EUROPE'S BIGGEST ACCELERATOR

B SOUTHWORTH

Brian Southworth describes the construction of Europe's largest accelerator, tells of problems overcome and progress made so far, and looks forward to the time when CERN's big machine will be ready for particle physics experiments

Three years ago, in February 1971, the Council of the European Organization for Nuclear Research, CERN, gave the go ahead to the '300 GeV program'. This program covers the construction of a high energy proton synchrotron for a total budget of 1150 million Swiss francs (at 1970 prices) spread over eight years. Eleven European countries – Austria, Belgium, Denmark, Federal Republic of Germany, France, Italy, Netherlands, Norway, Sweden, Switzerland and the United Kingdom – finance the project with contributions in proportion to their net national income.

The accelerator is often referred to as the sps, standing for super proton synchrotron. It will ensure that CERN con-

tinues to provide frontline research facilities to over 1000 high energy physicists from universities and research centres throughout Europe and will join the 400 GeV accelerator of the USA National Accelerator Laboratory as the highest energy machine in the world.

By now, virtually all the design decisions have been taken. Civil engineering work is well advanced and accelerator components are arriving at the CERN site for assembly and testing. Detailed preparations for the experimental program have already started.

Constructing the tunnel

The sps is being built in CERN Laboratory II alongside Laboratory I where the 28 GeV proton synchrotron and the intersecting storage rings are in operation.

This has influenced a number of major design features. The proton synchrotron of Laboratory I will be used as injector for the sps providing protons at an energy of 10 GeV. The sps will be built in a near circular tunnel about 50 m below ground level. This depth allows the tunnel to be bored in good rock and minimizes the disturbance to the farming and forestry on the site which spans the Franco-Swiss frontier (412 hectares in France and 68 hectares in Switzerland). It also ensures ample shielding against radiation.

The maximum tunnel diameter which can be accommodated on the site is 2.2 km and, using a full ring of magnets capable of a peak field of 1.8 T, the protons can be taken to 400 GeV. It had been hoped that pulsed superconducting magnets would have been sufficiently developed by this stage of the project to give the option of higher energies, taking advantage of their higher peak fields. However questions of reproducibility, reliability and cost remain to be answered for these magnets and the decision has been taken to install only conventional magnets. It proved possible within the budget to add sufficient magnets to achieve a peak energy of 400 rather than the 300 GeV initially foreseen.

Another design feature related to the proximity of Laboratory I is the use of an existing hall (west experimental area) for sps experiments. In this area are located a large spectrometer, Omega, and the 3.7 m European bubble chamber, BEBC. These large items of experimental equipment can be adapted for use at sps energies. In another area (north experimental area) two new halls will be built to accommodate further experiments.

The major task of the civil engineering for the project is the boring of the 7 km circumference of the accelerator tunnel. This is being done by a Robbins boring machine (known familiarly as 'the mole') which has a cutting head 4.8 m in diameter. The cutting head is followed by a semiautomatic device for putting prefabricated concrete tunnel lining sections in place which is, in turn, followed by a two storey wagon train. The wagons bring in the concrete sections and excavate the spoil bored out by the cutting head.

The mole was lowered down an access shaft in January 1973 and by December had bored its way around half of the circumference at an average speed of 20 m/day. It is due to complete its job this year. The main concern in the tunnelling work is to achieve high positional accuracy. A geodetic network was established to an accuracy of 2 mm over the surface of the Laboratory II site using triangulation and trilateration. Surface coordinates were then transferred to tunnel level at several access shafts. A gyro theodolite has been used to plot directions underground and survey monuments have been installed every 32 m as the tunnel has progressed. A laser beam from a monument points the way for the Robbins machine by illuminating two grid targets (giving horizontal and vertical positions) which

Figure 1 The model tunnel in which magnets and all the related supplies are being installed to optimize their layout and check the installation techniques (photograph courtesy of CERN)

are fixed with relation to the axis of the machine. Using this technique, the mole emerges within about 2 cm of its scheduled position after travelling over 1 km.

