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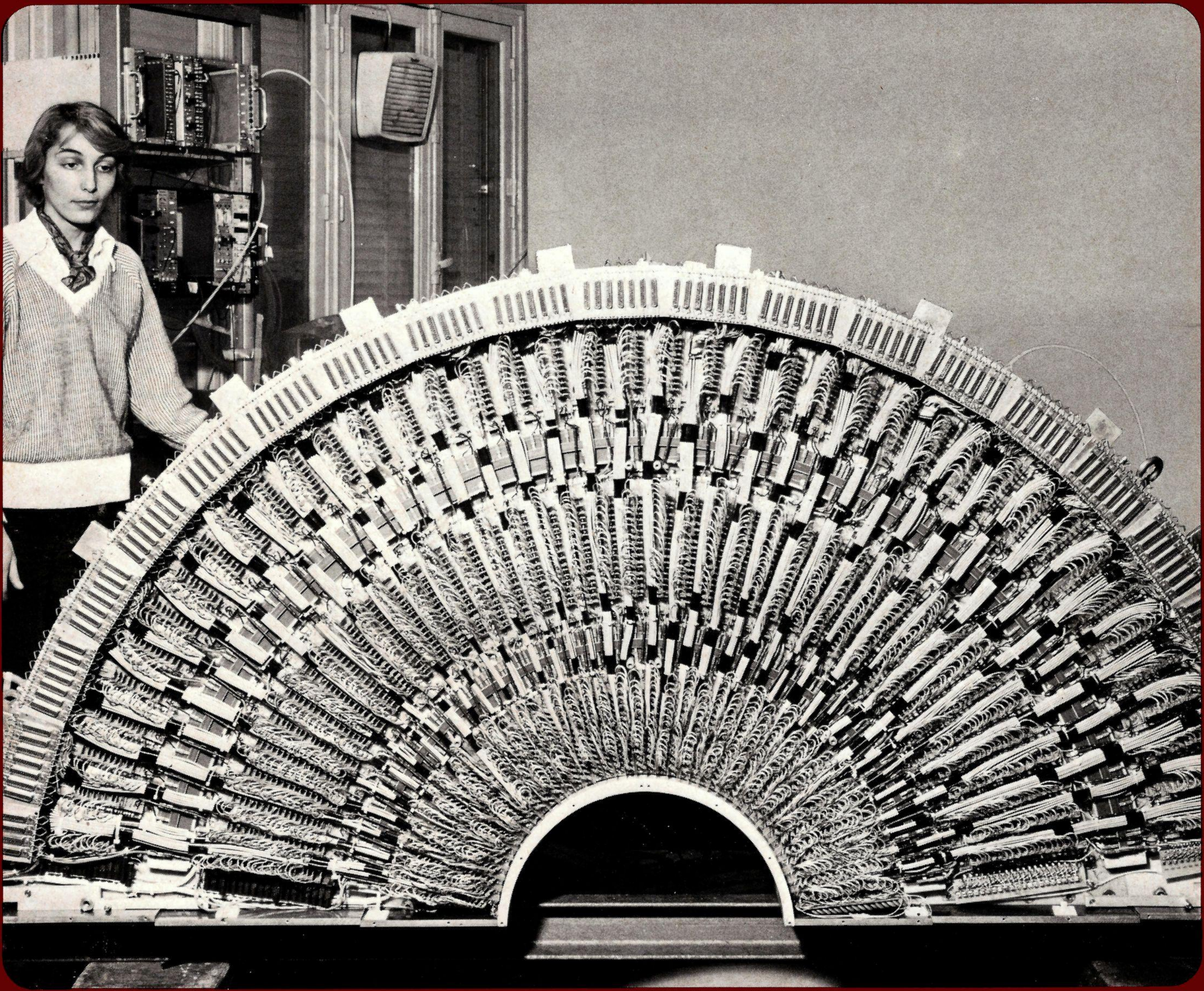

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Cover photograph: A peacock's tail of electronics form an end section of half a cylindrical drift chamber which will be installed as the central detector at intersection 8 of the CERN Intersecting Storage Rings. The experiment (by a Brookhaven/CERN/Copenhagen/Lund/Rutherford/Tel Aviv collaboration) will study deep inelastic proton-proton collisions. It will also be able to look at similar phenomena when antiprotons are injected into the ISR, as described in our main article this month. (Photo CERN 370.1.80)

Proton-antiproton colliding beams coming nearer

On 16 June the CERN SPS will start its 'big shutdown', with no operation for almost a year while the machine and experiments are prepared for proton-antiproton colliding beams. Such a major sacrifice of prime research time has never been seen before and is as sure a pointer as any to the importance of the extension in CERN's research potential which the proton-antiproton collider will bring.

This article recalls the major features of the CERN scheme, and of the project at Fermilab, and describes the preparations now under way or imminent at CERN for the experiments and for the machines.

The CERN scheme

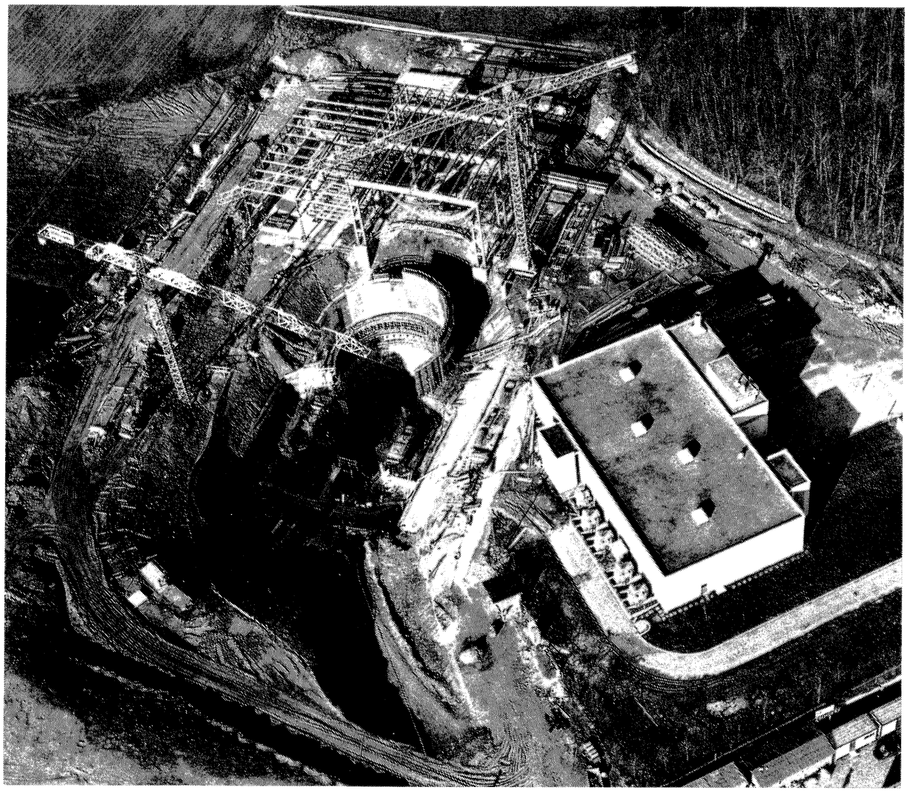
The first CERN plans, orchestrated particularly by Carlo Rubbia, emerged in 1976 following crucial advances in accelerator physics — the demonstration at Novosibirsk of Gersh Budker's idea of electron cooling, and at CERN of Simon van der Meer's proposal for stochastic cooling. These beam cooling techniques enable intense beams of stable particles to be built up, and thus make it feasible to do physics with colliding beams of antiprotons.

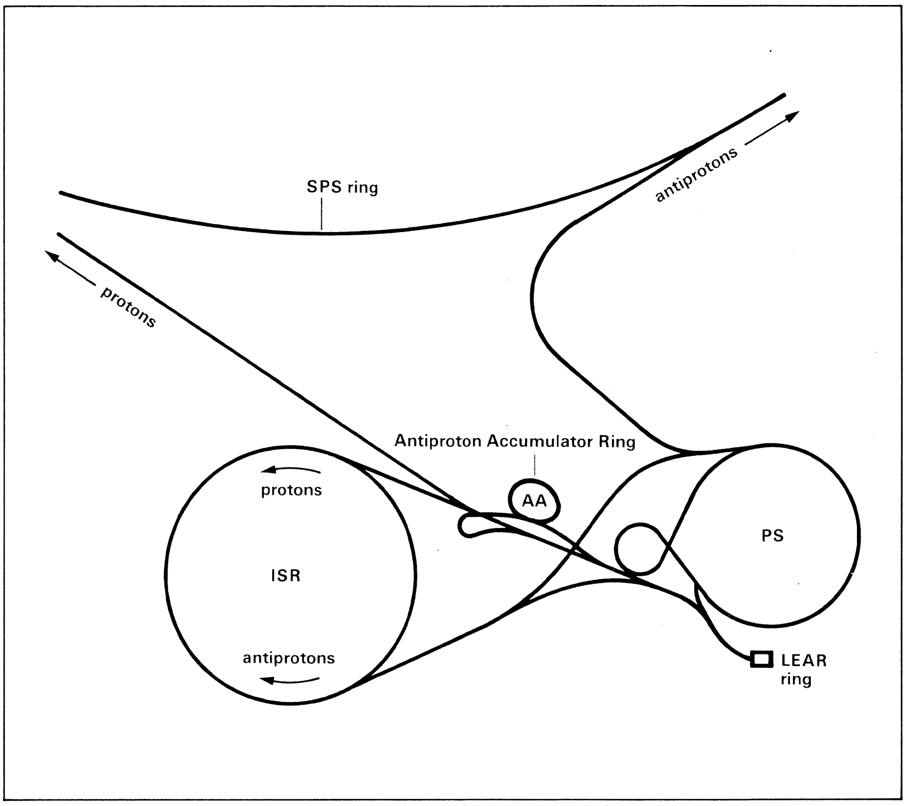
The system which is now under construction at CERN will take 10^{13} protons, at 26 GeV and concentrated in five bunches, every 2.4 s from the PS to yield 2.5×10^7 antiprotons at 3.5 GeV from a target for subsequent injection into the Antiproton Accumulator ring (AA).

In the AA ring a fast precooling (about a factor of ten in the beam spread over 2 s) will be carried out. The newly injected pulse will then be

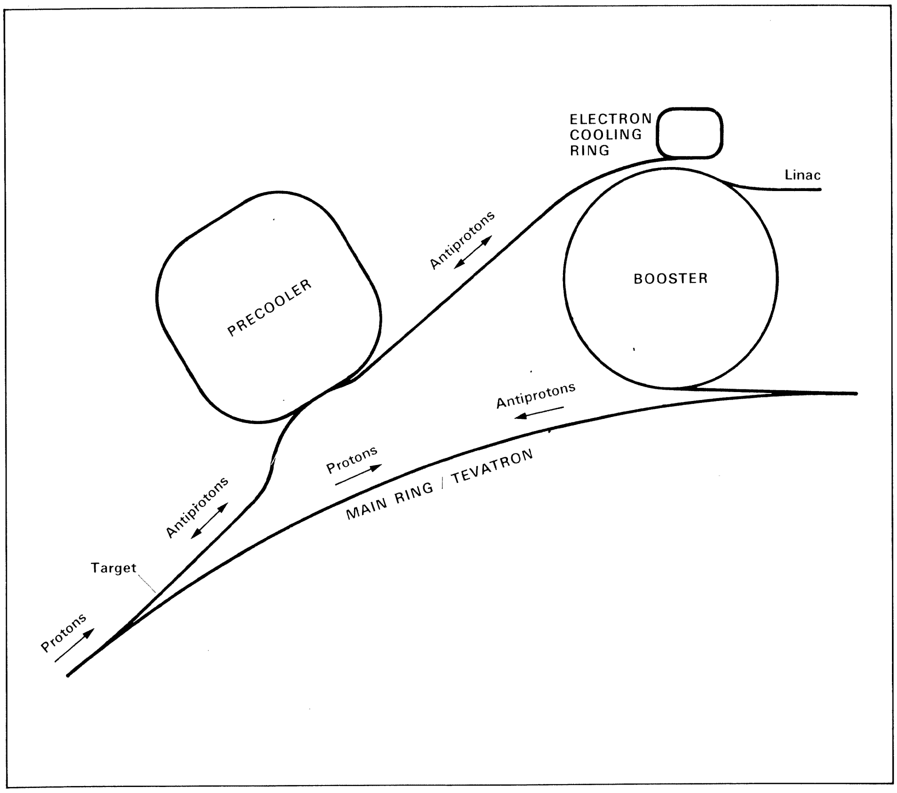
Work well under way for one of the experimental areas at the CERN proton-antiproton collider. The apparatus for the UA1 experiment will be assembled in the cylindrical shaft seen in the picture, and then rolled into position in a second shaft, to be excavated around the SPS tunnel.

(Photo CERN 104.2.80)





The components of the CERN proton-antiproton colliding beam scheme. Antiproton beams will be cooled and stored in the Accumulator and sent, via the PS, for experiments in the SPS and the ISR.



A plan of the Fermilab proton-antiproton colliding beam project. Two cooling rings are involved in producing a high intensity antiproton beam — the Precooler (using stochastic cooling) and the Electron Cooling Ring. With the superconducting Tevatron ring, collision energies of 1000 GeV per beam should ultimately be available.

moved into the storage region of the wide aperture of the AA vacuum chamber by lowering a shutter. In the storage region, stochastic cooling will achieve a further factor of 10^8 in cooling to build up an intense beam of antiprotons. Pulses of 6×10^{11} antiprotons will be drawn from the AA ring every 24 hours.

The 3.5 GeV antiproton beam will be sent to the PS for acceleration to 26 GeV before being transferred to the SPS, distributed in six bunches. Proton injection into the SPS will then take place and the two beams will be accelerated simultaneously to the energy selected for the experiments. In the stored beam mode this could be up to 300 GeV, once transformers in the power supplies are changed. The anticipated luminosity is 10^{30} per cm^2 per s. Two long straight sections will be modified for the installation of detectors for experiments with the colliding beams.

Provision is also being made to send antiprotons to the Intersecting Storage Rings, where the present detection systems can then study proton-antiproton collisions at up to 26 GeV. Because of lower energy physics interests, the PS will also be used to decelerate the antiproton beam from 3.5 GeV to 0.6 GeV for injection into an additional small Low Energy Antiproton Ring (LEAR) in the South Hall at the PS. LEAR could serve as a stretcher/storage ring, providing a much higher intensity of antiprotons in this energy range than has ever been available before (see September 1979 issue, page 260).

The Fermilab scheme

The possibility of colliding proton-antiproton beams at Fermilab was first indicated in a Harvard/Wisconsin proposal in 1976, with Dave Cline as spokesman. The latest plans were assembled in 'The Fermilab High Intensity Antiproton Source design report', presented in October 1979 by a group with participants from Argonne, Berkeley, Fermilab, Novosibirsk and Wisconsin. Given the different machine configurations and energies, etc., the Fermilab scheme has taken a considerably different form from that at CERN.

The overall aim is to achieve proton-antiproton collisions at a luminosity of 10^{30} per cm^2 per s, and to have collision energies as high as 1000 GeV per beam in the superconducting magnet ring of the Tevatron.

Preparations at Fermilab are by no means as far advanced as those at CERN, either in experimentation in cooling techniques or in machine construction. Nevertheless use of the Tevatron could follow on very logically from CERN's first years of experience in colliding proton and antiproton beams, and allow collision energies to be increased up to 2000 GeV in the centre of mass.

The antiproton beams will be produced through an intricate sequence. About 2×10^{13} protons per pulse will be accelerated in the Main Ring and ejected at 80 GeV towards an antiproton production target. The antiprotons will be collected at 4.5 GeV in a large aperture ring, called the Precooler, about the size of the present 8 GeV Booster. Here stochastic cooling will be used in several steps interspersed with deceleration down to 200 MeV, a process requiring several seconds. (Stochastic cooling was achieved at the Laboratory for the first time in February with the collaboration of machine physicists from Berkeley.)

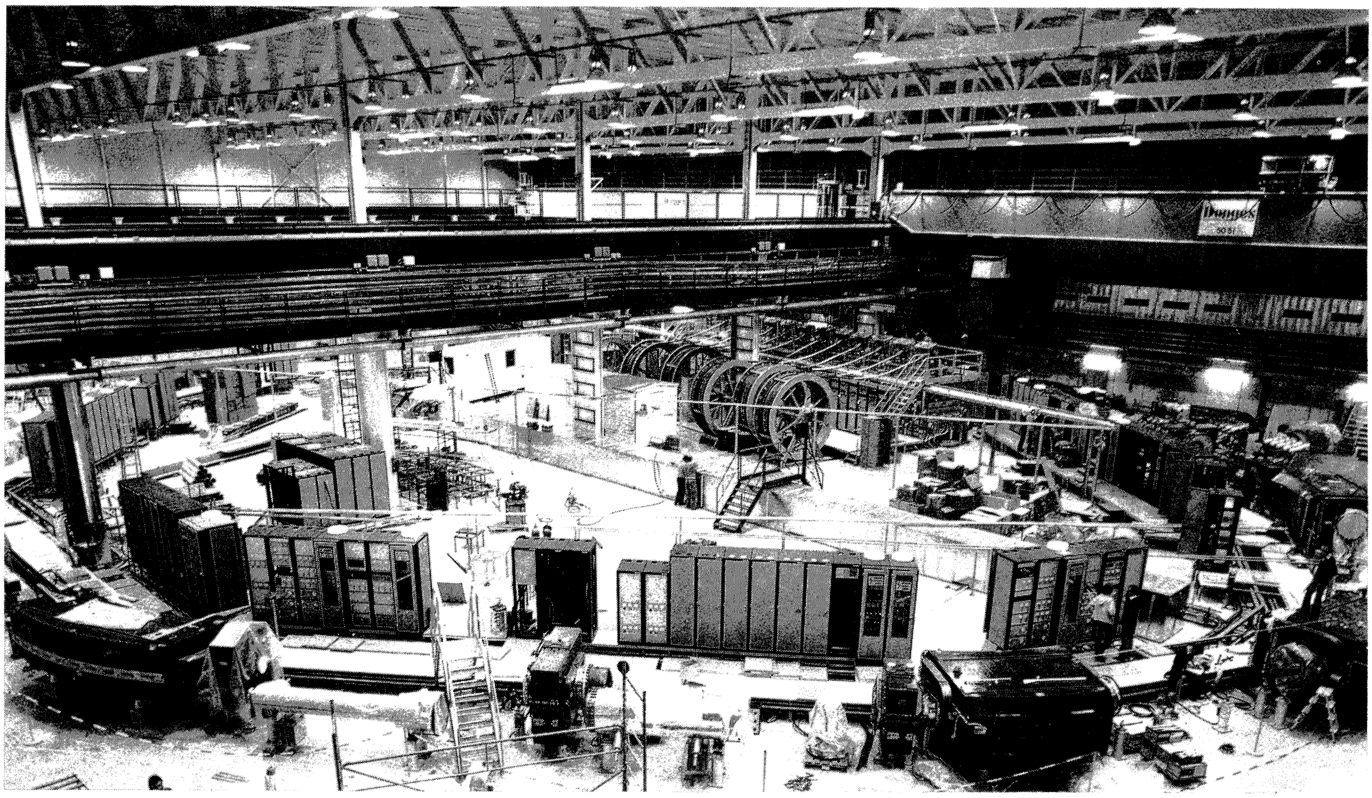
The 200 MeV beam will then be transferred to an Electron Cooling Ring where cooling will be carried out while antiprotons are added and stored. When some 10^{11} antiprotons have been obtained (a process which is expected to take about five hours), they will be transferred back to the Precooler, reaccelerated to 8 GeV and injected into the Main Ring — in the opposite direction, of course, to the protons.

