Machine Detector Interface

Lau Gatignon / CERN-EN
Overview

- Introduction to Machine Detector Interface
- QD0 magnet design
- QD0 stabilisation and integration
- Backgrounds
- Post-collision line
- IP Feedback
- Other items
- Conclusion
What is the MDI

The MDI is the part of the CLIC facility (approximately) inside the detector cavern, i.e. the area in which there is a strong coupling of technical sub-systems of the machine and of the physics detectors. The lines for the spent beams shall also be considered part of the MDI.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>ILC</th>
<th>CLIC</th>
<th>Impact on MDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Center of Mass energy [GeV]</td>
<td>1000</td>
<td>3000</td>
<td>Detector design, backgrounds</td>
</tr>
<tr>
<td>Luminosity $L_{99%}$ [cm$^{-2}$ sec$^{-1}$]</td>
<td>$2\times10^{34}$</td>
<td>$2\times10^{34}$</td>
<td>Instrumentation</td>
</tr>
<tr>
<td>Bunch frequency [Hz]</td>
<td>5</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Bunch spacing [ns]</td>
<td>369</td>
<td>0.5</td>
<td>Background, IP feedback</td>
</tr>
<tr>
<td># Particles per bunch</td>
<td>$2\times10^{10}$</td>
<td>$3.7\times10^9$</td>
<td></td>
</tr>
<tr>
<td># Bunches per pulse</td>
<td>2670</td>
<td>312</td>
<td></td>
</tr>
<tr>
<td>Bunch train length [$\mu$s]</td>
<td>985</td>
<td>0.156</td>
<td></td>
</tr>
<tr>
<td>Beam power per beam [MW]</td>
<td>9</td>
<td>14</td>
<td>Spent beam line</td>
</tr>
<tr>
<td>Bunch length [$\mu$m]</td>
<td>300</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Crossing angle [mrad]</td>
<td>14</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Core beam size at IP horizontal $\sigma_x^*$ [nm]</td>
<td>639</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>Core beam size at IP vertical $\sigma_y^*$ [nm]</td>
<td>5.7</td>
<td>0.9</td>
<td>QD0, stabilisation</td>
</tr>
</tbody>
</table>
MDI Priorities

Highest priority for the work until end 2010 are those subjects linked to the “CLIC critical feasibility items”, nota bene:

- Choice of the magnet technology for the FF magnets
- Integration of these magnets into the detectors, and their alignment
- Feasibility study of sub-nm active stabilization of these magnets
- Luminosity instrumentation
- Spent beam disposal
- Beam background backsplash from the post-collision collimators and dumps into the detector
- Intrapulse-Beam feedback systems in the interface region

From the CLIC MDI working group mandate
Other items to be addressed in MDI:

- Issues where the beam delivery system (BDS) influences the beam/background conditions for the detector
- Issues where the BDS physically impacts on the detector
- Beam background and its impact on the forward (det.+accel.) elements, including backsplash of background particles from one hardware element to the surrounding elements
- Beam pipe, beam vacuum and vacuum infrastructure in the interface region
- Radiation environment and radiation shielding in the interface region
- Cryogenic operational safety issues in the interface region
- Magnetic environment in the interface region (shielding of FF quadrupole, correction coils, anti(-DID), stray fields from the detector, etc.)
- Overall mechanical integration (including the routing of services) in the interface region
- Pull-push elements and scenarios (detector-to-detector interface)
- Cavern layout and services (handled principally under CES WG)

*From the CLIC MDI working group mandate*
From ILC to CLIC Detectors

Detectors for CLIC (3 TeV) are based on the two Detectors for ILC (500GeV)

Changes:
- 20 mrad crossing angle (instead of 14 mrad)
- Vertex Detector, due to Beam-Beam Background
- Hadron Calorimeter (due to higher energetic Jets)
- For CLIC_SiD: Moved Coil to 2.9m (CMS Like)

