Beam Injection and Collimation in the ACD Project X

Project X Collaboration Meeting

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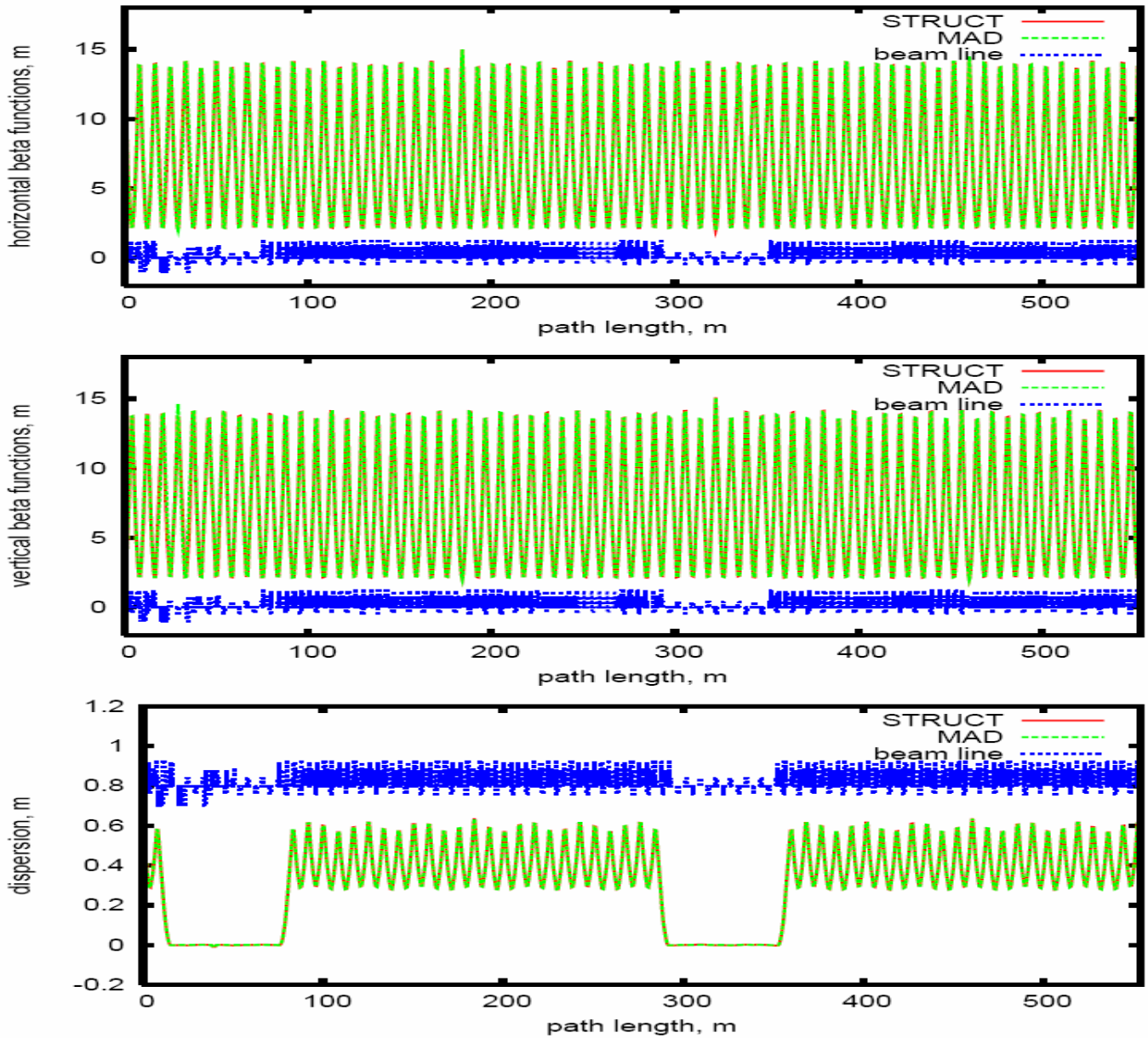
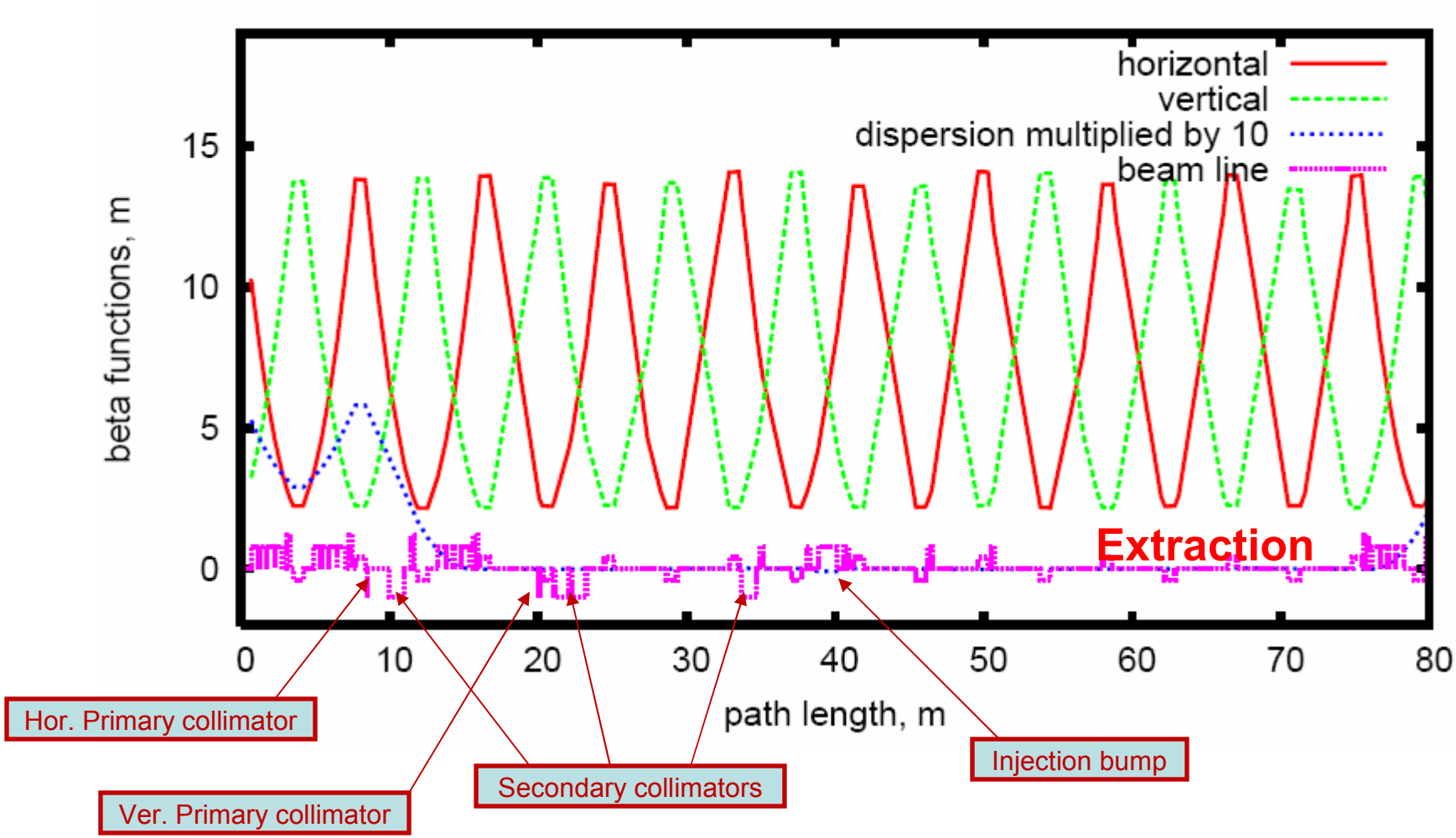
Beam parameters for painting modeling

