European XFEL

Preliminary study of single spike SASE FEL operation at 0.26 nm wavelength for the European XFEL

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Overview

- Single spike condition and calculation of the cooperation length
- European XFEL layout and e-bunch compression
- Studies for the strong compression of 50 pC and 20 pC bunches, analysis of obtained phase space distributions and RF-tolerances
- SASE radiation
- Conclusions and outlook

Single spike condition

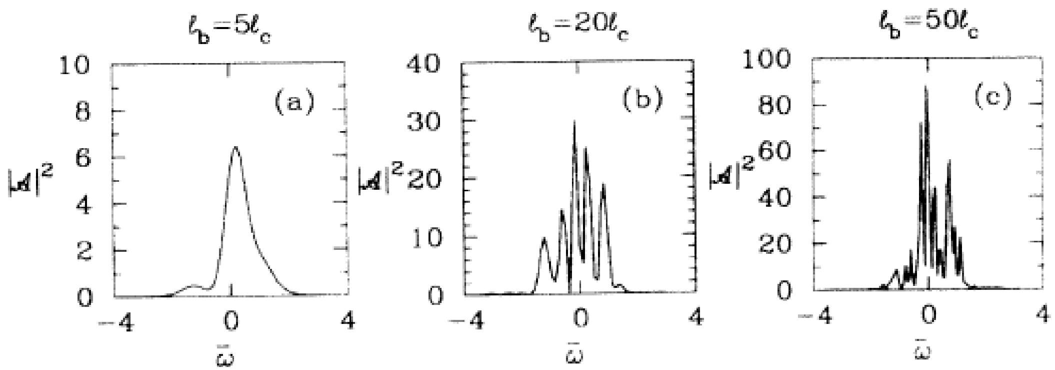
$L_b \leq 2\pi L_c \rightarrow$ single spike regime

L_b = bunch length

The Cooperation length Lc is the length spanned by the radiation in one undulator passage in its slippage over the e- bunch. The radiation emitted by one slice of the e- bunch having this length is coherent.

Advantages of Single spike regime w.r.t. normal SASE:

- Extremely short radiation pulses (fs or sub fs) to be used as probe for time resolved experiments.
- The typical noise of SASE spectrum is not present



Spectrum, Temporal Structure, and Fluctuations in a High-Gain Free-Electron Laser Starting from Noise

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The cooperation length

$$L_C = L_{c1d}(1+\eta)$$

$$L_{c1d} = \frac{\lambda}{\sqrt{3}\cdot 4\pi\rho}$$

$$\rho = \left(\frac{1}{16}\cdot\frac{I}{I_A}\cdot\frac{K_0{}^2[JJ]^2}{\gamma^3\sigma_x{}^2 k_u{}^2}\right)^{1/3}$$

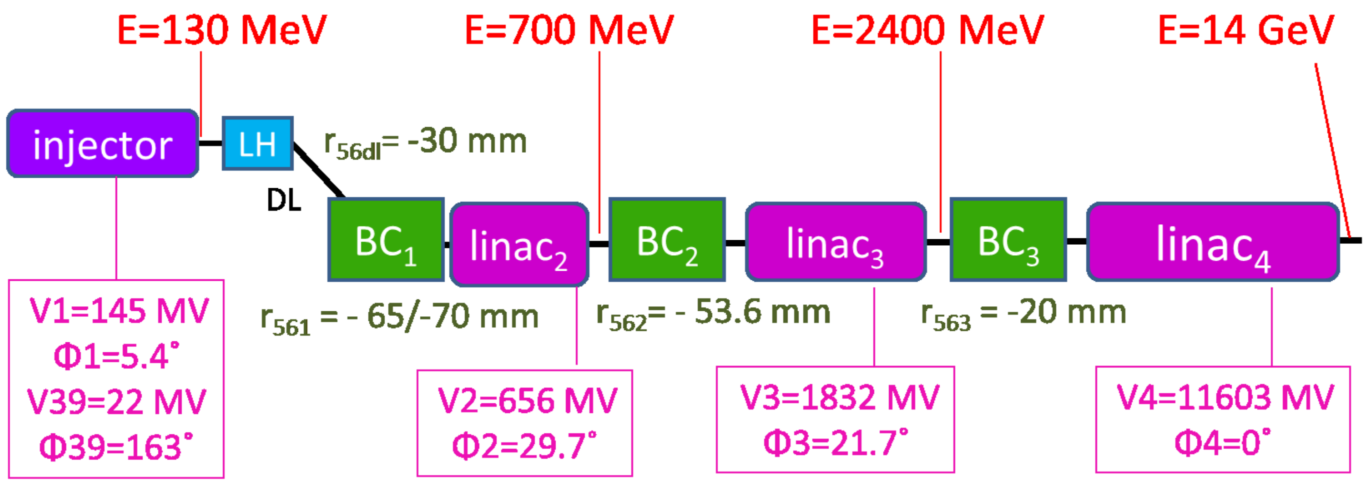
$$JJ = (J_0(\xi) - J_1(\xi)) \qquad k_u = 2\pi/\lambda_u$$

$$\xi = \frac{a_w^2}{2(1+a_w^2)} \qquad K_0 = \sqrt{2}\,a_w$$

- In order to fulfil the single spike condition without degrading e-beam emittance, extremely small charges are needed (1 pC or less).
- Attosecond radiation pulses are in principle obtainable
- Problem concerning the diagnostic of the e-bunch in order to match it with the undulator

- Working with tens of pC the single spike condition can not be reached without degrading a little bit the emittance (in order to increase the cooperation length)
- Femtosecond radiation pulses are obtainable
- The e-bunch is diagnosticable

