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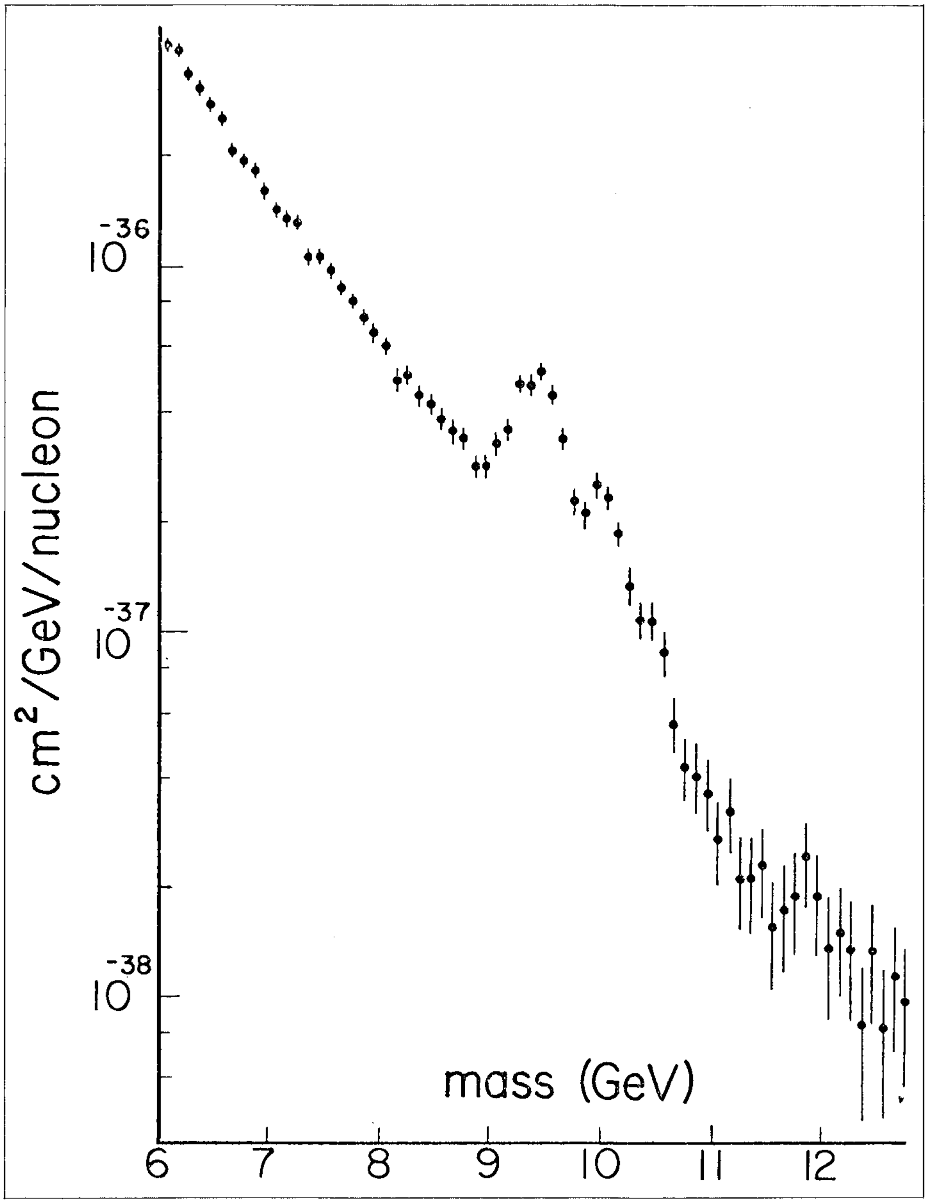
Contents

Cover photograph: The outer shell of a prototype cylindrical multiwire proportional chamber being manufactured at the Rutherford Laboratory for the TASSO (Two Arm Spectrometer SOlenoid) experiment on the PETRA electron-positron storage ring at DESY. The spectrometer, including proportional chambers, scintillators, Cherenkov counters, liquid argon shower counters, time-of-flight counters, etc., will identify and measure charged particles and photons over a wide energy range and a wide angular distribution. It is being provided by an Aachen / Bonn / DESY / Hamburg / London / Oxford / Rutherford / Weizmann collaboration. (Photo Rutherford)

Upsilon hunting

The latest data from the Columbia / Fermilab / Stony Brook experiment at Fermilab, which measures two muons emerging from the high energy collisions of the protons from the 500 GeV synchrotron, shows two 'bumps' at 9.4 GeV and 10 GeV and a suspicion of another at 10.4 GeV. This is a dramatic discovery of what looks like a new family of very heavy particles which is probably the consequence of the existence of another type of heavy quark.



The most fascinating news in high energy physics over the past year (see August issue, page 223) has been the discovery of Upsilon — a 'stable' particle three times heavier than those of the famous J/psi family, which fits into no known scenario of the sub-nuclear world. It suggests the existence of yet another brand of quark to add to the familiar four — up, down, strange and charmed quarks.

Our knowledge of the world of particles had seemed, briefly, to be condensing to an understanding of the behaviour of four quarks and four leptons (the electron, the muon and their neutrinos). Now, with strong evidence of an additional heavy lepton from experiments on the SPEAR storage ring at Stanford and strong evidence for an additional heavy quark from the experiment on the synchrotron at Fermilab, the door is wide open to yet another world of great variety as we penetrate one layer deeper into the structure of matter.

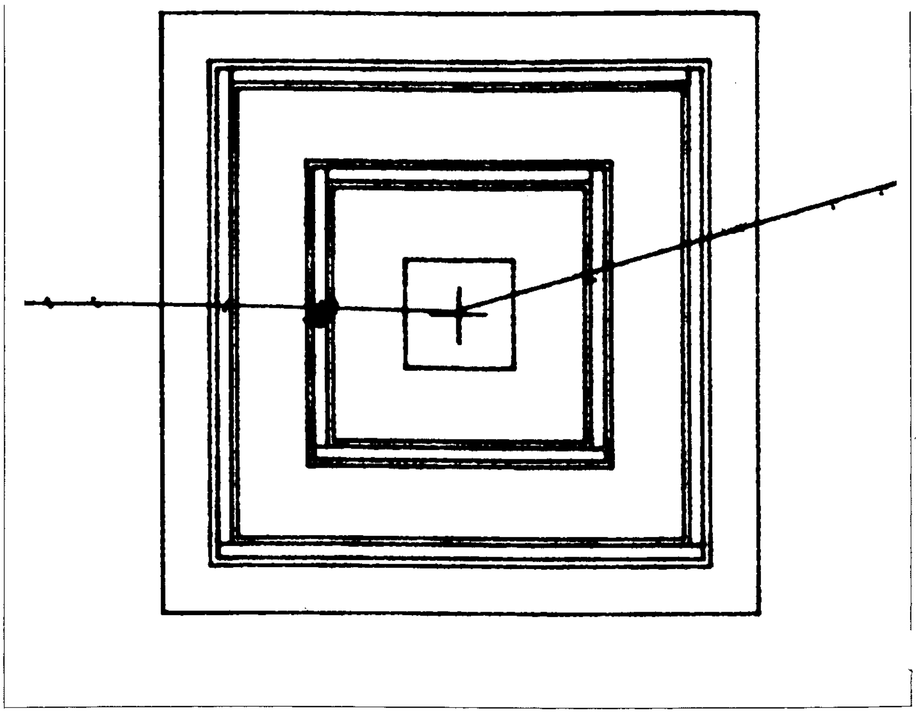
This article brings together some information and ideas about the newcomer, Upsilon.

At Fermilab, the discoverers (the Columbia / Fermilab / Stony Brook group led by Leon Lederman) have accumulated about three times as much data since their dramatic announcement at the Budapest Conference. They can now see a clear separation into two peaks in the enhancement that they found in the two muon spectrum — Upsilon at 9.4 GeV and Upsilon prime at 10 GeV. There is a suggestion of a third peak at 10.4 GeV but this is not yet established. The peaks are consistent with the expected mass resolution of the detection system which is 2.1 %. This means that the rms width for the observed peaks is less than 100 MeV.

The Columbia / Fermilab / Stony Brook group are currently running their experiment with the synchrotron energy set at 300 GeV with a 200 GeV 'front porch'. Using the muon energy range covered by these beams they can study the excitation curve of the Upsilon production and the accompanying continuum. A very important aspect here is how the transverse momentum of the emerging two muons behaves as the energy changes.

The next change will be an attempt to improve the luminosity of the experiment and to collect of the order of five times the data. Part, or all, of this will also have improved mass resolution in the detection system which will be achieved by installing some new chambers upstream of the magnets where, previously, no detectors have been placed.

Additional magnetized iron shielding should help these chambers survive the extremely high rates in this area. One set of chambers are of the multiwire proportional chamber type



with a 1.5 mm wire spacing which are being constructed at Fermilab with special amplifiers designed at the Nevis Labs. The other set is an experimental Directional Drift Chamber which is designed to respond only to particles originating in the target which have not scattered by more than about 4 mr.

The goals of the next eight to ten months include improving the knowledge of the Upsilon and Upsilon prime widths, their mass separation, the Upsilon double prime, the s-dependence of the Upsilon family, and the surrounding muon continuum. In addition, a search with good sensitivity will be carried out for new bumps in the 11 to 16 GeV mass range.

There are other collaborations at Fermilab also about to attack the Upsilon family. A Princeton/Chicago group is preparing to run with the Chicago Cyclotron Spectrometer in the Muon Laboratory to search for Upsilon production by pions. Another group in the Muon Laboratory (Berkeley/Fermilab/Princeton) will be working with a muon beam and a new multimuon spectrometer. They may be able to see Upsilon production by virtual photons. A Michigan/Northeastern/Washington group, which has a multimuon detector already in operation, is preparing to run in the Meson Laboratory. Their detector will have a large acceptance for the Upsilon angular distribution and the Feynman x distribution. This information might help to shed light on Upsilon production systematics.

At CERN, the energies available from the SPS for the counter experiments which have appropriate detector configurations in the West Area are too low for fruitful Upsilon hunting. A CERN / Collège de France / Orsay / Palaiseau / Saclay experiment will be coming into action next year in the North Area using the full 400 GeV of the synchrotron. They will be able to look at dilepton production with a sophisticated detection system and can investigate Upsilon production by different hadrons (pions, kaons...) as well as protons in a similar way to the Omega spectrometer investigation of J/psi production.

The CERN Intersecting Storage Rings have the highest available collision energies in the world at present and it is an obvious place to look for Upsilons or any other higher mass particles. The limitations are the production rates in the colliding beams and the special measures which are needed to distinguish the particles from the multitude of other possible events.

Two experiments now taking data could shed further light on the Upsilon. The CERN / Columbia / Oxford / Rockefeller collaboration, which includes Leon Lederman, is looking at the production of electron-positron pairs in the I-1 intersection, while the Frascati / Genoa / Harvard / MIT / Naples / Pisa collaboration, led by Sam Ting, turns its attention to muon pairs produced at the I-2 intersection.

Both experiments expect one or two events per day in the Upsilon mass region and can go well beyond this region to look for heavier enhancements at up to about 20 GeV effective mass. While the I-1 experiment is designed as a general study of high transverse momentum phenomena and could make it possible to study other particles emitted with the electron-positron pair, the I-2 experiment is very clean and free from background, with all hadrons away from the interaction region and the forward area removed by a total of 130 cm of iron.

Electron-positron colliding beams are almost certain to provide a much cleaner experimental situation for investigating the Upsilon family than the proton machines. The difficulty of studying the J/psis at the Brookhaven and CERN proton synchrotrons compared to the Stanford and DESY storage rings illustrates this point very clearly.

The SPEAR electron-positron storage ring at Stanford unfortunately cannot be coaxed to high enough energies to cover the Upsilon mass. The r.f. system, the magnets and the space available are all inadequate for 5 GeV and more per beam. The same is not necessarily true for the DORIS ring at DESY and there are moves afoot to see whether 10 GeV can be reached.

It was already planned to push to 4.3 GeV per beam (up to now standard operation has usually been up to 3 GeV and 3.5 GeV has been reached in tests). The extra energy will be possible by installing two extra r.f. cavities which are not now needed for the PETRA ring. This installation is under way during a shutdown which will finish at the end of October. In November, it will be known if the

A computer reconstruction of a muon pair seen by the Frascati / Genoa / Harvard / MIT / Naples / Pisa collaboration led by Sam Ting at the CERN ISR. In this experiment, the interaction region (marked by a cross in the diagram) is surrounded in turn by 50 cm of iron to remove hadrons, a first layer of drift chambers, another 50 cm of iron, a second layer of drift chambers, and a final 30 cm of iron. Upsilons and similar effects could show up in the spectra of the muon pairs.

magnetic fields remain good up to the levels necessary for 4.3 GeV operation and the physics programme at these energies could start in December.

The Upsilon news has obviously provoked the urge to go a bit higher still and this will be tried if all goes well at 4.3 GeV. Four more r.f. cavities could then be stolen from the 64 to be installed in PETRA (which would only trim 2 % off the PETRA peak energy) to take DORIS to 5 GeV per beam. The PETRA cavities could be wheeled in fairly quickly and Upsilons could then be accessible from about May of 1978.

One of the DORIS intersection regions houses the DASP double arm spectrometer and this would be an ideal instrument to scan the Upsilon region and to investigate decay modes in the Upsilon family since it has good particle identification. The previous collaboration of physicists working with DASP has dispersed to prepare for PETRA experiments but a DESY group is still in action and is likely to attract others.

In the other intersection region the PLUTO spectrometer was scheduled to move to PETRA next year and the extent to which it could participate in Upsilon studies if these become feasible is still being discussed. It depends greatly on the speed with which 5 GeV energies would be achieved in DORIS.

The two large electron-positron storage rings now under construction — PETRA at DESY and PEP at Stanford — are both designed to have their peak luminosities around 15 GeV per beam and they might both find it a strain to cover the 'low' energies needed for Upsilon production. Happily, the electron-positron storage ring CESR at Cornell has just been authorized (see page 322) and the main motivation behind the CESR project was to cover the energy range between SPEAR / DORIS and PETRA / PEP with high luminosity. That motivation has proved a real winner.

The discovery of the Upsilon has made everyone at Cornell work twice as hard to try to get CESR into action at the earliest possible date. The new particles fall right in the centre-of-mass energy range (4 GeV to 16 GeV) planned for the machine and there may well be more surprises beyond 10 GeV. The experimentalists who are preparing to use a large magnetic detector at CESR (a collaboration of Cornell / Harvard / Rochester / Rutgers / Syracuse / Vanderbilt physicists) are eager to get at them.

