PLANS FOR THE BACKGROUND STUDIES

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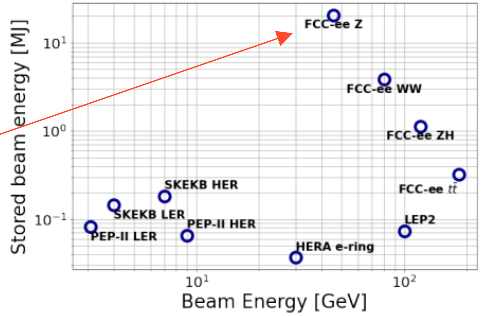
Collimation for FCC-ee

FCC-ee presents unique challenges:

- At Z pole 17.5 MJ of stored beam energy (two orders of magnitude bigger than any other lepton collider)
- Beams are highly destructive



M. Hofer – paper

Collimation system must:

- Minimize background for the experiments
- Protect the machine and the detectors from unavoidable beam losses

Collimation system foresees:

- Beam halo collimation + local protection collimators
- Synchrotron Radiation (SR) collimation, nearby IPs
- Secondary particle shower absorbers under study

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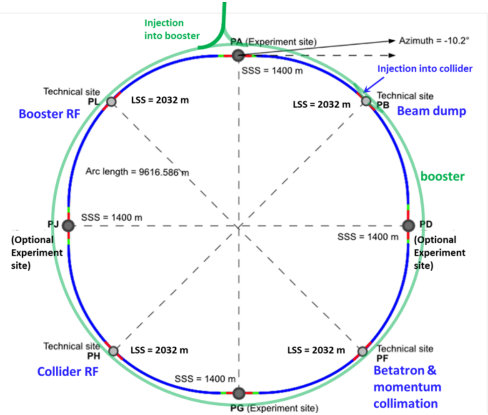
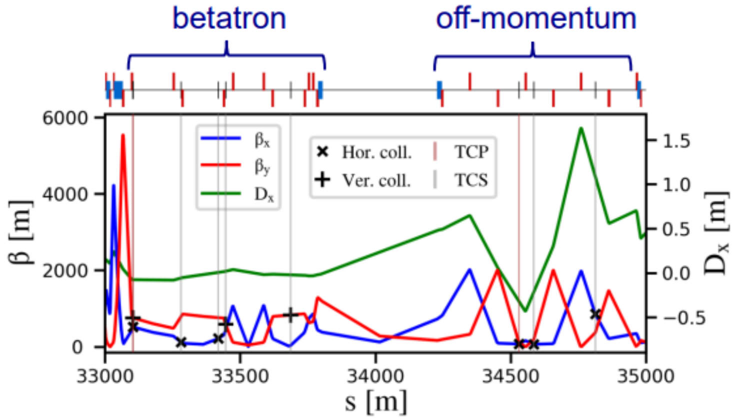
FCC-ee halo collimation system

- Collimation system located in the **LSS F**
- Two stage betatron and off-momentum collimation system
- Protect the aperture bottlenecks (at Z 14.6 sigma (H) and 84.2 (V))

- First collimator design for cleaning performance
  - Ongoing studies for optimizing the collimator design (**G. Broggi & R. Bruce - slides**)
  - Alternative crystal collimation under investigation (**G. Broggi - slides**)

