Beam halo losses in the FCC-ee MDI

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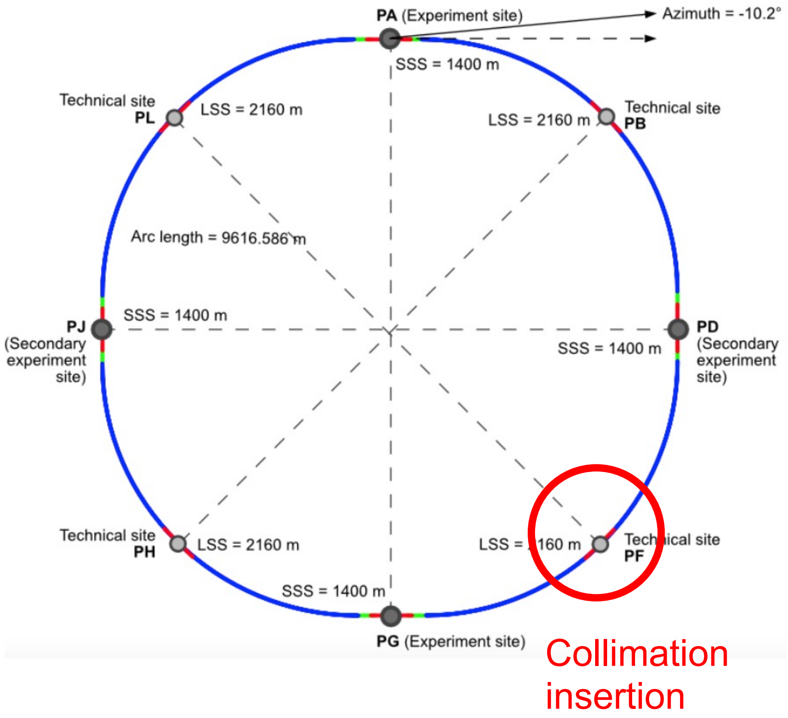
FCC-ee beam halo collimation

- **Studies are ongoing for a collimation system in the FCC-ee.**
  - The stored beam energy in the FCC-ee reaches **20.7 MJ**
  - Such beams are highly destructive: a collimation system is required
  - The main roles of the collimation system are:
    - Protect the equipment from unavoidable losses
    - Reduce the backgrounds in the experiment
  - The beam halo collimation system:
    - Betatron and off-momentum collimation in one insertion
    - Define the global aperture bottleneck
    - Protect against regular and anomalous beam losses
    - Localise the beam losses away from the experiments



  - Talk last week on the simulation tools for beam collimation (link)
  - Talk last week on aperture, collimation optics and layout (M. Hofer) (link)
  - **In this talk: studying beam halo losses in the MDI**

