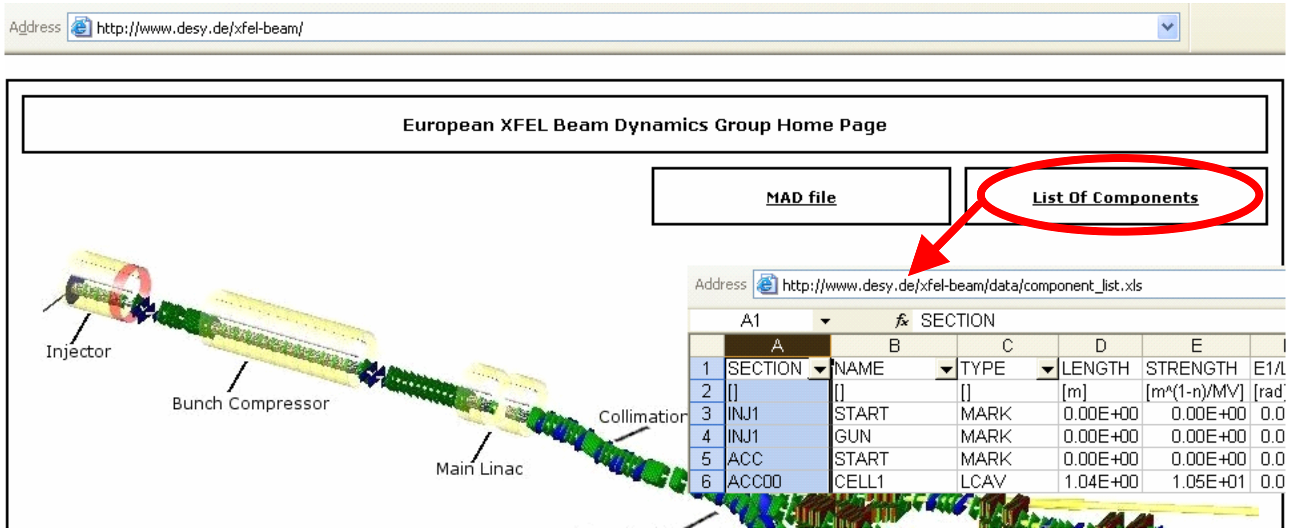
BC System – Review
Simulation Calculations

- official setup
- “start to end” simulation
  - technical aspects
  - methods
- sensitivity on rf parameters
- µ-bunch “instability”
- shielding and wall conductivity
- beam loading

official setup

Winni's EXCEL table (Dec 2005)



Klaus's gun & ACC0 settings: 1nC, 50A $\rightarrow \varepsilon_{slice} \approx 0.58$ µm
(used for s2e simulations)

$\rightarrow$ 6.9 MeV
$\rightarrow$130 MeV, dog leg, laser heater
$\rightarrow$500 MeV, 3r harm. rf, 50A $\rightarrow$ 1kA, r56 $\approx$ 103 mm
$\rightarrow$2 GeV, on crest, 1kA $\rightarrow$ 5kA, r56 $\approx$ 14 (17) mm
$\rightarrow$ 17.5 MeV

"start to end" simulation

methods

ASTRA, (ELEGANT,) CSRtrack, GENESIS

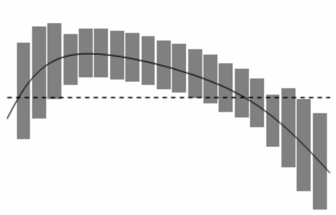
tools

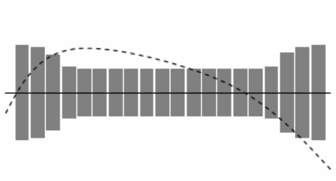
format conversion, some phase space manipulations,
semi-analytic space charge impedance
longitudinal predictor (~ LiTrack)

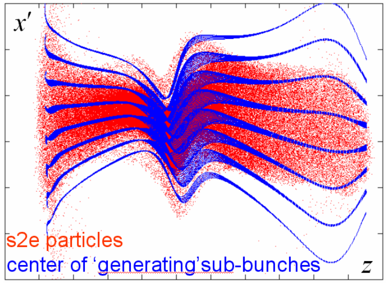
tuning

longitudinal: rf phases to 0.01 deg, amplitudes to 0.01%
semi-analytic space charge impedance
steering & matching (at some locations)
transverse: additional 180 deg phase advance before BC2

tricks





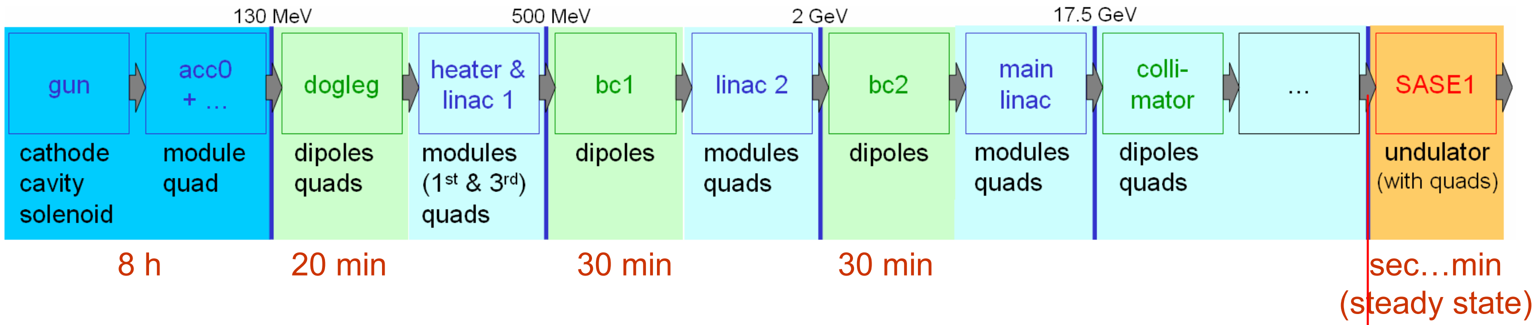


200000 particles

details see FLS2006:
http://adweb.desy.de/mpy/FLS2006/proceedings/TALKS/WG314_TALK.PDF

method 1 (fast)