- Two tertiary collimator have been added for local protection of SR collimators

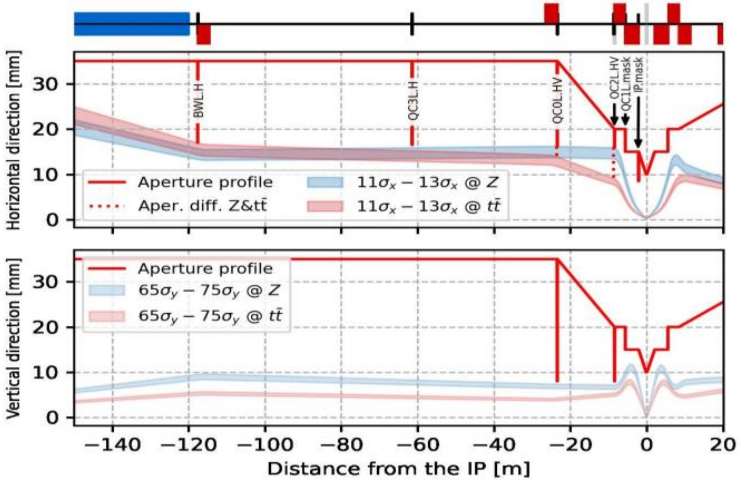




Name	Plane	Material	Length[m]	Gap[σ]	Gap[mm]	δ_{cut} [%]
TCP.H.B1	H	MoGr	25	11	6.7	8.9
TCP.V.B1	V	MoGr	25	65	2.4	-
TCS.H1.B1	H	Mo	30	12	5.0	6.0
TCS.V1.B1	V	Mo	30	75	2.5	-
TCS.H2.B1	H	Mo	30	12	7.0	22.8
TCS.V2.B1	V	Mo	30	75	3.0	-
TCP.HP.B1	H	MoGr	25	18.5	4.2	1.3
TCS.HP1.B1	H	Mo	30	21.5	4.6	2.1
TCS.HP2.B1	H	Mo	30	21.5	16.8	1.6
TCT.H.B1	H	MoGr	25	13	3.4	-
TCT.V.B1	V	MoGr	25	80	6.1	-

FCC-ee SR collimation system

- Synchrotron radiation collimators nearby the IPs (**K. Andre - <u>slides</u>**):
  - 6 collimators and 2 masks upstream of the IPs
  - Designed to reduce detector backgrounds and power loads in the inner beampipe due to photon losses



Name	Plane	Material	Length[m]	Gap[σ]	Gap[mm]
TCR.H.WL.B1	H	W	10	14.0	17.0
TCR.H.C3.B1	V	W	10	14.0	16.5
TCR.V.C0.B1	V	W	10	84.2	8.0
TCR.H.C0.B1	H	W	10	14.0	16.2
TCR.V.C2.B1	V	Mo	10	84.2	8.0
TCR.H.C2.B1	H	Mo	10	14.0	16.0

FCC-ee beam loss scenarios

Important to investigate different beam loss scenarios and identify the ones to protect against. Currently the one under investigation and planned to be studied are:

- Generic beam halo losses
- Beam losses from interactions with residual gas
- Beam losses from spent beam due to the collision processes

} **G. Broggi - slides**

- Synchrotron radiation (**K. Andre - slides**)

- Beam losses due to fast instabilities (**Current**)
- Beam losses from interactions with thermal photons
- Beam losses from top-up injection

- Beam losses from Touschek scattering

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Rise time instability: Introduction

- The ring impedance can generate an instability that leads the **beam to be lost within few turns**.

- A feedback system is under development to dump the beam in case of rising instability.

- However, **feedback failures might happen and need to be investigated**.

- Effects on machine and detectors need to be understood to avoid damage and backgrounds.

- Collimation system must protect the machine/detectors also in this scenario.

- If not, both collimation and feedback systems must be improved.

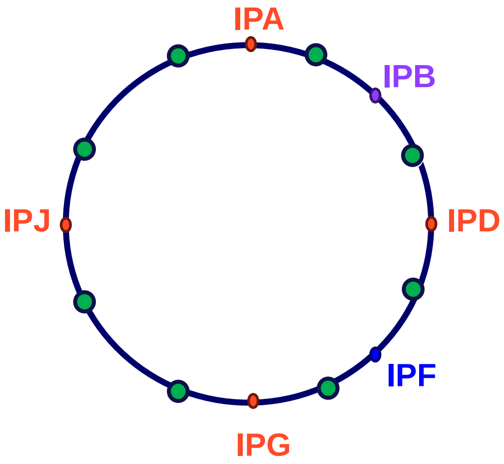
Simulation setup

- Performed with **Xsuite-BDSIM** simulation tool.
- Building on the **state-of-the-art FCC-ee optics**.
- Fast instability introduced as **8 exciter placed along the ring** (one per arc, shown as green points).
- Kicks (H/V) are **equally distributed in phase advances across 90° and 180°** (smooth change in amplitude within 1 turn).
- The exciter **strengths change with time** as:

$$k = \frac{A_0}{\beta_{x,y}} \cos\left(2\,\pi\,Q_{x,y}\,t\right) e^{\frac{t}{\tau}}$$