One experiment being planned for the detector is, of course, a detailed study of the Upsilons. They will look for the array of states with radiative transitions occurring between them, predicted by E. Eichten and K. Gottfried. They have suggested that a mass resolution of 3 MeV might be required to resolve the fine structure of the P-states lying between the Upsilon states seen at Fermilab. To achieve this, the detector must be capable of very good angular resolution for photons and for charged particles. One would then look for rather simple events, where the Upsilon prime decays by radiating a photon to an intermediate state, which then decays to the ground state Upsilon by radiating another photon. Finally, the ground state Upsilon shows the characteristic two-lepton decay.

An experiment to study the Upsilon states is also a possibility for the smaller North interaction area on CESR. Proposals for this area will be considered in December, and it is expected that some of them will be aimed specifically at studying the structure around 10 GeV.

On the theoretical side, the Upsilon has been widely interpreted as some new variety of quark-antiquark combination. There has been a great deal of theoretical activity trying to extend the J/psi experience to the Upsilon, applying the same ideas but using a heavier quark (about 5 GeV mass) in the calculations.

One of the first things to be noticed about the Upsilon spectrum was that the mass spacing between the two observed peaks is the same (0.59 GeV) as that between the J/psi and psi prime. The first potential models which tried to explain the quark-antiquark interaction (see September issue, page 288) did not predict such constant spacings and this has been interpreted in some quarters as a need to overhaul the type of potential used. A new model has been proposed by Chris Quigg and Jon Rosner which can clear the mass spacing problem. However, the larger spacing can be expected to encourage decays of the Upsilon prime to the Upsilon via the emission of two pions though rigorous calculations are difficult.

Meanwhile other theorists have used the possible existence of new quarks beyond charm to enable them to absorb the phenomenon of CP violation, displayed by the neutral kaon, in a natural way. This mechanism was first demonstrated by M. Kobayashi and K. Maskawa, who showed that if CP violation were to form an integral part of any quark-lepton theory, then the quark quartet of up-down-strange-charmed would have to be augmented.

It is obvious that we are entering a new period of ferment where both experiment and theory are in as lively a state as they could be.

To bring something light-hearted into the discussion about a heavy particle, try the 'unauthorized autobiography' of Leon Lederman, page 337.

Around the Laboratories

CORNELL
Funding for CESR

The National Science Foundation has approved the programme to convert the present 12 GeV electron synchrotron at Cornell to an 8 GeV electron-positron colliding beam facility, CESR (described in April issue 1976). The total cost for the project is 20.7 million dollars. Included in this figure are funds from the present operating budget which have been reprogrammed to begin the CESR conversion since the total effort of the Laboratory is now concentrated on the colliding beam facility. The cost covers the construction of the new storage ring and a large magnetic detector, the modifications to the synchrotron, and all staff expenses.

The last high energy physics experiment to run on the 12 GeV machine stopped taking data on 19 September thus ending a decade of fruitful experiments on the highest energy electron synchrotron in the world. The synchrotron started up in October 1967 and has operated continuously since then, except for short periods for improvements.

The synchrotron is now being used mainly for studying positron acceleration, production of high intensity electron beams, etc., and for testing prototype apparatus for the CESR detector. This type of operation will continue until about the end of November, when tunnel modifications will require a temporary shutdown.

Positrons were accelerated in the synchrotron for the first time on 2 September up to an energy of 4.5 GeV. Meanwhile, work is proceeding towards transferring beams from the synchrotron to a short section of the storage ring. The transfer line and the first few sections of the protosector of the storage ring should be in place in late October when studies of the transfer system can begin.

DARESBURY
Progress on the 30 MV tandem

The progress of construction at the Daresbury Laboratory of the Nuclear Structure Facility (NSF) with its 30 MV tandem Van de Graaff was last reported in the March 1976 issue. At that time the main accelerator tower was complete up to the 56 m level of the injector room floor, construction of the rectangular service tower was well advanced and the accelerator pressure vessel had been lifted in five sections into the main tower. Since then the service tower has reached its full height of 72 m and the structure of the injector room has been completed.

During 1976 the pressure vessel sections were welded together and the vessel was successfully tested with a pressurised filling of 2000 tonnes of water. Assembly and interconnection of the compressors, vacuum pumps, circulators and heat exchangers of the gas handling system for the 100 tonnes of sulphur hexafluoride insulating gas is now well advanced.

An extensive research and development programme has continued on the machine itself as a basis for the design of accelerator components. The insulated column legs were developed in this way — a glass was selected for its bulk and surface electrical breakdown properties, which were measured in a 1.5 MV d.c. generator, whilst the configuration of the protective annular spark gaps were determined by electrostatic field calculations and tests in a 1 MV Marx generator. Long term prototype tests were then performed on the pilot test machine, a 10 MV Van de Graaff. About 200 out of a total of 288 column legs, each containing 31 insulators, have now been manufactured.

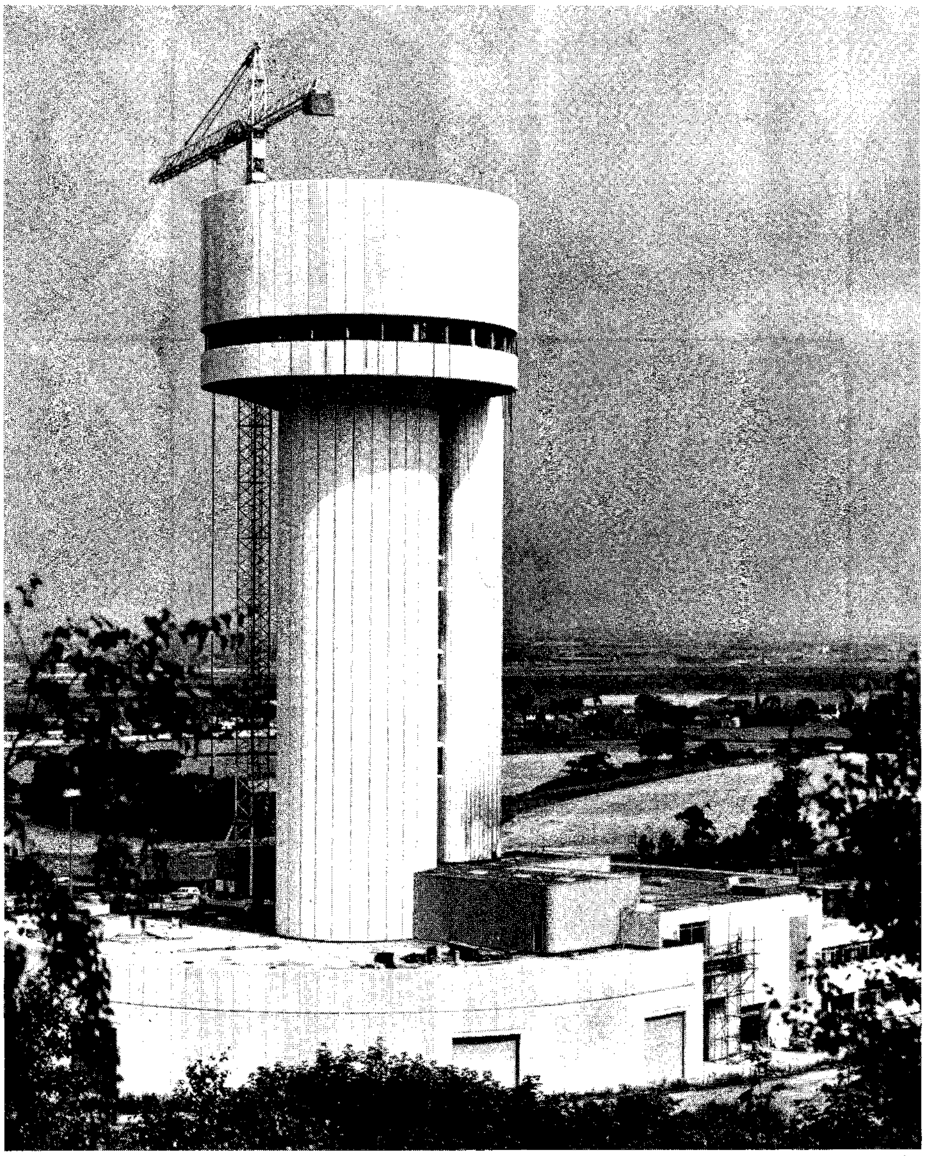
The laddertron inductive charging system was evolved from a similar development programme and the final design has been thoroughly tested up to very high voltage gradients for over a year in the pilot machine. The full length laddertron for the NSF has recently been assembled and operated successfully in air in a specially constructed rig 25 m high in a building belonging to the UK Atomic Energy Authority.

One of the most critical, but leas understood, components in electrostatic accelerators is the evacuated accelerator tube. Much attention has been devoted to developing a method of bonding the insulators and electrodes together to produce a vacuum tube free of organic materials and to studying the electrical breakdown processes taking place inside the tube during operation. Good quality bonded alumina-titanium alloy tubes can now be produced routinely. Early breakdown studies were made on single vacuum gaps, with and without insulators, and provided information about the influence of surface finish and insulator profile. More recently, high voltage tests on complete tube sections have given highly reproducible 'long tube' effects. These results will be used to determine the final tube configuration.

Most of the accelerator components are now on site including magnetic and electrostatic lenses and their power supplies, vacuum components, such as ion pumps with specially reinforced cases to withstand the insulating gas pressure, and beam diagnostic devices such as beam scanners and biassed apertures. All are being tested very thoroughly before installation.

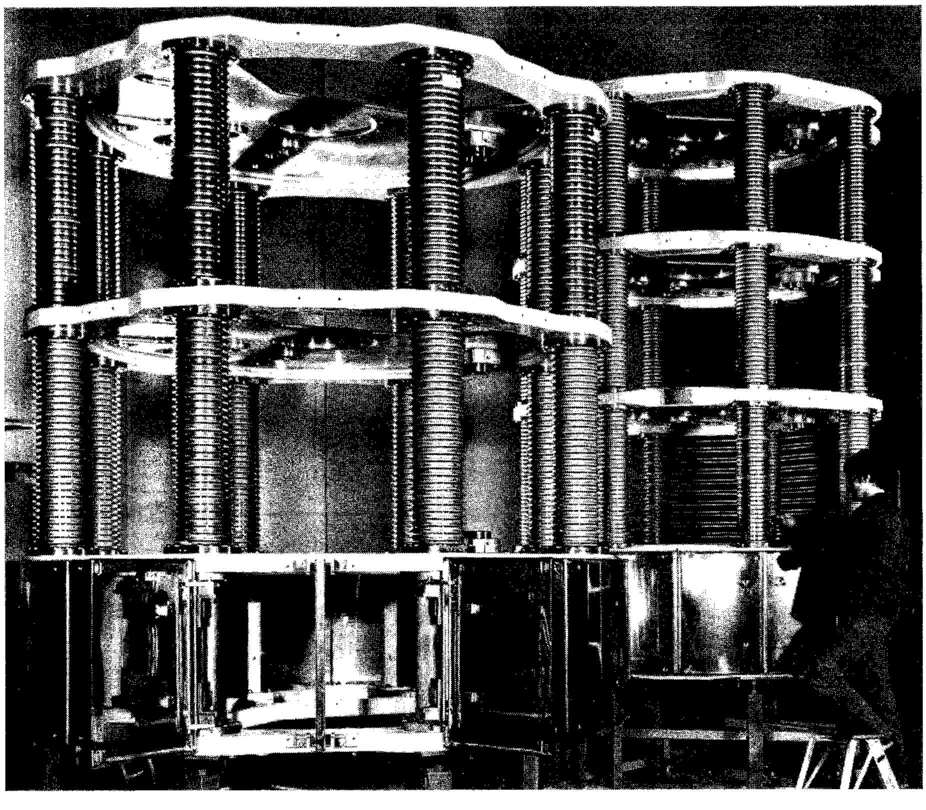
The control system, based on a number of mini-computers with interactive colour TV displays interconnected by a 5 Mbit/s serial data link, is well advanced. The link is used for the transmission, in digital form, of both analogue and digital information. The loop controllers are interfaced to the computers by standard CAMAC equip-

The Nuclear Structure Facility, NSF, taking shape at Daresbury Laboratory to house a 30 MV Van de Graaff. The main tower and services tower are now topped by the ion source room. The semicircular experimental building at the base is divided into three areas and is in use at present for pre-assembly of the accelerator components.



The accelerator column and the 'dead' sections being pre-assembled prior to installation in the pressure vessel.

(Photos Daresbury)



ment and the controllers themselves, which have been developed and constructed at Daresbury, make use of fast microprocessors in very high density configurations. They are capable of autonomous control of data transfers when necessary to transmit high priority information. Regular data updating is under the control of the minicomputers via the CAMAC units. Work on the software is progressing well. The operating system using Interdata computers has been upgraded and utility and applications programmes are being prepared. The high level language RTL2 is used throughout.

The accelerator column and the 'dead' sections of the structure with their associated instrumentation are being pre-assembled in approximately 10 m lengths prior to installation in the pressure vessel. All instrumentation, including the infrared light links which transmit information inside the machine, the control electronics, power supplies and vacuum and beam handling components will be commissioned prior to installation. This work is taking place in one of the experimental areas and has now been under way for several months.

In general the NSF is progressing well but it will not be completed on schedule. About six months were lost due to delays in the building programme which delayed access to the experimental area where components are being assembled. With limitations on the number of staff and on funding during the present financial year there is no hope of catching up the lost time.

STANFORD HEPL
Tunable laser

Experiments at the superconducting linac in the High Energy Physics Laboratory of Stanford University have demonstrated that free electrons from an accelerator or storage ring can be

Participants at the Novosibirsk meeting on experimental methods with high energy electron-positron colliding beams, photographed at the entrance to the Institute of Nuclear Physics.

used as a source of laser radiation. As well as providing a new 'spin-off' application for electron machines, the technique has the major advantage of enabling the wavelength of the laser radiation to be continuously varied over a wide range, in contrast to the small operating band of present 'tunable' lasers.

Since the discovery of stimulated coherent radiation back in 1954, physicists have been looking for a laser source which could operate over a wide range of wavelengths. The tunable laser idea tested at HEPL originated with John Madey who worked on the concept with William Fairbank, Alan Schwettman, Luis Elias, G.J. Ramian, Todd Smith and David Deacon.

Conventional lasers supply radiation originating from transitions between atomic or molecular energy levels, which severely limits the range of output wavelengths. These atomic and molecular structure constraints limit the tuning range to just a few per cent around the base operating wavelength. These constraints do not apply to stimulated radiation obtained from free electrons which, in principle, could permit laser radiation to be produced over the range 100 — 0.1 μm, i.e. from the far infra-red, through the visible to the ultra-violet. This range of tunability results from the possible relativistic variation in the electron energy.

When an electron is deflected by a periodically varying magnetic field, it can emit coherent as well as the more commonly encountered incoherent synchrotron radiation. These possibilities were discussed for example at the SLAC Wiggler Workshop in March (see May issue page 144). In the Stanford experiment, a 43 MeV electron beam was fired through a 5.2 m superconducting helix which gave a periodic transverse field of 0.24 T. The emitted coherent radiation was confined in a resonant cavity made by having a pair of mirrors along the axis, one at each end of the helix. Each time the light, trapped between the two mirrors passed through the magnetic field together with the electron beam its power increased. A 10^8 increase was achieved in the tests.

