Simulations for 3D ellipsoidal laser shape at 1nC: Current status

"Re-optimization" of emittance at 1nC charge for the 3D ellipsoidal laser shape: Description and obtained results

Difficulties and future work

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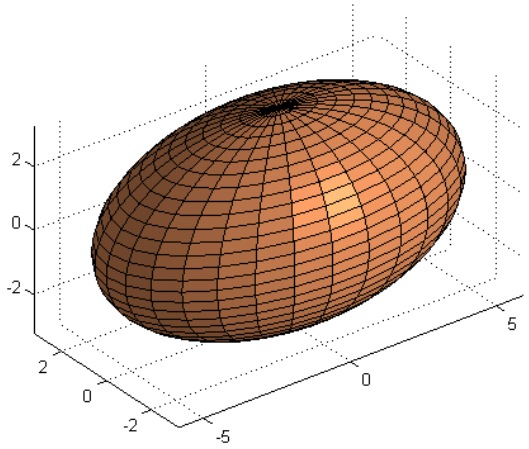
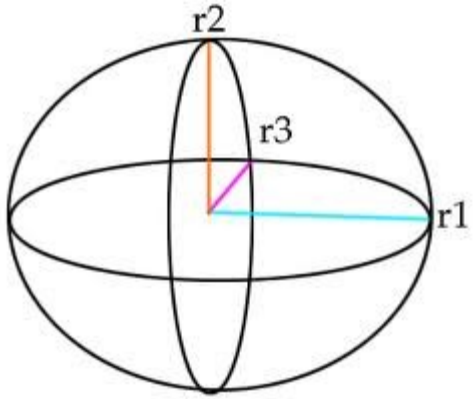
DESY

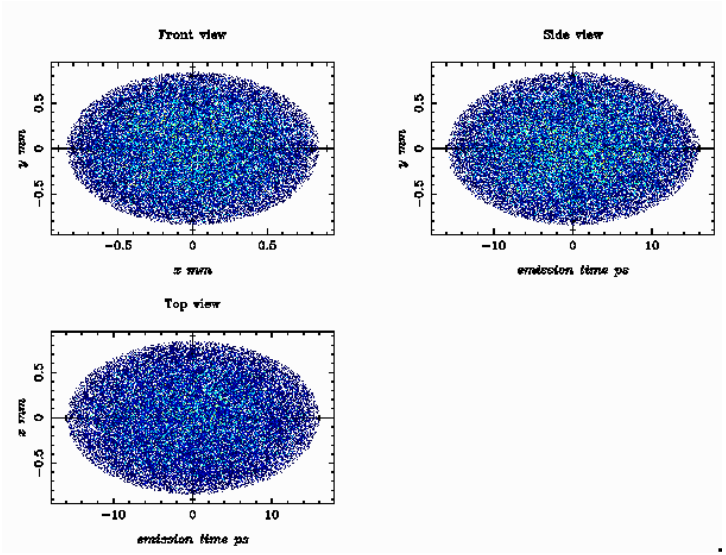
Cathode laser: 3D ellipsoid

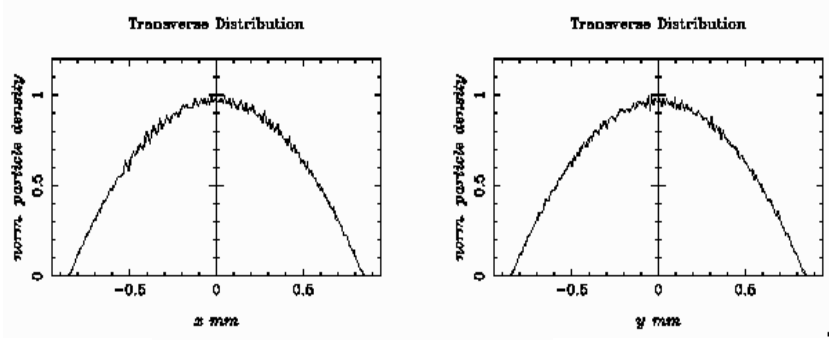


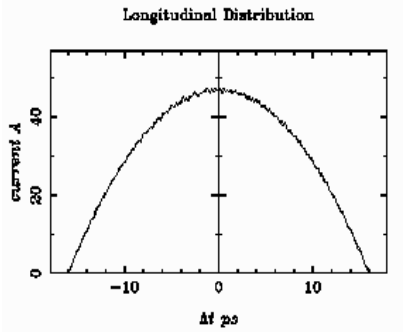


$$r1 \rightarrow \quad , r2 \rightarrow \quad , r3 \rightarrow$$

$$\frac{x^2}{L_x^2} + \frac{y^2}{L_y^2} + \frac{z^2}{L_z^2} \leq \quad , \; T_{rms} = \; / \sqrt{5}$$







E-beam overview at 5.74 m.

Full emittance optimization: Description

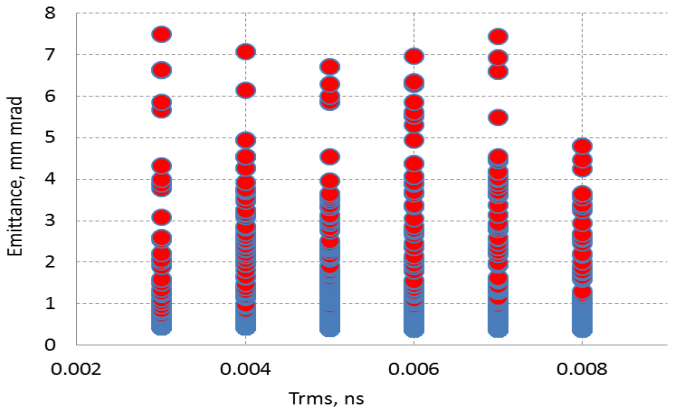
Fixed parameters during emittance optimization

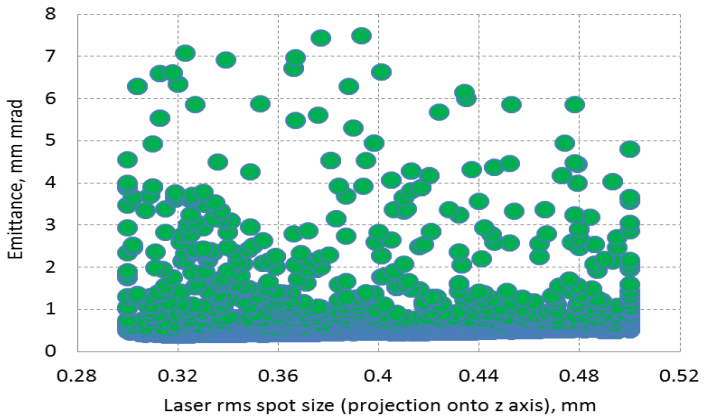
- bunch charge (1nC),
- Electrons thermal kinetic energy at the cathode (0.55eV),
- gun gradient (60.58MV/m), corresponding to Pz~6.7MeV/c after gun, at on-crest phase
- CDS booster phase was fixed to on-crest phase
- The reference point was EMSY1 (5.74m downstream the cathode).

