Collimation Efficiency with Imperfections

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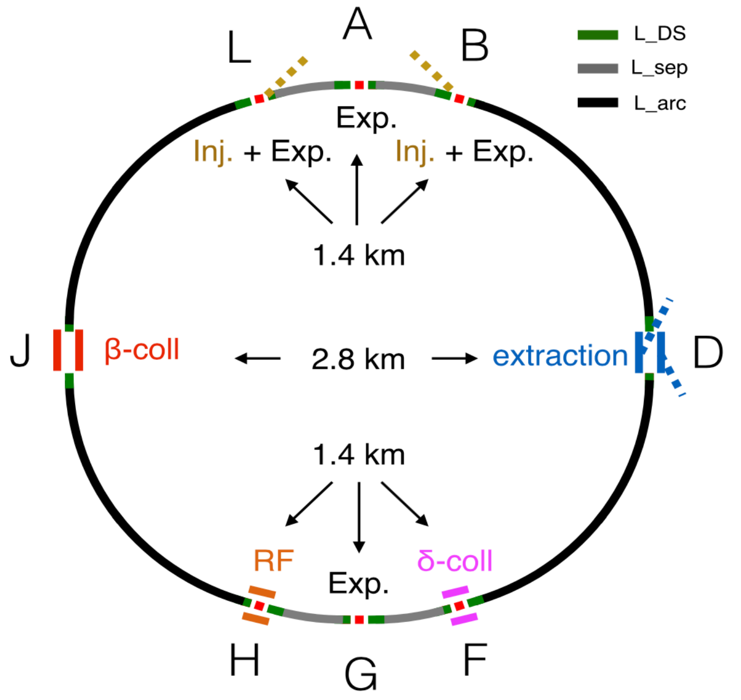
10/04/2018 FCC week Conference 2018, Amsterdam, Netherlands

