Updated comparison of feedback implementation for e^+e^- and e^-e^- modes of operation with realistic errors in the BDS

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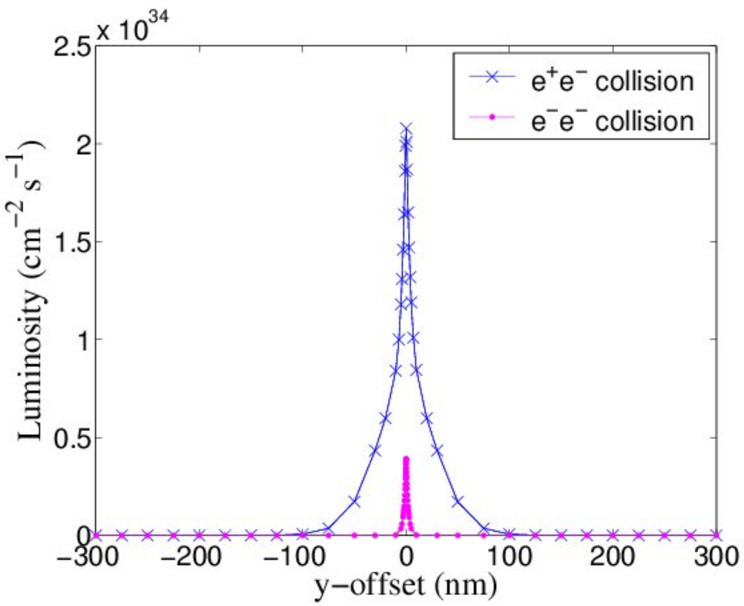
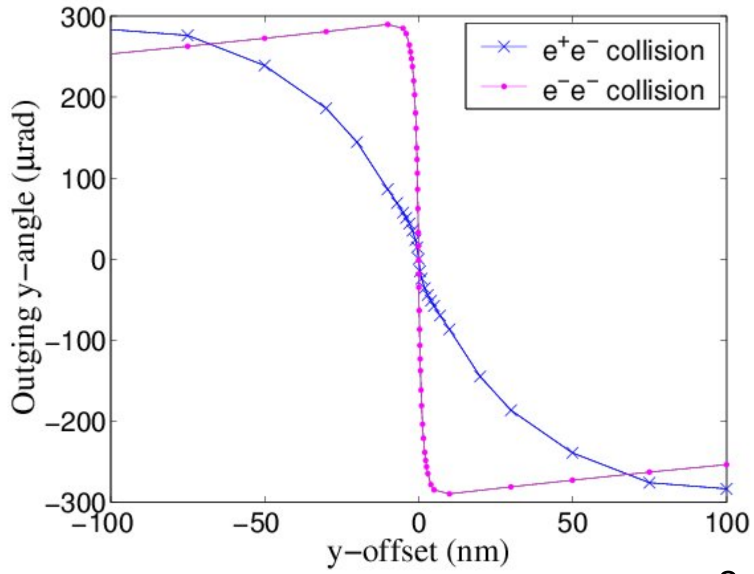
Beam-beam effects

e^-e^- collision → anti-pinch effect

- e^-e^- luminosity is ~20% of the e^+e^- luminosity and drops rapidly with the vertical offset
- e^-e^- shows sharper deflection curves (different performance for feedback?)

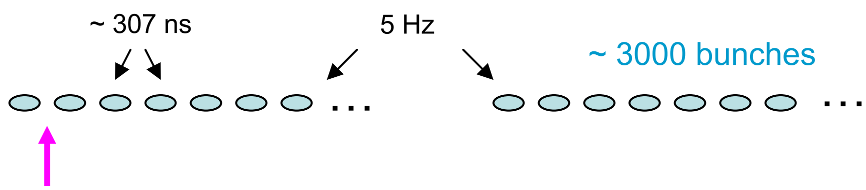




Beam-Beam Deflection Feedback Simulation*

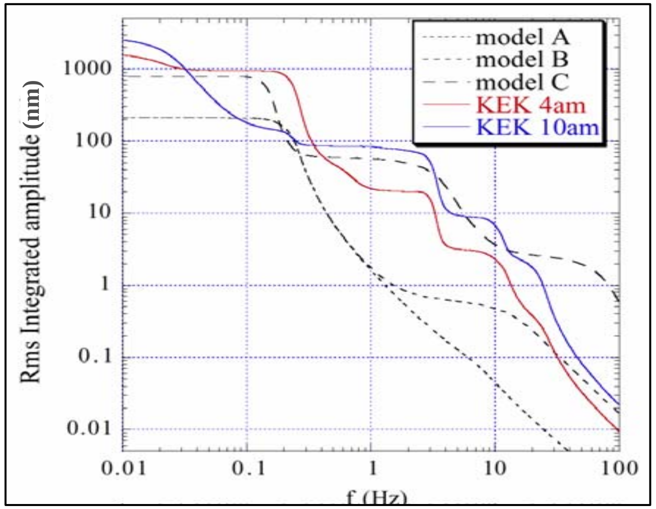
Structure of the beam:

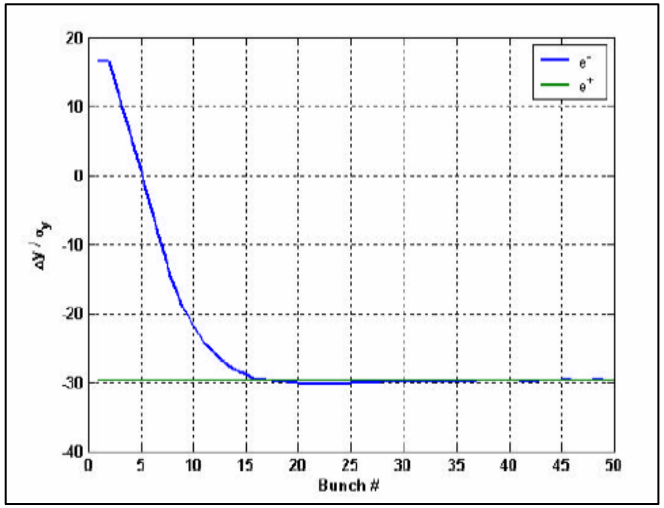
Sources of noise { natural, cultural → offset at IP



intra-train feedback

to get a fast correction





*See e.g. G.White, N.Walker, D.Schulte, An Example of Integrated Simulations- A LINAC to IP Simulation of the TDR TESLA Accelerator, CARE/ELAN Document-2004-013

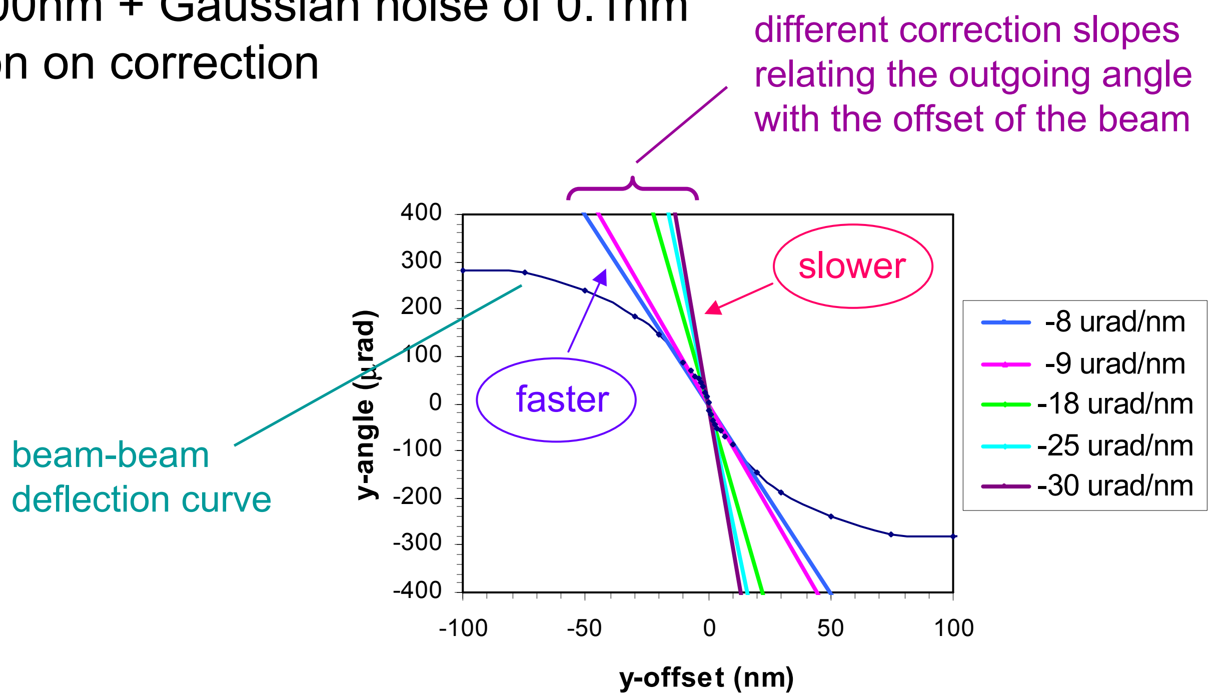
Simplified Beam-Beam Feedback Simulation (1)

Simplified simulation:

- Correction of the position at the IP only (not the angle)
- Considered only one correction slope
- Parametrized correction based only on the previous bunch

