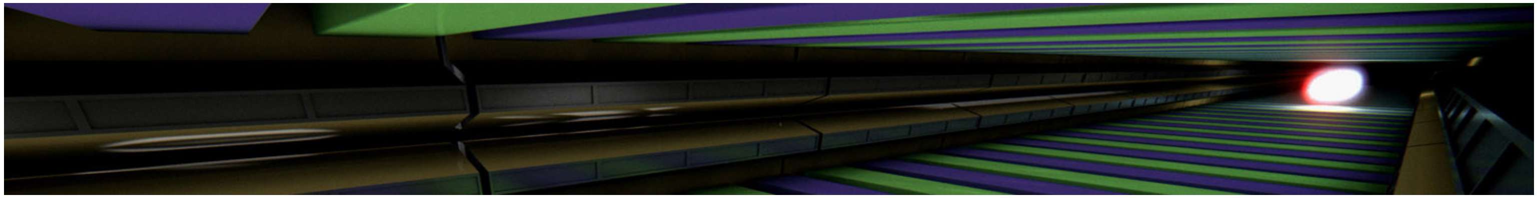


Beam Dynamics Optimization for the Hard X-ray Self-seeding at European XFEL

Shan Liu

S2E Meeting, DESY, 28 March 2017

Outlines

- Work transfer from Guangyao Feng
- Hard X-ray Self-Seeding (HXRSS) simulations
- Beam dynamics optimization for HXRSS
- Preliminary results of optimization
- Future plans for S2E simulation

Work transfer from Guangyao Feng

1. EXFEL

- S2E simulations (20pC, 100pC, 250pC, 500pC, 1nC SASE1 & SASE3)
- Bandwidth calculation for SASE1
- Radiation calculation for SASE1 with optimized tapered undulator
- Short X-ray pulses with emittance-spoiler foil method
- Energy dechirper study with flat top current profile (250pC, 500pC)

2. FLASH

a. S2E simulation for FLASH1

b. FLASH2

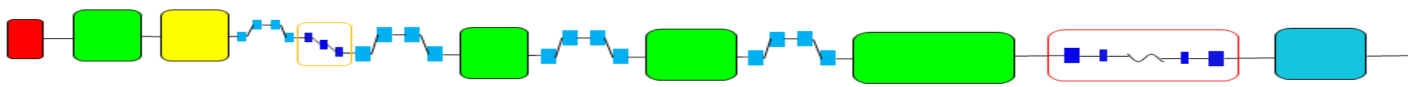
- S2E simulation for SASE, Ip=2.5 kA
- Beam dynamics study for low slice energy spread
- Examples of S2E simulation for seeded FEL study for FLASH2 (Ip ~ 1.0 kA)

3. Other Matlab scripts

Code used in simulation

S2E simulation to get flat top current profile with 100pC for the HXRSS at EXFEL

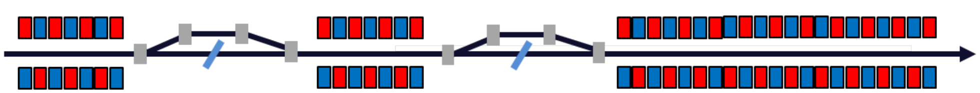
Electron Source



- **Injector** - ASTRA →
- **ACC1** - ASTRA →
- **ACC39** - ASTRA →
- **Laser Heater** - CSRTrack →
- **Straight section** - ASTRA →
- **Dogleg** - CSRTrack →
- **BC0** - CSRTrack →
- **Linac1** - ASTRA →
- **BC1** - CSRTrack →
- **Linac2** - ASTRA →
- **BC2** - CSRTrack →
- **Linac3** - ASTRA →
- **Collimator** - CSRTrack →
- **TL+T2** - ASTRA

X-ray Source

- **Stage 1** - Genesis →
- **Stage2** HXRSS - OCELOT →
- **Stage 3** - Genesis →
- **Stage4** HXRSS - OCELOT →
- **Stage 5** - Genesis

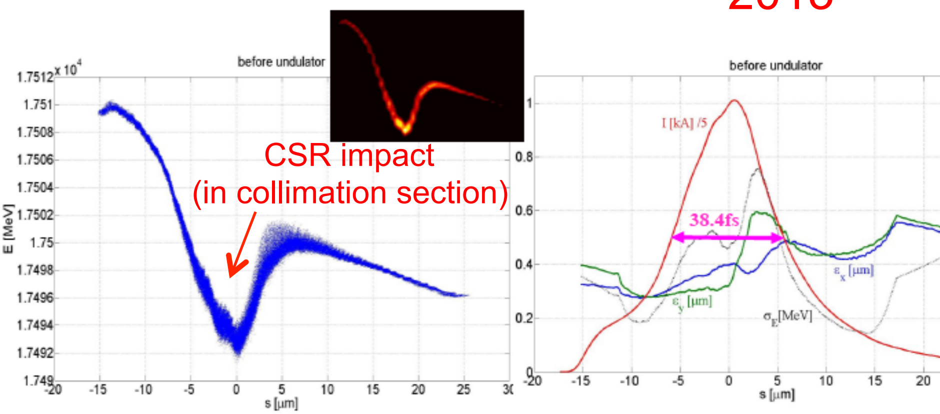


Examples of S2E simulation result from Guangyao Feng

Beam dynamics simulation for EXFEL for different bunch charge cases

Q=0.25nC

2013



$\varepsilon_x{}^{proj} = 0.5\mu m \cdot rad, \varepsilon_y{}^{proj} = 1.6\mu m \cdot ra$

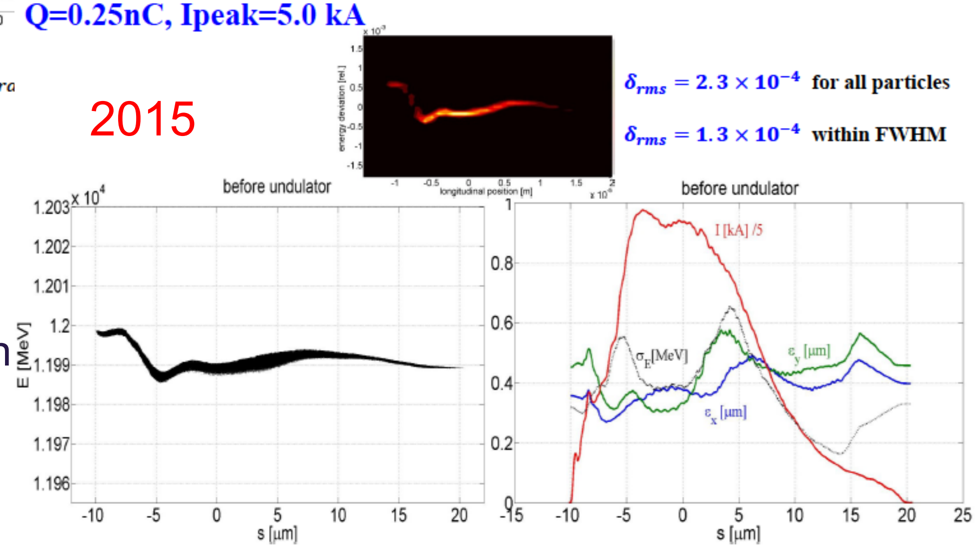
4% bad particles are removed

17.5GeV, 250pC, 5kA
before undulator

Beam dynamics simulation for EXFEL for different bunch charge cases

Q=0.25nC, Ipeak=5.0 kA

2015



$\delta_{rms} = 2.3 \times 10^{-4}$ for all particles

$\delta_{rms} = 1.3 \times 10^{-4}$ within FWHM

$\varepsilon_x{}^{proj} = 0.50\mu m \cdot rad, \varepsilon_y{}^{proj} = 0.71\mu m \cdot rad$

