Simulation for EXFEL SASE3 and FLASHII

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16.09.2013

MPY, DESY

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- Achieved progress
- The plan for this month

The plan for last month

1. The particle distribution file conversion from genesis output to Astra input at the exit of SASE1 for 0.5nC charge case. (100%)

2. Beam dynamics simulation between SASE1 and SASE3 for 0.5nC charge case. (50%)

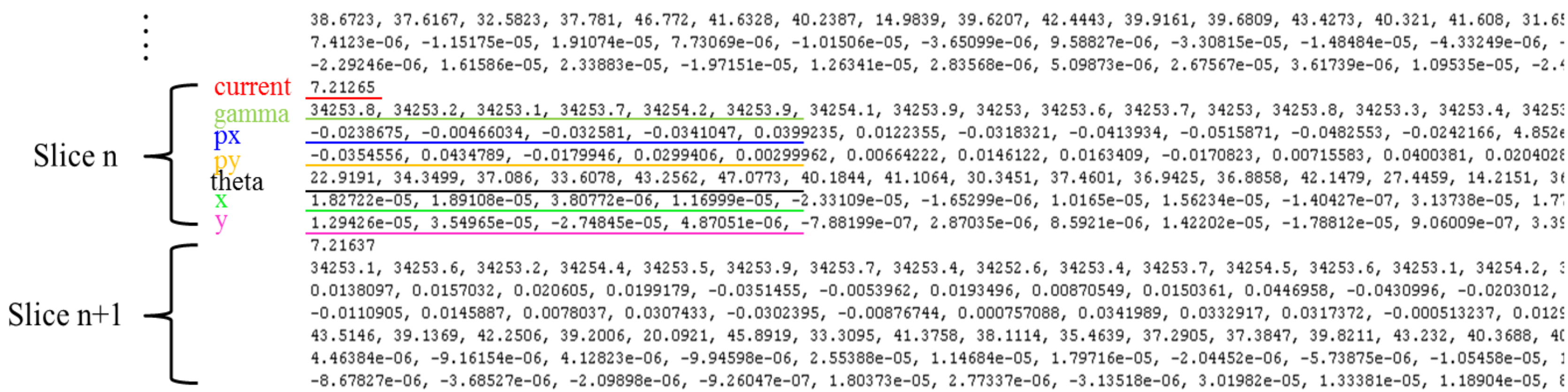
Particle distribution files conversion from Genesis to Astra (Done)

1. The newest version of Genesis which supports HDF5 output.
2. Setting IONE4ONE=1.

   The macro particles have the same charges per slice. The number of particles in each slice can be adjusted automatically to keep the original current profile (Npar=8000).
3. ZSEP=20

   Nslice=(s1-s0)/(ZSEP×XLAMDs)

Structure of Genesis particle output file

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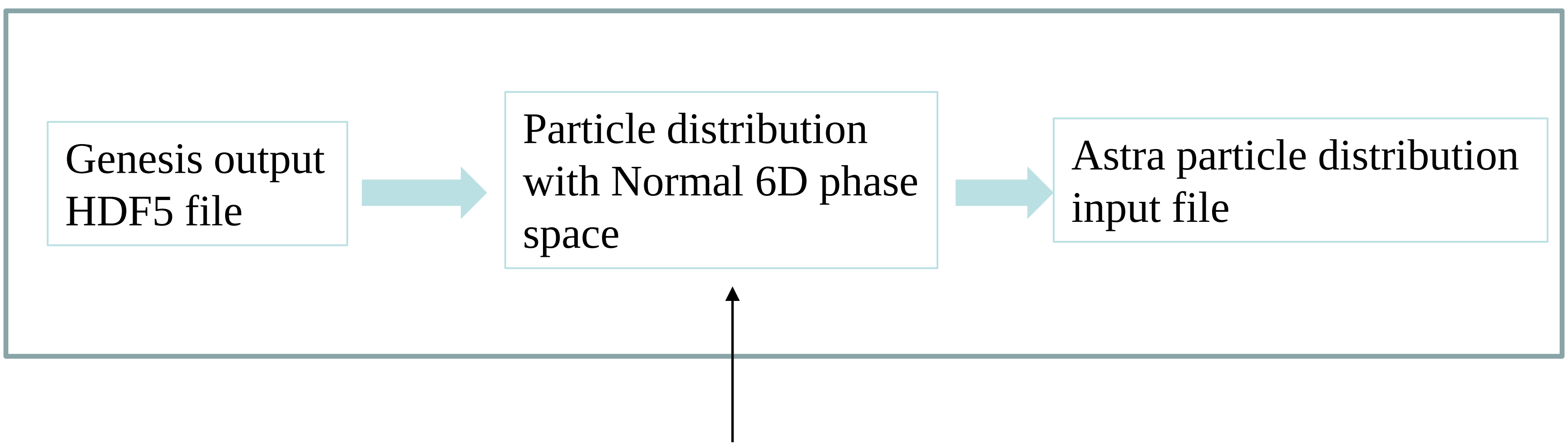
4.46384e-06, -9.16154e-06, 4.12823e-06, -9.94598e-06, 2.55388e-05, 1.14684e-05, 1.79716e-05, -2.04452e-06, -5.73875e-06, -1.05458e-05, 1
-8.67827e-06, -3.68527e-06, -2.09898e-06, -9.26047e-07, 1.80373e-05, 2.77337e-06, -3.13518e-06, 3.01982e-05, 1.33381e-05, 1.18904e-05, 8
```

$$z = \frac{\phi\lambda}{2\pi} + i \times \lambda \times ZSEP$$

Two methods to get the Genesis output particle distribution file

(1) IDMPPAR
Dumping the particle distribution at the exit of the undulator.

(2) IPPART and ISPART
Writing the particle distribution to file at each IPPARTth integration step.
Wrting the particle distribution to file for every ISPART slice.

