Influence of laser beam temporal profile on the electron beam emittance

Martin Khojoyan
PITZ Physics Seminar
23.05.2013

HELMHOLTZ ASSOCIATION

PITZ Photo Injector Test Facility Zeuthen

DESY

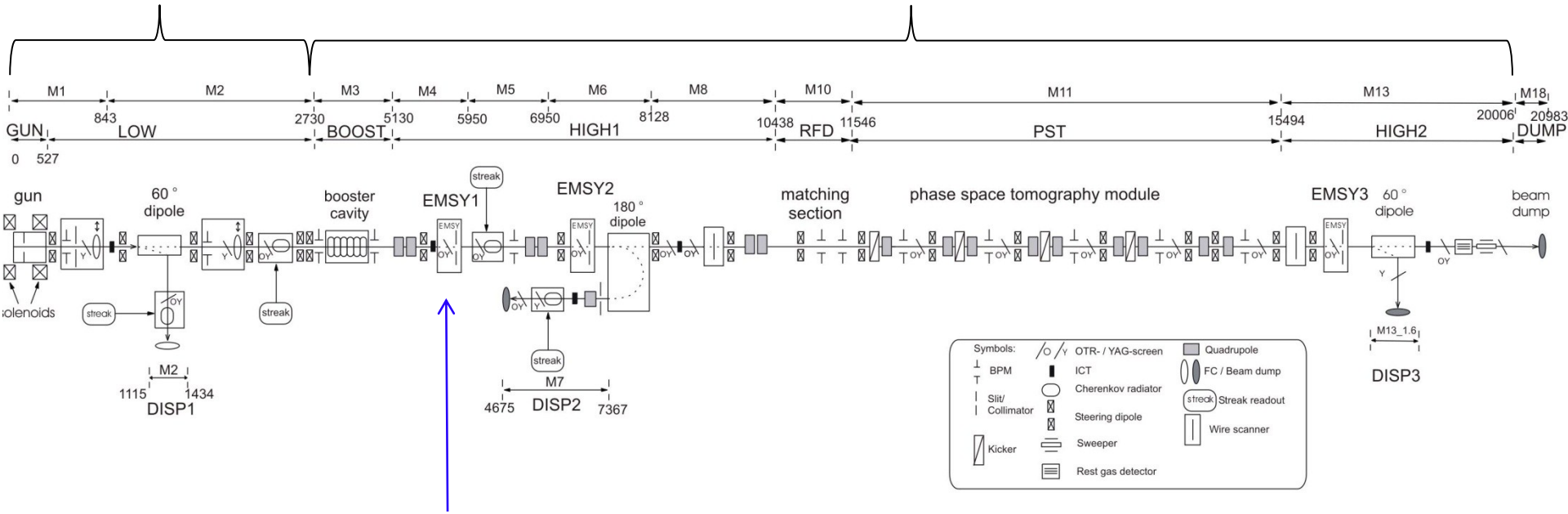
The study plan

- To optimize transverse emittance for Gaussian, Flat-top and 3D ellipsoidal laser profiles with the same bunch rms length at EMSY1
- To minimize the impact of numerical errors on the emittance by adjusting the space charge parameters in ASTRA
- To study the e-beam tolerances at 3 different temporal laser shapes
- To monitor electron bunch parameters at EMSY1
- To summarize the comparison for 3 cases of laser temporal profiles

PITZ setup used for emittance optimization

Low energy part
(~7 MeV/c)

High energy part (~25 MeV/c)



Emittance optimization screen-
5.74 m downstream the cathode

Minimizing numerical errors on transverse emittance

- Space charge (Nrad, Nlong, Nmin and cell_var in ASTRA) parameters tuning to minimize numerical errors on transverse emittance
- E-beam tolerance studies by keeping optimized and the same SC settings in ASTRA for 3 cases of laser temporal profile

