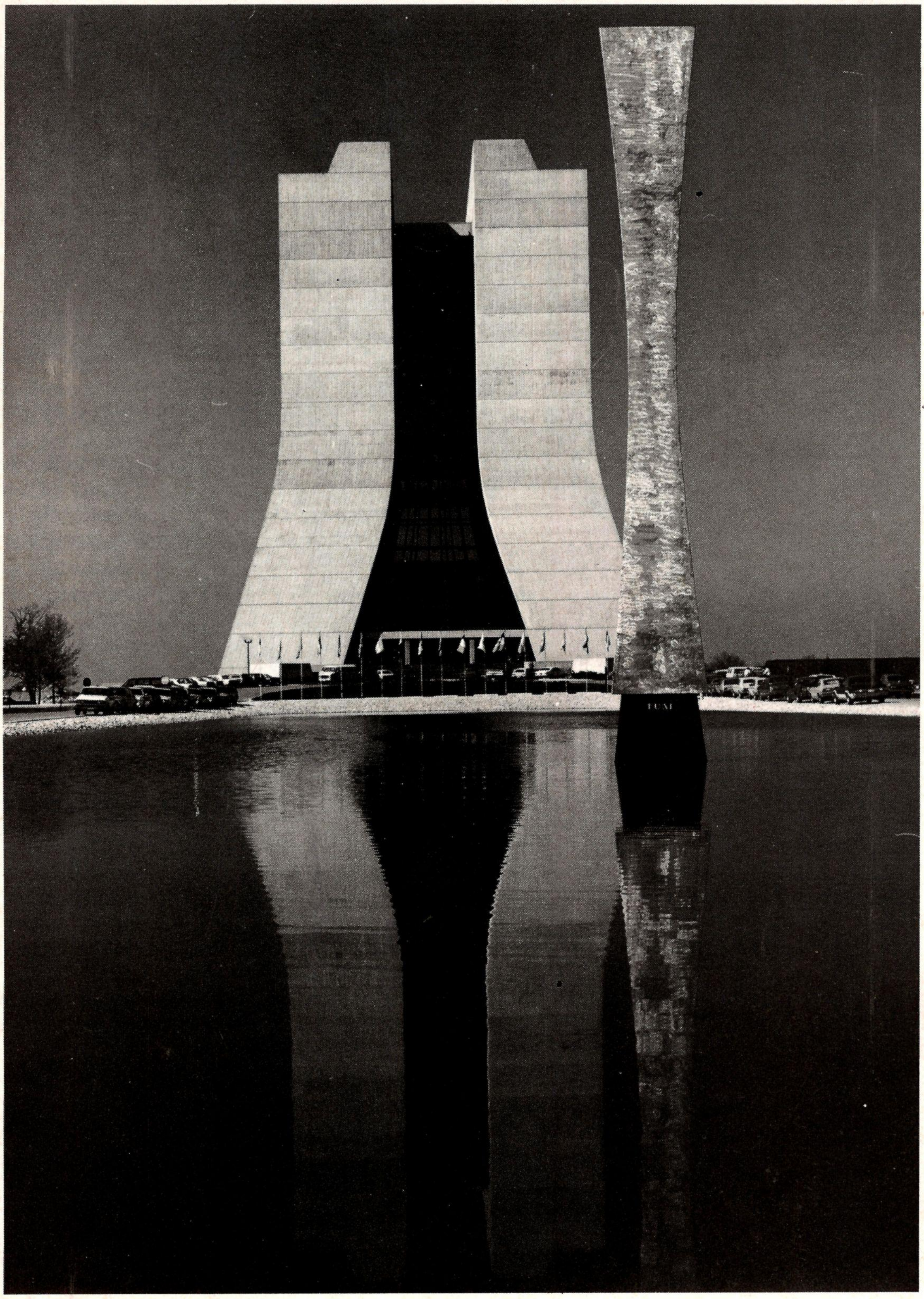
CERN COURIER

NO. 6 VOL. 18 JUNE 1978



CERN COURIER
Journal of High Energy Physics
Editors: Brian Southworth
Henri-Luc Felder
Gordon Fraser
Advertisements: Micheline Falciola

Laboratory correspondents:
Argonne National Laboratory, USA
Ch. E.W.Ward
Brookhaven National Laboratory, USA
P. Wanderer
Cornell University, USA
N. Mistry
Daresbury Laboratory, UK
V. Suller
DESY Laboratory, Fed. Rep. of Germany
D. von der Ropp
Fermi National Accelerator Laboratory, USA
R.A. Carrigan
KfK Karlsruhe, Fed. Rep. of Germany
F. Arendt
GSI Darmstadt, Fed. Rep. of Germany
H. Prange
INFN, Italy
M. Gigliarelli Fiumi
Institute of High Energy Physics, Peking
Tu Tung-sheng
JINR Dubna, USSR
V.A. Biryukov
KEK National Laboratory, Japan
K. Kikuchi
Lawrence Berkeley Laboratory, USA
W. Carithers
Los Alamos Scientific Laboratory, USA
O.B. van Dyck
Novosibirsk Institute, USSR
V. Balakin
Orsay Laboratory, France
J.E. Augustin
Rutherford Laboratory, UK
J. Litt
Saclay Laboratory, France
A. Zylberstejn
SIN Villigen, Switzerland
G.H. Eaton
Stanford Linear Accelerator Center, USA
L. Keller
TRIUMF Laboratory, Canada
M.K. Craddock

Copies are available on request from:
Federal Republic of Germany —
Frau I. Schuetz
DESY, Notkestieg 1, 2 Hamburg 52
Italy —
INFN, Casella Postale 56,
00044 Frascati,
Roma
United Kingdom —
Elizabeth Marsh
Rutherford Laboratory, Chilton, Didcot
Oxfordshire OX11 0QX
USA/Canada —
Margaret Pearson
Fermilab, PO Box 500, Batavia
Illinois 60510
General distribution —
Marie-Jeanne Blazianu
CERN 1211 Geneva 23, Switzerland

CERN COURIER is published ten times yearly in English and French editions. The views expressed in the Journal are not necessarily those of the CERN management.

Printed by: Cherix et Filanosa SA,
1260 Nyon, Switzerland
Merrill Printing Company
765 North York, Hinsdale,
Illinois 60521, USA

Published by:
European Organization for Nuclear Research
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 41 03, Telex 23698
USA: Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510
Tel. (312) 840 3000, Telex 910 230 3233

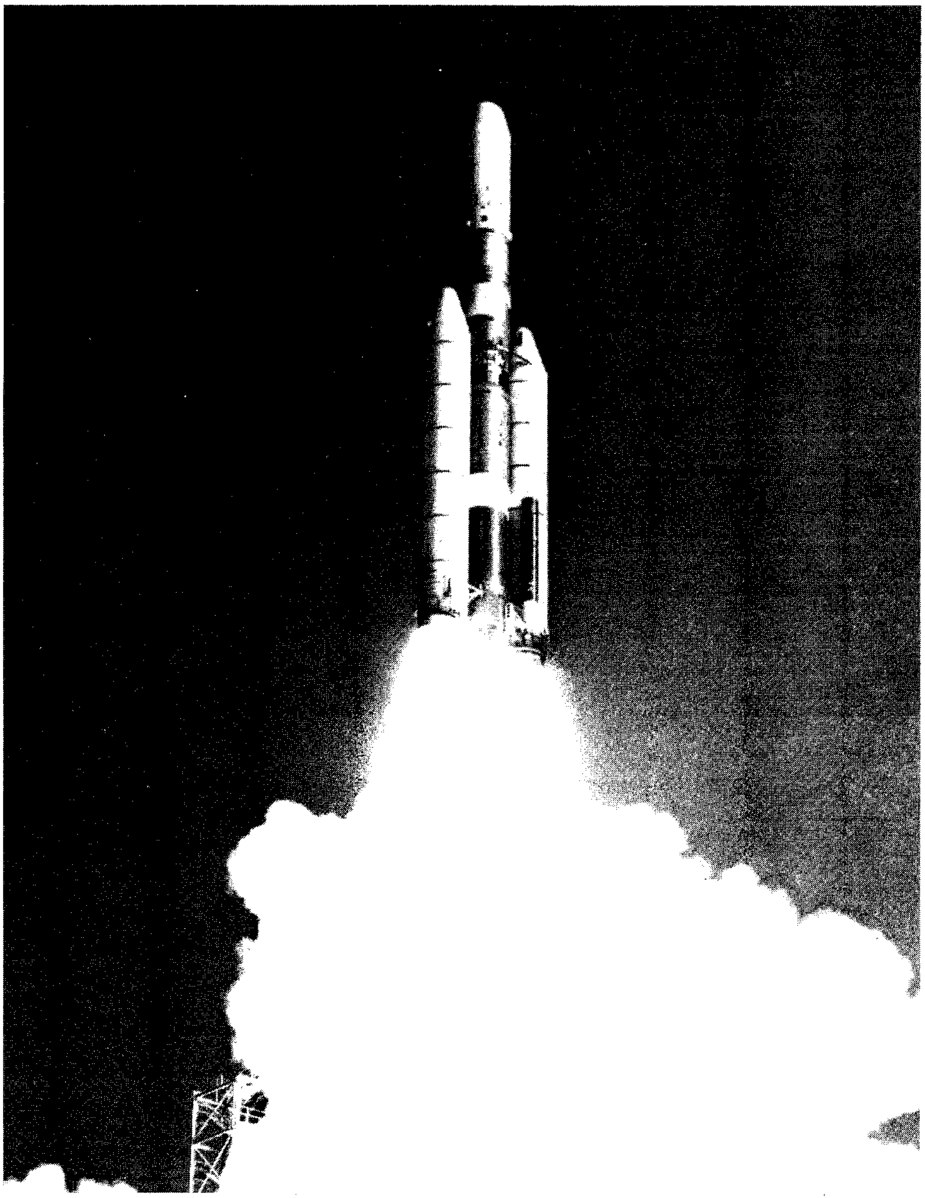
Contents

Cover photograph: A new metal sculpture, a hyperbolic obelisk 10 m high, by R.R. Wilson has been installed in the reflecting pond in front of the 'hirise' building at Fermilab. Bob Wilson produced the sculpture after an apprenticeship in welding in the Fermilab machine shop. He has entitled the work 'Acqua alle funi' (Water to the ropes) after the obelisk erecting incident at the Vatican in the 16th century. (Photo Fermilab)

Lift-off for STELLA

Lift-off from Cape Kennedy. On 1 May, a modified Thor-Delta rocket launched the new European communications satellite OTS-2, which will be used in experiments on high-speed data transmission between Laboratories.

(Photo US International Communication Agency)



After an ill-fated first attempt last September when the launch rocket had to be destroyed soon after blast-off, the successful launching on 8 May from Cape Kennedy, Florida, of the European Space Agency's new Orbital Test Satellite (OTS) marks the beginning of an important new data communications project. The project (first mentioned in the September 1977 issue, page 292) involves European high energy physics Laboratories. For the first time, it will test the techniques involved in moving data accurately over large distances at very high speeds. The experience which it will provide could have a significant impact on working methods for high energy physics and for other mass-producers of data in Europe.

Called STELLA — Satellite Transmission Experiment Linking LAboratories — the new project is a collaboration between the European Space Agency (ESA), the European Economic Community (EEC), CERN, Rutherford Laboratory in the UK, DESY in Germany, Saclay in France and Pisa in Italy, together with the Post and Telegraph (PTT) authorities in the respective countries. It is receiving financial support from ESA, the EEC and the national PTTs.

The project has been promoted and coordinated at CERN by Mervyn Hine. If it succeeds, it will ensure that Europe is not left behind in this technology which has already been supported by considerable investment in the USA. The participation of the national PTTs in the project means that the benefits should be quickly realized in general communication systems.

The objectives of the exercise are manyfold. ESA can explore the potential of satellites for multipoint high speed data links. The EEC can gain valuable experience for the development of European data transmission projects. The participating Laboratories can evaluate the use of such links to improve the operation and management of high energy physics experiments.

In the project itself, ESA is providing the communications satellite and expertise in the design of ground transmitting and receiving stations at the participating Laboratories. The EEC is contributing funds mainly for the ground station and other equipment at CERN, while the national authorities are providing equipment for their respective participating Laboratories.

The increasing size and scope of high energy physics experiments together with the increase in manpower required for each experiment and the growing sophistication of experimental techniques, have added to the difficulties of planning and managing the research. At CERN, additional complications arise because of the extent of international collaboration, where the accumulated data has to be shared out between physicists whose home institutes are often hundreds of miles apart in different countries.

The bulk of the experimental data at present has to be sent to scientists' home Institutes by mail or by courier for processing and analysis on their home computers (possibly after copying to allow full sharing of data between participants). On the other hand, the necessary rapid analysis of small data samples to check the progress of the experiment can, today, only be done at the accelerator Laboratory, whose computers are not necessarily compatible with those at the home Institutes.

The extra costs in using and programming computers at the central Laboratory as well as those at home Institutes, together with the delays resulting from this primitive form of data 'communications' add to the overhead of experiments in terms of time, manpower and money. The hope is that they could be reduced significantly using high speed communications by satellite, once the necessary techniques and expertise have been developed and perfected.

The aim is to be able to transmit data from CERN to the distant computer centres at speeds comparable to the processing speeds of the computers (about 10 Megabits per second) and at extremely low error rates. In this way the power of the home computers is added to those at CERN and the home Institutes have a degree of remote control over the running of an experiment. Satellite communications also offer the possibility of sending data to several receiving stations simultaneously at no extra cost and of allowing interconnection between pairs of stations.

However, this is still a relatively unexplored field and one major objective of the STELLA project is to evaluate the potential of existing equipment using the 11-14 GHz frequency band.

Once the necessary techniques have been perfected, the full implications of the scheme can be assessed. Many factors in the management of experiments could be influenced, including:

— the design and cost of data handling systems for experiments
— the requirement for computing power and computer expertise at the accelerator Laboratory where the experiments are carried out
— the balance of manpower between the accelerator Laboratory and scientists' home Institutes
— the sharing of computer resources between Institutes
— the general efficiency of large-scale collaboration in a big experiment.

After operational tests of the OTS satellite, 1979 should see the installation of earth transmitting and receiving stations at the participating Laboratories and the first satellite links established. Regular operation of the scheme would come later, in 1980-1981. Only then could final conclusions be drawn as to the value and potential of these far-sighted new communications schemes.

Parity

Although confirmation has yet to come from other Laboratories working on the same problem, experiments at Novosibirsk seem to have detected a tiny atomic physics effect due to the neutral weak current interaction between nuclei and orbital electrons. Its observed magnitude agrees with the standard theory.

The effect measured at Novosibirsk is due to the parity-violating component of the neutral weak current, and, as well as being the first evidence of the neutral current outside of experiments at accelerators, is also the first sign of parity violation in neutral current interactions. That this observed parity violation is as predicted by the theory is a great success for the standard 'Weinberg-Salam' model of weak and electromagnetic interactions, as well as being a tribute to the ingenuity of the Novosibirsk experimenters in carrying out such delicate measurements.

Parity violation — the non-existence of a universal right-left symmetry — has been seen in charged current interactions for some 25 years and the theory says that a similar right-left asymmetry should also show up in neutral current interactions. In the absence of experimental evidence for such parity violation, many theorists tinkered with the original model to produce a framework which required a smaller level of parity violation in neutral current interactions. However, this can usually only be done at the expense of introducing extra parameters; a theory with a minimum of input in the form of unknown parameters is always more attractive.

The Novosibirsk experimenters looked at the rotation of the direction of polarization of light passing through bismuth vapour. Similar experiments have been carried out at the Universities of Oxford and Washington (see May 1977 issue, page 156) but, so far, have not detected comparable levels of parity violation.

violation and neutral currents

*At a press conference on June 10, SLAC announced the observation of parity violating effects in neutral current interactions which agree with the standard theory. More details in the next issue.

The idea of these experiments is that in a heavy atom like bismuth, atomic electrons can be close enough to the nucleus to be affected by the weak neutral current. Any parity-violating component in this interaction would affect the polarization of a beam of laser light passed through the bismuth vapour.

One big problem has been that difficult calculations are required to quantify the effect of nuclear mechanisms on the orbital electrons. The results of these calculations, which include complicated screening effects, have been constantly on the move, making it difficult to draw definite conclusions. However, the detected rotation of the plane of polarization in the Soviet experiment averages about 7×10^{-8} radians, which agrees with the predictions of the Weinberg-Salam model to within 25 per cent. This microscopic angle of rotation is roughly equivalent to the width of a needle seen from five miles away!

This agreement is good news for the Weinberg-Salam model but it is not the end of the story. Other Laboratories are still looking at this minute effect, some using atoms whose structure is much easier to handle than that of bismuth. The problem is also being attacked directly in electron-nucleus collision experiments at SLAC. While the atomic physicists strive to perfect both their experimental techniques and their calculations, it might require this additional evidence from free particle interactions at accelerators before the situation can be resolved. The results from SLAC are therefore eagerly awaited.*

Until this problem of parity violation in neutral current interactions is finally resolved, the theory of weak interactions is still on uncertain ground, and progress is difficult.

From dream to reality, almost

Addressing the Nobel symposium at Lerum, near Göteborg in Sweden in 1968, Abdus Salam spoke of the 'dream' of unifying weak and electromagnetic interactions in a single theory. Apart from the aesthetic appeal of having one single theory instead of two separate ones, Salam pointed out that there are a number of clues which point towards such a unification. Both weak and electromagnetic interactions affect leptons and hadrons; both are 'vector' interactions involving exchange of quantities with unit spin and negative parity; both have their own universal coupling constant.

Salam was certainly not the first to dream of such a unification. Quite apart from the attempts of Einstein and other general relativists to achieve a grand unification of all fields of force, Enrico Fermi had proposed a synthesis of weak and electromagnetic forces back in 1934. By 1961, theoreticians such as Sheldon Glashow were putting forward detailed models. These came to rely on 'spontaneous symmetry breaking' in which degrees of freedom are 'frozen' out of a theory in much the same way as the formation of ice crystals destroys the symmetry properties of water.

There were two big obstacles in the path of this unified theory. The first was the embarrassing proliferation of unwanted massless 'Goldstone bosons' in such theories. The way around this obstacle was provided by the so-called 'Higgs mechanism' in which gauge particles acquire mass and can be identified with the intermediate bosons which bring about the weak interactions. It was Weinberg and Salam who, working independently, showed how this idea could be exploited to produce a unified theory of weak and electromagnetic interactions which was hopefully free of 'unphysical' particles.

The second big obstacle was the lack of a method to handle calculations. The way around this obstacle was provided by Gerard 't Hooft, who demonstrated how calculations could be handled in a consistent way. The development of these theoretical techniques has been described at length in a previous article (see September 1977 issue, page 271).

In the Weinberg-Salam formulation, the neutrino and its appropriate lepton (electron or muon) are put together into a doublet of 'left-handed' particles which appear to spin anticlockwise when viewed from behind (the neutrino only exists as such a left-handed particle), while the right-handed component of the lepton remains as a separate singlet. In this way, leptons and neutrinos can be linked together in a framework which describes both their weak and electromagnetic interactions.

