Parallel operation of European XFEL SASE1 and SASE3 undulator sections

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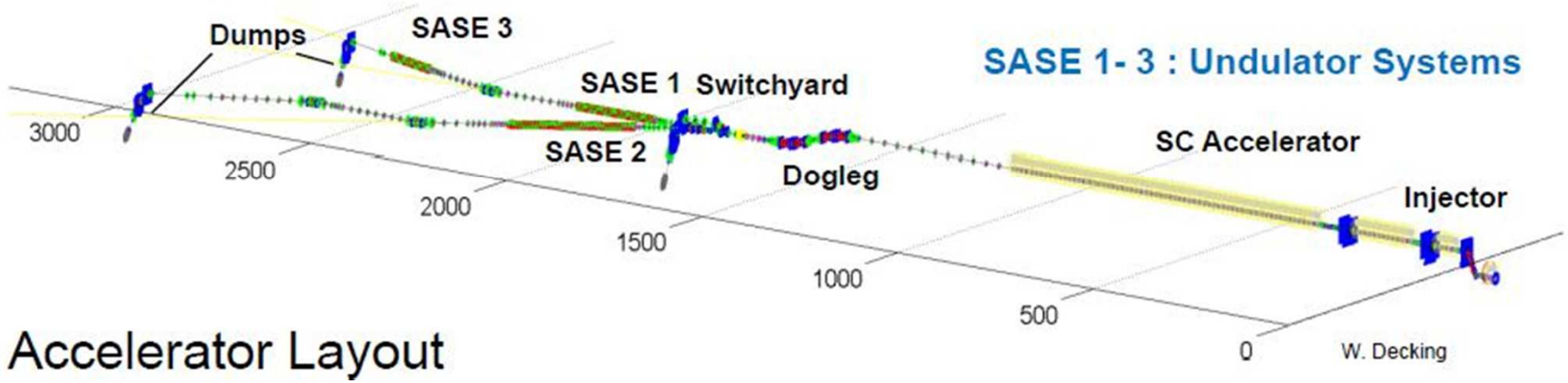
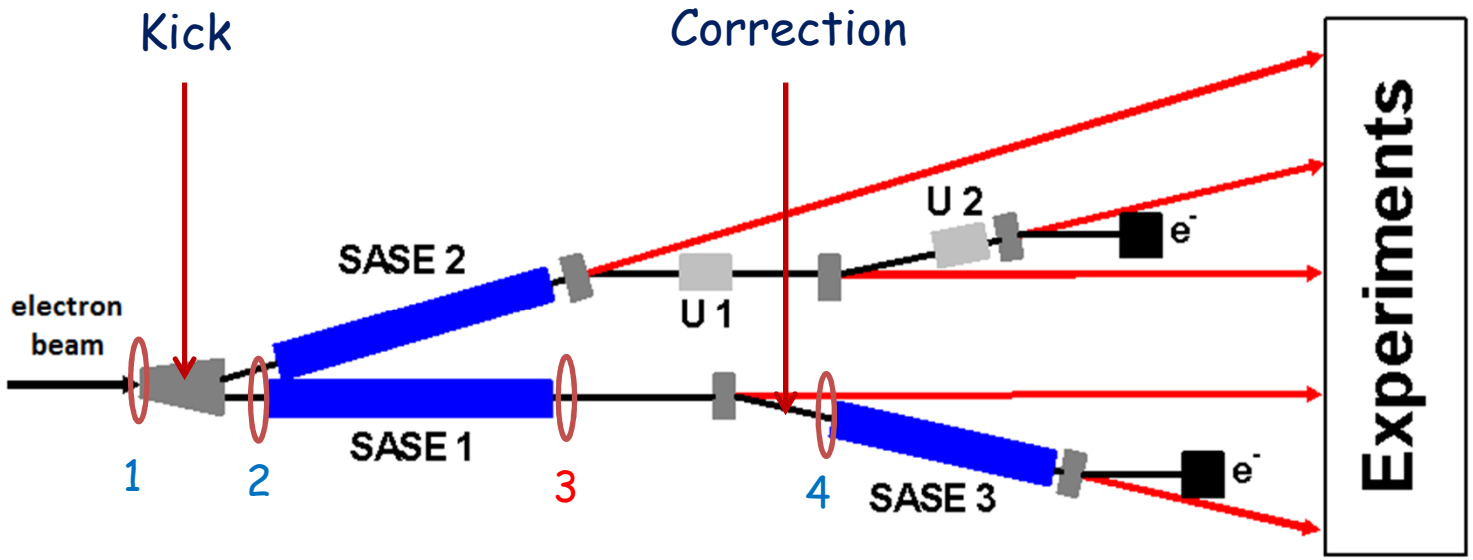
European XFEL (current status)

	SASE1/2	SASE3
λ_0 [mm]	40	68
Operational Gap Range [mm]	10-20	10-25
K-Range	3.9–1.65	9.0-4
Radiation Wavelength Range [nm]		
@ 17.5 GeV	0.147-0.040	1.22-0.27
@ 14.0 GeV	0.230-0.063	1.90-0.42
@ 8.5 GeV	0.625-0.171	5.17-1.15
# of Segments	35	21
System Length [m]	213.5	128.1



Introduction

Goal: To achieve lasing in SASE3 by disturbing the beam trajectory before SASE1 using fast kicker.



Considered cases

Beam energy (GeV)	SASE1 λ(nm)	SASE3 λ(nm)
17.5	0.1	0.4
14	0.23	0.4
8.5	0.62	1.1

Conversion scripts

1. astra2elegant (MATLAB script)
2. elegant2genesis (SDDS ToolKit)
3. genesis2elegant (MATLAB script)
4. elegant2genesis

Conversion scripts

1. astra2elegant

ASTRA beam file (x, y, z, px, py, pz, ….) → MATLAB script → ELEGANT beam file (x, x′, y, y′, t, γ, ….)

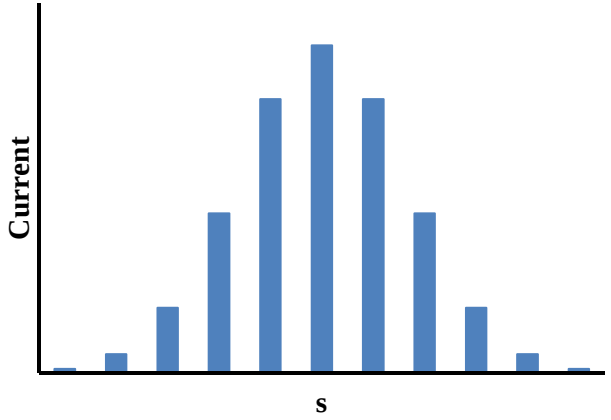
2. elegant2genesis

This program is a part of SDDS ToolKit

3. genesis2elegant

GENESIS	ELEGANT
All slices have the same number of macro particles, but different currents.	All macro particles, have the same charge.

