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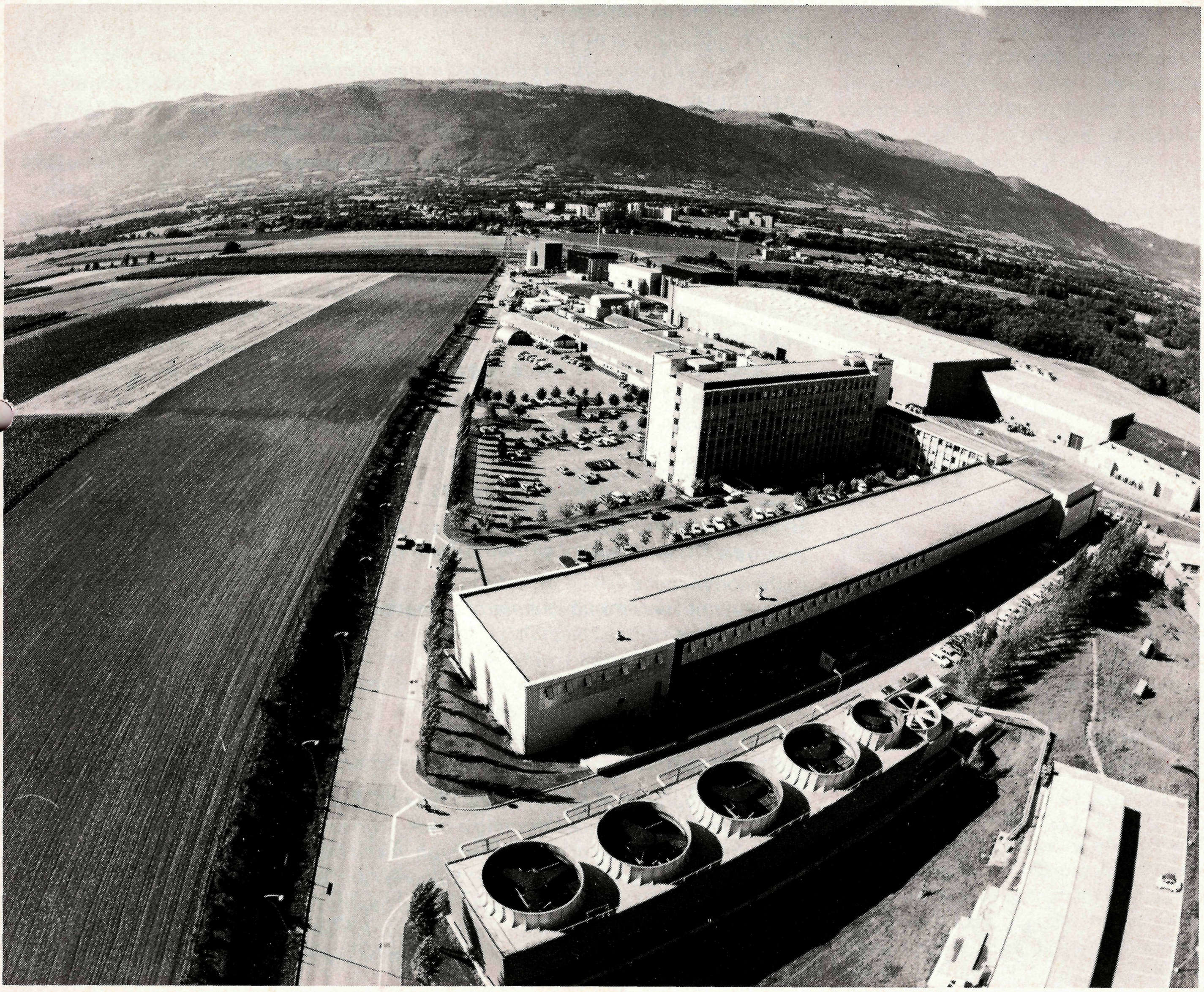

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Editors: Brian Southworth
Henri-Luc Felder
Gordon Fraser
Advertisements: Micheline Falciola
Laboratory correspondents:
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Copies are available on request from:
Federal Republic of Germany —
Frau I. 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
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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

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Cover photograph: A fish-eye lens gives an interesting distortion of the regular line of the Jura mountains forming a back-drop to the western corner of the CERN site. In the foreground of the photograph, taken from the top of the 57 metre-high water tower at the ISR, are the ISR buildings and on the right the large West Hall housing electronics experiments receiving beams from the SPS, followed by four buildings lined up in the neutrino beam which emerges from the underground accelerator. These buildings are the home of the BEBC and Gargamelle bubble chambers and three neutrino electronics experiments. (Photo CERN 43.9.78)

Quantum chromodynamics shows its paces

One of the striking features of the International High Energy Physics Conference held at Tokyo at the end of August (see September issue, page 283) was the demonstration of the predictive power of quantum chromodynamics (QCD) — the candidate theory of interactions of the pointlike components hidden deep inside nucleons.

With a number of impressive agreements with experiment now to its credit, QCD must be considered much less of a speculative theory and more of a real physical picture which accurately reflects the mechanisms at work inside hadrons.

The first evidence for the existence of small hard scattering centres deep within nucleons came from electron scattering experiments. These small nucleon constituents were termed partons and evidence soon began to build up which enabled these minute particles to be identified with the quark building blocks which successfully accounted for the proliferation of observed hadrons and their classification into families.

In this way, two different pictures of the composition of hadrons were brought together — the parton model describing dynamical interactions and the quark model dealing with static properties. As a result, the words parton and quark can be interchanged freely.

In the simplest parton picture, high energy lepton-hadron scattering is described by the interactions of the incident pointlike leptons as they probe inside the target nucleons and find a target parton. In each such interaction, an incoming lepton hits one parton while the others behave as 'spectators'.

By adding together these individual lepton-parton interactions, in principle one could predict the overall behaviour of the nucleon when bombarded by lepton beams. However the dynamical description of the partons bound inside the nucleons is difficult to pin down and it therefore becomes difficult to extract exact results.

However for those cases where the incident lepton probes deep inside the nucleon and interacts violently with one of the constituent partons, the calculations can be simplified. When such large amounts of momentum are transferred from leptons to partons, the result is dominated by the kinematical variables of the scattering process and on the distribution of the partons inside the nucleons.

These results for high momentum transfer processes therefore turn out to be governed by the kinematical variables and are independent of quantities like particle masses or sizes of interaction regions. As a result, once behaviour has been measured under one set of kinematical conditions, predictions for scattering at other energies can be made simply by 'scaling' the appropriate kinematical variables.

This scaling behaviour was seen early on in lepton-nucleon scattering experiments at SLAC and provided valuable evidence for the existence of partons. (An earlier article on this subject, in January / February issue, page 7, referred to these pioneering electron scattering experiments, but in one of the diagrams, data which was in fact collected at DESY was inadvertently attributed to SLAC.)

While the parton picture provided the first glimpses of the mechanisms at work inside hadrons, theorists were more ambitious. Instead of a semi-empirical model with limited applications, they sought a full-scale quantum field theory which naturally described the behaviour of hadron constituents in the same way that quantum electrodynamics provides a self-contained framework for describing electromagnetic interactions.

The contender for this theory is quantum chromodynamics (QCD), in which the interaction between partons is attributed to the exchange of gluons which carry the so-called 'colour' forces (hence 'chromodynamics') between the quarks in much the same way as photons mediate the electromagnetic force. Some of the ideas behind the introduction of colour as a new quantum number have been described in a previous article (see November 1977 issue, page 380).

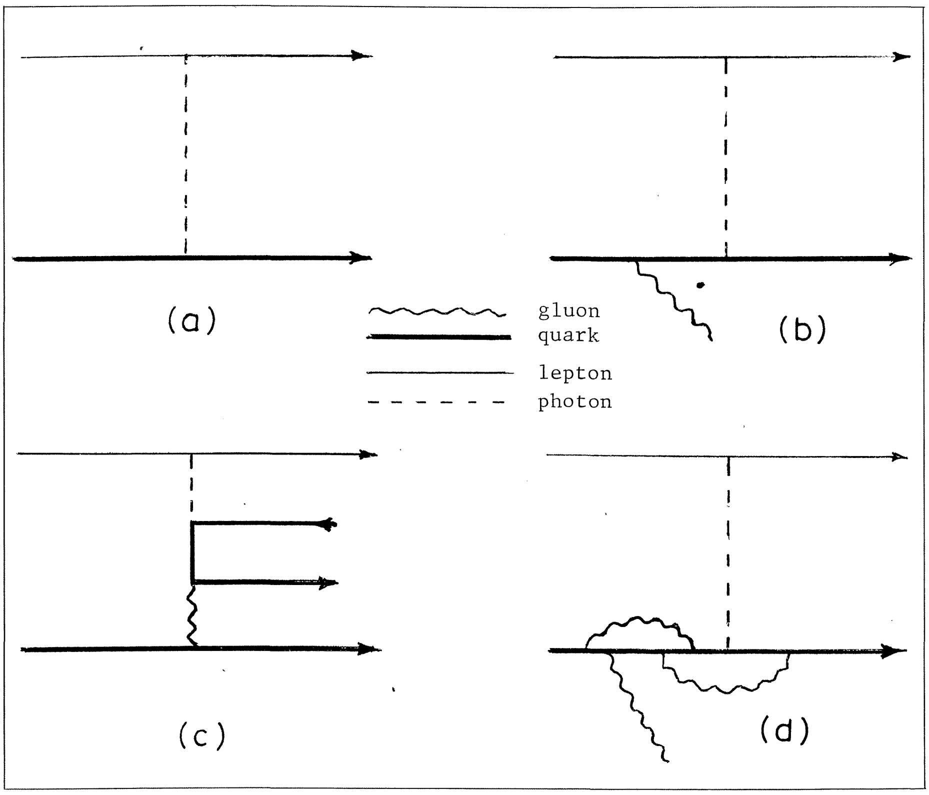
In quantum electrodynamics, observed interactions are the net result of a number of individual processes involving charged particles and photons, each of which can be represented pictorially by a Feynman diagram. These individual processes combine together in a well-defined way (perturbation theory) and successive approximations to the required result can be obtained by including more and more of them in the calculation.

The same approach is taken in QCD, where each individual interaction mechanism is represented by a Feynman-type diagram which indicates the particles involved and the way they interact. Hopefully a meaningful prediction can be made by including contributions from a manageable number of individual diagrams.

In QCD, variables describing intrinsic particle properties (such as isospin and flavour) are allowed also to depend on space and time. If such a technique (called a 'Yang-Mills' theory) is used inside successively smaller regions of space-time, it was found on theoretical grounds that the interaction between the individual particles would diminish. This property is known as 'asymptotic freedom'. On the other hand, if the space-time volume of the interaction region is increased, the magnitude of the inter-particle interaction also increases.

This result is incorporated in QCD by introducing a running coupling constant, the square of which behaves as the inverse of the logarithm of the square of the momentum transferred in the interaction. As the momentum

Diagrams showing some of the possible mechanisms contributing to lepton-nucleon scattering. In the simplest diagram (a), the incoming lepton exchanges a photon with one of the constituent quarks of the nucleon. Diagrams (b) and (d) are complicated by emission of gluons, while diagram (c) shows an interaction with a 'virtual' quark emitted from the constituent or 'valence' quark.



transfer gets larger (i.e. the space-time volume of the interaction gets smaller), the effective coupling constant decreases.

It is as though the partons, although strongly bound inside hadrons, can 'forget' about this strong binding if they are made to interact quickly enough. This means that if the conditions are right, the techniques of perturbation theory can be used in QCD and predictions can be made by summing contributions from relatively few individual processes represented by Feynman-type diagrams.

These limitations usually mean that QCD calculations are restricted to processes where a lot of momentum is transferred in the interaction. For example an experiment can be set up to be triggered by a pion coming out at a relatively large scattering angle. In this way the data is automatically selected to be suitable for treatment by QCD techniques.

While the introduction of the running coupling constant enables some calculations to be made, the reason for the apparently perpetual confinement of quarks within nucleons and their reluctance to appear as free particles remains a mystery. This may emerge naturally from a more mature version of the theory but now all that can be done is to embed the QCD effects in a smooth wave function which describes the hadronic material surrounding the inner partons.

This outer hadronic dependence cannot be calculated and has to be determined from nucleon structure functions measured by experiments. The structure functions can be compared to the form factors used in the analysis of electron-nucleus scattering some twenty years ago.

With these techniques, calculations using the simplest diagrams for individual lepton-nucleon scattering reproduced the broad scaling effect seen in initial electron-nucleon scattering experiments. However, the inclusion of additional diagrams (see figure) involving internal gluon exchanges produce additional effects and these spoil the overall scaling behaviour.

A close examination of the experimental results had shown that scaling is in fact not exact and systematic deviations occur. These systematic deviations agree with the QCD predictions, the recent results from neutrino scattering using the BEBC bubble chamber at CERN providing particularly impressive agreement with the theory.

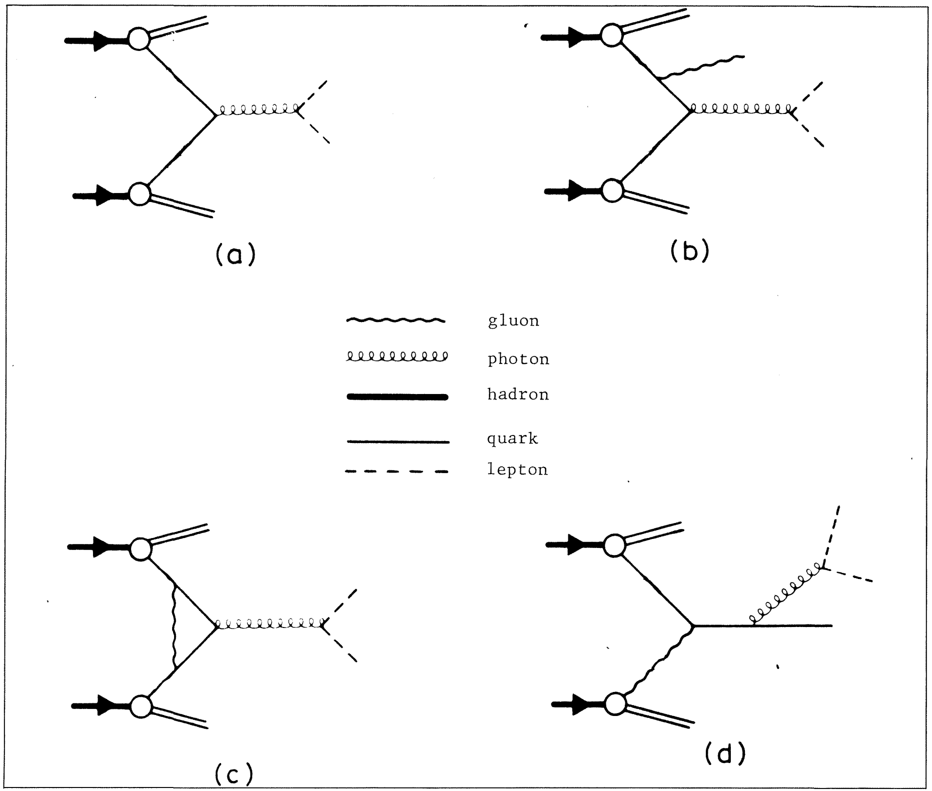
Despite the observation of scaling violations in lepton-nucleon scattering, the predictive power of QCD still remained limited. Only lepton-nucleon scattering (together with lepton-antilepton annihilation) could be handled by QCD without encountering major obstacles in the underlying formalism.

For other applications, there were apparently insurmountable technical difficulties. For example it is not known how to handle states with more than one hadron, so QCD calculations for hadron-hadron interactions at first sight appeared impossible. Other calculations on the production of certain types of particle did appear possible but it was not clear which diagrams should be included to obtain a good approximation. Many different diagrams provided comparable contributions, so that it appeared impossible to isolate a manageable subset of diagrams more important than the others.

The new breakthrough in QCD in recent months is that a method has been developed which preserves the good results obtained for lepton-nucleon scattering using the old technique, but which opens the door to calculations which before were impossible.

One immediate application of this new technique is to the production of lepton pairs in hadron-hadron collisions. In the appropriate kinematical

Some of the possible mechanisms for lepton pair production in hadron-hadron collisions, in which a quark from one hadron annihilates with an antiquark from the other. This produces a heavy photon, which decays into the pair of leptons. The basic process is shown in diagram (a), and the additional effects including gluon interactions — diagrams (b), (c) and (d) — can now be calculated using the techniques of quantum chromodynamics.



regions, these lepton pairs show signs of heavy resonances such as psions and upsilons, but away from these resonance regions, the lepton pair spectrum is smooth.

This smooth background is attributed to the so-called 'Drell-Yan' mechanism in which a quark from one hadron annihilates with an antiquark (coming from the 'sea' of virtual particles surrounding the three 'valence' quarks) from the other. This produces an intermediate heavy photon, which decays into the pair of leptons (see diagram).