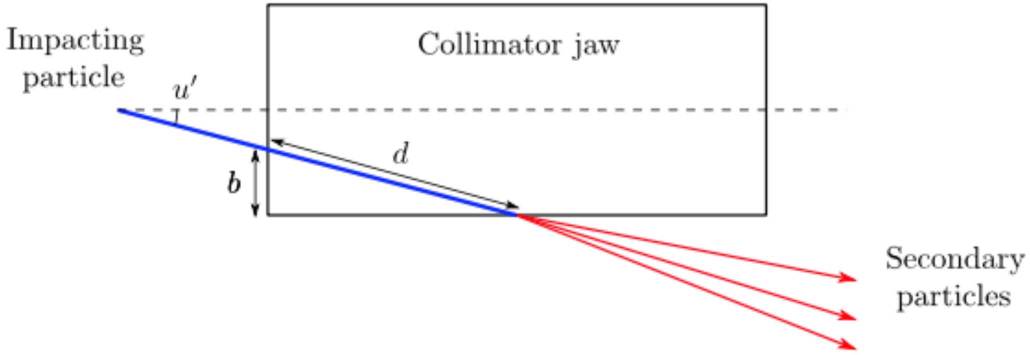
Collimation study requirements

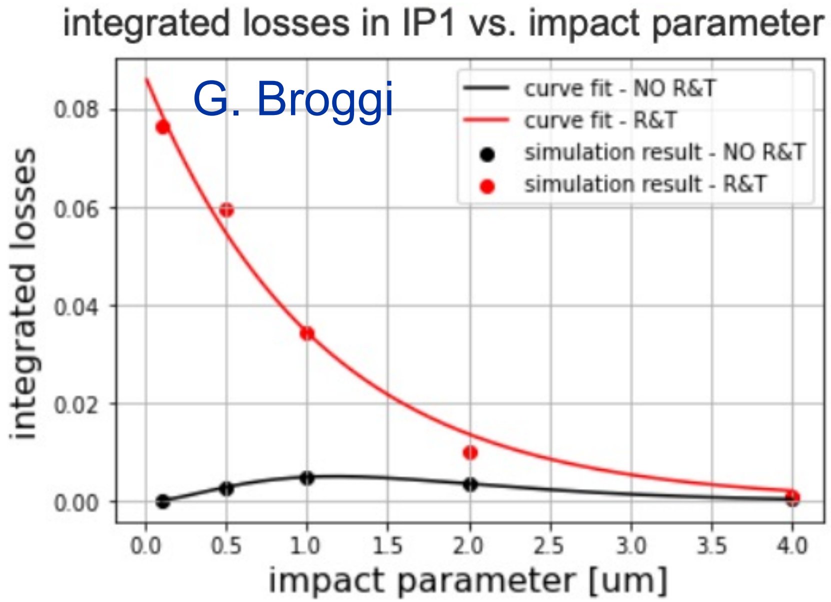
- **Simulation model:**
  - Lattice, optics, corrections
  - Mechanical aperture model
  - Collimation system model
    - Layout, collimator parameters, settings
- **Beam loss scenario**
  - Beam distribution
  - Loss power estimate
- **Equipment loss tolerances**
  - Quench limits for superconducting elements
  - Damage limits for warm equipment
  - Detector background tolerances

} Collimation system performance

Current study: beam halo losses

- **"Generic halo" beam loss scenario:**
  - Assume a slow diffusion process – halo particles intercepted by the primary collimators
  - The diffusion is not simulated, all particles start impacting a collimator
  - The particles have the "worst" impact parameter
    - Determined with an impact parameter scan
    - Provides a conservative performance estimate
  - Study horizontal and vertical betatron halo, and off-momentum halo impacts
  - Track the particles scattered out from the collimator and record losses on the aperture
  - Specify a beam lifetime that must be sustained
    - Currently assuming **5 min**

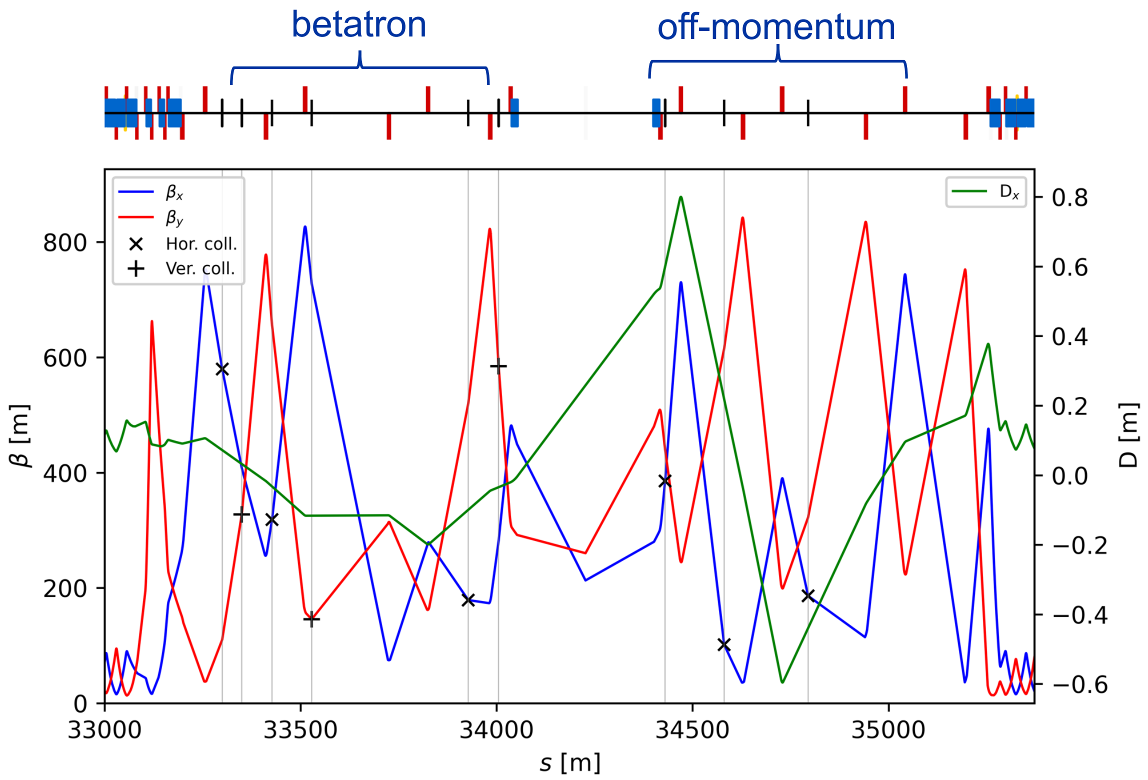




Impact parameter scan for 2 IP CDR lattice with MoGr primary collimator, with and without radiation and tapering (R&T)

Collimation at ttbar

- **Status**
  - Using the 4IP lattice with the latest settings
  - Collimator settings based on machine aperture and top-up injection requirements (M. Hofer)
  - First guess on FCC-ee collimator parameters (G. Broggi, talk)
  - Focus on studying the collimation performance
  - Still resolving issues with RF matching – radiation and tapering not included yet.