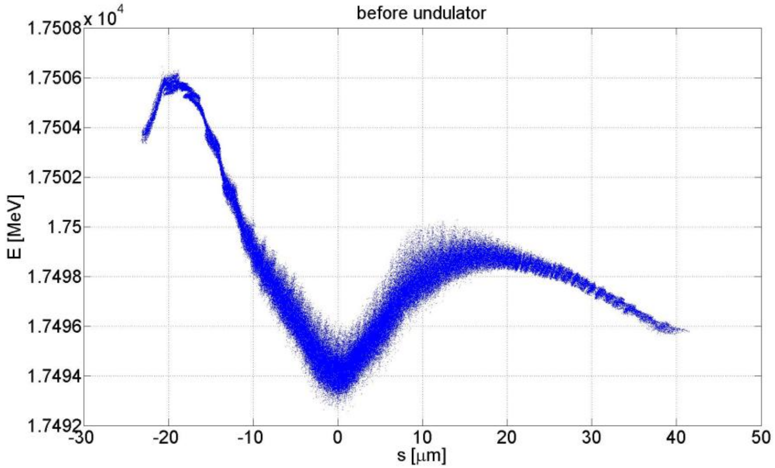


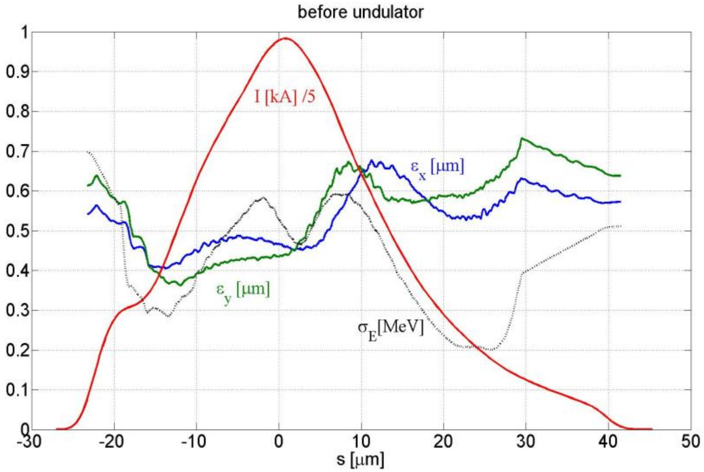
Number	1	2	3	4	5	6
Parameter	x	y	z	px	py	pz
Unit	m	m	m	eV/c	eV/c	eV/c

Beam dynamics simulation and radiation calculation for SASE3 (Done)

Q=0.5nC, E~17.5GeV, I_{peak}~5kA

Before SASE1





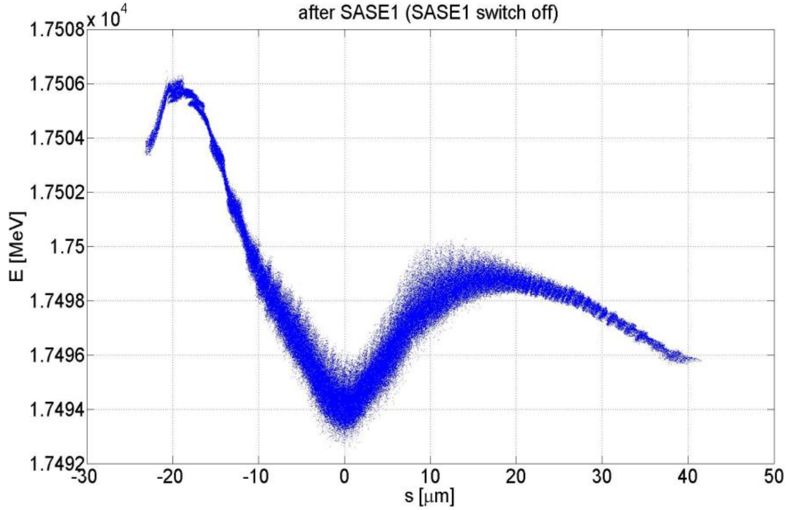
$$\varepsilon_x{}^{proj} = 0.65\mu m \cdot rad, \varepsilon_y{}^{proj} = 1.8\mu m \cdot rad$$

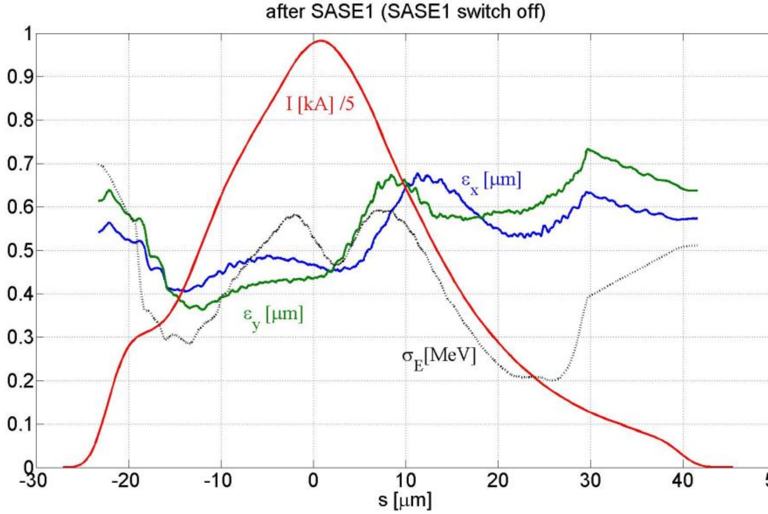
❖ SASE3 simulation for two cases:

(1) SASE1 switched off

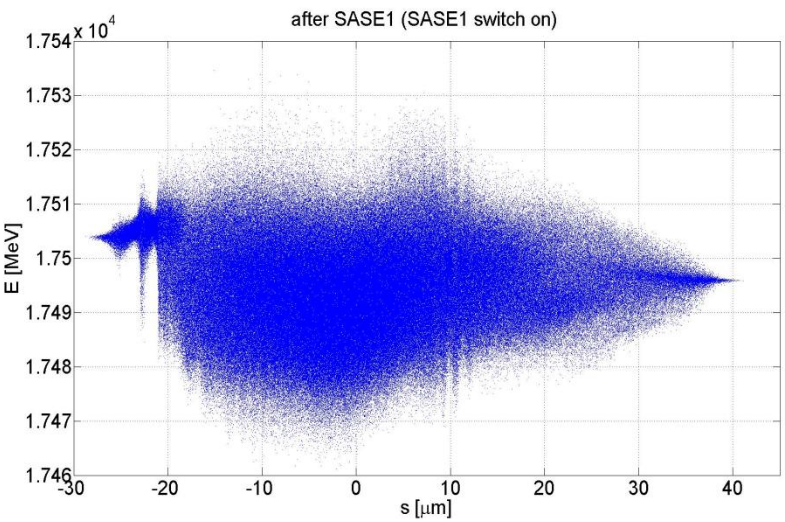
(2) SASE1 switched on

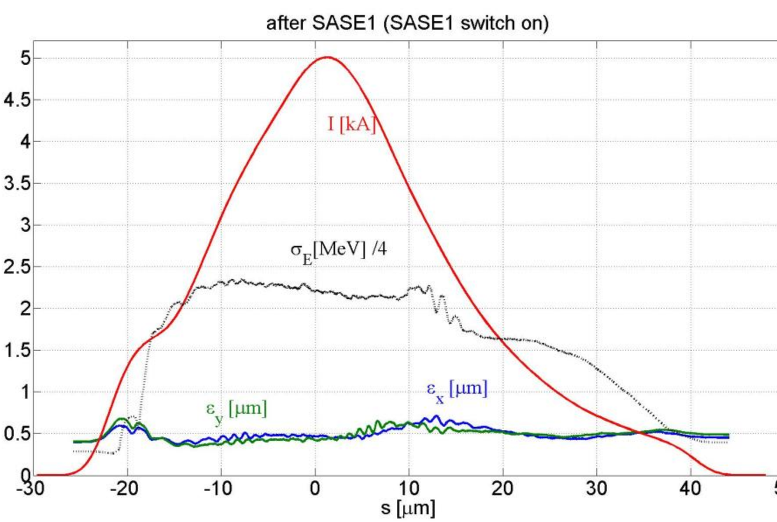
(1)


after SASE1 (SASE1 switch off)
x 10^4
E [MeV]
s [μm]

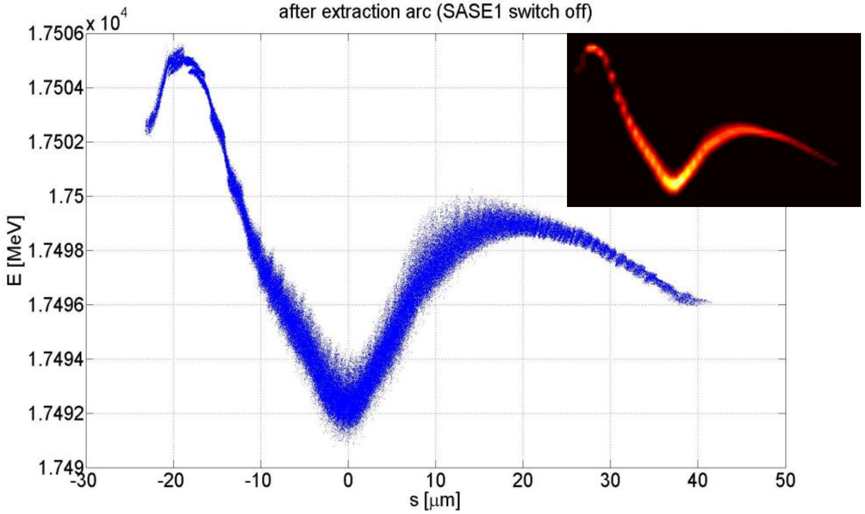

after SASE1 (SASE1 switch off)
I [kA] /5
ε_x [μm]
ε_y [μm]
σ_E[MeV]
s [μm]

(2)

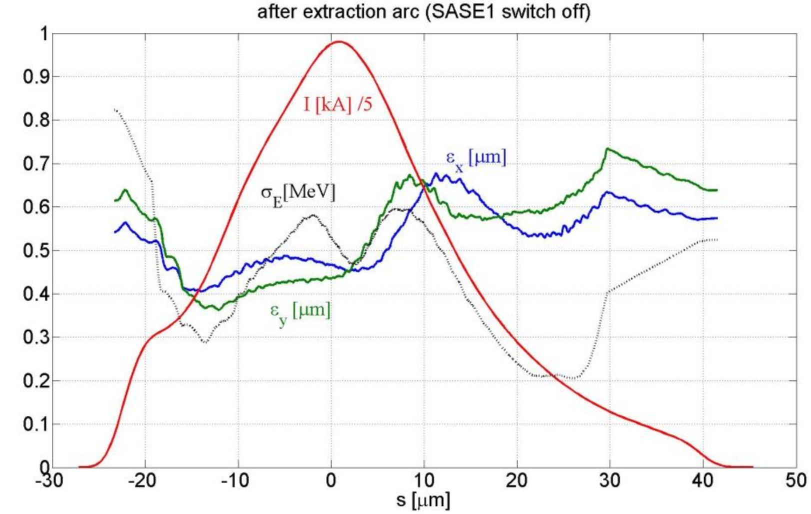