- We will show simulations of strong compression of e-bunches having charge of 20 and 50 pC.
- We characterize different compression setups considering the most recent layout of the European XFEL.
- Our aim is to give a starting point for further optimization.



$$-120 \le \frac{r_{56,1}}{\mathrm{mm}} \le 0$$

$$-120 \le \frac{r_{56,2}}{\mathrm{mm}} \le -50$$

$$-80 \le \frac{r_{56,3}}{\mathrm{mm}} \le -20$$

Used codes:

- **ASTRA (tracking with 3d space charge, DESY, K. Flötmann) in the injector;**
- **CSRtrack (tracking through dipoles, DESY, M. Dohlus, T. Limberg) in the LH, DL and BCs**
- **Linear transport matrices multiplication in the linac sections;**
- **RF-wakefields and longitudinal space charge along the linac sections have been added analytically (I. Zagorodnov, M. Dohlus, Phys. Rev. ST Accel. Beams 14, 014403 (2011)).**

The transport and compression of the e-bunch has been recently optimized for different charges, always considering a bunch produced by a 20ps lasting flat-top laser pulse illuminating the cathode:

- Y. Kot, MOP003, Proceedings of LINAC 2010
- I. Zagorodnov, M. Dohlus Phys. Rev. ST Accel. Beams 14, 014403 (2011).
- I. Zagorodnov, Beam Dynamics Simulations for XFEL, www.desy.de/xfel-beam/s2e/data/xfel_2011/NewResults.pdf

Evolution in the injector

50 pC

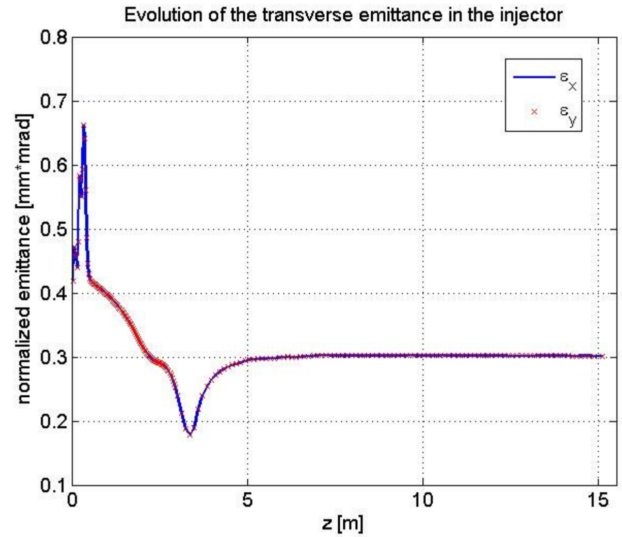
Input distribution:

- Lt=7.4 ps
- rt=2ps
- Xrms,Yrms=0.15 mm
- Width E distr. = 0.00055 keV

- 200000 particles tracked

E-bunch at the gun exit:

- horizontal beam size sig x = 0.1350 mm
- vertical beam size sig y = 0.1351 mm
- longitudinal beam size sig z = 0.7938 mm
- average kinetic energy E = 6.046 MeV
- energy spread dE = 13.90 keV
- transverse beam emittance eps x = 0.2401 pi mrad mm
- transverse beam emittance eps y = 0.2402 pi mrad mm
- longitudinal beam emittance eps z = 3.120 pi keV mm
- correlated energy spread cor z = 13.34 keV
- uncorrelated energy spread = 13.9 keV



20 pC

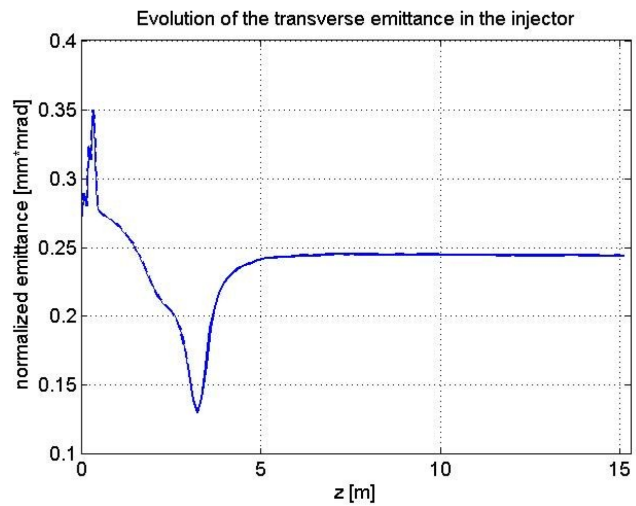
Input distribution:

- Lt=5.43 ps
- rt=2ps
- Xrms,Yrms=0.11 mm
- Width E distr. = 0.00055 keV

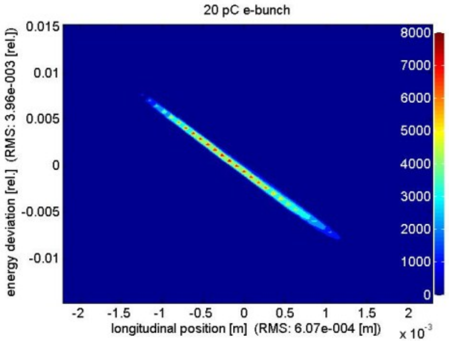
- 200000 particles tracked

E-bunch at the gun exit:

- horizontal beam size sig x = 9.5765E-02 mm
- vertical beam size sig y = 9.5800E-02 mm
- longitudinal beam size sig z = 0.6029 mm
- average kinetic energy E = 6.047 MeV
- energy spread dE = 9.330 keV
- transverse beam emittance eps x = 0.1584 pi mrad mm
- transverse beam emittance eps y = 0.1585 pi mrad mm
- longitudinal beam emittance eps z = 1.380 pi keV mm
- correlated energy spread cor z = 9.046 keV
- uncorrelated energy spread = 9.331 keV

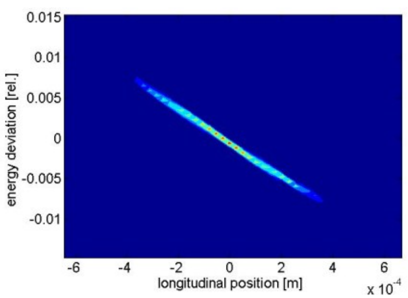


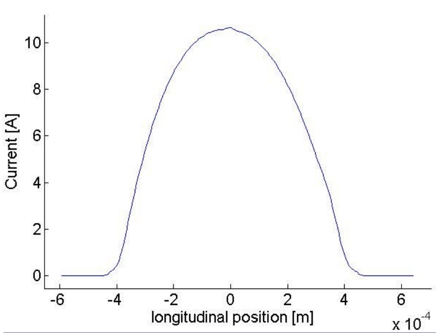
Compression (example 20 pC)



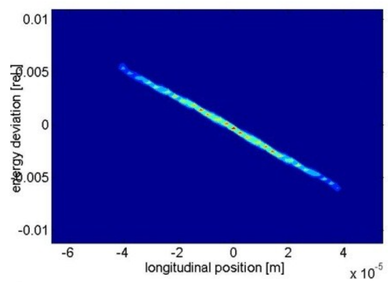
- Injector exit
- (RMS: 6.07e-004 [m])

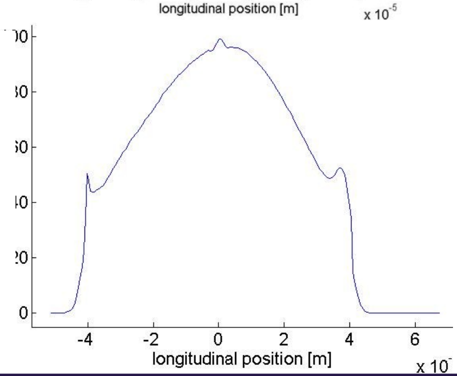
- BC0 exit (RMS: 1.87e-004 [m])
- (RMS: 3.93e-003 [rel.])



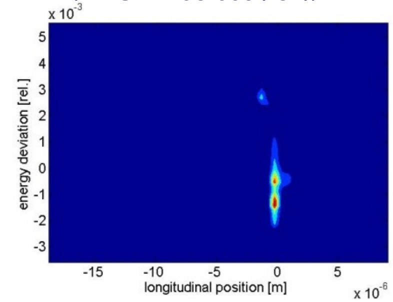


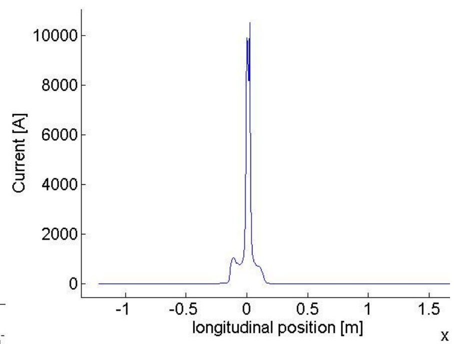
- BC1 exit (RMS: 2.12e-005 [m])
- (RMS: 3.08e-003 [rel.])



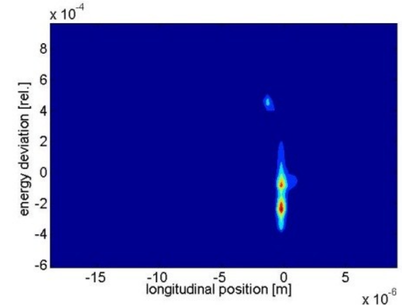


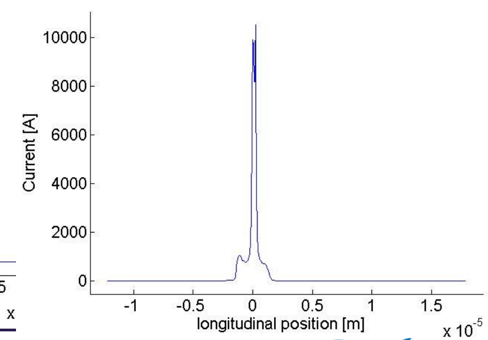
- BC2 exit (RMS: 7.86e-007 [m])
- (RMS: 1.49e-003 [rel.])



