Undulator gap error tolerances for wakefield compensation in XFEL

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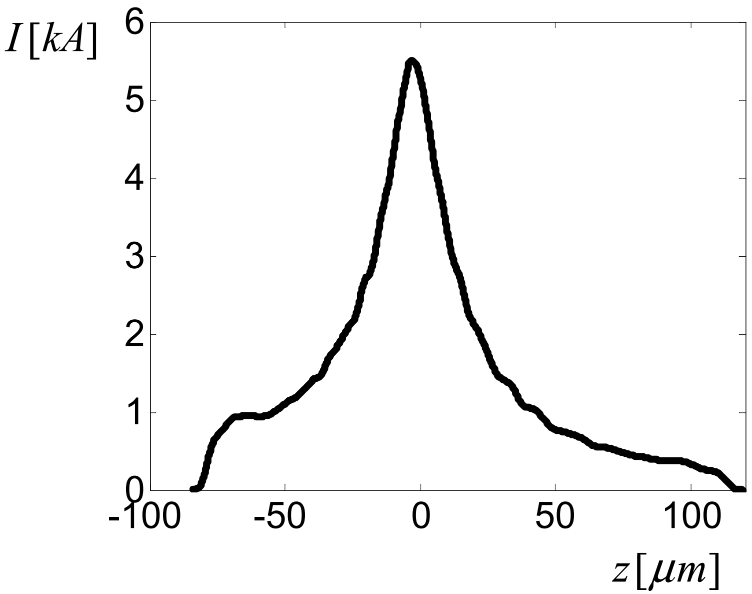
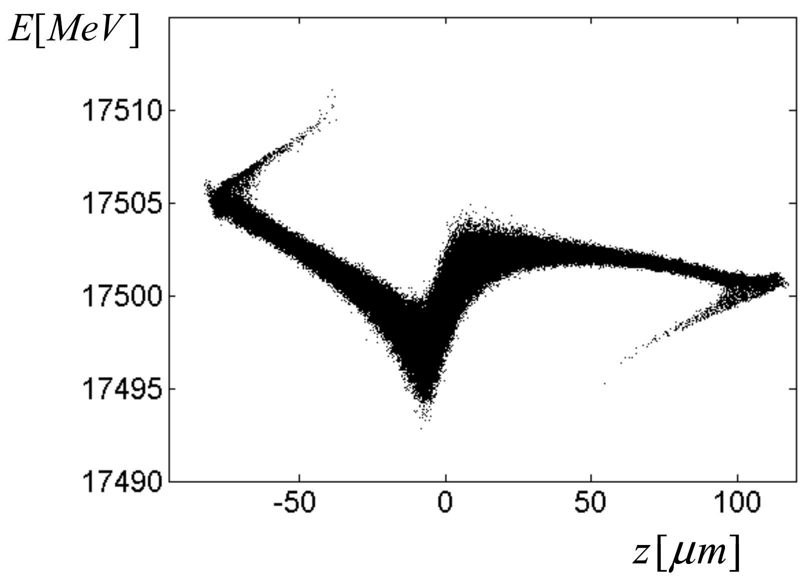
27.03.06

Current profile and longitudinal phase space
at the undulator entrance (1nC at 17.5GeV)*

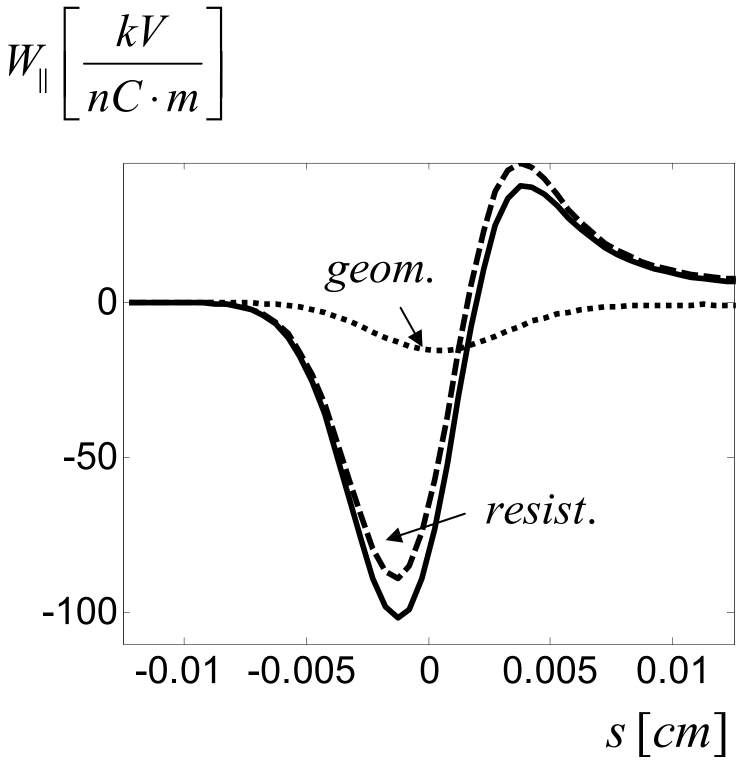




*Martin Dohlus

Geometric wake?

