

TESLA - A CHALLENGE IN PLANNING LARGE FACILITIES

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1. BASIC PARAMETERS OF THE TESLA PROJECT

TESLA - the name stands for Tera Electron Volt Energy Superconducting Linear Accelerator - has two main scientific goals : To extend our knowledge about matter beyond the standard model and to use it as a unique x-ray light source for many different applications in applied sciences.

Therefore the basic facilities there will be two superconducting linear accelerators with an energy of 250 GeV each. This energy can be extended up to 400 GeV without increasing the length of the machine. [1]

The accelerators will consist of 1781 modules with 4 to 12 cavities and some with a quadrupole in a cryogenic tank. Totally there will be 21200 cavities and 801 quadrupoles [2].

To achieve a luminosity of $3.4 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ the beam has to have a shape of 500nm width and 5nm height at the interaction point. This has to be done by a 1.5 km long beam delivery system at each side of the interaction zone. On each side will be 288 magnets for each interaction zone [2].

The total length of the facility is about 33 km.

2. OVERALL LAYOUT

TESLA as a linear collider mainly consists of two linear accelerators each some 15 km long. One will accelerate electrons coming from the DESY site, the other one positrons starting at the village of Westerhorn. Before they collide in the experiment located near the village of Ellerhoop they are guided by beam delivery systems each 1500 m long.