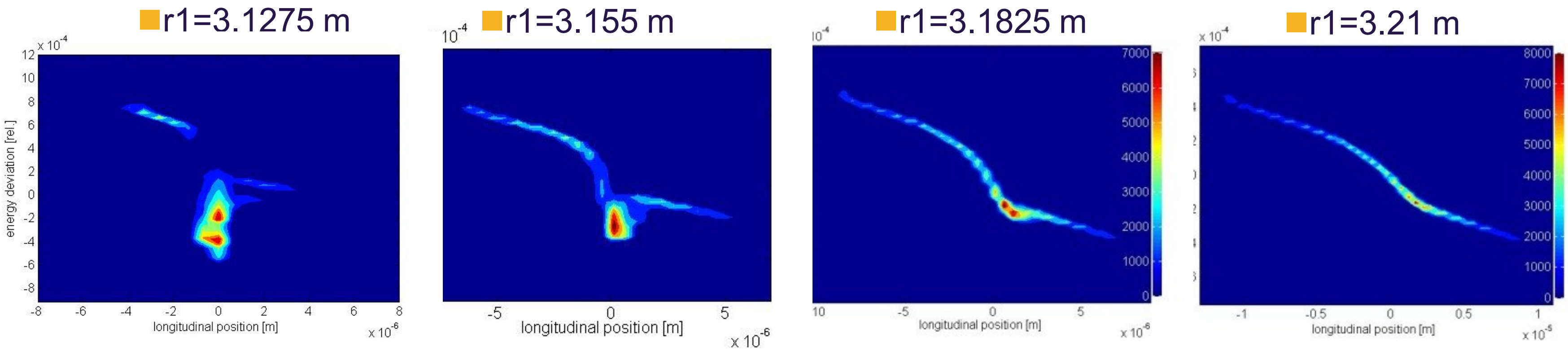


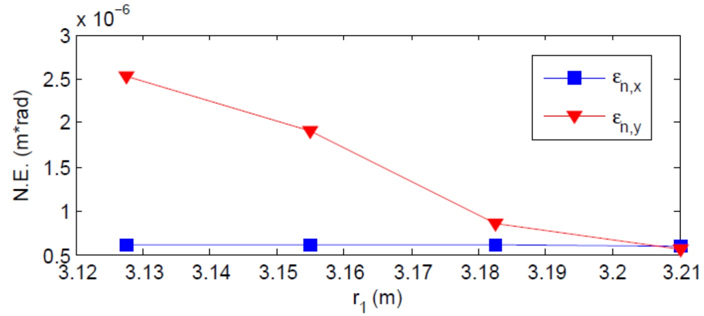
- Linac exit (RMS: 7.86e-007 [m])
- (RMS: 2.52e-004 [rel.])