ASTRA | CSRtrack 1d | transport matrix | GENESIS | rf-field cavity wake & s.c. field



PC (Pentium 4, 3GHz)

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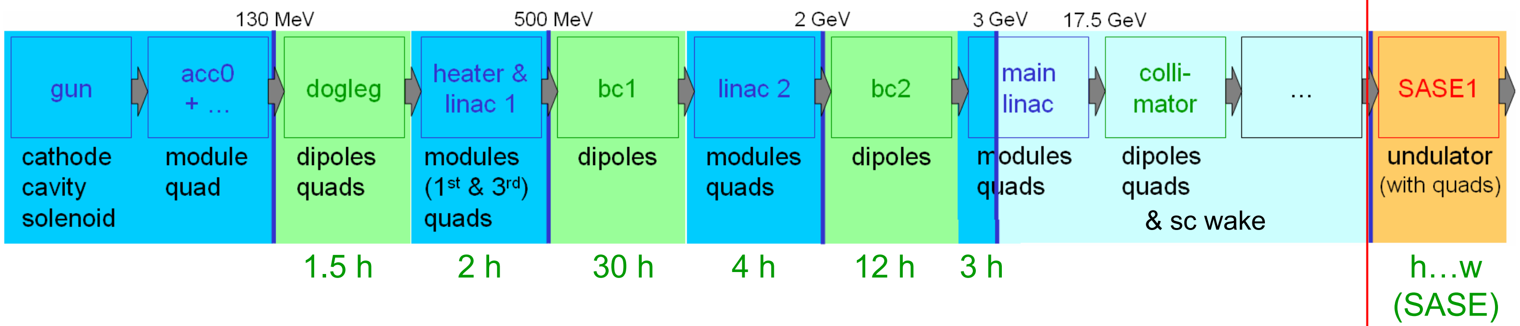
method 2 (reference)

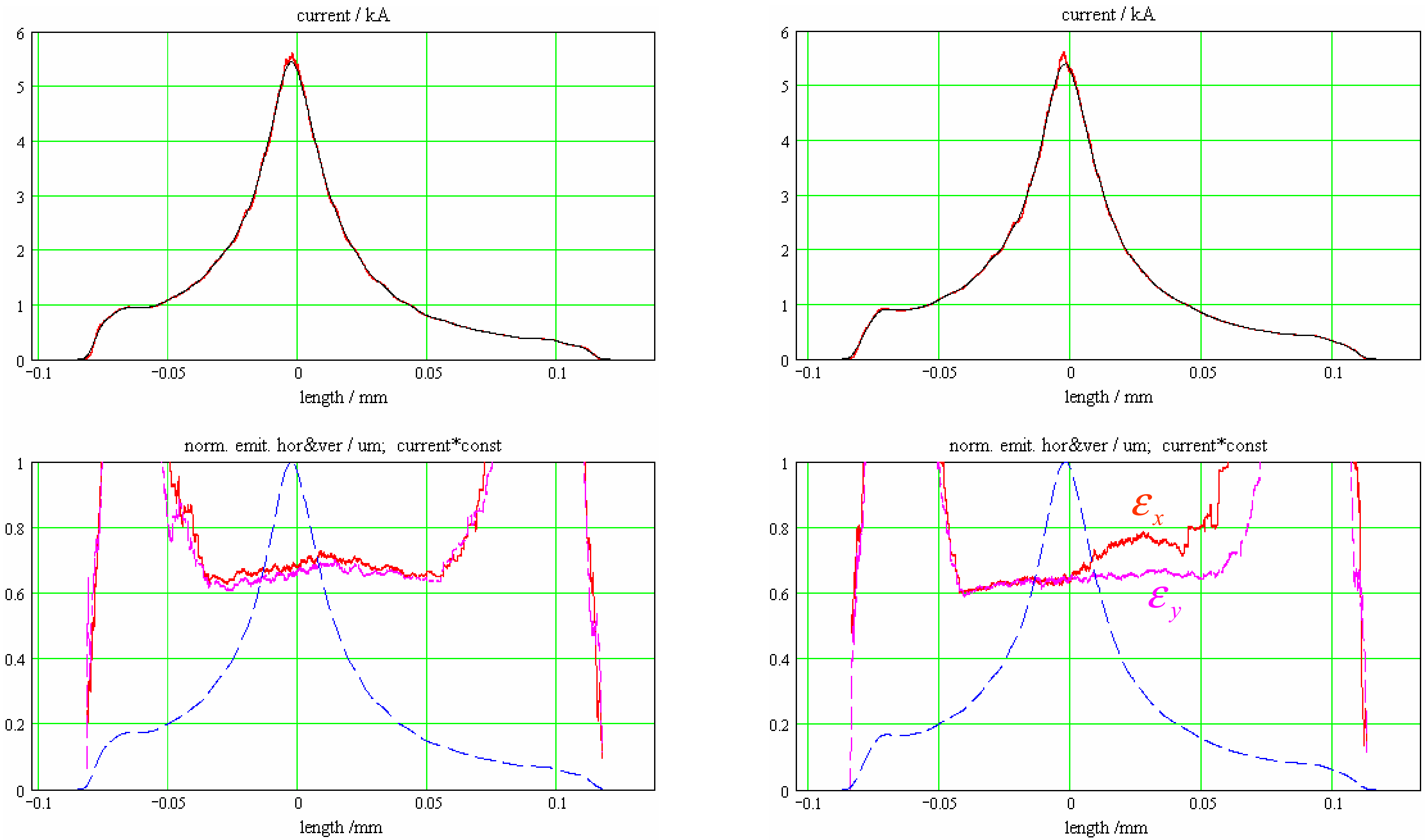
ASTRA | CSRtrack sub-bunch | ELEGANT | GENESIS