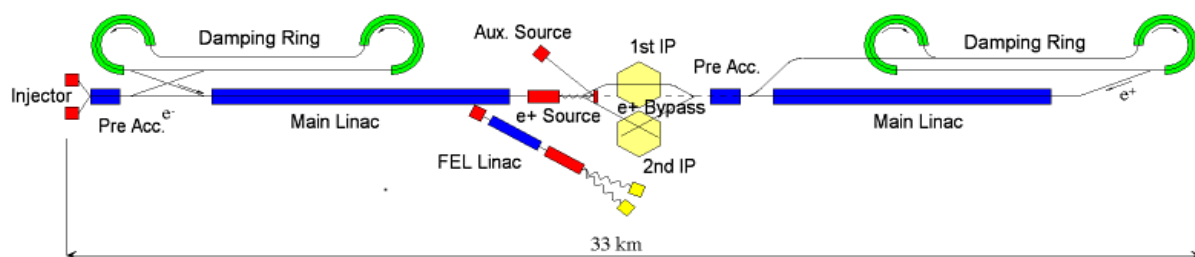


Fig. 1 Overall layout scheme

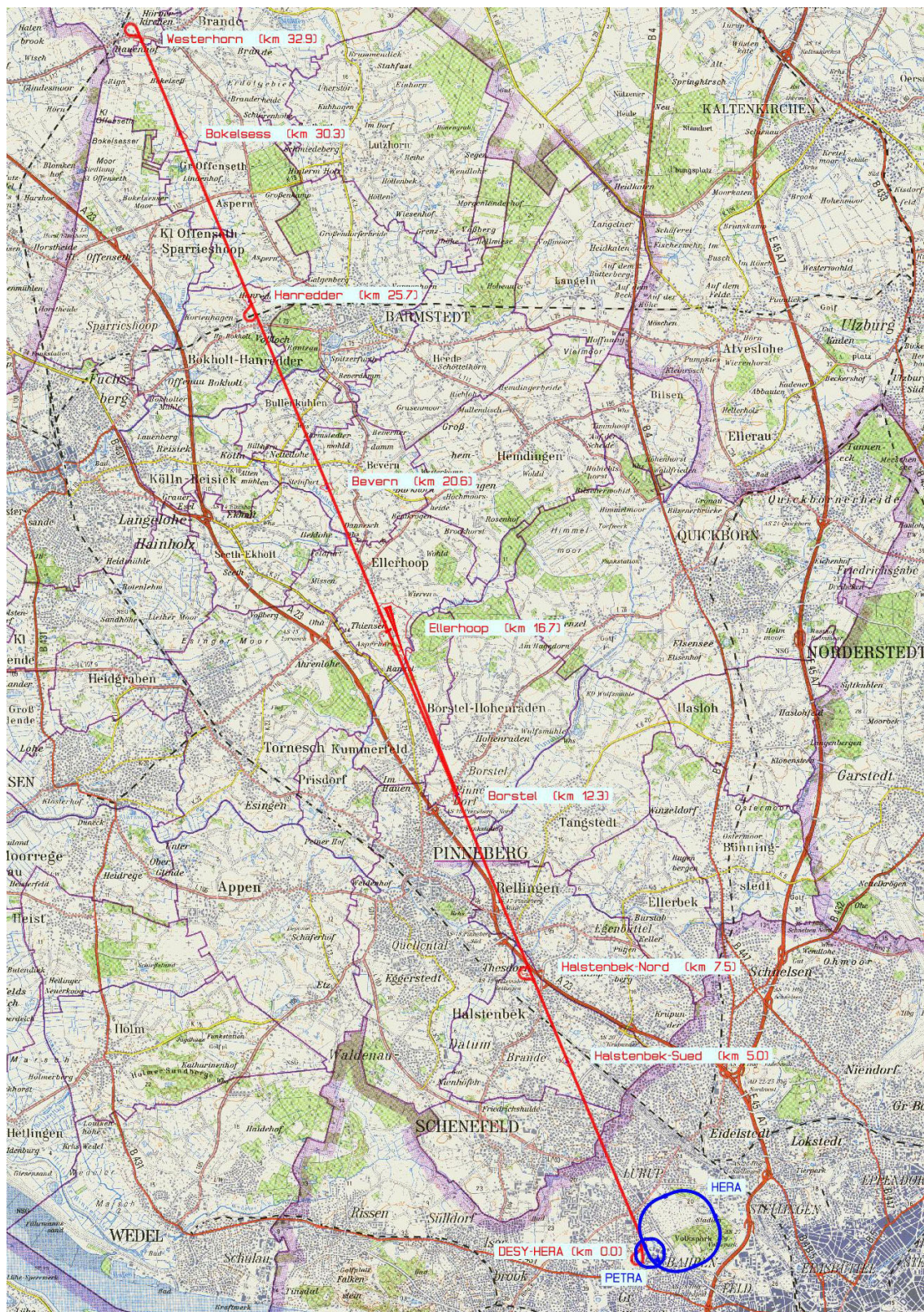


Fig. 2 Overview map

The electrons come from one of two injector linacs located at the DESY site. Before they go into the main linac the beam is formed by a damping ring some 17 km long. The main part of this ring is located in the main linac tunnel. Here are also mounted some wigglers which have to form the beam. At each end of this dog bone shaped ring are arcs with a radius of 145 m. A straight section within the arcs is used for superconducting accelerator modules. There are 1377 Magnets (without steering magnets) and 162 wigglers in one damping ring.

Before the electrons are reaching the interaction zone they go through a wiggler which produces high energy photons. These photons are the source of positrons. These positrons have to be guided around the interaction zone in a bypass tunnel under the experimental hall. Then they are guided through the main tunnel to a similar damping ring than that for the electrons at the other end of TESLA. Then the positrons will start their journey through the main linac from Westerhorn to Ellerhoop. This is a mayor change to the layout described in [4] where the positrons were produced after the electrons have been traveled through the interaction zone.

Both the electron and the positron beam have to be dumped after (or before) passing the interaction zone. So two beam dumps have to be placed at a distance of 240 meters from the experimental hall.

As an option a second interaction zone is planned parallel to the first one at a distance of 23 meters. So there have to be additional beam delivery systems located in additional tunnels to reach this second interaction point. What kind of experiment this second interaction zone will be is not decided yet. It may be a second electron-positron or a gamma-gamma experiment.

A further option is a successor of the HERMES experiment at HERA which is a fixed target experiment with polarized positrons. It will need another beam line separated from the positron linac and ending at the Ellerhoop site.

The most important option for the geometry of TESLA is the possibility to connect the linac tangentially to the western straight section of HERA, allowing the TESLA electron beam to collide with protons of HERA [2]. So the place and direction of the TESLA tunnel is fixed and no other possible sites have to be investigated.

3. CONSTRUCTION ENGINEERING

3.1 Geology

The Schleswig-Holstein region consists of glacial deposits with different hydraulic conductivities. To find out what it means to build a tunnel in this soil and to pump water for cooling purposes an investigation has been made by a specialized engineering bureau [5]. They found that the tunnel will lay completely under the groundwater level with one exception near the DESY site.

For a deeper investigation 17 new test borings have been carried out along the tunnel route. 8 of them remain as groundwater measurement stations. At some of them the water is under pressure when it comes to the surface.

To get more information about the different layers of soil there will be made some 150 borings more and the gaps between them have to be filled by geophysical methods.

