



MD4224 High Brightness: Simulations

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MD4224 Parameters

Parameter	MD	Simulation
Intensity $N_p [10^{10}]$	≈72.5	72.5
Normalised horizontal RMS emittance $\epsilon_x^n [\text{mm mrad}]$	1.2	1.2
Normalised vertical RMS emittance $\epsilon_y^n [\text{mm mrad}]$	1	1
Bunch length $\sigma_t [\text{ns}]$	140	140
Momentum spread $\frac{\Delta p}{p} [10^{-3}]$	0.87	0.87
Horizontal maximum tune spread $\Delta Q_{x,\max}$	0.2	0.16
Vertical maximum tune spread $\Delta Q_{y,\max}$	0.28	0.24
Harmonic number h	9	9
RF voltage $V_{rf} [\text{kV}]$	21.2	21.2
Horizontal chromaticity Q'_x	0.77	0.80
Vertical chromaticity Q'_y	-2.85	-3.05
Kinetic energy of the stored beam [GeV]	1.4	1.4
Relativistic β	0.916	0.916
Relativistic γ	2.4921	2.4921
Synchrotron Frequency [Hz]	634	634



Table 1: Beam and machine parameters



Simulation Parameters

Parameter	Simulation
SC Grid x	128
SC Grid y	128
SC Grid z	64
N_{mp}	$0.5 \cdot 10^6$
Turns	2200

Table 2: Simulation parameters

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Matching The Initial Distribution

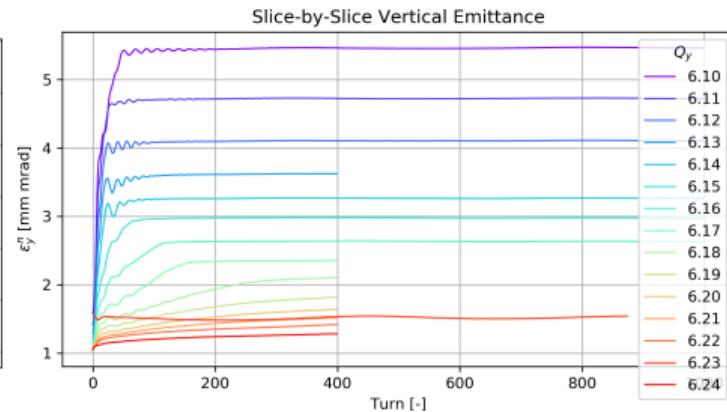
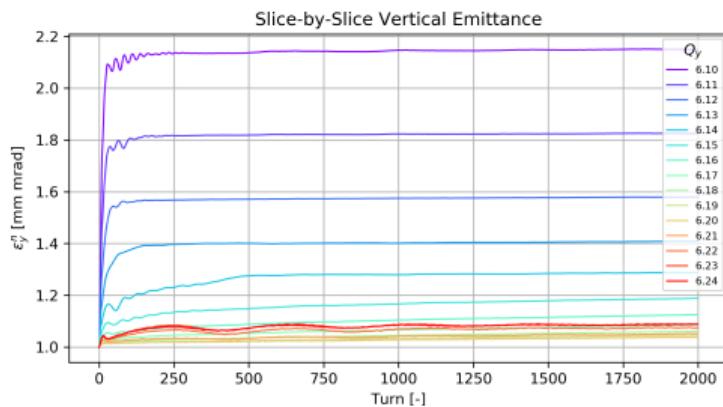
3 approaches used so far:

- ▶ **Linear Nominal:** Linear optics (no SC) from MAD-X/PTC used at nominal working point (6.21, 6.24). Used for all simulations.
- ▶ **Tracked WP:** Take dumped bunch from first approach at turn 875 for each working point, track for one turn, extract Twiss, use this to generate new bunch.
- ▶ **Averaged WP:** Use averaged values (ignoring first 200 turns) of Twiss from first approach, use these to generate new bunch for each working point.

Note that the same tomo file at (6.21, 6.24) is used to generate the longitudinal distribution for all approaches.

Comparing Approaches

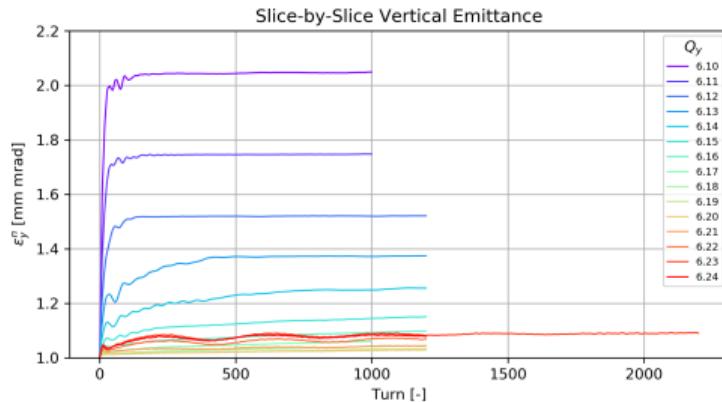
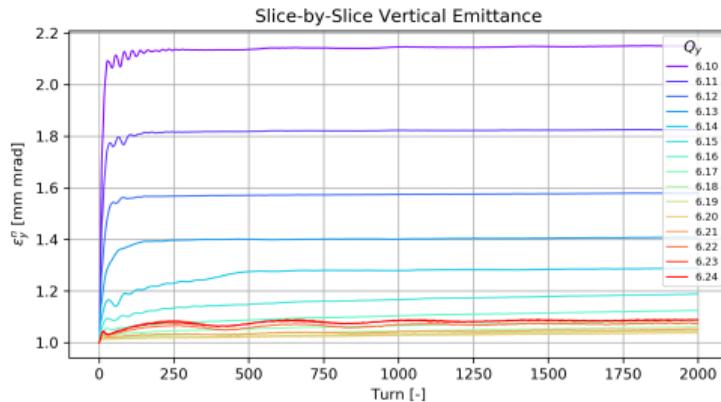
Left: Linear Nominal. Right: Tracked WP.



Concluded that the 'Tracked WP' approach is not effective.

Comparing Approaches

Left: Linear Nominal. Right: Averaged WP.



The ‘Averaged WP’ approach is more reasonable. Simulations reached time limit - re-running on longer queue.

All simulation results from this point on use the ‘Averaged WP’ approach unless stated otherwise.

