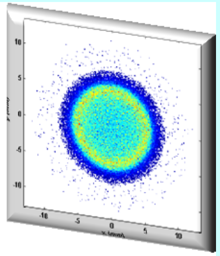
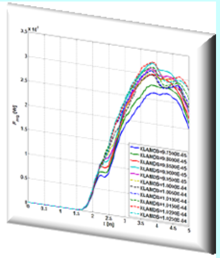
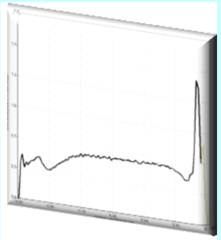
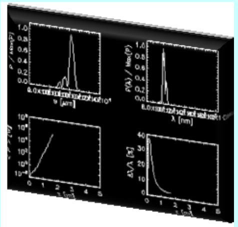
Simulation of Undulator Radiation for PITZ-like THz Sources Project









Prach Boonpornprasert
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PITZ Physics Seminar
24.10.2013

HELMHOLTZ | ASSOCIATION

PITZ Photo Injector Test Facility Zeuthen

DESY

Outline

> Introduction
> Comparison with Benchmark
> Generation of Initial Beam Distribution Files
> Simulation with Selected Distribution Files
> Conclusion
> Outlook

PITZ-like THz sources

- Single cycle radiation, few MV/m Electric field
  - Transition radiation (TR) or Synchrotron Radiation (SR) obtained using a compressed electron beam
    - Ongoing simulations for compression of a 200 pC electron bunch
- Narrow band
  - SASE FEL obtained using an uncompressed e-beam accelerated on crest
    - Ongoing simulations for 4nC, 15 MeV, high emittance beam production and t
- Modulated beam
  - TR or SR obtained using a comb beam

TUNABLE IR/THZ SOURCE FOR PUMP PROBE EXPERIMENTS AT THE EUROPEAN XFEL

E.A. Schneidmiller, M.V. Yurkov, DESY, Hamburg, Germany
M. Krasilnikov, F. Stephan, DESY, Zeuthen, Germany

Proceeding of FEL2012 conference (Nara, Japan, 2012), WEPD55

Introduction : I/O of GENESIS1.3 code

Main Input
- undulator parameters
- e-beam parameters
- simulation parameters
- etc.

Beam Description
- slices description
- particles distribution

Seeding Field

Magnetic field Description

GENESIS 1.3

Main Output
- radiation power
- radiation tr. size
- radiation diff. angle
- e-beam size
- e-beam position
- energy spread
- etc.

Particle Records

Radiation field Records

Comparison with Benchmark

Initial Parameters for GENESIS

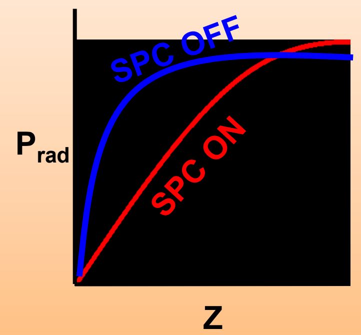
Parameter	Detail
undulator type	Helical
$K / \sqrt{2}$	1.9092
undulator period length (λ_u)	4 cm
number of period	125
radiation wavelength (λ_{rad})	100 µm
bunch charge	4 nC
rms current length	2.4 mm
peak current	200 A
e-beam energy	15 MeV
energy spread	20 keV
β_x, β_y	14.4 cm
ε_x, ε_y	10 mm.mrad
α_x, α_y	0

σ_x, σ_y = 0.2178 mm

Sources
- Benchmark Paper
- E-mail from M.Yurkov

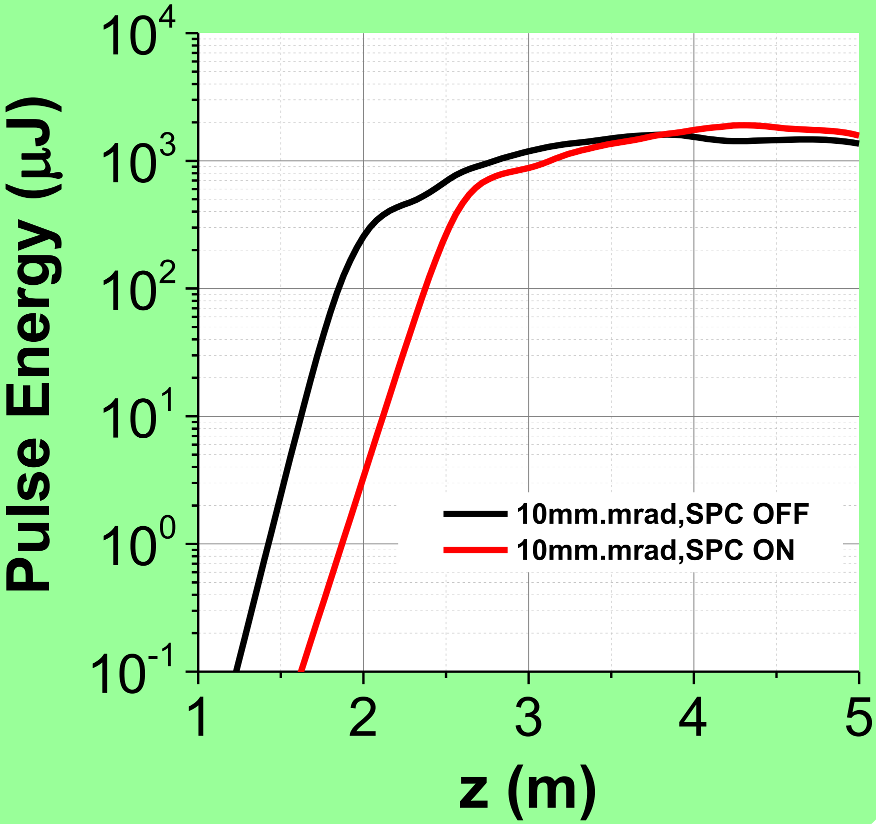
statement from e-mail

- *Space charge field has been switched off during simulations.*
- *With space charge effects "on" saturation length increases by about 50%, and saturation efficiency increases as well.*
- *Since saturation length fits into the undulator segment, we left bulky simulations with space charge for the future.*