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

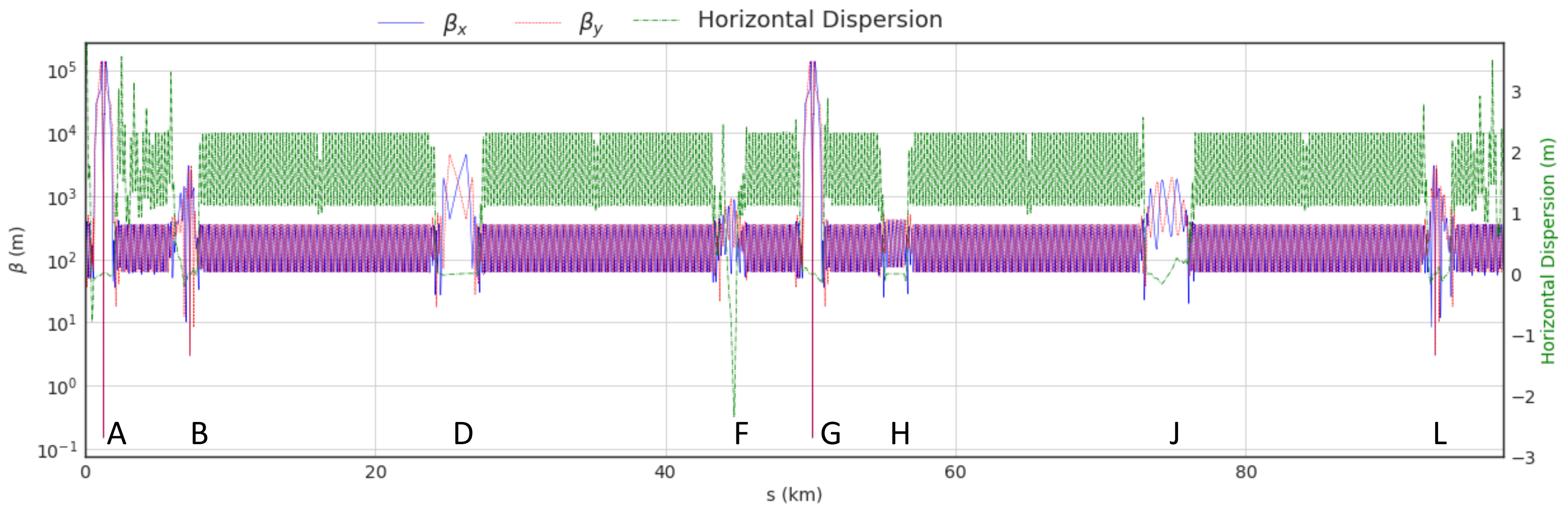


FCC layout V9

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

FCC optics

- ε_n (H and V) = 2 mm mrad
- β^* (A and G) = 15 cm
- β^* (L and B) = 3 m
- Q_x/Q_y = 111.31/ 109.32

