intermediate summary of uB simulations for XFEL

proposed optics: case 1 (standard), case 2 (increased beta), case 3 (case 2, LH chicane off)

effects: effective (one dimensional) SC impedance (per length)
for beams with elliptical cross-section, no CSR

method: periodic three dimensional particle distribution in linear particle transport
real shot noise (macro particle = particle!)

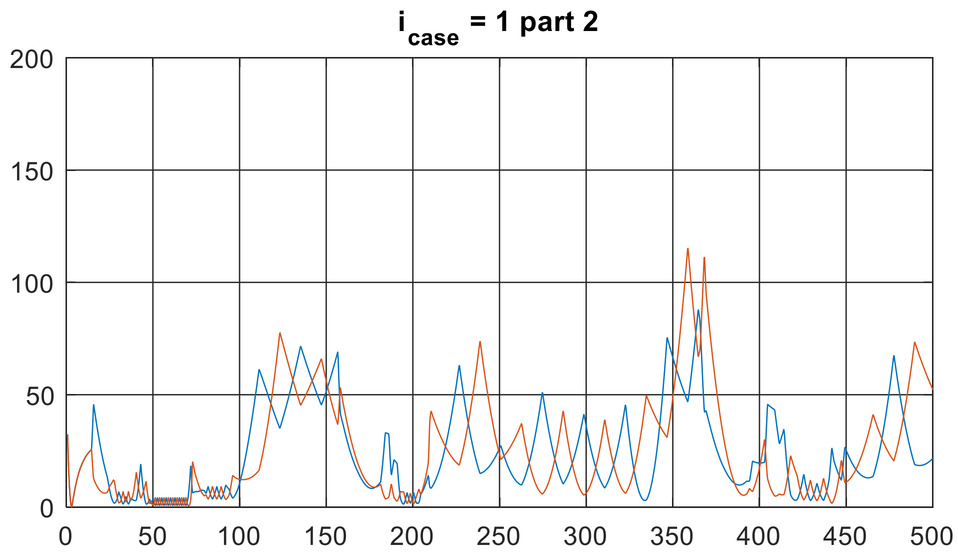
beam parameters and setup: close to 250 pC standard case, calculation to BC1 exit

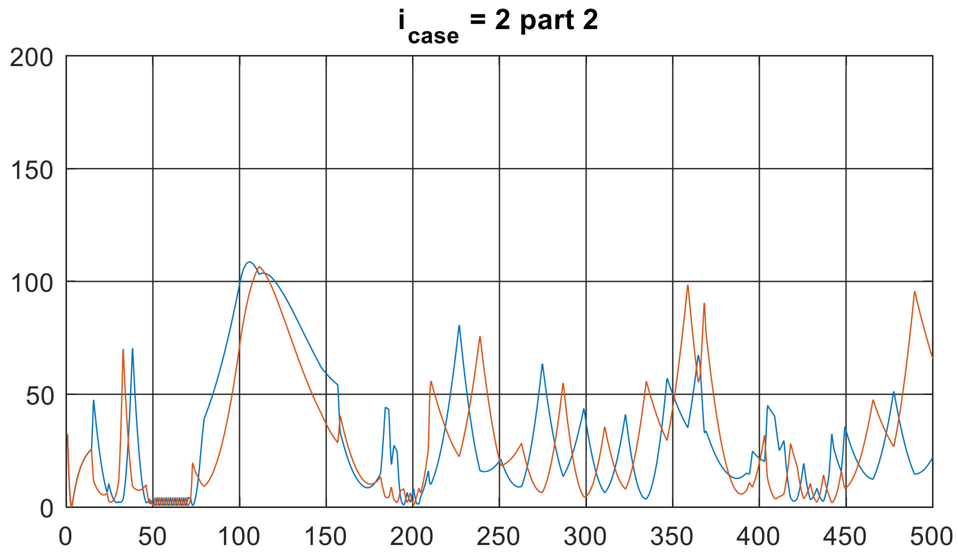
quantities of interest: rms current fluctuation, rms energy spread

scan vs initial energy spread
fluctuation and spread vs. linac coordinate (multiple seeds), noise spectrum
effect of dogleg and emittance
effect of BC0 (r56), different compression setup

earlier investigations: uB in XFEL, (periodic linear, three dimensional SC)
https://www.desy.de/xfel-beam/s2e/talks/2019_11_05/martin.pdf

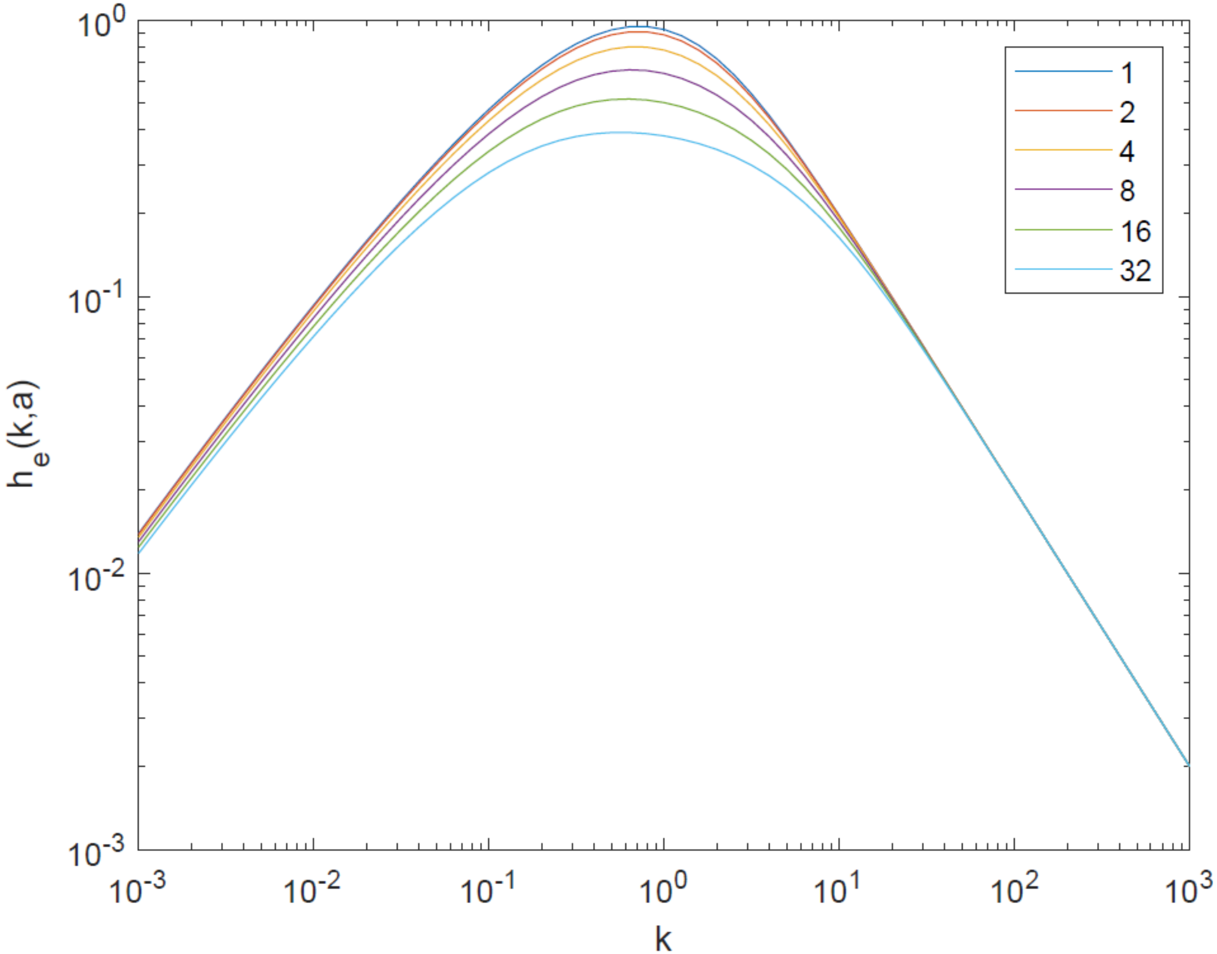
in preparation: full bunch simulation on cluster (10x more particles, non-lin. transport) proposed optics: case 1 und case 2





effects: effective SC impedance (per length) for beams with elliptical cross-section

$$Z'_{av}(\omega) = \frac{Z_0}{4\sqrt{2}\pi\sigma}\frac{-j}{\gamma\beta}h_{\mathrm{e}}\left(\sqrt{2}\frac{\sigma\omega}{\gamma\beta c}, a\right) \qquad a = \left(\frac{\sigma_{\max}}{\sigma_{\min}}\right)^2$$



beam parameters and setup:

case 1, 2 and 3 with 20A, emit=0.5 and BC0=nominal
compression= 3.5 / 28 / 250

periodic simulation with 10^8 electrons
the initial period length is $L_p = \frac{10^8 q_0}{20 \text{ A}} v = 0.24 \text{ mm}$

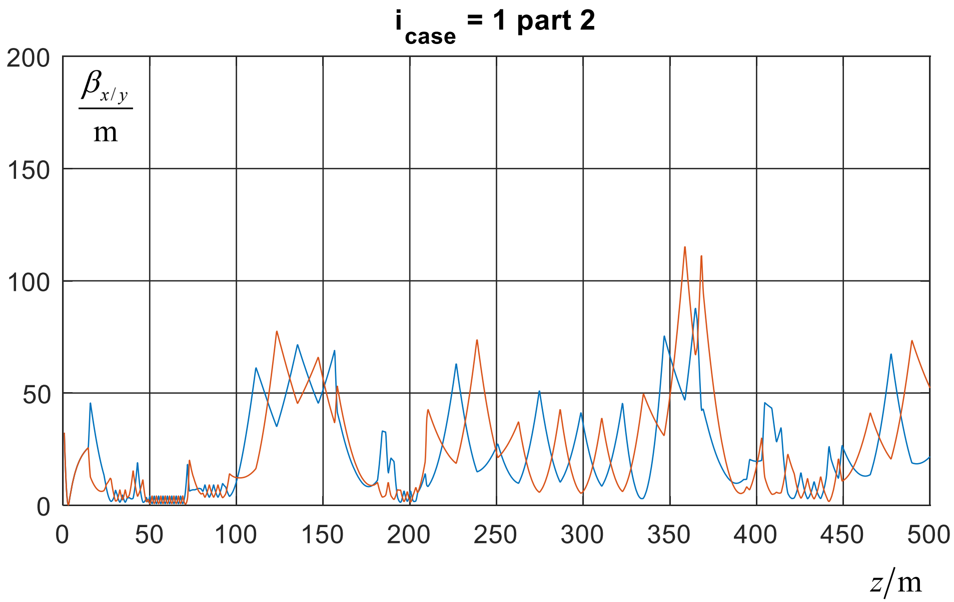
bandwidth: $\lambda_{\min} = \frac{L_p}{500}$

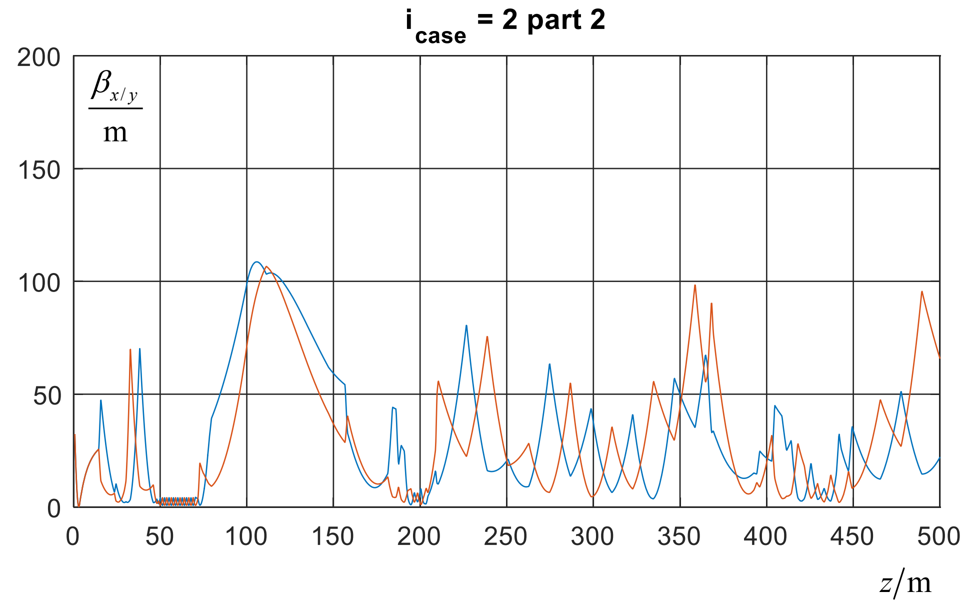
impedance weight from 1 to 0 between 0.8 and 0.9 of $\lambda_{\min}$

