Observation of Current-Driven Features of 2.5 MeV Ion Bunch With Complete and Efficient 5D Measurements at the SNS Beam Test Facility

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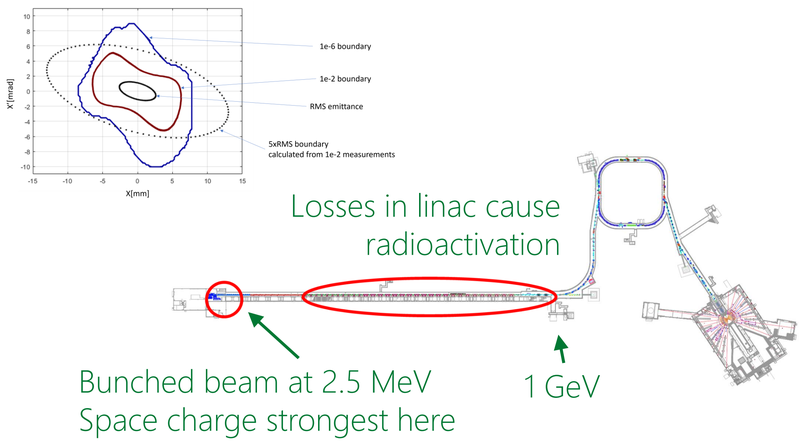
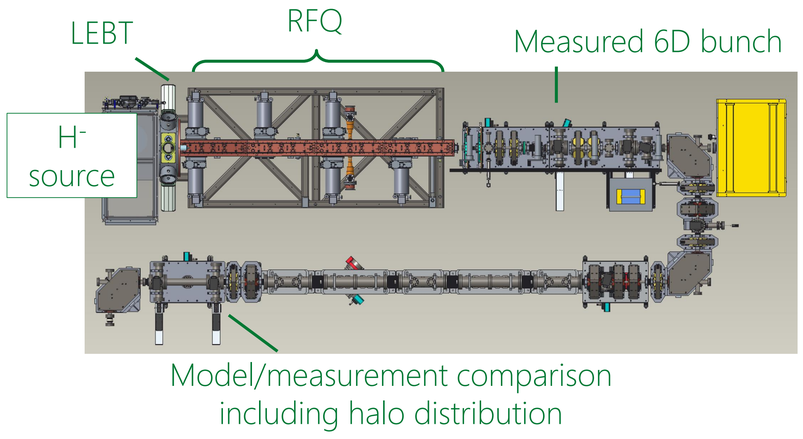
Motivation and Approach

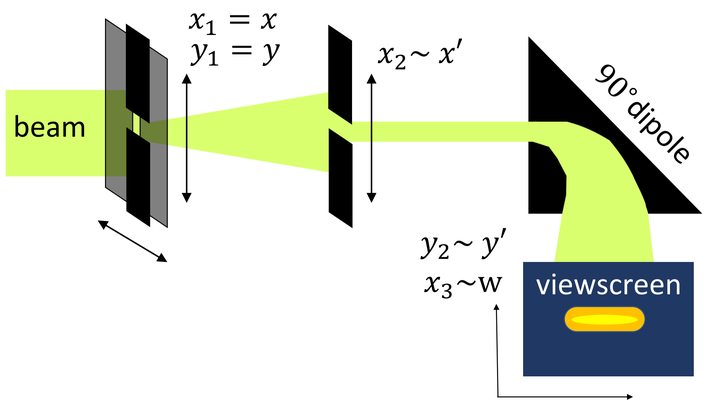


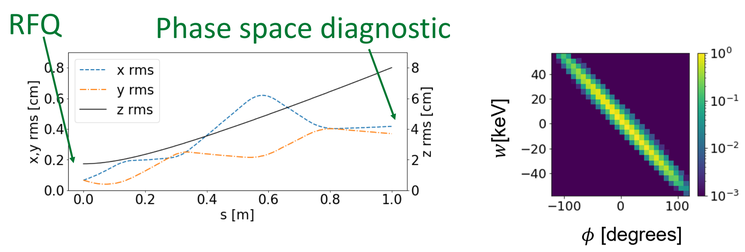
Typical discrepancy in model predictions and measured distributions are above the halo level.[1,2] Better predictive capability will support better accelerator performance. A universal limitation is complete information about the initial beam distribution.



The SNS Beam Test Facility enables advanced diagnosis of beam distributions, including full and direct 6D measurement [3] as well as 2D phase space imaging with resolution of beam halo down to 10^{-6} fractional levels [4].