Different treatment of macro particles



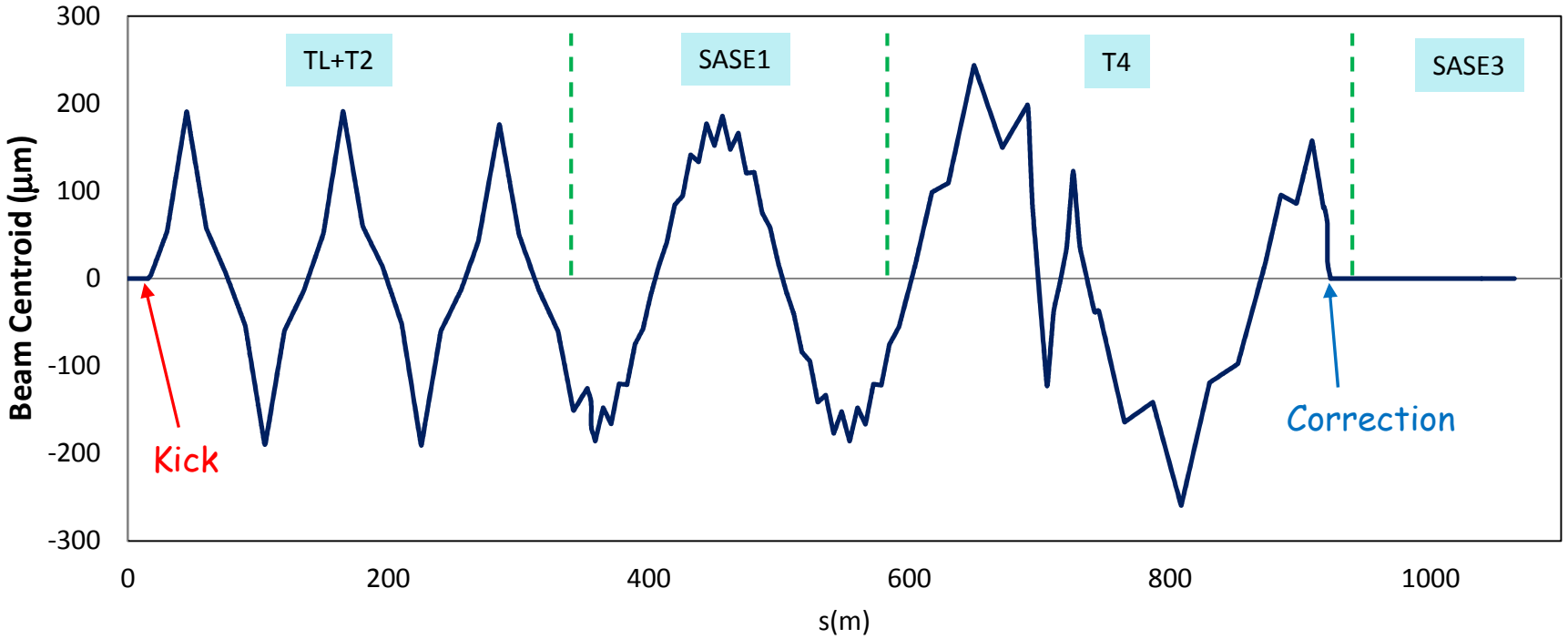
genesis2elegant

$$N_i = N_p \cdot \frac{I_i}{I_{\max}}$$

N_p -particles per slice
I_i -current of i-th slice
$I_{\max}$ -max. current

Numerical simulations

Kick by KFBX.1893.TL fast kicker and correction by CEX.2795.T4 and CEX.2799.T4 correctors



Beam centroid for 17,5 GeV case when kick is equal to 4 µrad

Considered cases for kick values

17,5 GeV
- 2 µrad kick
- 4 µrad kick
- 6 µrad kick

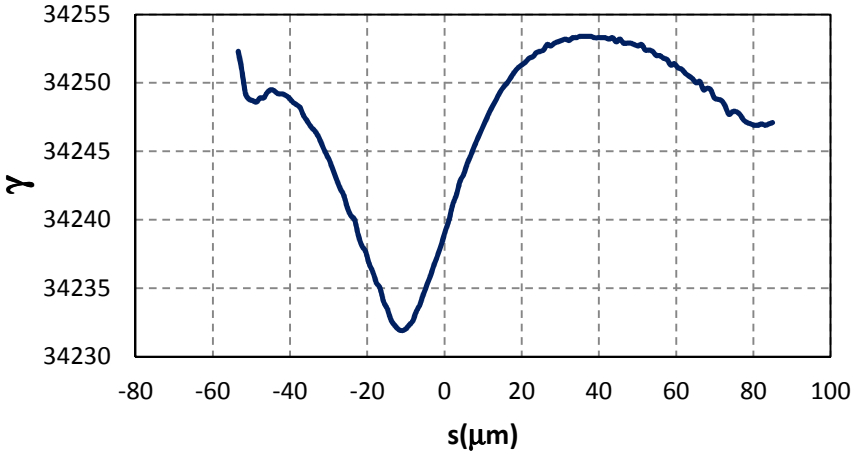
14 GeV
- 4 µrad kick
- 6 µrad kick
- 8 µrad kick

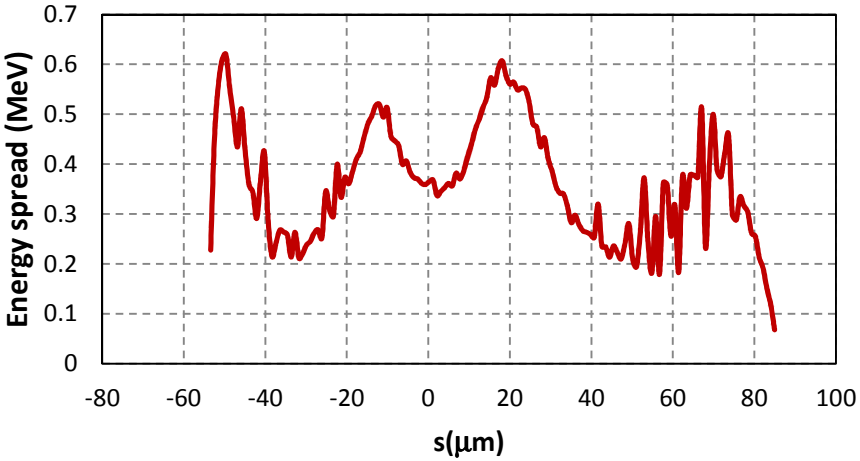
8.5 GeV
- 4 µrad kick
- 6 µrad kick
- 8 µrad kick

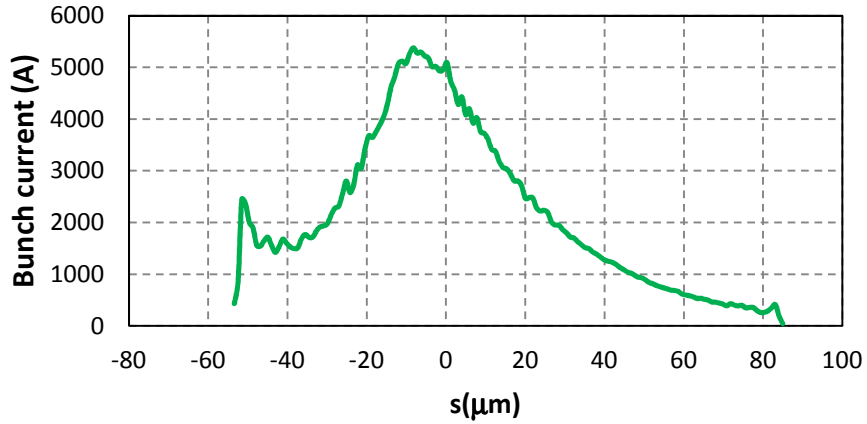
Max. traj. deviation	500 µm
Corrector max. kicks	20 µrad

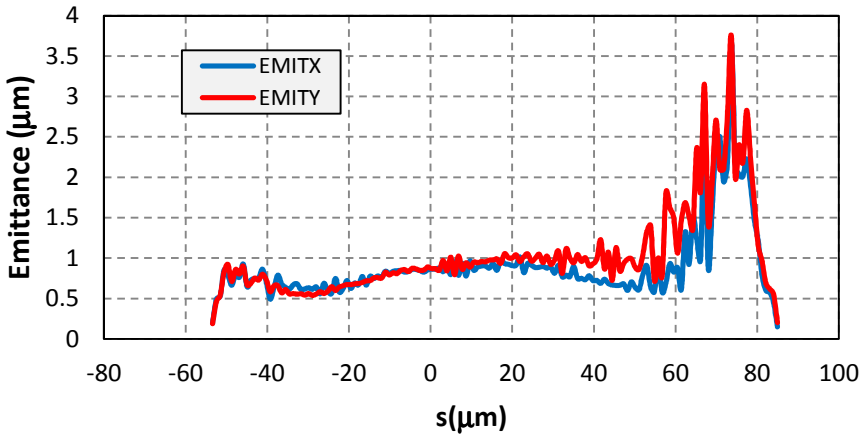
Numerical simulations (E=17,5 GeV, Q=1nC)