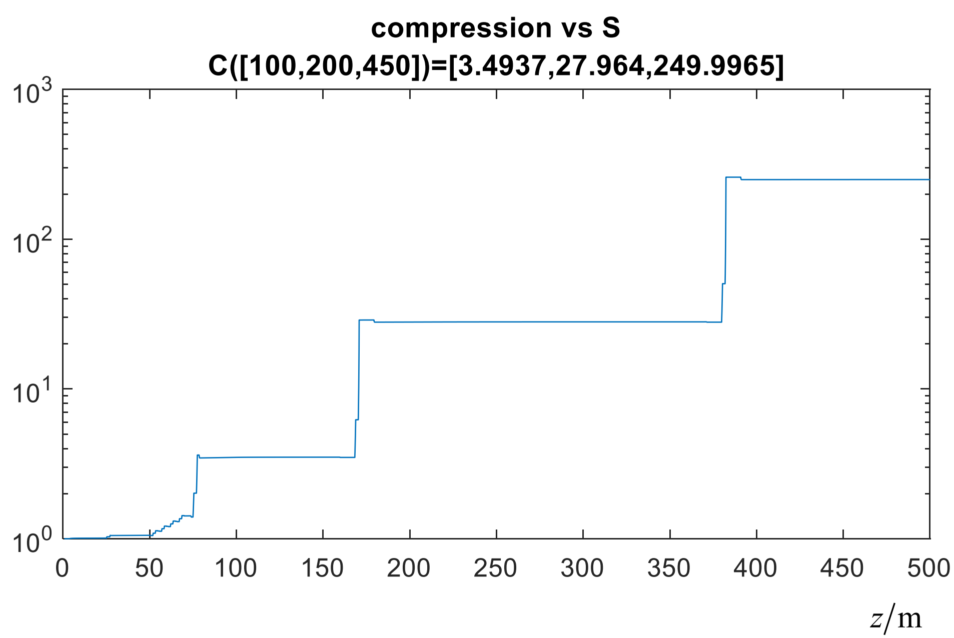
calculation to BC1 exit

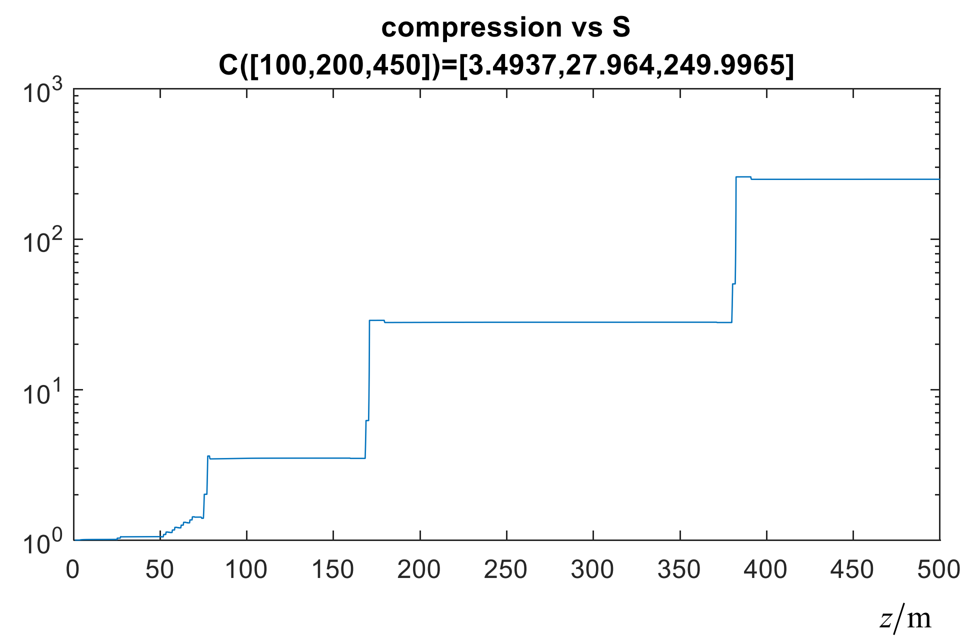
it does not make sense to compress further: either the period length gets too short or the number of electrons too large

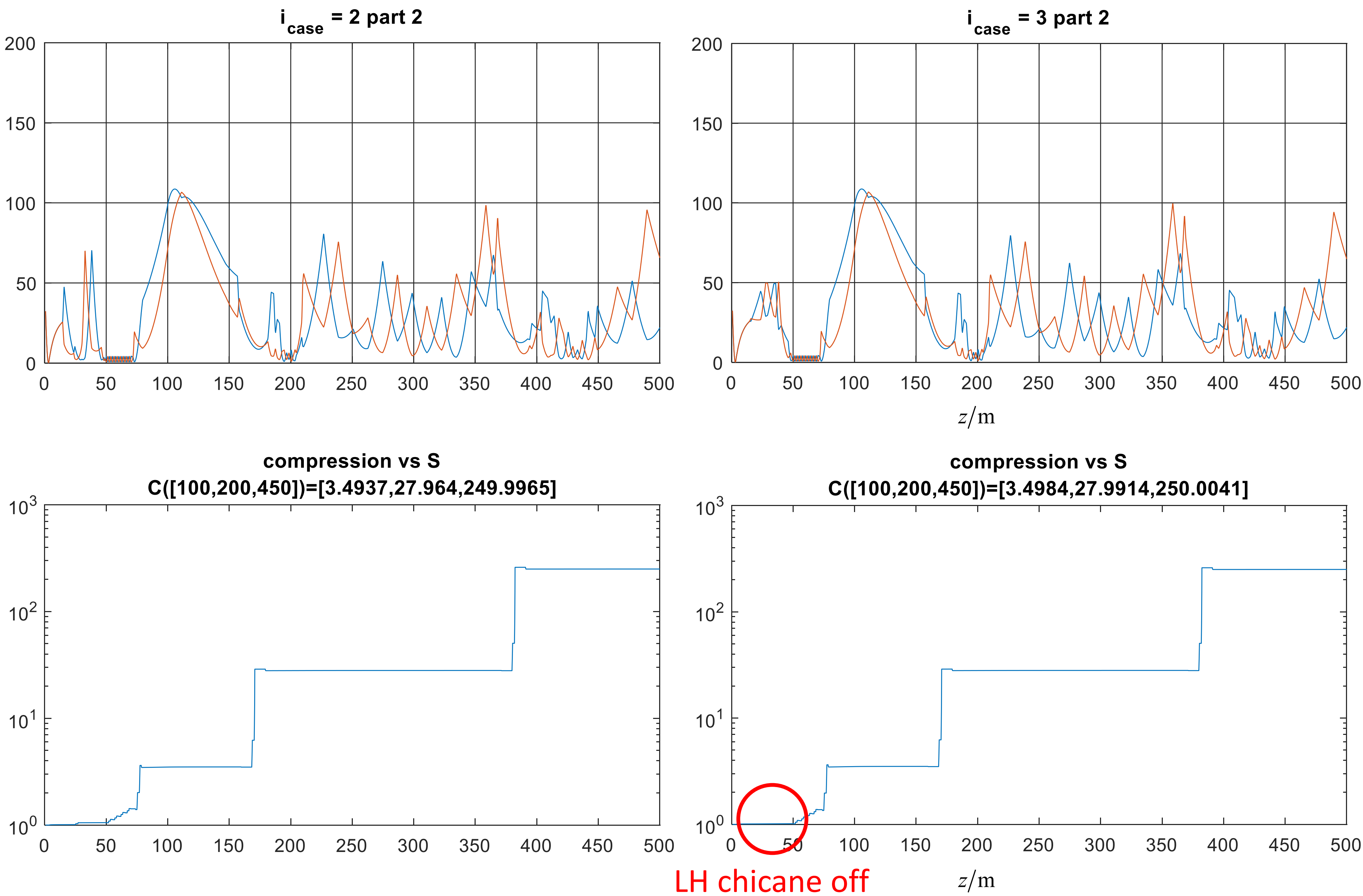
beam parameters and compression setup:







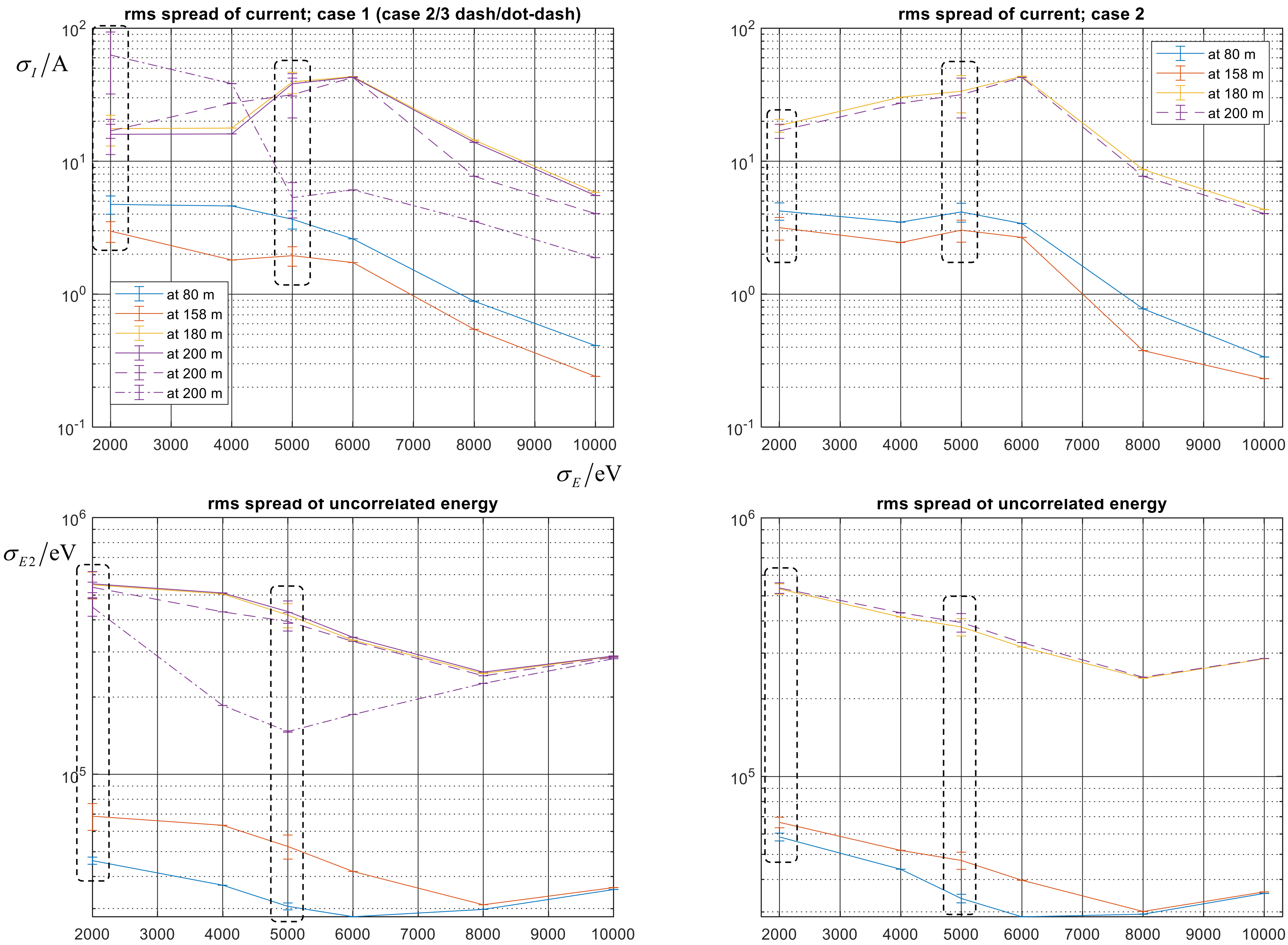




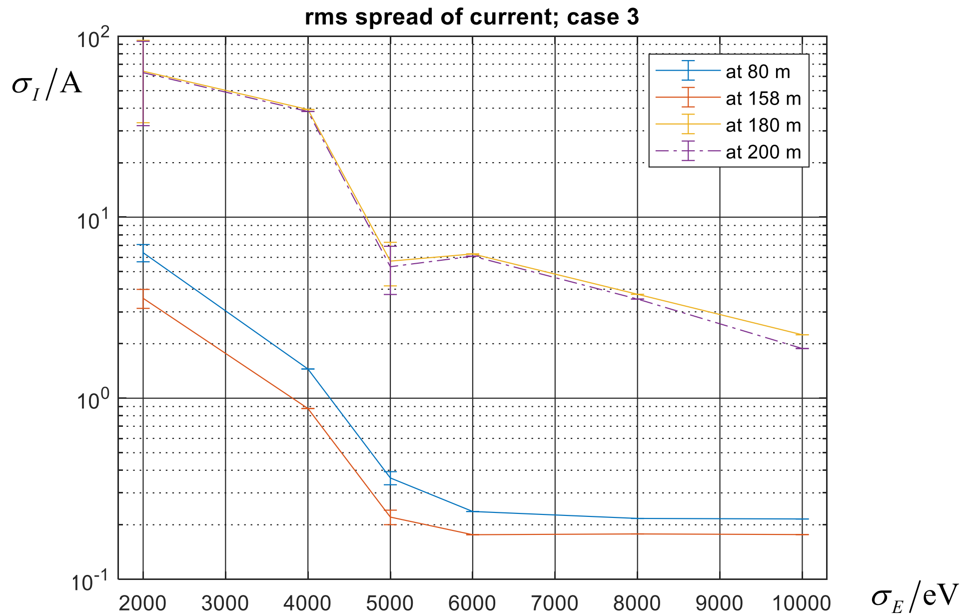
i_{case} = 2 part 2
i_{case} = 3 part 2
z/m
compression vs S
C([100,200,450])=[3.4937,27.964,249.9965]
compression vs S
C([100,200,450])=[3.4984,27.9914,250.0041]
LH chicane off
z/m

