Transverse emittance reconstruction along the cycle of the CERN Antiproton Decelerator

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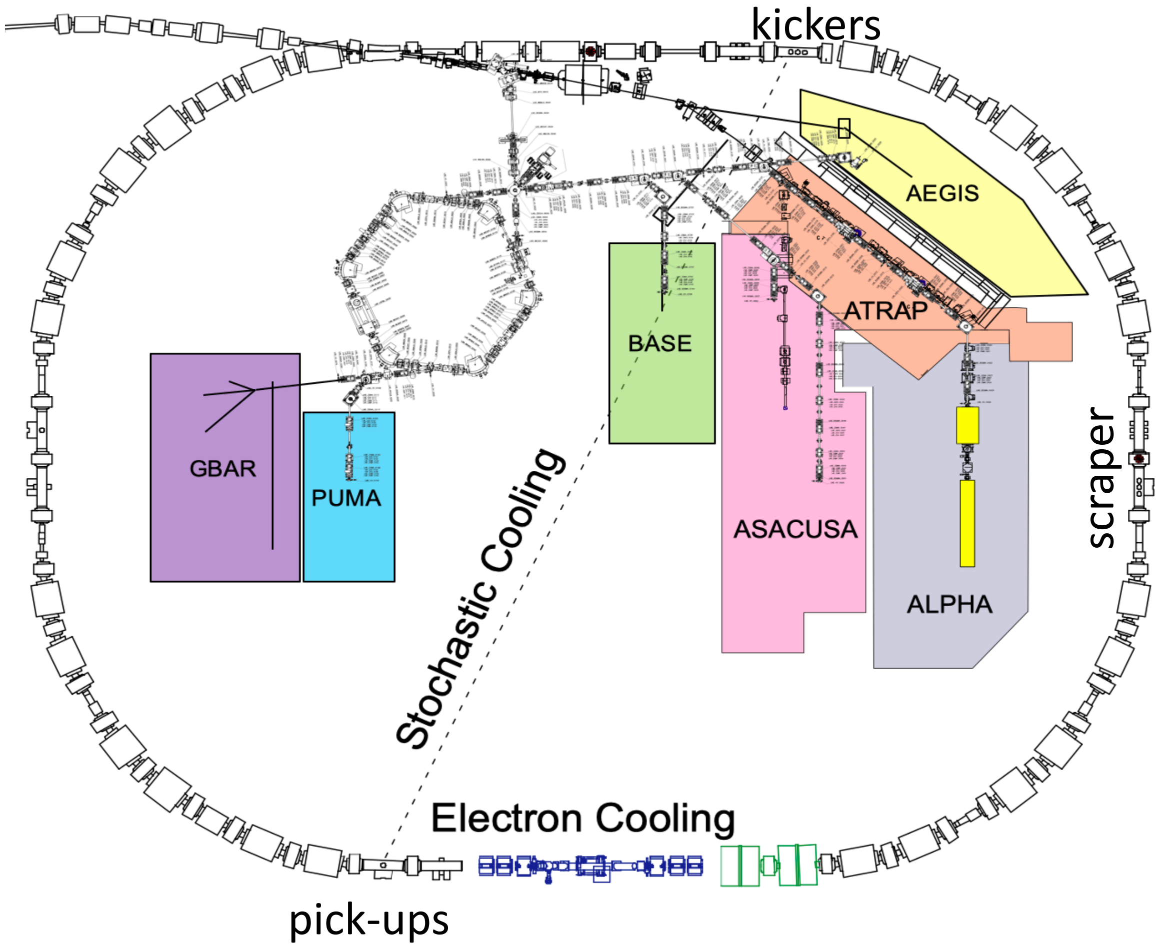
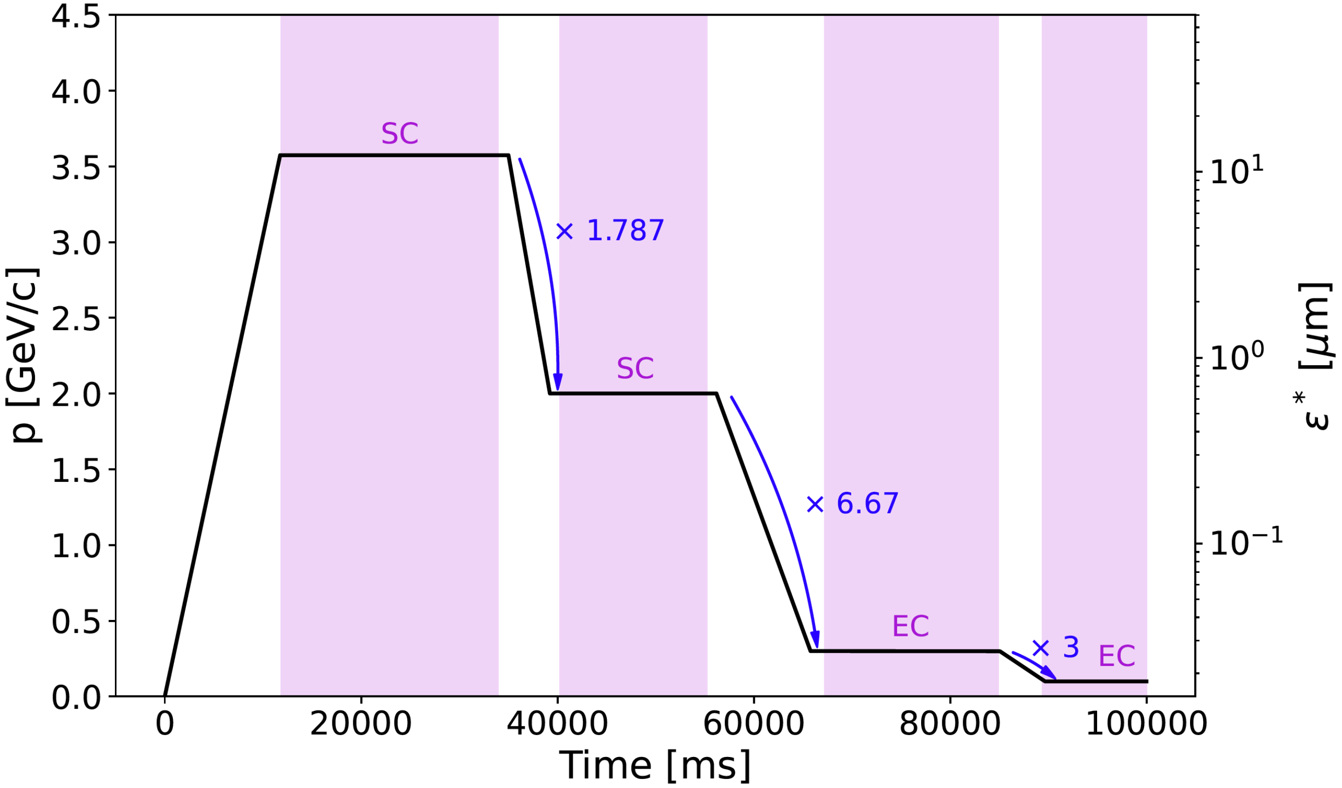
The AD cycle

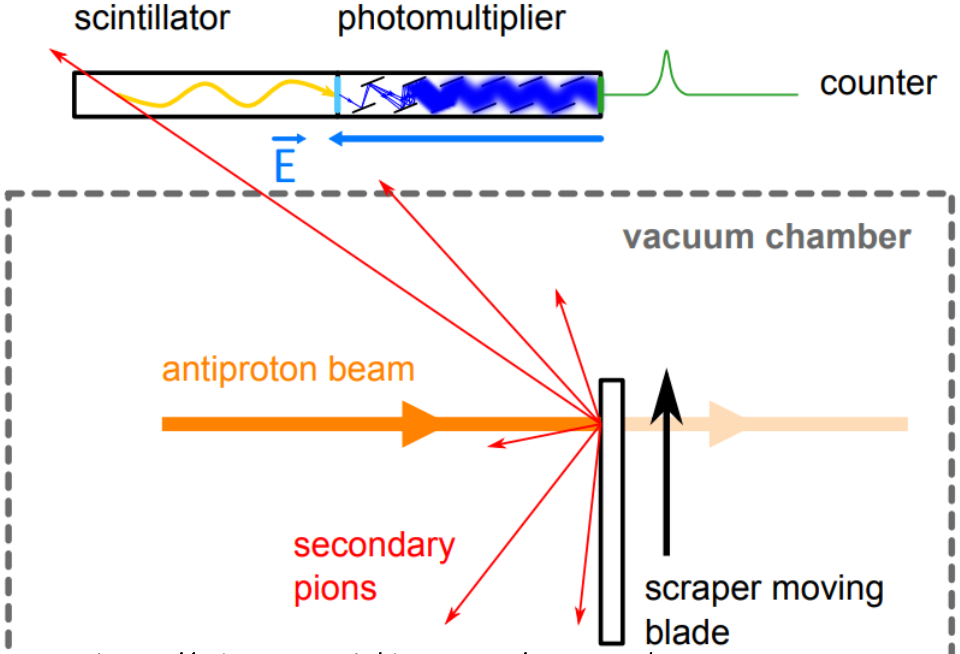
The $\bar{p}$ beam is generated from the collision of p^+ at 26 GeV against a target. After a cleaning from other secondaries the $\bar{p}$ are focused and injected into AD.



