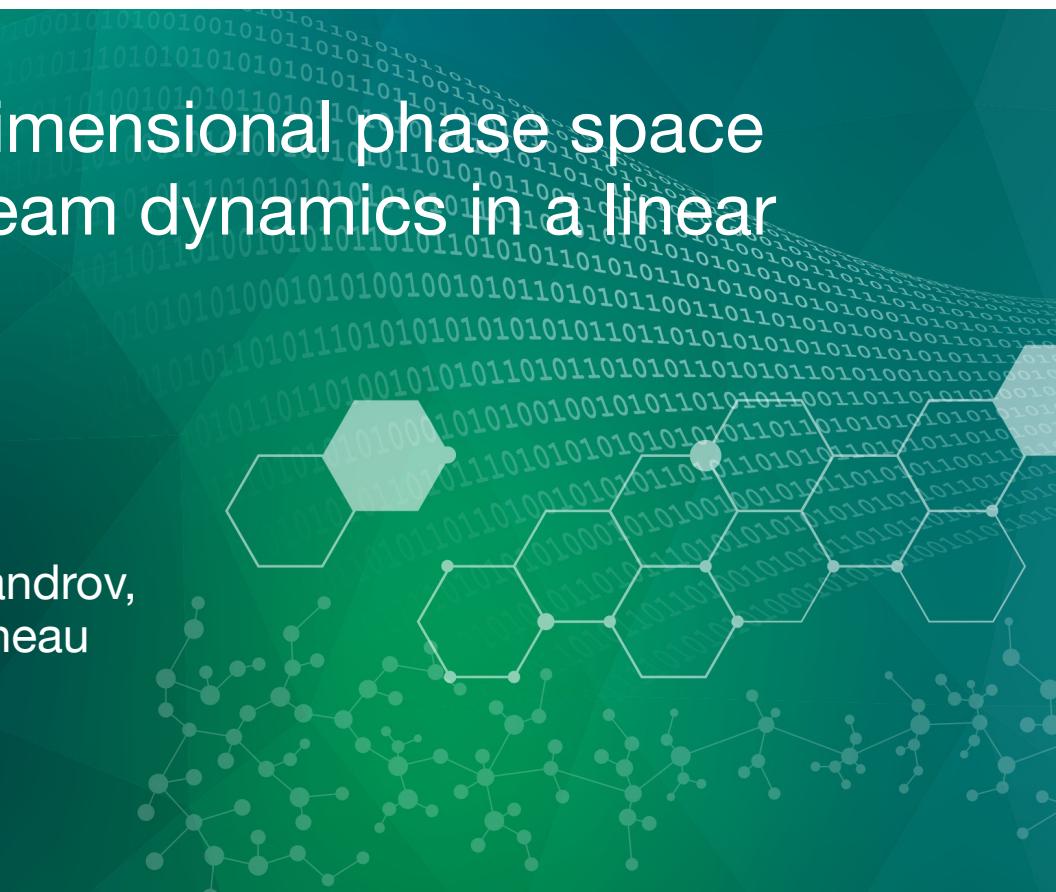


# The impact of high-dimensional phase space correlations on the beam dynamics in a linear accelerator

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

HB Workshop, CERN

October 10, 2023



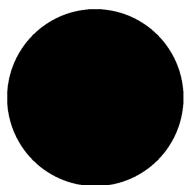
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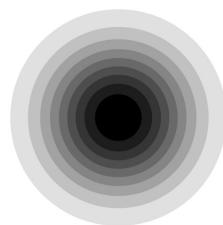
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# LEDA: halo is sensitive to initial distribution

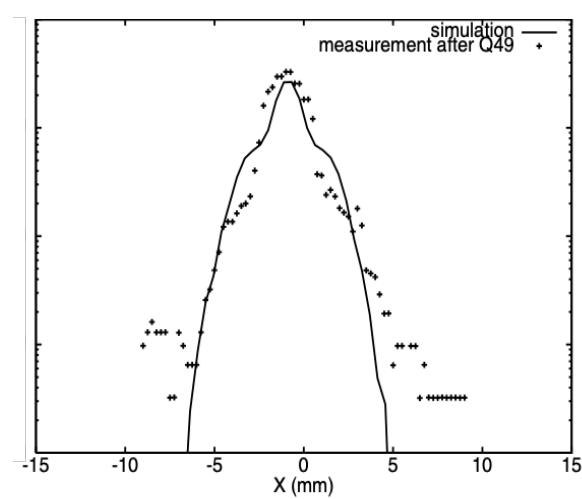
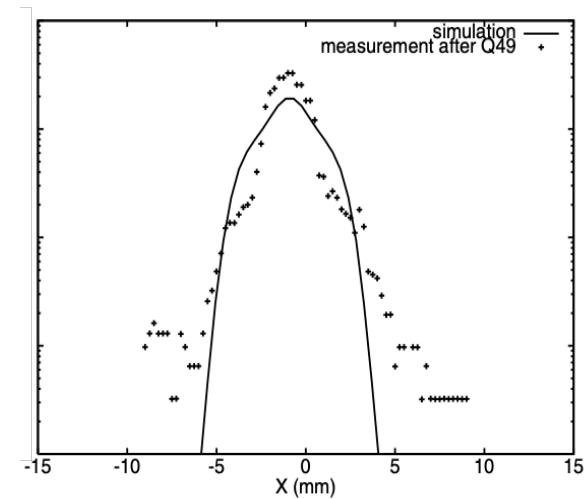
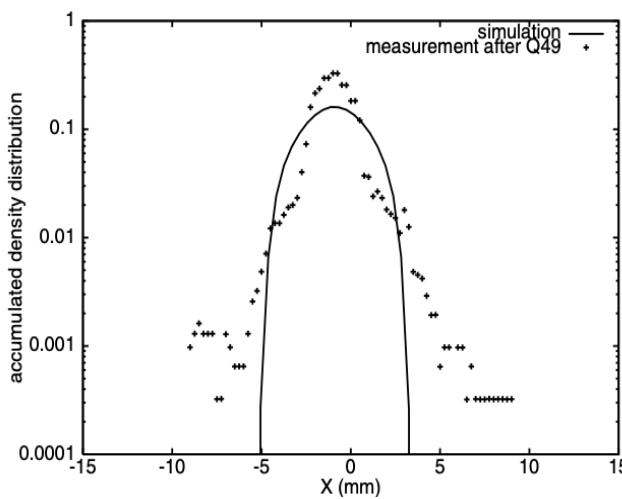
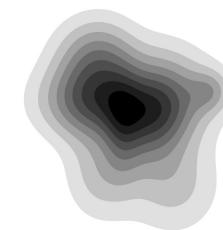
Waterbag



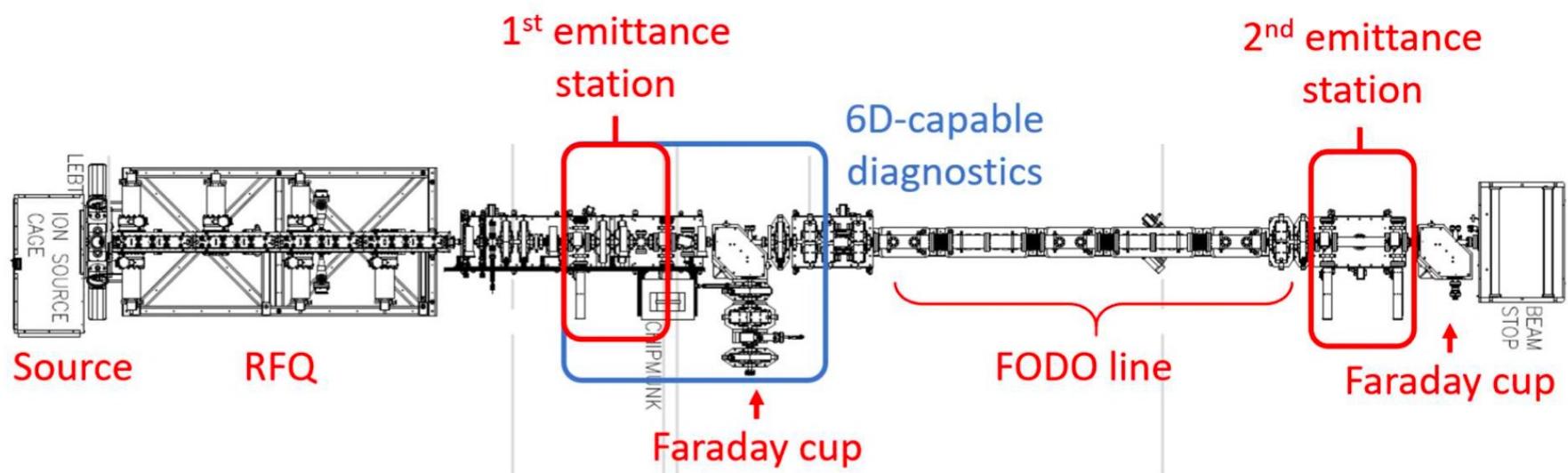
Gaussian



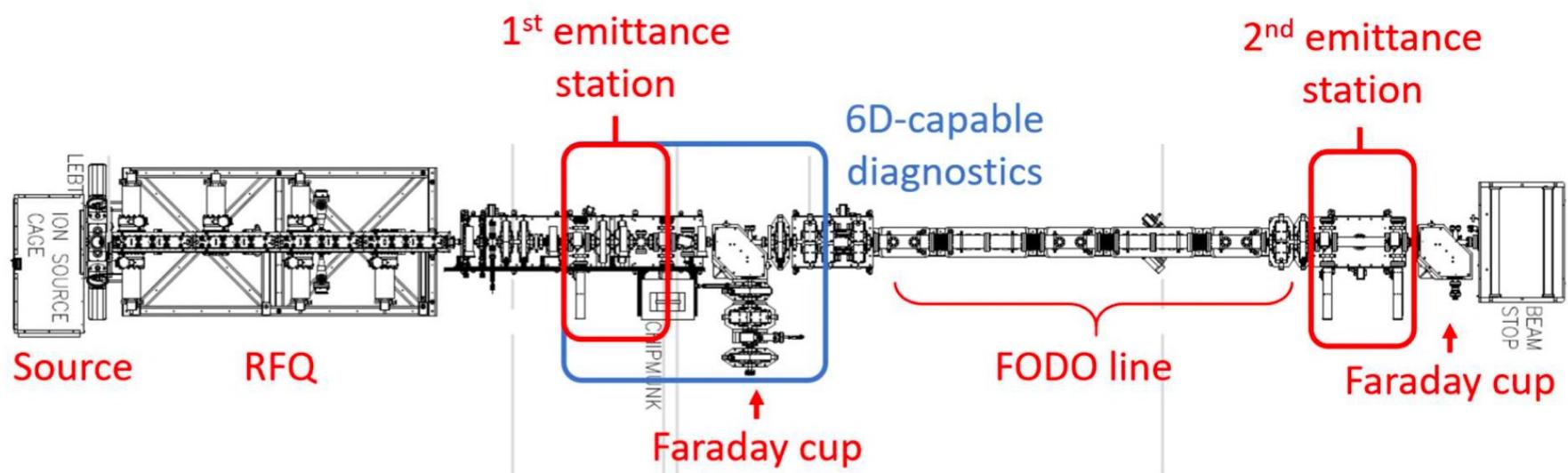
RFQ



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



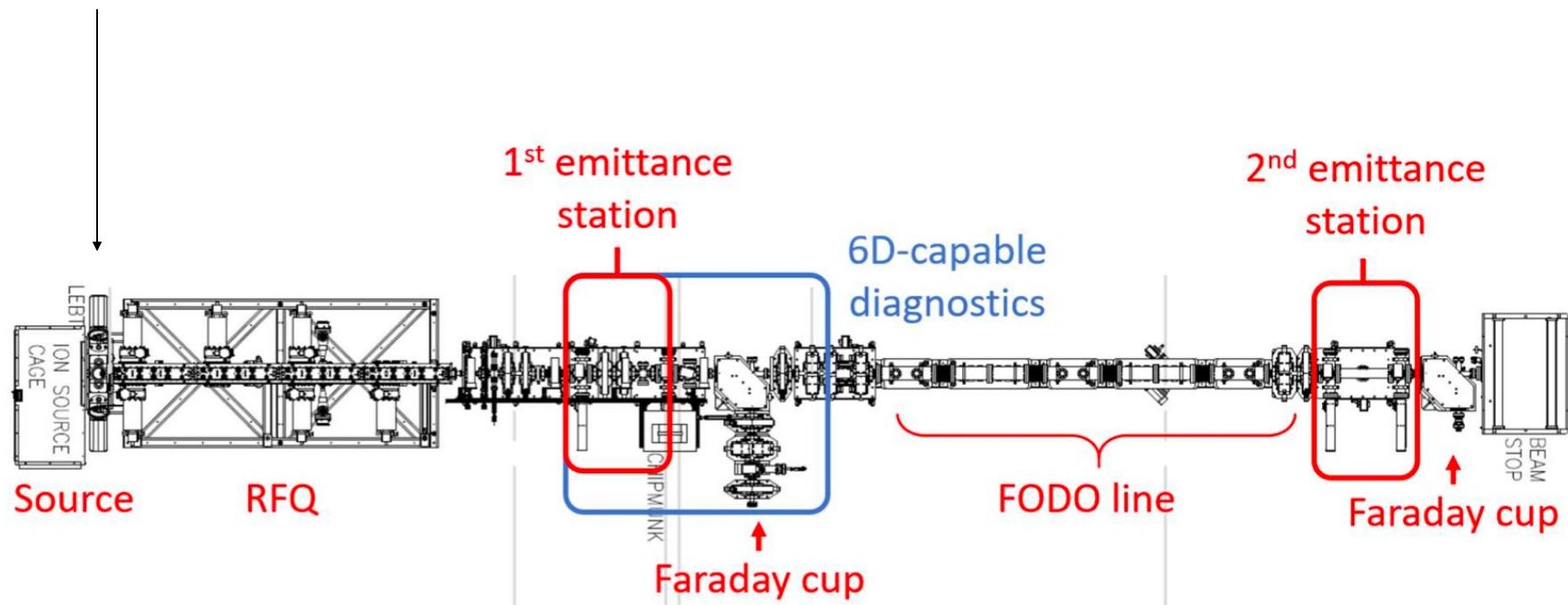
The SNS-BTF aims to predict halo formation over a short distance