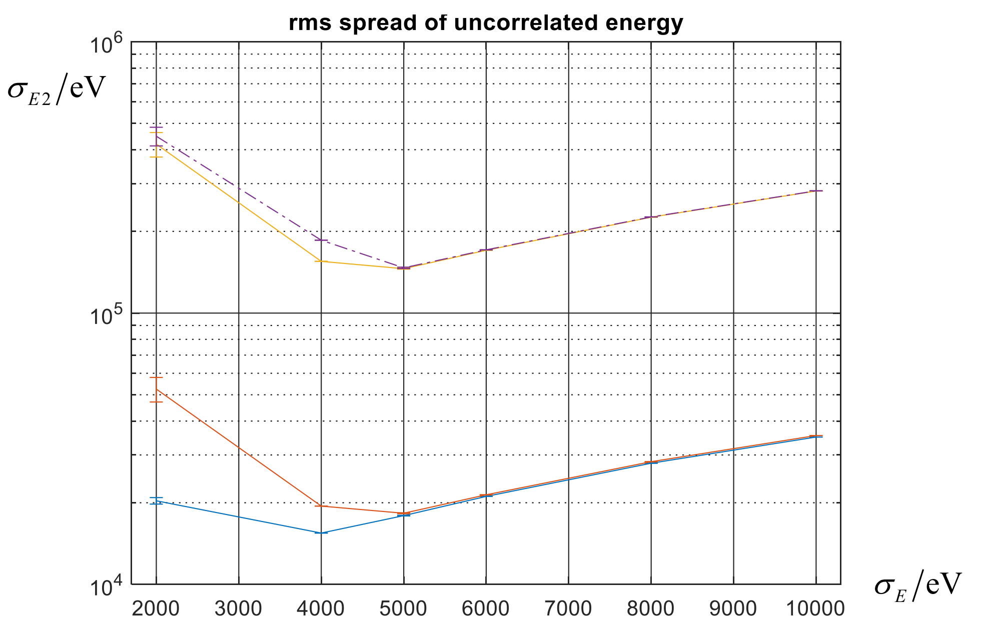
scan vs initial energy spread

10 random seeds

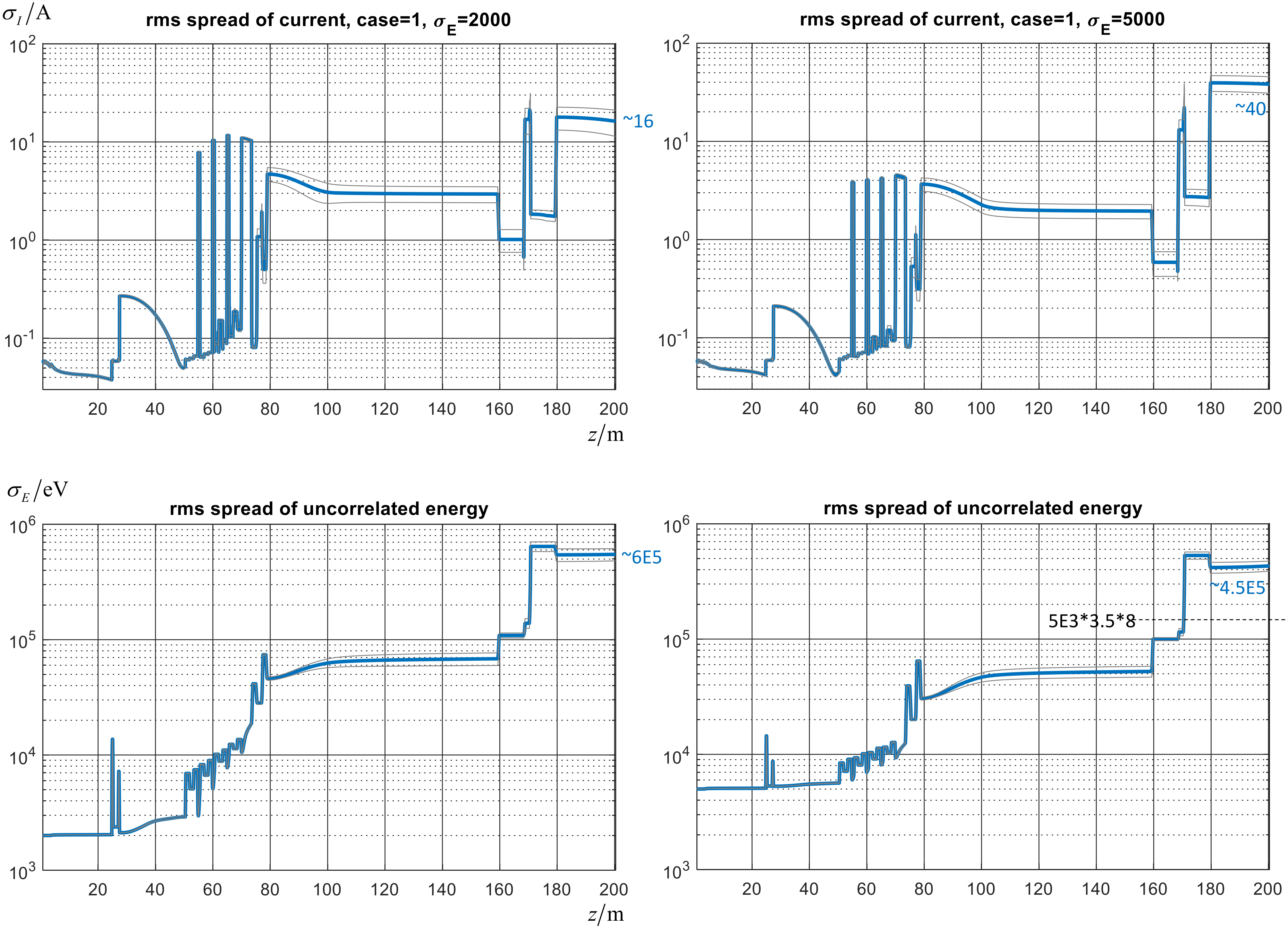


scan vs initial energy spread

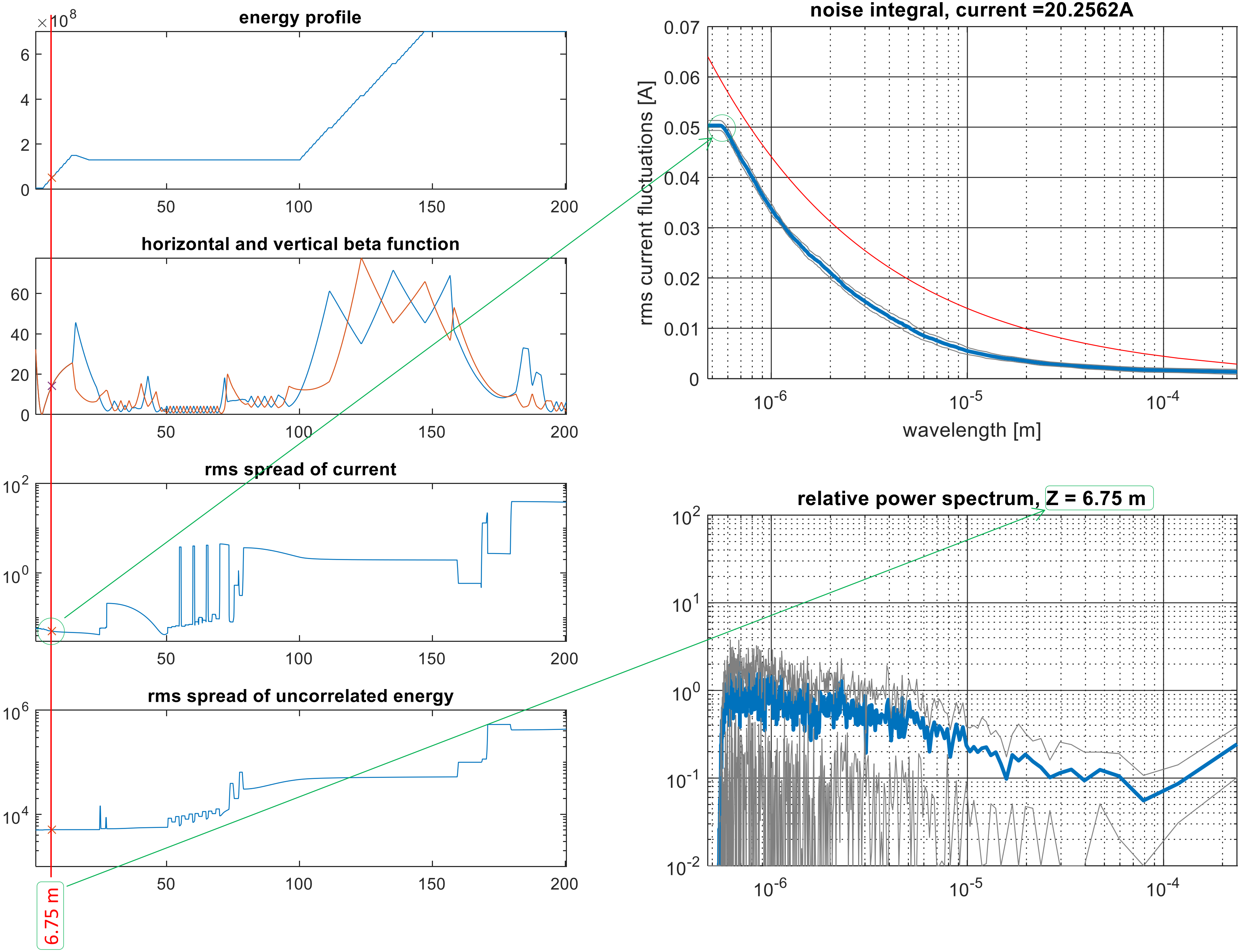


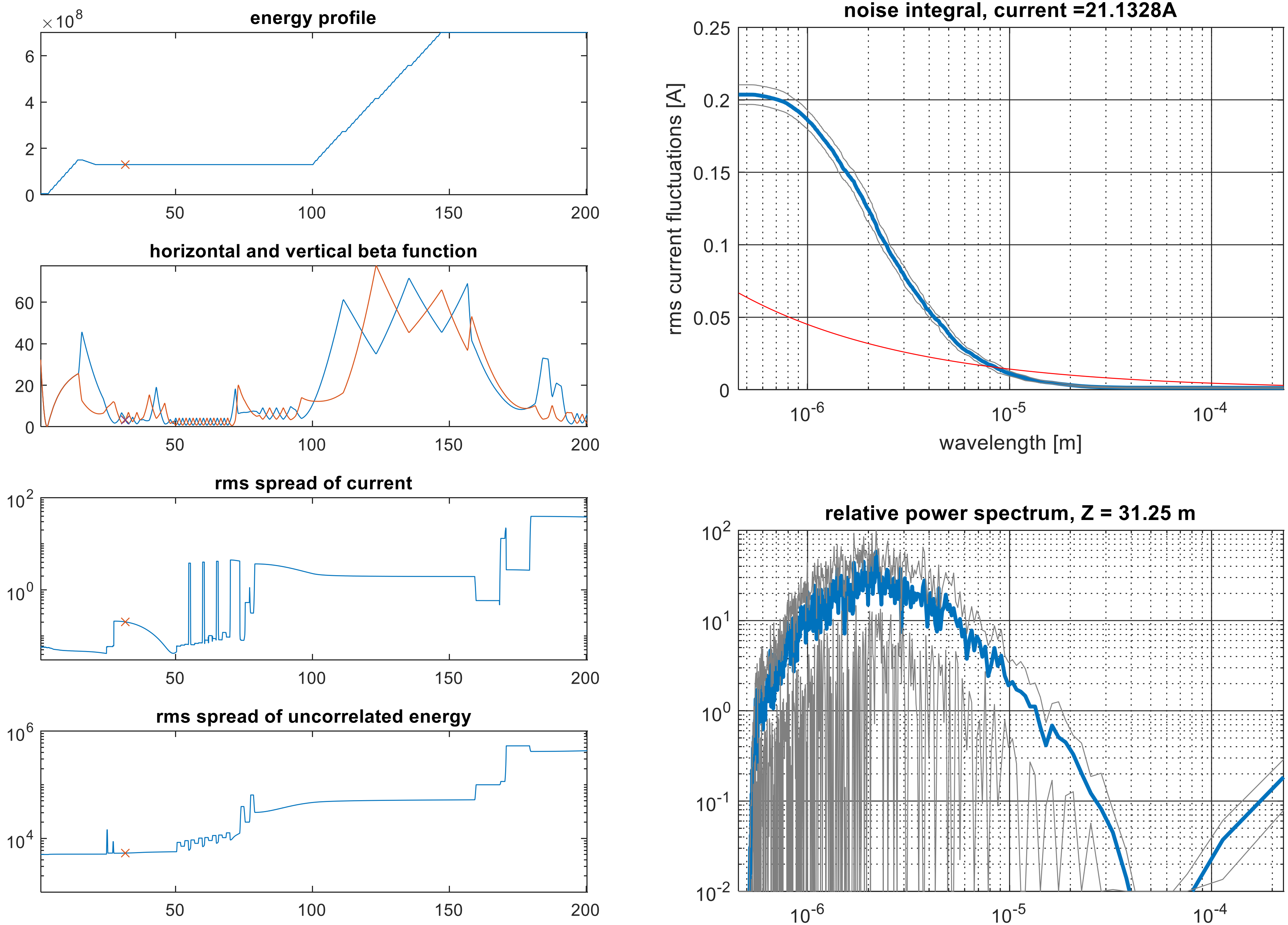


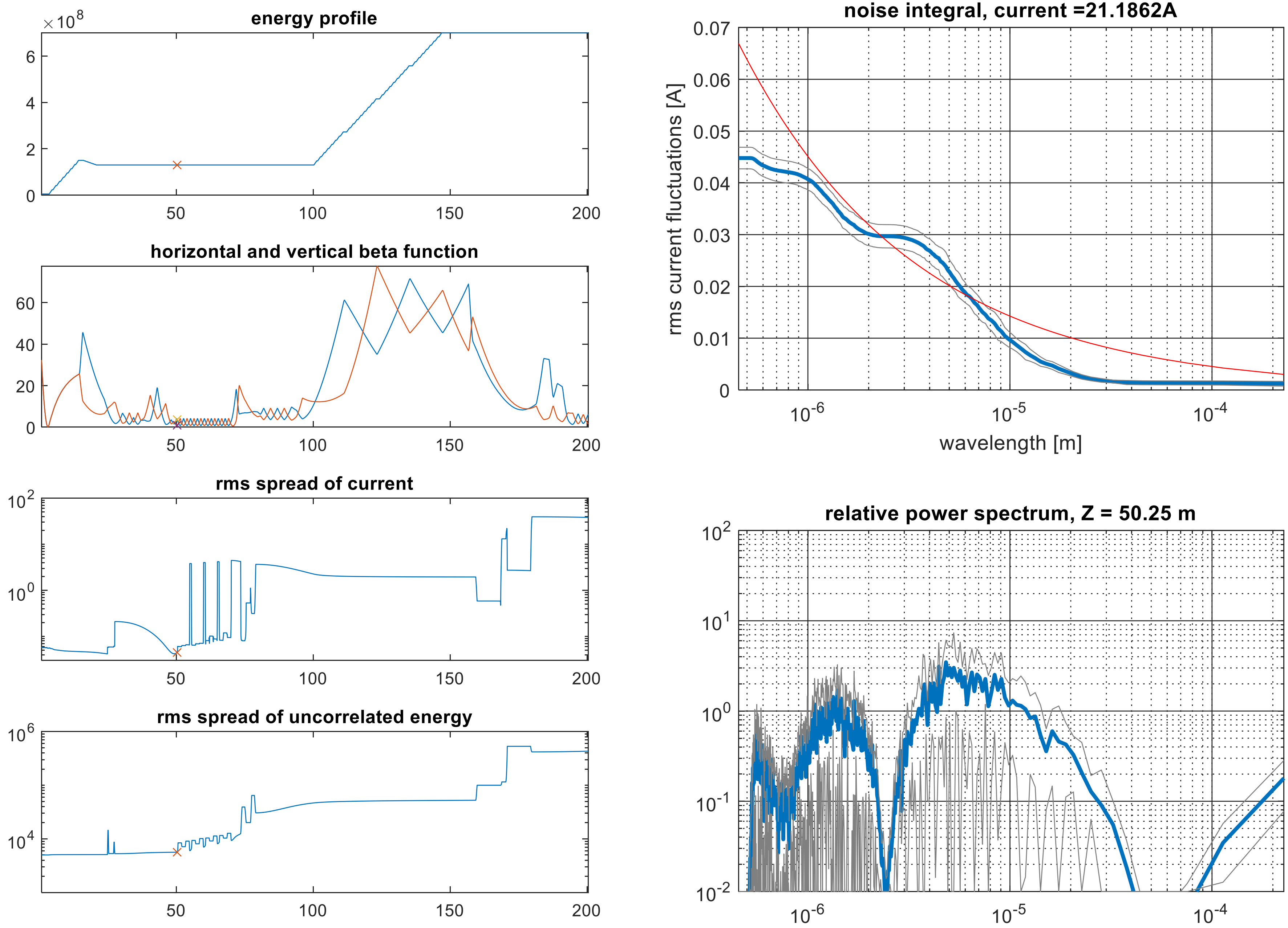
fluctuation and spread vs linac coordinate (10 random seeds)