One important consequence of this synthesis is the neutral current of weak interactions, which co-exists with the more well-known charged current responsible for beta decay and other conventional weak interaction effects. The discovery of this neutral current at Gargamelle in 1973 provided impressive evidence for the Weinberg-Salam theory and since then further supporting evidence has accumulated steadily.

However, the recent results from Gargamelle on high energy electron-neutrino scattering (see May issue, page 151) indicate that leptonic weak interactions do not behave according to the basic set of Weinberg-Salam rules. To explain the results, new intermediate vector bosons and new currents, could be introduced. Another idea involves bringing in a new right-handed lepton to join the right-handed component of the electron forming another doublet. Such a new right-handed lepton would have to be heavy,

Around the Laboratories

otherwise it should have revealed itself by now in experiments.

The charged and neutral intermediate vector bosons held to be responsible for weak interactions are among the experimental fruits expected from the next generation of colliding beam machines. However, even if these particles are found, the unified gauge theory of weak and electromagnetic interactions would still stand on uncertain ground. The real proof would come from the discovery of the Higgs particle, or other similar mechanism, which lies at the heart of the symmetry breaking effects.

DESY
The upsilon at DORIS

As was briefly announced in the May issue, upsilons have been seen at DORIS. DESY physicist Tom Walsh followed the developments and wrote the following notes on how this important result was achieved:

The DESY storage rings, DORIS, started life as a double ring multibunch electron-positron machine. Electrons and positrons were segregated in different rings (one stacked on top of the other) and collided at two points where the beams crossed at a small vertical angle. In this form, DORIS contributed greatly to the exciting physics of the past four years. It discovered charmonium states and the strange and charmed F^+ (2060) meson, and added decisive evidence for the existence of the new tau heavy lepton with a precise determination of its mass. But in this multibunch mode, the maximum energy of DORIS was limited.

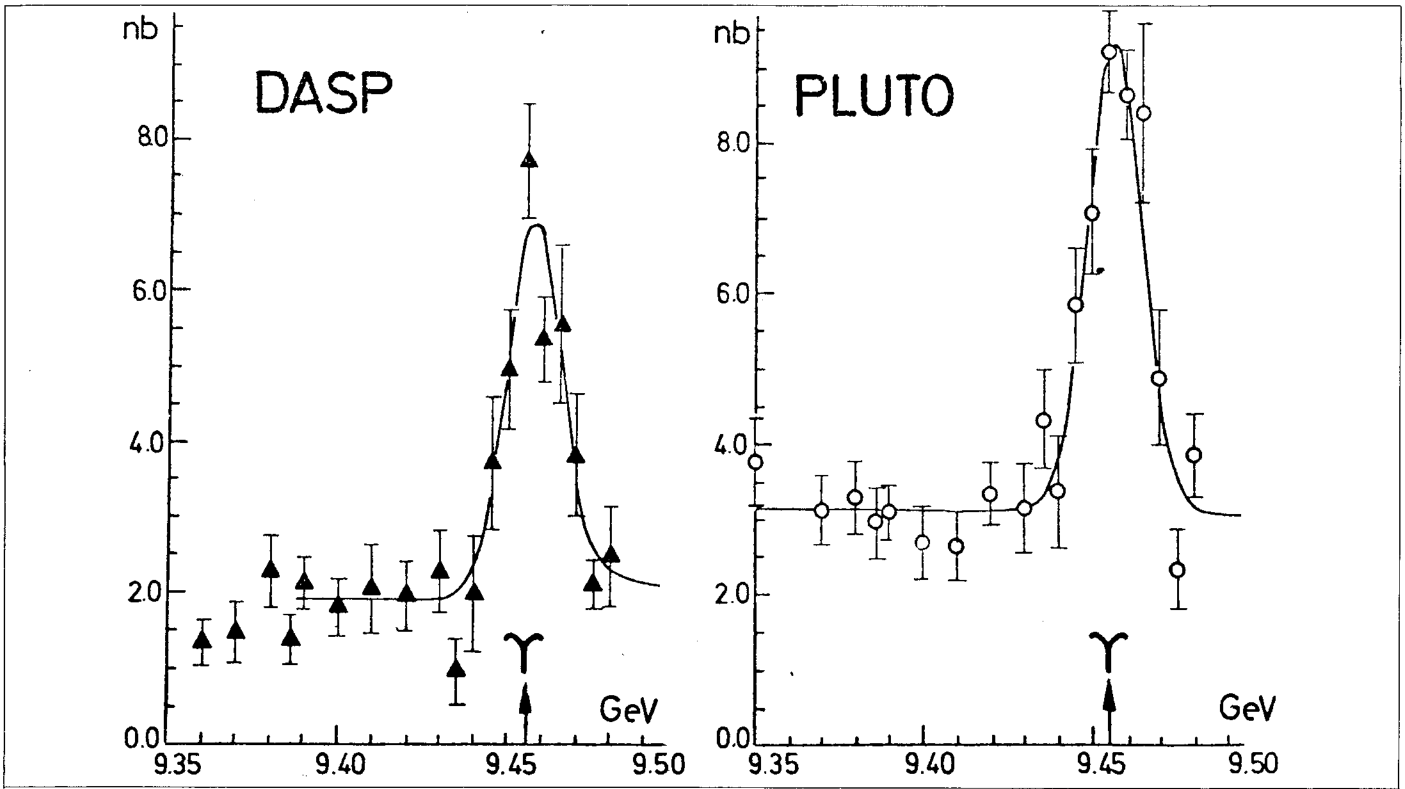
DORIS is now a single ring machine with one bunch of electrons and one bunch of positrons circulating in the upper of the two vacuum chambers. In this reincarnation DORIS saw the upsilon (9460) as a narrow resonance in electron-positron annihilation into hadrons. The upsilon was seen by two groups - one (a newly formed collaboration of physicists from DESY / Dortmund / Heidelberg / Lund) using the detector built by the original DASP collaboration and the other (the PLUTO collaboration) using the PLUTO detector.

The two groups established the mass of the upsilon to be 9460 $\pm$ 10 MeV and its width for decay into electron-positron pairs to be 1.3$\pm$ 0.4 keV which is about one fourth of the width for J/psi decay to electron-positron pairs. This favours the view of the upsilon as a bound state of a new quark and antiquark of charge 1/3. In

The finding of the upsilon luckily coincided with the official visit at DESY of Bundespräsident Walter Scheel. From left to right: Herwig Schopper (Director of DESY), Walter Scheel, Dieter Biallas 2nd Mayor of the City of Hamburg, Gus Voss (member of the DESY Directorate leading the PETRA project) touring the Laboratory.

(Photo DESY)

The rate for particle production at different centre-of-mass energies in the DORIS storage ring at DESY, as seen by the two detectors DASP and PLUTO. The enhancement at the upsilon mass is found exactly at the same position by both groups. The absolute height of the curves comes from the detector geometry and the event selection criteria.



addition, the PLUTO collaboration has convincing evidence at these energies that the hadronic final state in one photon, electron-positron annihilation off resonance consists predominantly of two back-to-back jets.

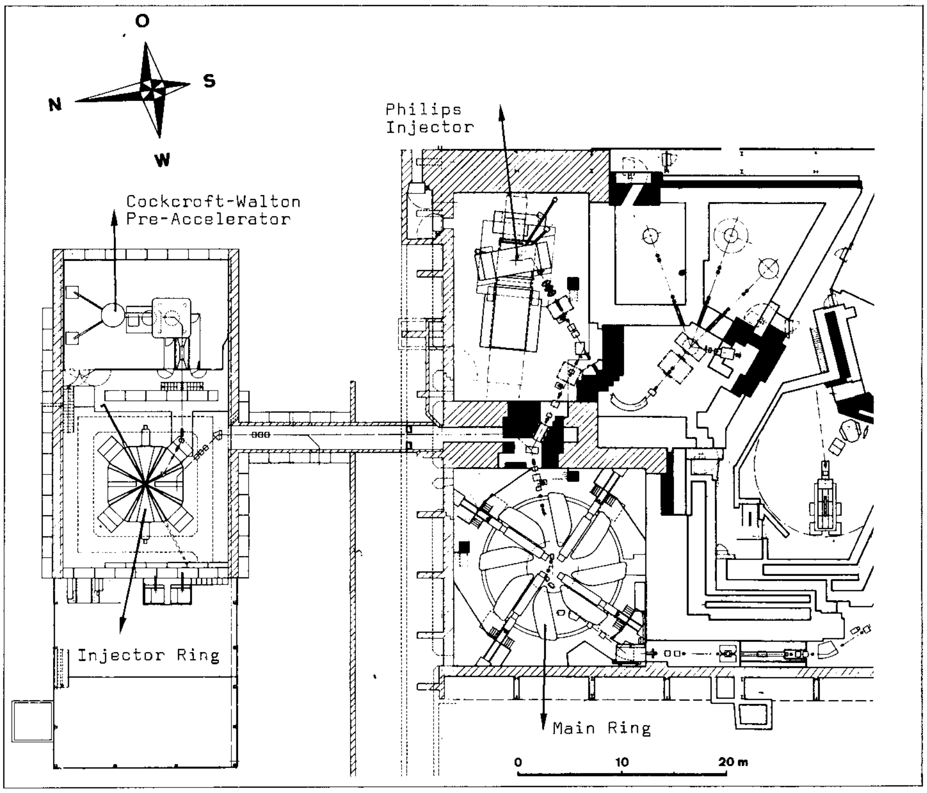
The decision to convert DORIS to single ring operation was made about a year ago when upsilon was found in proton-nucleon collisions. The conversion was not easy since at the maximum energy, DORIS' magnets are 10% into saturation and non-linearities have to be taken into account. Even now, each filling (every 2 to 3 hours) requires the magnets to be run through a full hysteresis loop (up to 5 GeV, down to 500 MeV and then up to injection energy). The injection 'window' is small at high energy, requiring carefully coordinated efforts of the DORIS and the DESY synchrotron groups. A small undetected drift of some component can still cause an occasional failed injection.

Providence allowed the chromaticity of the machine to be controlled by the old sextupoles and another piece of good fortune was the availability of PETRA r.f. cavities (6 now, 8 after June). Without these, operation at upsilon energies would not have been possible. A new feedback system was built to damp coherent beam oscillations and works well. After learning how to improve control of the closed orbit distortions, stable running conditions at 9.2 GeV centre of mass energy were attained for experimental shifts on 10 April. This was the date promised months earlier by the machine group led by D. Degèle.

The scan for upsilon began after a period of running at 9.2 GeV and was only briefly interrupted by minor machine mishaps. On April 22-23 there was some evidence for a signal at 9.41 GeV but it was a false alarm. On the last week-end in April the DASP 2 and PLUTO collaborations found upsilon (9460). To date about 200 nb^{-1} integrated luminosity has been collected on resonance and the same amount off resonance. This corresponds to a sample of about 1500 to 2000 upsilon decays. For PLUTO in particular, the upsilon sighting is an achievement. As well as contending with the new DORIS energies, PLUTO was scheduled to be moved in May to its new position in the PETRA electron-positron colliding beam machine, which is now nearing completion. The search for upsilon at PLUTO was therefore a race against time.

The two groups have submitted their first publications and continue to analyse data. PLUTO has now left DORIS for PETRA (soon to follow as the highest energy electron-positron machine). The DASP 2 group continues together with a new group (DESY / Heidelberg / Munich / Erlangen) in the old PLUTO zone. Hopes are high that DORIS can be coaxed over 5 GeV to reach upsilon prime. The attempt begins in July.

Much excitement surrounds the experimental study of upsilon decay. The new colour gauge theories of the strong interactions imply decays into three gluons (elementary vector gauge quanta). If these gluons evolve into jets as do quarks, a fraction of upsilon decays should involve three jets. (Two of the three jets are sometimes expected to be close in angle, giving an apparent two jet structure.) If three jets are seen and if angular distributions support the spin one assignment for the gluons, these would be established as elementary constituents on the same level as the quarks. If the three jet search is inconclusive, it can be repeated at the next quark-antiquark bound state confidently expected at PETRA.



Plan view of the new two stage injector (on the left) to be built at SIN together with part of the main experimental hall and accelerators. A Cockcroft-Walton pre-accelerator feeds a 0.8 MeV beam line which crosses a sector magnet 3 m above the mid-plane of a new 72 MeV injector ring cyclotron entering the centre of the machine vertically. The new injector will be installed in a separate building to be erected north of the present experimental hall. The extracted proton beam will partially use the present beam line for injection into the 590 MeV Main Ring.

SIN
New injector cyclotron approved

Construction of a new injector cyclotron for SIN received final approval by the Swiss Parliament on 28 February. This new machine, which has been under study since 1972, will provide at least 1 mA of protons for injection into the main ring accelerator and is expected to be operational by 1982. It will be constructed by SIN.

The present accelerator system consists of two isochronous cyclotrons. A small Philips accelerator is normally used for nine weeks in every eleven as injector for the main ring accelerator. For the other two weeks it provides a variety of beams for low energy physics research in separate experimental areas and, during this time, about 85 % of the financial investment (namely the main ring cyclotron and all the high energy beams and experimental equipment) cannot be used.

Another consideration is that the present injector cannot provide extracted proton currents above 100 μA. The injector is designed as a multiparticle machine and as such its mechanical system is very complex. Maintenance and repair work in the future will become extremely difficult because of the activation levels generated by the beam losses during extraction.

Over the last few years the ring machine has proved very reliable. It has also been found that, given a sufficiently high quality injected beam, extraction from the ring can be virtually complete (over 99 %). Therefore, with increased r.f. power and flat-top acceleration, beam currents above 1 mA could be used without inducing an intolerable level of radioactivity. The theoretical limit of the ring is believed to be 2 to 4 mA.

Starting from the 590 MeV ring requirements, the following design goals for a new 72 MeV injector were established: average beam current about 1 mA, energy spread below 150 keV, pulse repetition rate of 50.7 MHz, pulse width of about 20° (r.f.) and axial and radial beam quality of 2π mm mrad.

The protons will be accelerated in two stages. The first is a d.c. accelerator of the Cockcroft-Walton type with an energy of about 0.8 MeV. The ion source and the accelerating column are key elements in achieving high currents of good quality. In order to study the general performance of these components, a development programme has started with special emphasis on space charge effects. The second stage is an isochronous cyclotron with the unique property of a large ratio of extraction energy to injection energy.

The new machine employs many ideas of the 590 MeV ring and is similar in size. It consists of four magnets with a magnetic field of 1 T and an azimuthal width of 28°. The weight of each magnet is approximately 180 t. The accelerating frequency is 50.7 MHz (as for the big machine) and the harmonic number is 10.

The 0.8 MeV d.c. beam of protons from the pre-accelerator is guided towards the centre of the ring cyclotron and injected on a quasi-equilibrium orbit by a magnetic cone in the gap of one sector magnet.

Two different r.f. systems with a total of four resonators are used. The acceleration is achieved by two Delta-type half wavelength cavities operating at peak voltages of 100 to 250 kV from injection to extraction radius. Maximum energy gain per turn varies from 400 keV to 1 MeV. Flat-topping is achieved with two separate cavities operating at 152 MHz situated 90° apart from the main cavities, superimposing a third harmonic oscillation on the fundamental accelerating voltage. A turn separation of 2 cm at extraction radius allows an extraction efficiency of 100%.

No sizable modification in the experimental hall will be needed for currents up to 400 to 500 μA but above these intensities, the beam lines and associated equipment will have to be extensively modified. This is under study and is closely connected with considerations about setting up a spallation neutron source at SIN. A discussion meeting on this subject was held on 14 April and a great deal of enthusiasm for the idea was expressed by solid state physicists, chemists and biologists who would eventually use such a facility.

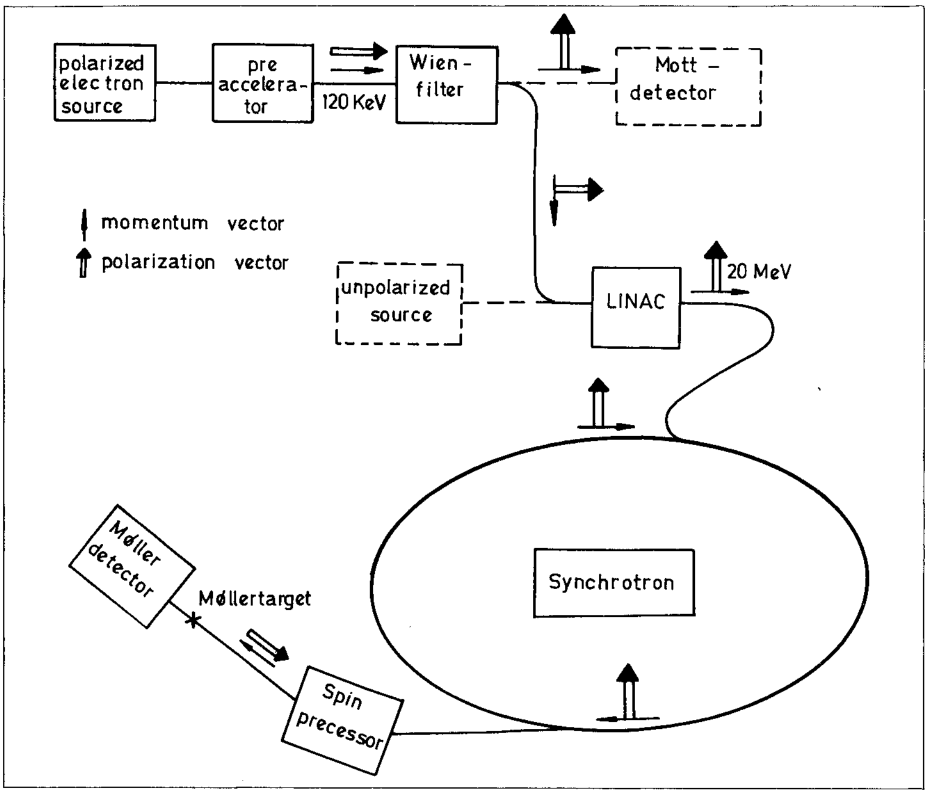
BONN
Acceleration of polarized electrons

In the course of improvements to the 2.5 GeV electron synchrotron at Bonn University, polarized electrons have been accelerated. It is the first time that this has ever been achieved in an electron synchrotron. Previously, polarized electrons have been moved across resonances in the VEPP storage rings in Novosibirsk but not accelerated in a synchrotron.

The polarized electron source developed at Bonn, is a pulsed source with high intensity and repetition rate. It employs the Fano effect on alkali of rubidium — by ionizing unpolarized alkali atoms with circularly polarized light of the appropriate wavelength (UV-region) photoelectrons can be produced with a high level of polarization. A quadrupled Nd-YAG laser (1064 to 266 nm) with a repetition rate of 50 Hz is used as an intense light source and a quarter-wave plate converts the polarization from linear to circular. This polarized light pulse interacts with an array of rubidium atomic beams to give 2 × 10^9 electrons / pulse within a pulse length of 20 ns and with a polarization of 65%.

