

1000 GeV next stop

(*) See page 27.

The preoccupations of the Fermilab accelerator specialists at present are to push the proton beam intensity higher towards the goal of 5×10^{13} (*) per pulse and to tame the accelerator components to operate at 500 GeV. Looking beyond these tasks, there is the vision of doubling the peak energy by adding a ring of superconducting magnets — a project known as the Energy Doubler/Saver. This project is now playing a bigger part in the life of the Laboratory and the Director, Professor Wilson is spending a considerable part of his time working on it. Bob Wilson heads the Doubler project with Bill Fowler as assistant.

A move to higher energy has never yet failed to uncover new features of particle behaviour. The latest advances have perhaps been the most fruitful of all — 400 GeV protons at Fermilab, colliding proton beams in the CERN ISR and colliding electron-positron beams at SLAC and DESY have been

the source of such radical discoveries that we seem to have crossed a threshold into a new era of understanding Nature. Extending to 1000 GeV could confront some of the questions raised in this new era.

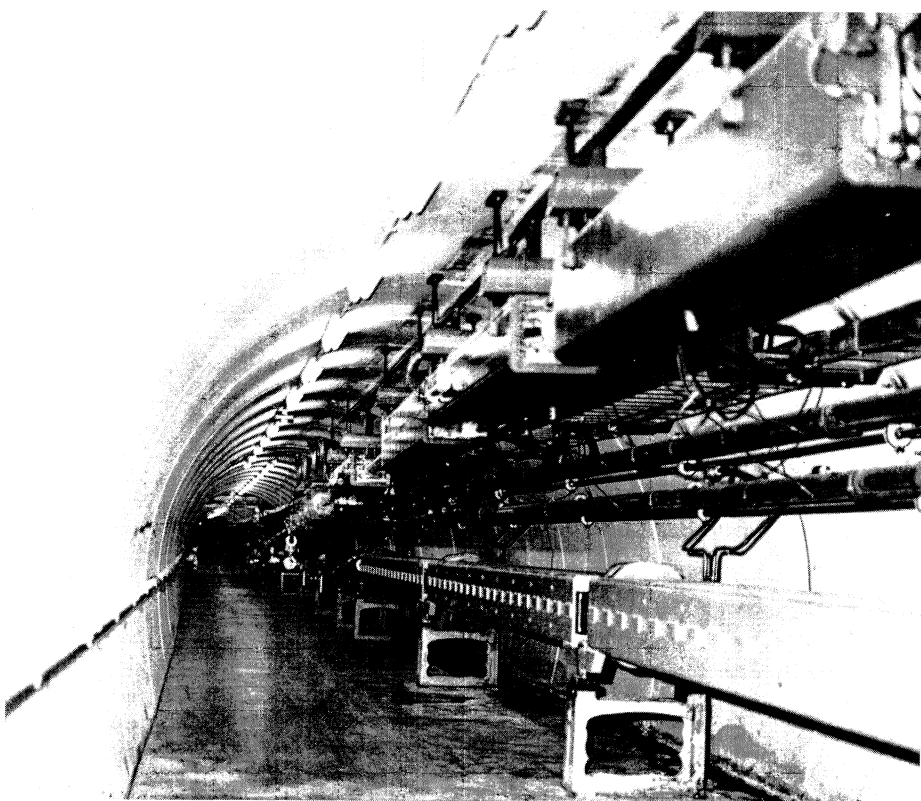
One of the most important is to look for the intermediate boson, the particle which is postulated as the carrier of the weak force. The discovery of neutral currents has strengthened those theories which seek to unify our descriptions of the weak and electromagnetic forces and those theories predict boson masses to be greater than 37 GeV. Certainly, the intermediate boson has not been seen with neutrino beams up to energies around 150 GeV at Fermilab and its mass must therefore be above 10 GeV. Protons of 1000 GeV yielding neutrinos of 750 GeV could look for bosons up to a mass of 60 GeV and to find this particle would be a crucial contribution to our understanding of the weak force.

Other particle searches are obviously suggested by the new charm picture of the hadrons. Higher energy neutrino beams would be able to produce charmed particles, if they exist, and the way in which the neutrino interaction cross section increases with energy will also depend on the existence of such particles.

Several other topical areas of research would benefit from higher energies. They include the production of dimuons, which was discovered at Fermilab, about which little is known and even less understood, the jet phenomena, high momentum transfer events, J/psi production with higher energy photons, ... And then higher energies, as in the past, could initiate phenomena which cannot be conjectured at present.

