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Contents

Cover photograph: High level descent as VIPs view the PETRA installations at DESY following the official inauguration ceremony on 26 April. From top to bottom, Federal German Research Minister Volker Hauff, DESY Director Herwig Schopper and German Bundespräsident Walter Scheel. (Photo DESY)

Inauguration of PETRA

Amid pomp and pride, Europe's newest high energy machine was officially inaugurated at DESY, Hamburg, on 26 April, when German Bundespräsident Walter Scheel handed over the PETRA electron-positron storage ring to the scientific community.

The ceremony was attended by epresentatives of the PETRA users from all over the world, and DESY Director Herwig Schopper, introducing the proceedings, emphasized how the new machine already caters for a large international community of physicists.

Federal German Research Minister Volker Hauff pointed out how the 2.3 km circumference machine had been completed in record time, with just 2 1/2 years separating groundbreaking and the storage of the first beams.

Jean Teillac, President of CERN Council, spoke of the present harmony and status of European high energy physics resulting from 25 years' activities at CERN and the npressive progress at DESY.

In an articulate address, EPS President Antonino Zichichi underlined man's constant struggle to understand the world around him, and hoped that the esoteric description we now have of the structure of matter would one day be comprehensible to everyone.

Behind the glamour and the lights, PETRA had been running for the past few days at 13.7 GeV per beam and the first hadronic reactions at this energy monitored. This was its first experimental run with 32 r.f. cavities in action, and the remaining 32 cavities required to attain maximum beam energy of 19 GeV per beam are scheduled to be installed later this year.

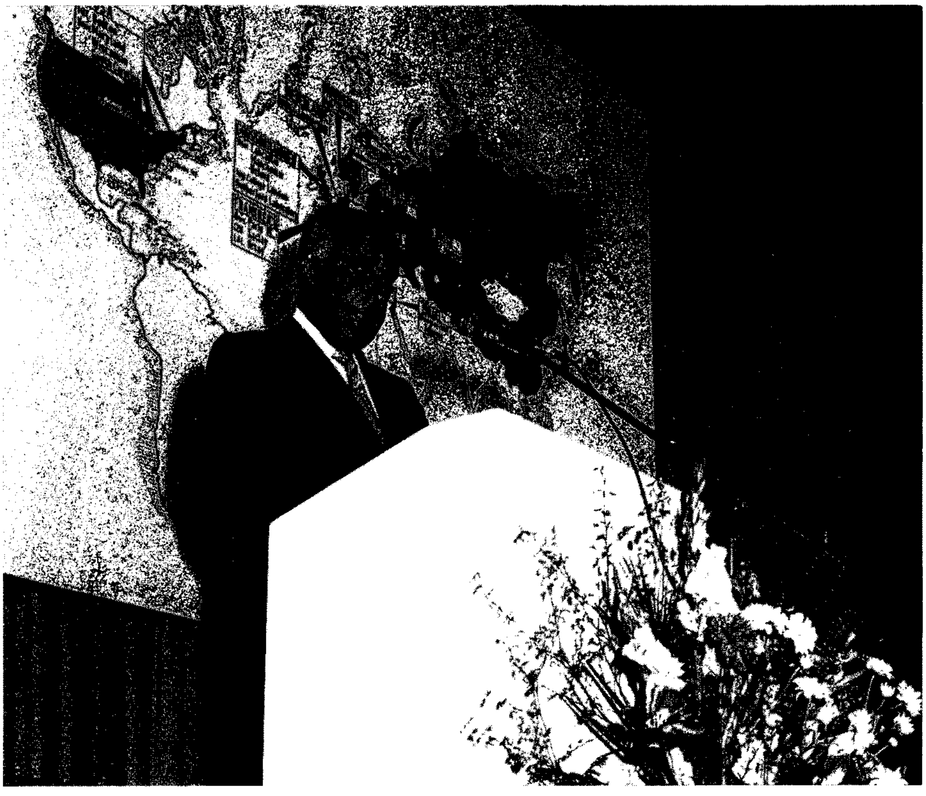
Beam luminosity is still far from the design figure of an average 10^{31} per cm^2 per s, but steady progress is being made with beam handling techniques and people are confident that this figure is within reach. Present luminosities are around the 5×10^{29} mark.

Progress depends on taming the optics required to concentrate the beam in the collision areas, but luminosity could be given another boost through a plan to install 'mini-beta' quadrupoles to squeeze the beam even further. While the normal low-beta quadrupoles are several metres from the interaction regions, additional magnets could be placed right up against the detectors.

Even with only half the r.f. cavities installed, the present collision energies of up to 30 GeV could be within the realm of hidden 'top' (or whatever a sixth quark might be called), where a new heavy quark and its antiquark could form bound states like the psions and the upsilons seen at lower energies. In the few events seen so far at 27.4 GeV, no trace of new quark flavours has been seen, but these are early days.

Apart from the detectors already assembled (PLUTO, CELLO, JADE, MARK-J and TASSO), there are plans to use two more intersection regions as yet unexploited. These regions have longer straight sections than those so far in use, and would be good for polarization experiments.

While experiments can plan for new heavy quarks, more leptons, Higgs particles, etc., there is always the chance that something completely new will be revealed, and in conclusion Research Minister Hauff wished the experimental teams that



Jean Teillac, President of CERN Council, speaks at the official inauguration of the PETRA electron-positron storage ring at DESY.

(Photo DESY)

additional stroke of luck often necessary for scientific breakthroughs.

With the PEP storage ring at Stanford delayed (see page 150), Europe seems for the moment to have stolen the electron-positron thunder. However PEP will inject at higher energy and there still could be a close race.

PLUTO results

As the English edition of our May issue was to going to press, we heard that an experiment with the PLUTO detector at PETRA had seen signs of the production of three gluons in upsilon decays, and the story was printed on page 108. We later learned that the data was collected last year when PLUTO was still working with the DORIS storage ring. Although there was time to correct the story in the French edition, the English edition had already been printed in Europe and was distributed with a correction slip. (A correction was printed as stop press in the North American edition.) Later it became clear that the evidence is inconclusive, as other mechanisms can reproduce the three-jet pattern seen in the upsilon decays, and cannot yet be taken as confirmation of the gluon picture of inter-quark forces.

Low energy antiprotons

The development of beam cooling techniques has opened the door to high energy proton-antiproton colliding beam techniques which only a few years ago would have seemed impossible. But as demonstrated by a recent meeting in Karlsruhe at which more than one hundred physicists from all over Europe participated, interest is also growing in the possibility of exploiting cooling techniques to produce low energy antiproton beams over a thousand times more intense than existing sources. At the Karlsruhe meeting, proposals for these sources were described and the physics possibilities outlined.

Nucleon-nucleon scattering at low energies has been studied in detail over the years, but data on the low-energy nucleon-antinucleon channel is relatively sketchy. Strong interactions arise in both nucleon-nucleon and nucleon-antinucleon channels through meson exchanges, and the contributions in the two channels are linked by G-parity. However for the nucleon-antinucleon channel, an additional 'annihilation' contribution comes from the creation and annihilation of quark pairs, and the re-arrangement of the residual quarks.

At low energies, nucleon-antinucleon interactions are dominated by these annihilation processes where the baryons disappear and produce, for example, mesons or electron-positron pairs. These annihilation reactions occur when the particle and antiparticle are very close to each other and new results could reveal more of the internal structure of the nucleon. The study of electron-positron production, for example, could help determine the distribution of charges and currents caused by the movement of the quarks inside the nucleon.

At low energies, the variety of possible annihilation reactions is limited, so that the number of secondary particles is manageable, and they are well separated. In this way few would avoid detection and the events would be completely defined. Study of these processes could provide deep insight into the structure of nucleons and the dynamics of quark interactions.

At low energies, the nucleon antinucleon system provides a bridge between the realms of nuclear physics — often (but not always) non-relativistic with nucleons being viewed as elementary particles — and quark physics — a relativistic picture of composite nucleons.

Both the quark and the nuclear physics pictures predict as yet unseen states in the nucleon-antinucleon channel. Nuclear physics says that narrow states should be formed both above and below the nucleon-antinucleon threshold — and the region just above this threshold has yet to be explored.

The quark model says that as well as the familiar hadrons, other state containing more quarks are possible, and should turn up in experiments (see October 1978 issue, page 349). Signs of these so-called 'baryonium' states have been seen, but more data is required before a clear picture can emerge.

Studies using low energy antiprotons thus could throw new light on nuclear potentials and quark models and help link these two complementary pictures of particle behaviour.

The scattering experiments of high energy physics have frequently been compared to trying to understand the intricate mechanism of a watch by smashing two watches together and examining the fragments — hardly the best way of learning about watches, but if the watches are very difficult to prise open, there is little choice.

With strong interactions there is another option open through the study of special states, such as the so-called 'exotic atoms', in which the orbital electrons of everyday atoms are replaced by heavier negatively-charged particles such as pions, antiprotons or hyperons.

Atoms are held together by electromagnetic forces, and their electromagnetic properties can be accurately predicted. However in exotic atoms, the artificially-introduced negative particles are much heavier than their electron counterparts and pass close to the nuclei, where they interact through the strong force. This additional effect shifts the properties of the atom from the pure electromagnetic prediction, and provides a means of measuring strong interactions.

In contrast with many high energy scattering experiments, these delicate effects can be followed in detail, and enable the intricate mechanisms of strong interactions to be examined directly. While this approach potentially has a lot to offer, the required states are nevertheless difficult to obtain and observe in quantity, and precision measurements are difficult.

However with stored antiproton beams available thanks to cooling techniques, the intensity of particles with well-defined momentum could be increased by a factor of at least a thousand, promising a plentiful supply of exotic states.

The study of exotic atoms has so far been restricted to atoms at rest, but with new sources of low-energy antiprotons, light antiprotonic atoms could be produced in flight, so that Doppler shifts could be exploited to make more precise measurements.

Through charge exchange, an intense source of antiprotons could also furnish a useful supply of antineutrons. These particles could also be used to investigate possible new resonances and bound states without the complications of electromagnetic effects and with simplified isospin structure, so providing a very clean source of low energy data.

Another possibility is to collide beams of low energy protons and antiprotons. This opens the door to charm spectroscopy, but would be able to examine all kinds of mesons, in contrast with the traditional electron-positron approach which can only directly produce the vector (spin one, negative parity) particles coupled to the photon.

While big machines strain to attain higher energy domains, our knowledge of particle interactions at low energies around the nucleon-antinucleon threshold still has a lot of gaps, which need to be filled. This new information would complement that from higher energy projects.

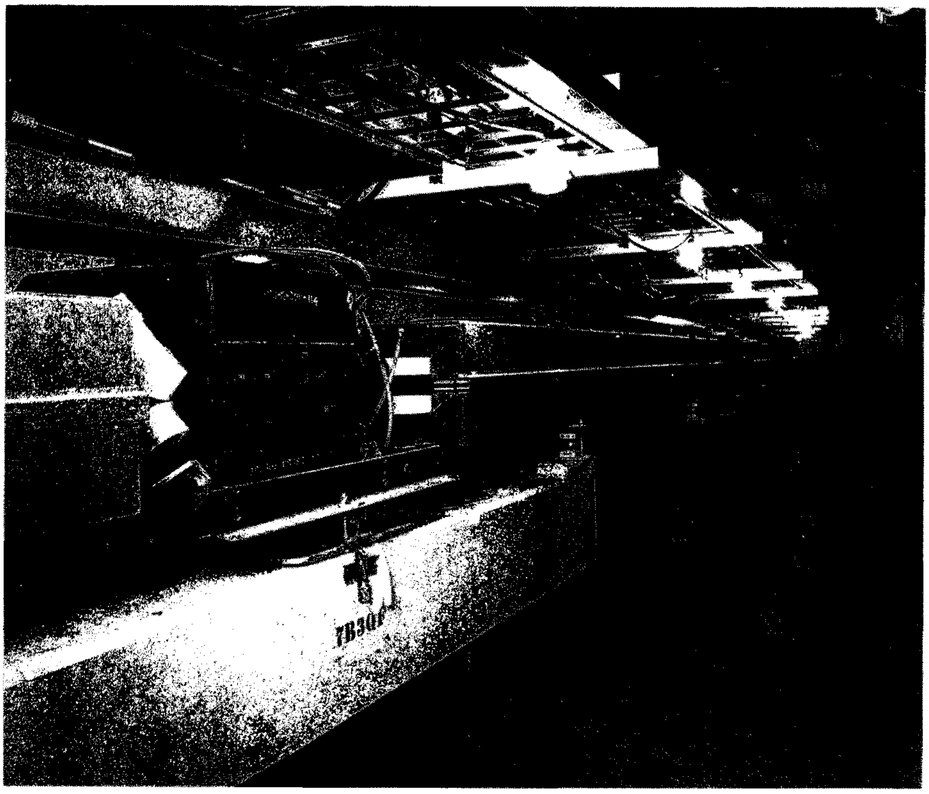
Informal discussions at the recent Karlsruhe Workshop on Physics with Cooled Low Energy Antiprotons. Left to right, A. Citron of Karlsruhe, G. Plass of CERN and L. Hoffmann of CERN.

(Photo Karlsruhe)

Around the Laboratories

A sector of the Berkeley-Stanford 18 GeV electron-positron storage ring, PEP. Completion of the ring is now expected in November.

(Photo SLAC)



STANFORD
PEP beams scheduled for November

The construction of the buildings for the Berkeley-Stanford 18 GeV electron-positron storage ring, PEP, continues to feel the effect of the very wet Californian winter of 1977–78. The first major contractor for conventional construction (concerned with the tunnelling and experimental halls) has been months late in the completion of buildings. Because of the tightness of the overall schedule, this delay is spreading throughout the rest of the construction.

The support contractor, the mechanical and electrical contractors and the contractors installing technical components are all therefore late and, although some time has been made up, it now does not seem possible to have all the installation complete by the target date of 1 October. The technical components will be ready for installation well in advance but, because only limited amounts of installation work can go on at the same place at the same time, not all the ring will be completed by October.

