Simulation studies on the self-seeding option at FLASH

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Future Light Sources

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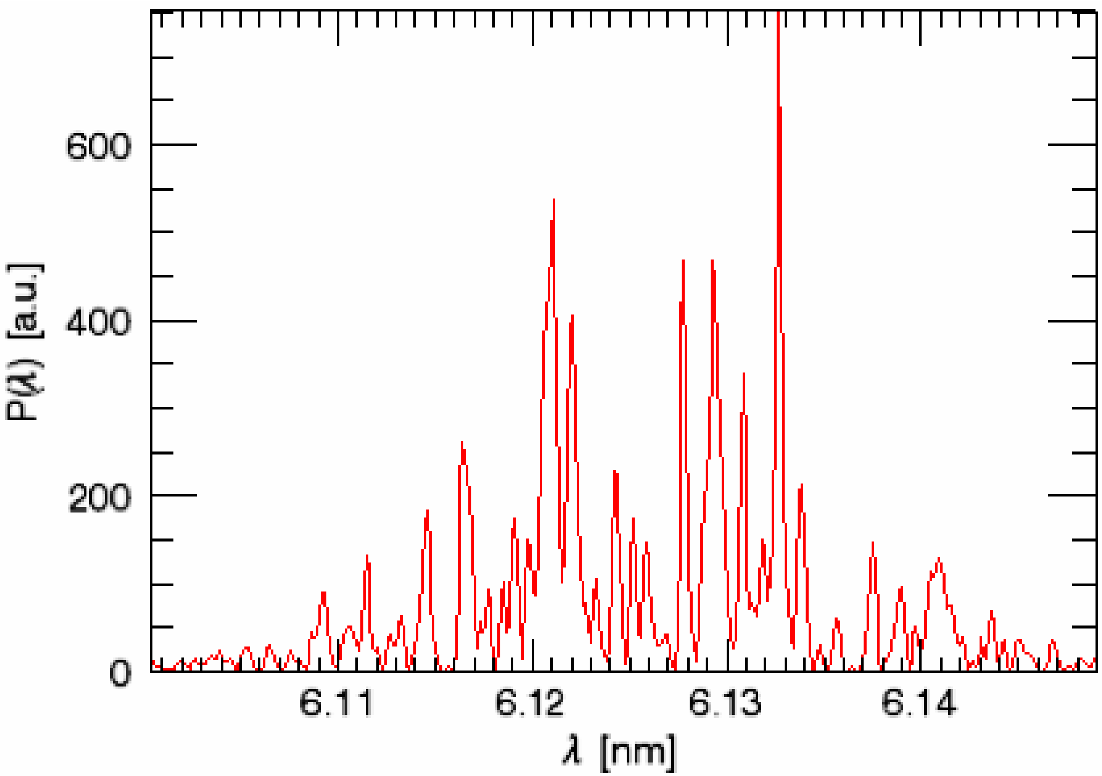
Motivation

typical spectrum of SASE FEL radiation



Due to the start up from noise:

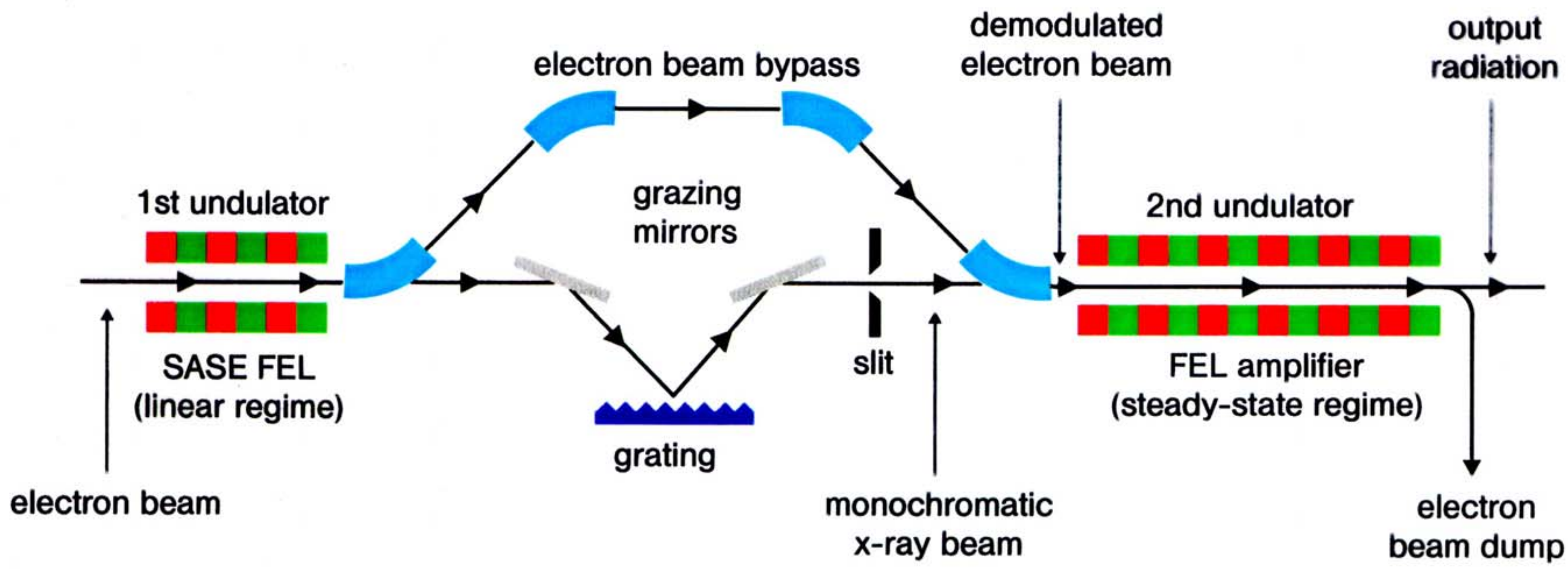
⇒ wide band output radiation (~0.5%)

⇒ the output consists of a number of uncorrelated spikes

⇒ poor temporal coherence of the generated light

Basic principles of the self-seeding option [1)]

1) J. Feldhaus et al. / Optics Communications 140(1997) 341-352



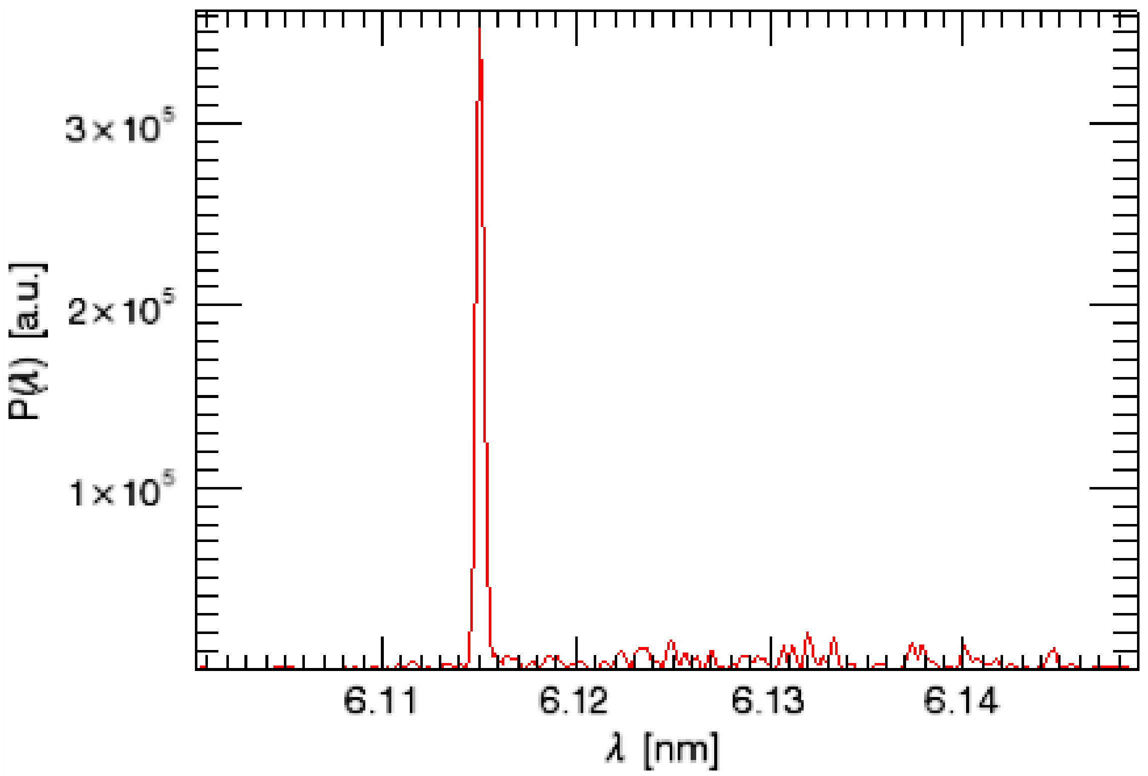
Schematic view of the seeding option for FLASH

Basic requirements:

1) The 1st section operates in linear high-gain regime, <P_{SASE}>~10MW
2) The micro bunching is smeared out after the magnetic chicane
3) The monochromator resolution $\Delta\omega/\omega \approx 5 \cdot 10^{-5}$
4) The seeding power P_{SEED}~10kW >> shot noise power P_{SHOT}~10W
5) The seed pulse is amplified to saturation in the 2nd undulator section