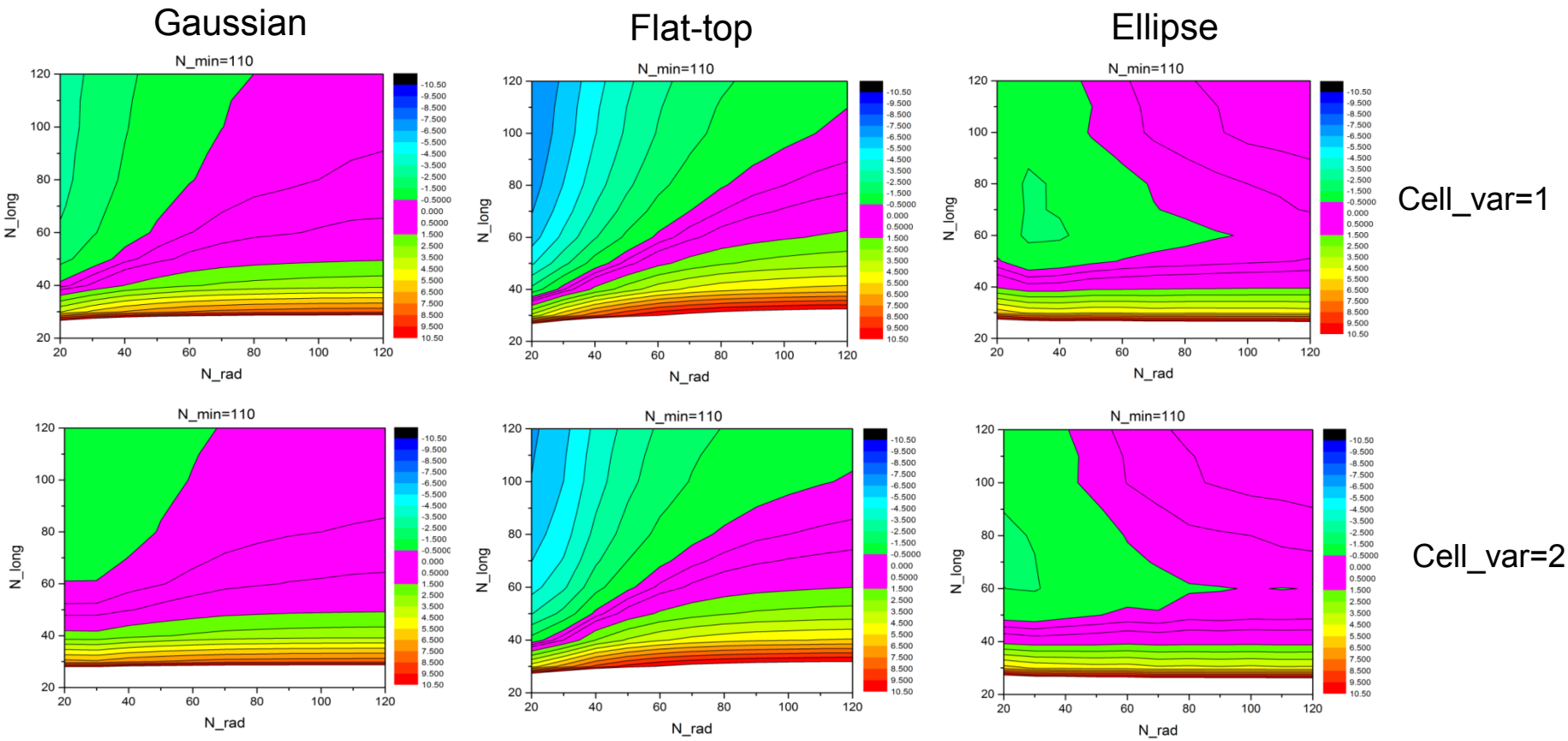


Fig.1. Emittance growth with different SC parameters in ASTRA (cell_var=1 and cell_var=2)