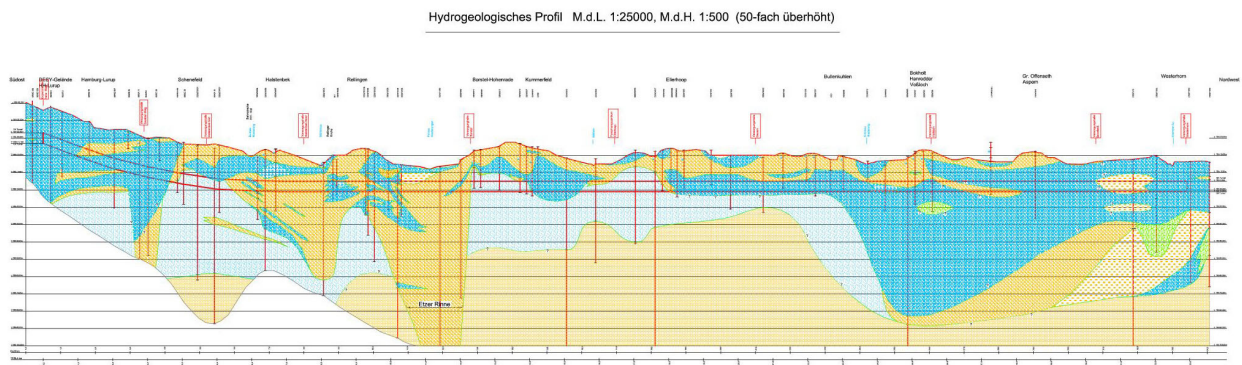
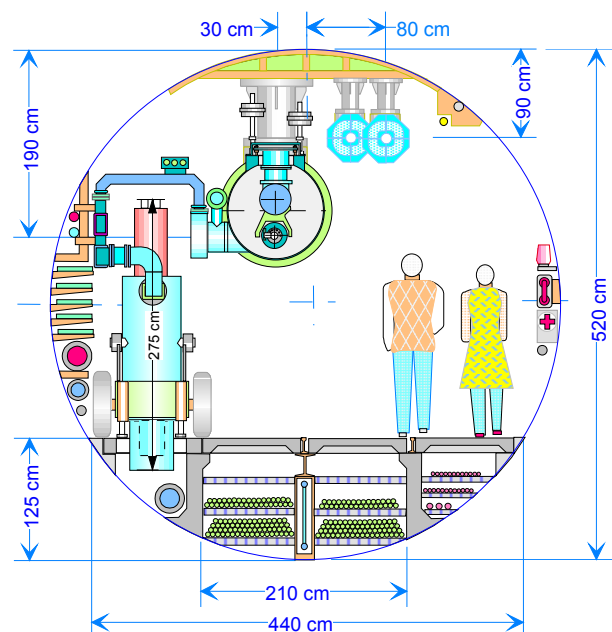
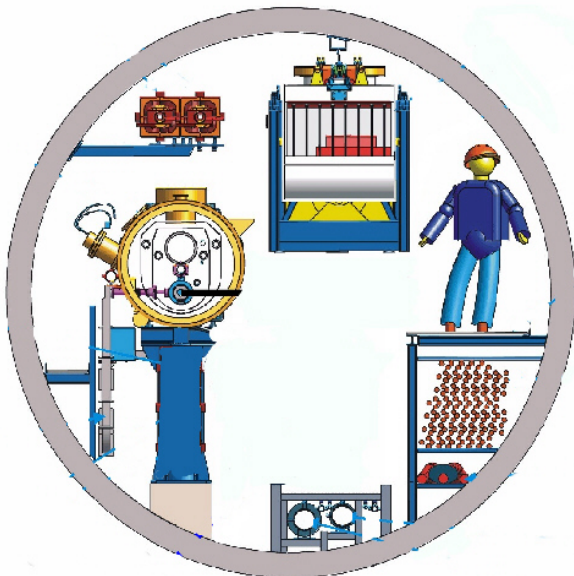


Fig. 3 Hydrogeological profile

3.2 Main Tunnel

The main tunnel has to house up to 3 beamlines, clystrons, waveguides, waterpipes, cables and a transportation system. So together with necessary walk- and escape space it has to have a minimum inner diameter of 5 meters. With a survey and construction tolerance of ± 0.15 meter it has to be at least 5.3 meters wide.

The layout of the tunnel installations have recently been changed to get more space for cables. The modules are now hanging from the ceiling instead of standing on the floor.



For reasons mentioned above the direction of TESLA is that of the HERA straight section at hall west. The TESLA accelerator does not begin at HERA hall west but at the western border of the DESY site with 3 injector linac tunnels. The main tunnel then after a straight section of several hundred meters makes a curvature with a radius of 500 meters to get into the direction shown above. In this area the tunnel has not only the direction of the HERA machine but also its tilt in longitudinal direction (8 mrad). The height of the tunnel has to be chosen so that the TESLA main accelerator points at the HERA proton machine in hall west.

