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"The Future of High Energy Physics"

Executive Summary Working Group Environmental Control (T6)

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Working Group Conveners
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Charge

For the next generation of large accelerators, the civil engineering of accelerator tunnels and associated underground enclosures will be a major component of the technical challenge of building such machines. Because of the large scale involved, the engineering will be required to be as cost-effective as possible, and issues such as ground motion and artificial sources of vibration in the environment will need to be carefully considered. Installation and alignment of the machine components will be tasks of unprecedented scope, and will require unprecedented precision. Examine in detail the most important and most difficult aspects of these challenges, both from the point of view of performance and cost-effectiveness. In particular, identify what the site requirements are for the different machines under discussion (NLC, TESLA, VLHC, Muon source), and describe how tunneling methods are affected by them. Identify, for the different types of accelerators, the different length scales that are involved in defining the alignment tolerances, and what are the tolerances over that length scale. Specify the R&D efforts needed to define the scope of the most critical challenges, and prioritize the efforts, in terms of the potential to provide maximal performance and/or cost-effectiveness. Establish a technology-limited time line, and the resource requirements, for the most important of these efforts.

Speakers

Fred Asiri, SLAC; Ralph Assmann, CERN; Wilhelm Bialowons, DESY;
Reinhard Brinkmann, DESY; Phil Burrows, Oxford; John Cogan, SLAC; Clay Corvin, SLAC;
Bill Foster, FNAL; Joe Frisch, SLAC; Peter Garbincius, FNAL; Lindemar Hänisch, DESY;
Linda Hendrickson, SLAC; Vic Kuchler, FNAL; Joe Lach, FNAL; Chris Laughton, FNAL;
Catherine LeCocq, SLAC; Tom Mattison, UBC; Rainer Pitthan, SLAC;
Johannes Prenting, DESY; Armin Reichold, Oxford; Michael Schmitz, DESY;
Andrei Seryi, SLAC; Nick Simos, BNL; Steve Smith, SLAC; Peter Tenenbaum, SLAC

Tunneling experts (attended the workshop during July 9-10)

Robert Bauer	Illinois State Geological Survey
Philip Frame	Consultant geophysicist
Donald Hilton	Donald Hilton & Associates
Dennis Lachel	LACHEL & Associates, Inc.
Dave Neil	NSA Engineering, Inc.
Lars Babendererde	Babendererde Ingenieure GmbH
Toby Wightman	American Underground Construction Association

Scope. For the next generation of large accelerators, the civil engineering of accelerator tunnels and associated underground buildings will be a major component of the technical challenge of constructing such machines. Between a sixth and a half of the total costs for these machines must be used for the civil engineering. Because of the large physical scales of these machines the engineering will be required to be as cost-effective as possible, and because the considered beam sizes are of nanometer scale, issues such as structural and thermal stability, ground motion and artificial sources of vibration in the environment will need to be carefully studied. The working group concentrated on tunneling, ground motion, stability, alignment and environmental issues.

Ground motion. Known information on ground motion (spectral, correlation) suggests that the considered machines (NLC, TESLA, VLHC, Muon source) are feasible. Particular concerns for each of the machine are summarized below.

In the VLHC the main effect of ground motion is emittance growth; for the high energy stage, the rms uncorrelated motion of 0.3nm above ~250Hz would result in doubling the emittance in ~2.5 hours. This is still a modest growth rate in comparison with the one for TMCI and resistive wall instabilities that would need to be cured by feedbacks. The natural ground motion in deep tunnels is much smaller than 0.3nm above ~250Hz, the concern for VLHC is not the natural ground motion, but vibrations that may be created by equipment installed in the tunnels, the enhancement of vibrations by girders and internal mechanics of cryostats. These issues need to be addressed in design and further engineering tests.

In linear colliders the primary concern is beam offset at the IP induced by ground motion. In the TESLA and NLC designs, the tolerance for uncorrelated motion of quadrupoles is about 10nm, though the relevant frequency range roughly defined as $f>F_{rep}/20$ is different (f>0.2Hz for TESLA and f>6Hz for NLC). For the NLC case, even in modestly quiet sites, the motion is below these tolerances. For TESLA, due to low repetition rate of collisions, the motion, even in quiet sites, may reach the tolerance limit. However, due to large separation between bunches, a correction within a bunch train is possible for TESLA. An issue of concern for NLC, and to a lesser extent for TESLA, is cultural noise that may greatly increase vibration in the tunnel. In an urban area, a deep tunnel solution appears to be the best alternative. Local geologic factors (soil and rock stiffness, structure and water table) will strongly influence the in-tunnel vibration characteristics. Site-specific models of vibration propagation need to be studied in more detail. In terms of slow ground motion (minutes to months), the impact on NLC performance is more serious than on TESLA due to higher RF-frequency. Nevertheless, measured amplitudes are tolerable for NLC with a shallow site in glacial till being the most critical case. Studies are planned that would clarify this conclusion.

