CERN

Collimation system performance

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Introduction

- The collimation system design must be tested to ensure it performs as expected during the operation of the FCC-hh.
- This includes possible misalignments, field errors and equipment failure scenarios.
- This can only be done via simulations of beam losses.
- A selection of simulation results will be shown.

Previous collimation issues

Previously issues were found in a number of areas:

- TCLDs did not cover the dispersion peaks at both injection and collision in beta/energy collimation insertions.
- Energy collimation cut was not as effective as it could be.
- Extraction region had debris coming from the TCDQ impacting the cold downstream regions.
- Impedance due to the collimation system was over the limit.

Collimation updates since the last FCC week

- Now all simulations have been performed with the latest lattice V10 and the up to date TCDQ model, and added collimators.
- Extra TCLD collimators have been added in each collimation insertion.
- Extra TCLA type collimators have been added at the end of the extraction straight section.
- The dispersion has been increased in the energy collimation region.
- Removal of the skew TCP.

Simulation tools and configuration

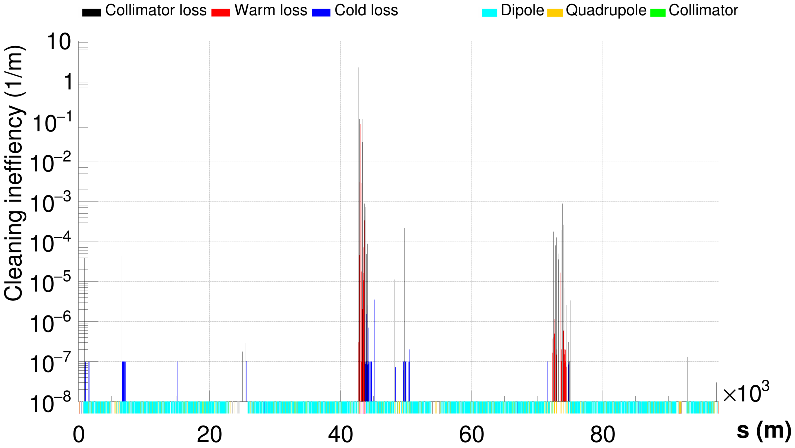
- All simulations have been performed with the SixTrack-FLUKA coupling.
- The latest versions of each code have been used including all bug fixes.
- 100 million particles, 400 turns per simulation.
- A 30% rigidity cut from the reference is used. All baryons are returned from FLUKA.
- Track from IPA and vary the beam halo distribution.

Collimation at injection

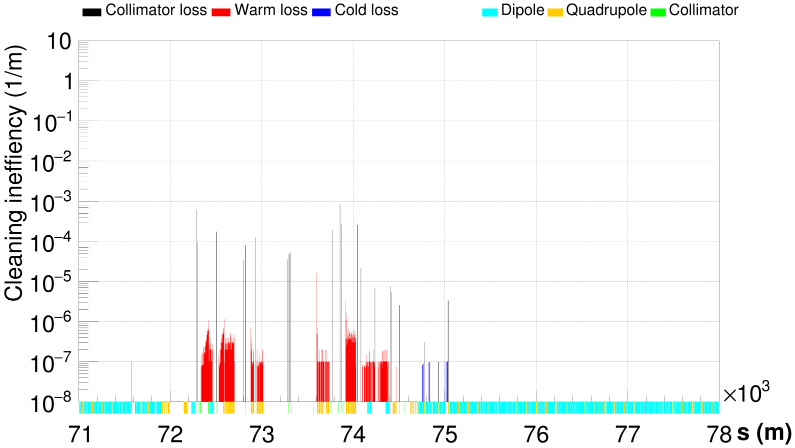
Injection configuration

- 3.3 TeV beam energy
- 4.6m β^* at each IP.
- No crossing at each IP.
- 16MV RF.
- For the off-energy simulation, an offset of -5.1975 GeV was used for all generated particles.
- 7.570001σ amplitude was used for the horizontal beam halo.

