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A Point of View

Cover photograph : Kjell Johnsen prepares to cut the cake at the celebrations on 30 November marking the 1000th run at the CERN Intersecting Storage Rings (see story page 439). (Photo CERN 474.1.78)

A giant LEP for mankind *

During the past three years, the European high energy physics community has debated future facilities which would best respond to the foreseeable physics needs towards the end of this century. The consensus has come out strongly for an electron-positron machine to take colliding beam energies well beyond those which are accessible with PETRA at DESY and PEP at Stanford. This colliding beam machine is commonly known as the LEP (Large Electron-Positron) project.

The reason that LEP so rapidly attracted the enthusiastic support of the full European high energy physics community is that it is the ideal machine to address many of the most important physics issues to have emerged from the past five feverish years of discovery.

Neutral currents, a new form of the weak interaction, were seen at CERN in 1973. The J/psi particle was dramatically discovered at Brookhaven and Stanford in 1974, rapidly leading to the confirmation of a further type of quark — the charmed quark — and new families of particles. Multimuon neutrino events, discovered at Fermilab in 1975, underlined the existence of new phenomena which were shown, in 1977 at CERN, to be related to charmed particle production. The tau heavy lepton was found at Stanford in 1976 and the upsilon was found at Fermilab in 1977.

The theoreticians, remarkably quickly, made sense of much of what was being seen. Dominant in their thinking is the theory which unites our understanding of both the weak and electromagnetic interactions. This seems certain to be one of the great physics insights of this century. It will enable us to interpret, in terms of the same 'electro-weak' laws of physics, such vastly different phenomena as the beta decay of a nucleus, a flash of lightning, a neutrino interaction, the swing of a compass needle...

To really clinch the present theories, experiments have to provide several further pieces of evidence and the ideal conditions for these experiments are those which would be provided by very high energy electron-positron collisions.

The emergence of LEP

Studies of a large electron-positron machine began at CERN in 1976 as part of a major exercise (involving also the study of a higher energy proton colliding beam machine and physics with a higher energy proton fixed target machine) to analyse physics needs and machine possibilities in the decades after the coming into operation of the 400 GeV proton synchrotron, the SPS.

Interest eventually concentrated on the electron-positron option, initially considered as having a 100 GeV energy per beam, because of the strong attraction of the physics it offered and because other major regions of the world seemed likely to build alternative higher energy machines. (In the USA construction of a 400 GeV proton-proton colliding beam machine ISABELLE is starting at Brookhaven. In the USSR a 5 TeV fixed target proton machine is under consideration.)

The European Committee for Future Accelerators was obviously deeply involved in the early thinking and, urged on by its then Chairman, Guy von Dardel, on 25 May 1977 emerged with a strong recommendation for 'an electron-positron storage ring of about 200 GeV centre-of-mass energy, possibly with an initial phase of 140 GeV', as the prime candidate for a major European project for the 1980s. (The full text of the recommendation can be found in CERN COURIER June 1977, page 186.)

Work at CERN resulted in a preliminary report in August 1977. It then looked as if technical machine problems (such as orbit stability and magnet tolerances) would make life difficult with energies of 100 GeV per beam in a large diameter ring. In a second phase of the studies, effort concentrated on the design of a machine of smaller diameter (7 km) which would give 70 GeV per beam maximum energy and could reach 100 GeV per beam using superconducting r.f. cavities. The machine studies were led by Eberhard Keil, Wolfgang Schnell and Kees Zilverschoon.

At the same time the physics use of the machine was studied in groups led by Pierre Darriulat, Emilio Picasso and Erwin Gabathuler. Many accelerator specialists and experimental physicists from throughout Europe have been involved. The studies were supervised by a LEP Steering Committee, chaired by John Adams, which also had representatives from 'electron Laboratories' — Daresbury, DESY, Frascati and Orsay.

From 10-22 September (as reported in the October issue page 353) all this work was subject to a major review at a LEP Summer Study held at Les Houches. After the Summer Study, a third phase of the studies began on a large diameter (10 km) machine to give 80 GeV per beam at maximum luminosity which later could reach 120 GeV per beam with superconducting r.f. cavities.

Some of the physics accessible to LEP

When electrons and positrons collide with centre-of-mass energies in the LEP range many of the long predicted features of weak interactions can be expected to show up in one way or another. With existing machines, electromagnetic and weak effects are difficult to compare directly, but at LEP energies any unified electro-weak phenomena could be seen much more clearly. LEP will be the ideal tool to study the synthesis of the electromagnetic and weak forces.

**With apologies to Neil Armstrong*

Although experimental evidence for this electro-weak synthesis has become apparent only fairly recently (see July / August edition, page 245), our ideas on the weak interaction date back much further. Some forty years ago, it was customary to work with the so-called 'four-point' interaction in which the incoming and outgoing particles involved in a weak interaction all met at a single point in space-time. However, it was soon realized that such a description could not hold at very high energies where it would be incompatible with basic ideas of probability.

In quantum physics, theoretical calculations give only relative probabilities of different outcomes and the macroscopic effects seen in the laboratory are averages reflecting these probabilities. Whatever the relative probabilities, one thing is certain — something is bound to happen. This is called 'unitarity' in the trade and is incorporated into the theory by insisting that the sum of all the probabilities must be unity. Although this idea may seem trivial at first sight, it produces powerful constraints on any theory.

For the simple weak four-point interaction, extrapolating the theory to very high energies was soon seen to give problems with probability. Although such high energies were remote at that time, the theoretical picture was amended to suppress this high energy behaviour by introducing heavy intermediate vector bosons.

The intermediate vector bosons are postulated as the universal mediators of weak interactions, in much the same way as the photon is responsible for electromagnetic phenomena. However, while the photon is massless and produces important effects at large distances, the intermediate bosons are heavy particles which act only at short distances. Also, unlike the photon, the bosons can carry electric charge.

This concept of the intermediate vector boson has haunted the history of weak interactions. Each generation of machines has failed to find any trace of it and its postulated mass has been progressively shifted higher to await machines providing a new range of high energies. Now, however, we have good reasons for believing that the bosons must appear at LEP energies.

LEP will penetrate the energy range where unitarity problems have been foreseen for so long. With high energy behaviour observable directly, some of the true nature of the weak interaction must be revealed.

These unitarity arguments have to be borne in mind whatever theoretical scenario is used. However, recent developments in the application of gauge theory techniques have made spectacular progress and the scenario based on 'standard' gauge theory is very popular. Despite these successes, the theory is not completely watertight and we should be careful not to close our eyes to other possibilities until some important predictions are confirmed. It is still possible (although increasingly difficult) to account for the present observed particle behaviour in other ways.

The discovery of the neutral current in 1973 showed that the 'standard' gauge theory of weak and electromagnetic interactions had important predictive power. Steven Weinberg and Abdus Salam first proposed this theory in 1967-8, but several years elapsed before its potential was realized and before it became clear, thanks particularly to the work of Gerard 't Hooft, how calculations were possible.

Subsequent experimental results have consistently underlined the validity of the electro-weak gauge theory but the bosons participating in the inner mechanisms of the theory have yet to appear.

A vital ingredient of the theory is the existence of three types of intermediate vector bosons — the massless photon of electromagnetism and two heavy particles responsible for the neutral and charged current weak interactions. On the basis of presently available data, the standard model predicts that the two missing bosons have masses in the region of 80-90 GeV, and should therefore turn up in experiments at LEP energies. (It is possible that they will first be seen at the proton-antiproton collider at the CERN SPS but their detailed study would still await the 'clean' experimental conditions of LEP.)

In addition to opening the door on the inner workings of weak interactions, higher energies will provide additional information. The effects of weak interactions increase with energy and near the intermediate boson masses they should be comparable in strength to those of the electromagnetic force. If the electroweak theory is correct, it should really come into its own in this energy domain of LEP.

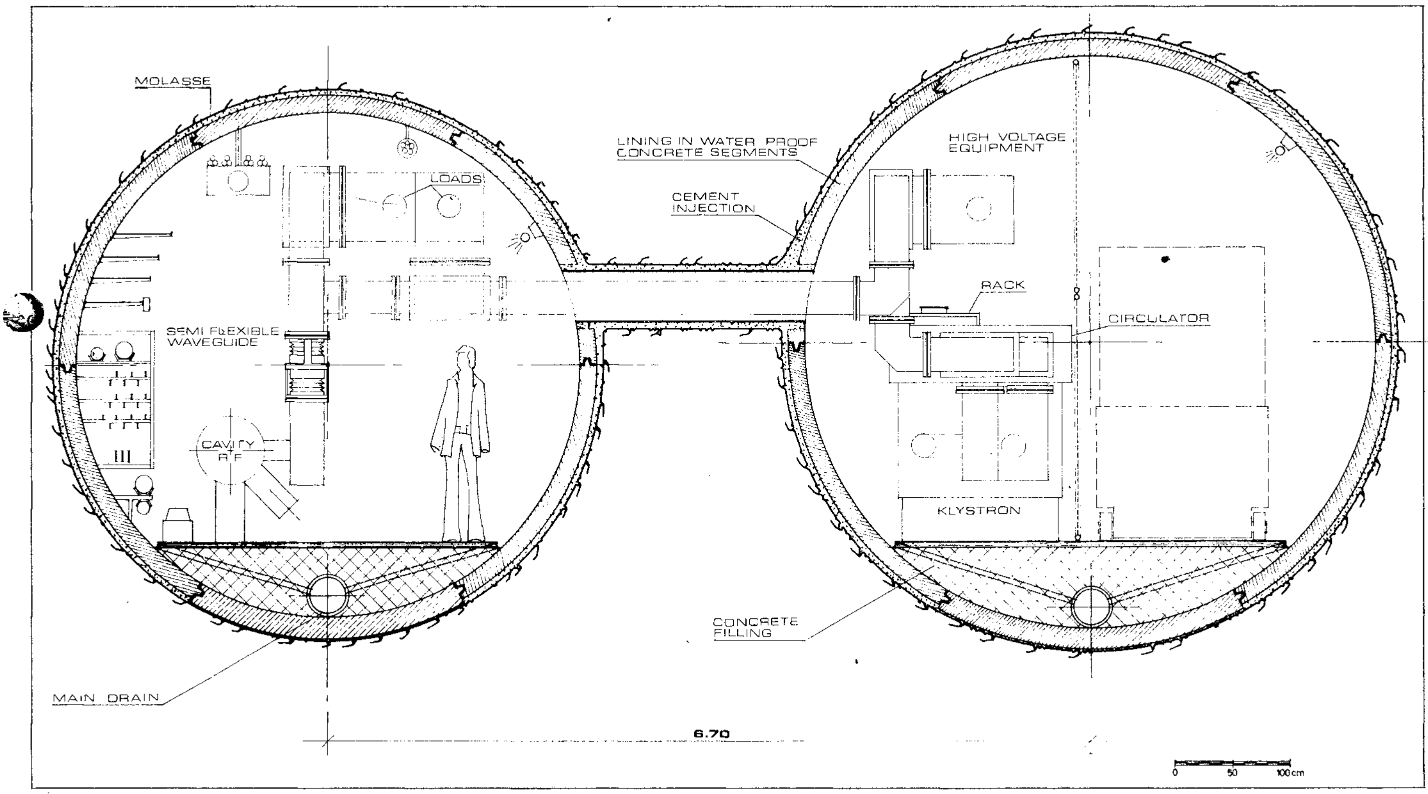
As well as the vector bosons, another vital ingredient of the gauge theory approach is the so-called 'Higgs bosons'. As a gauge theory, the standard model of weak and electromagnetic interactions is based on an underlying symmetry. However, this symmetry is said to be 'spontaneously broken'.

Normally when this happens, massless particles are produced, but the intermediate particles of the weak interactions are required to be extremely heavy.

The idea proposed by Weinberg and Salam was to use the 'Higgs mechanism' to give the gauge particles their required mass. This can only be achieved at the expense of additional particles — the Higgs bosons.

No trace has ever been seen of such particles. The hope is that with LEP, physicists will have the tool to explore in depth the details of the symmetry breaking mechanism at the heart of weak interaction dynamics.

A drawing of the LEP tunnel cross-section at the location of an r.f. cavity. Parallel with the accelerator tunnel is a slightly larger tunnel housing the r.f. klystrons.



LEP will also extend the energy range to study quark and lepton spectroscopy. One of the spin-offs from the original Weinberg-Salam formulation of the theory of weak interactions is the Glashow-Iliopoulos-Maiani (GIM) model which incorporates strange and charmed quarks and provides a framework for weak interactions involving hadrons as well as leptons. The observation of charm and subsequent heavy quark flavours was a great success for GIM, confirming that quarks and leptons do seem to fall into predictable multiplets.

At present three massive leptons are known, the electron, the muon and the recently-discovered tau, and according to theoretical arguments this could restrict the number of quark flavours to six. Four of these have been observed explicitly — up, down, strange and charmed — and a fifth has been detected implicitly in the heavy upsilon particles — explained as the bound states of a new heavy quark and its antiquark. Thus a sixth flavour is expected and could reveal itself in colliding beam experiments (perhaps at PETRA and PEP energies or in the proton-antiproton collider at the SPS).

More flavours and heavier leptons could turn up at still higher energies, although cosmological arguments say that there is an upper limit to the number of massless neutrinos, and hence perhaps to the number of different types of lepton which can exist. This can also lead to limits on the number of quark flavours to be expected. A good check of all these ideas can be carried out with LEP.

Hadron production from electron-positron collisions is a good testing ground for theories of inter-quark interactions of which quantum chromodynamics is the present front runner.

