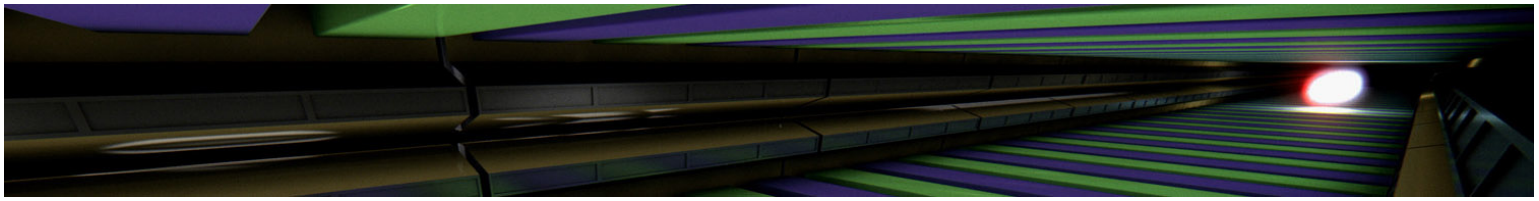


Preliminary study of single spike SASE FEL operation at 0.26 nm wavelength for the European XFEL

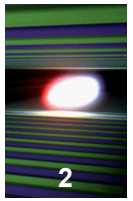
B. Marchetti, M. Krasilnikov, F. Stephan (DESY, Zeuthen, Germany),
M. Dohlus,Y. Kot, I. Zagorodnov (DESY, Hamburg, Germany),
J. Roensch-Schulenburg (University of Hamburg, Hamburg, Germany)

ICAP, Rostock

19-24 August 2012

European XFEL

Outline



- 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

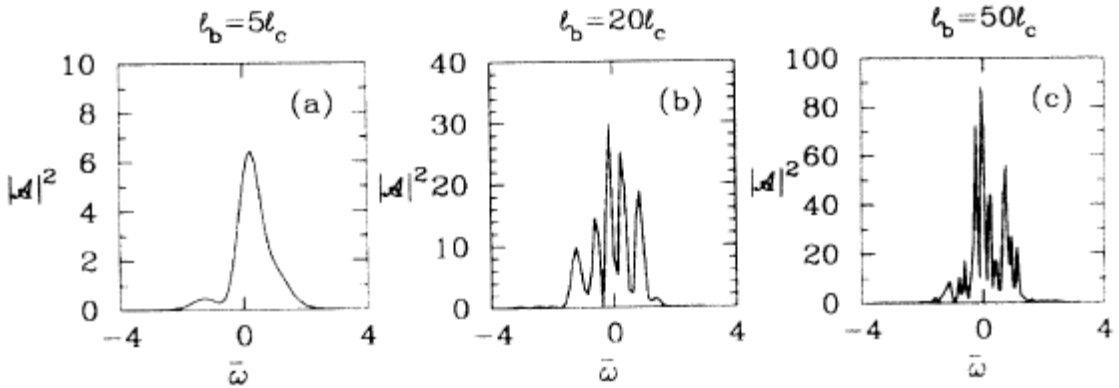
$L_b \leq 2\pi L_c \rightarrow$ single spike regime

L_b = bunch length

The cooperation length L_c is the length spanned by the radiation in one gain length 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:

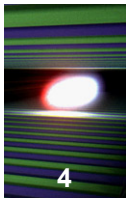
- Extremely short radiation pulses (fs or sub fs) to be used as probe for time resolved experiments.
- The typical noise of SASE spectrum is not present.



R. Bonifacio et al., PRL vol.73, num. 1 (1994)

European XFEL

The cooperation length



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

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

Includes radiation diffraction, transverse emittance and energy spread

- **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**

- J. B. Rosenzweig et al., NIM A 593 (2008) 39-44.
- S. Reiche et al., NIM A 593 (2008) 45-48.

- **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 can be fully characterized by diagnostics.**

- L. Wang, Y Ding, Z. Huang, THPC104, Proceedings of IPAC 2011

- 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.