Longitudinal wake for the case of the elliptical pipe (3.8mm)

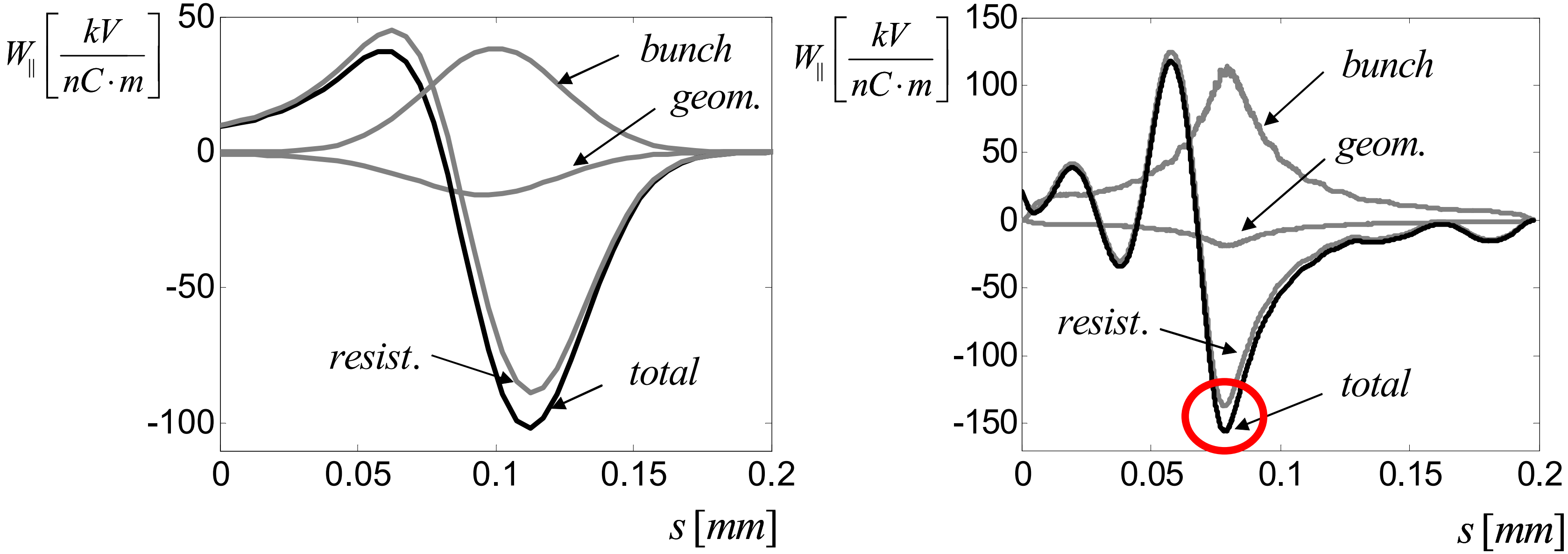


	pro section (6.1 m)	Loss, V/pC
absorber	1	42
pumping slot	1	<0.2
pump	1	9
BPM	1	
bellow	1	13
flange gap	1	6
Total geom.		**70**

