

# CESR – Cornell Electron Storage Ring

which specifically mentions high energy physics as a field for cooperation — 'Scientific and technological cooperation constitutes an important contribution to the strengthening of security and cooperation... in that it assists the effective solution of problems of common interest and the improvements of the conditions of human life'. ECFA considers that also in this respect an international high energy physics project on a very large scale would be a particularly important step.

Leon Van Hove, Research Director General of CERN, reviewed the actions taken by CERN following the recommendations of ECFA Working Group 3 mentioned above. Some new principles have been established inside CERN to help smooth the working conditions of visiting teams. They concern particularly the degree of technical support supplied from within CERN and its balance with the technical support provided by home Laboratories. Contacts with Users are being expanded by improving the information flow and by transforming an ad hoc 'Commission of Associates' to be more representative of the User community. Finally the general question of communicating high energy physics is being tackled by more effort on the 'public information' front beginning with activities based on CERN itself.

John Mulvey reported the recent decisions on future computing facilities at CERN (covered in the March issue) and Mervyn Hine of CERN described plans in Europe for tests of high speed data links using both ground links and satellites. In his usual provocative way he described this as the solution to the present problem of trying to carry out a 21<sup>st</sup> Century Science using a 19<sup>th</sup> Century communications system. We will have an article on this topic in our next issue.

An electron-positron colliding beam facility is being planned at the Wilson Synchrotron Laboratory, Cornell University. The project calls for a ring to be built in the tunnel housing the 12 GeV electron synchrotron. The synchrotron will be used to inject both positrons and electrons into the storage ring, which is designed for a luminosity of  $10^{32}$  per  $\text{cm}^2$  per s at electron and positron beam energies of 8 GeV. Eventually, the energy range could be extended to 10 GeV by increasing the r.f. power.

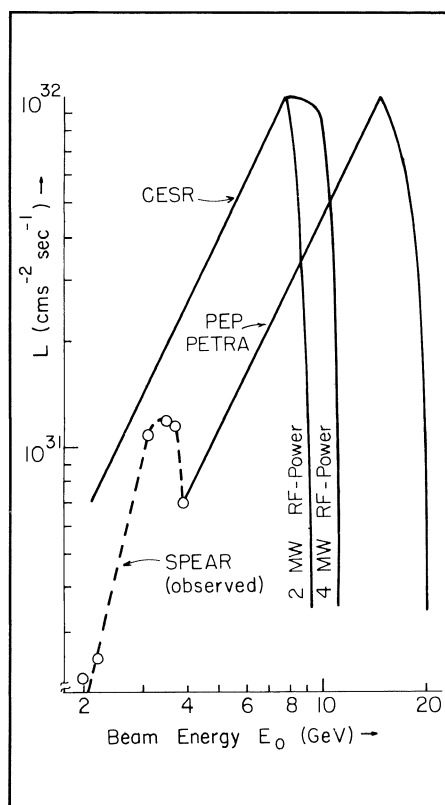
The Cornell facility is intended to complement the DESY (PETRA) and Berkeley/Stanford (PEP) storage rings which will operate at beam energies of 15 GeV and higher. These machines are designed for an optimum luminosity of  $10^{32}$  at 15 GeV beam energy and in the lower energy range of 4 to 10 GeV their luminosity is appreciably less. CESR is optimized for just this energy region, intermediate between the presently operating SPEAR/DORIS rings and the future PETRA/PEP rings. For beam energies up to 10 GeV, CESR will have a luminosity several times greater than PEP and PETRA.