Further acceleration will be carried out before transfer to the superconducting ring. Some 10^{12} protons will then be accelerated and fed to the superconducting ring, and both beams could then be raised in energy simultaneously and collided.

The scheme thus makes use of both types of cooling technique in situations where their application is appropriate. Stochastic cooling is most effective for high energy beams with large momentum spread, while electron cooling is better suited to low energy beams with comparatively small spread in momentum.

The Antiproton Accumulator ring (AA) approaching completion. The ring as been designed and built very rapidly to accomplish the most complex and crucial stage of the antiproton scheme at CERN.

(Photo CERN 258.4.80)



Preparations at the CERN SPS

The SPS has had to endure major civil engineering work at two straight sections, which are being enlarged to become colliding beam experimental halls, plus the construction of the new TT70 beam transfer tunnel. It also has to confront many machine physics refinements in order to achieve the design luminosity. The vacuum will be improved from 8×10^{-9} to 2×10^{-9} by the 'brute force' addition of more pumps. A special low-beta insertion has been designed to concentrate the beams in the collision region. The r.f. cavities will be applied two per beam; there may be a need to increase the r.f. voltage and the possible advantages of using standing wave cavities are under study.

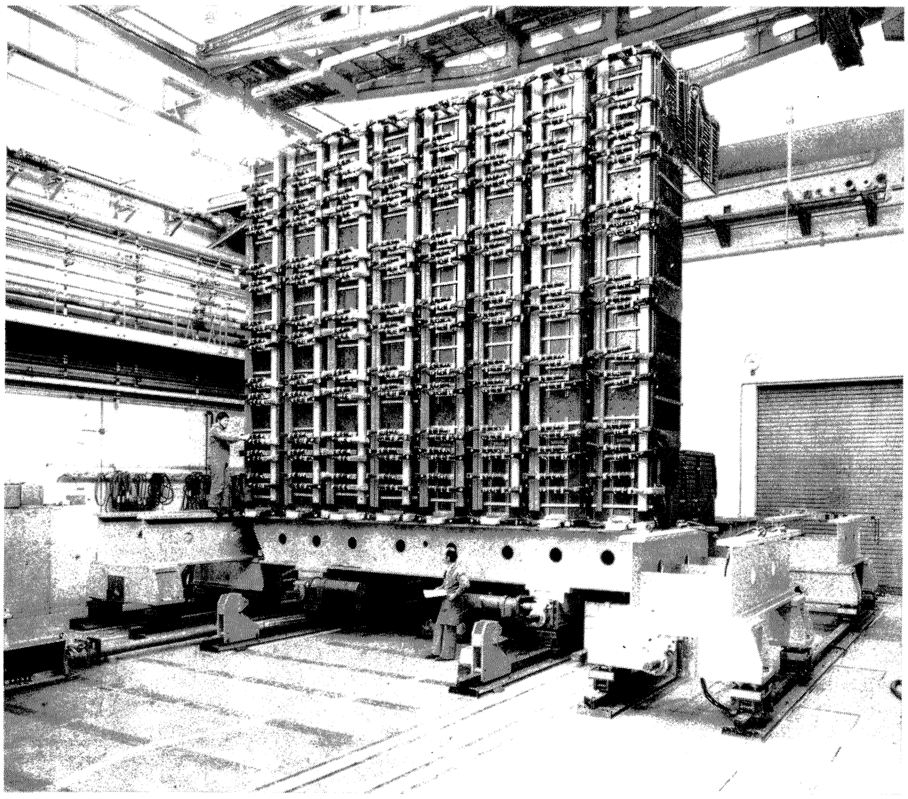
Machine physics studies have been carried out using the present proton beams injected at 10 GeV with 2.5×10^{10} protons per bunch, and stored at 270 GeV. These figures will change to 26 GeV and 10^{11} per bunch for proton-antiproton operation. Studies have been carried out on beam-gas interactions, on possible resonances, on instabilities, on simulation of the low-beta insertions and on r.f. noise. It was r.f. noise which initially looked like being a major problem, limiting beam lifetime to minutes in the first machine physics experiments. This is being overcome by reduced bandwidth and frequency spread which gives shorter bunches requiring higher r.f. voltage (hence the interest in standing wave cavities). By now, proton beams have been held for 18 hours.

The possible disturbance to the stored beams by beam-beam interactions is also being considered. Some practical experience can be gained by having a non-linear lens installed in the SPS to simulate one bunch of particles passing through another. In addition, computer simulation can be tried, but is very heavy on computer time. The large Cray computer at the Daresbury Laboratory is being used initially with data from the PETRA storage ring at DESY.

A lot of thought has gone into beam monitoring systems and three techniques will be used. Synchrotron light from the beams as they pass through discontinuities in the magnetic field is one novel method (see January/February issue, page 446). However it is limited at present to high energies (over 250 GeV) and requires a fairly intense beam. For the injection energy region, a rapid wire scanner will be operated (50 μm beryllium wire passing across the beam). In addition the Schottky scan technique, developed at the ISR, will be used.

Assembly of the 800 ton magnet for the UA1 experiment at the CERN proton-antiproton collider.

(Photo CERN 173.4.80)



The experiments at the SPS

The circulating proton and antiproton beams in the CERN SPS will be brought together at two intersection regions, situated in long straight sections LSS4 and LSS5.

At LSS5, the SPS tunnel is at its shallowest point below ground and the experimental area is being excavated from the surface. It will consist of two cylindrical shafts, 20 m in diameter and roofed over, with a connecting chamber.

LSS5 will be the home of the UA1 experiment, an Aachen / Annecy / Birmingham / CERN / London (Queen Mary College) / Paris (Collège de France) / Riverside / Rome / Rutherford / Saclay / Vienna collaboration. The large detector, weighing well over 2000 tons, will be assembled on rails in the 'garage' shaft. When complete it will be rolled into place in the second shaft and the vacuum chamber integrated into the SPS ring. The basic apparatus was described in the September 1978 issue, page 292.

Along with UA1, an Annecy/CERN team will be looking for signs of magnetic monopoles in a passive experiment, codenamed UA3, using plastic detector material wrapped inside and outside the beam pipe inside the UA1 apparatus. The kapton plastic will withstand the high vacuum bakeout.

The components of the main UA1 detector are gradually taking shape, and should be completely assembled in the 'garage' by the end of the year. The forward detectors will then be installed along the SPS beam pipe, and finally the outer muon detector will be completed early next year.

The central dipole magnet, itself weighing over 800 tons, was the first item of equipment to be ordered. It is now being assembled in the old 2 m bubble chamber hall at CERN and should soon undergo its first tests. Inside this magnet and surrounding the beam intersection will be the central portion of the detector, consisting of six shells of drift chambers with image readout. One of these shells is complete and the rest will soon follow. To minimize shower production in this region of the detector, a light honeycomb supporting structure is used, supplied by Concorde manufacturers Aerospatiale.

Surrounding the central detector will be the photon and electron detector, consisting of 48 'gondolas' of lead-scintillator sandwich. Hardware is being constructed at Saclay while Vienna takes responsibility for the electronics. This part of the detector will be closed by two 'bouchons' which are being built at Annecy. These use petal-shaped components rather than the arrangement of concentric circles originally planned.

The British contingent of the UA1 collaboration has a large investment in the hadron calorimeter which will be installed in the return yoke of the magnet. End-caps will close the effective volume. Sophisticated electronic trigger logic for UA1 is being developed at Rutherford.

Muons traversing all this apparatus will be picked up by an outer layer of drift tubes, which are the responsibility of Aachen. Assembled by Dornier in Germany, the total length of extruded aluminium for these tubes is longer than the vacuum chamber planned for the 30 km circumference LEP ring.

A lot of hadron energy will be released in narrow forward cones around the beam pipe, and this is covered by forward detectors, supplied by Collège de France, and magnets, supplied by CERN, to compensate for the dipole field in the central detector where the interactions occur. These will be installed around the SPS beam pipe on either side of the main UA1 apparatus. More forward energy will be picked up by 'very forward' detectors supplied by INFN Rome, placed further along the beam pipe.

Beyond these twin forward and very forward detectors will be the SPS low beta quadrupoles to squeeze the beams together in the intersection region. Even further out, some 23 m on either side of the main detector, will be further UA1 detectors, supplied by CERN and Riverside, to monitor beam luminosity.

The completed UA1 detector will have essentially a complete angular coverage for calorimetry — down to an angle of 10 mrad with the beams — and good muon detection capability. A number of novel features have been used in the development work, for example the image readout electronics of the central wire chamber, and a new cheap scintillator (see October 1979 issue, page 315).

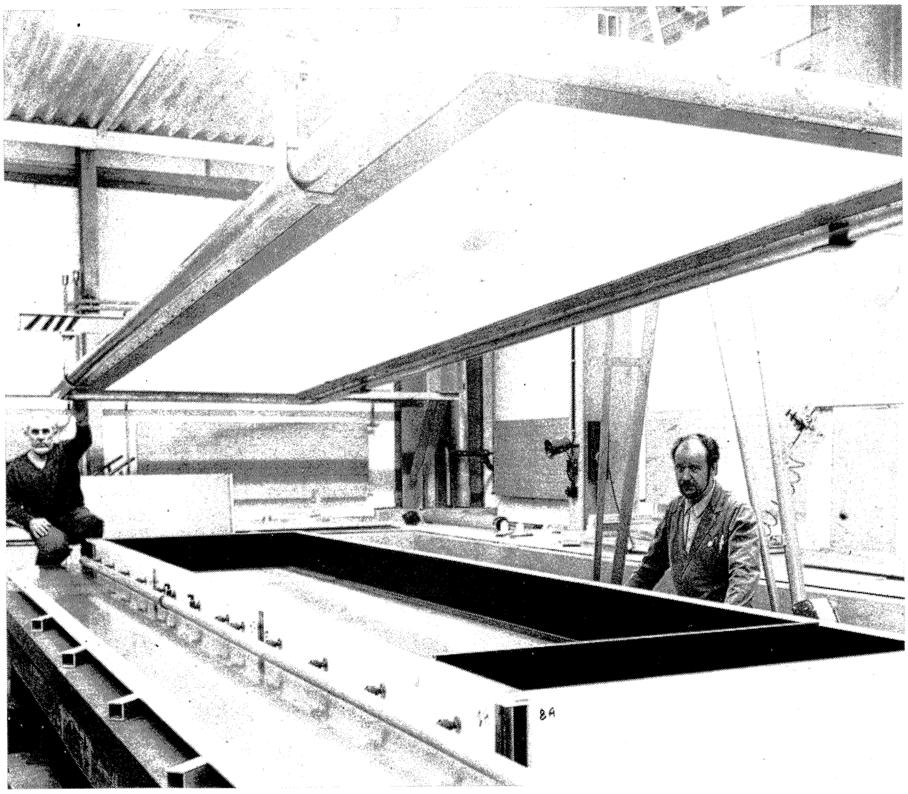
The central part of the UA1 apparatus will be assembled in the 'garage' early next year. When everything is ready, the UA1 vacuum pipe will be baked out and closed off ready for positioning in the SPS ring. In this way a minimum of high vacuum bakeout will be necessary at the last minute. The UA1 team is optimistic that good physics will follow soon after the first SPS proton-antiproton collisions.

The second collision area

The LSS4 intersection occurs at one of the deepest parts of the SPS, where the machine is 63 m below ground. A vast underground 'cathedral' is being excavated to house the experiments (see cover picture of April issue).

Assembly of one of the large streamer chambers for experiment UA5 at the proton-antiproton collider at the CERN SPS. The completed chamber has recorded stray muon tracks 6 m long — the longest particle tracks ever seen.

(Photo CERN 213.2.80)



The first experiment proposed for this intersection was that of the UA2 group, a Berne / CERN / Copenhagen / Orsay / Pavia / Saclay collaboration. The hunt for intermediate vector bosons figures high on the UA2 agenda, but the apparatus is also designed with a view to studying particle production at large angles and events with high transverse momentum. A description of the apparatus was given in the March 1979 issue, page 16.

The apparatus of the UA4 Amsterdam / CERN / Genova / Naples / Pisa collaboration, which will measure proton-antiproton elastic scattering and total cross-sections, is classified as a separate experiment, but will use the inner UA2 detector together with additional equipment housed in the two narrow forward cones of the UA2 apparatus. More obtrusive in the LSS4 underground experimental area will be the UA5 visual detector (Bonn / Brussels / Cambridge / Stockholm), using a streamer chamber to hunt for exotic events.

The idea is to have one of the two big experiments taking data in the colliding beams while the second is withdrawn into a shielded garage. Switching round the UA2 and UA5 experiments in the LSS4 pit deep underground will be a tricky business. The UA5 apparatus will have to be lifted up and turned round while UA2 is slipped underneath on air cushions.

The apparatus for UA2 is gradually taking shape at the participating Laboratories, and should go underground in the first few months of 1981, leaving some three months for assembly work.

With UA2, the emphasis is on electron detection and measurement. The inner vertex detector is being constructed at Orsay, and uses cylindrical proportional chambers with cathode strip readout, à la CELLO, interleaved with drift chambers. Work on this central part of the apparatus is progressing rapidly, and assembly on the surface will begin at the end of the year.

The central calorimeter surrounding the vertex detector is designed to achieve accurate energy measurements of both electromagnetic and hadronic showers and to provide good electron identification, despite the absence of a magnetic field. It will be composed of 24 'orange slices', using iron supplied by a Danish shipyard for the hadronic part, and lead-scintillator sandwiches manufactured in the CERN central workshop for the electron-photon part.

For the first experiments, a wedge will be left in the central calorimeter to accommodate a magnetic spectrometer. The magnet should arrive by October, and the instrumentation for this wedge already exists.

The forward and backward detectors will look for possible electron-positron asymmetries. The toroidal magnets for these should arrive later this year. Drift chambers for this part of the detector are being built by Pavia and Copenhagen. The original design has been extended by the addition of proportional tube chambers, supplied by Berne, for installation behind these drift chambers with the aim of improving electron localization. Calorimeters will provide accurate energy measurements of electromagnetic showers. They are being constructed at Saclay and a few sectors have already arrived at CERN. The supports are being built in Austria, and because of their size, delivery to CERN will test the capabilities of European road and water transport.

The measurement of the rise in the proton-proton total cross-section at higher energies was one of the first and most important physics results to emerge from the ISR. Laboratory energies available so far have been insufficient for us to see any similar rise in the total proton-antiproton cross-section.

Signs of an increasing proton-antiproton cross-section could be seen early on in ISR antiproton experiments which would parallel the early work with protons. However with colliding proton and antiproton beams at the SPS, the energies will cover the region in which the proton-antiproton total cross-section is expected to rise considerably.

Measurements of total cross-sections at the collider require separate determinations of elastic and inelastic event rates. The idea of the UA4 experiment is to use a technique which was very successful at the ISR. In addition, it will exploit the capabilities of the inner detector of the UA2 apparatus.

To measure elastic scattering, drift chamber telescopes will be mounted inside 'Roman pots' — sections of the vacuum chamber which can be moved vertically towards the beam. These pots will have steel 'windows' 0.1 mm thick. Four pots are to be installed on either side of the intersection region, two entering the beam region from above, and two from below.

The steep angular dependence of elastic scattering requires detectors with very good angular resolution. The precision of the UA4 drift chambers will allow a measurement of the scattering angle to within 0.015 mrad, comparable to the angular spread of the beams.

To measure the total inelastic reaction rate, the inner detector of UA2 will be complemented by UA4's drift chambers and scintillators, mounted in the two forward cones so as to maximize angular coverage.

As well as immediately adding to our knowledge of hadrons, the measurement of proton-antiproton cross-sections at the SPS collider energies would also complement proton-proton data which will eventually emerge from the ISABELLE project at Brookhaven.

The visual detector

The UA5 detector, which will share the LSS4 experimental area with UA2, uses two giant streamer chambers, each 7.5 m long, which will be mounted immediately above and below the beam pipe. It will be triggered by big external scintillator hodoscopes.

This unique detector will provide the first direct visual records of the interactions at an energy range far beyond anything ever reached before in a Laboratory, and hopes to see evidence of the strange multiplicity patterns reported by high energy cosmic ray experiments (see June 1979 issue, page 155).

One of the UA5 streamer chambers is already complete and has recorded stray muon tracks 6 m long — the longest particle tracks ever seen. It will soon be installed for extensive testing in Intersection 7 at the ISR where its external scintillator detectors are already waiting.

Later this year the second streamer chamber will be ready and the full apparatus will take some photographs of proton-proton interactions in the ISR. The detector should also be in position to record the first proton-antiproton interactions in the ISR early next year.

Subsequently, the apparatus will be transferred to its home at the SPS and mounted on its 10 m high support structure. As luminosity is not important for a first general search, UA5 will be placed in position in the SPS ring ready for the first tests with colliding proton and antiproton beams.

The apparatus will be behind 5 m of removable concrete shielding, with exposed film being extracted through 25 m of specially-constructed ducts. Outside, the experimenters will be eagerly awaiting the results of these first interactions.

Initially, the triggering system will not be selective, and a hit in any of the 128 external hodoscope modules will produce a photograph. In this way UA5 could tell us what is going on in this new energy range even before physics runs begin in earnest.

At the end of the antiproton machine development run, UA5 will be taken out of the SPS and UA2 will take its place, ready for the first scheduled run for collider physics.

Although having to contend with a crowded schedule of installation and testing, the UA5 team has the promise of a quick return on investment for antiproton physics both at the ISR and the SPS.

Preparations at the ISR

Two initial options were open at the Intersecting Storage Rings — either to take 3.5 GeV antiprotons direct from the Accumulator and accelerate them in the ISR, or to store 26 GeV antiprotons previously accelerated in the PS. The second option was chosen as it exploits to the full the ISR's unrivalled storage capabilities, and promises higher luminosities. In fact an antiproton luminosity of nearly 10^{30} per cm^2 per s could be achieved using a superconducting high luminosity insertion to compress the beams. This figure is comparable to the original design luminosity for protons!