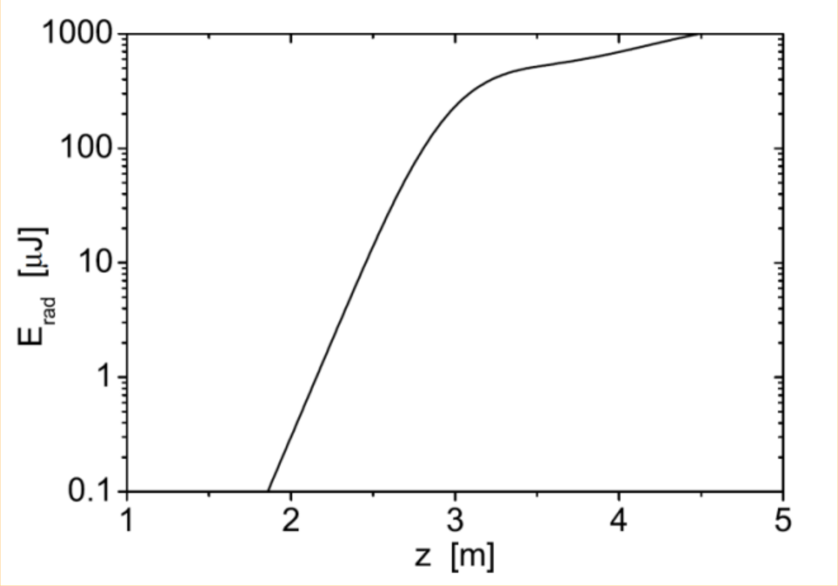


Comparison with Benchmark

Results from GENESIS, 10 mm.mrad

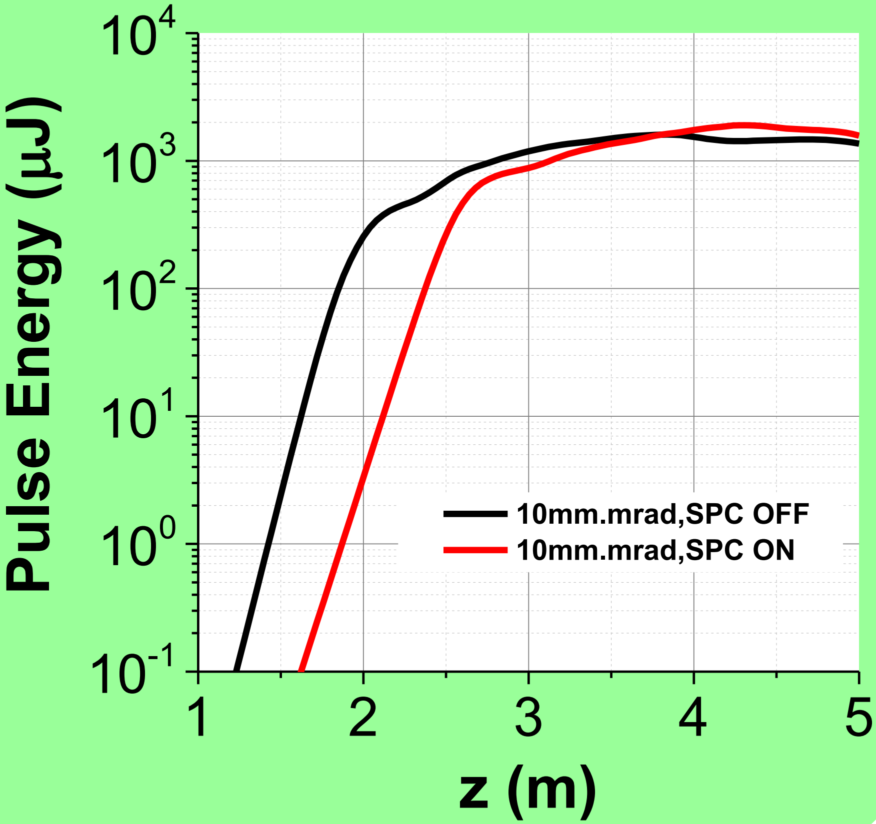


Results from the Benchmark

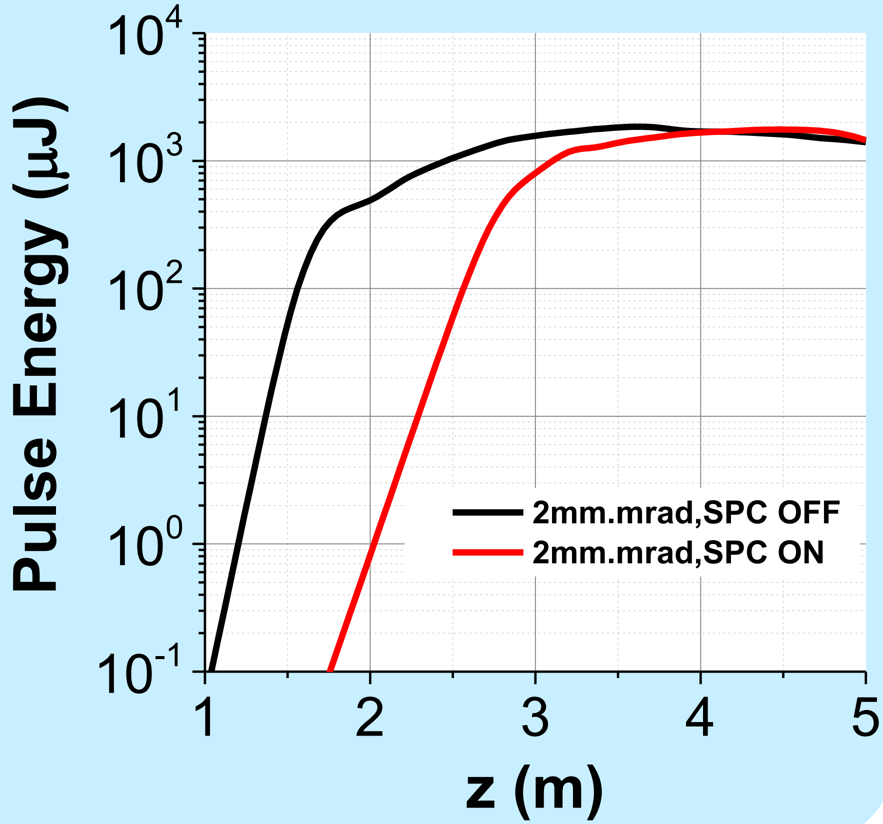


Comparison with 2mm.mrad

Results from GENESIS, 10 mm.mrad



Results from GENESIS, 2 mm.mrad



Generation of Electron Beam Distribution files

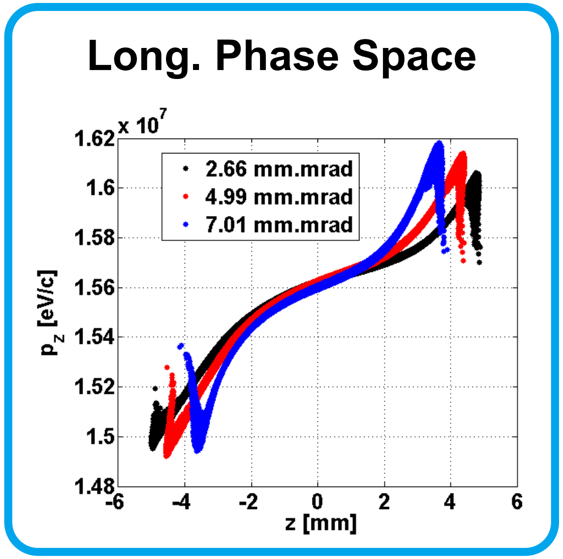
Determine initial parameters for ASTRA
- main solenoid current
- laser spot size
- gun phase
- maximum E-field of booster

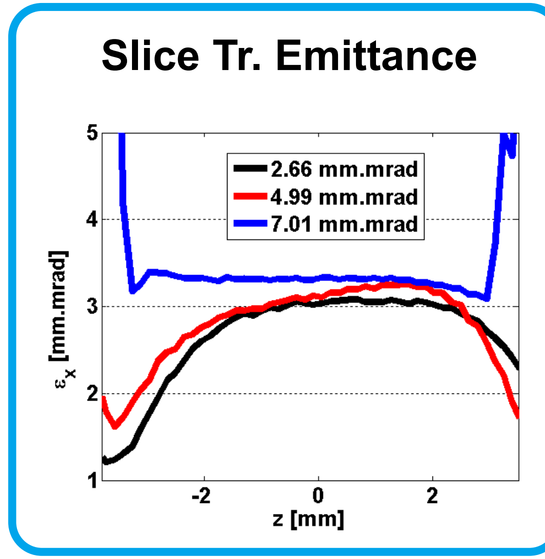