FCC-ee optics repository: link
FCC-ee collimation optics repository: link

Collimator settings

	name	type	length[m]	nsigma	half-gap[m]	material	plane
betatron	tcp.h.b1	primary	0.4	15.0	0.013802	MoGR	H
	tcp.v.b1	primary	0.4	80.0	0.002466	MoGR	V
	tcs.h1.b1	secondary	0.3	17.0	0.011591	Mo	H
	tcs.v1.b1	secondary	0.3	89.5	0.00184	Mo	V
	tcs.h2.b1	secondary	0.3	17.0	0.008688	Mo	H
	tcs.v2.b1	secondary	0.3	89.5	0.003685	Mo	V
off-mom.	tcp.hp.b1	primary	0.4	23.0	0.017253	MoGR	H
	tcs.hp1.b1	secondary	0.3	26.0	0.010004	Mo	H
	tcs.hp2.b1	secondary	0.3	26.0	0.013558	Mo	H

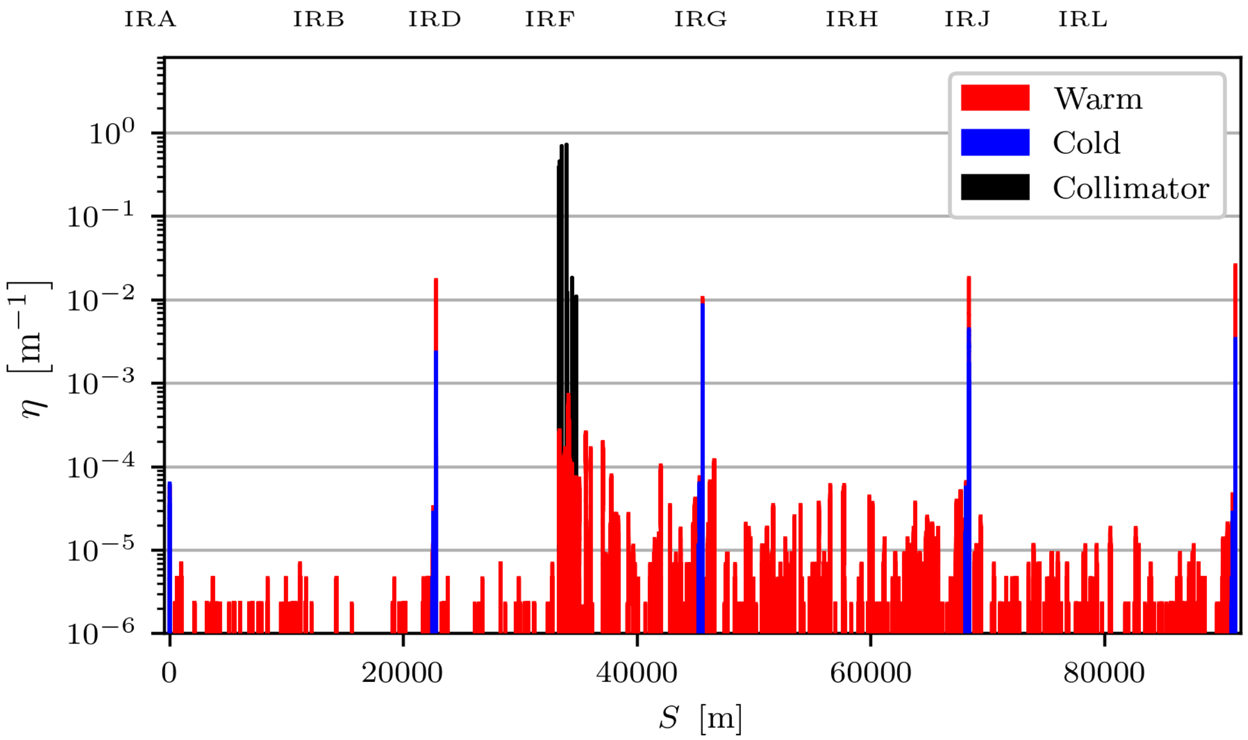
Loss map studies at ttbar

- **Results from tracking studies**
  - Horizontal betatron collimation, **no radiation and tapering**, 5×10^6 macro-particles, 700 turns, 1 um impact parameter
  - Significant losses observed in all 4 IPs