The decision to feed the ISR with 26 GeV antiprotons required the construction of the new TT6 transfer tunnel to take antiprotons from the PS to the ISR. This work is substantially complete (see March issue, page 17).

Operation with 26 GeV antiprotons in one ring and protons in the other will be essentially the same as for colliding proton beams, except that antiproton pulses would be received about once per day, rather than every few seconds. After accumulating about five antiproton pulses, the ISR would continue running for as long as would be useful.

Some slim dipoles, with apertures larger than their core lengths, have been designed for steering the beams. The monitoring and control systems for the antiprotons in Ring 2 are being modified to handle the low-intensity pulses.

Stochastic cooling systems are being installed to protect the beams against the otherwise inevitable growth in size due to intra-beam and gas scattering and consequent luminosity loss.

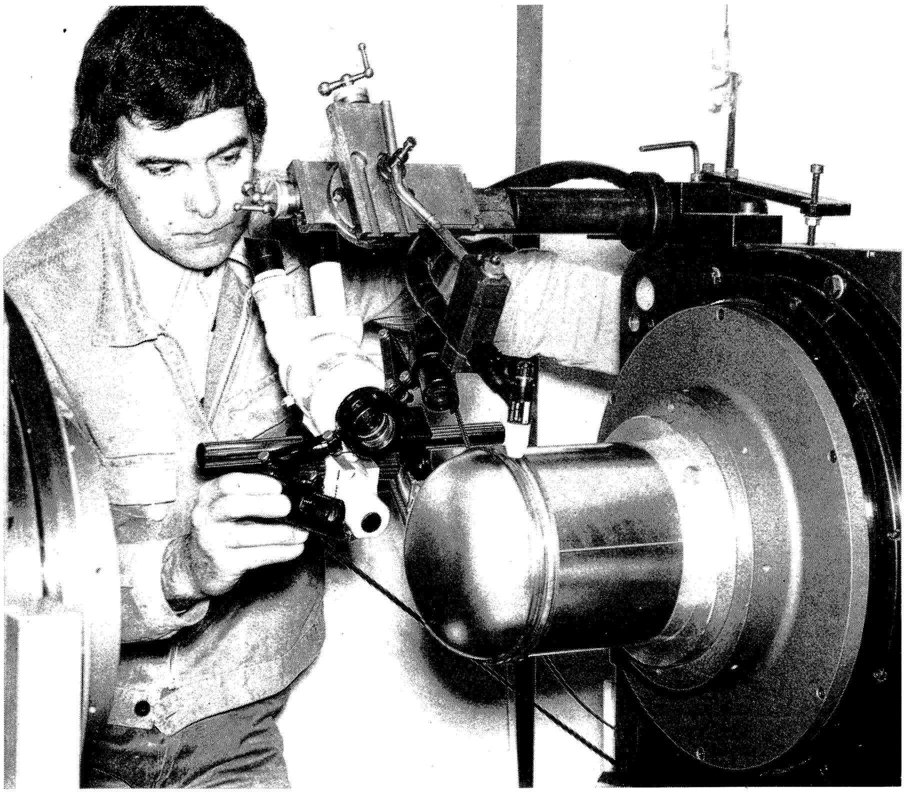
The existing experimental microwave stochastic cooling system in Ring 2 is being transferred to Ring 1 to handle proton stacks, while a simpler system, operating at lower frequencies, is being installed in Ring 2 for the antiprotons.

Because the accumulation of antiprotons will be a slow process, long physics runs of up to ten days are being considered, and it is here that the cooling systems will become specially important. Cooling may also compress the beams to give a useful luminosity bonus.

The scarcity of antiprotons also makes the normal method of ISR injection optimization impractical. This problem will be partly overcome by an active feedback system which

Jacques Haffner making a 'Roman Pot' for an experiment at the CERN ISR. Using such precision-made components, the first ISR experiments some ten years ago gave fresh information on the behaviour of the proton. The plan is to use Roman pots in the first antiproton runs in the ISR.

(Photo CERN 24.5.80)



will damp the beam oscillations after injection while they remain coherent.

Additional work is also required on the existing detectors. The vacuum chamber of the large Split Field Magnet at Intersection 4, for example, is being modified to take the new colliding beam profile. In this way, existing detectors will be able to monitor the proton-antiproton collisions.

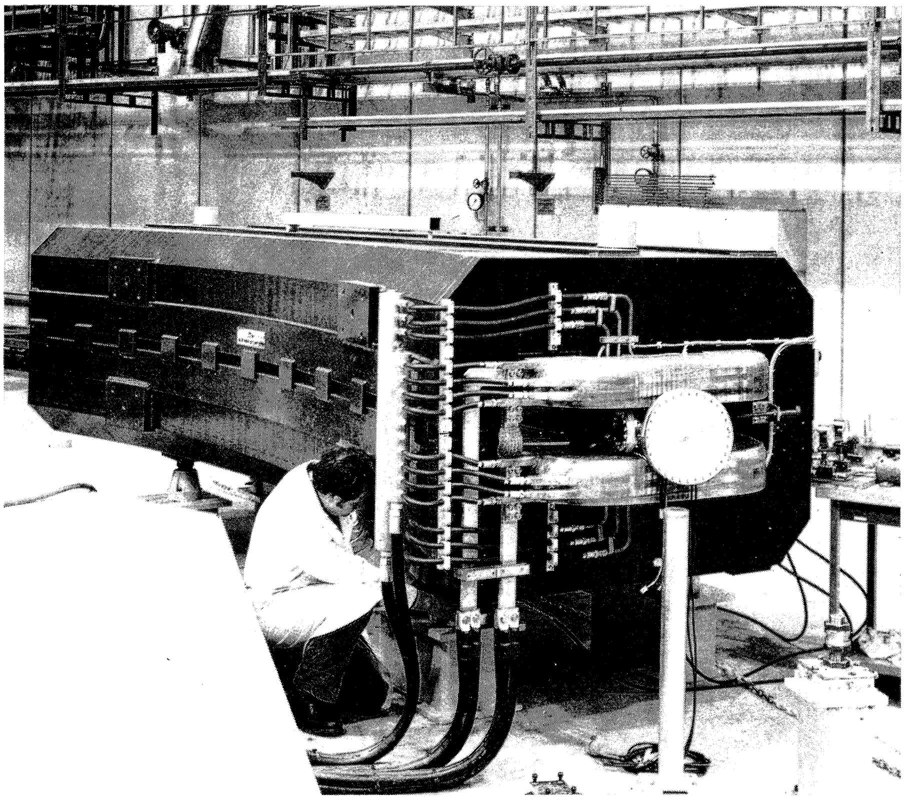
In addition, 'new' experiments are being prepared for Intersection 2 to measure the proton-antiproton total cross-section. One of these will use a suitably modified system of the 'Roman pots' which gave fresh information on proton structure in a new energy range in the first experiments at the ISR, nearly ten years ago. Roman pots are also to be used in one of the antiproton experiments at the SPS.

ISR antiproton data should be available soon after the first runs next year of the machine in its new role. The initial comparison of proton-proton and proton-antiproton data at these high collision energies will be eagerly awaited.

Preparations at the PS

The preparations for antiproton beams 'in and around' the PS can be divided into three parts — the role of the PS itself, the Antiproton Accumulator ring, and the LEAR ring.

The PS has a dual role to play. First it has to provide appropriate beams for antiproton production. This involves vertical combination of bunches of protons from two rings of the Booster (giving ten bunches circulating in the PS) followed by r.f. gymnastics to combine bunches longitudinally so as to send five bunches to the AA ring. The second role is the acceleration of these antiprotons from the AA ring from 3.5 to 26 GeV before sending them to the SPS (and the ISR). This again involves some delicate manoeuvering of the r.f. to convert the long bunches from the AA ring to fit into the short r.f. 'buckets' in the SPS.



One of the bending magnets of the AA ring. Note the very large aperture where the intense beam of antiprotons will be accumulated and stochastically cooled.

(Photo CERN 49.3.80)

The addition of the PS in this second role is a complication because it adds a further machine to the antiproton acceleration cycle. However it does greatly ease injection problems into the SPS, makes it much easier to have intense beams in the ISR at high energies, and also makes it possible to have LEAR.

The AA ring is the crucial element of the whole CERN scheme. It is one of the most complicated machines ever to be built, and yet is being put together on schedule in less than two years. Authorization for its construction in the context of the proton-antiproton project came in June 1978, following the spectacularly successful cooling experiments in the ICE ring (see for example January/February issue 1978, page 12). The AA ring is scheduled for completion by July of this year. At that time we will be covering in some detail its most unusual ring configuration and sequence of operation.

The present AA schedule aims to start commissioning with protons from the PS in July and August — carrying out target heating tests, checking the operation of the ring systems and beginning to master the machine performance. By the end of the year, the first cooling tests with antiprotons will have been conducted. From early next year, beam stacking and transfer will begin. With luck, antiproton beams will be in the ISR in March and the SPS in June.

On 8 May, the CERN Executive Board approved the financing of the LEAR ring to provide for experiments with intense beams of low energy antiprotons. The interest in this development was highlighted at a 1979 Karlsruhe Workshop on Physics with Cooled Low Energy Antiprotons (reported in the June 1979 issue, page 148), where as many as 76 papers on the physics and technical aspects of LEAR were presented.

In contrast to the wealth of data available on low energy nucleon-nucleon interactions, information on low energy nucleon-antinucleon behaviour is still sketchy. In addition, the annihilations possible when particles and antiparticles pass close to each other would provide a good probe of the inner nucleon structure.

The low energy nucleon-antinucleon system is also a unique link between two types of physics not normally considered together — the (usually) non-relativistic picture of nuclear behaviour and the description of the nucleon in terms of its quark constituents. New experiments would also be possible with exotic atoms in flight.

Beyond the immediate goal of fixed target experiments, collision of low energy proton and antiproton beams in LEAR would open a new door in particle spectroscopy. In all, LEAR promises a fruitful programme of physics in an as yet relatively unexplored area.

LEAR will be built in the South Experimental Hall at the PS, receiving antiproton beams decelerated to 0.6 GeV via a beamline passing through the old linac building. A link with the linac would also allow proton and negative hydrogen ion injection quite separate from antiproton operation or even normal PS operation. The 'ring' will be square in form, with an r.f. system which can accelerate or decelerate the stored beam over the range 0.1 to 2 GeV. The significant contribution of LEAR is that it will provide antiproton beams of a purity, intensity, duty cycle and momentum definition far better than anything which has been available before. Experiments on the machine are likely to improve presently available experimental statistics by factors of a thousand to a million.

In the first half of the 1980s, Europe's particle physicists are likely to be leaning hard on the unique research possibilities opened up by high intensity antiproton beams at CERN. The production of such beams in itself will be a remarkable achievement of machine physics which would have been unthinkable only a few years ago. From the point of view of the particle physics and of the machines, the project should ensure plenty of excitement for several years to come.

Around the Laboratories

CORNELL

CESR crosses the threshold

The two experiments at the new Cornell Electron Storage Ring (CESR) have evidence for a new upsilon resonance in electron-positron annihilations whose relatively large width indicates that it can decay in new ways — probably into two mesons carrying equal and opposite 'beauty'.

The upsilon resonances, discovered at Fermilab in 1977, are interpreted as bound states of the fifth (beauty) quark and its antiquark, and so have 'hidden beauty'. However the quark binding energies preclude the first upsilons from decaying into mesons carrying 'naked' beauty.

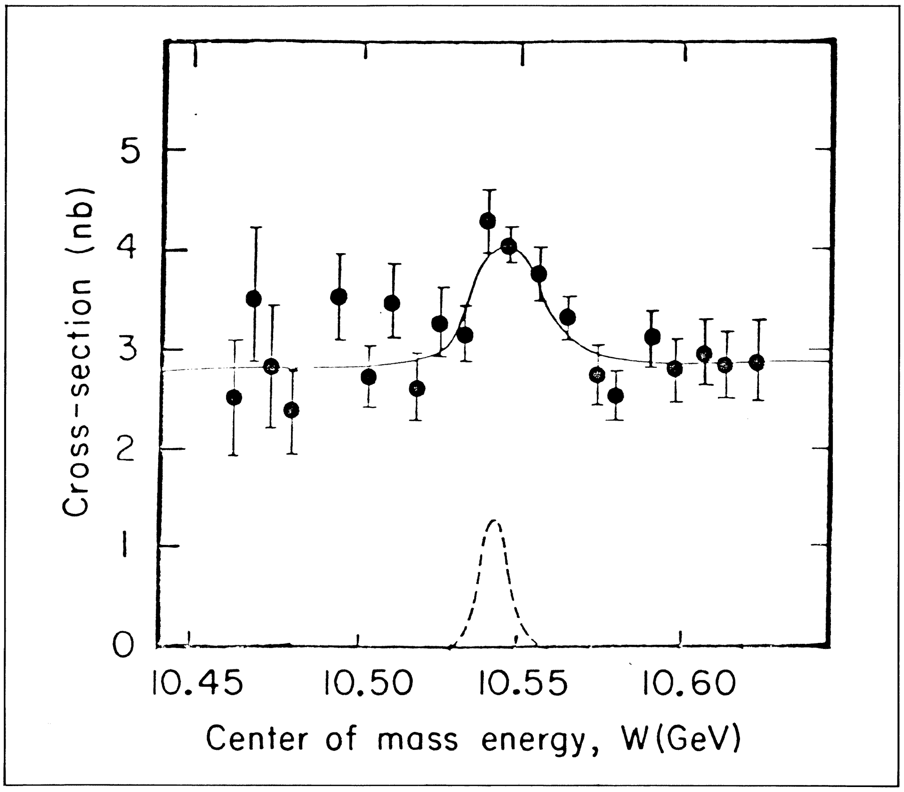
The first upsilons can of course decay in other ways, but are reluctant to do so since this means getting rid of their beauty quarks by annihilation. They appear therefore as exceptionally stable particles with narrow resonance widths.

In addition to these stable upsilons, there should be a whole spectroscopy of particles made up of beauty quarks and antiquarks, and at some excitation energy the upsilons should be able to start decaying easily into meson pairs carrying equal and opposite beauty.

(A similar phenomenon happens with the psions, which are made of charmed quarks and antiquarks. The J/psi and other light psions cannot decay directly into charmed meson pairs and are much more stable than the heavier psions which can decay in this way.)

During runs in November and December of last year (see March issue, page 3) the CLEO experiment (Cornell / Harvard / Rochester / Rutgers / Syracuse / Vanderbilt) and CUSB (Columbia / Stony Brook) observed the first two upsi-

Measurements of the total hadronic cross-section from the CLEO experiment at the Cornell Electron Storage Ring, CESR, showing the fourth upsilon resonance. The dashed curve corresponds to CESR's energy resolution. The relatively large width of this upsilon indicates that the resonance probably lies above the threshold for production of beauty mesons.



lons — the upsilon and upsilon prime, first seen at Fermilab and later confirmed at DORIS. Also at CESR, the third upsilon, the double prime, was seen for the first time in electron-positron annihilations.

The upsilon mass splittings and relative rates for decays into leptonic final states agreed with calculations for beauty quarks bound by a simple potential. The widths of these first upsilon resonances were consistent with CESR's energy resolution, indicating that the real widths were even smaller, corresponding to very stable particles.

The established parameters from these calculations predicted the next upsilon to be very close to the expected threshold where decay into pairs of beauty mesons becomes possible. The width of this upsilon depends crucially on whether it is above or below this threshold.

During the December run, the two experiments did a preliminary scan of the 10.6 GeV region where the next upsilon was expected, and had indications that something was happening in the total cross-section.

After a shutdown in January in which various improvements were made to the machine, including the addition of electrostatic separator plates to improve the electron injection rate, the search for the next upsilon continued. During the next six weeks the machine ran very well, with integrated luminosities of over 50 nb^{-1} per day.

Both experiments confirmed a new state 1112 MeV above the first upsilon (9460 MeV). This mass split and the ratio of the decay rates into electron-positron pairs were consistent with the predictions of the quark potential model.

Both groups found the newest upsilon to have a width near 10 MeV, while the energy resolution of CESR at this energy is 4.7 MeV. This indicates that the threshold for decay into pairs of beauty mesons has been crossed, so that the new upsilon is much more unstable than its lighter predecessors.

Fixing the threshold for production of pairs of beauty mesons between the third and fourth upsilons gives an indication of the mass of the lightest beauty meson. During the next CESR run, the hunt will be on for beauty mesons.

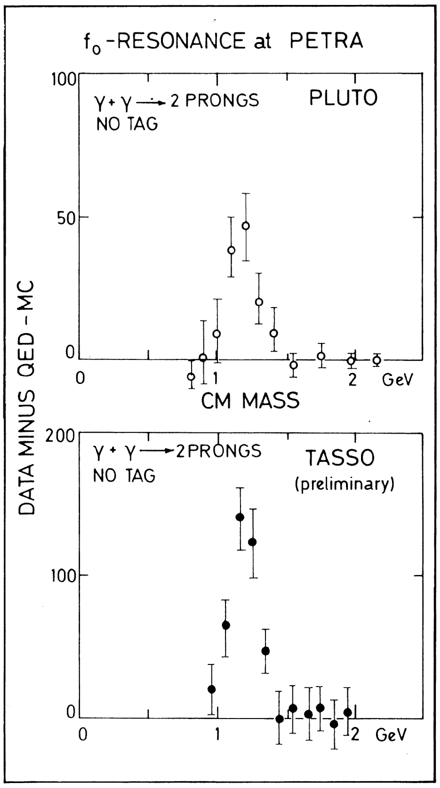
First evidence for beauty mesons came last year from a CEN-Saclay/Imperial College London/Indiana/Southampton group working at the SPS, who saw a resonance near 5.3 GeV in the mass spectra of particles produced by high energy pion beams (see September 1979 issue, page 249).

