FEL Bandwidth Calculation for EXFEL SASE1 and Work Progress for FLASH2 Seeded FEL simulation

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S2E Meeting

DESY

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FEL Bandwidth Calculation for EXFEL SASE1

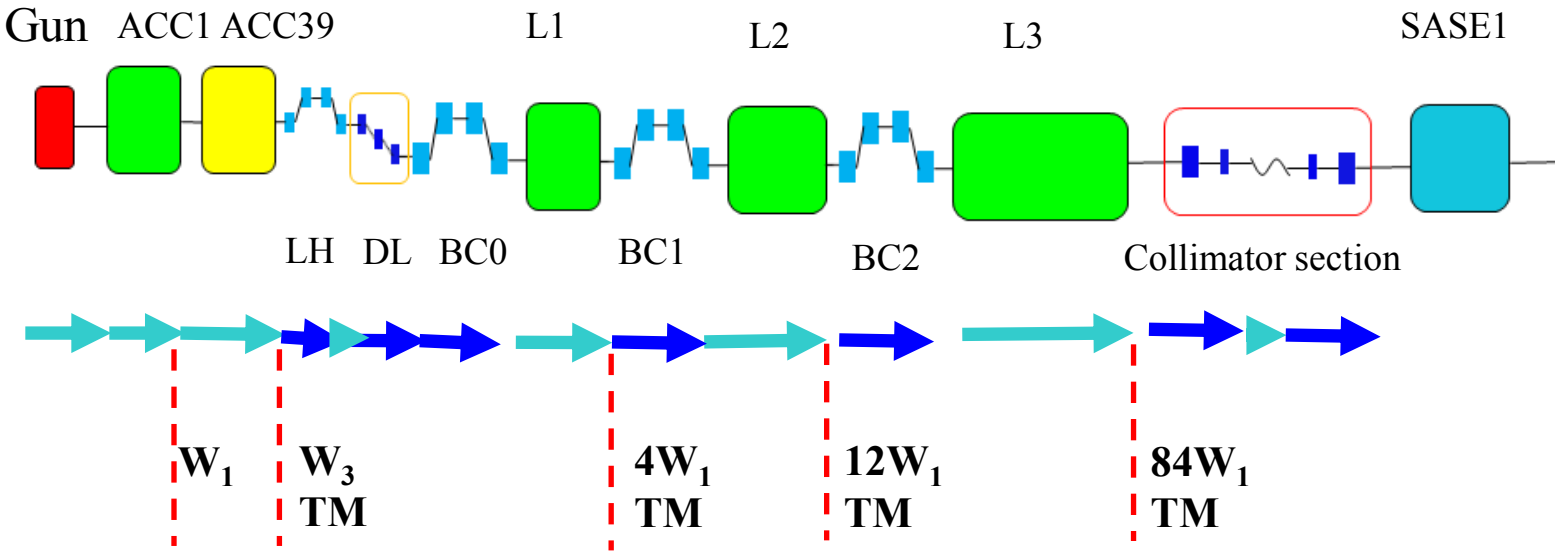
The energy chirp related FEL bandwidth calculation for different beam energy and different bunch charge cases.

E= 17.5 GeV, 14.0 GeV, 12.0 GeV, 8.5 GeV
Q= 1.0 nC, 0.5 nC, 0.25 nC, 0.1 nC, 0.02 nC

λ=0.1 nm

FEL Bandwidth Calculation for EXFEL SASE1

Beam dynamics simulation



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

200000 particles

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

CSRtrack (tracking with CSR effects)

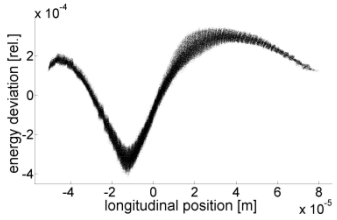
W1 -TESLA cryomodule wake (TESLA Report 2003-19, DESY, 2003)

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

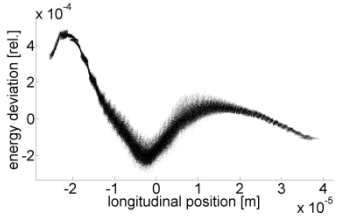
TM - transverse matching to the design optics

FEL Bandwidth Calculation for EXFEL SASE1

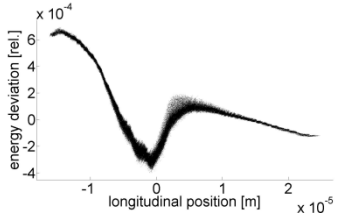
Longitudinal phase space before SASE1 undulator:



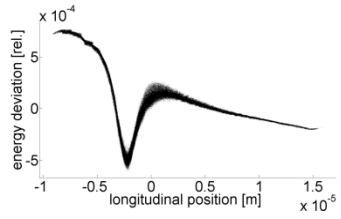
E=17.5GeV, Q=1.0nC



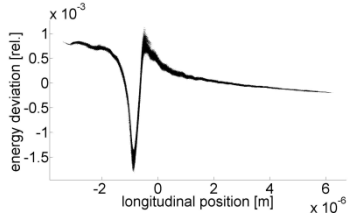
E=17.5GeV, Q=0.5nC



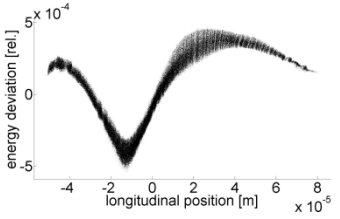
E=17.5GeV, Q=0.25nC



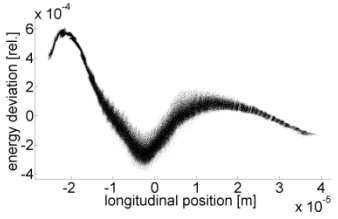
E=17.5GeV, Q=0.1nC



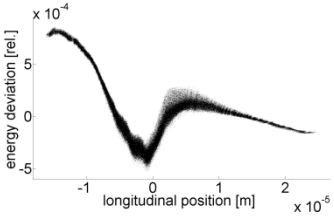
E=17.5GeV, Q=0.02nC



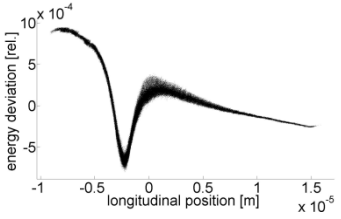
E=14.0GeV, Q=1.0nC



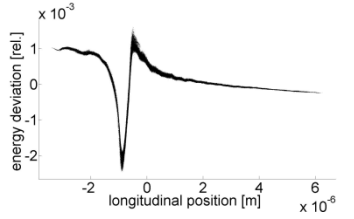
E=14.0GeV, Q=0.5nC



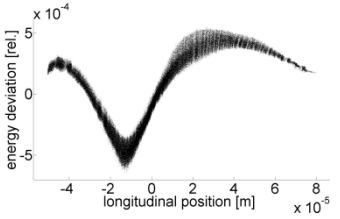
E=14.0GeV, Q=0.25nC



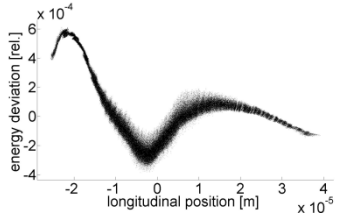
E=14.0GeV, Q=0.1nC



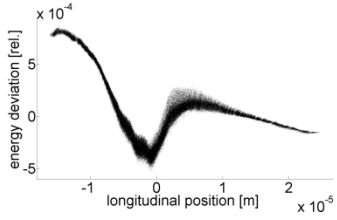
E=14.0GeV, Q=0.02nC



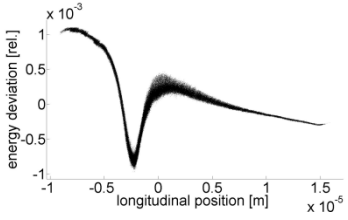
E=12.0GeV, Q=1.0nC



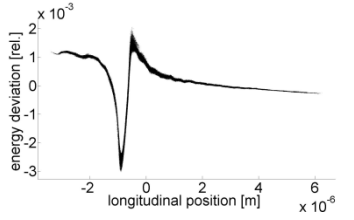
E=12.0GeV, Q=0.5nC



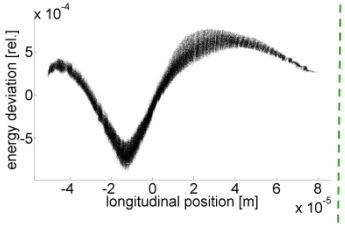
E=12.0GeV, Q=0.25nC



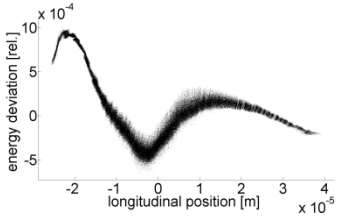
E=12.0GeV, Q=0.1nC



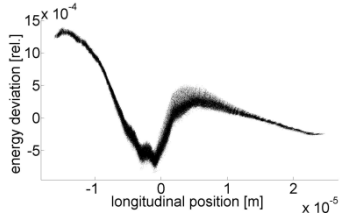
E=12.0GeV, Q=0.02nC



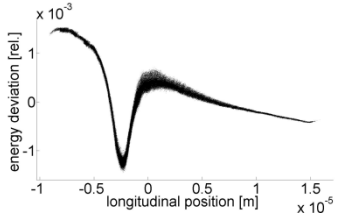
E=8.5GeV, Q=1.0nC



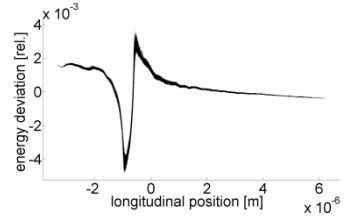
E=8.5GeV, Q=0.5nC



E=8.5GeV, Q=0.25nC



E=8.5GeV, Q=0.1nC



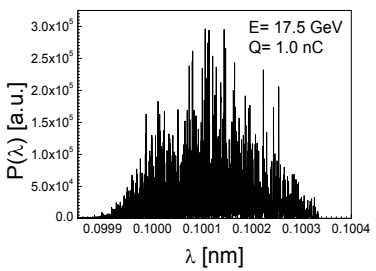
E=8.5GeV, Q=0.02nC

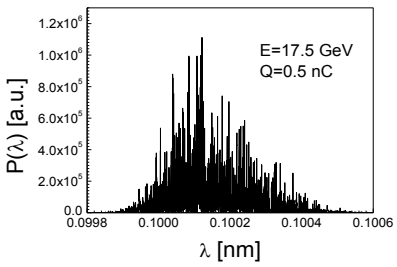
FEL Bandwidth Calculation for EXFEL SASE1