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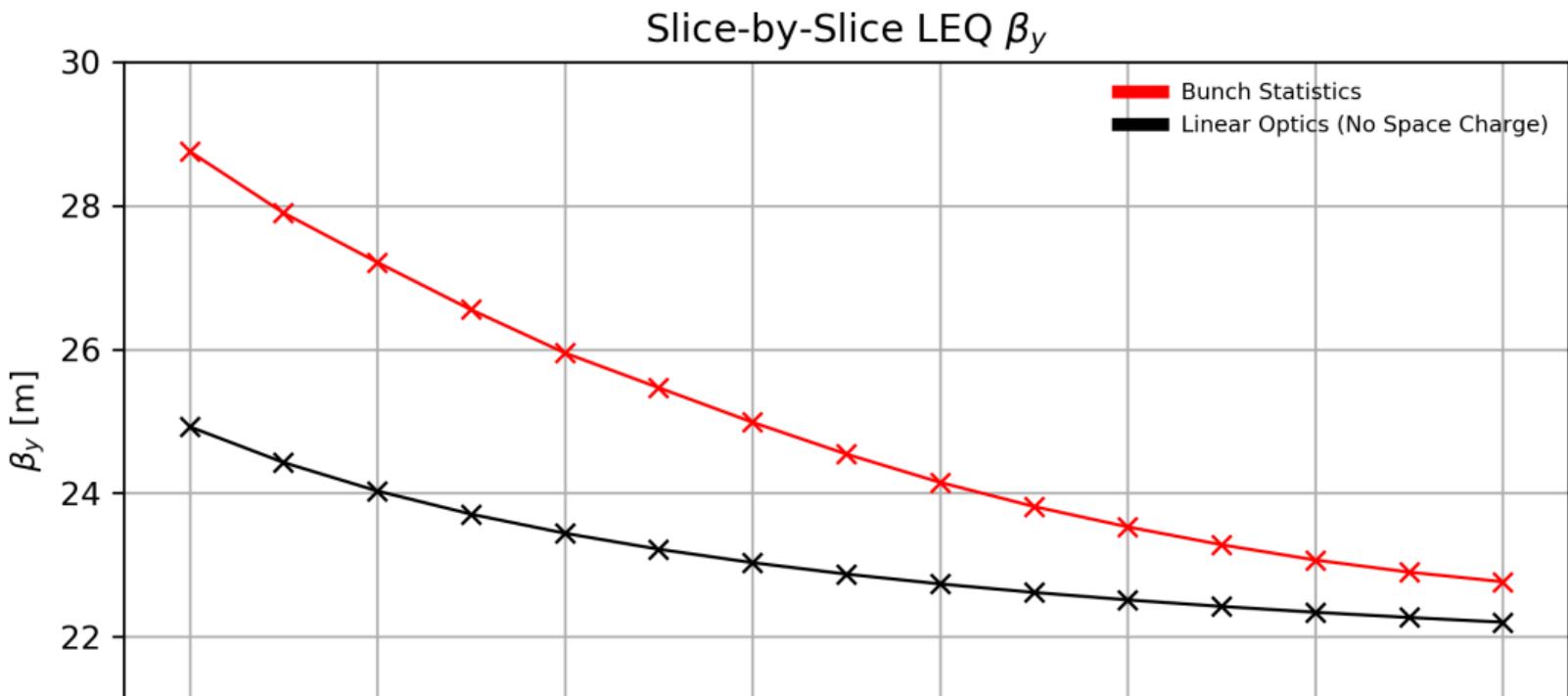
Emittances Using Simulation Optics
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172 ms

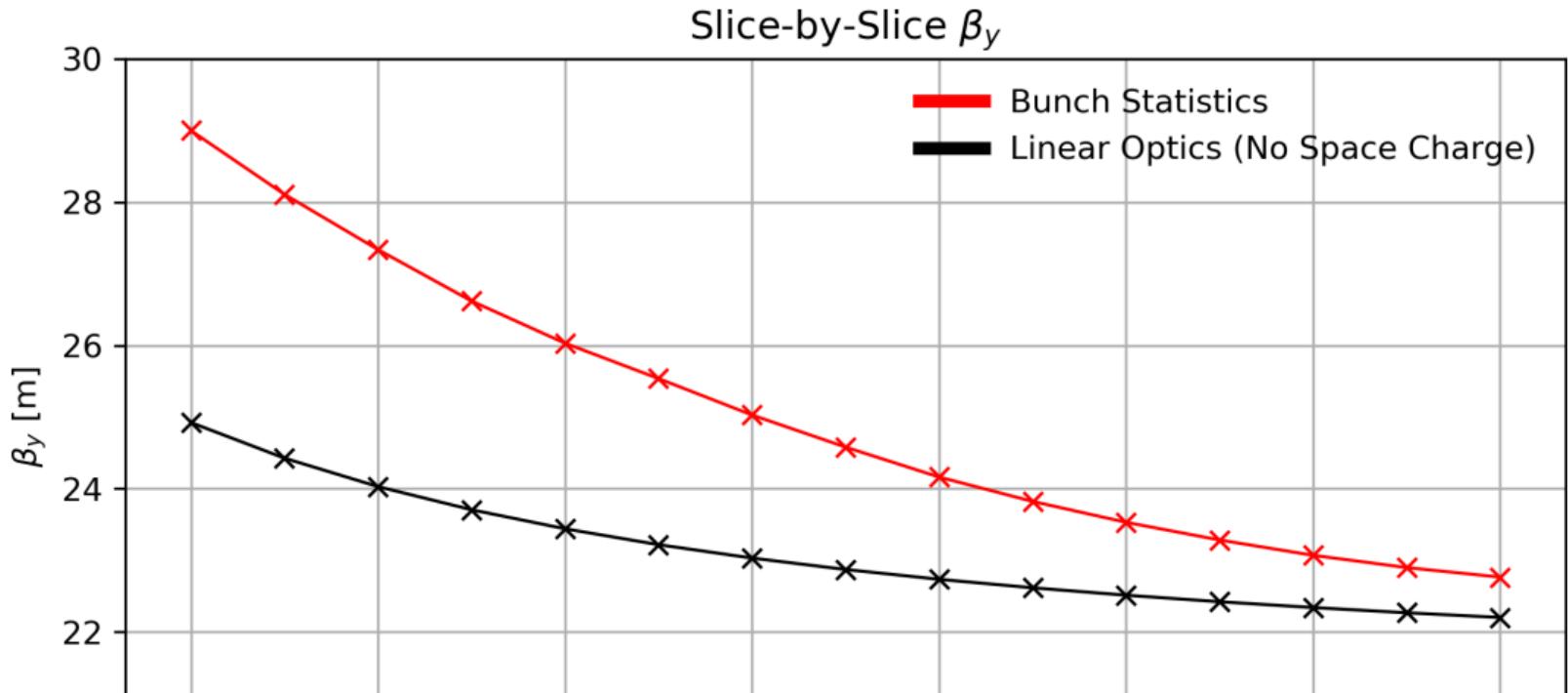
Vertical Beta Function

Linear Nominal approach.



Vertical Beta Function

Averaged WP approach.



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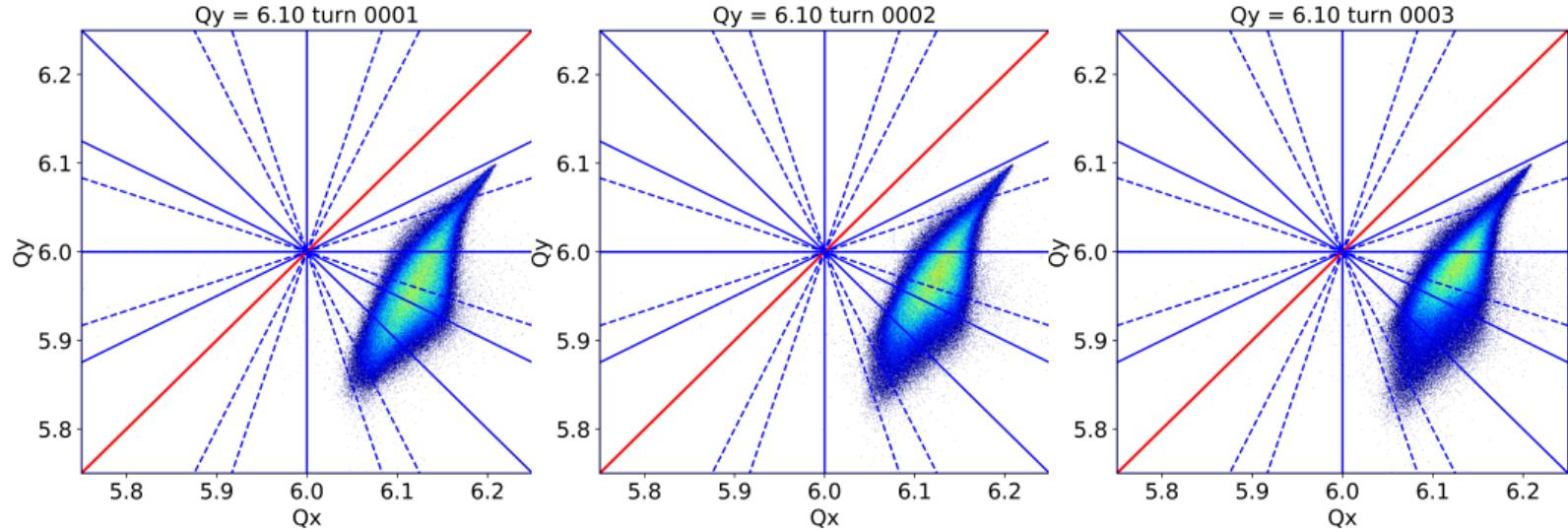
Emittances Using Simulation Optics

