

will also cost an order of magnitude more, Smith points out that each photon collected in space will cost a hundred times more than those gathered on the ground.

—BMS

## Reference

1. L. I. Snezhko, *Soviet Astronomy* **24**, 498 (1981).

# Cornell plans 100-GeV $e^+e^-$ ring

Cornell University is hoping to build an electron-positron storage ring with 50 GeV in each beam. With superconducting rf cavities, for a given energy the diameter of the ring can be substantially reduced as can the power bill. If the research and development continues to go well, Cornell plans to submit a proposal to the National Science Foundation next year. The estimated cost is \$200 million in 1981 dollars. NSF has supported Cornell's previous accelerators, the 12-GeV electron synchrotron and its successor, the Cornell Electron Storage Ring, CESR, with 8-GeV electrons colliding with 8-GeV positrons.

Meanwhile, last year SLAC submitted a proposal to the Department of Energy to build a new type of collider—the SLAC Linear Collider (PHYSICS TODAY, January 1980, page 19) for electrons and positrons; the SLC would also have a center-of-mass energy of 100 GeV.

This June, at its meeting, the CERN Council decided to go ahead with the procedure for approval of Phase I of the LEP Electron/Positron Collider Project, which would also have 50-GeV electrons colliding with 50-GeV positrons. In its final phase, the LEP project would have 130 GeV per beam (PHYSICS TODAY, July 1980, page 19).

The Japanese government has ap-

proved an  $e^+e^-$  storage ring, Tristan, which will have 30 GeV in each beam; construction has already begun at the KEK laboratory in Tsukuba, an hour's drive from Tokyo.

These new  $e^+e^-$  devices would all exceed the center-of-mass energy available at PETRA (at the DESY laboratory in Hamburg), which has 37 GeV center-of-mass. However, PETRA will have its center-of-mass energy raised to 45 GeV two years from now. At present, the PEP  $e^+e^-$  storage ring has 29 GeV center-of-mass energy but may run at 35 GeV this fall.

**Cornell design.** Last year Cornell produced a paper design for an  $e^+e^-$  storage ring, CESR II, and presented the idea to a HEPAP subpanel (headed by Sam Trieman) that met at Woods Hole June 1980. The subpanel encouraged Cornell to continue its research and development program for superconducting cavities and to develop an accelerator design.

The basic problem with circular electron devices is synchrotron radiation. The energy loss per revolution varies as the fourth power of beam energy divided by radius. In the past, storage rings were designed to make the accelerating voltage economically and to make the radius big. If Cornell did not use superconducting cavities in CESR II, the

radius of the ring would have to be twice as large.

The cost of the storage ring is the sum of the fixed cost (experimental halls, injector with beam transport and site preparation) and the cost of making magnets, controls, vacuum and supports (which is fairly constant per running foot and hence the bigger the radius, the higher the cost) plus the cost for the required accelerating voltage. As Maury Tigner of Cornell explains, "cheap volts give less magnets and tunnels"; so superconducting cavities are desirable to minimize cost.

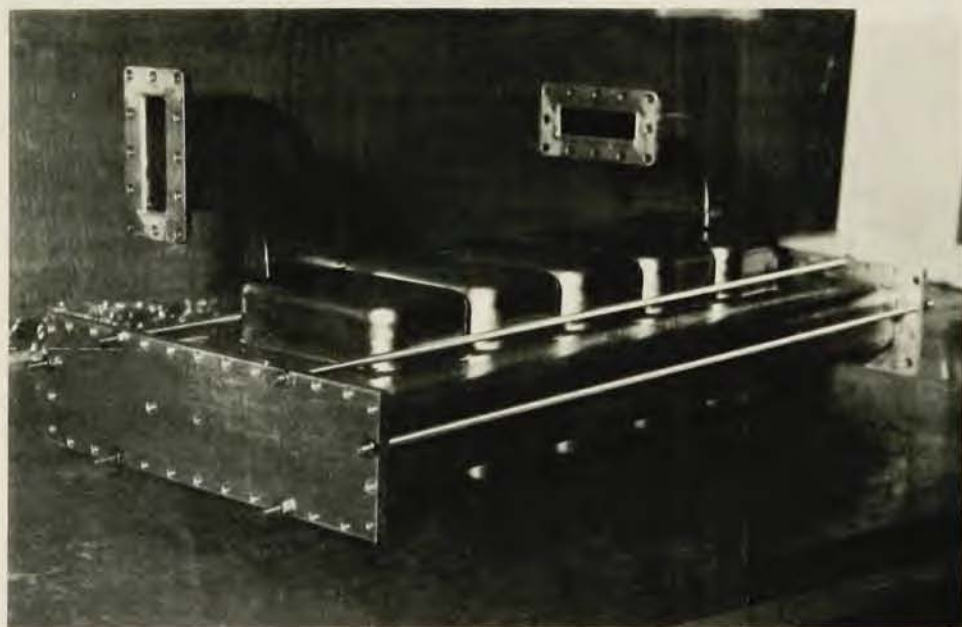
Cornell has had a small experimental program on superconducting cavities for about ten years. Originally the group expected to use them in a synchrotron. They developed a mass-production technology for producing niobium superconducting cavities and fittings (waveguides, elbows, directional couplers and vacuum windows). A two-foot section was tested at the old 12-GeV electron synchrotron in 1976. By that time, Maury Tigner told us, electron synchrotrons had "become a drug on the market," and Cornell was converting its synchrotron into CESR.