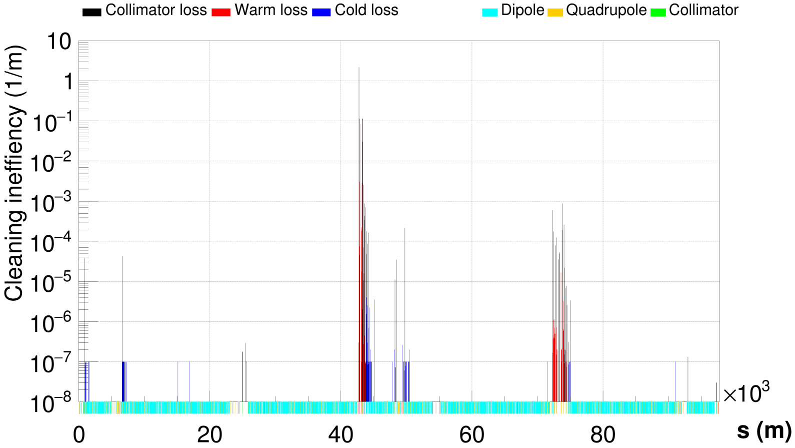
Horizontal betatron halo



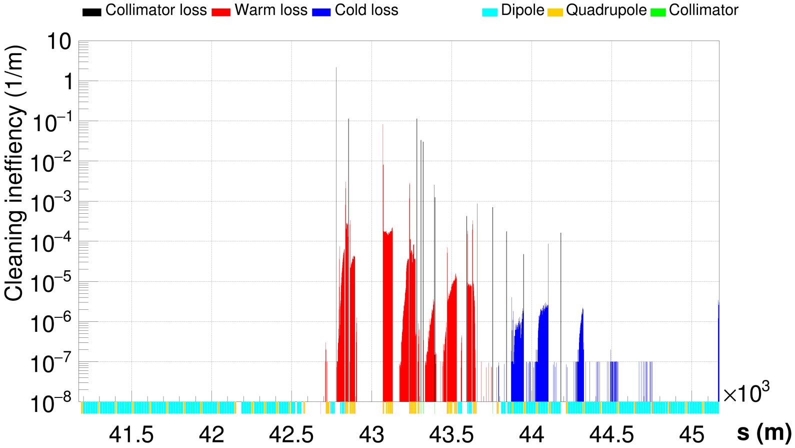
Horizontal betatron halo



Off-momentum halo



Off-momentum halo



Injection summary

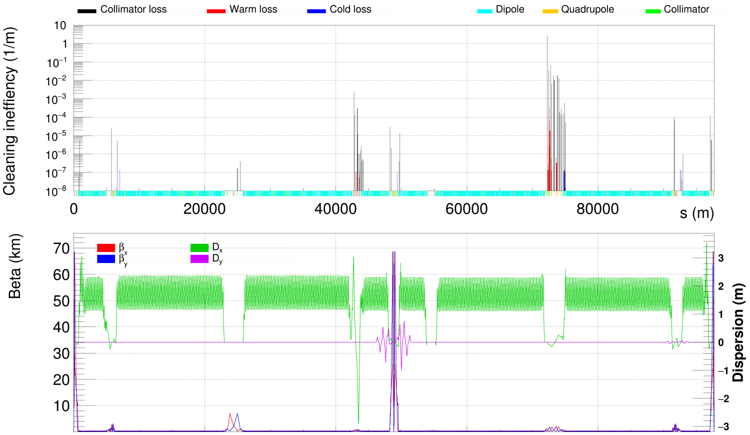
- Cleaning at injection is not perfect, but acceptable.
- Extra TCLA/TCLD collimators perform well in the energy collimation insertion.
- The higher margin to quench at injection gives more headroom.
- Potentially the start of the ramp might need to be slightly slower than in the LHC due to losses from un-captured beam in the energy collimation.

