Beam Dynamics Simulation for EXFEL with 0.5nC

Guangyao Feng

18.06.2013

MPY, DESY

Contents

- Parameters setting
- Beam optics comparison between Elegant results and Astra+CsrTrack results (without collective effects)
- Beam dynamics simulation for EXFEL with collective effects

Parameters Setting

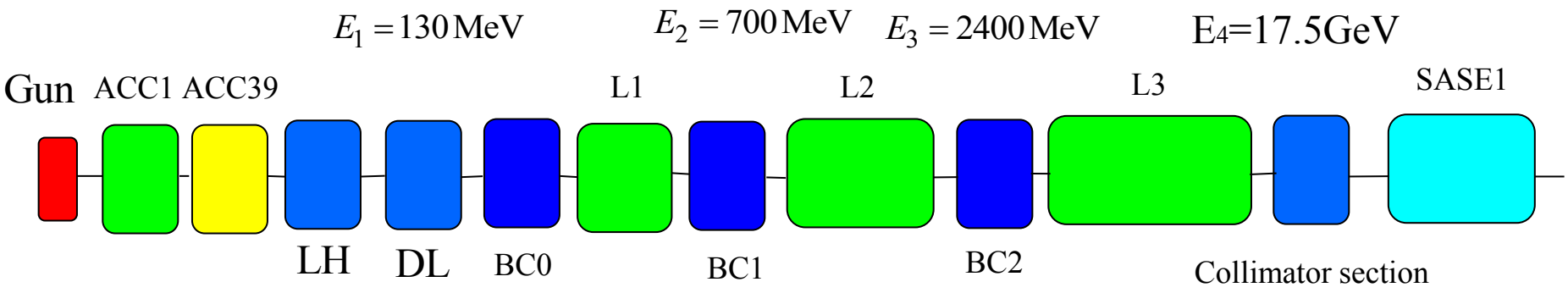
Q=0.5nC

❖ At the end of the linac

E=17.5GeV

I_{peak}=5.0kA

❖ Beam energy at some key positions



Parameters Setting

Parameters for the bunch compressors*

Charge Q, nC	Momentum compaction factor in Dogleg section $R_{56,dogleg}$ [mm]	Compr. In Dogleg C_{dogleg}	Momentum compaction factor in BC_0 $R_{56,0}$ [mm]	Compr. in BC_0 C_0	Total compr. $C_{dogleg}*C_0$
0.5	-30.1	1.21	-54.8	~2.90	**~3.5**

Momentum compaction factor in BC_1, $R_{56,1}$, [mm]	Compr. in BC_1 C_1	Momentum compaction factor in BC_2, $R_{56,2}$ [mm]	Total compr. C
-50	**8**	-20	**217**

r_0=3.5m

r_1=9.4m

r_2=14.8633m

* Igor Zagorodnov, Beam Dynamics Simulations for XFEL, BD meeting, 2011

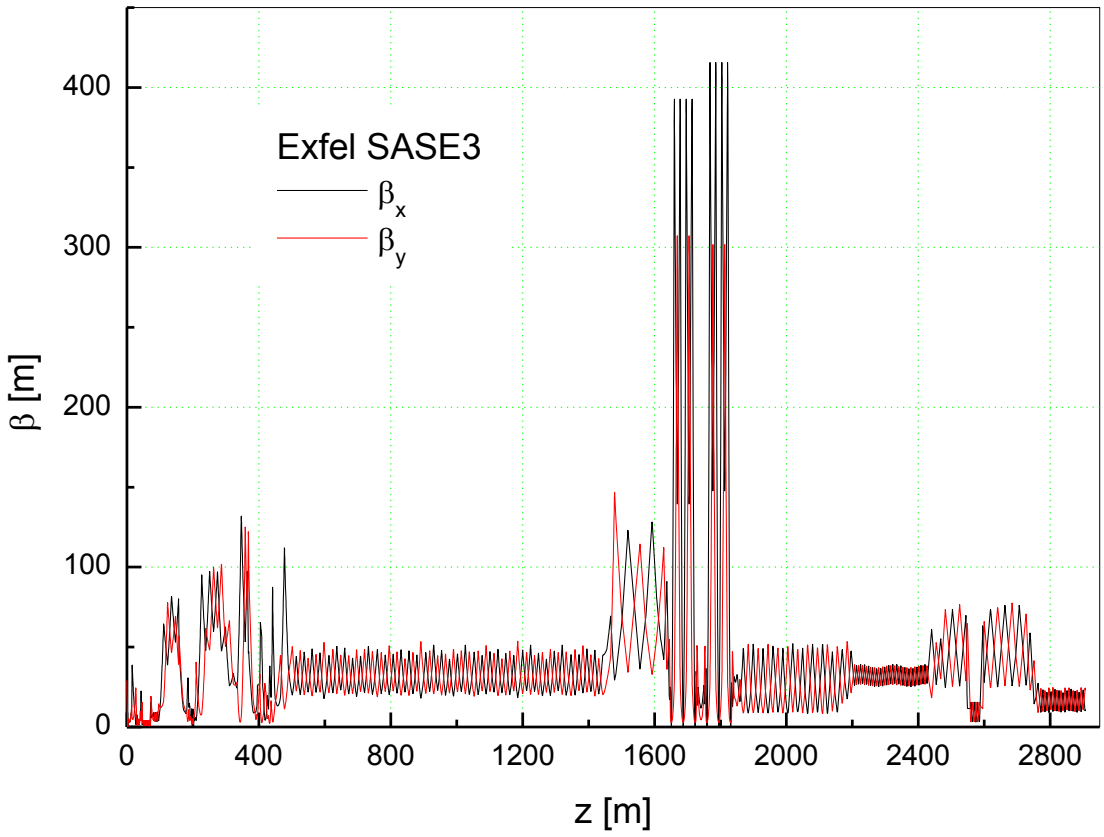
Parameters Setting

RF parameters of accelerating modules

Element	Phase shift	V_{max}
ACC1	16.7106°	153.474MV
ACC39	184.539°	23.4928MV
L1: ACC2	29.6937°	656.403MV
L2: ACC3-5	5.50000°	1708.990MV
L3: ACC6-26	0.0°	15108.175MV

- Parameters values of quadrupole and sextupole magnets are from the new Elegant lattice file.