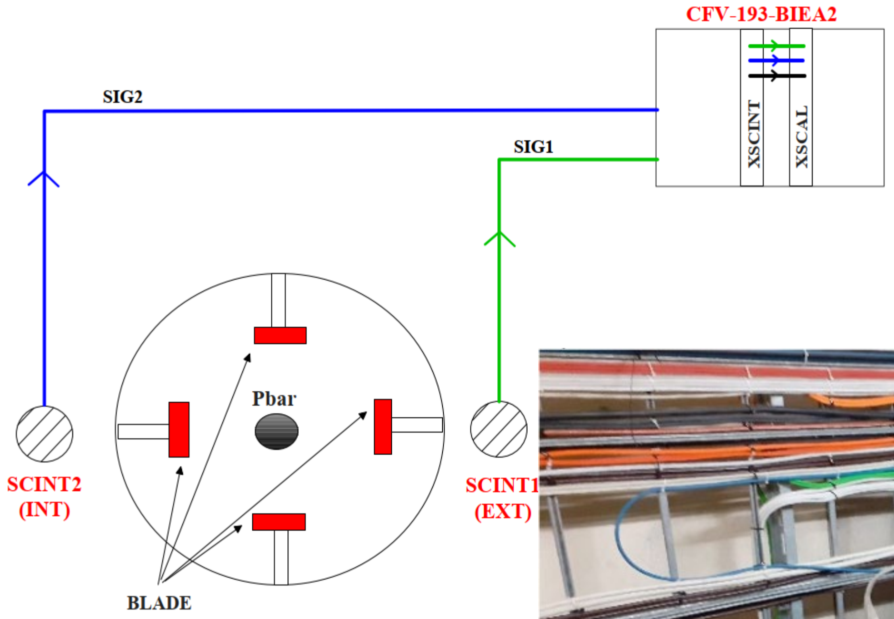
We can assess:
1) Cooling performance
2) Decelerating performance

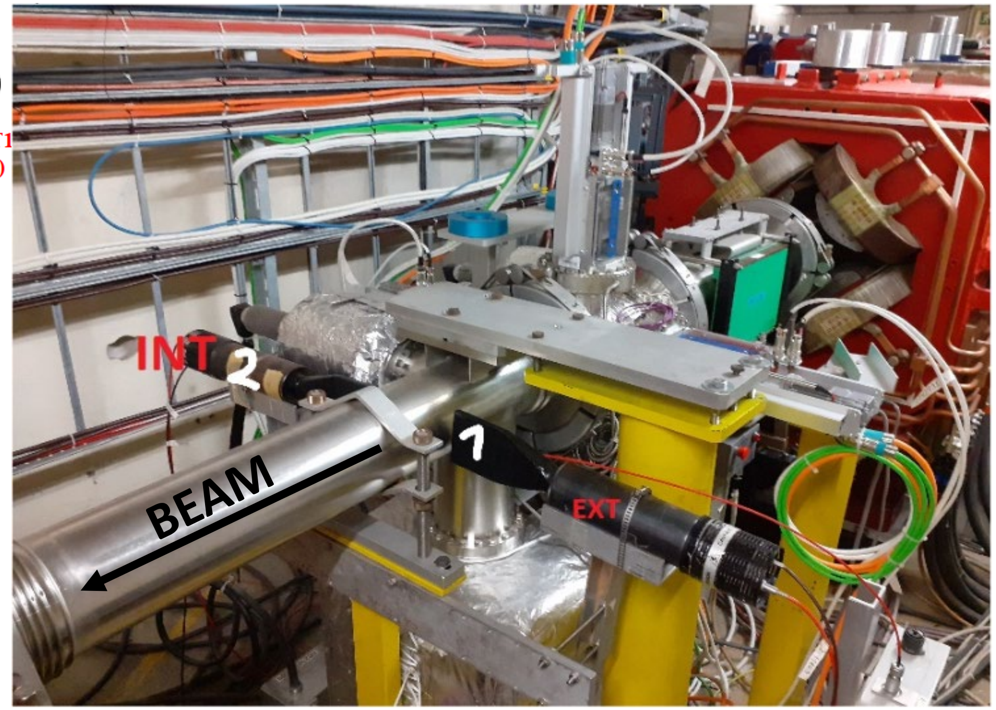


Emittance from scraper measurements: setup



From https://edms.cern.ch/document/1732558/0.1





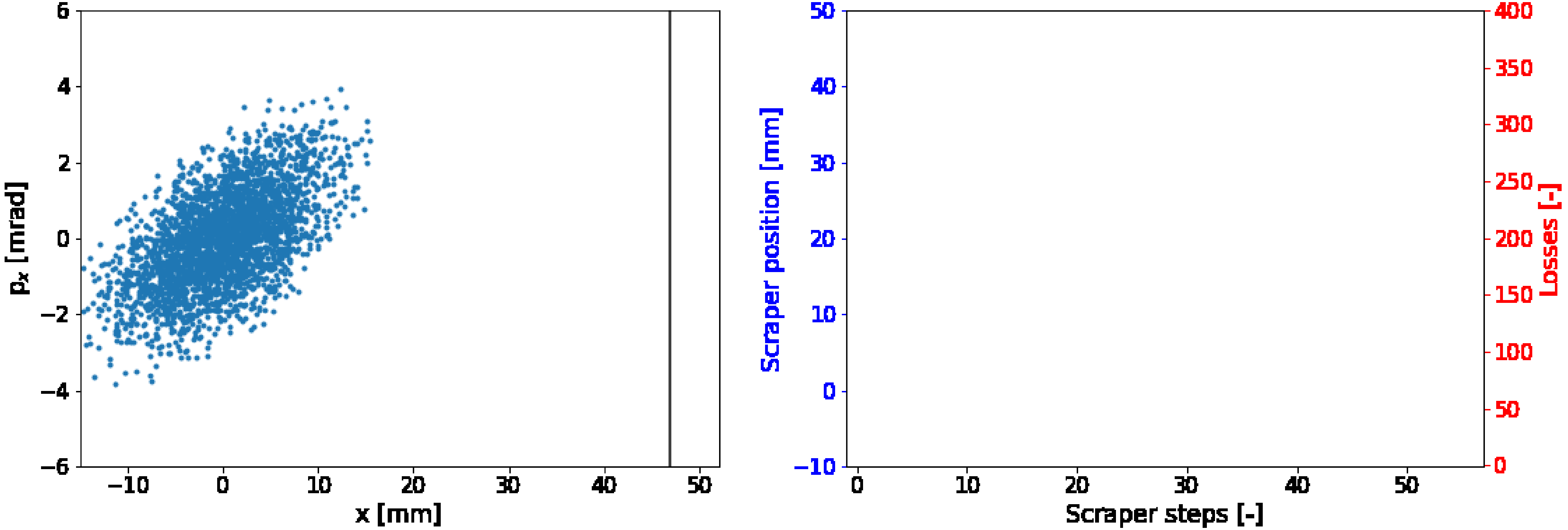
Emittance measurements with the scraper is a disruptive measurement → the entire beam is lost.

Two scintillators are installed horizontally and symmetrically w.r.t. the vacuum chamber.