LINUX cluster with 20 cpus (64 bit)

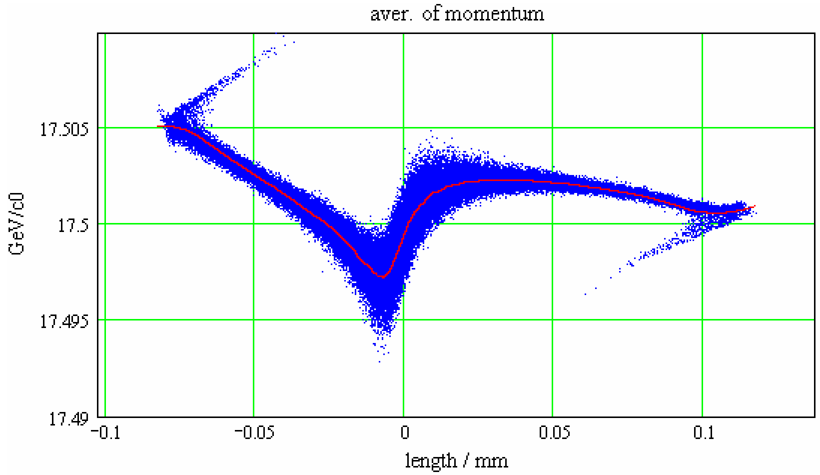
method 1	method 2

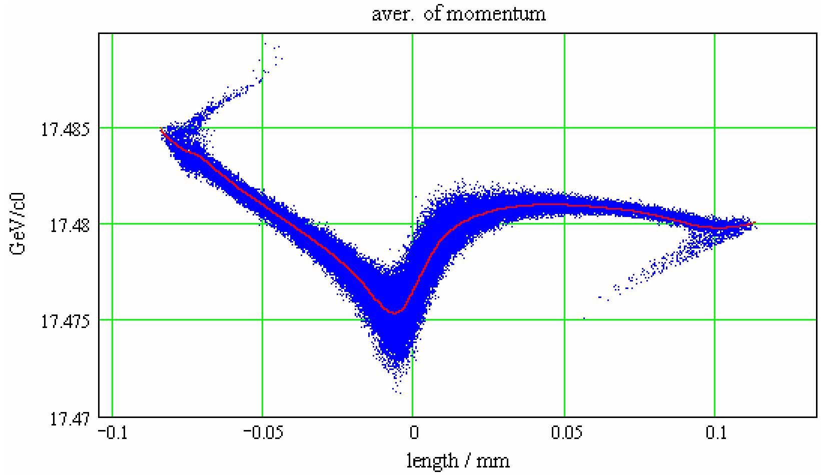
current & slice emittance

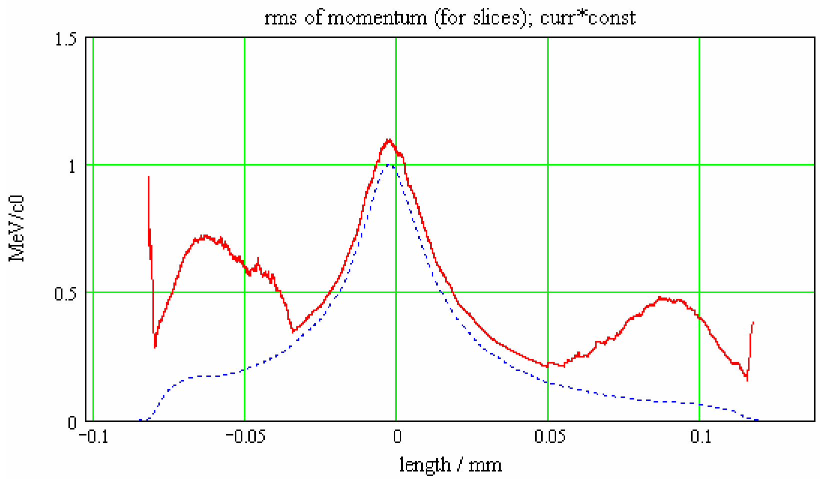


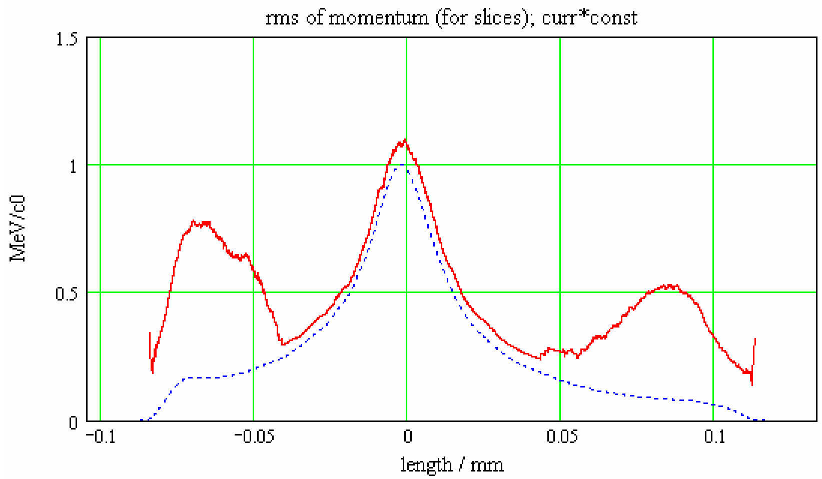
method 1 method 2

long. phase space





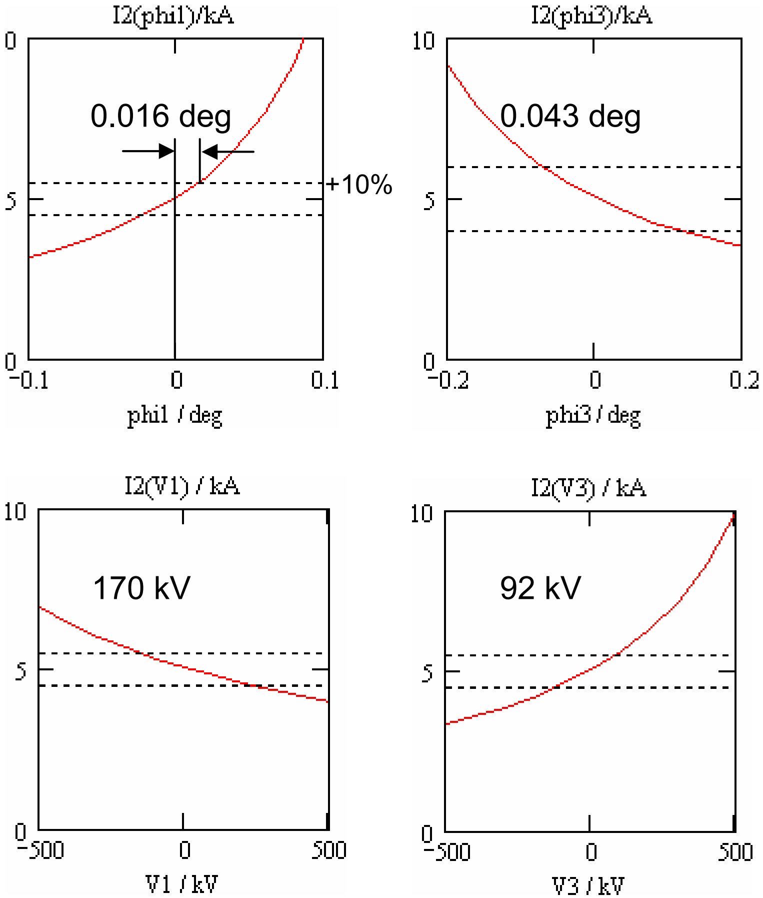




sensitivity on rf parameters

peak current after BC2

E1/MeV = 500