4% bad particles are removed

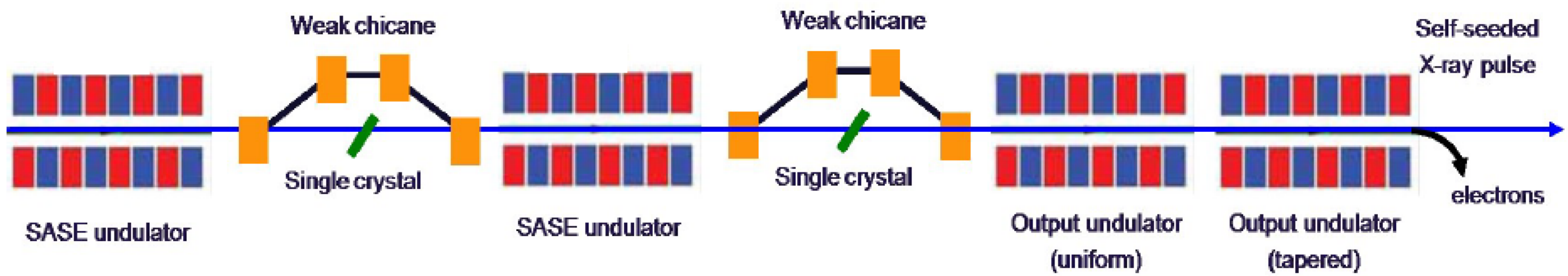
Flat-top current distribution (increase of σ_z)

-> mitigate the CSR effect in collimation section

-> mitigate the distortion in longitudinal phase space in the center

HXRSS simulation status

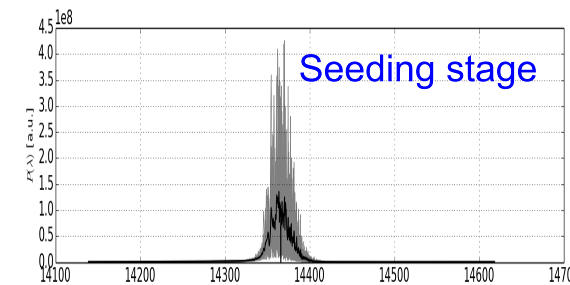
G. Geloni, V. Kocharyan, E. Saldin (*DESY 10-133*)

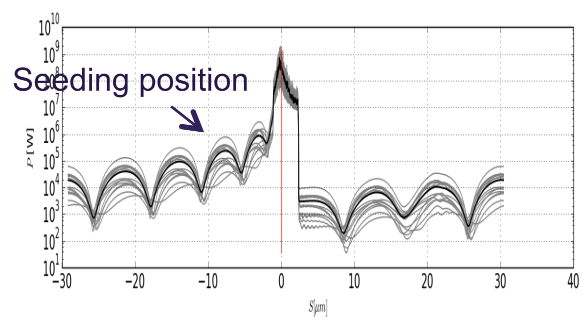


SASE2 line (3 keV -25 keV) will be first equipped with HXRSS

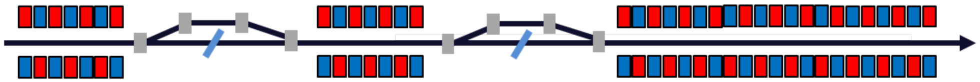
- Combination of high rep-rate HXRSS and Tapering
- Tapering: increases power
- HXRSS: decreases bandwidth

- Used S2E simulation beam distribution (from 2013) before undulator as input
- Short bunches (FWHM<20μm) are prefered (longer bunches -> larger spatio-temporal coupling effect)





HXRSS simulation status



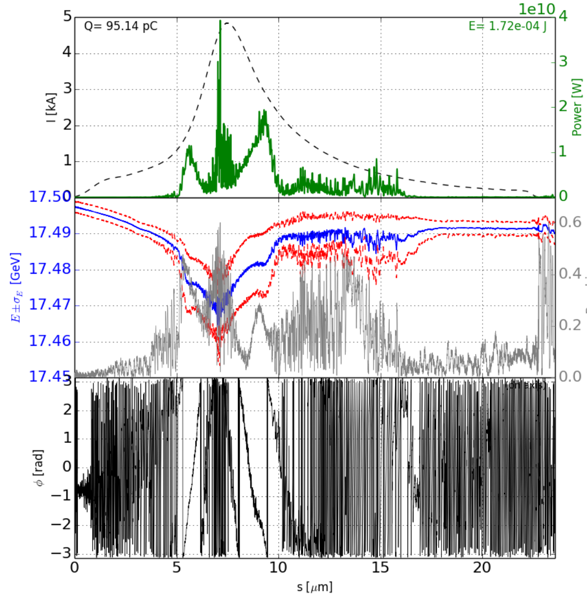
- Lower photon energy (<12keV)
- Less than 6 undulator cases
- ➢ works well

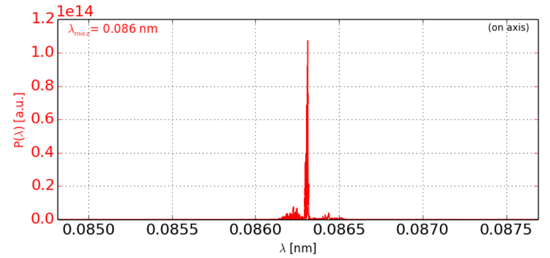
- Higher photon energy (e.g.14.4keV)
- More than 6 undulators cases
- ➢ multi-peaks in power distribution
- ➢ SASE noise in spectrum

Flat energy distribution in the center preferred for HXRSS performance study:

- What is the critical energy for HXRSS?
- How many undulators should be reserved for 1st and 3rd stage?

