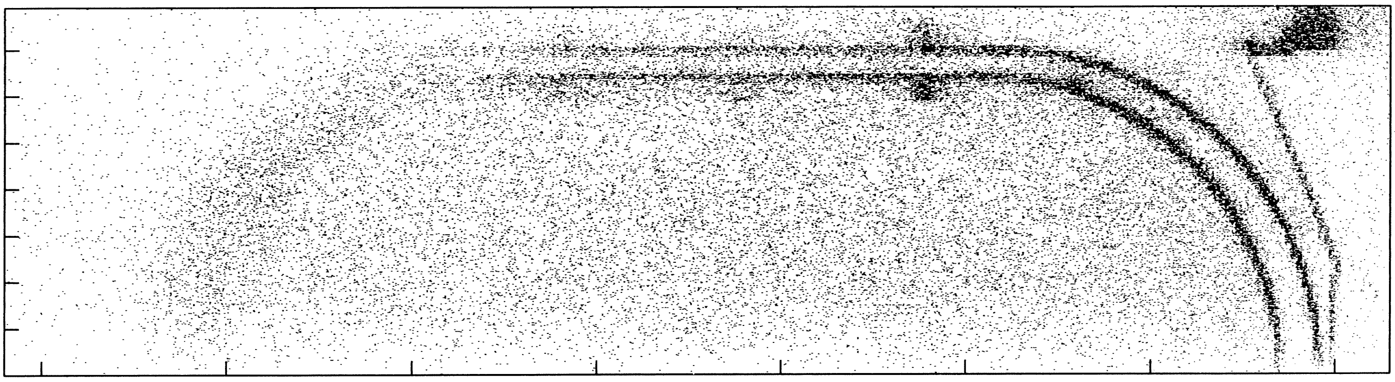
Gerard 't Hooft from Utrecht lectured on 'The birth of asymptotic freedom'. Starting from problems in the renormalization of the toy sigma-model (including certain symmetric breaking terms) Symanzik was led to the partial differential identities which became famous under the name Callan-Symanzik equations. Then after Symanzik found a vital clue (the negative sign of the Callan-Symanzik beta-function in a model theory), 't Hooft, Gross and Wilczek and Politzer attacked the 'nonabelian' gauge theories which describe the quark and gluon fields, going on to show that in these theories the perturbation approach was valid at high energies. The decisive steps in understanding the high energy behaviour of modern gauge theories had been made.

Up to that time, the analysis of deep inelastic scattering experiments had relied on the 'parton' model, qualitatively useful but by itself not rigorous enough to satisfy more stringent demands. Otto Nachtmann (Heidelberg) showed how it had to be interpreted as the lowest approximation to the new 'asymptotically free' quantum chromodynamics which has become the accepted theory of strong interactions. There are still unsolved problems around, as Nachtmann pointed out, with the 'EMC effect' on nuclei (see opposite).

Arthur Jaffe (MIT) called Symanzik 'the father of Euclidean field theory'. The trick of changing the time variable from real to imaginary, making four dimensional space look spherical, proved to be exceedingly fruitful for both field theory and statistical mechanics. In the latter, applications in gauge theories and problems with fermions have just been started. Jaffe recommended rereading the classical papers of Symanzik, specially the Varenna lectures, still a valuable source of ideas and inspiration.

Although Symanzik published only a few papers on statistical mechanics, Edouard Brezin (Saclay) pointed out that the Callan-Symanzik equations turned out to be an indispensable tool for the description of critical phenomena, permitting both the number and values of critical exponents to be fixed. Applications range from complicated ferromagnetic problems to surface effects in the vicinity of the critical points. Of great

The world's first neutrino radiography, given by the CERN / Dortmund / Heidelberg / Saclay experiment in the CERN SPS neutrino beam. A liquid hydrogen target was installed upstream of the main apparatus, and this reconstruction clearly shows the 'shadow' of neutrinos hitting the double iron walls of the 6 metre-long liquid hydrogen container. The exposure required 6 x $10^{18}$ SPS protons, corresponding to several months of continuous running.



importance was the proof that at the critical point the calculation could be restricted to the simplest massless theory. Martin Luescher (DESY) described a fundamental paper of Symanzik on the Schroedinger representation in quantum field theory. This picture, with its intuitively appealing concept of wave functions, poses difficult mathematical problems which Symanzik was able to solve. His aim was to provide a description of the Casimir Effect (the attraction between two conducting plates in vacuum), but the methods have proved to be useful in a much wider context.

The lattice approach to field theories, now the subject of much activity, both human and electronic, received an important boost from Symanzik's work. Giorgio Parisi (Rome) explained how Symanzik became motivated by a study of the cut-off dependence of field theories, going on to develop a systematic procedure to reduce the intrinsic error due to the lattice approximation. The experience collected so far suggests that this method will continue to pay dividends. Parisi stressed also how stimulating, helpful and patient Symanzik was in guiding younger colleagues.

Finally Harry Lehman (Hamburg), a close friend of Kurt Symanzik, presented a personal portrait.

The colloquium emphasized Symanzik's great contributions to physics, and how strongly his work has influenced, and will continue to influence, research.