Features of the self-seeding option

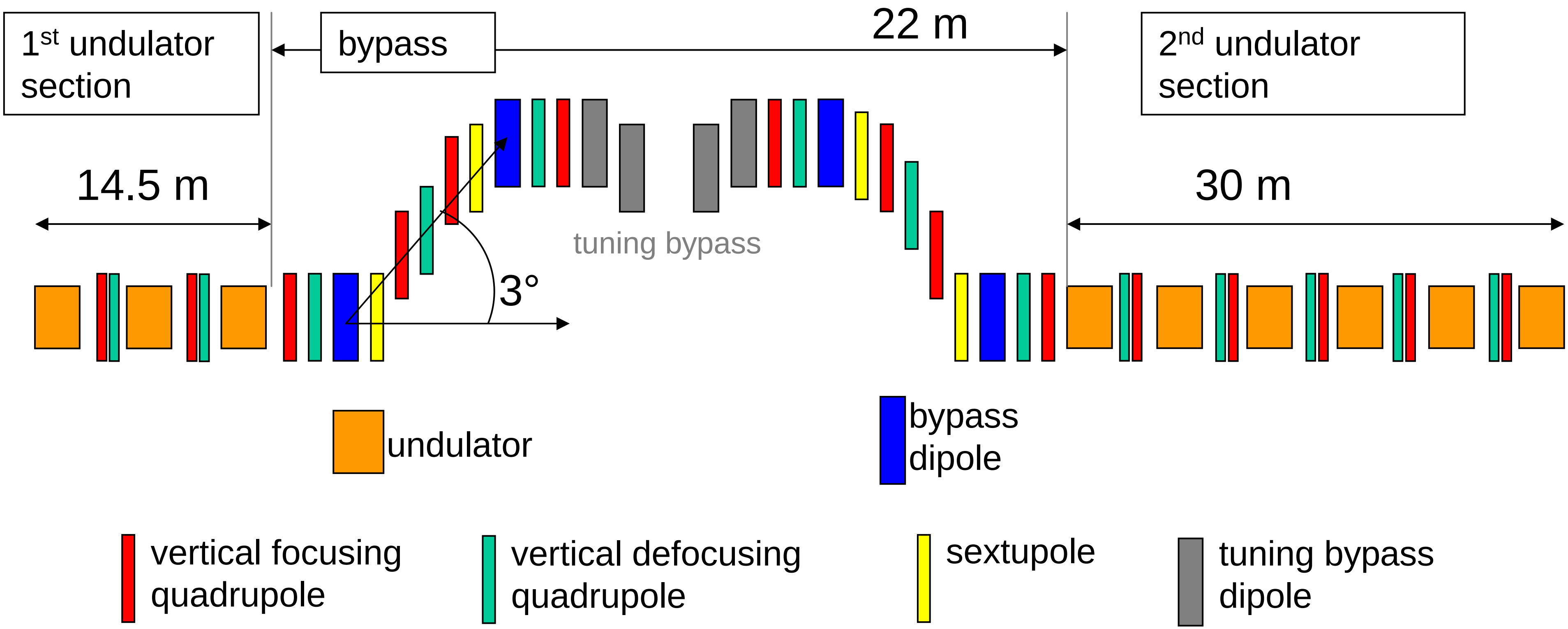
spectrum of the radiation after the second undulator



- output radiation of narrow bandwidth ($\Delta\omega/\omega$ ~ 100 times smaller than SASE)
- full transverse and temporal coherence
- continuously tunable output wavelength (λ_R=6..60 nm)
- independent on external radiation sources
- minimized intensity fluctuations (σ_W~ 5%)[1)]

1) E. Saldin et. al. NIM A 445(2000), 178-182

Electron beam optics [1, 2]



for each radiation wavelength λ_R

- tune the quad strength to achieve linear regime in the 1st section
- use the bypass magnets to match to the optics in the 2nd section

1) B. Faatz et. al., NIM A475, 603 (2001)

2) R. Treusch et. al. "The Seeding Project for the FEL in TTF Phase II", HASYLAB annual report 2001

Simulation techniques

FEL calculations

Step 1: **1st section** - GENESIS

- 8192 macro particles/slice. The particle distribution exported into partfile

Step 2: **bypass + 2nd section** – GENESIS

- import the particle file from the 1st run
- bypass integrated in GENESIS by means of a transfer matrix (A.Meseck)
- bypass transfer matrix calculation, matching etc. – ELEGANT
- certain power and wavelength assumed for the external seeding. Implemented using P_{SEED}~10kW, λ_{SEED}=6..60nm

CSR-effects studies

Step 1: **1st section + bypass** - ELEGANT

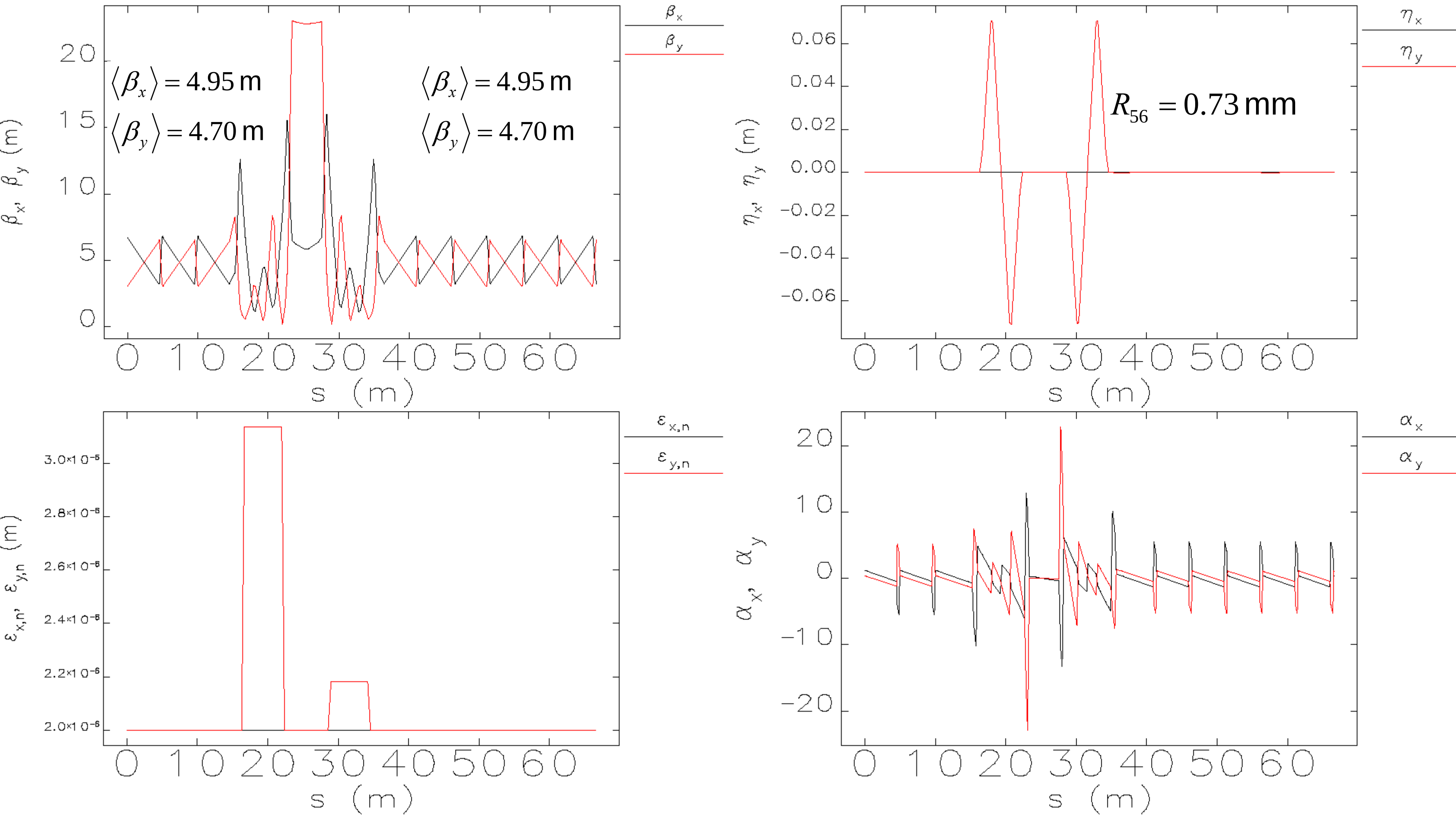
- 10^6 macro particles/bunch. ELEGANT2GENESIS is used to convert the final phase space distribution into averaged slice information for GENESIS (beamfile)

Step 2: **2nd section** – GENESIS

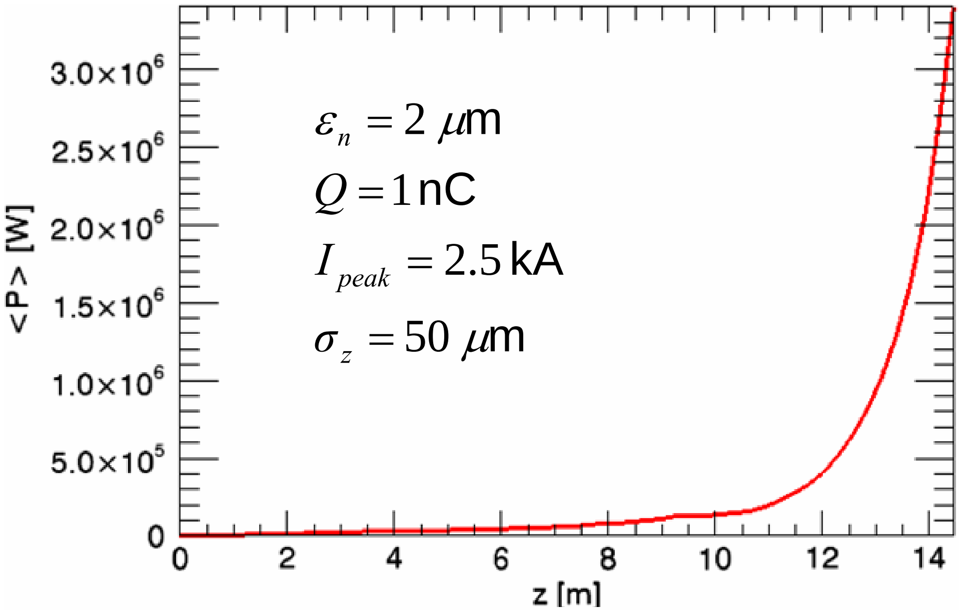
- import the beamfile from the 1st run
- certain power and wavelength assumed for the external seeding. Implemented using P_{SEED}~10kW, λ_{SEED}=6..60nm