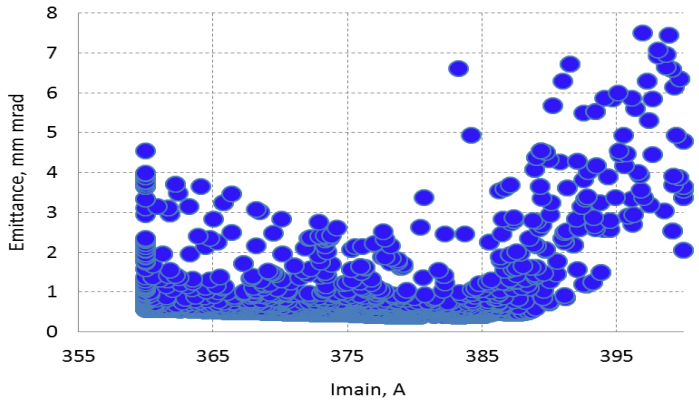
The following parameters were variable:

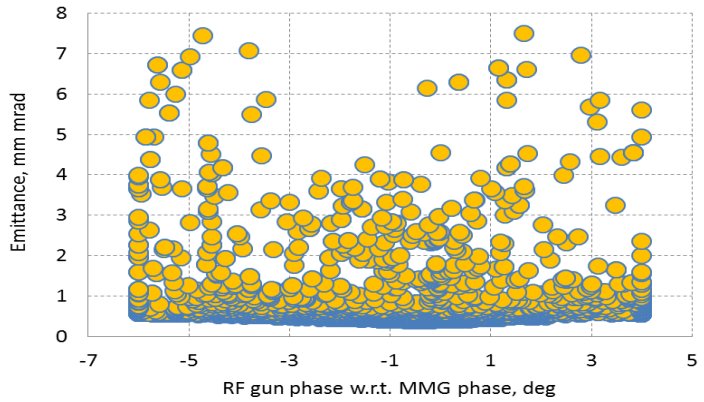
- Dimensions of the 3D ellipsoid (Trms (r1), XYrms (r2,r3) → projection onto z axis)
- Peak field of the main solenoid, Solenoid calibration: B(T)=B1*I(A)+B2, where B1=0.00058838, B2=0.000004084
- Gun phase
- Peak field in the CDS booster
- **Optimization was done with 25kp (7500 ASTRA runs !!)**

