The Particle Distribution at the end of ESS Linac

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March 26th, 2012

Non-linear Beam Expander Systems in High-power Accelerator Facilities

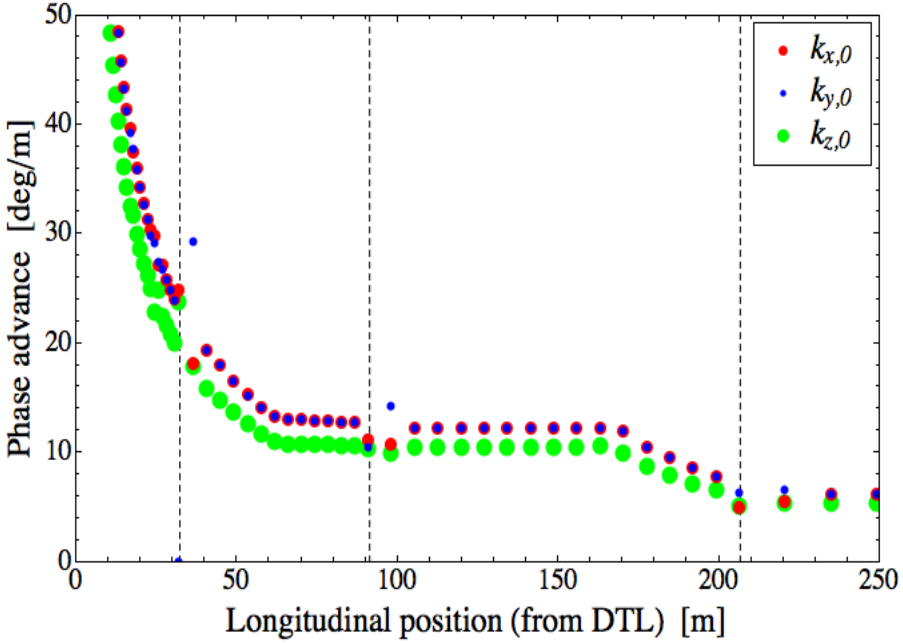
Introduction

Halo/loss study on focus of the MEBT collimators has been initiated. Very simple numerical tests have been conducted and no evidence of why they won't work has found so far. I'll cover

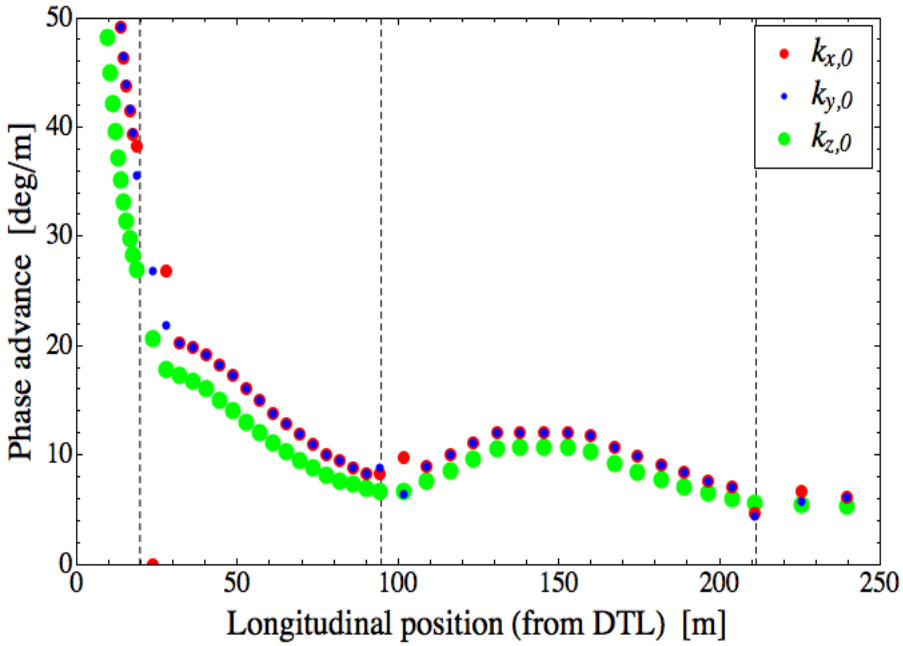
- Ongoing lattice modification
- Halo definition (reminder)
- Particle distribution into HEBT from the old (2011) and new (modification ongoing) lattices
- Some simple tests:
  - Does the distribution into HEBT depend on that going into DLTs?
  - Transverse and longitudinal planes well decoupled?
  - Collimators in the short MEBT in the old lattice
- Comments on the beam loss
- Summary

Transition energy from DTLs to spokes increased

New

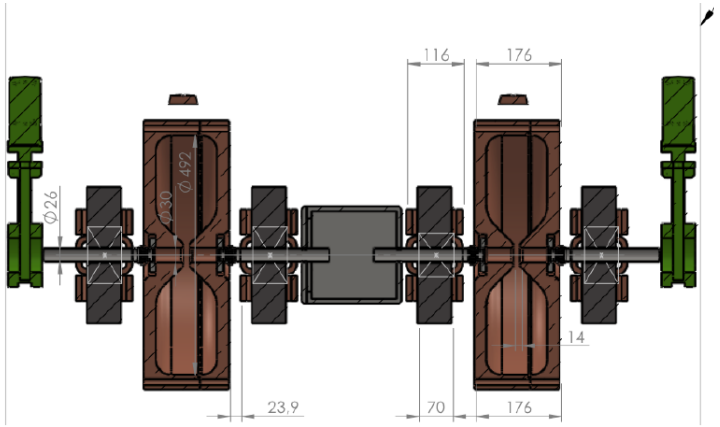


Old



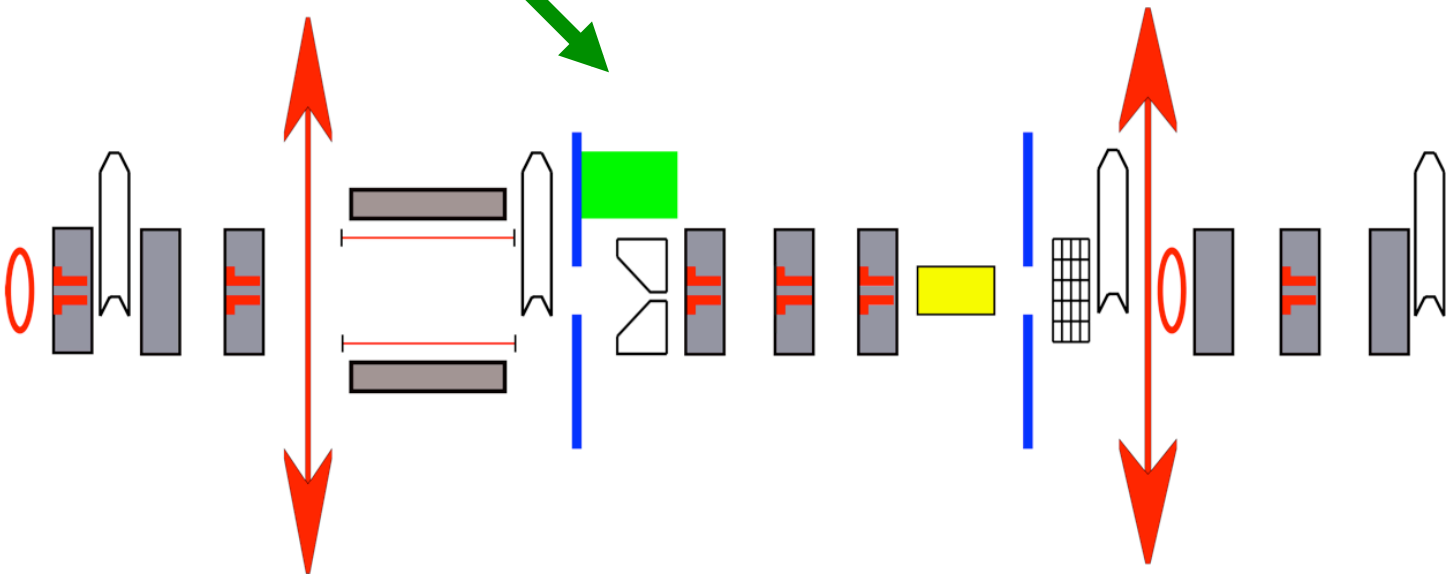
- The transition energy from DTLs to spokes has been increased, providing smoother connections of the phase advances. (Better overall beam dynamics)
- Cryo modules are still hybrid ones in this particular lattice and will be changed to segmented ones.

New MEBT



- Matching between RFQ and DTL
- Fast chopper
- Beam instrumentation
- Collimation

In CDR



Halo definition

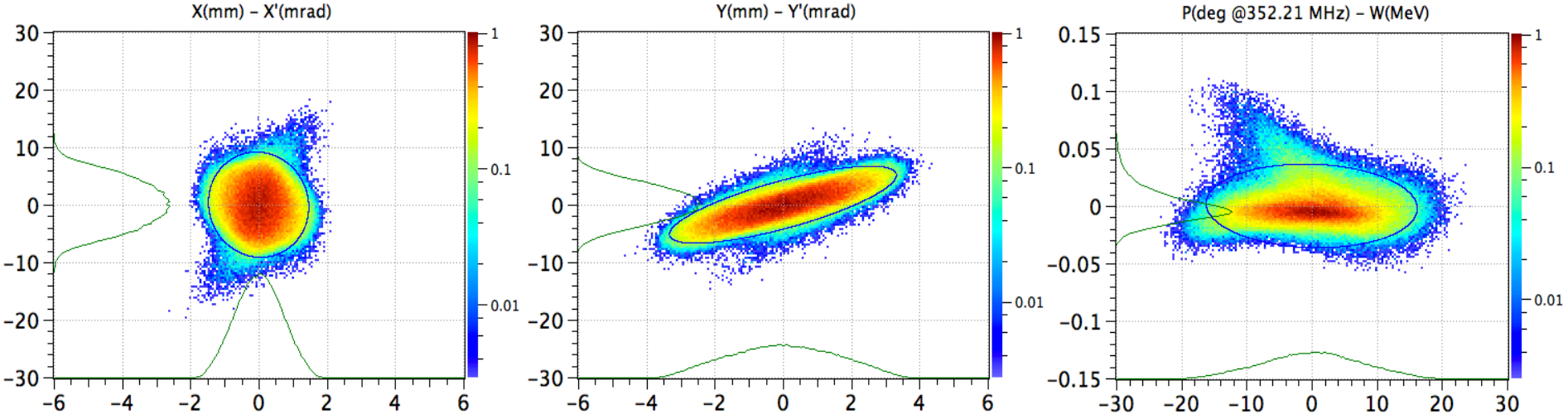
- The *spatial profile parameter* (Kurtosis):

$$h = \frac{< x^4 >}{< x^2 >^2} - 2$$

- The *halo intensity parameter* (extension to 2D)

$$H = \frac{\sqrt{3}}{2} \frac{\sqrt{< x^4 >< x'^4 > +3 < x^2 x'^2 >^2 -4 < x^3 x' >< x x'^3 >}}{< x^2 >< x'^2 > - < x x' >^2} - 2$$