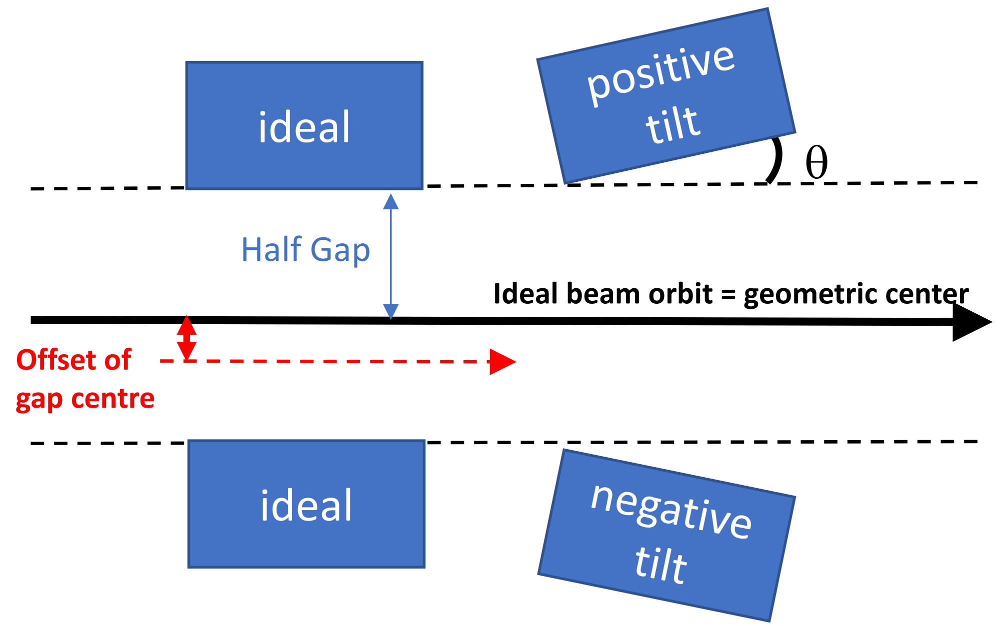


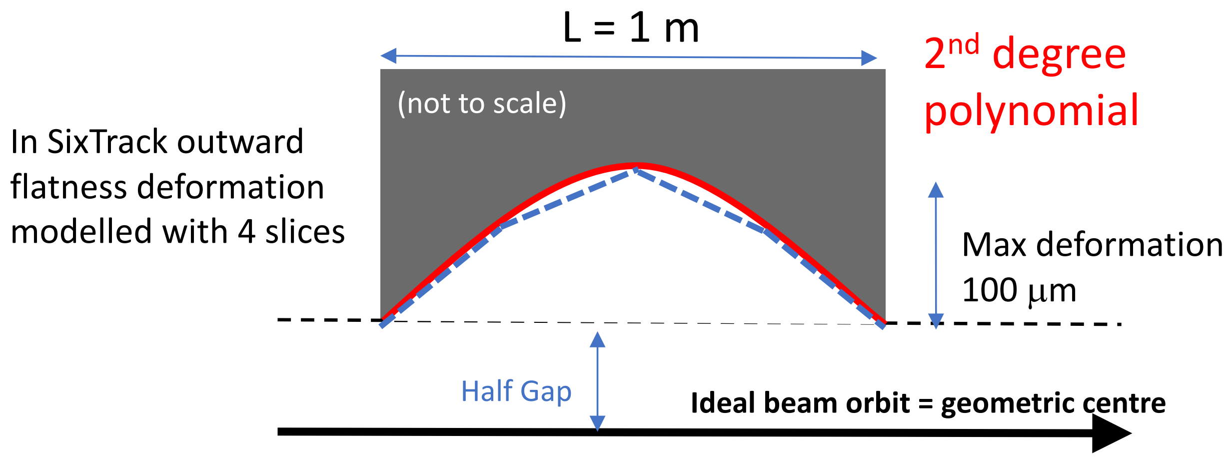
Collimator and optics imperfections

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 σ impact parameter
- Gaussian vertical distribution cut at 3 σ