, where $\boldsymbol{\tau}$ is the **rise time.**

- Resulting in **betatron oscillations exponentially growing with time**.



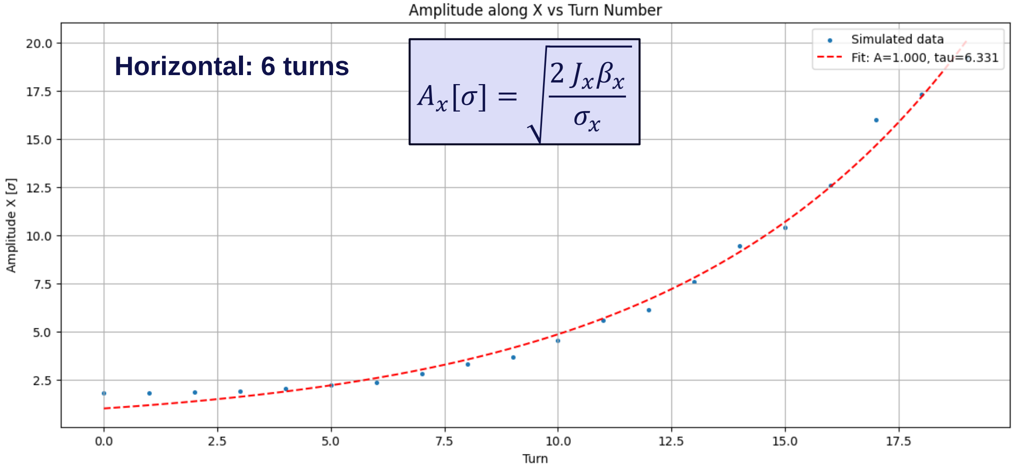
Simulation parameters:

- **5×10^5 45.6 GeV electrons**.
- **SR** (mean model), **RF** cavities, magnet **tapering.**
- detailed **aperture model**, **halo and tertiary collimators**, **SR collimator**, wiggler.

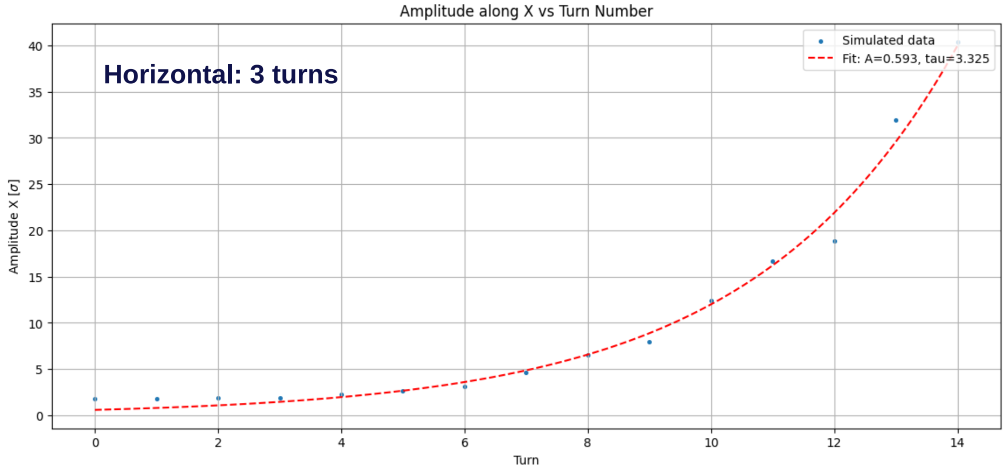
Case studies

- Since the instability can start at any point, it is relevant to **explore the phase dependence**.
- Exciters shifted along the ring to have **four different phase advances between the first exciter and the primary collimator**.
- **16 different cases** have been investigated:

	$3\ turns$	$6\ turns$
Horizontal	$\Delta\mu_0 = 0°, 30°, 60°, 90°$	$\Delta\mu_0 = 0°, 30°, 60°, 90°$
Vertical	$\Delta\mu_0 = 0°, 30°, 60°, 90°$	$\Delta\mu_0 = 0°, 30°, 60°, 90°$



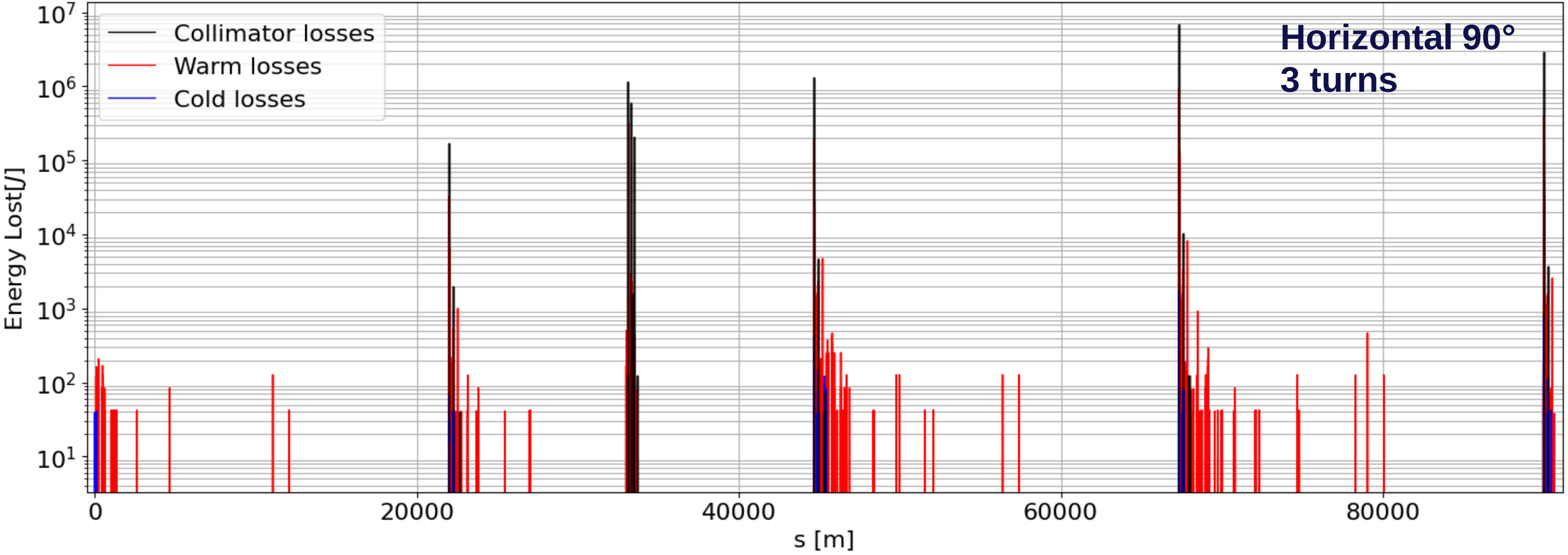
$$A_x[\sigma] = \sqrt{\frac{2\,J_x\beta_x}{\sigma_x}}$$