DESY
Two-photon physics

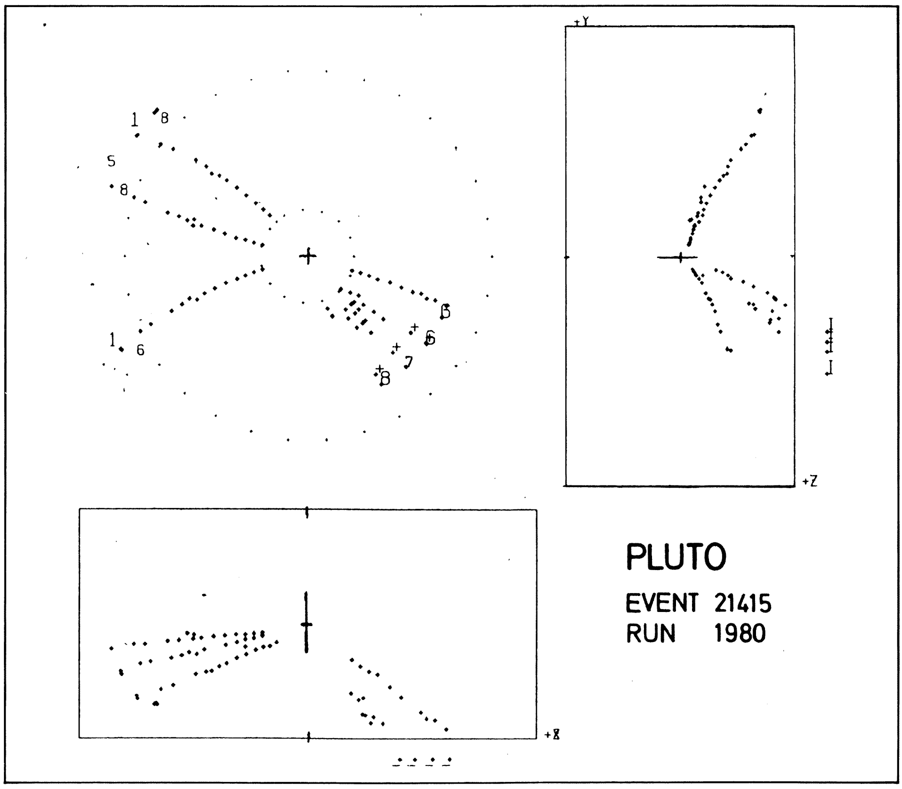
After the interesting results on three-jet events observed in electron-positron annihilation which provided first evidence for gluon-bremsstrahlung (see November 1979 issue, page 358), now photon-photon interactions have been studied using high energy data from PETRA. They take place when the colliding particles are slightly deviated (emitting a virtual photon each) but do not annihilate. Data collected by the PLUTO, TASSO, JADE and MARK-J collaborations on this topic were discussed in a workshop organized by the University of Amiens (France) from 8–12 April.

The PLUTO group (PLUTO has now been replaced by CELLO at PETRA) put from the beginning of their measurements at PETRA a strong emphasis on the study of two-photon reactions. In fact, they

The f^0 meson created in photon-photon collisions decays into two pions which are observed in the detector while the electron and positron generating the reaction escape through the beam-pipe at angles smaller than about 1°. The f^0-signal is observed in the plot of the invariant mass of the two observed particles (assumed to be pions) and is shown after subtracting the smooth background of two-prong events arising from electromagnetic processes.



Three projections of a two-jet event produced in a photon-photon interaction observed in the PLUTO detector.



presented at Amiens an interesting set of results on several different aspects of this promising field of high energy physics. First they measured the cross-section for the formation of the f^0 (1270) meson in photon-photon collisions.

Obviously all resonances decaying into two photons can also be produced by the inverse mechanism in the collision of two photons and the probability for such a process is then expressed by its 'radiative width'. At lower energies and using the same procedure, the radiative width of the eta prime (958) meson was determined last year by the MARK-II collaboration at SLAC. The PLUTO group presented the first evaluation of the radiative width of the f^0 (1270) meson. The value obtained is 2.3 ± 0.5 keV.

Data on the production of electrons and muons via two photons were also presented. The results are in excellent agreement with quantum electrodynamics calculations. These facts, as well as the observation of the f^0-meson, have provided the necessary confidence in the methods used for the analysis of photon-photon interactions. The main interest is now concentrated on the analysis of interactions yielding several hadrons. The total cross-section for hadron production has been determined earlier in the energy region from 1 to 8 GeV by the PLUTO group and is now also provided by TASSO. At the higher energies it has a fairly constant value of about 300 nb and can be understood with usual Regge pole models. At the lowest energies there is an excess of events which must be explained by some other mechanism.

An exciting result presented at Amiens was the evidence from PETRA experiments for two-jet events generated by the two-photon mechanism. As it should be in the collision of two photons of different energy (both nearly parallel to the beam), the two jets are coplanar but not collinear. The features of these jets are very similar to those observed in normal electron-positron annihilation at lower centre of mass energies. The hypothesis that these jets are the fragmentation products of quark-antiquark pairs is strongly supported by the distribution of transverse momenta of the single final decay particles. It presents a long tail which may be due to the quark-antiquark events. The conclusion is therefore that two photons can 'annihilate' into two quarks, establishing the fact that photons do not only interact like rho mesons as described by the vector meson dominance model, but also have pointlike particle properties.

Meanwhile effects due to photon-

photon interactions have been seen in proton-proton collisions at the CERN ISR. A CERN / Harvard / LAPP / MIT / Naples / Pisa collaboration, studying the production of heavy muon pairs in association with hadrons, has picked up about 100 dimuon events where no additional hadrons are produced. The corresponding cross-section agrees with what is expected from photon-photon interactions. This is the first time that evidence for photon-photon effects has been seen in hadronic experiments. As the two-photon process becomes more important at higher energies, this indicates that two-photon processes could be studied at high energy proton-antiproton colliders.

CERN/ RUTHERFORD Holography for bubble chambers

One of the limitations in bubble chamber physics has been to obtain good spatial resolution of the bubble (and hence particle track) position while also retaining good depth of field for the photographs, so that tracks could be accurately located over most of the volume of the bubble chamber liquid. A possible solution to this problem is to use the technique of holography.

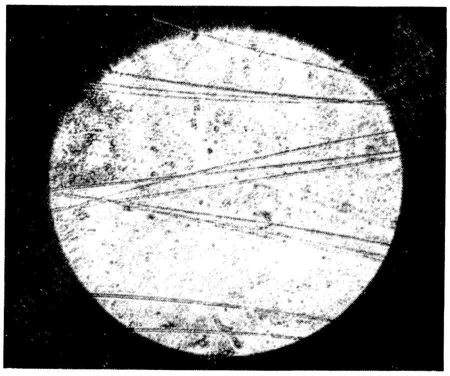
Holography, first conceived by Denis Gabor in 1948, records all the light coming from a scene and thus captures on film more information than the human eye can normally extract from the scene. As opposed to normal photography, this information is three-dimensional. Holograms became feasible when lasers were invented, providing usable intensities of light of a single wavelength. Holograms using normal white light are blurred because of the multi-wavelength nature of the light.

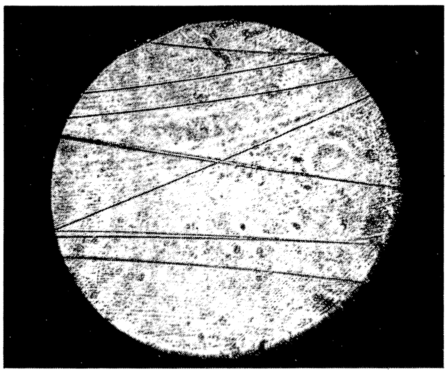
The first person to expound the potential of holography in bubble chamber physics, to the best of our knowledge, was the well-known optics specialist Walter Welford from Imperial College London who wrote a paper on the subject in 1965 (which appeared in 'Applied Optics' May 1966). At that time, however, bubble chambers were escalating in size to contain liquid volumes of many cubic metres. Holograms of such volumes were too technically difficult to contemplate.

Two factors have swung attention back onto this subject in recent months. The first is the fashion change in bubble chamber physics towards small rapid cycling chambers used as vertex detectors in hybrid systems with electronic detectors. The second is a physics interest which can be met by higher resolution. The charmed mesons, such as the D mesons, have lifetimes in the range of 10^{-12} to 10^{-13} s which is just tantalizingly beyond what can be seen with the resolution available in conventional bubble chamber optics. If resolution could be improved by some two orders of magnitude the special abilities of bubble chamber physics could be brought to bear on the particles composed of charmed and bottom quarks.

Another attraction of holography for bubble chambers is that a hologram can store many thousands of times more information than a conventional photograph. It would be possible to spread incoming particles over several planes separated by a few millimetres (enough to avoid tracks from interactions crowding on top of one another) and thus make use of the whole chamber volume. This would increase the event rate and allow the rarer interactions to be studied.

1, 2 – *Photographs of 5 μm fibres in two different planes, extracted from a hologram taken by the Rutherford /CEGB collaboration studying the application of holography in bubble chambers.*


1.

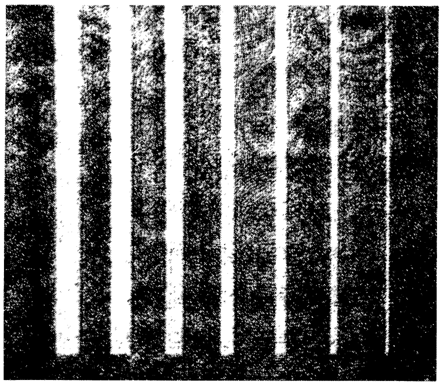

2.

During the course of last year, in the USA, Fred Eisler wrote a (rather optimistic) paper in Nuclear Instruments and Methods about the potential uses of holography in bubble chambers and at Fermilab Walter Welford helped develop ideas with Wes Smart and Lou Voyvodic about possible applications in the 15-foot chamber. In Europe, practical work started at Rutherford, prompted by Colin Fisher and Peter Smith, and at CERN by Malcolm Dykes and Paul Lecoq with Derek French.

In the Rutherford and CERN work the immediate aim is to achieve a spatial resolution of a few microns while retaining a depth of field of some tens of centimetres. Such a system might well be immediately applicable in the new generation of small bubble chambers such as

3 – A line of wires photographed from a hologram taken at CERN. The smallest, which is still clearly distinguishable, is only 2 µm in diameter.

4 – Also from the CERN work — a line of 10 µm data simulating a bubble chamber track. Such tracks can be identified with such clarity over a depth of field of up to 16 cm. On this scale, a BEBC bubble would show up the size of an orange.



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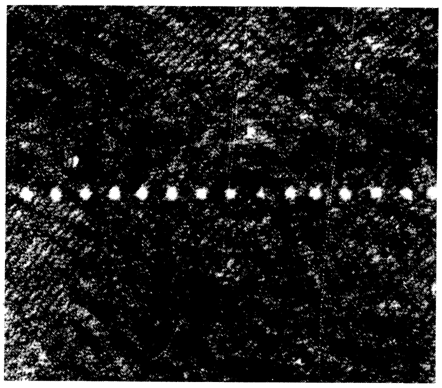


4.

BIBC and LEBC (see April issue, page 58). For comparison, in the 3.7 m Big European Bubble Chamber, BEBC, the bubble size is some 500 microns with a depth of field of several metres.

Rutherford Laboratory holograms have been taken of arrays of 5 µm glass fibres immersed in a liquid whose refractive index was different from glass by a factor of 1.1. This simulated the optical properties of gas bubbles in liquid hydrogen. The location of the 5 µm fibres could be very clearly reconstructed from the hologram.

This work was done in collaboration with CEGB (Marchwood) using a c.w. argon laser and an off-axis reference beam. Experiments are planned at Rutherford itself using larger scale track simulations (up to 20 cm). The experiments will look at such effects as turbulence in the liquid and how to optimize the optical system to overcome the effects. They will also study various possibilities for reprojecting and scanning the three dimensional image.

At CERN clear resolution down to 2 µm has already been demonstrated over depths of field up to 16 cm and a field of 7 cm. Planes of wires, centimetres apart, can be easily picked out when scanning the holograms through a microscope coupled with a TV system. Following such encouraging results, it is hoped to carry out a preliminary test of the technique on BIBC before the big SPS shutdown, in collaboration with Berne and the Institut Saint-Louis (Mulhouse).

Before moving to true operational systems, more development work needs to be done. It will be necessary to use a pulsed laser (some 20 ns pulse length) rather than the c.w. laser to fight the problem of vibration and to 'freeze' the rapidly growing bubble while it is still small. Fortunately suitable lasers, with repetition rates of 20 to 50 Hz, are already available commercially.

ARGONNE

Ultracold neutrons at ZING-P'

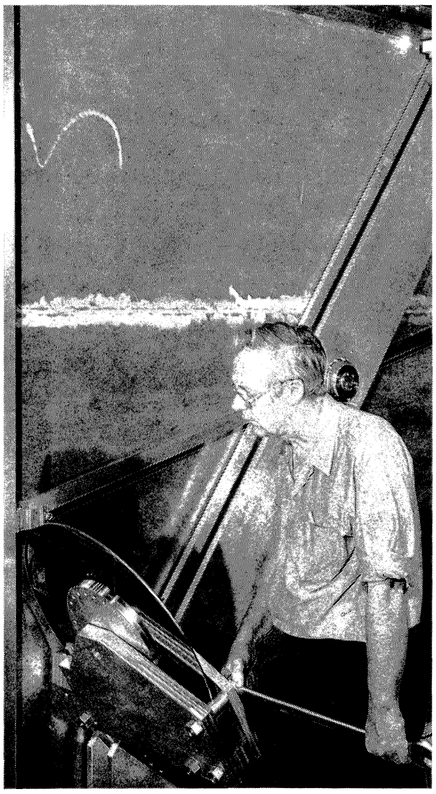
Physicists from an Argonne / Chicago / Maryland / Missouri collaboration have operated a new source of ultracold neutrons using the Argonne ZING-P' pulsed neutron spallation source.

There has been considerable interest in ultracold neutrons (with velocities less than 7 m/s and wavelenghths of about 1000 angstroms) due to the possibility of containing them for long periods in material 'bottles'.

These stored neutrons can be used to perform such fundamental experiments as the search for the neutron electric dipole moment (see for example November issue 1979, page 364).

The Doppler-shifting rotor which was used in producing ultracold neutrons at Argonne. The rotor arm, with a crystal package mounted on the end, is 1.2 m in radius and operates inside a vacuum box. The shutter mechanism that closes the bottle entrance between pulses consists of a polished disc with a slot cut in it, rotating synchronously with the rotor.

(Photo Argonne)



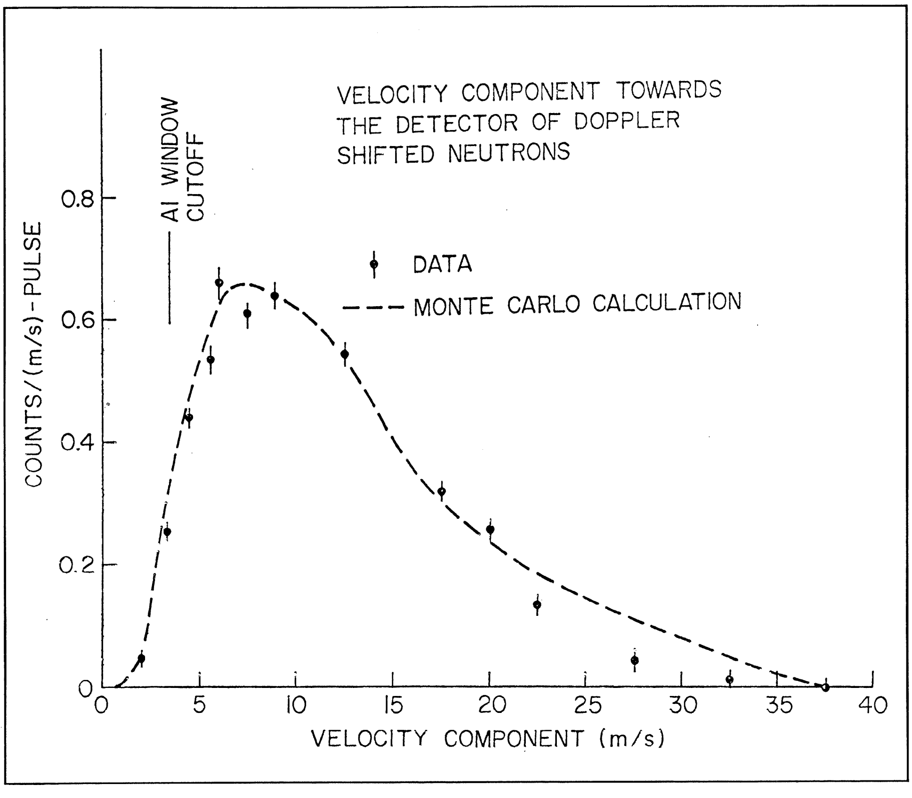
The new ultracold neutron source exploits the pulsed nature of the neutron beam from ZING-P'. Neutrons in the incident pulse with velocities near 400 m/s (wavelength 10 angstroms) are Bragg-reflected off a crystal moving at a velocity near 200 m/s and in the process are Doppler-shifted into the ultracold velocity range.

The crystal consists of a package of synthetic mica slabs separated by thin aluminium wedges which artificially increase the mosaic widths of the package and allow a larger velocity spread to be reflected.

The synthetic mica was chosen for its high neutron reflectivity and large interstitial spacing (about 10 angstroms). The package is mounted on the end of a 1.2 m radius rotor rotating in the direction of the incident neutrons and synchronized to the 30 Hz pulse rate of the ZING-P' beam.

The reflected neutrons enter a container through an opening that is closed between pulses to prevent neutrons escaping. This permits the bottle to be filled over a number of pulses to an asymptotic density which equals that in the incident pulse, so that the density is determined by the peak flux in the incident beam. The ultracold neutron density at ZING-P' has been measured to be 0.12 per cm^3, which is the same order of magnitude as the densities recorded at steady-state reactors.

The velocity spectrum of reflected neutrons at Argonne's ZING-P', measured by a time-of-flight method. Only one velocity component is shown, so only 70 per cent of the neutrons below 7 m/s are ultracold. The dashed curve is a computer simulation of the Doppler-shifter. The detector was insensitive to neutrons below 3 m/s because the aluminium window over the counter reflected lower velocity neutrons.



One advantage of having an ultracold neutron source at the pulsed neutron facility is that higher stored densities should be available in the near future when more intense pulsed facilities become operational. It is doubtful that much higher thermal fluxes will be possible from steady-state reactors due to heat transfer limits and construction and operating costs. Another advantage is the lower background level.

In addition, heat load and radiation damage is smaller than in reactors which suggests that better cold moderators may be possible. This could result in an increase in the flux at the long wavelengths needed for the Doppler-shifter.

The Intense Pulsed Neutron Source is under construction at Argonne and should provide a higher flux of neutrons than currently available at ZING-P'. An experiment is being prepared to search for the neutron electric dipole moment that will take advantage of this higher intensity source when it becomes operational in 1981.