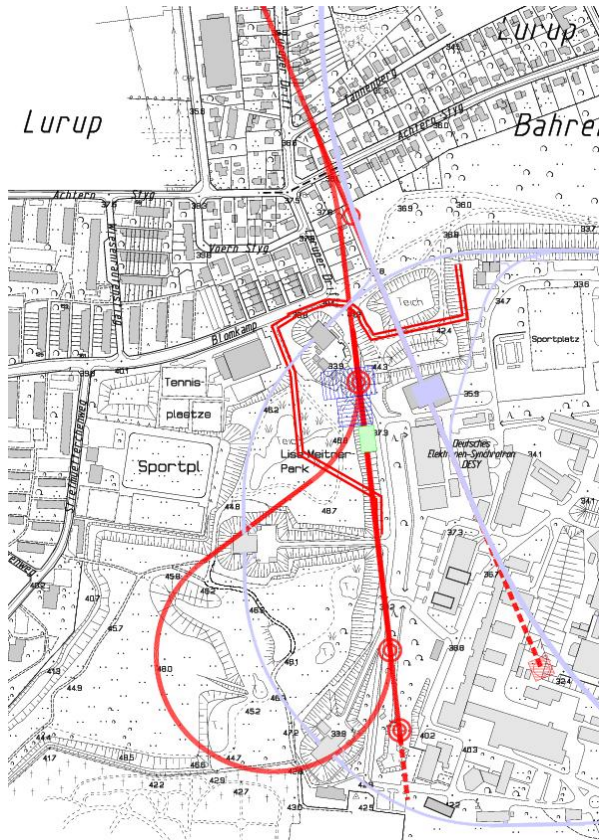


Fig. 6 DESY site

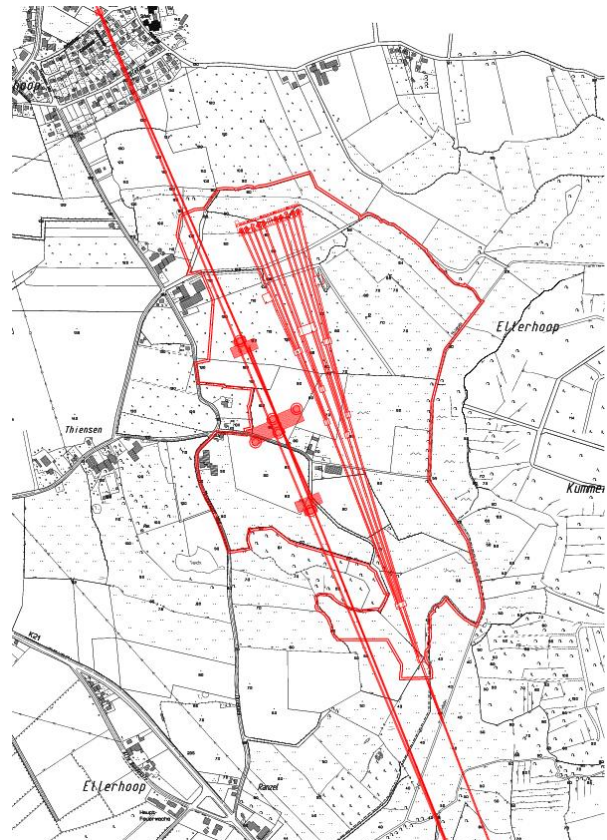


Fig. 7 Ellerhoop site

For reasons of cost minimization (not to have too deep shafts) and to have the possibility to extend the linac beyond Westerhorn it was decided to let the main part of the tunnel follow the earth curvature with a height of 8 meters below sea level.

The first section will be a geometrical straight line. Both sections of the tunnel are connected by a radius of 5000 meters vertically.

The construction method of the tunnel is not finally decided yet but most likely it will be done by a tunnel boring machine and tubbings.

