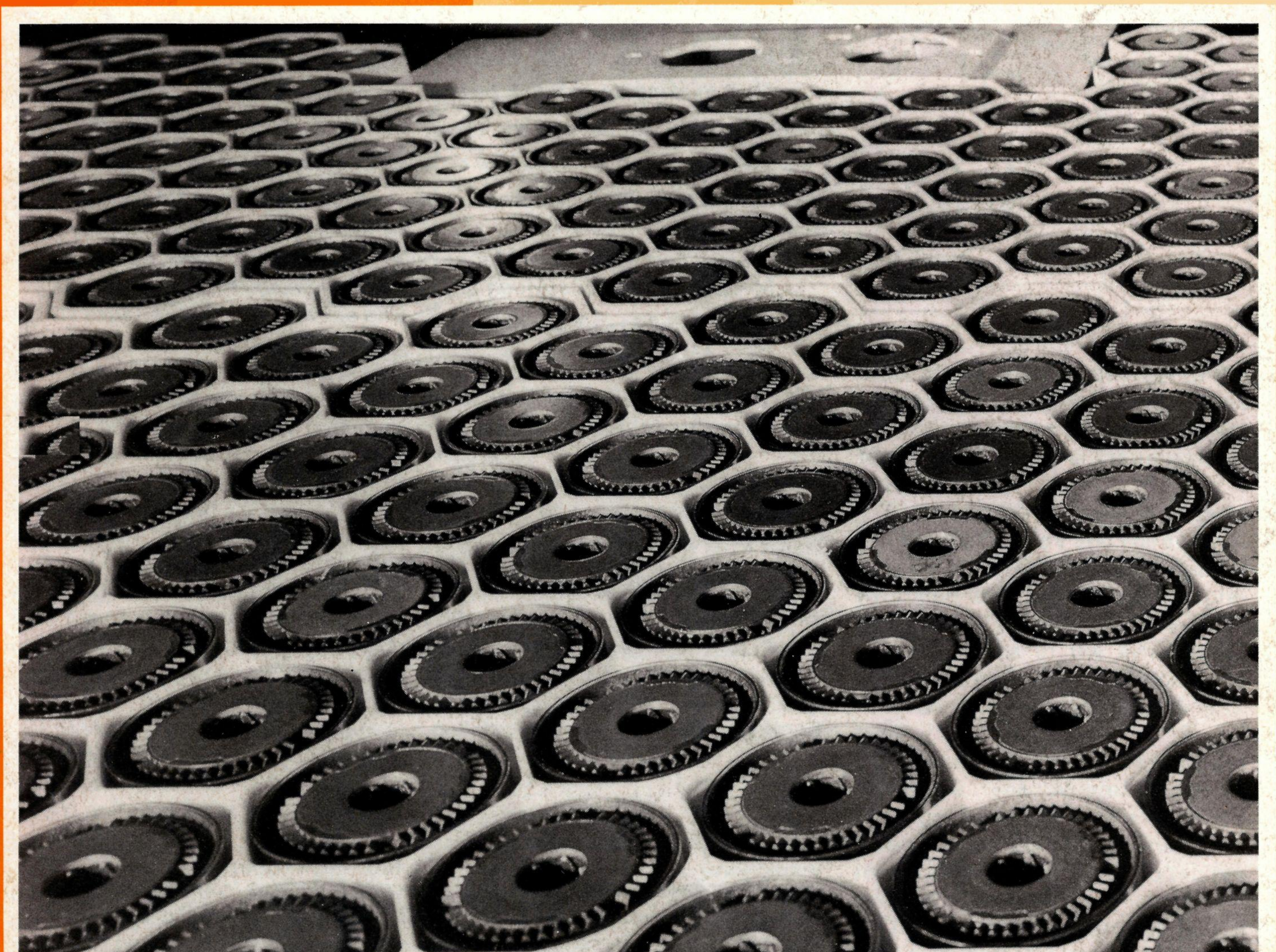
CERN COURIER

NO. 2 VOL. 19 APRIL 1979



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
P. Waloschek
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, China
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 —
Monika Wilson
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.

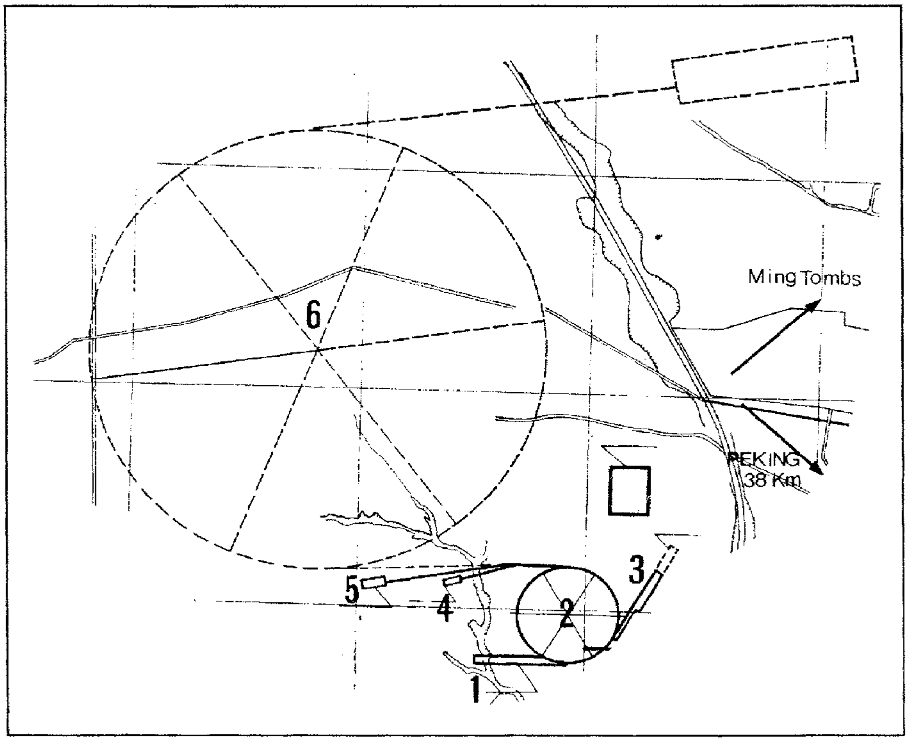
Printed by: Presses Centrales S.A.
1002 Lausanne, Switzerland
Merrill Printing Company
765 North York, Hinsdale,
Illinois 60521, USA

Published by:
European Organization for Nuclear Research
CERN, 1211 Geneva 23, Switzerland
Tel. (022) 83 61 11, Telex 23698
(CERN COURIER only Tel. (022) 83 41 03)
USA: Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510
Tel. (312) 840 3000, Telex 910 230 3233

Contents

Cover photograph: Looking rather like biscuits emerging from an oven are the magnetic tape cartridges of the IBM 3850 Mass Storage System now in regular use in the computer centre at CERN. Data is stored on these 50 Megabyte cartridges, which can be automatically transferred to disc, giving an effective on-line storage capacity of 35 000 Megabytes. (Photo CERN 349.1.79)

The proton synchrotron for China



Layout of the 50 GeV BPS on the site near Peking as it appears in the preliminary design report. 1 is the 200 MeV negative hydrogen ion linac; 2 is the 50 GeV proton synchrotron; 3 is the hall for counter experiments; 4 is the bubble chamber; 5 is the hall for neutrino experiments; 6 is the possible location of a future high energy machine.

There has been much news recently about the 50 GeV proton synchrotron to be built near Peking in China. The collaborations with our Chinese colleagues for construction of the machine are taking formal shape.

From 19 to 23 February a delegation from the People's Republic visited CERN and the groundwork r the collaboration between the Peking Institute of High Energy Physics during the machine construction period was laid. In particular, visits of Chinese scientists to CERN to benefit from the experience of CERN's specialists have been planned. Their interests will cover linac computer control, vacuum, r.f. design, radiation protection, site and services questions, and workshop planning.

To prepare for the exploitation of the machine some five or six Chinese physicists will participate in the CERN experimental programme and three or four in the Theory Division. For the future, two accelerator physicists will work on stochastic ooling and the antiproton accumu-.ator ring and several others will spend a year or more at CERN to study the design of a large accelerator to follow the 50 GeV machine.

Other collaborations in Europe are also under way. Contacts between DESY and the Peking Institute are already well developed and a number of Chinese scientists are participating in the experimental programme at the electron machines. The delegation which visited CERN was moving on for discussions at DESY, in Paris and at the Rutherford Laboratory.

The same delegation from the People's Republic visited the USA earlier this year. We reported in our March issue (page 28) the meeting which took place at Stanford on 15-19 January. Representatives from Argonne, Brookhaven, Fermilab and SLAC discussed details of collaboration at the major USA Laboratories with their Chinese colleagues.

In January Deng Xiaoping visited the USA and concluded an Agreement on scientific and technological cooperation with the American administration which was signed at the White House on 31 January. A major item in the Agreement, alongside the purchase of communications and mapping satellites was collaboration in the construction of the 50 GeV accelerator.

The machine design

At the end of 1978 a preliminary design study for a 50 GeV BPS (Beijing Proton Synchrotron — where Beijing is Peking) was produced at the Institute. After studying some twelve sites in the suburbs of Peking, a site 38 km to the north-west of the city (south-west of the location of the Ming Tombs) was selected. It has an area of 500 hectares. Road and rail communications are good.

The proposed linac injector has an energy of 200 MeV and will accelerate up to 100 mA of negative hydrogen ions, fed in from the pre-injector at 750 keV, to achieve the intensity gains in the synchrotron which are possible by stripping the ions on injection to liberate protons.

The linac will be 160 m long and will have nine Alvarez structure tanks powered by 5 MW r.f. stations operating at 200 MHz. The pulse repetition rate may be up to ten per second.

The proposed synchrotron ring is 432 m in diameter having 180 'window-frame' bending magnets with fields rising from 215 G at injection to 1.7 T at peak energy. The design beam intensity is 10^{13} protons per pulse at a pulse repetition rate of one every 4 s.

The ring will have a FODO separated function structure, including 120 quadrupoles, with six 9.7 m long straight sections. The magnets will be powered direct from the mains using a static compensator system. The vacuum in the ring will be 3×10^{-7} torr. Twenty-eight r.f. stations, each with two cavities operating at 3 to 5 MHz will give 175 keV energy per turn to the protons. Two extraction systems (one fast and one slow) will eject the protons to the experimental areas. Accelerator control will be via a system of twelve computers, one being the master computer at the control centre.

Three experimental areas are envisaged to be fed by the 50 GeV beams — a hall 150×50 m^2 for counter experiments using slow ejected beams, a bubble chamber and neutrino hall using fast ejected beams.

A proton beamline and three secondary beams (high energy unseparated beam, medium energy separated beam and low energy separated beam) plus a test beam are foreseen for the counter hall. R.f. separation is intended for the beam to the bubble chamber. The neutrino hall is some 200 m from the neutrino target to allow for parent particle decays and muon shielding.

For the future, the transport of the proton beam beyond the neutrino hall would be feasible towards a ring of 2 km diameter where energies in the 500 GeV range might be reached at some future date.

The delegation from the People's Republic of China taking a train ride around the CERN SPS tunnel.

(Photo CERN 294.2.79)

Ted Wilson, right, who has spent some time at the Peking Institute of High Energy Physics, describes the CERN synchrotron to the Chinese visitors.

(Photo CERN 281.2.79)

Hunting the weak bosons

Thanks to the very rapid development of 'cooling' techniques to control beams of charged particles, equally rapid preparations are now under way at CERN and Fermilab for proton-antiproton colliding beams. This will enable a whole new range of experiments to be carried out with a minimum of additional construction work. These projects could provide us within the next few years with important glimpses into new physics results which would otherwise only be available later with completely new machines.

With collision energies of the order of several hundred GeV available, these projects could at last bring within reach the long-awaited intermediate vector bosons of weak interactions. Several versions are expected to exist — positively and negatively charged particles (the Ws) mediating the charged current of weak interactions, and the Z^0, the uncharged particle responsible for neutral current interactions.

These particles have haunted particle physicists for the last forty years, and each generation of higher energy accelerators has failed to find any trace of them. However, with the unified theory of electro-weak interactions currently in such good shape, a confident prediction can be made of the mass of these elusive particles (see December 1978 issue, page 432).

This electro-weak theory includes a free parameter which as yet can only be determined by experiment, although more ambitious unification theories which bring in strong interactions can give a value for it (see November 1978 issue, page 399). This parameter is the mixing angle which relates the two electrically neutral electro-weak vector bosons — the photon, mediator of electromagnetism, and the Z^0.

Experiments seem to be homing in on a value for this parameter which when put into the theory places the charged and neutral vector bosons at about 80 and 90 GeV respectively, which is beyond the reach of any of the existing machines. Experimental evidence so far points to the version of the theory where the Higgs mechanism of spontaneous symmetry breaking takes the simplest possible form, although this is not yet definite and more complex Higgs mechanisms could change the predictions for masses for the weak bosons.

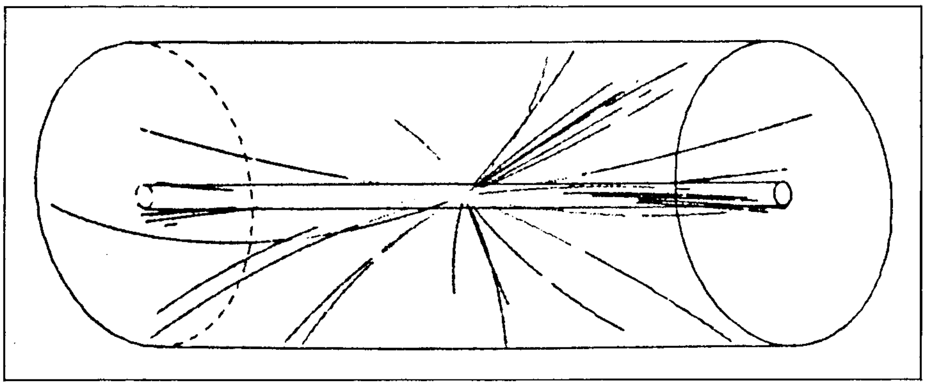
Production and decay of the weak bosons

In high energy hadron collisions, the weak bosons are expected to be produced in quark-antiquark 'fusion' processes, for example between an up quark and a down antiquark (giving a positively-charged boson), or between a down quark and an up antiquark, (giving a negatively-charged boson).

This means that proton-antiproton experiments have the advantage that the participating quarks are real valence quarks, while weak boson production in proton-proton collisions would have to rely on the rarer antiquarks from the 'sea' of virtual quarks in the nucleons. As well as giving a larger cross-section for W production in proton-antiproton collisions, this means that if the W is heavier than expected, its production will be less severely damped. The behaviour of valence quarks is also much better known than that of sea quarks, so that theoretical predictions are more confident.