The superconducting cavities developed for synchrotron use were S band, 10-cm wavelength, and were not suitable for the 500-MHz frequency of CESR.

CESR II would operate at 1500 MHz, L band; so the superconducting cavities need to be larger in all dimensions—10-cm long and 15 cm transverse to the beam. The niobium cavities are shaped like two muffin tins, one above and one below the median plane, along which the beam passes.

The current CESR design calls for a tunnel 5485 meters in circumference with a 10-foot inside diameter and eight straight sections. Four of the straight sections would have accelerating stations and four would be interaction regions. Within each of the accelerating stations would be 45 or 50 10-cm superconducting chambers, then a 1-meter focusing quadrupole (at room temperature), then more superconducting chambers.

One of the problems in the use of such cavities in storage rings is caused by what is known as higher-mode loss. As Boyce McDaniel, director, explained, when the short (compared to the rf wavelength), intense bunch in the storage ring passes through the superconducting cavity, the effect is like striking a gong, and higher frequency modes are excited in the cavity. If this energy is absorbed in the cavities, they would go normal, unless the refrigerator were huge. The energy from higher-order modes is removed by cutting longitudinal and transverse slots in some of the cups, thus transferring the higher-order-mode energy to



**Prototype superconducting rf cavity** for CESR II electron-positron storage ring. Beam traverses five-cell muffin-tin cavity longitudinally between top and bottom muffin-tins. Cavity is shown closed off with end plates. Horns at top are wave guides that couple to the higher-harmonic-mode excitations, conducting the energy away from the cryostat.

the room-temperature region.

The Cornell group plans to use standard iron quadrupoles with windings of aluminum or copper operating at less than 20 kG and with a pole tip field of a few kG. For electron storage rings, bending and focusing magnets need not be superconducting because the required fields are so low, compared to those in proton devices. The LEP magnets produce a field of 1-2 kG and are in fact to be two-thirds concrete: C-shaped steel laminations would be stacked, and instead of filling the space with iron, CERN plans to use concrete, which is cheaper and makes the magnet more rigid.

Two of the interaction regions are planned to have high luminosity with four meters of clear space for experiments, that is no magnets for 2 meters on either side of the crossing point. The other two interaction regions would have 6 meters of clear space, and correspondingly lower luminosity.

Inspired by recent success at PETRA, the  $e^+e^-$  device at DESY, with "mini- $\beta$  insertions," Cornell is working on a design to bring its focusing magnets even closer to the crossing point, so that focusing is tighter, producing a denser beam. Tigner told us the optimal size for the depth of focus is the length of the beam. This summer the group designed an interaction region with a clear space of 1 meter on each side. In this interaction region Cornell might use superconducting quadrupoles inside the detector, because the pole-tip field is 40 kG and the magnet size must be small.

The design luminosity for CESR II was  $3 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1}$  for 4-meter straight sections. With 2-meter straight sections and a superconducting magnet, triple that luminosity could be expected based on the experience at PETRA. The value reached at PETRA for the envelope function,  $\beta$ , at the crossing point is 5-7 cm. CESR II would lower  $\beta$  to 1 cm.