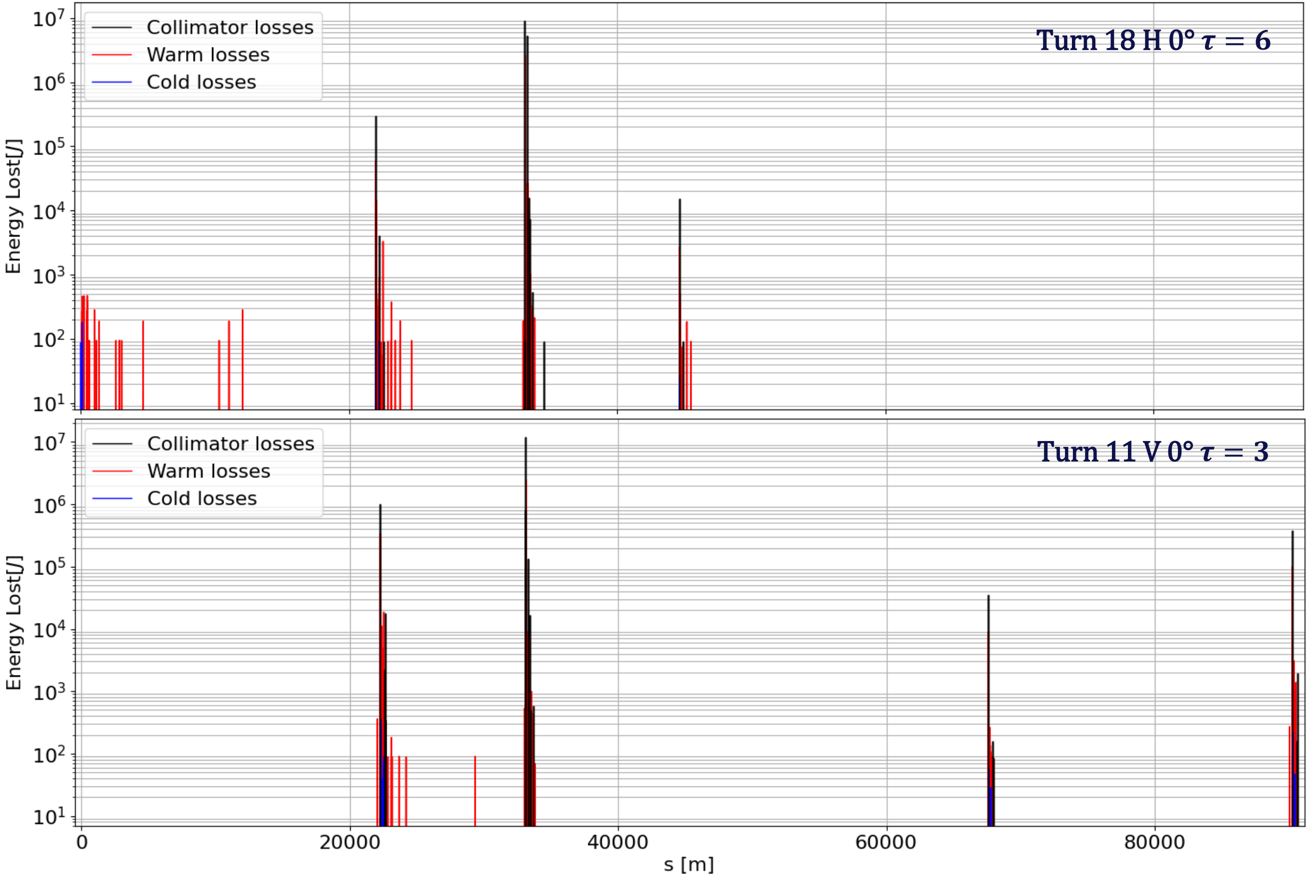
Preliminary results

Lossmaps at each turn have been generated to study the **time distribution of the losses**:

- Entire beam is lost within 22(15) turns for $\tau = 6(3)$ turns.
- Losses start to be observed during the last ~ 5 turns for H and ~ 10 turns for V.
- Most of the configuration presents a **turn where up to $\sim 50\%$ of the beam is lost**.
- **Order of MJ lost across collimators and apertures in one turn!**
- The energy lost in first turns might be detected to damp the beam before damages.