However if the kinematics are such that the collisions pick up the small fractional momenta where the sea quarks tend to be found, then some of the potential advantages of proton-antiproton interactions might be lost.

The W should decay mainly into hadrons, but with about a 10 per cent branching ratio for leptonic decays producing an electron (or muon) and a neutrino. The hadronic decays are the inverse of the production mechanism, giving a quark and an antiquark coming out in opposite directions (in the rest frame of the W) to conserve momentum. Rather than emerging as free particles, these quarks would produce back-to-back jets of hadrons, characterized by a limited amount of transverse momentum relative to the jet axis.



Computer simulation of a high transverse momentum event in the central detector of the UA1 experiment for the proton-antiproton collider at the CERN SPS. This and its UA2 counterpart will be ready to catch the first fragments produced by the colliding beams to search for signs of the elusive intermediate bosons of weak interactions.

In the decays of the W, there are parity violating terms at work. For Ws produced in proton-antiproton collisions, this would make for marked asymmetries in the angular distributions of the emerging charged leptons and provide a valuable signature of W decay.

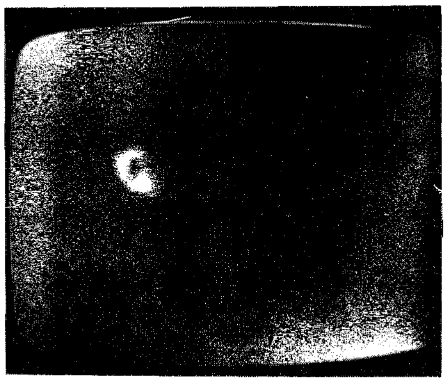
While leptonic decays would provide the main evidence for the existence of the weak bosons, study of the more copiously produced hadronic jets could provide valuable additional information.

Hadronic decays of the Z would also produce back-to-back jets, similar to those now seen in electron-positron annihilations. The tell-tale production of lepton pairs is expected to occur with a branching ratio of about five per cent, and could be expected to show up as a narrow enhancement. Thus the Z, produced singly, could be more evident than the Ws, produced in pairs.

The discovery of these intermediate vector bosons would rate as one of the great triumphs of modern physics, rivalling closely the saga of the neutrino, where the suspense between theoretical prediction and experimental discovery lasted nearl thirty years.

Around the Laboratories

A significant signal in the history of the development of superconducting magnets for use in accelerators: a screen at Fermilab records the successful transmission of a proton beam through a sector of twenty-five Energy Doubler superconducting magnets under the Main Ring.



FERMILAB
Protons through Doubler sector

On 1 February a proton beam extracted from the Fermilab main ring was successfully transported through a five hundred foot string of energy doubler magnets. By the next test on 1 March the operation was so well in hand that the first pulse injected into the Doubler segment was transported cleanly to the end of the magnet string. Beams of more than 10^{13} protons per pulse have now been transported through the system.

The twenty-five magnet test is one step in the Energy Doubler sector test that is being carried out at Fermilab. In the full scale sector test, a 'super period' of energy doubler magnets will be installed. In the present test a fast kicker in the transfer hall long straight section deflects the proton beam into two Lambertson magnets. These bend the beam down into the Doubler magnets twenty-five inches below the main ring. A short segment of conventional magnets matches the system into the doubler operating around 100 GeV.

At a long straight section, one sixth of the way around the ring, the beam will later be deflected back into the main ring. In principle this arrangement could permit coasting beam in the hybrid doubler-main ring combination. In practice the 'double dogleg' perturbation may limit the number of turns.

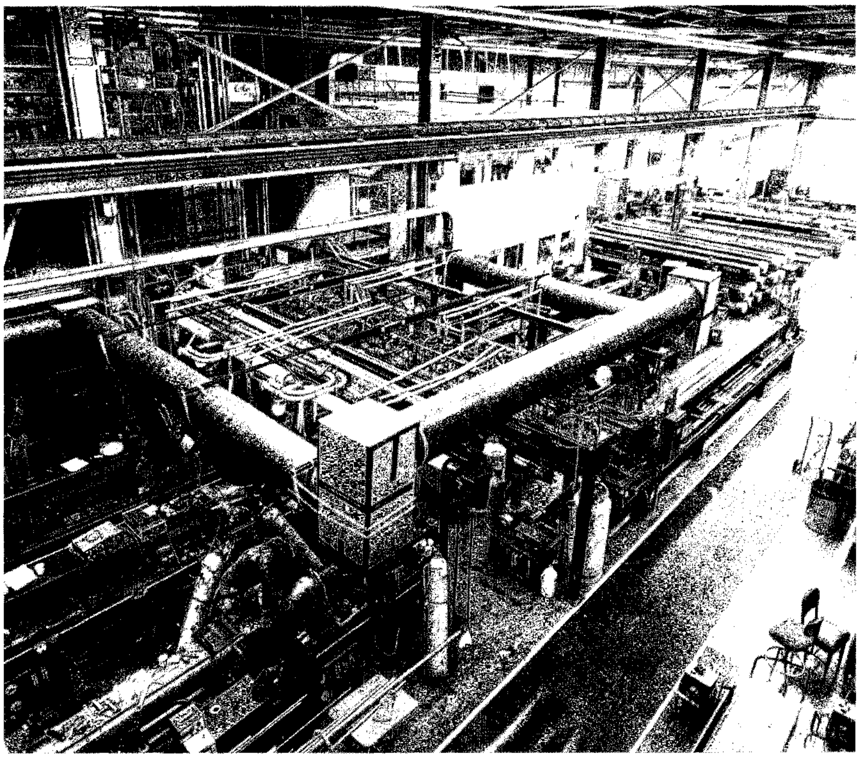
The present segment consists of twenty bending magnets and five quadrupoles. The magnets are early Doubler prototypes that will ultimately be used in the experimental areas. The system is cooled by one satellite refrigerator system operating at a fraction of its final load. The refrigerator is presently able to cool the magnet string down from nitrogen temperature in forty-eight hours.

The cryogenic and vacuum systems are operating quite well. No trim magnets are installed along the superconducting segment and one power supply is driving the entire chain, so that the beam is a 'one knob' device. Sensitive parallel plate position monitors are installed after each quadrupole for beam sensing.

During initial tests a few beam-induced quenches occurred in the first and second dipoles because the liquid helium level in the magnet cryostats was low at the time. What was particularly encouraging was the rapid recovery from these quenches. A 30 s 'time-out' period had been programmed into the system and, after the quench, the

The Magnet Test Facility at Fermilab for the production and testing of superconducting magnets for the 1000 GeV Energy Doubler. All the test stands are now in action. Completed magnets can be seen stocked at the top right of the picture.

(Photos Fermilab)



system was immediately superconducting at the end of the period. In the recent tests it has been possible to put more beam into the system without inducing quenches, so that straightforward magnet tuning and injections were possible.

The twenty-five magnet segment was installed last fall. A great deal has been learned about practical Doubler construction, particularly in checking out the vacuum. The first cooldowns began in December and initially took a week as the bugs were shaken out of the system. The magnet chain was superconducting for the first time on 21 December. Then on 1 February beam was successfully transported to end of the line.

The present segment will be studied through the spring. The installation of forty to fifty more magnets is envisaged during the summer and a refrigerator is already in place and operating to cool these additional magnets.

Test of superconducting magnets

During January, Fermilab successfully tested two superconducting magnets in the beam transport line to the Meson Laboratory. The magnets performed satisfactorily at their 400 GeV field levels with a proton beam of more than 1.8×10^{13} particles per pulse from the accelerator being extracted along the line.

The results of the test give increased confidence in the plans for transporting 1000 GeV protons to the experimental areas when the Energy Doubler comes into operation. They also indicate how operation may proceed during acceleration in the Doubler.

The Doubler will accelerate protons to 1000 GeV and the beam must be extracted, split into three portions and transported to the three experimental areas. The existing transport lines have to be upgraded with superconducting magnets to raise their energy to 1000 GeV. For example, in the Meson line fifty-six of the present conventional magnets in the left bends to the Meson Laboratory will be replaced with twenty-two superconducting magnets like those being built for the Doubler. The tests in January go a long way to demonstrating that this energy enhancement is possible in practice.

The system that has been in operation consists of two superconducting magnets (sandwiched between four conventional trim magnets), two hundred feet of superconducting transfer line (carrying liquid helium and current to the two magnets) and a satellite refrigerator system. The fields in the two superconducting magnets were opposed so that no net bend was introduced in the beam.

Roger Dixon, head of the Fermilab switchyard group, reports that even with beam losses higher than usual for normal operation, the magnets did not quench. Several quenches were induced by the beam during tuning but the systems recovered immediately so that little time was lost. Estimates indicate that stray beam losses of several times 10^{11} protons per pulse did not induce quenches. These losses are substantially larger than normal due to the 'dogleg' path of the protons through the magnets (because of the opposed fields).

The system has been operated with 350 GeV beam and approximately 400 GeV fields provided by 1500 to 2000 A currents in the superconductor demonstrating that 400 GeV beamlines can be built with Energy Doubler magnets. Earlier tests in the Proton Laboratory suggest that it takes about one fifth as much beam loss to quench magnets at 1000 GeV field as at 400 GeV field. Since no upper limit on beam intensity was found at 400 GeV, the results are encouraging for 1000 GeV operation. Tests at higher fields will follow.

Bubble chamber ups and downs

Late last year, the Fermilab 15 foot bubble chamber was filled for the first time with liquid deuterium, with 29 m³ of liquid coming from Argonne and 8.5 m³ from Brookhaven. Picture taking in the broad band neutrino beam began on 10 November 1978. The accelerator was run at 350 GeV in order to enable two experiments at an upstream location along the neutrino beamline to collect data with reduced muon backgrounds..

It was established earlier that toroids installed as part of the muon shielding would not permit planned compatible operation of the upstream experiments with the chamber at 400 GeV. These toroids reduced the upstream backgrounds but concentrated muons on the bubble chamber, which was unacceptable to both the external muon identifier and the chamber. A reduced accelerator energy of 350 GeV was therefore chosen.

However, the neutrino interaction rates remain essentially the same over a period since the accelerator cycle has been shortened. One of the advantages of the new operating mode is that cycle times during day and night are the same.

The run for experiment E-545 was highly successful despite extreme weather conditions. It ended one day early on January 16, with a total picture count of 328 000. This happened just after the 'Blizzard of 1979' when one crew was on duty for 24 hours because snow-clogged highways prevented their reliefs from reaching the Laboratory. December was marked by a new calendar month record of 174 136 pictures, with the accelerator reliability, the seven second repetition rate and the continuously available neutrino horn and targeting contributing to the result. An average of near 1.5×10^{13} protons per pulse was recorded on the neutrino target, resulting in a total flux of about 4.9×10^{18} protons for experiment E-545. The background on the pictures and refrigeration load were somewhat higher than for hydrogen operation.

On 21 January, shortly after the start-up of the deuterium-filled chamber on 19 January for experiment E-390, the chamber piston stuck in the down position and the run was terminated.

When the piston was removed, a somewhat dented stainless stee cap was found on its top. This ca was one of fifteen covering the bolts which secured the E-564 emulsion boxes (see October 1978 issue, page 346).

A week was required to remove the piston. The shaft and shaft housing were damaged in two areas. Present understanding is that the cap caught between the piston and the chamber, bending the shaft enough to touch the shaft housing. The two stainless steel surfaces continued to rub together and eventually they stuck.

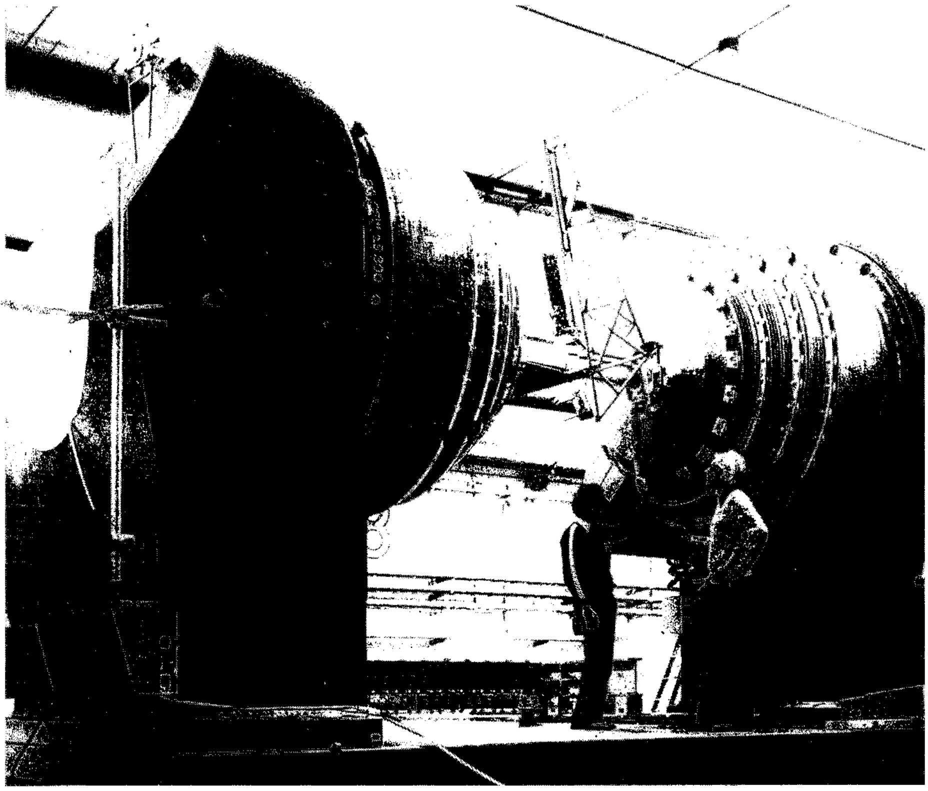
Repairs to the damaged shaft and housing are expected to take over two months, and hopefully the big Fermilab 15 foot bubble chamber will soon be back in action for neutrino physics.

Leon Lederman, Russ Huson and Phil Livdahl showing Senator Adlai Stevenson (second from right) a superconducting Energy Doubler magnet during his visit to Fermilab in January. Senator Stevenson is one of the two senators from the Fermilab host State of Illinois.

(Photo Fermilab)

The 300 ton Open Axial Field Magnet for the forthcoming experiment at the CERN Intersecting Storage Rings by a CERN/Copenhagen/Lund/Rutherford collaboration to study deep inelastic proton-proton and proton-antiproton collisions.