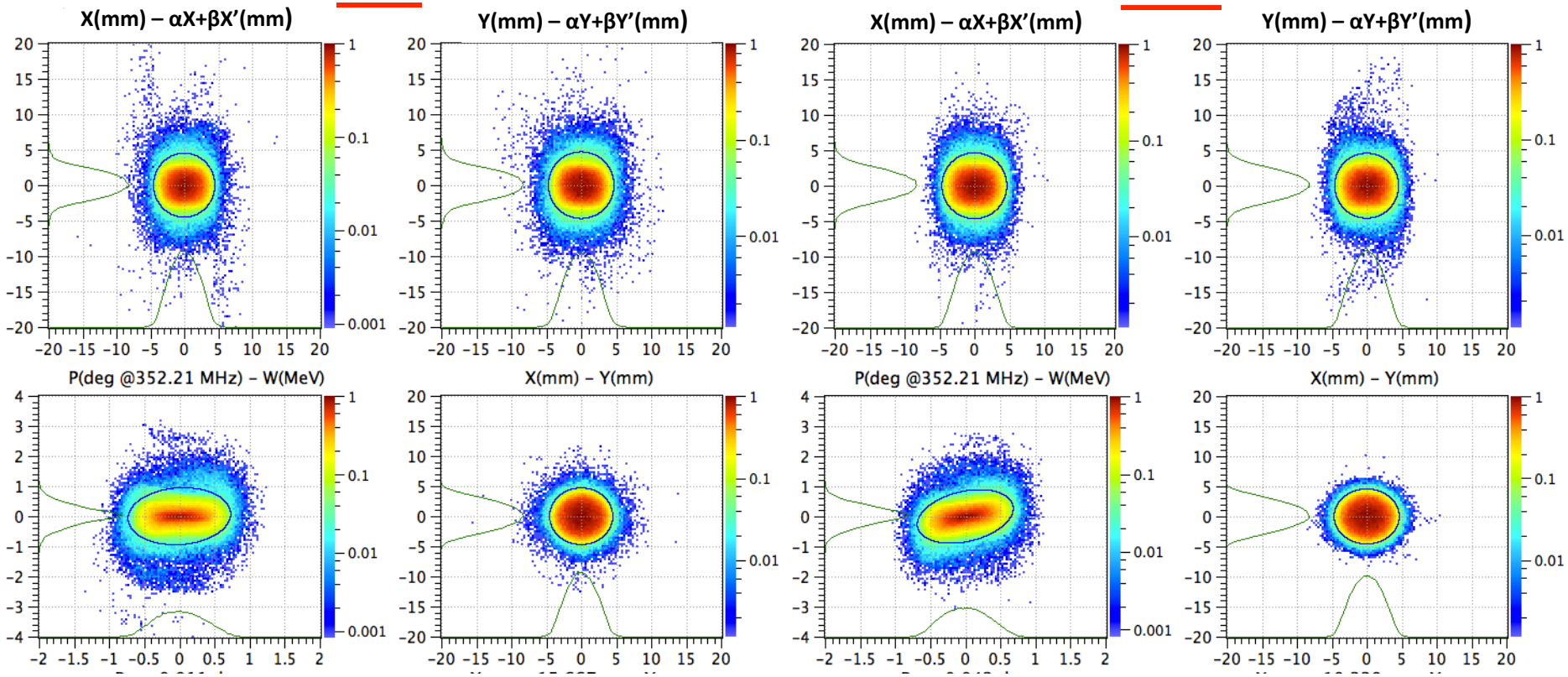
- The normalization "2" to make the "KV" = 0 and "Gaussian" = 1.



Distribution into DTL (from a simulation of RFQ by A. Ponton)

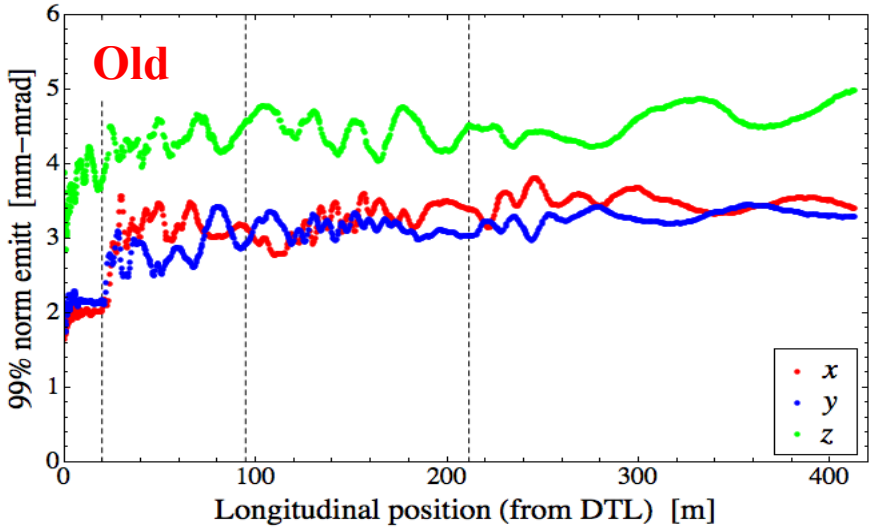
Distribution into HEBT: new vs. old lattices

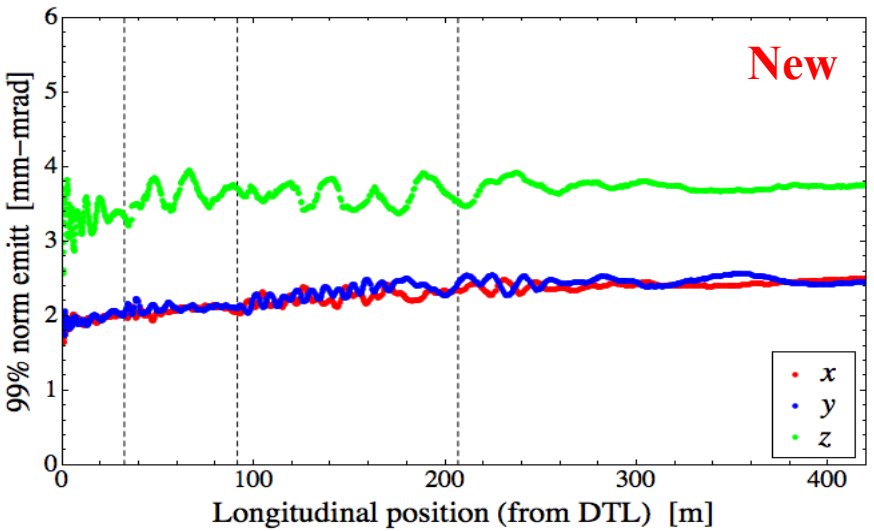
Old **New**

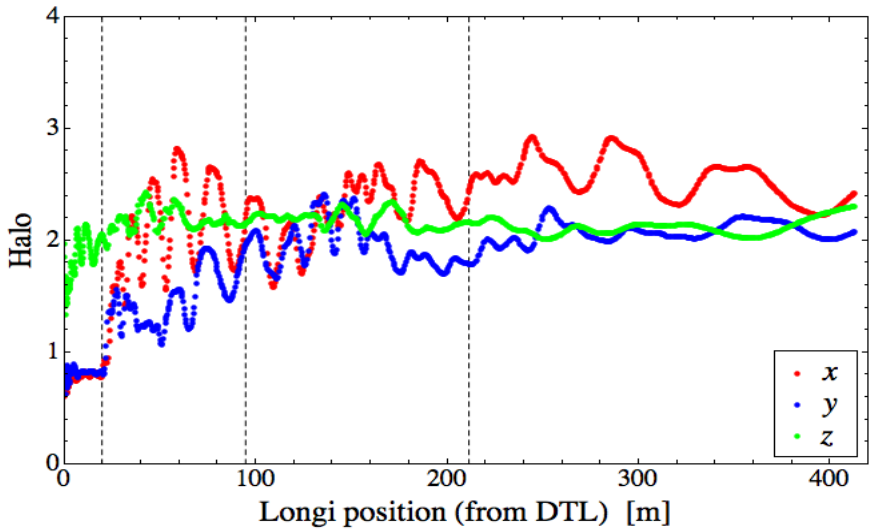


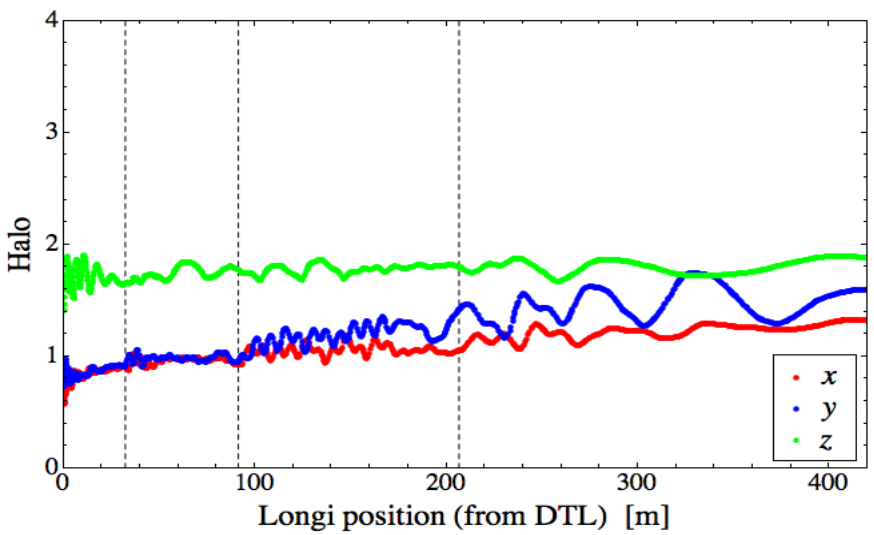
- Halo controlled better in the new lattice.
- Emittance is similar.
- 248k particles from a simulation of RFQ used as the input.
- H and V phase spaces normalized.