ASTRA beam before TL section







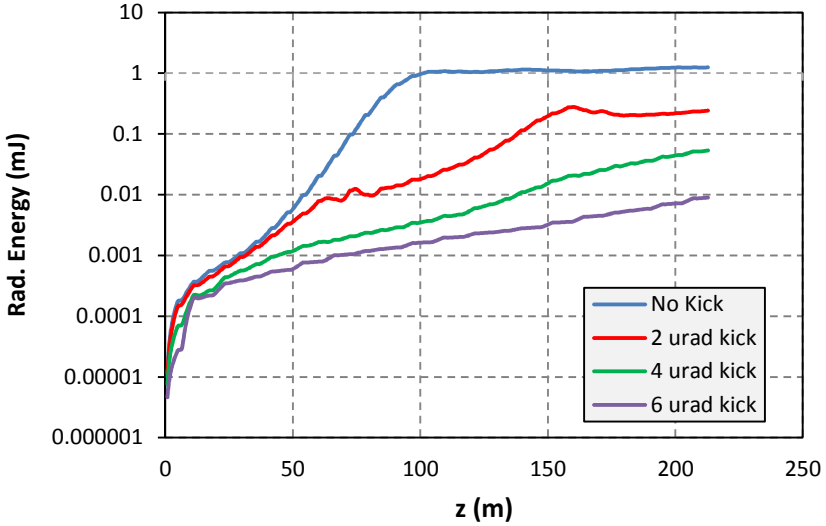


ε_x = 0,9 μm, ε_y = 1,08 μm

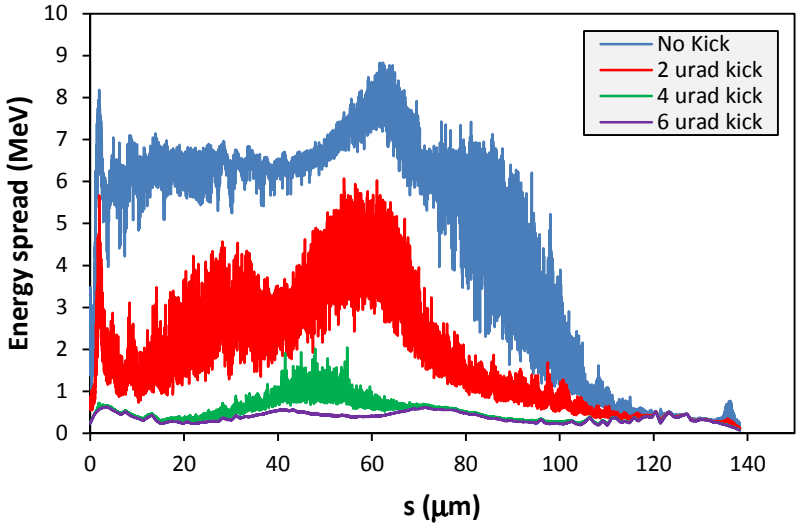
Beam file provided by Guangyao Feng

Numerical simulations (E=17,5 GeV, Q=1nC)

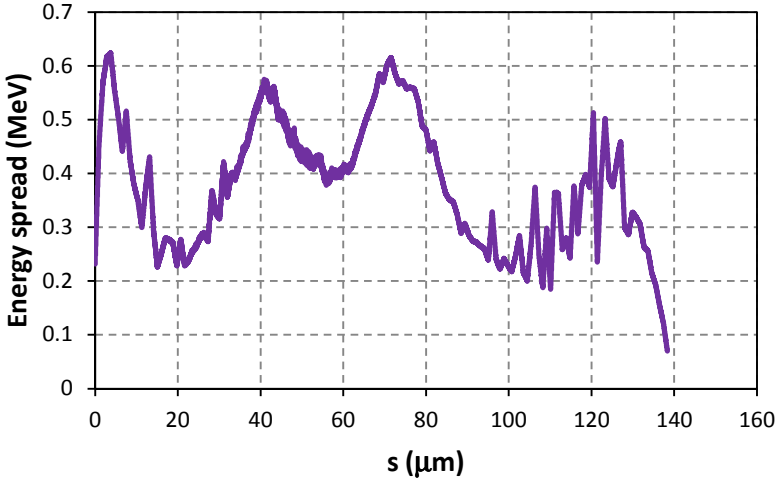
Rad. energy along SASE1 (0,1 nm)



Energy spread after SASE1



Energy spread after SASE1 for 6 μrad kick

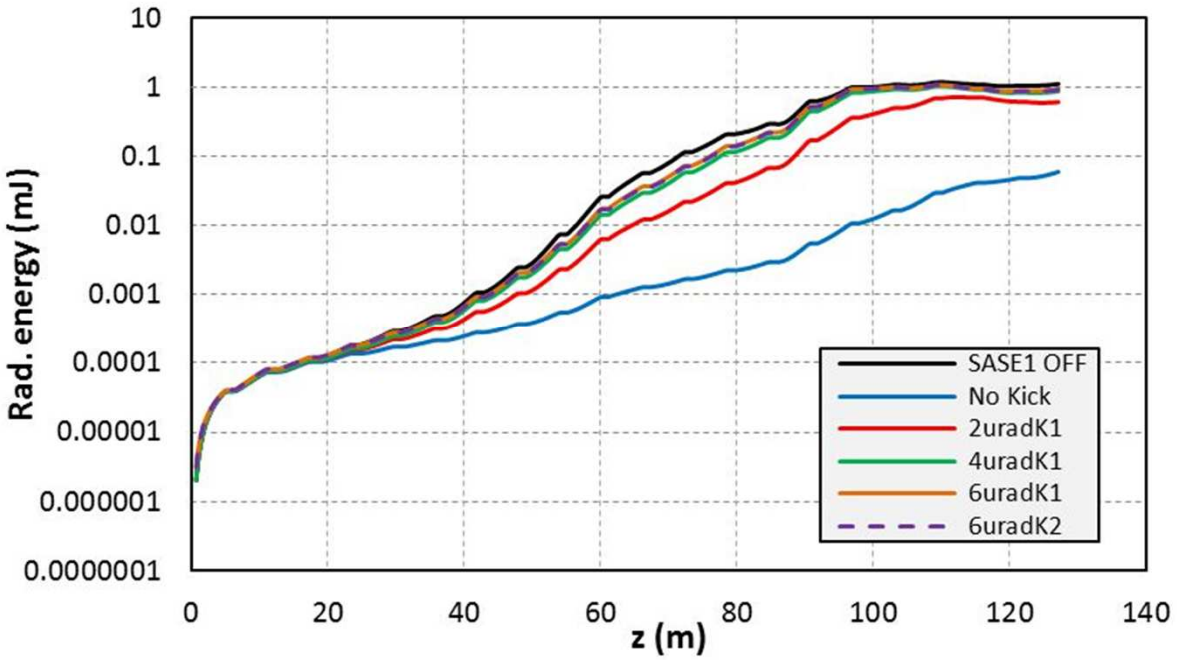


Rel. changes of sat. length and rad. energy at sat.

Kick value	L_{sat}	E_{sat}
No kick	1	1
2 μrad	1,75	0,43
4 μrad	-	-
6 μrad	-	-

Numerical simulations (E=17,5 GeV, Q=1nC)

Rad. energy along SASE3 (0,4 nm)