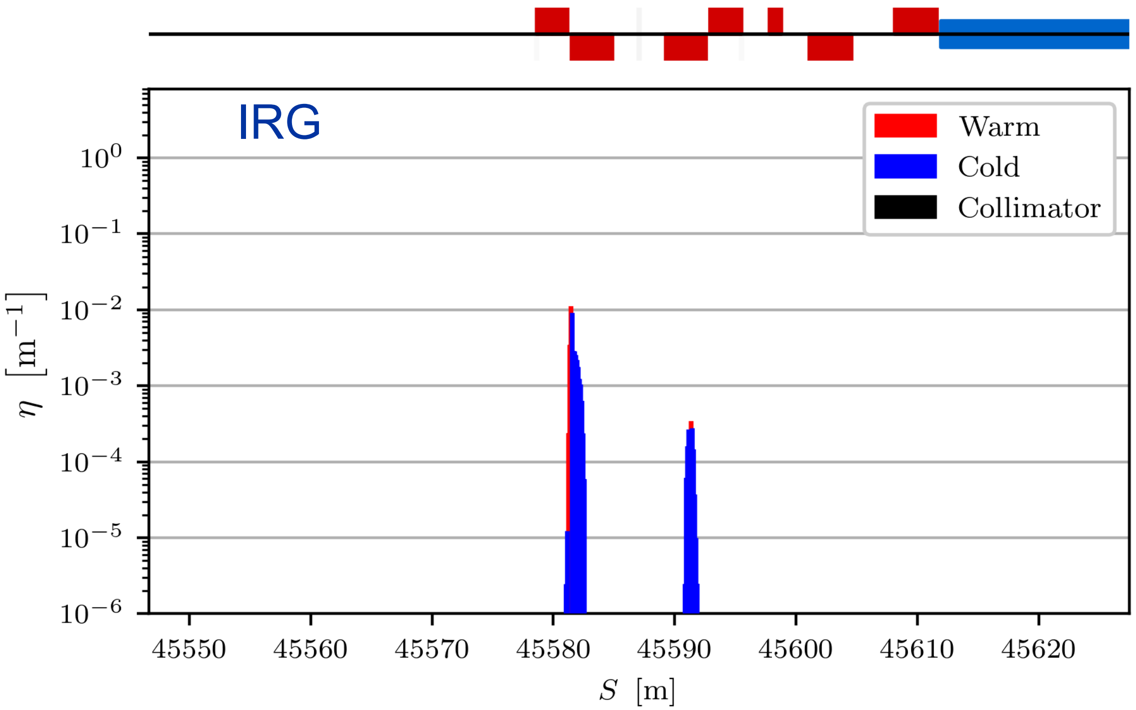
Total loss power P = 923.97 W

	P [W]	R [p/s]
IPA	4.404	1.5e8
IPD	3.192	1.0e8
IPG	3.041	1.0e8
IPJ	4.630	1.5e8

Integrated losses +-100 m from IP for a 5 min beam lifetime



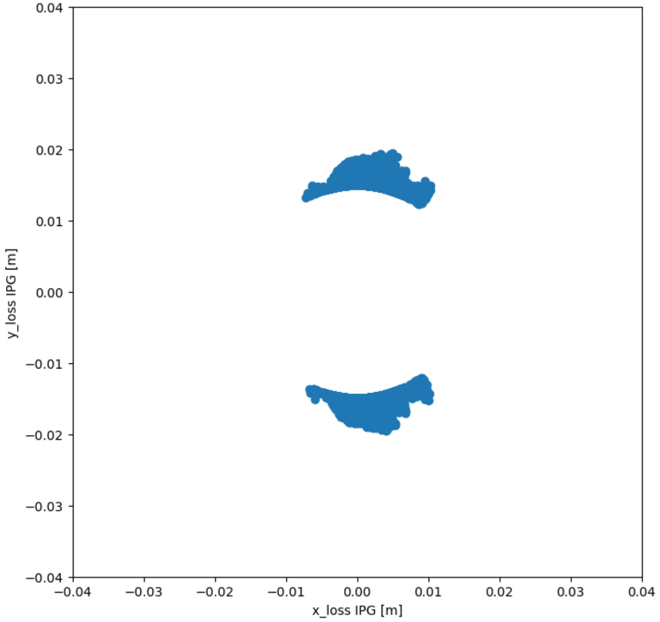
Loss map for FCC-ee ttbar B1H

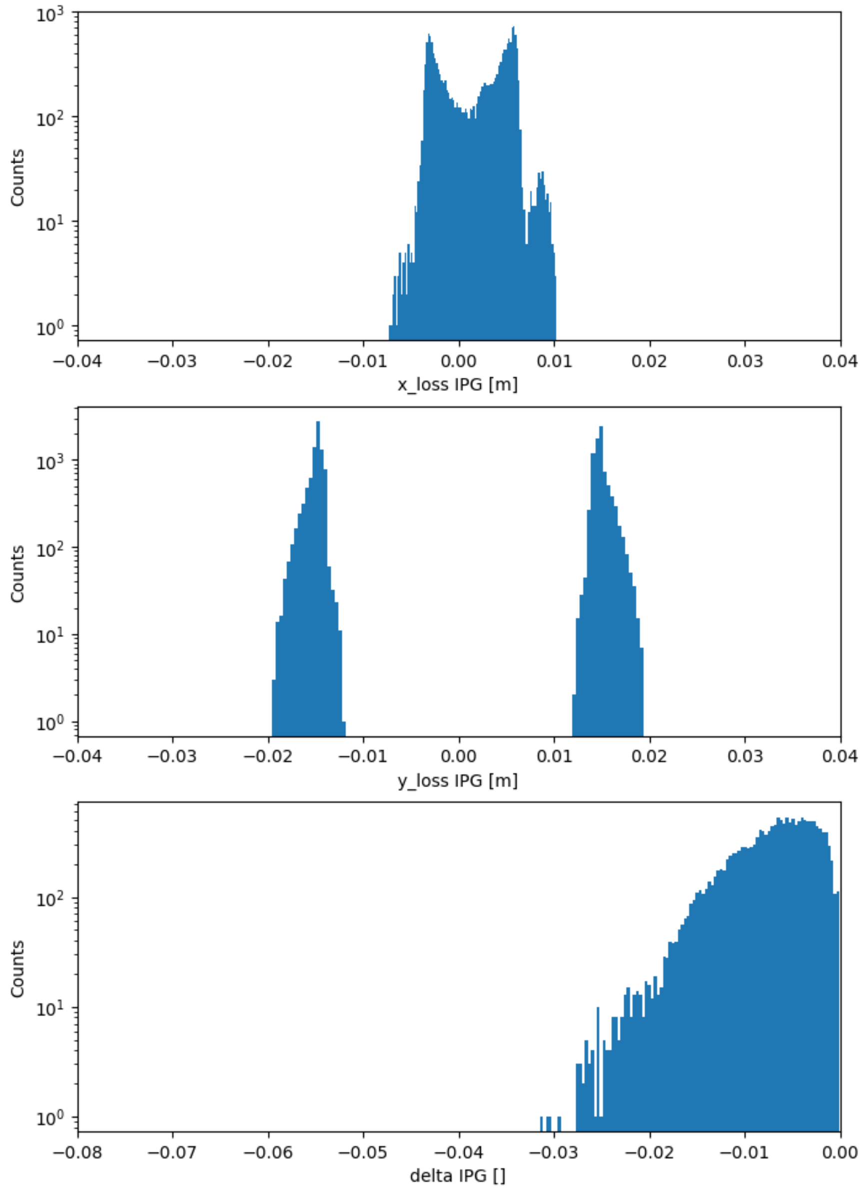


Zoom to IR region

Losses in the IRs for ttbar

- **Loss distribution in the IRs:**
  - Particles scattered by the primary collimator and not intercepted by the secondary ones
  - Most of the losses in the vertical plane, on the final focus quadrupole aperture
  - Losses passed on to MDI team (A. Ciarma) for detector background studies