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

# PARMTEQ generates “model” bunch at first measurement station

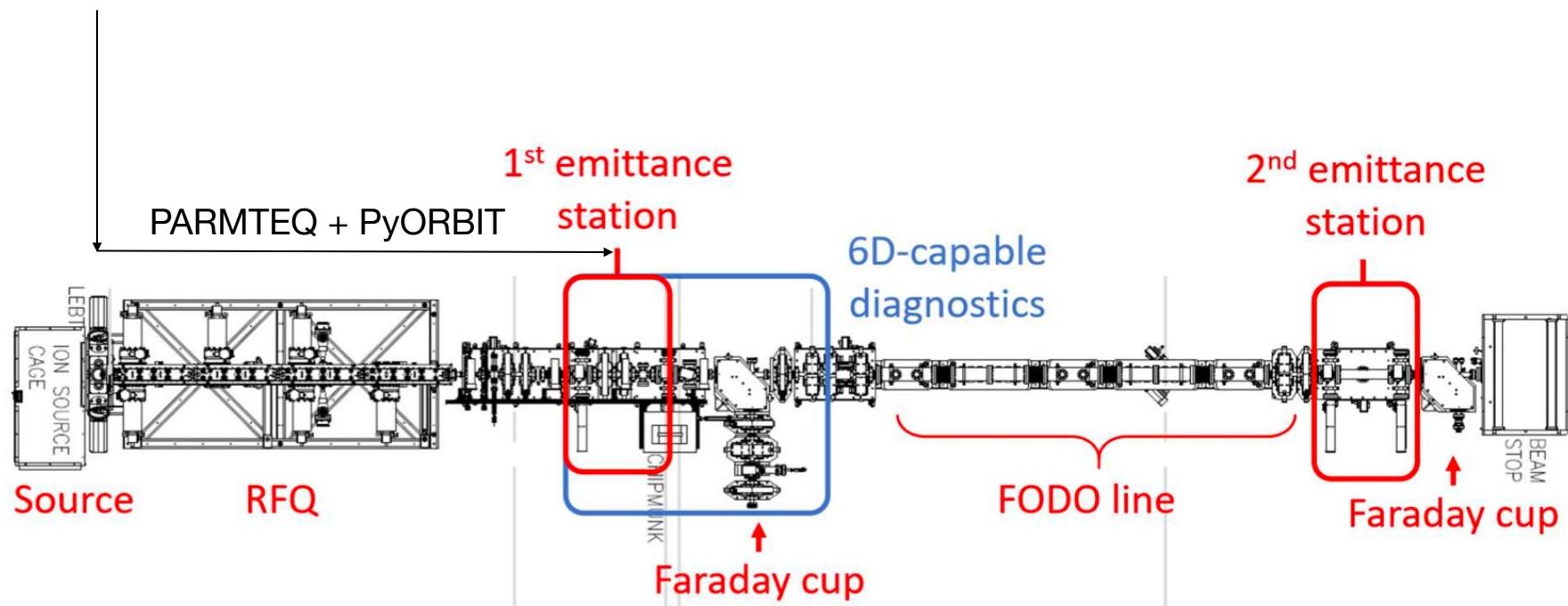
$\{f(x, p_x), f(y, p_y)\}$  from Ion Source Test Stand



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

# PARMTEQ generates “model” bunch at first measurement station

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



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

## Main points

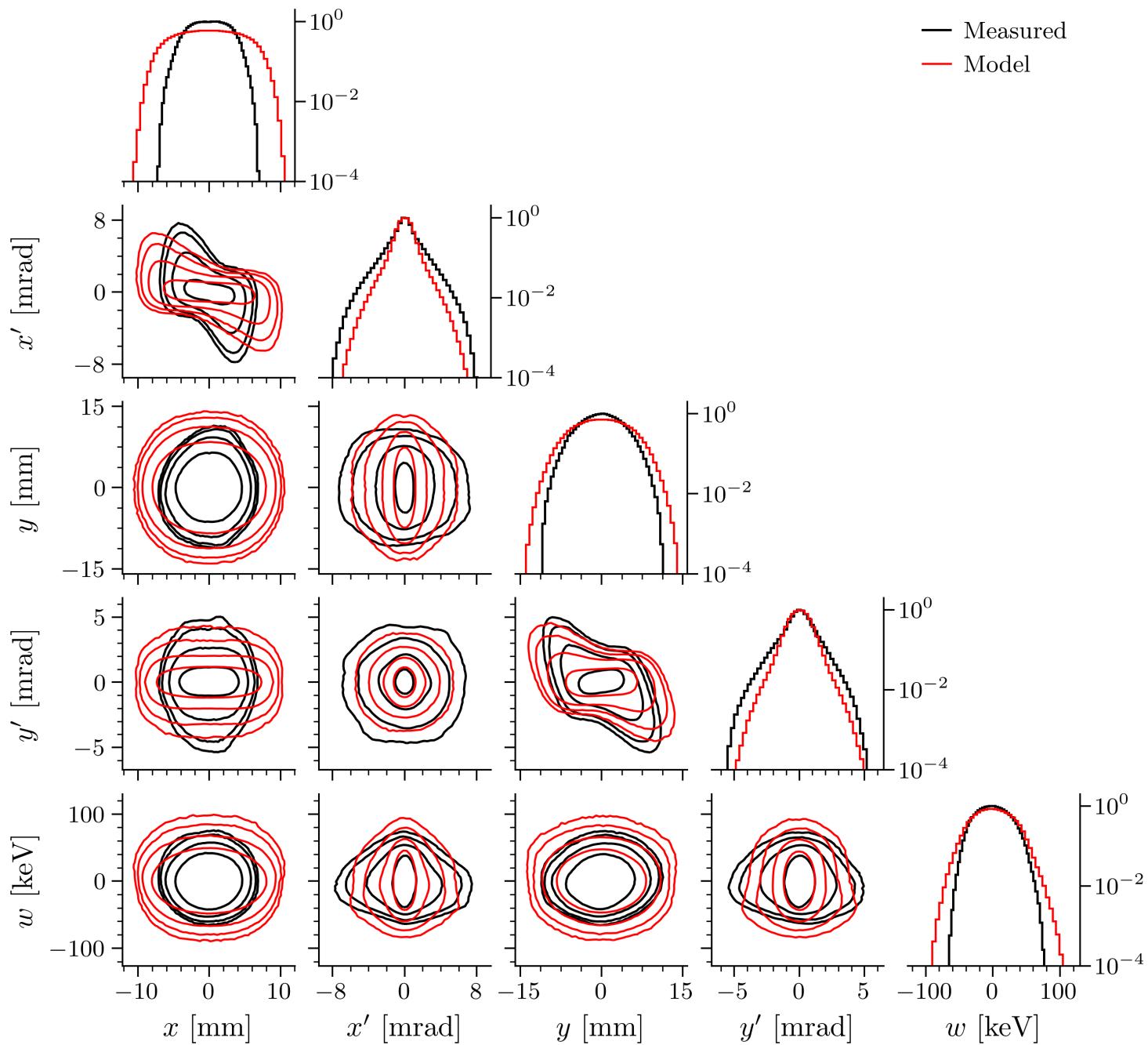
- RFQ model reproduces measured 6D phase space structure.

