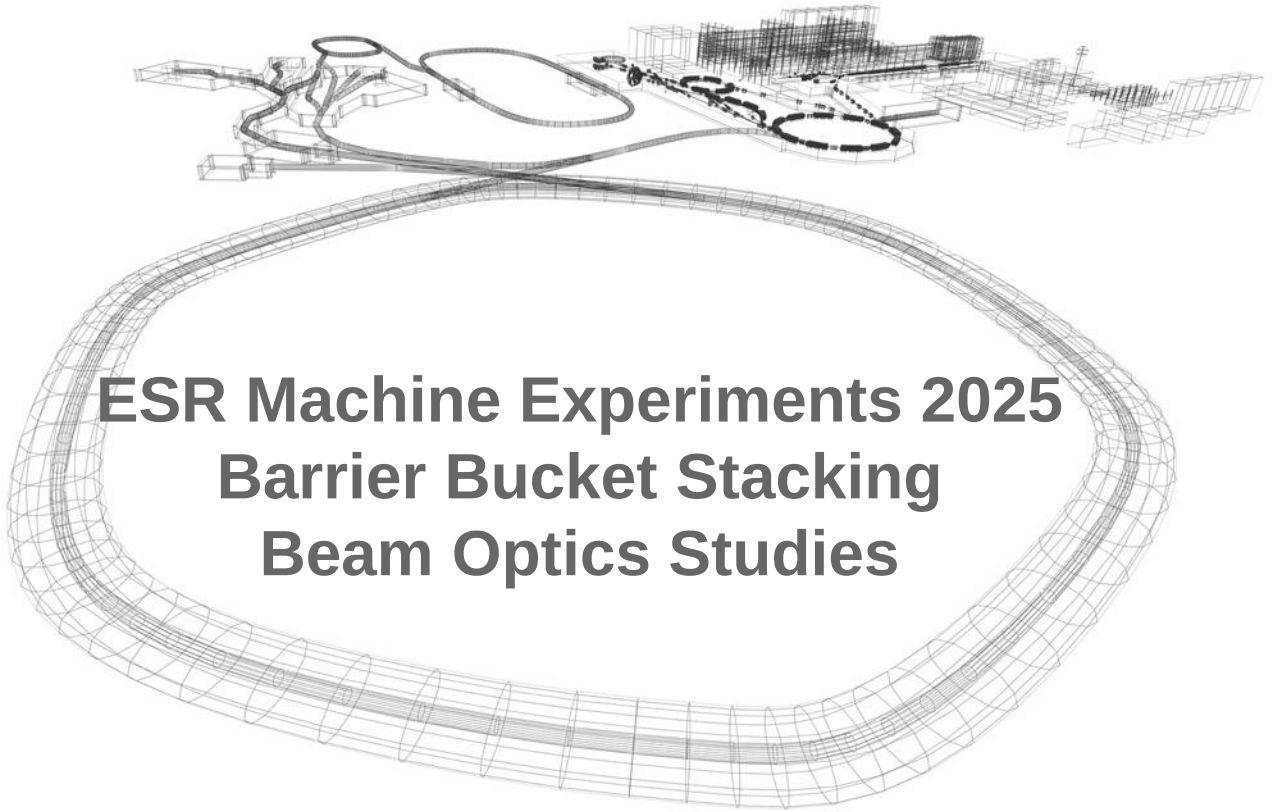
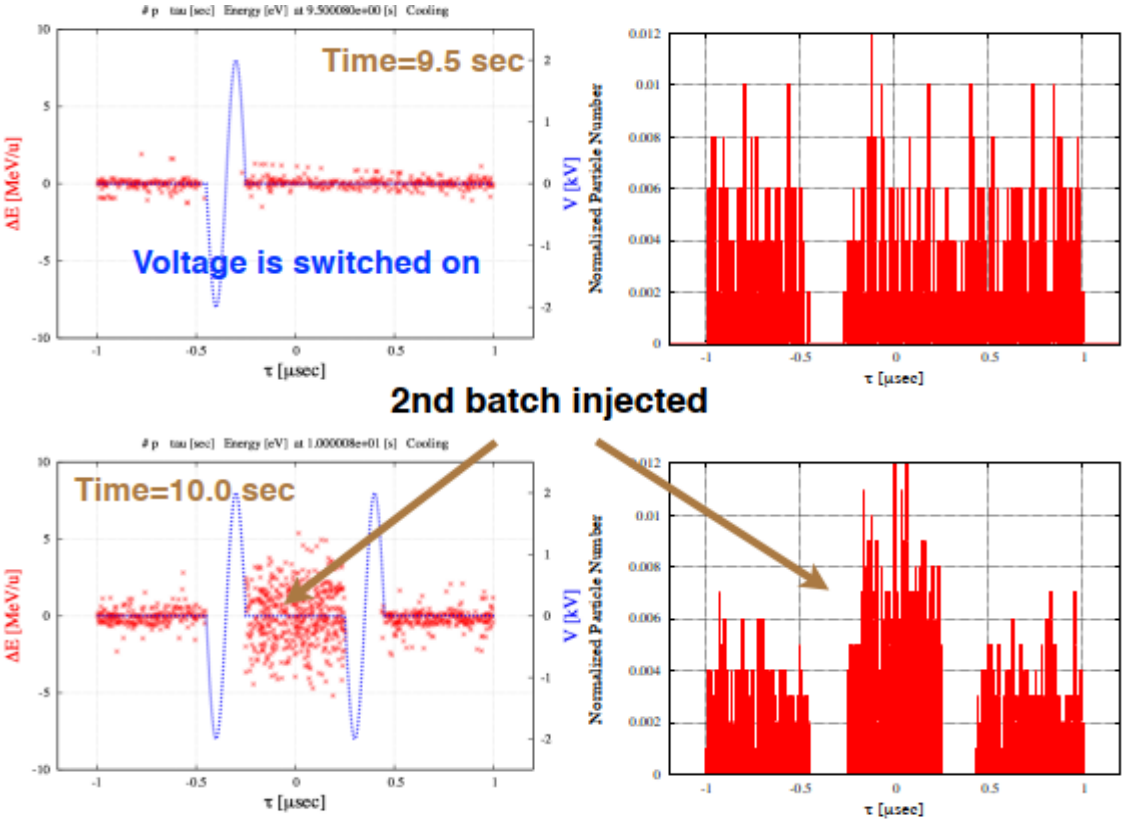