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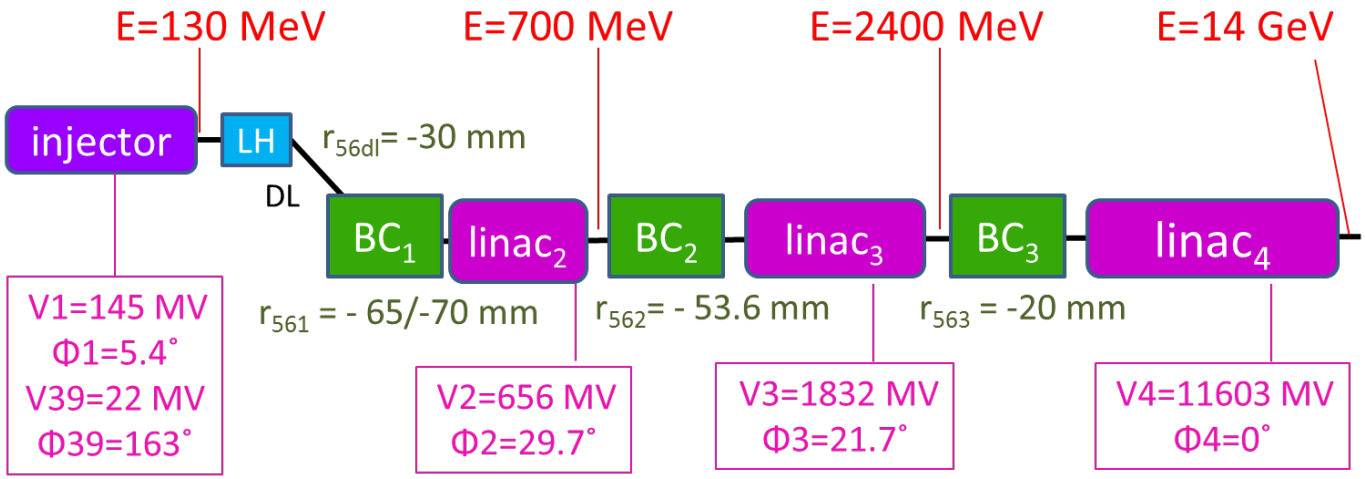
European XFEL layout



Used codes:

- **ASTRA (tracking with space charge, DESY, K. Flöttmann) in the injector;**
- **CSRtrack (tracking including CSR effect, 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

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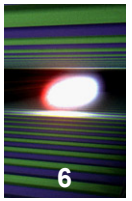
Evolution in the injector



Input distribution:

- Flat-top laser pulse having a duration (FWHM) of 7.4 ps and rising/decaying times of 2 ps
- Transverse radial homogeneous distribution having size: Xrms,Yrms=0.15 mm

200000 particles tracked

50 pC

Input distribution:

- Flat-top laser pulse having a duration (FWHM) of 5.43 ps and rising/decaying times of 2 ps
- Transverse radial homogeneous distribution having size: Xrms,Yrms=0.11 mm

200000 particles tracked

20 pC

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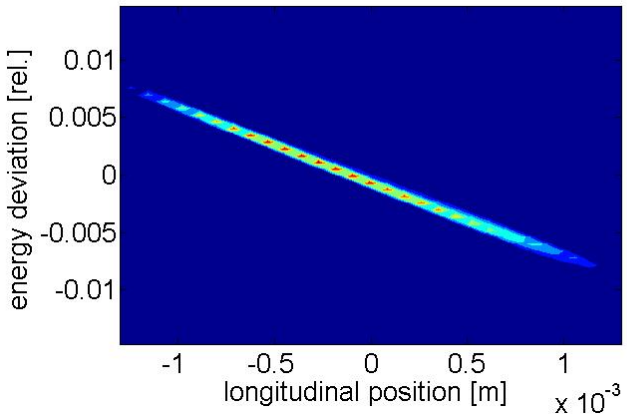
Compression (example 20 pC)

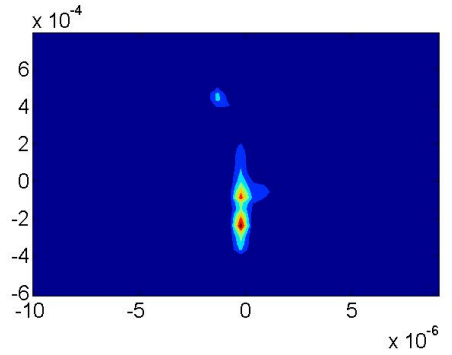
Distributions of longitudinal phace space of the e-bunch at a different position along the linac

20 pC e-bunch



Injector exit

RMS length : 6.07e-004 [m]
RMS energy spread: 3.96e-003 [rel.]



Accelerator exit (zoomed)

RMS length : 7.86e-007 [m]
RMS energy spread : 2.52e-004 [rel.]