(Photo CERN 358.1.79)



CERN Action at Intersection 8

Thanks to continual technical improvements, the luminosity in the CERN Intersecting Storage Rings (ISR) has progressively increased and is now many times the original design value. In addition, further increases in interaction rates are possible by using quadrupole magnets to compress the beams in a single intersection region. At Intersection 1, a system of classical quadrupoles installed in 1974 boosts the particle density in the vertical direction by a factor of 2.3.

Still higher compression of the beams in an intersection region can only be achieved using superconducting magnets with high magnetic fields. After successful construction and operation of such a quadrupole at CERN, the decision was taken to proceed with the construction of a full superconducting high-luminosity insertion for intersection 8, to contain eight quadrupoles.

Besides the physics interest of high luminosity, this project is also the first attempt to use superconducting magnets in the beam guiding system of an operating storage ring. Also the construction of eight magnets to tight specifications by industry is a significant technological challenge in its own right.

The eight quadrupoles will be capable of producing gradients of 43 T per m over a diameter of 173 mm, so accommodating the normal ISR vacuum chamber and its bakeout jacket. Four of the magnets will have a magnetic length of 1.15 m and the remainder 0.65 m. All will be equipped with additional sextupole and dodecapole windings. To provide an additional means of control, two conventional quadrupoles are to be installed in adjacent sections of the inner ISR beam pipes.

The conductor in the main coils is a rectangular solid composite wire 1.8 × 3.6 mm^2, containing about 1250 50 μm diameter twisted niobium-titanium filaments inside a copper matrix. Two full scale prototype magnets have operated repeatedly and reliably at a gradient of 45 T per m with a current of 1680 A and a maximum field of 5.8 T. They showed no retraining after repeated warmups and cooldowns.

The insertion will reduce the effective beam height in the diamond-shaped interaction region by a factor of about six, with a corresponding increase in particle luminosity.

The first magnet has been delivered, assembled in its cryostat and tested, with satisfactory results, and the fully equipped insertion should be ready for physics in 1980.

Now also taking shape at Intersection 8 of the ISR is the impressive apparatus for an experiment by a CERN/Copenhagen/Lund/Rutherford collaboration to study highly inelastic collisions where particles may be produced at very wide angles and at energies beyond the range of existing electron-positron storage rings.

As well as looking at the normal proton-proton interactions in the ISR, the experiment will also run with the colliding proton-antiproton beams soon to become available (see March edition, page 14). Results from this experiment could supply vital new information to increase our understanding of quark behaviour.

Using a big new magnet, a cylindrical drift chamber, large Cherenkov counters and a 200 ton uraniumscintillator calorimeter, the apparatus will be able to analyse wide angle production of both charged and neutral particles over a large range. The event rate at this intersection will be increased by the new superconducting high luminosity insertion (described above).

An integral part of the apparatus is the large 300 ton Open Axial Field Magnet. Specially designed and built for the experiment, it produces a magnetic field suitable for the momentum analysis of particles produced at wide angles with a minimum of target material blocking the particles. This will make it possible to identify and study particles even outside the volume of the magnetic spectrometer and clear of the confusion of secondary interactions.

The experimental programme will have two phases, reflecting the two special features of the apparatus. Emphasis will first be placed on particles with high transverse momentum identified by the three layers of Cherenkov counters. These cover a larger solid angle and energy range than in previous storage ring experiments, and allow pions, kaons and protons to be identified from 1–15 GeV.

Powerful trigger logic and special processors allow selection of events with a high transverse momentum particle of specified type, while the remainder of the associated hadron jet can be studied in the magnet and calorimeter. The calorimeter can also be used to select jets of a specified transverse momentum in an unbiassed manner free of any dependence on the topology or nature of the event.

Given the new kinds of information available from these measurements, especially the ability to compare proton-proton and proton-antiproton events, more should be learned about the quark constituents of the proton and their gluon interactions. For example, quantum chromodynamics predicts dramatic changes in the behaviour of high transverse momentum antiproton production in the ISR energy range, and these predictions need to be verified. Also the identification of kaons and electrons will be useful in charm studies.

In the second phase of the experiment, the complete azimuthal coverage of the calorimeter will allow rare multiparticle states to be studied. Here the wide solid angle coverage and the high event rates from the high luminosity insertion play a special role.

One example of such rare events would be the production of new mesons above 20 GeV, observed through dilepton or hadronic decays and supplying possible evidence for new heavy quarks. The angular coverage allows searches for events with three hadronic jets or other unusual configurations which supply information about the quark/gluon interactions.

The jet studies will complement similar work at the SPS and future measurements at the proton-antiproton collider at the SPS, so that eventually a full picture can be built up of the change in behaviour in hadronic reactions over a very wide energy range.

Concrete progress towards LEP

One of the problems confronting the designers of LEP, the Large Electron Positron storage ring which is Europe's high energy physics project for the future, is to produce low magnetic fields around a huge circumference reliably and economically.

Builders of proton machines design their magnets for the highest magnetic fields they can reliably attain so that, for a given peak energy, they can build as compact a ring as possible — saving tunnel and service distribution costs. Builders of electron machines design their magnets for low magnetic field so that they can have as large a bending radius in the ring as is feasible and economically acceptable, to reduce the energy loss due to synchrotron radiation.

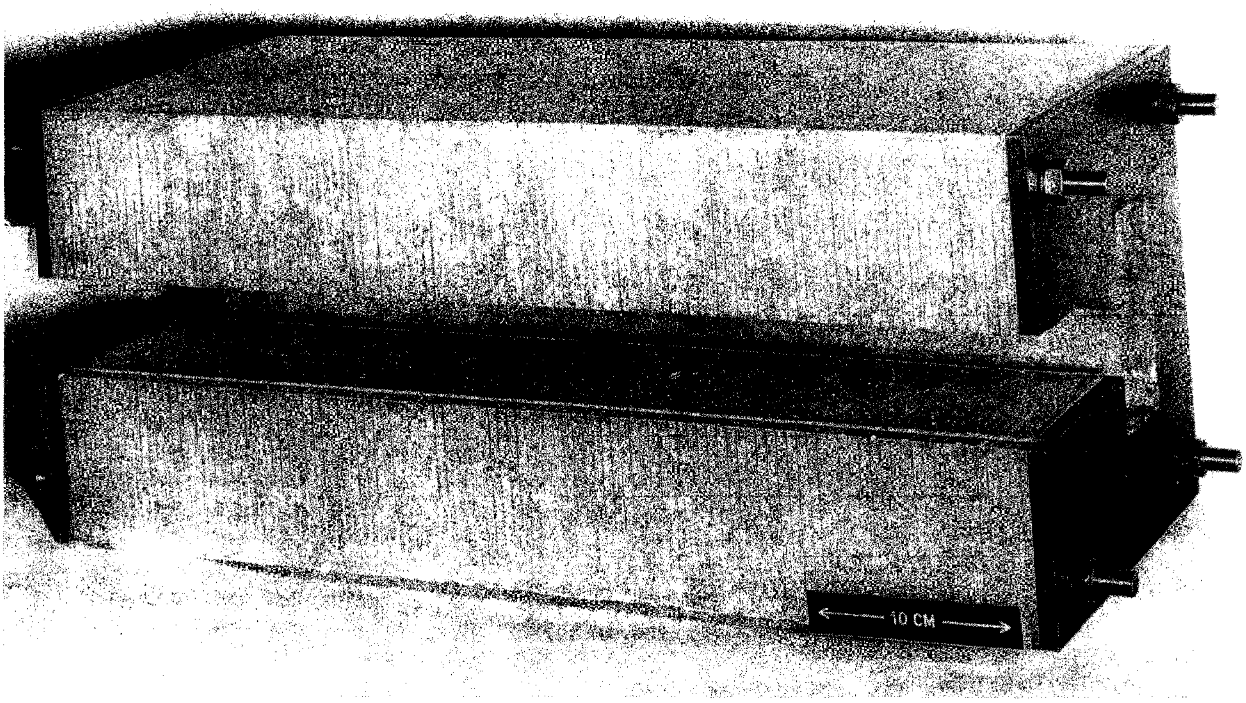
For LEP, where it is hoped to reach energies in the 100 GeV range, the energy loss will be very high and will have to be made up by pouring power back into the circulating beams via the r.f. cavities. The larger the LEP ring can be made, the less the power demand on the r.f. cavities (or conversely, given an available peak r.f. power, the higher the beam energies can be taken).

But a large ring implies very low bending fields, particularly at the injection energies, and magnets have to be built to provide this without being troubled by such things a remanent fields. To give some feasi ble parameters — an injection energy of 20 GeV into a 10 km diameter ring would require fields around 0.02 T (200 gauss) rising to around 0.12 T for a peak energy of 120 GeV.

The work on LEP magnets at CERN has recently had some very encouraging results with a novel type of magnet using concrete to separate the laminations in the magnet core. Jean-Pierre Gourber had the idea of spreading the laminations out so that, although the field in the gap is at the desired low level, the field in the laminations is higher by a factor which is the ratio of the total thickness to the lamination thickness. This reduces the impact of low field effects. To keep costs down the inter-lamination material must be

The model magnet for the LEP project using concrete in the core to spread the laminations. The tested properties of the model are very encouraging.

(Photo CERN 337.1.79)



cheaper than the laminations themselves. Lorenzo Resegotti had the idea of filling the interlamination spaces with concrete which also acts as a binding agent in the core. Concrete has been used successfully before in coil insulation but not, so far as is known, in magnet core construction.

A model C-magnet has been made 60 cm long, 24 cm high and 25 cm wide. It has laminations 1.5 mm thick separated by 4 mm of concrete. Indentations in the laminations ensure correct spacing in the lamination stack while the concrete is poured and longitudinal bars help the rigidity of the structure. Fairly straightforward methods were used in building the model and further refinements, such as pouring under vacuum, different concrete mixes and pre-stressing, could be used if they lead to significant gains in quality.

Nevertheless, mechanical tests on the magnet showed it to be adequately resistant to bending and shearing stresses and many times more rigid than its conventional all-steel equivalent.

Field quality is as good and the lamination periodicity does not appear in the field in the useful region of the gap above the level of one part in 10^3. The magnets are about half the weight of their steel equivalents.

Costs will depend upon the detail of the construction technique which is finally selected but, if the assembly does not cost more than the assembly of a conventional magnet, the costs will be about halved compared to a conventional magnet.

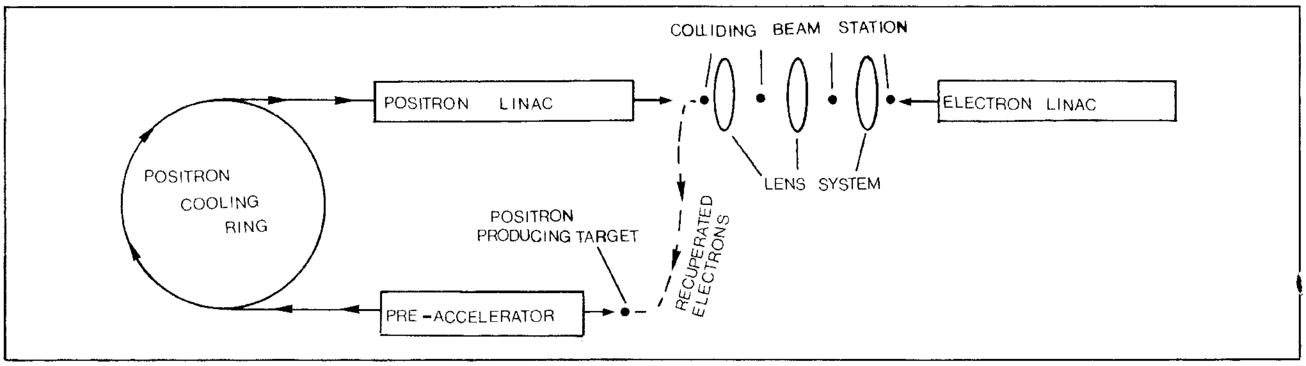
A full scale model of this novel design of magnet is being built and is expected to be ready for its tests about the middle of this year.

Colliding linac beams

As pointed out above in the CERN article on the new model magnet for the LEP project, circular electron and positron machines have a hard time at high energies because of the power which has to be fed to the beams to compensate for synchrotron radiation losses. Because of this, several people have been thinking in recent years about the feasibility of using two linacs to achieve electron-electron or electron-positron collisions at energies beyond the LEP range by firing the linac beams at one another.

Among the thinkers have been Maury Tigner from Cornell, A. Skrinsky from Novosibirsk and Ugo Amaldi from CERN, who considered a scheme which he entitled 'Peloron' for Positron and Electron Linear Oscillator Radiating Only

A scheme for colliding beams at extremely high energies from electron and positron linacs. The major problem of achieving adequate positron intensities is envisaged to be solved by the recuperation of the surviving electron beam to generate positrons which would be fed to the positron linac via a pre-accelerator and cooling ring.



Negligibly (it is also the Greek name for an object of huge dimensions).

The subject came up again at the 'Workshop on Accelerator and Detector Possibilities and Limitations' held at Fermilab in October of last year under the auspices of the International Committee for Future Accelerators (see November 1978 issue, page 390).

At that Workshop a Working Group, under John Rees of SLAC, emerged with some more knowledge about a phenomenon they termed 'beamstrahlung' which occurs when two very high energy electron and positron bunches pass through one another. Just as an electron emits synchrotron radiation when it passes through the electromagnetic field of a magnet, so it emits synchrotron radiation when it passes through the electromagnetic field of a bunch of positrons. The Working Group estimated that beamstrahlung could start to be troublesome in the operation of an electron-positron storage ring above energies of some 200 GeV per beam.

Whenever this beam-beam limit sets in, it seems clear that at some very high energy a storage ring will no longer be a viable system for electron-positron colliding beam physics. This is an inducement to dream about colliding linac beams. Also, the scaling laws of the two systems dictate that at some point linacs should win out on storage rings. For a given luminosity, the power requirement in a linac is independent of energy while in a storage ring the power is proportional to the energy.

These considerations, however, prejudge whether colliding linac beams is a feasible proposition. In a storage ring the beautiful symmetry of the electron and positron behaviour as they travel around the ring ensures that two bunches will be brought into collision. With two linacs this symmetry does not exist.

Can 'jitter' in the system be held to acceptable limits? Will phase space degradation be a problem? Some feel for the answers to this type of question should come from studies on the properties of the electron beam emerging from the SLAC linac which are to be carried out by Roger Miller, Burt Richter and Ray Steining. Can sources be improved to give an adequate number of particles in a single bunch? At present some 4×10^9 are obtained at SLAC and some 10^{10} to 10^{11} would be needed. Would unwanted transverse deflecting modes then appear in the linac? Can sufficiently intense positron beams be built up?