Summary of 3 cases: The same rms bunch length at EMSY1

cathode laser

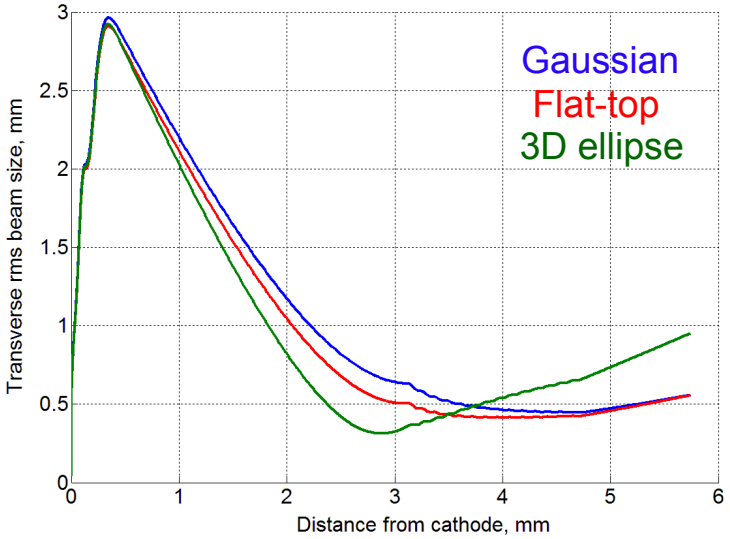
RF gun

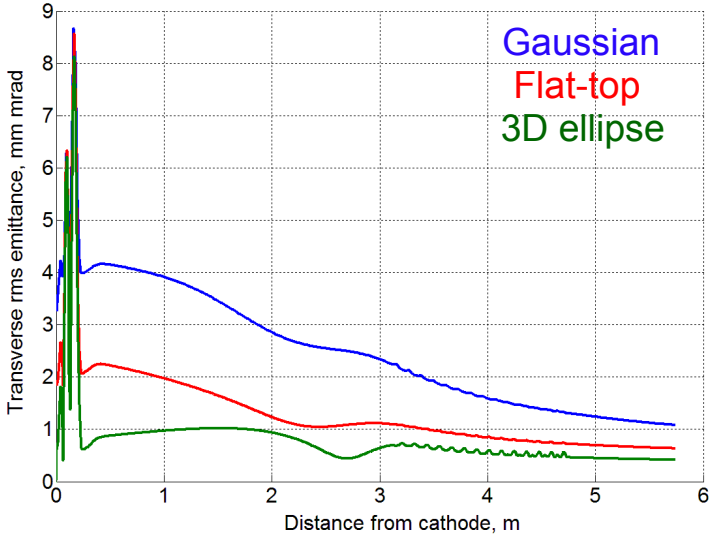
CDS

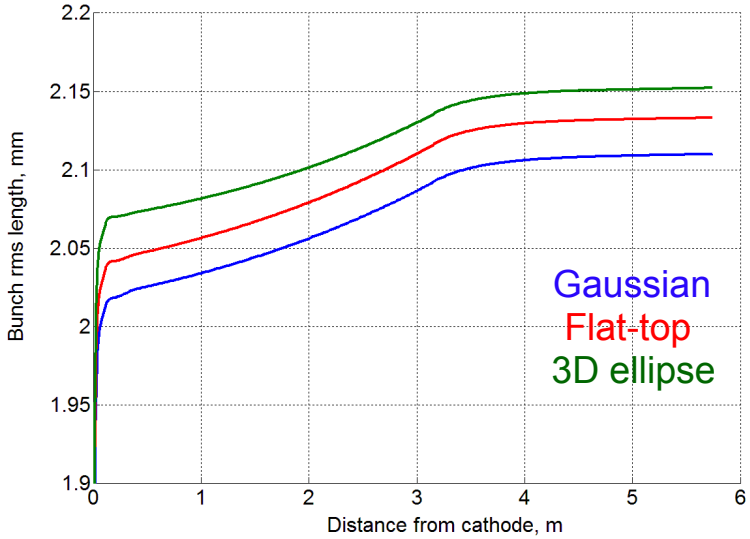
beam @ EMSY1

Parameter	Unit	Laser shape type			
Temporal	profile	cylindrical		3D ellipsoidal	
		Gaussian	Flat-top	3D homogeneous	Gaussian2
Transverse	distribution	radial homogeneous		3D homogeneous	
Trms	ps	6.09	6.27	6.27	6.27
XYrms	mm	0.42	0.415	0.4	0.4
Th. emit.	mm mrad	0.36	0.35	0.34	0.34
Ecath.	MV/m	60.58	60.58	60.58	60.58
Phase	deg	-1	-1	-1.8	-1.5
MaxBz	T	0.227	0.228	0.2297	0.226
MaxE	MV/m	18	19.76	20	16
Charge	nC	1	1	1	1
Momentum	MeV/c	22.4	24	24.2	20.7
Proj. emittance	mm mrad	1.08	0.635	0.416	1.15
Th. / proj.	%	31	55	82	30
<Sl. emit.>	mm mrad	0.635	0.57	0.393	0.65
‘Peak’ slice emit.	mm mrad	0.84	0.6	0.5	0.9
Peak current	A	47.5	43	46.7	45.5
Longitudinal emittance	pi keV mm	101.7	95.7	89.2	103.1

3 different e-beam shapes with the same rms bunch length at EMSY1







The same SC settings in ASTRA for 3 cases: Nrad=100, Nlong=70, Nmin=100, cell_var=2

Fig.2. E-beam transverse sizes, emittances and bunch lengths for 3 different laser shapes.

