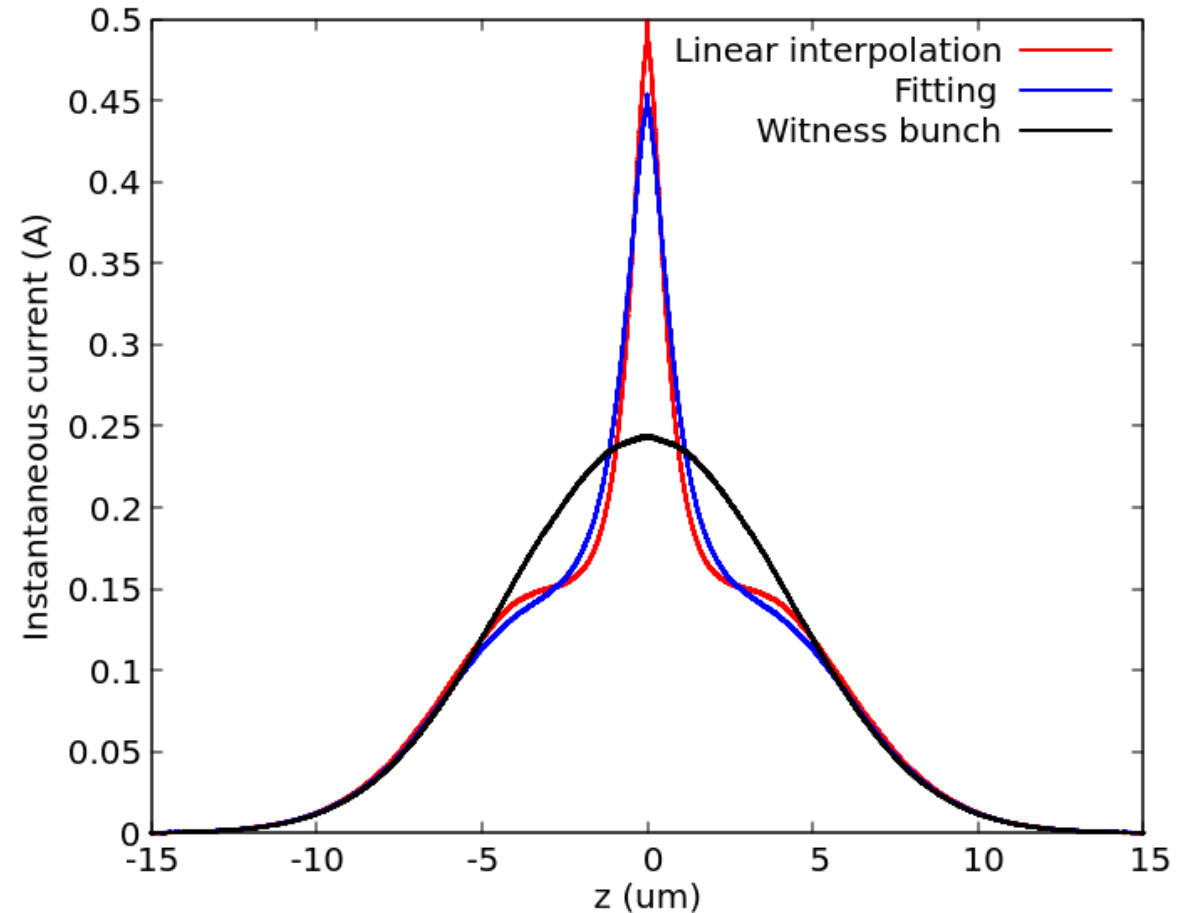
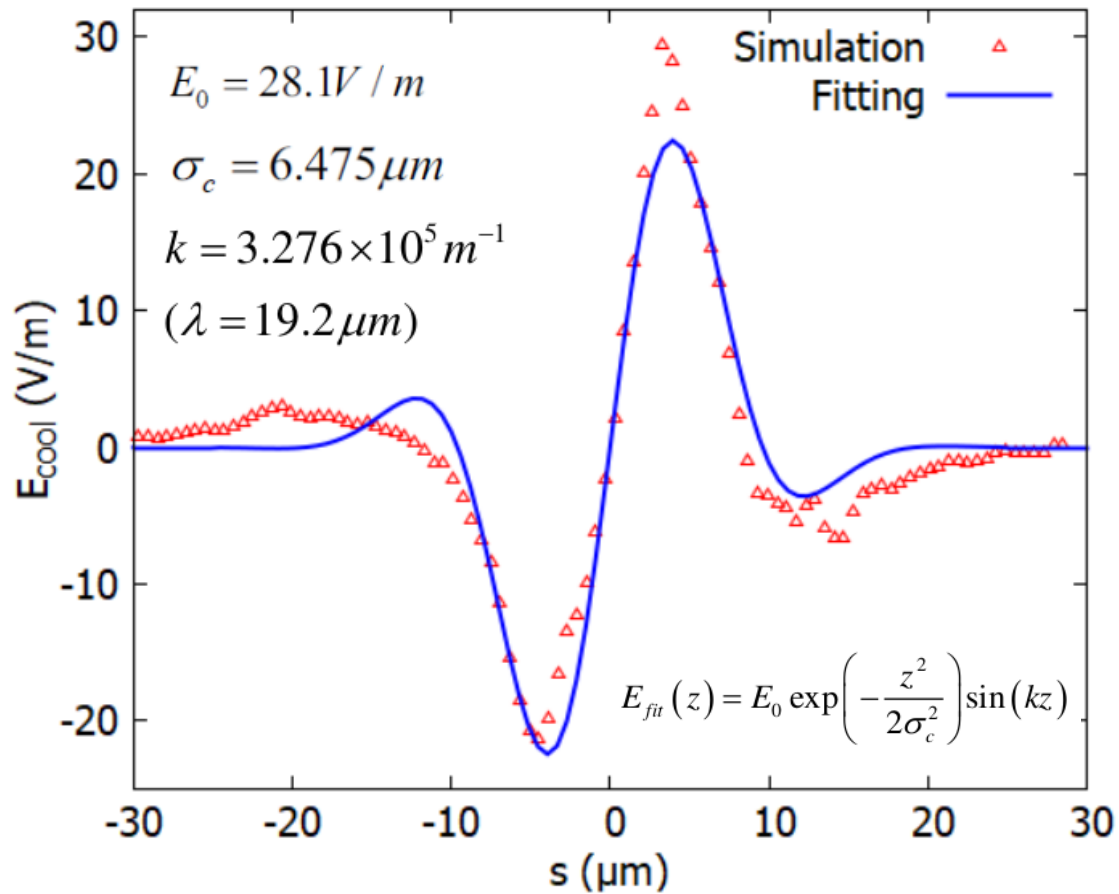


Tracking of the Ions for the CeC experiment with Cooling Force Depending on Longitudinal Location of the Ion