Only a tiny fraction of the kinetic energy in the electron beam is extracted in the process and the output power of the laser could be considerably increased by using continuously circulating electrons in a storage ring. An efficiency above 20 per cent (the level achieved by carbon dioxide lasers) should then be possible.

The availability of high power laser radiation over such a wide range of wavelengths would considerably extend the scope of laboratory spectroscopy experiments. Also, if the power can be stepped up towards the megawatt range, many industrial applications would be opened up in photochemistry.

NOVOSIBIRSK Meeting on experimental methods

A Soviet/American Meeting on Experimental Methods with Electron-Positron Colliding Beams was held at Novosibirsk from 5-11 September. It was initiated by Pief Panofsky, Director of the Stanford Linear Accelerator Center who participated in the Meeting, and by the late Gersh Budker who did much to pioneer experiments with electron-positron colliding beams ten years ago. About seventy physicists took part in the Meeting including a sizable contingent from the USA and representatives from DESY, Frascati and Orsay.

The detection systems proposed for the storage rings SPEAR, VEPP-2M, PEP, VEPP-4, PETRA, DCI and CESR and the techniques that they incorporate were the main focus of atten-

A. Skrinsky shows the VEPP-4 electron-positron storage ring to visitors at the Novosibirsk meeting. VEPP-4 stored 5 mA electron beams during the Summer with a lifetime of about an hour at 1.5 GeV. Also visible in the photograph (left to right) are Pief Panofsky, V. Baier, B. Gittelman, E. Coleman and V. Sidorov.

(Photos Novosibirsk)

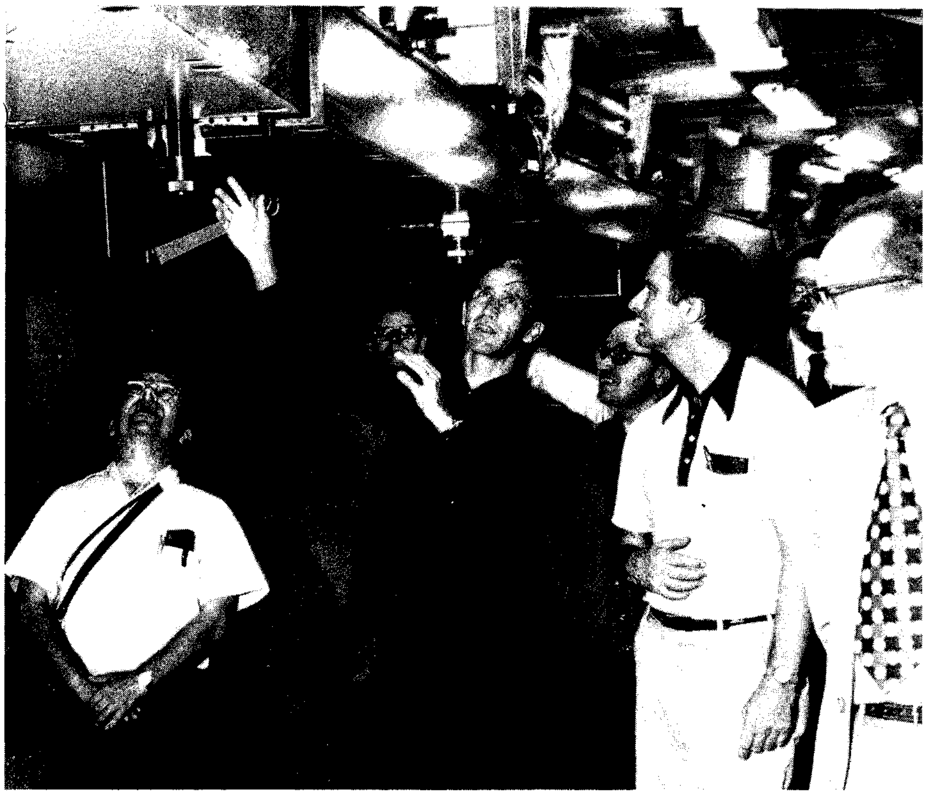
tion. The 'Time Projection Chamber' for PEP (see September issue, page 277), which has very versatile abilities for particle measurements and identification, and the MD-1 detector for VEPP-4, which has a large volume of vertical magnetic field, attracted a lot of interest.

Among novel detection techniques, which were the subject of lively discussion, were the huge liquid argon calorimeters at Stanford, the picosecond time of flight spectrometer at Novosibirsk and the idea of having Cherenkov counters with photo-ionization chambers rather than photomultipliers.

The synchrotron radiation emerging from high energy circulating electron and positron beams was of interest for two reasons. The negative reason is that it can be a source of very high background from which detection systems need careful shielding. The positive reason is that synchrotron radiation makes possible a very precise calibration of the storage ring energy. On VEPP-3 the calibration accuracy has been pushed to the level of about 10^{-4}.

Considerable attention was aroused by the possibilities of radiative self-polarization of electron and positron beams — achieving polarization, transverse to longitudinal transformation of the polarization, measurement and utilization of the polarized beams.

The number of reports given per day was limited to about five plus a longer talk of an hour. Breaks after each of these sessions gave ample time for detailed discussions amongst the participants. The atmosphere at the Meeting was very open and get-togethers of this type may well be organized on a regular basis. As W. Bartel put it 'When we first came we met people with tongue-twisting names; we left friends whom we would like soon to see again'.



FERMILAB Improvements in the Meson Lab.

During the August / September Maintenance and Development period at the Fermilab 500 GeV synchrotron, the Meson Department installed a new targeting system which allows independent control of the vertical and horizontal targeting angles.

The vertical angle may be varied from 0.3 mrad to 1.1 mrad providing a range of more than four orders of magnitude in the available proton intensity in the M2 diffracted beam line (from less than 10^7 to 10^{11} particles per pulse). This system has operated successfully. The horizontal angle may be varied from 0 mrad to 7 mrad for the M1 and M6 beam lines. Commissioning of the horizontal system is proceeding. With these developments, experimenters can look forward to significantly increased intensity and improved negative kaon and antiproton ratios in M1 and M6.

A Meson Workshop was held on 16 September to acquaint users with the improvements in the Meson Laboratory beams and facilities and to plan for further improvements during a projected six month 'Mesopause' starting in July 1978. There was considerable interest in the proposal to provide a mini-split in the Meson Laboratory proton beam line so that the M1 beam can be independently targeted from the rest of the Meson beam lines. The separate M1 target allows zero-degree production of a high intensity pion beam using the present M1 enclosures with some modifications. Interest was also expressed in using the intense pion beam to produce a 'clean' neutral kaon beam.

As a result of the Workshop, working parties have been set up to study an M1 high intensity pion beam design, tertiary neutral kaon and beams from the pion beam, polarized proton beams, reconfiguration of the neutral hyperon facility for 1 TeV operation, and 1 TeV operation of the Meson Laboratory in general. A report will be presented in January as a basis for the presentation of proposals to the Spring meeting of the Program Advisory Committee which will be considering post-Mesopause experiments.

DESY
Another storage ring - PIA

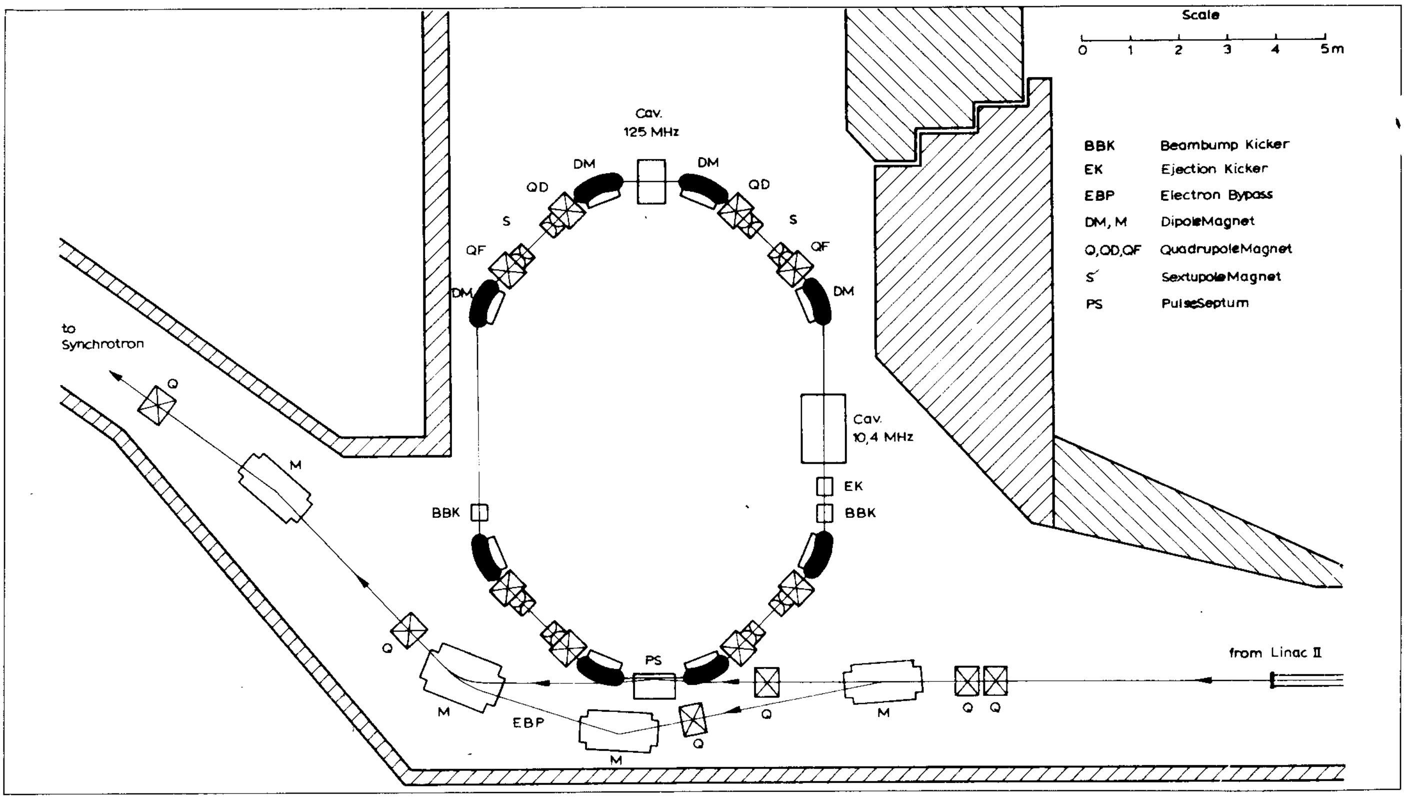
The storage ring PETRA now under construction at the DESY Laboratory is designed to store 4 x 10^{12} electrons and positrons and it is a major design challenge to be able to build up such intense beams in an acceptable period of time.

Since the intensity of the positron linac is only about 2 x 10^7 particles per pulse, 2 x 10^5 pulses are required for injection and accumulation in PETRA. At 7 GeV (the maximum transfer energy between the DESY synchrotron and PETRA) the damping time constant in PETRA is about 100 ms and, allowing for 10 Hz injection rate, these numbers would lead to a total filling time for positrons of about 6 hours.

Because of the 200 times higher density of the electron source, this scheme is quite satisfactory for electron accumulation but to shorten the positron injection time it was planned to use the smaller DORIS ring for intermediate storage at 2.2 GeV. With the shorter damping time in DORIS, thirty linac bunches can be stacked every 20 ms and single bunches can subsequently be transferred from DORIS, via the synchrotron, to PETRA. This brings the filling time down by a factor of 150 and the scheme was successfully tested earlier this year (see May issue). After completion of PETRA in autumn 1978 this was intended to become the routine method for positron filling of PETRA.

The exciting discovery of the Upsilon particle at energies around 10 GeV (a region not easily accessible at the higher energy PETRA) and the increased demand for synchrotron radiation experiments at DORIS, have prompted the idea of relieving DORIS from its PETRA injection role, which would have absorbed a fair fraction of its total operating time.

An additional small storage ring has therefore been proposed for intermediate accumulation and storage of positrons. It is called PIA (for Positron Intensity Accumulator) and will be situated at the end of the Linac II building where there is enough space for a ring of about 40 m circumference. Because of synchronisation conditions, the orbit length will be 28.8 m which corresponds to a tenth of the



Layout of the Positron Intensity Accumulator, PIA, which is to be built at the output end of the DESY linac in order to relieve the DORIS storage ring of its role in the injection system for PETRA.

DORIS circumference and 1/80 of PETRA's.

To compensate for the smaller length as compared to DORIS, injection and accumulation will be done in a multiturn mode using four to five turns, and the bunch will be compressed by two r.f. systems that act on the beam one after the other. To simplify ejection, the stored particles will be contained in only one bunch and accumulation will therefore be achieved by using a 10 MHz cavity first. About 50% of the injected positrons will be captured and damped down to a bunch length of about 80 cm. After one second (50 accumulated linac pulses), the second r.f. system working on the 12th harmonic (125 MHz) will come on to compress the bunch further to a length of 25 cm. The ejected bunch will be taken to the synchrotron and accelerated to 7 GeV before transfer to PETRA.

PIA will store positrons at 450 MeV. With combined function bending magnets giving 1.5 T, the damping time constant will be 24 ms for betatron oscillations which is short enough to work with 50 Hz injection repetition rate. Only small modifications will be needed on the linac and on the transport system between the linac and the synchrotron. Construction of various components has already been started and the first injection tests are scheduled for early 1979.

STANFORD
Polarized electrons

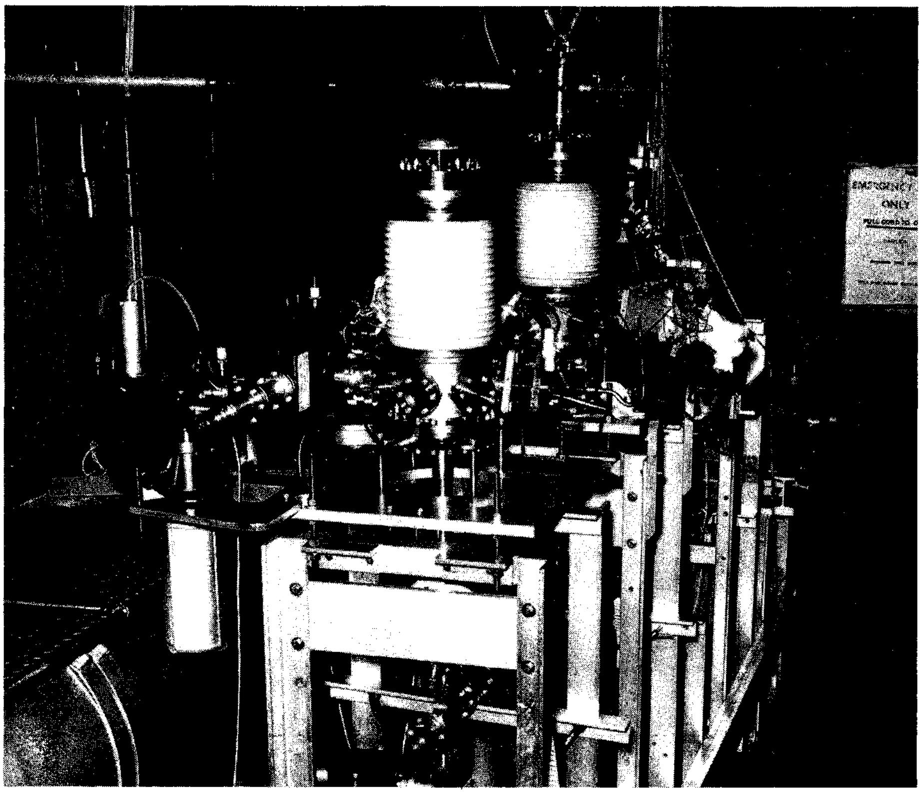
In November, a new polarized electron source, called PEGGY II, will come into operation on the electron linear accelerator at SLAC. It is a dual gun device developed by Ed Garwin, Charlie Prescott, Roger Miller and Charlie Sinclair.