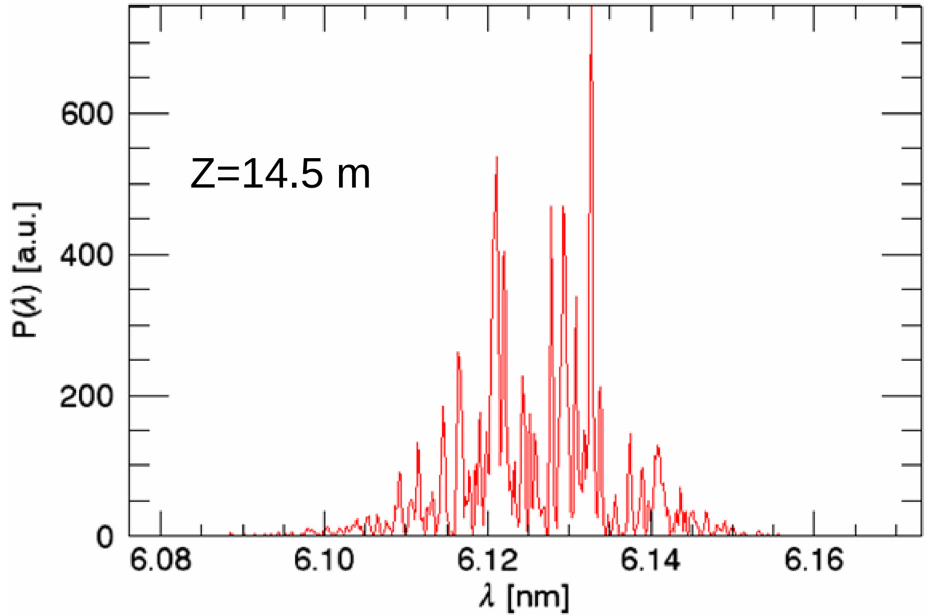
Not included: space charge effects, wave front propagation through the monochromator beamline (to be done)

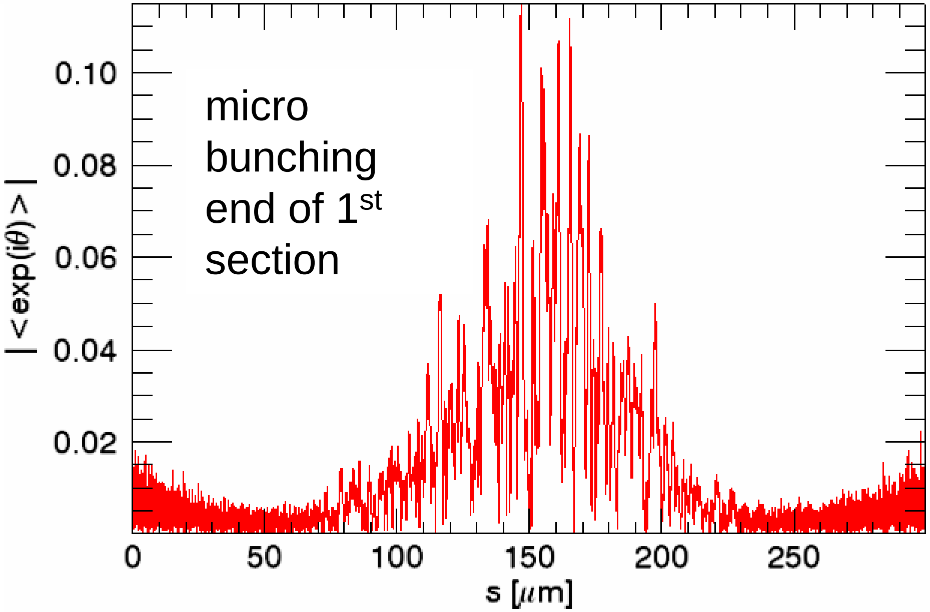
Electron optics – 6 nm

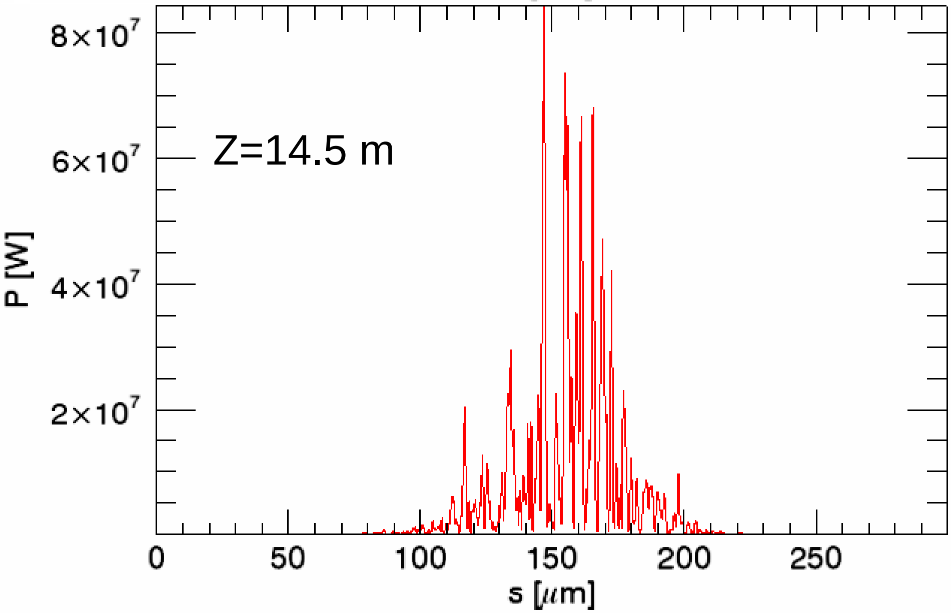


FEL calculations – 6 nm(1st section)









