3.10 Conventional Facilities and Site Considerations

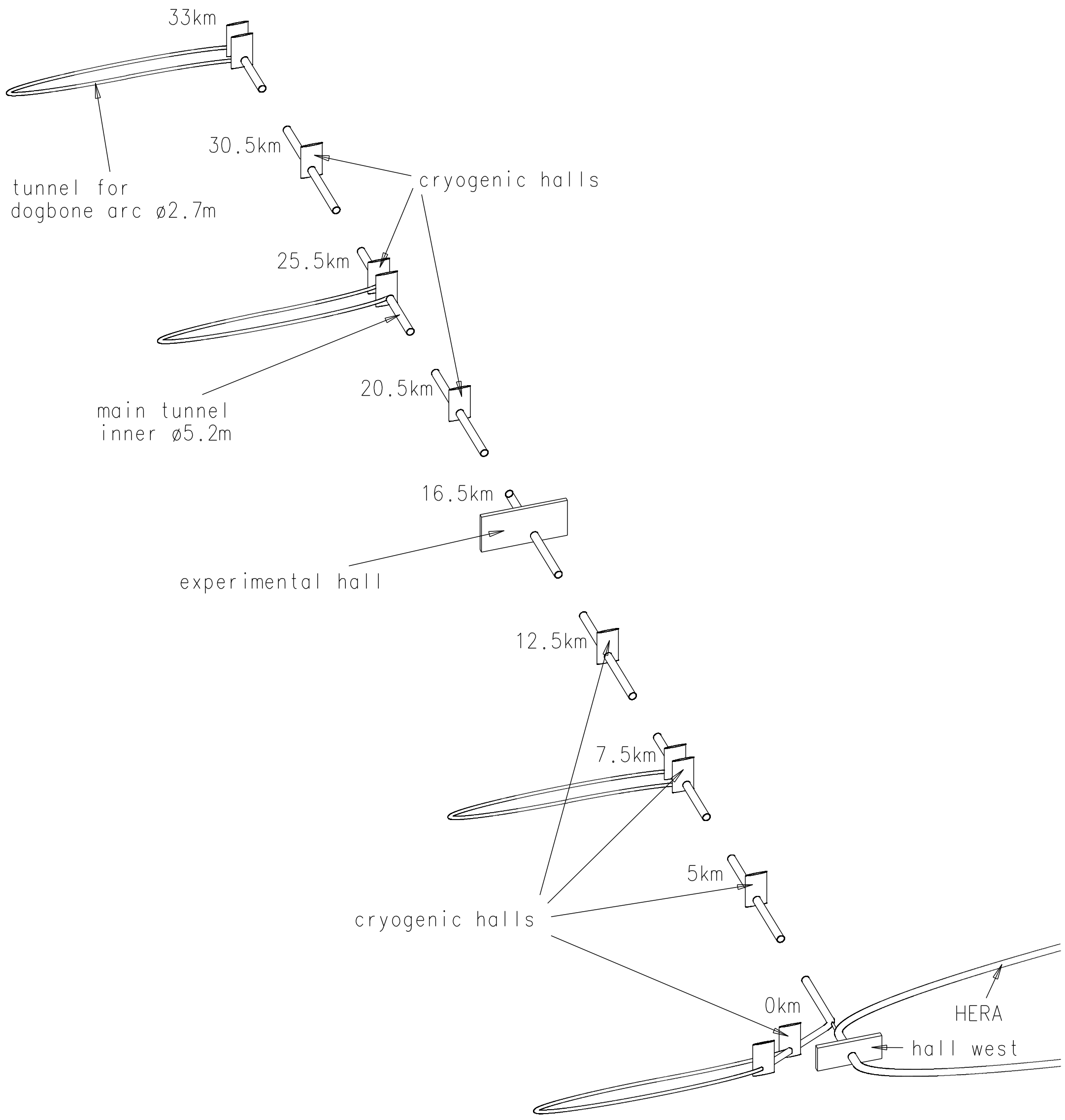

Figure 3.10.1: *Schematic view of the TESLA Linear Collider at DESY.*

3.10.1 Introduction

Different conventional facilities must be set up for the future Linear Collider. The detailed considerations in the following assume that the Linear Collider facility is built at DESY in Hamburg. Not all of them are valid at other locations without modifications. A discussion of Fermilab as a possible site is given in section 3.10.11. In any case coupling a new large accelerator complex to an existing laboratory site is advantageous from the point of view of investment cost, construction time and available know-how in accelerator technology, particle physics and synchrotron radiation research. Further boundary conditions we take into account here are the integration of the Free Electron Laser facility and the possibility to make use of existing accelerators and infrastructure at the DESY site.

These considerations predefine that the tunnel starts on the DESY site and runs in direction North-Northwest, parallel to the straight section West of HERA. By far the largest single construction is that of the tunnel for the accelerators, the beam lines and for the various auxiliary components. This tunnel has a total length of about 33 km and an inner diameter of 5 m. An underground experimental hall for the Particle Physics detector is located in the central area which is layed out to also accomodate the X-ray Free Electron Laser laboratory. Administrative, social and technical buildings are placed on this common site, too. Additional underground halls are located at the two ends of the linac tunnel. Seven cryogenic plants are distributed along the tunnel, with one plant at the beginning of the electron linac. The other six plants are connected to the tunnel by shafts. The four arcs for the two damping rings are located next to the main tunnel.

3.10.2 Overall Site Layout

The Linear Collider tunnel will be built underground at a depth of about 15 m. The main part of the tunnel is in sand and in ground water. With well-proven tunnel boring technology, buildings at the surface above the tunnel remain completely unaffected. As shown in the top view (see Fig. 3.10.2) the complete tunnel is straight (except for a short initial section, see below) and in a profile view (see Fig. 3.10.3) it is mainly horizontal (i.e. following the earth's curvature). HERA is rotated counterclockwise by an angle of 22.7^o out of the northerly orientation (approximately North-Northwest orientation). This orientation was chosen as the main direction of the Linear Collider to enable the option for producing collisions of protons stored in HERA with electrons from the main linac (note that the beam direction in the HERA-p ring has to be reversed for this option). The beginning of the tunnel starts laterally shifted with respect to the HERA hall West and after 250 m bends with a radius of 500 m into the main direction. The main electron linac starts at the beginning of the straight tunnel. The initial section of the tunnel houses the prelinac together with the beam preparation for the FEL operation.

The interaction point HERA West is about 20 m above sea level. The axis of the main part of the linac tunnel lies about 10 m below sea level. The straight section

