CERN

Linear Collider Study Task 1 and 2

Technical Basis for Study

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1 Introduction

This document defines the basis for two studies relating to the construction and operation of the detector region of a new Linear Collider (LC) as discussed at the recent ILD Workshop held at LAL, Orsay on 24th May 2011.

Presently two forms of collider are being developed, the CLIC and ILC. These differ in a number of aspects, but share some key technical challenges. Arup will be assisting the technical teams by evaluating two of these challenges from a civil engineering perspective:

Task 1 - The development of a design concept for a platform that is compatible with both air-pad and roller movement systems to move two large detectors in and out of the beam line

Task 2 - The layout of the detector cavern complex from a geotechnical standpoint, using the current CLIC layout and CERN geology as the initial model

The general approach for task 1 and 2 are discussed in this report, followed by a set of performance and design criteria defined at the ILD workshop. These criteria define the technical basis for the Arup studies. These will be considered as “fixed” for the purposes of Task 1 and 2; however it is recognised at such an early stage of a complex project that these do not necessarily fix the design criteria for the LC design and may subsequently change.

As the studies progress the need for further design input is likely. This report will be updated and re-circulated periodically to capture this new data and update the collider design teams. The frequency of update will depend on the impact and quantity of data affected.

The programme for the studies will be to progress studies and present an interim report to the next workshop to be held in Granada, Spain in September. This workshop will be an opportunity to refine the study before a final report is produced by the end of 2011.

2 Task 1 Work Plan

The general scope is as per our proposal to Fermilab "CERN Fermilab LC Interaction Region (IR) Design Studies - Engineering Proposal for Technical Services" of 25 May 2011. The following points detail the main aspects of the design of the platform and transportation system which will be included in our interim report in September 2011.

2.1 Structural Design Basis

The platform design will be developed from the basic parameters listed in Section 4 of this report. From these a series of specific load cases and performance criteria will be developed for the platform design. These will include

- Ultimate Limit States (ULS) to be developed for platform strength.
- Serviceability Limit States (SLS) to be developed for platform deflection.
- Completion of platform scheme design and dimensioning to meet ULS and SLS requirements.

A design basis document will be developed for the system including the ULS and SLS load cases and acceptance criteria.

2.2 Platform Design Development

Using this design basis, a Finite Element Analysis will be completed in Oasys-GSA and/or MSC NASTRAN for all SLS and ULS load cases identified (several of which are highlighted in the bullet points below).

Case 1 - Analysis of the jacking of the platform onto long-term supports (in the garage) for the first time after construction, to include:

- Platform strength design - ULS load case,
- Check cavern floor ULS and SLS load cases

Case 2 - Analysis of the platform with the detector "slices" positioned in a series of different locations when the platform is in the garage on its permanent supports (several platform SLS and ULS load cases to be identified for the Design Basis).

Case 3 – Analysis of the detector when on the beam line

- Deflection and dynamic response in situ
- Movement when detector slices are opened on the beam line
- Long term stability of the slab/floor as a system and ongoing settlement effects

2.3 Transport System

The development of a scheme design of the transportation system is an ongoing process with the use of air pad and roller solutions in discussion. The platform design will be progressed with the goal of allowing either system to be utilised. Key impacts of the transport system on the platform design will include:

Case 1 - Analysis of the process of transfer from the permanent supports to the transportation system (eg. A jack system on rollers or air-pads).

- Design the platform (or consider other design changes/concepts) to limit the platform deflection to meet the SLS limits.
- Evaluate bending moments and shears in the platform for scheme design of reinforcement.

Case 2 - Develop a concept for the movement process which meets the SLS limits (other than the movement system itself):

- Develop a cavern base profile to allow access to the transportation system in the garage, on the beam line or between the two.
- Develop a methodology for placing the platform in approximately the correct place near the beam line (circa +/- 5mm).
- Develop a methodology for positioning of the platform and detector on the beam line in accordance with the Design Basis (+/- 1mm).
- Develop a concept for adjusting level whilst the platform is on the beam line (if considered required).
- Develop a methodology for transferring the platform from the transportation system to long-term supports on the beam line whilst meeting the SLS limits.
- Analyse the platform under the effect of magnetic field when on the beam line and ensure that the performance criteria are met. Feed back into the design and modify the design if necessary. This will consider the effects of Stainless steel and non-metallic reinforced bars for possible detector solenoid interference

2.4 Geotechnical input

In parallel with Task 2, the cavern study team will provide input to platform design by considering the effects of excavation, lining and operation on the ground. This will establish the ground response element of the platform design and will involve the following tasks. The cavern analysis will utilise CERN data as a basis. Should measurement results and data be available from other detector sources they will be reviewed for relevance to the cavern study prior to inclusion in the study data.