Beam optics comparison



the rf cavities on-crest

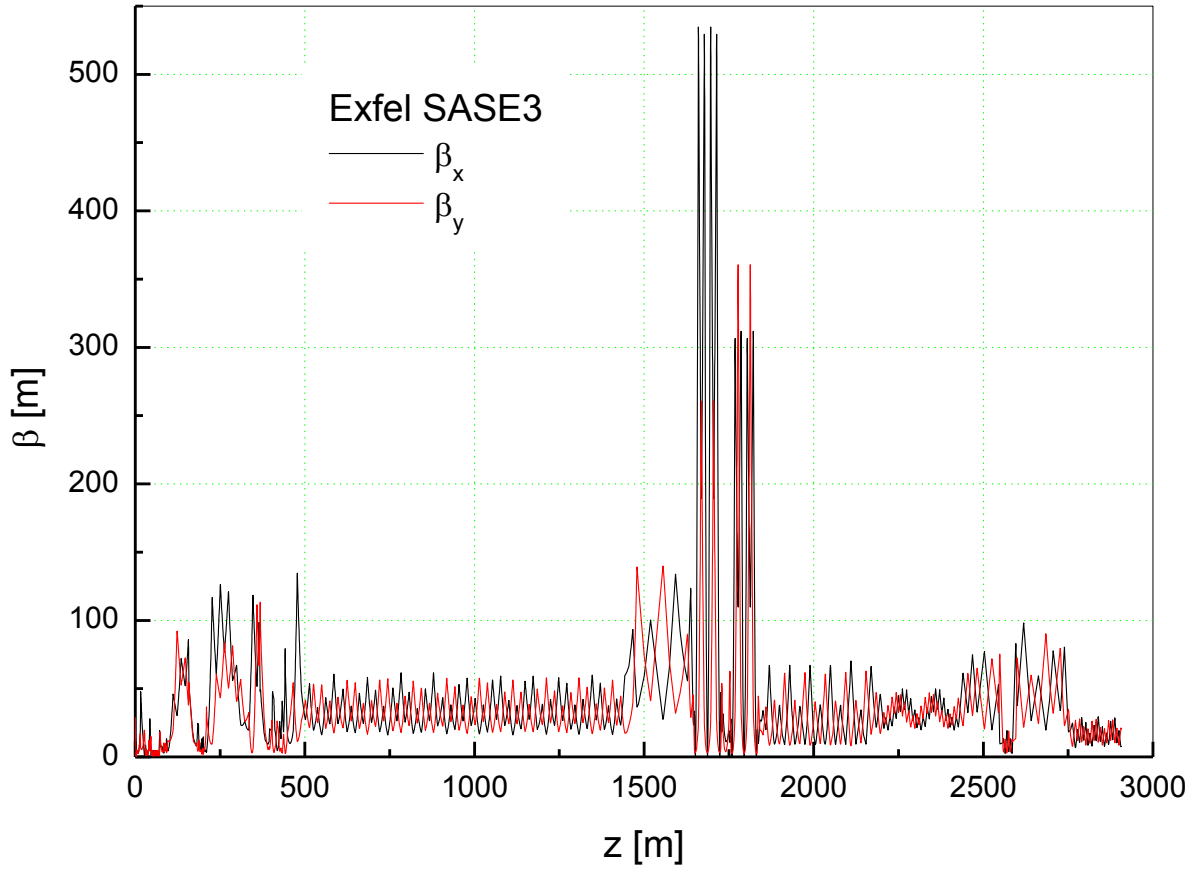
r_0=3.778m

r_1=10.011m

r_2=12.012m

New design optics for EXFEL SASE3 (Elegant)

Beam optics comparison



Beta function distribution by using the exact parameters values of the accelerating cavities and bunch compressors (Elegant)

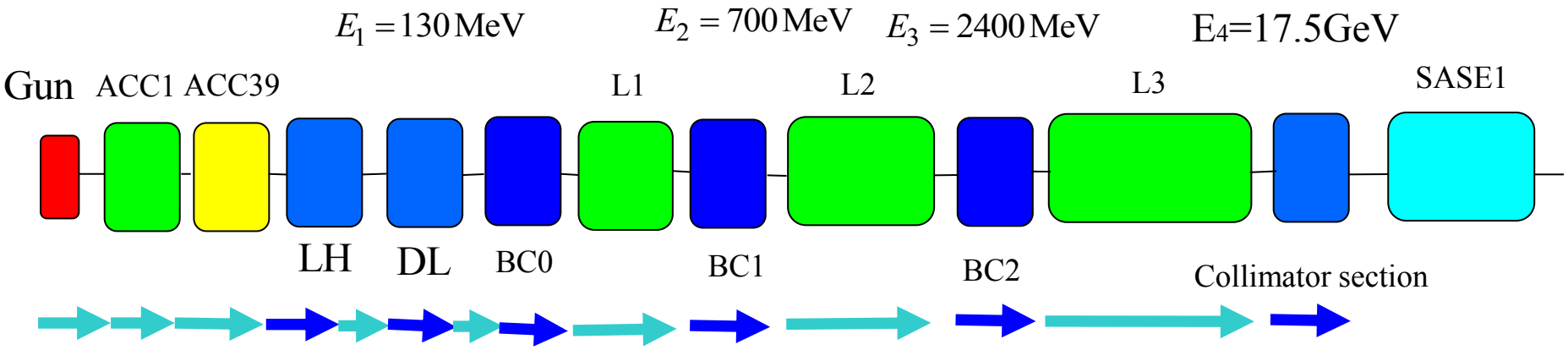
Beam optics is sensitive to:

- Beam energy gain in the first cavity of ACC1
- Deflection angle in BC0

Beam optics comparison

Beam optics calculation using Astra+CSRTrack

✓ 200000 particles

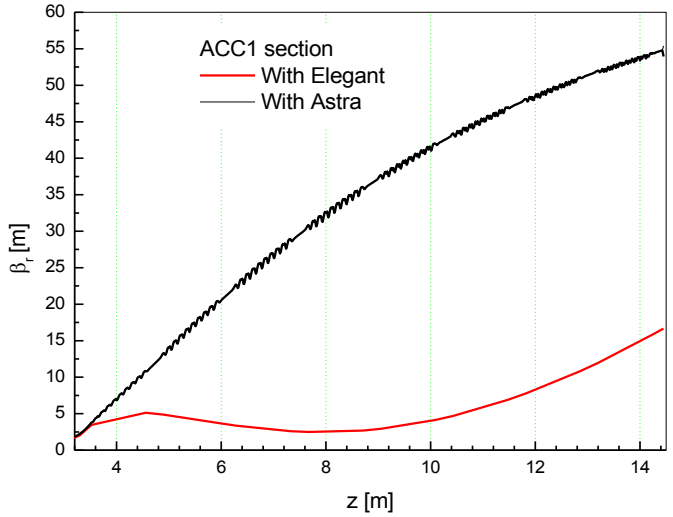


L1: ACC2
L2: ACC3+ ACC4+ ACC5
L3: ACC6+ …+ ACC26

ASTRA (without space charge effects)

