**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)*

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

case 1 und case 2

\[ i_{\text{case}} = 1 \text{ part 2} \]

\[ i_{\text{case}} = 2 \text{ part 2} \]
effective SC impedance (per length) for beams with elliptical cross-section

\[ Z'_{av}(\omega) = \frac{Z_0}{4\sqrt{2}\pi\sigma\gamma^2} h_e \left( \sqrt{2} \frac{\sigma_0 \omega}{\gamma \beta_c}, a \right) \]

\[ a = \left( \frac{\sigma_{\text{max}}}{\sigma_{\text{min}}} \right)^2 \]
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
$$L_p = \frac{10^8 q_0 v}{20 \text{ A}} = 0.24 \text{ mm}$$

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

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

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:

\[ \beta_{x/y} \text{ m} \]

\[ \text{compression vs S} \]

\[ C([100, 200, 450]) = [3.4937, 27.964, 249.9965] \]
scan vs initial energy spread

10 random seeds

rms spread of current; case 1 (case 2/3 dash/dot-dash)

rms spread of current; case 2

rms spread of uncorrelated energy

rms spread of uncorrelated energy
scan vs initial energy spread

rms spread of current; case 3

rms spread of uncorrelated energy
fluctuation and spread vs linac coordinate (10 random seeds)

$\sigma_i/A$

rms spread of current, case=1, $\sigma_E=2000$

$\sigma_E/eV$

rms spread of uncorrelated energy

$\sim 16$

$\sim 6E5$

$\sim 5E3*3.5*8$

$\sim 10^2$

$\sim 10^6$

$\sim 10^3$

$\sim 10^0$

$\sim 10^{-1}$
noise spectrum

energy profile

horizontal and vertical beta function

rms spread of current

rms spread of uncorrelated energy

noise integral, current = 20.2562A

relative power spectrum, Z = 6.75 m
out of spectrum
effect of DOGLEG
effect of emittance

case 1, 2 and 3 with 20A, \text{emit}=0.7 \text{ and BC0=nominal compression}= 3.5 / 28 / 250
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
different compression (2.5 x 10 x 10) for 1 x random
different compression $2.5 \times 10 \times 10$, BC0 max, some matching

rms spread of current, case=1, $\sigma_E=2000$, loop5

rms spread of current, case=1, $\sigma_E=5000$, loop5

rms spread of uncorrelated energy

rms spread of uncorrelated energy

$5 \times 10 \times 2.5 \times 10$
1 mrad bend after LH

beamline: Gun to LH

beamline: to DOGLEG, BC0, L1, ...

bend
$C = \frac{3.5}{28}/...$ approximately; \textbf{V bend after LH chicane}

- **RMS spread of current, case=2, $\sigma_E = 2000$, VBEND 0.001**
  - Graph showing current spread with a scale from $10^{-1}$ to $10^2$.

- **RMS spread of current, case=2, $\sigma_E = 5000$, VBEND 0.001**
  - Similar graph with a scale from $10^{-1}$ to $10^2$.

- **RMS spread of uncorrelated energy**
  - Graph showing energy spread with a scale from $10^3$ to $10^6$.

- **RMS spread of uncorrelated energy**
  - Similar graph with a scale from $10^3$ to $10^6$. The graph includes a dotted line labeled $5 \times 3.5 \times 8$. 
C=3.5/28/... approximately; H bend after LH chicane

rms spread of current, case=2, $\sigma_E=2000$, HBEND 0.001

rms spread of current, case=2, $\sigma_E=5000$, HBEND 0.001

rms spread of uncorrelated energy

rms spread of uncorrelated energy