

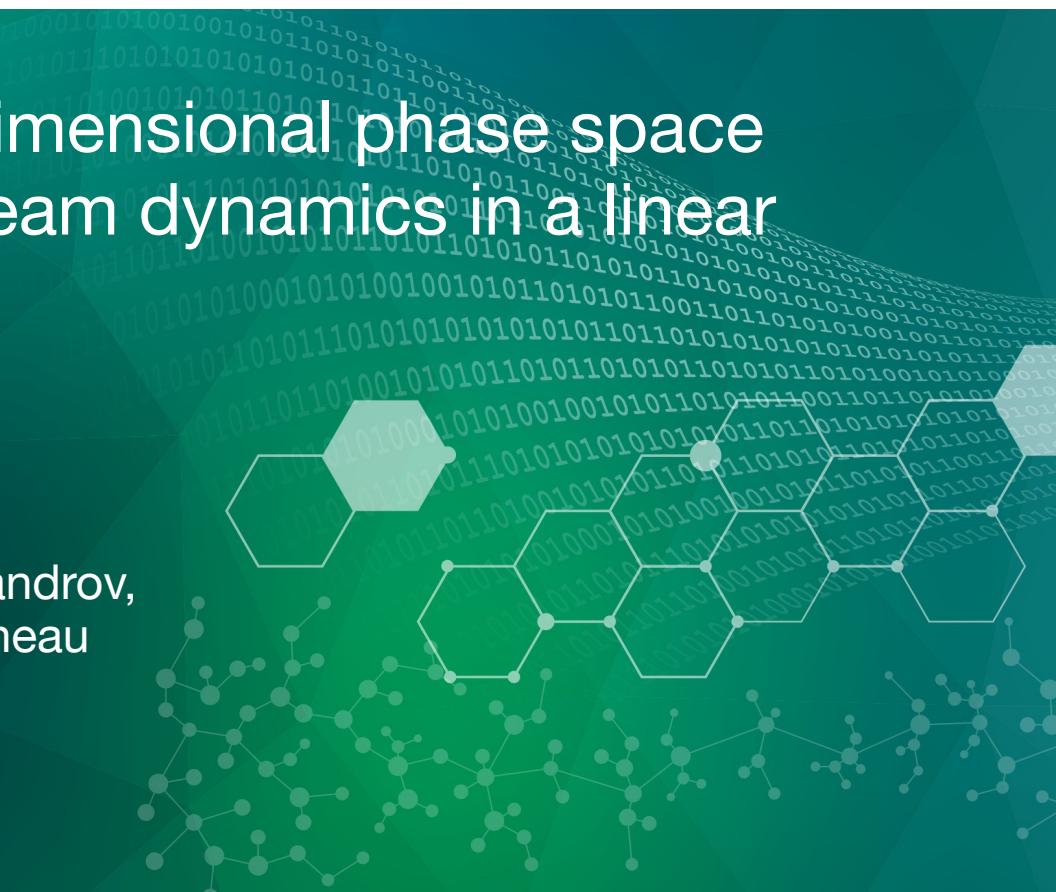
The impact of high-dimensional phase space correlations on the beam dynamics in a linear accelerator

A. Hoover, K. Ruisard, A. Aleksandrov,
A. Zhukov, A. Shishlo, S. Cousineau

HB Workshop, CERN

October 10, 2023

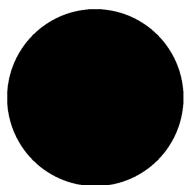
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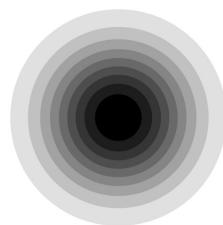
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LEDA: halo is sensitive to initial distribution

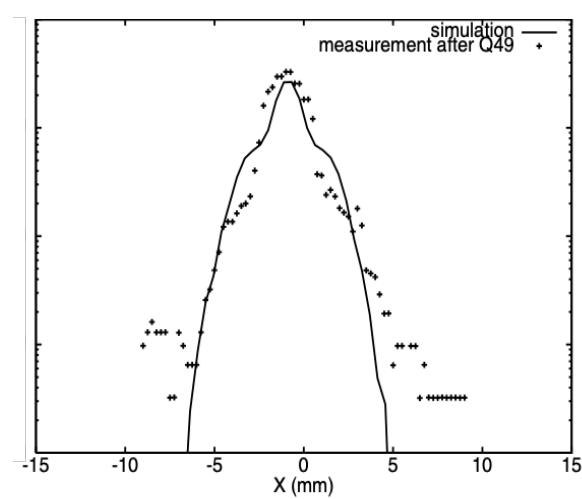
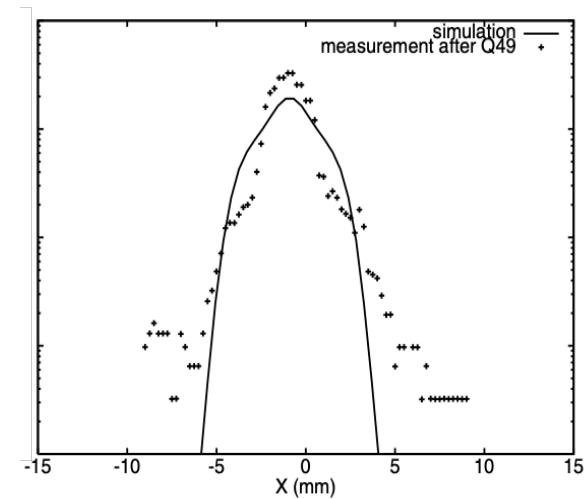
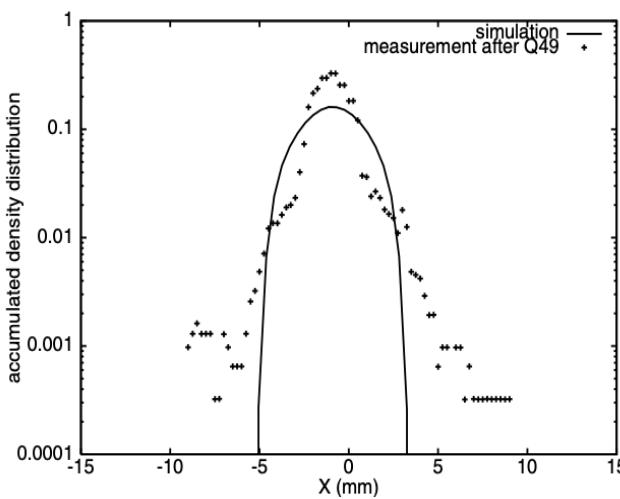
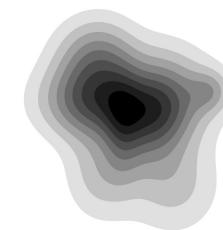
Waterbag



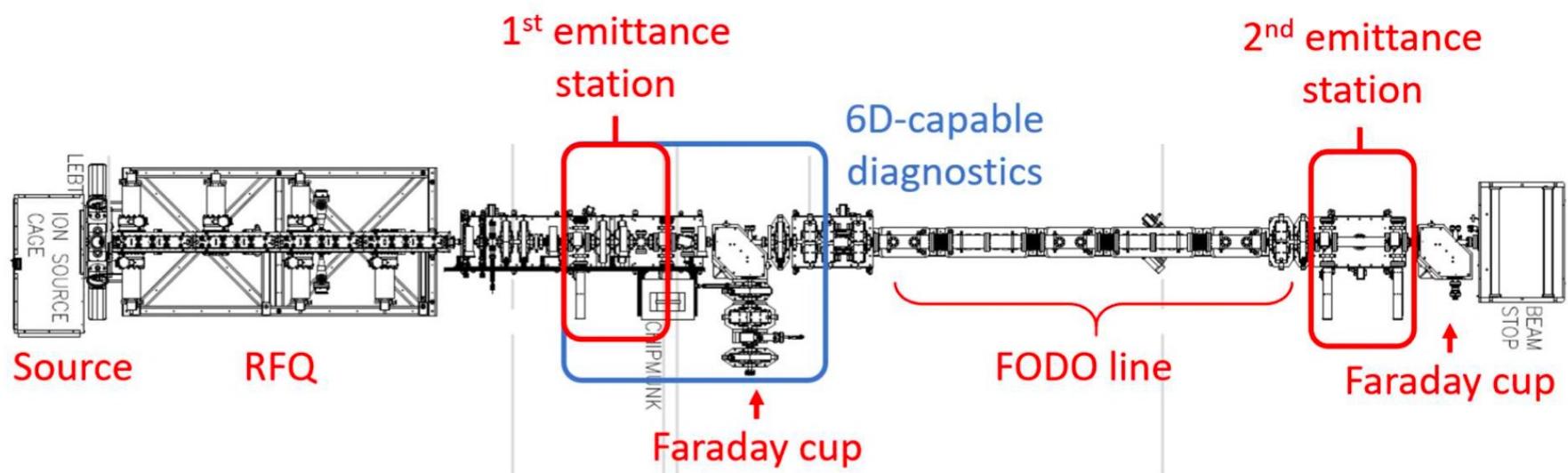
Gaussian



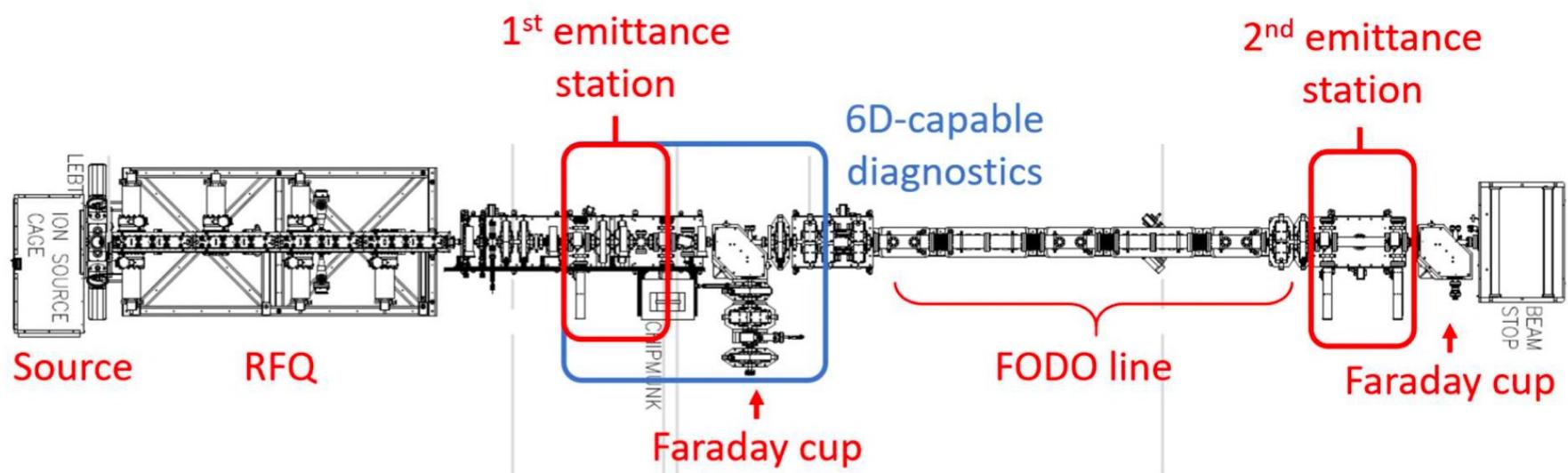
RFQ



The SNS-BTF aims to predict halo formation over a short distance



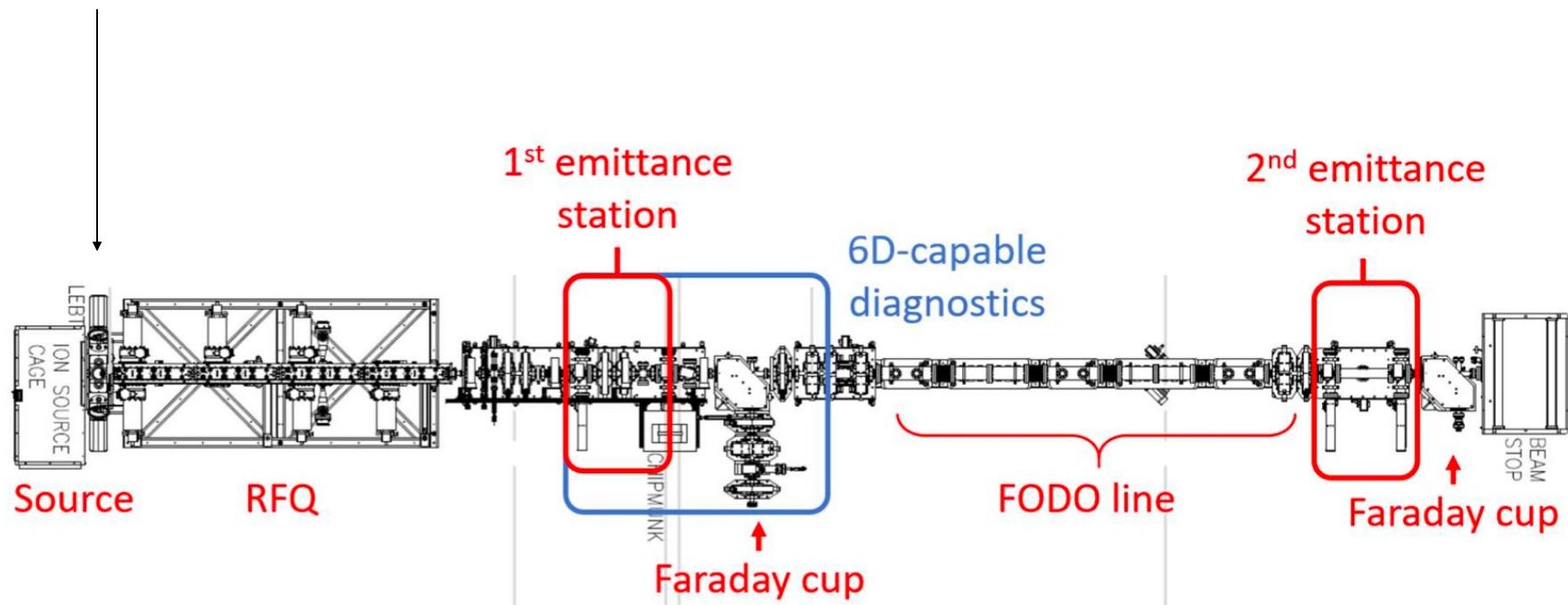
The SNS-BTF aims to predict halo formation over a short distance



