Optimization of Guinea-Pig grid for ILC feedback simulations

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The luminosity issue: flat beams

To maximise the luminosity need to make $\sigma_x\sigma_y$ small

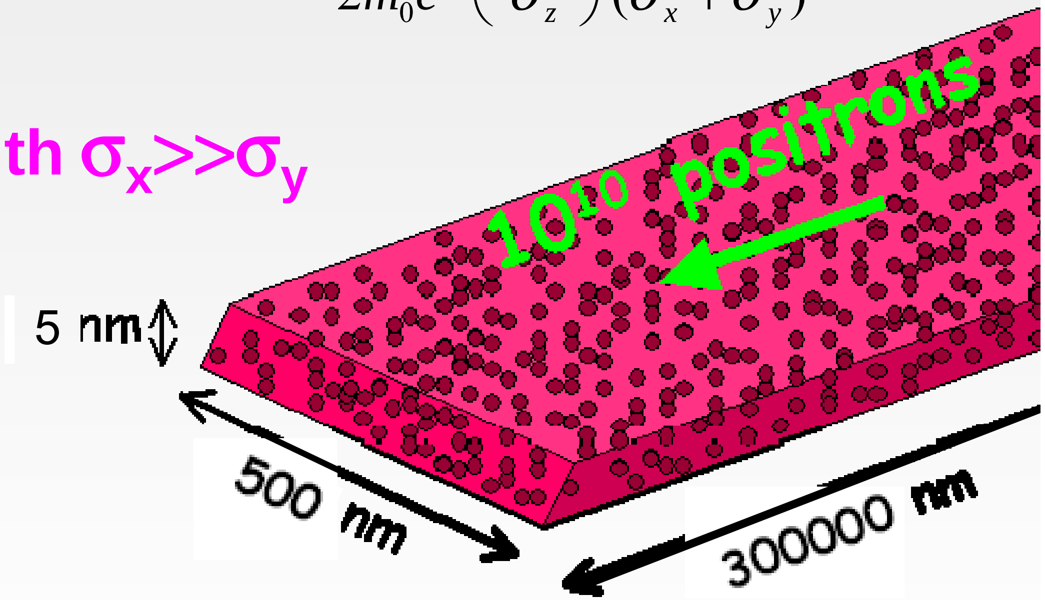
$$L = \frac{\eta_{RF} P_{RF} N}{4\pi\sigma_x\sigma_y E_{cm}} H_D$$

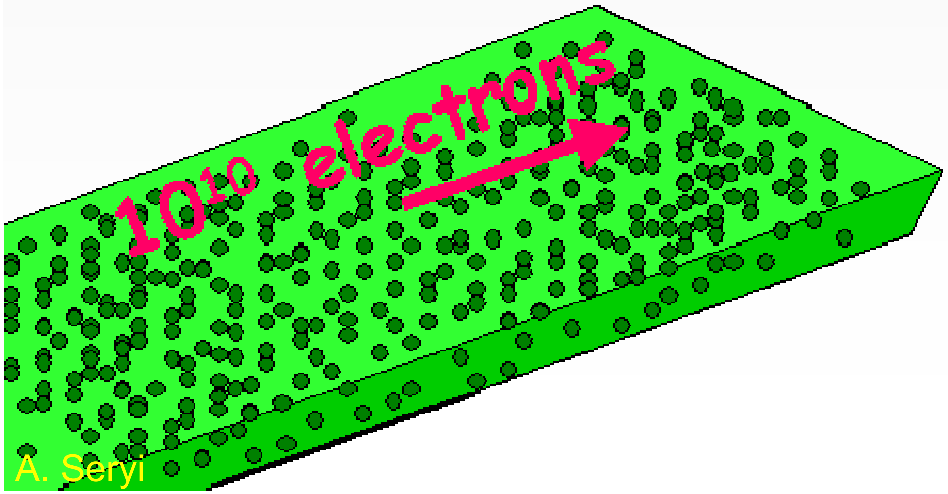
BUT keep $(\sigma_x+\sigma_y)$ large to reduce δ_B

$$\delta_B \approx 0.86 \frac{e r_e^3}{2 m_0 c^2} \left(\frac{E_{cm}}{\sigma_z}\right) \frac{N^2}{(\sigma_x^2+\sigma_y^2)}$$

Trick: use "flat beams" with $\sigma_x >> \sigma_y$

Very sensitive to small vertical offsets



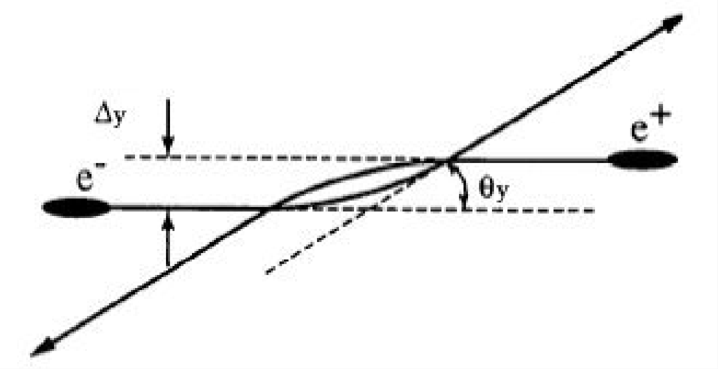


Need to maintain the beams aligned at the IP with ~0.5 nm precision !

Beam-beam deflection

Beam-beam interaction focuses (defocuses) the beams.