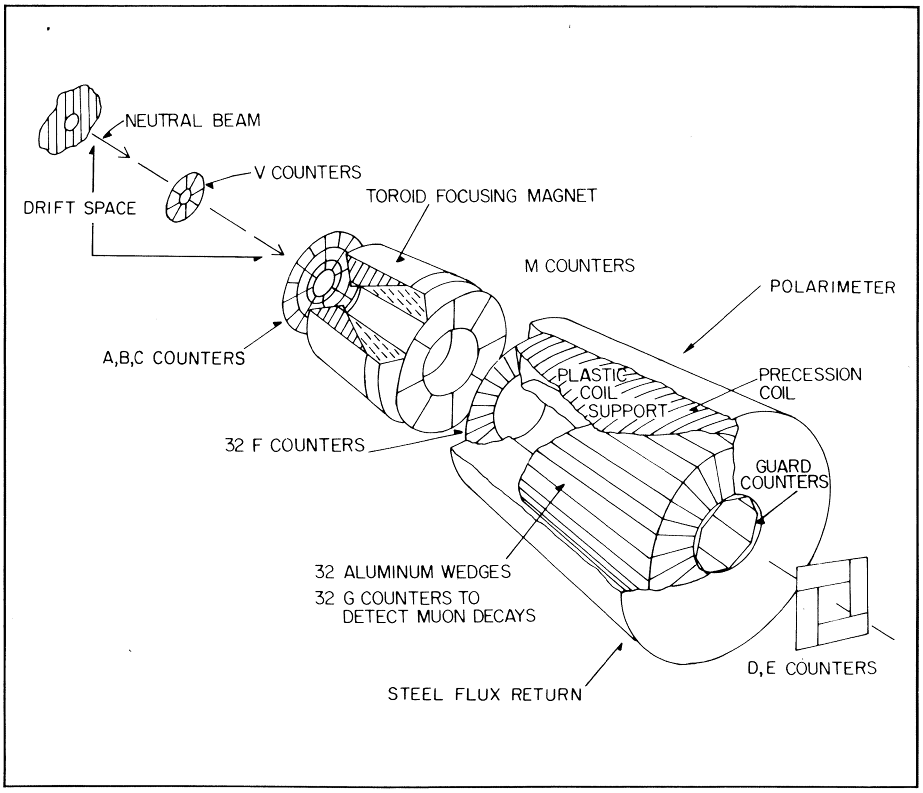
BROOKHAVEN
Search for violation of time symmetry

The violation of charge-parity (CP) symmetry is still not completely understood despite the passage of years since its discovery at Brookhaven in the decay of the long-lived neutral kaon. With the apparent success of gauge theories in unifying the electromagnetic, weak and possibly the strong interactions, there is some optimism that CP violation can be included naturally in such a framework.

Although gauge theories of CP violation have been formulated, a question which is not yet settled experimentally is whether CP violation is 'superweak' or 'milliweak' in character. Superweak models predict that all CP violating effects are confined to the neutral kaon system. Milliweak models predict deviations from the superweak predictions in the neutral kaon system and small (about 10^{-3}) CP or time symmetry (T) violating effects outside the neutral kaon system.

Physicists from Yale and Brookhaven have performed a sensitive search for a milliweak violation of time reversal invariance by measuring muon polarization in the long-lived neutral kaon decay into a negative pion, a positive muon and a neutrino. The polarization is determined by detecting the positron momentum from the subsequent decay of the muon.

The T violating correlation of interest is the component of muon polarization normal to the decay plane in the kaon rest frame. This results



The detection system of the Yale/Brookhaven experiment which has carried out a refined search for time symmetry violation in neutral kaon decays.

from the complex interference of the two amplitudes describing the decay of the kaon. A value for the interference phase of about 2 × 10^{-3} is expected from milliweak models. In the long-lived neutral kaon decay this phase is equal to the ratio of the T violating and T conserving transverse polarization components of the muon.

The experiment was conducted at the Brookhaven AGS in a 6° neutral beam which travelled through a cylindrically symmetric detector. Positive muons occurring in the 5 m drift space upstream of the detector were focused by a steel toroidal magnet and brought to rest in an aluminium polarimeter. The path of the muons was determined from the coincidence of scintillation counter pulses from hodoscopes. Field Programmable Logic Arrays determined the azimuthal position of stopping muons and aborted any triggers for which one unambiguous muon stop was not found. Event selection was accomplished by fast ECL trigger logic which required observation of a pion in coincidence with the muon.

After coming to rest in the aluminium, muon spins precessed with period of 1.2 μs in an axial magnetic field. The positron from the muon decay was detected by one of two counters flanking the muon stop position. Each of these counters was associated with a 'clock' which was switched on by the fast trigger. Detection of the positron thus recorded the time and direction of the muon decay.

The geometry of the polarimeter and the applied magnetic field allowed a measurement of two components of the muon polarization. For the ensemble of muons (12 million events collected) the polarization was determined from the asymmetry in the number of positrons detected to the right or the left of the muon stop position. Reversing the direction of the precession field before each beam pulse allowed an independent determination of the polarization components. The results give a T conserving polarization of 0.40 ± 0.06, which is consistent with Monte Carlo expectations and serves to calibrate the detector. For the T violating data the fit implies a value for the polarization which is consistent with zero, so that time reversal invariance is implied.

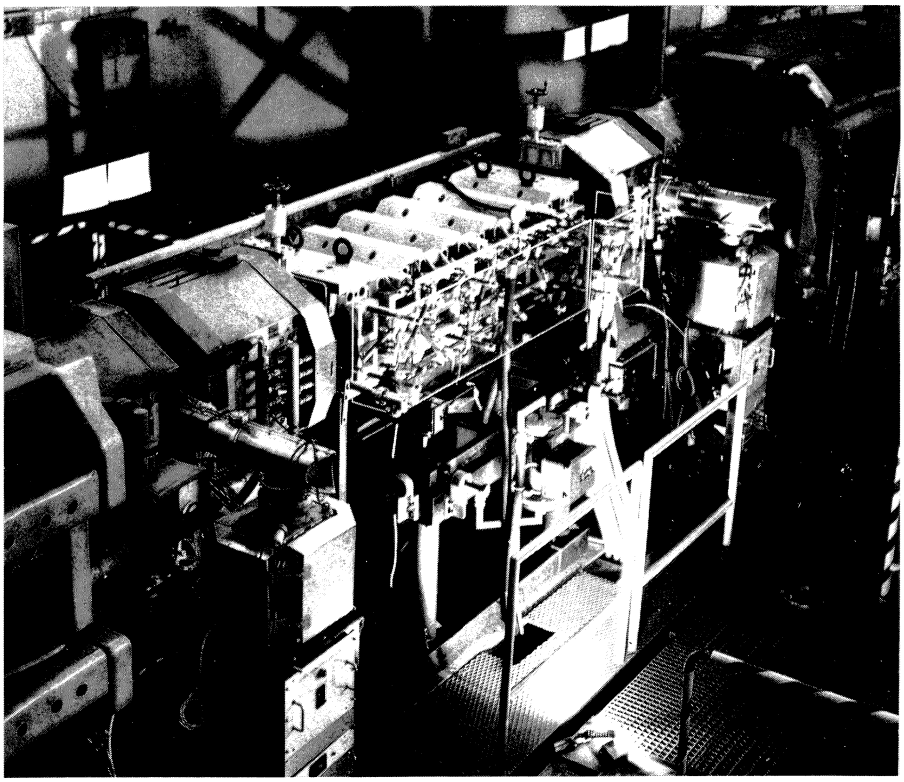
This completed experiment is the first of a programme to detect milliweak CP violation in kaon decays and the experimental conditions at Brookhaven are well-suited for such precision measurements. This spring the Yale / Brookhaven collaboration began collecting data on muon polarization in the decay of the positive kaon into a neutral pion, a muon and a neutrino. The use of a 4 GeV monochromatic positive kaon beam and the detection of the gamma rays from the neutral pion decay in a lead glass array will give reduced background and increased sensitivity. A prototype of the Brookhaven fast-bus system (developed in collaboration with D. Makowiecki) will be used for data acquisition. It is expected that events will be collected at ten times the rate (about 150 pulse) of the neutral kaon experiment so that 150 million events are expected, providing an exacting test of T violation.

FRASCATI
Wiggler magnet experiments

Experiments to study the characteristics of the radiation produced by a 'wiggler magnet' are beginning on the ADONE 1.5 GeV electron-positron storage ring at the Frascati

The 'wiggler magnet' installed on the ADONE storage ring at the Frascati Laboratory. The magnet has performed as expected and a study is beginning of the emerging radiation. The magnet in the centre of the picture is flanked by ADONE quadrupoles and bending magnets.

(Photo Frascati)



Laboratory. Such magnets are comparative newcomers to the research scene (the first operating wiggler in the SPEAR storage ring dates from February 1979). They enable the spectrum of radiation emerging from electron rings to be extended to higher frequencies. The magnets do this by introducing higher fields in the ring to bend the beam more so that the synchrotron radiation spectrum is extended. The magnets then wiggle the beam back to continue its way around the ring.

The Frascati magnet was installed in ADONE in September of last year. It is 2 m long with conventional (rather than superconducting) coils to produce fields up to 1.9 T with six poles.

Commissioning on the machine has been extremely smooth and all major effects on the machine optics were as predicted, to the required accuracy. It extends the performance of the existing synchrotron light facility well into the soft X-ray region to a critical wavelength of 4.4 angstroms with high intensity when the ring runs at its top energy of 1.5 GeV.

When the wiggler magnet is operated at full field at the low end of the machine energy range, the perturbation to the ring optics in the vertical plane is large and a special machine configuration, having a low beta value in the wiggler straight section, has to be set up. To test this mode of operation, the machine has been run at 0.5 GeV with the wiggler field set at 1.8 T. The effects on the beam were in agreement with the computed values; the amount of energy radiated in the wiggler magnet alone was 1.4 times that radiated in all the ring bending magnets.

Although the magnetic field introduces only three full oscillations into the beam, coherent emission in the visible light region is striking. In a set of measurements at low machine energies and low fields one can observe the first and the second harmonic of the coherent radiation obtained at 0.536 GeV. The beamline to take the radiation from the wiggler to experiments is ready. The radiation will be extracted through a 380 μm thick beryllium window.

Daresbury Laboratory is participating in the commissioning experiments on the ADONE wiggler so as to gain experience in readiness for the operation of their Synchrotron Radiation Source. The SRS is scheduled for first operation at the end of June and its 2 GeV electron storage ring will have a 5 T superconducting wiggler being prepared at the Rutherford Laboratory. The coils have been tested and the design fields achieved.

*** Late news: Electron and positron beams have been collided in the Berkeley/Stanford PEP storage ring at SLAC. We hope to have the story of the first operation of the machine in our next issue.**

Physics monitor

Charm from hadrons

So far, most of the results on charmed particle production have come either from electron-positron colliding beams, or from neutrino experiments. Some information also exists on charm production by hadrons (see, for example, September 1979 issue, page 247).

Now more data is available thanks to experiments on charm hadroproduction at Fermilab using a streamer chamber, and at CERN using a specially-built high resolution hydrogen bubble chamber.

In the Fermilab experiment, a high resolution streamer chamber was used to look at particle production by 350 GeV protons. As charmed particles make up only a very small fraction of the total event rate, the apparatus uses a fast trigger to sift out candidate charm events and is designed to record the short decay lengths of charmed particles.

The trigger selected interactions producing single muons which penetrated a steel hadron filter. Each interaction was measured with a space resolution of 40 μm, and events selected where one or more tracks did not appear to originate from the primary production vertex.

After analysing the outgoing tracks, a sample of some 1000 muon triggers gave 10 candidate charm events, a few of which had to be attributed to other sources, such as the decay of strange particles.

The remaining short-lived particles produced in association with muons are calculated to have an average lifetime between 10^{-13} and 2×10^{-12} seconds, in agreement with the Fermilab neutrino experiment using an emulsion hybrid spectrometer (see March issue, page 15).

Data on charm production by hadrons is also available thanks to the Brussels / CERN / Oxford / Padova / Rome / Rutherford / Trieste collaboration using the 20 cm diameter LEBC high resolution bubble chamber (see September 1979 issue, page 258). Filled with liquid hydrogen, this mini detector, exposed to a 340 GeV negative pion beam from the SPS, has provided valuable indications of charm production levels from a sample of 48 000 events.

A simple trigger was used to select those events suitable for photographing. No magnetic field was applied, so that only topographical analysis of the tracks was possible. Charm candidates were selected on the basis of a detectable transverse decay length corresponding to the expected charm lifetime (10^{-12} to 10^{-13} s).

In the analysis of events where a pair of short-lived particles is seen, 12 events cannot be attributed to background effects like strange particle decays, and so are interpreted as charmed particle pairs. The cross-section for this production is estimated at some 40 μb, and is relatively insensitive to possible variations in lifetime between different types of charmed particle (see March issue, page 15), or to the exact nature of the production mechanism.

A significant number of decays producing three charged particles are seen. Of the eight events found, only two can be explained as background. This gives a cross-section of about 35 μb for the production of charged charmed (D) mesons.

This initial work with LEBC has shown how useful such a high resolution bubble chamber is for charm physics. However for more detailed information, additional particle detection capabilities are required to complement the bubble chamber photographs.

This has been achieved in a new experiment by using LEBC as the visual detector in the apparatus being prepared for the European Hybrid Spectrometer (EHS) at CERN. Although not yet complete, the EHS apparatus already available provides precise momentum analysis for charged particles and for photons, while a version of the Oxford ISIS detector (see May 1978 issue, page 160), provides some particle identification. About half a million photographs have already been taken, and the run is continuing.

People and things

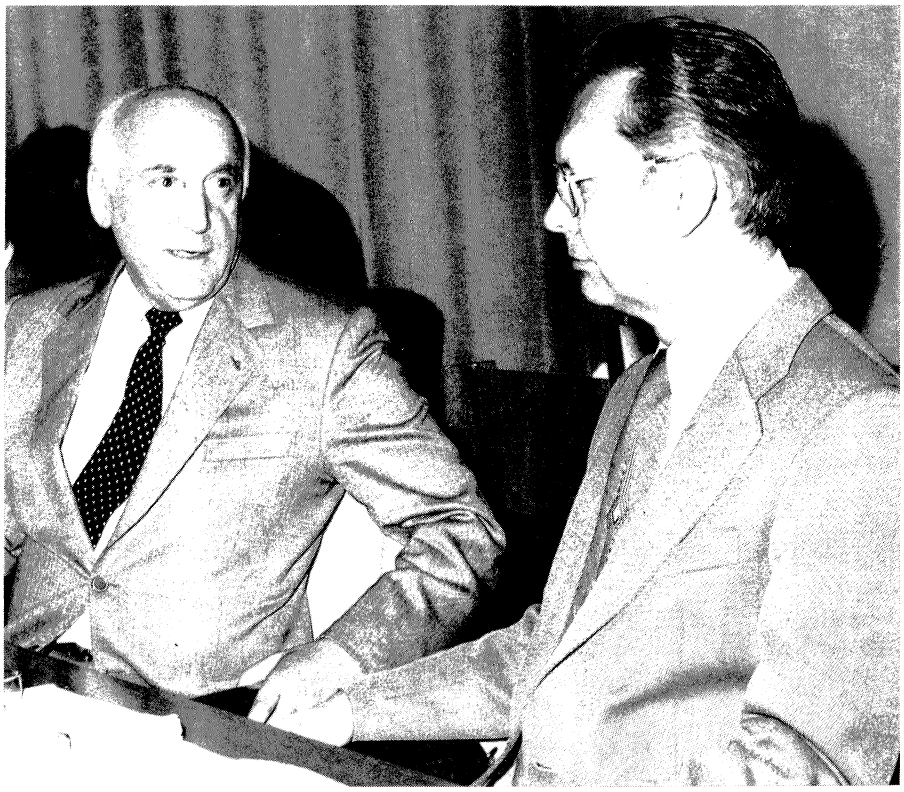
Herwig Schopper CERN's next Director General

On 25th April, at a specially convened session of the CERN Council, delegates of the twelve CERN Member States unanimously appointed Professor Herwig Schopper as Director General of CERN for the five years 1981–85. He will succeed John Adams, Executive Director General, and Leon Van Hove, Research Director General, on 1 January 1981.

Herwig Schopper will move to CERN from his present position as Chairman of the Board of Directors at the DESY Laboratory, a position he assumed in 1973. Under his leadership, DESY has enhanced still further its reputation as a leading high energy physics Laboratory — the physics programme on the DORIS electron-positron storage rings has been amongst the most fruitful in the world, and the rapid construction of the large PETRA ring has been one of the major feats of accelerator building. Professor Schopper has guided DESY through this period with total commitment to its physics aims and skilful judgement as to how these aims could be achieved.

He is no stranger to CERN. In 1970 he became Head of the Nuclear Physics Division and, before he returned to the Federal Republic of Germany in 1973, he was member of the CERN Directorate for the Experimental Programme.

He returns to lead the Laboratory when it is hoped that the world's largest machine will be under construction — the electron-positron storage ring LEP. Schopper's knowledge and experience in particle physics and in the management of large machine projects should prove a valuable asset to CERN during this challenging time.



Herwig Schopper (right) talks with Jean Teillac, President of CERN Council, at a special Council meeting in April. At this meeting, Professor Schopper was unanimously appointed as the next CERN Director General, to take up office on 1 January 1981.

(Photo CERN 208.4.80)

On people

At the recent annual meeting of the American Physical Society in Chicago, Herman Feshbach of MIT began his term as APS President. Maurice Goldhaber, Distinguished Scientist at Brookhaven, was named vice-president elect. Arthur Schawlow of Stanford became this year's vice-president.

Norman Ramsey, Higgins Professor of Physics at Harvard University, has been elected Chairman of the Governing Board of the American Institute of Physics. Norman Ramsey is a well-known personality on the US high energy physics scene. He was among those who established the Brookhaven Laboratory and has also been closely associated with Fermilab, where he is President of the Universities' Research Association which operates the Laboratory.

Ron Russell retired from the Rutherford Laboratory at the end of March. Ron had participated significantly in the construction and operation of the Nimrod proton synchrotron, becoming Head of the Nimrod Division. In recent years he has headed the Division building the Spallation Neutron Source, and was Chief Engineer at Rutherford.

Royal visitor at TRIUMF

On 1 April, His Royal Highness Prince Charles went on a short tour of the TRIUMF site during a visit to Vancouver. This included an inspection of the operation of the accelerator itself, a typical experiment in the basic physics programme, the biomedical facilities

Prince Charles has the muon to electron conversion experiment at the TRIUMF cyclotron explained by Doug Bryman (left) and the Laboratory Director, Jack Sample (right).

(Photo TRIUMF)

of the British Columbia Cancer Foundation and their programme of cancer therapy, and finally the radiochemical facilities installed in the chemistry annexe by Atomic Energy of Canada Ltd. for commercial production of radioisotopes. While inspecting the AECL hotcells, Prince Charles used the master-slave manipulators to turn a stopcock and thereby symbolically inaugurate the chemical processing of irradiated targets.