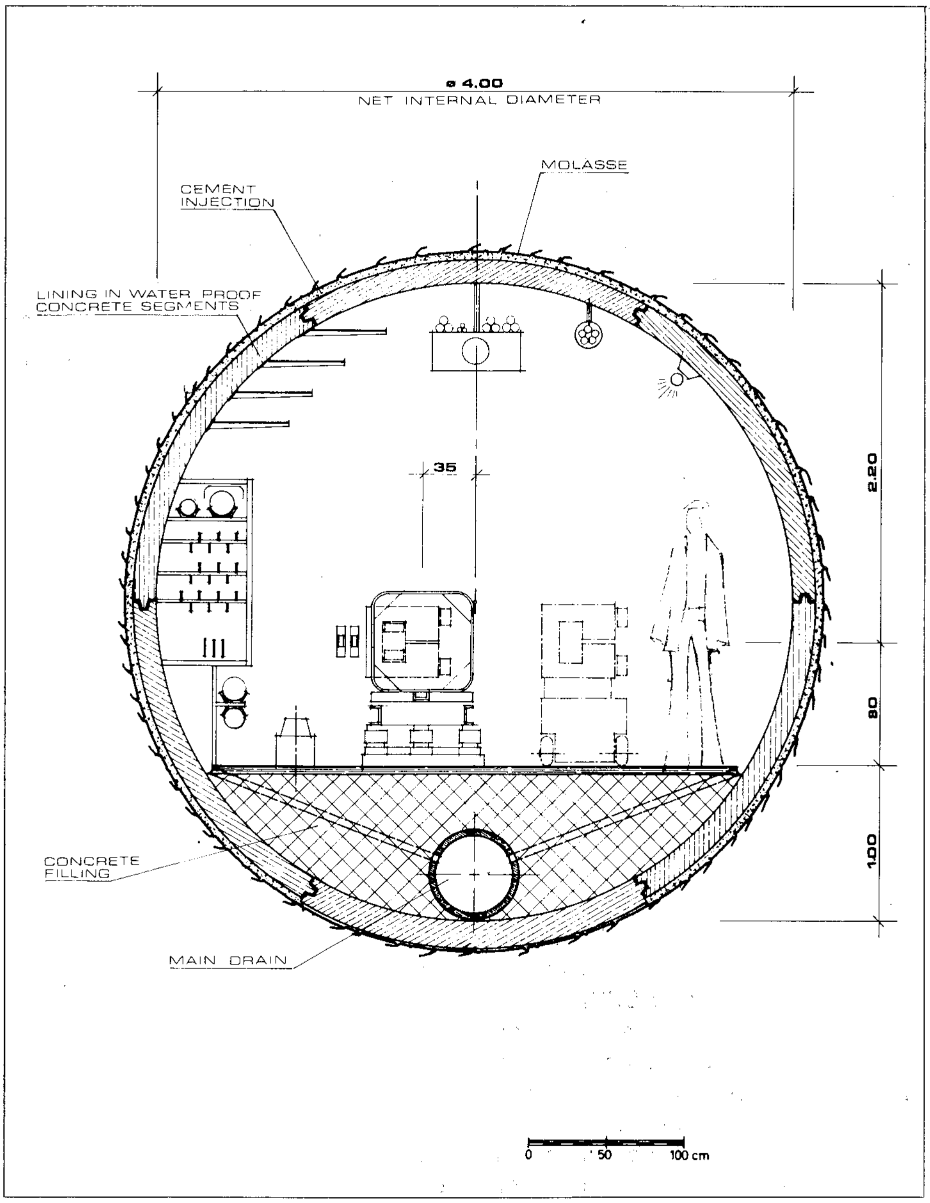
The scaling properties, jet structure and spectra of heavy quark-antiquark states would all reveal new information on inter-quark forces. And there is, of course, always the possibility that one of these days a new high energy machine might come up with the first sighting of a free quark, liberated from a hadron.

Another possibility is that, even with quarks, we might not have reached the fundamental layer in the structure of matter and there might be smaller constituents lurking inside the quarks themselves. First signs of these could turn up at LEP energies.

At the LEP meeting held at Les Houches, there was some eager crystal ball gazing about the likely behaviour at LEP energies. The recent success of electro-weak and quantum chromodynamics theories led to many predictions as to what will be seen.

However in his concluding talk, Sheldon Glashow explored many possible new physics scenarios for LEP. The range of alternatives he proposed underlined that, despite the present

A drawing of the LEP tunnel cross-section at the location of a bending magnet. The tunnel itself could be built using similar techniques to those used in the construction of the CERN SPS.



conviction in the popular theoretical predictions, LEP would still be a giant leap into the unknown.

The design study presented at Les Houches

By the time of the Les Houches meeting, work on the machine design had progressed to the stage where a 'Design Study of a 15 to 100 GeV e^+e^- Colliding Beam Machine (LEP)' was produced (CERN / ISR-LEP / 78-17). We pick out here the major features of this design, which was based on a 7 km ring, to convey some idea of what such a machine would look like.

The '7 km design' envisages the machine reaching its peak energy in two stages. The first, covering the range 15 to 70 GeV per beam, would use conventional copper r.f. cavities. The bottom end of its energy range would make it possible to link up with PETRA and PEP results and the top end would be limited mainly by the high r.f. power needed. The second stage, carrying the peak energy to 100 GeV could be implemented when superconducting r.f. cavities are mastered, reducing the power requirement.

The luminosity of the machine is set at 10^{32} per cm^2 per s at 70 GeV and it varies as E^2 (using wiggler magnets) down to 15 GeV. For the second stage a luminosity of 2×10^{31} is anticipated at 100 GeV.

Eight interaction regions are provided for the experiments and at each region a scheme is envisaged whereby one experiment can be in preparation while another is installed in the beams.

ECFA had asked CERN to examine the possibility of building LEP at the present CERN site. This has been done and looks feasible. Since the machine would be built well underground (where construction of the SPS revealed no major problems), the impact on the existing environment would be minimal.

Injection energy into the storage ring is 15 GeV. It may involve a 130 MeV, 6A electron linac, followed by a positron conversion target and 460 MeV positron linac, followed by an accumulator ring, followed by a synchrotron to fill LEP in 15 minutes. The other possibility is a preliminary storage ring, operating from 2 to 15 GeV, fed by a 200 MeV linac and a synchrotron, to fill LEP in 5 minutes.

The main ring will hold currents of 10.5 mA (5×10^{12} particles) circulating in four bunches to give the design luminosity. The r.f. will need to provide 900 MeV energy per turn to compensate for synchrotron radiation loss at 70 GeV. The total r.f. power requirement (adding in cavity losses, klystron efficiencies, etc.) is about 140 MW. When magnet power, experiments, cooling systems... are also added, the total power for LEP is just over 200 MW at 70 GeV.

The total cost of the first stage of this design of LEP is estimated at 1050 million Swiss francs.

The coming years

A possible 'masterplan' for the project sees the continuation of design studies (including some model component building and site work) through to 1981. The machine energy and the site for construction should be fixed in advance of this date and, as mentioned above, the implications of a 10 km ring are now under investigation. (The CERN Member States have given their blessing for these LEP studies to continue.)

A further period of preparatory work, which could also benefit from experience with PETRA and PEP operation, could see the start of construction from the end of 1981. At this time the money for LEP construction would probably have to be largely found by closing down other elements of the CERN research programme since, at the moment, no large jump upwards in CERN funding can be anticipated.

Taking about seven years as a reasonable construction time for LEP (so that operation could start at the end of 1988, some twelve years after the start of the SPS) would require a rate of funding of about 150 million Swiss francs per year. Closing down the Intersecting Storage Rings and the 600 MeV Synchro-cyclotron could make a major contribution to this budget and also liberate qualified manpower for the building of the new machine.

There are many more bridges to be crossed before the LEP project can get the go ahead. But the physics is of the greatest fundamental interest, the machine is technically feasible and the project has behind it the enthusiasm of the European high energy physics community.

Around the Laboratories

ARGONNE
Polarization Symposium

The 3rd International Symposium on High Energy Physics with Polarized Beams and Targets was held at Argonne from 25-28 October. The meeting was truly international for the first time with some 60 of the 225 attendees from Institutes as distant as Novosibirsk, Kyoto and Hanoi. It was again multidisciplinary with participants from accelerator science, chemistry and almost every branch of physics. There were surprises and controversies concerning recent experimental results and significant progress was reported in the development of polarized facilities.

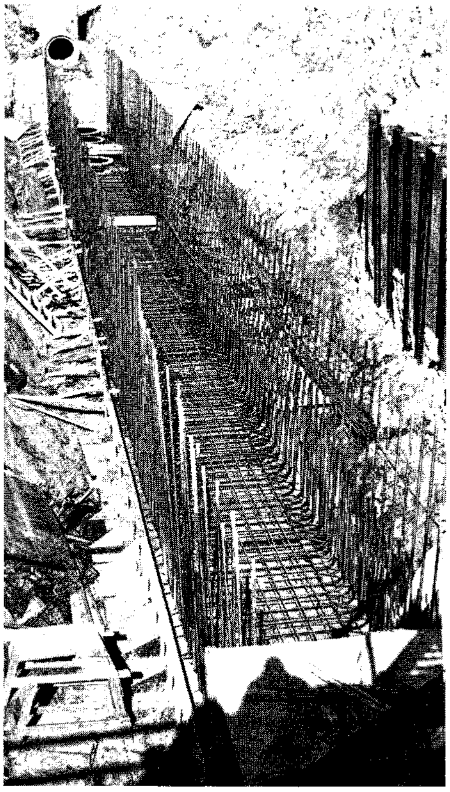
Much interest centred on exciting plans for new polarized facilities and (less happy) plans for old ones. The Symposium marked the beginning of

L. Michel of Bures-sur-Yvette (left) and L. Dick of CERN talk spin physics while touring a Pompeii exhibit at the Chicago Art Institute after the banquet at the Argonne Polarization Symposium.

the last year of operation of the Argonne Zero Gradient Synchrotron. In spite of the success of the experiments using the unique polarized beams at the ZGS, there seems little hope of extending its life much beyond October 1979.

The most exciting new project was a proposal to accelerate polarized protons to 26 GeV in the Brookhaven AGS by 1981 and, later, to transfer them to the ISABELLE storage rings using the 'Siberian Snake' scheme. This proposal was described in detail by Ernie Courant. The theory of depolarizing resonances and of 'Siberian Snakes' was reviewed by Lee Teng and Ya. Derbenev. The newly developed negative hydrogen ion polarized sources, which will make high intensities available, were discussed by W. Haeberli and E.F. Parker.

There was general agreement that 26 GeV polarized protons at the AGS seemed the logical step after the ZGS. Lee Teng felt that it would be too big a jump to the SPS or Fermilab machines with their many very strong depolarizing resonances. A decision on the Brookhaven proposal is expected by the end of the year. There were many reports on planned or operating polarized proton facilities at LAMPF, SIN, TRIUMF, Saclay and KEK.



There was considerable interest in polarized electron accelerators and storage rings, which is not surprising in view of the current interest in lepton physics. Planned or operating polarized facilities at PETRA, Bonn, SLAC, and LEP were described. An overall review of the production and use of polarized lepton beams in electron-positron storage rings was given by Roy Schwitters. The prospects for important developments seem promising.

One of the Symposium highlights was a beautiful lecture on the physics of polarized targets by A. Abragam. The possibility of better target materials was studied at a four-day Workshop just after the Symposium with about twenty experts, from various branches of physics and chemistry, who tried to design more radiation-resistant polarized targets with higher hydrogen content. These would allow improved high momentum transfer experiments and inclusive experiments.

Several interesting new ideas emerged such as a diffuse gas of hydrogen and CrF_5 which is instantly frozen by a He^3 refrigerator. They are still far from being practical and much more hard work and understanding is clearly needed. A longer, more detailed, polarized target Workshop may be held next summer in Liverpool.

Meanwhile, preparing for the future — an October photograph of the antiproton target area at Fermilab under construction between the Main Ring and the Booster. The 130 foot target vault, seen looking towards the Booster, is followed by a 4 foot diameter tunnel. The beamline configuration will allow reverse injection into the Main Ring for protons, for proton-proton collisions using the Energy Doubler, and injection of antiprotons into the Booster en route for cooling. These preparations are for the colliding beam projects of the future.

(Photo Fermilab)

The major controversy was unexpectedly generated by David Bugg who finished his review of spin effects in intermediate energy physics with a detailed critique of the evidence for dibaryon resonances. He concluded that either the well-known measurements from Argonne (reported in October 1977, page 330) must be wrong or a series of measurements of inelastic proton-proton scattering at the TRIUMF cyclotron must be wrong.

With many dibaryon resonance enthusiasts in attendance, the question period following the lecture could politely be described as lively and extended. It took the firm hand of the session chariman, Phil Livdahl, to halt the discussion and move the Symposium somewhat back on schedule.

No clear conclusion was reached and the situation was perhaps best represented by Michel Borghini in the Symposium summary. 'If dibaryon resonances exist they are very exciting but being very exciting does not make them exist.'

Much of the physics interest centred on high momentum transfer spin effects and the SLAC parity violation experiment reported at Tokyo (see September issue, page 285). The impact of these spin experiments on high energy physics is now being more fully appreciated.

The parity violation was discussed by C.Y. Prescott and V.W. Hughes. This beautiful polarized electron beam experiment has very important implications for the Weinberg-Salam theory of electro-weak interactions (see August issue, page 245). The theoretical ramifications were covered in an excellent review by J.J. Sakurai. The SLAC / Yale / CERN / Aachen / Hamburg team described plans to extend their measurements to test the theory further.

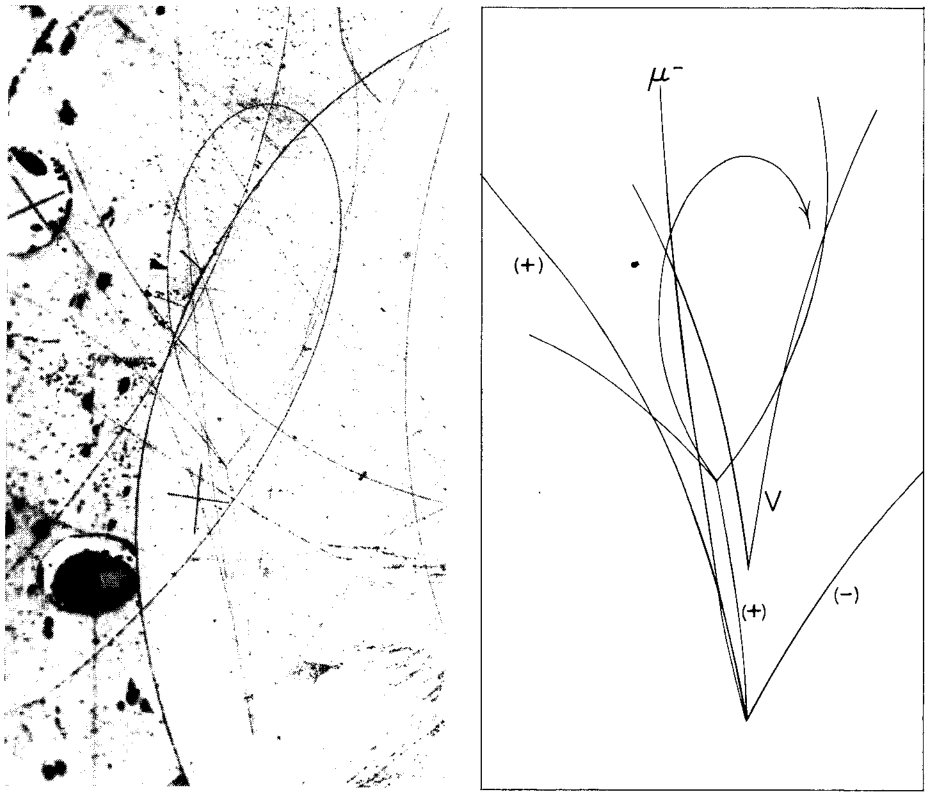
High momentum transfer hadronic experiments were reviewed by K.M. Terwilliger. Surprisingly large spin effects in inclusive lambda production were reported from Fermilab by a Michigan / Rutgers / Wisconsin team. They may be caused by direct constituent scattering.