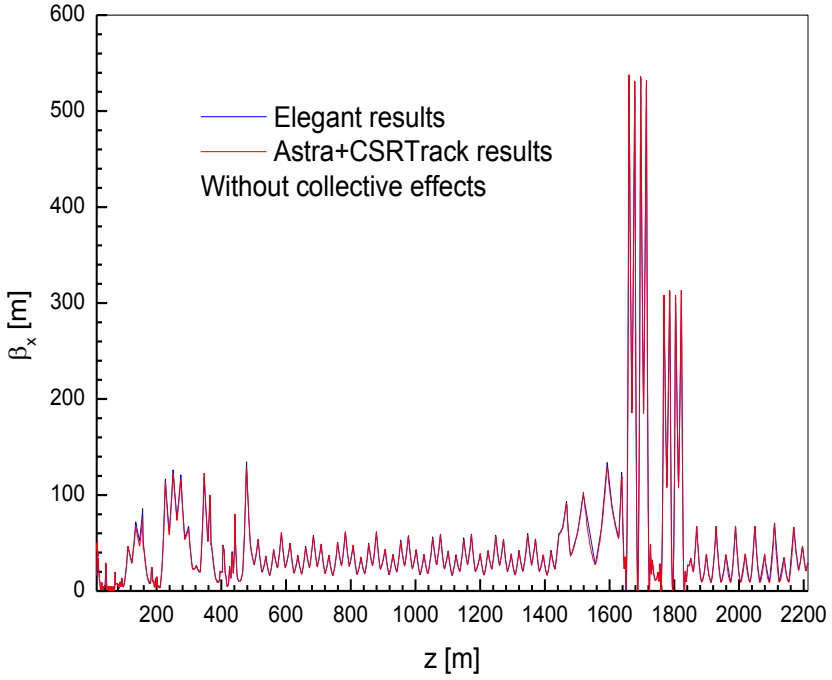
CSRtrack (without CSR effects)

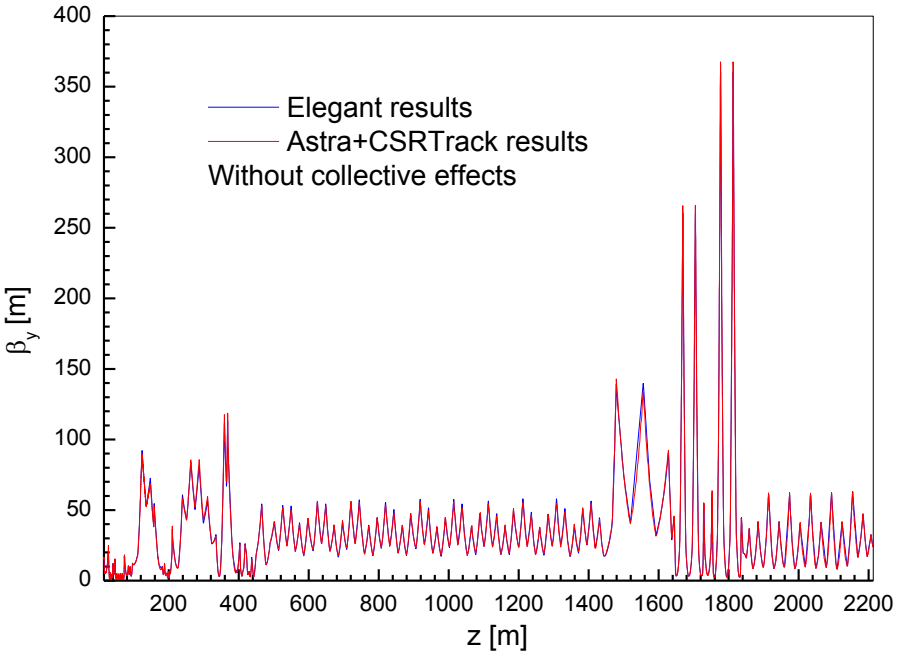
✓ Without wake field effects



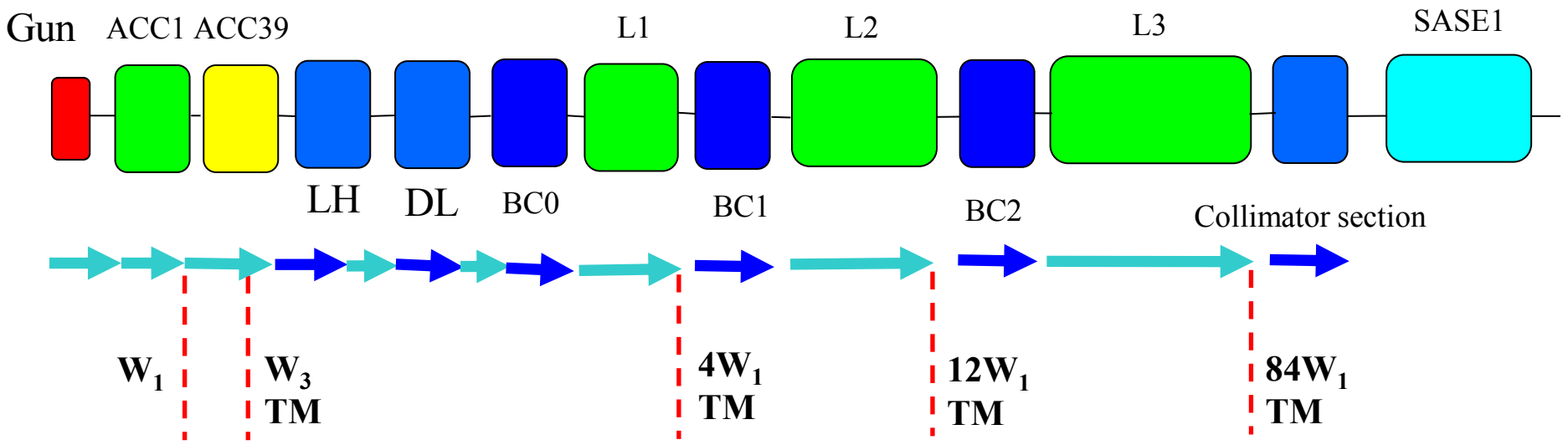
Elegant calculation,
Initial twiss parameters:
βx = 29.171, βy = 29.171
αx = 10.955, αy = 10.955