after SASE1 (SASE1 switch on)
x 10^4
E [MeV]
s [μm]


after SASE1 (SASE1 switch on)
I [kA]
σ_E[MeV] /4
ε_y [μm]
ε_x [μm]
s [μm]

(1)

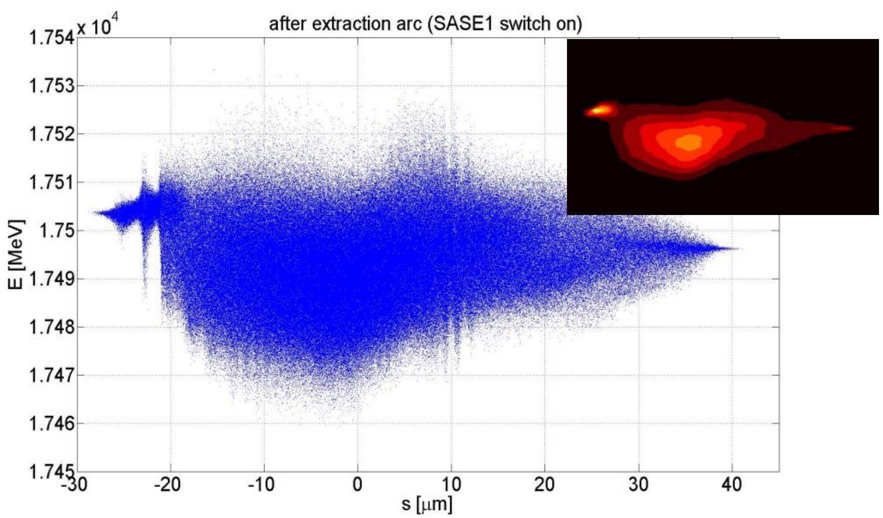


after extraction arc (SASE1 switch off)
x 10^4
1.7506
1.7504
1.7502
1.75
1.7498
1.7496
1.7494
1.7492
1.749
E [MeV]
-30
-20
-10
0
10
20
30
40
50
s [μm]

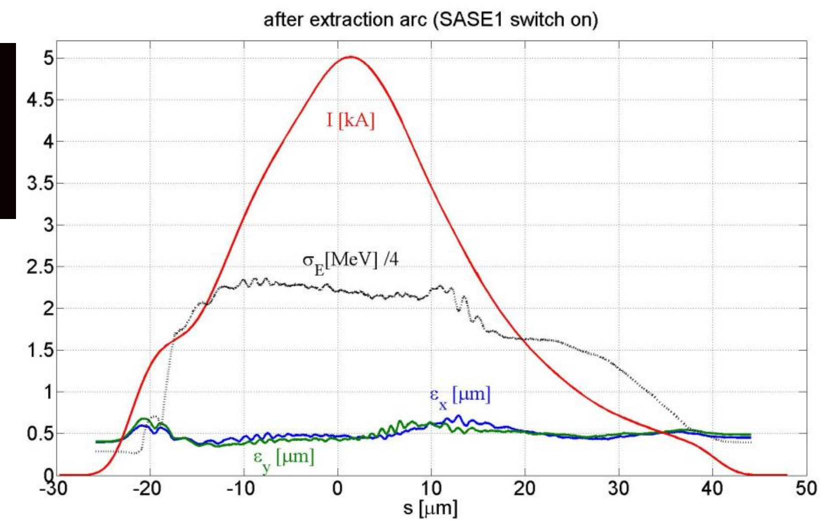


after extraction arc (SASE1 switch off)
I [kA] /5
εx [μm]
σE[MeV]
εy [μm]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-30
-20
-10
0
10
20
30
40
50
s [μm]

(2)



after extraction arc (SASE1 switch on)
x 10^4
1.754
1.753
1.752
1.751
1.75
1.749
1.748
1.747
1.746
1.745
E [MeV]
-30
-20
-10
0
10
20
30
40
s [μm]

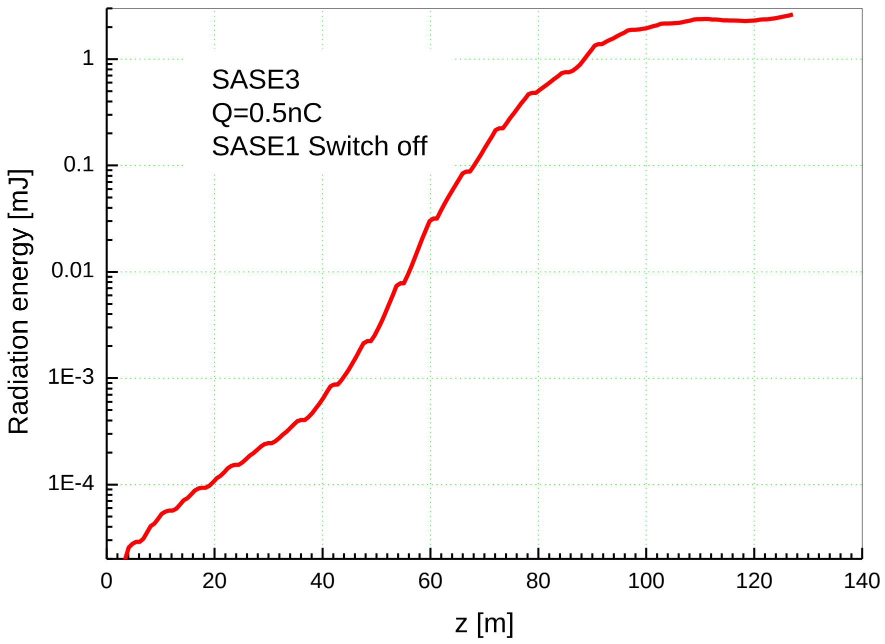


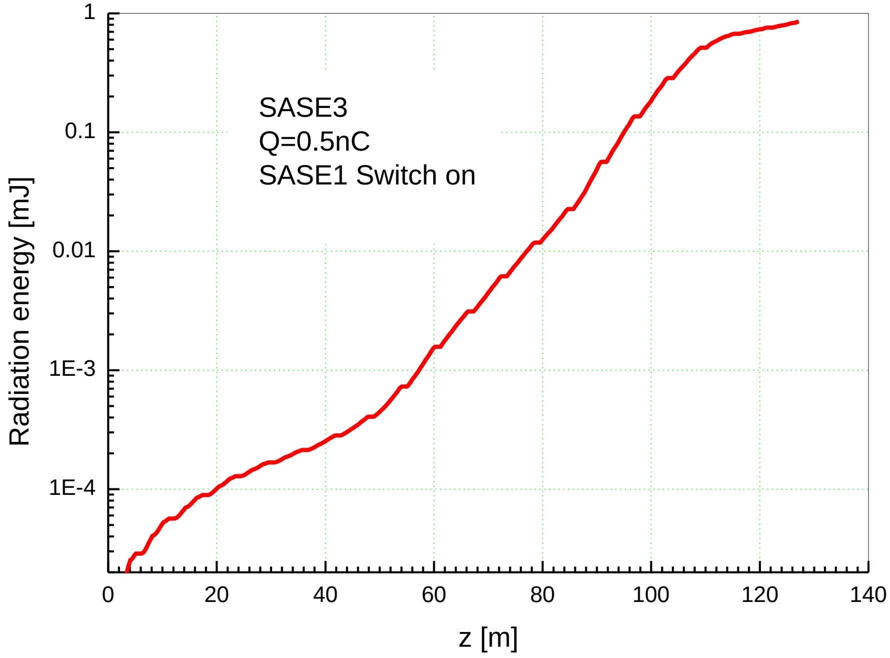
after extraction arc (SASE1 switch on)
I [kA]
σE[MeV] /4
εx [μm]
