FCC-hh heavy-ion collimation

A. Abramov, R. Bruce, N. Fuster-Martinez, A. Mereghetti,
J. Molson, L. Nevay, S. Redaelli
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Introduction

• The FCC-hh includes a multi-stage collimation system:
  • Designed to clean the beam halo and protect the ring from beam losses.
  • See earlier talks by R. Bruce and J. Molson.

• Heavy-ion operation involves additional challenges:
  • Ion collimation efficiency in the LHC is a ~2 orders of magnitude worse for ion than for protons
  • The stored ion beam energy in the FCC-hh is a factor ~25 larger than in the LHC.

β-coll.

*Figure from FCC-hh long CDR 2
Simulation tools

- Studying ion collimation requires specialised tools:
  - Beam ions can undergo nuclear fragmentation and electromagnetic dissociation in the primary collimator, producing multi-species secondary ion beams.

- The simulations are performed using the SixTrack-FLUKA active coupling.
  - Thanks to A. Mereghetti, J. Molson, P. Hermes and the FLUKA team

- Combination of tracking and physics interactions:
  - Symplectic tracking in the accelerator magnetic lattice is performed by SixTrack.
  - Monte Carlo simulation of beam ion interaction with the collimators is performed in FLUKA.
Simulation

• Study the collimation system performance for Pb ion beams:
  • Investigate the most demanding cases – betatron collimation in collision mode and off-momentum collimation in injection mode.
  • Evaluate the performance of the dispersion suppressor collimators (TCLDs)

• Simulation procedure:
  • Perform loss studies for Beam 1 in the horizontal (B1H) using a halo beam.
  • Compare the results against an estimate of the quench limit. (See talk by M. Varasteh)
  • Analyse in more detail the losses in DS.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Beam particle</td>
<td>(^{208}\text{Pb}^{82+})</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>2760</td>
</tr>
<tr>
<td>Ions per bunch</td>
<td>(2 \times 10^8)</td>
</tr>
<tr>
<td>Injection energy</td>
<td>3.3 Z TeV</td>
</tr>
<tr>
<td>Collision energy</td>
<td>50 Z TeV</td>
</tr>
<tr>
<td>Beam lifetime</td>
<td>12 min</td>
</tr>
<tr>
<td>Quench limit</td>
<td>(2 \times 10^{-5}) 1/m</td>
</tr>
</tbody>
</table>
Betatron cleaning at collision – B1H

NOMINAL

\[ \eta (1/m) \]

\[ s (m) \]

NO TCLDs

\[ \eta (1/m) \]

\[ s (m) \]
Betatron cleaning at collision – B1H IRJ

NOMINAL

NO TCLDs

detailed loss analysis later
Momentum cleaning at injection – B1H
DS losses analysis – B1H collision, \( S = 76000 – 77000 \text{ m} \)

- The dispersion suppressor of the betatron cleaning insertion is one of the critical areas for losses.
- Analysis of the losses on the cold aperture shows more losses on the inside of the ring.
- Light ion fragments make up most of the losses on the aperture.
• Connect the aperture losses to the collimator where they originated.

• All the fragments coming from the TCPs and TCSGs are successfully intercepted by the TCLDs.

• The dominant contribution to energy lost in the DS are light fragments leaking out from the TCLDs.
Conclusions

• The study of ion collimation for the FCC-hh shows good cleaning performance. Beam losses can be sustained without quenching within the specification for 12 minute beam lifetime.

• The TCLD collimators are shown to be critical for ion operation as they intercept heavy-ion fragments coming from warm collimation insertion upstream.

• Further energy deposition studies are necessary to fully assess the quench risk.