Collimation at collision

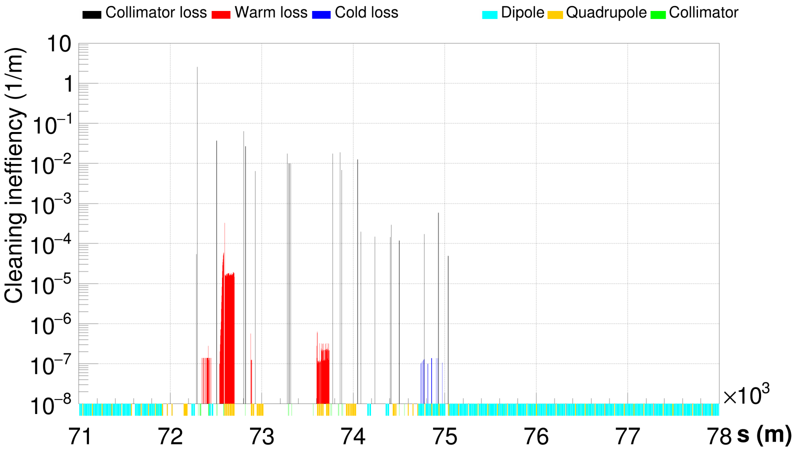
Collision configuration

- 50 TeV beam energy.
- 0.3m β^* at each high luminosity IP.
- Crossing on at each IP.
- 32MV RF.
- 7.570001σ amplitude was used for the horizontal beam halo.

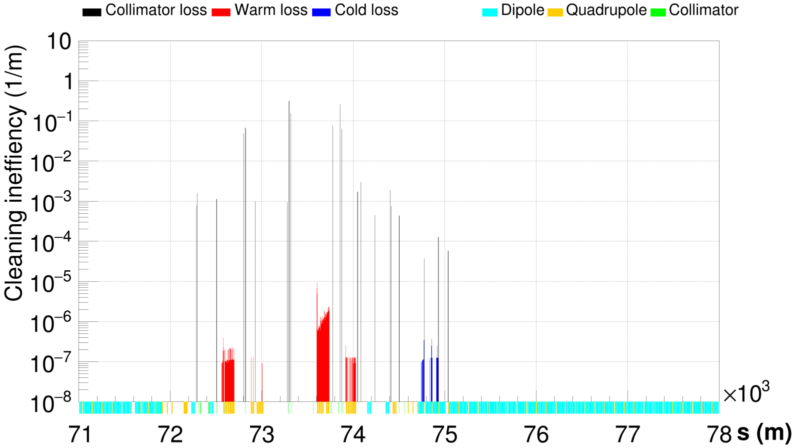
Horizontal betatron halo



Horizontal betatron halo



Skew halo



Collimator loss
Warm loss
Cold loss
Dipole
Quadrupole
Collimator
Cleaning ineffiency (1/m)
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
$\times 10^{3}$
71
72
73
74
75
76
77
78
s (m)

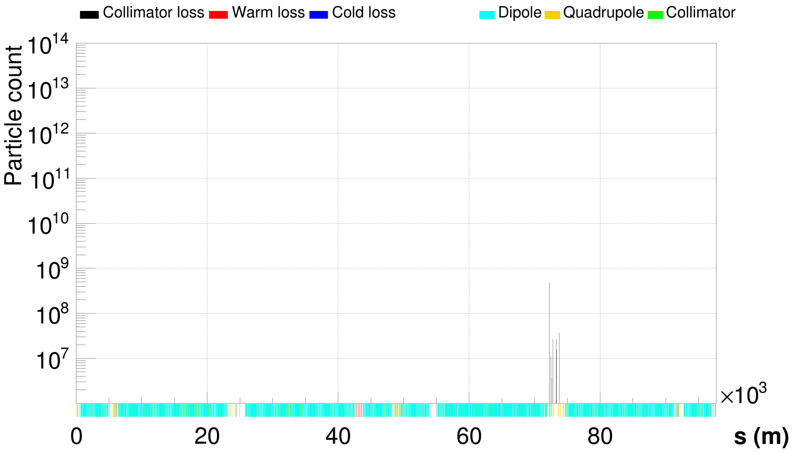
Collision summary

- Cleaning at top energy in the collision configuration is good.
- One potential worry are skew losses with the removal of the skew TCP collimator.
- Potentially the beam lifetime limit for skew losses will need to be changed.