17.5GeV, 100pC, 14.4keV, 7+7+12 undulators





Optimization procedures

- Global compression function $C_N = \frac{1}{Z_N}$
- Inverse global compression function $Z_N = \frac{\partial s_N}{\partial s}$

*Igor Zagorodnov and Martin Dohlus Phys. Rev. ST Accel. Beams 14, 014403 (2011)

*Bolko Beutner, FEL Seminar 17.2.2015

- 2nd deviation Z_3'> symmetry of current distribution $Z_3' = \frac{\partial^2 s_3}{\partial s^2}(0)$
- 3rd deviation Z_3''->flatness of current distribution (FWHM) $Z_3'' = \frac{\partial^3 s_3}{\partial s^3}(0)$
- 1st deviation chirp -> change compression (keep 5kA of peak current)

	setpoint (Before Optimization)	setpoint (After Optimization)
ACC1/39 chirp (1th)	-8.9821	-8.9821
ACC1/39 curvature (2nd)	463.0532	456.0574
ACC1/39 skewness (3rd)	-226.2876	-4.0603e+04
L1 energy gain (0th)	568.8440	568.8448
L1 chirp (1th)	-11.4276	-11.6056
L2 energy gain (0th)	1.7046e+03	1.7046e+03
L2 chirp (1th)	-7.6320	-7.7720

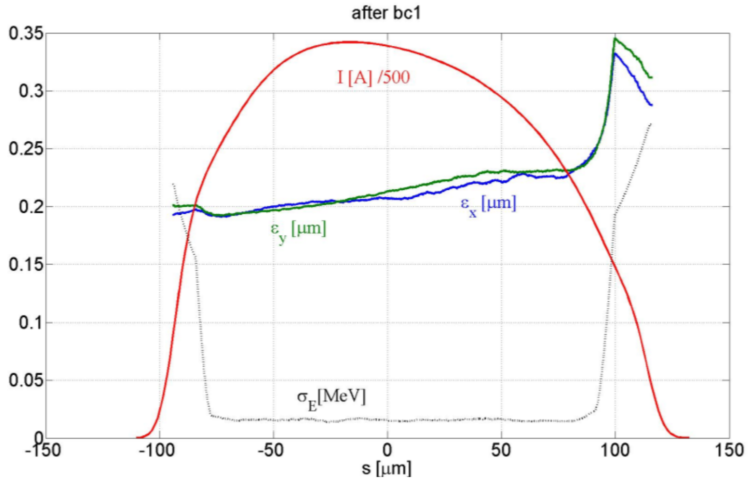
	amplitude [MV] (Before Optimization)	phase [deg] (Before Optimization)	amplitude [MV] (After Optimization)	phase [deg] (After Optimization)
ACC1	156.7200	17.9900	169.4372	28.4996
ACC39	25.6400	-175.8700	28.3990	-153.5228
L1	639.5700	27.2000	641.6646	27.5615
L2	1.8321e+03	21.5000	1.8367e+03	21.8576
L3	1.5107e+04	0	1.5107e+04	0

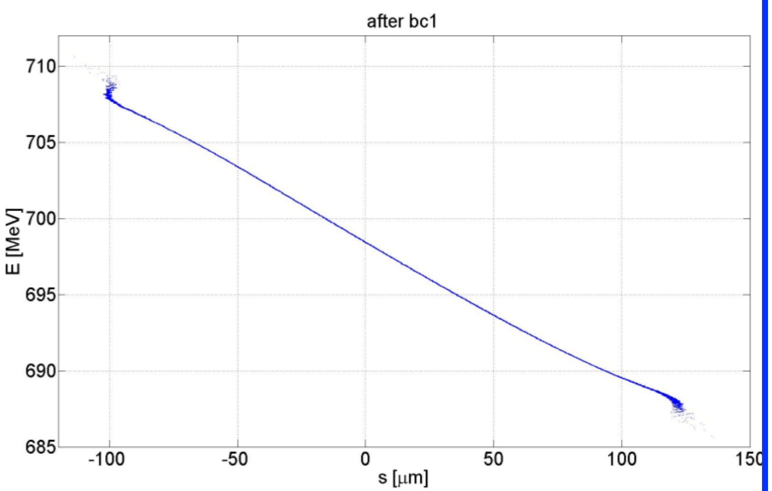
Before Optimization — After Optimization