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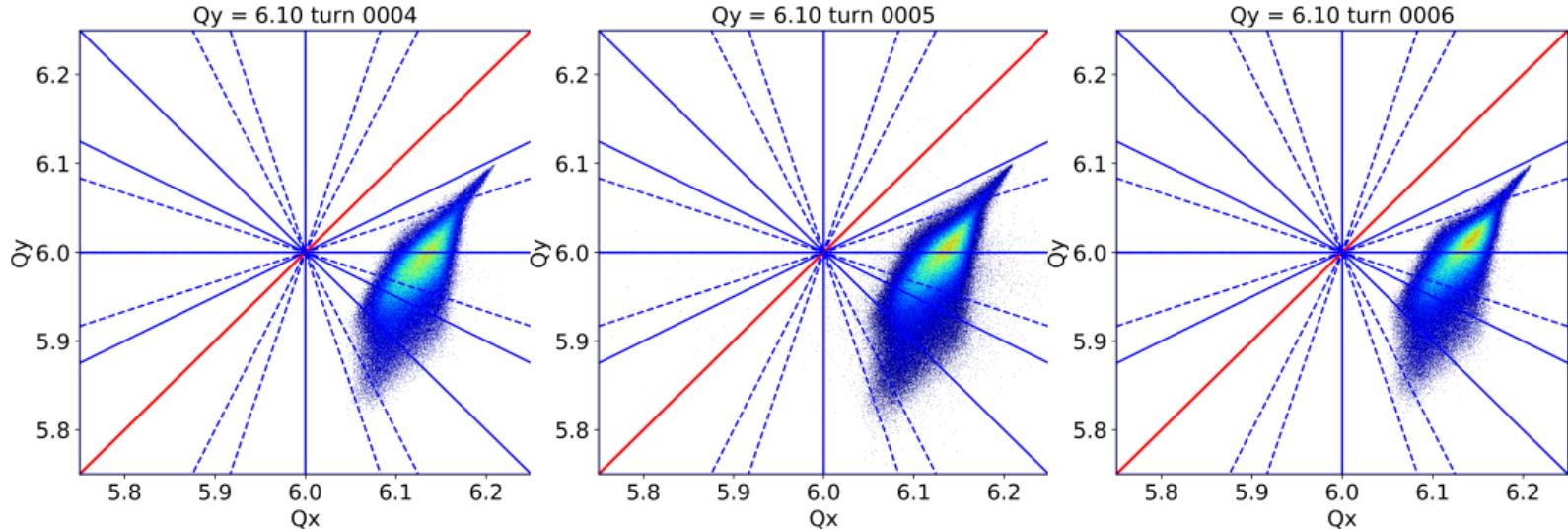
Beam Profiles

172 ms

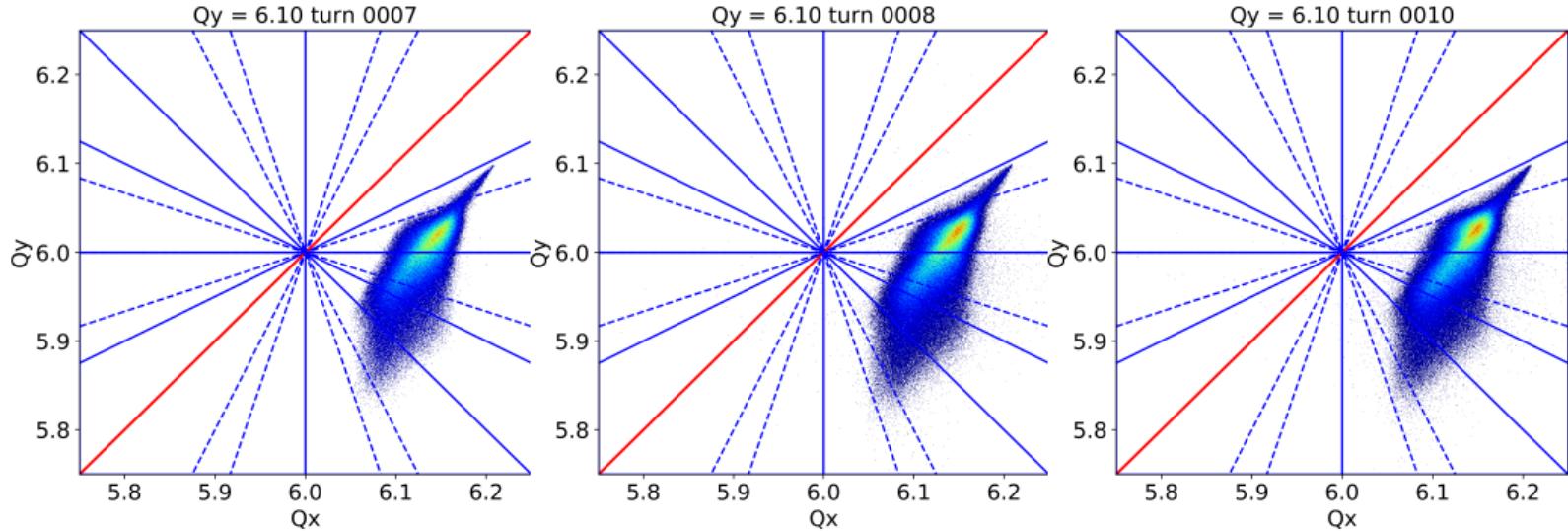
Tune Footprints: Slice-by-slice with longitudinal kick



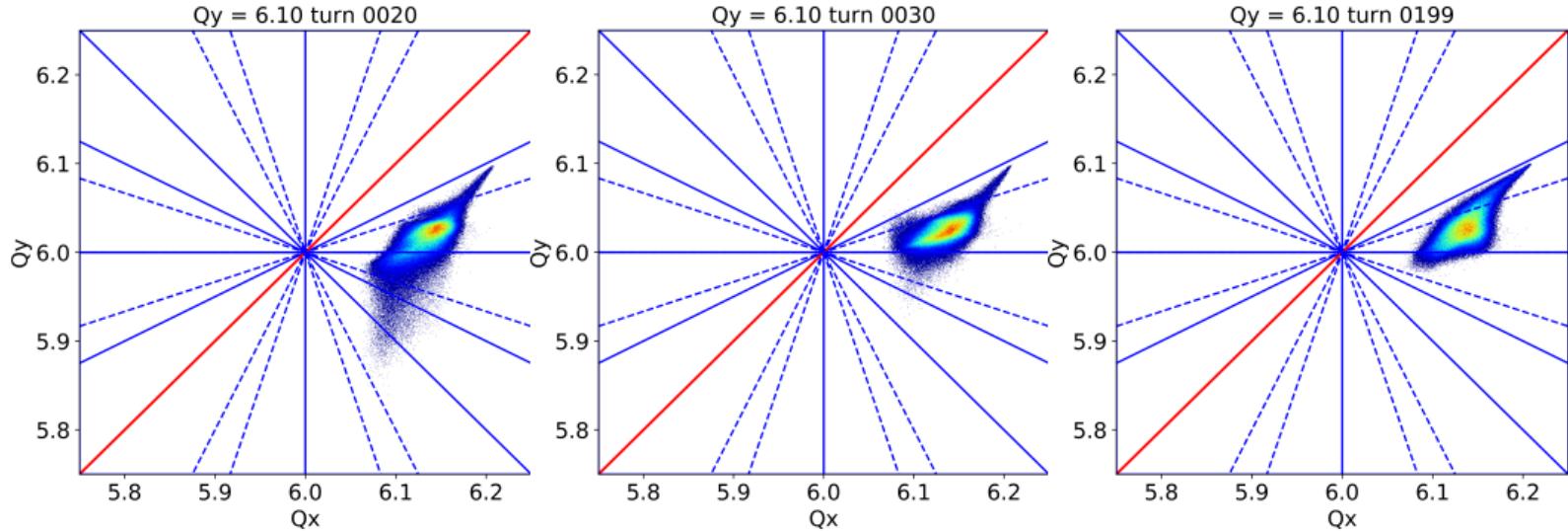
Tune Footprints: Slice-by-slice with longitudinal kick