εy [μm]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-30
-20
-10
0
10
20
30
40
50
s [μm]

SASE3 calculation

λu=68mm, K=3.63497, λ ~ 0.4nm

One random seed





E=2.64mJ at the exit of SASE3
(SASE1 switched off)

E=0.85mJ at the exit of SASE3
(SASE1 switched on)

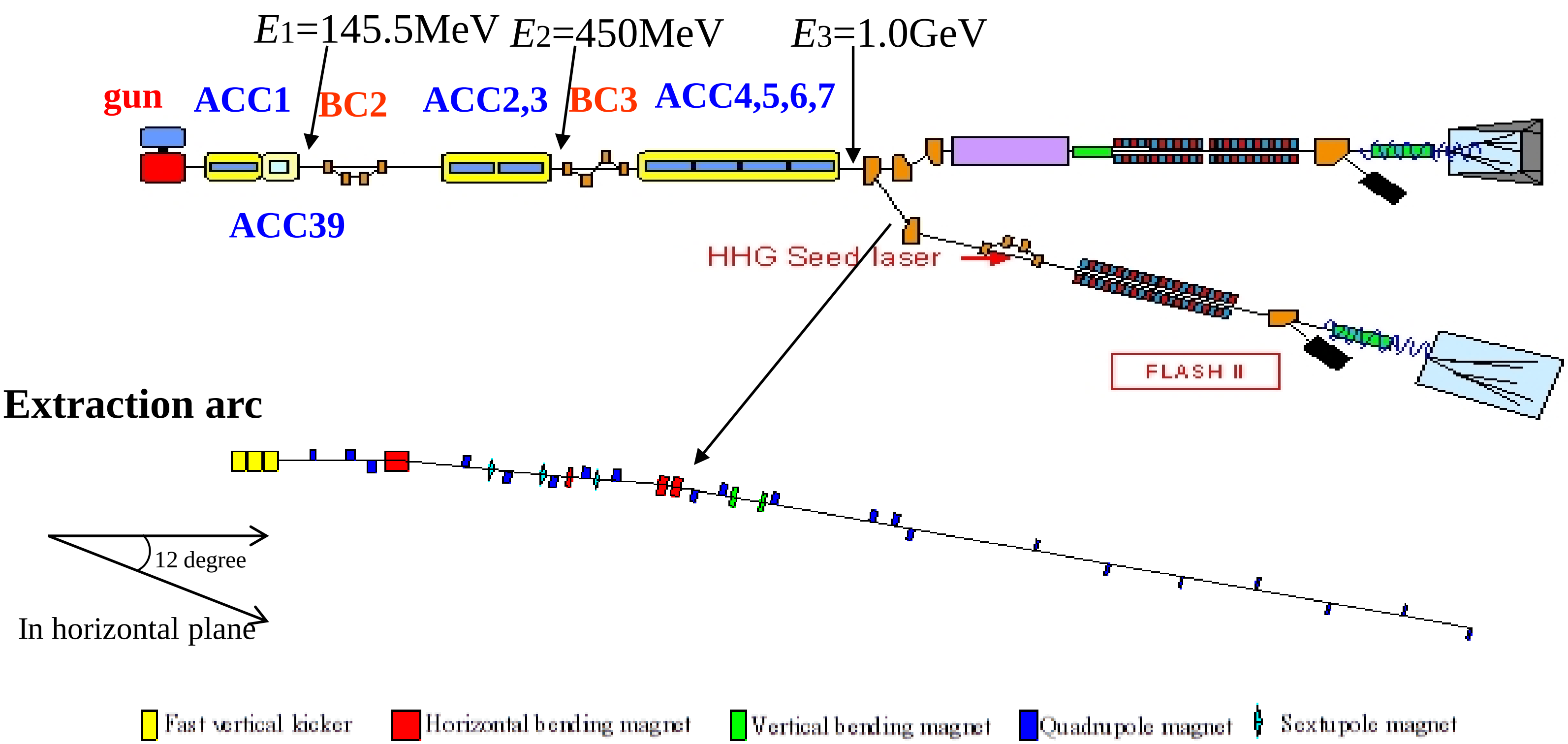
Simulation for FLASHII

- **At the end of the linac**

  E=1.0GeV

  I_{peak}=~2.5kA

- **Beam energy at some key positions**



Parameter Settings

Parameters for the bunch compressors

Charge Q, nC	Curvature radius in BC_2 r1 [m]	Momentum compaction factor in BC_2, $R_{56,2}$ [mm]	compr. In BC2	Curvature radius in BC_3 r2 [m]	Momentum compaction factor in BC_3, $R_{56,3}$ [mm]	Total compr. C
1.0	**1.618**	**180.7**	**2.7**	**5.770**	**83.6**	**55**
0.5	**1.618**	**180.7**	**4.7**	**6.615**	**63.5**	**82**
0.25	**1.618**	**180.7**	**6.4**	**7.210**	**53.4**	**120**