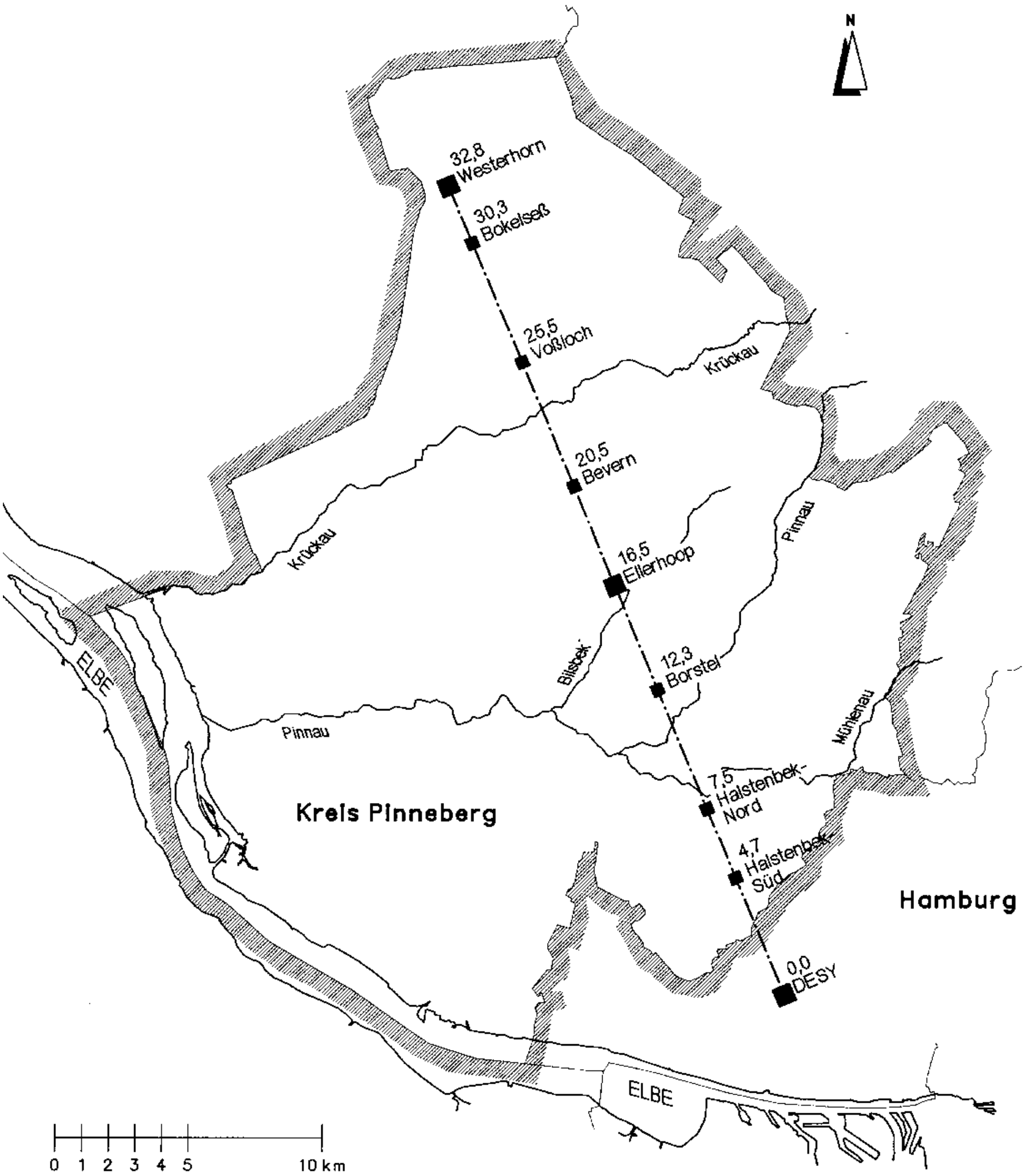

Figure 3.10.2: *Overall view of the Linear Collider site at DESY.*

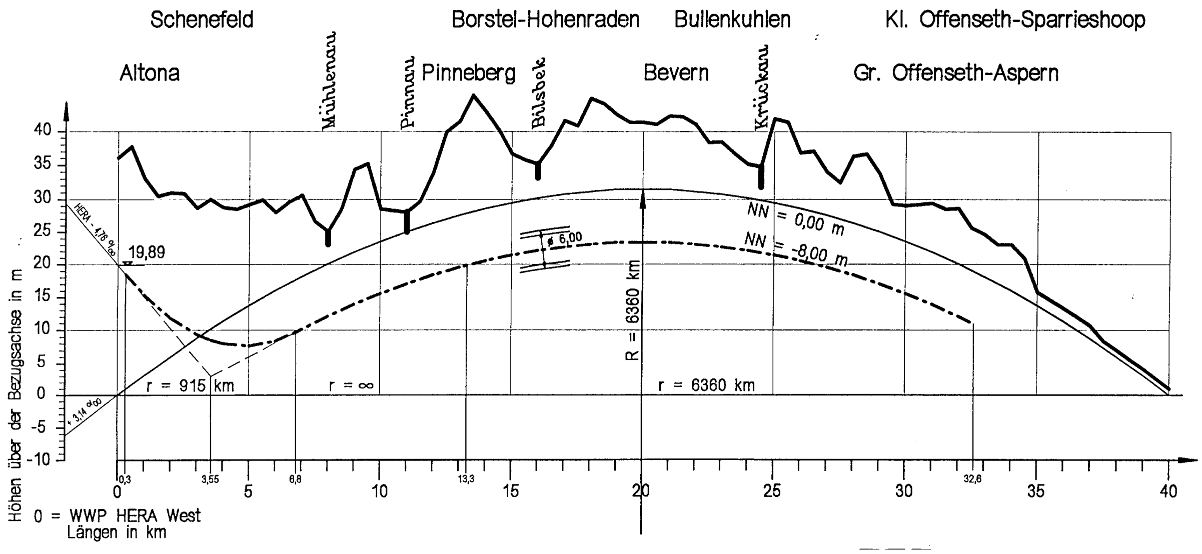

Figure 3.10.3: *Expanded profile of the Linear Collider area North-Northwest of DESY.*

HERA West has a slope of about 8 mrad out of the horizontal. Therefore there is a smooth transition from the initial slope into the horizontal direction with a bending radius of about 1000 km. Figure 3.10.3 shows an expanded profile of the linear collider area North-Northwest of DESY together with the collider tunnel. The depth of the tunnel below ground level of about 15 m is more than sufficient to guarantee shielding against radiation. The tunnel is below the ground water level over nearly the entire length.

The tunnel will be built by a tunnel boring machine similar to that used to construct the HERA tunnel. Identical concrete segments have been chosen for the lining of the main tunnel. The minimum inner diameter is 5 m, with the actual diameter increased to 5.20 m due to tolerances in the tunnel boring. An underground experimental hall is in the center of the Linear Collider complex, with additional underground halls at the two opposite ends. These three halls are built in open-cut excavations. The experimental hall and the end station are located on new areas. The start station together with one cryogenic plant are located on the existing DESY site. Additional areas are necessary for the six remaining cryogenic plants. The plants are connected with the collider tunnel through shafts. Two dog-bone damping rings are foreseen for the damping of the electron and positron beams before the main acceleration. The straight sections for the rings are located in the main tunnel, but additional tunnels must be bored for the four arcs. They are at the ends of the tunnel and at a distance of 7.5 km from these points at a cryogenic plant. These tunnels have an inner diameter of 2.5 m and the arcs have a radius of 80 m.

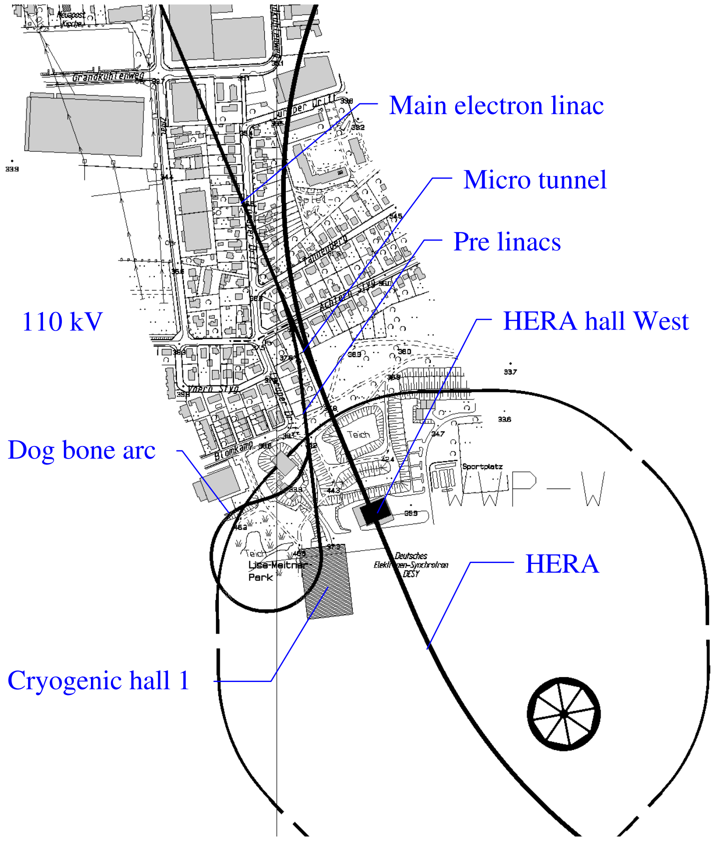

Figure 3.10.4: *DESY site of the TESLA Linear Collider.*

3.10.3 DESY Site

The Linear Collider tunnel starts on the existing DESY area next to the HERA hall West. At the beginning there is an underground hall. The tunnel boring machines for the main tunnel and for the dog-bone arc can start in this hall. An additional shaft is necessary for the other connection of the arc to the main tunnel. The starting point for the main tunnel boring machine is laterally shifted from the HERA hall West. After a distance of about 250 m the tunnel bends with a radius of 500 m into the main direction. From that point on the tunnel is straight in a top view up to the end station. The same point is the beginning of the main linac. The initial section houses the beam preparation (injector, bunch compressors) for the FEL and the collider operation. On ground level above the underground hall is a cryogenic plant for the first 2.5 km of the superconducting electron linac. The connection between the collider and the HERA tunnel can be made by a small tunnel. In Figure 3.10.4 an overview of this complex is shown.

3.10.4 Experimental Area

The experimental hall with the interaction point is located at the center of the Linear Collider, at a distance of 16.5 km from the hall HERA West. The underground hall has an area of $35\,\mathrm{m} \times 80\,\mathrm{m}$ and a height of 20 m below the portal crane in present planning. Space for a second hall with the same dimensions but laterally shifted is available in case a second detector would be installed. The X-ray Free Electron Laser laboratory is also located on this common area together with the administrative, social and technical buildings. The electron beam dump is located at a distance of about 600 m from the interaction point; the positron beam dump at a distance of about 300 m. Both dumped beams are orientated downwards with an angle of 20 mrad. Small underground halls with access from the ground level are foreseen for the dumps. The total length available for the beam delivery system is 3 km, the length of the central experimental site about 800 m. The positron dump is located outside the main experimental area below an additional external area. Sufficient concrete shielding around the beam dump is foreseen to avoid any activation of the surrounding soil and ground water.

Site	Position L/km		Power S/MVA
DESY	0	Cryogenic plant 1	12
		Modulators	17
Cryogenic hall 2	5	Cryogenic plant 2	12
		Modulators	17
Cryogenic hall 3	7.5	Cryogenic plant 3	12
		Modulators	11
Cryogenic hall 4	12.5	Cryogenic plant 4	12
		Modulators	11
Experimental area	16.5	Experiment	3
		FEL laboratory	3
Cryogenic hall 5	20.5	Cryogenic plant 5	12
		Modulators	11
Cryogenic hall 6	25.5	Cryogenic plant 6	12
		Modulators	11
Cryogenic hall 7	30.5	Cryogenic plant 7	12
		Modulators	11
End station	33		3
		Sum	182

Table 3.10.1: *Installed electric power for the TESLA Linear Collider. These values include redundancy and the reactive currents, and allow for the energy upgrade with a nominal power consumption of* $P = 130\mathrm{MW}$.

3.10.5 End Station

The end station is a small underground hall. This hall is necessary as a starting point for the tunnel boring, for access to the tunnel during installation and operation and for one connection of the dog bone arc. An additional shaft is necessary for the other connection of the dog-bone arc.

3.10.6 Cryogenic Halls

In addition to a new cryogenic plant located on the existing DESY site six additional plants are distributed along the linac. At each of these points a hall with an area of 35m $\times$ 100m is planned. A hall houses a cryogenic plant which supplies 5 km of the superconducting linac. The first 5 km are designed for a higher linac repetition rate (including FEL and Nuclear Physics operation). Here the cooling power of one plant supplies 2.5 km of the linac. Each external hall is connected to the main tunnel through a shaft of about 12 m inner diameter. The modulators for the klystrons are on a second level in these cryogenic halls. These areas are also needed for the power distribution and water cooling plants.

3.10.7 Tunnel Layout

The main tunnel of the TESLA Linear Collider has a minimum inner diameter of 5 m (5.20 m minus construction tolerances). The main components installed in the tunnel are the cryomodules for the superconducting linac and the beam lines for the dog-bone damping rings, for the FEL laboratory and for the ELFE@DESY (Nuclear Physics) option. In addition there are numerous auxiliary components. In Figure 3.10.5 a tunnel cross section is shown, chosen at a position of the most complex situation. The cross section is divided vertically into three parts. One third is for sensitive accelerator and beam line components and for the rf distribution. A walk path is located on the outer side for installation and maintenance. The place for the transport system is in the center above the place for components which need easy access. On the bottom the hot and cold water pipes are installed in a small channel; this channel serves for the collection and detection of leakage water. The klystrons, electronics and vacuum pumps are mounted in special containers, the center of mass of which are just below the hook of the transport system. This allows for easy installation and exchange of components with a relative short lifetime. The transport system is a so-called monorail, utilizing an I-beam fixed at the top of the tunnel. The vehicle is used to transport equipment and persons.

The last part is the main walk path. The space above the grids is free at all times and the space below is reserved mainly for the cable connection between modulators and klystrons. The free space is for an escape route and for lines-of-sight for optical survey.