ESR Machine Experiments 2025
Barrier Bucket Stacking
Beam Optics Studies

Barrier Bucket Stacking



Barrier Bucket Stacking

Original proposal: ‚Experimentally verify the moving barrier bucket stacking‘

During preperation for experiment we switched to ‚Testing of Stacking with fixed barrier bucket‘

reason: not enough space for the stacked beam:

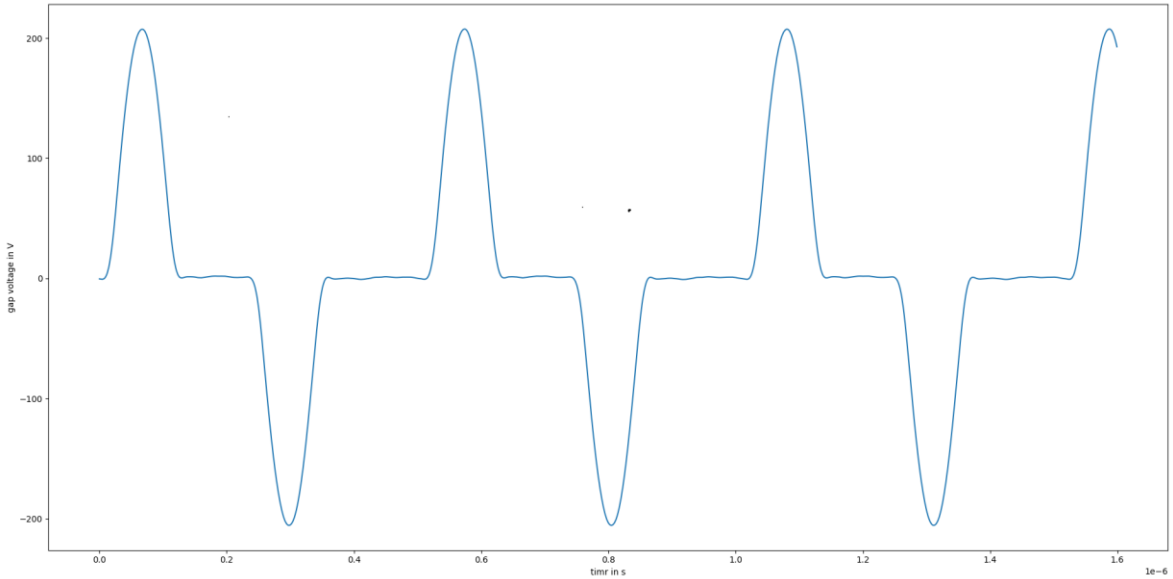
barrier bucket frequency presently restricted to 5 MHz-> 200 ns

we need two of them: 400 ns

minimum length of inj. kicker flattop: 100 ns makes 500 ns

stoch. cooling only available at 400 MeV, 2 MHz -> 500 ns

Barrier Bucket Stacking



Thanks to the RHF people for preparing an adequate BB signal with one of the BB cavities on short notice (Measurement at Beginning of Experiment)

Barrier Bucket Stacking

The three types of Stochastic Cooling:

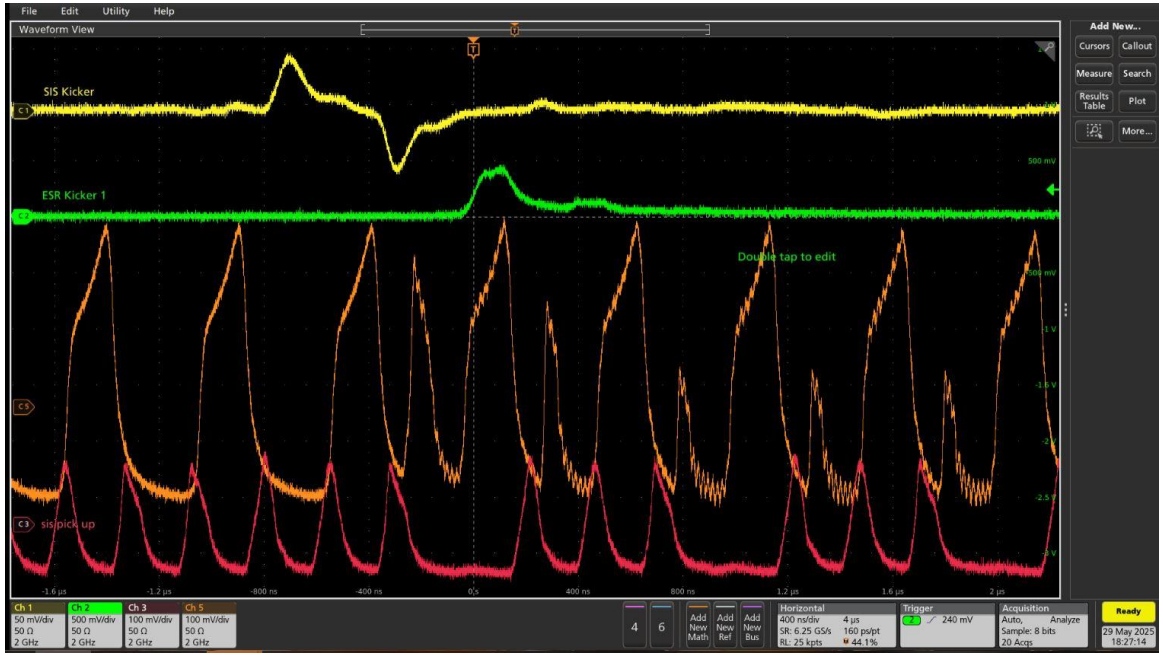
- Palmer Cooling: all three planes independently, long. Cooling via Dispersion at Pickup and Kicker, fast, this is what we always use for stacking
- TOF Cooling, lower acceptance, higher final momentum spread, slower
- Notch Filter Cooling: lower acceptance, lower final momentum spread, slower