0.10	**1.618**	**180.7**	**11.7**	**8.770**	**36.0**	**298**
0.02	**1.618**	**180.7**	**54.8**	**14.000**	**14.1**	**670**

E_1=145.5MeV, E_2=450MeV

Curvature radius in BCs# $1.4 \le \frac{r_1}{\mathrm{m}} \le 1.93$ $5.3 \le \frac{r_2}{\mathrm{m}} \le 16.8$

Exciting current* **I_{BC2}~70.93A I_{BC3}~ <62.00A**

Igor Zagorodnov, Beam Dynamics and FEL Simulations for FLASH, 2010, BD meeting, DESY

* Estimation formula from Martin Dohlus

Parameter Settings

RF settings in accelerating modules for different bunch charge cases

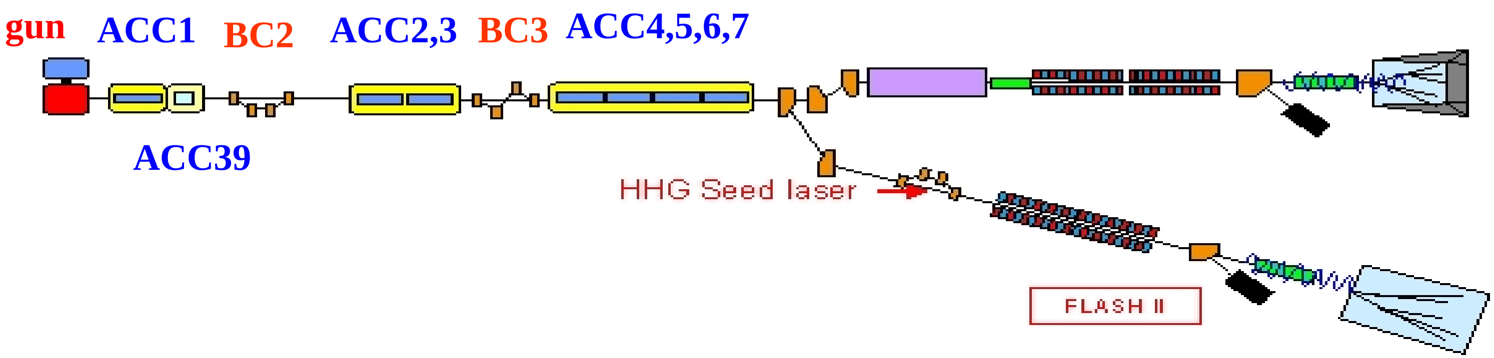
Charge nC	V_{acc1} [MV]	φ_{acc1} [deg]	V_{acc39} [MV]	φ_{acc39} [deg]	$V_{acc2,3}$ [MV]	$\Phi_{acc2,3}$ [deg]	$V_{acc4,5,67}$ [MV]	$\Phi_{acc4,5,6,7}$ [deg]
1.0	160.4	-3.2	21.9	153.4	337.3	25.0	550.0	0.0
0.50	159.5	2.4	19.8	162.6	337.3	25.0	550.0	0.0
0.25	159.9	1.9	20.5	160.5	337.3	25.0	550.0	0.0
