A World of New Accelerators

From Japan to Geneva, new equipment for the study of the fundamental structure of matter is coming into being

By DIETRICK E. THOMSEN

An accelerator — the basic apparatus for particle physics, much of nuclear physics and some studies in materials science and solid state physics — is an apparatus that takes protons, antiprotons, electrons, positrons, ions or some combination of those and imparts energy to them. The energetic particles are then struck against targets or against each other in order to produce phenomena that reveal something of the structure and dynamics of matter on the subatomic scale.

The acceleration is done electromagnetically. In low-energy installations it may be done electrostatically, by attracting the particles — all these are charged particles — to properly biased electrodes in a manner analogous to the way a battery starts a current. High energy machines use radio waves in special waveguides. The waves push the particles in a manner similar to what an ocean wave does to a surfboard that catches it properly. The energies imparted are measured in electron volts; an electron volt is the amount of energy that a proton or an electron gains while passing between electrodes with one volt of potential difference between them.

The building and management of accelerators is a specialized craft within the profession of physics. From time to time its members gather together to talk shop and compare notes as they did at the recent 12th International Conference on High Energy Accelerators held at the Fermi National Accelerator Laboratory in Batavia, Ill. There was lots of shop to talk. All over the world there are new accelerators being built or ready to start.

Accelerators have been with us since about 1930. They began in the United States and Great Britain, and the United States, Western Europe and the Soviet Union have been the traditional locales of new developments in the field. Now Japan and China are making serious entries into the advanced part of the field.

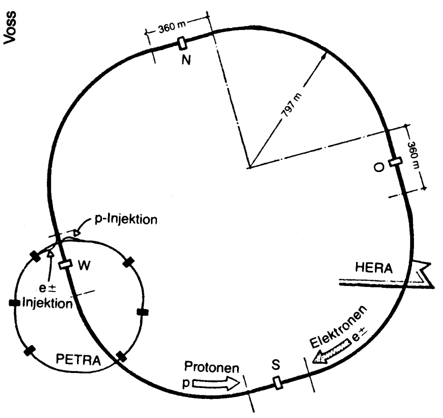
T. Nishikawa of Japan's KEK laboratory near Tsukuba described the Japanese project, Tristan, being built at KEK and the Chinese Beijing Electron Positron Collider (BEPC, pronounced "bep-see"), being built near the Chinese capital. In recent years there has been much cooperation and exchange of information between Japanese and Chinese physicists, Nishikawa says, and the Chinese chose him to present their plans at the Fermilab meeting. He thanks Chow Man-yu of the Chinese group for supplying the information about BEPC.

Like all the installations to be discussed in this article, Tristan and BEPC are colliding beam machines. That is, they will accelerate two beams of particles and collide them with each other. This technique has a tremendous energy advantage over striking a single accelerated beam against a fixed target. In the single beam much energy is tied up in the forward momentum of the beam, which must be preserved after the collision. This energy is thus unavailable for the creation of new phenomena. If two beams approach each other from opposite directions with equal momenta, the net momentum is zero, so all the energy they carry is available to make new phenomena in the collision.