Emittance & halo: new vs. old lattices





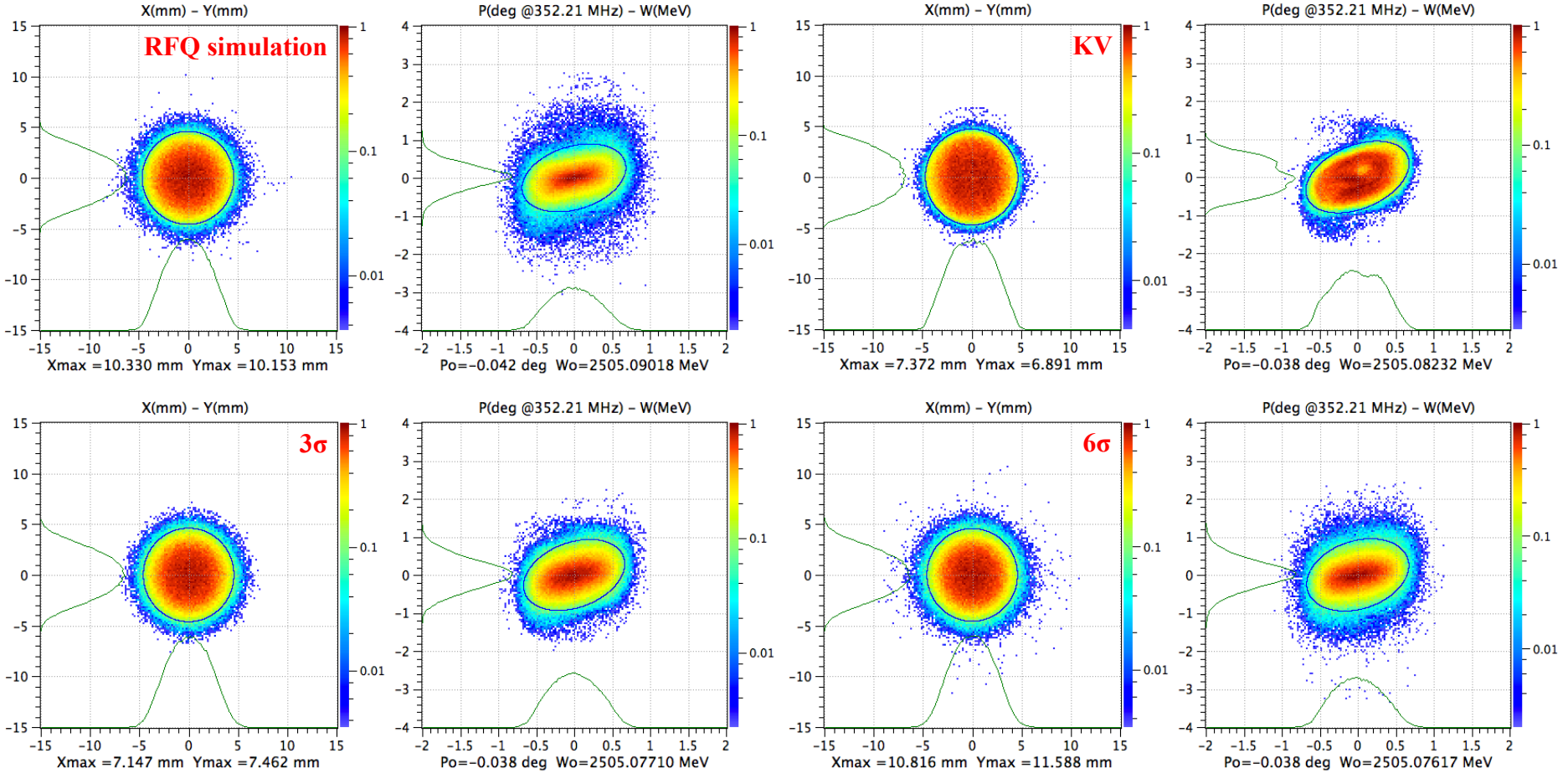




- The transition from DTLs to spokes improved.
- The halo is under a better control in the new lattice. (Good enough?)

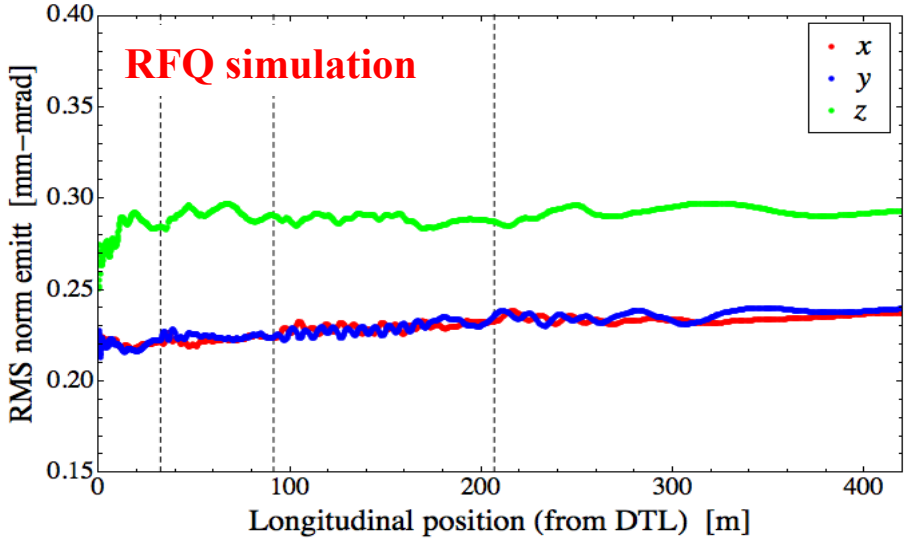
Does the input distribution affect the output?

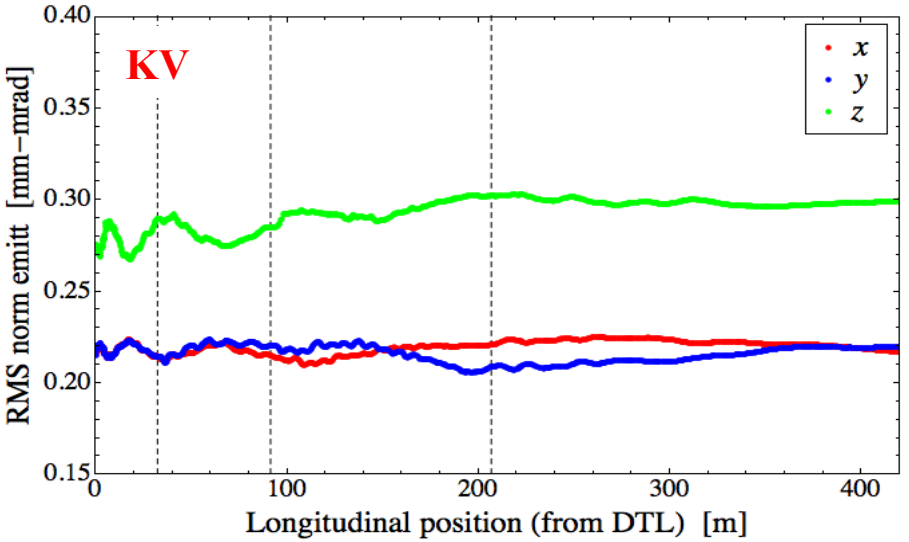
Distributions into HEBT from the new lattice

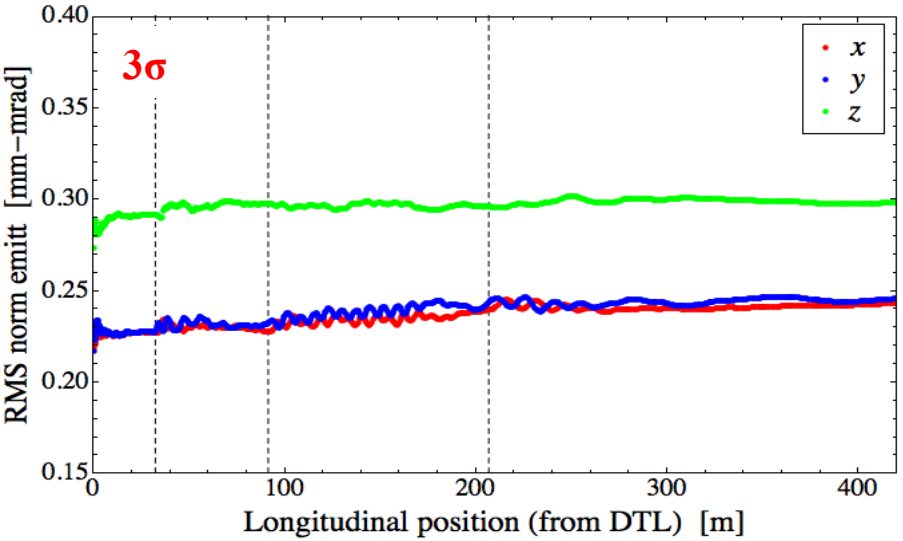


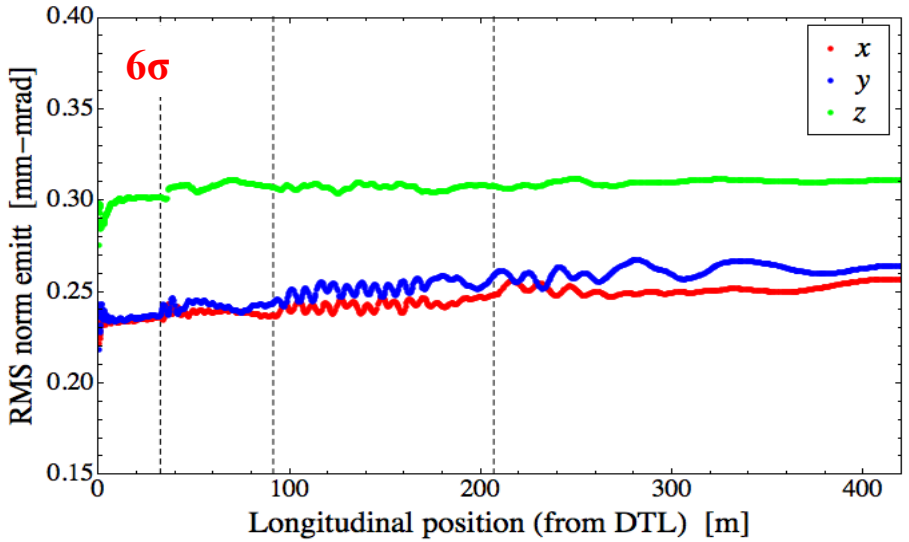
- Input distribution types are changed while emittances and optics parameters are kept the same.
- The input clearly affects the halo but doesn't have large impact on the emittance.

