Some studies on CLIC luminosity performance with intra-train FB system at the IP and (‘slow’) orbit correction in the BDS

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Introduction

- In order to provide the required small beam sizes and to provide the necessary beam stabilization at the IP it is necessary a combination of ‘slow’ and ‘fast’ beam-based feedback systems, active feedback systems and beam tuning strategies

IP jitter control strategy:

- IP beam stability mainly provided from:
  - Selection of a site with sufficiently small ground motion
  - Pulse-to-pulse FB systems for orbit correction in linac and BDS
  - Active stabilization of the FD quadrupoles
  - Interaction region stability (detector stability, etc.)

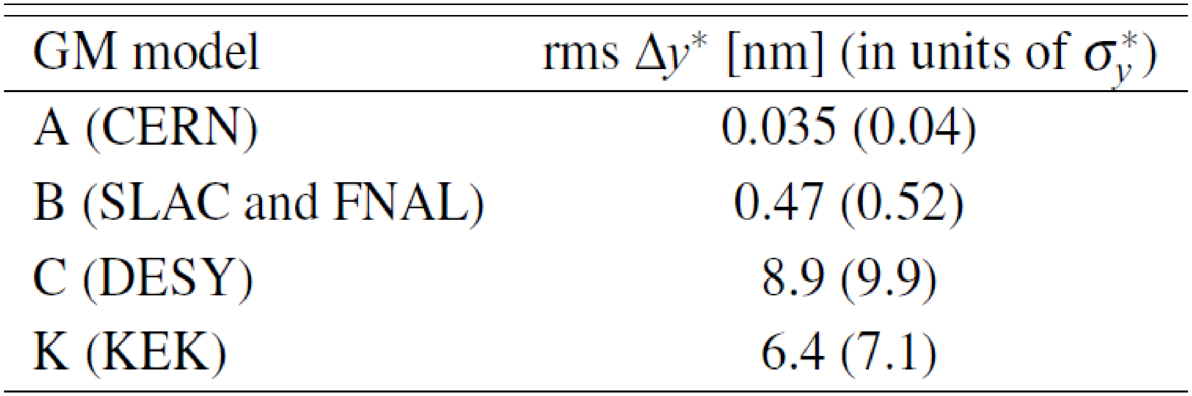
- A fast intra-train FB system is thought as an additional line of defence to recover at least ~ 80% of nominal luminosity in case of failure of the above stabilization subsystems.

- A fast FB system can also help to relax the FD sub-nanometer position jitter tolerance, which in the case of CLIC ~ 0.1 nm for the vertical position

Here we show some example results of luminosity performance improvement using a orbit correction with global SVD (in the BDS) + beam-based intra-train FB systems in terms of correcting vertical IP jitter generated by ground motion (BBA techniques to deal with static errors shown in other presentations)

Beam tracking simulations

- Ground motion:
  - In the following simulations we apply 0.02 s (corresponding to f_{rep}=50 Hz) of GM (A. Seryi’s models) to the CLIC BDS
  - What is the RMS vertical beam-beam offset at the IP we have to deal with?
    - Simulation of 100 random seeds:

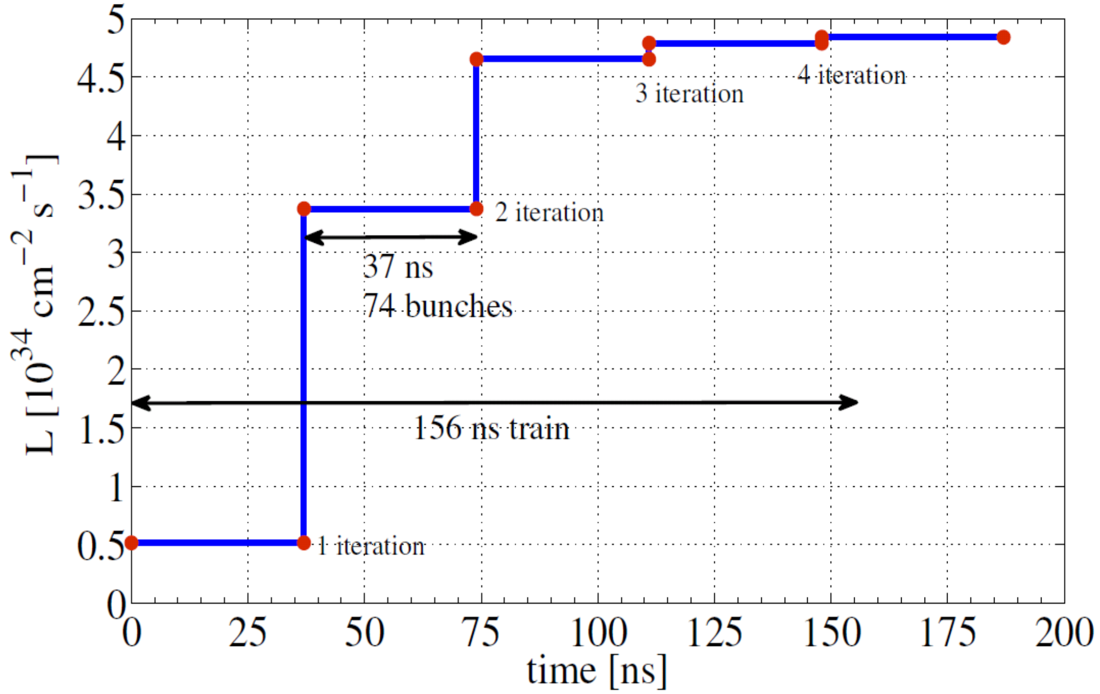


GM model	rms Δy^* [nm] (in units of σ_y^*)
A (CERN)	0.035 (0.04)
B (SLAC and FNAL)	0.47 (0.52)
C (DESY)	8.9 (9.9)
K (KEK)	6.4 (7.1)

- Macroparticle tracking through the BDS using the code PLACET
- Luminosity calculation using the code Guinea-Pig
- In the simulations we take the average luminosity over a train

Luminosity performance with IP intra-train FB

Simulation time structure:
Example applying a single random seed of GM C



- For the simulations we have considered a total feedback latency of 37 ns. The systems performs approximately a correction every 74 bunches (4 iterations per train)

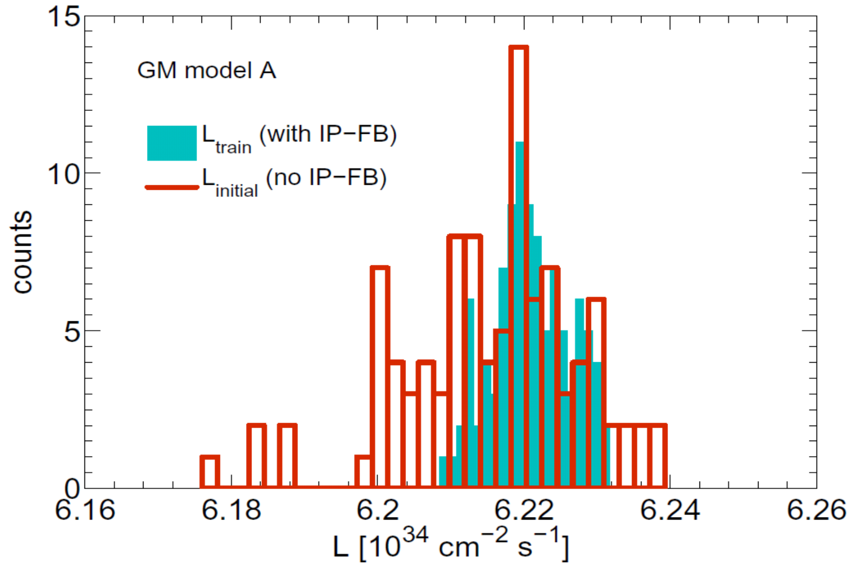
- For details on the IP-FB system of CLIC, see for example slides from the MDI CLIC meeting, 6 November 2009: http://indico.cern.ch/conferenceDisplay.py?confId=69100