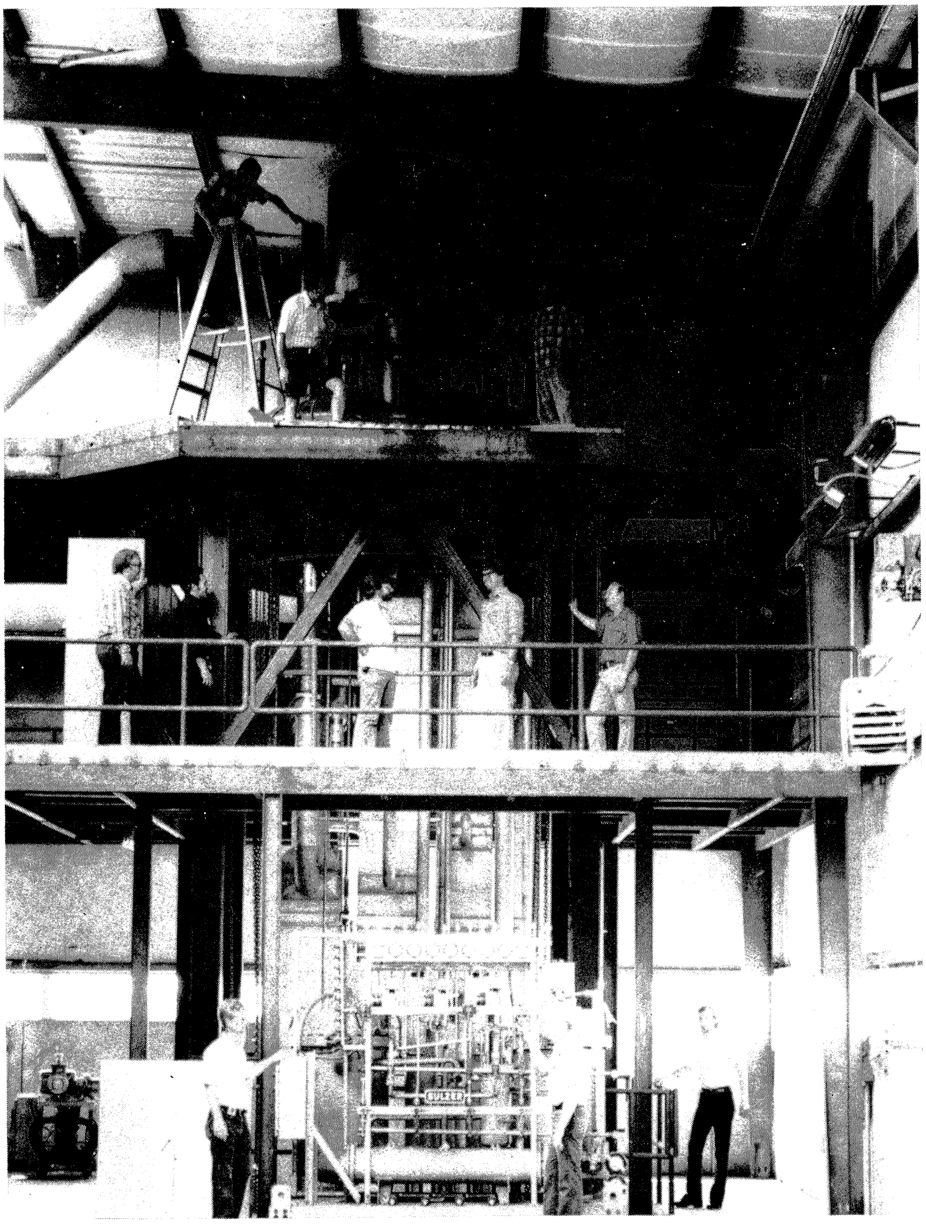
Jacques Prentki, leader of CERN's Theory Division, celebrated his 60th birthday on 17 April. To mark the occasion, some close friends reminisced on different periods in his career: Ph. Meyer spoke on 'good times in Paris', Bernard d'Espagnat on 'the pioneering years at CERN', Daniele Amati on 'the Golden age', Tatiana Fabergé on 'theory division through the years' and Paul Musset on 'the theorist in interaction'. This was followed by a short concert of chamber music.

History of particle physics

An International Symposium on the History of Particle Physics was held at Fermilab from 28-31 May. It concentrated on the origins of particle physics back in the 1930s and 40s before the advent of the big particle accelerators. The impressive list of main speakers included Paul Dirac, Gilberto Bernardini, Viki Weisskopf, Carl Anderson, Satio Hayakawa, Robert Serber, Bruno Rossi, Willis Lamb, Julian Schwinger and Murray Gell-Mann.

Seen here together with Jacques Prentki (left) at the celebrations at CERN to mark his 60th birthday are Tatiana Fabergé of Theory Division Secretariat, and Daniele Amati.

(Photo CERN 120.4.80)



One of the 4000 horsepower compressors used by the Fermilab Central Helium Liquefier.

(Photo Fermilab)

SCIPP at Santa Cruz

The Regents of the University of California have approved the formation of a new Institute for Particle Physics on its Santa Cruz Campus. Acronymed SCIPP (the Santa Cruz Institute for Particle Physics), it builds on the strength of existing groups of theoretical and experimental particle physicists. Benefitting from its close proximity to SLAC, the experimental group (started in 1970) has carried out programmes on inelastic muon-nucleon scattering, early charm searches in pion-nucleon scattering and dimuon production, all in collaboration with SLAC Group D. In addition, a tagged photon scattering experiment has been performed at Fermilab. The principal new enterprise of SCIPP is co-responsibility, again with SLAC Group D (plus groups from the Universities of Illinois and Washington) for the next-generation SPEAR detector, called MARK III.

Senior fellows at SCIPP are theorists Richard Brower, Michael Nauenberg, and Joel Primack; experimentalists David Dorfan, visitor Hartmut Sadrozinski, Terry Schalk, Abe Seiden, and Dennis Smith. Clemens Heusch is Acting Director. Serving on its Advisory Committee are Geoffrey Chew, George Trilling, Sidney Drell, Frederick Reines and Donald Osterbrock.

Helium starts to flow at Fermilab

On 18 April, Fermilab brought into operation the world's largest helium liquefier plant. The liquefier, converted from an oxygen/nitrogen plant previously used in the US space programme, is destined to supply the cooling for the superconducting magnets of the 1000 GeV Tevatron proton synchrotron. Initial operation provided liquid helium at the rate of 2000 litres per hour, which is just below half the maximum capacity. The helium will eventually be distributed via satellite plants to the one thousand superconducting magnets of the Tevatron.

PETRA improving

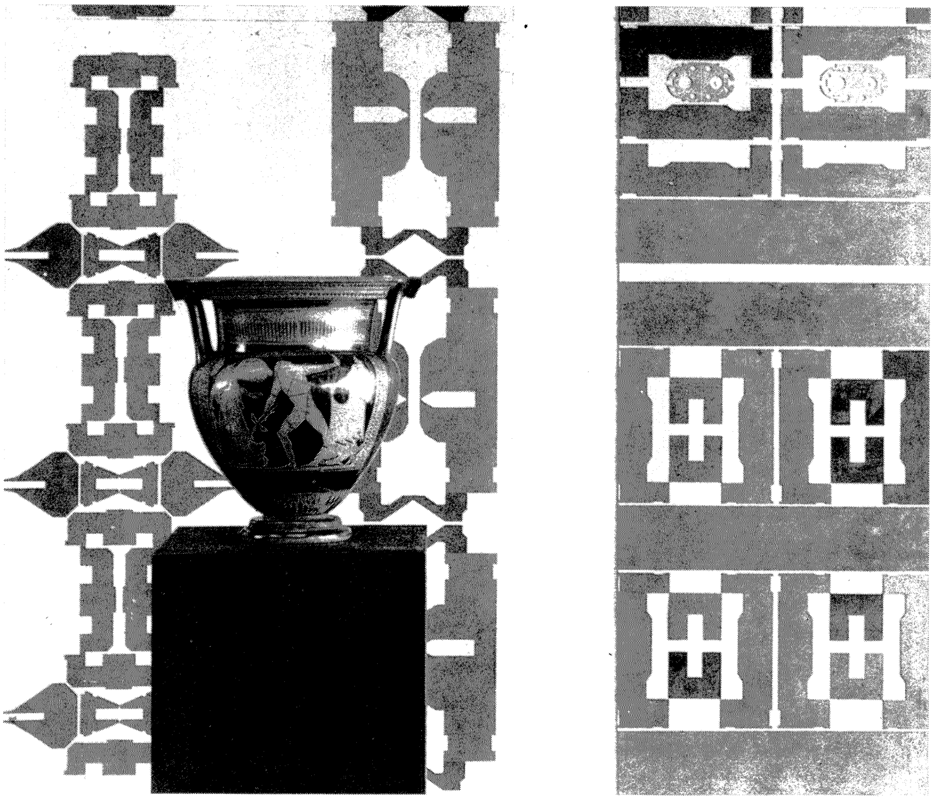
During a few shifts devoted to machine developments on 20 April, the stored beam of PETRA reached the design energy of 19 GeV. Within the next weeks the conditions for production runs at energies near to 19 GeV will be worked out by the machine group. Major progress has also been achieved in the beam currents which can be stored in PETRA. The reason for the earlier 'current limit' at the 7 GeV injection energy seems to be understood and the machine can now be tuned in such a way that this limit has completely disappeared. Under the new conditions no difficulty was found in storing up to 18 mA in a single bunch. Such currents were already stored in PETRA when only 4 r.f. cavities were installed but could not be reproduced once the 60 cavities needed for higher energies were built in.

Chinese meeting

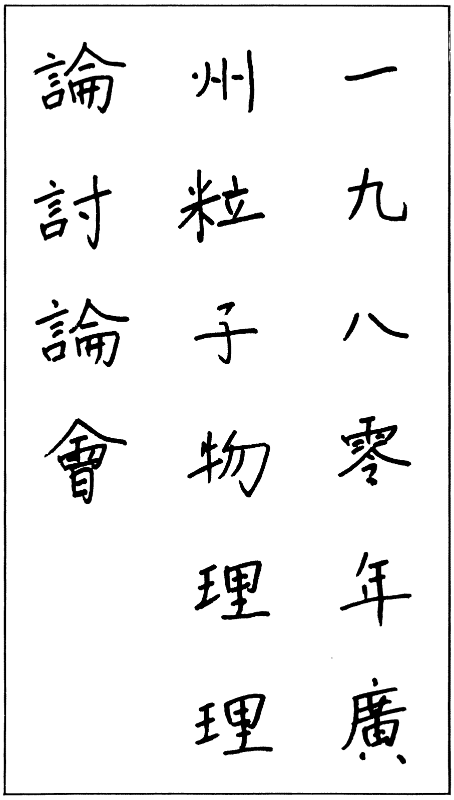
Earlier this year, a high energy physics meeting, organized by the Academia Sinica, was held in the pleasant winter climate of Guangzhou, Canton. This was one of the first major scientific meetings to be held in China in recent years. It attracted some 100 physicists from within China, together with some 50 researchers of Chinese origin working in other countries, and the physics was of a high standard.

A recent display of fifth century BC Greek vases has been exhibited at Fermilab using an interesting background of magnet laminations.

(Photo Fermilab)



The inscription reads 'The 1980 Guangzhou Conference on Theoretical Particle Physics'. The meeting was one of the first major scientific meetings to be held in China in recent years.



一九八零年廣州粒子物理理論討論會

The meeting was conducted in Chinese, but it is planned to publish the proceedings in English. Afterwards, all participants joined in an extensive tour of the country, visiting Beijing, Shanghai and Hangchow.

From 10 – 30 August the 21st Scottish Universities' Summer School in Physics (a NATO Advanced Study Institute) on Gauge Theories and Experiments at High Energies will be held at the University of St. Andrews. Further information from A. Walker, Department of Physics, University of Edinburgh, Edinburgh EH9 3JZ, Scotland.

Profession of faith in fundamental research

At a Physics Congress in Ulm the Chancellor of the Federal Republic of Germany, Helmut Schmidt, voiced his unambiguous support for fundamental research. Here are a few excerpts from his statement: '...pure research provides the nourishment for future development. Non-applied research, such as particle physics or astrophysics, is done because it springs from an inborn human curiosity to find the truth. A culture conscious of its own value must interest itself in fundamental knowledge concerning the nature of matter, the universe and life itself.'

The Chancellor expressed his satisfaction at the recent, widely acclaimed results from the PETRA machine at DESY. 'The indirect evidence for the existence of gluons appears to be an important breakthrough in the understanding of one of the fundamental forces of Nature.' He concluded by saying that 'Scientists are responsible for considering any undesirable consequences of their research. Those who dispose of knowledge have a special responsibility which must find expression in practical action. In particular, scientists must try to make their knowledge comprehensible to the public and to politicians.'

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XP2020Q	bialkali on quartz	1,5	2,4	0,25	0,25	56DUVP
XP2233B	trialkali	2,0	3,2	0,50	0,70	56TVP
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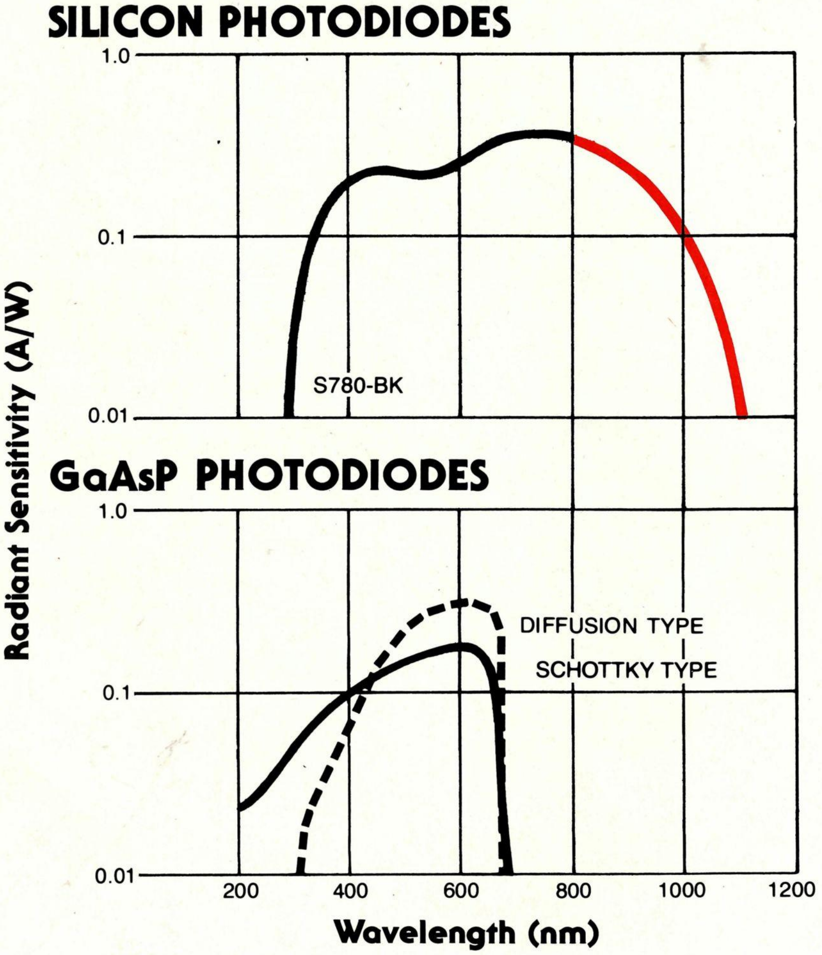

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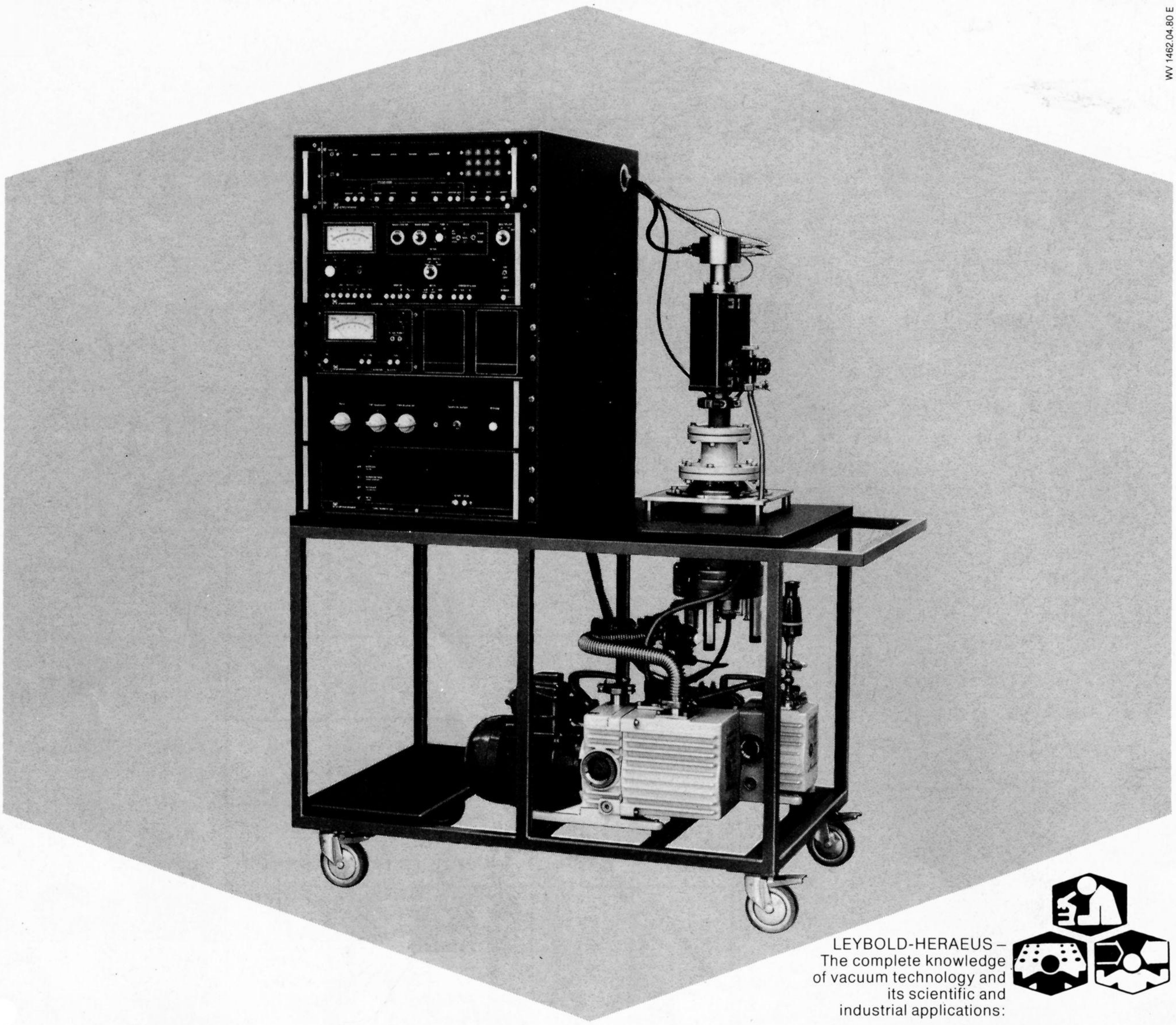