17.5GeV, 100pC, 5kA case. Optimization performed with RF tweak 5*

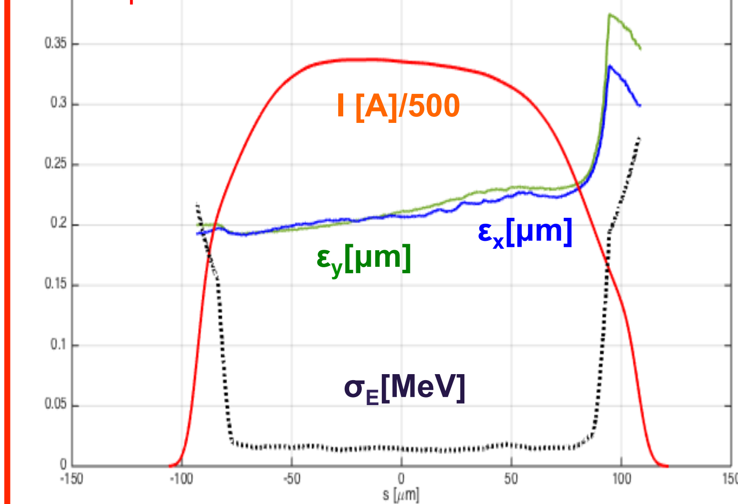
Comparison of distributions after BC1

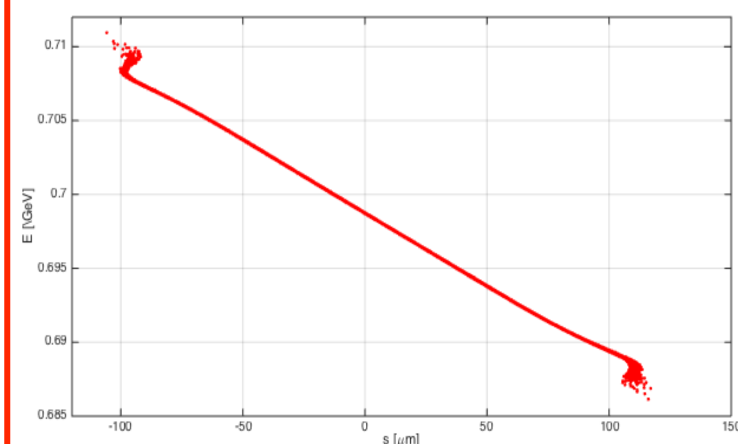
Before Optimization





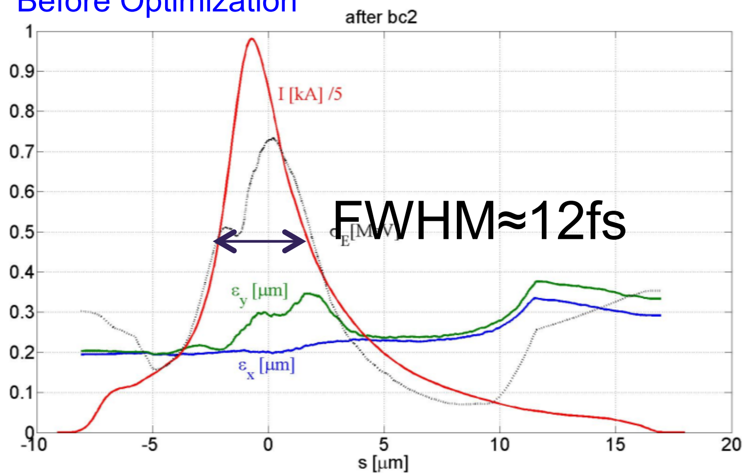
After Optimization

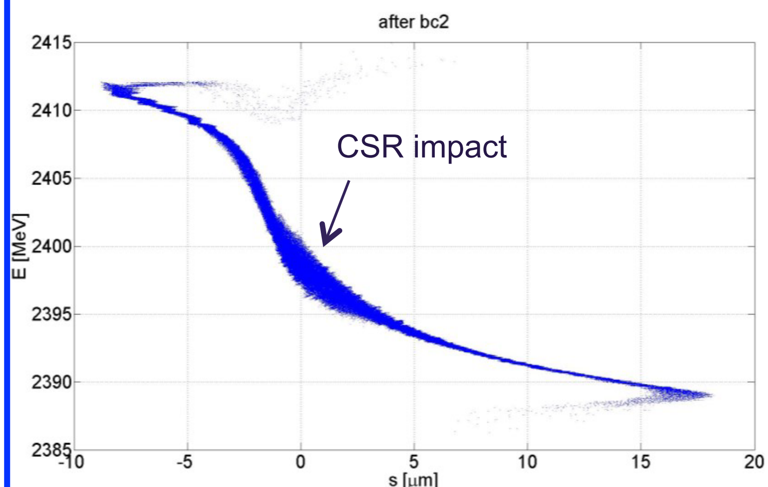




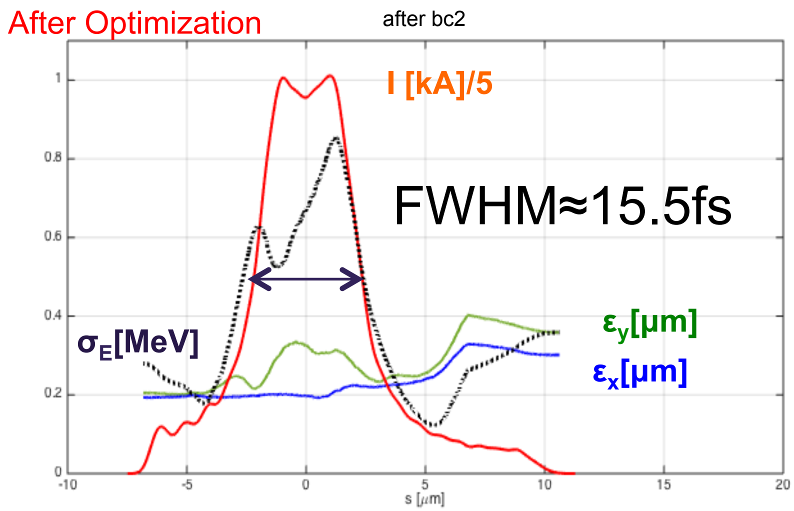
Comparison of distributions after BC2

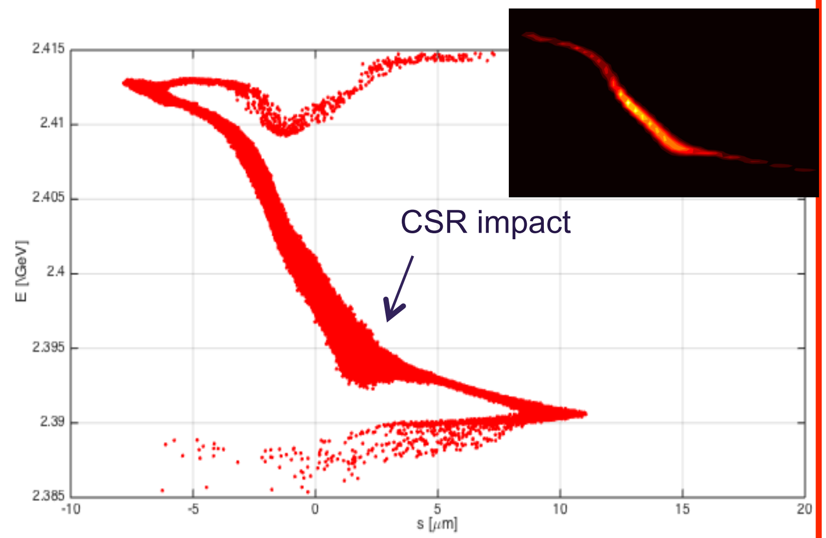
Before Optimization





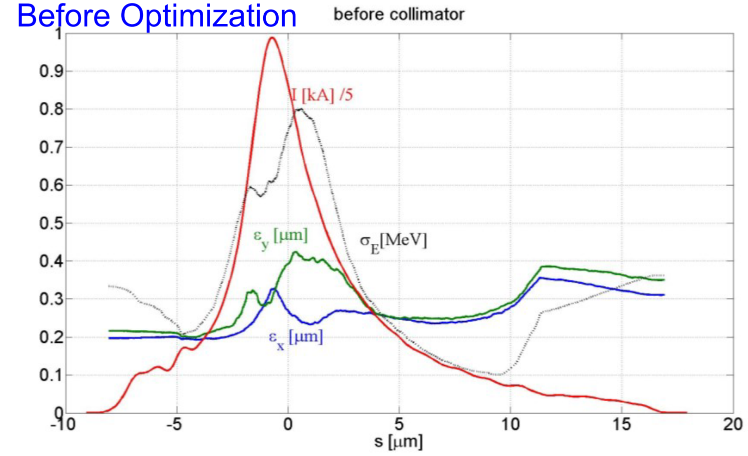