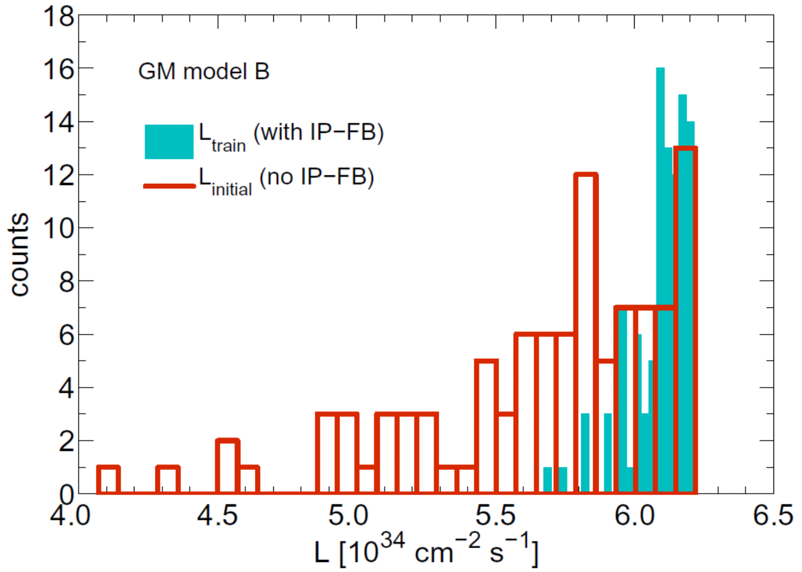
CLIC luminosity result with IP-FB

Different scenarios of ground motion

Luminosity distribution for simulation of 100 random seeds of the GM

For quiet sites:





The generated IP-jitter is relatively small after 0.02 s of GM

Model A:

- Without any correction: mean $\langle L/L_0\rangle_{train}$=99.88%
- With IP-FB: mean $\langle L/L_0\rangle_{train}$=99.97%
  std reduced by a factor 2

Model B:

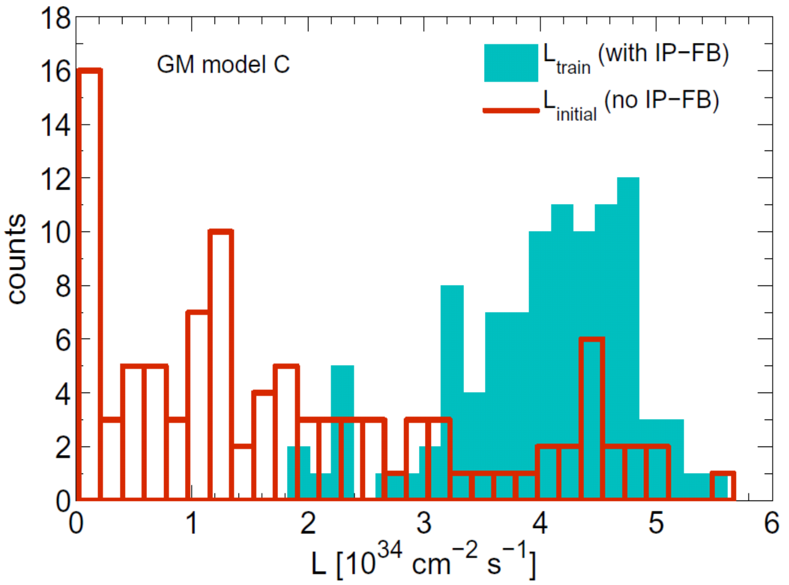
- Without any correction: mean $\langle L/L_0\rangle_{train}$=91.1%
- With IP-FB: mean $\langle L/L_0\rangle_{train}$=97.86%
  std reduced by a factor 4