*From Fritz Gutbrod*

## CERN
## Of hydrogen and iron

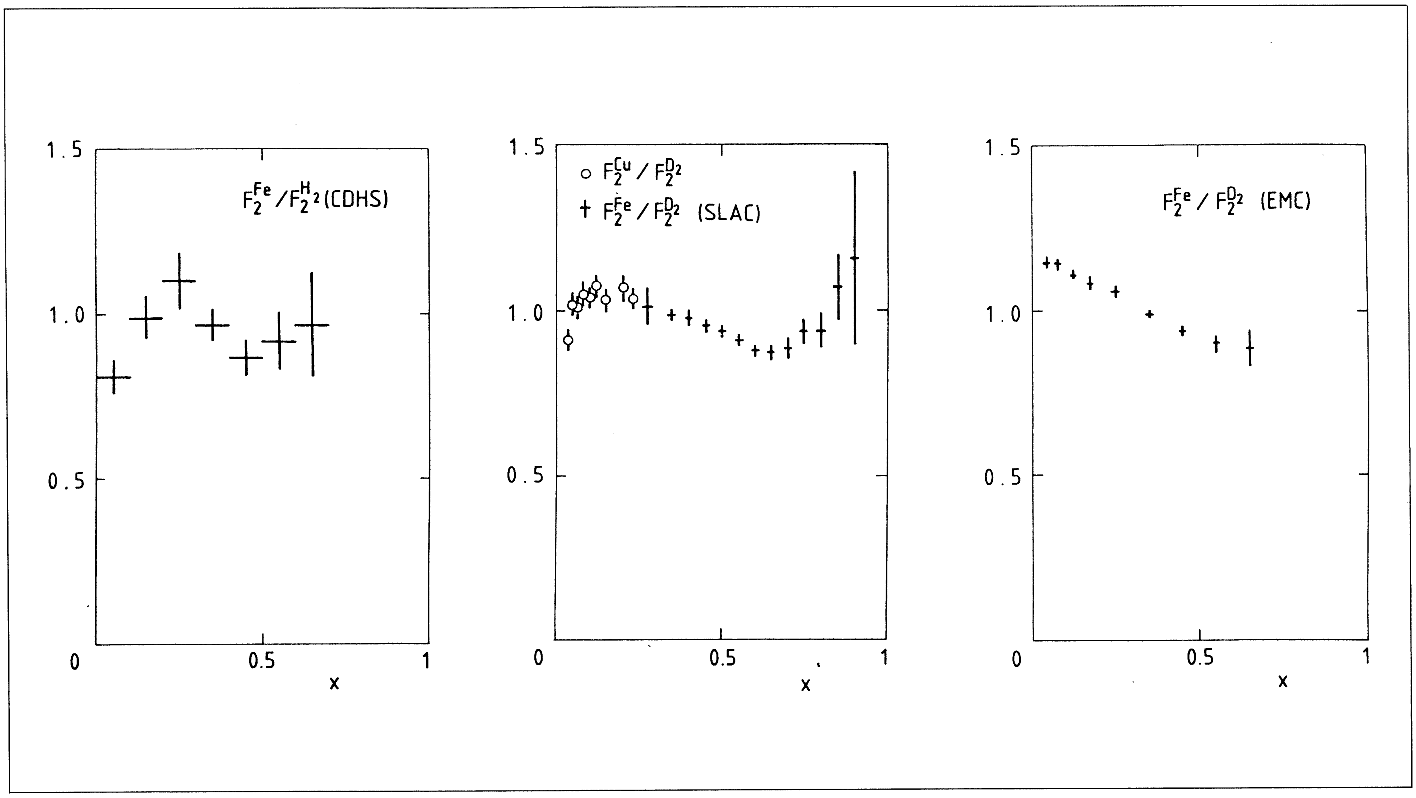
Experiments using high energy beams of non-strongly interacting particles on different nuclear targets have established that the quarks hidden deep inside nuclei do not necessarily always behave in the same way. Results from the European Muon Collaboration (EMC) using high energy muon beams from the CERN 450 GeV SPS proton synchrotron, together with archival data unearthed from old electron beam experiments at the Stanford Linac (see April 1983 issue, page 90), showed what has come to be known as the 'EMC Effect'—the measured quark distribution depends on the type of nucleus being studied.

These experiments compared heavy nuclei with deuterium, where the nuclear effects are already small. But it was important to compare heavy nuclei directly with hydrogen, where the target nucleons (protons) are free of all nuclear effects, and meanwhile the mighty CERN / Dortmund / Heidelberg / Saclay detector in the 400 GeV SPS neutrino beam had been equipped with a 35 $m^3$ liquid hydrogen target.

With 1500 tons of downstream detector, this experiment has been analysing the hadrons and muons produced in high energy neutrino interactions since 1976, and has furnished a wealth of precision data. With its hydrogen tank, it became the world's first fully electronically-equipped neutrino experiment studying interactions in hydrogen.

A vertex detector triggered on events in the tank. After reconstruction, collisions in the liquid hydrogen could be clearly distinguished from those due to neutrinos hitting the tank wall (thus providing the world's first example of neutrino radiography — see photo).