The plan now is to have a considerable fraction of the ring ready to receive beam when the SLAC linac comes back on early in October after its scheduled summer shutdown. In this way beam can be brought into the ring and the whole injection system can be checked as well as segments of each subsystem of the storage ring. Power supplies, circuits and general systems can then be tested and any necessary debugging can be done.

The new schedule calls for completion of all installation by 15 November. With good luck there could be some improvement on that date, but good luck with conventional construction contractors has not been thick on the ground and it seems realistic to expect circulating beam in PEP in late November.

Plans and schedules for installation of experiments are unchanged, though the later availability of the halls puts a tight squeeze on the experimenters to be finished on the new schedule.

FERMILAB
Structure function of pions

The quark picture provides a beautifully simple classification of the huge number of strongly interacting particles which have been discovered in high energy collisions. So far all observed hadrons can be explained as either baryons composed of three quarks or mesons composed of quark-antiquark pairs. Although five species, or flavours, of quarks are needed to compose all the known hadrons, the most common particles (the proton, neutron and pion) require only two flavours, usually named up (u) and down (d). These quarks carry charges which are a fraction of the charge on the electron as follows, $u = +2/3$ and $d = -1/3$. Nucleons and charged pions have the simple structure: $p = uud$, $n = ddu$, $\pi^+ = u\bar{d}$, and $\pi^- = \bar{u}d$.

In most interactions the antiquark in the pion does not betray its existence in a striking manner. However quarks can annihilate electromagnetically with antiquarks to form virtual photons, which then can create a pair of muons. This process, first proposed by Drell and Yan, is completely analogous to the production of muon pairs in electron-positron annihilations. The cross-section is proportional to the square of the quark charge and therefore a large charge asymmetry is predicted in the π^+ versus π^- induced muon production.

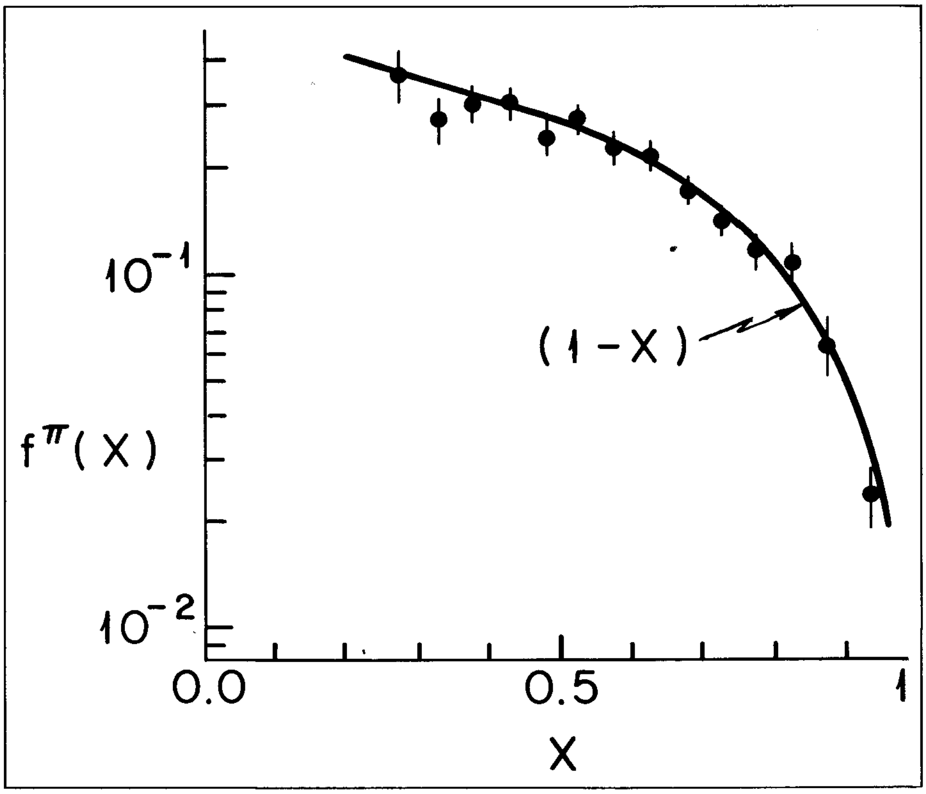
The most dramatic prediction is very simple — pions contain antiquarks and protons do not, so pions should be much more effective than protons in producing muon pairs off nuclear targets. Production of muon pairs by protons is not exactly zero because all hadrons are surrounded by a cloud, or sea, of quark–antiquark pairs. However these sea quarks have very small probabilities of having sufficient momenta to produce high-mass muon-pairs.

In a recent experiment at Fermilab, a group from Chicago and Princeton Universities found dramatic differences in the effectiveness of pion and proton beams in producing muon pairs. The results are beautifully explained by the existence of an antiquark in the pion but not in the proton. They demonstrate that the quarks, and more importantly, the antiquarks, have distinct dynamical properties and hence are more than just elegant mathematical structures expressing the symmetries of fundamental interactions.

The experiment used the large Chicago cyclotron magnet spectrometer to measure the muons. Beams of pions and protons interacted in a target which was followed by a 3 m iron shield to absorb all particles except muons. The directions and momenta of the muons penetrating the shield were measured by many planes of proportional and spark chambers.

In the course of the experiment, the mass spectrum of muon pairs was measured over many orders of magnitude of cross-section. At masses below 4 GeV, other processes, including strong production of vector mesons, can contribute and to test the quark picture the experimenters studied the mass interval from 4 to 8.5 GeV, where no vector mesons have been found. In this region the magnitude of the cross-section is consistent with that for quark-antiquark annihilation.

Graph of the pion structure function obtained from a Chicago / Princeton experiment at Fermilab. Their results are in excellent agreement with predictions of the quark model.



For much of the experiment a carbon target was used, which contains equal numbers of neutrons and protons, and hence equal numbers of u and d quarks. Therefore, the cross-sections for muon-pair production by positive pions ($d\bar{d}$ annihilation) should be a quarter of that by negative pions ($u\bar{u}$ annihilation). The experimenters found a large asymmetry consistent with the predicted value.

In comparing pion and proton beams, the Chicago Princeton data were compared with the proton data of the Columbia / Fermilab / Stony Brook group. At pair masses around 10 GeV, pions were found to be a hundred times more effective than protons in making muons! Other more subtle features, such as the angular distribution of the muons in the rest frame of the virtual photon, also agree beautifully with the picture of quark-antiquark annihilation.

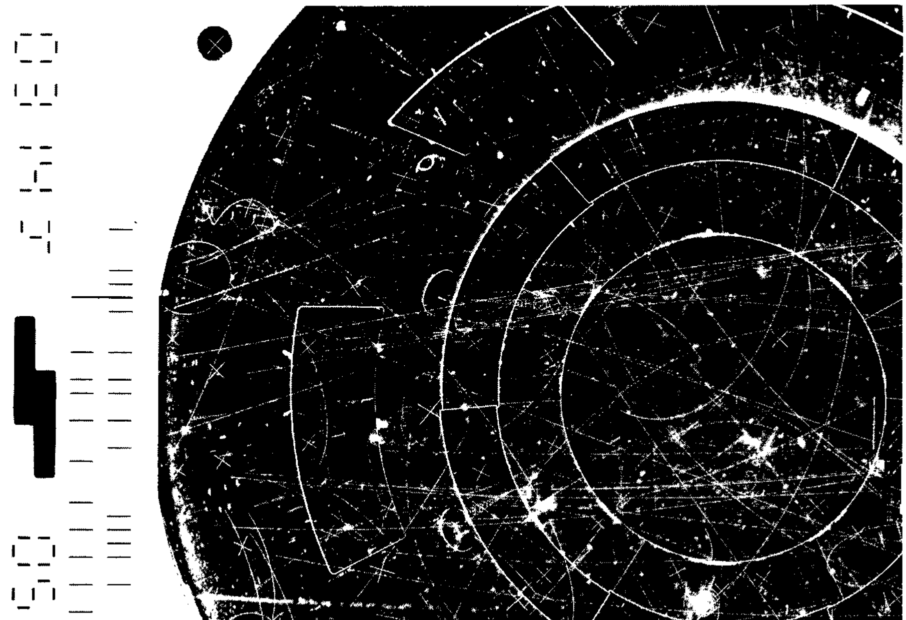
With all the conclusive evidence that such annihilation is responsible, the muon-pair process can actually be used to X-ray the pion, or more precisely, to measure the momentum distribution of the quarks and antiquarks inside it. The proton's quark structure has been determined more directly by deep inelastic lepton-proton scattering, in which a virtual photon scatters off the quarks in the target proton. Measuring the momentum distribution of the scattered lepton then determines the quark momentum distribution, or structure function. Because the pion lives only 10^{-8} s, similar measurements for the pion are not possible.

Observation of a charmed lambda in emulsions at the SPS. The initial interaction of a neutrino, which produces the charmed lambda, takes place in the emulsion at point A. At point B the lambda decays giving three charged tracks which are subsequently picked up in the BEBC photograph below.

The Chicago / Princeton data indicate that the structure of the pion is very different to that of the proton; the quarks in the pion have a probability of about $(1 - x)$ of carrying a fraction x of the pion's momentum, whereas in the proton the structure function is approximately $(1 - x)^3$. Hence the pion's quarks are much more broadly distributed in their momenta. This is consistent with fewer valence quarks sharing the momentum in the pion.

In calculating how much of the pion's momentum is carried by the quarks, the experimenters find that 40 per cent is missing! A similar result pertains to the proton, and is ascribed to the neutral quanta (gluons) of the strong interaction. The absolute magnitude of the muon-pair cross-section gives a final important result: a further property of quarks, known as colour, suppresses the predicted muon-pair cross-section by a factor of three from what it would be if colour is not taken into account. The Chicago / Princeton measurements are consistent with this suppression and provide a confirmation of this somewhat elusive concept.

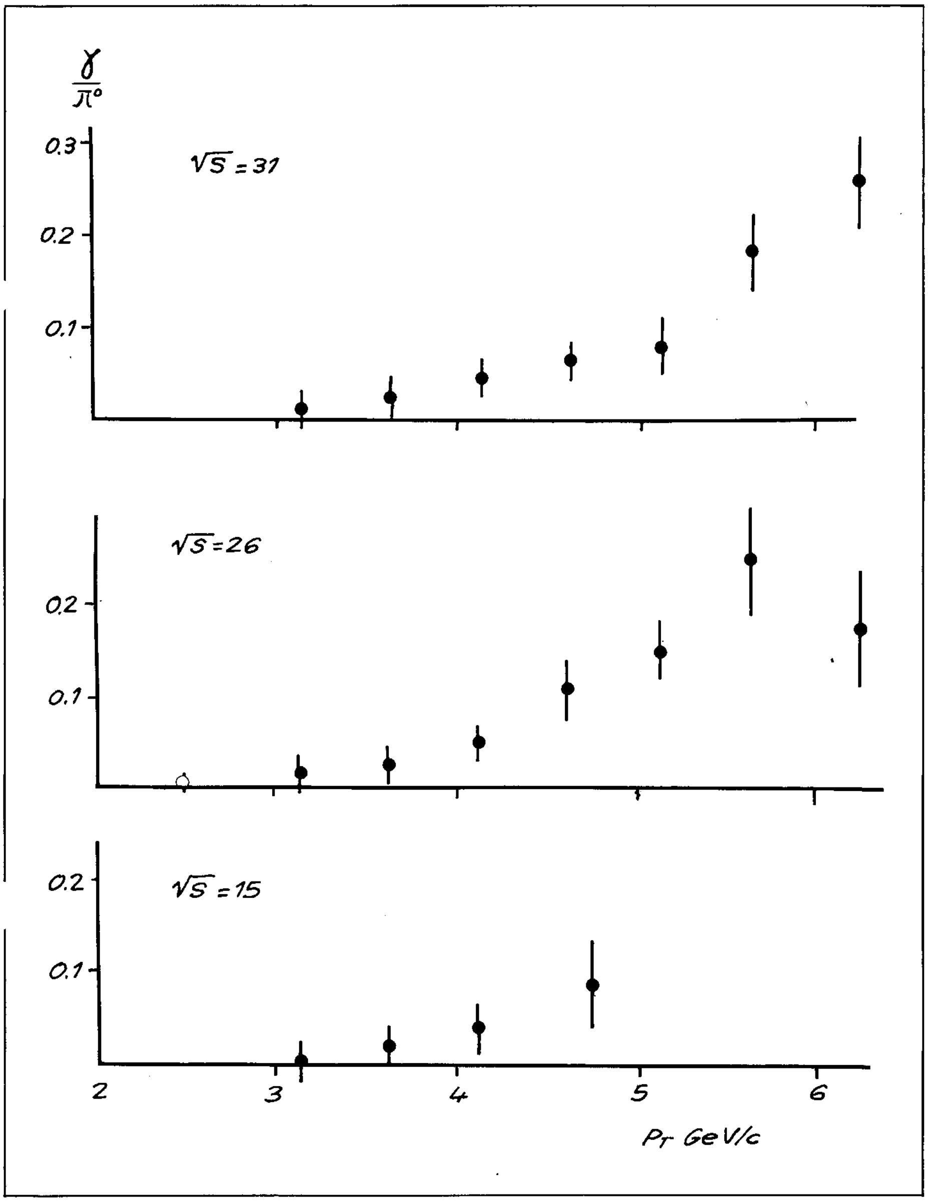
The demonstration by this experiment and others that the Drell-Yan process gives a very accurate description of quark-antiquark annihilation has important engineering applications. The new proton-antiproton and proton-proton colliding beam machines being developed at CERN, Brookhaven and Fermilab depend on quark-antiquark annihilation to produce the very massive (about 80 GeV) intermediate vector bosons of the weak interaction. The measurements show that feasible rates of production can be expected and the so far very successful theories will therefore soon be confronted with another test.



CERN
Some more charming results

Despite severe background problems and a struggle with poor emulsion quality, some more interesting results have emerged from the hybrid experiment on charmed particles carried out at the SPS by the Ankara / Brussels / CERN / Dublin /

Preliminary results from experiment R806 at the CERN ISR showing the ratio of the single direct photon yield to neutral pion production. The open circle at a transverse momentum of 2.5 GeV comes from an earlier run utilizing internally converted low mass electron pairs. The results show that above 3 GeV transverse momentum, the single photon contribution becomes increasingly evident.