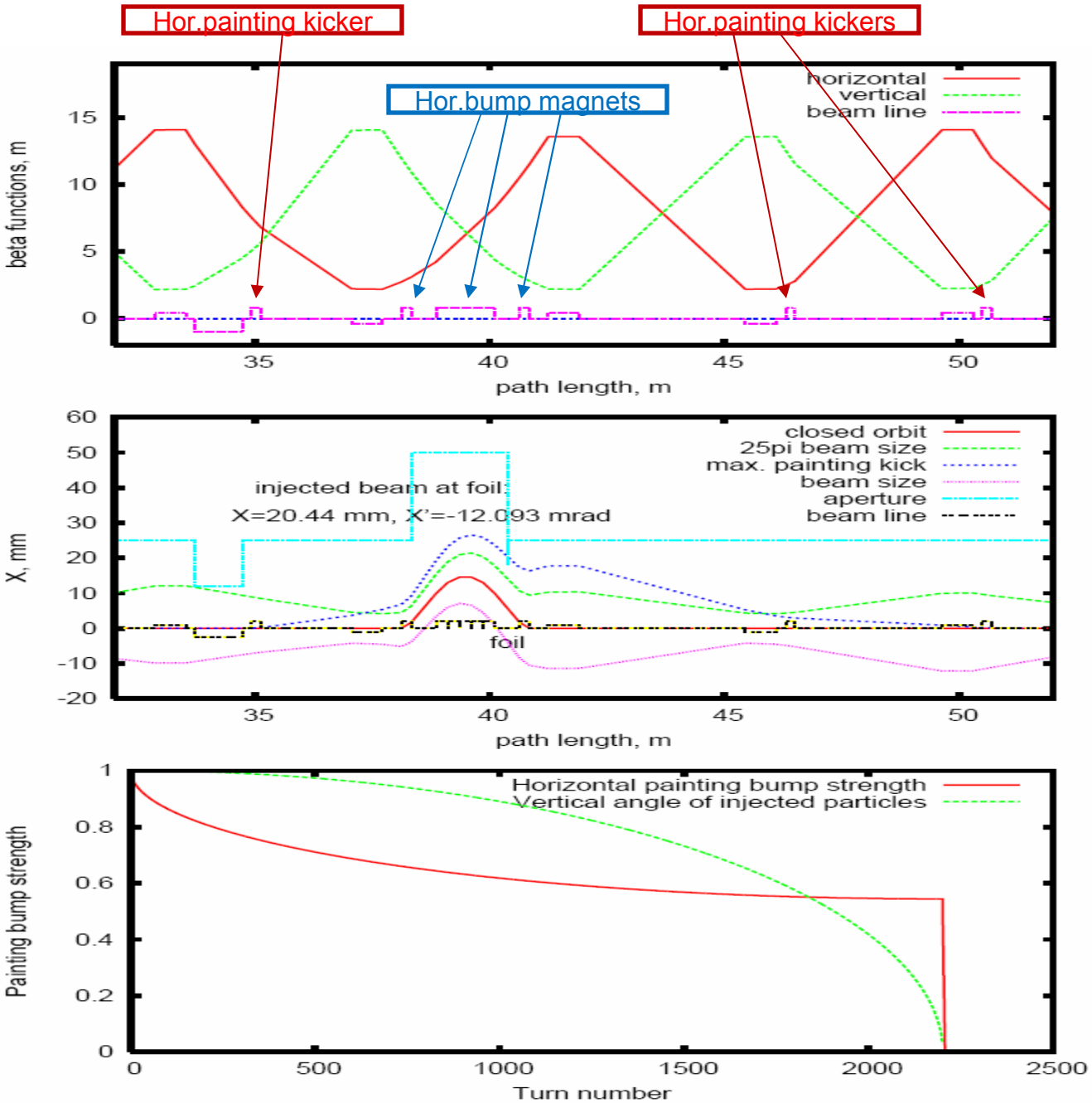
parameter	value
Beam	
Proton momentum P	2.784437 GeV/c
Equilibrium total energy	2.938272 GeV
β-factor	0.947644
γ-factor	3.13158
2-8 GeV Ring	
α	0.00445
Transition γ	14.988
Revolution time for Recycler Ring	1.9473 μsec
Orbit length	553.233m
Momentum spread, dP/P at 3σ level	1×10^{-3}
RF frequency for 2 GeV central orbit	50,326,093.0 Hz
Revolution frequency for Recycler Ring at 2 GeV	513,532 Hz
Harmonic number	98
Painting Injection	
One painting cycle duration (train)	4.284 msec (2200 turns)
Repetition rate of injection to Recycler Ring	10 Hz (0.1 sec cycle)
Accumulated intensity in the Recycler Ring	$2.67 \times 10^{13} ppp$
Power of the beam in the foil at injection	85.44 kW ←
95% normalized emittance of injected beam, $\varepsilon_{95\%}$	$2.5\ \pi\ mm \cdot mrad$
Geometric emittance of injected beam	
$\varepsilon_{1\sigma} = (2.5\ \pi/6) \times (0.938272/2.784437)$	$0.1404\ \pi\ mm \cdot mrad$
Momentum spread of injected beam, dP/P at 3σ level	8.4×10^{-4}
normalized acceptance	$40\ \pi\ mm \cdot mrad$
normalized emittance of the beam after painting, ε_{total}	$25\ \pi\ mm \cdot mrad$ ←
Geometric emittance after painting	
$\varepsilon_{total} = 25\ \pi \times (0.938272/2.784437)$	$8.4243\ \pi\ mm \cdot mrad$
Momentum spread after painting, dP/P at 3σ level	1×10^{-3}
Beta functions in the injection beam line at the foil, β_x, β_y	$5.28\ m$, $2.21\ m$
Injected beam half-size, $3\sigma_x = 3 \times sqrt(5.28 \times 0.1404)$	$2.58\ mm$
$3\sigma_y = 3 \times sqrt(2.21 \times 0.1404)$	$1.67\ mm$
Beta functions in the Recycler at the foil, β_x	$9.38\ m$
β_y	$3.73\ m$
Circulating beam half-size after painting, $3\sigma_x = sqrt(9.38 \times 8.4243)$	$8.98\ mm$
$3\sigma_y = sqrt(3.73 \times 8.4243)$	$5.61\ mm$
Longitudinal "slippage" of injected particles during one turn	$\delta\phi_{RF}$=0.6493 radian
6.457883=325MH/50.326093MH	
$\delta\phi_{RF} = 2\pi \times 98 \times 0.457883/6.457883 = 43.658649 rad = -0.323648$ radian	
0.972948rad=6.283185/6.457883 - distance between bunches	
-0.323648rad is equivalent to -0.323648+0.972948=0.6493rad	

B-functions and dispersion by STRUCT and MAD

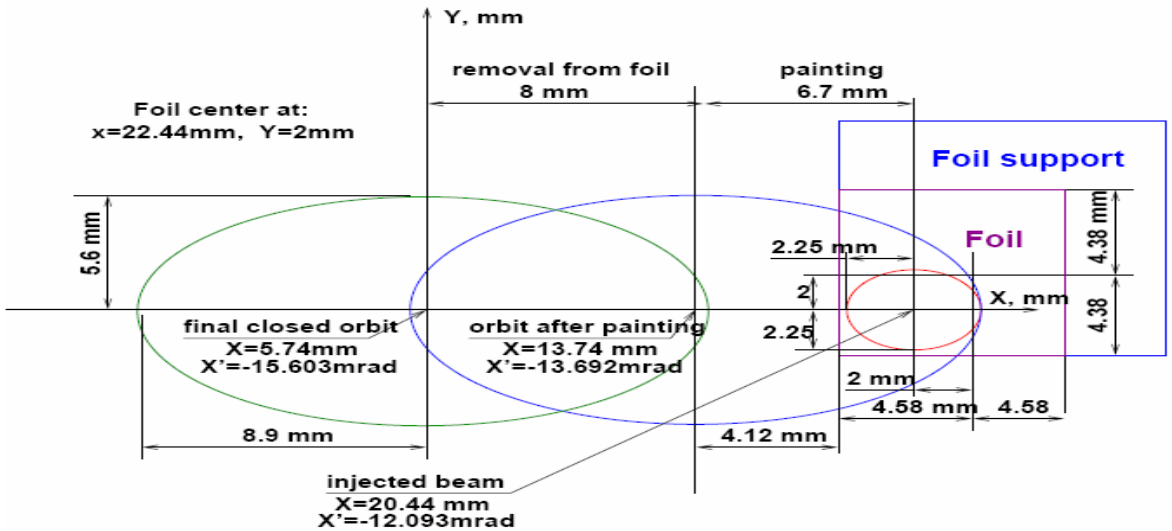


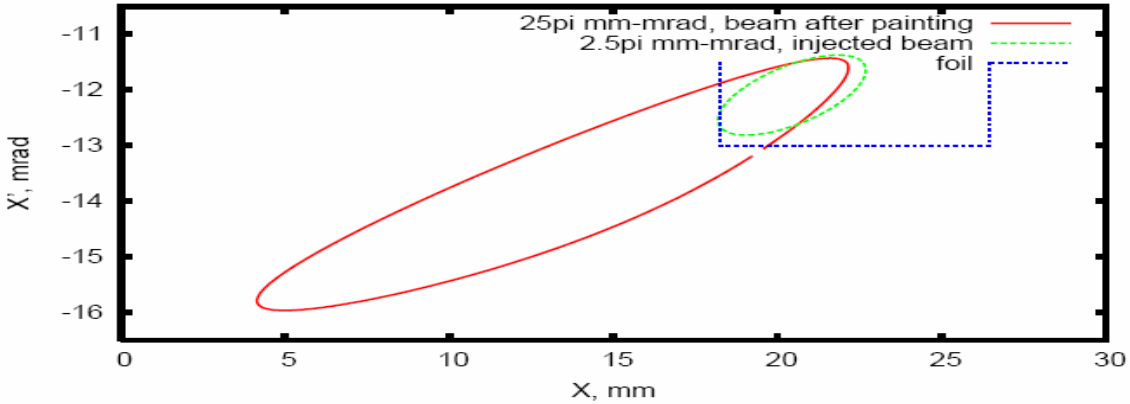
B-functions & dispersion in the straight section at injection.