Simulation parameters

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

NAME	N-SIGMA	LENGTH (M)	MATERIAL
TCP	7.6	0.6	C
TCSG	8.8	1	C
TCLA	12.6	1	INER
TCT	10.5	1	INER
TCLD	35.1	1	INER

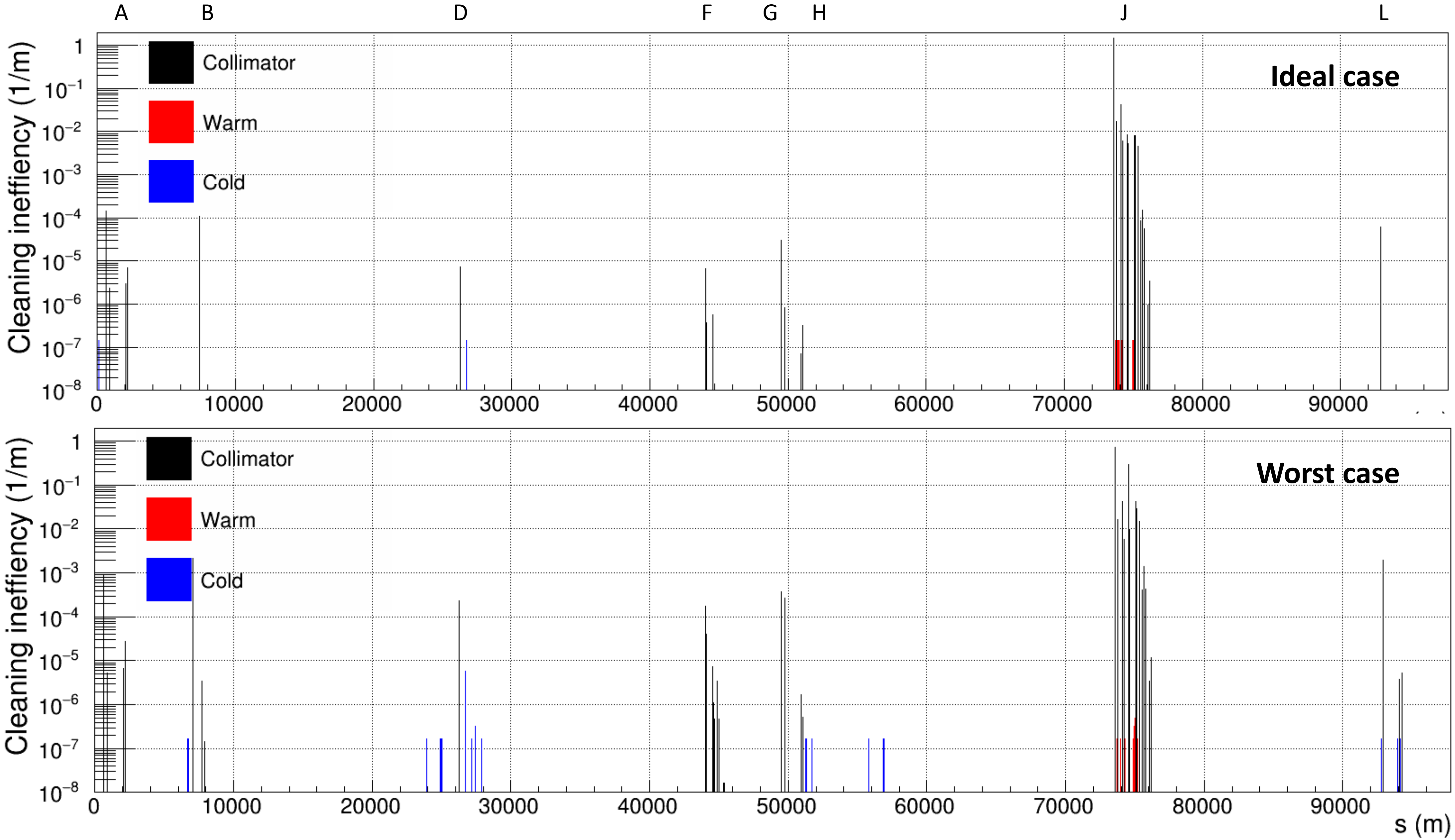
Betatron collimator settings

Imperfections

- Offset error: 100 μm rms
- Tilt error: 200 μrad rms
- Gap error: 0.17 σ (Assuming a beta beating of 4%)
- Flatness error: inward fixed max deformation of 60/100 μm (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

Taking into account all seeds and imperfections a total of 8 10^9 protons tracked for 200-500 turns

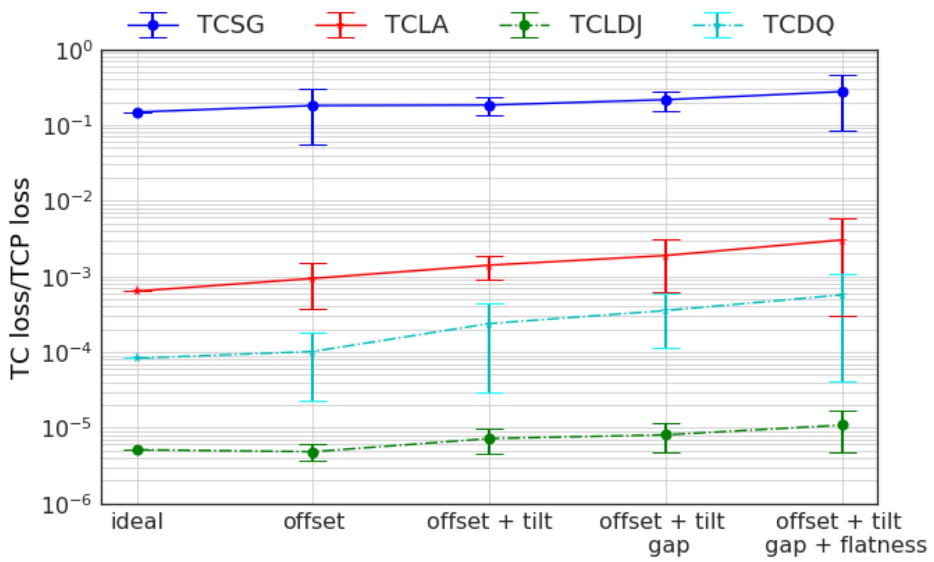
Loss Map with and without imperfections



Influence of imperfections on collimator losses

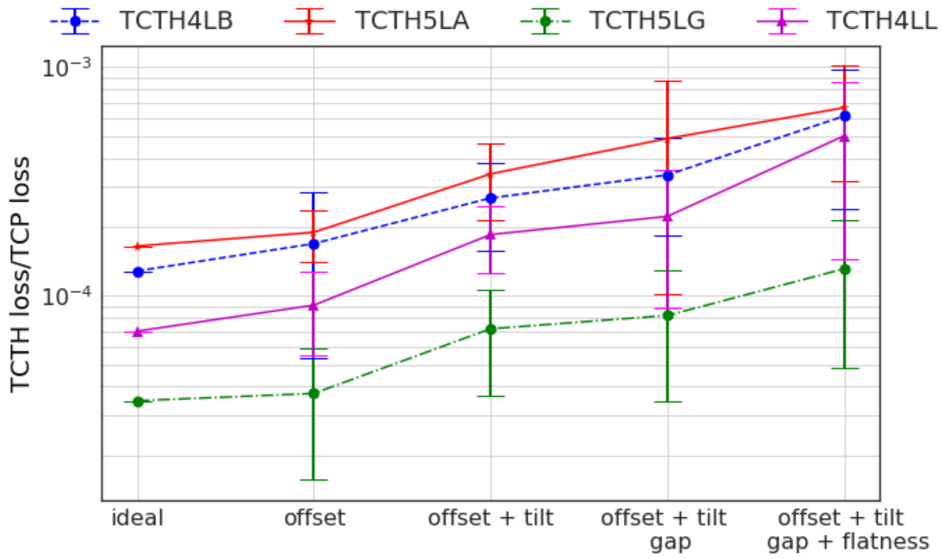
Losses ratio of betatron cleaning insertion with respect to TCP