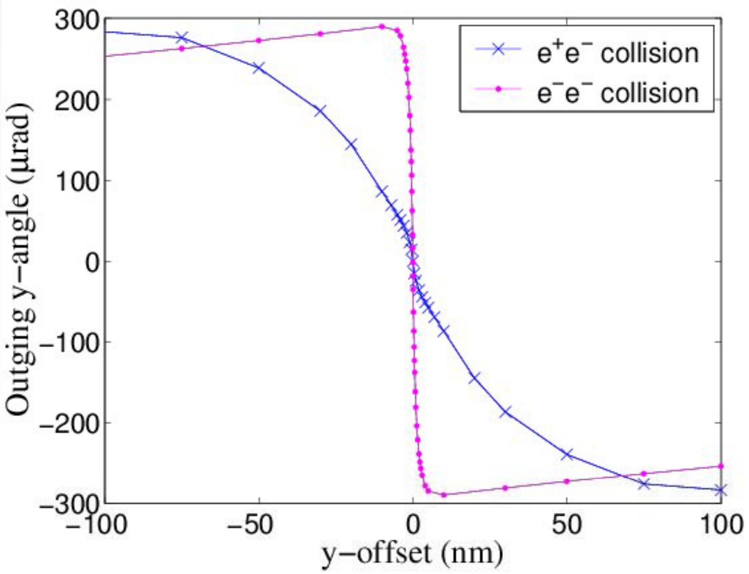
In addition, if there is an offset between the beams, there is a net force that deflects the trajectories.



deflection angle for $|y_0| << \sigma_y$

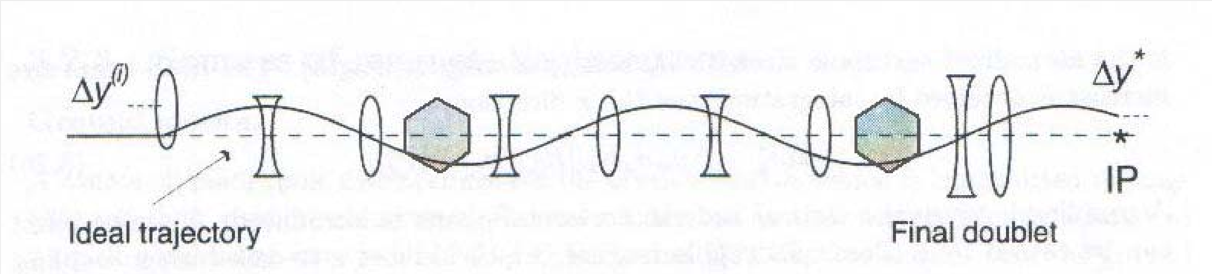
$$y' = -\frac{2Nr_e}{\gamma} \frac{y_0}{\sigma_{x,y}(\sigma_x + \sigma_y)} = -\frac{y_0}{f_y}$$

out-going angle is the main signal for the IP position feedback system



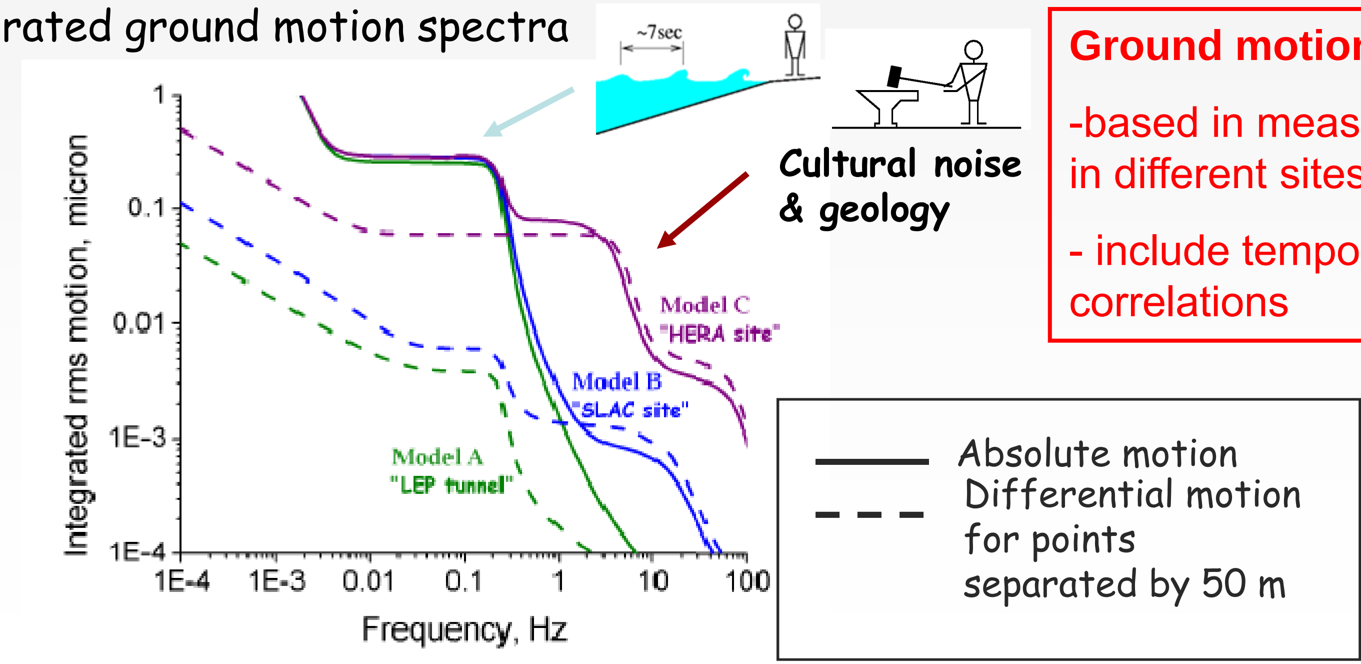
Sources of magnet displacements

Magnet displacements introduce offsets at the IP



Source of magnet displacements: ground motion

Integrated ground motion spectra



Ground motion models:

-based in measurements taken in different sites

- include temporal and spatial correlations

* See e.g. A. Seryi, Ground Motion and Vibration Issues for Accelerators, Proceedings of the 2001 PAC, Chicago

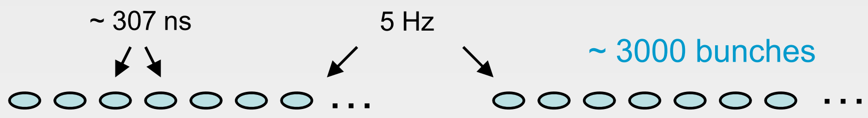
Beam-based IP position Feedback Simulation