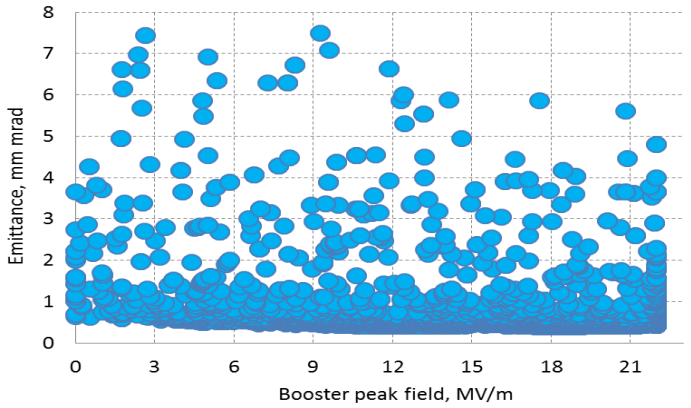
Emittance optimization: Results

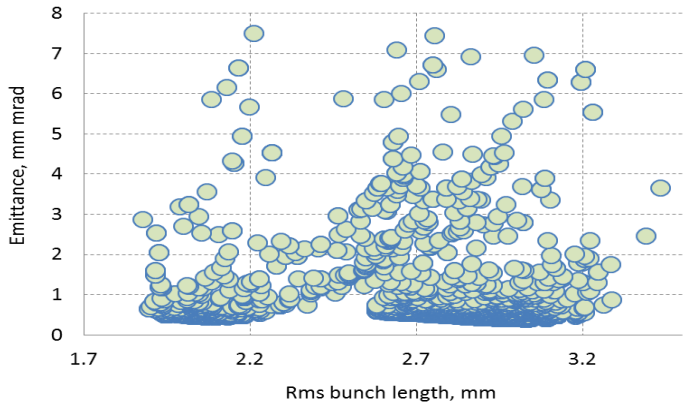




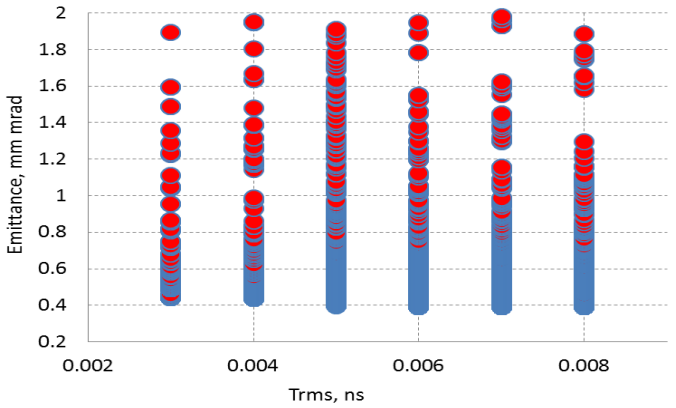


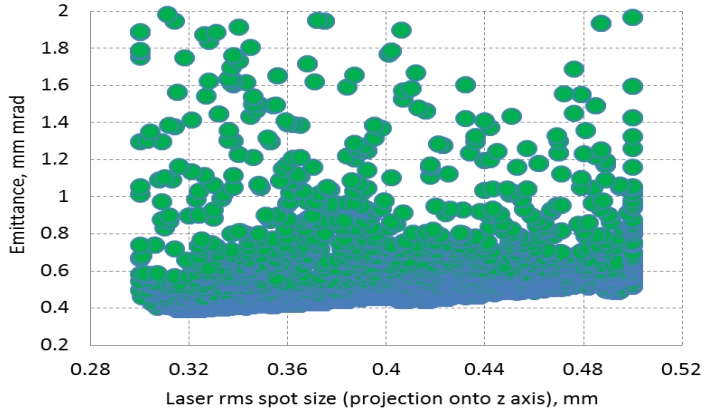


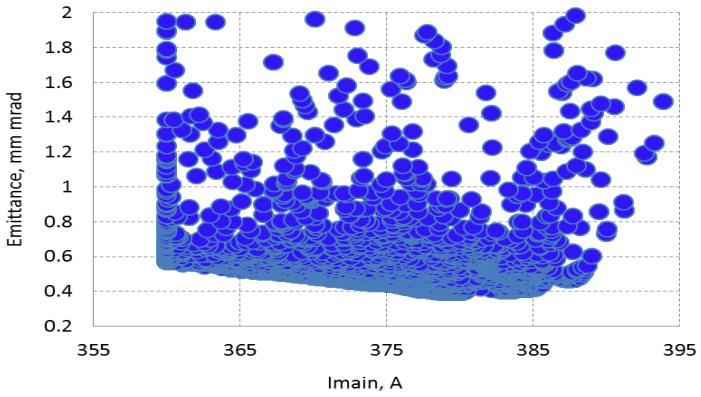


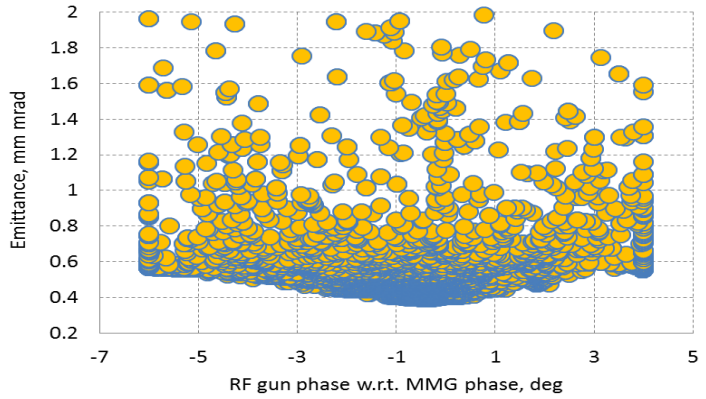


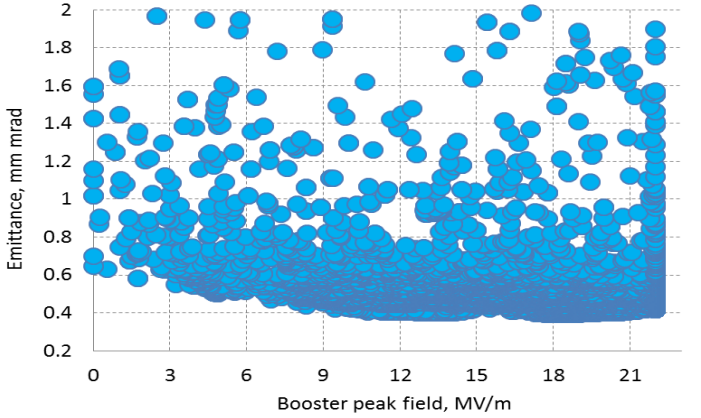
Emittance optimization: Results → vertically zoomed