Unlike the original SLAC/Yale polarized source, which obtained polarized electrons through the photoionization of a beam of aligned lithium atoms, the new source produces its polarized electrons by illuminating a gallium arsenide crystal with circularly polarized light from a dye laser. Since there are considerably more electrons available in the crystal than in the lithium atomic beam, the new source can produce a far more intense electron beam (between two and three orders of magnitude more has been achieved so far).

It also uses a different method of polarization reversal. The original source reversed the polarization by reversing a magnetic field, a process which is relatively slow and affects the beam steering at the injector. The new source has its polarization reversed by reversing the sense of the circularly polarized laser beam, a process which can be done very rapidly and randomly in time under electronic control. This latter feature is very important in eliminating small systematic effects in experiments which hope to see very small beam polarization effects.

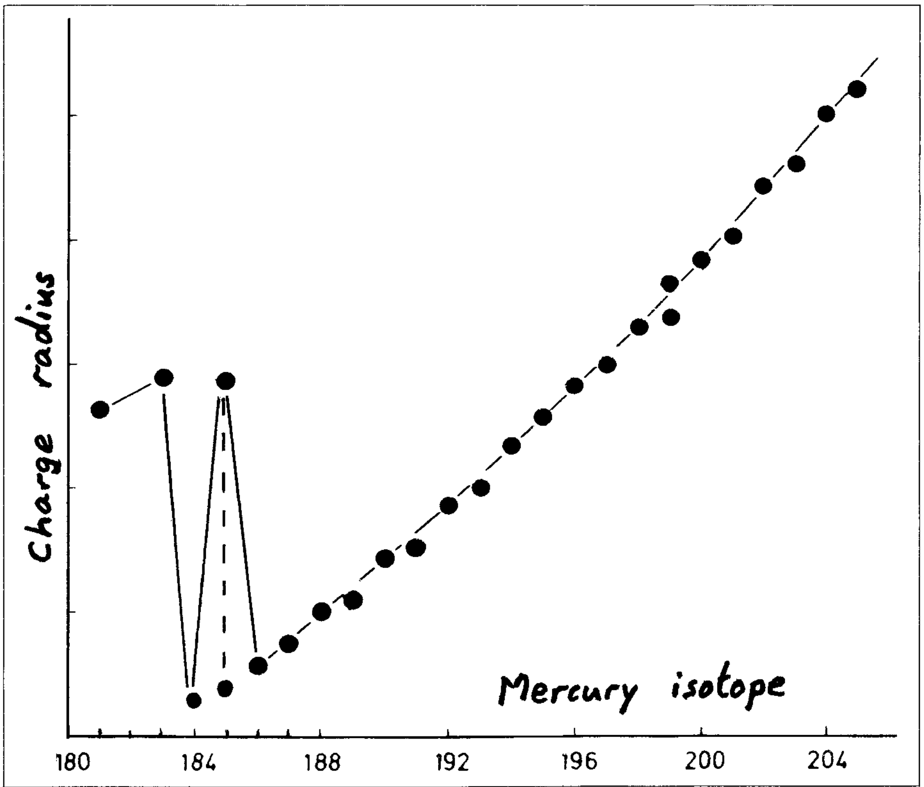
All is not pure bliss, however, as the new source produces only 50% polarization, while the original source delivered about 85%. In principle, higher polarizations (perhaps 100%) can be obtained either by stressing the crystal to deform its band structure a little, or by using crystals of different material. Work on this potential improvement is beginning.

PEGGY II has two identical electron guns so that beam can be delivered to the accelerator from one gun while the other undergoes vacuum bakeout and preparation of the crystal surface. In tests to date, a single gun has been repeatedly used to prepare good quality crystal cathodes and has been operated non-stop for 29 hours with a beam of over 10^{11} electrons per pulse with a 45% polarization. Intensities of 25×10^{11} electrons per pulse have



The polarized electron source, PEGGY II, which is coming into operation on the linear accelerator at Stanford. There are two identical guns (the vertical white cylinders) each of which should be able to flood the linac with polarized electrons.

(Photo SLAC)



A graph of the charge radius of mercury isotopes against the number of nucleons illustrating the unusual behaviour discovered at ISOLDE. The radius gradually decreases as the atomic mass of the isotope decreases from 205 to 186, while the 185, 183 and 181 isotopes have much larger radii, corresponding to a more deformed shape. The isotope 184 is spherical, so that between atomic masses 183 and 186, the nucleus 'staggers' from one shape to another. It has been newly discovered that the 185 isotope — the 'flip-flop nucleus' — has two charge radii, corresponding to two very different nuclear shapes which coexist but do not mix.

been achieved but further work is necessary before this becomes a standard operating condition. In principle, this new source should be able to deliver more electrons than the linac can possibly accelerate.

The first use of the source will be in an experiment to search for very small parity violating effects in the inelastic scattering of electrons from an unpolarized target. Such effects are predicted as a consequence of the weak neutral current and their observation would be an important step forward in our understanding of the weak interaction.

CERN Discovery of 'flip-flop' nuclei

Experiments by physicists from the University of Mainz working at the ISOLDE on-line mass separator at CERN have discovered that certain mercury nuclei can exist in both spherical and deformed shapes.

The study of the properties of the unstable mercury isotopes by means of optical techniques has long been a speciality at ISOLDE (see November issue 1971). Optical pumping was used to determine spins, magnetic moments and radii of mercury isotopes with odd numbers of nucleons over the range 205 to 181 nucleons. Down to 187 the usual behaviour was seen, with the nuclei shrinking as the number of neutrons decreased, but below this point the isotopes with 181, 183 and 185 nucleons turned out to have much larger radii. This was interpreted as a transition of the nuclei from a spherical to a deformed (ellipsoidal) shape.

New measurements with tunable lasers were started on the rebuilt ISOLDE facility and this technique allows measurements to be made also for the isotopes of even mass, which have spin zero. The first results (see February issue, page 17) confirmed the previous trend also for the even isotopes down to mass 186. Since then the new discoveries have been fascinating.

It was found that the mercury isotope 184 has a radius corresponding to a non-deformed shape and thus fits in with the trend in the heavier isotopes but not at all with the strong deformation seen for its neighbours 183 and 185. This dramatic 'staggering' in the nuclear shape from isotope to isotope is of a magnitude not previously observed in any other region of the nuclear chart.

The latest series of measurements by the Mainz group (reported at the Tokyo Conference in September) has now revealed that the 185 isotope in addition to having a deformed ground state, has a long-lived isomer at low energy which has a radius corresponding to a non-deformed nucleus. These adjacent states of very different shapes seem to exist independently of each other and do not 'mix'. To describe this behaviour, the Mainz group has coined the term 'flip-flop nucleus'.

It does not seem as if the final theoretical word has been said about this exotic corner of the nuclear chart around mercury 184, although the main features now seem to be understood. In qualitative terms the explanation seems to hinge on the very different behaviour of the neutron and proton systems in the nuclei. The proton number of the mercury nucleus is 80 which is close to the 'magic' number of 82 where, according to the shell model, a spherical shape is favoured. The neutron numbers fall midway between the magic numbers of 82 and 126 where a permanently deformed nuclear shape is favoured.

The apparent independence of the two types of state poses interesting theoretical and experimental questions. It looks as if the mercury beams at ISOLDE will retain their popularity for some time to come.

Hybrid detector taking shape

In the beginning there were two types of particle detector — bubble chambers and electronic counters. Bubble chambers were general-purpose detectors used for a wide range of different experiments over a considerable period of time, while counters were normally custom-built for a particular experiment and so had a relatively short working life.

This broad distinction became blurred as the electronic detectors grew in size and large systems such as the Omega spectrometer at CERN are as much general-purpose particle detectors as a large bubble chamber. In

Part of a map of nuclear stability as calculated by S. Nilsson of the University of Lund. It plots neutron number against nuclear deformation factor (EPS) for nuclei with minimum proton number. Zero deformation factor implies a spherical nucleus, while a positive value denotes a prolate shape (like a rugby ball) and a negative value an oblate shape (like a pancake). The contours show the relative nuclear energies, with valleys of spherical stability near the 'magic numbers' of 20, 50 and 82 neutrons. A valley of stable prolate nuclei can be seen between neutron numbers 56 and 80.

addition, large bubble chambers like BEBC and Gargamelle became used in conjunction with arrays of electronic counters to help identify emerging particles.

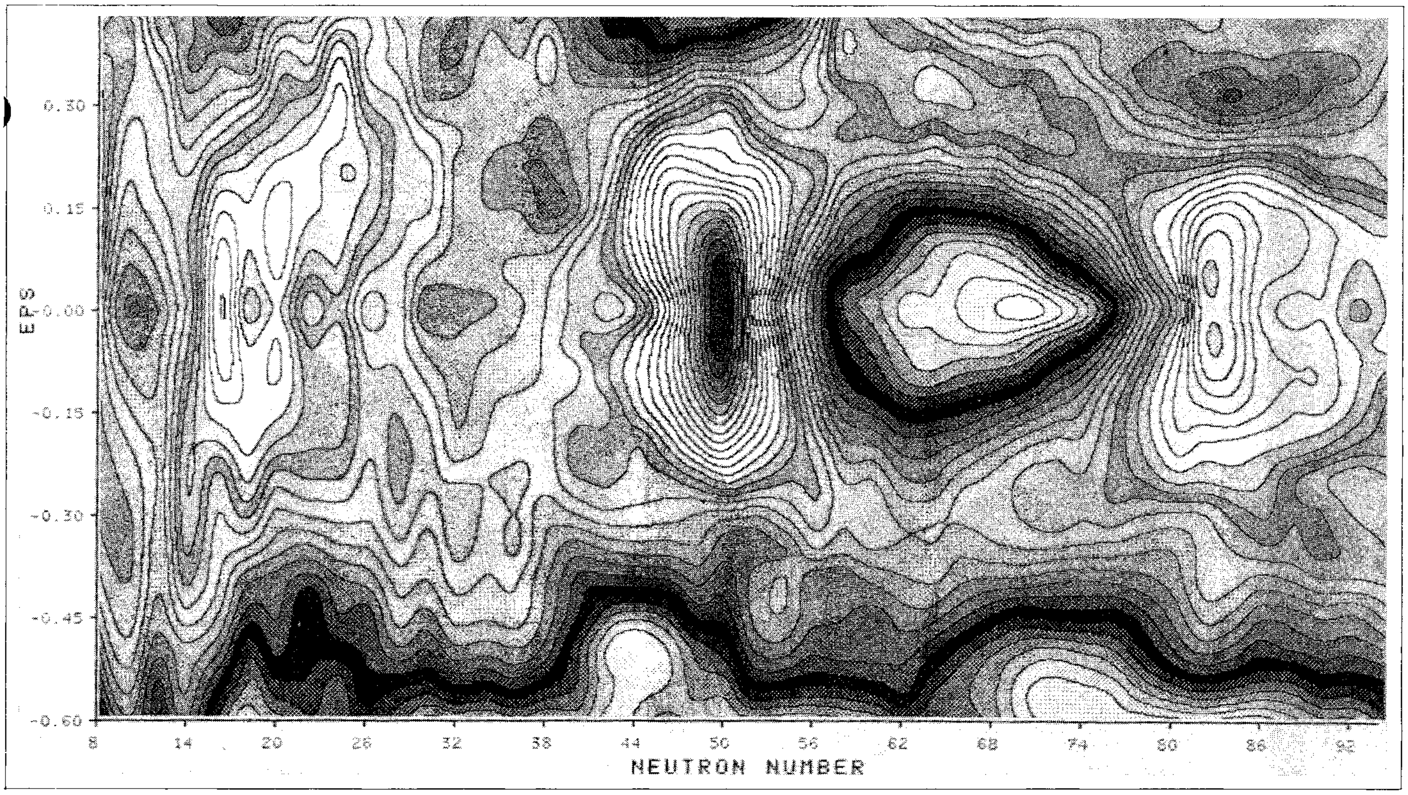
Now bubble chamber and counter techniques are being fully integrated at CERN into a single large 'hybrid' system for experiments at the SPS which will use a 'rapid-cycling' bubble chamber as the primary interaction detector, together with electronic counters for particle identification and analysis. This hybrid system combines the desirable features of the different detection techniques and is especially relevant to the study of strong interactions at SPS energies.

This new project now getting under way could provide insights into the details of particle interactions at very high energies and enable physicists to exploit the high potential of the SPS to the full. Called the European Hybrid Spectrometer (or EHS for short), it already involves physicists from Austria, France, Germany, Italy, the Netherlands and the UK and, very likely, Belgium and the USSR as well as CERN. Already some twenty universities and laboratories have expressed an interest in using EHS, and several Laboratories outside CERN are helping in its development.