The extracted photoelectrons are polarized longitudinally. Reversing the sense of the circular polarization of the light also reverses the longitudinal polarization of the electrons. This is done regularly by rotating the quarter-wave plate (from pulse to pulse) in order to avoid systematic asymmetries.

After accelerating the extracted electrons to 120 keV, the polarization vector is rotated from longitudinal to transverse by a Wien filter. A switch magnet makes it possible to direct the



Schematic diagram of the various stages in the acceleration of polarized electrons in the Bonn synchrotron. It is the first time such acceleration has been achieved in a synchrotron with electrons.

electrons either to a Mott scattering detector for polarization measurements or to the linac for further acceleration. The beam transport system between the switch and the linac can adjust the direction of the polarization vector parallel to the guide field of the synchrotron.

During acceleration in the synchrotron the electrons may be depolarized by two different resonance effects. Depolarization occurs if the Thomas frequency of the electrons is an integer multiple of either the cyclotron or betatron frequencies. In the first case, the energies of the respective resonances are multiples of 0.44 GeV independent of the machine optics. The second type of depolarization resonances depends in energy on the working point chosen. At Bonn one energy for such a depolarization resonance is 1.5 GeV. For the first test, the synchrotron was run to 0.85 GeV (above 0.44 GeV, just below 0.88 GeV and well below 1.5 GeV). The troublesome resonance energy could be passed through quickly to limit the decrease of the polarization.

The polarization of the ejected electron beam is measured by exploiting the spin dependence of the elastic electron-electron scattering (Moller scattering). This process shows a large asymmetry in the cross sections for polarizations of the projectile electrons parallel and antiparallel to the polarization of the target electrons. The ejected electrons from the synchrotron, which are transversely polarized, become longitudinally polarized by deflecting them in the plane of their momentum and polarization vectors. The polarized electron target is a fragmentation foil of a special alloy magnetized by an external field.

Due to a small target polarization and to the fact that at this energy the beam polarization vector is not rotated completely into the longitudinal direction, the expected asymmetry of the counting rates is only about 1.5%. Thus other sources of asymmetry have to be carefully avoided; the direction of the beam polarization is reversed from pulse to pulse, as mentioned previously.

The first test showed a considerable polarization for the ejected electron beam. The mean value for both directions of target polarization was $(50 \pm 7)\%$. During the measurements, the source delivered electrons with an average polarization of $(61 \pm 5)\%$. Thus the level of polarization after acceleration in the synchrotron was still more than 80% of the value before acceleration. This proves that polarized electrons can be accelerated in a synchrotron while maintaining a high degree of polarization.

It is hoped that further studies, including those at higher energies, will reveal ways of maximizing the polarization of the accelerated electrons.

CERN
Cooling in three dimensions

For the near future, the most exciting advance in the research facilities available at CERN is likely to be the proton-antiproton project which is now at the stage of decision as regards its definite parameters. The project will make available colliding beams of protons and antiprotons in the SPS and ISR. It requires the accumulation of intense beams of antiprotons to achieve usable beam luminosities and for this the stochastic cooling technique invented by Simon Van der Meer is to be used.

In May there were further tests of this technique in the ICE (Initial Cooling Experiment) storage ring from which we reported encouraging results in the April issue, page 112. There had been a worry, following some theoretical work at Novosibirsk, that reducing the beam cross-section by cooling might give an increase in momentum spread or vice versa. This worry was removed in May when contraction of a proton bunch was achieved in all three dimensions simultaneously. The resulting beam lifetime was 20 hours (compared with about half an hour without cooling), which is consistent with the anticipated losses due to gas scattering.

Three stochastic cooling systems were operating — two of the type used in the earlier work at the ISR and one using a new 'filter method' invented by Lars Thorndahl who was also responsible for preparing the equipment and the tests for stochastic cooling.

There were several important results. With a beam of 7×10^7 protons (which is a higher intensity than is anticipated per injected bunch of antiprotons in the cooling ring of the final project) a cooling time of only 15 s was observed. In addition, an increase in momentum density by a factor of 20 was achieved.

Perhaps most satisfying of all is that the results are in excellent agreement with the theory of stochastic cooling as refined particularly by Frank Sacherer. This gives confidence in the predicted performance of the cooling ring for the proton-antiproton project.

Tests of electron cooling in ICE are being prepared by Frank Krienen and his group. For this equipment was moved into the hall where the ICE storage ring is installed early in June and tests in the ring itself start in the summer.

Helium (and other) ions for nuclear research

By changing its radiofrequency range, the CERN synchro-cyclotron (SC) can now provide 900 MeV helium-3 ions in addition to the standard 600 MeV protons. This extends considerably the

Design work to adapt the 600 MeV synchro-cyclotron (SC) at CERN for use with 900 MeV helium ions was helped by this fifth-scale model. To handle the helium ions, the r.f. range covered by the real machine is shifted from 30-17 MHz (150-85 MHz with the model) used for protons to 20-14 MHz (100-70 MHz with the model). This is accomplished by using an additional length of transmission line, seen here between the rotating capacitor (left) and the dee electrode (right). With the SC model is Reinhold Hohbach of the SC r.f. group.

(Photo CERN 236.5.78)

physics potential of both the SC and its ISOLDE on-line isotope separator.

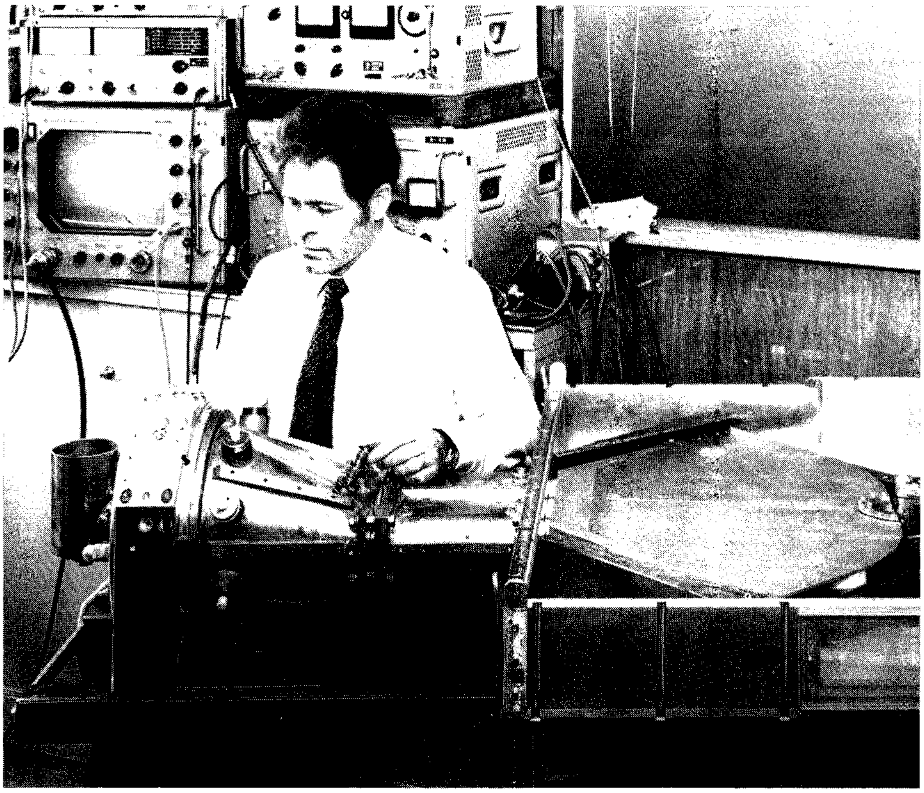
Despite being the oldest machine on the CERN site, the SC, which began operation in 1957, continues to be a major research tool for nuclear physicists and the availability of new ion beams will ensure that it maintains this position.

The main motivation for the new helium-3 ion ('helion') beam has come from the ISOLDE collaboration, which relies on 'spallation' reactions for the production of exotic unstable nuclei. In these reactions, the incident particle probes deeply into a target nucleus and releases many neutrons and protons, thus transforming the target into a highly unstable isotope.

Only a small fraction of all reactions transfer enough energy for deep spallation, so these reactions are relatively rare. In addition, the residual nucleus will normally be left in an excited state, so that subsequently it rapidly loses some of its interesting excess of protons.

The hope is that a heavier composite incident particle like a helion will, on average, increase the amount of energy deposited in each collision and so boost the deep spallation yield. In addition, the extra protons, which can be transferred from the incoming ions to the target nuclei will enable new nuclear products to be manufactured. Particularly interesting are tellurium (atomic number 52) and thallium (atomic number 81) which lie very near the 'magic numbers' of proton stability at 50 and 82.

The interaction of helions with nuclei is relatively unexplored and the full potential of the new SC beam is as yet unknown. However, preliminary tests, when helions were accelerated to 335 MeV using the old SC r.f. system, showed that at these energies some of the properties of the helions were already comparable to those of protons. This bodes well for the new higher energy 900 MeV helion beam.



Besides investigating the general form of the helion-nucleus interaction, initial experiments using the new 900 MeV helion beam at the SC will also study the production of pions and kaons in nucleus-nucleus interactions. In these coherent interactions of nuclei, the thresholds for meson production are lower than with free nucleons.

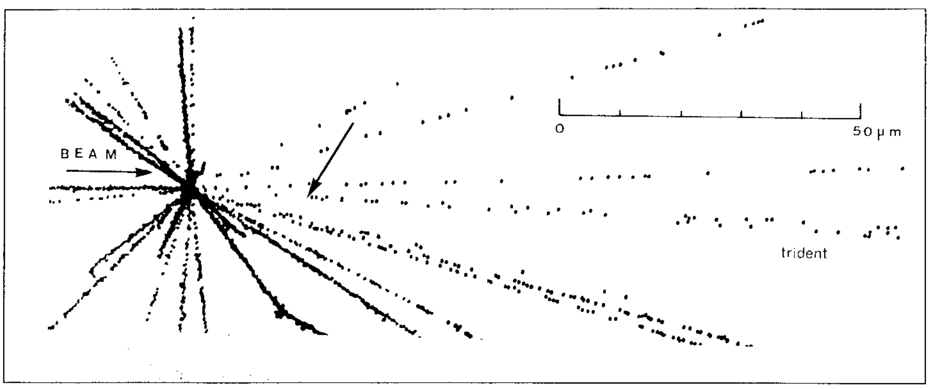
A Cagliari / Strasbourg / Torino collaboration (unofficially burdened by the name 'Castrato') will investigate pion production in nucleus-nucleus collisions in a pilot experiment which could open up a whole new field of nuclear study.

To accelerate the helions in the SC, an additional 120 cm of transmission line had to be inserted between the machine's rotating capacitor and the dee electrode. This shifts the r.f. range from 30-17 MHz for work with protons to 20-14 MHz for helions with their lower charge to mass ratio.

The same machine conditions which produce a 3 μA 600 MeV proton beam provide 1 μA of 900 MeV helions. Apart from the additional transmission line, the only other change required is the exchange of one gas bottle for another in the ion source. The change-over from protons to helions takes less than a day.

From this development with helions, it is a logical step to still heavier ions. For fully stripped ions, the provision of a suitable ion source in the existing SC configuration becomes a problem. Fortunately, with the present type of source (a Penning Ion Gauge), a number of partially stripped ions can be produced. Attention at CERN is now turning to carbon atoms stripped of four electrons ($^{12}C^{4+}$).

To handle these particles, the r.f. system has to cover an even lower and smaller range (11-8 MHz). It is planned to achieve this again by increasing the effective length of the transmission



An interaction 'star' produced in emulsion by an incoming high energy photon seen by a collaboration working at the Omega spectrometer at CERN. The candidate charmed particle track, decaying into a trident of secondary particles is arrowed. It is only about 20 microns long, indicating a very short-lived particle.

line of the dee. Investigations on an existing fifth scale model of the SC r.f. system have shown that this can be achieved economically by placing another inner conductor inside the extension used for the work with helium ions.

To supply a sufficient number of ions, the arc current in the ion source must be increased considerably and this requires the development of a cooled source chimney. Reducing the vacuum level in the machine could also pay dividends, as the electron configuration of the partially stripped ions is affected by collisions with residual gas.

Already in the first physics runs with the new helium beam, dramatic increases were seen in the production yields of some exotic nuclear states, and physicists expect further interesting results from this new lease of life at the SC.

A Charmed Life

Candidate events from an experiment at CERN looking for the decays of charmed particles in nuclear emulsions at the Omega spectrometer suggest that the lifetime of charmed particles could be smaller than expected. While still requiring further confirmation, this ties in with recent results from 'beam dump' experiments at CERN.

The emulsion experiment is being carried out by a Bologna / CERN / Florence / Genova / Paris / Santander / Valencia team working with another collaboration using a high energy photon beam at the Omega spectrometer in the West Area of the SPS. These photons come from the secondary electron beam produced from the SPS protons and are 'tagged' to give the energies of the individual photons.

A specially-built pneumatic loading device places successive plates of emulsion, 0.6 mm thick, in the path of the photon beam and particles emerging from interactions in the emulsion are detected by Omega. From this information, the Omega event reconstruction program indicates the interaction vertices in the emulsion. The regions of the emulsion plates around the interaction vertices are then examined under a microscope to search for signs of charmed particle production.

In a run in May 1977, 680 emulsion plates were exposed, and a total of some 450 events were obtained in which the photons produced hadrons which correlated with the triggers in Omega. This is the largest number of matched events ever collected in a single emulsion experiment.

Estimates, applying conventional beta-decay formalism to the decay of a charmed quark, give a lifetime for charmed particles of some 10^{-13} seconds. At SPS energies, this lifetime corresponds to a particle track a few hundred microns long, which should show up in an emulsion. In the Omega experiment, single tracks emanating from interaction stars in the emulsion are followed for a distance of up to 3 mm to search for any characteristic charm decay.

In the 450 plates scanned so far, no candidates for charm decay have been found with paths longer than 20 microns, while candidates have been found with decay paths of the order of 15 microns. If confirmed as charmed particles, these would indicate that the lifetime of charmed particles is in the range of 10^{-14} to 10^{-15}s, about an order of magnitude smaller than the theoretical estimate.

This brief lifetime ties in with the results of neutrino beam dump experiments carried out at CERN in the last experimental period of 1977 (see March issue, page 80), which uncovered signs of short-lived secondary particles decaying very quickly before they are absorbed in the beam dump material itself.

While these short-lived particles showed charm-like behaviour, production rates did not tally with previous results on charm production in an early experiment at Fermilab using 300 GeV proton interactions in emulsion. The fact that no charm decays were observed in this Fermilab experiment (involving a European collaboration) gave an upper limit for charm production which was subsequently used as a yardstick. However searching for charm decays in the complex interactions of protons at 300 GeV, with high multiplicities of secondary particles produced at small angles, is no easy business and short paths are difficult to spot.

The photon-emulsion collaboration at CERN has now exposed a new batch of 4500 plates. If results from this new run confirm the behaviour seen with the initial candidates, it will give a new yardstick to measure charm production.

A single muon emerging from the interaction at Fermilab of a 400 GeV proton in the calorimeter of experiment E 379 and traversing the 3.5 diameter muon spectrometer. Shown below the calorimeter are the measured parameters for this event and above the calorimeter are the readings from the 'thermometers' recording the longitudinal distribution of the hadronic energy.

FERMILAB Single prompt muons

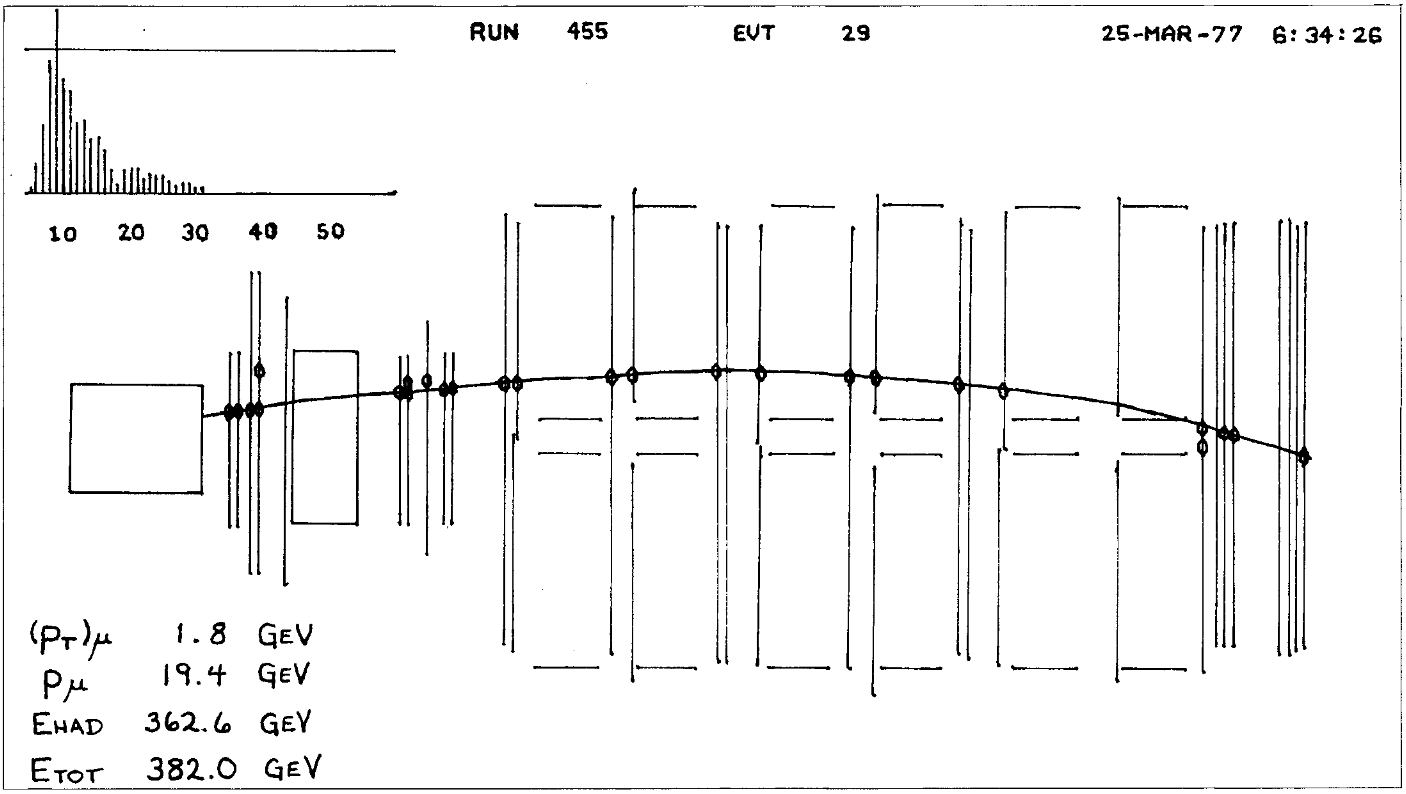
In recent years, experiments studying direct lepton production by hadrons have had a major place in the Fermilab experimental programme. Earlier experiments found that prompt leptons are produced copiously over a wide range of kinematics; muons (or electrons) are produced with about 0.01 % the rate of pions in high energy hadron-hadron collisions.