- Each point is an average over the 20 seeds
- Hierarchy preserved
- Slight losses increase in TCLA, TCSG and DS collimators



Losses ratio of tertiaries around detectors with respect to TCP

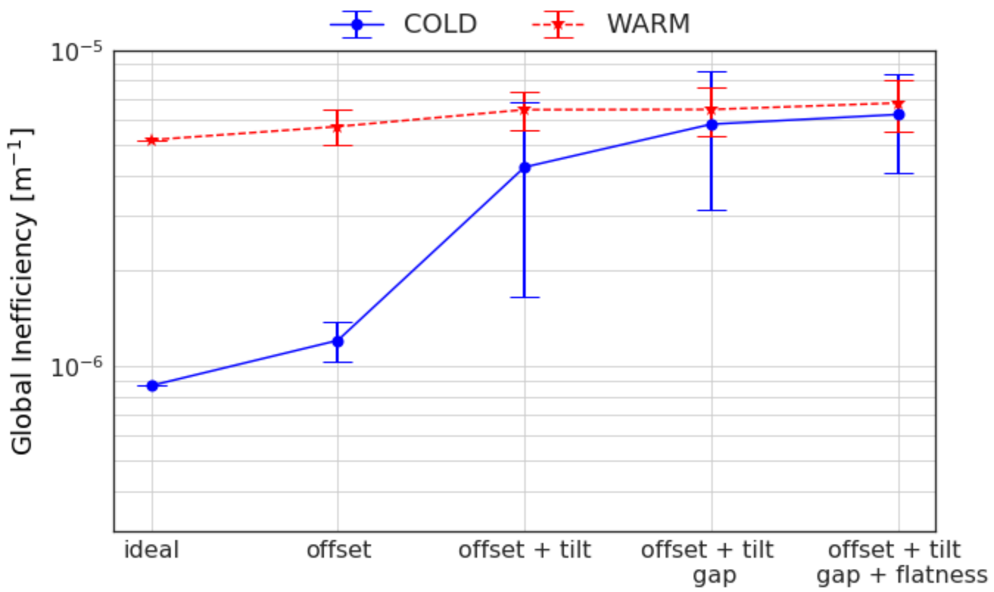
- Similar scaling for all collimators
- Highest losses around A and B insertions
- Factor 4 increase with all imperfections with respect to the ideal case



