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Editors: Brian Southworth
Gordon Fraser
Henri-Luc Felder (French edition)
Advertisements: Micheline Falciola
Laboratory correspondents:
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TRIUMF Laboratory, Canada
M.K. Craddock
Copies are available on request from:
Federal Republic of Germany
Frau G.V. Schlenther
DESY, Notkestr. 85, 2000 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

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(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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Physics monitor

Cover photograph: the courtyard of the Main Building at CERN, as recorded through a fish-eye lens. (Photo CERN 547.10.80)

Nobel Prize for Physics 1980

Once more it is the elementary particle fraternity which is honoured with the Nobel Prize for Physics. This year the prestigious award goes to James W. Cronin of the University of Chicago and Val Fitch of Princeton for their epic experiment at Brookhaven in 1964 which showed that the so-called charge-parity (CP) symmetry was subtly violated in the decays of neutral kaons.

Although recent theoretical developments have provided some strong suggestions, this fundamental discovery has yet to fall neatly into place in our understanding of fundamental particles and their interactions.

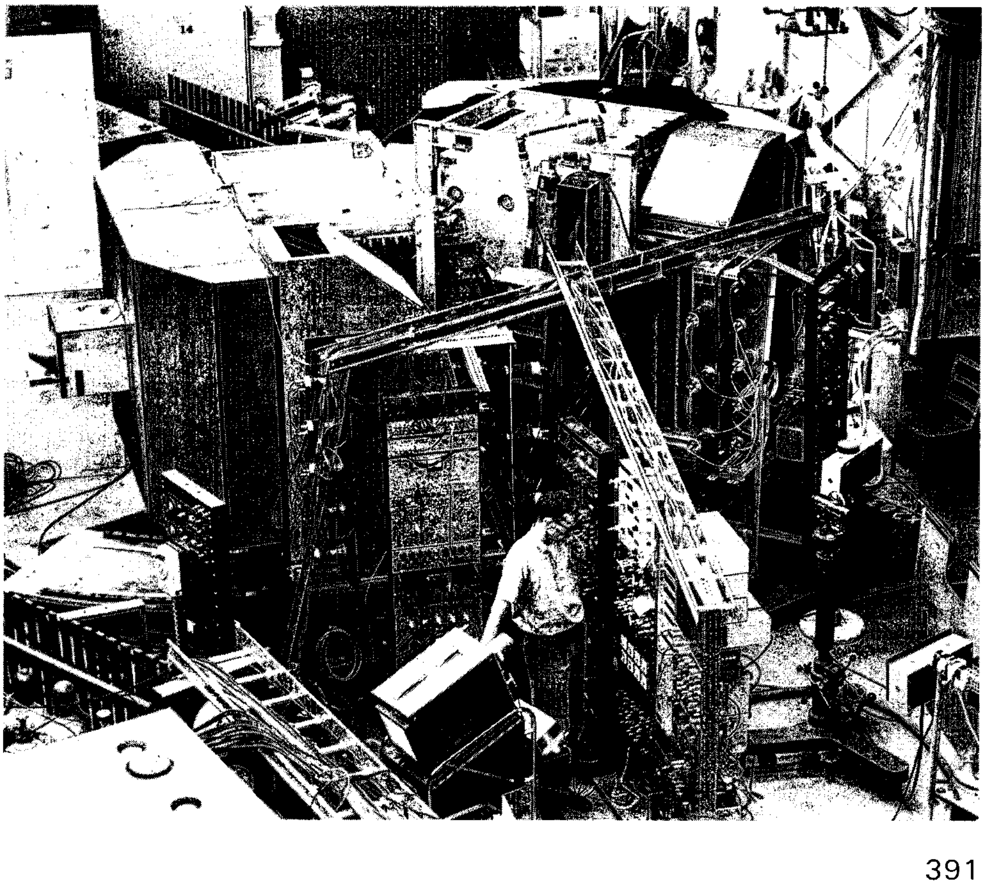
After the Cronin-Fitch discovery, it was soon realized that if we could run physics backwards in time, we would not necessarily reencounter the past. CP violation means that at least as far as the neutral kaons are concerned, the symmetry of time between past and future is not perfect.

For many years, physicists had believed that everything obeys three basic symmetries – parity (P), charge conjugation (C) and time reversal (T). Rotations in space can be either right-handed or left-handed, and the principle of parity symmetry implies that Nature makes no underlying distinction between right and left, so that both options are equally possible. This means that the distinction between right and left is mere human convention, and that for any natural object or event, a 'mirror image' counterpart could exist. Charge conjugation symmetry says that for any natural particle, there can exist a corresponding antiparticle which carries opposite (but equal) electric charge and other such quantum numbers. This symmetry implies that the phenomena seen in a world composed entirely of antimatter would be exactly the same as those seen with ordinary matter, so that the distinction between what is called matter and what is called antimatter is totally arbitrary. Time reversal symmetry says that if the motion of a physical system were to be subsequently reversed, the system would inevitably return to the situation from which it started.

Just twenty-five years ago, all these symmetry principles were believed to be universally valid, but since then it has been found that when the weak force is in action, in fact all of them are violated.

The first symmetry to fall was that of parity. In the early 1950s, physicists were worried about the so-called 'theta-tau puzzle'. Two different weak decays were being seen, one giving two pions, the other giving three. These two pionic configurations have opposite parity, but apart from this, the properties of the decaying particle were highly similar. In 1956, T.D. Lee and C.N. Yang concluded that there was no evidence for the conservation of parity in weak interactions, and perhaps one particle, the neutral kaon, could be responsible for the two observed decay modes. New experiments were proposed to test conclusively whether parity symmetry was violated.

Soon afterwards, C.S. Wu and her collaborators looked at the radioactive (weak) decays of polarized nuclei and found that the emitted electrons preferred to emerge on one side relative to the direction of spin of the parent nucleus. Other

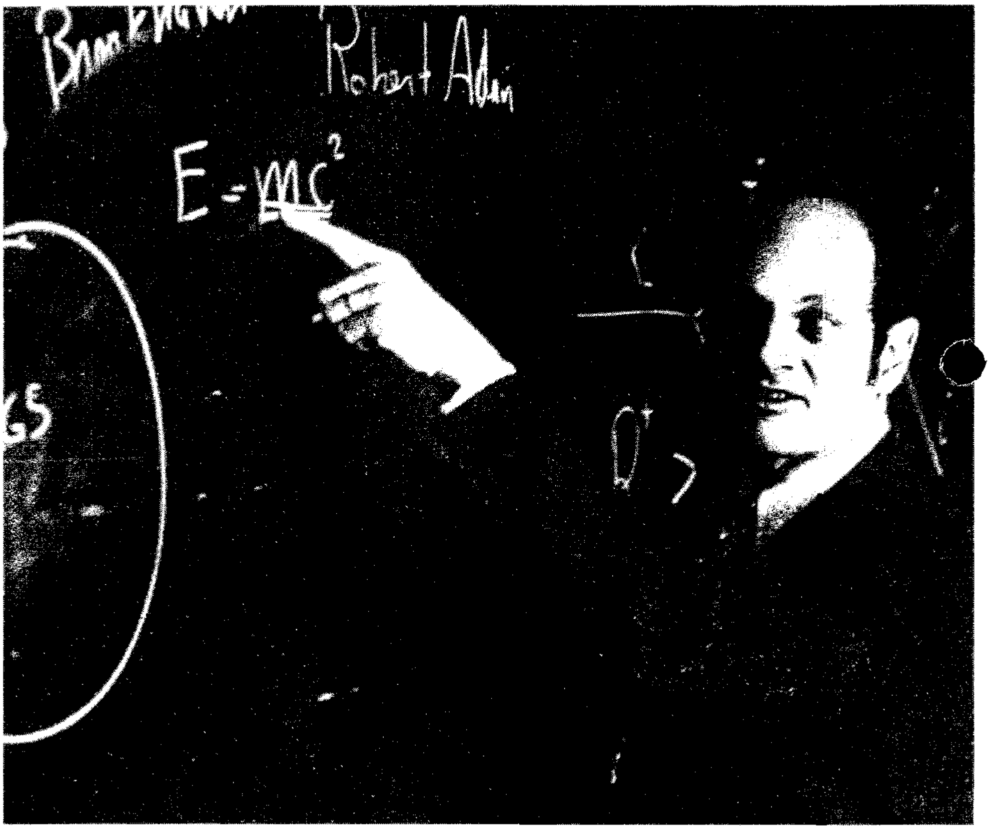


Apparatus used by Cronin and Fitch at Brookhaven in 1964 to detect the two pion decay mode of the long-lived neutral kaon and so overthrow charge conjugation/parity (CP) symmetry. The two spectrometer arms, symmetrically placed about the incoming neutral beam, picked up the charged products of the neutral kaon decays.

(Photo Brookhaven)

James W. Cronin at a news conference after the announcement of the award of the 1980 Nobel Prize for Physics.

(Photopress)



experiments soon saw similar behaviour, which confirmed that when the weak force is in action, Nature definitely cares about the direction in which things can happen. In 1957, the Nobel Prize for Physics was awarded to Lee and Yang.

In weak decays, antimatter moreover behaves in the opposite way to ordinary matter, for example a decaying neutron prefers to emit electrons spinning left-handedly while a decaying antineutron gives mainly right-handed positrons. This means that charge symmetry too has to go by the board. However if the double CP operation – particle to antiparticle and left to right transformations – were carried out, this CP symmetry would be good and order would seem to be restored.

The strange world of the neutral kaon

In the study of the basic symmetries of the weak interactions, the neutral kaons, which carry strangeness but no electric charge, play an especially important role. In strong interactions, strangeness is a 'good' quantum number, so that the neutral kaon and its antiparticle can be distinguished. However weak interactions do not conserve strangeness, so that in these interactions the neutral kaon and its antiparticle have to be considered together.

In high energy collisions both the 'true' neutral kaon and its antiparticle are formed. For the subsequent weak interactions, one can have either a symmetric or an antisymmetric superposition of the two kaons. According to CP symmetry, the symmetric mixture can decay into two pions, but the antisymmetric cannot. The latter therefore has to find some other way of decaying, for example into three pions. Such a decay is more difficult, so that the antisymmetric combination lives longer than the symmetric one.

Up to 1964, this was in agreement with all experiments. The symmetric mixture, called the short-lived kaon, was known to live for about 10^{-10} seconds and subsequently decay into two pions, while the antisymmetric one, called the long-lived kaon, was about a hundred times more durable, decaying eventually into three pions. It had never been seen to decay into two pions, or put more precisely, experiments had shown that any decay into two pions did not exceed one three-hundredth of all decays.

The Cronin-Fitch experiment set out to improve this limit using spark chambers to detect kaon decay products in a narrow beam of secondary neutral particles at the Brookhaven Alternating Gradient Synchrotron. Their detector consisted of two identical spectrometer arms, one either side of the neutral beam axis, which looked for events in which one charged decay product passed through each arm. The distance from the production target to the dec region in front of the spectrometers was long enough to ensure that the short-lived kaons had decayed away, and that only the decay products of long-lived kaons were detected.

The pairs of charged particles picked up in the detector arms could come from several different decay modes of the long-lived neutral kaons – pion plus electron plus neutrino (the neutrino being undetected), or pion plus muon plus neutrino, or three pions (with the third pion eluding the spectrometer arms), as well as the possible two-pion mode.

To eliminate the first two possibilities, an effective mass of the parent particle in each decay event was calculated, assuming each particle recorded in the spark chambers was a pion. By selecting only those events giving an effective mass which correponded to the neutral kaon, decays giving electrons and muons could be eliminated.

The next step was to calculate the combined momentum of the pair of pions picked up in the two spectrometer arms, and to compare the rection of this momentum with that of the neutral beam. For decays into three pions, the angle between the momentum of the detected muon pair and the beam would be the result of the 'missing' third pion. However this angular distribution revealed an excess of two-pion events whose combined momentum coincided with the direction of the neutral kaon beam and which could not be explained by any other effect. From a sample of 22 700 long-lived kaon decays, some 45 events were found which corresponded to the production of just two pions.

Although only a tiny effect (0.2 per cent), this evidence was enough to overthrow CP symmetry. This discovery immediately had serious implications because the belief in an overall CPT symmetry, combining charge conjugation, parity and time reversal, is a vital part of the theoretical description of particle behaviour. If CPT were to have been found invalid, then theoretical physics would have been in serious trouble. Subsequent experiments on neutral kaon decays showed that time reversal, as well as CP symmetry, is violated, but in such a way that the overall CPT symmetry is still good.

The origin of this CP and T symmetry violation is attributed to a 'superweak' force, whose strength is only 10^{-9} that of the already feeble weak interaction. Recently, theorists have proposed that the existence of at least two heavier quarks beyond charm could naturally explain this force. Whatever its explanation, CP violation is an integral part of physics and has to be an integral part of physical theory. Until it is, only optimists can say that particle physics is understood.

Val Fitch, chairman of Princeton's Physics Department.

(Photopress)

Taking stock at the CERN SPS

Smiles in the SPS control room on 17 June 1976 at the start of operations at 400 GeV. The subsequent four years have seen more fine achievements.

(Photo CERN 313.6.76)

With the SPS 400 GeV proton synchrotron at CERN now undergoing a long shutdown to adapt it for its new role as a proton-antiproton collider, members of the SPS user community met recently at Cogne in the Aosta Valley, Italy, to review the physics programme. It was also a good time to take stock and look back over the machine's past performance.

SPS achievements to date are impressive, with the average number of protons on target per hour of scheduled physics time having increased significantly over the years – from 1.5×10^{15} in 1977 to 5.5×10^{15} this year. This can be partially attributed to the natural increase in operations experience, but a major contribution resulted from the move to double batch injection (see October 1978 issue, page 345). Previously, a single pulse of 10 GeV protons from the PS proton synchrotron was peeled off over ten turns to almost fill the SPS ring. In double batch injection, two PS pulses are ejected over five turns. This technique soon established new records for intensity and number of protons on target, but even these figures have since been made to appear modest. Another significant development was the commissioning of the new linac for the PS (see March 1979 issue, page 13).

However the SPS has not been without its share of setbacks. Initial teething problems, especially during the summer thunderstorm period, affected performance, while early in 1979 a serious incident at the main power supplies hindered progress. Although previous machine development work had shown that 450 and even 500 GeV were possible, the first scheduled physics runs at 450 GeV in 1979 were not as successful as might have been hoped.

So far, a total of 51.3×10^{18} protons have been received on target for scheduled SPS physics runs (representing about the same number of protons as are contained in a cubic centimetre of hydrogen gas under normal conditions). Some two-thirds of these SPS protons have fed the West Area, with the North Area, which only came on-line in 1978, accounting for the remainder. The lion's share (some 43 per cent) of all the protons has been used to generate the neutrino beams for the West Area.

For physics in the West Area, a total of 30 electronics experiments using secondary hadron and photon beams have run at the SPS, of which 27 had been completed at the time of the shutdown in June. Over half of these experiments used the Omega spectrometer, quite an achievement in itself (see page 400). Also in the West Area, an additional 21 experiments have used the neutrino beams, and six hadron experiments have been carried out using the BEBC bubble chamber. At the SPS, BEBC has taken some four million pictures for hadron and neutrino interactions. No new proposals for hadron experiments have been received for BEBC, and it looks as though this type of investigation has come to an end, at least temporarily. In the North Area, over 20 experiments have been approved so far, of which nine have been completed. However with the restart of fixed target physics, the North Area will see increased activity with the full commissioning of big new detectors such as the European Hybrid Spectrometer, whose experimental programme is now beginning to take shape. In addition, the high intensity facility in the North Area, which came into operation late last year, will soon figure prominently in the experimental programme.

For the future, attention obviously centres on the progress of the antiproton project, in which 270 GeV proton and antiproton beams will be brought together in two collision areas, serving a total of five experiments (see June issue, page 143). For fixed target work, increased intensity and efficient running at 450 GeV are the immediate aims. or the longer term, other possibilities being discussed include the provision of polarized proton beams, antiprotons for fixed target work, and higher energy experiments in the West Area. The SPS could also have to serve as injector for the proposed new LEP electron-positron ring (see July/August issue, page 192). Whatever the future may bring, the SPS looks like being the workhorse of European high energy physics for a long time to come.

Around the Laboratories

FERMILAB

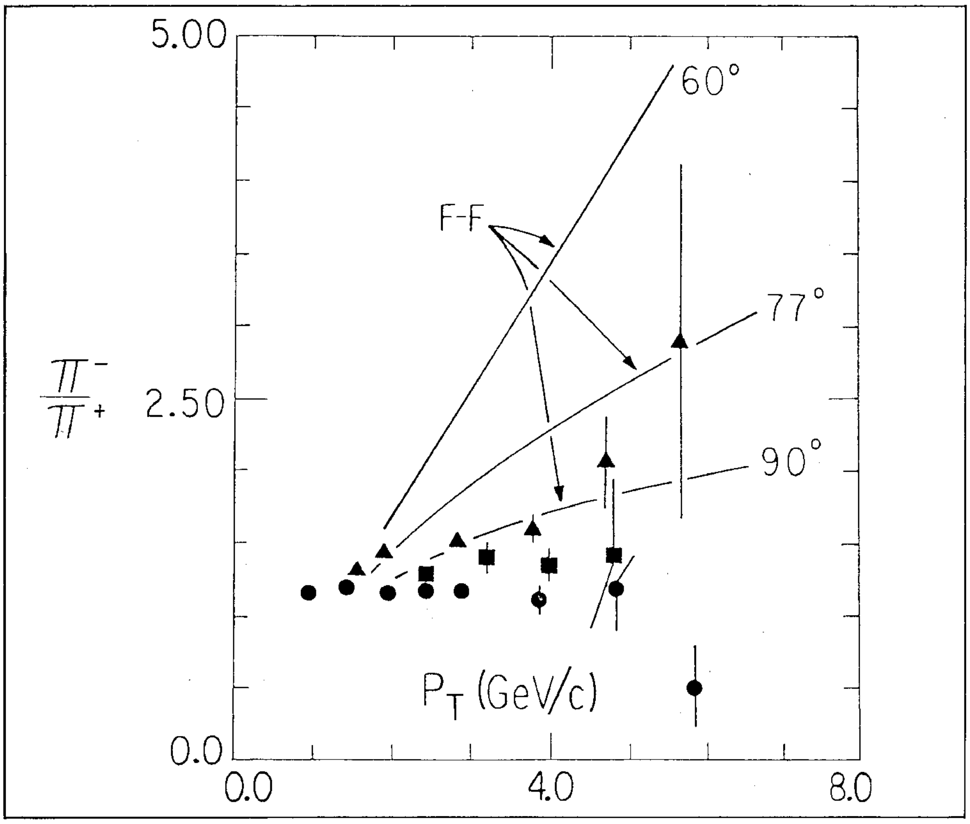
Surprising scattering results

Recent results from Experiment 258 at Fermilab are puzzling to theorists who make models of high transverse momentum reactions. The experiment, a Chicago/Princeton collaboration, uses an elegantly simple single particle spectrometer to measure production of single pions, kaons, and protons by pions using the high intensity beam in Proton West.