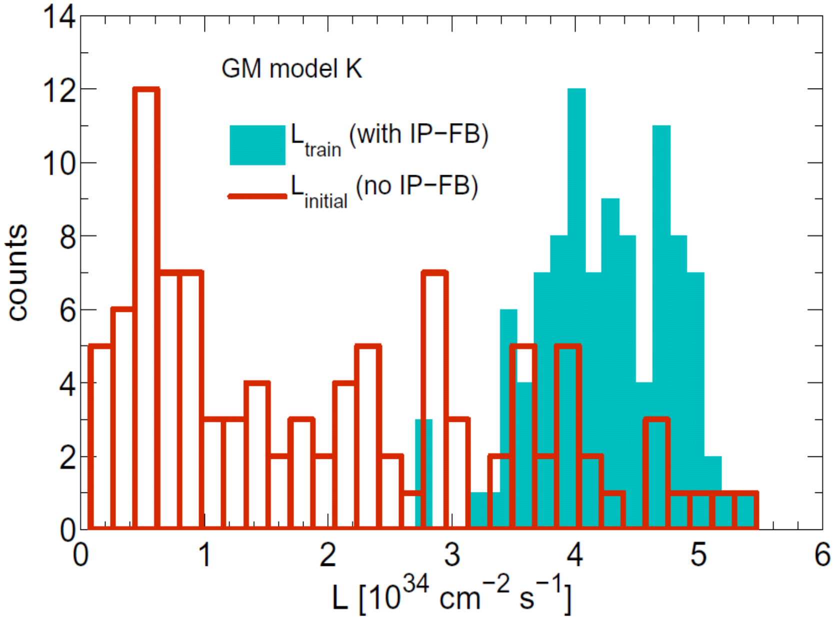
CLIC luminosity result with IP-FB

Different scenarios of ground motion

Luminosity distribution for simulation of 100 random seeds of the GM

For noisy sites:





In these cases significant luminosity degradation

Model C:

- Without any correction: mean $\langle L/L_0\rangle_{train}$=30.52%
  & High standard deviation!
- With IP-FB: mean $\langle L/L_0\rangle_{train}$=64.15%
  std reduced by a factor 2

Model K:

- Without any correction: mean $\langle L/L_0\rangle_{train}$=32.53%
  & High standard deviation!
- With IP-FB: mean $\langle L/L_0\rangle_{train}$=67.82%
  std reduced by a factor 3

SVD for orbit correction in the BDS

- Here, in ‘brute force’, we consider a global SVD method for orbit correction. SVD is a very robust algorithm, broadly available in the literature.

- Obtaining the response matrix **R** and knowing the BPM readings $\mathbf{\Delta x}$, the kicks given by the controllers to correct the orbit are:

$$\mathbf{\Delta c} = -\mathbf{R}_{pinv}\mathbf{\Delta x}$$

where $\mathbf{R}_{pinv}$ is the pseudo-inverse of the response matrix, which using SVD can be written as:

$$\mathbf{R}_{pinv} = \mathbf{U}\mathbf{S}_{pinv}\mathbf{V}^{T}$$

in terms of unitary matrices **U** and **V**, and a diagonal matrix **S**

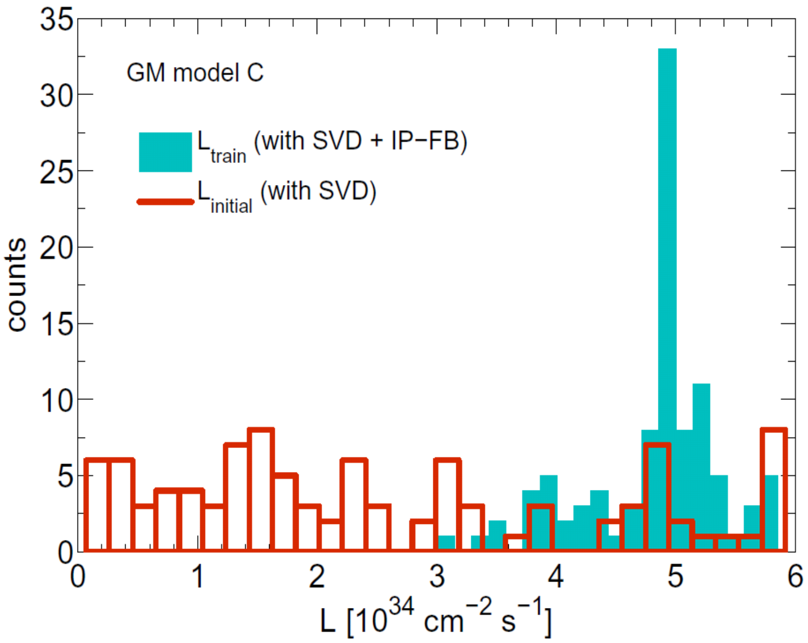
- Possible controllers:
  - Using dipole correctors along the beam line
  - Using transverse magnet movers

