Benchmarking Impact-T and SPACE in the CeC PAC Section

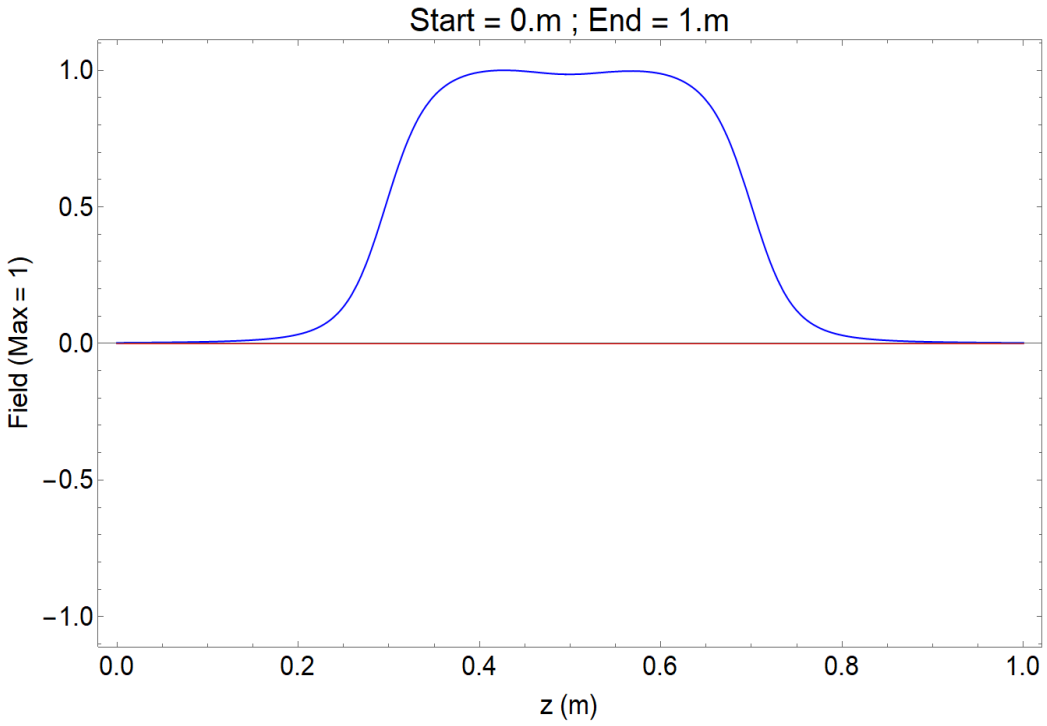
Kai Shih

03/10/2023

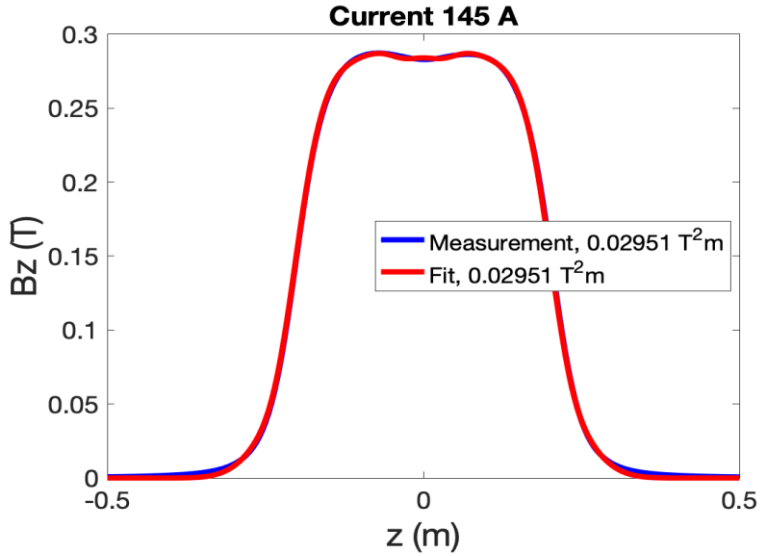
From Yichao's latest beam dynamics simulations: Slice 15

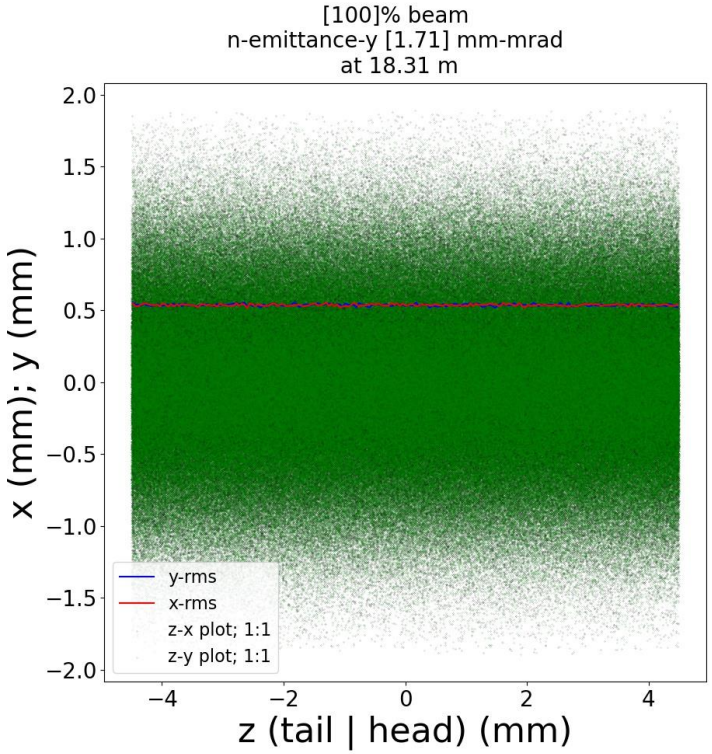
Beta function : 4.85148 m
Alpha function : -0.21765
Gamma : 28.4976
N-emittance : 1.723135 um
Current : 49.58 A
Sol 1–7 : 58.77, -117.54, 120, -120, 120, -117.54, 58.77 A

