BEAM REALISTIC ERROR ORBIT IMPACT ON SASE PERFORMANCE

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CANDLE-DESY/MPY

(discussions and input from W.Decking, M.Vogt, T.Limberg)

- problem definition
- the best, intermediate and the worst cases
- residual misalignments
- impact on FEL peak power
- quadrupole magnets misalignments and the beam launch
- single kick effect
- conclusions

Beam parameters at the entrance of the undulator system SASE1

Electron energy [GeV]	17.5
Bunch length (RMS) [m]	$2.5\text{x}10^{-05}$
Bunch charge [nC]	1
Emittance, ε_x [mm-mrad]	1.4
Emittance, ε_y [mm-mrad]	1.4
Energy spread [MeV]	1.5 ($8.57\text{ x}10^{-05}$)
Peak current [kA]	5
γ	34246.6

SASE1 FEL design parameters

K value	3.3
Period length [cm]	3.56
Segment length [m]	5
Number of segments	33
Segment interval [m]	6.1
Inter-segments drift space [m]	1.1
Periods per segment	140
Total length [m]	201
Resonant radiation wavelength [nm]	0.1
# of quadrupole magnets	34
Total length [m]	201
FODO period length [m]	12.2
Av. Beta function [m]	32
Quad. Magnet's integrated field [T]	3.6

T. Tanaka, H. Kitamura, and T. Shintake, Nucl. Instrum. Methods Phys. Res., Sect. A **528**, 172 (2004).

After the kick gain length increases:

$$L_G \to L_G / \left(1 - \frac{\vartheta^2}{\vartheta_c^2} \right)$$

where the critical angle corresponds to the kick that completely destroys further radiation growth

$$\vartheta_c = \sqrt{\frac{\lambda_R}{L_G}}$$

A gain length is calculated for SASE1 at =0.1nm is about 6.1m, and real real gain length is ~9m , that gives

$$\vartheta_c \approx 3\mu rad$$

due to quad. misalignment $x_Q \approx 50\mu m$

Best

A300em6_B300em6_X001em6t20_D005em7t20_M001em6_vi01_x.txt

D=5x10^-7m

Intermediate

A300em6_B300em6_X001em6t20_D002em6t20_M001em6_vi01_x.txt

D=2x10^-6m

Worst

A300em6_B300em6_X001em6t20_D050em6t20_M001em6_vi05_x.txt

D=5x10^-5m

Intermediated005

D=5x10^-6m

Intermediated010

D=10x10^-6m

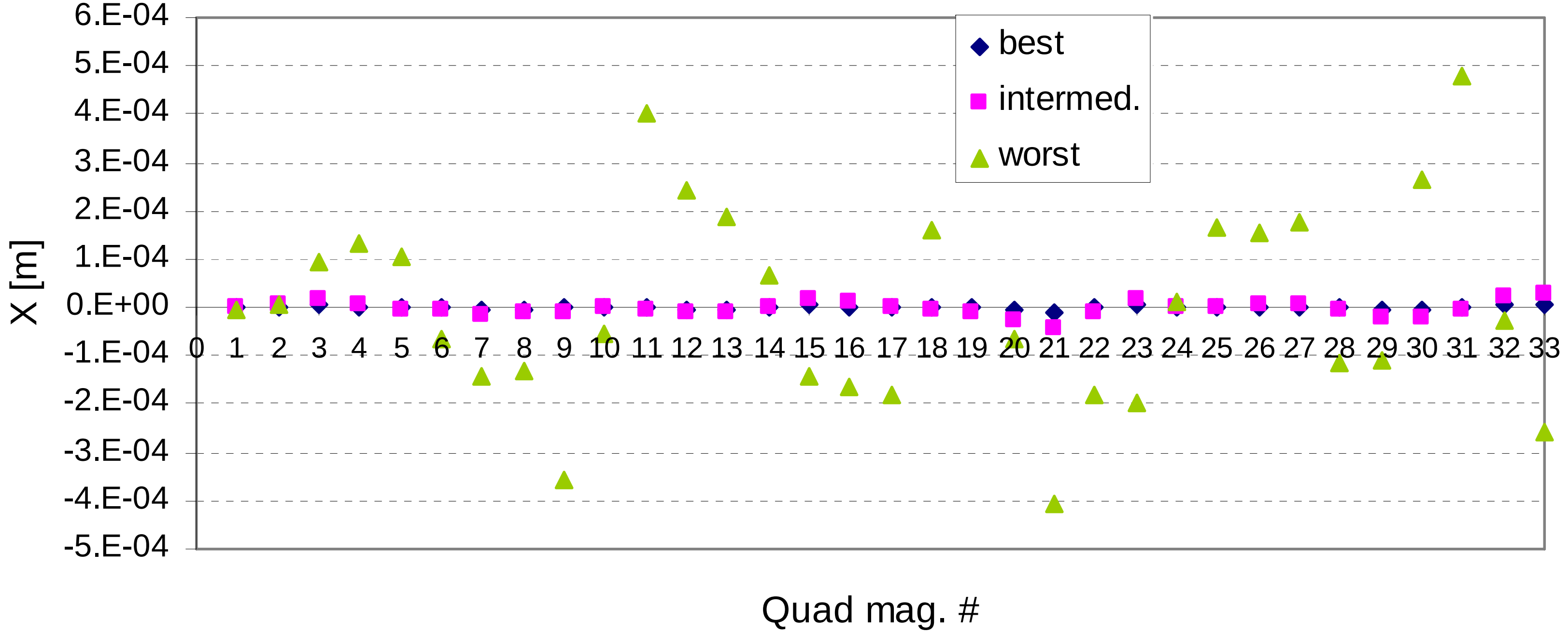
A=300x10-6m --- quad initial rms misalignment