The new aspect of these measurements lies in their angular dependence. Previous measurements, mostly in CERN ISR experiments, have been in proton-proton collisions, and show only a weak angular dependence.

The new measurements are of particles produced in negative pion-proton collisions. In contrast to the proton-proton case, the angular distribution in pion-proton scattering need not be symmetric about 90°. If one makes the reasonable assumption that a particle observed at large transverse momentum comes from a valence quark, one can identify a positive pion as coming from the proton, or a negative kaon or antiproton as coming from the incident pion. Furthermore, if one assumes that the observed particle carries a large fraction of the scattered quark's momentum, then the particle's direction is close to that of the scattered quark. Hence the measured angular dependence would be strongly correlated with the angular dependence of the underlying hard scattering process.

The results are somewhat surprising. The models (for example the calculation of R. Field) predict a strong dependence of the ratio of



The ratio of negative to positive pions produced by 200 GeV negative pions on a hydrogen target measured against transverse momentum (p_T) by a Chicago/Princeton experiment at Fermilab. The triangles, squares and circles refer to production angles of 60°, 77° and 90° respectively. The curves labelled F–F are the predictions of R. Field.

outgoing negative to positive pions on the angle. The data show some dependence, but not as strong as the Field predictions and in fact look to be dependent mostly on impact parameter, measured by the transverse momentum.

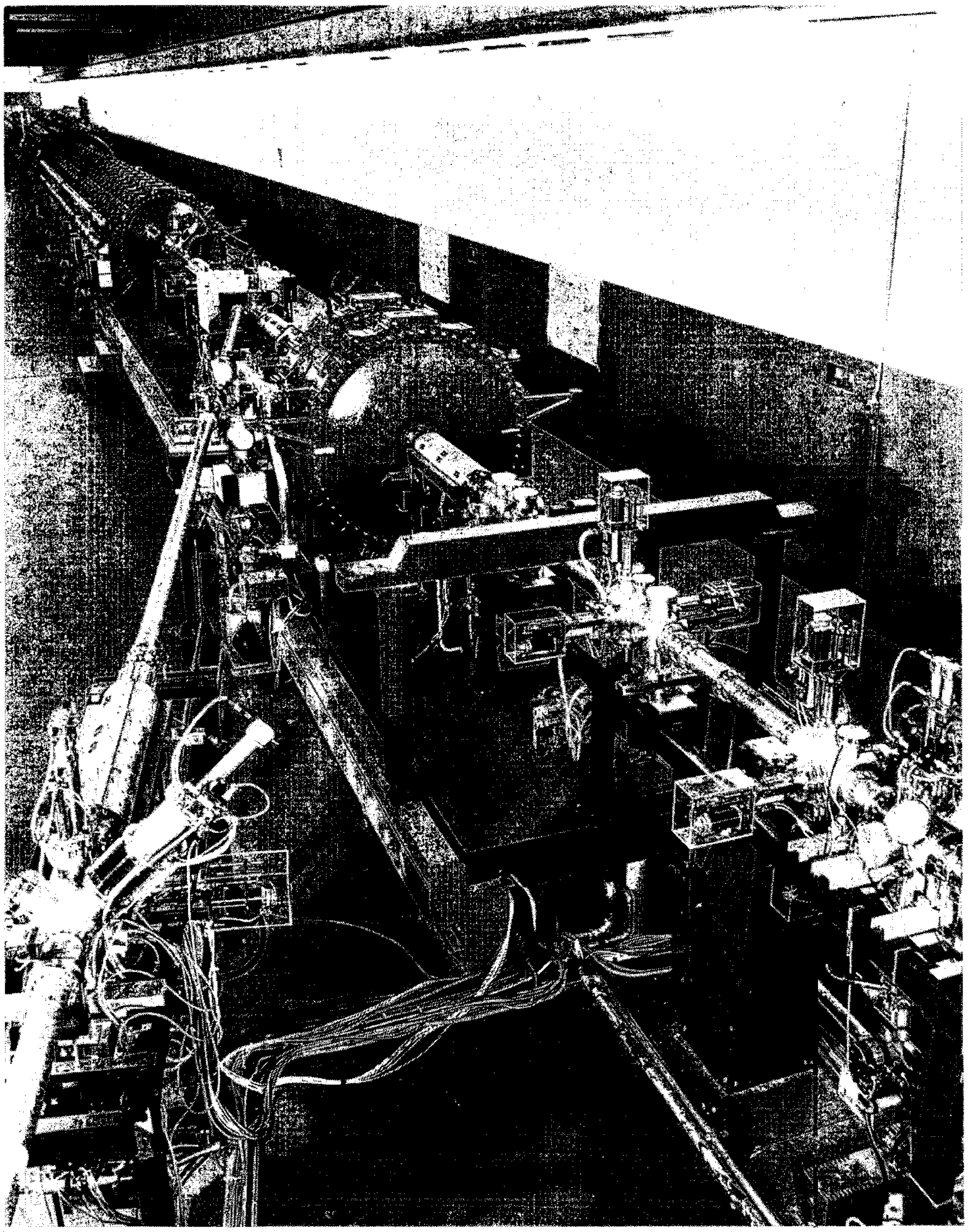
What parameters in the model affect this ratio? The fundamental hard scattering dependence is given by quantum chromodynamics, and so is 'non-negotiable' to most theorists. The amount of momentum carried by gluons affects the ratio, as gluons produce positive and negative pions equally. So changing the gluon structure function is a possible alternative. Finally, 'smearing' from the fragmentation of the quarks and from their so-called 'primordial transverse momentum' make small changes to the ratios, but not enough to significantly affect the results.

However there is a problem in changing the structure functions. There are at least three sets of high transverse momentum single particle data which bear on the problem: (1) the new Chicago/Princeton results; (2) older data from the same group on the negative to positive pion ratio in proton-proton collisions; and (3) the 'beam ratio' data which compares neutral pion production by protons and by pions, as measured by a Caltech/Fermilab/Berkeley collaboration. The problem is to fit all three sets of data with a consistent set of structure functions. Neil Fleishon and James Stirling of the University of Washington have tried to do this, and find that they can fit any two out of the three sets of measurements, but not all three. More calculations, and more experiments, may be necessary.

DARMSTADT Nuclear collisions under discussion

At the 'Workshop on Future Relativistic Heavy Ion Experiments' held at GSI Darmstadt from 7 to 10 October, research topics were discussed that are of common interest both to particle and nuclear physicists.

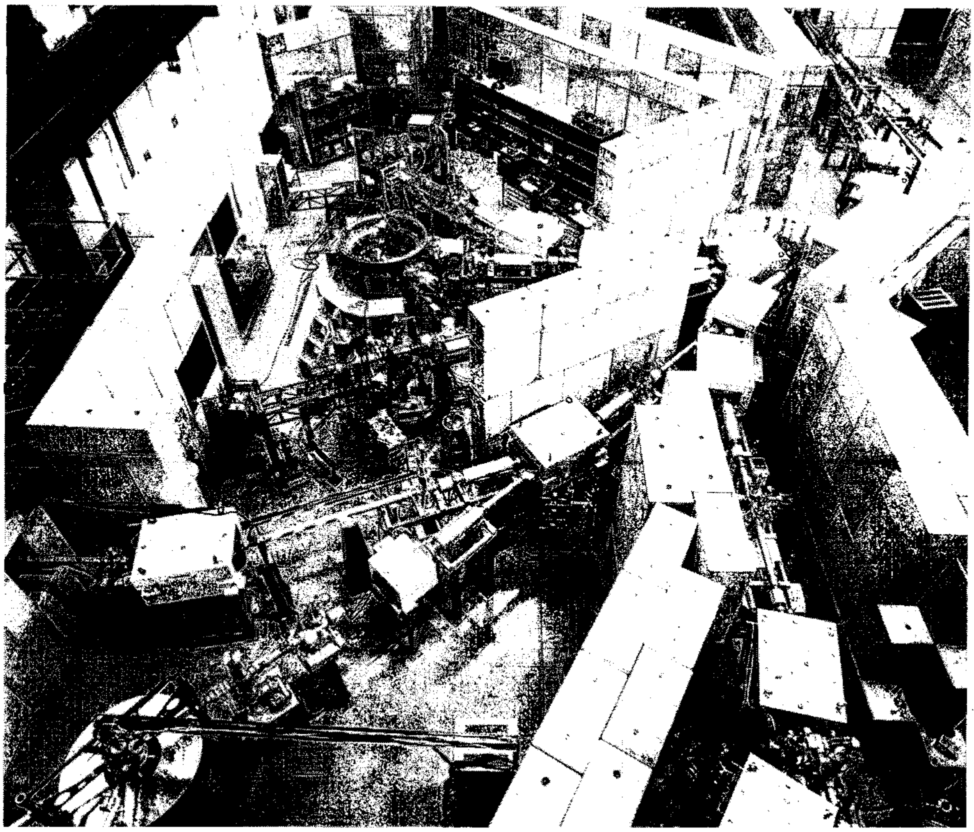
First results of studies carried out at the Berkeley Bevalac energies of up to 2 GeV per nucleon indicate that central nucleus-nucleus collisions do in fact produce a short-lived state of high particle and energy density. The density, since it is a transient condition, is not easily measured directly. However if the particle emissions from the high density state are changed in a characteristic way, due to the prevailing local conditions, one might obtai



The UNILAC at Darmstadt which is used for the acceleration of heavy ions. In October, Darmstadt was the scene of a 'Workshop on Future Relativistic Heavy Ion Experiments'.

A view of part of the experimental hall at the Darmstadt UNILAC. The ion beams enter from the top right in the picture. The experimental programme includes a thorough search for highly unstable nuclei.

(Photos GSI Darmstadt)



indirect evidence for phase transitions from 'normal' nuclear matter to other metastable forms of quark matter, or for the formation of exotic objects, like a gluon plasma.

The first of these possibilities has been suggested by nuclear physicists who are interested in nuclear matter as a quasi-macroscopic state. The conditions required to reach quark matter are now predicted to fall at an energy density of a few GeV per fm^3 which, for example, could be within the reach of fixed target running at CERN PS energies. Possible 'fingerprints' of this new behaviour discussed at the Workshop were changes in strange and antistrange production abundances, as well as interaction temperatures.

At still higher energies the packing density of quarks may not increase much further, but a qualitatively new state may emerge in the plateau region due to the overlapping or bundling of many gluon/colour strings merging into an exotic extended object. Specific decay properties of such an object are unknown but changes in the behaviour of the production of lepton pairs and in high transverse momentum processes were suggested as an initial probe. Clearly, this research is an ideal colliding beam topic but it may require even higher energies than the 24 GeV per nucleon that could be reached even if calcium ions could be collided in the CERN ISR.

A lot of discussion at the Workshop centred around the possible eventual homes of this research. One possibility which was discussed was CERN, where in principle, the PS and ISR complex could accommodate most of the foreseen short-term needs including instrumentation for a first investigative phase. Fresh external efforts would be required to bring about a solution of the heavy ion injection instrumentation problem (source, pre-linac low beta structure, etc.). On the other hand, GSI Darmstadt has a proposal to build a synchrotron (SIS) for such research (see October issue, page 298). At Berkeley the more ambitious VENUS project calls for a superconducting intersecting storage ring for 20 on 20 GeV per nucleon collisions (see December 1979 issue, page 406).

In general it was felt that the Workshop succeeded in stimulating particle and nuclear physicists to consider future collaborations to investigate these intriguing questions.

UNILAC experiments

One of the main themes in the current experiments at the Darmstadt UNILAC is the question of the boundaries of nuclear stability — whether in the chart of nuclides or in extreme states of excitation. The latter are obtained in heavy ion collisions when the collision energy is just below the Coulomb barrier so that very high electromagnetic forces determine the interaction. In these collisions, the excitation of very high nuclear angular momenta (up to 50 units) is observed.

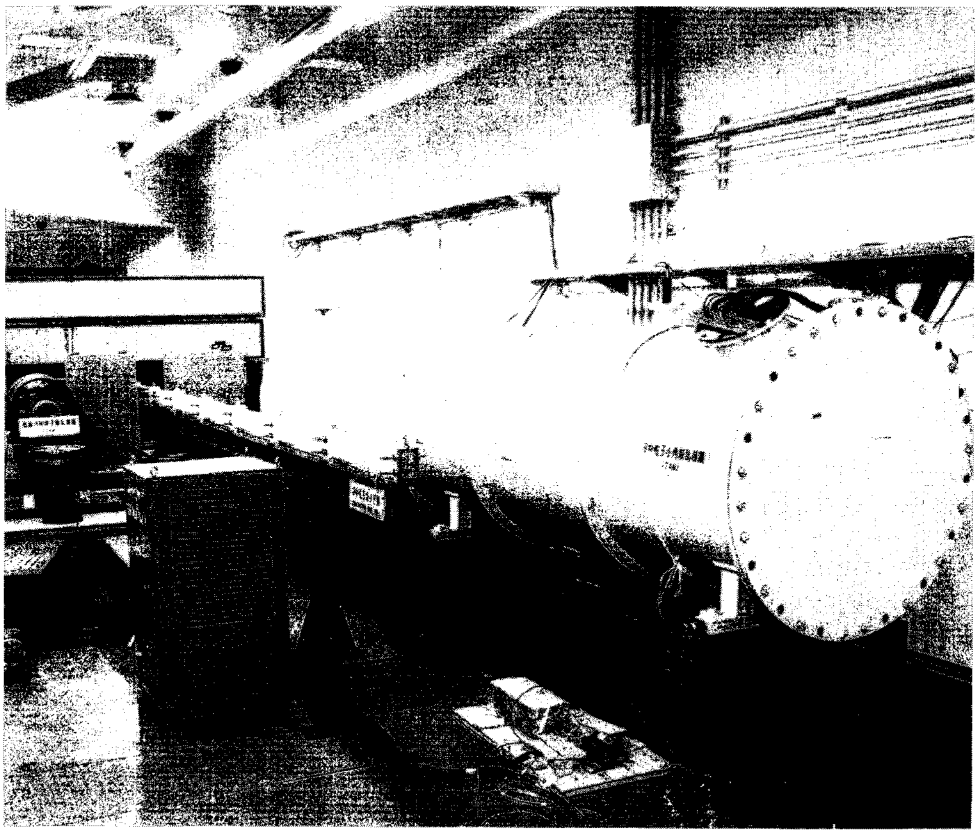
These nuclear states can be understood by considering the nucleus as a classical object with form, moment of inertia, viscosity and surface friction. The upper limit of angular momentum is given by the loss of balance of attractive and centrifugal forces and what are perhaps at first sight surprising effects in the excitation energy/angular momentum correlation can well be described by the action of Coriolis forces upon single nucleons.

En route to the limits of stability in the chart of nuclides, more than sixty new isotopes have been identified, among them tellurium 107, the lightest alpha-emitter. But all attempts have failed to form nuclei which emit protons from their ground state or have charge and mass higher than the known existing elements. Trying all the promising nuclear reactions, the upper limits for the production cross-section of any such superheavy elements have been established at values of 10^{-32} to 10^{-36} cm^2, covering lifetimes from 10^{-6} to 10^{+9} s.

Chemical methods combined with fission-fragment detection and time-of-flight with kinematic coincidence techniques were used, as well as a specially-designed device for the rapid separation, detection and measurement of decay modes for complete-fusion reaction products. By this method, isotopes of the elements 104 and 105 were produced by fusion of titanium and lead/thorium/uranium.

To cover extreme possibilities, curium targets were used with a uranium beam. From a technical point of view, the handling of curium targets introduces considerable difficulties, apart from the fact that curium is only available in quantities of several hundred milligrams worldwide (the targets were from Oak Ridge / Livermore / Los Alamos). Measuring the three-particle exit channel of this very heavy collision system, products with nuclear charges of up to 115 were observed. However there are several indications that these products do not reach thermal equilibrium, so they cannot be called nuclei. All these investigations are continuing systematically and are being refined.

Atomic physicists have fastened onto a special quality of the UNILAC. Rather than using it as an accelerator, they see it as a source of highly charged ions. For this purpose, the last UNILAC section of twenty single gap resonators is used to decelerate the ion beam after it passes through a stripper foil at 5.9 MeV per nucleon. In this way highly charged ions at energies below the nuclear reaction barrier are made available.



A view of the cold neutron channels in operation in the neutron experimental area of the new KEK Booster Synchrotron Utilization Facility.

(Photo KEK)

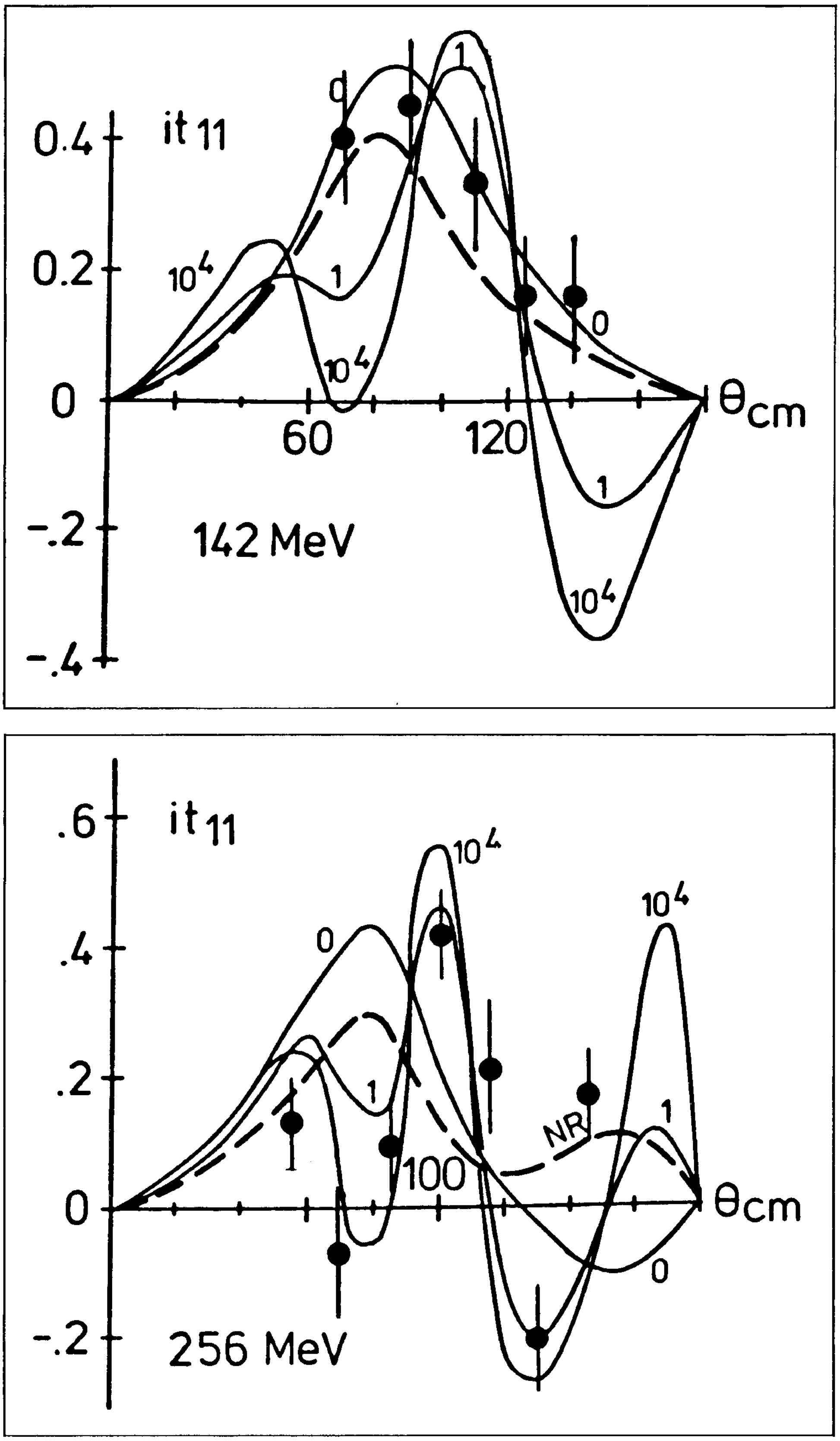
KEK
Exploiting the Booster

The new KEK Booster Synchrotron Utilization Facility started operation on 16 June. This makes use of about three-quarters of the 500 MeV booster beam not injected into the main ring, which uses nine 20 Hz pulses with a repetition time of 2 s. The new facility caters for three kinds of research — neutron scattering experiments, pion and muon studies, and medical research.