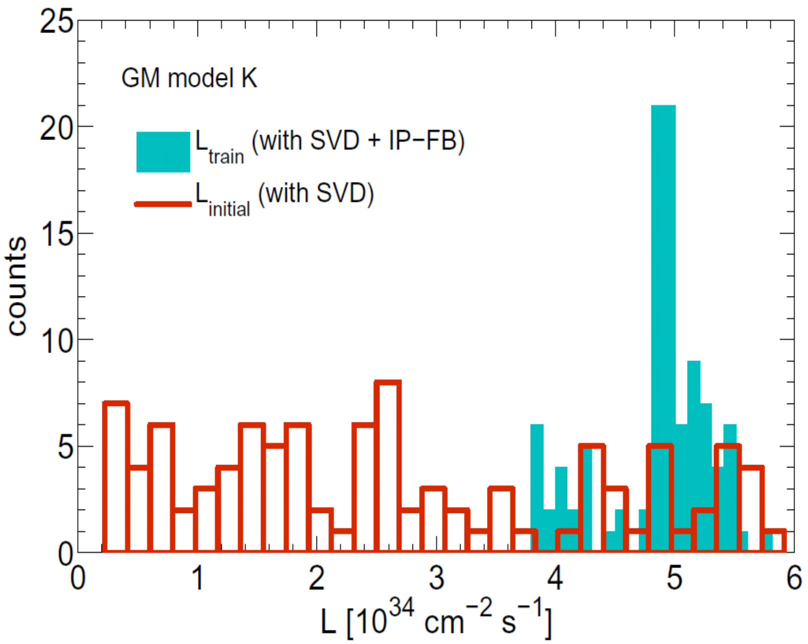
- Here we use 78 BPMs and 66 dipole correctors available in the BDS lattice (the IP BPM and the IP dipole not used)

Luminosity result with SVD orbit correction+ IP-FB

Different scenarios of ground motion

- If we consider:
  - GM (100 random seed simulation) +
  - orbit correction in the BDS (SVD) using the available BPMs (resolution 100 nm) and dipole correctors in the BDS +
  - IP-FB





Model C:

- SVD orbit correction: mean $\langle L/L_0\rangle_{train}$=41.1%
- SVD orbit + IP-FB: mean $\langle L/L_0\rangle_{train}$=77.51%