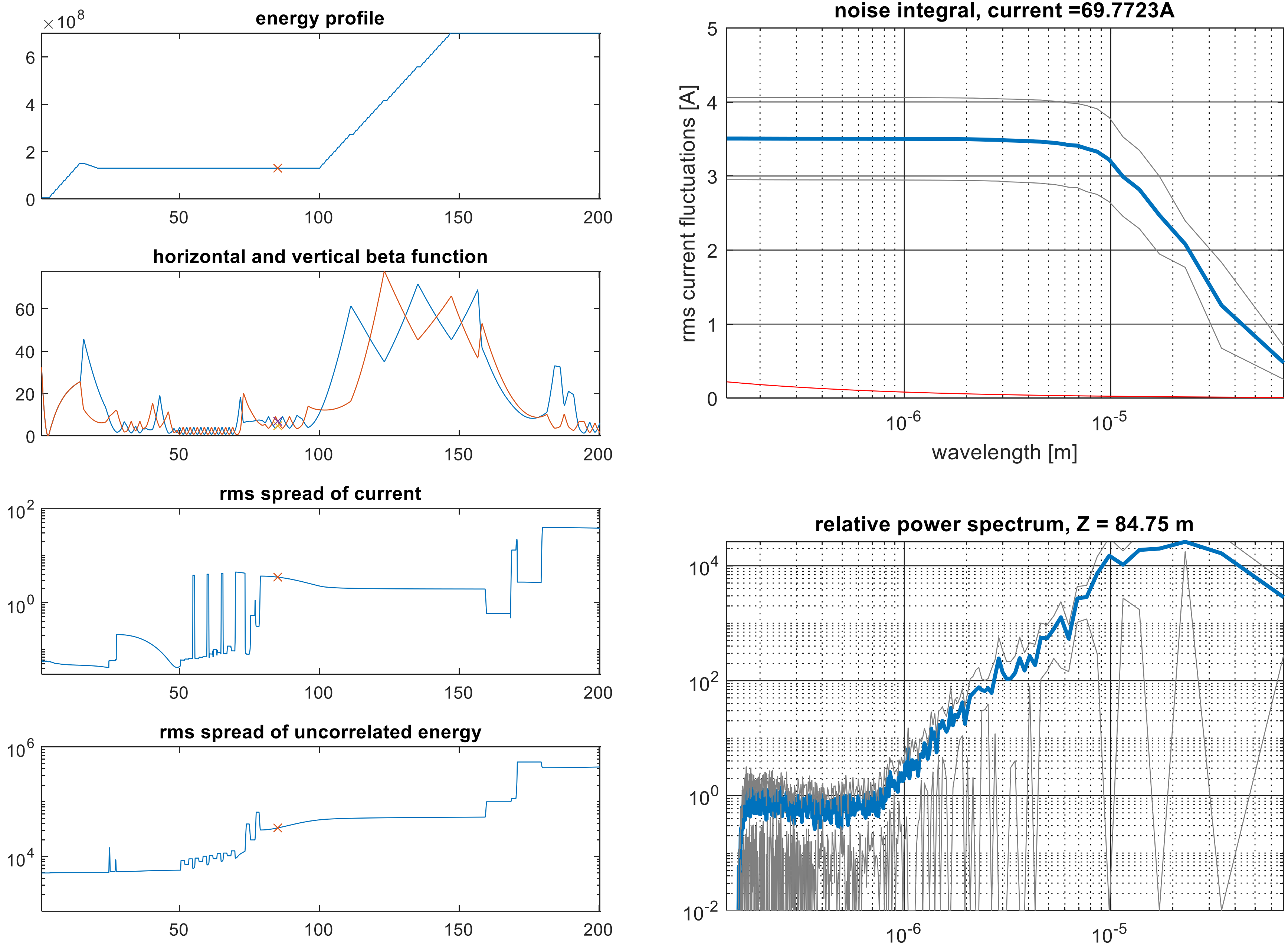
noise spectrum

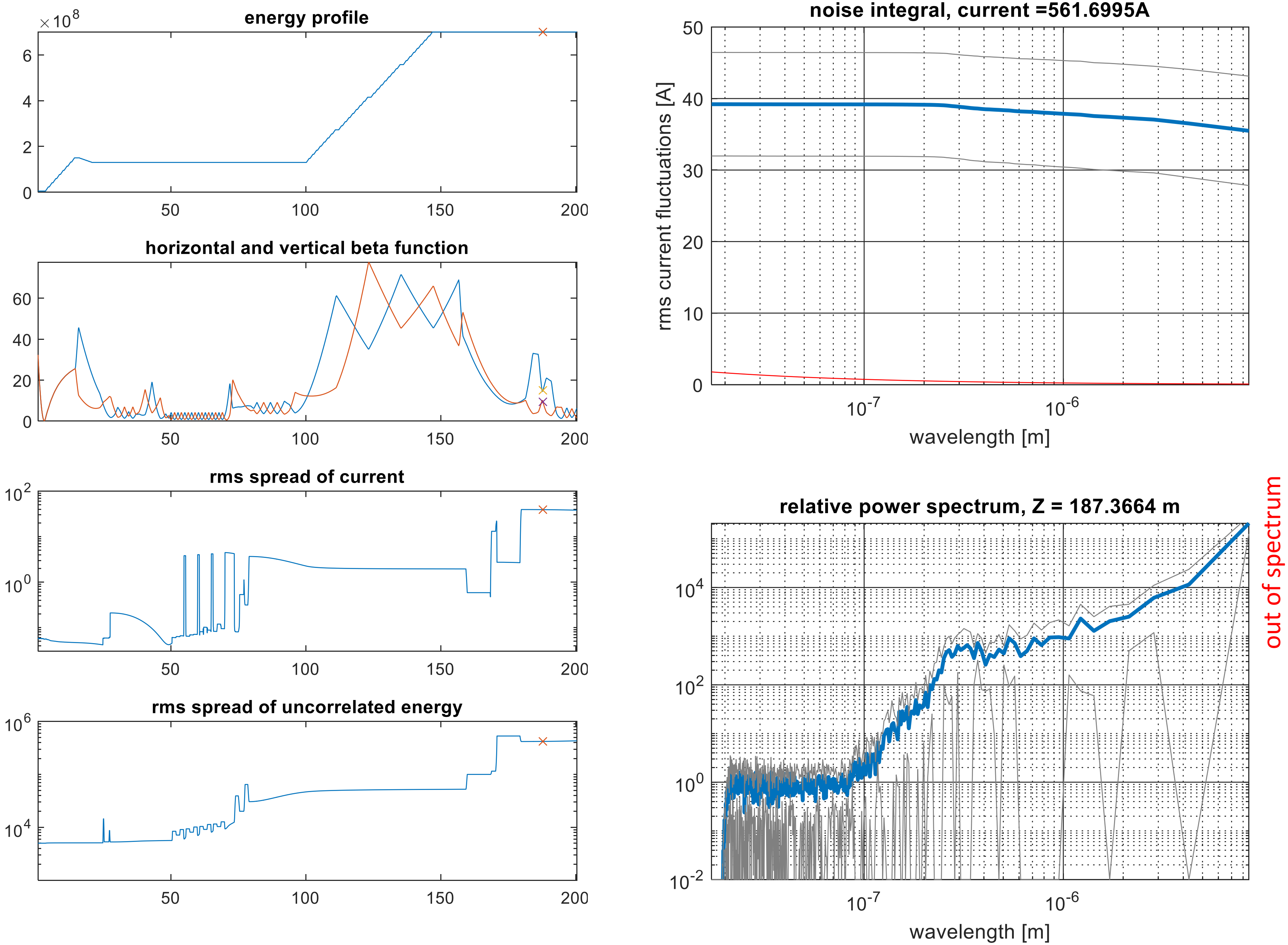



energy profile
×10^8
horizontal and vertical beta function
rms spread of current
rms spread of uncorrelated energy
noise integral, current =21.1328A
rms current fluctuations [A]
wavelength [m]
relative power spectrum, Z = 31.25 m