BC_0 exit

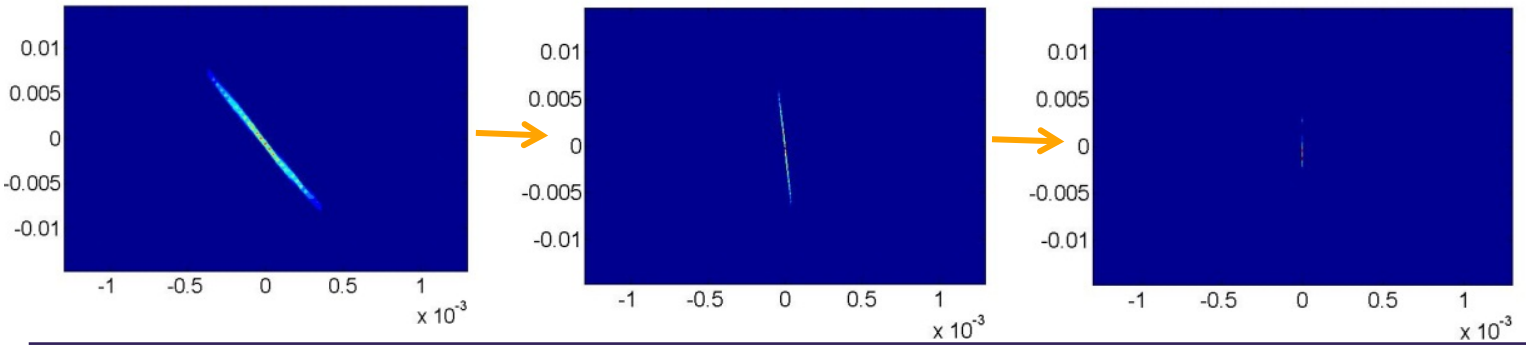
RMS length : 1.87e-004 [m]
RMS energy spread: 3.93e-003

BC_1 exit

RMS length: 2.12e-005 [m]
RMS energy spread: 3.08e-003 [rel.]

BC_2 exit

RMS length : 7.86e-007 [m]
RMS energy spread: 1.49e-003 [rel.]