L1: phi^{1st}/deg = 2.016
V^{3rd} /MV = 91.62
phi^{3rd}/deg = 146.56
E2/MeV = 2000
L2: on crest
r56_BC1/mm = 103.26
r56_BC2/mm = 14.060



phase of LINAC2:	2.7 deg
amplitude of LINAC2:	18.5 MV
r56 of BC1:	0.1%
r56 of BC2:	2.4%
bunch charge, Igun = const:	5.3%
bunch charge, shape = const:	5.7%
Igun, bunch charge = const:	2.9%

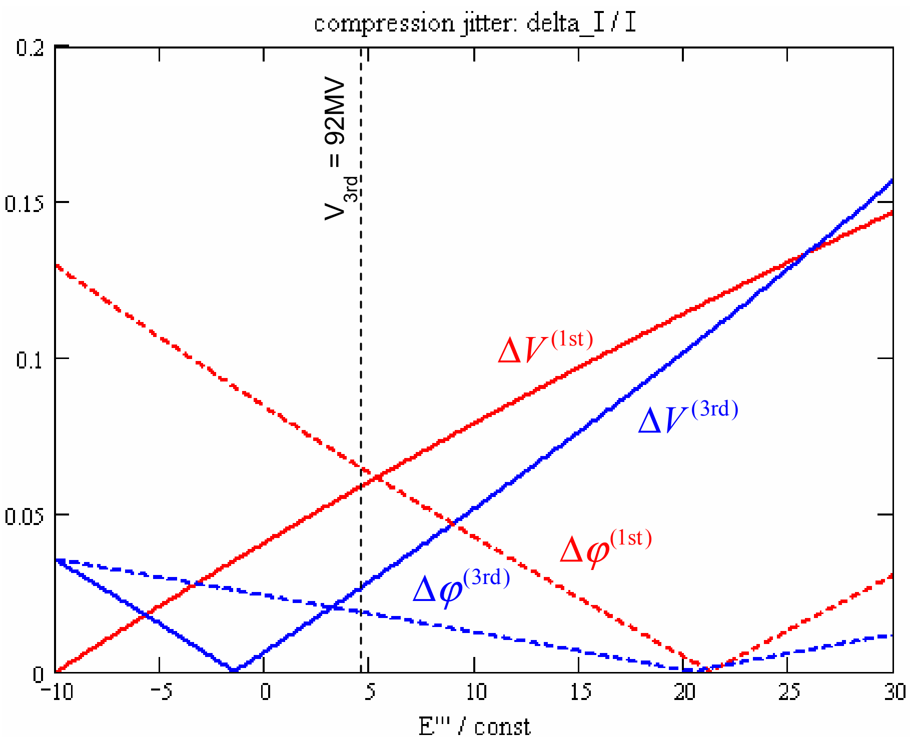
with cavity wakes and injector SC effects

