Geology and Tunneling

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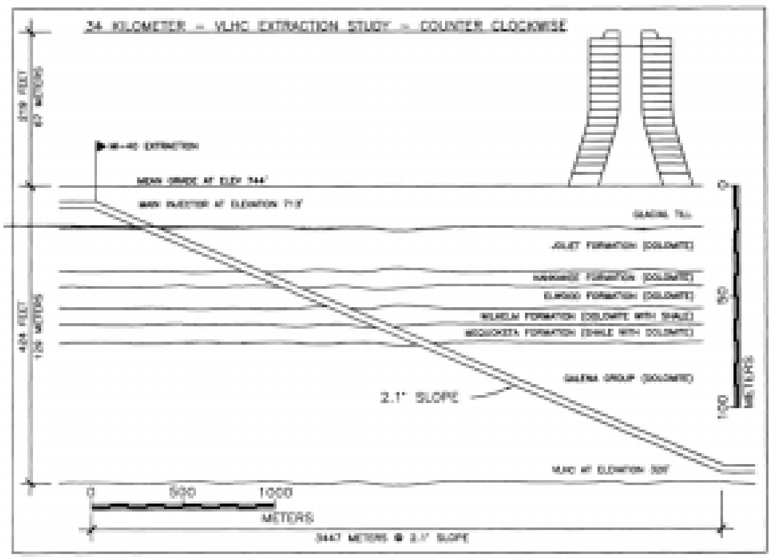
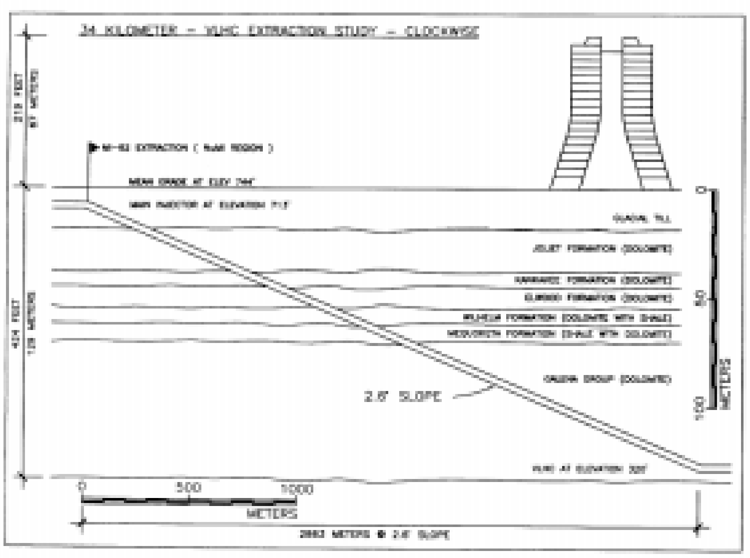
Geology

The geology and hydrology of the Fermilab region are ideally suited for a new large collider project. Site conditions at Fermilab are well understood. The Illinois State Geological Survey (ISGS) has extensive data on the regions under consideration from drill holes, and additional data compiled when there was active consideration given to siting the SSC in Illinois. [1]

There are predictable rock and tunneling conditions and relatively homogenous rock mass. There are no settlement problems at the depths being considered. The region is seismically stable. There is a relatively vibration free environment, important to minimize emittance growth problems. A systematic vibration measurement program is now underway.



The dolomite layers under Chicago and under Fermilab are quite uniform. The large regional extent of dolomite can serve as an excellent host for a tunnel in the Fermilab region. A tentative decision by the VLHC Study Group to site both the 3 TeV and 50 TeV rings at an elevation of 320 feet above sea level (msl) has been made. This places both machines in the Galena-Platteville dolomite layer. This layer has sufficient thickness so even with variations in depth the 3 TeV ring can most likely lie in a plane and be parallel to the surface. The depth below the surface is about 400 feet. At the North Aurora quarry that a group of us visited on September 3, we learned that the Galena-Platteville layer is 297 feet thick and does not vary much going to the east.



Since it is easier to transfer 150 GeV beams than 3 TeV beams, it is felt advantageous to have the 3 TeV injector at the same depth as the final 50 TeV ring. Shown are injection lines from the Main Injector to the 3 TeV ring using MI-62 (NuMI stub) and MI-40 (abort) as the extraction points from the Main Injector.

Hydrology

As one goes down through the various layers shown in the figures, the water seepage varies by 3 orders of magnitude. The Galena-Platteville layer is an aquatard and water seepage is very small, confirmed on our recent field trip.

Trenchless Technology

Trenchless Technology is a generic term for tunnel or pipe construction without surface disturbance. Trenchless Technology is growing in importance as a practical solution to expansion and repair of underground utilities. Trenchless construction is helping solve huge, complex underground infrastructure problems economically, safely, and with minimum of inconvenience to the public and damage to the environment. This is an area where the VLHC will benefit from the expanding technologies but may also be a catalyst to this environmentally crucial industry by pushing the envelope on advance rate over very large distances.