✓ Beam optics matching before the laser heater





Beam dynamics simulation for EXFEL with 0.5nC



L1: ACC2
L2: ACC3+ ACC4+ ACC5
L3: ACC6+ …+ ACC26

200000 particles
100CPUs, ~18 hours

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

CSRtrack (tracking with CSR effects)

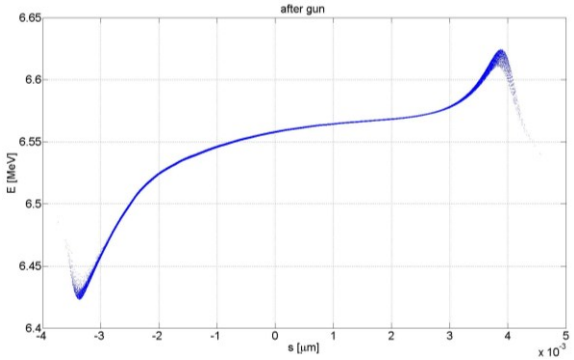
W1 -TESLA cryomodule wake (TESLA Report 2003-19, DESY, 2003)

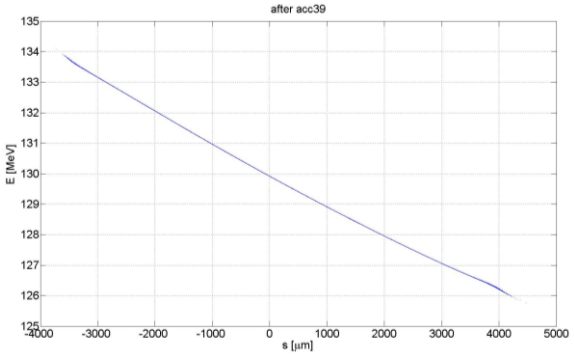
W3 - ACC39 wake (TESLA Report 2004-01, DESY, 2004)

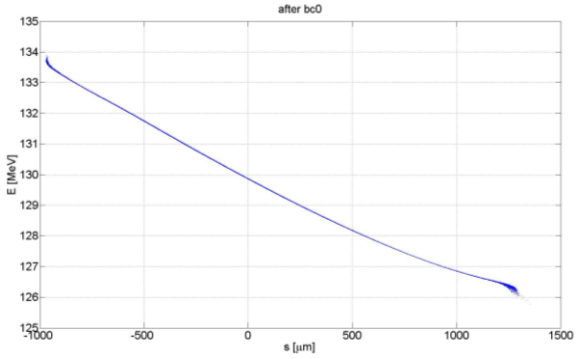
TM - transverse matching to the design optics

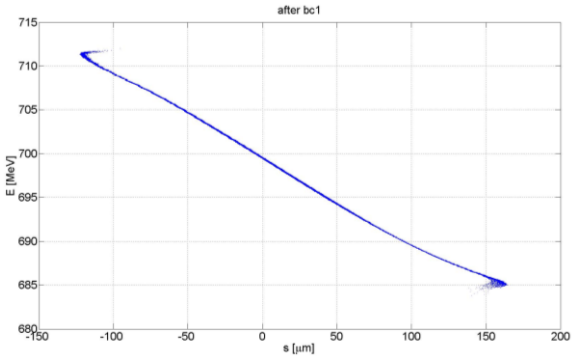
Beam dynamics simulation for EXFEL with 0.5nC

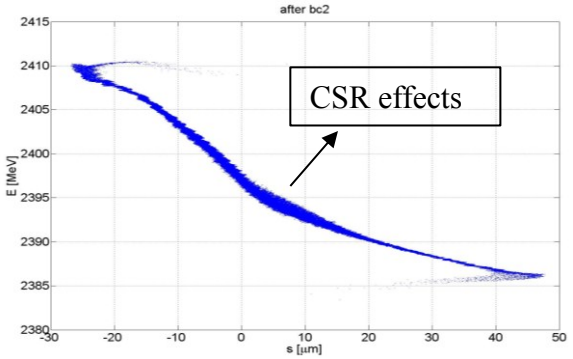
Longitudinal phase space for Q=0.5nC with collective effects

