Proposal for benchmarking FCC-ee collimation simulation tools at DAΦNE

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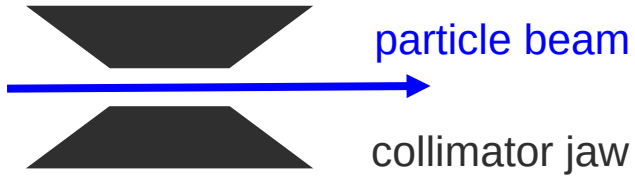
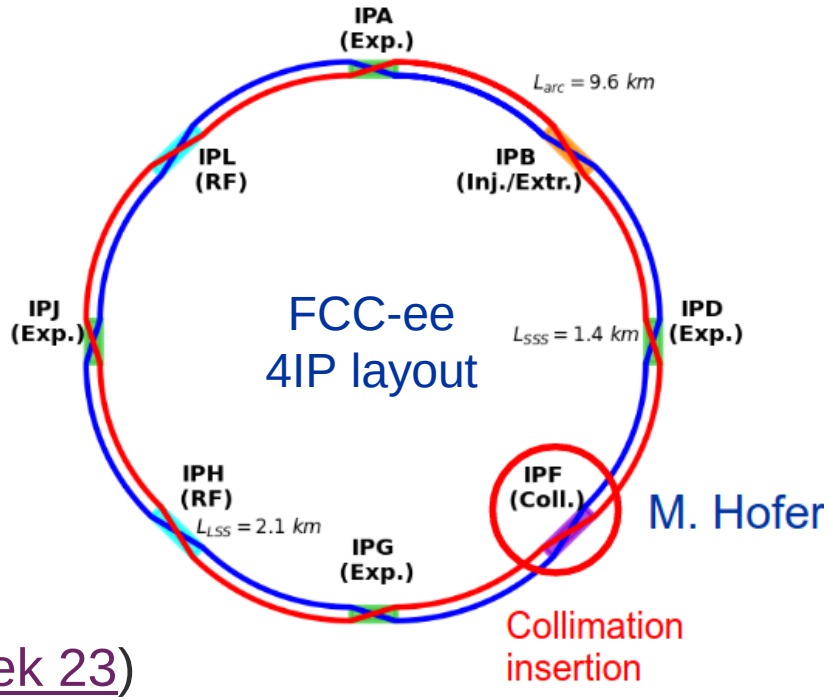
FCC-ee: collimation requirements

- **FCC-ee** will have an **unprecedented stored beam energy for a lepton collider**
  - Up to **17.8 MJ** (Z mode) → highly destructive beams

- **Collimation system** indispensable
  - **Reduce the background in the experiments**
  - **Protect the machine from unavoidable losses**





M. Hofer

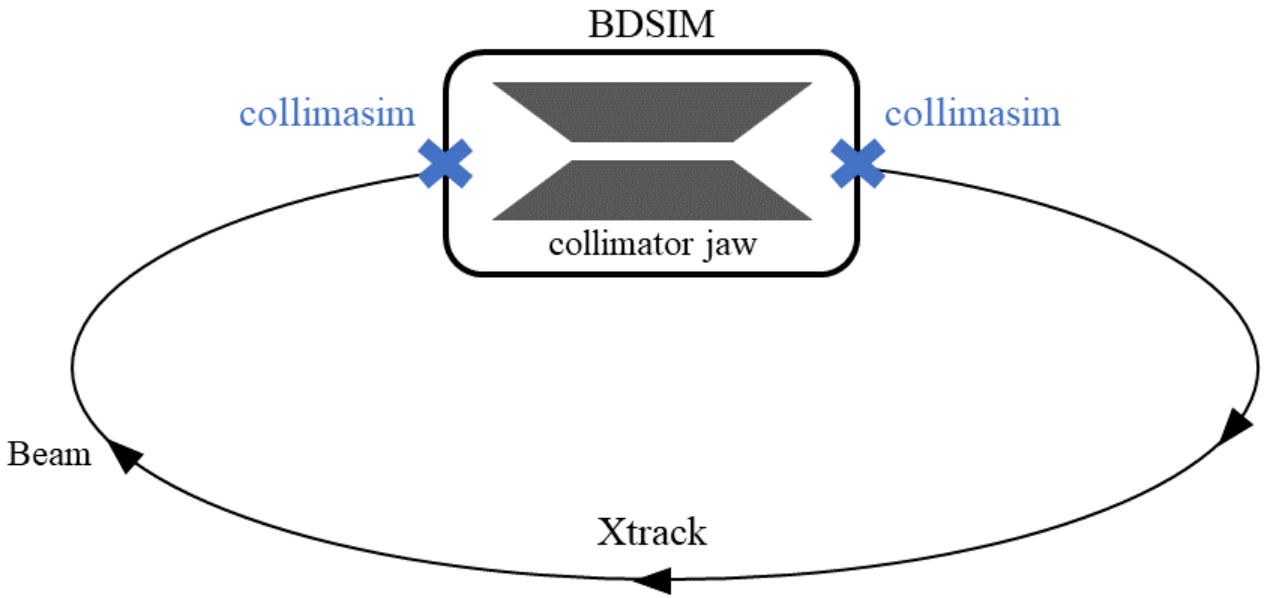
- **Dedicated halo collimation system in PF** (A. Abramov – FCC week 23)
  - Two-stage betatron and off-momentum collimation in one insertion