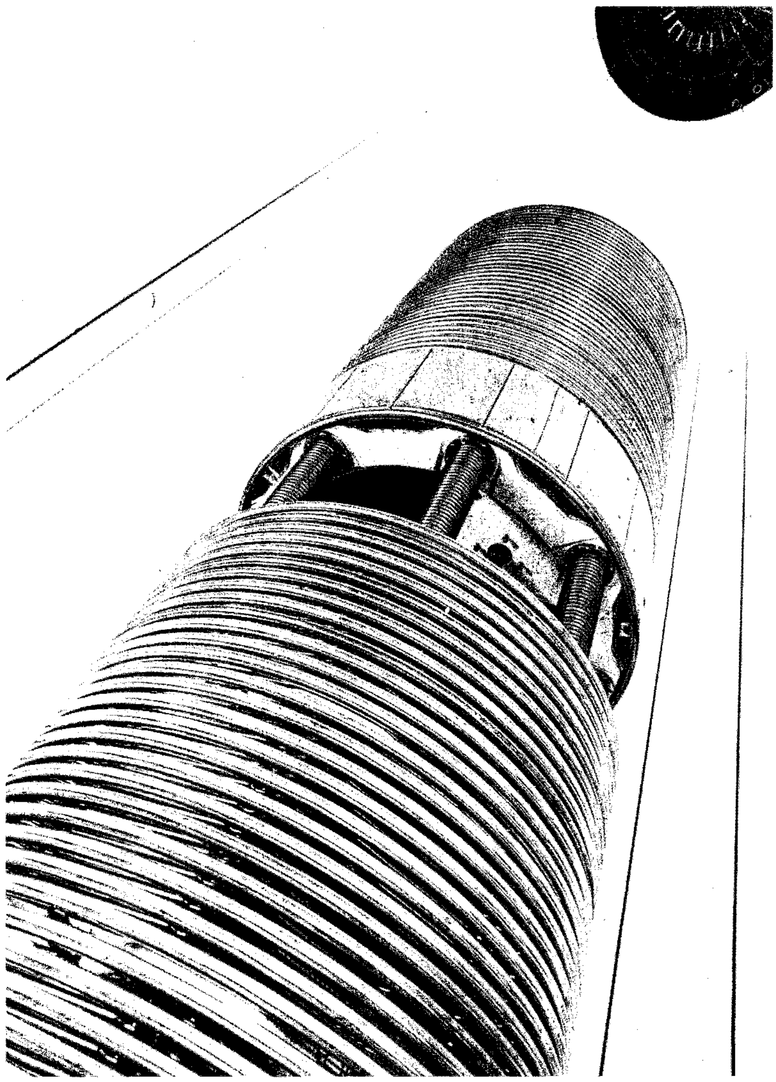
A conceptual scheme for colliding linac beams, due to Burt Richter, is shown in the diagram. It has two multi-hundred GeV linacs firing electron and positron beams at one another. Several colliding beam stations in series might be possible with interleaved lens systems. The positrons are 'thrown away' but the remaining electrons are recuperated to generate more positrons which are preaccelerated and fed to a cooling ring where synchrotron radiation damping would help achieve an intense beam of adequate quality. This would be the input to the positron linac and the process repeated.

If the potential physics still looks interesting and if Nature gives kind answers to the above questions, a system like this might be built some time next Century.

DARESBURY
NSF climbs the tower

Considerable progress has been made on the construction of the world's largest tandem Van de Graaff Nuclear Structure Facility being built at the Daresbury Laboratory. The buildings which house the accelerator and the associated experimental equipment have been completed and installation of sections of the accelerator within the giant pressure vessel housed in the 70 m high tower is well advanced.

The tandem is designed to work with a terminal voltage of up to 30 MV. By stripping electrons from



Inside the NSF tandem pressure vessel at Daresbury looking up the high voltage column. The vessel top is 30 m above the column which is at present 12 m high. Several of the glass support legs can be seen; they will be covered by the polished stainless steel hoops to form a smooth structure. The polished doors cover a 'dead section' in which vacuum pumping and beam diagnostic equipment are housed.

(Photo Daresbury)

the accelerated ions within the machine, 'tandem' operation is obtained and the machine can produce output energies ranging from 60 MeV for protons up to almost 1 GeV for uranium ions. The output energy will exceed, by a considerable factor, that available at present tandems where the terminal voltage is limited to 14 MV. For heavy ions in particular this will open up a new field of research using the high quality beams typical of this type of accelerator.

The completion of the building has been delayed by approximately two years and there has been a consequent slippage in the rest of the construction programme. Now that this phase is completed, it is expected to keep to the revised programme. The basic high voltage structure of the tandem should be built by the end of this year. Commissioning, which involves a series of high voltage tests on the column, intershield and accelerator tube, will be carried out in 1980 and the production of the first beam is scheduled for early in 1981.

The high voltage column has been manufactured and assembled entirely at Daresbury. It is a 2.2 m diameter 42 m high modular structure made from glass insulators and steel strengthening members. It has now been built up inside the main accelerator pressure vessel to a height of 12 m and further sections are being added. Installation involves the use of special techniques to minimize the mechanical stresses in the glass. Parts of the column contain vacuum pumps and beam handling equipment and two of these sections, completely fitted out and commissioned, have already been installed.

The first instalment of the 100 tonnes of sulphur hexafluoride has started to arrive from Italy and is being put into liquid storage. The plant used to transfer this gas to and from the main vessel is being commissioned using a computer control system — the first to come on-line in the project.

The machine will be controlled by a number of small computers connected together by CAMAC data links. Specially designed 5 MHz infra-red links will be used to reach the isolated sections of the high voltage column. Already the system has proved extremely useful in testing and commissioning the hundreds of valves and monitoring points throughout the gas plant. Work on other parts of the facility such as the ion sources and the injection and analysing systems is progressing well.

For some years a research and development programme has been carried out at Daresbury into various aspects of tandem design. Test machines including a 10 MV single ended Van de Graaff have been used to develop many new techniques. One of the most successful has been the laddertron inductive charging system. A commercial version of this is now being marketed by High Voltage Engineering Corporation under licence from Daresbury. The new electrostatic accelerators in Italy, Nigeria and China will be charged in this way and a laddertron has recently been installed in the tandem at Orsay, France.

Currently under development are accelerator tubes and stripper foils. Tube design has achieved clear advances and foil work, carried out in collaboration with AERE Harwell, has given an order of magnitude enhancement in foil lifetimes with promise of further improvement.

On the experimental physics side, with all the first round proposals selected and the apparatus approved, most of the equipment is now on order. There will be eight beamlines, three for gamma ray correlation experiments, one for a magnetic spectrometer, one for a general purpose scattering chamber, one for a charged particle recoil separator and two for an on-line isotope separator facility.

The data acquisition system for the experimental programme is off to a very good start. Six GEC 4070 computers which form the local network have been in operation in the NSF Control/Counting Room for some time and programming is proceeding well. These computers are linked to the main IBM 370 on site and links will be provided to the Users at a number of Universities. Particular attention has been paid to developing special CAMAC to provide the good interactive displays which are so important in nuclear physics research.

SIN
Operation of the cyclotron

The accelerator of the Swiss Institute for Nuclear Research was designed to deliver a 590 MeV proton beam of 100 μA for the production of intense fluxes of mesons. It consists of two cyclotrons, a sector-focused injector of conventional design, accelerating high intensity proton beams to 72 MeV, and a separated-sector ring cyclotron continuing acceleration from 72 to 590 MeV. The injector can also be used separately as a variable energy machine for protons up to 75 MeV and deuterons up to 65 MeV as well as for other particles.

The machine began operation in 1974 and since then the performance has steadily improved. At present it operates reliably at 100 μA.

Beam losses at high energies are appreciably lower than originally anticipated because the ring cyclotron runs with high stability in the separated orbit mode (providing almost complete extraction of high quality beam) and the beam quality from the injector has been considerably improved.

Present performance

The accelerator reached its design goal in December 1976 and now delivers a continuous 100 μA beam of 590 MeV protons to two consecutive meson production targets. All primary and secondary beams in the main experimental hall are operational. During the shutdown which ended in March 1979, the beamline to a new medical target was installed. Building of a second high intensity injector has started.

In routine operation 110 to 120 μA c.w. are obtained from the injector with an extraction efficiency of 90 to 92%. The 72 MeV beam is 'cleaned' by a system of emittance defining slits and an energy slit scraping some 1 to 3 μA off. An adjustable beam splitter also allows 3 to 7 μA to be sent to an isotope production target.

At injection in the ring cyclotron less than 0.1 μA is lost and transmission and extraction efficiency is between 99.5 and 99.9%. A first thin target (6 mm beryllium or carbon) causes a loss of 3 to 5% of the beam up to the second thick target, where beams of about 100 μA are now routinely available for secondary beam production.

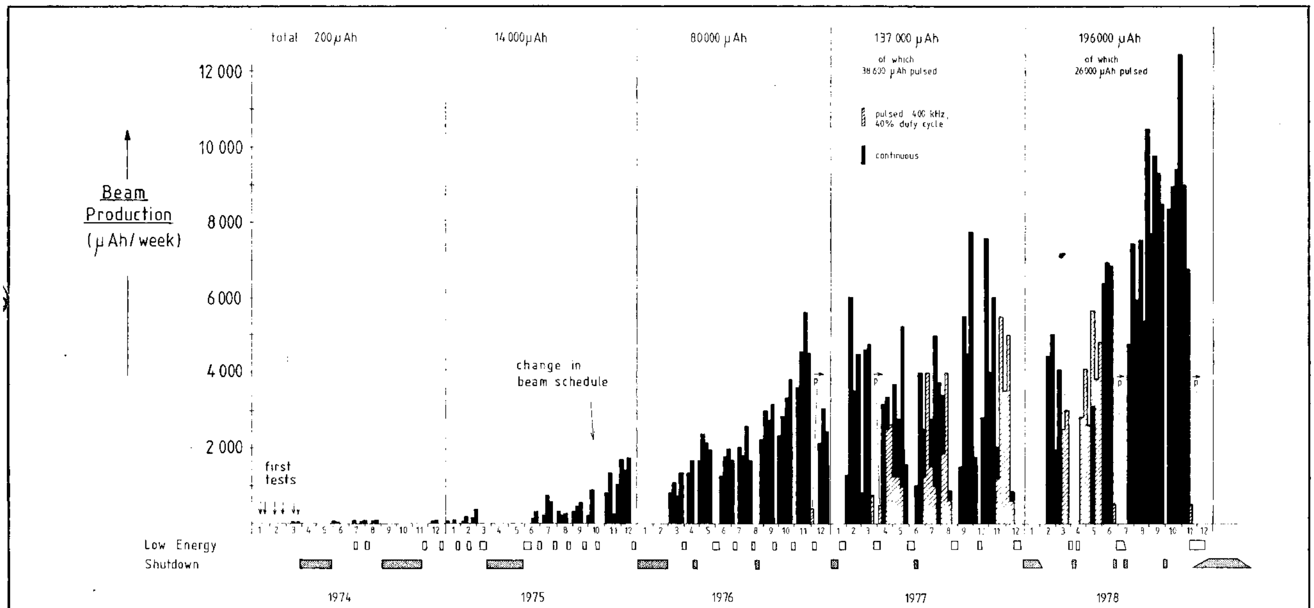
Recent increases in beam production per week (used as a figure of merit for the experimental use) are not only due to the increase of beam intensity. A reduction in machine development time, as well as time for beam set-up and training, increased the high energy beam time to more than 130 hours per week.

Even though the demand on high energy beam time is still increasing, the injector is committed to low energy nuclear physics and isotope production for 25% of its total beam time. There is regular isotope production for 4 to 6 hours per week and a large fraction of the low energy beam periods has been devoted to polarized proton and deuteron beams at various energies.

Stable 100 μA beam

Many features of the ring accelerator are important in providing high intensity beam with low losses. Probably the most significant is that the ring cyclotron can operate reliably in the separated orbit mode allowing single turn extraction. When a coherent radial betatron

Diagram reflecting improvements in the performance of the cyclotrons of the Swiss Institute for Nuclear Research since the meson factory came into operation in 1974.



Achieved

Beam Time (hours per week)	30	50	55	85	85 - 90	90 - 100	90 - 130 h/w
Availability (% of scheduled)	39	44	51	74	80 - 90	89	85 - 95 %
Intensity (operational, μA)	2 - 4	5 - 8	10 - 15	15 - 20	20 - 60	40 - 80	60 - 100 μA

oscillation with an amplitude of 2.5 mm is introduced in the beam at injection, the last beam revolution is clearly separated from the previous revolution and can be picked off by an electrostatic deflector. This operation mode requires highly stable magnetic field and r.f. voltage and phase. The injected beam must have small emittance and energy spread and (in the absence of flat-topping of the accelerating voltage) a rather narrow pulse width.

For stable operation, signals from non-interfering beam phase probes at different beam locations are used which compare the beam pulse passage with the r.f. master oscillator. These signals can be used in an automatic feedback, via a control computer, to stabilize the magnetic fields of the injector and ring cyclotron to 1 part in 10^6. The correct timing at ring injection is achieved by a comparison between these probe signals. At 11 radial positions the isochronism within the ring cyclotron can be observed and corrections are possible via trim coils.

To obtain the required beam quality from the injector cyclotron was not easy. Already in 1976 an effort was made to reach high extraction efficiency. Vertical beam collimation near the centre improved the extraction rate from typically 70% to 85%. Since there is strong coupling between beam phase and vertical focusing near the machine centre it was possible to find empirically the right combination of phase slit position (and opening) and d.c. voltage on the deflecting plates to obtain a coherent vertical beam oscillation where particles of undesired properties were clipped off at low energy. The extraction rate was thereby pushed up to 90% or more.

However, to obtain high intensity, the ion source had to be run at maximum output (near the present limits of the arc power supplies). Changes were made in the filament assembly and the anti-cathode, using lanthanum hexa-boride, which brought about 80 μA while still keeping the extraction efficiency around 90%.

To meet the beam time schedules, no risk of lowering the extraction rate in favour of higher external currents could be taken, especially until a complete spare unit of a septum was available. (A newly built septum burned out in Spring 1978.) A significant improvement was achieved recently by a small change of the ion source extraction geometry — the 'useful' output of the source at given arc power increased by about 30%, depending on filament conditions. This effect is not understood and investigations, taking into account space charge effects, are continuing.

The flat-topping cavity has been tested successfully and will be installed during the present shutdown. First tests with beam are imminent.

The 'pion therapy applicator' is nearing completion with the superconducting coils being made. Assembly and technical tests of the coils will take place in the Summer and tests with beam are expected in the second half of the year. First operation will be for experiments on dosimetry and radiobiology and treatment of patients may start in 1980.

In Spring 1978 the Swiss Government approved construction of Injector II to give higher beam currents. The building construction programme has started, the main magnets are ordered and model work on the r.f. accelerating structure has achieved good results. A prototype resonator and r.f. power generator have been designed and ordered.