$$f(x, p_x, y, p_y, z, p_z) = f(x, p_x)f(y, p_y)f(z, p_z) ?$$

PARMTEQ generates “model” bunch at first measurement station

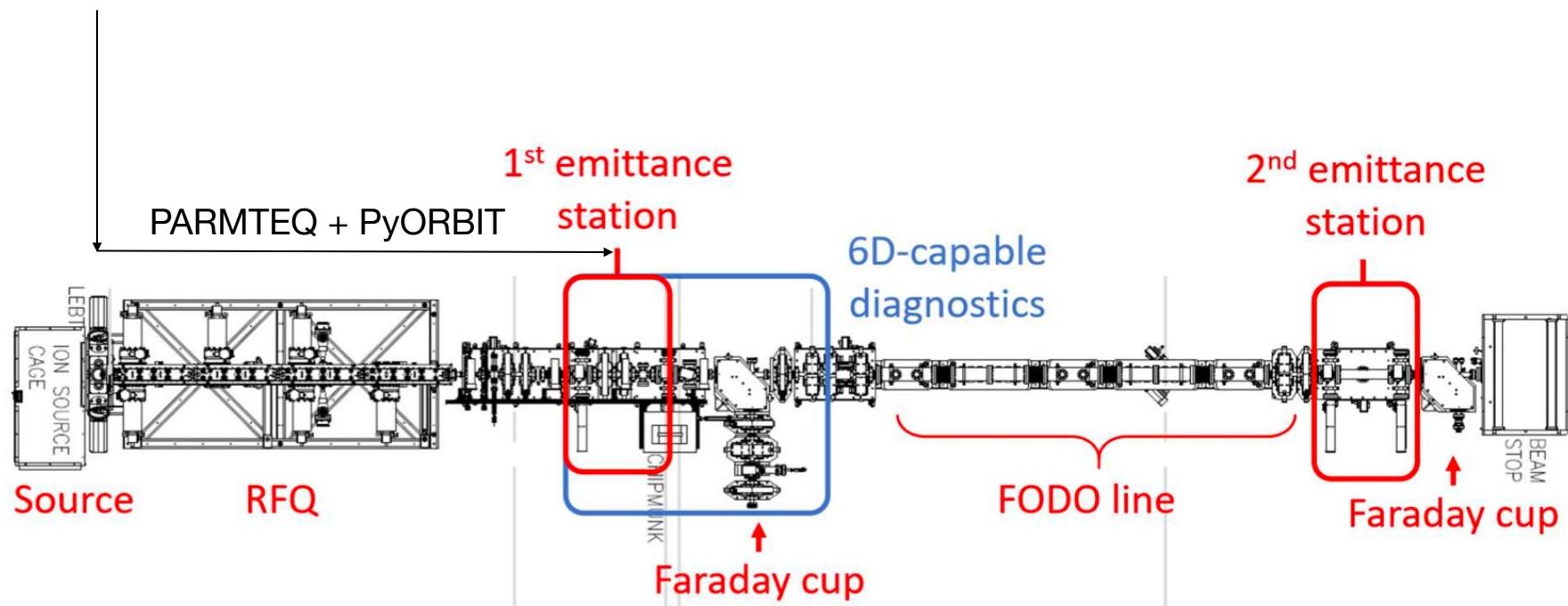
$\{f(x, p_x), f(y, p_y)\}$ from Ion Source Test Stand



$$f(x, p_x, y, p_y, z, p_z) = f(x, p_x)f(y, p_y)f(z, p_z) ?$$

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$$f(x, p_x, y, p_y, z, p_z) = f(x, p_x)f(y, p_y)f(z, p_z) ?$$

Main points

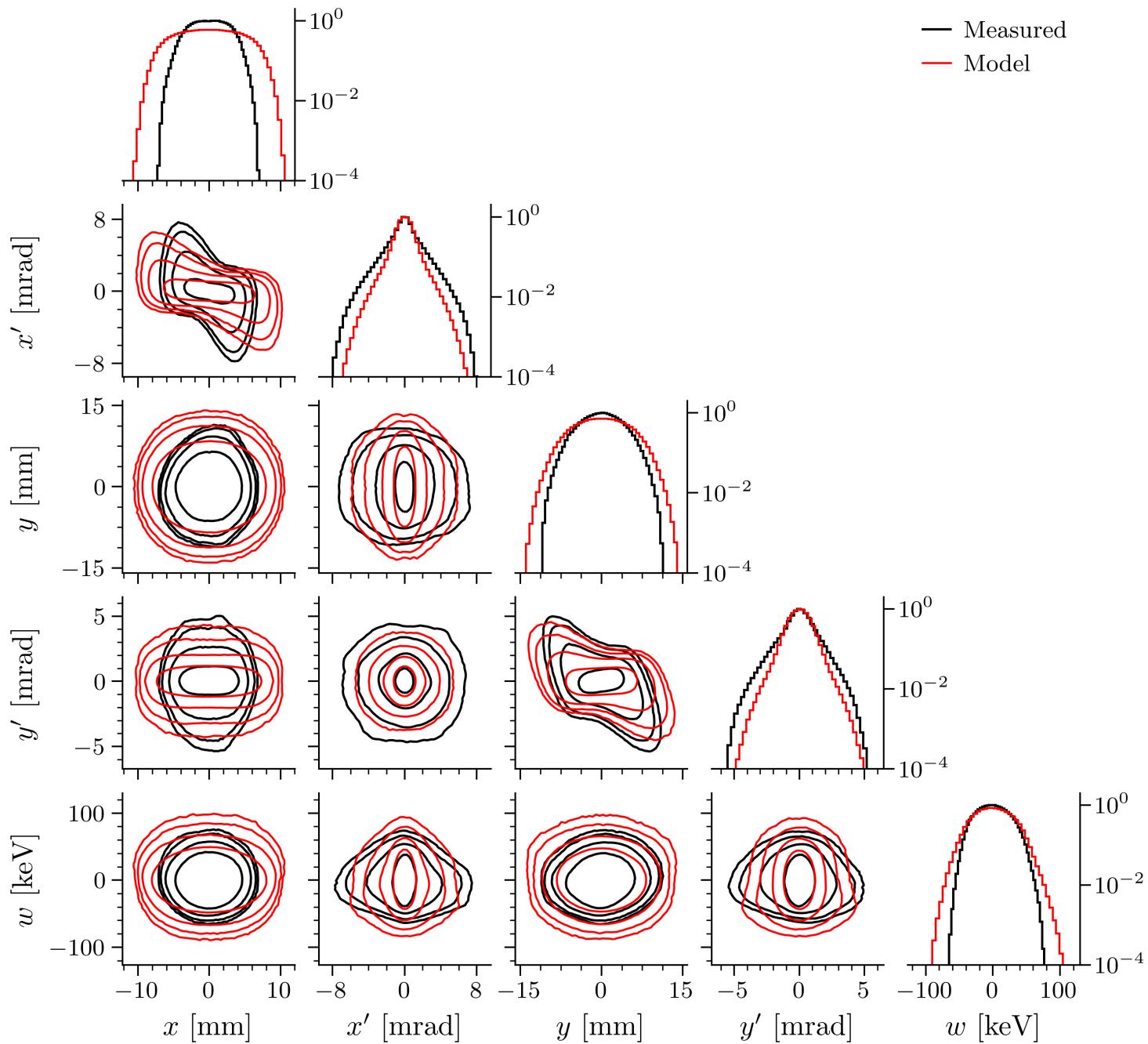
- RFQ model reproduces measured 6D phase space structure.

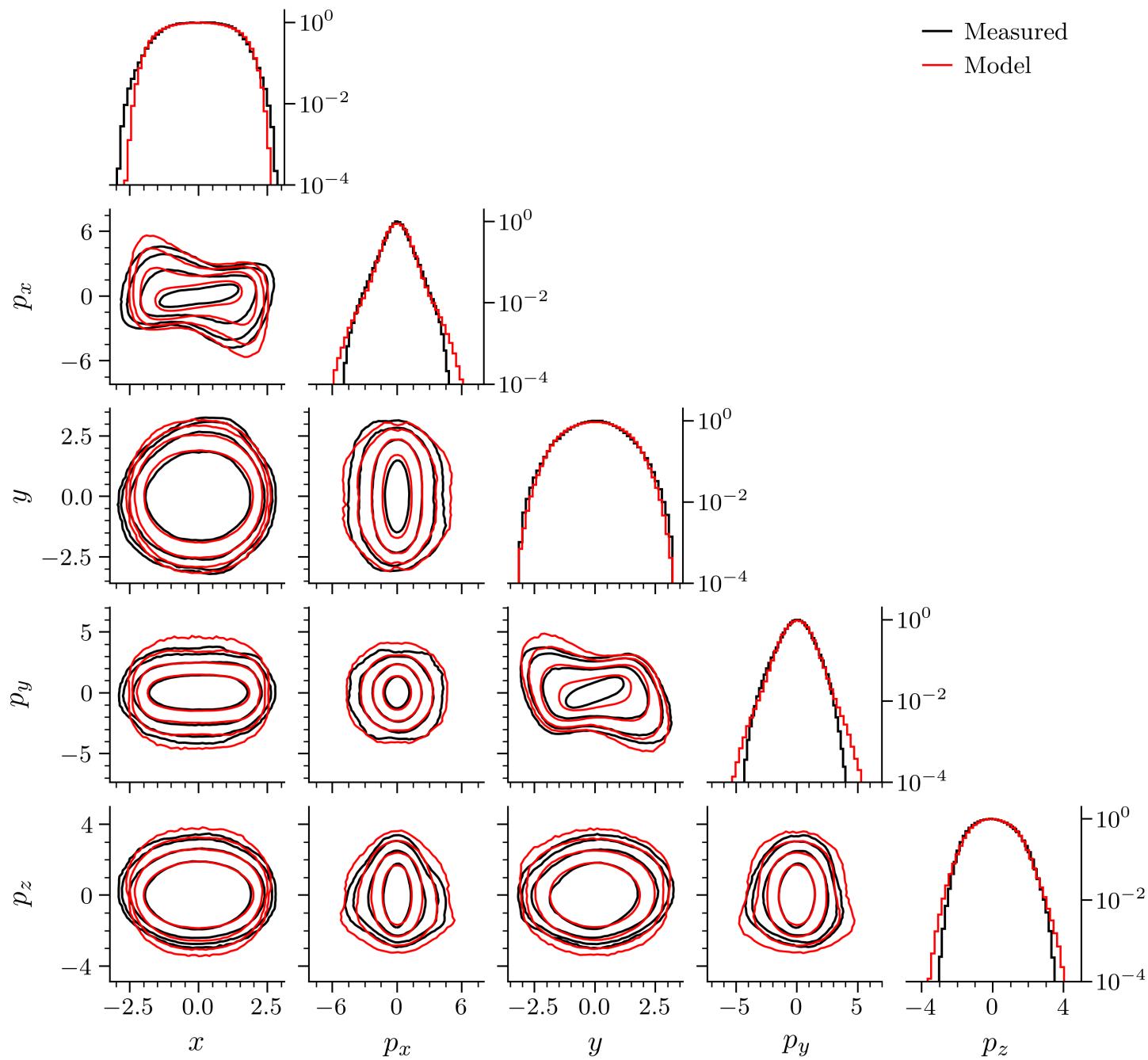
Main points

- RFQ model reproduces measured 6D phase space structure.
- Artificial decorrelation should have a small affect on the beam dynamics.

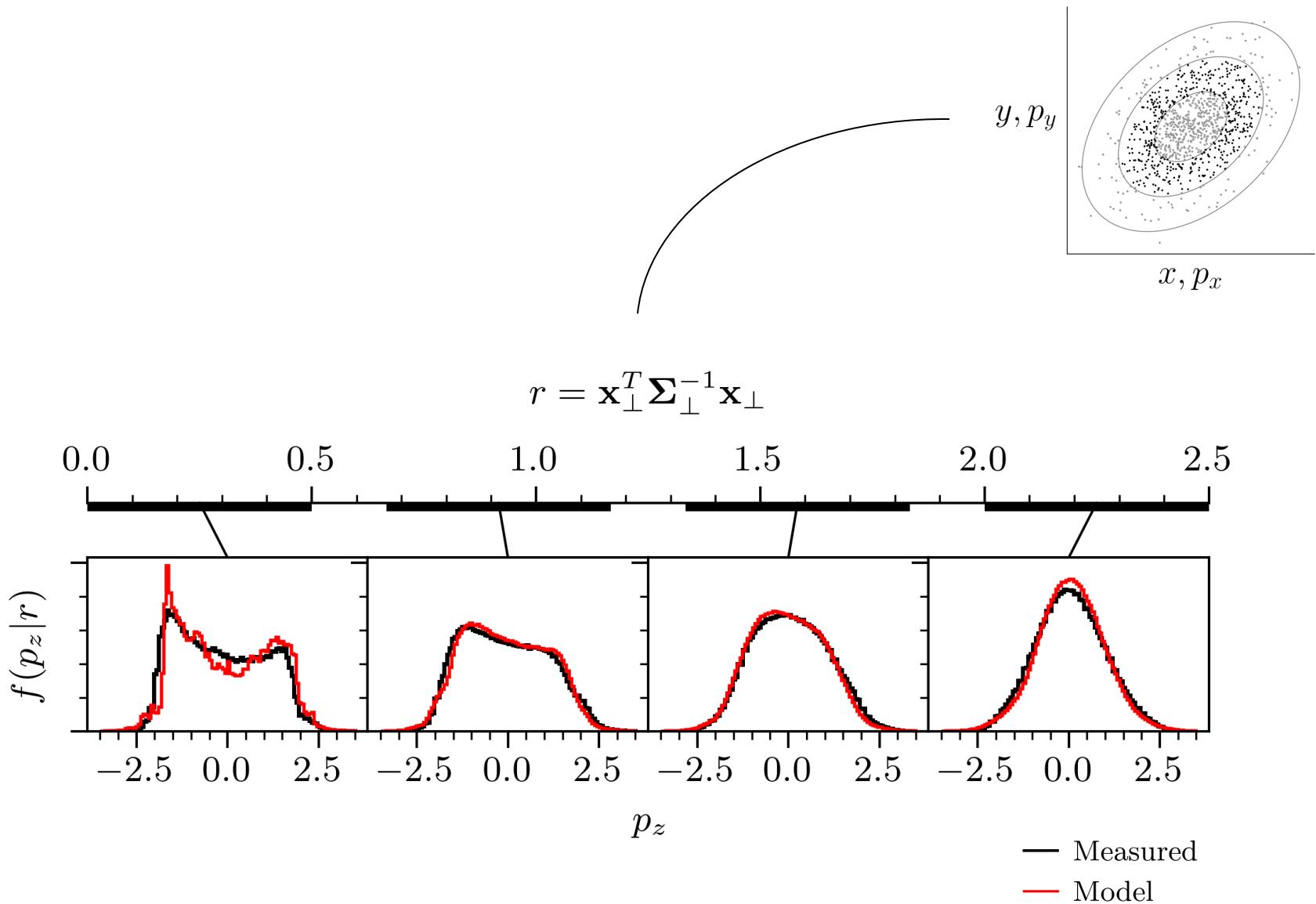
Main points

- **RFQ model reproduces measured 6D phase space structure.**
- Artificial decorrelation should have a small affect on the beam dynamics.