Emittance vs. initial distribution



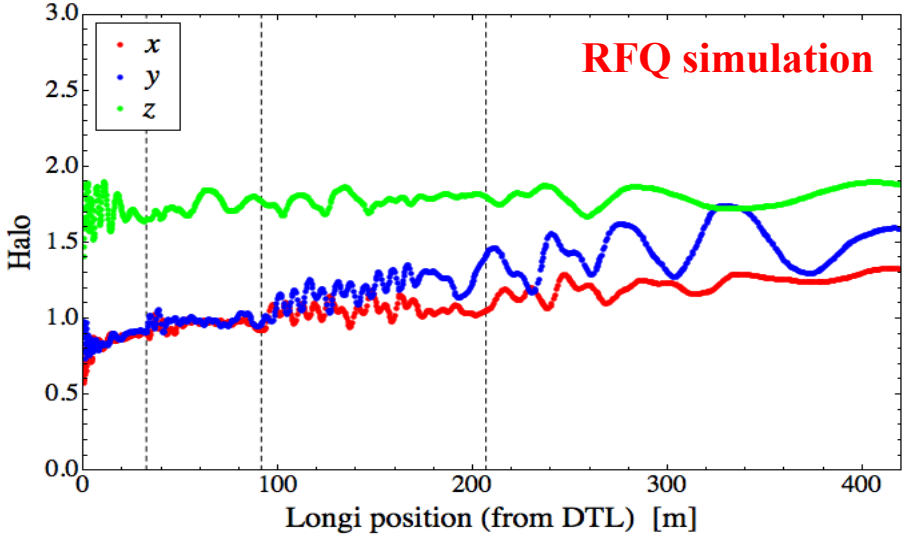


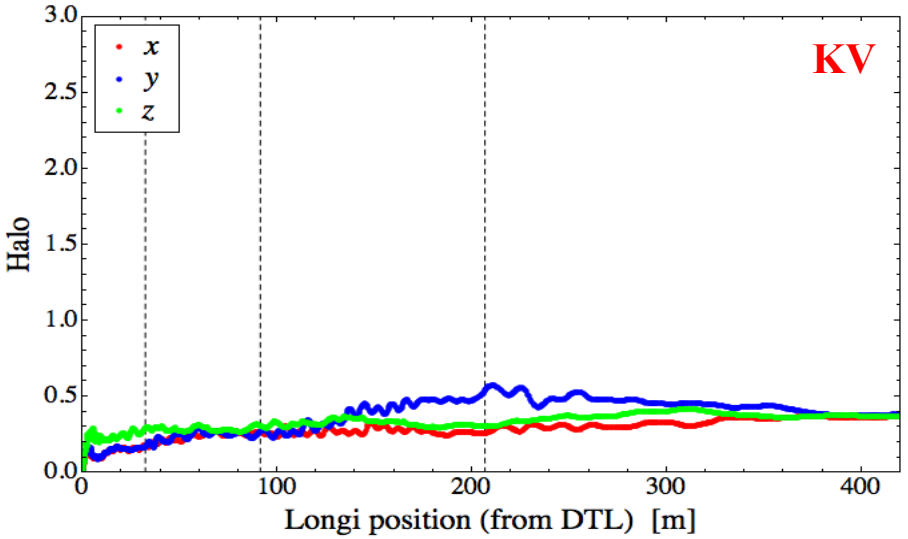


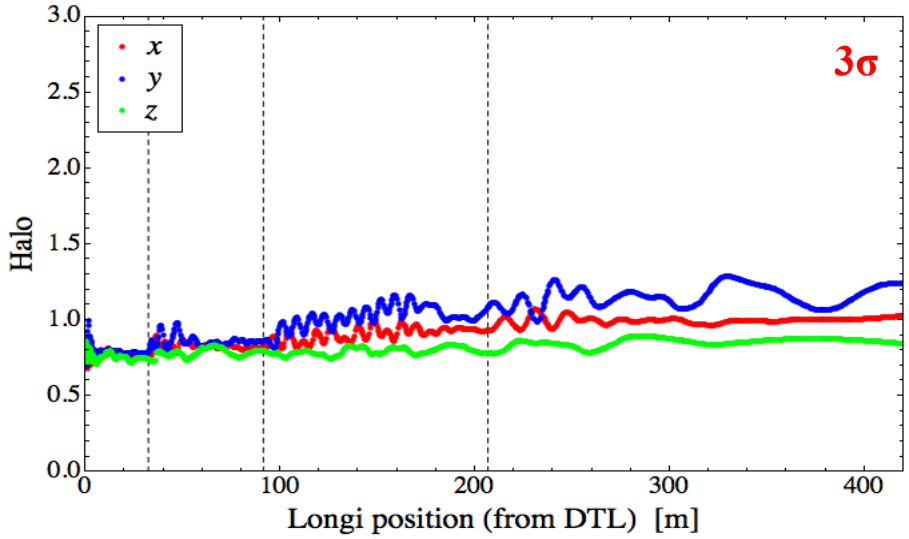


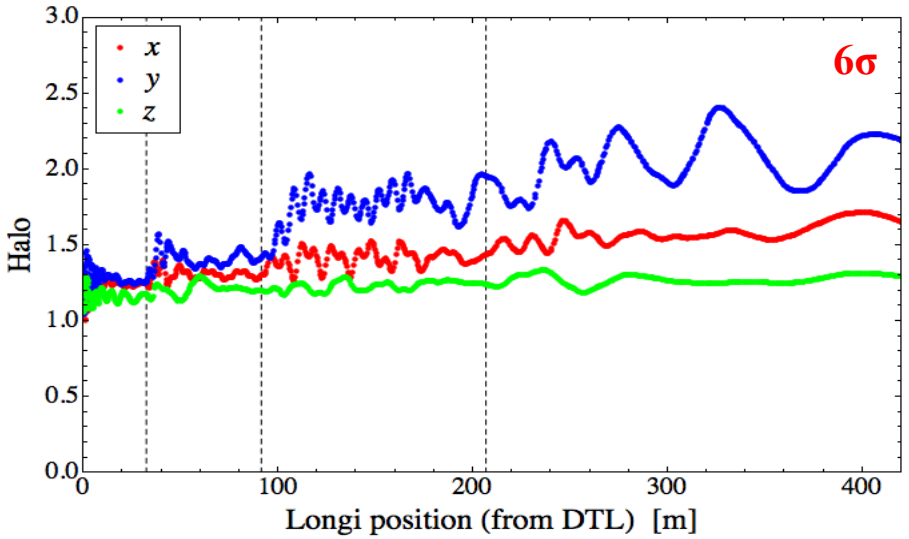
RMS emittance is not very sensitive to the input distribution.

