

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 technology, including applications outside the 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 tailored 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 CHES.

The storage ring has been oper-

ated 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 4×10^{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,

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.

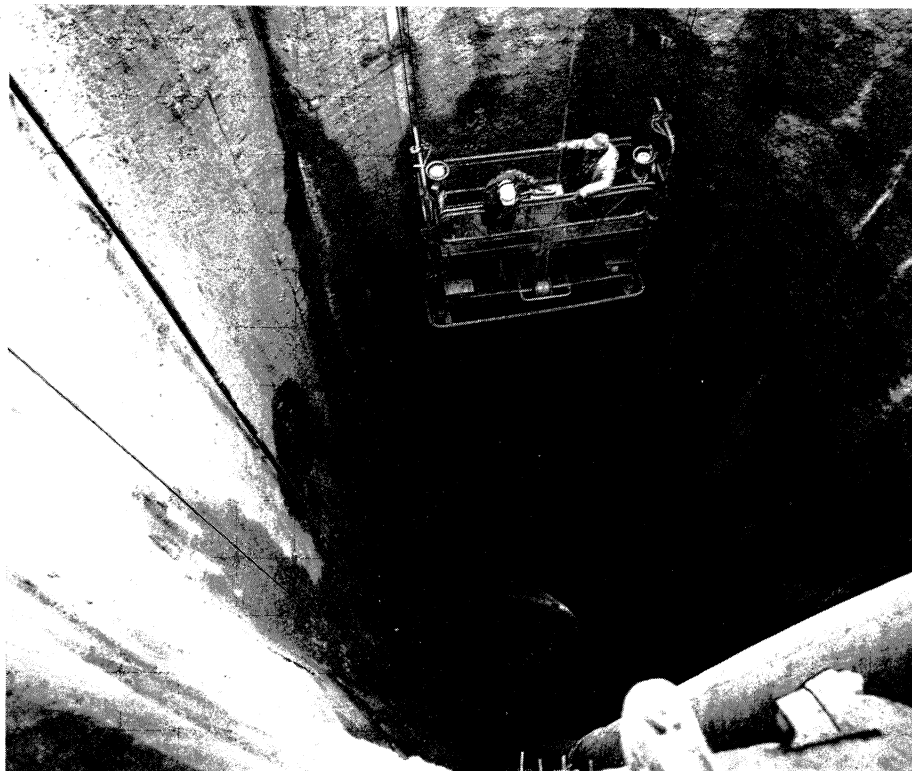
The battle for high luminosity in storage rings has proved to be less painful with protons. The CERN Intersecting Storage Rings have by far exceeded the design figure, and at the end of March a new record of 1.2×10^{32} was reached during commissioning of the new superconducting low beta section.

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

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 'over-voltage' 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 Conference 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.

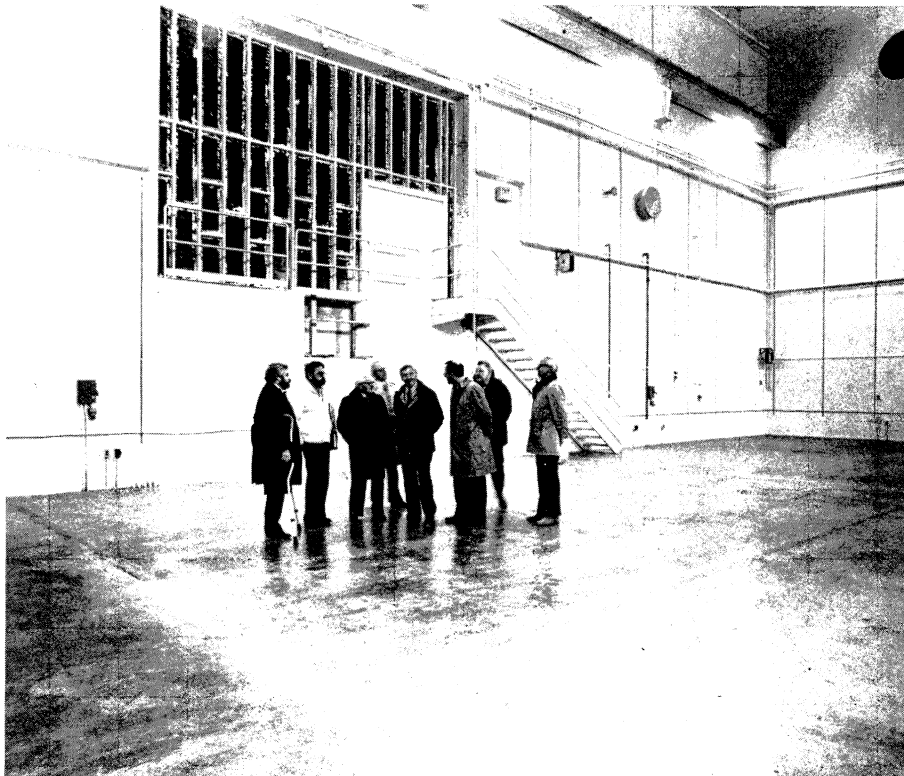
However it is here at ISABELLE that a high proportion of the budget cut mentioned at the beginning of this report is to be applied (a reduction of some \$20 million, which is half the anticipated construction budget for Fiscal Year 1982). There is no doubt that the reason for the axe falling heavily 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, begin-

ning 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. Con-

struction, over the years 1981-1990, has been authorized. The project uses the upgraded (to give an intensity of 5×10^{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 vocifer-