According to QCD, additional interactions, for example involving internal gluons, are also relevant to this process, but in the original formulation of the theory these corrections could not be calculated. In the new prescription, these additional diagrams are seen to be related to the processes which cause scaling violation in lepton-nucleon scattering.

Thus the correction terms for the 'naive' Drell-Yan mechanism can be calculated using data from deep inelastic lepton-nucleon scattering, and the results agree with experiments on lepton pair production.

This new predictive power for QCD brings within reach a whole new range of calculations which before were out of the question and shows that our understanding of Nature does seem to have managed to penetrate the mysterious inner regions of the nucleons — perhaps the ultimate of all microscopic worlds ?

One of the most remarkable things about the theory is that — given the right conditions — the traditional tools of perturbation theory can still be exploited. Not so long ago, it was thought that any meaningful theory of inner hadronic mechanisms would have to wait for the development of some new mathematical technique to replace perturbation theory.

This may still be the case, as most of the manifestations of the colour force seen so far are only small effects which are added as some sort of 'fine structure' to other more gross phenomena, such as scaling.

One place where experiment could break out of the straitjacket of small colour effects is in the decays of heavy particles such as the upsilon. If the upsilon is the bound state of a heavy quark and its antiquark, it should in principle be able to decay into three gluons in much the same way that positronium (a bound state of an electron and a positron) decays into three photons.

Such a decay would not be a small correction effect, and in its present form QCD can make predictions for the three gluon spectrum. Experimentally, this decay seems difficult to pin down with the present upsilon data, but further statistics on upsilon decays would provide a valuable proving ground for larger scale QCD phenomena.

Other theorists are homing in on the problem from another direction by studying the non-perturbative aspects of QCD such as instantons (see September 1977 issue, page 290). Here the hope is that eventually a picture can be built up which describes the 'long distance' interactions of quarks and gluons and the mechanism which confines quarks inside hadrons.

Despite the problems which remain to be solved, QCD has shown its paces. With a number of good predictions to their credit, QCD theorists can face the future with confidence.

Around the Laboratories

FERMILAB
Cooling ring in operation

A new storage ring was born at Fermilab in September when a beam of protons was injected and stored in the 200 MeV cooling ring. The ring is part of the antiproton cooling project aimed at providing high intensity antiproton beams for colliding with protons in the main ring or the Energy Doubler in the future. The ring will be used initially to study electron cooling of protons with tests beginning later this fall.

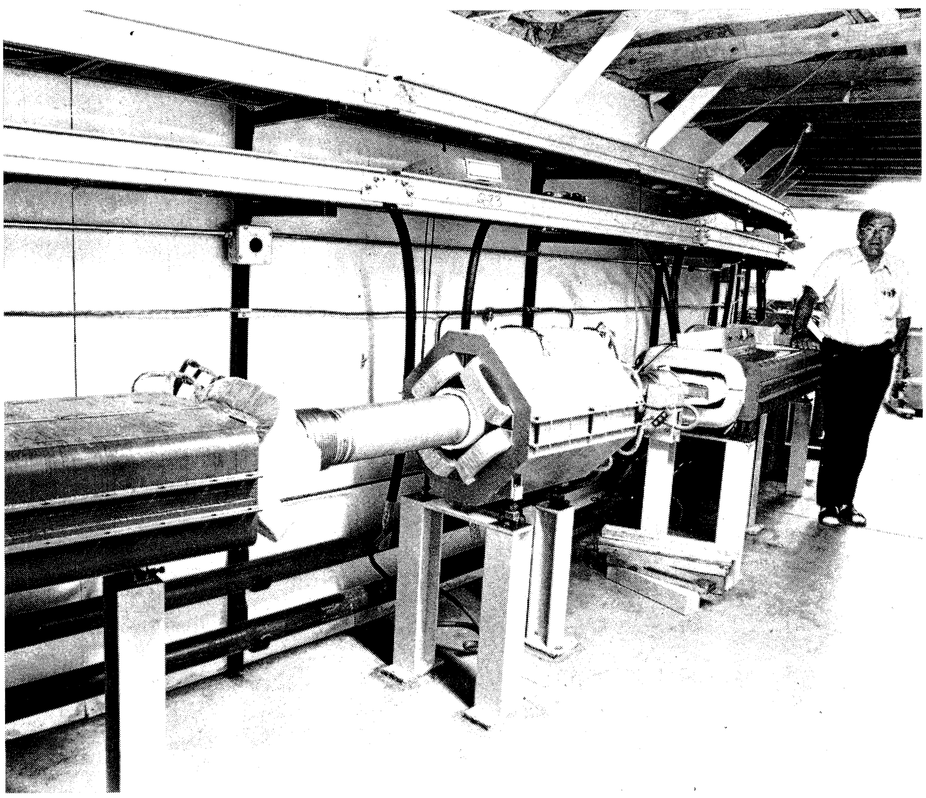
The new 'racetrack' ring is located West of the Booster at the 200 MeV end of the Linac from where it receives its protons. Initial operation was very gratifying. The calculated magnet currents resulted in a good circulating beam with a mean lifetime of 30 s, consistent with the limitations imposed by the present vacuum. No corrections were required.

The cooling of protons by electrons is a process which was first demonstrated at the Soviet Institute of Nuclear Physics, Novosibirsk. Transverse and longitudinal momenta of the protons are transferred to electrons so that the proton beam is 'cooled' to a particular momentum value. This reduces the size of the proton beam. Successive pulses of protons can be stored in the storage ring for long periods of time.

The Fermilab project was proposed in the fall of 1976. Construction of the major components started in late summer 1977 with a small group of physicists and technicians. The Antiproton Cooling Group, under Don Young and Fred Mills, has been primarily involved with the construction and development of the storage ring accelerator while Internal Target Group led by Peter McIntyre prepared the electron beam cooling system.

Fred Mills stands beside the 200 MeV storage ring which is now in operation at Fermilab. The ring will be used for studies of electron cooling for the proton-antiproton project.

(Photo Fermilab)



The cooling ring has 32 quadrupoles, 24 4-foot bending magnets and two 45-foot straight sections to accommodate the electron-beam cooling system. The circumference is about 1/3 that of the Booster. A bakeable vacuum system is capable of achieving a vacuum of 10^{-10} torr to ensure the long beam lifetime required for the accumulation of antiprotons. A pressure of about 10^{-8} torr was obtained before baking with only about 5% of the ultimate pumping speed available.

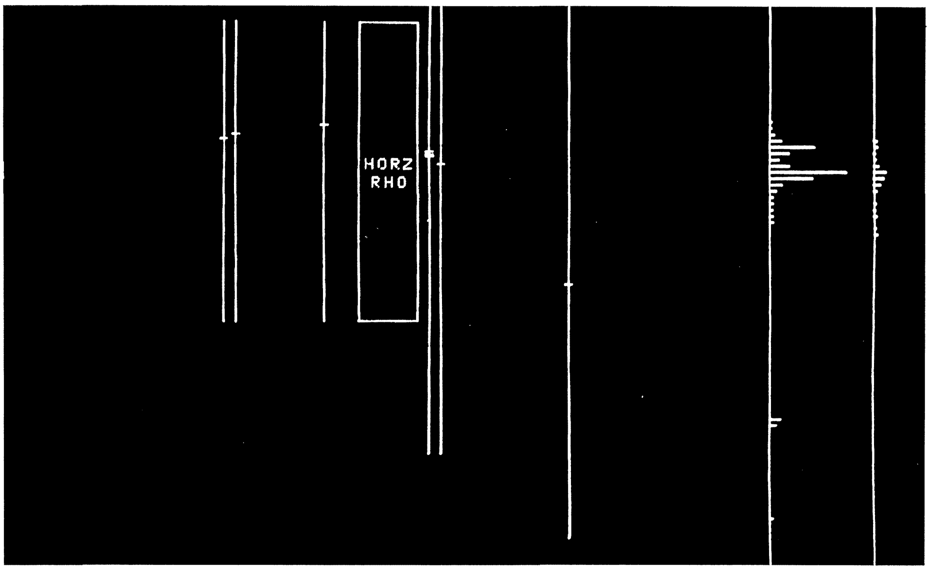
Argon calorimeter for pion dissociation

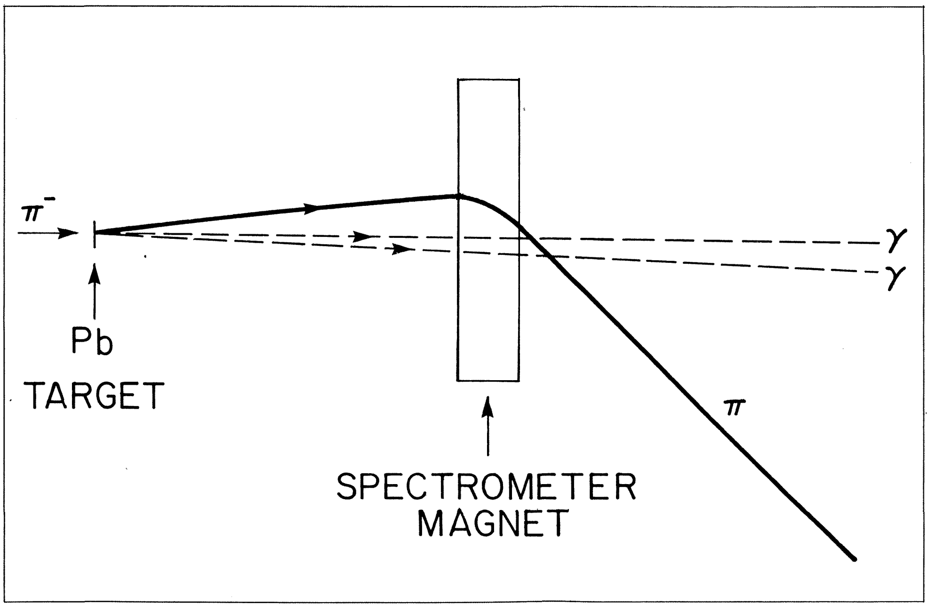
Although the nature of the photon is well understood and its interactions with other elementary particles can be predicted, it would certainly not be unusual if Nature unleashed another surprise and revealed new phenomena in the scattering of mesons with photons. A group of physicists from Fermilab / Minnesota / Rochester have embarked on a programme to examine meson-photon collisions at high energy in the hope of finding just such surprises.

Since it is not possible to have a meson target (the longest-lived stationary mesons exist for only about 10^{-8} s) nor a real photon target (photons exist only insofar as they have momentum) it is difficult to scatter photons on mesons. At very high energies, however, a large nucleus can be regarded as a target providing a sea of photons. These photons arise from the presence of nuclear electric charge and the consequent Coulomb field surrounding the nucleus.

To study meson-photon collisions it is necessary to have mesons interact with nuclear targets at distances where the electromagnetic properties of the nucleus dominate over the strong nuclear forces. Such collisions ensure that the entire nucleus is still in-

Online computer display of a typical meson-photon event from the Fermilab / Minnesota / Rochester experiment on pion dissociation using a lead target. The two vertical lines on the right define the positions of the front and back sections of the liquid argon calorimeter. Horizontal lines are used to indicate the distribution of energy deposited in the calorimeter. The remaining vertical lines represent drift or proportional chamber planes and the tic-marks indicate the trajectory of the pion through the spectrometer. The diagram below shows the event in schematic form.





tact after the interaction has occurred and guarantee that the meson collided with an electromagnetic photon rather than with the hadronic material in the nucleus proper.

The probability that a meson-photon collision produces some particular particle increases by about a factor of ten in going from AGS/PS to Fermilab / SPS energies while the probability that a similar particle is produced in the strong interaction of a meson and a nuclear target drops typically by about a factor of ten. As the energy of the incident meson increases, it also becomes easier to interpret the meson-photon collision because the photon becomes less virtual — more like a real photon.

The first theoretical suggestions for this possibility of examining collisions of real particles with photons provided by the nuclear Coulomb field were made by H. Primakoff some thirty years ago but it is at Fermilab and at SPS energies that such studies can come to fruition.

To take advantage of the physics possibilities of photon targets, the Fermilab / Minnesota / Rochester collaboration has built a spectrometer system located in the M1 beamline of the Meson Laboratory. One of the key elements of the spectrometer is a high resolution photon detector — a liquid-argon calorimeter of the type developed over the past few years by Bill Willis at CERN. A preliminary calibration of the detector shows an energy resolution of $\pm 2\%$ for 50 GeV photons and a position resolution of $\pm$ 1 mm.

The first experiment of the series planned by the collaboration was finished in July. The calorimeter and spectrometer performed exceedingly well, and the experimenters obtained valuable data on the reaction $\pi^- + \gamma \rightarrow \pi^- + \pi^0$. The results will be used to check SU(3) symmetry predictions and quark-model rules relating the decays of vector mesons produced in $\pi^- \gamma$ collisions.

In particular, the production of the rho meson has already been observed and its probability of decay into a negative pion and a photon ascertained. The decay probability is much smaller than expected on the basis of present theory but is consistent with earlier measurements of the same process at the AGS where, because of the lower energy, the interpretation of data was somewhat more difficult.

High intensity lab on the air

The High Intensity Laboratory situated in the Proton West beamline at Fermilab was commissioned during the latter part of the summer. The area was designed and built by a team from the Proton Department headed by Brad Cox.

Initially a zero degree negative charged beam was set up and the first high intensity pion flux was transported to the experimental hall. The beam transport system was then set in a zero degree neutral beam configuration and a unique high intensity antiproton beam was generated by collecting antiprotons from lambda decays. Fluxes of these two beams have been measured to be greater than 10^{10} negative pions and approximately 10^{7} antiprotons per 10^{13} incident protons respectively, making them the most intense beams of their type in the world by two to three orders of magnitude. In addition, the antiproton beam is the cleanest antiproton beam with proton/pion ratios approaching 50% at 100 GeV/c.

The complex of targets, shielding, beam dumps, tunnels, beam transport, and experimental hall has been under construction for two years. Over 1000 feet of tunnel including the 230 feet long experimental hall had to be constructed 20 feet underground because of the high intensity of the secondary beams. The proton beam target system posed particularly difficult shielding problems because of the design requirement to take several times 10^{13} protons per pulse. Also the area was constructed such that the 1000 GeV beams from the Energy Doubler can be accommodated.

Approximately thirty magnets are involved in the targeting and secondary beam transport. They operated up to 250 GeV in the initial tests and with few changes can be adjusted to 300 GeV/c. The implementation of the full capacity of the beam for the Energy Doubler era requires a superconducting transport system to replace the largely conventional transport which is now in place.

Two major steps were taken this summer in preparation for this superconducting transition. A group led by Brad Cox, Peter Garbincius, Peter Mazur and John Satti, project engineer of the Proton Department, successfully completed and operated a prototype large aperture, low current superconducting dipole. These dipoles (and the comparable quadrupoles which are now under design) operate at 220 A and have a 15 cm diameter bore. With them, the beam transport can be upgraded to 1000 GeV with an increase in beam acceptance.

The second step involved the operation of an Energy Doubler dipole in the proton targeting system during commissioning of the High Intensity Laboratory. For the first time at Fermilab an Energy Doubler dipole, similar to the type to be used in the 1000 GeV accelerator, was used in a beam transport system. During the months of July to September, it deflected protons onto the secondary beam production target. The effects of beam loading and single pulse beam quenches were studied. An additional benefit from the use of this magnet was the experience gained in operating the helium refrigerator systems.

In October the first round of experiments using the unique capabilities of this experimental area began. Three experiments will be installed in the hall in the coming year. A Chicago/Princeton group plans to study high transverse momentum inclusive particle production and dimuon production by pions with a detector system which consists of a small aperture single arm spectrometer and a large aperture iron toroid. A second group of scientists from Princeton / Saclay / Brookhaven is installing a two arm spectrometer to study negative pion production of D*. A third set of experimenters from Fermilab / Athens / Michigan / McGill is using a large aperture forward spectrometer to study dimuon production by antiprotons using the lambda beam.

With these experiments, work with high intensity secondary beams will have begun in earnest.

KEK
Open house

After the International Conference at Tokyo in August (see September issue, page 283), participants had the chance to visit the Japanese National Laboratory for High Energy Physics (KEK) and to see for themselves the progress which has been made and the range of experiments under way.

Although only some 60 km northeast of Tokyo, KEK is reached after a tortuous drive of several hours through narrow roads. It is situated in the new Tsukuba Academic District, a new development which houses nearly fifty different research centres and institutes of higher education together with their staff and their families. Approved only in 1970, Tsukuba has grown quickly, its present population being around 120000.

Work started at KEK in 1971, and the main proton synchrotron reached its initial 8 GeV design energy in March 1976. The physics programme, which began last year, can exploit the full 12 GeV output from the main ring. Maximum beam intensity reached so far is 2×10^{12} protons per pulse.