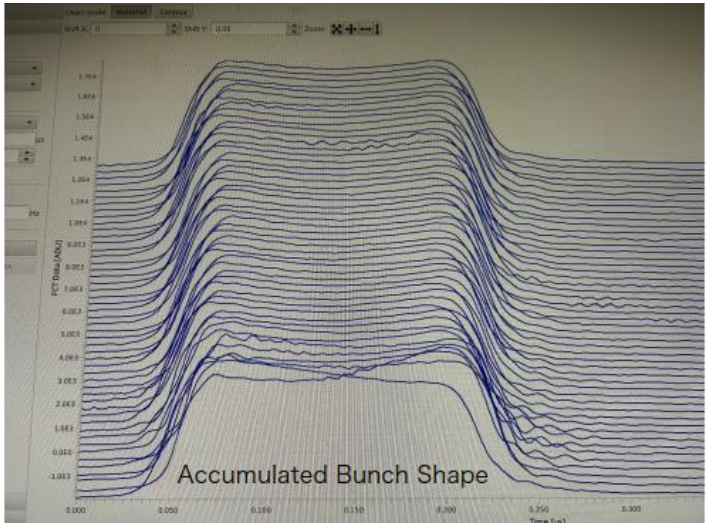
According to simulation, Palmer Cooling is the best choice, so we started out with that
Unfortunately: we couldn‘t reach longitudinal cooling with the standard setup procedure.
There was intensiv search for any hardware failure, but nothing could be found (because most likely there was none, two weeks later it worked as it should for Bi beam, not understood, may be caused by the low charge and mass of the available carbon beam)

So we did the measurements with TOF cooling, and even Notch Filter Cooling worked.

Barrier Bucket Stacking

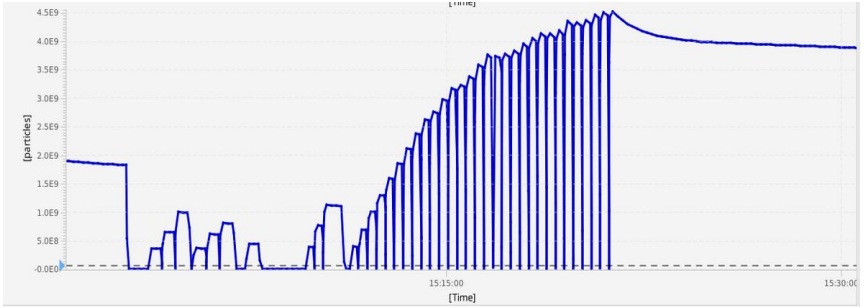
A selection of results



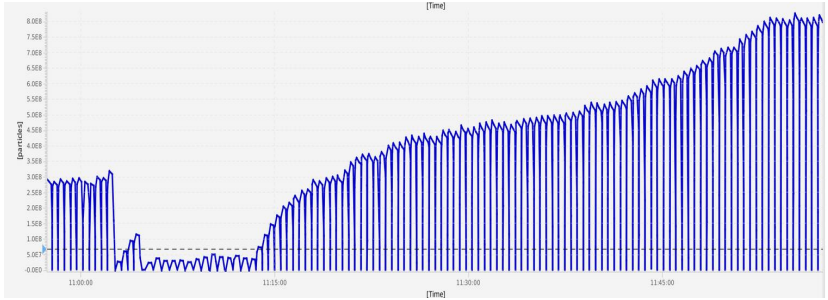


Barrier Bucket Stacking

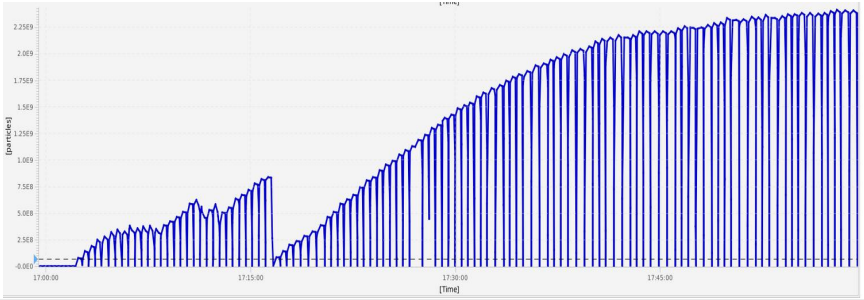
Highest Intensity (5E9) reached with e-cooling (500 mA) and BB (50V)



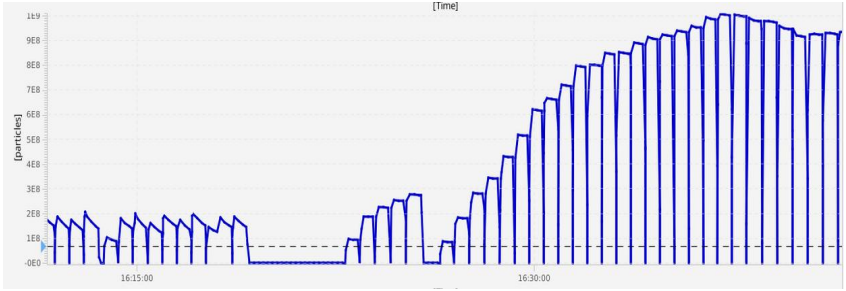
TOF cooling, adjustment of gain, Intensity increase by factor 15 increase



e-cooling and BB, Intensity increase by factor 20
Efficiency goes down over time as predicted by simulation



H=1 & e-cooling, works as well, maybe less efficient, but settings not optimized here (one of the last runs)



Barrier Bucket Stacking

Summary:

- All observations agree well with predictions of simulations
- Electron cooling works well, but is slow (similar efficiency for longer cooling times)
- TOF cooling doesnt work as well, probably because of too much noise in the system
- Notch Filter Cooling was tried, but only slightly better than the TOF cooling.