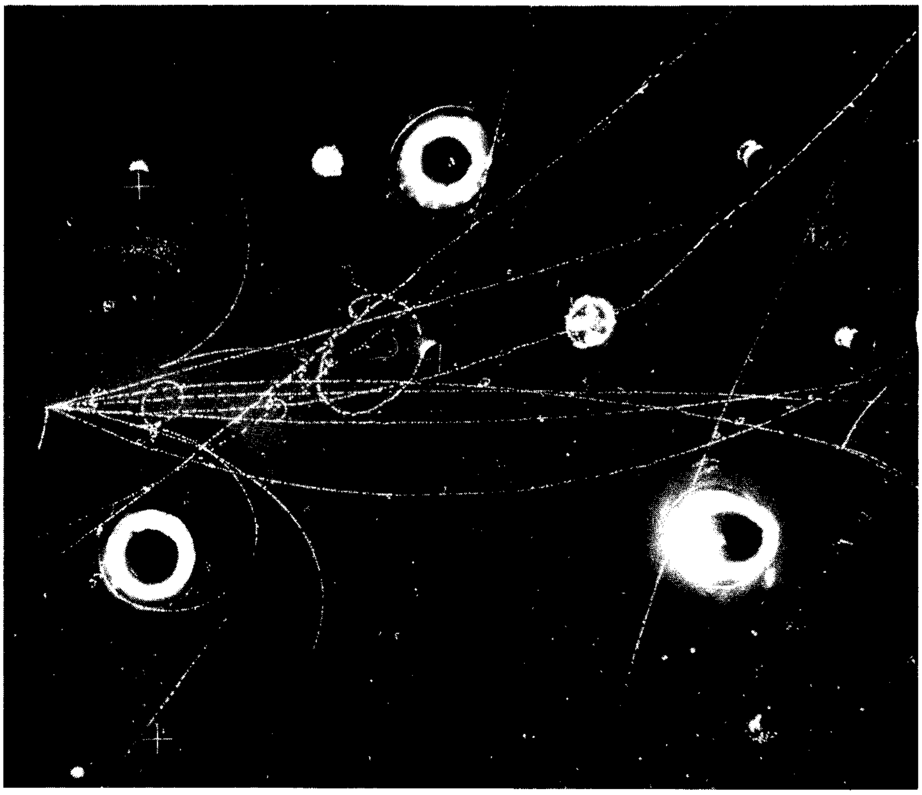
At SPS energies, interactions producing large numbers of particles are more abundant than at lower energies, and special detection equipment is needed to collect and analyse the details. Without such equipment, these plentiful reactions could not be analysed so fully and much of the potential usefulness of the high energy accelerator would be lost.

The idea is to use a 'rapid-cycling' bubble chamber to photograph the initial interaction which produces all the many final particles, as bubble chambers still provide the best way of recording the details of complicated interactions. The chamber will expand 30 times a second and take pictures some 15 times a second (rather than just twice a second as, for example, with the late 2 metre bubble chamber). This will enable data to be collected much more quickly, so that experiments will be able to accumulate more data in a given time. Designing such a high performance chamber requires special expertise, particularly in hydraulics and optics, but preliminary work has shown that the problems can be overcome.

After passing through the bubble chamber, the secondary particles go on to the downstream spectrometer. As well as measuring the direction and momenta of the particles, this arrangement can also be set to 'trigger' the bubble chamber when the particle configurations of interest are produced. Plans are also well advanced for a neutral particle detection system consisting of two large photon detec-



The heavy liquid bubble chamber, Gargamelle, scene of some of the most important physics results at CERN, has recently come back into action in its new location to receive high energy neutrinos generated by the 400 GeV proton synchrotron, the SPS. The photograph shows one of the first neutrino events recorded by the chamber.



tors, which will enable the high multiplicity events at SPS energies to be studied more fully by covering also the interactions where neutral pions are produced. This will considerably increase the number of types of interaction which can be studied.

The various parts of the EHS are being built by different European groups. The Rutherford Laboratory is constructing the bubble chamber, which will be about 80 cm in diameter and 40 cm deep with a volume of 300 litres. The walls and piston of the chamber will be lined with Scotchlite, as in BEBC, so that the particle tracks will show up black against a light background. A 3 Tesla superconducting magnet is being built at Saclay in France.

CERN is handling the overall project coordination, the local infrastructure and the necessary computer developments. Dutch and Austrian groups are building some of the electronic particle detectors. The first part of the downstream spectrometer, which handles particles of up to 30 GeV/c momentum, uses multiwire proportional chambers and drift chambers, while the second part, handling the higher momentum range, uses a second large spectrometer magnet followed by planes of drift chambers.

The first stage of the project, which will provide for the detection and measurement of charged particles, is now under way and is scheduled for completion by 1980. Manufacture of the second stage, involving the photon detection equipment, should soon begin and a third stage is being planned to achieve charged particle identification.

ARGONNE
A diproton resonance ?

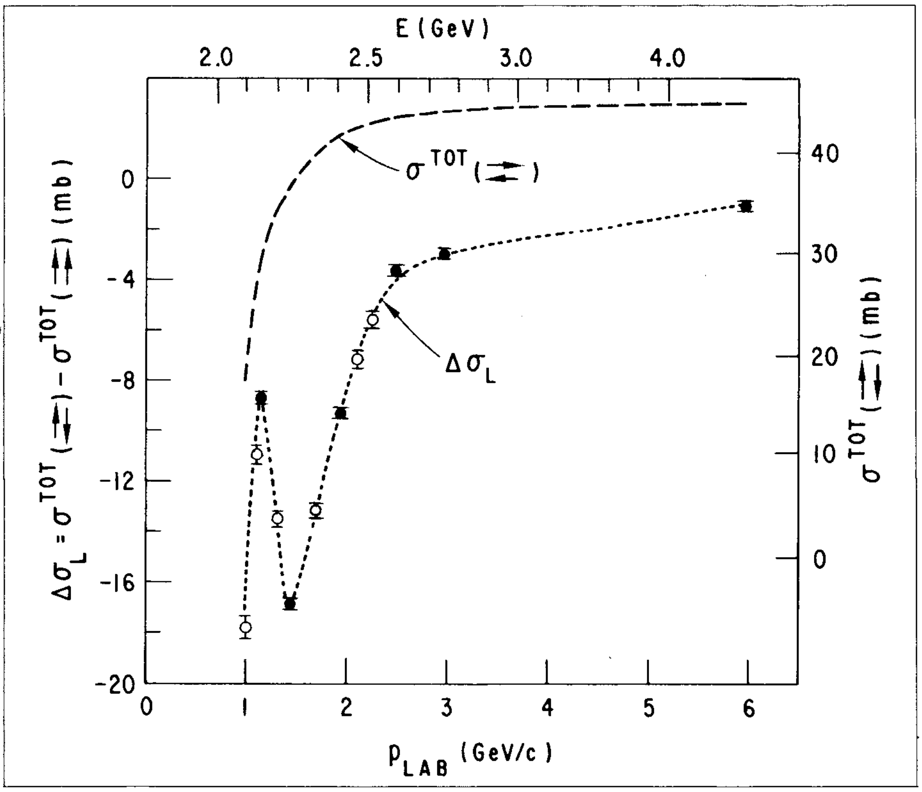
Recent experiments at the Argonne Zero Gradient Synchrotron strongly suggest the presence of a resonant state composed of two protons, with a mass of roughly 2250 MeV. Such a resonance, which would have an electric charge of two units and a baryon number of two, had previously been thought too 'exotic' to exist in Nature.

The experimental data which suggest this unconventional particle state come from experiments with a polarized proton beam and a polarized target, with the polarization of both beam and target aligned along the incident beam direction. The difference between the proton-proton total cross sections with the beam and target spins aligned in the same direction, compared to when they are aligned in opposite directions, was measured. The difference is unexpectedly large, and furthermore shows a striking energy dependence near 1.5 GeV/c. In terms of pure longitudinal spin states, the parallel-spin cross-section is found to have a peak near 1.5 GeV/c where it is 50% larger than the anti-parallel spin cross-section which does not show such structure.

Earlier theoretical speculations were that some structure might be observed in proton-proton interactions in this energy region, due to the threshold for the production of the delta resonance of mass 1236 MeV. However, this would be expected in the singlet spin state (rather than in the triplet states contributing to the total cross-section) and at a lower momentum near 1.2 GeV/c. The data seem consistent with a diproton resonance with a mass of 2250 MeV, a width of 200 MeV, elasticity greater than 20% and quantum numbers of spin 3 and negative parity.

In the simplest quark model of hadrons, where baryons are made up of three quarks and mesons of a quark-antiquark pair, there is no room for such a bizarre object as a diproton

The variation with energy of the difference between the proton-proton total cross-sections with spins antiparallel and spins parallel seen in experiments at Argonne. The dotted curve is drawn to guide the eye. The dashed curve shows the structureless energy dependence of the total cross-section when the proton spins are antiparallel. The structure in the cross-section difference is attributed to the pure spin-triplet cross-section with spins parallel. (Open circles represent data points which are still preliminary.)



resonant state. However, some of the theoretical models, developed to explain the binding of quarks into conventional hadrons, leave room for states composed of more quarks than just the required minimum. The existence of such 'quark molecules' is in fact expected by some currently fashionable models of hadron structure. Possibly the structure revealed by the ZGS experiments for the proton-proton system is the manifestation of this next level of complexity in the subnuclear world of the quark.

SACLAY Large chambers for the SPS

The Department of Elementary Particle Physics (DPhPE) at Saclay has successfully built and tested two proportional chambers of 17 m^2 and 12 m^2 which will be used in experiments at the CERN 400 GeV proton synchrotron.

The larger chamber is a full-size prototype of a chamber having four independent planes with a useful area of 17 m^2 each and a total volume of about 3 m^3, which will be one of the components of the spectrometer of the NA3 experiment to be installed in the SPS North Experimental Area at the beginning of 1978. Built by the CERN / Collège de France / Ecole Polytechnique / LAL Orsay / Saclay collaboration, the spectrometer will be used to study dimuon production up to masses of at least 10 GeV, hadronic processes with large momentum transfer (jets), and electron pairs and associated hadron production.

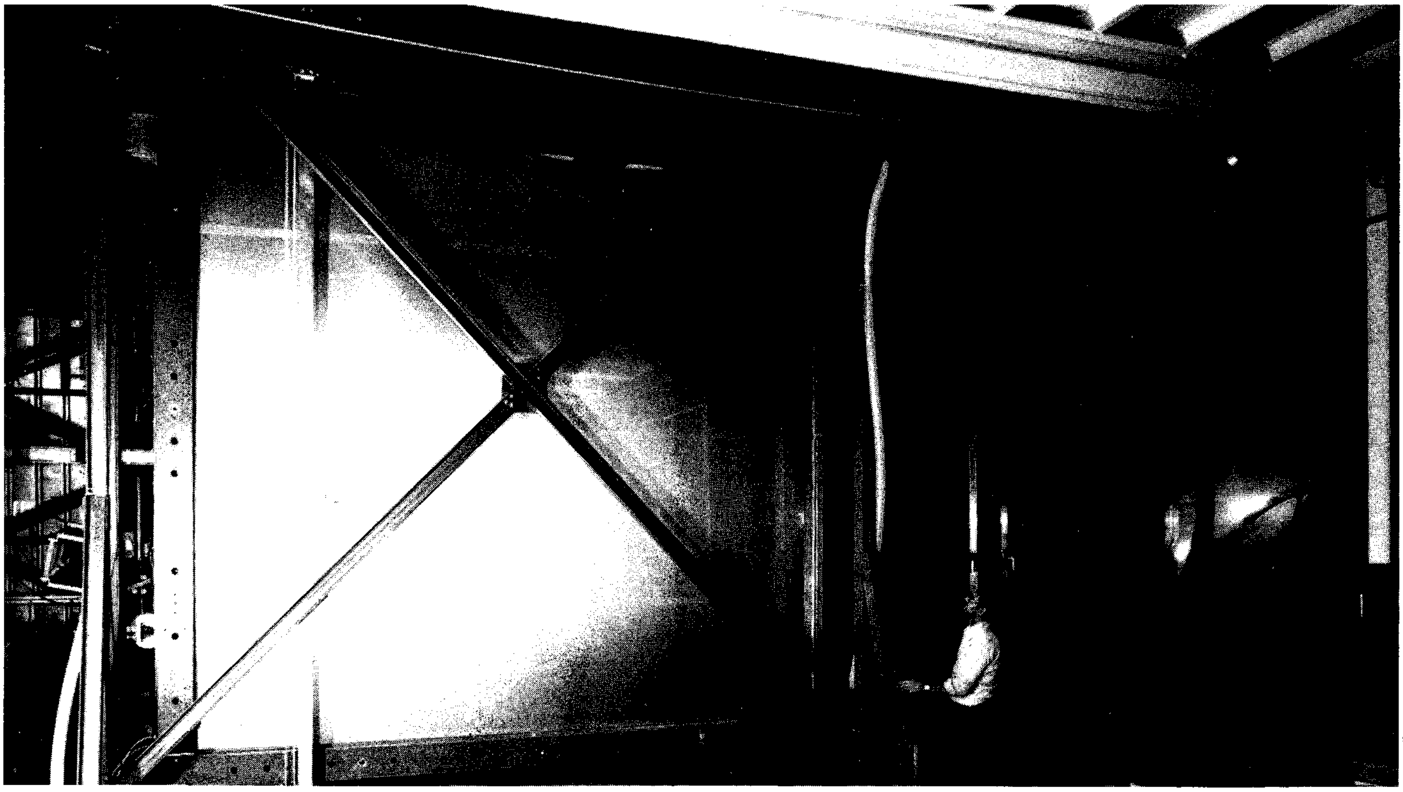
These phenomena will be investigated with incoming beams covering the energy region from 200 to 400 GeV. A circular aperture magnet (1.60 m diameter) will provide large acceptance requiring large particle detectors. Multiwire proportional chambers were selected and the largest is now being built at Saclay.

The prototype measures 4.25 x 4 m^2 and weighs 3 tons plus a supporting chassis of 4 tons. It comprises a plane of 1414 vertical wires between two high voltage planes. The read-out wires, 3 mm apart, are of gold-plated tungsten 20 μm in diameter while the high-voltage wires are of 25 μm Mylar coated with a thin film of graphite loaded paint.

There are two advantages in using the graphite-Mylar — the high resistivity of graphite makes a cathode wire unlikely to rupture in the event of a flashover and it is very easy to temporarily neutralise heavily irradiated regions. The prototype has two rectangular regions, with completely independent high voltage power supplies, separated by a thin, ungraphited strip 3 mm wide, which in the final chamber will be located in the path of the beam from the SPS (maximum intensity of 10^8 ppp) and in the path of the particles from the diffractive cone of the interactions in the target.

The spacing between the planes is 6 mm maintained by a 5 mm Kapton strip, folded concertina-fashion, with a PVC-sheathed wire 1 mm in diameter glued on its surface. These wires are arranged perpendicular to, and in contact with, the read-out wires, with a spacing of 50 cm and, when taken to a voltage of 1.5 to 2 kV, they make it possible to correct any local inefficiency caused by the presence of the kapton strip. This system gives the assembly the rigidity needed for the proper operation of the chamber.

The electronics for the signals from the read-out wires consists of MOS integrated circuits, of the FILAS type, as normally used for proportional chambers. It is installed on printed circuits which are plugged into the read-out wire base by a set of connectors allowing the electronics to be replaced, if



necessary, without disturbing the rest of the chamber.

The gas mixture for the tests consisted of 20% isobutane, 80% argon and 0.1% freon, which gave an efficiency better than 99% over the voltage range of 2.7 to 3 kV and was completely uniform over the whole 17 m² area.