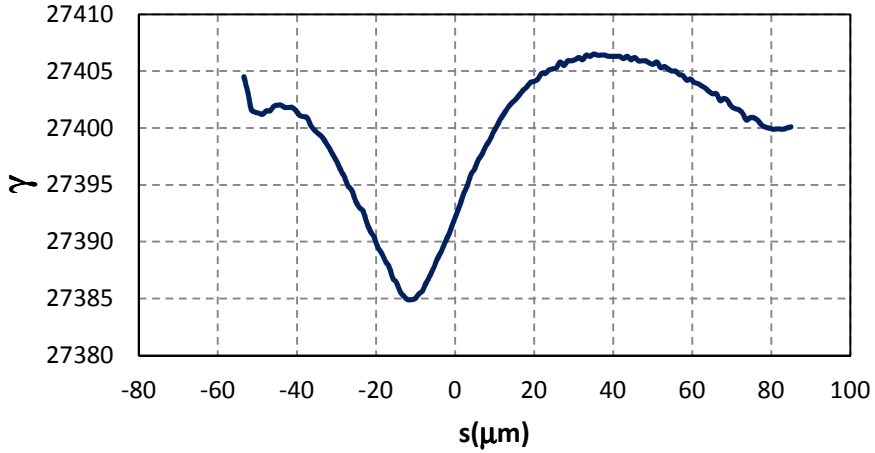


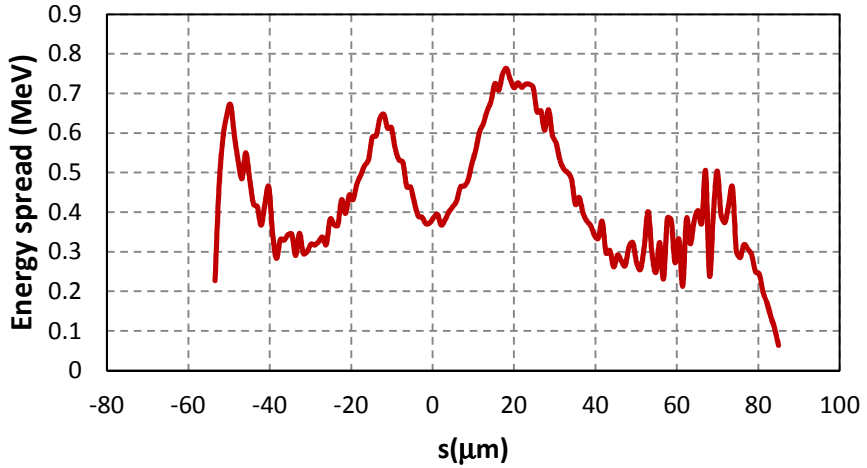
Rel. changes of sat. length and rad. energy at sat.

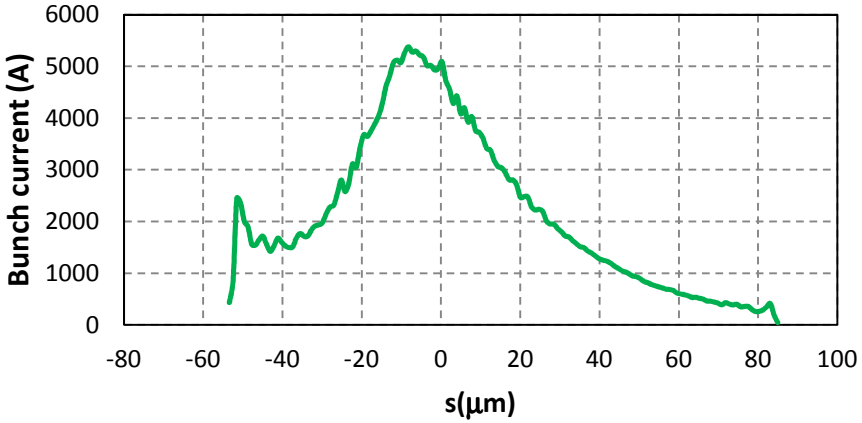
Kick value	L_{sat}	E_{sat}
SASE1 OFF	1	1
6 μrad	1,02	0,95
4 μrad	1,04	0,91
2 μrad	1,12	0,7
No kick	-	-

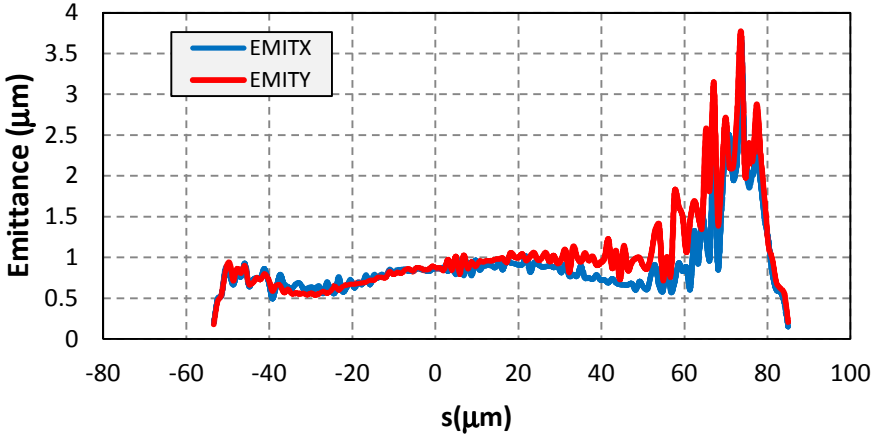
Numerical simulations (E=14 GeV, Q=1nC)

ASTRA beam before TL section





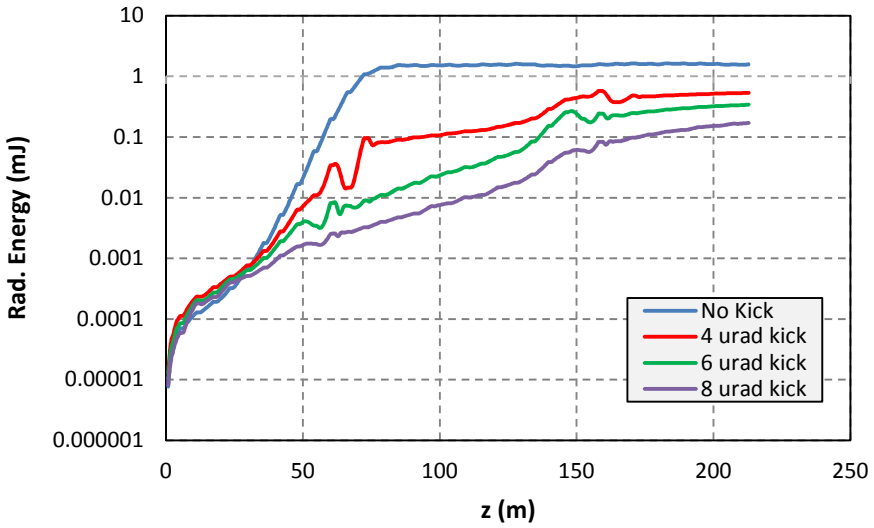




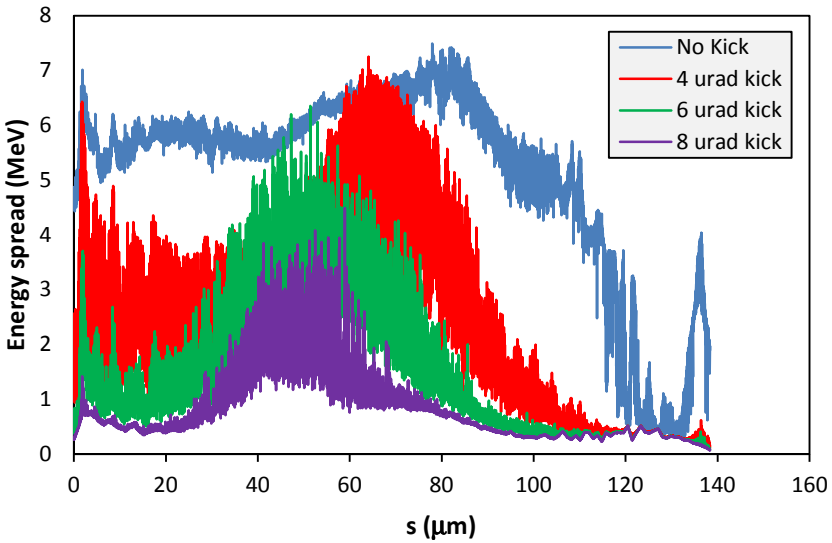
ε_x = 0,91 μm, ε_y = 1,08 μm

Numerical simulations (E=14 GeV, Q=1nC)