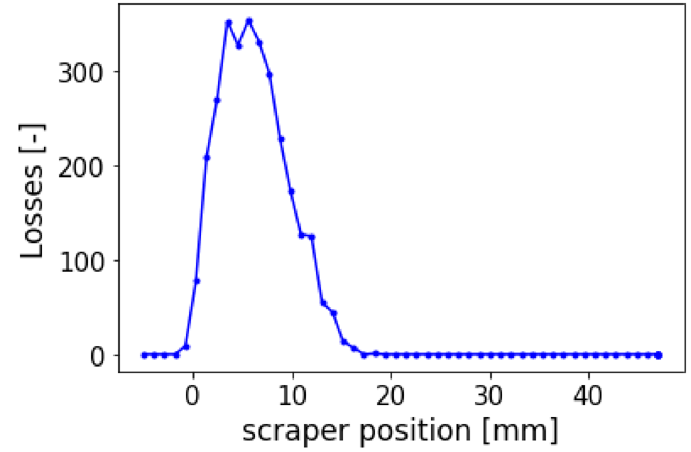
Working principle

For a 4D Gaussian beam, in the absence of any coupling, the losses can be described as:

$$\ell(x_s) = \frac{x_s - x_0}{\epsilon_{RMS}\ \beta_x(x_s)} \exp\left(-\frac{1}{2}\frac{(x_s - x_0)^2}{\beta_x(x_s)\epsilon_{RMS}}\right)$$



Emittance reconstruction



Python-based routine

Fit procedure can be implemented to determine emittance and beam closed orbit

$$\ell(x_s) = \frac{x_s - x_0}{\epsilon_{RMS}\ \beta_x(x_s)} \exp\left(-\frac{1}{2}\frac{(x_s - x_0)^2}{\beta_x(x_s)\epsilon_{RMS}}\right)$$

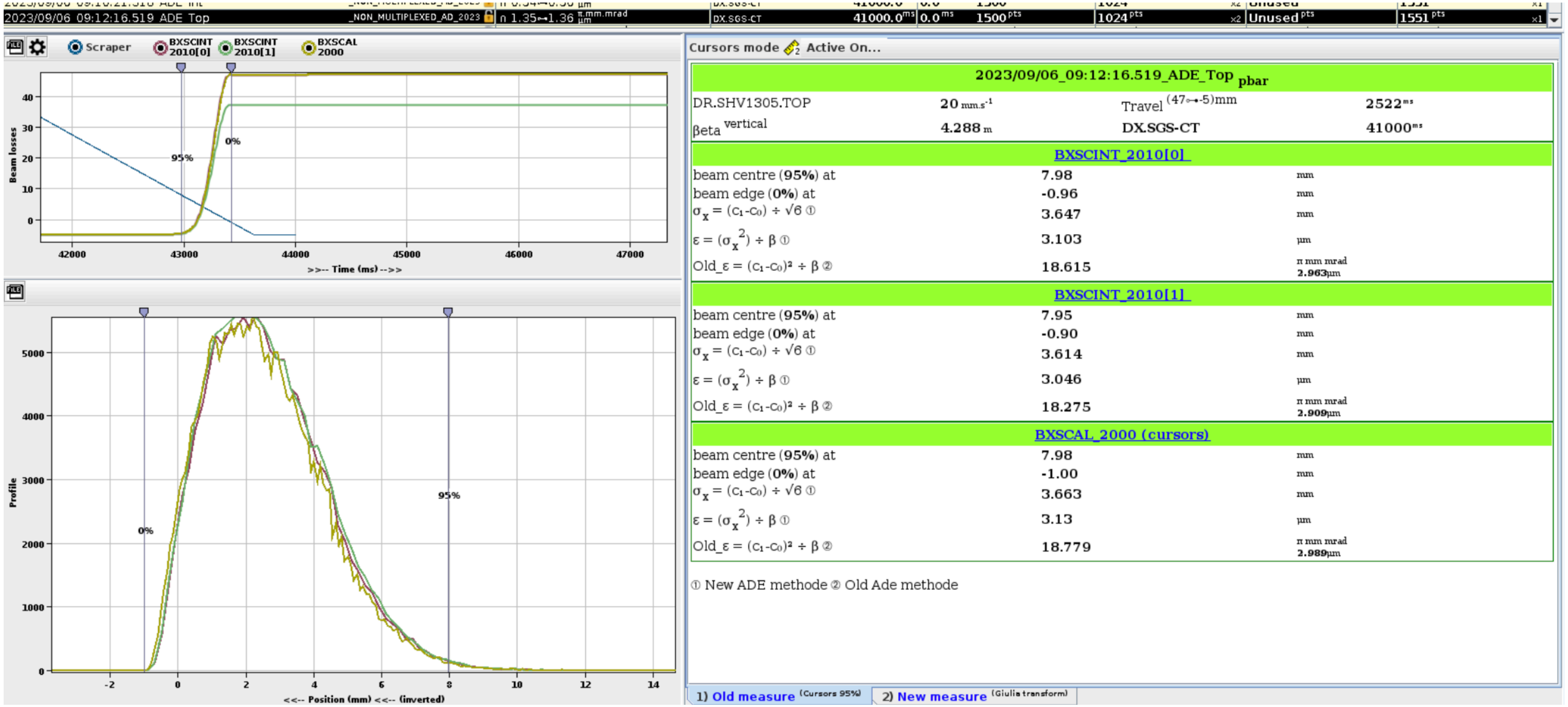
Benchmarking tool

The transverse beam profile can be reconstructed by means of the Abel Transform (AT)