The latest experiments have been concerned with the mechanisms for producing these leptons and they were reviewed in the February issue 1977 under the title 'Dileptomania', since at that time they consisted mainly of experiments studying production of electron and muon pairs. These experiments led to the discovery of the upsilon (Columbia / Fermilab / Stony Brook group), the observation of a very large muon-pair continuum at relatively low invariant mass (Chicago / Princeton group), and substantial evidence that the bulk of the observed direct lepton signal is accounted for by production of electrons or muons in pairs.

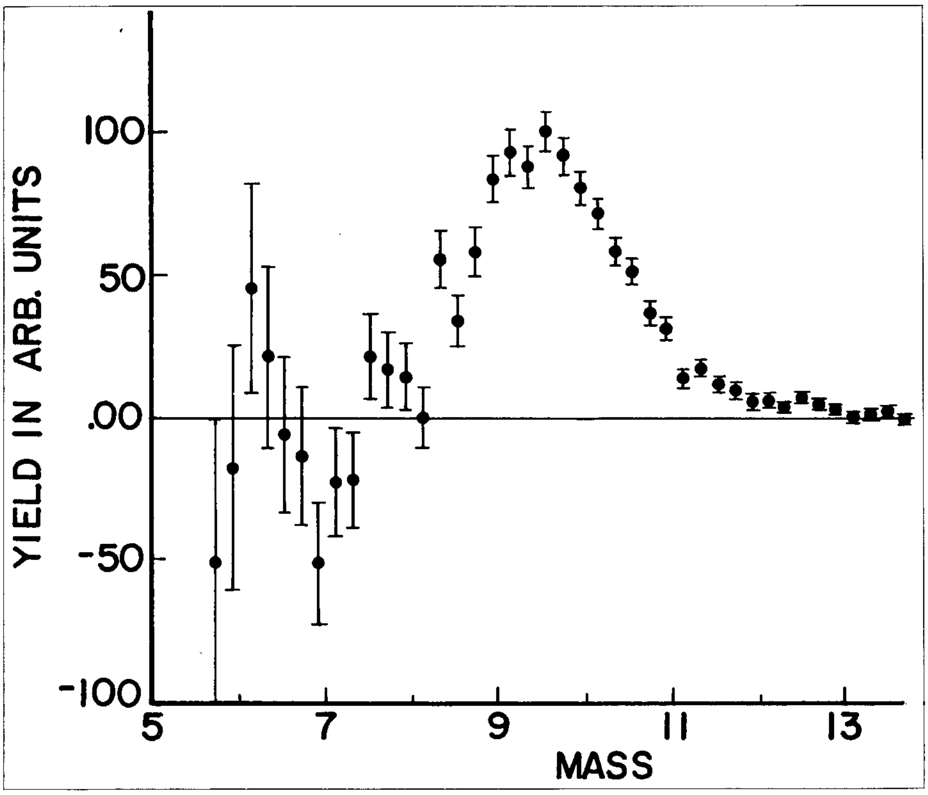
The sources yielding pairs of charged leptons are electromagnetic decay and pair production. An important question remains — when are direct leptons produced weakly from the semileptonic decays of short-lived states such as charmed particles? These weak decays would have the characteristic signature of only a single observed charged lepton emerging from the interaction since the other lepton is a neutrino.

The production mechanism for such new heavy states is not well understood theoretically and predictions vary widely. Also, a variety of charm searches in hadronic collisions, using other methods than the direct measurement of single prompt leptons, have indicated that the cross-section might be small. A new experiment at Fermilab, E379, has carried out a direct measurement of what fraction of direct muons are produced singly. The experiment was done by a Caltech / Stanford group under the leadership of B. Barish and S. Wojcicki.

A 400 GeV proton beam was brought to the Caltech / Fermilab neutrino apparatus and the protons interacted in a highly-instrumented target-calorimeter followed by a 3.5 m diameter muon spectrometer. This combination provided almost complete solid angle acceptance for the detection of muons. Data were taken in two different kinematic regions, using different configurations of the spectrometer — first, events were recorded with a muon of transverse momentum greater than about 8 GeV/c and, second, events were recorded with a muon of lower transverse momentum but of significant longitudinal momentum. The



The di-muon mass distribution measured in the Michigan / Northeastern / Seattle / Tufts experiments at Fermilab where the upsilon appears clearly.



prompt muon signal was extracted by varying the target density to determine any contribution from decays of long-lived particles (pions, kaons or hyperons).

The first results have been announced. The experiment has produced convincing evidence for the production of prompt single muons in hadronic collisions. In the events having no second muon, a comparison of the average final-state energy (obtained from the hadron calorimeter plus the muon spectrometer) with the known incident beam energy gives the missing energy carried away by the unseen neutrino.

The results are complementary to, and qualitatively agree with, those of the CERN neutrino beam dump experiment (see March issue, p. 80). Both indicate a substantial cross-section for charm production in hadronic collisions. It is interesting to note that for transverse momentum of about 1 GeV/c the single muon rate is comparable to the muon-pair rate. This region, where the largest signal has been observed, is precisely the region where M. Bourquin and J.-M. Gaillard predicted a significant charm signal several years ago.

Upsilon production

A unique magnetized solid iron muon spectrometer at Fermilab has provided an independent observation of upsilon production. The spectrometer, operating in a high intensity proton beam in the Meson Laboratory, was constructed and operated by a group from Michigan / Northeastern / Seattle (University of Washington) / Tufts. By now the experiment has observed more than three thousand upsilons.

The spectrometer consists of a series of three solid iron magnets following a tungsten target. This provides a very large acceptance for muon pairs, covering essentially the forward hemisphere in the centre-of-mass system, which permits measurements of upsilon production over a wide kinematic range. Typical mass resolution (one standard deviation) at the upsilon is 6%.

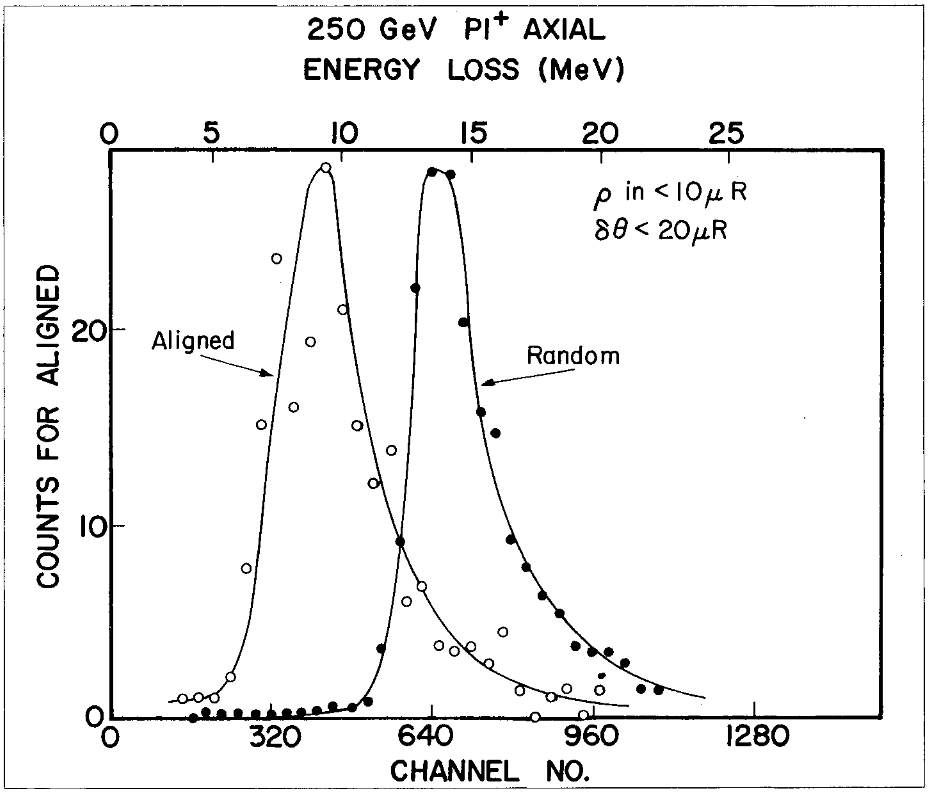
The spectrometer is able to handle high beam intensities — in excess of 10^{11} protons per beam pulse — and through the efforts of the Meson Department, the M2 beam has been specially modified to provide these intensities. Principally by providing more shielding, M2 can operate at beam rates that exceed earlier operating parameters by more than a hundred.

First data for the experiment was taken in April 1977 and results from that run already showed evidence for the upsilon. Since then the beam rate and the upsilon harvest increased dramatically. Recent attention has concentrated on the spectrum at higher mass and a search for signals in the multi-muon (three or more) spectrum.

Workshop on channelling

Channelling of relativistic particles by single crystals is an interesting conjunction between high energy and solid state physics. The interface between these two fields has long been recognized as important in detector systems but in channelling it is even more direct and symbiotic. Exploration of the status and prognosis of particle channelling at high energies was the subject of an Informal Workshop at Fermilab on 7-8 April, co-sponsored by the State University of New York at Albany (SUNYA) and Fermilab.

Descriptions of experiments carried out at CERN by the Aarhus / Strasbourg / CERN collaboration and at Fermilab by the Dubna / Fermilab / Lehigh / SUNYA / UCLA collaboration comprised the status, and contributions from Dubna, SLAC, Livermore, *Particle energy loss as measured in an oriented single crystal of germanium at 250 GeV. The positive particles lose much less energy in the crystal when they travel along a crystal axis.*



Yerevan, and Moscow supplied the prognosis.

High energy channelling was described in the September 1977 issue, page 280. Briefly, a charged particle moving through a crystal at a small angle to a row or plane of atoms, experiences correlated deflections from each atom that can add up to a gentle steering of its trajectory away from the row or plane (if the particle is positive) or towards the row or plane (if the particle is negative). If the transverse energy of the particle exceeds the electrostatic potential of the crystal structure, the particle is not so gently steered away and the whole picture breaks down.

This leads to the idea of a critical transverse energy or (for a given particle energy) critical angle between the row or plane direction and the particle direction of motion. According to the electrostatic model this angle depends on the inverse square root of the particle momentum-velocity product.

Experiments have demonstrated that the critical angle scales over the energy range from 10 keV up to recent 250 GeV measurements at Fermilab. Such tests of scaling are one reason for studying high energy channelling. Also, the stability of channelled particle trajectories is of central importance. This is, from the channelling point of view, the main reason for doing such measurements at very high energies.

Destruction of channelling trajectories, appropriately called dechannelling, comes about by multiple scattering of particles from electrons or from thermally displaced nuclei in the crystal. This scales in angle as the inverse of the particle momentum-velocity product; hence, as the energy increases, channelling should become more stable. Dechannelling lengths (at which half of a channelled beam is lost) should increase from tens of microns at a few MeV particle energy to tens of centimetres at 250 GeV/c and the Fermilab measurements confirm this. The increased stability at high energies may make it possible to see effects that would otherwise be masked by dechannelling and may also be important for possible applications.

The energy loss of channelled particles was reviewed in some detail at the Workshop. Well-channelled positive particles lose energy in the crystal less rapidly than non-channelled particles because they are confined to low density regions. These differences are easy to measure if the crystal is itself a semiconductor detector. Applications for selection (or identification) of particles, which are well-channelled and therefore have specific directions of motion, are obvious.

At energies as high as 250 GeV/c, density effects are expected to be important in the energy loss process. These should effect non-channelled and channelled particles differently so quantitative analysis of the ratio of the energy loss of channelled and non-channelled particles may provide a sensitive test of the theory.

One of the most interesting applications of channelling (actually of its complementary effect involving particle emission from crystals called 'particle blocking'), is the measurement of short nuclear decay times. Decays as short as one atto-second (10^{-18} s) have been measured. For relativistic particles it should be possible, in principle, to go to even shorter times because of the Lorenz contraction — perhaps as short as 10^{-20} s. A systematic survey of possibilities by the Aarhus group shows the eta lifetime to be a promising candidate for measurement by this technique.

The newest, and perhaps the most exciting, possibility from high energy channelling involves synchrotron radiation from channelled particles. Channelled particle trajectories oscillate with a short period and these curved trajectories will result in synchrotron radiation. The effective bending radius can be very small (about 2 cm for 100 GeV/c) and for planar channelled particles the radiation should be tightly collimated along the particle direction, perhaps producing coherent interference between successive oscillations.

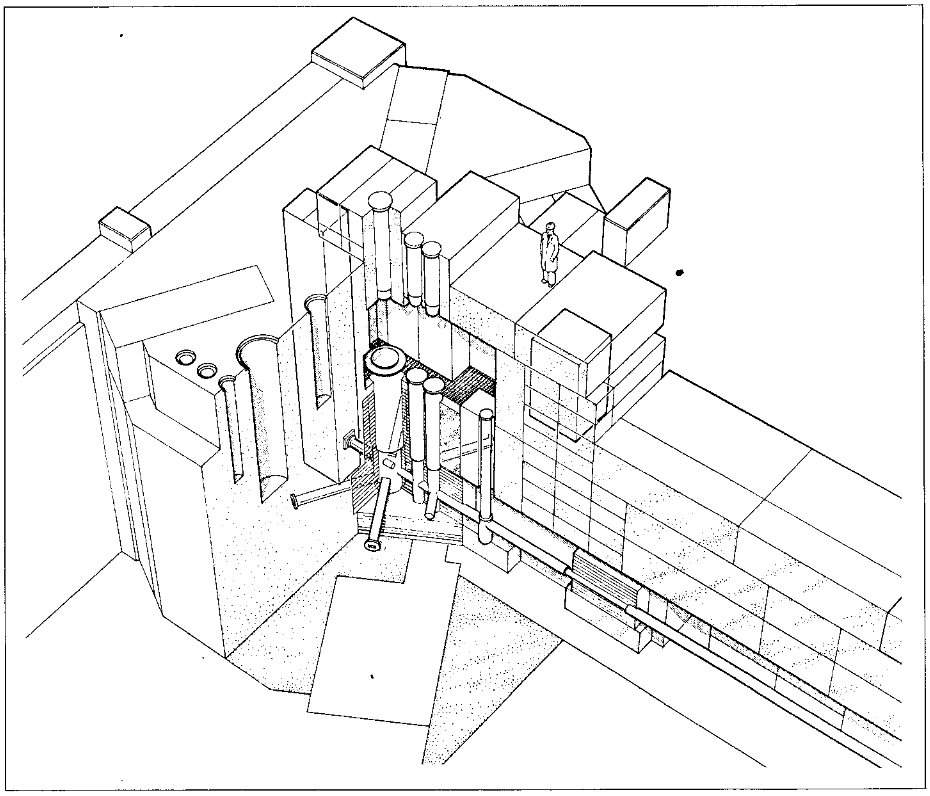
It was generally concluded at the Workshop that the radiation intensity and frequency should scale as $\gamma^{3/2}$. There was lots of speculation as to how this phenomenon can be used. No measurements have yet been made of channelled particle synchrotron radiation but experiments are planned or under way. Saclay and Livermore will soon start measurements on positron and electron beams up to about 40 MeV; SLAC, Dubna and Serpukhov studies will go to higher energies.

There was discussion concerning the possibilities of bending or cooling beams using channelling but experts very much discount these possibilities. There is now some evidence that the most probable angle of a distribution of particles moves towards the crystal axis but that the net distribution preserves phase space. This looks possible from channelling theory and is not cooling in the accepted sense.

It isn't yet possible to say with conviction what high energy channelling has to offer either for solid state or for high energy physics. The effect is, however, well established up to the highest available particle energies. Thus far, only dislocation-free germanium and silicon have been identified as being perfect enough to use for such studies, since the extremely small critical angles (about 40 micro radians at 250 GeV/c) require nearly perfect crystals.

The experimental challenges to continue and extend these studies are formidable but the promise makes such efforts worthwhile. Perhaps one great benefit is the stretching of minds that accompanies the marriage of such disparate disciplines.

The 180 kW beam stop and thermal neutron facility at the TRIUMF cyclotron. 500 MeV protons enter from the right and are stopped in a cylindrical lead target (centre), surrounded by a water/heavy water moderator and steel and concrete shielding. Thermal neutron channels at 60° and 120° radiate from points below the target. Immediately upstream are target mechanisms for producing isotopes and a muon beam.



TRIUMF 120 μA to Thermal Neutron Facility

Last July we reported the delivery of a 114 μA proton beam to a temporary beam stop at the TRIUMF cyclotron in Canada. Between September and December the high intensity proton line was rebuilt and extended and the permanent beam stop-cum-Thermal Neutron Facility (TNF) was completed. The new line received its first proton beam (0.1 μA) on 10 January.

The intensity was gradually raised over the next month while the performance of the TNF and the spills along the beam line were carefully monitored, culminating in a run of well over an hour at 120 μA on 13/14 February. The longest high intensity run before the spring shutdown took place on 7/8 April when a 75 μA beam was delivered for sixteen hours. For the moment, only a limited number of 100 μA shifts are scheduled but their frequency will be increased in pace with improvements in remote handling capability in the cyclotron and along the beam lines.

The TNF is designed to produce thermal neutron fluxes of 10^{12} to 10^{13} neutrons per sq. cm per s for irradiation and neutron beam experiments, the nearest Canadian reactor providing fluxes approaching this being 1900 kilometres away. The proton beam is stopped in a lead target contained in an evacuated stainless steel can, which is surrounded by a moderator of light and heavy water. The target is designed to dissipate a maximum beam power of 180 kW (400 μA at 450 MeV). At beam intensities above 25 μA of 500 MeV protons, an increasing fraction of the total lead volume is molten. The power is dissipated by convection in the molten lead, by conduction through the can wall to the moderator water and then by heat exchange to a cooling water supply. An extensive array of interlocks, involving temperatures, flow rates, and vacuum readings, is part of the cyclotron safety system to interrupt beam to the TNF should parameters depart from the nominal range.