After selection criteria had been applied, there remained 4457 neutrino-proton and 4178 antineutrino-proton collisions. Comparing this data with that from collisions in the tank wall (2105 and 1075 events respectively) gives the relative interaction level (ratio of total cross-sections) of neutrinos in hydrogen and iron, while comparison of the tank wall data with that recorded in the main part of the detector allows the handling of the complex tank geometry to be checked. The measured relative rates (cross-sections) in iron and hydrogen tie in with previous results from neutrino experiments using hydrogen bubble chambers,




*Comparison of quark distributions (structure functions) in different nuclei from experiments using neutrino (CDHS), electron (SLAC) and muon (EMC) beams. The behaviour of quarks in nuclei seems to be dependent on the experimental conditions as well as the nature of the nuclear matter itself.*

# More nuclear effects

*The observed dependence of quark distributions on the conditions and type of nucleus being studied has important implications for nuclear electromagnetic interactions.*

*These interactions are mediated by the exchange of a 'virtual' photon between the incoming charged particle and the target nucleus. This photon strikes a quark inside the nuclear target, which then 'fragments' to produce a spray of hadrons. The various spectra of these produced hadrons provide valuable clues to the 'confinement' mechanism which ensures that quarks appear to us to be locked inside hadrons.*

*This hadron production can be studied by looking at the scattering of charged, non-strongly interacting particles (electrons and muons) from large nuclear targets. Previous experiments were either at low energy (so that the struck quark could only travel a small distance inside the nucleus) or had only limited statistics. Thus the European Muon Collaboration at CERN embarked on a comparison of hadron production by 200 GeV muons from copper and carbon targets, and by 120 GeV and 280 GeV muons on hydrogen.*

*The lower energy experiments had reported that produced hadrons tend to be absorbed before they leave the target nucleus. A similar effect was seen in the EMC experiment at low virtual photon energies (about 50 GeV). However at higher photon energies (100 GeV), secondary interactions are less important and these effects tend to disappear. This implies that under these conditions the quark struck by the virtual photon produces hadrons outside the nucleus—the distance travelled by the quark before it fragments into hadrons is greater than the size of the nucleus. The struck quark also interacts rather weakly with the nucleons in the nucleus.*

*With the behaviour of quark distributions in nuclei still largely a mystery to most people, this new information should help provide new insights into the properties of quarks in nuclear matter.*

and there is no significant variation with neutrino energy.

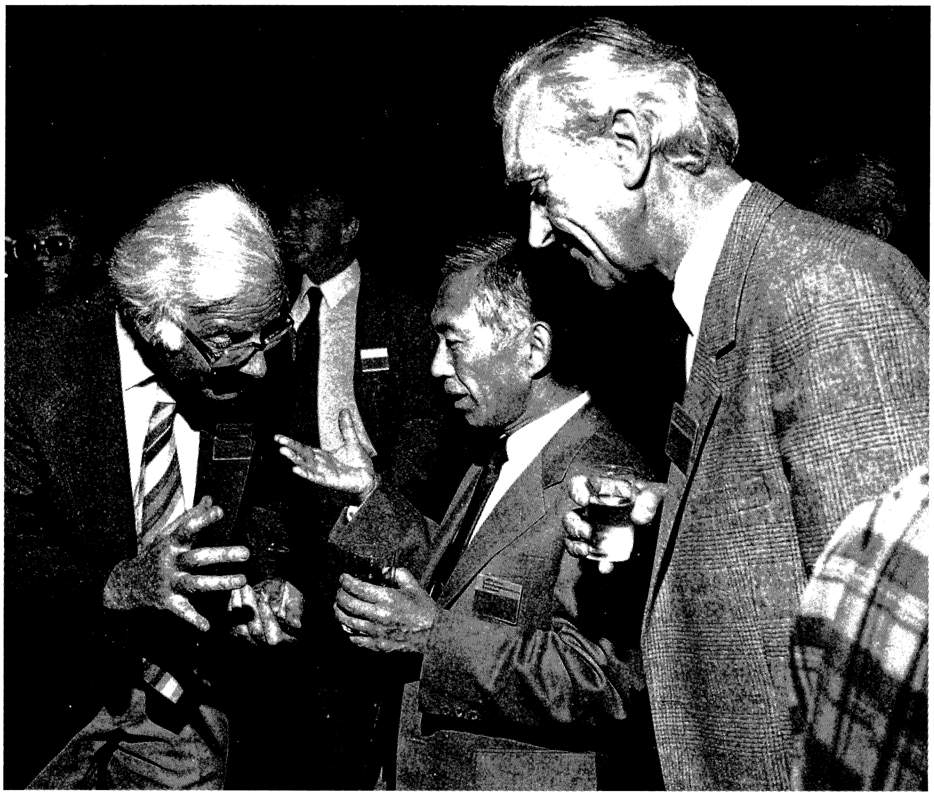
The experiment went on to compare explicitly the quark distributions (structure functions) in hydrogen and in iron. The highly anomalous behaviour seen in the EMC experiment is not reproduced, but there is some similarity with the results from the SLAC electron scattering experiment.