After Optimization

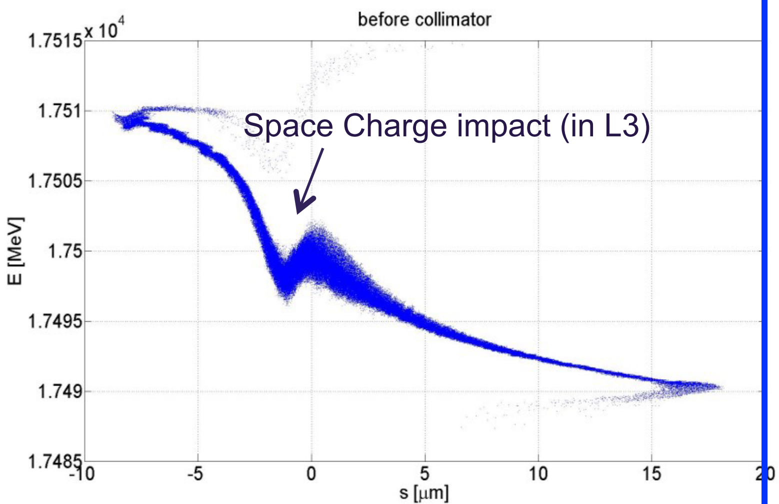




Comparison of distributions before collimator

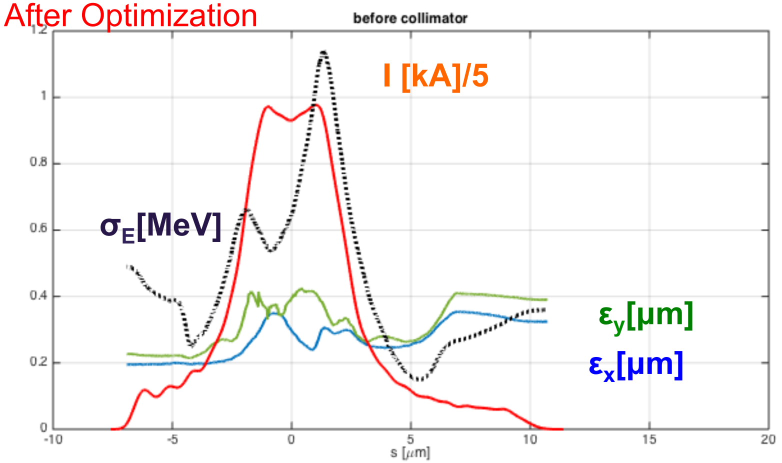
Before Optimization

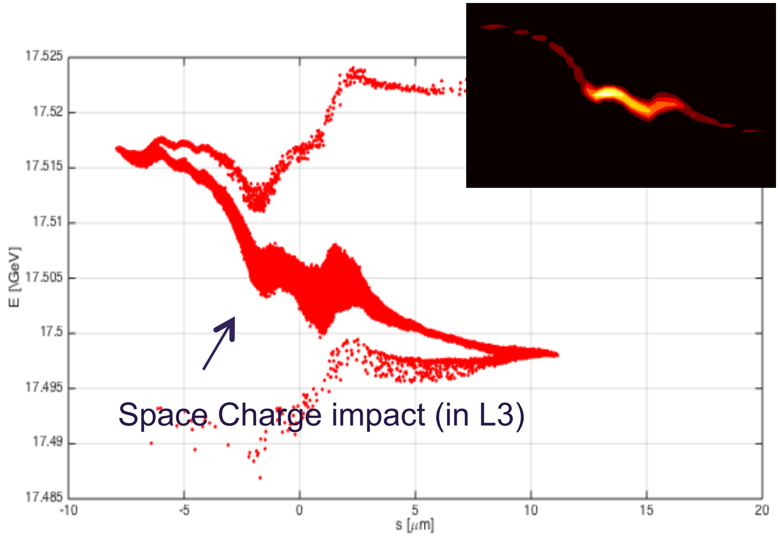




Space Charge impact (in L3)

After Optimization

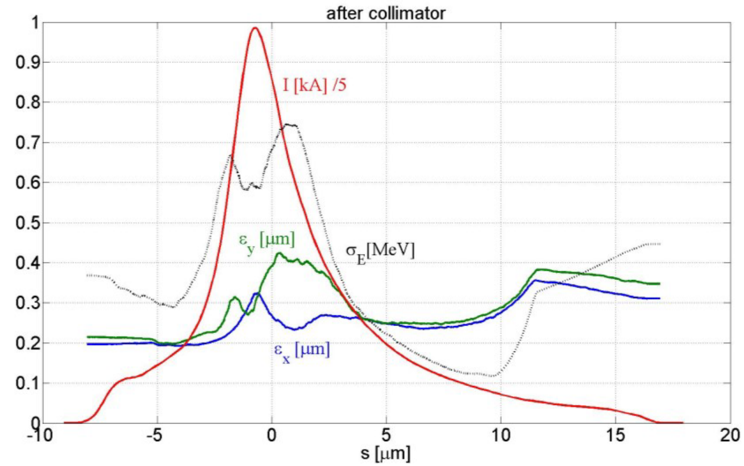


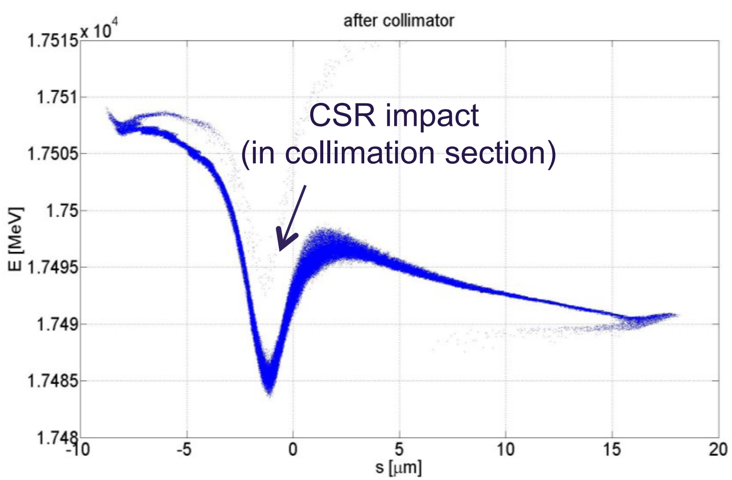


Space Charge impact (in L3)

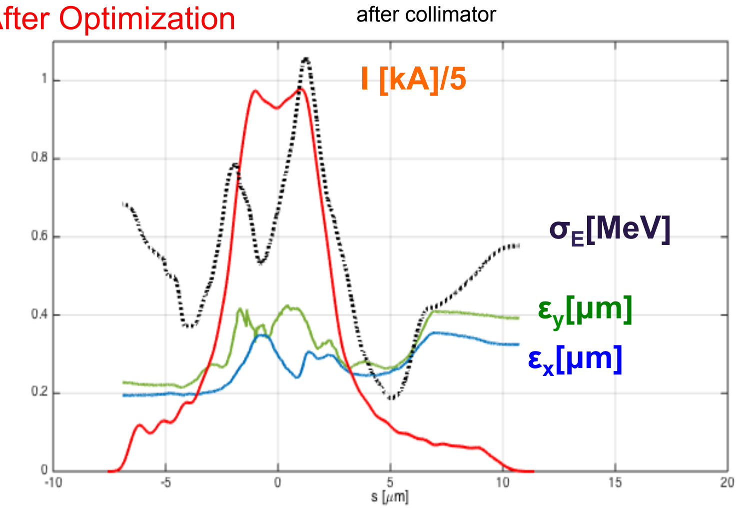
Comparison of distributions after collimator

