HEL design, magnet system, e-gun and collector

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What do we want to do?

Reasonable precision of a middle size single component: ± 0.05 mm.
Reasonable precision of an assembly of many components: ± 0.2-0.5 mm.

Therefore we need corrector coils.

Beam-beam overlapping: ~3m , e current intensity: up to5 A.
Use at injection and at collision level => different ring size
## Existing electron lenses and HL-LHC hollow electron lenses

<table>
<thead>
<tr>
<th></th>
<th>RHIC EL</th>
<th>Tevatron EL</th>
<th>HL-LHC HEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective length [m]</td>
<td>2.1</td>
<td>2</td>
<td>2.9</td>
</tr>
<tr>
<td>Current from cathode [A]</td>
<td>1</td>
<td>0.6-3</td>
<td>Up to 5</td>
</tr>
<tr>
<td>Main solenoid field [T]</td>
<td>6</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Solenoid inner bore [mm]</td>
<td>200</td>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>E-gun field [T]</td>
<td>0.2-0.8</td>
<td>0.3</td>
<td>0.2-4</td>
</tr>
<tr>
<td>Cathode radius [mm]</td>
<td>4.1 @250GeV 7.5 @100GeV</td>
<td>7.5</td>
<td>4 – 8.05 Hollow 1.53</td>
</tr>
<tr>
<td>Cathode surface* [cm²]</td>
<td>0.53 @250GeV 1.77 @100GeV</td>
<td>1.77</td>
<td>3.27</td>
</tr>
<tr>
<td>Current density [A/cm²]</td>
<td>1.89 @250GeV 0.53 @100GeV</td>
<td>1.69</td>
<td></td>
</tr>
<tr>
<td>E-beam compression</td>
<td>1.6-5.5</td>
<td>3.26</td>
<td>1.41-4.47</td>
</tr>
</tbody>
</table>

HL-LHC HEL is a new object.
Candidate locations for the electron lenses are RB-44 and RB-46 at Point 4, on each side of the interaction region IR4.

The beam to beam distance is 420 mm. The longitudinal available space is limited.

Compact design
Confinement of an electron beam
Elements of an Hollow Electron lens

- Electron gun solenoid and electron gun
- Bending solenoid(s)
- Main solenoid
- Bending solenoid(s)
- Collector
- Instrumentation, vacuum chamber, cryostats, supports etc.

Correctors
The field level determines the radius of the e-beam. The dimensions of the electron beam in two points along its path follow the equation:

\[
\frac{r_0}{r_1} = \sqrt{\frac{B_1}{B_0}}
\]

Where \(r_0\) and \(r_1\) are the radii of the electron beam in point 0 (cathode) and 1 (main solenoid) and \(B_0\) and \(B_1\) are the magnetic field in points 0 and 1 respectively.
Z_G, \( \alpha \), B_1 and B_2 are not independent parameters. A change of the ratio \( B_1/B_2 \) calls for different Z_G and \( \alpha \)

Why two solenoids are not enough?
It is necessary to iterate between mechanical design and simulations of e-beam dynamics.
### Nominal magnetic field of the main solenoid
5T

### Nominal magnetic field in the e-gun cathode
0.2 T – 4 T

### Inner radius of the hollow electron beam @ nominal fields
0.9 mm (3 σ)

### Outer radius of the hollow electron beam @ nominal fields
1.8 mm (6 σ)

### Inner diameter of the cathode
8.05 mm

### Outer diameter of the cathode
16.10 mm

### Inner radius of the hollow electron beam @ 5 T with 2.5 T @ cathode
5.67 mm

### Outer radius of the hollow electron beam @ 5 T with 2.5 T @ cathode
11.34 mm

### Nominal current at the cathode
Up to 5 A
Changes of the last months

Field of the main solenoid from 4T to 5T. Main solenoid bore from 200 mm to 180 mm.

Pressure load on the he tank 20 bars.

One single beam gas monitor in the centre of the system.

Simplified construction.

Some of the circuits can be in series (less power supplies)
Today
- Separate cryostats for the man and bending solenoid.
- Magnets attracts each other. Strong supports without heavy thermal loads.
- Complicate assembly procedures: welding in difficult configuration, little space to put the hands in.

- The electron ring trajectory is bending where the field is lower.
Next steps

Optimization of the main solenoid bore. Can it be lower?

Optimization of the number and strength of the correctors

Study and optimization of the electron trajectory. Possible small changes of the e-gun solenoid size and position.
Continue the tests of e-guns and high performance cathodes.

2 guns during 2018.
Thank you for your attention