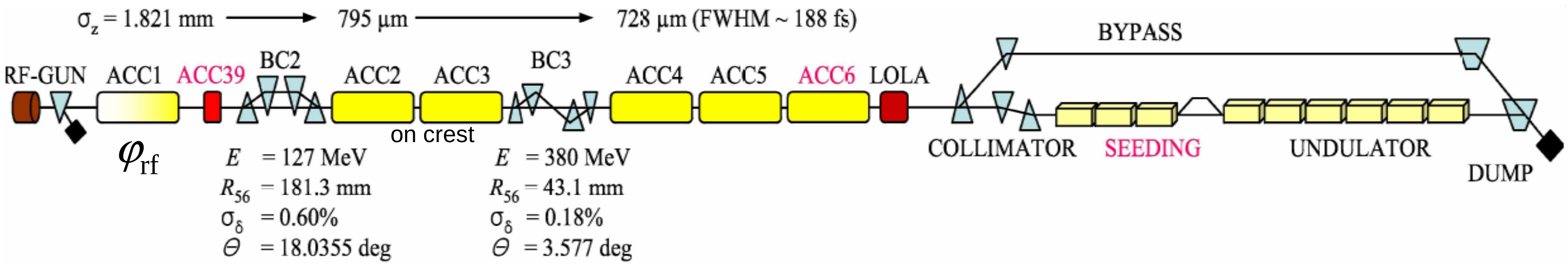
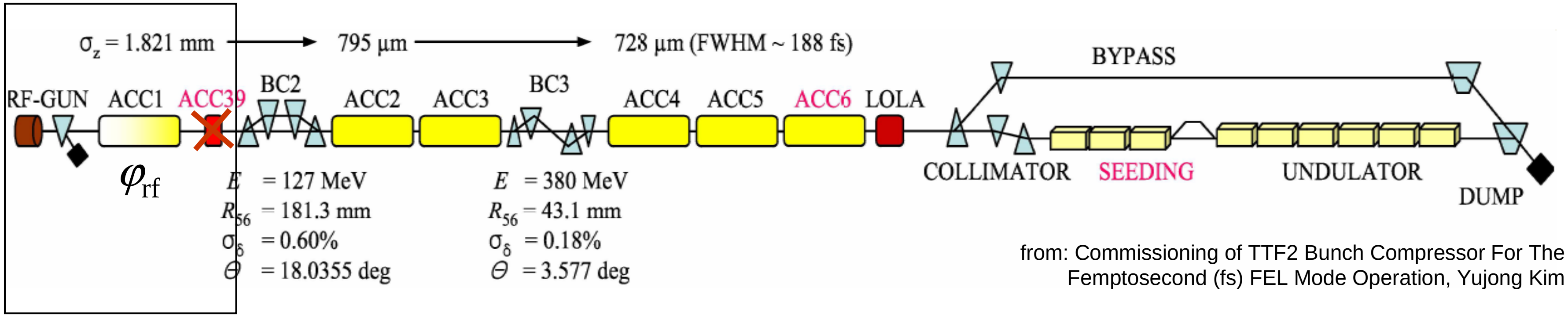
CSR Calculation for TTF2



1. method
2. no CSR, φ_{rf} = 8 deg
3. CSR “projected”, optics = option 1 & 2, φ_{rf} = 8 deg
4. CSR “projected”, optics = option 1 & 2, φ_{rf} = 12 deg
5. CSR “projected”, optics = option 1, φ_{rf} = 7 deg
6. some LOLA pictures
7. conclusion / remarks

1. method



from: Commissioning of TTF2 Bunch Compressor For The Femptosecond (fs) FEL Mode Operation, Yujong Kim

ASTRA distribution (xfel.1200.001.txt)
1nC, 200000 particles

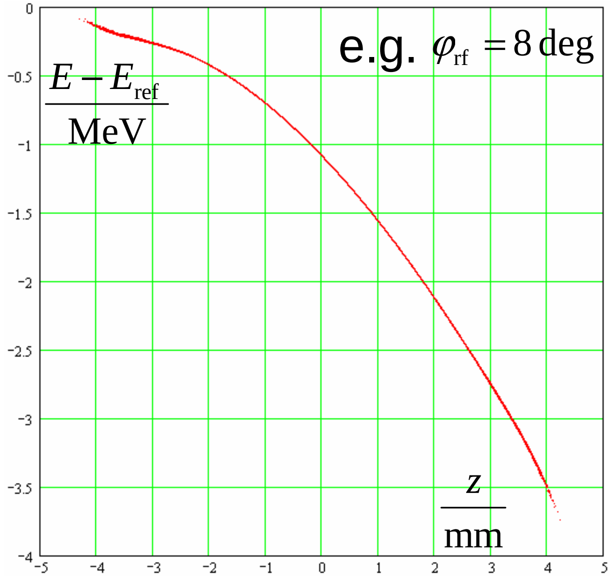
1) extract rf (longitudinal momentum)
2) add ACC1 rf as required

$$V(s) = V_{\mathrm{acc}} \frac{\cos(ks + \varphi_{\mathrm{rf}})}{\cos \varphi_{\mathrm{rf}}}$$

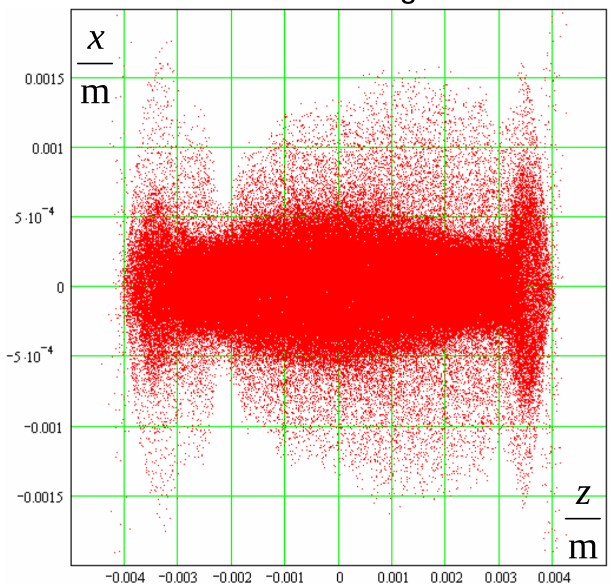
3) calculate Twiss parameters from
   core of bunch (particles between ±2mm)
   use transport matrix for matching to
   required values (Nina Golubeva)

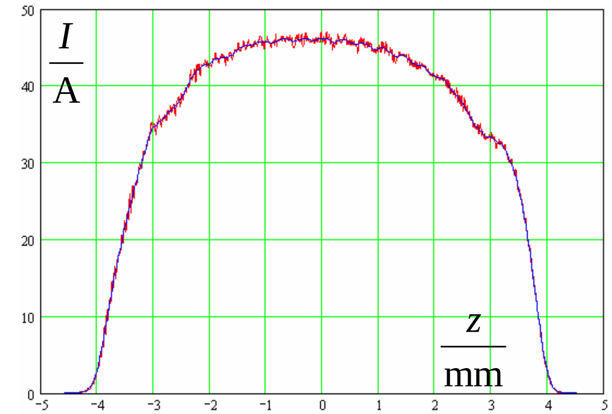
$$\alpha_x = 4.619 \quad \beta_x = 20.174\,\mathrm{m}$$
$$\alpha_y = -0.012 \quad \beta_y = 2.809\,\mathrm{m}$$