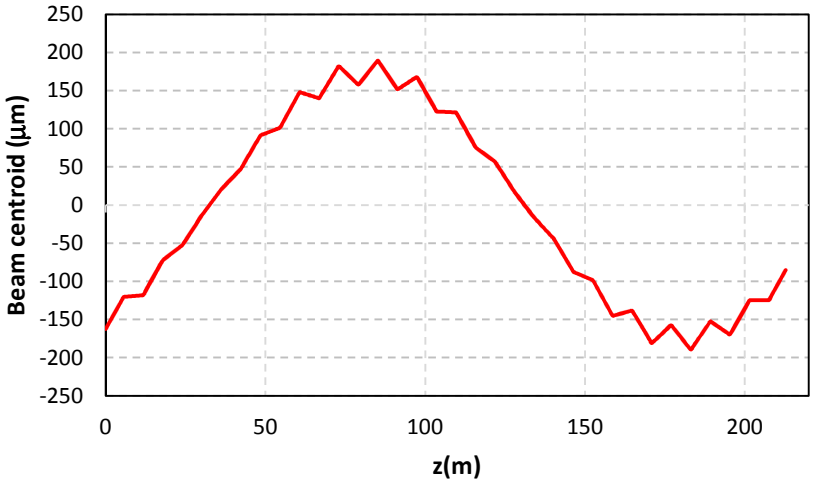
Rad. energy along SASE1 (0,1 nm)



Energy spread after SASE1



Beam centroid along SASE1 for 4μrad kick

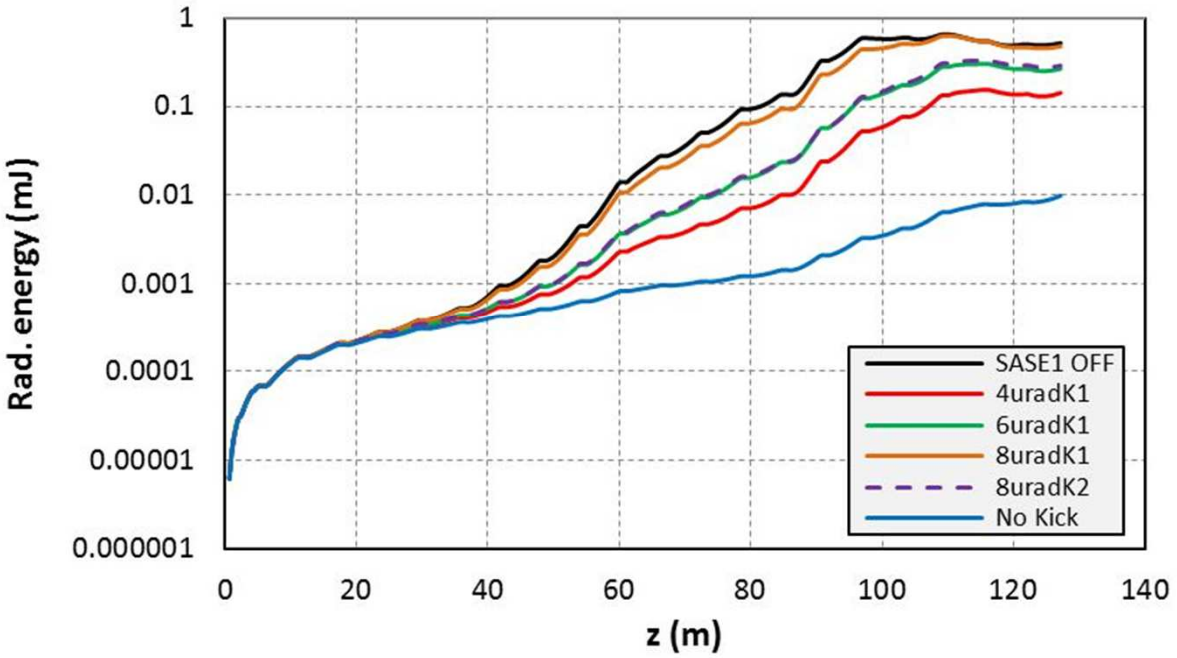


Rel. changes of sat. length and rad. energy at sat.

Kick value	L_{sat}	E_{sat}
No kick	1	1
4 μrad	1,95	0,35
6 μrad	-	-
8 μrad	-	-

Numerical simulations (E=14 GeV, Q=1nC)

Rad. energy along SASE3 (0,4 nm)

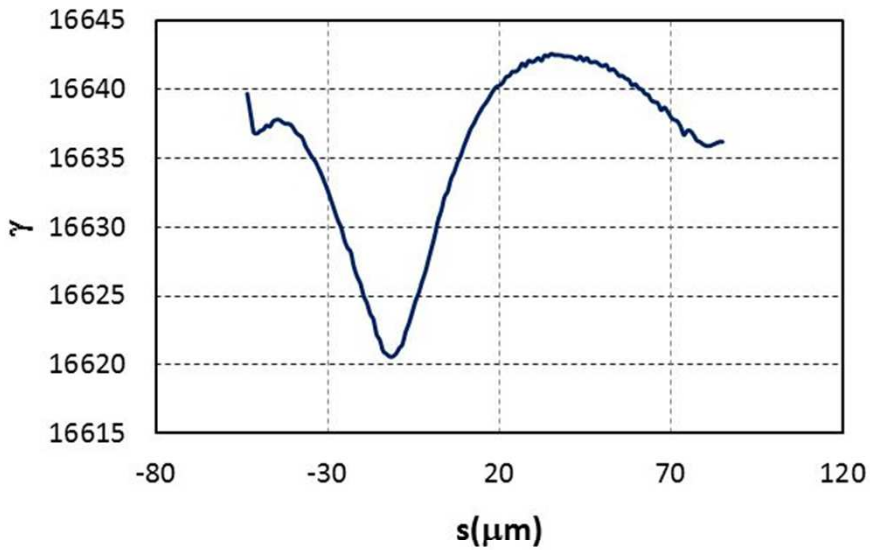


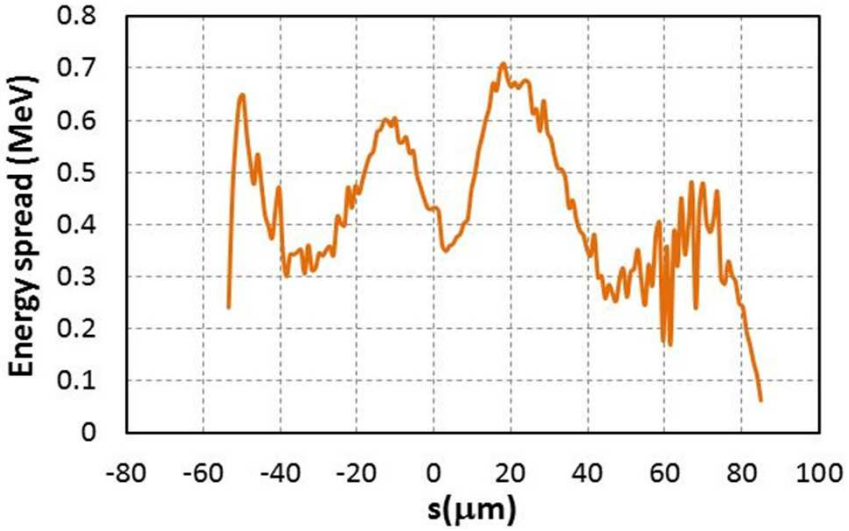
Rel. changes of sat. length and rad. energy at sat.

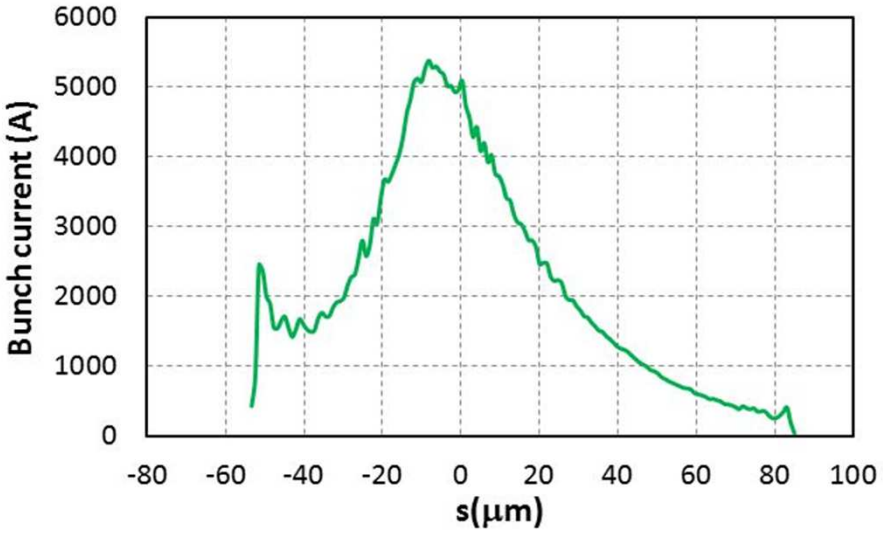
Kick value	L_{sat}	E_{sat}
SASE1 OFF	1	1
8 μrad	1,02	0,78
6 μrad	1,12	0,5
4 μrad	1,14	0,23
No kick	-	-