Length: 6.9m
Height: 6.9 m

Length: 7.1m (not to Scale)
Height: 7.0 m
# Final Focus Quadrupole (QD0): Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradient [T/m]</td>
<td>575</td>
</tr>
<tr>
<td>Length [m]</td>
<td>2.73</td>
</tr>
<tr>
<td>Aperture radius [mm]</td>
<td>3.83</td>
</tr>
<tr>
<td>Outer radius [mm] — for spent beam</td>
<td>&lt; 50</td>
</tr>
<tr>
<td>Peak field [T]</td>
<td>2.20</td>
</tr>
<tr>
<td>Tunability of gradient from nominal</td>
<td>[-10%, 0%]</td>
</tr>
</tbody>
</table>

*A conceptual design has recently been proposed by TE-MSC
see presentation by M.Modena tomorrow*
### “Halbach” vs. “Super Strong” Performances:

**Diagram:**
- Two circular diagrams illustrating the magnetic field configurations for Halbach and Super Strong patterns.
- The diagrams show the orientation of arrows indicating the magnetic field direction.
- The diagram contains a note indicating an angle of 30°.

**Table:**

<table>
<thead>
<tr>
<th>Material</th>
<th>R=3.8 [mm] (no chamber)</th>
<th>R=4.125 [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sm$<em>2$Co$</em>{17}$</td>
<td>Nd$<em>2$Fe$</em>{14}$B</td>
</tr>
<tr>
<td>Grad [T/m] “Halbach”</td>
<td>450</td>
<td>593</td>
</tr>
<tr>
<td>Grad [T/m] “Super Strong”</td>
<td>564</td>
<td>678</td>
</tr>
</tbody>
</table>
“Hybrid” approach, Version 2:

<table>
<thead>
<tr>
<th></th>
<th>( l_w = 5000 , [A] )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grad ([T/m]) (\text{Sm}<em>2\text{Co}</em>{17})</td>
<td>531</td>
</tr>
<tr>
<td>Grad ([T/m]) (\text{Nd}<em>2\text{Fe}</em>{14}\text{B})</td>
<td>599</td>
</tr>
</tbody>
</table>

- The presence of the “ring” decreases slightly the Gradient (by 15-20 T/m) but will assure a more precise and stiff assembly

- EM Coils design will permit wide operation conditions (with or without water cooling) that can be critical for performances (ex. stabilization)
QD0

- Inner radius for Endcaps
  - CLIC_ILD: 35 cm
  - CLIC_SiD: 26 cm
  - Add ~10 cm masking
    - Protect Calorimeter
  - Anti-Solenoid?
- QD0 Prototype
  - 33cm height
  - Should fit into forward region
  - Easier for CLIC_ILD than for CLIC_SiD
  - How is the Magnet attached to support structure?
  - How far do the coils extend beyond 3.5 m?
Any movement (vibration) of the QD0 quadrupole would lead to a displacement of the beam at the IP comparable to the movement of the magnet.

As the vertical spot size is about 1 nm, the quadrupole position must be stabilised to 0.15 nm in the vertical plane and 5 nm in the horizontal plane for frequencies > 4 Hz.

Beam-beam feedback will help.

A R&D program is under way for the stabilisation, based on passive and active stabilisation and cantilever based stabilisation.

The integration in the experiment (push-pull) is still an open issue. Studies are under way.

A review of stabilisation options is planned around the end of the year.

In case the $L^*=3.5$ m (present baseline) option seems unrealistic, larger $L^*$ values may have to be considered for the CDR.

See presentation by A.Jeremie in the parallel session tomorrow.
Achieved performance

- LAPP active system for resonance rejection
- CERN TMC active table for isolation

- The two first resonances entirely rejected
- Achieved integrated rms of 0.13nm at 5Hz
Current work

Replace big stabilisation table by a compact passive+active stabilisation system

Active system

Passive system

Instrumentation study (sensors and actuators)

- **Seismometers** (geophones)
  - Velocity
- **Accelerometers** (seismic - piezo)
  - Acceleration

![Sensor and Actuator List](image_url)

- Streckeisen STS2
- Guralp CMG 3T
- Guralp CMG 40T
- Eentec SP500
- PCB 393B31
- Endevco 86
- PCB 393B12
- B&K 450B3

*Courtesy A. Jeremie*
Current work

Simulations

Ex: force (actuator) applied to a point

SAMCEF  MATLAB  Simulink

FE Model Creation  State-Space Model Creation  State-Space Model Use

FF magnet design

Evgeny Solodko

Different strategies studied:
• A knowledge only at strategic points
• A local model for the disturbances amplified by eigenfrequencies.
• A complete model
Perspectives for the future

