Machine Detector Interface

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DESY

ILC Project Advisory Committee
Eugene, OR
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1. The ILC Machine-Detector Interface Organisation
2. Push-pull System Design Study
   a. Detector Motion System
   b. Underground Hall Design
   c. Detector Assembly and Integration
   d. Detector Services
   e. Final Doublet Magnet Developments
   f. Alignment Systems for Final Doublet Magnets and Detector Elements
   g. Vacuum System Design
   h. IR Feedback System Design
3. Conclusions and Outlook
The MDI Common Task Group

- Common task group of the Research Director’s organisation:

- **Members:**
  - K. Buesser (DESY, convener)
  - P. Burrows (Oxford, dep. convener)
  - A. Hervé (ETH Zürich)
  - T. Markiewicz (SLAC)
  - M. Oriunno (SLAC)
  - T. Tauchi (KEK)

- Usually meets in phone meetings (~ monthly)
- Close contact to the GDE BDS group
  - A. Seryi participates regularly in the phone meetings
IR Interface Document

- Common document of the MDI-D common task group together with the GDE-BDS group
- Definition of the functional requirements to allow a friendly co-existence of two detectors and the ILC machine in a push-pull scenario
- Provide a set of ground rules, not technical solutions to the problems!

- Document has been discussed in detail between the MDI-D and the GDE-BDS groups
- Approved by concept groups, BDS technical area leaders and PM for accelerator systems
- Published as ILC-Note-2009-050
Bi-lateral Discussions

Interface Doc.

Functional Specifications

SiD
ILD
IDAG Review

Today

Technical Solution #1
Technical Solution #2
Technical Solution #3
Technical Solution #n

Tomorrow

IR / MDI

Technical Specifications

One day

IDAG + MDI

(IDAG + MDI)

(Platform)
(Rollers)
(QD0 supp.)
(Pacmen)
• Most important topic in ongoing MDI work is the design of a realistic push-pull system for the detectors

• Push-pull design study proposal:
  • Originated in request by ILCSC:
    • Offered help to find additional engineering resources for detector developments and push-pull design
  • MDI group prepared a proposal for a design study on the push-pull system
  • Submitted to ILCSC by B. Barish and S. Yamada in July 2010

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Design Study for the Interaction Region
Push-Pull System for the ILC

Authors
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Motivation
The Interaction Region push-pull system represents one of the most technically challenging areas of the ILC, whose performance may determine the success of the entire collider. Challenges range from civil construction to detector sub-system performance. Design of the push-pull system is progressing; however, the complexity of the problem requires enhancement of the current efforts. In particular more support for the engineering design of the components is needed in order to arrive to a mature design before the end of 2012. Besides the clear alignment of the work to the ILC Technical Design Report, it should be noted that synergies are expected to come from close collaboration with similar efforts in the CLIC collaboration.

Current Status of Work
The push-pull arrangement of detectors is not a new idea; however, it was never realised in practice to the extent required for ILC in terms of reliability and efficiency. For ILC, the push-pull arrangement was evaluated on the conceptual level in 2006, and while it has been determined that the technical issues have conceptual solutions, it was deemed that “careful R&D and engineering studies will be needed during the TDP time to validate and optimize the proposed configuration”, as stated in the GDE push-pull Configuration Change Request (CCR) to the ILC baseline approved in early 2007.

Interrelation of technical challenges for the push-pull system is best expressed and grasped pictorially as an interrelation diagram (c.f. Figure 1).
Identified Tasks:

1. Design of the detector motion system; study of its vibration properties in simulation and experiment.

2. Design of the IR underground hall for push-pull, including facilities and services for the operation of the detectors, radiation shields, seismic issues, impact of safety rules.

3. Optimisation of the detector integration and its impact on assembly procedures, magnetic and radiation shielding, vibration sources.

4. Design of detector services supplies for push-pull (data and HV cables, cryogenics).

5. Design and prototype of the final doublet quadrupoles and verification of their stability.

6. Design of alignment system for the final doublet magnets and the inner detector components, including the design of a laser interferometer system.

7. Study on IR vacuum design, including vacuum requirements and design of quick connection valves.

8. Study of intra-train feedback systems in a push-pull system.
Push-pull Design Study Proposal

- Estimated resources over two years:
  - at 14 institutions
  - Existing:
    - ~9.25 FTE (best estimate)
  - Requested new:
    - 14.5 FTE
    - 1.5 FTE out of those are recently supported by KEK for detector integration and hall design
  - CERN is taking relevant steps towards a contribution of 2 FTE
  - Waiting for more
- Critical milestone: decision on common detector motion system by March 2011
- Programme is under progress with existing resources, re-scoping might need to take place
Push-pull is not an easy task!