Amplitudes of the IP y-offsets:

Train frequency:
~ hundreds of nm

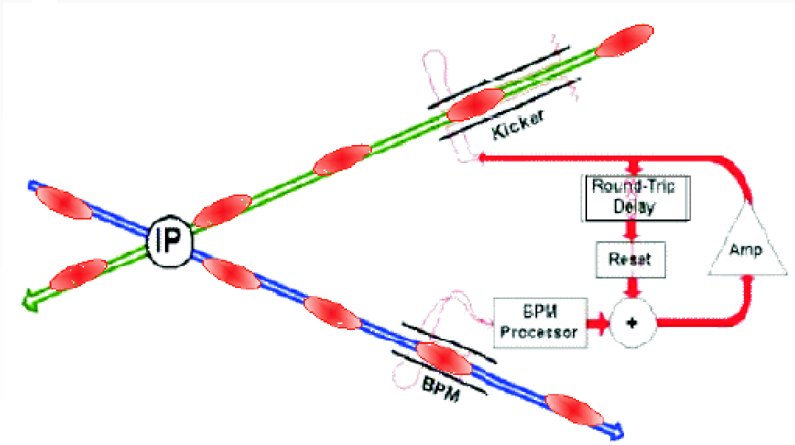
Bunch-to-bunch frequency:
~ fraction of σ_y

Structure of the beam:

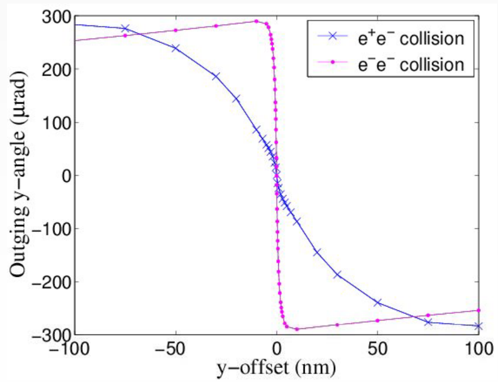


Beam-beam deflection IP position feedback system

1. Measure the out-going angle



2. Predict the offset between the beams



3. Correct the next bunch

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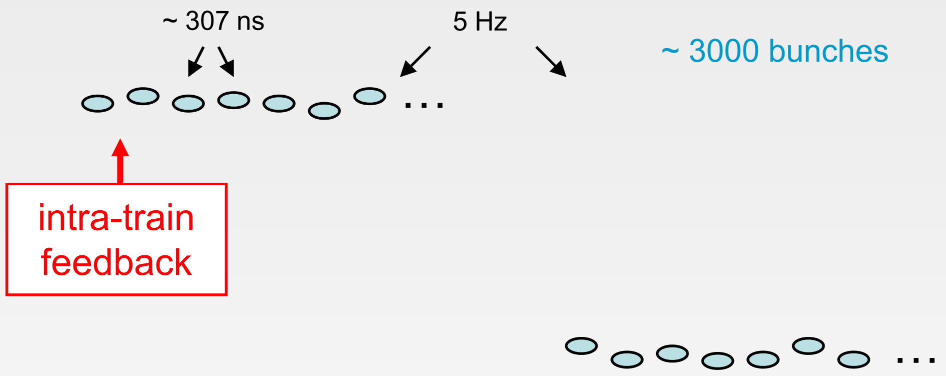

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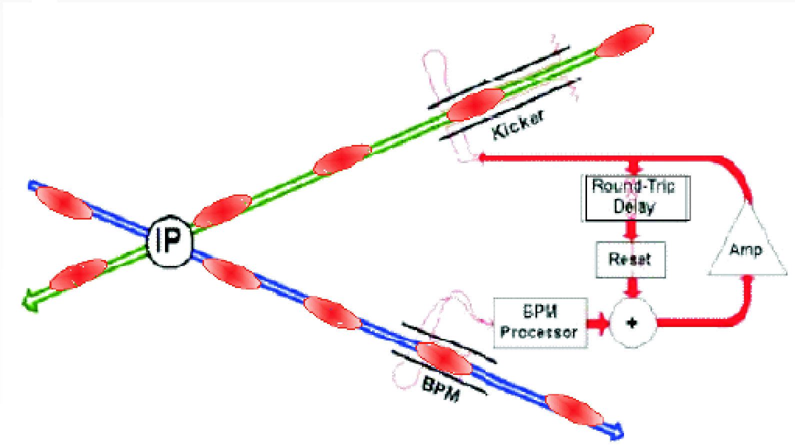

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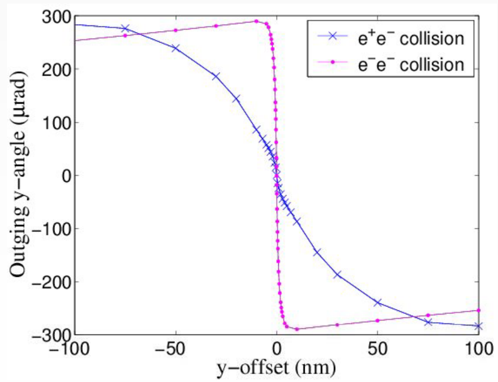


3. Correct the next bunch

Beam-Beam Feedback Simulation with Realistic Errors in the BDS (1)

Beam-based IP position feedback simulation using the code PLACET:

- Misalignment of the elements of the BDS applying ground motion model B* every 0.2 seconds, for each train (without misalignment inside a train)