Palmer Cooling is inevitable (fast, large acceptance, acceptable final momentum spread)

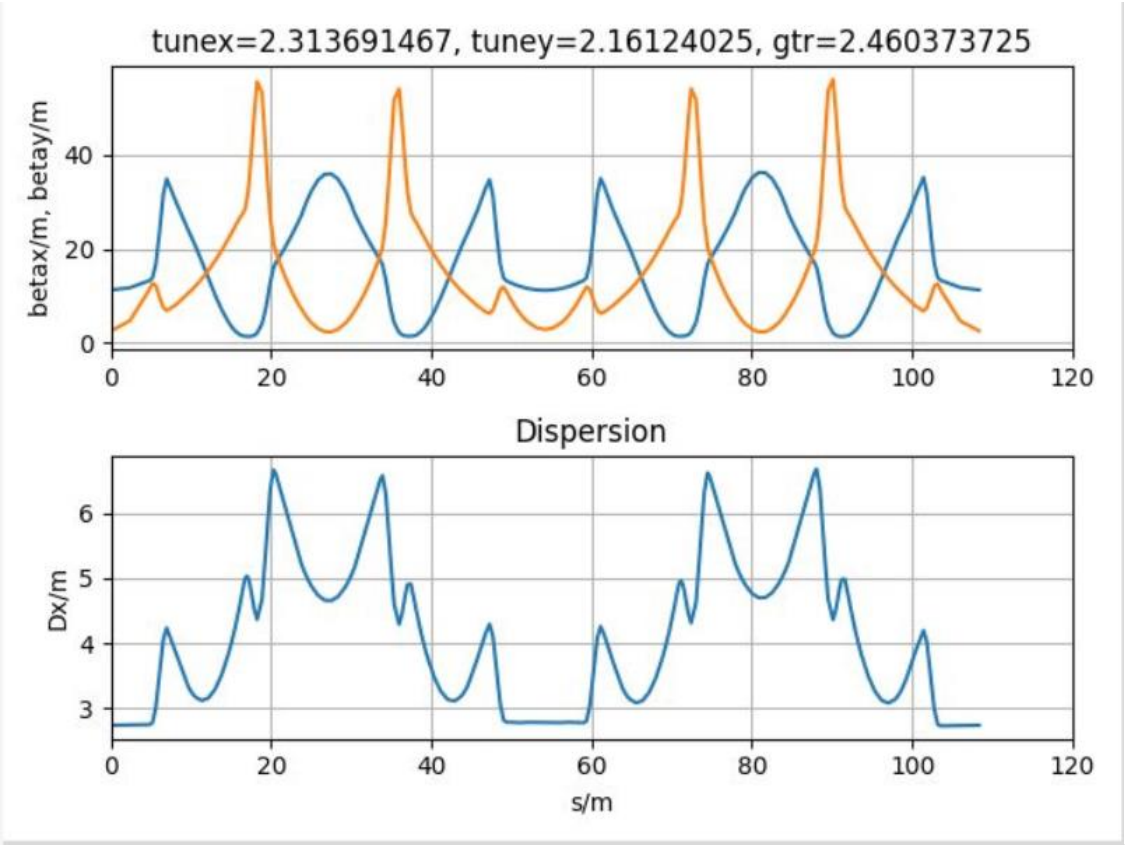
Still open question: especially the question of efficiency for moving barrier bucket stacking with Palmer Cooling (is expected to be higher than with electron cooling) Once BB frequency can be higher, this could be a further study. (and Palmer Cooling should work, maybe better with a more frequently used, heavier ion with higher charge state)

Beam Optics

Standard optics settings always used for the ESR

It has significant dispersion in the straight sections, that means also at the electron cooler

There is no real reason.



Beam Optics

Consequence of Dispersion at the electron cooler:
via the Dispersion some coupling of longitudinal cooling into the horizontal plane is introduced, the cooling force is redistributed and can improve transverse cooling.
This is not needed and also not intentional.
But in turn it means: best longitudinal cooling is achieved with Dispersion zero

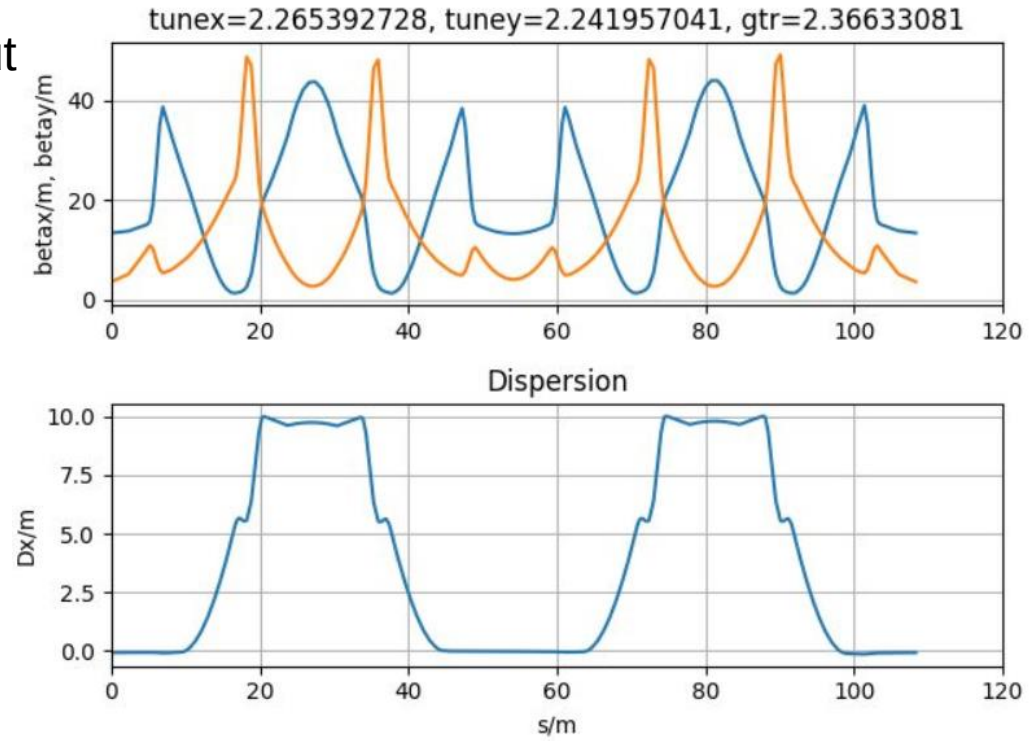
Transvers emmittance is with typically below 2 mrad sufficiently small anyway.
The longitudinal dp/p is of large importance for the performance, so improving it is a good choice.

