RESULTS FROM THE 6D DIAGNOSTICS TEST BENCH AT SNS

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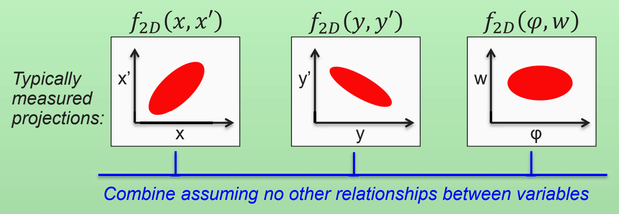
LINAC18

Phase Space Measurements

The conventional psuedo-6D approach:

Measure projections and use them to reconstruct a 6D distribution:



$$f_{3*2D} = f_{2D}(x,x') * f_{2D}(y,y') * f_{2D}(\varphi,w)$$

But this is not a complete 6D distribution:

$$f_{2D}(x,x') * f_{2D}(y,y') * f_{2D}(\varphi,w) \neq f_{6D}(x,x',y,y',\varphi,w)$$

Assumes all cross-terms = 0

Includes cross-terms: $[(x,y),(x,y'),(x,\varphi),(x,w),(y,x')\ldots]$

The cross-terms may be important for accurate simulations: skew or solenoid magnets, space charge.

A 6D phase space measurement is necessary to determine the existence of cross-terms.

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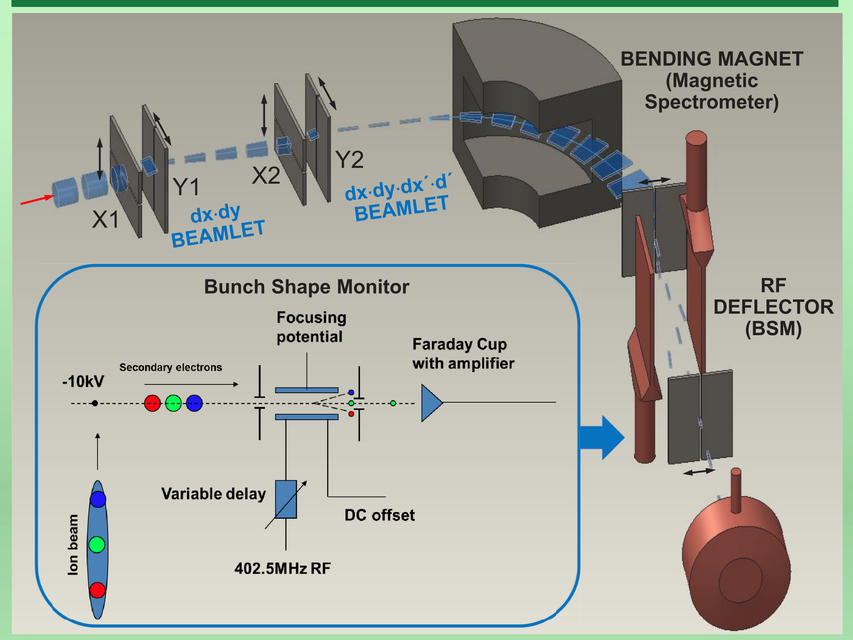
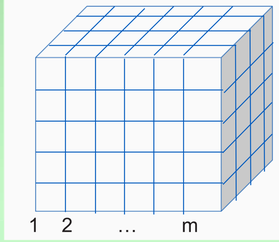
6D Measurement



"The Curse of Dimensionality"



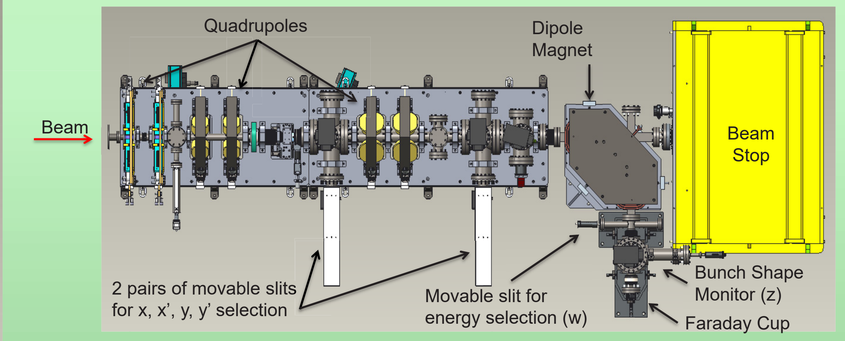
$$N_{bins} \sim m^{D}$$

For a course measurement: $D \sim 6$, $m \sim 10$ $\rightarrow N_{bins} \sim 10^{6}$

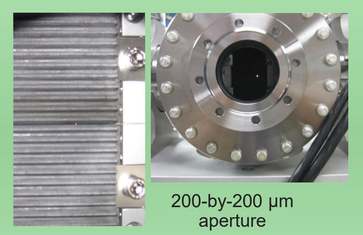
Scan rate 1 step/sec: 10^6 sec = 280 hrs
Scan rate 10 step/sec: 10^5 sec = 28 hrs

The measurement is feasible with enough time.
A dedicated facility is ideal.