Inter-relations of technical challenges:
Detector Motion System
ILD prefers platform based design:

- All services would be run through cable-chains (including cryogenics)
- Main bus-bar for voltage supply to the detector solenoid
- Aim: two days for the push- or pull-operation
  - one day for the mechanical movement
  - one day for calibration
  - after significant learning curve experience
SiD Push-Pull Concept

- SiD wants to run on hardened steel rails using Hilman rollers
- Time needed ~1 day for luminosity-luminosity transition
  - learning curve effects will be involved....
Motion System Options

- **Option 1**: ILD and SiD moving on the floor

- **Option 2**: ILD on a platform, SiD moving on the floor

- **Option 3**: ILD and SiD on platforms
  - could have different heights
Pros and Cons of a Platform

**PROS**
- Decouples detector support from ground floor behaviour
- Separates push-pull moving system from detector
- Reduces vibrations during detector movement
- Keep inter-alignment of detector parts
- Movement directions are decoupled
- Possible earth-quake damping system
- ILD design depends on it (yet)
- Potentially less expensive
  - if ground preparations for non-platform system are difficult

**CONS**
- Adds additional complicated system to a challenging task
- Easier access to detector motion system
- Proper floor preparation and proper designed rail based motion system might be easier to realise
- Platform is an additional source or amplifier for vibrations
- Potentially more expensive
  - cost for platform
With Airpads a simple positive indexing mechanism is possible giving ≈mm precision.
QD0 Supports

ILD00 model  ILD QD0 support system

M. Joré

Independent Supports (Cavern, Pillars Platform)

Low Coherence

Common Supports (Detector under mag.field)

High Coherence

Introduction

Vibration properties of the ILD QD0 support system has been studied.

ILD QD0 support system

ANSYS model

QD0(700kg)

BeamCAL(100kg)

LHCAL(3000kg)

LumiCAL(250kg)

ECAL(420kg)
ILD QD0 Vibration Calculations

**Calculation (Presented at Beijing meeting)**

Respond amplitude at each position is estimated.

- **Inner cylinder:** Self-weight + 1 tonne (QD0)
  - 0.6 nm > 5 Hz: 2% damp
  - 0.4 nm > 5 Hz: 5% damp

- **Outer cylinder:** 4 tonnes
  - 3.8 mm (outer) 8.6 Hz (1st mode)

- **Additional ribs**
  - Fixed
  - Thicker: 200 → 400t

- **Integ. Amp.**
  - 100 nm > 5 Hz: 0.5% damp
  - 54 nm > 5 Hz: 2% damp
  - 38 nm > 5 Hz: 5% damp

- **P.S.D.**
  - 1 nm > 5 Hz: 0.5% damp
  - 0.6 nm > 5 Hz: 2% damp
  - 0.4 nm > 5 Hz: 5% damp

H. Yamaoka
Random vibration Studies: SiD O.K. on the floor, no platform

PSD

fo = 5 Hz

PSD

fo = 10 Hz

Integrated r.s.m. displacement

30 nm

20 nm

M. Oriunno
Platform Vibration Analysis

Total mass 1800 t

Reinforced concrete Slab

2 m
18 m
20 m

Steel plate 30 mm at the bottom

Steel re-bars 16mm²

Four support lines for 4’000 tons each

10kt Anti-seismic supports

M. Oriunno
Platform Vibration Analysis

Static deformation, 1 mm

Normal mode, 43 Hz

Normal mode, 58 Hz

Normal mode, 58 Hz

M. Oriunno
Steel reinforcement of CMS Plug ⇒
Models need benchmarking
to evaluate damping and Young’s modulus
New Vibrations Measurements done at CERN last week, Analysis of the data in progress (CERN-EN Department)

- Absolute PSD spectra on various locations on the top of the platform, P1…P7, with the reference points PREF1, PREF2
- Relative PSD spectra, P12, …. P17 (Coherence) (can be calculated from the previous measurements)
- Transfer functions on various locations on the top of the platform P1-2-3-4-5 with respect to the reference points
- Transfer Functions P1…P7 with reference to the ground vibration

Data taken at CERN in October

Reference geophones
Platform geophones
Vibration Calculation Benchmarking at KEK

Vibrations (Amplitude)

- Beam dir.
- Perpend.

Graphs showing integrated amplitude vs. frequency for different conditions and directions.

- Vertical and horizontal vibration calculations.
- Comparison between platform, floor, and calculated values.

H. Yamaoka
Cavern: Magnet powering and Cryoline

Magnet power lines

Rack space

H. Gerwig
The detector motion system must never fail!

• Any failure of the system has the potential to shut down ILC operations for very (!) long times
• The system must be designed for repeated reliable and safe operations

• This needs to be studied carefully:
Moving Heavy Devices is Difficult!
Moving Heavy Devices is Difficult!
Moving Heavy Devices is Difficult!
Detector Motion System Decision Process

- Either both detectors will be on a platform or no platform at all
- ILD detector design - integration and assembly procedures - is interwoven with the platform concept
- SiD prefers a possibly simpler rail based system

Most important topics:
- Vibration analysis:
  - Benchmarked FEM calculations of the full system:
    - Ground → Motion System → QD0 Support → Magnets
- Risk analysis
- Design changes to existing concepts
- Cost

Decision needs to be taken in 2011
- Design changes to the detectors need to be done
- DBD/TDR is due in 2012