$$W_{\parallel}^{geom}(s) = cZ_{hi}\lambda(s)$$

$$Z_{hi} = 3.36[\Omega / m]$$

The wake repeats the bunch shape

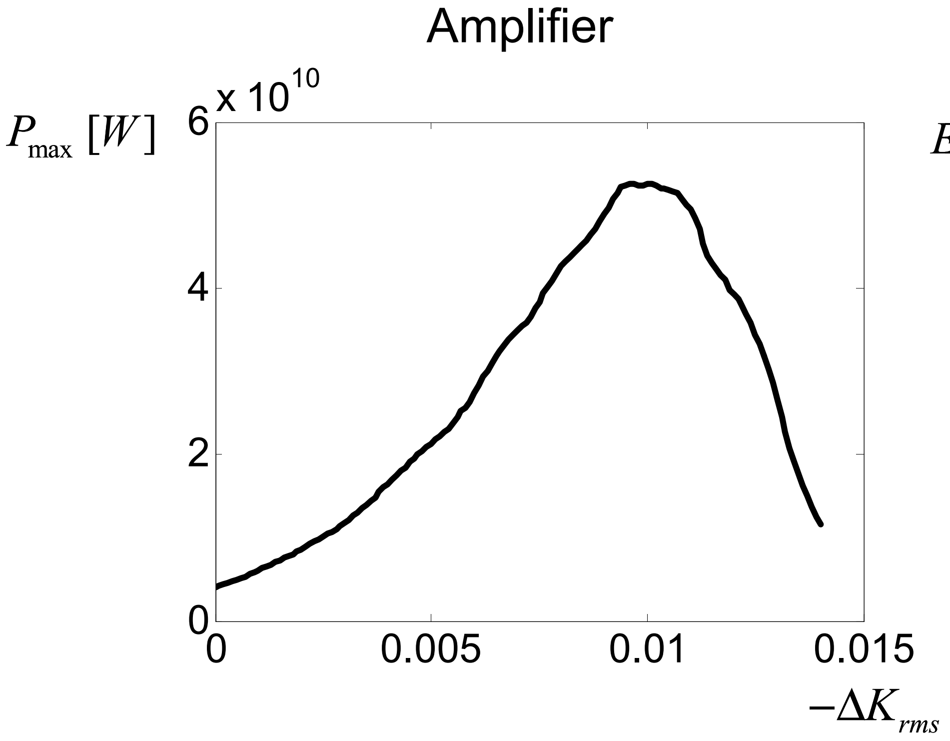


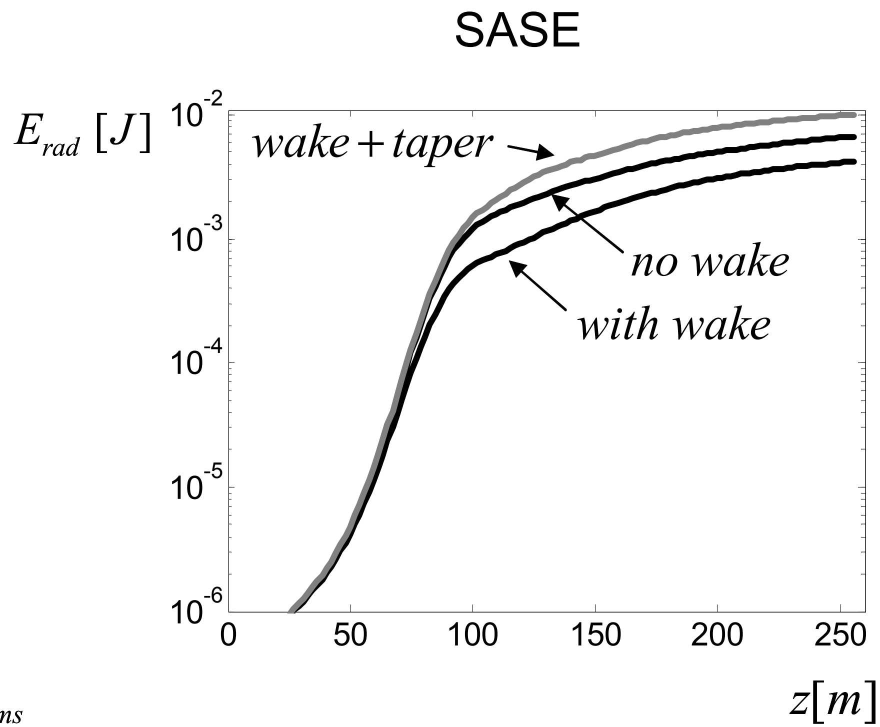
Longitudinal wake potentials for Gaussian (left) and simulated (right) current profiles