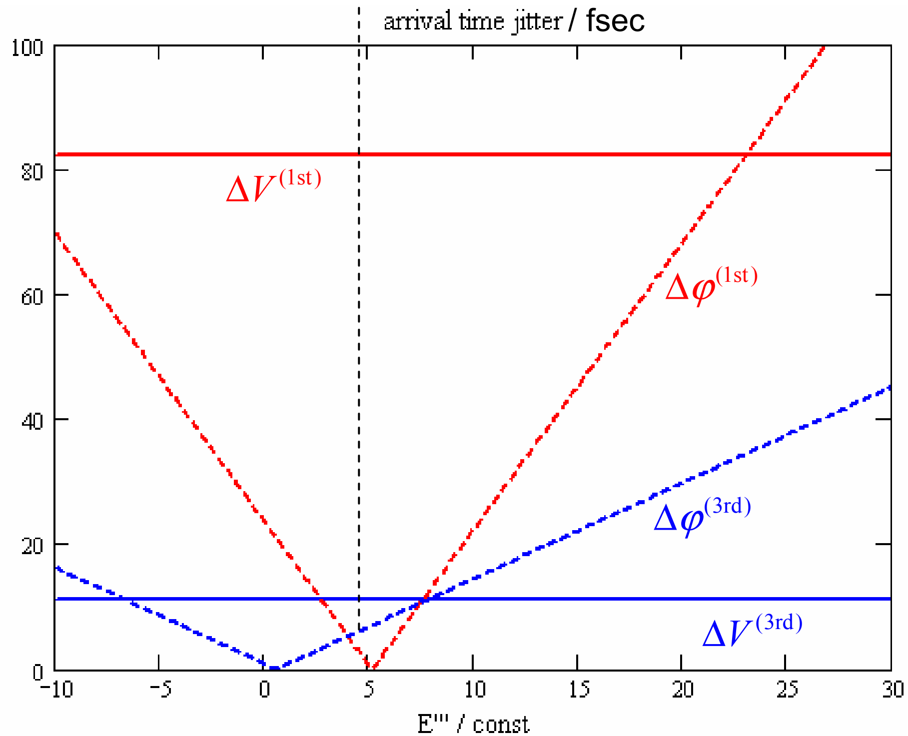
peak current after BC2
arrival time jitter

$$\frac{\Delta V^{(1st)}}{V^{(1st)}} = 2\cdot 10^{-4} \qquad \Delta\varphi^{(1st)} = 0.01 \text{ deg}$$

$$\frac{\Delta V^{(3rd)}}{V^{(3rd)}} = 2\cdot 10^{-4} \qquad \Delta\varphi^{(3rd)} = 0.01 \text{ deg}$$

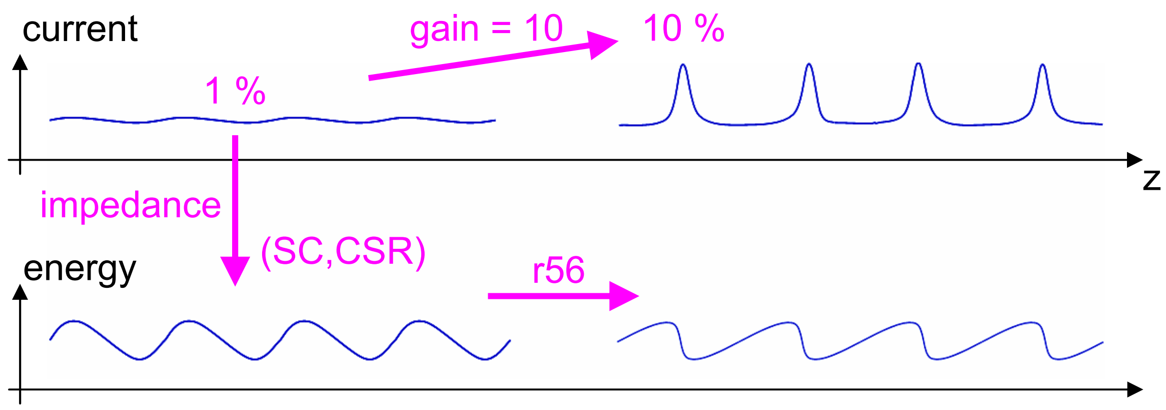
E1/MeV = 500
L1: phi^{1st}/deg = 2.016
V^{3rd} /MV = 91.62
phi^{3rd}/deg = 146.56
E2/MeV = 2000
L2: on crest
r56_BC1/mm = 103.26
r56_BC2/mm = 17.41



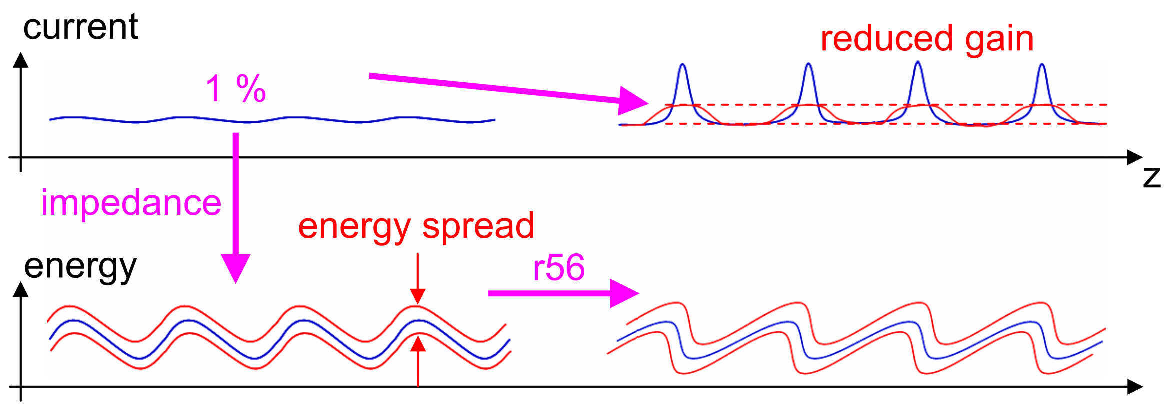


without cavity wakes and injector SC effects

μ-bunch “instability”