Envisage decision by the time of the Oregon workshop: 03/2011
Civil Facilities and Underground Hall Design
Detector Assembly and Integration
Plan and Sections (Europe)
For Comparison: CMS

- RDR Design needs to be elaborated w.r.t. the real needs of the experiments:
  - Optimisation of underground space
  - Detector services needs
- Close collaboration with CFS group planned

ILC hall design study

CMS

Pressurised emergency escapes

CMS – Surface buildings

- CMS assembly building staged construction
Site Adoptions

- Mountainous sites might change the CFS requirements significantly:
  - No vertical access shafts $O(100 \text{ m})$
  - Horizontal access tunnels $O(1 \text{ km})$ with smaller diameter

- Has impact on transportation of detector parts
  - Assembly procedures might be different
  - Surface assembly à la CMS not possible
  - Coupling of schedules between detector and machine construction need to be studied in detail
Detector Assembly

- RDR baseline:
  - Surface assembly of major detector parts
  - Lowering of big parts into the hall
  - Relatively short underground assembly and commissioning time needed

- If horizontal access tunnels:
  - Pre-assembly in smaller parts (e.g. maybe coil cannot be delivered in one piece)
  - Optimisation of underground assembly procedure (space and time) needed

![Access tunnel diagram](image)

Access tunnel

1/3 of cryostat outer shell

R = 5100

R = 10200

Y. Sugimoto
Final Doublet Magnet Developments
Alignment System Developments
QD0 split coil variant may be useful for low-energy running as a Universal Final Focus.

QD0 Split Coil Winding Implementation

View Inside QD0 Cryostat to Show Coil Positions and Support Infrastructure

“ILC QD0 R&D Update,” Brett Parker, BNL-SMD
QD0 R&D Tests and 2012 Time Scale

• Parallel to finishing QD0 R&D coil winding we are producing the Magnet and Service Cryostats needed for horizontal testing.

• Look to have operational experience on 2012 (TDR) time scale.

• Recently new ideas were put forth on measuring the field centers & vibrations.

• Also address issues for new Universal Final Focus.

Service Cryostat Under Construction at BNL

- Strain relieved lead connections
- Evaporator
- 4K heat exchanger
- Optimized copper leads
- High temperature superconductor leads

R&D Goal: Make and test Service Cryostat with 1.9K cryogenic transfer line for ILC-like running conditions.
• Conceptual studies to use an interferometric laser system for alignment of QD0 and detector parts:
MDI Alignment at CLIC

- **CLIC requirements:**
  - Position of QD0 w.r.t BDS: ± 10 µm rms
  - Monitoring left QD0/ right QD0: ± 5 µm rms

- **ILC requirements:**
  - ± 50 µm for QD0s before beam-based alignment

- **Synergies obvious**

**Monitoring of QD0:**
- Network of over-determined nodes linking each QD0
- Each node consists of a combination of RASNIK systems performing measurements through the detector, using the dead space between polygons and circular detector areas
- RASNIK systems calibrated with a sub-micron accuracy
- This project is part of a collaboration with NIKHEF institute.

**Alignment channels:**
- Typically ‘dead’ space between polygons and circular detector areas

**Preferred alignment channel:**
- Link stretched wires on both side by a common references (like in the LHC), using the survey galleries

H. Mainaud-Durand
Vacuum System Design
Vacuum

- Vacuum up to the valves between QD0 and QF1 will be provided by the BDS ($<10^{-9}$ mbar)
- Vacuum downstream of these valves is the choice and responsibility of the detectors

ILD beam pipe conceptual design:
- Made from beryllium (8kg mass in total)
- Vacuum simulation study done, $10^{-9}$mbar will be difficult to reach
Vacuum Studies at the IP

• Example ILD:

VACUUM DISTRIBUTION ON ILD
UNDER STATIC CONDITION

WITHOUT BAKING

What pumping?

Annular triode ion pump from LHC
15 cells 18 l/s(N₂) nominal, φ_{int} = 62, φ_{ext} = 200, L = 25.4

Optimized annular triode pump for experimental areas in the LHC, M. Busso and all, LHC Project Report 670

With ≈200 cells

M. Joré
IR Feedback System Design
IP intra-train feedback system - concept

Last line of defence against relative beam misalignment
Measure vertical position of outgoing beam and hence beam-beam kick angle
Use fast amplifier and kicker to correct vertical position of beam incoming to IR

FONT – Feedback On Nanosecond Timescales
(Oxford, Valencia, CERN, DESY, KEK, SLAC)
Integration in IP Region

Final Doublet Region (SiD for illustration)

- Cam/support
- Reacting bars
- Spool tubes
- QD0
- QF
- Oriunno
P2 $\rightarrow$ K1 loop performance
(February 2010)
Conclusions

• Machine-Detector Interface work is concentrating mainly on a design study plan for a realistic push-pull system for ILC
• Many related topics and technical issues need to be studied to some engineering detail
• Most urgent decision is the choice of a common detector motion system
• Engineering resources are very limited, ILCSC has offered help to find more
• Synergies with CLIC will be exploited

• Thank you!