Four hexagonal 12 m² chambers will be installed for the neutrino experiment of the CERN / Dortmund / Heidelberg / Saclay collaboration. A tank filled with hydrogen or deuterium is to be added in front of the existing detector, to allow the interactions of neutrinos and antineutrinos with protons and neutrons to be studied separately, and the chambers will determine the point of interaction in the tank.

Each chamber consists of three layers of 1232 20 µm wires, spaced at 3 mm, and oriented in three directions with an angle of 120° between them. The read-out wires are fitted between two graphited Hostaphan planes at high voltage. A spacing of 10 mm between the anode and cathode planes is maintained by a Kapton concertina strip system. The electronics are the same as for the 17 m² chamber. The efficiency in the three elements of the first chamber, using a gas mixture of 20% isobutane and 80% argon, is over 98% with a voltage of between 3.5 and 3.9 kV.

A large quantity of ancillary equipment is needed for the construction of these very large chambers, because of their exceptional size and weight. It includes a wire-weaving loom, a loom for tensioning the Mylar planes, an automatic wire welding machine, a spray-painting booth, handling devices, etc. One of the last, but certainly not least, knotty problems to be solved will be that of transport to CERN. Saclay has already acquired some experience in this field with the transport of the twenty drift chambers already installed for the neutrino experiment.

Neutrons against cancer

The Cancer Therapy Facility at Fermilab treated its first patient a year ago (7 September 1976). Since then a total of 86 patients have completed the prescribed course of radiation and, overall, the results have been very satisfactory.

The Facility draws a neutron beam from a beryllium target bombarded by 66 MeV protons from the linac of the 500 GeV synchrotron. It has been used for biomedical experiments, as well as for cancer treatments, mainly aiming to determine parameters of neutron radiation which are important for therapy and for comparisons with other forms of radiation.

It has been gratifying that, with the patients treated so far, the use of neutron beams as the sole method of treatment was very successful in controlling radiation resistant tumours. Side effects have been mild.

Encouraged by this experience, the National Cancer Institute has extended the research grant for the CTF for a further three years and its budget has been trebled. This will enable the number of patients treated per day to be increased and will also enable the fundamental questions about the efficacity of neutron radiation to be answered more quickly.

The Medical Research Council Cyclotron Unit at Western General Hospital, Edinburgh was officially opened on 27 September. It houses a cyclotron for the production of neutron beams for cancer treatment.

Two neutron beams are produced by the cyclotron and a special feature is that one of them is steerable. The compact cyclotron, manufactured by The Cyclotron Corporation, provides 100 µA of deuterons at 15 MeV. A switching magnet enables the output beam to be directed onto a fixed target or an isocentric target to give the manoeuvrable beam.

The considerable clinical experience in the use of neutron beams for cancer therapy at the Hammersmith Hospital, London, was of great value in the design of the new unit. The first

The full scale prototype of the 17 m² proportional chamber built at Saclay for an experiment at the CERN SPS. On the right is the first of four hexagonal proportional chambers which are to be installed as vertex detectors in the WA1 neutrino counter experiment at the SPS.

(Photo Saclay)

patients were treated in March of this year and some 70 patients have now completed their treatment. All have received neutrons from the fixed beam up to now and the steerable beam is scheduled to be in operation in a few months' time.

A team of biologists (Frank Ngo, Antun Han, Hiroshi Utsumi and Mortimer Elkind) from the Biological and Medical Research Division at Argonne are carrying out a detailed study of the relative effects of neutron irradiation and conventional X-ray and cobalt-60 gamma rays on cancerous cells.

They have access to three neutron sources in the Chicago area each covering a different energy spectrum. These are — the JANUS reactor at Argonne, the cyclotron at the Franklin McLean Institute of Chicago University and the Cancer Therapy Facility at Fermilab.

The results so far show that smaller doses of neutrons than X-rays are needed to kill equal numbers of cells. As the neutron energy increases (from reactor energies to CTF energies) the dose needed increases. Neutrons are more effective in killing the oxygen starved, radiation resistant cells often found in tumours. Also the cells are less able to repair damage after neutron irradiation.

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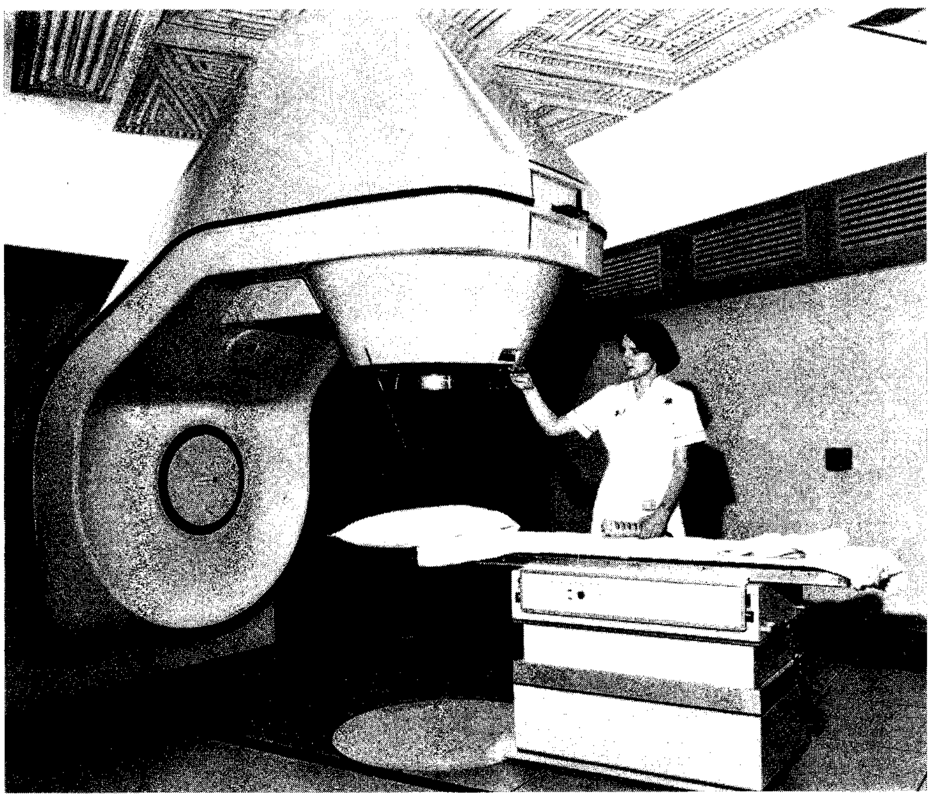


2.

1. The preparation of a patient for treatment at the Cancer Therapy Facility at Fermilab in front of the beam-line which brings neutrons from the linac.

(Photo Fermilab)

2. The isocentric neutron beam equipment at the Cyclotron Unit of Western General Hospital in Edinburgh.

(Photo John Porteus)

Physics monitor

From black bodies to black holes

Recent work, which has brought together the disciplines of particle physics, general relativity and thermodynamics, has been acclaimed by some physicists as the greatest single advance in understanding since the discovery of quantum mechanics. Until these new developments, classical thermodynamics was considered by many as a closed book, but it is worth remembering that Planck's original discovery of quantum theory was in his formulation of 'black body radiation' — a thermodynamical effect. With these new developments concerning radiation due to black holes, quantum mechanics can be said to have turned full circle.

As well as forging a link between thermodynamics and particle physics in a dramatic new way, these latest developments are another example of a growing trend to study common problems in particle physics, astrophysics and general relativity. As Steven Weinberg points out in his book 'The First Three Minutes', the availability of high energy machines is only now enabling Man to recreate cataclysms such as might have occurred during the formation of our Universe. This observation led one cynic to suggest that Weinberg's book be re-named 'The Last Fifty Years'.

What are black holes?

The intense gravitational attraction which tends to make large stars like the Sun collapse is balanced by an outward pressure due to continual thermonuclear fusion. This supply of fusion energy is not inexhaustible and one day the Sun will fizzle out and start to cool down. As it does so, it will contract as the gravitational attraction becomes dominant and this contraction will continue until a 'dwarf star' is created in which the component atoms are frozen into a compact solid instead of being dispersed as a hot gas.

For stars somewhat more massive than the Sun, the residual gravitational attraction at the dwarf star stage is sufficient to overcome the electromagnetic force crushing the component atoms so that the orbital electrons combine with nuclear protons to form neutrons. In such a 'neutron star' all the Sun's mass could be contained in a ball of neutron matter some 20 kilometres in diameter.

For yet more massive stars, even the pressure of closely packed neutrons could not resist the stranglehold of gravitation. It was J. R. Oppenheimer and H. Snyder in 1939, who first pointed out in the context of general relativity that a star of these proportions would collapse for ever. As far back as 1796, the Marquis de Laplace proposed that if a star were heavy enough, its gravitational pull could be sufficient to choke off its own light. It took many years to discover that this idea was also lurking deep inside the field equations of Einstein's formulation of general relativity.

When a massive collapsing star reaches a critical 'Schwarzschild radius', the velocity needed by any projectile to escape its gravitational field reaches that of light. At this point, even light (and therefore information) cannot escape from the star and any objects or radiation coming within its influence are sucked in, crushed by gravity and lost for ever. Surrounding the star is an 'event horizon', corresponding to the last sightings of everything which is subsequently swallowed up. It was John Wheeler who first gave the name 'black holes' to these voracious concentrations of mass.

Whatever falls into a black hole is lost, implying that a black hole remains a black hole whatever it may 'contain' or have devoured — even a black hole containing antimatter would be indistinguishable from one containing only ordinary matter. These are the so-called 'no hair' theorems of the black hole researchers.

Black holes and thermodynamics

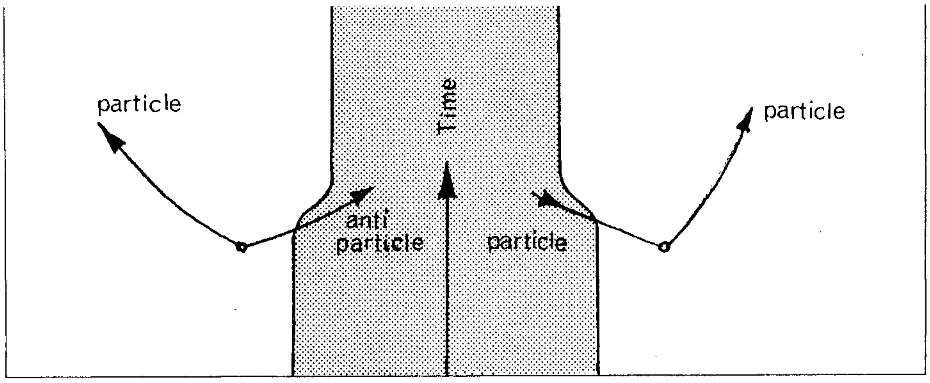
The Second Law of classical thermodynamics tells us that whatever else may happen, there is an irreversible process going on throughout the Universe in which overall organised structure and activity invariably erode away. This is quantified by introducing the idea of entropy — a measure of the degree of indistinguishability within a single observable macrostate. Because a black hole has indistinguishability, it must have entropy, which furthermore increases as required by the Second Law as the black hole eats up more material. It was proposed that the entropy of such an expanding black hole is proportional to the surface area of its event horizon.

To extend this thermodynamical picture of black holes, some notion of temperature must be introduced. But any body with temperature must radiate heat, the more so the blacker it gets — a good absorber of heat (a black body — not to be confused with a black hole !) is also a good emitter of heat. Nothing absorbs better than a black hole, so that a black hole must radiate !

The only thing which can escape from a black hole is gravity, and Stephen Hawking proposed that the intense gravity around the event horizon of a black hole can create particle-antiparticle pairs. Some of these particles can fall into the hole and be lost, while others escape.

If the antiparticle in the produced particle pair is sucked into the black hole while the particle escapes, this process can be likened to a net outflow of particles from the black hole. The black hole is slowly being drained of gravitational energy through this pair production process. The net outflow of

Two ways of looking at particle emission from black holes as a result of pair creation in the intense gravitational field near the event horizon. On the left, an antiparticle is sucked into the black hole while the particle escapes. Note that the boundary of the black hole shrinks as a result of the energy lost. On the right is a different way of looking at the same process, with a particle tunnelling out of the black hole backwards in time, but appearing finally as a conventional particle.



these gravitationally produced particles constitutes the temperature radiation of the black hole.

Simple arguments show that the temperature of an electrically neutral, non-rotating black hole depends inversely on its mass. This means that such a black hole has negative specific heat — as it radiates and loses energy (mass), it gets hotter and radiates faster, eventually evaporating away completely. Like a snowman melting in a sudden thaw and leaving no trace of its existence, such a black hole would disappear leaving no clue of the matter and radiation devoured in its lifetime.

Hawking concludes that the intrinsic uncertainty about the interior of black holes is as intimately linked with the underlying mechanisms of the Universe as is Heisenberg's Uncertainty Principle. This idea is now embodied in the 'Principle of Ignorance', implying that gravity imposes a new level of uncertainty or randomness into our picture of the Universe over and above that imposed by quantum mechanics. While Einstein himself found quantum mechanics sometimes hard to swallow, as epitomised by his famous maxim 'God does not play dice', Hawking now retorts saying that 'God not only plays dice, sometimes he throws them where they cannot be seen'.

While there are many potential astronomical candidates for black holes, none of them have yet been confirmed; Cygnus X-1 is currently the most likely contender for black hole honours. Nevertheless, the concepts continue to provide volatile fuel for theorists' imaginations. Hawking's new link between general relativity and quantum mechanics provides the first real example of a successful encounter between these two main avenues of theoretical approach. That the synthesis was achieved by introducing only thermodynamical arguments could point towards a radically new way of understanding.

More on dibaryons

Results coming from polarised proton experiments at Argonne have for some time been giving indications of a possible dibaryon resonance. Now a full partial wave analysis of the results gives strong evidence for a dibaryon resonance at 2260 MeV, with a width of 200 MeV, spin three and negative parity (as reported in the 'Around the Laboratories' section).

Only one dibaryon state — the deuteron — is well established, but some ten years ago in the heyday of group theory, Freeman Dyson and N.H. Xuong used the SU6 model to predict the existence of a series of different spin and parity dibaryon states as companions for the deuteron. The deuteron itself belongs in an SU3 decuplet in this model, while each additional dibaryon state has its own SU3 family.

In addition to the Argonne data, measurements of proton polarisation in deuteron photodisintegration experiments at Tokyo have also indicated the existence of a heavy dibaryon state, this time with spin three and positive parity, which is interpreted as a bound state of two baryon resonances. Other dibaryon evidence has been seen at Dubna, Berkeley and Rutherford.

Evidence for a dibaryon resonance was reported earlier this year by a CERN/Heidelberg/Munich collaboration (see May issue, page 152). This effect at 2129 MeV with spin one and positive parity is in the lambda-proton channel and corresponds to a unit strangeness state in the SU3 multiplet in which the deuteron, also with spin one and positive parity, forms the lowest-lying state.

While such experiments, using statistics of precise polarisation measurements, have only now begun to show signs of the existence of these companions for the deuteron, additional dibaryon states could also exist as a result of quark 'bag' or 'string' forces.