The neutron project has been promoted mainly by a group from Tohuko University and has been funded by KEK. The pion and muon project is in the hands of the Meson Science Laboratory of the University of Tokyo (see October issue, page 302). Construction of the building and the experimental apparatus for these two projects was started in 1977 and was recently completed. After preliminary test runs, the neutron facility became available for users in November.

The fourth ICANS (International Collaboration on Advanced Neutron Sources) meeting was held at KEK from 20–24 October, while finishing touches were being put to the neutron facility. About 90 physicists participated, including about 40 from abroad.

Construction work will soon begin for the other part of the new facility, for medical research. As these studies will be very different to high energy physics, the medical research centre will belong to and be operated by the University of Tsukuba.



SIN

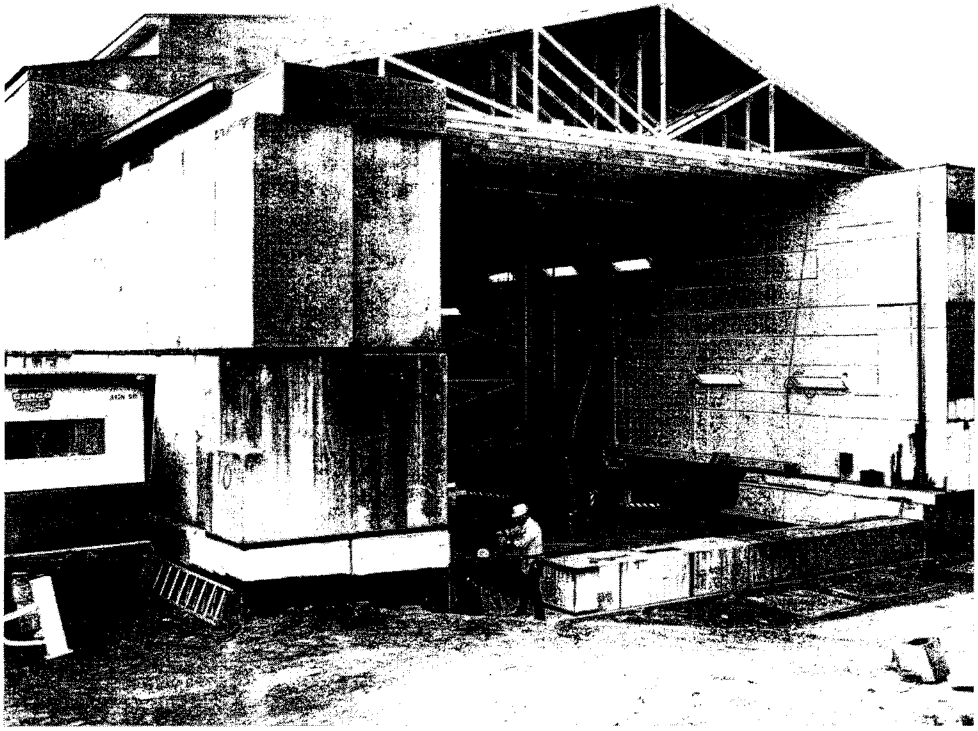
More on dibaryon resonances

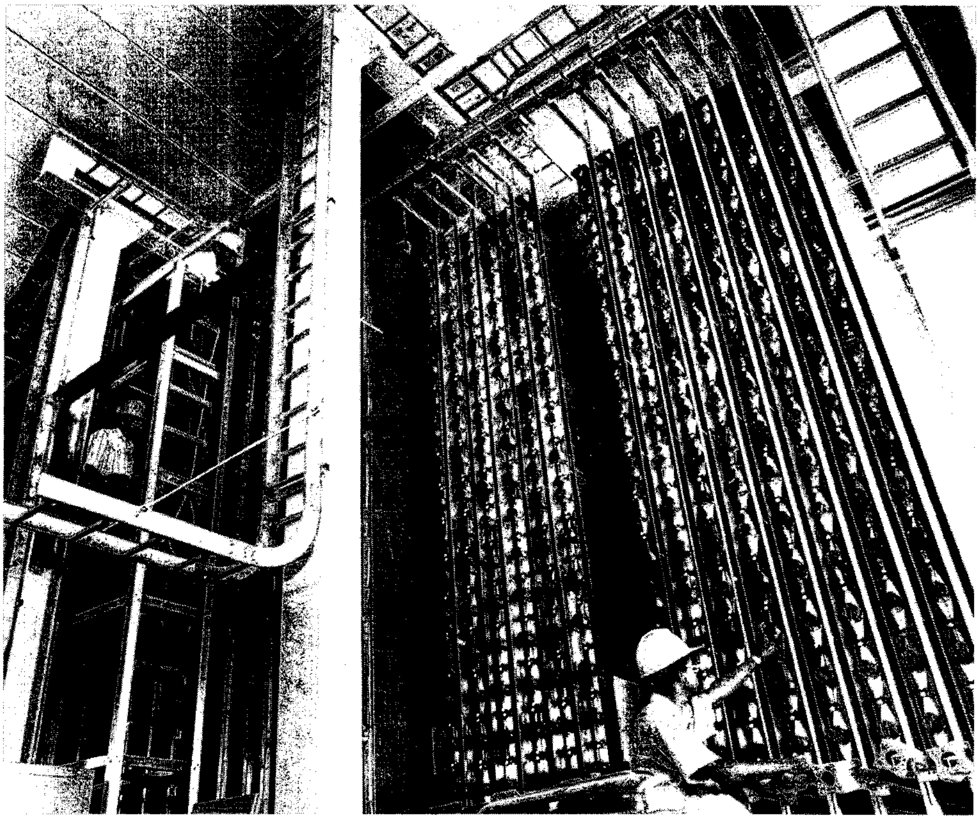
There is a lot of interest, both theoretical and experimental, on the question of whether or not dibaryon resonances exist. Data on this controversial topic has been provided by an experiment at SIN by the Karlsruhe/SIN/Erlangen/Nurnberg/British Columbia / Grenoble group working with the SIN pion spectrometer and high resolution pion beam has recently obtained data on the vector analysing power (it_{11}) in elastic positive pion-deuteron scattering. The pion spectrometer was used in conjunction with a polarized deuterium target and the data were taken at a number of scattering angles for incident pion kinetic energies of 142 and 256 MeV. The results are shown in the figures, where comparisons are made with calculations with and without the inclusion of dibaryon resonances. The dashed curves are the results from Faddeev calculations without dibaryons, and this prediction can be seen to agree well with the data at 142 MeV, but not at the higher energy. The solid curves are those derived by Kubodera et al including the effect of various possible dibaryon states. The dibaryon of given angular momentum J couples to two pion

Results from a SIN experiment which provide more evidence for the existence of dibaryons. The data show the vector analysing power (it_{11}) as measured in the elastic scattering of positive pions off a polarized deuterium target at two different pion kinetic energies (142 and 256 MeV). The dashed curves show the results of calculations without dibaryons, which agree well with the data at 142 MeV, but not at the higher energy. The solid curves show the results of calculations including various possible dibaryon resonances for different mixtures of possible angular momentum states. These seem to follow the oscillation effect seen at the higher energy. For detailed explanation, see text.

A major new experiment is being constructed in the Brookhaven neutrino beamline by a Brookhaven/Brown/KEK/Osaka/Pennsylvania/Stony Brook/Tokyo collaboration. Top photo shows a general view of the new blockhouse, while the bottom view is of the equipment being installed inside. Eventually this will comprise 150 tons of liquid scintillator, interspersed with drift tubes. The experiment is designed primarily to study the elastic scattering of neutrinos from electrons and protons, but will also be used to look for neutrino oscillations.

(Photos Brookhaven)





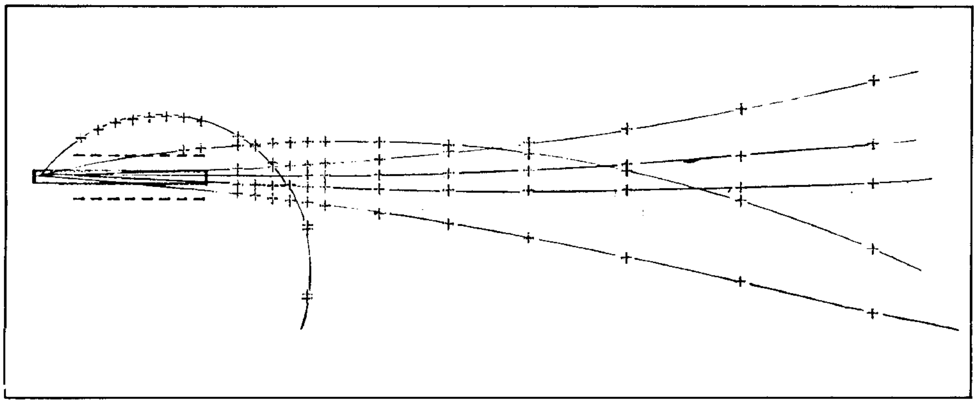
angular momentum (L_π) states in the pion-deuteron channel: $L_\pi = J \pm 1$. The various solid curves are labelled by the mixing parameter (this has a value of 10^4 for $L_\pi = J+1$ coupling, and zero for $L_\pi = J - 1$). While the conventional theory fails to reproduce the data at the higher energy, the observed oscillations with angle are well reproduced by the calculation including the effect of dibaryon resonances. This result is considered to be good evidence for the presence of at least one dibaryon resonance in the pion-deuteron channel. Independent of any model, the observed oscillation of the vector analysing power is direct evidence for a strong contribution from a higher partial wave interfering with the background. The group will continue their measurements at other energies in January.

CERN
Omega's worth

One aspect of the physics being carried out at today's big machines is the move toward detector 'facilities' — flexible, user-friendly spectrometers which can be easily used or quickly adapted for a wide range of experiments, catering for the different requirements of a relatively large number of users.

A good example of such a detector, which has been in use for some time with notable success, is the Omega spectrometer in the West Experimental Area at CERN. At the recent Cogne meeting to appraise the past achievements and discuss the future programme at the SPS (see page 394), Omega was highly commended for both the range of experiments which it has been possible to cover, and the speed and ease with which these studies have been completed. With other general-purpose spectrometers being built or

Typical event as recorded in the Omega spectrometer at CERN, now with its original spark chambers and TV readout system replaced by multiwire proportional counters.



considered, Omega could be an example of how physics will be done in the future.

The large spectrometer, equipped with a superconducting magnet, was originally built for use at the 28 GeV proton synchrotron and was used by a number of teams from 1973–5. It was then upgraded for use at the SPS — new computers were installed for data acquisition and monitoring, downstream lever-arm drift chambers were added and multiwire chambers incorporated near the target for better track resolution. Other improvements included an additional Cherenkov counter and the OLGA electromagnetic shower counter. The central region of the detector still contained the original optical spark chamber configuration with TV readout.

In this form, Omega catered for eight different experiments and 135 physicists during the first two years of SPS operation, including the very first physics ever to come from the new CERN machine — a comparison of the production rates of J/psis by different particles (see May 1977 issue, page 150). Other results included the first data from what was to become a very fruitful collaboration studying high energy photoproduction, using a 20–70 GeV beam with a 'tagging' system giving the energies of individual photons. Baryonium reports came and went, and study began of the interaction of high energy antiprotons. As well as unseparated hadron beams of energies up to 85 GeV, Omega users also had separated beams of energies up to 20 GeV thanks to the special superconducting radiofrequency equipment developed in collaboration with Karlsruhe. This greatly enhanced the available levels of kaons and antiprotons.

During this time, new electronic readout and triggering systems worked well and allowed rapid changeover between different experiments. However the limitations of the basic detector, especially due to the TV readout, were becoming evident at the SPS energies and event rates.

In November 1977, the 'Omega Prime' project was approved. The original spark chambers were replaced with multiwire proportional counters, track analysis was optimized and the computer system improved. This new Omega configuration started work in May 1979, but already by the time of the SPS shutdown in June of this year it had carried out seven experiments and three tests for a community of 170 physicists.

The tradition of photoproduction studies has been continued, providing some examples of new heavy mesons (see April issue, page 59), and useful results on charm production, including F mesons and the first example of double charm photoproduction (see November issue, page 360). The baryonium hunt has been dutifully continued, but no candidate has withstood the test of confirmation.

With the new Omega system, operation has been very reliable and rapid switches have been possible from one experiment to another. Good, well-monitored data has been obtained, and experiments have been completed quickly, with some groups even having physics results before their runs were complete.

For the next step, it is hoped to move towards higher beam energies. With hadron and photon beams of hundreds of GeV, a detailed study could be made of the basic interactions between quarks, gluons and photons. This would provide a comparison of hadron- and photon-induced reactions, together with a thorough study of the final states.

More hyperon results

The study of hyperons is steadily accumulating a list of results which require explanation. The recent spin symposium at Lausanne (see November issue, page 335) again underlined the mystery of why the hyperons produced in high energy proton-nucleus scattering should be polarized. In addition, the relative values of the hyperon magnetic moments also provide food for thought.

Some more interesting hyperon results, this time on hyperon cross-sections, come from the Bristol/ Cambridge / Geneva / Heidelberg/ Lausanne / Queen Mary College / Rutherford collaboration using the charged hyperon beam at the CERN SPS. This beam has already provided examples of the decays of the rare omega minus baryon (see July/ August 1978 issue, page 257) and has allowed measurements to be made on the relative production rates of hyperons and their antiparticles (see July/August 1980 issue, page 204).

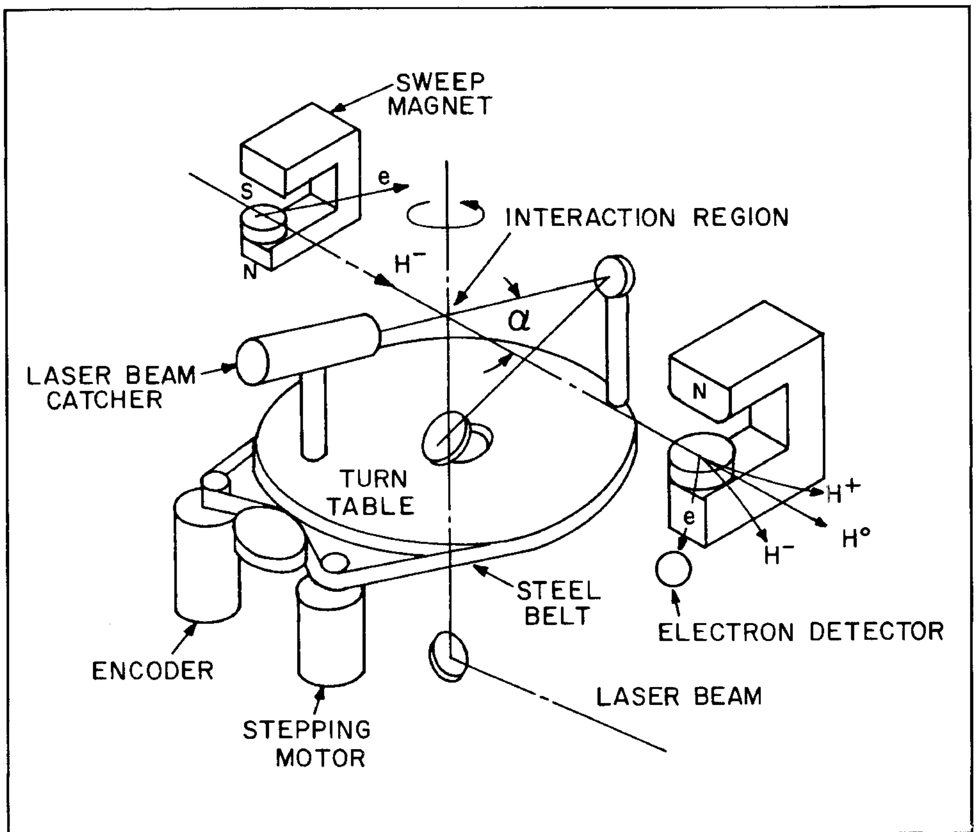
The experiment has measured the total cross-sections of negative sigma and ksi particles on both protons and deuterons (thus enabling the cross-section on neutrons to be extracted). The sigma particle data are taken at five beam momenta between 74 and 137 GeV and achieve an accuracy of one per cent or better, while the ksi results, with similar statistical accuracy, come from momenta of 101 and 134 GeV. Data is also taken for antiprotons, and these results are in good agreement with earlier Fermilab data.

The different hyperon-nucleon cross-sections decrease strongly with increasing strangeness, and rise steadily with increasing energy. Their behaviour is not accounted for by any conventional quark model with complete success. The only model agreeing with the data is an empirical idea put forward by Harry Lipkin, using an unusual two-component Pomeron, one part of which has some SU3 dependence.

The CERN experiment has also given useful indications of the formation of higher hyperon resonances, and this study is to be continued.

LOS ALAMOS Photon-ion colliding beams

An inventive application of the colliding beam technique to atomic physics is being carried out at LAMPF by a New Mexico/Los Alamos/Connecticut collaboration. It involves intersecting a laser beam with the LAMPF 800 GeV negative hydrogen ion (H^-) beam, from which a rich spectrum of unbound resonant states of electrons and hydrogen atoms is produced by photodetachment. In addition, magnetic fields are applied to study the resulting Stark-effect modification of the resonances in the ions' rest frame.



A schematic of the apparatus using colliding ion and photon beams at Los Alamos which has produced some new atomic physics results.

