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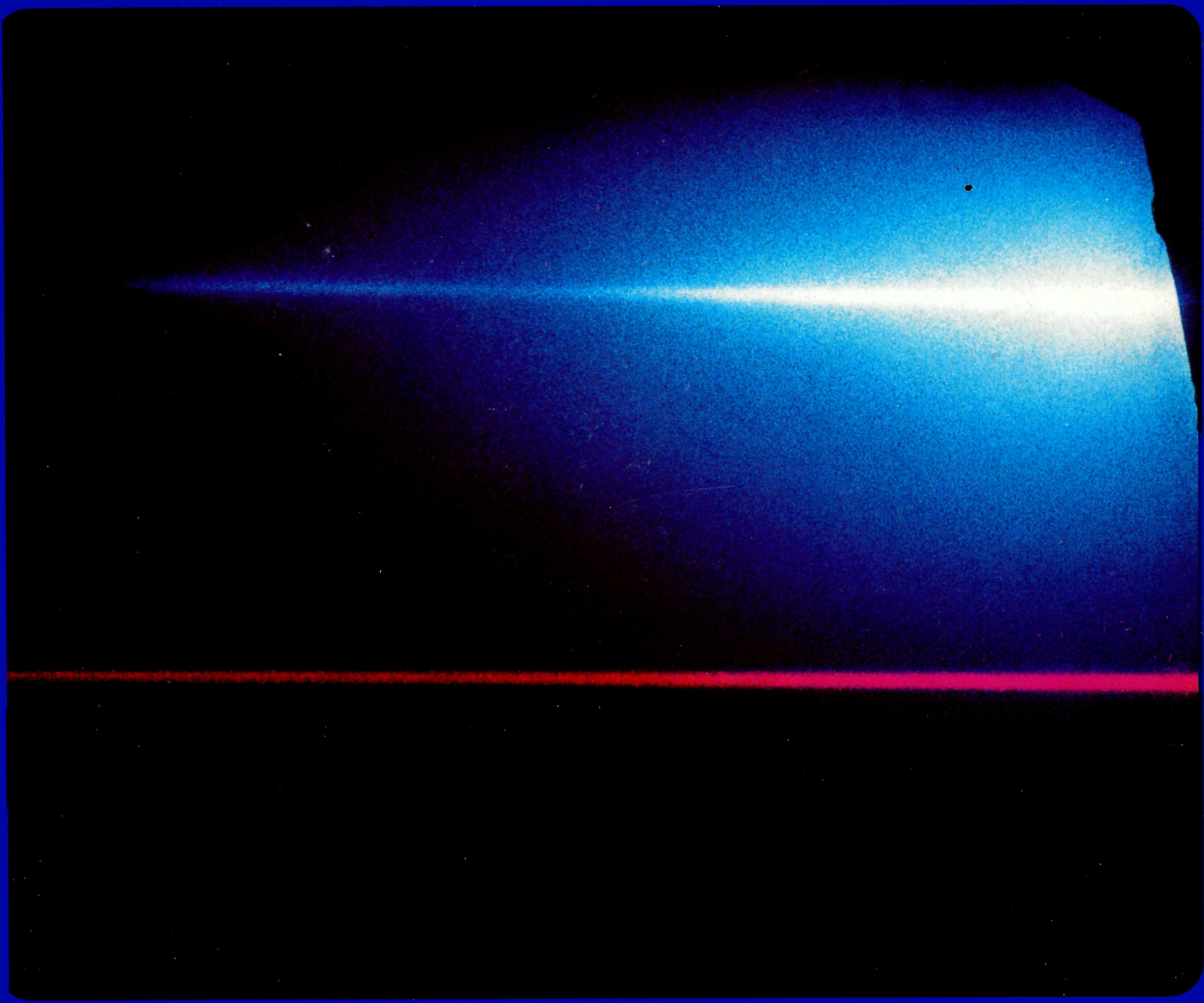

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CERN COURIER

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Cover photograph: a beautiful illustration of the behaviour of light in silica aerogel. The picture shows two parallel laser beams entering a piece of aerogel from the right. For blue light, where Cherenkov radiation is more abundant, the diffusion is more marked than with red light. See page 156 for a story on the application of silica aerogel.

Washington Conference

Recent photograph of the Cornell tunnel with the electron synchrotron on the left and the CESR electron-positron storage ring on the right. Laboratory Director Boyce McDaniel described CESR performance in the opening talk at the recent Washington accelerator Conference.

(Photo Cornell)

The 1981 Particle Accelerator Conference was held in Washington from 11-13 March. It was the ninth in the series of meetings organized in the USA which differ from the 'International' meetings (such as the Conference at CERN in July 1980) in their coverage of the full range of accelerator engineering and techno-'ogy, including applications outside .e field of high energy physics.

The Conference took place under the cloud of further budget cuts for Fiscal Year 1982 in the USA which the Department of Energy has applied in line with the financial policy of the new administration. Coming on top of many years of budget trimming which have reduced the number of high energy physics Laboratories funded by the DOE to three (Brookhaven, Fermilab, Stanford - Cornell is funded by the National Science Foundation) and reduced the exploitation of these Laboratories to less than half of their potential, the new cuts did not exactly help to boost morale. Nevertheless, the huge amount of tailed work in accelerator physics and technology which was presented at the Conference showed how alive the field is. It was impossible to keep pace with up to three information-packed parallel sessions at the same time as 'poster' presentations, many of which were also well worth attention.

The newcomers

Pride of place in the opening talks was given to the new electron-positron storage rings which have come into operation in the USA since the San Francisco Conference in 1979 - the 8 GeV CESR ring at Cornell and the 18 GeV PEP ring at Stanford.

To bring CESR into operation in September 1979 only two years after authorization of the project and at a cost of $13 million was a fine achievement, particularly when considering the smallness of the team at Cornell. This enthusiasm is perhaps not unrelated to the Cornell theme of 'if you want to use it, help build it'! Boyce McDaniel described present performance and proposed improvements.

CESR shares the tunnel of the Cornell electron synchrotron which serves as its injector (providing high stored positron beam intensities via the vernier filling scheme invented by Maury Tigner - see April 1976 issue, page 129). Designed for maximum energies of 8 GeV per beam, it has one large experimental hall (the South Area occupied by the CLEO general purpose detection system), one small hall (the North Area occupied by the CUSB detector), and a synchrotron radiation laboratory called CHESS.

The storage ring has been operated so far at energies between 4 and 6 GeV while experiments have concentrated on studying the upsilon and its excited states. The maximum observed luminosity is 3×10^{30} per cm^2 per s and the average about 1.2×10^{30}, with a typical lifetime of four hours. Detailed machine physics is under way to understand beam behaviour so as to approach the design luminosity of 4×10^{31} at 5 GeV (10^{32} at 8 GeV). Low beta insertions to increase the luminosity at both interaction regions are also being studied, but space limitations, particularly in the South Area, may make them difficult to introduce.

A second r.f. cavity has recently been installed so that the peak energy can be taken to 7 GeV. Two further klystrons will later enable the design figure of 8 GeV to be reached. To reduce the filling time for positrons, a small intermediate storage ring, like PIA at DESY, is planned.

The PEP ring at Stanford has been brought into operation progressively during the past year and was reported by John Rees. At the time of the Conference a peak luminosity of 4 x 10^{30} per cm^2 per s had been achieved at an energy of 14.5 GeV per beam. However reliability is not all it could be and the average luminosity at the experiments is well down on this figure.

Usual operating currents are around 18 mA per beam in three bunches (so as to achieve collisions in the six interaction regions). As much as 24 mA have been stored in the electron beam but attempts to operate at these intensities have so far been thwarted by the incoherent beam-beam limit which is frustratingly low. When currents in the two beams approach this limit one of the beams blows up vertically. As on the PETRA storage ring at DESY, it is found that the tune shifts beyond 0.025 cannot be used (the design figure was 0.06). This is an important factor in limiting the luminosity well below the design value of 10^{32}. But machine studies are obviously in comparatively early days and, in addition, it is hoped that the introduction of three mini-beta sections will help.

Though not a newcomer since the last Conference, PETRA was covered in a short paper by J. Rossbach. Peak operating energy is now 18.3 GeV per beam and this is being taken to 20.5 GeV with the addition of more r.f. power. Again the peak luminosity (5 × 10^{30} at 17.8 GeV) was well below the design figure, but a series of measures are being taken to push this higher, including a mini-beta scheme (see box) and the addition of second harmonic cavities.

Just prior to the Conference, a Workshop on instabilities in high energy electron-positron storage rings was held at Cornell. CESR, PEP and PETRA are all having great difficulty climbing anywhere near their design luminosity. It is clear that extrapolation from what has been experienced at lower energy machines is not valid and much more detailed knowledge of beam behaviour is needed. Perhaps a general comment is that, with the laudable aim of getting into particle physics programmes quickly, not enough time has yet been given to machine physics so as to understand the beam-beam phenomena which are limiting all three rings.

For the future: electron machines

The latest authorization for a high energy machine, TRISTAN at the KEK Laboratory in Japan, was not covered at the Conference. Construction of the electron-positron phase of the project, a 30 GeV storage ring, is beginning. This was described in some detail in our April issue, page 103. The addition of a proton ring, particularly to study electron-proton interactions, is envisaged in a second phase.

The two vital applications of superconductivity are under attack at KEK with a view to their use in TRISTAN. Superconducting r.f. cavities are being developed for the electron-positron ring and superconducting pulsed magnets for the proton ring.

European physicists are optimistic that their own large electron-positron project, LEP, is nearing authorization and Eberhard Keil described the latest progress in optimizing the LEP design. The design retains, of course, the major parameters of LEP Phase 1 as approved by the CERN Council in June 1980 - the peak machine energy will be 50 GeV, the existing PS and SPS accelerators will be used in the injection system, four experimental areas will be equipped for the start of the experimental programme and the cost of Phase 1 will be 900 million Swiss francs at 1980 prices, to be found from within existing CERN budget levels (623 million Swiss francs at 1980 prices) over eight years.

Development of machine components is continuing. Two full size bending magnets have been built

Post-Conference News: PETRA achieves 10^{31} luminosity

The luminosity of the PETRA storage ring at DESY has been significantly increased following the installation of the so-called 'mini-beta intersections'. Only a few weeks after the rebuilding of the four interaction regions to incorporate the mini-betas had been completed, the luminosity passed 10^{31} per cm^2 per s, with integrated values above 700 per nb per day at energies of 17 GeV per beam. This is a considerable improvement over the previous bests. So far there is no indication that incoherent beam-beam limits are lower in vertical beta values as small as 6-8 cm, compared with the previous 15-20 cm.

The battle for high luminosity in storage rings has proved to be less painful with protons. The CERN Intersecting Storage Rings have by far exceeded the design figure, and at the end of March a new record of 1.2 × 10^{32} was reached during commissioning of the new superconducting low beta section.

Work under way for a reconnaissance gallery to investigate the conditions which might be met in constructing the LEP tunnel.

(Photo CERN 9.4.81)

using the novel technique of introducing concrete into the cores (see April 1979 issue, page 66). Other w techniques are applied in the r.f. system where a complete module including a low-loss cavity is being operated. A new type of vacuum pump has been installed on PETRA where it is achieving a lower pressure than on the rest of the machine. Work on the preinjector (the linac and accumulator ring) is proceeding in collaboration with the Orsay Laboratory.

In preparation for the major task of boring the LEP tunnel, a 'reconnaissance gallery' was started recently to investigate geological and hydrological conditions under the Jura mountains and to test use in the Jura rock of a full-face boring machine as was used in the SPS construction. Concerns about tunnelling under the Jura have influenced the decision to reduce the LEP circumference from 30 to 27 km (as reported briefly in our April issue, page 119).

The proposed new location of the smaller tunnel retains its link with the SPS, which serves in the injection system of the electrons and positrons, and keeps the proton options open for the future. The reduction in size avoids the most worrying strata - the Trias at the deepest region under the Jura where problems of tunnel stability and water pressure could have been at their most severe. Some of these problems may still exist but at least they will be minimized by reducing the distance traversed under the Jura from 12 to 8 km. The access to three of the experimental regions will also become easier.

The reduction in radius would imply a small increase in the power loss via synchrotron radiation from LEP due to the stronger bending by the magnets. However the LEP team had already been thinking about applying stronger focusing in the ring which would reduce the 'overvoltage' needed to retain the particles with the radio-frequency accelerating fields. This stronger focusing allows a slightly higher voltage to be applied to the particles in the r.f. cavities and no additional power is then required to compensate for the radius reduction. There is some trade-off on beam stability but this would be tolerable.

In the USA there are plans for future electron machines at Stanford and at Cornell. The SLAC Linac Collider was reviewed by H. Wiedemann. It aims to achieve colliding electron-positron beams, accelerated in the SLAC linac, at 50 GeV with a luminosity of at least 10^{30}. Quite apart from the physics which such a collider would make possible itself, it is seen as a pilot project for future schemes with colliding linac beams since linacs will probably be the only reasonable route to electron-positron colliding beam energies much beyond 100 GeV per beam.

The Collider (described in the December 1979 issue, page 403) will have two small low energy storage rings, one to hold two bunches of electrons, the other two bunches of positrons. One electron bunch will be accelerated to produce positrons which will be brought back to the positron ring. The other electron bunch will be accelerated together with a positron bunch and these bunches will be taken through separate areas of magnets, strongly focused to a spot size of about 3 microns, and collided head-on.

Work is under way on such things as high intensity electron guns (using photoemission and laser techniques), energy increase in the linac (the SLED programme has now given a peak energy of 33 GeV) and

Late news: On 3 April, the world's first collisions between stored proton and antiproton beams took place in the CERN Intersecting Storage Rings and were recorded. Experiments continued to take data over the next few days. In the June issue, we will have further details of this latest success for the CERN Antiproton Project, which has now produced its first physics (see photo on page 165).

the special beam dynamics. If authorization were forthcoming it is estimated that the construction could be finished in 1985 and the present cost estimate is $63 million.

At Cornell, thinking is concentrating on a higher energy electron-positron ring, CESR II, to provide 50 GeV beams. It would be fed by the existing synchrotron and two possible locations are being studied. The aim is to present a proposal in 1982. The cost is likely to be in the region of $165 million and whether such a project could be funded from Cornell's traditional sources is not obvious.

An important aspect of CESR II would be the use of superconducting technology for the r.f. accelerating system. To prepare for this, the research on superconducting r.f. structures which has been going on at a modest level for many years at Cornell is being reinforced. Before presenting the proposal, a 2 m length of 'muffin tin' structure will be installed on the existing machine towards the end of this year for initial feasibility studies.

For the future: Hadron machines

Most imminent is the operation of the 270 GeV proton-antiproton collider at CERN. The vital technique of stochastic cooling, being applied in the Antiproton Accumulator, which makes intense beams of antiprotons possible, was covered at the Conference by its inventor Simon van der Meer. We have been reporting on this project regularly over the past months and intend to carry a general review article around the time of first operation later this year.

Don Young reported on the equivalent work at Fermilab. They now have experience with electron cooling and stochastic cooling and intend to incorporate both of them in their scheme to achieve proton-antiproton collisions at energies up to 1000 GeV in a few years. The work is being done in collaboration with Argonne, Berkeley, Novosibirsk and US universities.

Progress towards the 1000 GeV Tevatron ring at Fermilab means, especially, progress towards constructing pulsed superconducting magnets. This was described by Alvin Tollestrup. At the time of the Conference they had built over 350 half coils and about 120 were installed in their yokes and cryostats. Some 40 of them are installed in the tunnel. Magnets are now being produced at the rate of one per week and the bottleneck in the construction programme is proving to be the rate at which they can be tested.

There is confidence that Fermilab has emerged from the long development programme with magnets of adequate quality for the Doubler. The successful performance of the 21 magnet string in the 'left bend' (reported in last month's issue) has boosted this confidence. Tollestrup listed some lessons which had been learned – quality control is much more difficult than expected and has to go on at each stage of the construction rather than on completed units. For initial operation the amount of refrigeration required can be twice what is needed when the magnets settle down. The magnet test facility ideally should have been much bigger. They do not believe that superconducting magnet construction is yet in a state which can be put out to industry.

Fermilab still hopes to complete the superconducting ring by June 1982 and to have protons of at least 800 GeV on target by the beginning of 1983. Another important impact of the start of the Energy Doubler will be in improved exploitation thanks to energy savings. Bob Wilson's prediction of $ 5 million per year savings on the energy bill has been overtaken by events – the updated figure is near $20 million.

The other Laboratory in the midst of a superconducting magnet programme is Brookhaven for the 400 GeV proton–proton storage rings, ISABELLE, reviewed at the Confe' ence by Kjell Johnsen. ISABELLE the only hadron-hadron collider which promises to achieve high luminosity (10^{32} per cm^2 per s) and will thus be complementary in its physics programme to other machines which are being built or proposed.

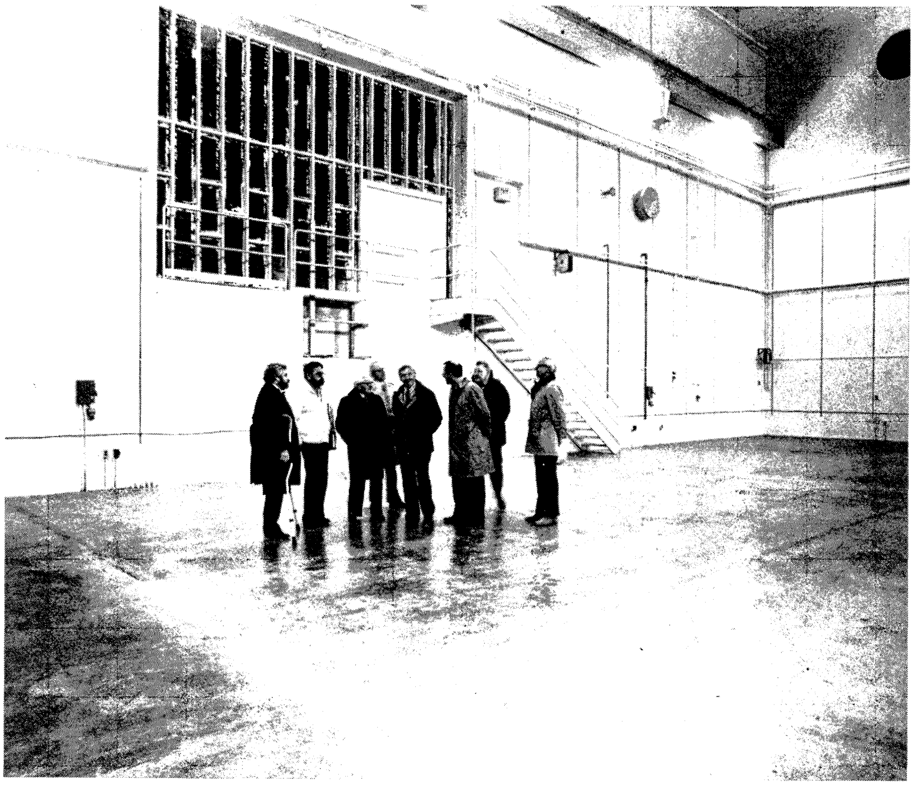
However it is here at ISABELLE that a high proportion of the budget cut mentioned at the beginning of this report is to be applied (a reduction of some $20 million, which is half the anticipated construction budget for Fiscal Year 1982). There is no doubt that the reason for the axe falling heavily at Brookhaven is because progress with the magnets does not indicate that the construction schedule could be met in a case.