Preliminary results

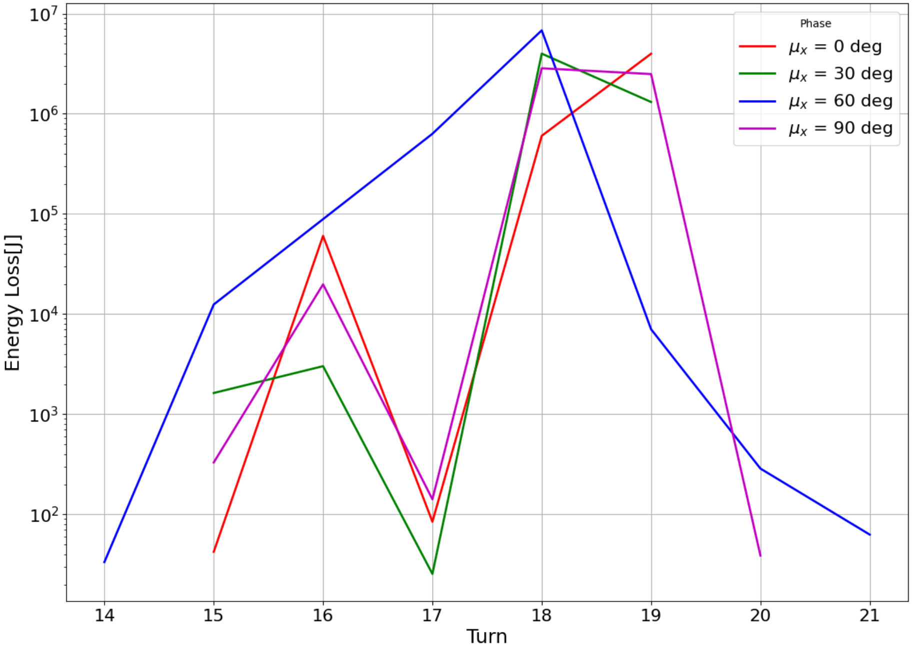


- Example of turns in which almost half of the stored beam energy would be released.
- For 6 turns the losses at the first util turn are up to $\sim$ kJ
- For 3 turns the losses at the first util turn are already of the order of $\sim MJ$
- In the vertical plane the losses are more spread across the turns.

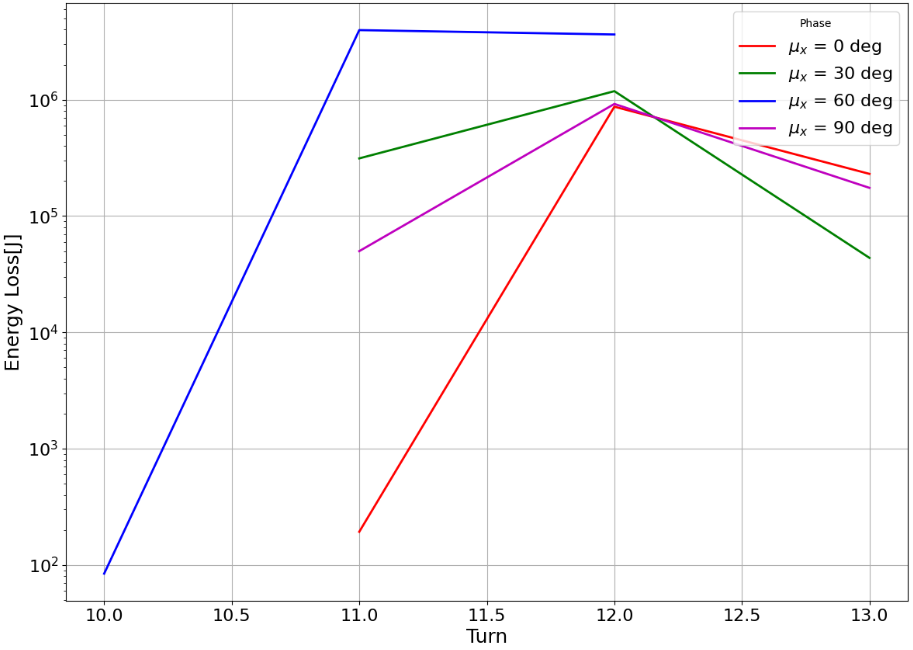
Losses at the primary collimators: horizontal