An SPS team presented a rather striking result on spin effects in proton-proton elastic scattering at 150 GeV. They see sharp structure near the position of the well-known dip near 1 (GeV/c)^2. On the other hand, a Fermilab team found no conclusive evidence for such structure at 100 GeV and at 300 GeV. The Fermilab error bars were somewhat larger but the difference was surprising unless the spin effects have a very strong energy dependence.

A quite astonishing result came from the Michigan / Argonne / AUA team which studied spin-spin effects in proton-proton elastic scattering near 12 GeV. They reported a dramatic rise in spin-spin forces at large momentum transfer (see October issue, page 347); at 90°, the spin parallel scattering is four times more probable than spin anti-parallel scattering.

The theory was reviewed by D. Sivers and vigorously discussed by a theory panel led by F.E. Low. There was a strong feeling that these effects were caused by the spin of the constituents and might be somehow related to quantum chromodynamics.

The Symposium ended on a note of enthusiasm. There was a general feeling that progress in polarized beam development and the important new spin experiments have finally moved spin from being an 'unimportant complication at high energy' to the forefront of high energy physics. The participants look forward to further surprises and technical progress at the 4th Symposium, planned for Lausanne in 1980.



A four prong event recorded in the Fermilab 15 foot bubble chamber filled with deuterium. The V is due to a neutral kaon or a lambda particle. One of the positive particles interacts in the chamber volume and the negative muon is detected in the External Muon Identifier.

FERMILAB
Deuterium in 15 foot chamber

In mid-November the 15 foot bubble chamber started operation at Fermilab with a deuterium fill. The chamber is operating in a neutrino beam employing a new 1 ms horn.

The first run of the chamber is for a neutrino experiment by an IIT / Maryland / Stony Brook / Tohoku / Tufts collaboration; an antineutrino exposure by a Purdue / ANL / CMU group will follow. More than 34000 litres of deuterium is required to fill the chamber and it must have less than 10^{-14} tritium contamination for successful operation. The deuterium fill has a value of $ 2.5 M dollars and it has taken several years of cooperation with Brookhaven and Argonne to assemble the inventory.

The operating region for deuterium is narrower than for hydrogen and the chamber operates at 31 K in comparison to normal temperature of 25 K. George Mulholland reports no problems in finding an operating range but there was a little difficulty getting good track contrast and the first pictures were taken by letting the bubbles brew slightly longer than normal to improve the contrast. As the operating parameters have been refined, the picture quality has improved.

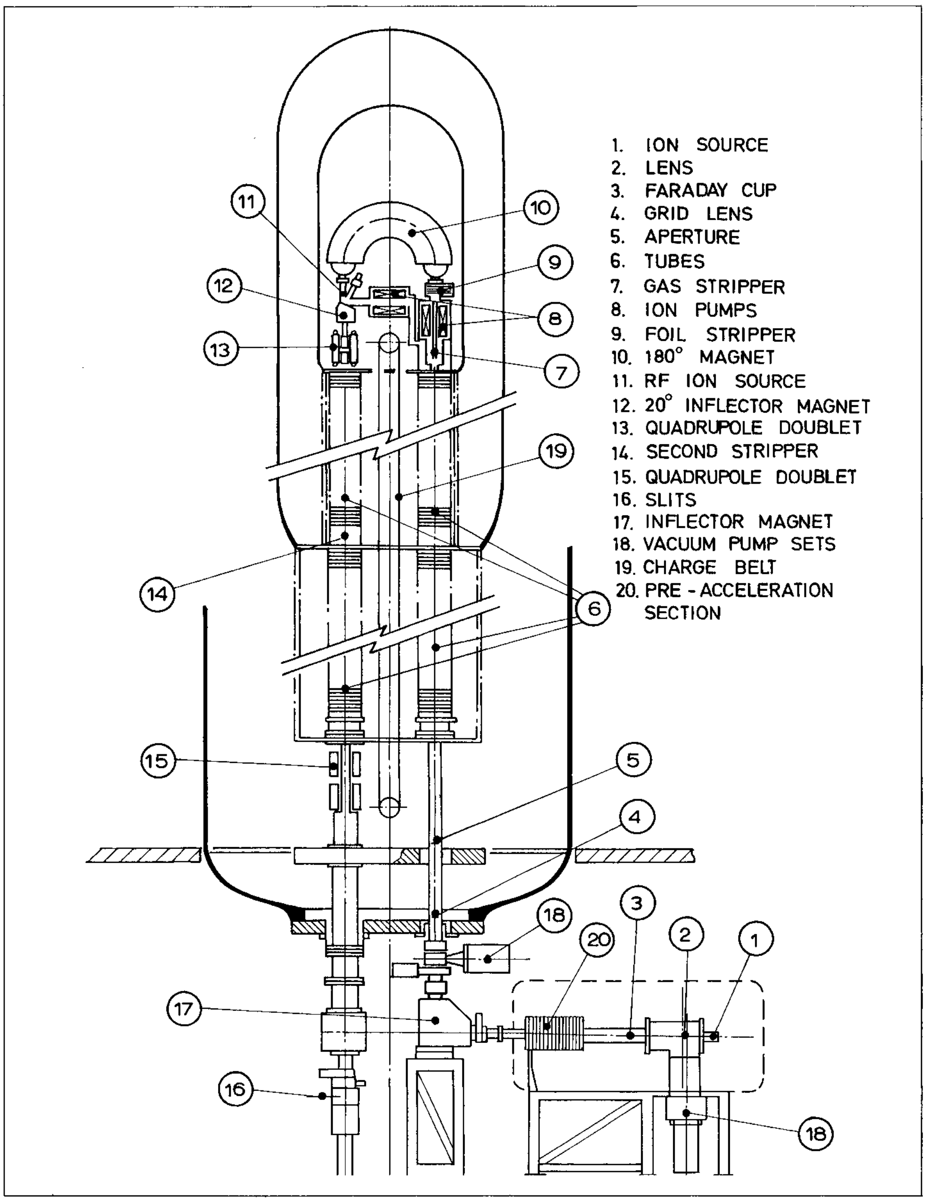
Neutron events from neutrino production have already been identified. Neutrons are tagged by the presence of an even number of tracks coming out of the vertex. Proton recoil stubs have also been seen.

The new focusing horn in the neutrino beam is fitted with a wider neck to improve reliability; some previous horn problems have been due to high stresses in the narrow neck and missteered proton beams. The wider neck helps both of these problems. A transformer is used to stretch the current pulse and the 1 ms pulse length improves External Muon Identifier and counter experiment operations.

The horn consists of a 30 mrad inside straight cone with a cylindrical return pipe. Overall the device is 2.4 m long. It can give a transverse momentum kick of 300 MeV/c when operated at 140 kA. At present, it is being operated at a conservative 80 kA which yields 86 % of the rated neutrino flux. When spares are available, currents will be boosted to 100 kA. By mid-November the system had been pulsed more than one hundred thousand times.

The horn system was designed by S. Mori with the mechanical work being supervised by J. Grimson and the electrical work by R. Trendler. The designers were helped by useful information on CERN horn designs.

Schematic drawing of the 'folded tandem' of the Nuclear Physics Laboratory in Oxford. It is the first large machine of its type to come into operation.



OXFORD
Folded tandem in operation

The first large 'folded tandem' ever to operate is now in action at the Nuclear Physics Laboratory in Oxford, UK. A 10 MV Van de Graaff, closed down in July 1977, was a vertical single stage generator, and this has now been converted to a two-stage folded tandem. First beams emerged from the new accelerator on 7 September at a terminal voltage of 4.4 MV. Since then, the voltage has been increased progressively and operation at the rated 10 MV is anticipated before the end of the year.

In his original 'swindletron' proposal, which drew attention to the advantages of two stage acceleration using negative ions and stripping them to positive ions (so that the same voltage difference can be used twice) Alvarez envisaged a 180° magnet in the high voltage terminal to reverse the direction of the accelerated ions after stripping. However, all tandems constructed using this basic idea (with one exception — the 4 MV tandem in Auckland, New Zealand) have employed 'in-line' accelerating tubes. This is because it is not practical in a horizontal machine to put a heavy magnet in the cantilevered high voltage terminal, and in the vertical machines built in the late 1950s the terminal was not large enough to accommodate a 180° bending magnet.

In a large vertical tandem, however, there are obvious financial savings to be gained by adopting a 'folded' configuration. The length of the column is only half that of the 'in-line' design, giving savings both in cost of the tank and of the building to house the accelerator. For these reasons, in addition to the scientific advantages of complete charge separation made possible by the terminal magnet, large tandems now being manufactured by the National Electrostatics Corporation (such as the 25 MV tandem electrostatic generator for Oak Ridge National Laboratory) are 'folded'.

A further advantage of the folded design is that the negative ion sources and injection systems are at ground level rather than at the top of the tower above the pressure vessel, so that the cost of personnel and equipment lifts is saved.

Oxford decided in 1975 to convert their large vertical Van de Graaff, completed in 1966, to a 10 MV folded tandem. The decision was not easy, since the vertical machine had a number of attractive features, supported a lively experimental programme and was used as a negative ion injector for a horizontal 6 MV tandem.

The possibility of replacing the horizontal tandem by a large accelerator of similar design while maintaining the vertical injector unchanged was considered but the low cost of the conversion (less than £100000), the fact that it was possible to retain an ion source in the terminal for high current single stage acceleration, and the possibility of adding a superconducting booster accelerator at a later stage, won the day.

Negative ions are preaccelerated to about 100 keV, magnetically analysed and injected vertically into the low energy (negative ion) tube. After acceleration, the ions are stripped in the terminal using a thin foil or a tube of gas at low pressure. The emerging positive ions are deflected through 180° by the terminal magnet and then enter the high energy (positive ion) accelerating tube. Finally, the accelerated ions are directed to the selected target position by a rotable 90° analysing magnet.

The column, 1.67 m in diameter, was originally designed to have a differential pumping tube to remove most of the gas flowing out of the ion sources. In practice, an ion pump has been used in the terminal to remove gas locally and the differential pumping tube was not installed. Happily the separation of accelerating tube and differential tube was exactly that needed for coupling two accelerating tubes by a 180° magnet in the folded configuration, so no major structural changes in the column were needed.

The conventional belt charging system was also retained, although the installation of a pelletron or laddertron is contemplated at a later stage. A single intermediate electrode, or intershield, surrounds the upper part of the column and increases the voltage which the terminal can support; a potential of 12 MV without accelerating tubes was obtained in a test with an insulating gas mixture of nitrogen and carbon dioxide. The tank is 3.96 m in diameter and 13.4 m long.

The accelerating tubes are each 20 ft long and constructed in two sections. The tubes have inclined titanium electrodes, separated by glass insulators 19 mm thick, and both electric and magnetic transverse fields are used to suppress electrons. The static pressure is about 2×10^{-7} torr using ion pumps in the terminal and at the base of the tubes, and a single vertical turbo-molecular pump at the base of the machine. The 180° magnet has a gap of 15 mm and a field of up to 1.5 T.

The successful operation of the folded tandem is the first stage of accelerator upgrading in the Nuclear Physics Laboratory. Substantially higher heavy ion energies will be available (such as 80 MeV oxygen and 30 MeV ^{3}He and ^{4}He) which will make the Laboratory more competitive in many areas of nuclear structure research.

There is now a strong scientific case for heavy ions at least an order of magnitude higher in energy and, in due course, funds will be sought for a superconducting booster cyclotron to achieve these high energies in a compact accelerator probably not more than 5 m in diameter which can readily be accommodated in the existing accelerator vault.

CERN
Records at the ISR

Celebrations at the end of November marked the 1000th run of the CERN Intersecting Storage Rings (ISR), the highlight of a very successful year of ISR operations in which the time available for physics research increased by 15 per cent over the previous year.

Thanks to improvements in r.f. equipment, power supplies, magnetic field control and vacuum techniques, peak luminosities were increased from 1.35×10^{31} cm^{-2}s^{-1} to 2×10^{31}, while the time taken to stack 26 GeV protons from the PS and accelerate them to 31 GeV was reduced from 12 to 8 hours. The ISR now can achieve intensities at 26 GeV many times its original design value of 20 A.

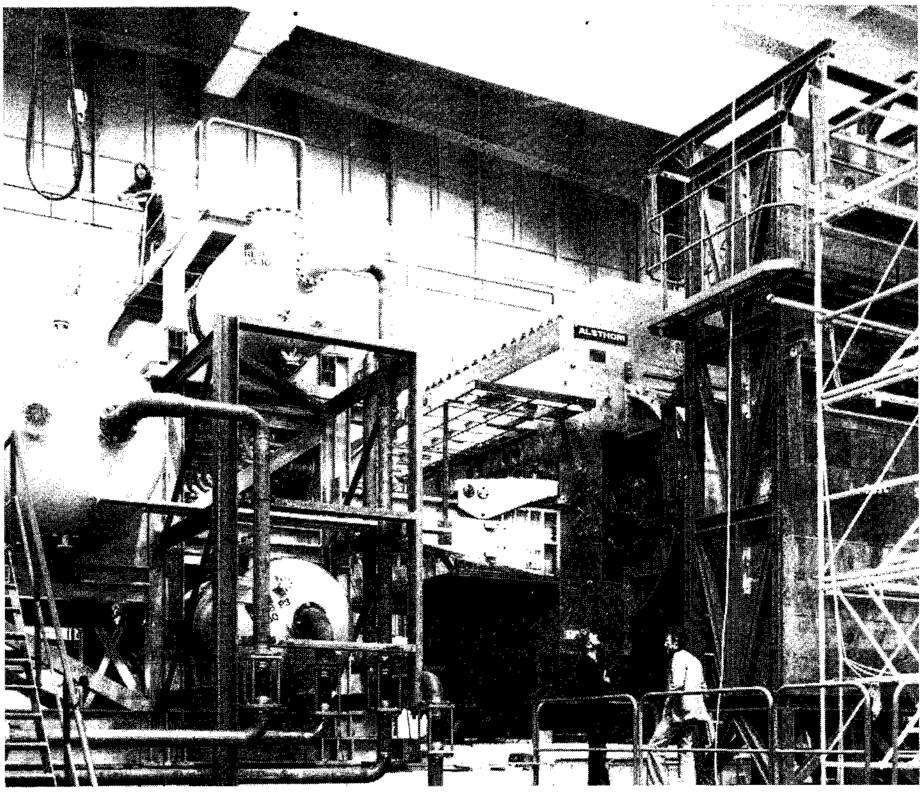
The ISR began operation in 1971, and by the end of that year luminosity had reached 2×10^{29} cm^{-2}s^{-1}. Maximum beam current reached 10 A. In the following year, the design luminosity of 4×10^{30} cm^{-2}s^{-1} had been reached with 26 GeV protons. For the first time, the ISR also accelerated protons from 26 GeV (supplied by the CERN Proton Synchrotron) up to 31.4 GeV, and the first physics runs at this higher energy were carried out.