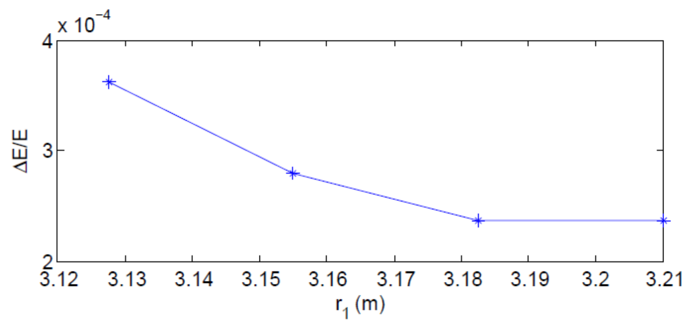


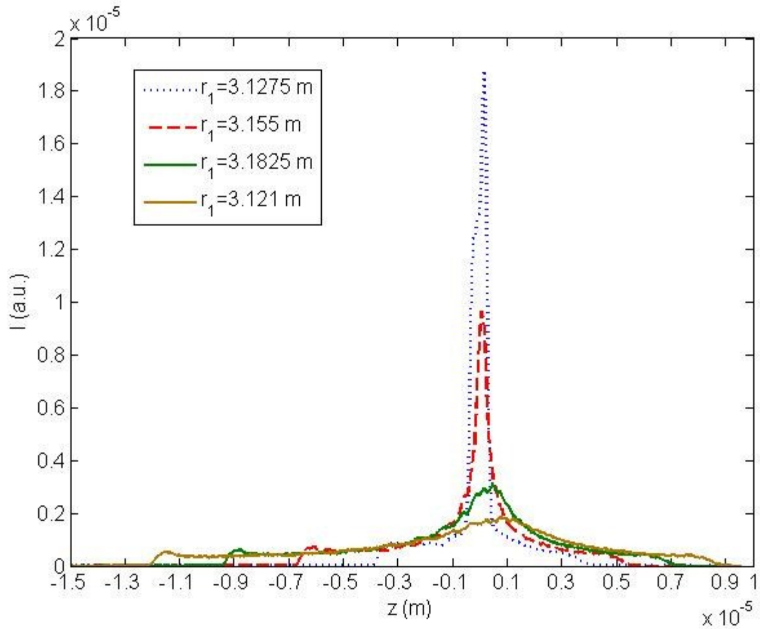


Summary of the scan 50 pC: e-bunch at the exit of the linac





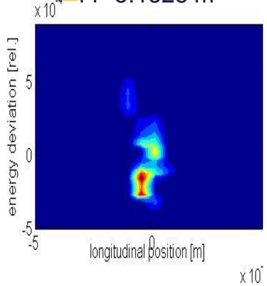




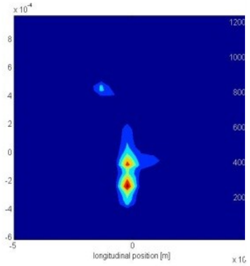
Summary of the scan 20 pC

- 2 plots missing

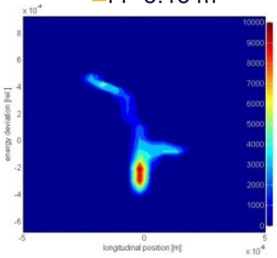
- r1=3.1325 m



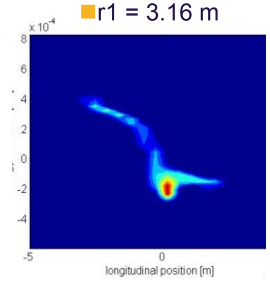
- r1=3.14 m



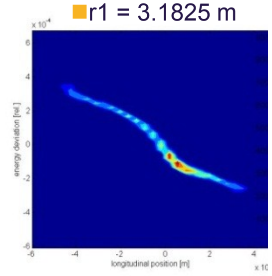