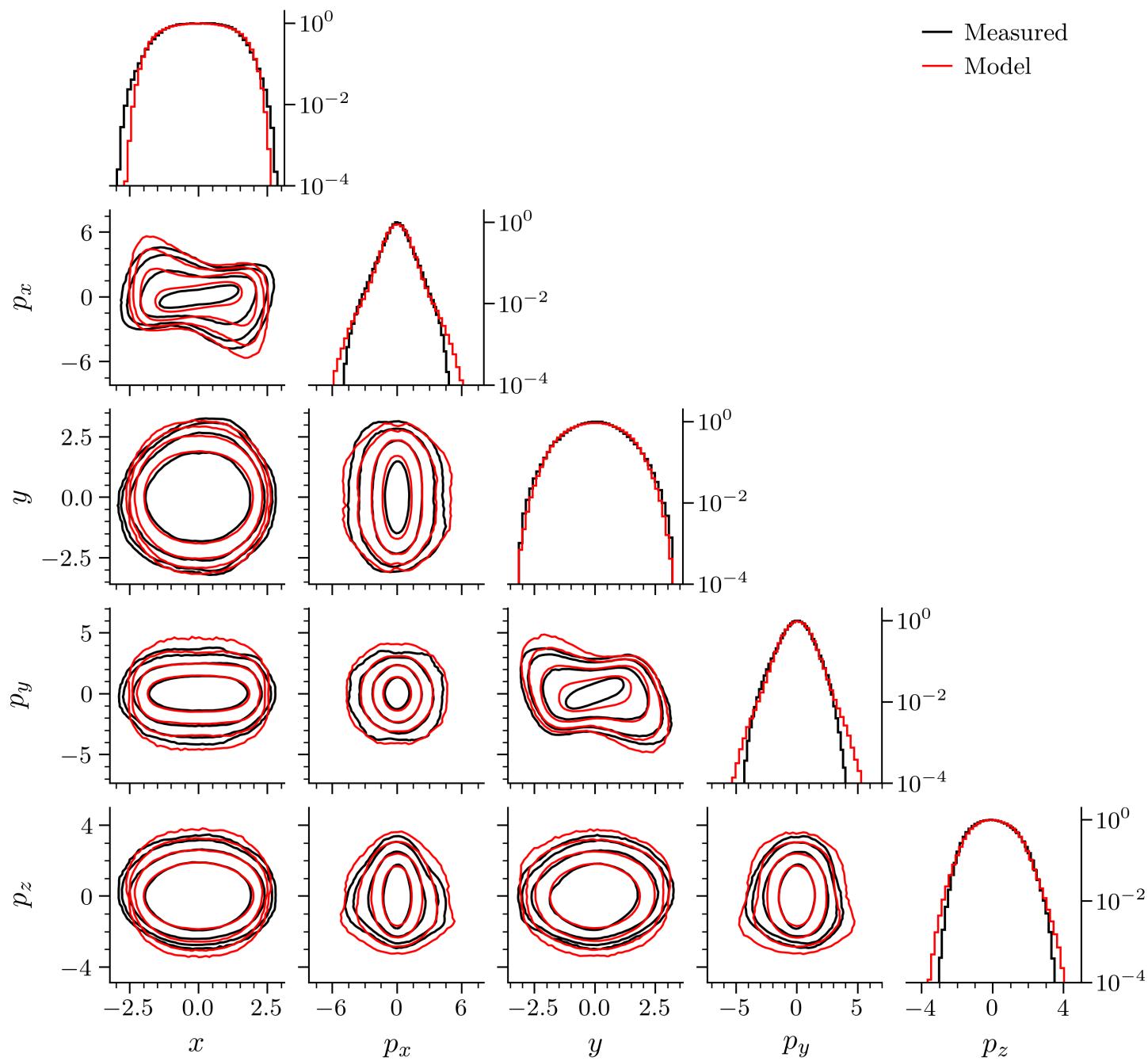
## Main points

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

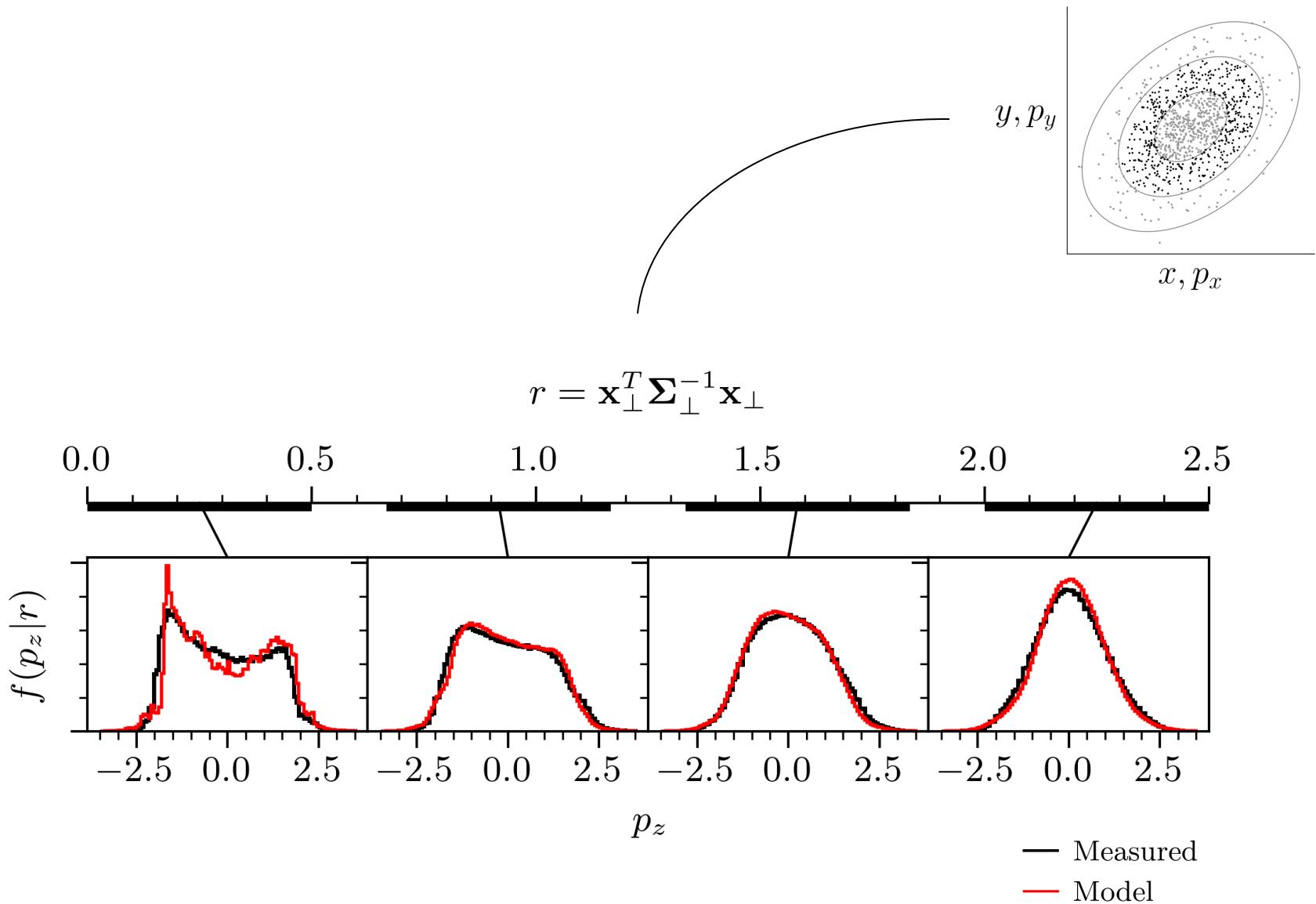
## Main points

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

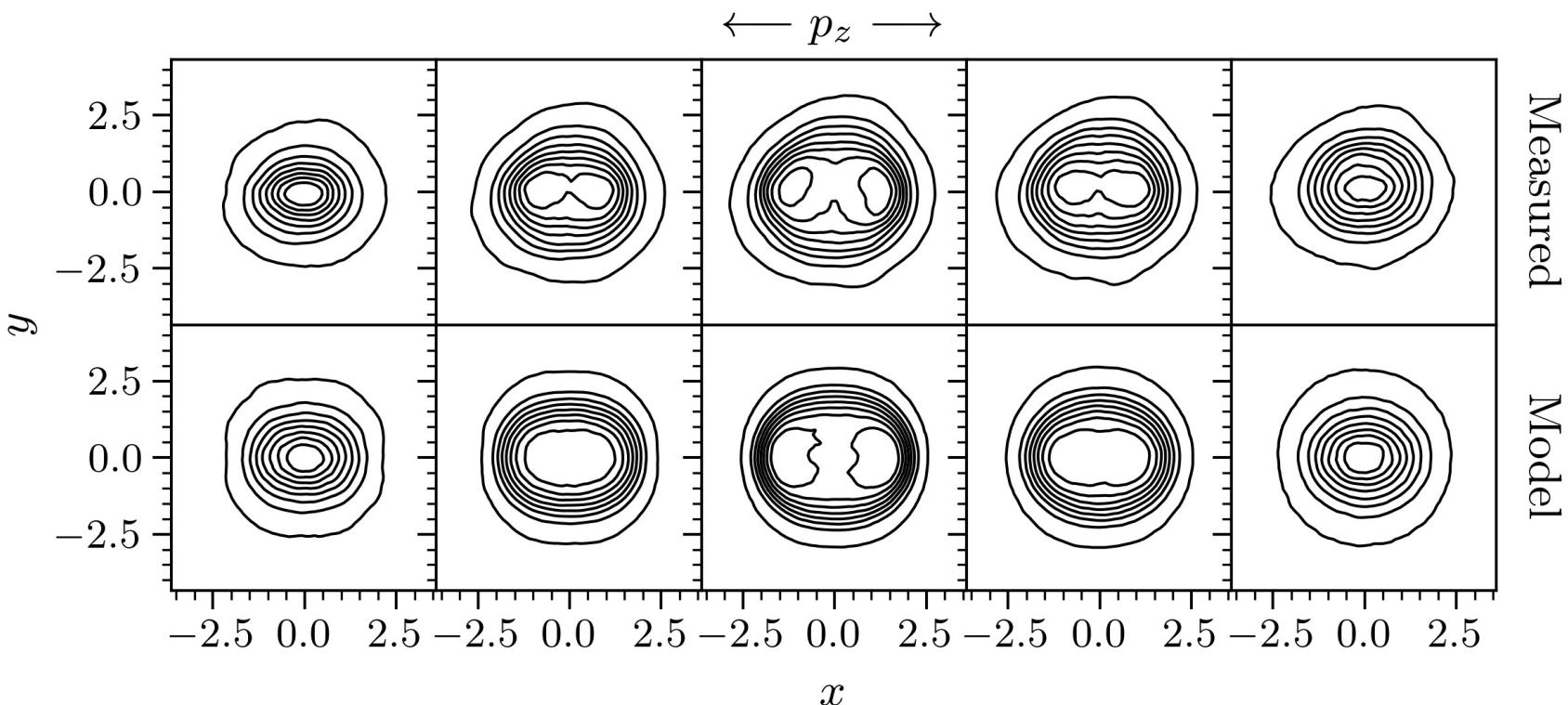




# Longitudinal hollowing – probably occurs in RFQ



# Transverse hollowing – probably occurs in MEBT

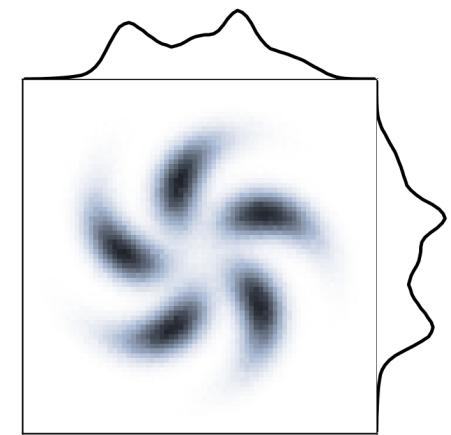
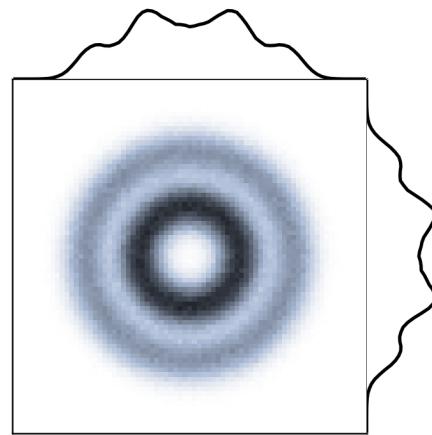
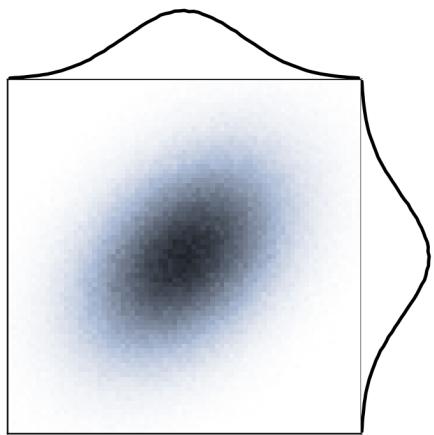


## Main points

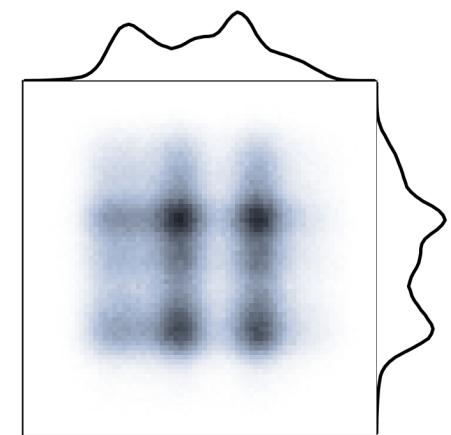
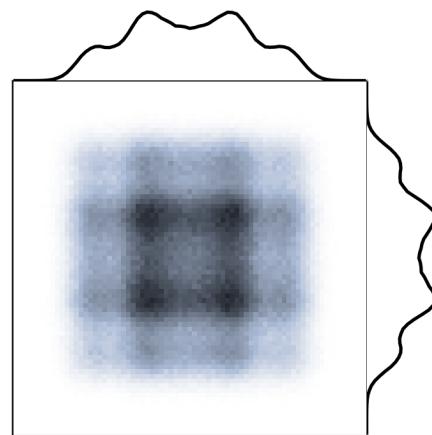
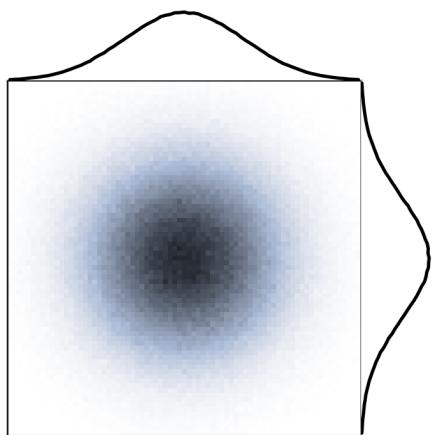
- RFQ model reproduces measured 6D phase space structure.
- **Artificial decorrelation should have a small affect on the beam dynamics.**

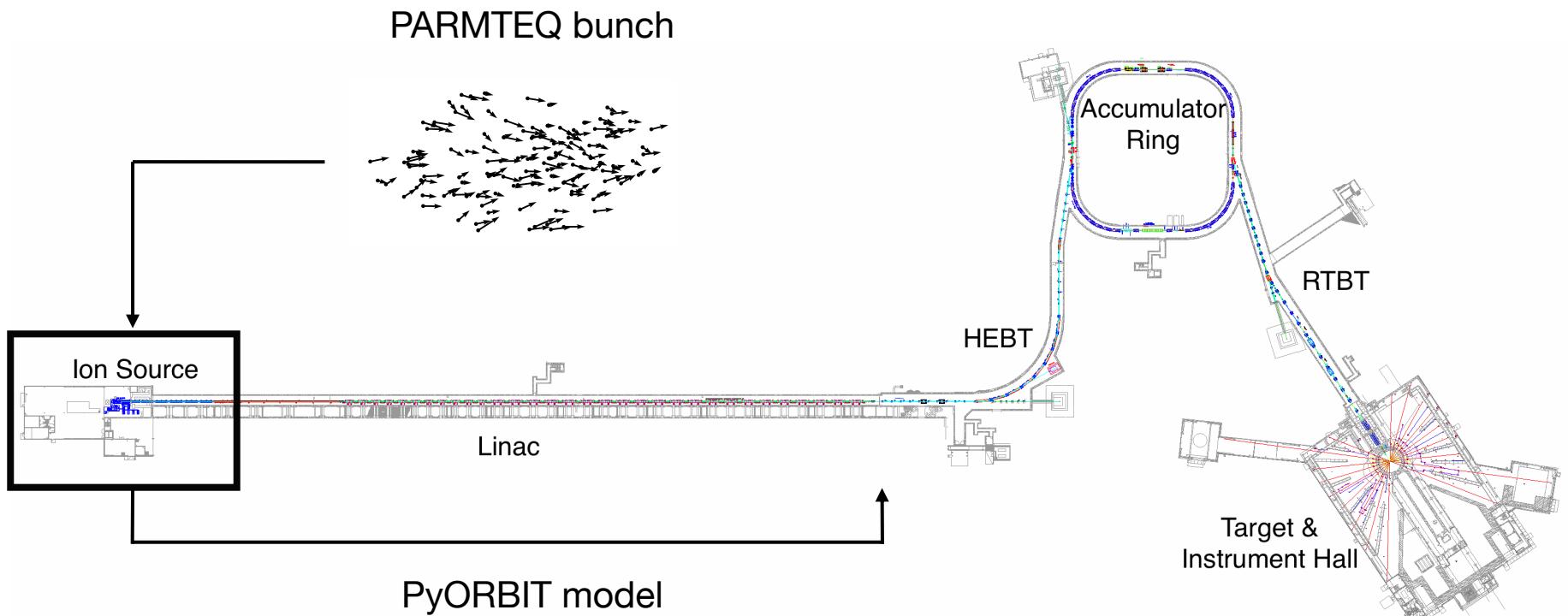
Decorrelation removes both linear and nonlinear relationships

$f(x, y)$



$f(x)f(y)$





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

12th Int. Particle Acc. Conf.  
ISBN: 978-3-95450-214-1

IPAC2021, Campinas, SP, Brazil  
ISSN: 2673-5490

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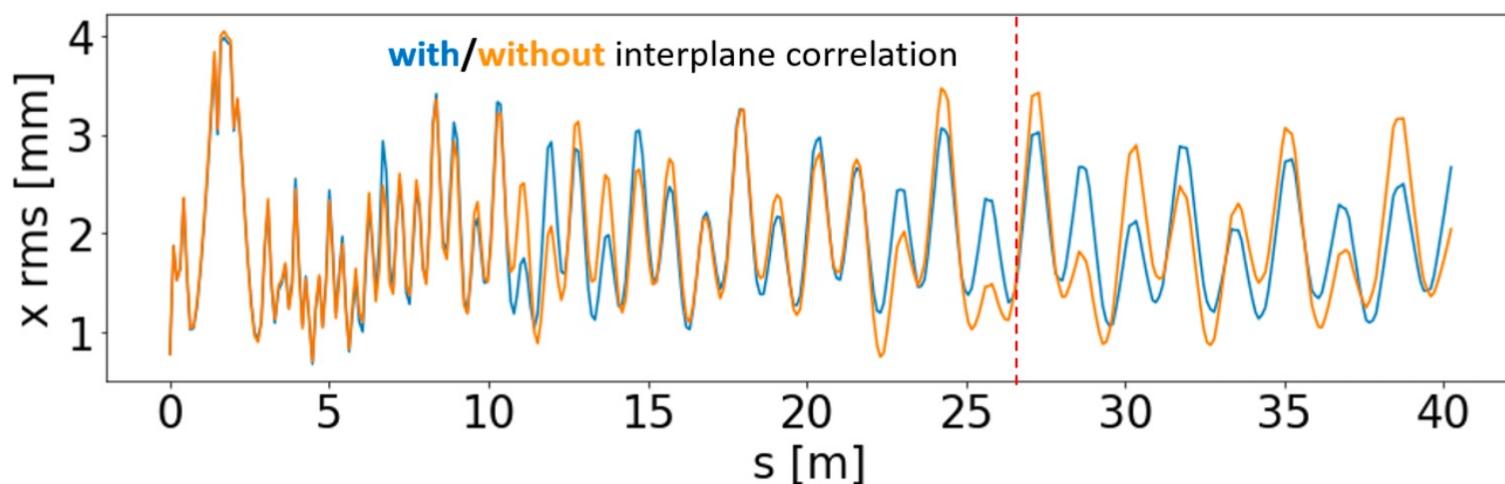


Figure 2: Comparison of horizontal beam size through PyORBIT simulation of SNS MEBT and DTL.