Distributions of lost particles in IRG

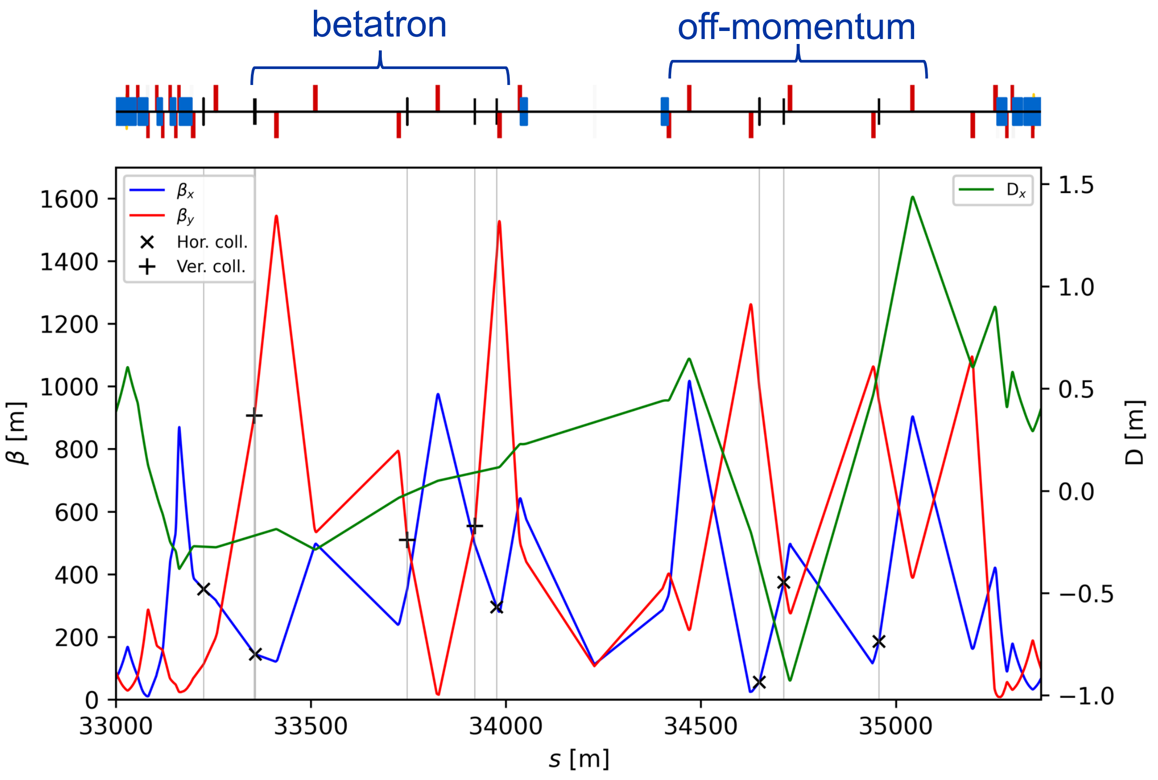
Loss mitigation strategies for ttbar

- **The option of using tilted collimators considered**
  - Collimator aligned with the beam divergence
  - Sensitivity studies required
  - May not be feasible for operation
  - The tilt simulations are also useful for error studies

- **There are other possible approaches to mitigate the losses**
  - Optimizing the optics, layout, and settings of the collimation insertion
  - The integration of SR collimators can help
  - Additional local collimation stages in the IR to be considered

Collimation at Z

- **Status**
  - The model is set up in a similar way to ttbar
  - The layout of the vertical collimators has been adjusted to reduce the impedance
  - Radiation and tapering not included in the collimation models yet, also some minor issues with the DA remain



FCC-ee optics repository: link
FCC-ee collimation optics repository: link

Collimator settings

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	tcp.v.b1	primary	0.4	65.0	0.002332	MoGR	V
	tcs.h1.b1	secondary	0.3	13.0	0.004162	Mo	H
	tcs.v1.b1	secondary	0.3	75.5	0.00203	Mo	V
	tcs.h2.b1	secondary	0.3	13.0	0.005956	Mo	H
	tcs.v2.b1	secondary	0.3	75.5	0.002118	Mo	V
off-mom.	tcp.hp.b1	primary	0.4	29.0	0.005755	MoGR	H
	tcs.hp1.b1	secondary	0.3	32.0	0.01649	Mo	H
	tcs.hp2.b1	secondary	0.3	32.0	0.011597	Mo	H