The civil engineering work has gone very well. Most of the tunnel is complete and several of the experimental halls have been handed over. All the 'conventional' systems are also at an advanced stage – injection, vacuum, r.f., beam dump, controls. Lack of success with the magnets, however, has resulted in a return to studies of design details and to the start of model work on alternative designs.

The ISABELLE dipole has several unique features – the use of braid as the conductor, the choice of warm bore and cold iron yoke. Thus the development of the magnet has gone on somewhat in isolation, unable to compare and profit from experience elsewhere. Its most diffi-

Civil engineering for the ISABELLE 400 GeV proton-proton storage rings is well advanced. Most of the tunnel is complete, and the picture shows one of the experimental halls (the 'Wide Angle Hall') being inspected in March for 'beneficial occupancy'.

(Photo Brookhaven)



cult task is to achieve a peak operating field of 5 T; this was accepted somewhat reluctantly by the Brookhaven team in 1977 under pressure from the High Energy Physics Advisory Panel who wished to see the machine energy increased from 200 to 400 GeV. It is now widely recognized that though individual magnets will top 5 T, the operating field with all 732 dipoles is likely to be down on this, giving a machine energy of say 370 GeV.

Early experience was perhaps too encouraging (Johnsen remarked that 'with hindsight, we recognized that it is as important to find out why things go well as it is to find out why they go badly'). The Mark V prototype trained rapidly and reached the desired field and gave every reason to believe that a viable design had been developed. Magnets were then put out for construction to industry but they performed poorly, beginning training at a very low level and training very slowly afterwards.

The recent measures to improve performance include a 'double shrink' assembly sequence, attempting to reduce conductor movement by increasing the prestressing. The coils are first shrunk into aluminium (or epoxy) bands and then shrunk into the magnet yoke. A significant improvement seems to have been achieved. Magnets Mark 18 and 24 with aluminium bands reached 5 T after about fifteen quenches. The braid is being studied to try to reduce eddy currents by increasing the surface resistance of the wire. More dipoles are now ready for testing and it is hoped that the concentrated attack on the magnet problems will conclude in a viable design in the near future.

Victor Yarba described the preparations for the 3 TeV proton synchrotron, UNK, at Serpukhov. Construction, over the years 1981-1990, has been authorized. The project uses the upgraded (to give an intensity of 5 x 10^{13} protons per pulse) existing 70 GeV machine to feed a 400 GeV conventional ring which in turn will feed a 3 TeV superconducting ring in the same tunnel. The two concentric proton machines will obviously allow proton-proton collisions with energies up to 0.4 on 3 TeV. In collaboration with Novosibirsk, antiproton options are also being studied.

Perhaps the most interesting news from the project concerned the superconducting magnets (similar to the Fermilab design) being developed in collaboration with Leningrad and Saclay. Ten 1 m models of full cross-section have been built. Those that have been tested exhibit almost no training and top 5 T fields. The field configuration is not yet good enough but the cause is understood and magnet modifications are being made. Tooling for the 6 m-long magnets for UNK is ready and the magnets will be built at Serpukhov itself.

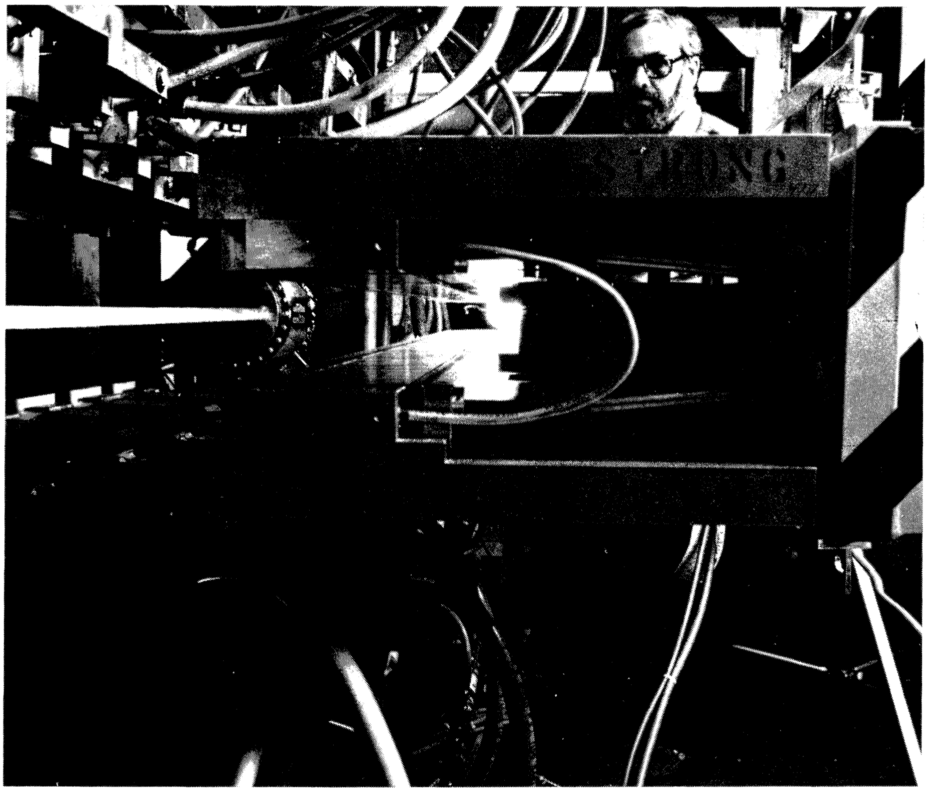
Bjorn Wiik reported on the electron-proton project, HERA, planned for the DESY Laboratory. This project was covered in detail in our May 1980 issue. It has been recommended in principle by the Committee set up to study big projects in the Federal Republic of Germany, but with the proviso that construction should not be authorized before 1984.

Synchrotron radiation

The use of low energy electron storage rings as sources of synchrotron radiation is now an 'everyday' use of accelerator technology and the research programmes they are supporting have escalated beyond the expectations of their most voci-

Herman Winick beside the permanent magnet undulator which has been successfully operated at the Stanford Synchrotron Radiation Laboratory on the SPEAR storage ring. On the left is a wiggler magnet split in half and the halves withdrawn to permit the undulator to be moved in over the vacuum chamber.

(Photo Stanford)



ferous proponents. We will pick out here some of the interesting news concerning these machines which emerged at the Conference.

In the USA, the National Synchrotron Light Source (NSLS) at Brookhaven is nearing completion. The 50 MeV linac is operating and there has been spiralling beam in the 700 MeV Booster. The Vacuum Ultra-Violet Ring (700 MeV with a potential of sixteen emerging beam ports for the synchrotron light) is expected to have beam this summer. The X-ray ring (2 GeV with a potential of 28 ports) is being surveyed.

It is typical of the field that a very large community of users has built up rapidly and long lists of experiments using both rings have been approved. As the machine comes into action, its experimental exploitation is expected to build up over many years after first operation. Brookhaven has already been encouraged to present a proposal for Phase II of the development of its synchrotron radiation facilities. More experimental hall area and office accommodation are planned and it is hoped that their construction can start in Fiscal Year 1983.

From Wisconsin, the ALADDIN 1 GeV ring was reported as nearing completion. The ring is 'closed' – the microtron of the injection system was scheduled for operation by the end of March and it is hoped to have beam by the end of May. It is good to see one of the spiritual, and practical, homes of synchrotron radiation research being refreshed in this way.

At SPEAR, Stanford, 50 per cent of the operating hours have for some time been in the hands of the Stanford Synchrotron Radiation Laboratory. A nice technological development is the successful introduction of a permanent magnet undulator in the storage ring. This Berkeley/SSRL achievement was communicated by K. Halbach, who did some of the important early work on permanent magnets at Berkeley.

The undulator is a thirty-period permanent magnet, almost 2 m long, made of samarium-cobalt blocks and designed to increase the flux of radiation in the 1 keV region by a factor of a hundred. (A 'wiggler' is a device introduced into a magnet lattice to produce a sharper bend than usual and thus increase the usable energy range of the available radiation. An undulator is a multi-wiggle device introduced to produce a large flux of radiation of particular wavelengths pointing at a single exit port.)

The undulator gap is variable from 6 to 2.7 cm and in the closest position gives sinusoidal fields with a peak value of 0.28 T. Further developments anticipate introducing the undulator into the storage ring vacuum vessel where it will be necessary to be able to move the poles apart during injection. The use of permanent magnets has reduced cost and complexity and will also be more economical in operation.

It is impressive how rapidly permanent magnet technology has caught hold. Following the Berkeley work, permanent magnets were adopted for the Los Alamos PIGMI project (Pion Generator for Medical Irradiations), as described in the July 1977 issue, page 231, and now permanent magnet quadrupoles are available commercially.

On the European front, we reported in January (page 8) the coming into operation at Daresbury of the world's first large dedicated synchrotron radiation facility, while the formal opening of HASYLAB at DESY is covered on page 157. For the future, the Group set up by the European Science Foundation to examine the needs and machine possibilities produced a paper on an 'All Wiggler' synchrotron radiation source. This source attempts to cover all likely radiation needs while adapting the machine to fit an existing tunnel which could become available in the near future. The characteristics of wiggler radiation as opposed to conventional magnet radiation need more study to ensure that they are appropriate for the full range of foreseeable experiments.

Heavy ion fusion research

This may be the last time for a while that this topic appears in an accelerator Conference report as the financial support for research in heavy ion fusion has been reduced from $5 million to zero for the next Fiscal Year. Groups at Argonne and Berkeley are affected.

Lee Teng gave a general review of progress. The aim is to achieve fusion by imploding deuterium-tritium pellets via simultaneous bombardment with several intense high energy beams of heavy ions. Two main routes have been followed – a system involving r.f. linacs and storage rings, promoted at Argonne by Ron Martin and Rick Arnold, and a system involving induction linacs, promoted at Berkeley by Dennis Keefe.

The r.f. linac scheme builds up the necessary high intensity by combining beams from banks of linacs. Argonne has operated a dynamitron accelerating column followed by a bank of three independent 12.5 MHz cavities. A 2 MeV, 40 mA xenon ion beam has been achieved. It was intended to add three more cavities, raising the energy to 3 MeV and then inject into three linacs. The beam combination schemes could thus have been tested.

Induction linacs have to be adapted from their traditional role of accelerating intense electron beams to accelerating intense ion beams. Berkeley have produced a 1 A caesium beam from a 500 kV surface contact ionization source and accelerated about 500 mA to 1.5 MeV in a three drift tube structure. Design studies were under way for a 50 J industrial linac.

Two important new technologies were being pursued in the course of the heavy ion fusion research but will undoubtedly also have applications elsewhere. The first (proposed by I.M. Kapchinskii and I. Teplyakov) is the idea of self-focusing linac structures. This has been tried very successfully at Los Alamos in the form of r.f. quadrupoles (RFQs, see May 1980 issue, page 108). By moving away from the standard symmetric cylindrical drift tube structure, radial electric fields are produced which focus as well as accelerate the particles and produce the required bunched beam. The concepts could find their way, in several forms, into the linacs of the future.

The other important new technology came from Al Maschke of Brookhaven when he was thinking about the intense beam requirement for heavy ion fusion. The maximum current that can be transported down a quadrupole channel is not a function of the aperture of the channel. High intensities could thus be achieved by accelerating (and subsequently bringing together) many 'beamlets' passing through tiny adjoining apertures. However magnetic focusing quadrupoles cannot be brought to very small sizes and electrostatic focusing fields need to be used instead – hence the name of the technique, MEQALAC, Multiple-beam Electrostatic Quadrupole Array Linear ACcelerator, invented by Maschke.

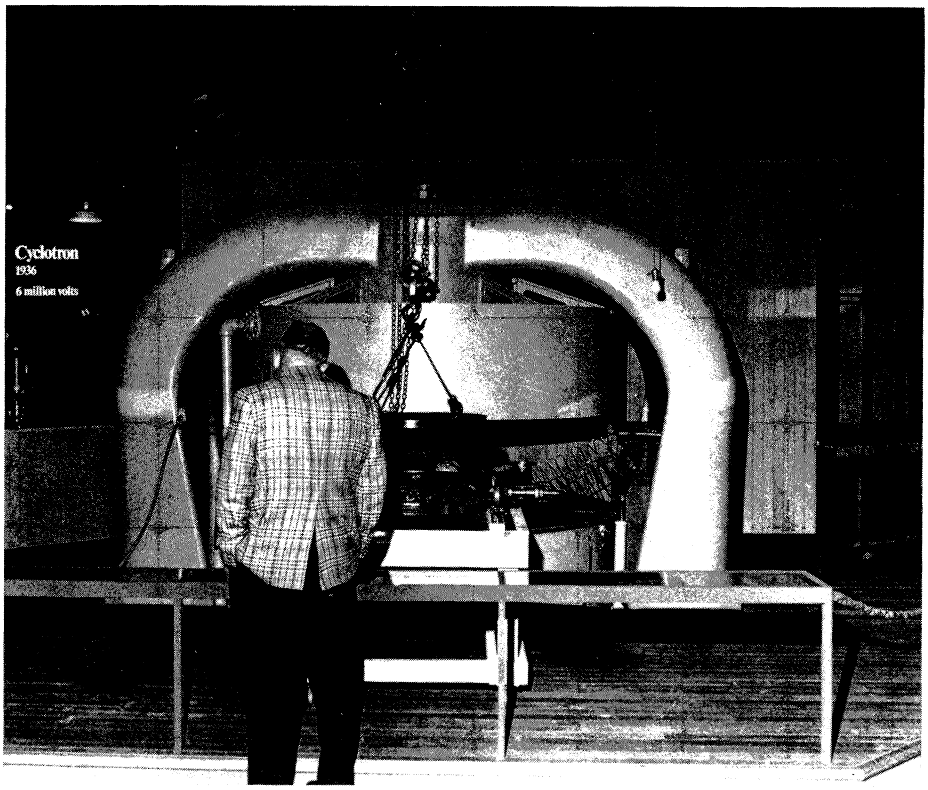
The concept has been demonstrated at Brookhaven and a linac accelerating xenon ions from 15 to 75 keV at 4 MHz has operated. A 200 MHz, 40 to 700 keV structure to accelerate four beams of negative hydrogen ions is being built. A lot of effort has gone into methods of making the pepper-pot grids to transport the beamlets. The latest achievement is a 1000 beam grid of one square inch with channel radius of 250 microns. It is hoped to attain a channel radius between 50 and 100 microns.

Ideas for MEQALAC applications include an S-band proton linac which would have accelerating gradients like an electron linac. This would at last be the route to cheap proton machines for hospital use, competing with electron linacs with costs around $300 000. Even the excellent work at Los Alamos on the PIGMI project (see September 1978 issue, page 297) never reached comparable figures. The chemists are interested in studying the low energy scattering of atoms on atoms at high intensities in the microamp, rather than the nanoamp, range, and this would be feasible with MEQALACs. There may be applications in high voltage electron tubes (high efficiency multibeam klystrons). In industry, a tiny mobile linac would be able to implant ions, like nitrogen in steel, for corrosion resistance on existing structures. (Implantation before forming gives mechanically difficult materials.)

Miscellaneous

There were many more topics covered at the Conference, but space restrictions mean that we have to leave large blocks of information aside. However some topics, for example the latest news of the new large high voltage tandems and the accelerator-based high flux neutron

During the Washington Conference, a nice perspective of where we are today was given by W. Brobeck who was invited to speak about the early days at the Radiation Laboratory, now the Lawrence Berkeley Laboratory. This year, LBL celebrates the fiftieth anniversary of its founding as the Radiation Laboratory under E.O. Lawrence in 1931. The photograph shows one of the 'big' cyclotrons built at the Laboratory in 1936, capable of reaching 6 MeV. This relic is now on display in the 'Atom Smashers' exhibition at the Smithsonian Institution in Washington.



sources, we expect to be coming back to in future editions. Other interesting developments are included here in scrapbook form.

The use of accelerators in pion production for cancer treatment is extending. Los Alamos has now treated over 150 patients and has gone on to treat 'general' cases rather than specially selected ones. TRIUMF in Canada has treated eight patients so far and SIN in Switzerland is just bringing a sophisticated system (including a mutiple beam device like that proposed at Stanford High Energy Physics Laboratory) into action. Neutron therapy, as at London's Hammersmith Hospital, and heavy ion therapy, as at Berkeley, are also extending.

The use of proton linacs for isotope production, as for example at Brookhaven and Los Alamos, is going commercial. New England Nuclear are building a 45 MeV, 5 mA linac particularly for producing the thallium-201 isotope which is used in carrying out heart scans.

The Fusion Materials Irradiation Test facility, FMIT, was to be used (following a Brookhaven idea) to produce very high fluxes of 14 MeV neutrons for rapid studies of the material damage problems which will be encountered in fusion machines. Los Alamos was working with Hanford to develop a 35 MeV, 100 mA deuterium linac. This project is also stopped by the budget cuts.

The work on gyrocons as a potentially higher efficiency r.f. power source than klystrons was reviewed by Vic Granatstein. Novosibirsk still has the finest results (see page 159). Work has started in the USA, for example at the Naval Research Laboratory, at Varian and at Los Alamos. The interests outside the accelerator field are related particularly to communications applications.

The free electron laser is, to quote one participant, 'the sexiest thing in accelerator technology today!' Phil Morton gave a very thorough seminar on the topic. Several papers covered present work. In view of its apparent sex appeal, it is certainly a topic we should and will cover when we understand it.

The Conference closed with Carlo Rubbia encapsulating the present frontiers of particle physics into forty minutes, with Maury Tigner pleading to funding agencies and Laboratories not to desert research and development in hard financial times, and with J. Leiss reminding us of the host of contributions in science, industry and medicine which have all evolved from developments in accelerator technology. There was every reason to believe in Washington that these contributions will increase in the future.