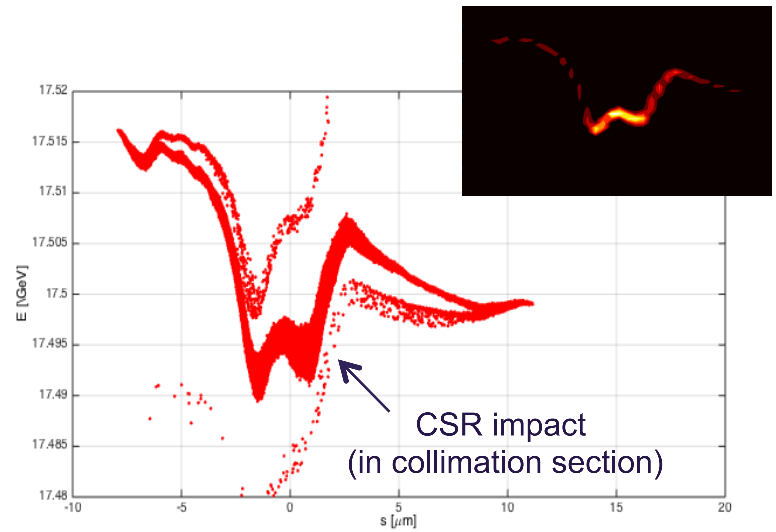
Before Optimization





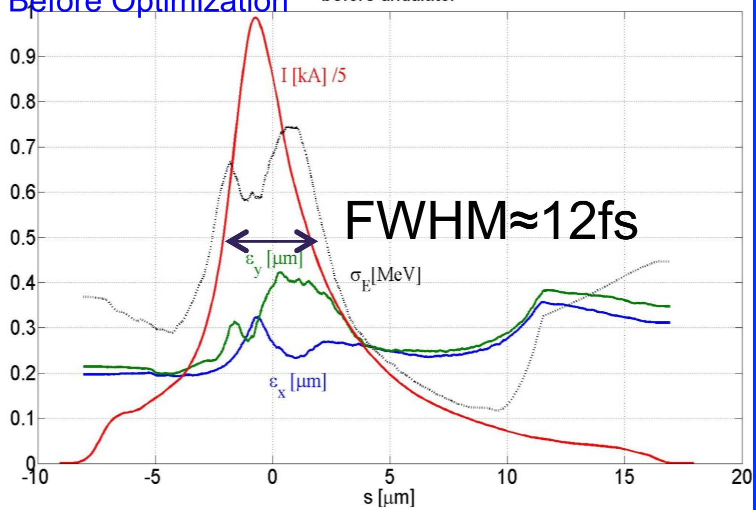
After Optimization

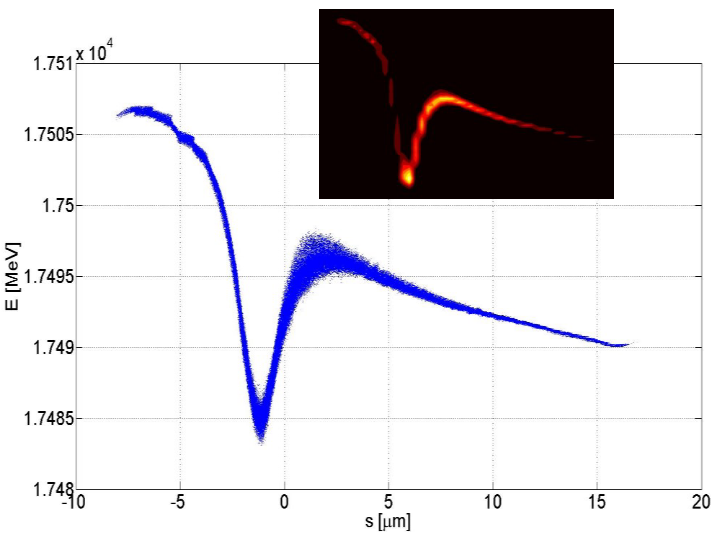




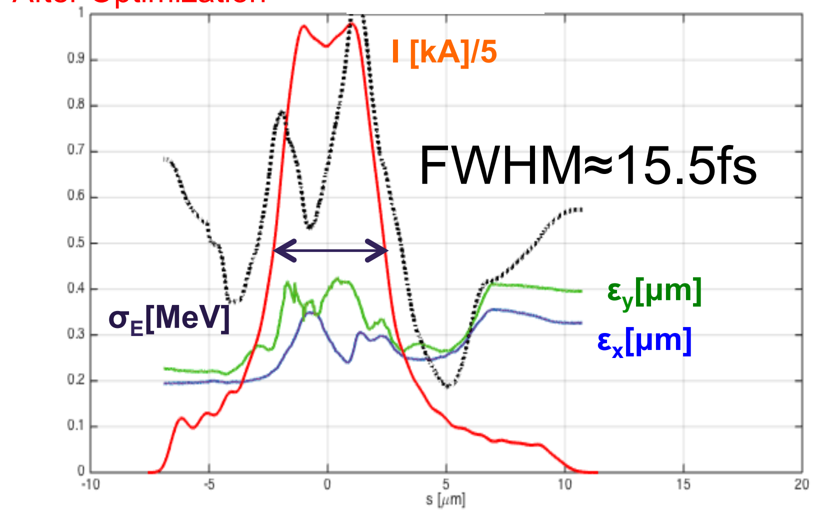
Comparison of distributions before undulator