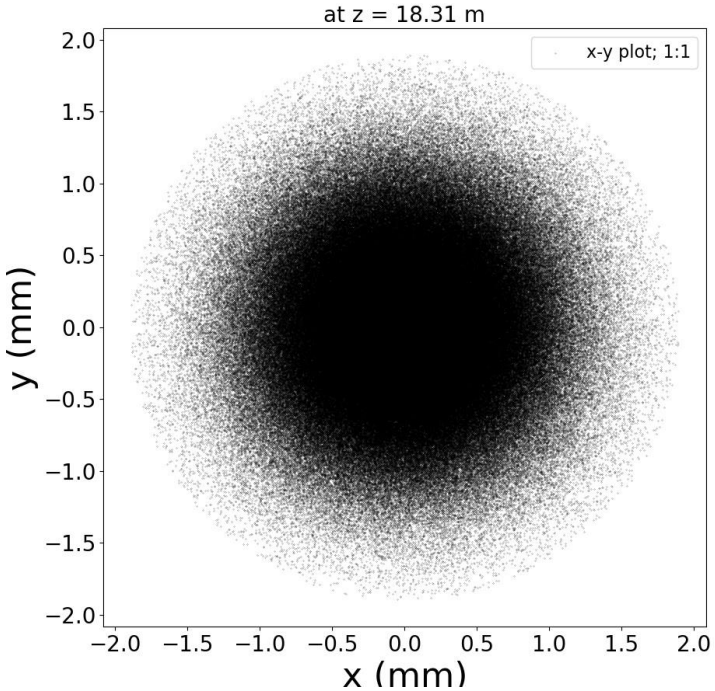
PCA Sol field used in Impact-T

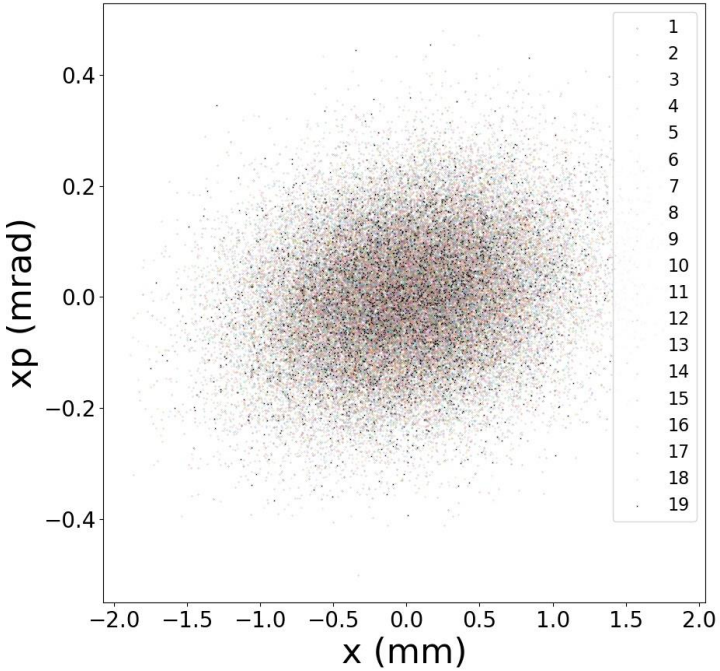


PCA Sol field calibration :
19.813793103448276 T/A

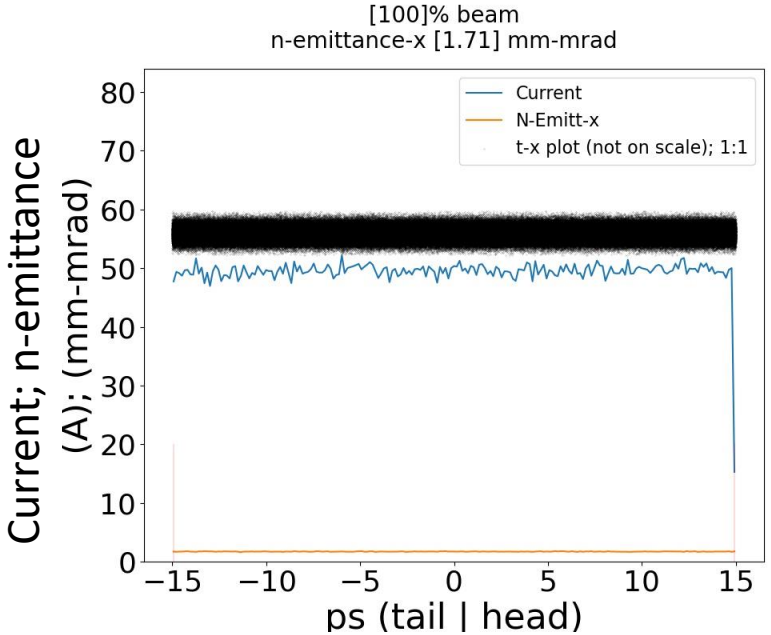


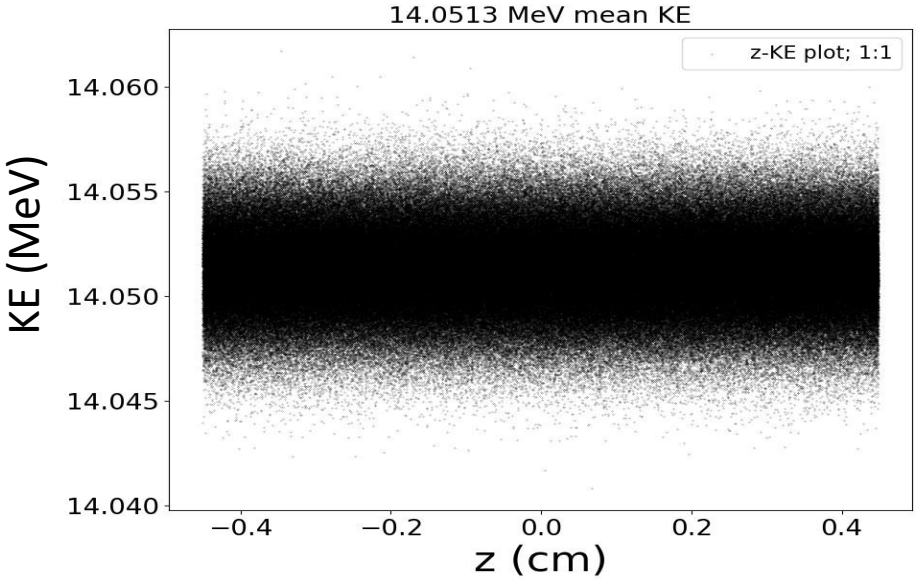




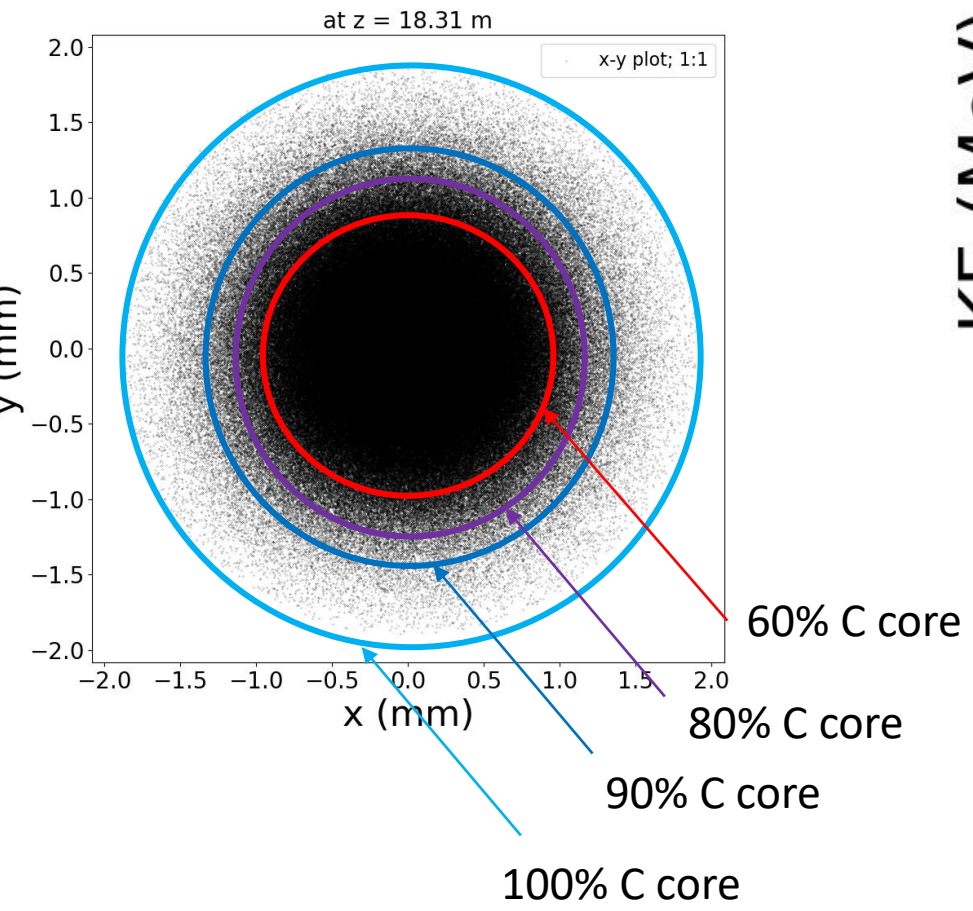


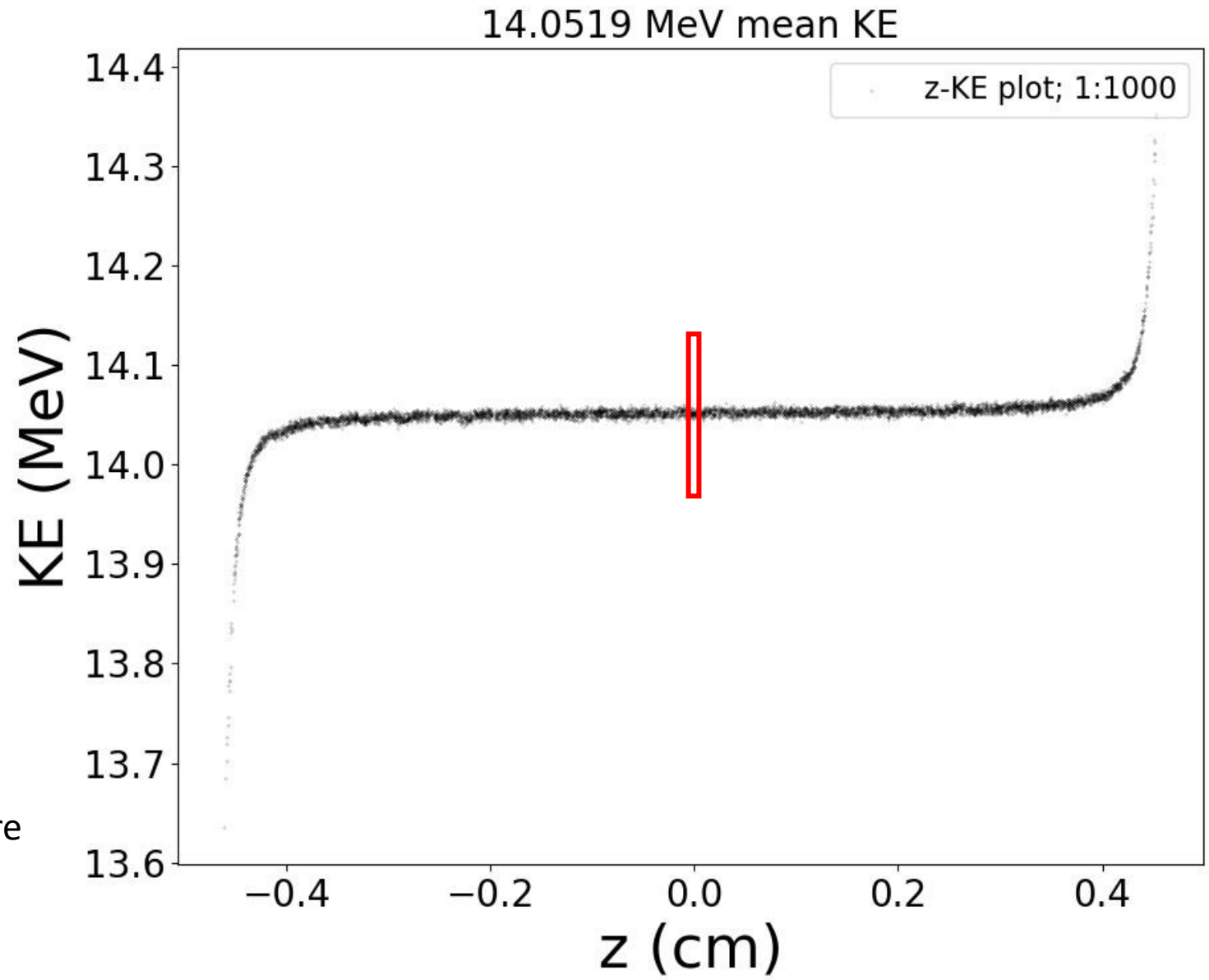
600k Particle
30 ps uniform in time
5D Gaussian
3.5 sigma cutoff
Mesh 32X32X256
Timestep 1e-13 s
2D spherical sim.





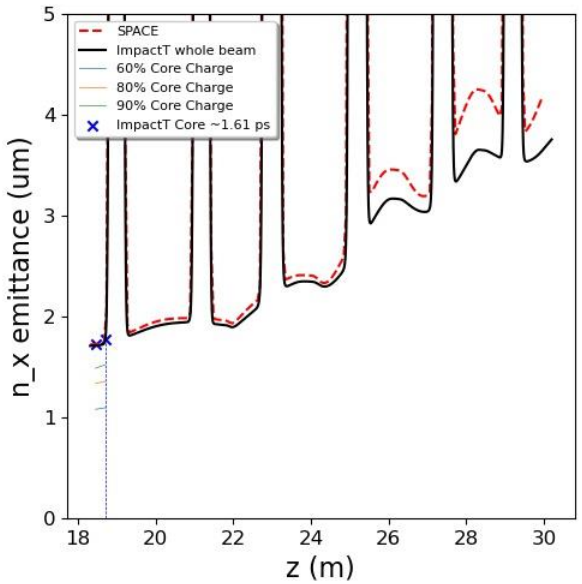
- Slice analysis:
- Central 47.5 % to 52.5 % in length
- ~ 1.6 ps long
- N-Emittance were calculated in diff. % of beam charge core

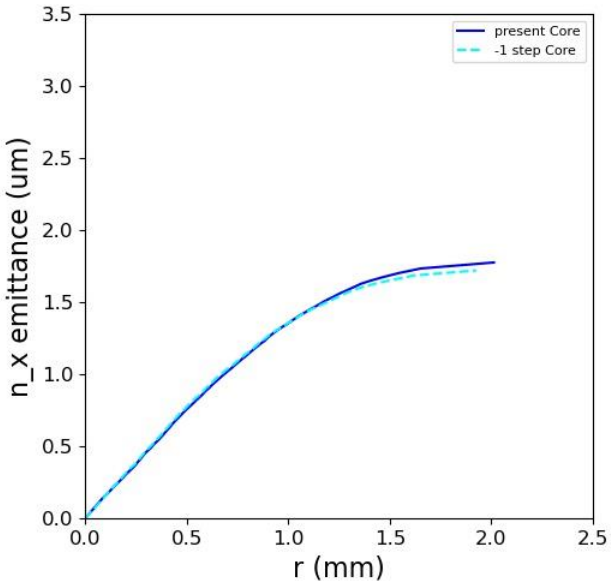


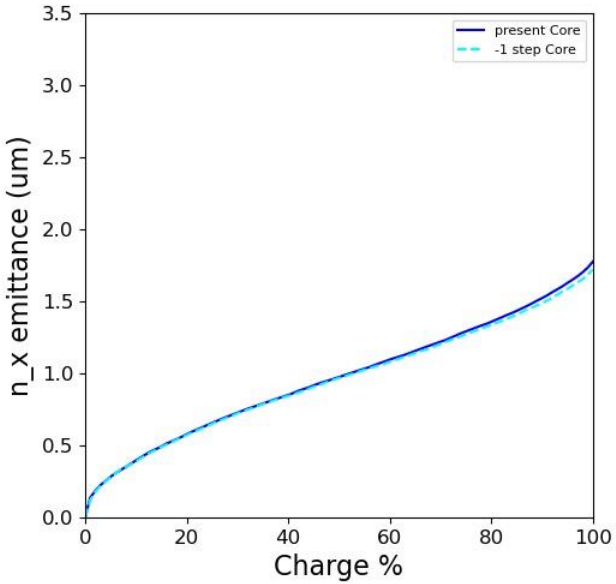


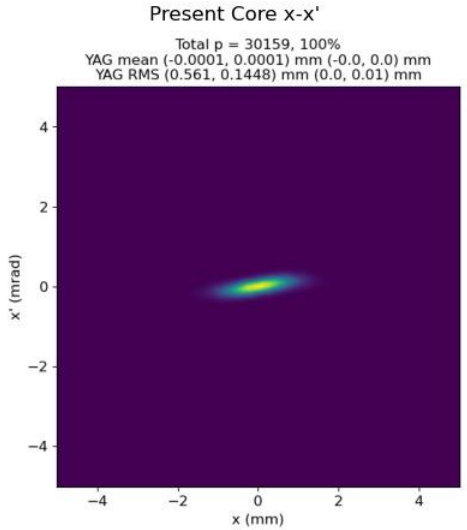
Tring to answer these two question :

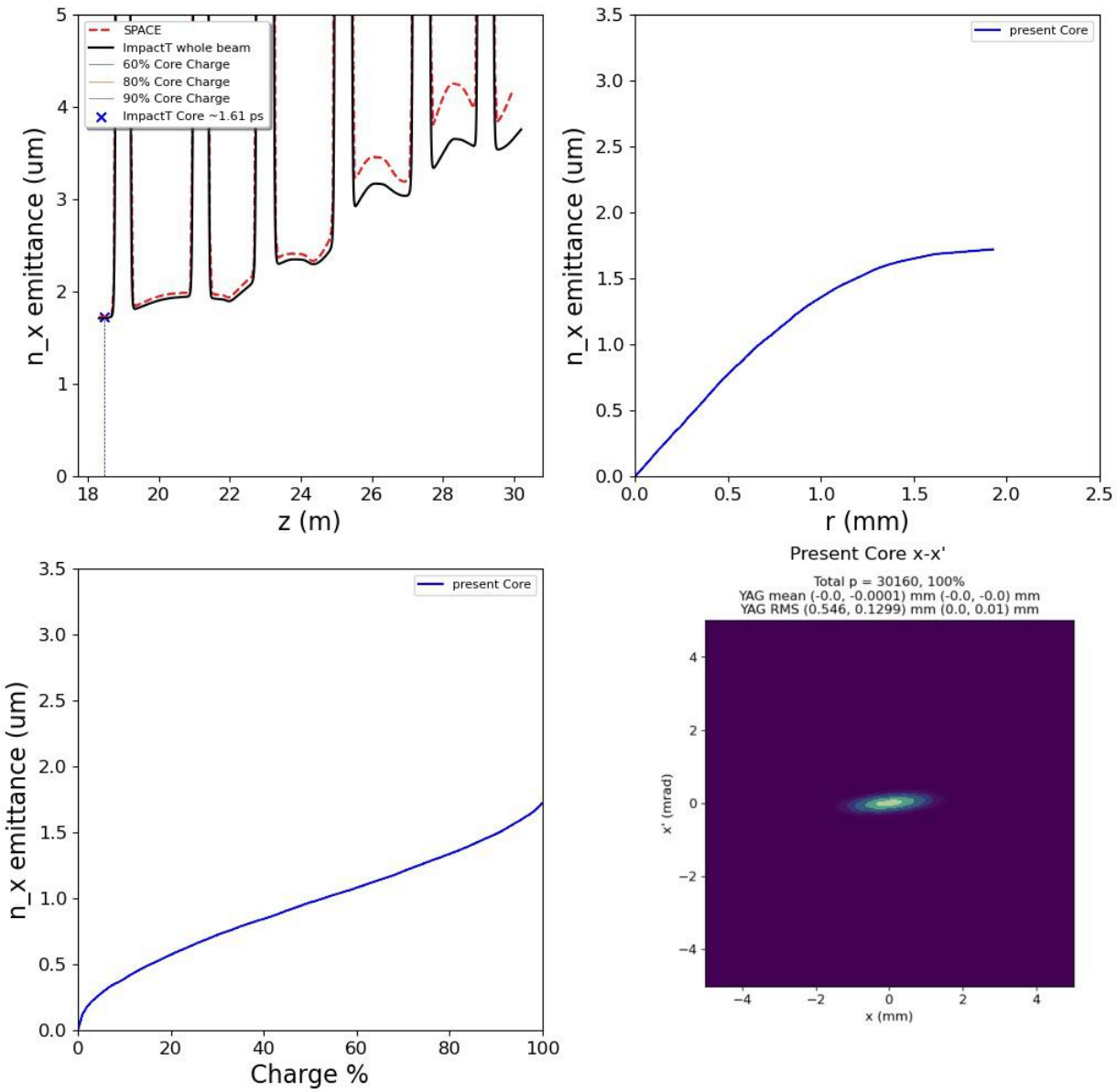
1. The increases of emittance after PCA
2. Why SPACE and Impact sow diff. result

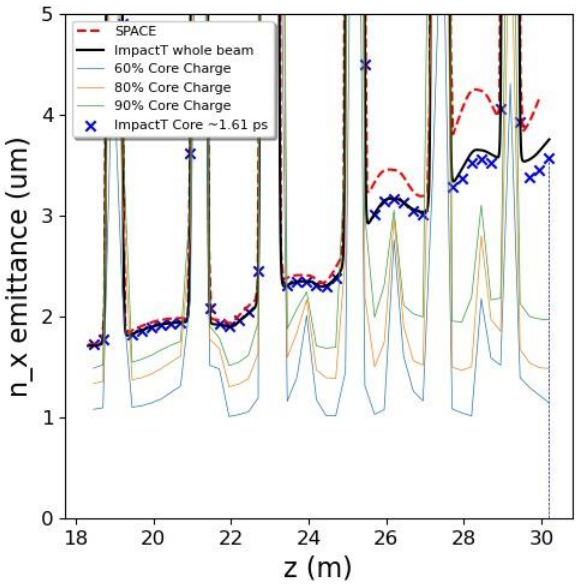


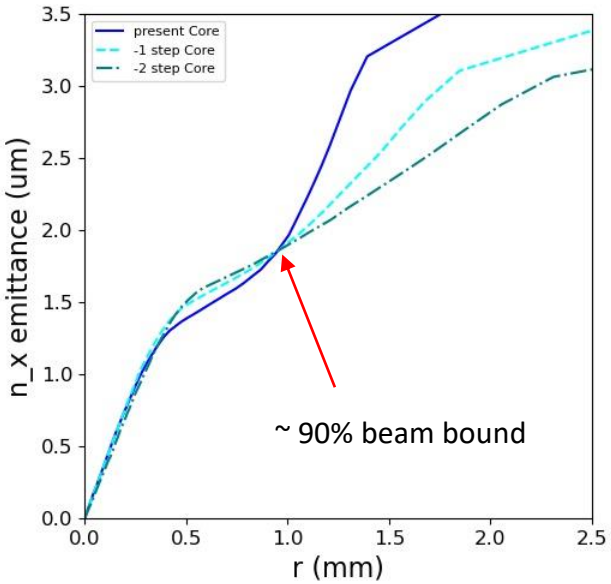


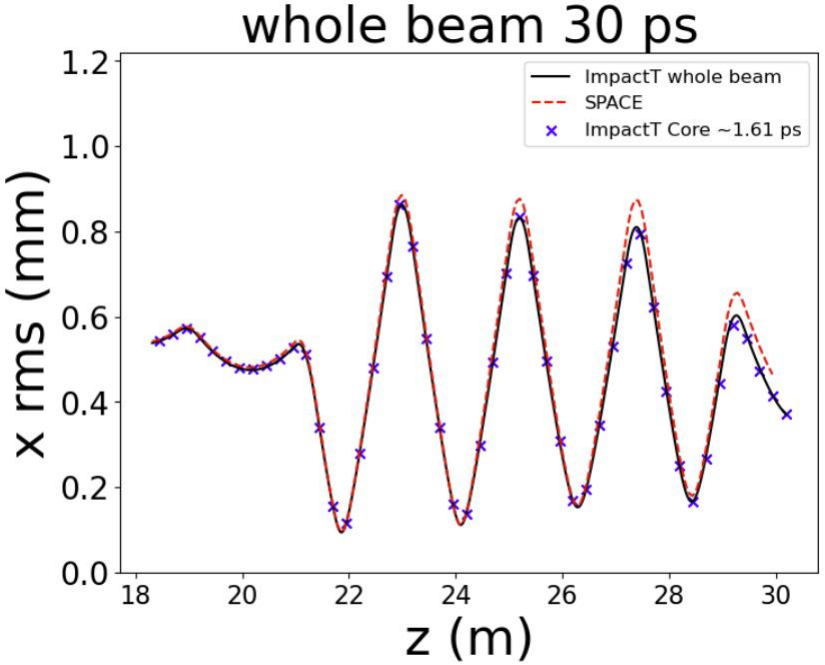


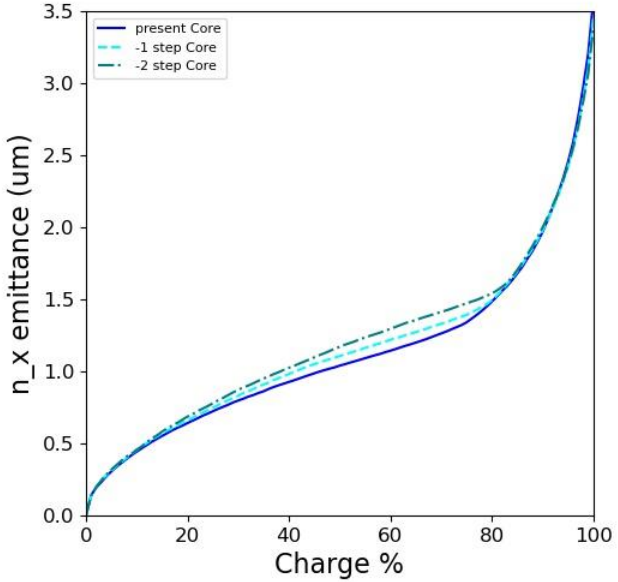


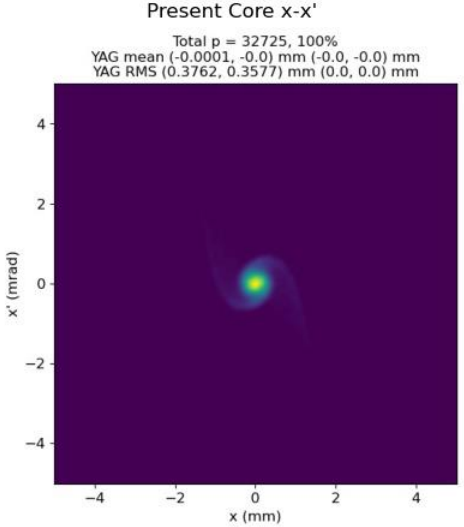

SPACE
ImpactT whole beam
60% Core Charge
80% Core Charge
90% Core Charge
ImpactT Core ~1.61 ps
n_x emittance (um)
z (m)
present Core
n_x emittance (um)
r (mm)
present Core
n_x emittance (um)
Charge %
Present Core x-x'
Total p = 30160, 100%
YAG mean (-0.0, -0.0001) mm (-0.0, -0.0) mm
YAG RMS (0.546, 0.1299) mm (0.0, 0.01) mm
x' (mrad)
x (mm)