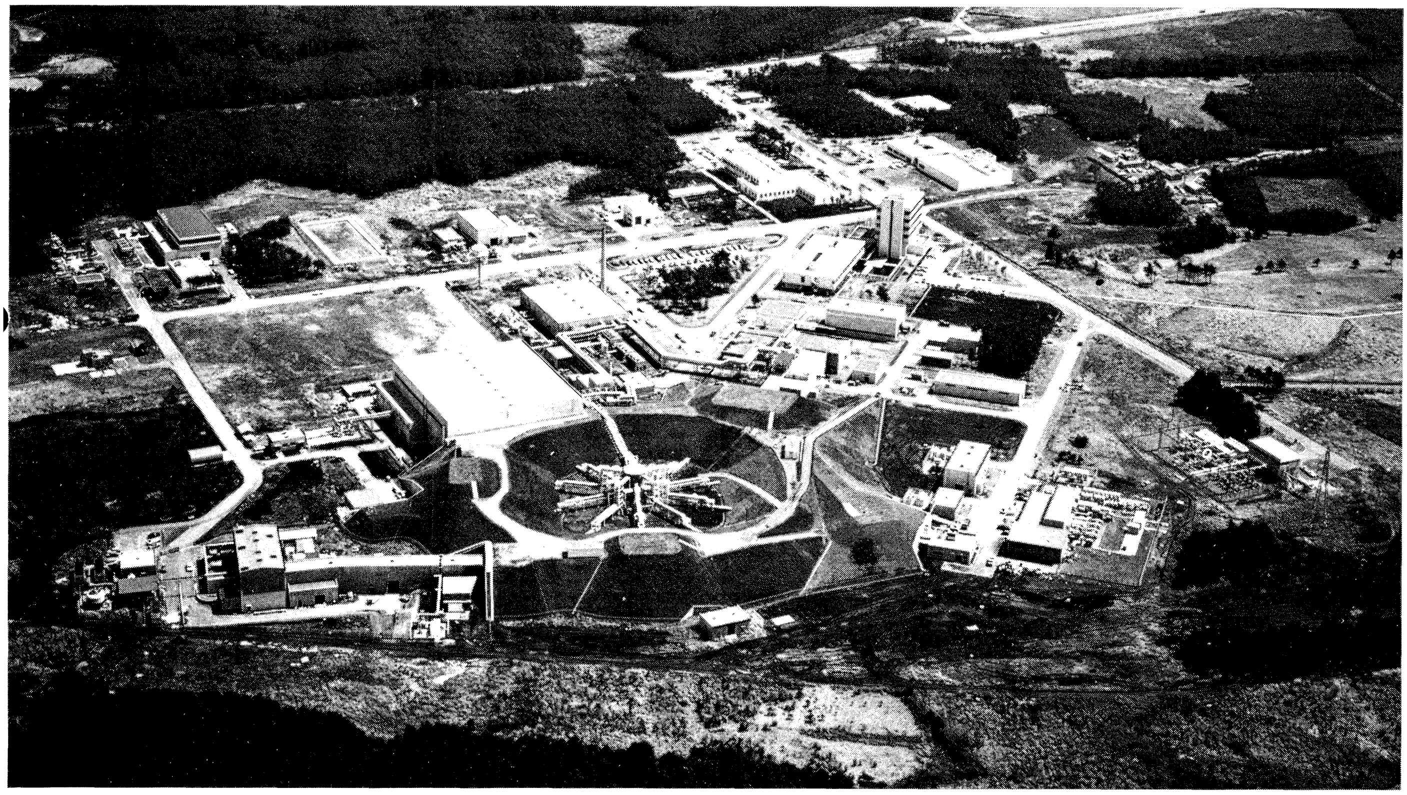
With the central synchrotron complete, work began on a 500 MeV booster beam. As well as serving the main KEK ring, the booster also supplies additional protons for experiments in nuclear physics, neutron diffraction and radiobiology.

This year saw the start of construction work for a synchrotron radiation source, including a 2.5 GeV electron linac and storage ring. This is scheduled for completion in four years' time (see May issue, page 158).

Initial KEK experiments used a fast extracted beam with the 1 m bubble chamber and an internal target supplying beam to counter experiments. This year work is continuing on a slow extracted beam to increase the scope for counter experiments.

Aerial view of the Japanese KEK High Energy Physics Laboratory. The 12 GeV proton synchrotron, centre, serves two experimental halls, the smaller one at the bottom of the picture housing the 1 m bubble chamber, while the larger is the scene of counter experiments.

(Photo KEK)



This new beamline makes use of a three-way proton beam splitting system. Two of these beams irradiate targets producing kaon and antiproton secondary beams and are the scene of preparations for experiments on kaon decays, on hypernuclei and on the interactions of kaon beams with polarized targets. The third beam is being used in a new experiment studying direct lepton production.

Work on these beamlines is well advanced, and proposals have been put forward to extend further the range of experimental facilities at the main machine. These include a low momentum pion and muon beam for nuclear physics experiments, a hyperon beam and a high momentum (up to 8 GeV) unseparated beam using superconducting magnets.

Preliminary results from counter experiments at KEK were reported at the Tokyo Conference and covered the differential cross-section and polarization behaviour of charge exchange reactions of negative pions on protons in the 2-3 GeV energy range. This experiment took beam from the internal target to irradiate a specially-constructed polarized target of ethylene glycol.

Bubble chamber experiments with the 1 m chamber started in 1977 and soon amassed 280000 pictures with 6 GeV negative pion beams. A subsequent experiment, investigating lepton production with 8 GeV protons, used tantalum plates inside the chamber and has exceeded the 1 million picture mark.

The measurement and analysis of the bubble chamber film is helped by the KAMA (KEK Automatic Measuring Apparatus) system, based on a Hitachi HITAC computer. As well as handling KEK film, KAMA also takes photographs from a pion-proton experiment at SLAC. However the majority of the bubble chamber film analysis load is borne by the universities, with Tohoku in particular taking a lot of film.

Computing at KEK is based on a twin Hitachi HITAC 8800 configuration, with the KEKOPEN system handling the batch processing load. Use of on-line terminals is not widespread. For monitoring experiments there is the KEKNET system, where individual minicomputers (mostly PDP-11/45s) in the experimental hall are connected to the main computer centre through a 250 kbyte/s link.

No high energy physics Laboratory these days is complete without its large-scale plan for the future and KEK is no exception. The site is big enough to accommodate a ring of more than 2 km in circumference, and with a 12 GeV proton synchrotron and a 2.5 GeV electron linac available, a number of different colliding beam schemes can be envisaged.

Called TRISTAN — Transposable

Ring Intersecting STorage Accelerators in Nippon — the project could use a ring equipped with conventional magnets to store electrons and to act as an intermediate accelerating ring for protons before they are injected into a superconducting ring to be taken to several hundred GeV.

FRASCATI
Electron-positron physics at medium energies

A meeting on electron-positron physics at medium energies has been held in Frascati with the participation of more than a hundred physicists. The opening address was given by INFN President A. Zichichi in the presence of G. Postal (Italian Under-Secretary of the Ministry for Scientific Research) and the closing address by M. Pedini (Italian Minister of Public Education).

The meeting was intended to give specialists working in this field the possibility to review results since the Hamburg Conference in 1977 and to discuss the new perspectives opened up by the recently proposed high luminosity electron-positron storage ring to be built in Frascati.

The general consensus was that this low beta, high luminosity storage ring (ALA - Anello a Luminosita Alta) designed by the Frascati Accelerator Group, which would work at a luminosity a hundred times higher than the ADONE storage ring at a centre-of-mass energy of 2.4 GeV (and still be greater than 10^{30} per cm^2 per s at 1 GeV) would be a unique instrument to increase our knowledge of a large range of phenomena in this energy range.

The ALA design is a 17 m diameter, 1.2 GeV storage ring with four straight sections — one for injection, one for the r.f. system and two 3 m low beta insertions for the experiments. The peak current would be 150 mA per beam with one bunch in each beam. Injection may be directly from the existing linac used to feed ADONE, or may use ADONE as a booster.

Notwithstanding the efforts at many Laboratories to search for new resonances in the 1 to 3 GeV mass range, the experimental situation is far from clear. In fact, while some of the resonances observed up to now have been confirmed, others need to be supported by more statistically significant data.

As discussed during the meeting from many theoretical points of view, high statistics electron-positron searches will, for example, clarify the problems connected with complex quark states like baryonium. A detailed analysis has also shown the great interest of some more conventional aspects of electron-positron physics: the pion/kaon form factors, the radial and orbital recurrences of vector mesons, radiative decays, problems of mixing, two-photon physics, exotic states, rare processes involving quarks.

To carry out this physics programme, a powerful detector will be needed coupled to ALA. A longitudinal magnetic detector covering about 90 % of the total solid angle, with the ability to distinguish between pions, kaons and protons, will meet this requirement and help physicists improve the understanding of the interesting phenomena now just showing up in ADONE. The new project will ensure an active scientific life at Frascati in the coming years.

DESY
Luminosity at PETRA

The electron-positron storage ring, PETRA, at the DESY Laboratory has

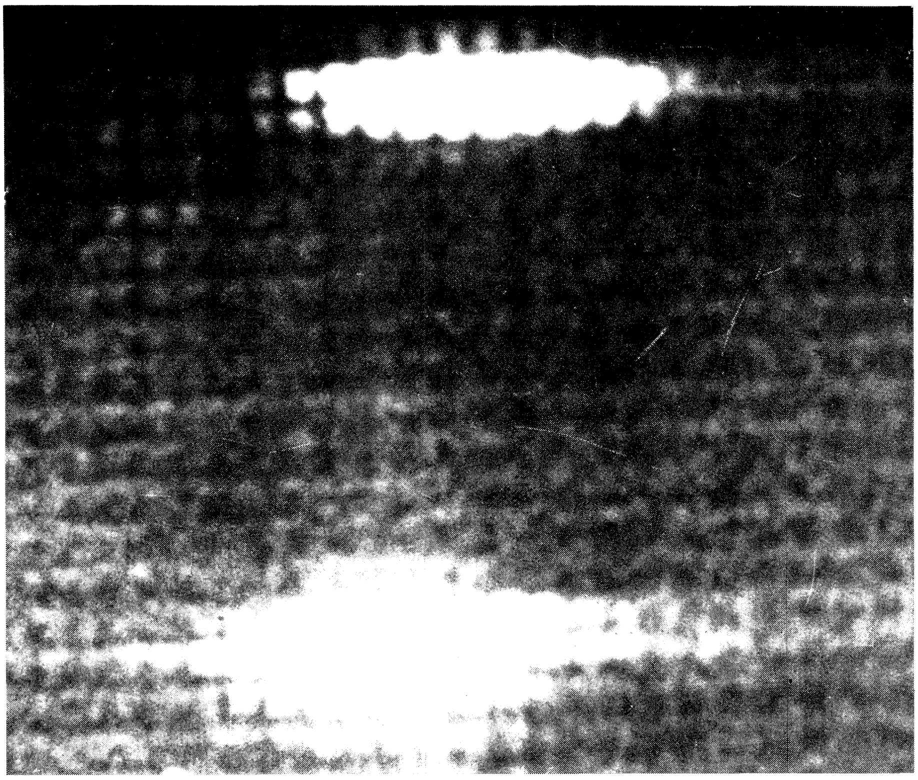
Nino Zichichi gives the opening talk at the first session (chaired by Sam Ting) of a meeting at Frascati to discuss electron-positron physics at intermediate energies.

(Photo Frascati)

Beams in the new electron-positron storage ring, PETRA, at DESY. Above is the signal from a 2 mA electron beam and below from a 1.5 mA positron beam.

been in operation for most of the time since beam was first stored on 15 July (see August issue, page 243). During the first six weeks, however, priority was given to the operation of the DORIS storage ring, which, following its observation of the upsilon resonance in an electron-positron storage ring was carrying out a successful hunt for the upsilon prime.

It was not until the first week in September that positrons became available for PETRA. This is because, until the construction of an additional ring called PIA, DORIS is part of the positron accumulation system for injection into PETRA. By mid-September positron bunches collided with electron bunches at an energy of 5 GeV per beam resulting in the first measured luminosity of 2×10^{29} per cm^2 per s. This figure was about one quarter of the maximum theoretical luminosity per bunch interaction at this energy for the particular optics used in the test.



In August, while PETRA was waiting for DORIS to become available for intermediate positron accumulation, a number of interesting developments took place. Single bunch currents of electrons were accumulated up to 6.5 mA, which is already a third of the maximum design current of 20 mA. (After positrons became available, single positron bunches with currents up to 5.5 mA were achieved.) Also stored beams were accelerated to energies of 11.11 GeV without any observable loss.

The most surprising result came when the bunch lengths of stored electrons and positrons were measured. The observed bunch lengths of 1.7 to 2.5 cm corresponded very well with theoretical expectations for small currents and the anticipated 'bunch lengthening effect' was much smaller than expected. At average currents up to 3 mA the lengthening effect was smaller than 35%. This is good news for the experimenters, who can look forward to a very small energy spread for the production of narrow resonances.

KARLSRUHE Superconducting r.f. cavities

In the design study for the LEP electron-positron colliding beam machine (see page 353) a two stage procedure is foreseen. A peak energy of 70 GeV is to be achieved in the first stage using normal r.f. cavities and in the second stage the energy will move finally to 100 GeV by exchanging the cavities with superconducting ones. This will circumvent the extremely high r.f. power consumption at higher energies.

The technology of superconducting cavities has reached a state which makes such a scheme feasible. The improvement factor — the ratio between cavity losses (comparing copper at room temperature to niobium at 4 K) — is 10^4 to 10^5 for the operating frequencies considered for storage rings and accelerating field gradients of 2 to 3 MV/m can be expected. Confidence in the reliability of superconducting r.f. systems has increased very much with the operation of the superconducting r.f. separator at the CERN SPS since December 1977 without trouble.

There are, however, several open questions when considering the application in storage rings. Can the initial performance be maintained for an appreciable period of time in the presence of a particle beam (giving synchrotron radiation and scattered particles) and with the cold cavity being connected to a long warm beam tube? Can the excitation of higher modes in the cavity be handled? Is it possible to couple the large amount of beam power into the cavity?

Most of these questions can be studied only by testing a superconducting cavity in an operating storage ring. Moreover, concepts for mass production of cavities plus ancillary equipment (like tuners, cryostats and couplers) at reasonable costs have to be worked out.

A collaboration between CERN, DESY and Kernforschungszentrum Karlsruhe has been set up, according to which Karlsruhe is developing two cavities for tests in the DORIS electron-positron storage ring at DESY. The costs are being equally shared between the three centres.

The cavities will be fabricated from sheet niobium by argon arc welding. The input coupler is designed to bring a beam power of about 100 kW from room temperature down to 4 K. This makes it necessary to have a very careful design of the coaxial line inside the cryostat. The heat influx is reduced by capacitive separation of the line at temperatures of 4 K, 80 K and 300 K. The parts close to the cavity are superconducting to minimize heat losses.