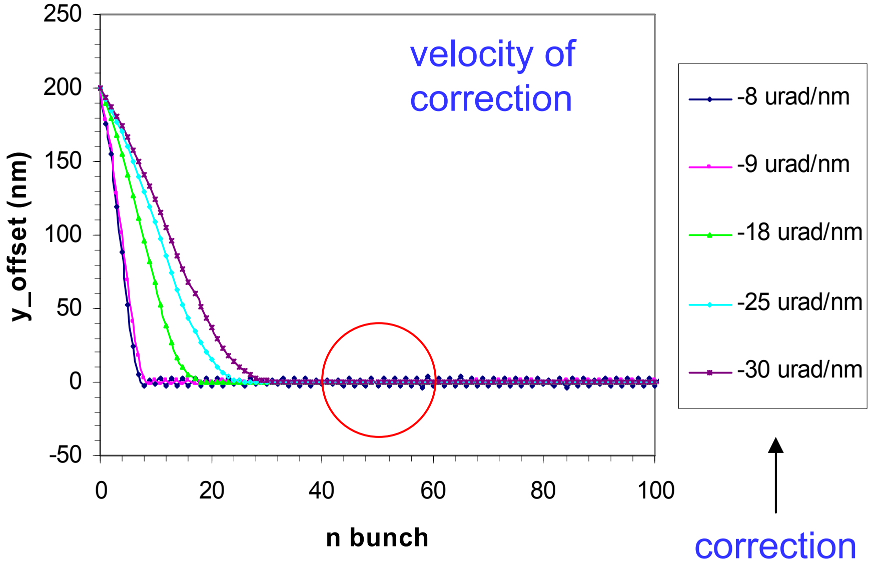
Hypothesis of work:

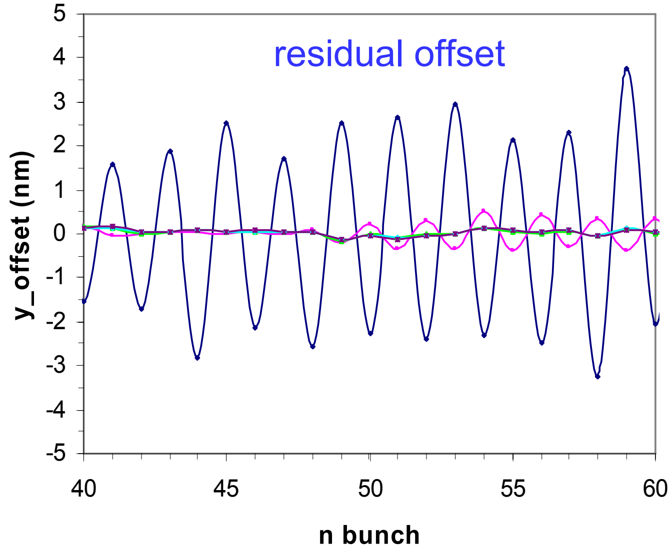
- Initial offset 200nm + Gaussian noise of 0.1nm
- 10% fluctuation on correction



Simplified Beam-Beam Feedback Simulation (2)

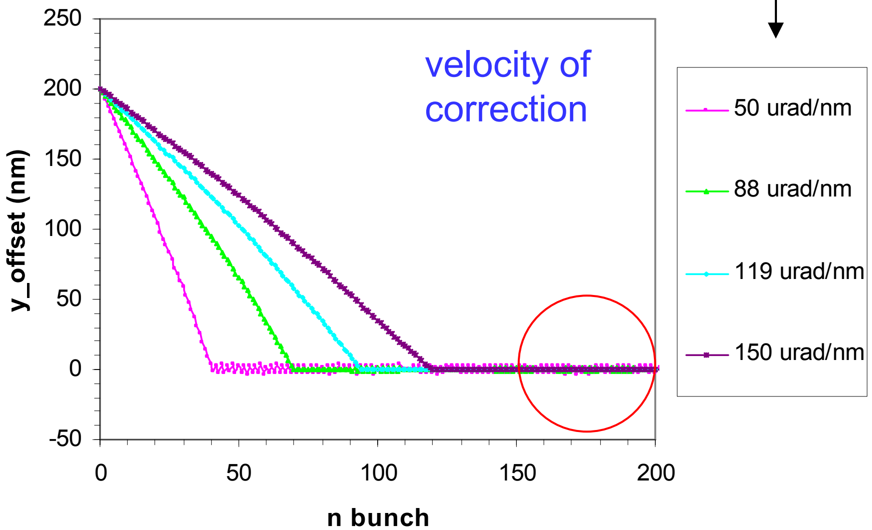
e^+e^-

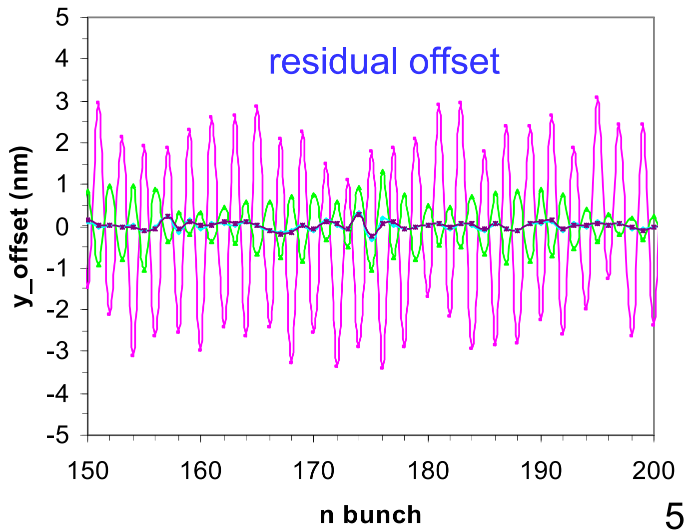




correction slope

e^-e^-





Simplified Beam-Beam Feedback Simulation (3)