The H^- ion (which contains a proton and two electrons) has attracted much theoretical attention as a proving ground for models and their extension to more complicated systems. The ion is a prototype three-body system for which an exact quantum solution is not yet available, although good approximations can be obtained. Unfortunately the resonance region of the H^- ion is difficult to study experimentally. The photon energies for photodetachment lie in the vacuum ultraviolet region where no tunable laser yet exists. The electron-hydrogen atom reaction is complementary to photon-H^-, but a sufficiently monochromatic electron beam and atomic hydrogen source have not yet been available. Stark-effect studies on the lower-lying states of hydrogen require electric fields of the order of Megavolts/cm, which are not attainable under laboratory conditions.

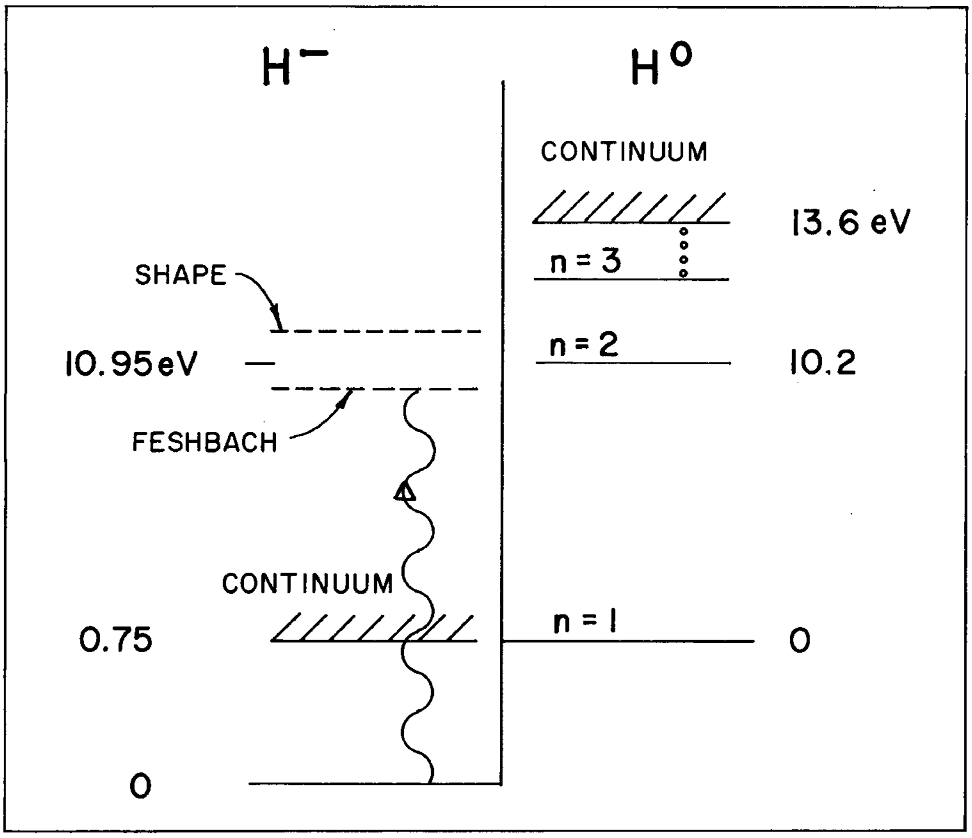
The photodetachment team at LAMPF has overcome these difficulties by exploiting the large Doppler shift of an ordinary ultraviolet laser to obtain photon energies from 0.35 eV to 20 eV in the rest frame of the ions. In addition an 0.22 T electromagnet produces an electric field of 1 MV/cm in the ions' rest frame.

The H^- system has a stable state at 0.75 eV. All excited states are unstable and de-excitation occurs mainly via autodetachment. The experimental technique relies on detection of the ejected electron (440 keV in the lab frame) to observe the reaction.

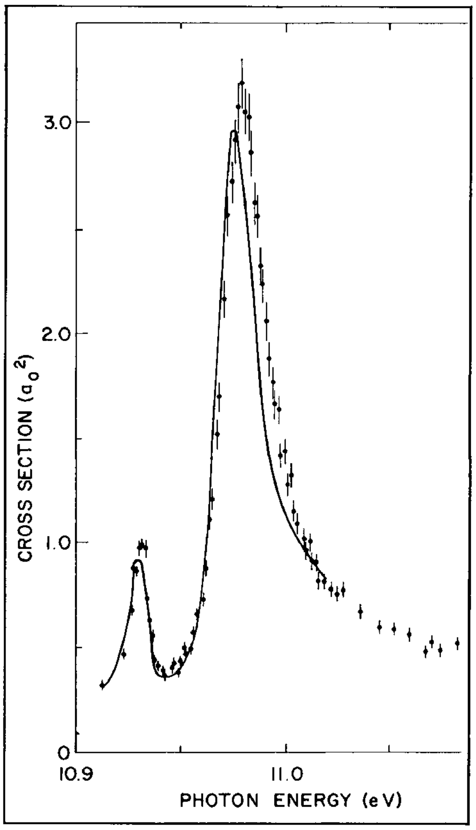
The experimenters originally set out to observe the 'shape' resonance that lies just above the n (principal quantum number) = 2 threshold the parent hydrogen atom. Although the shape resonance had been seen in electron scattering from hydrogen, attempts to find it in an arc discharge plasma and in stellar spectra had failed. The experimenters not only observed the shape resonance, but also saw for the first time the Feshbach resonance just below the n = 2 threshold of the parent atom. Due to its narrow width, the Feshbach resonance was thought to be unobservable.

Both the shape and Feshbach resonances can be pictured as doubly-excited states in which one of the electrons is momentarily confined within the potential well formed by the excitation and polarization of the residual neutral atom.

The Los Alamos experiment set out to look at the 'shape' resonance of the negative hydrogen ion which lies just above the n (principal quantum number) = 2 level of the hydrogen atom. In fact they also observed the nearby Feshbach resonance, previously thought to be unobservable.



Cross-section for photodetachment of negative hydrogen ions near the n = 2 level of the parent atom, showing the Feshbach (left) and shape resonances. The line is a theoretical prediction, and the cross-section is in units of squared Bohr radius.



Feshbach resonances appear just below the various excitation thresholds of the hydrogen atom and can be thought of as virtual bound states of electrons and excited atoms. The name owes itself to the Feshbach projection technique that was originally developed in nuclear theory. Shape resonances on the other hand appear just above excitation thresholds and can be thought of as an electron trapped in the centrifugal barrier created by the combination of its angular momentum and the potential of the polarized hydrogen atom. Near the n = 2 level the shape resonance is relatively narrow due to the thickness of the potential barrier and its proximity to threshold.

The failure to observe the shape resonance in the arc discharge plasma has been attributed to Stark broadening by fields in the plasma. The LAMPF investigators applied an electric field to the interaction region to check this idea. At the highest fields then available (about 1 MV/cm) the shape resonance was almost unaffected. However at fields of about 0.1 MV/cm the Feshbach resonance split into three components and then disappeared. This is attributed to Stark mixing of the p-state (unit angular momentum) Feshbach with a nearby s-state (with n = 2 and zero angular momentum).

The experimenters have since observed other resonances near the n = 3 threshold, and another Stark-induced resonance, and have begun an investigation of double photodetachment and neutral atoms. Future work will include high field studies to see where the shape resonance quenches. An important practical application has been for time-resolved energy measurements of the LAMPF beam. Future applications may include the generation of a monochromatic hydrogen atom beam using the narrow Feshbach or Lyman-alpha resonances to select a narrow velocity group.

Physics monitor

The quest for pion condensation

Some two thousand different nuclei have been studied, covering a wide range of different proton/neutron configurations. However the bulk properties of all these nuclei are much the same, which means that the range of nuclear matter accessible to experiment is limited. Recently this has led to the speculation that nuclear matter under different conditions (pressure, temperature, etc.) could have properties very different to conventional atomic nuclei. Nuclear theoreticians are confident that the first conclusive signs of such interesting new behaviour will soon be discovered.

These theoretically-proposed nuclear properties reflect new aspects of the meson exchange forces at work in nuclear matter. For a number of reasons, the pion is predicted to play an especially important role in these phenomena, which are known as 'pion condensation'. Under definite conditions (critical points), nuclear matter is predicted to undergo abrupt changes in composition and properties (phase changes), analogous to the well-known critical phenomena (boiling, freezing, etc.) seen in other branches of physics when matter changes its macroscopic properties. Pionic phase changes would manifest themselves as a drastic reordering of the usual nuclear structure, with pions (or pion-type behaviour) much in evidence.

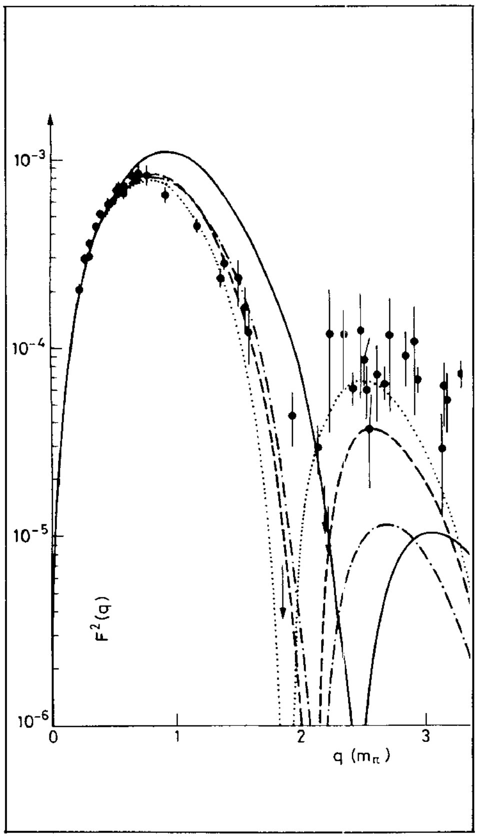
These speculations could soon become a reality, as the observed pion-nucleon scattering behaviour, together with information on pion-nucleon interactions gained from experiments with pionic atoms (atoms where the usual orbital electrons are replaced by pions), indicates that the onset of pion condensation could show up under nuclear conditions not too different from those of actual nuclei. For this reason, pion condensation and its implications have become a vital new issue in nuclear physics.

Why condensation of pions and not other particles? The pion is by far the lightest of the strongly-interacting particles, so that it is relatively easy for it to be bound to a nucleus tightly enough for all its rest mass to disappear. At the same time, the pion wave packet has dimensions comparable to internuclear spacing, so that nuclear matter looks fairly homogeneous to a pion. The pion also experiences a special nuclear attraction, as indicated by the existence of pion-nucleon resonances. In addition, waves carrying both spin and isospin can be set up in nuclear matter, analogous to the phonons (sound waves) in elastic solids. These waves can have the same quantum numbers as pions and couple strongly to them, so contributing to the attraction.

A simple model can be used to illustrate the principle of pion condensation. Suppose we have initially a (hypothetical) system composed entirely of neutrons. These particles are fermions obeying the Pauli Exclusion Principle, so that each allowable energy level up to the Fermi energy of the neutrons will be populated by a single neutron.

While an isolated neutron cannot decay into a proton and a (negative) pion, the conditions (density, temperature, etc.) of the assembly of neutrons could be such that the neutron and proton Fermi energies permit the neutrons occupying the higher energy levels to decay into protons and pions. This process would then continue until the difference between the neutron and proton Fermi energies becomes less than the pion rest mass. At this point the process stops. Unlike the nucleons, the pions are bosons and can all coexist in the lowest available energy level (Bose condensation). This will result in a strong pion field in the nuclear sample.

Observed behaviour of the magnetic form factor for electron scattering from the 15.1 MeV level of carbon-12. The curves are for different values of a renormalization parameter for the pion field. As this parameter nears a critical value, there is good agreement with the data. This could mean that the onset of pion condensation is being seen.



For this process to happen, the critical (neutron) density has to be about four times that of ordinary nuclei, so is of little relevance to laboratory experiments, although it could be important in neutron stars. The mechanisms which are proposed for pion condensation in actual nuclei are somewhat more elaborate.

At present there is no conclusive evidence that a pion condensate has been seen in actual nuclei. But even if the actual phase transitions of pion condensation may be out of reach in the laboratory, the onset of any phase transition is usually accompanied by local fluctuations due to the growing instability of the sample.

At the critical point, any transient local reordering becomes a long range effect which spreads across the whole sample.

These critical effects resulting from local reorderings would be expected to show up in a number of ways. Instead of falling off exponentially, Yukawa-style, as in isolated nuclei, the nuclear pion field is xpected to spread out as the condensation point is approached. In addition, the pion field is expected to oscillate, so that all kinds of new effects could be expected. (Conditions for the formation of pion condensates are more favourable in neutron stars for example, but evidence, and conclusions, are necessarily more indirect.)

The present attitude seems to be not whether pion condensation will be found, but when. Already some phenomena are seen which could be due to enhancements of the pion field in actual nuclei. For example the properties of the 15.1 MeV level of carbon-12 cannot easily be explained in conventional terms and ould be indicative of the onset of a uclear critical point (see December 1979 issue, page 411). However more work is required to pin down these new effects.

(For more current ideas on possible new nuclear behaviour, see the report on the recent Heavy Ion Workshop at Darmstadt, page 396.)

PEP talk

The newly operating PEP electron-positron storage ring, built by the Berkeley and Stanford Laboratories, was dedicated on 5 September. At the banquet, Fermilab director Leon Lederman was as usual in great form — here are some extracts from his speech.

I have been concerned to understand why I was chosen for this great honour — to speak at such an historic occasion. Is it that I am known as a dedicated scientist? I've been involved in the dedication (in one way or another) of a large number of accelerators. Somehow these accelerators overcome this handicap and manage to do great science anyway. This is however the first machine I've been involved in dedicating in which I have no experiment. I think this could be a bad omen so I brought along a modest proposal...

Seriously I decided, after reflecting on my thirty-five years in physics, to take three aspects of this standard career and make three solemn and related points.

Could I have been invited because of my teaching career? I probably hold some kind of record in particle physics with fifty-two or so Ph. D.s, most of whose theses I have personally rewritten. It isn't easy. You sit down at midnight after a hard day in the lab with a nicely typed, bound thesis of your best student (call him Fauntleroy Rabinowitz to protect living persons). This student is good! Harvard College, A+ whiz in the lab, hardware / software, etc.... You should read his software — it is absolutely lyrical. We thought of him as the Emily Dickinson of machine assembly language. He could do Feynman diagrams with one hand and with the other hand, be on the telephone, arguing down the price of phototubes. He worked like a dog sixteen hours a day for three years,

The SLAC landscape, with the linac coming in from the top left. The service road for the PEP electron-positron ring and the buildings at the intersection areas can be clearly seen at the bottom. Not visible is Leon Lederman giving an entertaining speech at the PEP dedication banquet on 5 September.

(Photo Joe Faust)

Leon Lederman giving one of a series of Saturday morning talks on particle physics to high school students. The ten-week series takes the students through relativity, quantum mechanics, accelerators and detectors, quarks, cosmology and even spin-offs. Many Fermilab physicists are participating in the programme.

(Photo Fermilab)

making apparatus work, curing background problems, critically analysing data... and his thesis is 90 per cent THEORY! 'In 1935 Yukawa discovered the pion...' Then there is his command of language: listen to this pinnacle in the saga of mixed metaphors: 'This is a field of physics, so virginal that no human eyeball has ever set foot in it.'

Another one of my great students, Irving Tweed-Harris, came from an old British family that invented the hyphen, much used in physics today. Tweed-Harris illustrates failures in other educational systems. After the standard British period of general education, Tweed-Harris began specializing in the pion-nucleon problem at the age of nine!

In the easy informality of the graduate student lounge at Columbia they used to call him Mr. Tweed-Harris, Sir. He was just not the sort you could call Irving. His thesis also began with stuff about Yukawa.

Of all the informal and formal courses I have taught — the most difficult one by far was the 'Physics for Poets'. The Columbia Lib Arts students were bright, and sceptical. I looked at them as future newspaper editors, lawyers, company executives, Congressmen — in all aspects of industry and government. I had them for three hours a week for a year — what an opportunity and what a responsibility! Could my physics course influence their way of thought? Could I diffuse an appreciation of the scientific attitude deep enough to affect their personality, their judgement and taste? It was difficult and I really don't know how successful. Richard Feynman is better at it. Who can forget his method of explaining velocity as a ratio of infinitesimals?

Cop: Lady, you were speeding. I clocked you at 60 miles an hour.

Motorist: That's ridiculous. I've only been driving for fifteen minutes!

Now when we realize that I and perhaps as many as twenty or so of my equivalents can reach a few thousand students a year — we see the magnitude of the problem faced by science in what may be an issue as large as the survival of democracy in the technological age. How can we maintain democracy if the citizens are scientifically illiterate? In general the college science requirement doesn't work and the problem is compounded by the illiteracy of the teachers in the private and secondary schools. And yet there are large efforts going on and much concern. For all I know there are special committees with the responsibility to do something.

The problem is not newly perceived. There have been alarms in ever-increasing intensity since World War II. The possibilities for improvement are vast. We have compulsory education. We have private and secondary schools. We have an impressive college population and we have the TV. We have succeeded in educating people to accept inoculations, drink fluorinated water, jog and quit smoking. Do we have the clout to install a long range and insidious programme of fostering public understanding of science?

Of course we have to be clear ourselves as to what are the key issues: Are there limits to science capabilities? How does one distinguish between good and bad technology? Can there be such a thing as a dumb Ph. D. in physics?

It seems obvious to me that the responsibility for finding a solution is in the University, both for its students and for the wider community. Install a four year science requirement — sponsor prime time TV

Leon Lederman: 'theorists get too much credit'. Here he is (looking for theorists?) at a buffalo roast at Fermilab.

(Photo Fermilab)

science spectaculars, ... I don't know but do something!

The next topic relates to my experience and involvement in the content of particle physics. I think that most of the spouses, non-physicist types who have some relationship to a particle physicist, must catch some of the intense excitement that characterizes the field today. It is fair to ay that we are now in the midst of ne of these rare revolutionary periods — that come once every twenty to thirty years. If we recognize Relativity and Quantum Theory as two of the great intellectual revolutions, we are in the midst of a third one now. It doesn't yet have an agreed-upon name — Constituent Theory, Grand Unification...

The trouble with this period is that, as with all previous revolutions, the theorists get much too much credit. I don't want to discuss Einstein and Dirac because they aren't here to defend themselves but when you think of how long it took the current heros to come up with quarks and Quantum Chromodynamics, after almost rubbing the data up their noses, nd then to know that future generations will only know about a few theorists!

We were finding new particles like mad from 1950 to 1964 before theorists finally came up with quarks as the underlying scheme. We discovered the second neutrino in 1962 and it should have been totally obvious that we needed a charmed quark but it took theoreticians several years to see it. And I could go on.

What gets me is that they are so over-confident. Theoretical over-confidence is probably the worst problem we face. Shortage of funding comes next.