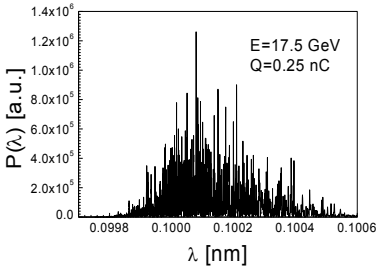
Peak-to-peak energy chirp in the lasing fraction of the bunch (FWHM)

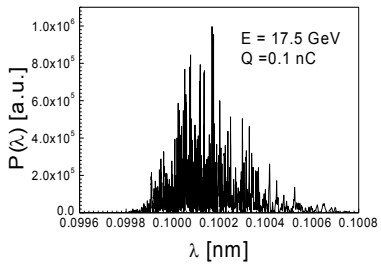
	17.5 GeV	14 GeV	12 GeV	8.5 GeV
1.0 nC	9.91 MeV	9.86 MeV	9.91 MeV	10.12 MeV
0.5 nC	7.05 MeV	7.05 MeV	7.00 MeV	6.75 MeV
0.25 nC	8.23 MeV	8.02 MeV	7.82 MeV	7.61 MeV
0.10 nC	11.19 MeV	12.01 MeV	12.52 MeV	14.05 MeV
0.02 nC	37.4 MeV	41.85 MeV	45.73 MeV	53.65 MeV

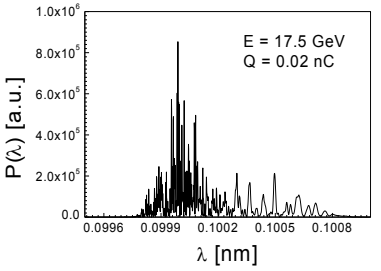
FEL Bandwidth Calculation for EXFEL SASE1