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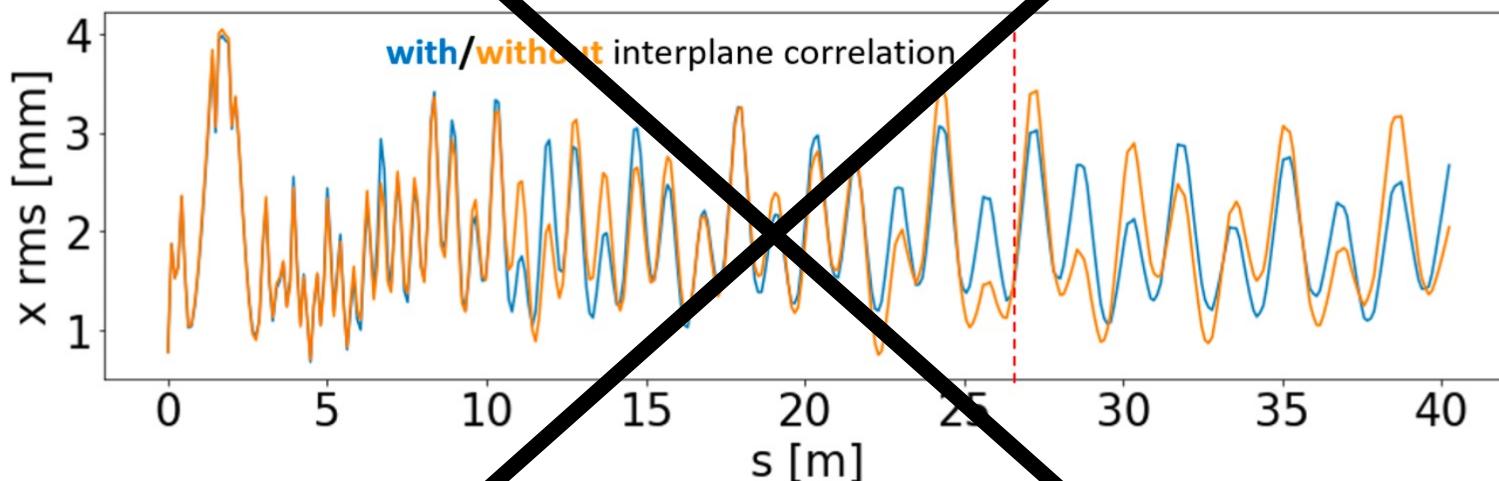
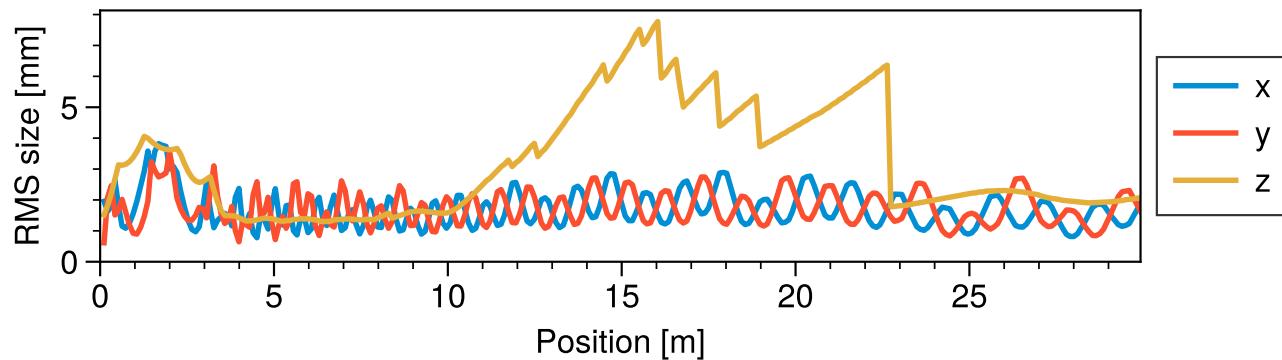
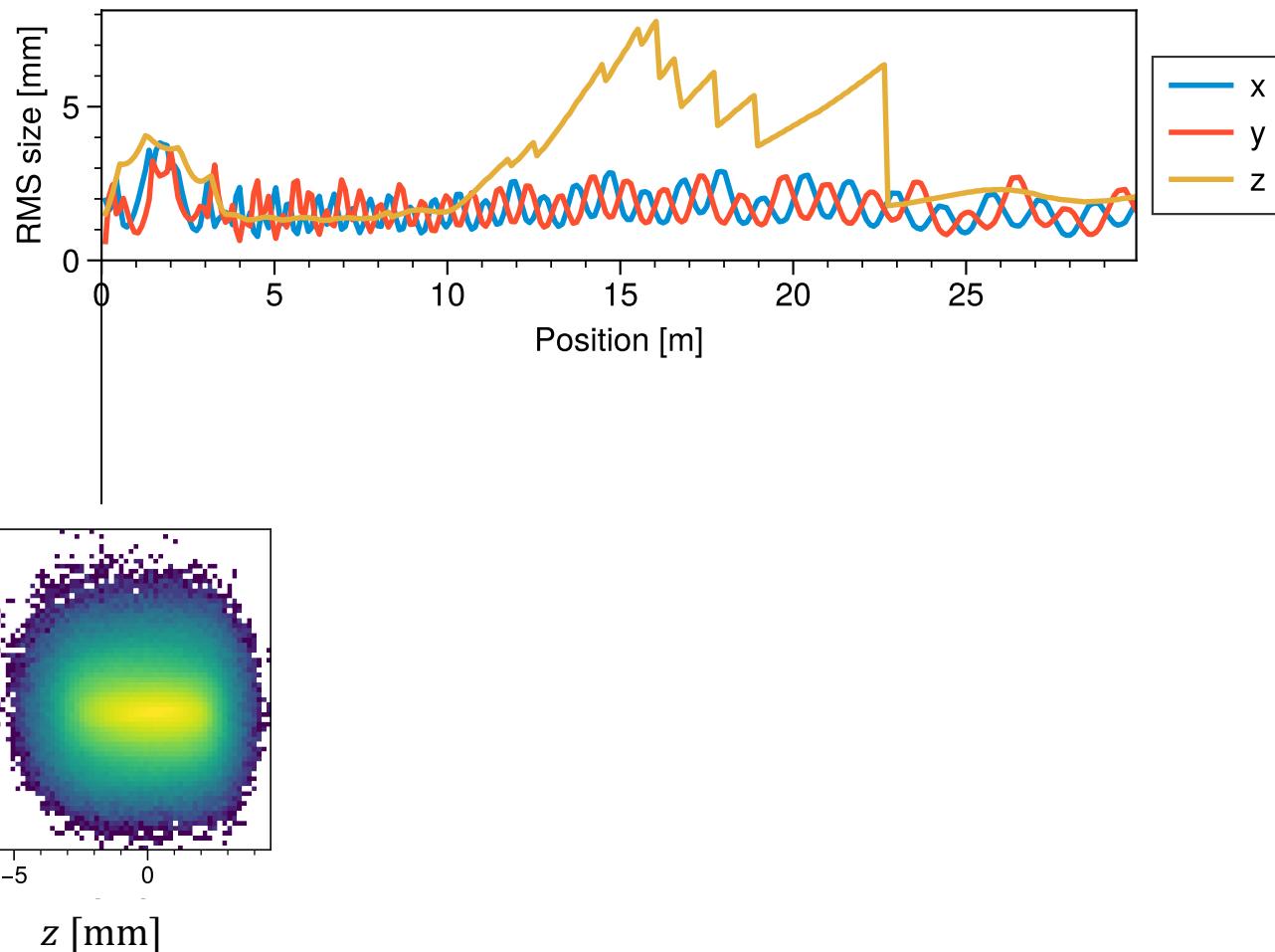


Figure 2: Comparison of horizontal beam size through PyORBIT simulation of SNS MEBT and DTL.