Around the Laboratories

FERMILAB
New proton intensity record

On 16 March the Fermilab accelerator achieved a record intensity of 3.003×10^{13} protons in a single pulse. The accelerator was operating 400 GeV and running a full exper-ental programme incorporating the superconducting left bend and neutrino experiments in both the Meson and Neutrino Laboratories.

Bob Mau, head of the Accelerator Operations Group, attributes the new record to several factors. The booster achieved a record intensity due, in part, to steady progress with negative ion injection. In addition overall reliability has been extremely good, making it possible both to service the experimental programme and systematically adjust the accelerator.

As well as the main ring intensity record, many other best performance figures were achieved. The Booster went up to 4.108×10^{13} otons per Main Ring cycle several ours after the Main Ring record was set. Good Booster–Main Ring transfer permitted a record injection into the Main Ring of 3.29×10^{13} protons per pulse. In recent weeks a record weekly average of 10.1×10^{17} protons was set at 400 GeV, even with restricted power levels. In the same interval the accelerator intensity averaged 2.3×10^{13} per pulse for high energy physics.

Fourteen hours after the record was set up, the accelerator was turned off for a week and a half to take care of Doubler projects. It is expected that operation through the rest of the spring will be able to continue near the record levels since no special arrangements were necessary. In addition, the experimental programme will continue to need all the protons the accelerator can deliver.

In the Fermilab main control room on 15 March witnessing the new proton intensity record are (left to right) Jim MacLachlan, Director Emeritus Robert Wilson and Director Leon Lederman.

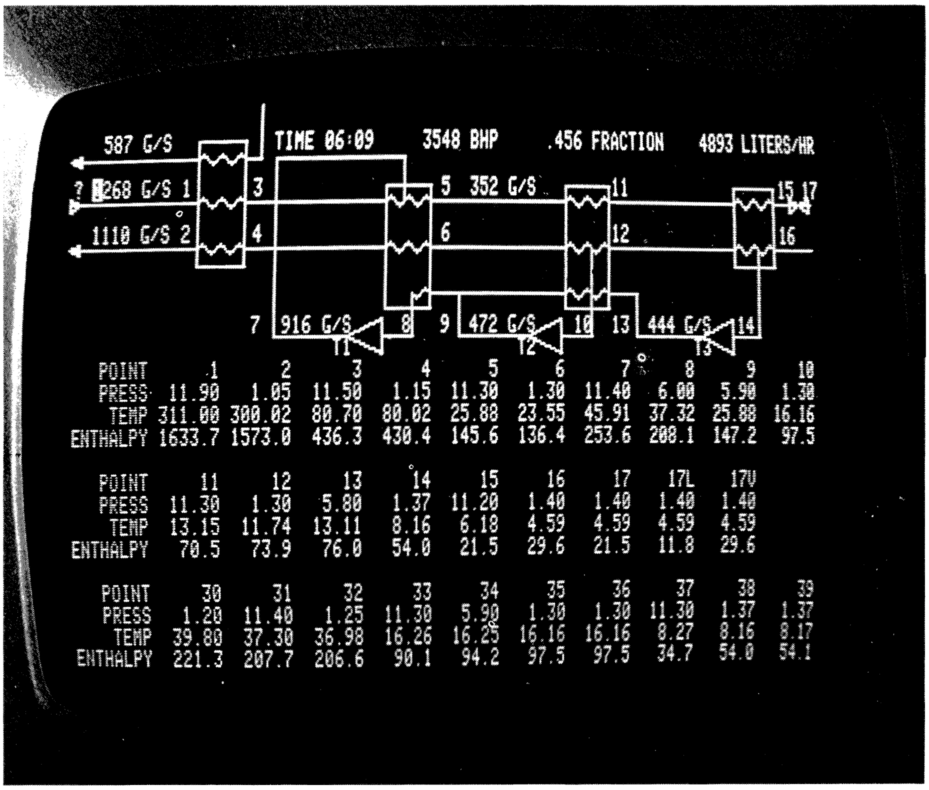
(Photo Fermilab)

Superconducting Chicago Cyclotron Spectrometer

Superconducting coils for the venerable Chicago Cyclotron Magnet spectrometer have been successfully operated at Fermilab. This magnet now becomes one of the largest operating superconducting magnets in the world, second only to BEBC at CERN and larger than the fifteen foot magnet at Fermilab. The coils, with a mean diameter of 210 inches, have produced a field of 14.6 kilogauss.

The conversion of the spectrometer to superconducting operation began several years ago under a special United States Department of Energy grant for energy conservation. The old conventional coils required nearly three megawatts. The new superconducting coils require 14 litres/hour of liquid helium with the field off and 15 litres/hour when the field is on. This corresponds to 10 watts of refrigeration at liquid helium temperature, or 30 kilowatts of refrigeration at room temperature. Power delivery and liquid nitrogen add to this but the overall power saving is enormous. Typical savings are expected to be several hundred thousand dollars, equivalent to tens of thousands of barrels of oil a year.

The magnet was originally the major component in the Chicago Cyclotron. That machine, built by Herb Anderson, Enrico Fermi and



One of the computer terminal displays produced by the Fermilab refrigeration simulator. The four heat-exchanger modules are represented by rectangles and the three turboexpanders are labelled T1, T2 and T3. Temperature, pressure and enthalpy data are displayed so that an operator can run the simulated system to study any desired operating conditions.

Simulated refrigeration

An interactive software simulator has been developed at Fermilab to study the refrigeration available from the cryogenic system of the Energy Saver over a wide range of operating conditions. The simulator predicts the system performance of any available compressor flow, nitrogen consumption, expander efficiency, heat exchanger effectiveness, or heat load.

The helium refrigeration system for the Energy Saver is installed over a 1.25 square mile area and includes 24 satellite refrigerators and a Central Helium Liquefier. The changes in performance of the components in the refrigeration system have been modelled. The overall effects on the system during these abnormal operating conditions can be calculated and presented in a real-time display to develop operating procedures appropriate for running during reduced performance.

others, went into operation around 1951 and went on to produce some of the first evidence on the famous 3-3 pion-nucleon resonance. In 1971, after two very fruitful decades of research in cyclotron physics, the magnet was moved to Fermilab, where it was installed as a spectrometer in the muon beam. Old cyclotron hands Herb Anderson and Courtney Wright participated in that first series of experiments which observed the first scaling violations in muon-proton scattering. Later, a Chicago/Princeton group found evidence for significant quark charge effects in J/psi production. Recently Tom Kirk and others have used the spectrometer to look at production of bare charm and chi mesons.

The designers and builders, led by Bob Kephart, have paid careful attention to minimizing heat leaks on the new superconducting coils. One aspect of this has been the construction of coil support columns with a very high mechanical strength to thermal conductivity ratio. This was made possible by the use of epoxy-fibreglass laminates. These coils must support a magnetic load of more than one million pounds for each of the coils. The sophisticated suspension allows radial motion of the coils including the possibility of a slight ellipsoidal distortion due to the return yoke. A second feature of the design is the use of high purity aluminium tape on the 4 K surfaces to reduce the radiation transfer of the surfaces. The coils are cryogenically stabilized with copper. Pool boiling is used on the coils. At present helium is supplied from a dewar, but eve tually the system will have its own refrigerator.

Self-quenching streamers

Self-quenching streamers have been observed both optically and electronically at Fermilab. These streamers develop with a constant applied high voltage so that no trigger is necessary. Electronic pulses from such chambers are fast, relatively constant in amplitude, and about forty times larger than normal drift chamber pulses. Possible applications include inexpensive, noise-free, high accuracy drift chambers and extruded drift tube systems as well as improved energy resolution in gas sampling calorimetry. E-594, a new neutrino experiment at Fermilab, is currently preparing inexpensive multiplicity hodoscopes based on their use.

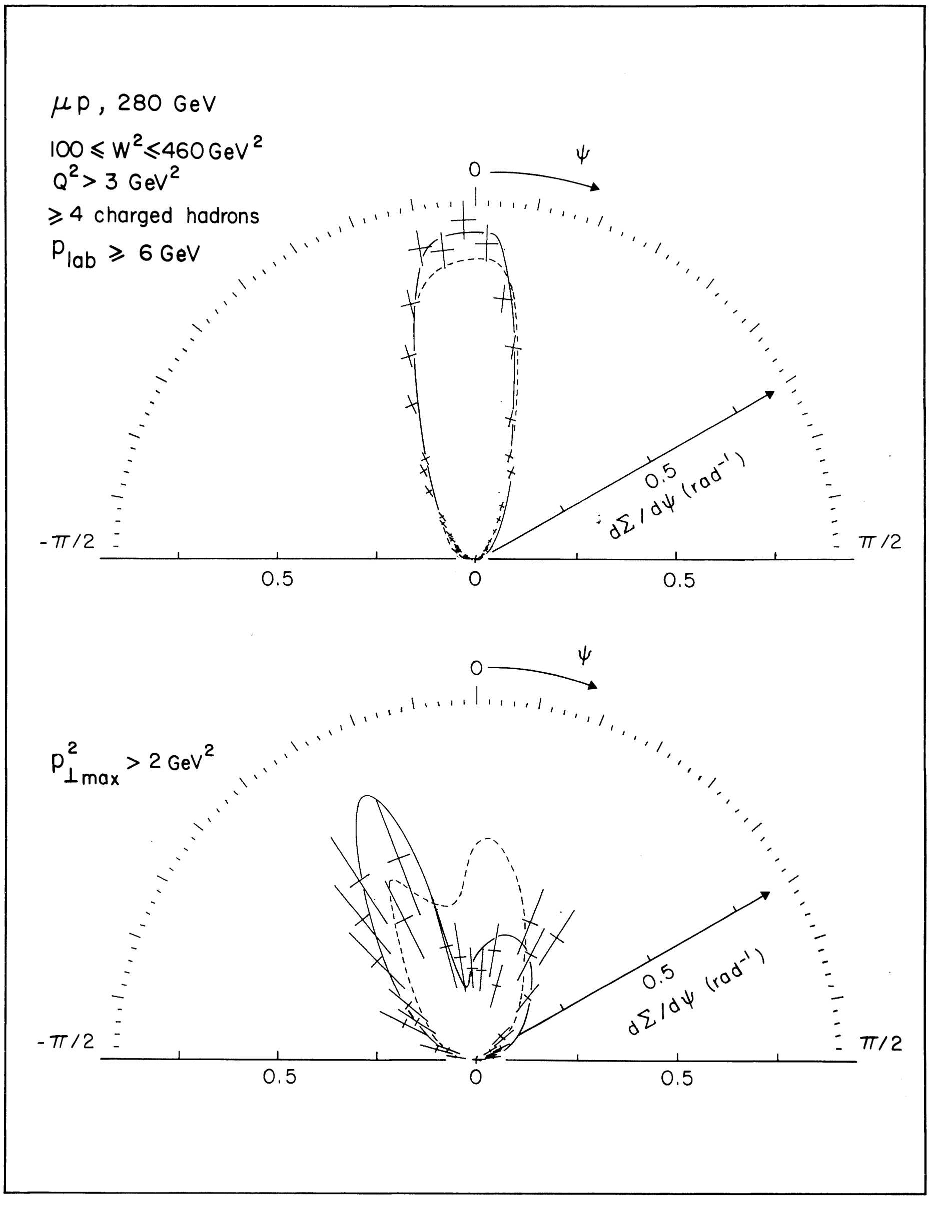
The experiments, carried out by Muzaffer Atac, reveal that when avalanche size reaches a critical value as the electrical field is increased, a discontinuously fast transition occurs from the limited proportional mode (the normal operating regime for proportional and drift chambers) to a self-quenching streamer mode. Measurements show that pulses rise to about 50 mV (fifty times normal proportional chamber pulses) in 5 ns.

Photographs of the self-quenching streamers were recorded using a double image intensifier video camera. The streamers are 200-300 microns thick and are formed orthogonal to the anode wire with a height of several millimetres starting from the anode. The height and width of the streamers shrink as the pressure is increased.

Pulse height distribution is very uniform in this mode, independent of initial ionization (minimum ionizing tracks and X-rays produce the same type of distribution). The Landau tail disappears and the distribution becomes gaussian for minimum ionizing tracks. The typical charge obtained from the anode is larger than 10^8 electrons, thus requiring no amplifier and with practically noise-free readout.

CERN
Finding jets

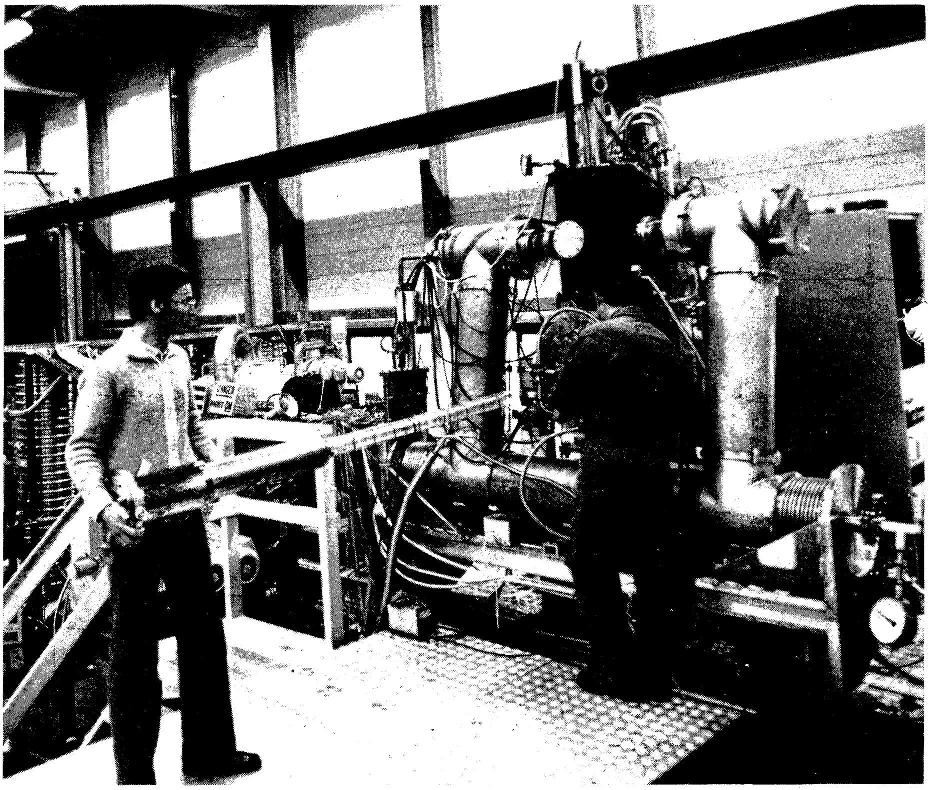
With the interactions of leptons apparently well understood, experiments using high energy lepton beams on fixed targets now tend to look hard at the hadrons which are produced. When the leptons penetrate deep inside the target hadrons and interact with the constituent quarks, violent collisions occur which are characterized by the release of particles with large momentum transverse to the collision axis. By looking carefully at the results of these collisions, experimenters are finding more and more effects due to quark dynamics and which can be calculated by quantum chromodynamics (QCD), the theory of the 'colour' force acting between quarks.



Energy flow of the hadrons produced by muons in the European Muon Collaboration experiment at the CERN SPS. For events with high energy forward-produced hadrons, the energy is contained in a narrow forward cone (top). However for a subset of the data containing at least one hadron produced with large transverse momentum (bottom), a clear two-jet structure shows up. The data is in good agreement with a quantum chromodynamics calculation (solid line), while the broken line shows the results of a quark jet fragmentation model.

Tapio Niinikoski holds the world's largest polarized target ready for insertion into its cryogenic magnet.

(Photo CERN 396.3.81)



Big polarized target

The world's largest polarized target, 1 m long and 50 mm in diameter, has been successfully tested at the European Muon Collaboration (EMC) experiment at the CERN SPS. This target will be used in future data-taking to measure the dependence of the muon interaction on quark spin.

To operate the target requires a very large liquid helium dilution refrigerator, supplying 1.3 W of cooling power at 0.5 K. The polarizing field is provided by a superconducting magnet specially built by the Rutherford Laboratory (see May 1980 issue, page 113), providing a magnetic field of 2.5 T accurate to one part in 10^4 over the target volume. In the first tests, polarization of up to 80 per cent was achieved with good homogeneity.

In addition to the dilution refrigerator and specially constructed superconducting magnet, the EMC polarized target uses an impressive array of state-of-the-art technology, including a multichannel r.f. system, developed by Liverpool University, for polarization measurements using nuclear magnetic resonance.

According to Erwin Gabathuler of the CERN Directorate and a member of the EMC team, this type of close collaboration between home institute, national institute and CERN is foreseen for the development of detectors by the future collaborations to work at the LEP electron-positron ring.

However so far these lepton scattering experiments, which have been mainly confined to neutrino beams, have not revealed signs of the 'jet' structure seen in colliding beam experiments. These jets are understood to be due to the fragmentation of quarks and gluons produced in the initial collisions with quarks (see following story).