Different beam shapes with the same rms length at EMSY1

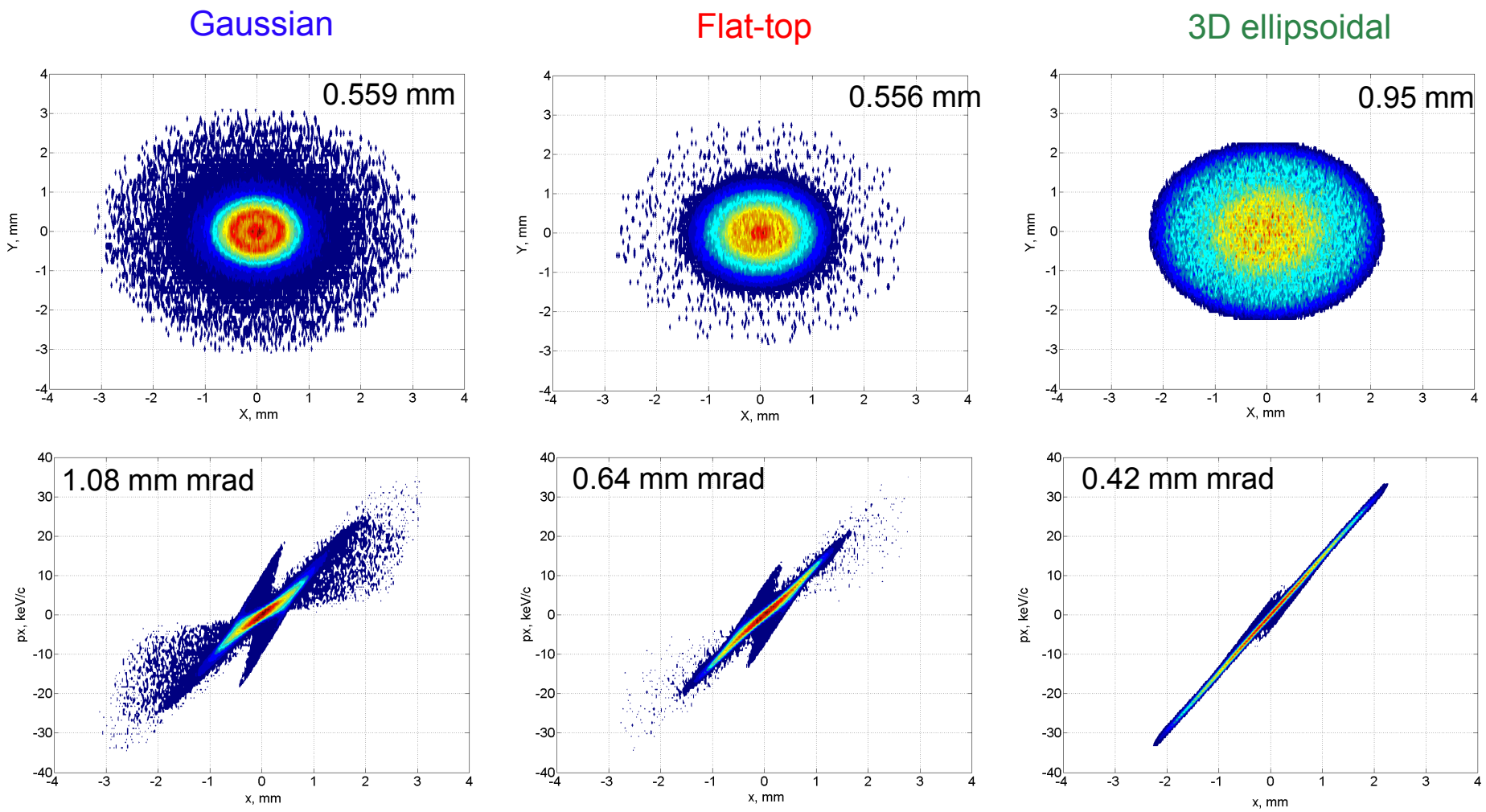