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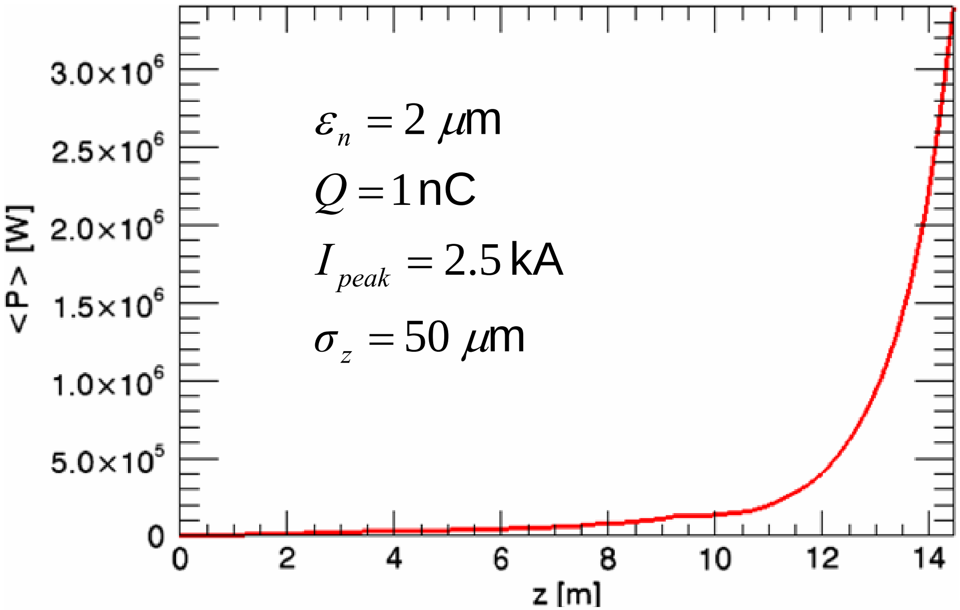
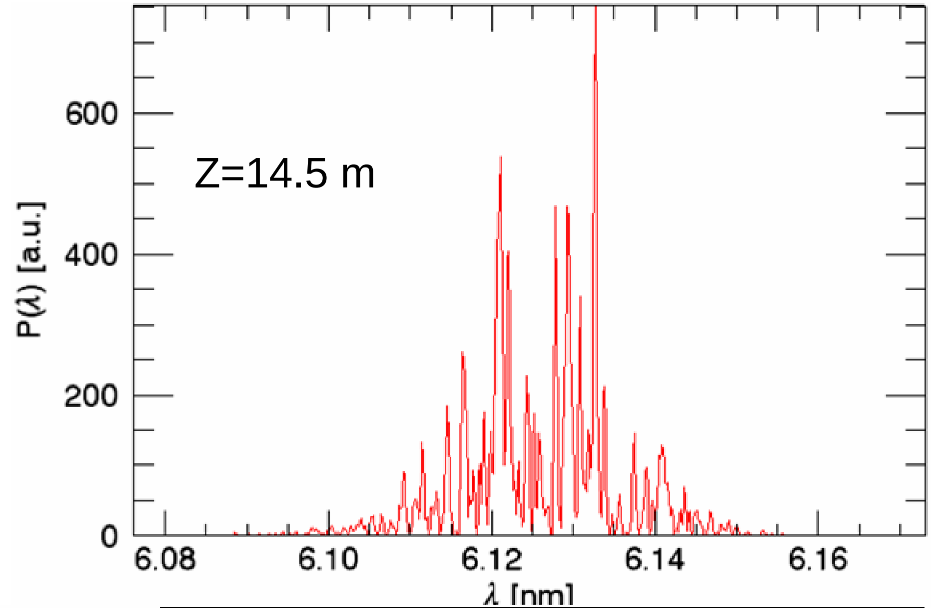
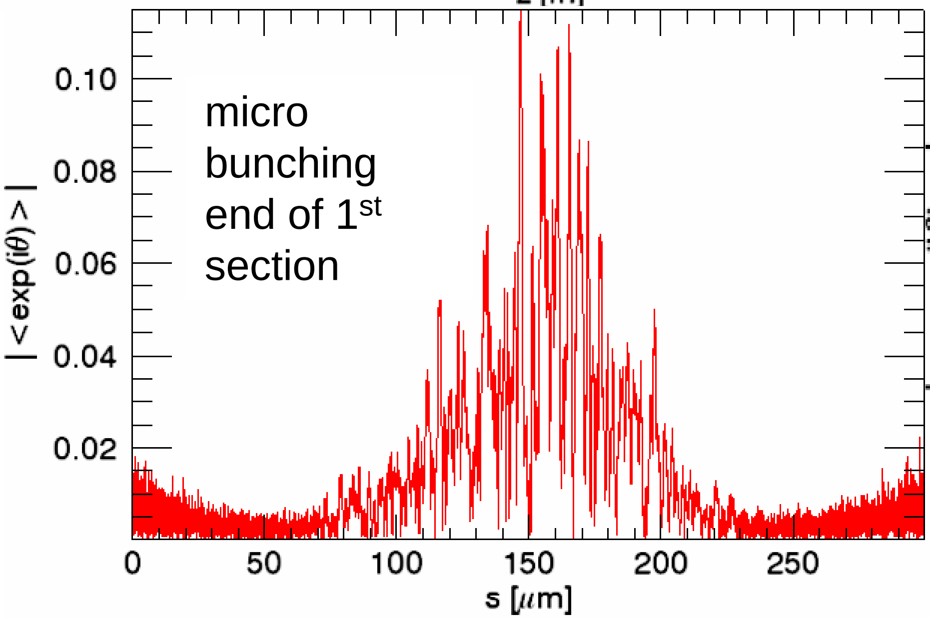
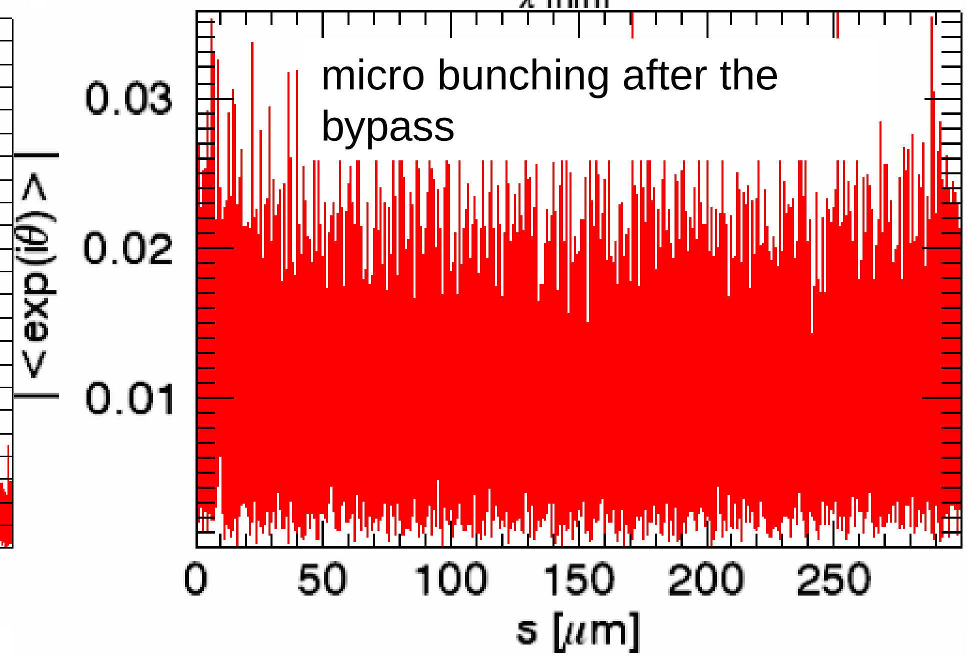
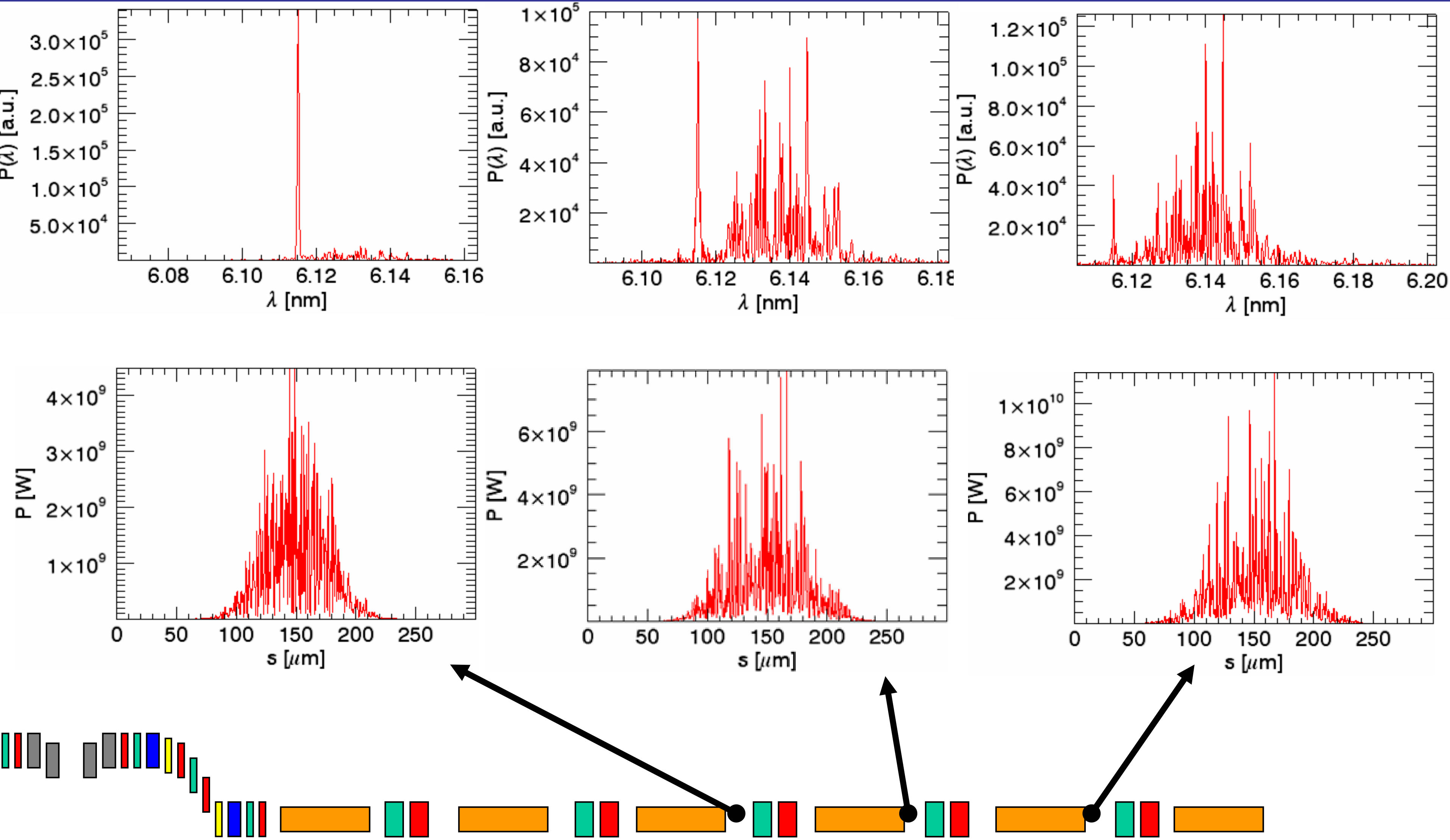