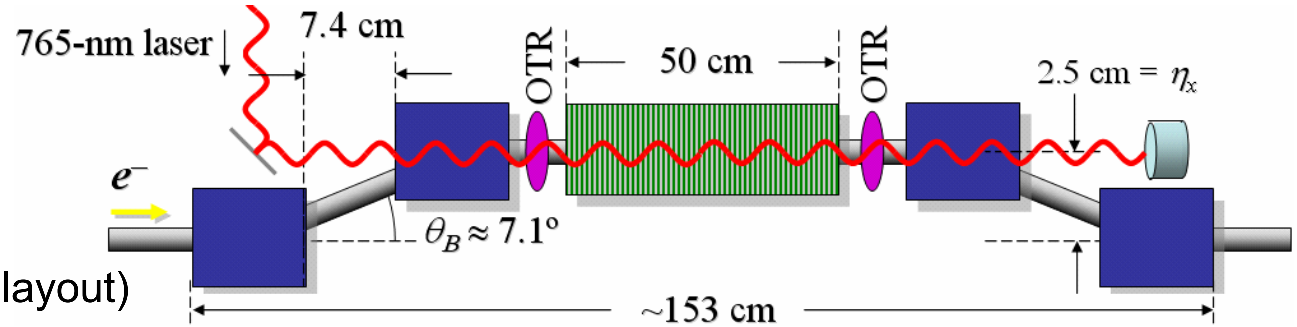
increase uncorrelated energy spread:

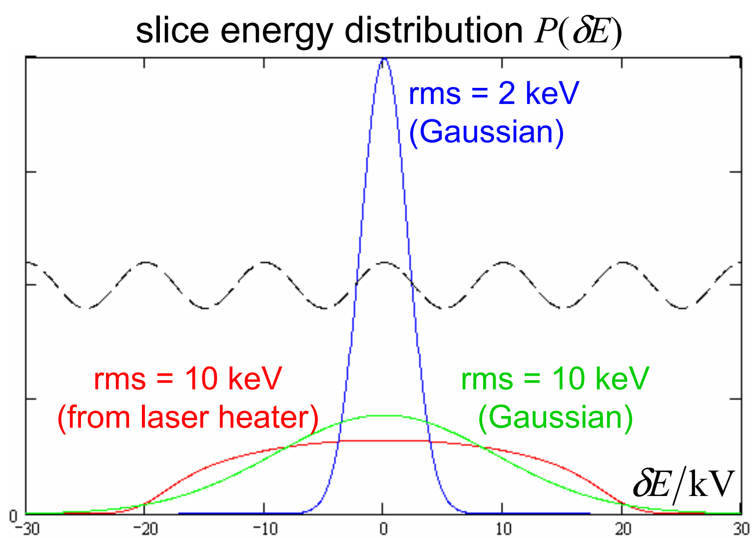


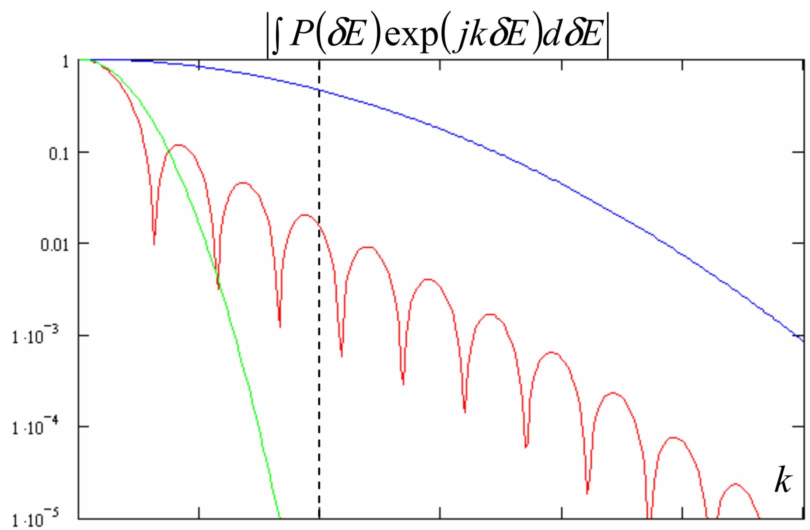
→ ‘laser heater’

'laser heater'

(LCLS layout)