- Simulations for successive time intervals of ground motion applied

- Track the beam through the BDS

- Collision with GUINEA-PIG to obtain the outgoing angle used for the correction

- Correct the beam position with the kicker located just after the final doublet

repeat bunch-to-bunch

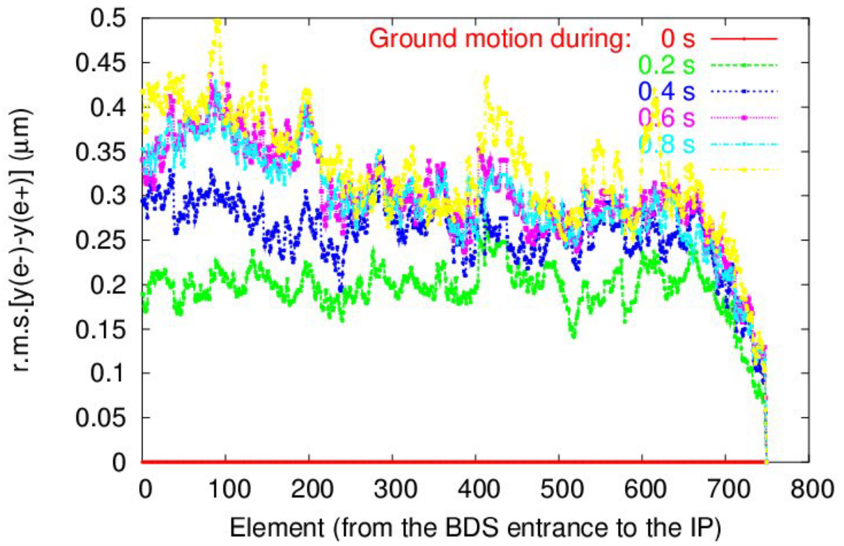
* See e.g. A. Seryi, Ground Motion and Vibration Issues for Accelerators, Proceedings of the 2001 PAC, Chicago

Beam-Beam Feedback Simulation with Realistic Errors in the BDS (2)

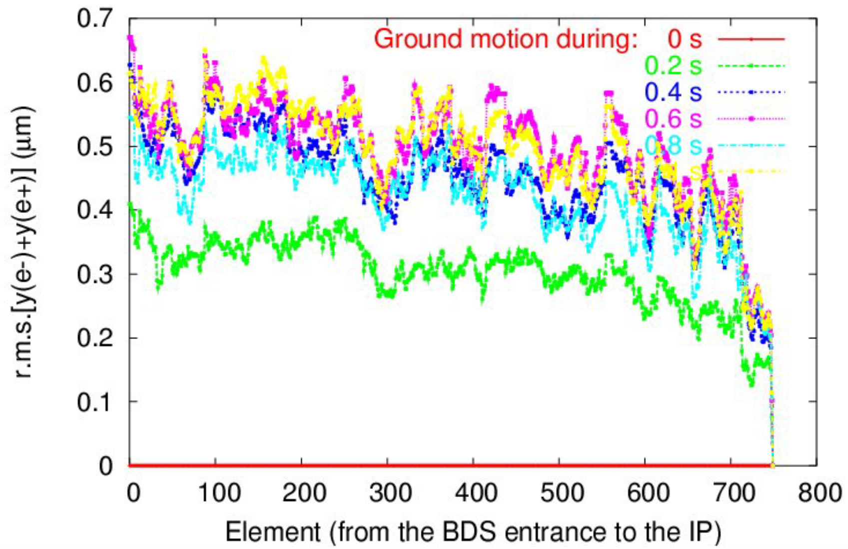
Effect of the ground motion in the lattice elements:

<u>Misalignment of the elements</u> with ground motion model B (50 seeds)
(ground motion applied at successive time intervals)

Misalignment difference of each element in the e^- line respect to the same element in the e^+ one



Addition of the misalignment of each element in both lines

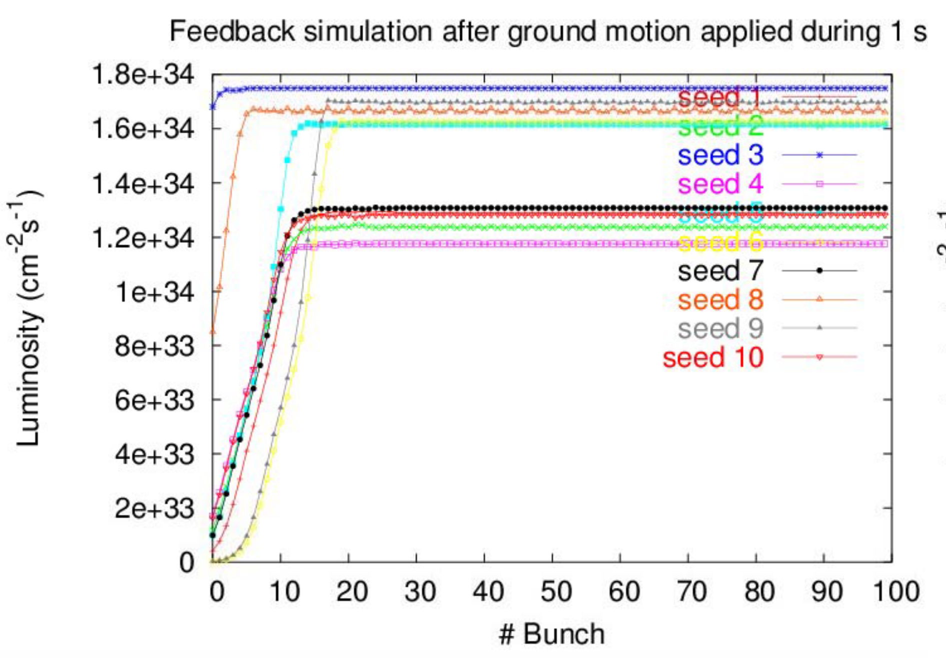


Beam-Beam Feedback Simulation with Realistic Errors in the BDS (3)