On the surface, offices and a large assembly hall (11000 m²) are complete. Service buildings near the access shafts are under construction, as are two 5000 m³ reservoirs to receive cooling water pumped up from Lac Léman, and the 380 kV power line to bring electricity from Gnsiat which is the nearest station on the European grid.

Assembling the accelerator

Components of the accelerator itself are being put together in the assembly hall. Half the hall is a magnet factory through which over a thousand magnets will pass on their way to the accelerator ring. There are 744 bending magnets of two types, each 6.25 m long but differing in aperture (39 mm x 129 mm and 52 mm x 94 mm) so as to adapt to the beam profile. They arrive as cores, coils and vacuum chambers and are assembled in the hall. The main problem has been to achieve simplicity in the design and in the construction techniques so as to keep costs down while mass producing very high quality magnets.

The other magnets arrive already assembled and are tested thoroughly in the hall. They include 216 quadrupole focusing magnets and a variety of correction magnets – dipoles, sextupoles, octupoles.

By the end of February about 100 of the bending magnets were assembled. Most of them have also been mechanically and magnetically tested. As many as 24 magnets (including quadrupoles) can be installed in special bays where they are either being measured, waiting to be measured or being modified. Once through this inspection they are stacked ready for the time (beginning about the middle of this year) when they can be wheeled off for installation in the accelerator tunnel.

The radiofrequency accelerating system is of a novel type involving the use of two travelling wave cavities operating at 200 MHz. A complete cavity and power amplifier will come together this year. Up to now, tests on individual components have gone well. Other novelties appear in the beam ejection systems which have to bend the very 'stiff' high energy beams of several hundred GeV coming out of the machine in a controlled fashion. New types of electrostatic septum magnet, where the septum is a 3 m long plane of molybdenum wires 0.1 mm thick, are being built. The wires are stretched individually by springs to pull them clear of the proton beam if they should break.

The control system

The control system of the sps, based on the use of computers, is extending the concepts of accelerator control in several ways. The philosophy of having one large central computer overseeing the functions of smaller ones has been abandoned in favour of having many small or medium sized computers which are effectively interchangeable. The loss in number crunching ability is likely to be a very rare inconvenience while the gains in cost,

simplicity and flexibility are considerable. The software techniques are also new with a specially developed control language called NODAL and the use of an interpreter rather than a compiler. It will be possible to call all the control functions from a single console using a new touch button panel. The console will have conventional control aids (such as black and white television display screens and computer input keyboards) and also special aids such as colour screens (allowing more information to be transmitted and absorbed on one display) and a knob with feedback from the computer (stiffening the turning mechanism when, for example, megawatts are being controlled). Several of the small computers have been delivered to CERN and are being used in developing these control techniques.

Meanwhile, back in Laboratory I, the 28 GeV proton synchrotron is having a wash and brush up in preparation for its task as injector for the sps. It has been in operation for 14 years and is now accelerating beams 1000 times more intense than were anticipated during its design. Some components have wilted under the strain (for example, some magnets need attention because of insulation damages due to the accumulated radiation dose); some need improving or replacing so as to

ensure reliable operation under new conditions (for example a new 50 MeV linac is being built). An ejection technique to send the protons at 10 GeV energy for feeding into the sps is being developed. It is known as 'continuous transfer' and consists of peeling off the beam while it makes 11 turns in the machine so that the lengthened ribbon of protons will fill the full circumference of the sps (the ratio of the two circumferences being 1 : 11).

Planning ahead

In line with CERN tradition, a committee of physicists coming mainly from other European high energy research centres has been set up to examine the proposals for experiments at the new machine. The high energy physics community has, in fact, from the very beginning of the project been involved in evolving the plans for the experimental facilities. Experimentation at energies in the hundreds of GeV range requires large, sophisticated detector systems and building must be started soon if they are to be ready for the scheduled start of the experimental program. It is planned to provide high energy beams in the west area by the end of 1976 and in the north area by early 1978 ■

Brian Southworth is the editor of the monthly *CERN Courier*

Figure 2 The tunnel boring machine known as the 'mole' breaks through at pit 4 halfway around the 7 km circumference of the accelerator ring (photograph courtesy of CERN)