0.10	160.0	-1.0	21.9	152.6	337.3	25.0	550.0	0.0
0.02	160.4	3.3	21.0	162.0	337.3	25.0	550.0	0.0

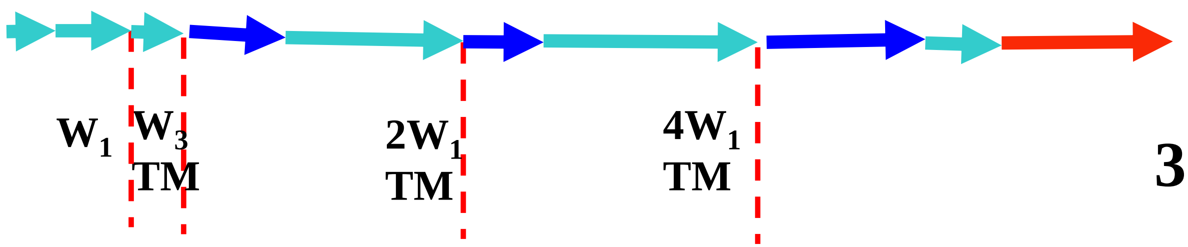
***RF power restrictions:**

Maximum energy gain for accelerating modules

ACC1	**165 MeV**
ACC39	**22 MeV**
ACC2/3	**345 MeV**
ACC4/5	**320 MeV**
ACC6/7	**430 MeV**

Beam dynamics simulation for FLASHII for different bunch charge cases





300000 particles

ASTRA (tracking with space charge effects, cylindrical symmetric algorithm)

CSRtrack (tracking with CSR effects)

Genesis

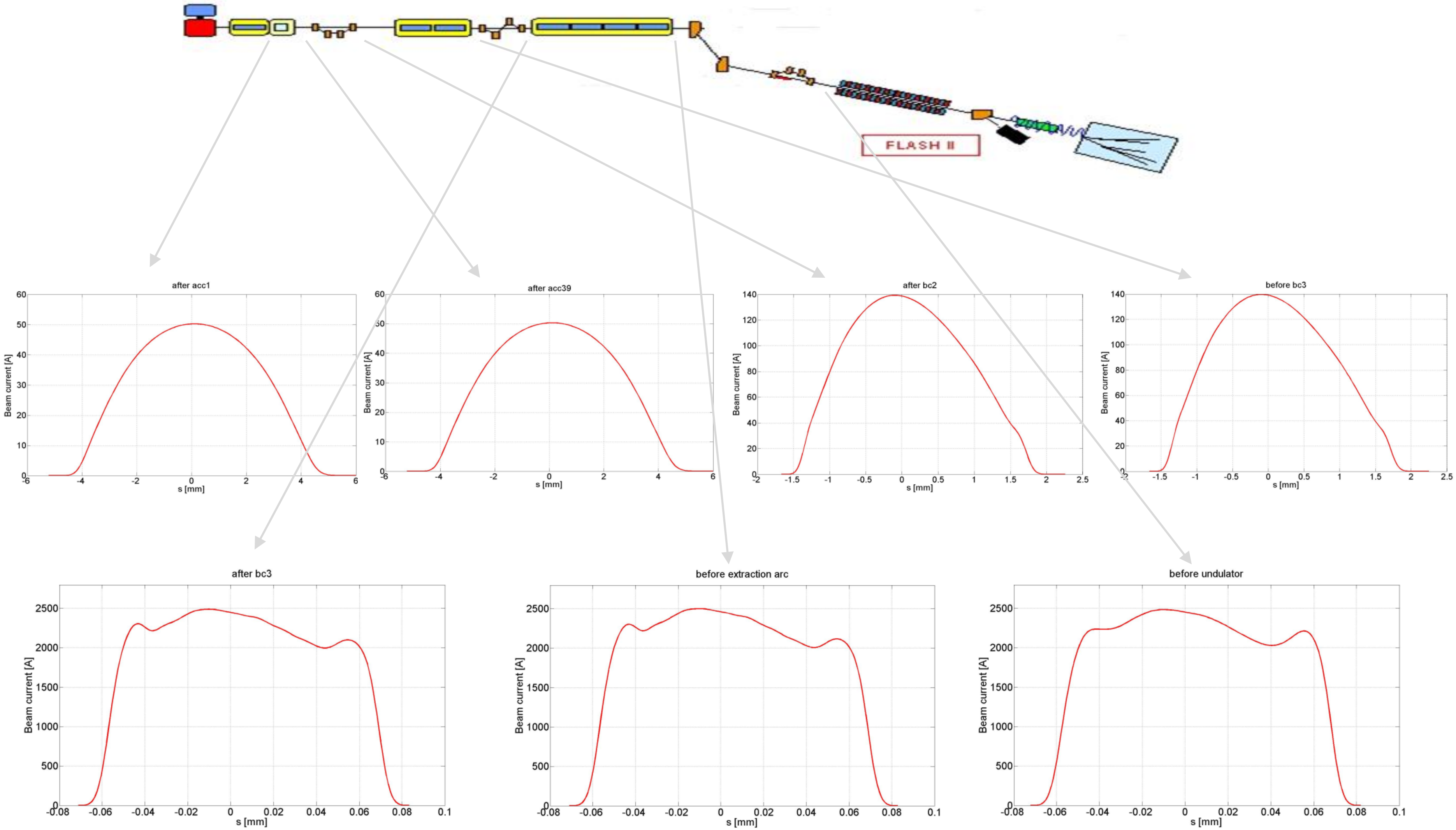
W1 -TESLA cryomodule wake (TESLA Report 2003-19, DESY, 2003)

W3 - ACC39 wake (TESLA Report 2004-01, DESY, 2004)

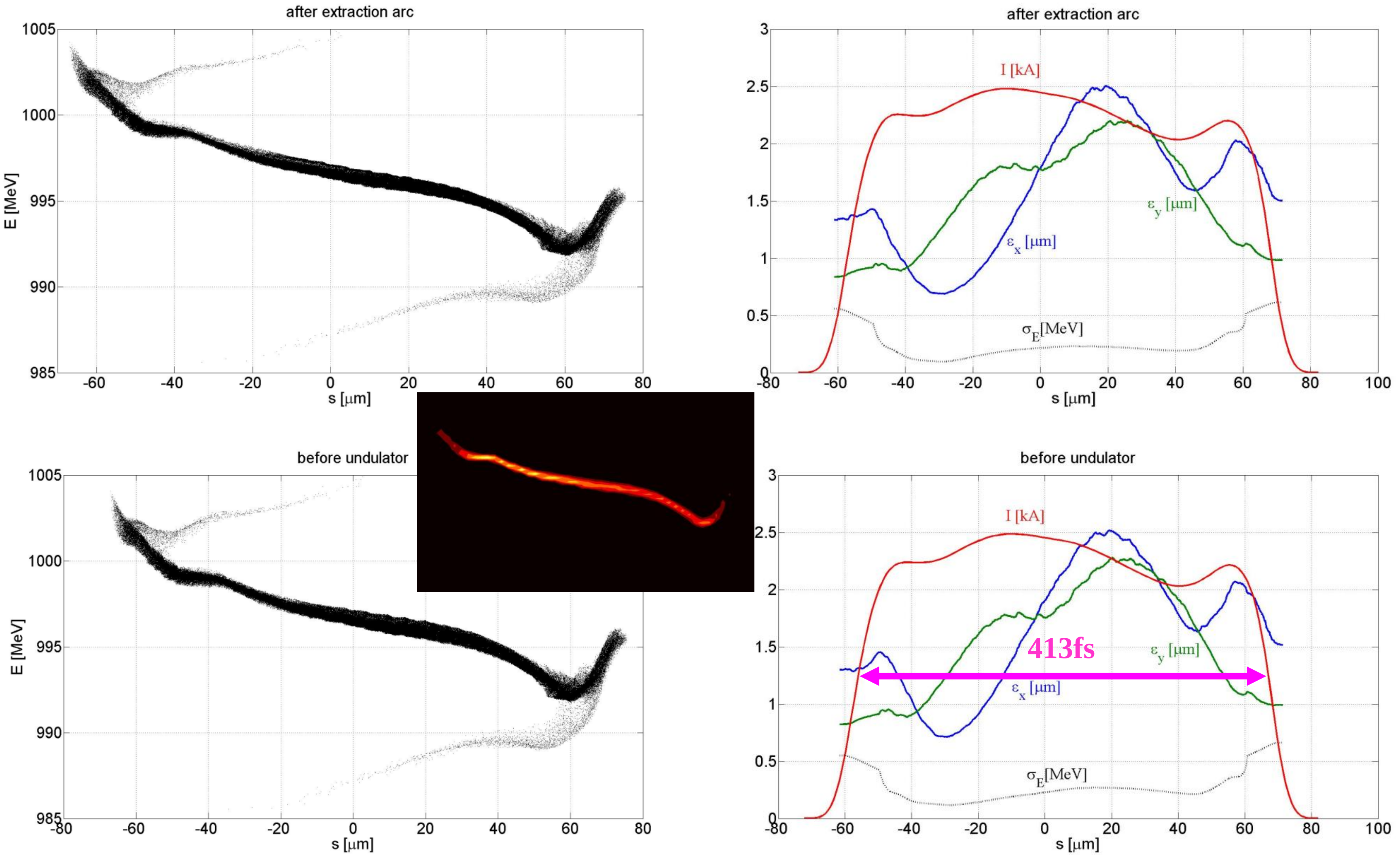
TM - transverse matching to the design optics

Beam dynamics simulation for FLASHII for Q=1.0nC

Current profile along the beam line