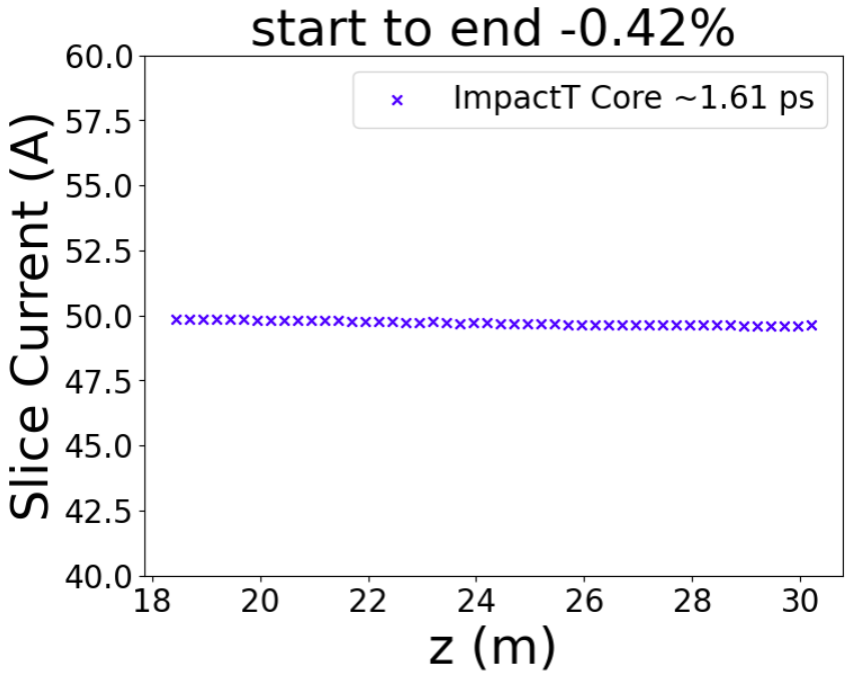

SPACE
ImpactT whole beam
60% Core Charge
80% Core Charge
90% Core Charge
ImpactT Core ~1.61 ps
n_x emittance (um)
z (m)


present Core
-1 step Core
-2 step Core
~ 90% beam bound
n_x emittance (um)
r (mm)

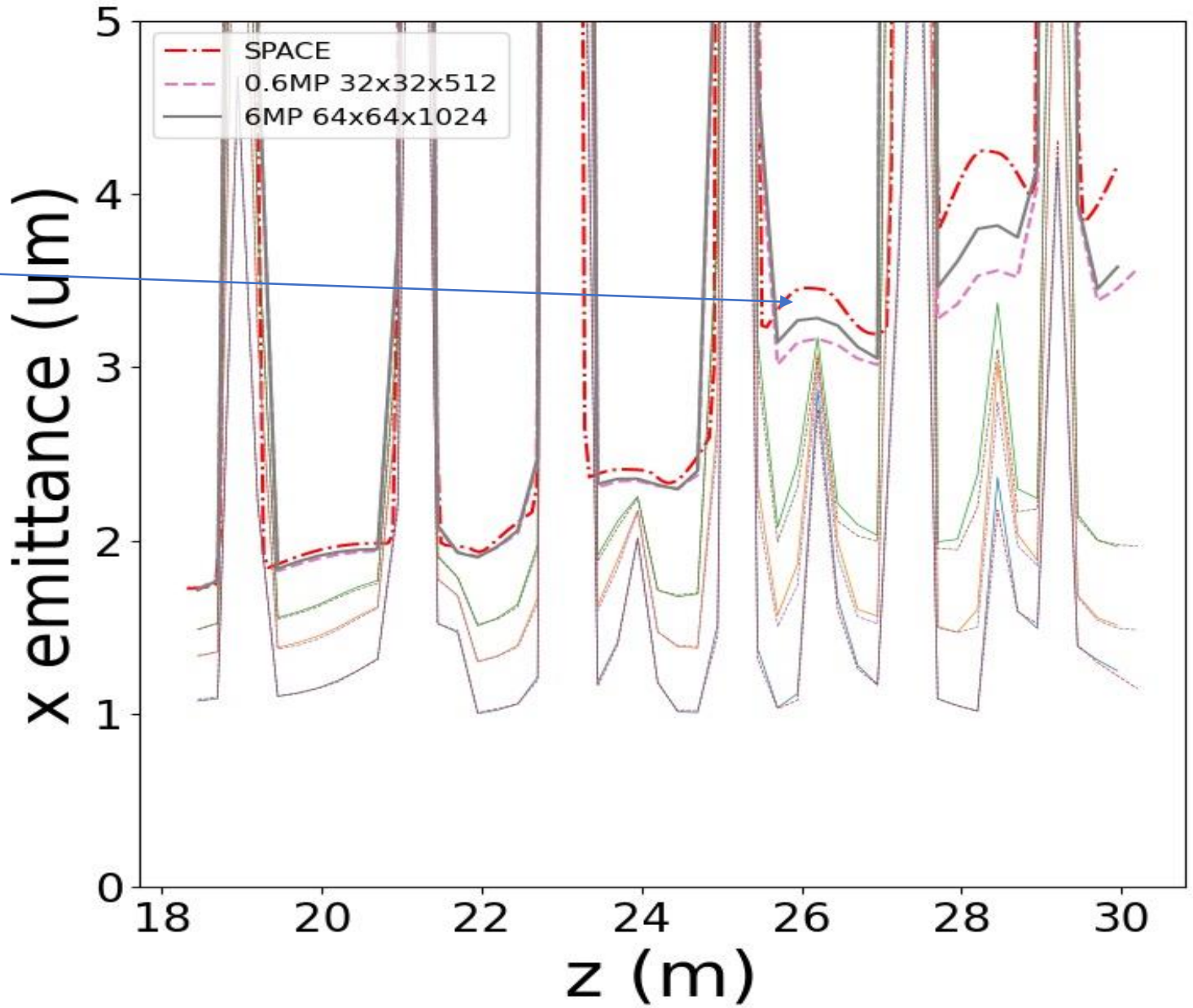

whole beam 30 ps
ImpactT whole beam
SPACE
ImpactT Core ~1.61 ps
x rms (mm)
z (m)


present Core
-1 step Core
-2 step Core
n_x emittance (um)
Charge %


Present Core x-x'
Total p = 32725, 100%
YAG mean (-0.0001, -0.0) mm (-0.0, -0.0) mm
YAG RMS (0.3762, 0.3577) mm (0.0, 0.0) mm
x' (mrad)
x (mm)


start to end -0.42%
ImpactT Core ~1.61 ps
Slice Current (A)
z (m)

- Maybe diff. comes from # of mesh and # of the sim. Particle
- Also may be due to diff. particle dynamics calculation after sol 3

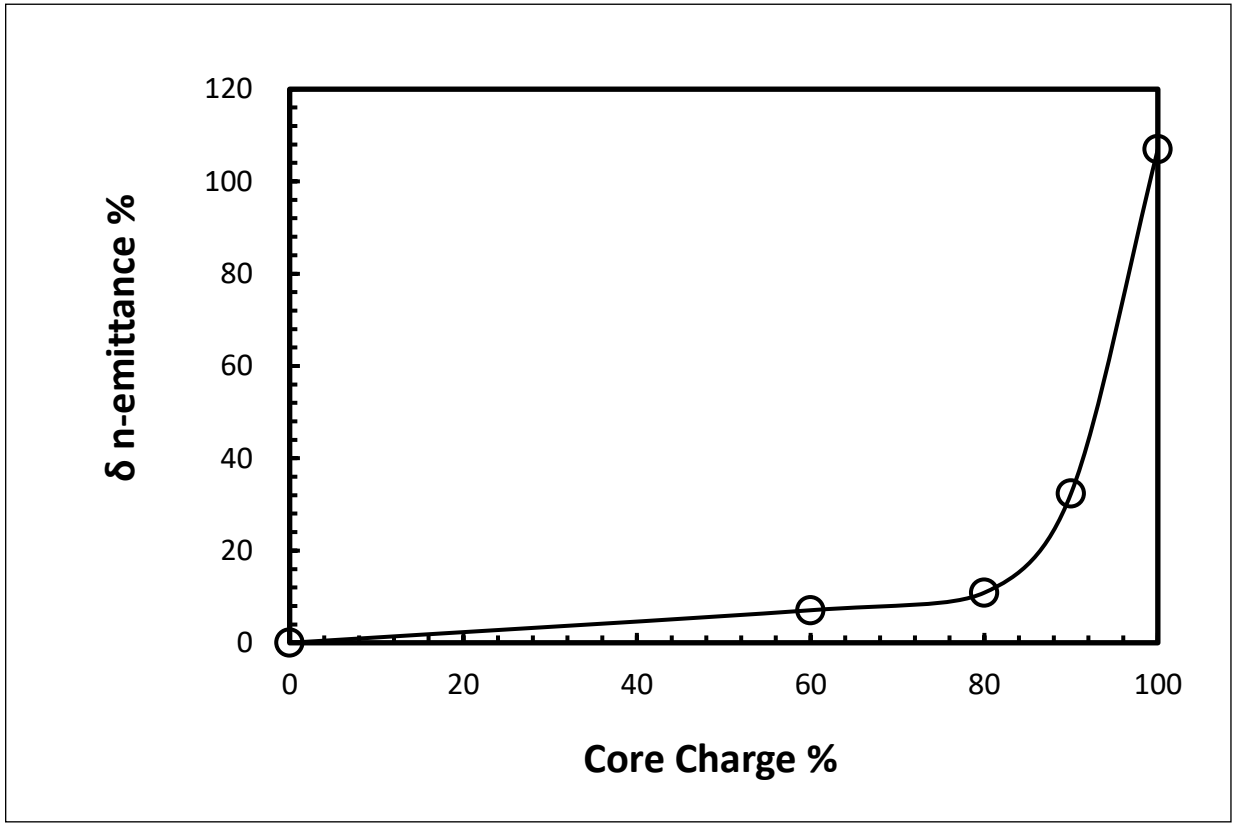


Impact-T 6Mp

Core	δ n-emittance
60%	7.06 %
80%	10.85 %
90%	32.34 %
100%	106.93 %

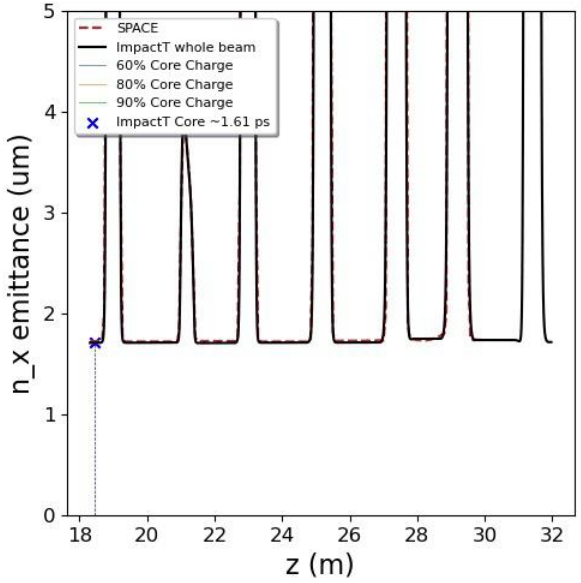
SPACE	δ n-emittance
100%	140 %

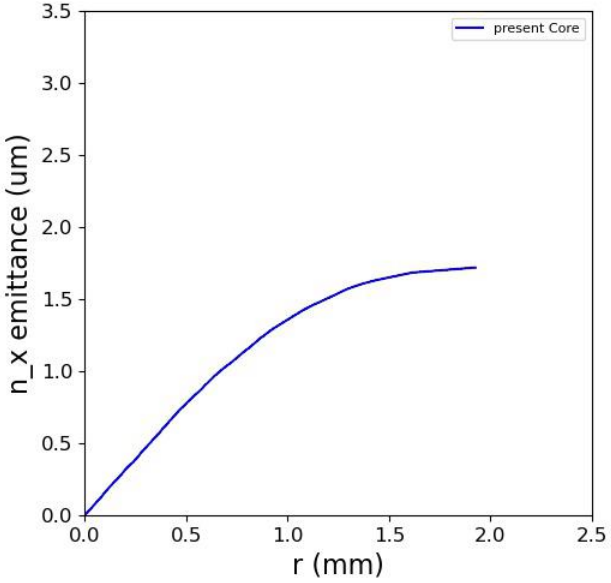
From 18.45m to 30.20 m (first 6 Sol in PCA)

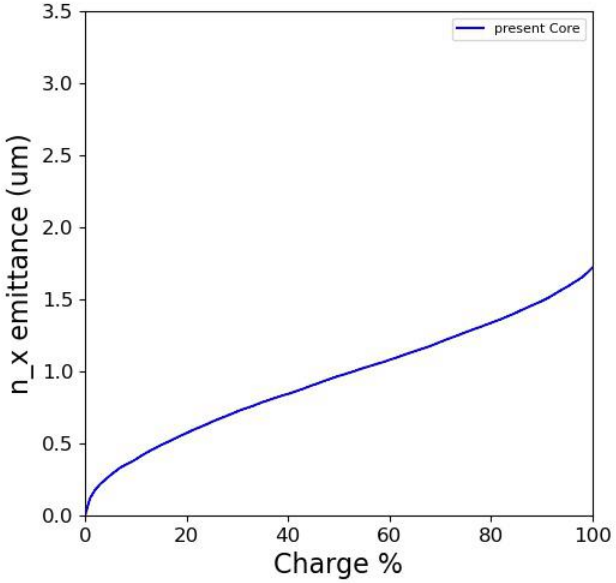


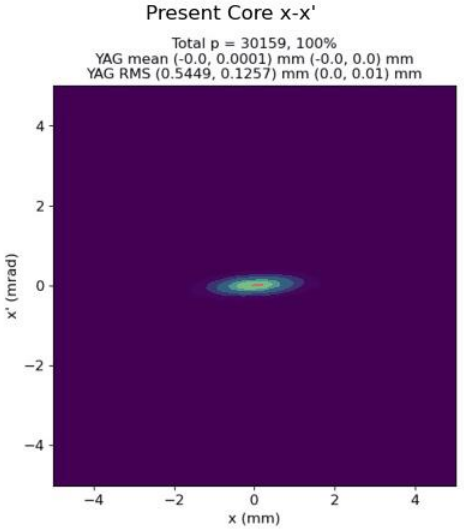
No Space-charge

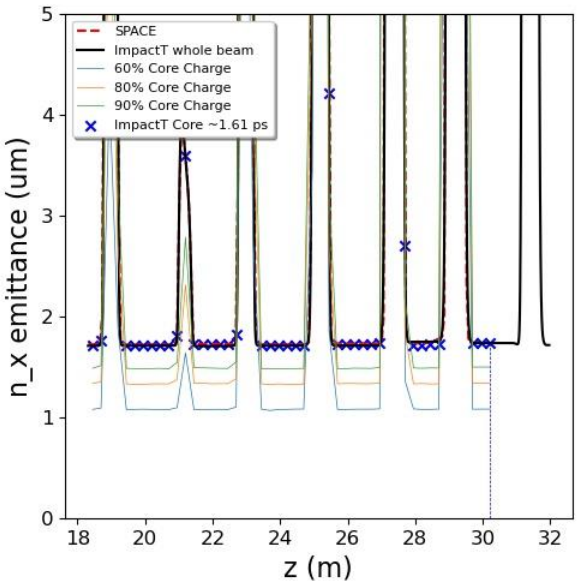
Sol 1–7 : 58.77, -117.54, 121.65, - 121.65, 121.65, -117.54, 58.77 A