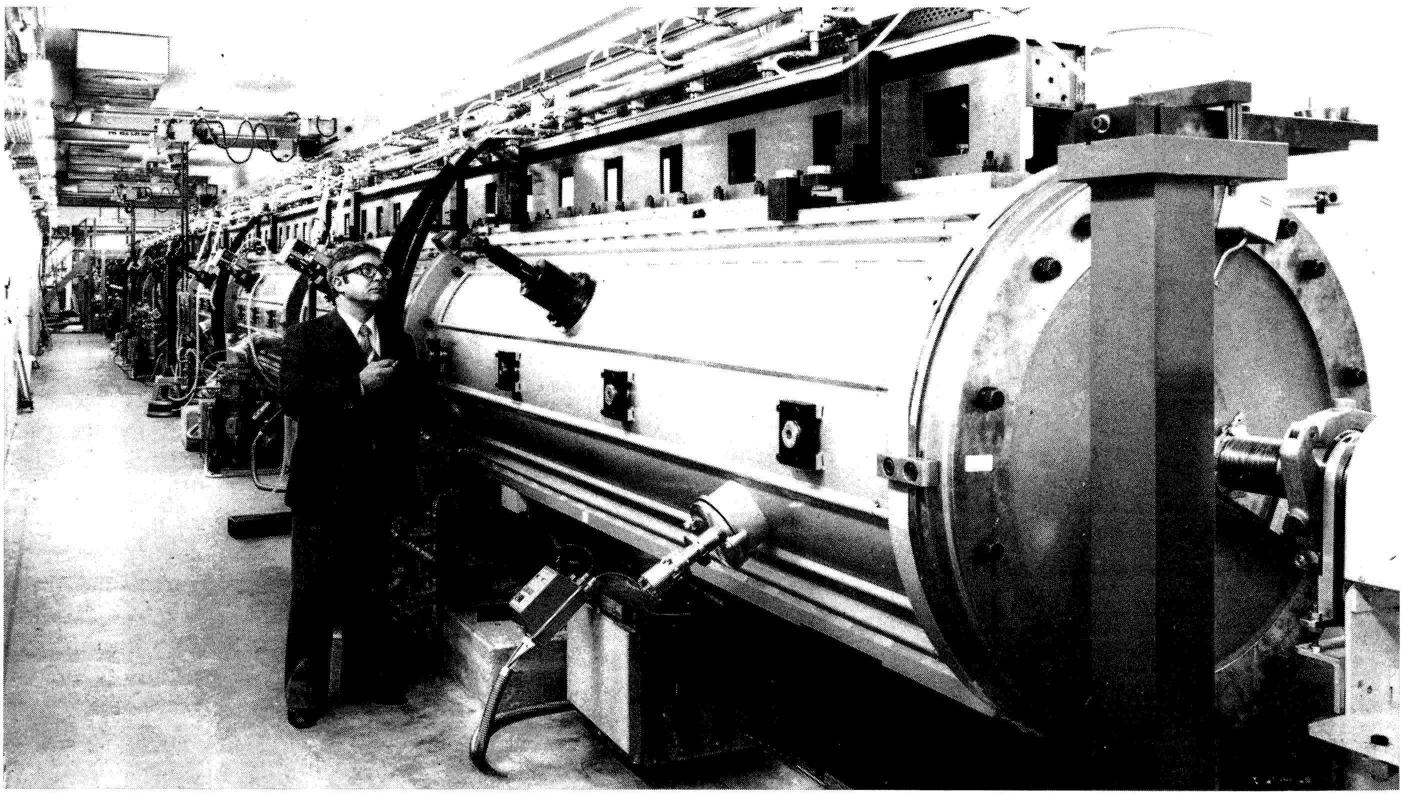
The higher mode output coupling system has been developed to couple 99.9 % of the power delivered by the beam out to a room temperature load without affecting the fundamental accelerating mode. The cavity is cooled in a liquid helium bath at atmospheric pressure to 4 K. The beam entrance tubes of the cryostat are cooled before the cavity in order to freeze out gases from the rest of the beam pipe in the beam tube rather than in the cavity.

The cavities are under construction and will be available for laboratory tests at the end of this year. After completion of all additional equipment it is hoped that the test in DORIS can take place in the second half of 1979.

CERN
New linac reaches design energy

With the 28 GeV proton synchrotron (PS), the Intersecting Storage Rings (ISR) and the 400 GeV proton synchrotron (SPS) all in action at the same time, CERN is the scene of the widest diversification of high energy physics experiments with protons. To this will soon be added the proton-antiproton colliding beam project (see September issue, page 291).

The source of all these protons (and antiprotons) is the linac at the PS. It is obviously of vital importance to have a top quality, high reliability linac, and a

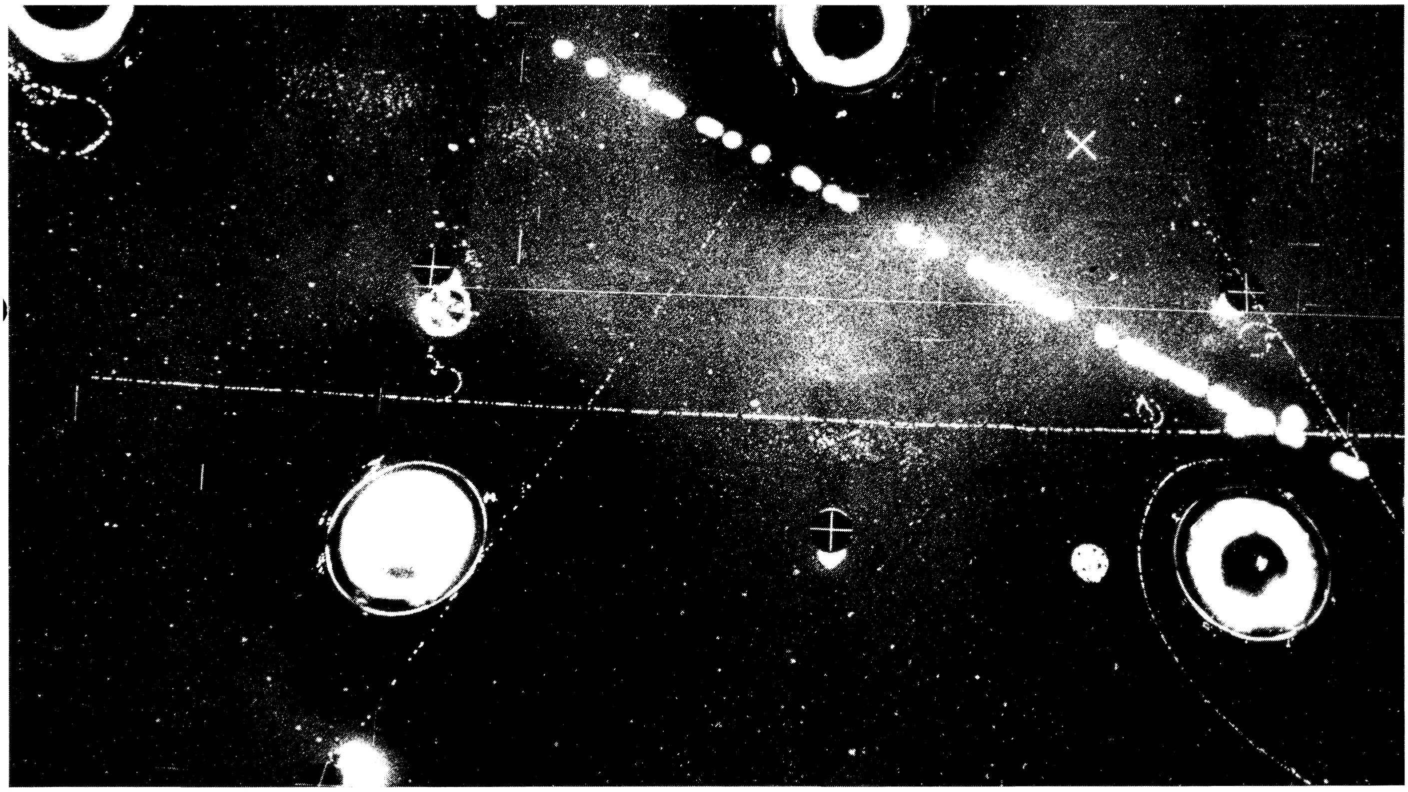


The new linear accelerator for the CERN 28 GeV proton synchrotron has now attained its 50 GeV design energy and is scheduled to come into service early next year, replacing the existing linac which has been in service since 1959.

(Photo CERN 14.9.78)

One of the events recently observed by a Bari / CERN / Milan / Orsay / Palaiseau collaboration in the Gargamelle bubble chamber using the SPS wide band neutrino beam. This is the first observation of the reaction $\nu_\mu + e^- \rightarrow \nu_e + \mu^-$. *The isolated horizontal track, originating in the liquid and directed to the right, is the secondary muon emitted in the reaction. It is the inverse of the beta decay of the muon* $\mu^- \rightarrow e^- + \nu_\mu + \nu_e$. *These are the only weak interactions in which only leptons are involved. The existence of this new reaction has been expected for several decades and the measurement of the cross-section will enable the universality of the weak charged current theory to be verified.*

To distinguish the events from possible backgrounds, several requirements have to be satisfied. First, the interaction region has to be observable with great precision to eliminate the possibility of other tracks. Secondly, the muon has to be identified and selected with high efficiency. This is done by the counters surrounding the bubble chamber: veto, picket fence, and the two-plane muon identifier. Finally, the angle of the muon to the neutrino beam has to be measured with a precision of the order of one milliradian to isolate this reaction from the elastic type which takes place on nucleons. The first measurements give hope that a good separation of this reaction can be achieved.



new one has been built. The construction of a new linac for the PS was launched in 1973 and is presently scheduled to take over the responsibility early next year for supplying protons to the PS.

Protons come from a duoplasmatron source and 750 keV Cockcroft-Walton pre-accelerator. The 750 keV beam transport system provides for careful matching into the linac which consists of three Alvarez-type tanks with post coupler stabilization, operating at 202.5 MHz. The r.f. power system uses FTH 170 triodes (anode with direct water cooling) and contains wide band phase and level servo-loops. The whole machine is controlled by a very flexible system based on PDP 11-45 computers.

The machine reached 50 MeV for the first time on 6 September and the design current of 150 mA was obtained at the end of tank 3 on 4 October. During a 48-hour run which began the following day, beams of 90 mA (standard operation level) and 120 mA were injected into the Booster. Up to 2.6×10^{13} ppp instead of 2×10^{13} previously were obtained in the Booster after multiturn injection leading to a new intensity record of 1.67×10^{13} at 800 MeV, limited, as anticipated, mainly by longitudinal instabilities and beam loading. Ease of adjustment and stability during the beam pulse as well as from pulse to pulse were improved.

Some of the necessary improvements to the Booster are already under way to exploit this new and, it appears, very healthy member of the CERN family of accelerators.

SPS ups intensity

At the opposite end of the proton acceleration scenario at CERN from the linac is the proton beam emerging from the 400 GeV synchrotron, the SPS. The accelerated beam intensity has reached record levels in the last two operating periods.

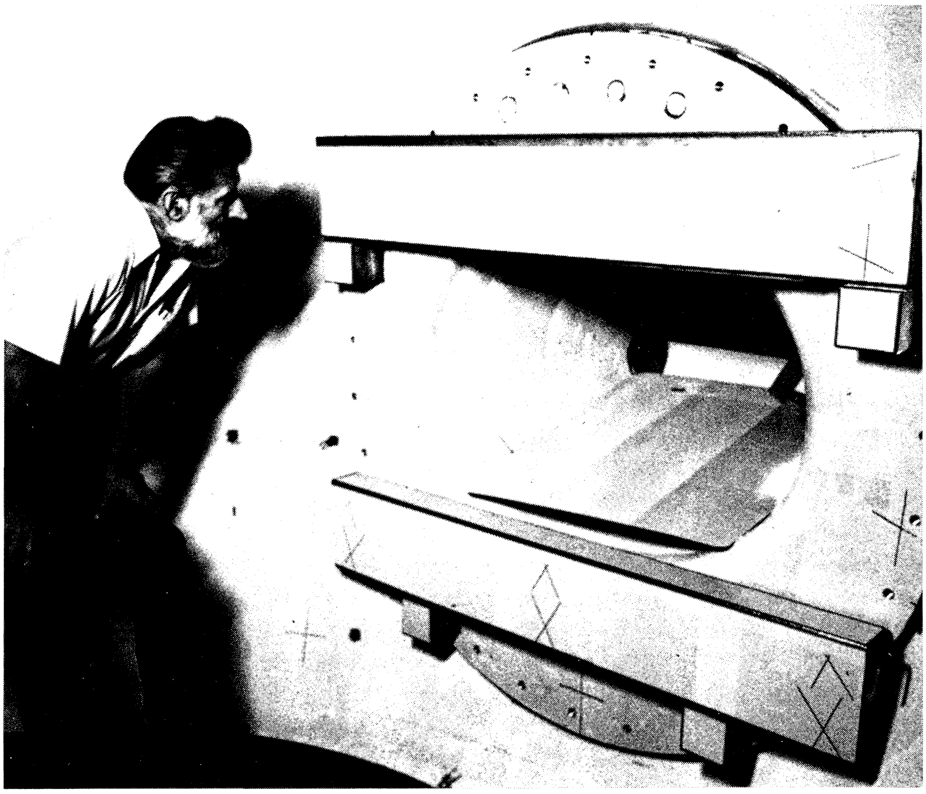
These achievements followed the implementation of double batch injection from the PS. Instead of sending a single pulse of 10 GeV protons to the SPS ejected over ten turns and distributed almost all the way around the SPS ring, in double batch injection, the PS sends two pulses ejected over five turns giving nearly half a ring's worth each pulse. The total cycle time is increased from 8.4 s to 9.6 s. The PS beam is ready bunched at the SPS r.f. frequency of 200 MHz before being ejected.

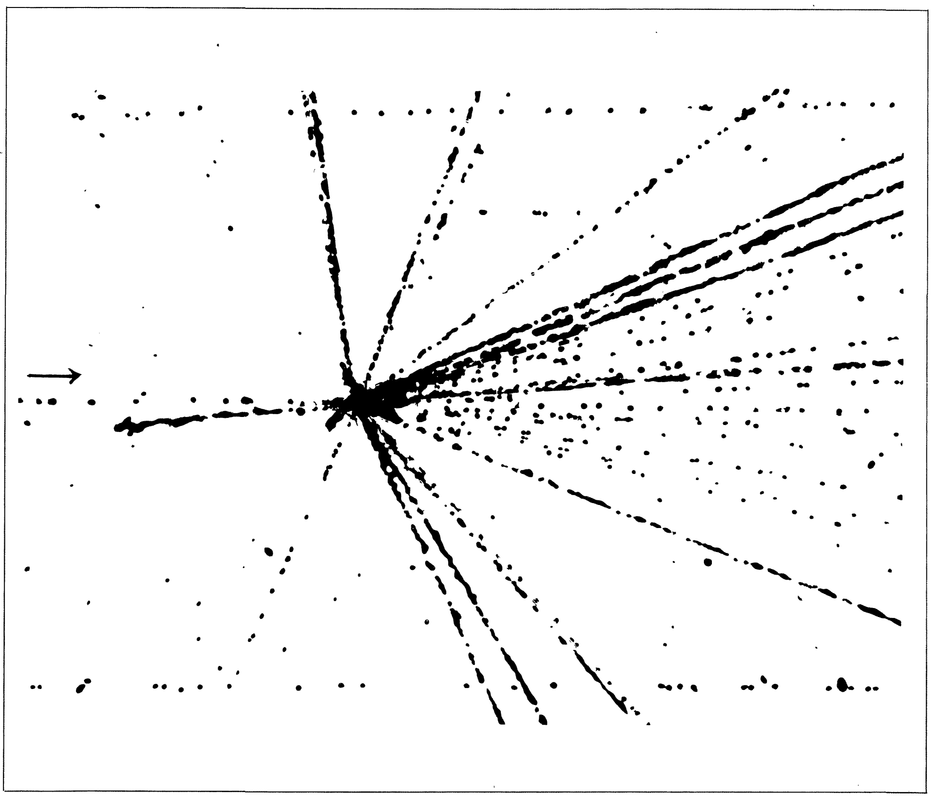
With these manoeuvres the accelerated beam intensity was taken to 1.5×10^{13} protons per pulse (sustained for at least fifteen minutes) in period 5 and to 1.6×10^{13} in period 6. A record number of protons was sent to the experiments during period 6.

The installation of 22 litres of Cryogenic Sensitized nuclear emulsions from Moscow in two neutrino target boxes being checked inside the Fermilab 15 foot bubble chamber by Lou Voyvodic, spokesman for the US / USSR / Poland collaboration. The hybrid bubble chamber / emulsion technique is being used to study the production and decay of charmed particles.

(Photo Fermilab)

Particle tracks from the exposure of Cryogenic Sensitized nuclear emulsions maintained at liquid hydrogen temperatures to a 45 GeV negative pion beam at Serpukhov. The horizontal scale covers about 100 microns. Such tests showed the feasibility of using these emulsions inside cryogenic bubble chambers. An experiment by a US / USSR / Poland collaboration using this technique is soon to get under way at the 15 foot chamber at Fermilab.





More 10 GeV pulses into the SPS per cycle are scheduled and, next year, four additional amplifiers will double the r.f. power available. The aim is to achieve 3 x 10^{13} protons per pulse from the SPS and to push the peak energy to 450 GeV.