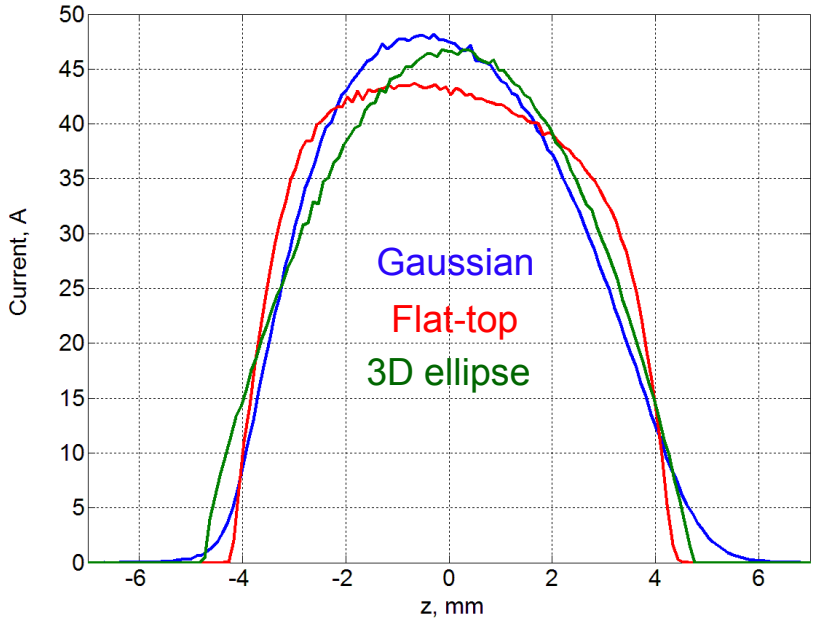
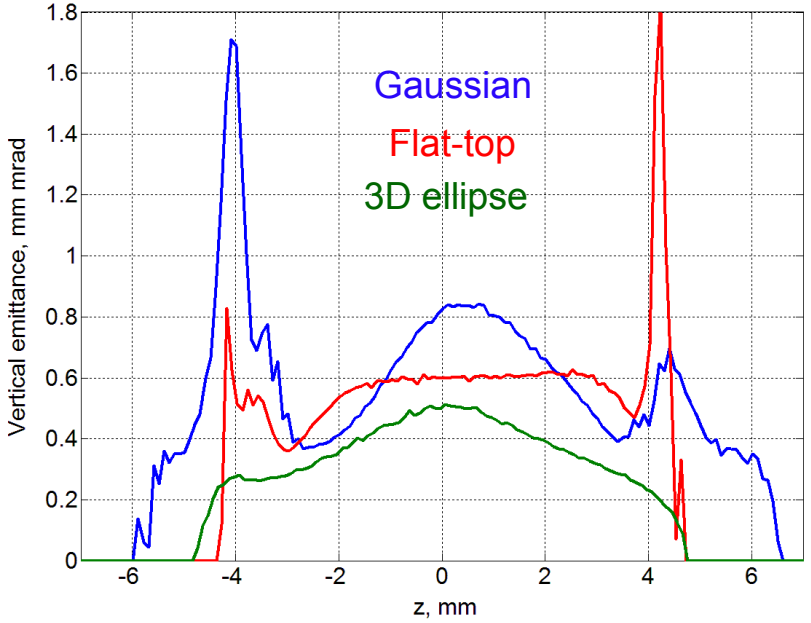