To compare the various cases is useful to look at the first collimator with time:

$\tau = 6$



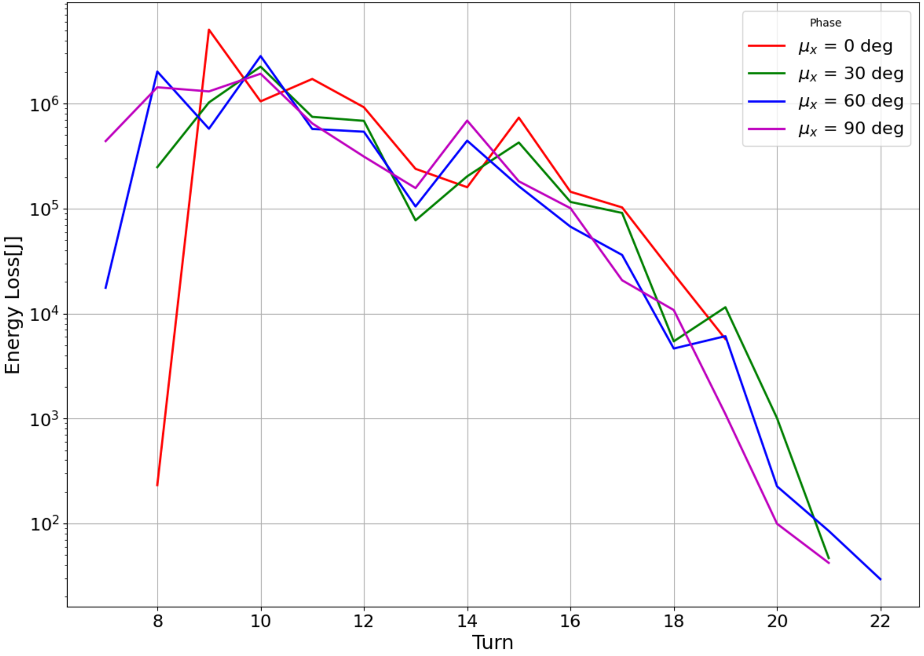
$\tau = 3$



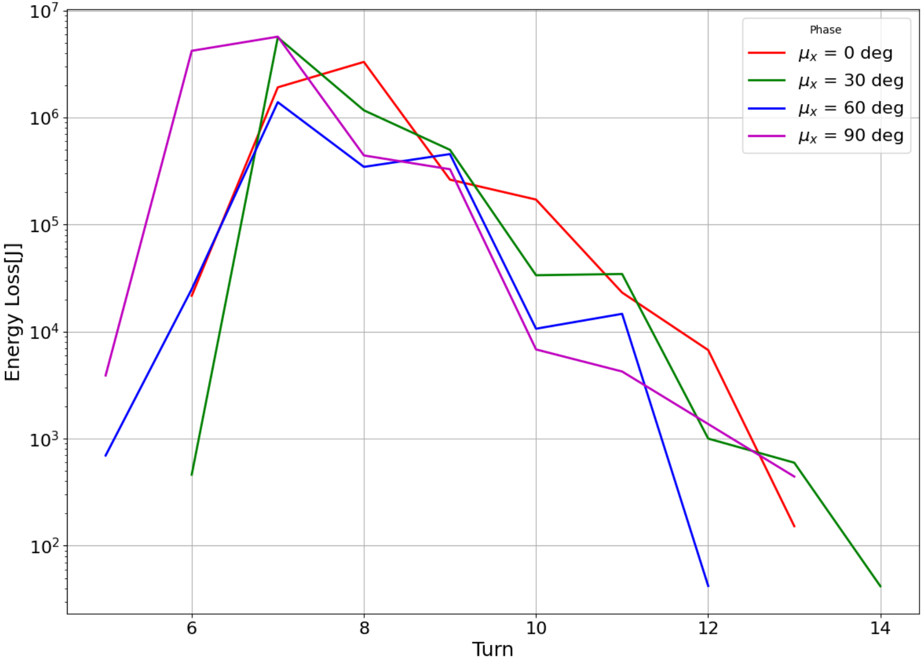
Losses at the primary collimators: vertical