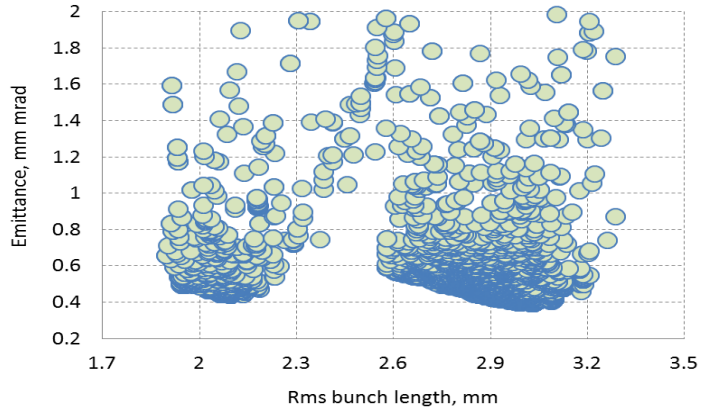




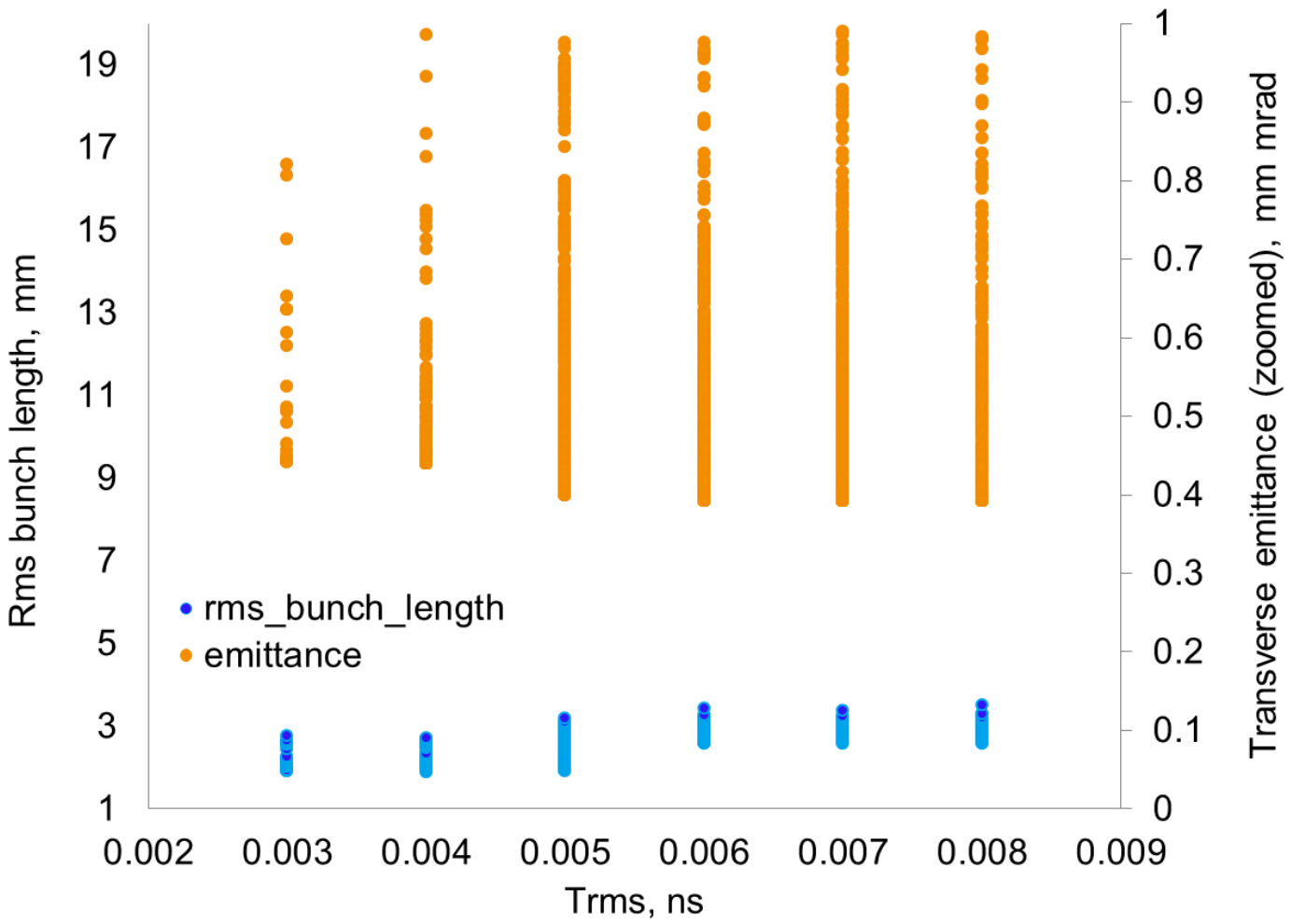








Emittance and bunch length at 5.74m depending on Trms



Taking into account the smallest emittance for each initial “bunch length”, we have emittance reduction of ~12% ([3:1:8] ps), but rms bunch length increases by ~44%

Emittance optimization: 500kp

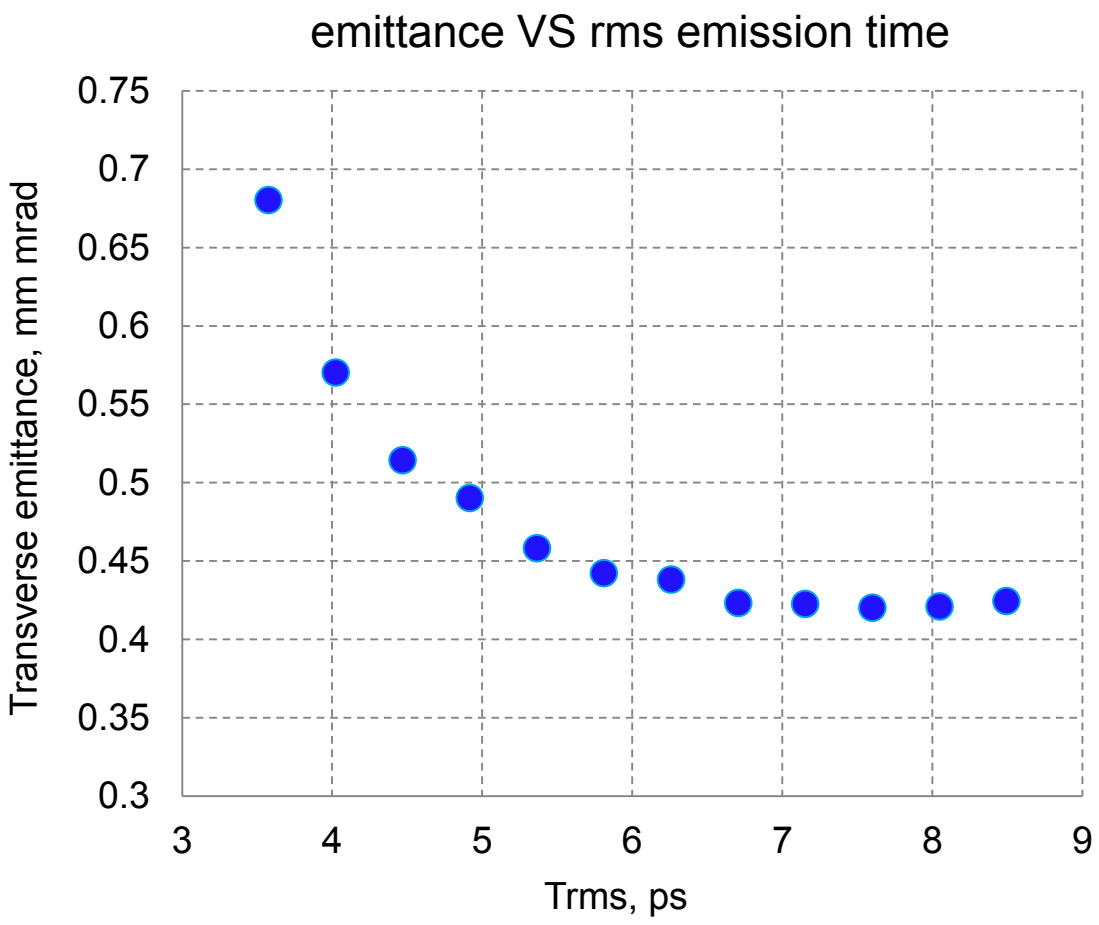
Fixed parameters during emittance optimization

- bunch charge (1nC),
- Electrons thermal kinetic energy at the cathode (0.55eV),
- gun gradient (60.58MV/m), corresponding to Pz~6.7MeV/c for on-crest gun phase
- Gun phase was fixed to on-crest phase
- CDS booster peak field (20MV/m), corresponding to Pz~24MeV/c at gun and booster on-crest phases
- Booster phase was fixed to on-crest
- The reference point was EMSY1 (5.74m downstream the cathode).