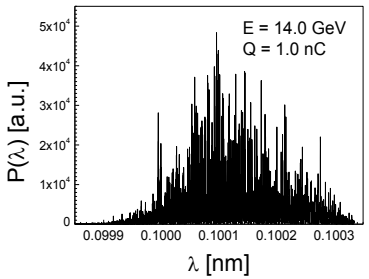


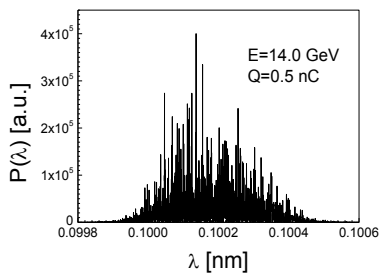


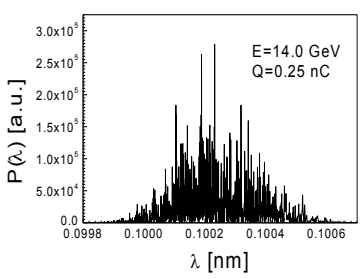


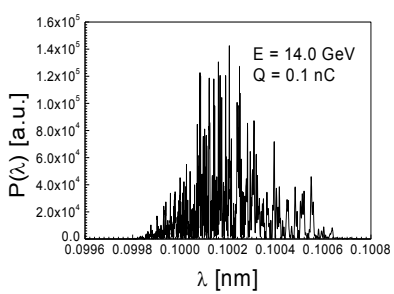


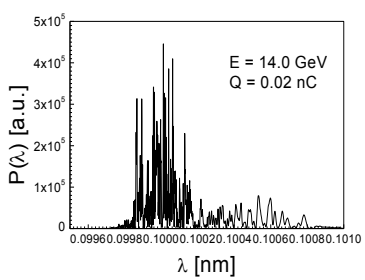


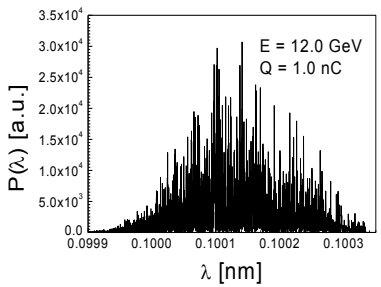


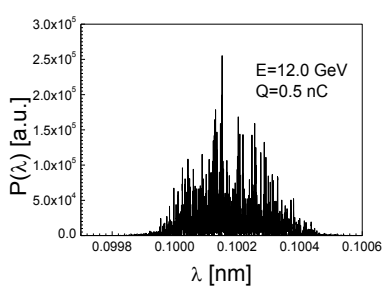


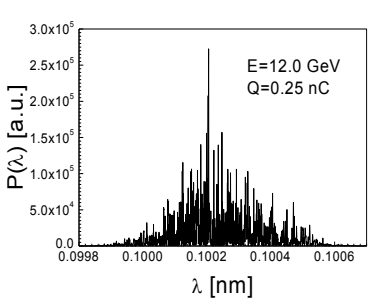


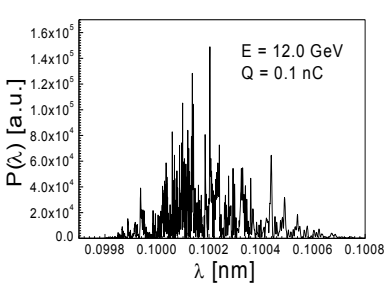


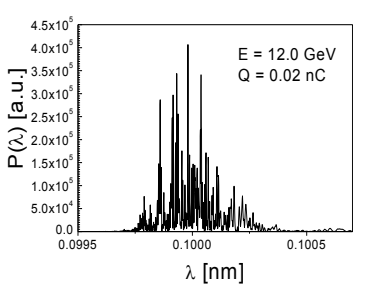


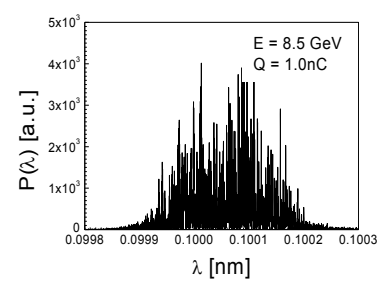


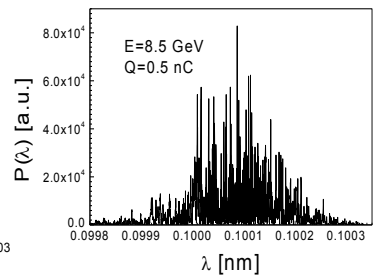


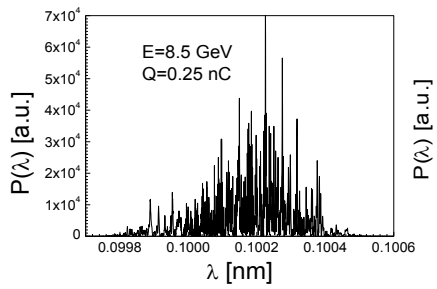


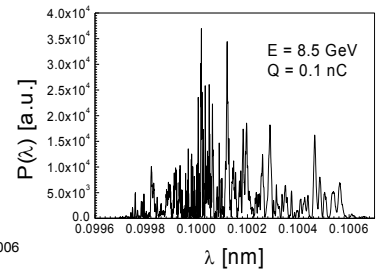


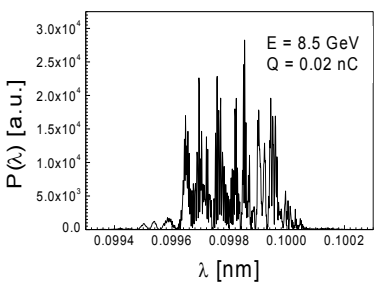












FEL Bandwidth Calculation for EXFEL SASE1

λ=0.1 nm

		17.5 GeV	14 GeV	12 GeV	8.5 GeV
1.0 nC	Natural bandwidth	0.11%	0.1%	0.090%	0.068%
	Spectrum increase	0.113%	0.14%	0.165%	0.238%
	Simulation results	0.225%	0.22%	0.22%	0.22%
0.5 nC	Natural bandwidth	0.133%	0.124%	0.103%	0.078%
	Spectrum increase	0.081%	0.101%	0.117%	0.159%
	Simulation results	0.229%	0.25%	0.237%	0.235%
0.25 nC	Natural bandwidth	0.14%	0.134%	0.110%	0.083%
	Spectrum increase	0.094%	0.114%	0.13%	0.179%
	Simulation results	0.256%	0.25%	0.248%	0.264%
0.10 nC	Natural bandwidth	0.16%	0.155%	0.120%	0.090%
	Spectrum increase	0.127%	0.165%	0.209%	0.331%
	Simulation results	0.292%	0.36%	0.33%	0.464%
0.02 nC	Natural bandwidth	0.167%	0.160%	0.152%	0.122%
	Spectrum increase	0.427%	0.598%	0.762%	1.262%
	Simulation results	**0.640%**	**0.65%**	**0.56%**	**0.58%**

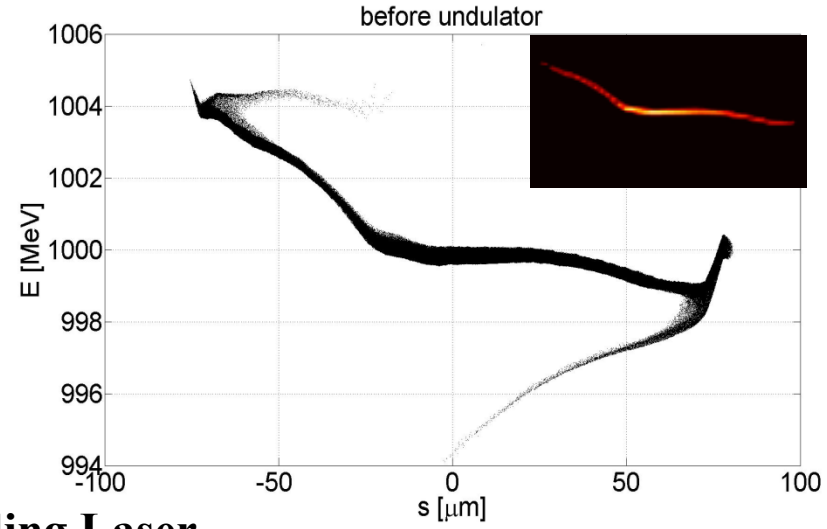
1) **Natural bandwidth:** $|\Delta\lambda/\lambda_0|_{FWHM} \sim 2\rho$ (ρ: FEL parameter)