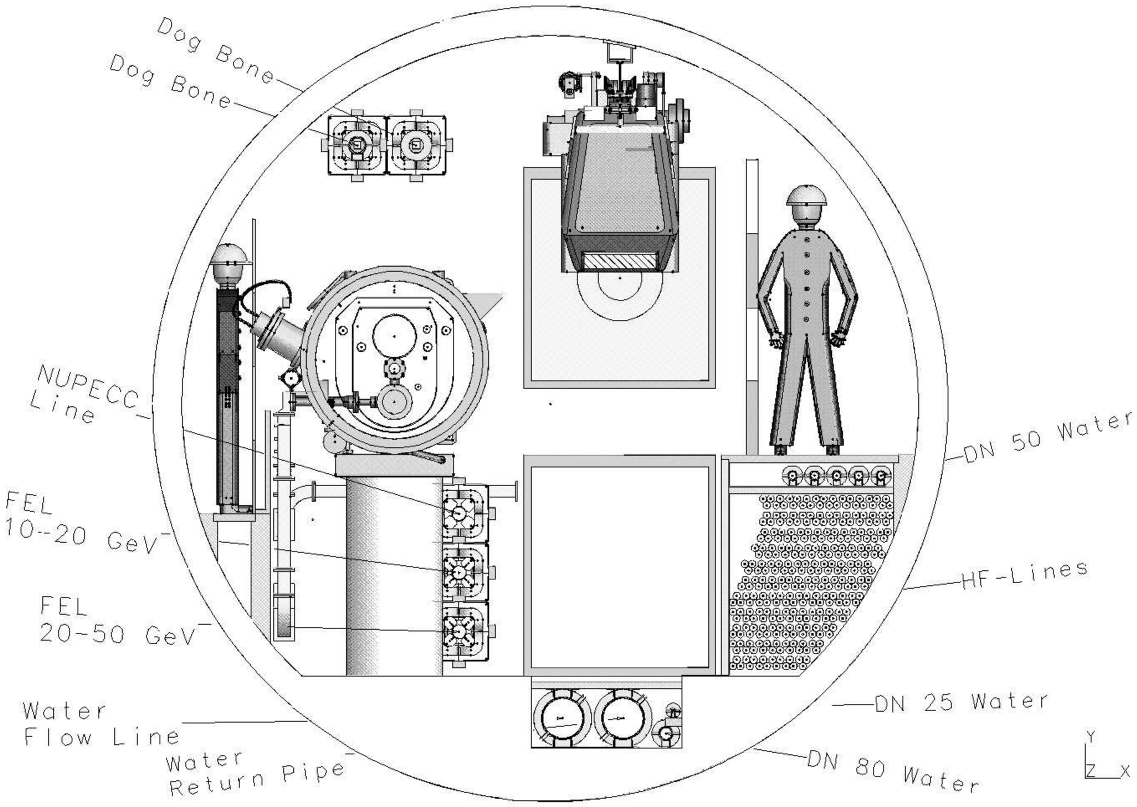

Figure 3.10.5: *Cross section of the TESLA Linear Collider tunnel.*

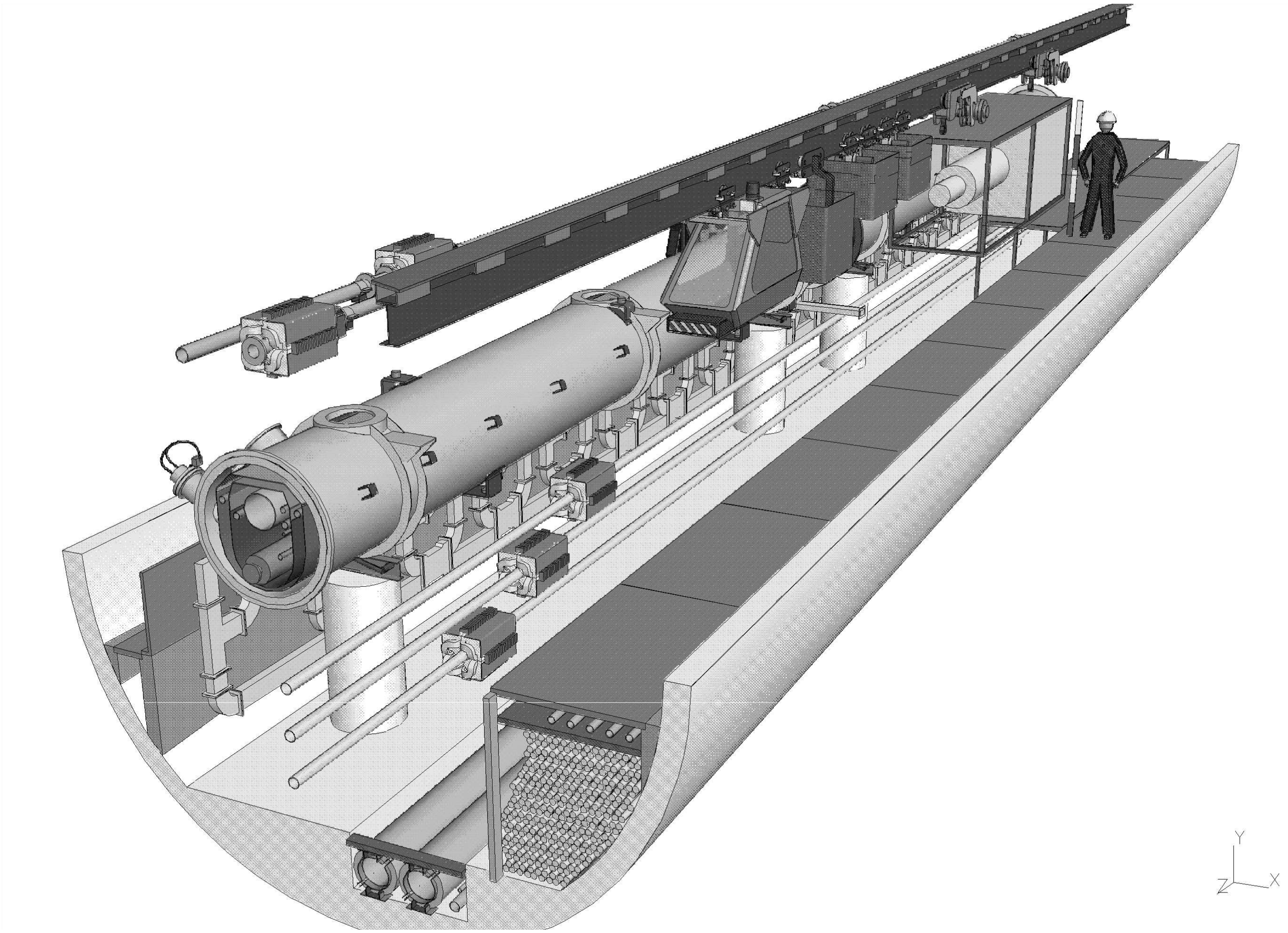

Figure 3.10.6: *View into the TESLA Linear Collider tunnel.*

3.10.8 Power Distribution

In order to provide sufficient redundancy and a margin for reactive power, the power distribution system is layed out for a total AC-power of 182 MVA. There are essentially two options to distribute the power to the cryogenic/modulator halls. First, the local medium voltage grid can be used to supply each hall individually. Second, the power can be obtained from 110 kV high voltage lines and distributed to the individual halls at medium voltage level (36 kV) through the accelerator tunnel. The latter option is sketched in Fig. 3.10.7. Guided by the availability of 110 kV lines in this part of the country, 4 high-to-medium voltage transformer stations are foreseen: one on the DESY site and three others at external halls along the linac. For the distribution to the other halls medium-high voltage cables ($3\times$ 240 mm^2 Al) are installed in the tunnel. The losses on these cables amount to about 50 W/m.

The decision which of the two options for the power distribution is preferable can only be taken once the availability of power lines and cost aspects have been analysed in more detail.

The amount of AC-power required inside the linac tunnel is relatively small. Power is needed for utilities such as klystron focussing magnets, water distribution pumps and tunnel light. In total, about 10 MW have to be distributed in the linac tunnel over the full length of 30 km. The supply voltage in this cases is chosen at 690 V. It is also foreseen to have the magnet power supplies installed in the tunnel. There are about 400 quadrupoles and 600 steering coils in each of the two linacs which have to be powered individually. The estimated total AC-power for the magnet supplies amounts to 5 MW and the heat load to the tunnel air from this source is about 20 W/m. The magnet power supplies are also connected to the 690 V system.

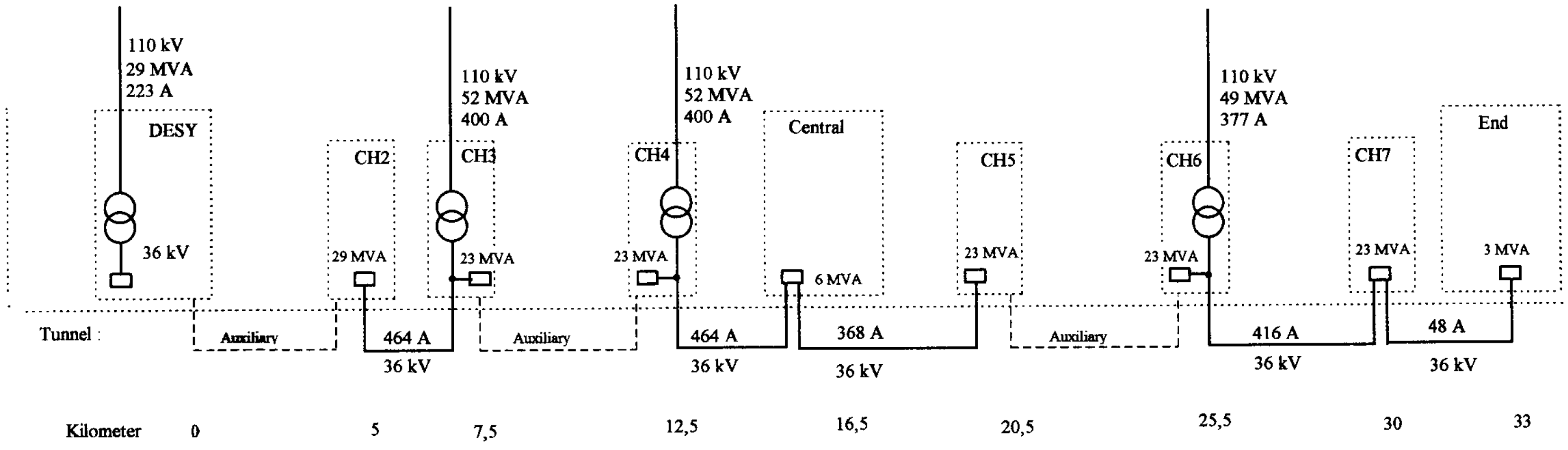

Figure 3.10.7: *Sketch of the power distribution system.*

3.10.9 Water Cooling System

The layout for the cooling circuit of the TESLA linear accelerator is divided up into separate sections in the same way as the cryogenics system. Every cooling station has cooling towers, heat exchangers, pumps and control systems. The layout of the cooling plant is depicted in Fig. 3.10.8.