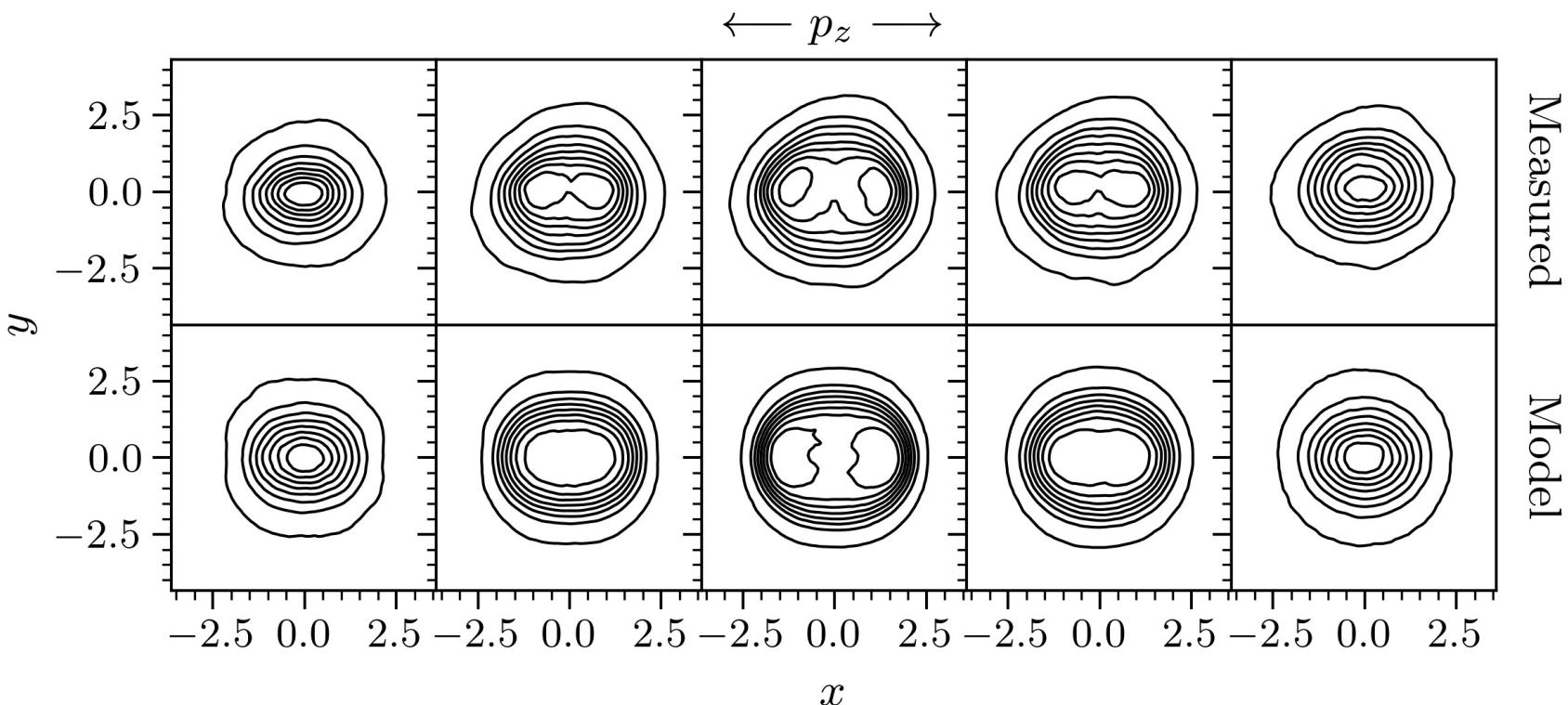




Longitudinal hollowing – probably occurs in RFQ



Transverse hollowing – probably occurs in MEBT

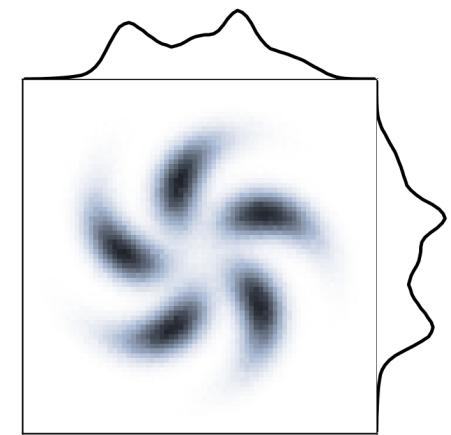
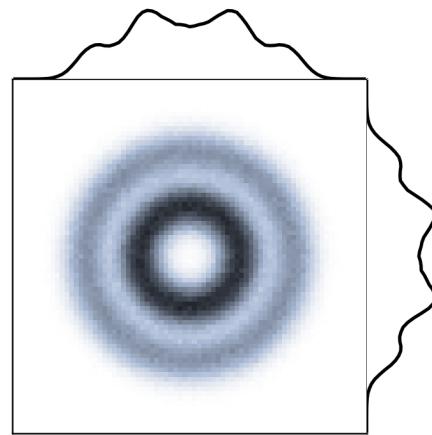
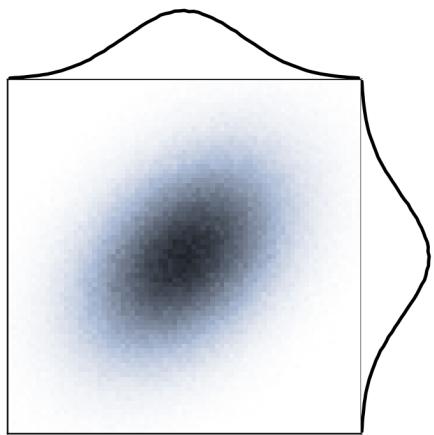


Main points

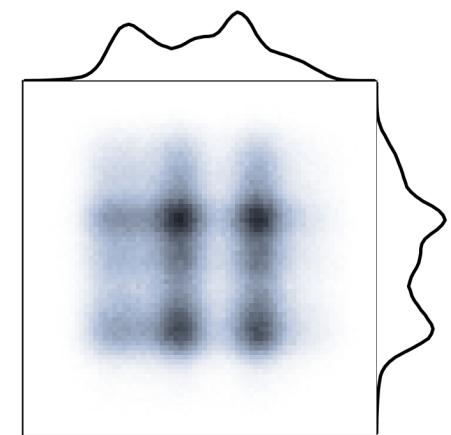
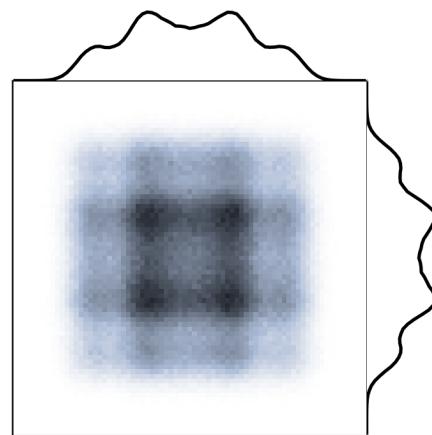
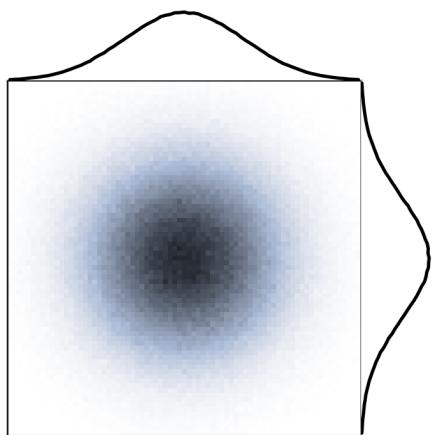
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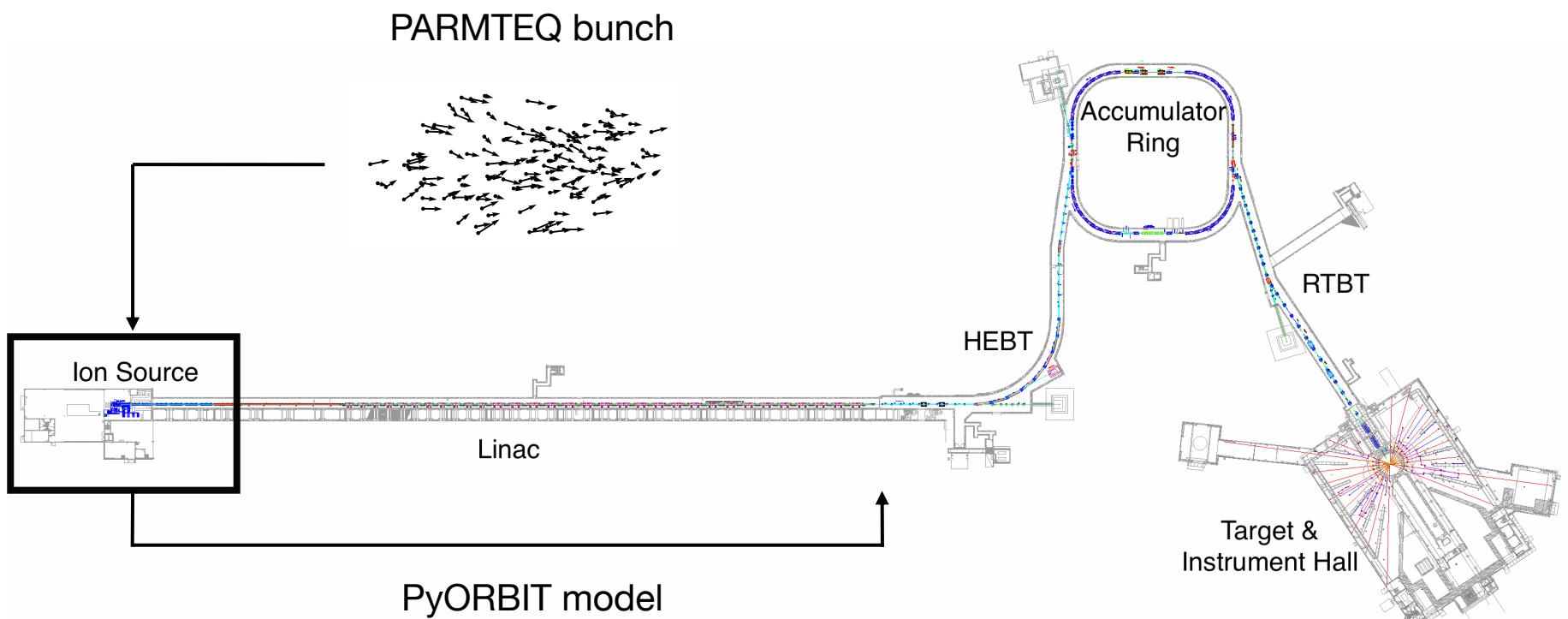
Decorrelation removes both linear and nonlinear relationships

$f(x, y)$



$f(x)f(y)$





Previous studies found intensity-dependent discrepancy between correlated and decorrelated bunches

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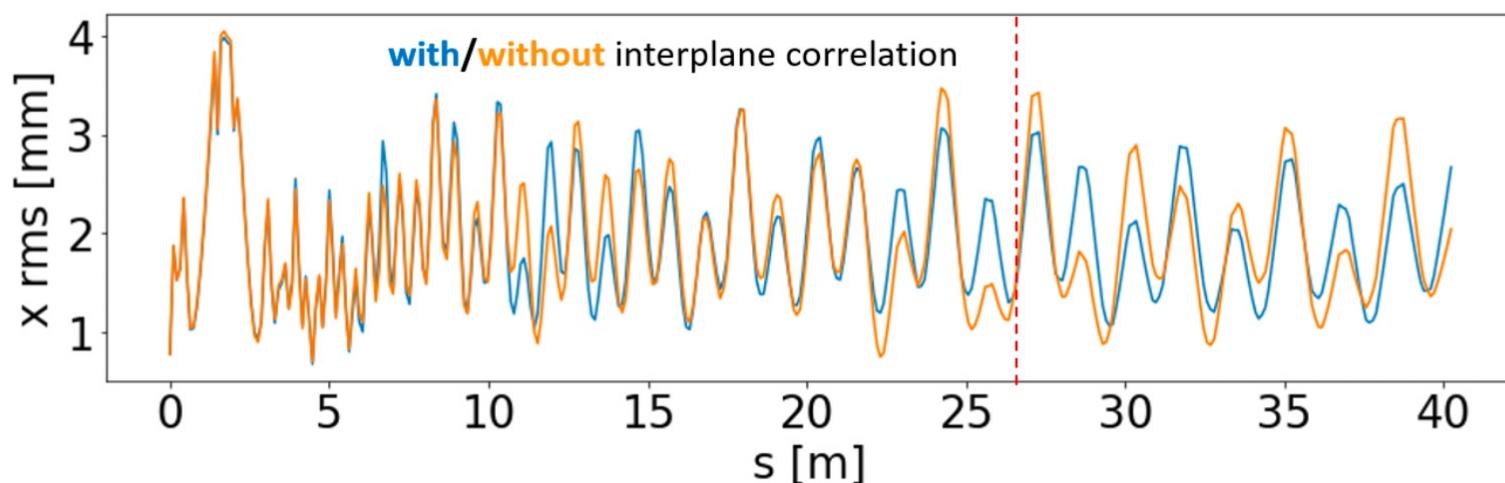


Figure 2: Comparison of horizontal beam size through PyORBIT simulation of SNS MEBT and DTL.