Halo vs. initial distribution



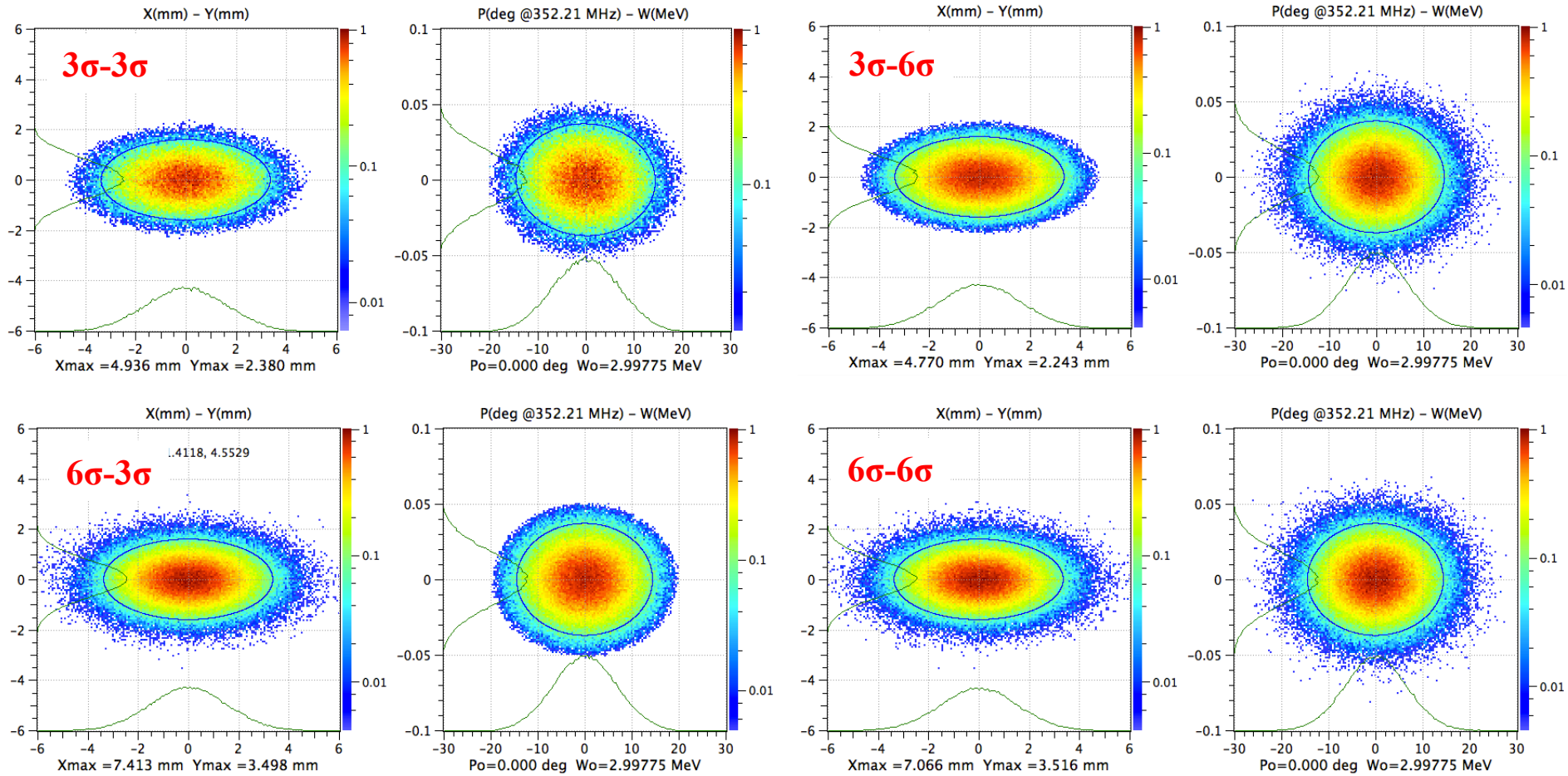






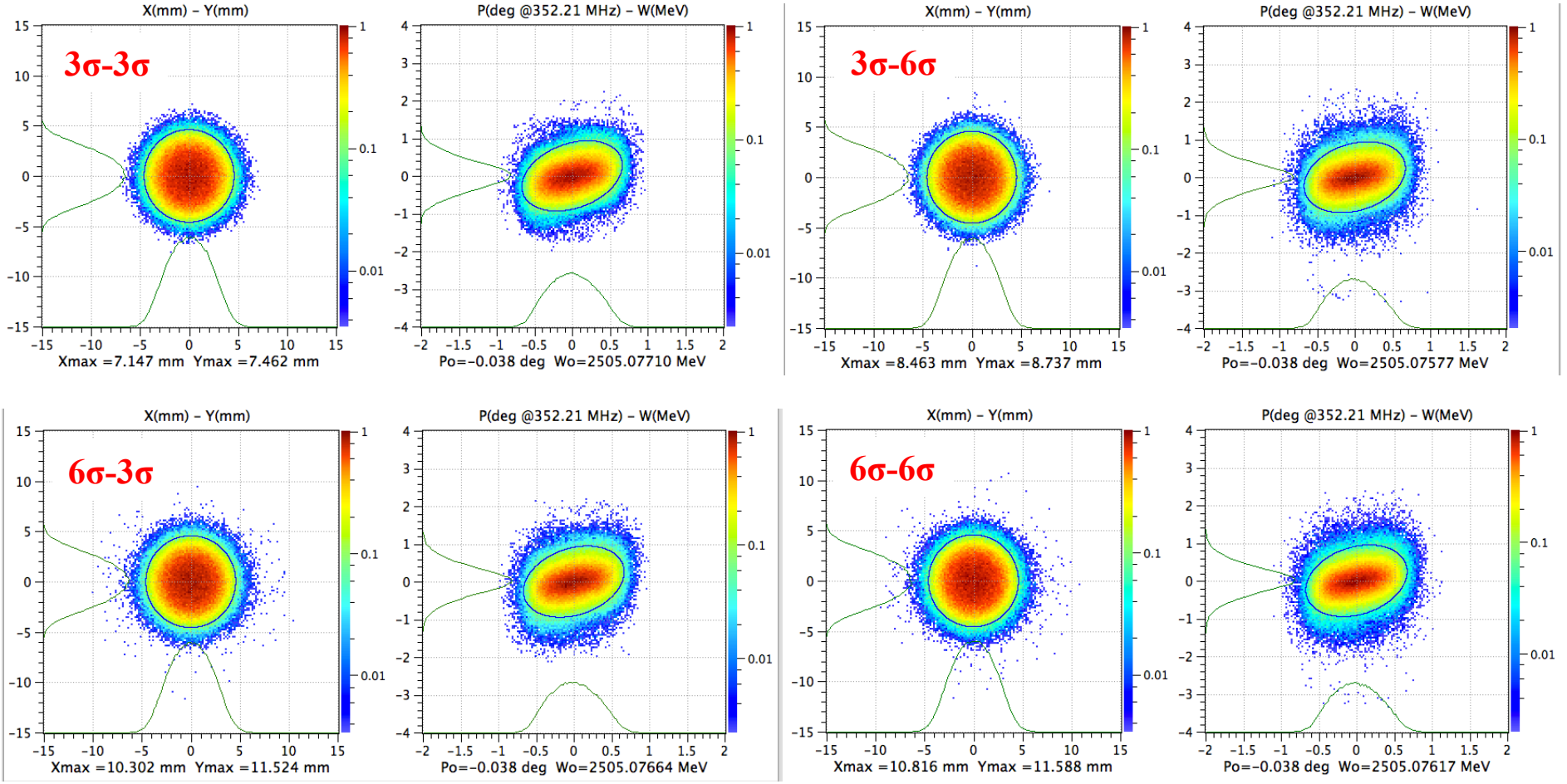
How do we define “good” and “bad” for the HEBT and linac?
For the linac, only the loss matters?

Correlation between transverse and longitudinal?



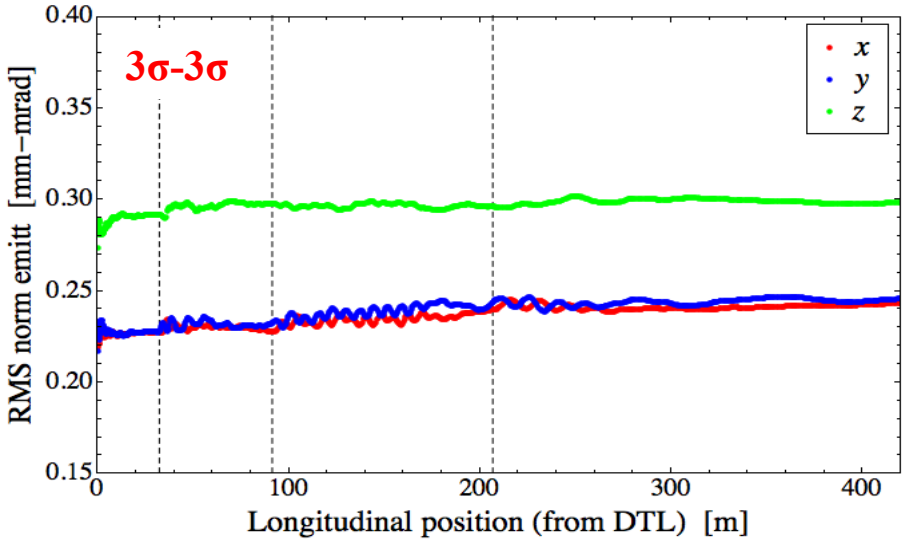
Particle distributions into the DTLs. Different cuts are applied to 6D Gaussian distributions.

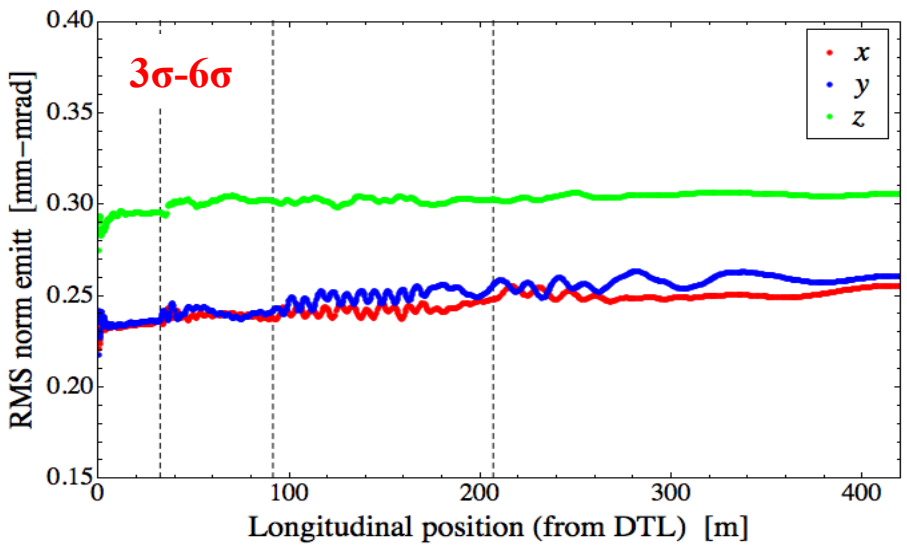
Correlation between transverse and longitudinal?

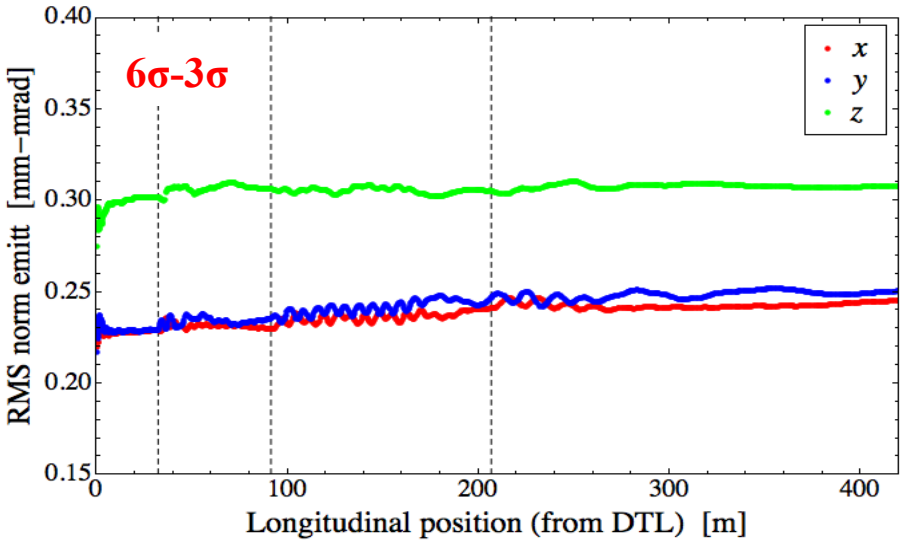


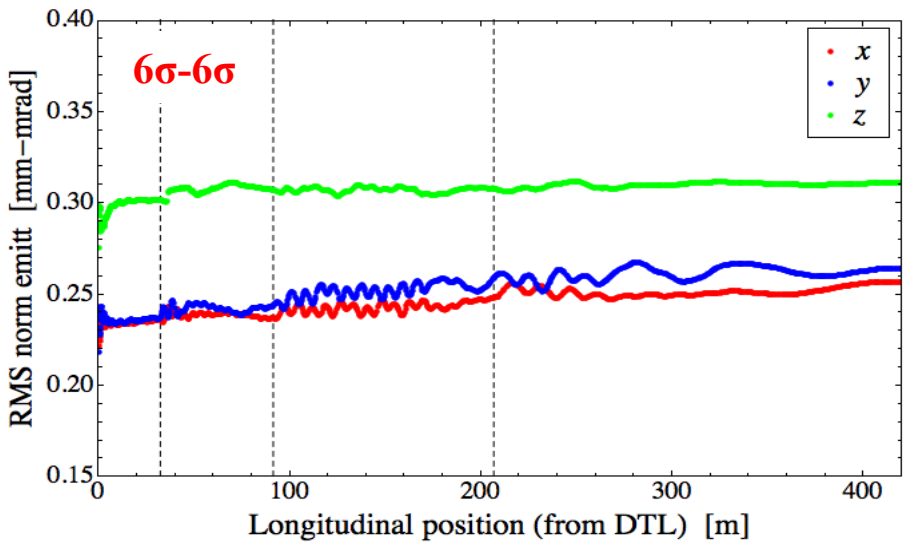
Distributions into the HEBT (new lattice). Transverse and longitudinal planes seem well decoupled. Good for the MEBT collimators.