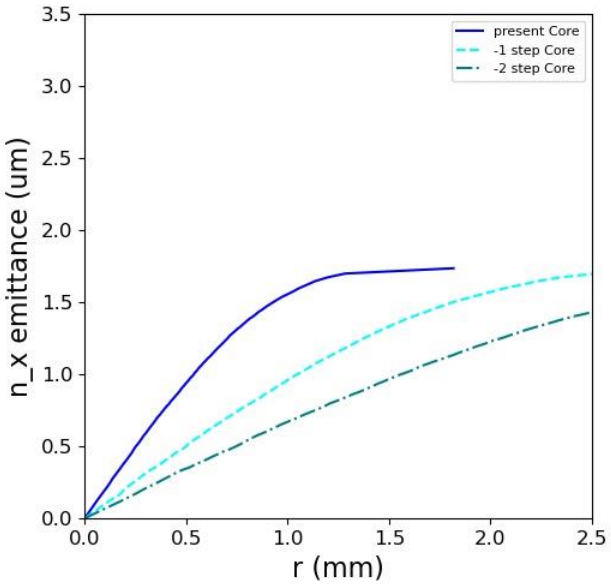


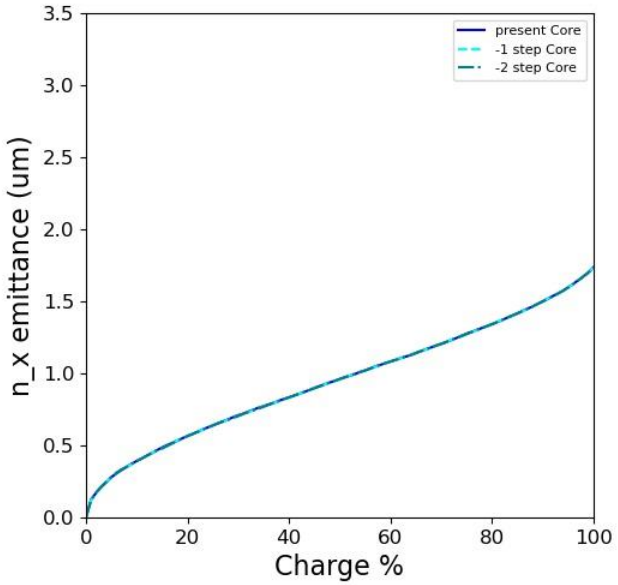


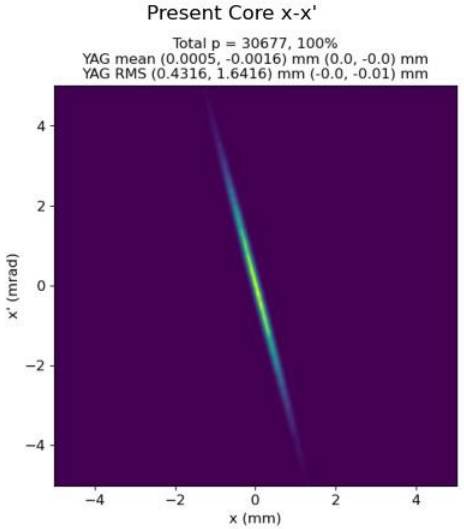


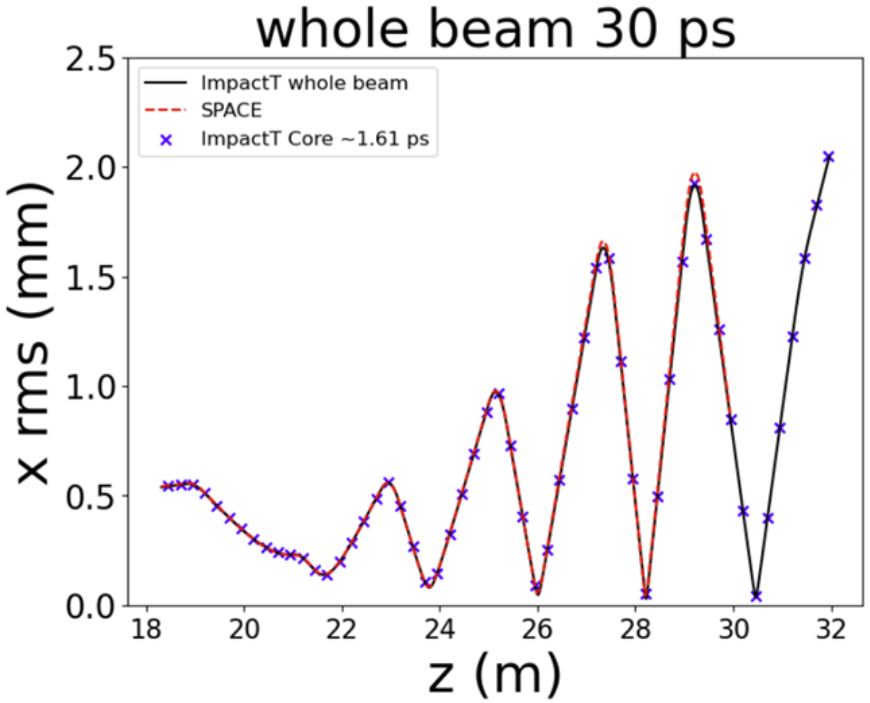


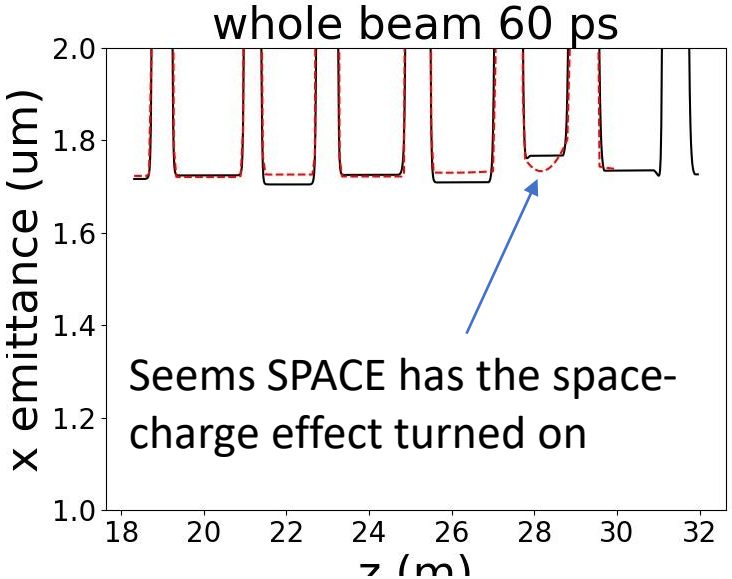

SPACE
ImpactT whole beam
60% Core Charge
80% Core Charge
90% Core Charge
ImpactT Core ~1.61 ps
n_x emittance (um)
z (m)


present Core
-1 step Core
-2 step Core
n_x emittance (um)
r (mm)

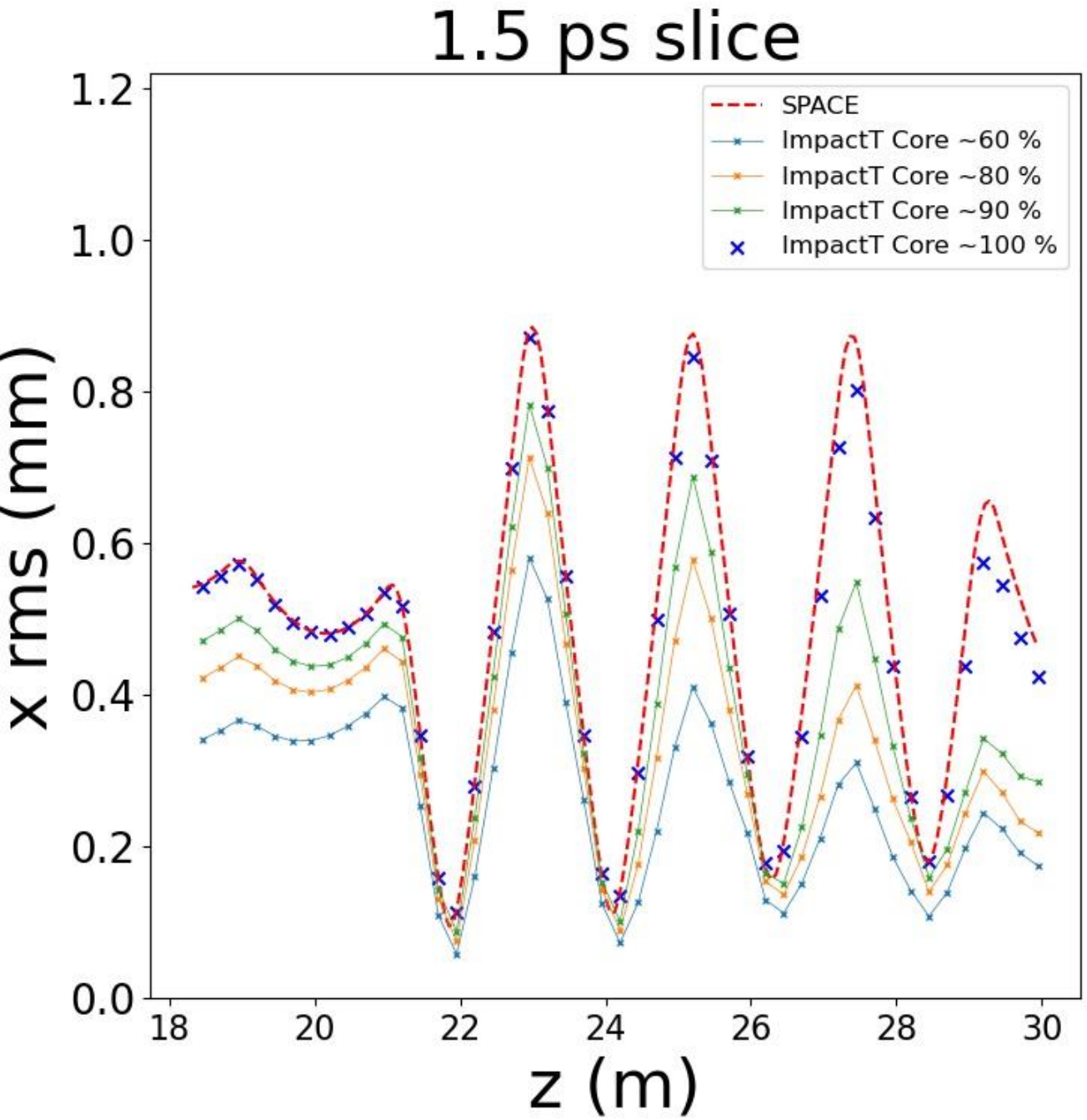

present Core
-1 step Core
-2 step Core
n_x emittance (um)
Charge %

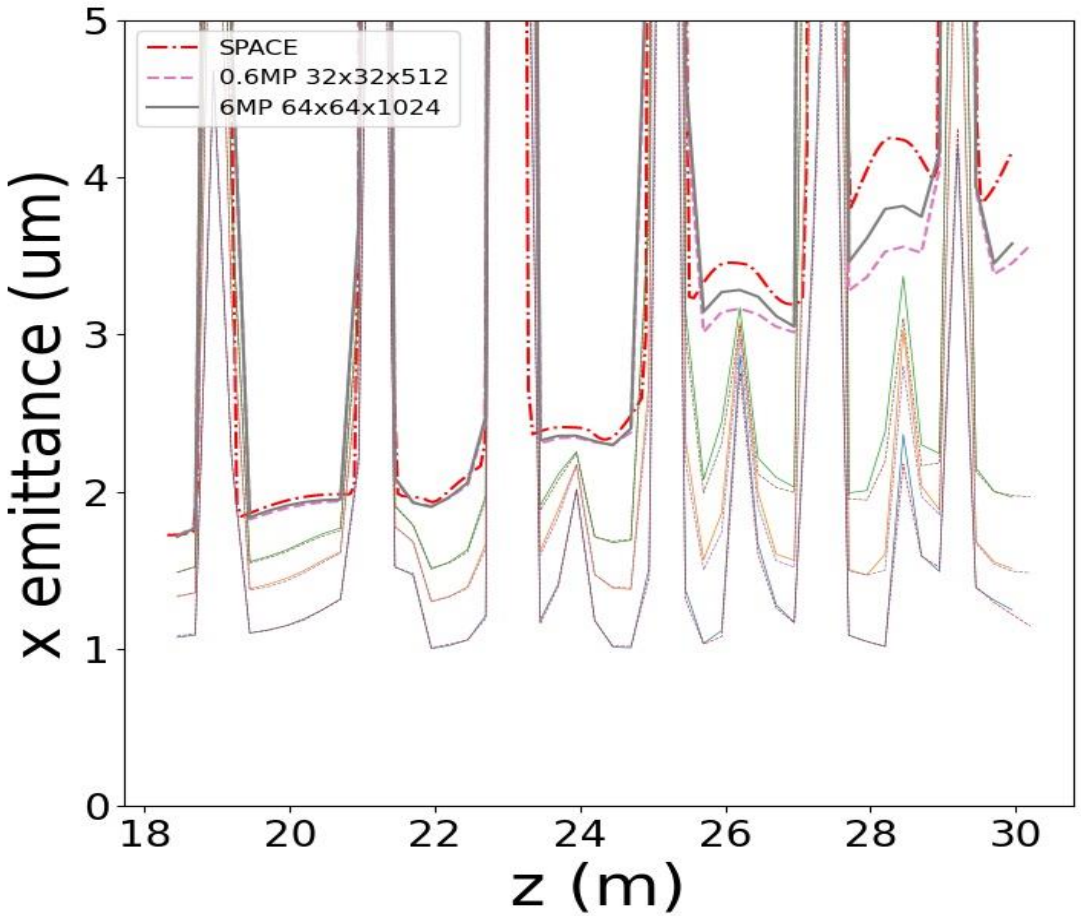

Present Core x-x'
Total p = 30677, 100%
YAG mean (0.0005, -0.0016) mm (0.0, -0.0) mm
YAG RMS (0.4316, 1.6416) mm (-0.0, -0.01) mm
x' (mrad)
x (mm)