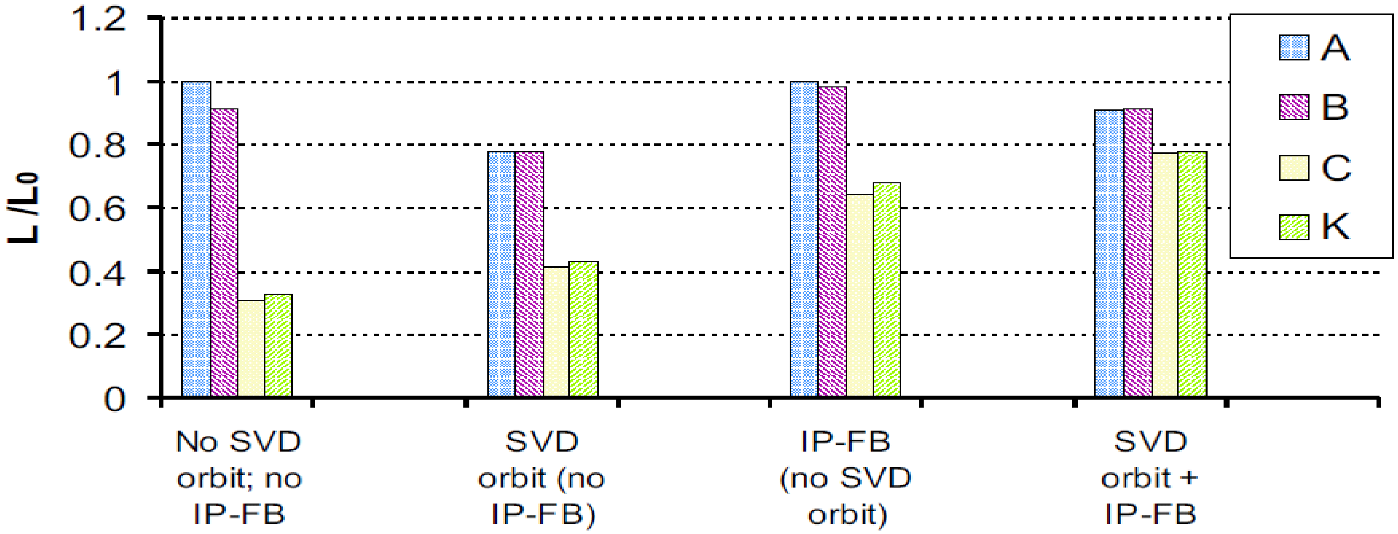
Model K:

- SVD orbit correction: mean $\langle L/L_0\rangle_{train}$=42.63%
- SVD orbit + IP-FB: mean $\langle L/L_0\rangle_{train}$=77.84%

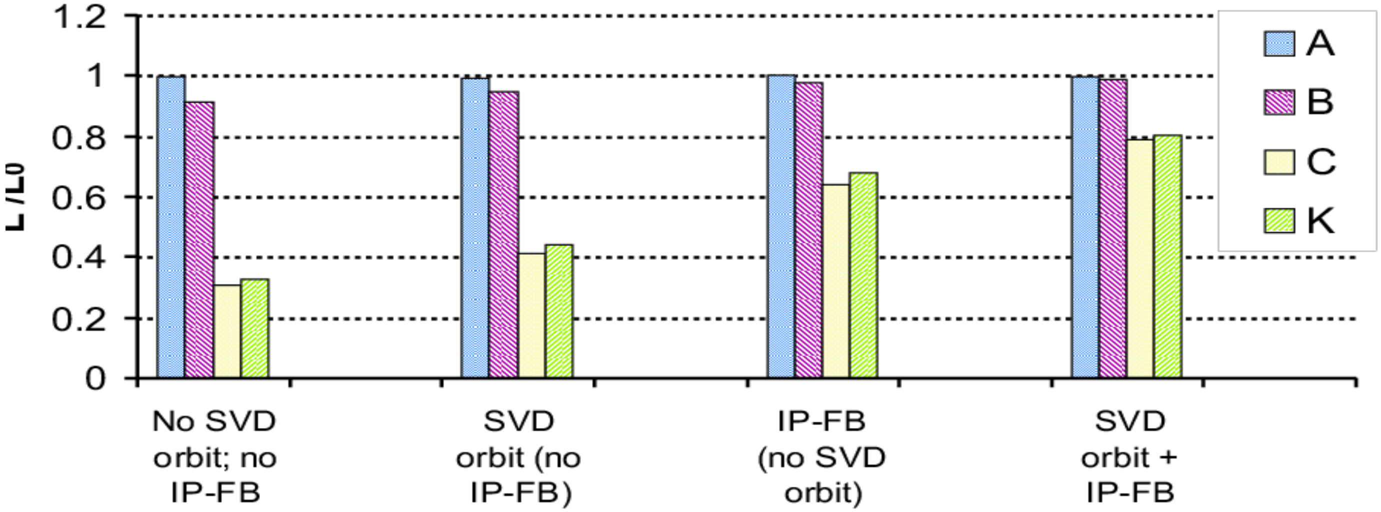
Luminosity results summary

Different scenarios of ground motion

- Summary of results:



SVD orbit correction BPM resolution ~100 nm



SVD orbit correction BPM resolution ~10 nm

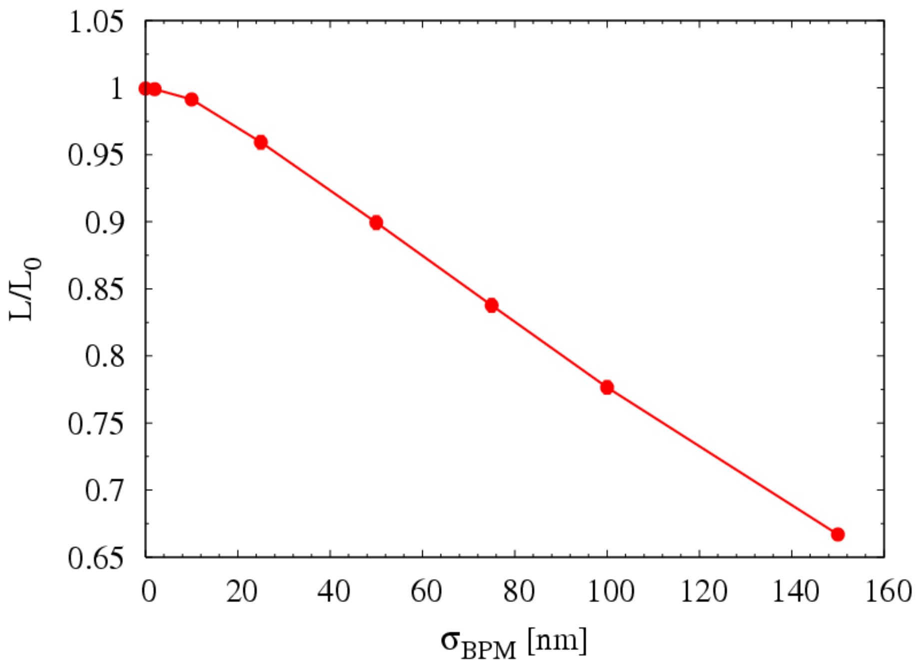
Luminosity performance

SVD orbit correction in the BDS

The SVD orbit correction improves the situation with the most severe cases of GM (C & K), but decreases the luminosity (increases the IP-jitter) with the cases of quiet sites (A & B) with the conditions assumed in this presentation

The SVD orbit correction limited by the BPM resolution.

- Applying 0.02 s of GM model A (CERN site)
- Orbit correction in the BDS (SVD algorithm) : using the available BPMs and dipole correctors in the BDS lattice
- Relative luminosity versus BPM resolution



Some items for discussion on SVD orbit correction

- Necessary to define the hardware details:
  - 100 nm BPM resolution achievable with cavity BPMs
  - Possibility of ~< 10 nm resolution? In principle ~9 nm position resolution has been proved by cavity BPMs designed for the IP at ATF2 [Y. Honda, et al., Proceedings of LCWS/ILC 2007]
  - Introduce corrector limitations
  - etc

- Optimization selecting the most efficient correctors (using MICADO algorithm, studied by A. Latina et al., CLIC-Note-715); other optimization algorithms?

- Define realistic time of convergence of the SVD correction

- Compare performance of SVD:
  - Using dipole correctors as controllers
  - Using magnet movers as controllers (smaller mover step-size as compared to the dipole corrector currents, therefore, in principle finer granularity kicks)
  - Using a combination of both dipole correctors and magnet movers

- Probably I am missing other many items which need to be discussed …