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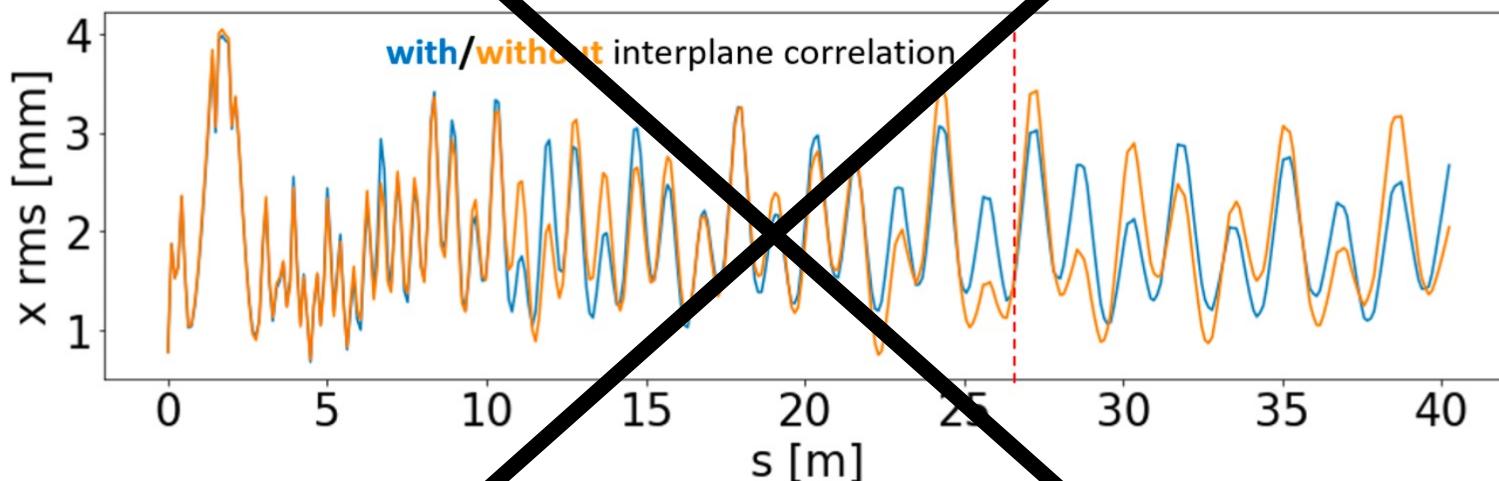
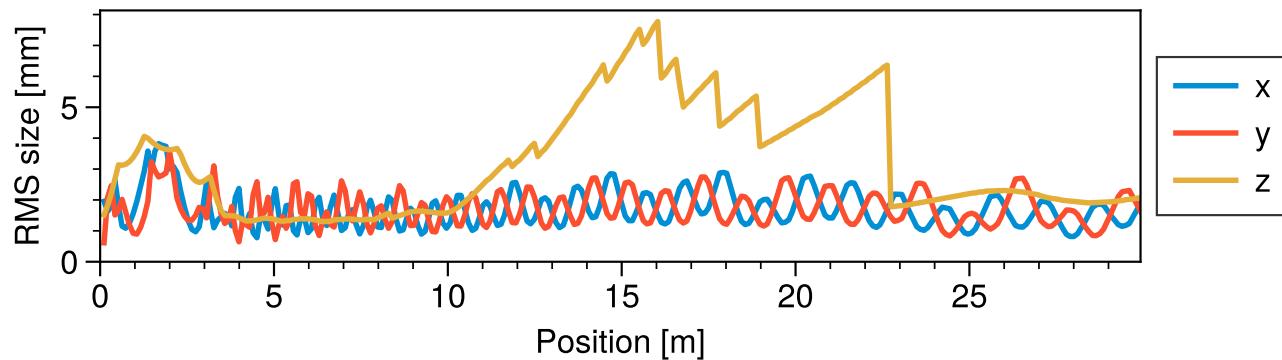
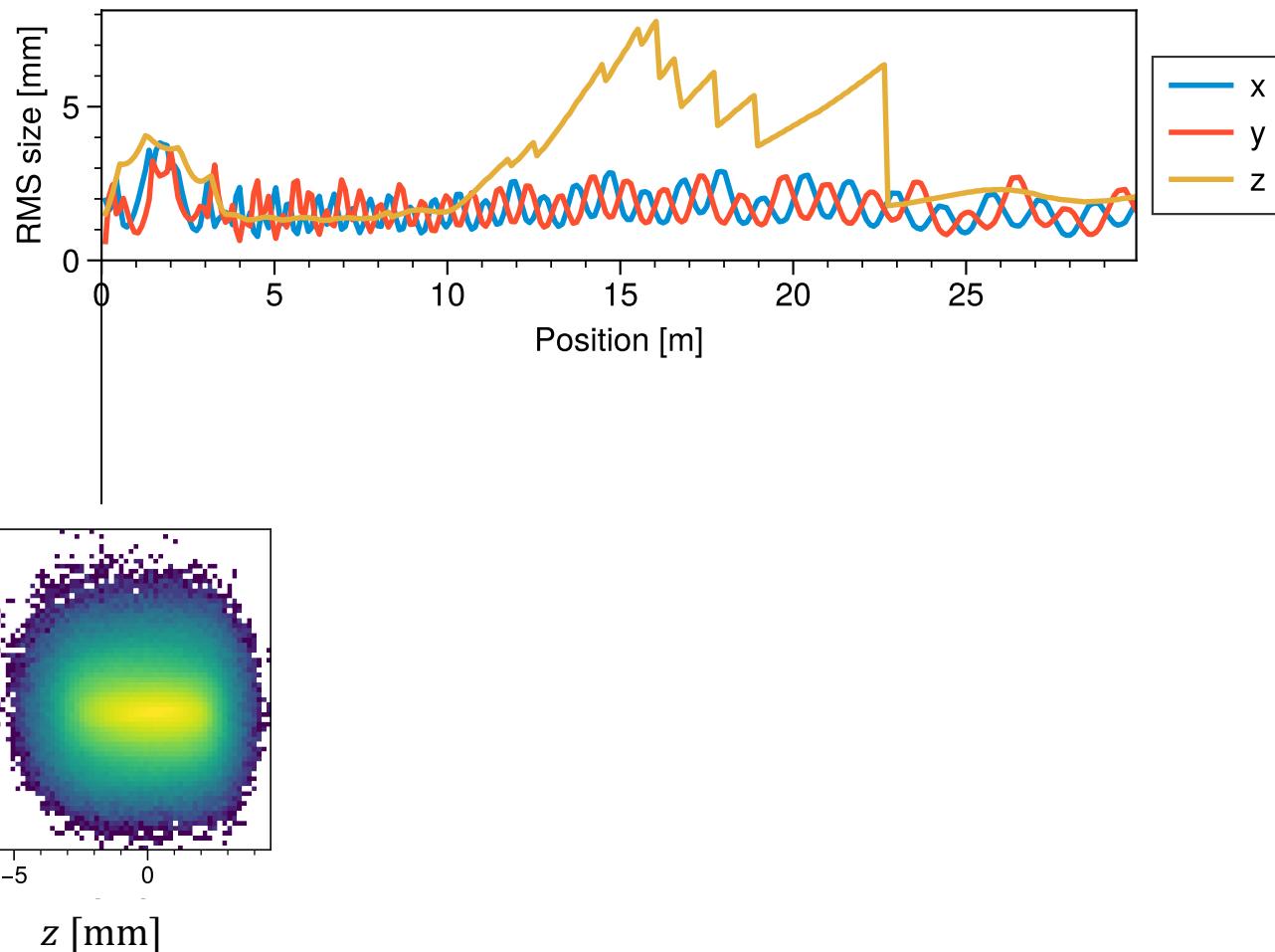


Figure 2: Comparison of horizontal beam size through PyORBIT simulation of SNS MEBT and DTL.