B=300x10-6m --- BPM offsets

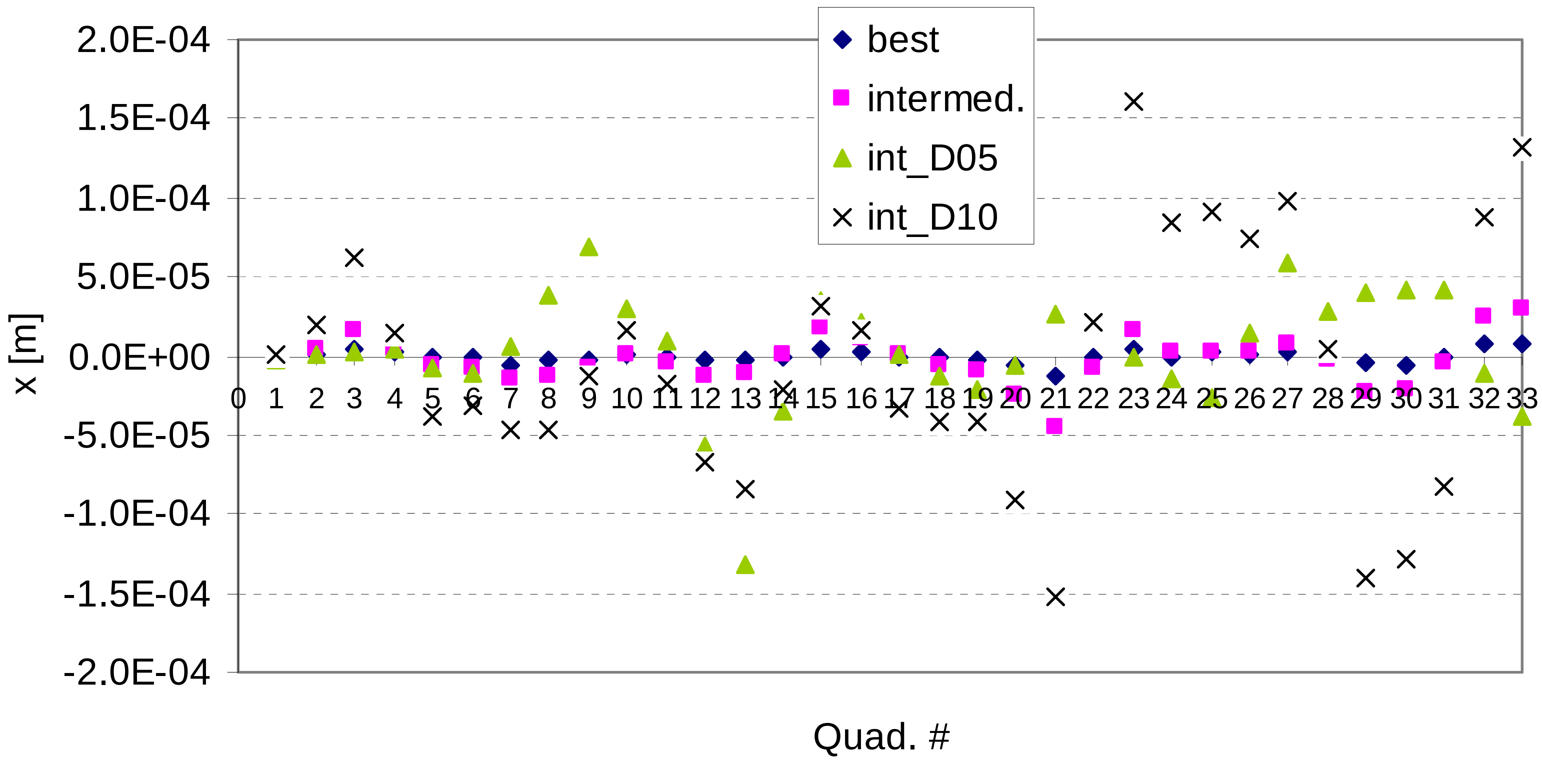
X=1.0x10-6m --- BPM X/Y resolution

D=5x10-7m --- rms dispersion resolution [x/max(dE/E)]