The cooling tower is a so called wet cooling tower which works by evaporation of part of the falling water. Therefore an important number for such a cooling tower is the maximum value of the humidity in the air. A derived number of this is the wet bulb temperature. For this linac a value of 19.5 °C to 20.0 °C is preferred. There will be 15 towers for every station, placed beside the cryogenic halls. The fan velocity of the cooling towers will be controlled to maintain a constant temperature at the heat exchangers. The heat exchangers themselves will be controlled by a bypass system to provide a nearly constant temperature into the tunnel. The main tubes in the tunnel are distribution tubes. Because all elements are connected in parallel, there will be a subdivision system to avoid too many connections to the main tube. The material of the main tubes will be stainless steel and copper for the subdivision tubes. The length of the subdivision system will be 144 metres, this is the distance between six klystrons. The RF-power is either in the collector or in the loads, and therefore these elements can be connected in series. To make up for the pressure losses in a klystron/collector, a booster pump will be necessary.

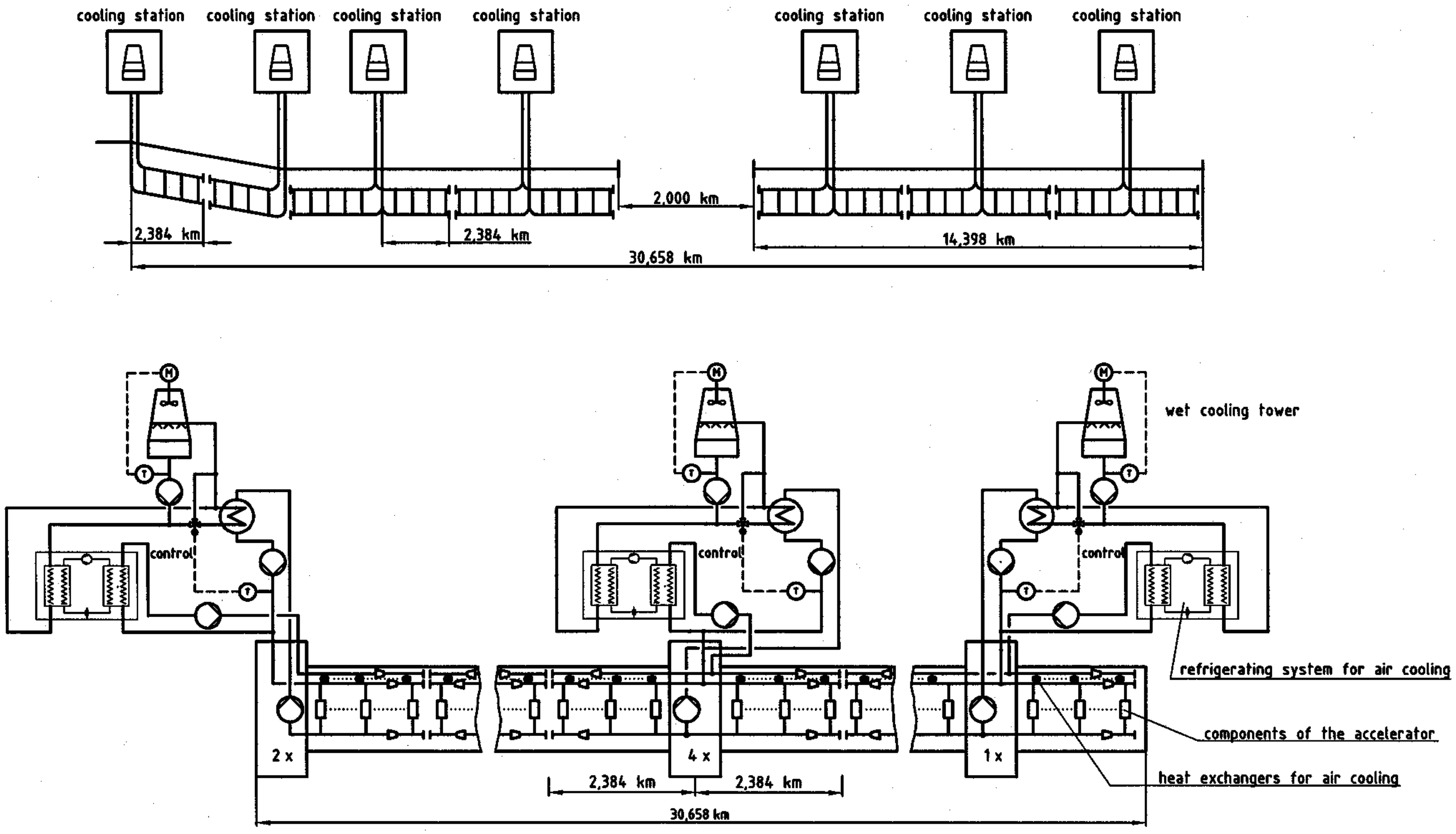

Figure 3.10.8: *Sketch of the cooling tower plant.*

The water will be de-ionised water with a conductivity of 1 mS/cm. Therefore the only allowed materials are stainless steel, copper and bronze (gunmetal) . The maximum pressure in some RF-elements in the present design is low. Therefore boosterpumps in the return water line will be necessary to keep the pressure in the return line as low as possible. The diameter of the tubes varies over the length, so that the pressure gradient has a nearly linear characteristic. The first diameter is 250 mm. The pressure loss over the length is 2.5 bar. The temperature of the return water is 60 °C - 70 °C . Therefore the return water tube will be insulated with mineral wool of 100 mm thickness. Then the heatloss from the return water into the tunnel will be 50 W/m. To minimise the mechanical stress in the tubes by thermal expansion there are compensators in the tubes. Every six metres will be a slide support point for the tube and between two compensators a fixed support point. For the slide elements PP-sheets are preferred. These elements are already used as slide sheets in the other DESY accelerators. The last or direct connections to all elements (e.g. magnets, klystrons etc.) will be done by EPDM-rubber tubes. The advantages are: resistance to radiation, high flexibility for the connections, good and quick installation, direct connection between elements at a high electrical potential and earthed copper tubes, etc.

3.10.10 Air Conditioning and Ventilation

The tunnel sections between cryo halls have a length of 5 km with no intermediate access. The tunnel is an underground building and therefore forced ventilation is required. Note that the ventilation does not contribute significantly to cooling, which is almost completely dominated by the tunnel walls. The heat emission to the tunnel air must be minimized in order to avoid excessive temperature rise over long periods of operation. Removal of the heat from the main sources by the water cooling system and shielding of hot surfaces will ensure this. In addition, a cold water cooling pipe can be installed.

During access persons have to work in the tunnel and in case of emergency a smoke-free escape must be provided. In case of a fire the ventilation removes the smoke in one direction, and fire fighting would begin from the opposite direction.

The regular velocity of the tunnel air should be 0.6 m/s (corresponding to a volume flow of 30,000 m^3/h) and for smoke removal >0.8 m/s. The pressure drop over 5 km is 500 Pa, which creates a force of 1,000 N on a 2 m^2 door. This must be taken into account in the design of the escape exit. The speed at which the smoke moves is sufficiently slow to be able to leave the tunnel safely in the direction of air flow.

The fire risk, determined by the product of fire load times fire probability, should be minimized. The fire load is given by the amount of inflammable materials. These are in particular the oil in the pulse transformers and the cables. The fire probability is related to heat sources and high-voltage devices (klystrons, power supplies, etc.). Since the first 15 min. after ignition of a fire are very important as fire fighting is most effective, a smoke detection system will be installed. After detection of smoke, klystrons and power supplies can be automatically switched off.

During access to the tunnel the fire probability can be drastically reduced by shutting down the main ignition sources. There will be no access during machine operation.

A recirculation of the tunnel air is not possible. At the beginning of the linac tunnel fresh air is blown into the tunnel. The cryo halls are bypassed and only a small fraction of fresh air is added. At the endstation hall the air from the tunnel is extracted. In case of a fire, fresh air is blown directly into the respective section of the tunnel and the smoke is extracted at the next hall. The ventilators are switched to high speed in that case.

3.10.11 Fermilab as a Potential Site for the Linear Collider

3.10.11.1 Introduction

Fermilab like DESY is a potential location for a future Linear Collider. The existence of a functioning High Energy Physics Laboratory, which can provide the organizational structure, experienced staff, physicist and engineering teams and know-how, the basic infrastructure and plant, and the user support, is key to carrying out a project as large and technically challenging as TESLA in a cost effective and timely way. Even if major civil and technical components of the existing facility are not used, the stable organization and general infrastructure are of great value in proceeding effectively with project design and construction.

The Fermilab site was originally chosen in the 60's because it and the surrounding area fulfilled the major requirements of rational site selection: easy access to a major city and airport, good highway and rail transportation, work force availability, good and stable geology, good power and water availability, reasonably flat and open land (to west now), good community resources and infrastructure, weather, etc. Though the local area has been one of the fastest growing in the country, it still is reasonable to consider off site location of a large accelerator complex, as most construction will be underground. This is especially true if one looks to a site in the open farm lands that still start just a few miles to the west of Fermilab and the Fox River.

Two significant features of the area surrounding Fermilab are the geology and the availability of electric power. The dolomite bedrock of the area is ideal for underground tunnel construction and extensive experience exists from the Chicago water project TARP. This project has constructed almost 100 miles of tunnel throughout metropolitan Chicago.

Near to Fermilab is a large power distribution net of Commonwealth Edison with a hub centered at Electric Junction just 2 miles south of the laboratory. Commonwealth Edison is one of the largest generating systems in the country with over 20,000 MW of owned capacity. The transmission network provides two 345 kV power corridors of particular interest. One runs north south on the east side of the lab and the other runs from just south west of the lab, across the Fox river straight westward for almost 40 miles. It is advantageous to consider linear collider site locations in conjunction with these power lines, and to adopt the natural north, south, east, west, road grid of the region. Easements for the collider will undoubtedly be easier to obtain if associated with utility or road right of ways. This strategy has been used by TARP which has extensively sited its tunnels under roads, canals, and rivers. In this sense linear colliders maybe much easier to site than circular accelerators.

In the discussion which follows substantial use has been made of work carried out, reports written, and information provided by the State of Illinois and its Illinois Department of Energy and Natural Resources (ENR). Extensive work was carried out by the State in its preparation of the Illinois SSC site proposal. This information remains invaluable for any future project proposal. Figures depicting the geology of the area have been supplied by Illinois State Geology Survey, Illinois Dept. of Natural Resources.