2) **Spectrum increase** according to: $2\,|\Delta E/E_0|_{FWHM}$

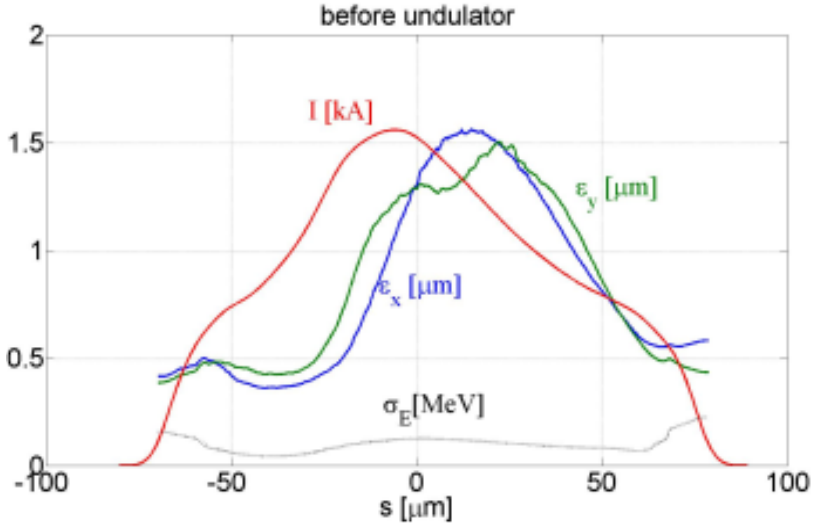
3) **Simulation results: FWHM values of the spectrum from Genesis** (5 random seeds for shot noise)