- **Synchrotron radiation collimators around the Interaction Points** (**IPs**) (K. André – FCC week 23)

- Suitable **collimation simulation tools** are **essential** in the collimation design phase **to converge on an optimum performace**

Simulation tool

- **Xtrack-BDSIM simulation tool** used to evaluate beam losses along the accelerator ring
- **Xtrack**: single particle tracking library belonging to the Xsuite collection of Python packages
- **BDSIM**: C++ software package based on the Geant4 toolkit to simulate radiation transport in accelerators and beam lines
  - ➢ Can be used together for studies including particle tracking and particle-matter interaction



- Other tools available, e.g., Xsuite (Xtrack-Xcoll), Xtrack-FLUKA (soon)

Simulation tool benchmark

- To **test** the **degree of reliability** of such simulation tools a **benchmark with existing tools and** (especially) **measurements** is **needed**

- **Xtrack-BDSIM** coupling **already benchmarked** against:
  - **Existing tools**: Sixtrack-FLUKA, K2, PyAT-BDSIM
  - **Measured data** from **proton machines**: LHC, PS

- For the FCC-ee needs this is **not fully satisfactory** (different particle type and energy)
  - **Benchmark with data from a lepton machine is needed**
  - **DAΦNE** could be an **excellent candidate** (**SuperKEKB** is also being considered)

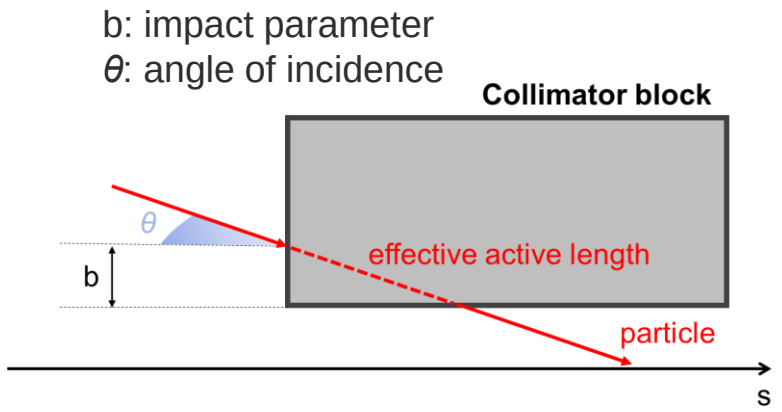
- A **benchmarked simulation tool** could also be **beneficial for DAΦNE**
  - Better understanding of beam losses and of the machine in general

- However, for a **succesfull benchmark**, some **requirements** are needed
  - **Simulation model**
  - **Experimental measurements**

Simulation tool benchmark: simulation model

- To succesfully run a Xtrack-BDSIM simulation, the following inputs are required:
  - **Accelerator parameters**: beam energy, emittance, …
  - **Accelerator optics**: optical parameters and magnetic strengths for the accelerator under study
  - **Aperture model**
  - **Beam Intercepting Devices (BID) database**: database containing BID specifics (geometry, opening, material, movable / not movable ?)

- **Different loss scenario can be simulated**
  - Given beam distribution impacting a BID ← simplest case
  - (top-up) injection losses
  - BID scraping (if movable BIDs are present)
  - Known beam excitation
  - Touschek / beam-gas losses (to be implemented)



- **1st step to check feasibility**: perform **pure tracking simulations** (no particle matter interactions with BIDs) **with Xtrack to reproduce equilibrium conditions**
  - Some regions (e.g., IRs) could be challenging to be modelled (SuperKEKB case)