In order to increase the 590 MeV beam intensity into the range of a few mA, the r.f. power of the ring cyclotron must be increased and this is being investigated. Last, but not least, the feasibility of having a spallation neutron source at SIN, using this high intensity proton beam, is being considered as part of the long term improvement programme.

Radioisotope production

The Swiss Institute for Nuclear Research is well-known for its pioneering efforts in Europe in the use of pion beams for cancer therapy (see for example, the September issue 1977, page 285). The new facility for this purpose is nearing completion and dosimetry and radiobiological trials should start in the Summer.

Another contribution in medicine, which is less well-known but becoming of increasing importance, is the large-scale production of radioisotopes at the injector cyclotron for use in medicine. This work is helped by the proximity of the Swiss Federal Reactor Institute, where expertise in radiochemical handling is essential in the collaborative effort between the two Laboratories.

At present, work is concentrated on the routine production of iodine-123, which has increased in significance in nuclear medicine in recent years. Only a few accelerators are able to produce this valuable isotope regularly, in large quantities and with high purity.

Among over thirty radioactive iodine isotopes, only three (123, 125 and 131) find applications in medicine. They bind easily into bioactive molecules and are particularly useful for thyroid diagnosis. Iodine-131 (at present the most commonly used for in-vivo diagnostics) can be produced economically in nuclear reactors. However, being a beta emitter of rather long half-life, it places a relatively high radiation load on the thyroid. Iodine-125 emits only low energy photons, has a sixty day half-life and is not suitable for imaging deep-seated organs.

The physical properties of iodine-123 make it almost ideal for in-vivo studies. It is free from beta emission, has a 13.2 hour half-life and a favourable gamma energy. Organ imaging with this nuclide can be done with far less deposited dose than for iodine-131 and so is especially useful for diagnosis during pregnancy and for children. The soft, almost monoenergetic, gamma radiation is easy to shield, reducing the doses received by medical personnel. The short half-life reduces radioactive waste disposal problems at the hospitals. These advantages are diminished if there is iodine-124 and 125 contamination — hence the importance of high purity samples.

Many reactions can be used in producing the isotope. The relatively high proton energy (72 MeV) from the SIN injector allows the use of the reaction where iodine-127 with a proton gives xenon-123 (and five neutrons) which rapidly decays to iodine-123 via beta emission. This has a high yield and the highest purity yet obtained (less than 0.5% activity percentage). Other isotopes are easily separated away and the production of a gaseous product (xenon) allows an on-line target to be used.

Work on routine production started in 1971 and concentrated on the irradiation apparatus, the target and isolation techniques. The first few millicuries were produced in December 1974 and regular weekly production of Curie quantities was achieved by Summer 1975. Four hours per week of injector beam are devoted to production of this isotope. Subsequent chemical separation is carried out at the Reactor Institute and, after processing into suitable radiopharmaceuticals, the end products are used at hospitals the next day.

In an attempt to increase weekly production without disturbing the physics programme, a new parasite facility was commissioned after the Spring 1978 shutdown. This consists of an electrostatic beam splitter which separates 5 to 10% of the beam coming from the injector. The target consists of a small stainless steel box containing 10 g of pure sodium iodide, from which the xenon which is produced is continuously carried away by helium gas.

With this facility and short exposure times (two to six hours), yields of approximately 25 mCi per μAh have been achieved with low (0.1 to

0.2%) iodine-125 contamination. A recent twelve hour exposure with 4.3 μA of protons scraped off the main beam produced 1.13 Ci.

An entirely new facility on a large scale is under construction in conjunction with the new high intensity injector project. It will have three irradiation stations fed by about 100 μA of 72 MeV protons continuously peeled off the injector beam. This will enable SIN, in collaboration with the Reactor Institute, to produce well over 10 Ci of high-purity iodine-123 daily.

A development programme has been started to produce other medically interesting isotopes such as indium-111, xenon-127, bromine-77. The new injector will allow this work to be extended to the short-lived 'biological' isotopes carbon-11, nitrogen-13 and oxygen-15 which are expected to open new applications in medicine.

More on muon research

As a by-product of the study of muonium chemistry in liquids, the ETHZ / Mainz group (M. Camani, F.N. Gygax, E. Klempt, W. Rüegg, A. Schenck, H. Schilling, R. Schulze and H. Wolf) have determined the magnetic moment of the positive muon with a precision of ±0.9 ppm, compared with the previous most precise result (±1.4 ppm). They stopped muons in liquid bromine where they are expected to form a diamagnetic molecule. To take full advantage of the high muon stopping density, a stroboscopic method was used based upon observing the positron rate in time windows controlled by the r.f. of the SIN machine.

About 10^{10} muon decays were detected. Earlier determinations of the magnetic moment used μSR studies in water where the ultimate precision was limited by uncertainties concerning the chemical environment. For the SIN experiment pure bromine was used and only one molecular species containing the muon was formed. A small water contamination is always present and care was taken to correct for this. The final result for the ratio of the muon to proton magnetic moment was measured as 3.1833448(29) (±0.9 ppm).

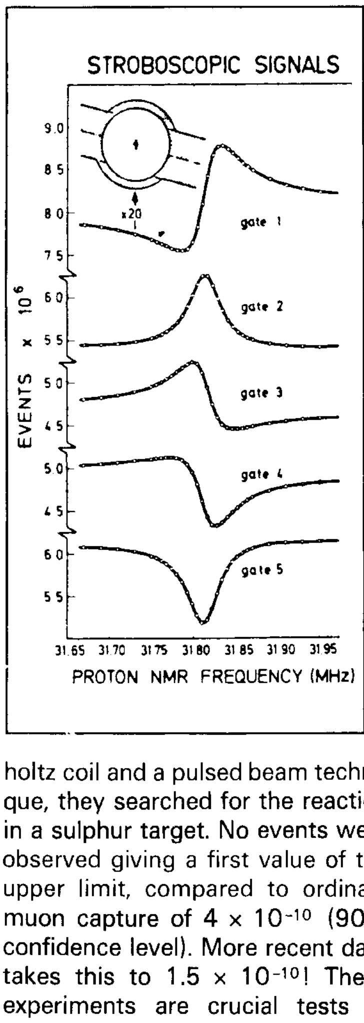
Muon physics

High muon beam intensities allow more precise evaluation of the properties of the muon itself, like the magnetic moment and its rare or 'forbidden' decay modes. The latter subject is of particular current interest because in the framework of unified gauge theories of weak and electromagnetic interactions, many theoreticians predict rare decay rates, which are measurable at the new meson factories such as SIN.

An ETH Zürich / Zürich / SIN group (H.P. Povel, W. Dey, H.K. Walter, H.J. Pfeiffer, U. Sennhauser, J. Egger, H.J. Gerber, M. Salzmann, A. van der Schaaf, W. Eichenberger, R. Engfer, E. Hermes, F. Schlepütz, U. Weidmann, C. Petitjean and W. Hesselink) recently established a new upper limit for the muon decay to an electron and a gamma of 1.1×10^{-9} an improvement of more than a factor of ten over the previous limit.

Another experiment is that of a Bern group (A. Badertscher, K. Borer, G. Czapek, A. Flückiger, H. Hänni, B. Hahn, E. Hugentobler, A. Markees, U. Moser, R.P. Redwine, J. Schacher, H. Scheidiger, P. Schlatter, G. Viertel) searching for muon-electron conversion on nuclei which is not allowed by the ordinary lepton scheme. Using a streamer chamber coupled to a superconducting Helmholtz coil and a pulsed beam technique, they searched for the reaction in a sulphur target. No events were observed giving a first value of the upper limit, compared to ordinary muon capture of 4×10^{-10} (90% confidence level). More recent data takes this to 1.5×10^{-10}! These experiments are crucial tests of the muon number nonconservation which can be incorporated in a natural way in the latest developments in gauge theory.

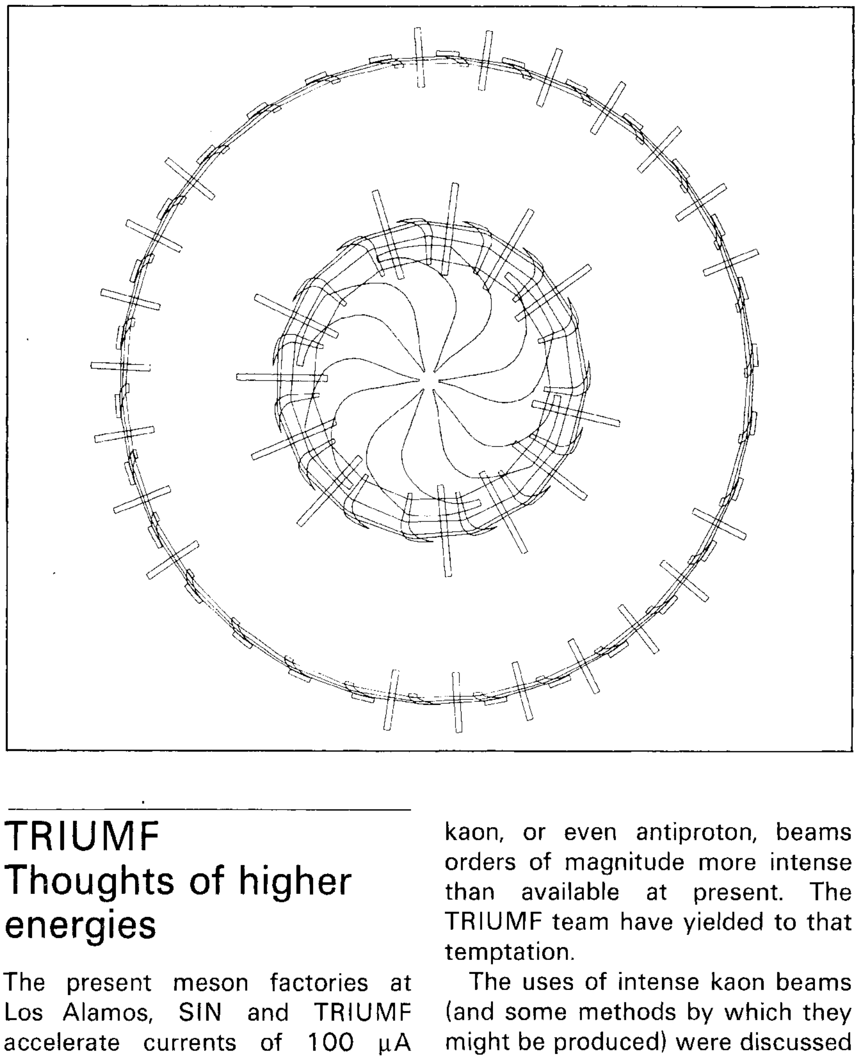
Stroboscopic signals from an ETH Zurich/ Mainz experiment which has used an elegant technique to determine the magnetic moment of the muon to better than one part in a million.



In our coverage of muonium chemistry developments last month (see page 23), the first direct observation of muonium in a liquid should have been credited to the Zurich/ ETH group of P.W. Percival, H. Fischer, M. Camani, F.N. Gygax, W. Rüegg, A. Schenk, H. Schilling and H. Graf.

This was the first stage in a programme of liquid phase muonium chemistry.

Sketch of a possible kaon factory design for TRIUMF, using 3 GeV and 8 GeV (the outer ring which has a radius of 20.7 m) isochronous ring cyclotrons with superconducting magnets and SIN-style cavities. The 520 MeV cyclotron magnet poles are drawn to scale at the centre for comparison.



TRIUMF Thoughts of higher energies

The present meson factories at Los Alamos, SIN and TRIUMF accelerate currents of 100 μA (6×10^{14} protons/s) or above to energies of 500 to 800 MeV with the primary aim of producing intense fluxes of pions. These currents are several hundred times larger than those accelerated into the GeV range by proton synchrotrons, whose intensities are limited by their injectors and the problems of injection into the synchrotron rings.

It is, therefore, tempting to consider the possibility of using the meson factories as injectors for higher energy machines which would accelerate 10 or 100 μA to many GeV with the aim of producing kaon, or even antiproton, beams orders of magnitude more intense than available at present. The TRIUMF team have yielded to that temptation.

The uses of intense kaon beams (and some methods by which they might be produced) were discussed at the 1976 Brookhaven Summer Study Meeting on 'Kaon Physics and Facilities'. Topics of interest in particle physics include rare decays of strange particles and the negative kaon-nucleon interaction and, in nuclear physics, include positive kaon – nucleus scattering (because of its weak absorption), kaon reactions (which could yield $S = -2$ nuclei) and neutral kaon regeneration on nuclei. Improved statistics would also benefit the studies of kaonic and hyperonic atoms and hypernuclei. Intense beams of other particles would also be available (nucleons, pions, muons and neutrinos) and kaon decay provides a possibly unique source of electron-neutrinos of moderate energy.

At LAMPF, since the proton linac is a pulsed machine, thinking has centred on a fast-cycling proton synchrotron as a second stage. At TRIUMF, on the other hand, where the cyclotron runs c.w., two options are being considered to accelerate a 30 μA beam to 8 to 10 GeV — a fast cycling synchrotron or a two-stage isochronous ring cyclotron.

In the case of the synchrotron, the main problem is to match the time structure of the two new machines; the synchrotron would be pulsed at 20 Hz, while the existing 500 MeV cyclotron operates c.w. at 23 MHz. The most promising solution seems to be the extraction of hundred turn stacks from TRIUMF because it would provide an intermediate pulse frequency.

The beam would be allowed to drift 90° out of phase at 450 MeV, after which it would begin decelerating back toward the centre of the cyclotron (this behaviour has already been observed). The outermost fifty accelerating and fifty decelerating turns, which would be located in a 25 mm wide radial interval, could then be extracted in one bunch 0.44 μs long by pulsing an axial electric field. The repetition period would be 22 μs, corresponding to fourteen synchrotron turns.

200 macropulses per synchrotron cycle would be adequate to achieve an intensity of 2×10^{14} protons per second (32 μA), assuming 400 μA in the present cyclotron. This machine in turn could act as injector to a high intensity 40 GeV synchrotron.

The alternative proposal is for a two-stage isochronous ring cyclotron to accelerate protons to 8.5 GeV. (Isochronous cyclotron designs for several GeV have previously been considered by L.A. Sarkisyan of Moscow State University and M.M. Gordon and H.G. Blosser of Michigan State University.) Since there would then be no incompatibility in time structure, the full beam current from the present cyclotron (400 μA eventually) could, in principle, be injected into the ring machines.

The first stage, of 15 sectors and 10 m radius, takes a 450 MeV beam from TRIUMF to 3 GeV and then a second stage, of 30 sectors and 20 m radius, completes the acceleration to 8.5 GeV. Superconducting magnets are used, the weight of steel being estimated to be 2000 tons for the first stages and 1800 tons for the second, less in total than in the present 500 MeV machine.