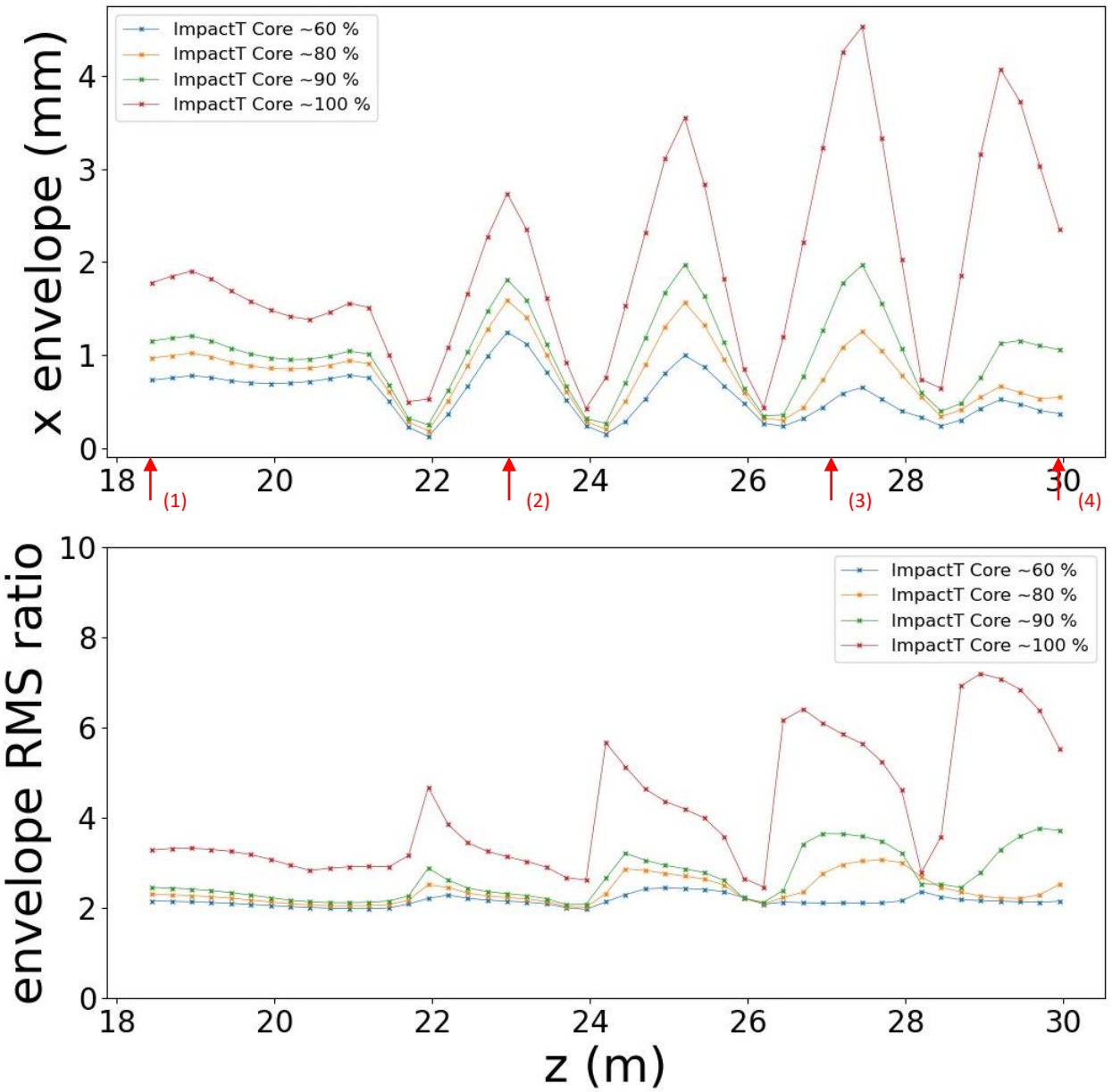

whole beam 30 ps
ImpactT whole beam
SPACE
ImpactT Core ~1.61 ps
x rms (mm)
z (m)


whole beam 60 ps
x emittance (um)
Seems SPACE has the space-charge effect turned on

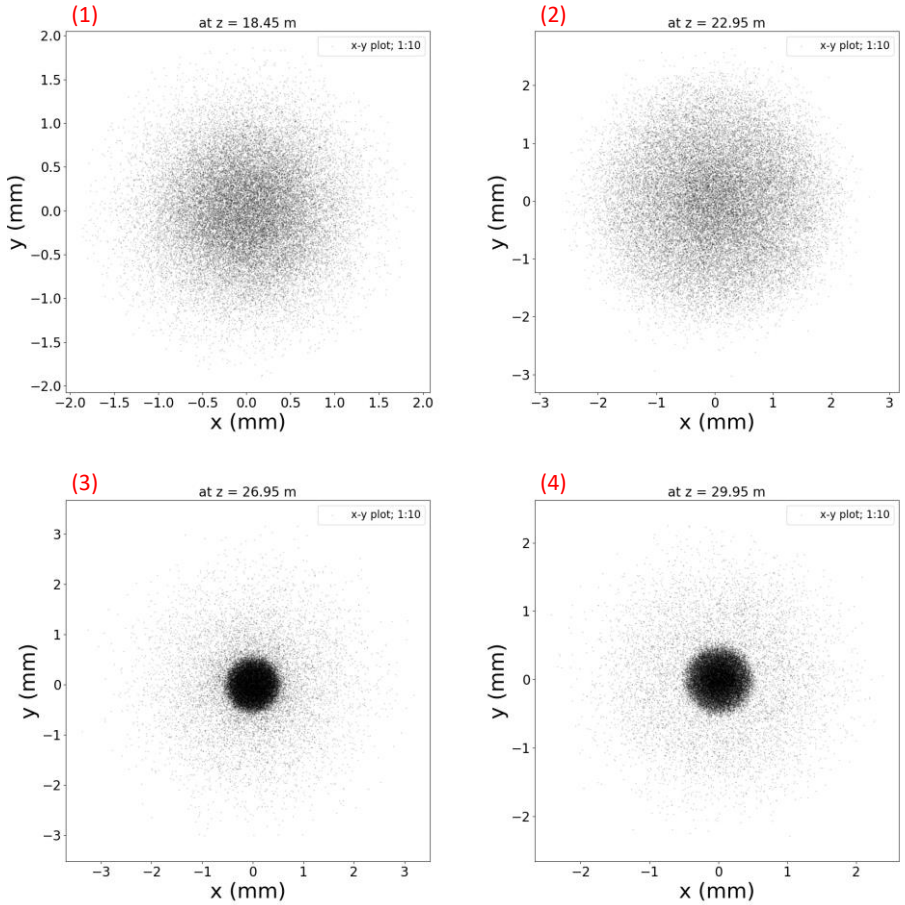
03/31/2023 Updates

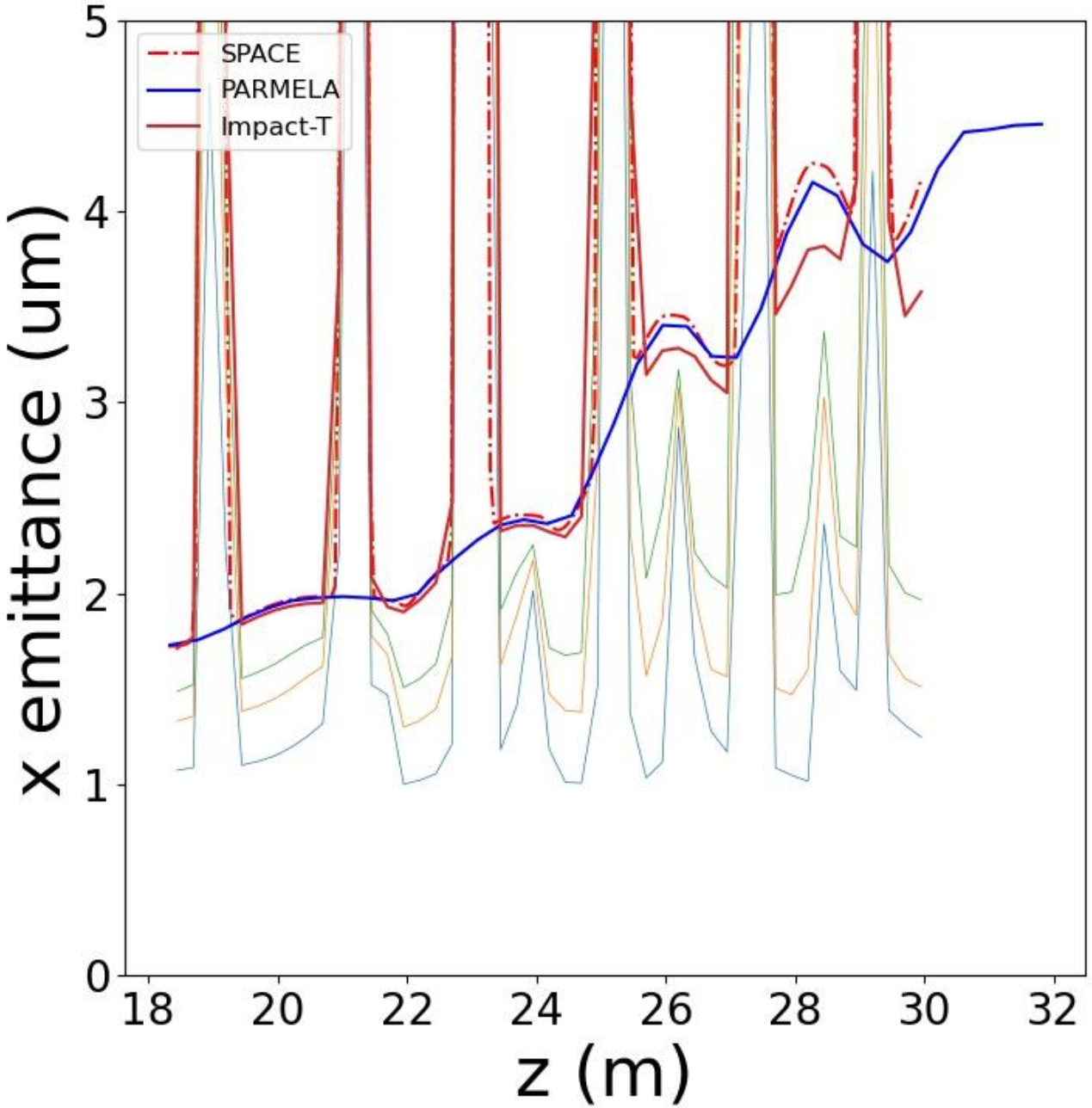

1.5 ps slice
SPACE
ImpactT Core ~60 %
ImpactT Core ~80 %
ImpactT Core ~90 %
ImpactT Core ~100 %
x rms (mm)
z (m)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
18
20
22
24
26
28
30

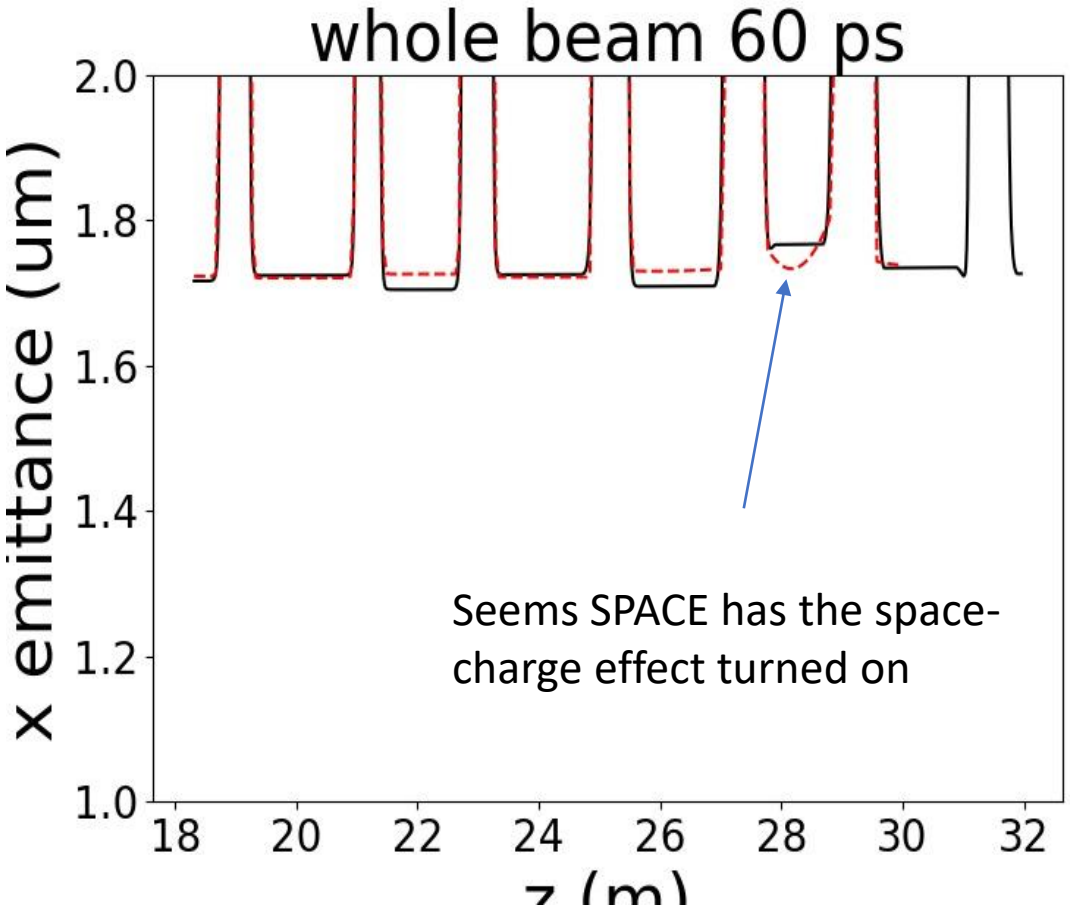

SPACE
0.6MP 32x32x512
6MP 64x64x1024
x emittance (um)
z (m)
0
1
2
3
4
5
18
20
22
24
26
28
30



X_env(x%) = [r(x%)+ r(x-1%)]/2




SPACE
PARMELA
Impact-T
x emittance (um)
z (m)
0
1
2
3
4
5
18
20
22
24
26
28
30
32

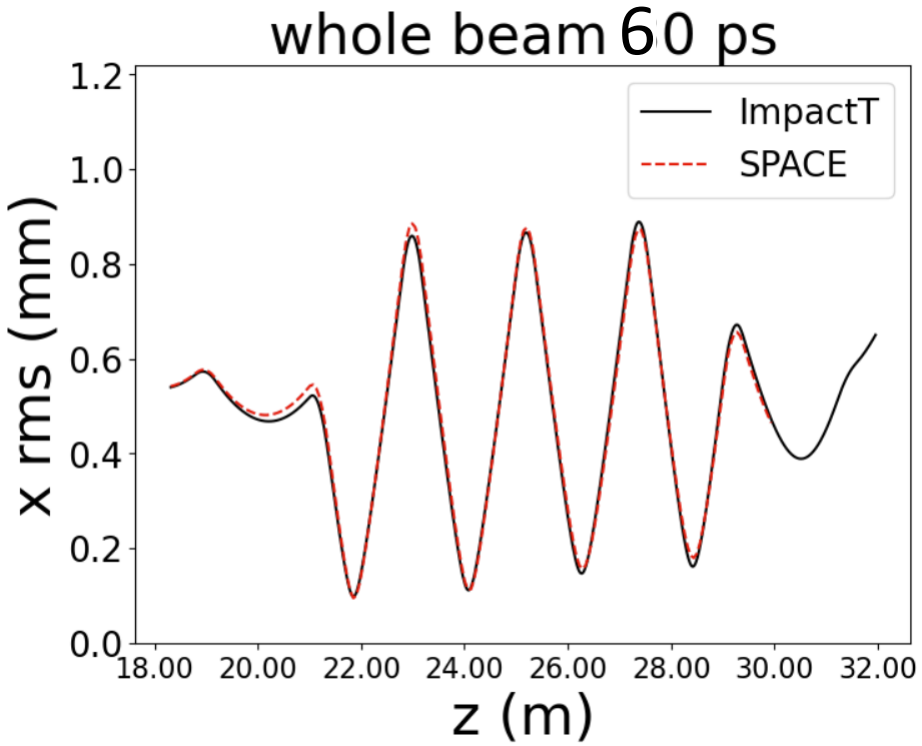

whole beam 60 ps
x emittance (um)
1.0
1.2
1.4
1.6
1.8
2.0
18
20
22
24
26
28
30
32
Seems SPACE has the space-charge effect turned on

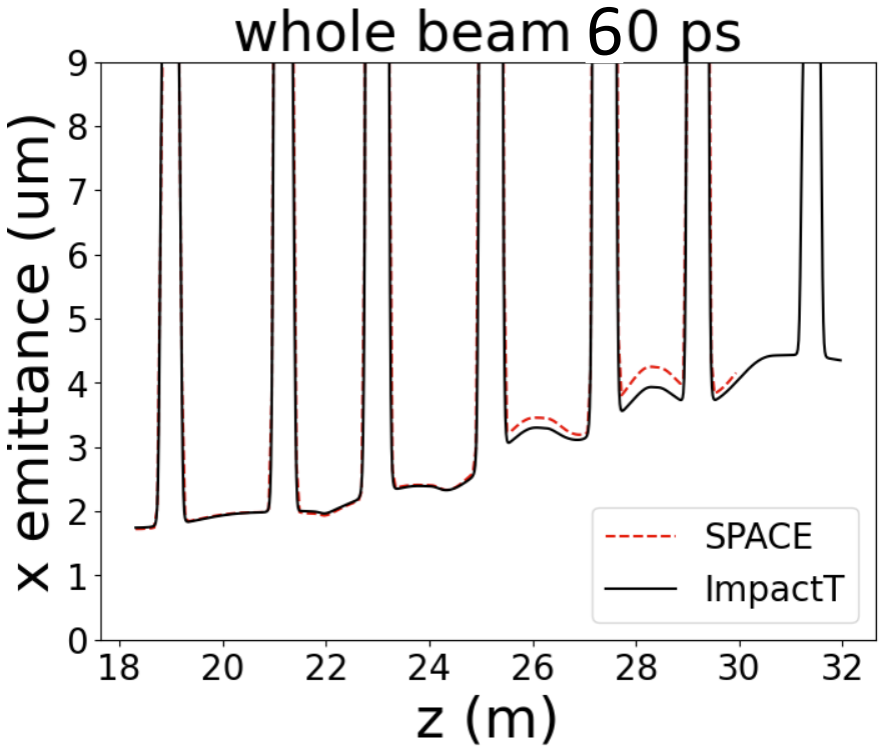
04/05/2023 Updates

Quick Sim.