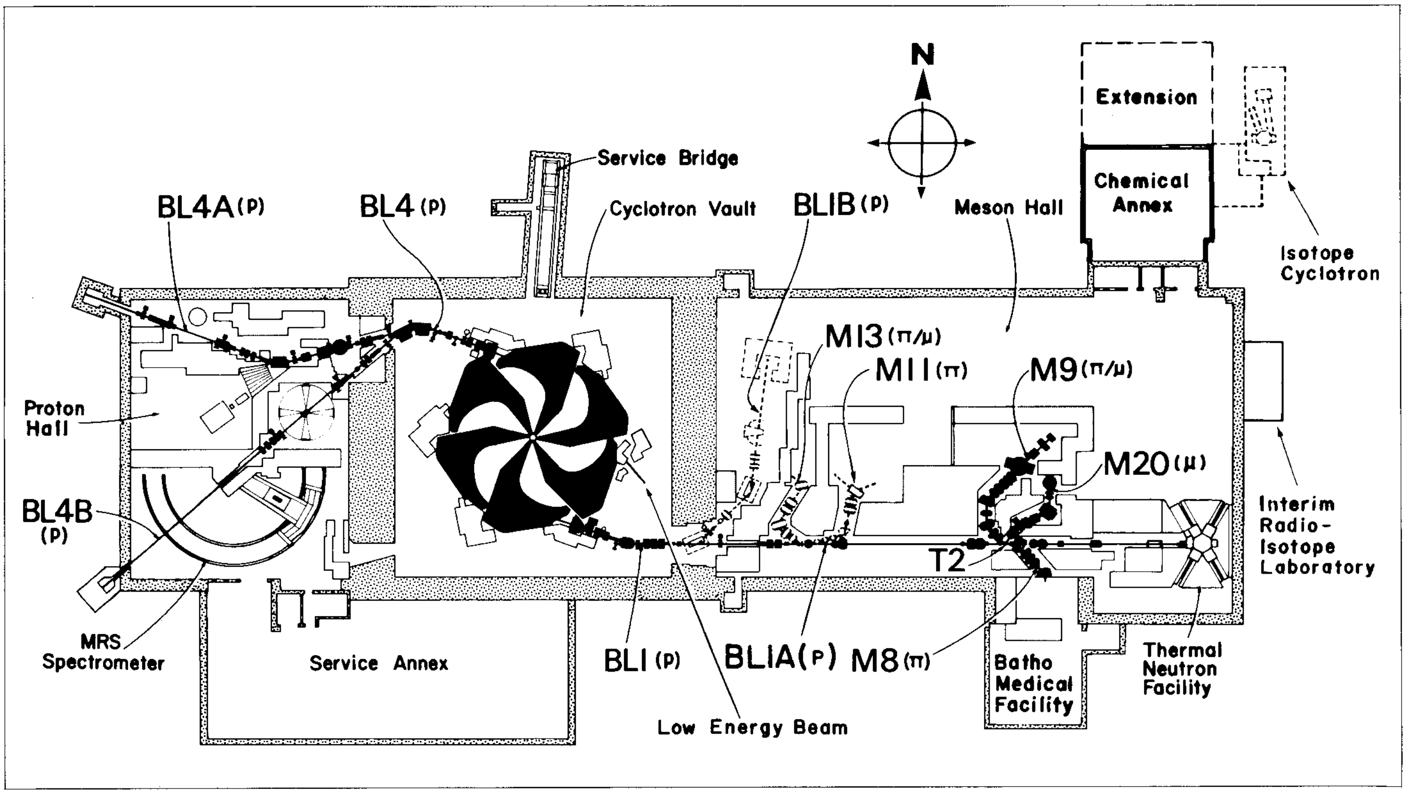
During the high current test temperatures in the lead, moderator water and cooling circuits behaved as had been predicted from heat transfer experiments in 1977. On 10 March, the target was withdrawn for inspection and there was no apparent damage and negligible distortion of the front wall, about which there had been some concern. Radiation levels in the TNF cave, outside the shielding, and from the target and other components during inspection, were all acceptable and within predictions. The commissioning tests provided the information necessary to design the active gas effluent holding system. The system, which is more elaborate than initially envisaged because of the large quantities of mercury isotopes that evolve from the molten lead, will be installed during the summer.

Alterations to the high intensity proton line feeding the meson area were undertaken for many reasons. The first was to extend the line 20 m beyond the thick pion production target (T2) to the TNF; this section includes collimators and scrapers to intercept protons multiply-scattered through too large an angle at T2 (up to 25 % of the primary beam). The second reason was to install a new thin target (T1) for two new secondary lines — a high resolution line (M11) collecting forward pions at small angles and a low energy line (M13) collecting pions or muons emitted at a backward angle of 135 °. The third reason was to install the front end of a new proton line (BLIB) for polarized proton and other low intensity proton experiments; this line, along with M11 and M13 will be completed later this year. Finally, the opportunity was taken to radiation harden the high intensity proton line and improve its remote handling capability; this process is now complete downstream of T2.

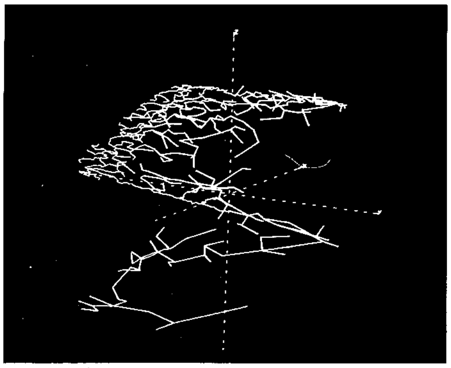
For the cyclotron and the proton area the autumn shutdown was limited to less than two months and the remaining period, overlapping with the meson area reconstruction, was dedicated to polarized beam operation. Highlights of the shutdown were r.f. reliability improvements with more cooling in the dee gap region, more diagnostics, and upgrading of remote handling in the cyclotron tank. In the proton area, the beam stop on line 4A and the 500 keV medium resolution spectrometer (MRS) were completed for fixed angle operation along the 100 nA bean line (4B).

During the seven week spring shutdown work has continued on new lines in the meson area and preparations have been made for extending M9 with an electrostatic separator as a muon channel. The main emphasis, however, has been on the cyclotron and the proton area. In the cyclotron the items installed included an improved alignment system for the resonators, a port for 100-180 MeV beam extraction, and a port and stripping mechanism for extracting 65-100 MeV beams for isotope production. In the proton area the MRS spectrometer moving system was installed, and the beam line 4B extended to a permanent beam stop outside the building.

Beam lines at the TRIUMF cyclotron. Those drawn as full lines are already in existence and those drawn as dashed lines are under construction.



A 'minimal spanning tree' of the reaction $\pi^+ p \rightarrow \pi^+ \pi^0 p$ in the prism plot. The xy-plane corresponds to a Dalitz plot, the z-axis is the Van Hove longitudinal phase space angle. The structure shows (from top to bottom) proton diffraction dissociation, forward rho, Δ^{++} and backward rho production.



NIJMEGEN Analysis meeting

As a sequel to similar meetings held at CERN in 1974 and 1976, a topical meeting on Multidimensional Analysis of High Energy Data was held in Nijmegen from 8 - 11 March.

After a review of the previous meeting by T. Ludlam (Yale), the meeting started with presentations of recent results on the application of 'non-parametric multidimensional cluster searching' techniques. The use of information on shape and direction in space was generally found important for the separation of physically meaningful clusters. For these methods, crucial support from display techniques was demonstrated on short films and on the Nijmegen Vector-General 3D display system.

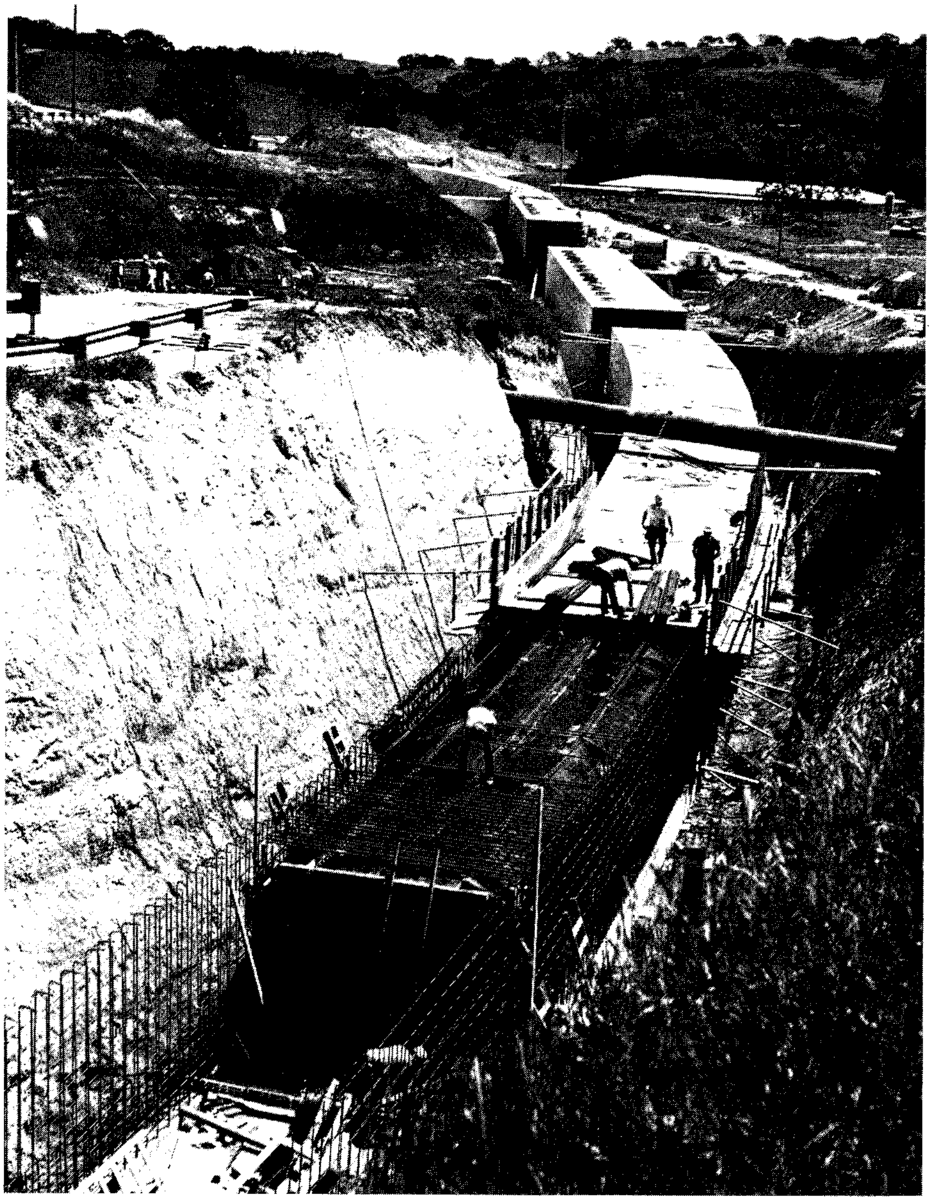
Another topic of central interest was the application of analytical methods to multi-dimensional data. Results were presented from Prism Plot, Channel Likelihood and Multichannel Analyses. In particular, it was convincingly shown that these techniques allow detection, isolation and study of low cross-section channels and interference effects usually hidden when using conventional techniques.

Resulting models have to be tested in multi-dimensional space as well. J. Friedman (SLAC) made use of the 'minimal spanning tree' to show how two one-dimensional tests (Wald-Wolfowitz test and Smirnov test) can be elegantly generalized to more dimensions.

The importance of multi-dimensional analysis of inclusive data was demonstrated by L. Van Hove (CERN) in the framework of the analysis of quark and gluon structure of hadrons. In the closing lecture the statistician J. Benzécri (Paris) congratulated high energy physicists on their techniques for handling multi-dimensional problems and encouraged continuing work on applications and on perfection of the techniques.

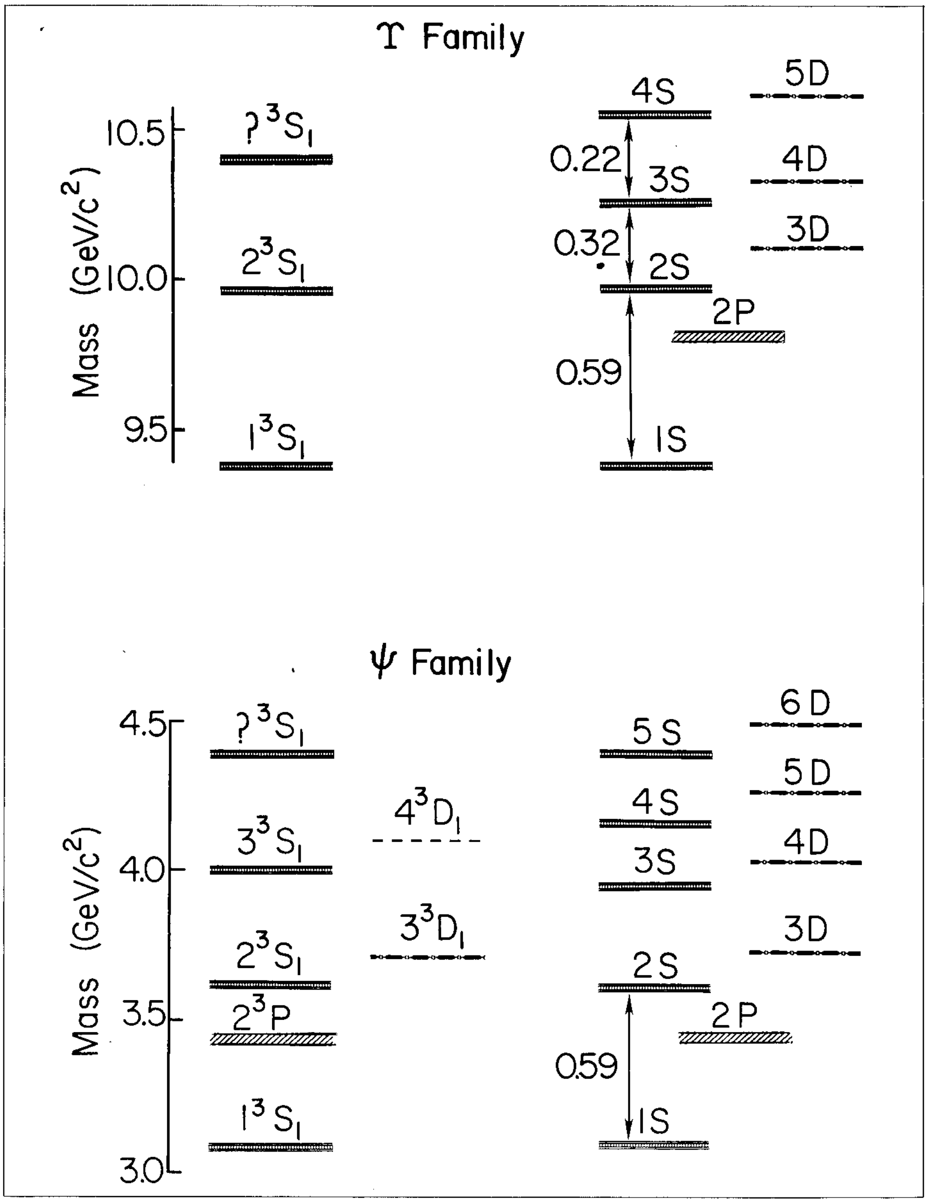
The ring tunnel for the Berkeley/Stanford electron-positron storage ring, PEP, being built at SLAC is advancing steadily around its circumference. This shows a 'cut and fill' section in regions 5, 6 and 7.

(Photo Dick Muffley)



Physics monitor

Heavy quark-antiquark bound states — experiment and theory: the left-hand side shows the observed spectra of psions and upsilons (the psions labelled 1^3S_1 and 2^3S_1 correspond to the J/psi and the psi prime). The right-hand side gives the predictions of a non-relativistic quark-antiquark potential which behaves logarithmically. In this picture, the level spacing between the ground state (1S) and the first excited state (2S) is the same for psions and upsilons.



Quarkonium quantum mechanics

The discovery of the J/psi and upsilon families of new particles has had a revolutionary effect upon particle physics. The rich array of states observed with the psions and expected with the upsilons has given rise to a new spectroscopy. This has encouraged the hope that heavy quark-antiquark systems might serve as a 'hydrogen atom' of hadron physics.

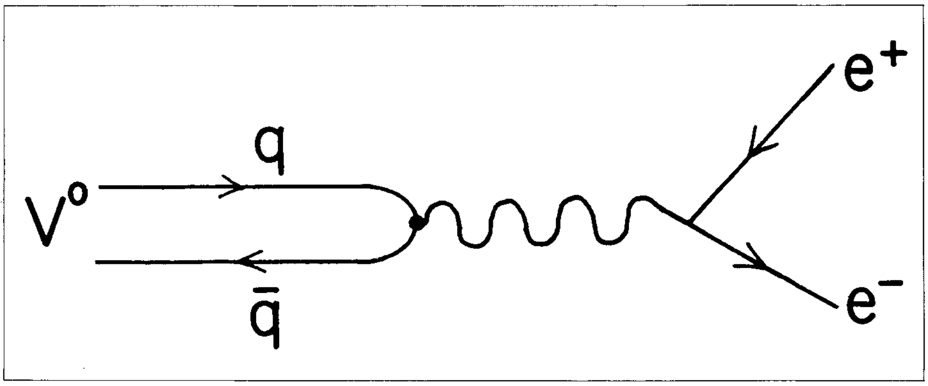
High energy physics is concerned with the relativistic domain in which particle creation and annihilation are routine. However it has frequently been possible to find restricted situations in which non-relativistic quantum mechanics is useful. Some familiar illustrations are the application of the Weisskopf-Wigner formalism to the mixing of short and long-lived kaons and the meson classification scheme based on the non-relativistic harmonic oscillator model for quark-antiquark states.

In scattering theory, non-relativistic examples have been an important source of inspiration for the relativistic domain. Regge poles, on which the phenomenological description of high energy scattering is based, were derived and understood in non-relativistic theory and applied to the relativistic problem by conjecture. Similarly, the Glauber multiple scattering approach emerged from non-relativistic theory and optics. With the discovery of the psion and upsilon families, theorists are turning again to non-relativistic quantum mechanics for inspiration and understanding.

Candidate gauge theories of the strong interactions (see November 1977 issue, page 380) suggest that the force between quarks is weak at short distances but becomes very strong at large distances. This 'explains' the paradox where quarks appear to behave as quasi-free particles within hadrons but cannot be liberated from the hadrons. On the basis of these arguments it was conjectured that heavy quarks would move non-relativistically within hadrons. Thus bound states of a heavy quark and antiquark should be a hadronic analogue of the positronium system of a bound electron and positron.

This so-called quarkonium system might then be interpreted according to the familiar rules of non-relativistic quantum mechanics using a potential to describe the inter-quark force. An explicit form for this potential has not yet been derived from the general theory but forms for very short and very long distances can be suggested. At very small distances the potential is expected to take a form like the Coulomb force, corresponding to the exchange of a single massless gluon. At very large distances a linear confining potential seems to be appropriate.

Looked at from the left, this diagram represents the decay of a vector meson, V°, into an electron and positron through an intermediate photon (wavy line). The meson could be a psion, an upsilon, or any other heavy vector (spin one, negative parity) particle. Looked at from right to left, the diagram shows the production of the vector meson in an electron-positron collision, via an intermediate photon.



The first opportunity to test the applicability of atomic physics ideas to hadrons came with the discovery in 1974 of the J/psi and psi prime which are long-lived by strong interaction standards. These particles could readily be interpreted as the first two levels of a charm quark-antiquark system. A natural starting point is to regard the potential as a combination of the Coulomb and linear forms, and then to vary potential strengths and the charmed quark mass to reproduce the experimental results.