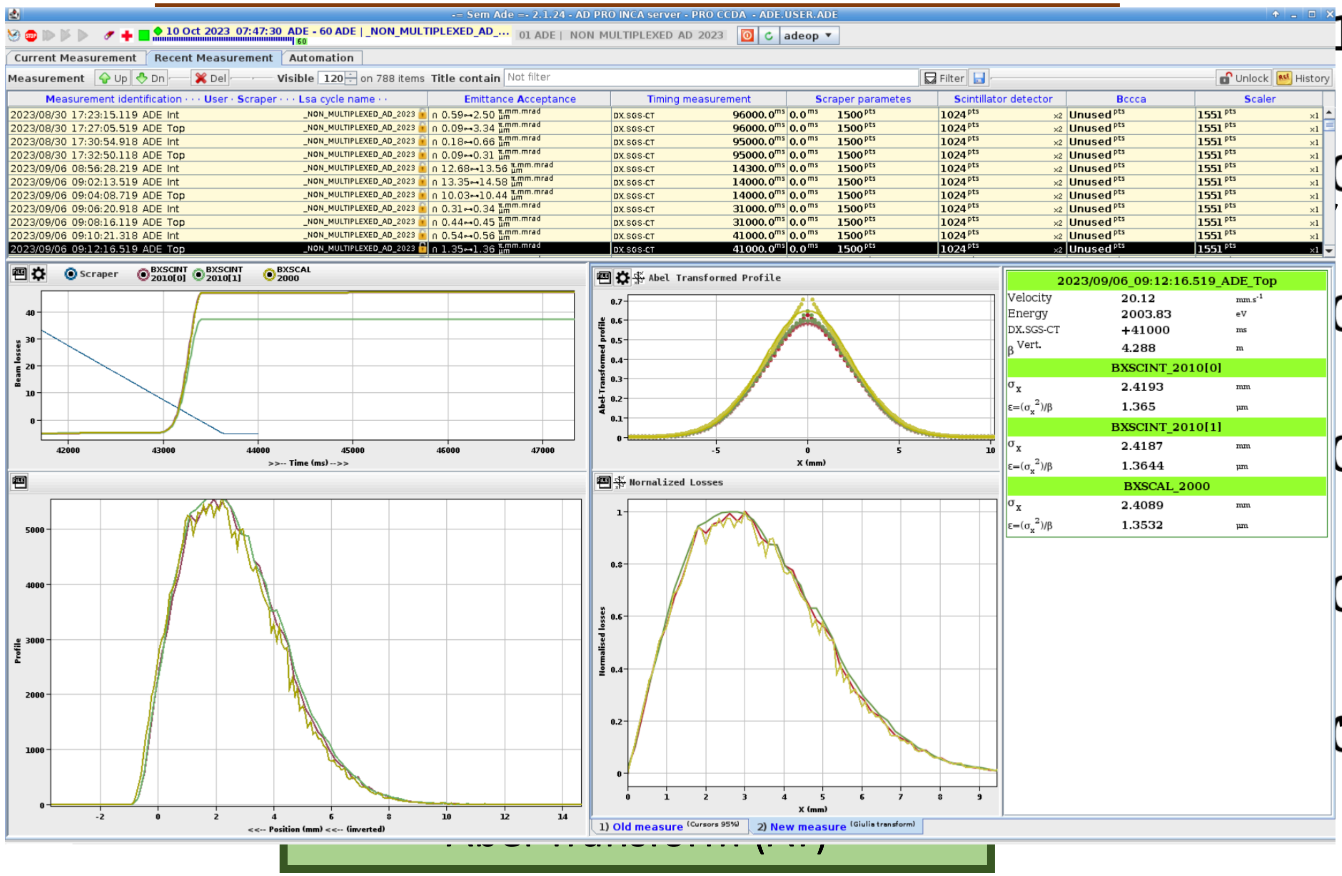
Now operational in AD

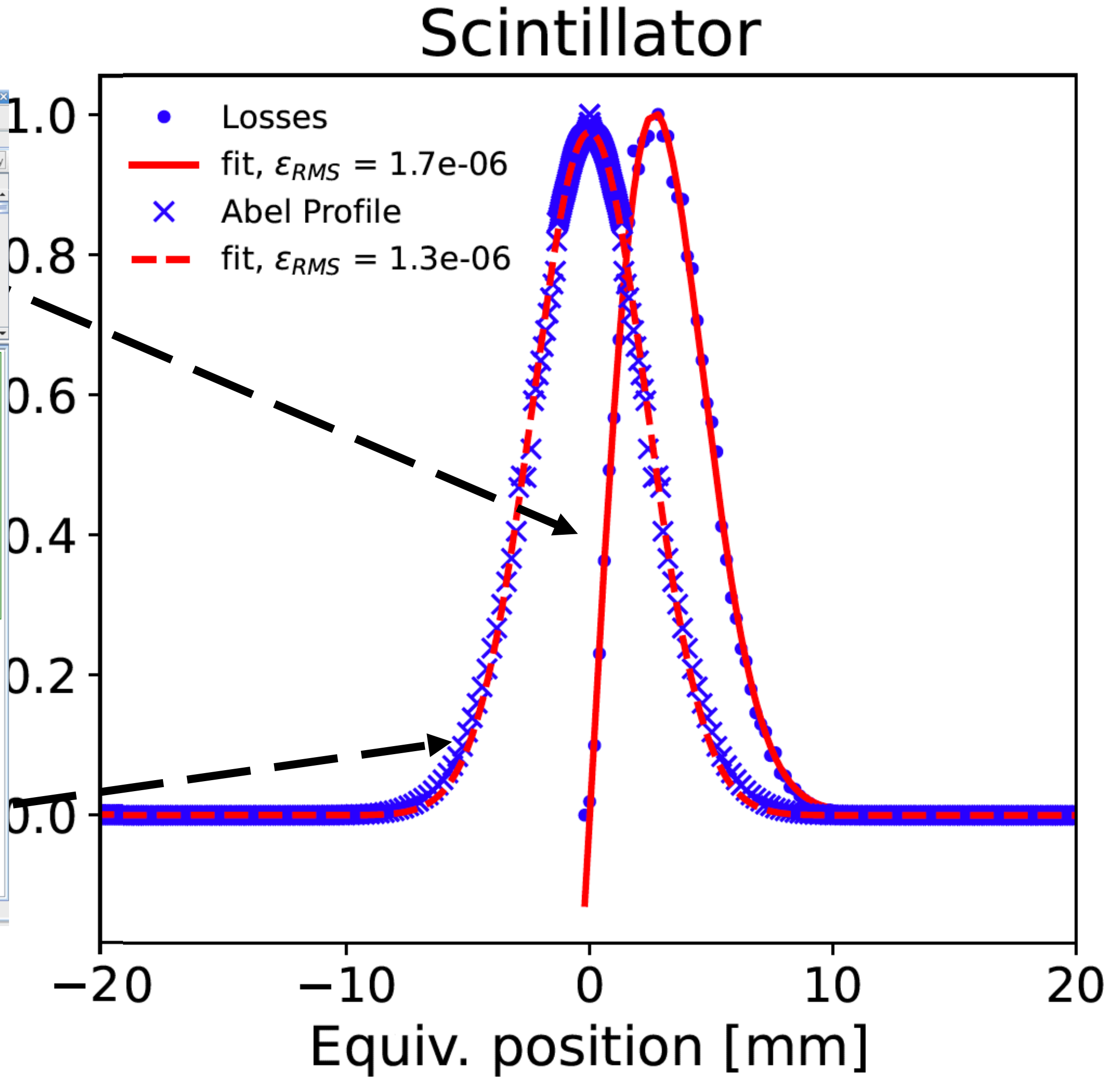
Problem discussion

In the past, emittance was calculated considering the distance between the 0% and the 95% of loss particles → user dependent