The following parameters were variable:

- Dimensions of the 3D ellipsoid (Trms (r1), X,Yrms (r2,r3) → projection onto z axis)
- Peak field of the main solenoid, Solenoid calibration: B(T)=B1*I(A)+B2, where B1=0.00058838, B2=0.000004084
- **Optimization was done with 500kp**

Emittance optimization results (scanning laser "length")



Summary

Trms , ps	Emittance , mm mrad
3.6	0.68
4	0.57
4.5	0.514
4.9	0.49
5.4	0.458
5.8	0.442
6.3	0.438
6.7	0.423
7.1	0.4225
7.6	0.42
8	0.4207
8.5	0.4243

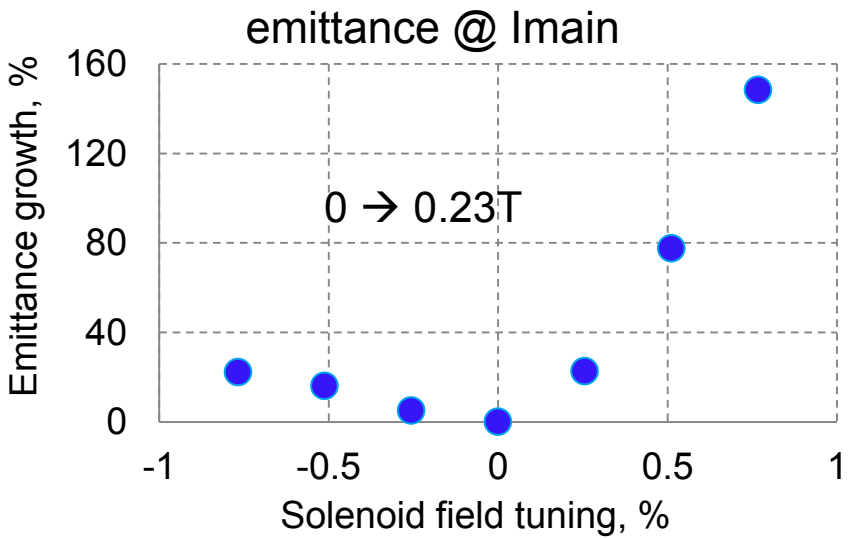
Flat-top, $20\,ps\ FWHM \rightarrow \ _{rms} = 5.8\,ps$

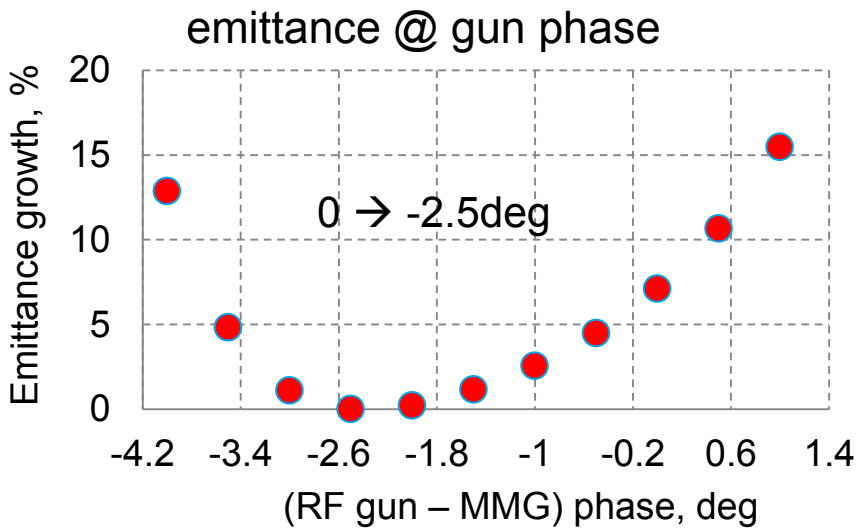
Comparing beam parameters for 4 different cases

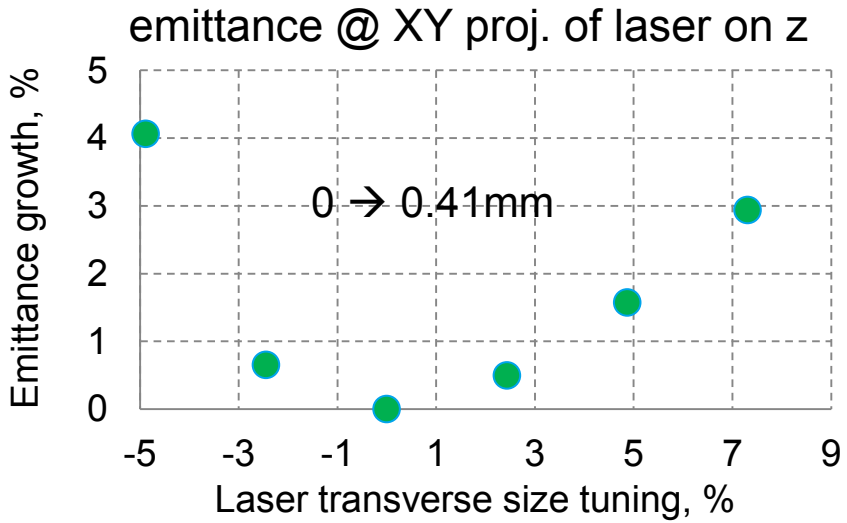
- Transverse emittance was optimized (included gun phase and booster gradient) for 4 fixed Trms “lengths”
- Tolerances have been studied. More detailed scans still needed