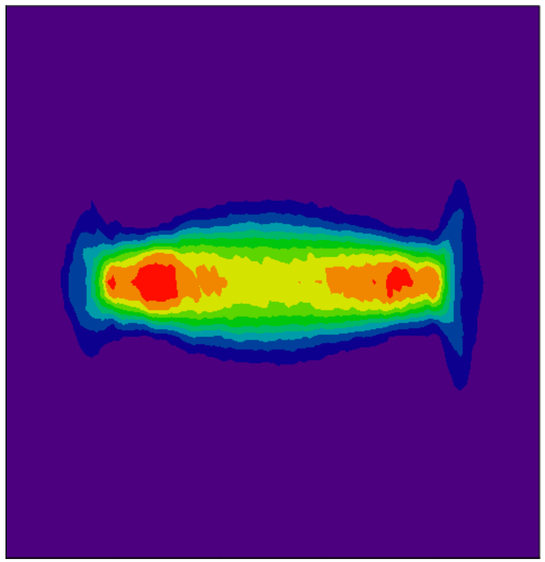
particles at entrance of BC1



horizontal vs. longitudinal

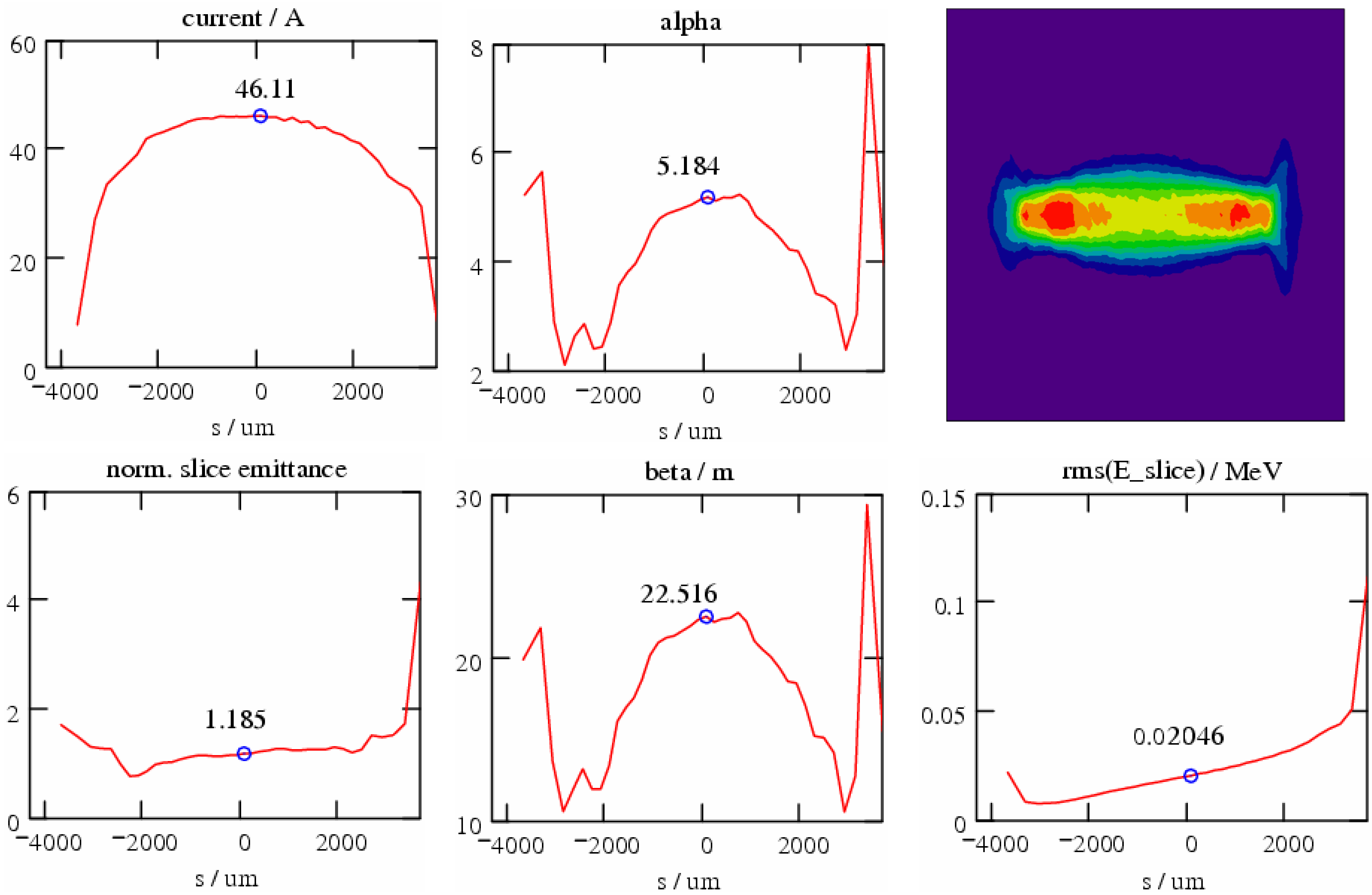




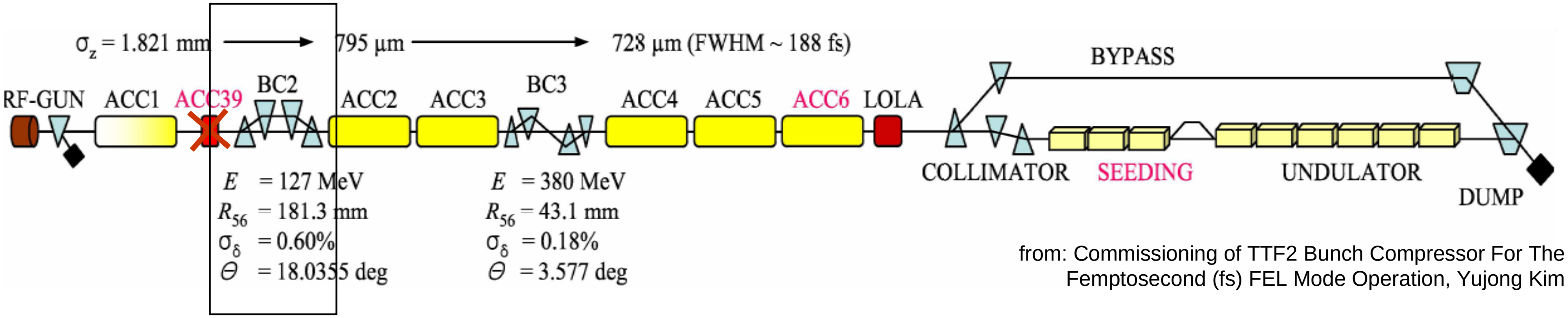


particles at entrance of BC1

(“slices” with 5000 particles)

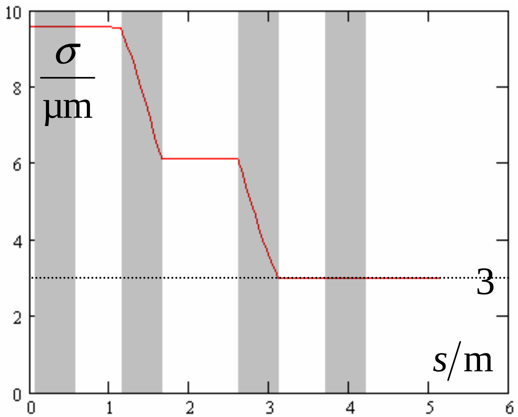


method ...



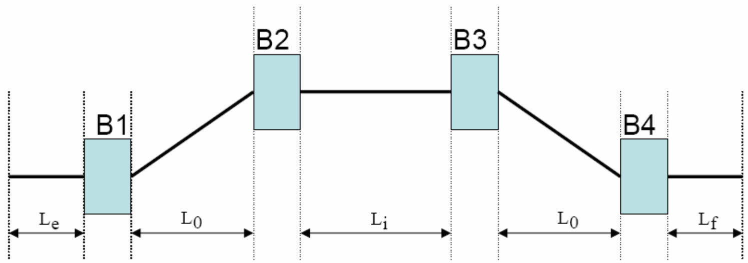
from: Commissioning of TTF2 Bunch Compressor For The Femptosecond (fs) FEL Mode Operation, Yujong Kim

4) calculate BC2 with projected method
sub-bunch length:



reference plane = 1 m after BC

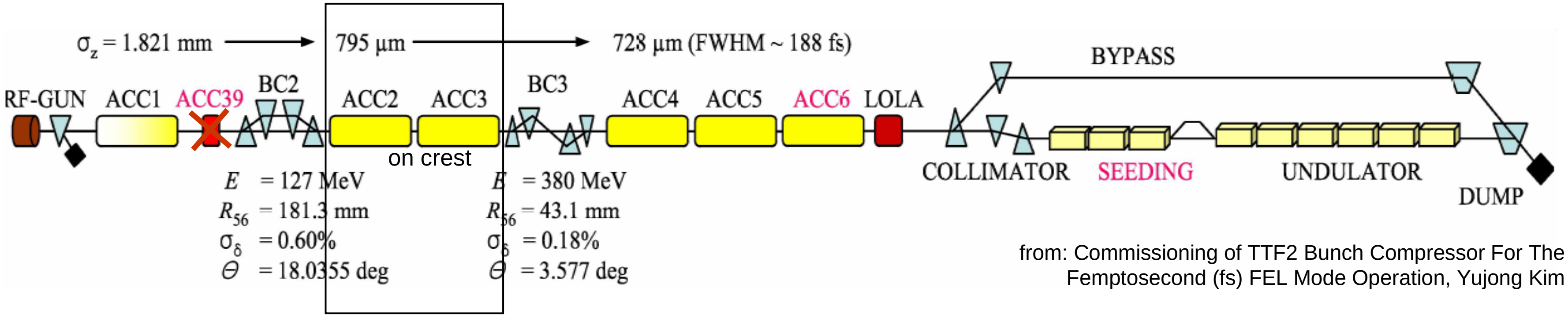
BC2 chicane description



Parameters	*Symbol*	*Value*	*Unit*
Bend magnet length (projected)	L_b	0.5	m
Drift length B1→ B2 and B3→ B4 (projected)	L_0	0.5	m
Dirft length B2→ B3	L_i	0.963	m
Pre chicane drift	L_e	0.1	m
Post chicane drift	L_f	0.1	m
Bend radius of each dipole magnet	R	2.40486	m
Bending Angle	Φ	12	deg
Momentum compaction	$\|R_{56}\|$	76.17403	mm
2nd order momentum compaction	$\|T_{566}\|$	118.9555	mm
Total projected length of chicane	L_{tot}	4.163	m
Full gap height pole/chamber	g / h	25.0 / 8.0	mm

R = 1.614955 m
r56 = -0.181496 m
t586 = 0.296575 m

method ...



from: Commissioning of TTF2 Bunch Compressor For The Femptosecond (fs) FEL Mode Operation, Yujong Kim

5) transformation from exit BC2 to entrance BC3:

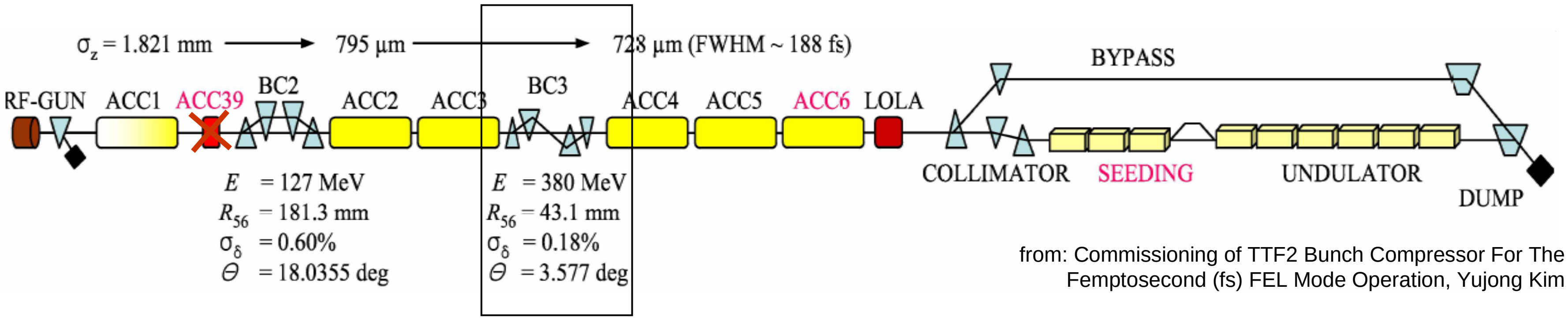
longitudinal: add rf-field and wake of two modules

transverse: use transport matrix

option 1: αx=-0.284, βx= 0.976m μx=0.328*2π to αx=-0.284, βx= 0.976m μx=1.427*2π
αy= 2, βy=31.037m μy=1.427*2π αy= 2, βy=30.021m μy=1.465*2π

option 2: … to αx=-0.495, βx=17.150m μx=1.478*2π
αy=-0.152, βy=19.719m μy=1.830*2π

method ...