CERN/FERMILAB Emulsions inside bubble chambers

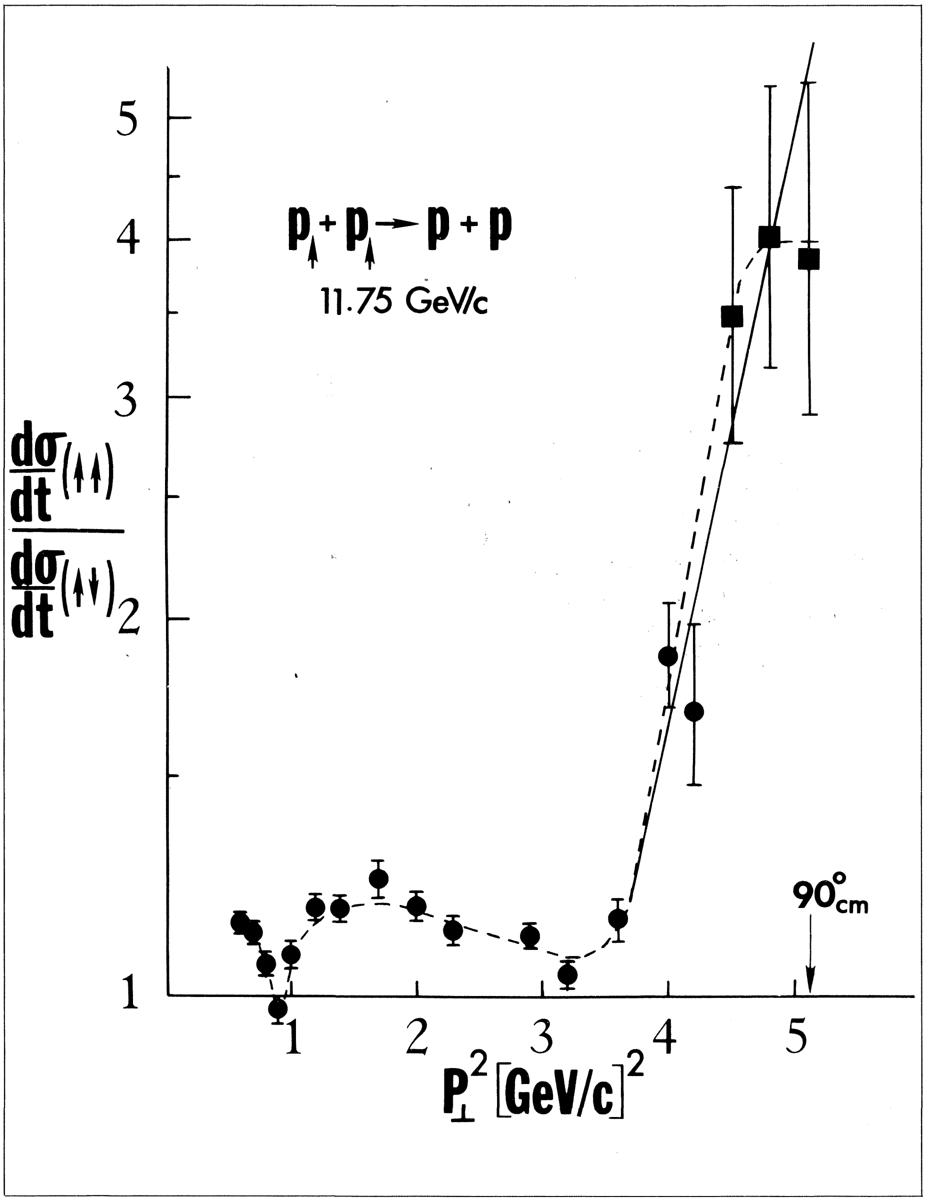
In the continual quest for rare events like charm production, different detection techniques are increasingly being used in conjunction to facilitate the search. One example of this trend is the use of emulsions with additional downstream detectors to monitor the decay products of interactions in the emulsion target.

Measurements on charm decays are in progress using emulsion targets with the Omega spectrometer at CERN (see June issue, page 208), where the reconstruction of events in the downstream detector helps locate the interaction vertices in the emulsion plates. Another experiment by an Ankara / Brussels / CERN / Dublin / London / Pisa / Rome / Turin collaboration has exposed an emulsion stack in front of the BEBC bubble chamber.

For maximum effect, the emulsion and the downstream detector should form a continuous system, as gaps between the emulsion and the detector lead to inaccuracies in locating the interaction in the emulsion. Tests have recently been carried out to investigate the possibility of obtaining a continuous system by mounting an emulsion target actually inside a bubble chamber.

At Fermilab, an experiment is to be carried out in the 15 foot chamber. This makes for special problems in handling emulsions in a low temperature environment. At CERN, the periodic use of the Track Sensitive

New data from polarized proton scattering experiments at Argonne (square points) show that the spin effects first observed last year continue to grow with energy. At the highest energies it is not clear whether the effects have reached a limiting value or whether they will grow further.



Target (TST) inside BEBC makes it difficult to install emulsion targets inside the chamber.

While in a cryogenic chamber the problem is low temperature, emulsion targets inside the Gargamelle heavy liquid chamber at CERN have to contend with a relatively high temperature. The interior of Gargamelle is maintained at 54°, but to ensure its preservation an emulsion target has to be kept below 15°.

Some tests have been carried out using a small aluminium alloy refrigerated box built and mounted inside the access door of Gargamelle. In preliminary trials with a dummy load, the cooling system for the box worked satisfactorily and, thanks to the optically clean coating on the outside of the box, the quality of the bubble chamber photographs remained good. Tracks were visible right up to the surface of the box. In subsequent trials, 2.5 litres of emulsion were placed inside the box and exposed to neutrino and antineutrino beams.

For the next running period of the Fermilab 15 foot chamber for neutrino and antineutrino interactions in deuterium, an additional experiment by a collaboration of groups from Fermilab / Kansas / Washington and Krakow and from the IHEP / ITEP / JINR Institutes in the USSR will make use of special nuclear emulsion targets inside the chamber.

The use of emulsions inside cryogenic or freon bubble chambers was proposed at Fermilab in February 1976. After tests at Serpukhov in September 1977 confirmed good track characteristics in Cryogenic Sensitized BR-2 emulsions exposed at liquid hydrogen temperatures, 22 one-litre stacks of these emulsions were prepared in Moscow and are now installed in two target boxes mounted on the inside of the upstream nose cone of the chamber.

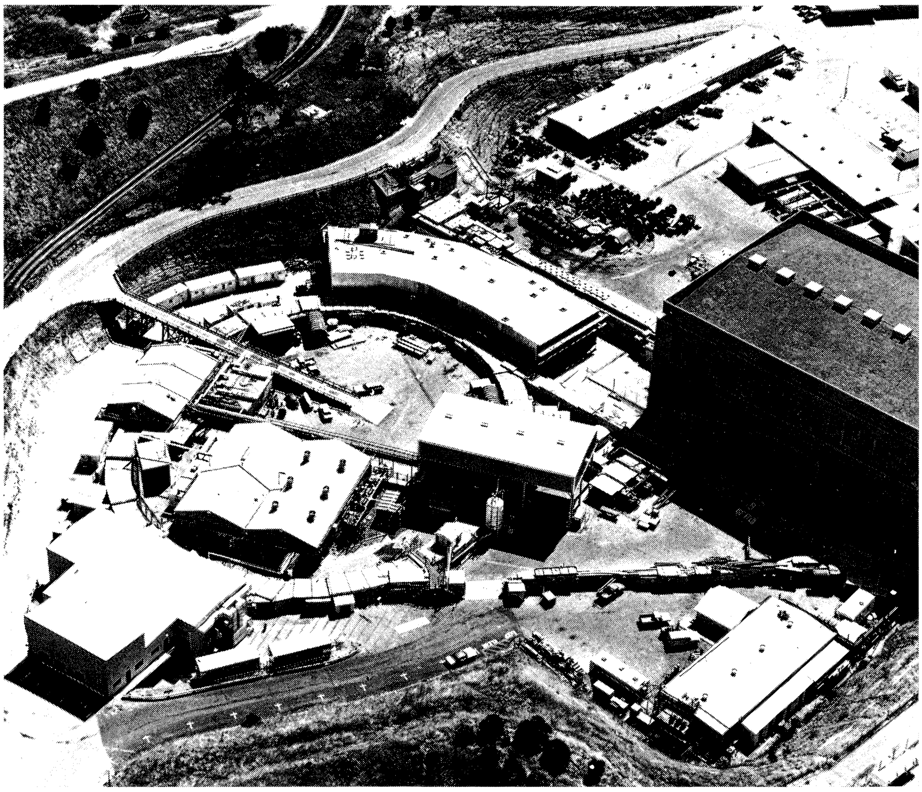
Reconstruction of tracks emerging from the emulsion boxes is expected to provide accurate predictions for locating approximately 1000 neutrino interaction vertices in the emulsion layers, as well as helping to provide full analysis of each event.

As well as charmed particles, this technique could show signs of other species of particles whose lifetimes range from 10^{-11} to 10^{-15} seconds.

ARGONNE
Proton scattering still in a spin

Last year a team, working with the polarized proton beam and polarized targets at the Argonne Zero Gradient Synchrotron, discovered that proton-proton elastic scattering had a large and totally unexpected spin-spin force at large transverse momentum (see

Recent aerial view of the SPEAR storage ring at SLAC. The two straight sections of the ring house the high energy physics detection systems (Mark II on the right, Crystal Ball on the left). The two arcs house the synchrotron radiation experiments with the recent addition on the south arc at the top.

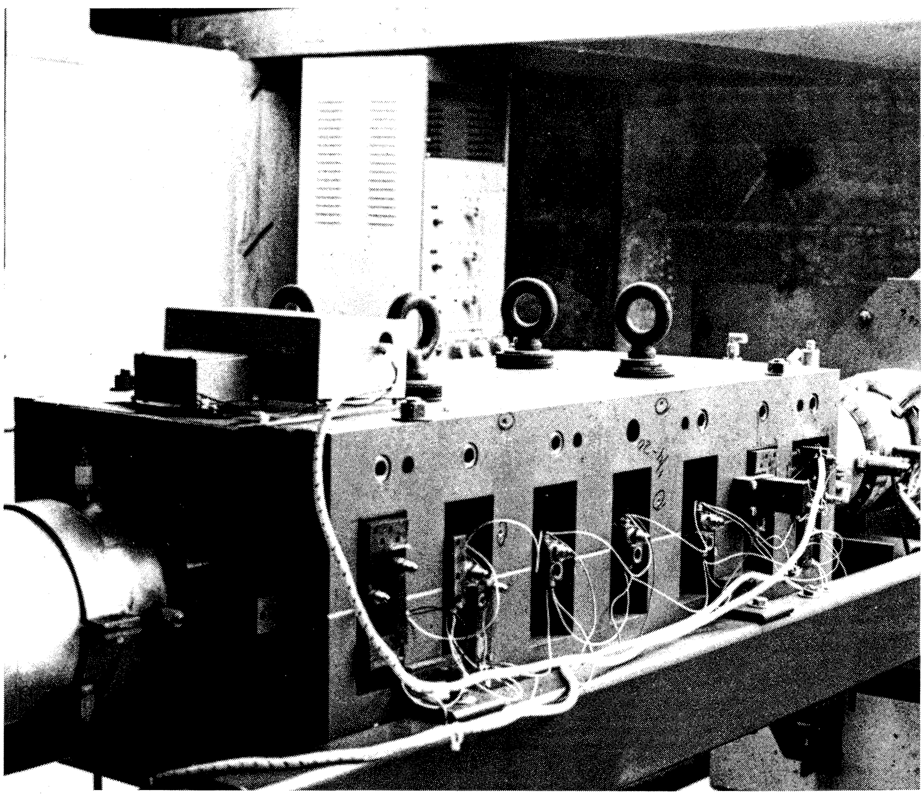


August 1977 issue, page 237 and November 1977 issue, page 283). This spin effect developed very abruptly at a value of the transverse momentum squared of 3.5 $(GeV/c)^2$. The Michigan / Argonne / AUA team has now extended their measurements to larger values.

Using the new record polarized beam intensity of 5×10^{10} protons / pulse and running continuously for two months at a beam energy of 11.75 GeV/c, the team has extended the measurements out to 90° in the centre of mass and a value of 5.1 $(GeV/c)^2$. The new spin measurements are shown in the graph as the ratio of scattering with parallel proton spins to that with antiparallel spins.

At the largest available values, the spin-parallel cross-section is four times larger than the spin-antiparallel cross-section. There is presently no theoretical explanation of this astonishingly large effect. However, there is a strong belief that elastic scattering at large transverse momentum is caused by the direct scattering of the proton constituents and that these constituents must, for some reason, rarely scatter unless their spins are parallel.

At 11.75 GeV one cannot go to larger values since they are already maximized at 90° in the centre of mass. However, the experiments hope to extend the measurements by increasing the polarized beam energy and to distinguish between the present uncertainties as to whether the ratio of cross-sections has reached a limiting value or is still growing.



The six-pole, 18 kG wiggler magnet installed in the SPEAR storage ring to generate 'hard' synchrotron radiation by inducing sharp bends in the electron beam. Thus hard radiation will be available for experiments even when SPEAR is working at comparatively low energies. This is the first wiggler to be installed in an operating ring.

(Photos SLAC)

Physics monitor

STANFORD SPEARhead

The electron-positron storage ring SPEAR continues to be the centre of intense scientific activity for both high energy physics and synchrotron radiation experiments. During the first half of this year there was the longest running period in SLAC's history (14 January to 13 July) when the storage ring operated almost continuously. The only interruption was seven days during which SPEAR could not run because of incompatibilities with the high-priority parity violation experiment performed in end station A. The asymmetries being studied in that experiment were so small that they could be overshadowed by small electrical transients caused, for example, by switching from positron to electron injection for SPEAR !

During that period SPEAR ran for 344 colliding-beam eight hour experimental shifts for the Mark II detector and for the DELCO experiment. Synchrotron radiation experiments were also under way on a parasitic basis. In addition, SPEAR operated as a single-beam dedicated synchrotron radiation source for one week (21 shifts) and during that week the stored beam energy was 3.0 to 3.7 GeV with currents as high as 100 mA in four bunches. Most of the colliding beam operation used stored beam energies of 1.8 to 2.2 GeV with 10 to 25 mA stored in one bunch.

A 14 week shutdown ending in mid-October saw the DELCO experiment removed from the east interaction region and the Crystal Ball experiment installed in its place. The Mark II continues in residence in the west interaction region until the summer of 1979 when it is scheduled to move to PEP. It has recently been decided that DELCO will also be installed on PEP as one of the first round experiments.

During this same shutdown period the Stanford Synchrotron Radiation Laboratory (SSRL) began installation of its major new experimental hall and several beam channels on the South arc of SPEAR as reported last month. A six-pole, 18 kG wiggler magnet was also installed in a SPEAR straight section. This is the beginning of the three year expansion programme for SSRL to provide 12 to 14 additional experimental stations beyond the ten now in operation. The first of these new stations will begin operation early in 1979 and the rest will be completed by the end of 1980.

There is an agreement between SSRL and SLAC that when PEP is well under way with its experimental programme, SPEAR will be available as a dedicated synchrotron radiation source for half of its operation time. With first stored beam trials of PEP now scheduled for October 1979 the transition to the new mode of operation for SPEAR should begin by early 1980.

Colour chemistry

Although our present picture of strong interactions is still in a formative stage, there are already signs that the range of hadronic states discovered so far might just be the tip of an iceberg. Once the experimental techniques have been developed, the mechanisms of strong interactions could rival those of chemistry in their ability to create new and interesting compounds.

It hinges on the idea of 'colour', alleged to play a role in strong interactions analogous to that of electric charge in electromagnetism. Additional particles called gluons carry colour between the quarks in much the same way that photons mediate electromagnetic interactions.

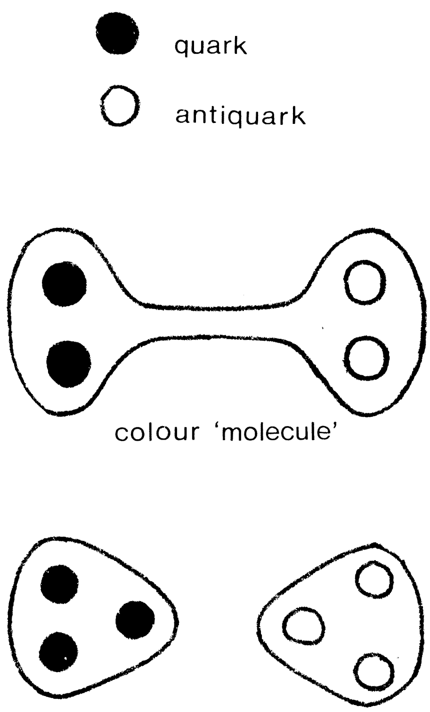
Although not many manifestations of colour have been seen, it enables us to account for the wave function of the decuplet of baryons being symmetric in flavour (electric charge and strangeness) and spin, while the Pauli exclusion principle would like the wave function to be antisymmetric. This dilemma can be solved by the addition of colour to bring in the required degree of asymmetry.

In the colour picture, quarks are attributed with another quantum number in addition to charge, flavour and spin. However little trace of this colour attribute is seen — it is as if the extra colour degree of freedom has been frozen out. The colour affinity between quarks seems to be so strong that they want to bind together to form 'colourless' (zero net colour) states.

Normally, when an extra degree of freedom exists in physics, it eventually shows up in spectroscopy, in the way that spin degrees of freedom add fine and hyperfine structure to the normal atomic spectrum. With hadronic spectroscopy, the question is where to look to see any additional effects due to colour.