track particles by ASTRA from cathode(z = 0) to z = 10 m

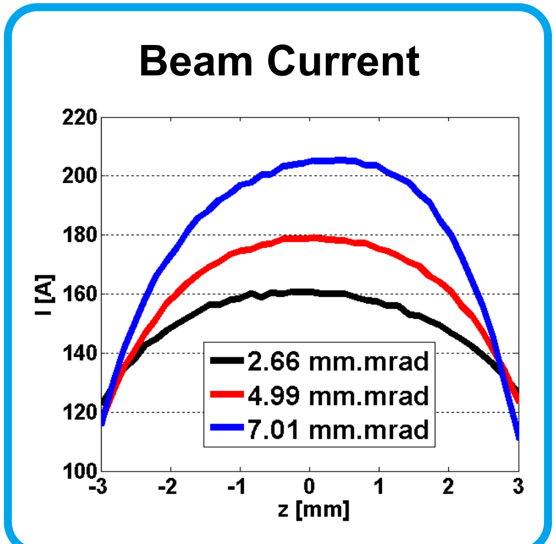
select interest beams

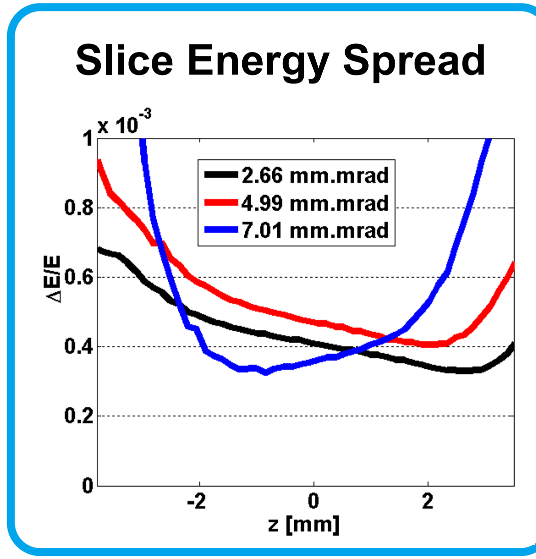
beam matching by PS-viewer (β=14.4cm)

convert to input file format of GENESIS1.3







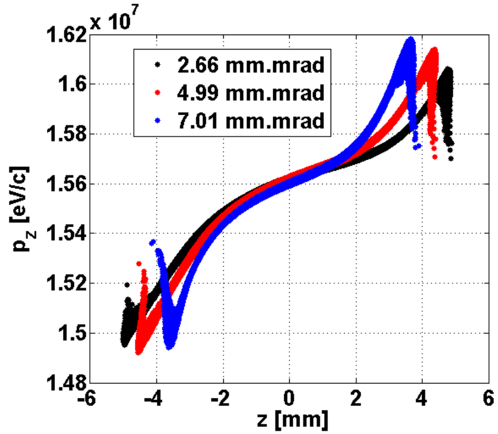


Generation of Electron Beam Distribution files

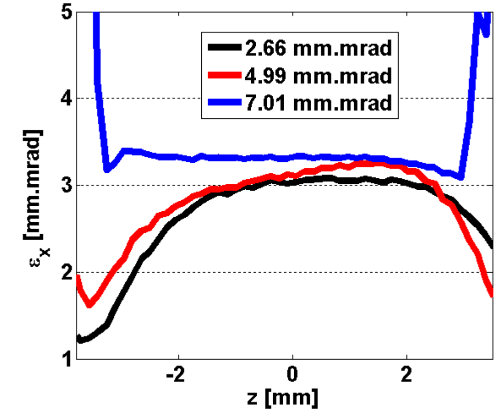
Details of Selected Beams

$\varepsilon_{tr,n}$ [mm.mrad]	$\varepsilon_{slice,mid}$ [mm.mrad]	$E_{spread,mid}$ [keV]	I_{peak} [A]
2.66	~2	~6	160
4.99	~3	~8	170
7.01	~3	~5	205