3.10.11.2 Overview of Possible Site Layouts

Fig. 3.10.9 shows two possible site areas which might be considered. a) the West Line site could be connected to Fermilab or not. The Fermi Main Ring tunnel could be used for the damping ring, for instance. The collision area would lay to the west about 10-15 miles near the same interstate highway that serves Fermilab. b) the North South site could have the interaction area on site and possible use the MR tunnel for the damping ring(s) as well.

West line proposed site This proposed line runs due west 28 miles (45 km) from Kane- Dupage County Line boundary (which runs north south through the west side of the Fermilab site). This site line is located about 1/2 to 1 mile south of Fermilab south boundary . It is chosen to align with a 345 kV power line which starts about 2 miles to the west of County Line and east of the Fox River. The 30 mile extent of the possible site is approximately defined by the Troy bedrock valley just west of Dekalb. This valley is cut deep into the bedrock and is filled with glacial sediments of clay, sand and gravel. (The 30 mile extent is not a firm limit but the top of the bedrock drops below an elevation of 450 ft in this region and ground elevation has risen to 900 ft .)

Fig. 3.10.10 depicts the geological cross section. The tunnel and experimental hall would be located completely in the Galena - Platteville dolomite and would be about 350 ft below the ground surface. The tunnel could as well be situated on a slope from west to east following the contour of the bedrock (150 ft/10 miles).

The 345 kV power line has a dogleg horizontal offset of 0.3 miles at one location alone its length. The bends of this dogleg are about 12 degrees. It would be interesting to see just what impact incorporating this offset into the collider design might have.

The center of the layout is near the RT. 47 exit on Interstate 88. The Interstate would pass over the tunnel near here (about 2 miles). The Interstate exit is about 10 miles from the one that serves Fermilab site.

The far end of the line is within easy access of US 30 which runs parallel about 2 miles to the south. A railroad track runs adjacent to US 30 throughout the area. This rail could be an asset for construction but must be evaluated as a potential ground vibration source.

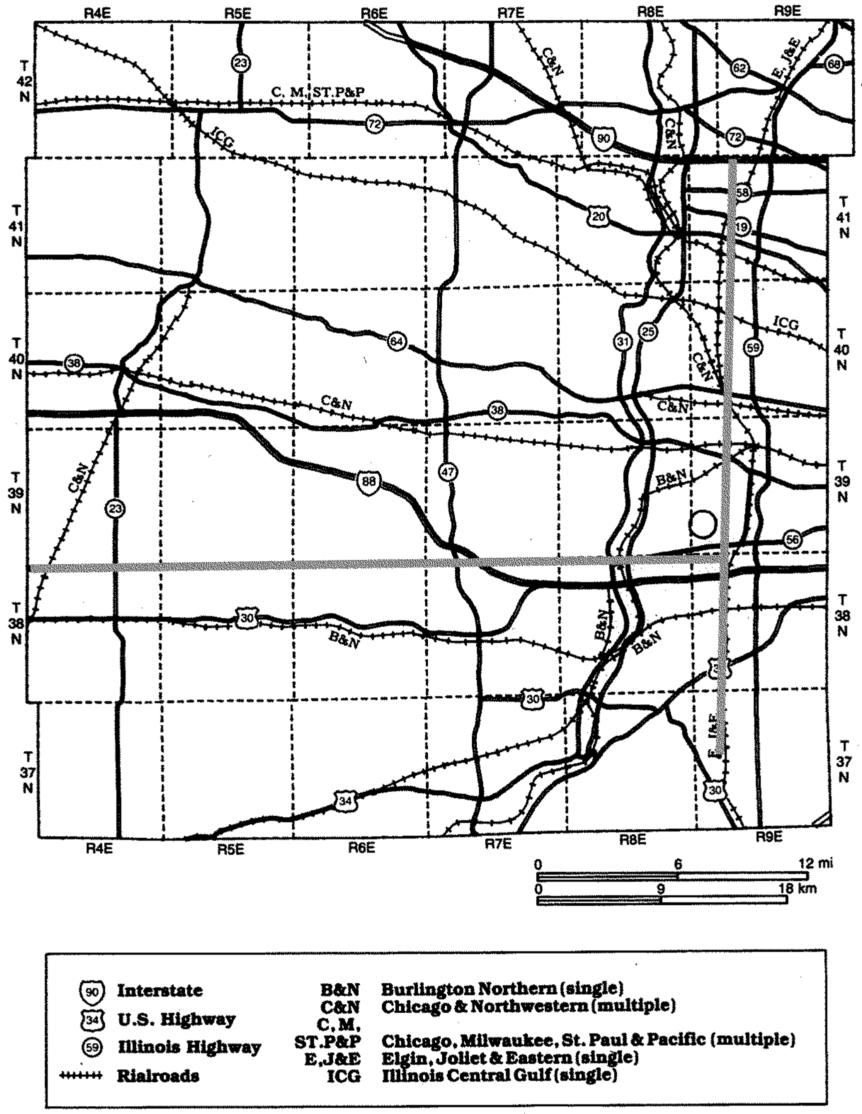

Figure 3.10.9: *Map of the possible site areas.*

North South line proposed site The line for this proposal would have the interaction region located near the eastern side of the Fermilab site. The tunnel line would follow or be closely associated with a combination of road, rail, and power corridors.

Fig. 3.10.11 shows the geological cross section. Two tunnel elevations are possible. One option has the tunnel and the hall completely within the Galena. The exact elevation would be chosen so that the roof of the hall would be about 25 to 30 ft below the top of the Galena. The tunnel depth would be about 370 ft below the surface at Fermilab.

The other option would put the roof of the experimental hall about 100 ft below the top of the Silurian dolomite. This keeps the hall out of the upper 75-100 ft of the

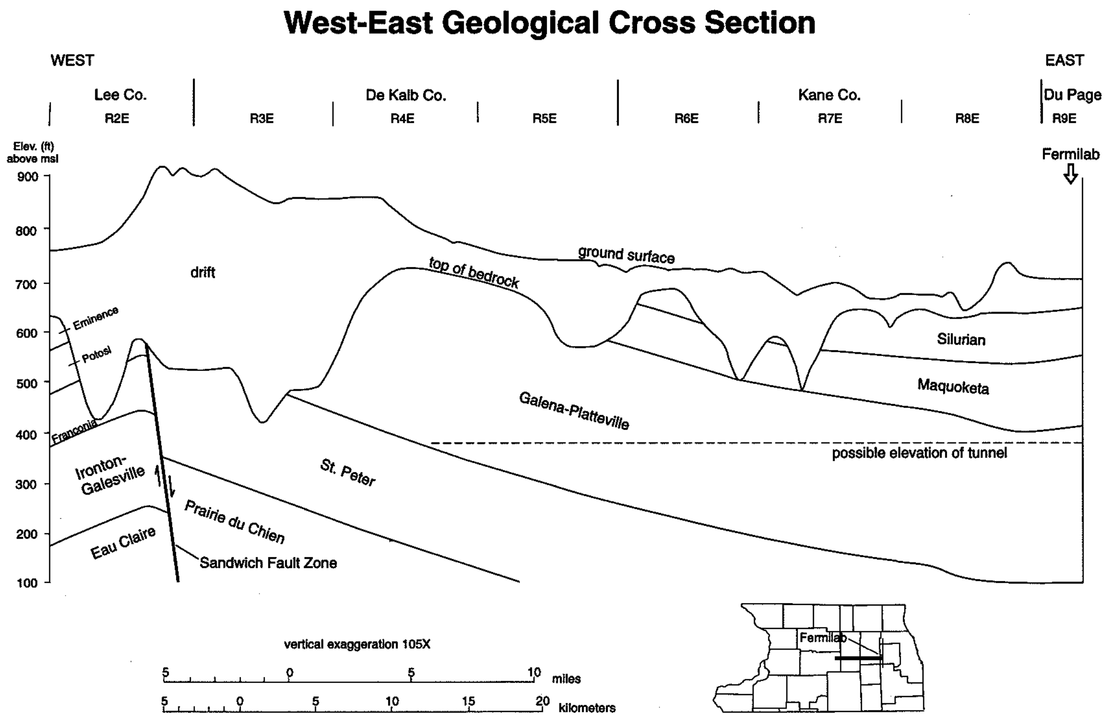

Figure 3.10.10: *West-East Geological Cross Section*

bedrock where more water can be present. The experimental hall could be entirely within the Silurian or the lower part of the hall could be in the dolomite portion of the Maquoketa. The tunnel would be about 175 ft below ground and entirely in the Maquoketa unit.

Cost estimates would need to be carried out to determine just what would be the best site choice.

3.10.11.3 Geology

The Illinois region consists of sedimentary bedrock units overlain with glacial deposits. The bedrock units consist of a number of carbonate dolomites (or limestones) and shales of considerable thickness overlying sandstone (Ancell Group). The bedrocks have not been significantly affected by folding or faulting. There is a general slope of the units of about 10 to 15 ft per mile to the southeast. There is negligible seismic risk and no potential for subsidence. There is an inactive fault system to the south west of the proposed siting areas. This fault system, the Sandwich Fault presents no major construction obstacle were it to fall in the site area. Sediments deposited over the fault indicate no movement has occured for 200,000 to 1 million years.