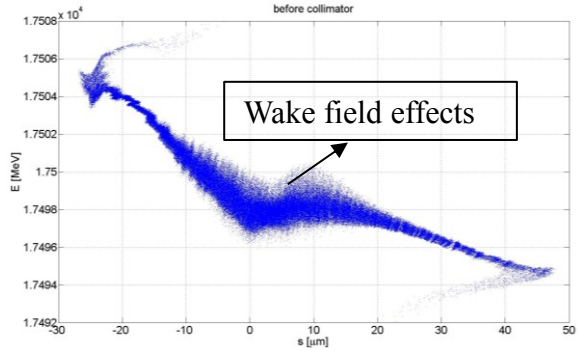


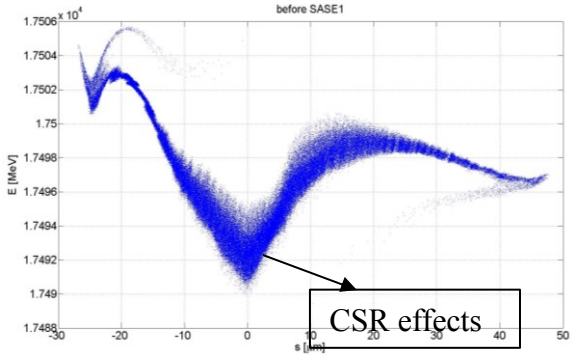






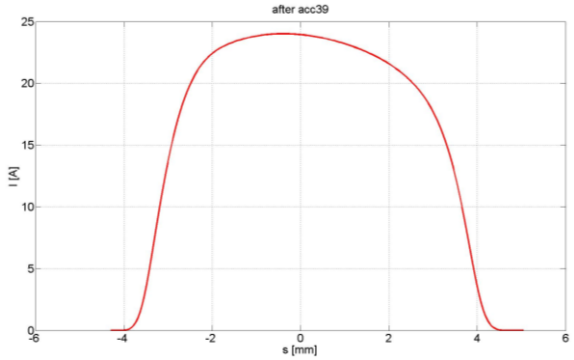


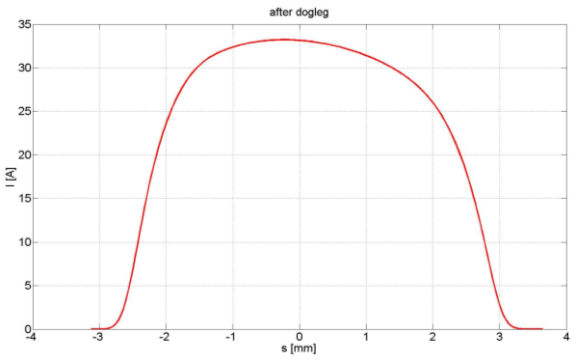


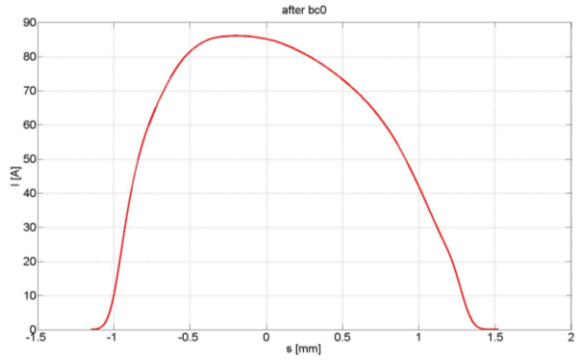


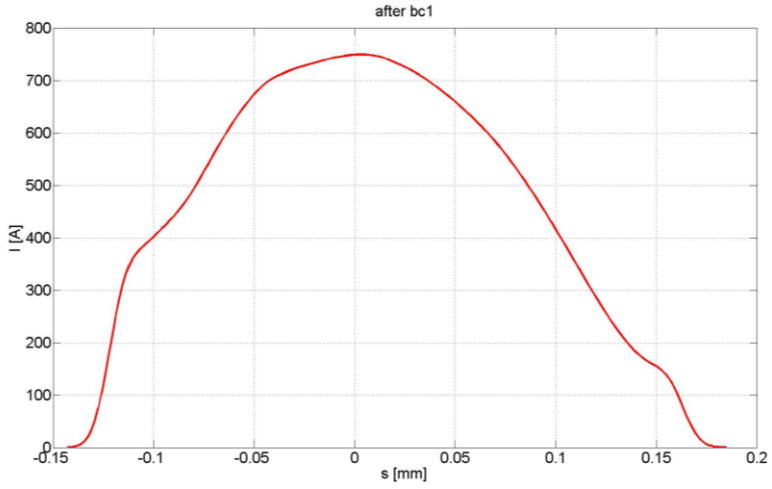
Beam dynamics simulation for EXFEL with 0.5nC