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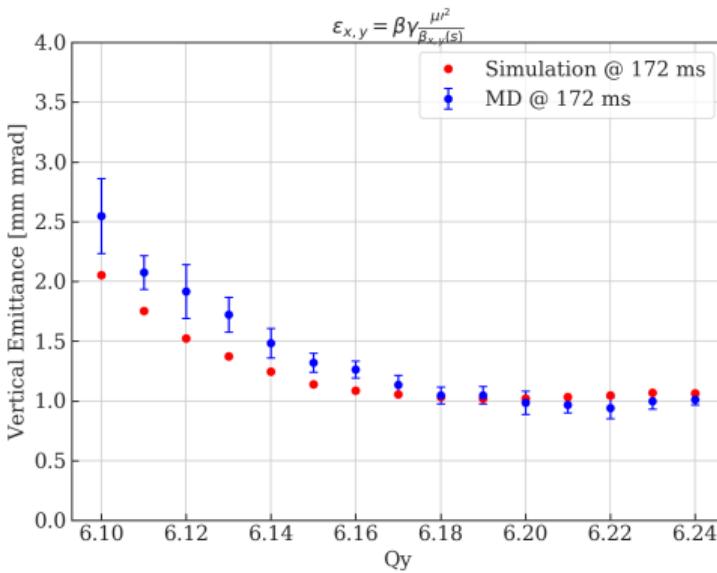
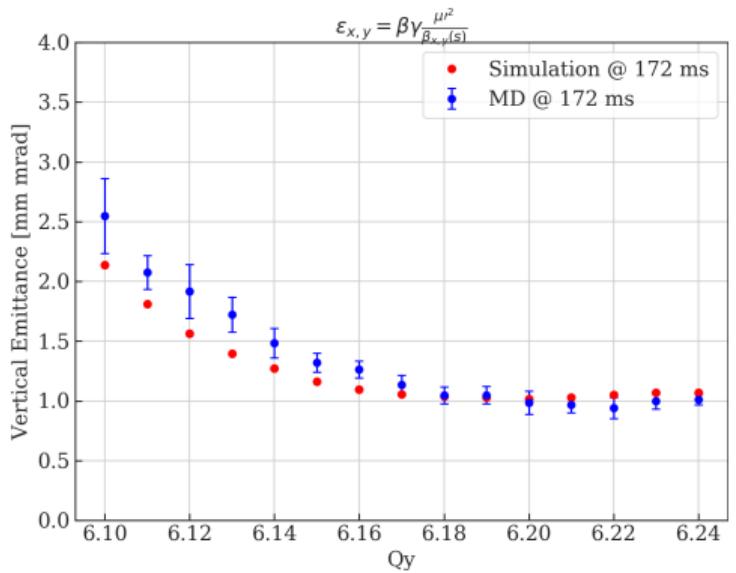
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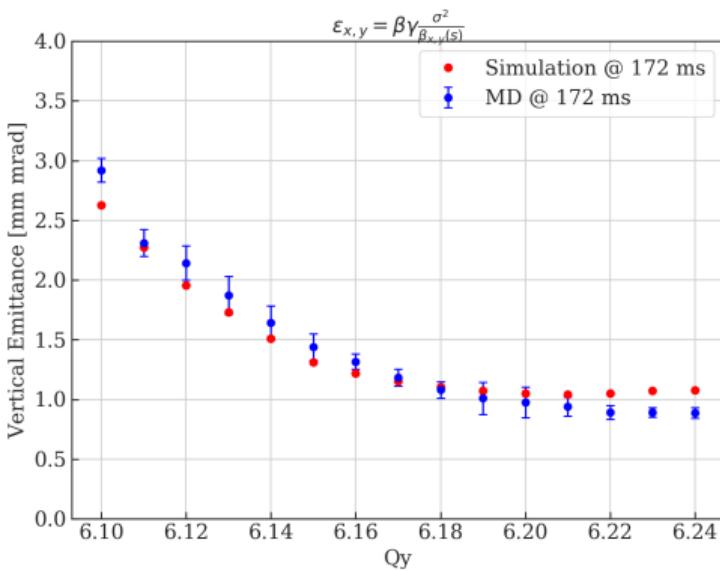
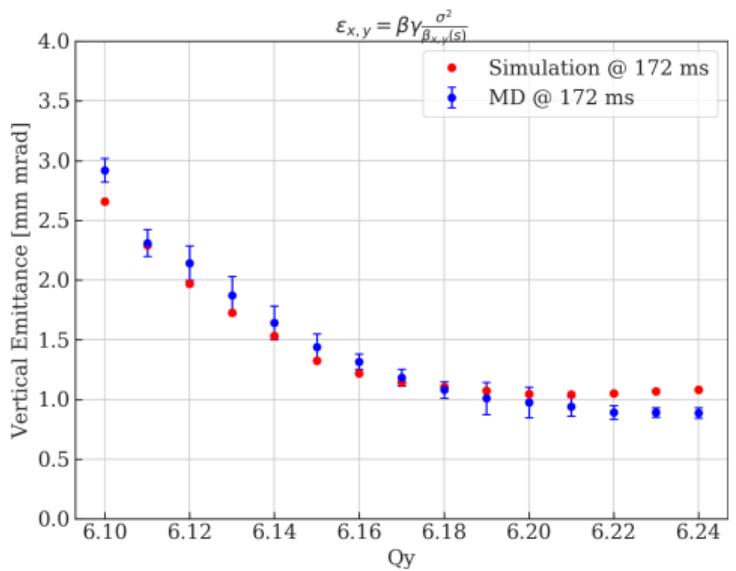
Emittance Plots

Left plot: 'Linear Nominal'. Right plot: 'Averaged WP'.

Emittance Using Sim Optics and 2nd Moment μ'