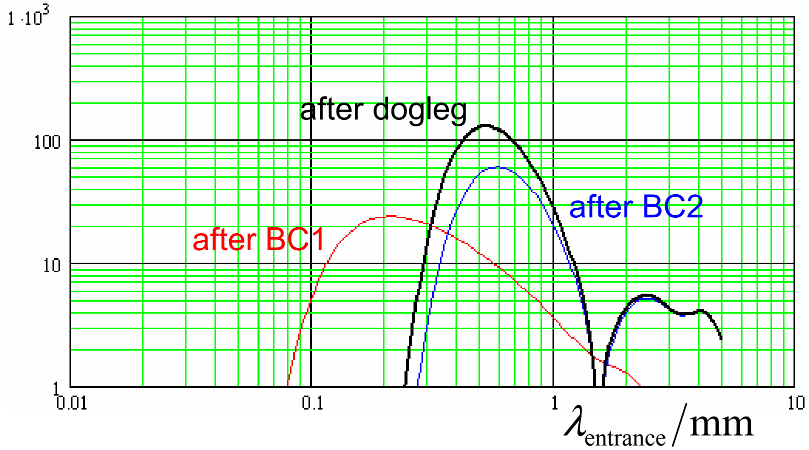




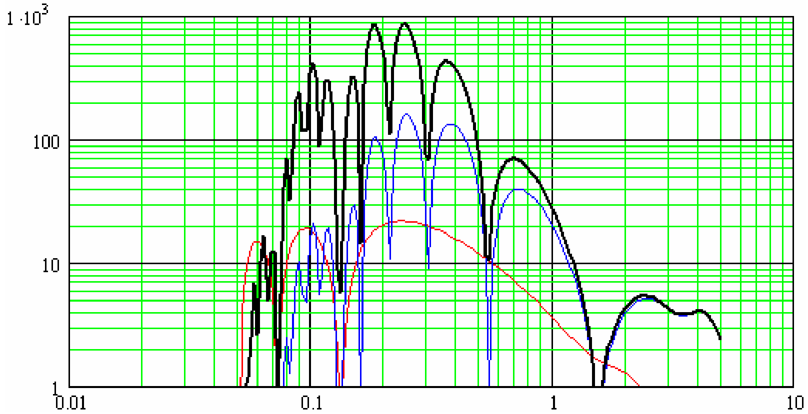


gain curves

TDR: gaussian distribution
rms = 10 keV



"real" heater:
rms = 10keV



shot noise

$$I_{\text{noise,rms}} \approx \sqrt{\frac{eI}{\pi} \int_{\omega>0} |G|^2 d\omega}$$

TDR: $I_{\text{noise,rms}} \approx 29\text{ A}$

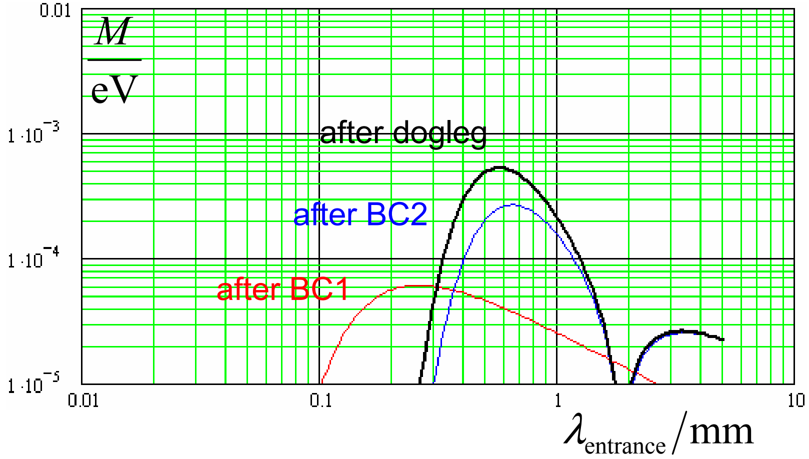
"real" heater: $I_{\text{noise,rms}} \approx 260\text{ A}$

dogleg, r56 = 0.84mm $\rightarrow$ 0

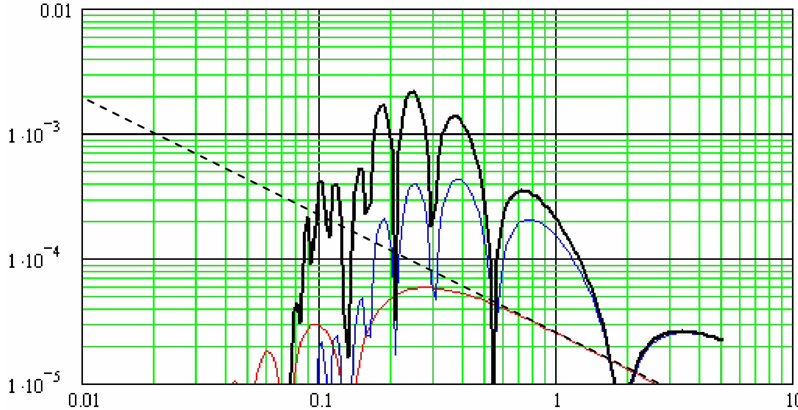
$\rightarrow I_{\text{noise,rms}} \approx 44\text{ A}$

energy to current modulation:

TDR: gaussian distribution
rms = 10 keV

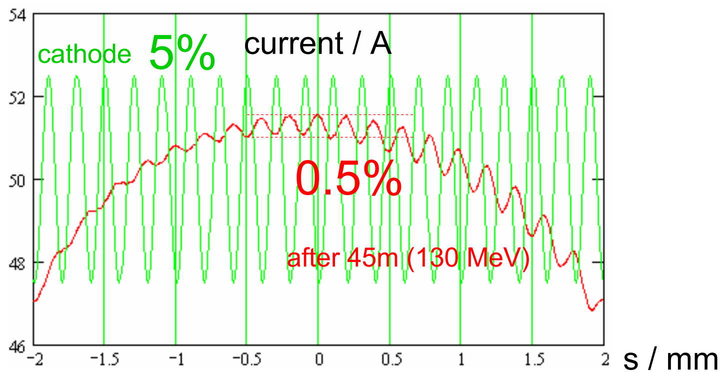


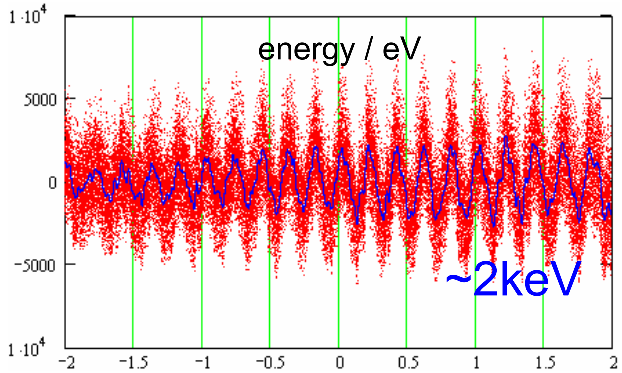
"real" heater:
rms = 10keV



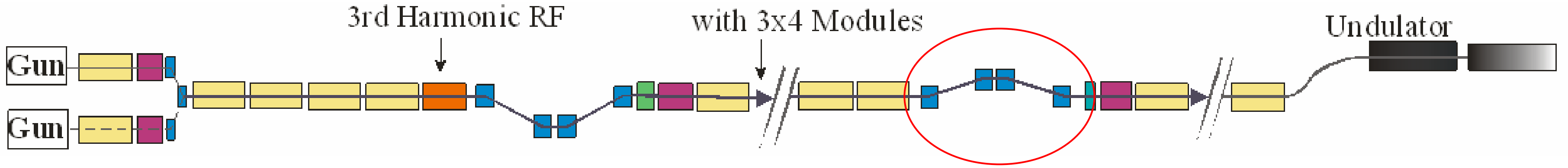
ASTRA simulation:

5% modulation at cathode, $\lambda = 0.2$ mm $\rightarrow$ injector dogleg (~45m after cathode):





shielding and wall conductivity



(same rf settings for all calculations)

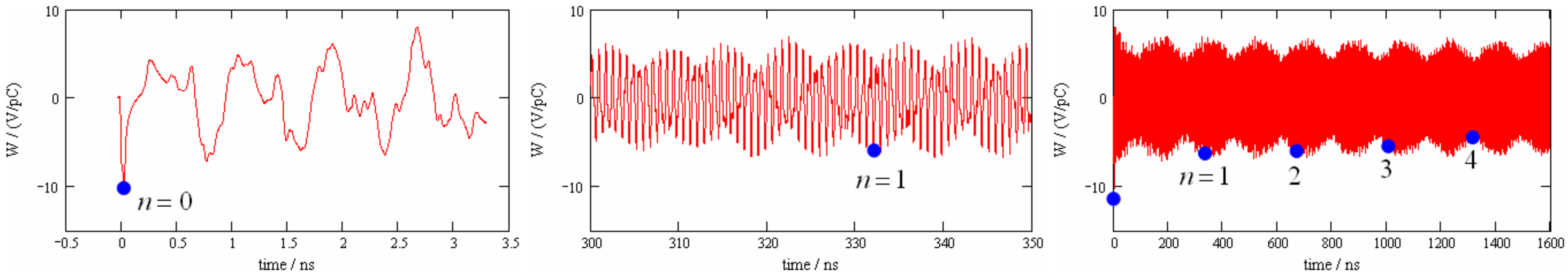
	material	gap (mm)	peak current (kA)	emittance norm., hor. (μm)
projected	PEC	8	5.4	1.4
	steel	8	12.5	8.5
	cu	8	5.9	2.5
	cu	10	5.8	2.2
	cu	16	5.7	1.7
	cu	20	5.6	1.5
		∞	5.18	1.16 ($\approx$3)
3d csr & ast.		∞	5.3	1.5

(same orientation of both chicanes)

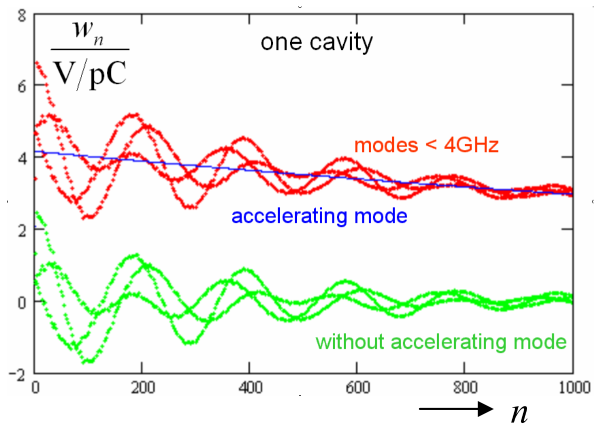
steady state r-wall-wake; see:
http://www.desy.de/xfel-beam/data/talks/talks/dohlus_-_rwall_wake_xfel_20060206.pdf

beam loading

"short" range



long range



single- & multi-bunch interaction:

$q_n = \overline{q} + x_n q_{rms}$ systematic & random charge

w_m "centroid wakes"

$u_n = \sum_{m=0}^{n} q_m w_{n-m}$ bunch energy (centroid)

$\rightarrow$ systematic & random part

about beam loading; see:
http://www.desy.de/~dohlus/2006.03.psi/beam_loading_02.pdf
http://www.desy.de/xfel-beam/data/talks/talks/dohlus_-_beam_loading_20060327.pdf

beam loading: some conclusions

systematic beam loading is important

- comes always to steady state
- transients not investigated now; (some unknown parameters)

random beam loading (by charge fluctuation)

- main modes: feed back required
- significant contribution from 3rd harmonic rf
- transverse deflecting cavities are not considered now
- self interaction $\frac{E_{\mathrm{rms}}}{E_0} \approx \frac{q_{\mathrm{rms}}}{q_0} \cdot 0.0017$
- self & multi-bunch interaction; (unknown parameters estimated)

$$\frac{E_{\mathrm{rms}}}{E_0} \approx \frac{q_{\mathrm{rms}}}{q_0} \cdot 0.002$$