The three experiments have different kinematic conditions. Thus it appears that the behaviour of quarks in nuclei is dependent on the prevailing quark kinematics as well as the nuclear composition. There is enough kinematic room for all the data to coexist happily, however the origins of these effects remain unclear.

# CONFERENCE
# Linacs at Seeheim

P. Lapostolle of the French GANIL Laboratory (right) observes with interest the handwaving argument between J. Lawson (left, Rutherford Appleton Laboratory, UK) and M. Odera (Riken, Japan).

(Photo GSI Darmstadt)



The 12th Linear Accelerator Conference, organized by GSI Darmstadt, was held from 8-11 May at the Lufthansa Schulungszentrum in Seeheim, West Germany. It was the first of this series of Linac Accelerator Conferences—started in 1961 with 20 participants and 17 contributions at Brookhaven—held outside North America. In Seeheim, 32 invited talks, 11 oral and 98 poster papers were presented to more than 250 participants from the USA, Canada, Europe, Japan, the USSR and China, representing 39 research institutions and 12 industrial laboratories.

The meeting opened with a survey of performances of present proton linacs which cover a spectrum of energies up to 800 MeV (Los Alamos), peak power up to 20 MW (Brookhaven), beam mean power up to 1 MW (Los Alamos), and beam currents up to 150 mA (CERN 2). Throughout the last 20 years, the trend has been to higher intensities and duty cycles, reflected now in the interest in beam loading phenomena and improved preinjectors.

At the previous conference (1981) in Santa Fe, seven institutions presented papers on radio-frequency quadrupole (RFQ) developments and this time speakers from 9 Laboratories reported results of RFQs in operation. Recently three of these have been installed in front of accelerators (at Brookhaven for negative hydrogen, at CERN in front of Linac 1 and at Saclay between a Cryebis ion source and SATURNE accelerating carbon, nitrogen and neon). Foreseen for the near future is the RFQ for ions up to mass 40 at the Berkeley Bevatron. Being tested are developments at Los Alamos ($H^-$ and d), INS Tokyo ($H^+$, $H_2^+$, $Li^+$), Chalk River (protons), GSI Darmstadt (heavy ions) and Frankfurt University (protons). Development work is also underway elsewhere. The obvious conclusion is that RFQ building and operation will soon become routine and all Cockcroft-Waltons will be replaced. This was underlined by the organizers' choice of a historical contribution by I.M. Kapchinsky (Moscow), who together with V.A. Teplyakov carried out pioneering RFQ work at the end of the sixties. Unfortunately Kapchinsky could not attend the conference. His paper—presented by N.V. Lazarev—revealed the similarity of developments in different parts of the world once the idea had been born. Now many people are working on RFQ innovations—for high current, high brightness, continuous wave operation and applications where space charge is of strong consideration.

For the future, it was encouraging to learn about experimental configurations of a wake-field scheme (DESY) and of a collective heavy ion accelerator (Dubna). Here significant progress should be expected by the

# People and things

next conference. Substantial progress could be announced in the development of superconducting cavities, where 5 MV/m accelerating gradients can now be achieved reliably in multi-cavity systems from 300 MHz to 3 GHz. Specialists have learned how to control the thermal stability and to find and to remove defects on the surface, so that the electron field emission limit may be the next barrier that will have to be considered.

There was a great deal of work presented on electron linacs, high current and continuous wave accelerators. In the theoretical field, the understanding of beam cavity interactions and high current beam transport were the centre of discussion. Finally there was the traditional coverage of ongoing projects, where the somewhat specialized linac field opens out to the vast accelerator landscape. Unfortunately the participants from Novosibirsk (V.E. Balakin, A.N. Skrinsky) could not join the conference and their announced contribution on the VLEPP project—a linear collider scheme—had to be cancelled, so that the report on the SLAC Single Pass Collider (by G.A. Loew) enriched by some ideas on future linear colliders was the only communication on this historical step in linear accelerator physics. The suggested site for the next Conference (1986) is Stanford.