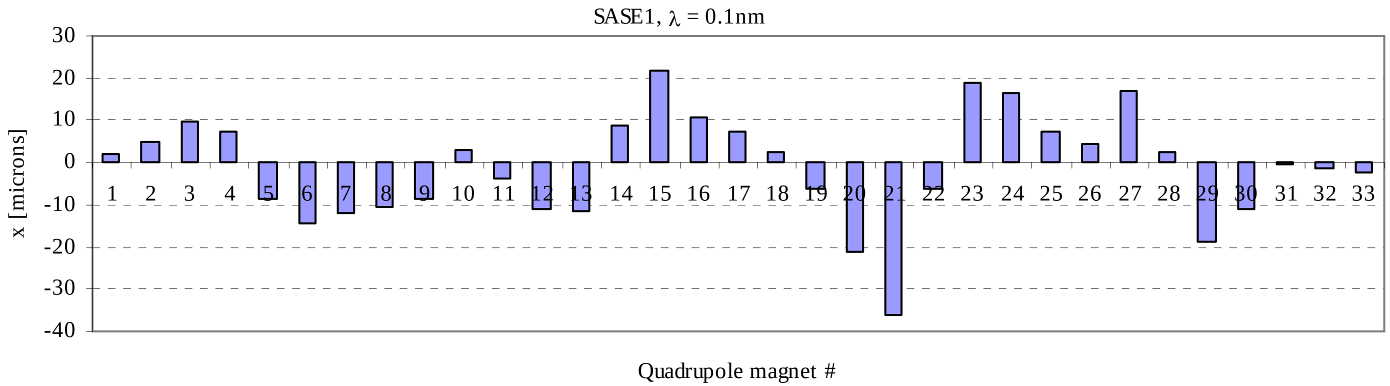
M=1.0-6m – mover (corrector) rms error



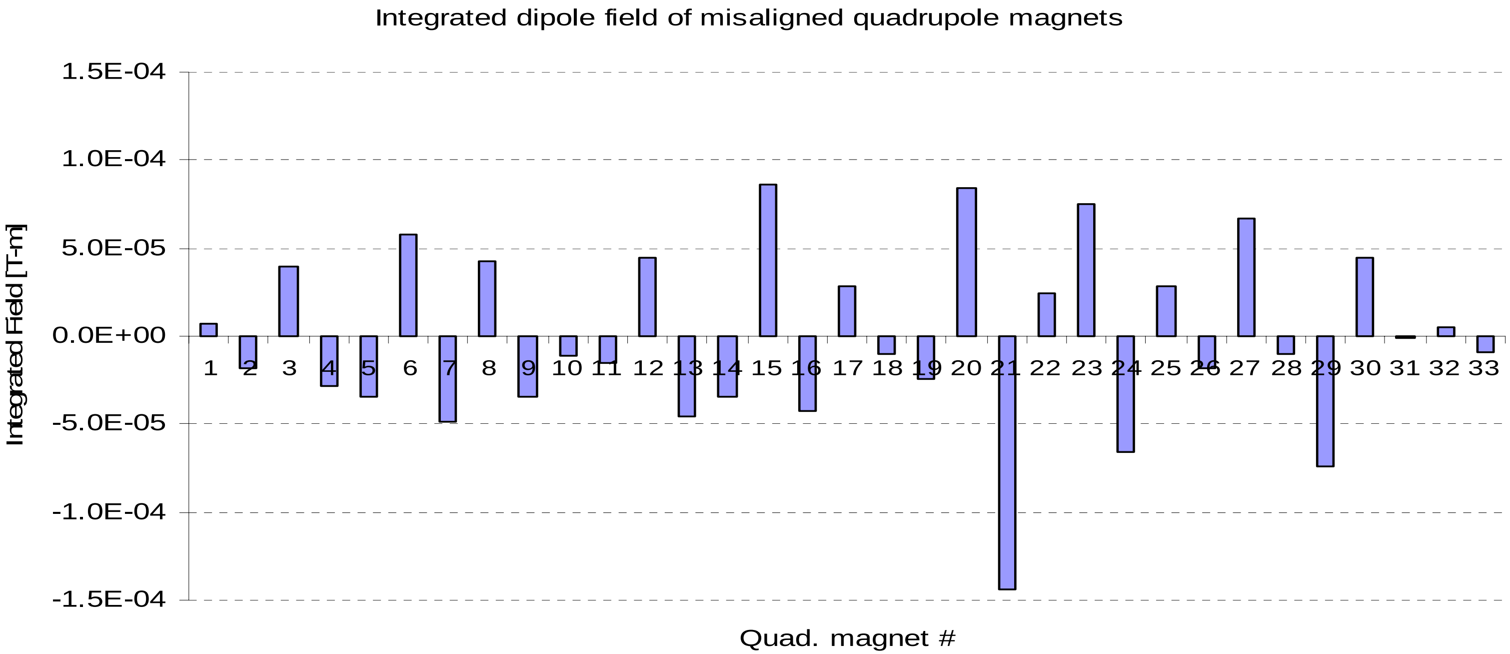
Quadrupole magnets residual misalignments