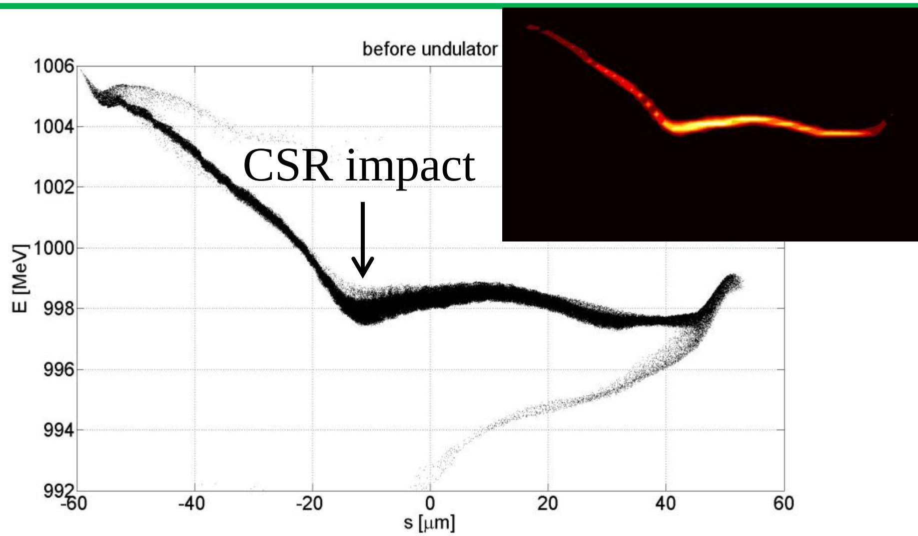
Beam dynamics simulation for FLASHII for Q=1.0nC

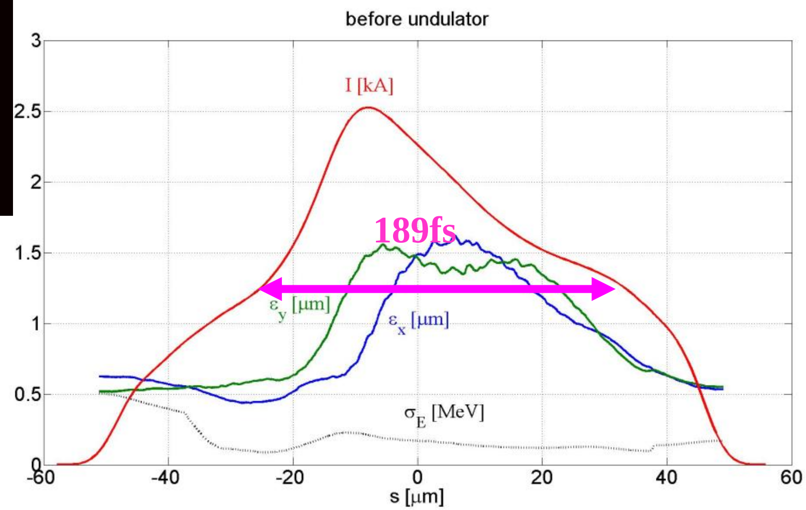


$$\varepsilon_x{}^{proj} = 2.89\mu m \cdot rad, \varepsilon_y{}^{proj} = 2.6\mu m \cdot rad$$

4% bad particles are removed

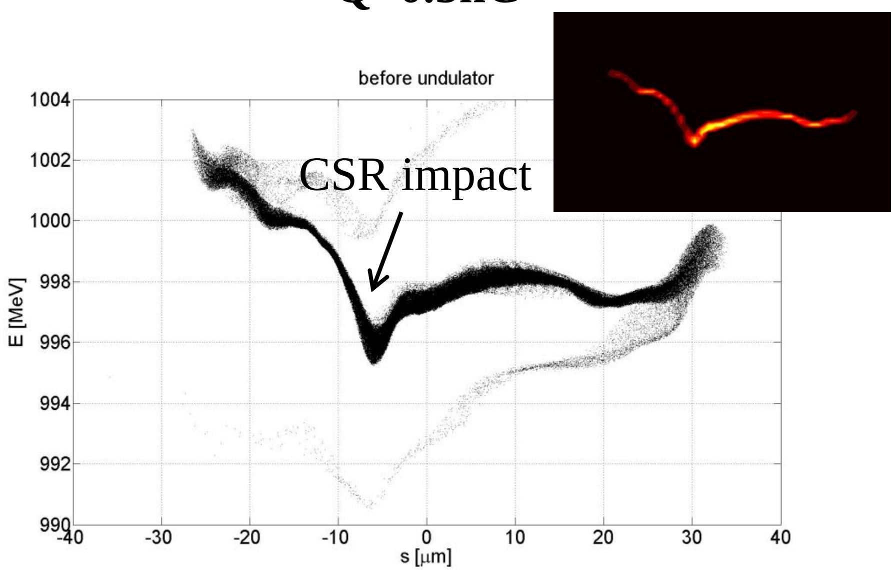
Beam dynamics simulation for FLASHII

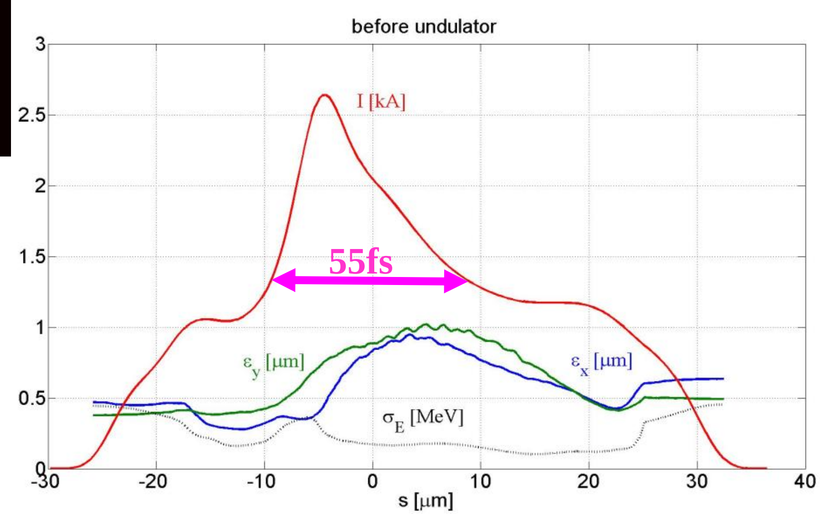




Q=0.5nC

$\varepsilon_x{}^{proj} = 1.84\mu m \cdot rad, \varepsilon_y{}^{proj} = 1.31\mu m \cdot rad$

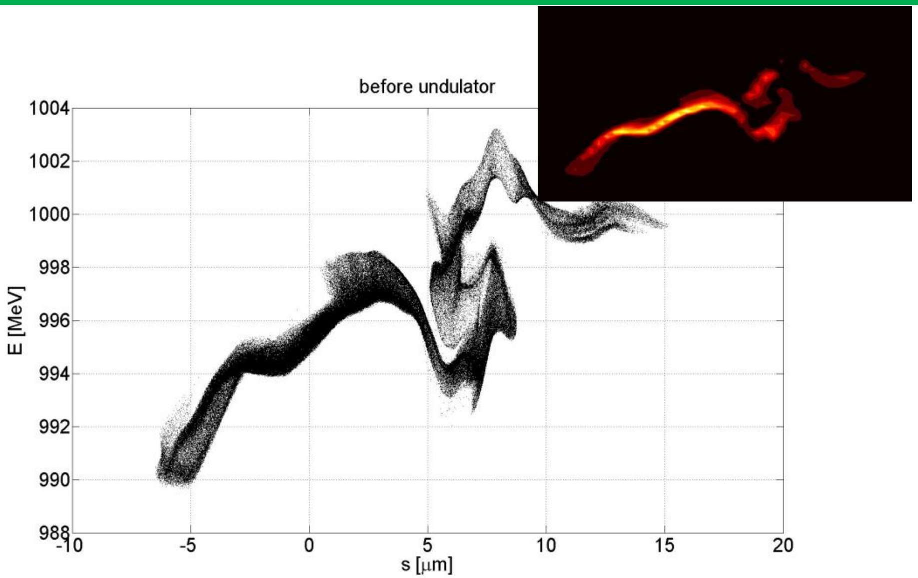


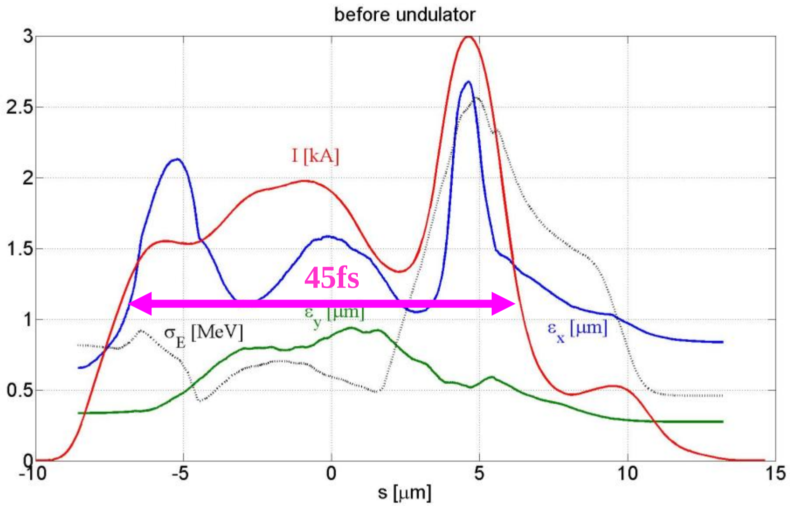


Q=0.25nC

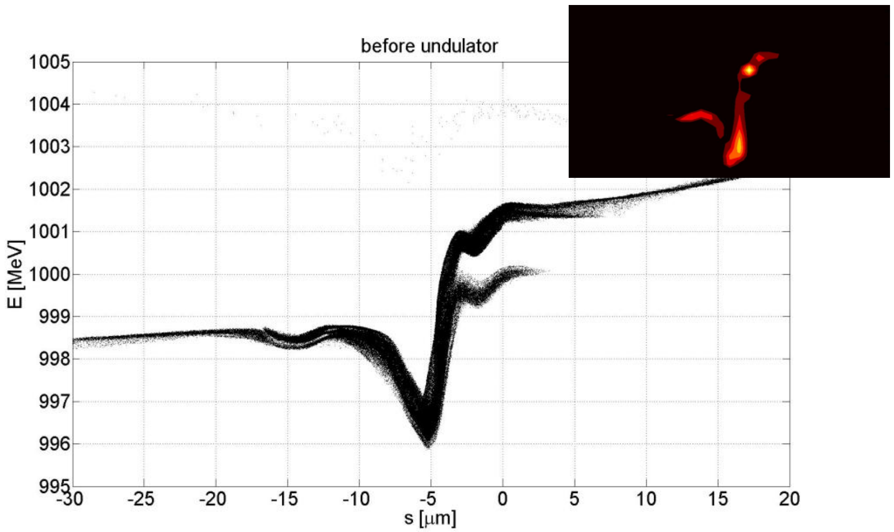
$\varepsilon_x{}^{proj} = 2.26\mu m \cdot rad, \varepsilon_y{}^{proj} = 0.80\mu m \cdot rad$

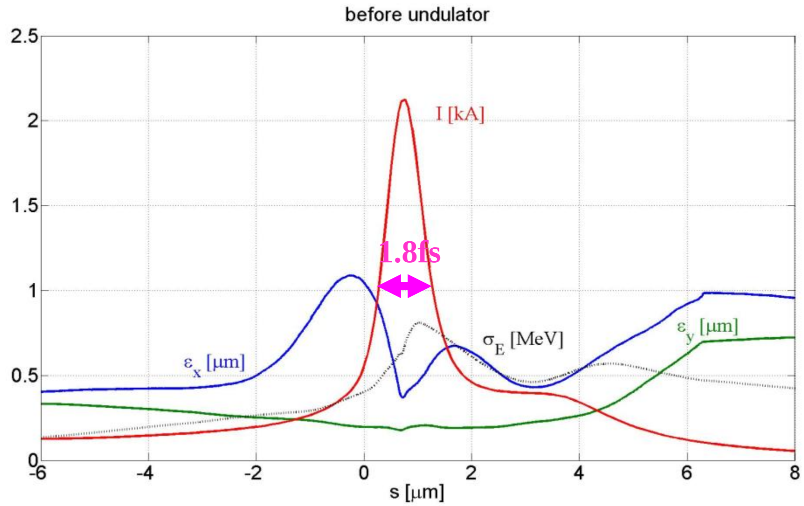
Beam dynamics simulation for FLASHII