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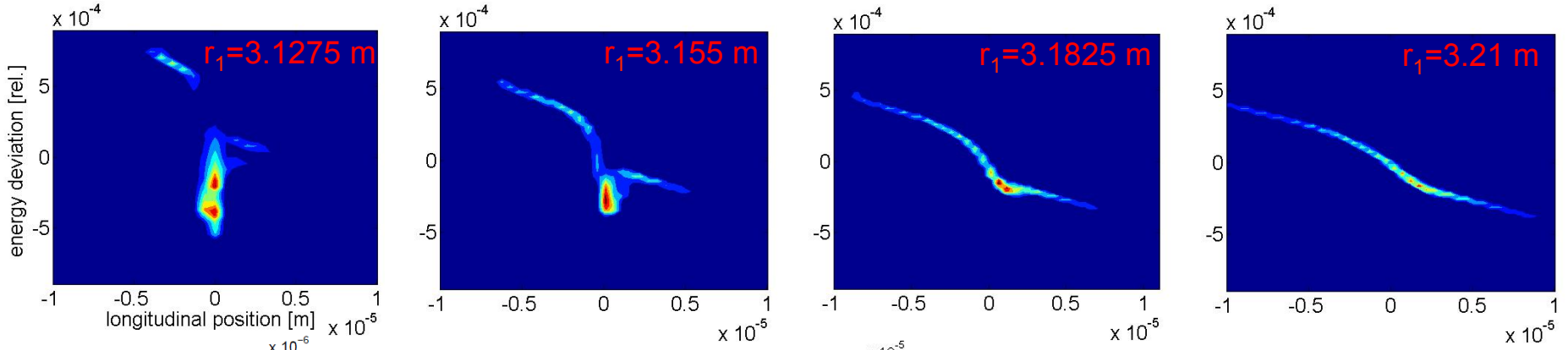
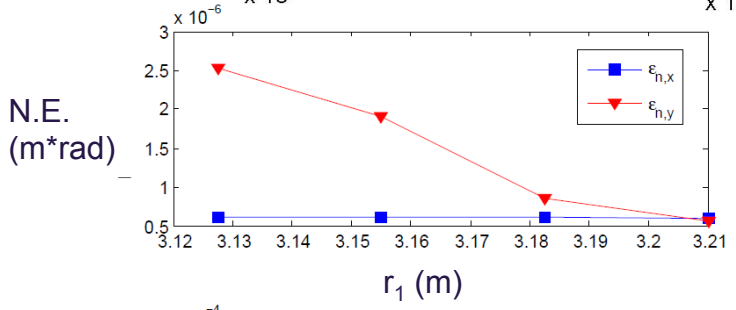
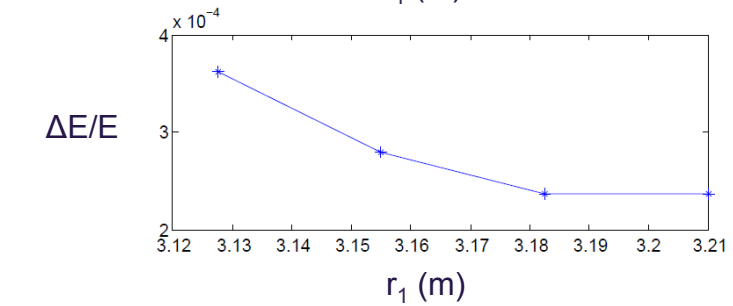
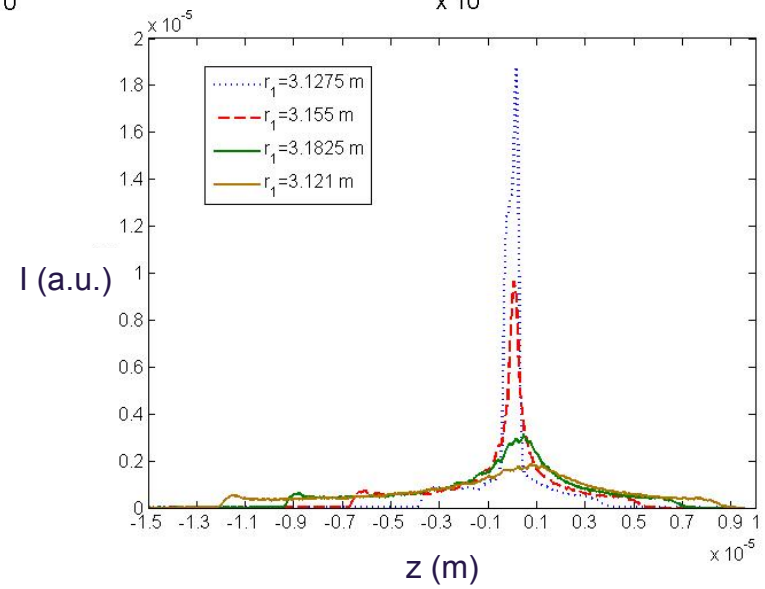
Summary of the scan for 50 pC: e-bunch at the exit of the linac