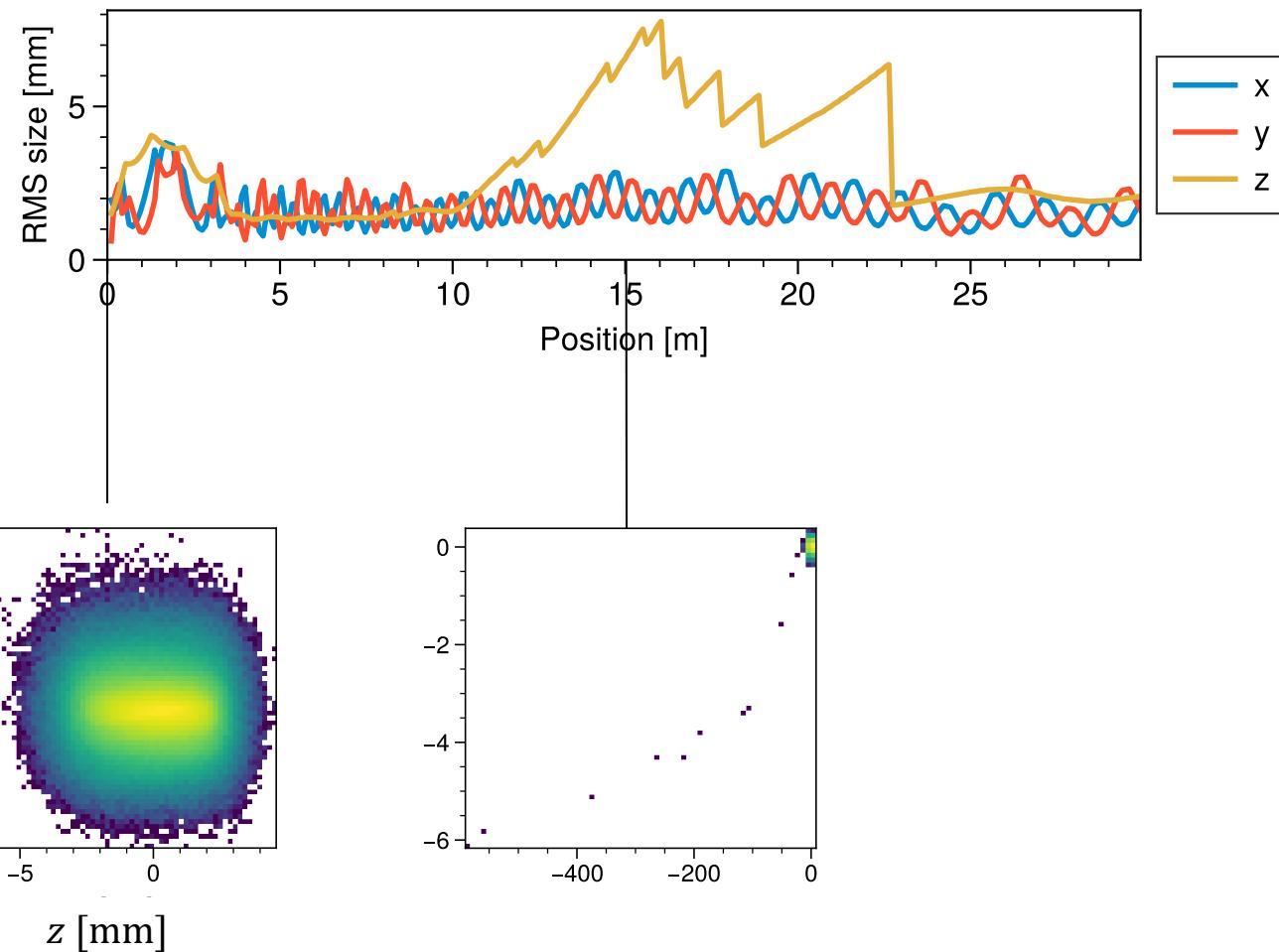
Some particles escape to infinity



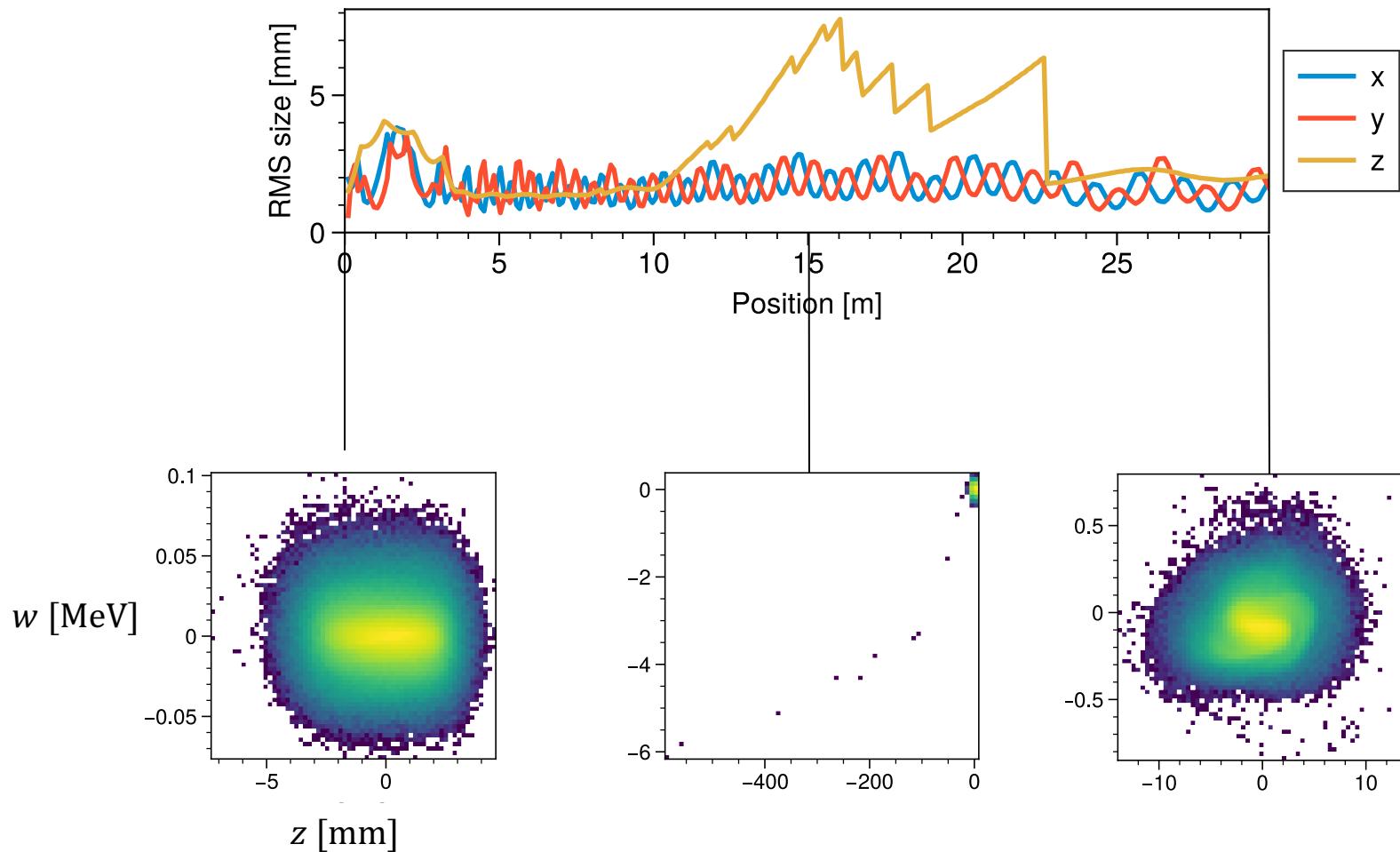
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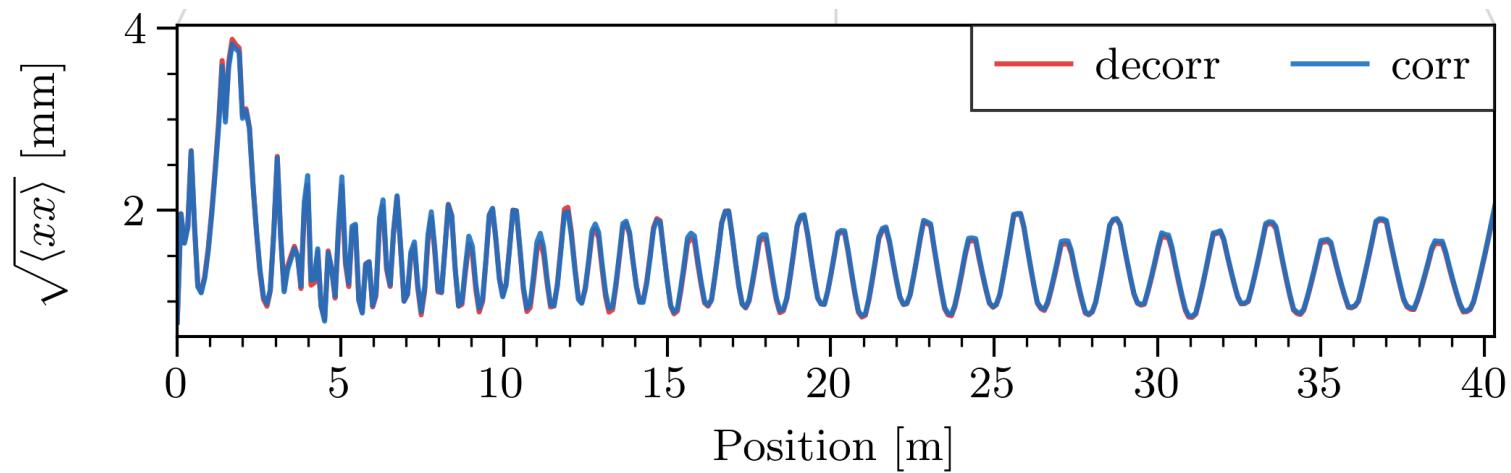
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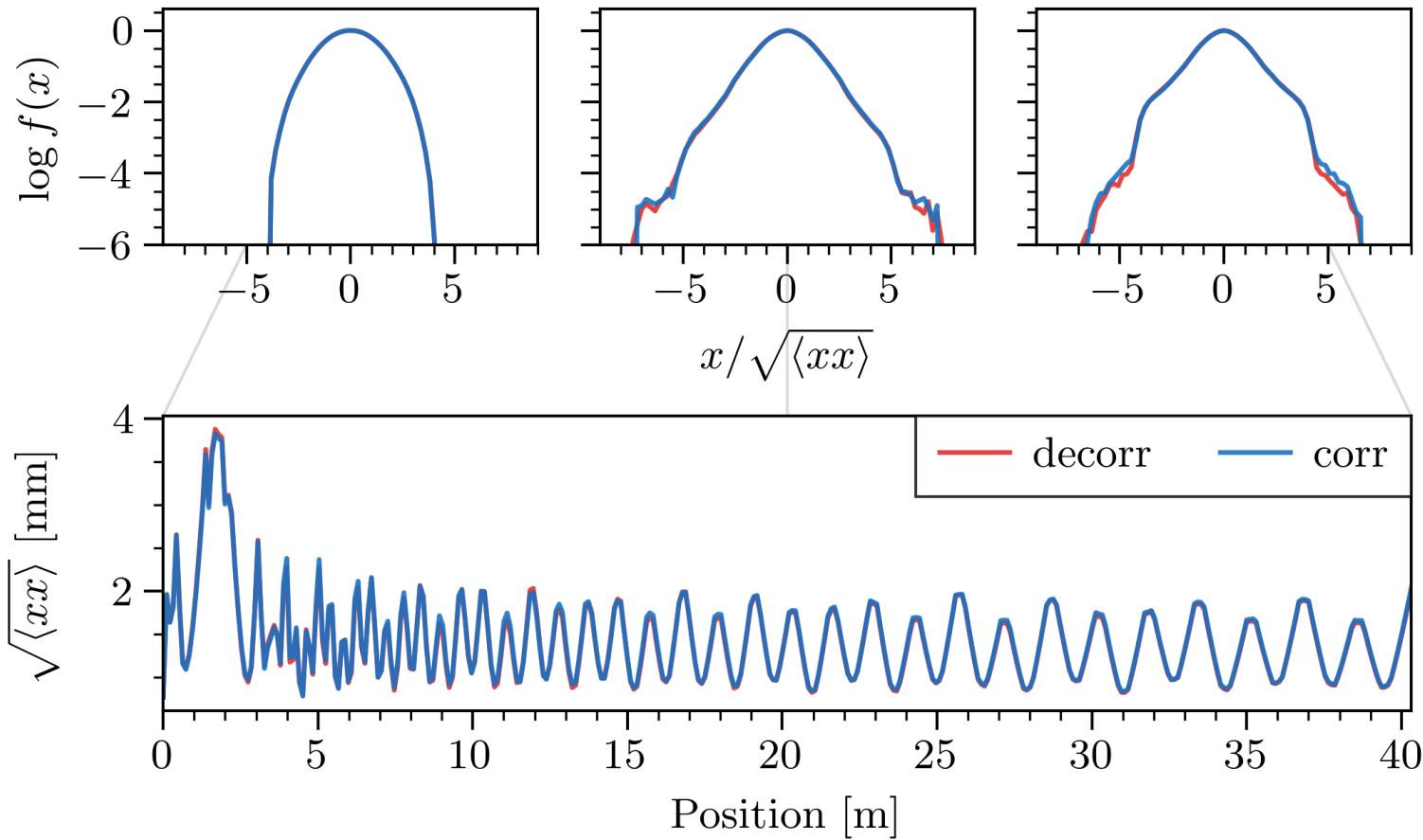
Some particles escape to infinity



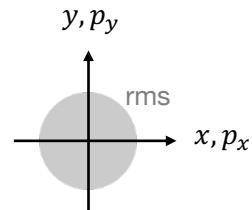
Adding longitudinal apertures resolves discrepancy



Adding longitudinal apertures resolves discrepancy



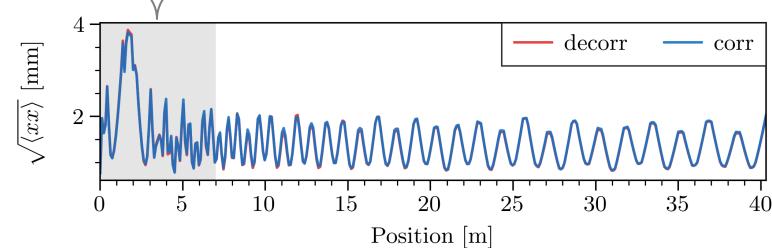
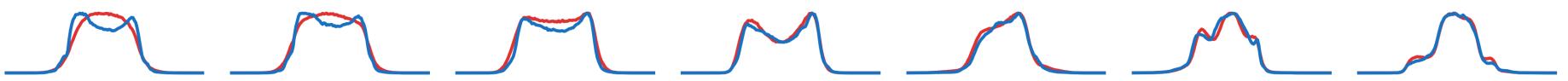
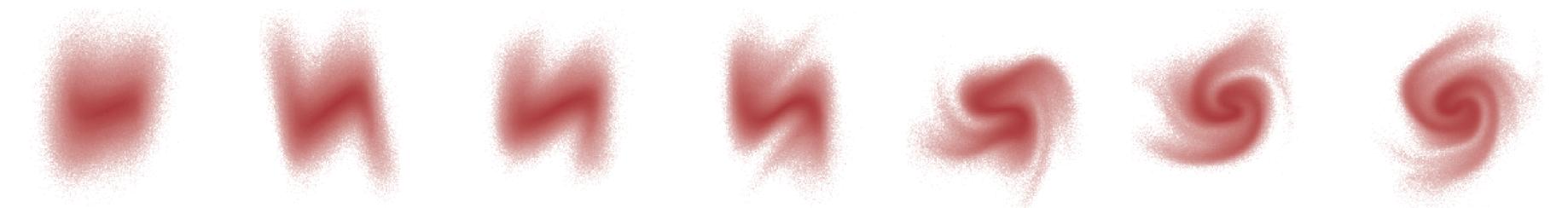
Correlated/decorrelated bunches quickly converge