The continuing ability of the naive quark model to predict particle properties, coupled with the continuing reluctance of the quarks to reveal themselves, has put physicists in a dilemma. One way out of this dilemma is the so-called 'bag model' which says that quarks exist permanently confined together. Normally these 'bags' which hold the quarks are the usual baryons and mesons, but additional bags could exist containing, for example, six quarks in a dibaryon system. Other models use 'strings' of gluons to confine the quarks (see June issue, page 199).

The attractive force between pairs of baryons (as in the deuteron) is the result of meson exchanges and is a relatively long-range effect compared with the sizes of the baryons themselves. In the bag or string-picture, the dibaryons are held together by short-range colour forces which give rise to whole new spectroscopies over and above those due to 'long range' interactions. These additional baryon of number 2 states could be detected in future experiments.

People and things

Money for ISABELLE

On 3 October it was announced that the USA House-Senate Conference Committee has included $ 10.5 million in the 1978 authorization bill for ERDA to start construction of the 400 GeV proto-proton storage rings, ISABELLE, at Brookhaven National Laboratory. The project was upgraded from 200 GeV to 400 GeV energy per beam following recommendations of the science community (see August issue, page 228) and of the House Committee on Science and Technology. This takes the total project cost from $ 173 million to $ 245 million.

ZGS programme

The programme at the 12 GeV Zero Gradient Synchrotron has switched to a four month run of neutrino beams following completion in July of the counter physics programme with unpolarized protons. The neutrino experiments will be carried out with the 12 foot bubble chamber filled with deuterium and fitted with tantalum plates for converting gammas. This run will complete neutrino physics at the ZGS and the machine will turn exclusively to the acceleration of polarized beams probably through to the end of 1979.

Scientists for Spacelab 1980

In August the names were announced of the German scientist candidates for participation in the joint European / American Spacelab mission to be launched by spaceshuttle in 1980. The ten member Countries of the European Space Agency (ESA) had been asked to propose candidates from whom ESA will choose six. The final selection of two Europeans, only one of whom will join the first flight crew is to be made by NASA in the mid 78. In spite of these very slim chances of being chosen after undergoing a lengthy series of gruelling tests, over 2000 highly qualified scientists applied, 703 from the Federal Republic of Germany. Of the Germans selected, three are active in high energy physics Laboratories. Ernst Messerschmid is working at DESY, Laszlo Baksay spent three years in Carlo Rubbia's group at CERN (perhaps the best training for an adventurous mission that could be devised) and Klaus Zieher is at GfK Karlsruhe.

Pelletron successes

The Brookhaven tandem Van de Graaff achieved a record 14 MV on its central terminal and accelerated heavy ions to 320 MeV following the installation of a Pelletron. The Pelletron is an inductive chain charging system which has replaced the conventional charging belt. The new voltage and energy records (previously 13 MV and 250 MeV) are extending the research capabilities at the tandem.

Experiments have begun on another Pelletron heavy ion tandem, known as the Koffler Accelerator, at the Weizmann Institute in Israel. It extends the range of ions and of energies which can be studied compared to the Institute's previous 6 MV tandem. Further development is under way with the installation of an 'electrostatic charge selector', consisting of three electrostatic quadrupoles, able to remove unwanted ions from the beam after stripping in the high voltage terminal. With the selector, beams of ions as heavy as iodine will be accelerated to 225 MeV.

Nimrod prepares for SNS

The 7 GeV proton synchrotron, Nimrod, at the Rutherford Laboratory has been used in some tests in preparation for the construction of the Spallation Neutron Source which will succeed it as the Laboratory's main research instrument. The Nimrod energy was held down to around 800 MeV and short bursts of protons were sent to a target to produce spallation neutrons. Neutron yields, spectra, pulse shapes and target configurations were investigated to provide more information for the final SNS design.

Sensitive SQUID

One of 'Industrial Research' magazines 1977 awards for technological achievements went to a highly sensitive device, named SQUID, developed at Argonne for the measurement of magnetic fields. Charles Falco and Cheng-Teh Wu succeeded in perfecting a SQUID which will operate at 15 K rather than at liquid helium temperature and the device can therefore be used in conjunction with a small portable refrigerator. The SQUID can measure fields in the 10^{-15} T range and has potential applications in electronics, geophysics and biomedicine.

On people

Malcolm Derrick has been appointed Acting Assistant Laboratory Director for High Energy Physics at Argonne National Laboratory as Tom Fields is taking a sabbatical year at CERN. Bob Diebold will take over Dr. Derrick's previous position as Acting Director of the High Energy Physics Division.

C. Thornton Murphy has succeeded Brad Cox as Head of the Proton Department at Fermilab.

Steven Weinberg has received the U.S. Steel Foundation Science Writing Award for his book 'The First Three Minutes' in which he describes the current ideas on the birth of the Universe and the experiment evidence which has led to these ideas.

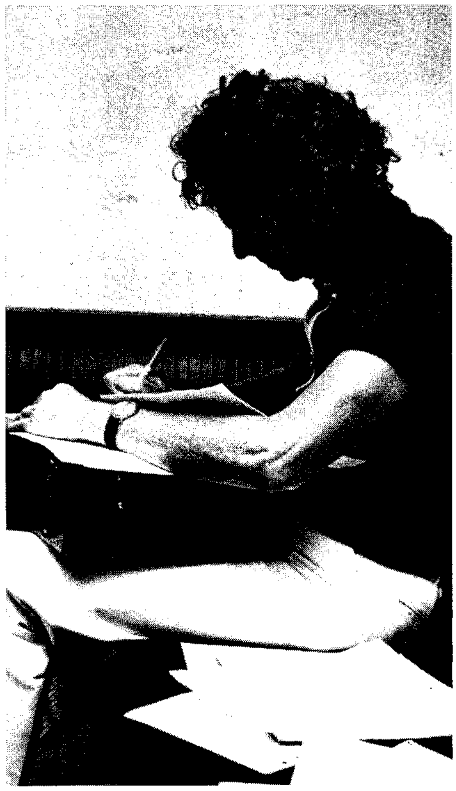
On 29 September a ceremony was held at Pavia University to mark the 150th anniversary of the death of Alessandro Volta. At the ceremony Felix Bloch, first Director General of CERN, and Leon Van Hove, present Research Director General of CERN, were among the recipients of the degree of Doctor Honoris Causa.

The High Energy Advisory Committee at Brookhaven met at the end of September. The present membership is R.R. Rau (Chairman), R.K. Adair, M.A.B. Beg, K. Goulianos, S. Ozaki, F.E. Paige, C. Quigg, J.L. Rosen, J.P. Schiffer, F.J. Sciulli and H.H. Williams.

Two important figures at SLAC have recently retired. Fred Pindar, Associate Director for Business Services, moved

1.

2.



3.

1. Steven Weinberg who has won a Science Writing Award.
2. Felix Bloch when first Director General of CERN.
3. Leon Lederman (busy on his memoirs?).

to SLAC at the beginning of the linac project. Jean Lebacqz, Head of the Klystron Department was the principal designer of the klystrons which have been crucial to the successful operation of the electron linear accelerator.

On 1 October, after four years in office, Cambridge physicist Sir Sam Edwards left the job of Chairman of the Science Research Council (SRC), the UK government agency responsible for planning and funding pure research. His successor is Geoffrey Allen, a chemist.

The Polish Physical Society has awarded its highest scientific distinction for 1977, the Marian Smoluchowski Medal, to Victor F. Weisskopf for his contributions to science.

HEP money in UK

During his four years as Chairman of the SRC, Sir Sam Edwards has had to cope with a chronic cash shortage as a result of the UK government's general cut-backs in public sector spending. Taking inflation into account, the spending power of the SRC's budget shrank by over eight per cent and the impact was especially felt in research areas like high energy physics which take the largest portions of the budget. In the proposed levels of public spending, still further reductions are likely over the next four years. The biggest cut could come in the nuclear (high energy) physics budget, whose slice of the SRC cake could be whittled down from its present 36 per cent to 26 per cent by 1981/2. Physicists W. Burcham and J. Polkinghorne have already spoken out against the further proposed cuts.

Meeting of ICFA

On 31 August the Inter-regional Committee for Future Accelerators (ICFA) met at Hamburg under the Chairmanship of Bernard Gregory. The Committee has been set up under the auspices of the International Union for Pure and Applied Physics (IUPAP) to provide a forum where representatives of the various regions of the world involved in high energy physics can meet to discuss further cooperation in the use of existing and planned facilities and the long-term possibility of collaboration in the construction of a 'Very Big Accelerator (VBA)'. All regions were represented at the Hamburg meeting and it was decided to set up Study Groups to provide ICFA with the basic information that it needs to nurture collaborations. The Committee plans to meet again early next year to draw up a list of topics for the Study Groups to tackle.

Unauthorized autobiography

In the flurry of excitement about the Upsilon discovery, the following 'unauthorized autobiography' appeared in the Fermilab newsletter 'The Village Crier'...

Leon Lederman is one of the oldest, barely active particle physicists seen at Fermilab. He began his career back in 1946 when delivering a telegram to someone in the Pupin Physics building of Columbia University; he got lost in the labyrinth of tunnels and emerged four years later with a Ph. D. He began his research at the Nevis cyclotron and helped invent the first pion beam. He started counting pions in 1951 and when he reached 4722938, two of his graduate students hung themselves, and one was committed.

In 1953 he carried out a brilliantly conceived pion scattering experiment that missed the N resonance. His period of greatest creativity came in 1956 when he heard a lecture by Gell-Man on the possible existence of neutral K mesons. He made two decisions: First, he hyphenated his name. Then he determined to find the neutral K meson. Working at top speed Lede-rman and his group constructed* *an accelerator at Brookhaven and put the cloud chamber in the beam. In 1956 they found the neutral K meson and proved that charge conjugation is conserved in weak decays.*

Flushed with success Lede-rman decided to have an END OF RUN PARTY. Unfortunately, due to a typist's confusion, it came out END OF PARITY RUN and led to the widespread, but mistaken, notion that parity had been violated. This also proved that charge conjugation was not conserved in weak decays. Oh well. Lede-rman was promoted and sent to CERN. There he started the famous g-2 experiment and managed to confuse it so badly it took 26 physicists nineteen years to finish. Incidentally, while at CERN he invented G. Charpak who in turn invented all the detectors currently used in high energy physics.

In 1961 he worked under M. Schwartz and J. Steinberger on neutrinos. He was in charge of finding neutral currents. Schwartz was in charge of finding Lede-rman. In 1968 he invented the di-muon experiment and missed the J/Psi particle. In 1969 Lede-rman invented the high speed digital computer but his ideas were stolen by IBM. Since that time he has resolutely refused to use computers.

In 1972 while at CERN to see what was delaying the g-2 experiment, he was adopted by the reknowned CCR group who were busy discovering high transverse momenta. Lede-rman was put in charge of discovering the J/Psi but failed because he accidently irradiated all the lead glass. In 1974 he gave the main Fermilab dedication address. Fortunately, his words were obscured by an unusual wind. His group then looked for direct leptons and missed the J/Psi. The great success of E-288 experiment owes much to the fact that Lede-rman was very busy on his memoirs during most of the crucial phases of the Upsilon experiment.

Visit to Peking

From 20 to 27 September the CERN Executive Director General, John Adams, and the Leader of the SPS Division, Michael Crowley-Milling visited Peking at the invitation of the Chinese Academy of Sciences to discuss collaboration between the Academy and CERN, in particular in the design and construction of particle accelerators.

This visit is the latest in a sequence of contacts which began in the Summer of 1973 when a delegation from China, headed by Chang Wen-Yu, made an extensive tour of high energy physics Laboratories in the USA, CERN and DESY. There were subsequent reciprocal visits to China, for example by Bob Wilson and Ned Goldwasser from Fermilab, Willi Jentschke, Georges Charpak, Leon Van Hove and Vicki Weisskopf from CERN and Pief Panofsky from SLAC. In the Summer of 1976 a more specialized delegation of Chinese physicists and engineers, led by Tu Tung-Sheng, spent several weeks at CERN in a detailed study of accelerator technology.

During 1974 the Chinese Academy set up a High Energy Physics Institute in Peking with Chang Wen-Yu as Director. There are now about 600 staff with activities in accelerator technology, experimental physics, theory (nuclear structure and field theory), workshops, new technology, computers...

The visit of John Adams and Michael Crowley-Milling was an intense week of lectures, discussions and tours at the High Energy Physics Institute, other Institutes of the Academy (Atomic Energy Institute and Computer Science Institute) and Peking industries.

While they were there, it was officially announced that a model accelerator will be built at the High Energy Physics Institute as a first step

John Adams is greeted by the Chinese Vice-Premier, Teng Hsiao-ping, during the visit to China at the end of September.

towards ultimately achieving a machine which will be at the frontier of research. The model is presently envisaged as a 1 GeV proton ring fed by a 3 MeV linac and a 250 kV Cockroft-Walton pre-injector. Its construction is intended to train accelerator builders, to clarify the capabilities of Chinese industry in component construction and to give experimental physicists some experience of a working machine.

The subsequent step is envisaged as a 5 GeV fast cycling booster fed by a 30 MeV linac and a 250 to 750 kV Cockroft-Walton pre-injector. A 200 GeV Main Ring is then seen as the third step. These plans are tentative and may be modified in the light of the discussions during the visit and in the light of experience in the coming years.

The Chinese science community recognizes that, at present, it is inexperienced in accelerator technology and is keen to learn from the accumulated experience elsewhere. At the same time, they are determined to implement the accelerator construction themselves. It is in this light that discussions about possible collaboration between CERN and the Institute took place.

The visit and the discussions on collaboration happened at a most opportune moment. On 18 September a statement was issued by the Central Committee of the Chinese Communist Party announcing a National Science Conference for the Spring of 1978. The Statement reversed many of the policies of the past ten years with regard to science and technology.

It calls for modernization of science and technology so as to have scientists and technicians of world rank and the most advanced scientific research facilities. It underlines Chairman Mao's principle of 'learning from abroad and creating independently'. These dictums are likely to influence the form of any collaborations which develop.

John Adams and Michael Crowley-Milling returned with memories of the warmth of the reception they received, of the openess of all the discussions and of the eagerness of the Chinese scientists to make their mark in our field of research as quickly as possible. It looks as if we can welcome new colleagues to the international community of high energy physics. The contacts which have begun so well are likely to become more frequent and fruitful in the future.

The official photograph of the meeting with the Chinese Vice-Premier Teng Hsiao-ping. On the back row on the left is Pan Hui-pao (Engineer at the High Energy Physics Institute), fourth from the left is Li Yi (Leading member of the Institute) and fifth Yen Hung-mo (Leading member of the Academy of Sciences). On the front row second from the left is Chang Wen-yu (Director of the Institute), third is Michael Crowley-Milling (Leader of the CERN SPS Division), fourth Li Chang (Leading member of the Academy), fifth John Adams (Executive Director General of CERN), sixth is Teng Hsiao-ping, seventh is Mrs. Rene Adams, ninth is Tsien San-chiang (Deputy Secretary General of the Academy).