Distributions of longitudinal phace space of the e-bunch at the end of the linac for different compression points (the curvature radius inside the first BC, named r_1, has been changed)









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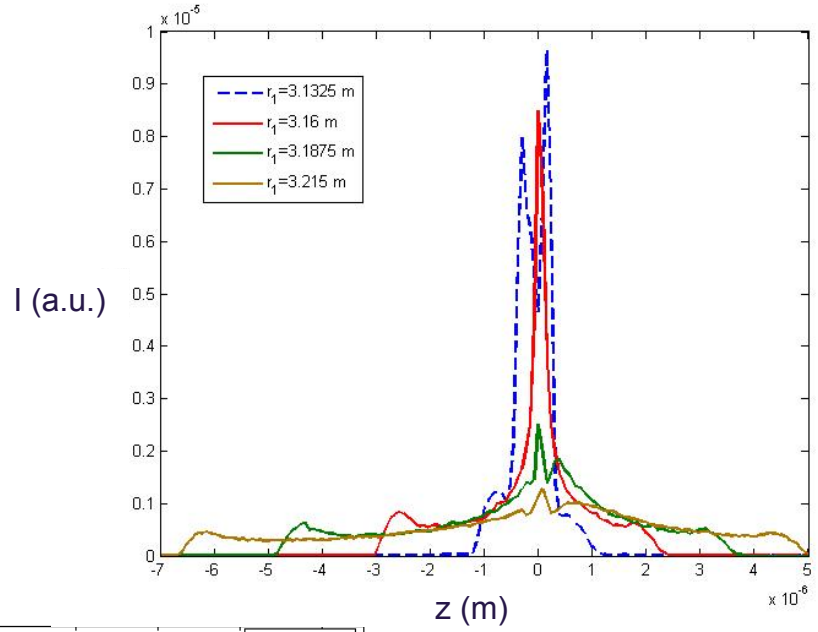
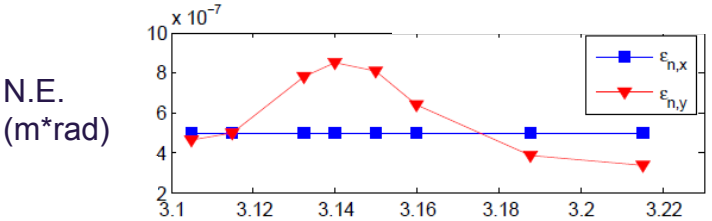
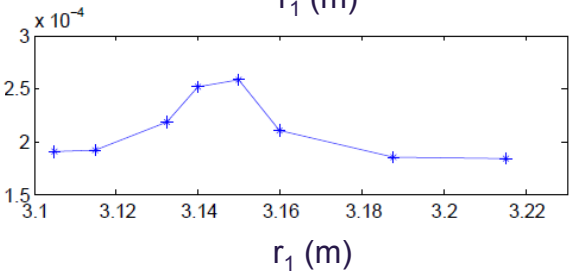
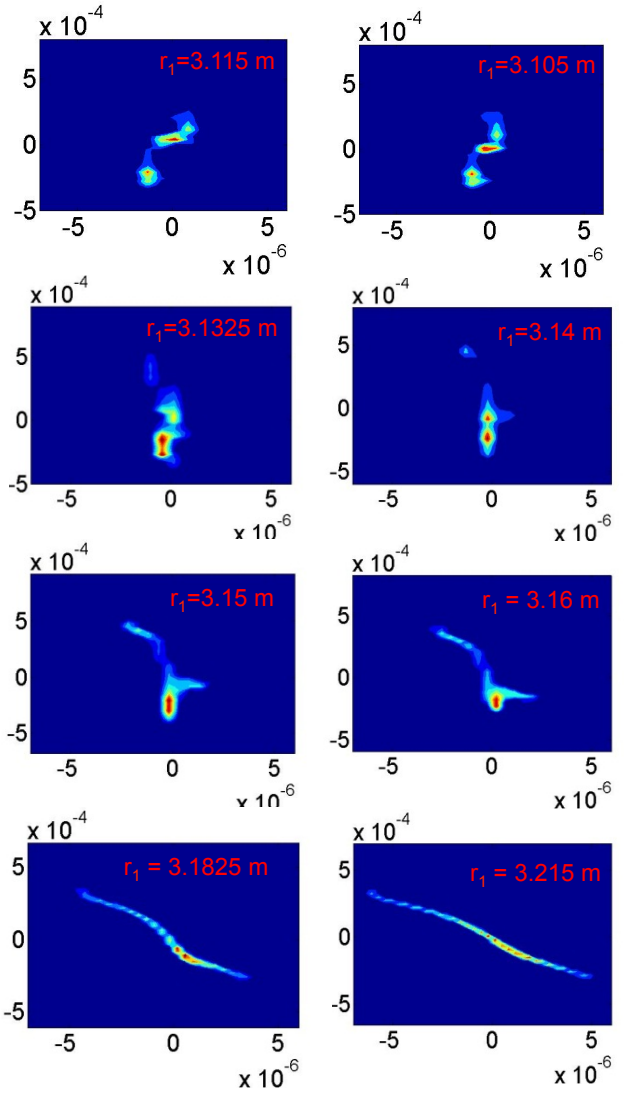
Summary of the scan for 20 pC e-beam