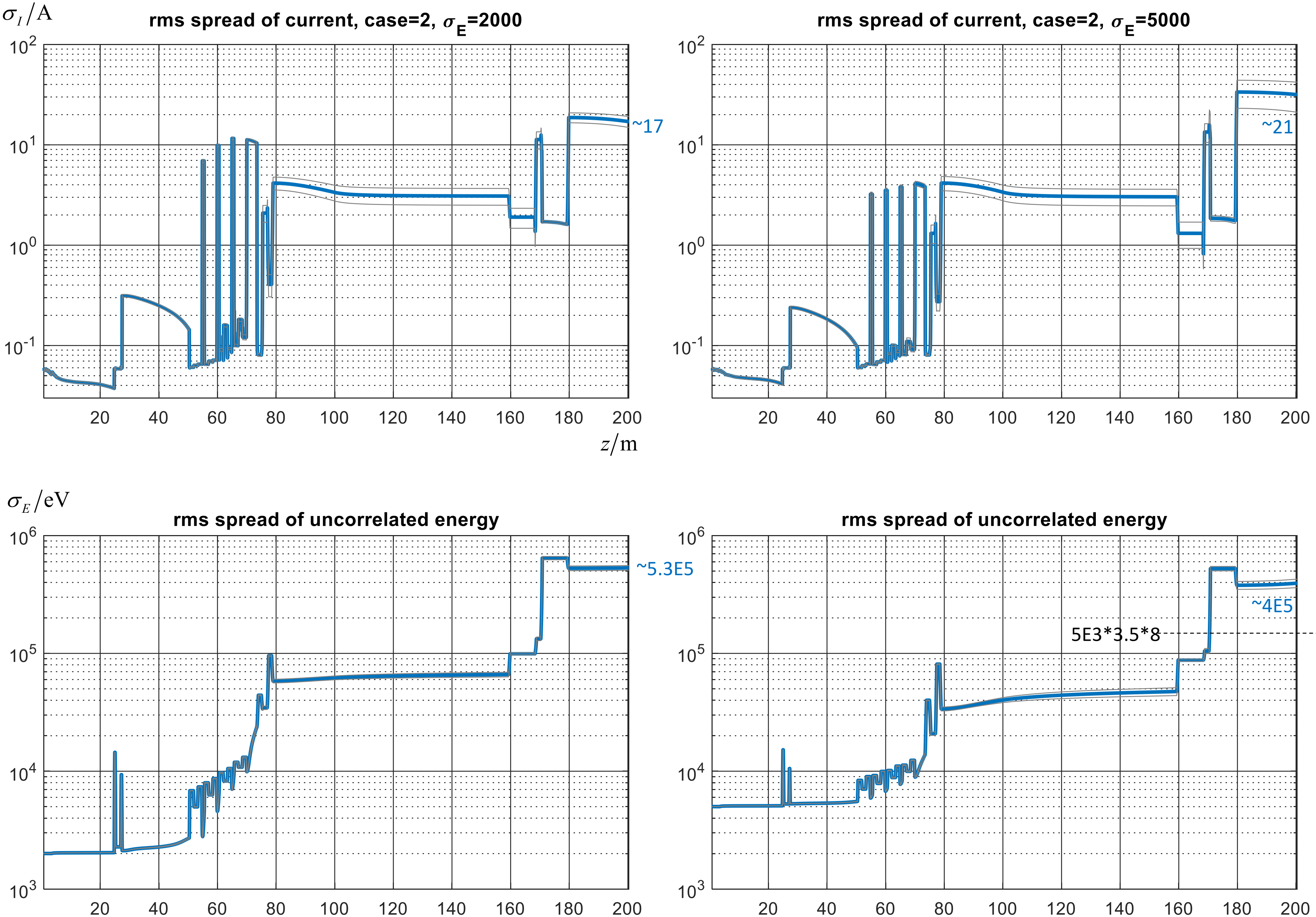


energy profile
×10^8
horizontal and vertical beta function
rms spread of current
rms spread of uncorrelated energy
noise integral, current =21.1862A
rms current fluctuations [A]
wavelength [m]
relative power spectrum, Z = 50.25 m

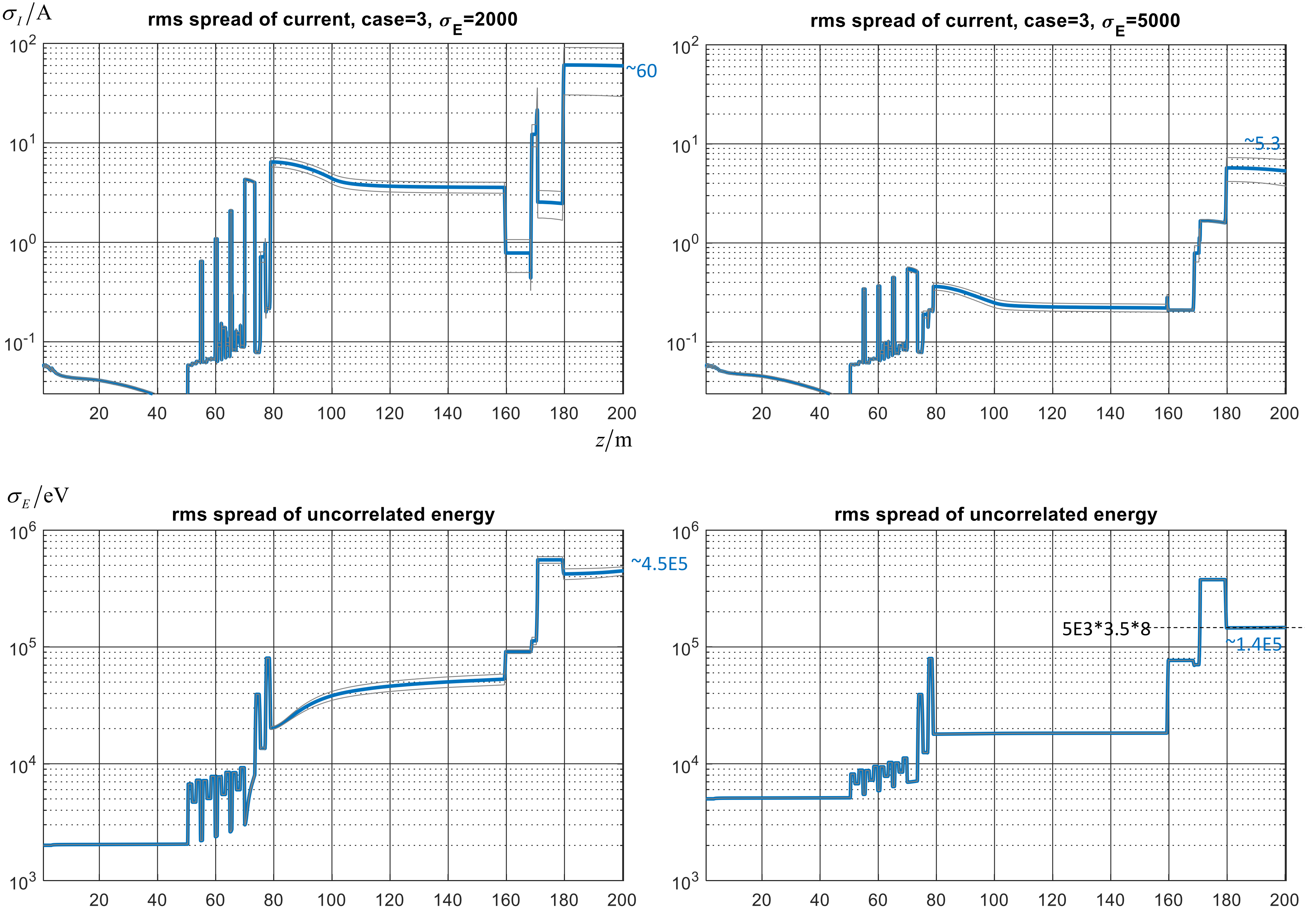

energy profile
×10^8
6
4
2
0
50
100
150
200
horizontal and vertical beta function
60
40
20
0
50
100
150
200
rms spread of current
10^2
10^0
50
100
150
200
rms spread of uncorrelated energy
10^6
10^4
50
100
150
200
noise integral, current =69.7723A
rms current fluctuations [A]
5
4
3
2
1
0
10^-6
10^-5
wavelength [m]
relative power spectrum, Z = 84.75 m
10^4
10^2
10^0
10^-2
10^-6
10^-5



energy profile
×10^8
6
4
2
0
50
100
150
200
horizontal and vertical beta function
60
40
20
0
50
100
150
200
rms spread of current
10^2
10^0
50
100
150
200
rms spread of uncorrelated energy
10^6
10^4
50
100
150
200
noise integral, current =561.6995A
rms current fluctuations [A]
50
40
30
20
10
0
10^-7
10^-6
wavelength [m]
relative power spectrum, Z = 187.3664 m
10^4
10^2
10^0
10^-2
10^-7
10^-6
wavelength [m]
out of spectrum

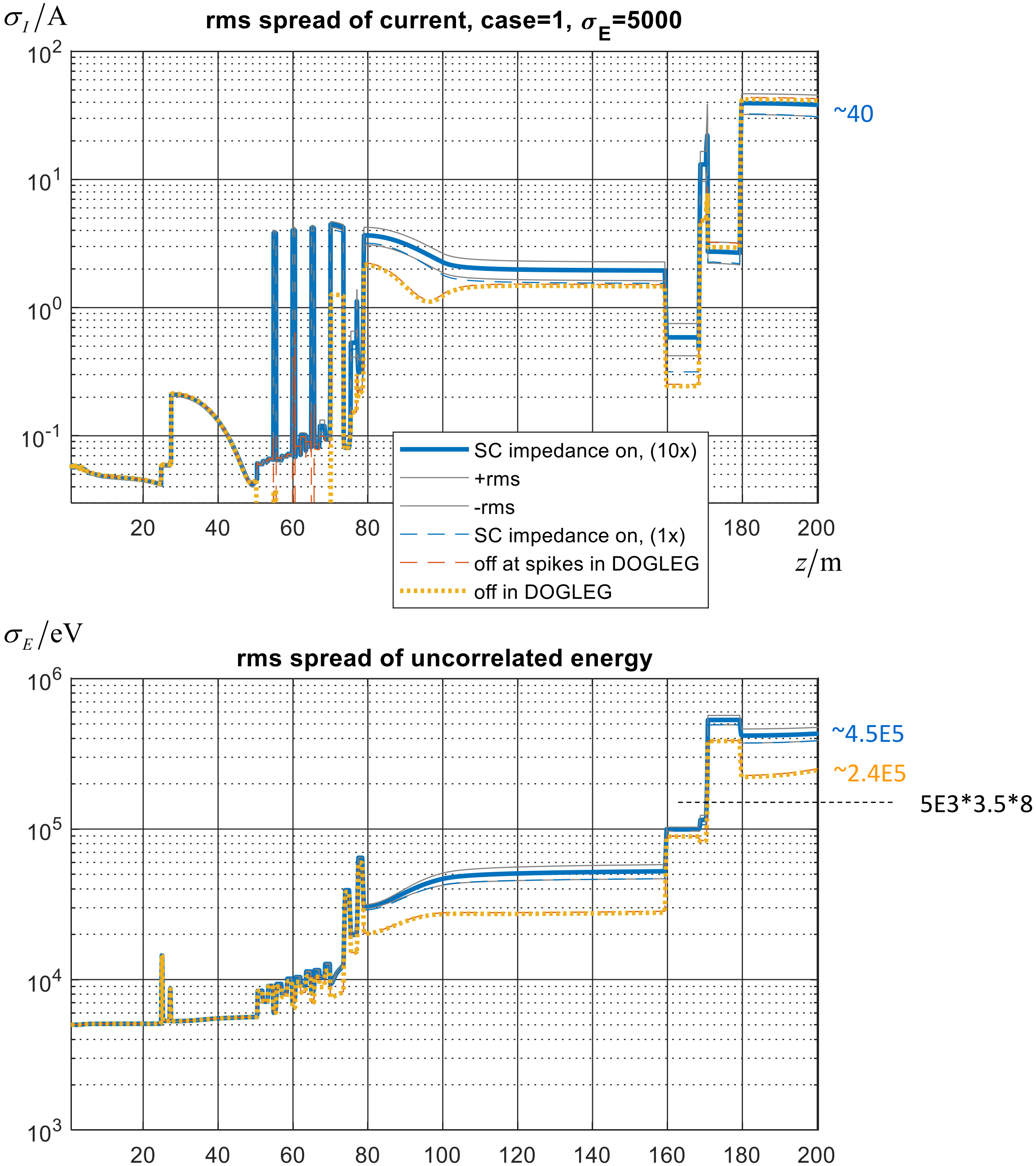


σ_I/A
rms spread of current, case=2, σ_E=2000
~17
z/m
rms spread of current, case=2, σ_E=5000
~21
σ_E/eV
rms spread of uncorrelated energy
~5.3E5
rms spread of uncorrelated energy
~4E5
5E3*3.5*8