- Feedback simulation for different $\begin{cases} \text{initial offsets} \\ \text{jitter bunch to bunch} \end{cases}$

  applied over full train (2820 bunches) for both e^+e^- and e^-e^- with nominal parameters

- Different slopes are chosen for e^+e^- and e^-e^- to avoid amplification of jitter

- Average train luminosity almost independent of the initial offset

  ↳ steeper deflection curve (slower correction) of e^-e^- turns out not to be a problem for feedback

- e^-e^- luminosity loss a factor 2 greater for the same assumption on jitter

  ↳ because of greater sensitivity of e^-e^- collision

Problems for e^-e^- Feedback with Nominal Parameters

With nominal parameters the sensitivity to the bunch-to-bunch jitter is greater for e^-e^-

↓

Can we decrease the sensitivity with alternative beam parameters to increase the average luminosity?

Advantageous to decrease the *disruption parameter* D_y

Taking into account the following scalings:

$$\boxed{D_y \propto \frac{N\sigma_z}{\sigma_x \sigma_y}} \qquad \boxed{L \propto \frac{N^2}{\sigma_x \sigma_y}} \qquad \boxed{\delta_B \propto \frac{N^2}{\sigma_x^2 \sigma_z}}$$

→ Reduce σ_x and σ_z, and increase σ_y

Alternative beam parameters

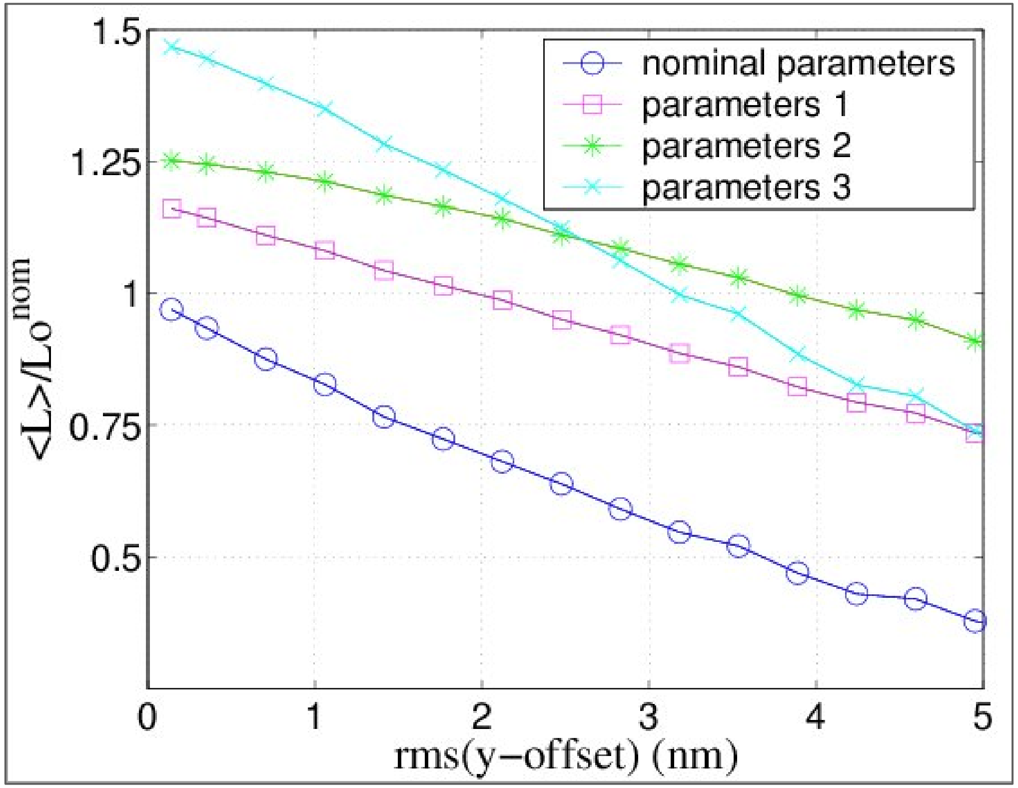
Sets of alternative beam parameters for the e$^-$e$^-$ option have been derived by varying the beam sizes, in order to maximize the luminosity (while limiting beamstrahlung energy loss to 5%)

	nom.	set 1	set 2	set 3	low P
N/N_o	1	1	1	1	0.5
σ_z^*/σ_{zo}^*	1	0.7	0.5	0.5	0.5
σ_x^*/σ_{xo}^*	1	0.7	0.8	0.9	0.7
σ_y^*/σ_{yo}^*	1	1.5	1.5	1	0.6
$\epsilon_x^*(\mu\mathrm{m})$	10	10	10	10	9.6
$\epsilon_y^*(\mu\mathrm{m})$	0.04	0.04	0.04	0.04	0.03
$\beta_x^*(\mathrm{mm})$	21.0	10.3	13.4	17.0	10.0
$\beta_y^*(\mathrm{mm})$	0.4	0.9	0.9	0.4	0.2
$L\ (\times 10^{33})\ (cm^{-2}s^{-1})$	3.9	4.6	4.9	5.8	3.0
δ_B (%)	2.24	4.9	5.0	4.3	2.2

higher sensitivity to IP vertical offset compared to the set 2

Simplified Feedback Simulation for the Alternative Beam Parameters

Feedback simulation for different jitter bunch-to-bunch:



Average train luminosity versus r.m.s. vertical offset difference between the beams

The alternative parameters have increased luminosity compared to the obtained for the nominal case for e-e-

*Results for 100nm of initial offset.

Optics studies for the e^-e^- mode of operation

- **20 mrad** crossing angle geometry
  - Final Focus System:

    - refitting quadrupoles upstream of chromatic correction section to obtain the new beta functions at the IP for the alternative parameters
    - optical bandwidth
  - Power losses along the extraction line for the alternative beam parameters

- **2 mrad** crossing angle geometry
  - Spent beam transported off-axis through the last defocusing quadrupole $\rightarrow$ extraction very difficult
  - Going to rounder beams is needed, which decreases the luminosity significantly $\rightarrow$ improvements with half of the σ_z have been studied

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

Fast 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 different times of ground motion applied

- Track the beam through the BDS with PLACET
- 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

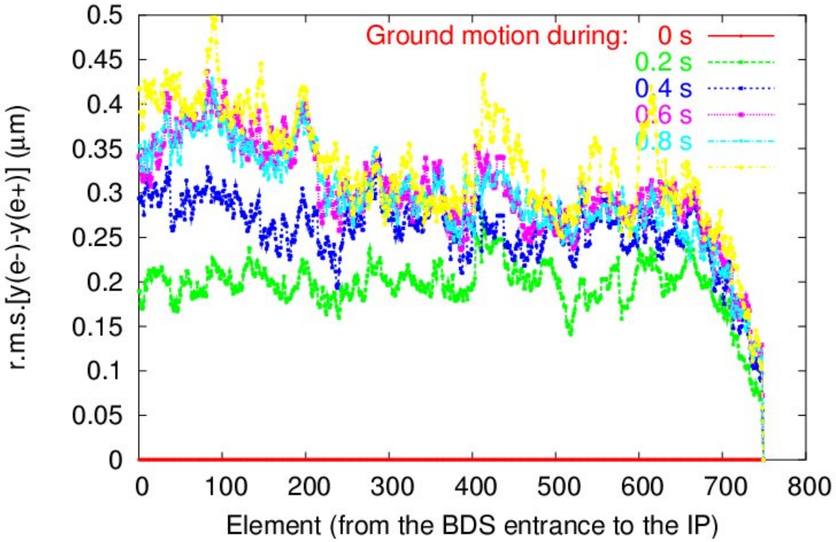
repeat bunch-to-bunch

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

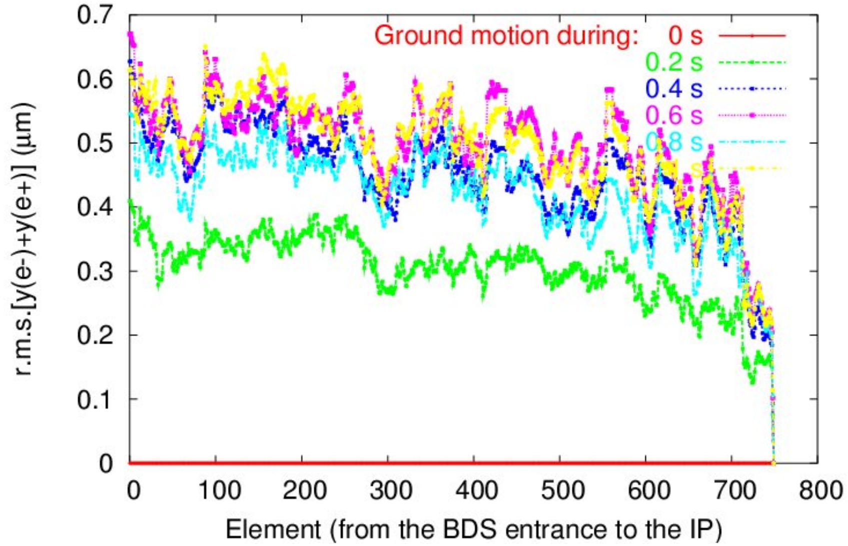
Beam-Beam Feedback Simulation with Realistic Errors in the BDS (2)

Misalignment of the elements with ground motion model B (50 seeds)
(ground motion applied at different times)