The dolomite bedrock is a relatively uniform and predictable medium. It provides an excellent and well understood tunneling environment. The dolomite itself is an aquatard. Where not cracked or fractured (e.g. surface interface) it is impervious to

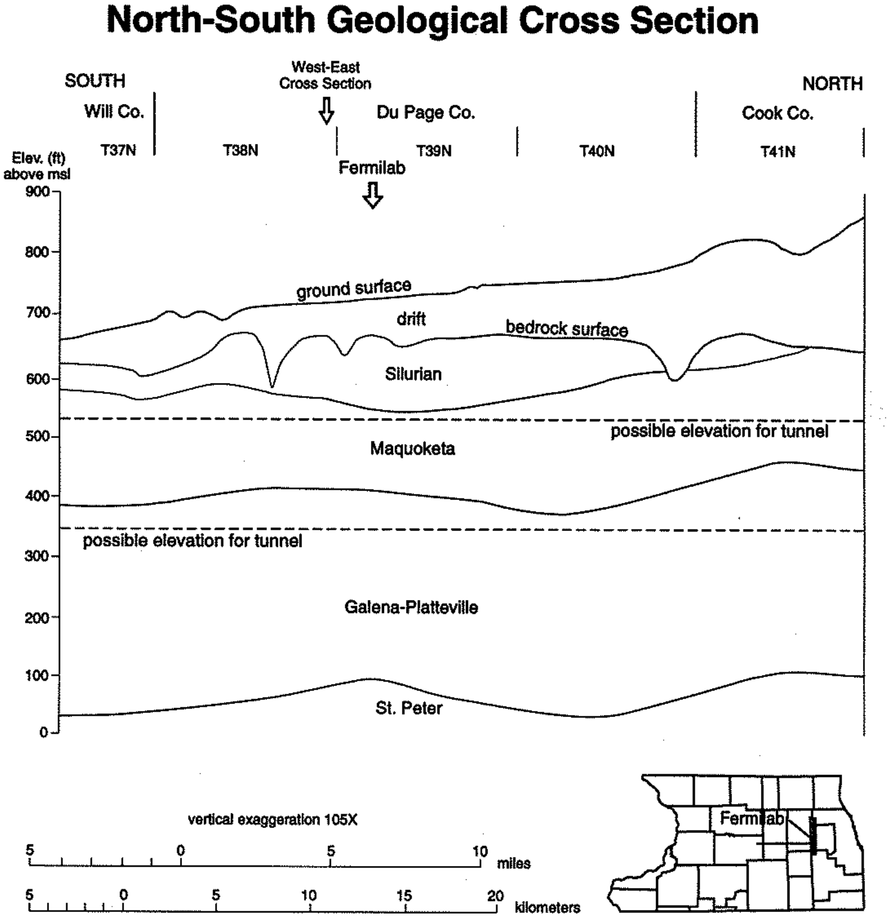

Figure 3.10.11: *North-South Geological Cross Section*

water. The glacial drift on the other hand is less predictable and not as desirable for tunneling. Water is found in the drift above the bedrock, at the very top of the bedrock at drift bedrock interface, and also in the deeper layers of sandstone below the dolomite. For the collider tunnel to stay located in uniform unfractured dolomite it may need to be located at typically 350 ft below the surface. (Considerably deeper than the about 15 m for the DESY site, but consistent with the LEP tunnel.)

The dolomite units consist of Silurian dolomite, Maquoketa- a shale with interbeded dolomite, and the Galena - Platteville dolomites. This latter group is of 300 to 350 ft thickness throughout the area. It is the preferred unit for tunnel construction. However both the Silurian and the Maquoketa can be viable alternatives. The Silurian does not cover the entire region but has been worn away to the west. For a North South collider alignment the Silurian may be an alternative where it exits as a thick enough layer above the Maquoketa.

The Maquoketa shales have medium to medium high slake durability and do not swell. It should be stressed that the Maquoketa though a shale has reasonable materials-

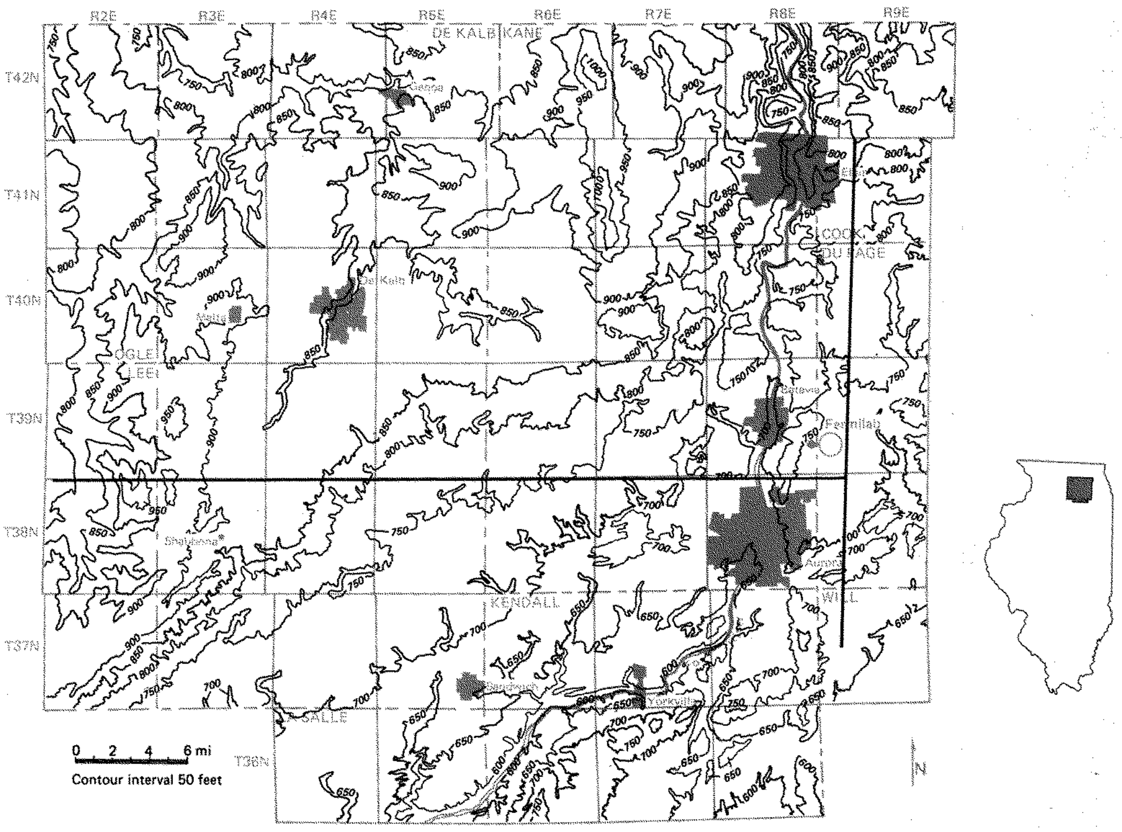

Figure 3.10.12: *Contour Map of the Surface Topography*

construction properties. The dolomite intermixed with the shale provides cement bonding. The unconfined compressive strength is 4400-9000 psi, whereas the Silurian and Galena - Platteville dolomites are 10,000-16,000 psi. This is to be compared with typical concrete 1500-3500 and with the Texas Eagleford Shale of 200-400 psi and Austin Chalk of 2000-3000 psi.

Fig. 3.10.12, Fig. 3.10.13, Fig. 3.10.14 and Fig. 3.10.15 show the topology of drift and bedrock layers in the area.

For tunnels located in the dolomite only spot rockbolting and grouting of cracks would be expected to be required. For tunnel in the shales more rockbolting and some steel straps may be required. These tunnel sections in shale would be covered with shotcrete. Halls if located in shale could be sited with shale at the foot but with the chamber roof in dolomite.

In the Illinois SSC proposal two alternative tunnel elevations were cost estimated. One in the Galena Platteville at an average depth of 430 ft. The other in a combination

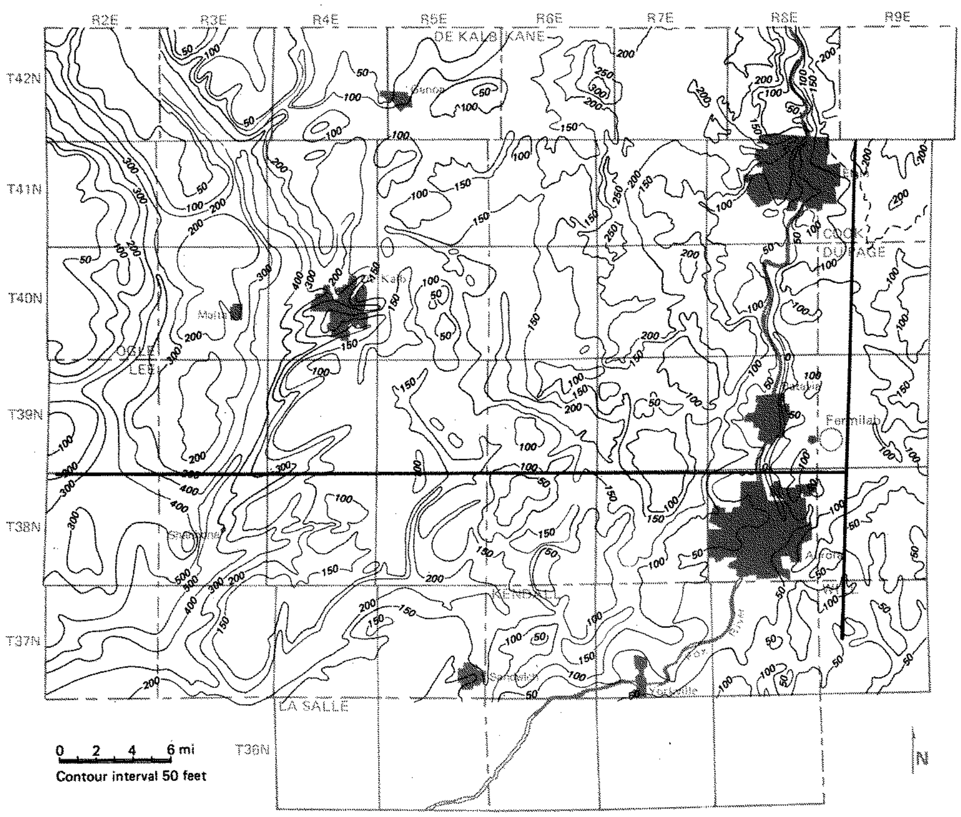

Figure 3.10.13: *Contour Map of the Thickness of the glacial Drift*

of shale and dolomite or limestone (25% shale) at an average depth of 270 ft.

Extensive tunneling has been done in the Chicago area as part of a water retention project (TARP). Over 100 miles of 8 to 32 ft diameter tunnel and over 250 shafts have been bored in the Silurian dolomite rock. Many areas of the TARP tunnels do not require tunnel linings. There are well understood and documented costs for this local tunneling.

The dolomite rock is suitable for cavern spans of 70-120 ft and heights of 130 ft. Tarp Main Pumphouse caverns in Chicago provide comparison with what would be possibly for collider experimental halls. Two of these caverns are 274 ft long, 96 ft high, 63 ft wide and 360 ft below ground.

Joints or cracks in the rock have a preferred 45 deg orientation to the 4 points of the compass-N,S,E,W and are nearly all vertical. Spacing is typically of order 100 ft. The preferred joint orientation implies that halls laid along N-S, E-W axis are more suitable for construction and reduce the need of rock bolts.