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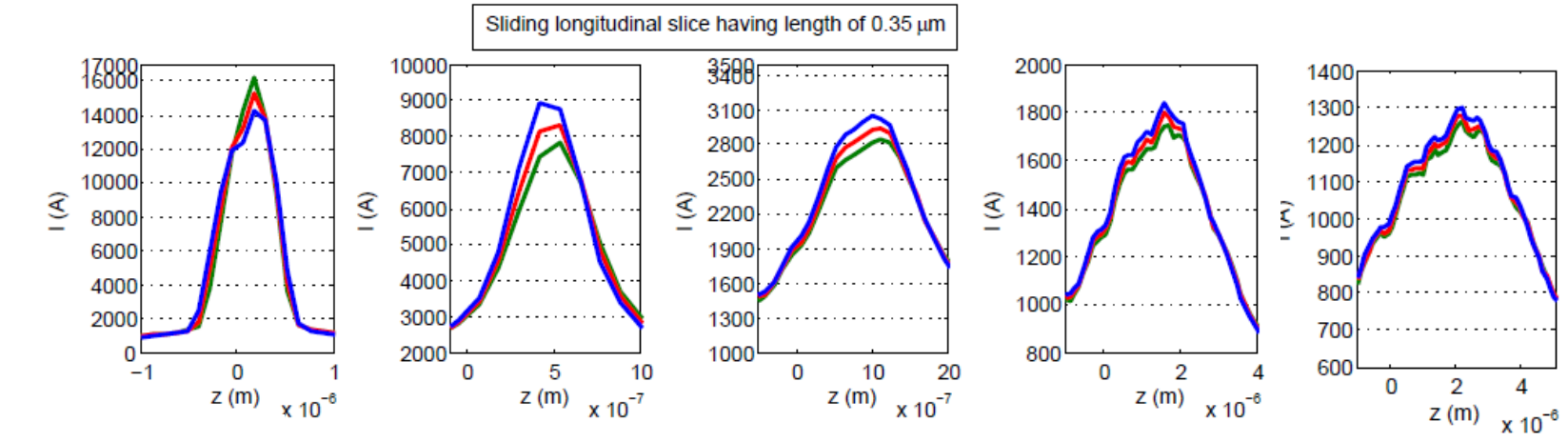
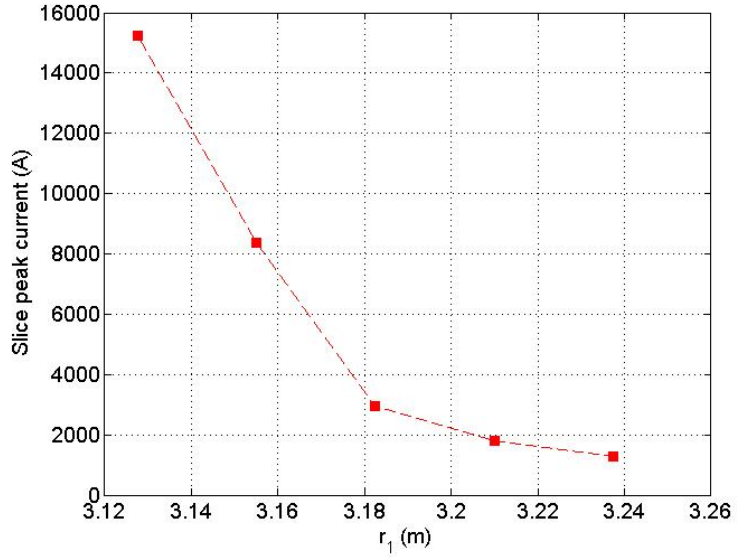
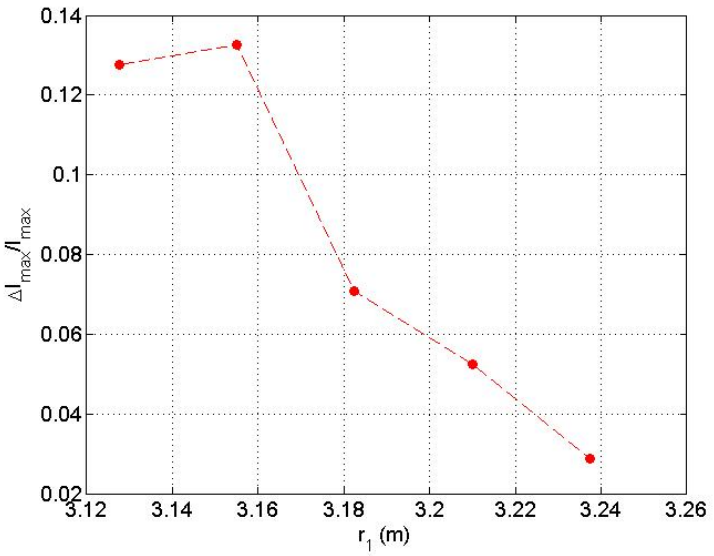
Tolerances study: 50 pC case