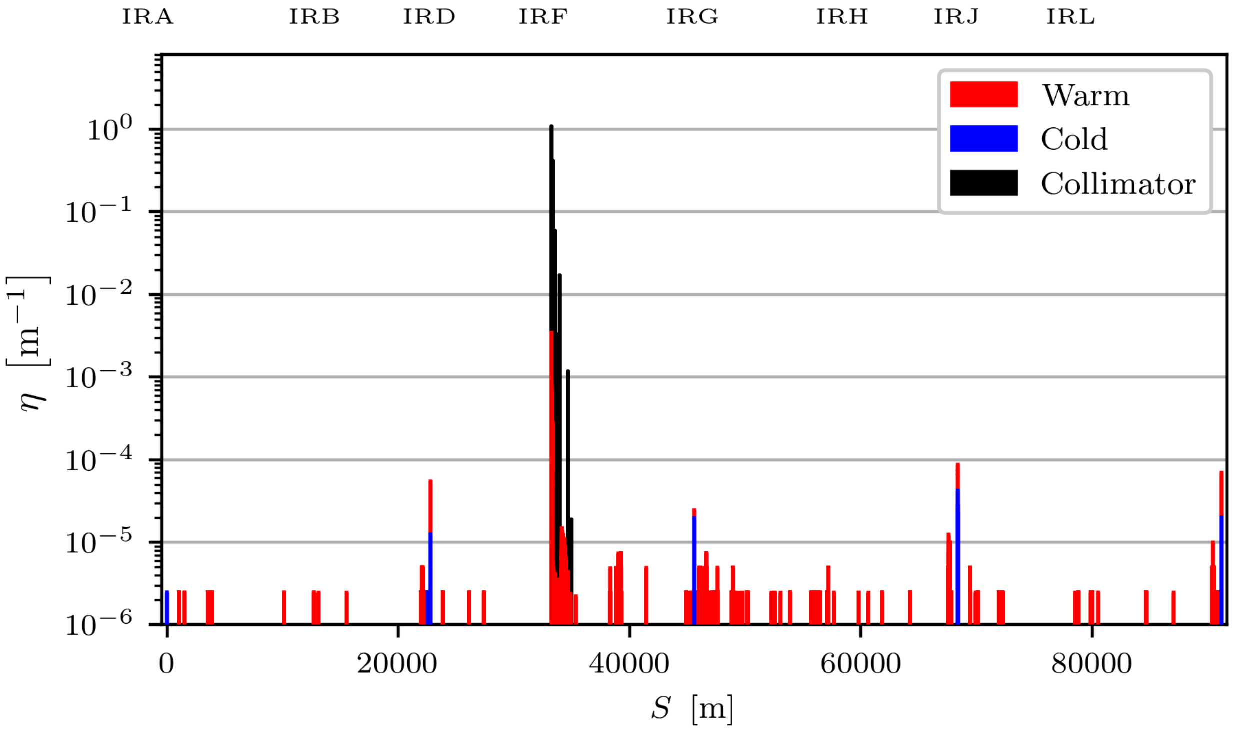
Loss map studies at Z

- **Results from tracking studies**
  - Horizontal betatron collimation, **no radiation and tapering**, $5x10^6$ macro-particles, 700 turns, 1 um impact parameter
  - Better cleaning efficiency than for ttbar