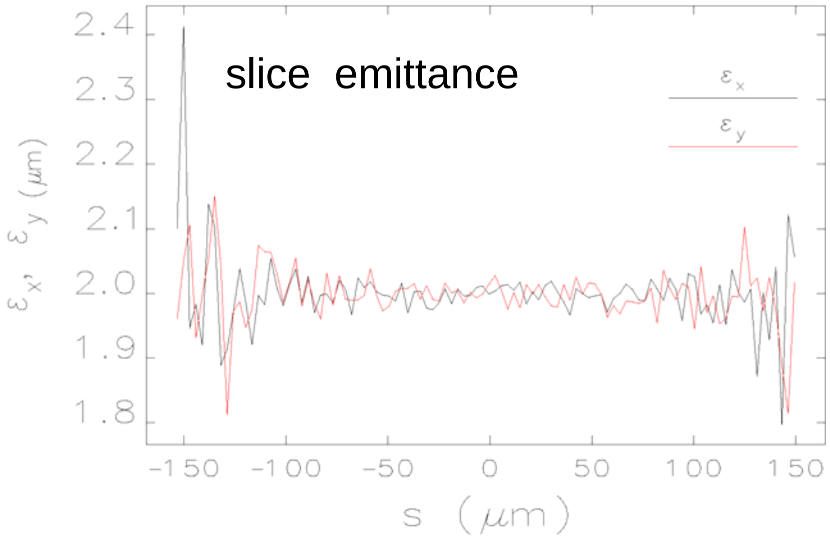


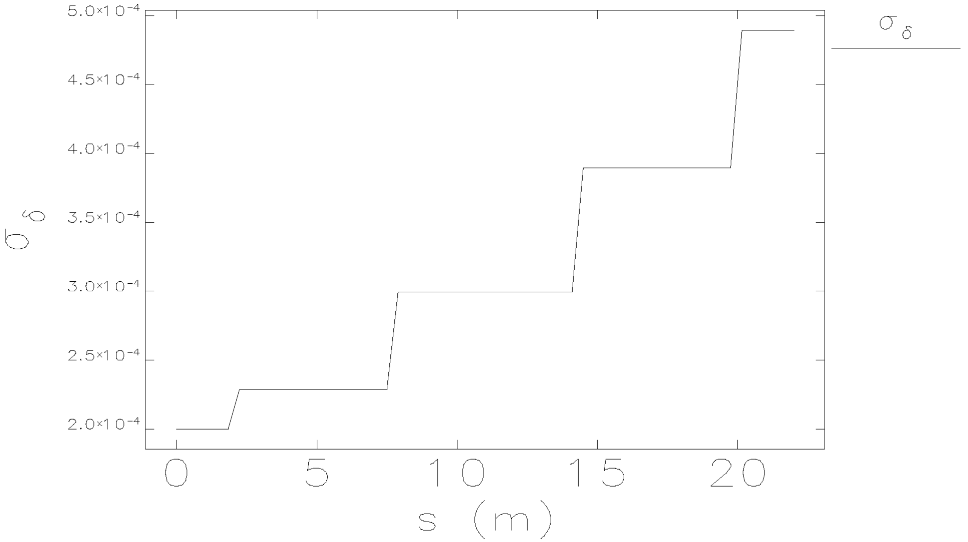


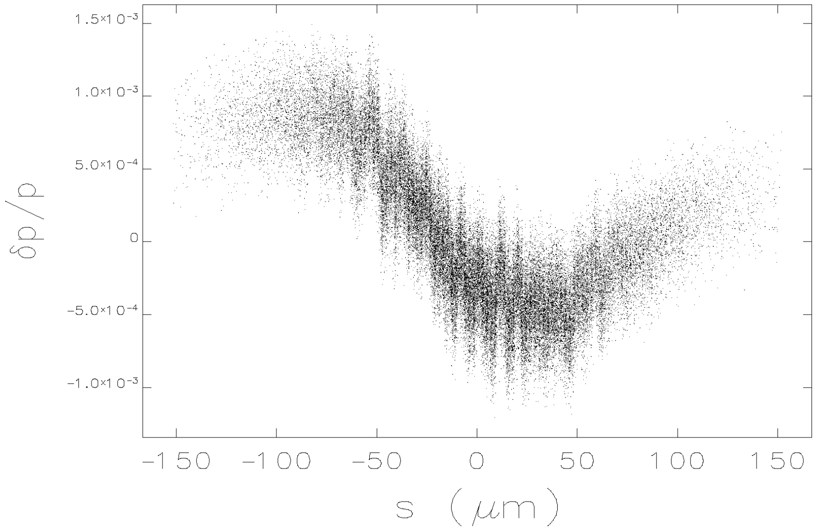
FEL performance – 6 nm(2nd section)

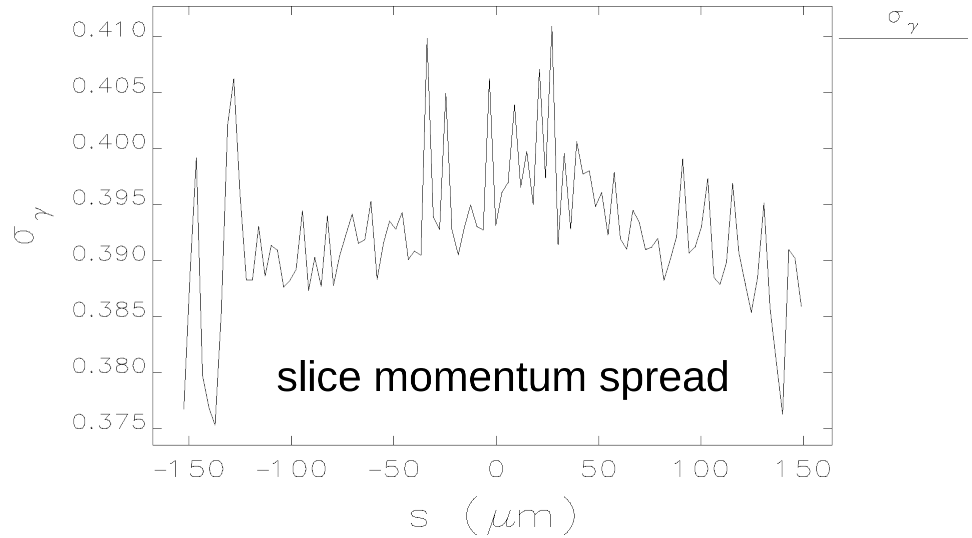


CSR effects at 6nm (ELEGANT)