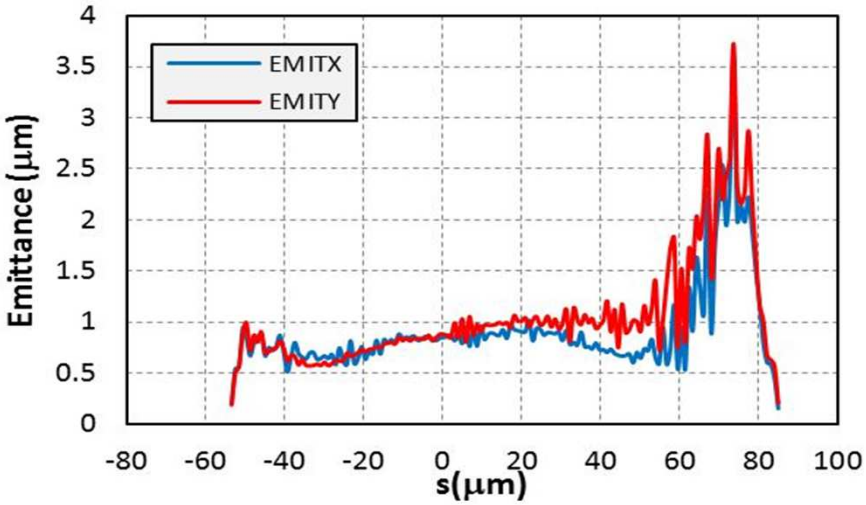
Numerical simulations (E=8.5 GeV, Q=1nC)

ASTRA beam before TL section





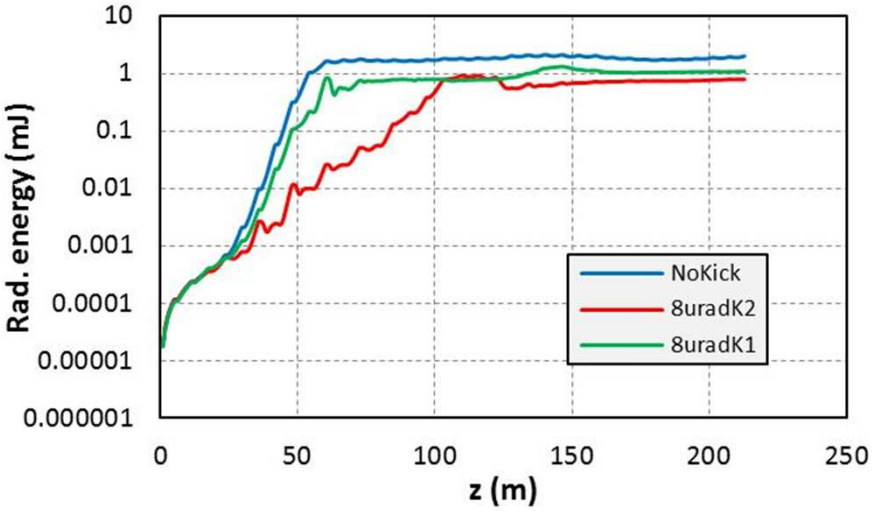




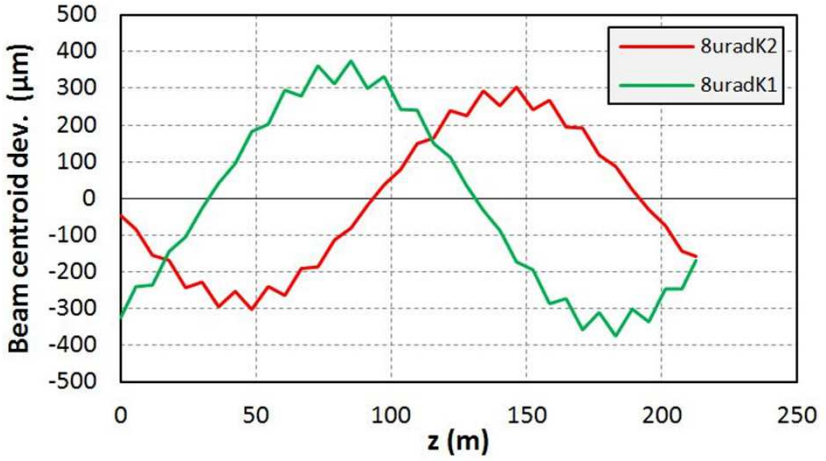
ε_x = 0,9 μm, ε_y = 1,08 μm

Numerical simulations (E=8.5 GeV, Q=1nC)

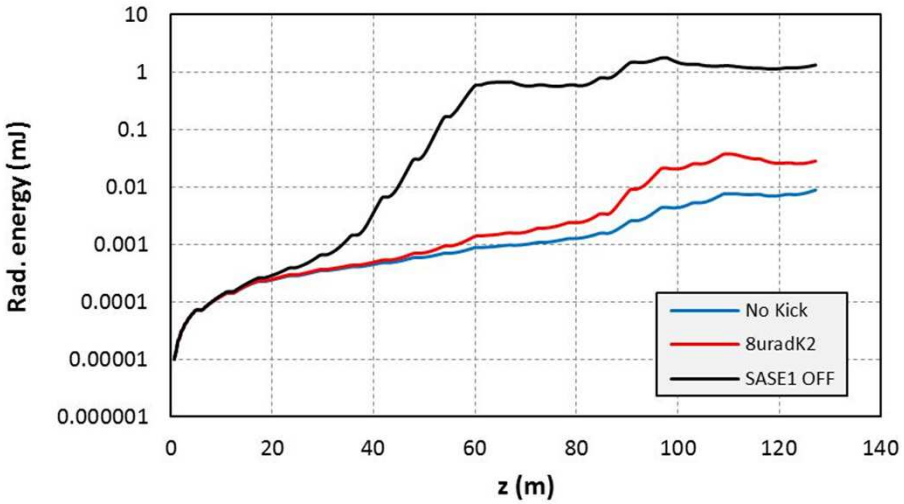
Rad. energy along SASE1 (0,62 nm)



Beam centroid along SASE1
for different kick position



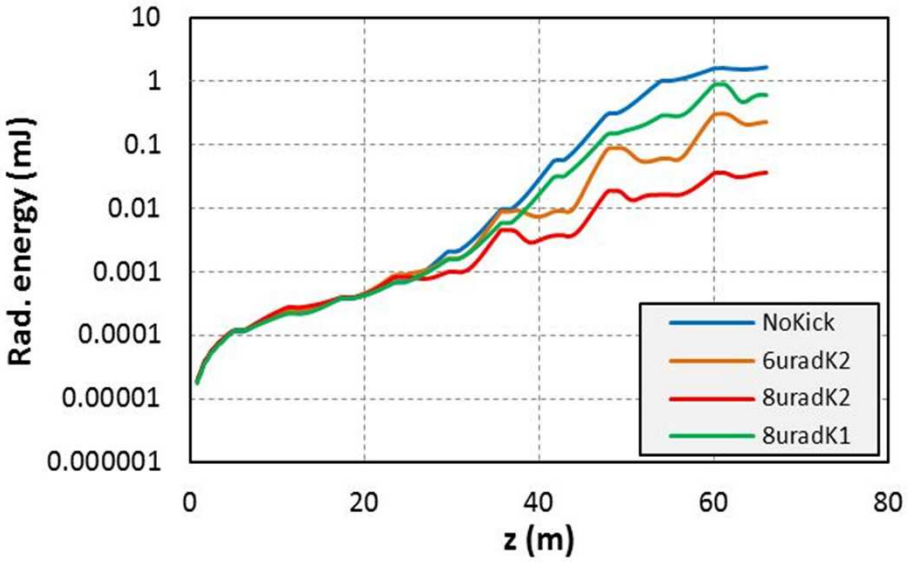
Rad. energy along SASE3 (1,1 nm)