Influence of imperfections on cold-warm losses

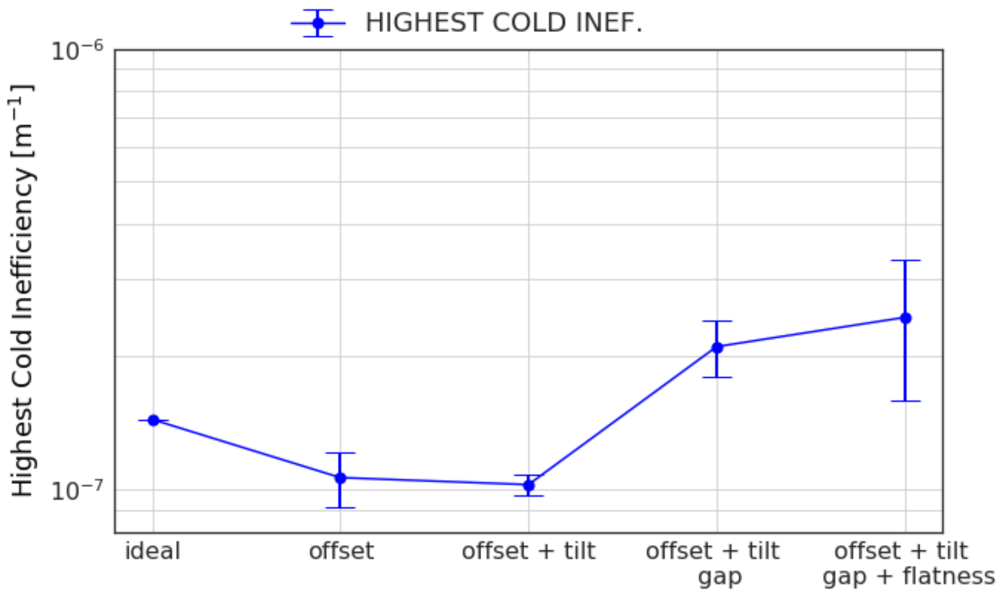
Global inefficiency

- 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

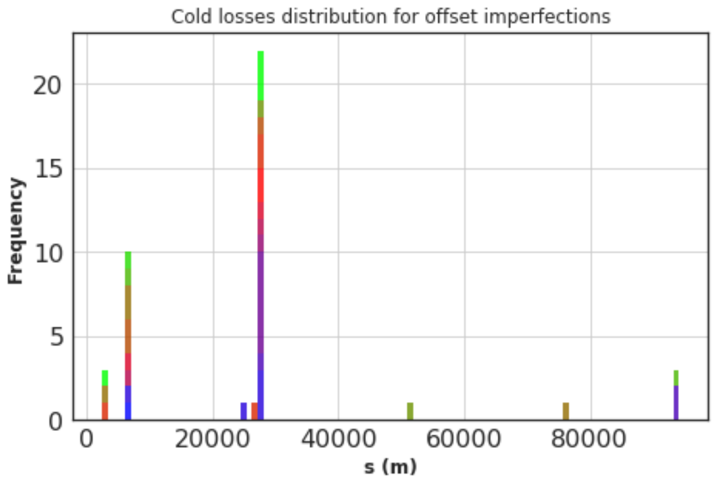
- Tilt and offset do not affect the highest cold peak
- Mean value of the highest cold loss with all imperfections increases by a factor 2 with respect to the ideal case

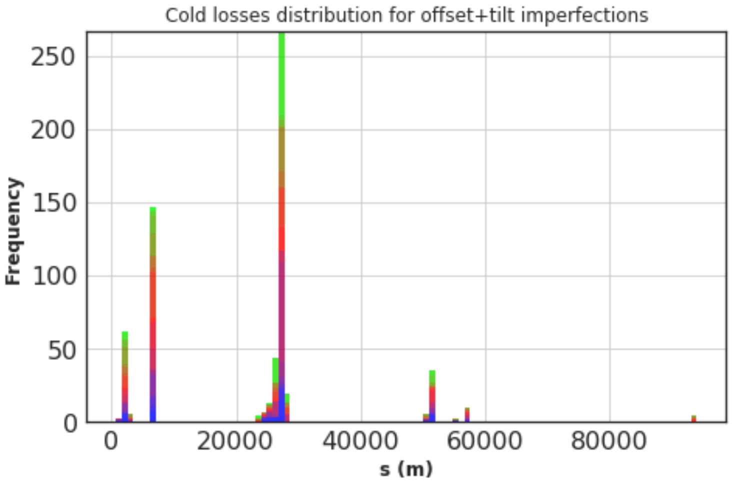


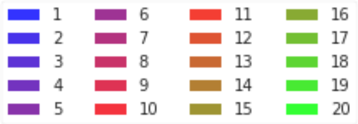
Influence of imperfections on cold losses locations