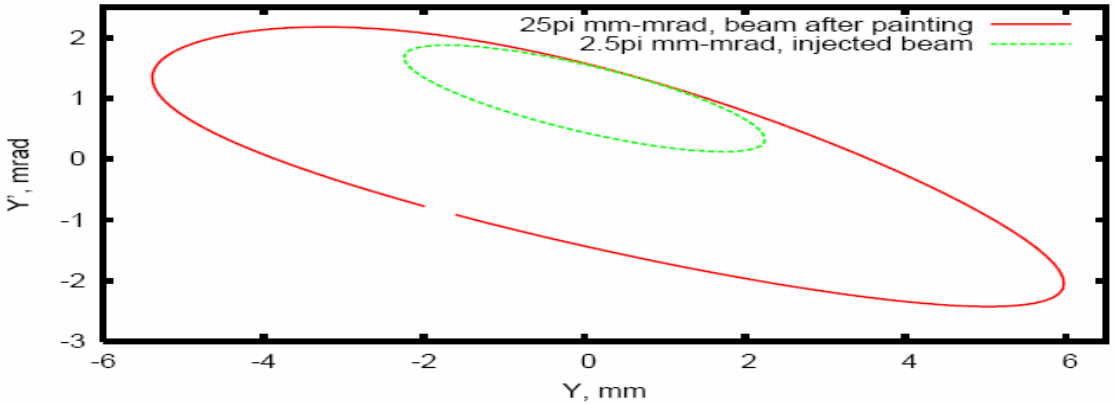




Beta functions (top), beam orbit (middle) in the injection section, and painting bump strength (bottom) with KEK type waveform.





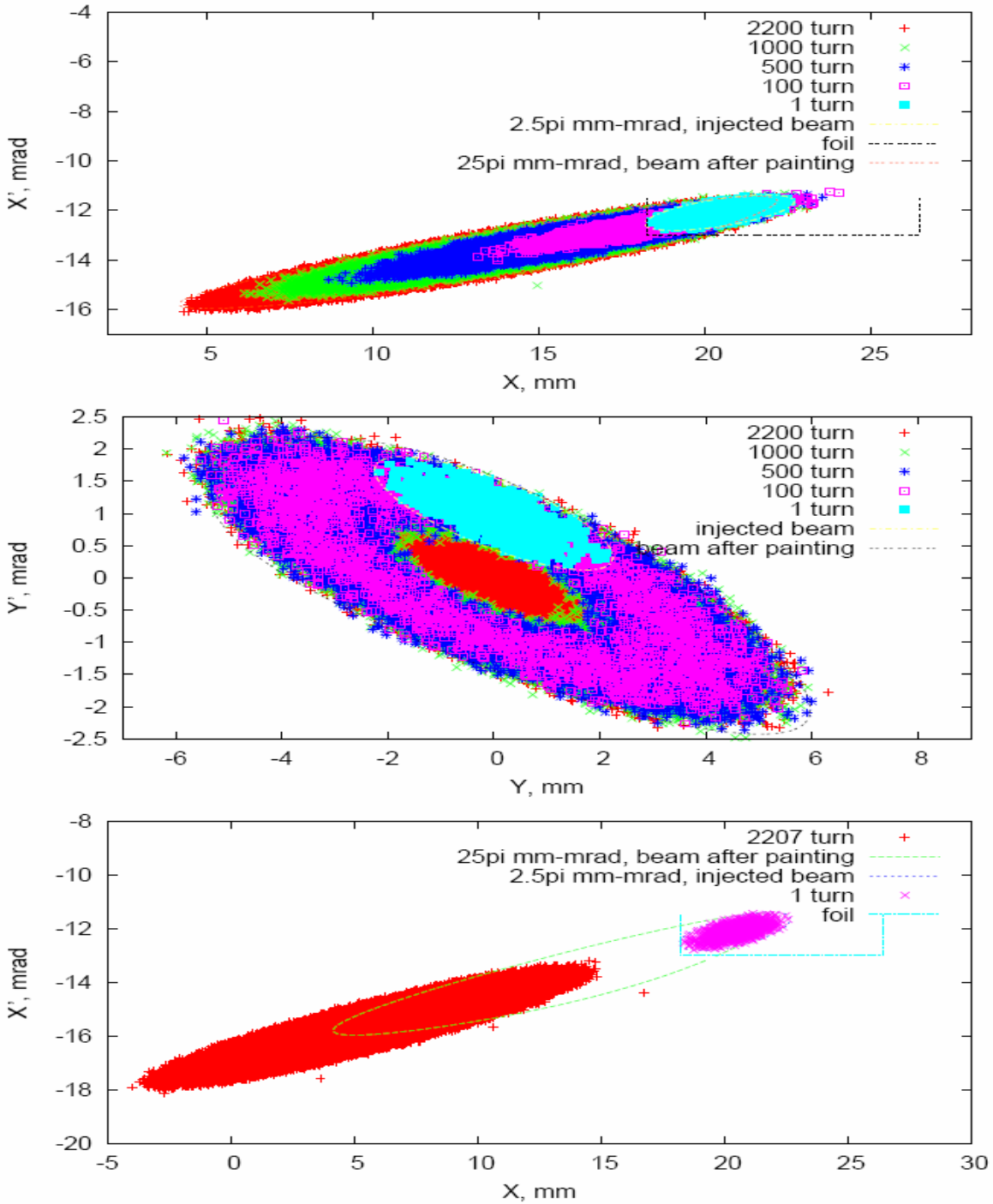


Beam position at stripping foil at painting injection with KEK-type waveform:

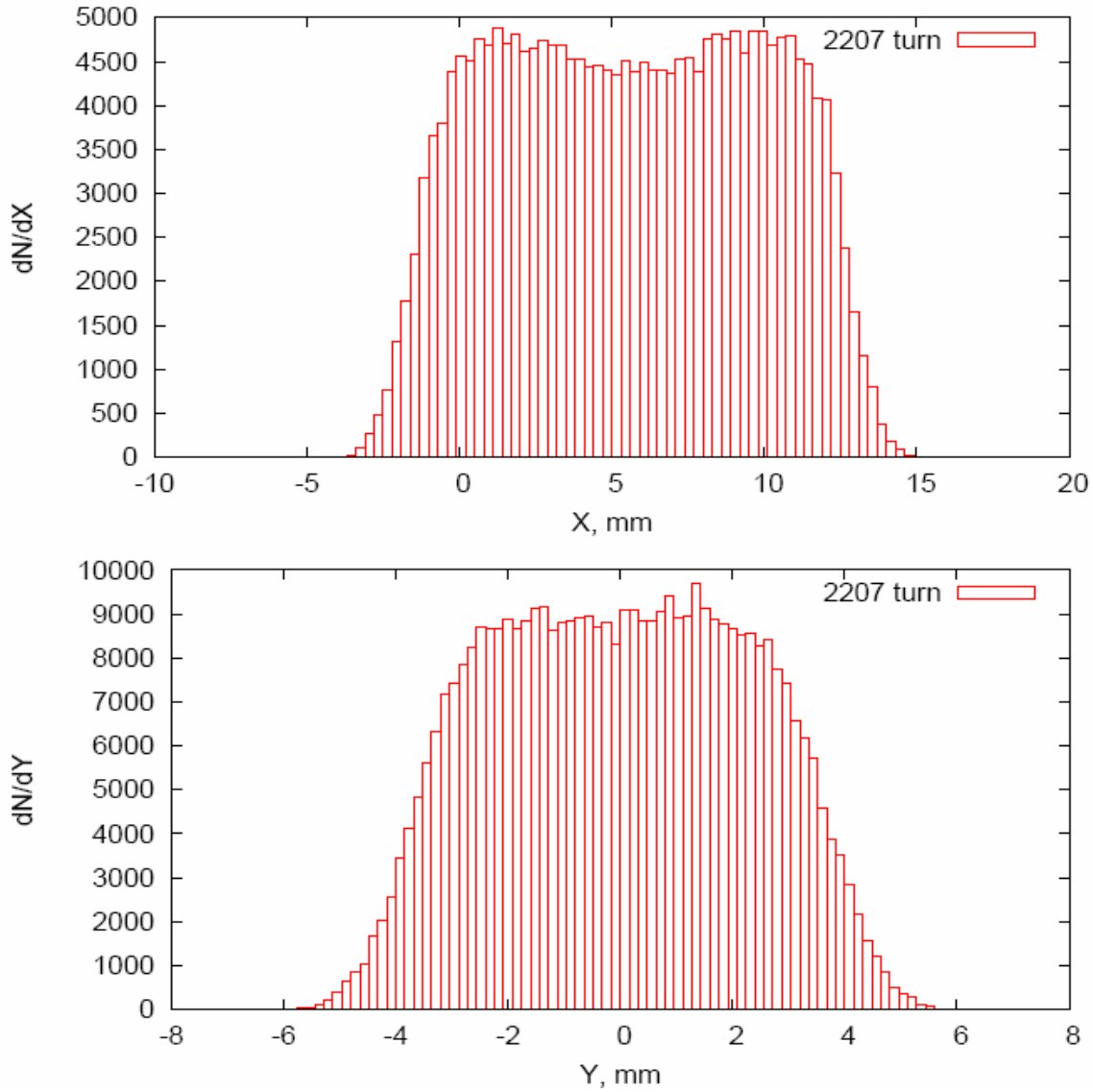
Painting horizontally

&

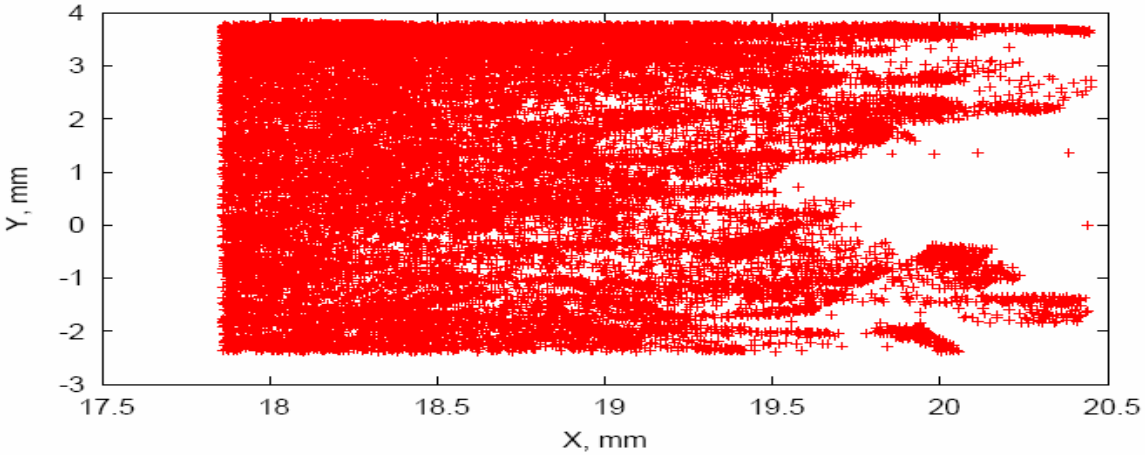
Steering vertically

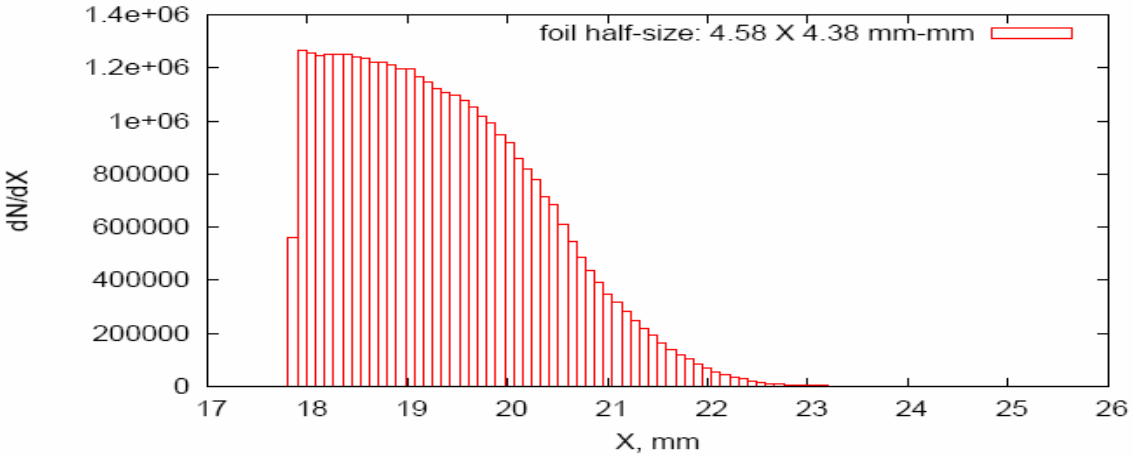


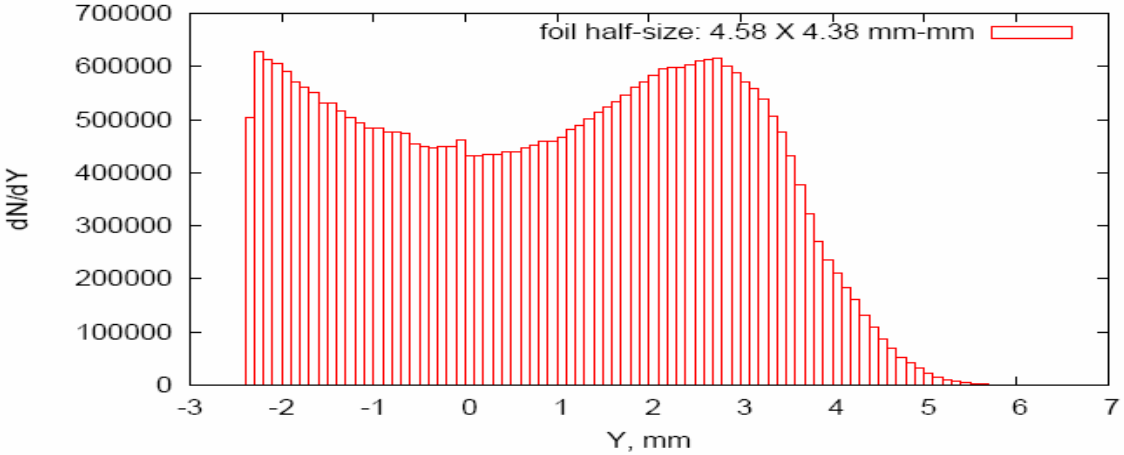
Horizontal (top) and vertical (middle) phase plane of circulating beam at turns 1, 100, 500, 1000 and 2200 of injection with KEK type waveform. Foil half-size is 4.58 X 4.38 mm. Injected beam is taken at 3 σ level: Ax=2.25mm, Ay=2.25mm. Horizontal plane after beam removal from the foil (bottom). Average number of each particle interaction with foil is 139. Statistics is 30 particles injected at every turn.



Horizontal (top) and vertical (bottom) particle distributions after beam removal from the foil at turn 2207 with KEK type waveform.

