Introduction to the HEL magnet system discussion

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122nd Collimation Upgrade Specification Meeting, ColUSM
22 November, 2019
CERN, Geneva, CH
Introduction

— CERN and BINP signed the agreements for a construction of hollow electron lenses for the HL-LHC!
— Endorsement for insertion in the upgrade baseline at the recent cost&schedule review!

Ahead of as: detailed finalisation of the design to prepare the construction at BINP!
Moving from a “best effort” study to a real construction project.

— Recent results on e-beam dynamics by the BINP team revealed various potential concerns for the present design.
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— Recent results on e-beam dynamics by the BINP team revealed various potential concerns for the present design.

*Important to review the open points and converge as soon as possible to a final design of the HEL magnetic system.*
The HEL-based collimation concept

**Active halo depletion**: control diffusion speed, selective by transverse amplitude.

- it is integrated into the hierarchy of the collimation system that remains responsible for the halo disposal.
- it allows distributing losses over a desired time interval.
- it controls tail populations close to collimator jaws (deplete tails).
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Tight tolerance in position / alignment / local optics to respect collimation constraints.
Requirements

— Depletion of tails by $\sim 90\%$ in time scale of $\sim 1\text{-}2$ minutes
  Even with linear machine and beams non colliding
— Selection of batches within LHC bunch time structure
  Leave “witness” halo for machine protection purpose
— Negligible core blow-up while depleting tails.
— Active on beams starting at the end of the ramp ($> 5$ TeV)
  Option for operation at injection as commissioning scenario

Main parameters in a nutshell:
— Rise time of electron beam $\sim 200$ns
— Various pulsing/modulated modes, turn-by-turn modulation of current
— 5A electron beam current, 3m overlap to proton beam
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Important to have feedback on what are the critical parameters affecting the design, for which more specific tolerances need to be specified.
## Present parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value or range</th>
</tr>
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<tbody>
<tr>
<td>Proton beam optics at HEL, $\beta$ [m]</td>
<td>280</td>
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<td>Length of interaction, $L$ [m]</td>
<td>3</td>
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<tr>
<td>Desired transverse scraping ($&gt; 3.5 \sigma$), $r$ [mm]</td>
<td>$1.1 - 2.2 @ 7\text{TeV}$</td>
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<td>Maximum electron beam current, $I$ [A]</td>
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<td>Cathode diameter, inner/outer [mm]</td>
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<tr>
<td>Magnetic field at gun [T]</td>
<td>$0.35 @ 7\text{TeV}$ to $4 @ 450\text{GeV}$</td>
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<td>Magnetic field at bend [T]</td>
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- x5 times e-beam current compared to e-lenses in other colliders (RHIC, Tevatron)
- Small electron beams
- **Pulsed operation mode**, with turn-by-turn variation of e-beam current.

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The HL-LHC HEL design

This is a small accelerator!
- Cryogenics and magnetic system;
- Electron gun and collector;
- Electron and proton beam diagnostics;
- Vacuum system;
- Support and alignment systems.
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— “S” shape to compensate effects on core from e-beam asymmetries.
— Small SC dipole to compensate effect on proton orbit from bending.
Main concerns for p beam dynamics

DC operation:
— Steering of e-beam with respect to p-beam: +/- 4 mm
   for (1) setup around closed-orbit; (2) alignment purposes.
   Recap.: tolerance on proton beam orbit = +/- 2 mm
— Stability of e-beam current

Pulsed operation:
— Minimization of residual fields seen by the core:
   (1) In/out as symmetric as possible in “s” shape;
   (2) Stability of e-beam at 5 A
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Recent concern from the shift of the e-beam at the location of the BGC to be studied, also for DC mode.
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Minimum requirement for “7TeV” setting up: $\Delta e = \pm 2\text{mm}$

Ideal proton orbit:

$r_p = 0 \rightarrow \Delta e = \pm 2\text{ mm}$ would suffice.

Reference LHC case:

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$r_p \rightarrow$ absolute orbit position, stable throughout a run (even across years?)
Dynamic changes (fill to fill or dynamics): ~ 150 μm [to be checked with OP]