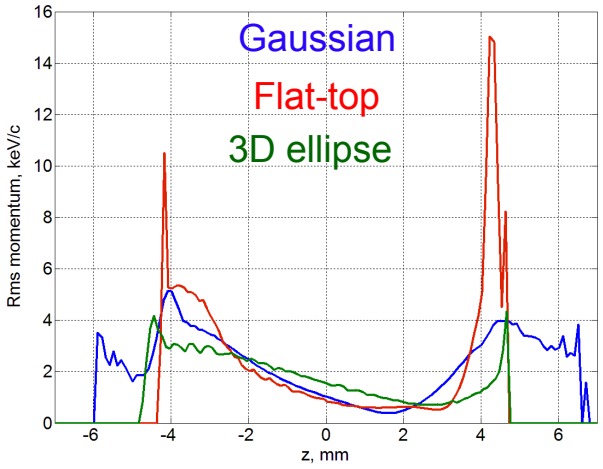
Fig.3. E-beam transverse phase spaces and projections at EMSY1. The same rms bunch length for 3 cases.

E-beam slice parameters for the same rms bunch length: 3 laser profiles

Fig.4. Beam slice parameters for Gaussian, Flat-top and 3D ellipsoidal laser profiles.







Gaussian profile yields to high peak current, huge peak slice emittance and energy spread comparable to the flat-top case

Longitudinal phase spaces and beam side views for 3 cases

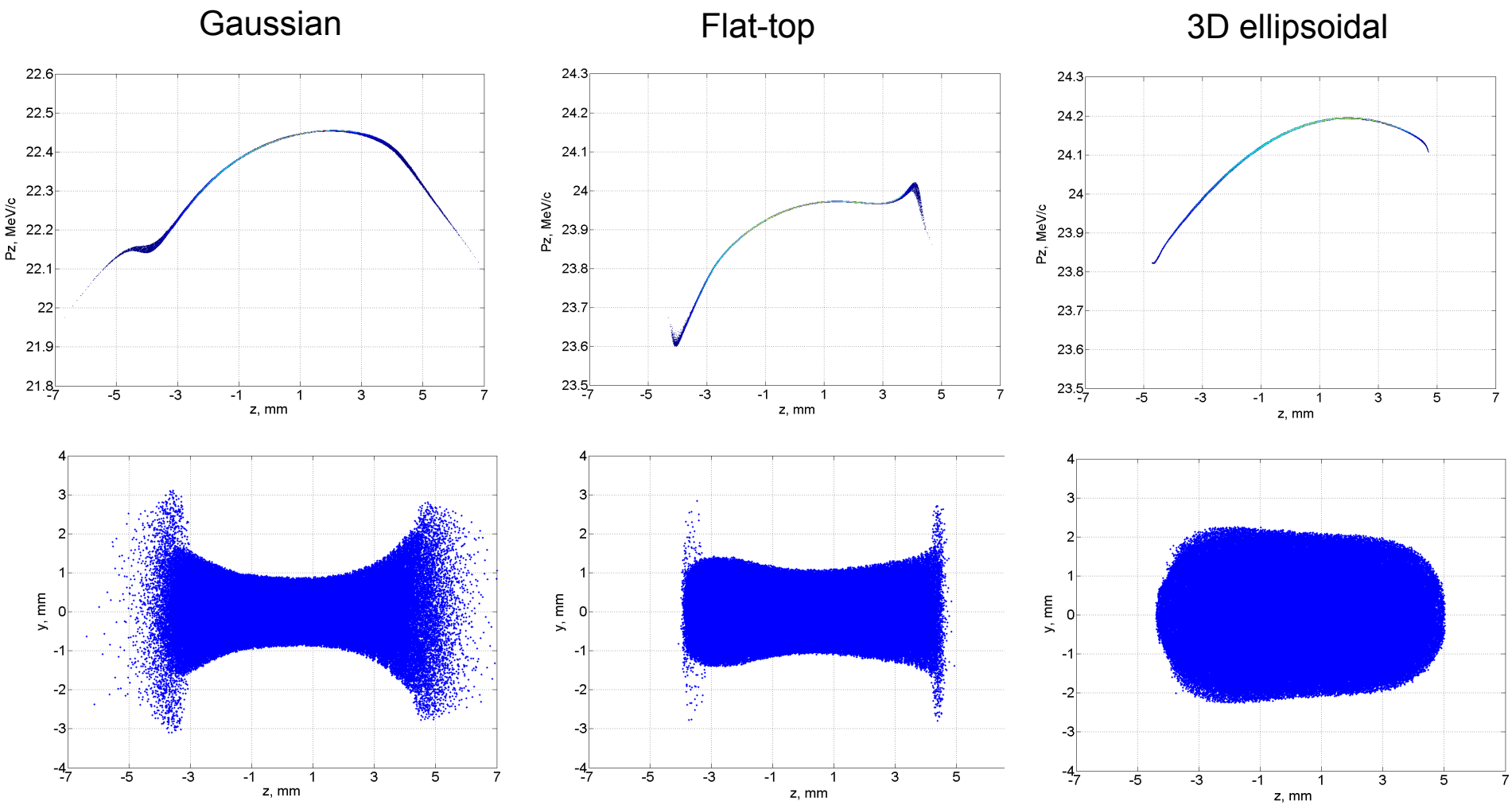
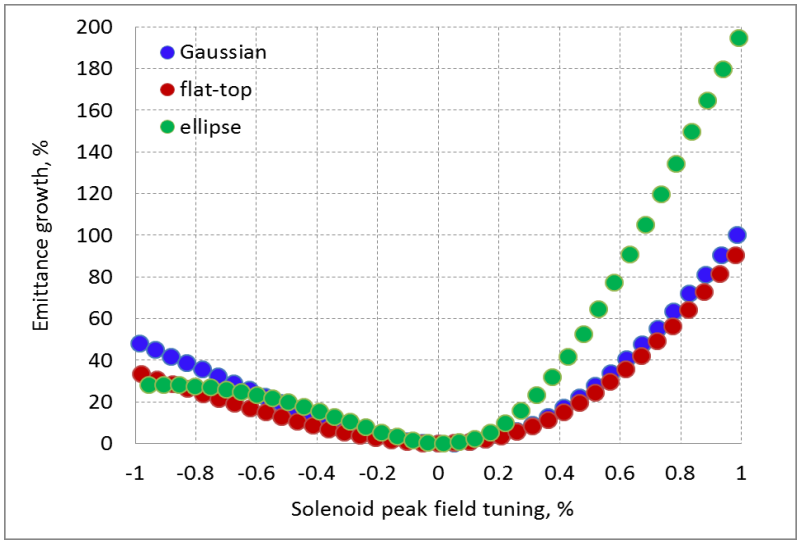
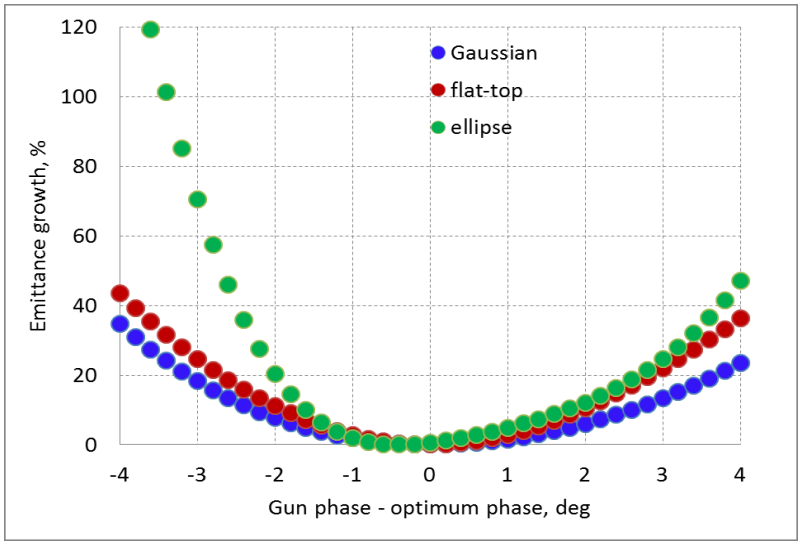
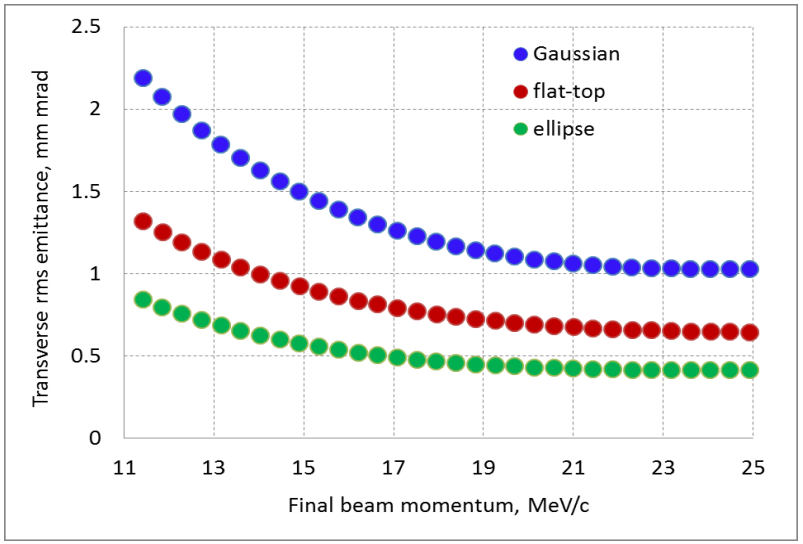