Emittance Using Sim Optics and beam size σ



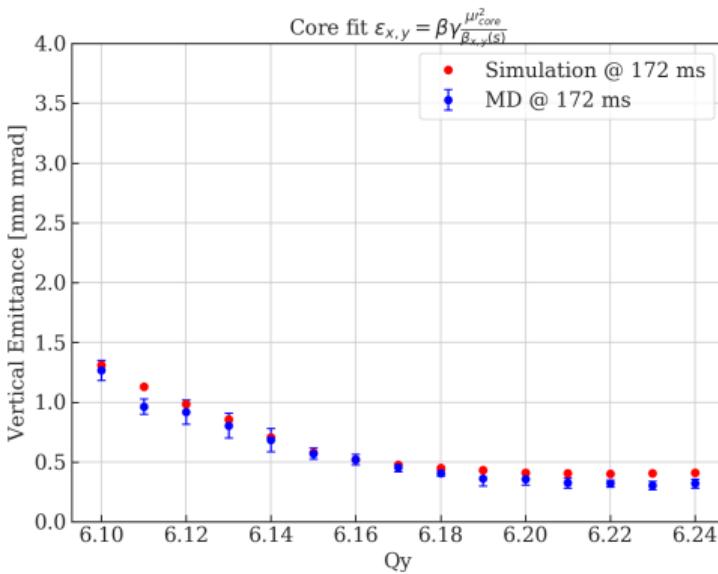
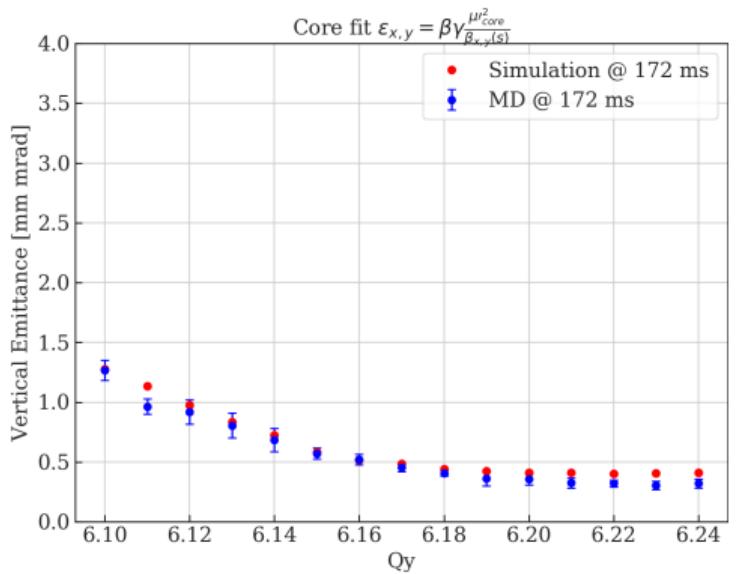
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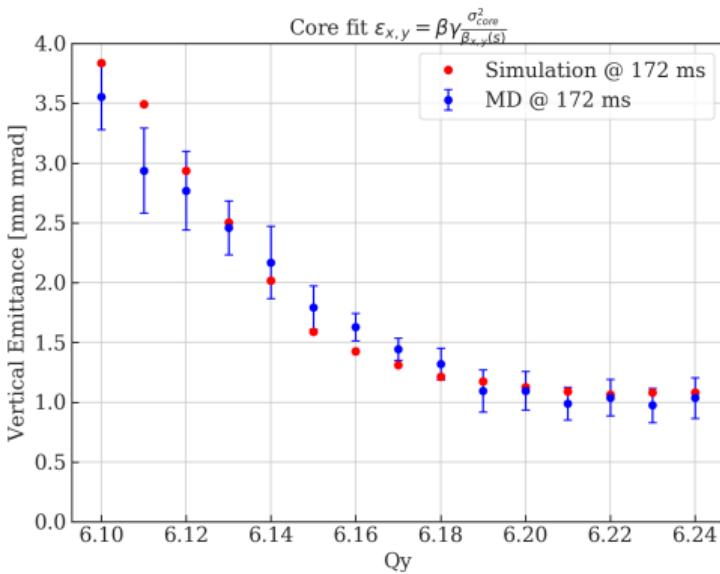
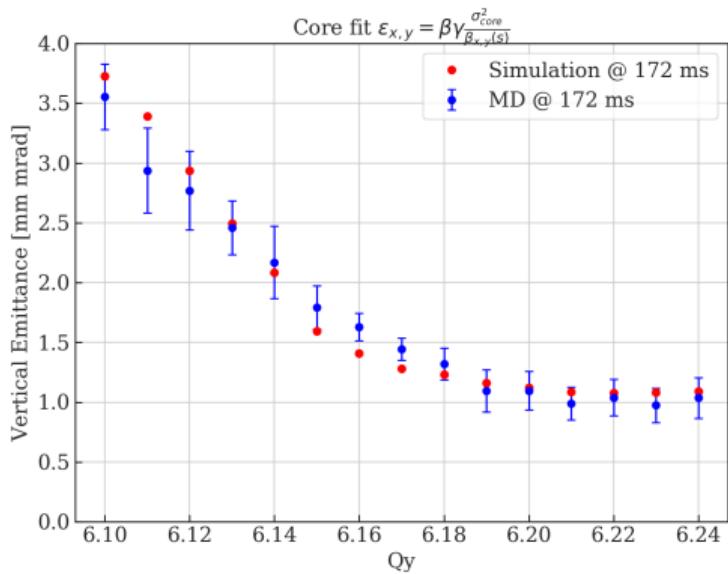
Beam Profiles

172 ms

Emittance Using Sim Optics and 2nd Moment μ'



Emittance Using Sim Optics and beam size σ



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Measured and simulated beam profiles.

PS turn $\approx 2.287 \mu\text{s}$. Using maximum of each data set to normalise to 1.

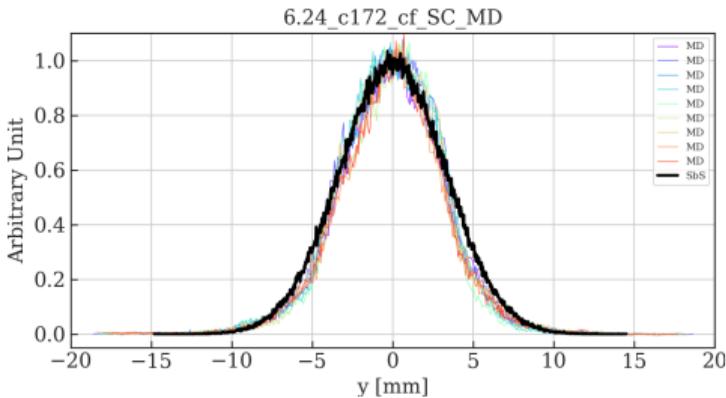
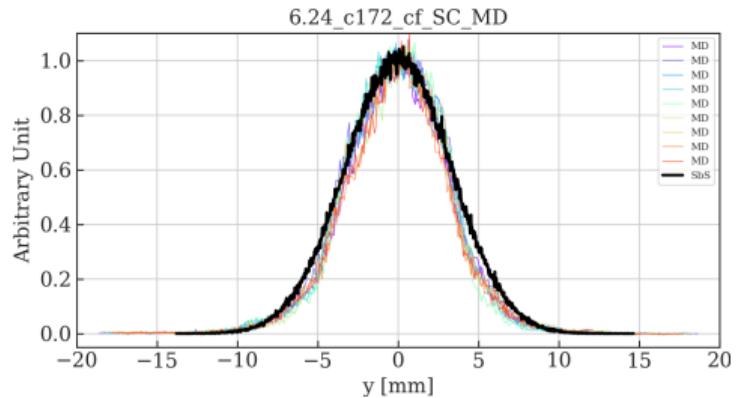
- ▶ c172 = 172 ms = 875 turns
- ▶ c175 = 175 ms = 2186 turns
- ▶ c185 = 185 ms = 6559 turns (not plotted)
- ▶ note the python start index is 0, thus plotted turns are 874 and 2185.