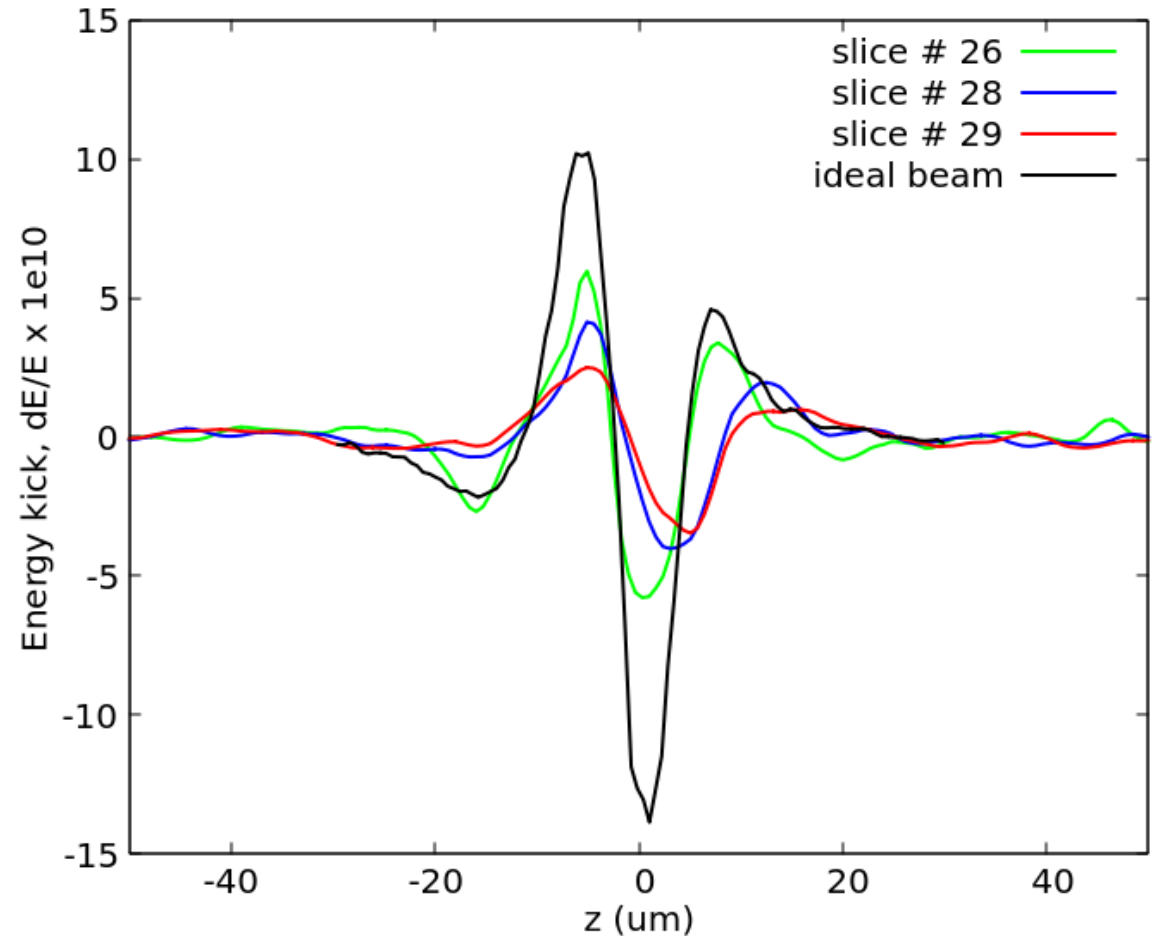
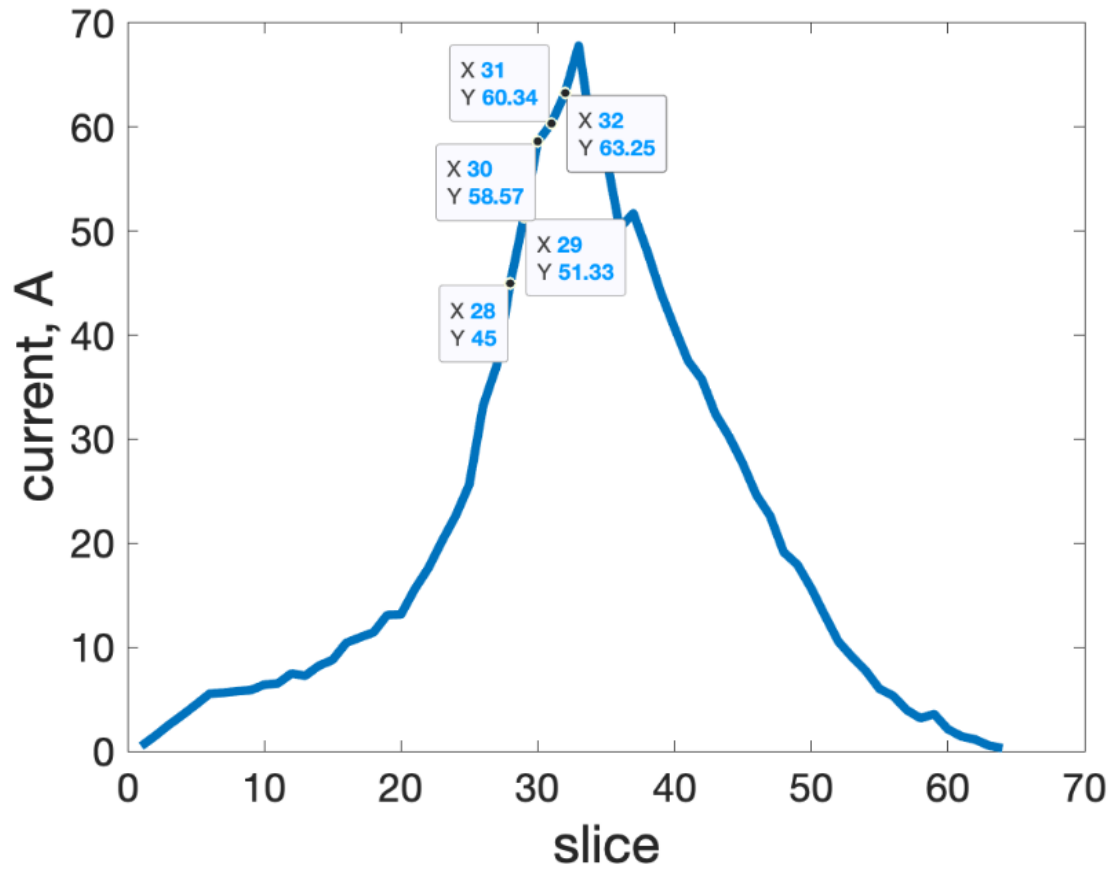
G. Wang

What has been done differently...

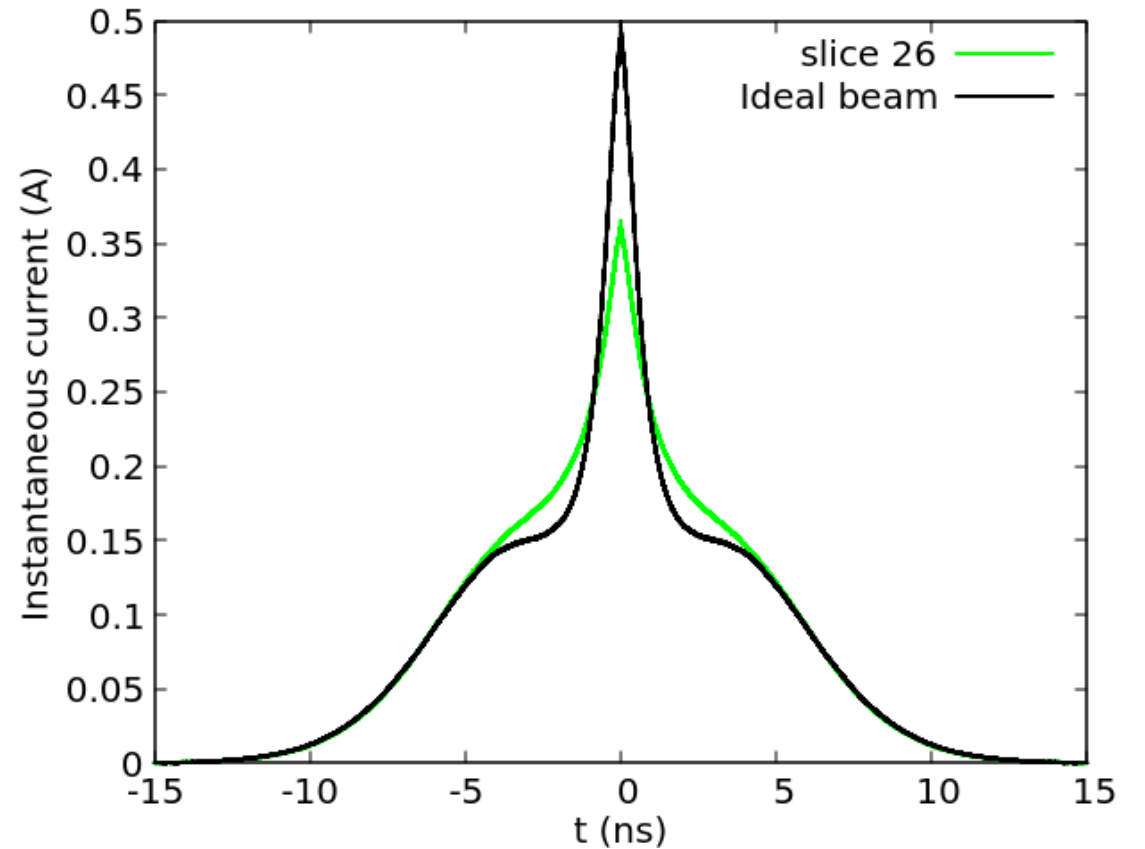
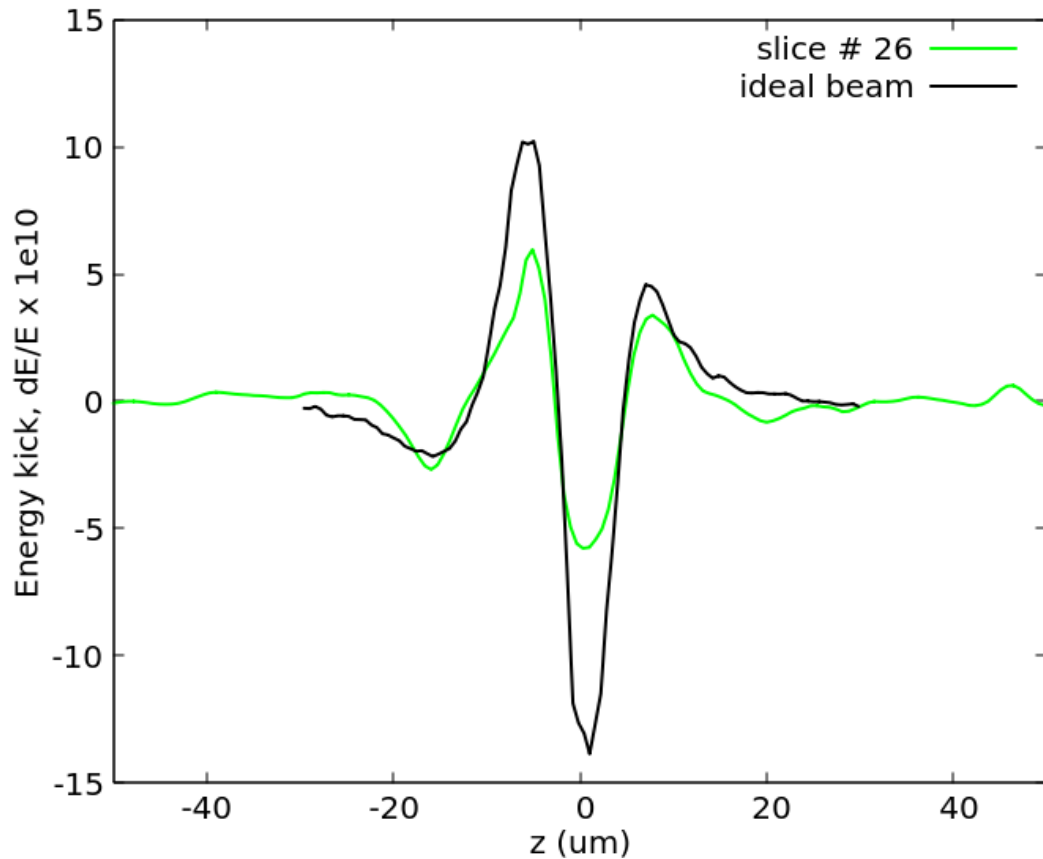
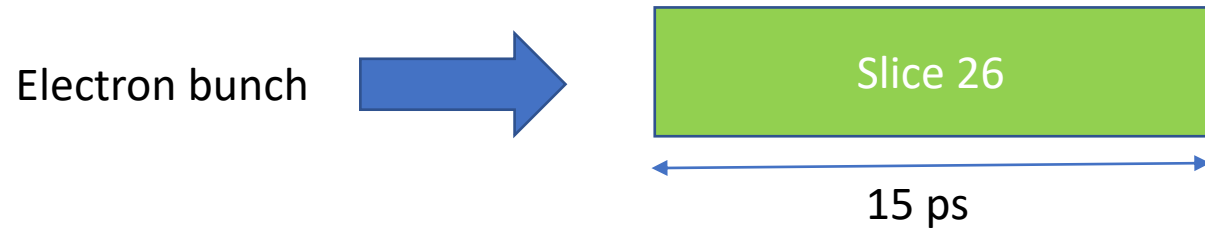
Fitting-> linear interpolation