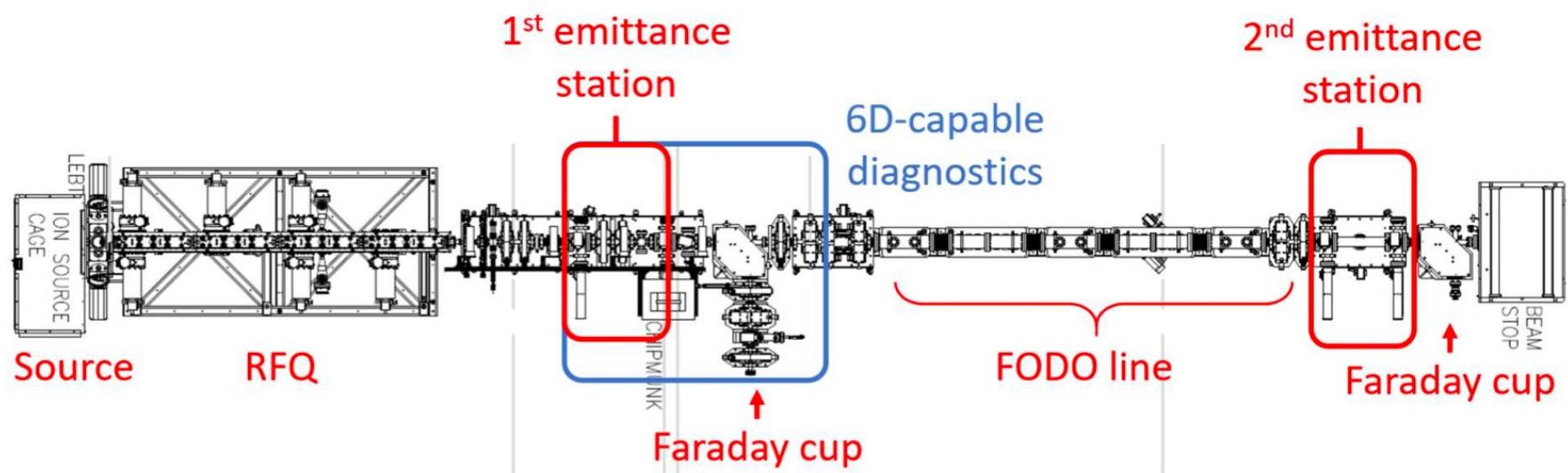


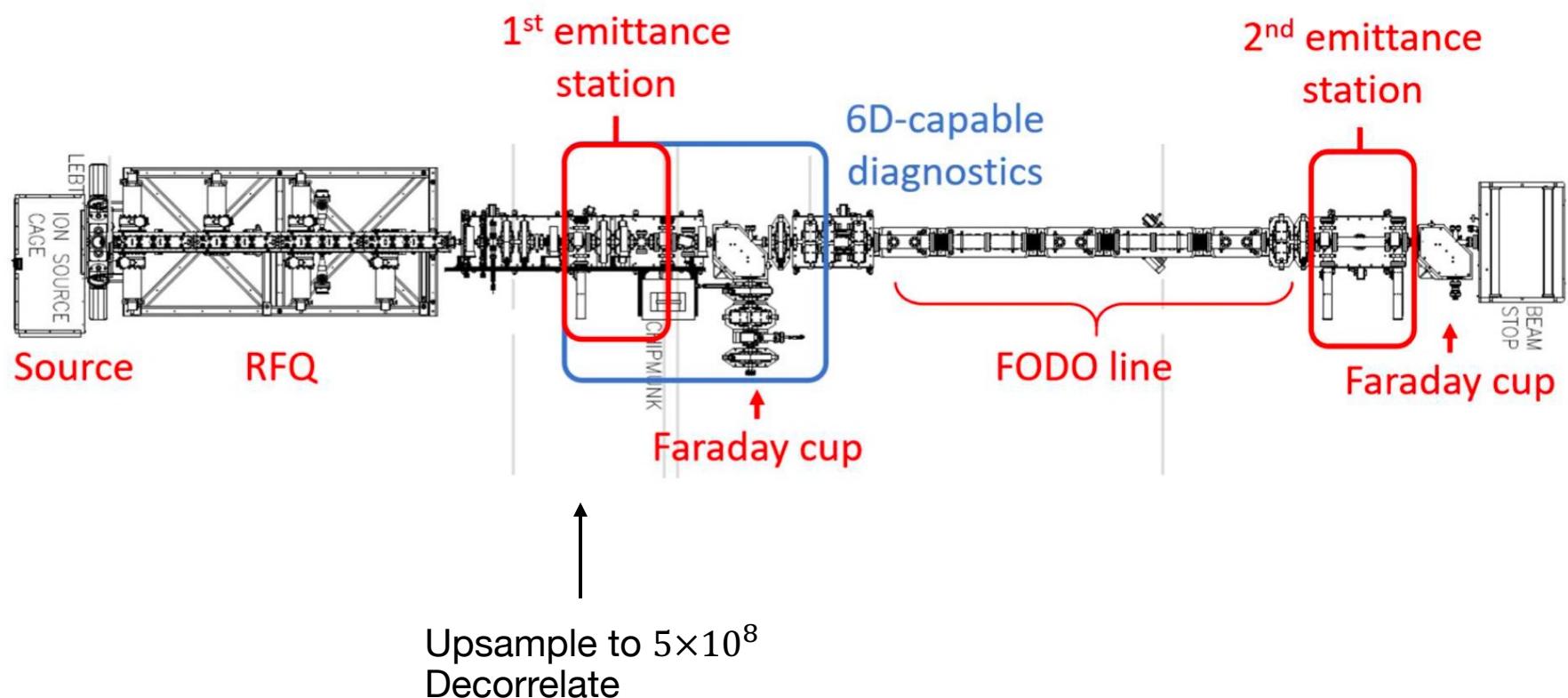
corr

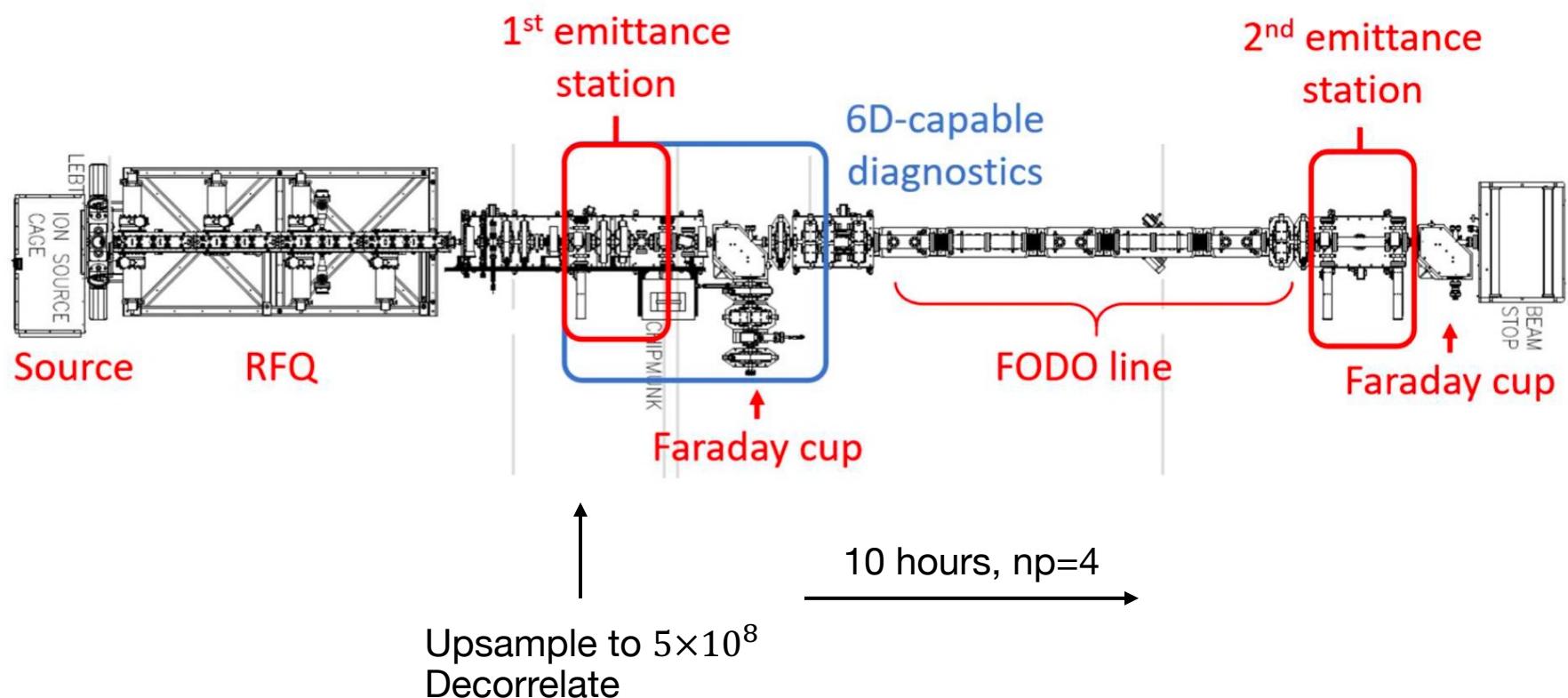


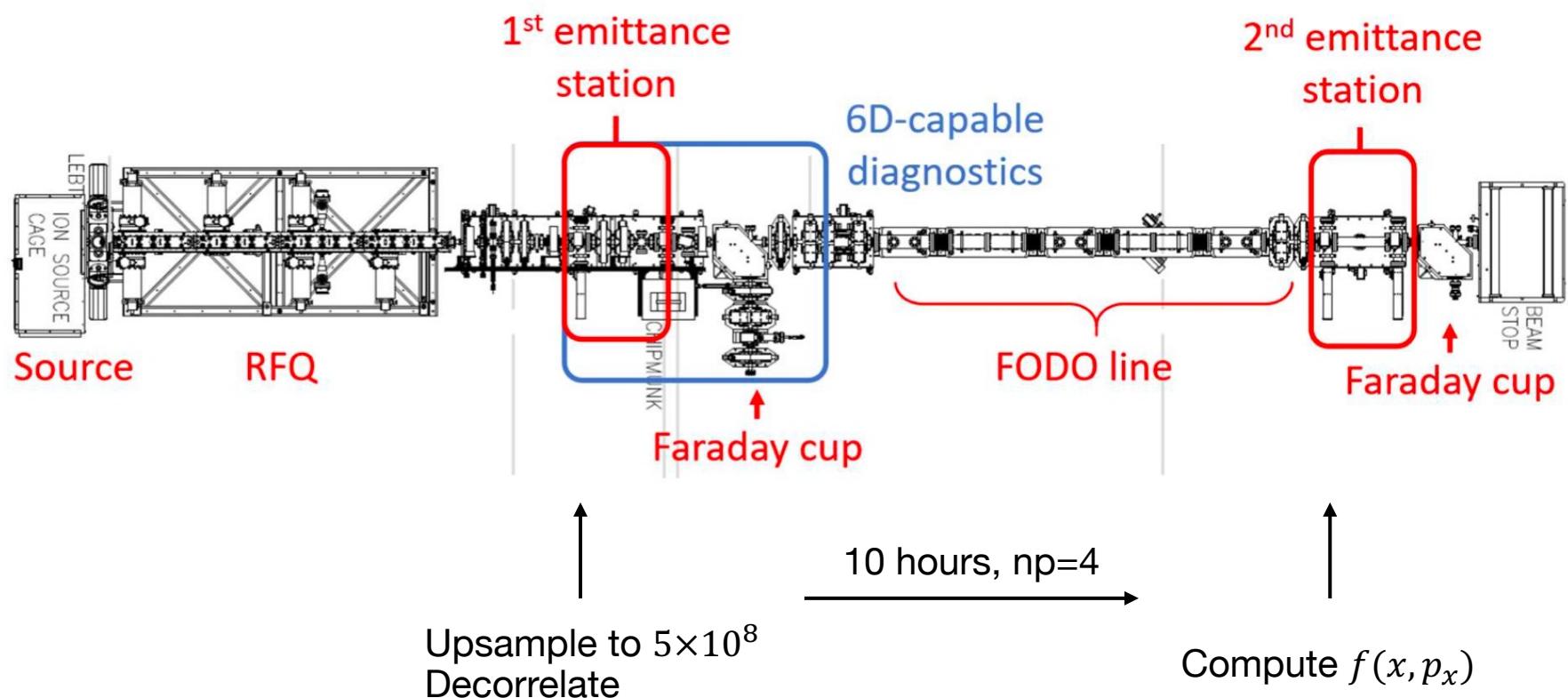
decorr



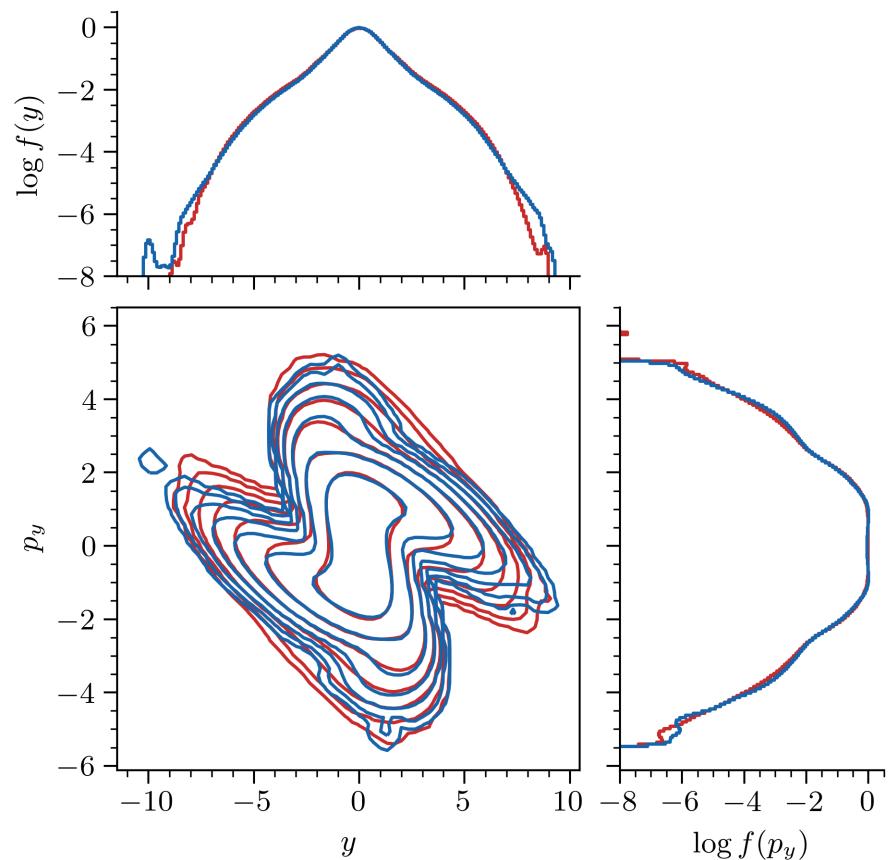
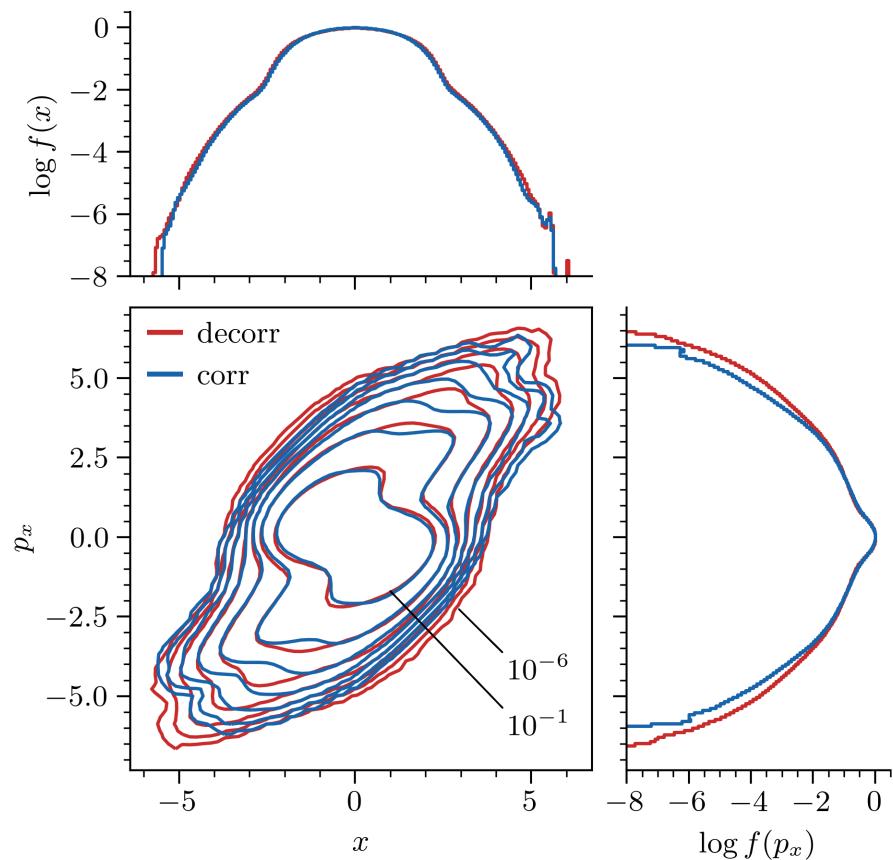




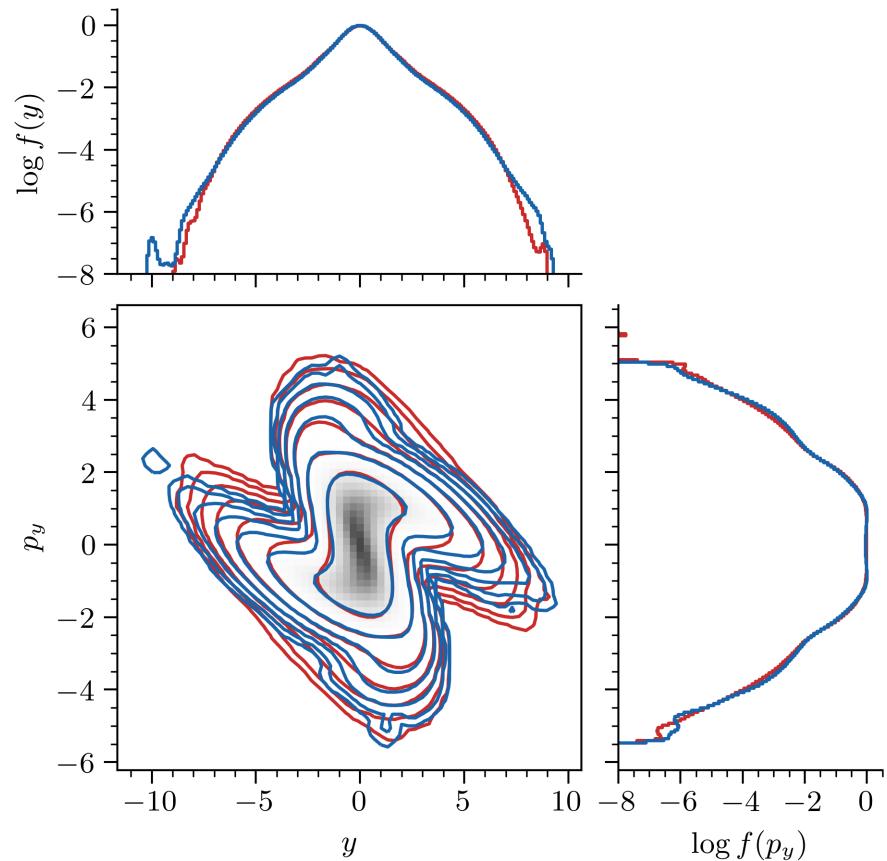
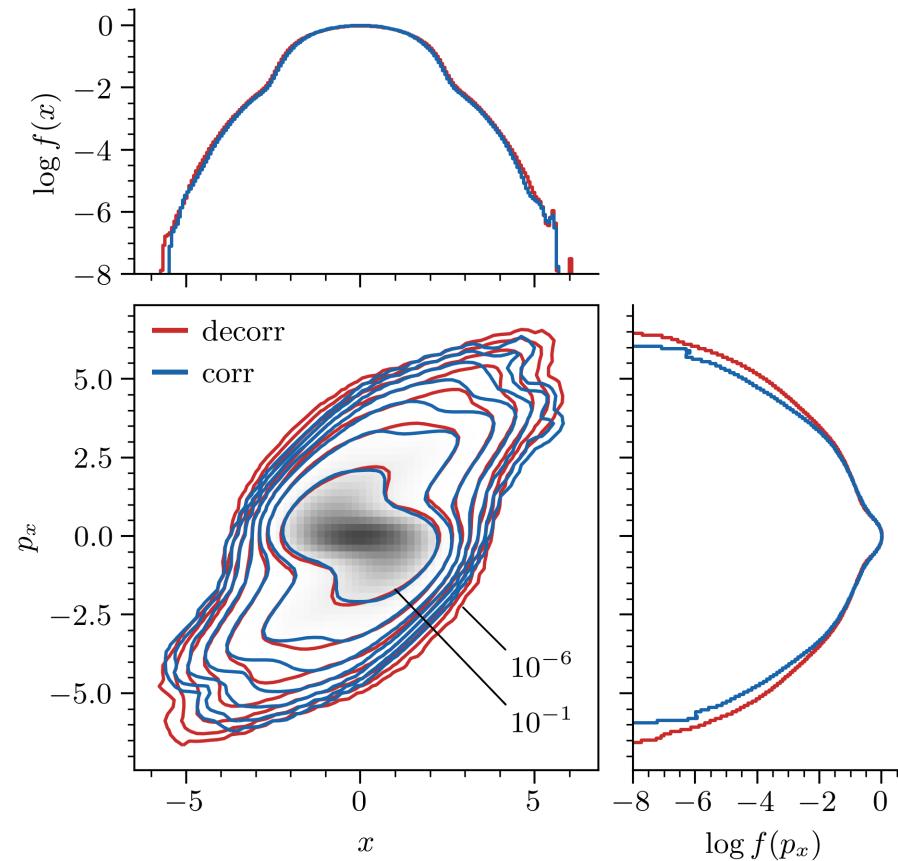