But still it is an exhilarating time and I'd like to tell you one fascinating story to illustrate this.

If I tried to characterize the results of the past two decades' probing of inner space, using accelerator-microscopes of ever increasing power, it is that — as we zoomed down and down past the atom, into the nucleus, focus sharp! Zoom into the nuclear proton — at first, a fuzzy cloud — then, three sharp but rapidly moving objects... and down... and suddenly we were making quantitative measurements of the motions of these quarks, we were detecting evidence of the glue that binds them together, and finding that, in the cloud-like environment of the quark there were traces of a new and unsuspected family. And then, when we look up from our accelerator-microscope, across the room our astrophysics colleagues look away from their telescopes. We talk and we find that we are looking at similar things.

They tell us that they hang on all developments in particle physics with great interest, that there wouldn't be any sensible progress if they didn't know about neutrinos and about quarks and about the quark forces. They are intensely interested in whether the proton — long thought to be perfectly stable — does in fact have a measurable half-life. In the past they needed to know about nuclear forces and beta decay to account for the sun's heat and the properties of neutron stars. But the story goes both ways — the cosmological evolutions of the Universe has phases which would make even Fermi's mythical globe-encircling accelerator look feeble. The early Universe (someone said) is an accelerator laboratory with a totally unconstrained budget. Some of this is contained in Steve Weinberg's book. 'The First Three Minutes.' (It sells like hot cakes because many people think it is a book on sex!)

Lederman paddling his own canoe (with the help of George Luste).

(Photo Fermilab)

At Fermilab where, in the next three or four years, we hope to explore an energy domain which is truly original, beyond any confident prediction, we are planning a long series of talks and symposia on the hints we can get from both cosmology and cosmic rays. Because the interaction is so fruitful, we are campaigning for the NASA Space Telescope Institute to be located at Fermilab so that astrophysicists and particle physicists can literally drink coffee and discuss.

One specific issue that excites us has to do with the neutrino.

This little fellow has provided a steady diet of surprises ever since Pauli proposed it in 1930. Enrico Fermi named it and used it in the first mathematical treatment of radioactive decay. His properties as developed both experimentally and theoretically were bizarre.

We now know that there are three different varieties or families of neutrinos. Until recently most physicists believed (and many still do) that these were all massless, precisely zero mass and therefore always moving with the velocity of light.

Recently there has been an accumulation of evidence, none of it convincing, which has raised the question of how 'zero' are the masses. These questions have profound philosophical implication — which tends to make physicists more critical of the data.

The new evidence is quite comfortably received by some theorists who are trying to unify the weak, electromagnetic and strong forces. In special cases of these new theories (modestly entitled Grand Unification), neutrinos do have small masses and could well 'oscillate' between themselves. But what is the evidence? To me, the more fascinating data come from our astrophysics friends who tell us that they can measure the mass of a galaxy by the properties of hydrogen atoms that orbit the galaxy. The result of this weighing of the galaxy comes out much greater than the mass obtained by counting stars and by well-tested rules associating mass with luminosity. Where is the residual mass? Dark stars? Black holes? These possibilities are made remote by the fact that the same data shows a continuation of mass density far away from the boundary of the visible galaxy. Then, why only dark stars there and no bright ones? One plausible hypothesis is that the unseen mass is vested in neutrinos which fill the galactic environment. An elementary calculation can explain the data if the neutrino weighs more than 20 electronvolts (25 000 times lighter than the electron). Implications are profound for theories of the evolution of our Universe.

Neutrinos with a rest mass of 20 eV would dominate the total mass of the Universe. If the mass of the neutrino were heavy enough, this would imply a gravitational mass density in the Universe sufficient to slow down the present expansion. This expansion, which began at the birth of the universe (Big Bang), would eventually come to a halt. Pulled by the gravitational attraction of the neutrinos (and more conventional stuff), all the matter in the Universe would rush together to form again the hot singularity, heralding a new cycle and so on ad infinitum.

Various pieces of laboratory data from reactors, from accelerators and from our own sun suggest or tend to support the notion that the neutrinos do indeed have a rest mass, but each one is flawed and the issue is surely still open. New experiments are now proposed — at reactors, at the large accelerators of Fermilab, Brookhaven and CERN — to settle this issue. The stakes are high in human comprehension of an enormous range of concepts: the basic laws of physics and especially the Grane Unification of Forces, the properties of particles of incredibly small dimensions, the mechanism of the sun's energy source, the significance of the Big Bang and the future evolution of the Universe. These are the kinds of mind-boggling issues that the PEP experimenters will deal with in the next years.

I come now to my most recent activity — the administrator or Director of Fermilab. Now I get into problems of community; we are part of a nested set of communities. Like the sequence of molecules to atoms to nuclei to quarks we are part of a world community of highly educated citizens with a special responsibility towards the preservation of the cultural heritage and the social well-being of this planet. We are a community, high energy physics, complete with all the internal dissension and competition that is so normal in families. But on the occasion of this solemn pause for the dedication of PEP we stand together in mutual respect, love and awe at the heritage of our science.

And basic research does (in spite of the grey areas and the difficulties of rigorous definition) define a community — again both culturally and socially. The mathematician, however pure, is influenced by and contributes to the developments in molecular biology. Cosmology and particle physics have never been closer; plasma physics supports fusion, physics of the upper atmosphere and astrophysics. And altogether, we are constructing what Viki Weisskopf calls '...one of the great creations of contemporary culture: a vast intellectual structure which, on the basis of a few constants, provides a framework for a unified description of the natural world from the fiery beginning to the existence of life on our planet.'

When you march forth to defend basic research you find there is no attack! Everyone loves basic research. So what are the difficulties? Basic research or many of the basic research disciplines are in deep trouble. Let me take high energy physics where all major accelerator Laboratories are in serious difficulty and discuss it from only one direction — that is the flow of young physicists into the field. We all know that graduate student enrolment in physics is dramatically down. It is not unusual to see two physics professors — colleagues and friends for thirty years — coming to blows over the sponsoring of one mediocre graduate student.

Look at the numbers of high energy physicists. Back in 1965, there were, in the US, 1100 experimentalists and about the same number in Western Europe. Today in the US there are still 1100 but there are 2000 in Europe. This comes from a region with the same GNP as the US and the same population base.

Now I worry enormously about those missing 900 experimental particle physicists. Where are they? I'm not reassured if you tell me they went to medical school — not that I'm against medical schools, I'd love to see so many doctors graduated that it would not be unusual to have your doorbell ring and a neatly dressed young man carrying a little black bag ask if anyone is sick inside!

I worry because one of them, turned off by a sour high school teacher, forewarned about job prospects by a sincere college advisor, discouraged by public attitudes or his perceptions of them — this one guy puts on a backpack and camps out and the world has lost a Newton or a Maxwell or a Panofsky or a Jonas Salk or an Edison or a Steinmetz — someone who could just save the world.

To achieve an intellectual breakthrough requires lots of delicately balanced conditions but the one essential ingredient is the young mind and it is obvious that the wider the base, the better the chance. One loss could be disastrous if we had to wait another twenty or thirty years. We don't have the time!

The books I have read teach me that societies vanished totally or slept for centuries because of errors of judgement — by failures of the culture to adapt to the problems facing the society.

A defensible perception of the problem facing us is that it is largely technological. It has to do with four billion people and a scale of living which cannot be set far lower than that which we now enjoy. We, the affluent 20 per cent, have already made significant inroads on the natural world which we inherited from geological ages. It has to do with minerals, laid down over geological history and now depleted. It has to do with natural geochemical cycles being accelerated. Atmospheric trace contaminants can alter climate. How do we extend a reasonable standard of nutrition, energy supply, health, transportation, shelter to the other three billion people in the face of these issues? It seems to me that this is the central question, first for science and technology, then surely for statesmen. This is why I worry so much about the missing 900 physicists.

PEP comes on with some unusual handicaps. It is of course competing with PETRA at DESY. It is late and it will take all the ingenuity and imagination that this great Lab, with its great traditions, can muster to catch up and show the world that US physics is strong and that the large funds vested here are well spent. In this respect this Lab and this Community owe a tremendous debt to John Rees, the man on the front lines who led PEP construction, and to Burt Richter, who not only was a seminal figure but had time to come and help me in my first shaky year at Fermilab.

We are a community and we depend upon one another's successes. Good luck!

People and things

New CERN Directorate Members

At a recent CERN Council meeting, Director General designate Herwig Schopper announced further nominations for the CERN Directorate. Erwin Gabathuler, now Leader of CERN's Experimental Physics Division, becomes Director of Research from 1 January 1981. Also appointed Director of Research is Robert Klapisch, now Director of Research at the French Centre National de la Recherche Scientifique, who takes office on 1 July 1981. Director of Administration from 1 February 1981 is Rudolf Heyn, presently Director, Physical and Life Sciences, Netherlands Ministry of Education and Science. Earlier this year, Giorgio Brianti was named as Technical Director, and Emilio Picasso as eventual LEP Project Leader.

Festschrift for Maurice Goldhaber

At a special ceremony at Brookhaven to honour his distinguished career in physics, Maurice Goldhaber (right), receives a Festschrift from Gerald Feinberg of Columbia University.

(Photo Brookhaven)

Over 300 of Maurice Goldhaber's friends and colleagues from around the world gathered at Brookhaven on 3 October to celebrate the presentation of a Festschrift honouring his distinguished career in physics. Sheldon Glashow of Harvard, Sir Denys Wilkinson of Sussex, Martin Deutsch of MIT, and Robert Marshak of VPI spoke at the afternoon symposium on a broad range of topics which reflected the remarkable span of Goldhaber's scientific accomplishments. Following a reception and dinner, George H. Vineyard, Director of Brookhaven National Laboratory, and Gerald F. Tape, President of Associated Universities Inc. (AUI, which operates the Brookhaven Laboratory), shared their reminiscences with the guests.

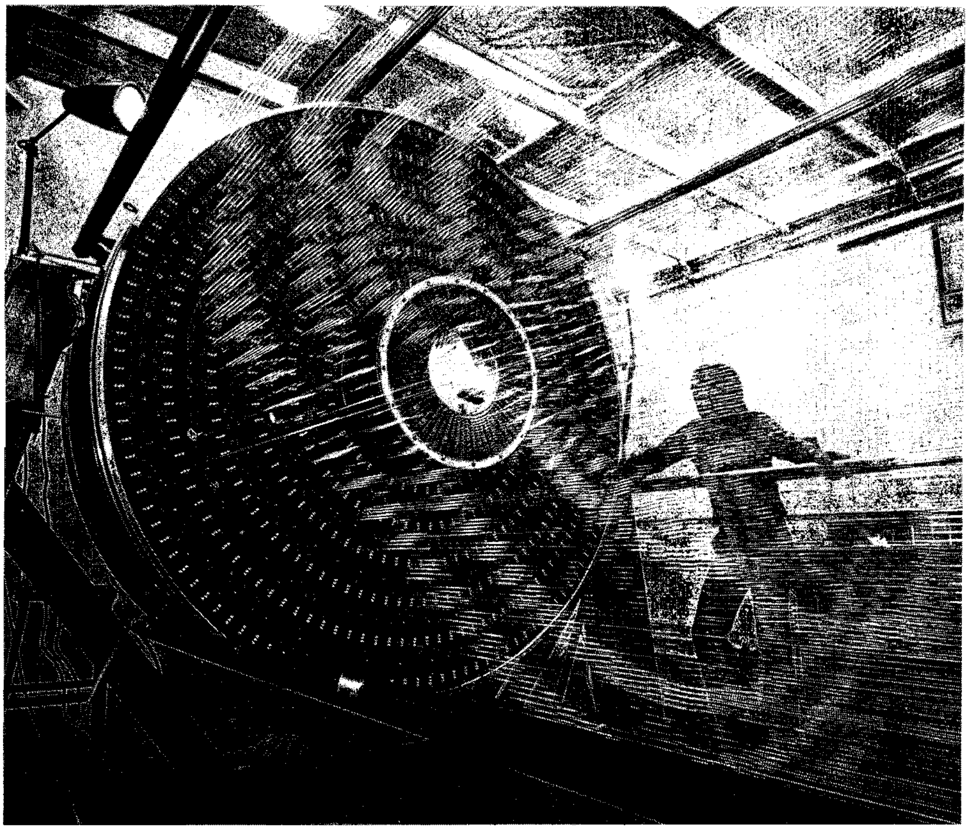
The climax of the evening was a Festschrift presentation by Gerald Feinberg of Columbia University. The articles deal with many areas of physics, including nuclear, particle, and atomic physics, as well as applications of nuclear techniques to medicine. The authors are well-known physicists, including such luminaries as Edward Teller, and Nobel Prizewinners T. D. Lee, C. N. Yang, and Rosalyn Yalow.

Maurice Goldhaber was appointed AUI Distinguished Scientist in 1973, after serving as Brookhaven's Director since 1961. He came to the Laboratory in 1950 as a Senior Scientist, following 12 years at the University of Illinois. Born in Austria, he received his Ph.D. from Cambridge University where he worked with Sir James Chadwick and R. H. Fowler at the Cavendish Laboratory. Dr. Goldhaber has been an adjunct Professor at the Institute for Theoretical Physics, SUNY, Stony Brook, since 1965. He is currently Vice-President Elect of the American Physical Society and will assume the presidency of the Society in 1982.

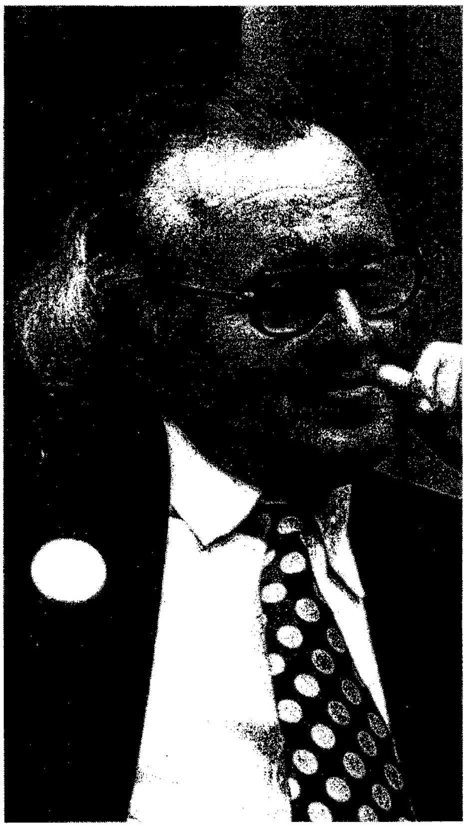
His main research contributions are in the fields of nuclear physics and fundamental particles, and cover experiment, systematics, technique and theory. He has participated in many discoveries, including the nuclear photo-effect, the role of spin in nuclear reactions, slow neutrons (interactions and neutron detectors), the first observations of nuclear disintegrations in photographic emulsions, classification of nuclear isomers, the giant dipole resonance, the helicity of the neutrino, and the suggestion of a hydrogen-neon filling for bubble chambers. Dr. Goldhaber is now engaged in a large-scale search for proton decay with physicists at the University of California at Irvine, and the University of Michigan.

Construction of the drift chamber for the new Mark III detector for the SPEAR ring at SLAC. Mark III will take over the pit vacated by its predecessor, Mark II, after its move from SPEAR to the big PEP ring.

(Photo Joe Faust)



Veniamin Sidorov



The fiftieth birthday of Veniamin Sidorov was celebrated on 19 October. One of the pupils and colleagues of Gersh Budker, Veniamin Sidorov has contributed greatly to the construction of the first colliding beam accelerators at the Novosibirsk Institute of Nuclear Physics and to the experiments carried out with them. His name is associated with pioneer work on quantum electrodynamics tests and on the investigation of vector mesons with colliding beams. He has also led experiments which resulted in the first observation of two-photon production of electron-positron pairs, the discovery of an anomalously high cross-section for electron-positron annihilation into hadrons, a high accuracy test of the equality of electron and positron magnetic moments, a high precision measurement of phi, psi and psi prime meson masses, etc. He has actively participated in the strengthening of Novosibirsk collaboration with CERN, SLAC and other physics centres. All his friends add their warm congratulations and best wishes.

Gerald Tape is retiring as President of Associated Universities Incorporated which operates the Brookhaven Laboratory. He has been associated with the Laboratory throughout its history. He will be succeeded by Robert Hughes.

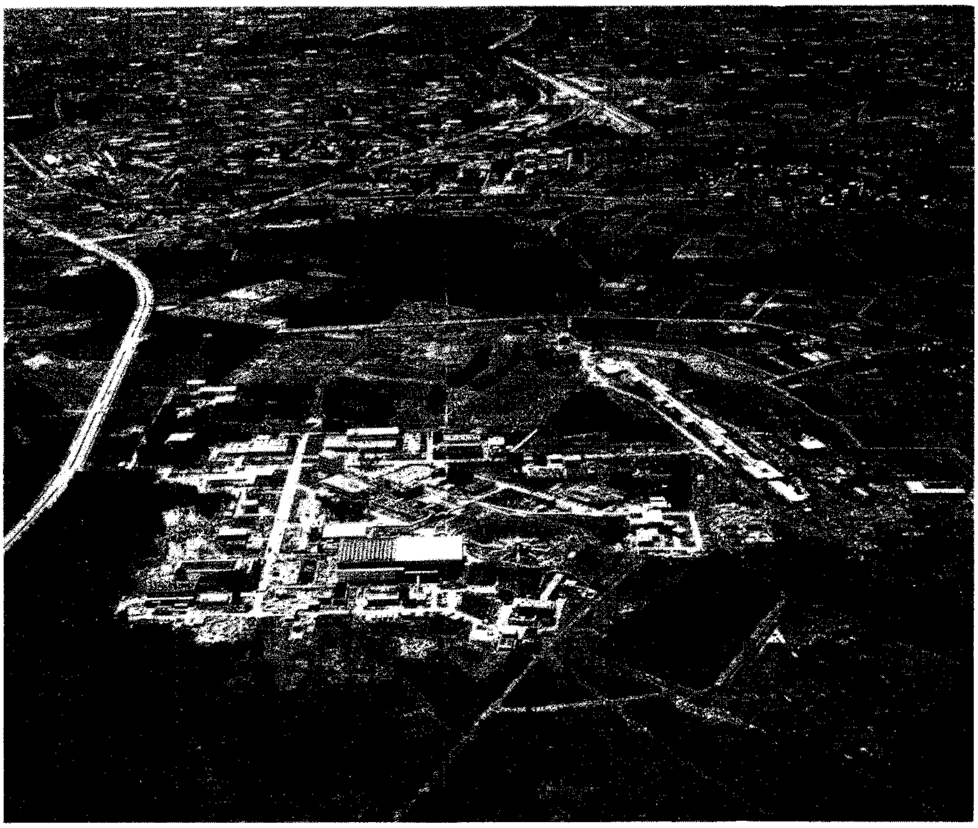
The Canadian Association of Physicists' medal for Achievement in Physics was awarded this year to Bernie Margolis of McGill University, Montreal. He has made important contributions to the theory of coherent and incoherent particle production, to the understanding of the role of vector dominance in photoproduction experiments on nuclear targets and to the statistical bootstrap approach to multiparticle production experiments. In addition he has been a leader in the formation and growth of the particle physics programme in Canada and was the first chairman of the Institute of Particle Physics (IPP).