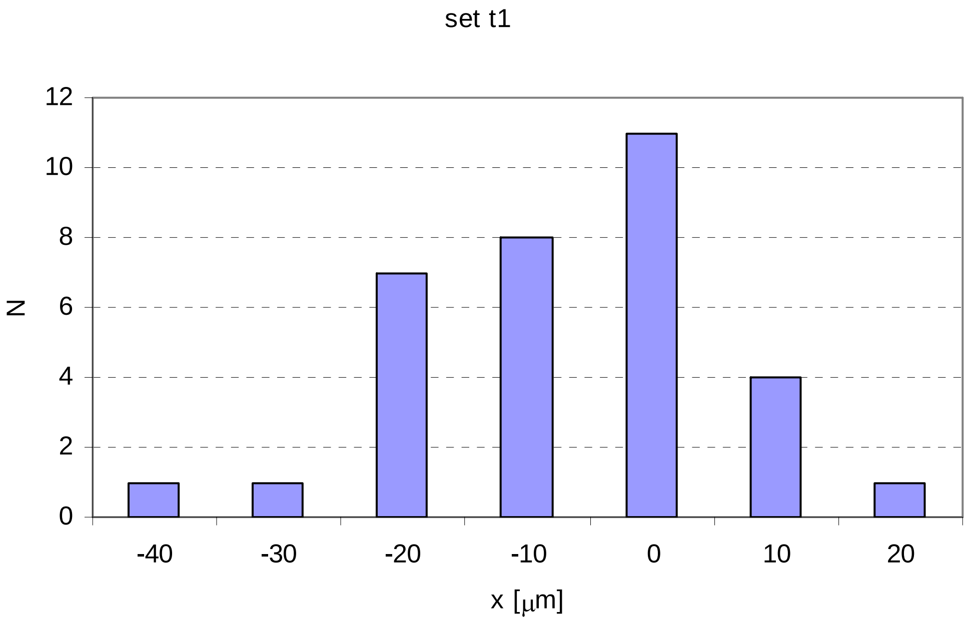
Quadrupole magnets residual misalignments



SASE1, λ = 0.1nm
x [microns]
30
20
10
0
-10
-20
-30
-40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Quadrupole magnet #



Integrated dipole field of misaligned quadrupole magnets
Integrated Field [T-m]
1.5E-04
1.0E-04
5.0E-05
0.0E+00
-5.0E-05
-1.0E-04
-1.5E-04
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Quad. magnet #