Emittances for different cuts



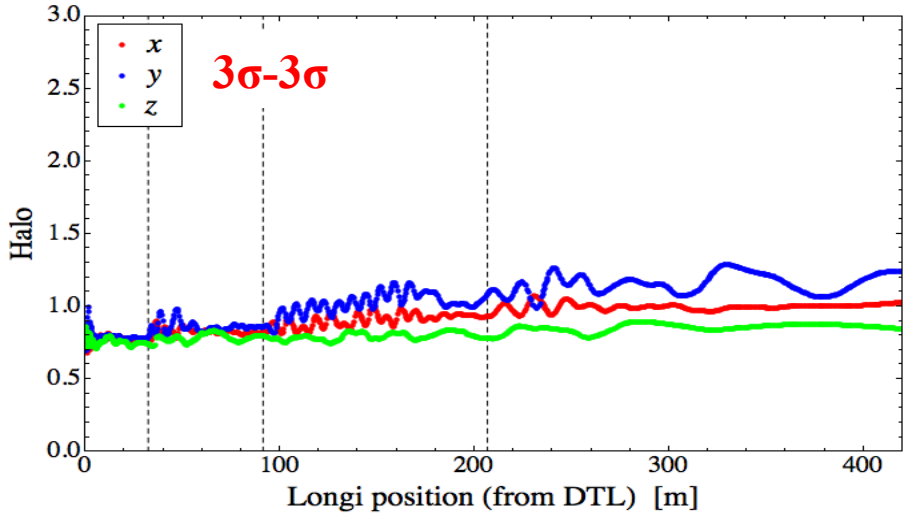


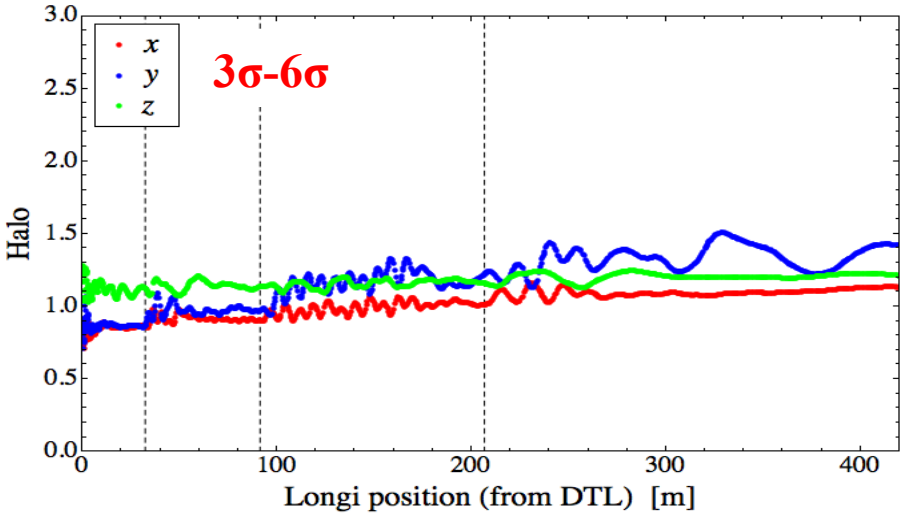


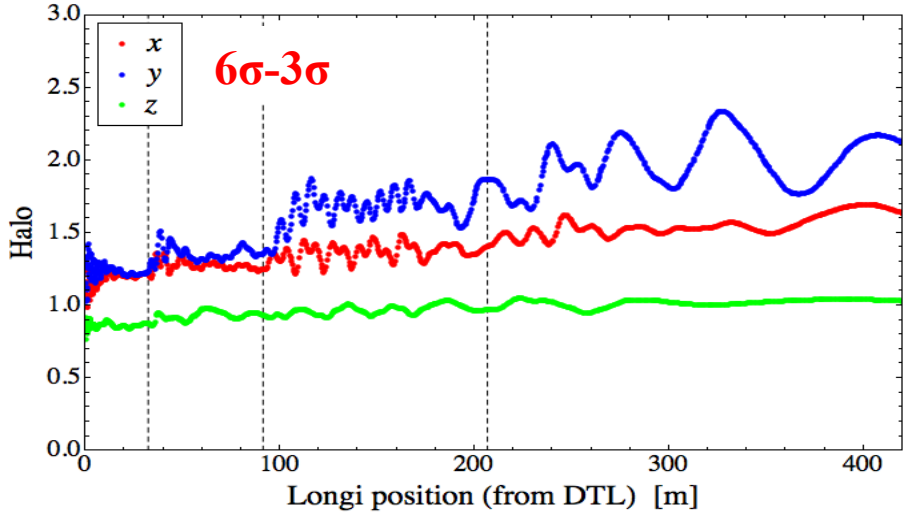


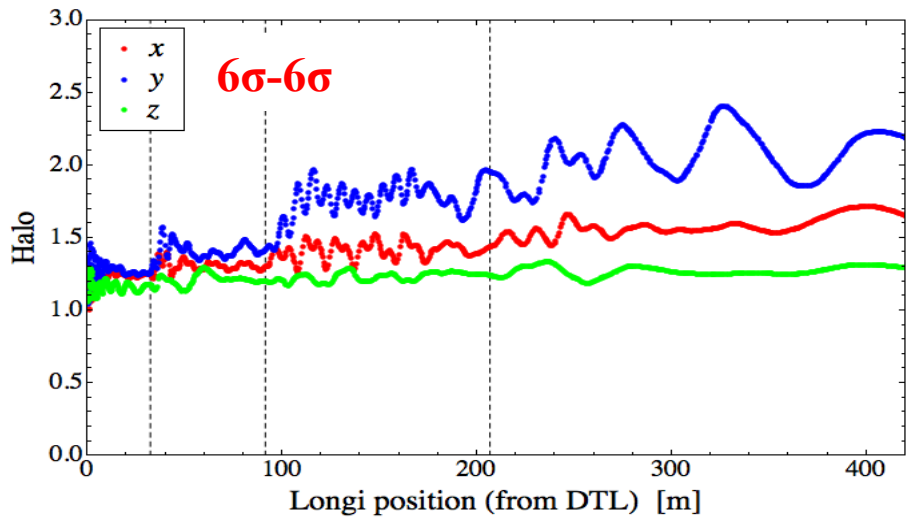
The correlation is almost invisible in emittances.

Halos for different cuts



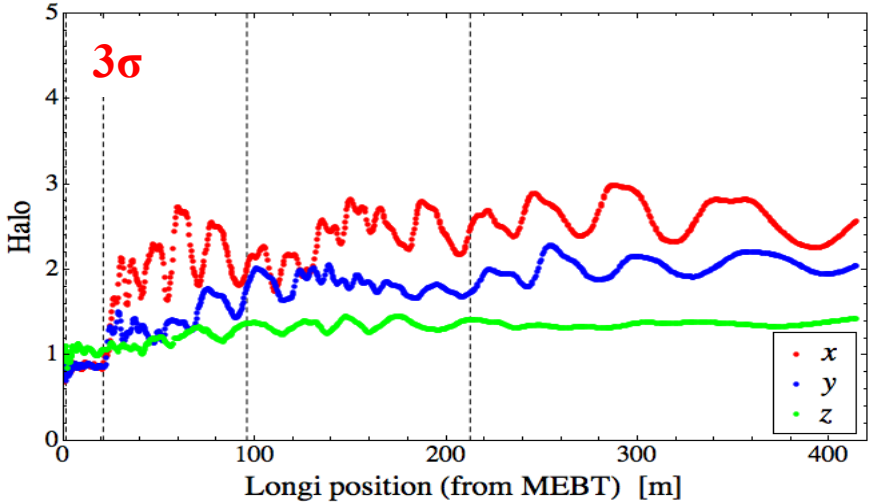


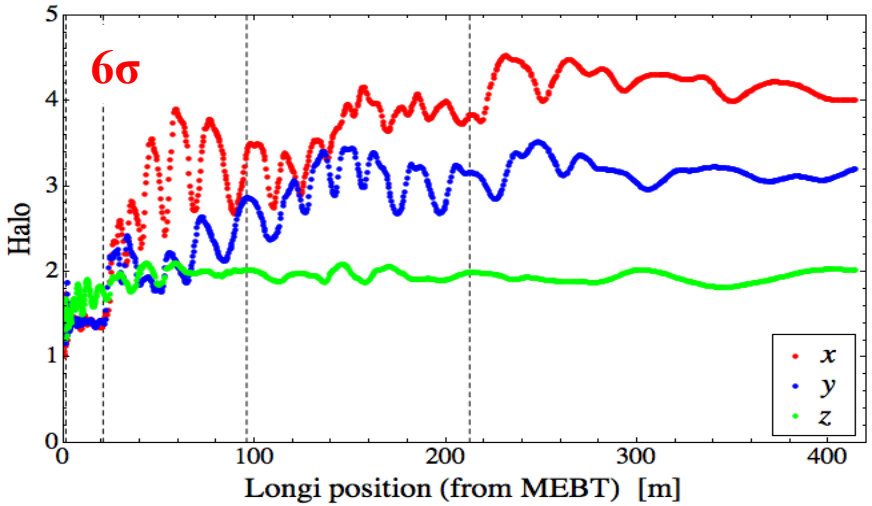


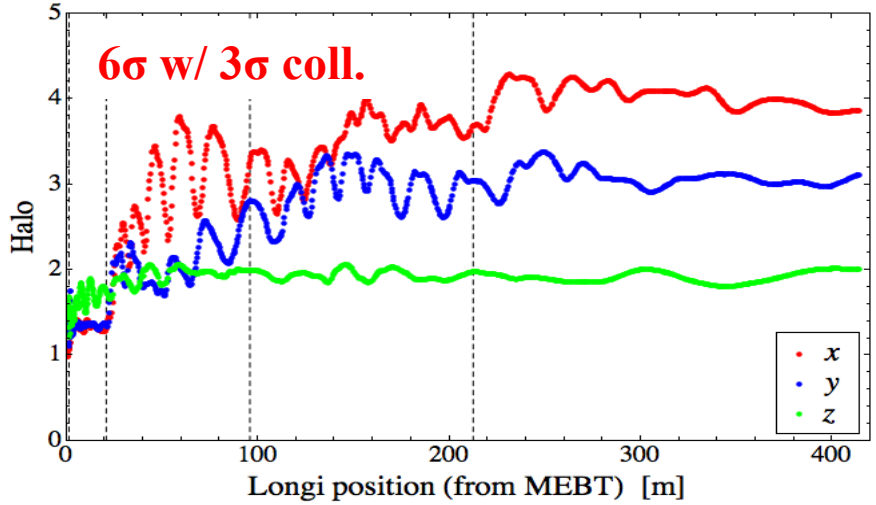


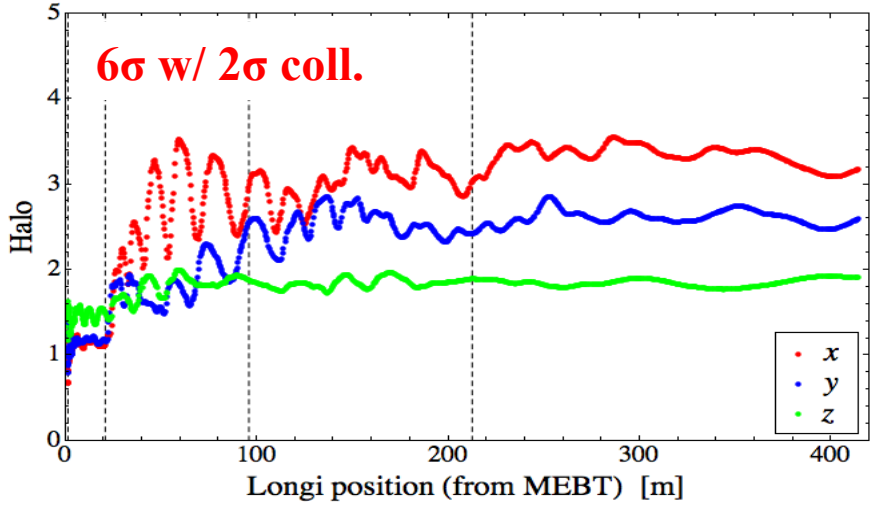
Halo throughout the linac obviously depends on the cut (initial halo) but the transverse and longitudinal planes are fairly well decoupled.