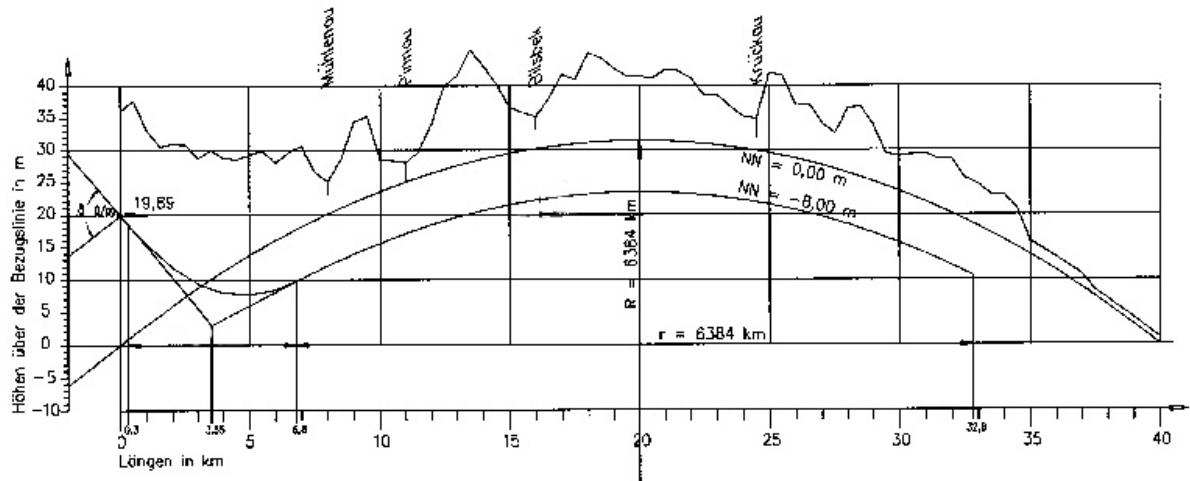


Fig. 8 Vertical profile

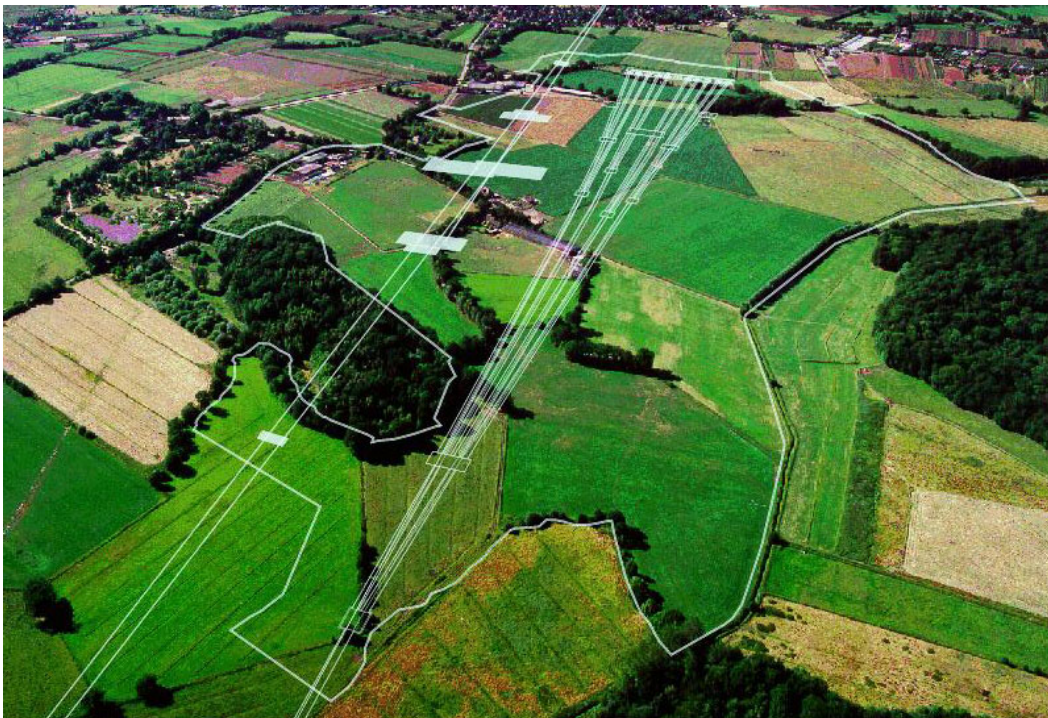


Fig. 9 Aerial photo of the Ellerhoop site

3.3 Damping Ring Tunnels

The arcs of the damping rings will be tunnels with an inner diameter of 3.4 meter and a radius of 145 meter. Because this radius is very narrow for a tunnel boring machine a greater tolerance (± 0.2 meter) has been chosen. These tunnels are connected with the main tunnel at the

access shaft under a cryogenic hall on one side and at a special separation shaft on the other. This shafts will be described later.

The arcs have to be positioned with respect to the main tunnel so that a total length of 17000 meters of the damping ring is achieved.

3.4 Other Buildings

3.4.1 Cryogenic Halls

The superconducting modules have to be cooled down to 2 Kelvin to achieve not only superconductivity but a special state of liquid helium called superfluidity. This is necessary to achieve a quality for an accelerating voltage of 23.4 MV/m.

This liquid helium is made by compressor rows in cryogenic halls which are placed roughly every 5 km so that they deliver the helium for two 2.5 km long parts of the machine. Together with the one on the DESY site there will be 7 of such halls.

The halls will have an extension of 35 x 65 meters and a height of 12 meters above ground. At one side will be an extension of 35 x 41.5 meters housing the modulators feeding the klystrons in the tunnel. For the 800GeV option the cryogenic hall has to be made 22 meters longer and the klystron hall has to be doubled.

No such halls are located at the interaction zone in Ellerhoop and at the end of the tunnel in Westerhorn. In Westerhorn will be only an access building over the access shaft.