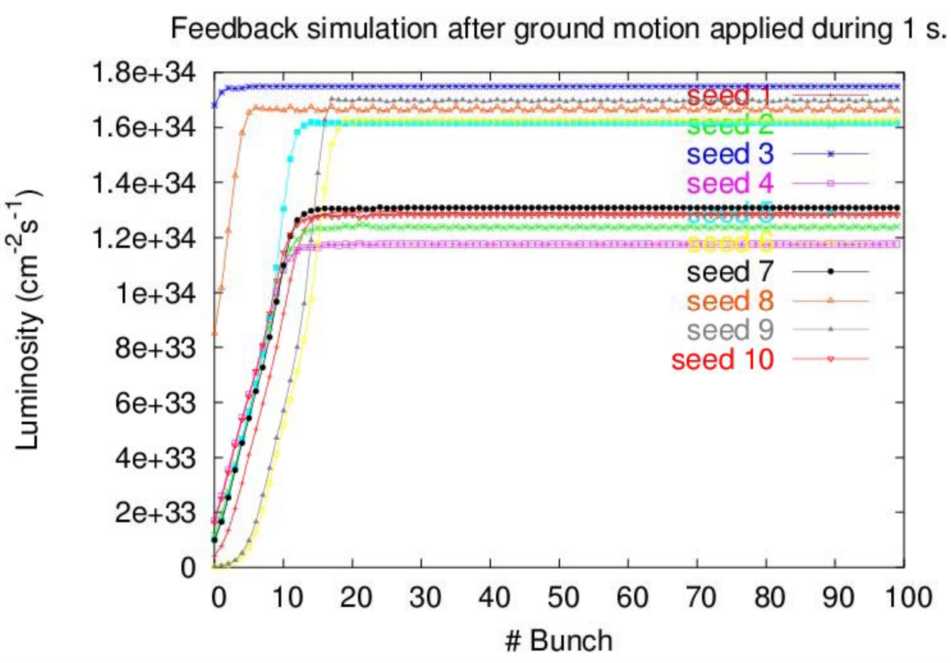
Feedback response:

Feedback simulation with ~50 seeds after ground motion applied during 1second

e^+e^-



e^-e^-

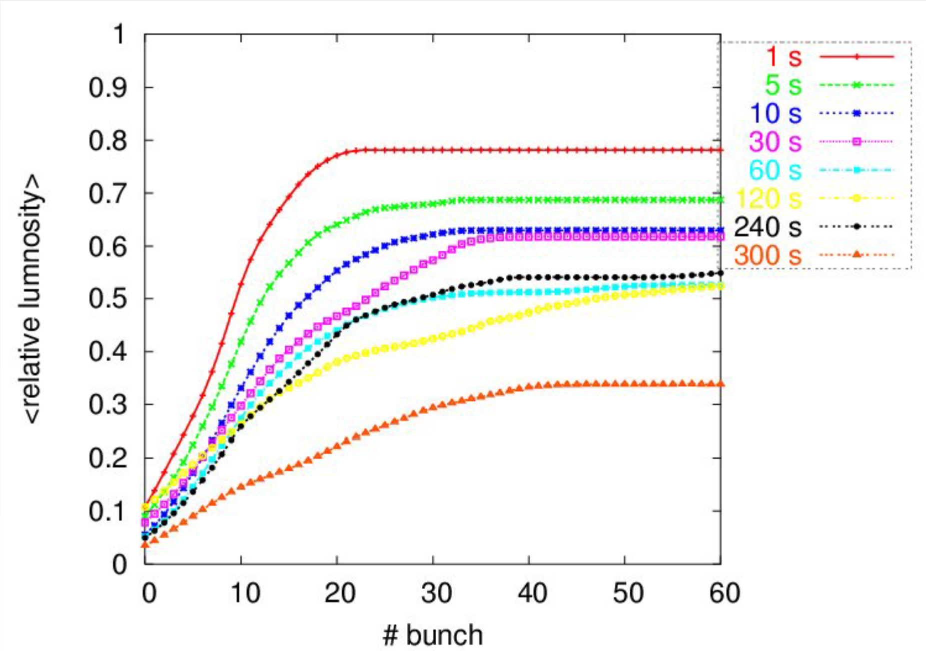


Feedback simulation for ground motion during different time intervals

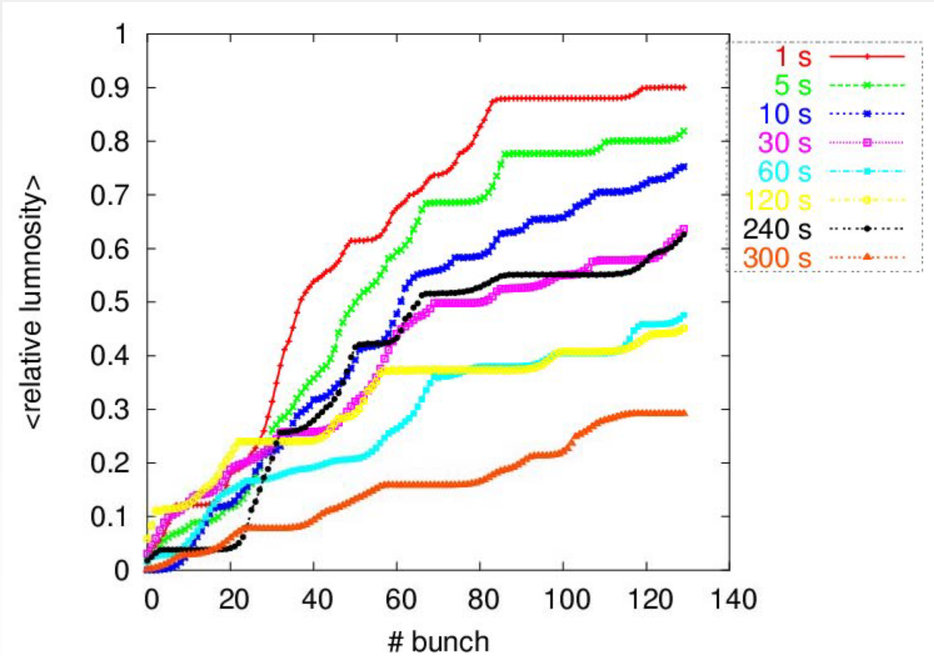
Beam-Beam Feedback Simulation with Realistic Errors in the BDS (4)

Feedback simulation after ground motion applied during different time intervals:
(average luminosity for ~50 seeds)

e^+e^-



e^-e^-



Correction for the e^-e^- mode is slower compared with e^+e^-, but the average luminosity over a full train can be recovered

Beam-Beam Feedback Simulation with Realistic Errors in the BDS (5)