*From Heinz Prange*

## On people

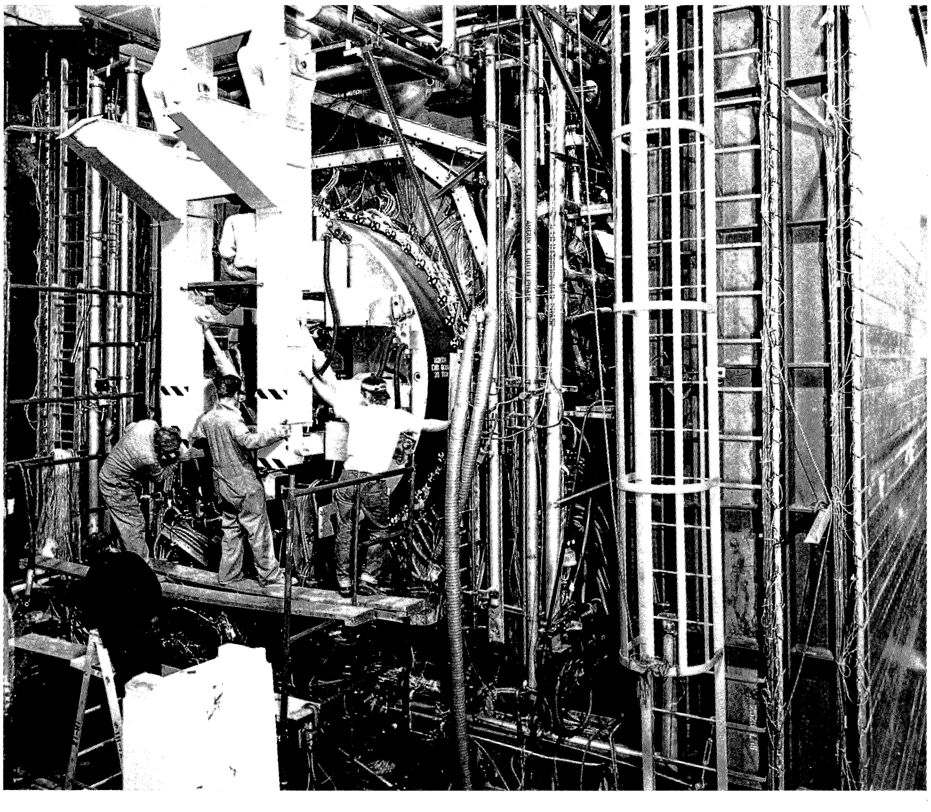
*New President of the European Physical Society is Godfrey Stafford, Master of St. Cross College, Oxford, former Director General of the Rutherford and Appleton Laboratories, UK, and for several years Chairman of the CERN Scientific Policy Committee.*

*European Physical Society Lecturer this year was Paul Matthews, now at Cambridge. Well known in the particle physics community for his numerous original theoretical contributions, and renowned for his skills as a lecturer, he presented talks on electroweak interactions and on stellar evolution to student audiences in Switzerland, West Germany and the Netherlands.*

*Special seminars organized by CERN's Theory Division recently marked milestone birthdays for Rolf Hagedorn (65), and Léon Van Hove (60).*

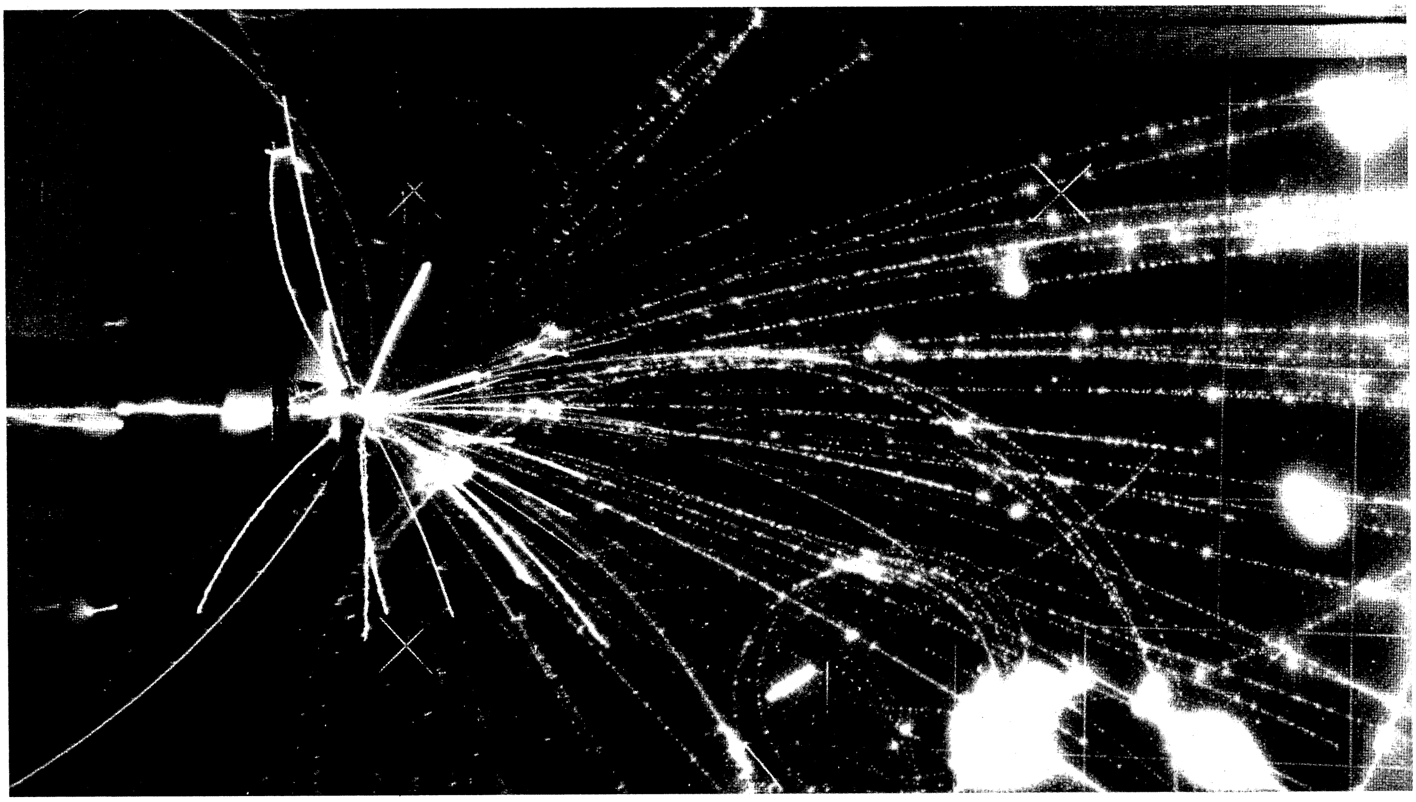
*Alan Schriesheim, senior deputy director and chief operating officer of Argonne National Laboratory becomes Director, succeeding Walter E. Massey.*