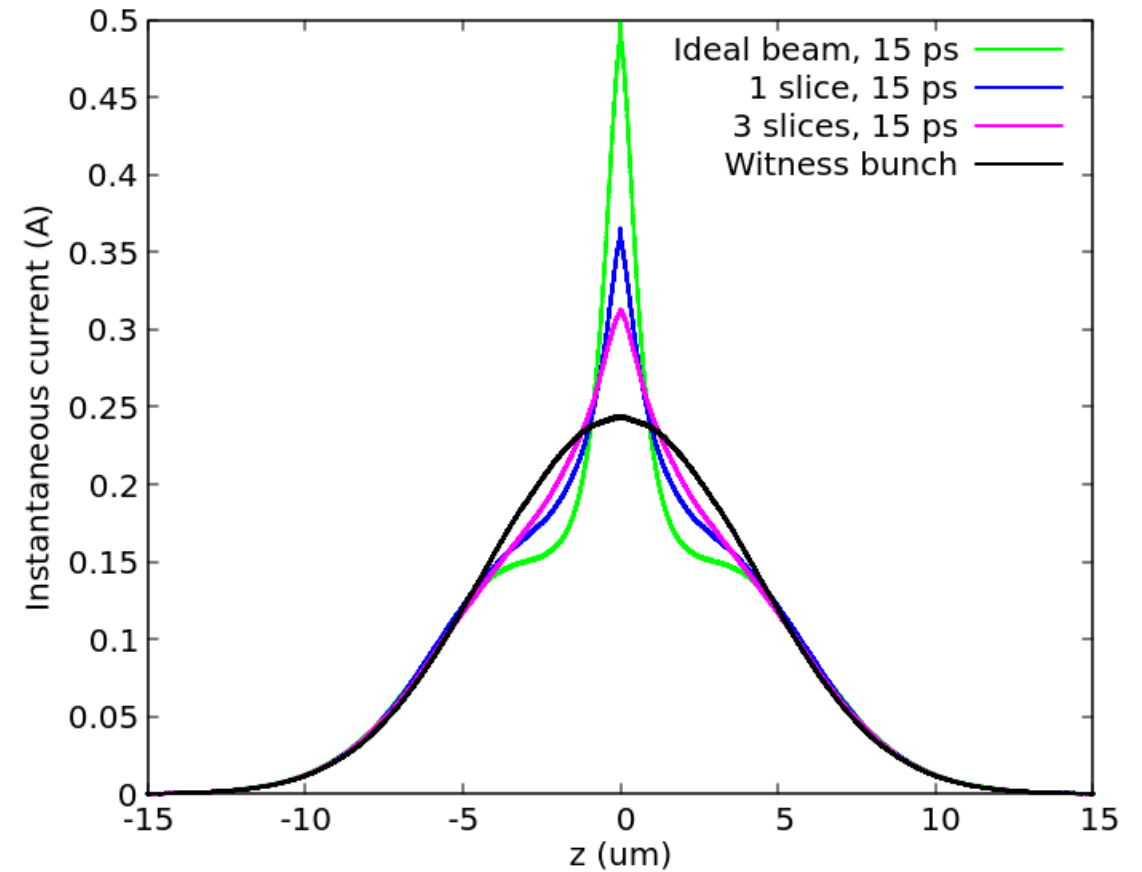
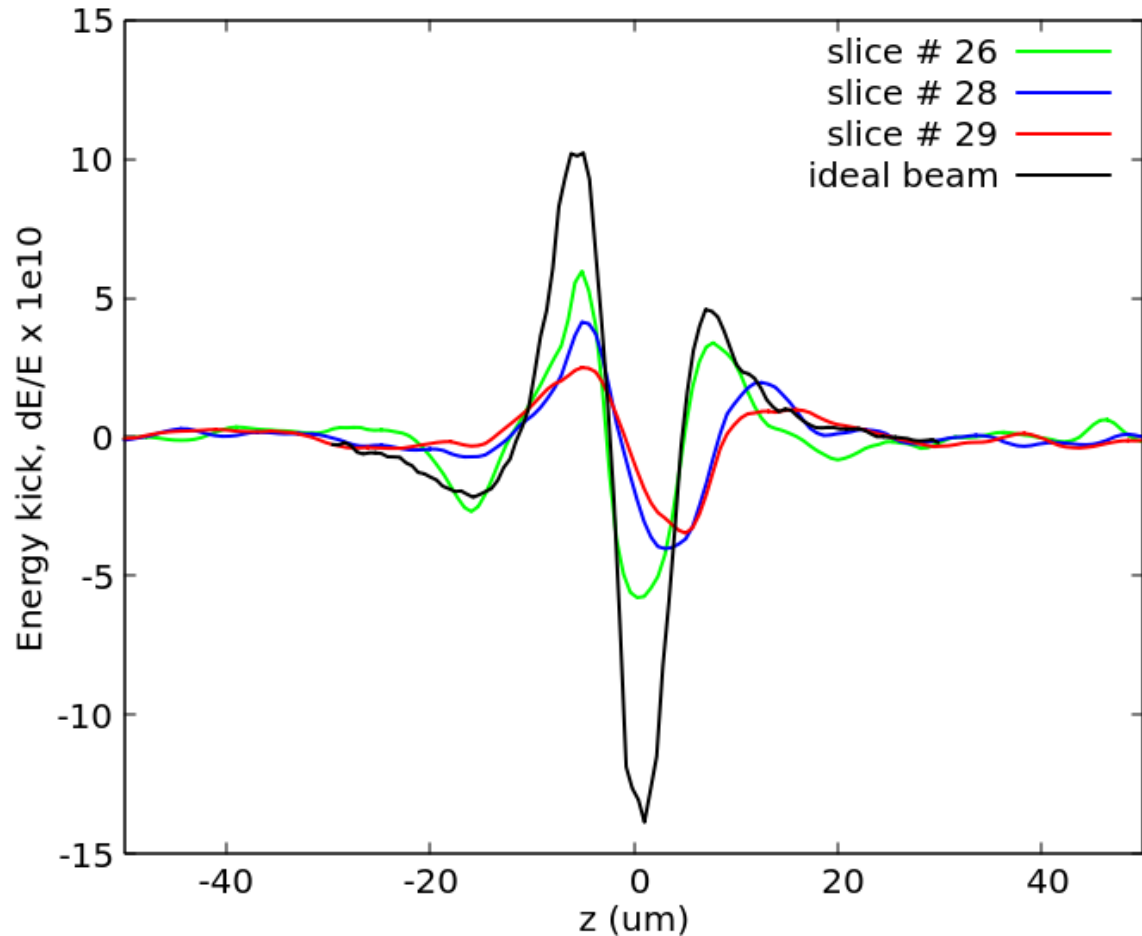
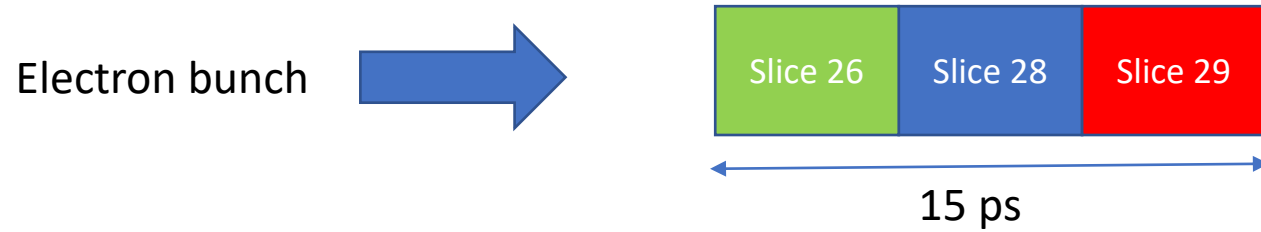
Energy kick from Ideal beam vs Simulated beam