For baryons made up of three quarks

Colour chemistry in action. A colour 'molecule' could consist of a pair of quarks and a pair of antiquarks held together by a 'tube' of colour force. Should this tube snap, a quark and an antiquark are formed either side of the break, in the much same way that sawing a bar magnet in half produces an additional pair of magnetic poles. The decay of the colour molecule produces a baryon and an antibaryon, and provides one explanation of 'baryonium' — states which although existing in mesonic channels, prefer to decay into baryon-antibaryon pairs.



and mesons composed of a quark-antiquark pair, the colour degree of freedom is completely frozen and in each case there is only one way of making a state with zero net colour.

However when hadron states become 'hot', so much energy can be brought in that at least one extra quark-antiquark pair is created inside the hadron and the colour configuration could change.

Then it would be possible to have colour isomers — states with the same quark content but with different physical properties as a result of the different distributions of colour. Such colour isomers could already have been seen in experiments, although this is not yet certain.

One of the proponents of the quark isomer idea, Chan Hong-Mo, prefers to talk in language borrowed from chemistry. Blobs of quark matter — 'chromions' — can bind together with tubes of colour field lines to form composite colour 'molecules' in much the same way that ordinary ionic molecules are formed.

If the constituent chromions are kept apart, for example by a high angular momentum barrier, they will keep their individual identities, so that the properties of the colour molecule could be deduced from the properties of its component chromions.

Normally when such a colour molecule breaks up, it will be as a result of the tube of colour field lines being broken, rather than the chromions themselves decaying. When the tube snaps, quarks and antiquarks appear on the two sides of the break, in much the same way as cutting a bar magnet in half produces an additional pair of magnetic poles.

Systems made up of two quarks (as opposed to a quark plus antiquark) do not have zero net colour and have unusual properties such as fractional electric charge. As a result they are not seen as free hadrons. However a diquark could be a simple form of chromion, and a simple colour molecule would be 'diquonium' — a diquark and an antidiquark, connected by a colour tube, rotating around each other.

Depending on the colour configuration of the diquarks, one or two quarks are formed on each side of the break if the connecting colour tube snaps and causes diquonium decay. If just one new quark is created on each side, the decay produces a baryon-antibaryon pair (see diagram).

These diquoniums could be identified with the 'baryonium' states now seen in a range of different experiments. A number of these states have been reported, all having the property of appearing reluctant to decay into mesons. Even though they appear in meson-like (integer spin) channels, they prefer instead to couple to baryon-antibaryon pairs.

Such states had been expected on a number of theoretical grounds. The meson exchange forces which make it difficult to form any bound state of two baryons other than the deuteron are expected to produce, on the other hand, a relative wealth of states which couple to the baryon-antibaryon system. Baryoniums also smooth out difficulties with the simple quark model in baryon-antibaryon reactions, where basic ideas of 'duality' seemed to break down (see June 1977 issue, page 197).

Experiments seem to show that there are two kinds of baryonium. Some states are broad, having typical hadronic decay widths of a hundred MeV or more, and are seen at 2190 and 2350 MeV in painstaking analysis of nucleon-antinucleon scattering data.

Other baryoniums have a much narrower width, usually of the order of tens of MeV, and are seen in selected channels of production experiments, such as the proton-antiproton pair in $\pi^- p \to p\pi^- p\bar{p}$.

In the diquonium picture, these two kinds of baryonium are explained as being colour isomers with the same quark content but different interior colour configurations. Depending on this configuration either one or two quark pairs are formed when the colour tube connecting the diquarks snaps.

It is more difficult to produce two quark pairs than one, so the diquoniums producing two quark pairs will have a narrower decay width than those which produce just one pair. They will tend to emit mesons and change into other diquoniums.

However the diquark is only one simple example of a chromion, and whole ranges of new hadronic states could be formed from other chromions. Some narrow resonant states which have been reported could be explained as colour molecules built from two chromions, one containing three quarks and the other a quark-antiquark pair.

According to the ideas of colour chemistry, these hadronic states are the forerunners of an infinite number of possible colour molecules. If so, this will provide fuel for many more years of experimental effort.

The solar neutrino problem

The puzzle of solar neutrinos has now been with us for some 20 years, but new technical developments afoot in the US and the USSR giving greatly improved capabilities for neutrino detection might soon resolve the problem.

It was W. Fowler and A. Cameron who first pointed out that the range of thermonuclear reactions in the sun's interior should produce an appreciable flux of neutrinos. These intense reactions provide the temperature which resists the immense gravitational forces trying to crush the sun, and the level of these reactions, as measured by neutrino fluxes, is a good thermometer for the sun's interior.

These neutrinos fly out through the sun and into space, some of them arriving on the earth. However observations so far show that the detected level of solar neutrinos is only a fraction of what is expected from theoretical estimates. If this is correct, it means that we do not understand well enough what is going on in the sun.

Solar neutrinos can be detected through a variety of neutrino-induced nuclear reactions, such as the conversion of chlorine-37 to argon-37. One of the pioneers of solar neutrino work, Ray Davis of Brookhaven, has built a neutrino detector consisting of a 100000 gallon tank of dry-cleaning fluid (perchlorethylene) buried 5000 feet below the ground in a disused gold mine in South Dakota.

Results from this huge installation give results that are consistently less than the predictions of various theoretical models, and moreover the results seem to be independent of the sun's position, showing that the recorded level might be due to some other source instead.

Theorists have tried to find ways out of the problem by tinkering with the parameters of the sun's interior, but these attempts appear to produce more difficulties than they remove.

One reason for the present impasse could be that the currently-used methods for neutrino detection have threshold energies which do not match well the spectra of the solar neutrinos. As a result, only the high energy tail of the neutrino spectrum is intercepted and the lower energy component of the flux remains undetected. To catch these more elusive but much more abundant neutrinos, other detection methods must be sought.

An example of such a method uses gallium-71, which is converted by neutrinos into germanium-71, but until recently it appeared difficult to extract the tiny amounts of produced germanium from the mass of gallium in the detector. However recent developments in the US now show how this can be done. All that remains is to find the money to purchase the gallium — some 15 million dollars would be required for a typical detector containing 50 tons of gallium.

In the USSR, a huge neutrino observatory in the Caucasus is now nearing completion. Among other things, this uses gallium detectors and should be able to identify solar neutrinos with much lower energies.

Asthenodynamics

In our July / August issue (page 246), we intimated that someone might come up with a name to describe the new unification of our description of the weak and electromagnetic interactions.

People and things

'Broken Symmetry' — the latest sculpture from Bob Wilson which stands over the Pine Street entrance of Fermilab. The Hi-rise building is visible in the background. The sculpture uses steel deck plate from the USS Princeton, stands 16 m high and weighs 21 tons.

(Photo Fermilab)

As a result of theoretical developments which have become known as the Weinberg-Salam model, the weak and electromagnetic interactions can now be understood by a single picture. In a way this parallels the developments in the last century when theoretical developments culminating in Maxwell's equations achieved a synthesis of electricity and magnetism, giving birth to the word electromagnetism.

No new word analogous to electromagnetism seems to be in common parlance among physicists to describe this newest unification. Many people still talk of the Weinberg-Salam or the 'standard' model. However Salam himself uses the term 'electroweak' fairly freely.

Another possibility that has been suggested is pointed out by one of our readers in Edinburgh University, who regrets that physicists don't resort to Greek for new nomenclature in the way they used to. The background of classical education which produced such elegant words as hadron, meson, lepton or baryon has now given place to a new candour, with homespun names like parton, gluon, colour and flavour.

The suggestion is for the new electro-weak phenomena to be given the name 'asthenodynamics', or the 'asthenic force'. The Greek adjective 'asthenis' has the virtue of meaning 'not strong', rather than merely weak. In this way it can be used logically to describe all phenomena not associated with the strong force.

The root of the word 'sthen' means strong, and the α prefix denotes 'not', as in asymmetric. This gives us quantum asthenodynamics (QAD) as the field theory of the forces to be distinguished from those attributed to quantum chromodynamics (QCD) and strong interactions.

EPS and Trends in Physics

The 4th General Conference of the European Physical Society was held at York in the UK from 25-29 September. Organized in collaboration with the British Institute of Physics, it attracted 700 participants from Europe and overseas to the modern campus of York University.

Under the wide-ranging theme of 'Trends in Physics' the great diversity of present-day physics research was evident as a full programme of plenary sessions, specialized Seminars and posters attempted to cover the spectrum of modern optics, surface physics, phase transitions, nuclear astrophysics, hot plasma, heavy ions, synchrotron radiation and quarks.

In addition to the quark sessions, high energy physics came into prominence during the opening address of Professor A. Zichichi, President of the Society, at the General Assembly. He pointed out that in 1978 (the 10th anniversary year of the EPS), we can look back 100 years to the formulation of Maxwell's equations that unified electricity and magnetism and we can also see the new unification of electromagnetic and weak interactions as the model of Salam and Weinberg comes to fruition.

The laser and synchrotron radiation, two remarkable new tools now at the disposal ot the experimental physicist, dominated the proceedings. Their almost ideal experimental characteristics have resulted in an increasing trend towards all forms of spectroscopy. A widening interdisciplinarity, with physics bridging the gap between such diverse disciplines as biology, ecology, medicine and telecommunications, was also noticeable.

Discussions on the role of education in popularizing science, on physics in the developing nations and on the

Top level meeting at the CERN-LAPP stand when the Annecy Fair was inaugurated on 29 September. In the foreground from left to right — Leon Van Hove (CERN Research Director-General), John Adams (CERN Executive Director-General), Raymond Barre (Prime Minister of France), Jean Teillac (President of CERN Council) and Marcel Vivargent (Director of LAPP, Annecy).

(Photo CERN 253.9.78)

physicist's attitude to the arms race drew animated audiences. Physics and science as a whole have a great role to play as a unifying force in human culture and the enthusiasm of the young physicists, so evident at York, augurs well for the Society which needs the support of a growing membership to fulfil its important task as a European forum of physicists.

CERN and LAPP at the Fair

From 29 September to 9 October, CERN and LAPP (Laboratoire d'Annecy de Physique des Particules) had a joint stand at the Annecy Fair — one of the biggest held in the region of Haute-Savoie in France. The stand presented high energy physics and the research facilities used by CERN and by LAPP to do this physics. The stand was a considerable success and attracted many thousands of people.

The Fair was inaugurated on 29 September by the Prime Minister of France, Monsieur Raymond Barre, who visited the stand and spoke very favourably of CERN in his opening address.

On 7 October the theme of the Fair was devoted to science. Films from CERN were projected throughout the day and talks on CERN and its work were given by Rafel Carreras and Robert Lévy-Mandel from CERN and by M. Pessard from LAPP.

A step to LEP

From 10-22 September, European high energy physicists and accelerator specialists gathered at Les Houches and CERN for a major review of the proposed large electron-positron storage ring, LEP, which is now unanimously acclaimed as the next desirable machine to extend particle physics research facilities for Europe in the future. This LEP Summer Study was under joint ECFA-CERN sponsorship with Marcel Vivargent and Sergio Fubini as Chairmen of the Organizing Committee.

The first eleven days drew some 80 people to Les Houches. Five working groups were set up — Electron-positron physics beyond PETRA energies (convener Ch. Llewellyn-Smith), Machine parameters and characteristic features (J. Le Duff), Design of interaction regions (P. Strolin), Experimentation at LEP (M. Davier) and New ideas about detectors (K. Winter). The last two in fact merged and resplit between physics topics.

On the machines itself, the focus of attention was a 'Design study of a 15 to 100 GeV e^+e^- colliding beam machine (LEP)', which was produced at CERN with the report number CERN / ISR-LEP / 78-17 and which is now commonly referred to as the 'blue book'. It emerged from the work, led jointly by E. Keil, W. Schnell and K. Zilverschoon, which aims to have a design and report ready for the December CERN Council Session. We shall be returning to a description of the project and its physics aims in CERN COURIER about that time.

On 21-22 September summary talks from the work at Les Houches were given at CERN to packed audiences by the conveners, P. Darriulat considering polarization at LEP energies, J.B. Adams looking at the political scenario in which LEP takes its place and S.L. Glashow looking at the physics scenario(s).

Sheldon Glashow did not limit himself to things serious during the Summer Study and decorated a blackboard at Les Houches with the following:

'They all think we are building the bombs
As they scream and shout in alarm
But if they only knew it
They'd all say 'LEPS do it'
LEPS verify Weinberg-Salam'

ACCU at CERN

The CERN research facilities are now used by a very large number of physicists — the 'CERN Users'. The vast majority of them are from the scientific Institutes of the Member States and are financially supported by those Institutes. Their number, registered with CERN as 'Unpaid Associates', has risen from just under 900 in 1973 to over 1400 in 1978. The remaining CERN Users are research physicists financially supported by CERN, as established Research Staff Members, Fellows, and Scientific Associates paid fully or largely by CERN. Their number in early 1978 was about 320 (90 established staff members, 130 Fellows, 100 Scientific Associates paid fully or largely by CERN for a period of one year or more).

1. Edoardo Amaldi.
2. Abdus Salam.

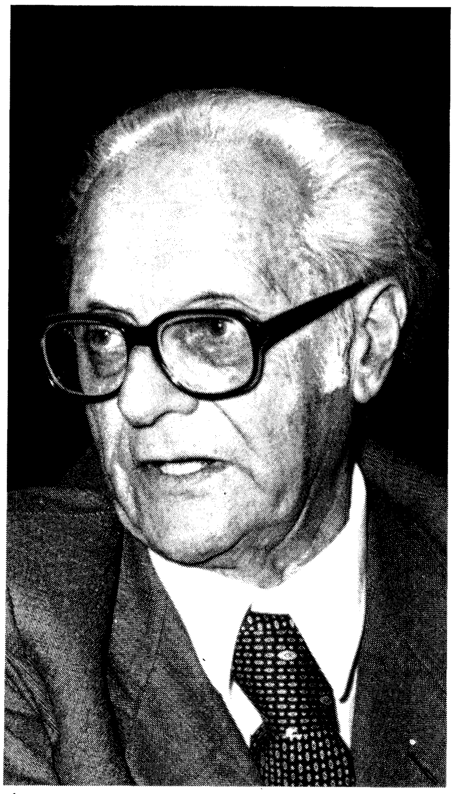
It has been apparent for some time that it would be useful to have an organized channel of consultation between the CERN Direction and a representative group of CERN Users to review, at regular intervals, the practical measures and arrangements taken by CERN for the work of the Users at the Laboratory.

To that end, CERN has set up an Advisory Committee of CERN Users (ACCU). Its task is to advise the Directors-General on the practical measures taken by the CERN Management to smooth the use of the research facilities. This concerns in particular the working conditions and the arrangements for technical support.

The Chairman and members of ACCU are appointed by the Directors-General of CERN for a period of two years, with the possibility of extension but with a reasonable rate of rotation. It is intended that the members should be active users of CERN and that, for the users not paid by CERN, a balance should be established in ACCU between those mostly residing in the Institutes of their own countries and those present at CERN for longer periods of time.

The membership of ACCU has two Users, not paid by CERN, coming from each larger Member State (France, Italy, Germany, United Kingdom); one User, not paid by CERN, coming from each smaller Member State; two Users paid by CERN. Further members may be added if necessary and meetings are attended by members or representatives of the CERN Management and by a representative of the CERN Staff Association.

The Chairman of ACCU is E. Lillestøl (University of Bergen) and the Secretary is W. Blair (CERN). So far three meetings have been held and topics discussed have ranged from hostel accommodation at CERN and on-site restaurant and transport arrangements, to computing and electronics facilities for users.


1.


2.