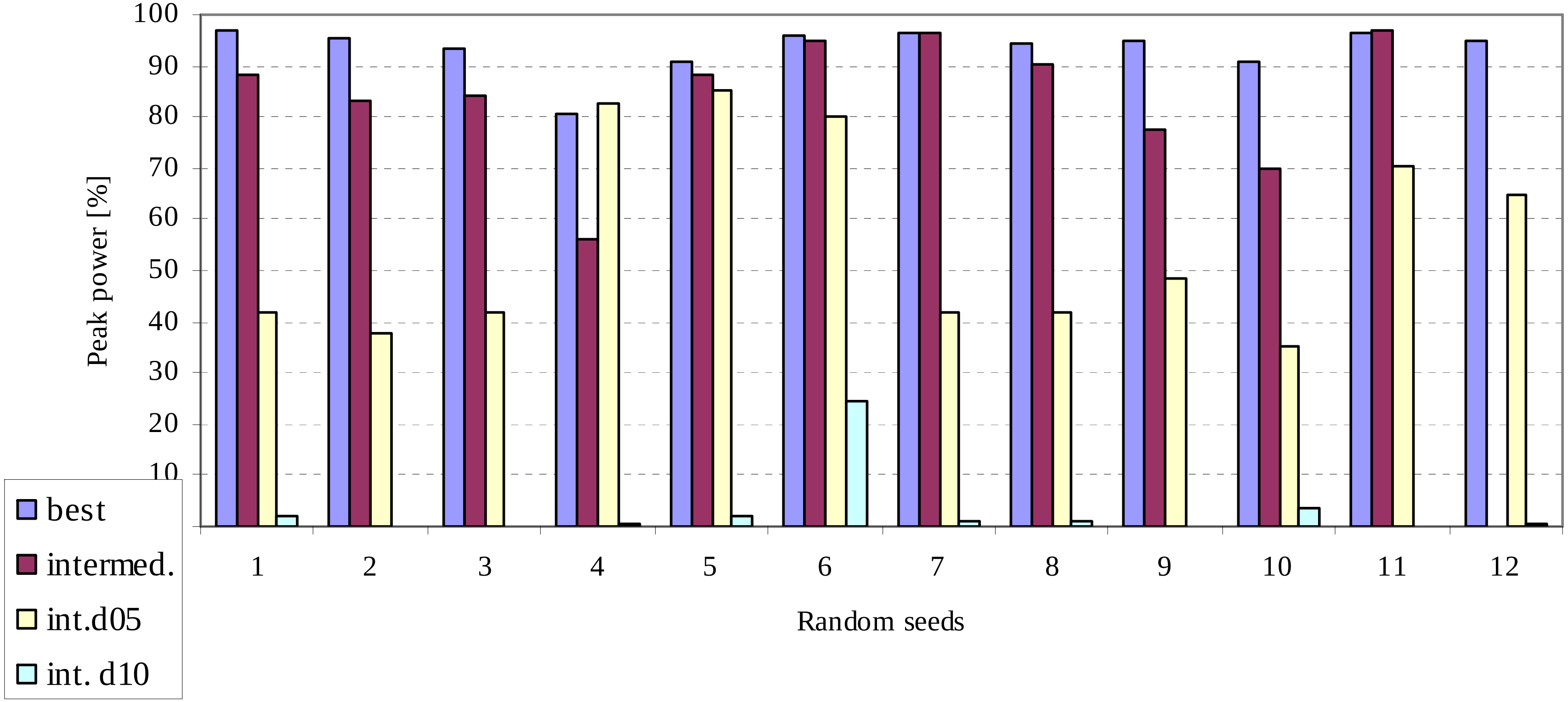


Misalignments distribution

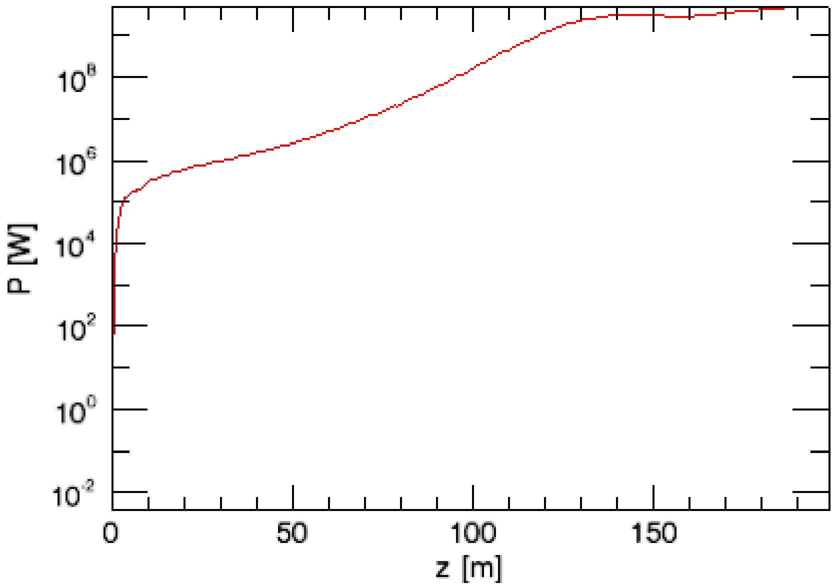
	Best [m]	Intermediate [m]	Interm.d_05 [m]	Interm d_10 [m]	Worst [m]
Dispersion resolution	5E-7	2E-6	5E-6	10E-6	5E-5
Av. Misalign.	-3.40E-07	-2.41E-06	3.90E-06	-5.05E-06	1.50E-05
RMS misalign.	3.92E-6	1.47E-5	1.22E-5	7.61E-5	2.17E-5

Peak power [%] for 12 different random seeds

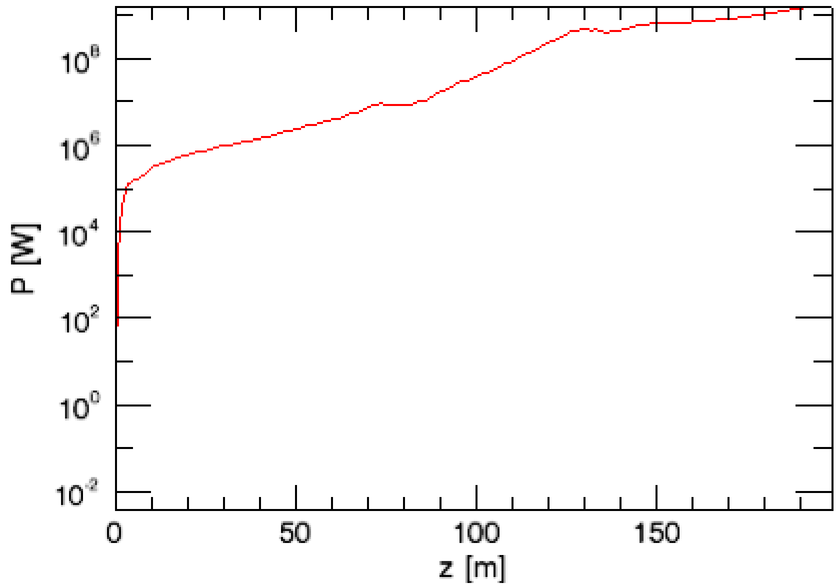
best	intermediate	int.d05	int. d10
97.14286	88.11475	42.04082	1.897751
95.5102	83.19672	37.7551	0.023149
93.46939	84.42623	42.04082	0.235583
80.40816	56.14754	82.85714	0.353374
91.02041	88.11475	85.30612	2.130879
95.91837	94.67213	80	24.66258
96.32653	96.31148	42.04082	1.263804
94.28571	90.16393	41.63265	1.173824
94.69388	77.45902	48.57143	0.050307
91.02041	69.67213	35.26531	3.431493
96.32653	96.72131	70.20408	0.182004
95.10204		64.89796	0.658487