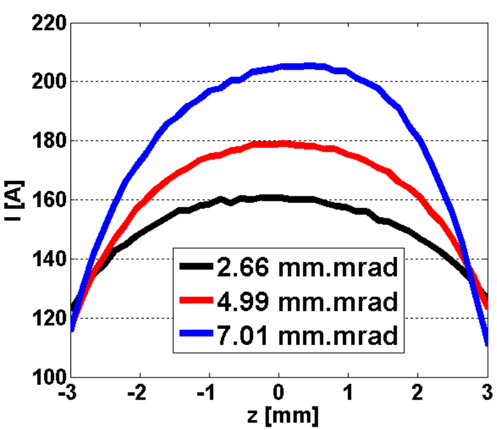
Long. Phase Space



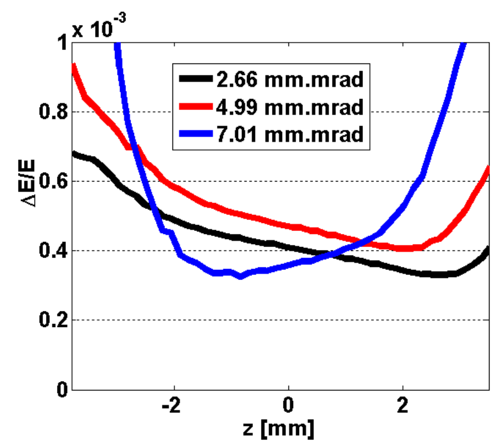
Slice Tr. Emittance



Beam Current



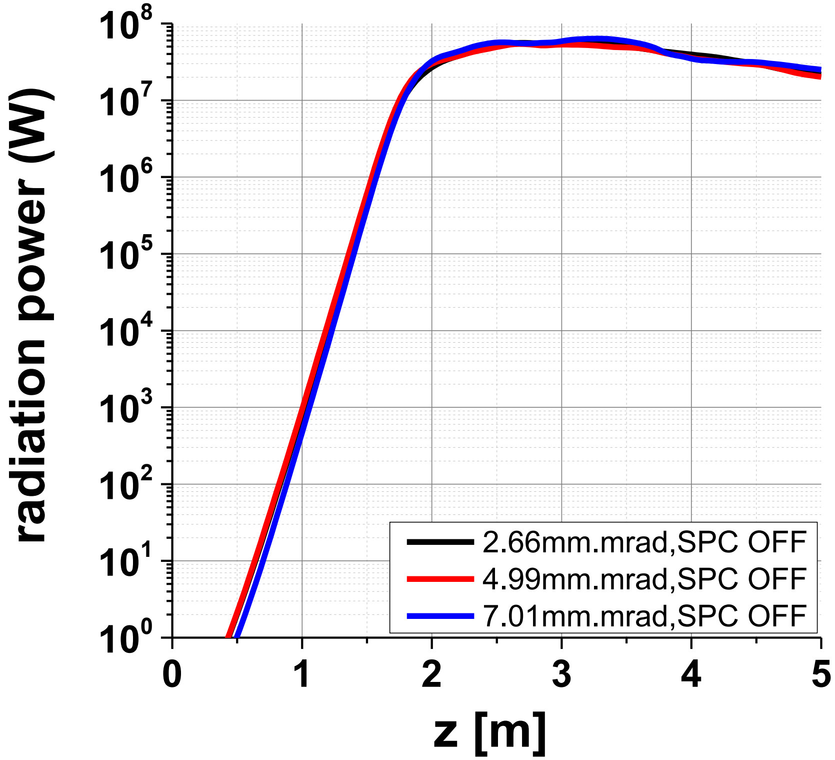
Slice Energy Spread



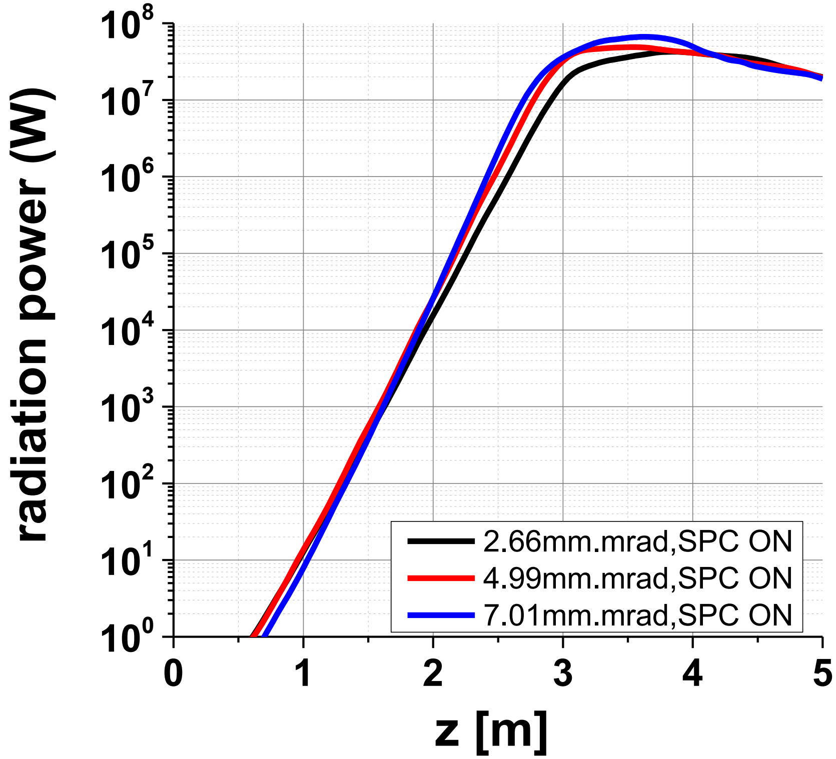
Simulation with Selected Distribution Files (Log Scale)

$\varepsilon_{tr,n}$ [mm.mrad]	$\varepsilon_{slice,mid}$ [mm.mrad]	$E_{spread,mid}$ [keV]	I_{peak} [A]
2.66	~2	~6	160
4.99	~3	~8	170
7.01	~3	~5	205