To hold 500 GeV protons, the magnets in the existing Fermilab Main Ring have to reach a peak field of 2.25 T. To hold 1000 GeV protons it is proposed to install above the existing ring an equivalent series of superconducting magnets capable of reaching a peak field of 4.5 T. This is where the name 'Energy Doubler' comes in.

The power consumption involved in operating the Doubler, with very low losses in the superconducting magnets plus the costs of refrigeration, is much less than for conventional magnet rings. There are a variety of possible combinations for operation of the existing ring in tandem with the Doubler so as to benefit from power savings. For example, at present a 7 s pulse to 400 GeV with a 2 s flat top soaks up about 90 MW of power. If the Doubler were run to 400 GeV field levels fed by the conventional ring at 275 GeV, the same cycle and flat top times could be maintained but with a power consumption of only 30 MW (23 MW conventional ring, 7 MW Doubler). This is where



1.

1. The Main Ring tunnel of the Fermilab accelerator where prototype magnets of the Energy Doubler/Saver can be seen suspended from the roof. It is hoped to have a length of twenty 6 m magnets installed in the tunnel by the middle of this year.

2. In building the Doubler, it will be important to interfere very little with the experimental programme which is under way on the existing machine. Techniques such as wheeling in the magnets on rails (Tony Rader, Ron Norton, Jerry Czop, left to right) at six points distributed around the Main Ring should enable most of the installation to take place during normal shutdown periods.

3. The transfer lines, which will take helium to the magnets to hold them at superconducting temperatures, are one of the trickiest Doubler components. Don Richied is photographed with two transfer line cross sections. The selected version is on the left.

(Photos Fermilab)



2.



3.

the name 'Energy Saver' comes in.

Another possibility is to feed protons from the conventional ring into the Doubler with its magnets held at constant field, so that protons could be drawn off with 100 % duty cycle. This gives the name 'Beam Stretcher' if any enthusiast wants three names for the same project.

The Doubler requires an injection system (preceded by an ejection system from the conventional ring), an r.f. accelerating system, vacuum system, power supplies, beam diagnostics, ejection system... but the components presenting the greatest technological challenge are the superconducting magnets and their associated refrigeration system. The Doubler needs about 800 dipole bending magnets, each 6 m long, and 200 quadrupole focusing magnets. They have to be retained at a temperature of about 4 K all around the 6 km ring circumference.

The magnet design has a cold bore, 7.5 cm in diameter, and warm iron which adds to the peak field. The coil is wound in two concentric shells sitting around the bore tube on ceramic rings. The two-phase helium coolant return path passes around the bore tube. The single phase helium channel, insulation and an outer vacuum tube are outside the coils and surrounded by iron laminations. The superconducting cable is of the type

developed at the Rutherford Laboratory with 2300 niobium-titanium filaments, 7 μm diameter, in 25 strand cable compacted to $1.25 \times 7.5 \text{ mm}^2$. It is designed to carry almost 5 kA. For the full project, a length of over 1500 km of such cable would be needed.

To provide the large amount of liquid helium there would be a central helium liquifier (2500 l per hour) from which coolant would be distributed by tanker to twelve satellite units spaced around the ring. From there it would be pumped along a length of Doubler through the magnets. A Joule-Thomson valve at the turn-around point gives boiling liquid helium which returns to the satellite unit, again through the magnet.

Both magnets and refrigeration are under attack at present. Development of the magnets has reached a fifth series. The first of this 'E-series' had 4 kA in the cable before its first quench, reached 3.8 T after a small amount of training and the 4.4 T when iron was added. Large amounts of cable are being purchased with Fermilab itself assembling the billets of superconductor and copper which are then extruded by the manufacturers. In 1975 Fermilab was possibly the largest single purchaser of superconducting materials in the USA. Wire costs have already dipped by a third and it is hoped to push them lower.

Plans for the coming months involve

a fast programme of superconducting magnet construction. By July it is intended to have twenty of the 6 m bending magnets installed in the Main Ring tunnel and to add another twenty by the end of September. Even if these magnets are not all of adequate quality for the Doubler, this exercise checks the installation procedures. If the project goes ahead, magnet construction may subsequently escalate to 60 per month.

For the central liquifier, an oxygen-nitrogen plant, previously involved in missile work near Los Angeles, has been purchased and will be converted to supply helium. It is being moved to Fermilab. The first components are scheduled to arrive in April and the plant should be ready for operation in October 1977. Meanwhile a small version of a satellite unit has been built and successfully tested linked to a helium transfer line and two magnets.

The optimist approach to construction schedules and cost gives Fiscal Year 1977 as the start of the project, June 1978 as the completion date and \$35 million as the cost. Costing for a less rapid schedule sets this figure at \$50 million.