Collimators in the short MEBT of the old lattice



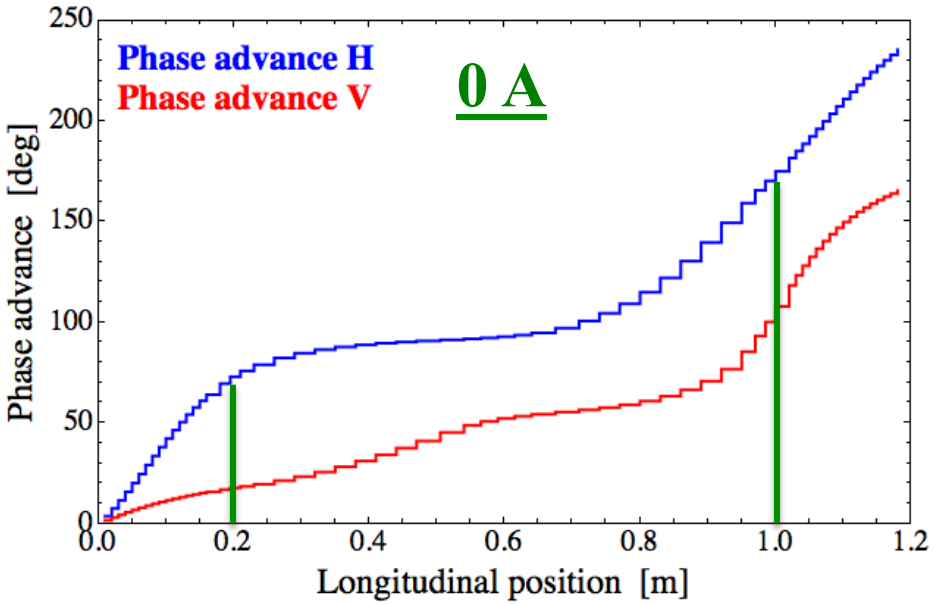


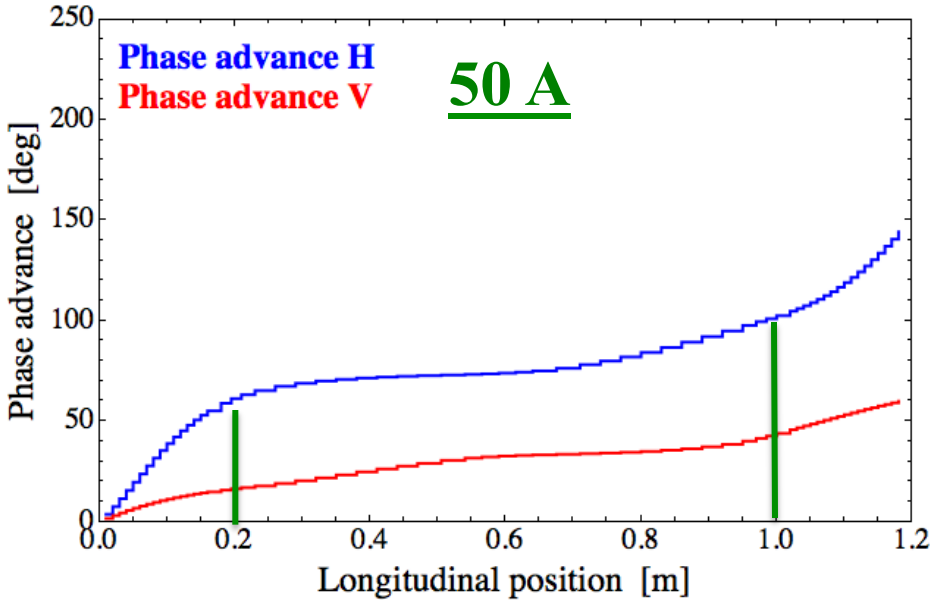




Collimators made almost no difference in this particular case, unless we largely scrape the core of the beam.

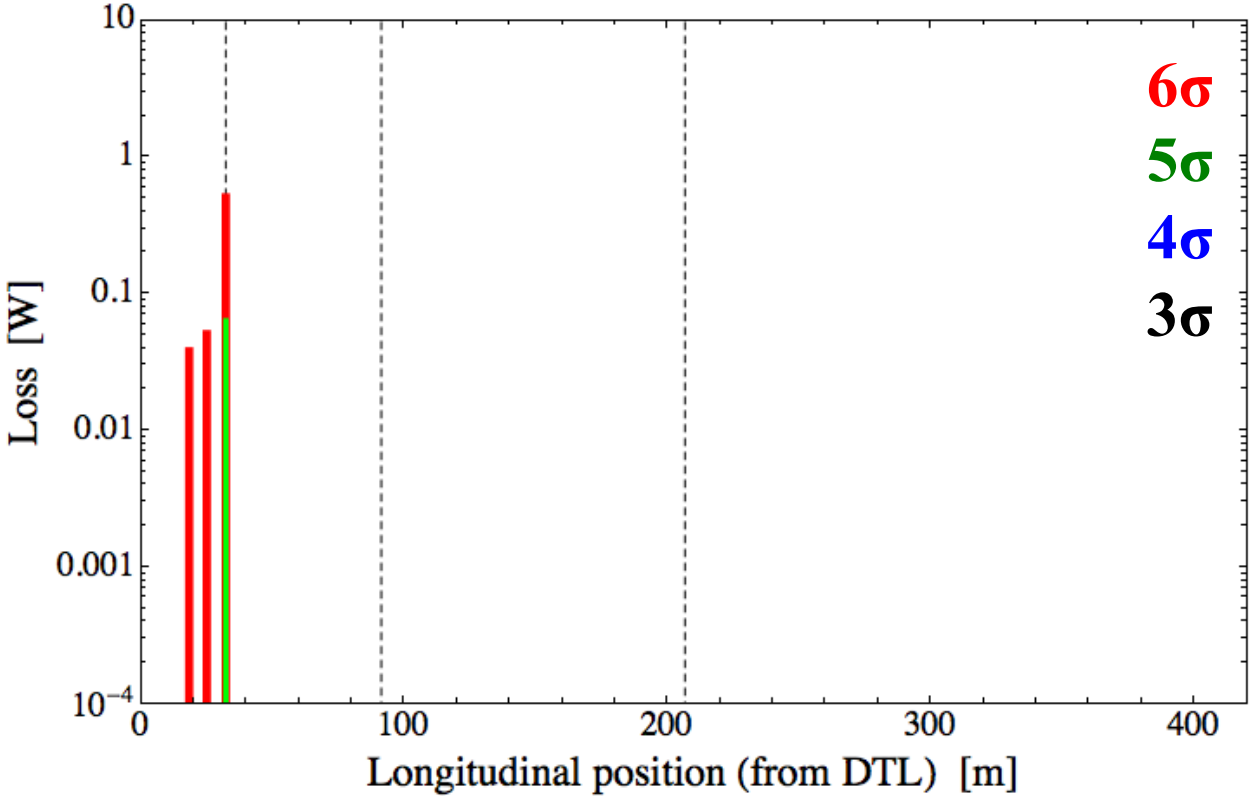
Collimators in the short MEBT





- Two square apertures are placed at the ends of the first (~0.2 m) and last (~1.0 m) quads.
- The distance between two collimators are too far?
- The collimators too close to the beam and the halo particles no longer follow the zero-current phase advance?
- Alpha-function?
- ….

We should study the loss studies as well…



- Tried with 2.5M particles for the new lattice but this is too small. (If we have 50M macro particles, loss of a single 2.5 GeV macro particle corresponds to ~0.1W.)
- Correlation with halo? (The MEBT collimators help?)

Summary

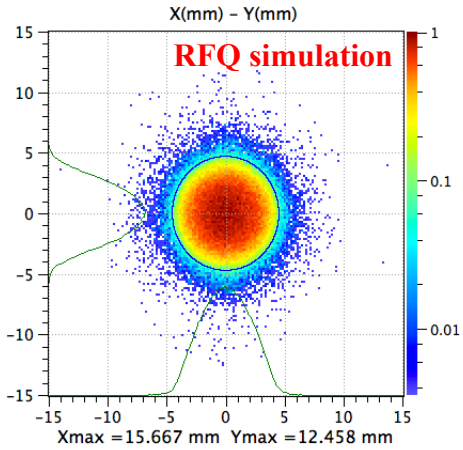
- The halo/loss study on focus of the MEBT collimators has been initiated. The study is closely connected to the two design modifications: 1) the increment of the transition energy from the DTLs to the spokes and 2) the longer MEBT. It is ideal if a more realistic particle distribution from the ion source is available.
- The new lattice has a smoother transition from the DTLs to the spokes and provides a better control of the emittance and halo throughout the linac.
- It is tested that the halo of the distribution going into the HEBT depends on that going into the DLTs. The simulation also indicated that the transverse and longitudinal halos in our linac is fairly well decoupled.

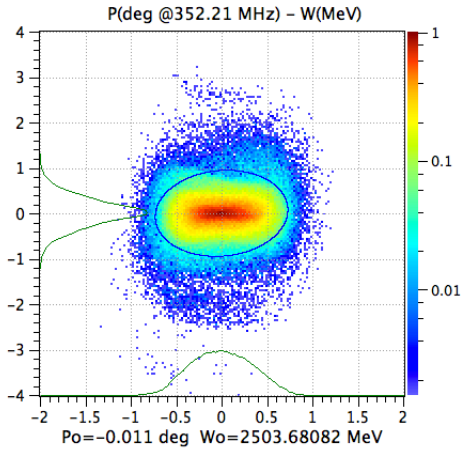
Summary (2)

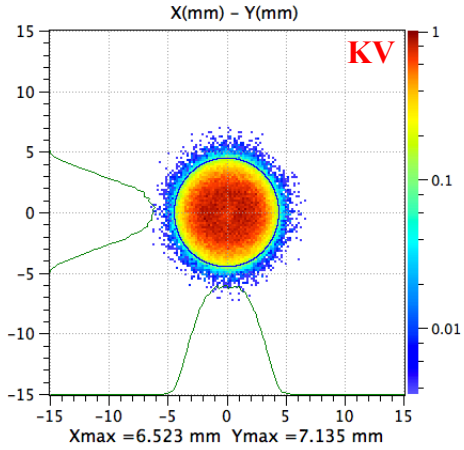
- The above simple tests have not excluded the MEBT collimations but no optimal solution has been found either.
- The primary purpose of the MEBT collimators is to reduce losses in the linac. We will conduct simulations of much larger number of particles to study the loss in general, the influence of the MEBT collimators on the loss, as well as the correlation between the loss and halo.
- Influences of the mismatch and lattice errors (steering, focusing, phase, voltage, …) will be studied.
- Does the HEBT take whatever comes out or require the emittance and halo within a specific range?