Under consideration

Priority 1: Understand this shoulder

Priority 2: Prepare a detailed experiment of a stabilized PM magnet in CESR-TA

Feedback Off

Feedback ON

Beam oscillation amplitude [nm rms]

Frequency [Hz]
QD0 Integration concept: first ideas

Courtesy A. Hervé
Vibration measurements (e.g. recently in CMS cavern, with cooling off by Artoos, Guinchard) suggest once more that:

- The QD0 quadrupole shall NOT be suspended from the detector
- However, it must penetrate in the experiment to maintain peak luminosity
- The QD0 supporting system must be strengthened (and shortened?)

Solutions may exist if opening the experiment on the IP is abandoned.

This implies that special efforts must be made in the machine and experiment, insulating e.g. rotating machines and water pipes mechanically

*See presentation by A.Hervé tomorrow*
Various effects occurring in the Beam Delivery System and Interaction Region impact significantly on luminosity, backgrounds and detector performance.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Consequences</th>
<th>How to deal with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coherent pairs</td>
<td>Main background. Tails in CM energy Blow-up, $e^+e^-$, $e^-e^-$</td>
<td>Spent beam Crossing angle Detector design</td>
</tr>
<tr>
<td>Incoherent pairs</td>
<td>Backgrounds, $e^+e^-$, $e^-e^-$</td>
<td>Detector</td>
</tr>
<tr>
<td>$\gamma\gamma \rightarrow$ hadrons</td>
<td>Backgrounds, radiation</td>
<td>Horiz. beam size at IP</td>
</tr>
<tr>
<td>Neutrons from dumps</td>
<td>Background via backscattering through spent beam aperture</td>
<td>Masks? Dump design and location</td>
</tr>
<tr>
<td>Muons from collimation</td>
<td>Backgrounds, e.g. catastrophic Bremsstrahlung</td>
<td>Magnetic shielding</td>
</tr>
<tr>
<td>Solenoid field + crossing angle</td>
<td>Couples to beam, luminosity reduction</td>
<td>Anti-solenoid Crab cavities</td>
</tr>
</tbody>
</table>
Pair production - Spent beam line

- Beam-beam interaction blows up & disrupts particles of opposite sign of main beam
- Pair production limits the minimum radius of the vertex detector
- Backscattering would cause serious background and radiation problems for the detector
- Therefore particles leaving the IP at up to 10 mrad must be transported away cleanly
- The energy contained in the outgoing beam is huge (14 MW) and must be dumped properly. A dump baseline design exists (ILC) but remains to be validated.
- The spent beam lines also houses instrumentation for luminosity monitoring, the background conditions for these detectors must be optimised
- Neutrons in the spent beam line and from the dumps remain to be simulated

See presentations in the parallel sessions
Present Conceptual Design (A. Ferrari, M. Salt et al)

Baseline: vertical chicane with dipole magnets to separate

1. particles from the e+, e- pairs with the wrong-sign charge and low energy tail
2. disrupted beam, beamstrahlung photon

E. Gschwendtner, EN/MEF
Power Deposition in Main Dump

E.Gschwendtner, EN/MEF
Luminosity Monitoring: $\mu^+\mu^-$ pair production

- Converter in main dump $\rightarrow$ muons
- Cherenkov detector
  - $\sim 4 \times 10^5$ photons/bunch

→ To be studied in more detail: background, converter, detector, etc..
The water-based dump

- normal cooling water
- exhaust / chimney?
- sand
- enclosure
- air treatment
- water-system
- basin
- emergency/comm. beam tilted = 15mrad
- spent beam, tilted = 15mrad
- water-dump vessel
- dump shielding

Figure: Schmitz, DESY
\( \gamma \gamma \rightarrow \text{Hadrons} \)

This process gives a particle density in the vertex detector which is only about a factor of 4 lower than the background from incoherent pairs:

\[ \frac{1}{\text{dN}} \frac{\text{dN}}{\text{pt}} \]

\[ 0 \quad 0.02 \quad 0.04 \quad 0.06 \]

\[ 0 \quad 10 \quad 20 \quad 30 \quad 40 \quad 50 \quad 60 \quad 70 \quad 80 \quad 90 \quad \text{Nb of Particles / BX} \]

\[ 0 \quad 0.05 \quad 0.1 \quad 0.15 \]

\[ 0 \quad 50 \quad 100 \quad 150 \quad 200 \quad 250 \quad 300 \quad \text{Total Energy / BX (GeV)} \]

Courtesy M. Battaglia and D. Schulte
50 Bunch crossings of $\gamma \gamma \rightarrow$ hadrons background in the vertex detector.