Results from SPC OFF



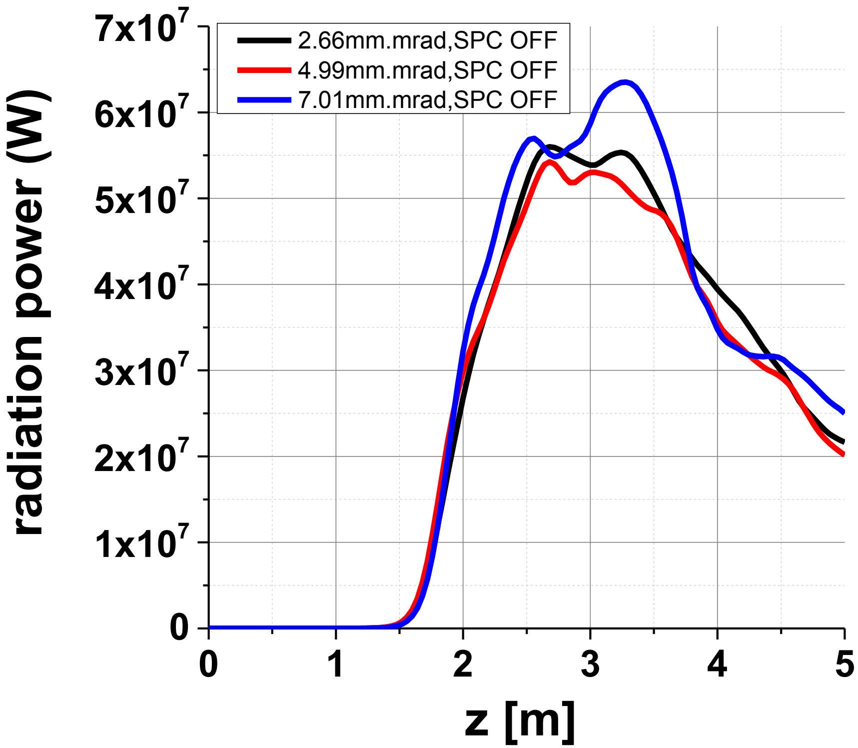
Results from SPC ON



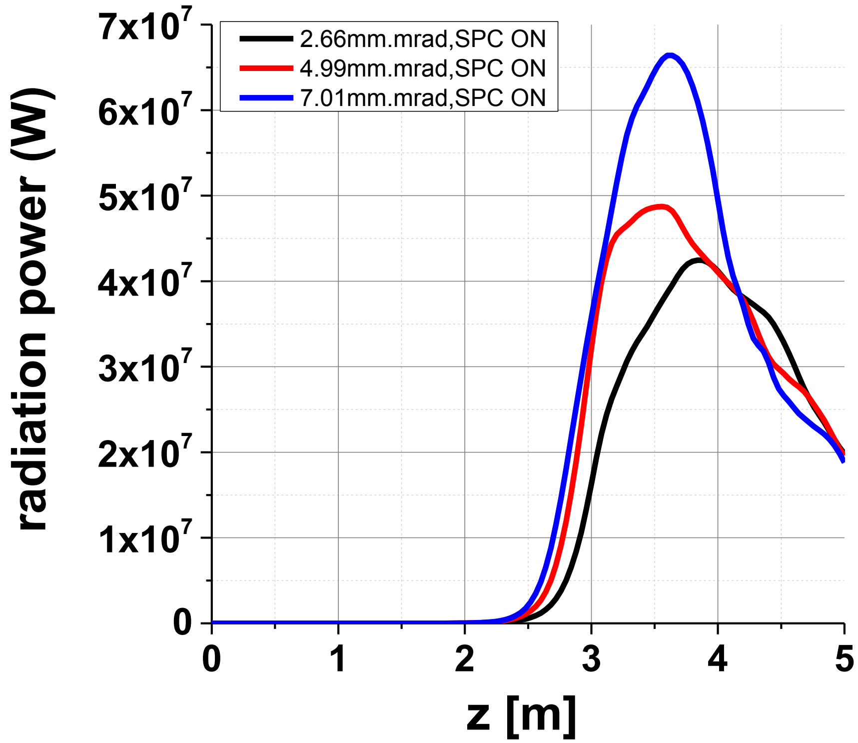
Simulation with Selected Distribution Files (Normal Scale)

$\varepsilon_{tr,n}$ [mm.mrad]	$\varepsilon_{slice,mid}$ [mm.mrad]	$E_{spread,mid}$ [keV]	I_{peak} [A]
2.66	~2	~6	160
4.99	~3	~8	170
7.01	~3	~5	205

Results from SPC OFF



Results from SPC ON



Conclusion

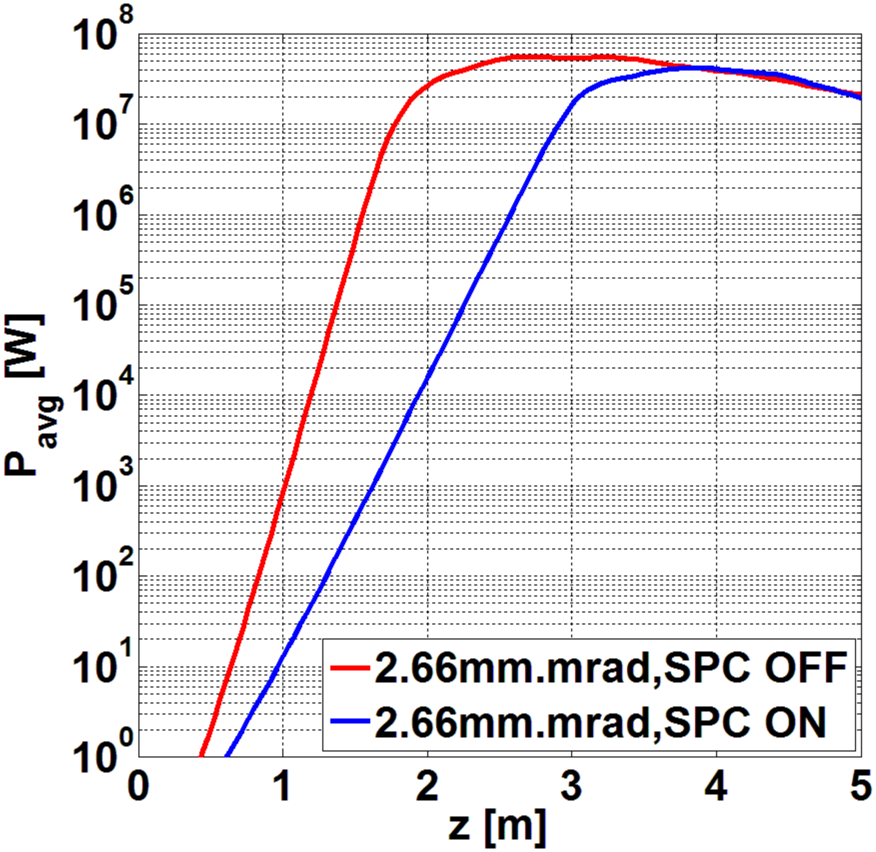
- The results from GENESIS simulation correspond well to the results in benchmark paper. We got radiation pulse energy in level of 10^3 μJ (10^7 W for power level).
- Among the simulation results from 3 beams (**2.66, 4.99 and 7.01 mm.mrad):**
  - For all cases, we got radiation power in level of 10^7 W.
  - We got maximum power from case of 7.01 mm.mrad, in which the beam has the highest peak current.
  - When including space charge effect into the simulations, the saturation length increases. However, it doesn't decrease the maximum power.