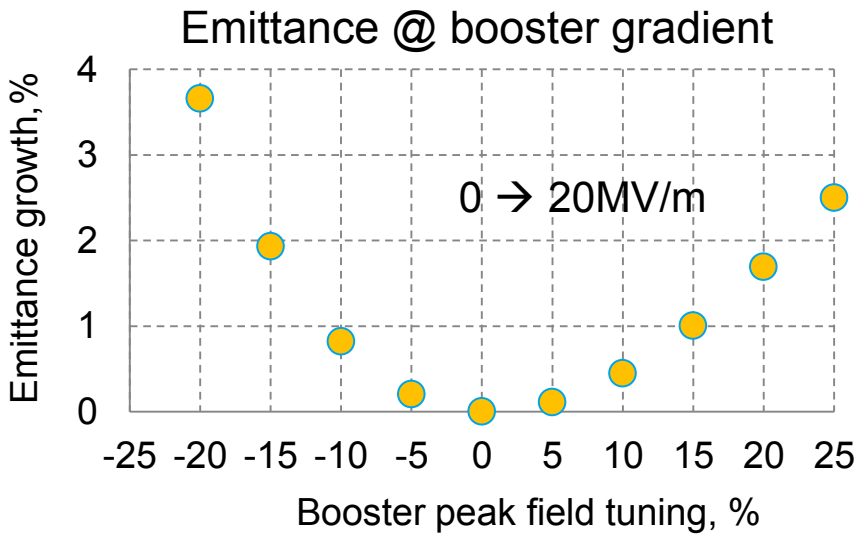
Rms emission time (Trms), ps	4.472	4.47	5.814	5.8	6.708	7.155
Transverse projection onto z axis	0.42	0.447	0.41	0.389	0.38	0.37
Thermal emittance, mm mrad	0.356	0.379	0.347	0.33	0.322	0.3134
Gun gradient, MV/m	60.58	60	60.58	60	60.58	60.58
RF gun phase w.r.t. MMG, deg	-3	-3.864	-2.5	-2.8	-2	-2
Peak field in main solenoid, T	0.23	0.2235	0.23	0.228	0.2295	0.2295
Booster gradient, MV/m	19	20.02	20	19.1	17	18
Booster phase, deg	0	0	0	0	0	0
Final beam energy, MeV	22.75	23.58	23.62	22.77	21	21.87
Proj. emittance, mm mrad	0.45	0.472	0.414	0.421	0.399	0.4005
Th/proj. emittance, %	79	80	84	78.5	81	78
<sl_emit>, mm mrad (100 slices)	0.382	0.388	0.358	0.356	0.338	0.335
Peak slice current, A	54.2	56.1	49	48	44.4	43.5