The Beam Test Facility



Particles	H^-
Energy	2.5 MeV
Current	< 50 mA
Pulse width	< 1 ms
Rep rate	< 60 Hz (10 Hz)
Beam Power	< 7.5 kW



200-by-200 μm aperture

Screens allow for an entire dimension to be measured at once.

800 μm aperture in luminescent energy screen:

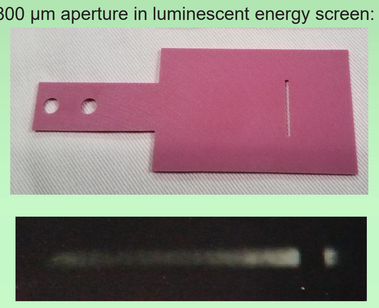
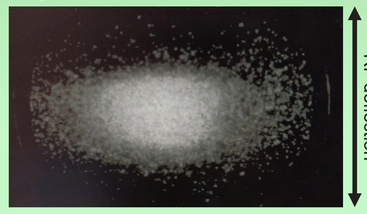
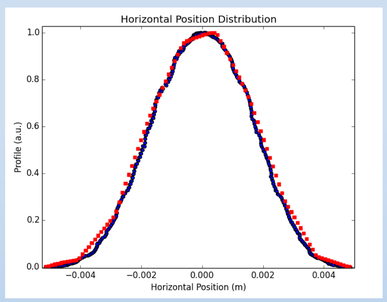


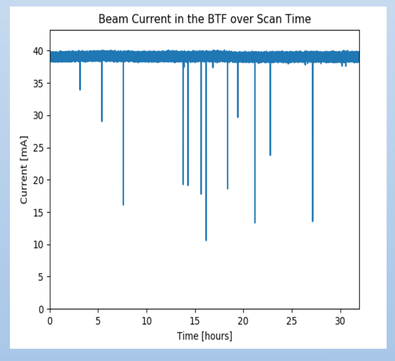
Image from Bunch Shape Monitor screen:



Reliability



The BTF made multidimensional measurements for almost a year. During that time, scans remained consistent, even between scans of different dimensionalities.



The SNS accelerator is very stable and quickly recovers from trips. This BTF is a function duplicate of the SNS Front End so it also retains these qualities.

Interpolation

$p(w_1, y'_1, x'_1, y_1, x_1) = f_{1,1,1,1,1}(\phi)$
$p(w_1, y'_1, x'_1, y_1, x_2) = f_{1,1,1,1,2}(\phi)$
$\vdots$
$p(w_1, y'_1, x'_1, y_2, x_e) = f_{1,1,1,2,e}(\phi)$
$\vdots$
$p(w_a, y'_b, x'_c, y_d, x_e) = f_{a,b,c,d,e}(\phi)$

Interpolate over each set of x

$p(w_1, y'_1, x'_1, y_1) = f_{1,1,1,1}(x, \phi)$
$p(w_1, y'_1, x'_1, y_2) = f_{1,1,1,2}(x, \phi)$
$\vdots$
$p(w_1, y'_1, x'_2, y_d) = f_{1,1,2,d}(x, \phi)$
$\vdots$
$p(w_a, y'_b, x'_c, y_d) = f_{a,b,c,d}(x, \phi)$

Interpolate over each set of y

$p(w_1, y'_1, x'_1) = f_{1,1,1}(x, y, \phi)$
$p(w_1, y'_1, x'_2) = f_{1,1,2}(x, y, \phi)$
$\vdots$
$p(w_1, y'_2, x'_c) = f_{1,2,c}(x, y, \phi)$
$\vdots$
$p(w_a, y'_b, x'_c) = f_{a,b,c}(x, y, \phi)$

Interpolate over each set of x'

$p(w_1, y'_1) = f_{1,1}(x, y, x', \phi)$
$p(w_1, y'_2) = f_{1,2}(x, y, x', \phi)$
$\vdots$
$p(w_2, y'_b) = f_{1,b}(x, y, x', \phi)$
$\vdots$
$p(w_a, y'_b) = f_{a,b}(x, y, x', \phi)$

Interpolate over each set of y'

$p(w_1) = f_1(x, y, x', y', \phi)$
$p(w_2) = f_2(x, y, x', y', \phi)$
$\vdots$
$p(w_a) = f_b(x, y, x', y', \phi)$