Although initial luminosities at 31 GeV were feeble, these pilot investigations indicated how the total cross-sections for proton-proton interactions increased with energy — an important result later confirmed in precision ISR experiments.

In 1973, the 26 GeV beam current reached its design figure of 20 A, and subsequent developments have enabled it to be increased beyond 40 A.

A hairline crack in the body of Gargamelle, the CERN heavy liquid bubble chamber, means that the 25-ton chamber body will have to be removed from its surrounding magnet and other equipment to enable a thorough examination of the damage to be made. The chamber, seen here with work well under way for installation in the neutrino beam from the SPS 400 GeV proton synchrotron, had worked at the 28 GeV Proton Synchrotron until 1975. It had completed just one year of operation at its new site before this unfortunate unscheduled shutdown.

(Photo CERN 29.11.76)



However most of the current physics demand is for 31 GeV particles, where beam currents can exceed 31 A and luminosities are of the order of 2 × 10^{31} $cm^{-2}s^{-1}$.

Stable beams can now be supplied over 80 hours, a far cry from the initial overnight runs back in 1971. This demonstrates the remarkable efficiency of the vacuum system, which can reach 10^{-12} torr in some intersections, and the stability and reliability of the 260 or so power supplies energized during a physics run.

Among the new experiments in preparation at the ISR is one lined up for intersection 8, where a CERN / Copenhagen / Lund / Rutherford collaboration will investigate high momentum transfer processes with the help of a new superconducting high luminosity insertion and a specially-developed Open Axial Field Magnet. The detection system comprises a large cylindrical drift chamber, Cherenkov counters and a 200-ton uranium-scintillator calorimeter.

For 1981, another generation of experiments at the ISR is being designed for colliding beams of protons and antiprotons, the antiparticles being supplied by the new cooled antiproton source now under construction (see September issue, page 291).

Unscheduled shutdown

On 26 October, the heavy liquid bubble chamber Gargamelle had just celebrated its first year of operation at the SPS 400 GeV proton synchrotron. Almost a million photographs had been obtained from 1.4 million expansions in the SPS neutrino beam, and physicists were looking forward to a productive new period in the experimental schedule.

Suddenly routine operations were interrupted as the alarms went, indicating that there was a leak in the chamber. Immediately all the security devices came into action, stopping further expansions and shutting down the chamber. Air extraction system was at maximum.

Fortunately readings showed that the leak could be kept under control, so that the operating team was able to transfer the 12 000 litres of propane from the chamber body to its safe storage place.

With all circuits emptied of propane and purged, a systematic search was begun to find the leak, which only showed itself at pressures above 20 bar. After four days of careful investigation with the help of ultrasonic equipment, a crack was discovered inside the chamber — much finer than a hairsbreadth, but about 12 cm long and going right through the thickness of the chamber body.

In order to make a more precise diagnosis, the 25-ton chamber body will have to be removed from the magnet and surrounding equipment and examined with X-ray and other techniques.

The changing computer scene

Computing power at CERN will soon get a boost with the commissioning of a new IBM 3032 processor with four Megabytes of main storage. Installation work began at the end of October and the machine will come into service at the end of January.

The 3032 joins the four Megabyte IBM 370/168 which was installed in the CERN computer centre at the end of 1976. It means that the IBM computer power available on site will be doubled, thus approaching that of the large Control Data Corp. (CDC) 7600 machine.

On-line storage capacity was increased earlier this year with the arrival of an IBM 3850 Mass Store System of 35 000 Megabytes.

Using the WYLBUR system (first developed at Stanford and subsequently adapted for use at CERN) the CERN IBM configuration is oriented towards the support of timesharing terminals. The majority of the computing load at CERN already arrives through the 230 or so terminals scattered around the site. While most of these terminals are installed in 'clusters' for general use, they are also starting to invade individual offices.

Reflecting the increasing amount of data communications work on site, the CERN Digital Communications Network CERNET (see May issue, page 162) is now in regular use. First links were to experiments in the new North Experimental Area, but its use is extending over the whole site.

As a result of the successful implementation of CERNET, the FOCUS system for processing samples of experimental data is being phased out at the end of this year. Based on CDC 3100 and 3200 computers, this system was commissioned in 1968 and provided on-line links to data collection minicomputers working at individual experiments.

This gave a considerably faster method of processing interim data samples than had previously been possible using the 'bicycle on-line' method where data tapes were taken by hand to the main computer for processing.

Software has been developed which allows programs for minicomputers to be developed on-line to the IBM system via CERNET, using terminals attached to the minicomputers. This means that an older system, based on a CII 10070 computer, can also be phased out.

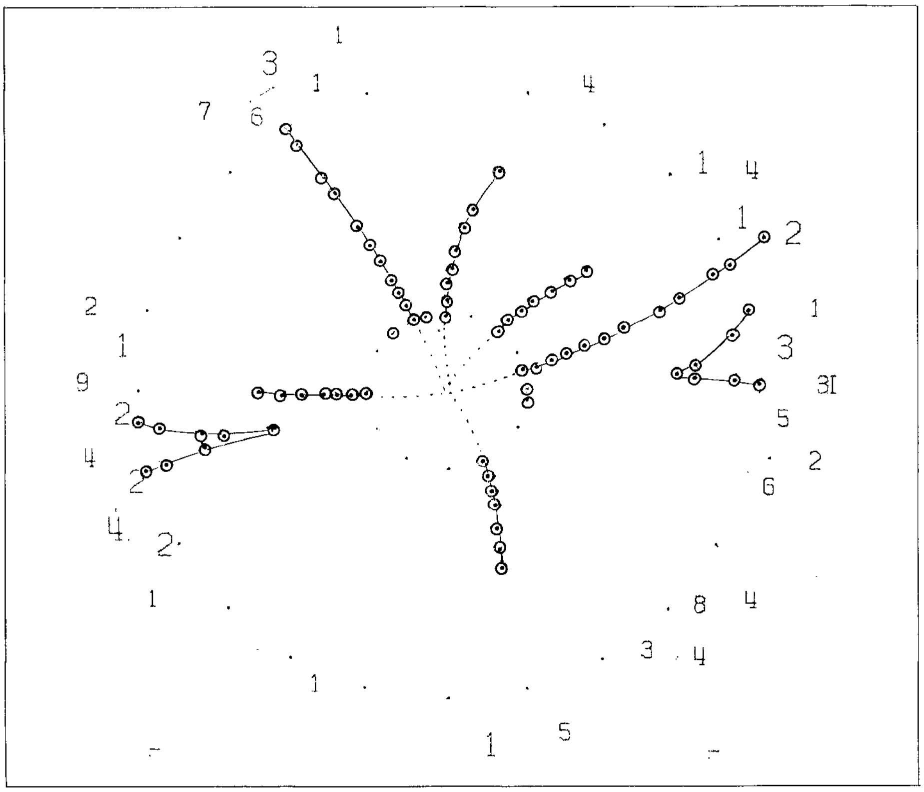
DESY
First annihilation event at PETRA

Less than four weeks after moving the detectors MARK-J, PLUTO and TASSO into their working positions at the PETRA storage ring, the first electron-positron annihilation into hadrons has been observed. The storage ring was running at a total energy of 13 GeV and the event was found by the PLUTO group in the early morning of 18 November.

It was the first hadronic event recorded at PLUTO since the observation of the upsilon in the DORIS storage ring last May (see June issue, page 202) and was just four years after the J/psi had been seen in PLUTO. Another happy day for its crew, which worked hard to improve the detector to cope with the 38 GeV total energy expected at PETRA.

Additional iron absorbers and drift chambers were mounted all around the 'old' PLUTO to provide better muon identification. Two new forward spectrometers are used to detect particles emerging at small angles and in particular to recognize electrons. This allowed identification of elastic scattering events which are now used to monitor the PETRA luminosity. Such events were already observed at 16 GeV. The rest of the PLUTO detector is ready for data-taking.

Four shifts per week have been available up to now for detector tests. The two new devices, MARK-J and TASSO, have made good progress and early next year the JADE detector is scheduled to move in. At present most of the time is devoted to machine studies. Progress has also been made on the accumulated beam current and up to 15 mA can now be stored in a single bunch. This is 75 per cent of the design current of 20 mA per bunch.



First hadronic event observed at PETRA. It was seen in the PLUTO detector at a total energy of 13 GeV. Several tracks and two converted photons can be clearly seen. The digits around indicate the approximate amplitudes in the shower counters. Vertex position and energy-sum correspond to the values expected in an electron-positron annihilation.

WISCONSIN
Aladdin project

The University of Wisconsin has been the scene of much of the pioneering work on synchrotron radiation using a 240 MeV electron storage ring called Tantalus. Now in the Synchrotron Radiation Center, directed by Ed Rowe, a new ring called Aladdin is under construction financed by the National Science Foundation. Construction is expected to take about two and a half years so that the first light will emerge from Aladdin's magic lamp early in 1980.

The ring was originally conceived for 750 MeV electrons with a radius of 2 m giving a critical wavelength of 27.6 angstroms (450 eV photon energy). To extend the research potential of the machine a move to a 'square' geometry will allow 1 GeV operation later in the machine's life and a 5 T 'wiggler' in one of the straight sections will extend the spectrum out to a critical wavelength of 3.7 angstroms (3.3 keV).

The plans of the building to house the ring and the experiments have been approved. Many machine components are being manufactured. All the magnet cores have been stacked and machining of the gaps and reference surfaces is under way. The first coils have been delivered. Quadrupoles are being built at the Laboratory and are nearing completion. The microtron injector, the inflector and the vacuum system are all progressing.

Work on dedicated synchrotron radiation sources is also under way elsewhere in the US at Stanford and Brookhaven.

LOS ALAMOS
New intensity record at LAMPF

To prepare for 500 μA beam operating current in the November-December operating cycle, tests with currents up to 675 μA were recently run at the Los Alamos 800 MeV proton linear accelerator, LAMPF. This is a world record for average beam current in high energy r.f. accelerators by a wide margin. The accelerator performed well and experience was also gained with the experimental area targeting systems. The tests gave confidence that the use of 1 mA beams is within reach.

A fourteen hour run at 600 μA showed satisfactory performance of the rotating wheel graphite targets (3 and 6 cm thick). Target lifetime is one of the most severe engineering problems, along with such basic

Artist's conception of the Synchrotron Radiation Center at the University of Wisconsin which will house the Aladdin storage ring.

problems as maintaining beamline vacuum in the presence of high thermal stresses. The 8 cm stationary graphite target used to generate the pion beam for biomedical use was limited to about 600 µA or less without direct water cooling but the rotating wheel targets at the first two target cells seemed happy at 675 µA.

No problems were seen with the water cooled exit window or beam stop. The beam stop dissipates about 350 kW with a beam current from the accelerator of 600 µA at 800 MeV when the biomed target is not taking beam. The beam switchyard showed no significant evidence of 'off-energy' beams or other problems. Accelerator and beamline reliability was close to 100% and beam loss in the accelerator was accurately monitored as below 1 µA.

With these high currents, systems for accelerator and beamline self-protection are now vital for reliable operation. At 1000 µA, it is estimated that severe mechanical damage could occur in as short a time as 100 to 200 µs. Several systems provide rapid protection against loss of most of the beam and slower response against loss of small amounts of beam.

In addition to these higher beam currents for the meson production areas, the nucleon physics programme will soon also rejoice in the provision of variable energy negative hydrogen ion beams. This programme has been given a great boost by the availability of a polarized H^- beam.

Several methods of producing lower energy H^- beams simultaneously with 800 MeV proton beams are under study. Until this manoeuvre is perfected, a time-shared mode of operation (dividing the machine duty factor between proton and H^- users) will be implemented. The required switchyard modifications set a time scale of six to twelve months for production use of variable energy negative hydrogen ions.

BROOKHAVEN ISABELLE construction plans

With the groundbreaking ceremony for the ISABELLE 400 GeV proton-proton storage rings just concluded, a 5 T magnet in hand and a 23 million dollar budget for this fiscal year in Brookhaven's pocket, a brief review of the construction plans for the machine is in order.

Site preparation for the whole ring will begin in the spring and construction of one-third of the tunnel and the 'wide angle hall' at the '6 o'clock' intersection region will begin later in the year. In subsequent years, the conventional construction will continue counterclockwise until the ring is closed.

The last two experimental halls to be built will be the major facility halls, so as to allow the experimenters' plans to progress as far as possible before the concrete is poured.

Components for a hundred magnets will also be ordered this fiscal year. Magnets for the first full cell of the machine are presently under construction by industry. These six dipoles and two quadrupoles will initially be operated in a mock-up of the tunnel to check the present designs for magnet hook-up and operation. Construction of the remaining magnets will be under way by the end of the fiscal year. The plan is to obtain the finished coils, the iron laminations and support tubes, and the vacuum envelopes from industry and then to assemble and test the magnets at Brookhaven.

Meanwhile, space (in the research area of the famous Cosmotron accelerator) is being cleared for a magnet factory as effort switches from research and development to large-scale production. To handle the cryogenic load for testing ISABELLE production magnets, a 1000 W refrigerator, dubbed PAT, is installed and being checked out.

The ISABELLE Summer Workshop did much to clarify plans for experiments at the high energies to be made available by the 400 GeV colliding proton beams. One of the main topics was a review of the experimental halls. The wide angle hall received the most detailed attention, since its construction is imminent. Suggestions regarding floor elevation and staging areas were incorporated into the design.

The experimental halls study group also checked the flexibility of the open areas, tried to increase the versatility of the narrow angle hall and studied whether the large facility halls would accommodate the large detectors built around the several possible magnet geometries. Detailed study of the next areas to be built is continuing this winter.