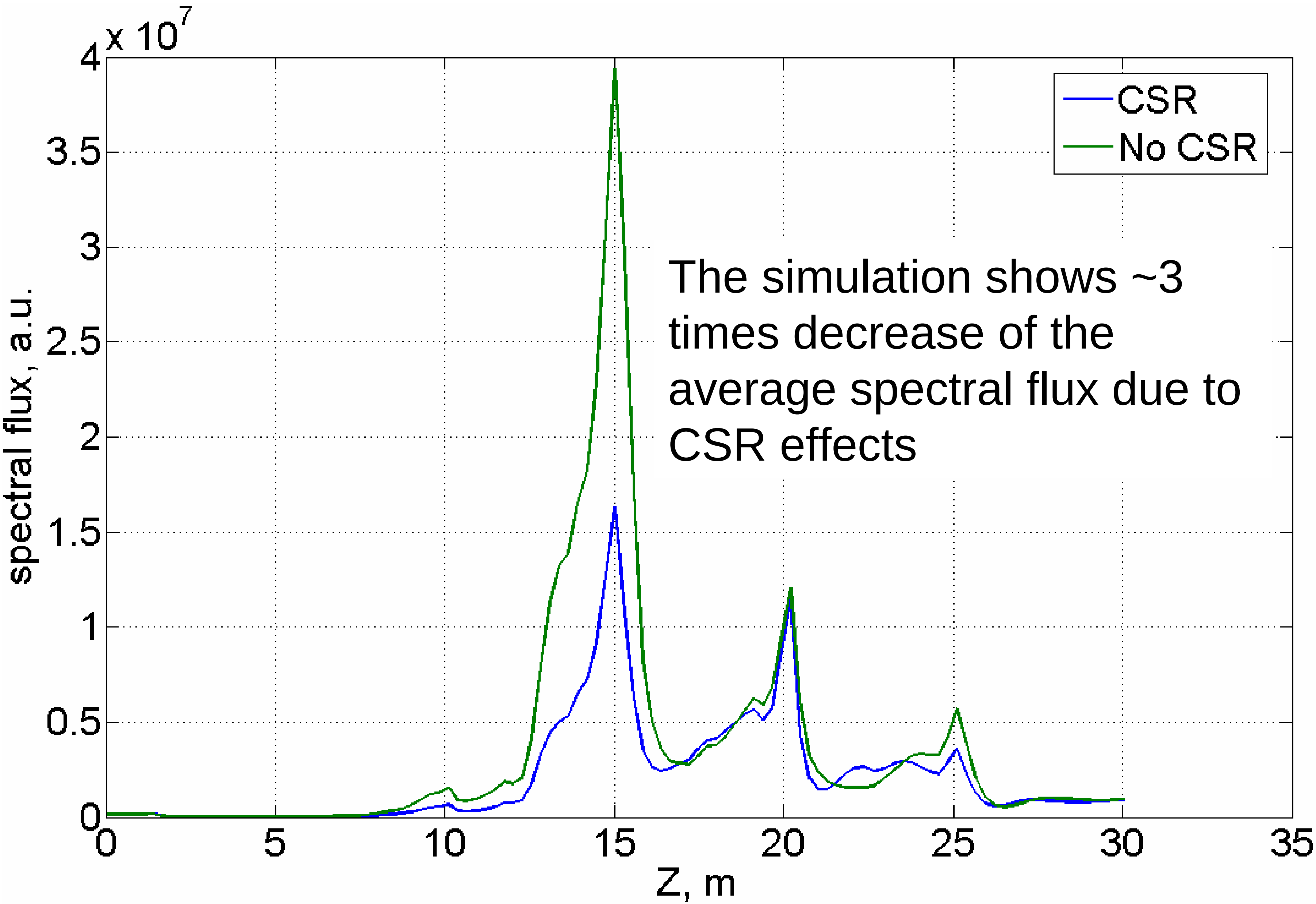






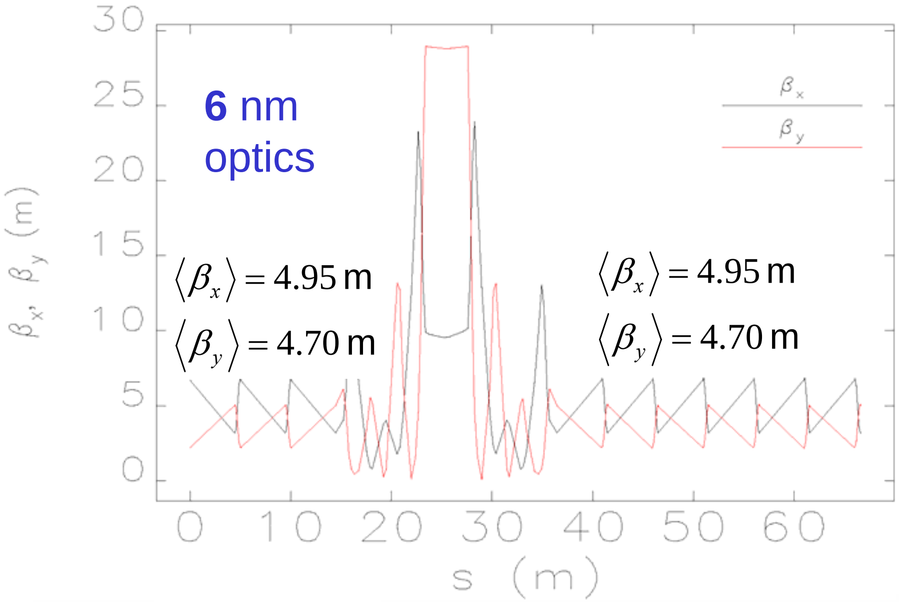


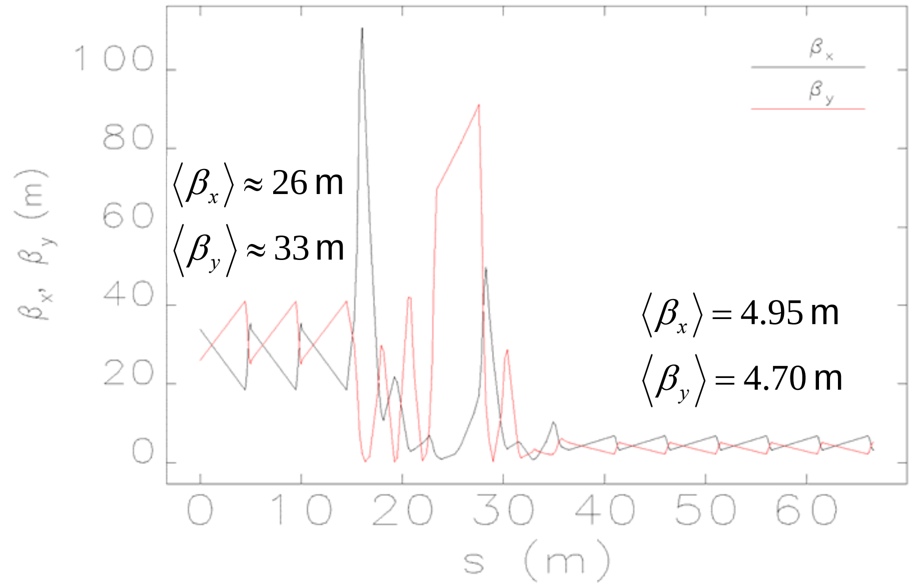
CSR impact on FEL performance at 6nm

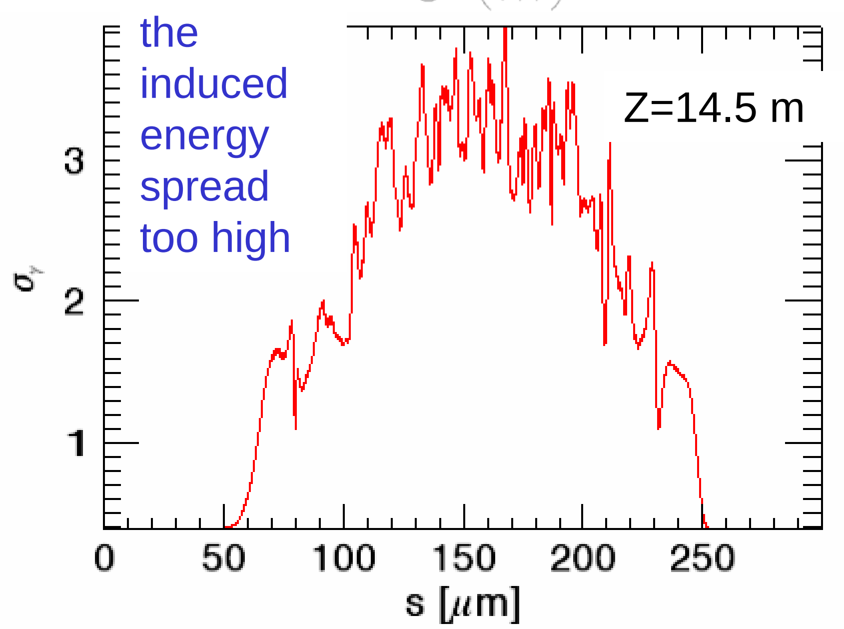


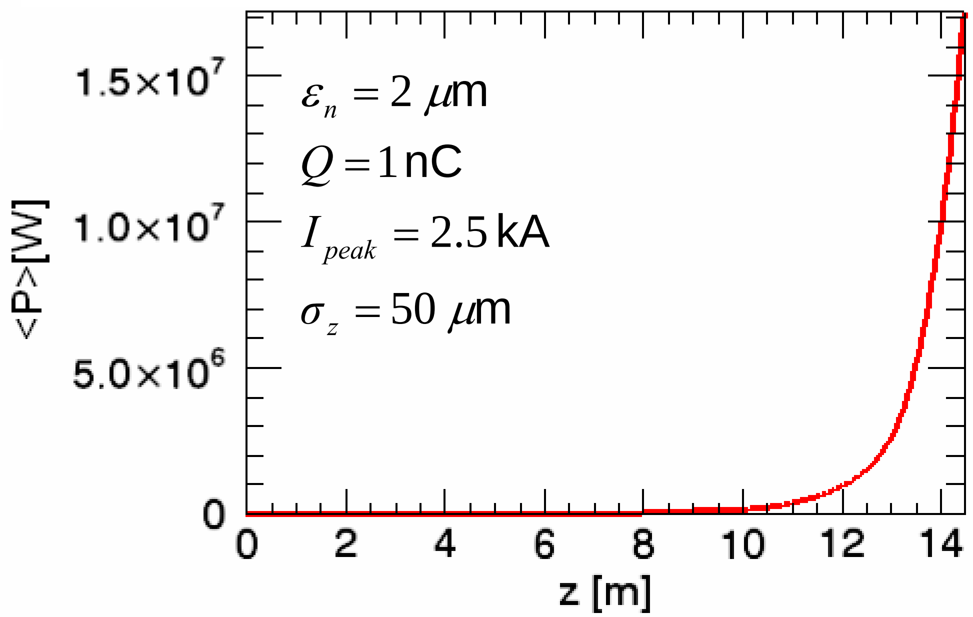
The simulation shows ~3 times decrease of the average spectral flux due to CSR effects