The masses of the psions are eigenvalues of the Schrödinger equation. Another observable, the square of the charmonium wave function at the origin, is measured by the leptonic decay widths of the spin one levels where the quark and antiquark have their spins pointing in the same direction. In the quarkonium picture, the decay of a vector (spin one, negative parity) meson into a lepton pair is described by the annihilation of the quarks into a virtual photon, which subsequently decays into the lepton pair. The rate of the process is governed by the probability for the quarks to coincide, i.e. the square of the charmonium wave function at zero separation.

Having adjusted the potential to fit the J/psi and psi prime positions and leptonic widths, it can predict the positions of other levels and rates for radiative transitions among levels, along with other quantities. Many of the predicted levels have been found with masses remarkably close to the theoretical expectations. For those accustomed to a purely descriptive hadron spectroscopy, this agreement supported the non-relativistic potential model approach. Inevitably, complications appeared in the form of relativistic corrections, tensor forces, and coupled-channel effects.

New opportunities arose with the discovery of the upsilon family. If these particles are a heavier quarkonium family, the non-relativistic approximation should be more reliable than for the psions, because the new quark is two or three times more massive than the charmed quark. The comparison of the psion and upsilon families should provide an incisive probe of the potential.

An elementary way to make this comparison is to exploit the variation in behaviour due to different simple potentials. So far, the only data to which these considerations can now be applied is the apparent equality of the three lowest level spacings for the psion and upsilon families. This disagrees with the prediction of the most popular charmonium potential, but is reproduced instead by a logarithmic potential, which has been adopted as a simple form useful for making predictions.

What lies ahead? Theorists are busily refining potential models and calculating the potential from the presumed underlying field theory of the strong interactions. Many useful theorems can be proved and the use of special techniques to reconstruct the potential from the data is an appealing dream. Experiment, of course, will be the final arbiter of the value of the non-relativistic approach. With work continuing on the upsilon at Fermilab, DESY and the ISR, and with the advent of higher energy electron-positron colliding beams at PETRA, SLAC and CESR, the best is yet to come.

This article is based on material supplied by Chris Quigg.

Imps at large

The puzzle behind the success of the quark model is the continued non-appearance of any free quarks. The classic way out of this dilemma is to buy the idea of quark confinement and to believe that the quarks are there but somehow permanently trapped inside hadrons. Another way out of the quark dilemma has been suggested by Barry McCoy and T.T. Wu, who say that instead of being single particles of definite mass, quarks (and possibly other particles too) could have indeterminate mass and other unconventional properties.

In conventional field theory, the 'propagator' which describes the simplest possible interaction between two particles has in its mathematical structure a point singularity (pole). This pole is interpreted as a single particle passing between the two external particles and the position of the pole depends on the mass of the exchanged particle. Such single particle poles are the most convenient objects to handle mathematically but there is no other reason why they should be the only singularities in the mathematical description of the interaction.

McCoy and Wu suggest that line singularities (branch cuts) could also appear. These cuts can be looked at as the limiting case where the mass spacing of a whole series of single particle exchanges gets smaller and smaller, so that they eventually fuse together into a continuous spectrum. Instead of having a series of single particle exchanges, each having a definite mass, such a cut describes a particle with a continuous mass distribution. This is embodied in the name imp (indeterminate mass particle) and the idea is that quarks are imps.

For a series of very close energy levels, the Uncertainty Principle says that the corresponding spatial wave functions must be broad. Looked at as the limiting case of closely-spaced levels, an imp also has a broad wave function and so is a large object.

However, it is unlikely that an imp quark can be created directly in a high energy collision as a large particle. The most plausible idea is that quarks are created as small particles but subsequently expand. If so, quarks would only be able to ionize or excite an atom for a short time and over a short distance, possibly smaller than a millimetre, after which they would grow too large and too diffuse to affect atoms in the normal way. This could explain the non-appearance of quarks in flight in conventional detection equipment.

Although imps would be difficult to detect directly, an imp production process still has to obey conventional conservation laws of electric charge, etc., so that a non-detected imp carrying off electric charge would result in conservation law problems with the remaining observed particles. Such non-conservation of charge could be seen, in principle, in a bubble chamber experiment using a 'hard' collision process where the incident particle probes deep inside the target nucleons and unleashes quarks. Neutrino interactions would be one possibility (see April issue, page 123).

Just to make things more difficult, there is no reason why quarks should be the only kind of imps at large in high energy particle interactions. The gluons acting between the quarks could also be imps!

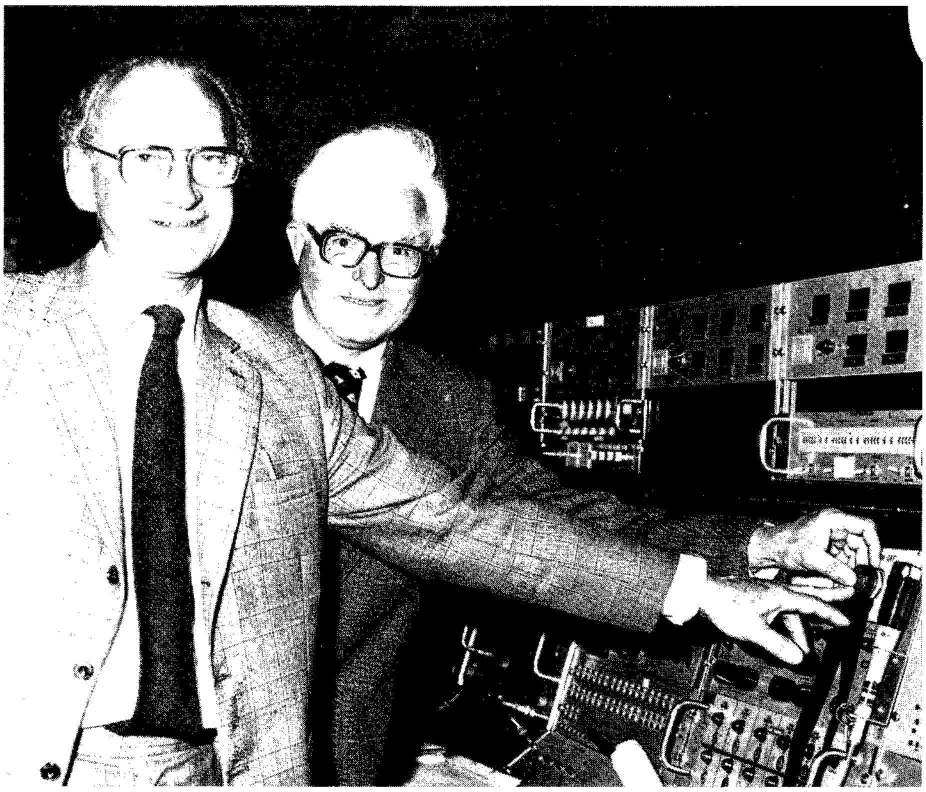
People and things

End of an era

The 7 GeV proton synchrotron, NIMROD, at the Rutherford Laboratory closed down on 6 June. This, coupled with the closure of NINA in April 1977, brings to an end an era of home-based research facilities for UK particle physicists, who now rely on CERN for their work.

NIMROD came into operation in 1963 and the research programme began in February the following year. The synchrotron has been successfully operated during fifteen years, providing about 60 000 hours of beam time for about 80 experiments. There has been great variety in the research programme which we hope to report in a forthcoming issue of the COURIER.

Some of the NIMROD components are now to be incorporated into a lower energy proton synchrotron to provide intense neutron beams by spallation.

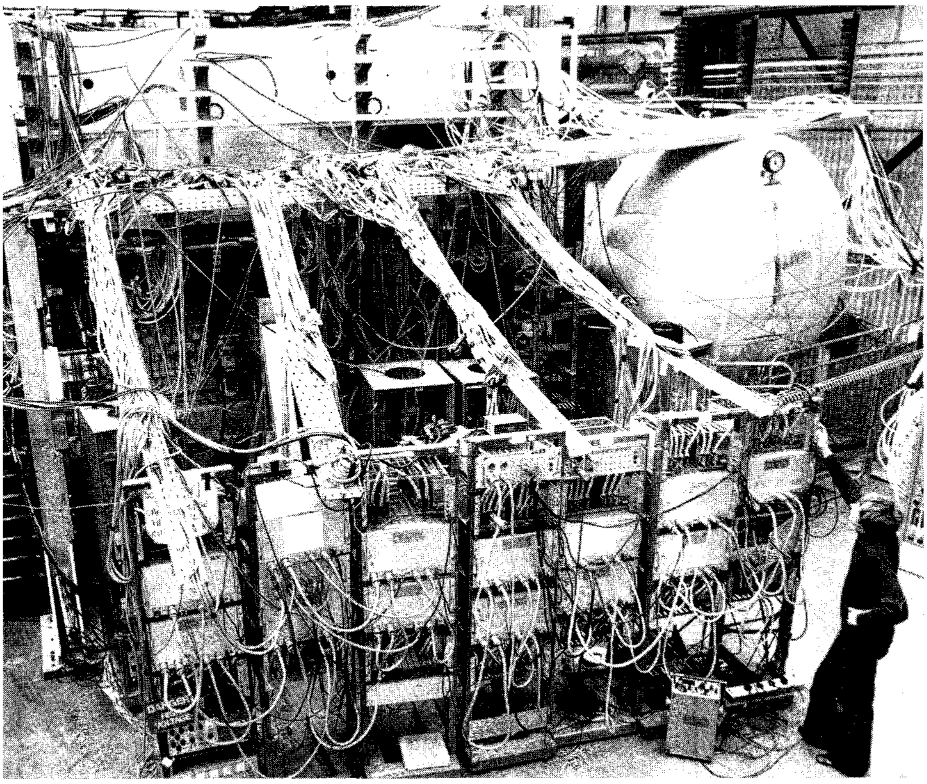


Rutherford Laboratory Director Godfrey Stafford and former Director T. G Pickavance together press the button at the official closing ceremony of the Nimrod proton synchrotron on 6 June.

(Photo Rutherford)

The multiparticle spectrometer at the Rutherford Laboratory finished its first experiment before the closure of the 7 GeV proton synchrotron, NIMROD. The spectrometer is being prepared for shipment to CERN for research at the 28 GeV PS.

(Photo Rutherford)



These neutron beams will be used by a new generation of research workers at Rutherford Laboratory.

On People

Professor Touschek died on 25 May at the age of 57. Bruno Touschek was born in Vienna in 1921. In his early career he studied at several Universities, including periods of time with A. Sommerfeld and W. Heisenberg, developing a lasting affection for theoretical physics where most of his research was done. His most significant contribution, however, came in accelerator physics, a field he came to know particularly in the 1940s working with Rolf Wideroe. In 1952 he moved to Italy, which remained his home base until his death, with periods at Varenna, Frascati and Rome, becoming inextricably linked with physics in Italy.

It was at the Frascati Laboratory in 1960 that he was the first to see the feasibility and the physics potential of electron-positron storage rings, now such a vital element of the high energy physics armoury. He pushed the construction of the first storage ring of this type, ADA, which Frascati operated in collaboration with Saclay, and directly contributed to it which his own hands.

Bruno Touschek was a man of very broad vision and deep insight in science with a rare ability for synthesis of knowledge from many fields. This ability was also reflected in the fact that he was an exceptionally good lecturer. All who met him came away enriched and his death has taken an important personality from science.

The fifth meeting of the USA-USSR Joint Committee on Cooperation in the Peaceful Uses of Atomic Energy took place in April. The photograph shows Robert Thorne (left, USA Acting Assistant Secretary for Energy Technology) and A.M. Petrosyants (right, USSR Chairman of the State Committee for the Utilization of Atomic Energy) signing the meeting record in Washington. The Soviet visitors toured American nuclear and high energy physics Laboratories.

(Photo DOE)

1. Paul Dirac at a Conference to mark the 50th anniversary of publication of the Dirac equation.
2. Ned Goldwasser who is leaving Fermilab to become Vice-Chancellor at Urbana.
3. Charles Peyrou whose sixtieth birthday is celebrated by a 'Festschrift'.

1.

2.

3.

Edwin L. Goldwasser is to leave Fermilab to take up un appointment as Vice-Chancellor for Research and Dean of the Graduate College at the University of Illinois at Urbana-Champaign as from 1 September. Ned Goldwasser has been Deputy Director at Fermilab since 1967 and has been influential in USA high energy physics policy for many years. He is currently also Chairman of the IUPAP Commission on Particles and Fields. His broad knowledge of the physics programme and his personal charm will be sadly missed at Fermilab while the Chancellor of Urbana, William Gerberding welcomes a 'distinguished scientist and humane scholar'.

We welcome Tu Tung-sheng to the list of CERN COURIER correspondents. Tu Tung-sheng heads the Theory Department at the Institute of High Energy Physics of the Academia Sinica in Peking and his nomination as COURIER contact is a further sign of the growing involvement of Chinese scientists in the world of high energy physics.

A Jubilee Conference was held at Florida State University 6-7 April to mark the fiftieth anniversary of publication of the Dirac equation. Gerard t'Hooft, Ken Wilson, J.J. Sakurai, John Ellis and Yuval Ne'eman spoke on 'Current Trends in the Theory of Fields' and Paul Dirac himself discussed his theory on the time variation of the gravitational constant.

A collection of papers covering contemporary aspects of high energy physics and related topics, under the title 'Physics from Friends' has been published, dedicated to Charles Peyrou on the occasion of his sixtieth birthday. Copies (470 pages at a cost of 100 Swiss francs) are available from Mrs. J. Ruiz, CERN, CH-1211 Geneva 23, Switzerland and payment should be made in advance directly to the Société de Banque Suisse, Agence du CERN, Account No. C7-754.676.5 'Peyrou Festschrift'.

Many leading figures in the USA accelerator world gathered in Princeton on 18 May to mark the retirement of Professor Milton G. White. Milt White had a distinguished career in accelerator physics. In 1954 he proposed (with Frank Shoemaker and Gerard O'Neill) the building of the fast cycling proton synchrotron which became known as the PPA (Princeton Pennsylvania Accelerator). The machine operated from 1963 to 1972 with Professor White as Director of the Laboratory. He remains active on the high energy physics scene and is at present Chairman of the Board of Trustees of the Universities Research Association which operates the Fermilab.

Nice summery picture. A deer has joined the famous buffalo herd on the Fermilab site.

(Photo Fermilab)

Accelerator Conference

The USA 1979 National Particle Accelerator Conference will be held in San Francisco from 12-14 March. Further information can be obtained from the Conference Chairman, Richard Neal, at SLAC and abstracts should be sent to the Program Chairman, Dennis Keefe, at the Lawrence Berkeley Laboratory, before 1 November.

Ten accelerator specialists from the Institute of High Energy Physics, Peking have begun several months of study at Fermilab. They are photographed here with Lee Teng the accelerator theorist from Fermilab (left to right) — Wang Shu-hung, Mao Chen-lung, Pan Hui-pao, Hsieh Chia-lin, Sui Ching-yi, Lee Teng, Hsiao Yi-hsuan, Shen Pao-hua, Chen Sen-yu, Hsu Chien-ming and Chung Hui.

POSITION OPPORTUNITY

RESEARCH SCIENTIST IN PARTICLE PHYSICS

The INSTITUTE OF PARTICLE PHYSICS OF CANADA invites applications for Research Scientist positions. Applicants should have proven ability in Experimental Particle Physics. Initial appointments will be for three years followed by a review which, if favorable, will lead to a continuing career appointment. Initially Research Scientists will be expected to join one of the existing I.P.P. collaborations at Fermilab or SLAC but the opportunity to initiate new experiments will also exist.

Applications including curriculum vitæ, transcripts and the names of 3 referees should be sent to:

J.D. PRENTICE
Department of Physics
University of Toronto
Toronto, Ontario M5S 1A7
Canada

POSITION OPPORTUNITY

RESEARCH ASSOCIATES IN PARTICLE PHYSICS

The INSTITUTE OF PARTICLE PHYSICS OF CANADA invites applications for Research Associate positions. Openings exist in the Canadian experimental particle physics groups located at Carleton, McGill, Ottawa, Toronto and York Universities. These groups are collaborating in experiments at Fermilab and SLAC.

Applications including curriculum vitæ, transcripts and the names of 3 referees should be sent to:

J.D. PRENTICE
Department of Physics
University of Toronto
Toronto, Ontario M5S 1A7
Canada

STATIONARY DIESEL GENERATING SET FOR SALE

As part of the plan to renew and increase the power of its stand-by electricity generating plant, CERN is closing down a complete 1500 HP generating set and replacing it by a larger power unit.

The set is of the stationary diesel-alternator type, designed to operate round the clock, and is in full working order. The set will be available on the CERN-Meyrin site from **1st October 1978.** A batch of spare parts is also for sale.

The main characteristics of the set are as follows:

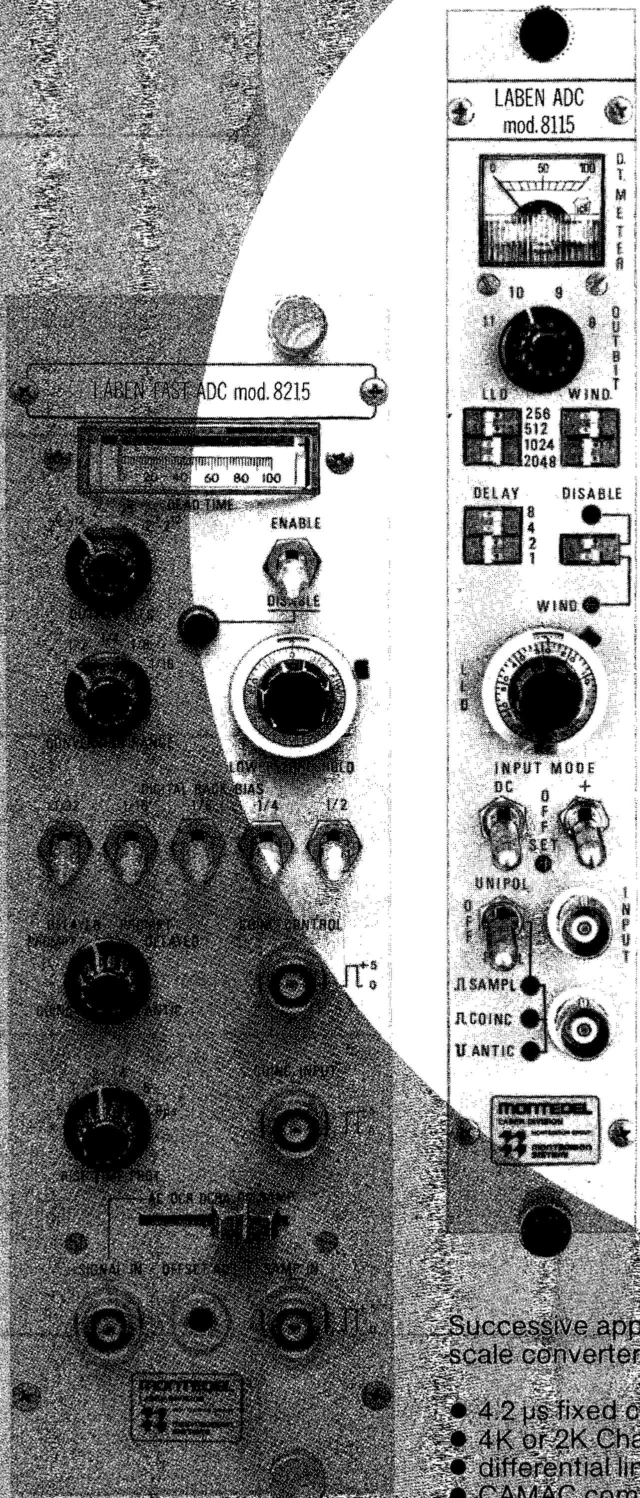
- First year of operation: 1956.
- Number of hours of operation: 17 500.
- **Diesel motor**: SULZER, Type: 8 TF 36.
  8 cylinders in line, producing 1520 HP at 300 r.p.m.
  Two-stroke. Weight: 57 tonnes.
- **Fuel**: DIESEL grade.
- **Alternator**: OERLIKON. Type SGD - 450 - 62.
  Star connection: 300 r.p.m., 230-400 V, 1910 A.
  Exciter fitted to end of drive-shaft. Type E 3 - 30.
  13.6 kW at 300 r.p.m. - 136 V, 100 A.
  Weight of alternator: 7 500 kg.
- **Method of starting**: automatic, by means of compressed air cylinders, 35 bar compressor, all included in the equipment for sale, together with:
  - control console;
  - voltage regulation switchboard;
  - circuit diagrams and instruction manuals.