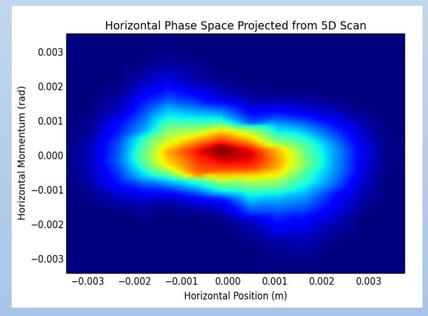
Interpolate over w

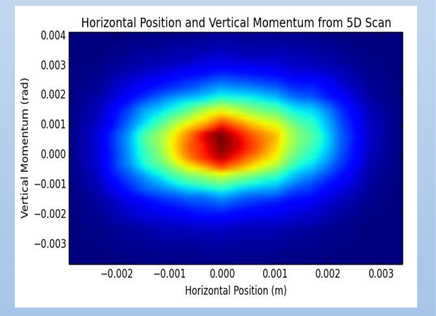
$f(x, y, x', y', w, \phi)$

- Data is too sparse for distribution generation.
- Regular gridding will help with analysis.
- Data size can easily get over a gigabyte.

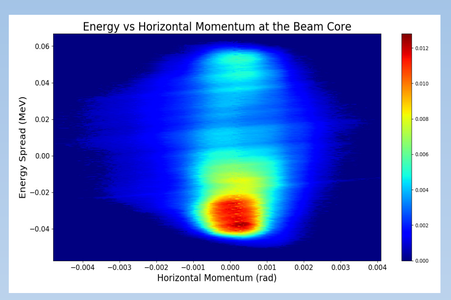
Results

Typical Scan Results	One Dimension	Two Dimensions	Four Dimensions (x, y, x', y')	Five Dimensions (x, y, x', y', E)	Six Dimensions
Time (Example)	< one minute	~ 10 minutes	4 hrs 50 min	4 hrs 40 min	32 hrs
Data Points (Example)	~50	~1300	~88000	~2.5×10^9	~5.6×10^6
Total Number of Scans	50	40	10	20	1

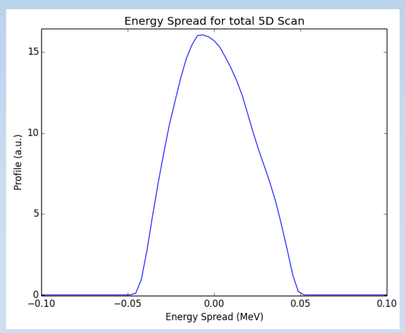


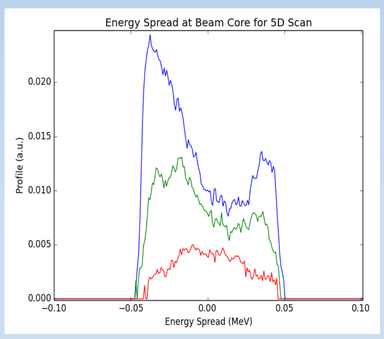


Energy Correlation

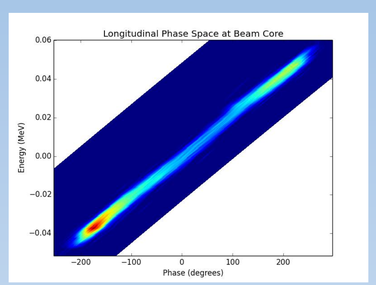


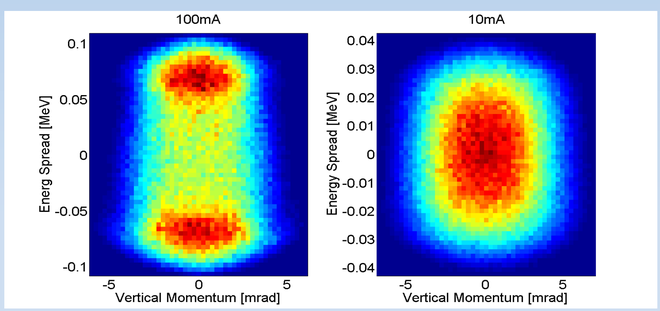
New correlation between energy and transverse parameters.



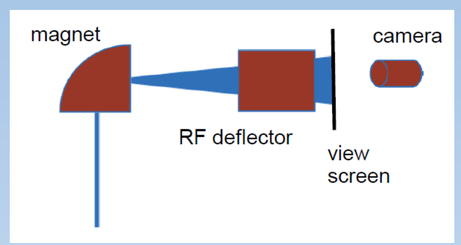


The effect is visible with both the BSM and in simulation.





Future Plans



Scan full longitudinal space on one screen.

FODO lattice is being added to BTF to repeat LEDA experiment for beam halo investigation.