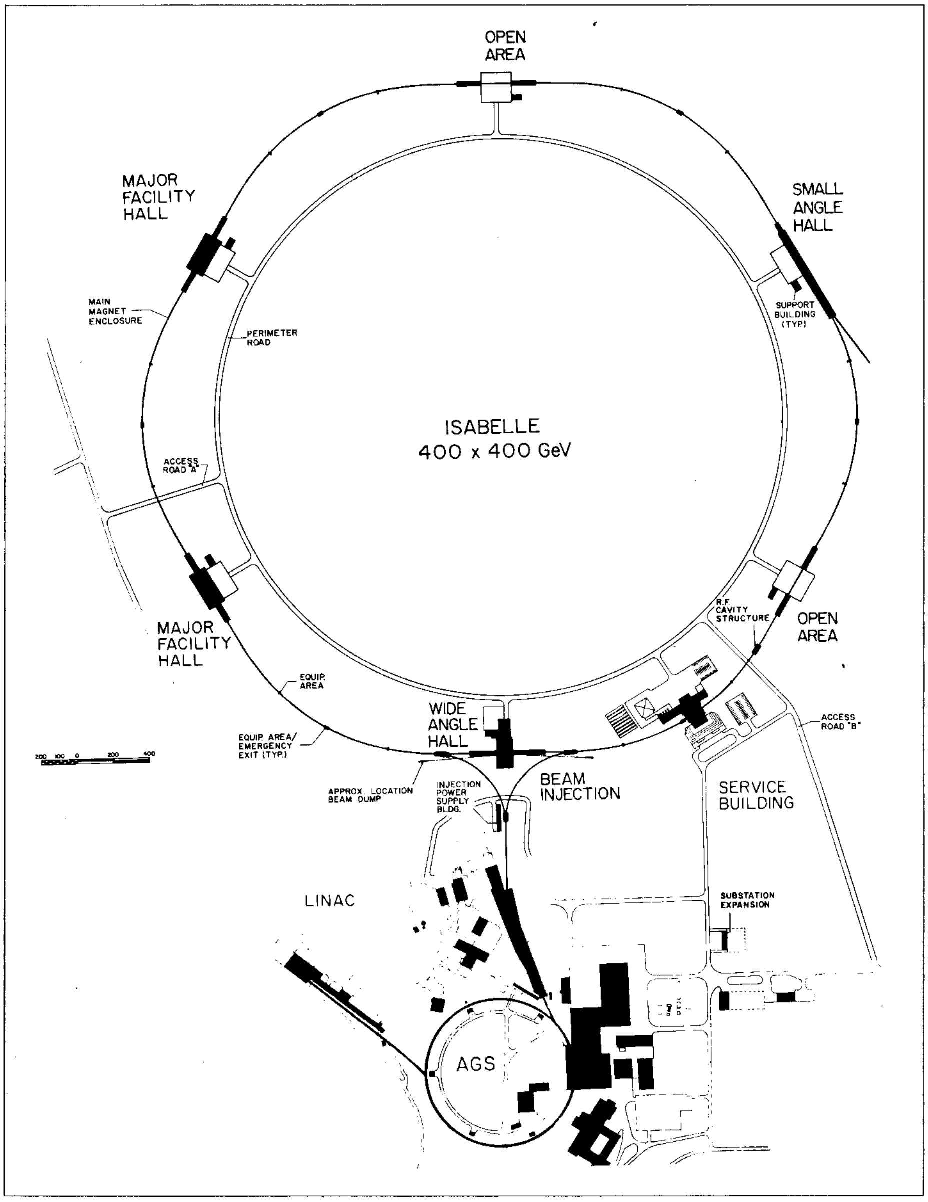
The summer Workshop also focused on data handling for ISABELLE experiments. A group considered both simple and complex detectors to get an idea of what the needs would be, although it was realized that only rough approximations could be made for the largest detector.

At the trigger level, extensive use of special function processors (hardware processors which perform a specialized task in triggering or analysing data) will be necessary in order to keep experiments from drowning in unwanted data. It was thought that an experiment would use triggers in several levels, from coincidences (which are fast but would not be sufficiently selective) to sophisticated track matching algorithms (which are used for only a fraction of the interactions).

The group also considered requirements for on-line and off-line computing. It was clear that, however sophisticated the triggers, significant increases in off-line computing power will be required.

The third major topic at the Workshop was particle detection. Drift

Plan of the ISABELLE 400 GeV proton-proton storage rings at Brookhaven fed by the Alternating Gradient Synchrotron. Construction of ISABELLE is scheduled to start early in 1979.



and proportional chambers, Cherenkov counters, calorimeters, and hodoscopes and microchannel plates were each looked at from the viewpoint of ISABELLE needs — good spatial and timing resolution, high rate capability and long lifetime in a high radiation environment.

Consideration was given both to optimization of present detectors (e.g. chamber lifetime) and to development of new devices. It was clear that considerable benefit will be derived from further research and after the Workshop the first round of grants from ISABELLE for research and development on new detectors was announced. Proceedings of the Workshop are being prepared.

A Point of View

Collaboration and Authorship

Despite the numerous possibilities for discord which could arise, for example when more than 50 physicists from about a dozen groups scattered over some six countries work together, the success of large international scientific collaborations shows that the common aim of scientific curiosity can transcend national and personal differences. However such collaboration is not without its problems. In this article, Douglas Morrison of CERN explains the problems of authorship in large collaborations. It is taken from the paper 'Sociology of International Scientific Collaborations' published in 'Physics from Friends' — the Festschrift dedicated to Charles Peyrou on the occasion of his sixtieth birthday (see June issue, page 219). The full version of the paper is also available separately as CERN preprint CERN/EP/PHYS 78-38.

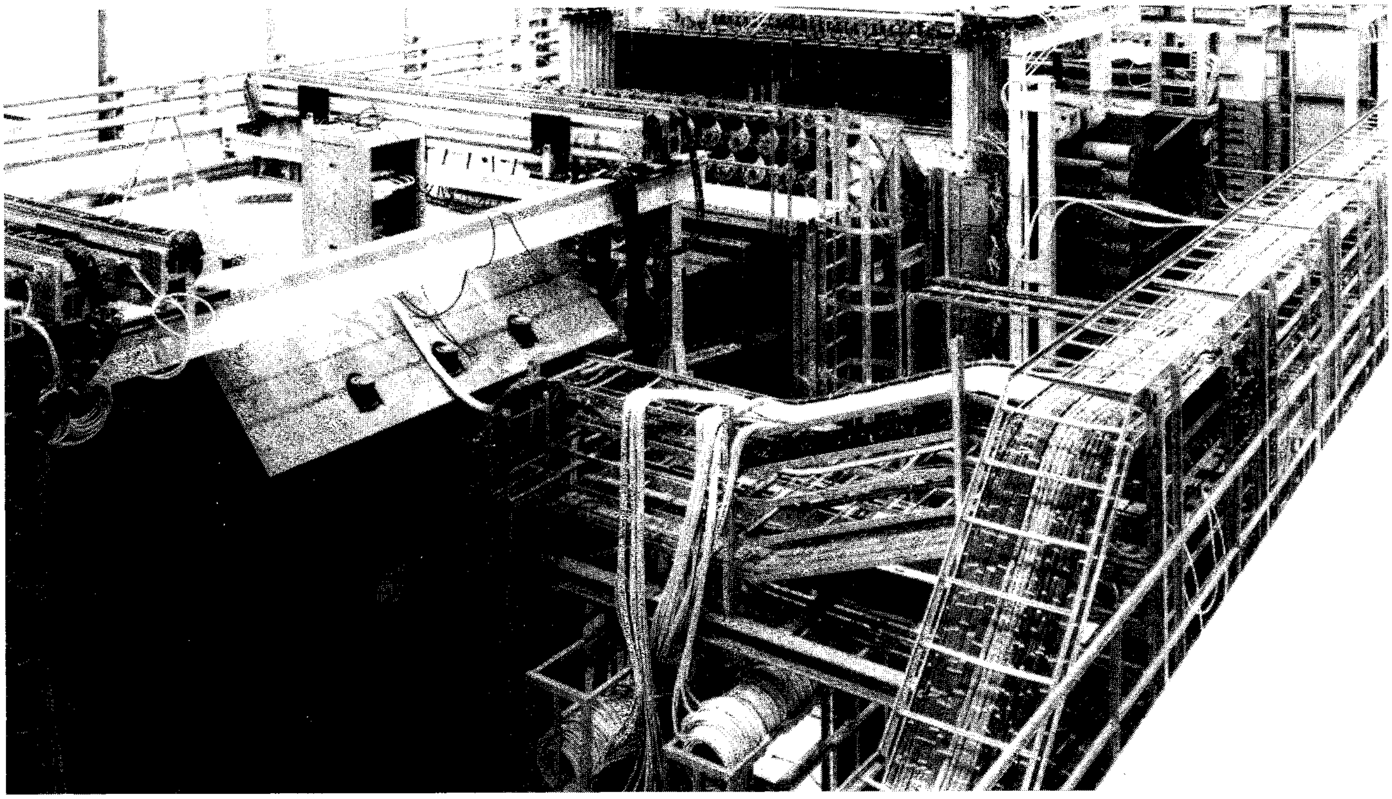
Authorship is one of the few aspects of international collaboration work where there can be serious friction and real unhappiness. Generally in discussing Collaboration affairs, its members speak freely and openly on scientific and technical matters. But on questions of authorship, a good proportion of the physicists do not say what they feel and this may result in frustration and feelings of injustice.

The problem is complex but may be split into three parts: firstly the distinction between 'basic work' and 'physics analysis'; secondly different opinions of physicists often varying with age or with the stage they are at in their career, and thirdly the number of papers the Collaboration is producing.

Basic work can be defined as the preparation of the proposal, designing and constructing the apparatus, test

The forward spectrometer of the apparatus used by the European Muon Collaboration at CERN — a team of more than 60 physicists from over a dozen institutions spread over five countries and truly an international collaboration in its own right.

(Photo CERN 164.4.78)



runs, data-taking runs; analysis of the data, checking and correcting input data and putting them on data summary tapes (DST). This is a large amount of work involving many people and usually is spread over several years though first results may be available after less than one year. The physics analysis often starts from the DST and tends to require a shorter time — usually a few months to about a year. The people who do the detailed calculations of the physics analysis are usually few in number (we will call them 'principal authors') although many more may be involved in the discussions or secondary calculations.

For authorship different suggestions have been made, for example: (1) that all should sign in alphabetical order; (2) that all should sign, but the principal authors should be recognized, possibly by being mentioned first, (3) that only the principal authors should sign. Some senior physicists with established reputations may favour (3), arguing that only those really involved should sign, but a younger physicist who is not a principal author and who would like to establish his scientific reputation and get a job, often prefers to sign several papers. It is the classic Catch 22: he feels reluctant to speak out, but if he agrees not to sign he has the feeling that all the basic work he has done has not been duly acknowledged.

For a Collaboration which has few papers to publish, the usual solution is for all authors to sign in alphabetical order. However other Collaborations may publish many papers and intend to publish many more — say at the rate of one every month or two months. At this stage in a Collaboration's life it is generally agreed to reduce the number of authors. Another solution (4) allocates to each participating group (e.g. a university) a basic number of authors reflecting in some way the contribution that the group has made to the Collaboration. In addition if a particular group has done most of the physics analysis for a paper, then it will have an extra allocation of authors for that paper.

Most Collaborations adopt Solution 1, where all physicists are authors and their names are given in alphabetical order — this has the great advantage of avoiding long unpleasant discussions and possibly long-term feelings of unfairness. Several Collaborations adopt Solution 2 where all physicists sign but the principal authors' names are given first. To some this is a just reward and often it is introduced on a paper where the principal author or authors are clearly defined. But later there are cases when the principal authors are not clearly defined and delicate discussions ensue. Again visiting scientists are favoured by Solution 2, as they are usually in the Laboratory too short a time to perform usefully much basic work and hence concentrate on the physics analysis. In one Collaboration, Solution 2 is generally adopted for minor papers but for major results of the Collaboration Solution 1 is used with names in strictly alphabetical order. Solution 3 using only the principal authors is rarely used, except when the Collaboration is dying.

There is an alternative solution which is applied but rarely discussed. The authors are listed in alphabetical order to avoid controversy, but people who do outstanding work are rewarded in other ways. One way is to promote them or to give them strong recommendations that enable them to get a good position in another Laboratory — however this solution is not very successful as it is not obviously correlated with a paper and anyway most people who are promoted or highly recommended do not consider it, and rightly so, as a reward but as their due.

A better and more immediate solution is to arrange that the principal authors present the results at seminars or international conferences. This is very effective and commonly done though not everyone realizes that it is a replacement of the use of authors in non-alphabetical order.

The qualification for a person to be an author is usually that he has contributed to the experiment and is fully able to defend the paper in public. Normally this restricts the authorship to physicists, but not infrequently a non-physicist who has made an important contribution has his name added to a paper.

In summary, the question of authorship in large Collaborations is a controversial one, involving strong feelings. There is no perfect solution and generally the policy adopted is to name all participants, following the principle of preferring minor dissatisfaction of the many to great unhappiness for the few.

People and things

Not a cleverly camouflaged piece of artillery, but the CERN two-metre bubble chamber, packed and ready for transit to its new home at the Deutsches Museum, Munich.

(Photo CERN 385.11.78)

On people

On 30 November, Abdus Salam was presented with the Royal Medal of the Royal Society in the UK. The citation notes that 'his work on renormalization theory and the neutrino greatly added to our understanding of the weak atomic interactions.'

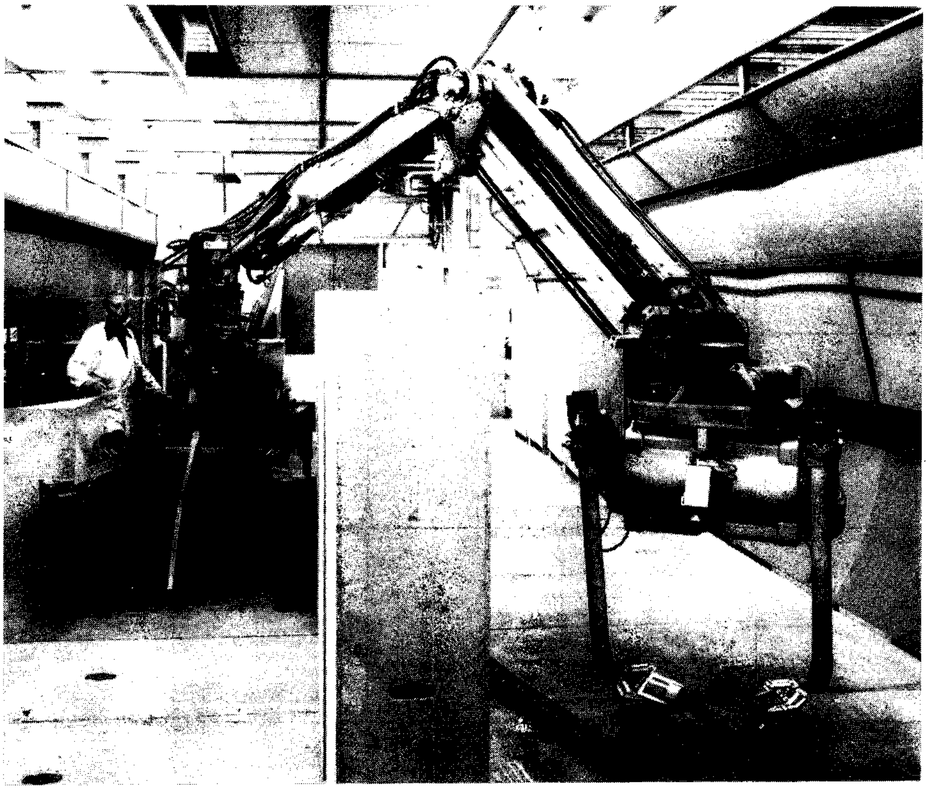
It was with great sadness that we learned of the death in Paris on 8 August of Mme Stéphanie Tixier. All who were privileged to know her during her years at CERN, from 1954 to 1967, recognized in Stéphanie Tixier very great qualities both in mind and heart. The part she played during the negotiations for the Headquarters Agreement and later in those concerned with the first extension of the site in France, which made the ISR project possible, was an extremely valuable contribution to the progress of the Organization. The older staff members of CERN pay tribute to the memory of a very dear friend.