Site criteria and technical requirements. High Energy Physics frontier accelerators are large and complex. Ideally, they should be constructed close to an existing laboratory site. The environmental impact of the project is minimized for a tunnel solution rather than a cut and cover that would involve greater surface disruption. In many respects, the tunnel design requirements for the beamline housings are not unlike the requirements for underground rail or metro tunnels. However, some key requirements, related to stability and watertightness, are more stringent than those normally associated with underground design. Meeting such criteria could be difficult to achieve in some ground units and may require design and construction mitigation measures that are not currently accounted for within in the framework of the pre-project plans. Better knowledge of key design parameters of certain ground units is necessary in order to be able to evaluate, with some confidence, the types of design mitigation measures that will be needed to meet stability and watertightness requirements.

Subsurface ground conditions. None of the projects have performed site investigations of the subsurface conditions (borings, seismic work or laboratory testing) along a specific tunnel alignment. At present, TESLA is the only project that has selected a tunnel alignment. Site-specific investigation of this alignment is scheduled to start soon. Confidence in ground conditions along the TESLA tunnel route is already fairly high given the relatively large amount of existing geologic, geotechnical and construction reference data available in the Hamburg area. Based on this data, site conditions along the alignment are projected to be similar to those encountered during the construction of HERA. There is only a limited amount of geological, geotechnical and construction data available to describe some of the ground units in which the proposed NLC and VLHC tunnels will be sited. For these ground units there is a need for additional geotechnical data to be gathered before realistic plans and costs for excavation and tunnel construction can be developed with confidence. Geotechnical data and design studies are needed in the following key areas: For the California and Illinois Tunnels sited in Expansive Shales: The impact of swelling pressures and/or displacement on the excavation, arch support and foundations of beamline housings needs to be studied. For the VLHC tunnels sited in St. Peter Sandstone: The impact of groundwater, in situ stresses and presence of abrasive minerals on the excavation and support of beamline housings needs to be studied. For California sites: geologic and geotechnical properties related to tunneling and cut and cover excavation and long term facility stability; and groundwater conditions. For the Illinois Tunnels and Halls: The impact of high horizontal in situ stresses on the excavation and support of tunnels and, in particular, any large span openings (e.g. Interaction Regions), needs to be studied further. The Muon Source facility sited at Fermilab (the only site presented) benefits from geotechnical data archived from other projects, most recently the Main Injector and NuMI. Geotechnical parameters are anticipated to be similar with those collected for other local projects.

Construction issues. The layout and construction concepts being developed for TESLA will be largely consistent with those of the HERA Project. The design concepts for VLHC and NLC are still evolving. VLHC is looking at two representative sites in northern Illinois. NLC has identified a number of representative sites in California and Illinois. Cut and cover, cut and cover-tunnel combinations and various tunnel layout options are being studied. To date, none of these layouts has been subject to either "constructability" or value engineering reviews. Constructability reviews are designed to ensure that the layouts being developed to satisfy end-user requirements could actually be built cost-effectively using standard industry equipment and materials. Value Engineering reviews would enable technical and conventional designers to perform trade-off studies in the different areas of the project with the aim of identifying lower cost solutions that still respect the functional requirements of the project.

Conclusions and recommendations in terms of tunneling. For the VLHC and NLC sites, it is important that a scope be developed for preliminary site investigation requirements. The Scope of the investigation of proposed sites should identify key design issues. For the VLHC and NLC sites, it is important that a process be established for reducing the number of potential sites and selecting a single site as soon as possible. A prioritized list of site selection criteria should be developed that can be used to help select specific sites. All the projects would benefit from constructability and value engineering reviews. These reviews should be undertaken with the participation of industry professionals at key moments in the design process. In the future there may be potential for the use of R&D products on one or several of the proposed projects. However, cost benefits are only likely to be achieved if bidding contractors have seen such products successfully applied underground and such products are stated to be acceptable within the construction contract. It is recommended that on-going R&D projects continue to be actively monitored and periodic assessments made to evaluate if cost savings can be achieved through the adoption of a R&D product on a given site. To date, project plans for underground work have largely been developed in-house, at individual laboratories, with indirect input from the underground industry. The formation of an underground advisory panel is recommended to improve access to tunneling expertise and help develop and coordinate plans for site investigations, designs and technical reviews for all the projects. It is recommended that the panel include international members who can relate recent underground construction experience from overseas locations, such as the Australia, Europe and the Far East.