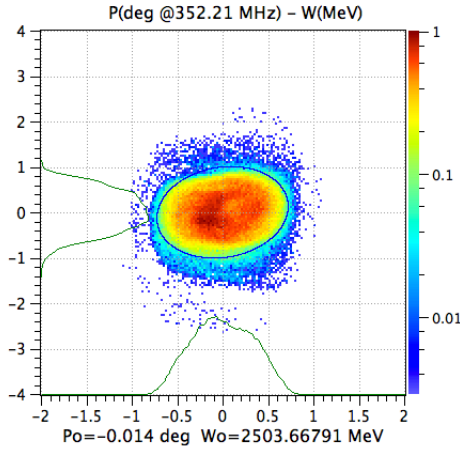
Does the input distribution affect the output?

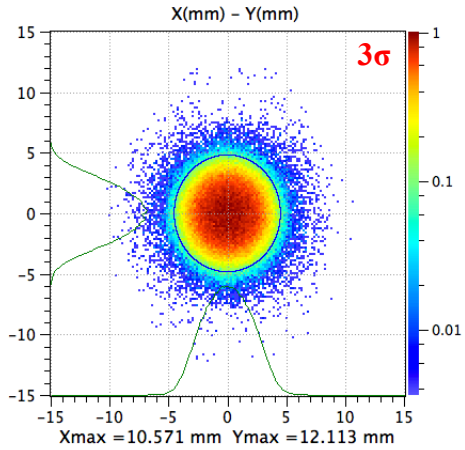
Distributions into HEBT from the old lattice

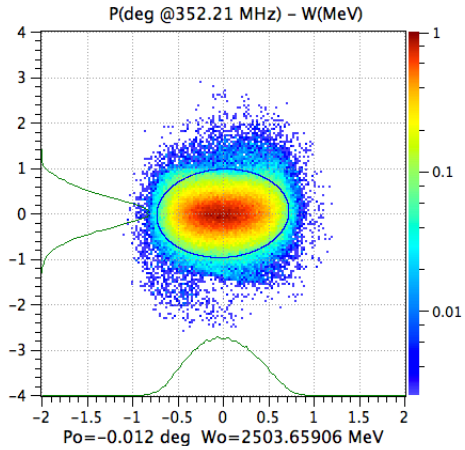


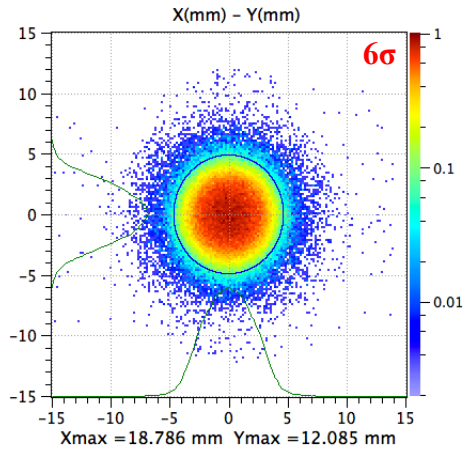


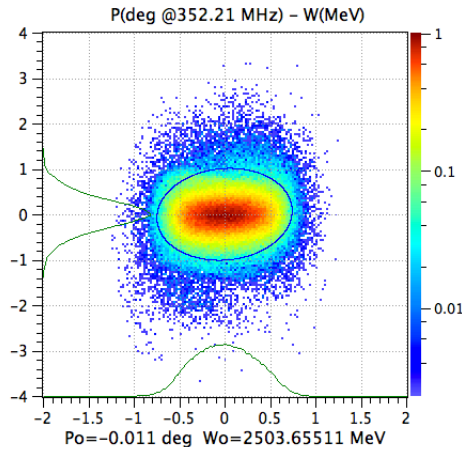






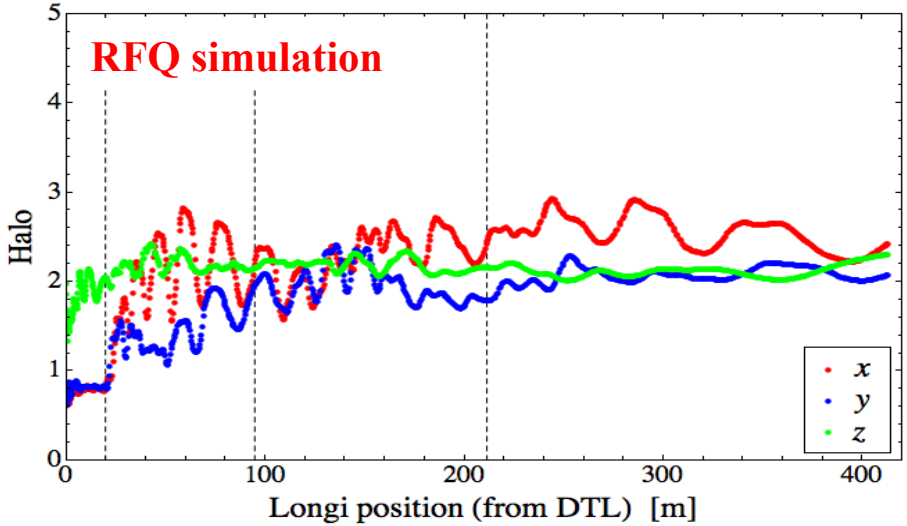


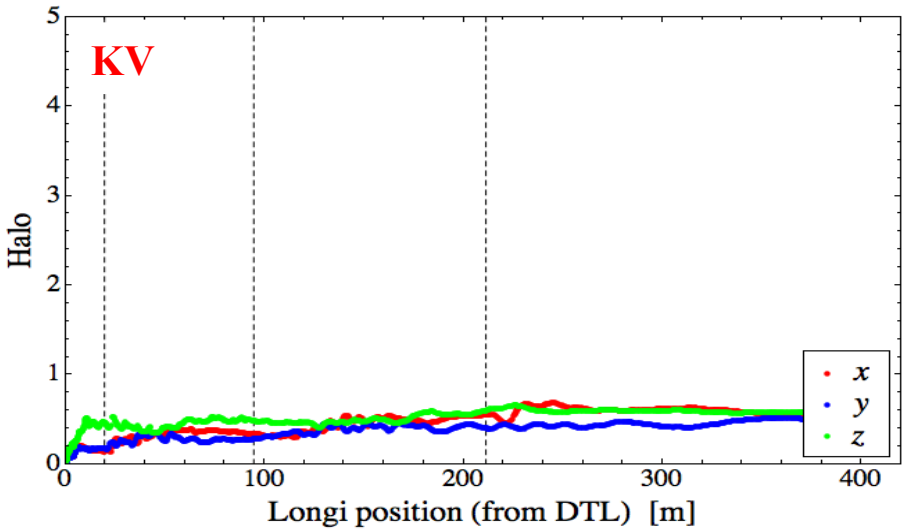


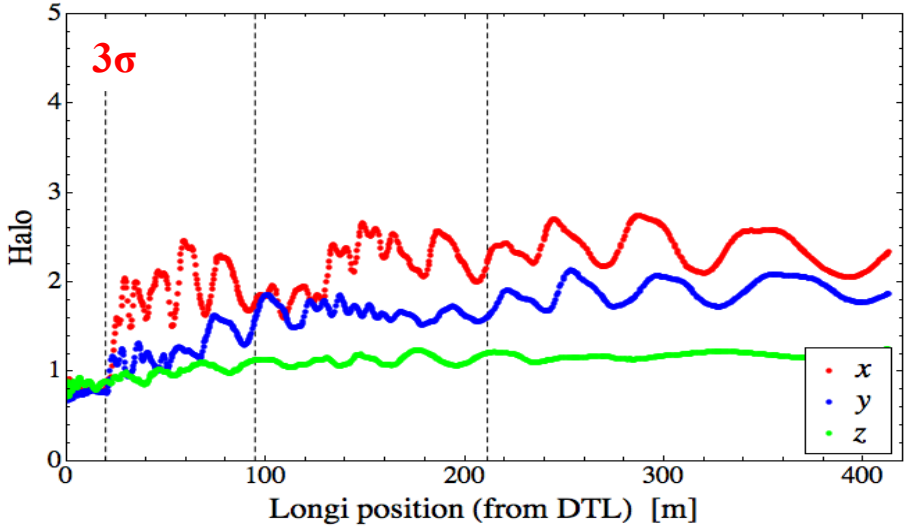


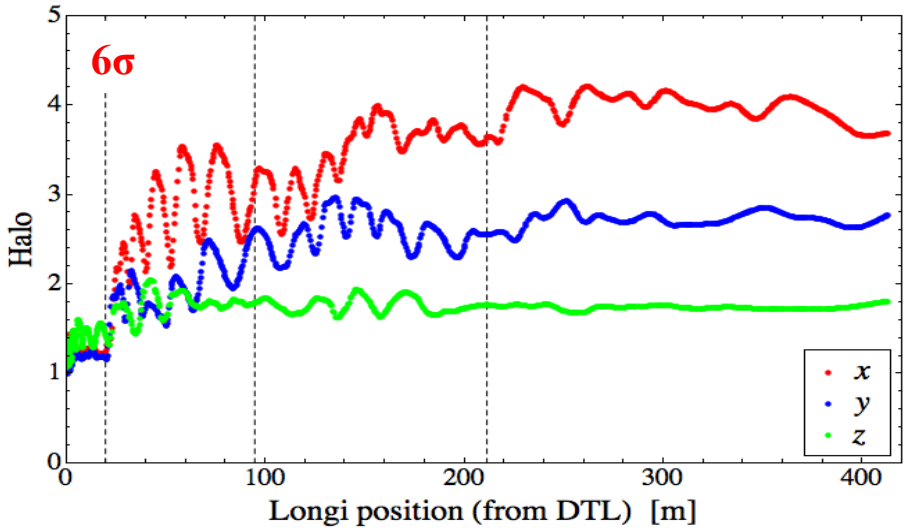
- Input distribution types are changed while emittances and optics parameters are kept the same.
- The input certainly affects the output in the old lattice.

Halo vs. initial distribution (old lattice)









Halo certainly depends on the initial distribution but how much the MEBT collimator can modify the distribution?