Simulation accuracy seems heavy
depending on the mesh not # of particle

2k particles 64X64X8 mesh → Optimization time ~ 2hr

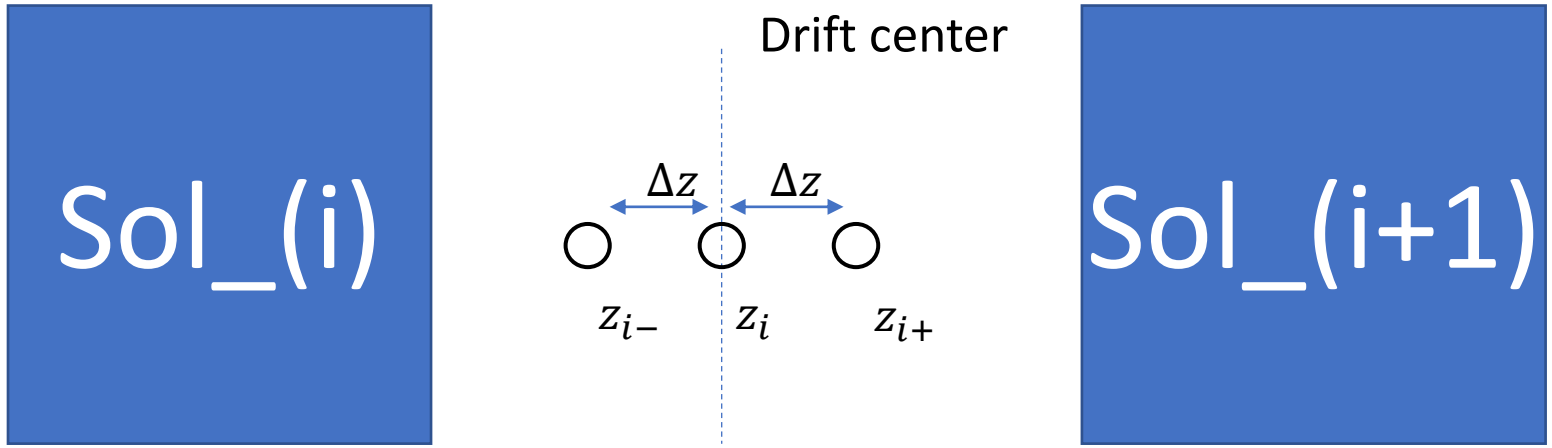




Optimization Goal

Three points measurement

i = 2, … , 5



Center goal : $$c = \sum_i |\sigma_x(z_{i+}) - \sigma_x(z_{i-})|$$

Matching goal : $$m = std[\sigma_x(z_i)]$$

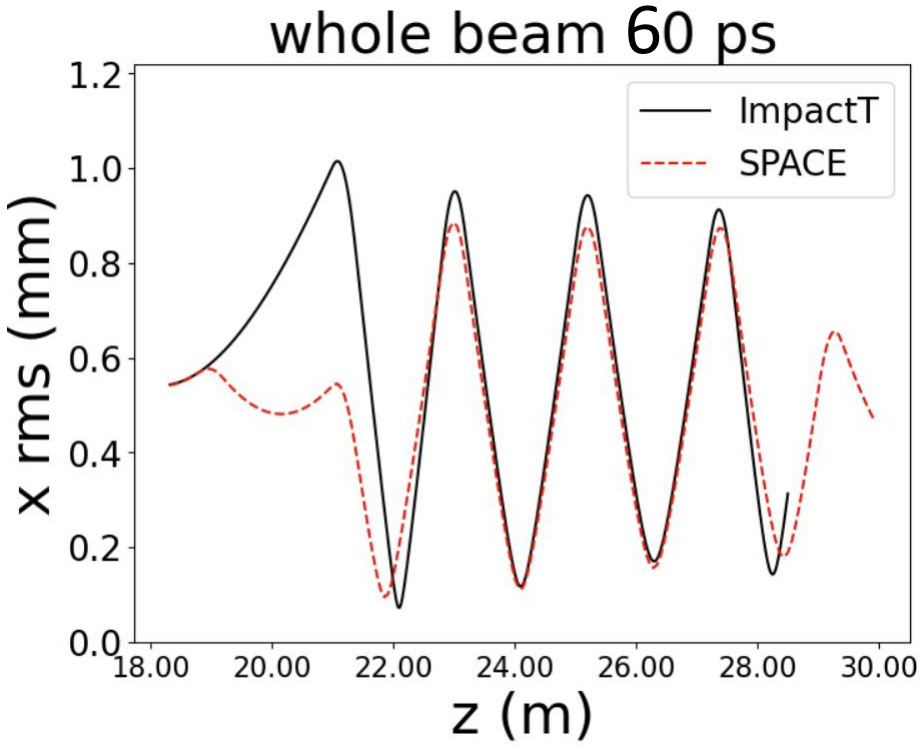
Level goal : $$l = mean[\sigma_x(z_i)]$$