The preferred direction for the long dimension of the halls is north - south. This is because the bedrock in the area has high compressive stresses roughly in the east west direction. These stresses can help hold up a roof arch in the east west direction. Analysis has been made for spans up to 125 ft in the east west direction, but would

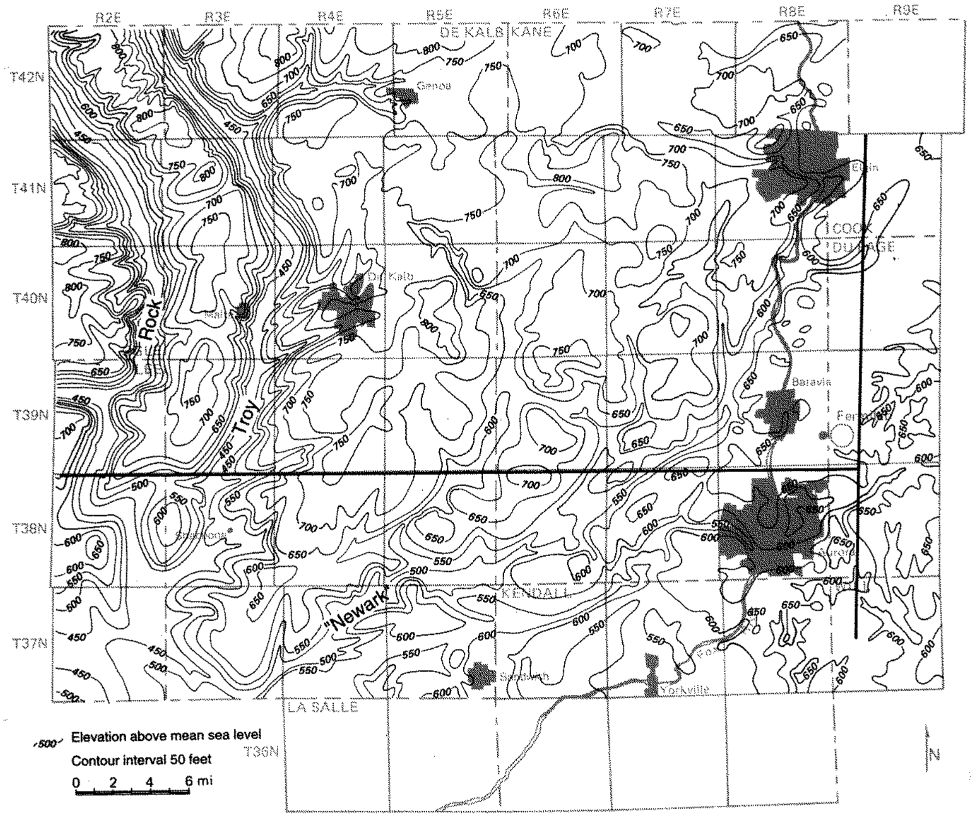

Figure 3.10.14: *Contour Map of the Bedrock Surface showing the Newark and Troy Bedrock Valleys*

need to be reevaluated for north south arch orientation. It is likely this orientation would be viable, but might need more support and have a cost implication.

Water permeabilities (hydraulic conductivity) in the bedrock basically range from 10^{-4} to 10^{-6} cm/sec except at top of Silurian bedrock where aquifers with 10^{-2} cm/sec can be found. The lower Ancell sandstone is an aquifer with $3 \cdot 10^{-3}$ cm/sec.

Initial water inflow rates during tunnel boring of up to 500 gpm/mile drop to 100 gpm/mile without grouting. Final rates of 10-50 gpm/mile can be expected with grouting. (This is lower than what has been measured in the Fermilab tunnels.) The TARP pump station caverns have been measured at only 16-30 gpm.

3.10.11.4 Vibration and Sound Velocity Measurements

Information on vibration and slow drift or diffusion of the tunnel in the bedrock is limited and will need further measurements. There are measurements of the Fermilab tunnel but that tunnel is near the surface in the glacial drift. Measurements were carried out of vibration associated with interstate highway and rail traffic very close to the highway and tracks. These measurements can only represent worst case conditions.

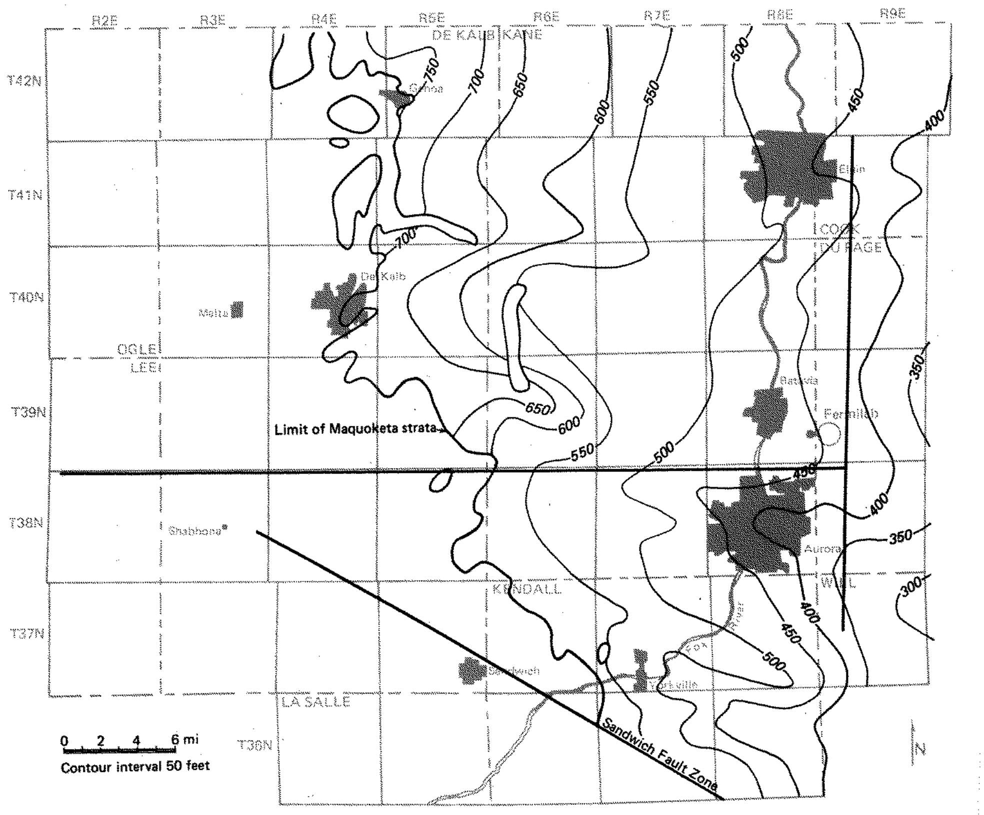

Figure 3.10.15: *Contour Map showing the Elevation of the top of the Galena dolomite*

Additional information on sound velocity in rock has been obtained as part of seismic reflection and refraction survey studies.

Fermilab Tunnel Ground motion vibration measurements have been made in the Fermilab Main Ring tunnel. These measurements were made under noisy conditions with accelerator utility systems in operation, e.g. the cryogenic system and water system. Thus they represent in some sense worst case conditions.

Over a relatively narrow frequency range of 1-25 Hz ground motion power spectra levels $[(2\pi \cdot f)^2 \cdot P(f)]$ of about 0.3 to 0.01 $(\mu m/sec)^2/Hz$ were observed. Also resonances as high as $3 \cdot (\mu m/sec)^2/Hz$ were observed at the Central Helium Liquifier compressor frequency. Higher levels were observed at the ground outside the tunnel location nearest the helium plant.

These levels are similar to those observed at other active accelerator installations [12, 13, 14] (APS, HERA, VEPP) and can be two to three orders of magnitude higher than measurements made under quiet conditions. This only points out that the design of accelerator infrastructure needs to take into account the vibration reduction requirements that are needed. Fig. 3.10.16 and Fig. 3.10.17 show the typical measured spectra.

It should be noted that the measurements carried out in the Fermilab tunnel do

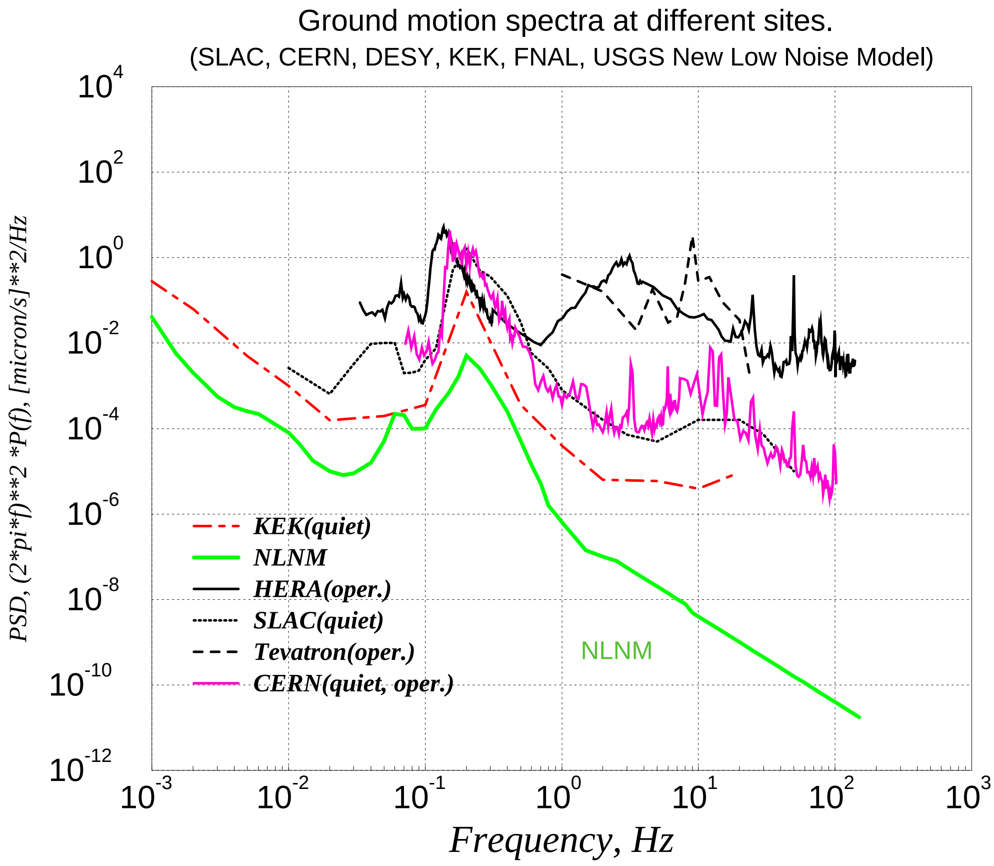

Figure 3.10.16: *Vibration Power spectrum* $(\mu m^2/Hz) \cdot (2\pi \cdot f)^2$

not have direct bearing on vibration spectra which would exist in bedrock tunnels and halls. Further measurements will need to be performed in order to determine these spectra.