Feedback simulation done for:

- e+e- and e-e-

- ~8 different successive time intervals of ground motion

- 50 seeds each lattice misalignment

Correction done bunch-to-bunch for 200 bunches:

200 collisions simulated with Guinea-Pig

Total: the order of 100000 collision simulations

Beam-Beam Feedback Simulation with Realistic Errors in the BDS (5)

Correction done bunch-to-bunch for 200 bunches:

200 collisions simulated with Guinea-Pig

if 1 min / collision ⇨ ~ 8 h

if 3 min / collision ⇨ ~ 24 h

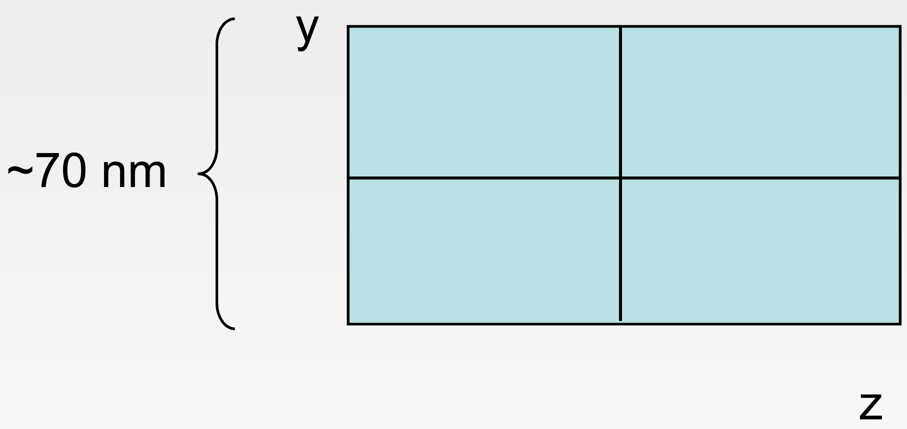
Time depends on size and precision grid:
Need to optimize the grid according to the offset between the beams

Guinea-Pig grid

Grid parameters for 0 nm offset (e+e-)

Size of the grid (half of the grid)

cut_x = 3 * sigma_x.1
cut_y = 6 * sigma_y.1
cut_z = 3 * sigma_z.1



Number of cells

n_x = 32
n_y = 128
n_z = 24

70 nm / 128 cells:

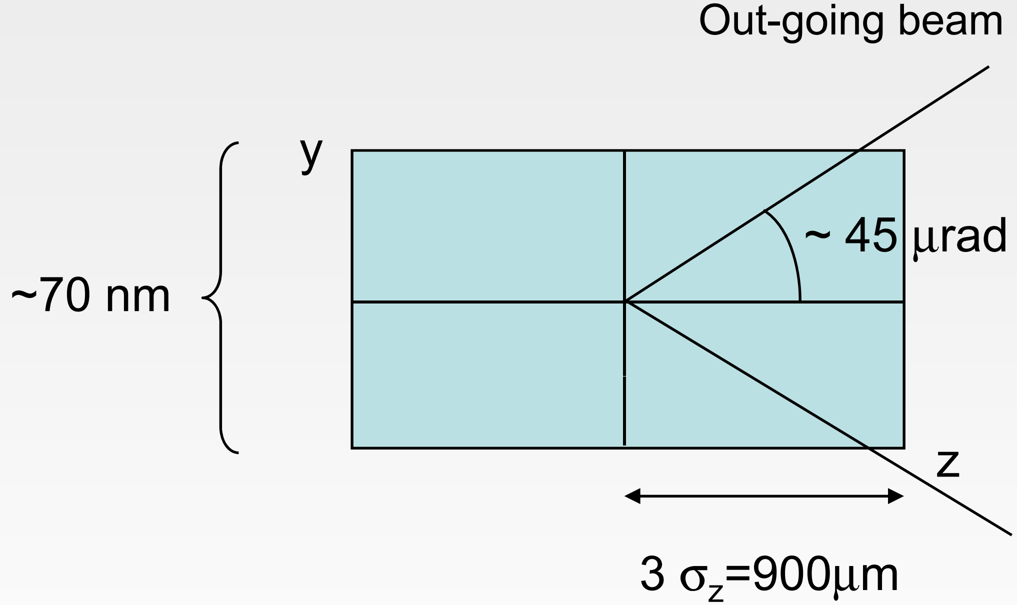
size_cell(y) ~ (1/10) σ_y

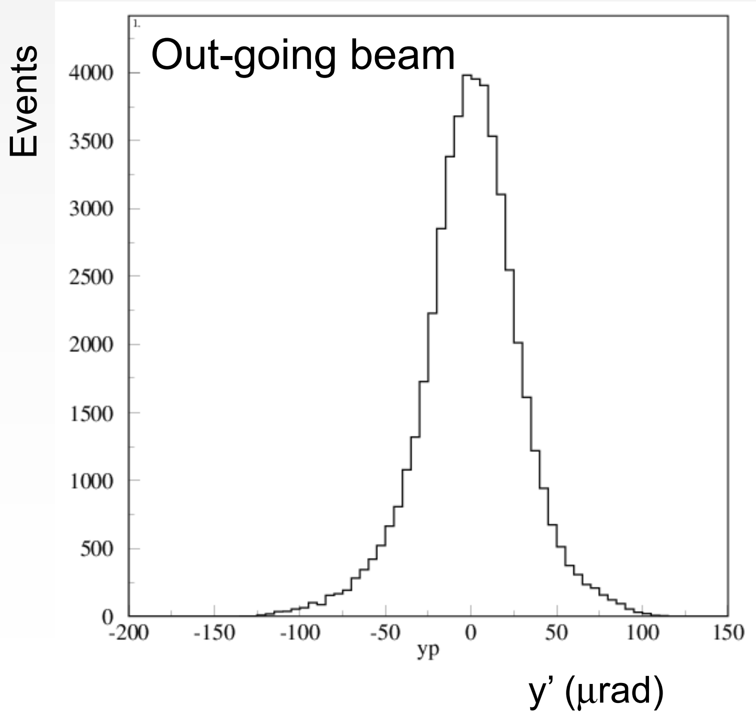
Guinea-Pig grid

Grid parameters for 0 nm offset (e+e-)