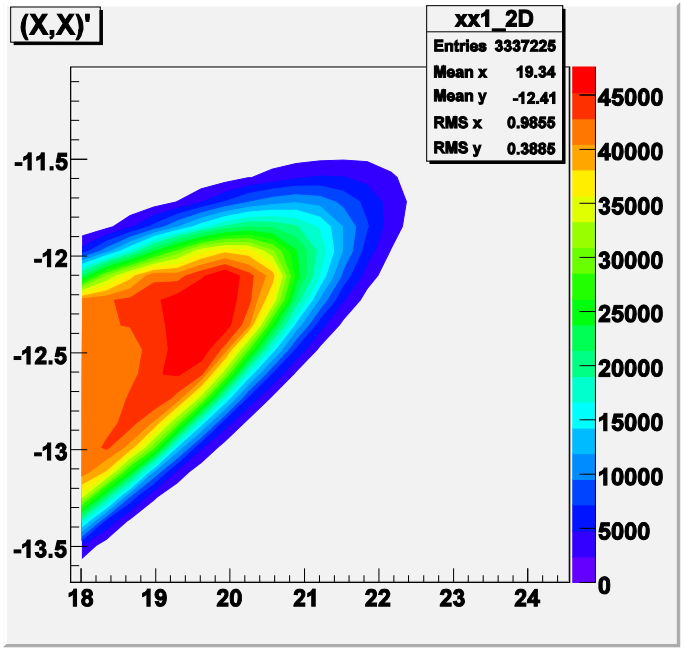


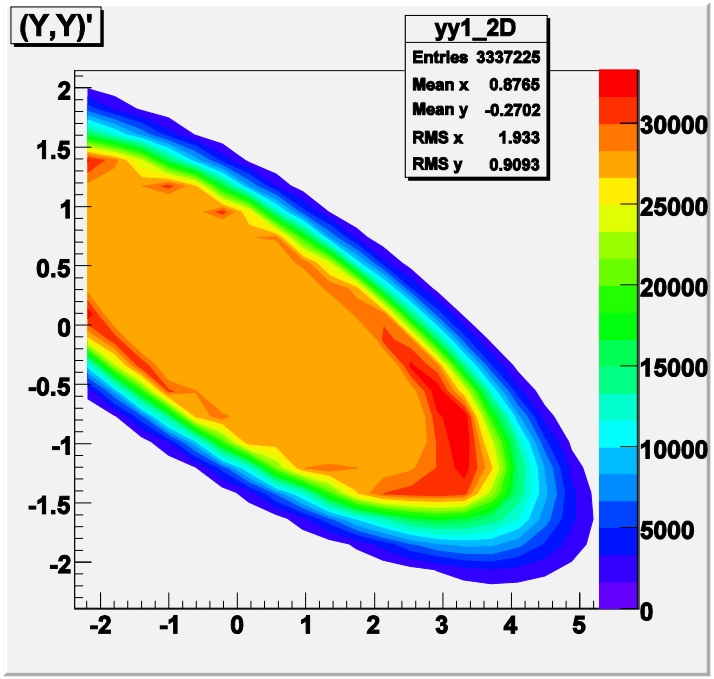


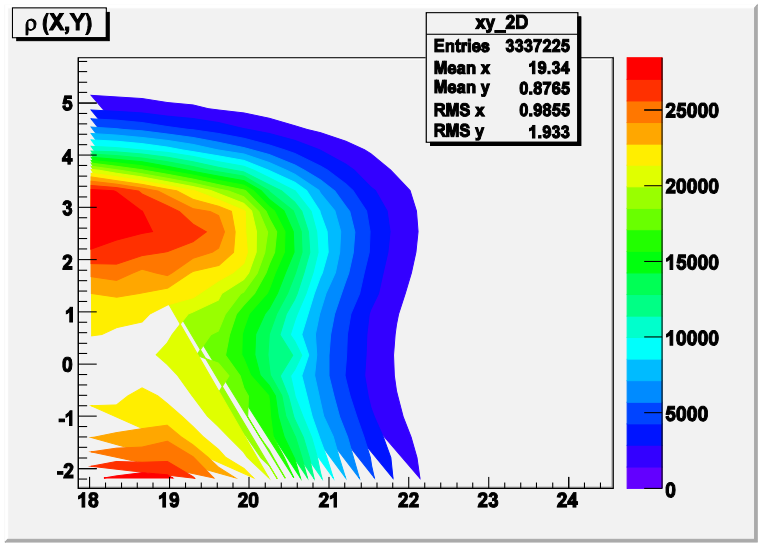


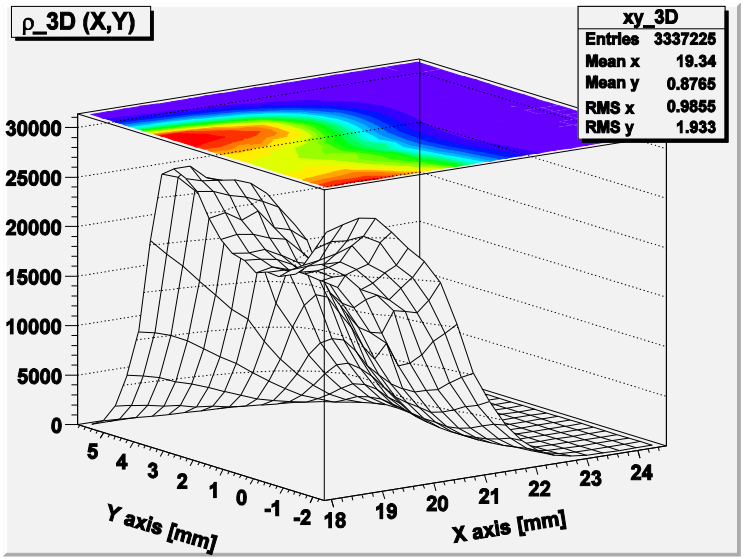
Particle hit population at foil (top), and horizontal (middle) and vertical (bottom) distributions at turn 2200, with KEK type waveform, for foil half-size of 4.58 X 4.38 mm. The edge of injected beam is located in dX=0.33mm and dY=0.13mm inside from the edge of the foil. Statistics is 8 particles injected at every turn.

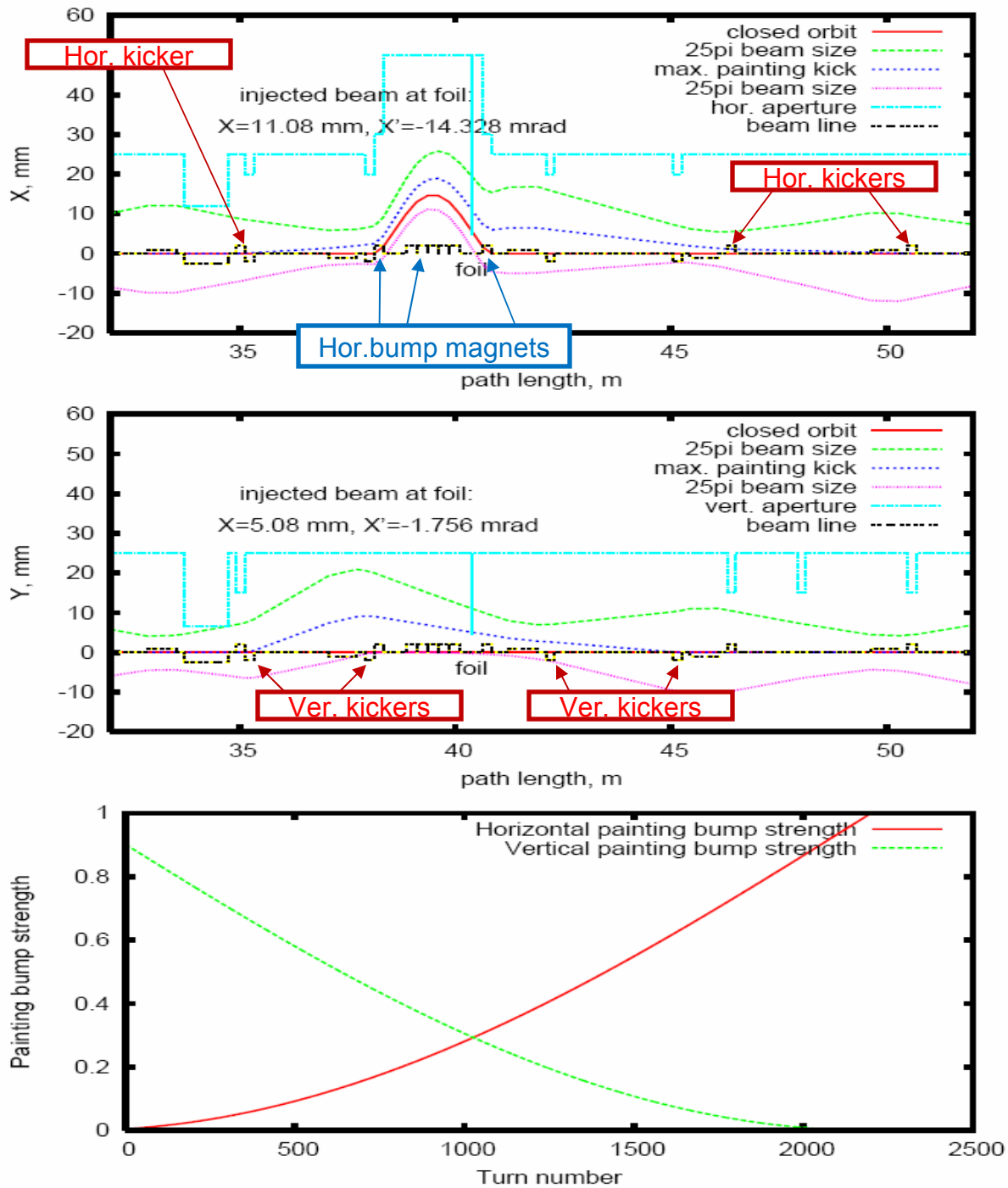
Same Statistics: 8 particles per turn.