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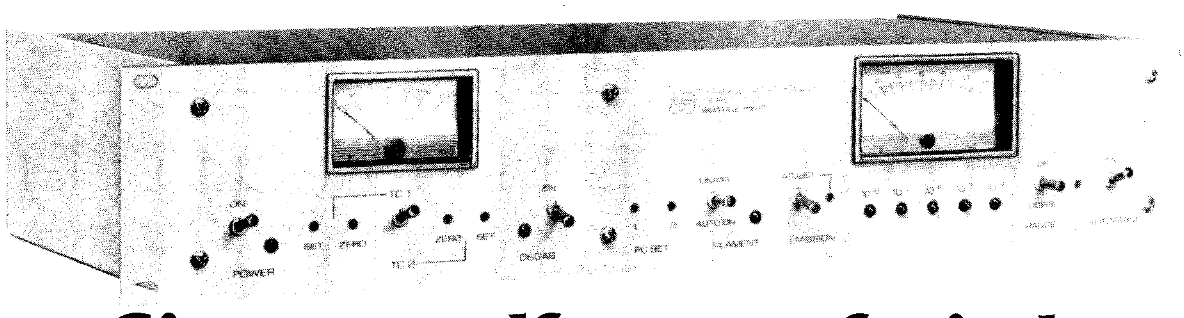

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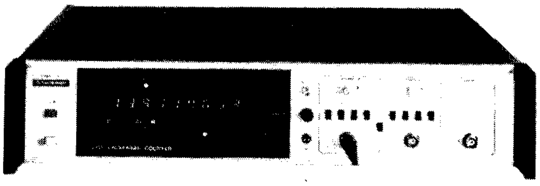

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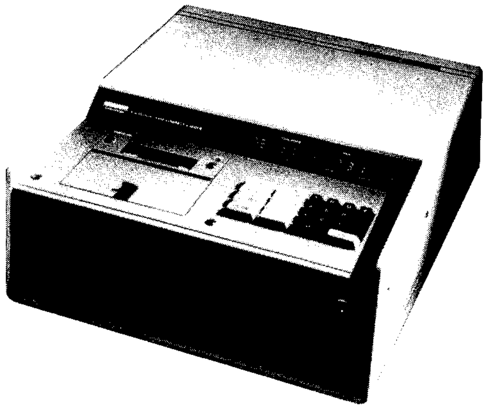

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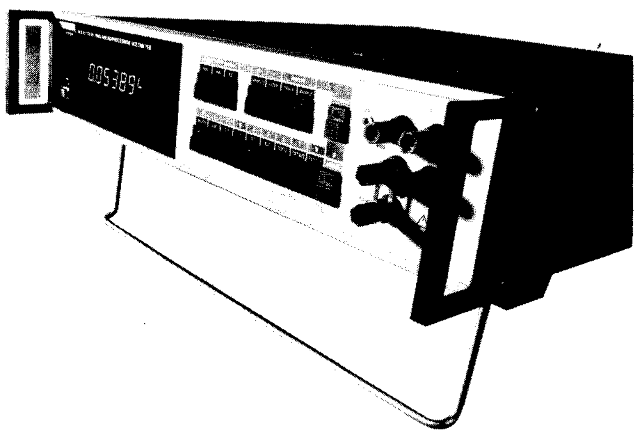

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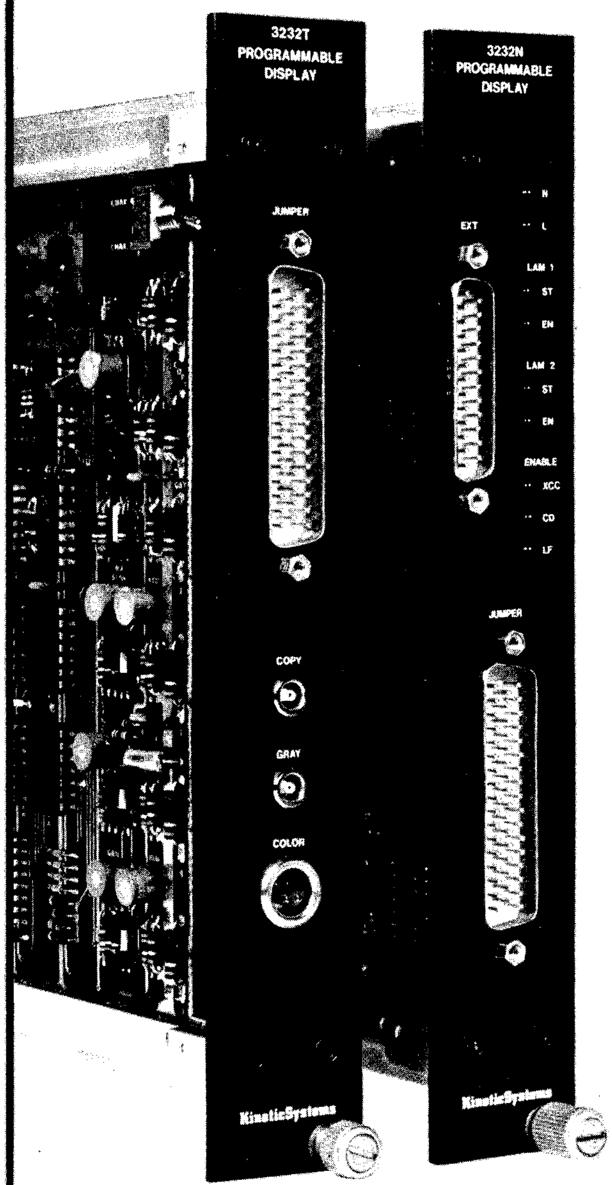

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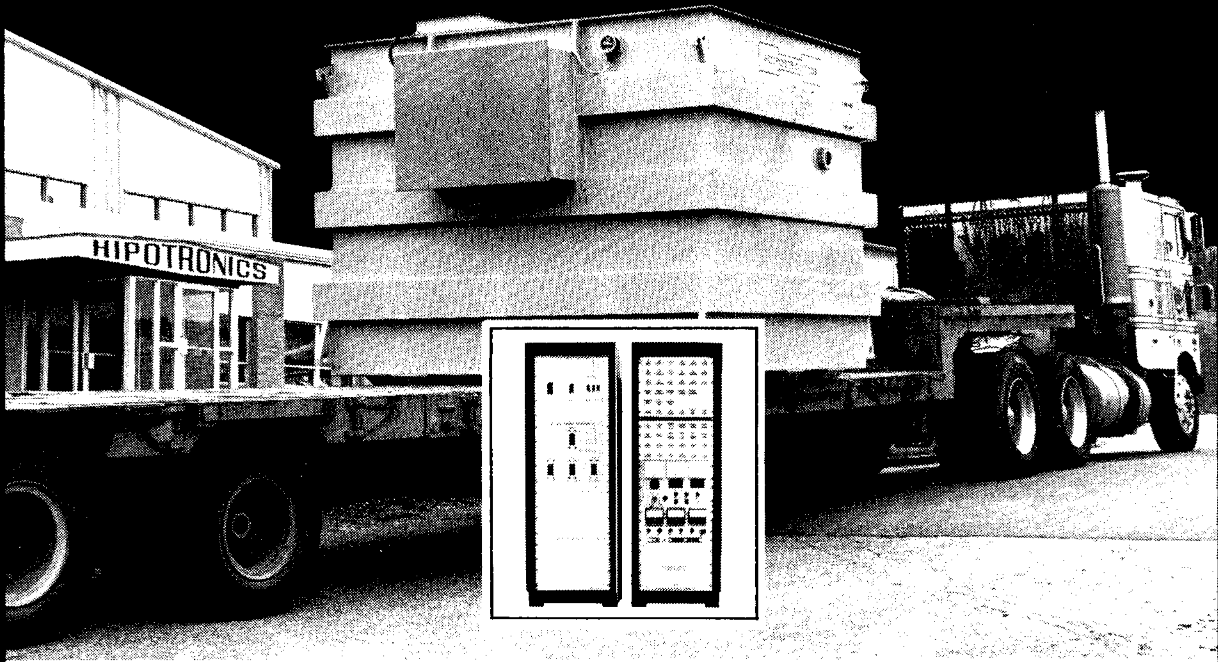

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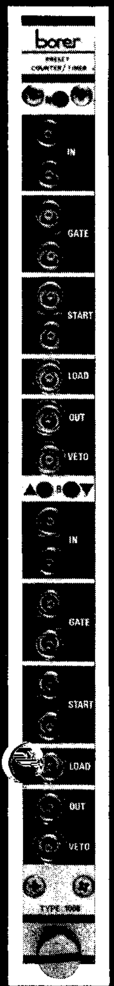

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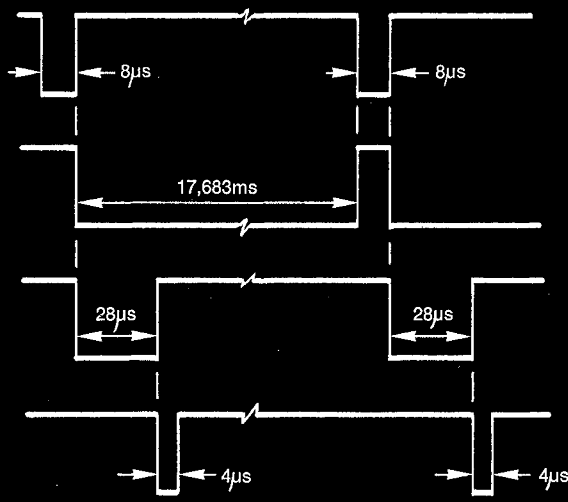

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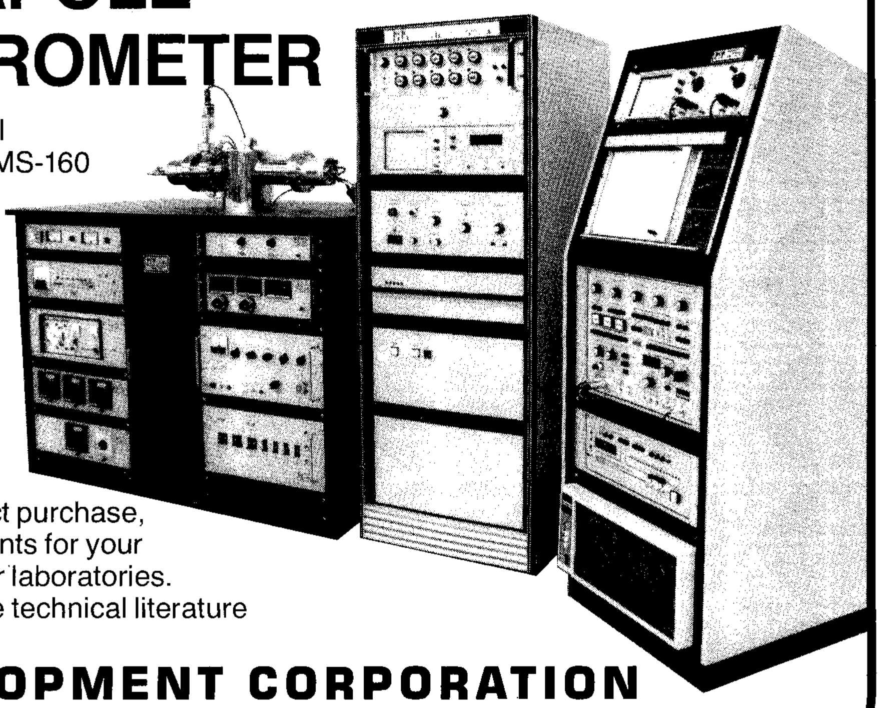

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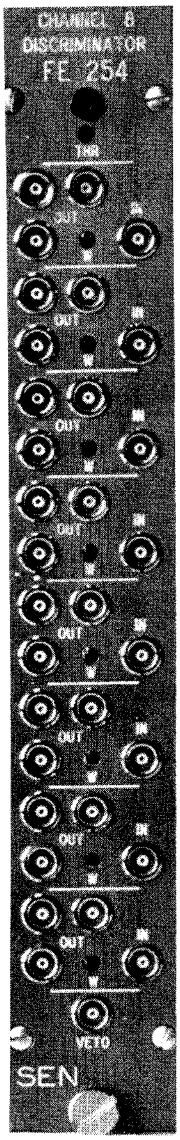

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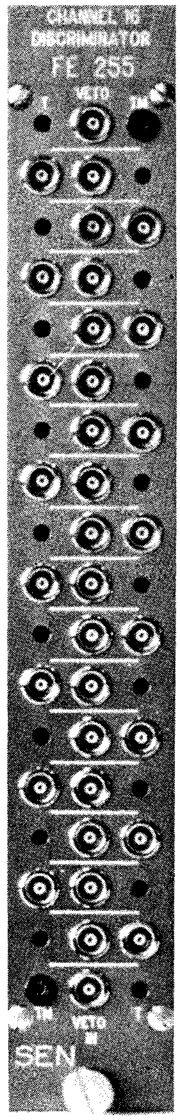
- eccellent sharpness, even at < 30mV threshold

input	:	1 per channel
threshold	:	from ⩽ 30mV to - 1V common for 8 channels screwdriver adjustable
threshold monitor	:	10 x threshold, accuracy ± 1%
output	:	3 per channel (FD 254) 1 per channel, driving one or two outputs using the LEMO FY/00-250 new adapter. (FD 255)
width	:	from ⩽ 5ns to > 40ns screwdriver adjustable rise time : < 2ns fall time : < 2ns (2 outputs loaded)
fast veto	:	1 per 8 channel zero dead-time
double pulse resolution	:	< 10ns
max. freq.	:	100 MHz (200MHz input)
I/O delay	:	⩽ 15ns
time slewing	:	< 1ns for 10% to 100% overdrive



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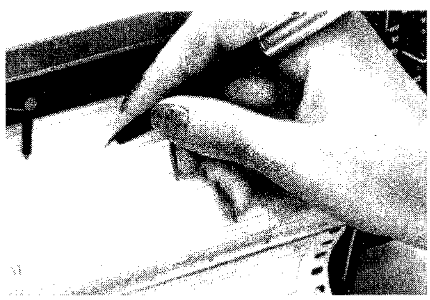

A convenient, projecting writing table also supports the hand while making notes on the graph paper.

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- *250 mm effective chart width*
- *12 calibrated input ranges from 10 mV to 50 V fsd, or variable from 3 mV to 50 V fsd*
- *Accuracy: better than 0.5%*
- *Step response: 0.6 s*
- *Chart speeds from 0.5 cm/min to 30 cm/min*

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- *Accuracy: better than 0.5%*
- *Step response: 0.25 s*
- *Chart speeds from 3 cm/h to 6000 cm/h*
- *Options for temperature recording, remote control and retransmitting.*

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