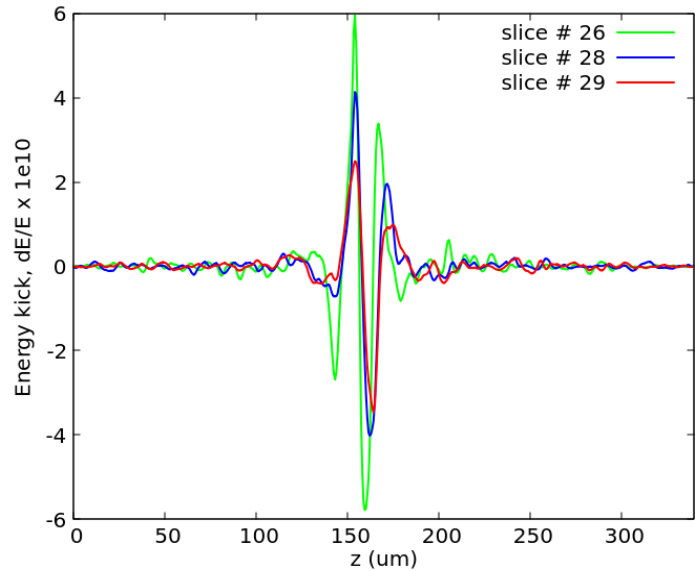
Using energy kick from the best slice, i.e. slice # 26 and assume the kick applies for 15 ps of electrons



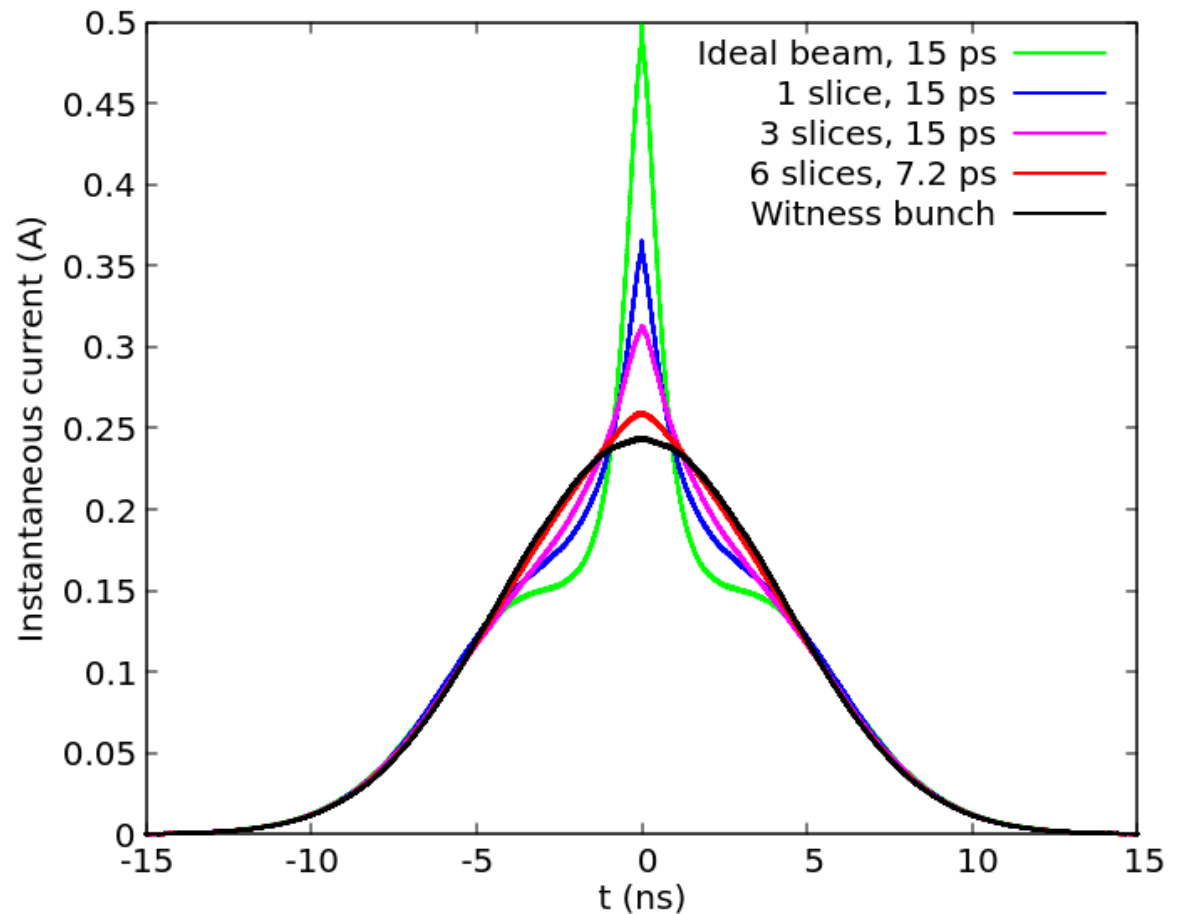
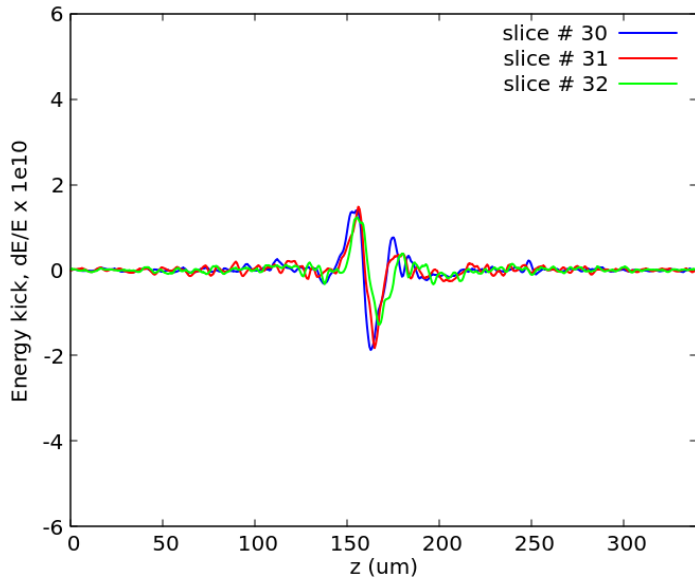
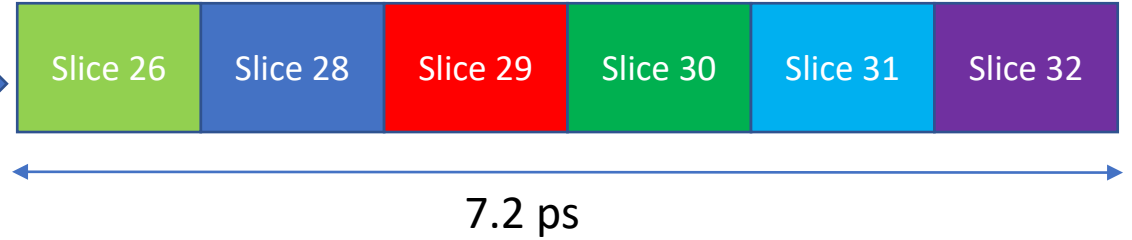
Using kicks from slice 26, 28 and 29 with each slice has 5 ps of duration