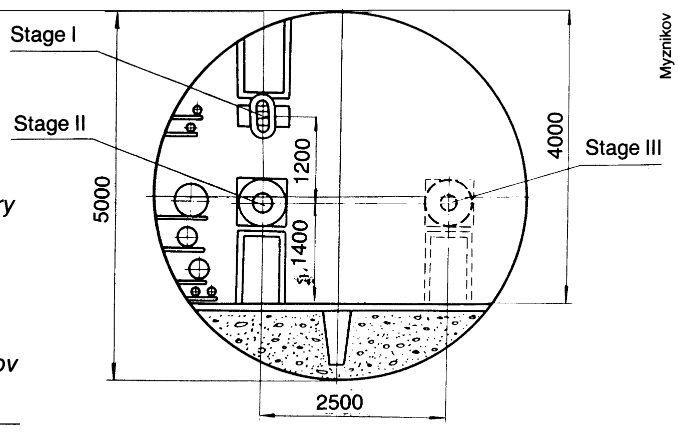
Some years ago the Chinese physicists had planned to build a proton accelerator with 50 billion electron volts (50 GeV) maximum energy. After much discussion, says Nishikawa, they decided to cancel that and build BEPC instead. BEPC will combine a linear accelerator and oval storage rings to provide electrons and positrons with energies between 2.2 and 2.8 GeV per beam or maximum total interaction energy of 5.6 GeV. In a linear accelerator, many accelerating waveguides are lined up interspersed with focussing magnets to keep the beam together. In a circular accelerator (or other closed shape) whether called a storage ring or not, bending magnets are inserted to make the beam go around the curves. The ring will be 60 by 80 meters; the linear accelerator and connecting beam pipes will be 265 meters long, making the whole 325 meters long by 80 meters wide. Beams will collide at two points around the ring. BEPC will be installed in the western part of the Institute for High Energy Physics in Beijing. The Chinese credit W. K. H. Panofsky, director of the Stanford Linear Accelerator Center (SLAC) in Palo Alto, Calif., with helping them make the design complete and reliable.

BEPC's maximum energy is modest compared to existing electron-positron colliders DORIS and PETRA at the Deutsches Elektronen-Synchrotron laboratory (DESY) in Hamburg and SPEAR and PEP at SLAC, the most energetic of which can provide a maximum of nearly 35 GeV. But its luminosity, up to 1.7×10^{31}, will be

Voss



The existing PETRA storage rings will be used as an injector for the new giant HERA ring at the Deutsches Elektronen Synchrotron Laboratory in Hamburg (left). Eventually three separate accelerating rings will occupy the tunnel of the UNK apparatus in Serpukhov in the USSR (right).



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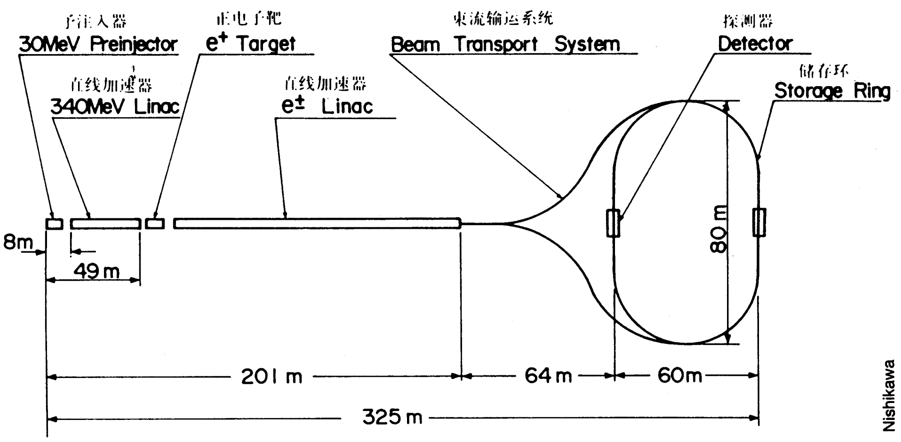

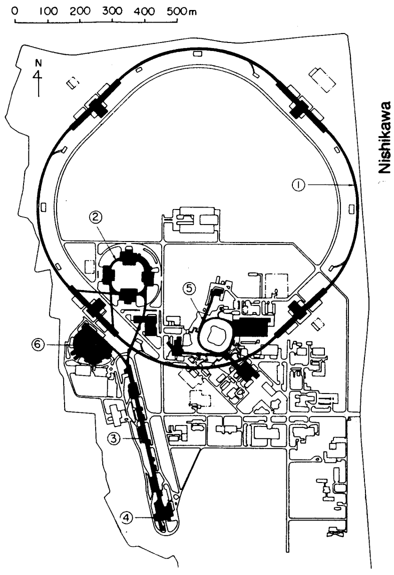

Particles for the Tristan machine at Tsukuba, Japan (right), start out in the linear accelerator (3 and 4), go around the small ring (2) and into the large ring. Collision points are shown on all four sides of the large ring. The Chinese choice (above) is a combination of a linear accelerator and storage rings for the high luminosity, medium energy BEPC.