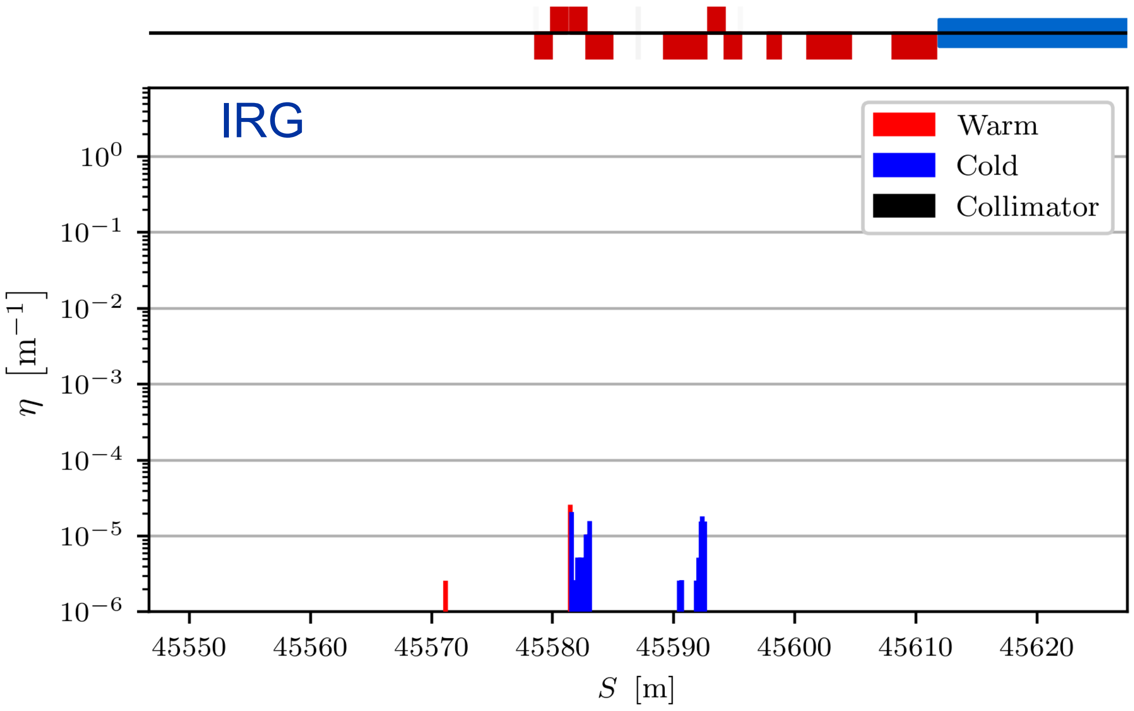
Total loss power P = 59178.12 W

	P [W]	R [p/s]
IPA	1.912	2.6e8
IPD	1.051	1.4e8
IPG	0.855	1.2e8
IPJ	2.808	3.9e8

Integrated losses +-100 m from IP for a 5 min beam lifetime



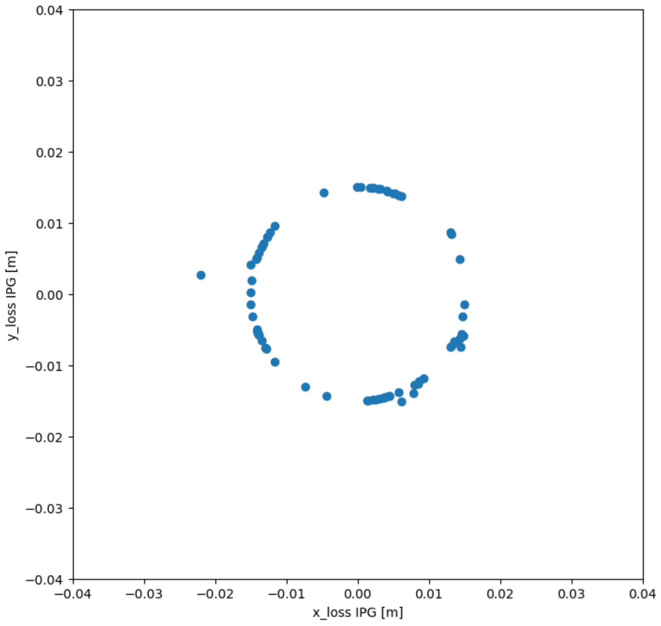
Loss map for FCC-ee Z B1H

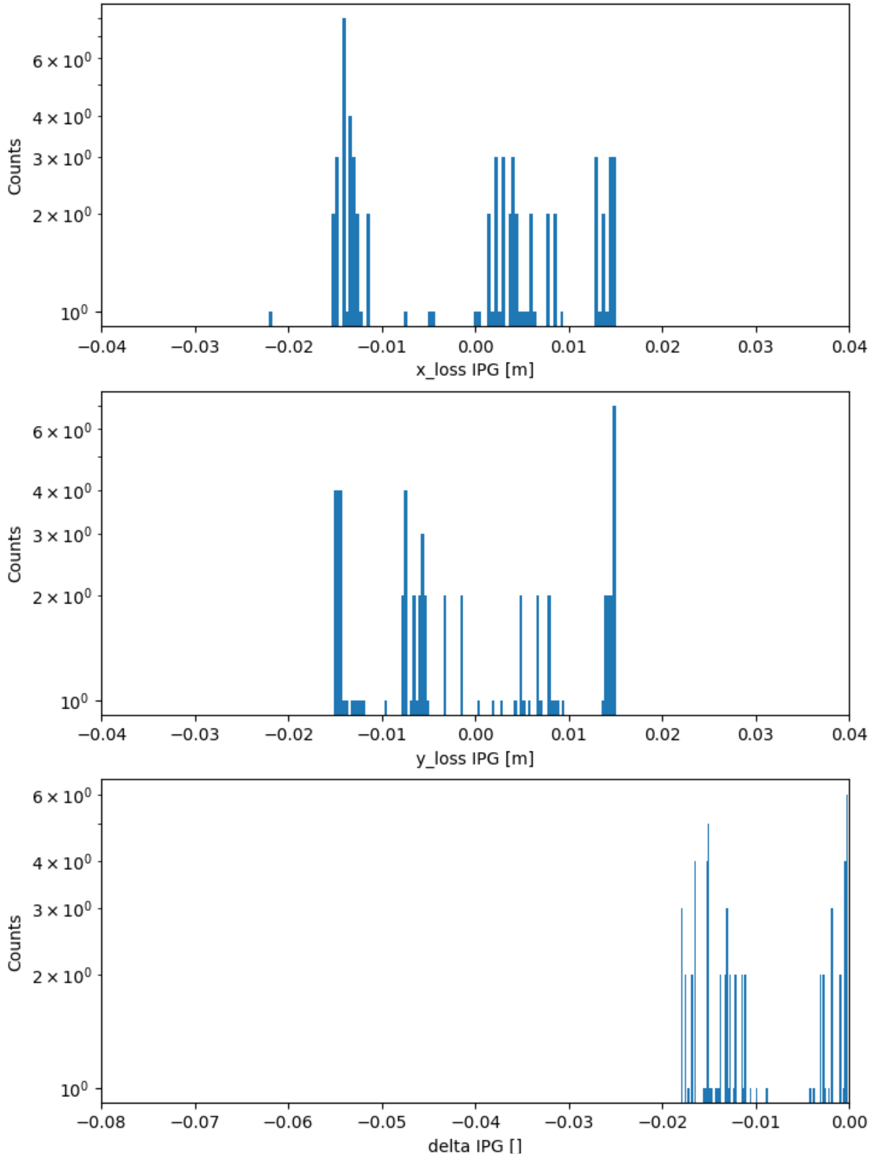


Zoom to IR region

Losses in the IR for Z

- **Loss distribution in the IRs:**
  - Particles scattered by the primary collimator and not intercepted by the secondary ones
  - Losses again in the final focus quadrupole, but distributed between horizontal and vertical
  - Losses for this case also passed on to the MDI team.





Distributions of lost particles in IRG

Next steps

- **Integrate the SR collimators and masks in the collimation system model**
- **Include radiation and tapering in the latest 4 IP models**
- **Refine the mechanical aperture model**
- **Study different beam loss scenarios**
  - Injected beam
  - Spent beam (Beamstrahlung, Bhabba, etc.)
  - Failures (injection, extraction, instabilities)
- **Obtain better equipment loss tolerances**
  - Detector background limits
  - Quench limit for the final focus quadrupoles (energy deposition studies required)

} Input needed

Thank you!