850 tracks reconstructed by local pattern recognition.

Courtesy M. Battaglia
$e^+ + e^- \rightarrow \chi^+ + \chi^-$  
$\rightarrow \chi^0 + \chi^0 + W^+ W^-$  

Without $\gamma \gamma$

Idem with 20 Bx  
$\gamma \gamma \rightarrow$ hadrons pile up.  
The background may spoil the jet energy resolution and affect discrimination variables e.g missing energy, $\Theta$ ,...  
But low $E, P_t$ particles.

**Courtesy JJ.Blaising**
Muons from beam halo

Beam tails are scraped away by a collimation system in the BDS. Below we show simulated profiles of the beam at the BDS entrance (core of beam in red).

From I.Agapov et al, 2009, to be published

From these simulations one estimates that a fraction $2 \times 10^{-4}$ hit the collimators, i.e. about $2.4 \times 10^8$ particles per train assuming a total flux of $1.24 \times 10^{12}$ per train. Preliminary estimates indicate that out of those $\sim 2 \times 10^5$ would reach the detectors.

The final rates remain to be studied with BDSIM using the final and detailed geometry.

See presentation by H.Burkhardt in BDS parallel session
In the presence of a crossing angle, the beam couples to the longitudinal field of the main detector solenoid.

The solenoid field would also affect the long-term stability of the permanent magnets in the QD0 quadrupole.

A proposal has been made for a compensating solenoid around the QD0 quadrupole. See presentation tomorrow by B.Dalena

Its mechanical design, integration in the detector and impact on the QD0 stabilisation remains to be studied.

The anti-DID effect has been simulated, in particular its impact on the luminosity. See presentation tomorrow by B.Dalena
# Intra-Pulse Feedback

Summary of latency times of different FONT tests:

<table>
<thead>
<tr>
<th>Test</th>
<th>Facility</th>
<th>Train length [ns]</th>
<th>Bunch spacing [ns]</th>
<th>Latency [ns]</th>
</tr>
</thead>
<tbody>
<tr>
<td>FONT1 (2001-2)</td>
<td>NLCTA (SLAC)</td>
<td>170</td>
<td>0.087</td>
<td>67</td>
</tr>
<tr>
<td>FONT2 (2003-4)</td>
<td>NLCTA (SLAC)</td>
<td>170</td>
<td>0.087</td>
<td>54</td>
</tr>
<tr>
<td>FONT3 (2004-5)</td>
<td>ATF (KEK)</td>
<td>56</td>
<td>2.8</td>
<td>23</td>
</tr>
<tr>
<td>FONT4 (2006-7)</td>
<td>ATF (KEK)</td>
<td>420</td>
<td>140</td>
<td>132</td>
</tr>
</tbody>
</table>

Note: 23 ns is the **TOTAL** latency time: 10 ns (tof + signal return time) plus 13 ns (electronics)

Scales with distance (Almost) invariant

Latest status will be reported by J.Resta Lopez
Cavern Layout

Based on ILC design
Detector moving

Concept of the platform, A.Herve, H.Gerwig

Air-pads at CMS – move 2000T

L.Gatignon, 13-10-2009
Summary and Conclusions

- The Machine Detector Interface region is full of challenges:
  - QD0 quadrupole
  - Its stabilisation and integration
  - Intra-pulse feedback system
  - Backgrounds
  - Handle the beam power of the spent beam
  - Vacuum
  - Civil engineering and services
  - ..........

- Work is going on enthusiastically to cope with these challenges towards a plausible solution for the CDR

- More details in the parallel sessions

- Thanks to the colleagues in the MDI group for their input