- r1=3.15 m



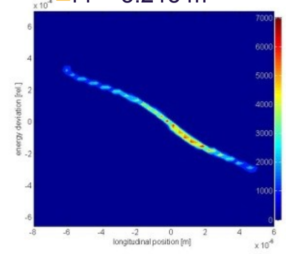
- r1 = 3.16 m

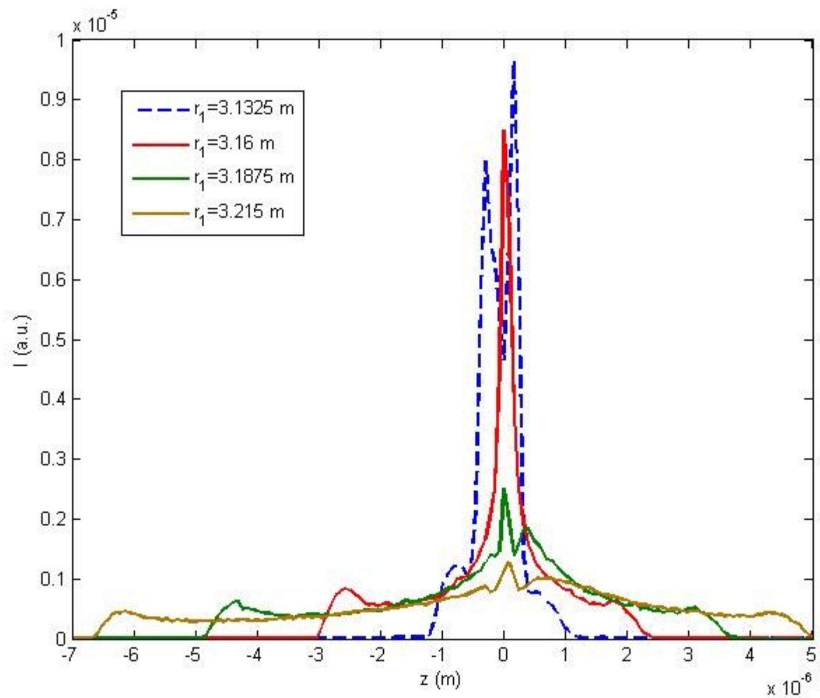


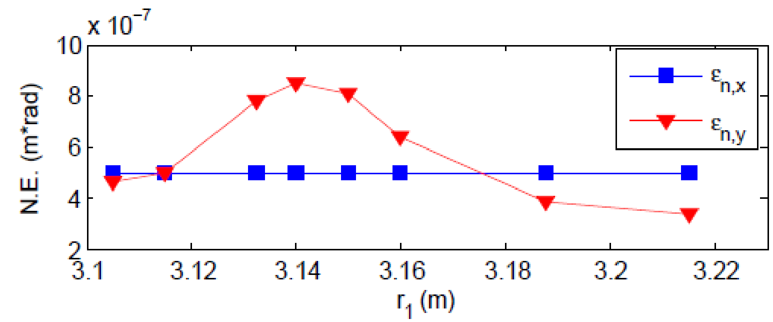
- r1 = 3.1825 m

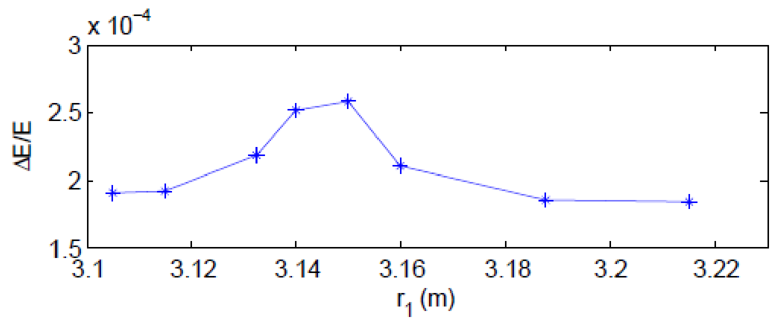


- r1 = 3.215 m

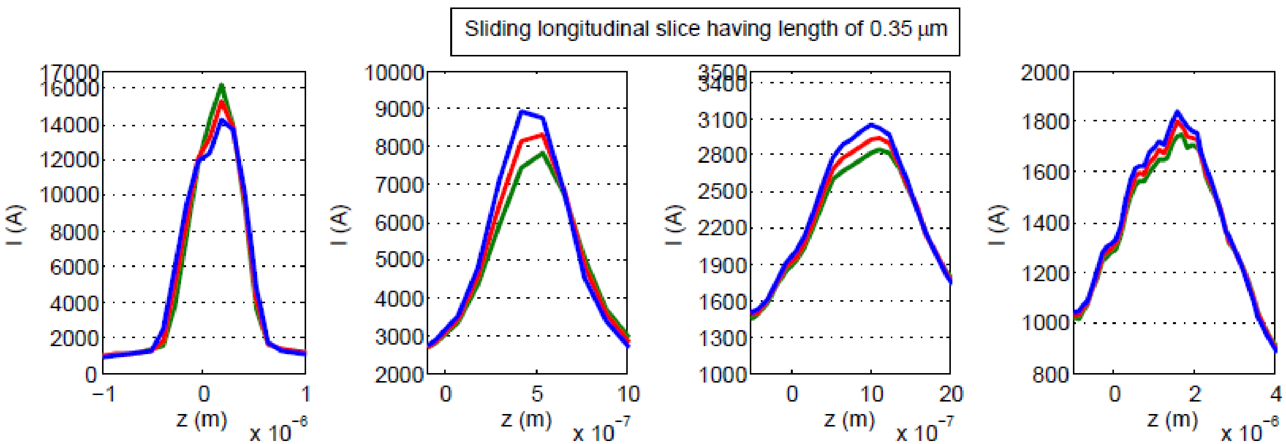


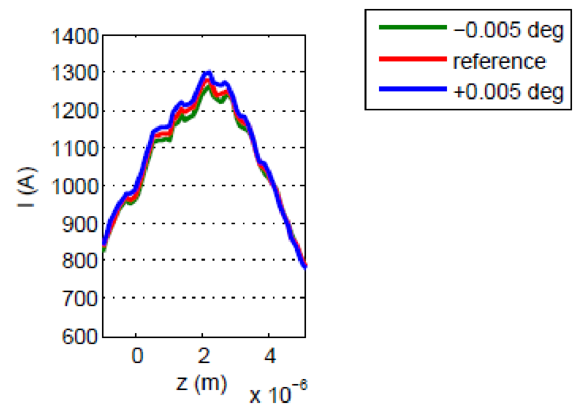


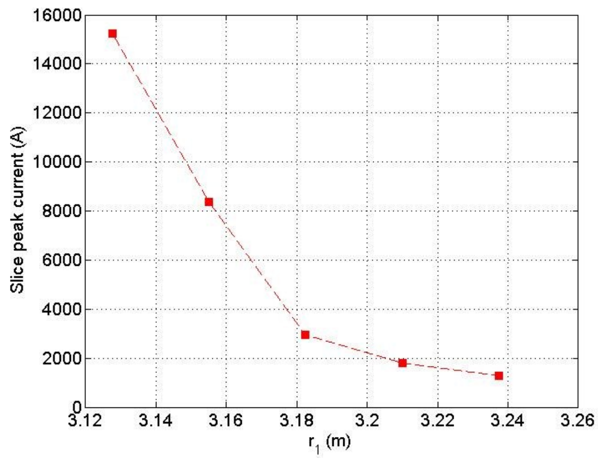


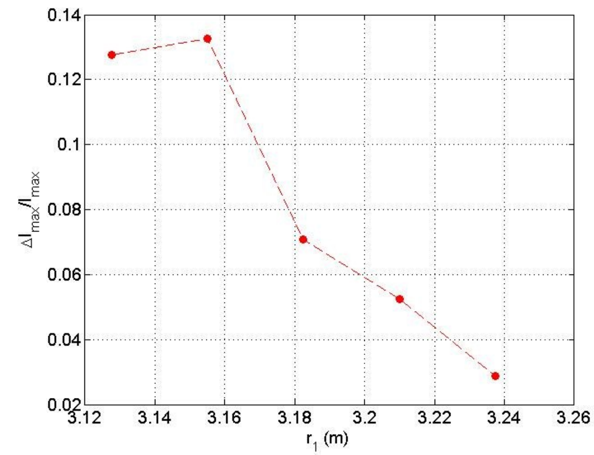


Tolerances 50 pC