Meetings

The sixth in the series of joint Schools organized by the Joint Institute for Nuclear Research (Dubna) and CERN will be held at Dobogoko near Budapest in Hungary from 2-15 September 1979. The School is aimed at young experimental high energy physicists mainly from the Member States of JINR and CERN. The programme will cover neutrino physics, quantum chromodynamics, new particles, large P_T phenomena and electron-positron physics as main topics. Further information may be obtained until 1 May from Mrs. T.S. Donskova, JINR, 10 1000 Moscow, Head Post Office, P.O. Box 79 or from Miss D.A. Caton, CERN, CH-1211 Geneva 23, Switzerland, or, after 1 May, from Dr. K. Szego, Central

Science fiction becoming science fact. Seen here on test in a tunnel mock-up is MANTIS - MANipulator Transport and Inspection System — a mobile remote manipulator specially developed at CERN for maintenance and repair jobs where radiation restricts personnel access.

(Photo CERN 304.6.78)



Research Institute for Physics, H-1525 Budapest, P.O. Box 49, Hungary.

The 1979 International Symposium on Lepton and Photon Interactions at High Energies will be held from 23-29 August at Fermilab. Attendance at the conference is by invitation and persons who are interested in attending are encouraged to write to the symposium secretary, Dr. C. Brown, Physics Department, Fermilab, P.O. Box 500, Batavia, Illinois 60510.

An International Seminar on 'The Great European Projects' is being organized by the European Physical Society for Rome on 26-27 March 1979. The LEP electron-positron colliding beam project, TeV fixed target proton synchrotrons and large synchrotron radiation sources will be amongst the subjects to be presented and discussed. A limited number of places have been reserved for people with a particular reason to be present and further information can be obtained from the EPS Secretariat, European Physical Society, P.O. Box 69, CH-1213 Petit-Lancy 2, Switzerland.

Mantis

CERN's own remote manipulator system will soon be available for use anywhere on site for jobs where the radiation level restricts access by maintenance staff. Called MANTIS - MANipulator Transport and Inspection System — it is already assisting in external repair and recuperation work on radioactive beamline components placed in a shielded storage compound. During the forthcoming shutdown, it will start internal maintenance work actually within the machine areas.

MANTIS comprises a 'slave' vehicle which enters the working zone, a master control station which remains in a safe area up to 400 m away and a communications system which links the two.

The operator controls MANTIS with the help of 'hearing' and 'touch' sensors, and several television cameras, three of which are mounted on the slave vehicle, while an independent camera system — nicknamed 'Private Eye' — can take up any chosen vantage point.

When folded for transport, MANTIS is compact enough to negotiate narrow access routes but once in position it can extend to reach 8 m, wielding loads of up to 500 kg, even over the top of shielding walls.

Column rising

The November issue of the NSF Newsletter reports that the building construction at the Daresbury Nuclear Structure Facility is virtually complete. Machine installation has started in the tower which is to house the 30 MeV tandem with the lowering into place of the first modules of the high voltage column.

Epilogue

To close the 1978 Volume of CERN COURIER, we would like to record our thanks to all those who have so readily provided us with information and assistance for our articles. This thanks goes especially to the Laboratory correspondents listed inside our front cover who have been a major source of input. Our next issue goes to press in February and will be available early in March 1979. Breaking with previous tradition, this issue will be cover-dated March. We look forward in 1979 to an exciting year of development and discovery in particle physics, and as always the CERN COURIER will aim to keep its readers well-informed of progress worldwide.

Massachusetts Institute of Technology

BATES LINEAR ACCELERATOR LABORATORY

RESEARCH AND DEVELOPMENT POSITIONS

Positions for physicists and engineers are available at the MIT Bates Linear Accelerator Laboratory in nuclear structure research and for facility and accelerator development. Research at present includes high-resolution electron scattering and medium-energy photo-reactions. The Laboratory is undergoing an expansion in its experimental facilities and is planning to increase the accelerator's present 400 MeV and 1.8% beam energy and duty factor. We seek individuals for both short-term and long-term appointments. For the latter, competence and enthusiasm for the solution of technical problems is essential, and successful candidates will be expected to make major contributions in one or more of the following areas:

Accelerator Design and Technology: Beam Optics; Microwave Structures and Systems; including Computer Interfaces; Beam Monitoring.

Facility Development: Spectrometer Design and Development; Power Supplies; Cryogenic Targets and Magnets; Detector Development, including CAMAC-Computer Interfacing; Mechanical Devices and Structures; Vacuum Systems.

The Laboratory is situated in Middleton, Massachusetts, a suburb of Boston, approximately one-half hour from the MIT Campus in Cambridge.

Please send complete Resume, in confidence, to:

Bates Linear Accelerator
c/o William Lobar
P.O. Box 95
Middleton, MA 01949
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Experimental High Energy PHYSICIST

The National Research Council of Canada's Division of Physics is located in Ottawa, Canada. The High Energy Physics Laboratory requires an experienced and dynamic experimental High Energy Physicist with proven leadership ability to work with a team of eight experimentalists, three theorists and several Research Associates. The group includes staff of Carleton University (also in Ottawa) which has a sophisticated high energy instrumentation capability.

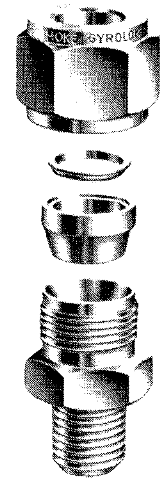
Studies are currently being carried out in meson spectroscopy at high energy accelerators, and meson physics at intermediate energy facilities. The successful applicant will be responsible for initiating and carrying out advanced research at modern accelerators such as SLAC and FERMILAB.

Salary is commensurate with experience and will be up to $ 39,000 per annum.

NRC

Apply in writing, giving complete details of education and experience to the Employment Officer, National Research Council of Canada, Ottawa, Ontario, Canada K1A 0R6. In reply, please quote P-77-1057.

Please reply by 9 January 1979.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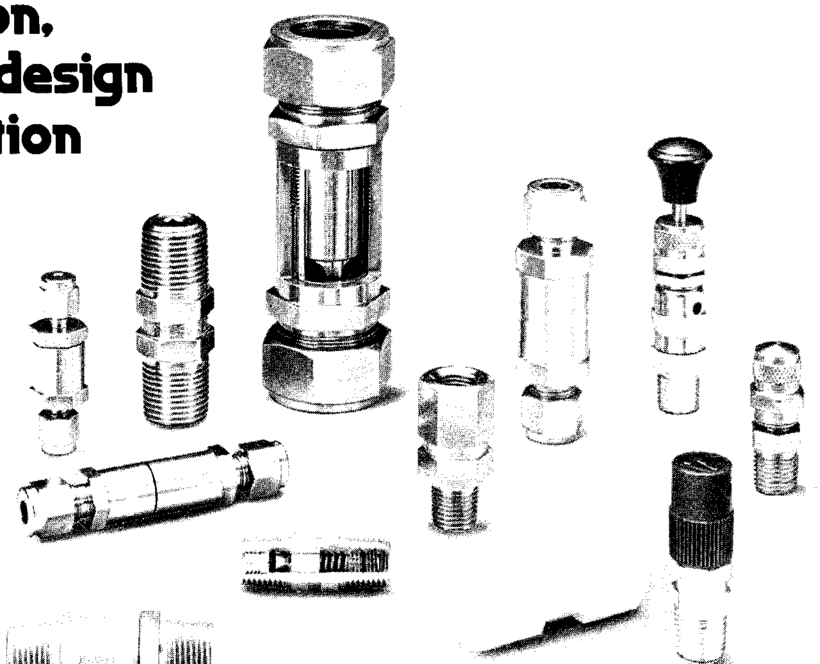


PRESSURE/FLOW CONTROLLER
SERIES 270
GRANVILLE-PHILLIPS
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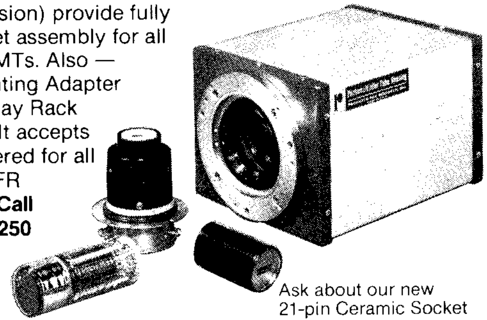
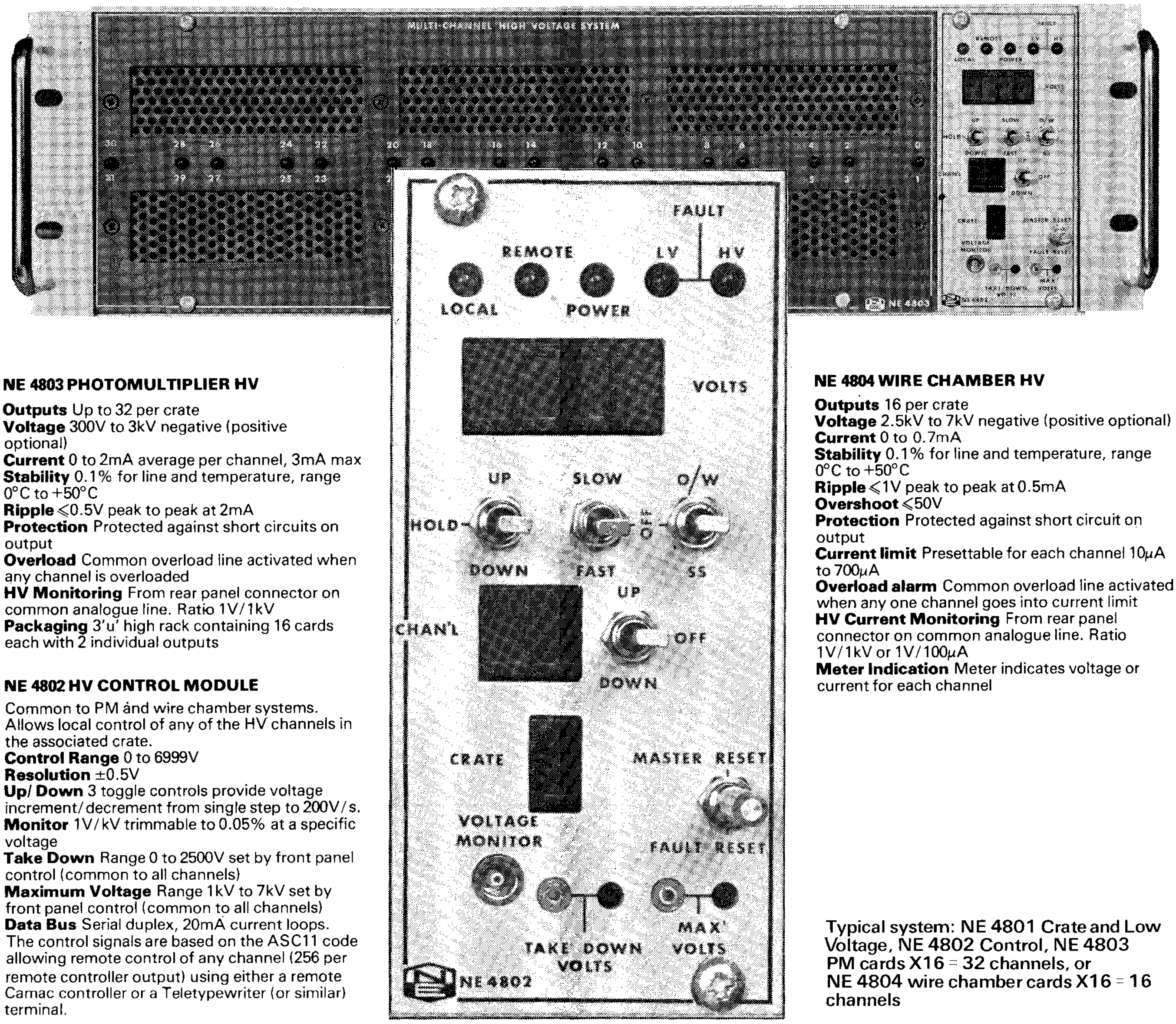
CONTROL
OPEN
CLOSED
OFF
CLOSE
REFERENCE
INPUT



Multichannel High Voltage System

NE 4800 SERIES

- ✱ For use with large photo-multiplier detector arrays and wire chambers.
- ✱ Economical
- ✱ Easily serviced
- ✱ Manual control of each channel or external control by Teletype or computer control via CAMAC



NE 4803 PHOTOMULTIPLIER HV

Outputs Up to 32 per crate
Voltage 300V to 3kV negative (positive optional)
Current 0 to 2mA average per channel, 3mA max
Stability 0.1% for line and temperature, range 0°C to +50°C
Ripple ≤0.5V peak to peak at 2mA
Protection Protected against short circuits on output
Overload Common overload line activated when any channel is overloaded
HV Monitoring From rear panel connector on common analogue line. Ratio 1V/1kV
Packaging 3'u' high rack containing 16 cards each with 2 individual outputs

NE 4802 HV CONTROL MODULE

Common to PM and wire chamber systems. Allows local control of any of the HV channels in the associated crate.
Control Range 0 to 6999V
Resolution ±0.5V
Up/ Down 3 toggle controls provide voltage increment/ decrement from single step to 200V/s.
Monitor 1V/kV trimmable to 0.05% at a specific voltage
Take Down Range 0 to 2500V set by front panel control (common to all channels)
Maximum Voltage Range 1kV to 7kV set by front panel control (common to all channels)
Data Bus Serial duplex, 20mA current loops. The control signals are based on the ASC11 code allowing remote control of any channel (256 per remote controller output) using either a remote Camac controller or a Teletypewriter (or similar) terminal.