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



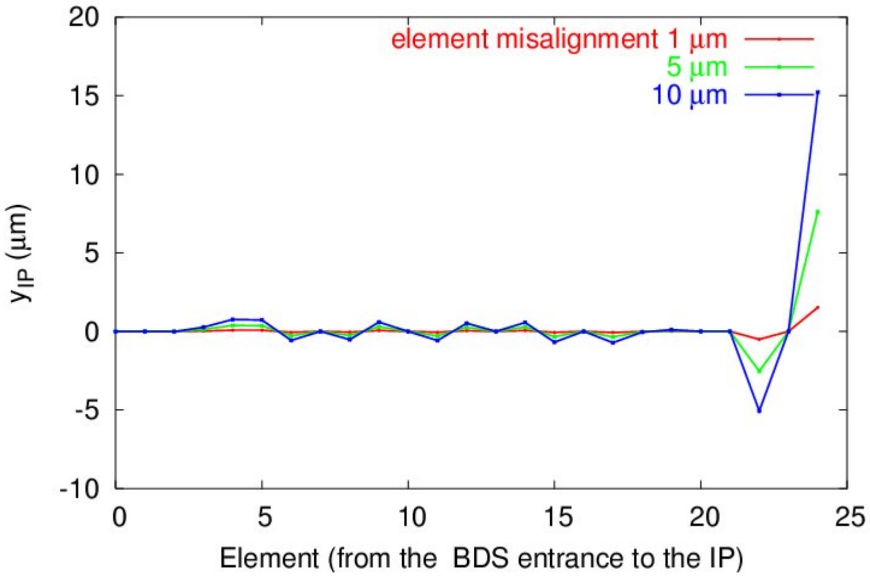
- For the moment correct only the difference between both beams at the IP
- Evaluate the influence of not also correcting trajectories along the whole BDS

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

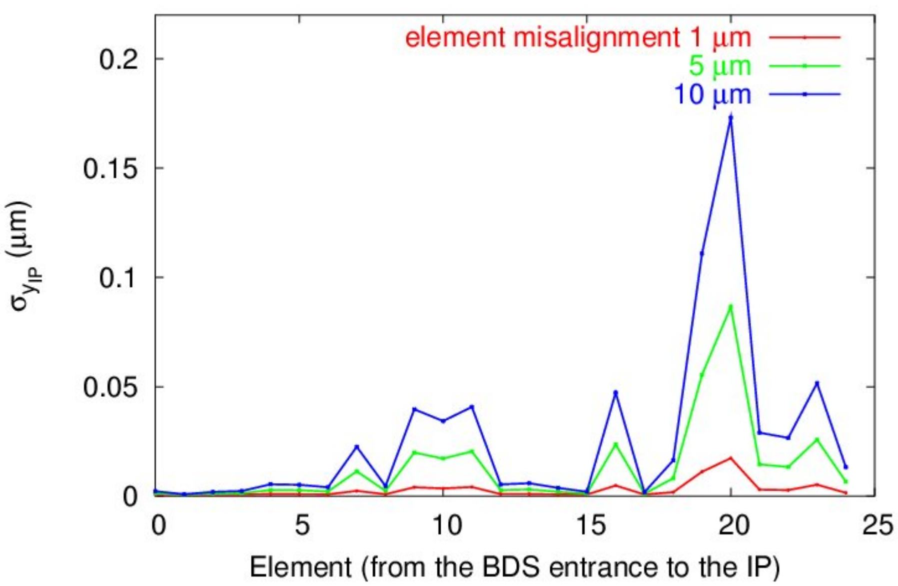
Study of the tolerances of each element to this displacements:

Misalignment element by element of the Final Focus System and study of the beam at the IP