Seeded FEL Simulation for FLASH2

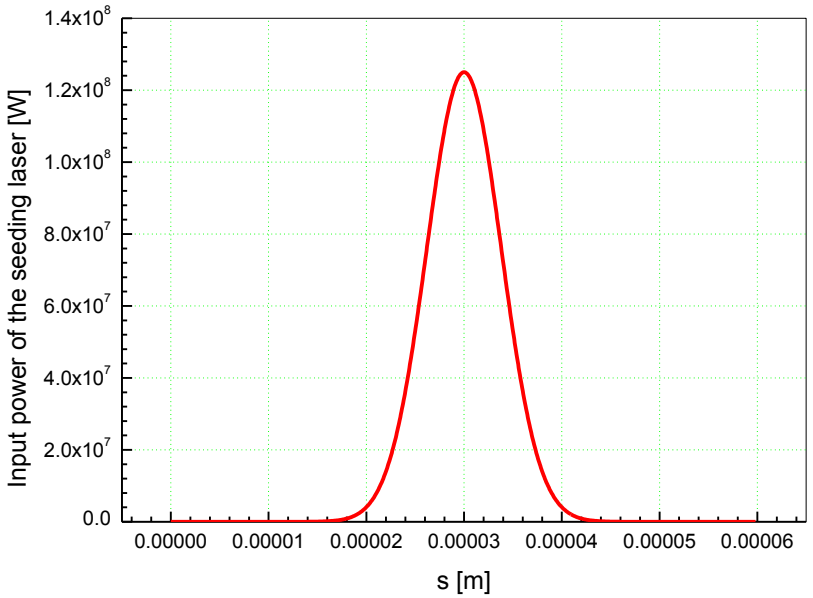
Previous work



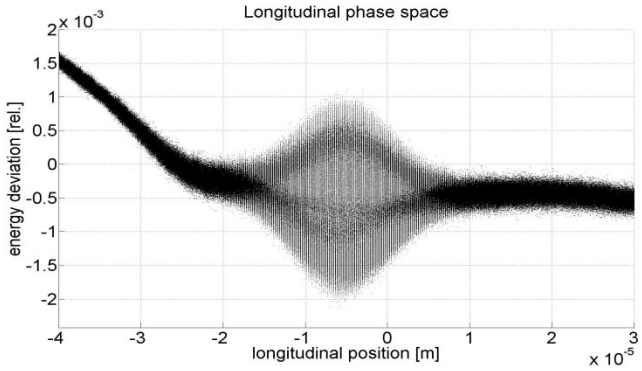
Q=0.5nC



Seeding Laser

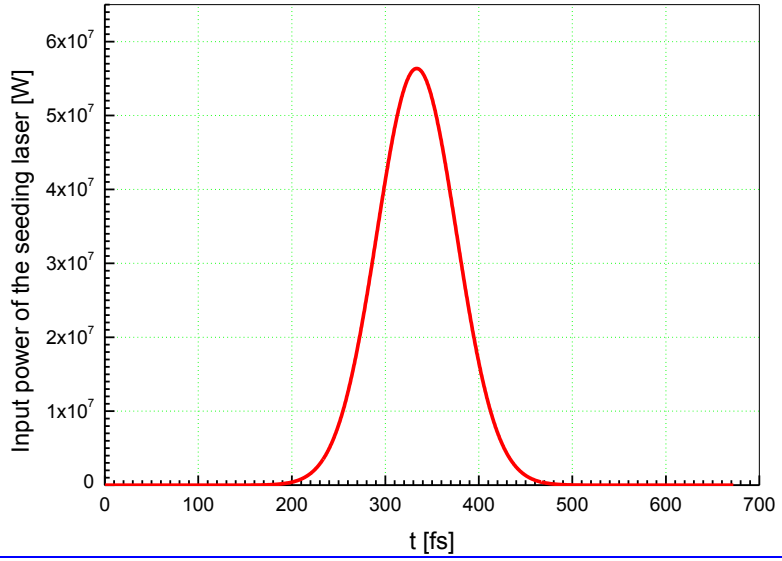


Peak power P_laser = 125 MW
Rayleigh length z_R = 4.2 m
Pulse duration of τ =30 fs (FWHM)
Wavelength λ= 235 nm



Seeded FEL Simulation for FLASH2

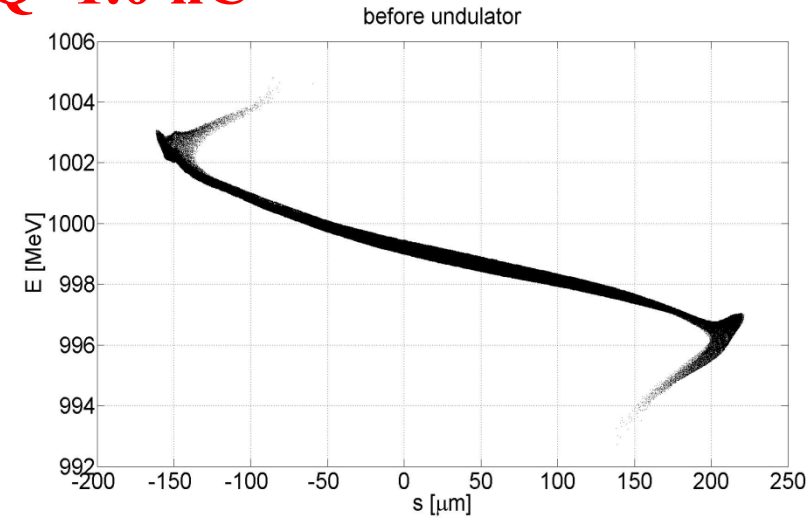
New model of the seeding laser

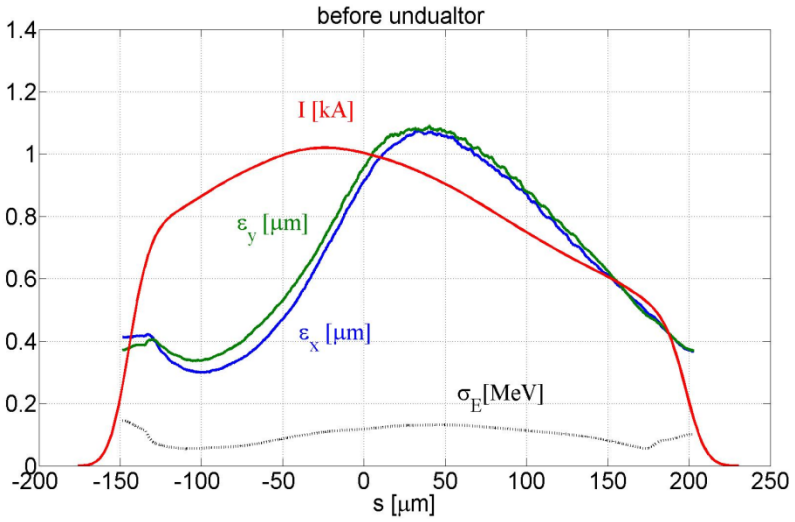


Pulse energy = 6.0 μJ
Rayleigh length z_R = 4.2 m
Pulse duration of τ =100 fs (FWHM)
Wavelength λ= 266 nm