Electron optics – 60 nm



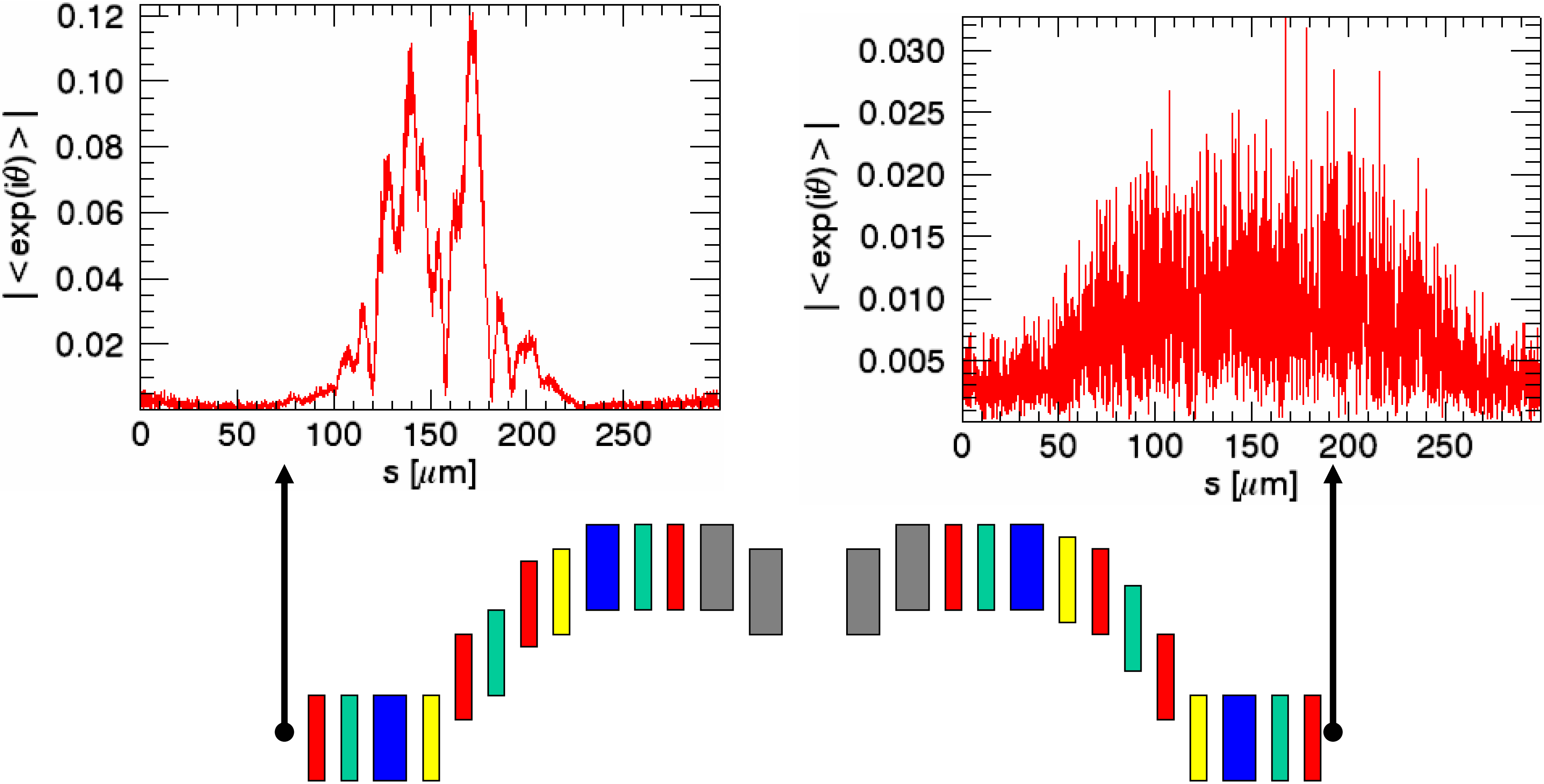




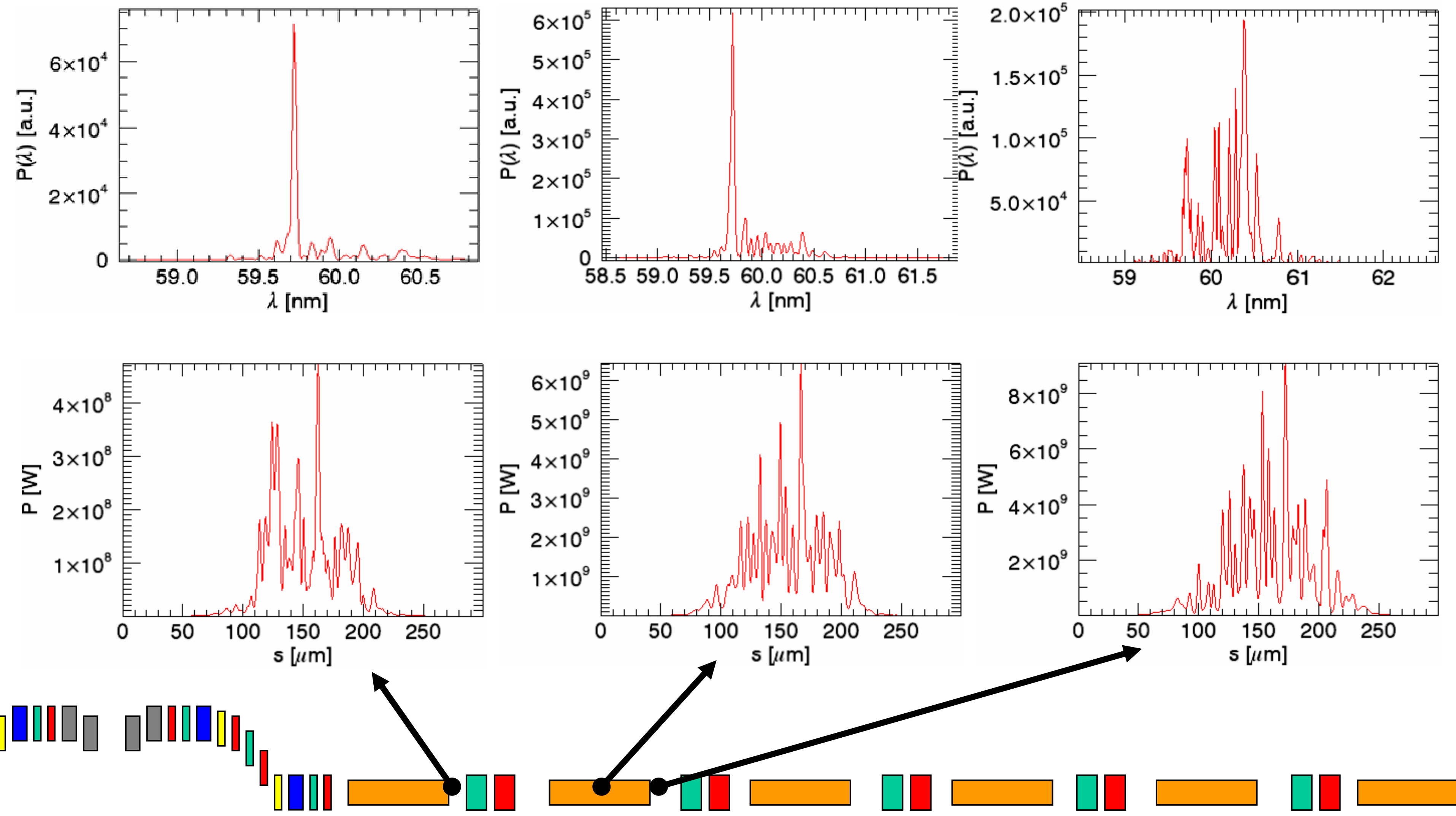


Electron optics – 60 nm

Micro bunching before and after the bypass



FEL performance – 60 nm



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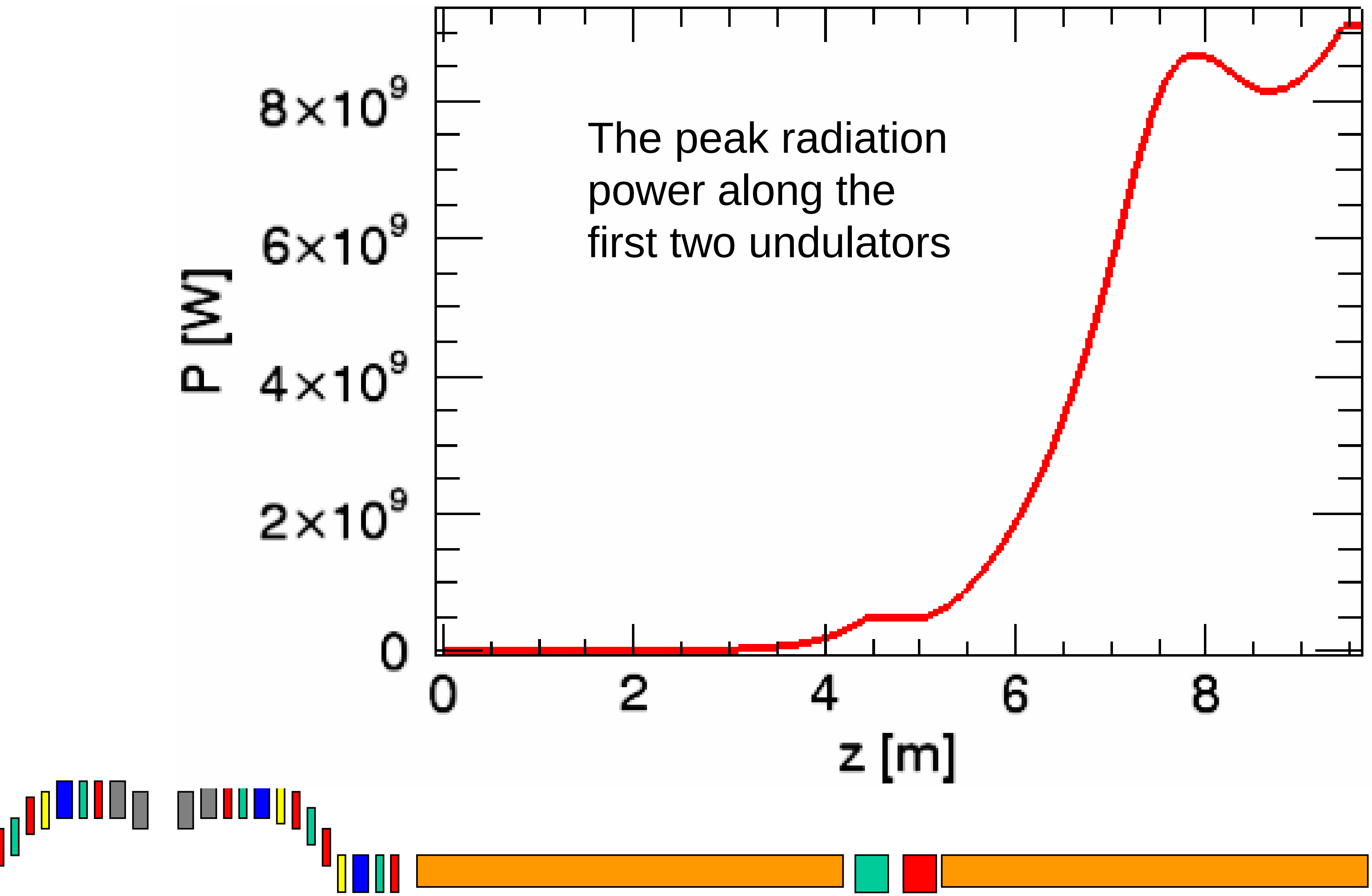
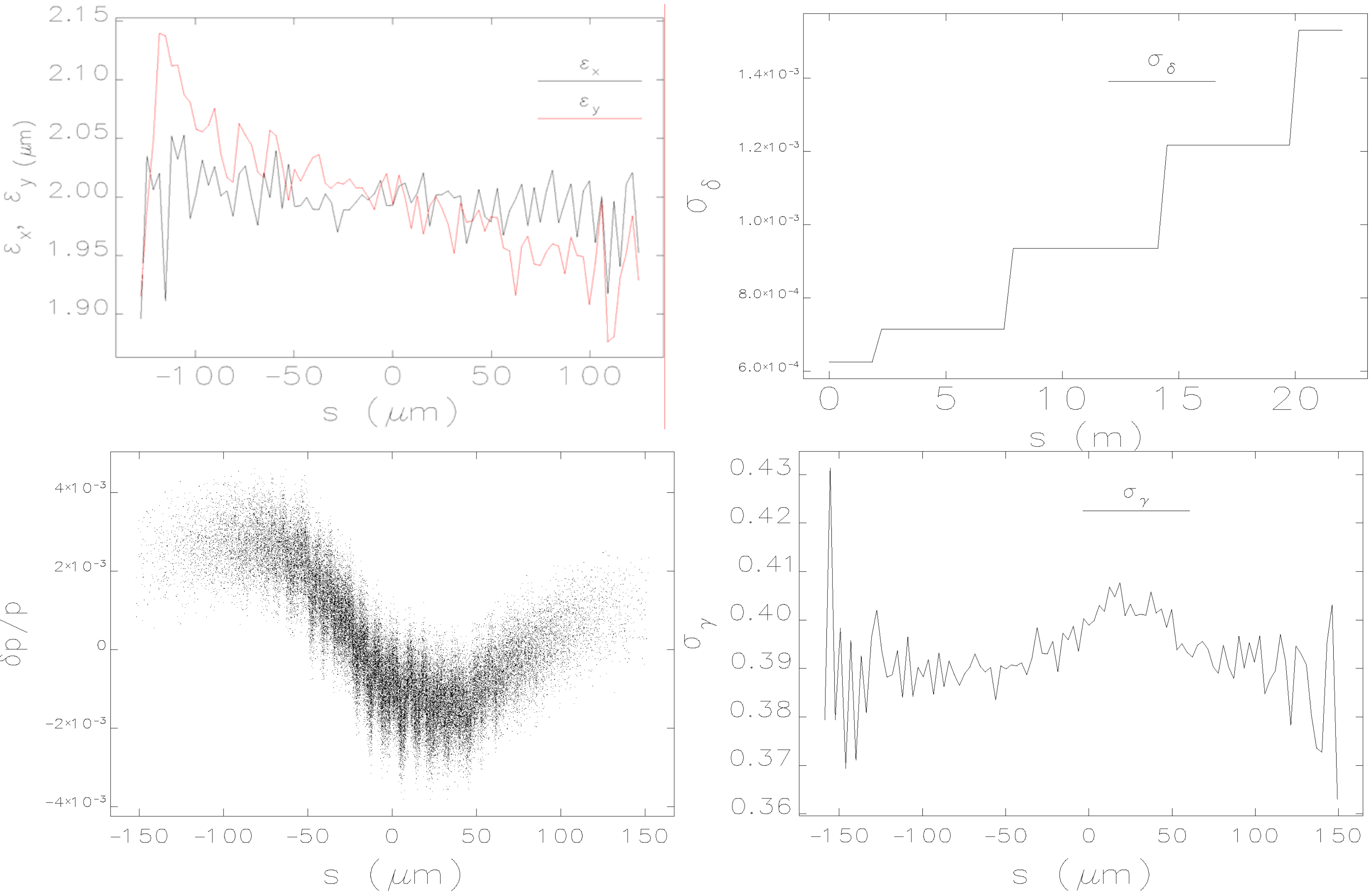
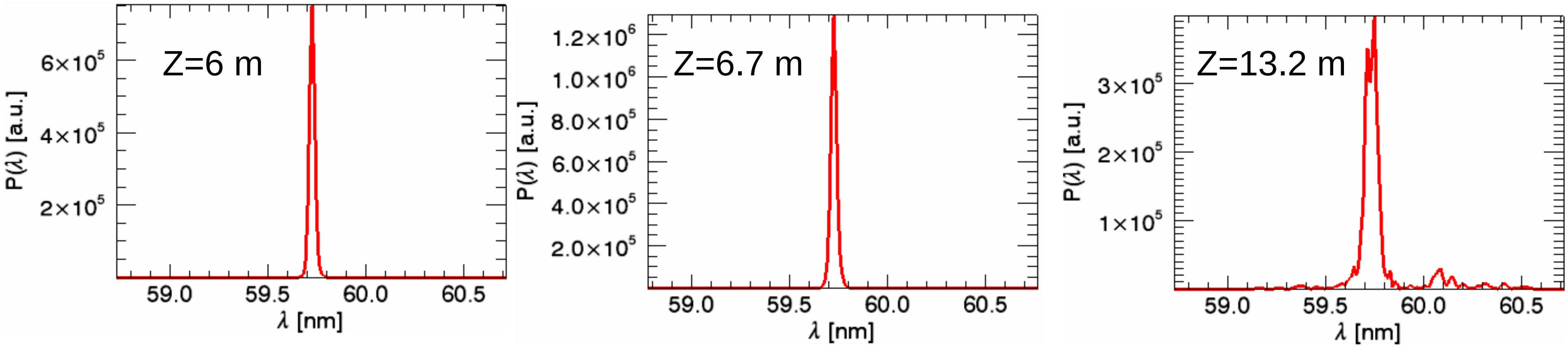