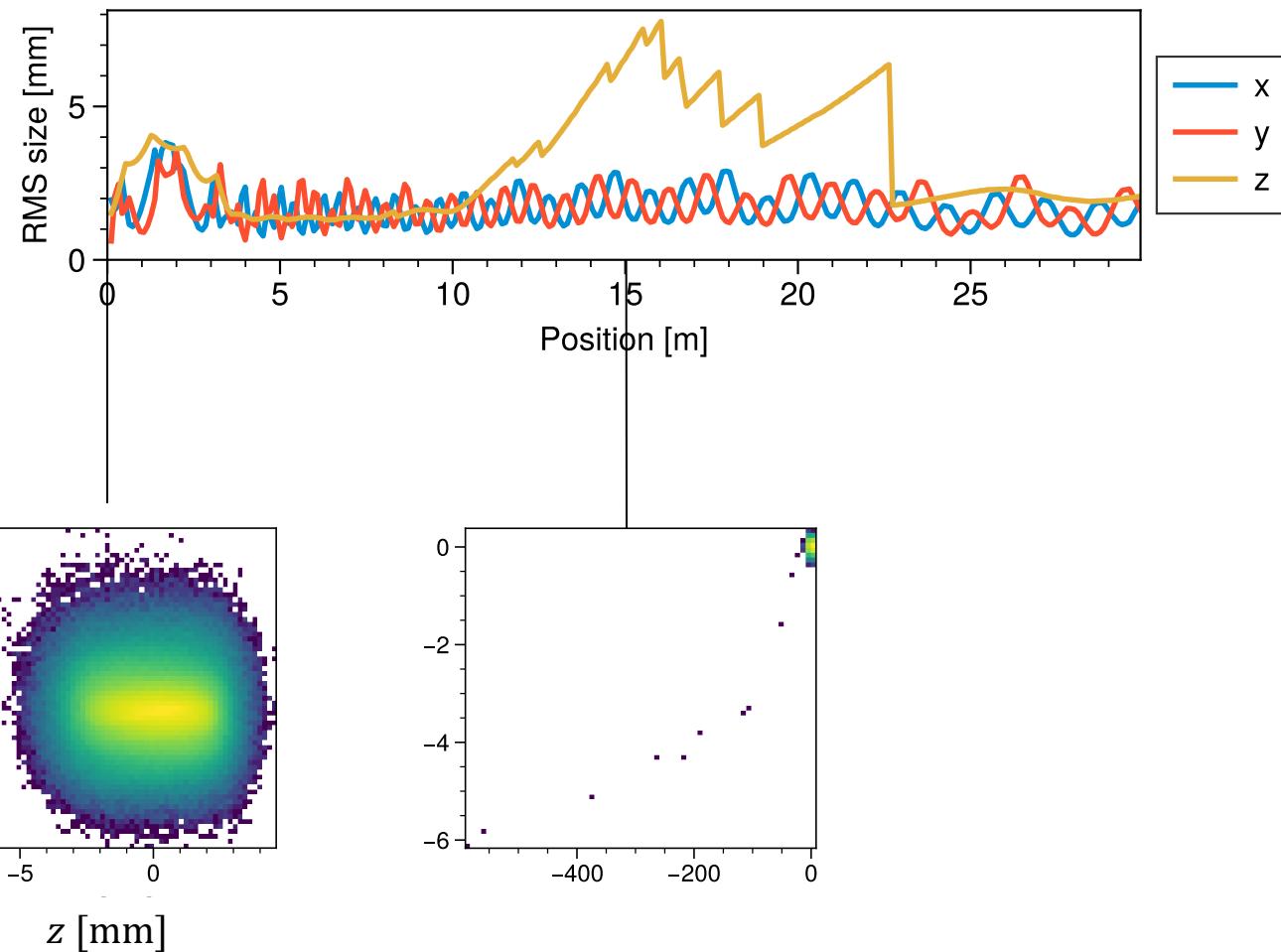
# Some particles escape to infinity



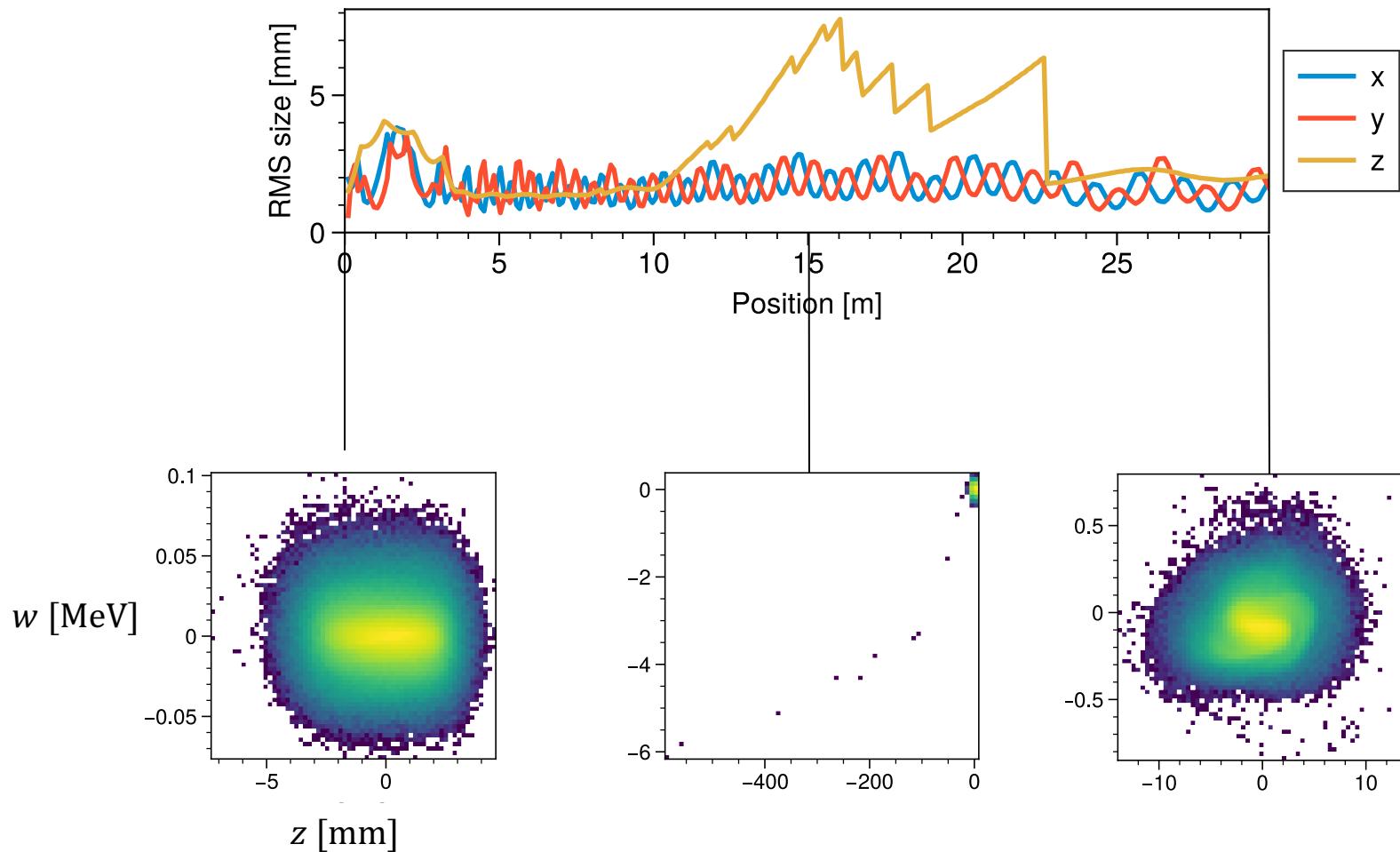
# Some particles escape to infinity



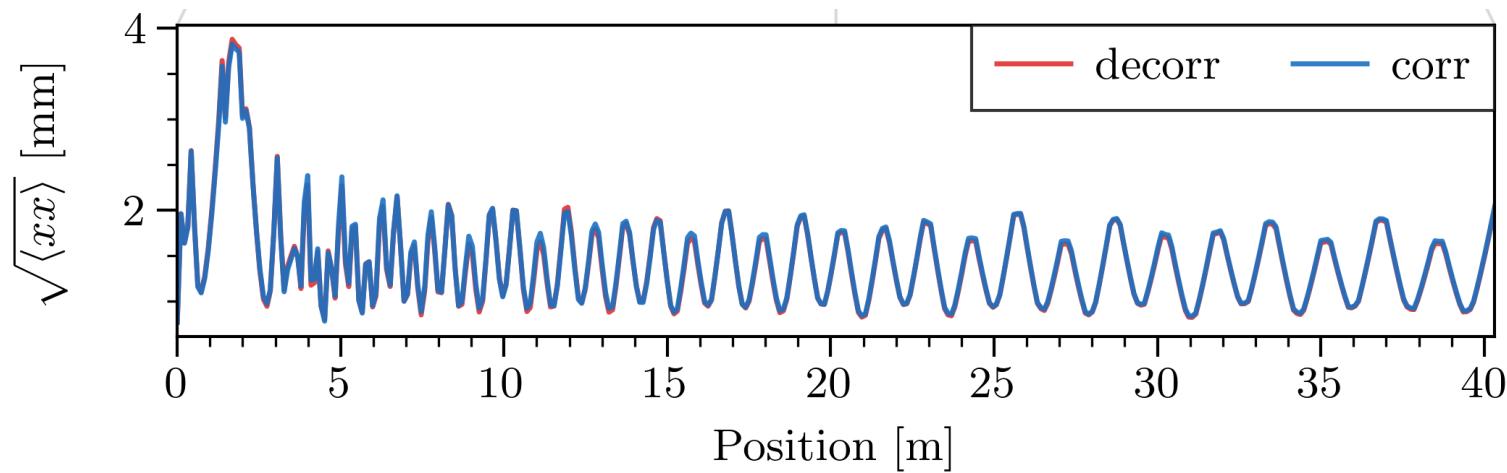
# Some particles escape to infinity



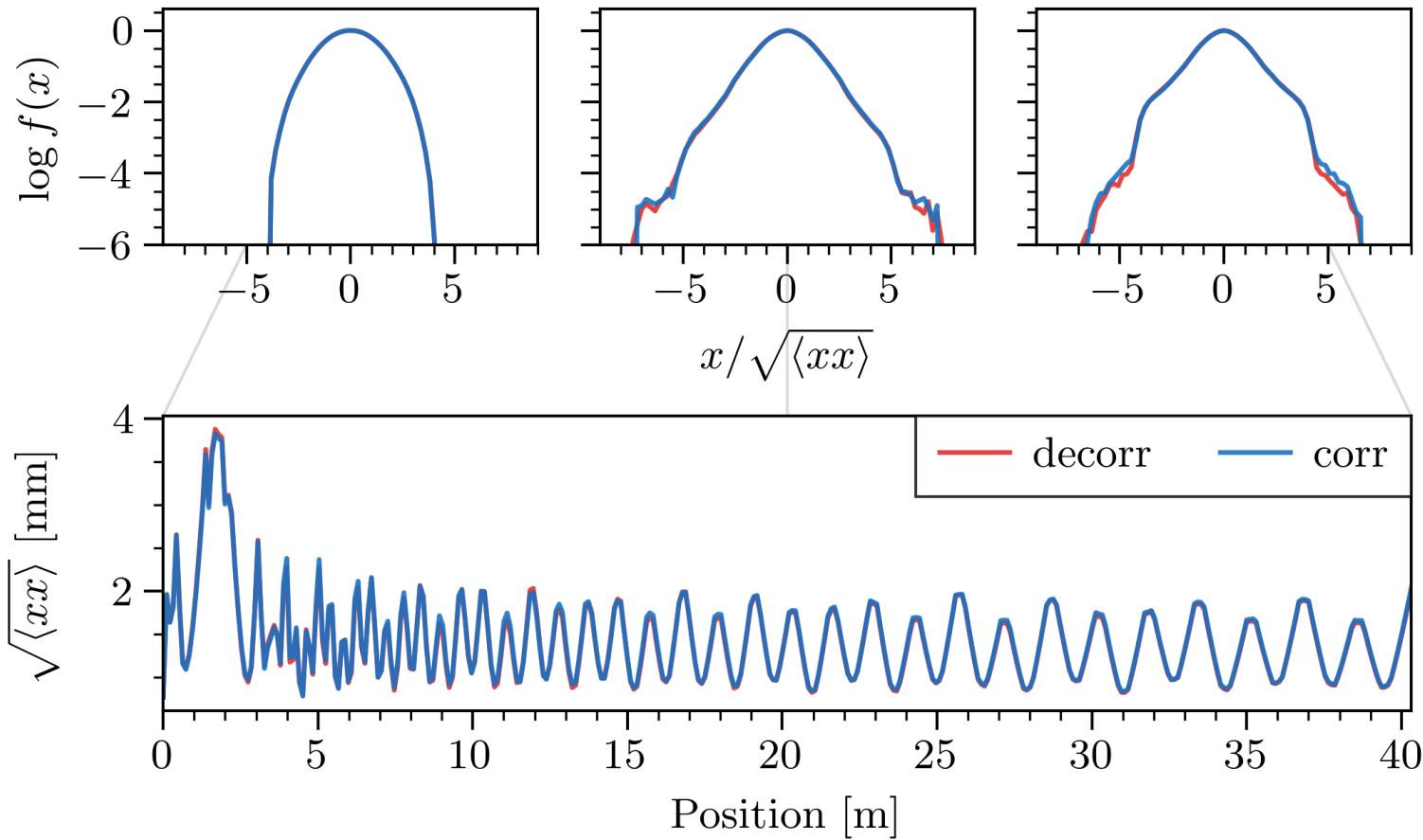
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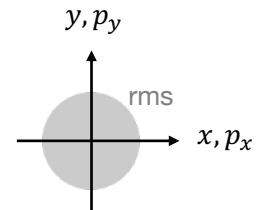


# Adding longitudinal apertures resolves discrepancy



# Adding longitudinal apertures resolves discrepancy



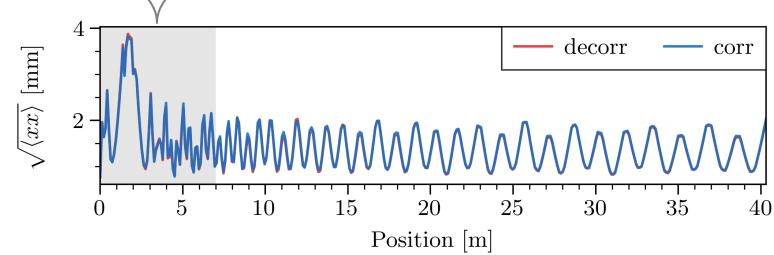
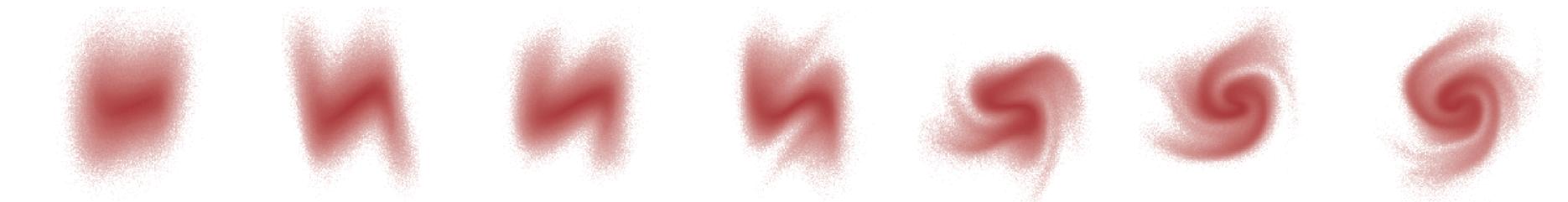