Stacked histograms of cold losses with 1 km bin width

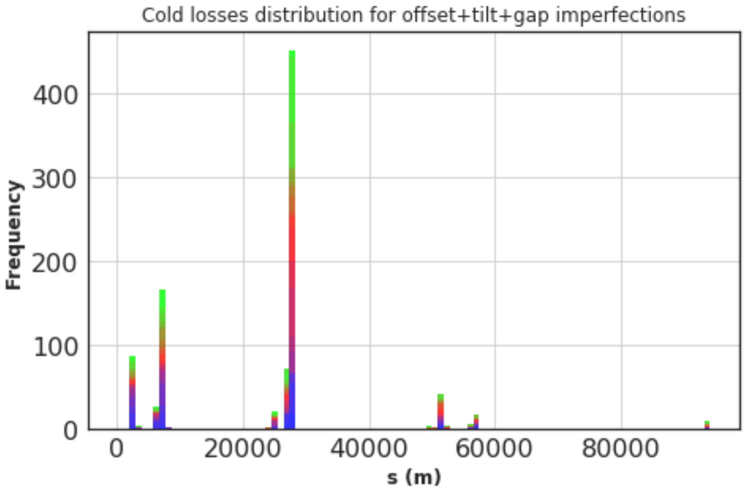
- Cold losses longitudinal locations are similar for all imperfections
- Main locations are around the A and B detectors, and in the dump area (D)