Method





Beam test facility uses a slit scan method to map high-dimensional distributions of 2.5 MeV H- bunch.

The schematic shows configuration for 5D measurement, $f_{5D} = \int d\phi f(x, x', y, y', \phi, w)$ where $w = E - E_0$

- 3 slits + 2 camera axes = 3D raster scan
- 65x65x65x512x612 grid takes 16 hours at 5 Hz

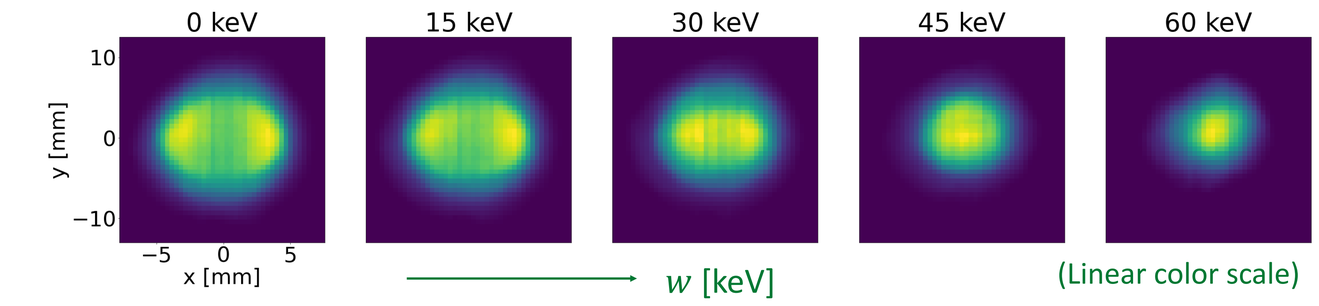
This is a significant performance increase from full 6D:

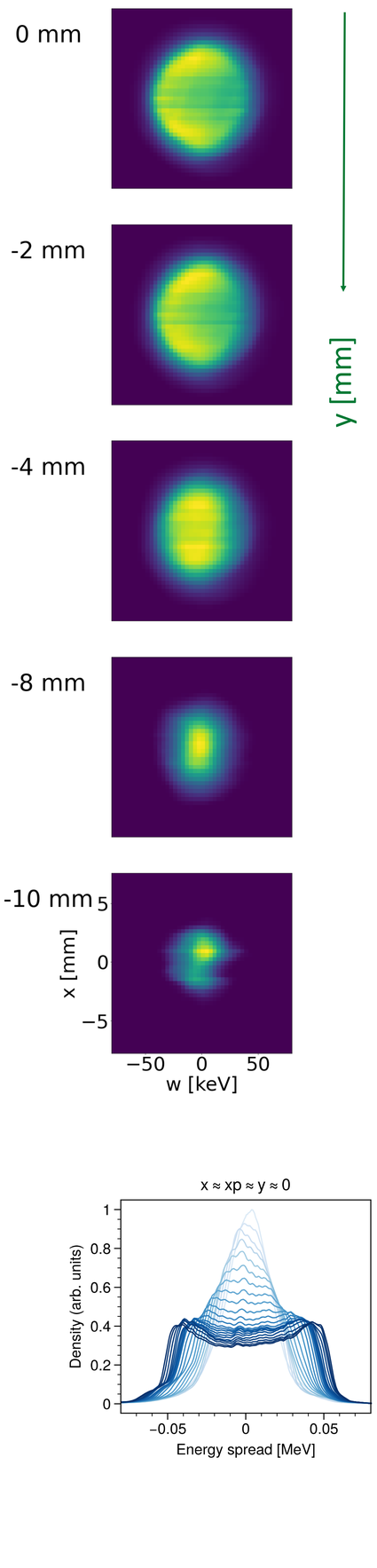
- 4 slits + 1 wire + 1 camera axis = 5D raster scan
- 10x10x32x10x512x12 grid takes 24 hours at 5 Hz