Total length ~ 90 μm

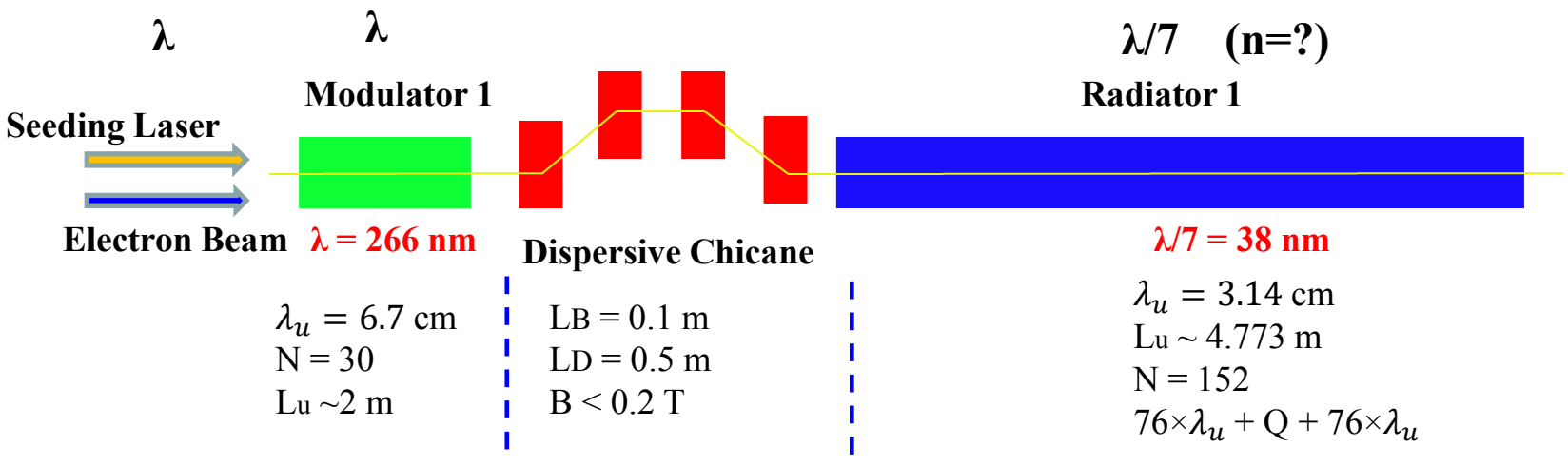
Q=1.0 nC

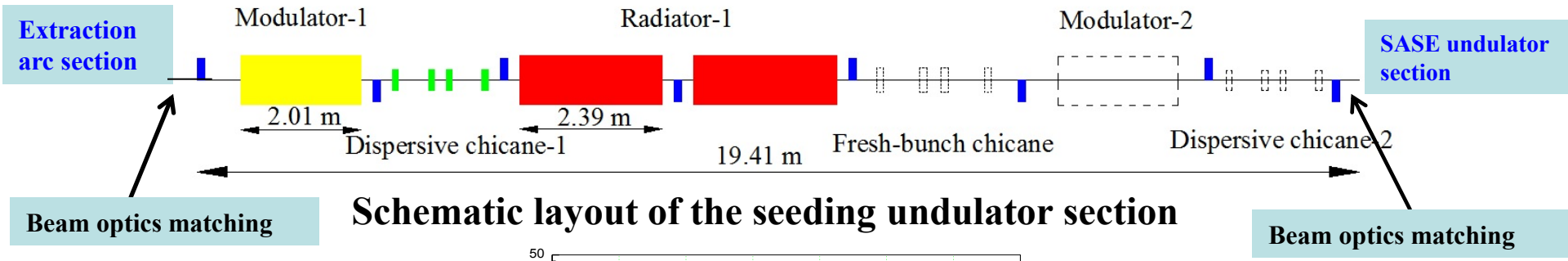




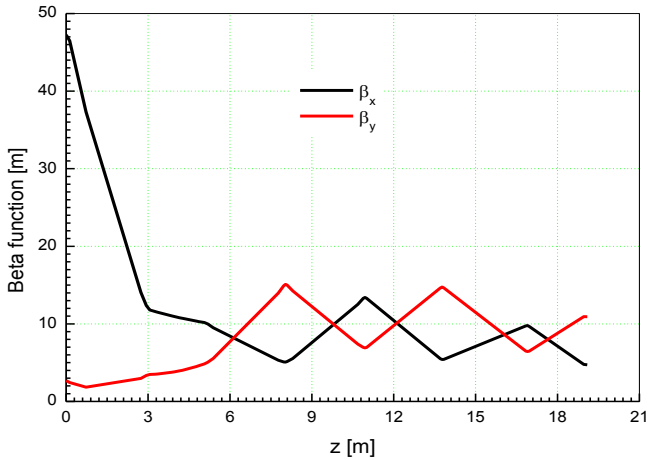
$\varepsilon_x^{proj} = 2.19\mu m \cdot rad, \varepsilon_y^{proj} = 2.18\mu m \cdot rad$