Size of the grid (half of the grid)

```
cut_x = 3 * sigma_x.1
cut_y = 6 * sigma_y.1
cut_z = 3 * sigma_z.1
```

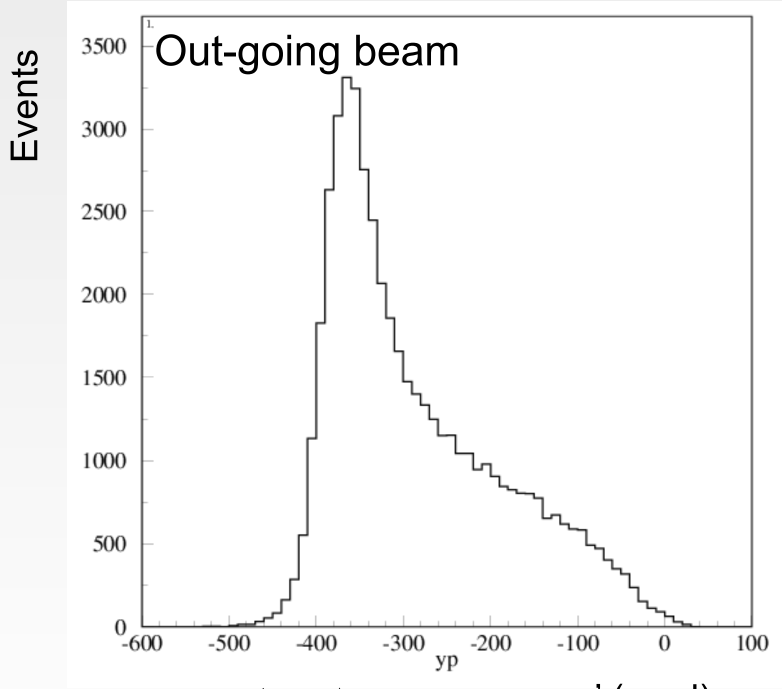


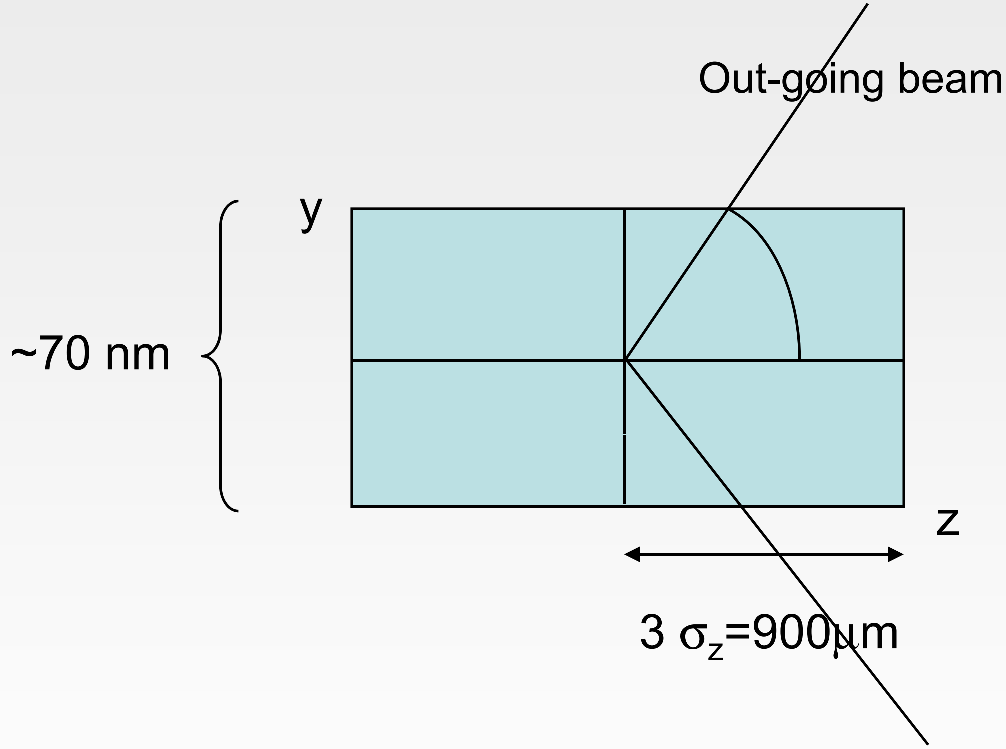


Guinea-Pig grid

Grid parameters for vertical offset between the beams:

200 nm vertical offset (e+e-)