/ UCL / Open University / Pisa / Rome / Turin collaboration. (Their first charmed particle event was reported in the March issue, page 17.)

They used an emulsion-bubble chamber-counter detection system to identify charmed hadrons and to obtain a value for the charmed particle lifetime. The fine detail which it is possible to extract from emulsions gave the lifetime from measurements of the short charmed particle track. The bubble chamber (BEBC) and counter combination, identified emerging particles in such a way as to point to the region of the emulsion where a candidate event had occurred. This avoided the near impossible task of scouring the full emulsion stack to find the short tracks of interest.

Four charmed particle events have now been identified with the system exposed to the SPS neutrino beam, bringing the world total to five (including the first one seen at Fermilab — see December 1976 issue, page 427). Using measurements of track length, the lifetime of charmed hadrons is coming out at about 5×10^{-13} seconds which is as expected from present theoretical ideas.

One beautiful event has been fully identified as involving the production of a charmed lambda particle, which decays into a proton (seen via elastic proton-proton scattering in BEBC) a positive pion and a negative kaon (identified via a momentum measurement on its track in BEBC). The mass of the charmed lambda, deduced from these observations is about 2.3 GeV and its lifetime 7×10^{-13} s.

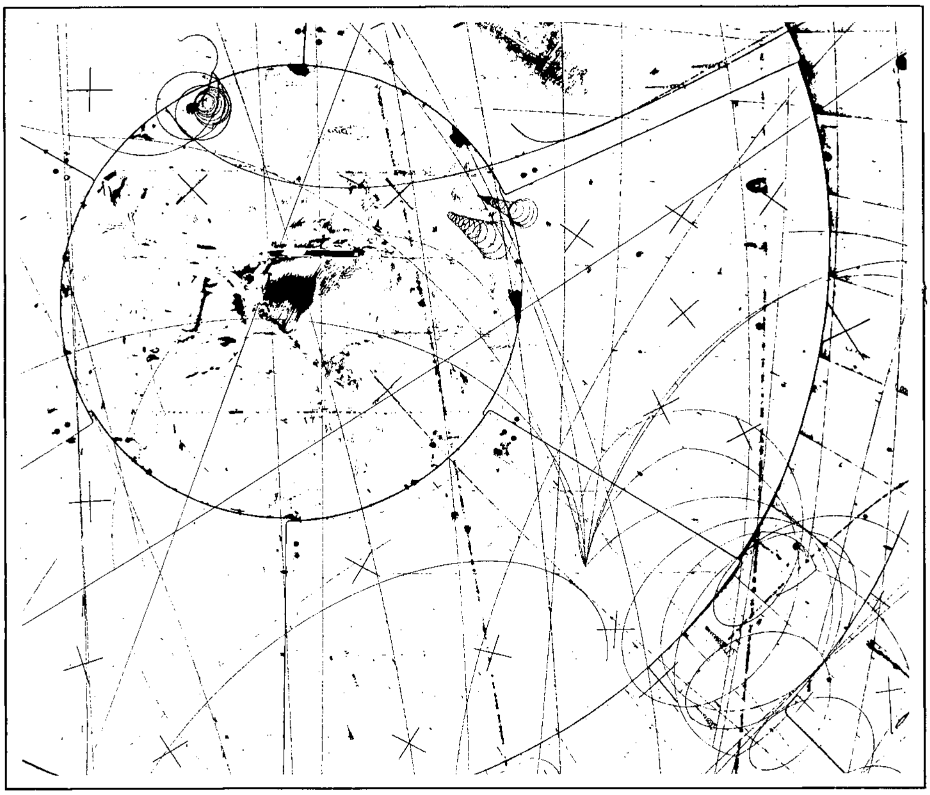
Direct single photons

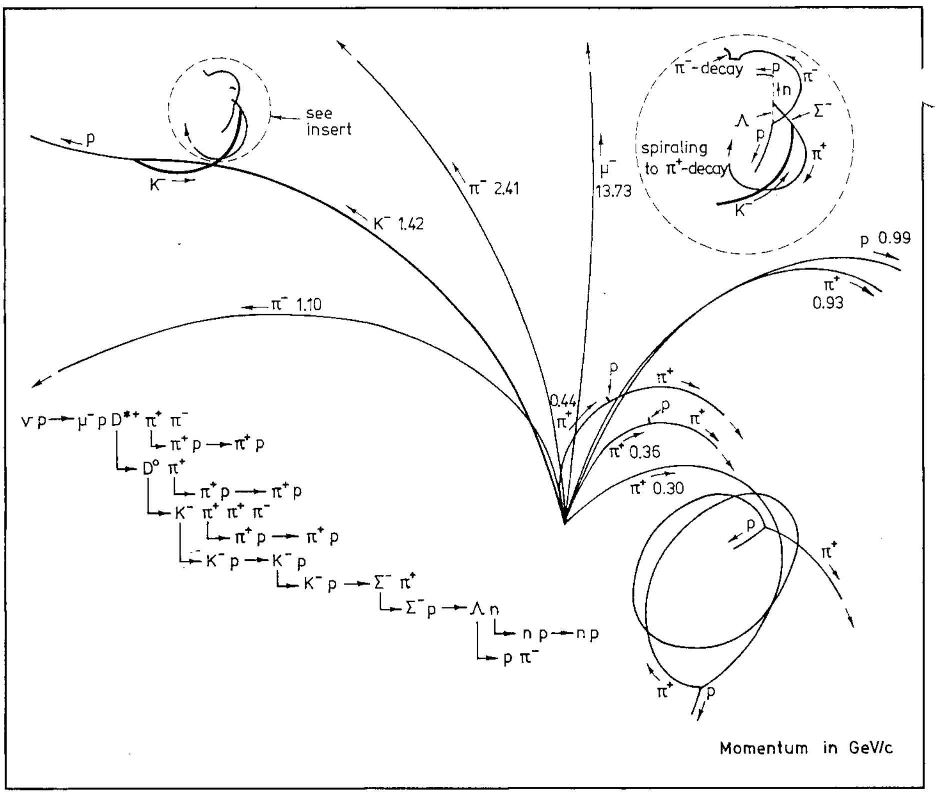
While we still have much to learn about the behaviour of quarks, they are nevertheless electrically-charged particles which like any others should give off electromagnetic radiation (photons) when disturbed. Tracking down this radiation in the debris of high energy collisions is not easy, but some results are now available from an Athens / Brookhaven / CERN / Syracuse collaboration working at the CERN Intersecting Storage Rings (ISR).

This experiment originally planned to study the production of electron-positron pairs and provided the first evidence seen at CERN for the production of upsilons (see January/February 1978 issue, page 15). The detector used lithium foil transition radiators to identify electrons and a liquid argon calorimeter to measure electron and photon energies.

By a simple rearrangement of the apparatus, the group was able to

The second example of the production of charmed mesons by a neutrino beam in the BEBC bubble chamber working at the CERN 400 GeV Super Proton Synchrotron in an experiment by an Aachen / Bonn / CERN / Munich / Oxford collaboration (the first example was published in our November 1978 edition, page 394). Energy-momentum conservation shows that there are no missing neutral particles to be taken into account. A charmed D^{*+} meson is produced which decays to give another charmed meson, this time the D^o. The K^- track which characterizes the D^o decay has 1.4 GeV momentum and normally would be too fast to be identified before it left the chamber, but by sheer good fortune the kaon hits a proton head on (see top left) and bounces back, eventually coming to rest. Then it undergoes a characteristic series of interactions (see insert) with the production of hyperons.





transfer its attention during a special run to the search for single photons. The electron detectors were removed and the calorimeter moved further away from the proton-proton collision region to improve the resolution of narrowly separated photon pairs coming from the decay of neutral pions or eta mesons.

Normally the photons seen in high energy collisions are the pairs from these meson decays, but the object of the search was to look for lone photons.

Although the mesons decay into pairs of photons, one or other of the photons might escape detection, or the photons might not be sufficiently separated for the pair to be resolved into two signals.

After a careful analysis to estimate the level of events which could simulate single photon production, the results show little evidence for single photons below 3 GeV transverse momentum. However above 3 GeV the single photon contribution becomes increasingly evident.

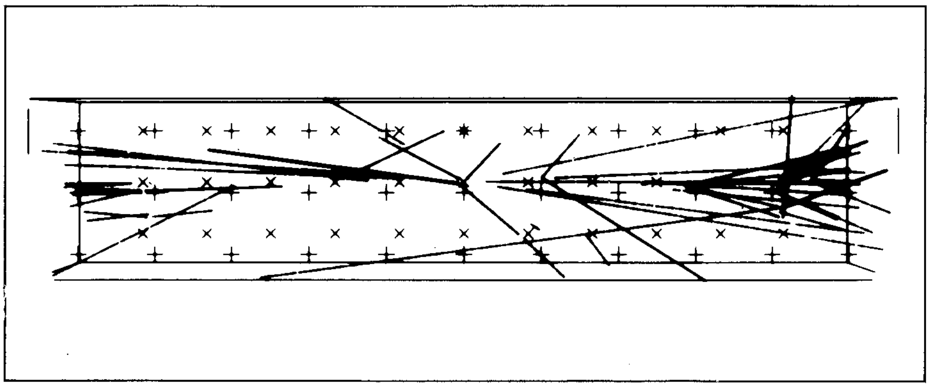
This initial evidence for the electromagnetic radiation of quarks needs to be confirmed, but will surely provide fuel for theorists eager to extend the applications of quantum chromodynamics.

Hunting the Centauro

Equipment is now being prepared for an experiment, codenamed UA5, by a Bonn / Brussels / Cambridge / Stockholm collaboration at the SPS proton-antiproton collider. When colliding beam experiments begin in 1981, in a relatively short time this experiment should be able to amass sufficient data to make a general survey of the behaviour of hadronic collisions at this new energy range.

While other experiments at the collider want to snare the elusive intermediate bosons of weak inter-

Computer simulation of a high multiplicity event in the streamer chamber being built by a Bonn / Brussels / Cambridge / Stockholm collaboration for an experiment at the SPS proton-antiproton collider. While such events would be bread-and-butter for this experiment, the team is hoping to glimpse the unexplained 'Centauro' events, seen so far only in cosmic ray experiments, with an abundance of charged particles, but a dearth of neutrals.



actions, the UA5 team hopes to photograph examples of the 'Centauro' events seen before only in high energy cosmic ray studies.

In these events (see September 1977 issue, page 289), extreme energy cosmic ray interactions in the upper atmosphere are seen to give unexpectedly large numbers of charged particles, but with little sign of any associated neutrals.

The production of about a hundred charged particles with few, if any, accompanying neutrals is totally unlike anything known at present accelerator energies. Extrapolation of familiar laboratory behaviour predicts a mean multiplicity of about 30 charged particles, and about half this number of neutrals.

With the SPS proton-antiproton project, laboratory energies will for the first time reach the range where Centauros could turn up, and physicists are agog to see whether this novel behaviour can be reproduced in the laboratory.

The cosmic ray studies indicate that Centauros could make up a few per cent of the total inelastic cross-section, and even with the reduced luminosities of initial collider operations, sufficient data in principle could be collected in a few days running at reasonable efficiency to turn up many examples of Centauro events. Even if none are found, this initial survey should be able to map the broad outlines of hadronic interactions in this new energy range.

To study the high energy collisions, the experiment will use two streamer chambers, each 6 m long, 1.25 m wide and 0.5 m high, one above and one below the SPS beam pipe. The detector will be triggered by external scintillator hodoscopes around the beam pipe either side of the main detector, and lead glass plates inside the central detector will catch the photons from neutral pion decay. This configuration should pick up nearly all the collision products.

The streamer chamber will operate in the avalanche mode with an intended inter-track resolution of 2 mm, using image intensifiers to record data on film in six cameras. Four of these, with independent stereo views, will between them cover the whole chamber, while two backup cameras will have wider angle coverage.

To enable it to be installed in the SPS as quickly as possible, the equipment is first to be tested out at the Intersecting Storage Rings (ISR), where if all goes well it might also be able to record data from the first ISR proton-antiproton collisions. A streamer chamber experiment has already been carried out at the ISR, and the experience gained showed the usefulness of a similar experiment covering maximum solid angle at the SPS collider.

Cosmic ray studies show that Centauros occur at a typical energy of 1000 TeV (1 TeV = 1000 GeV). The 270 GeV colliding beams in the SPS are equivalent to a fixed target energy of 155 TeV, which may just miss the Centauro range, although the exact threshold is not known with any certainty.

Atmospheric experiments also report so-called 'mini-Centauro' events at lower energies (down to 250 TeV) where the charged particle multiplicity is much less (about 15 particles), but with neutral particles still conspicuously absent. If UA5 misses the big Centauros, then there might still be lots of mini-Centauros to be caught.

Whatever the outcome, the SPS collider will certainly extend our knowledge of high energy interactions, but it would be remarkable if our present understanding still holds good when laboratory energy is increased by a factor of nearly a hundred.

Photons for the North

Now taking shape in (or rather under) the North Experimental Area at CERN is an underground hall to house experiments using high intensity beams at the highest available energies from the SPS proton synchrotron.

The first experiment to be approved for this 'cave' was a high resolution study of muon pair production by an Ecole Polytechnique / Strasbourg / ETH Zurich collaboration, using a pion beam of up to 10^{10} particles per pulse.

This experiment will now be joined in the underground hall by a CERN / London / Orsay / Saclay / Southampton collaboration studying high energy high intensity photoproduction. It will use a new Broad Band

Electron / Photon beam (called 'BEG') to achieve the highest possible flux of high energy photons with minimum hadron contamination.

In BEG, electrons are produced (as electron-positron pairs) from the gamma rays resulting from the decay of neutral pions. All charged secondary particles produced from the primary SPS proton beam are swept away by a magnetic field. The electrons are magnetically selected by a broad band channel covering 100 to 300 GeV, and produce photons as bremsstrahlung in a radiator. This technique gives excellent purity, as neutrons and neutral kaons are insensitive to the magnetic selection, and high intensity, as nearly all high energy electrons are accepted. By measuring the energy lost by each electron as it crosses the radiator, a rough indication (accurate to about 1 GeV) of the energy of each photon can be obtained.