Beam Optics

With Change of one quad family (out of five), dispersion will be zero in the straight section (cooler, target)

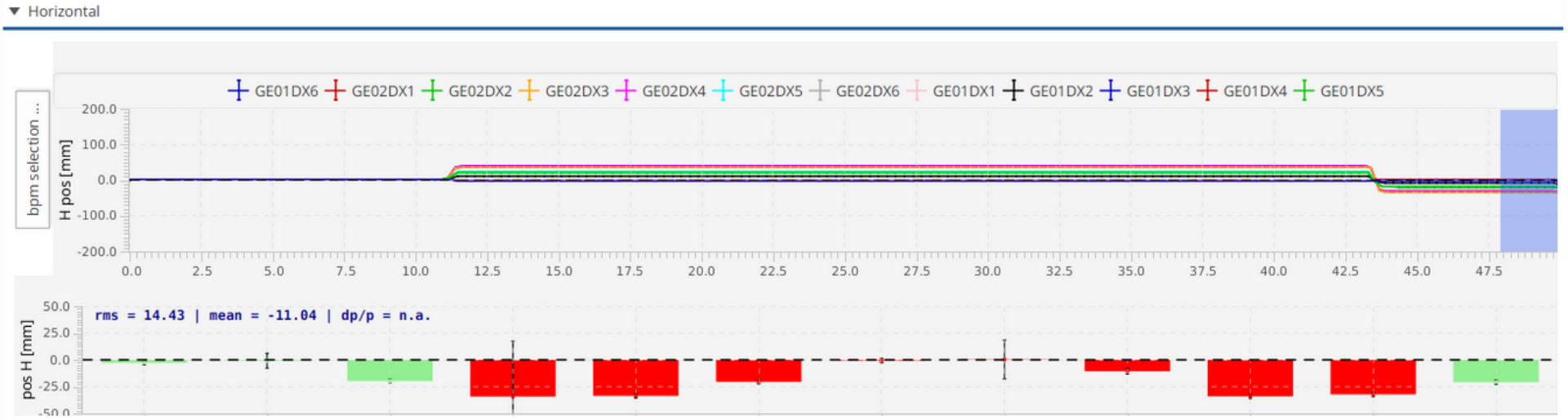
Tunes need to be corrected
Standard tune knob changes all (!?) families.

Instead now its done with only 2 families, Dispersion setting and tune settings are made independent



Beam Optics

Second try: Dispersion in straight practically zero
(in Manipulation, so Injection not effected



the bar plot is here the difference between the reference orbit, and a dp orbit
=> dispersion

Beam Optics

Next step was to apply it already at injection, injection intensity was practically unchanged

defined this as an alternative optics in LSA
towards the end of this years beamtime we checked again, and it works (we even saw overcompensation, so dispersion not exactly zero but with changed sign)

(we even used it for one of the physics experiments at the end of this years block)

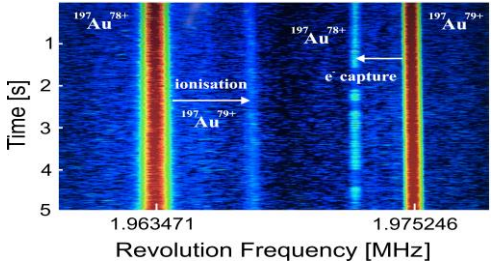
For the future this will be the standard optics for ESR!!

To be flexible we think to put a button for ‚Dispersion in Straight‘ in LSA in the future, as there may be reasons to use the old settings, the zero dispersion, or even a different sign for dispersion

Machine Experiments at ESR in 2025

Co-colliding beams,

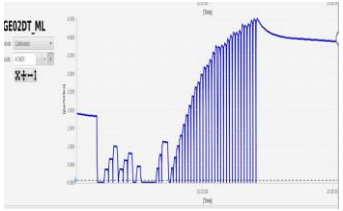
storage of two different ions , opening up the way to new experiments (demonstrated for Au78+,79+ and U91+, 92+)



Stacking with fixed Barrier Bucket

of importance especially for future FAIR storage rings

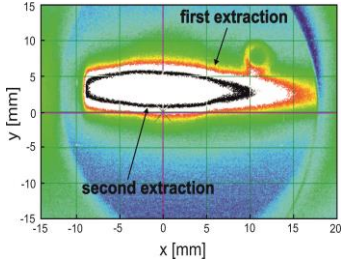
intensity increase from 5e8 upto 4e9 for 12C6+



Multiple extraction

possible improvement for HITRAP commissiong and operation

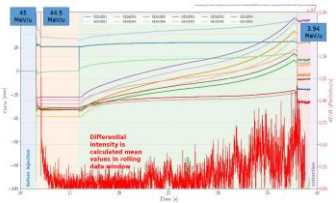
first screen after ESR in direction HITAP