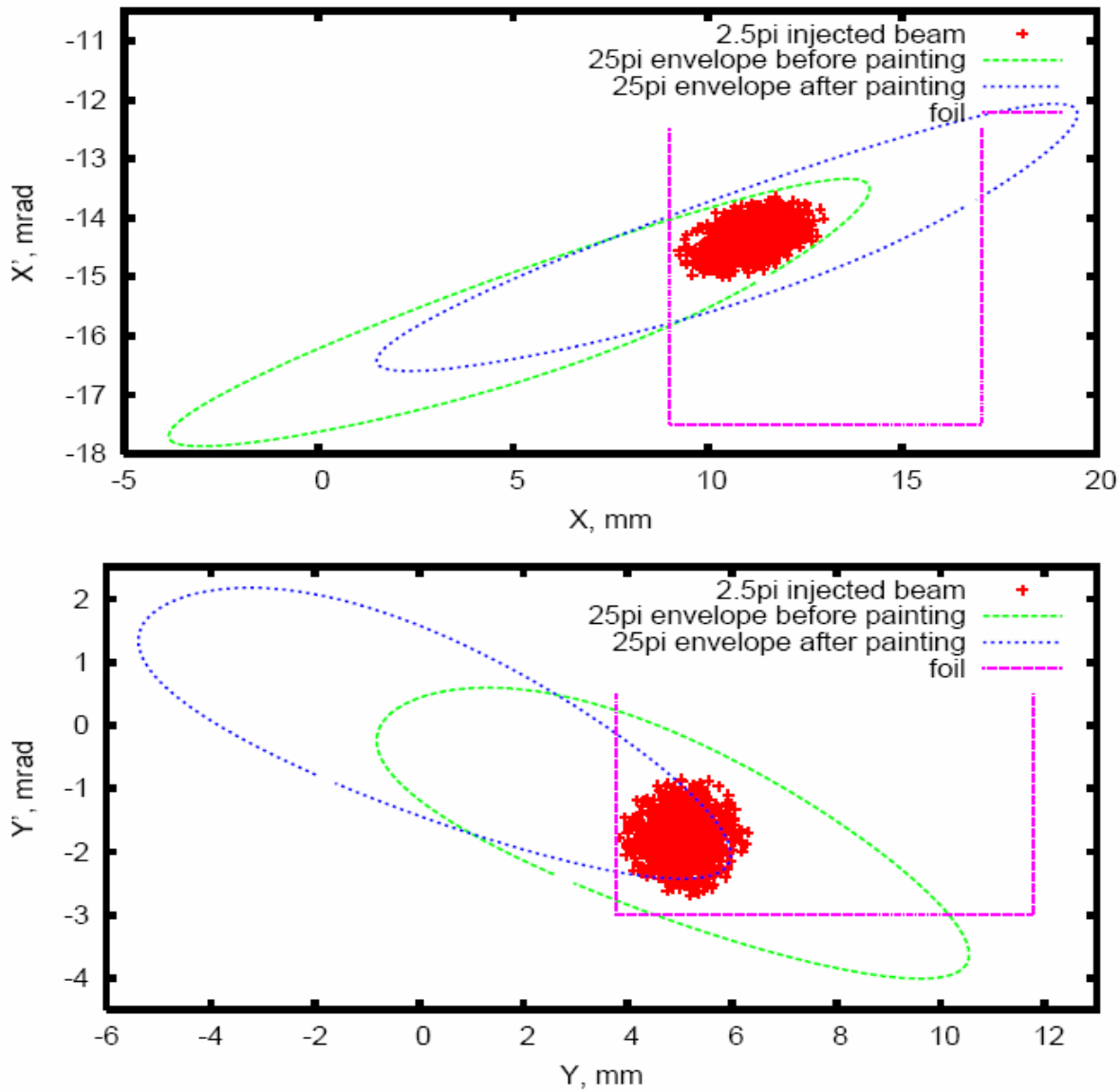




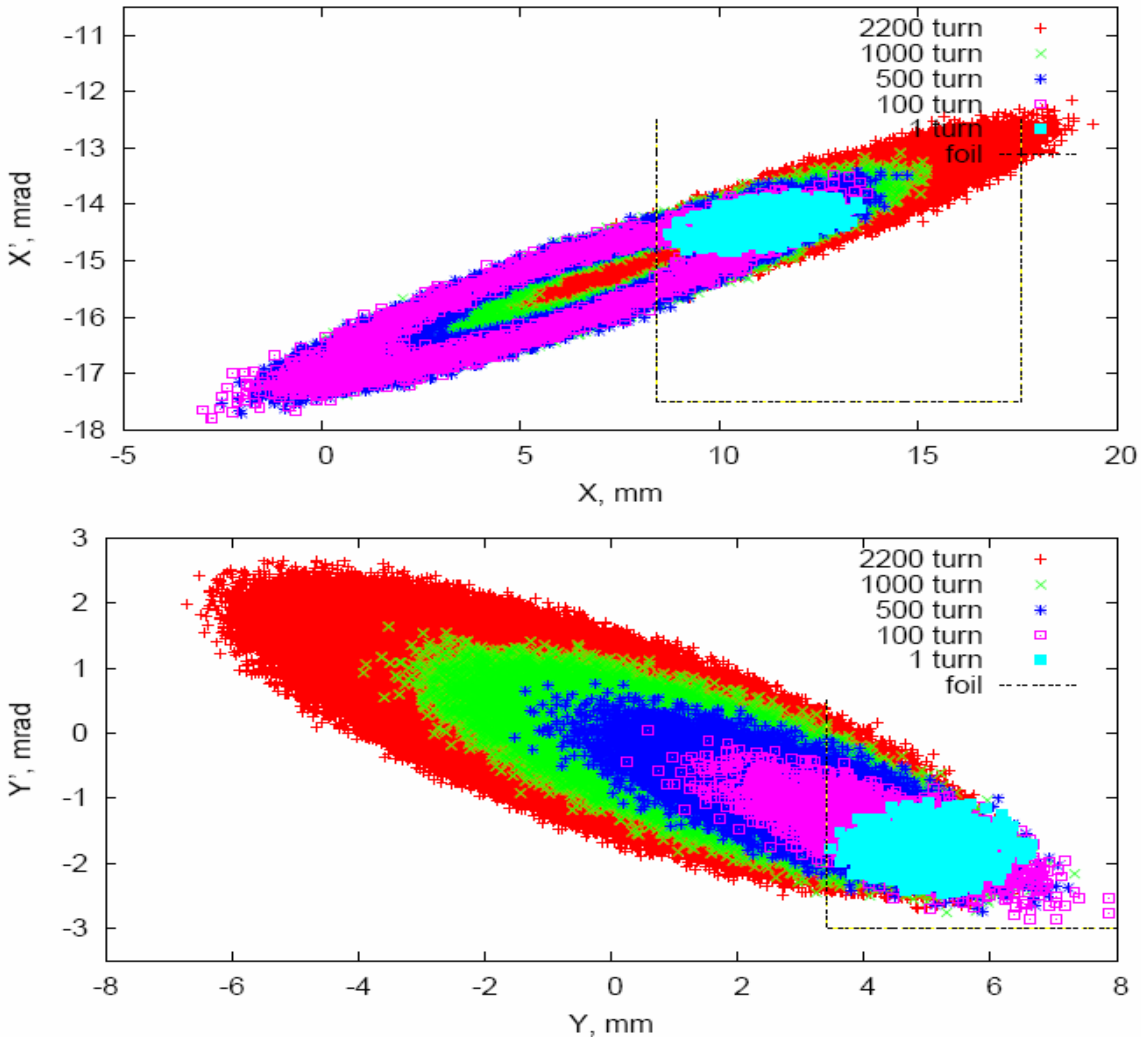




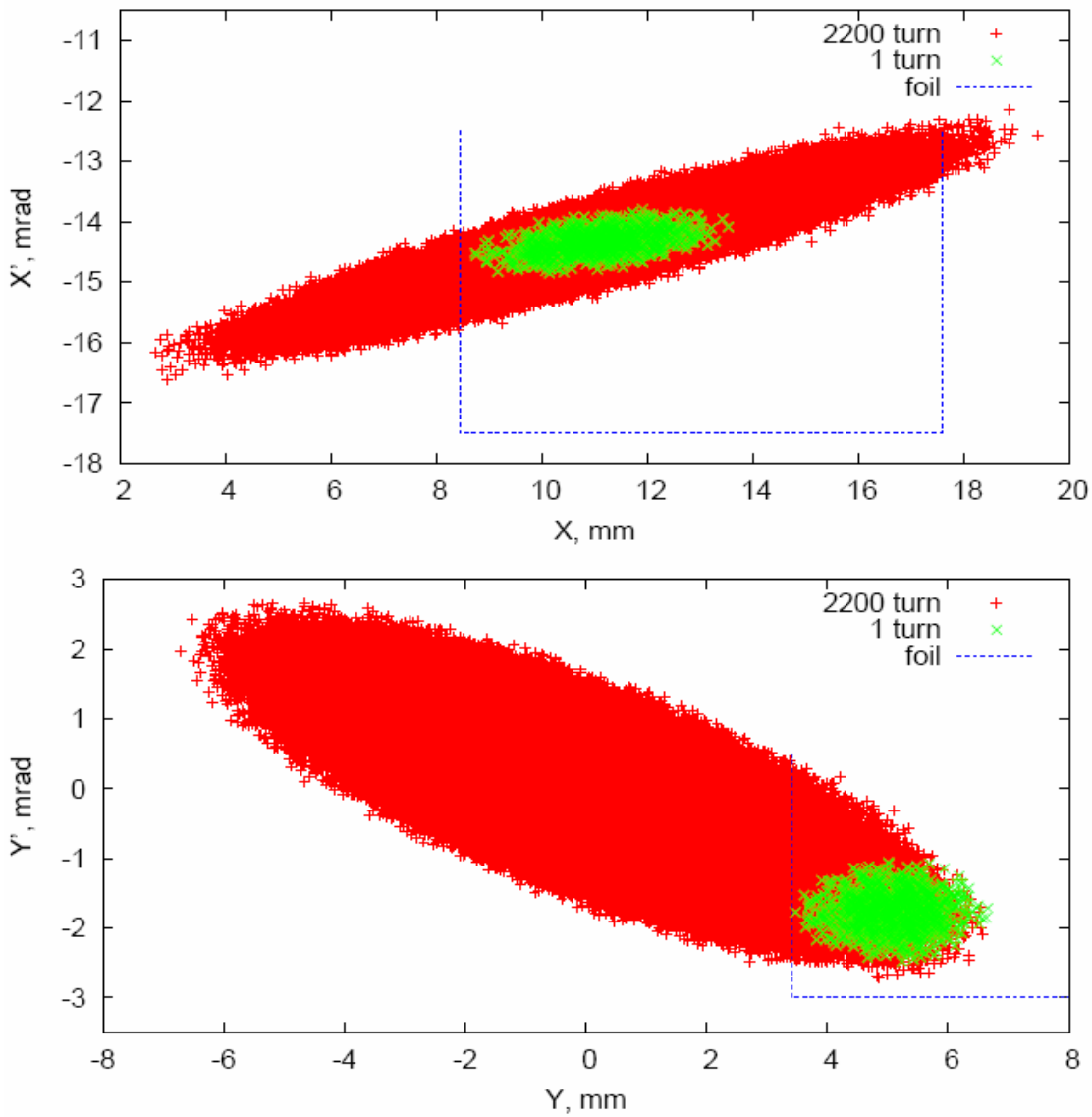
Horizontal (top) and vertical (middle) beam orbit in the injection section, and painting bump strength (bottom) with COS and SIN waveform.