Seeded FEL Simulation for FLASH2



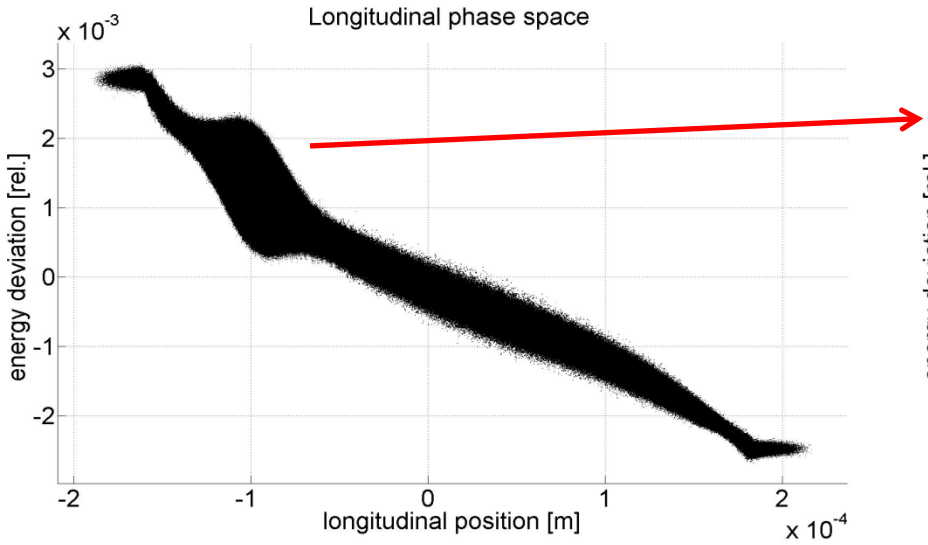


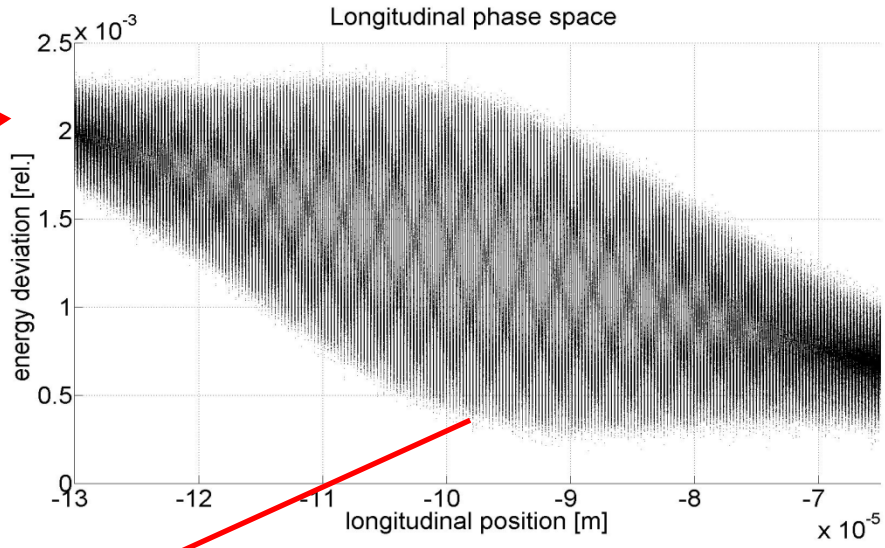
Schematic layout of the seeding undulator section

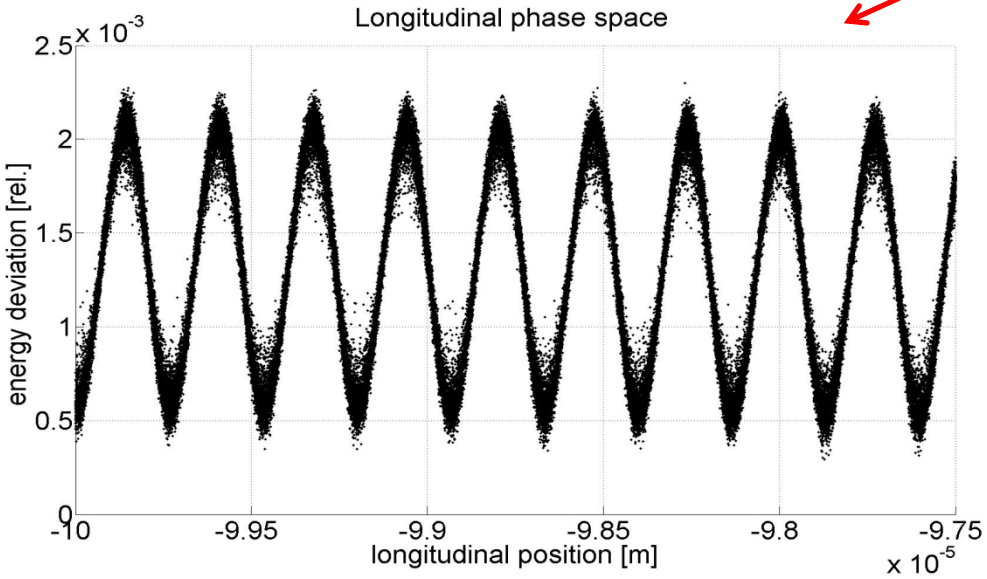


Seeded FEL Simulation for FLASH2

Energy modulation at the exit of the modulator







$$E_{mod} \sim 0.8\ MeV$$

$$\hat{I} = \frac{cqkE_{mod}}{\sqrt{2\pi}\sigma_E}$$

Seeded FEL Simulation for FLASH2

Estimations in the dispersive chicane:

(1) r_{56} for the complete compression (referring to the middle of the modulated part of the bunch): $r_{56} = E/(k\, E_{mod}) = 53\ \mu m \rightarrow R \sim 14.5\ m$

(2) rms length of the sub-bunches after complete compression: $\sigma = \frac{r_{56}\sigma_E}{E} \approx 8\ nm$

(3) Charge in one wavelength: $q_\lambda = I\frac{\lambda}{c} \approx 0.887\ pC$

(4) Charge which can be compressed: $q = q_\lambda/2$

(5) Scaling of steady state csr of gaussian bunch: $E_c = \frac{1}{\sqrt[3]{3}(2\pi)^{\frac{3}{2}}R^{\frac{2}{3}}\sigma^{\frac{4}{3}}}\frac{q}{\varepsilon} \sim 23.4\ \mathrm{MV/m}$

CSRtrack simulation:

(1) required resolution ~ 4 nm << σ

(2) required step width ~ 0.2 mm << R σ/σ_x = 1 mm

(3) Particle number ~ 15 M

CSRTrack simulation is in process …

Plans

(1) Harmonic optimization for the radiator.
(2) Continue to do the cascaded HGHG simulation.