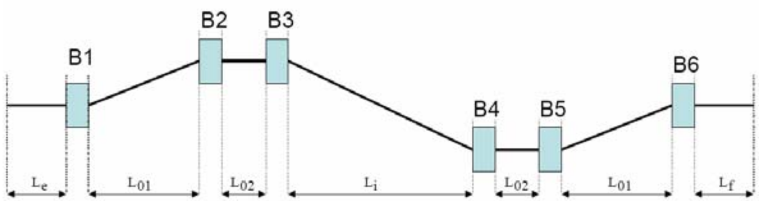


from: Commissioning of TTF2 Bunch Compressor For The Femptosecond (fs) FEL Mode Operation, Yujong Kim

6) calculate BC3 with projected method
sub-bunch length = 3 μm

reference plane = 1 m after BC

BC3 chicane description



Parameters	*Symbol*	*Value*	*Unit*
Bend magnet length (projected)	L_b	0.3	m
Drift length B1→ B2 and B5→ B6 (projected)	L_{01}	3.6412	m
Drift length B2→ B3 and B4→ B5 (projected)	L_{02}	0.5	m
Dirft length B3→ B4	L_i	7.5824	m
Pre chicane drift	L_e	0.1	m
Post chicane drift	L_f	0.1	m
Bend radius of each dipole magnet	R	11.46046	m
Bending Angle	Φ	1.5	deg
Momentum compaction	$\|R_{56}\|$	10.60772	m
2nd order momentum compaction	$\|T_{566}\|$	15.92241	m
Total projected length of chicane	L_{tot}	17.4648	m
Full gap height pole/chamber	g / h	25.0 / 8.0	mm

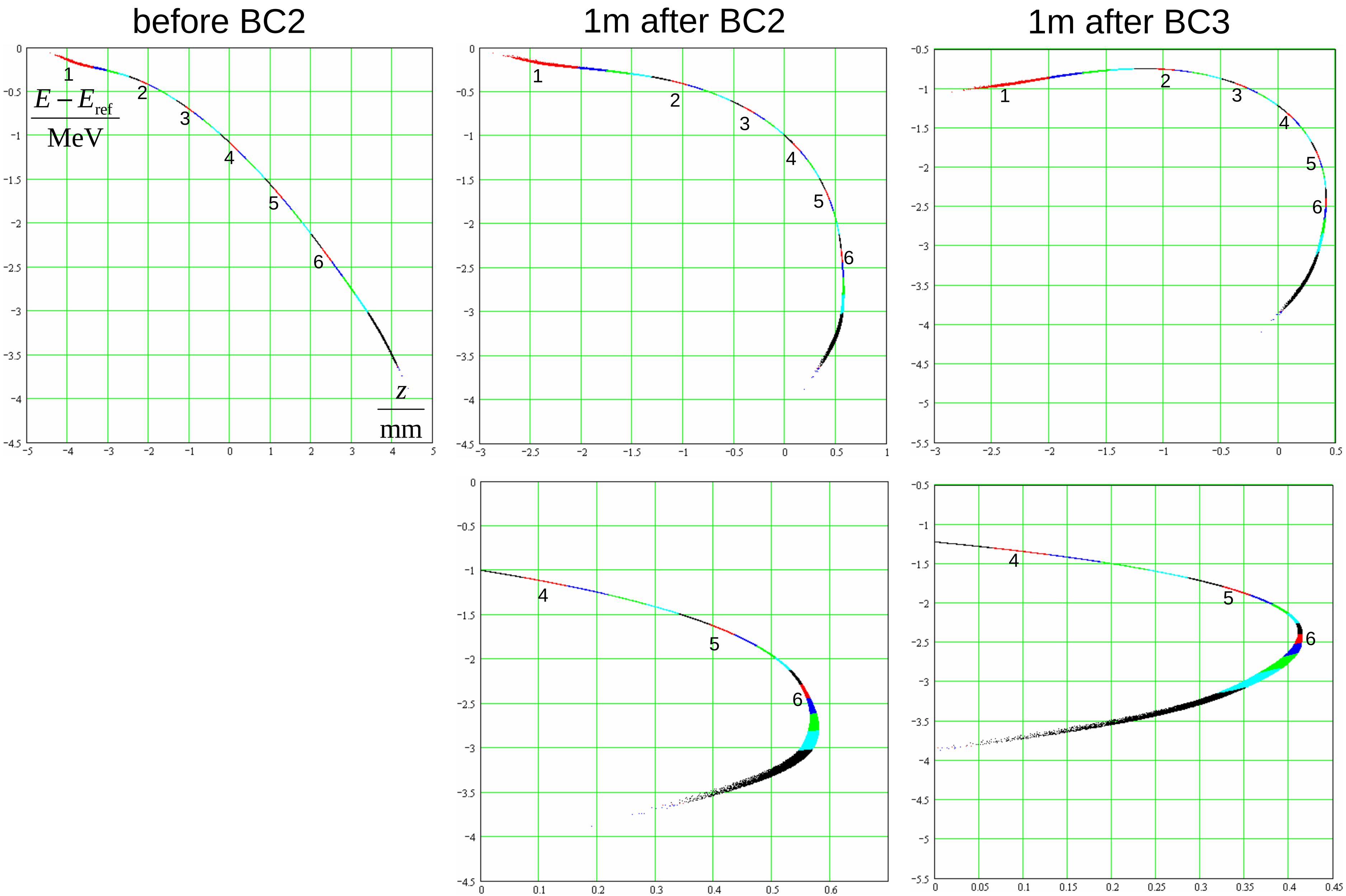
R = 5.695 m

r56 = -0.041226 m

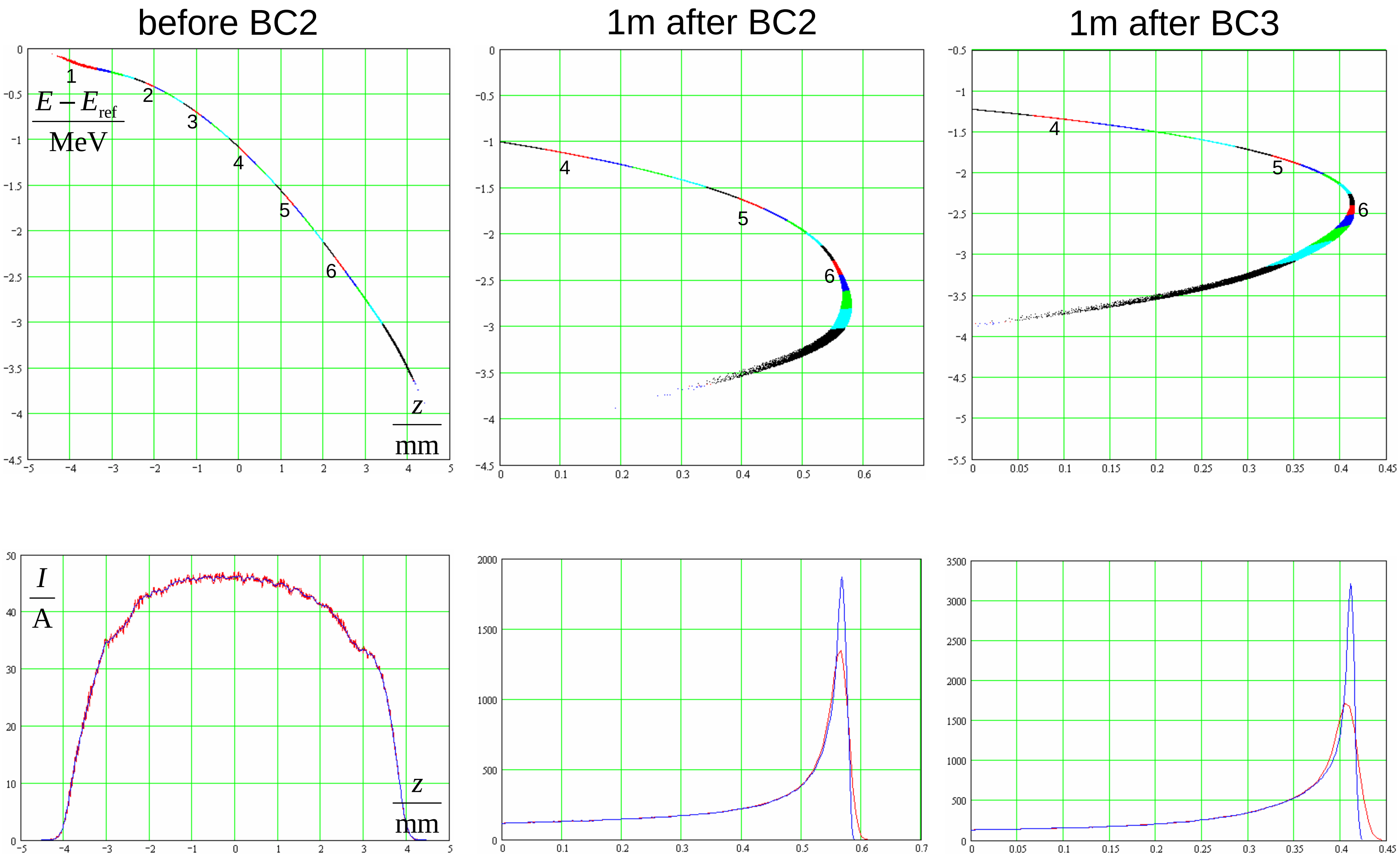
t586 = 0.064860 m

2. no CSR

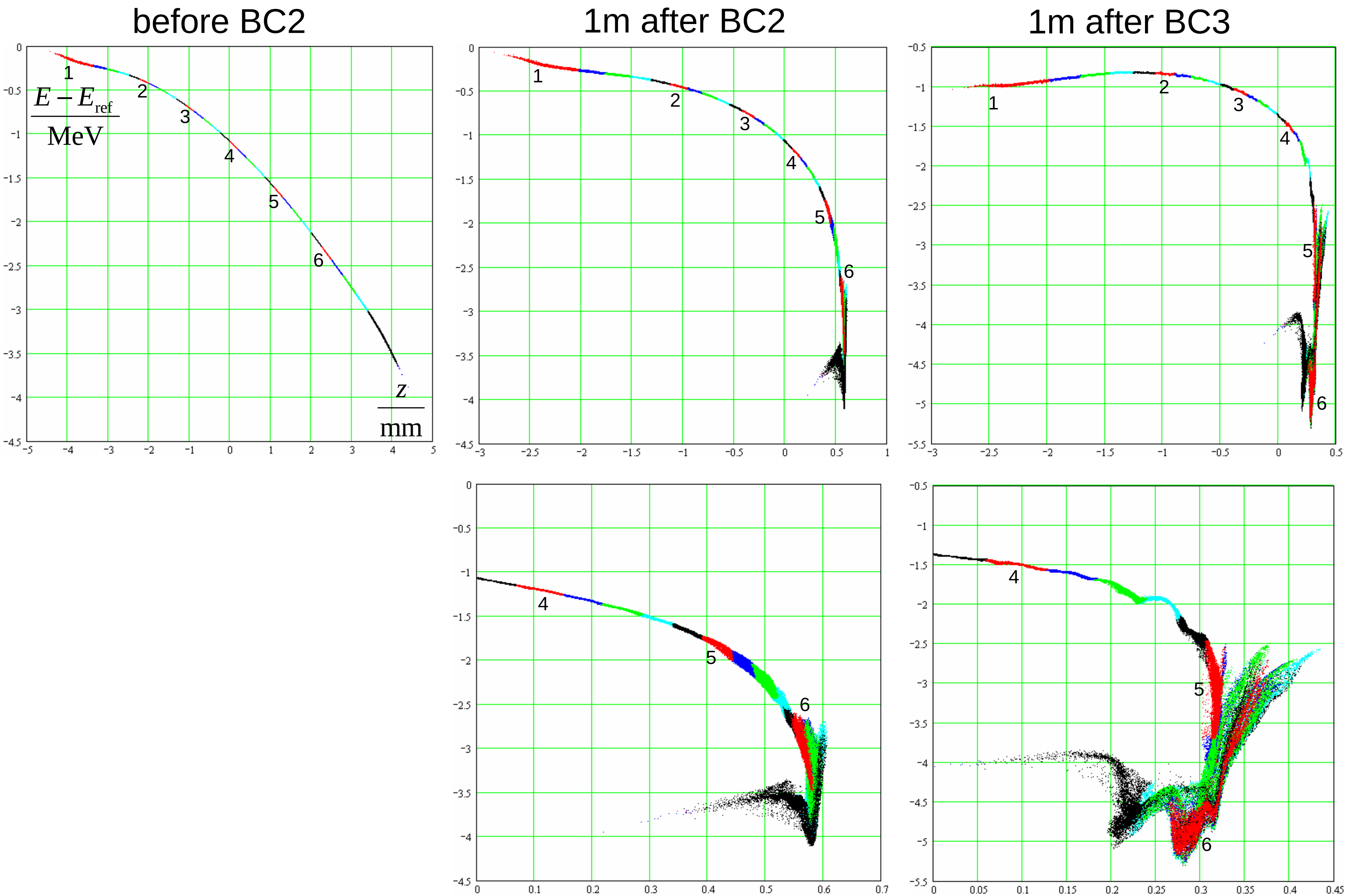
optics = option 1 $\varphi_{\mathrm{rf}} = 8\,\mathrm{deg}$