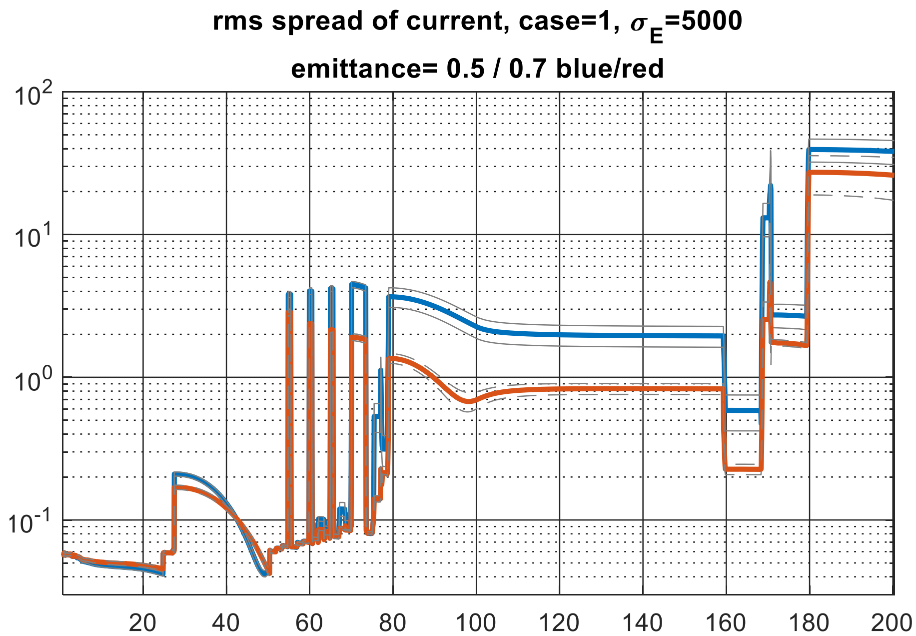
σ_I /A
rms spread of current, case=3, σ_E=2000
~60
rms spread of current, case=3, σ_E=5000
~5.3
z/m
σ_E /eV
rms spread of uncorrelated energy
~4.5E5
rms spread of uncorrelated energy
5E3*3.5*8
~1.4E5

effect of DOGLEG

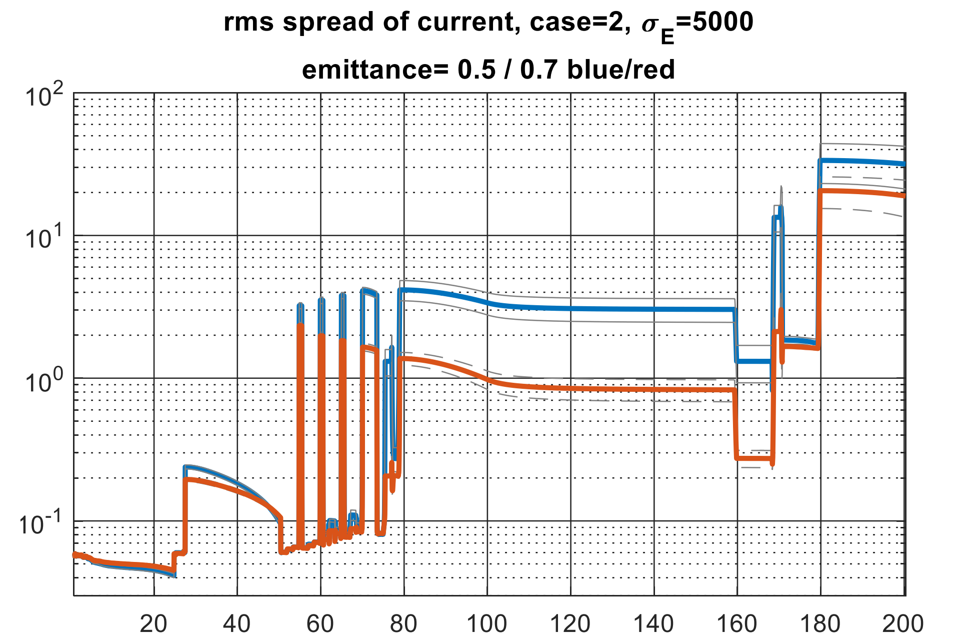


effect of emittance

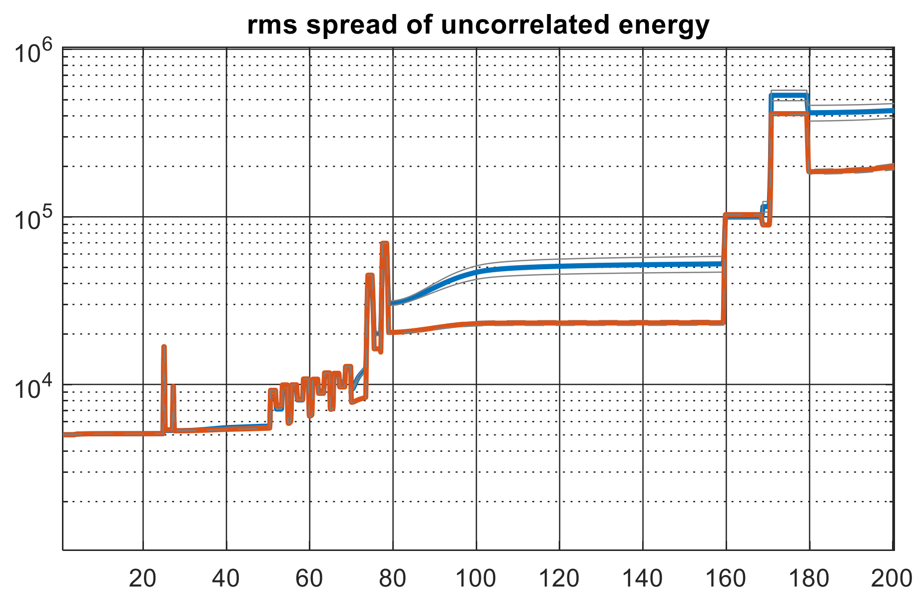
case 1, 2 and 3 with 20A, emit=0.7 and BC0=nominal
compression= 3.5 / 28 / 250



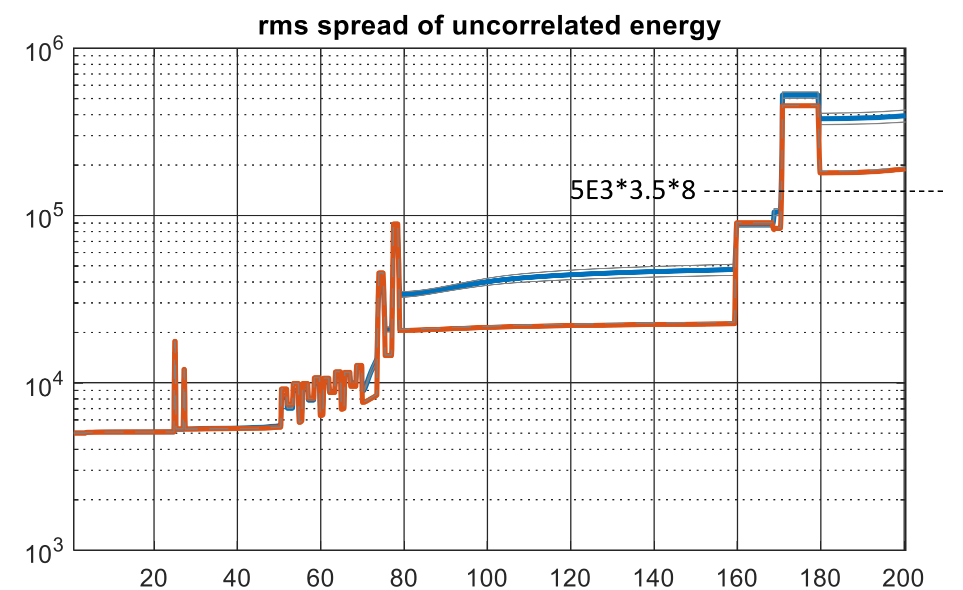
rms spread of current, case=1, σ_E=5000
emittance= 0.5 / 0.7 blue/red



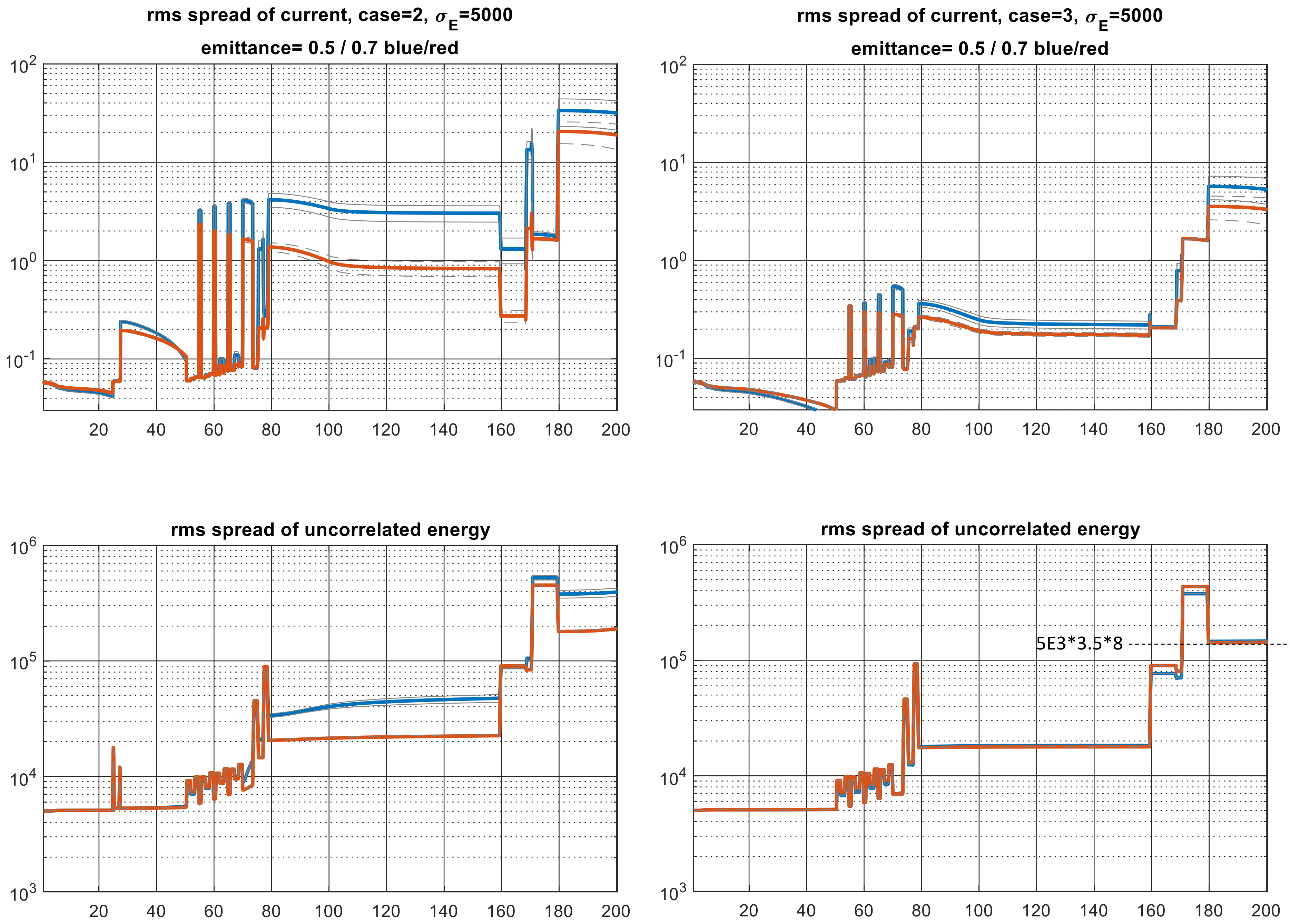
rms spread of current, case=2, σ_E=5000
emittance= 0.5 / 0.7 blue/red



rms spread of uncorrelated energy



rms spread of uncorrelated energy
5E3*3.5*8


rms spread of current, case=2, σ_E=5000
emittance= 0.5 / 0.7 blue/red
rms spread of current, case=3, σ_E=5000
emittance= 0.5 / 0.7 blue/red
rms spread of uncorrelated energy
rms spread of uncorrelated energy
5E3*3.5*8

effect of BC0 (r56)