Using kicks from 6 slices with 1.2 ps of duration for each slice



Electron bunch

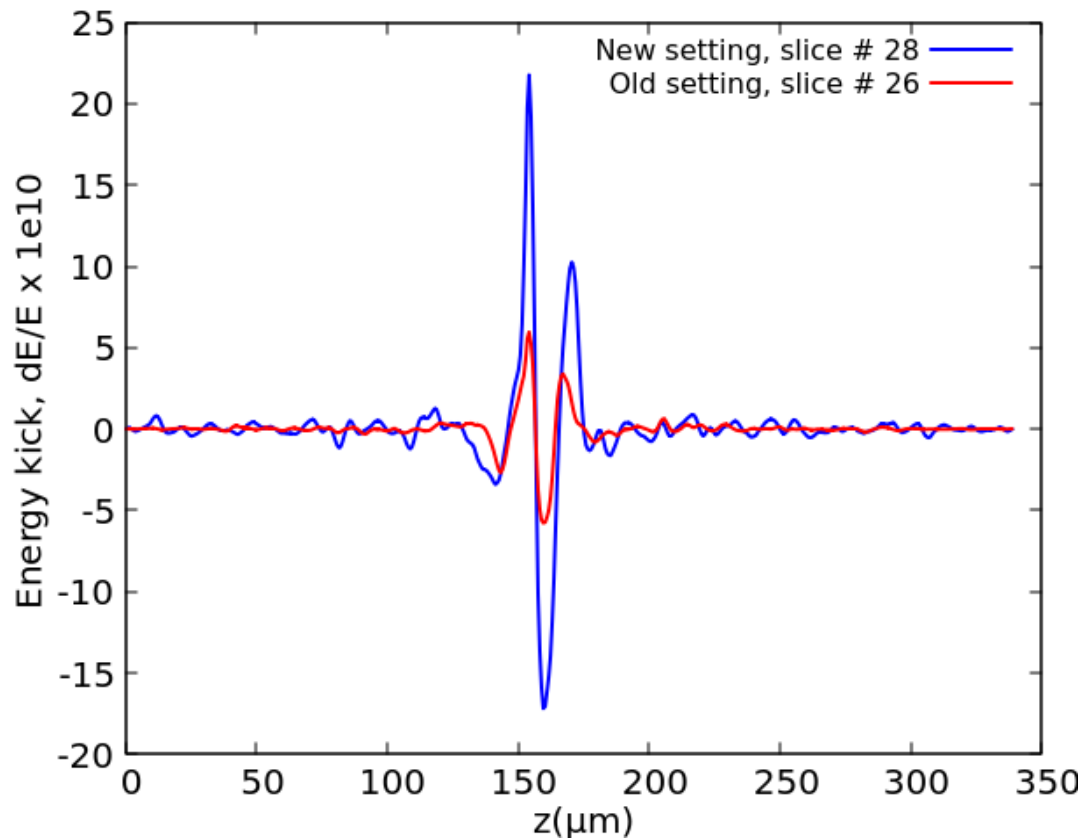


Summary

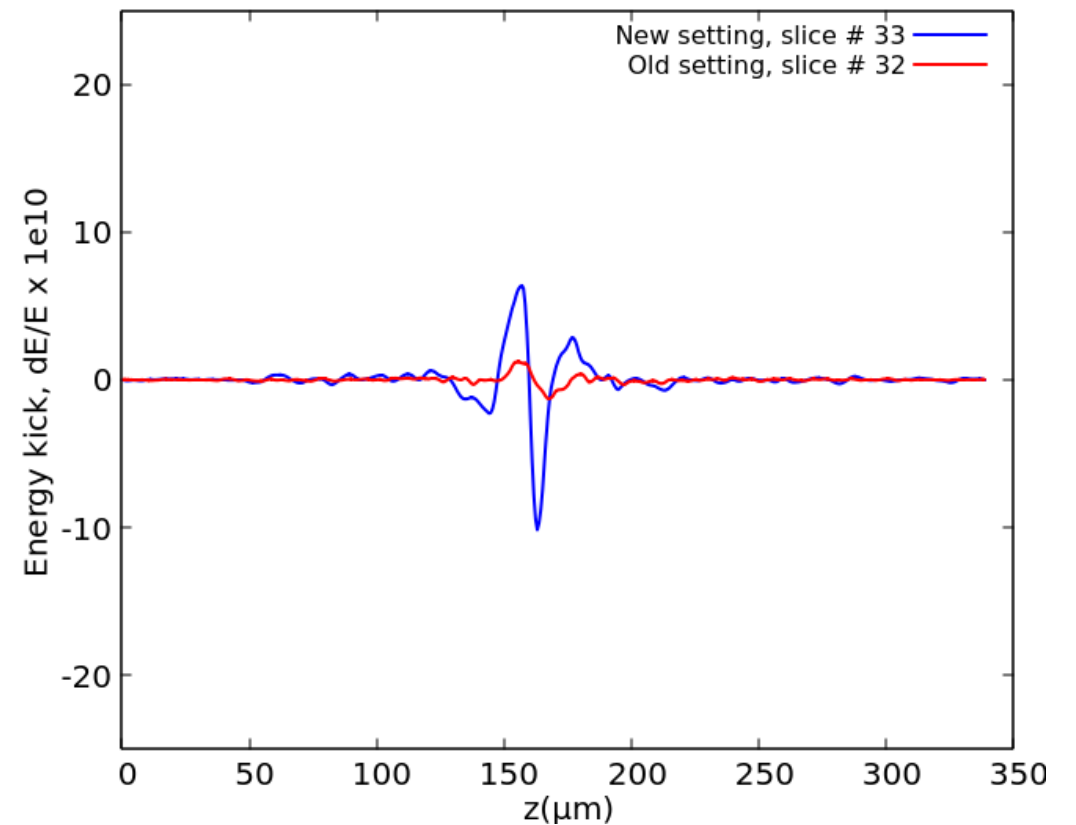
- The tracking code is updated so that the energy kick calculated from SPACE simulation is directly used with linear interpolation applied between data points.
- It has been implemented into the tracking code that ions sitting at different longitudinal slice of the electron bunch see different form of the cooling force. The cooling force for each slice of electrons depends on the local properties of the electrons and is provided by SPACE simulation.
- According to the simulation, cooling effect is very weak with the electron beam as obtained from the previous beam dynamic simulation, i.e. 7% of peak current increases over 40 minutes, even without energy jitter and other adverse effects.
- We need to improve electron beam quality so that we have 15 ps of duration with energy kick comparable to that of the best slice of the previous simulated electrons, i.e. slice 26.

Updates with new solenoid settings (comparison of cooling kicks)

Best slice

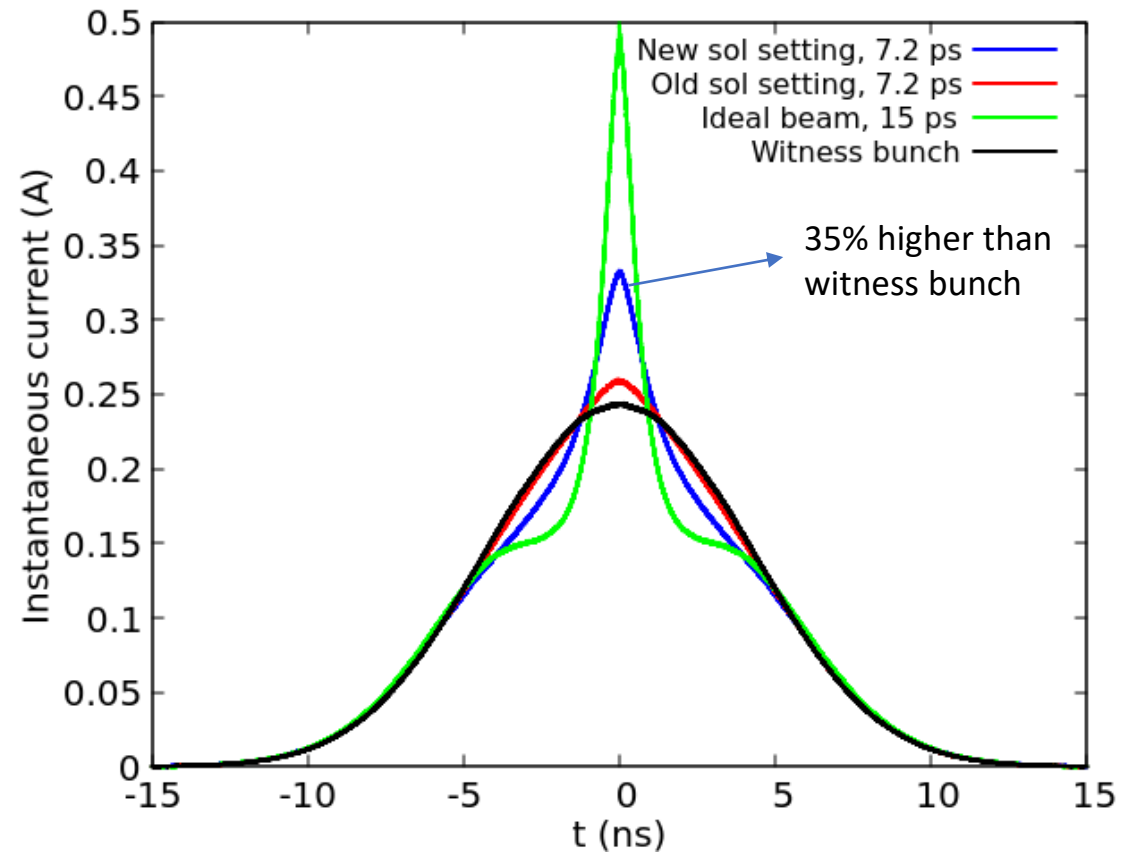
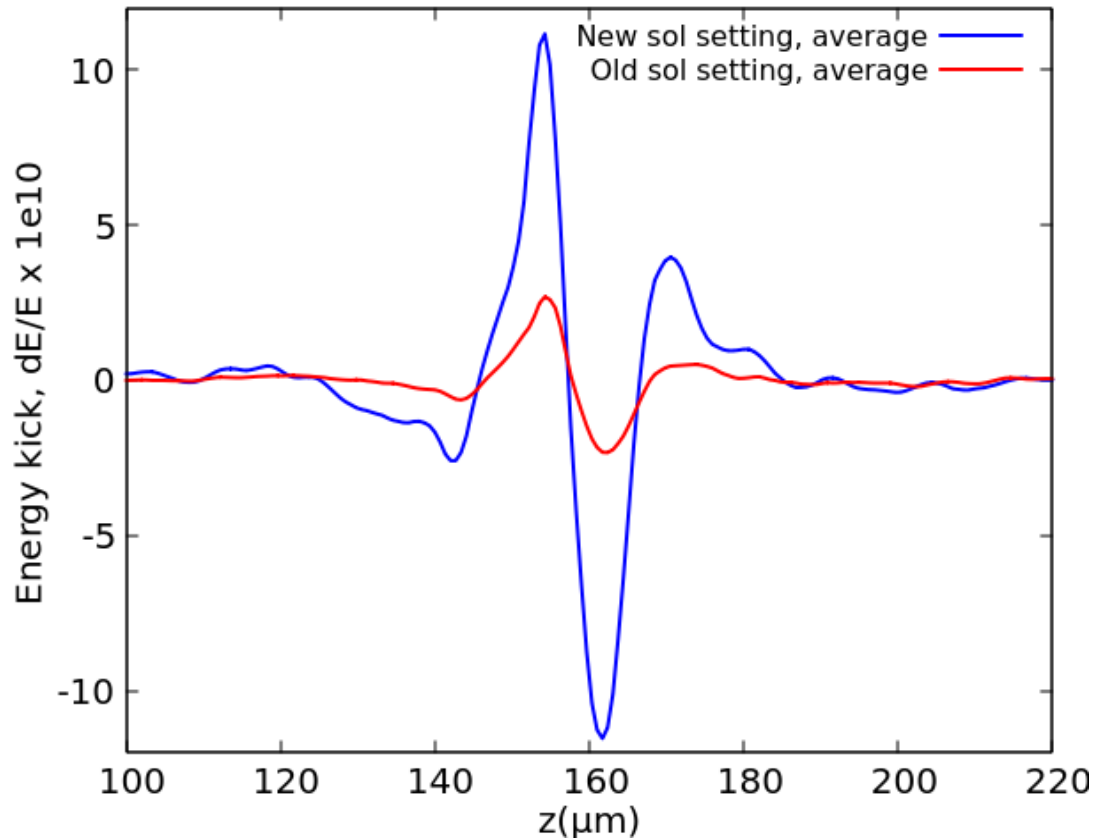
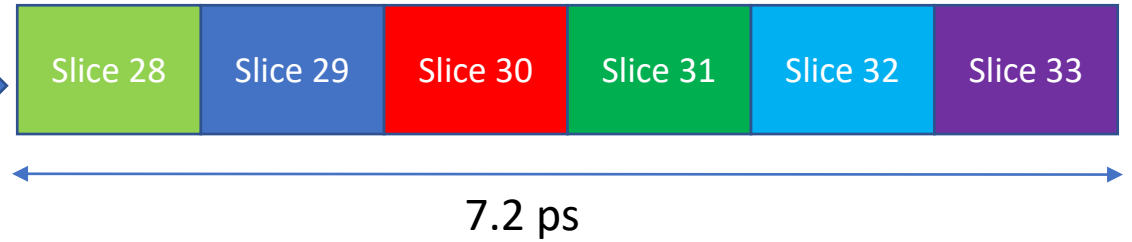