The collaboration will use photons from about 50 to 200 GeV, and the high intensity and purity of the beam will make it a unique tool for exploring rare photoproduction processes.

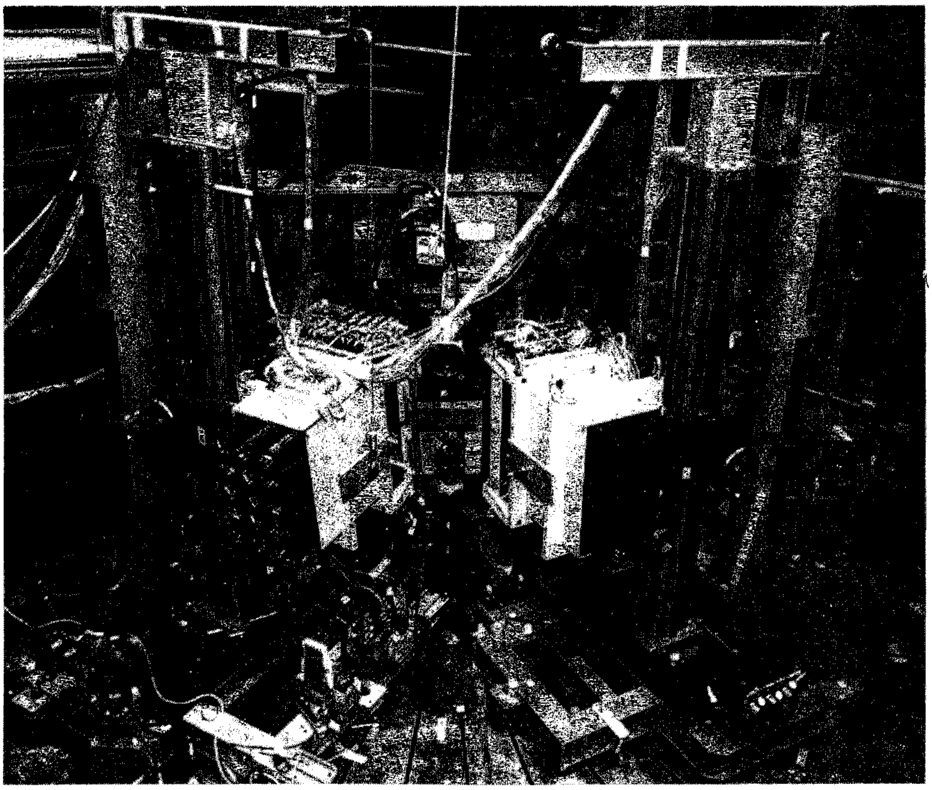
The proposed downstream detector is a two-magnet spectrometer with multiwire proportional chambers as charged particle detectors. Complete coverage of electromagnetic calorimeters up to 300 mrad and a forward muon filter provide good lepton and photon detection. A multicell Cherenkov counter identifies hadrons.

Most of the instrumentation already exists, for instance OLGA, the array of lead glass blocks for detecting forward photons. This is already in use with the Omega spectrometer in the West Experimental Area, and is portable enough to be able to alternate between experiments in the North and the West. With the characteristics of the detectors well known from previous experiments, data taking should be able to commence as soon as the new North Area underground hall is commissioned.

The main aim of the experiment is to study the Compton scattering of high energy photons on the quark constituents of hadrons and the results could provide valuable information on the nature of the quarks.

J. Piffaretti from Neuchâtel University works on the neutral pion spectrometer at LAMPF. The spectrometer, the first of its kind, is now in operation for physics.

(Photo Los Alamos)



LOS ALAMOS Physics from neutral pion spectrometer

The world's first high resolution neutral pion spectrometer operated at the LAMPF 800 MeV proton linac at the end of last year. As a reward for some five years of design and construction effort, its builders observed, for the first time, several pion charge exchange analog transitions. The spectrometer also gave angular distributions for pion-nucleus charge exchange to specific nuclear states and confirmed earlier, puzzling measurements of pion reactions on carbon-13.

Although the detection of neutral pions with high resolution has long been recognized as basic to the study of pion-nucleus interactions, the problem of simultaneously obtaining good pion energy resolution and large solid angle had not been solved. At LAMPF, two large position and energy sensitive photon detectors, which are the heart of the spectrometer, make possible the precise observation of photon pairs from neutral pion decays. The spectrometer becomes particularly powerful when coupled to an intense monochromatic pion beam such as is now available at LAMPF and other meson factories.

The simplest type of pion charge

exchange scattering involves transitions between nuclear isobaric analog states which occur in neighbouring isobars. These states have the same spatial and spin wave functions but different numbers of protons and neutrons. Until late last year, the only pion charge exchange reaction studied in detail was that on a nucleon (negative pion and proton going to neutral pion and neutron). Studies of transitions on nuclei are significant since they are the most direct way of determining the isovector component of the pion-nucleus interaction.

Prior to the LAMPF measurements, questions regarding absorption and multiple scattering of pions in heavy nuclei had led to differing opinions on whether isobaric analog states in a heavy nucleus, such as lead, would even be visible above the background of other states. Direct measurement of the neutral pion spectrum is the only feasible means of answering this question since radiochemical methods, recoil nucleus detection and decay proton detection are virtually impossible for heavy nuclei.

The spectra, measured in late 1978, clearly show the states standing out at very forward scattering angles on the light targets (hydrogen, lithium, carbon and aluminium) and it was particularly exciting to see the peak for heavy targets (niobium, zirconium, tin and lead). The atomic number and energy dependences of the cross-sections are in qualitative agreement with the predictions of a simple theory.

An angular distribution for the reaction on helium was obtained for laboratory angles out to 80° at an energy of 200 MeV. It fits well with earlier measurements at larger angles which detected the recoil nucleus rather than the neutral pion. The absence of a diffraction minimum near 60° supports the theoretical prediction of a large contribution from charge exchange with a spin flip.

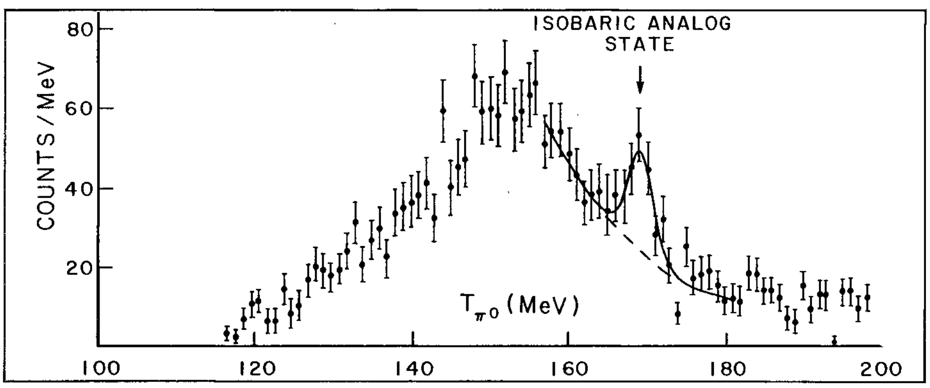
The new spectrometer was also used to study the pion single charge exchange reaction on carbon, which has been a mystery since no theoretical calculation comes within a factor of two of the cross-sections measured radiochemically on carbon-13 a few years ago. The experimental cross-section for excitation of the isobaric analog state is nearly constant at 1 mb between 70 and 250 MeV. All theoretical calculations indicate a dip near 150 MeV reflecting the pion-nucleon resonance at 180 MeV which gives strong absorption and multiple scattering of the pions within the nucleus.

In these first spectrometer measurements, the energy dependence of the charge exchange scattering shows the same sort of disagreement with theory as did the radiochemical data. The differential cross-sections agree with theory at low energies but are a factor of two larger in the resonance region.

The spectrometer was developed by physicists from Los Alamos, Tel Aviv University and Case Western Reserve University. It consists of two large photon detectors, arranged to favour detection of symmetric photon pairs. Each photon is converted into an electron-positron pair in one of three 0.7 radiation length active lead glass converters. The charged particle trajectories are determined by three planes of multiwire proportional chambers behind each converter. The distance between the targets and converter is typically 1 m and the opening angle between the two photons is determined to an accuracy of 5 mr.

The energy of each photon is measured by an array of total absorption lead glass Cherenkov detectors behind the active converters. Both the energy resolution and the solid angle represent considerable improvements over previous neutral pion detectors. The thin converters and the good energy resolution of the lead glass elements were the key factors in this achievement.

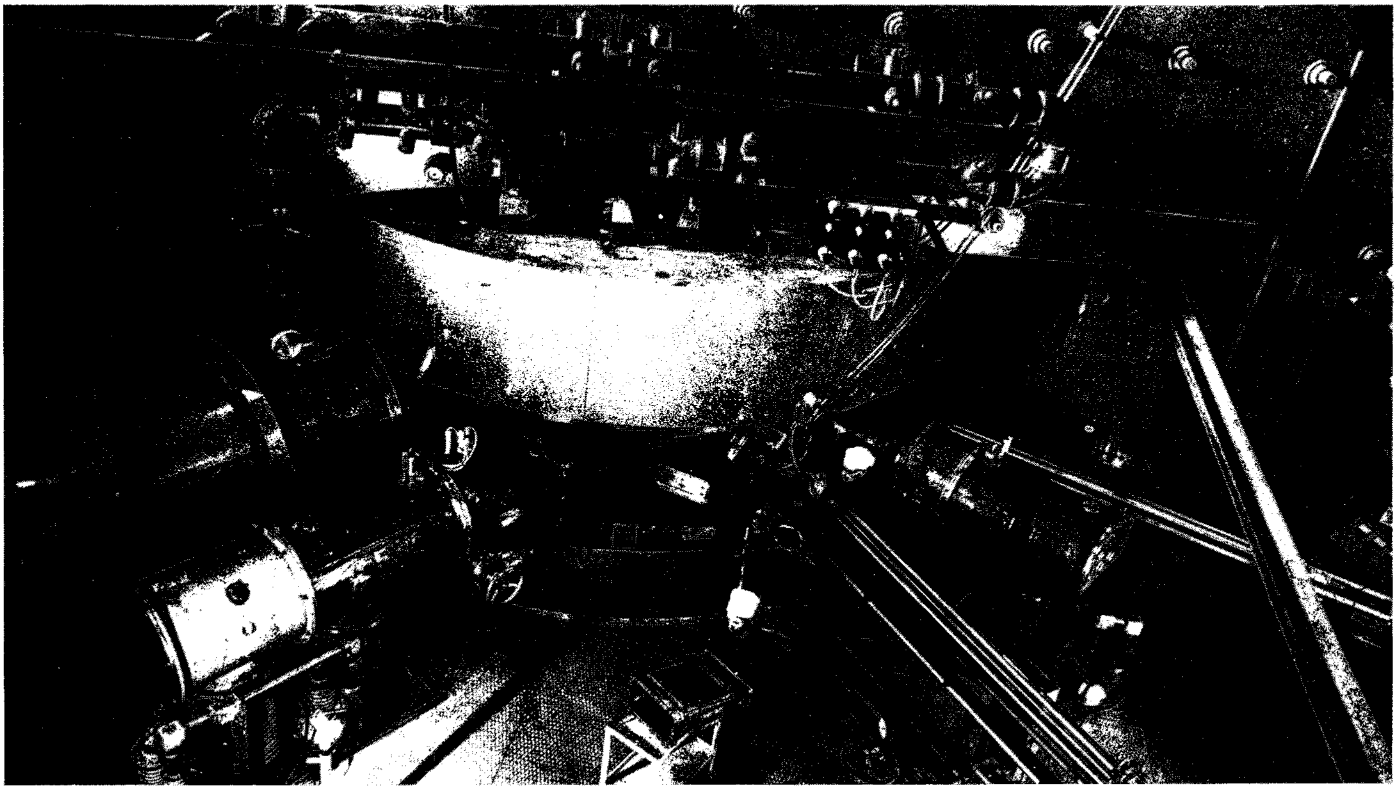
In the first runs, the resolution was 2.5 MeV. Further development is expected to give a substantially improved energy resolution and new possibilities will then open up for the study of nuclear structure using pion single charge exchange. It will be interesting to see how the mystery of the flat energy dependence of the carbon-13 transition is resolved.



An on-line spectrum of positive pion scattering on the heavy nucleus zirconium-90 giving a neutral pion (detected in the neutral pion spectrometer) and niobium-90. An analog state is clearly visible above the background.

A general view of the U-400 isochronous cyclotron recently brought into action for heavy ion physics research at Dubna.

(Photo Yu. Tumanov)



DUBNA
Isochronous cyclotron in operation

At the end of December 1978, a new heavy ion accelerator came into operation at the Joint Institute for Nuclear Research in Dubna. It is a 4 m isochronous cyclotron, known as U-400. The accelerator was designed and constructed by an international team of scientists, engineers and technicians working under G. Flerov and Yu. Oganesyan.

The new accelerator is designed to allow a wide range of research in heavy ion physics. In particular, it will be used for experiments concerned with the synthesis and study of the physical and chemical properties of ultra-heavy elements (beyond element 108). The elements will be produced in nuclear reactions with particles of mass number greater than 40, including the rare isotopes calcium-48, chromium-54 and zinc-70.