For further information please contact

CERN - Stores/Salvage Service, 1211 Geneva 23, Switzerland - Telex 23698 CH

or phone:

For commercial information: Mr. F. SPYSE - Tel. 022/83 21 80
For technical information: Mr. P. CIRIANI - Tel. 022/83 41 83 Mr. R. RAZUREL - Tel. 022/83 21 77



from Laben:

8215 ADC, a world wide success

now 8115: the same improved patented techniques at a very attractive price

Successive approximation sliding scale converter featuring:

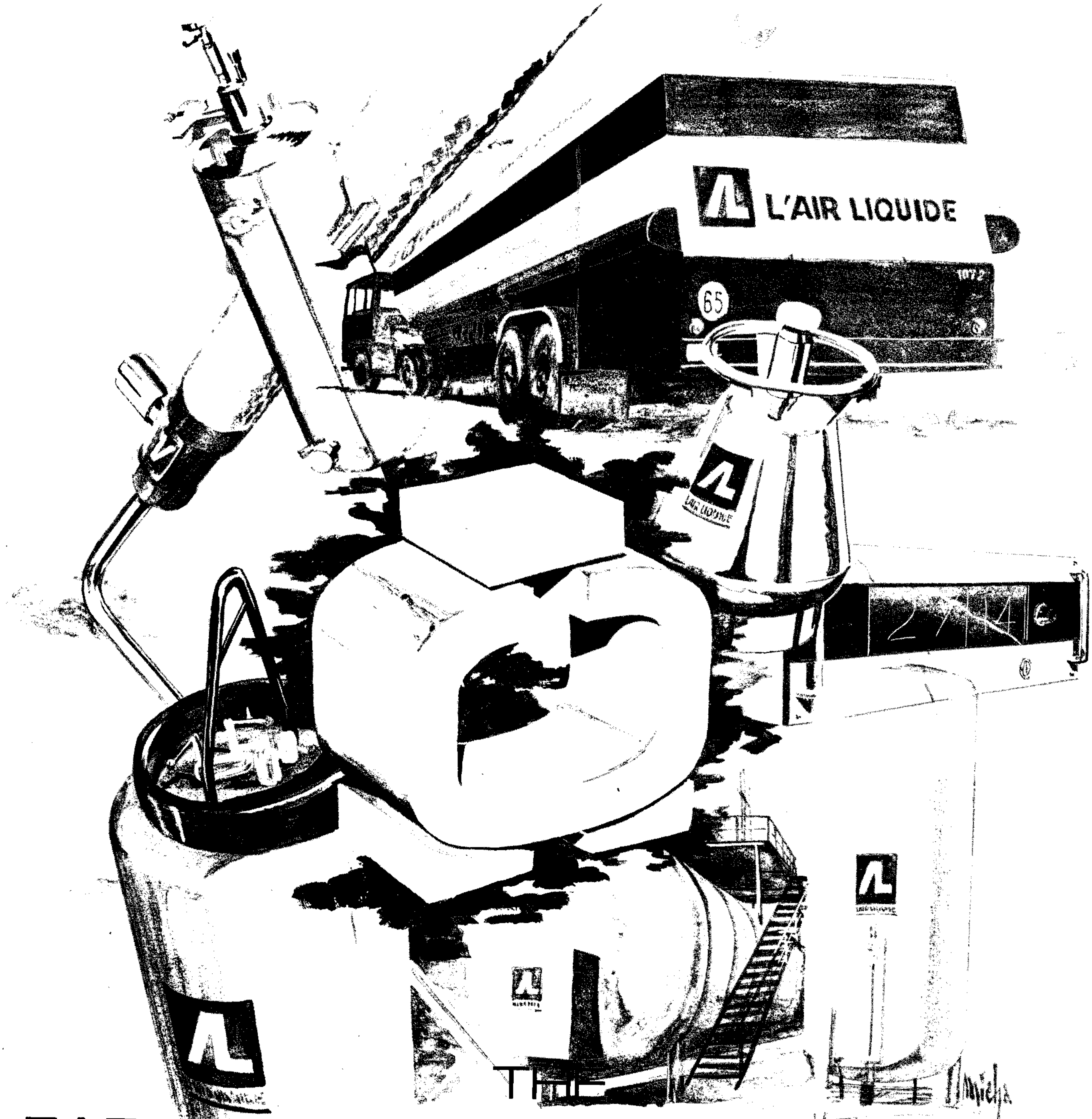
- 4.2 µs fixed conversion time
- 4K or 2K Channels resolution
- differential linearity error less than 0.2%
- CAMAC compatible through 5910 Interface
- Computer adaptable

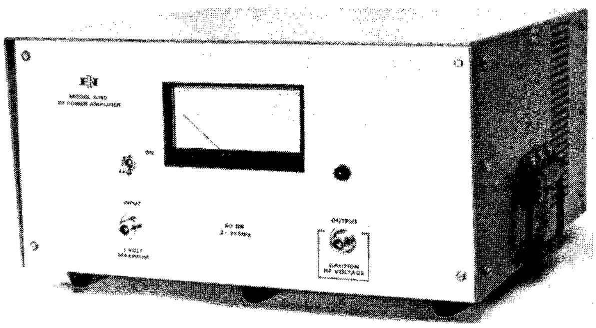
Official Sole Representatives for Europe:

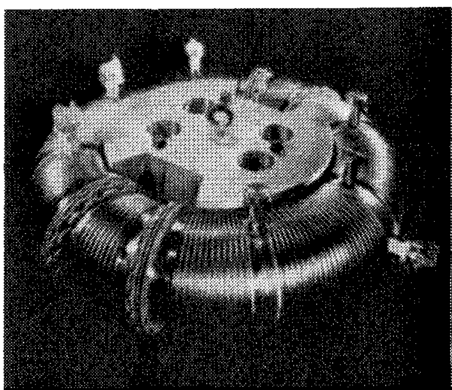
- Nuclear Enterprised Ltd. - Edinburgh
- Intechmij N.V. - The Hague
- Atomika Technische Physik GmbH - München
- Regulation Mesure SPRL - Bruxelles
- J. & M. Iversen & Martens A/S - Copenhagen

MONTEDISON GROUP
montedison sistemi

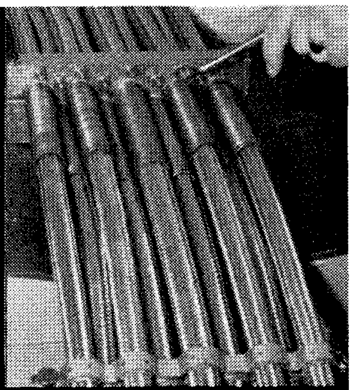
MONTEDEL
LABEN DIVISION
Via Bassini, 15 / 20133 MILANO, ITALY
Telephone: 23.65.551 / Telex: 33451


L'AIR LIQUIDE





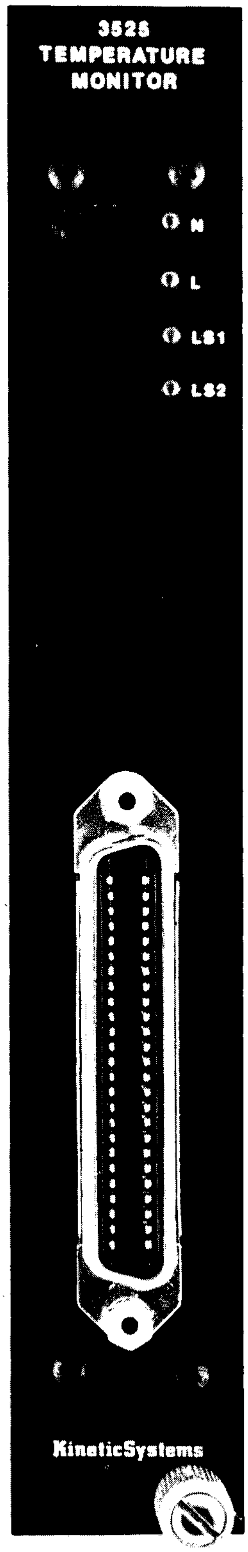
Tokamak for TOSCA experiment at U.K.A.E.A. Culham Laboratory



All-stainless-steel multiple flexible for irradiated fuel dismantling facility – Prototype Fast Reactor, Dounreay.

Temperature Monitoring

comes to CAMAC



OUR 3525 16-channel Temperature Monitor module is an exciting new development at KineticSystems. This module provides the interface to thermocouples without any external amplification or signal conditioning; temperatures are read on the Dataway in degrees Celsius or Fahrenheit.

Thermocouple linearization and alarm limits are provided on all channels. An on-board microprocessor controls the scanning of the inputs, calculates the temperature from the thermocouple linearization equation, and compares the current temperature to preset limits. A LAM interrupt can be set whenever any temperature is out-of-limits.

Now Available in a 16-channel Module

Features of the 3525 Module

- On-board microprocessor control
- 16 channels of differential inputs with guard per channel
- Readout via Dataway directly in degrees Celsius or Fahrenheit
- Resolution of 0.1° C.
- Accuracy of ±0.5° C. (excluding thermocouple)
- Reference junction input with optional on-board isothermal panel for direct connection of thermocouples to module
- Range of −200°C. to +760°C. with Type J thermocouple
- Optional linearization for various thermocouple types
- Can be used as general-purpose low-level monitor without linearization
- Upper and lower alarm limits for each channel written and read from Dataway
- LAM interrupt on out-of-limit temperature

Please contact us for additional information

the CAMAC people

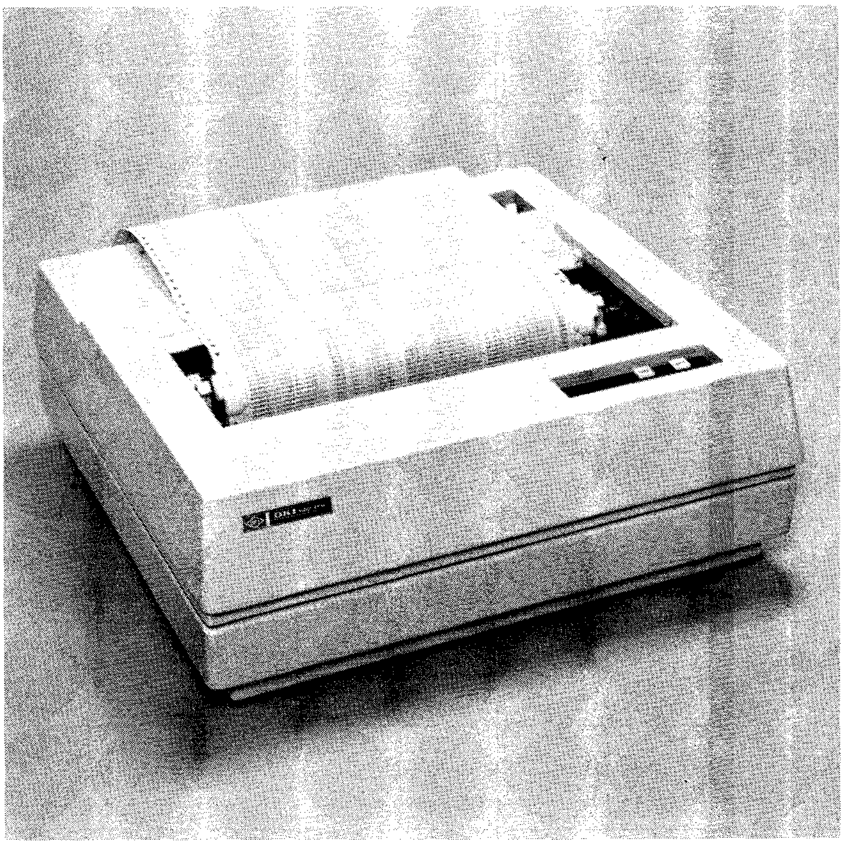
Kinetic Systems International S.A.

Dept. CC68 * 6 Chemin de Tavernay * 1218 Geneva, Switzerland * Tel. (022) 98 44 45 * Telex 28 9622

KineticSystems Corporation * 11 Maryknoll Drive * Lockport, Illinois 60441 * Tel. 815 838 0005 * TWX 910 638 2831

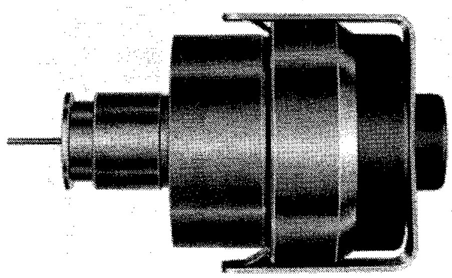
OKI electric

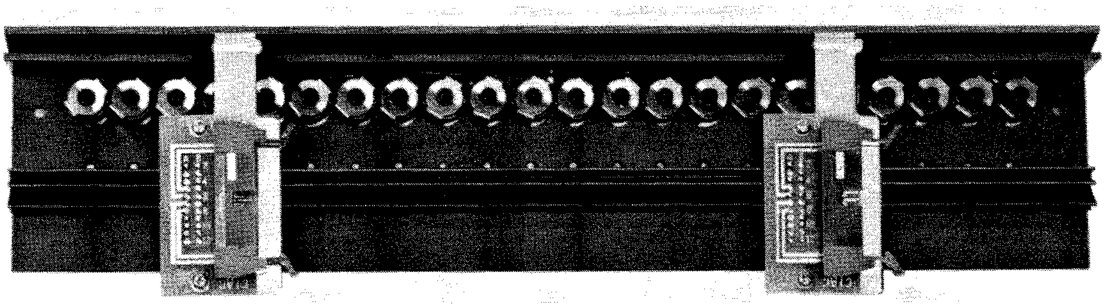
The OKI DP-100 Line Printer Designed to your advantage

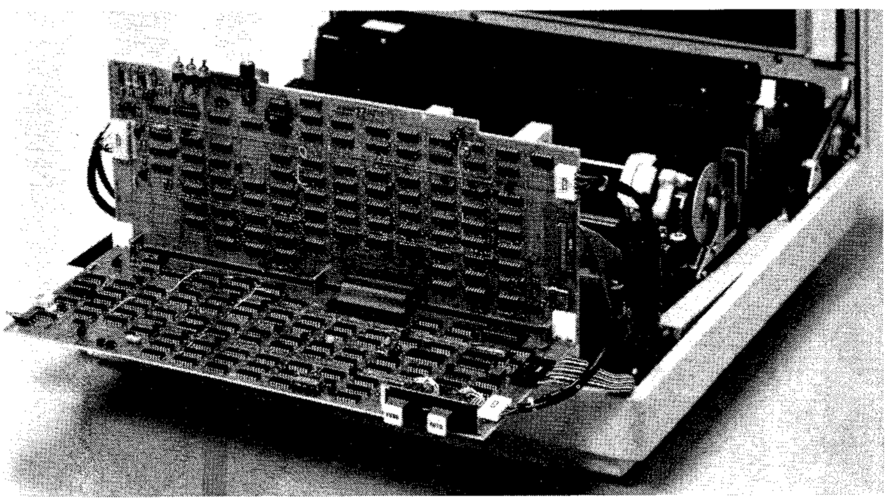


Model DP 100

- 22 print wires
- 125 lmp (275 cps)
- 132 column/9 by 7 dot matrix
- Roll- or Fanfold Paper
- 1-Line Buffer
- 96 ASCII characters, true upper/lower case
- Double characters width and height standard
- 12-channel electronic VFU
- Standard Interface: Parallel (Centronics)
- Option: Serie V 24







Prix du modèle standard: Fr. 7100.–

(prix OEM sur demande!)

Demandez la documentation.
Nous vous conseillerons volontiers.

Bellikonerstrasse 218
CH-8968 Mutschellen

STOLZ AG

Telefon 057 5 46 55
Telex 54070

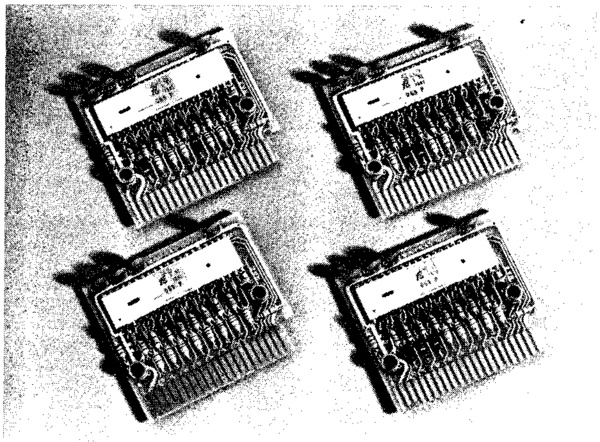
GOT MULTIWIRE PROPORTIONAL CHAMBERS ?

Save the pain of designing your own read-out system !
Here is the off-the-shelf answer from the european semiconductor industry

MONOLITHIC INTEGRATED CIRCUITS

associated to a fast, compact and powerful CAMAC system

From your MWPC requirements you can choose among three highly modular systems. Look...