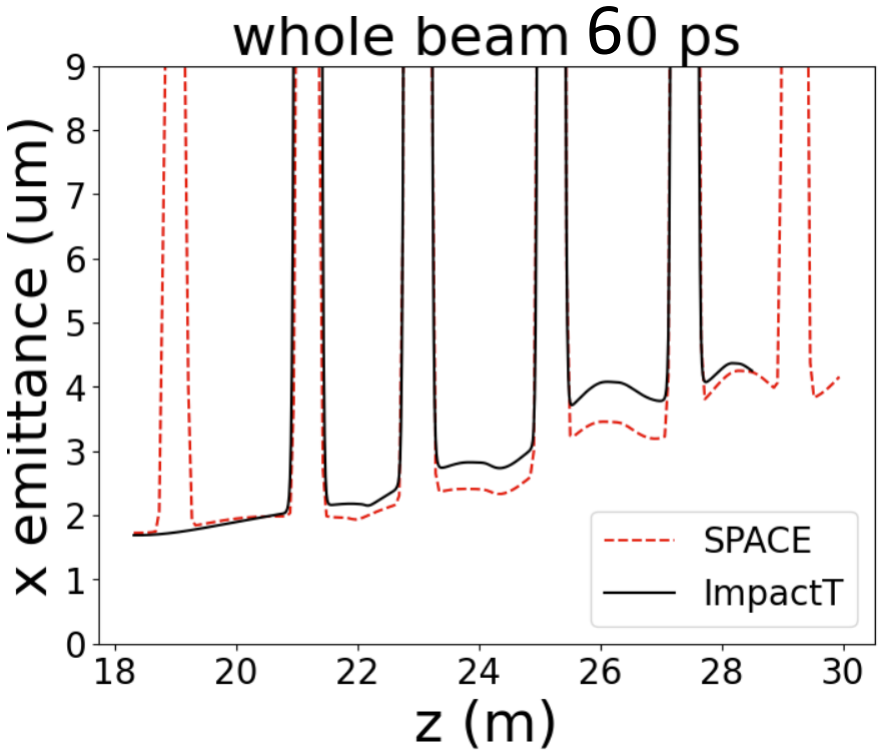
Minimizes

$$res = a_1 c + a_2 m + a_3 l$$

Sample RUNS **Nelder-Mead**

$$res = 100c + 10m + l$$

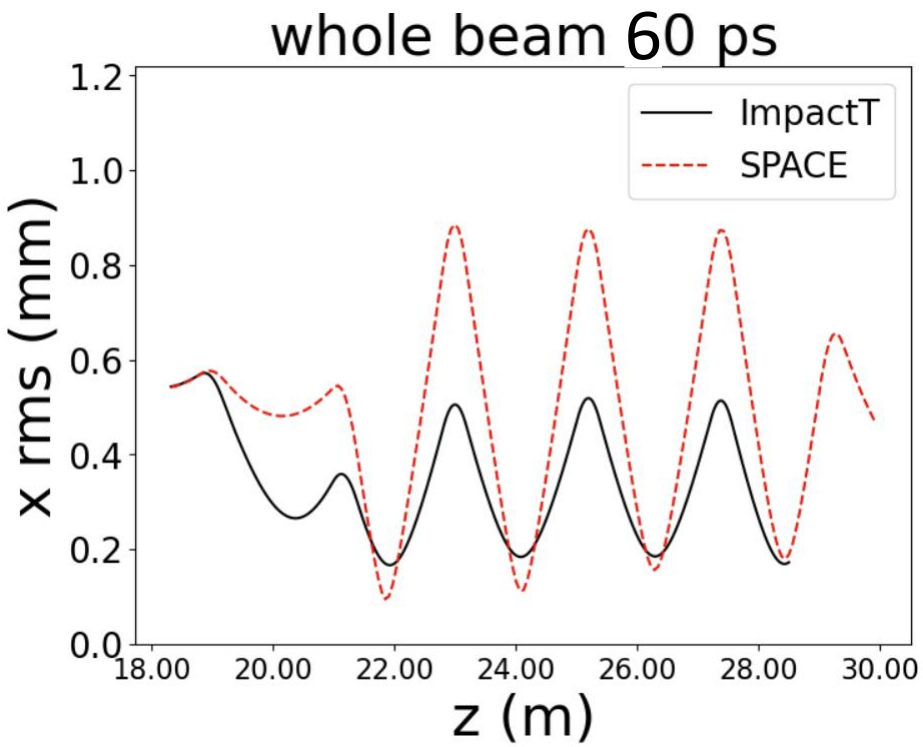


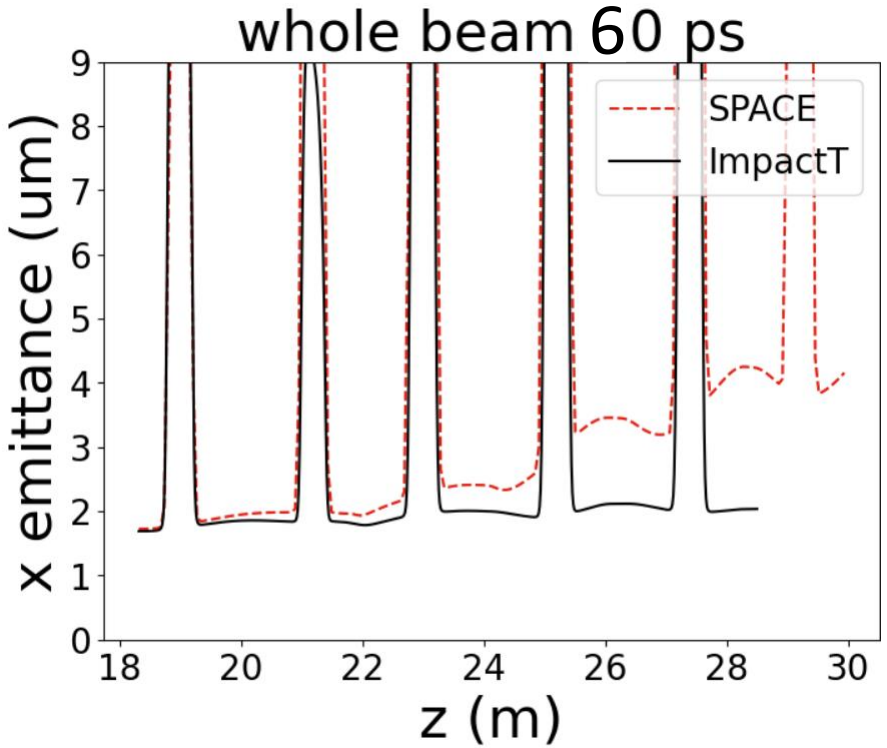


Sol 1	Sol 2	Sol 3	Sol 4
-0.020354213 ,	-102.592669,	127.089240,	- 118.987508

Sample RUNS **Nelder-Mead**

$$res = 10c + 100m + 0l$$





Sol 1	Sol 2	Sol 3	Sol 4
76.768642 ,	-121.69714385,	118.90675416,	-115.82580811

04/07/2023 Updates

Center goal : $c = \sum_i |\sigma_x(z_{i+}) - \sigma_x(z_{i-})|$

Matching goal : $m = std[\sigma_x(z_i)]$

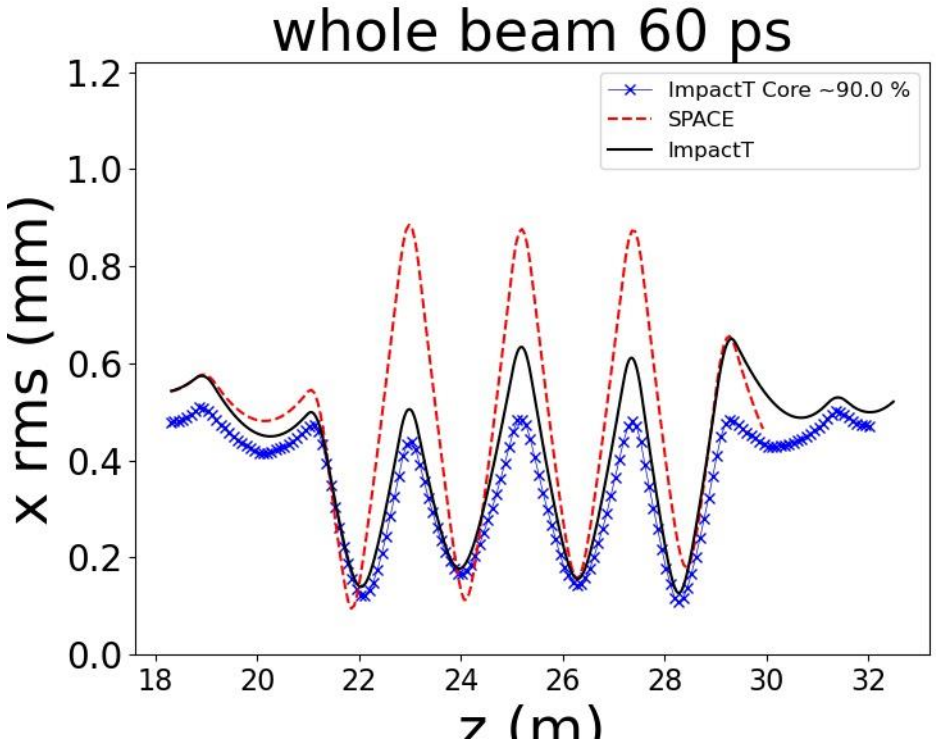
Level goal : $l = mean[\sigma_x(z_i)]$

Minimizes

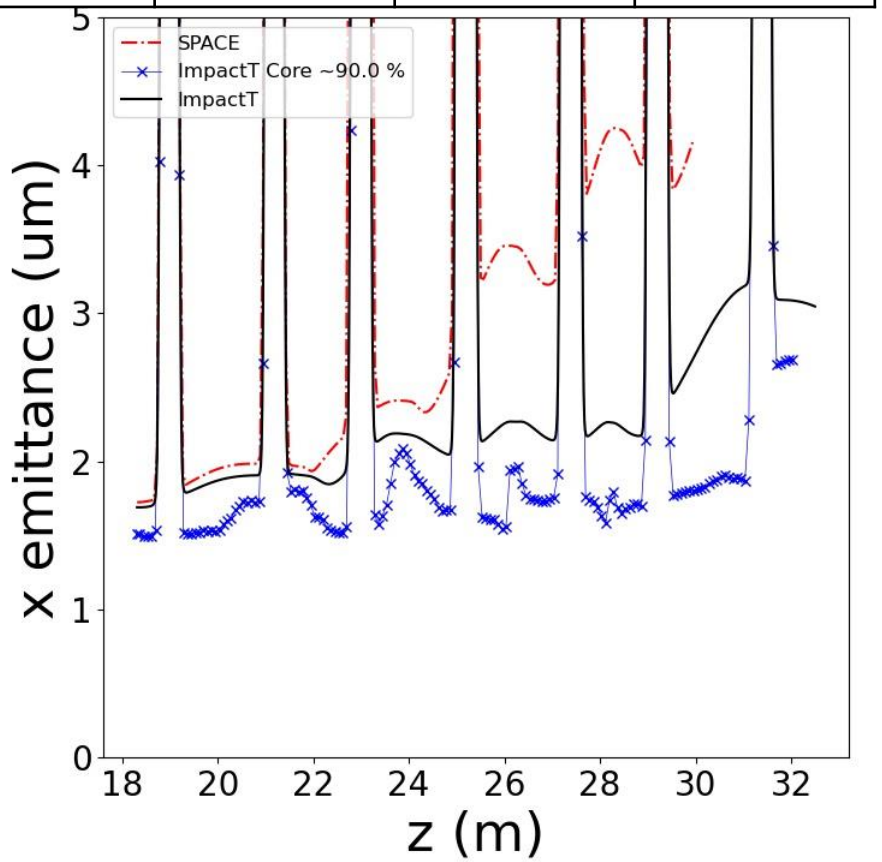
$res = a_1 c + a_2 m + a_3 l$

90 % core

a_1	a_2	a_3
100	10	100



Sol 1	Sol 2	Sol 3	Sol 4
60.52	-104.08	126.89	-115.35
	Sol 5	**Sol 6**	**Sol 7**
	Sol 3	Sol 2	Sol 1



Center goal : $c = \sum_i |\sigma_x(z_{i+}) - \sigma_x(z_{i-})|$

Matching goal : $m = std[\sigma_x(z_i)]$

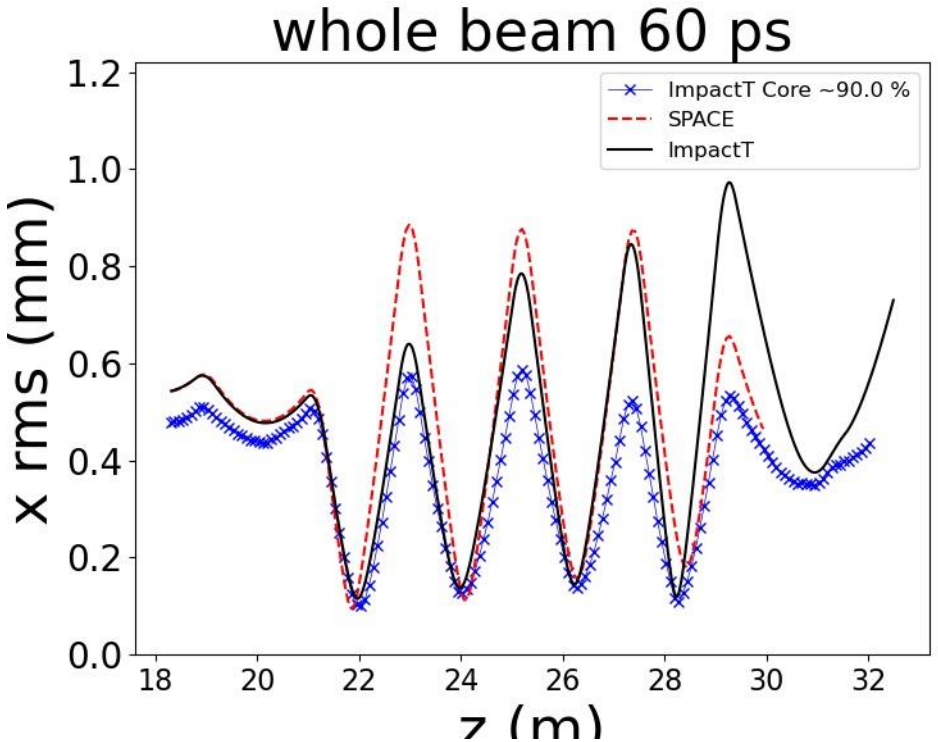
Level goal : $l = mean[\sigma_x(z_i)]$

Minimizes

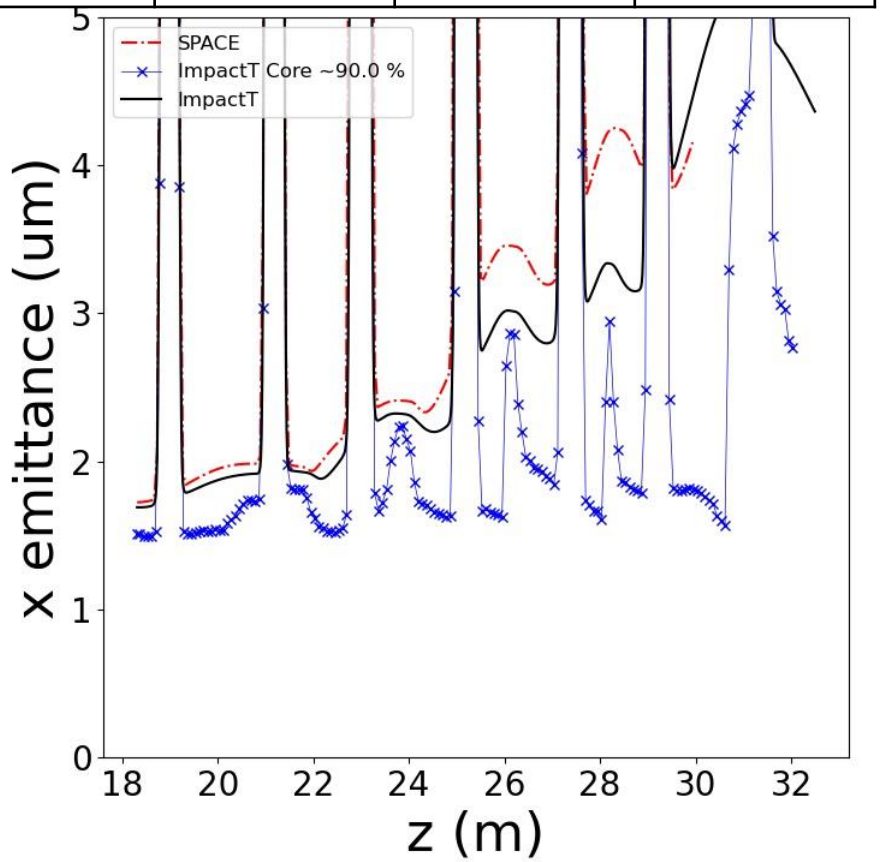
$res = a_1 c + a_2 m + a_3 l$

90 % core

a_1	a_2	a_3
10	100	10



Sol 1	Sol 2	Sol 3	Sol 4
57.91	-108.38	126.93	-118.26
	Sol 5	**Sol 6**	**Sol 7**
	Sol 3	Sol 2	Sol 1



Center goal : $c = \sum_i |\sigma_x(z_{i+}) - \sigma_x(z_{i-})|$

Matching goal : $m = std[\sigma_x(z_i)]$

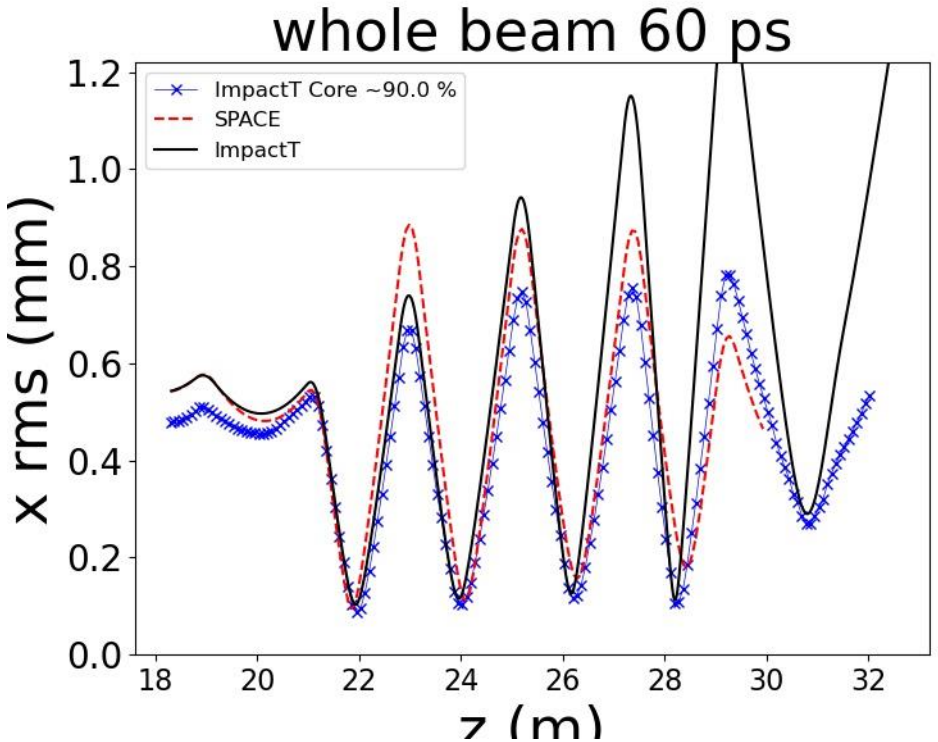
Level goal : $l = mean[\sigma_x(z_i)]$

Minimizes

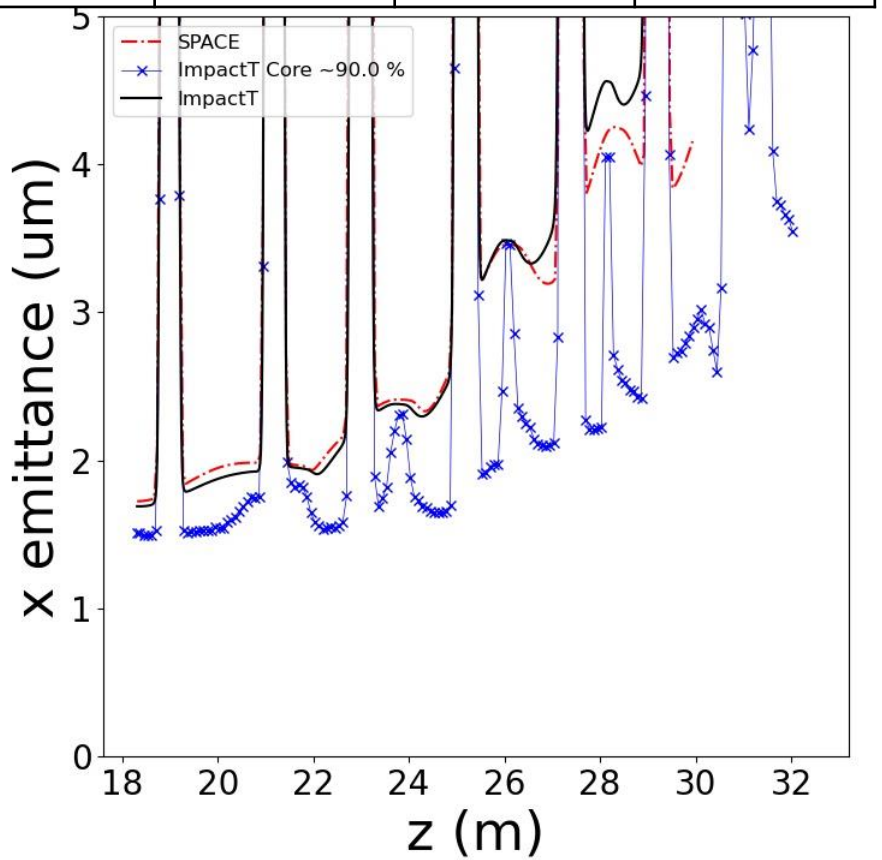
$res = a_1 c + a_2 m + a_3 l$

90 % core

a_1	a_2	a_3
1	10	100



Sol 1	Sol 2	Sol 3	Sol 4
55.90	-110.83	126.68	-120.21
	Sol 5	**Sol 6**	**Sol 7**
	Sol 3	Sol 2	Sol 1