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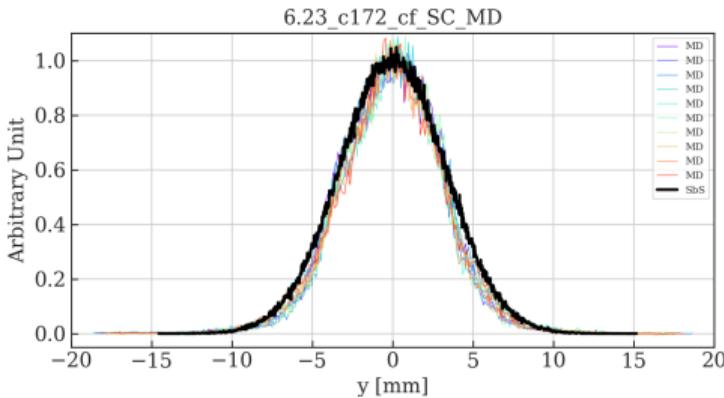
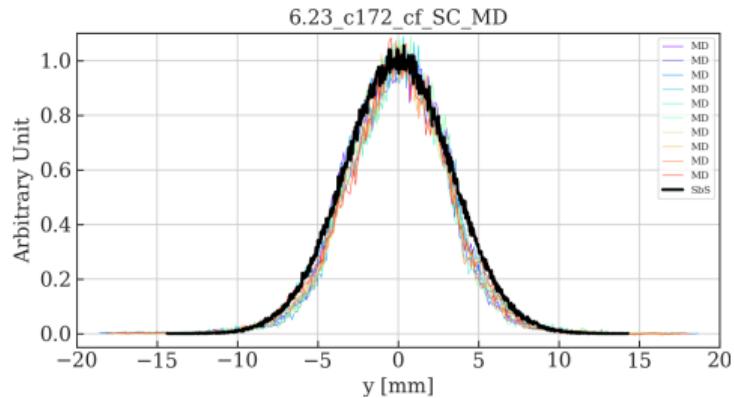
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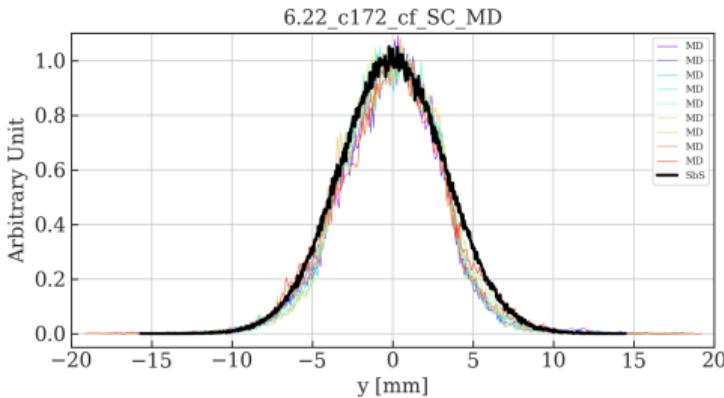
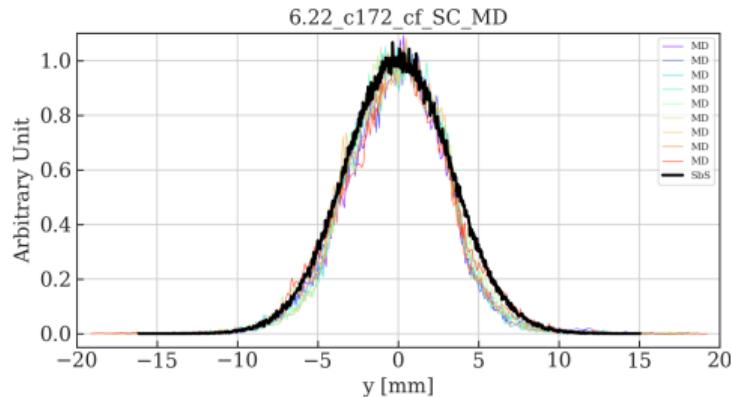
$Q_y = 6.24$, $t = 172$ ms



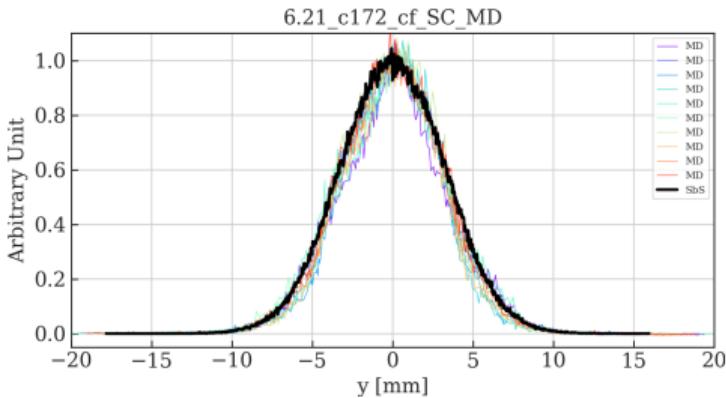
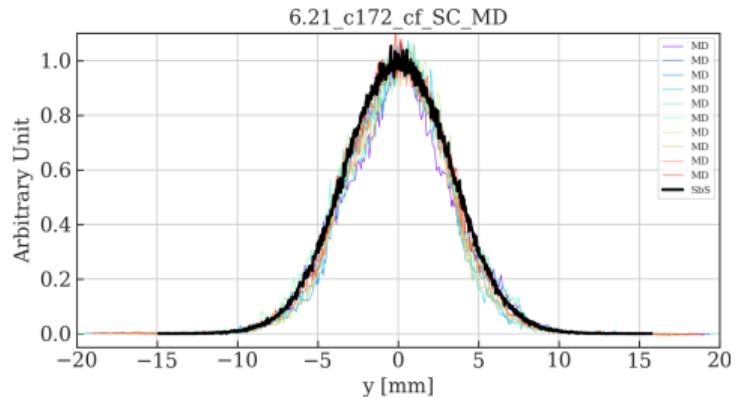
$Q_y = 6.23$, $t = 172$ ms



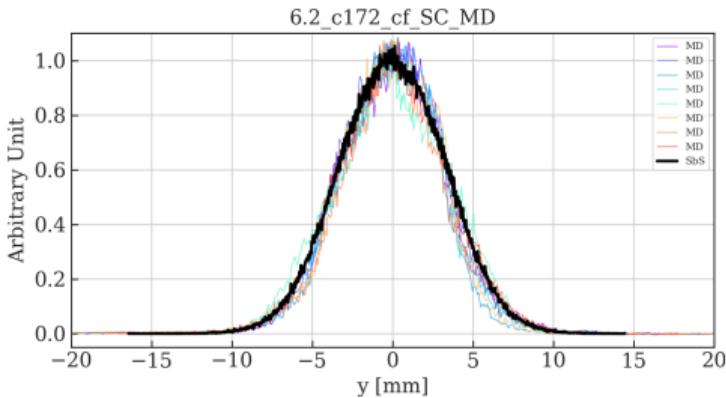
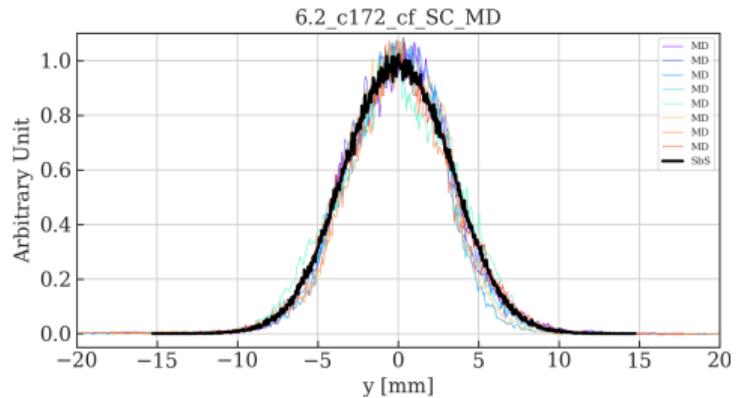
$Q_y = 6.22$, $t = 172$ ms