*A correction to the US National Synchrotron Light Source story published in our May issue, page 156. John McTague is no longer NSLS head. After McTague's departure to Washington to become deputy to Office of Science and Technology Policy Director George Keyworth, BNL Associate Director Marty Blume took over NSLS as Acting Chairman.*



*The Mark II detector is eased out of its position in the PEP electron-positron ring at Stanford prior to upgrading for eventual running at the SLC Stanford Linear Collider now under construction. The detector will receive a new central drift chamber. Before operating in SLC, the revamped Mark II will be put through its paces in the PEP ring.*

*(Photo SLAC)*



The spectacular firework display seen in a streamer chamber at the Berkeley Bevalac by a GSI (Darmstadt) / Berkeley team studying heavy ion (here an argon-40 beam) collisions. This work gives valuable clues to the properties of compressed nuclear matter, also of interest to astrophysicists.

## Stiff nuclear matter

*In our previous issue (page 196), we described work by a joint GSI (Gesellschaft für Schwerionenforschung, Darmstadt) / Berkeley team investigating the formation of compressed nuclear matter in heavy ion collisions at the Berkeley Bevalac using the Plastic Ball / Wall detector. Valuable information on collective nuclear matter has also come from another GSI / Berkeley team working at the Bevalac, this time using a streamer chamber to measure pion production in heavy ion collisions and infer the properties of the compressed nuclear matter formed in the $10^{-23}$ seconds following the collisions. Their studies suggest that such matter is relatively 'stiff', thus tying in with recent observations on neutron stars, and forming another bridge between astrophysics and high energy experiments.*

*The streamer chamber is scheduled to come to CERN for experiments using higher energy heavy ion beams produced in the 28 GeV 'proton' synchrotron (see July/August 1983 issue, page 223).*

## Intermediate energy future

*With proton machines at many major Laboratories being increasingly used as injectors for larger machines, the supply of intermediate energy beams for both particle and nuclear physics experiments could become tight. Recently there has been a series of workshops looking at the prospects for intermediate energy physics (see, for example, June issue, page 194, and March issue, page 56).*

*Physics objectives and future experimental facilities for particle and nuclear physics at intermediate energies were discussed at a workshop held in Freiburg (West Germany) from 10-13 April. The workshop was organized by the University of Freiburg and by Projektträger Mittelenergiephysik of the Federal German Ministry of Science and Technology.*

*During three days more than 200 invited participants from high energy and nuclear physics took part in lively discussions on future options in particle and nuclear physics at low and intermediate energies, grouped into six study groups. In a plenary session on the fourth day, discussion leaders reported on results, conclusions and recommendations of their study groups. The session ended with a delightful lecture by Wolfgang Paul on forty years of accelerator history in Europe.*

*Important topics covered at the workshop included: Kaon and Hyperon Physics; Physics with Antiprotons and with polarized Protons; Elementary Hadronic Systems in the Light of Quantum Chromodynamics; Rare and Ultrarare Decays and Reactions; Electroweak Interactions and Neutrino Physics; Nuclear Physics with Strangeness-Carrying Probes.*

*The contributions of some fifty speakers in the study groups gave an impressive overview of the promising and rich spectrum of this field of physics. These contributions included summaries of earlier workshops held in the US and in Canada (LAMPF II, TRIUMF Kaon Factory, AGS II Brookhaven). Although electron and muon beam facilities were also studied, the discussion of accelerator perspectives lead to the clear and rather unanimous conclusion that a rapid cycling, high intensity proton synchrotron at about 30 GeV would be best suited to meet the needs of experimentalists. The success of the meeting made it evident that there is a broad community of potential users—far beyond the German groups who have a long and successful tradition in this field of physics.*

*(From F. Scheck)*

*This year, over 60 runners lined up at the start of the traditional annual relay race round the CERN site. It was won by the UA 1 'Monojet' team, recapturing the trophy they lost last year while their attentions were diverted by the discoveries of the W and Z particles.*

*(Photo CERN 472.5.84)*

## Cheer at LEAR

*Judged by the bubbling enthusiasm of its 260 users, the LEAR Low Energy Antiproton Ring at CERN continues to be a great success. First trials last year encountered some teething troubles, and there were other factors which made scheduling LEAR beam about as difficult as predicting the weather. However the machine has emerged from its initial shakedown with flying colours.*