SASE 2 parameters

Parameter	symbol	unit	Value
radiation wavelength	λ	nm	0.1
Energy	E	GeV	17.5
energy spread	σ_E	MeV	1
undulator parameter	K_{rms}		1.97
Emmitance	ε_n	mm*mrad	0.7
peak current	I	kA	5
average beta function	β	m	17.25
undulator section length	$L_{\mathrm{sec}t}$	m	5
intersection length	L_{inters}	m	1.1
total length	L_{total}	m	260
undulator period	λ_u	m	0.048

$$\rho = 7.1 \cdot 10^{-4}$$

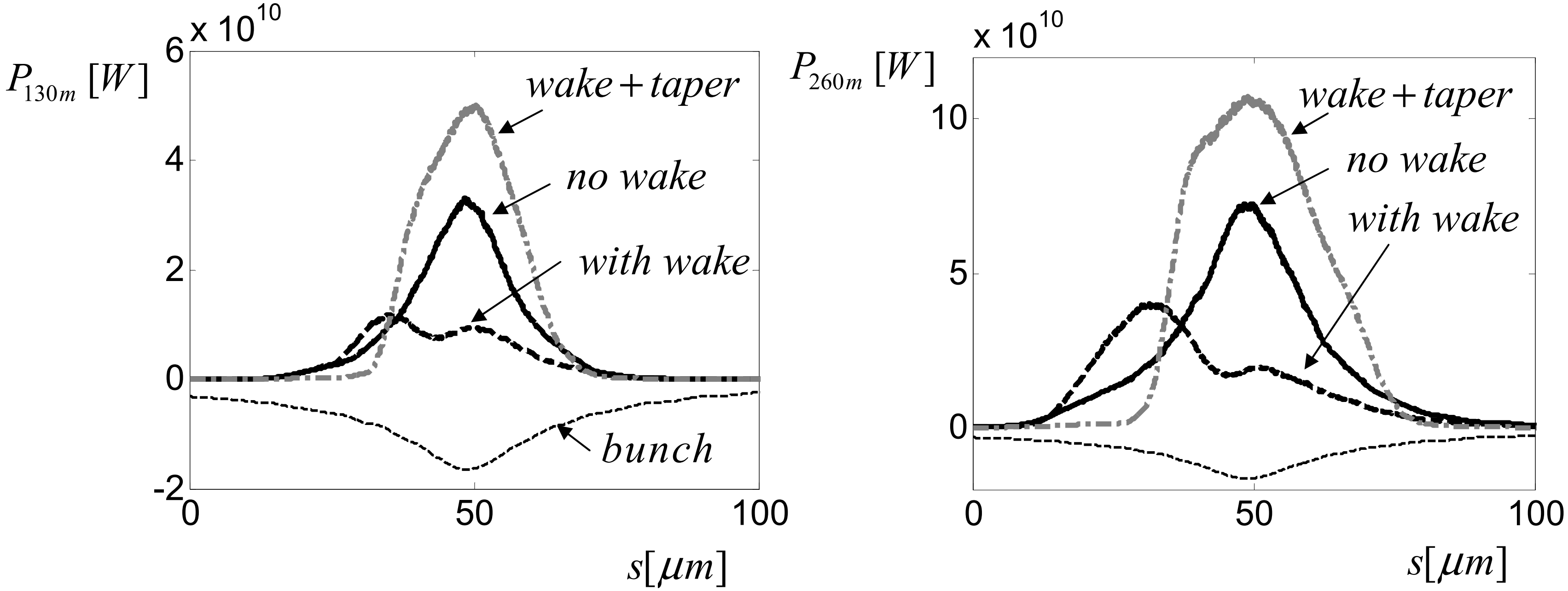




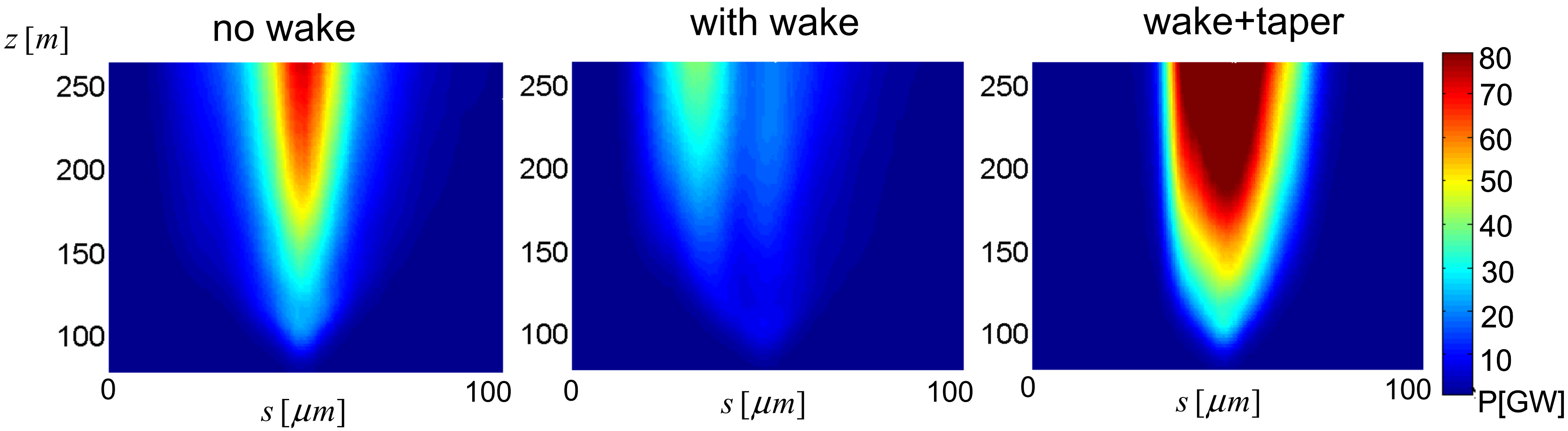
The maximum power dependence on tapering (left) and the radiation power along the undulator (right)