BC0 (r56) = nominal/min/max

case 1 with 20A, emit=0.5, sigma_E=5000

nom: compression= 3.5 / 28 / 250

min: linac_phases=0..2: [16.874 180-10 24.307 -29.71 0]/180*pi

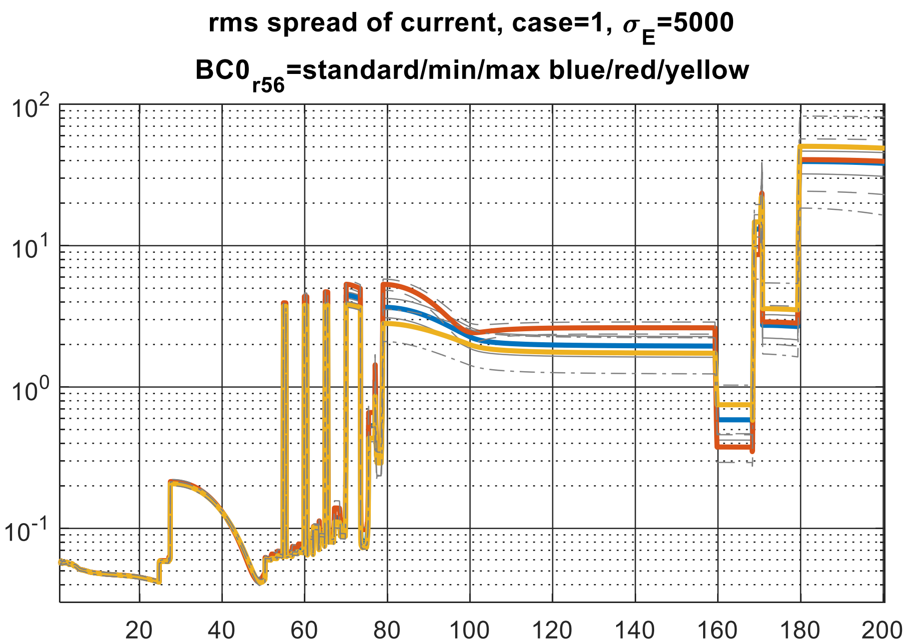
3: [18.447 180-10 23.038 -29.6893 0]/180*pi;

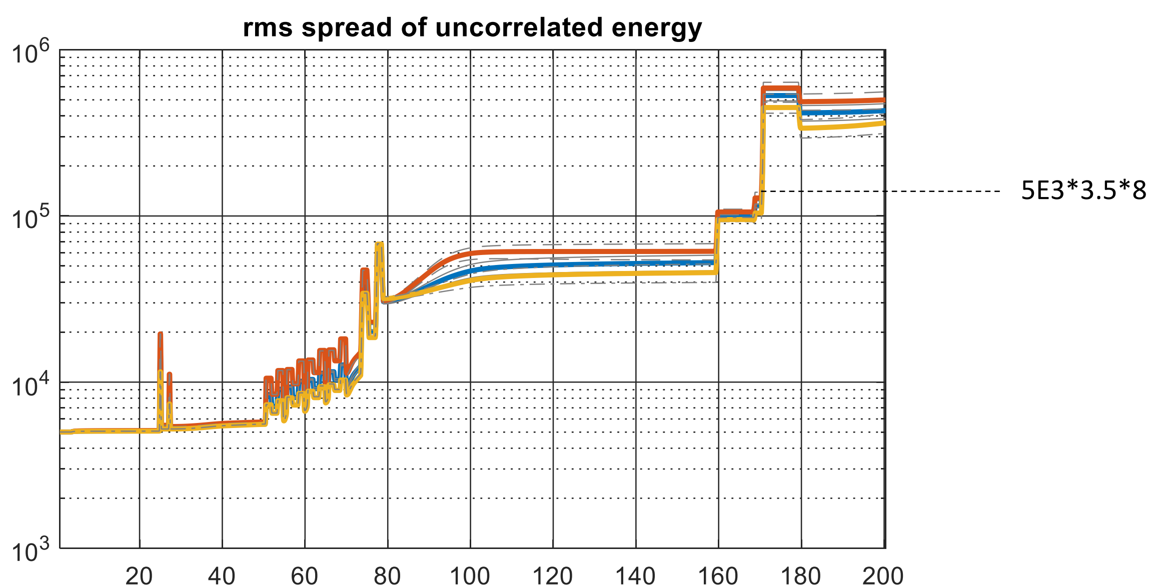
3.5/28/250

max: linac_phases=0..2 [7.6456 180-10 **30.0** -21.85 0]/180*pi

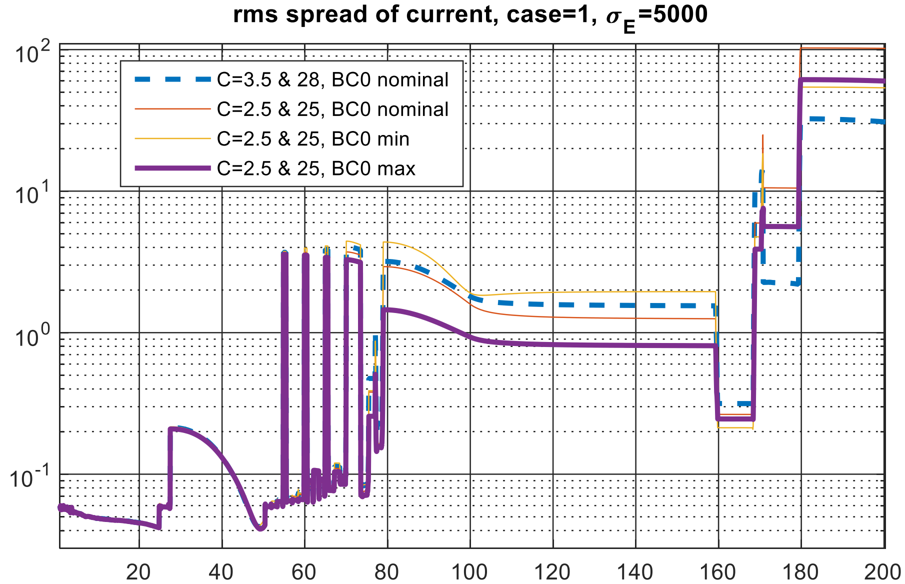
3: [8.0376 180-10 **30.0** -24.101 0]/180*pi

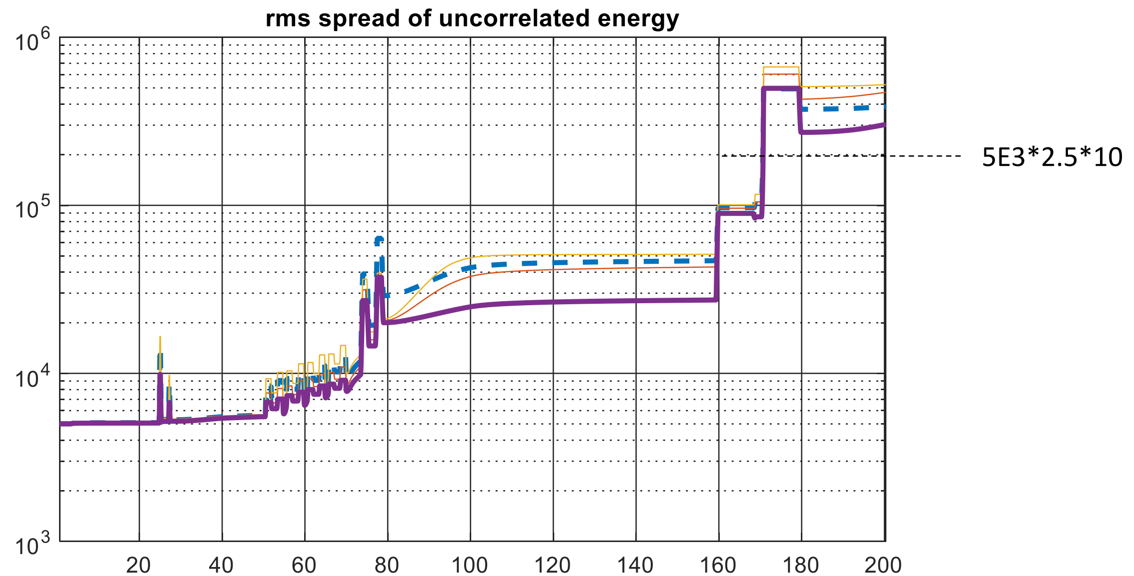
3.69/28/250


rms spread of current, case=1, σ_E=5000
BC0$_{r56}$=standard/min/max blue/red/yellow
10^2
10^1
10^0
10^{-1}
20 40 60 80 100 120 140 160 180 200

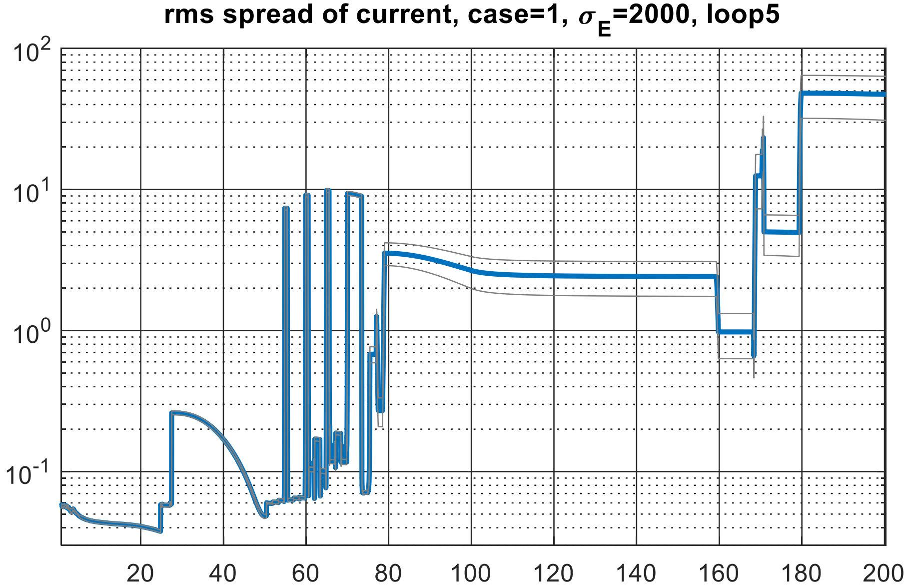

rms spread of uncorrelated energy
10^6
10^5
10^4
10^3
20 40 60 80 100 120 140 160 180 200
5E3*3.5*8