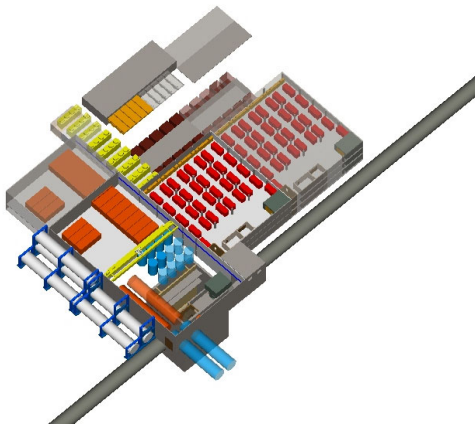


Fig. 10 Cryogenic hall

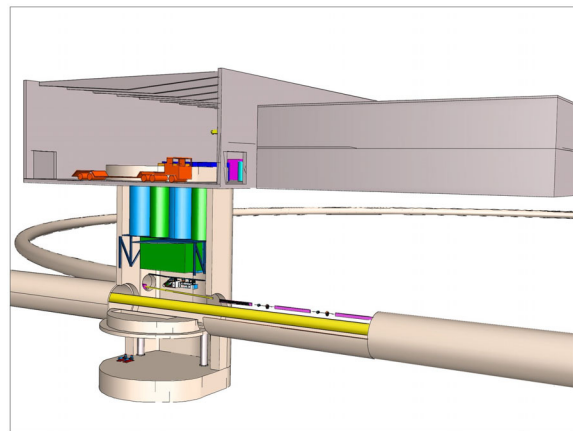


Fig. 11 Access shaft with damping ring

3.4.2 Shafts

Under each cryogenic hall and the access building in Westerhorn will be an access shaft. These shafts have to be wide enough to bring down a 17.5 m long module horizontally. Besides the transport shaft these shafts are housing the elevators, the steps, the air ducts, many cables and tubes. For survey purposes this shafts are the natural connection between the basic network on the earth's surface and the underground network.

Besides the access shafts which are used for separating the damping ring tunnels there have to be some more only for separation purposes. One additional for every damping ring arc and two for the beamlines of the second interaction point (the northern one can also be used for the TESLA-N experiment). The separation shaft south of Ellerhoop will also be the place for the positron source, the positron pre-accelerator and an auxiliary positron source. So that will be an underground hall of 100 m in length. The upper part of these shafts will be dismantled so there will be nothing left on the earth's surface.

3.4.3 HEP Experimental Hall

The experimental hall for high energy physics with the interaction points of the collider is located south of the village of Westerhorn. There will be a campus with a size of about 73 hectare. It is planned to be an open park with no fence around it.

The underground hall for two detectors has a size of 160m x 32m and a height of 19m below the hook of the portal crane.

Reviewing the experiences at HERA it was decided to separate the transportation into the tunnel from those into the hall. So there will be separated access shafts for the detectors and the tunnels.

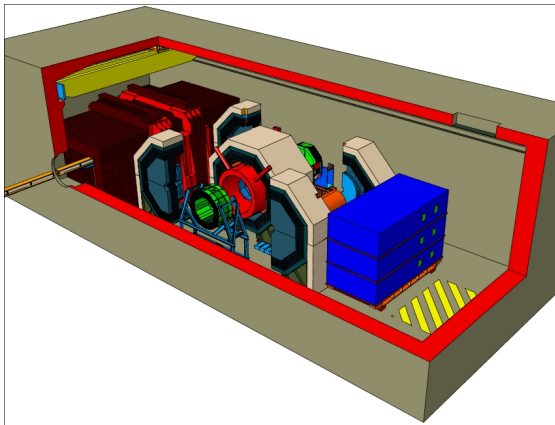


Fig. 12 Experimental hall

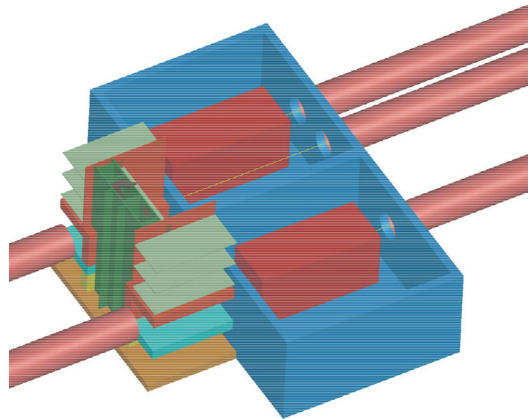


Fig. 13 Dump hall

3.4.4 Dump Halls

The energy of the beams (17.5 MW for the 800 GeV machine) will be absorbed permanently by water tanks about 10m long [2]. They need lot of radiation shielding and two independent water circuits for cooling. So there are 2 halls each 31 meter long and 74 meter wide (for both detectors) to be built 240 m away from the experimental hall.