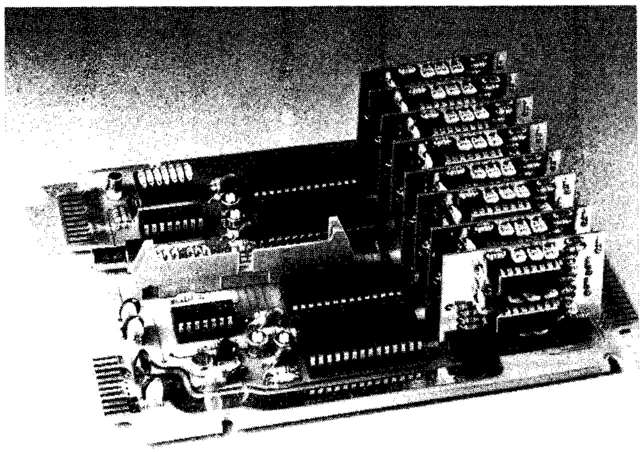


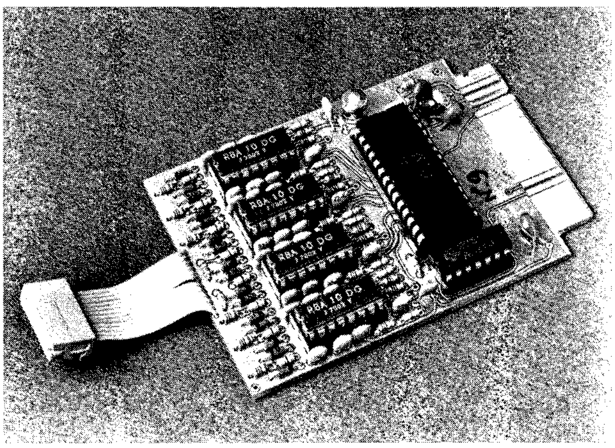
MWPC 1000 System

- 8-channel modules based on FILAS I.C.
- —3mV on 6kΩ min. threshold
- Delay adj. from 400 ns to 1.2μs
- 200 mW dissipation per channel
- Radiation resistant (up to 10^4 rad.)
- Small size (63 x 56 x 10 mm)
- Wire-OR able outputs (bus oriented)
- On-chamber 1005 modules
- Low, low, low cost : about 36 FF per channel
- More than 100 000 channels in use now or soon at SACLAY, CERN, DESY, SIN, JAPAN !

MWPC 2000 System

- ECL 2-channel front end (RBA I.C.)
- 8 ns time slewing, 2 X to 20 X
- PMOS 8-channel logic. processor (RBB I.C.)
- —250 μV threshold (on 100 Ω to 250 Ω)
- Delay adj. from 250 ns to 600 ns
- Dual monostable delay stacks
- Double memory points
- 350 mW dissipation per channel
- Size 170 x 225 x 40 mm
- Bus oriented outputs
- 32-channel on chamber 2001 modules
- Low cost : about 68 FF per channel
- Already 30 000 channels installed at CERN





New !

MWPC 2100 System

- Compacted version of MWPC 2000
- 8-channel 2101 on-chamber modules
- 2 mm wire-spacing compatible
- Electronics housed in a 100 x 45 mm min. section
- Possibility of pulsed supplies
- Wire-OR able outputs
- Low cost : about 60 FF per channel

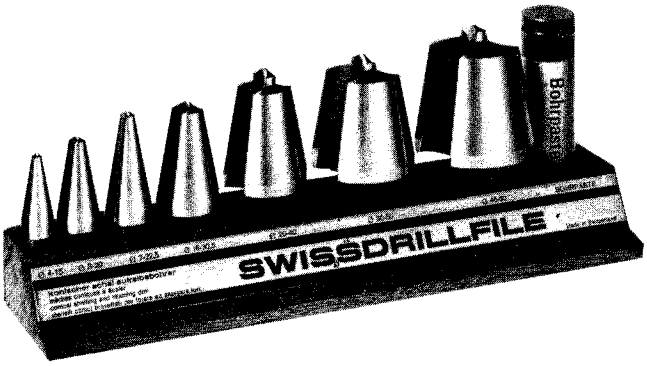
Do consult us for data sheets, application reports, delivery time, prices or any information you may need for your particular application experiment.

Write or call:

E.F.C.I.S.
85 X, 38041 GRENOBLE CEDEX
(FRANCE)
Tel.: (76) 97 41 11
Telex: EFCIS 320 226 F

Drills:

- sheet metal up to 1.5 mm ≠
- thin-walled piping
- car body sheet
- plastic sheet and tubing



For installing signalling devices, assembling instrument panels, automatic installations, fitting aerials, laying pipes and cables. For reaming out existing holes. For deburring.

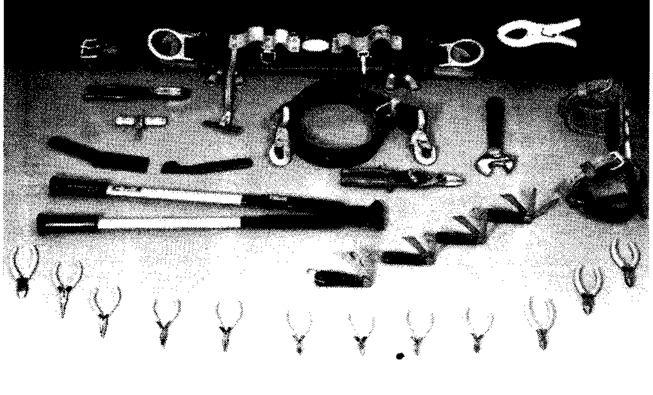
Indispensable for equipment assembly

Swiss and foreign patents

TIPSWITOOL®

Altkircherstrasse 30
P.O. Box - 4027 BÂLE/Switzerland - Tel. 061/396500

Klein Tools, Inc. KLEIN EST. 1857 TOOLS Chicago, U.S.A.



ANS 30 JAHRE
1948 Bugnard 1978

Ch. de Montelly 46
OUTILLAGE
WERKZEUGE
1000 Lausanne 20

Bugnard

(021) 257121
LAUSANNE
Télex: 25926

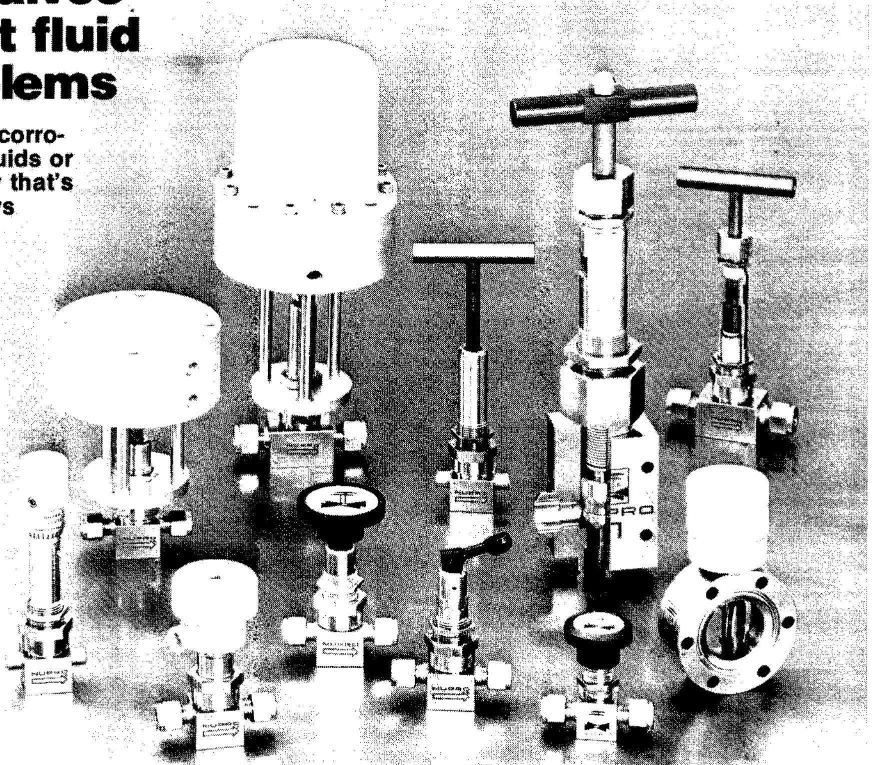
NUPRO Bellows Valves solve the toughest fluid containment problems

NUPRO Bellows Valves can handle corrosive, toxic, dangerous or expensive fluids or high vacuum with a leak-tight integrity that's available only with an all-metal bellows seal to atmosphere. They operate in a pressure range from vacuum to 2500 psi, and from cryogenic temperatures to 1500°F.

You can choose hand, toggle, micrometer or air actuation for on-off, regulating or fine metering applications. Materials are brass, 316 stainless steel and Monel.

Swagelok® end connections from 1/4" to 1/2" and weld ends from 1/4" to 1" are standard.

All models are available from local stocks to meet your needs quickly and exactly.



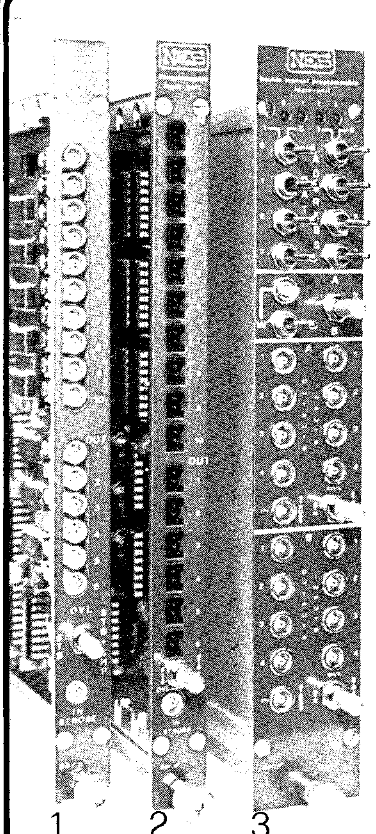
NUPRO®

KONTRON AG
ABTEILUNG PRÄZISIONSARMATUREN

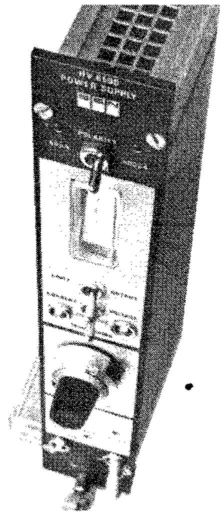
CH-8048 Zürich · Bernerstrasse-Süd 169 · ☎ 01 62 92 62
D-8057 Eching b. München · Oskar-v.-Miller-Str. 1 · ☎ (0 81 65) 7 72 88
A-1140 Wien · Ameisgasse 49 · ☎ 94 56 46

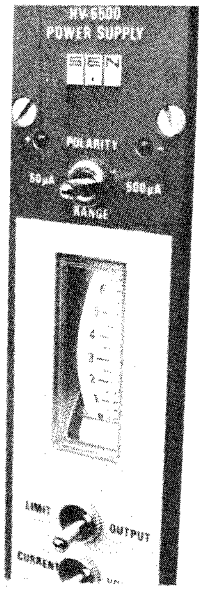
Patented

MONEL TM International Nickel
Swagelok TM Crawford Fitting Company


1
2
3

SEN introduces a new standard in multiwire and drift-chamber high voltage power supplies...



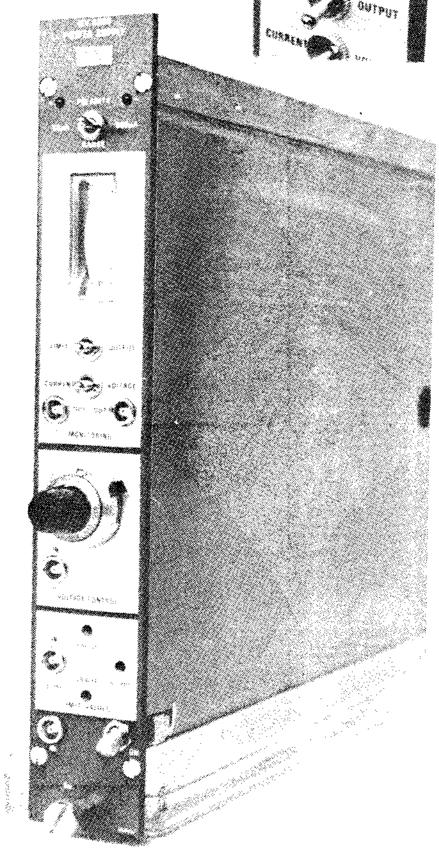


HV 6500 — HV 6350

These SEN units have been specifically designed for all types of chamber and incorporate far more comprehensive safety circuitry than is normally found in general-purpose high voltage systems.

New standards in chamber safety :

- $\leqslant$ 30 V overshoot at full load
- $\leqslant$ 5 ms dynamic response time
- $\leqslant 1.5\ 10^{-4}$ regulation
- fast trip-off on error detection
- dark current control



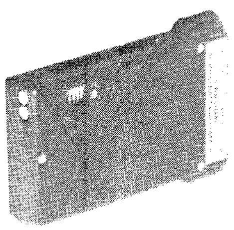
New standards in chamber monitoring :

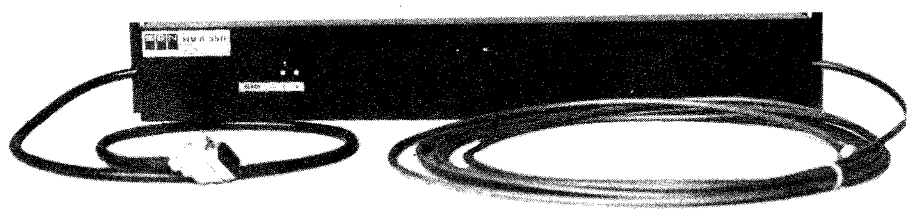
- multi-parameter control - voltage, load current and dark current, limit voltage and limit current.

- high monitoring accuracy - $\leqslant$ 0.2% on voltages, 2% resolution on dark current.

With dual range operation -0-50 μA, 0-500 μA, positive and negative 6 KV operation, these supplies are ideal for both small and large chambers.

Please contact our sales engineers for more details.





France: **ORTEC Sarl**; 7, rue des Solets; Tel. (1) 687 25 71 - Tlx 202553F, F - 94 - RUNGIS – **Germany: SEN ELEKTRONIK GmbH**; Postfach 223; Tel. 04 103 62 82 - Tlx 2189 548d, D - 2000 - WEDEL – **DIDAS Digital Data System**; Radspielstrasse 8; Tel. 089 91 67 10 - Tlx 529 167d - D - 8000 MUENCHEN 81 – **Switzerland: SEN ELECTRONIQUE SA.**; CP 39; Tel. (022) 44 29 40 - Tlx 23359ch - CH - 1211 GENEVE 13 – **SEN ELEKTRONIK AG**; Austrasse 4; Tel. (01) 945 51 03; Tlx 58257ch - CH - 8604 VOLKETSWIL – **United Kingdom: SEN ELECTRONICS LTD**; London Street; Chertsey; Tel. 9328.66744 - GB - KT168AP SURREY. – **OFFICES THROUGHOUT THE WORLD.**
Headquarters: SEN ELECTRONIQUE S.A.; Avenue Ernest Pictet 31; Tel (022) 44 29 40 - Tlx 23359ch - CH 1211 GENEVE 13.

SEN ELECTRONIQUE

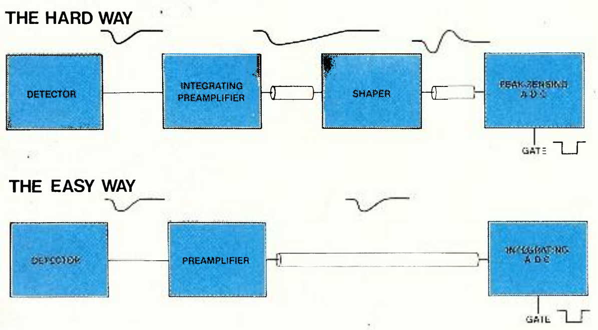
NEW

high-performance pulse preamplifiers

* low noise
* low cost
* low power
* wide bandwidth
* high gain

The monolithic TRA1000 and hybrid TRA510 are two new, high-performance pulse preamplifiers by LeCroy. These preamplifiers offer >7500 open-loop voltage gain, 20 MHz bandwidth, low power dissipation, compact packaging, and inverting and non-inverting dual outputs capable of driving coaxial or twisted cable directly. Both devices can be operated in either a charge-to-voltage mode or a current-to-voltage mode. In the current mode the TRA1000 offers <30 pA/$\sqrt{Hz}$ r.m.s. input noise contribution. For ultra-low-noise applications, the TRA510 with its FET input stage gives <3 pA/$\sqrt{Hz}$ r.m.s. input noise performance.

ideal for MWPC linear measurements and liquid argon chamber systems



Quantity	Model TRA1000	Model TRA510
>10,500	**$4.60**	**$11.90**
5,200-10,499	$4.90	$12.80
1,300-5,199	$5.30	$13.70
130-1,299	$6.00	$15.30
10-129	$6.50	$16.50
5-9	$7.30	$18.60
1-4	$8.70	$22.00

NO SHAPER NECESSARY

The exceptional low-noise performance of the Models TRA1000 and TRA510 allows accurate digitization of detector signals even without bipolar shaping. Actual tests in an experimental environment have proven comparable performance for the TRA510/Integrating ADC scheme and the TRA510/Shaper/Peak ADC scheme. The TRA510/Integrating ADC scheme not only simplifies the system, but it is especially useful for high-capacitance detectors, such as liquid argon ionization chambers, where the preamplifier signal-to-noise ratio is otherwise degraded. Used with either scheme, LeCroy's new TRA's provide high performance at low cost.

Call or write LeCroy or your nearest sales office for details.

LeCroy
RESEARCH SYSTEMS

Innovators in Instrumentation

Headquarters: 700 South Main Street, Spring Valley, New York 10977; Phone: (914) 425-2000; Offices in: Palo Alto, California; Geneva, Switzerland; Heidelberg, W. Germany; Paris, France; Wheatley, Oxford, England. Representatives throughout the world.

Get high power RF generation, switch and regulator tubes for tomorrow's accelerators and fusion machines from EIMAC today.

When combined RF power generation and high voltage switching and regulation requirements for accelerators and fusion machines develop, you need off-the-shelf power tubes—not proposals. That's why EIMAC has developed the highest power tetrode product line available for these requirements. And that's why EIMAC is dedicated to a policy of continued development of new tube materials, rf tubes, switch tubes and high power circuitry for tomorrow's requirements.

EIMAC high-current switch tubes with hold-off voltages up to 70 kV are ready right now and development of products up to 200 kV is underway.

RF power tubes with up to 1250 kW anode dissipation and cavities at 50 to 110 MHz are also available at reasonable prices from EIMAC. For example:

EXCITER → EIMAC 4CW50,000E AND CAVITY → EIMAC X-2170 AND CAVITY → 500 kW at 55 MHz

Because EIMAC is a leader in state-of-the-art high power tube development, EIMAC power tubes dominate the field of fusion power generation and related experiments in ERDA and world-wide national laboratories. For your high power needs, contact Varian, EIMAC Division, Attn: Tom Yingst, 301 Industrial Way, San Carlos, California 94070 USA. Or any of the more than 30 Varian Electron Device Group Sales Offices throughout the world.

varian