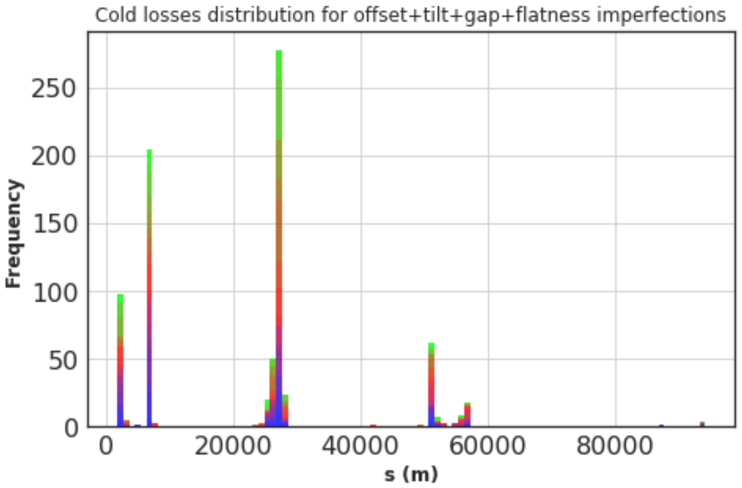






seed number

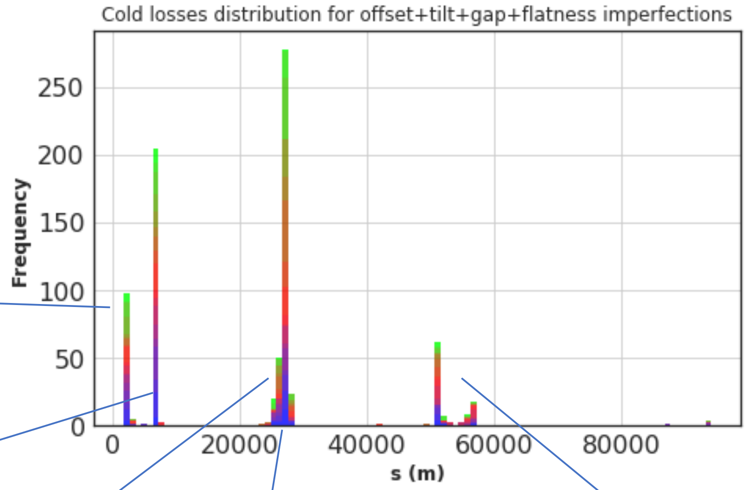


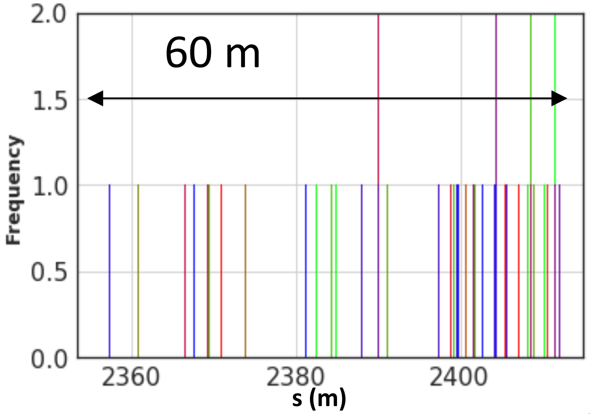


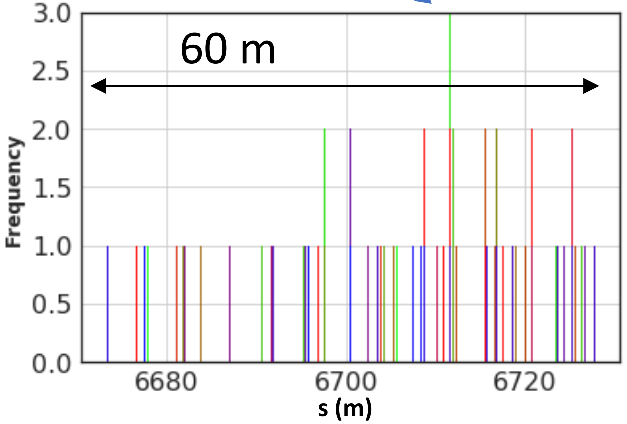
Influence of imperfections on cold losses locations

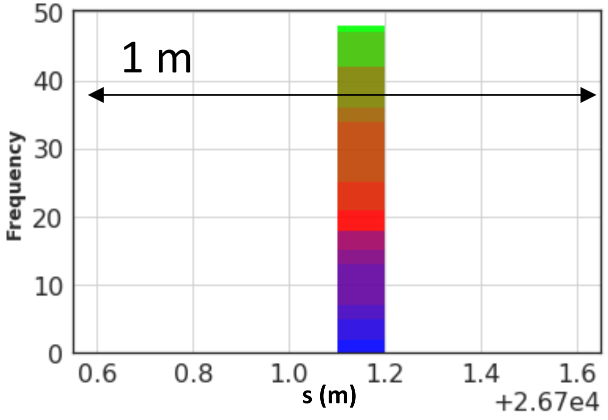
Stacked histogram of cold losses with all imperfections:

zoom of the peak areas with 0.1 m bin width

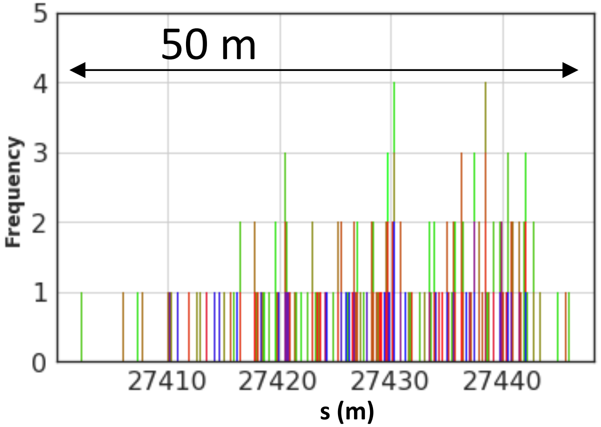


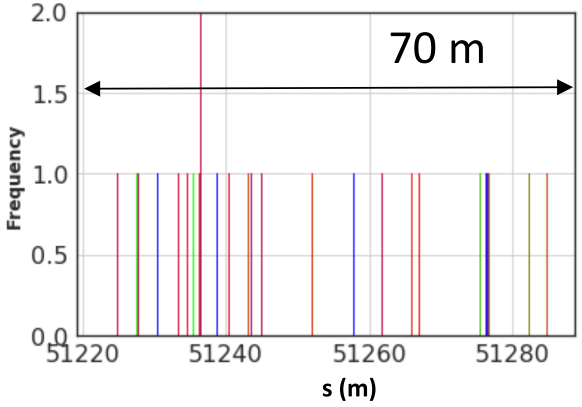






26701.1 m (MQI.4RD)





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