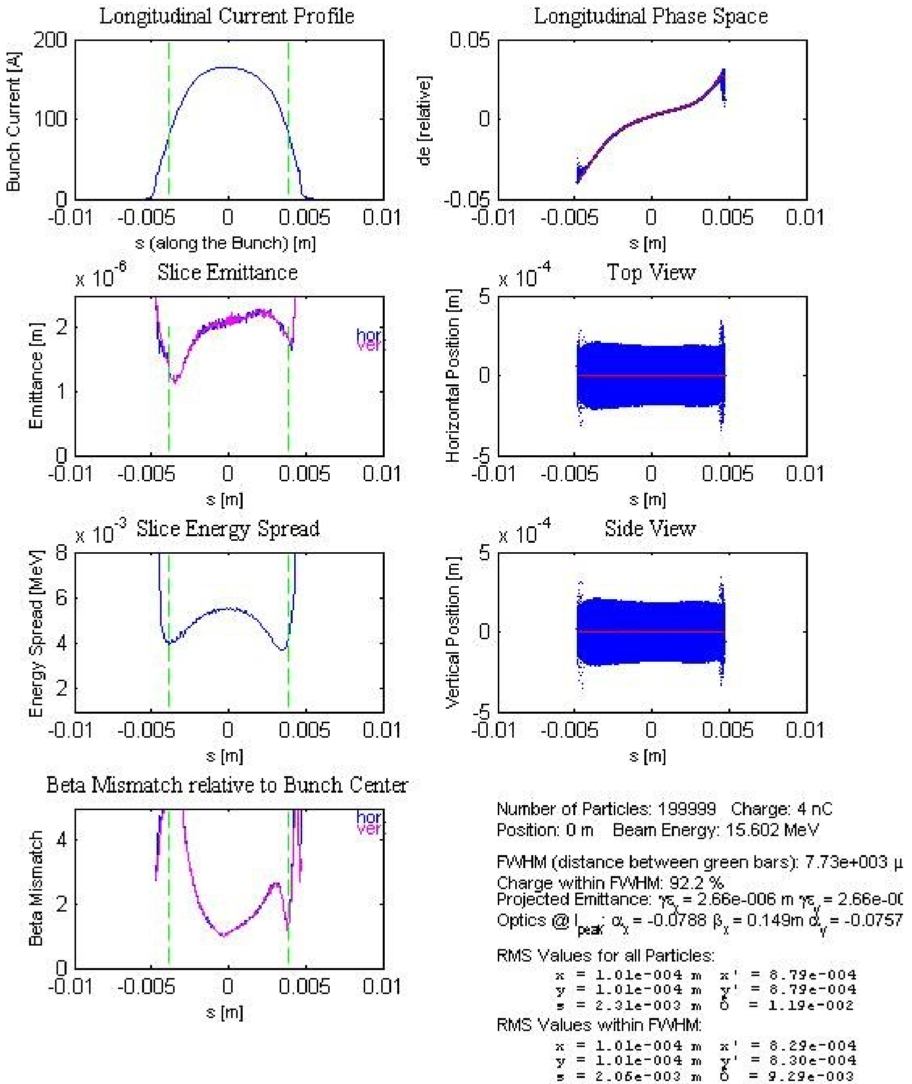
Outlook

- Matching with the real optical magnets
- Clarify what is the maximum laser spot-size at the gun that can be used.
- Perform simulations with:
  - various values of electron beam energy, beta functions,…
  - Planar Undulator
  - etc.

