Start-to-end CeC Simulations

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Let GENESIS generate particles for 400 slices with correct shot noise.

Take 5 slices for modulator simulations (background beam and modulated beam) with quadrupoles.

Replace 5 slices into GENESIS for FEL simulation (background beam and modulated beam).

Take 5 slices from output of GENESIS as the input of kicker simulation (background beam and modulated beam) with quadrupoles.
- Number of real electrons per slice : $2.83 \times 10^7$
- Number of macro electrons per slice : 1048576
- Number of wiggler period : 188
- Length of each wiggler : 4 cm
Longitudinal modulation

(a) Density

(b) Velocity

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Instant bunching factor

(a) Background

(b) Signal
Instant bunching factor

(a) Background

(b) Signal
Instant bunching factor

(a) Background

(b) Signal

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Start-to-end CeC Simulations
Instant bunching factor

(a) Background

(b) Signal
Bunching factor along time

(a) Background

(b) Signal

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Instant bunching factor

(a) Background

(b) Signal

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Instant bunching factor

(a) Background

(b) Signal

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Instant bunching factor

(a) Background

(b) Signal

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Longitudinal distribution

(a) Density
(b) Velocity
Longitudinal distribution

(a) Density

(b) Velocity

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Longitudinal distribution

(a) Density

(b) Velocity
Longitudinal distribution

(a) Density

(b) Velocity

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Longitudinal distribution

(a) Density

(b) Velocity
Longitudinal distribution

(a) Density
(b) Velocity

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Longitudinal distribution

(a) Density

(b) Velocity
Longitudinal distribution

(a) Density

(b) Velocity
Longitudinal distribution

(a) Density

(b) Velocity

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Start-to-end CeC Simulations
Start with distribution from beam dynamics simulation

- Total charge is 2 nC, with only $2 \times 10^5$ macro particles, so each macro particle represents 62500 real electrons
- These $2 \times 10^5$ particles are distributed in 3000 slices, with each slice containing very few particles (maximum value is 914 for the center slice)
- Up sampling is required
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Up sampling method in GENESIS is not good if we want to increase number of particles by orders.

We calculate beam parameters within each slice and reproduce desired number of particles.

As each slice has different number of particles, GENESIS can not generate initial distribution.

A routine is implemented in our code to generate initial particles from beam parameters.

A special method is used to maintain the real shot noise when we use macro particles.
- We use the center slice containing 914 macro particles, with representing number 62500

- We increase number of particles by $1e+2 / 1e+3$, with representing number decreased to 625 / 62.5
Longitudinal density modulation

(a) up sampling by $10^2$

(b) up sampling by $10^3$

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- Up sampling by $1e+2$ gives good results
- For FEL and kicker simulation, we will use 200 slices instead of 1 slice, and up sampling by $1e+3$ will be very time consuming
- All following FEL and kicker simulation use up sampling by $1e+2$
In previous work, only the center slice passes through modulator, and the other slices don’t.

Now, we also let the 200 slices pass through modulator, and use them for FEL simulation.
• The 200 slices at entrance of modulator are generated with correct shot noise

• The 200 slices at end of modulator contains too large shot noise

• A possible reason is that, during modulator, particles may go between slices, and affect the bunching factor of those slices
For comparisons, we use three copies of these 200 slices:

- 200 slices at the entrance of modulator, with correct shot noise
- 200 slices at the end of modulator, with large shot noise
- Based on the 200 slices at the end of modulator, re-generate them with correct shot noise
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at entrance of modulator

(a) Background

(b) Signal

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Start-to-end CeC Simulations
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at entrance of modulator

(a) Background

(b) Signal

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Start-to-end CeC Simulations
200 slices at entrance of modulator

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, large noise

(a) Background

(b) Signal

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200 slices at end of modulator, large noise

(a) Background

(b) Signal

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200 slices at end of modulator, large noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal

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200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
200 slices at end of modulator, correct noise

(a) Background

(b) Signal
Longitudinal density distribution

(a) 200 slice at entrance of modulator
(b) 200 slice at end of modulator
Beam parameters at entrance and end of modulator

<table>
<thead>
<tr>
<th>Parameter</th>
<th>At entrance</th>
<th>At end</th>
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<tbody>
<tr>
<td>$\alpha_x$</td>
<td>-2</td>
<td>16</td>
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<tr>
<td>$\alpha_y$</td>
<td>-2</td>
<td>-30</td>
</tr>
<tr>
<td>energy spread</td>
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<td>1e-3</td>
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</tbody>
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