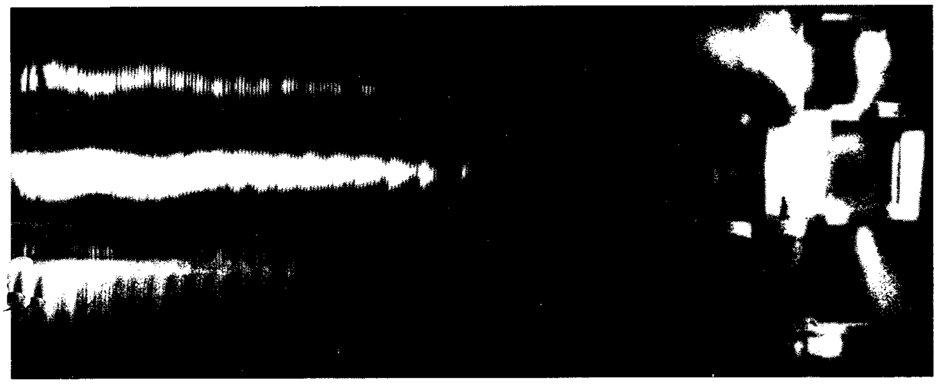
The accelerator will also be used for studies of the interaction mechanisms of complex nuclei, the properties of nuclei remote from stability, some topical problems in atomic physics and the quantum electrodynamics of ultra-strong fields.

When designing the accelerator, special attention was devoted to obtaining intense beams of ions of elements in the first half of the periodic table. The design was naturally optimized to ensure simplicity of construction, high reliability and low running costs. Following an analysis of the various alternative types of machine, the cyclotron was selected. This technique for accelerating heavy ions is in keeping with the tradition of the JINR Nuclear Reactions Laboratory where the U-400 project was developed.

Important milestones in twenty years of research at the Nuclear Reactions Laboratory were: the development of arc-type ion sources, the construction and operation of the conventional U-300 cyclotron (in service since 1960), the U-200 2 m isochronous cyclotron commissioned in 1968, which served as a half-size prototype for U-400, the construction of the U-300 – U-200 tandem-cyclotron which gave accelerated ions of xenon, krypton and germanium.

The decision to construct U-400 was taken by the Scientific Council of JINR in 1974. The first components were produced in July 1975 and installation was completed in August 1978. In November work began on the beam and a month later particles were brought to the outer radius of the cyclotron and

A beam of argon-40 ions in the cyclotron chamber. On the left can be seen the light coming from fine tungsten filaments in the path of the ion beam; on the right, the light coming from the ion source.



ejected. The accelerator was entirely constructed by JINR which helped speed its completion.

The 2000 ton magnet of the cyclotron has separate sets of conventional steel laminations and was manufactured in the actual hall of the cyclotron. It is designed to obtain a high field (2.13 T) in the gap. On the outer radius of the cyclotron (180 cm) the energy of the accelerated ions is about 700 (Z^2/A^2)MeV/nucleon.

The azimuthal variation in the field is produced by four pairs of sectors with a field from 2.7 T at the crest to 1.6 T in the valley. This ensures strong focusing up to an energy of 33 MeV/nucleon. The isochronous shape of the mean field is achieved by stepped annular shims and by current-correcting coils.

The r.f. system is composed of two co-axial resonators, charged by two Dees extending over an angle of 42°, and located in two opposed dips. Over the entire frequency range of 6 to 12 MHz, the potential on the Dees is approximately 100 kV. Such a system makes it possible to accelerate the ions on the second, third and fourth harmonics of the r.f. The average power of the r.f. is about 30 kW.

Vacuum is maintained in a volume of 25 m^3 by seven oil diffusion pumps. They achieve 2×10^{-6} torr and it is envisaged that this will be improved to 5×10^{-7} torr by incorporating cooled surfaces.

Beam ejection is by the charge-exchange method proposed by Yu. Oganesyan and others in 1964. As ions pass through a thin carbon foil they increase their charge, leading to a strong radial instability in their motion. Describing a rapidly widening spiral in an axially non-uniform field, the particles emerge from the accelerator. A gradual variation in the ion energy is achieved by moving the foil across the radius. If it is moved azimuthally beams of ions of varying energies can be directed at the target, located in a fixed position.

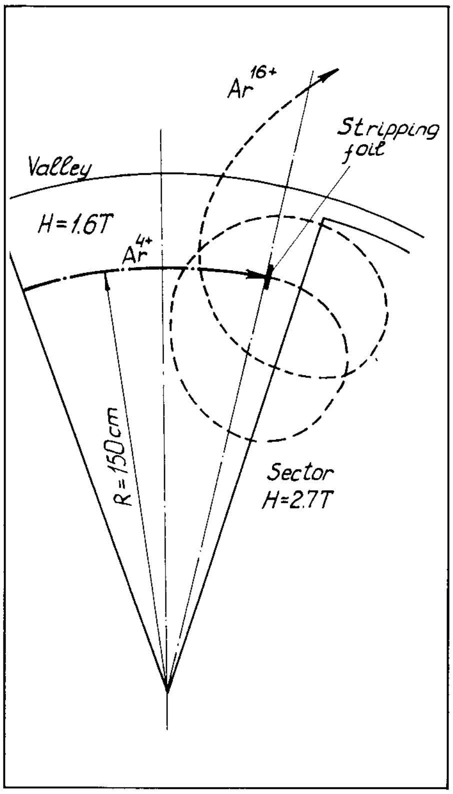
This method was investigated in 1965 on the CEVIL cyclotron at Orsay and was first used on the U-200 cyclotron at Dubna to extract helium ions and obtain a gradual energy variation from 27 to 41 MeV. The method was later used for heavier ions up to neon. In U-400, two-revolution ejection is employed providing three beams simultaneously with charges differing by a value of one or two.

U-400 is equipped with intense ion sources of the arc-type, with radial injection (the power of the arc in a 1 ms pulse, with a duty factor of 0.25 is up to 50 kW). It is planned to develop ion sources based on the laser and other principles.

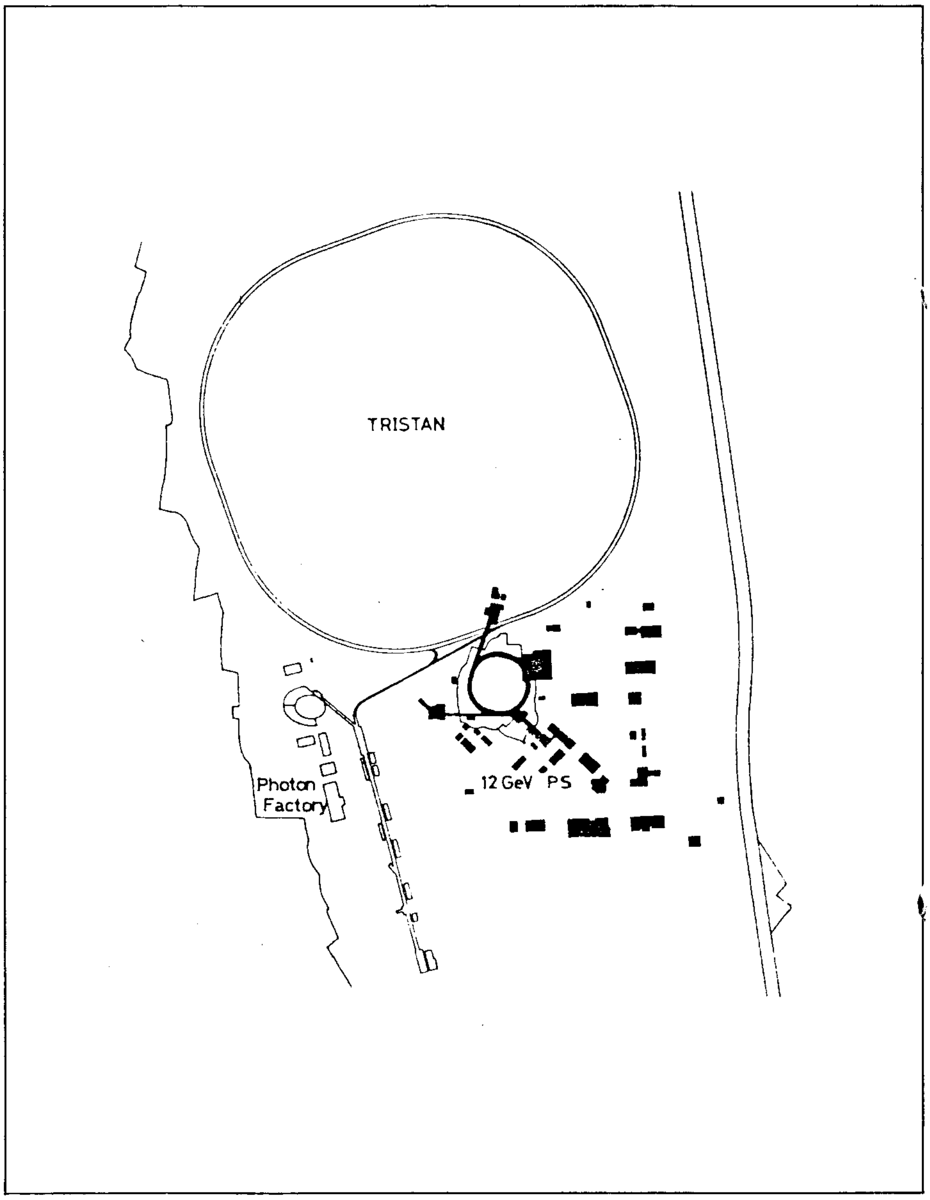
In December 1978 a beam of argon-40 (+4) ions was obtained with an intensity of 8×10^{13} particles per pulse and an energy of 5 MeV/nucleon. The first experiments are due to begin soon. The beam intensity and energy will then be increased and the range of accelerated particles extended; the ejected beam transport systems will also be developed and the experimental areas equipped.

The U-400 cyclotron project is based on the developments in accelerator technology and nuclear physics of more than twenty years experience in the Nuclear Reactions Laboratory of the Joint Institute for Nuclear Research at Dubna. Its extended abilities should help the research to new achievements.

Schematic drawing of two-revolution ejection of a beam of ions from the U-400 cyclotron chamber using the foil stripping technique proposed at Dubna.



Plan of the KEK Laboratory in Japan. The existing buildings around the 12 GeV proton synchrotron are blocked in and the location is shown of the 2.5 GeV Photon Factory, being built for synchrotron radiation research, and of the proposed TRISTAN storage ring complex.



JAPAN
Progress at the KEK Laboratory

The KEK Laboratory in Japan is extending its research facilities with the addition of three specialized experimental areas at the Booster of the proton synchrotron, the construction of a 'Photon Factory' for synchrotron radiation work and, hopefully, in the future a large storage ring complex called TRISTAN.

At the proton synchrotron itself, since November of last year, slow extracted beams have been available at energies up to 12 GeV and are feeding two new kaon beamlines constructed during the 1978 shutdown. The proton beam intensities in the Main Ring have reached 2×10^{12} protons per pulse at a pulse repetition rate of one pulse about every two seconds.

The intensity increases have followed a hard struggle, particularly in the 500 MeV Booster which exceeded its design intensity of 6×10^{11} protons per pulse (operating at 50 Hz) for the first time at the end of November last year. It had been experiencing considerable losses immediately after injection and at the end of the acceleration cycle. The latter problem was solved by the operation of sextupole and octupole correction magnets and the injection problem was solved by adding more r.f. stations and increasing the r.f. accelerating voltage. Adding more refined adjustment of the r.f. cycle has given the desired Booster parameters and it is now feeding nine pulses per cycle to the Main Ring.

The remainder of the Booster pulses are to be used to feed three experimental areas with 500 MeV protons. The first is a neutron area where a uranium or tungsten target is expected to yield some twenty neutrons per incident proton for neutron diffraction experiments. Typical expected fluxes are 10^{13} fast neutrons per pulse, 10^{16} cold neutrons, 10^{15} thermal neutrons and 0.5×10^{15} epithermal neutrons per cm^2 per s.

The second area will be used for medical applications. Neutrons will be used for cancer therapy. Protons, after being slowed to 200 MeV, will be used for proton radiography. The third area will be used for meson research and a superconducting magnet is under construction to capture more particles so as to bring the fluxes nearer to those experienced at the meson factories. Some 10^4 muons per cm^2 per s are anticipated.

The Photon Factory was authorized last year at a cost of 1.65×10^{10}

yen of which 8×10^9 yen is for the construction of a 2.5 GeV electron linac and storage ring. The system is scheduled to come into operation for synchrotron radiation research in 1982 with stored beams of up to 500 mA in a 187 m diameter ring. The ring will be equipped with wigglers to extend the radiation spectrum into the region of hard X-rays.

Electrons and positrons from the linac could also be available for the TRISTAN storage ring complex which is the Laboratory's big project for the future. A tunnel of 2 km circumference will fit on the existing site and it is intended to house three rings. One would serve for electron-positron physics up to energies of 20 GeV. A second would be a superconducting ring, with magnetic fields up to 4.5 T, to hold 300 GeV protons. The third would act as intermediate ring covering the 12 to 100 GeV range for protons, since injection at 12 GeV into the superconducting ring would not be reasonable.

Obviously, with such a complex, electron-positron, electron-proton and proton-proton colliding beams are feasible. Quite a lot of emphasis is being given to the electron-proton option at the moment since injectors for those two rings already exist or are under construction at the Laboratory.

Research work at KEK started in 1977, but is now well under way, and as present developments and current plans come to fruition, a vigorous programme should emerge in the years to come.