*During a successful run at 300 MeV/c earlier this year, up to 100 000 antiprotons per second were focused to a spot as small as 1 mm$^2$. Recently LEAR delivered a new 1.5 GeV/c beam in record time, providing experiments with more than 200 000 antiprotons per second in a fine beam less than a millimetre wide in one direction and 1.5 mm in the other. These are just the conditions for physics discoveries and more new LEAR results are eagerly awaited.*

## Oscillation hint

*As mentioned briefly in our previous edition (page 196), the Annecy / Grenoble team working at the Bugey (France) reactor has seen some indications for neutrino oscillations. The search for this phenomenon has been (and continues to be) the subject of wide experimental interest (see March issue, pages 62-4). The Annecy/Grenoble team look for variations in the electron neutrino signal between two different positions of their detector and find a small range of neutrino variables where such an effect cannot be definitely ruled out. Work is continuing with a view to confirming (or otherwise) this initial indication.*

## Aladdin has light

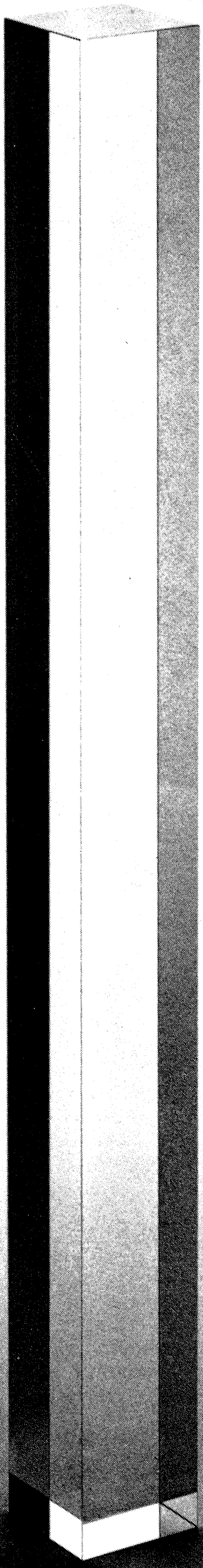
*Electron beams have been taken to 800 MeV in the Aladdin storage ring at the Synchrotron Radiation Center, University of Wisconsin-Madison. Work is now concentrating on higher injection efficiencies and overcoming beam instabilities. It is soon expected to be running reliably with beam intensities of 10 mA, and with the first beamline for experiments in position.*

## How UA 1 won

*The UA 1 'Monojets' were first past the post in this year's traditional 3.9 km relay race round the CERN site. Last year, with all the panic about the W and Z particles, the experiment's first team could only manage second place. This year UA 1 fielded no less than seven teams, meriting some additional award for mass participation. Not all the UA 1 teams could reproduce the form of the 'Monojets', with the aptly named 'Missing Energy' sextet finishing near the other end of the spectrum of results. However the real 'run' is scheduled to begin in September, when the SPS proton-antiproton Collider comes back into action.*

## HERA meeting

*A meeting on experiments for the HERA ring will be held in Italy from 1-3 October. More information follows.*



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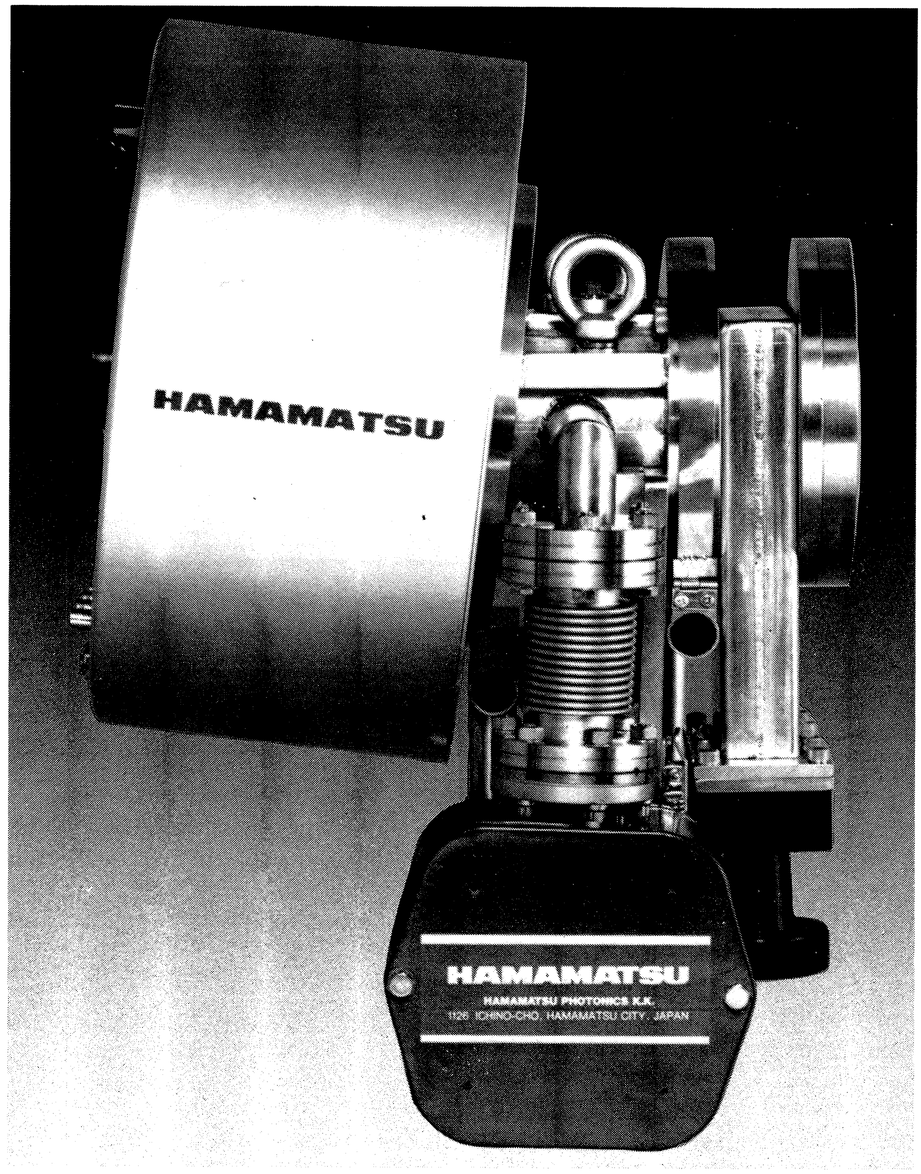