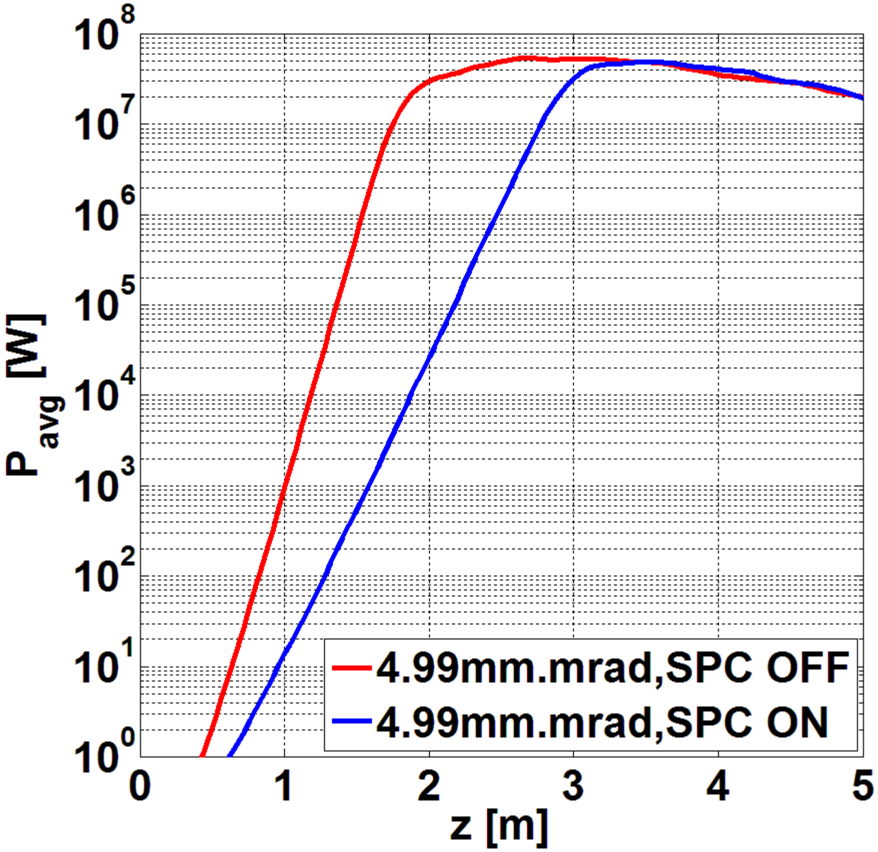
Thanks for your attention

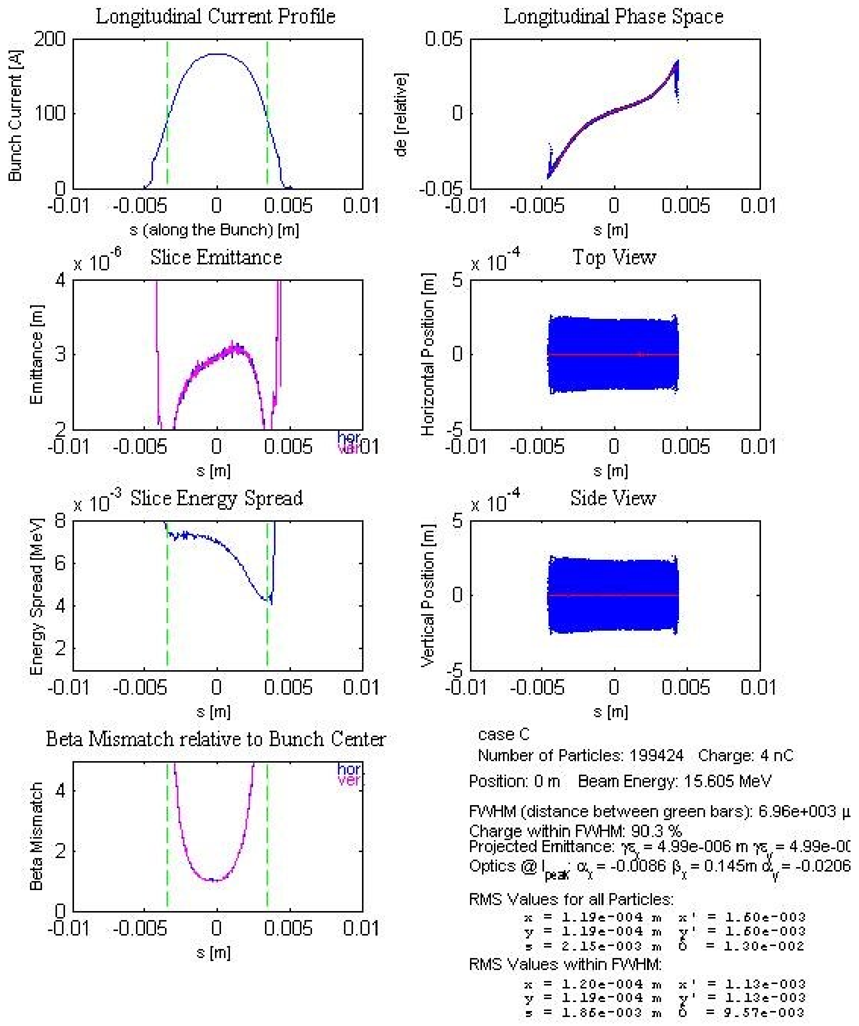
Backup: Simulation Results of 2.66 mm.mrad