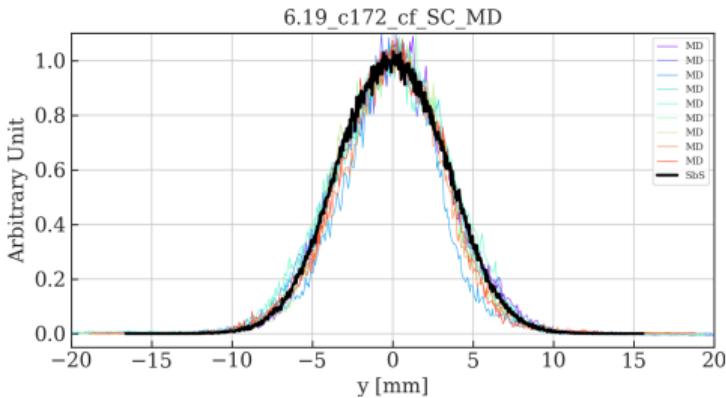
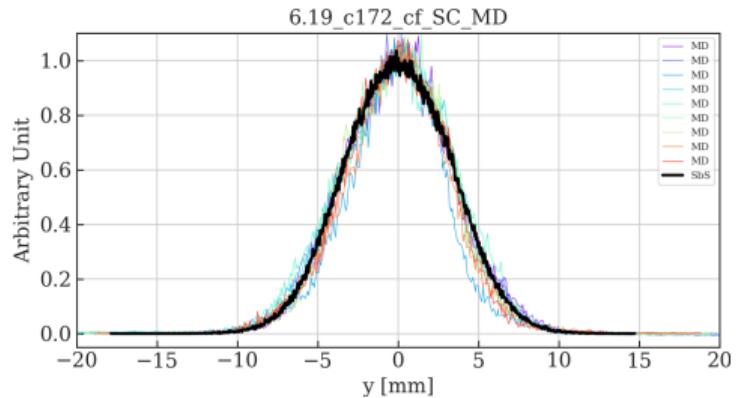
$Q_y = 6.21$, $t = 172$ ms



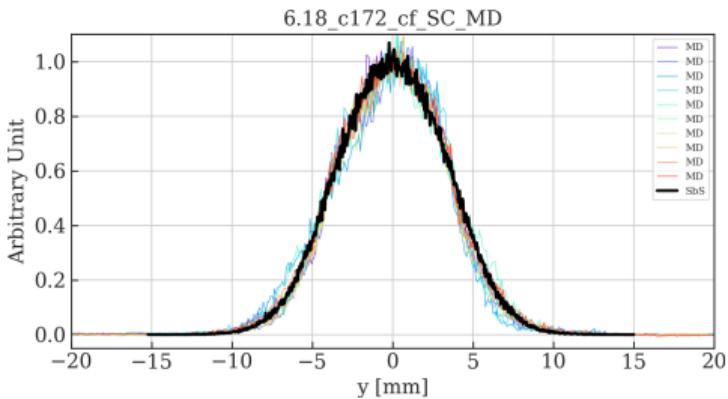
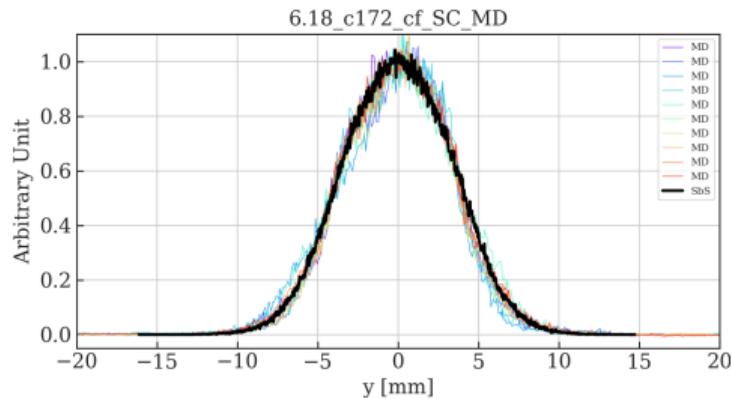
$Q_y = 6.20$, $t = 172$ ms



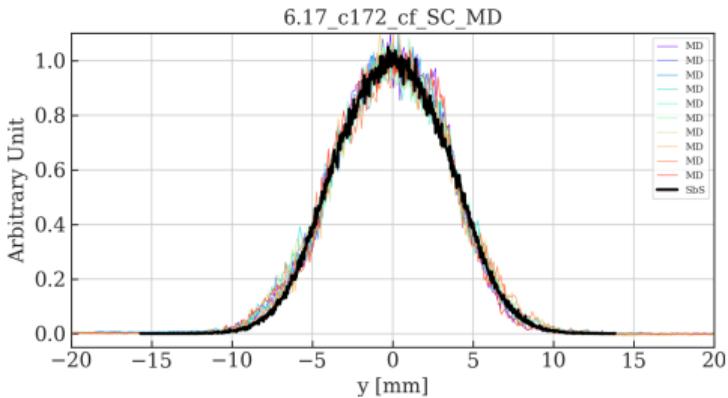
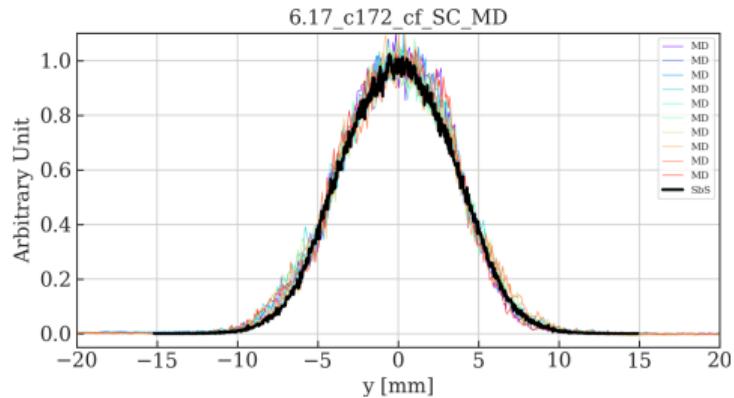
$Q_y = 6.19$, $t = 172$ ms



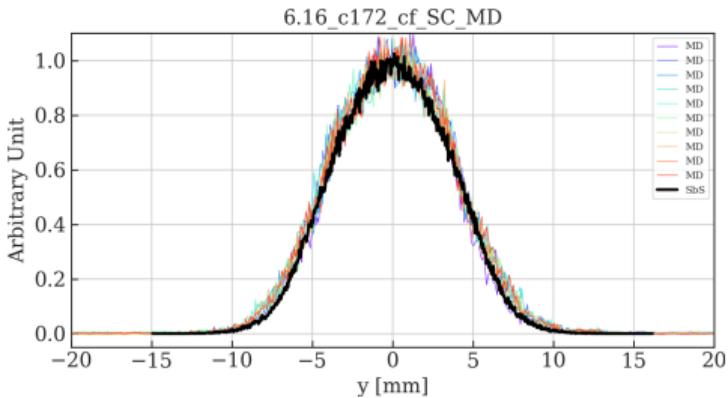
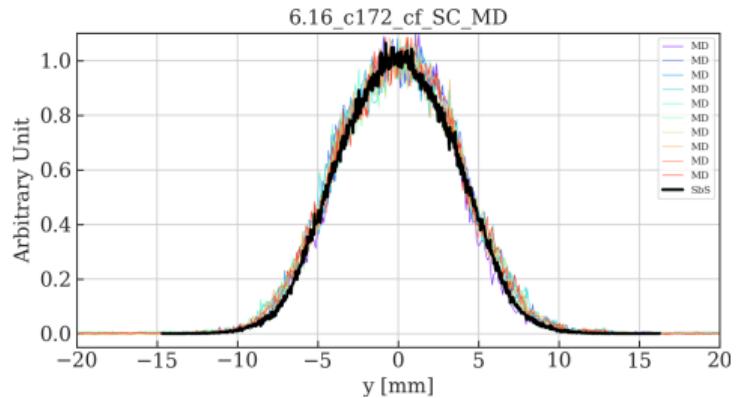
$Q_y = 6.18$, $t = 172$ ms