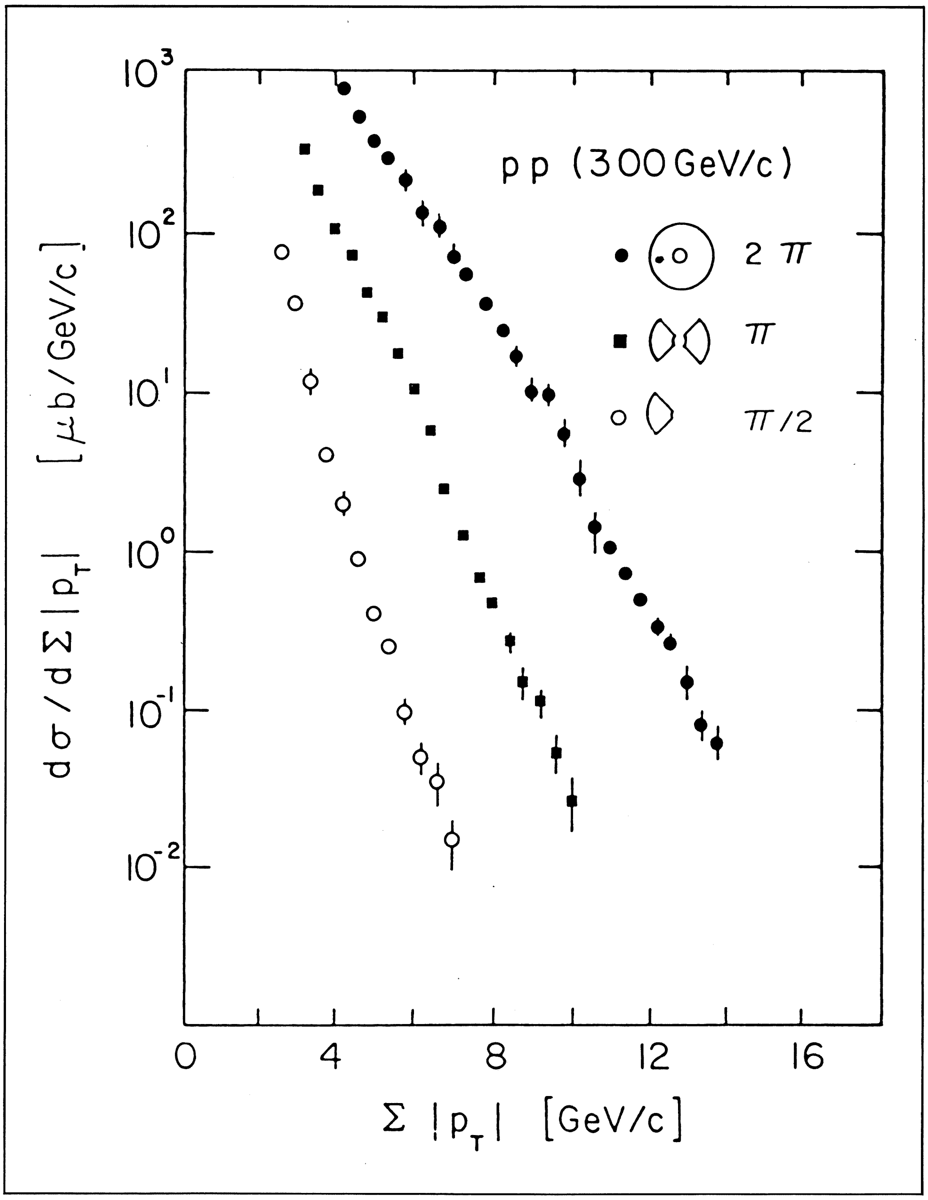
Now some new results from the European Muon Collaboration (EMC) at CERN show definite signs of jet production in high energy muon-hadron collisions, and the results agree with the predictions of the QCD theory.

EMC is a major collaboration of twelve research centres involving some eighty physicists, and is one of the largest installations in the North Experimental Area of the SPS 400 GeV proton synchrotron. The muons have a mean energy of 280 GeV and are scattered from a hydrogen target six metres long. The produced hadrons are measured in the forward spectrometer, a comprehensive piece of experimental apparatu incorporating a large aperture bending magnet and a magnetized iron muon filter.

Earlier analysis of the data showed how the transverse momentum of the produced hadrons increases with their energy. This is interpreted as being due to the emission of gluons as well as quarks in the primary collisions, and has also been seen in high energy neutrino scattering experiments.

A subsequent analysis of the EMC data looked at 2700 muon scattering events with large momentum transfer and containing high energy forward-produced hadron showers with at least four charged hadrons. For each of these events, an event plane was calculated which contained the event's virtual photon

Preliminary results from the NA5 experiment at CERN on particle production in high energy hadron-hadron collisions using a wide angle calorimeter to intercept as many of the produced particles as possible. Data was taken in three ways: using the full calorimeter, using two opposite arms making up half the calorimeter, and using just one arm (one quarter of the calorimeter). The measured cross-sections as presented are difficult to reconcile with a jet model.



(responsible for the interaction between the muon and the struck hadron), and which contained a maximum amount of the transverse momentum of the produced hadrons. The results were corrected for systematic errors by a simulation of the whole experiment.

The analysis showed a significant umber of events where the calcu-ated event planes contained very high transverse momenta, strongly suggesting that the events themselves were basically planar.

In addition, the energy flow and particle flow in this topology were calculated, and not surprisingly most of the hadrons and the energy were found to be contained in a narrow forward cone in front of the calculated direction of the events' virtual photons. However when a subset of 124 events was taken which contained at least one produced hadron with transverse momentum greater than 2 GeV^2, then a clear two-jet structure showed up. Moreover these energy and particle flow patterns are in agreement with the pre-ictions of QCD.

Looking for jets

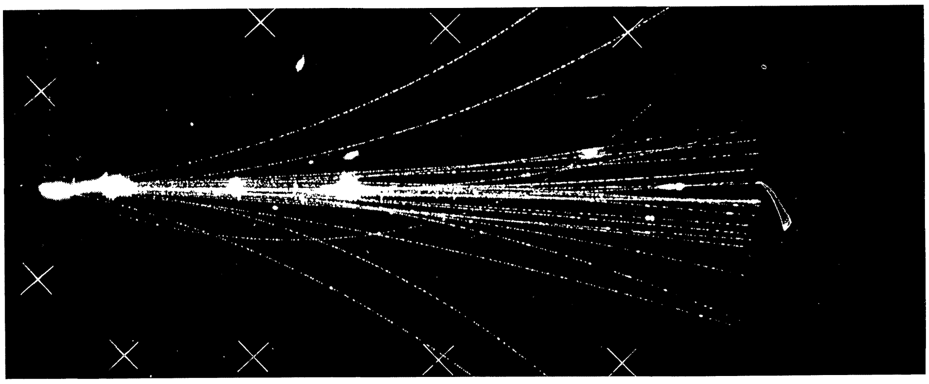
The study of 'jets' – more or less well defined sprays of particles emerging from high energy particle collisions – is now a well established part of high energy physics. However preliminary results from an experiment at CERN by a Bari/Cracow/Liverpool/MPI Munich/Nijmegen (NA5) collaboration show that the study of jets in hadron-hadron collisions might pose some difficulties.

Jets are understood to arise from the liberation and subsequent fragmentation of quarks and gluons. They are seen in violent collisions which probe the inner structure of hadrons, and in electron-positron annihilation.

In jet studies, experimenters monitor the particles emerging with large momentum transverse to the collision axis. In colliding beam experiments, for example with proton-proton collisions at the CERN Intersecting Storage Rings, jet-like events are sought by triggering the apparatus on single particles with large transverse momentum. However this may mean that jets with high transverse momentum leading particles are being selected in preference to jets whose large transverse momentum is smeared over many particles. This is known in the trade as 'trigger bias'.

To remedy this, experiments have been carried out at CERN and Fermilab using large angle calorimeters to catch the products of fixed target collisions and where the events are triggered by a threshold transverse energy in the calorimeter.

Streamer chamber picture from the NA5 experiment, showing the large secondary multiplicities seen in high energy hadron-hadron collisions.



At CERN, preliminary results from the NA5 collaboration, using a large acceptance calorimeter, do not show conclusive strong evidence for jets in collisions using SPS beams. First results were announced at the Madison Physics Conference last year (see September 1980 issue, page 240), but the latest results are nevertheless still described as preliminary.

The aim of the experiment is to investigate violent hadron collisions producing large numbers of secondary particles. A streamer chamber, mounted in a magnetic field, is used to capture the interaction vertex. Downstream, a series of magnetostrictive wire chambers gives improved momentum resolution, while photon detectors and hadron calorimeters cover a maximal angle and trigger the streamer chamber. In this way the experiment is able to select highly inelastic events independent of the nature of the final state, and to reconstruct the event using the streamer chamber. A novel feature of the apparatus is the use of plastic scintillators with fluorescent converters to colour the light and so enable hadron and photon signals to be readily distinguished (see January/February 1980 issue, page 447).

Using proton and pion beams, the experiment took data in three ways: using the full calorimeter, using two diametrically — opposed segments (half the calorimeter), and using just one calorimeter arm (one quarter of the calorimeter). With the full calorimeter being used, typical events are found to have many (about 25) secondary charged particles spread evenly around the collision axis, rather than being confined to narrow jets. This high multiplicity makes analysis of the streamer chamber output difficult.

Cross-sections have been measured using the three different trigger modes described above, and the results do not resemble what would be expected in terms of a jet model. Instead, the behaviour looks more like an extrapolation of what is seen in 'soft' collisions producing particles with low transverse momentum. Analysis of the data to find the planarity and thrust ('jettiness') of the events also fails to reveal any strongly jet-like behaviour.

These preliminary results suggest that jets, as they have been understood so far from colliding beam experiments, look difficult to study in hadron-hadron experiments under fixed target conditions. However analysis of the data continues with a view to obtaining final results.

Silica aerogel detector

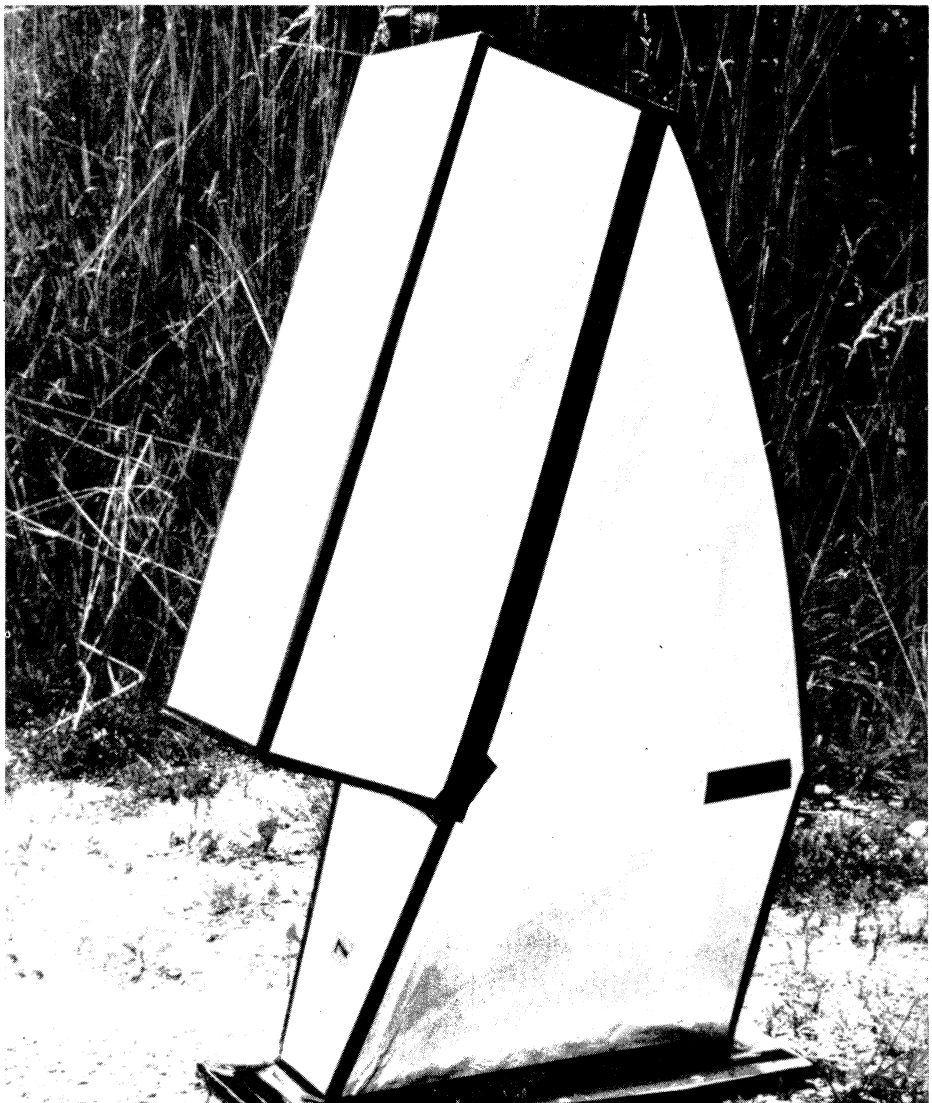
Even in high energy collisions, a large fraction of the produced particles have relatively low momenta. At the SPS 400 GeV proton synchrotron, about 40 per cent of the secondary particles have momenta below 5 GeV, a momentum range in which particle identification usually has been difficult. In bubble chambers, the ionization information can be used for particle identification up to about 1 GeV. Particle identification in the range 1-5 GeV is possible with very high pressure gas Cherenkov detectors, but they tend to become rather complex and very bulky. With the development of silica aerogel, a very light and fragile material, particle identification in this range is possible, and some very neat and simple Cherenkov detectors can be constructed.

Silica aerogel can be produced with refractive index ranging from 1.01 to 1.10. However the fragility increases rapidly with decreasing refractive index, making it very difficult both to produce and handle samples with refractive index around the lower limit.

The SAD detector has been bu by a Brussels/Mons/Stockholm collaboration. Brussels and Mons took care of the mechanical structure and magnetic shield, while Stockholm designed the light collection system and supplied the aerogel, manufactured at Lund. Composed of 18 identical modules, it will be used for particle identification in the momentum range 1-5 GeV in the EHS (European Hybrid Spectrometer) in the North Experimental Area at CERN, where it is installed a few metres downstream of the rapid cycling bubble chamber (see March issue, page 64). The photomultipliers are situated in a region where the magnetic field is around 0.1 T, which constrains both their position and orientation.

Because aerogel is a new material

A futuristic-looking module of the silica aerogel detector built by a Brussels/Mons/ Stockholm collaboration for use in the European Hybrid Spectrometer at CERN.



with relatively unknown optical properties, the optimization of the individual Cherenkov modules was not entirely straightforward. A large number of measurements were done with different types of light collection systems, using both diffusingly reflecting walls of millipore and mirrors made of aluminized mylar. In the optimization process a 'Cherenkov detector kit' (composed of a roll of aluminized mylar, cardboard, scissors, tape and a measure) was found to be extremely useful to complement computer simulations. An optimized light collection system made of aluminized mylar was found to be clearly superior to the diffusing light collection system. On the other hand the detector response was rather sensitive to the mirror orientations, and as a result the module was more difficult to optimize.

In each module, the detector surface is 23 x 55 cm^2 and the aerogel thickness is typically 15 cm. The aerogel volume is made up of blocks with dimensions 18 × 18 × 3 cm^3. The refractive index is 1.03, giving momentum thresholds of 0.6, 2 and 3.8 GeV for pions, kaons and protons respectively. The light collection system is composed of cylindrical and plane mirrors made of aluminized mylar 75 microns thick. The light is collected by two RCA 8854 photomultipliers with 11 cm diameter photocathode. The complete detector surface measures 2.3 m^2.

The response of all 18 modules has been determined in a particle beam at the CERN PS. The light yield averaged over the whole detector surface is close to 11 photoelectrons for particles travelling at the speed of light.

DESY
HASYLAB opens

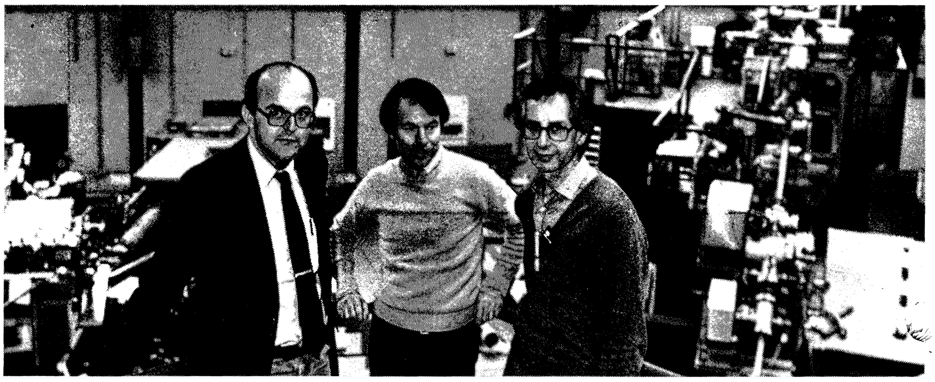
Recent highlight at DESY was the inauguration ceremony for the new Hamburg synchrotron radiation laboratory (HASYLAB) at the DORIS electron-positron storage ring. The presence of many distinguished guests and speakers and other representatives of user groups from both Germany and abroad gave an international flair to the ceremony.

The inauguration was followed by a two-day seminar for present and potential users of HASYLAB and the smaller (800 MeV) BESSY storage ring presently under construction in Berlin. The large audience of approximately 300 scientists and the 60 entries registered for the poster session reflected the high level of current interest in the use of synchrotron radiation.

HASYLAB, short for Hamburger Synchrotronstrahlungslabor, was built in less than two and a half years and its costs remained well within

HASYLAB project heads (left to right) Ernst-Eckhard Koch (DESY), Bernd Sonntag (University of Hamburg) and Christof Kunz (University of Hamburg).

(Photo DESY)



the envisaged budget of 14.4 million German marks, much to the delight of project heads Ernst-Eckhard Koch (DESY), Christof Kunz (University of Hamburg) and Bernd Sonntag (University of Hamburg).

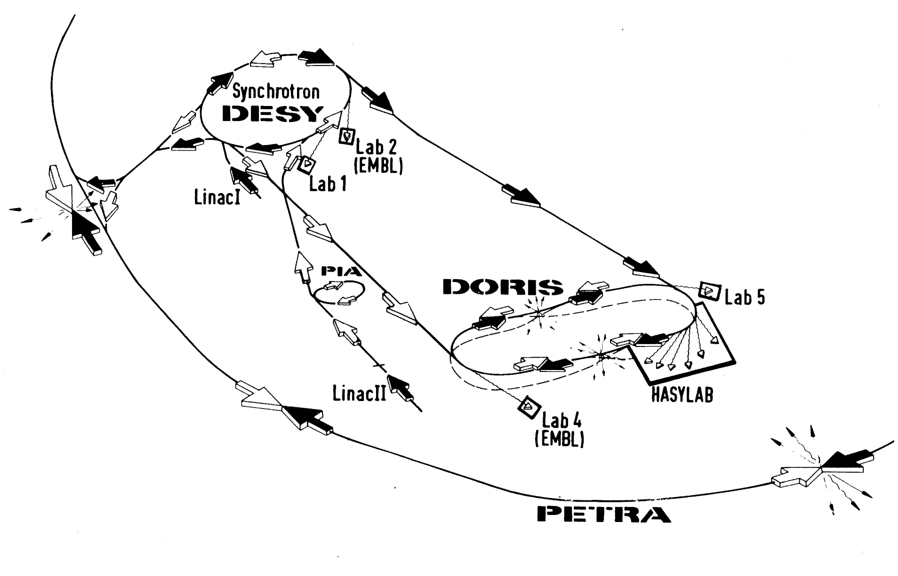
The large experimental hall with roughly 1500 square metres of floor space at the northwest arc of DORIS was completed early last year. It is linked directly to the DORIS buildings and part of the DORIS tunnel is in fact inside the HASYLAB hall, making it possible to install experiments close to the DORIS magnets.