Highway and Train Measurements Highway and train vibration measurements have been carried out for the Ill. Geological Survey. These measurements were performed in a rock quarry within 150 ft (horizontal) of an Interstate highway overpass bridge (I88) and 210 ft from rail tracks (and 330 ft from rail road crossing). Vertical distance from the source was about 70 and 50 ft respectively. Maximum zero to peak amplitudes of 2-3 micro inches (0.05-0.07 μm) at about 14 Hz were observed from heavy (18 wheel) trucks traveling at speed over the bridge and from the train with 50 cars traveling at 8 miles/hr. At ground surface displacements 60-200 times greater

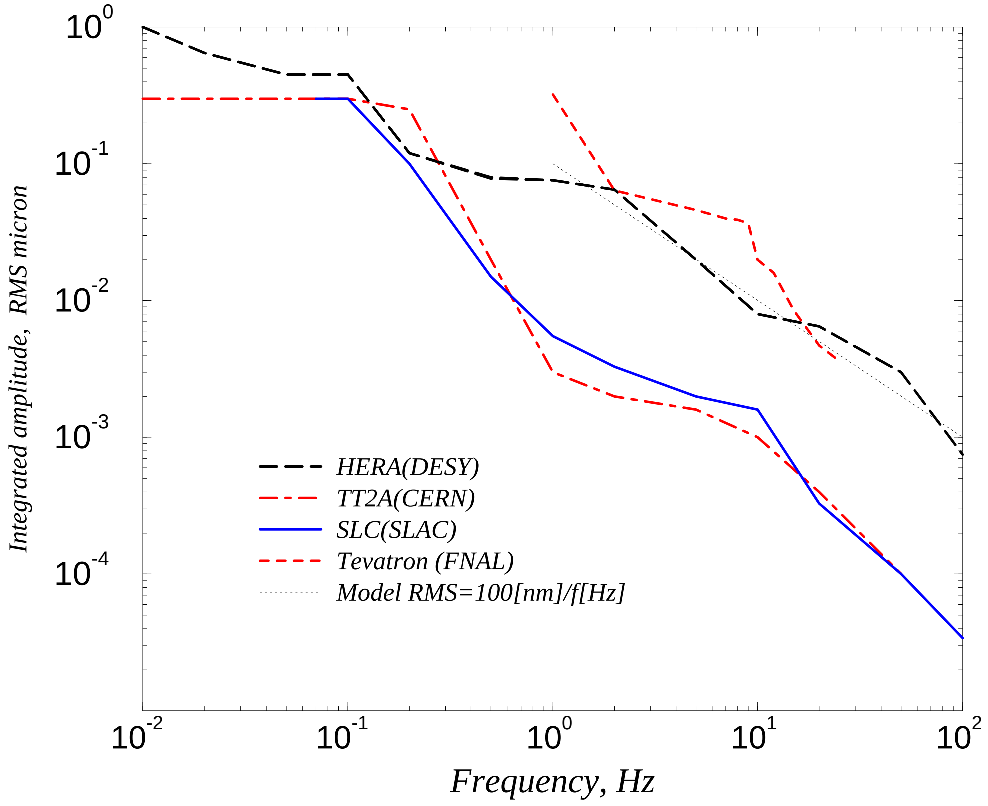

Figure 3.10.17: *Integrated Vibration Amplitude*

were observed. It appears from the measurements of greater vertical displacement that body waves (shear waves) are more dominant than surface waves at the transducer. These observed displacement magnitudes are not unlike those observed at HERA.

Motions of $0.05\,\mu m$ are about an order of magnitude greater than typical integrated amplitudes from a "noisy site" (100 nm/f[Hz]). They clearly represent worst case and transient conditions. The TESLA tolerances of 100 nm at frequencies above 1 MHz and $1\,\mu m$ at low frequencies clearly should not be a problem.

Velocity measurements Velocities of the compression and shear waves have been measured in the various rock groups. Typical compression velocities are from 8,700-12,300 ft/sec in the Maquoketa, and 15,700-18,100 ft/sec in the dolomites. Shear velocities are 5,300-7,100 and 8,800- 10,100 ft/sec respectively. Coherence lengths have not been measured.

3.10.11.5 Hydrology

Water supplies will be required to provide the make up water necessary to cool the (nominal) 180 MW of power used. This amount of power will require about 2,400 gpm (3.5 mgd-million gallons per day) of make up water.

It is likely the most economical water cooling system will be separate systems located at the typically 9 service areas (2 end, 1 IR, 6 cryo areas). Each area would have its own water supply source, and cooling towers or ponds. It can be expected that each area may require from 200 to 400 gpm depending on its specific function.

The northern Illinois area is rich in water resources and there are a number of ways to meet the required make up demands. The choice will be mainly economic. The Ill. Dept. of ENR in a study carried out for the SSC came to the conclusion that generally use of water from wells was most economic especially when both potable and cooling water requirements were included and when the cost of piping transport over any substantial distance was considered. Where available without too great piping distance, municipal sources are viable and economic.

Local wells provide most municipal industrial and private sources in the region. In recent years the western suburbs of Chicago have begun to use water from Lake Michigan. Towns along the Fox River have begun to use the river as a source of city water as the water quality has improved. Even so the four Townships along the Fox River which contain Aurora, Batavia, Geneva and St. Charles use about 23 mgd (million gallons per day) of ground water. Thus the Linear collider usage would represent a small but not negligible increase. It would be distributed over a different and wider area.

Wells Wells in the area are footed in the sand and gravel of the glacial drift, at the top of the dolomite surface of the Silurian, or in the sandstones (St. Peters and Ironton- Galesville) below the dolomite. The Maquoketa and the Galena Platteville are non water bearing.

Wells in the sands and gravels yield typically 100 to 1000 gpm. In the Newark bedrock valley to the west of Fermilab test wells have yielded 1200 gpm and this region is estimated to have a potential yield of 10 mgd.

In the region east of the Fox River where Silurian dolomite is uppermost of the bedrocks, wells yield typically 500 gpm from the top of this layer. Fermilab has one such well that has been tested to 500 gpm and two others that are rated at 200 gpm. Presently one well is used for potable water at about 0.1 mgd.

The St. Peter sandstone, highest of the sandstones under the dolomite yield typically 200 gpm.

The most economical water sources have been estimated by the Ill Dept. ENR to be the Silurian in the east, the St. Peters and Newark Valley sand and gravel to the west. The expense for the development of the necessary water resources is not expected to be a large fraction of either construction or operation of the collider.

Tunnel Inflow Tunnel inflow is estimated to be 10 to 50 gpm/mile after grouting of cracks and joints in the tunnel. This rate is less than experienced in the present Fermilab tunnels. The rate will be dependent on both rock quality and the specific hydraulic head in the area of the specific aquifer. The potentiometric surfaces show considerable variation especially that associated with the deep sandstone aquifers. Thus though rates of 50 gpm/mile would be almost enough to supply half the make up water requirements, their variability would suggest that they could be used only as supplemental water sources.

Rivers The Fox River is the largest in the area with an average flow of 1100 cfs (cu ft per sec, 7.5 gal/cuft, 1 cfs = 450 gpm). The mean annual high flows are about 5000 cfs, and lows 200 cfs. Reliable sole source usage can be based on the 7 day low flow expected in 10 years. For the Fox this is about 150 cfs. In comparison the total estimated collider water need of 2400 gpm amounts to 5 cfs. Fermilab has a present capability of pumping 1000 gpm from the Fox.

Other smaller streams in the area have average flow rates of 20-50 cfs. They would not be suitable for sole source usage but can be used for discharge of tunnel or cooling tower blowdown water if proper environmental standards are met.

Fermi water system The existing Fermilab water system of wells, ponds (and the connection to the Fox River) are good sources for makeup water and drinking water. It could easily supply in excess of 1000 gpm.

Fermilab has an extensive pond system. There are about 230 acres of pond surface on the 6800 acre site. This area is sufficient to cool the total 180 MW at slightly over 1 acre/MW. However the water reservoir or pond depth would not be sufficient for long drought periods without makeup rain water (nominal 82 days) or supplemental well or Fox River sources. Dredging the existing ponds or additional deep retention ponds could be constructed if cooling of more than about 33-40 % of the total nominal 180 MW load were required from rain water makeup alone. 40 % fractional load requires that about 1600 acre-ft/yr. (1.4 mgd, 1000 gpm) of rain water be collected . This represents about 8 % of the site wide annual precipitation (34 in/yr.). As discussed above, additional potential sources of make up water are the Fox River with a maximum capacity to site of 1000 gpm providing the river has sufficient flow, and a number of wells (11), three of which are known to be able to supply 900 gpm total. At present, Fermilab uses wells only for potable water.

Though the combination of Fermilab ponds supplied by rain water, the Fox River, and existing Fermilab wells a large fraction of the total cooling water demands can be met by what presently exists at Fermilab. However to be cost effective it is likely that many of the distributed service areas may be best served by local well, pond or tower cooling systems.

3.10.11.6 Power

The power utility requirements of a Linear Collider (nominally about 180 MW) should present no difficulty for Commonwealth Edison, one of the largest electric generating systems in the country. Peak load in 1995 was 18,600 MW with a reserve margin of 18.6% of the over 22,000 MW installed. Thus a 180 MW load would be less than 1% of the total installed. The 345 kV lines typically have 1400 MVA capacity. Two points of service could provide power from separate grids so that essential loads could be maintained if either line is out of service.

Fermilab has an estimated usage of 400 GWH at present, or an average load of 45 MW. Prior to Tevatron operation power usage of 60 MW during peak operation periods was not uncommon. Line capacity for a new 345 kV line to site is 900 MW.

3.10.11.7 Conclusions

Fermilab is a natural focus point from which to base a future High Energy Physics project. The area in north-east Illinois around Fermilab is well suited as a potential site for a linear collider. Much successful experience in deep tunnel construction exists in the area.

Two possible configurations have been looked at and further analysis and cost comparison of different tunnel locations and depth could be carried out.

The possible ramifications of slight horizontal deviations from a completely linear configuration should be explored so as to understand the possible flexibilities in the collider footprint.

Further measurements of vibration spectra and their attenuation, and coherence length should be performed in the bedrock environment. These measurements should focus in particular on vibrations associated with highways and trains as the most convenient siting may follow these public easements. Vibration may not be a particular issue for the TESLA design, but it may have significant ramifications for other collider designs.

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