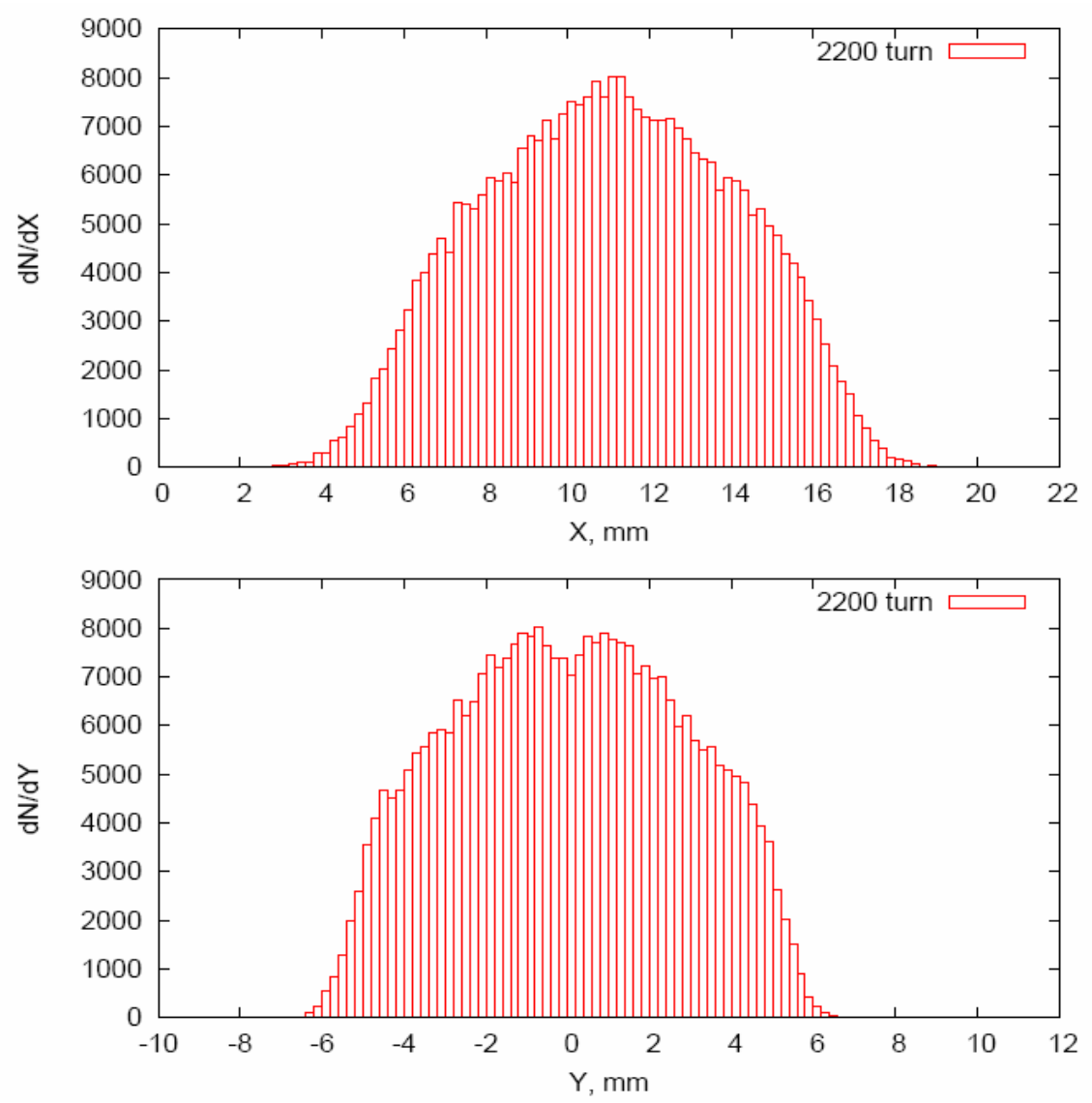
Horizontal (top) and vertical (bottom) beam position at stripping foil at injection with COS and SIN waveform of painting bump strength.



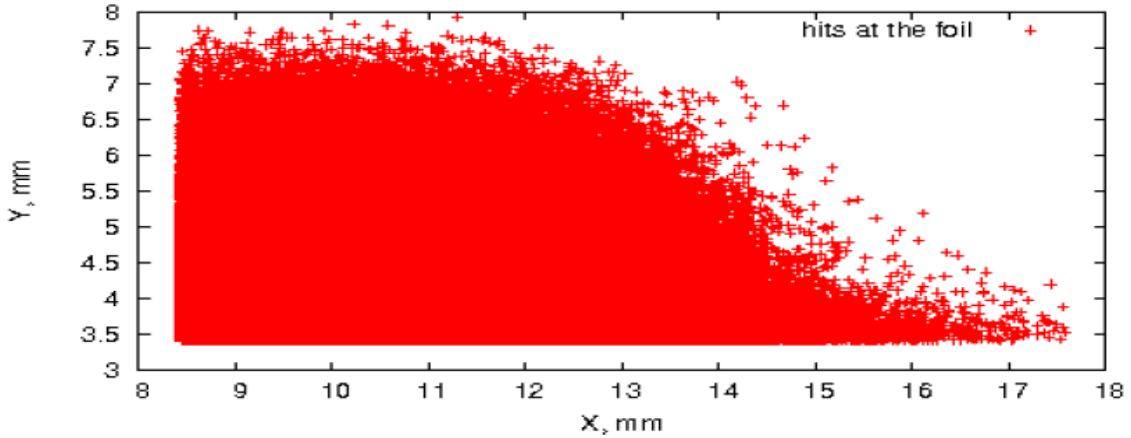
Horizontal (top) and vertical (bottom) phase plane of circulating beam at turns 1, 100, 500, 1000 and 2200 of injection with COS and SIN waveform of painting bump strength. Average number of each particle interaction with foil is 100.4. Injected beam is taken at 3 σ level: Ax=2.66mm, Ay=1.67mm. Foil half-size is 4.58mm X 4.38mm. Statistics is 30 particles injected at every turn.

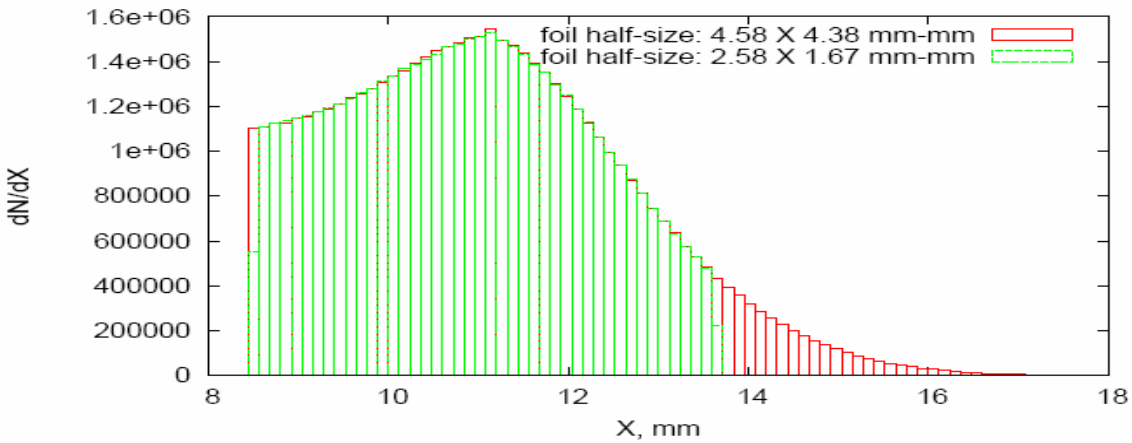


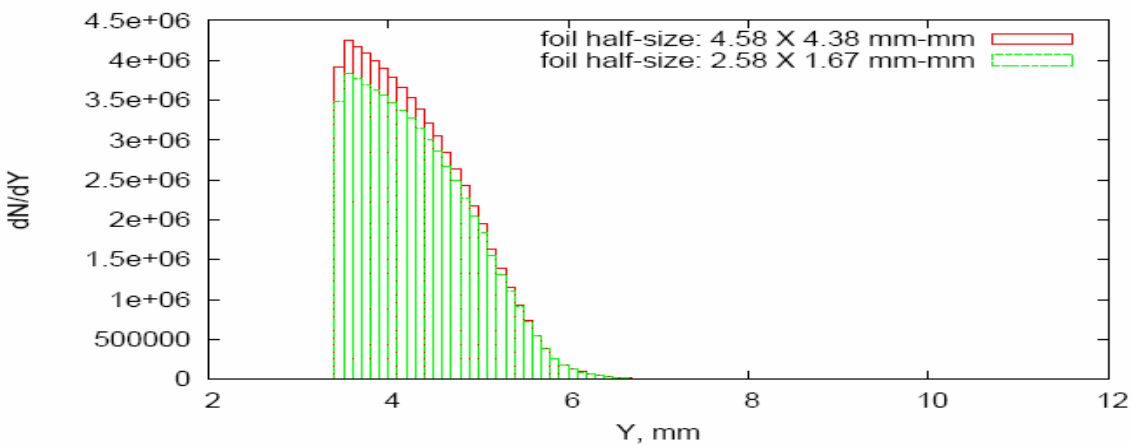
Horizontal (top) and vertical (bottom) phase plane of circulating beam at turn 2200 of injection with COS and SIN waveform of painting bump strength. Statistics is 30 particles injected at every turn.