To compare the various cases is useful to look at the first collimator with time:

$\boldsymbol{\tau = 6}$



$\boldsymbol{\tau = 3}$



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Conclusions

Collimation system for FCC-ee is being developed.

- **Beam losses scenarios must be investigated** to further improve the design where needed.

The **fast instability could be dangerous** if the feedback system fails.

- This instability can cause damage both at the machine and detectors, as well as increasing backgrounds.
- **Chances of damaging collimators/detectors**. The beam is lost within few turns, almost 50% of beam energy lost in one turn.
- The effect depends also on the phase advance.
- High losses nearby experiments, shower calculation in the detector region is needed.

Next steps

- Study of the spatial distribution on collimator jaws, small impact area expected.

- Further check in collaboration with the FLUKA team to verify collimation performance in this scenario. Might need to change the collimation system to mitigate the effect.

- Shower calculation to estimate eventual background/damage in collimators as well as in the detectors.

- Study of other beam losses scenario and background sources, such as:
  - Top-up Injection background
  - Thermal photon background

- Estimate of shower reaching detector region coming from beam losses (FLUKA/GEANT4).

Thank you
for your attention.

Backup

Fast instability: Introduction

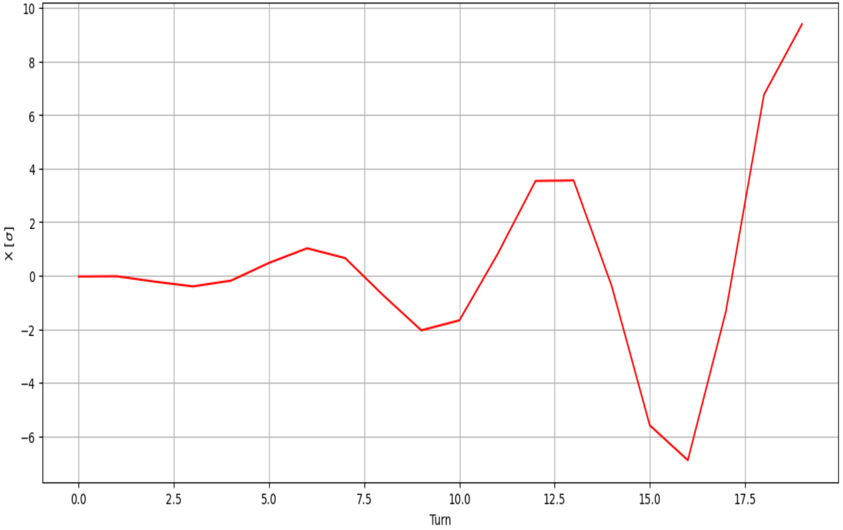
Assuming the beam as a single particle of charge $N_b e$ (no coupling) under the influence of an external force(wake fields/impedance) and neglecting the longitudinal motion.

A complex tune shift is generated due to the impedance of the ring $\Delta\omega = U - jV$:

- The betatron motion is influenced by such impedance.
- The real part of the impedance define growth/damping rate of the betatron oscillation.
- The **instability rise-time** is given by:

$$\tau_{x,y} = \frac{1}{V_{x,y}} = \frac{4\,\pi Q_{x,y}(\frac{E_t}{e})}{I\ c\ \times \{-Re[Z_{x,y}(\omega)\}}$$

- **If $\tau > 0$ → betatron oscillations grow exponentially.**



For more detalies X. Buffat.