Peak power [%] for 12 different random seeds



P [W]
10^8
10^6
10^4
10^2
10^0
10^{-2}
0
50
100
150
z [m]



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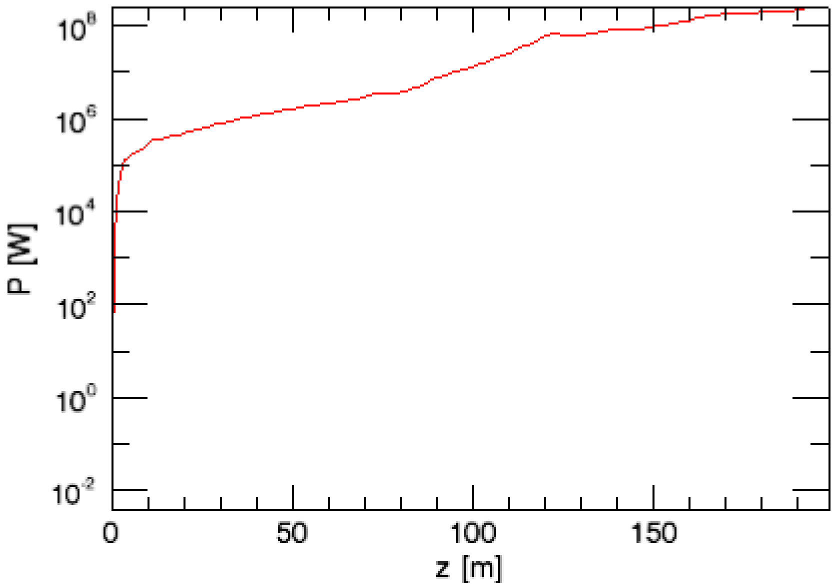

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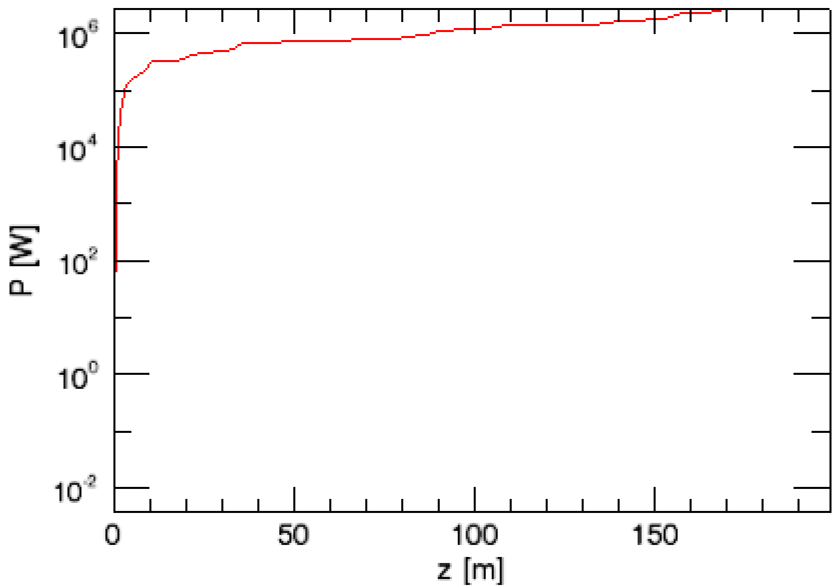