Two of the techniques used in trenchless technology are microtunneling and “standard” Tunnel Boring Machines (TBM). Microtunneling can be as large as 6 ft in diameter but refers to construction methods without human access. TBM’s bore tunnels over a large size range. In this technique humans are in the tunnel during construction.

Fermilab is a member of the North American Society for Trenchless Technology as well as the American Underground Construction Association. Through these connections we are keeping up with this rapidly evolving field. We have learned that for smaller diameter tunnels in the range 6 - 14 ft, there is a merger of technologies in the direction of more automated tunneling with less need for human access. These advances are gradually improving the utilization rate and thus the linear advance rate which, in turn, is lowering the cost. R&D in the trenchless technology industry is aimed at several advances that will aid us in the construction of the VLHC tunnel:

- increasing distances between shafts
- utilization of remote liner installation methods
- development of long-distance muck removal strategies
- development of guidance for tunneling in a gentle curve and following the best terrain to stay in the optimal geology
- system monitoring to improve utilization percentage

Tunnel Costs and local experience

Preliminary estimates for tunnels in hard rock in the 10 - 14 ft diameter range vary from $300/foot to $1500/foot. In order to sharpen up these numbers Fermilab has issued purchase orders for two independent consultants to develop a cost model for the 3 TeV, 34 km tunnel used as a model for us to study siting and the effect of varying parameters such as depth, number of accesses, diameter on the cost and construction time.

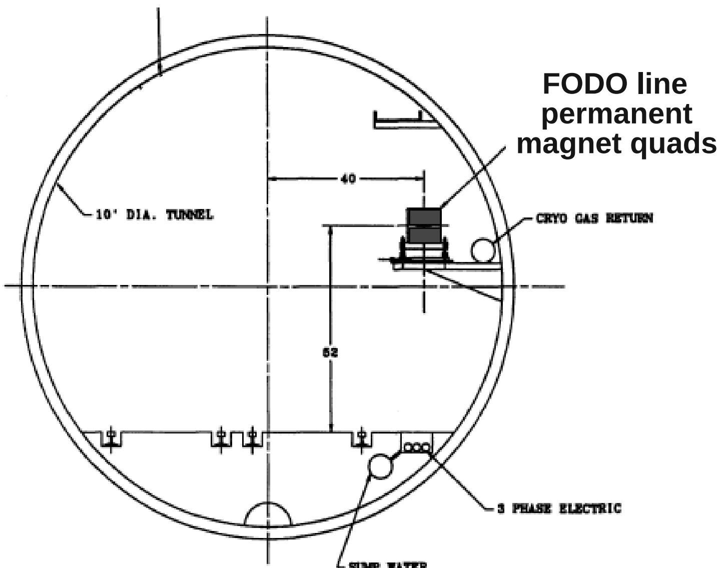
Besides having excellent geology for the VLHC enclosure, we are benefiting greatly from local expertise in hard rock tunneling. In the TARP (Tunnel and Reservoir Plan) under Chicago in the similar rock as we are proposing for the VLHC 93.4 miles of tunnel in the diameter range 8 to 33 ft has been completed out of a total planned length of 109 miles.

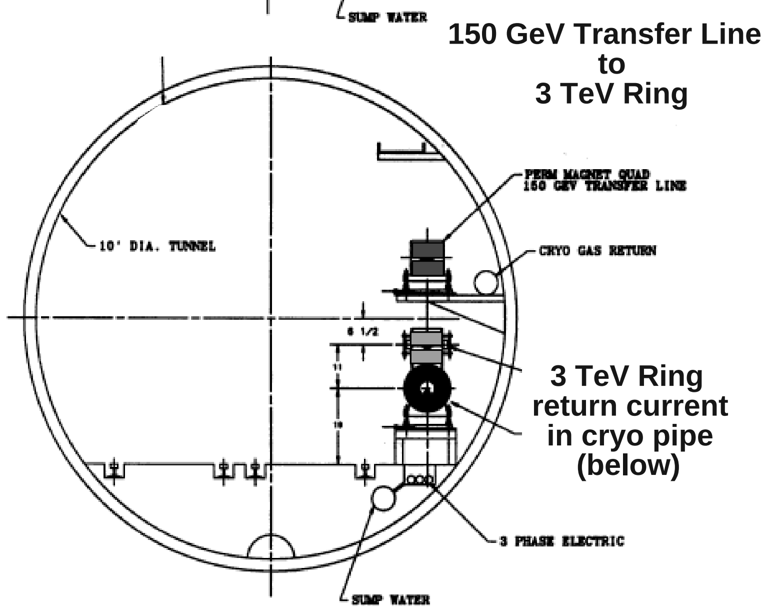
Choosing the tunnel size

There are three considerations in choosing the tunnel size:

- lowest cost
- room for other machines (Fermilab & CERN strategy)
- although we will strive to automate the installation, alignment, and repair as much as possible one must retain the ability to deal with unknown problems using human access