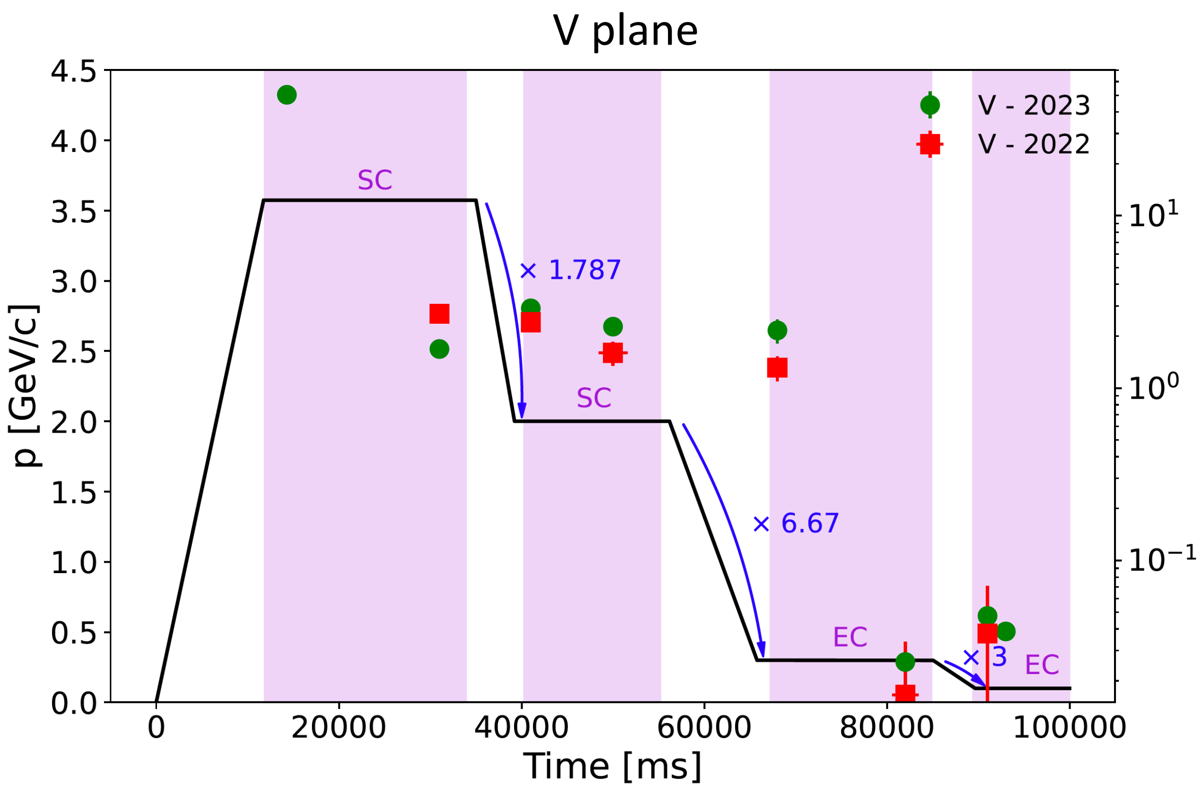
Emittance comparison

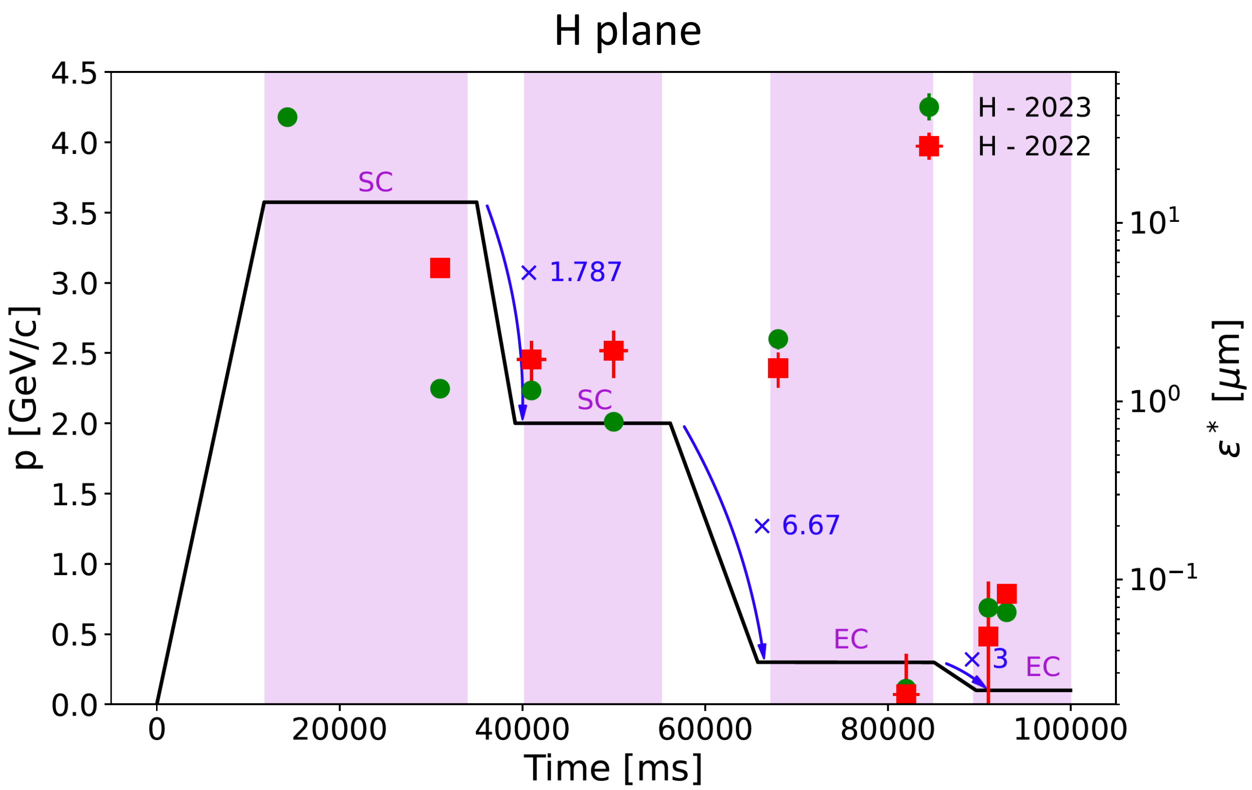




AD emittance along the cycle

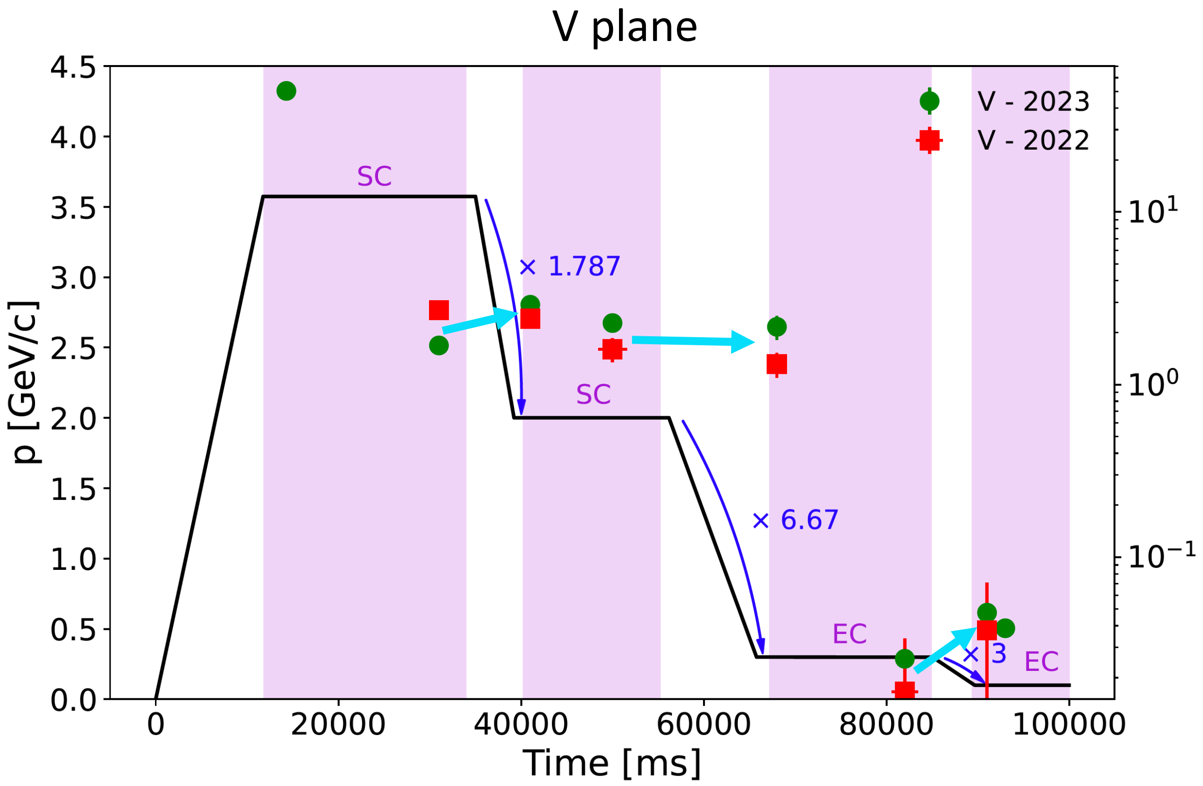
Normalised emittance should → remain constant during decelerations → Performance assessment
→ decrease along cooling plateaus