higher than theirs. Luminosity, the product of the number of particles per pulse in each of the colliding beams, divided by the cross-sectional area of the beams, is the measure of the rate at which collisions can be expected. With higher luminosity the Chinese believe they can study interesting phenomena of the physics of this energy range that are too rare to be practical for the other machines. BEPC received its final authorization earlier this year. Completion is expected in 1987.

Tristan will be an electron-positron collider with a maximum energy of 30 GeV per beam or 60 GeV total (60 GeV in the center of mass, as physicists say). It is a squared-off circle three kilometers in circumference, "the largest ring that can be accommodated on the site," Nishikawa says. There will be four points where the beams collide and particle detectors can be placed. At most installations, collision points are merely numbered; Tristan's are named Fuji andTsukuba for the mountains of those names, which two of the points face, and Nikko and Oho for nearby towns.

Construction of Tristan began in 1981. The earthmoving and other civil construction for the main ring is now complete, and the electronics are beginning to be fabricated. First collisions are expected in 1986. Two detectors, Topaz and Venus, are being built. Topaz will have in its center a time projection chamber, a very new form of detector recently invented in California (SN: 2/13/82, p. 103). Venus is designed along more conservative lines and is expected to be ready first.

Far to the west of Tsukuba and Beijing, in fact over the Ural Mountains in Europe, lies Serpukhov, a town not far from Moscow. At the Institute for High Energy Physics there, the Soviets are building a truly ambitious accelerator called UNK. UNK will be built in three stages, according to K. P. Myznikov of Serpukhov. The first, using conventional magnets, will be a 400 GeV proton accelerator. The second stage will use superconducting magnets to get protons to a maximum energy of three trillion electron volts (3 TeV or 3,000 GeV). These could then be collided against the 400-GeV protons. Finally a third stage will be another superconducting-magnet 3-TeV ring to provide collisions with 3 TeV per beam (6 TeV in the center of mass). The existing 70-GeV accelerator at Serpukhov, the Soviet Union's most energetic at the moment, will be used as an injector.

UNK will be an oval 20 kilometers in circumference. Like most of the really high energy machines now planned, it will lie underground, 20 to 60 meters deep. There will be four collision points where stages two and three will meet. Myznikov says that site preparation and access roads are complete. Construction of the tunnel is beginning. Prototypes of both conventional and superconducting magnets have been built and are acceptable. The radiofrequency accelerating cavities are being manufactured and are also acceptable. Stage one is expected to be complete by 1988; stage two will go into the 1990s. No schedule is yet foreseen for stage three.

Well to the west and a little bit south of Moscow is Hamburg, where the DESY laboratory is about to start construction of a set of storage rings unique among their kind. This apparatus, called HERA (Hadron-Electron Ring Accelerator), will collide protons at 820 GeV with electrons at 30 GeV. (Hadrons are the general class of particles built out of quarks, of which protons are one variety.) In such an arrangement the electrons will penetrate the protons and gain information about their structure. The intent is to study such things as how the electrons interact with the quarks inside the protons, and whether new kinds of quarks and new families of particles can be made in such collisions.

HERA will be built deep underground in a tunnel 6,330 meters in circumference. Gustav-Adolf Voss, director of DESY, told the meeting that the laboratory hopes to award construction contracts about Oct. 1, 1983, and to commence digging on Jan. 2, 1984. The cost of the machine is expected to be about $250 million. Nearly all the funds will come from the West German federal government and the Hamburg state government, but the governments have imposed a condition that a small part of the funds come from outside Germany. Voss says that several foreign laboratories are interested in contributing experimental equipment, and he believes that the letters he has from them will convince the two governments that the condition has been met.