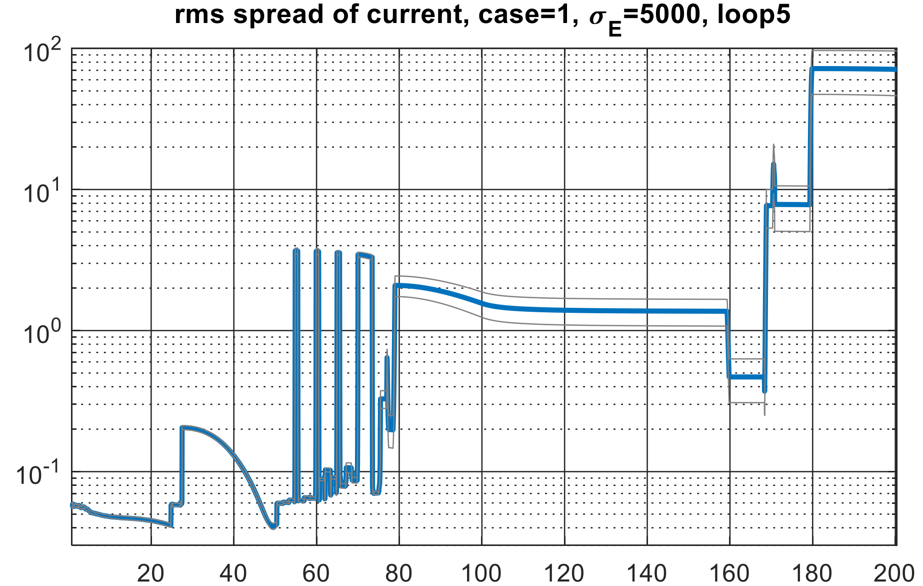
different compression (2.5 x 10 x 10) for 1 x random

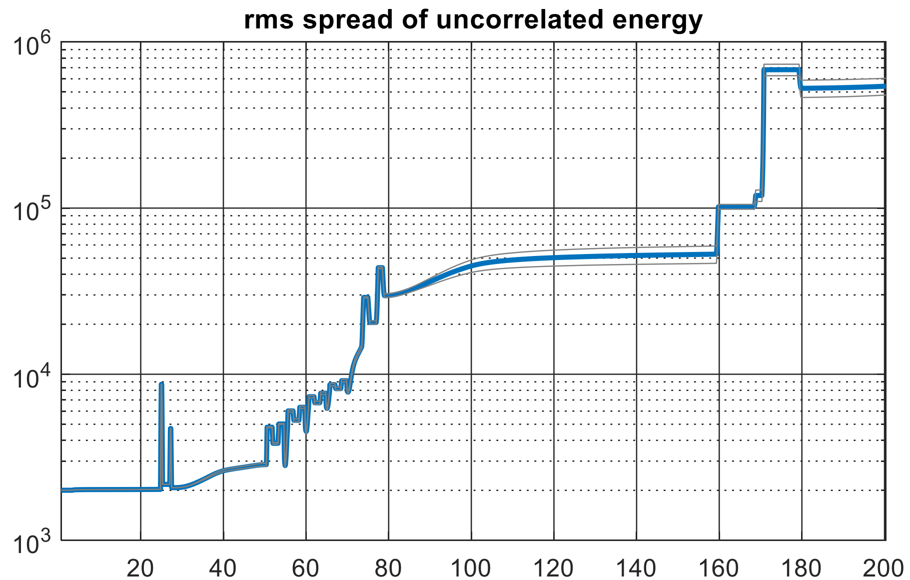


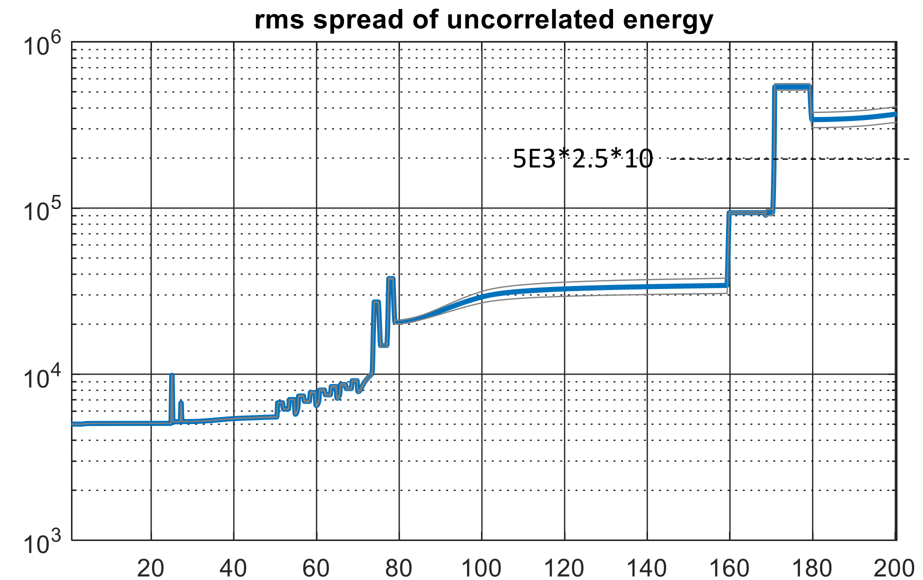


different compression 2.5 x 10 x 10, BC0 max, some matching

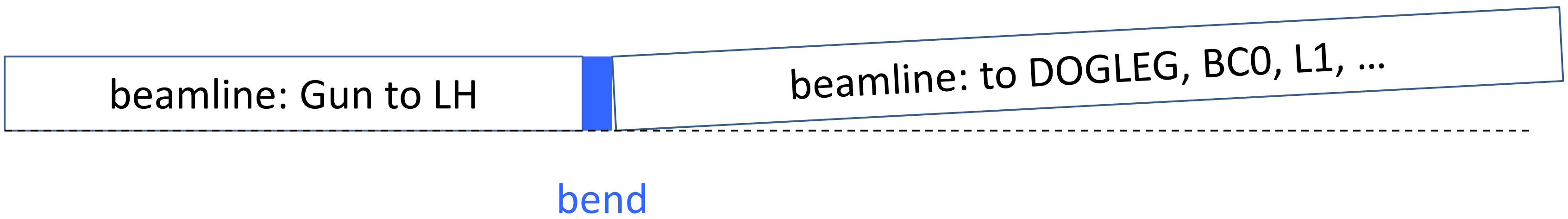




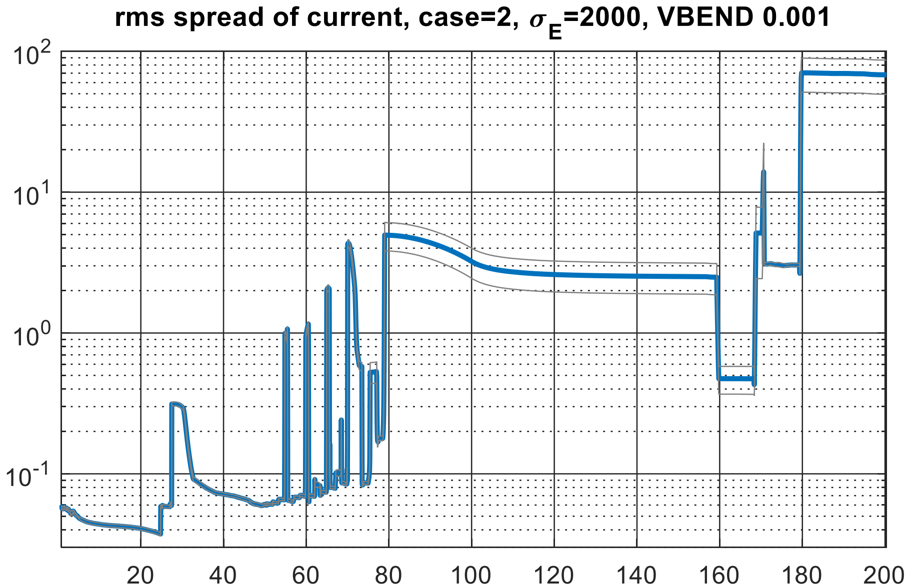


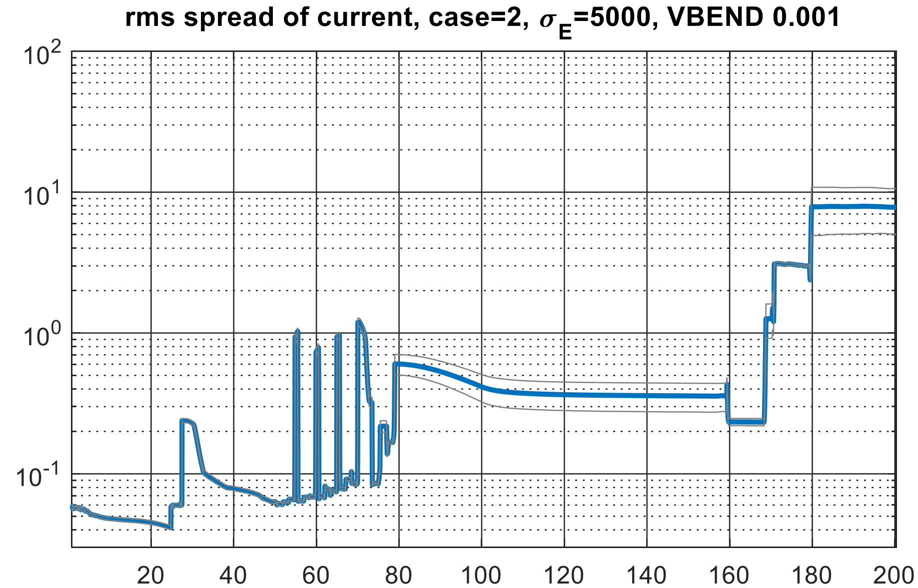


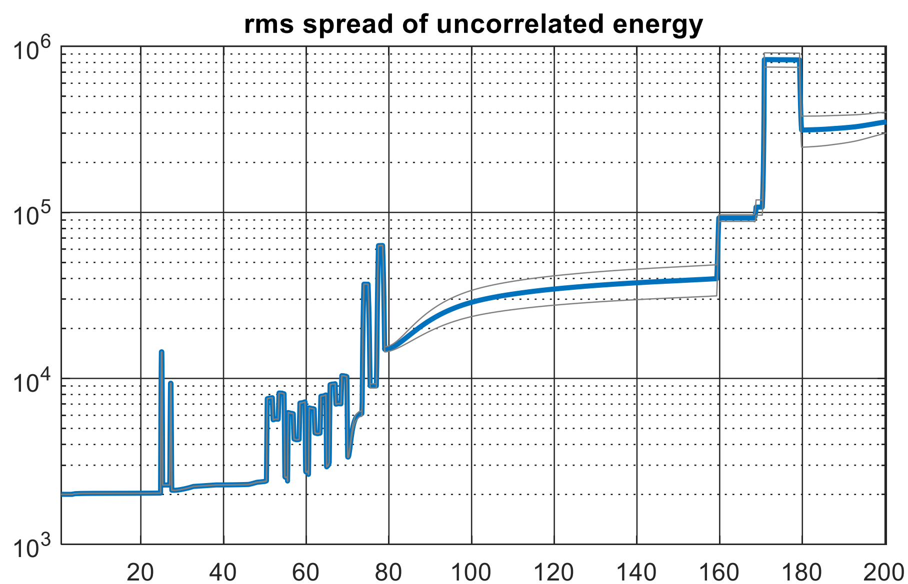
1 mrad bend after LH

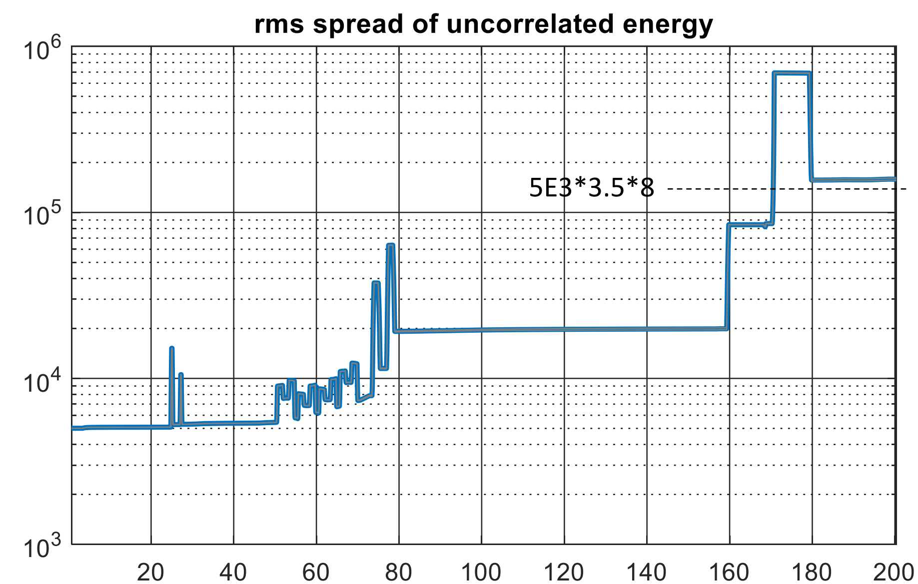


C=3.5/28/... approximately; V bend after LH chicane









C=3.5/28/… approximately; H bend after LH chicane