Although it came into service back in 1974, the 5 GeV DORIS storage ring is still among the most brilliant sources of vacuum ultra-violet and hard X-ray radiation. DORIS will be upgraded in 1982 and is scheduled to be used for both high energy physics experiments and as a synchrotron radiation source.

The first synchrotron radiation beam was brought to the new experimental area in April 1980, and by the end of January this year, five experimental stations were already in operation and most of the 24 stations planned for the first phase were nearing completion or waiting for beamlines and shielding to be installed.

Research with synchrotron radiation has something of a history at DESY. Peter Stähelin, supported by Willibald Jentschke (at that time both were members of the DESY directorate), had the foresight to initiate experiments exploiting the unique characteristics of synchrotron radiation. This work started almost simultaneously with the commissioning of the electron synchrotron in 1964 in a small laboratory at the accelerator, leading to first publications in 1966. Stähelin's student Ruprecht Haensel of the University of Hamburg, whose thesis was concerned with the characteristics of synchrotron radiation in the X-ray range, organized this research. He and a small group of young enthusiastic scientists, some coming as visitors from outside Hamburg, started an extremely fruitful and internationally recognized research programme. Haensel left in 1974 for a professorship at the University of Kiel.

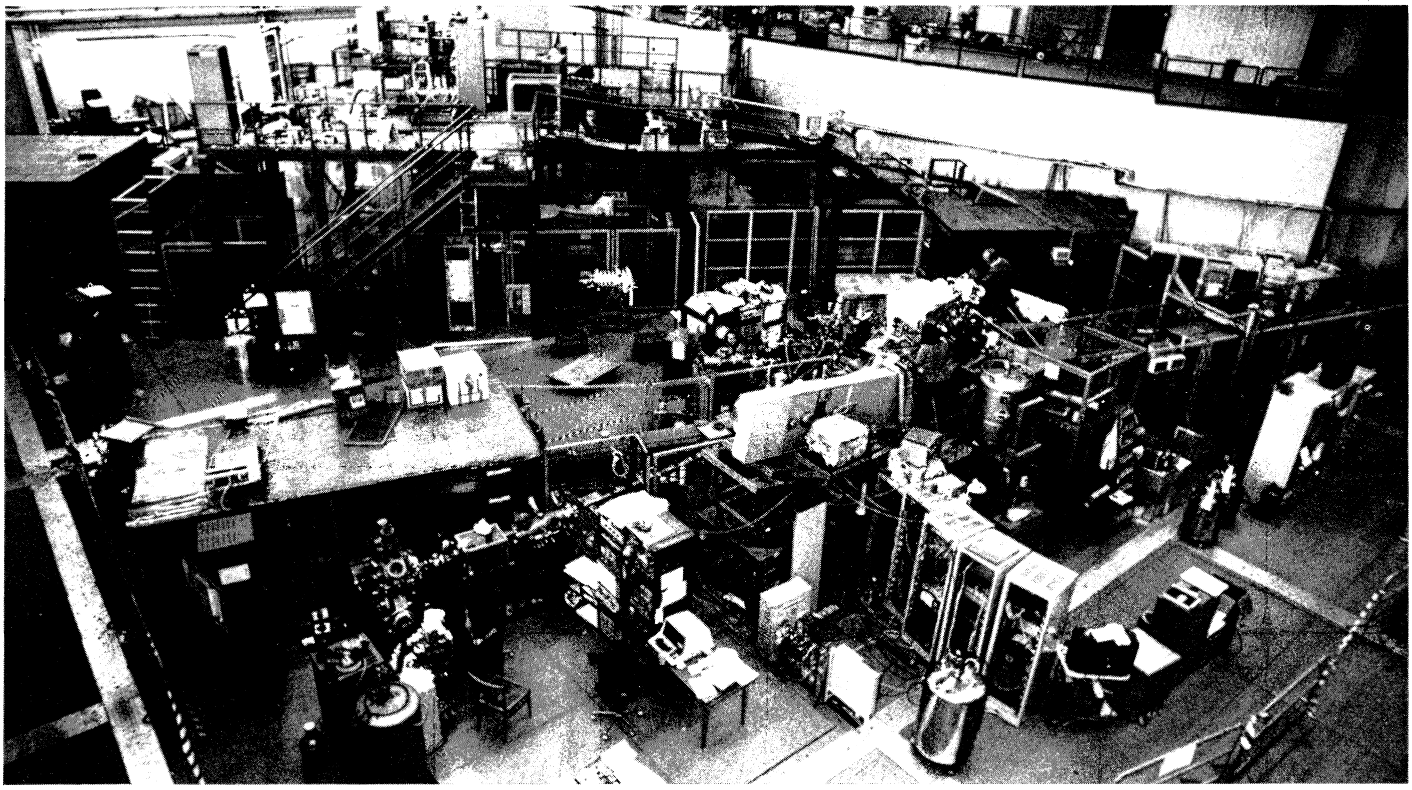
Major milestones in the development of the synchrotron radiation facilities at DESY were the addition of a second experimental floor to the laboratory at the synchrotron in 1970 and the installation of new beamlines. In 1974, a new laboratory came into service at the newly inaugurated DORIS ring. By subdividing a beam of horizontal width



Sketch of the synchrotron radiation laboratories (Lab 1, Lab 2, HASYLAB, Lab 4 and Lab 5) on the DESY site.

View of the already quite crowded new HASYLAB Experimental Hall. Part of the DORIS tunnel can be seen in the background.

(Photo DESY)



approximately 4 mrad with grazing incidence mirrors, simultaneous operation of five experimental stations was possible.

Since 1972, molecular biologists have been working at DESY using the X-rays from the synchrotron and from the storage ring for experiments in X-ray structure analysis. These activities, pioneered by Gerd Rosenbaum and Kenneth Holmes, have lead to the construction of two laboratories, one located at the synchrotron and one located at DORIS. Both laboratories are operated as an outstation of the European Molecular Biology Laboratory (EMBL) whose headquarters are in Heidelberg. In 1978, an exposure station for X-ray lithography located in a small building at DORIS was added. It is operated by the Fraunhofer Gesellschaft, Institut für Festkörpertechnologie in Munich.

The major part of the synchrotron radiation work at DESY is now organized within HASYLAB. The emphasis is on basic research in atomic, molecular, solid state and surface physics as well as in physical chemistry and applied physics. HASYLAB channels the efforts of the outside-user community, which has grown considerably over the last few years. Presently, the principal user community involves more than 40 institutes from universities and other research centres, while many more institutes collaborate on a smaller scale. HASYLAB helps these groups to make optimum use of the available facilities. In addition, HASYLAB research staff, frequently in collaboration with outside users and visitors, carry out their own research projects.

Of the 24 experimental stations which have been built for the first phase of the new Laboratory, a number have already had beam and started their experiments. It is hoped that soon 15 independent stations will have radiation. With the different instruments covering a large spectral range, projects include basic atomic and molecular spectroscopy, solid state and surface physics, crystallography, structural research on polymers and biological material, and microscopy and applied optical spectroscopy in the soft X-ray range.

NOVOSIBIRSK
News on VEPP-4

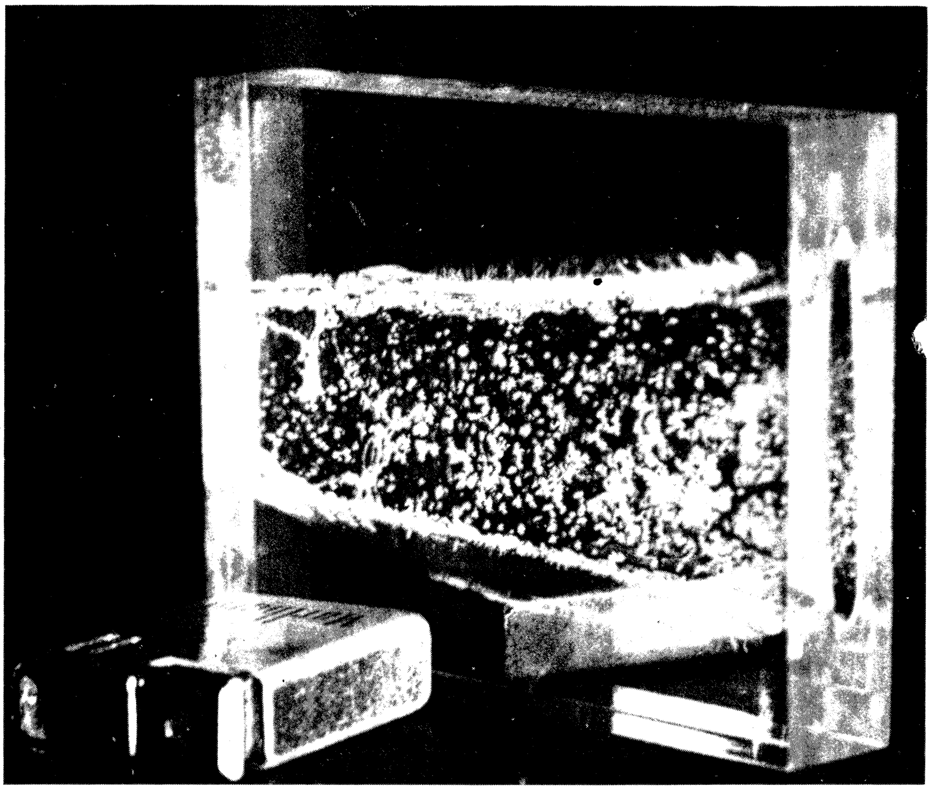
In the USSR, progress continues with the VEPP-4 electron-positron storage ring which began experiments last year (see October 1980 issue, page 297). Up to now VEPP-4 has operated mainly in the energy region appropriate for J/psi production. Recently, however, the peak available energy has been raised to

5.3 GeV per beam, enabling experiments to be carried out in the upsilon energy region. This will amplify the data from the electron-positron rings at DESY and Cornell.

Another recent achievement at VEPP-4 is the successful operation of the large MD1 detector. This is unusual in having a transverse magnetic field (of 1.5 T over 10 m^3) which is part of the magnet lattice of the ring. It will be particularly useful for the study of two-photon physics. It will be able to detect the final state electron and positron with high precision and high efficiency. Care has been taken to ensure that the synchrotron radiation produced in the magnet has a clear path to well outside the detector, and background conditions have been checked and found acceptable.

Two gyrocons are now in operation on the machine. One powers the 50 MeV electron linac and operates in the pulsed mode at 50 MW, 10 microseconds. The other powers the r.f. system of the VEPP-4 ring and has operated in the d.c. mode at up to 0.5 MW. This power is ample to take the storage ring energy to 5.5 GeV. It has been operated as high as 1 MW for short periods with gyrocon voltages of about 250 kV. Slight instabilities, for as yet unknown reasons, have been experienced (sudden small power losses for a few microseconds at high power levels – higher than 0.5 MW) but they are not troublesome enough to disturb operation of the storage rings.

Work also continues on the development of power generators for the long term project of colliding linac beams (VLEPP project - see December 1979 issue, page 403). Both gyrocons and klystrons are under study. Small sections of linac structure have been built and tested at low r.f. level to develop fabrication techniques.



A plexiglass block 10 cm long which was irradiated by the synchrotron radiation emerging from the superconducting 'snake' on the VEPP-3 storage ring at Novosibirsk. The block, positioned 4 m from the snake, was exposed for 2-3 minutes when the current in the ring was about 4 mA.

(Photo Novosibirsk)

Superconducting snake

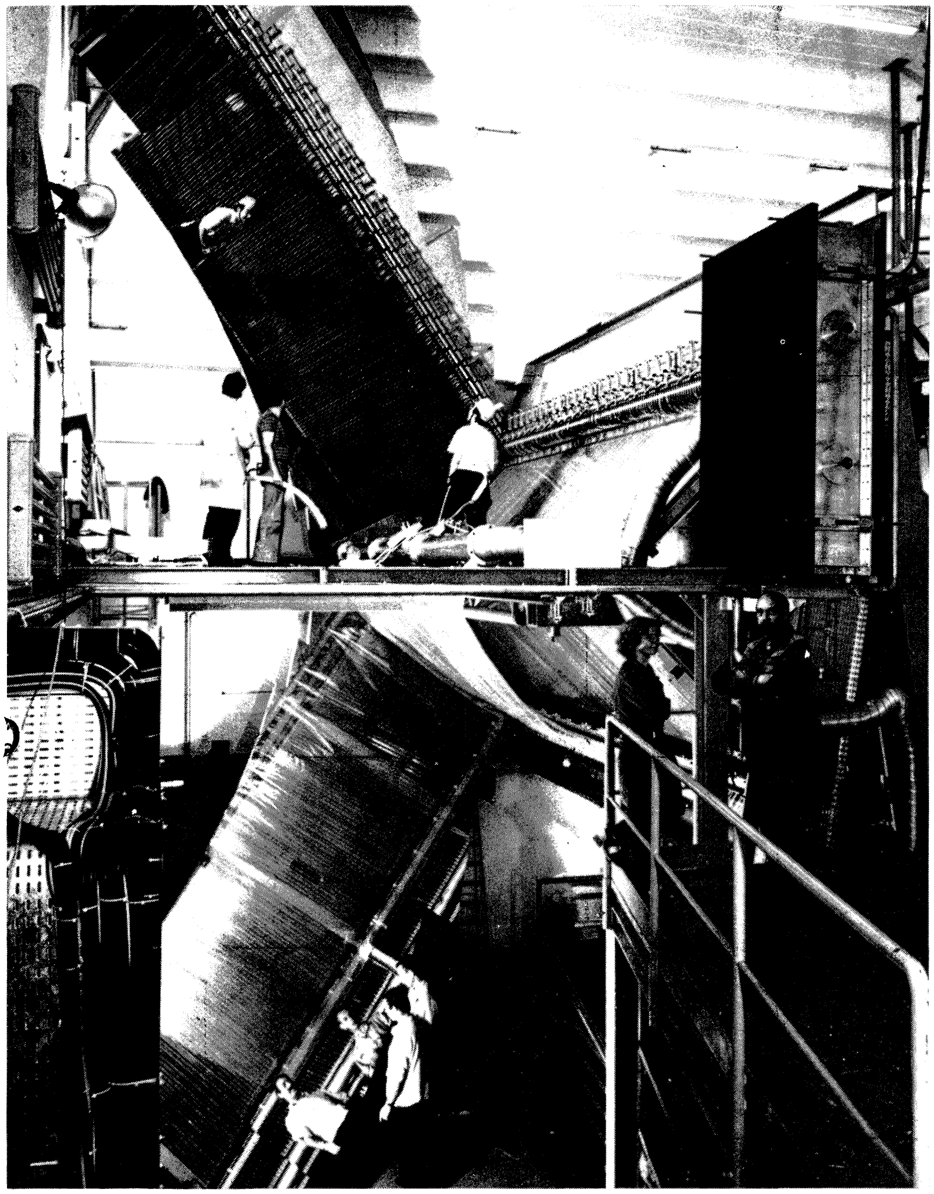
The first experiments on the synchrotron radiation produced using a superconducting 'snake' have been carried out on the VEPP-3 electron-positron storage ring at the Novosibirsk Institute of Nuclear Physics. This snake, about 1 m long with a 9 cm period, is located at the centre of a long straight section.

To lead out the synchrotron radiation into a special bunker, the orbit is locally distorted by four special bending magnets. The vacuum chamber of the superconducting snake has a wide section used for particle injection and a narrow section in which the magnetic field is generated by the superconducting magnets. Its vertical size is about 8 mm.

Once the required beam current had been obtained and the electron energy increased to 2.1 GeV, a smooth shift of the electron beam orbit into the narrow section of the vacuum chamber was performed and the field in the snake was switched on. At a maximum field of about 3.3 T in the snake and 2.1 GeV electron energy, the radiation was found to be concentrated within an angular range of about 14 x 0.25 mrad.

The powerful X-radiation was extracted from the vacuum chamber of the storage ring through a special window composed of three beryllium foils of 0.6 mm total thickness. The maximum extracted power was 0.6 kW with 22 mA current in the beam and the lifetime was about two hours.

The extracted synchrotron radiation beam is split into four parts to allow four experimental groups to work simultaneously. The first ex-



Spark chamber array (centre) of an experiment by an Aachen/Padua collaboration at CERN which studied neutrino-electron scattering. (The central spark chamber array is seen here reflected in two large mirrors.) A small unexplained effect was seen which appears to have shown up again in a new experiment at the Swiss SIN Laboratory.

(Photo CERN 315.6.74)

periments, which began in May 1980, were devoted to medical diagnostics, element analysis and the Mössbauer effect. They showed a significant improvement of the source brightness.

SIN
Aachions or axions?

Results from a 'beam dump' experiment by an Aachen group at SIN show a small unexplained effect. One possibility, as yet still remote, is that this is due to a new particle – the 'axion', a very light object predicted several years ago and which has eluded several other concerted attempts to find it.

Motivation for the SIN experiment came from some earlier neutrino work at the CERN 28 GeV proton synchrotron by an Aachen/Padua group. In these 1977/78 studies, which concentrated on neutrino-electron elastic scattering by the weak neutral current, there was something odd in a small corner of the data.

This experiment picked up a small excess of electromagnetic showers produced very close to the direction of the neutrino beam, and which could not be explained by any mundane background mechanism. While not substantial enough for publication in its own right, this effect nevertheless invited further investigation. If it were due to some new physics, it was associated with very small momentum transfers, in the region of 10 MeV or so, and should therefore show up better in a low energy experiment.

In the meantime the axion appeared on the theoretical scene (see March 1978 issue, page 80). The axion was invented to keep quantum chromodynamics, the candidate theory of inter-quark forces, free of troublesome effects which could upset well established symmetries like charge-parity (switching particles to mirror-image antiparticles). As well as being extremely light (near the mass of the electron), the axion was predicted to be highly penetrating, decaying eventually into an electron-positron pair.

High energy neutrinos come from the decay of pions and kaons, produced when a primary beam strikes a target. In the beam dump technique, the primary beam hits instead a block of material large enough to absorb the produced pions and kaons before they get a good chance to decay and produce neutrinos. In this way the conventional neutrino flux is considerably reduced, but any residual highly penetrating particles have a better chance of showing up. Despite repeated runs, high energy neutrino beam dump experiments have showed no signs of axions.

The new SIN beam dump experiment (using a primary beam of 590 MeV protons) looked closely for the production of pairs of photons by any particles managing to emerge from behind seven metres of shielding. The detectors were the old spark chambers from the CERN Omega spectrometer, now fully converted to electronics (see March 1978 issue, page 69). Because rare events were being searched for, a good deal of attention had to be paid to eliminating spurious effects due to cosmic rays.