References

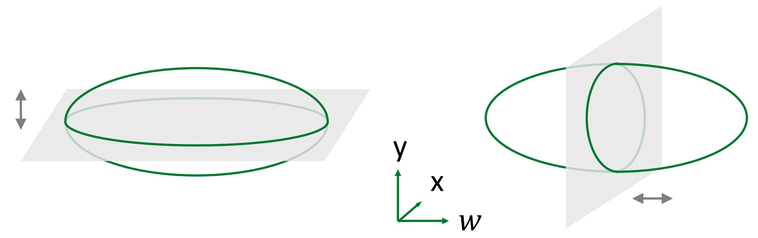
[1] J. Qiang, P.L. Colestock, D. Gilpatrick, H.V. Smith, T.P. Wangler & M.E. Schulze doi: 10.1103/PhysRevSTAB.5.124201
[2] Aleksandrov, A., Cousineau, S., & Ruisard, K. (2020) doi: 10.1088/1748-0221/15/07/P07025
[3] B. Cathey, S. Cousineau, A. Aleksandrov, & A. Zhukov, (2018) doi: 10.1103/PhysRevLett.121.064804.
[4] Aleksandrov, A., Cousineau, S., Ruisard, K., & Zhukov, A. (2021) doi: 10.1016/j.nima.2020.164829
[5] K. Ruisard & A. Aleksandrov, (2021) doi: 10.1103/PhysRevAccelBeams.24.014201.
[6] PARMTEQ; K. R. Crandall & T. P. Wangler, (1988) AIP Conf. Proc., vol. 177, no. 1, pp. 22–28.
[7] PyORBIT; A. Shishlo, S. Cousineau, J. Holmes, & T. Gorlov, (2015) doi: 10.1016/j.procs.2015.05.312.

Measurements of SNS 2.5 MeV H- bunch reveals core hollowing

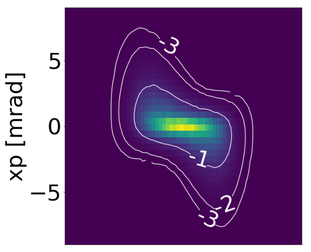




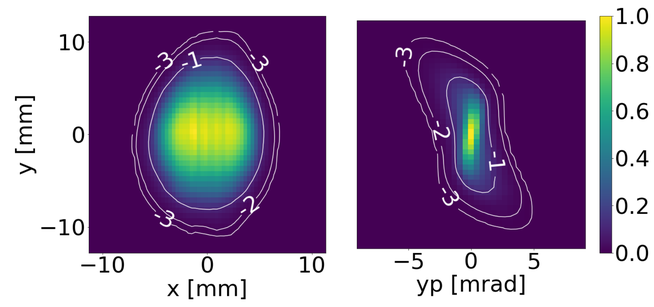
Beam distribution shown here was measured at 26 mA RFQ output current, on a grid of size 43x43x43x512x612.

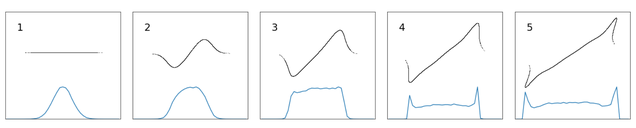


Slices through measured distribution reveal space-charge driven hollowing in beam core.
Slices have width $\delta w = 2$ keV, $\delta y = 0.2$ mm.



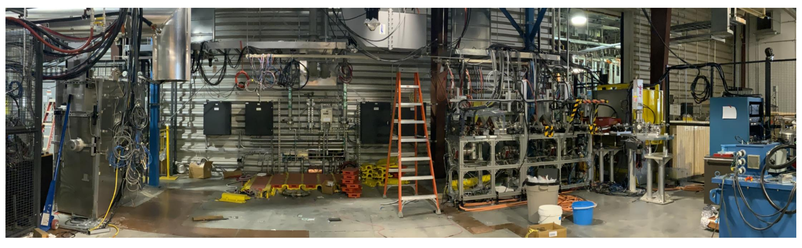
Internal hollowing is obscured in fully projected views. (logarithmic contours)



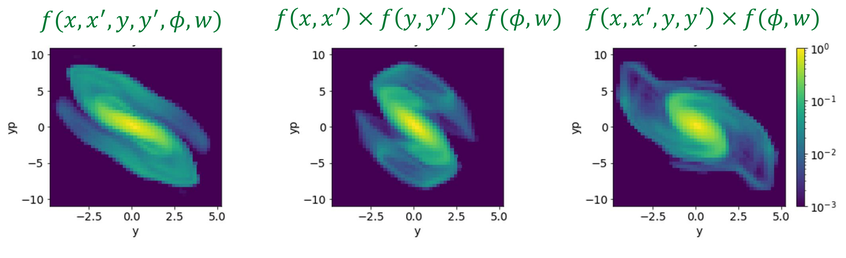


Hollowing is observed to be dependent on beam current (see Ref [3]). This can be understood as a signature of space charge nonlinear forces (above reproduced from Ref [5])

Outlook + Future Work



Commissioning of new RFQ will enable access to higher bunch charge via better transmission, 60→ 80% (35 →50 mA)



De-correlating the planes in the initial bunch produces very different predictions at end of SNS drift tube linac.

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