3.5 XFEL Buildings

The XFEL facility will consist of a tunnel for the injector and a superconducting linac like the TESLA main linac which will be 3.7 km long in a geometrical straight line. It will be followed by a switchyard (1.3 km long) of 10 beamlines (perhaps built in two stages) housing undulators up to 300 meters in length. There will be 8 separation shafts and 4 halls for beamdumps in this switchyard which follows a tilted plane to reach the experimental hall (196 x 34 x 15 m) which will be located on the surface of the earth. The switchyard will be covered with an additional layer of sand for radiation shielding.

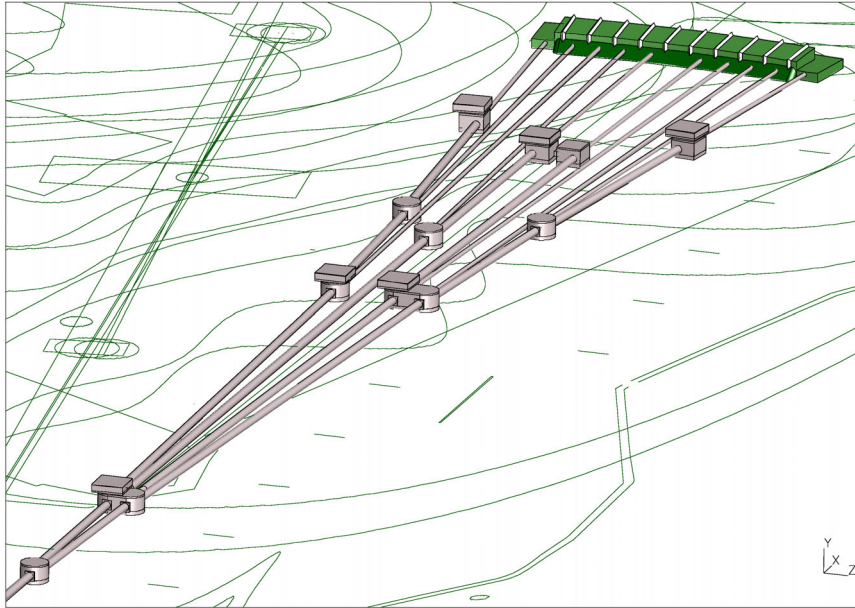


Fig. 14 XFEL building

4. PLANNING STEPS FULFILLED

In March 1998 a state treaty between the two federal German states of Freie und Hansestadt Hamburg and Schleswig-Holstein was signed to jointly prepare all the necessary planning steps and documents for the legal procedure. For the survey aspects this treaty says that it is allowed to go on private property and build geodetic monuments there. Furthermore all official documents are cost free [7]. The state treaty has been ratified by both parliaments.

In 1999 a Conceptual Design Report [3] was released.

In 2000 a meeting was held by the authority and attended by all parties concerned fixing the scope of the design and the next steps towards a formal planning procedure (scoping meeting).

In 2001 the Technical Design Report (TDR) was released [1] [2]. This paper was the basis for a review of the TESLA project by the German Science Council (Wissenschaftsrat) in preparation of the German position concerning the approval of the TESLA project. In July 2002 a positive statement was published [6].

5. LEGAL PROCEDURE

The state treaty says that the plan approval procedure has to be done by the rules of the German law of administration procedures (Verwaltungsverfahrensgesetz) [8]. The special procedure here to be obeyed is called Planfeststellungsverfahren. That is a public procedure in which everyone who is afflicted can take part so that no private negotiations are necessary.

Approval authority is the Head Bureau of Mining (Landesbergamt) in Clausthal-Zellerfeld and the Bureau of Mining (Bergamt) in Celle will supervise the construction.

An integrated environmental impact study is mandatory. An important part of this is a hydro-geological report which shows for instance the impact of pumping 50m³ water per hour [5].

Besides drawings of the buildings and sites and a report a list of all afflicted properties is an important part of the documents. Afflicted are besides those which are needed for the cryogenic plants all within a strip of 8 meters on each side of the tunnel. Here it is not allowed to dig into a region 9 meters above the tunnel. This restriction of the property has to be secured by writing it down in the public register and the owner will get a compensation in money.

It is planned to present all the documents to the public in an electronic way at so called “e-kiosks” in all afflicted communities.

After statements of the authorities a public hearing will be held for all neighbors of the facility. After that the approval authority will make its decision.

A positive decision means that the collider can be built (one must start within 5 years) and it is allowed to run the facility. No further approvals are needed, it is a one step procedure.

If the necessary land for the sites or the allowance to build the tunnel under private property cannot be got by negotiations then expropriations are possible.

6. TEAM ORGANISATION

To prepare the documents for the plan approval procedure a project group (TPL) was formed at DESY. Members of this groups come from different groups in the DESY hierarchy together with engineering bureaus for civil engineering, environmental study, geology and construction management. The DESY employees formally stay in their group but some of them are working together with the engineering bureaus in an extra building.