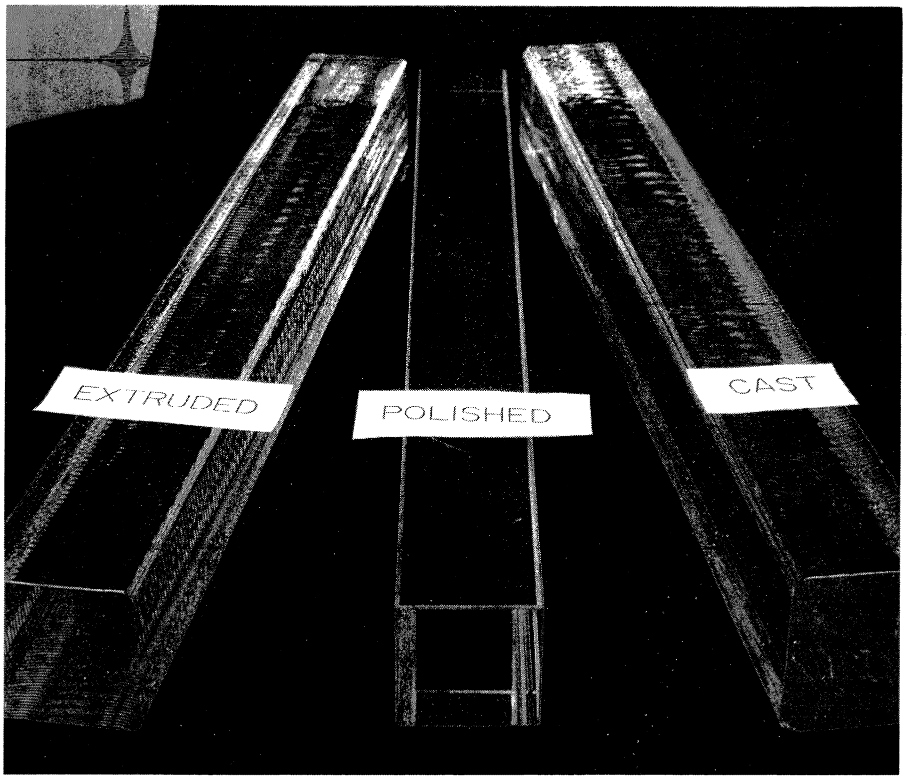
An excess of photon pairs was found at small production angles, significantly above anything which could be attributed to background. In addition, interposing an iron sheet just upstream of the spark chambers effectively removed the signal, while putting the iron sheet just behind the beam dump had no marked effect. This indicated that the observed photon pairs were produced in the decay region between the beam dump and the detectors.

In the absence of any other explanation, it is tempting to derive the parameters of the axion from the small amount of available data. The narrow opening angle of the photon pairs gives an upper mass limit of 1 MeV. However the evidence is as yet still very slim.

BROOKHAVEN
Reducing cost for lead glass

Lead glass has been widely used in high energy experiments for energy measurements of electromagnetic showers. Its utility stems in part from the short radiation length and the visibility of the shower development. One drawback which has inhibited even wider utilization has been its relatively high cost. A major share of the cost of standard lead glass blocks arises from the surface preparation; typically a raw block, cast or extruded from the molten state, is mechanically cut, ground and polished to produce optically flat surfaces.

A group from the State University of New York at Stony Brook (Paul Grannis, David Jaffe and Michael Marx) have performed tests at the Brookhaven AGS on three types of lead glass bars. One was a ground and polished block, typical of those currently used. The other two were cut and polished only on the ends, the other surfaces being produced by continuous casting or extrusion processes, showing a rippling or wavy surface. Measurements of the Cherenkov light-gathering properties of the three blocks were taken with particles travelling down the long axis of the blocks, perpendicular to this axis, and at various intermediate angles. It was found that the optical characteristics of all the blocks were virtually the same. Thus it appears possible that for many applications (e.g., where mechanical packing tolerances can be relaxed) considerable cost savings can be made.



Tests at Brookhaven of the Cherenkov light-gathering properties of these three lead glass blocks showed that they have similar characteristics, despite considerable differences in surface quality and relative cost.

(Photo Brookhaven)

Physics monitor

Physics from alpha particles

Last summer, alpha particles were stored in the CERN Intersecting Storage Rings and physics data on alpha-alpha collisions was gathered in a 60-hour run. This achieved a world record collision energy of 126 GeV (see July/August 1980 issue, page 194), and a luminosity of 2.8 x 10^{28} cm^{2} per s. This was followed by a run with 63 GeV alpha particles in one ISR ring and 31.5 GeV protons in the other, giving a centre-of-mass energy of 89 GeV.

A CERN/Heidelberg/Lund collaboration (R418) working at the large Split Field Magnet mounted a special study of alpha particle collisions, and several other ISR detectors were also able to benefit from the alpha particle runs.

Elastic alpha-alpha scattering data from R418, combined with results from a CERN/MIT/Naples/Pisa/Stony Brook collaboration (R210), show a nice diffraction-type pattern with two dips, one at squared momentum transfer about 0.1 GeV^2, and the other at about 0.4 GeV^2. Elastic alpha-proton scattering shows only one dip. Analysis of this data could provide valuable information on the scattering properties of compound nuclei to improve the current formalism.

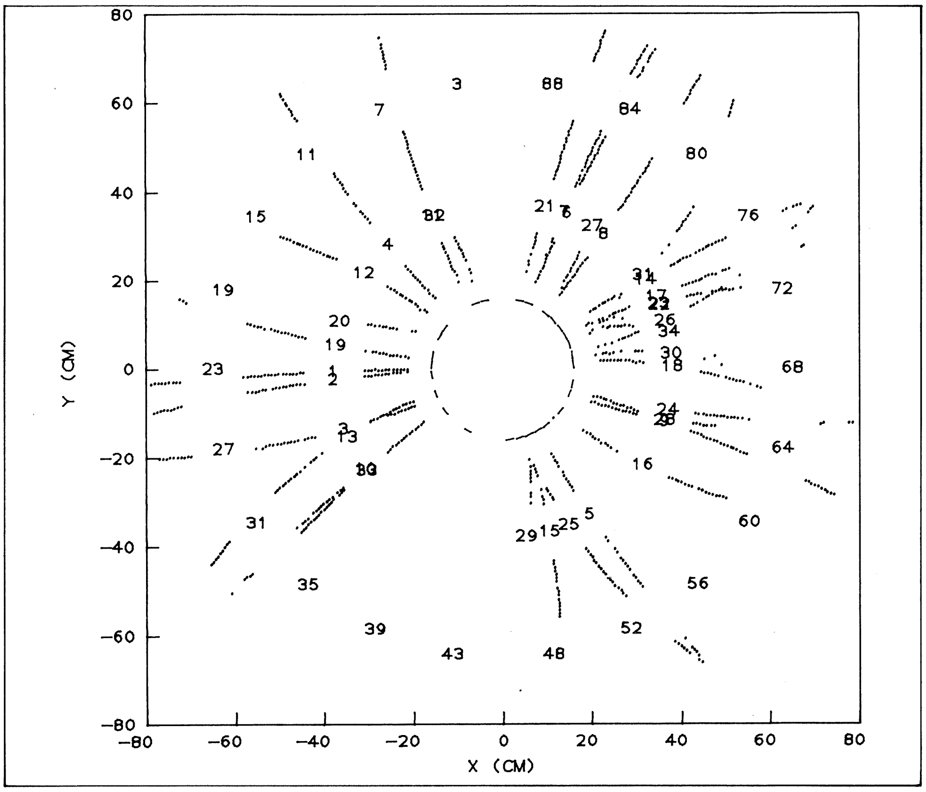
Data on inelastic reactions with low transverse momentum came from R210 and from the Brookhaven/CERN/Copenhagen/Lund/Rutherford/Tel-Aviv team (R807) using the Axial Field Spectrometer. In these reactions, it is found that the multiplicity of leading fragments seen emerging from the collisions is much higher than would be expected on the basis of multiple hadron collisions within the interaction region. This indicates that at the high collision energies in the ISR, the duration of the main interaction appears to be so short that particles are formed only after the main interaction is over. Such effects are best described by quark-parton models, so that the alpha particle results could supply new information on quark dynamics.

High yields were also obtained of secondary particles with large transverse momentum, resulting from the violent collisions between component quarks. Here spectacular effects were found. The production rate of large transverse momentum particles (say greater than about 5 GeV) turns out to be about 30 times that for proton-proton collisions at the same energy per nucleon. Earlier experiments at Fermilab had shown that in proton-nucleus collisions, the production rate of large transverse momentum particles appears to increase faster than just the mass number of the target nucleons. However the nucleon-nucleon collisions show even more violent effects, and could be the result of multiple scattering among the many quarks involved in alpha-alpha collisions.

Interesting results from R807 show that the multiplicity of produced particles tends to increase more with the overall transverse energy than is expected from proton-proton data. This could be used in the interpretation of other results from a fixed target experiment (see page 155).

Despite increases in multiplicity, interesting events are still not very frequent and more alpha particle data seems to be required before more definite conclusions can be drawn.

A high energy alpha particle collision, as recorded in the Axial Field Spectrometer at the CERN Intersecting Storage Rings last summer.



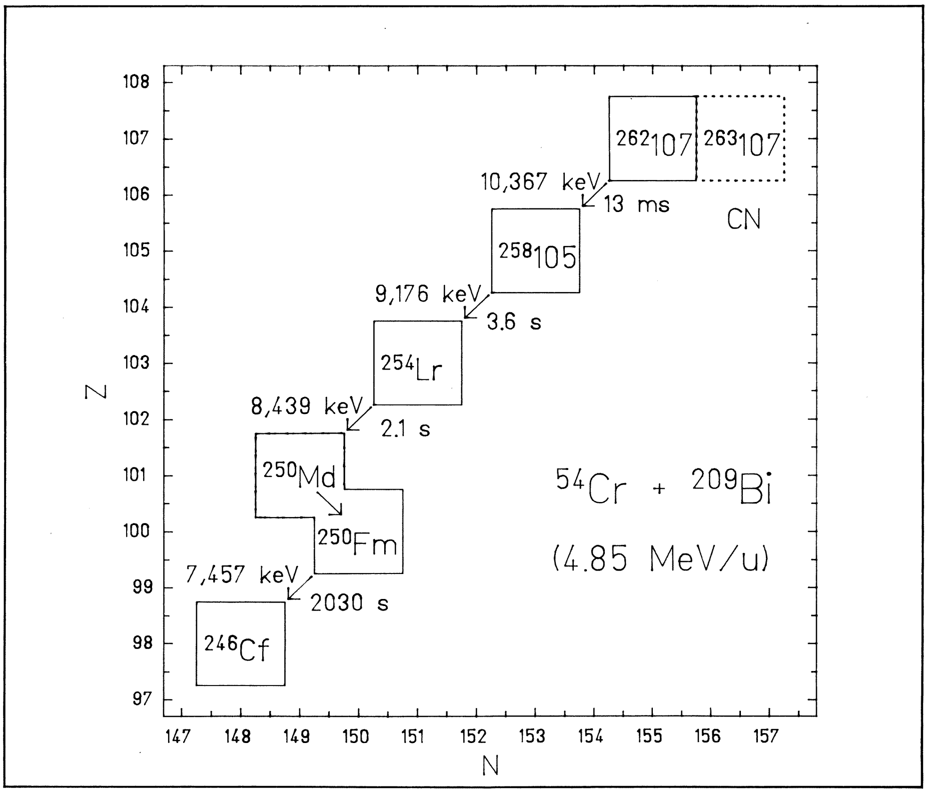
Element 107

A new isotope of the 107 th element in the periodic table (the heaviest yet seen) has been discovered at GSI Darmstadt. With mass number 262, it decays with a halflife of 4.2 + 2.0 − 1.4 ms by alpha particle emission of an energy 10.38 ± 0.03 MeV. This element was discovered in 1976 in an experiment at Dubna, which saw the mass 261 nuclide.

The mass and atomic number of the Darmstadt nuclide are uniquely determined thanks to two major experimental advances. The new nuclide is produced in the fusion of chromium-54 and bismuth-209 at 262 MeV using a beam of 10^{12} per s chromium-54 projectiles. The nuclide is filtered out by making use of the velocity difference between projectiles and fused compound nuclei. A separation factor of 10^{11} is obtained between the projectiles and the few evaporation residues hidden in the beam using the special SHIP (Separator for Heavy Ion reaction Products) velocity filter. The evaporation residues produced – separated with a 30 per cent efficiency – are implanted into the bulk silicon of a bench of position-sensitive surface barrier detectors. In a recent experiment about two nuclides per day have been implanted and their subsequent decay detected and analysed.

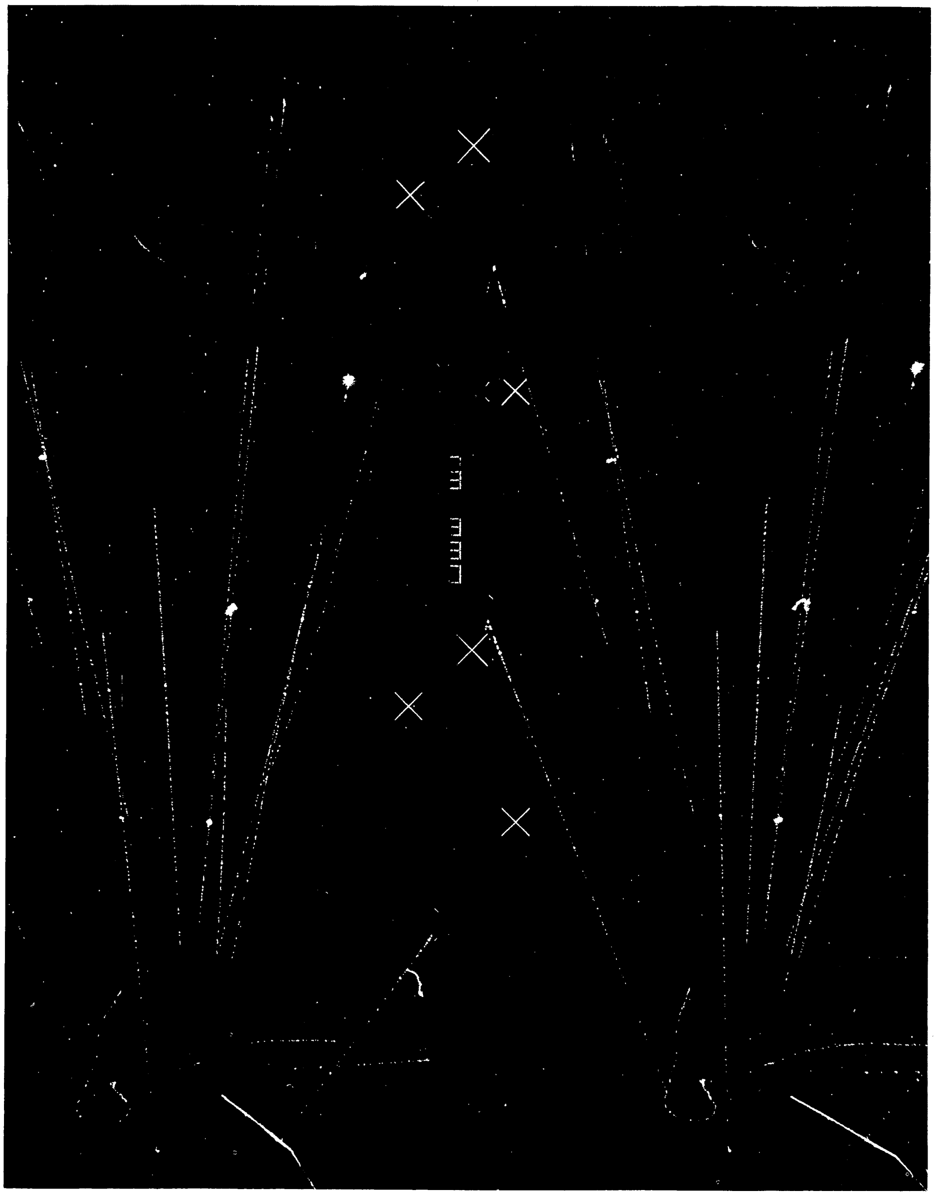
The events of interest are characterized by the velocity determined by the filter, and the energy, position and time of implantation obtained in an additional time-of-flight measurement. Furthermore, the alpha energies in the decay chain are determined in a position-time correlation experiment. In this way 17 parameters are measured. All positions of a decay sequence are shown to be within ±0.02 mm, and the last members of the decay chains agree with data known from previous measurements. The profusion of 17 parameters, partly preset by the above boundary conditions, is sufficient to identify the nuclide uniquely. Six decays have been found in an irradiation of 0.8 mg/cm² bismuth targets with 1.6 x 10^{17} chromium-54 projectiles.

The new techniques have been developed during a period of many years by the SHIP's 'crew' under the captaincy of G. Münzenberg, which is hoping to go on to search for heavier elements using their unique experimental tools and the excellent beams now available at the Darmstadt accelerator.



Alpha-decay chain of the newly discovered isotope of mass number 262 of the transuranic element 107. The numbers give the alpha energies and the times between the decays with the time of implantation as time zero. The isotope is produced via a single neutron fusion channel in the reaction of a 262 MeV chromium-54 projectile on a bismuth-209 nucleus. The excitation energy of the compound nucleus of element 107 with mass number 263 was less than 13 MeV. This is the smallest internal excitation ever seen in a fusion reaction between heavy nuclei.

People and things



Views of one of the first proton-antiproton collisions to be seen in the CERN Intersecting Storage Rings (see late news page 146).

On people

Sharing the prestigious Enrico Fermi Award for 1980 from the US Department of Energy are Alvin M. Weinberg, former director of Oak Ridge National Laboratory, and Sir Rudolf Peierls.

The 1981 Tom W. Bonner Prize in Nuclear Physics has been awarded to Bernard Cohen of Pittsburg University for his work in basic issues in nuclear structure and reactions, and his contributions to our understanding of low-lying collective states, the occupation of single particle levels, and the mechanisms of direct reactions.

The Dudley Wright Prize, awarded in the USA in recognition of distinguished scientific work of an interdisciplinary character, has been awarded to Luis Alvarez.

New director for Daresbury

Professor Leslie L. Green is being seconded from Liverpool University, where he is head of the Physics Department, to become Director of the Daresbury Laboratory from 1 July. He will succeed Professor Alick Ashmore who is retiring after eleven years in the post.

Professor Green's main research interest is in the area of nuclear structure. He supervised the installation and is still responsible for work on the 6 MV tandem Van de Graaff at Liverpool University, and since 1974 has been on the management committee of Daresbury's new Nuclear Structure Facility.