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)

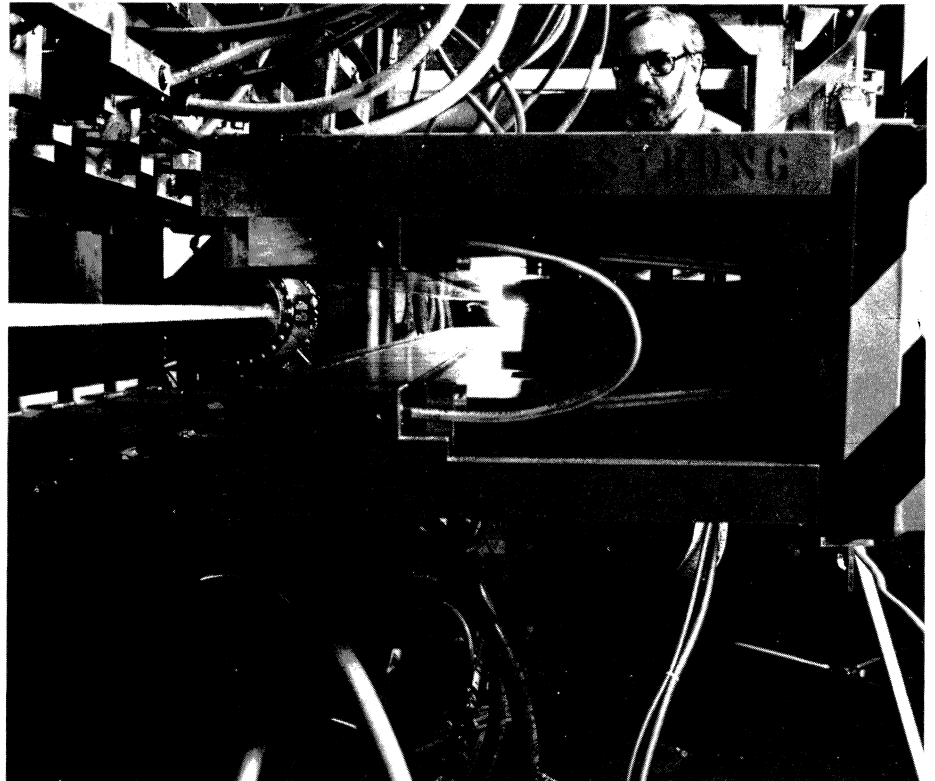
ferous proponents. We will pick out here some of the interesting news concerning these machines which emerged at the Conference.

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 communi-



cated 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

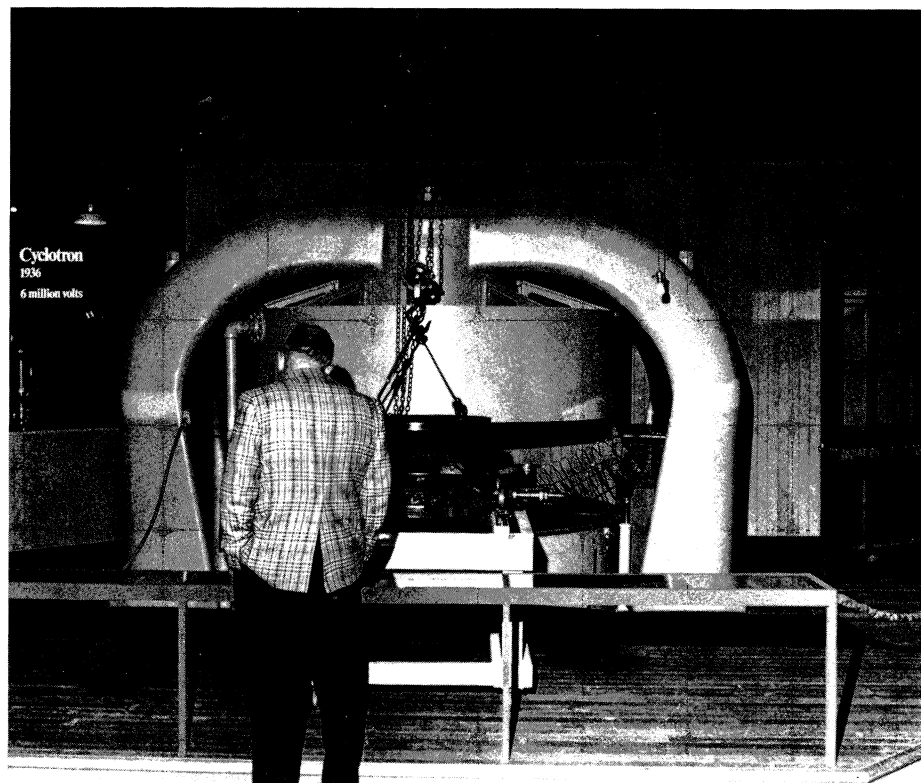
accelerating xenon ions from 15 to 75 keV at 4 MHz has operated. A 200 MHz, 40 to 700 keV structure to accelerate four beams of negative hydrogen ions is being built. A lot of effort has gone into methods of making the pepper-pot grids to transport the beamlets. The latest achievement is a 1000 beam 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 multiple 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 particu-

larly 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.