Vertical offset of the beam at the IP



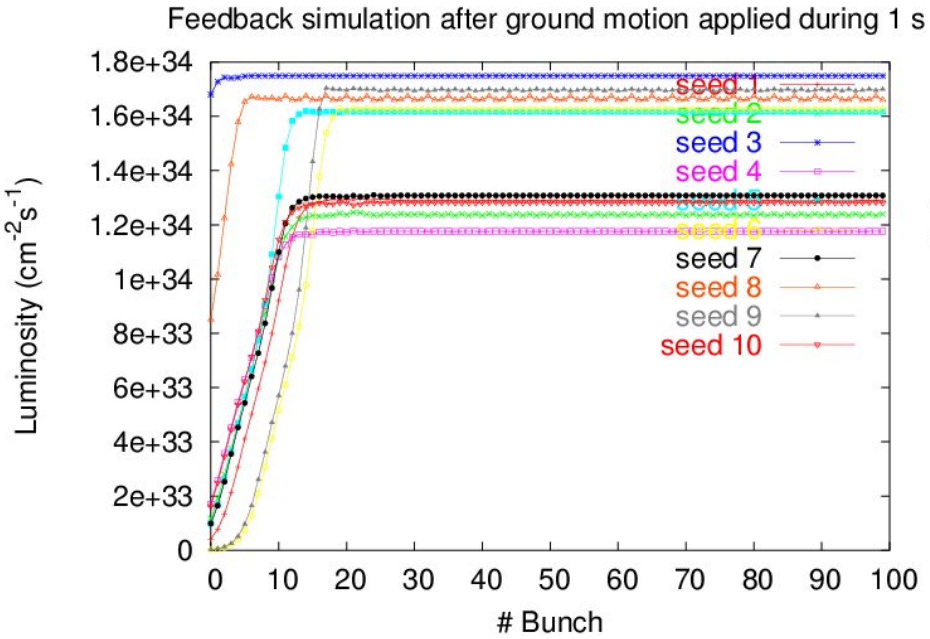
Vertical beam size at the IP



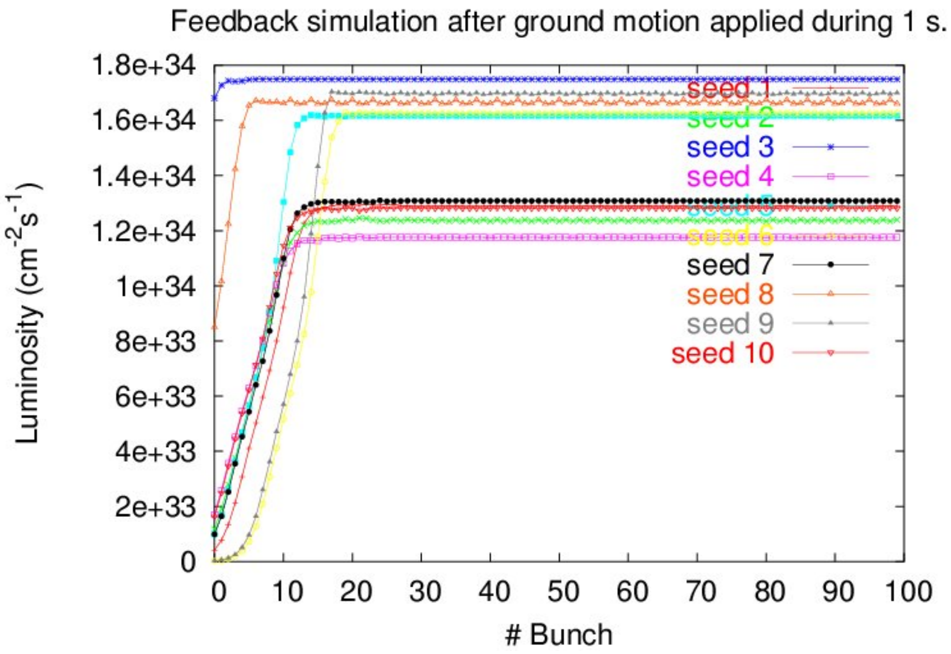
Beam-Beam Feedback Simulation with Realistic Errors in the BDS (4)