NE 4804 WIRE CHAMBER HV

Outputs 16 per crate
Voltage 2.5kV to 7kV negative (positive optional)
Current 0 to 0.7mA
Stability 0.1% for line and temperature, range 0°C to +50°C
Ripple ≤1V peak to peak at 0.5mA
Overshoot ≤50V
Protection Protected against short circuit on output
Current limit Presettable for each channel 10μA to 700μA
Overload alarm Common overload line activated when any one channel goes into current limit
HV Current Monitoring From rear panel connector on common analogue line. Ratio 1V/1kV or 1V/100μA
Meter Indication Meter indicates voltage or current for each channel

Typical system: NE 4801 Crate and Low Voltage, NE 4802 Control, NE 4803 PM cards X16 = 32 channels, or NE 4804 wire chamber cards X16 = 16 channels

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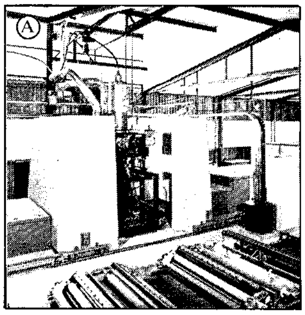

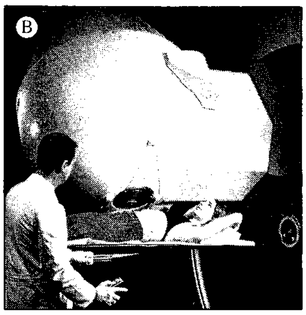

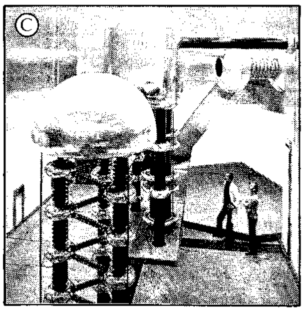

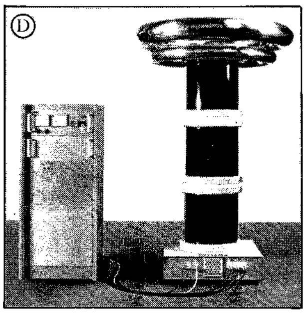

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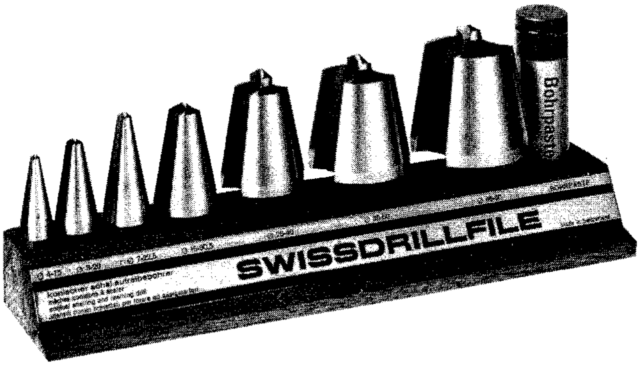

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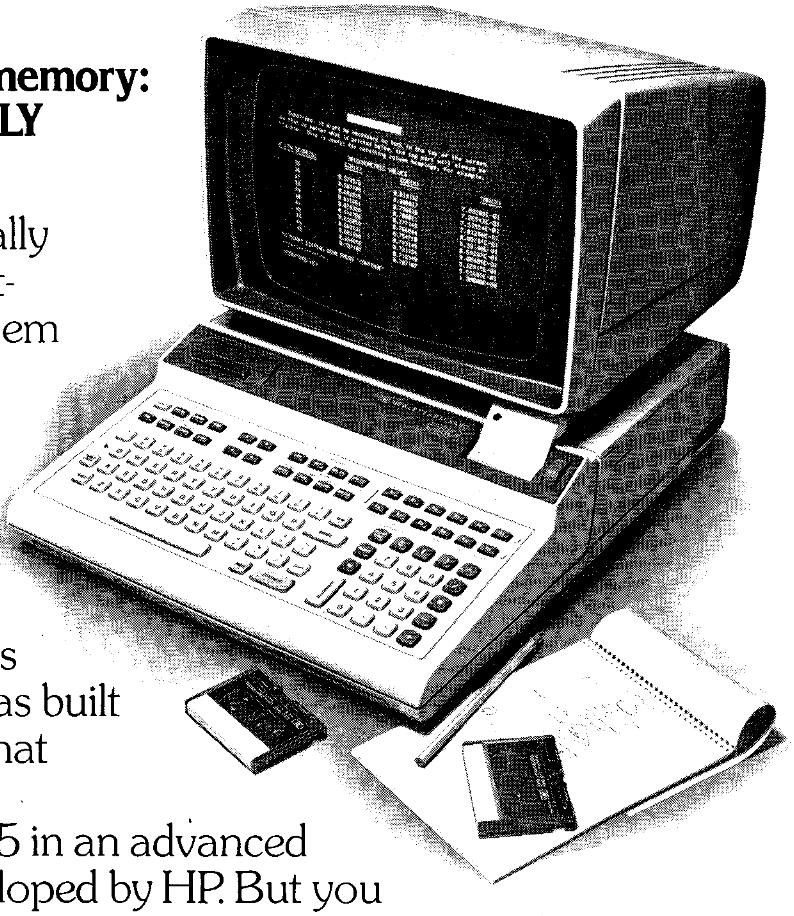

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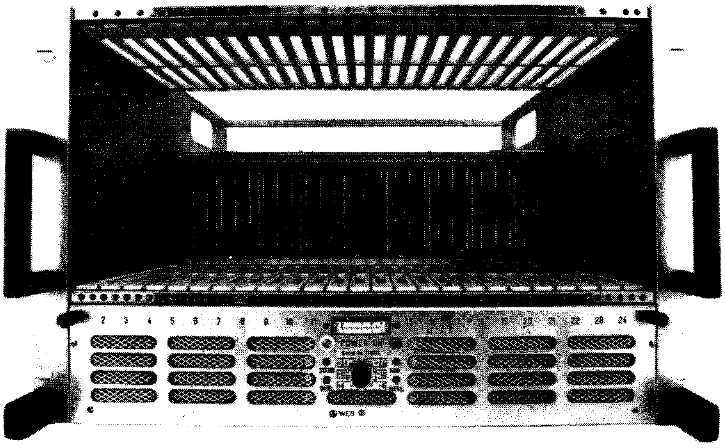

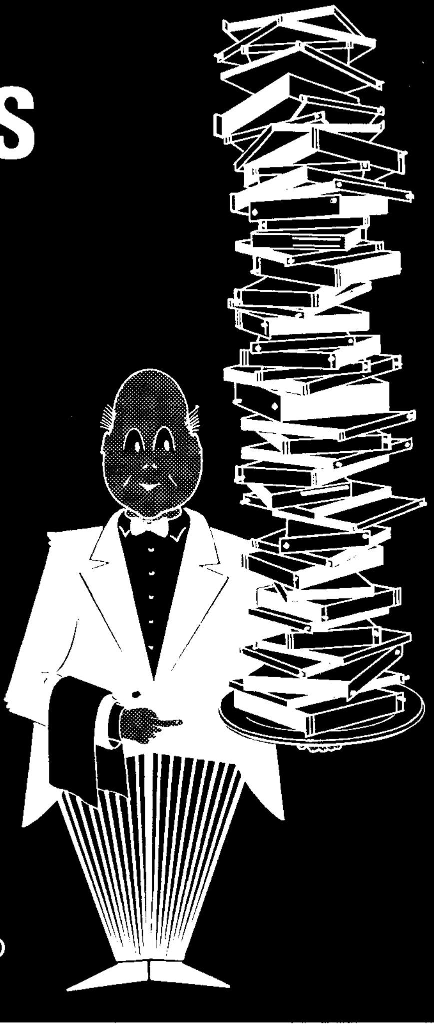

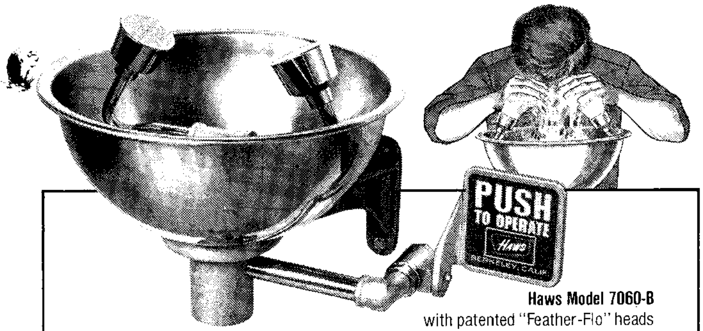

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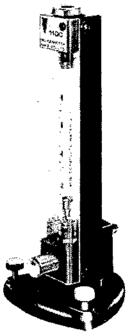

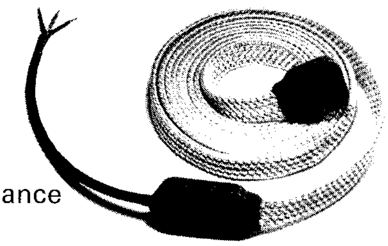

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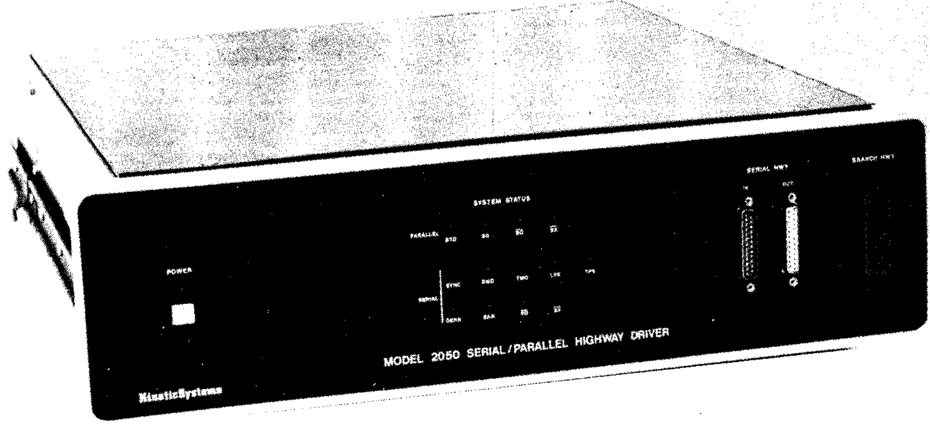

for use with
the PDP-11
computer line

2050

Good news for all PDP-11® users! Our new 2050 provides an efficient interface between the PDP-11 Unibus and CAMAC Dataway via the two CAMAC highways. It is available as a parallel highway driver, a serial highway driver, or a combination of the two. Operating modes utilize the CAMAC Dataway's use of Q responses for block transfers and the ability of Unibus devices to access memory directly via nonprocessor requests (NPR). Various serial highway conditioning (U-port) options are also available.

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FEATURES OF THE 2050

- resides in one PDP-11 system unit (BB11)
- controls up to seven parallel and/or 62 serial highway crates
- operates in bit or byte serial mode up to 5 MHz
- includes eight operating modes
  one programmed transfer - five DMA/block transfers - two special parallel highway functions
- complete serial system error analysis and recovery procedure derived by methods outlined in the ESONE/SD/02 recommendations
- twelve registers occupying 16 word addresses on the Unibus formatted for easy use
- four independently enabled interrupt vectors
- full 18-bit Unibus memory addressing

A WEALTH OF APPLICATIONS

- distributed process control and data acquisition systems with the CAMAC serial highway
- local high-speed process control and data acquisition systems on the parallel highway
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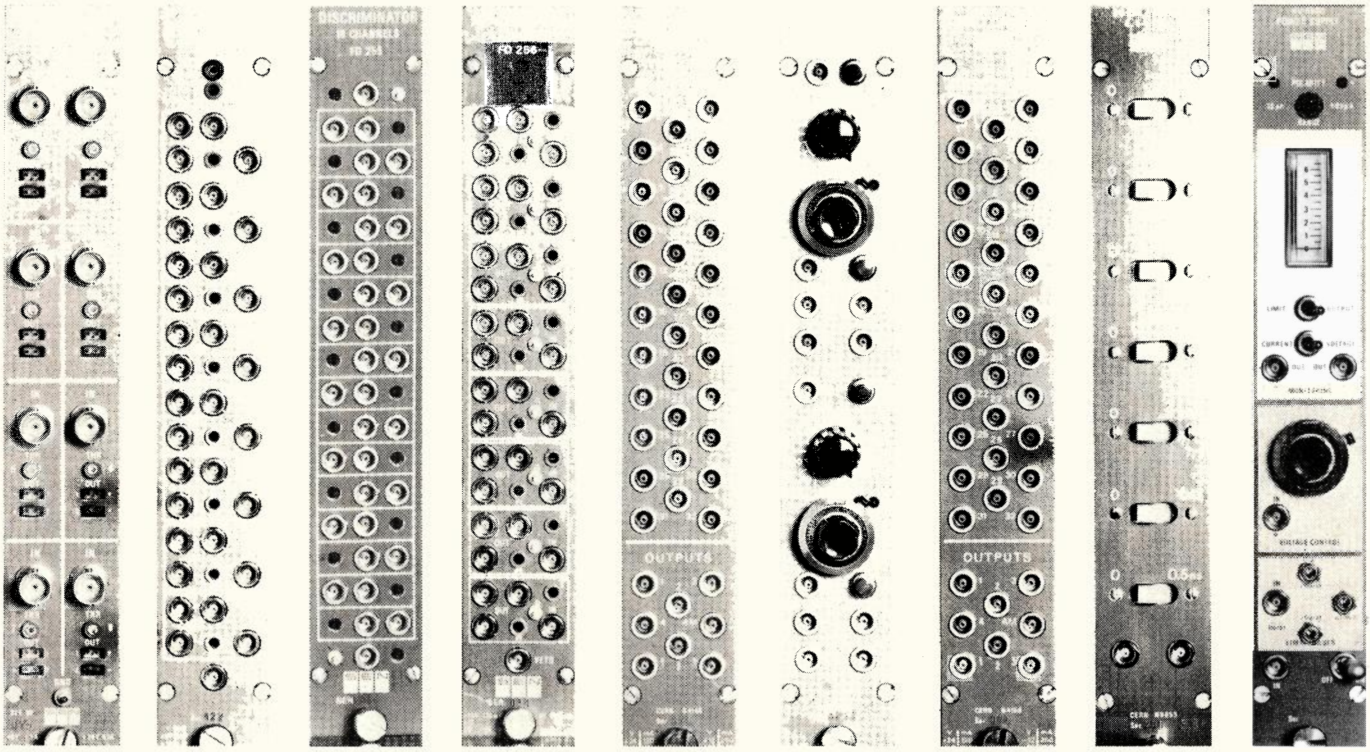

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computer controlled threshold, width and I/O delay via a rear mounted SATAN: SEN serial transmission system microprocessor unit.
BNC input and 2 MECL outputs per channel

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threshold: – 5 mV to – 1V
width: ⩽5 ns to 45 ns
fast veto
3 NIM outputs per channel

FD 255
16 ch. 100MHz updating discriminator
common threshold for 8 ch.
threshold: – 5mV to – 1V
width: ⩽5 ns to 45 ns
fast veto
1 double current NIM output per channel