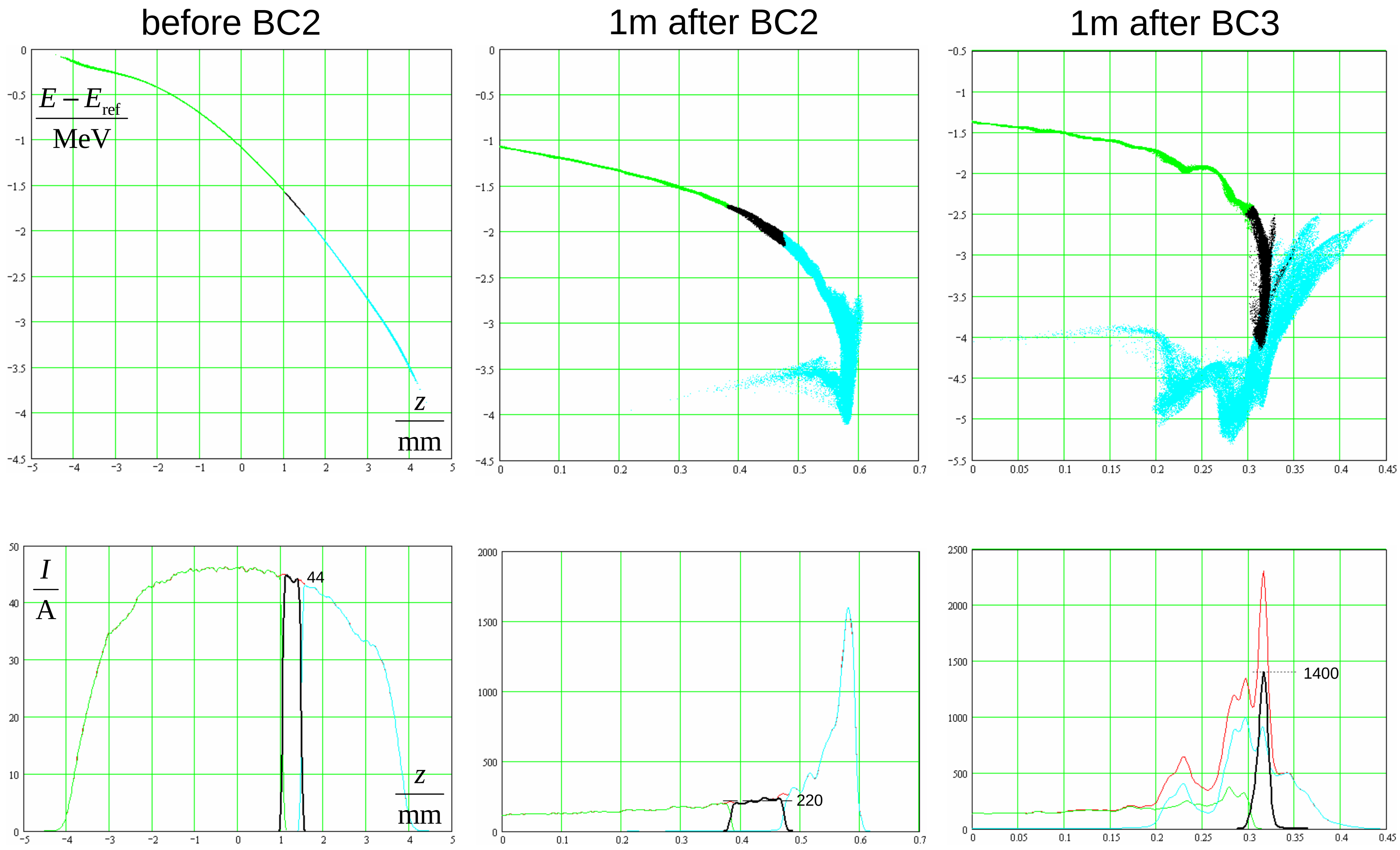
no CSR optics = option 1 $\varphi_{rf} = 8\,\deg$



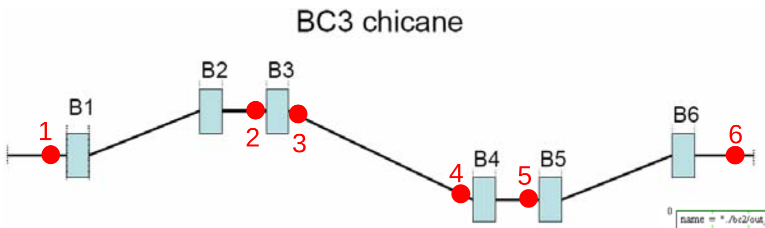
3. CSR "projected" optics = option 1 $\varphi_{\mathrm{rf}} = 8\,\mathrm{deg}$



CSR "projected" optics = option 1 $\varphi_{\rm rf} = 8\,\text{deg}$

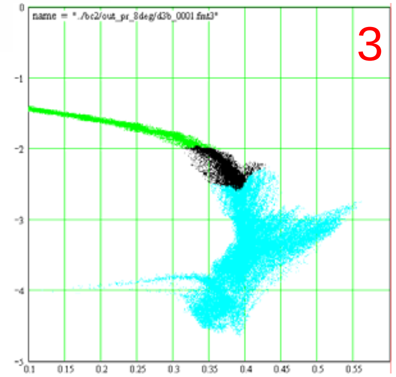


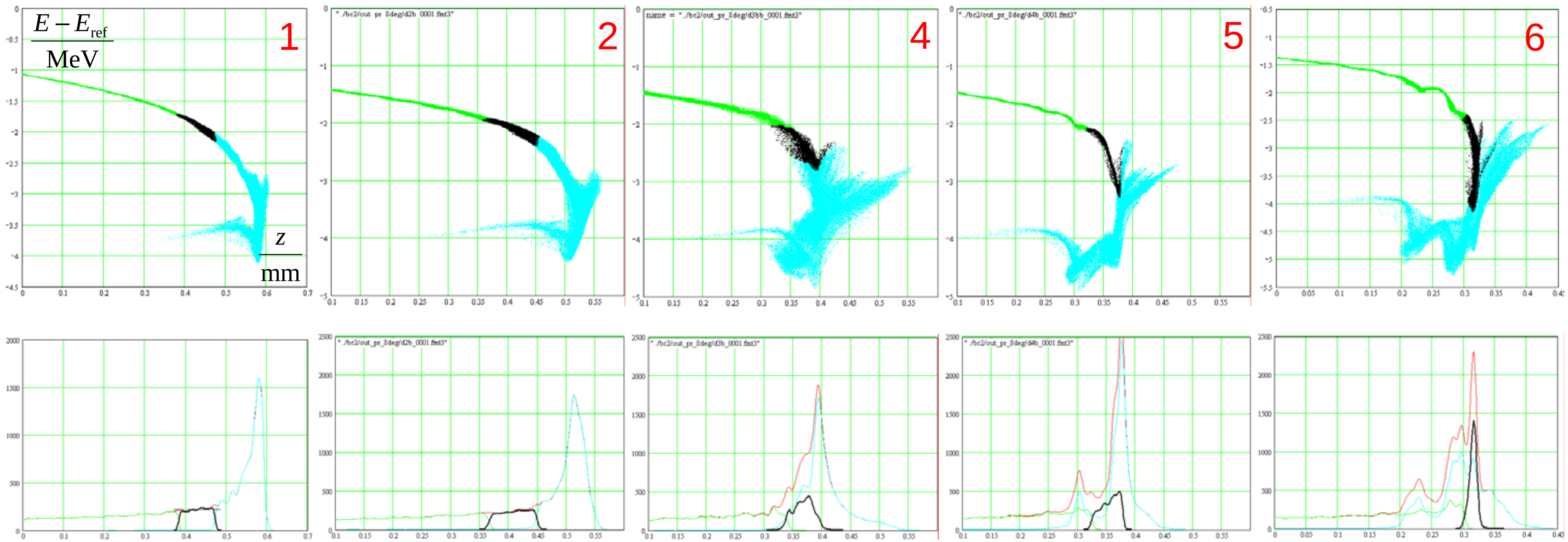
long. phase space in BC3



optics = option 1

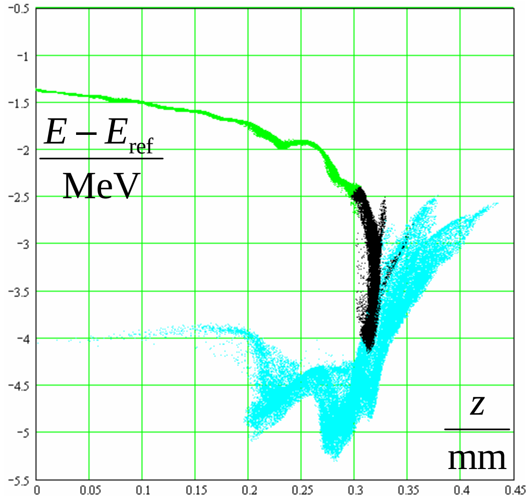
$\varphi_{\mathrm{rf}} = 8\,\mathrm{deg}$