From field theory to molecular biology

One of the recipients of this year's Nobel Awards, along with particle physicists James Cronin and Val Fitch (see page 391), is Harvard molecular biologist Walter Gilbert. He shares the Chemistry Prize with Frederick Sanger and Paul Berg for work on the chemistry of nucleic acids. Before turning to this line of research, Walter Gilbert was an elementary particle field theorist, and hidden deep in the physics literature can be found among other

A recent aerial view of the Japanese KEK Laboratory. A new feature is the 450 m-long 2.5 GeV electron linac for the Photon Factory, visible on the right. Construction is proceeding according to schedule.

(Photo KEK)



things the Deser-Gilbert-Sudarshan representation as a reminder of those days.

More on the free quark search

While the indirect evidence for quarks accumulates steadily, direct evidence for the existence of free quarks is still scanty. In our report of the recent Madison High Energy Physics Conference (September issue, page 242), we mentioned the searches for free quarks in matter being carried out at Stanford by the group led by William Fairbank, and Genoa by Giacomo Morpurgo. While the Stanford experiment (using niobium) has provided repeated evidence for fractional charges in multiples of one-third of the electronic charge, the Genoa study did not observe any free quark in 3.4 mg of iron, a quantity of matter three times as large as that explored at Stanford.

Morpurgo and his collaborator, M. Marinelli, have observed a continuous distribution of apparent fractional charges, which they could show was due to the effect of a magneto-electric force acting on the levitated balls used in the experiments. Morpurgo points out that such an effect cannot explain the Stanford results, which so far always indicate charges of one-third, rather than a continuous distribution.

Microprocessor Conference

From 4-6 May 1981 a Topical Conference on the Application of Microprocessors to High Energy Physics will be held at CERN. Its aim is to survey the use of programmable devices, especially microprocessors, which enhance the quality and integrity of recorded data from present and future high energy physics experiments, including triggering, event filtering, data compaction, equipment calibration and monitoring. Further information can be obtained from Mrs. Terry Jones, CERN 1211 Geneva 23, Switzerland. The deadline for the submission of abstracts is 31 December.

ZING bows out

The ZING-P' pulsed neutron facility at Argonne was closed down in August. It has done some important pioneering work for the coming first generation of accelerators as neutron sources. It will be succeeded by the Intense Pulsed Neutron Source (IPNS-1) which is scheduled to come into action at Argonne in April 1981.

HERA meeting

After the meeting at the Max Planck Institute in Munich on 24 and 25 October, there was no doubt that the high energy physics community fully supports ECFA's recommendation that two big accelerators should be constructed in Europe (see July/August issue, page 192). Besides LEP (which has priority), the necessity of an electron-proton machine, sited at DESY, was stressed by the 180 participants.
In an eloquent introduction, Haim Harari explained the need for electron-proton experiments to complement electron-positron and proton-antiproton studies. Active collaboration was assured by many Laboratories. Saclay is already participating in the construction of prototype superconducting magnets which could be used for HERA. A technical proposal meeting at DESY is scheduled for 2 and 3 December.

At the Munich meeting on the proposed HERA electron-proton machine for DESY: Haim Harari 'conducting' a talk on the need for electron-proton experiments.

(Photo Horst Laskus, MPI Munich)

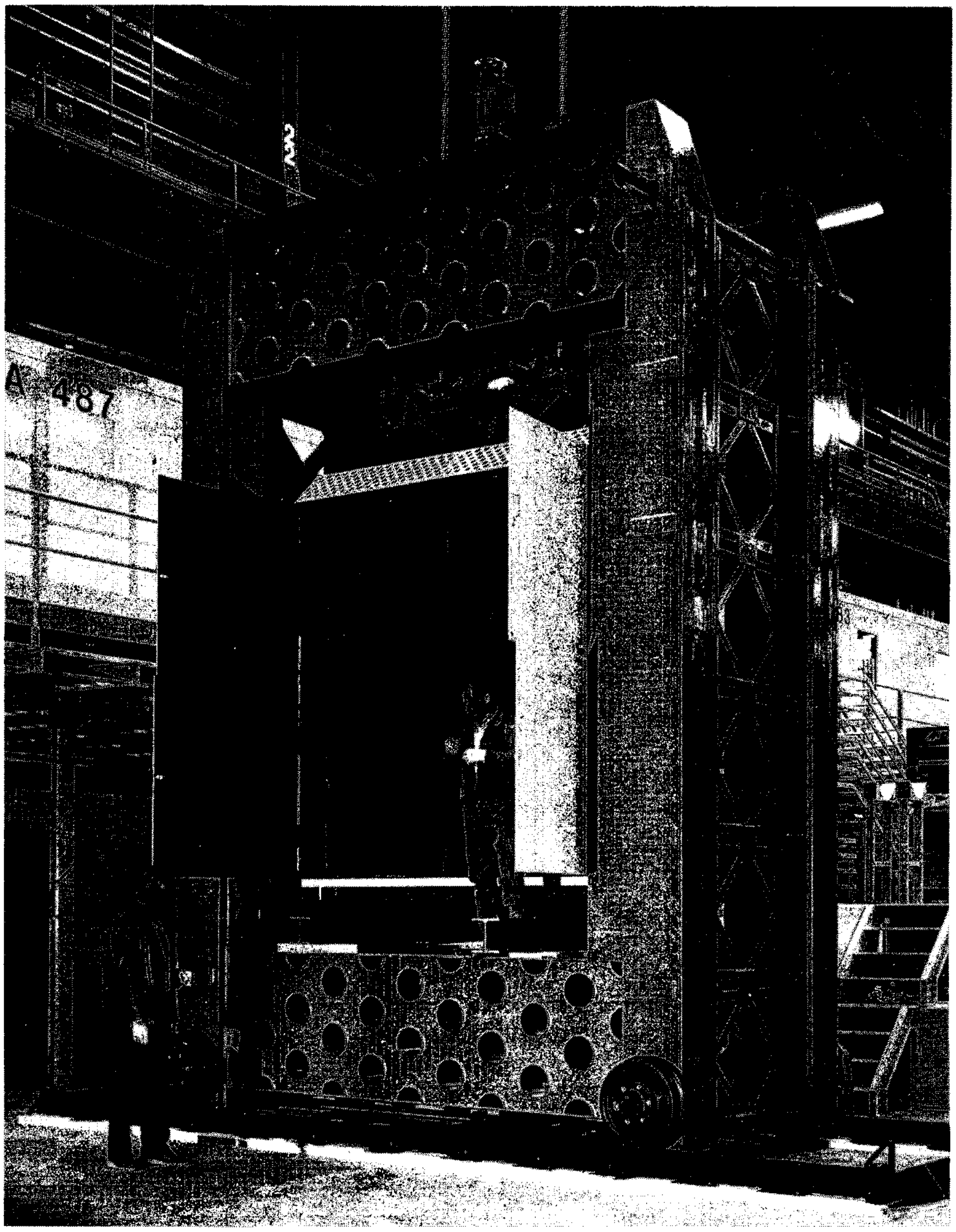
First electron cooling at Fermilab

On 17 October, for the first time at Fermilab, a 'hot' proton beam was cooled by a beam of electrons. The experiment was carried out at a proton energy of 115 MeV, the highest energy electron cooling achieved anywhere, and is a significant achievement on the way to the storage of antiprotons and proton-antiproton colliding beams.

The 115 MeV protons were cooled using a 62 keV electron beam, operating from 2 to 5 A. After optimization, in several seconds the proton beam was cooled by a factor of 50 in momentum spread, and a factor of five in transverse size. The cooled proton beam has been rapidly accelerated and decelerated without loss across the cooling ring aperture. This is essential if successive cycles of antiproton production are to be accumulated in the Fermilab antiproton source.

The 200 MeV cooling ring, located just west of the Booster, has two long straight sections – the east one containing equipment used principally for stochastic cooling, and the west one containing the electron beam for electron cooling.

The colliding beam development programme involves a Fermilab/ Berkeley/Argonne/Wisconsin/Novosibirsk collaboration. Electron cooling was first demonstrated experimentally at Novosibirsk in 1976, and was studied in the energy range 1.5 to 100 MeV, with a current of up to one ampere. Then about a year ago, electron cooling was



Recently arrived in the North Experimental Area of the CERN SPS is the 31-ton GAMS electromagnetic shower counter built at Serpukhov for an experiment by a Soviet/ Belgian/French collaboration.

(Photo CERN 543.10.1980)

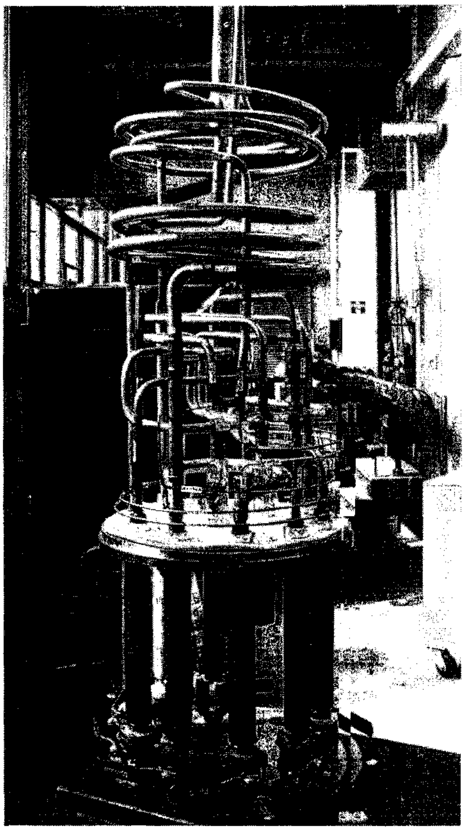
achieved at CERN at a proton energy of 50 MeV (see October 1979 issue, page 309).

The Fermilab system has higher energy and a greater electron current capability (up to 7 A). In achieving cooling under these new conditions, new space charge problems were encountered that were not seen in the earlier experiments.

Keeping cool

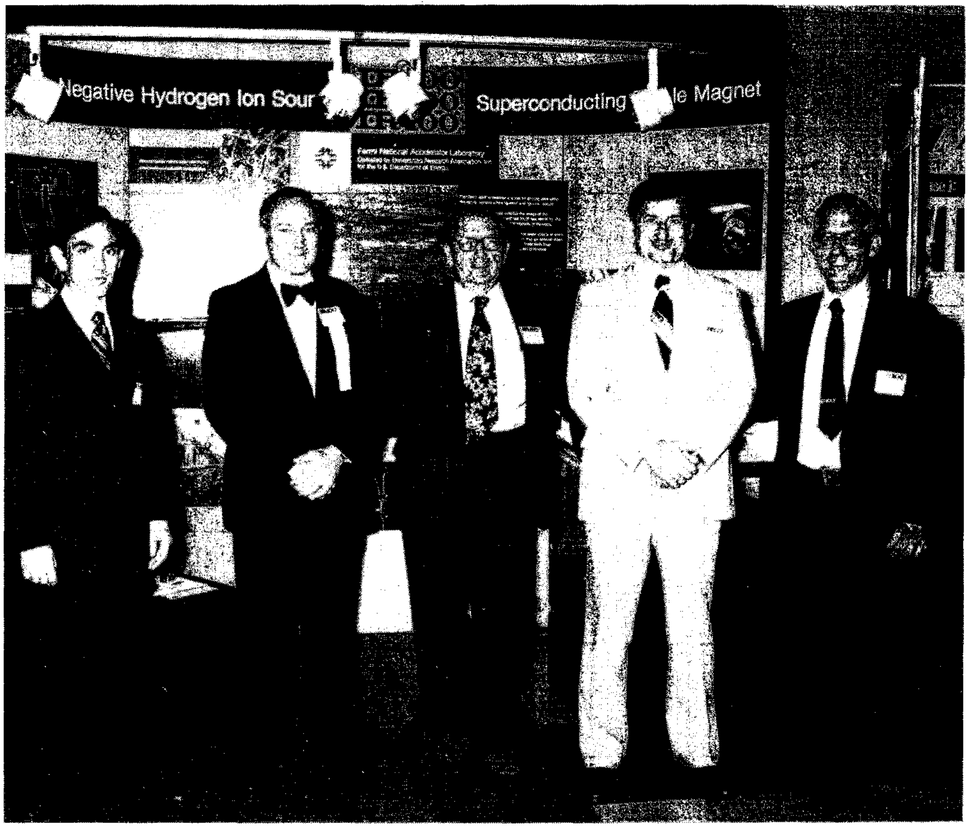
In September, two more significant milestones were passed at Fermilab in providing the massive liquid helium temperature refrigeration for the Energy Doubler/Saver. The heart of the cryogenic system is a central helium liquefier, operated for the first time on 18 April, together with 24 1000 W satellite refrigerators positioned every 300 m around the ring.

Last month the fourth and final A-sector satellite was moved into position. The 11 m-long horizontal exchangers are adjacent to the refrigerator building. An important simulation test was also carried out using a 300 m section of the helium transfer line which will carry liquid helium from the Central Helium Liquefier to the satellites. The most recent test used a satellite refrigerator at A-1 operating as a helium liquefier supplying 100 l/hour of liquid helium through the 300 m transfer line to the A-2 satellite refrigerator. This was operating in the final satellite mode with its load of 40 superconducting magnets in the main ring tunnel. The successful test simulated the running conditions of the Tevatron.



Inside of the valve box for a Fermilab satellite refrigerator, looking like the work of a bugle maker gone mad. Complex plumbing connects a satellite refrigerator into the main ring.

(Photo Fermilab)



Fermilab's energy saver dipole magnet and negative hydrogen ion source have been recognized by the magazine 'Industrial Research and Development' as among the 100 most important worldwide technological achievements in 1979, thus qualifying for the I-R 100 Award. Seen here at the presentation ceremony at Chicago's Museum of Science and Industry are, left to right, Chuck Schmidt, Russ Huson, Hank Hinterberger, Karl Koepke and Chuck Marofske.

(Photo Fermilab)

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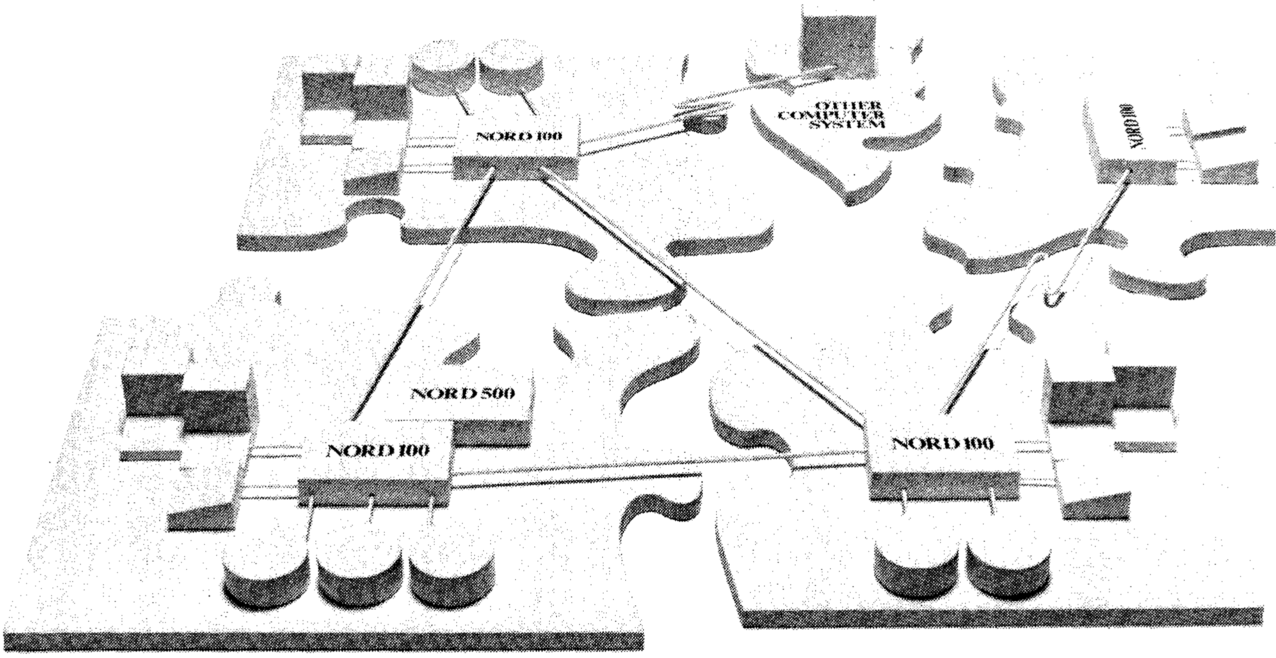
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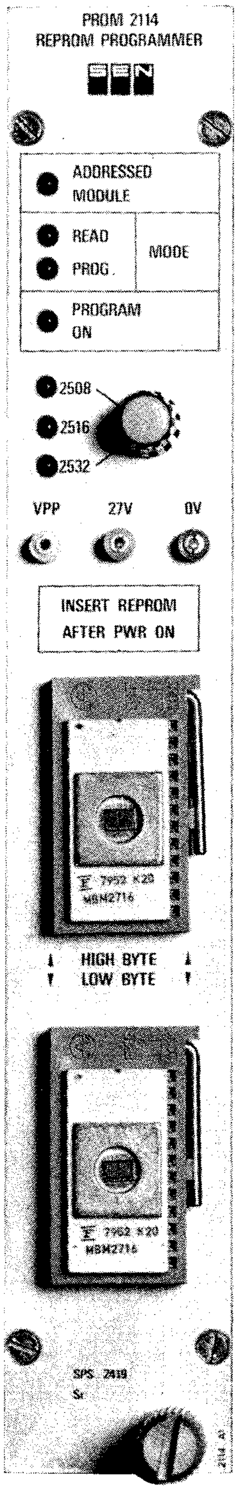

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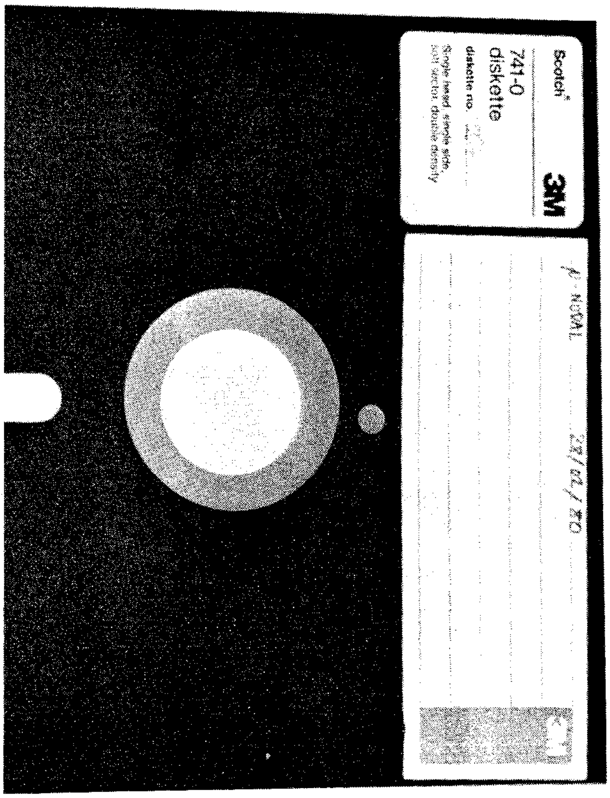