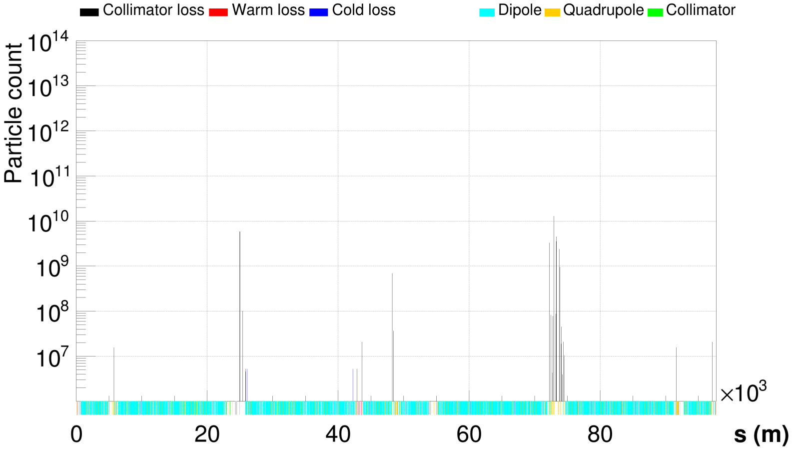
New vertical extraction

- A new extraction system now is in lattice V10, consisting of 150 segmented kicker magnets in the vertical plane instead of 300 in the horizontal.
- One possible failure is the pre-firing of 1 or more extraction kickers resulting in the beam potentially impacting the machine aperture.
- If this takes place the beam should be safely extracted at the next free abort gap.
- A safe limit of 1 bunch impacting a collimator is assumed. How many kickers can fire?

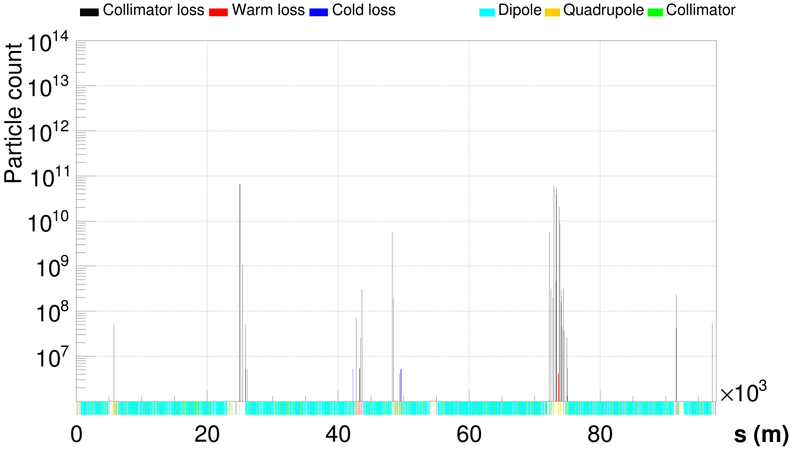
1 kicker pre-fire



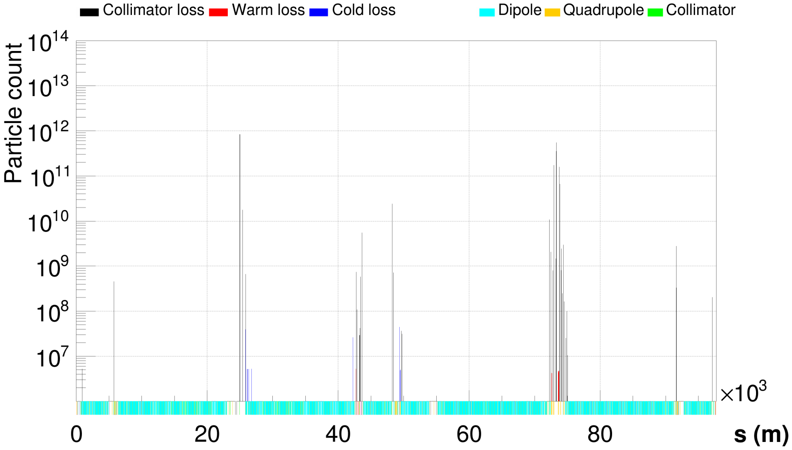
3 kickers pre-fire



4 kickers pre-fire



5 kickers pre-fire



Extraction kicker pre-fire summary

- With the new layout and assuming nominal beam parameters, up to 4 kickers can safely pre-fire without damage to the machine.
- When taking into account jaw errors, the 4 kicker pre-fire just passes the safe limit of 1×10^{11} particles, giving a more realistic safe limit of 3 kickers.
- This limit is highly dependent on the phase advance between the extraction kickers and the collimation insertion.

Conclusions

- The system performance is currently acceptable and within the required performance.
- Further enhancements and optimisation can be made.
- This includes a new placement for the skew TCP collimator, new simulations with errors and misalignments, and looking at new collimation system layouts and methods.

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