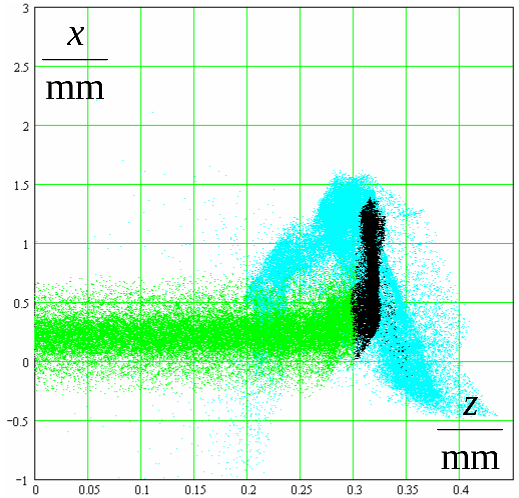


CSR “projected” optics = option 1 $\varphi_{\mathrm{rf}} = 8\,\mathrm{deg}$

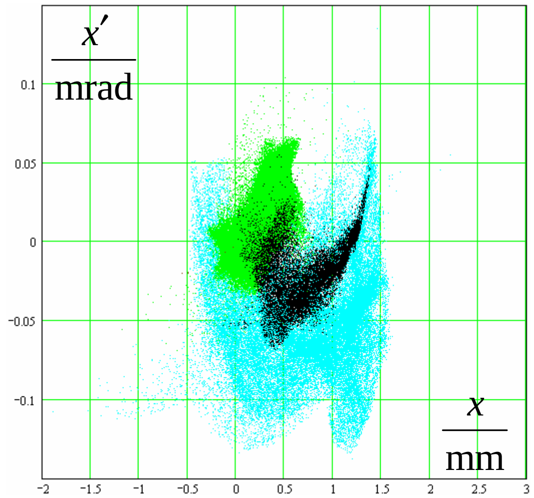
longitudinal

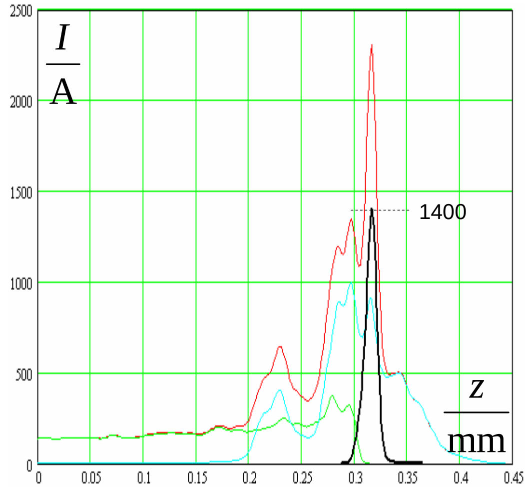


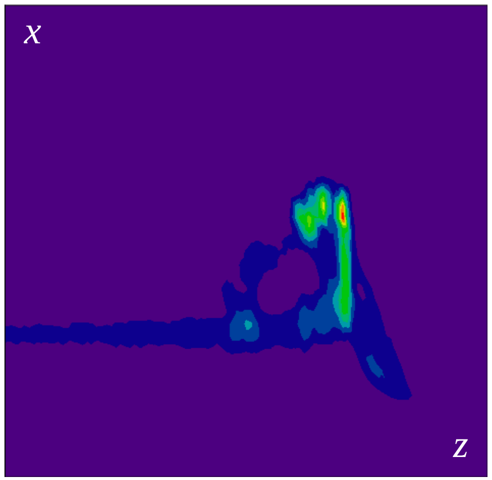
“top”



horizontal





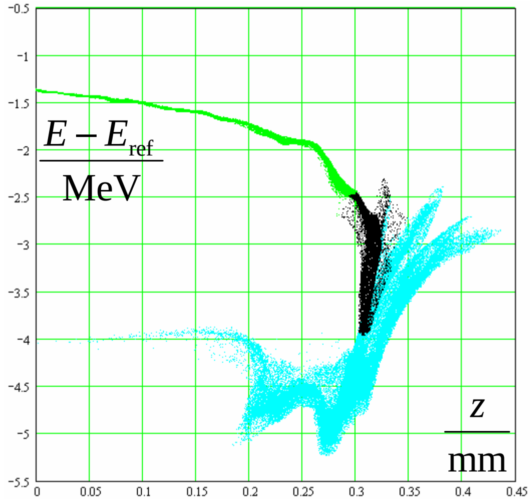


all particles:
emittance/um = 10.1
rms-length/um = 722
rms-energy spread/keV = 1450

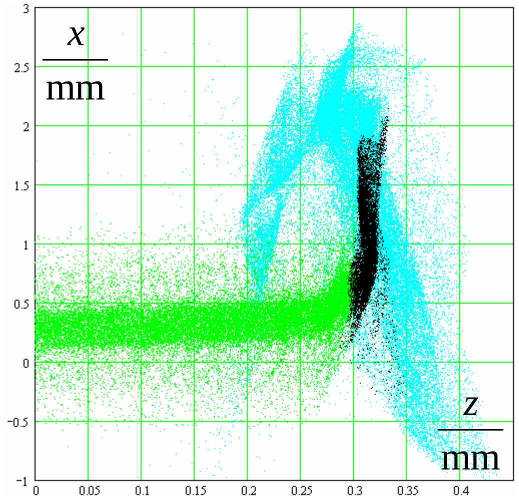
“black” particles:
emittance/um = 4.13
rms-length/um = 5.6
rms-energy spread/keV = 476

CSR “projected” optics = option 2 $\varphi_{\mathrm{rf}} = 8\,\mathrm{deg}$

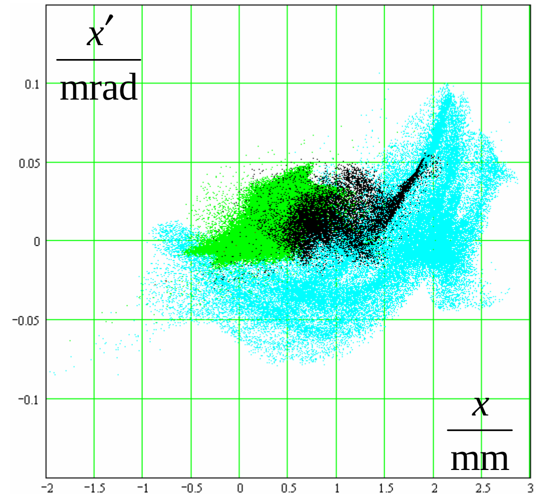
longitudinal

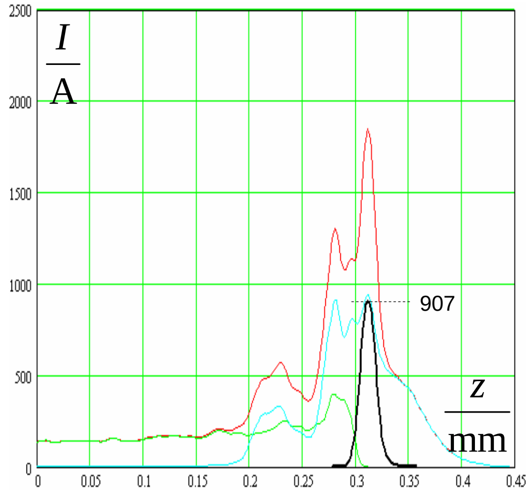


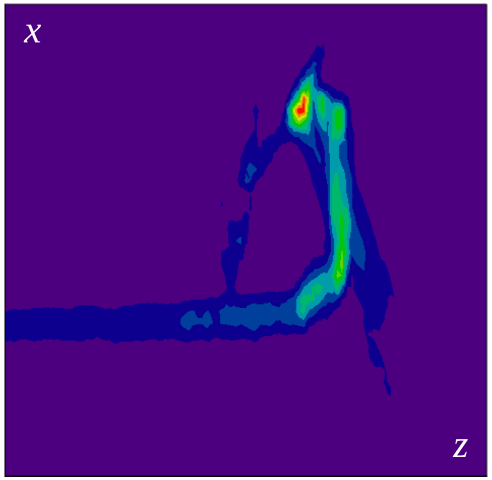
“top”



horizontal



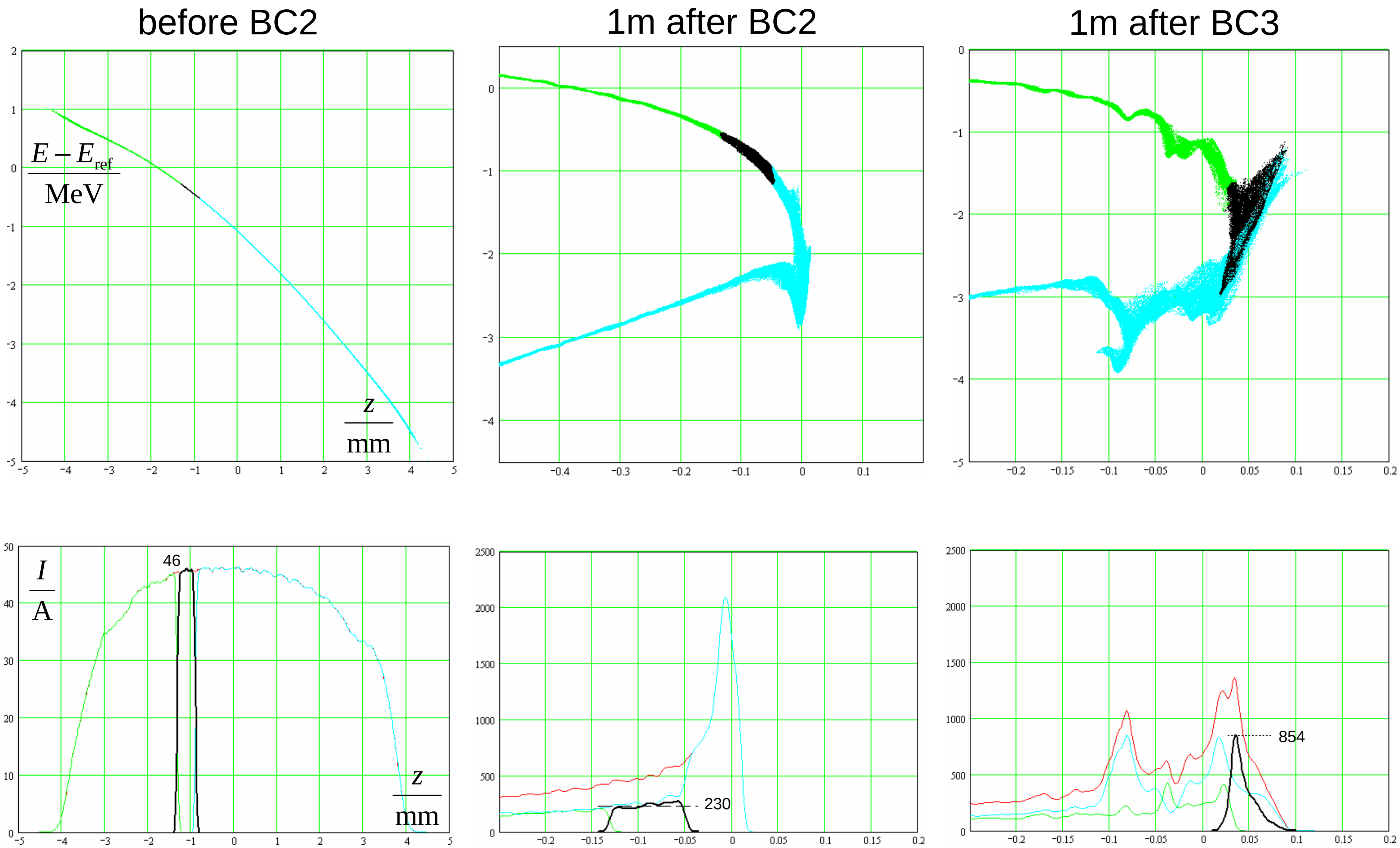




all particles:
emittance/um = 10.6
rms-length/um = 722
rms-energy spread/keV = 1419