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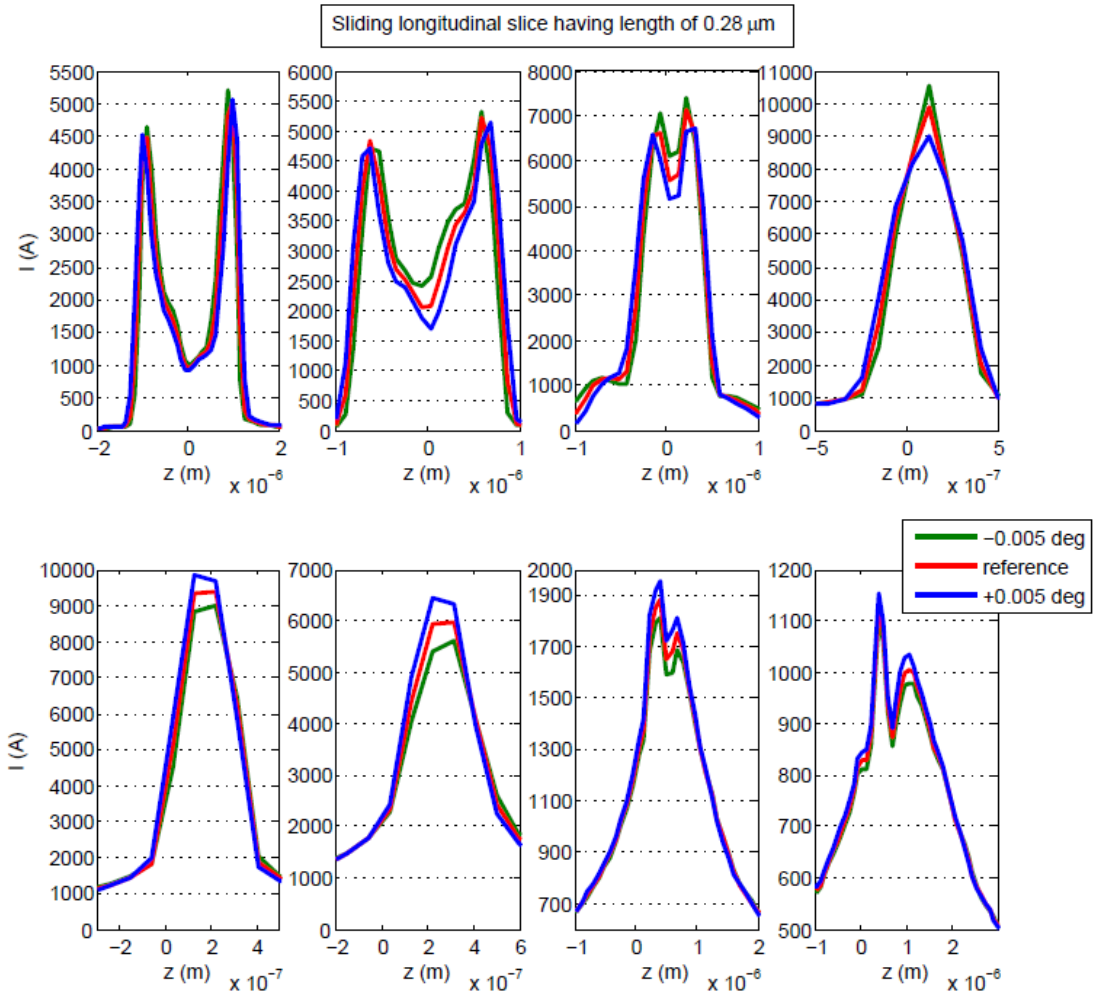
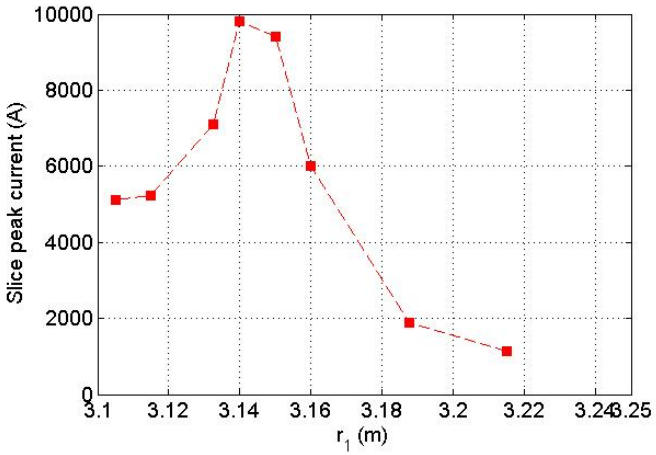
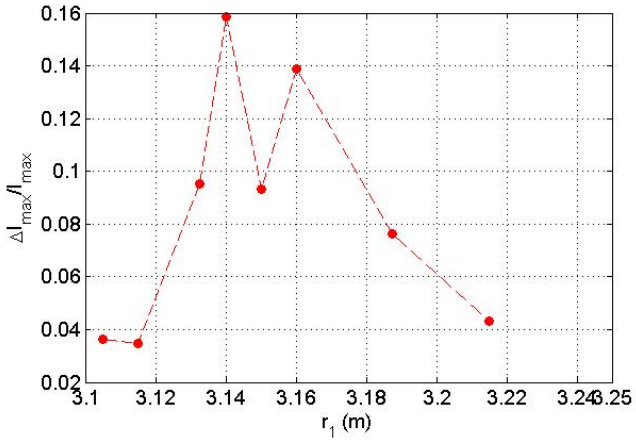
Tolerances study: 20 pC case







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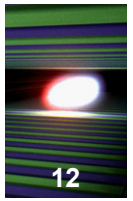
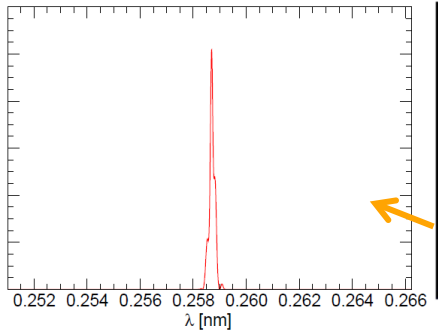
SASE radiation