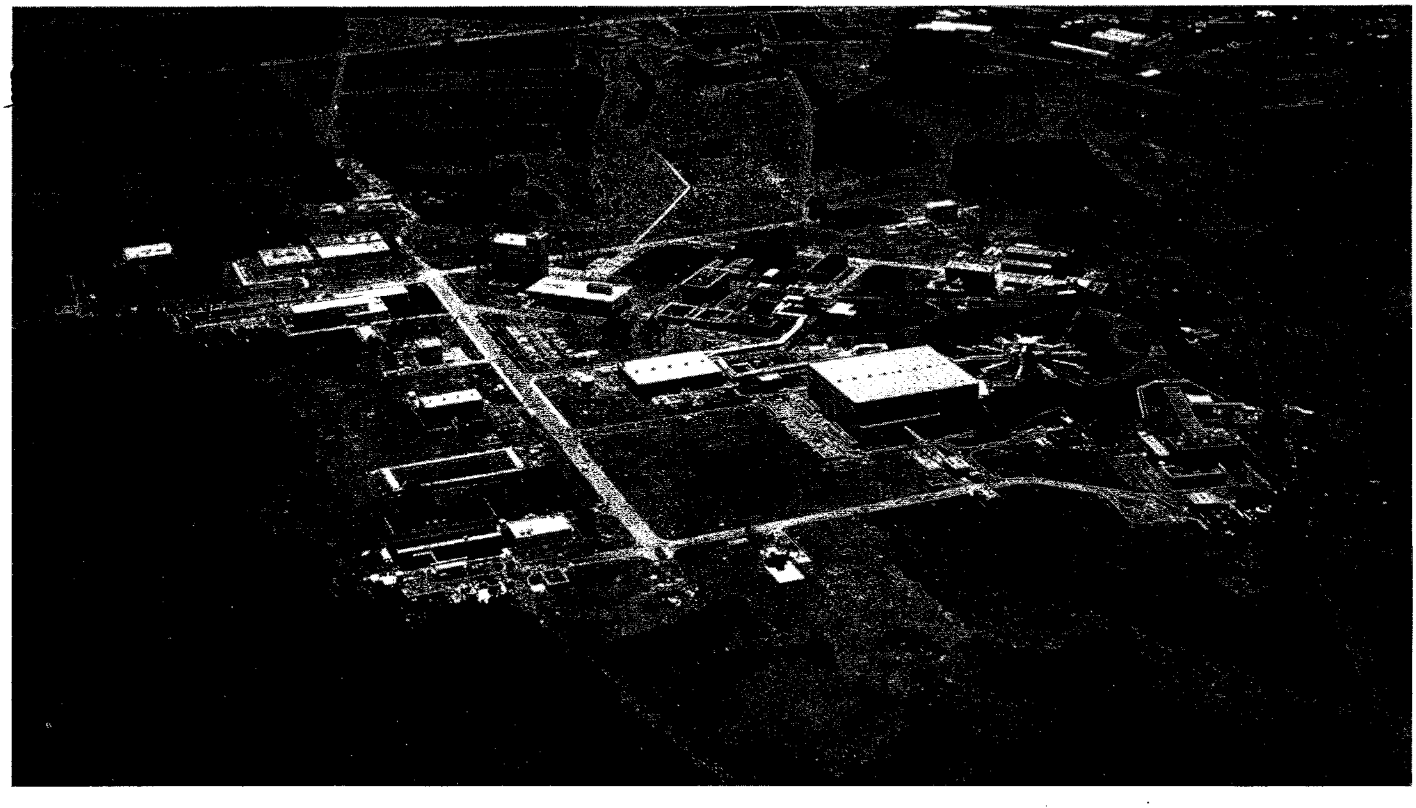
Aerial view of the Japanese KEK High Energy Physics Laboratory. The 12 GeV proton synchrotron, centre, serves two experimental halls, the smaller one at the bottom of the picture housing the 1 m bubble chamber, while the larger is the scene of counter experiments.

(Photo KEK)

SACLAY Rejuvenated SATURNE

To give fresh physics life to the Saturne synchrotron at Saclay, previously used to accelerate protons to 3 GeV, it has endured a major rebuild to accelerate heavy ions and to provide beams of a quality appropriate for nuclear physics experiments. Some major design features of Saturne II are: accelerated ions ranging from protons to argon (including polarized protons and deuterons), intensity of 2×10^{12} protons, high quality ejected beam with particles available simultaneously from two extraction beamlines, fast and flexible tuning for the different ion species.

Protons were accelerated in the rebuilt machine on schedule in July 1978 and the first ejected beam



appeared in November. Particles have now been provided for the nuclear physics programme at low intensity. Although 2×10^{12} protons have been injected and trapped, only 5×10^{11} particles are usually injected per pulse and less are fed to the experiments in order to retain beam quality. Some settling of the ground has led to a growth in the maximum deviation from the ideal closed orbit. This should be cleared when all the correction lenses are brought into operation. Longitudinal instabilities also appear and, to reduce them, the longitudinal impedance is being increased and feedback corrections are being considered. In March performance was improved to allow 6×10^{11} particles to be accelerated without longitudinal instabilities appearing.

One extraction channel has been in operation so far, using the one third integer resonance, and the second is due to come into action in June. Extraction efficiency has so far been lower than expected (55% compared to 80%).

Encouraging results have been achieved with the new pre-injector, named Cryebis, which will supply the heavy ions. The ion source has given 5×10^9 nitrogen-7 ions and 3×10^9 argon ions per pulse. Polarized protons and deuterons will be obtained from the same source using an atomic jet of the Saclay type.

The percentage transmission of particles from the source to the experiments is low at present (3%) though vacuum improvements should bring the number of particles delivered to the targets to 10^8 per pulse. A further improvement of a factor of ten is being pursued via the addition of an accumulator ring, called Mimas, fed by five to ten pulses. Particles will there be accelerated to 5 MeV per nucleon before injection into the Saturne II ring. Mimas will need a vacuum better than 10^{-10} torr and will be able to handle partially stripped ions.

The range of nuclear physics facilities around Saturne II will be among the finest in the world. Four sophisticated spectrometers have been built or are nearing completion, known as SPES 1 to 4. SPES 1 operated on Saturne I with 6×10^{-5} momentum resolution up to momenta of 1.7 GeV/c. SPES 4 carries the maximum momentum up to 4 GeV/c, SPES 3 concentrates on large solid angle and SPES 2 (now operating at CERN) is a reduced version of SPES 3. Other instruments will include a superconducting solenoid, for studies involving spin orientation, and polarized targets. In addition to nuclear physics there will be experiments in medical radiography, astrophysics and radiobiology.

The Saclay physicists are happy to see their rejuvenated machine already giving ten times the particle intensity in the same emittance as the old machine with much improvement still possible. The facilities and the extent of the experimental programme promise an interesting future.

People and things

To praise CESR

On 1 April, six months ahead of schedule, electrons were injected into the 8 GeV electron-positron storage ring, CESR, at Cornell. Two weeks later beam was accumulated at an energy of 5.5 GeV. We hope to have the full story in our next issue.

Willi Haeberli and Roy Middleton received the 1979 Bonner Prize for Nuclear Physics at the April meeting of the American Physical Society. The citation read 'for their unusual contribution to the development and use of ion sources for charged particle accelerators in both basic and applied fields'.

Hybrid emulsion specialist Eric Burhop retires (see page 166).

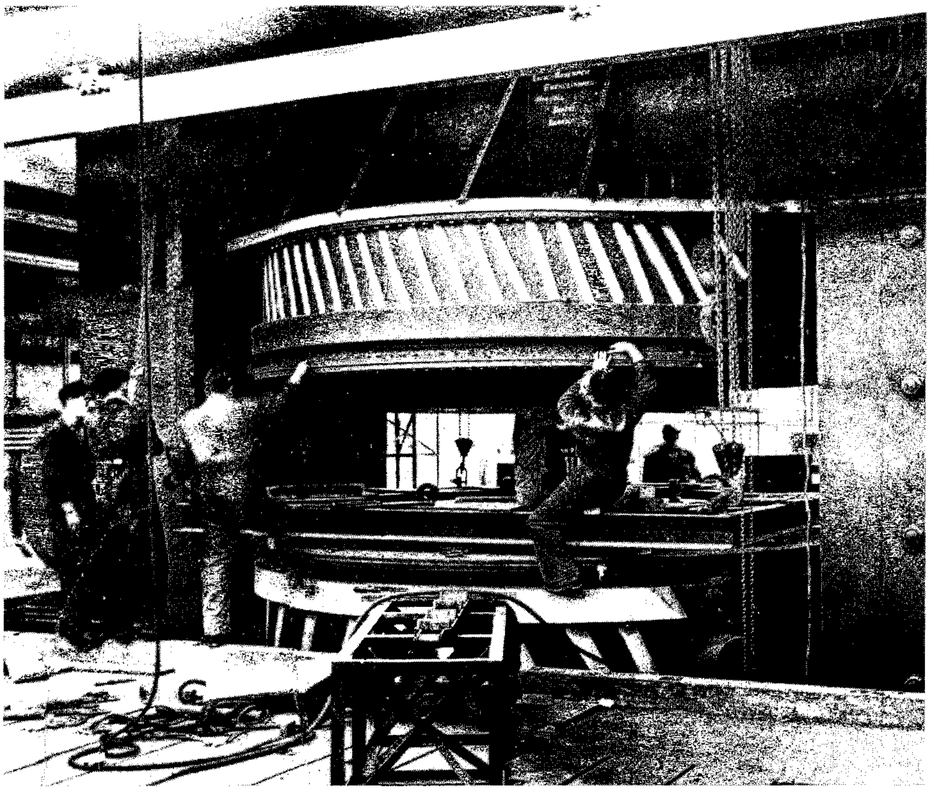
ISABELLE contract awarded

The contract for the management and construction of the conventional facilities of the ISABELLE 400 GeV proton storage rings to be built at the Brookhaven Laboratory has been awarded to the New York firm of Ammann and Whitney. The contract, worth about $40 million, covers the construction of the ring tunnel, experimental halls and support services buildings.

On 5 May a groundbreaking ceremony was held at the Synchrotron Radiation Centre of the University of Wisconsin-Madison for the building which will house the 'Aladdin' 1 GeV electron storage ring. Aladdin is to be used for research with synchrotron radiation, continuing the tradition established at Wisconsin with the Tantalus ring.

Diversification at the Rutherford Laboratory passed another milestone recently when the construction work for the new Electron eam Lithography Facility was completed and the electron beam pattern generator delivered. Assembly and acceptance tests are now under way.

The 160 MeV synchro-cyclotron at Harwell was closed down on 30 March after thirty years of operation. Construction began in 1946 under Gerry Pickavance, later Director of the Rutherford Laboratory, and operation continued under Basil Rose, Eric Taylor and Colin Whitehead. In its later years the physics potential was greatly increased by the acceleration of deuterons, alpha particles and helium ions. The photograph dates back to the construction days in 1948.

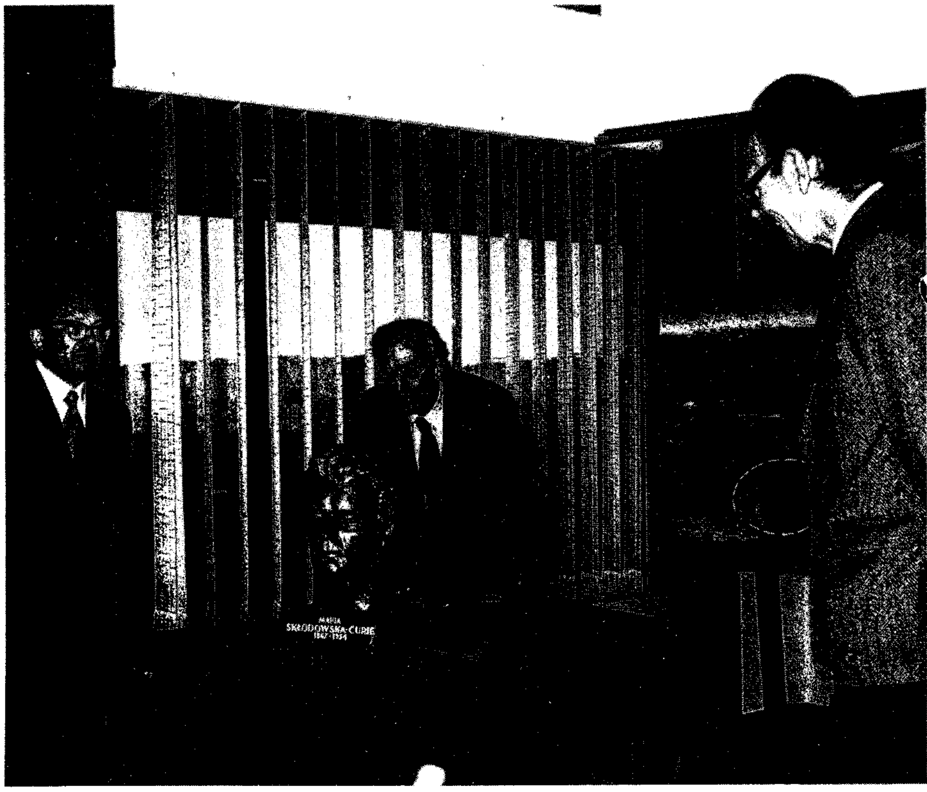


Speakers at the International Symposium in honour of Robert R. Wilson held at Fermilab in April. S. Chandrasekhar (left) spoke on beauty and the quest for beauty in science, taking as his keynote Keats' famous lines..." Beauty is truth, truth-beauty that is all ye know on earth, and all ye need to know." Wolfgang Paul (right) lovingly covered the very earliest days of accelerator history with fascinating slides of some early table top machines. Hans Bethe (below right) reminisced about Cornell and Los Alamos and Wilson's work at those places. He closed with a trenchant plea to return to a willingness to take chances while placing more reliance on our abilities to find solutions to the problems as they arose. Viki Weisskopf closed the formal programme with a perceptive talk on science and art. More than 450 guests attended the Symposium and proceedings will be published by Fermilab.

(Photos Fermilab)

On a visit to CERN, the Polish Deputy Minister of Energy and Nuclear Power, J. Felicki, presented the Directors General with a bust of Madame Marie Sklodowska Curie on behalf of the physicists of Poland in appreciation of the research possibilities which CERN has made available over the years.

(Photo CERN 375.3.79)



Booster records

Greatly helped by the quality of the beams from the new linac (see October 1978 issue, page 344), the CERN 800 MeV four-ring Booster has achieved several new records which bode well for the role it has to play with the PS in feeding the high energy machines in the coming years.

The SPS is most interested in beam intensity and there the normal figure in the Booster has now been raised to 1.8×10^{13} protons per pulse (80 per cent above the design value). The ISR are most interested in longitudinal phase density and previous Booster performance was already more than adequate. It is now improved to 6.4×10^{12} protons per eV per s and if the ISR were to be filled at this density it would correspond to proton currents of about 250 A!