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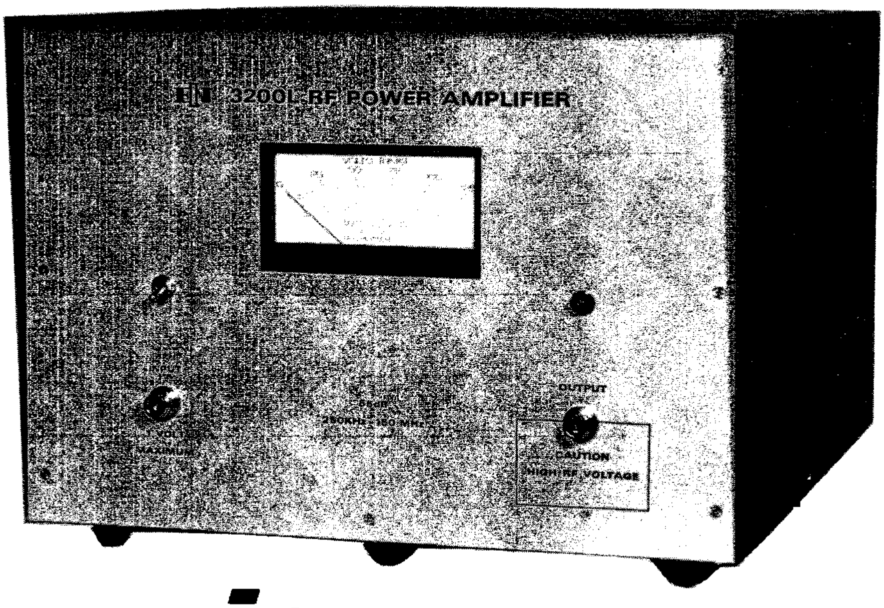
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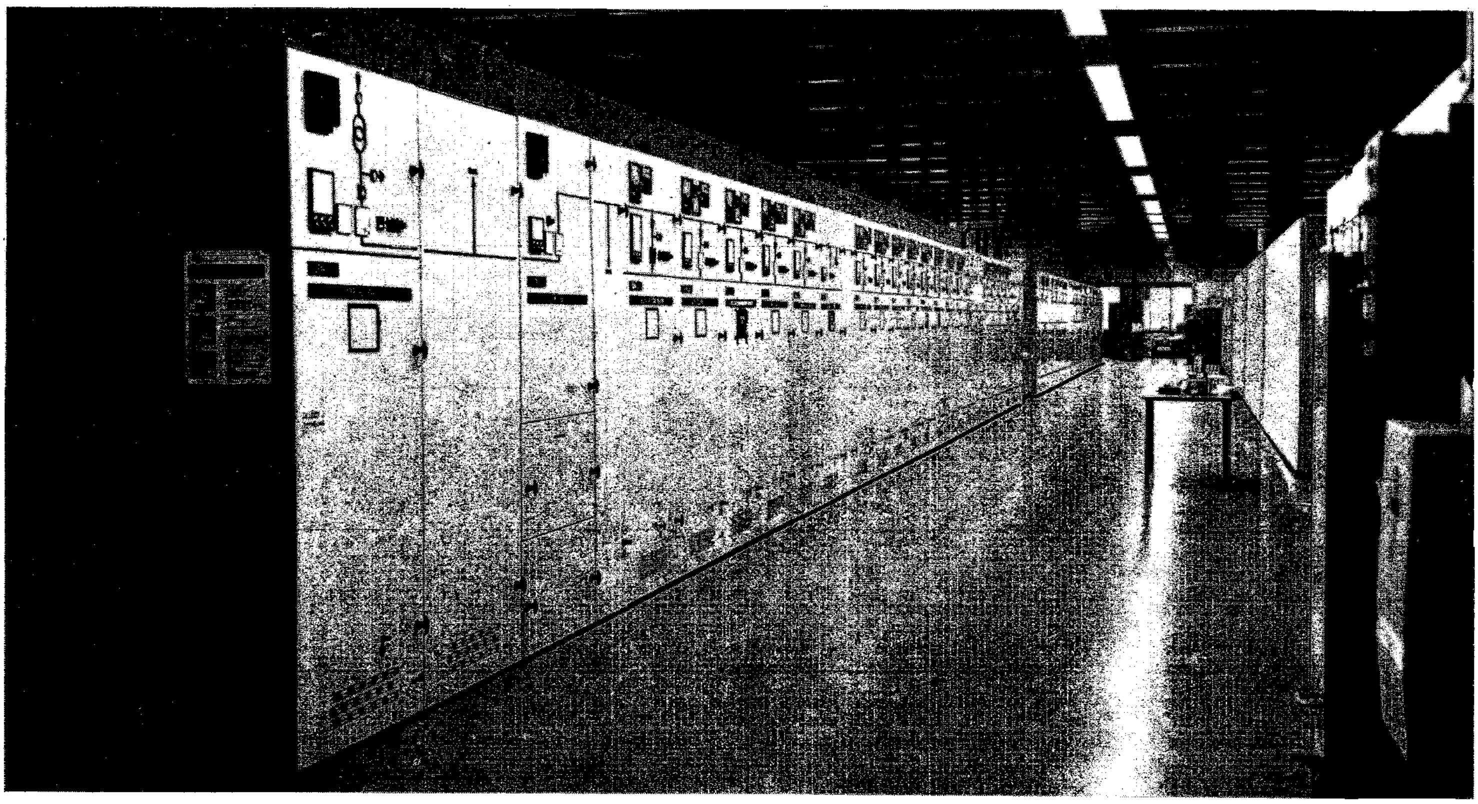

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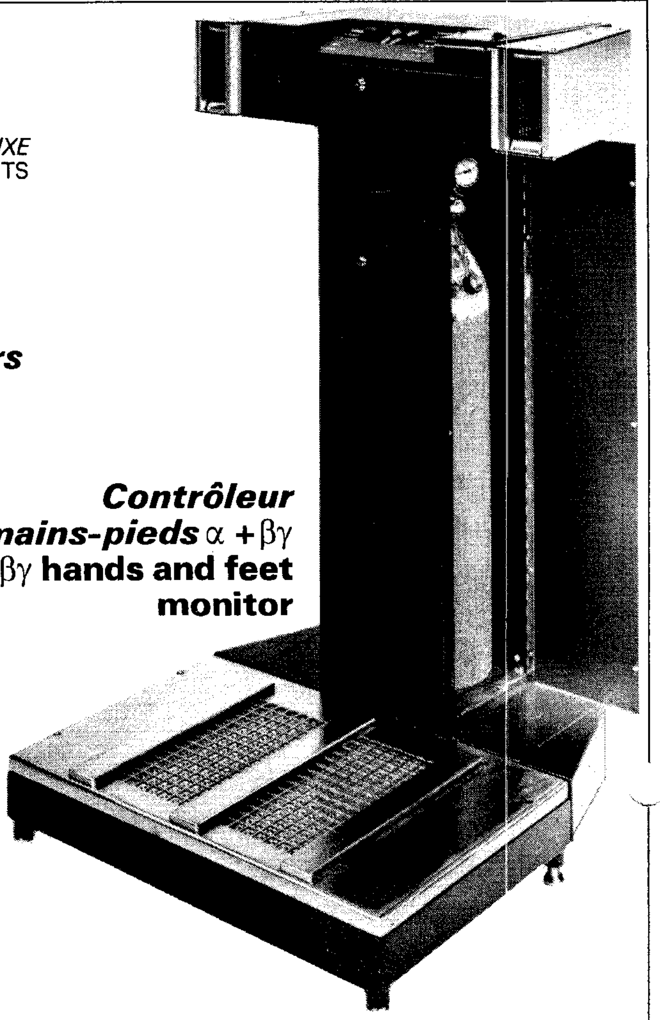

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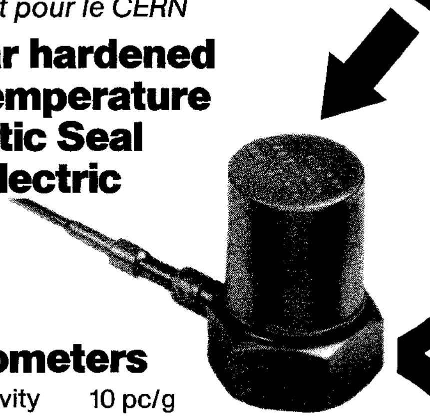

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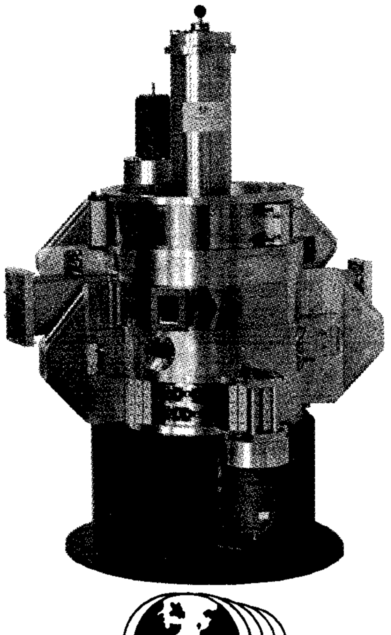

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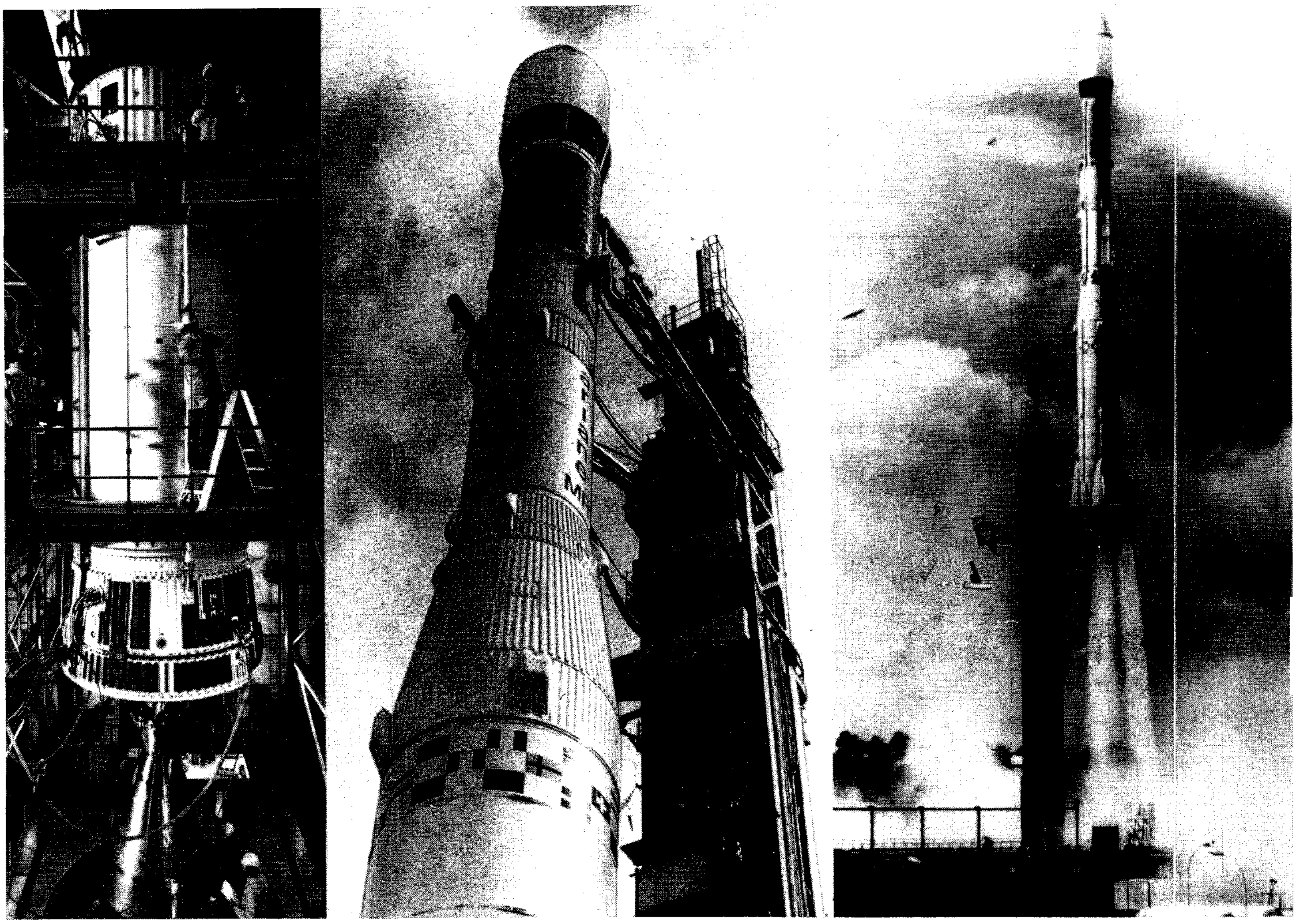

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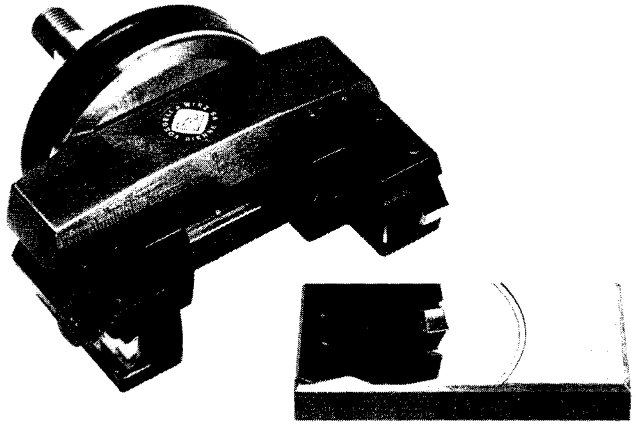