Simulation tool benchmark: experiment

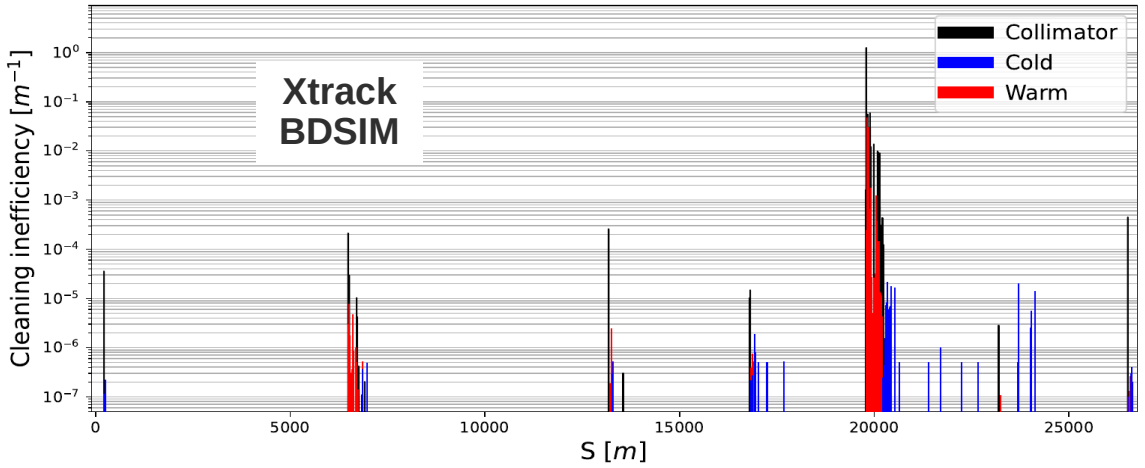
- Xtrack-BDSIM tool good for simulating particle-BID interactions and track the outscattered particles
- To succesfully perform a measurements that can be compared with simulations:
  - **Particle losses on a BID***: possibly generated on purpose in a controlled way
  - **Beam loss monitors (BLM)**: to record signals that can be related to beam losses on the aperture of the accelerator under study

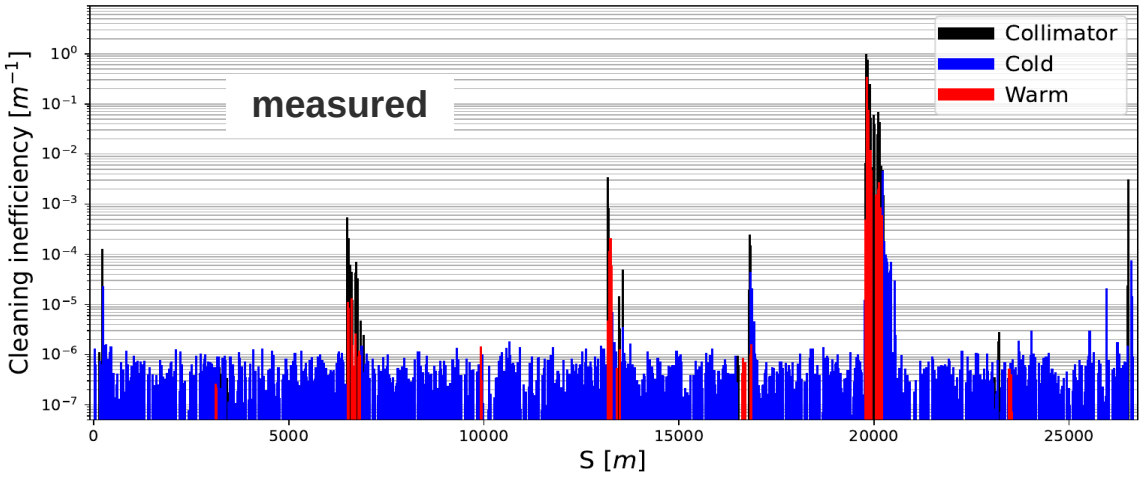
  ***e.g., collimator, scraper, aperture restriction**
  - **Beam intensity monitor**: to properly normalize our measurements (LHC BCT like)
- Ideally perform **single beam measurements** (NO collisions)

- **Possible caveats** (and possible solutions)
  - **Challenging regions to be modelled** (e.g., IRs)
  - **Accuracy of aperture model**
  - **Absence of beam loss monitors / not reliable BLM response along the accelerator**
    - Use collider detectors (if present) to record the outscattered particles («target experiment»)
    - Place a movable detector in a relevant position along the accelerator
  - **Low sensitivity on setting collimators/scrapers opening**
    - Beam based settings (BPM resolution ?)