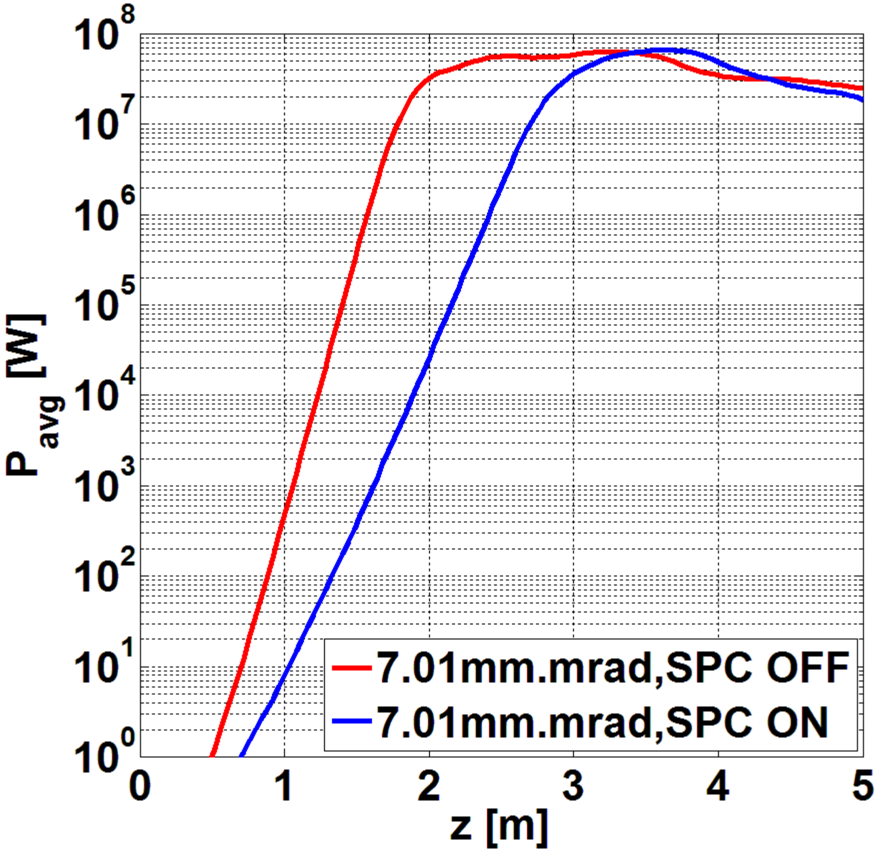


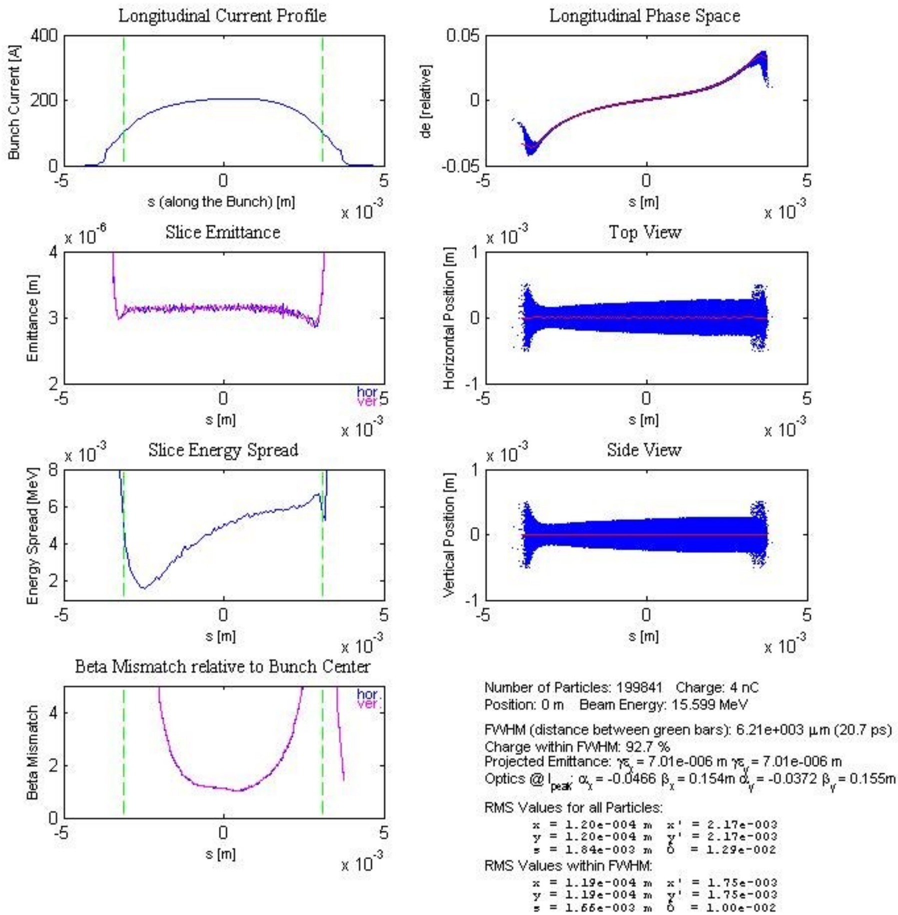
Backup: Simulation Results of 4.99 mm.mrad





Backup: Simulation Results of 7.01mm.mrad





Backup: Equations

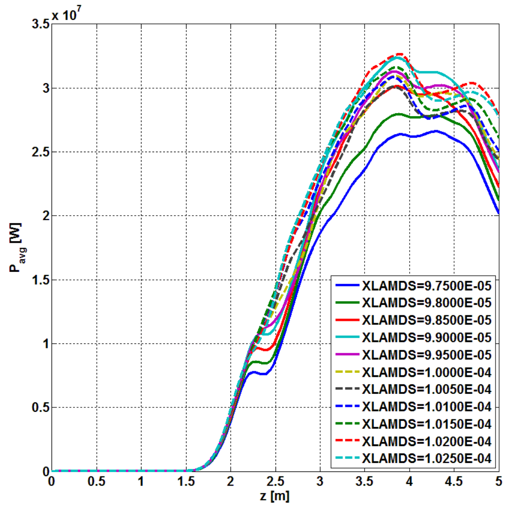
fundamental wavelength of undulator radiation

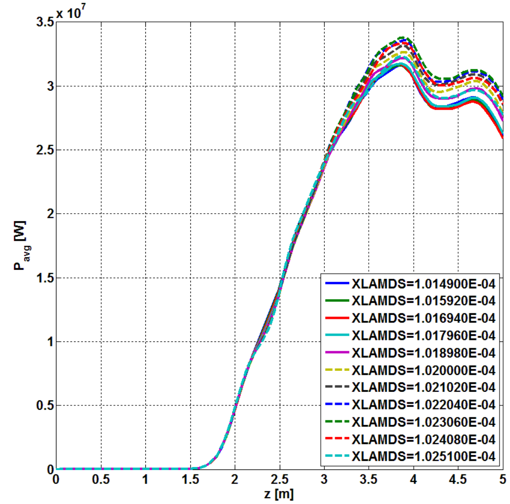
$$\lambda_{rad} = \frac{\lambda_u}{2\gamma^2}\left(1 + \frac{K^2}{2}\right)$$

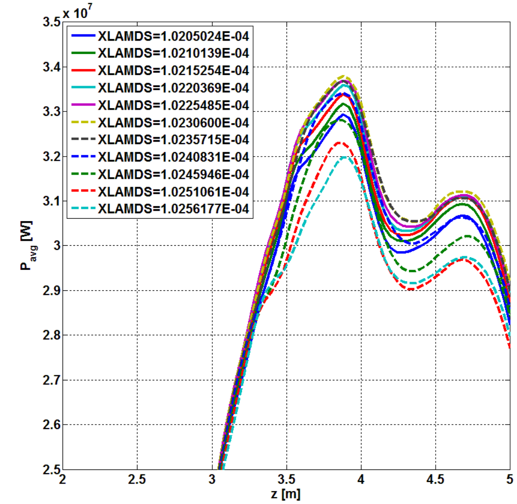
Saturation Efficiency

$$\eta = \frac{P_{out}}{\rho P_{beam}}$$

Backup: Optimization of Radiation Wavelength (XLAMDS)







$\lambda_{central} = 100.00\ um$

$$\frac{\Delta\lambda}{\lambda} = \pm 5E-3$$

$\lambda_{power\ max} = 102.00\ um$

$\lambda_{central} = 102.00\ um$

$$\frac{\Delta\lambda}{\lambda} = \pm 1E-3$$

$\lambda_{power\ max} = 102.306\ um$

$\lambda_{central} = 102.306\ um$

$$\frac{\Delta\lambda}{\lambda} = \pm 5E-4$$

$\lambda_{power\ max} = 102.306\ um$

rms Laser Spot-size at the Cathode

$\varepsilon_{tr,n}$ [mm.mrad]	rms laser spot size [mm]
2.66	1.092
4.99	1.455
7.01	3.500