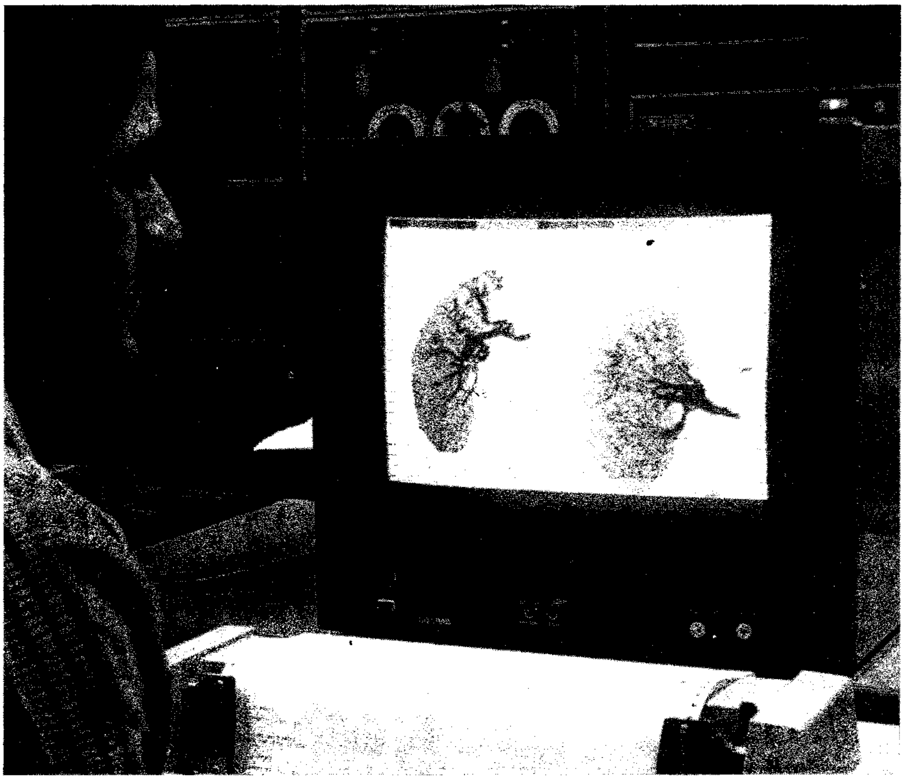
Numerical orbit tracking through simulated magnetic fields has confirmed that the focusing properties of the design are satisfactory. Several integer and half-integer radial resonances are crossed but, with a high energy gain per turn 3 MeV and 8 MeV respectively), this should cause no difficulty.

The most difficult technical problem is to extract the beam efficiently. Here again the high energy gain per turn is important and resonances help in exciting coherent radial oscillations. The accelerating system consists of SIN-style cavities, with flat-topping provided by operating some at the second harmonic (first stage) or third harmonic (second stage).

These possibilities were reported at the 8th International Conference on Cyclotrons at Bloomington, Indiana, in September 1978. Both designs are very much in their preliminary stages; during the coming year they will be looked at in depth to assess the feasibility of submitting a formal proposal.

Display showing in a single view the time of arrival of a contrast-medium to different points of a human kidney. A healthy kidney is shown on the left and can be compared with a diseased organ on the right.

(Photo DESY)



DESY Computer angiography

High energy physics requires advanced computer technology and an interesting application of these techniques was found in the field of 'angiography' — a method used in medicine to view blood-vessels in X-ray pictures by means of contrast media. In conventional radiological diagnosis, a sequence of images is inspected visually and the result is strongly dependent on the skill and experience of the physician. A great deal of the information contained in the pictures is not accessible and can get lost.

DESY and the Faculty of Medicine of the University of Hamburg have already carried out several joint research projects. These have led to the development of new methods for clinical chemistry and nuclear medicine and to the creation of a specialized Institute of Mathematics and Informatics at the University Hospital of Hamburg-Eppendorf. Now a collaboration has been working on a computerized method for angiographic analysis.

Each X-ray view is decomposed into 64 000 picture-elements (pixels) of 8 bits each. For each element, time dependent parameters are computed and stored for subsequent display. This can be done in black and white in which case the intensity (grey) shows the value that is being looked for. The process is much clearer in colour, because colours can then be made to represent the different values. This makes diagnosis much easier since characteristic colours for healthy organs are easily remembered. The brightness (or colour) in the produced picture is no longer a measure of the

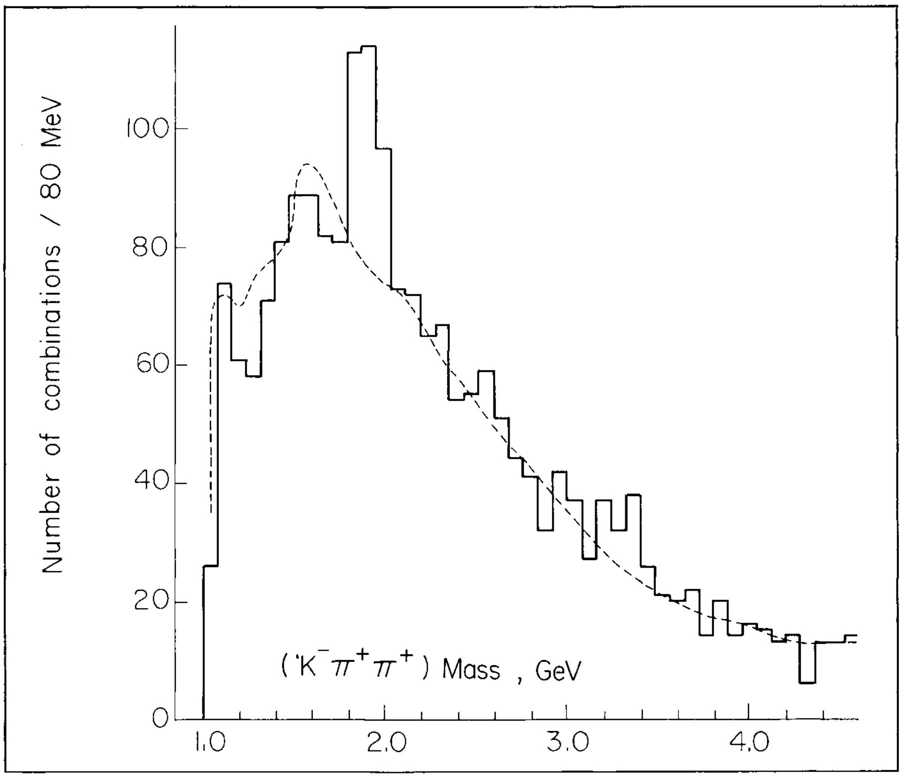
Physics monitor

transparency of the organ but represents a computed dynamical parameter. Another advantage is the absence of background or device-dependent inhomogeneities in the new picture.

Though the principle is quite simple — particularly if compared with flying-spot-digitizing and pattern-recognition in particle physics — its development (especially to achieve the processing speed needed) has required considerable technological effort.

The system has been specially prepared for quick diagnostic purposes. The hardware unit can be attached to a standard colour television set and could become quite popular among radiologists. The special purpose hardware unit (including a real-time digitizer for video images) and the software developed by the group, performs the analysis of 128 X-ray pictures in four minutes providing four functional images. It is used directly on-line with X-ray standard equipment and will now be tested under hospital conditions.

Evidence for charm production in proton-proton collisions from a CERN/Collège de France/Heidelberg/Karlsruhe collaboration working at the CERN Intersecting Storage Rings. Selecting those events where the $K\pi$ effective mass corresponds to the $K^*(890)$, the $K^-\pi^+\pi^+$ combination, which has 'exotic' quantum numbers, shows a clear signal at 1868 MeV. This peak is not seen in $K^-\pi\pi$ combinations with conventional quantum numbers.



Charm from hadron collisions

Ever since the discovery of charmed mesons in electron-positron annihilations at SLAC and DESY, a considerable effort has gone into looking for them in other types of reactions. Both neutrino interactions and photoproduction have provided further data on the production and decay of D mesons, but little has emerged concerning purely hadronic studies.

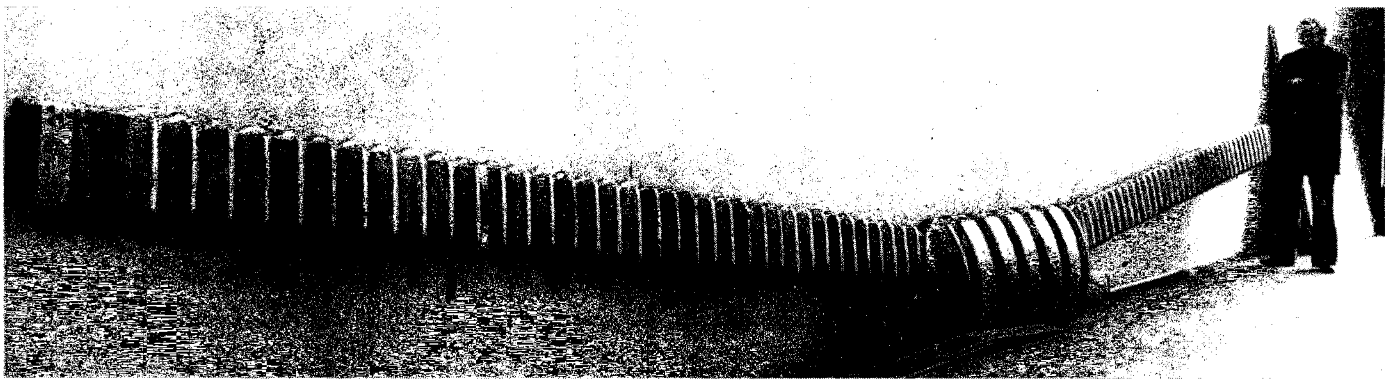
At the Tokyo Conference (see September 1978 issue, page 284), this led rapporteur Bob Diebold to remark that the study of charm production in hadron collisions looked confused, but he hoped that the situation would soon sort itself out.

On this optimistic note, some results from a CERN/Collège de France/Heidelberg/Karlsruhe collaboration using the Split Field Magnet at the CERN Intersecting Storage Rings (ISR) now show definite signs of D meson production in proton-proton collisions.

The experiment was carried out at a centre-of-mass energy of 52.5 GeV, and particle production events were selected by triggering on a negative particle coming out in the forward direction with a transverse momentum larger than 0.5 GeV. A gas-filled Cherenkov counter distinguished between produced pions and kaons, enabling mass spectra to be obtained for kaons plus one or two pions.

After preliminary selection procedures, these spectra show no evidence for enhancements in the D region (1868 MeV). However experiments at SLAC and DESY seem to show that a significant amount of semi-leptonic D decay proceeds through an intermediate K*(890), *Taken out of position, the vacuum chamber from the Split Field Magnet at the CERN ISR still provokes contemplation.*

(Photo CERN 169.2.79)



and it is conceivable that a similar significant K* contribution is present in the hadronic decay of the D into a kaon and two pions.

The $K\pi\pi$ mass spectrum was then re-examined under the condition that the mass of at least one of the two possible $K\pi$ pairs falls inside the K* region. After this selection is made, a definite enhancement is seen in the D region. The peak becomes even more pronounced when additional kinematic cuts are imposed.

The enhancement only appears in the $K^-\pi^+\pi^+$ mass combination. Such a positively-charged, negative strangeness state cannot be explained by the old three quark model, and is said to be 'exotic', while other $K^-\pi\pi$ combinations correspond to more conventional quantum number assignments.

The fact that the peak is only seen in the exotic channel indicates that the signal is genuine. The observed width of the peak is compatible with the mass resolution of the experiment.

Subtraction of background shows that a total of about ninety D production events are seen. However an absolute measurement of the cross-section for D production is difficult because it requires model-dependent assumptions for the production process.

Still there

According to the standard quark model, hadrons are built up from small numbers of fractionally charged constituents — the quarks. This model has been highly successful in explaining the observed proliferation of hadrons, and evidence for small constituents deep inside nucleons has now been seen in a whole range of experiments (see January/February 1978 issue, page 7).

However no convincing signs of free quarks liberated from nucleons have been seen, though several experiments have held up tantalizing results. For example, two years ago a Stanford University group reported fractional charges in niobium (see May 1977 issue, page 154).

These experiments used an updated version of the technique originally developed by R.A. Millikan to measure the charge on the electron. While Millikan used d.c. fields and oil droplets from an atomizer, the Stanford experiments use a.c. fields and superconducting techniques. Now after further painstaking work at Stanford, these fractional electric charges — in exactly the one-third units of electronic charge predicted by the standard quark model — are reported to be still there.

In the experiment, tiny superconducting spheres, about 0.01 cm diameter, are made to oscillate by an alternating electric field. These oscillations depend on the charges on the spheres, which are some multiple of the electronic charge, possibly with an additional 'residual' value.

These residual charges could be simulated by small dipole forces and the experimental technique has been improved to allow for such dipole effects. This increases the probability that the vestigial charges of one-third are genuine.

Such quark-type charges were detected on several of the tiny spheres. Also it was found that these charges were affected by electrical discharges in the apparatus, and could be removed by subsequently scrubbing the spheres with acetone. The physicists assert that this is a result of the fractional charges being near the surface of the spheres.

Current theoretical dogma says that quarks are perpetually confined inside hadrons, but this has yet to be proved. Some attempts have been made to construct approximate confinement schemes and, depending on the quark mechanics of these models, it is possible that matter containing free quarks might tend to have a definite chemical behaviour. This could be an explanation of an observation of fractional charges in niobium, but nowhere else.

People and things

Chris Llewellyn-Smith, recipient of this year's Maxwell Prize from the UK Institute of Physics.

On people

Following the resignation of Harold Agnew as Director of Los Alamos Scientific Laboratory, Robert N. Thorn, Associate Director for weapons at the Laboratory, has been named Acting Director. Dr. Thorn, at Los Alamos since 1953, received the E.O. Lawrence Memorial Award in 1967 for his work in nuclear physics.

Some changes in the UK Science Research Council: As from 1 September Godfrey Stafford will become Director General of the combined Rutherford and Appleton Laboratories. Geoff Manning will take over as Director of the Rutherford Laboratory. In the SRC Central Office Tony Eggington is now Director responsible for the Science and Engineering Divisions, Harry Atkinson has been appointed Director for the Astronomy, Space and Radio and Nuclear Physics Divisions and Jack Beattie has been appointed Head of the Science Division.