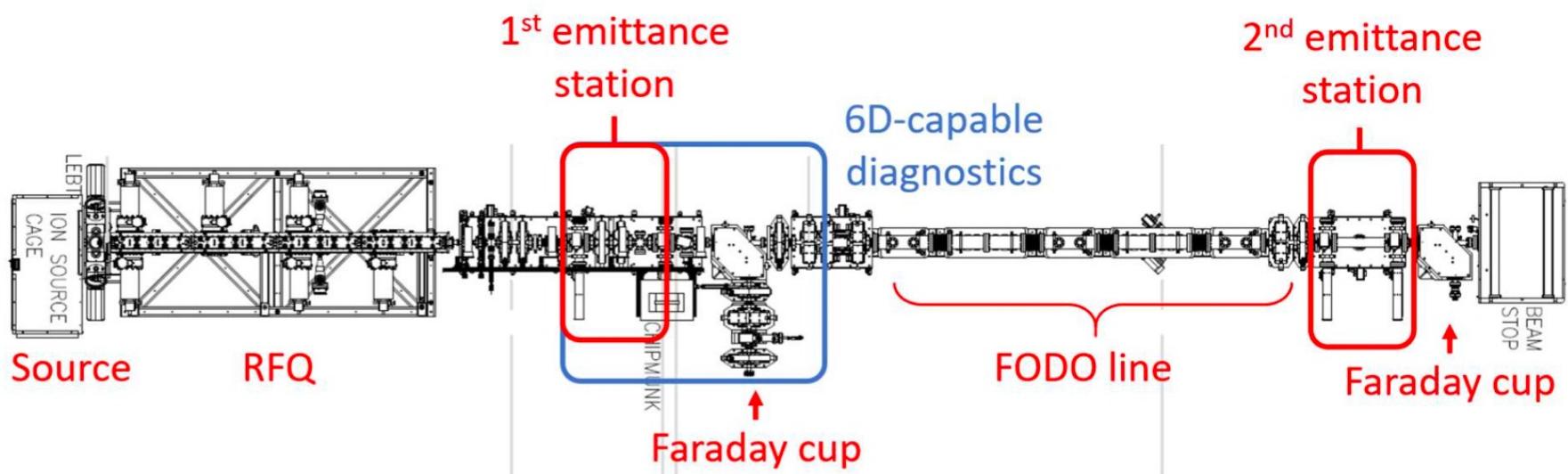
corr

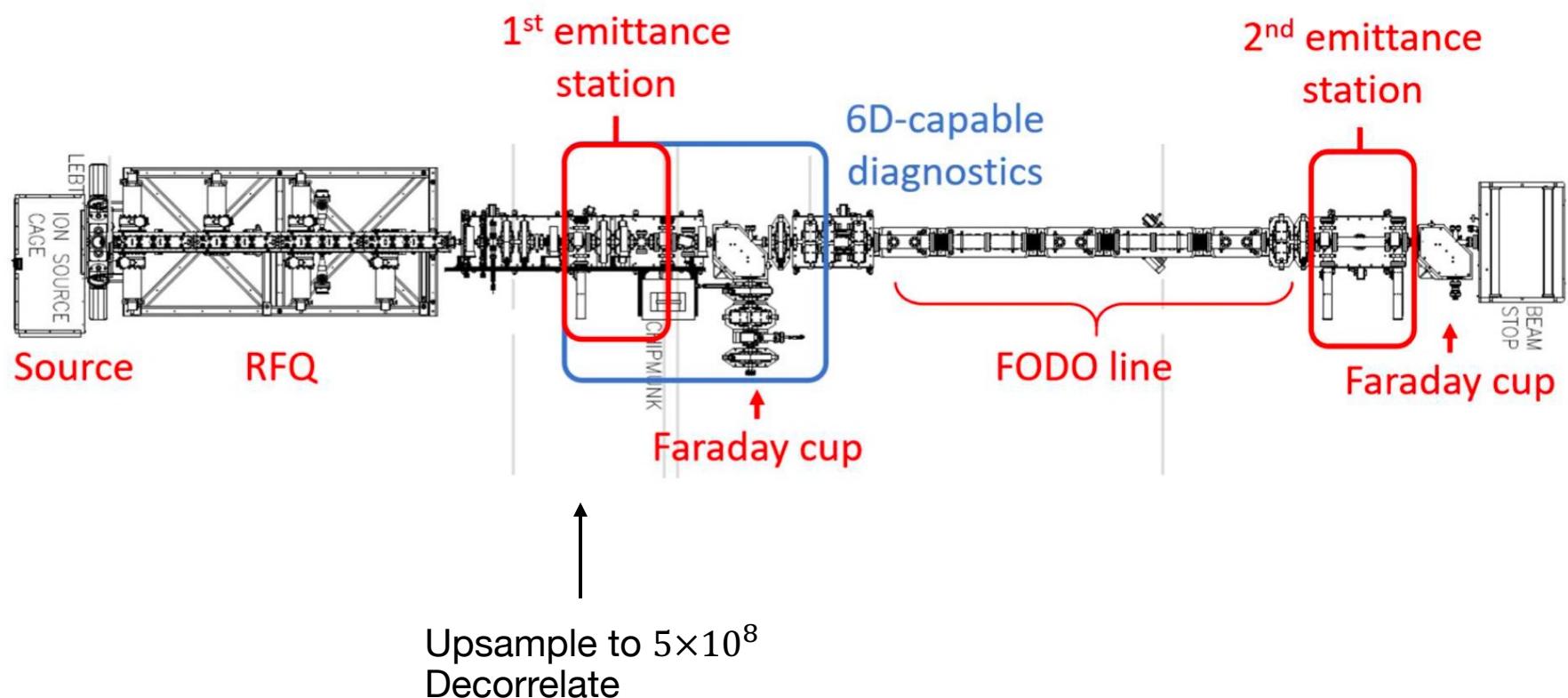


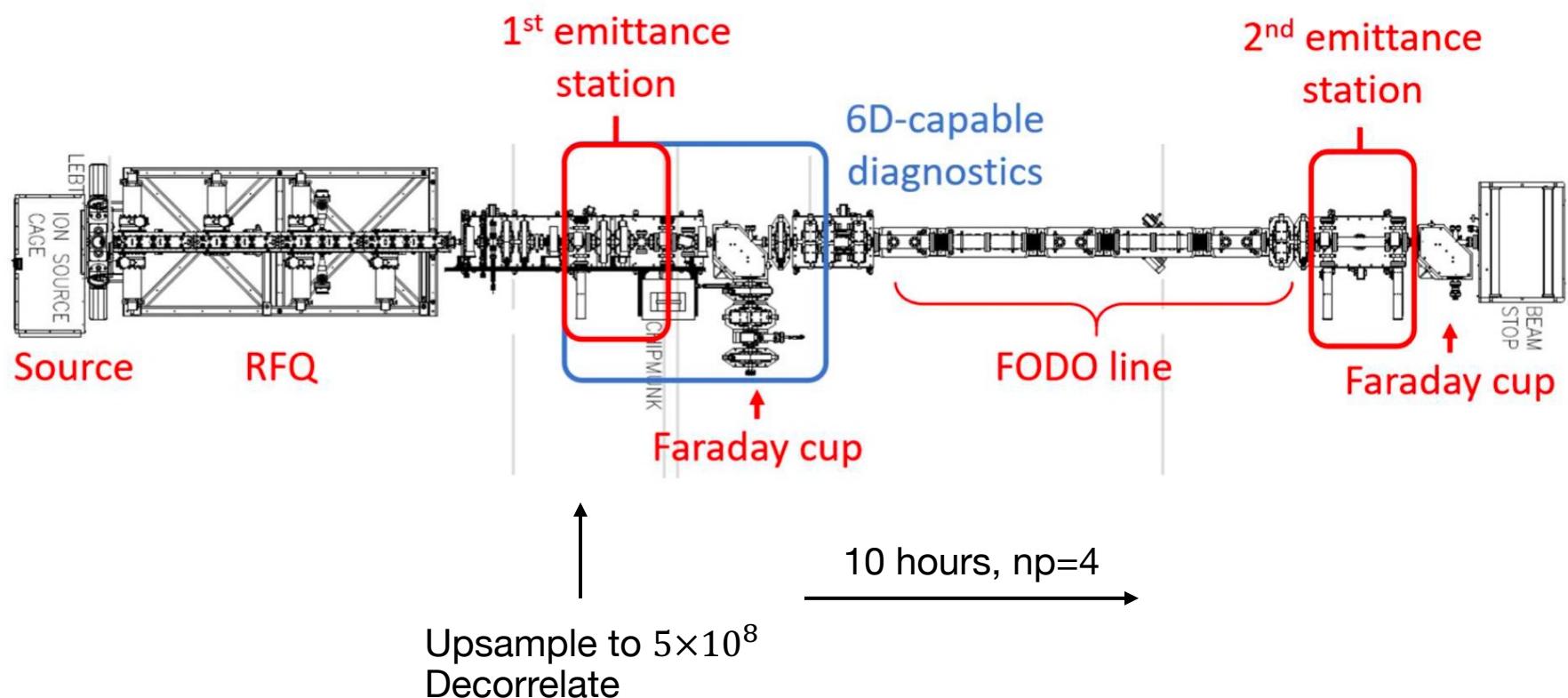
$p_z$

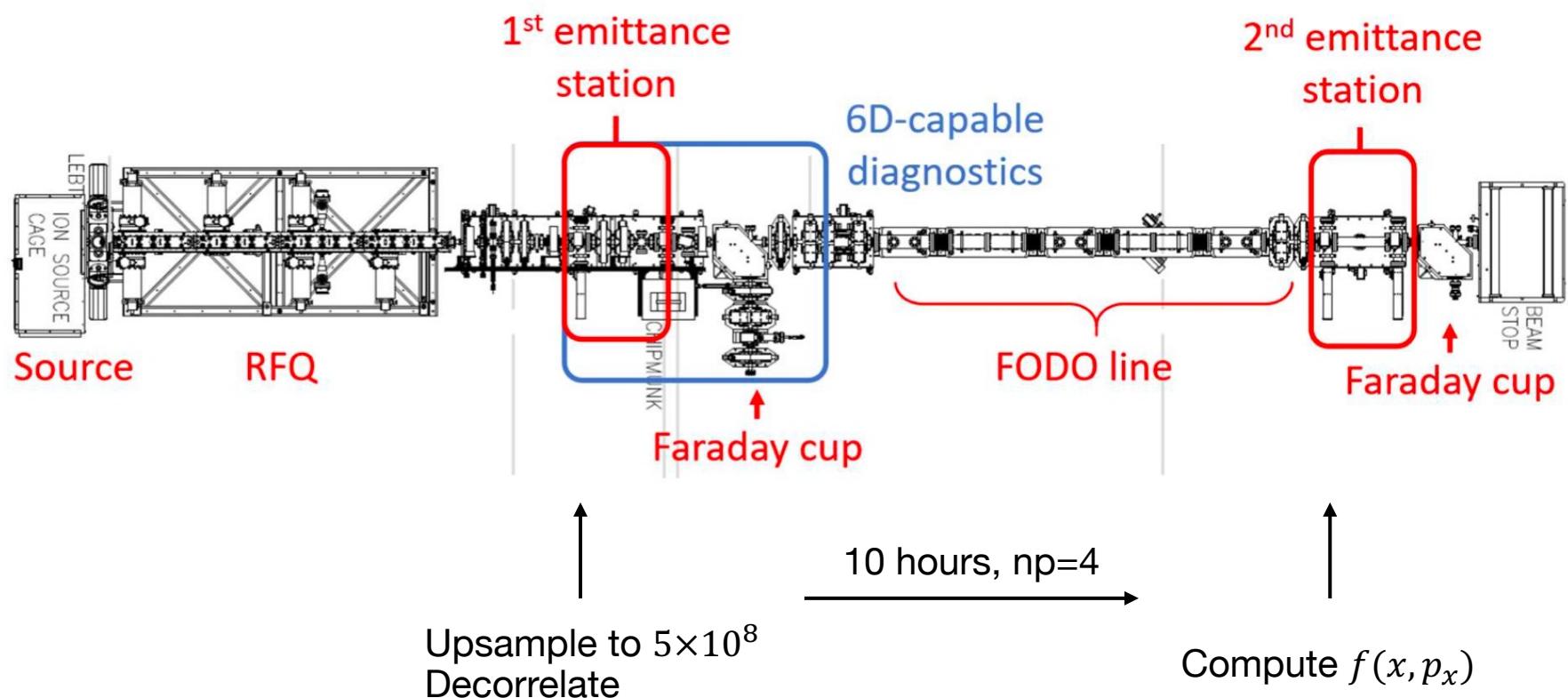
decorr



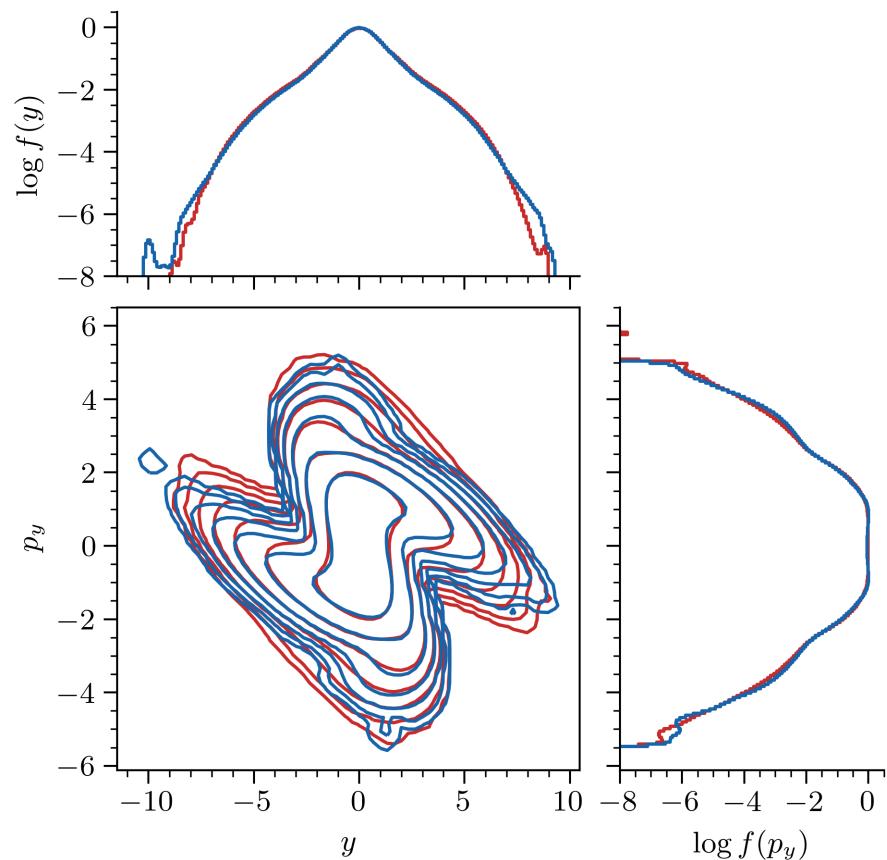
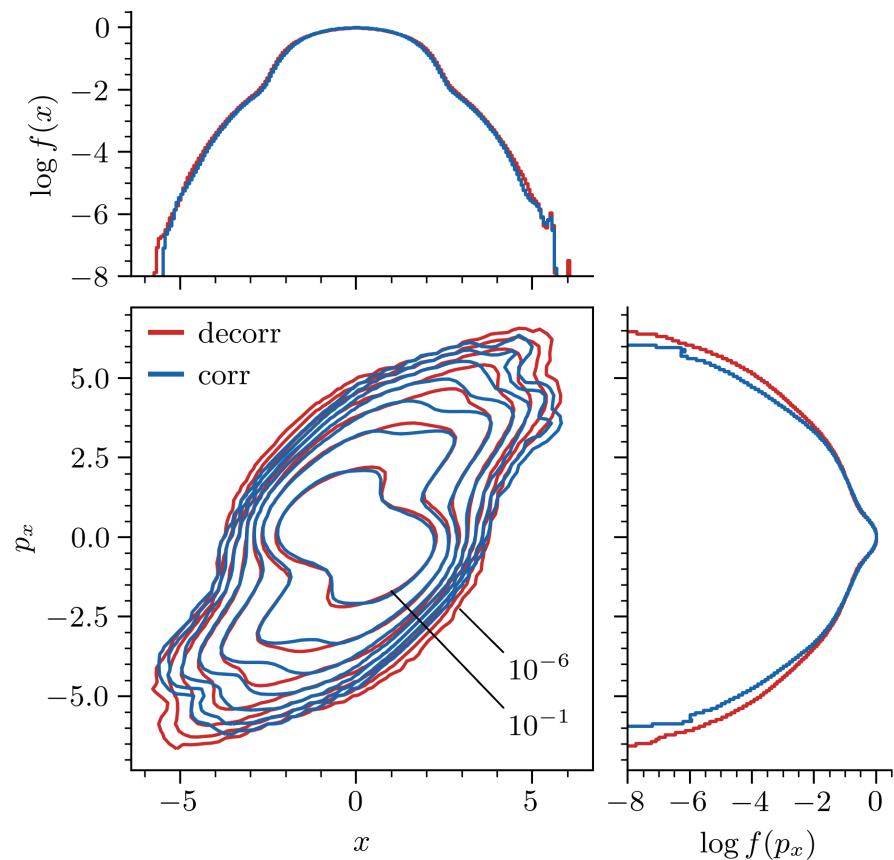




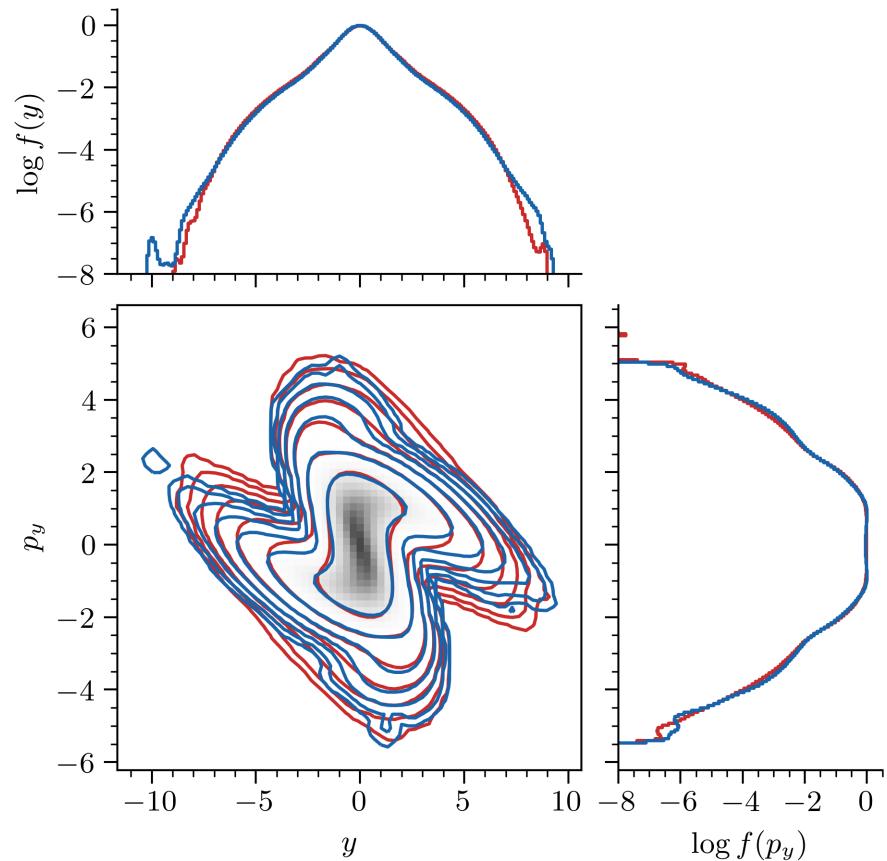
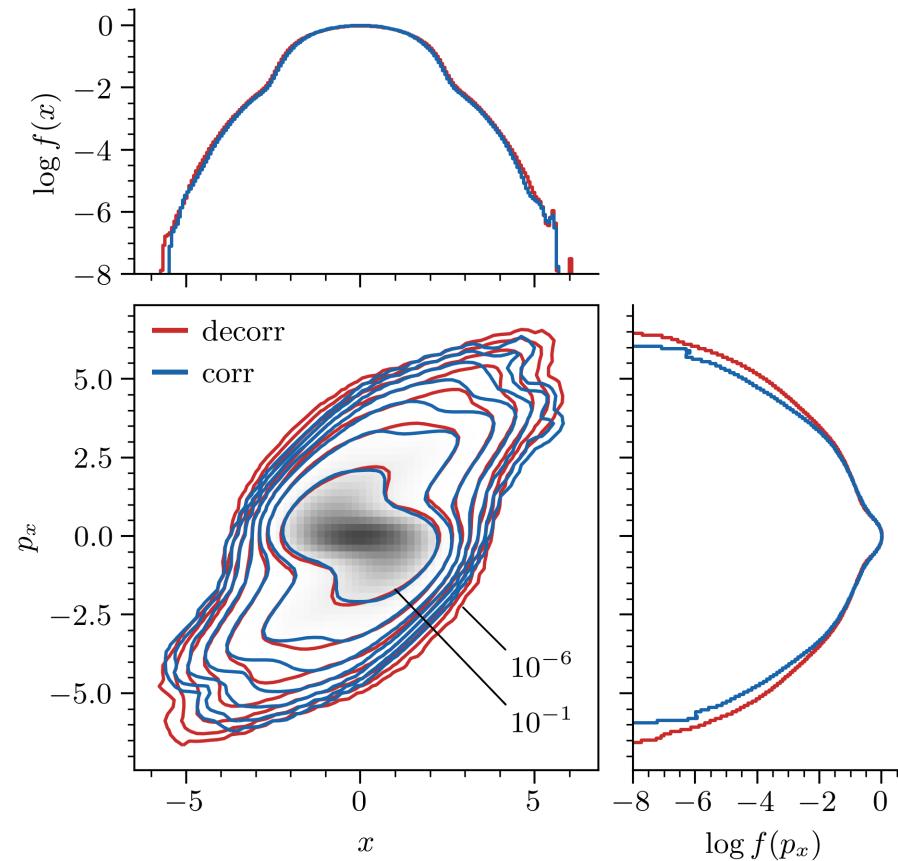