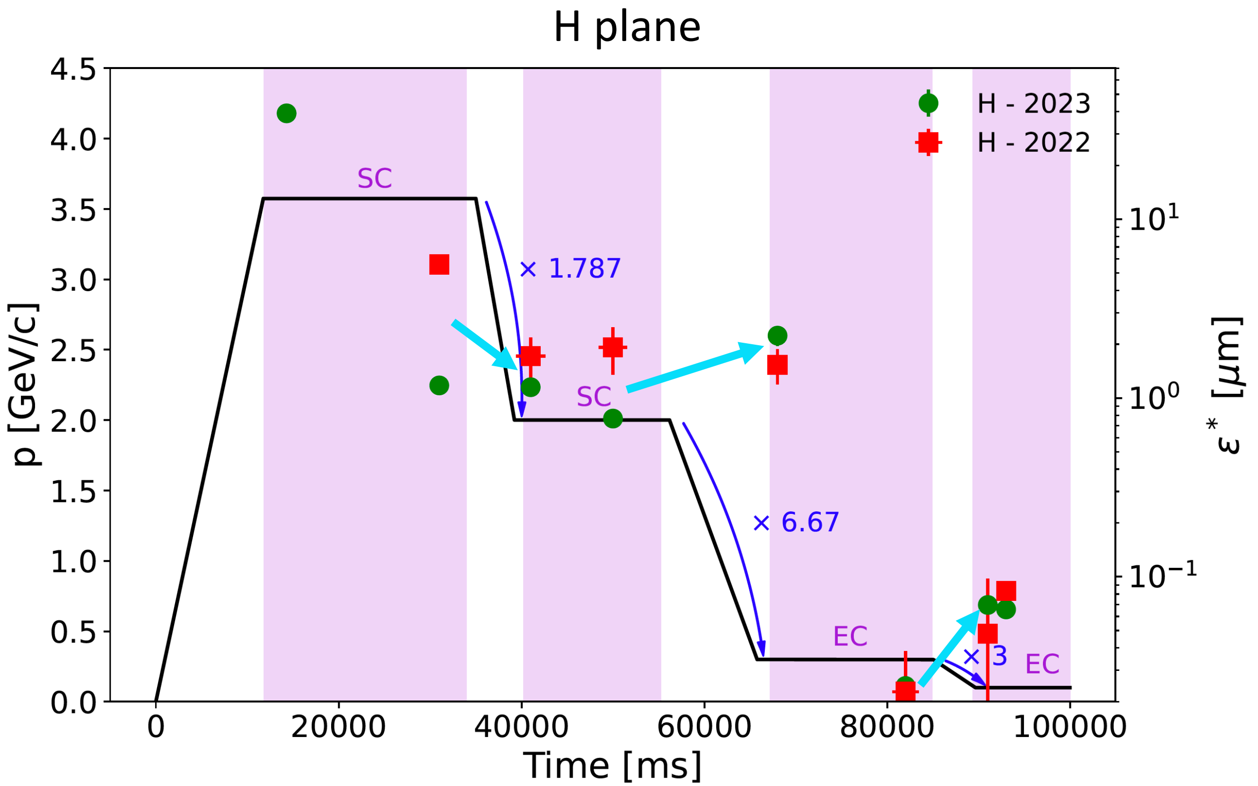




AD decelerating performance

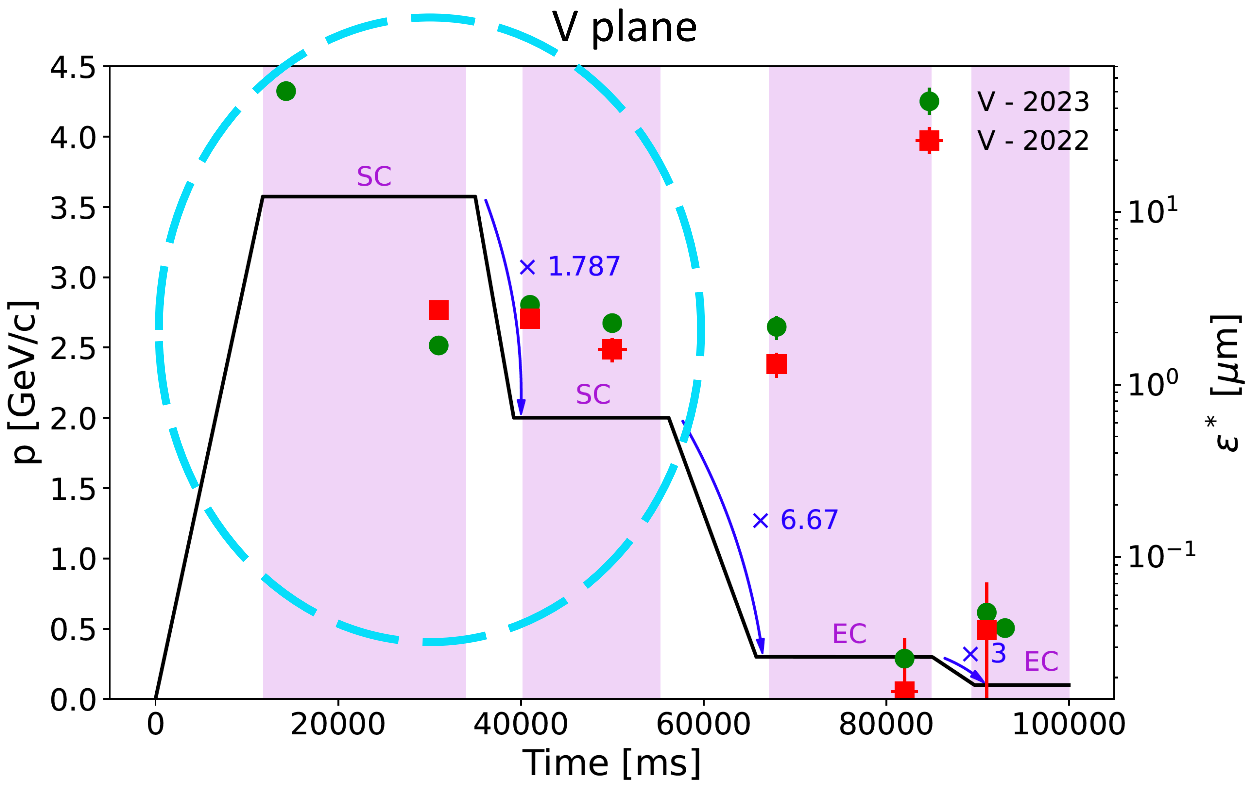
The normalised emittance is either constant during deceleration (as 2nd deceleration plateau on the V plane) or it increases, meaning that unwanted blow-up occurs. With a unique exception where a reduction on the H plane in 2022 is observed, possibly due to unexpected losses during the process.