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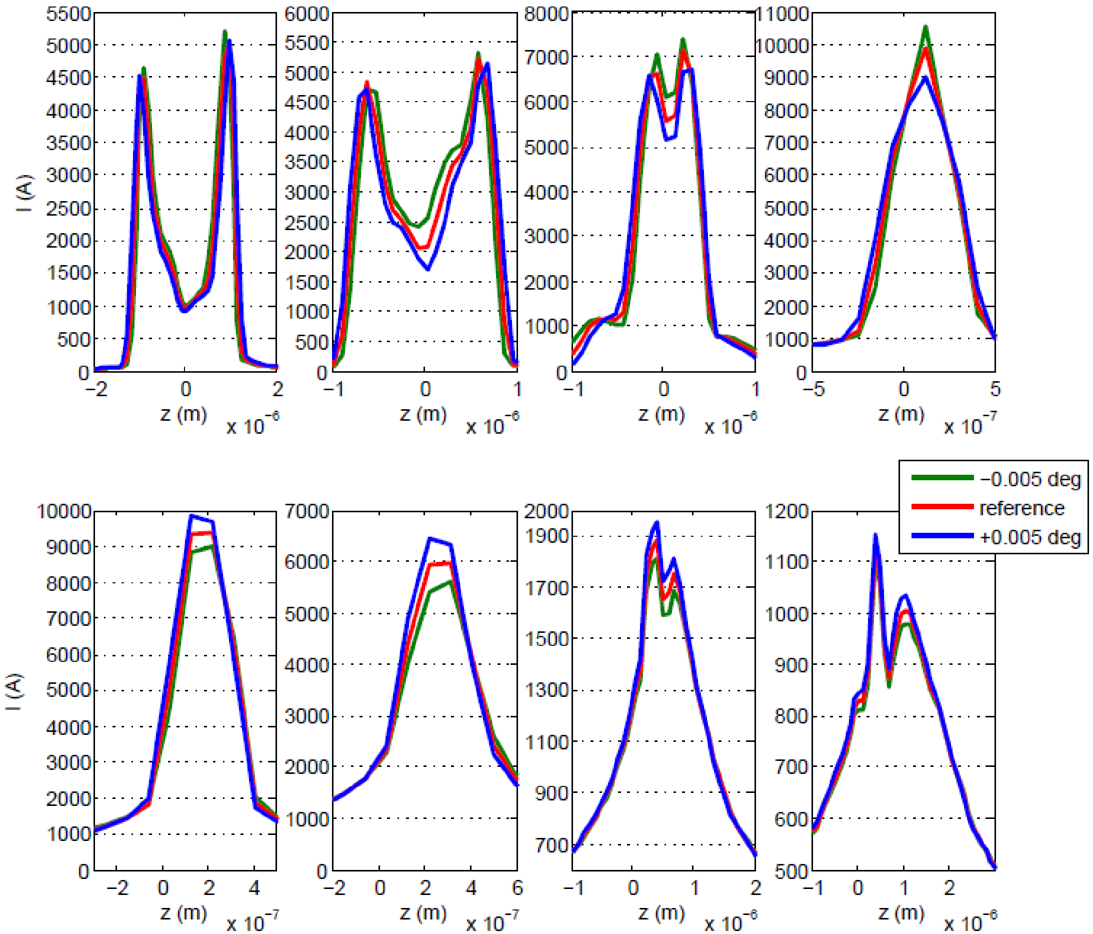
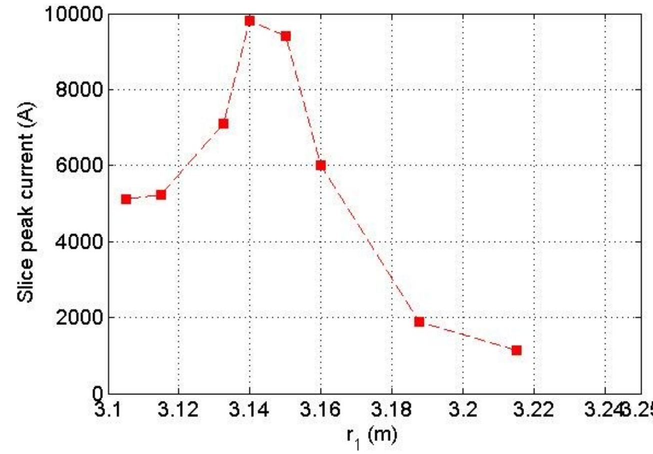
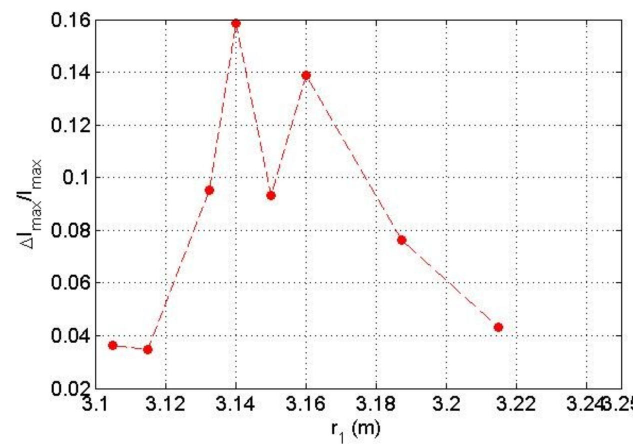
Tolerances 20 pC

Sliding longitudinal slice having length of 0.28 μm





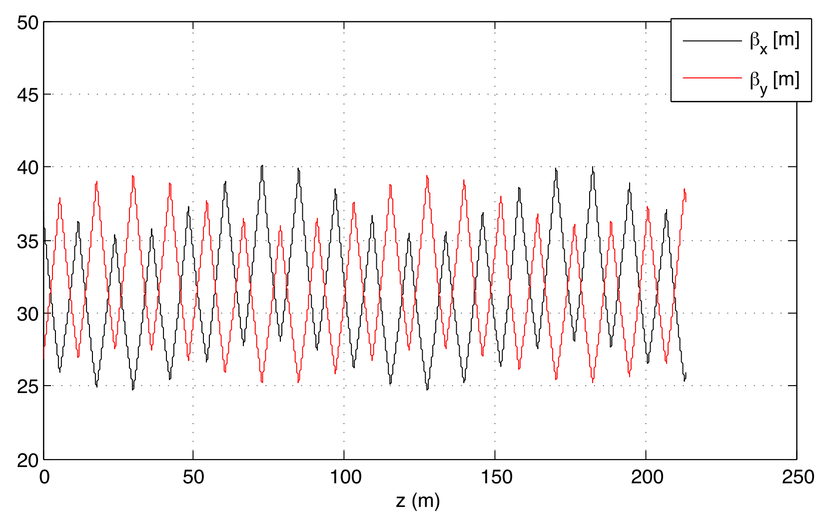


SASE 1 undulator imported in Genesis code

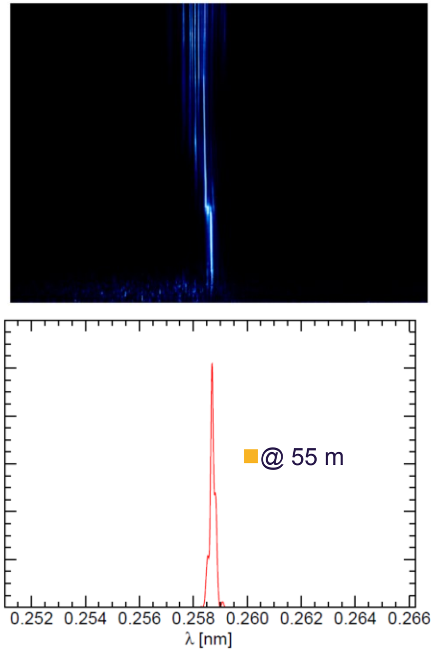
- 17 times + 1/2 cell -> total 35 sections