Investigation of Deceleration

Possible improvement of efficiency in the future

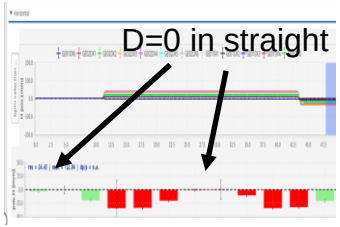
orbit during decelarition



Beam Optics studies

optimized optics for e-cooling and experiments

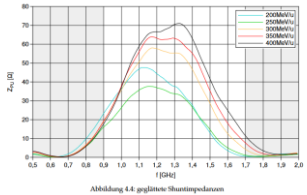
dispersion around the ESR



Stochastic Cooling

possible extension of energy range in the future

shunt impedance 250-400 MeV/u



The team:
B.Lorentz, M.Steck, S.Litvinov, R.Hess, R.Joseph, C.Crantz, A.Sherjan,
STOCO: C.Peschke, T.Katayama

Thank you for your attention

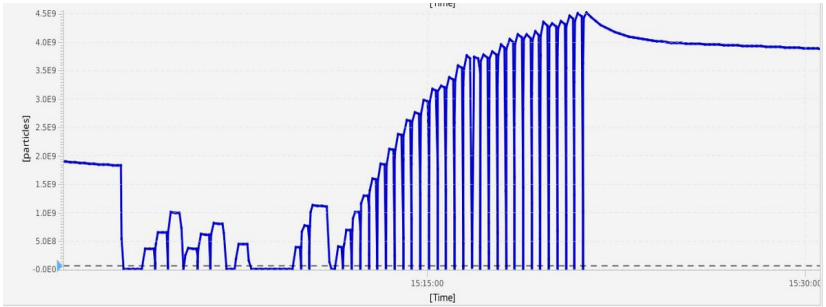
Barrier Bucket Stacking

As a consequence of the study, we already used the H=1 stacking with stochastic cooling (Palmer) successfully for a physics experiment.

Easier to setup than the so far used Stacking with stochastic cooling, and electron cooling on two different orbits.
And faster, as no orbit displacement is required.

Barrier Bucket Stacking

Highest Intensity reached with
e-cooling (500 mA) and BB (50V)



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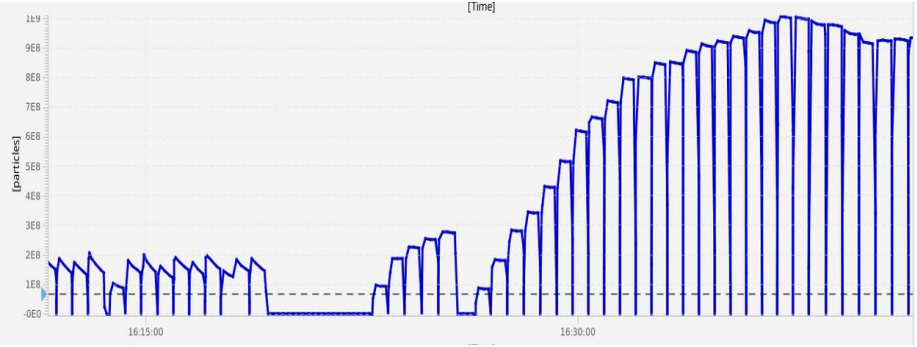
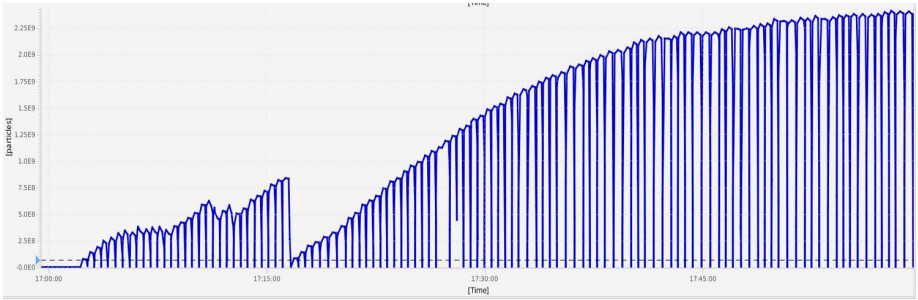
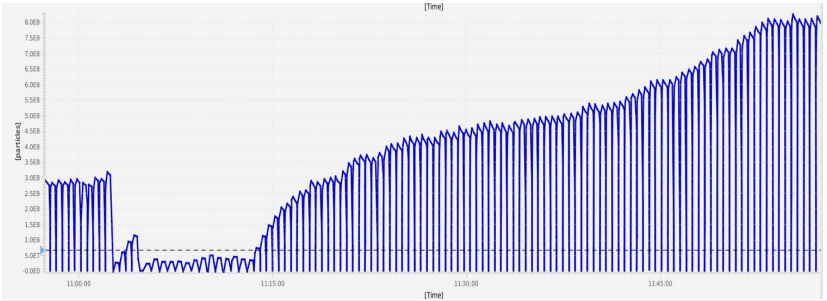


e-cooling and BB, Intensity increase by factor 20
Efficiency goes down over time as predicted by simulation