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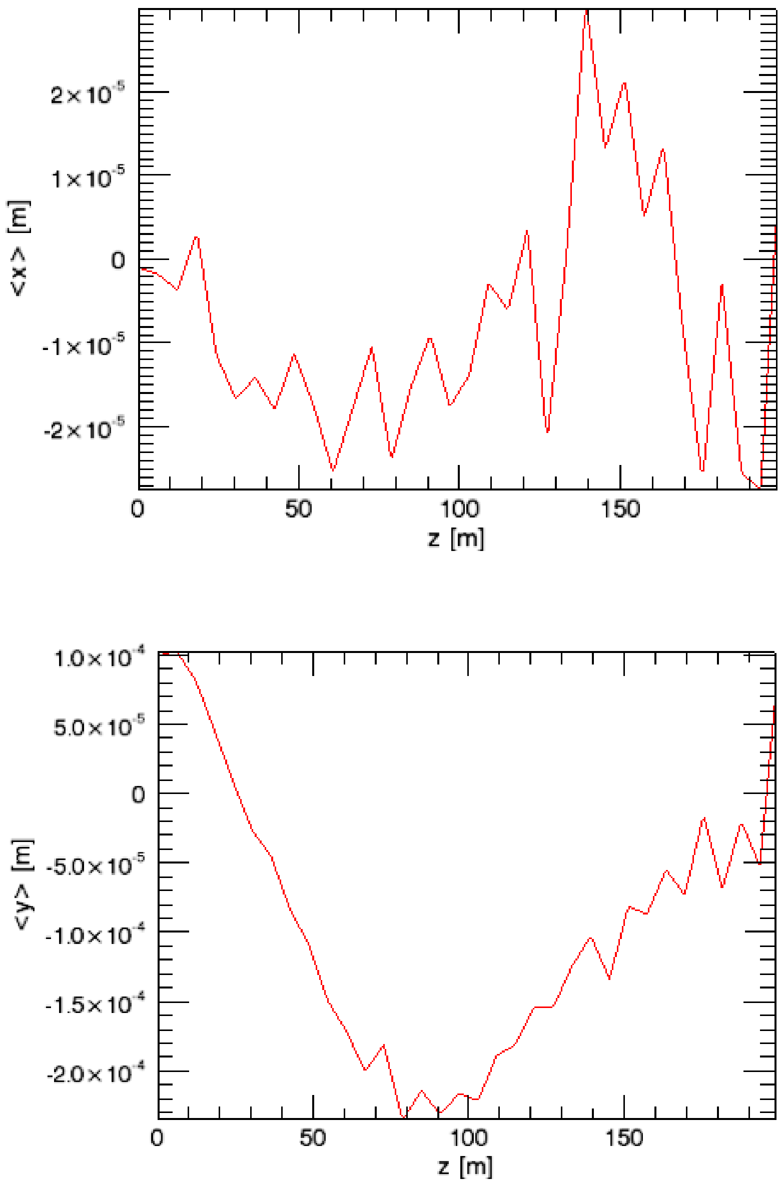
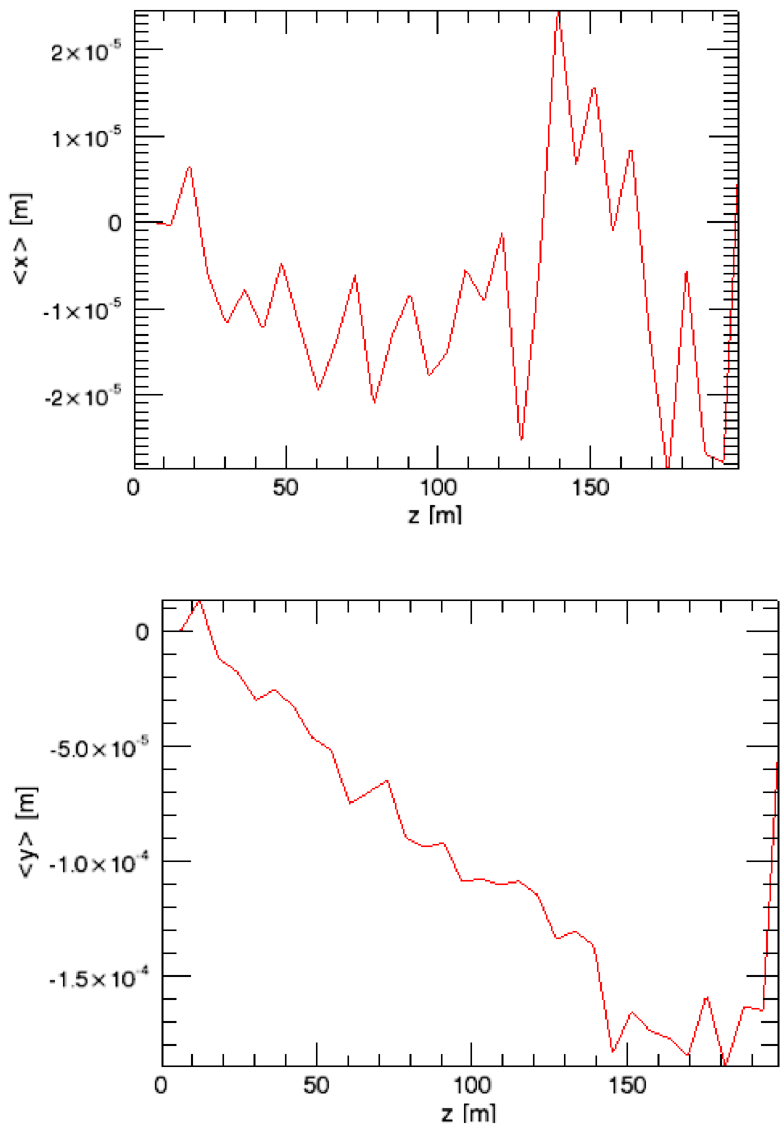
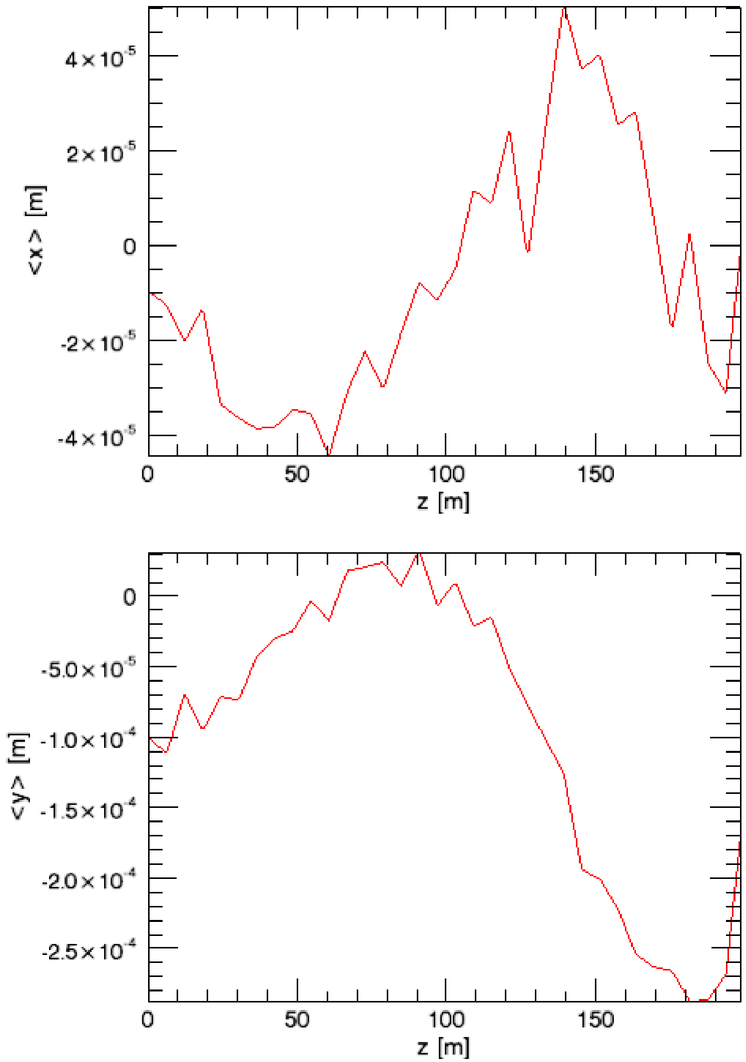