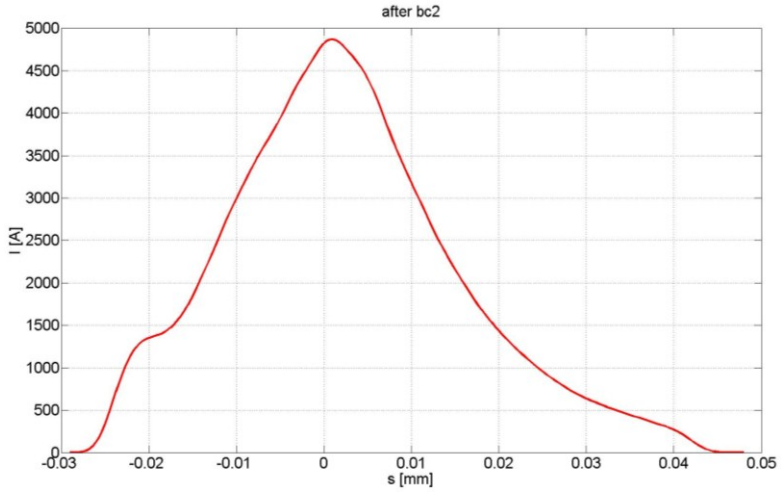
Current Profile



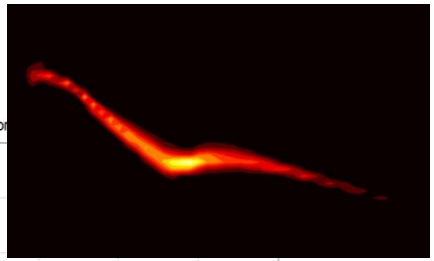


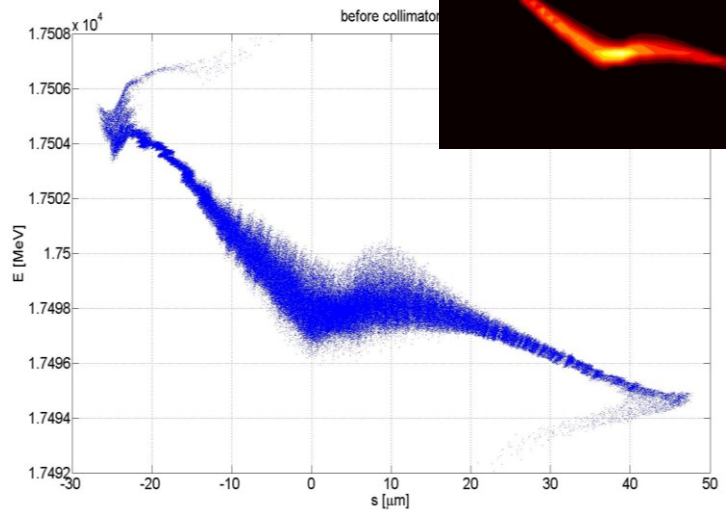


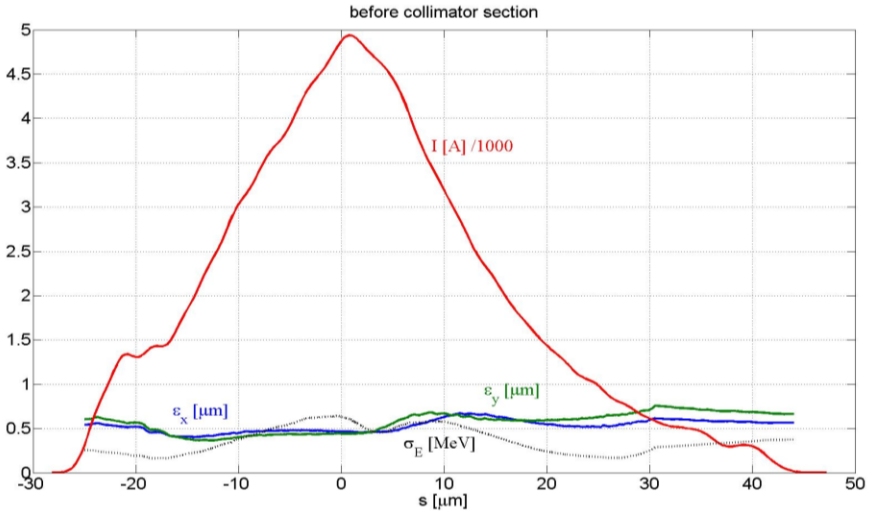




After the linac



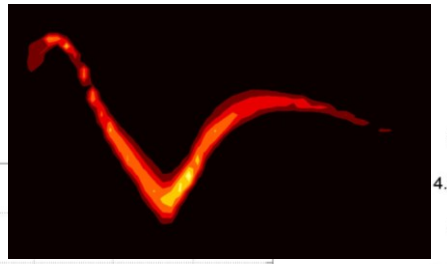


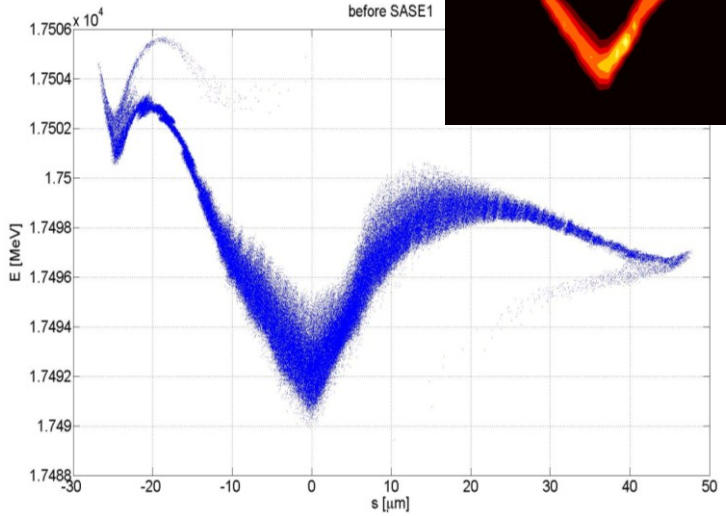


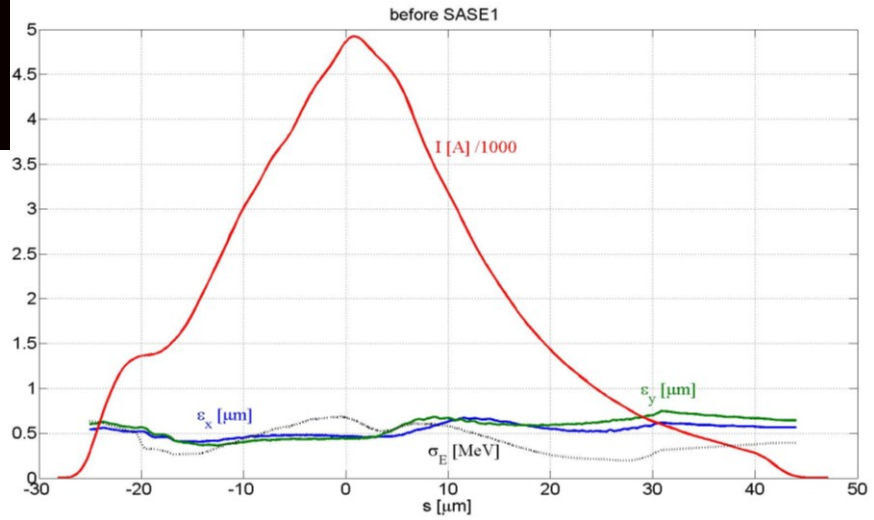
(4% bad particles are removed)

$\varepsilon_x{}^{proj} = 0.642\mu m \cdot rad, \varepsilon_y{}^{proj} = 1.94\mu m \cdot rad$

After the collimator







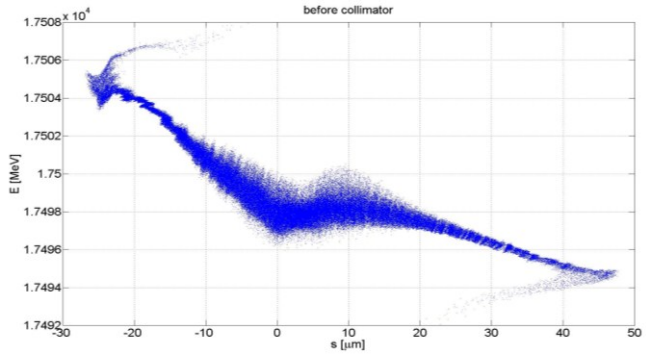
(4% bad particles are removed)

bunch head

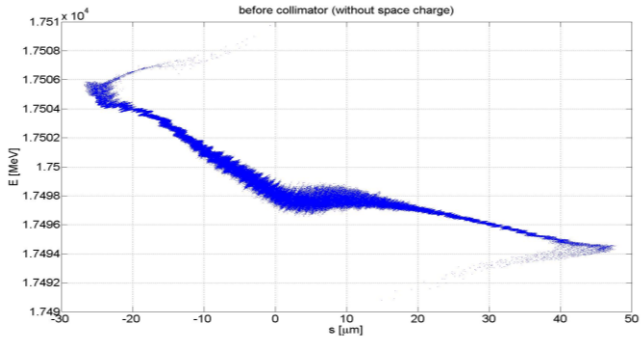
$\varepsilon_x{}^{proj} = 0.642\mu m \cdot rad, \varepsilon_y{}^{proj} = 1.96\mu m \cdot rad$

Beam dynamics simulation for EXFEL with 0.5nC

After the Linac



With space charge impact
L3 simulation (~8h18mins)



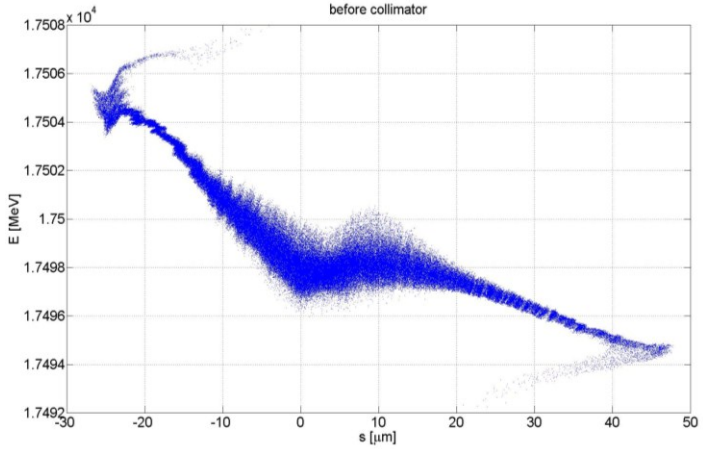
Without space charge impact
L3 simulation (~5h15mins)