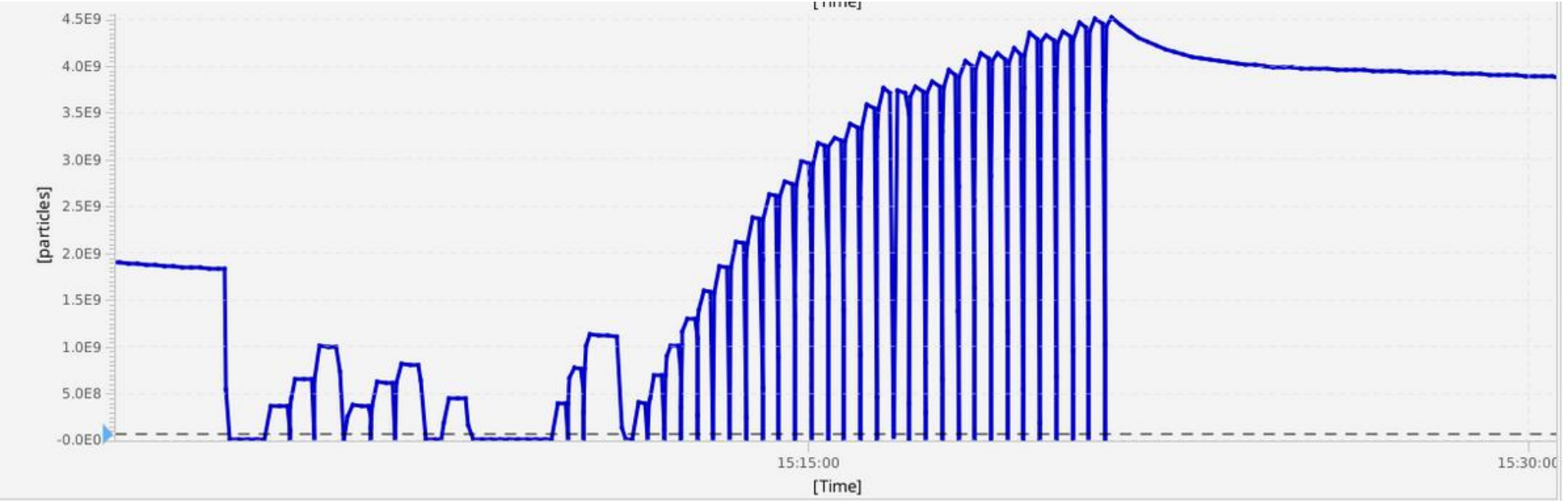


TOF cooling, adjustment of gain increases
factor 15 increase



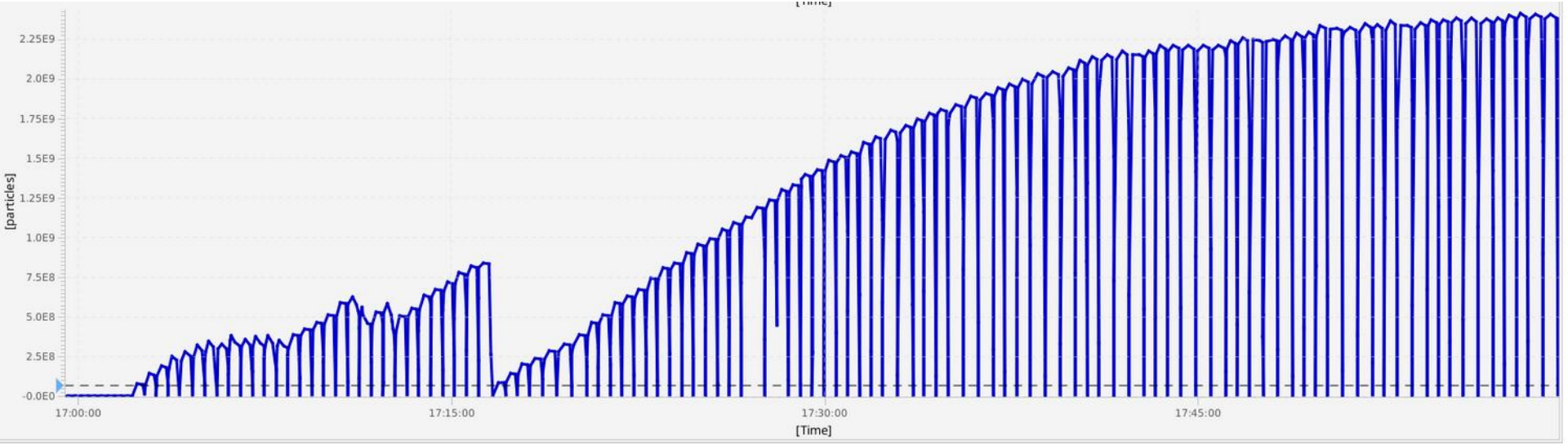
Barrier Bucket Stacking

Highest Intensity reached with e-cooling (500 mA) and BB (50V)



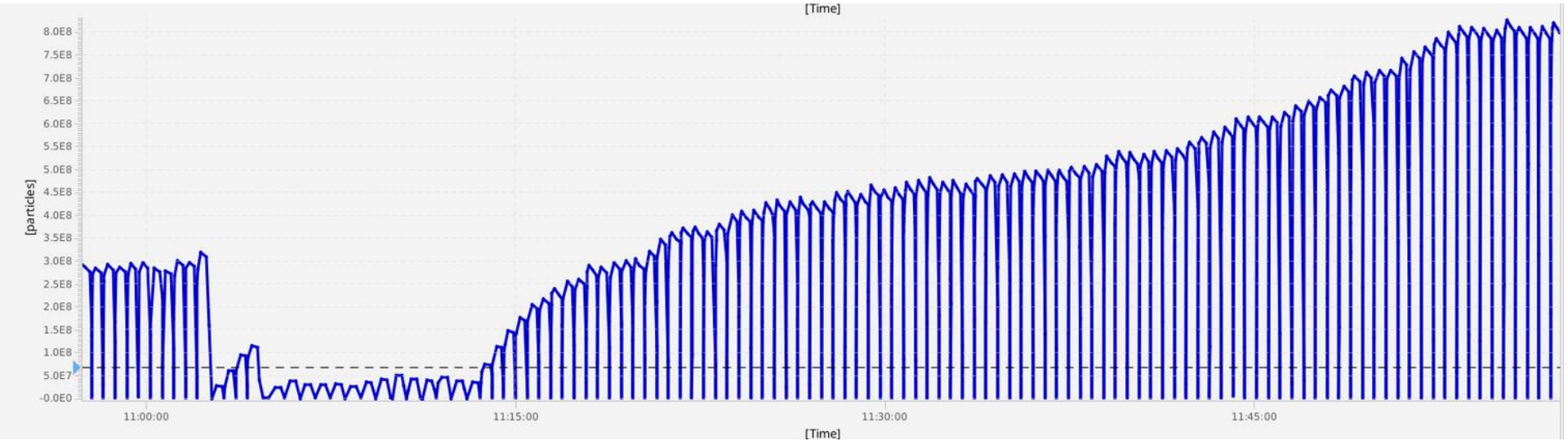
E-Cooling Barrier Bucket Stacking

Intensity increase by factor 20
Efficiency goes down over time as predicted by simulation



Barrier Bucket Stacking

TOF cooling, adjustment of gain increases efficiency when saturating
final intensity still lower than with e-cooling, but still factor 15 increase
(Palmer Cooling should be better...)