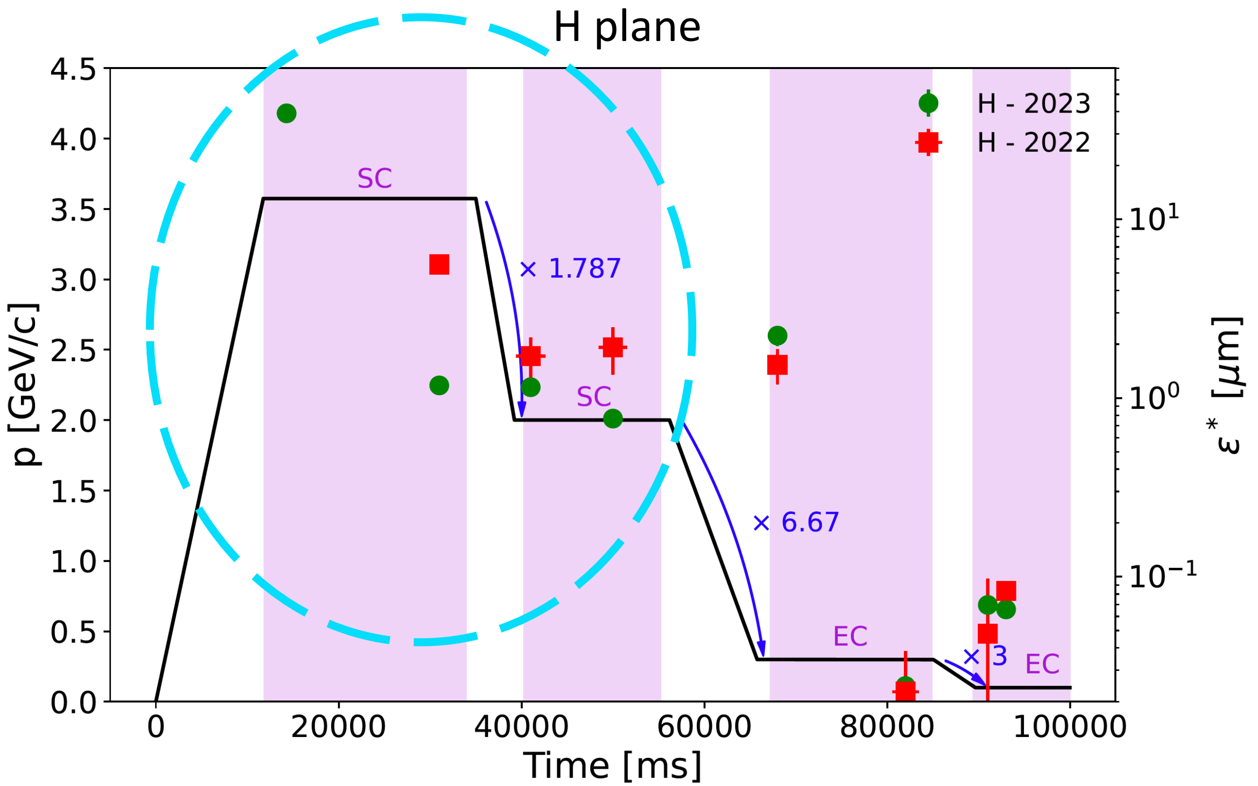




AD Stochastic Cooling performance

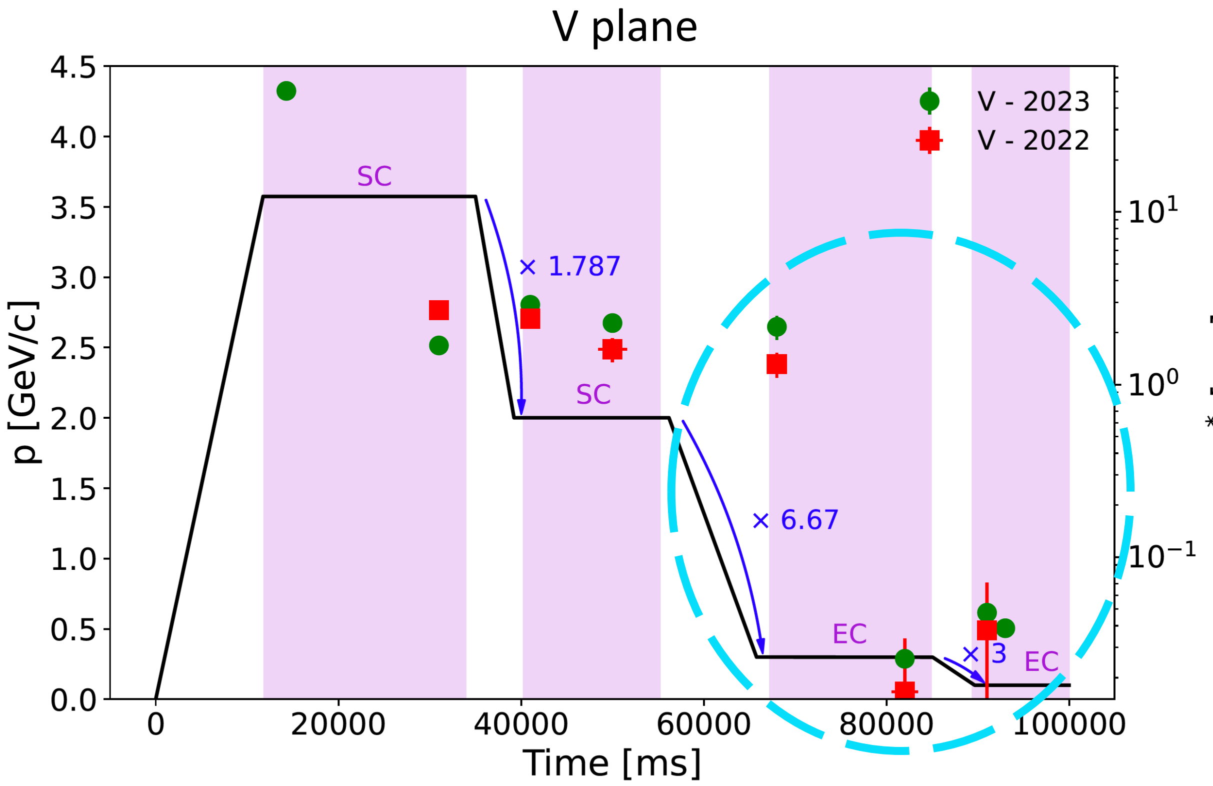
The normalised emittance is reduced on both SC plateaus with a significant improvement between 2022 and 2023 on both planes. Compartive analysese between the years is not feasible due to the lack of data at the start of the 1st SC plateau in 2022. In general, a good performance improvements has been achieved.