- Consideration of the effects of unloading the ground (by cavern excavation) and partial re-loading (by loading the cavern lining) prior to application of the slow cyclic detector loads. Simplified 2D models will be used for this purpose to develop representative stress-paths for the molasse subgrade.

- Assessment of the loading cycles and stress-path directions in the Molasse associated with movement of the detectors. This will require an iterative process between the geotechnical analysis and the optimisation of the transport mechanism. This is because the magnitude and distribution of loading will change with different transport systems; the different stress and strain distribution will result in variations in stiffness of the Molasse subgrade and hence the displacement of the transport system.

- Development of a simple non-linear and time-dependent constitutive geotechnical model for the molasse suitable for this study. This will be informed by the desk study work carried out in parallel for task 2 and will also benefit from in-house Arup experience in other heavily over-consolidated argillaceous “weak rocks”.
- Development of a simple 2D/3D finite difference numerical model of the platform-cavern invert-underlying molasse “system”, in order to calculate the effects of unload-reload cycles and the potential for hysteric behaviour over the lifetime of the facility. Optimisation of the geometry of the cavern invert will also be if time permits and will inform possible alternative cavern shapes in the Molasse to be considered under task 2.
- General comments on how this study would indicate different results were the detector halls located in a stronger rock such as limestone/dolomite/granite.
- General comment on Seismic effects at CERN and potential effects on slab and cavern performance in other locations will be commented on in general terms. It is envisaged that location-specific studies would be required to assess cavern and slab performance in detail in other candidate locations.

2.5 Scheme Design

Key deliverables for this stage will be drawings and reports describing the scheme design of platform and transportation system with indicative reinforcement. This will include a description of the main aspects of the transportation system and a step by step description of the movement process. It will not select either air pad or roller, but will comment where each system influences platform or cavern design.

3 Task 2 Work Plan

The scope of work envisaged for this task is as set out in our proposal letter (ref. 600156-16/147/270411/MJS/SRM) dated 27th April 2011. In summary the following aspects will be covered in this task:

- A desk based assessment of published and CERN data on the geology and geotechnical conditions at CERN
- Assessment of in situ stress conditions, geotechnical properties, structure, stratification, groundwater conditions and mineralogy of the Molasse. If feasible, discussions will also be sought with experts on the geology of the area known to CERN.
- Review of precedent experience at CERN, in particular the time-dependent ground movements around the Large Hadron Collider.
- Attempt to establish links with previous problem areas and particular stratigraphic horizons or mineralogy of the molasse.
- Briefly review of construction methods and analogous experience at other similar facilities (e.g. the Underground Research laboratories at Mol, Belgium and Mont Terri, Switzerland).
- Review geotechnical constitutive models that have been used and may be appropriate to characterise the inelastic and/or time-dependent behaviour of the molasse.
- Develop a 3D CAD model of the current layout of the CLIC detector halls for input to an elastic boundary element model in order to study the potential for over-stressed ground which can lead to time-dependent and inelastic behaviour.
- If time permits, an alternative cavern layout and shape, that may satisfy the experimental requirements set out below, whilst optimising the civil engineering requirements may be proposed.
- The design will be executed, bearing in mind that a future date, a similar study could be performed for other sites such as near Chicago or Japan Therefore general comments will be included on how this study could indicate different results were the detector halls located in a stronger rock such as limestone/dolomite for the Fermilab site and Granite for Japan.
- A generalised “risk register” will be compiled, summarising the potential risk issues to be addressed in future design/investigation stages.

On completion of this work a brief report will be compiled, summarising the results of these studies. Recommendations for future studies and investigations to be undertaken prior to the detailed design of the final detector hall layout will be made.

4 Design Basis for Study

The criteria defined below are to be used as the basis for Tasks 1 and 2. It should be noted that there are different criteria for ILC and CLIC designs. For task 1 particularly, the basis of design uses the most onerous requirements from each design. Typically this used the largest or heaviest elements of design where there is a difference between the two designs. On this basis the results of the analyses should demonstrate the viability of design concepts for all current IR designs.