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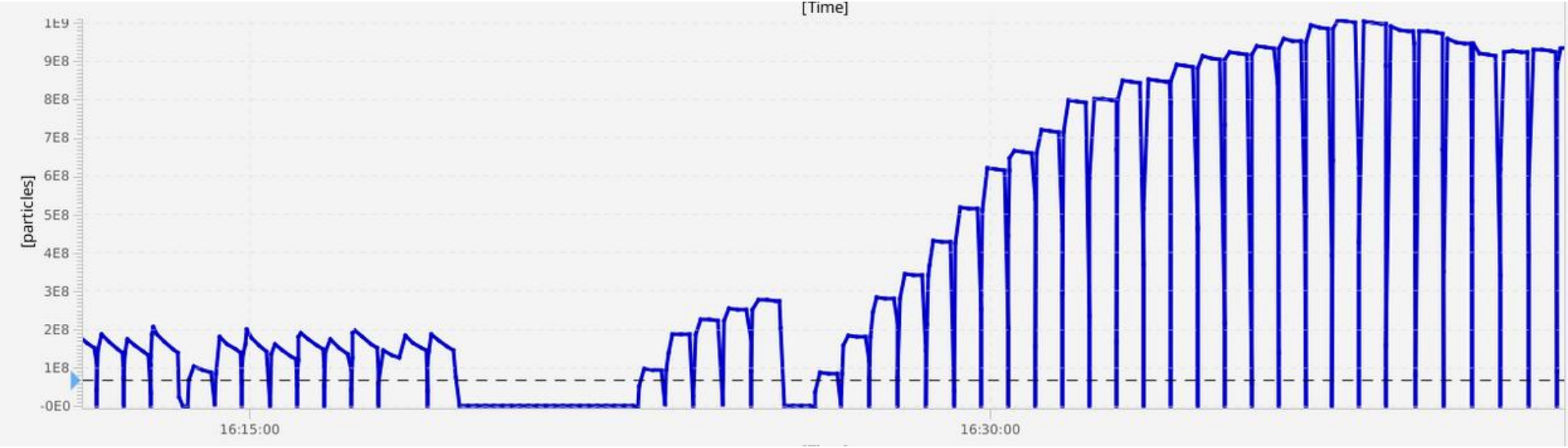

Beam Optics

There are more benefits of Dispersion zero in straight

We often change the momentum of the stored ion beam (e.g. for chromaticity measurement) by changing the energy of the electron beam, i.e. the cooler voltage. Frequently we were limited in the possible energy change, as the ion beam moved horizontally out of the electron beam.

For internal target experiments, the overlap of ion beam and Gas Jet is also effected by changing momentum witth non zero dispersion

Same for scraping,
or detector positioning
...

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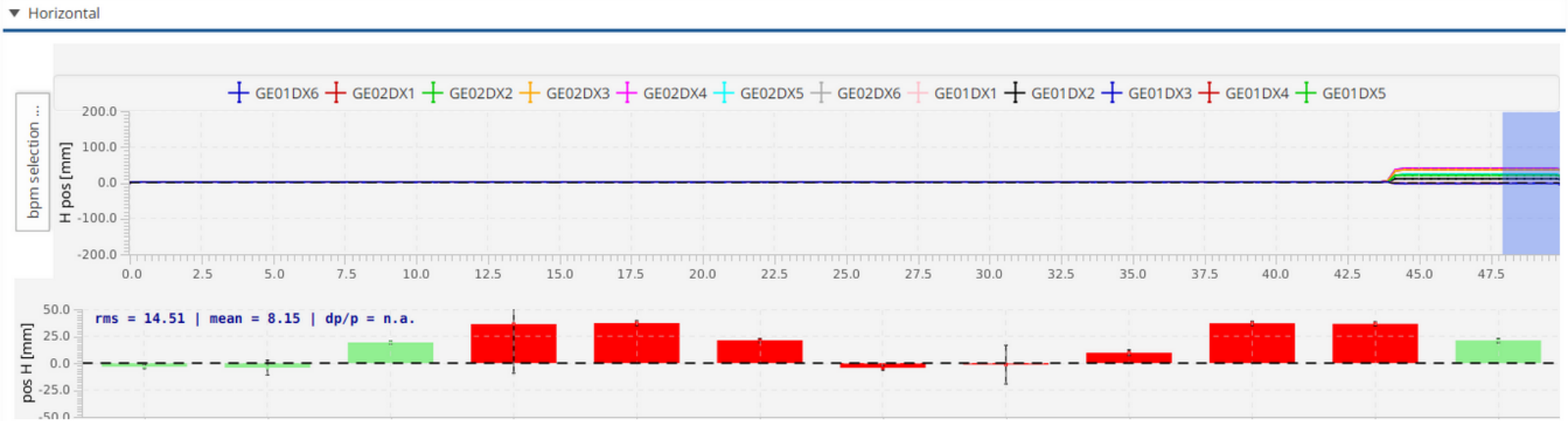
...

Beam Optics

First try (in Manipulation, so injection unchanged)



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