A 1 TeV on 1 TeV $\bar{p}p$ COLLIDER AT FERMILAB USING SUPERFERRIC MAGNETS

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A dedicated 1 TeV on 1 TeV $\bar{p}p$ collider at Fermilab would allow both collider and fixed-target experiments to proceed in parallel with a corresponding increase in physics capability. A 2.5 T (nominal) superferric magnet ring of 2 km radius would also allow the development of magnets, enclosure and refrigeration systems for a very large 32 km radius - 20 TeV machine of the future. An attempt is made to estimate the cost of a prototype ring using many of the cost saving ideas put forth by those working on the 20 TeV machine.

The magnets are based on Wilson's superferric magnet described elsewhere. The magnet system of the prototype, however, would not have the advantage of the economy of scale afforded by a machine 20 times larger. In the cost estimates that follow a hypothetical magnet design and production scenario are assumed along with a Main Ring type lattice. Costs are then based as nearly as possible on the Energy Saver experience.

The magnet for Fermilab prototype ring would be as close as possible to that used in the desert machine. The emphasis of the design would then be on low cost, ease of production, and reliability.

The dipole length would be one half cell (about 50 meters). The conductor would be a thin (<2.5mm) ribbon made of a thin array of NbTi wires or ribbons of NbSn. The conductor would be bonded to the sides of the beam pipe. The beam pipe itself is extruded aluminum containing the vacuum pipe and helium channels. In order to get the continuous lengths of beam pipe required an extrusion press would be incorporated into the magnet factory.

The magnet yoke would be laminated and stacked in much the same way as the Saver quadrupole. The laminations would be pressed around the beam pipe/conductor assembly. Keys would be pressed into the lamination stack for alignment and rigidity. Radiation shielding would by provided by another aluminum extrusion surrounded by superinsulation. The outer vacuum shell would incorporate guide bars for the suspension system. The magnets would be assembled in a long gallery adjacent to the ring.

For a superferric ring to be viable the enclosure costs must be drastically reduced. There are, however, some restrictions imposted by Fermilab vis-ävis some remote desert site. Fermilab is much less flat and more care must be taken in limiting radiation. Since the ring would be buried at Fermilab the magnets would have to be moved into the tunnel after fabrication and moved out for replacement.

A Saver type lattice with a 2km radius ring would give a half cell length of about 60 meters (50 meter dipole and 10 meters for quad and correctors). The dipole would be located in a minimal tunnel (a pipe) while the quad and corrections would be situated in a higher quality tunnel where all magnet inner connections would be accessible. A "half cell" of tunnel would consist of 50 meters of pipe, 10 meters of precast tunnel sections and a manhole. The underlying assumption here is that access would be greatly restricted and very infrequent because of the presence of helium in the magnets. This restriction, of course, puts a premium on reliability in the magnet design.

The magnet support system in the ring enclosure would consist of stanchions spaced every 3 meters which would contain the position adjustment system for the magnets. The support system would also incorporate rails along which the alignmment robot would ultimately move.

For installation the magnets would be picked up and moved via the robot rail system through the tunnel to their locations. Although the dipole would be rigid at the level of 3 meters, it would be flexible enough within the 50 meter length to assume the required sagitta (15 cm.). Connections would be made between dipoles, quads, and correctors in the quad enclosures.

The table shows cost estimates for the components of the magnet ring. An analysis of saver costs reveals that about half the cost of the dipole is in the ends. In themselves continuous magnets can greatly reduce the costs. Further reductions are achieved because of the absence of multiple winds and collars together with a simpler cryostat. Cost estimates are based on assumed production steps which are then related to similiar Saver activities.

The enclosure costs are based on four foot diameter precast concrete pipe for dipoles and precast tunnel sections for the quad enclosure. There is experience with both the pipe and tunnel sections at Fermilab.

The cold iron, relatively light magnet could be made to have a very low heat leak. Radiation losses could be made to be less than 0.030 watts/meter because of the length and continuity of the magnets. Even though interconnections and penetrations are infrequent, care must be taken at these points to make sure radiation shielding is continuous. A light weight suspension should keep the total heat leak under 0.150 watt/meter. The total refrigeration would be about 3 kw at 4.2°K The refrigeration could be accomplished with the upgraded Central Liquifier and four satellites. If an efficiency of 600 watts input for 1 watt at 4.2°K is assumed, the power usage would be about 1.8 megawatts. If a magnet could be designed using NbSn conductor that would operate supercritically at 8°K, the refrigeration costs would be about half as much.

Correction magnets costs are based on the Saver. Numbers choosen for controls, vacuum and power supplies also projected from the Saver. Estimates for injection and experimental areas are crude guesses. In addition to the machine components the development a robot alignment system would be critical to the desert machine. The robot would use lasers or an inertial guidance system for orientation and a x-ray system to locate the magnets.

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* Operated by Universities Research Inc., under contract with the U.S. Department of Energy.

Also included in the cost chart is a summary of costs that would be included in order to build a two ring system for a pp collider.

Not included in the cost summary are R & D, EDIA, administrative, and contingency and spares.

Cost Summary

Magnet Related

Magnets	Cost($1000, 1982)
Dipoles	10,500
Quads	1,400
Spools	2,000
Low beta magnets	2,000
Installation	3,000
Enclosure	
Tunnel	11,600
Support system	2,000
Utilities	400
Helium return header	1,600
Helium transfer line	3,600
Other civil (roads service bldgs. etc.)	6,000
Controls	2,000
Vacuum	4,000
Power supplies	3,000
Refrigeration	2,000
R.F.	4,000
Total magnet related	$ 59,100 (~$4500/meter)

Total Facility Cost

	one ring(pp)	two rings(pp)
Magnet related	59,100	88,200
Injection	15,000	15,000
Experimental areas	25,000	25,000
Total	$ 99,100	$128,200