Tolerances for Trms=5.8ps







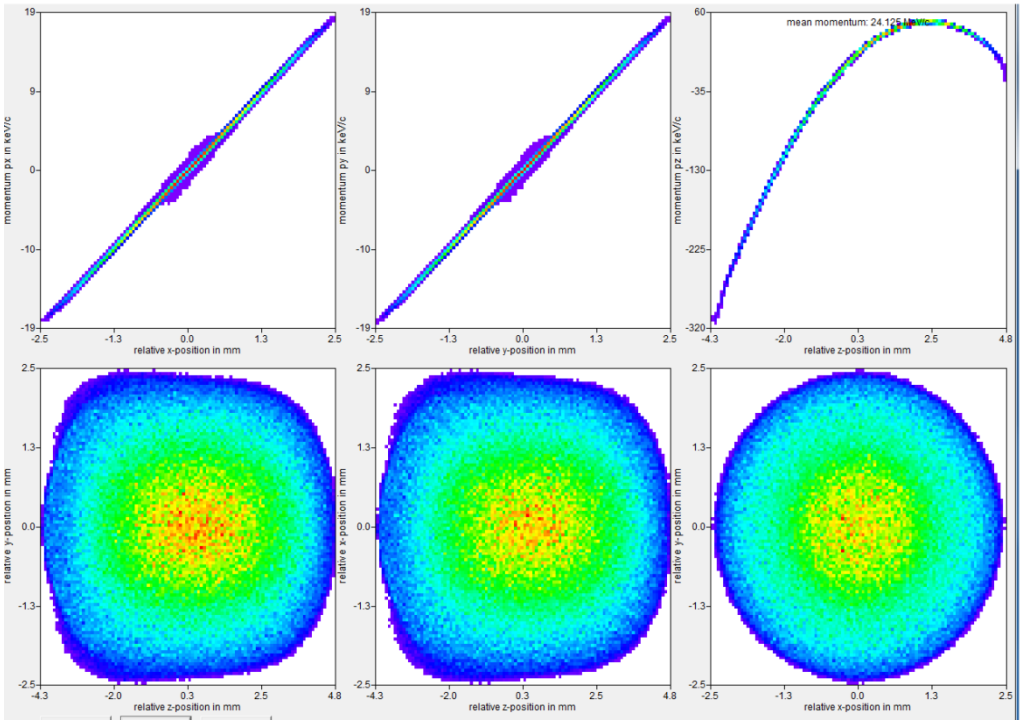


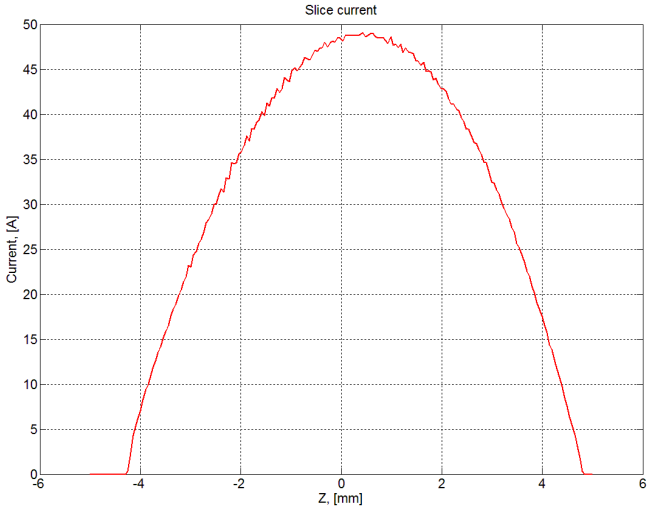
Difficulties, summary and future work

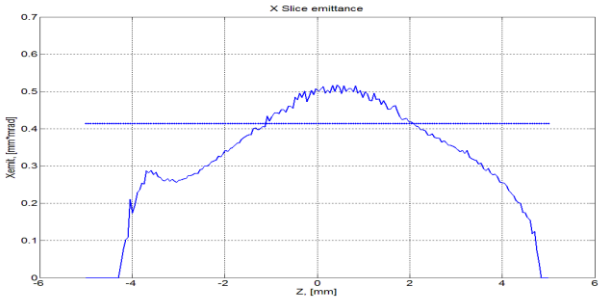
- Huge transverse beam size obtained at the location of EMSY1 (~1 mm rms)
- Emittance is more sensitive w.r.t. solenoid current compared to the flat-top case
- Besides the smallest transverse emittance (0.399 mm mrad) was obtained at Trms=6.71ps (corresponding to ~27.7ps FWHM length for flat-top case), Trms=5.8ps looks very promising (~50A peak current, projected emittance very close to the cathode emittance)
- More detailed tolerance studies needed (which simulation setup to choose ?)
- **Simulations to estimate an impact of 3D ellipsoidal laser shape imperfections on the transverse emittance**

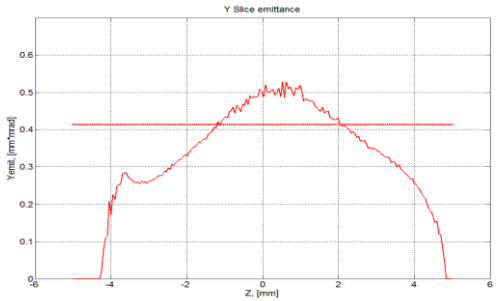
Thank you for attention !!

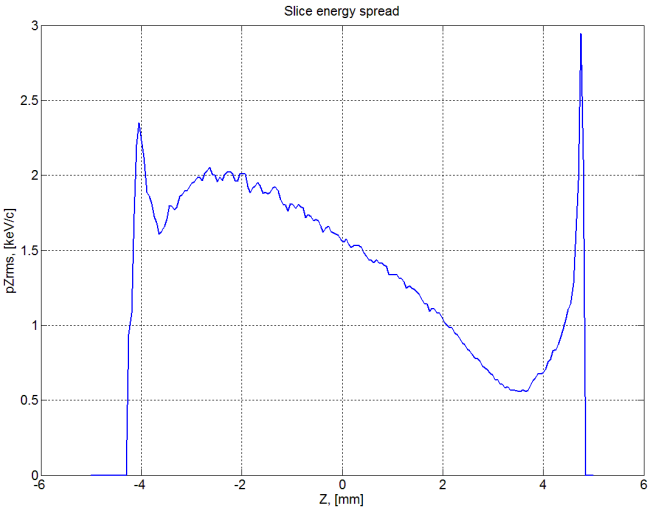
Beam properties (Trms=5.8ps)