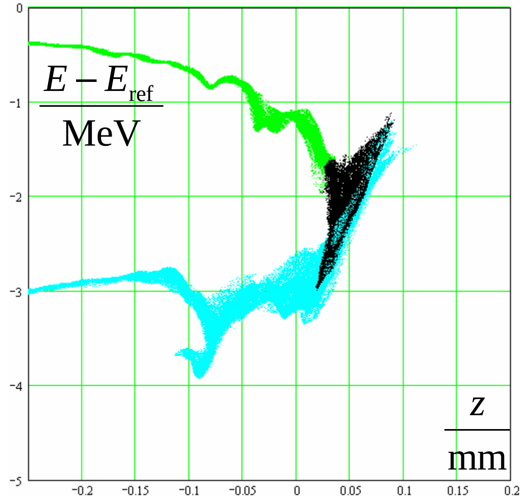
“black” particles:
emittance/um = 3.63
rms-length/um = 6.8
rms-energy spread/keV = 418

4. CSR "projected" optics = option 1 $\varphi_{rf} = 12\,\mathrm{deg}$

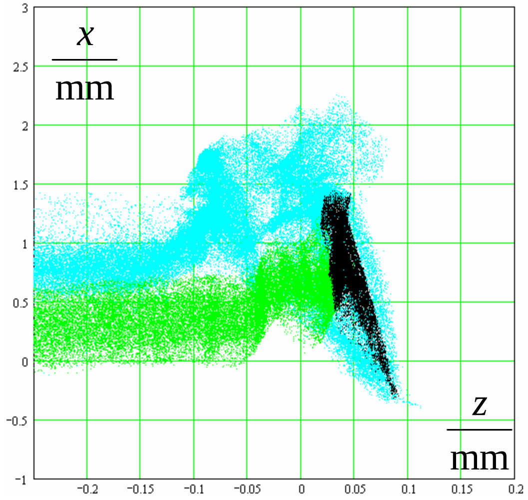


CSR “projected” optics = option 1 $\varphi_{\mathrm{rf}} = 12\ \mathrm{deg}$

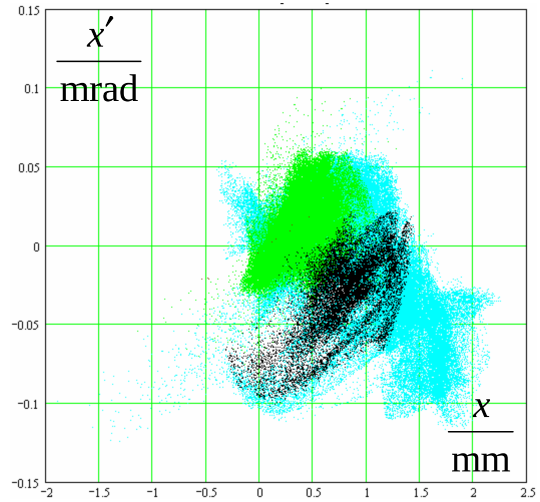
longitudinal

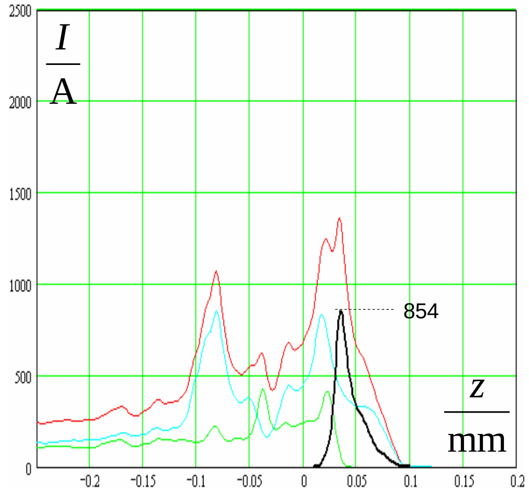


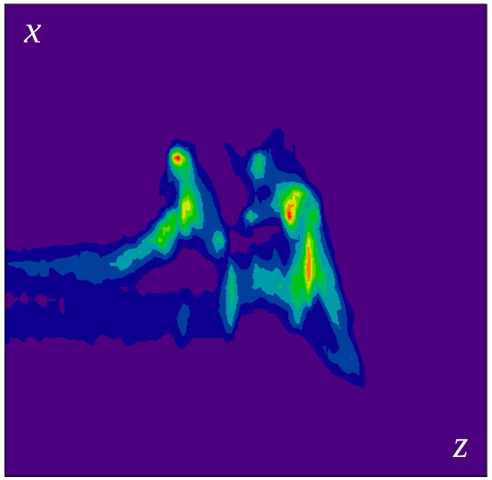
“top”



horizontal





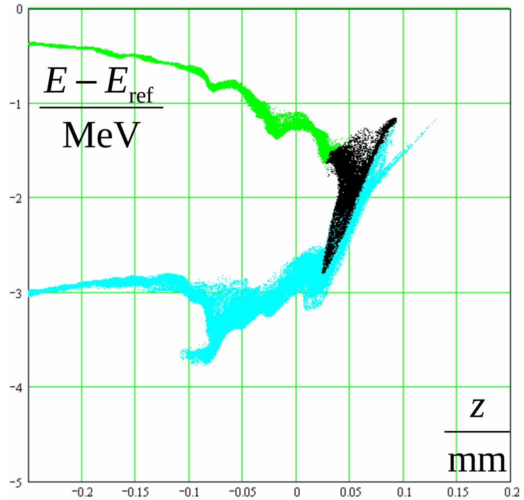


all particles:
emittance/um = 10.55
rms-length/um = 339
rms-energy spread/keV = 1380

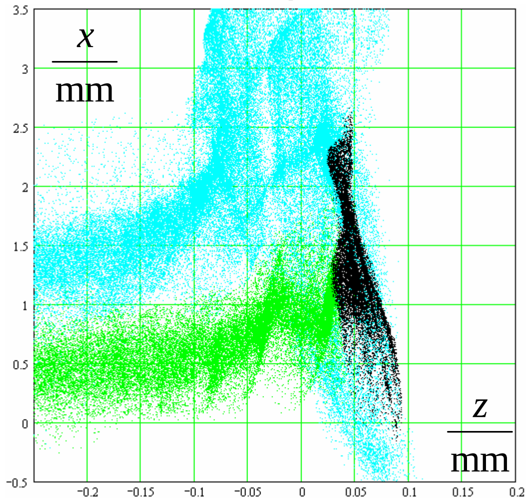
“black” particles:
emittance/um = 4.56
rms-length/um = 13.0
rms-energy spread/keV = 324

CSR “projected” optics = option 2 $\varphi_{rf} = 12\ \mathrm{deg}$

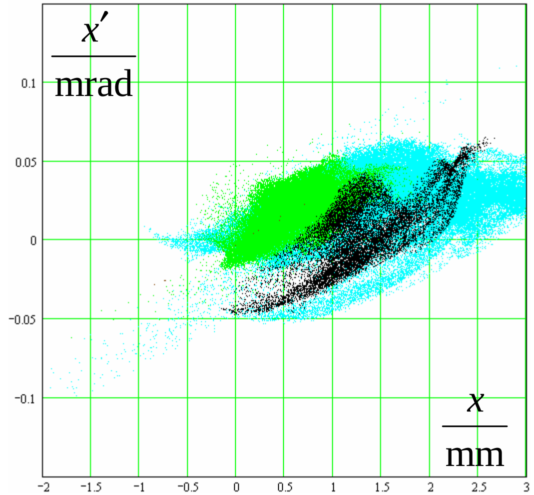
longitudinal

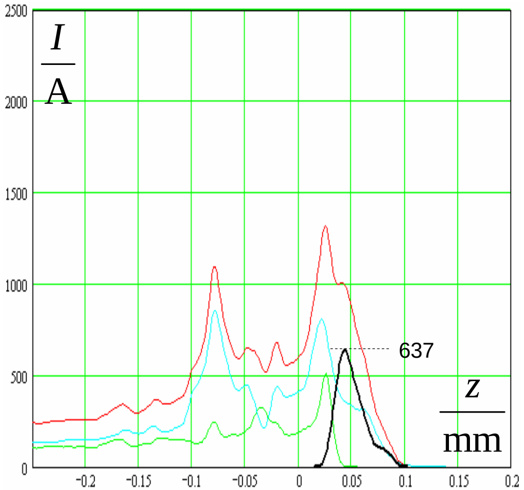


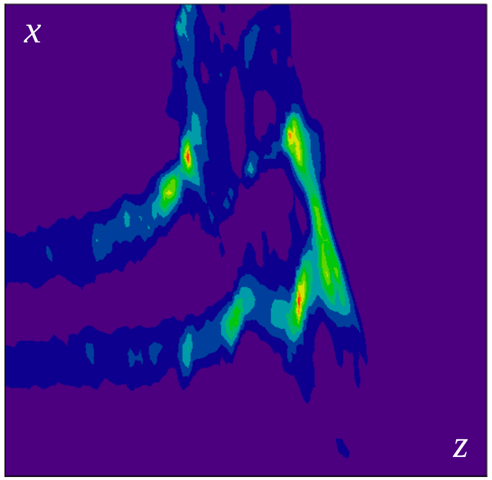
“top”