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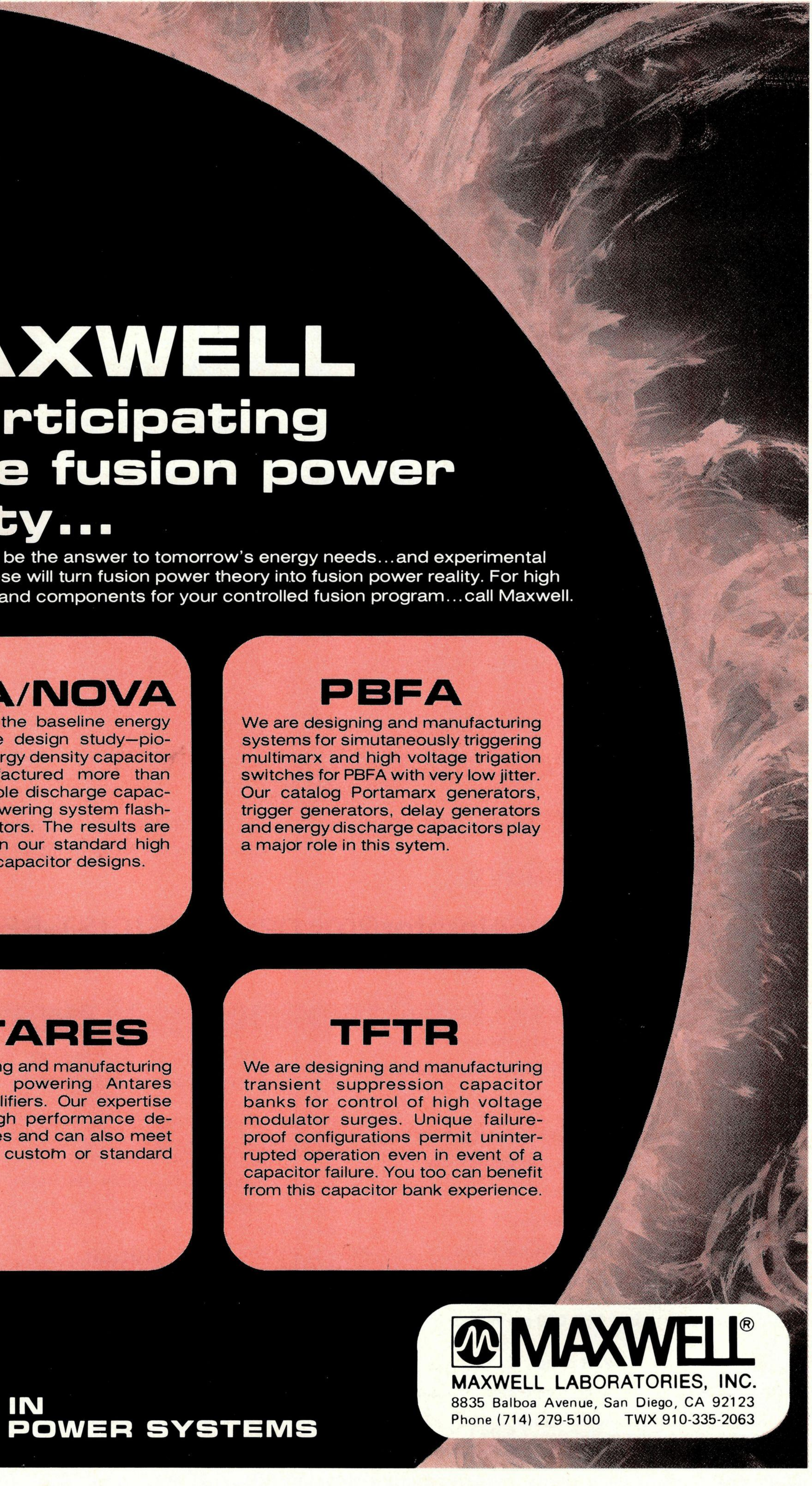

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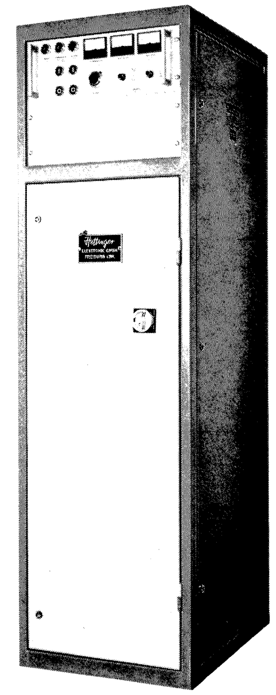

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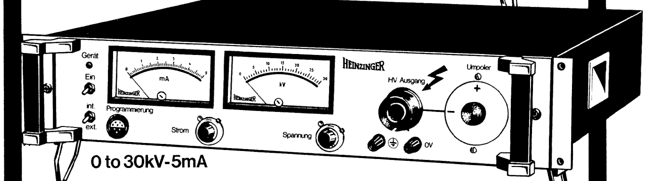

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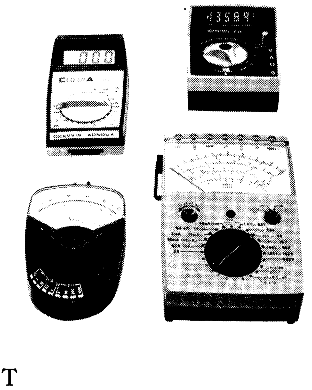

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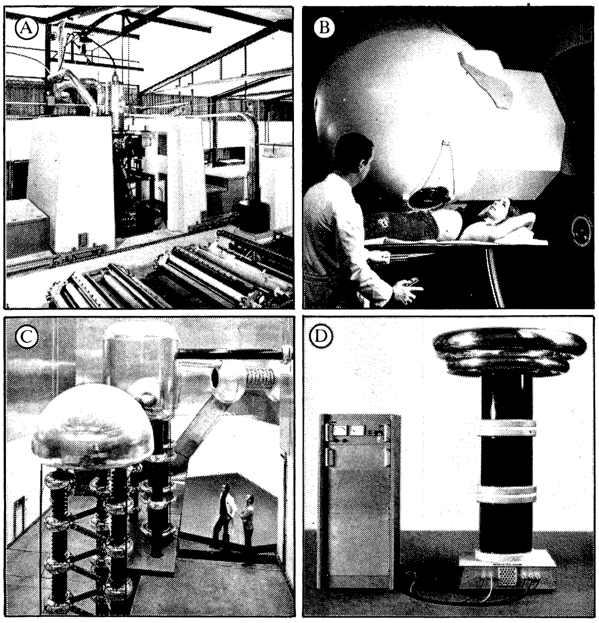

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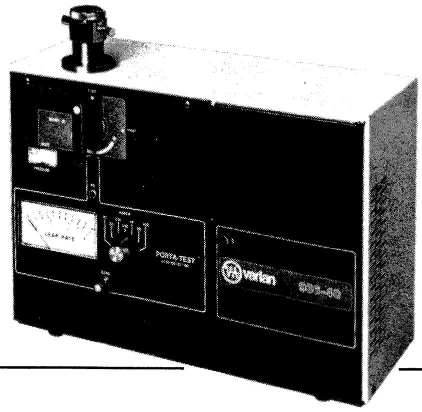

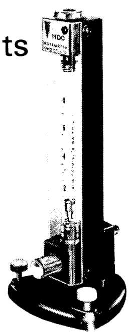

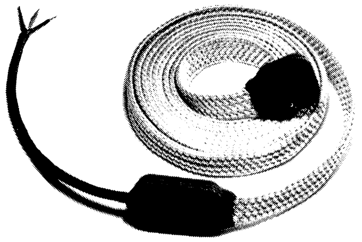

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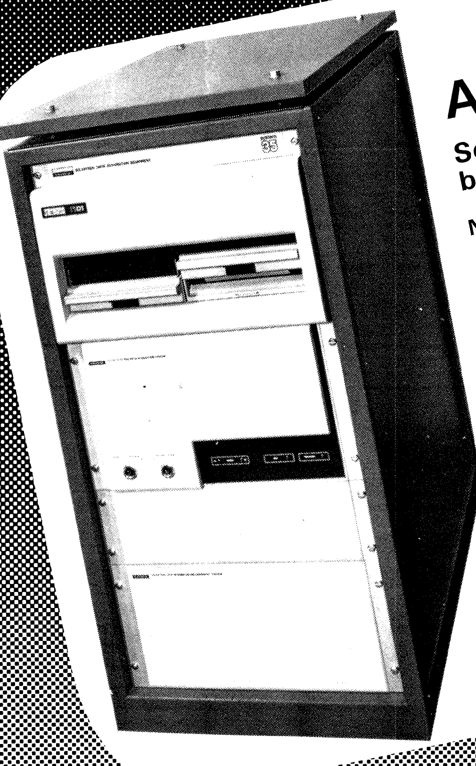

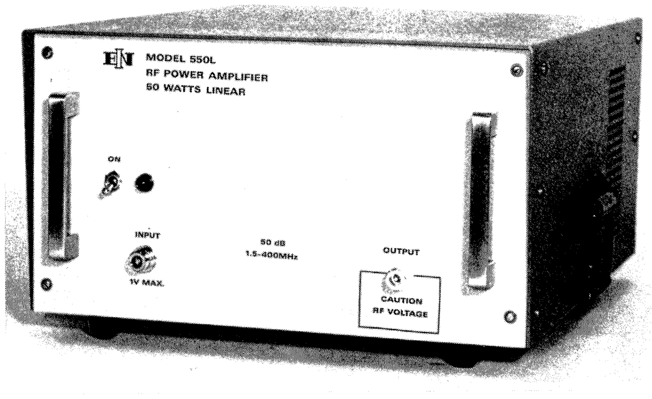

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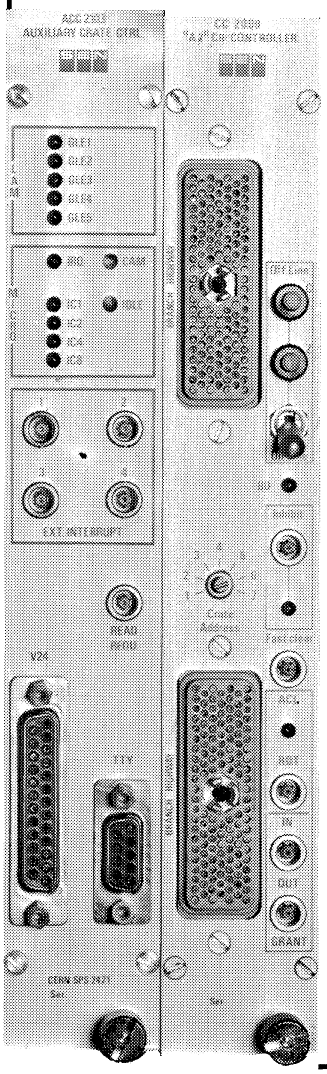

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- CAMAC Read/Write cycle less than 10 μs in autonomous mode
- also compatible with SCC-L2 and Nord 10-PIO Controllers

CCA2 2089 A2 Parallel Crate Controller

- fully conforms to the new EUR 6500 specs
- single board construction

SYSTEM OPERATION

The A2 Crate Controller is a parallel Crate Controller and includes all the same functions plus new control logic for local data handling using a microprocessor module (as ex. ACC 2103). The A2 provides access to the N and L lines via a rear panel connector for the Auxiliary Crate Controller placed in any normal station. It also handles the remote/local access request conflicts. Front-end data processing is governed by the ACC 2103 just as long as the man computer does not require access to this particular crate: However, when this occurs, the local processor is released, its status saved and the Branch Demand processed. Once the Branch Demand has been filled, control returns to the ACC 2103.

Brief configuration guide

- For systems not requiring permanently available high-level languages the ACC 2099 (single width) is normally sufficient.
- to improve input/output and intersystem communication, the SEN CI 2092 communications interface (high speed, multi-channel, buffered, micro-processor controlled) may be added.
- for fully autonomous systems, a version combining the features of the ACC 2103 and of a Crate Controller will be available shortly (Type STACC 2107 – Stand Alone CAMAC Computer).

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

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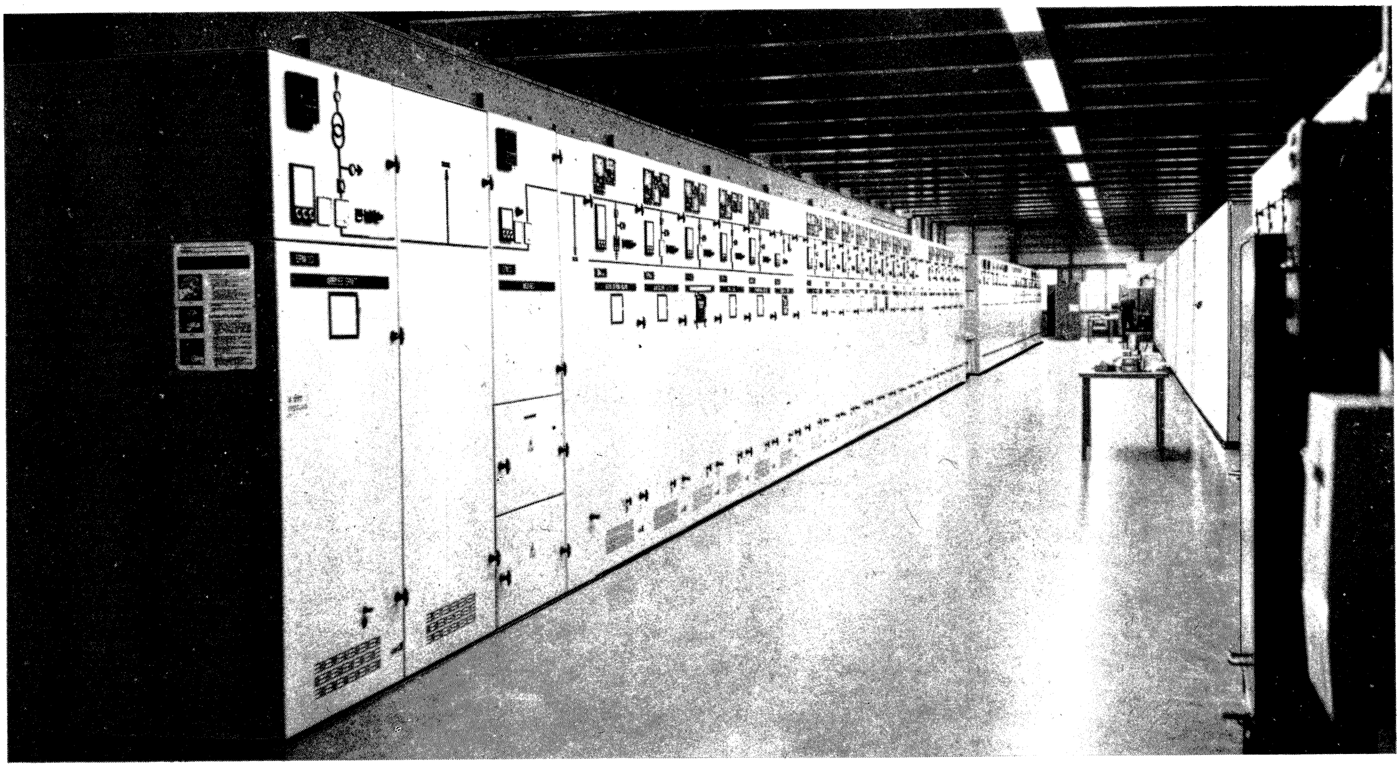
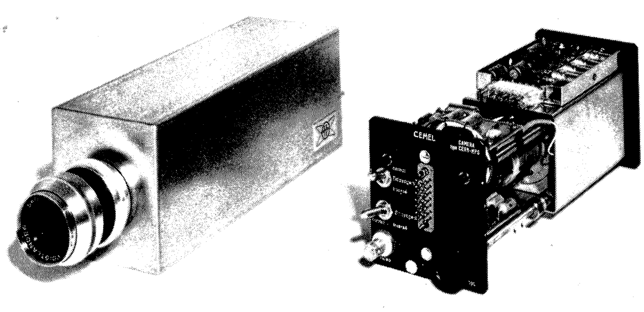
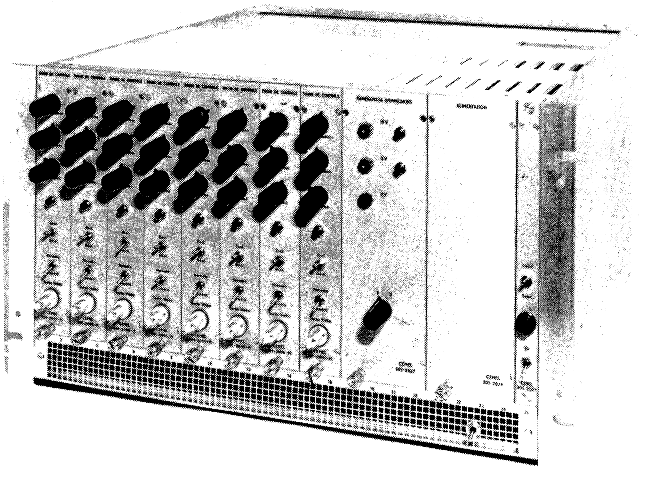