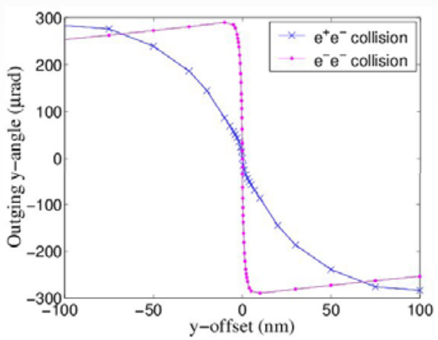




disruption

average kick

deflection curve

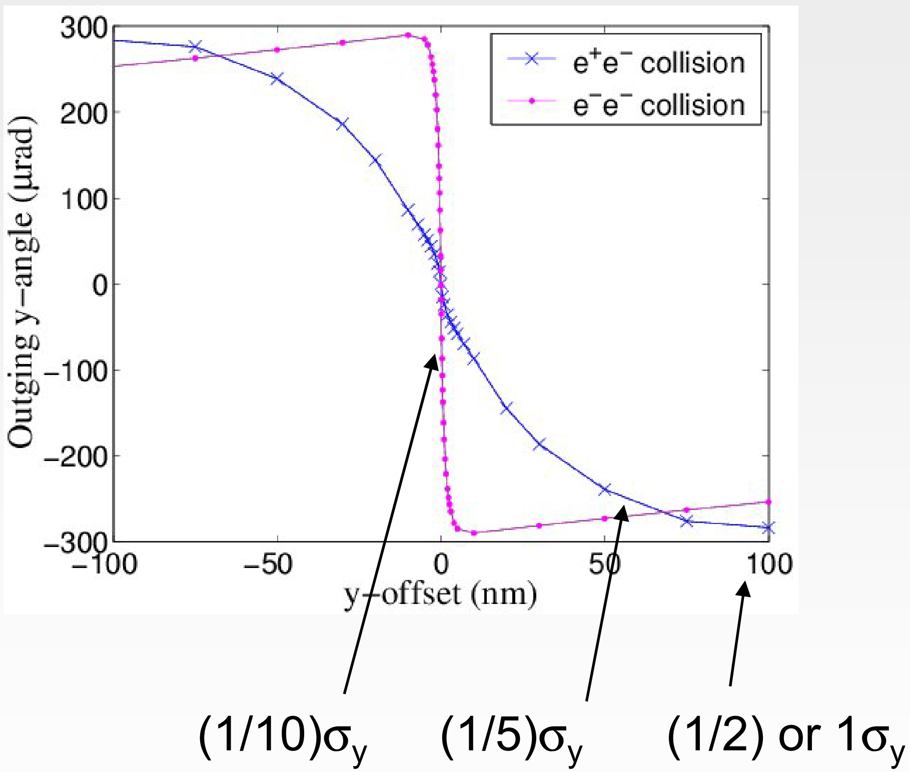


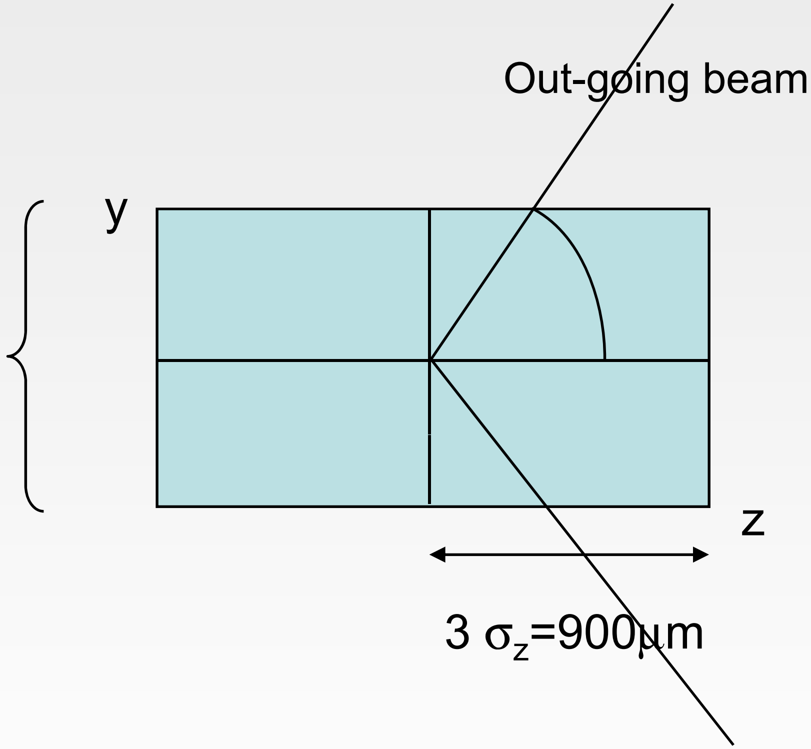
- **Increase y grid size**

- **Increase the cell size**

Guinea-Pig grid

Grid parameters for vertical offset between the beams:



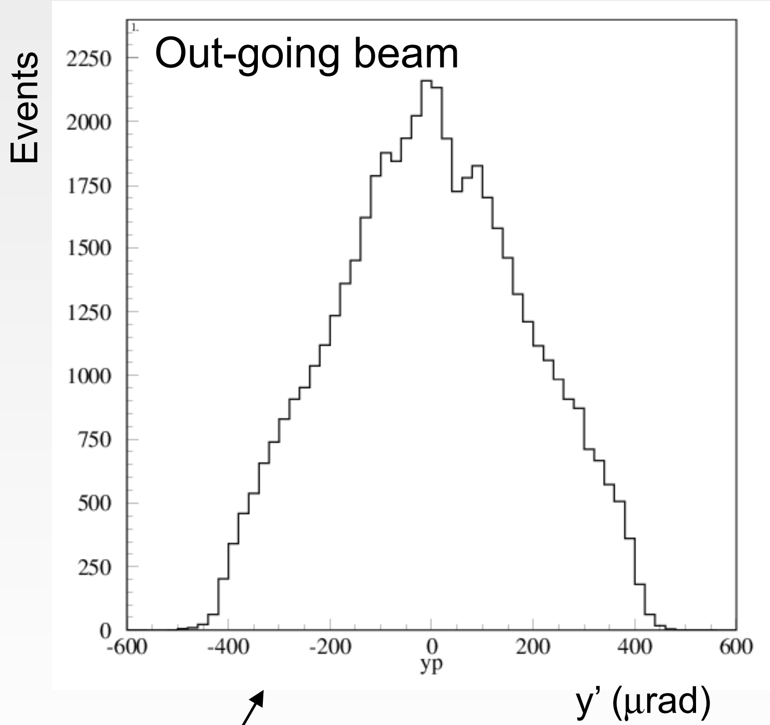


- Increase the cell size
- Increase y grid size: to loose maximum ~1% of the particles

Guinea-Pig grid

Grid parameters for e-e- collisions: need more time

0 nm vertical offset (e-e-)



disruption

Disrupted angle 8 times the e+e- one:

Vertical grid size 8 times the e+e- one

cut_x = 3 * sigma_x.1
cut_y = 48 * sigma_y.1
cut_z = 3 * sigma_z.1

To maintain the same precision:

Number of cells x 8

n_x = 32
n_y = 1024
n_z = 24