FD 256
8 ch. 100MHz updating discriminator
separate threshold
threshold: – 5mV to – 1V
width: ⩽5 ns to 45 ns
fast veto
3 NIM outputs per channel

LU 274
16 ch. logic unit
OR/AND gate majority
1, 2, 3, 4 ch. fired outputs and complementary outputs
analogue majority output

TU 277
2 ch. timing unit
width: 50 ns to 10 s retriggerable
end marker output
local/remote start/stop
NIM input/outputs

LU 278
32 ch. logic unit
OR/AND gate majority
1, 2, 3, 4 ch. fired outputs and complementary outputs
analogue majority output

DU 290
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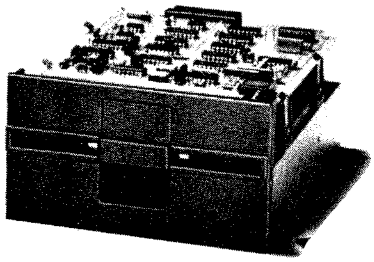

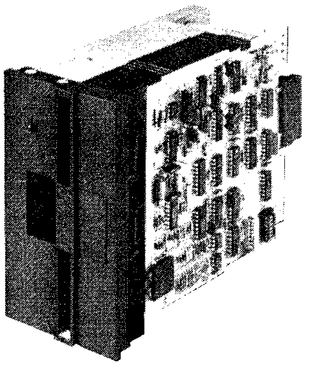

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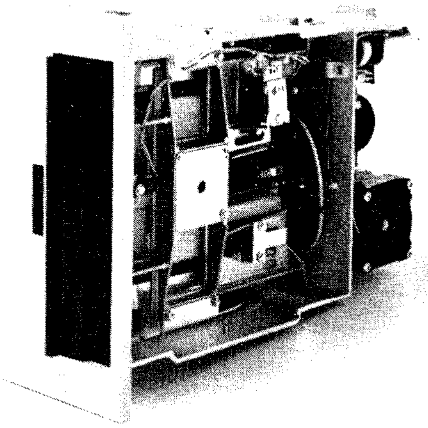

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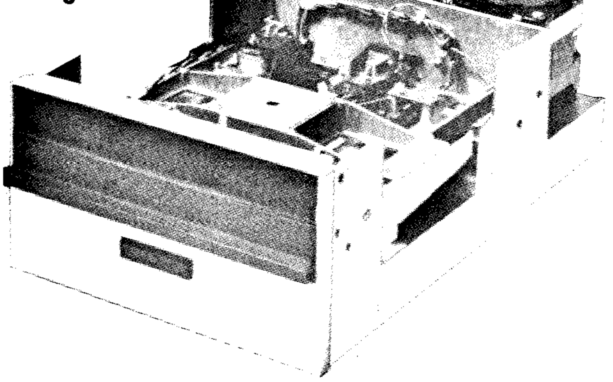

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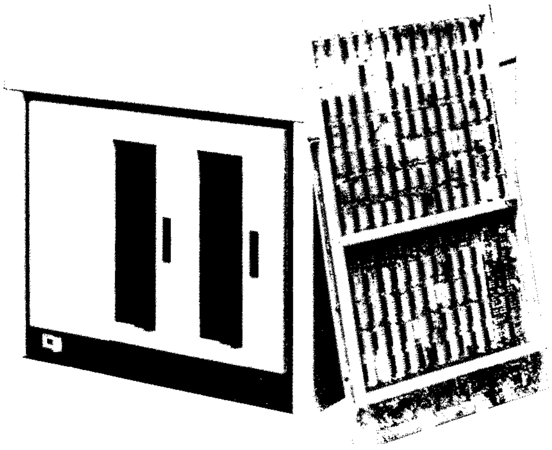

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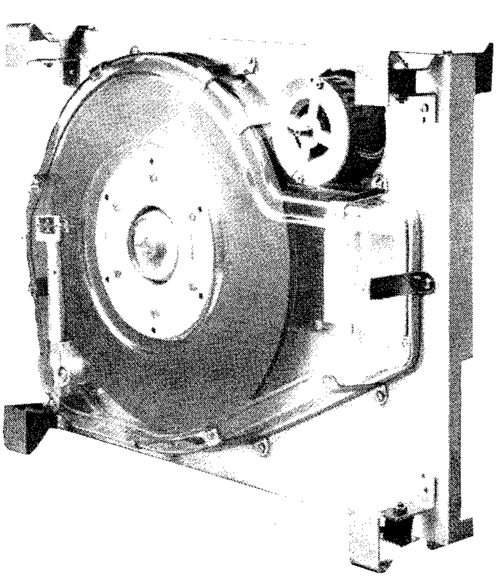

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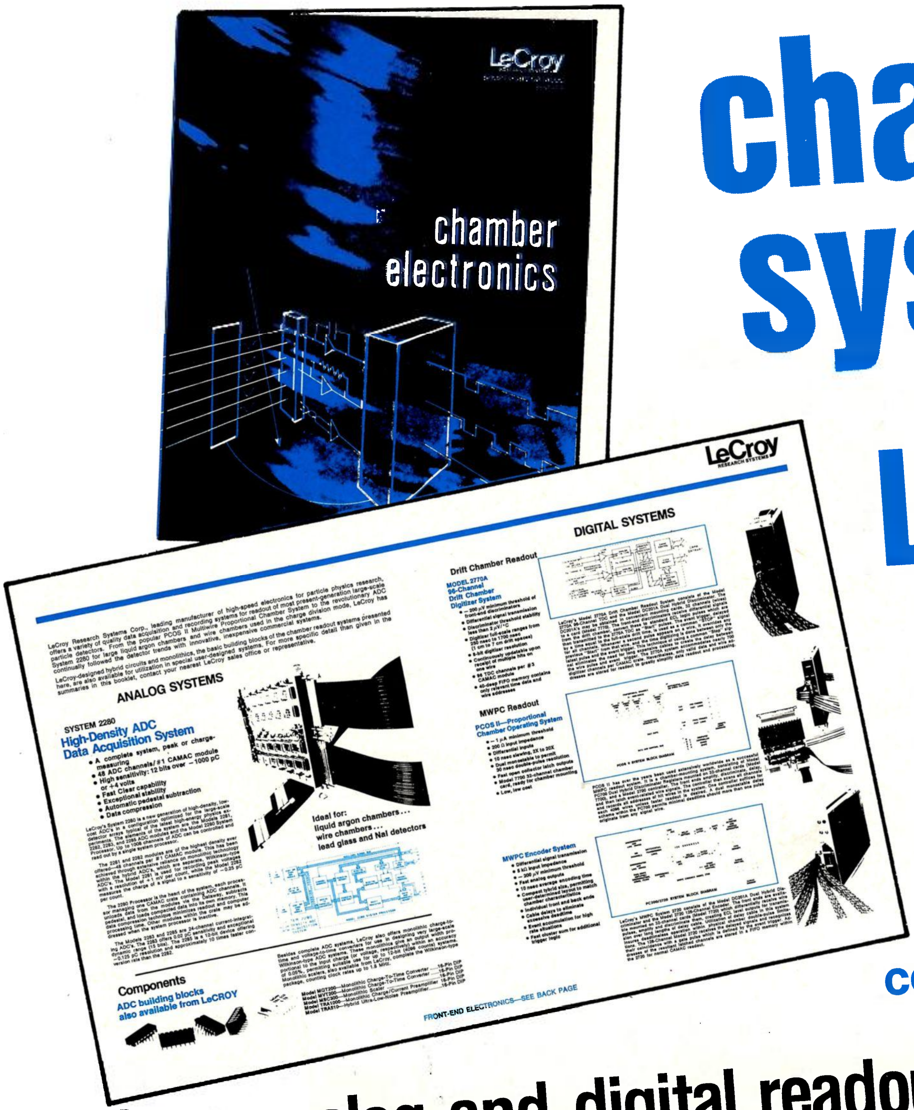
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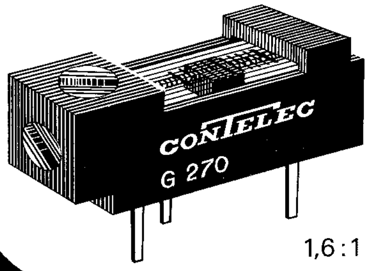

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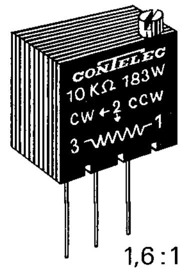

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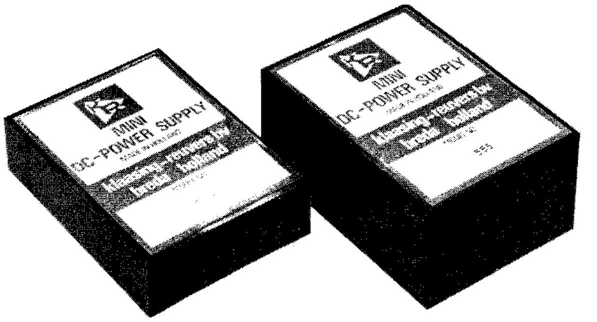

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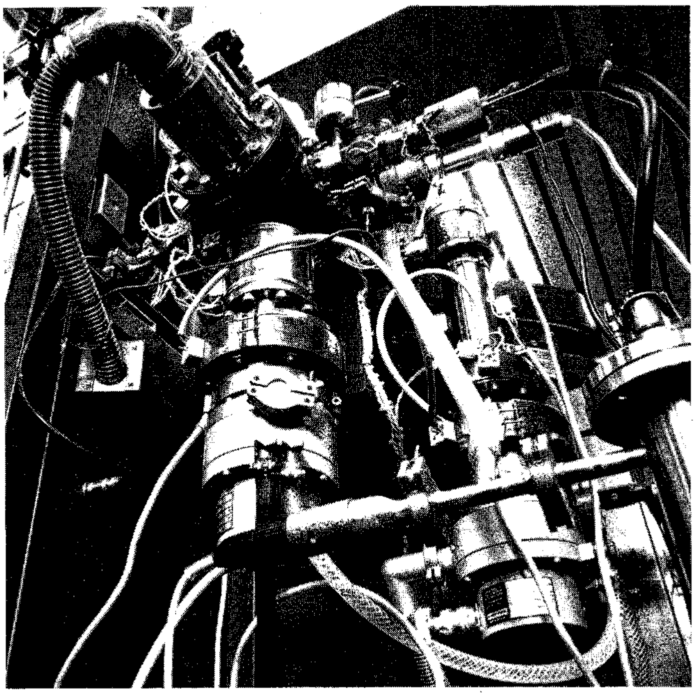

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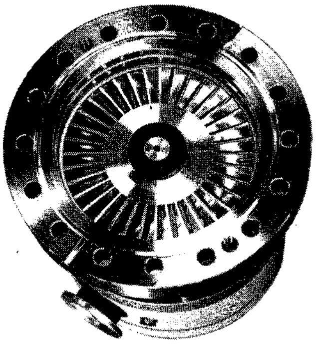

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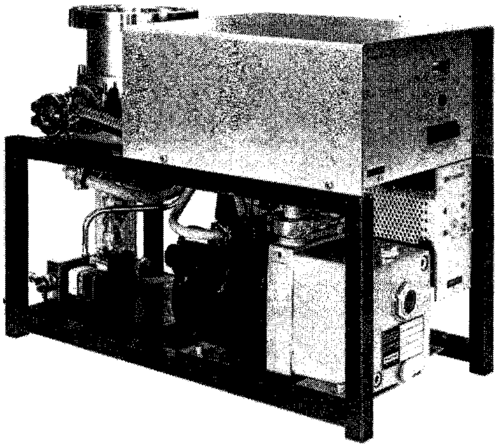
He	120 l/sec
H_2	110 l/sec

Ultimate pressure 10^{-11} mbar



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Speeding time	2 min
Weight	6 kg

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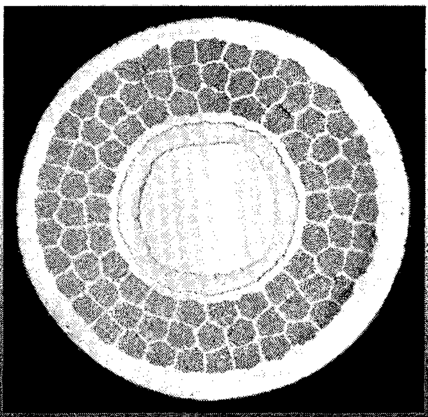

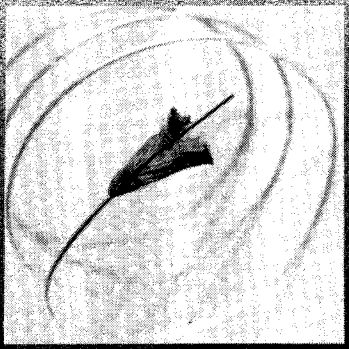

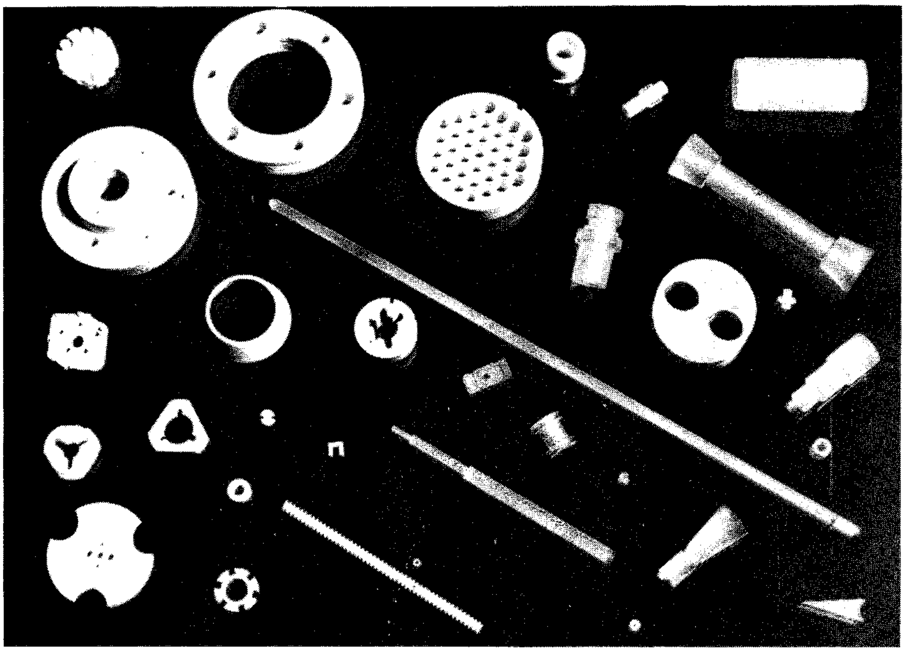

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