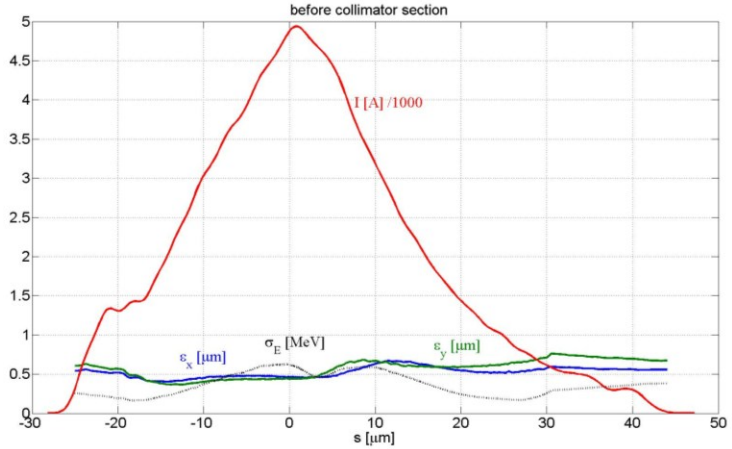
	E [MeV] (Without collective effects)	E [MeV] (With collective effects)	ΔE [MeV]
After ACC39	130.01	129.91	0.1
After BC0	130.01	129.86	0.15
After L1	700.19	699.82	0.37
After BC1	700.19	699.50	0.69
After L2	2401.3	2399.70	1.6
After BC2	2401.3	2396.70	4.6
After L3	17510.0	17498.0	12.0
After Collimator	17510.0	17492.0	18.0

Some progress in last two weeks

1. Speeding up the Astra simulation for **L3**

(1) Adjusting the maximum time step for the Runge-Kutta integrator.
(2) Decreasing the interval about ZSTOP-ZSTART.
(3) Using Astra code with the new version.



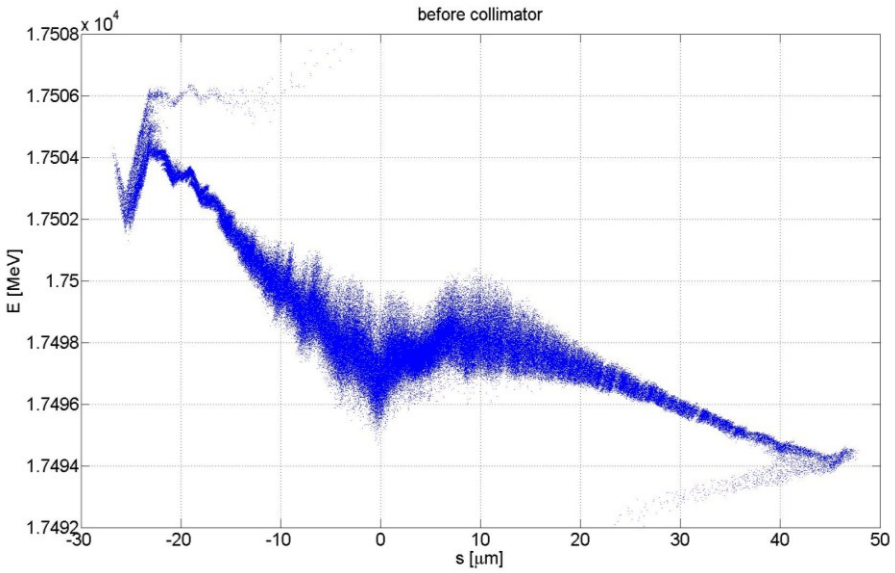


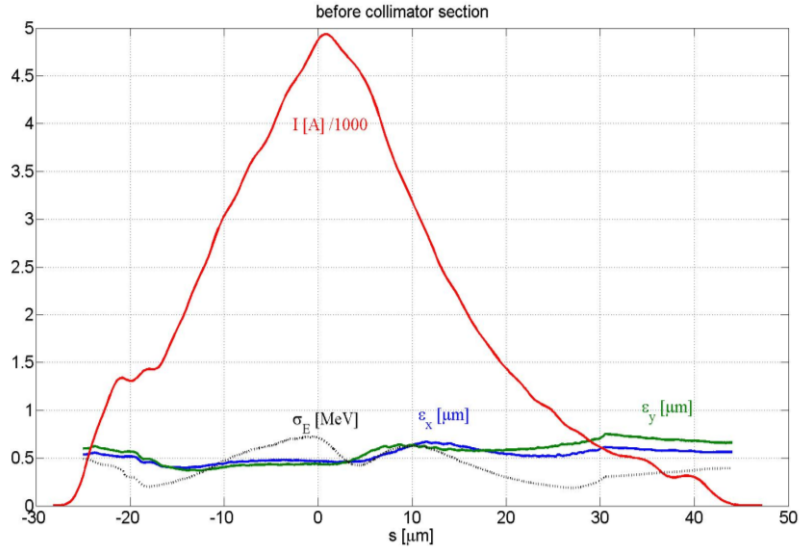
200000 particles, 100CPUs, SCH+Cavity wake field
3h10mins for L3 simulation !!!