horizontal



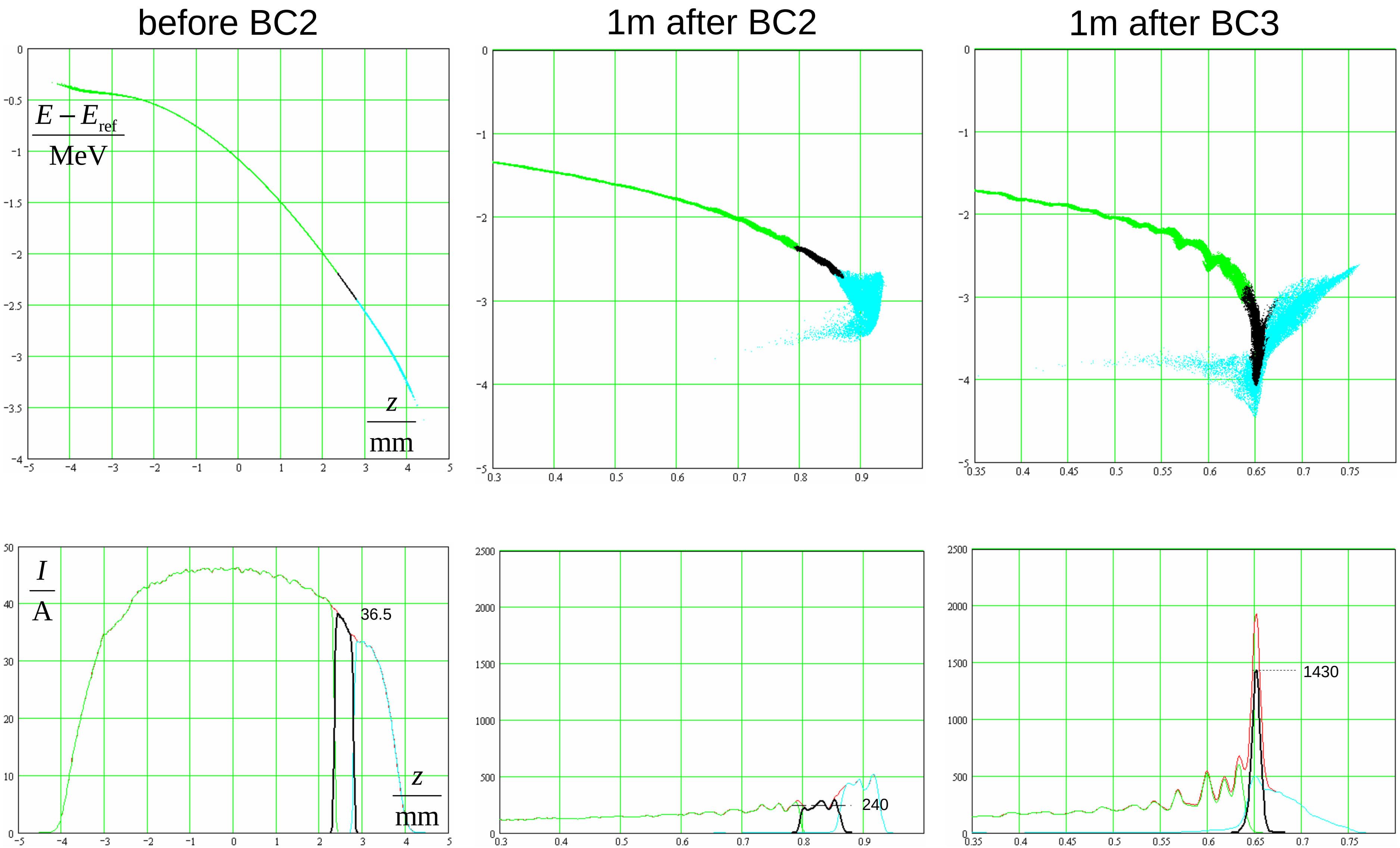




all particles:
emittance/um = 10.74
rms-length/um = 338
rms-energy spread/keV = 1380

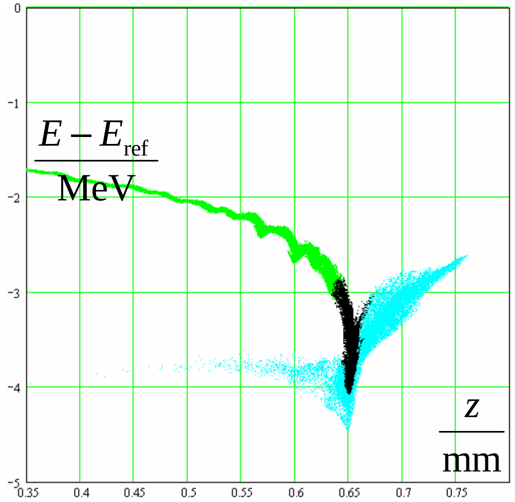
“black” particles:
emittance/um = 5.43
rms-length/um = 13.8
rms-energy spread/keV = 313

5. CSR "projected" optics = option 1 $\varphi_{rf} = 7$ deg

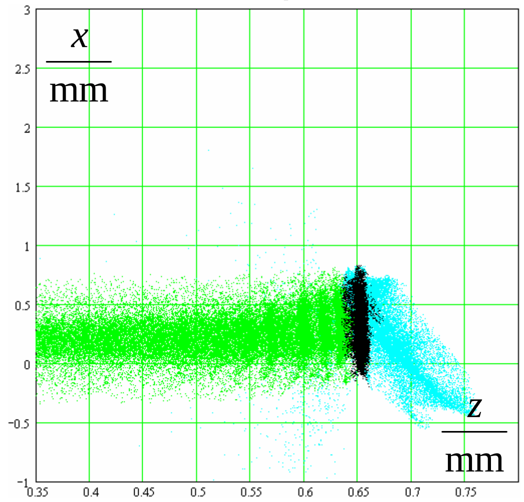


CSR “projected” optics = option 1 $\varphi_{\mathrm{rf}} = 7$ deg

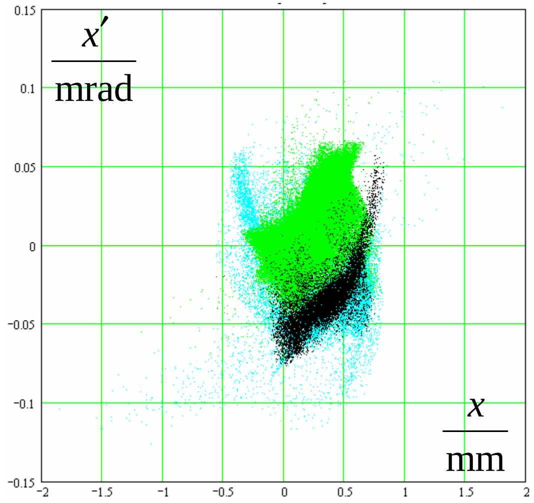
longitudinal

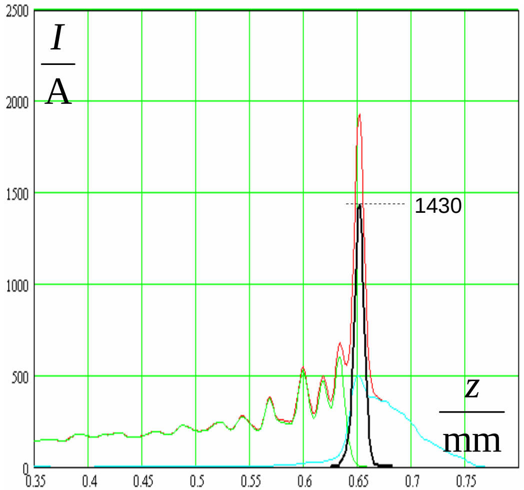


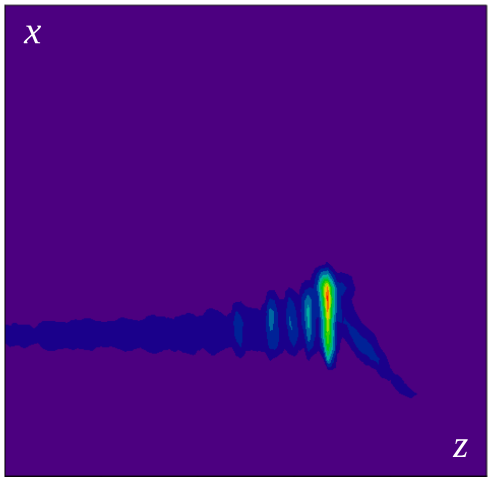
“top”



horizontal



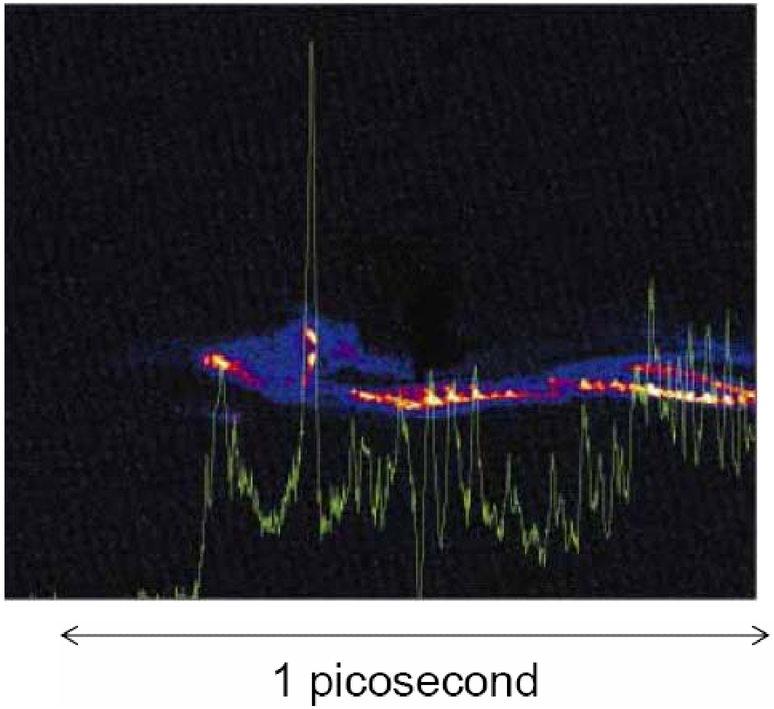




all particles:
emittance/um = 3.38
rms-length/um = 923
rms-energy spread/keV = 880

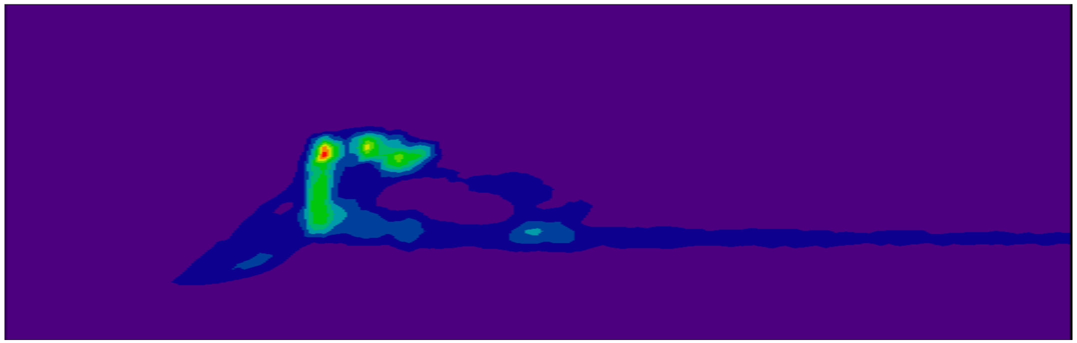
“black” particles:
emittance/um = 2.06
rms-length/um = 4.2
rms-energy spread/keV = 256