The impact of inter-plane correlations will be small in the BTF



Halo distribution is significantly different than core



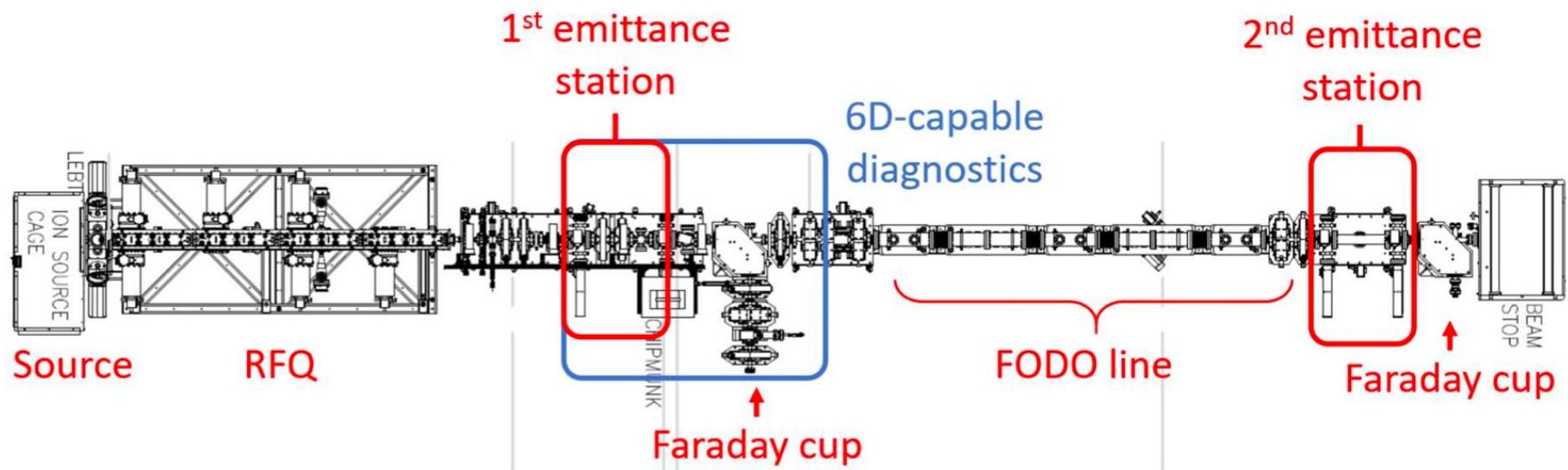
$$\langle x p_x \rangle = \langle y p_y \rangle = 0!$$

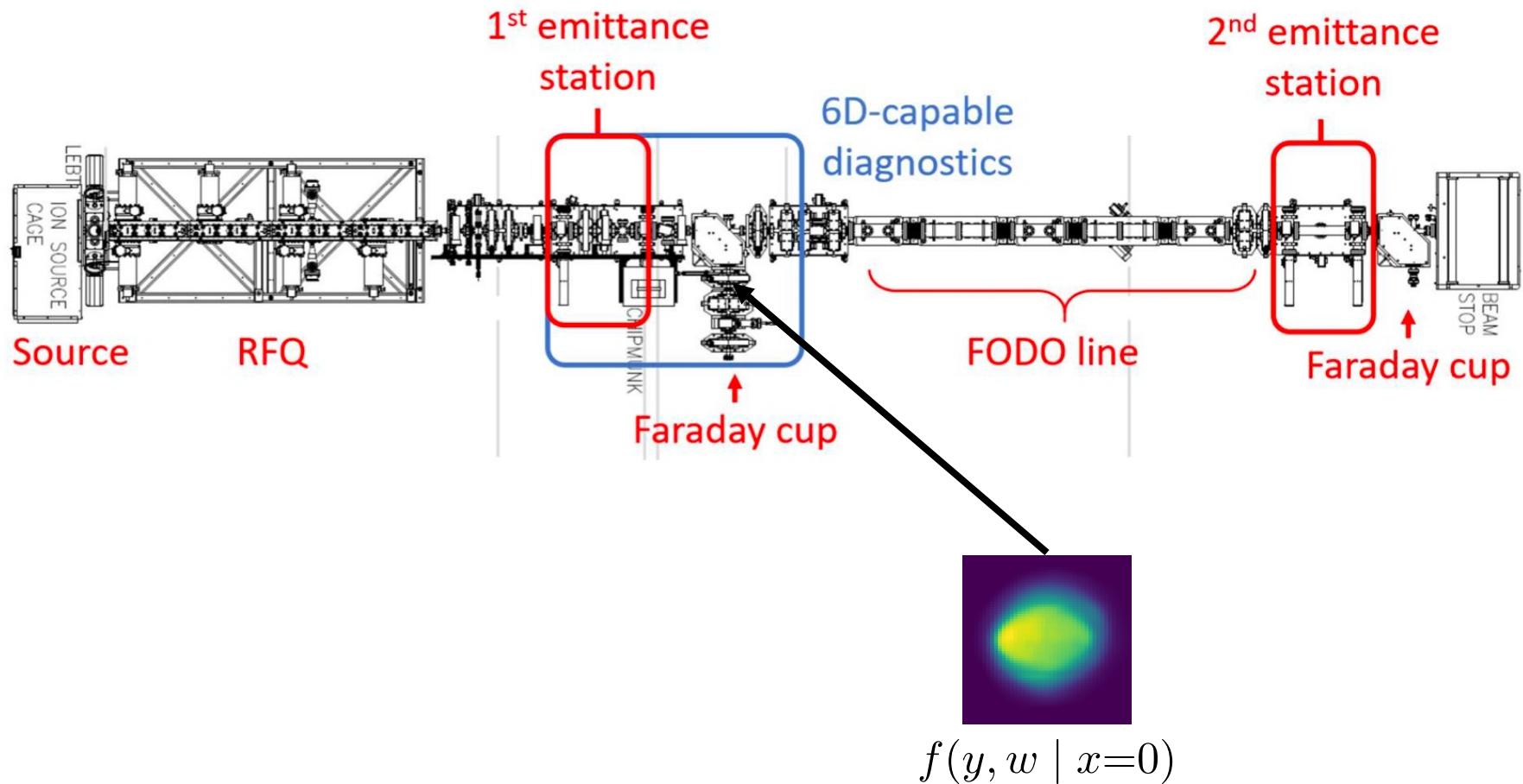
Conclusions

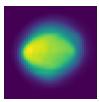
- RFQ model reproduces measured 6D phase space structure.
- Artificial decorrelation should have a small affect on the beam dynamics.
 - (For RFQ, beam current, and measurement location similar to those used in this study.)
 - Lattice model will be important.
- We expect significant halo in the SNS BTF.

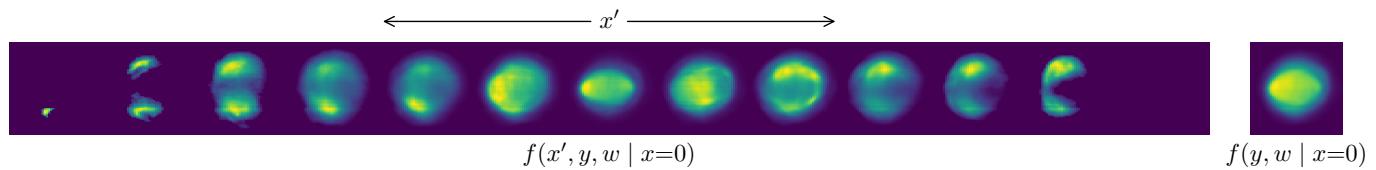
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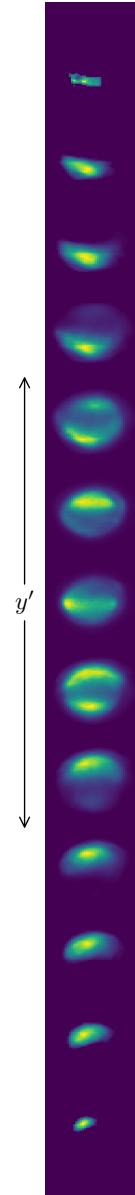