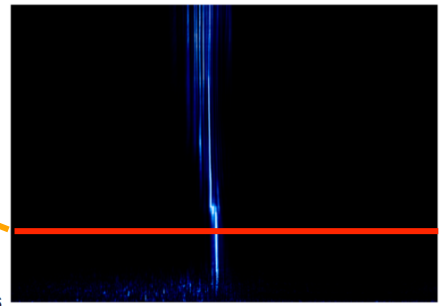


50 pC bunch @ max compression

Spectrum @ 50 m



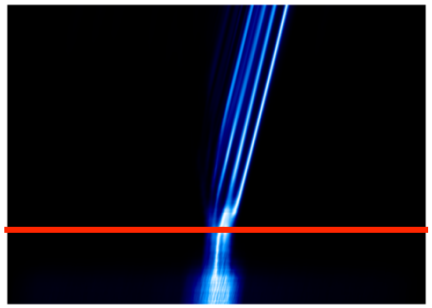
Spectrum of the emitted radiation along the undulator



Wavelength

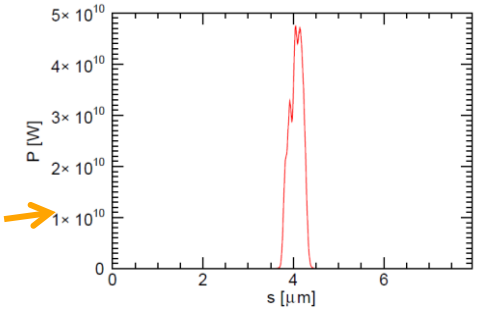
Longitudinal position along the undulator

Longitudinal profile of the radiation power emitted by the electrins along the undulator



Longitudinal position along the e-bunch

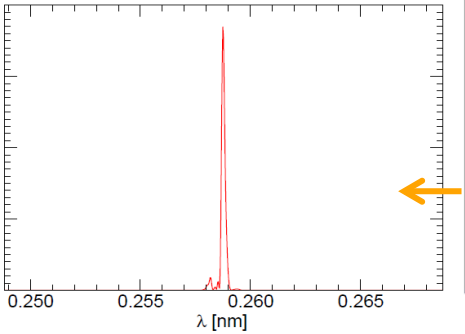
Longitudinal radiation profile @ 50 m

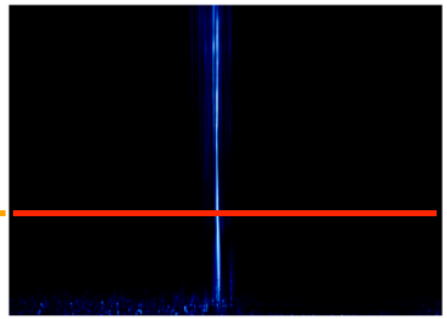


Length about 1um -> 3.3 fs

20 pC bunch @ max compression

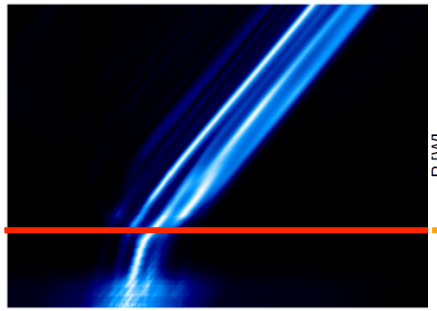
Spectrum @ 55 m





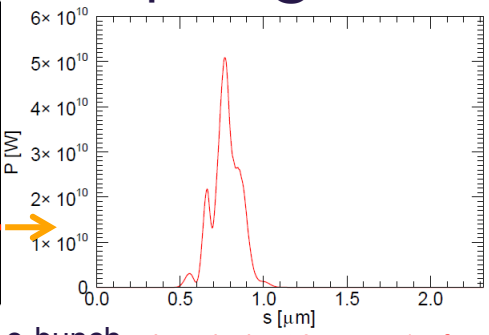
Wavelength

Longitudinal position along the undulator



Longitudinal position along the e-bunch

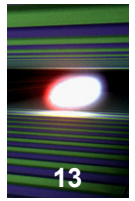
Longitudinal radiation profile @ 55 m



Length about 0.5um -> 1.7 fs

European XFEL

Conclusions and outlook



- Preliminary S2E simulations have been performed for the compression of 20 and 50 pC e-bunches at the European XFEL so to have a few spikes SASE emission at the wavelength of 2.6 Å.
- As a result, a peak power of 10 GW and radiation pulse length of 1-3 fs has been obtained.
- Further study is needed for reducing the number of the spikes by optimizing the central slice peak current (for example by changing the energy chirp before the first bunch compressor) and slightly spoiling the e-bunch emittance.
- The study of introducing a taper in the undulator is also foreseen.

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Thank you for the attention !