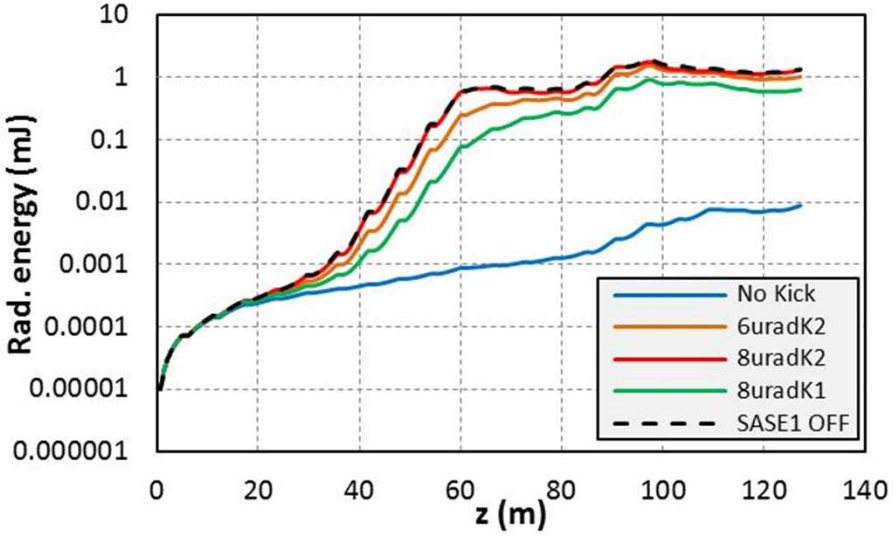
Two solutions
a) Shortened SASE1
b) Lowered average beta in SASE1

Shortened SASE1

Rad. energy along SASE1 (0,62 nm)



Rad. energy along SASE3 (1,1 nm)

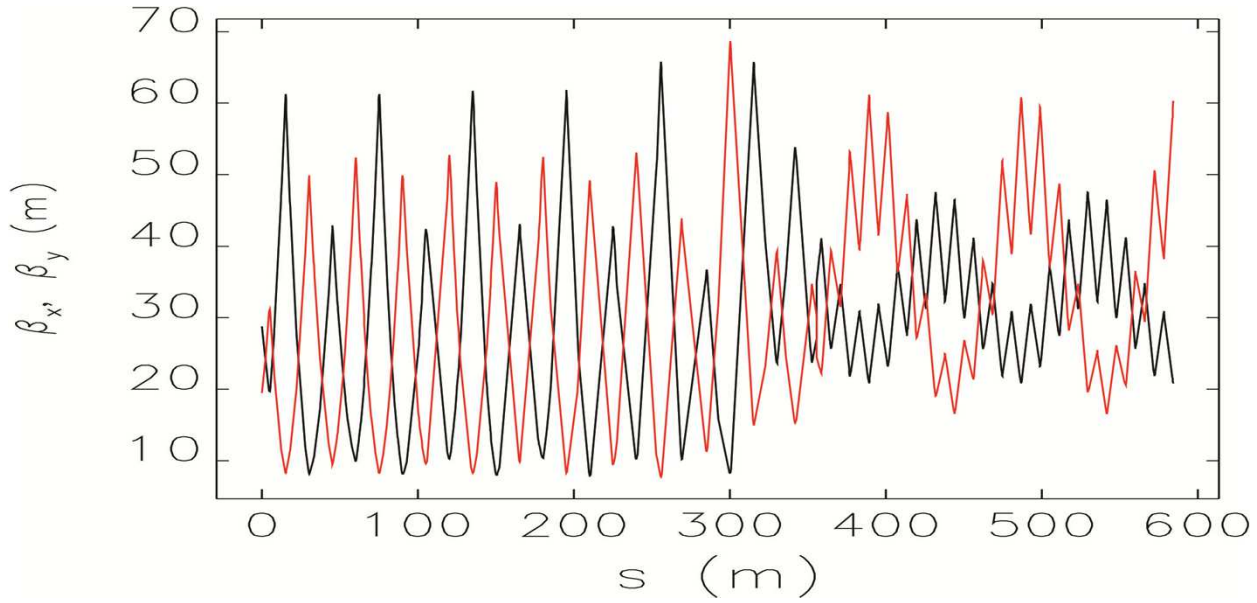


Relative change of saturation lengths and radiation energy at saturation

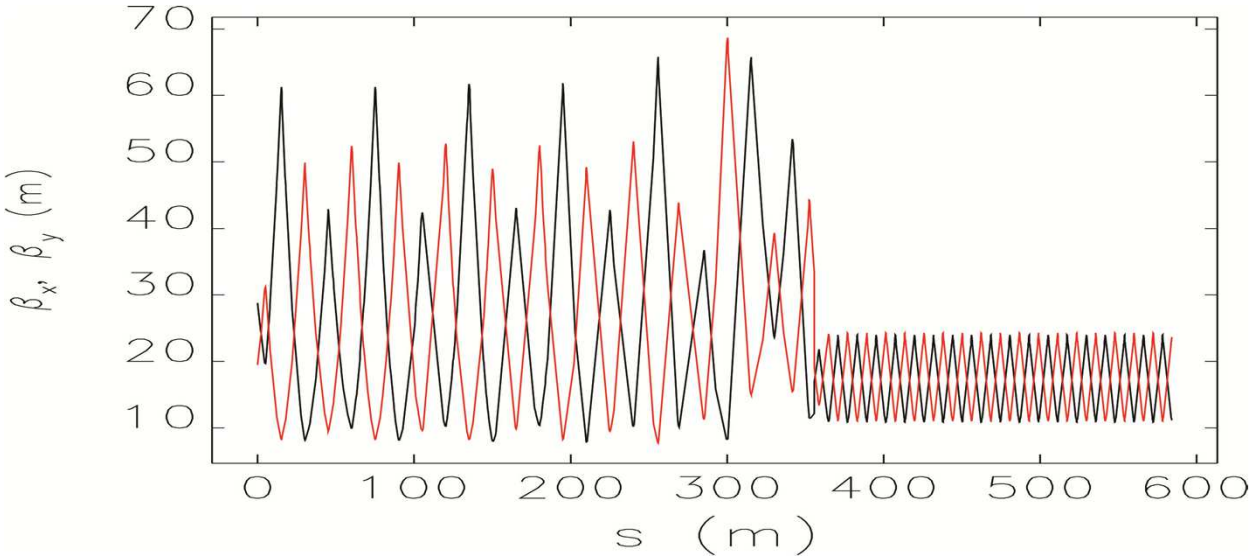
	short SASE1		SASE3	
Kick Value	$L_{sat}/L_{sat}^{(no\,kick)}$	$E_{sat}/E_{sat}^{(no\,kick)}$	$L_{sat}/L_{sat}^{(SA1off)}$	$E_{sat}/E_{sat}^{(SA1off)}$
6 μrad (K2)	-	-	1.02	0.4
8 μrad (K2)	-	-	1.01	0.98
8 μrad (K1)	1.11	0.81	1.03	0.14