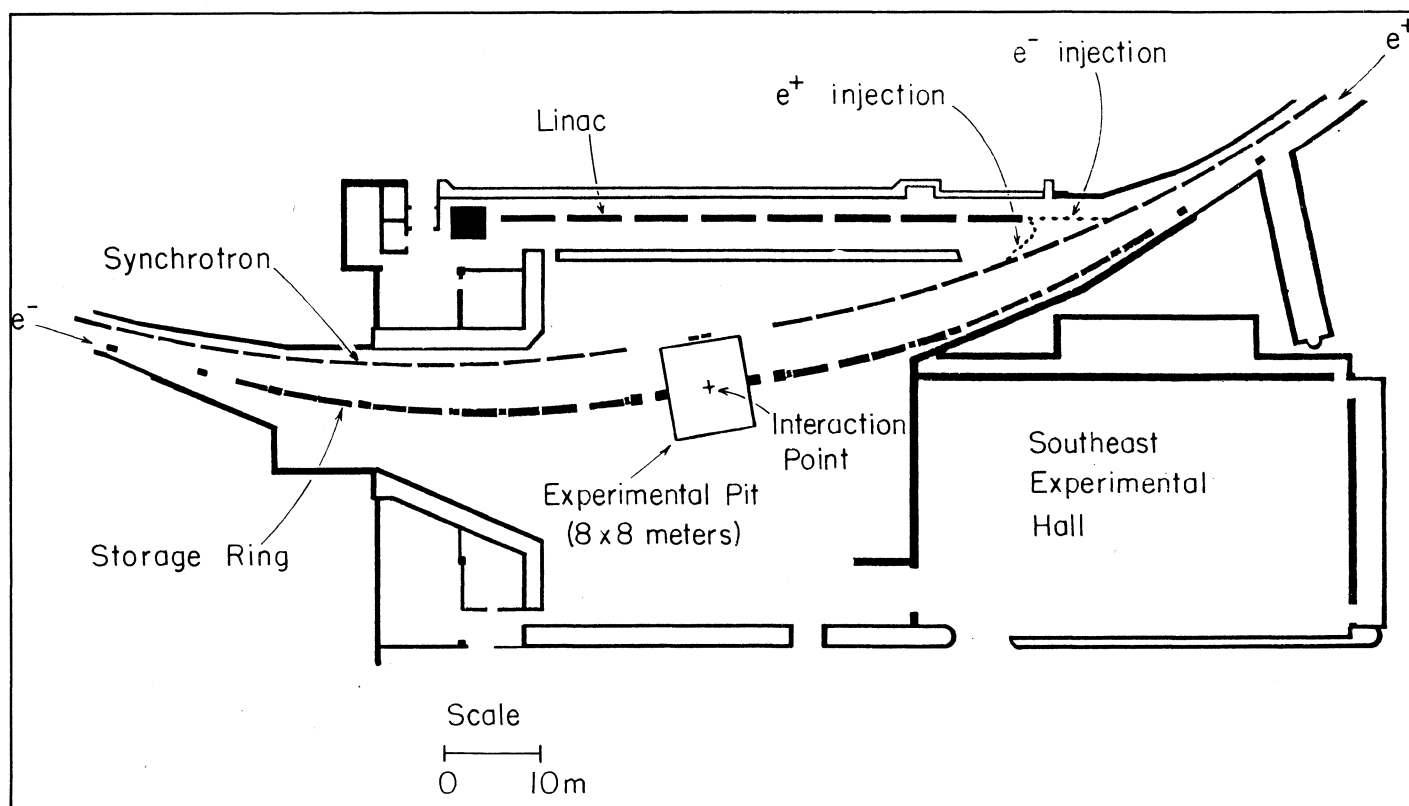
One of the drawbacks of storage ring operation is that all experimental areas must run at the same energy at any one time. Also major colliding beam experiments require many months to perform, even at high luminosity. Thus CESR, operating at high luminosity and low overhead cost in the lower energy ranges, can investigate phenomena from 4 GeV to 10 GeV efficiently, while PEP and PETRA press on with exploration of the higher energy regions using their maximum luminosity.

In May 1975, the Laboratory submitted a proposal to the US National Science Foundation (NSF) for construction of CESR beginning in 1976. Although this proposal was strongly supported by the NSF, it did not

appear in the President's budget for Fiscal Year 1977. A new proposal of reduced scope was submitted to the NSF involving conversion to colliding beam operation using 'operating funds' augmented by less than two million dollars per year for three years. This proposal is currently being considered by the NSF. By directing nearly all the resources and efforts of the Laboratory towards this programme, beam could be injected into the storage ring during the summer of 1979. By that date, construction of a large magnetic detector for colliding beam experiments can also be completed and

*Design luminosity as a function of beam energy for the electron-positron storage rings SPEAR, CESR and PEP/PETRA (PEP and PETRA being very similar). By increasing the r.f. power for CESR from 2 MW to 4 MW, operation can be extended to 10 GeV as shown. The high energy limit for PEP is shown for 9 MW of r.f. power with a total accelerating structure length of 76 m.*





the experimental programme could get off to a flying start.

The NSF has recently approved the expenditure of \$450 000 during 1976 for the development of final designs and prototype components. This work is proceeding at a fast pace with everyone pitching in while carrying on with synchrotron experiments. Animated discussions are held in all corners of the Laboratory on the design of the magnetic detector. Physicists from Harvard, Rochester, Syracuse and other research centres in the northeastern United States are enthusiastically taking part in the planning for this experimental facility. Prototype development of liquid argon shower detectors and large cylindrical drift chambers is already under way. Judging from the enthusiastic response from Cornell's 'neighbours' when the project was proposed, it is expected that more physicists will appear (with sleeves rolled up) to start working happily beside those already involved.

The electron linac from the Cambridge Electron Accelerator has been moved to Cornell and work is proceeding on the modulation of the linac beam and on the production of high intensities required for positron injection into the storage ring.

#### *General description of the storage ring*

The synchrotron and the 'separated

function' storage ring will both run through the South Experimental Hall where, at the storage ring intersection point, the separation between the two will be increased to 5.3 m. The nominal separation between the orbits in the tunnel is about 1.6 m. The 'bulge' in the storage ring is achieved by introducing long drift spaces and a few magnets of higher than average field. The two long drift spaces will be occupied by r.f. accelerating cavities. For installing the detection systems, the interaction region has a free length of 7 m between quadrupoles and a pit depth of 3.8 m below the beam line with a pit area of 8 m × 8 m.