$$W_{sh} = 3\rho \frac{W_b}{N_c \sqrt{\pi \ln N_c}} = 11800[W]$$

$$W_{\parallel} = 150 kV / nC / m$$



The radiation power in the middle (left) and at the end of the undulator (right)



$$B_u = 3.694\exp\left(-5.068\frac{g}{\lambda_u} + 1.52\left(\frac{g}{\lambda_u}\right)^2\right)$$

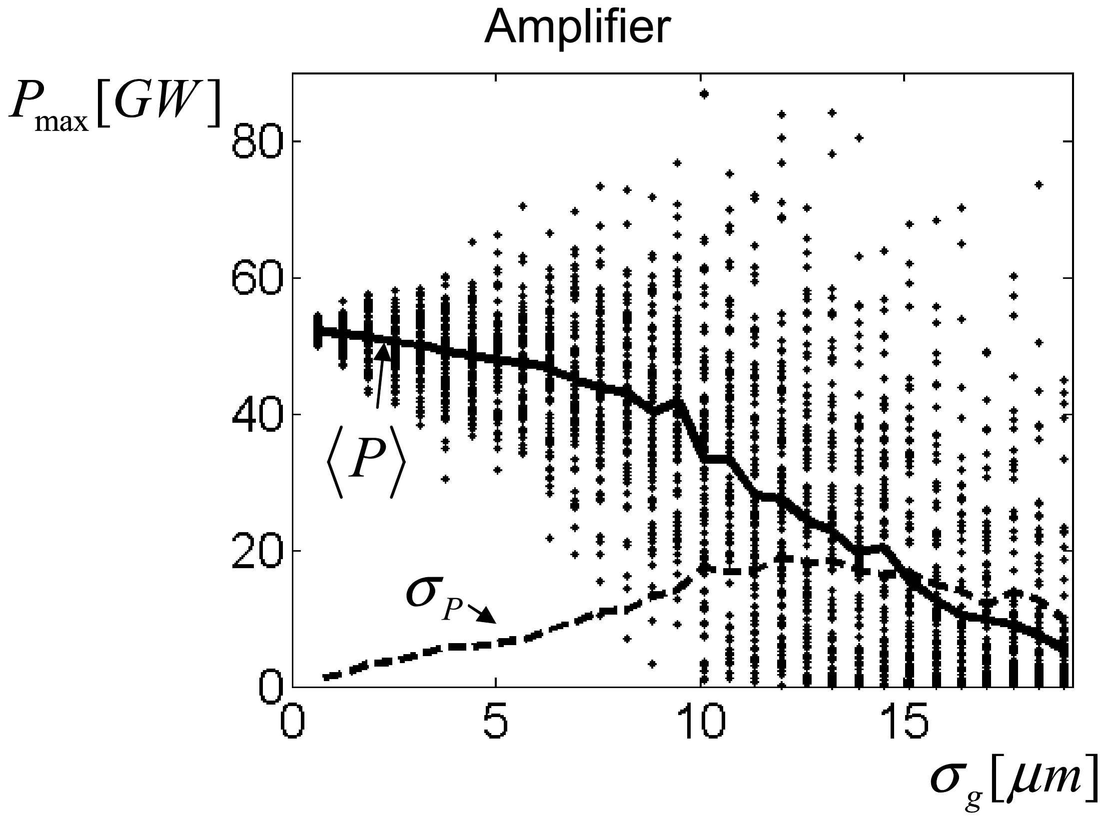
$$\frac{\Delta K_{rms}}{K_{rms}} \approx -\frac{\Delta g}{g}\left(-5.068\frac{g}{\lambda_u} + 3.04\left(\frac{g}{\lambda_u}\right)^2\right)$$