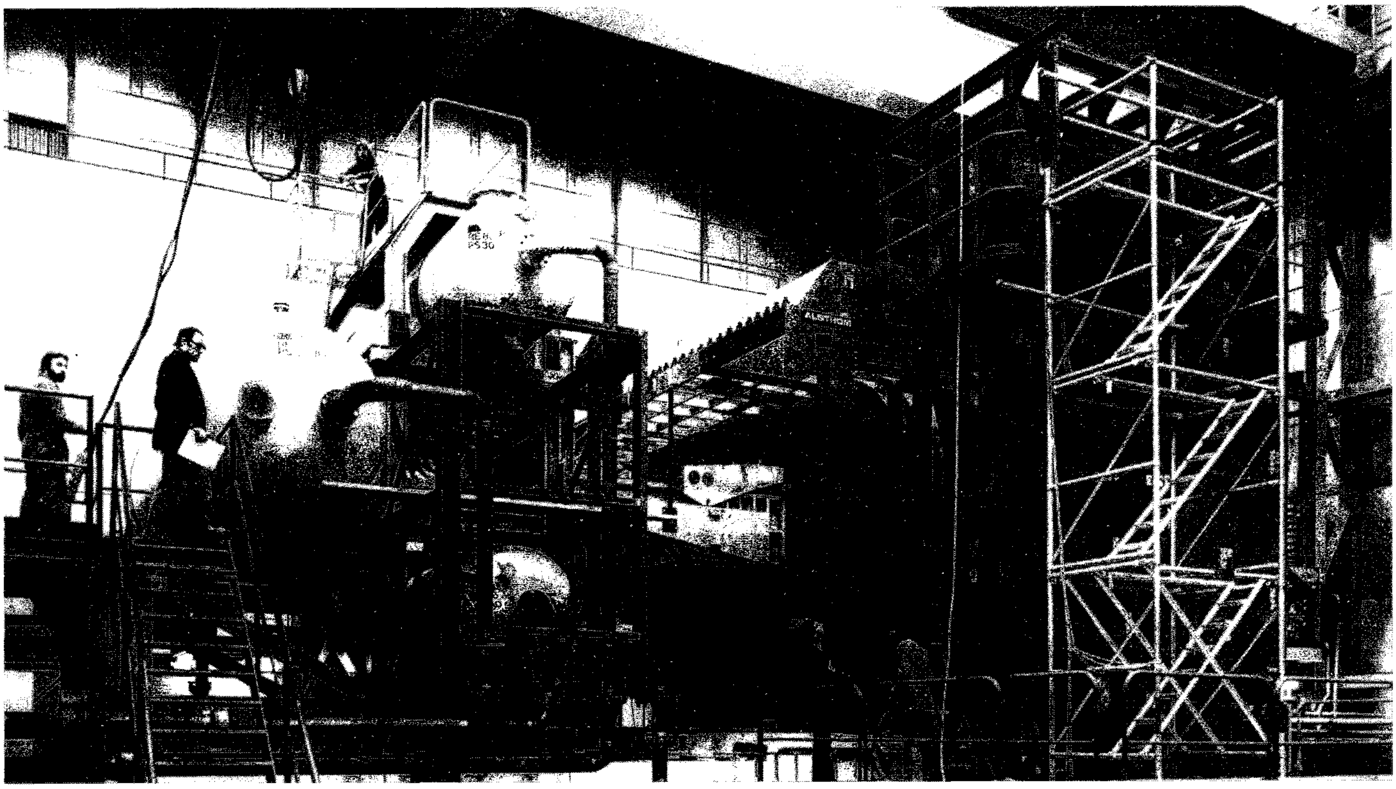
The coming antiproton accumulator ring is most interested in linear charge density which is proportional to the number of antiprotons injected. The Booster now gives 5×10^{10} protons per metre (and an even higher value is achieved in the PS — see September 1978 issue, page 291). To illustrate what this implies — if the SPS could be filled with such a charge density, 3×10^{14} protons would be circulating! The Booster has also preserved its healthy record of reliability. In 1978 it fed protons to the PS for 98.5 per cent of the scheduled time with all four rings in action and picked up another 0.5 per cent with three rings in action.

New British Prime Minister Margaret Thatcher during a visit to CERN in 1970 when Minister for Education and Science, seen here with, left to right, Peter Standley, Bernard Gregory, then CERN's Director General, and Edoardo Amaldi, at the time President of Council.

(Photo CERN 399.9.70)

The Gargamelle heavy liquid bubble chamber, seen here being installed in 1976 to receive neutrino beams from the 400 GeV proton synchrotron, has come to the end of its days. Investigation of the chamber body, following the appearance of a crack which led to a propane leak in October of last year, has revealed other cracks and the decision has been taken not to attempt repairs. CERN thus says goodbye to one of its most famous detectors which was the scene of the great discovery of neutral currents in 1973.

(Photo CERN 29.11.76)



In a recent editorial, George L. Trigg described as 'deplorable' the steady decline of the standard of writing in articles submitted for publication in Physical Review Letters. CERN COURIER makes no claim to be a paragon of written language style, and Trigg's exhortation — an extract is written here — is a salutary reminder to us all.

1. *Make sure each pronoun agrees with their antecedent.*
2. *Just between you and I, the case of pronouns is important.*
3. *Watch out for irregular verbs which have crope into English.*
4. *Verbs has to agree in number with their subjects.*
5. *Don't use no double negatives.*
6. *Being bad grammar, a writer should not use dangling modifiers.*
7. *Join clauses good like a conjunction should.*
8. *A writer must not shift your point of view.*
9. *About sentence fragments.*
10. *Don't use run-on sentences you got to punctuate them.*
11. *In letters essays and reports use commas to separate items in series.*
12. *Don't use commas, which are not necessary.*
13. *Parenthetical words however should be enclosed in commas.*
14. *Its important to use apostrophes right in everybodys writing.*
15. *Don't abbrev.*
16. *Check to see if you any words out.*
17. *In the case of a report, check to see that jargonwise, it's A-OK.*
18. *As far as incomplete constructions, they are wrong.*
19. *About repetition, the repetition of a word might be real effective repetition — take, for instance the repetition of Abraham Lincoln.*
20. *In my opinion, I think that an author when he is writing should definitely not get into the habit of making use of too many unnecessary words that he does not really need in order to put his message across.*
21. *Use parallel construction not only to be concise but also clarify.*
22. *It behooves us all to avoid archaic expressions.*
23. *Mixed metaphors are a pain in the neck and ought to be weeded out.*
24. *Consult the dictionery to avoid mispelings.*
25. *To ignorantly split an infinitive is a practice to religiously avoid.*
26. *Last but not least, lay off cliches.*

Gerard 't Hooft demonstrates a topological phenomenon at the Einstein Centennial in Jerusalem with the help of a full cup of coffee.

(Photos Judy Goldhaber)

1.

2.

3.

4.

On people

On 10 April an informal dinner was held at University College London to mark the retirement of Eric Burhop. It was an occasion for his colleagues from the WA 17 collaboration working at CERN to wish him well. During the dinner, Jerzy Priewski announced that Eric Burhop had been awarded an Honorary Doctorate at Warsaw University. Professor Burhop is a leading figure amongst high energy physics experimenters in the UK and was, for example, a prime mover of the recent hybrid emulsion experiments which have given unique information on charmed particles.

Topological 't Hooft

We are indebted to Judy Goldhaber for communicating to us the photographs of the beautifully choreographed sarabande of Gerard 't Hooft, demonstrating an interesting topological phenomenon (a displacement which requires a 720 degree turn, rather than the usual 360 degree, to return to its initial state) using a full cup of coffee.

The incident took place during the Einstein Centennial on 14–29 March in Jerusalem which attracted many leading theoreticians from the field of particle physics — Murray Gell-Mann, Yuval Ne'eman, Steven Weinberg, Jogesh Pati, Feza Gursey, Sheldon Glashow, Haim Harari, Raul Gatto, Roger Dashen, Yoichiro Nambu, Harry Lipkin, C.N. Yang, and Paul Dirac, who packed the lecture theatre with his talk on the early years of relativity.

Gerard 't Hooft's trick had, inevitably, many imitators whose degree of success brought joy to the hearts of the coffee barons of Brazil.

MICRONA

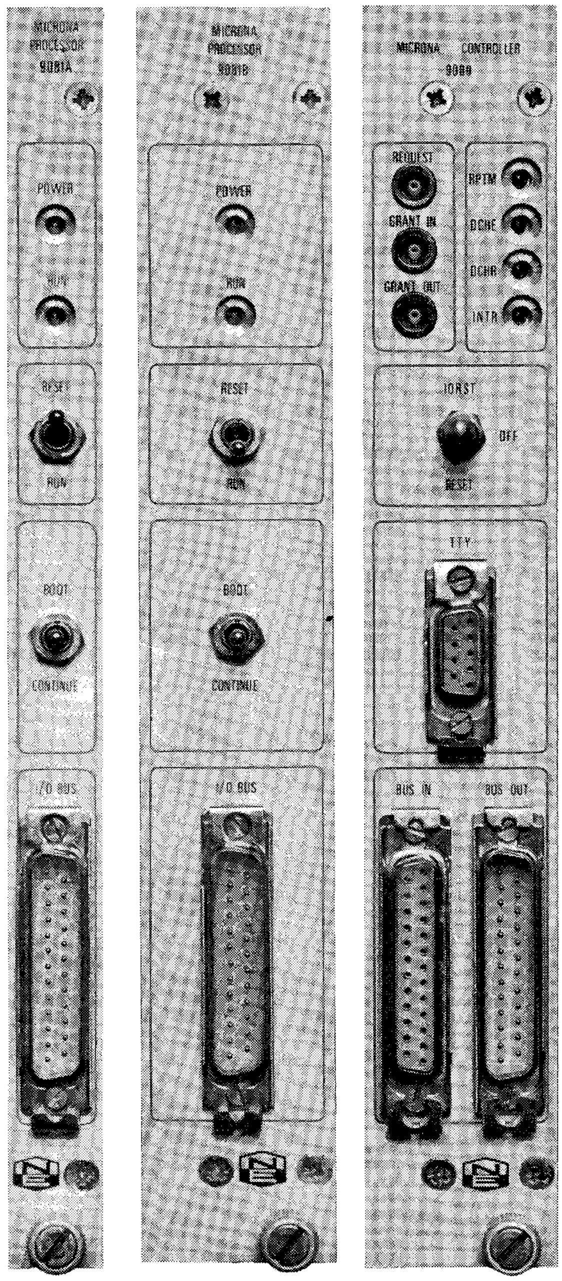
Nuclear Enterprises Micronova™-based Camac Computer

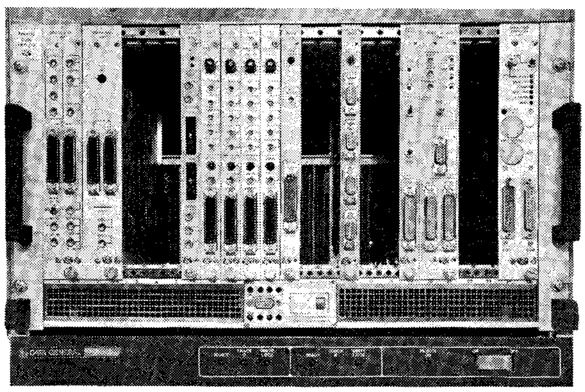
Nuclear Enterprises Microna series of modules can be combined within a Camac crate to form a NOVA® structured computer complete with Dataway access.

The 9081 Microna Processor is designed around Data General's MicroNova™ microprocessor chip. It is configured complete with 16k RAM (9081A) or 32k RAM (9081B), together with a PROM programmed for automatic program load. The Processor is connected to peripheral devices via a front panel serial I/O bus, and communicates with Camac via a 9089 Microna Controller. A series of printed circuit mounted switches allows the 9089 to be used as a Crate Controller in stand-alone systems, or as an Auxiliary Controller connected to a type L2 or A2 Crate Controller via its rear panel connected Auxiliary Control Bus, in distributed systems. Furthermore, a whole series of 9089 modules may be interconnected within a Crate via the ACB thus permitting multiprocessor configurations sharing the same Dataway.

The controller is equipped with a 20mA serial interface in order to connect a system monitor device such as an ASR terminal or visual display unit. In simple configurations this keeps the initial system cost at a low level.

- **Powerful NOVA® architecture and instruction set with 16-bit word length and integral hardware multiply/divide.**
- **Integral real time clock and data channel.**
- **Serial front panel I/O bus access.**
- **Multicrate capability.**
- **Switched Crate Controller/Auxiliary Controller facility.**
- **Integral terminal device interface.**
- **Integral Lam encode and interrupt.**
- **Program load from link-selected peripherals.**





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max. 30 entrées analogiques et 20 entrées digitales, linéarisation pour thermocouples.

Système 35: Système logger piloté par ordinateur (LSI-11), interpréteur BASAC IV,
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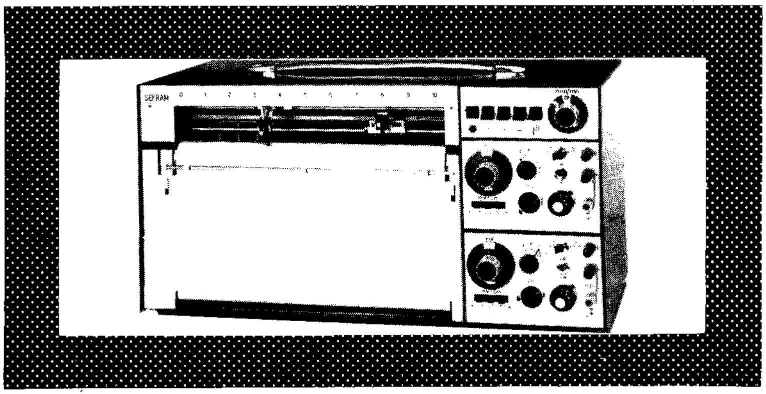
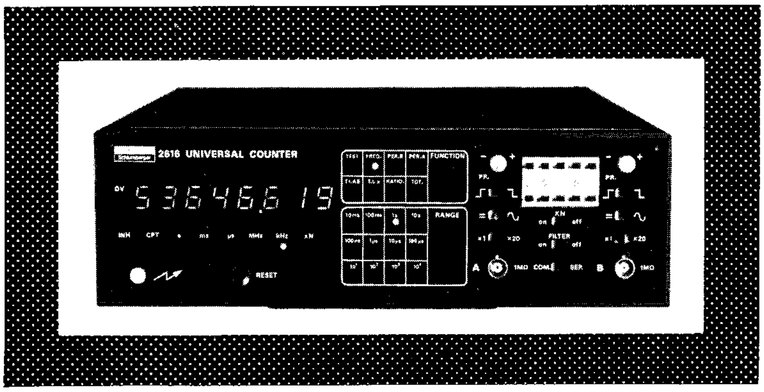


Enregistreurs potentiométriques 1 à 6 voies Y = f(t)

Une ligne complète d'appareils à hautes performances, exécution de table ou pour montage en rack. Egalement disponibles en X/Y; caractéristiques typiques:
précision 0,25%,
gammes de mesure de 0,4 mV à 100 V,
impédance d'entrée >60 MΩ, filtres d'entrées commutables, offset automatique jusqu'à 15 échelles,
synchronisme des voies par microprocesseur (option),
temps de réponse <0,3 sec.