The North intersection region lies underground, at a depth of about 15 m under the surface of a sports field on the Cornell University campus. Due to anticipated budget limitations, the present proposal does not include a major experimental area at this intersection point. (Earlier plans called for excavation of a new experimental hall, including a three-story underground building for associated facilities.) However, specialized smaller experiments may be mounted in this area, where the total available space is 12 m long by 9 m wide, with an arched roof 4.5 m high (floor to ceiling). If necessary, a pit may be excavated, to allow a depth of 3 m below the beam line. The free length for installing detection systems in this interaction straight section is 5 m between quadrupoles.

The bending magnets and quadrupoles are designed for a peak operating energy of 10 GeV and the r.f. system is designed for initial operation at 8 GeV (2 MW). Additional power would give eventual operation at 10 GeV. The vacuum chamber is of extruded aluminium, similar to the SPEAR design, with a built-in water channel to absorb the heat deposited in the wall by the intense synchrotron radiation. Distributed sputter-ion pumps will be installed within the chamber in the bending magnets, to cope with the desorption of gas by synchrotron radiation. An average pressure of about  $2 \times 10^{-8}$  torr will be maintained with both beams circulating, giving a beam lifetime of about 12 hours.

A synchrotron radiation facility will be available to make use of the intense, collimated beam of X rays available from the storage ring.

#### *Injection and stacking of beams*

In order to achieve adequate average luminosity, it is crucial that injection of electrons and positrons be accomplished in a time which is short compared to the useful 'luminosity lifetime'. The storage ring is designed for single bunch operation. The relatively long damping times would require too long a wait between successive 'stacking' of single synchrotron beam bunches into a single bunch circulating.

Floor plan of the South intersection area of CESR, in the main experimental hall. The synchrotron and storage ring are 5.3 m apart at the interaction point while in the common underground tunnel the separation is about 1.6 m.

ing in the storage ring. An ingenious 'vernier phase-space compression' technique proposed by Maury Tigner will be used to overcome this difficulty. It uses multiple bunch acceleration in the synchrotron for filling a single r.f. bucket in the storage ring. At 8 GeV the positron filling time will then be 2.4 minutes while the higher electron output of the linac gives an electron filling time of one minute.

The injection for positrons proceeds as follows. Sixty evenly spaced bunches are injected from the linac into the synchrotron and accelerated to 8 GeV. These bunches are all extracted from the synchrotron in a single turn and injected into the storage ring, where the betatron oscillations are allowed to die down while the synchrotron receives and accelerates another burst of 60 bunches from the linac. These are then stacked on top of the bunches already circulating in the storage ring. The whole process is repeated at 60 Hz, until the total required charge has been accumulated in the 60 bunches in the storage ring.

The vernier scheme is used to coalesce these bunches into one bunch. The circumference of the storage ring is larger than that of the synchrotron by one bunch spacing ( $L$ ) and this provides the vernier phase difference between the synchrotron and the storage ring. There is thus an extra space,  $L$ , between the first and last bunches between the 'head' and the 'tail' of the 60 bunch train in the ring.

The first bunch at the head is extracted from the storage ring using a fast extraction scheme and reinjected onto the equilibrium orbit of the synchrotron at the peak of its cycle. The bunch travels around the synchrotron (advancing in phase with respect to its companions still in the storage ring) until it reaches the extraction kicker, where it is extracted and reinjected into the storage ring. This

bunch has now advanced in phase as compared with its initial position. On the next synchrotron cycle, bunch number 2 is whisked from the storage ring and sent into the synchrotron for an extra turn past the extraction point to gain a full bunch-spacing  $L$  on bunch number 1, so that when re-injected into the storage ring it coincides in phase with bunch number 1. Then bunch number 3 gets the same treatment, except that three revolutions in the synchrotron are allowed before reinsertion into the storage ring, where it coincides in phase with bunches 1 and 2.

This routine is repeated 60 times in all, the last bunch making 60 circuits of the synchrotron to catch up with the first bunch. In order to allow thorough damping of the betatron oscillation between bunch manipulations, the cycle rate is kept at 30 Hz which gives a total time of 2 seconds for 'bunch compression'.

Various stages in the positron 'bunch compression' scheme for CESR. The top line shows part of the train of 60 bunches in the storage ring after repeated 'stacking' cycles. The second line shows the situation after bunch number 1 has been extracted from the storage ring, sent once around the synchrotron and reinjected into the storage ring. Bunch number 2 is then extracted, sent around for two revolutions and reinjected into the storage ring, coinciding in phase with bunch number 1, giving the situation in the third line. Bunch number 3 has three revolutions around the synchrotron to give the result shown in the forth line. The process continues until all bunches are compressed into one r.f. bucket.

### Magnetic detector

To examine as wide a range of phenomena as possible with limited resources, effort is concentrated on providing a single large, versatile detection system to be installed in the South interaction region. Various schemes are being considered for the ideal magnet — 'thin' superconducting solenoid, conventional solenoid, other more open geometries allowing access to the inner detectors, etc. No decision has yet been made, but partisans of each scheme are preparing their cases for the final selection. Prototype work on various particle detectors is proceeding and the detector is expected to be ready when the first stored beams are available in 1979. Further details of the chosen magnet, etc., will be presented as the design work progresses.