CSR effects at 60nm (ELEGANT)

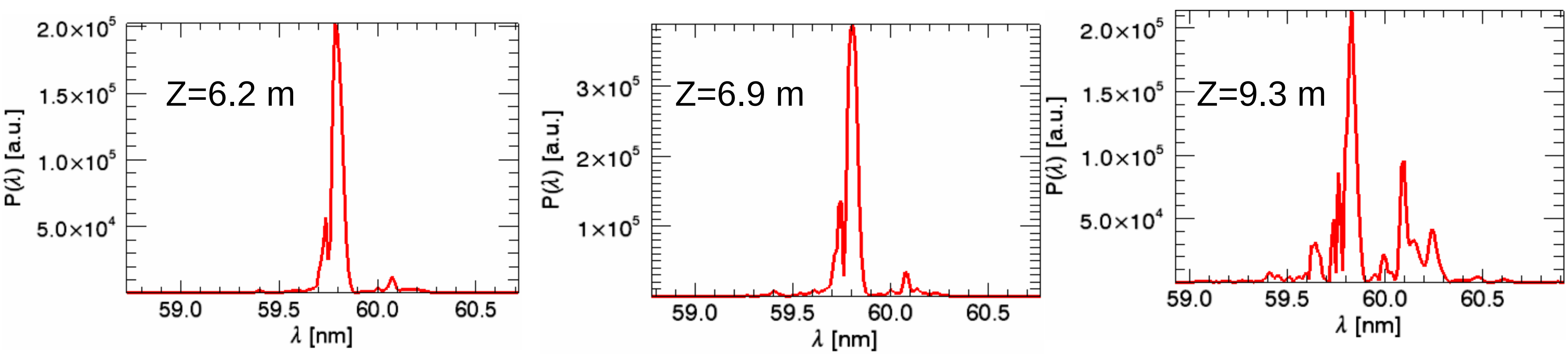


CSR impact on FEL performance at 60nm

CSR effects not included

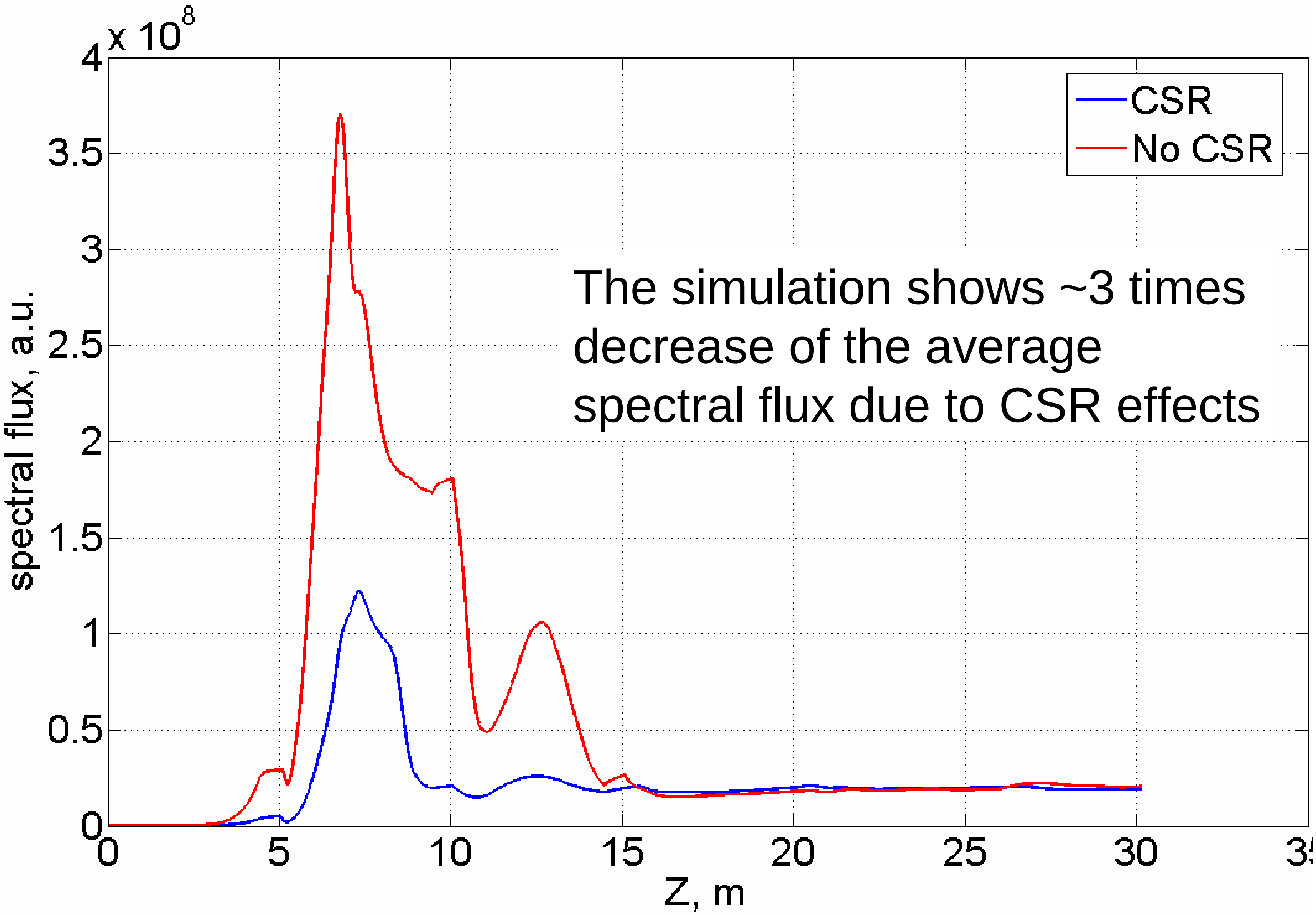


P_{peak}=1GW P_{peak}=2GW P_{peak}=3GW



CSR effects included

CSR impact on FEL performance at 60nm



Outlook

- Further investigations of the FEL performance
  - at different electron beam energies γ
  - at various seeding wavelengths λ (for fixed γ)
- Studies on the influence of the electron beam optics on the FEL output
  - include steerers at different locations in the 2nd section, vary the quadrupole strength
- Tolerance studies
  - errors in electron optics (e.g. quadrupole strength, offsets and position)
  - tolerances of the electron beam parameters (e.g. peak current, emittance, energy spread)
- Include wave front propagation through the monochromator beamline in the FEL simulations