Collimation Efficiency with Imperfections

M. Serluca\textsuperscript{1}, R. Bruce\textsuperscript{2}, G. Lamanna\textsuperscript{1}, J. Molson\textsuperscript{2}, S. Redaelli\textsuperscript{2}

\textsuperscript{1}: LAPP-IN2P3-CNRS, Université Savoie Mont Blanc, Annecy, France
\textsuperscript{2}: CERN, Geneva, Switzerland

10/04/2018 FCC week Conference 2018, Amsterdam, Netherlands
Outline

• FCC-hh layout and main parameters
• Collimator and optics imperfections
• Collimator gaps and simulation setup
• Loss map with and without imperfections
• Influence of imperfections on losses
• Influence of imperfections on cold losses locations
• Conclusions and outlook for future studies
FCC layout and main parameters

FCC layout V9

- Length = 97749 m
- Top Energy = 50 TeV
- Protons per bunch = $10^{11}$
- # of bunches (25 ns) = 10400
- Stored Energy = 8.4 GJ

FCC optics

- $\varepsilon_n$ (H and V) = 2 mm mrad
- $\beta^*$ (A and G) = 15 cm
- $\beta^*$ (L and B) = 3 m
- $Q_x/Q_y = 111.31/109.32$
Collimator and optics imperfections

The error model is introduced in SixTrack following the procedure and experimental data used for LHC [*]:

* C.Bracco, PhD Thesis: EPFL_TH4271

1. **OFFSET**: rms error offsets of the collimator centers
2. **TILT**: tilt angle of the collimator with respect to the beam axis
3. **FLATNESS**: imperfections of jaw flatness are modelled with a parabolic fit of the collimator jaw
4. **GAP**: RMS errors on the size of the collimator gap with respect to its ideal value
5. **MAGNETIC AND MISALIGNEMENT**: Phase advance and dispersion errors can only be simulated by adding magnetic errors and misalignments in the MAD-X lattice
6. **APERTURE**: Aperture of magnets could be misaligned. Design tolerances can be used to set random errors.

Imperfection 5 and 6 are not currently considered.
Collimator gaps and simulation setup

**Annular beam halo**
- Horizontal beam halo generated at primary collimator with 0.0015 $\sigma$ impact parameter
- Gaussian vertical distribution cut at 3 $\sigma$

**Simulation parameters**
- Horizontal loss map at top energy
- Mode: collision cross
- $N$ (protons) = 100M
- Turns = 200-500
- Bin width = 10 cm

**Imperfections**
- Offset error: 100 $\mu$m rms
- Tilt error: 200 $\mu$rad rms
- Gap error: 0.17 $\sigma$ (Assuming a beta beating of 4%)
- Flatness error: inward fixed max deformation of 60/100 $\mu$m (0.6/1 m coll. length) applied to betatron collimators
- Studied cases: ideal (no imperfection), offset, offset+tilt, offset+tilt+gap and offset+tilt+gap+flatness
- $N$(IMPERFECTION SEEDS) = 20

<table>
<thead>
<tr>
<th>NAME</th>
<th>N-SIGMA</th>
<th>LENGTH (M)</th>
<th>MATERIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP</td>
<td>7.6</td>
<td>0.6</td>
<td>C</td>
</tr>
<tr>
<td>TCSG</td>
<td>8.8</td>
<td>1</td>
<td>C</td>
</tr>
<tr>
<td>TCLA</td>
<td>12.6</td>
<td>1</td>
<td>INER</td>
</tr>
<tr>
<td>TCT</td>
<td>10.5</td>
<td>1</td>
<td>INER</td>
</tr>
<tr>
<td>TCLD</td>
<td>35.1</td>
<td>1</td>
<td>INER</td>
</tr>
</tbody>
</table>

Betatron collimator settings

**Taking into account all seeds and imperfections a total of $8 \times 10^9$ protons tracked for 200-500 turns**
Loss Map with and without imperfections

**Ideal case**

**Worst case**
Influence of imperfections on collimator losses

**Losses ratio of betatron cleaning insertion with respect to TCP**
- Each point is an average over the 20 seeds
- Hierarchy preserved
- Slight losses increase in TCLA, TCSG and DS collimators

**Losses ratio of terriers around detectors with respect to TCP**
- Similar scaling for all collimators
- Highest losses around A and B insertions
- Factor 4 increase with all imperfections with respect to the ideal case
Influence of imperfections on cold-warm losses

Global inefficiency

• Warm losses with imperfections are within the error bars
• Cold losses with tilts increase by a factor 4
• Cold losses with all imperfection increase by a factor 6

Highest cold inefficiency along the ring

• Tilt and offset do not affect the highest cold peak
• Mean value of the highest cold loss with all imperfections increases by a factor 2 with respect to the ideal case
Influence of imperfections on cold losses locations

Stacked histograms of cold losses with 1 km bin width

- Cold losses longitudinal locations are similar for all imperfections
- Main locations are around the A and B detectors, and in the dump area (D)
Influence of imperfections on cold losses locations

Stacked histogram of cold losses with all imperfections:
zoom of the peak areas with 0.1 m bin width

26701.1 m (MQI.4RD)
Conclusions

• Presented horizontal collimation performance of FCC-hh with imperfections
• Collimator hierarchy is preserved for all imperfections
• Imperfections increase by a factor 6 the global cold losses
• Cold Losses are mostly located in A, B and dump areas
• Most affected element of cold losses is MQI.4RD

Future works

• Complete the loss map studies with all possible imperfections (optics and aperture errors)
• Vertical loss map with imperfections
• Collimation performance with imperfections and new jaw-coating materials
• Impact of new collimator geometries on loss map with imperfections (e.g. 30 cm collimator)
• Study the asymmetry of impacts for left-right jaw with all imperfections as input for energy deposition studies