On people

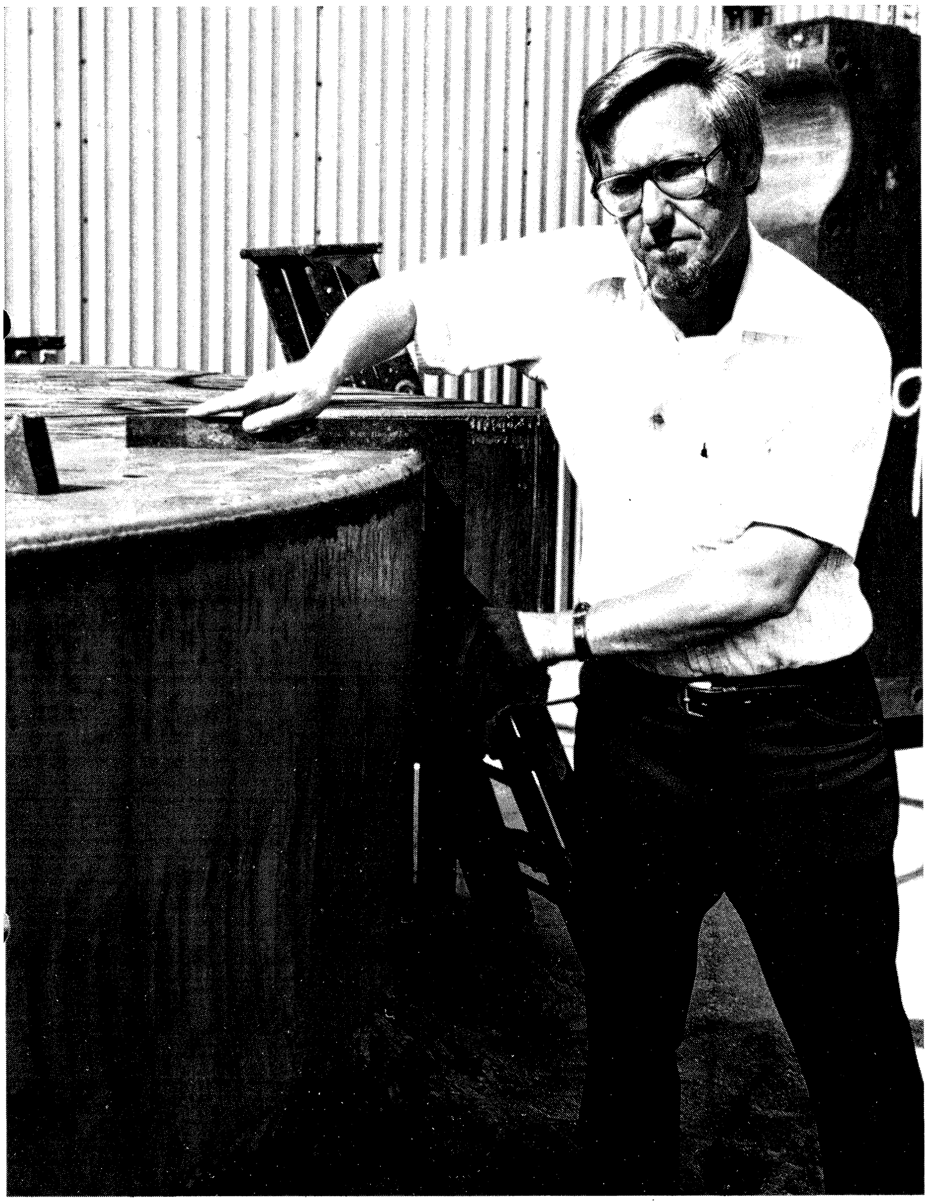
From 7-9 September a symposium, 'Perspectives of Fundamental Physics', was held in Rome to mark the 70th birthday of Edoardo Amaldi. Organized by Carlo Schaerf and Giorgio Tecce of the Faculty of Science of Rome University, it brought together some 500 scientists from throughout the world to honour Amaldi, who has contributed so much to science and to Europe, being one of the major personalities in the history and development of CERN. The topics at the symposium reflected Amaldi's science interests and the areas of physics where his political influence has had great impact. It is a pleasure to add our greetings to a personality of such integrity, commitment and achievement.

On 14-15 September a symposium devoted to the quark concept was held at Stockholm as part of the celebrations to mark the hundredth anniversary of the University of Stockholm. A very successful meeting opened by the Vice-Chancellor, Steffan Helmfrid, and Gösta Ekspong, heard talks by Don Cundy, Abdus Salam, Leon Lederman, Robert Jaffe, Gustaf Weber, Gerson Goldhaber, Harald Fritzsch, Erwin Gabathuler and Sheldon Glashow.

Abdus Salam has been awarded the American Institute of Physics 1978 John T. Tate International Medal for Distinguished Service to the Profession of Physics, for his successful efforts in bringing together physicists from different countries to collaborate on significant projects. The award no doubt recognizes in particular Professor Salam's role in creating the Trieste Centre for

The superconducting magnet of the Argonne 12 foot bubble chamber is being modified for use in the High Resolution Spectrometer (HRS) at the PEP electron-positron storage ring. Most of the 1600 tons of steel will be used intact but the end cap pieces are being extensively modified to allow access for the electronic detectors. This requires careful cutting through 60 cm thick steel pieces which, for reasons of economy, has to be done by cutting torches. Cuts of remarkable straightness were achieved with a maximum 1.4 cm kerf, demonstrated by Klaus Jaeger who is in charge of the magnet modification. The next job will be to modify mechanically the superconducting coils to operate with their axis in the horizontal direction, rather than vertical as in the bubble chamber. Tests of the new configuration are expected in January and reassembly at PEP will take place by the fall of 1979.

(Photo Argonne)



Theoretical Physics. The award was presented by William Koch, the AIP Director, on 28 September.

Edouard Regenstreif, one of CERN's earliest staff members, died on 1 September. He had worked on the building of the PS and edited the three volume book which describes the machine in great detail. From 1963 he was Professor at the Université de Rennes.

On 26 September the first meeting of a new CERN Experiments Committee took place. It is known as the PSCC and is the result of merging the previous PS and SC Committees. The Chairman is Professor R. Klapisch from Orsay.

On 30 August Frank Sacherer from CERN and Joseph H. Weis, who was a visitor in the CERN Theory Division, died in a mountaineering accident in the French Alps. Frank Sacherer had established himself as one of the world's leading accelerator theorists. He contributed greatly to the understanding of instabilities and, more recently, to the theory of stochastic cooling. Joe Weis was from the University of Washington in Seattle and an expert on multiparticle production. Some of his last findings were used extensively in the recent LEP Summer Study in Les Houches.

Edward Salant, for almost twenty years a member of the Brookhaven Physics Department prior to his retirement in 1966, died on 13 September. He was involved in many important emulsion experiments including the first observation of accelerator-generated kaons.

Meetings

The 1979 Particle Accelerator Conference on accelerator engineering and technology (the eighth in the USA series) will be held in San Francisco on 12-14 March. Further information may be obtained from Ruth Thor Nelson, SLAC, P.O. Box 4349 Bin No. 11, Stanford CA 94305, USA.

The International School of Nuclear Physics offers a course on 'Heavy Ion Interactions at High Energies' at Erice, Sicily from 26 March to 6 April 1979. Further information may be obtained from Sir Denys Wilkinson, University of Sussex, Falmer, Brighton BN1 9RH, UK.

The eighth International Conference of High Energy Physics and Nuclear Structure will be held at the University of British Columbia, Vancouver, Canada, on August 13-17, 1979. Enquiries should be sent to Dr. E. G. Auld at TRIUMF regarding registration and accommodation and to Dr. D.F. Measday regarding the programme and submission of papers.

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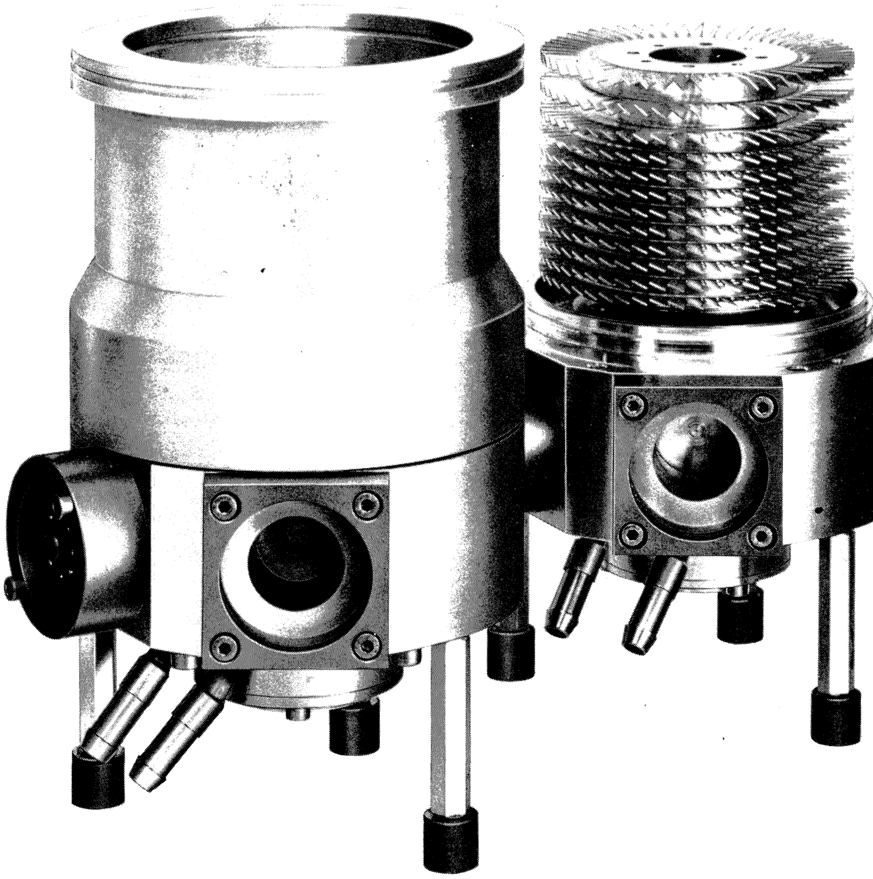

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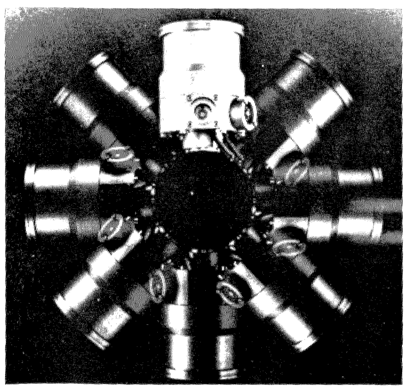

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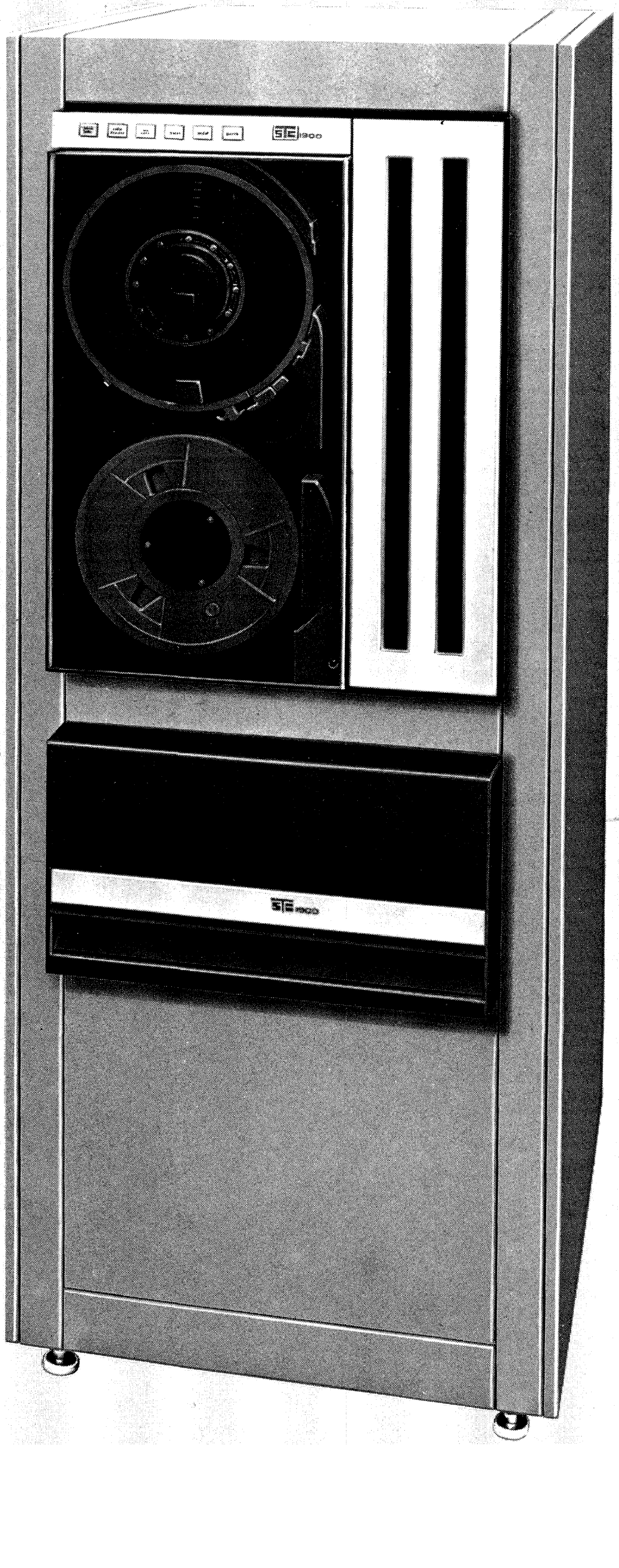

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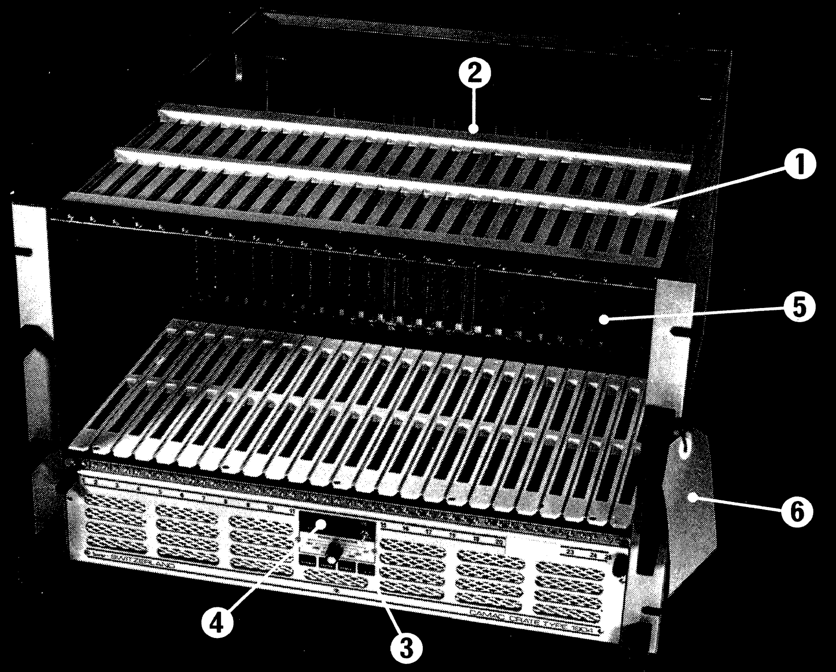

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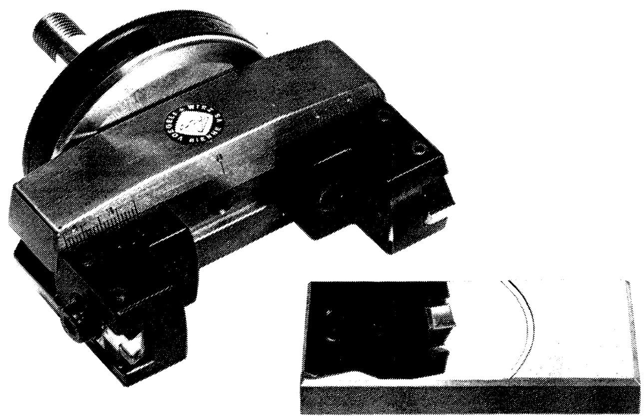

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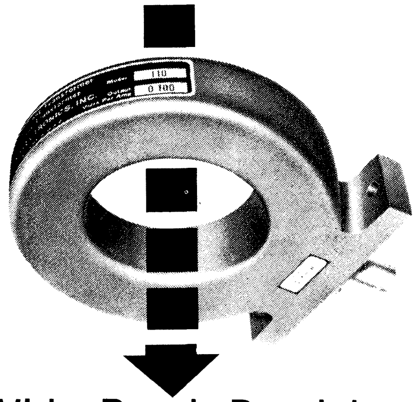

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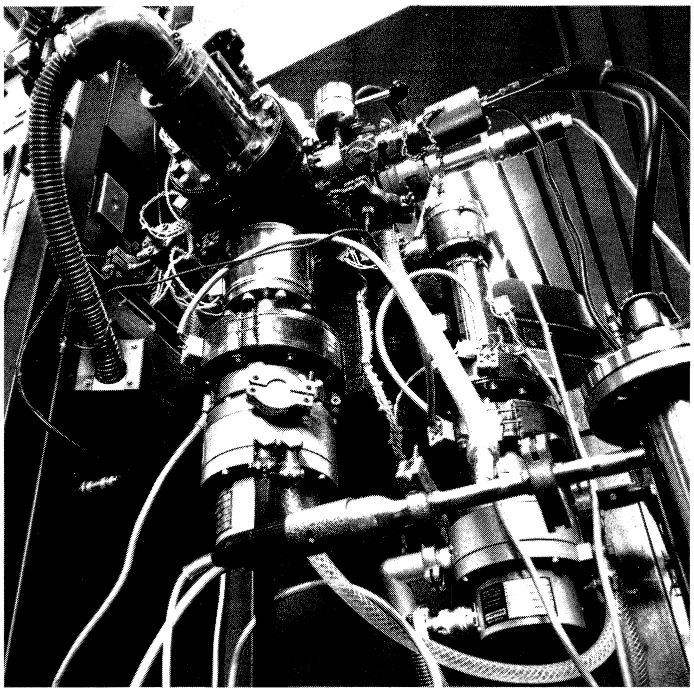