Center goal : $c = \sum_i |\sigma_x(z_{i+}) - \sigma_x(z_{i-})|$

Matching goal : $m = std[\sigma_x(z_i)]$

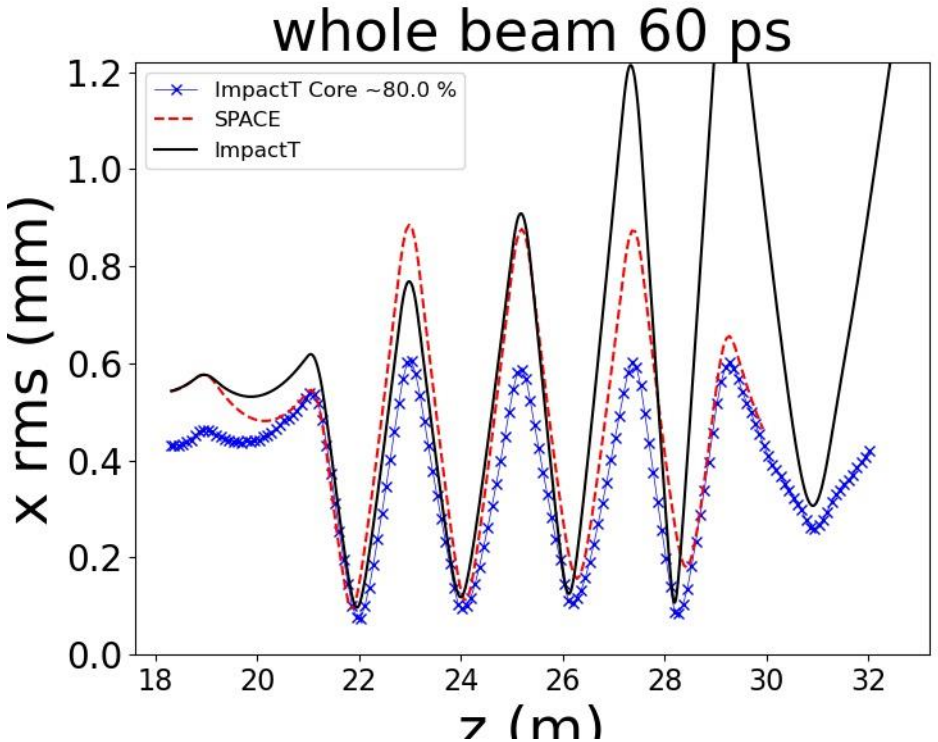
Level goal : $l = mean[\sigma_x(z_i)]$

Minimizes

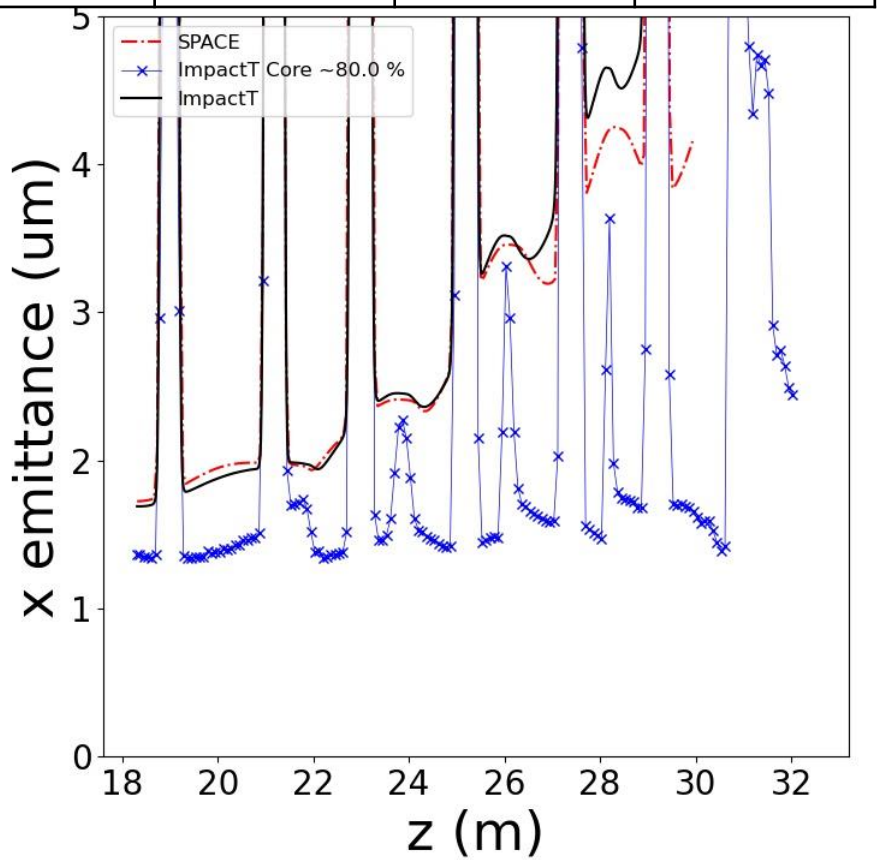
$res = a_1 c + a_2 m + a_3 l$

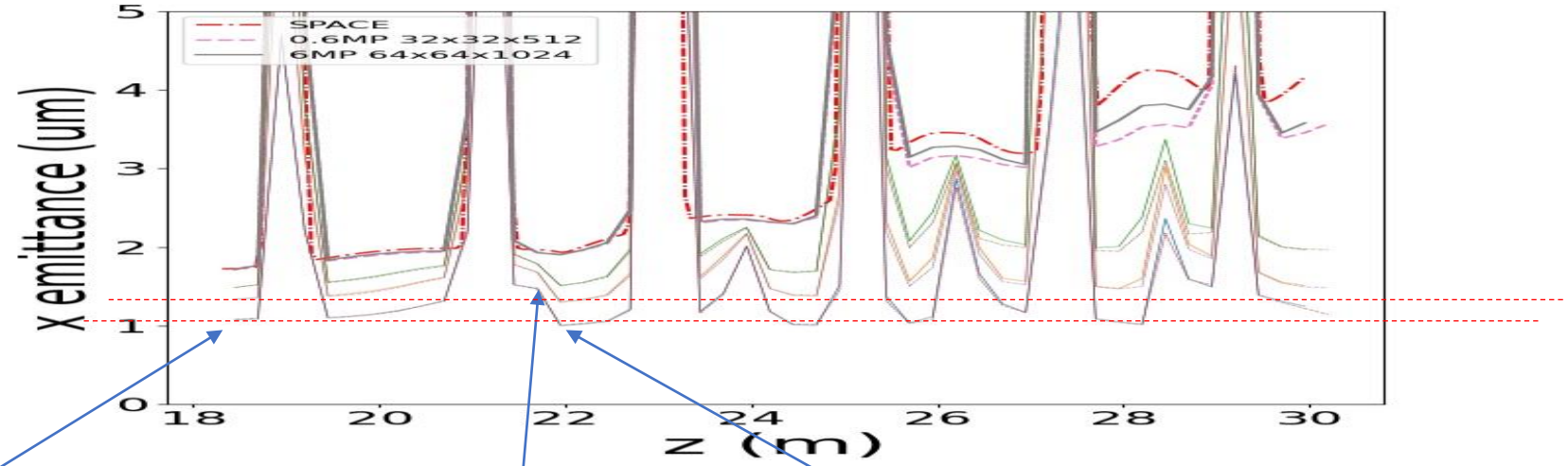
80 % core

a_1	a_2	a_3
1	10	100

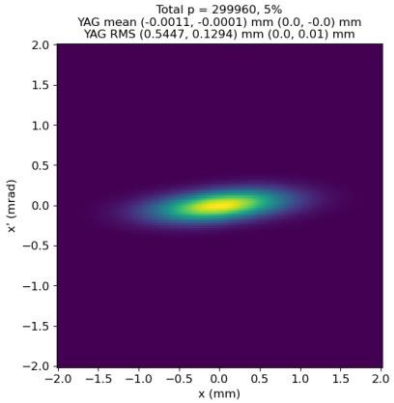


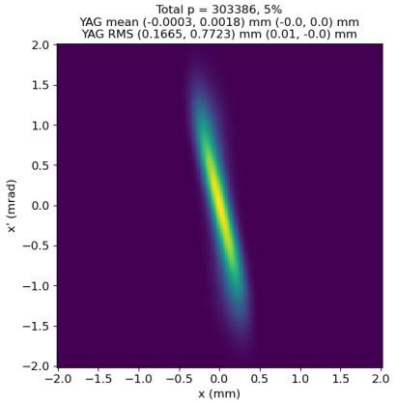
Sol 1	Sol 2	Sol 3	Sol 4
51.72	-109.03	126.08	-122.72
	Sol 5	**Sol 6**	**Sol 7**
	Sol 3	Sol 2	Sol 1

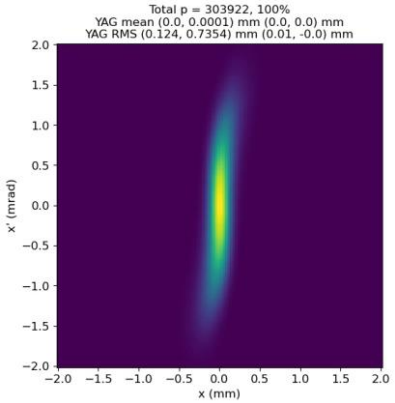



SPACE
0.6MP 32x32x512
6MP 64x64x1024
x emittance (um)
z (m)

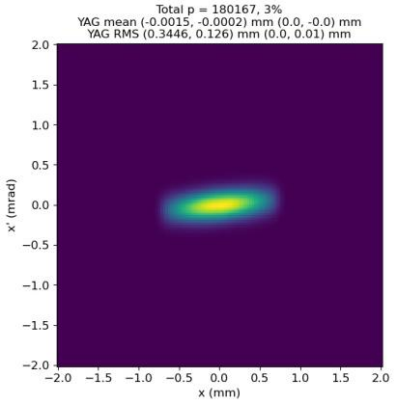
100%

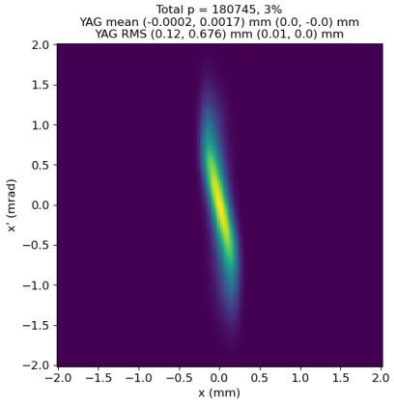

Total p = 299960, 5%
YAG mean (-0.0011, -0.0001) mm (0.0, -0.0) mm
YAG RMS (0.5447, 0.1294) mm (0.0, 0.01) mm
x' (mrad)
x (mm)

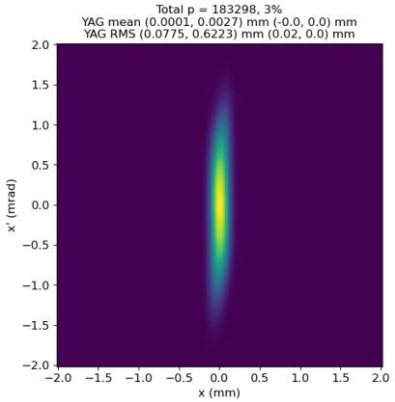

Total p = 303386, 5%
YAG mean (-0.0003, 0.0018) mm (-0.0, 0.0) mm
YAG RMS (0.1665, 0.7723) mm (0.01, -0.0) mm
x' (mrad)
x (mm)


Total p = 303922, 100%
YAG mean (0.0, 0.0001) mm (0.0, 0.0) mm
YAG RMS (0.124, 0.7354) mm (0.01, -0.0) mm
x' (mrad)
x (mm)

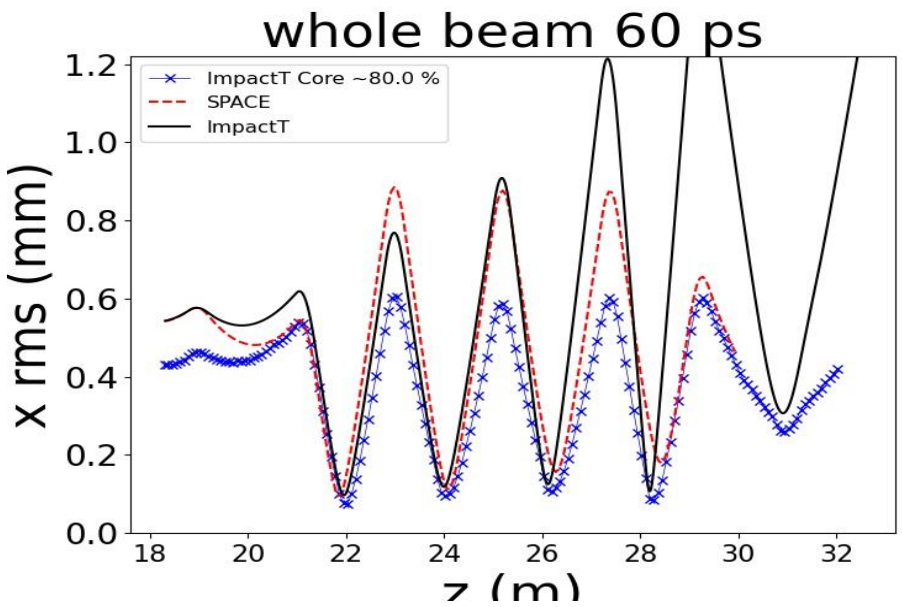
60%


Total p = 180167, 3%
YAG mean (-0.0015, -0.0002) mm (0.0, -0.0) mm
YAG RMS (0.3446, 0.126) mm (0.0, 0.01) mm
x' (mrad)
x (mm)


Total p = 180745, 3%
YAG mean (-0.0002, 0.0017) mm (0.0, -0.0) mm
YAG RMS (0.12, 0.676) mm (0.01, 0.0) mm
x' (mrad)
x (mm)

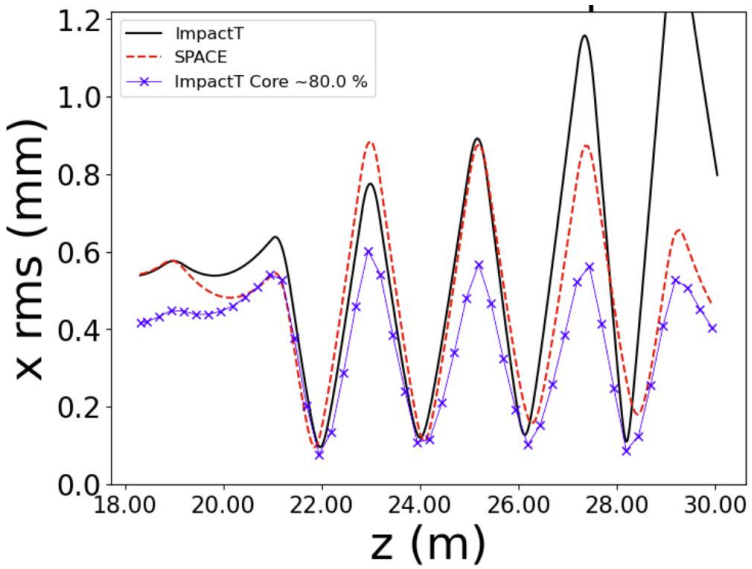

Total p = 183298, 3%
YAG mean (0.0001, 0.0027) mm (-0.0, 0.0) mm
YAG RMS (0.0775, 0.6223) mm (0.02, 0.0) mm
x' (mrad)
x (mm)

04/12/2023 Updates



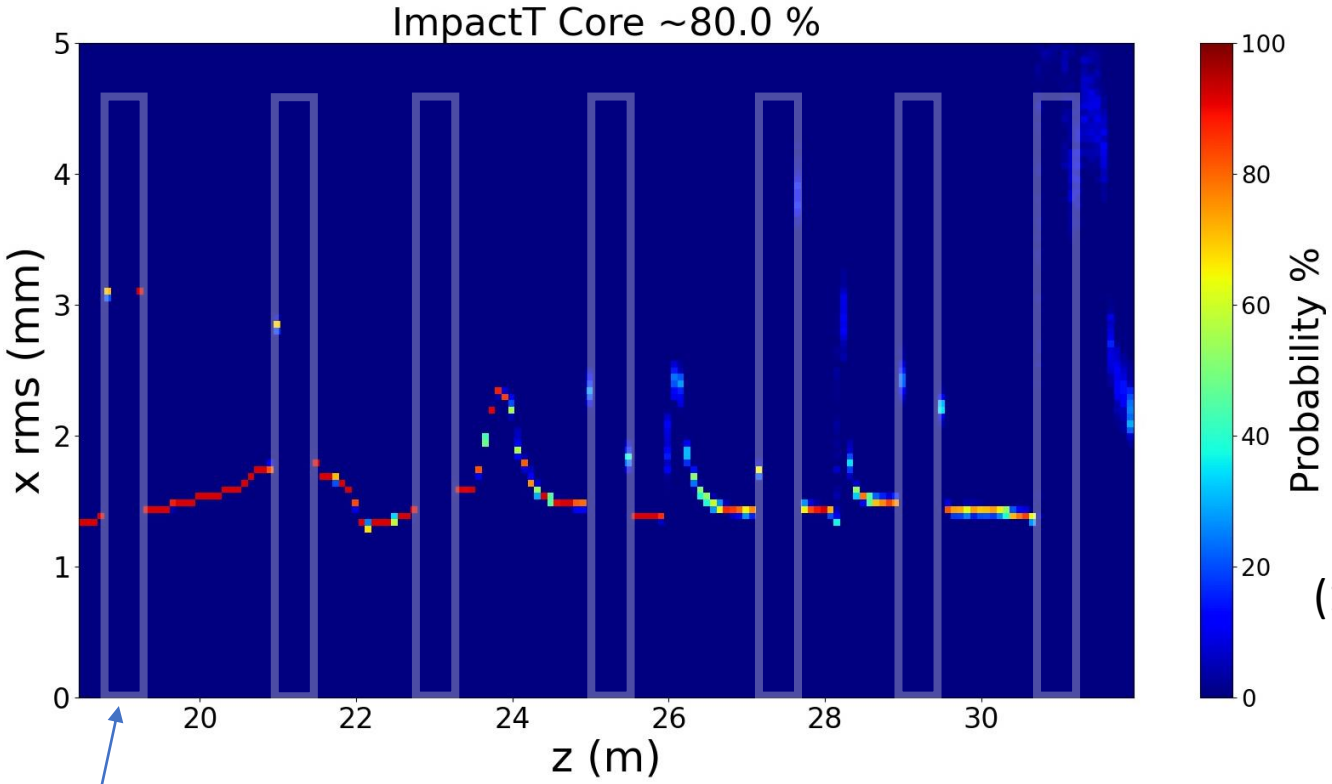
2k particles

Emittance plots are also similar



600k particles

Sol Sensitivity Test



Sol 1	Sol 2	Sol 3	Sol 4
51.72	-109.03	126.08	-122.72
δSol	**Sol 5**	**Sol 6**	**Sol 7**
+- 0.5A	Sol 3	Sol 2	Sol 1

(100 uniform random runs)

Sol 1