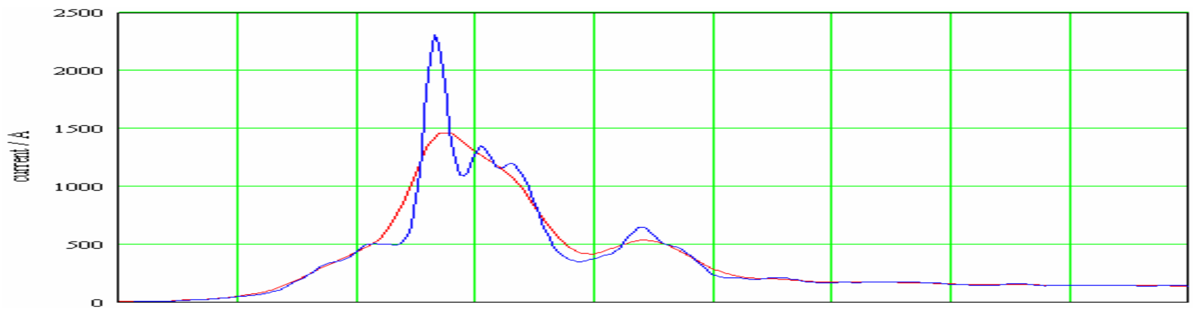
6. some LOLA pictures

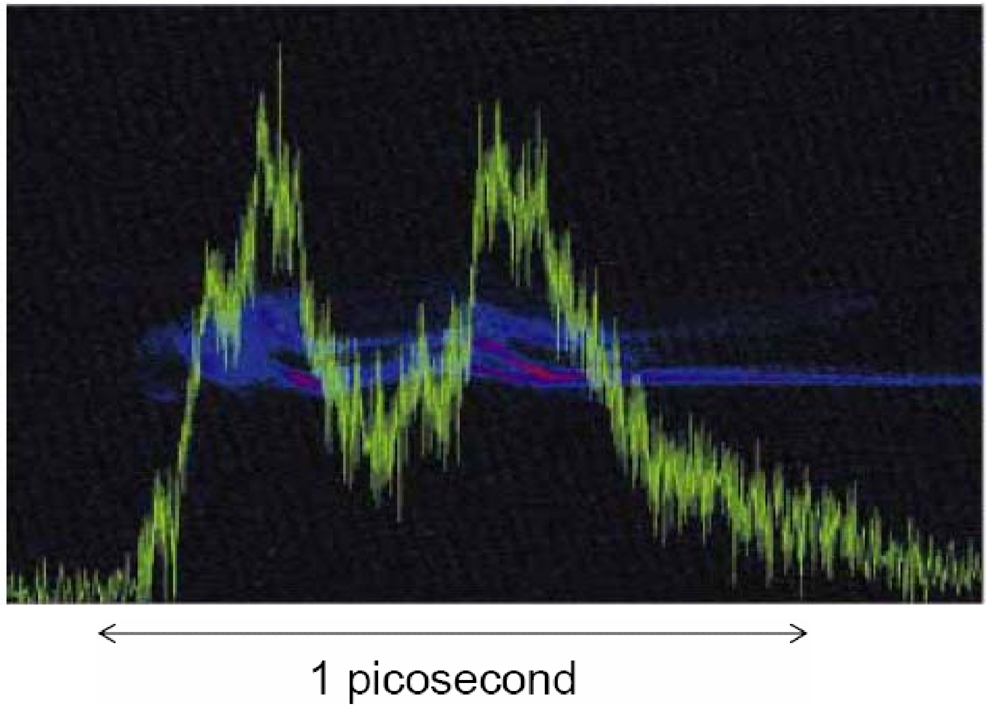


optics = option 1

$\varphi_{\mathrm{rf}} = 8\,\mathrm{deg}$

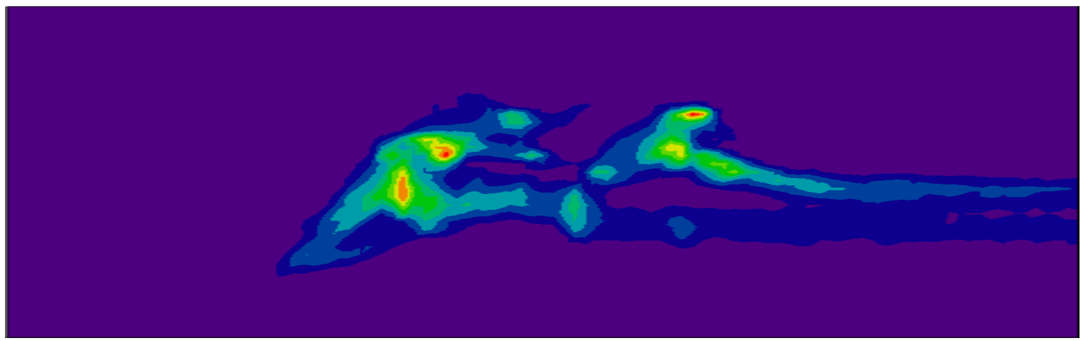


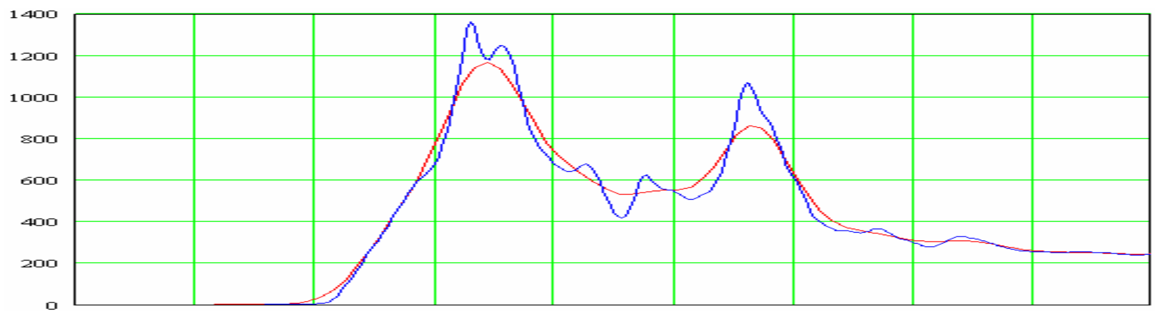




optics = option 1

$\varphi_{rf} = 12\,\mathrm{deg}$





7. conclusion / remarks

1. settings and beam parameters only known to a certain precision

2. CSR model for TTF2 with space charge in ACC1,
   "projected" method in BC2 & BC3,
   transport matrix for BC2 $\rightarrow$ BC3,
   ACC4 $\rightarrow$ undulator not considered jet

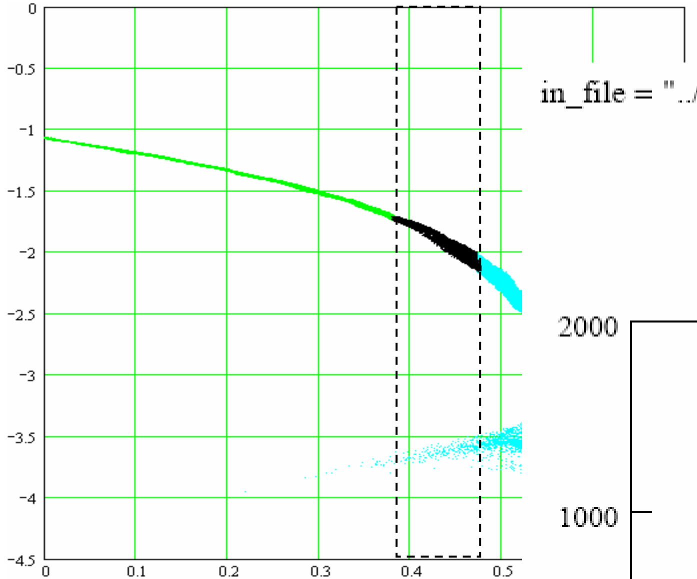
3. ASTRA calculations for BC2 $\rightarrow$ BC3 and ACC4 $\rightarrow$ undulator in preparation
   "projected" CSR calculations in ASTRA in principle possible

4. "3D" CSR calculations with full- & over-compression difficult
   (variable sub-bunch needed due to long tails $\leftrightarrow$ meshed green's function)
   "projected" CSR calculations need better smoothing/filter-algorithms

5. qualitative understanding of compression process,
   complicated interaction of "full" compressed part to rest of bunch

6. qualitative agreement with LOLA pictures

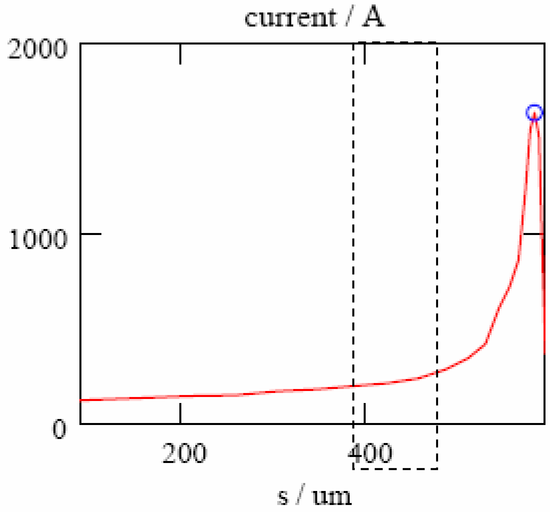
7. optics "option 1" and "weak over-compression" in BC2 seems preferable

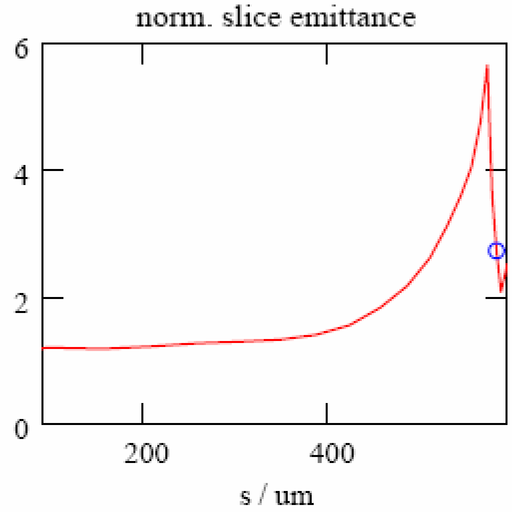


in_file = "../bc1/out_pr_8deg/end.fmt3"

$T_{k,4} \cdot x = 1.636 \times 10^{3}$

$T_{k,5} \cdot 10^{6} = 2.738$





$T_{k,6} = -16.013$

$T_{k,7} = 21.86$