HERA's circumference will surround the entire DESY site plus an adjacent public park. It will pass under some private property, the Hamburg airport and the autobahn that runs from Denmark to Italy. One difficulty anticipated is that the fields of its dipole magnets will alter the tint of color television in the houses above. However, the magnets are not expected to affect airplane guidance at the airport. There will be only one access to the HERA tunnel, through a shaft dug in the park and topped with a small building about the size of a changing room. There will be four interaction points where electrons and protons will meet.

HERA's magnets are already being built, both dipoles for bending and quadrupoles for focussing. The dipoles will be superconducting, of the sort pioneered at Fermilab. Two designs are under consideration, and 12 examples of each are being built by the NIKHEF laboratory in Amsterdam. A decision on which to use is expected by the end of 1984, Voss says. First collisions are expected in 1989 and a start on experiments in 1990.

South of Hamburg is Geneva, site of the CERN laboratory, which belongs to 12 European nations. There ground was formally broken in September for LEP (Large Electron Positron collider) in a ceremony attended by the presidents of France and Switzerland, the two countries in which LEP will lie. (Work on shafts and tunnels actually started in July.)

Herwig Schopper, director general of CERN, started his talk by remarking that some theorists have said that LEP should be scrapped now that the W and Z^0 particles have been found (SN: 2/5/83, p. 84; 6/18/83, p. 389) — LEP was originally planned to look for them — and a proton-antiproton collider be built instead. Schopper says no consideration is being given to the suggestion. The discoveries show that the right energy range was chosen for LEP, he says, and now it can study their physics in great detail. Schopper calls LEP "a Z^0 factory."

When LEP is complete, it will likely be the most energetic electron-positron collider in the world. It's first phase is planned for a maximum energy of 60 GeV per beam or 120 GeV in the center of the mass. LEP's American rival, the Stanford Linear Collider (SN: 9/30/83, p. 71), is planned for 100 GeV in the center of the mass, but small adjustments up or down have been known to occur during accelerator construction.

The 12 governments have authorized this first phase of LEP, which is expected to cost 910 million Swiss francs (1981 values) or about $500 million (1983 values), with the proviso that CERN's over-all budget remain static and new personnel not be hired. This means much internal shifting of personnel, which is causing some hardships, Schopper says, and the closure of certain other facilities, notably the Intersecting Storage Rings (a ten-year-old proton-proton collider) and the giant bubble chamber called BEPC (pronounced "beps" and not to be confused with the Beijing storage rings).

LEP will lie at an average depth of 82 meters in a tunnel 27 kilometers in circumference, which will straddle the French-Swiss border. Most of the site lies in the plain between Lake Geneva and the Jura Mountains, but a small portion is under the foreslope of the Jura. The portion in the plain will be in the stable bedrock called molasse, in which tunneling machines will be used, but the Jura part is in limestone, and there explosives are needed for excavation. The ring comes near the Geneva airport, and there the magnets will have to have special shielding, "or the airplanes won't like it," Schopper says.

In a tunnel as long as LEP's, workers cannot walk from place to place. A monorail will be installed to carry people and materials in the tunnel. Because of restricted space, all components will be assembled as completely as possible on the surface and then lowered into the tunnel.

LEP will have eight interaction points. Four detectors have already been selected: OPAL, an upgrade of the JADE detector now working at the PETRA rings at DESY; ALEPH, which will have a time projection chamber and a superconducting magnet; L3, a calorimeter for measuring energies and momenta of all kinds of particles, which will have a 7,000-ton magnet — "more iron than there is in the Eiffel Tower," Schopper says — and DELPHI, a large Cerenkov counter.

Completion of the first phase LEP is expected in 1988. Future options include an energy upgrade to 100 or maybe 125 GeV per beam (200 or 250 GeV in the center of mass). The circumference of the tunnel is actually optimum for 100 GeV per beam, Schopper says. Then, a long way off, is possibly the construction of a proton-antiproton collider in the LEP tunnel. □