Among the recipients of this year's awards by the UK Institute of Physics are T.G. Pickavance, formerly director of the Rutherford Laboratory, who gets the Glazebrook Prize for his contributions to the construction and utilization of large particle accelerators in the UK and the rest of Europe; Don Perkins of Oxford who receives the Guthrie Prize for his work in cosmic ray and elementary particle physics; Chris Llewellyn-Smith, who is awarded the Maxwell Prize for his contributions to high energy theory, and C. Cohen-Tannoudji of the Collège de France, Paris, who receives the Thomas Young Prize for his work on the interactions of photons with atoms.

Radiation Course

A third course is being organized from 16-26 September at Erice, Sicily, under the auspices of the International School of Radiation Damage and Protection, devoted to 'Advances in Radiation Protection and Dosimetry and Medicine'. It will be of interest to those involved in the use of ionizing radiation for the diagnosis or treatment of disease.

The advances of the past decade in radiological physics and health physics aspects of radiotherapy will be described. Advances in diagnostic techniques (CT scanners) and treatment planning using conventional radiation (photons) will be discussed and the application of new radiation (neutrons, protons, pions, heavy ions) described. Special emphasis will be placed on dosimetry and the protection of patients and staff.

Further information is available from Victor Perez-Mendez or Ralph Thomas, Lawrence Berkeley Laboratory, University of California Berkeley, CA 94720. For registration, contact A. Rindi, Fisica Sanitaria, Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, Casella Postale 13, 00044 Frascati, Italy.

Users Annual Meeting

The Fermilab Users Organization will hold its Annual Meeting at Fermilab on 28 April 1979, following the international symposium in honour of Robert Wilson. The agenda and other information regarding the meeting will be sent to all members after the March meeting of the Users Executive Committee.

Kaon Factory Workshop

A two day 'Kaon Factory Workshop' will be held in Vancouver, 13-14 August 1979, in conjunction with the 8th International Conference on High Energy Physics and Nuclear Structure. The Workshop will cover both the practical design of machines to produce intense beams of kaons and other hadrons, and their physics potential. Further information can be obtained from M. K. Craddock, 8-ICOHEPANS Secretariat, TRIUMF, The University of British Columbia, Vancouver, B. C., Canada V6T 1W5.

Cadmium monitors

In the November 1978 issue, page 402, we reported on the mobile unit of the Medical Department at Brookhaven which uses a neutron irradiator and gamma detectors to monitor cadmium concentrations in the body. Professor J. Dutton of the University College of Swansea has called our attention to two similar machines developed and used in Europe. One is operated by the group of Professor Fremlin at Birmingham

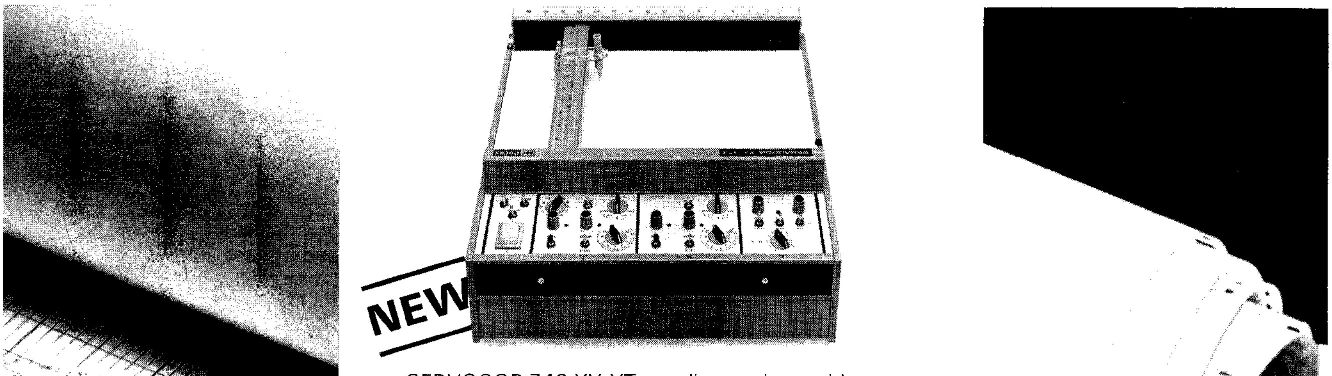
University. It has a plutonium/beryllium neutron source and has been used in cadmium surveys of liver and kidney in industrially exposed workers. The other, operated by a joint Hospital-University Group at Swansea, is known as NAOME. It has a californium neutron source and is used particularly at present in studying the suspected link between cadmium levels in the kidney and hypertension and investigating whether these are related to dietary and smoking habits.

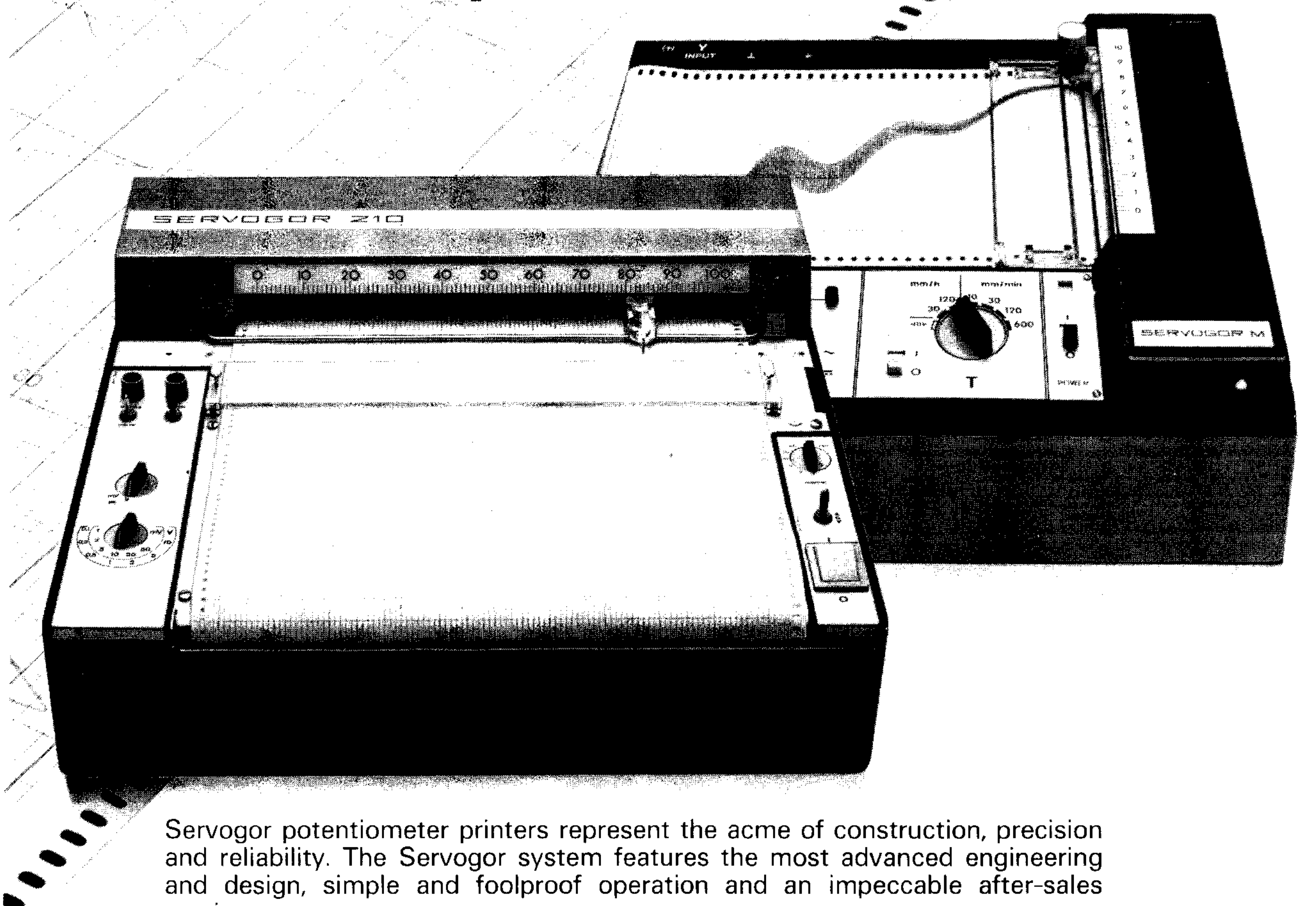
Bevalac tuning up by computer

The heavy ion accelerator, Bevalac, at Berkeley aims progressively to increase the proportion of time it can give to physics and biomedicine as the use of computer control and database techniques in tuning up the accelerator is being extended throughout the year. This is a much more demanding process with heavy ion machines, such as the Hilac-Bevatron combination or the Darmstadt linac, than with proton synchrotrons, which deal with a single type of particle and which can usually stay with a particular cycle for an extended period of time. The research programmes at heavy ion accelerators require regular changes of ion species and energies involving complete retuning. Performance of the Bevalac during the last fiscal year exceeded the general goal of 85% machine availability, reaching an average for the year of 87%, with a peak in the final run of over 90%. The time devoted to biomedical studies has increased so that they now receive an hour for every two hours going to nuclear science. Patient treatments for cancer and diagnostic radiography with heavy ion beams now benefit from improved equipment in the Treatment Room.

In Fermilab's tradition of interest in the environment, three rare barn owls have been released at the site. Barn owls have almost disappeared from the upper midwest and naturalists hope to use the Fermilab trio to explore the reasons why they have left. Telemetry was attached to the birds and they have been spotted on the site throughout the winter. It is estimated that the owls have eaten approximately two thousand mice since they were released!

(Photo Fermilab)

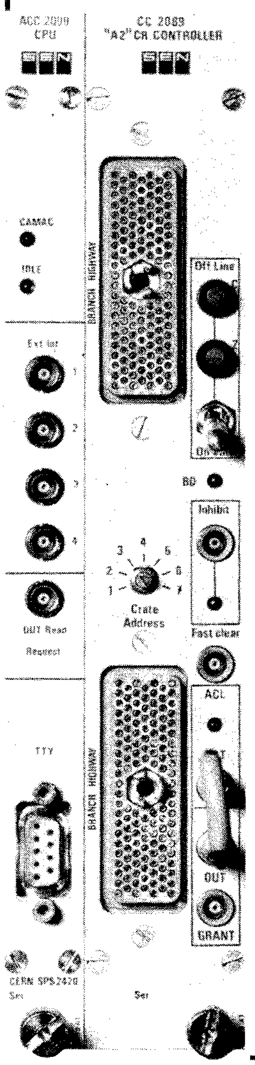

NEW


SERVOGOR 210
SERVOGOR M

CAMAC

Introducing the most powerful intelligent CAMAC controller system: ACC 2099/CCA2 2089

This combination provides all the facilities of the host computer through a parallel branch with sophisticated Front-end processing through a fast 16 bit microcomputer.



ACC 2099: Auxiliary Crate Controller.

- 16 bit Texas TM 9900 microcomputer
- single width multilayer CAMAC unit
- 16K-16 bit RAM memory of which up to 4K can be replaced by ROM for fixed program storage
- Teletype interface
- 4 Front-panel Real Time Interrupts
- easy software with CAMAC modules addressed as memory positions
- 10 μs CAMAC Read/Write cycle
- Also SCCL2 and Nord 10 PIO controller compatible

CCA2 2089: A2 Parallel Crate Controller

- Fully conforms to the new EUR 6500e specs.
- single board construction
- fast clear input

SYSTEM OPERATION

The A2 Crate Controller is a parallel Crate Controller and includes all the same functions plus new control logic for local data handling using a microprocessor module (as ex. ACC 2099). The A2 provides access to the N and L lines via a rear panel connector for the Auxiliary Crate Controller placed in any normal station. It also handles the remote/local access request conflicts. Front-end data processing is governed by the ACC 2099 just as long as the main computer does not require access to this particular crate: However, when this occurs, the local processor is released, its status saved and the Branch Demand processed. Once the Branch Demand has been filled, control returns to the ACC 2099.

Next month:
The new ACC 2103 – an extended version of the ACC 2099 with additional EPROM for high-level languages.

France: ORTEC Sarl; 7, rue des Solets; Tel. (1) 6872571 - Tlx 202553F, F-94 RUNGIS – **Germany:** SEN ELEKTRONIK GmbH; Brandstücken 11; Tel. 041 802046 - Tlx 2163705d, D-2000 HAMBURG 53 – **DIDAS Digital System;** Radspielstrasse 8; Tel. 089 916710 - Tlx 529167d - D-8000 MÜNCHEN 81 – **Switzerland:** SEN ELECTRONIQUE SA; CP 39; Tel. (022) 442940 - Tlx 23359ch - CH-1211 GENÈVE 13 – **SEN ELEKTRONIK AG;** Austrasse 4; Tel. (01) 9455103; Tlx 58257ch - CH-8604 VOLKETSWIL – **United Kingdom:** SEN ELECTRONICS LTD; London Street; Chertsey; Tel. 9328.66744 - GB - KT168AP SURREY – **OFFICES THROUGHOUT THE WORLD.**

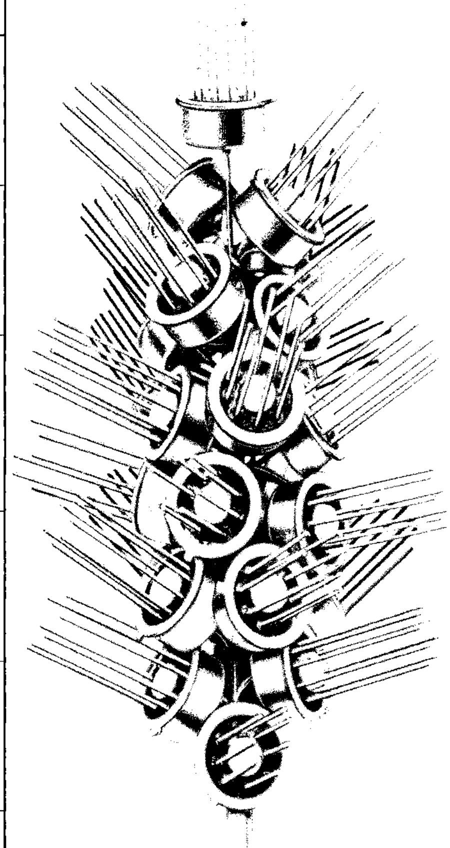
Headquarters:
SEN ELECTRONICS S.A.; Avenue Ernest-Pictet 31; Tel. (022) 442940 - Tlx 23359ch - CH-1211 GENÈVE 13.

SEN ELECTRONIQUE

HAS A BROAD SELECTION OF SINGLE-DUAL-QUAD-OPERATIONAL AMPLIFIERS

FOR GENERAL PURPOSE, HIGH SPEED, LOW POWER, PRECISION, HIGH INPUT RESISTANCE........................AND ECONOMY!

