CLIC Machine Detector Interface

MDI mini workshop, HKUST IAS

Philip Burrows on behalf of Lau Gatignon

17 January 2020
Outline

Quick reminder: what is MDI

Changes to detector model

Changes to MDI
  • Luminosity and tuning
  • Stabilisation
  • Some other implications

Plans
What was CLIC MDI at the time of the CDR?

The Machine Detector Interface must ensure optimum luminosity for the experiment(s) with minimal backgrounds and includes the local environment and infrastructure. It integrates the post-collision line.

- The baseline for the CDR was based on a concept with two detectors operating in push-pull mode and with the final focus quadrupoles QD0 as close as possible to the interaction point ($L^* = 3.5$ m), i.e. inside the detectors.
- The MDI design included concepts for the QD0 design as well as its stabilisation and pre-alignment, but also IP feedback, BeamCal and Lumical integration, vacuum layout, cavern layout, and so forth.
The CDR concept:
MACHINE DETECTOR INTERFACE

- Anti-solenoid
- Post collision line
- Support tubes
- QDO quadrupoles
- +Stabilization + prealignment
- IP Feedback
- Beamcal+
- Lumical
- Plus others
Announced changes to the detector model

- The detector team has decided to concentrate for the time being on a single detector with all-silicon tracking.

  No push-pull of two detectors, but this does remain an option

- A number of parameters have been frozen to allow consistent studies on detector optimisation and performance.

- For the forward region design they concentrate now on the long L* solution with QD0 in the tunnel, i.e. outside the detector. The exact value of L* has been defined as 6 m.

  This has major implications for MDI
Solenoid B-field

Detector

L* = 3.5 m

AntiSol

QD0

Integration

Radiation

Space

Forces

Stabilisation

Prealignment

Lever arm

Tunnel floor

Detector

L* = 6.5 m

AntiSol?

QD0

Stabilisation

Prealignment

Tunnel floor
QD0 in the tunnel or not?

QD0 inside the detector takes away a significant fraction of the acceptance in the forward region. Although with recent HTS magnet technology it may be possible to reduce the loss.

Due to the presence of a strong magnetic field, higher radiation and lack of space and access inside the detector some critical components may require more or longer interventions, leading to loss of integrated luminosity.

For the chosen L* value the BDS optics must be re-optimised (impact on QD0 parameters, required pre-alignment precision, etc).

In case QD0 moves to the tunnel, the question is legitimate whether the anti-solenoid and/or IP feedback are still required inside the detector and how their implementation must be revised.
Cavern layout

- Proposal by detector group
- Detector opening not on IP
- Mechanical and civil engineering stability to be verified
Parameters and performances with $L^* = 6$ m

<table>
<thead>
<tr>
<th>Motivation for longer $L^*$</th>
<th>CLIC 380 GeV FFS with $L^* = 6$ m</th>
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<tbody>
<tr>
<td>Final Focus System</td>
<td>CLIC 3 TeV FFS with $L^* = 6$ m</td>
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</table>

**CLIC 3 TeV**

Final Focus System

<table>
<thead>
<tr>
<th>$\sqrt{\beta_x}$ ($L^* = 6$ m)</th>
<th>$\sqrt{\beta_y}$ ($L^* = 6$ m)</th>
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<tbody>
<tr>
<td>$\sqrt{\beta_x}$ ($L^* = 3.5$ m)</td>
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**CLIC Energy**

<table>
<thead>
<tr>
<th>CLIC energy</th>
<th>3 TeV</th>
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<tbody>
<tr>
<td>$L^*$ (m)</td>
<td>3.5</td>
<td>6</td>
</tr>
<tr>
<td>FFS length (m)</td>
<td>450</td>
<td>770</td>
</tr>
<tr>
<td>$\gamma_{x} / \gamma_{y}$ (nm)</td>
<td>660 / 20</td>
<td>660 / 20</td>
</tr>
<tr>
<td>$\beta_{x} / \beta_{y}$ (nm)</td>
<td>7 / 0.068</td>
<td>7 / 0.10</td>
</tr>
<tr>
<td>$\sigma_{x} (\sigma_{x, design})$ (nm)</td>
<td>47.7 (40)</td>
<td>49.7 (40)</td>
</tr>
<tr>
<td>$\sigma_{y} (\sigma_{y, design})$ (nm)</td>
<td>1.8 (1)</td>
<td>2 (1)</td>
</tr>
<tr>
<td>$L_{tot}$ / $L_{tot, design}$ $(10^{34} \text{cm}^{-2} \text{s}^{-1})$</td>
<td>7.5 (5.9)</td>
<td>6.44 (5.9)</td>
</tr>
<tr>
<td>$L_{1%}$ / $L_{1%, design}$ $(10^{34} \text{cm}^{-2} \text{s}^{-1})$</td>
<td>2.3 (2)</td>
<td>2.06 (2)</td>
</tr>
<tr>
<td>Chrom. $\chi_y (L^* / \beta_{y}^*)$</td>
<td>51500</td>
<td>60000</td>
</tr>
</tbody>
</table>

**Beam Luminosity**

<table>
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<th>Beam energy deviation $d_p$ [%]</th>
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<tr>
<td>$L_{tot}$ with $L^* = 6$ m</td>
</tr>
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</table>
$\beta_y^*$ changes for tuning performance