As a starting point we consider a 10 foot diameter tunnel. The invert and its infrastructure is an item which will need a lot of attention. There are many different design scenarios which will work and each one has different advantages and disadvantages. The design which is depicted in the cross sections below can save money in the fact that it only needs to be installed once, and is used for both the tunnel contractors needs, and later for the technical components. During construction (by a TBM with conveyor belt muck removal) the contractor will install a rail system for bringing people and equipment to the tunnel face. We are investigating whether or not the rail system installed by the contractor could be retained and used by us for the magnet installation vehicles. The risk that is taken is that the inverts are installed behind the TBM after the tunnel walls have been sealed for moisture, and as a result, the TBM cannot be removed from the tunnel for major repair by pulling it backward.





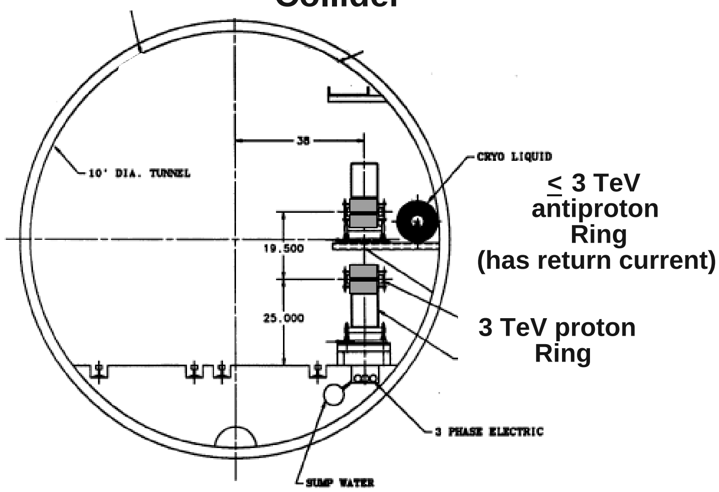
The usual way that tunnels are bored, is to have the contractor bore a tunnel to a given size. The construction infrastructure is removed, and the tunnel is turned over to another contractor to install the infrastructure that is needed for its final use. Power, air and transportation are common needs of the contractor and of Fermilab. If there is a way of installing these functions once, money can be saved.

Shown are two cross sections, one of the injection tunnel where the 150 GeV beam is transported in a simple FODO line made out of permanent magnet quadrupoles, and the second cross section showing the main tunnel at the point where the transport line is approaching the injection point.

Sharing the tunnel with other machines

The small magnet aperture and the large number of bunches makes it unattractive to attempt to have counter rotating beams of protons and antiprotons in the same vacuum tube. A better solution for a 6 TeV cm antiproton-proton collider is to put in a second set of VLHC magnets and only use one magnet gap of each. The return current then can power the other string. Furthermore at a later stage, when the 50 TeV/beam machine is built, it may be possible to recycle the second 3 TeV ring and use it for a portion of the 50 TeV ring (or for the 3 TeV transfer lines).

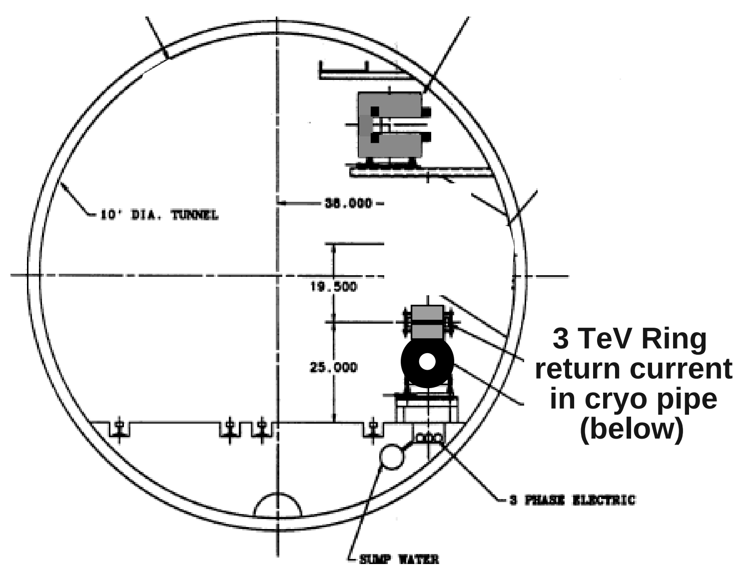
6 TeV cm antiproton-proton Collider



Another idea is to put an electron ring in the 3 TeV tunnel and do ep physics during the several year period that the "ultimate" VLHC is under construction. Heat removal and operating costs are an important issues for the electron ring. If the RF power is limited to 50 MW, then the electron energy would be 81 GeV.

ep Collider

81 GeV Electron Ring (50 MW RF Power)



Reference:[1] R. A. Bauer & D. L. Gross, "Geology of the Greater Fermilab Region," Snowmass '96.