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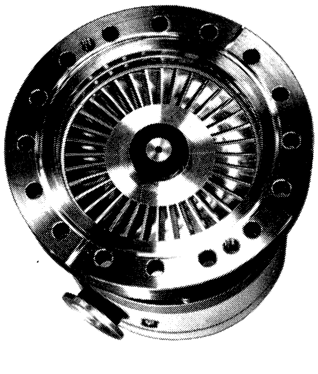

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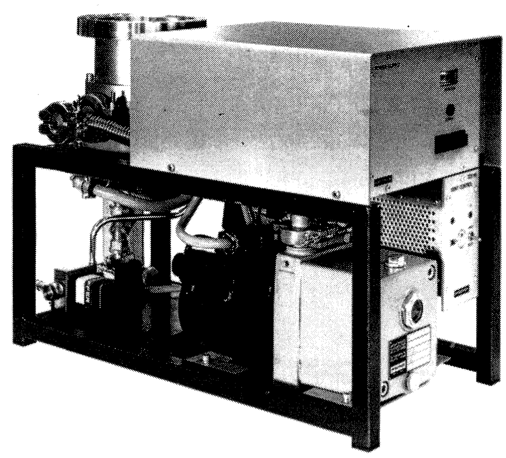

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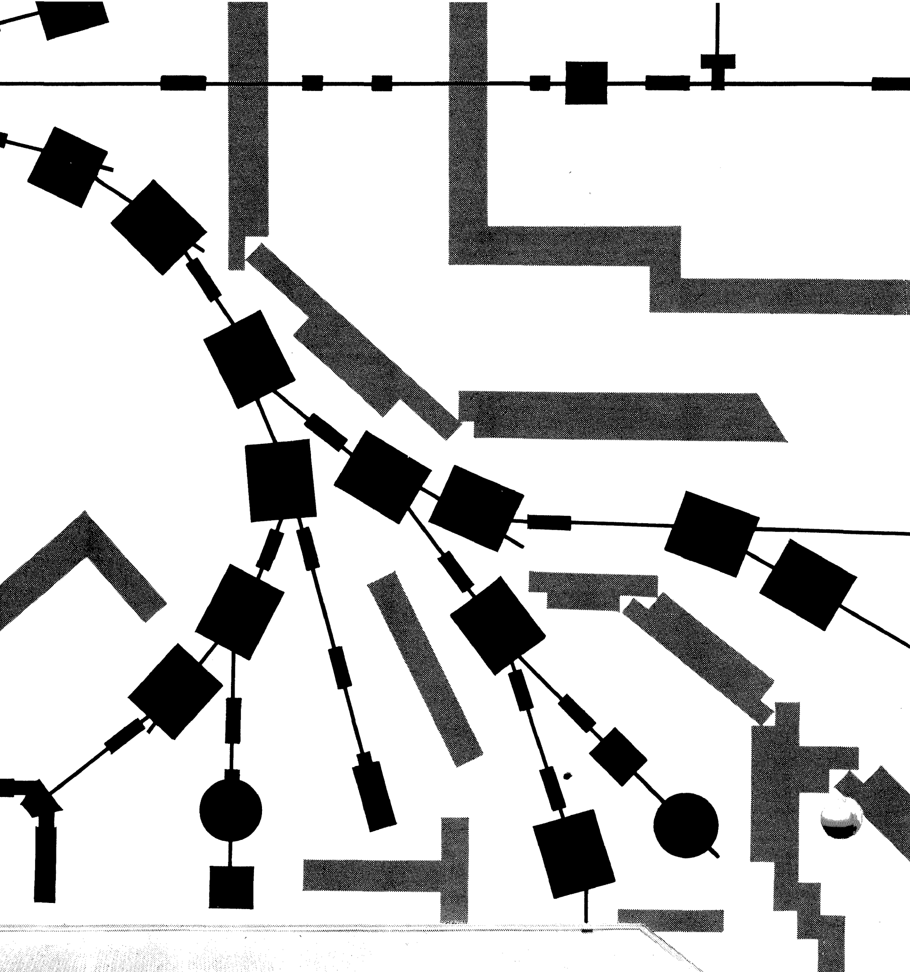

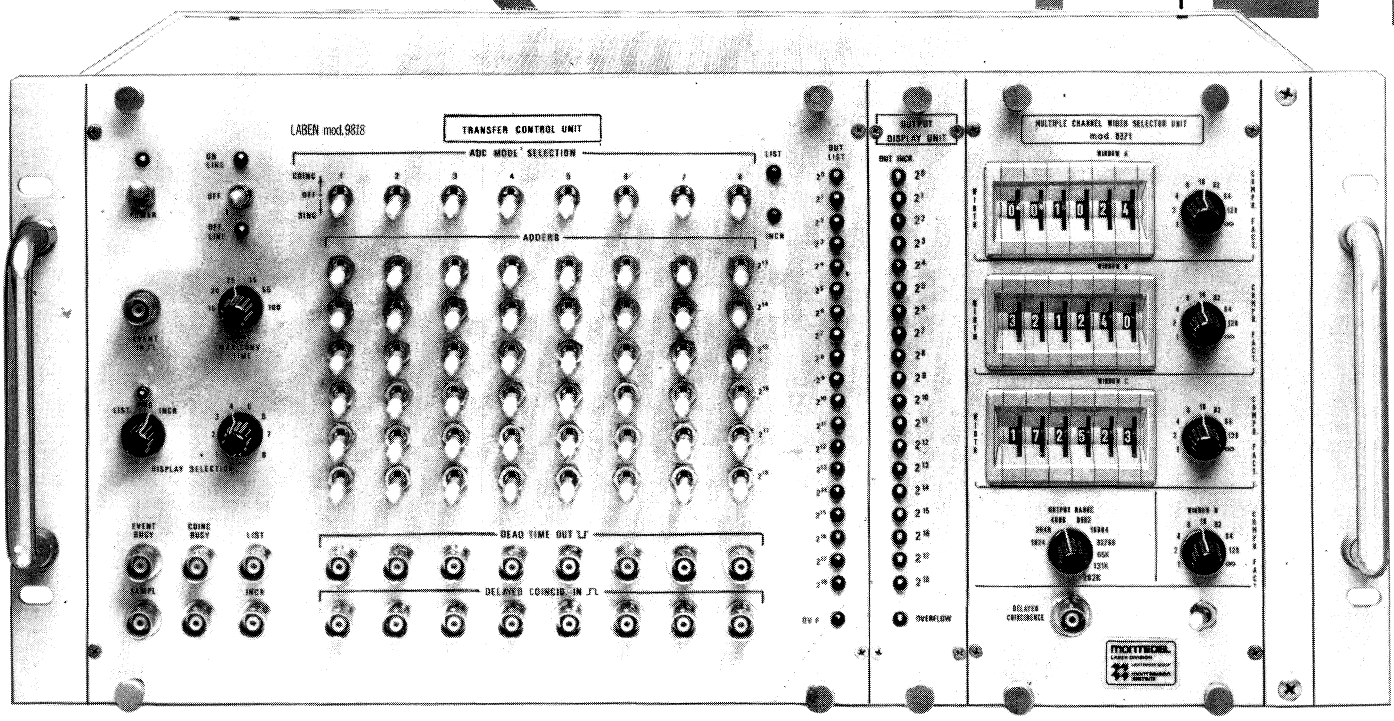

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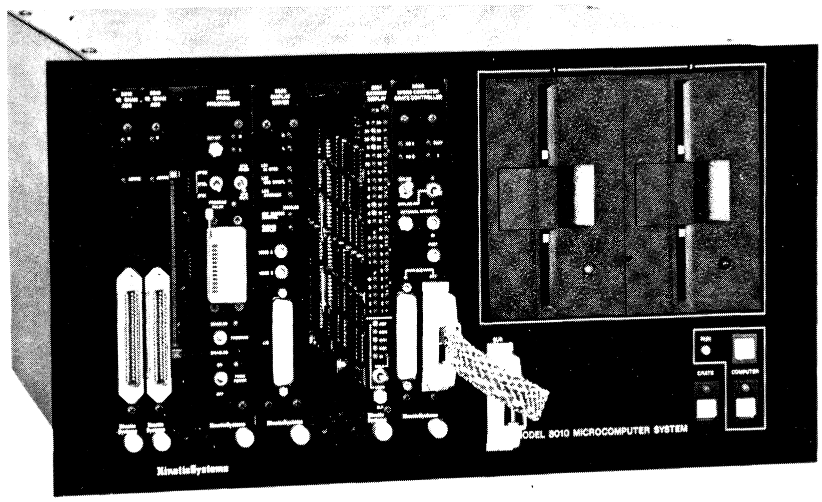

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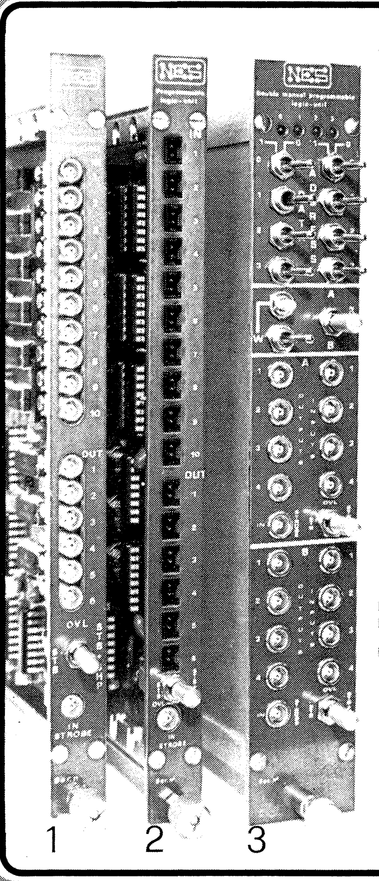

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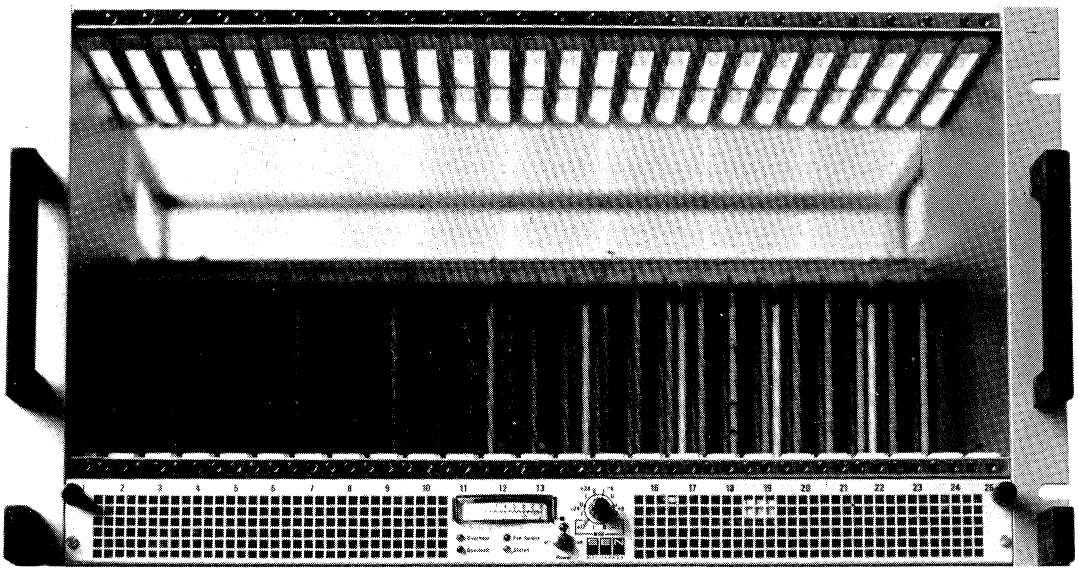
WHAT'S NEW IN CAMAC 300 WATT POWERED CRATES?



THE NEW SEN 2093 AND 2094
CRATES MEET CERN SPECS TYPE 087
AND FEATURE THE FOLLOWING IMPROVEMENTS:

* less power dissipation through mains pre-regulation
* larger output ballasts for better MTBF.
* increased protection from mains fluctuations.
* output cards interchangeable with SEN CPC 2057.

The new crates are available in the following versions:
SEN 2094: 300W, 6 voltages: ± 6V, ± 12V, ± 24V.
SEN 2093: 300W, 4 voltages: ± 6V, ± 24V.

PLUS
* SEN 470: 300W NIM crate, 6 voltages, especially designed for the new high-density ECL-based NIM electronics.

For more details, please contact your nearest SEN office or agent at any on the addresses given below.

France : ORTEC Sarl; 7, rue des Solets; Tel. (1) 687 25 71 - Tlx 202553F, F-94 RUNGIS – **Germany : SEN ELEKTRONIK GmbH;** Brandstücken 11; Tel. 041 80 20 46 - Tlx 216 3705d, D-2000 HAMBURG 53 – **DIDAS Digital 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.**

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Multichannel High Voltage System

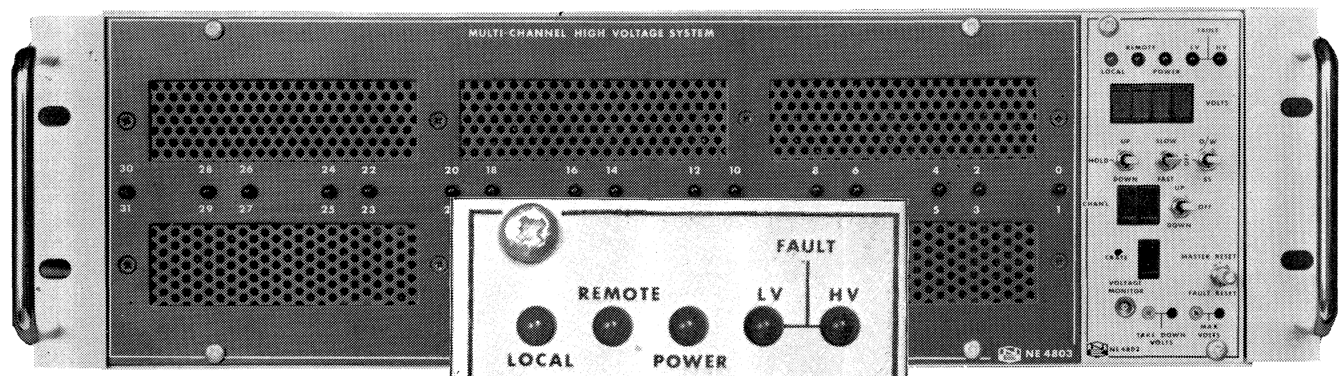
NE 4800 SERIES

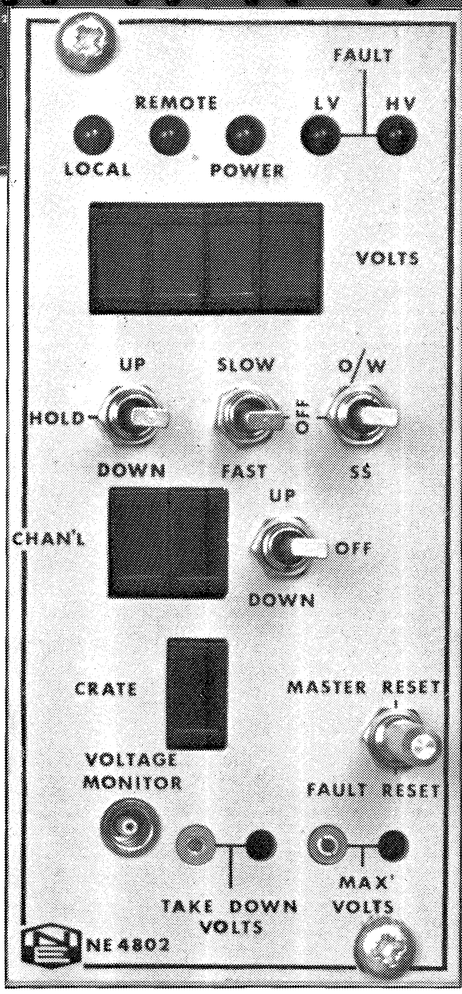
✱ For use with large photo-multiplier detector arrays and wire chambers.

✱ Economical

✱ Easily serviced

✱ Manual control of each channel or external control by Teletype or computer control via CAMAC





NE 4803 PHOTOMULTIPLIER HV

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

NE 4802 HV CONTROL MODULE

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

NE 4804 WIRE CHAMBER HV

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

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

Request full details and new NIM Catalogue from:

N.E. NUCLEAR ENTERPRISES S.A.

25 Chemin François-Lehmann, 1218 Grand Saconnex, Genève Tel. (022) 98 16 61/62. Telex 289066.

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Nuclear Enterprises GmbH
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Germany Telephone 53-62-23
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Nuclear Enterprises Inc.
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