CAMERA HEAD



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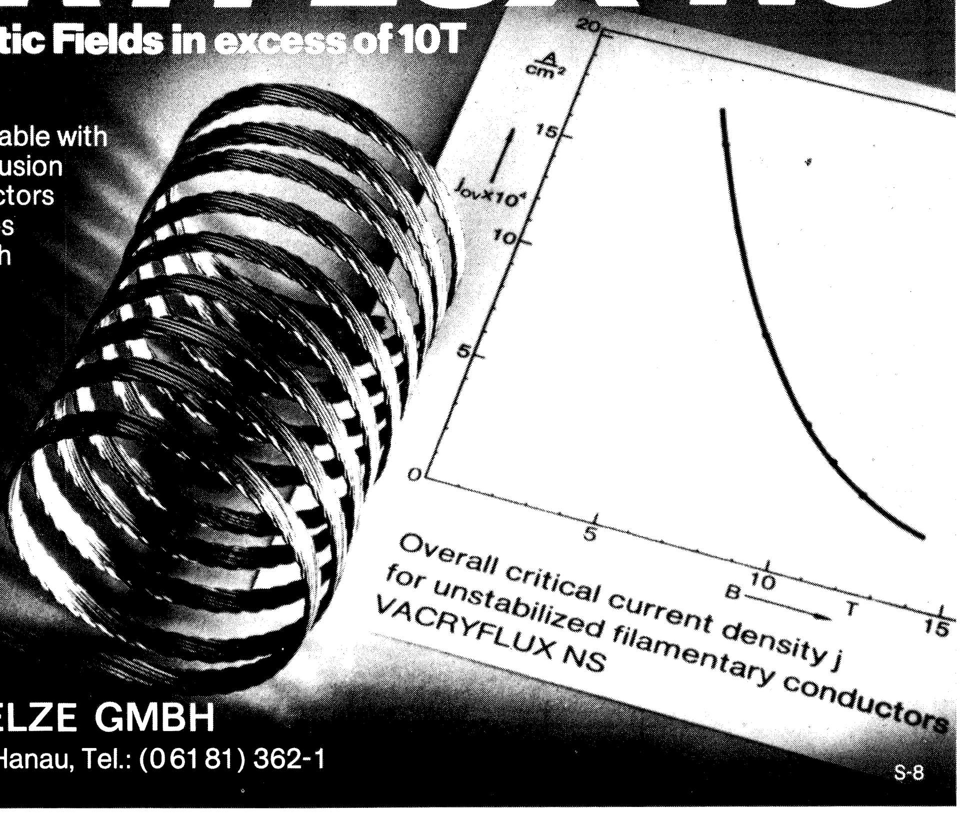
20
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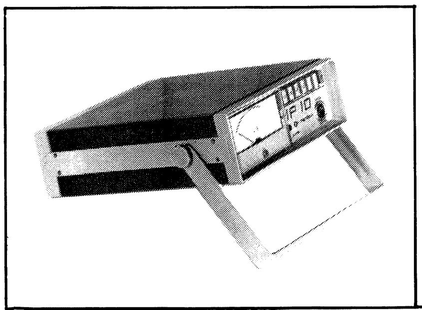
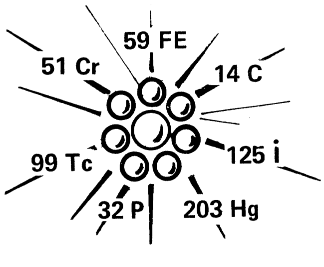
Overall critical current density j
for unstabilized filamentary conductors
VACRYFLUX NS

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99 Tc
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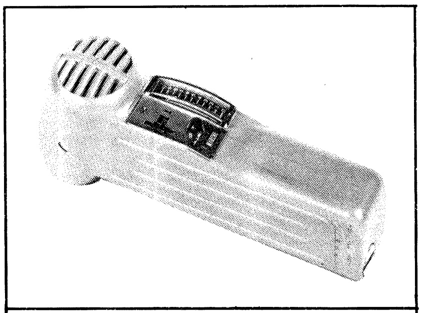
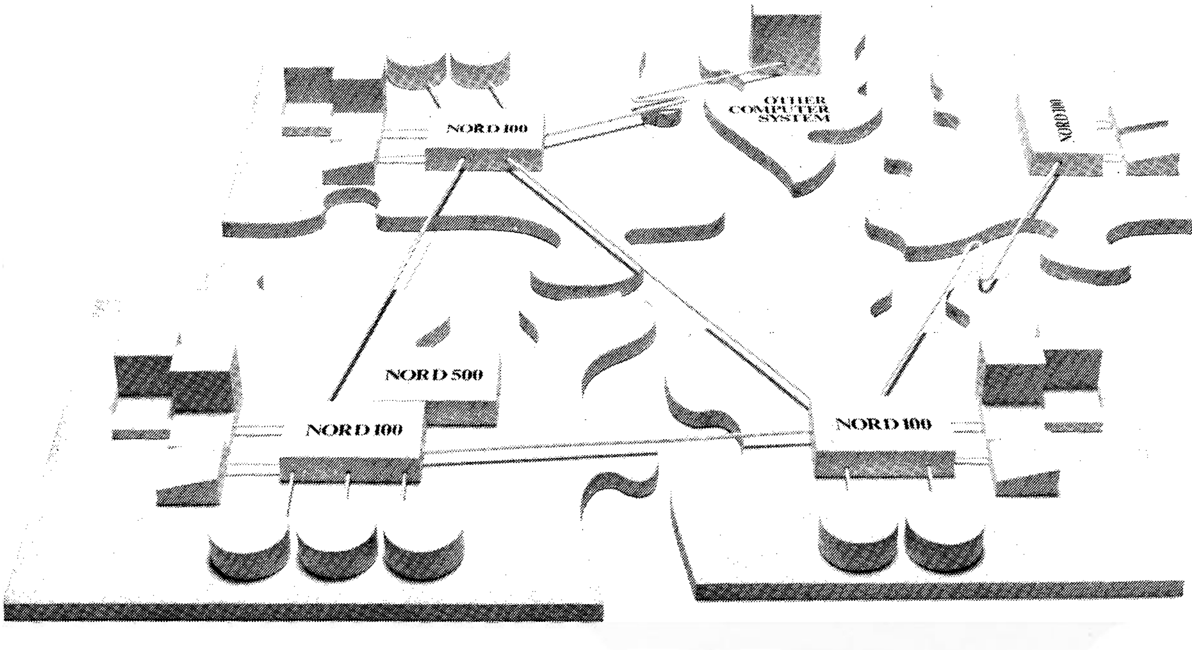
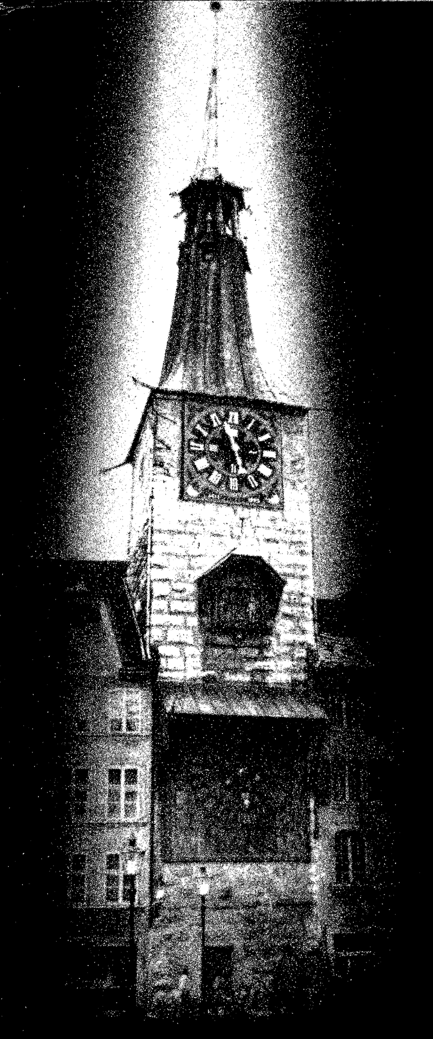
32 P
203 Hg




NORD 100
OTHER COMPUTER SYSTEM
NORD 100
NORD 500
NORD 100
NORD 100



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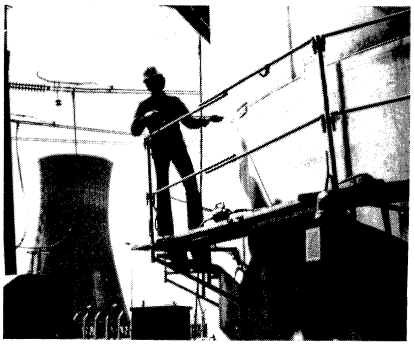

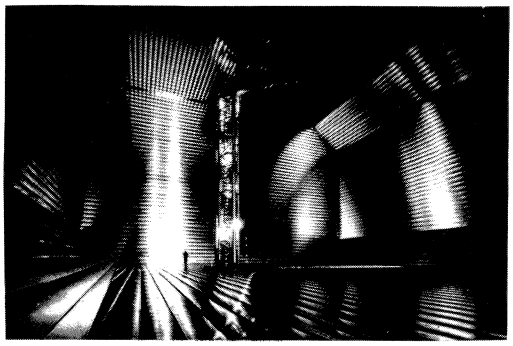

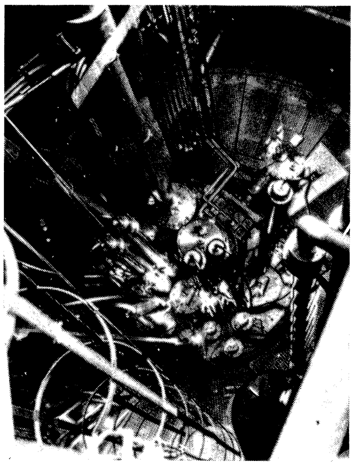

SILENA

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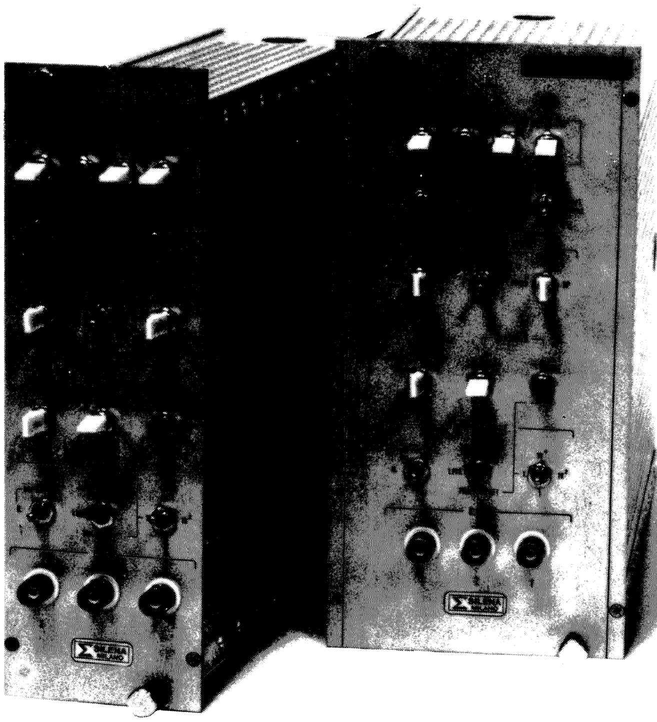

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Character generator
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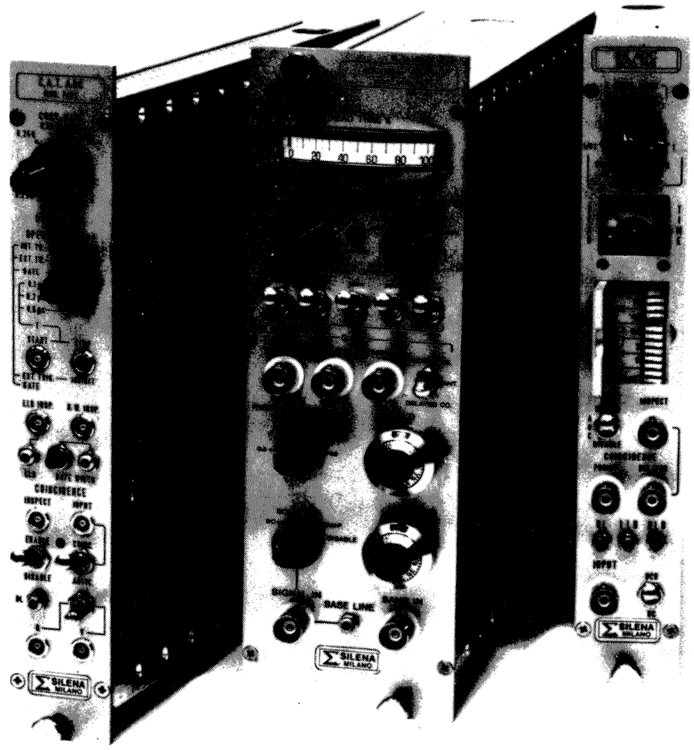

2048 channels Charge, Amplitude and Time converter
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0,3% differential non linearity
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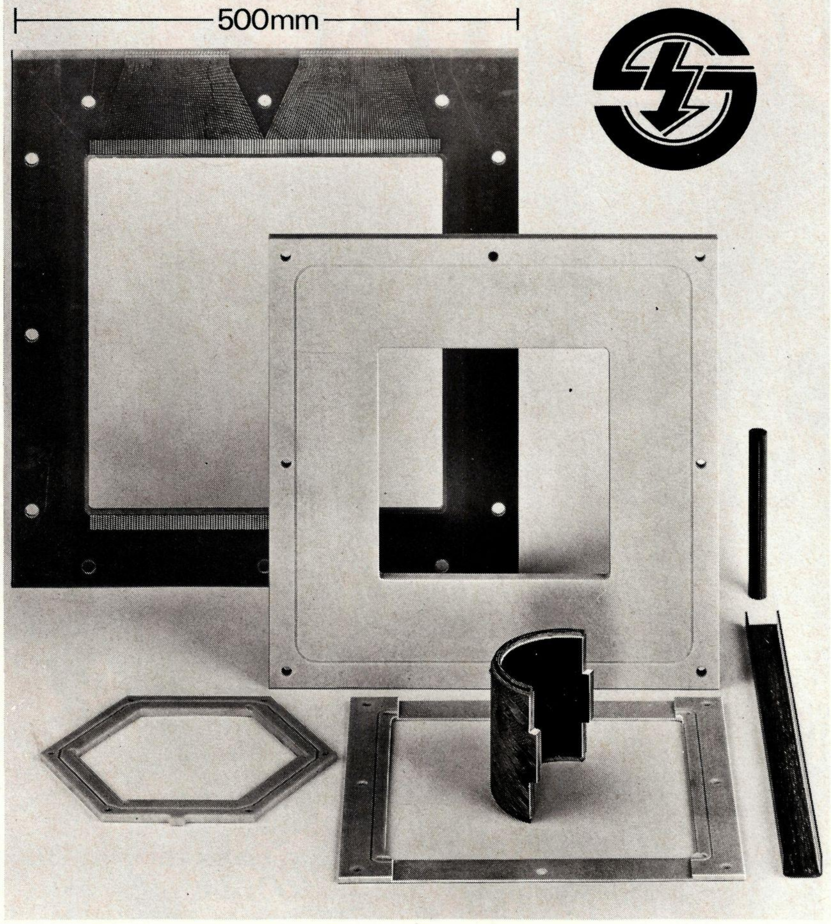
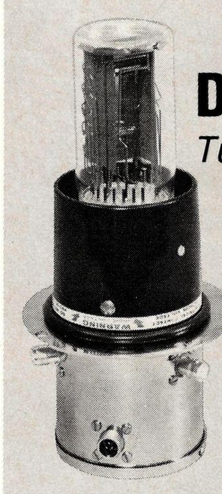
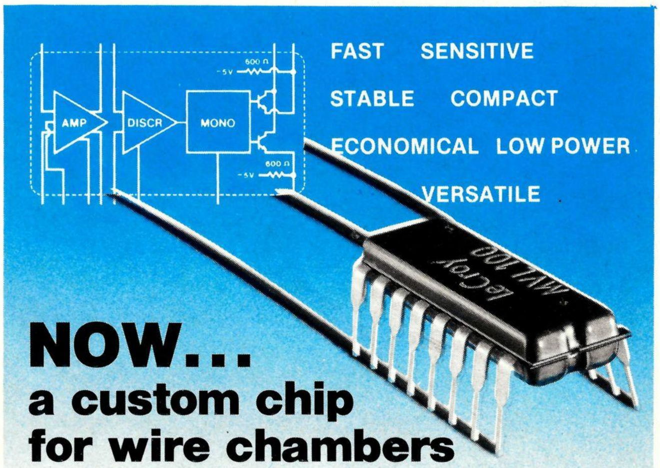
Base 2/Grafici Associati


500mm

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EIMAC tetrodes for switching and regulating.

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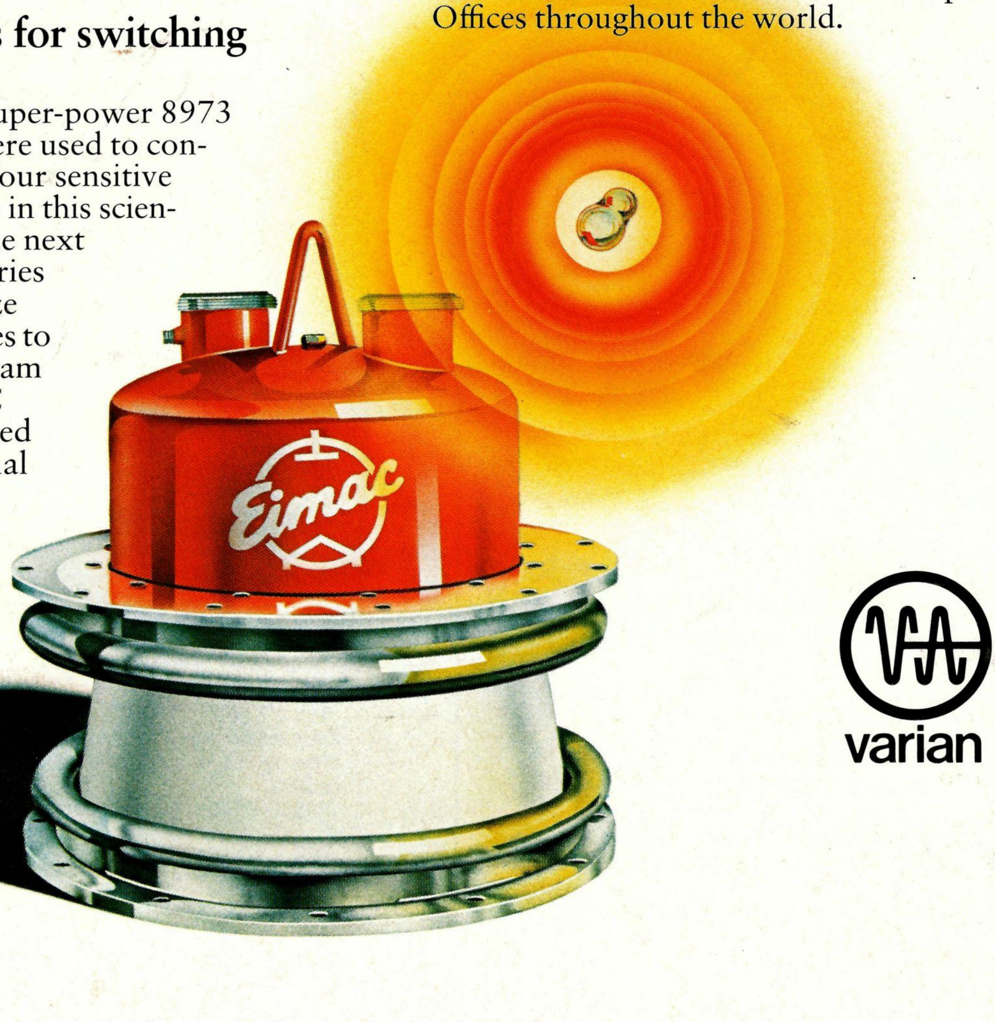
For information

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



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