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

e^+e^-



e^-e^-

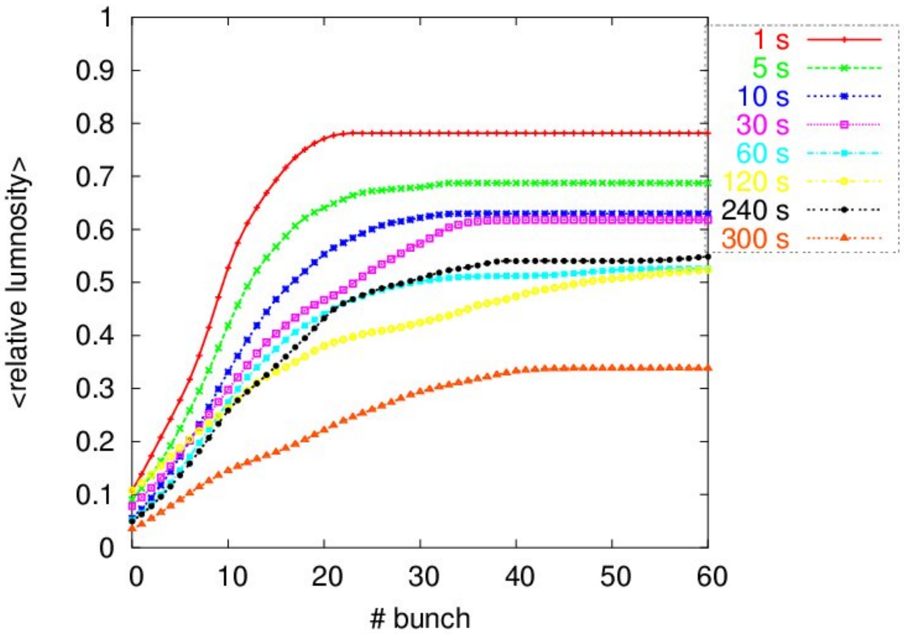


Feedback simulation for ground motion applied during different times

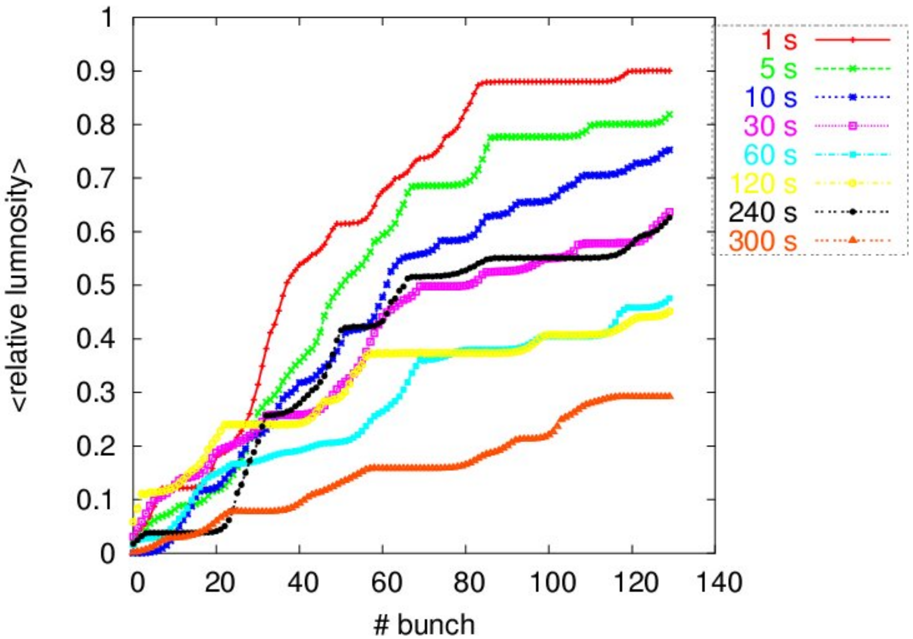
Beam-Beam Feedback Simulation with Realistic Errors in the BDS (5)

Feedback simulation after ground motion applied during different times:
(average luminosity for all the seeds)

e^+e^-



e^-e^-

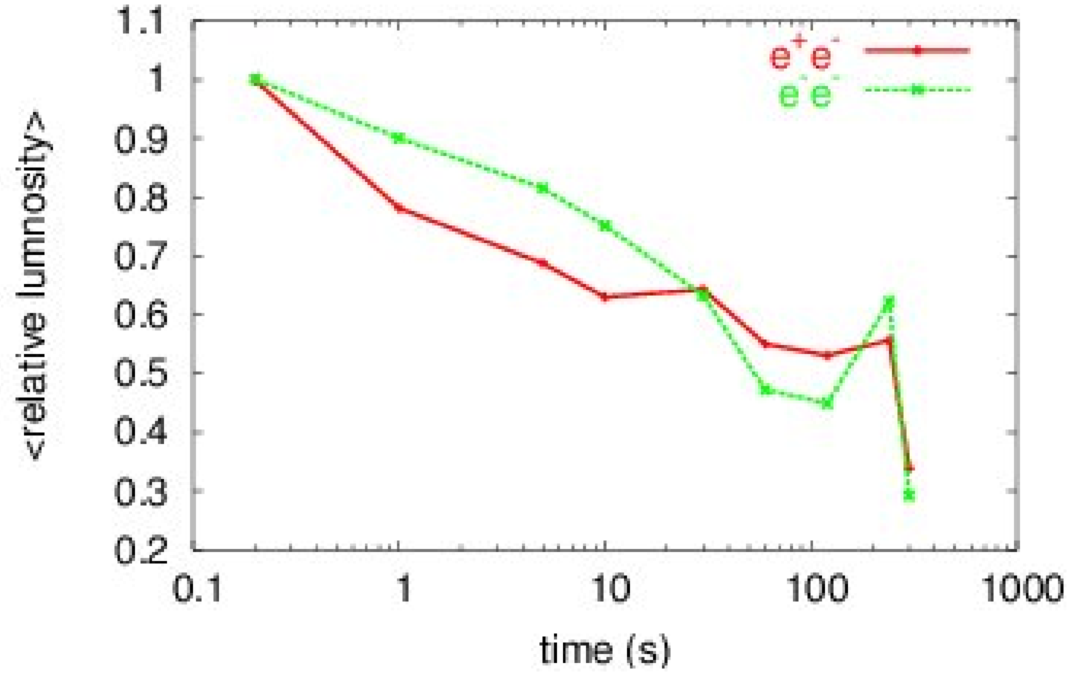


Correction for the e^-e^- mode is slower compared with e^+e^-, but the average luminosity over a full train can be recovered

Beam-Beam Feedback Simulation with Realistic Errors in the BDS (6)

Once the fast feedback has recovered the luminosity:

relative luminosity vs time of ground motion



The luminosity is not totally recovered with the position feedback: trajectory correction feedback is needed

Conclusion

● The beam-beam based feedback correction for the e^-e^- mode of operation is slower compared to the e^+e^- one, but the average train luminosity can be recovered. The performance is comparable to the e^+e^- case.

● The fast position feedback is not enough to recover the luminosity totally.

● Need to study the cause of this degradation to apply an efficient trajectory correction feedback. Is it sufficient to just add an angle correction ?