Fig.5. Longitudinal phase spaces and beam side views for 3 different temporal laser profiles.

E-beam tolerances for 3 different laser profiles at 1nC







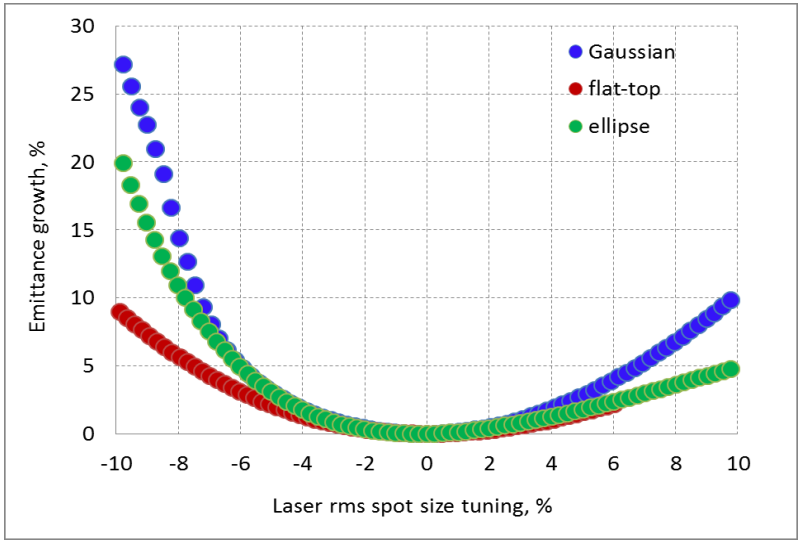


Fig.6. E-beam tolerance studies for Gaussian, flat-top and 3D ellipsoidal laser profiles.

Summary

- Emission parameters in ASTRA were optimized to obtain the smallest numerical impact on the emittance
- Tuned the laser length to have the same rms beam length at EMSY1 for Gaussian, flat-top and 3D ellipsoidal laser shapes. Machine parameters were optimized afterwards for the best transverse emittance for 3 cases
- E-beam tolerances have been studies for 3 cases

Thank you for your attention !!

Comparing Gaussian profiles with different lengths

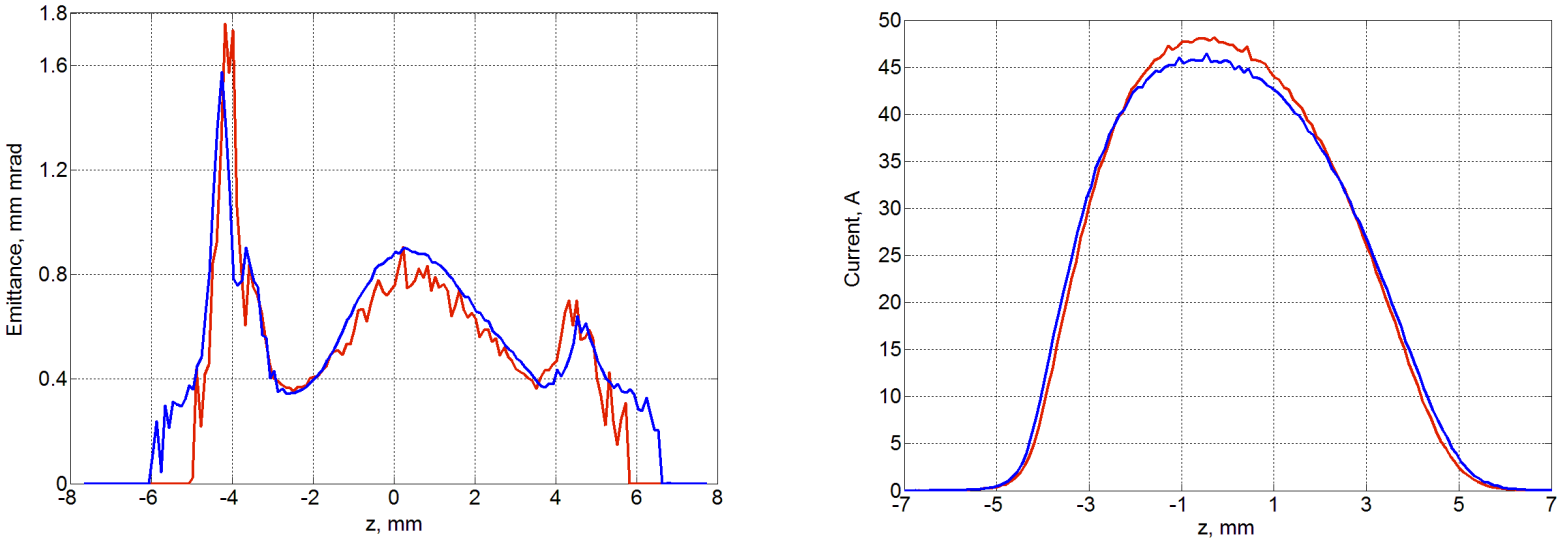


Fig.7. Beam slice parameters for two cases:
a) The same laser length as flat-top and ellipse
b) The same e-beam rms length as for flat-top and ellipse