<table>
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<th>CLIC energy</th>
<th>3TeV</th>
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<td>$L^*$ [m]</td>
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</tr>
<tr>
<td>$\beta_x^* / \beta_y^*$ [mm]</td>
<td>7 / 0.10</td>
<td>7 / 0.12</td>
</tr>
<tr>
<td>$\sigma_x^<em>$ ($\sigma_x^</em>_{\text{design}}$) [nm]</td>
<td>49.7 (40)</td>
<td>49.4 (40)</td>
</tr>
<tr>
<td>$\sigma_y^<em>$ ($\sigma_y^</em>_{\text{design}}$) [nm]</td>
<td>2 (1)</td>
<td>1.9 (1)</td>
</tr>
<tr>
<td>$L_{\text{tot}}$ ($L_{\text{tot, design}}$) [$10^{34}$ cm$^{-2}$ s$^{-1}$]</td>
<td>6.44 (5.9)</td>
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<tr>
<td>$L_{1%}$ ($L_{1%, \text{ design}}$) [$10^{34}$ cm$^{-2}$ s$^{-1}$]</td>
<td>2.06 (2)</td>
<td>2.1 (2)</td>
</tr>
<tr>
<td>Chrom. $\xi_y$ ($L^<em>/\beta_y^</em>$)</td>
<td>60000</td>
<td>50000</td>
</tr>
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Tuning of the CLIC 3TeV FFS with $L^* = 6$ m

Tuning of the CLIC 3TeV FFS with $L^* = 6$ m
Status of Tuning: $L^\ast = 6$ m

- 10th iteration: Nominal FFS length have 93% of machines that reach 0.9$L_0$
- 10th iteration: Nominal FFS length have 85% of machines that reach $L_0$
- 10th iteration: Nominal FFS length have 77% of machines that reach 1.1$L_0$
- Luminosity measurements $\approx 4000$

![Graph showing the tuning of the CLIC 3TeV FFS with $L^\ast = 6m$.](image)
Stabilisation

LAPP CNRS¹ & SYMME² : B. Aimard¹, G. Balik¹, J.P. Baud¹, L. Brunetti¹, B. Caron², A. Jeremie¹

Before 2016 : CLIC feasibility demonstration at reduced scale dedicated to the QD0 magnet final focus

- Developed active foot with commercial sensors (geophones and accelerometers)
- 2 sensors used in feedforward and 2 sensors used in feedback

  Obtained results : 0.6 nm RMS@4Hz (vs 0.2 nm RMS@Hz specification of CLIC)

- Sensors dedicated to measurement but not to control
- Two technologies needed for the selected bandwidth (geophones for low frequencies and accelerometers for high frequencies)
  - complexity of the control

Main limitation : SENSORS (Experimental and theoretical demonstration).


MDI workshop, Hong Kong, 17-01-2020

Ph.Burrows, CLIC MDI
Before 2016 : Development of a vibration sensor

- Promising results (similar to the best commercial sensors)
- French patent (FR 13 59336)
- Dedicated to control

**Comparison with industrial sensors at CERN (ISR – January 2015):**

- The mechanical system of the sensor is used by P. Novotny (PhD PACMAN) to evaluate the most efficient sensitive sensor which could be integrated inside the sensor (capacitive sensor, interferometer, optical encoder…)

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MDI workshop. Hong Kong. 17-01-2020

Ph.Burrows, CLIC MDI
• CLIC specification (displacement of the QD0 final focus) : 0,20 nm RMS@4Hz
• Previous results with LAPP active foot + 4 commercial sensors : 0,60 nm RMS@4Hz
• Development of the vibration sensors at LAPP dedicated to control

Results of control (autumn 2016) with LAPP active foot + 1 LAPP vibrations sensor : 0,25 nm RMS@4Hz

• Only 1 sensor in feedback -> control less complex and more efficient
• Published in December 2016, in collaboration with SYMME (approbation in progress)

- LAPP active foot + LAPP sensors (one on ground used to monitor ground motion and 1 on top used in feedback) -

Already an application in CMS, but need also passive insulation in detector environment
IP Feedback System

See presentation by Ph.Burrows later today
Beam Line Sectorisation Scheme

- = Pumping ports*
- = Sector valve

= bellows
= fixed point (sliding support not represented)

*Pumping port number and position could change depending on pressure requirements or space constraints…
Summary and Outlook

- A new detector model with $L^* = 6$ m has been evaluated.
- The optics for $L^* = 6$ m leads to $< 15\%$ luminosity loss and the tuning is approaching the nominal level.
- The QD0 stabilisation tests reached $0.25$ nm RMS at $4$ Hz.
- Now ready to also study more detailed MDI integration aspects.
- This is now the new baseline for CLIC.
The MDI working group

home.cern
Beginning of 2017: Collider application

- Simulation of the system (foot + sensors) with disturbances equal to the CMS detector motion
  - Disturbances don’t reveal the same distribution (more cultural noise).
  - Control is not efficient enough in this case (above 100 Hz)

- Necessity to have a passive insulation under the concrete or under the last elements

- A passive insulation at about 25 Hz is common to the standard industrial solutions