For some special tasks like experimental hall, tunnel layout, beam dump or safety issues working groups have been formed. The results of these groups are regularly reported to the project group.

7. PLANNING TOOLS

Based on experiences at CERN and with large-scale projects in industry the full life cycle of TESLA has to be supported with consistent data. This includes design, construction, installation and operation in the proposed “Global Accelerator Network”[1].

For spacial data like maps the DESY geographic information system based on the CAD software GDS will be used until a more modern system will be implemented. All 3D modeling including that for civil engineering has to be done with the IDEAS software from SDRC which is

mainly a mechanical CAD system. Viewing and printing of the 3D models can be done without having an IDEAS license installed with the digital mockup (DMU) tool EAI VisView.

An Engineering Data Management System (EDMS) is used to maintain access in a structured way for everyone involved in the project to any kind of documents. The software Metaphase from EDS has been chosen as that strategic tool.

For preparing the documents for the plan approval procedure it is crucial to have an overview about the requests from all working groups for a specific building. That is supported by a Request Management System based on an Oracle database. The tool chosen is Requisite Pro from Rational.

The project management is supported by MS Project.

8. TIME AND COSTS

It is planned to begin with construction in 2004. One year later 4 tunnel boring machines will start simultaneously at different places so that in 2008 the construction phase will be finished. The installation phase will begin in 2007 after finishing the first tunnel section and last until the end of 2012.

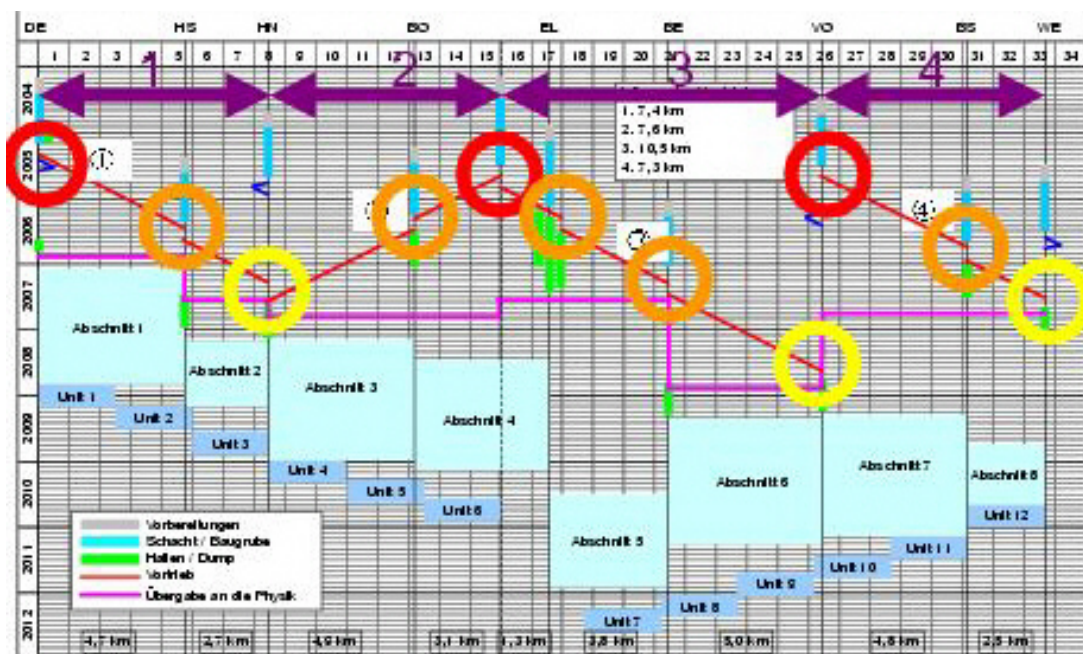


Fig. 18 Possible time schedule

Based on industrial studies the costs of the TESLA project for the baseline design has been evaluated for :

- The 500 GeV electron-positron collider : 3136 million €
- The accelerator components for the X-ray FEL : 241 million €
- The equipment cost for the FEL : 290 million €
- One detector for particle physics : 160 million € to 280 million €

So the total cost will be 3947 million € [1].

9. NEXT STEPS

In November 2002 the Technical Design Report for a separate XFEL linac will be handed out to the German Science Council so that it can publish its final report.

In parallel to this evaluation a number of international review processes are taking place all over the world [1].

In 2003 after the principal approval by the German Federal Government the legal procedure can be started and after successfully finishing of this procedure start of construction can take place in 2004.

To get the commitment of long term involvement and financing of the project by the participating institutions and countries a new legal structure outside the DESY structure has to be found. This may be a German “Gesellschaft mit beschränkter Haftung (GmbH)” which corresponds to a Limited Liability Company in English and American Law [1].

10. REFERENCES

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