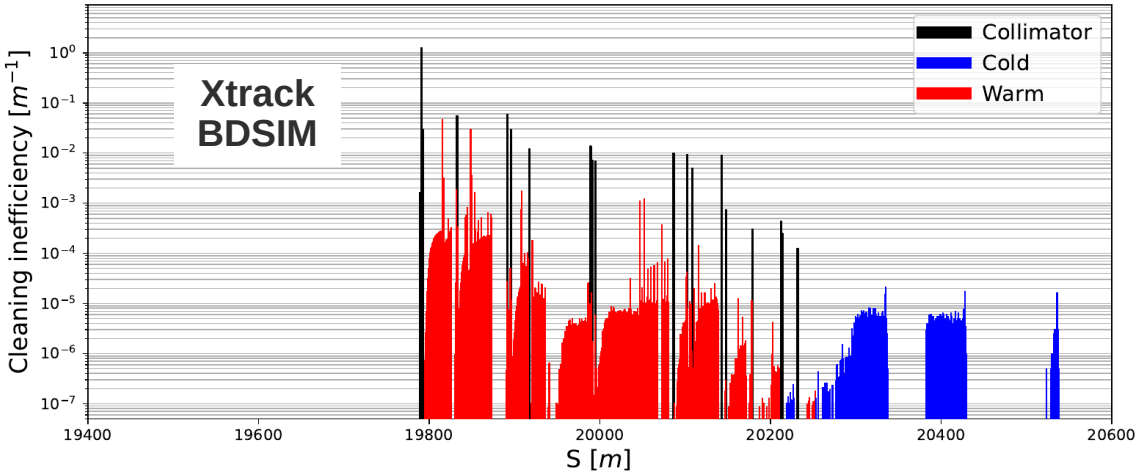
Example: benchmark of Xtrack-BDSIM at the LHC

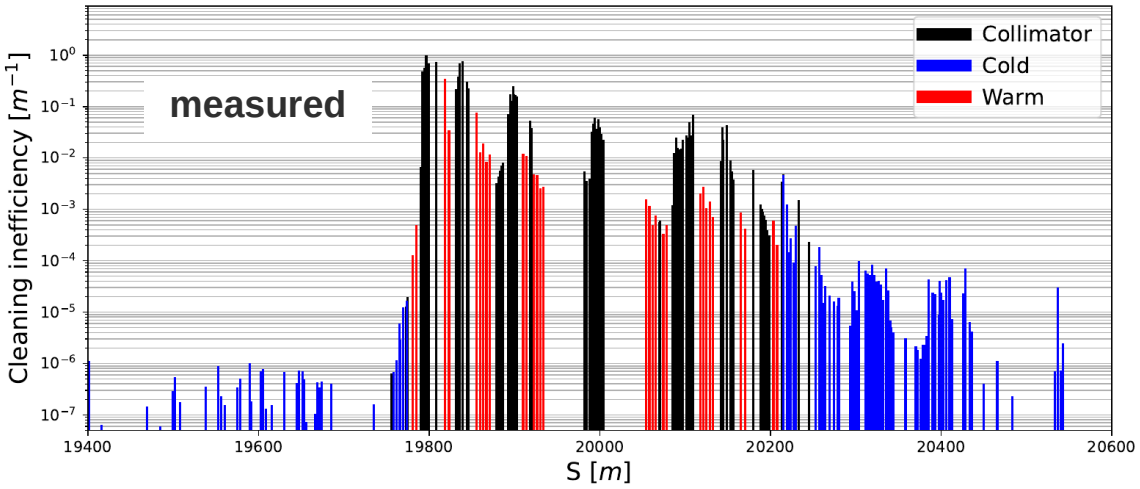
full ring (27 km)





IR7 (betatron collimation)





B1H (protons in LHC), stable beams, XRP_IN, 6.8 TeV, β*=30 cm

From G. Broggi, Master's thesis

Summary

- **Simulation tools to evaluate FCC-ee collimation performance are available**
  - Essential in the collimation design phase to converge on an optimum performance
  - Benchmarked with existing tools (Sixtrack-FLUKA, K2, PyAT-BDSIM)
  - Benchmarked with data from proton machines (LHC, PS)

- **A more satisfacory benchmark with data from lepton machines is needed**
  - DAΦNE could be an excellent candidate (SuperKEKB is also considered)
  - Benchmarked simulation tool useful to better understanding the machine: FCC-ee/DAΦNE win-win

- **For a successfull benchmark some ingredients are needed**
  - **Simulation model**: accelerator parameters, accelerator optics, aperture model, BID database (geometry, opening, material, movable / not movable ?)
  - **Experiment**: losses on a BID*, reliable diagnostic system for particle losses, beam intensity monitor

*e.g., collimator, scraper, aperture restriction, …

Thank you!