$$K_{rms} = 93.4\lambda_u B_u / \sqrt{2}$$

$$\Delta g = -0.0124\,\Delta K_{rms} / K_{rms}$$

Optimal taper

$$\Delta g = -0.0124\,\Delta K_{rms} / K_{rms} = 60 \cdot 10^{-6}[m]$$

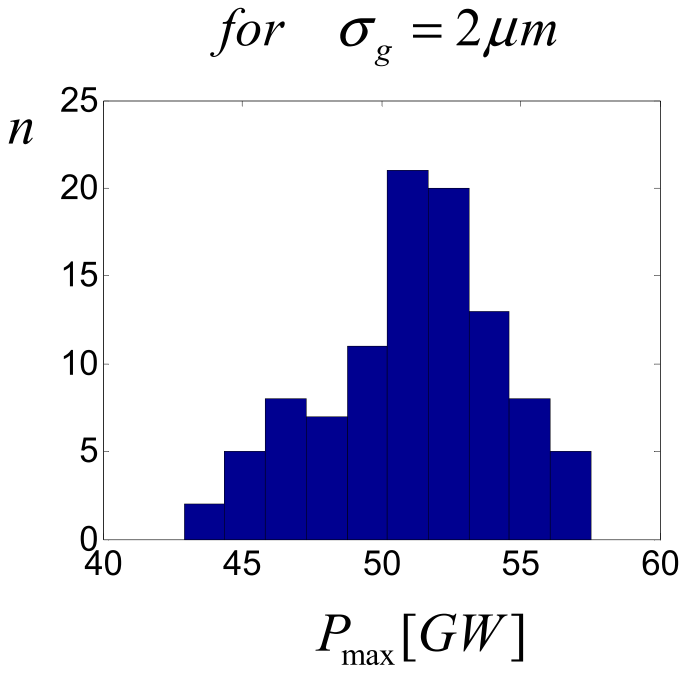


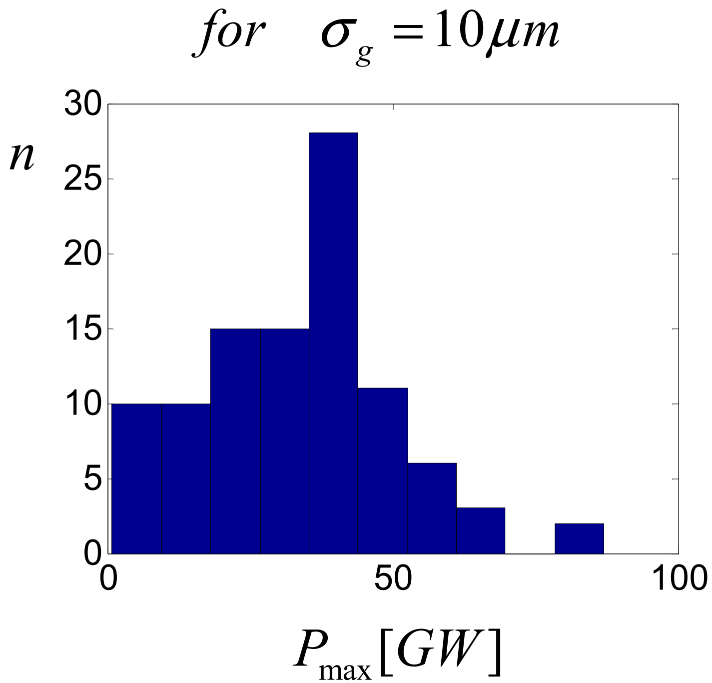
$$f(\delta g) = \frac{1}{\sqrt{2\pi}\sigma_g} \exp\left(-\frac{\delta g^2}{2\sigma_g^{\ 2}}\right)$$

Impact of statistical errors of undulator gap on power gain.

$$\frac{P_0 - \langle P \rangle}{P_0} 100\% \approx 20\% \qquad for \quad \sigma_g = 10\mu m$$

$$\frac{P_0 - \left[\langle P \rangle - 3\sigma_p\right]}{P_0} 100\% \approx 20\% \qquad for \quad \sigma_g = 2\mu m$$





power distribution law?

Open questions:

- distribution law of gap errors?
- distribution law of radiation power P?
- errors in estimation of <P> and s_P?
- accuracy of GENESIS calculations?
- relation of the amplifier model results to SASE?