PMI MODEL	GENERAL PURPOSE	HIGH SPEED	LOW POWER	PRECISION	HIGH INPUT R	SINGLE	DUAL	QUAD	SECOND SOURCE	ECONOMY
OP-01		●				●				
OP-02	●					●			○	
OP-04	●						●		○	
OP-05				●		●			○	
OP-07				●		●			○	
OP-08			●	●		●			○	
OP-09	●							●	○	
OP-10				●			●			
OP-11	●							●	○	
OP-12			●	●		●			○	
OP-14	●						●		○	
OP-15		●			●	●			○	
OP-16		●			●	●			○	
OP-17		●			●	●			○	
OP-20			●	●		●				
PM 108A/308A			●	●		●			●	
PM 108/308			●			●			●	●
PM 155A-355		●			●	●			●	●
PM 156A-356		●			●	●			●	●
PM 157A-357		●			●	●			●	●
SSS 725				●		●			●	
PM 725				●		●			●	●
SSS 741	●					●			●	
PM 741	●					●			●	●
SSS 747	●						●		●	
PM 747	●						●		●	●
SSS 1558/1458	●						●		●	
PM 1558/1458	●						●		●	●
PM 4136	●							●	●	●



Second Source available: ● direct ○ limited

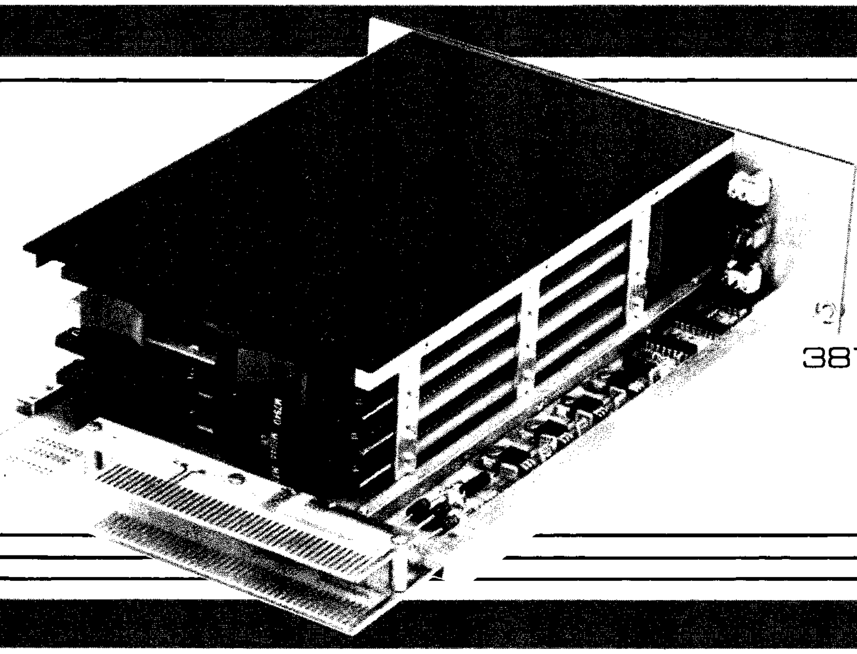
PMI IS A LEADING MANUFACTURER OF OPERATIONAL AMPLIFIERS, A/D/A CONVERTERS, VOLTAGE COMPARATORS, ANALOG SWITCHES, SAMPLE-AND-HOLD AMPLIFIERS, VOLTAGE REFERENCES! ALL PMI MODELS AVAILABLE IN MIL-STD-833 VERSIONS AND AS CHIPS.

PRECISION MONOLITHICS INC.
Santa Clara, California, USA
A Subsidiary of Bourns Inc.

EUROPEAN HEADQUARTERS
Bourns AG, 6340 Baar, Switzerland
Phone: 042 33 33 33, Telex: 78 722

Now Available!

a CAMAC module



with LSI-11/2 power

Our 3875 LSI-11/2 Microcomputer is a multiwidth module containing standard off-the-shelf LSI-11/2 processor, memory, and interface cards without modification. When combined with the LSI-11 version of our 3912 Crate Controller, the 3875 provides a versatile self-contained CAMAC computer system which can be used as a development system for laboratory automation or industrial process control. This combination can also be used for remote intelligence in a distributed CAMAC system.

The 3875 connects to the CAMAC Dataway for power only. Inter-module communication is made via a prewired connector which conforms to the LSI-11's bus specification and is mounted to the rear of the 3875's front panel. Using the 3912 and its software, programs can be developed on a PDP-11 and then transferred to the LSI-11, if desired. If your application outgrows a crate-mounted computer, the 3912 can be used with an LSI-11 in a mounting box.

NOTE THESE FEATURES

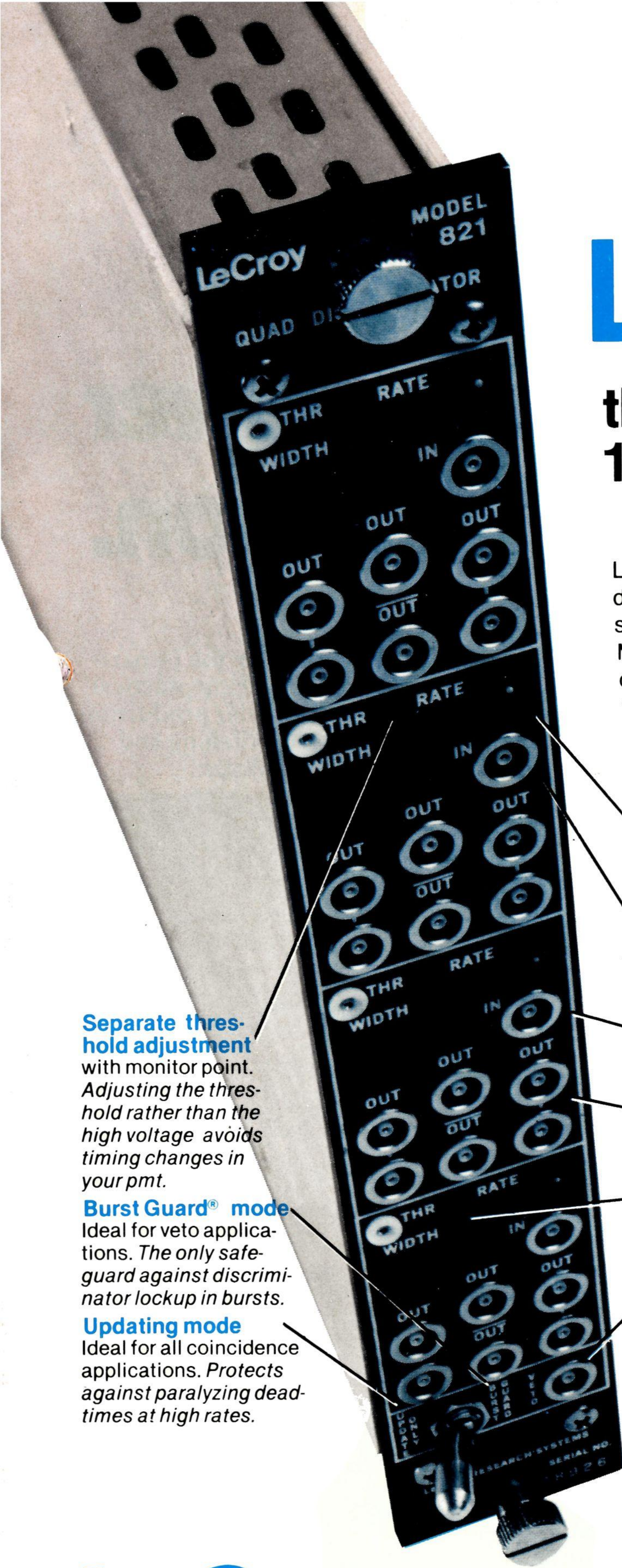
- powerful 16-bit microcomputer with PDP-11 instruction set
- supported by RT-11 and RSX-11 operating systems as well as KSC FORTRAN calls and BASIC CAMAC extensions
- convenient CAMAC crate mounting
- options include 32K x 16-bit memory, serial ports, and diskette controller
- any LSI-bus compatible module can be plugged into backplane
- two available housing options for versatility, mounting up to four or five LSI-11/2-size cards, respectively

Please contact us for additional information

Kinetic Systems International S.A.

the CAMAC people

Dept. CC49 * 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



LeCroy 821

the new standard for 100 MHz discriminators

LeCroy continues as the leader in multichannel fast discriminators. Over the years, higher density, higher sensitivity, and greater versatility have originated at LeCroy. The Model 821, designed in response to the ever increasing demands from the field, offers all of the performance advantages of its predecessors...and *more* ...making it the new standard for quad 100 MHz discriminators.

Separate threshold adjustment
with monitor point. *Adjusting the threshold rather than the high voltage avoids timing changes in your pmt.*

Burst Guard® mode
Ideal for veto applications. *The only safeguard against discriminator lockup in bursts.*

Updating mode
Ideal for all coincidence applications. *Protects against paralyzing deadtimes at high rates.*

Rate Lite®
Easy visual monitor of each channel. *Instantaneous indication of failed detector channel—means no surprises later.*

Low threshold
– 30 mV to – 1 V. *Low enough for use with low-cost pmt's, yet high enough for pulse restandardization applications.*

Low reflections
<1% for 3 nsec risetimes *to guard against spurious retriggers on reflections.*

Versatile output
Fanout of 6, all with exceptional pulse shape. *How often do you need one more output?*

Separate width adjustment
5 nsec to 1 μsec. *Custom-tailor each channel to its detector performance.*

Common inhibit
Simplifies trigger logic. *Gating early in the logic can save kilometers of cable to data acquisition channels and maximize trigger efficiency.*

Hysteresis
Each channel individually trimmed *to eliminate multiple-pulsing.*

Detailed information may be obtained by contacting your nearest LeCroy sales office.

LeCroy
RESEARCH SYSTEMS

Innovators in Instrumentation

Headquarters: 700 S. Main St., Spring Valley, N.Y. 10977. Offices: Chicago, (312) 626-6726; New England, (603) 483-8755; New York, (914) 425-0412; Palo Alto, (415) 328-6063; Geneva, Switzerland, (022) 98 97 97; Heidelberg, W. Germany, (06221) 28192; Hamburg, W. Germany, (040) 54 2713; Paris, France, 907.38.97; Wheatley, Oxford, England, (08677) 3540.
Representatives throughout the world.

August 5, 1978

EIMAC 8973 tetrodes helped bring fusion power a step closer at Princeton.

Project PLT—a significant achievement

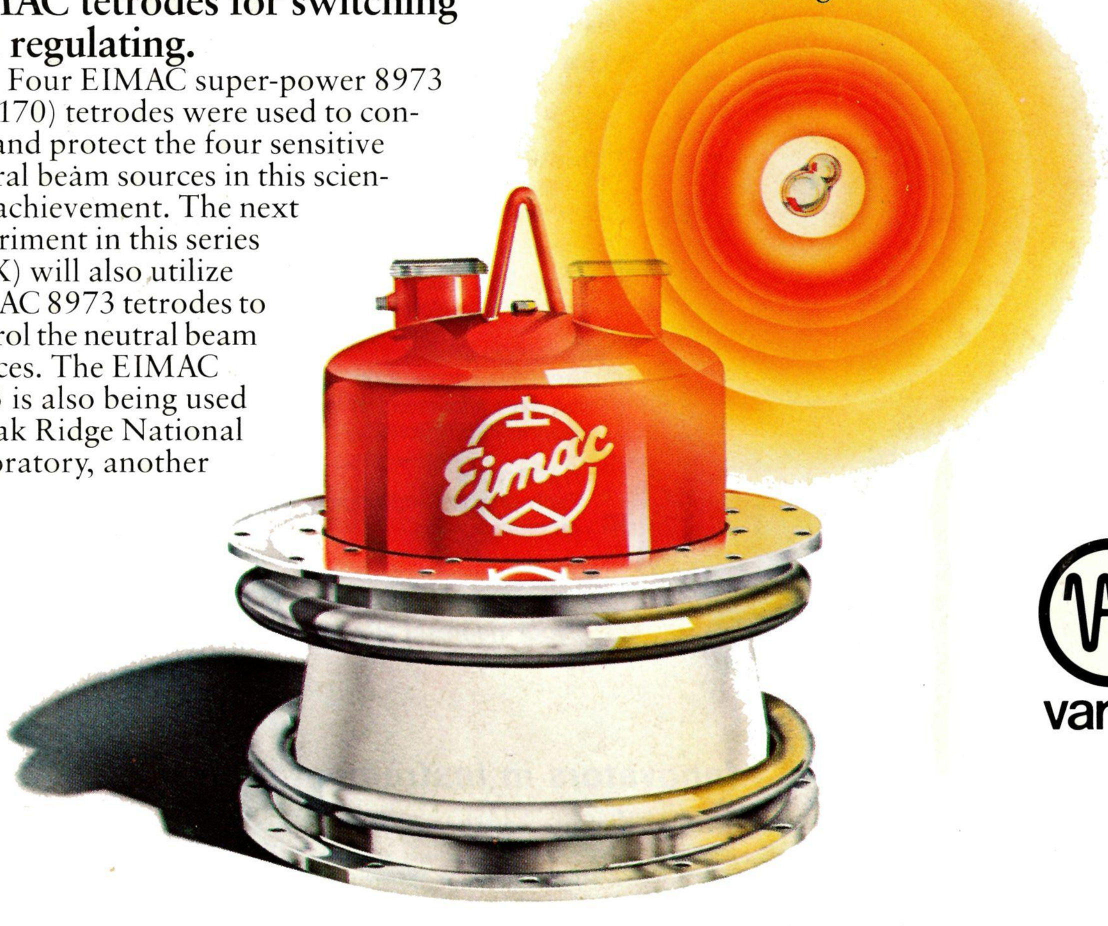
On August 5, 1978 scientists at Princeton University Plasma Physics Laboratory succeeded in heating a form of hydrogen to more than 60 million degrees Celsius and produced the highest temperature ever achieved in a TOKAMAK device—four times the temperature of the interior of the sun, thus bringing fusion power a step closer for mankind.

EIMAC tetrodes for switching and regulating.

Four EIMAC super-power 8973 (X-2170) tetrodes were used to control and protect the four sensitive neutral beam sources in this scientific achievement. The next experiment in this series (PDX) will also utilize EIMAC 8973 tetrodes to control the neutral beam sources. The EIMAC 8973 is also being used at Oak Ridge National Laboratory, another major research facility involved in the Department of Energy's program to develop practical fusion power. The 8973 is a regular production tube designed for high power switching and control by EIMAC division of Varian.

For information

Contact Varian, EIMAC Division, 301 Industrial Way, San Carlos, California 94070. Telephone (415) 592-1221. Or any of the more than 30 Varian Electron Device Group Sales Offices throughout the world.



varian