Compteurs-fréquencemètres universels

Nouvelle famille série 2615 (4 versions),
fréquences 120 MHz, 520 MHz ou 1,25 GHz,
base de temps prédéterminée,
fonctions: fréquences, périodes, intervalles de temps, quotient, totaliseur d'événements,
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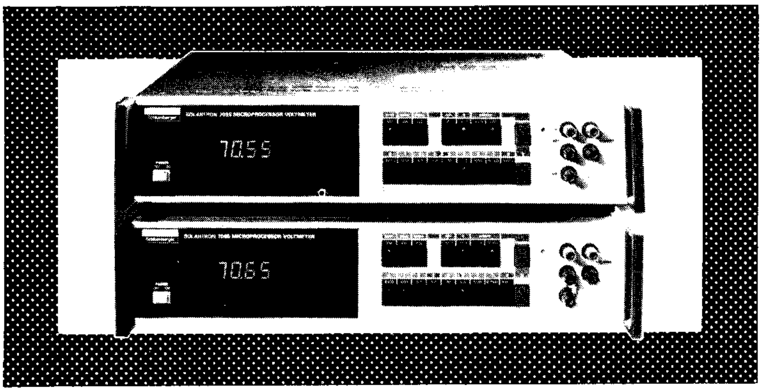

Voltmètres numériques à microprocesseur avec traitement «on line» des informations

Modèles 7065/55 avec 6½ resp. 5½ digits,
conversion A/D par largeur d'impulsions,
haute linéarité et grande précision,
3 fonctions: volts DC, volts AC, ohms,
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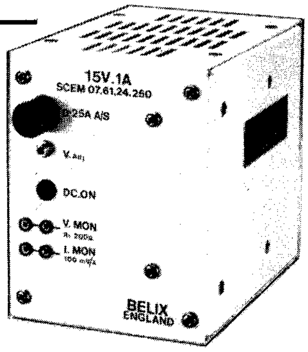

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FEATURES:—
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4. Low Cost

SWITCH MODE TYPES

RATING	TYPE	CASE
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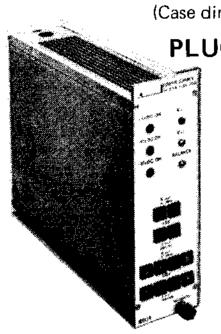
5V 20A	07.61.24.200.0	B
24V 5A	07.61.24.400.0	B

LINEAR REGULATOR TYPES

RATING	TYPE	CASE
5V 3A	07.61.24.100.0	A
15V 1A	07.61.24.250.0	A
±15V 0.5A	07.61.24.300.0	A
24V 1A	07.61.24.350.0	B

CASE	A	B
DIMENSIONS	110H X 85W X 120D	110H X 170W X 120D

(Case dimensions in millimetres)



PLUG IN LINEAR SUPPLIES

NIM RACK SIZE 3H 1L

RATING	TYPE
5V 2A	07.61.28.050.0

NIM RACK SIZE 3H 2L

RATING	TYPE
5V 5A	07.61.28.053.0
±15V 1A	07.61.28.085.0
24V 2A	07.61.28.101.0

ALSO AVAILABLE TRIPLE UNIT
IN 5H 2L 5V 2.5A PLUS ±15V 250MA

NIM RACK SIZE 5H 2L

RATING	TYPE
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5V 10A	07.61.28.062.0
±15V 1A	07.61.28.088.0
24V 2A	07.61.28.104.0
24V 5A	07.61.28.110.0

NIM RACK SIZE 3H 4L

RATING	TYPE
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24V 5A	07.61.28.107.0

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- Ultra stable precision controllers 1-400 kelvin
- High stability fixed and programmable current sources
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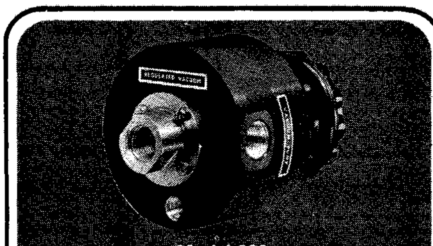
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Vacuum Regulator Valve

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- GaAs diode sensors 1 K to 400 K
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- Rhodium iron resistors
- Chromel-gold/iron thermocouples
- Hall generators

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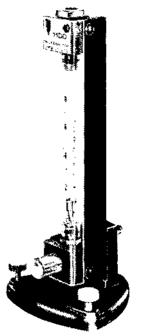

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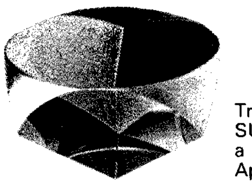

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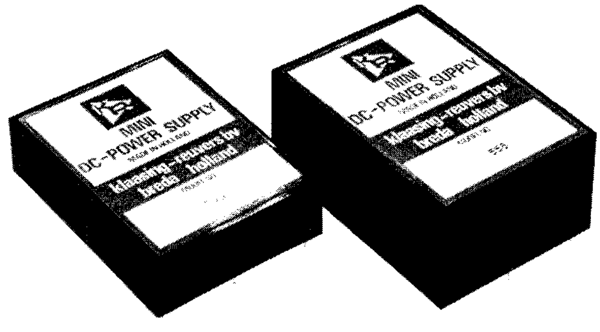

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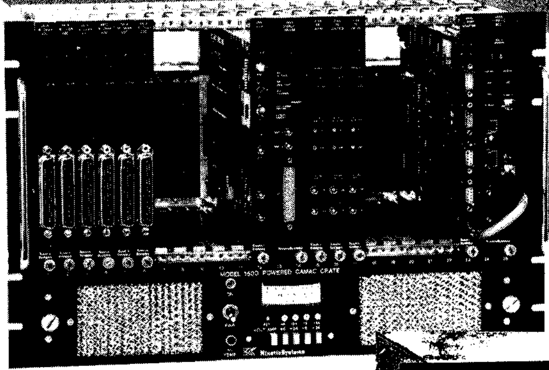
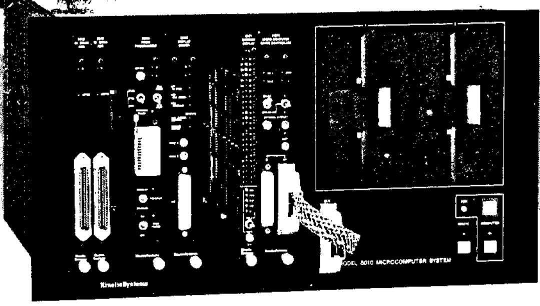


microcomputer-controlled



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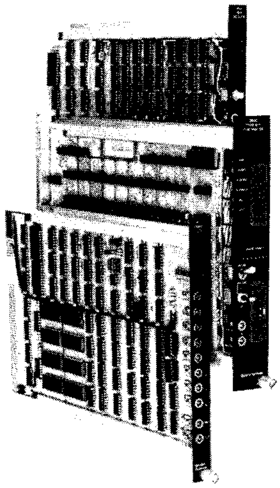
- Editor



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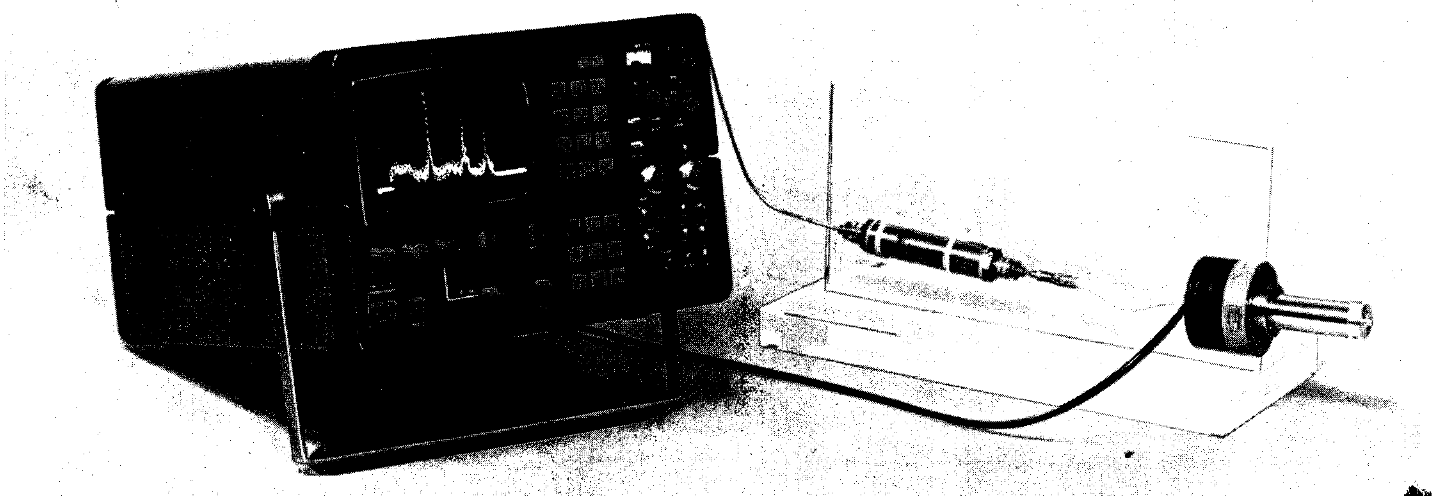
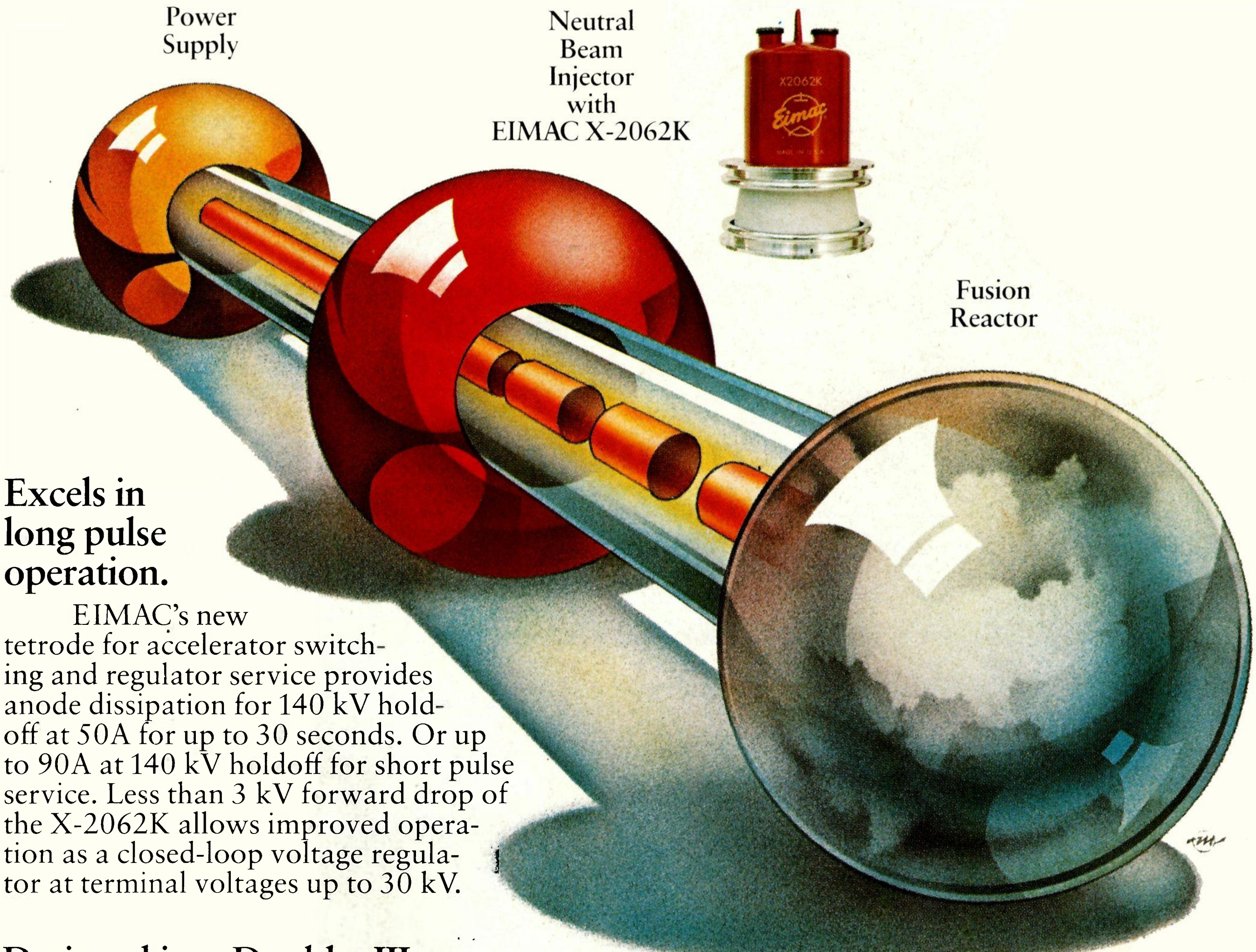


Control tomorrow's neutral beam guns with today's EIMAC X-2062K.



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