'Worst' slice



Updates with new solenoid settings

Electron bunch



Latest SPACE simulation results for e beam size (old electron distribution)

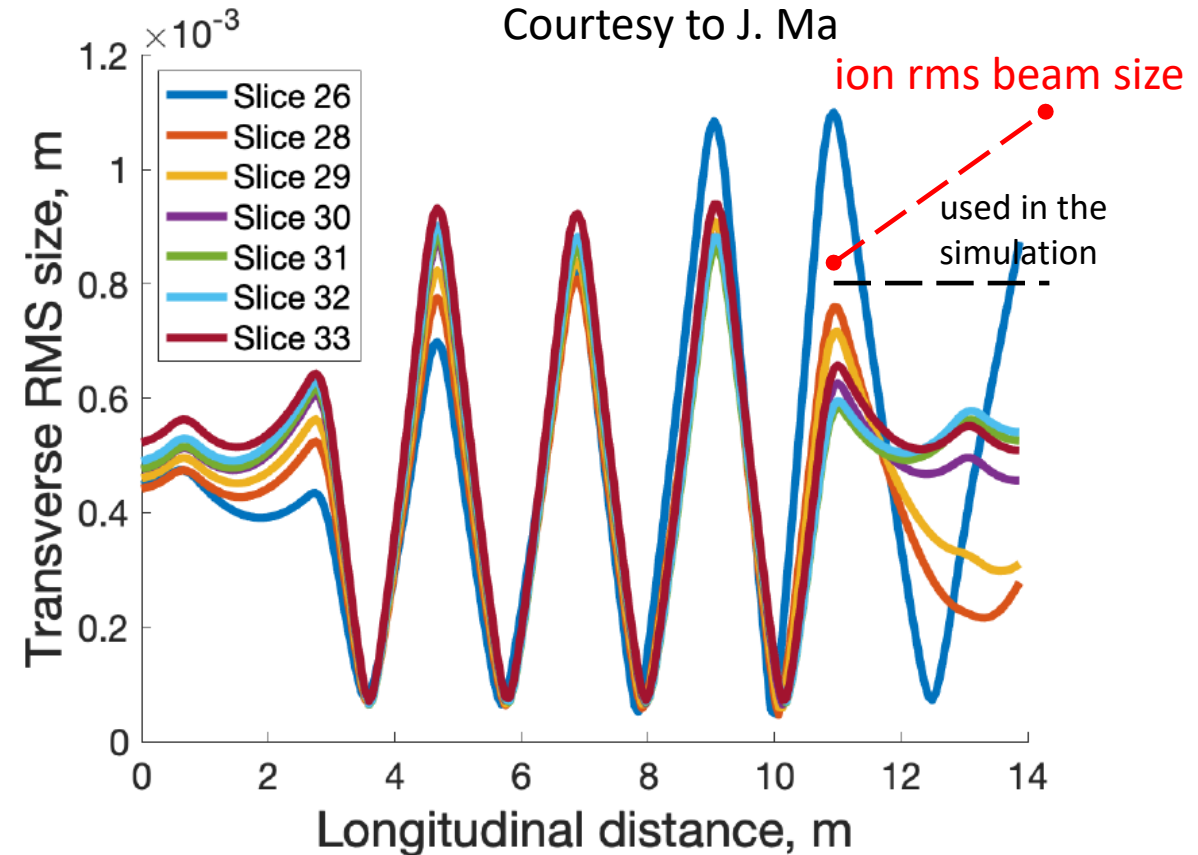
$$\sigma_{ion} = \sqrt{\frac{2.5 \mu m \cdot 7.5 m}{28.5}} = 0.8 mm$$

(*The beta function at kicker varies from 8.5 m to 14.3 m, corresponding to average ion beam size of 1 mm. To be corrected...)

- Poor spatial overlapping of the electrons with the ions can reduce the cooling effects.
- In order to properly study the effects, one need to obtain the dependance of the cooling energy kick on the transverse offset of the ion.
- As a start, I assumed Gaussian dependance in the simulation for now.

$$dE(z) \rightarrow dE(z) \exp\left(-\frac{x^2}{2\sigma_x^2} - \frac{y^2}{2\sigma_y^2}\right)$$