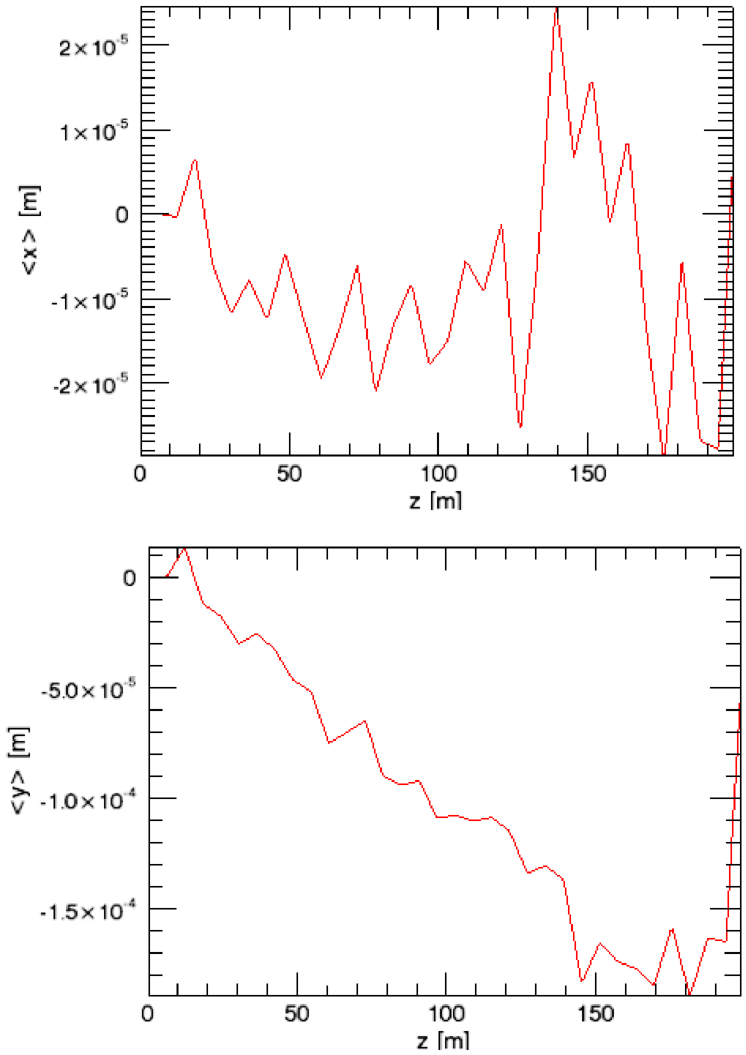
Beam orbit fitted to central axis



Beam error orbit



Beam orbit corrected to straight line



Beam error orbit

conclusions

- SASE FEL simulations has been performed to define the impact of beam trajectory errors due to quadrupole magnets residual (after correction) misalignments on the FEL radiation.
- Trajectory errors arise from the technically feasible requirements of quadrupole magnets and BPM alignments, BPM resolution in the result of realization of the different DF steering scenarios.
- 0.5 micron rms dispersion resolution should be provided to ensure that radiation power reduction is ~ 5%.
- No beam offset and tilt at the undulator entrance have been considered.
- Can radiation power reduction be partly compensated by beam launch optimization?