$$\varepsilon_x{}^{proj} = 3.72\mu m \cdot rad, \varepsilon_y{}^{proj} = 0.769\mu m \cdot rad$$





$$\varepsilon_x{}^{proj} = 1.42\mu m \cdot rad, \varepsilon_y{}^{proj} = 0.54\mu m \cdot rad$$

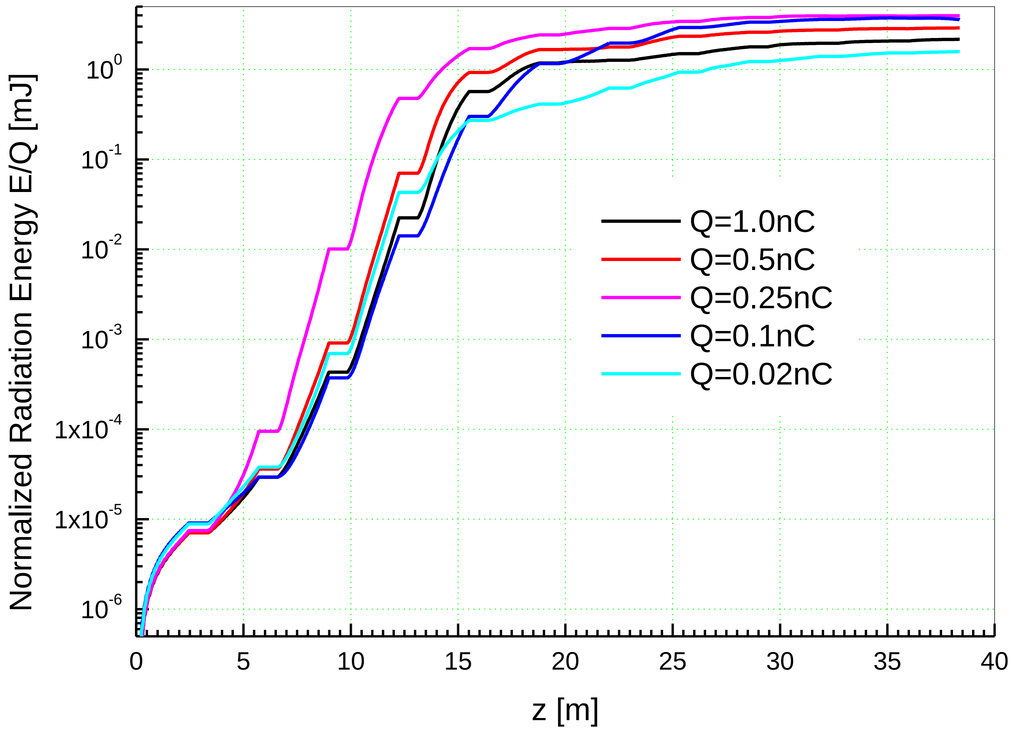
Radiation calculation for FLASHII for different bunch charge cases

SASE FEL simulation*

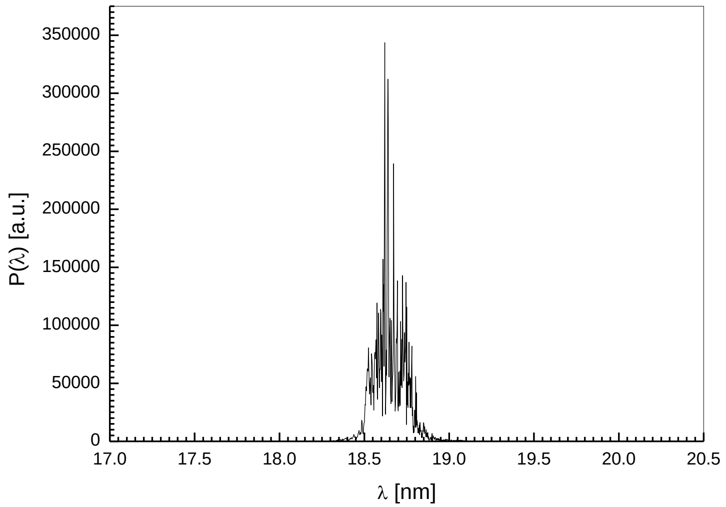
Slice parameters are extracted from s2e simulations for SASE simulation

$$\gamma \quad \Delta\gamma \quad \varepsilon_x \quad \varepsilon_y \quad \beta_x \quad \beta_y \quad \langle x \rangle \quad \langle y \rangle \quad \langle x' \rangle \quad \langle y' \rangle \quad \alpha_x \quad \alpha_y \quad I$$

λ_u=31.4mm, K=1.87



10 random seeds for each bunch charge case



* The magnet description file for the undulator system comes from Matthias Scholz.

The plan for this month

Preparing the internal report for EXFEL simulation.