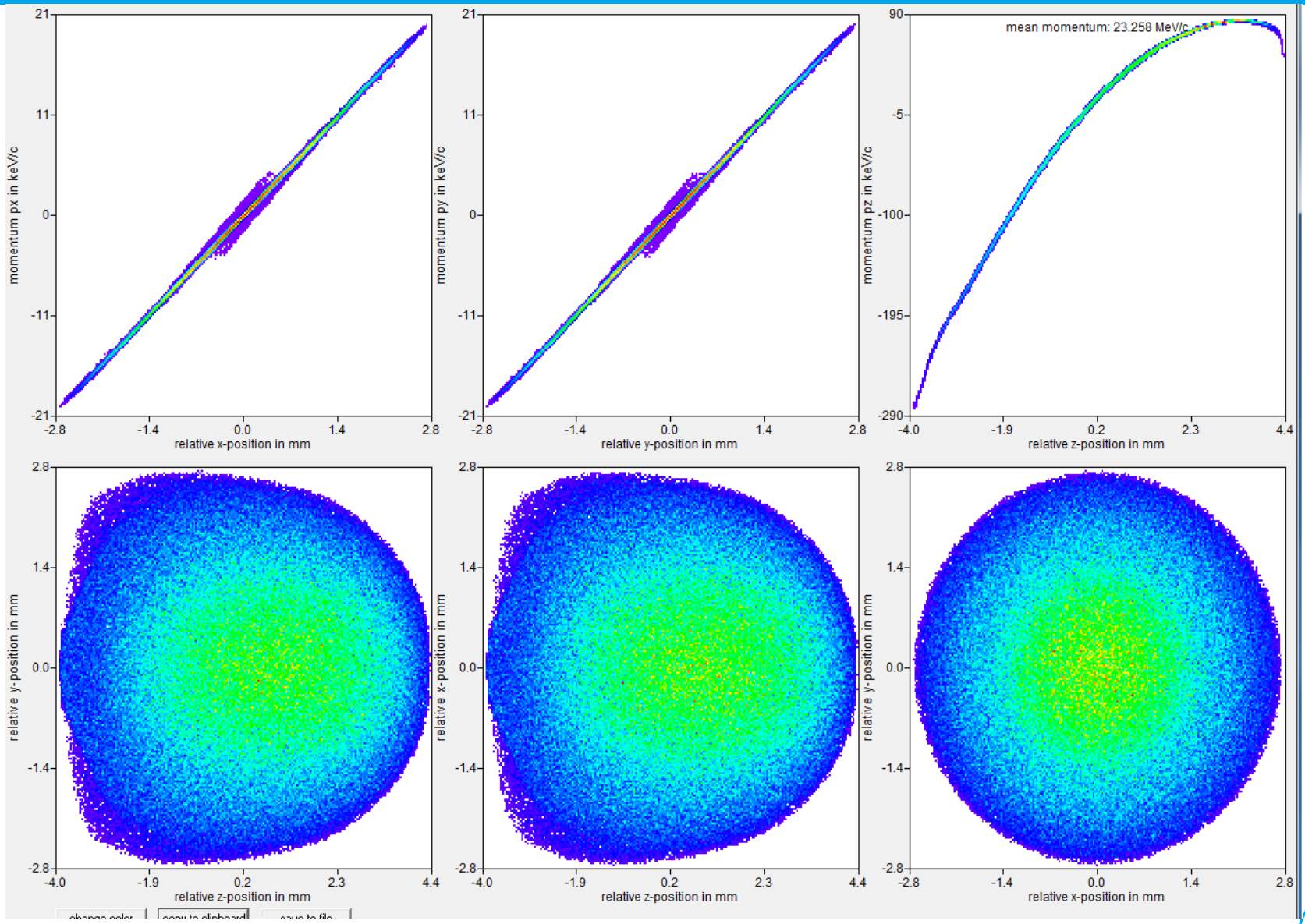




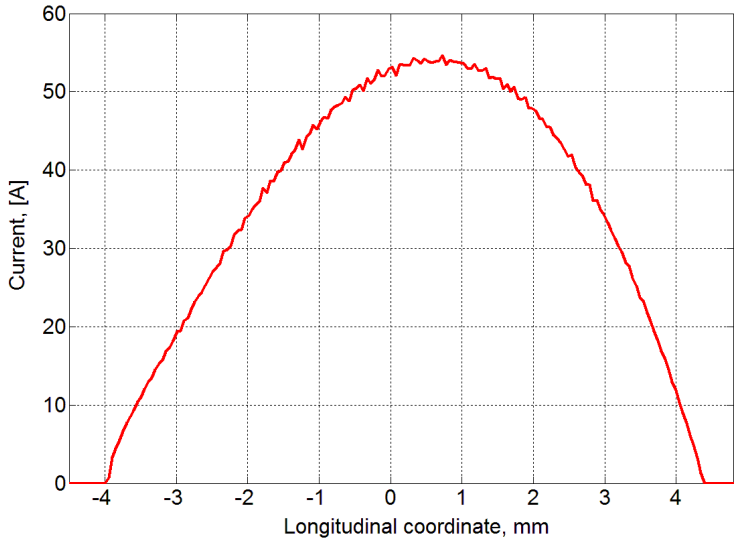


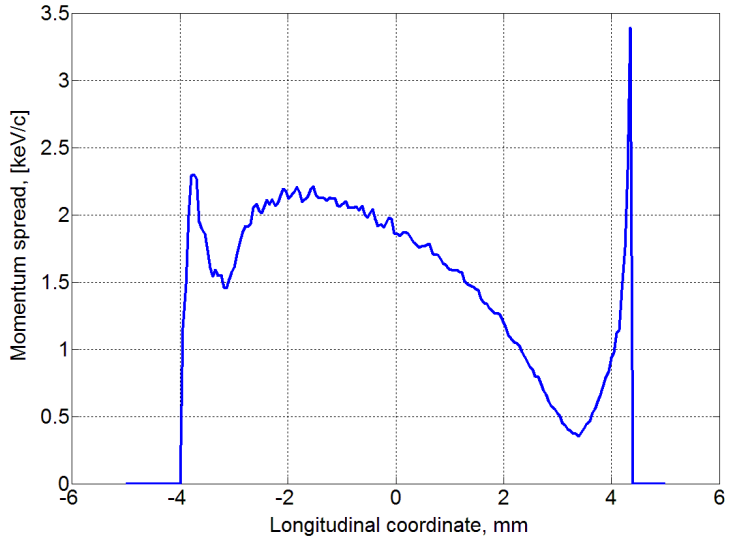
E-beam transverse and longitudinal properties at 5.74m after cathode.

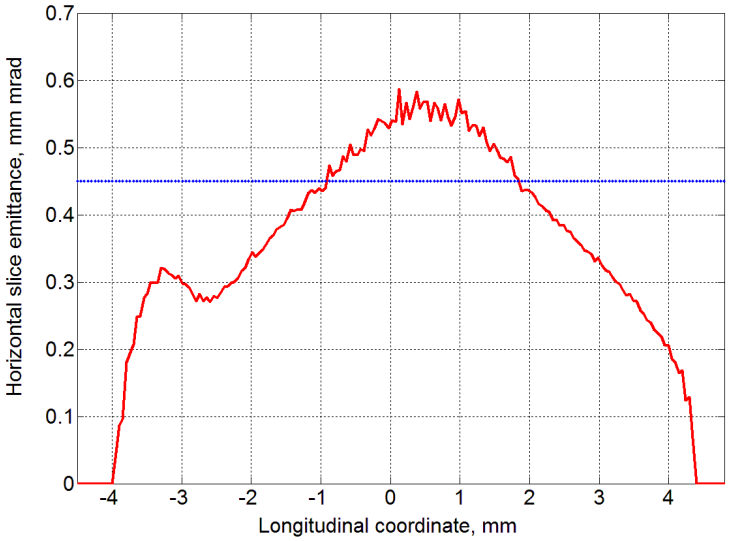
Beam overview (5.74m) at Trms=4.47ps

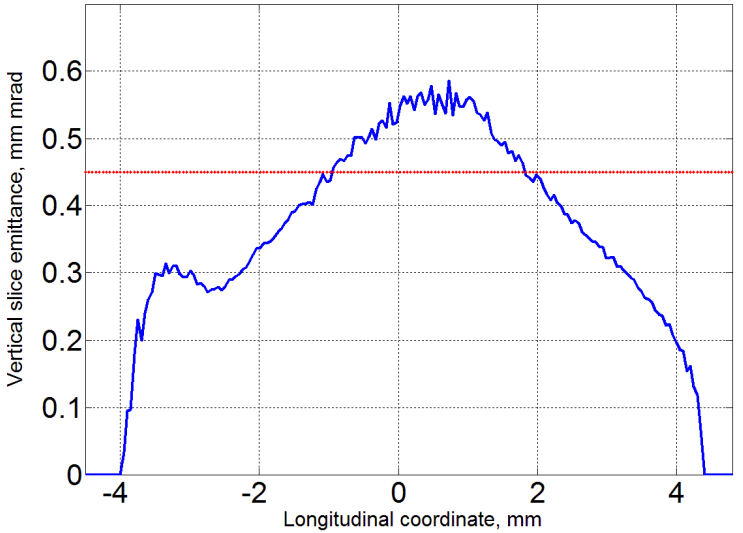


Slice beam properties (5.74 m) at Trms=4.47ps









Tolerances for Trms=6.708ps