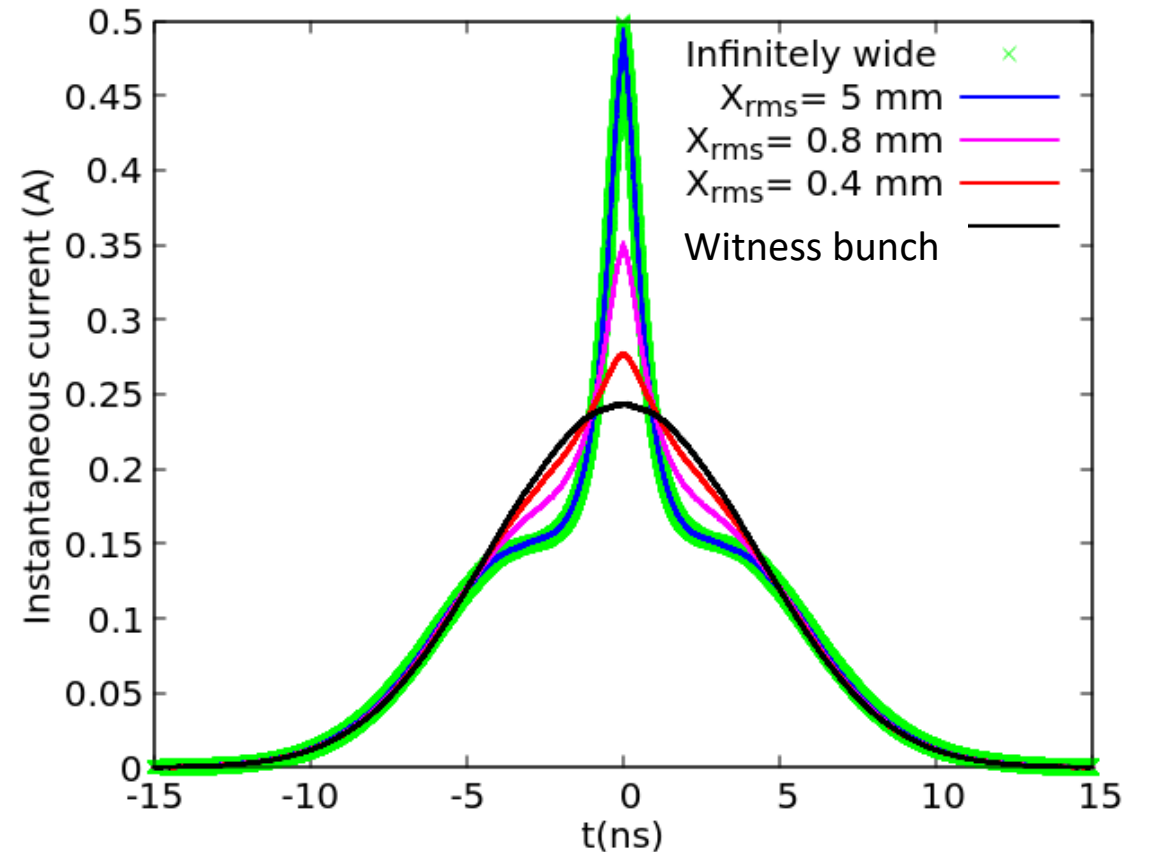
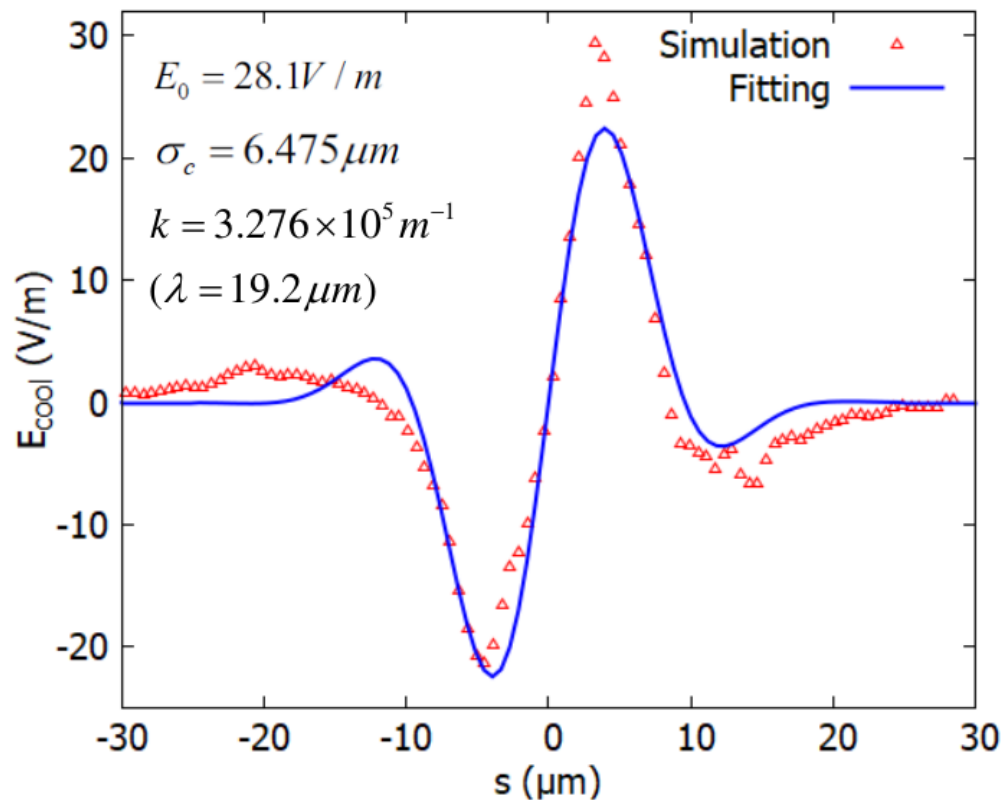
$\sigma_{x,y}$: rms width of the slice of electrons that the ion is overlapping with



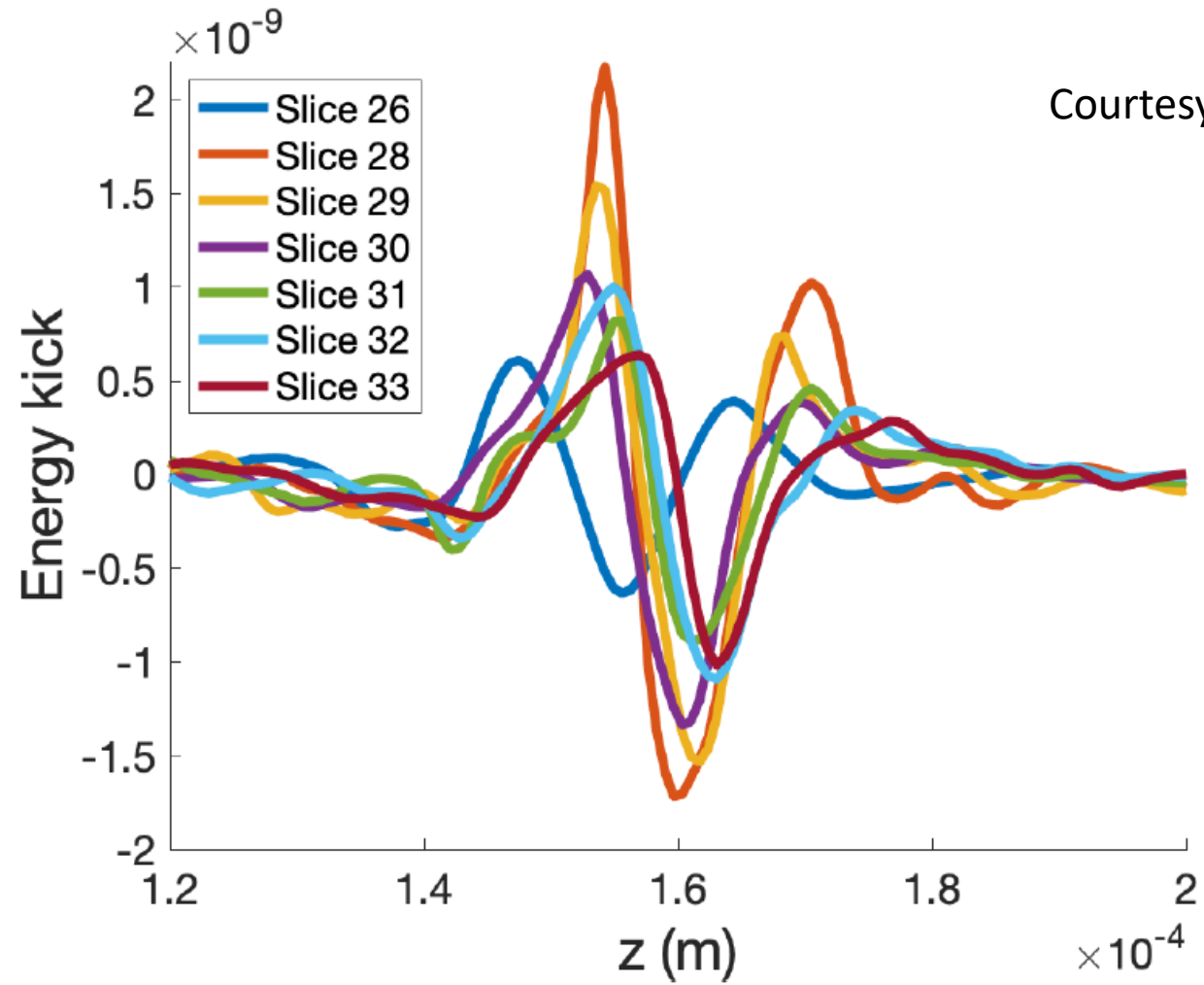
Influences due to finite transverse size of the electron bunch

- Assuming the energy kick in CeC section has Gaussian dependance on the transverse offset of the ion with the R.M.S. width given by the R.M.S. size of the electron slice.

As a test, start from the ideal case...