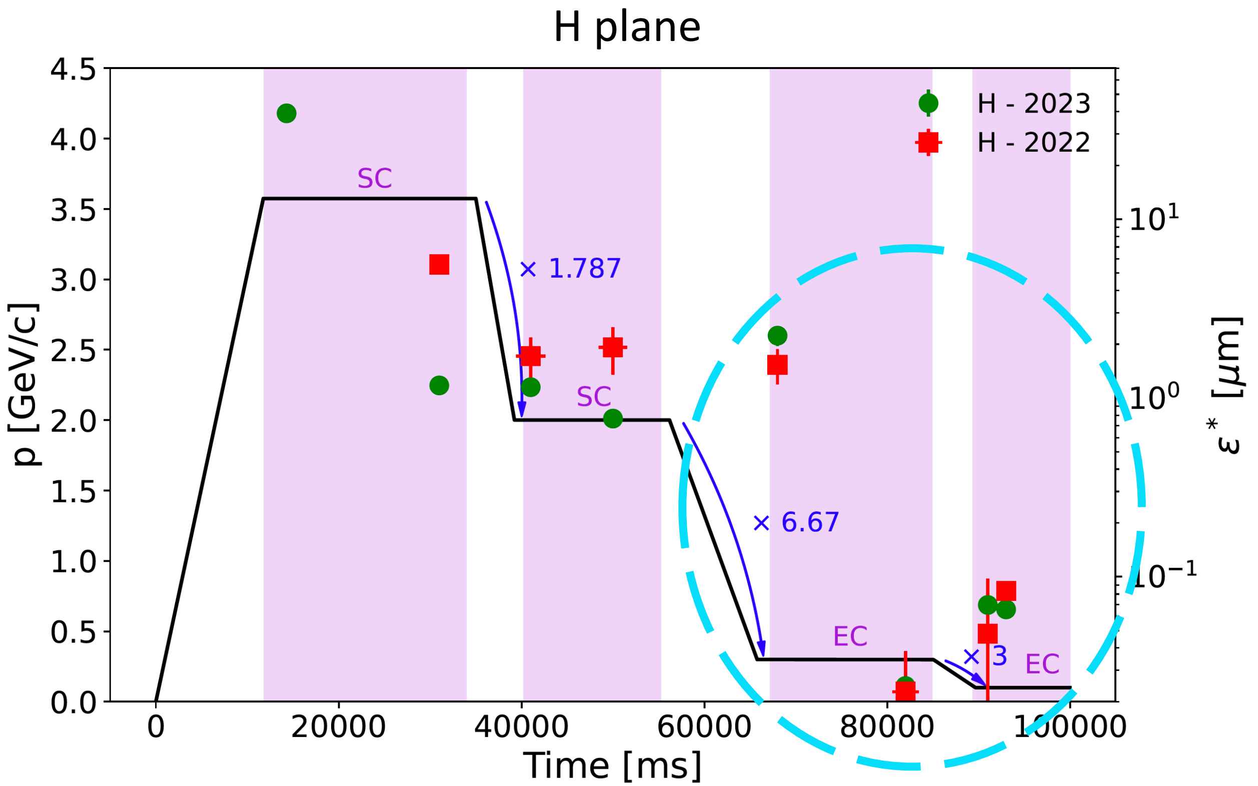




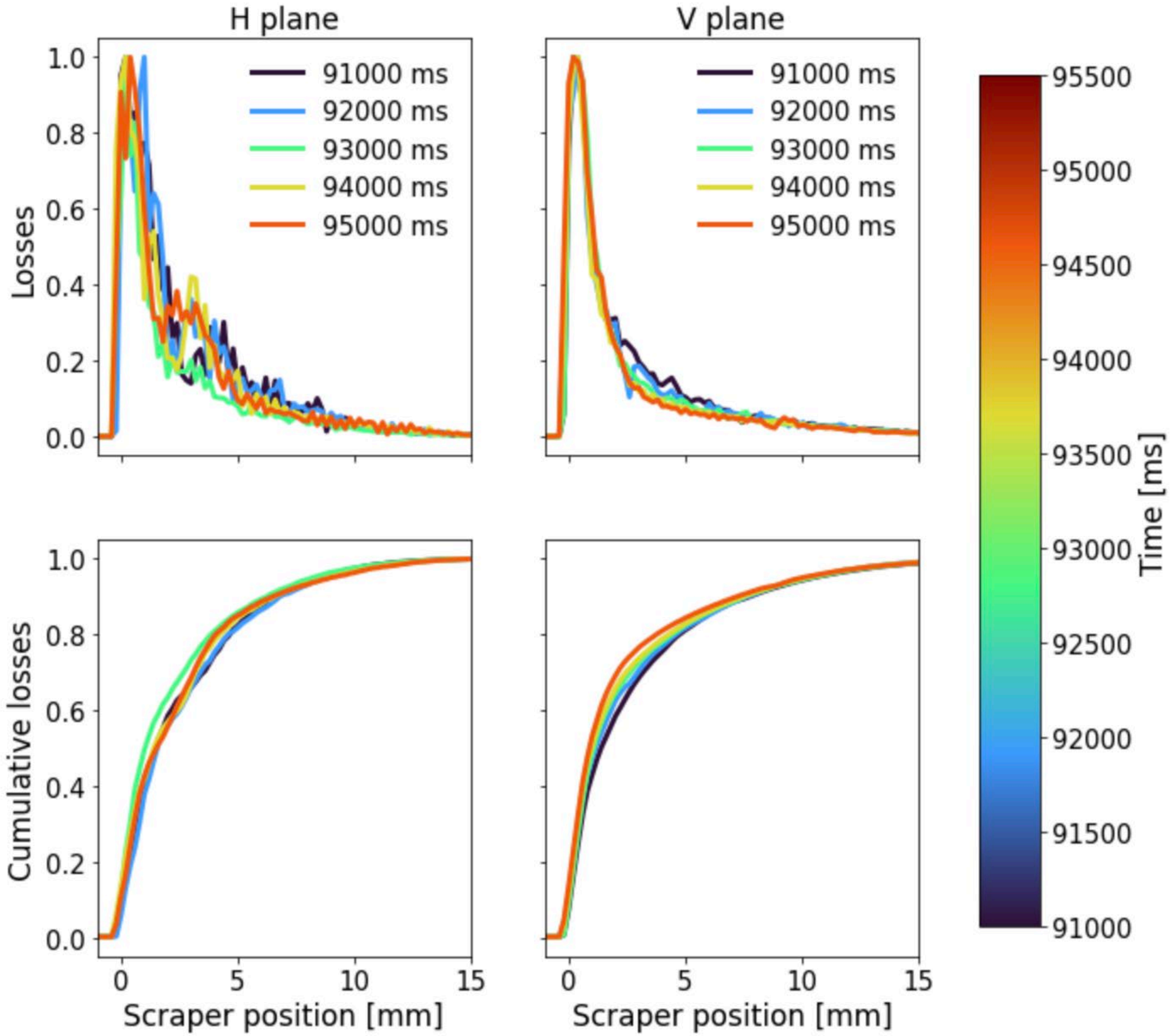
AD Electron Cooling (EC) performance

The normalised emittance is significantly reduced along the two EC plateaus. Along the 1st plateau emittance is reduced of a factor 91 (H) and 84 (V), significantly better than 2022 where the reduction factor was 67 (H) and 79 (V). Performance on the 2nd plateau have been imporved compared to 2022.



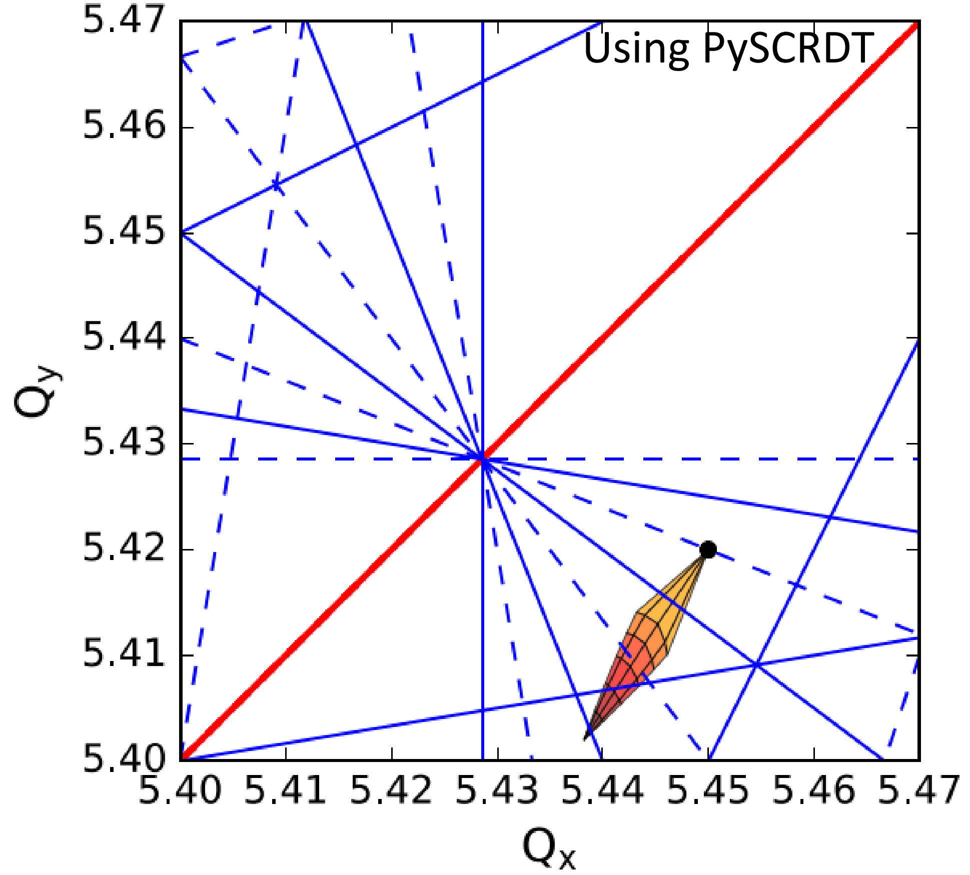


AD EC performance @ 100 MeV/c



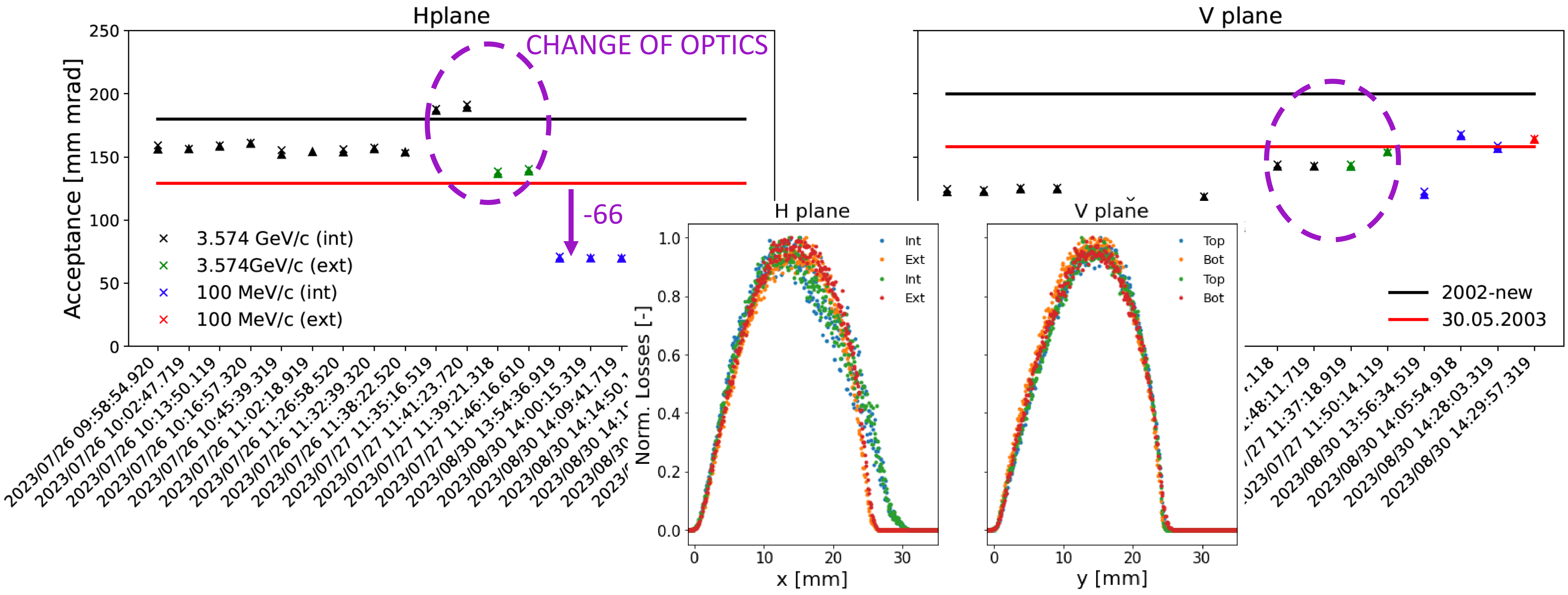
Orbit shift of ~ 10mm in the EC (beam is fully debunched).

Maximum tune shift due to space charge of $dQ_x \sim -0.01$ and $dQ_y \sim -0.02$ for a bunched beam.



AD Scraping for acceptance measurements

Verifying the actual beam acceptance at the highest and lowest energy plateau:



Conclusions and outlooks

Conclusions:

- ✓ A user-independent emittance procedure has been developed and it is now used during daily operation in AD
- ✓ Performance assessment of AD deceleration and cooling (stochastic and electron) highlighted strong and weak points
- ✓ Acceptance measurements at high energy are in agreement with 2002-2003 data
- ✓ For the first time acceptance at 100 MeV/c has been determined

To be done:

- ❑ Better understanding the deceleration ramp between 2GeV/c and 300MeV/c
- ❑ Improve cooling for high action particles at 100 MeV/c
- ❑ Optics studies to improve acceptance

Thank you for your attention!