During Alick Ashmore's term of office, Daresbury has successfully made the change from being a high energy physics Laboratory, centred on the 5 GeV NINA electron synchrotron, to other areas of science, employing among the world's most advanced machines for research using synchrotron radiation and for nuclear structure studies.

ISABELLE workshop

A summer workshop will be held at Brookhaven from 20 to 31 July, with the primary focus on physics opportunities at ISABELLE. Other topics will include experimental areas and large detectors. The workshop will be co-chaired by Nick Samios and Sam Ting, and the organizing committee will include C. Baltay (Columbia), B. Beg (Rockefeller), W. Carithers (Berkeley), V. Fitch (Princeton), R. Lanou (Brown), A. Mann (Pennsylvania), J. Sandweiss (Yale), K. Strauch (Harvard), S. Treiman (Princeton) and L.L. Wang, H. Gordon, S. Aronson and

On 23 March Mark Carlisle, UK Secretary of State for Education and Science, visited CERN. He is seen here (centre) receiving explanations from Director General Herwig Schopper during a tour of the Laboratory.

(Photo CERN 375.3.81)

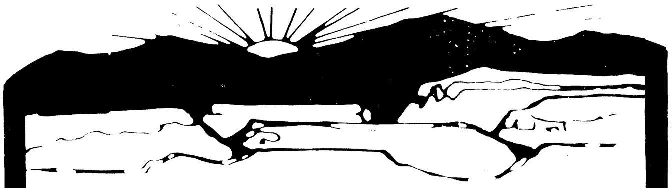
T. Ludlam (Brookhaven). For further information, contact Kit D'Ambrosio, Building 510A, Brookhaven National Laboratory, Upton NY 11973, USA.

Muon capture in hydrogen

Experiments which measure muon lifetimes have a habit of being elegant. One illustration of this is the new result from a Bologna/CERN/Saclay/TRIUMF collaboration giving a precision value for the muon capture rate in hydrogen. Muons disappear predominantly through their decay into electrons and neutrinos. In addition, a negative muon at rest can also react with a proton, forming a bound state which subsequently decays into a neutron and a neutrino. By comparing the observed lifetimes of positive and negative muons, the experiment was able to determine the muon capture rate in isotopically pure hydrogen without having to measure the produced neutrons. The measurements cleverly exploited the periodicity of the muon beam from the 600 MeV Saclay linear accelerator, determining the muon lifetimes in hydrogen down to a few parts in 10^5.

SLAC Summer Institute

The ninth annual SLAC Summer Institute, to be held from 27 July to 7 August, is to be given over to strong interactions, and quantum chromodynamics in particular. Results from hadron production and spectroscopy experiments will be reviewed with emphasis on heavy quark systems and jet production. As well as a summer school, it will include a three-day topical conference covering the most recent results in the field. Applications should be sent to Anne Mosher, Stanford Linear Accelerator Center, PO Box 4349, Bin 62, Stanford, CA 94305, USA.



The new 32-bit ND-500 for the discerning user!

The new ND-500 system has proved in benchmarks that it is considerably faster than any other 32-bit machine now available. This multi-user, multi-programming system handles time-sharing, real-time, batch and communications concurrently.

The heart of this multi-processor system is the powerful 32-bit ND-500 processor with an instruction set specially chosen to execute high-level language programs efficiently. Several functions such as FORTRAN DO-loops are performed by a single machine instruction. In this byte-oriented system instructions are variable in length, and the most common are executed in one 200-nanosecond machine cycle. Instructions are pre-fetched to increase throughput. Floating point instructions in both single and double precision are carried out by special hardware which performs arithmetic operations on parallel arrays. This gives very short instruction times: double-precision addition and subtraction take only 400 nanoseconds, multiplication 500 and division 2900 nanoseconds.

The system has 32 to 128 Kbytes of cache memory divided into two parts, one for instructions and one for data, so these may be fetched in parallel. The logical address space is almost unlimited–more than 4 Gigabytes for instructions and the same for data. And the high-speed shared main memory of the system can be as large as 32 Mbytes.

The software and peripherals are fully compatible with those found on the well-known ND-100 system. And those of you who have an ND-100 will be glad to know that it can be field upgraded to a complete ND-500 system.

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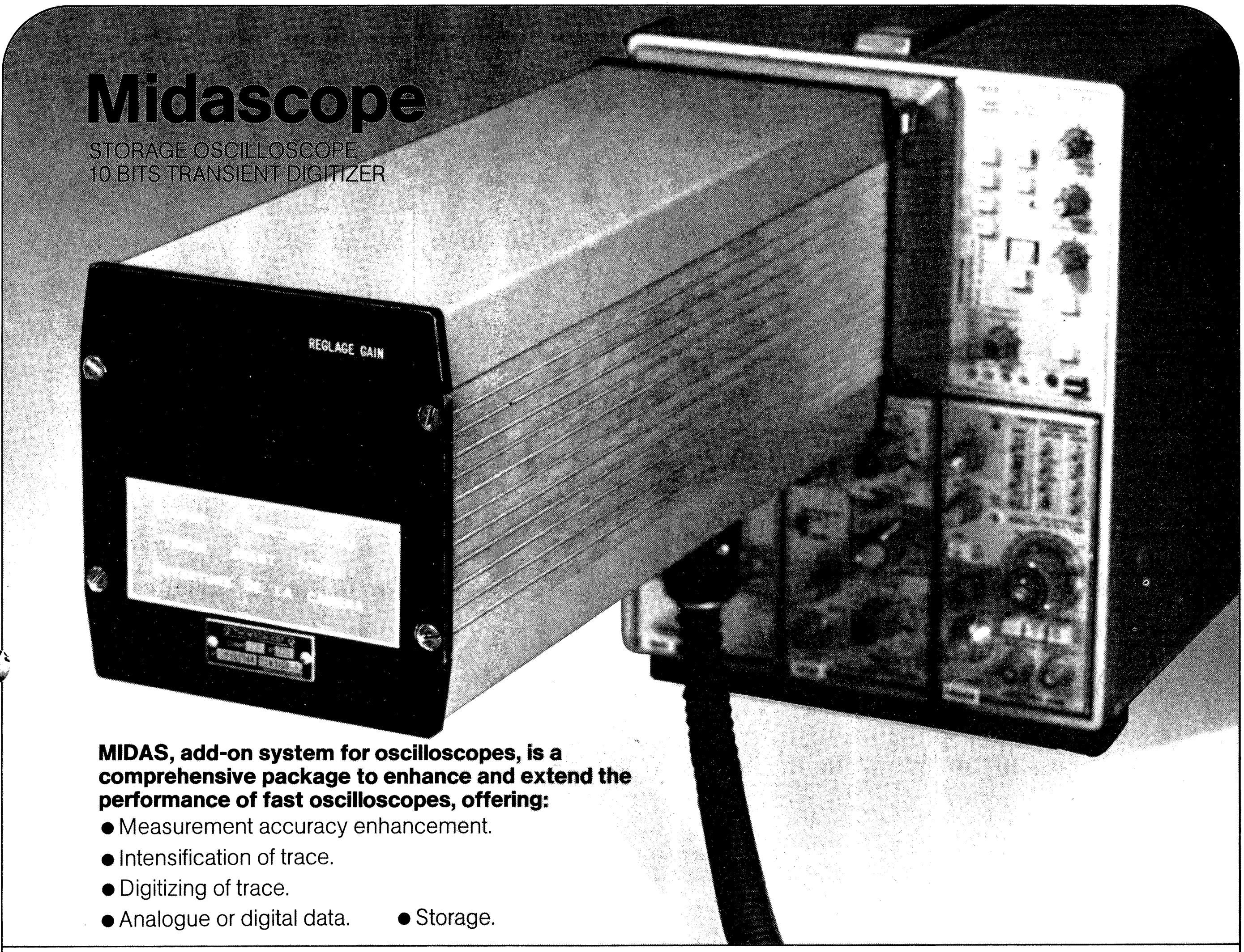

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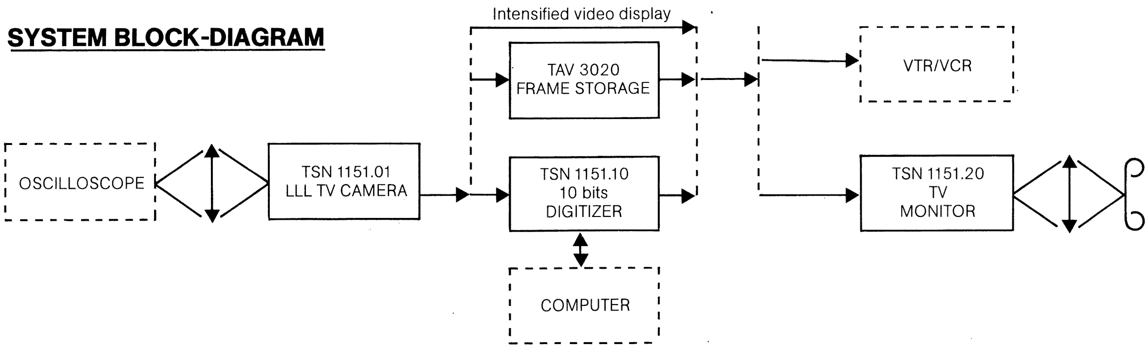

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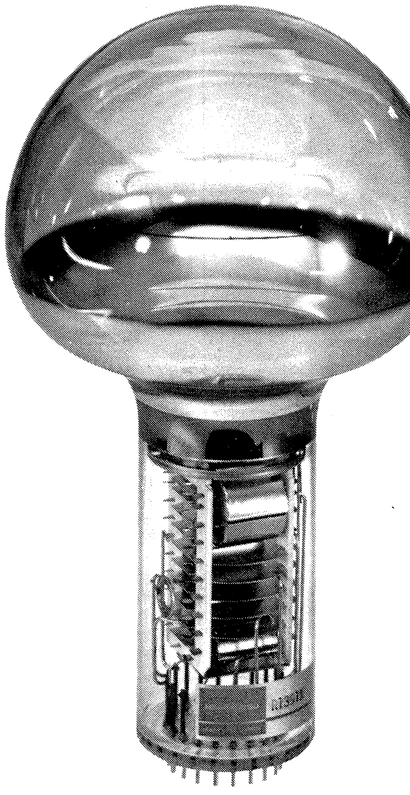

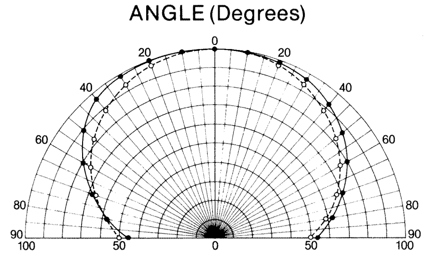

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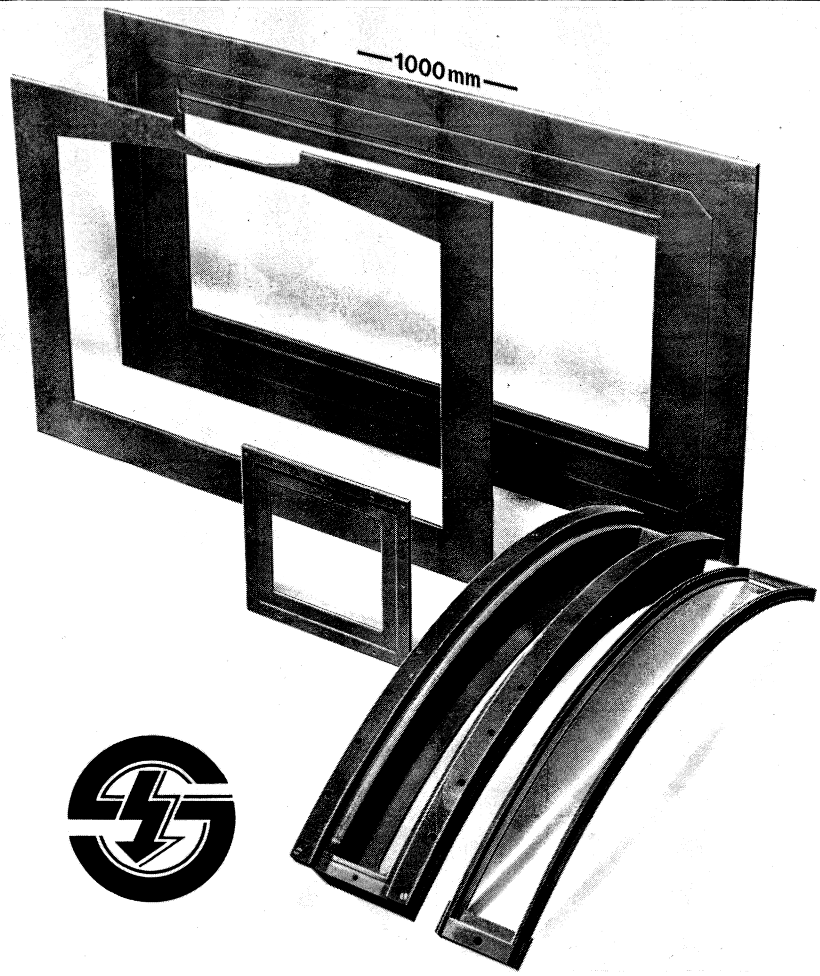

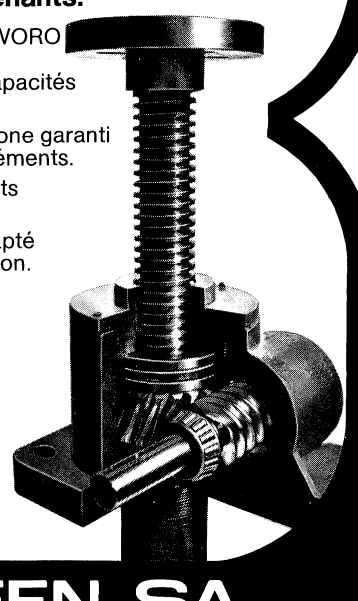

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XP2020Q	bialkali on quartz	1,5	2,4	0,25	0,25	56DUVP
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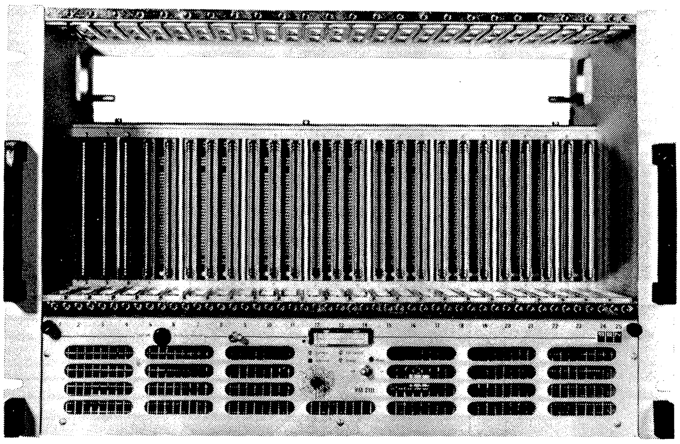

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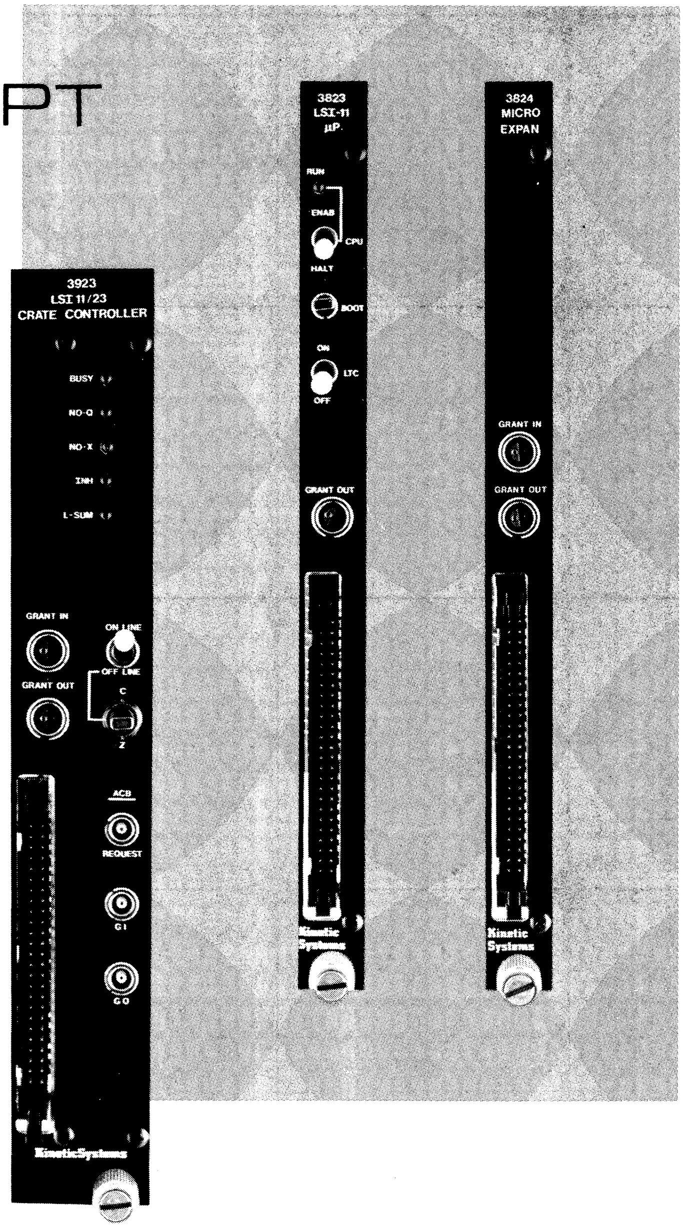

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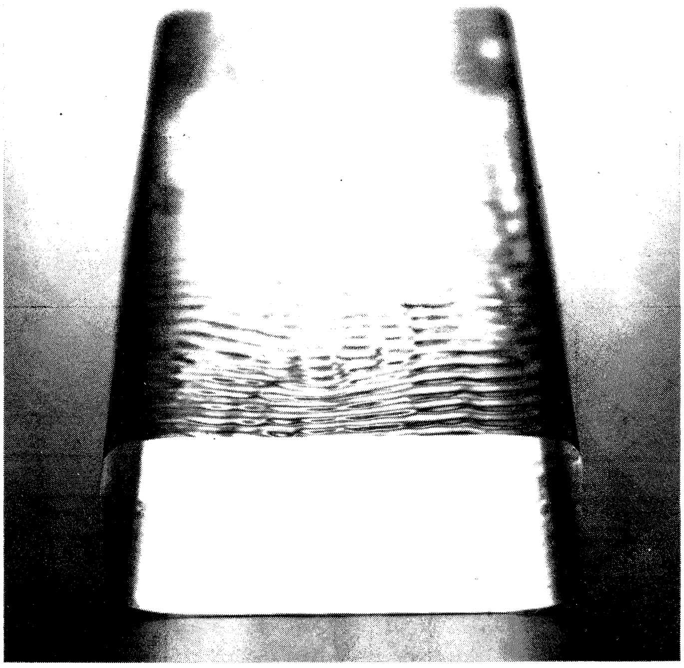