It is recognised that in certain circumstances selection of the largest/heaviest element may not be the most onerous design case. Where these situations are identified, additional criteria may be sought from LC design teams.

The criteria have been separated by task and then split into performance requirements or design criteria.

Please note all figures are SI and in "English" form (i.e. one thousand is 1,000)

4.1 Task 1 – Movement Platform

Platform Design Criteria		Value	Unit	Notes/assumptions
Detector		ILD		ILD is currently the most onerous system in terms of spatial and weight requirements
Detector Total Weight		15,500	tonnes	Fully installed weight including services and supply etc for movement to beam. It is assumed that additional weight is not added to the detector (and therefore the platform) once on the beam line, or at the garage
Detector Segment Weight	Door -Z	3,500	tonnes	An important design case for the platform will be when the detector is split for maintenance either on the beam line, or in the garage position. Weights provided by email (Oriunno-Osbourne 27th May 2011). The SiD and ILD have different combinations of slices when split. The worst loading case will be determined from the various combinations of ILD and SiD ring maintenance arrangements
	Barrel -1	2,500	tonnes	
	Barrel 0	3,500	tonnes	
	Barrel +1	2,500	tonnes	
	Door +Z	3,500	tonnes	
Slab Vibrations Modes	First Mode	20	Hz	Assumed feet and ground infinitely rigid with damping ratio of ~2%
	Further Modes			To be advised and informed by study, to include feet, invert slab and ground are expected to add compliance to the platform system
Magnetic field at top of platform		<1,000	gauss	It has been assumed that this is at the top of the platform
Operating Temperature Range		20^{o}C $\pm$ 2^{o}C		

Platform Design Criteria (continued)		Value	Unit	Notes/assumptions
Movement System	Mechanism	Rollers or air pads		The platform design will be developed to be compatible with either roller or air pads. Should the design place any onerous performance requirement on one particular system this will be identified and where appropriate a mitigation measure identified. If a single platform design cannot service both systems clarification will be sought on the movement system to be used.
	Drive	Gripper jacks		
Platform	Concept	Single platform per detector		The design will be progressed on the basis that the two detectors are moved independently on separate platforms
	Material	Reinforced Concrete		A Steel support truss will not be considered further
	Footprint	20x20	m	
	Elevation	Study to confirm this		Beam to top of platform set by detector, platform depth below to be established during study. ILD to be used as greater beam to base distance (thinnest platform for same rail level)
Minimum distance between detectors		15	m	Minimum proximity of detectors at any location measured from exterior of iron

Platform Performance Requirement		Value	Unit	Notes/assumptions
Movement duration		5	hours	This is assumed to be the detector "speed" when travelling and would therefore not include preparation time to disconnect/connect detector or preparation of the movement system
Speed		>1	mm/s	(after acceleration). Assumed that the 5 hour requirement governs
Number of movements		10	year^{-1}	Assumed that both detectors will be moved an equal number of times
Limit of acceleration		0.05	g	This is a limit during movement
Maintenance allowances	On Beam	2	m	This is the between adjacent sections (end cap to centre section) when detector opened in the beam location
	In Garage	6	m	This is the between adjacent sections (end cap to centre section) when detector opened in the garage location
Static Deformation of platform		+-2	mm	In all locations, including during movement (as a single element or in sections)
Positioning relative to beam		+-1	mm	In relation to the beam location

4.2 Task 2 – Cavern Study

Cavern Design Criteria		Value	Unit	Notes/assumptions
Initial Geometry		CLIC		Initial Geometry to be based on CLIC geometry as indicated in CLIC drawing number CLIC.CE-17000001D
Geometry concepts	**Configuration**	"Z"		No crane beam in transfer tunnel, cranes in garage area leading to Z configuration (garage axis notionally parallel to beam), cable chain and umbilical provision above detector at beam position
	Passive provision for shielding			Space provision to be maintained for shield doors (dual shield and ventilation isolation function). Provision to be maintained in movement system to allow shielding to move into position
Geology		Current CERN Geology		The ground model for the studies will be developed based on information currently available from previous projects at CERN. This information is held and will be accessed from the CERN data systems