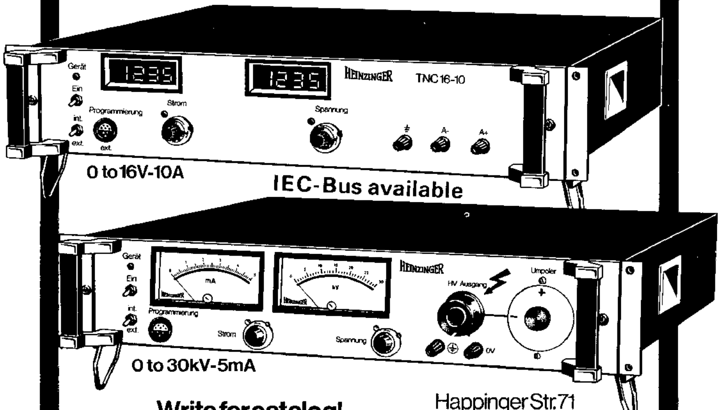

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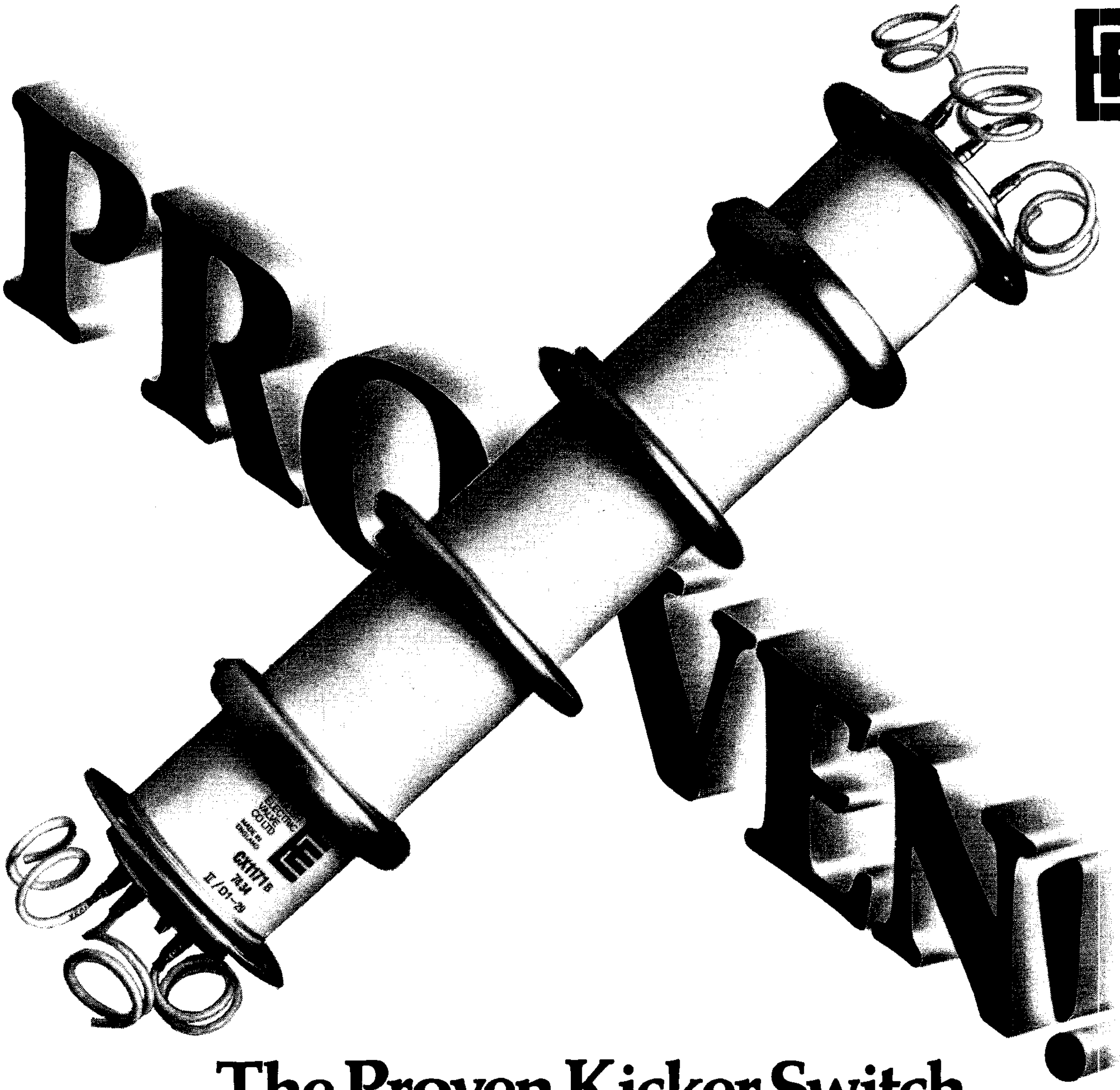
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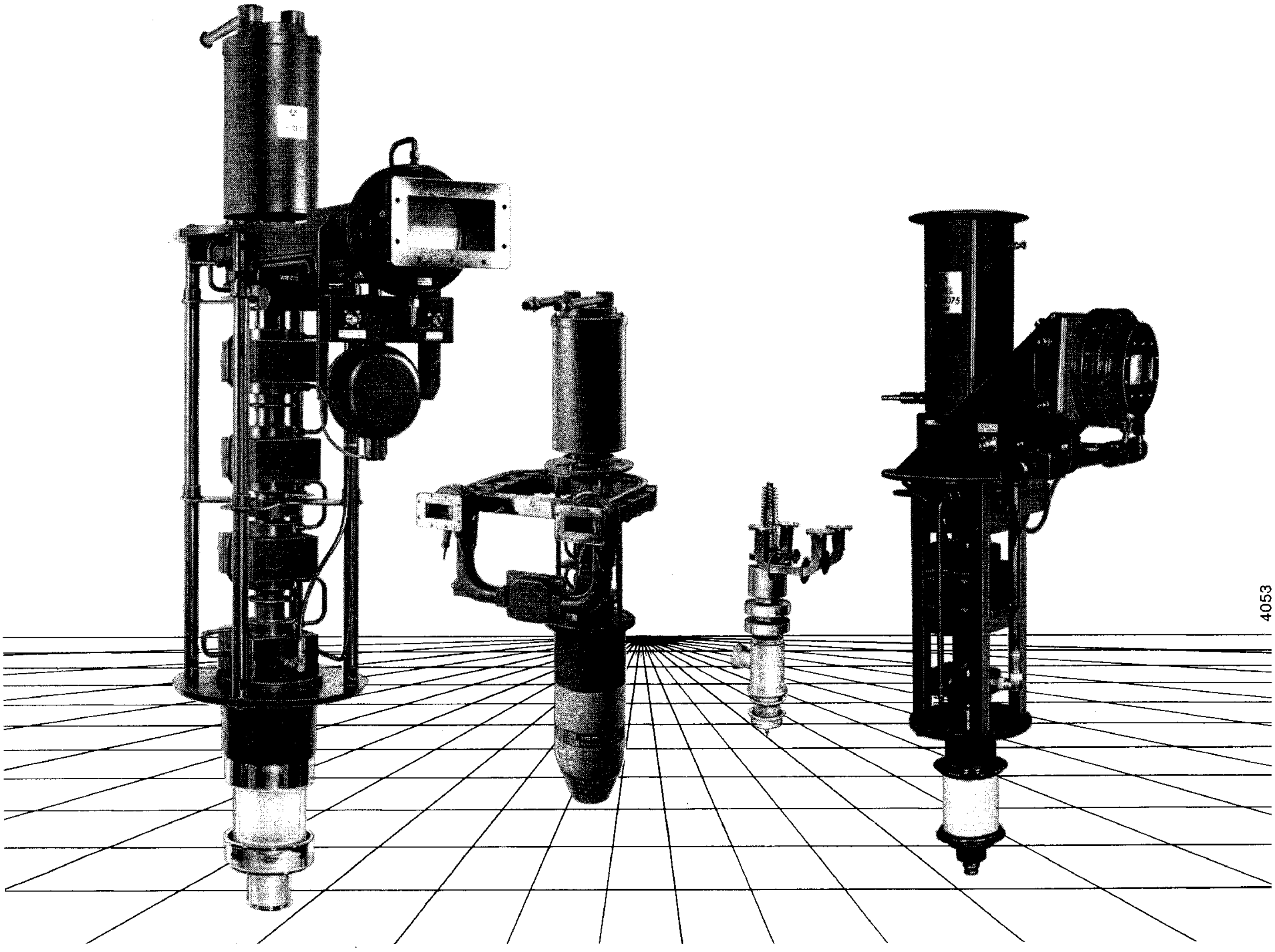
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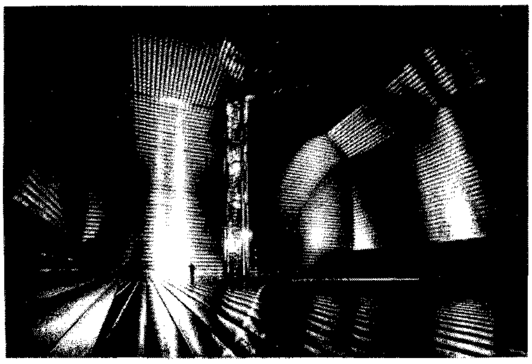

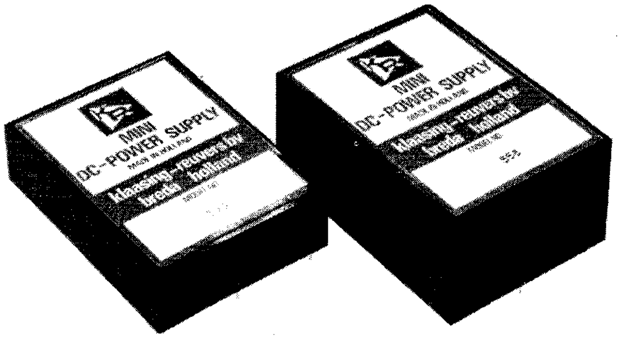
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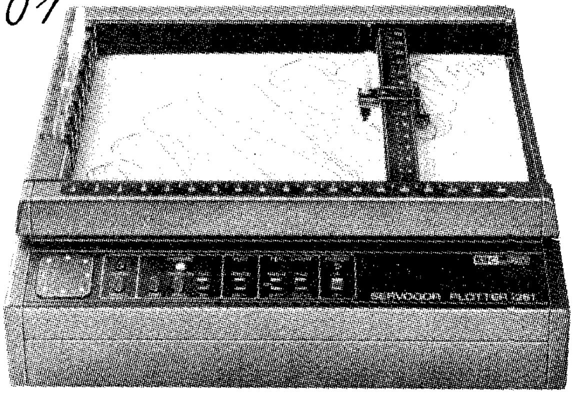
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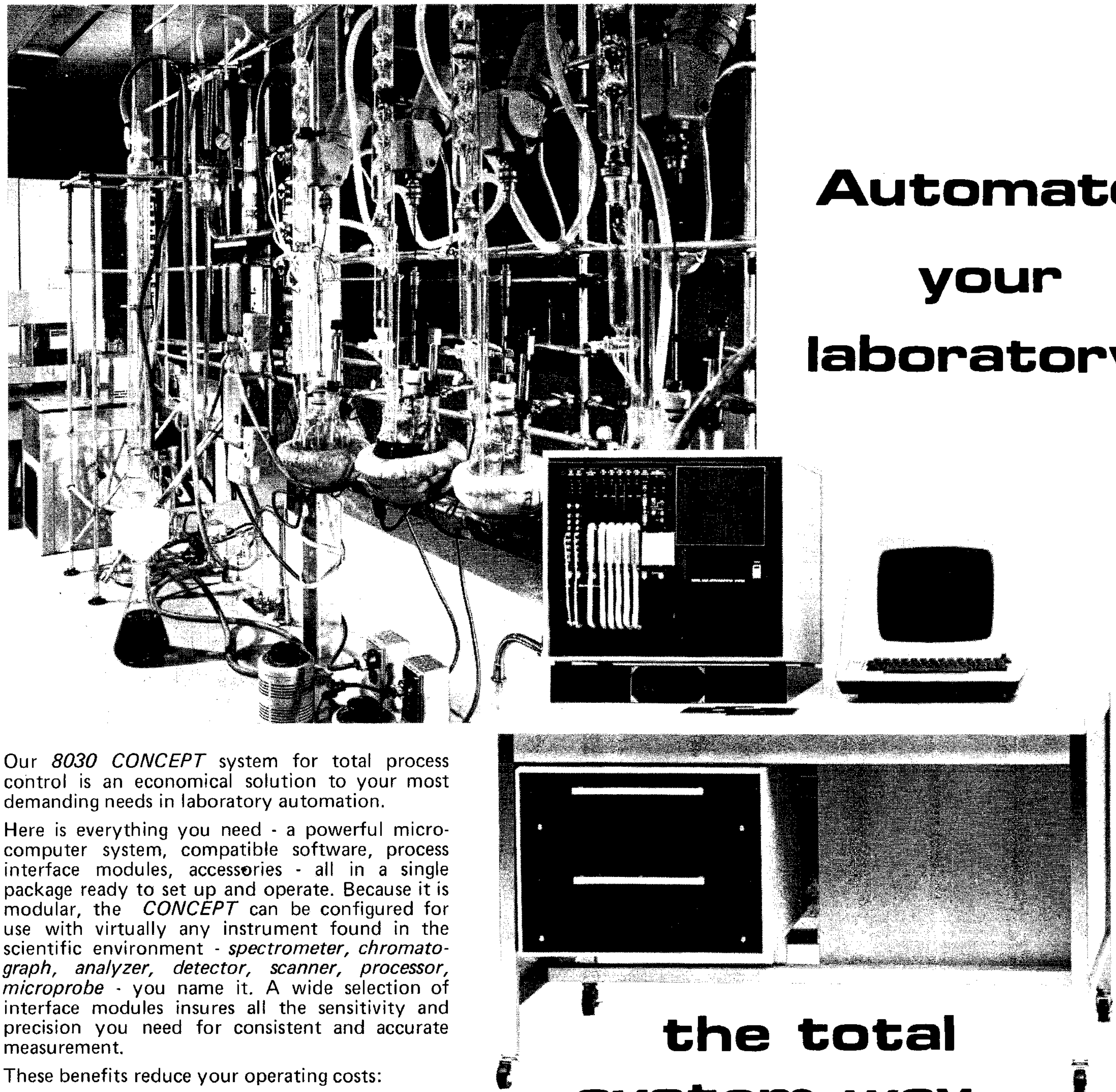

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Dept. CC120 * 6 Chemin de Tavernay * 1218 Geneva, Switzerland * Tel. (022) 98 44 45 * Telex 28 9622
KineticSystems Corporation * 11 Maryknoll Drive * Lockport, Illinois 60441 * Tel. 815 838 0005 * TWX 910 638 2831

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ANTEL

Représentation générale pour la Suisse

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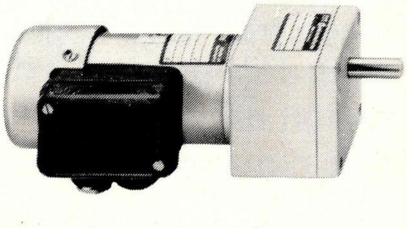
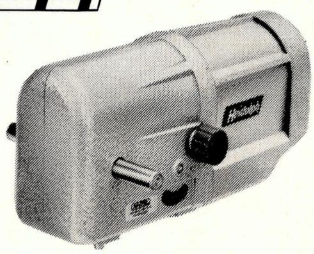
dunkermotoren



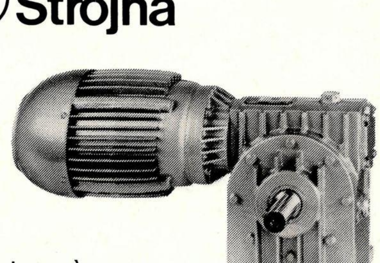
Réducteurs à engrenages, à vis sans fin et planétaires. Couples jusqu'à 2400 Ncm
Moteurs triphasés, monophasés, synchrones et à courant continu jusqu'à 80 watt
Partiellement **du stock**

Heidolph



Variateurs de vitesse mécanique. Couples nominales de 2,5 Ncm à 4000 Ncm. Gamme de vitesses de 0,003 min^{-1} à 2000 min^{-1}.
Gamme de réglage 1:10.
Partiellement **du stock**

Strojna



Réducteurs à engrenages ou à vis sans fin avec pied ou flasque équipés de moteurs triphasés I.E.C., puissances de 0,18–4 kW, possibilités de réduction i = 6,26 à 99,75.
Partiellement **du stock**

ANTEL
Antriebselemente AG
CH-8055 Zürich
Birmensdorferstrasse 470
Tel. 01 35 38 50 Telex 54 506 tzco

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protection... as well as high voltage for wire chambers— NEW 7 KV PLUG-IN POD

The fine, fragile wires of proportional or drift chambers can be snapped by an arc within the detector. Conventional protection circuits, such as current-limiting, are too slow to protect a chamber against an arc. Even a fast current trip ($<100\ \mu$sec) is inadequate if long high-voltage cables are used.

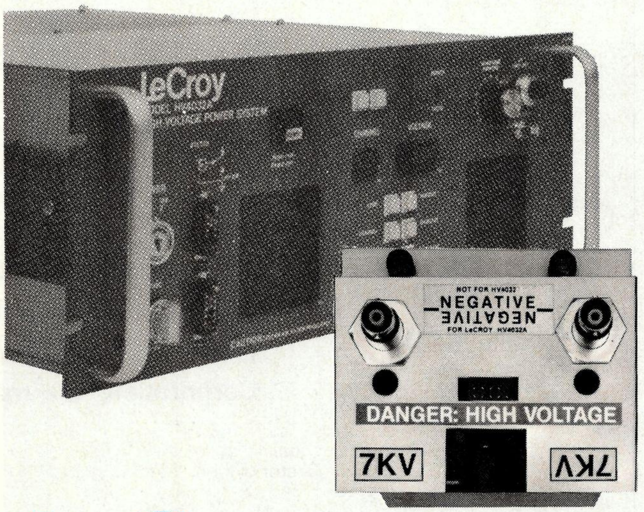
LeCroy's new 7 KV high-voltage system plug-in provides a longer life for your chamber wires by combining a fast current trip ($<50\ \mu$sec) with a crowbar circuit which clamps the output to ground through a resistor, dissipating the stored energy in the supply rather than in the chamber.

LeCroy's Model HV4032A High-Voltage System has been in the field for several years with plug-in 3.3 KV modules. The 7 KV plug-in may be used in the HV4032A/M mainframe and even mixed with positive and/or negative 3.3 KV plug-ins.

Consider these advantages:

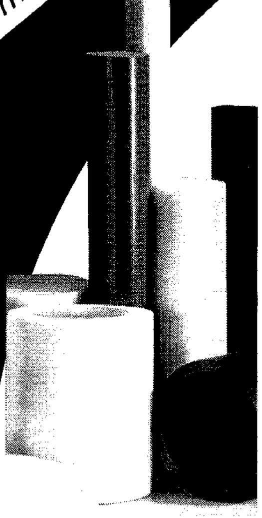
- **± 7 KV, up to 500 μA**
- **Manual, CAMAC, or TTY control**
- **Remote current and voltage monitoring**
- **Progammable in 2-volt steps**
- **16 channels per mainframe**
- **Remarkably low cost**

For more information on the new 7 KV plug-in, or any other LeCroy high-voltage distribution systems, contact your local LeCroy representative.



LeCroy

LeCroy Research Systems Corp., 700 S. Main St., Spring Valley, N.Y. 10977, (914) 425-2000, TWX 710-577-2832. Far West Office: Palo Alto, California, (415) 856-1806. International Offices: Geneva, Switzerland, (022) 98 97 97; Heidelberg, W. Germany, (06221) 28192; Orsay, France, (6) 907.38.97; Botley, Oxford, England, 865 72 72 75; Toyo Corp., Tokyo, Japan, (279) 0771.



Technique des matières plastiques

Semi-produits en matières plastiques

Notre vaste stock comprend:

- jets ronds – tubes – plaques – feuilles et profils en
- PTFE-Lubriflon® – PTFCE-Voltalef® – PVDF – PA-Ertalon® – POM-Ertacétal® – PETP-Ertalyte® – PUR-Vulkollan – PVC dur – PE-Polyéthylène – RCH 1000 – PP-Polypropylène – PC-Polycarbonate – PMMA - Verre acrylique

Vos avantages:

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- la bonne qualité dans la dimension exacte
- découpage et fraisage jusqu'à la dimension finale
- de stock
- à emporter

Nous manufacturons également des pièces finies injectées ou par enlèvement de copeaux, en toutes matières synthétiques.

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Votre partenaire dans tous les cas

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range of **inexpensive** scintillating materials

Exists in sheets and thick blocks

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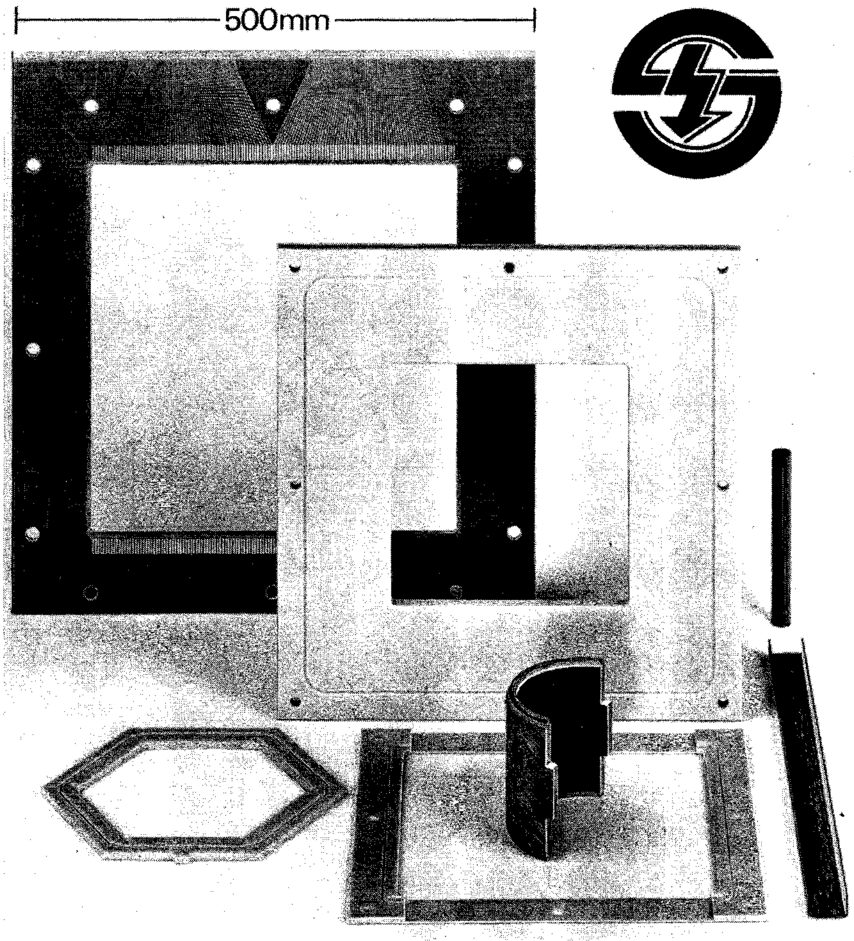
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