Beta matching

Average beta =33m

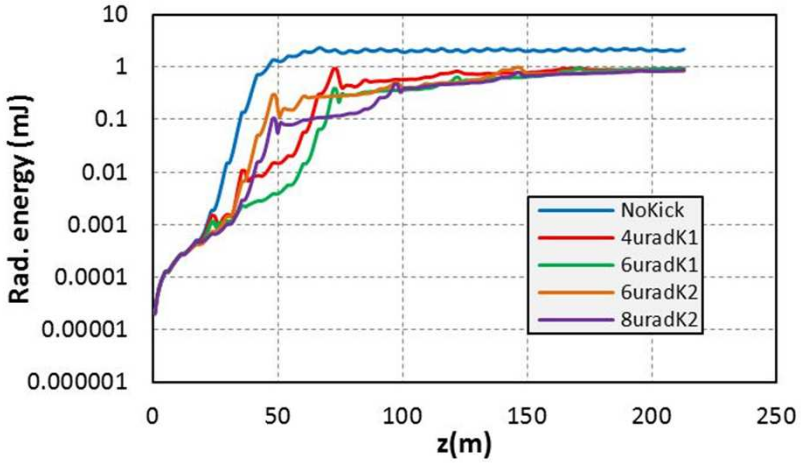


Average beta =17m

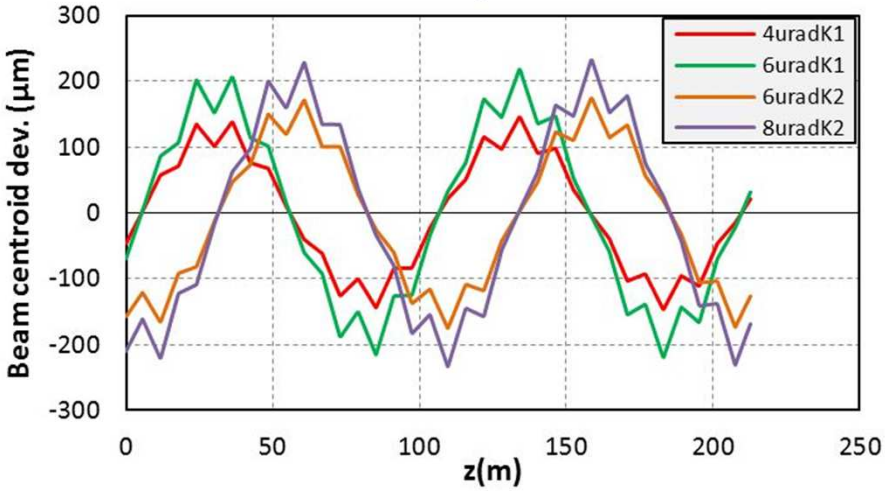


Lowered average beta in SASE1

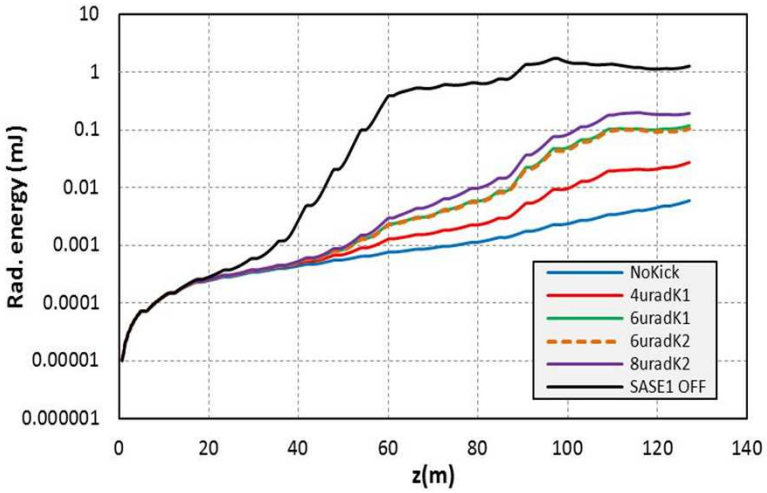
Rad. energy along SASE1 (0,62 nm)



Beam centroid along SASE1
for different kick position



Rad. energy along SASE3 (1,1 nm)

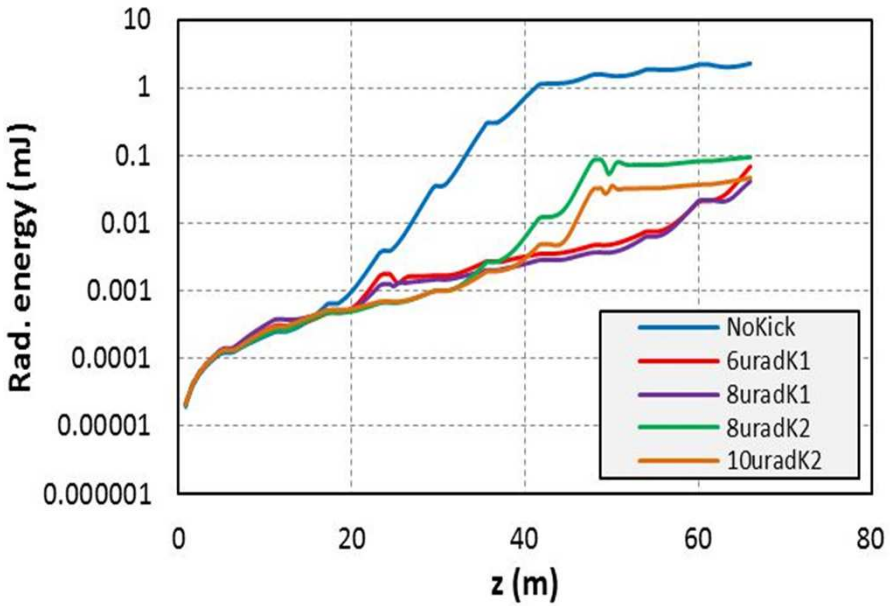


Rel. changes of sat. length and rad. energy at sat.

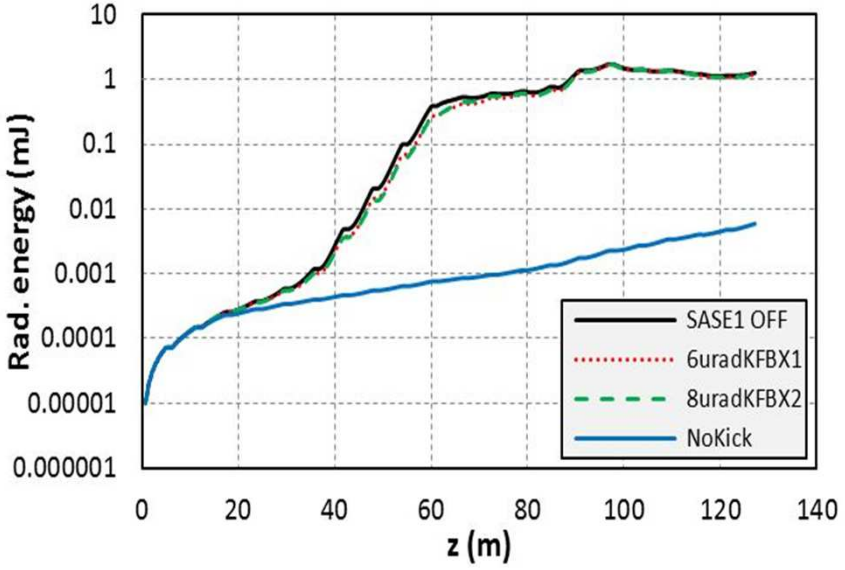
	SASE1		SASE3	
Kick Value	$L_{sat}/L_{sat}^{(no\,kick)}$	$E_{sat}/E_{sat}^{(no\,kick)}$	$L_{sat}/L_{sat}^{(SA1off)}$	$E_{sat}/E_{sat}^{(SA1off)}$
4 µrad (K1)	1.54	0.72	-	-
6 µrad (K1)	1.55	0.31	1.73	0.37
6 µrad (K2)	1.03	0.25	1.74	0.37
8 µrad (K2)	1.04	0.08	1.78	0.45

Shortened SASE1 (15m average beta)

Radiation energy along shortened SASE1



Rad. energy along SASE3



Summary

Traj. max. deviation in SASE1 and rel. change of sat. length and rad. energy at saturation

Beam energy (GeV)	λ_{SA1} (nm)	λ_{SA3} (nm)	Pref. kick value	Traj. max. dev. in SASE1 (μm)	SASE3	
					$L_{sat}/L_{sat}^{(SA1off)}$	$E_{sat}/E_{sat}^{(SA1off)}$
17.5	0.1	0.4	4μrad at K1	173	1.04	0.91
14	0.23	0.4	8μrad at K1	352	1.02	0.78
8.5(β_{av} = 33m) short SASE1	0.62	1.1	8μrad at K2	300	1.01	0.98
8.5(β_{av} = 17m)			8μrad at K2	227	1.78	0.45
8.5(β_{av} = 17m) short SASE1			6μrad at K1	195	1.01	0.7

- TESLA-FEL-2015-01
- Will be presented at IPAC´16