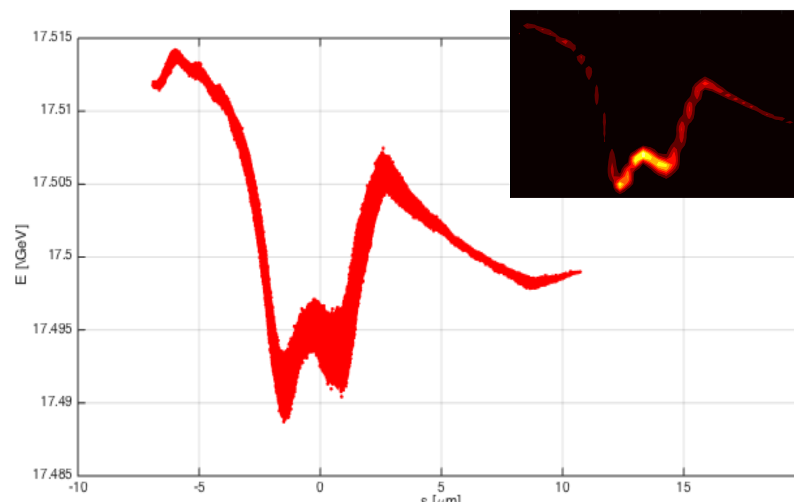
Before Optimization





After Optimization





*4% bad particles removed from head and tail

HXRSS simulation results comparison

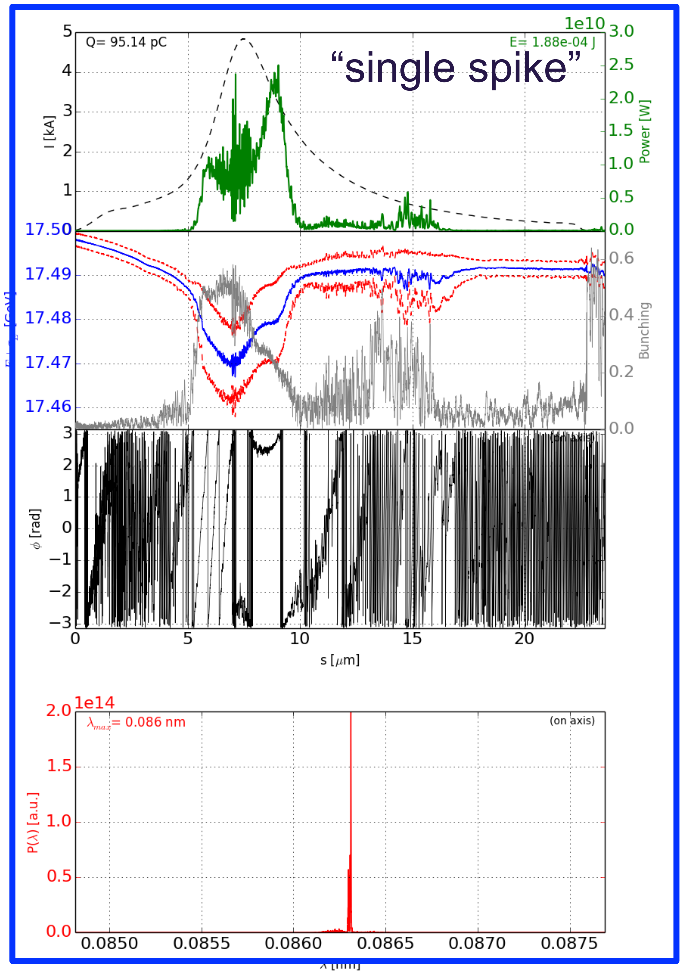
7+7+10 undulators
14.4 keV case

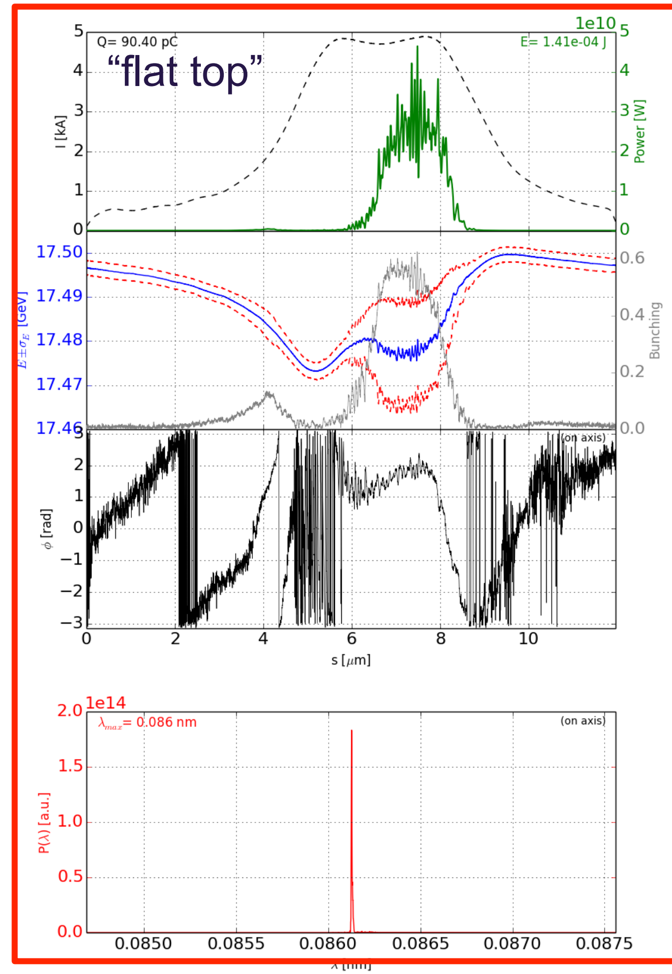
Radiation power

E & ΔE

Radiation phase

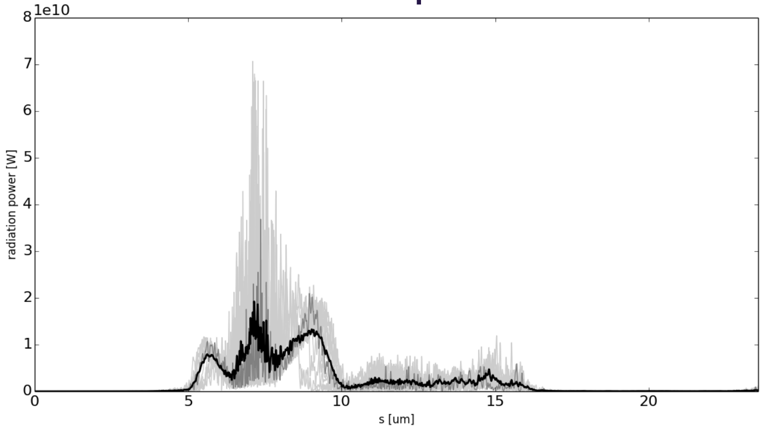
Spectrum intensity



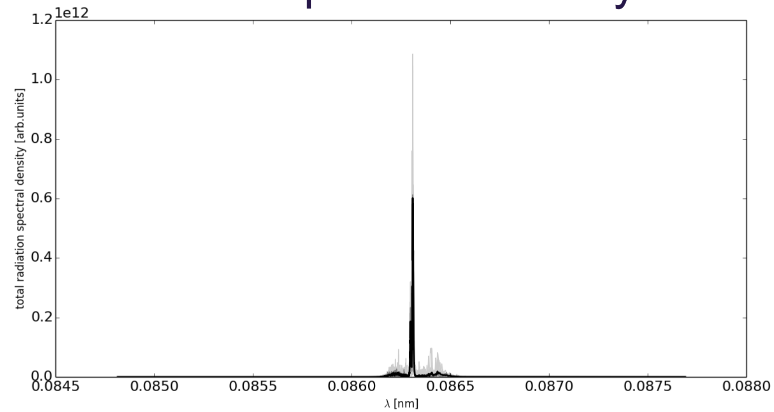


HXRSS simulation results comparison

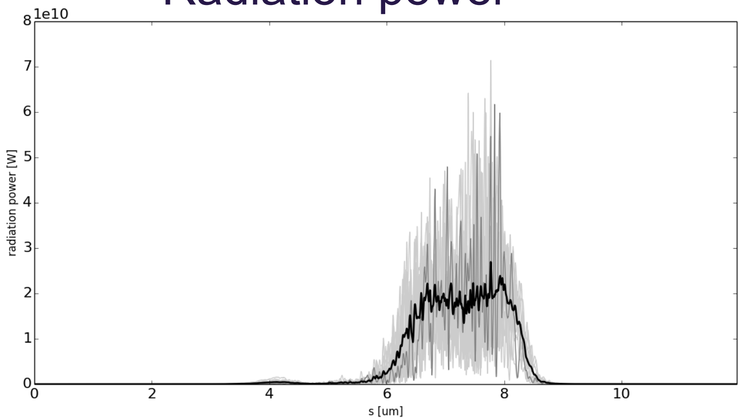
Radiation power



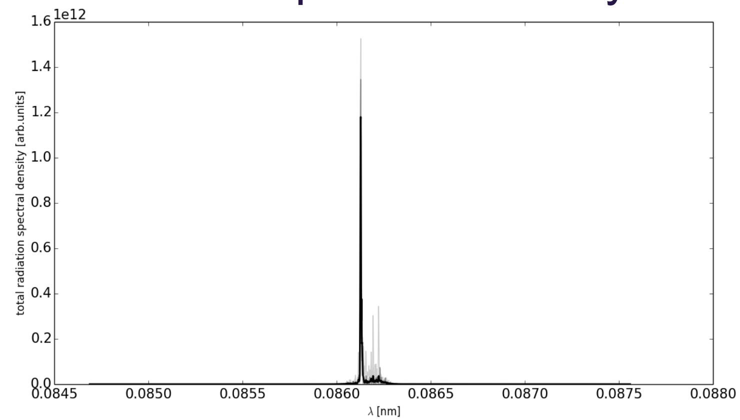
Total spectral intensity



Radiation power



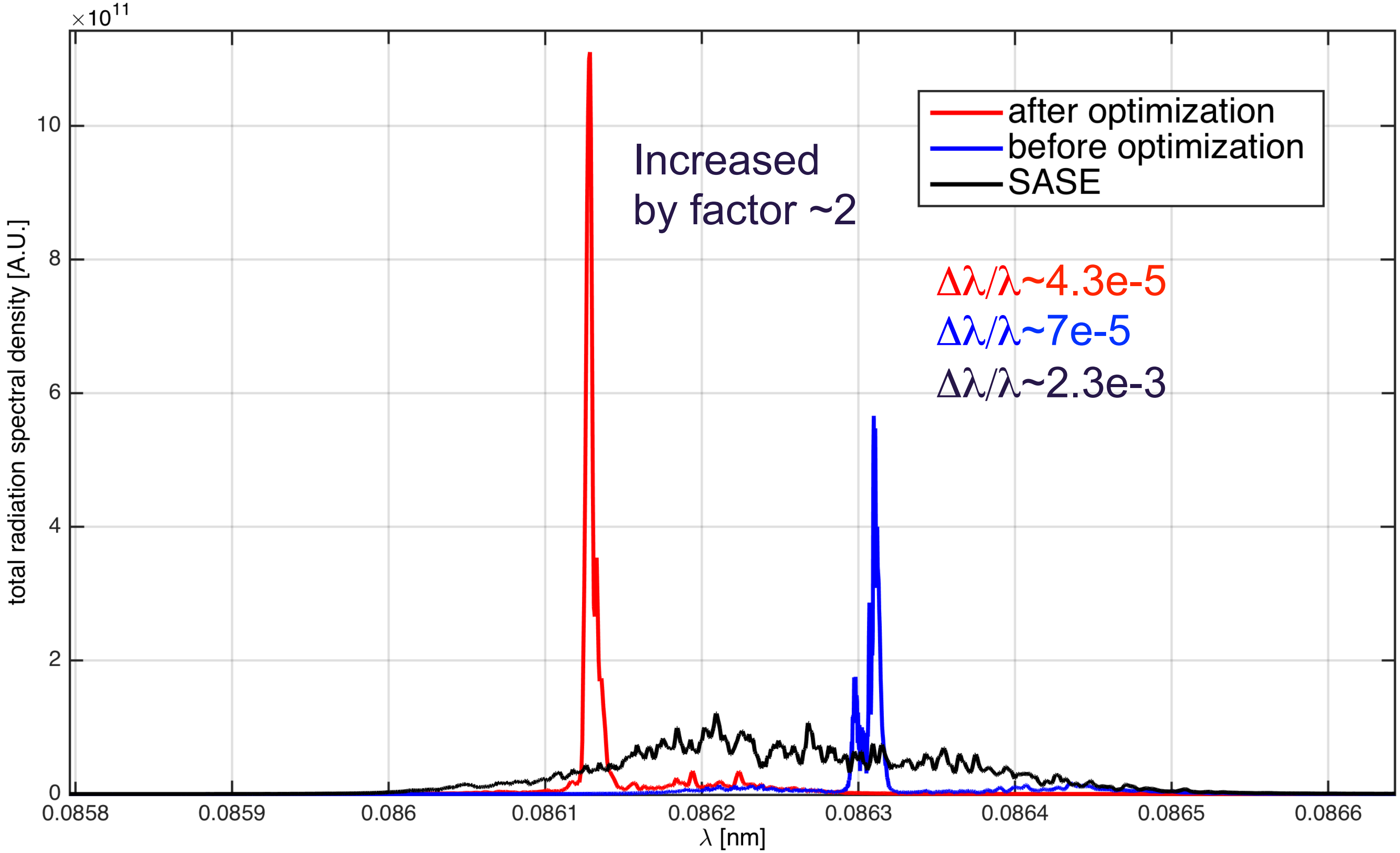
Total spectral intensity



after 7+7+12 undulators, tappering not implemented yet …

HXRSS simulation results comparison

Averaged total spectral intensity (15 events)



Future plans

- Further HXRSS studies with 100pC case
- Improve (atomization) of optimization procedure?
- Energy chirp optimization for other charges (20pC, 1nC)
- Add wakefield in collimation section
- S2E simulation for SASE2
- Simulation with updated gun parameters
- Compare simulation results with commissioning results
- …

Thank You!

- Thanks to Guangyao Feng for all the information and discussions!
- Thanks to Gianluca Geloni, Svitozar Serkez and Sergey Tomin for support on HXRSS simulations!