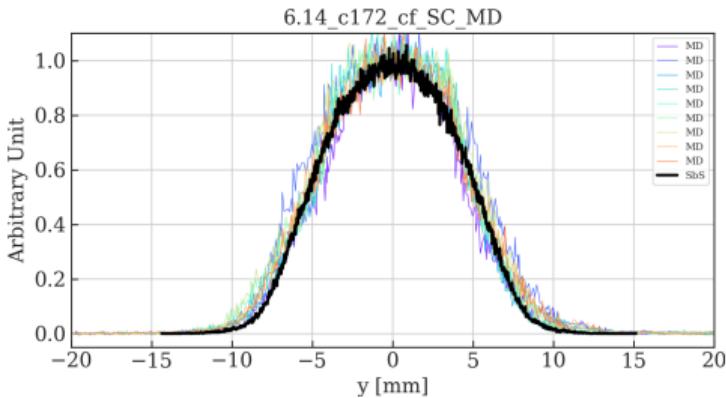
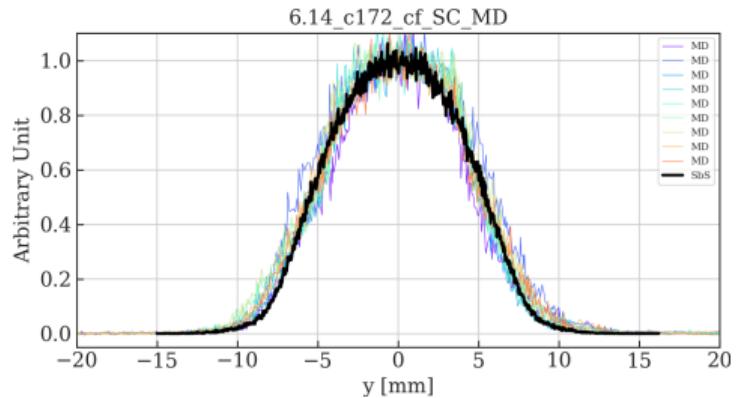
$Q_y = 6.17$, $t = 172$ ms



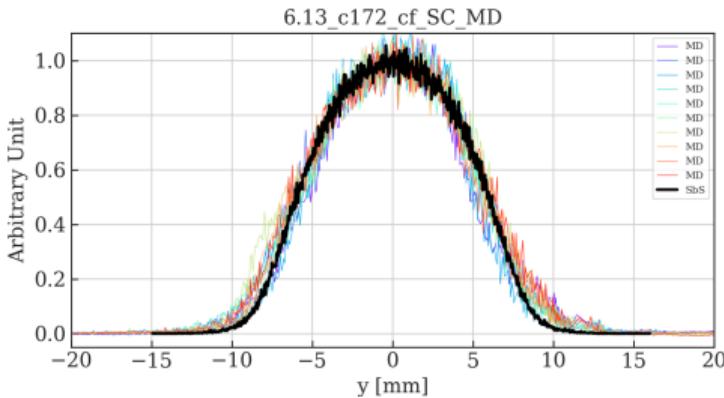
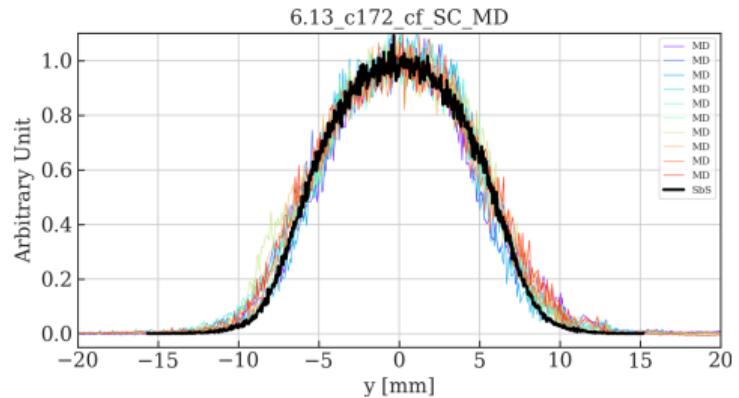
$Q_y = 6.16$, $t = 172$ ms



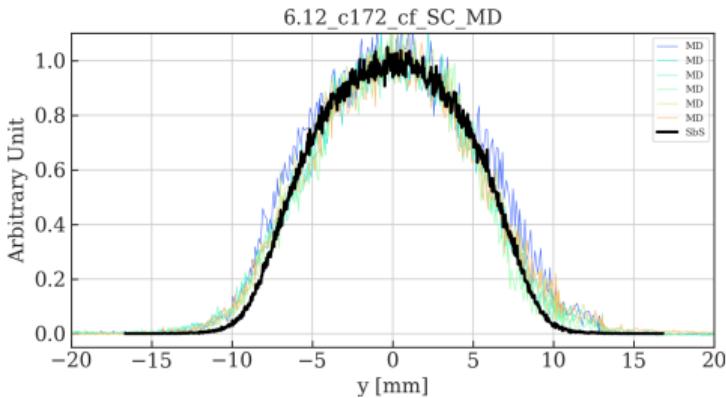
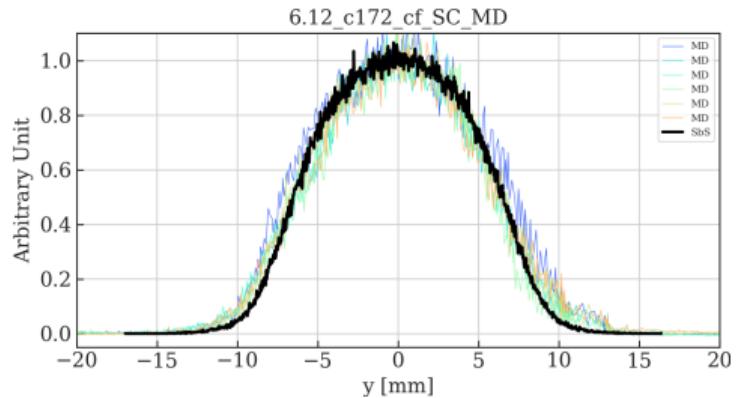
$Q_y = 6.14$, $t = 172$ ms



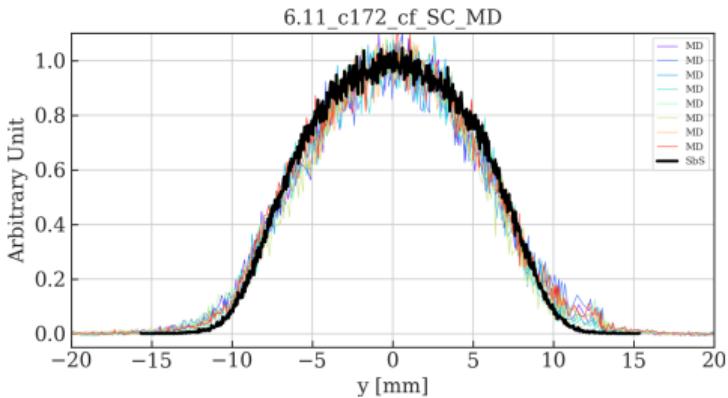
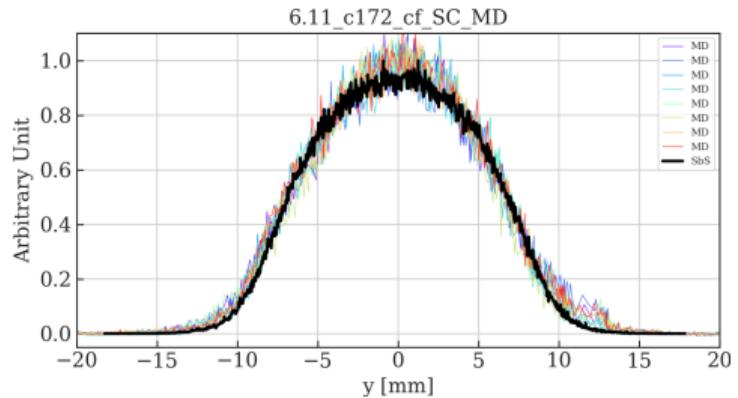
$Q_y = 6.13$, $t = 172$ ms



$Q_y = 6.12$, $t = 172$ ms



$Q_y = 6.11$, $t = 172$ ms



$Q_y = 6.10$, $t = 172$ ms