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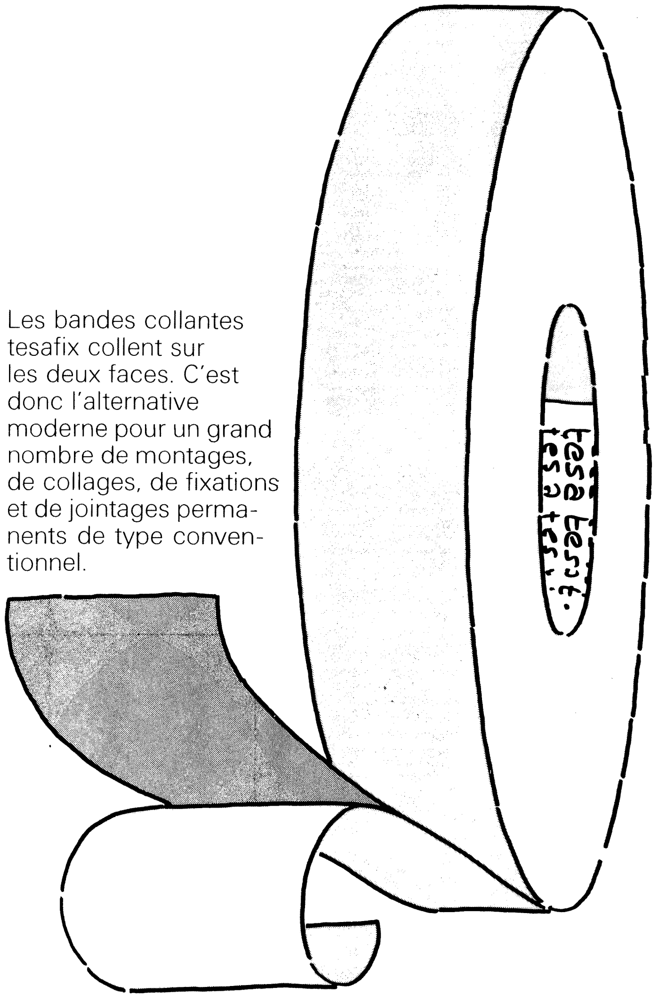

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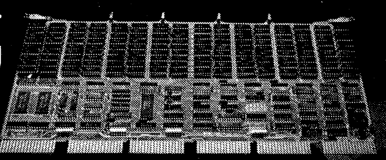

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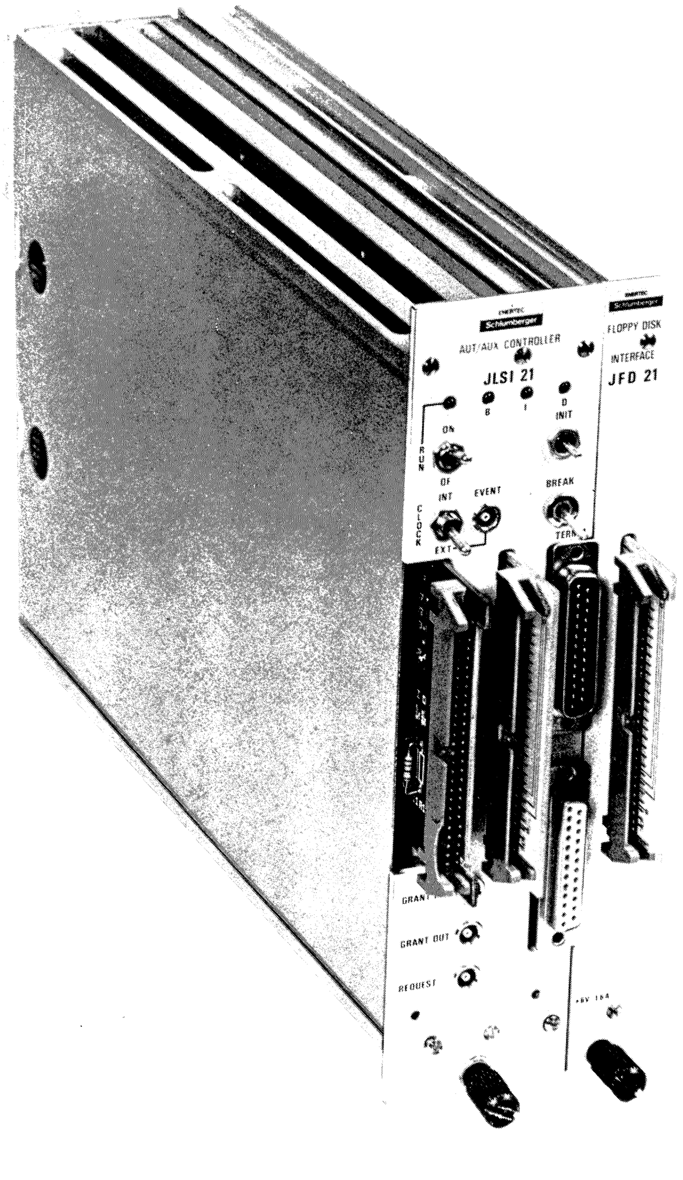
Further dedicated crate controllers JCC 20 and JLSI 10 for PDP 11
Enertec Schlumberger offers a crate controller including the computer

AUTONOMOUS OR AUXILIARY CRATE CONTROLLER JLSI 21



- Treble width CAMAC module
- LSI-11/02 or LSI-11/23 microprocessor*
- 128 K words – 16 bits RAM memory, 64 K words included in the basic module
- 2 serial I/O interfaces (current loop or RS 232)
- Real time clock (internal or external)
- Dual Floppy disk drive with one unit CAMAC interface JFD 21*
- Floating Instruction Set
- As a crate controller. JLSI 21 drives up to three other crates via a dedicated crate controller JLSI-10
- Software: All DEC software operating under RT-11 can be used: FORTRAN, CASIC,...
- CASIC: high level language running under RT-11, written by Enertec in order to allow CAMAC to be considered as a standard peripheral of RT-11

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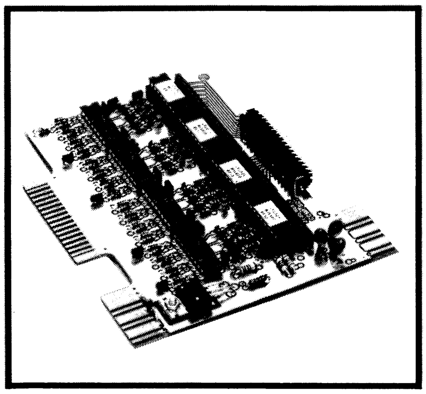
PCOS III . . . Multiwire

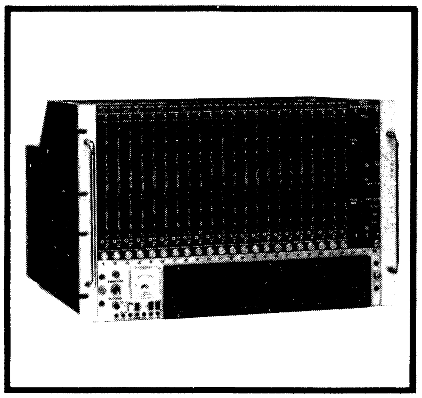
Modern High Energy Physics experiments utilizing MWPC's produce exceptionally high singles rates as well as high event rates. LeCroy's new PCOS III uses exciting advanced technology to produce a totally integrated system for these applications. Unprecedented high density is achieved through the use of LeCroy's 4-channel MSI amplifier and discriminator chips. A unique LeCroy Ripplethru 4-channel integrated circuit offers stable matched delays without adding deadtime.

PCOS III consists of exceptionally compact 16-channel chamber cards, remote 32-channel delay/latch modules and a priority encoder to scan and encode at high speed. Readout is performed via LeCroy's CAMAC DATABUS system. PCOS III integrates well into modern experiments, allowing the MWPC system to participate in trigger logic at many levels, including Trigger Processor logic.



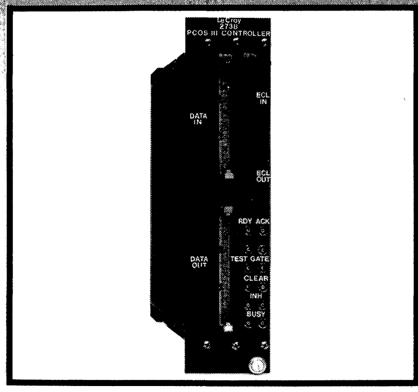
Exceptional Compactness—16 channels of amplifier/discriminator on an 8 x 12 cm. card! Two new LeCroy monolithics make this possible while maintaining excellent sensitivity and interchannel isolation. (These chamber cards can also be used compatibility with Drift Chamber readout system).

Programmable Threshold
—CAMAC programmable in 1 mA steps. Makes computer-controlled plateau a reality!



Programmable Pipeline Delay
—LeCroy's new Ripplethru chip provides CAMAC programmable delay with 1.5 nsec resolution (300-684 nsec) with the double pulse resolution of a cable but without the bulk, waste, or cost.

Trigger Aids—Prompt, undelayed wire outputs and latched outputs are supplied. Provision for outputs from 2-fold to 16-fold in any combination, compatible with LeCroy's ECLine family of logic modules.



Rapid Encoding—Use of distributed intelligence and well thought out system architecture results in a total encoding time for typical events of 1-2 msec.

Cluster Compacting—Built-in logic allows automatic on-line calculation of the cluster centroid and width.

Interface to a Track Finder
—Prompt digital addresses of hit wires are supplied as they are encoded. Unique ECLport format optimizes readout rate even with long interconnecting cables.

Future Fastbus Compatibility
—Utilization of this dedicated crate fast encoding system within LeCroy's CAMAC DATABUS standard makes the system readily adaptable to the FASTBUS standard. This, like all new LeCroy large detector readout systems, requires only a FASTBUS Interface/Buffer, planned for availability upon firm final definition of the FASTBUS standard.

PCOS III offers many user-selectable options. It integrates into virtually any modern experiment. Options include user assignable logical wire addresses, programmable delay and threshold, user assignable fast outputs, cluster-compacting control and many more. PCOS III is available now at extremely competitive prices. Contact LeCroy for details.

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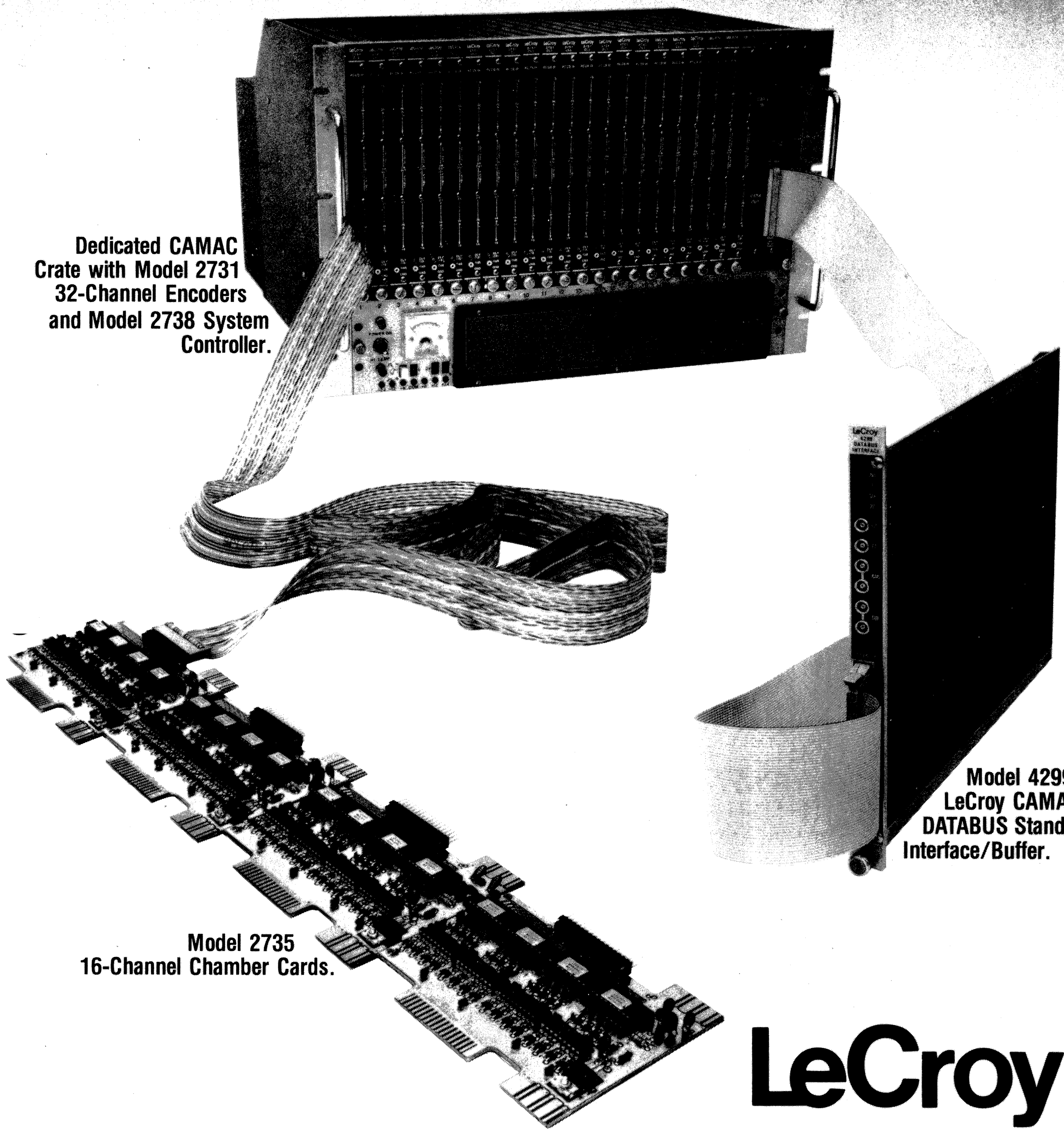
Proportional Chamber System

new technology throughout + system engineered



Dedicated CAMAC Crate with Model 2731 32-Channel Encoders and Model 2738 System Controller.

Model 4299 LeCroy CAMAC DATABUS Standard Interface/Buffer.

Model 2735 16-Channel Chamber Cards.

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RECORD FOR 8973: 1.6 MEGAWATTS AT 108 MHz.
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EIMAC 8973 tetrodes helped bring fusion power a step closer at Princeton.

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

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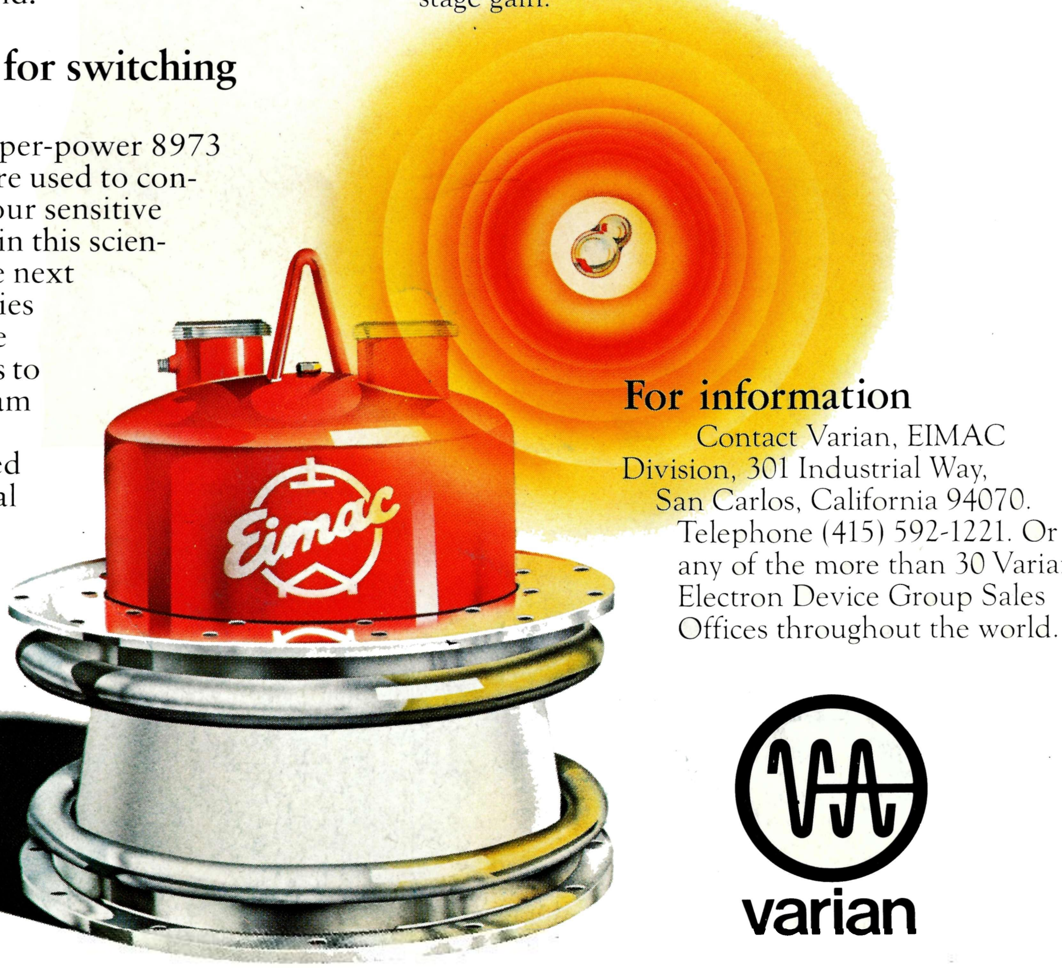
Four EIMAC super-power 8973 (X-2170) tetrodes were used to control and protect the four sensitive neutral beam sources in this scientific achievement. The next experiment in this series (PDX) will also utilize EIMAC 8973 tetrodes to control the neutral beam sources. The EIMAC 8973 is also being used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

January 1981

EIMAC 8973 provides over one megawatt CW power output at 78 MHz with 14 dB stage gain.



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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