Then use the latest SPACE simulated energy kicks for 7 slices

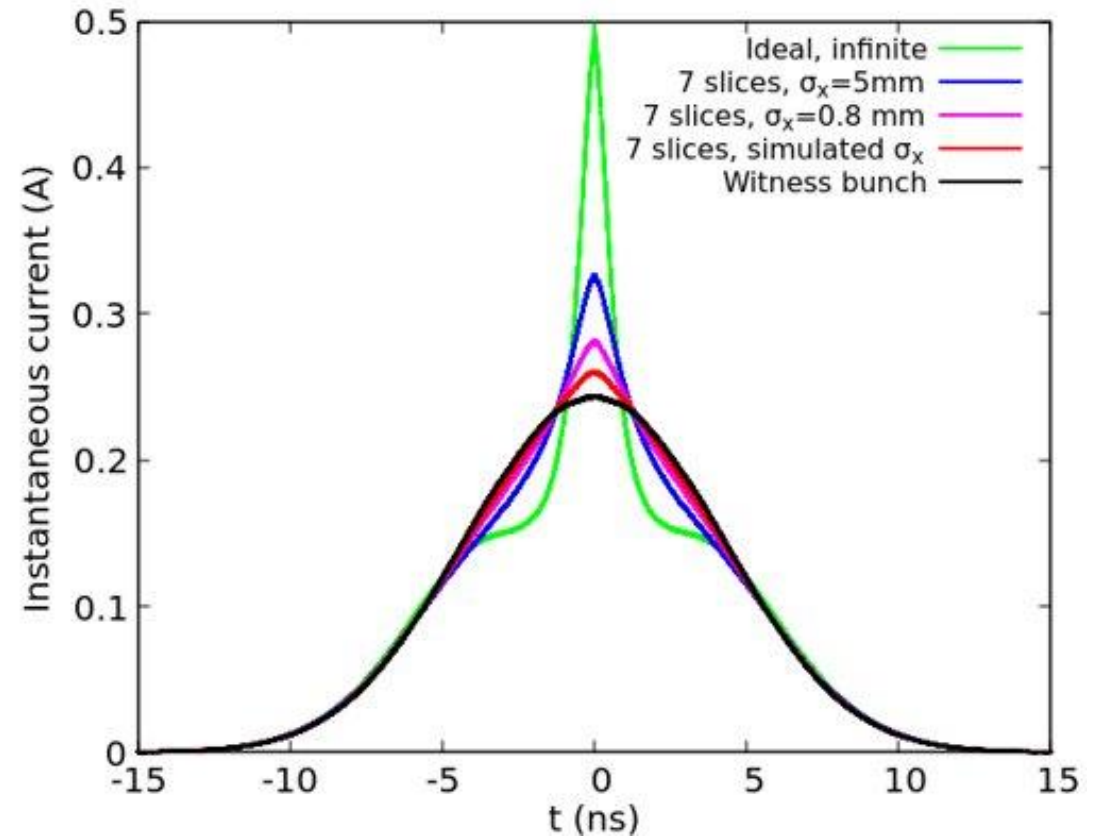
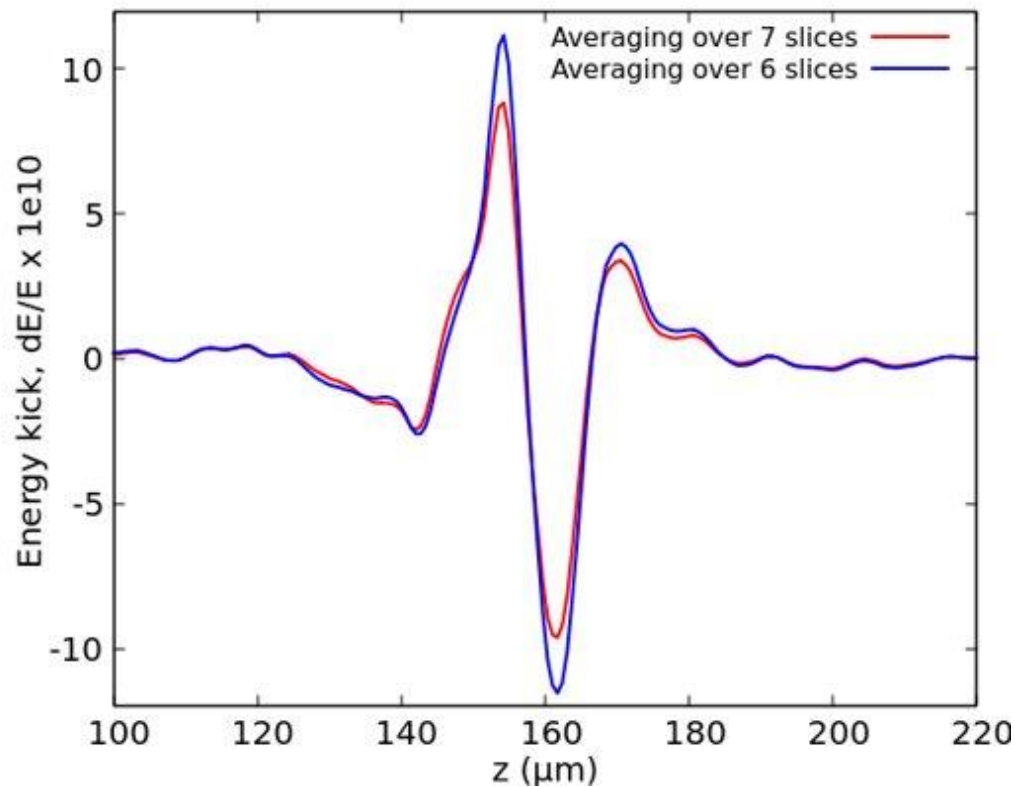


Results for Solenoids Matched to e Slice with the Maximal Current

Electron bunch



8.4 ps



Summary on influences from transverse dependance of the cooling force

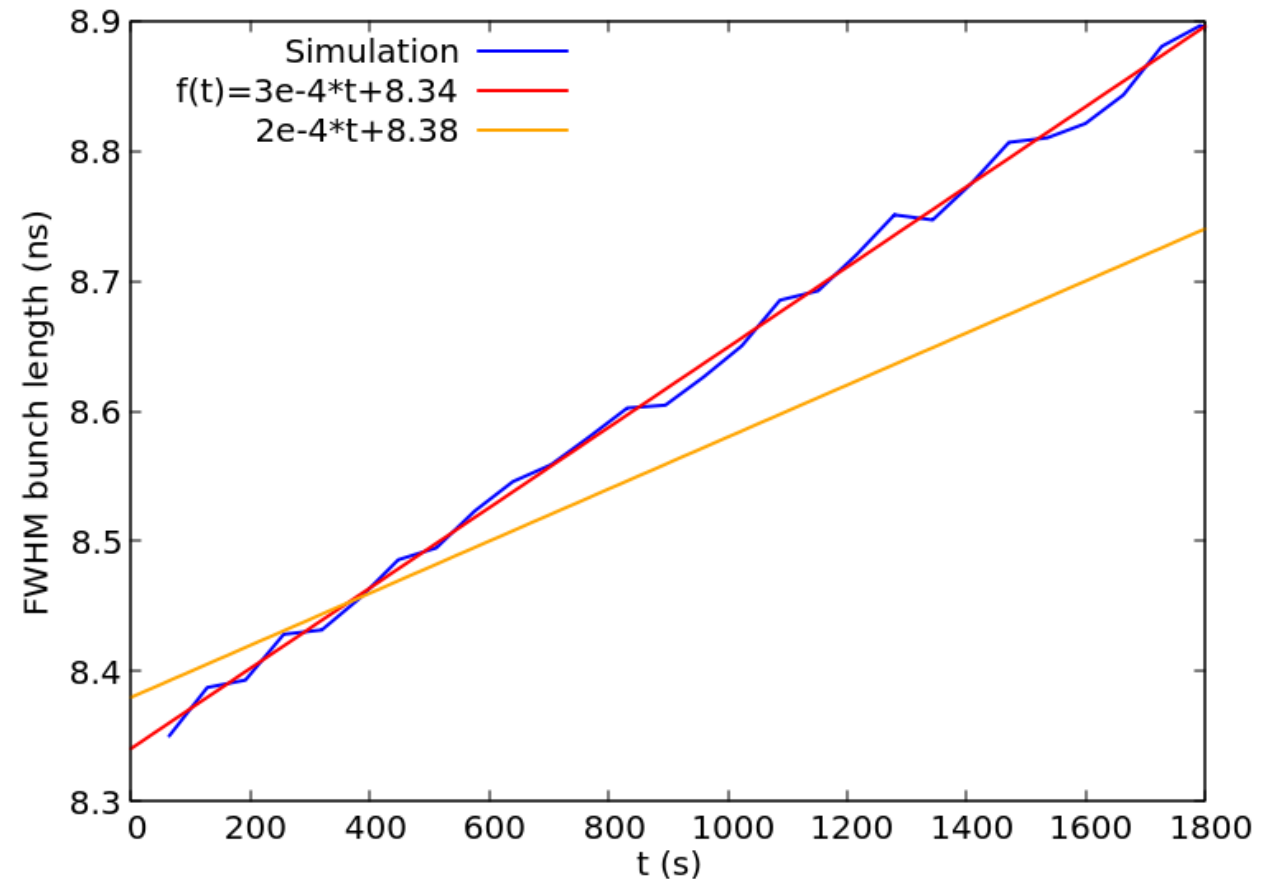
- If we assume Gaussian dependance of the cooling force on the transverse offset of the ion with the rms width given by that of the electron slices, the observable of the cooling effects, i.e. the enhancement of the peak current of the ion bunch w.r.t. the witness bunch, reduces by a factor of ~ 4 compared with the case when these effects are ignored.
- The significant reduction is related to the fact that the electron bunch is smaller than the ion bunch in the transverse plane (0.2-0.5 mm for the electrons vs 0.8 mm (should be 1 mm) for the ions). If we can make the transverse size of the electrons the same as that of the ions without reducing the cooling force at the center of the electron bunch, the cooling effect can be improved by a factor of 2.

Next step...

- Implement a better model for cooling dependance on the transverse offset: disk model and then SPACE simulation.

Check IBS routine with measurement in FY 21

7/4/2021 20:44



I can't find any IPM emittance measurements during CeC dedicated time in Run 21, but the measurement for regular RHC store looks smaller than 15 mm.mrad



Ion beam size

$$\beta(s) = \beta^* + \frac{s^2}{\beta^*}$$

$$s_1 = 4m$$

$$s_2 = 7m$$

$$\bar{\beta} = \beta^* + \frac{s_1^2 + s_2^2}{2\beta^*} \geq 2\sqrt{\beta^* \frac{s_1^2 + s_2^2}{2\beta^*}} = \sqrt{2(s_1^2 + s_2^2)}$$

The minimal average beta happens at $\beta^* = \sqrt{\frac{s_1^2 + s_2^2}{2}}$.