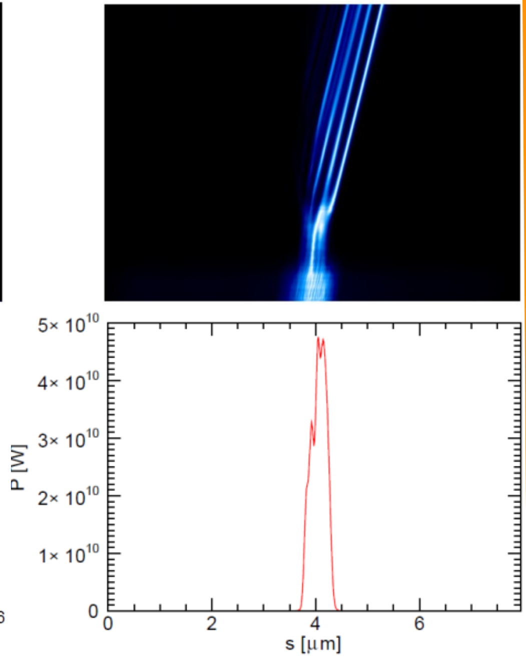
- From XFEL_Lattice_8.0, File XFEL_UND.txt (rounded)
  - **! Period = 40 mm**
  - **! Gap = 10 - 25 mm => Field = 1.14 - 0.28 T**

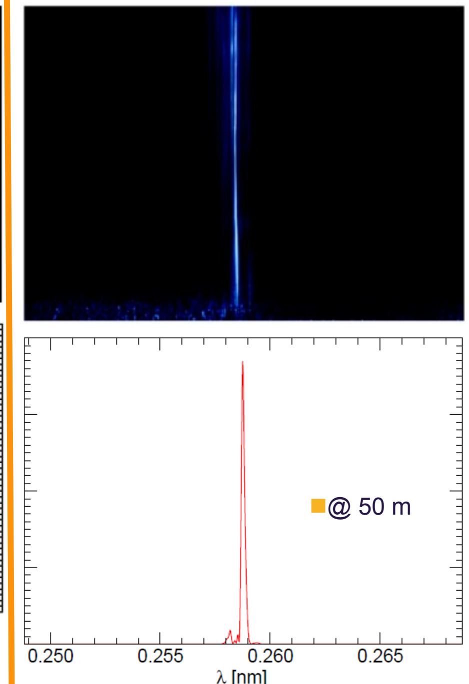
  - **Bund1 = 1.1442 T;** **! Lph = 2.7 angstroem**
  - **Kund1 = 4.27351;**

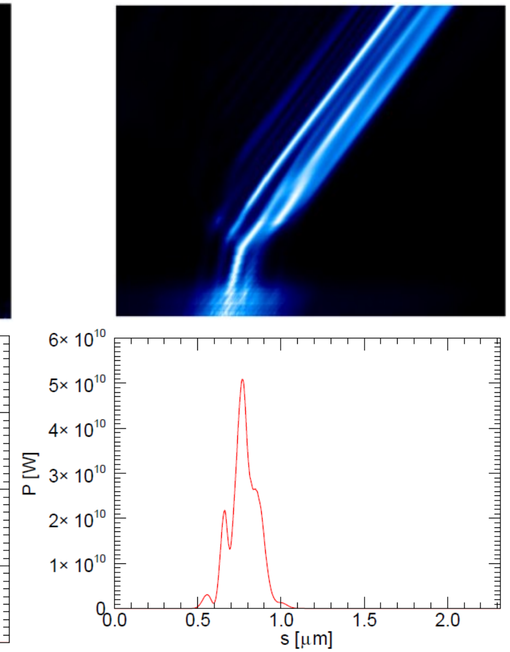


SASE radiation

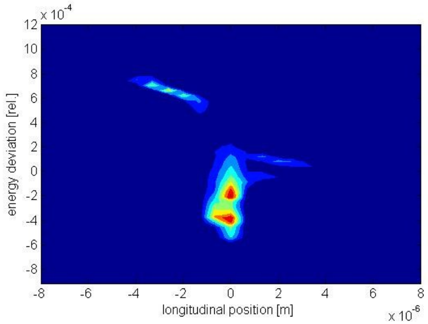






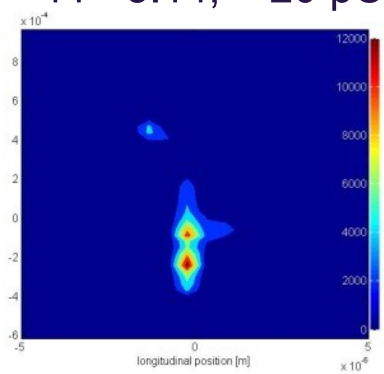


- r1= 3.1275, 50 pC



- Emittance, e-spread, tolerance

- r1= 3.14, = 20 pC



- Emittance, e-spread, tolerance

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Conclusions

- Preliminary S2E simulations have been run for the optimization of single spike emission at the wavelength of 2.6Ǻ at the European XFEL.
- By compression bunches of tens of pC it is possible to obtain SASE emission with a few spikes in the spectrum
- Further study is needed for reducing the number of the spikes by optimizing the central slice peak current and slightly spoiling the e-bunch emittance

Thank you for the attention !

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  - second level
    - third level

Headline

Texttext texttext texttext texttext texttext texttext

Keyword

1. Keyword
2. Keyword

- keyword
- keyword

Result Headline

- result text
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Result headline

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