Another possible problem with all kinds of rf cavities, McDaniel told us, is "multipactoring." In this process a single electron, perhaps originating from ionization of the residual gas in the cavity from field emission, may be driven into the cavity wall to release additional electrons by secondary emission. These are then drawn away from the wall by the alternating electric field and upon later reversal of the field are driven back to the wall again, producing still more secondary electrons. Repetitive cycles lead to a secondary emission cascade. This multipactoring can reduce the almost infinite  $Q$  (stored energy divided by input per energy per cycle) to a low value, making the cavity go normal. To lower multipactoring, Cornell is etching grooves in the face of the muffin

cup. This July, with such grooved cavities, the Cornell group got an accelerating field of 8 MeV/meter, far better than the design field of 3 MeV/meter.

**Work at other labs.** A group at CERN is working on superconducting rf cavities, which would eventually be added to LEP to raise its energy from its full-scale operation with 90 GeV/beam to 130 GeV/beam. This group contains physicists from Karlsruhe, Orsay, Genoa and the Technische Hochschule in Wuppertal. This fall the group will put a superconducting cavity into PETRA. KEK is also looking into superconducting rf cavities to be added later to Tristan.

The High-Energy Physics Lab at Stanford has been operating a high-duty-cycle superconducting electron linac that recirculates the beam, each time picking up more energy, with a total of about 100 MeV after three or four passes. The HEPL-type cavities operate at 1300 MHz, L band. A group at the University of Illinois has used the HEPL-type cavities to do nuclear-physics experiments at energies of the order of hundred MeV. Unlike storage rings, these linacs do not have problems with shock excitation from the passage of large bunch, but they do not

achieve the high electric field gradients (tens of MeV/meter) originally anticipated, Tigner told us. Such high field gradients are not required for storage rings, because the cavities are used over and over as the beam circulates in the ring.

Two groups are making superconducting postaccelerators for heavy non-relativistic particles; the postaccelerator follows a tandem electrostatic accelerator, which permits one to retain high beam quality and raise the energy. A Stony Brook-Caltech group is using lead-plated copper cavities (operating at 150 MHz) while a group at Argonne uses niobium cavities (at 92 MHz). Both groups use a modular construction, allowing portions of the accelerator to be used while others are not installed. Florida State University is planning to add two Argonne modules to its existing tandem to double its beam energy.

A group from Wuppertal and Darmstadt is planning to make an electron accelerator that is a hybrid between a synchrotron and a linac; it will use S-band superconducting cavities (instead of the L band cavities used by HEPL). This higher frequency appears to improve performance. —GBL

## Superconducting cyclotrons

The impending completion of a 500-MeV superconducting heavy-ion cyclotron at Michigan State University—first beam is expected in September—is indicative of two important trends in nuclear physics. Although very few data exist at present on collisions of heavy ions at beam energies between the nuclear Fermi energy (about 36 MeV per nucleon) and the GeV regime of relativistic energies, it is generally believed that this "intermediate" region will soon provide much enlightenment about the properties of nuclear matter. Secondly, there is a growing consensus that superconducting cyclotrons are a particularly efficient and cost-effective way of attaining this region of heavy-ion beams.

A few months ago a ground-breaking ceremony was held at Michigan State's National Superconducting Cyclotron Laboratory, to mark the beginning of construction on a building to house an 800-MeV superconducting cyclotron and its experimental areas. This "Phase II" cyclotron is scheduled for completion in 1984. The "Phase I" 500-MeV machine will then serve as an injector into the 800-MeV cyclotron, providing heavy-ion beams with energies up to 200 MeV per nucleon. In the meanwhile, the 500-MeV machine, standing alone, will accelerate light ions to 80 MeV per nucleon, and heavy ions

(out to copper) to 10 MeV per nucleon.

The National Superconducting Cyclotron Laboratory, so designated in 1979, is a national user facility. It expects to issue a call for experimental proposals for the Phase I cyclotron as soon as the first beam tests have been completed in September. The director of NSCL is Henry Blosser.

"We're in a race with Chalk River, to see who will have the world's first superconducting cyclotron in operation," Walter Benenson, associate director of NSCL, told us. The Chalk River Laboratory, in Ontario, is building a superconducting cyclotron to serve as a booster, or "after-burner," for their tandem Van de Graaff accelerator. The Canadian tandem-cyclotron coupled system will accelerate heavy ions to a maximum of about 50 MeV per nucleon. Blosser credits the Chalk River group with being the first to realize the feasibility and economic desirability of building superconducting cyclotrons for heavy-ion physics.

The Michigan State machines are essentially conventional cyclotrons, except that their bending magnets are superconducting. They can therefore be made smaller, and can operate with much less power than room-temperature cyclotrons of comparable energy. Their 50-kilogauss bending fields—more than three times the intensity of