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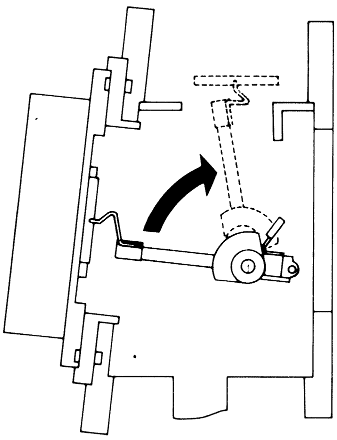

The photocathode manipulator illustrated above is based on a design by Livermore National Laboratories.

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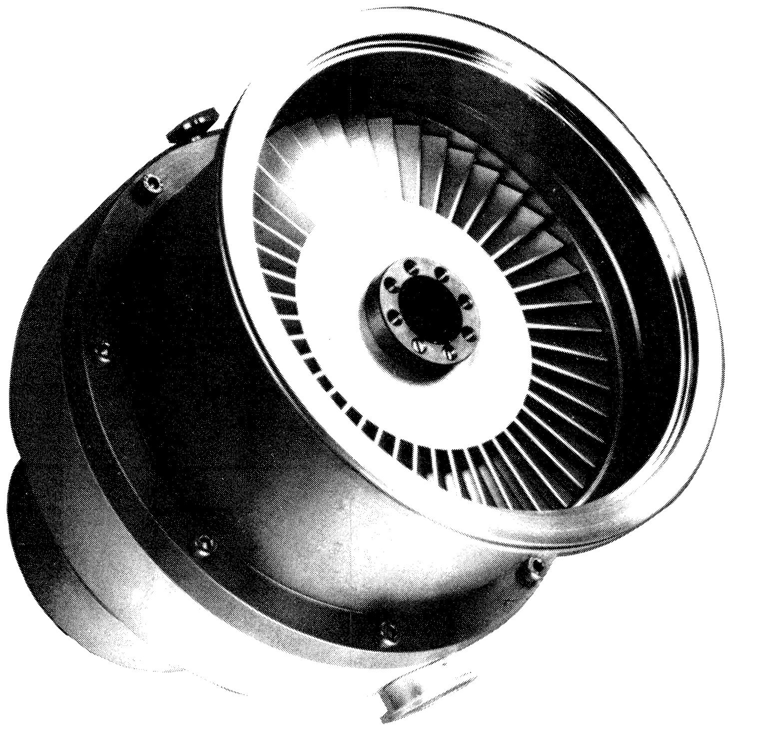
# A step towards the future: The new Turbo 1500



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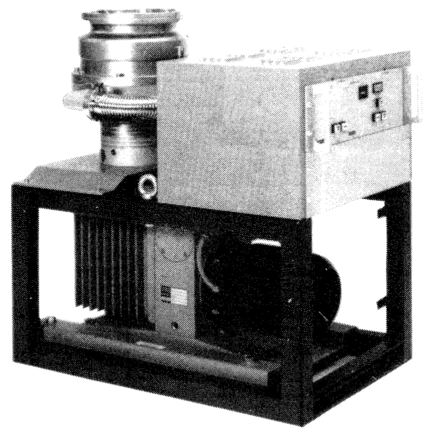
**The '84 Turbo pump range**

Balzers offer a range of seven pump sizes. The proven dual flow pumps with their unsurpassed smooth running, and the high-efficiency single flow pumps satisfy all user requirements. Several types of flanges and selection of the cooling medium allow the seven basic pumps to be expanded to ten pumping speeds between 27 l/s and 6500 l/s.



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