Δt=~5h

2. Astra 3D calculation for L3 to study the space charge impact on slice energy spread

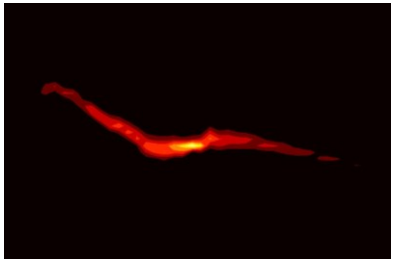
200000 particles

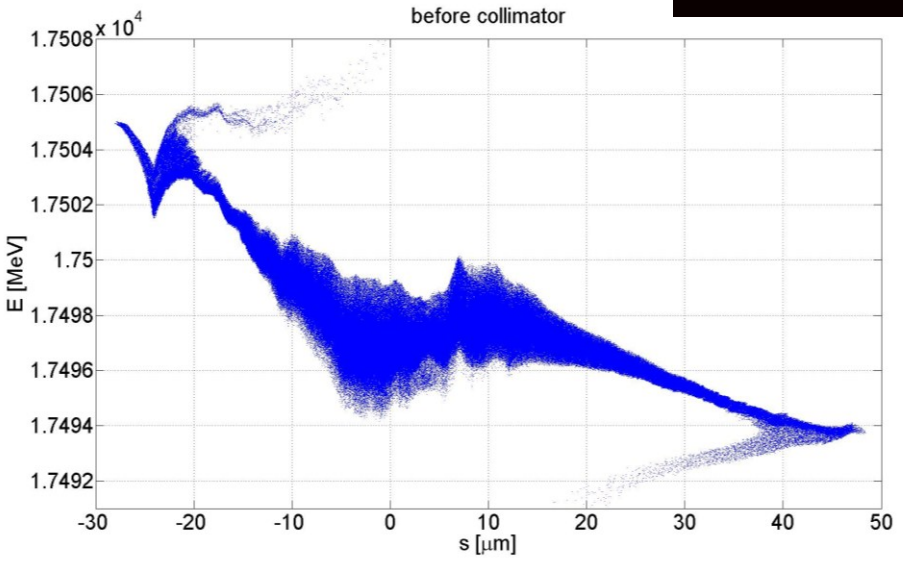


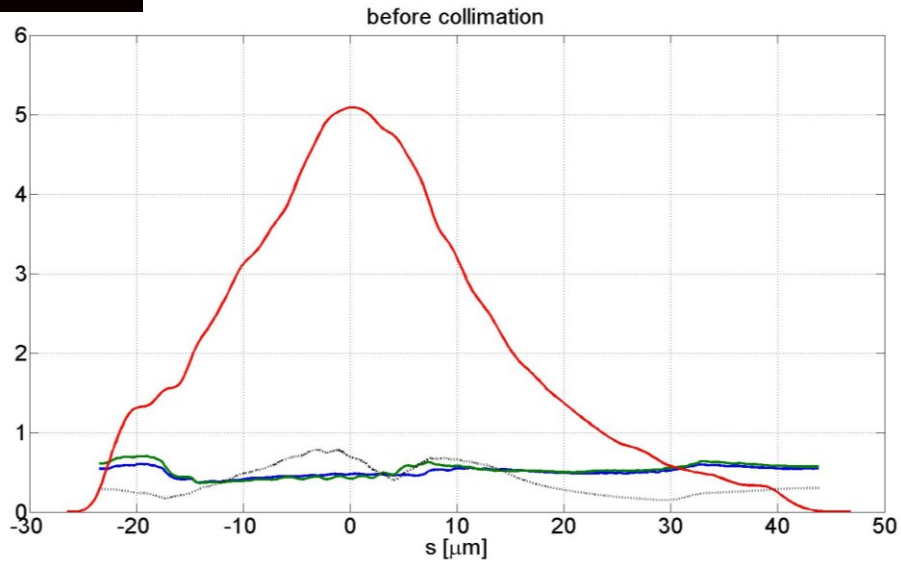


3. S2E simulation for EXEL with CSRTrack and Astra3D calculation.

1000k particles, 100CPUs

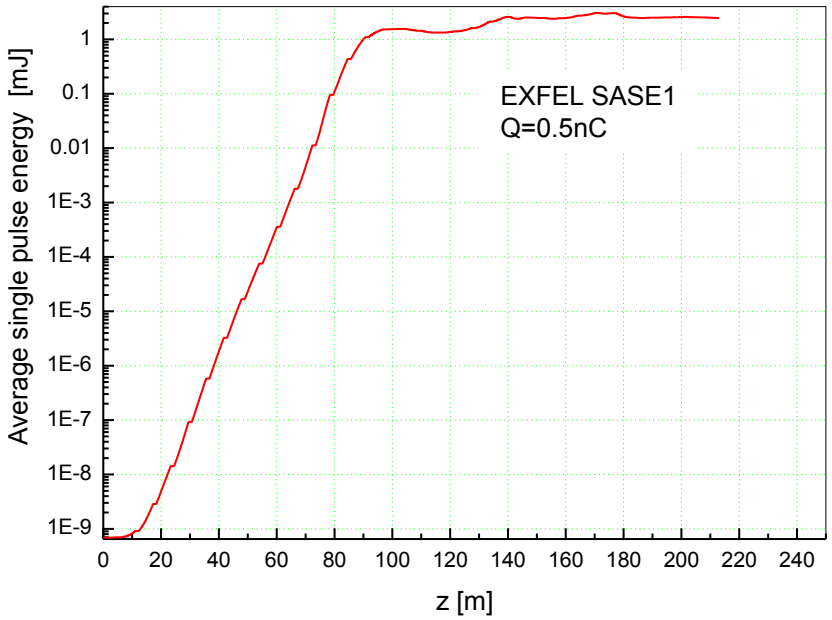


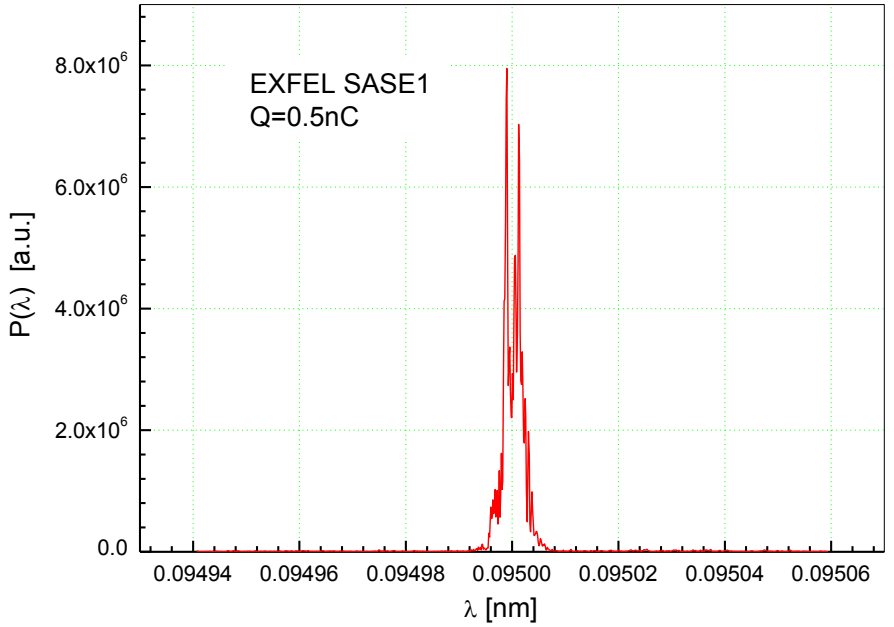




4. Radiation calculation for SASE1

SHOTNOISE = 0.0





Plan:

(1) Generating particles distribution file after SASE1 from Genesis output.

(2) Beam dynamics simulation for the extraction arc section between SASE1 and SASE3.

(3) Radiation calculation for SASE3.