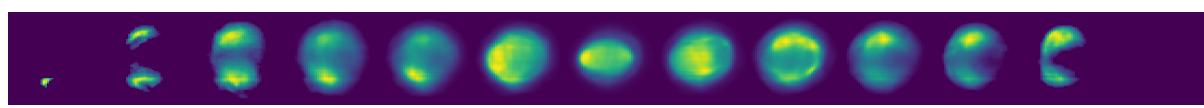
 $f(y, w \mid x=0)$



$$f(y, y', w \mid x=0)$$



$$\xleftarrow{\hspace{1cm}} x' \xrightarrow{\hspace{1cm}}$$

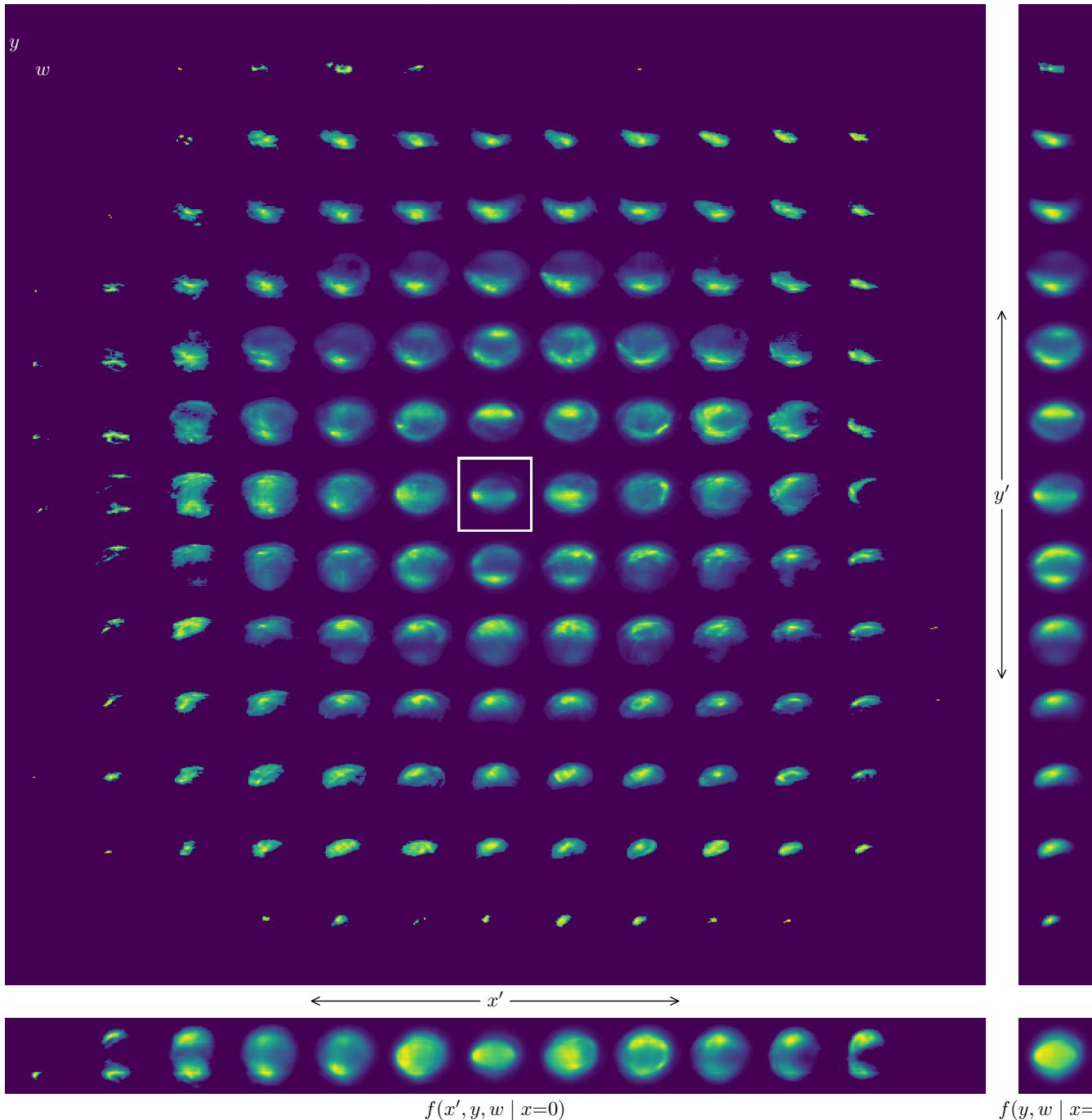


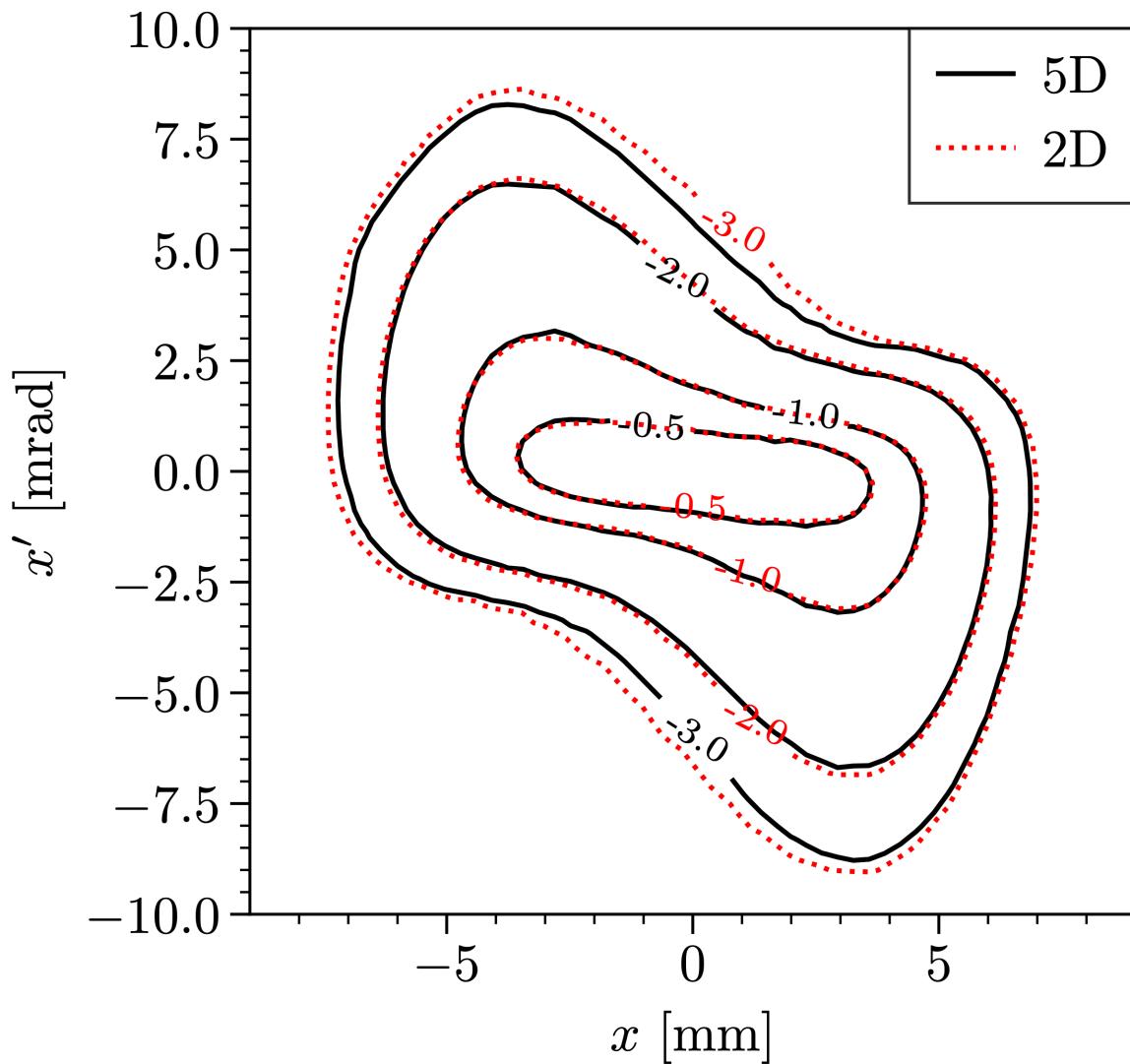
$$f(x', y, w \mid x=0)$$

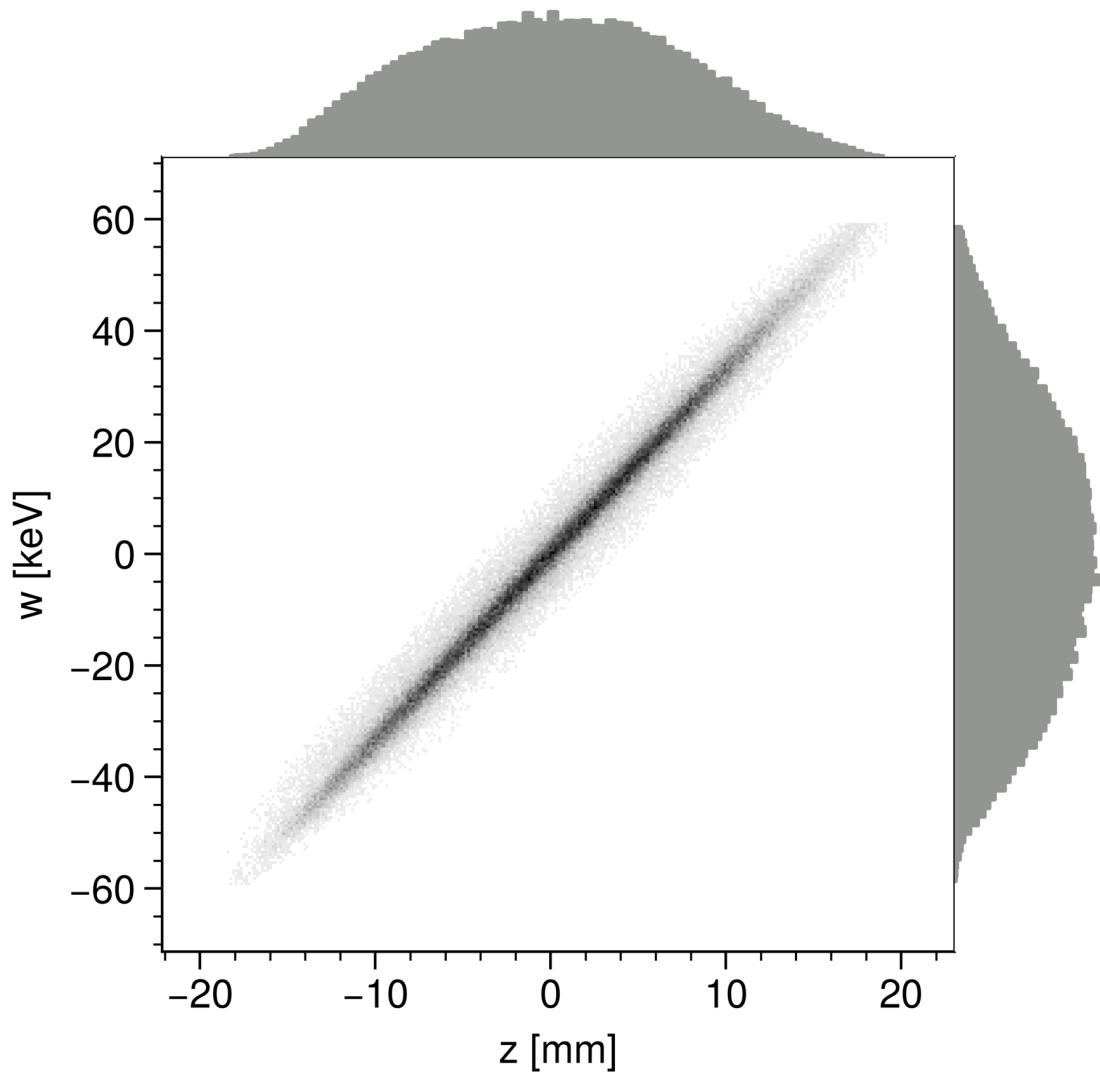
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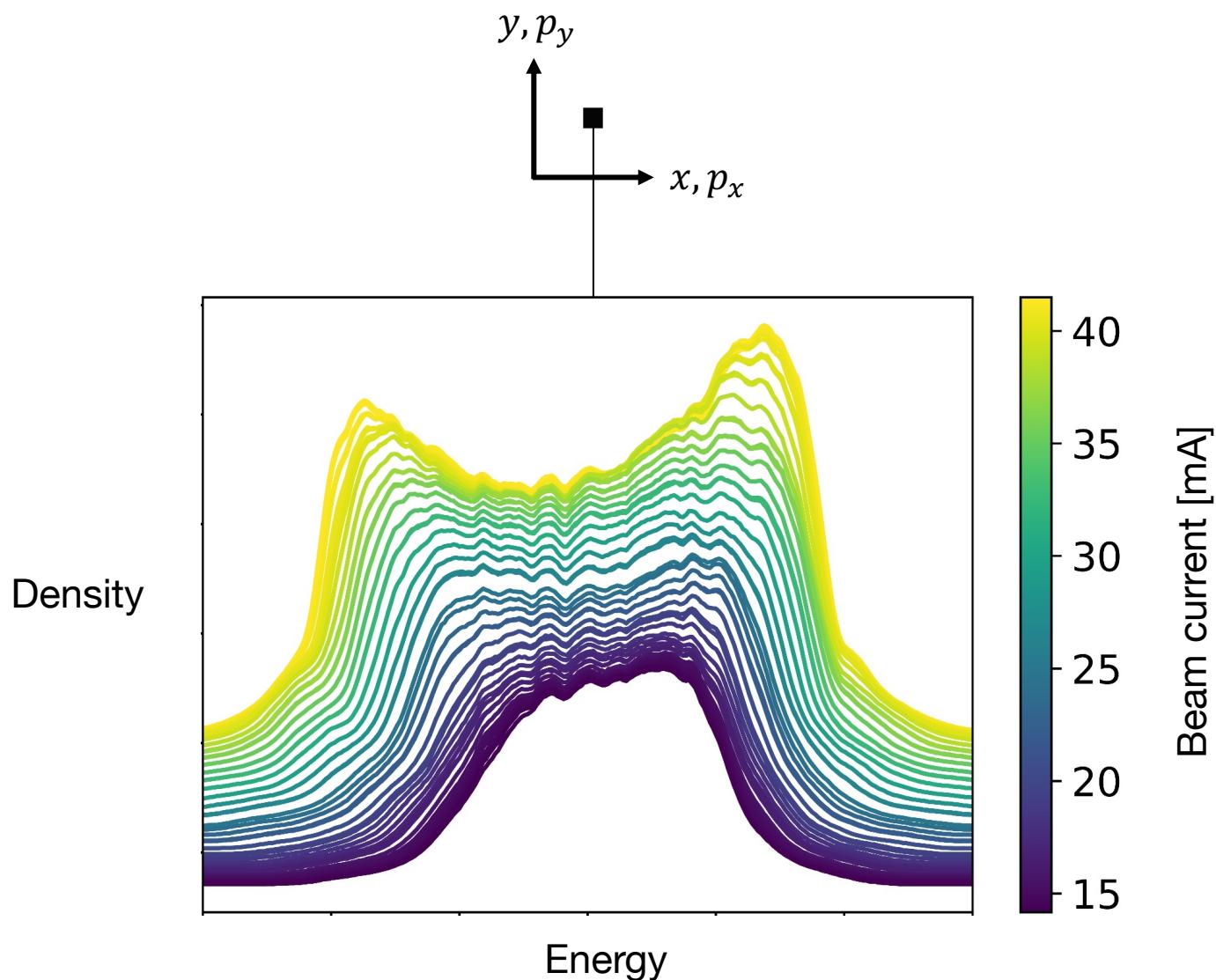
$$f(x', y, y', w \mid x=0)$$

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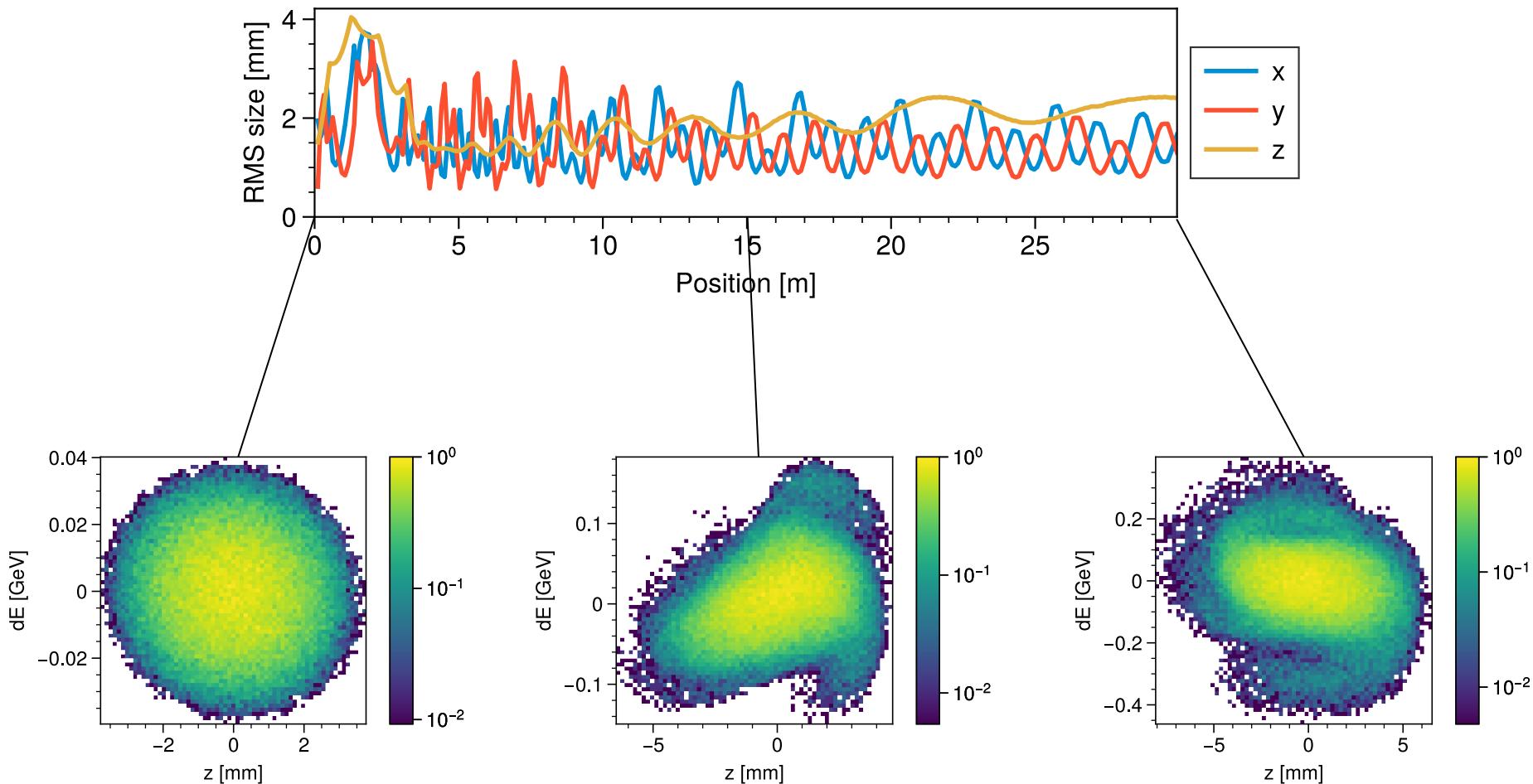








No particles escape from rms-equivalent Waterbag



Old BTF layout