# The impact of inter-plane correlations will be small in the BTF



# Halo distribution is significantly different than core



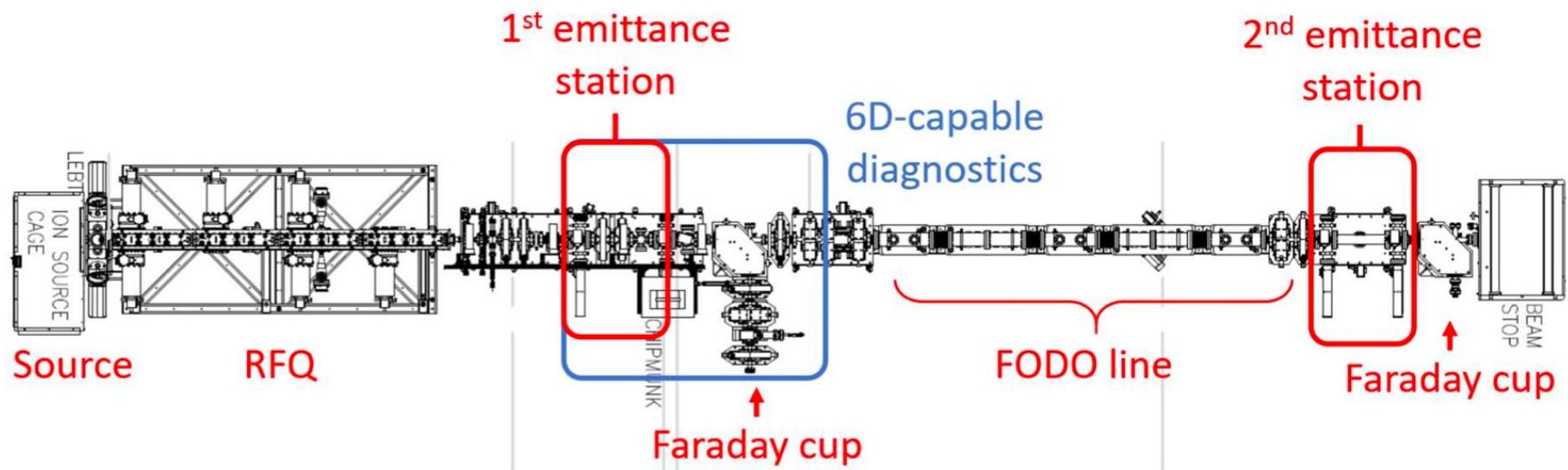
$$\langle x p_x \rangle = \langle y p_y \rangle = 0!$$

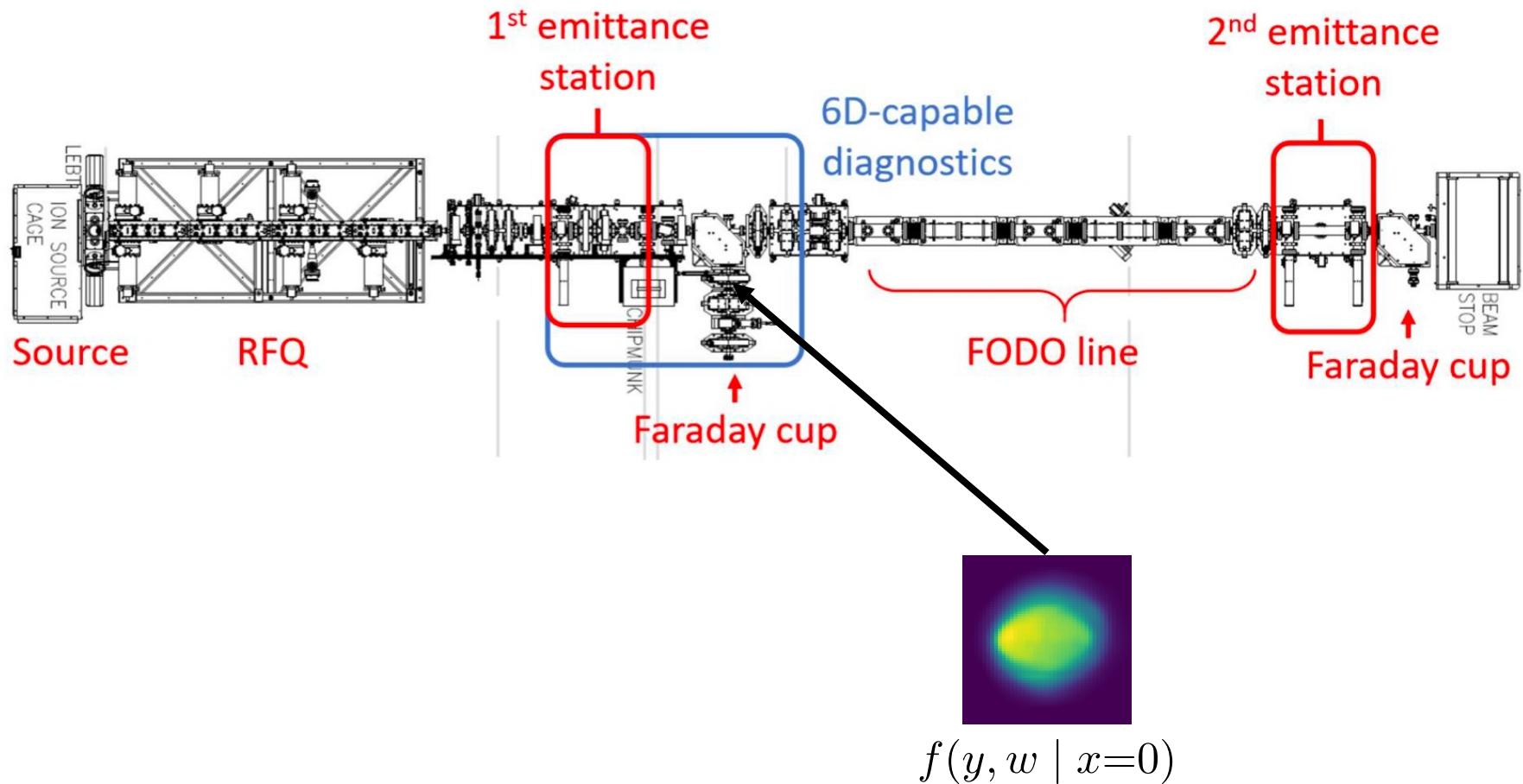
# Conclusions

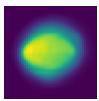
- RFQ model reproduces measured 6D phase space structure.
- Artificial decorrelation should have a small affect on the beam dynamics.
  - (For RFQ, beam current, and measurement location similar to those used in this study.)
  - Lattice model will be important.
- We expect significant halo in the SNS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

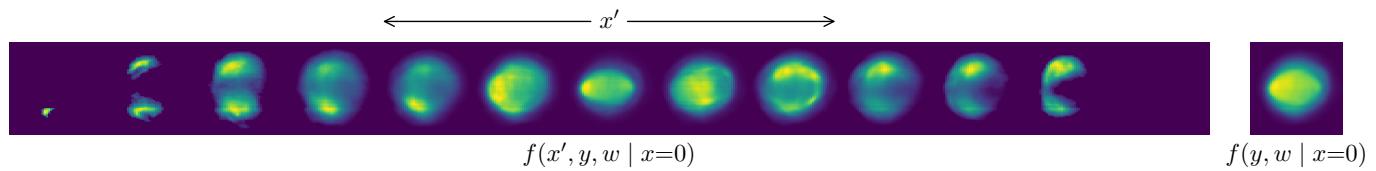
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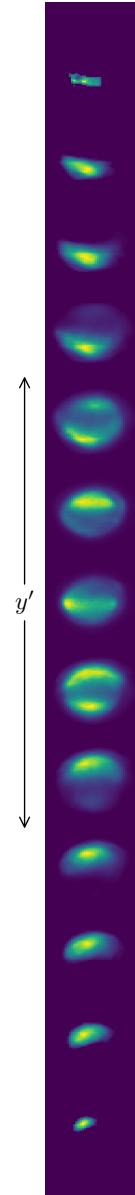