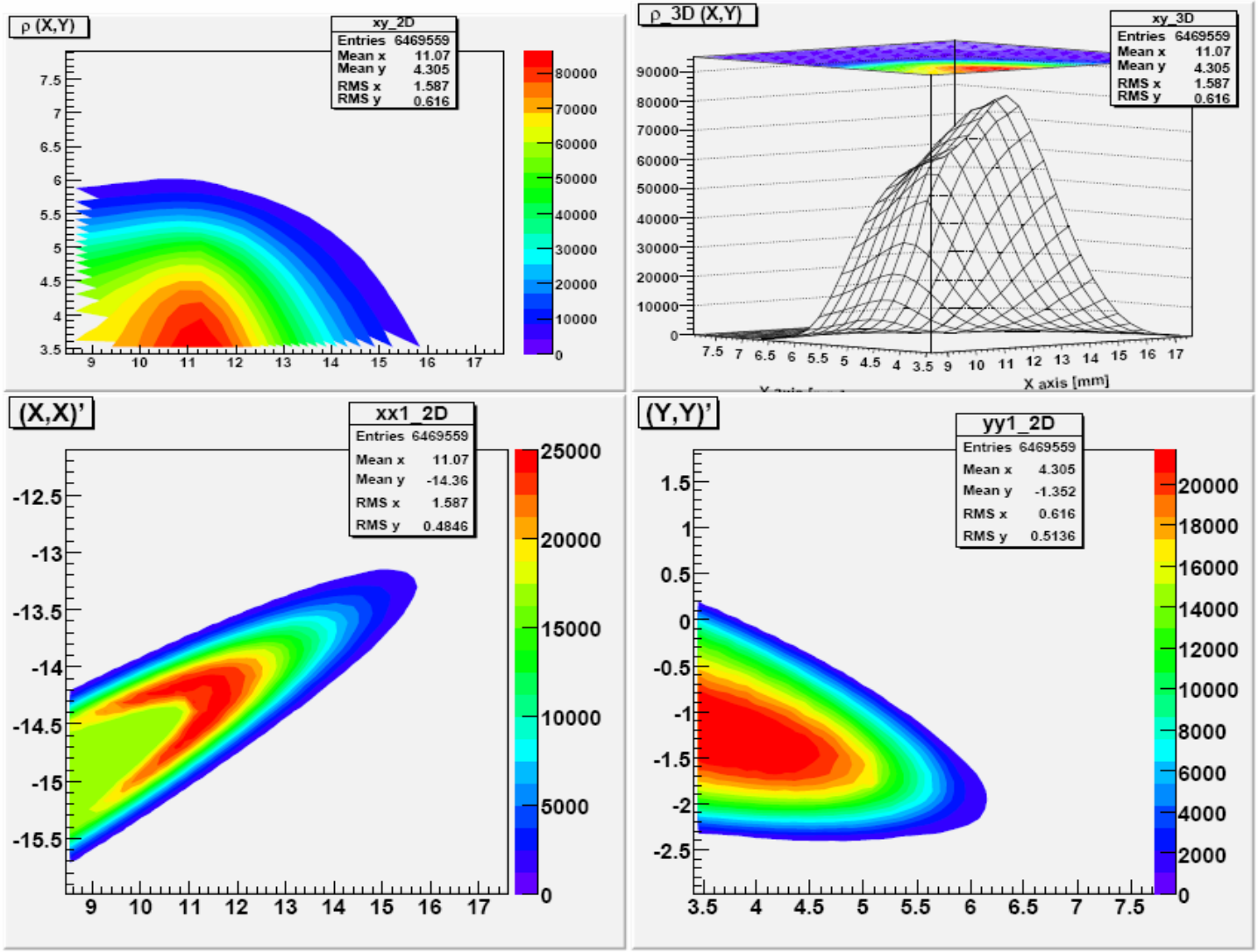
Horizontal (top) and vertical (bottom) particle distributions after beam removal from the foil at turn 2207 with COS and SIN waveform of painting bump strength.



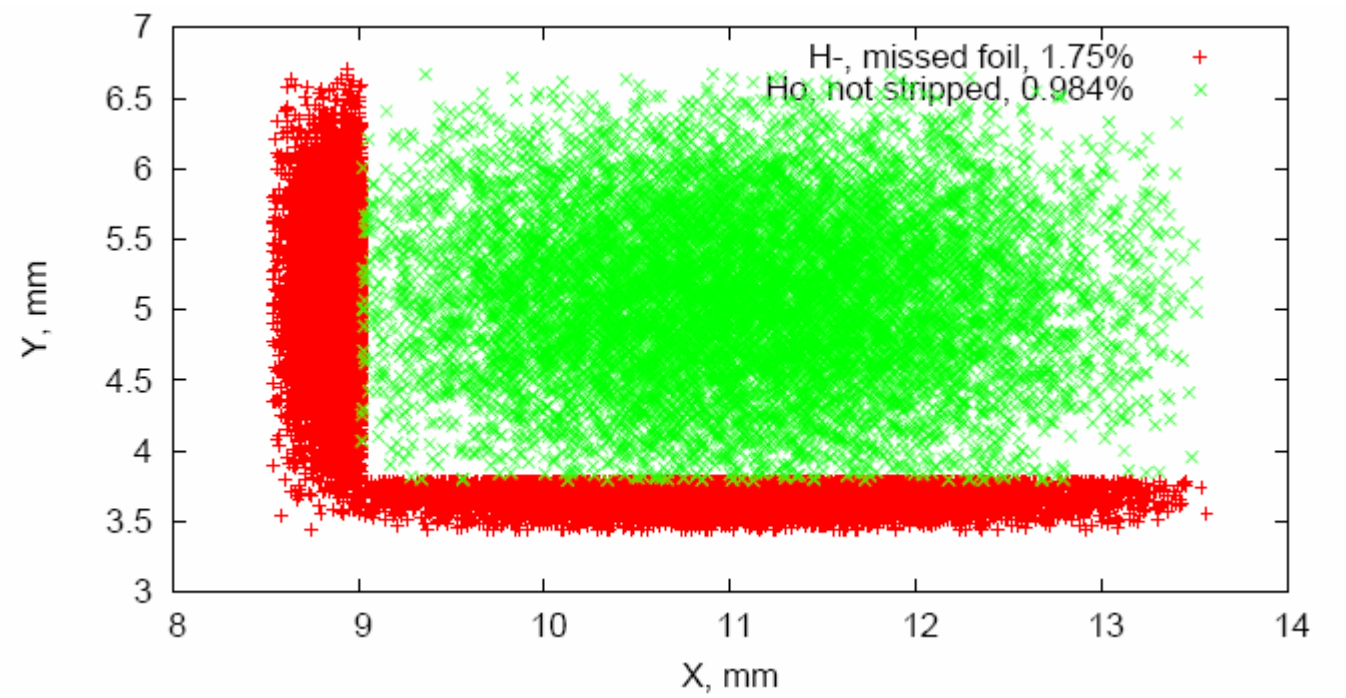




Particle hit population at foil (top), and horizontal (middle) and vertical (bottom) distributions at turn 2200 with COS and SIN waveform of painting bump, for foil half-size of 4.58 X 4.38 mm-mm, and foil with size equal to size of injected beam (half-size of 2.58 X 1.67 mm-mm). In both cases injected beam is located at the edge of the foil. This shows that density of particle hits in the maximum of distribution almost does not depend on the foil size. Statistics is 30 particles injected at every turn.



Particle hit population (top), and horizontal and vertical phase distributions (bottom) at the foil with COS and SIN waveform of painting bump strength. Hit density in a maximum of distribution is 776700 hits/mm^2.



Ho atoms population at the foil and H- missed the foil in case of injected beam center location in 2.32 $\sigma_{x,y}$ distance from the foil corner with COS and SIN waveform of painting bump strength. Foil half-size is 4mm X 4mm.

Summary

- Multiple painting algorithms/wave-forms were considered for RCS.
- Total number of hits/Density distributions evaluated.
- Multiple optics settings in straight section: the injection point position, the collimation region (TODO).
- Multiple species (after-stripping) behaviour to be analysed (TODO)
- Foil performance issues to be addressed.