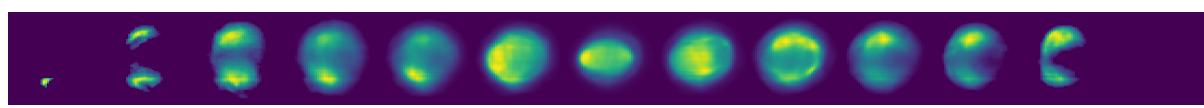
 $f(y, w \mid x=0)$



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



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

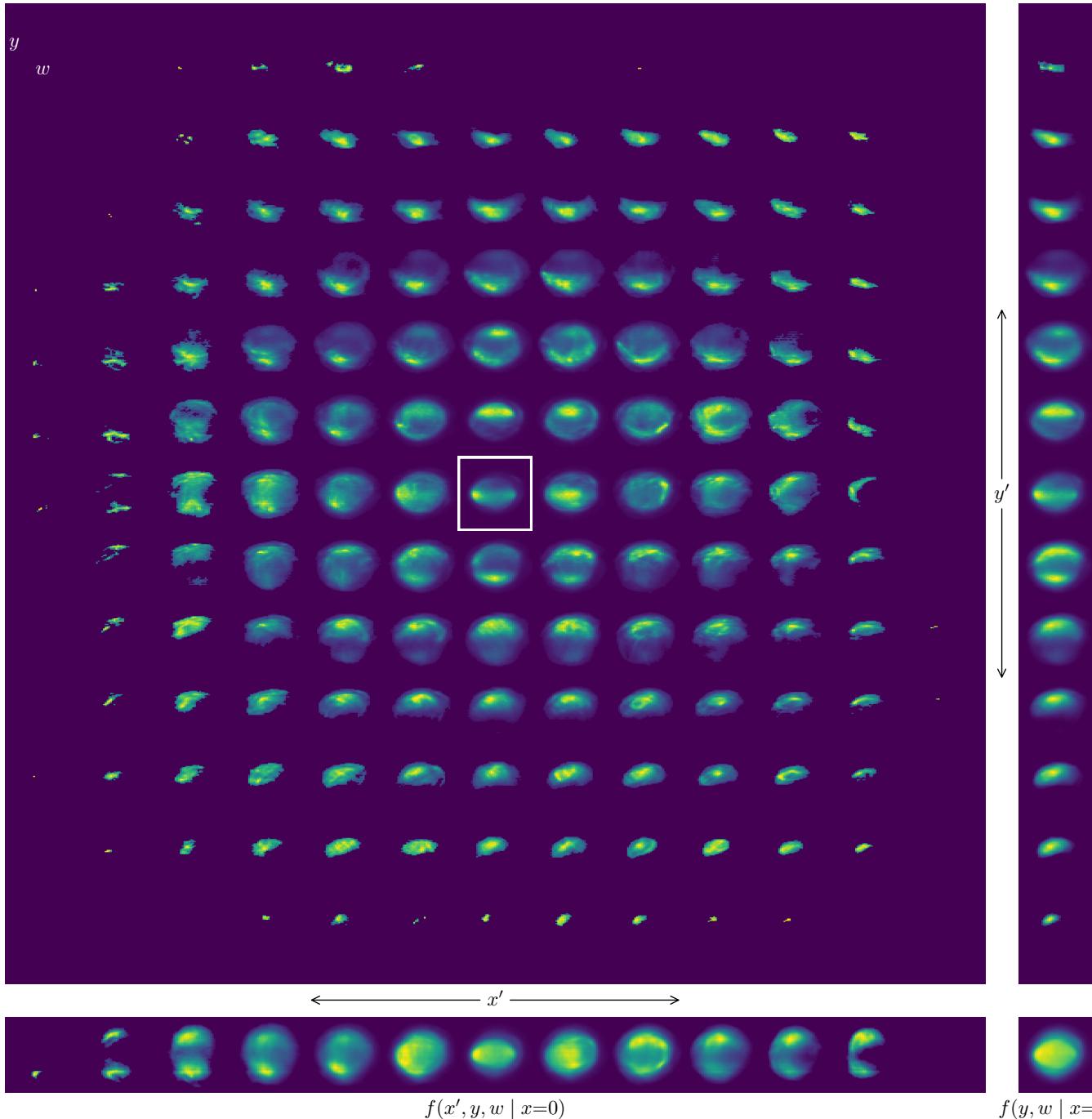


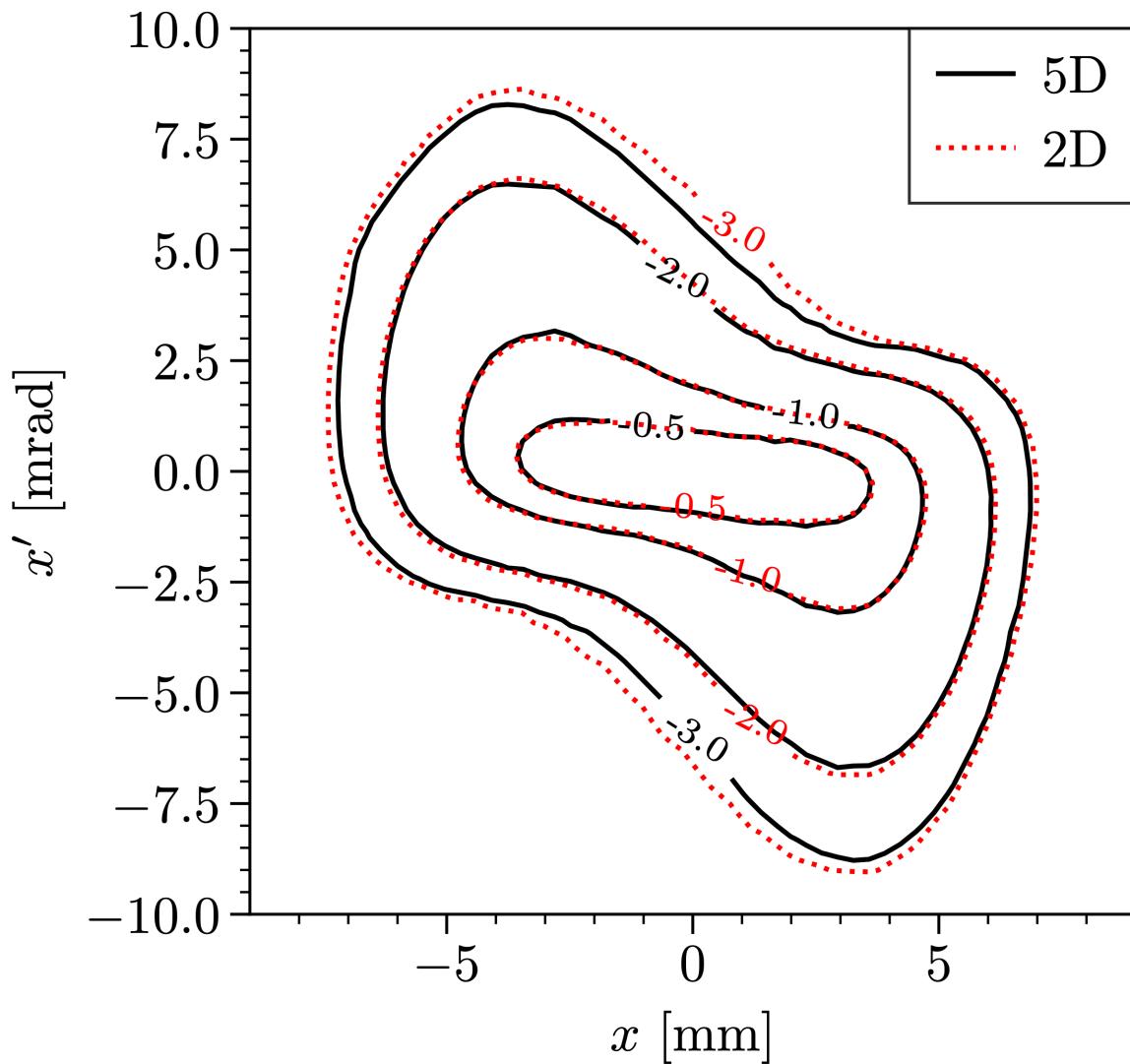
$$f(x', y, w \mid x=0)$$

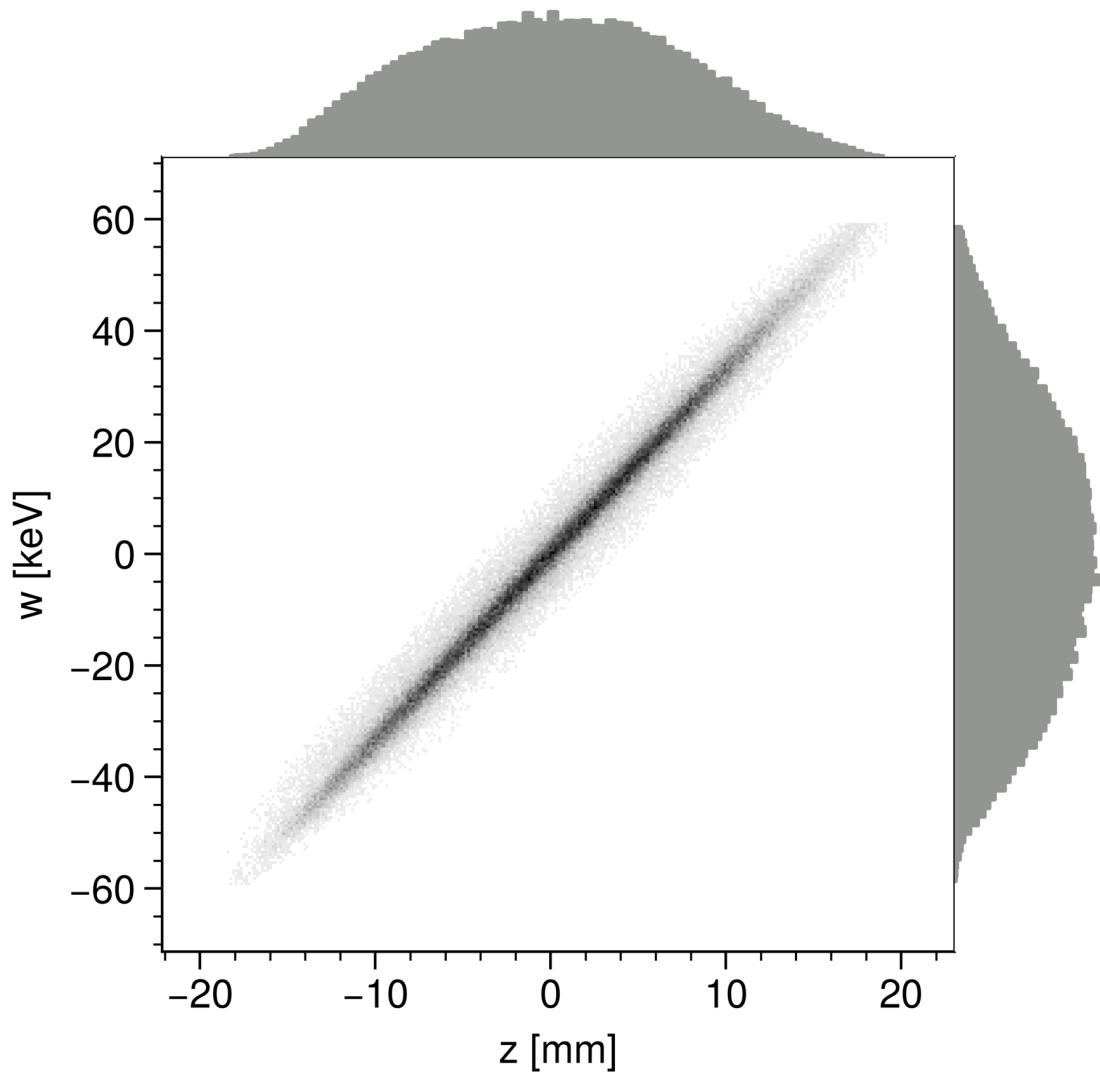
$$f(y, w \mid x=0)$$

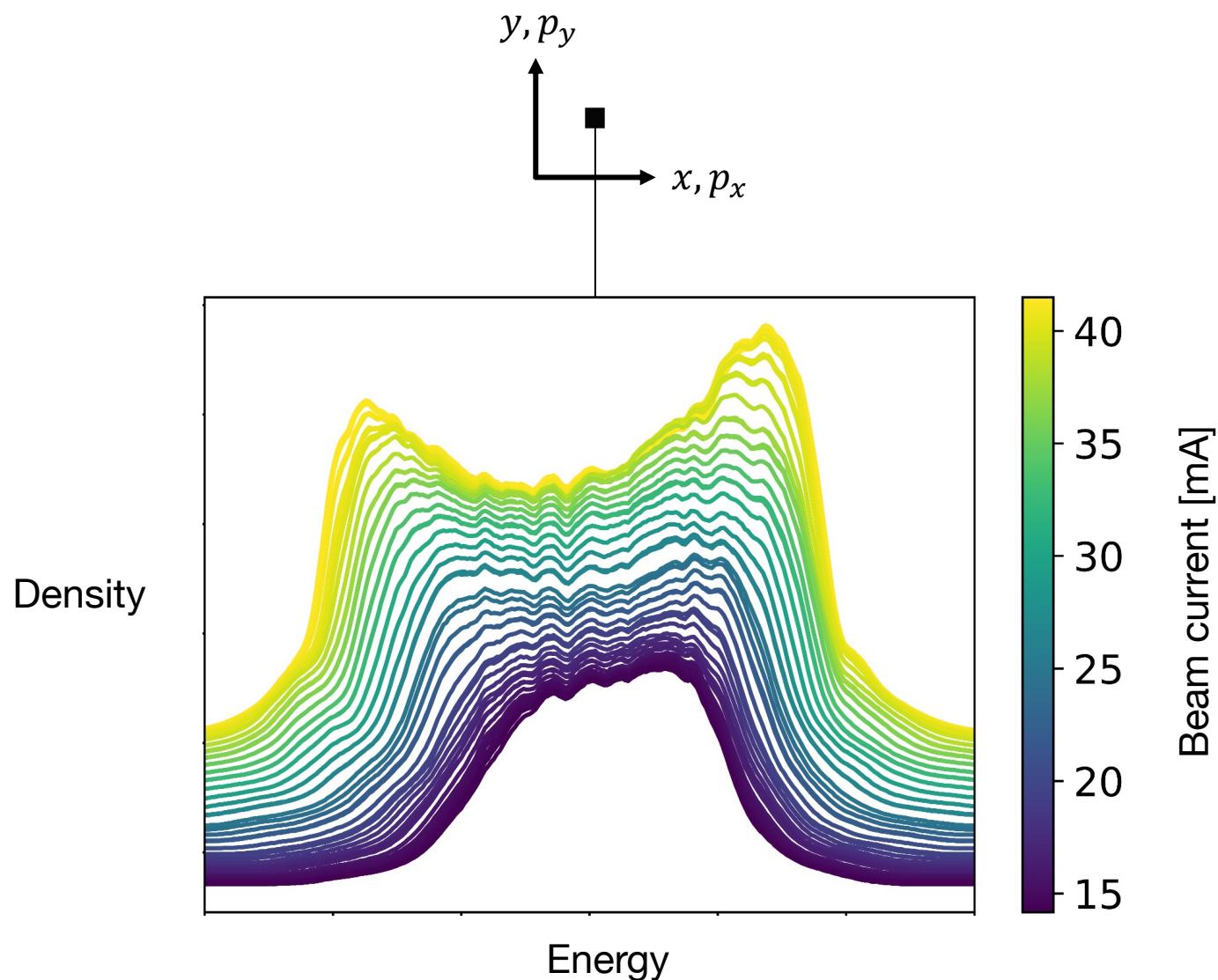
$$f(x', y, y', w \mid x=0)$$

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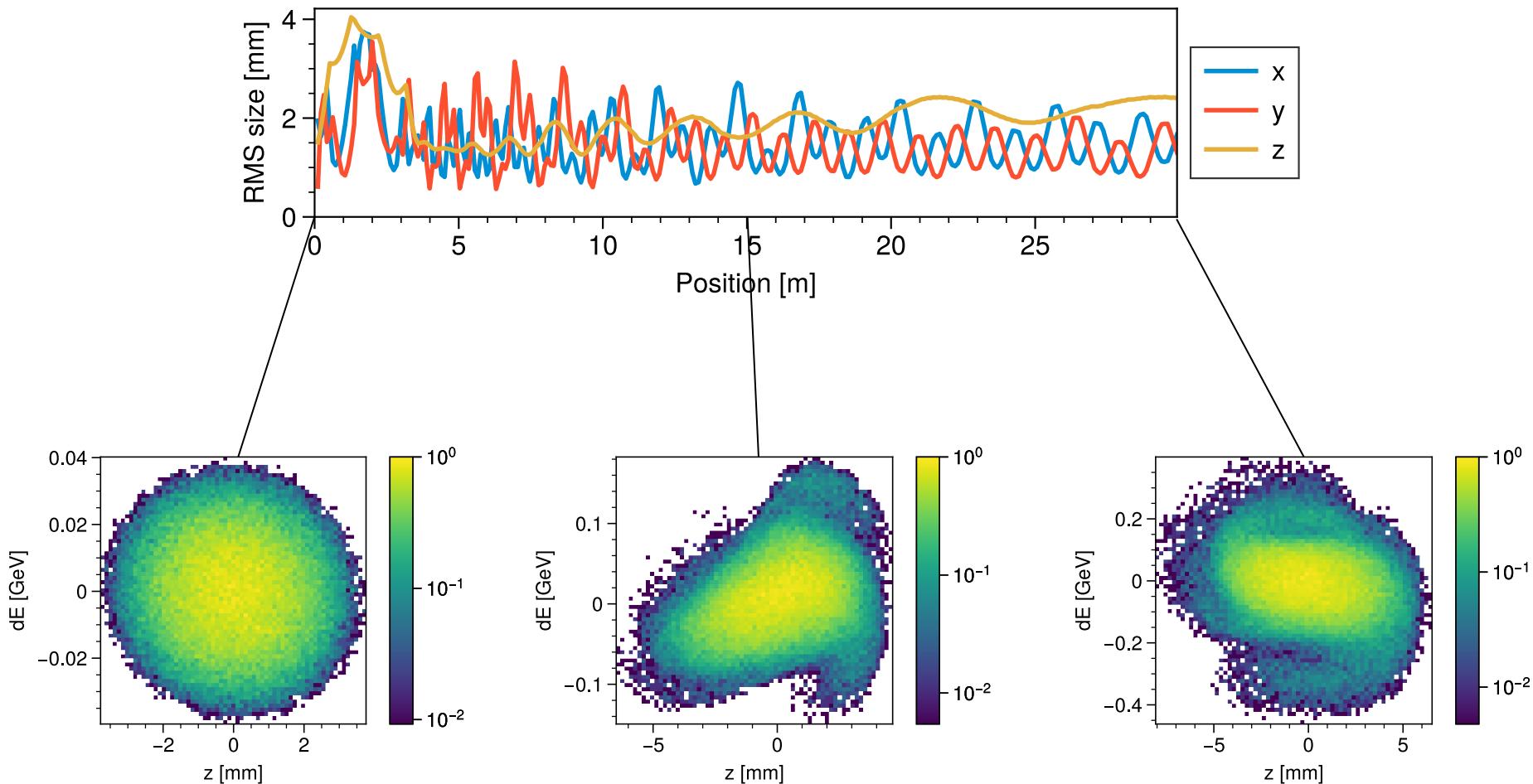








# No particles escape from rms-equivalent Waterbag



# Old BTF layout

