Orbit feedback design for the CLIC ML and BD

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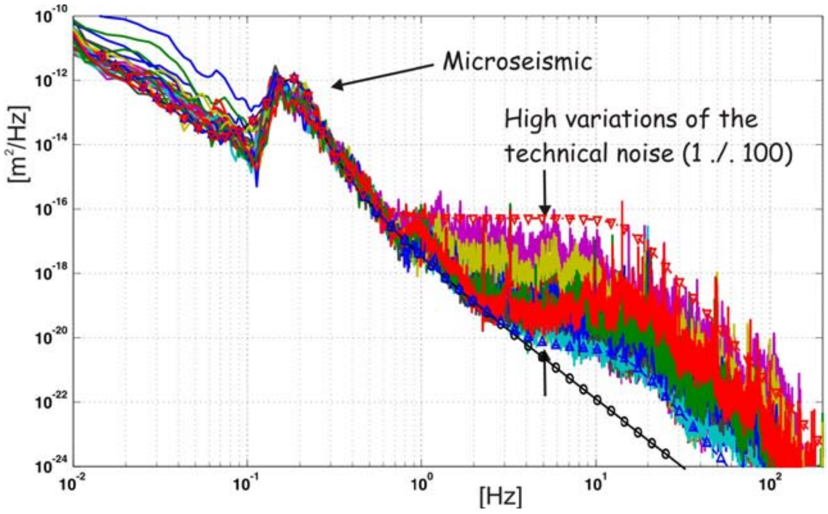
22th of March 2011

Outline



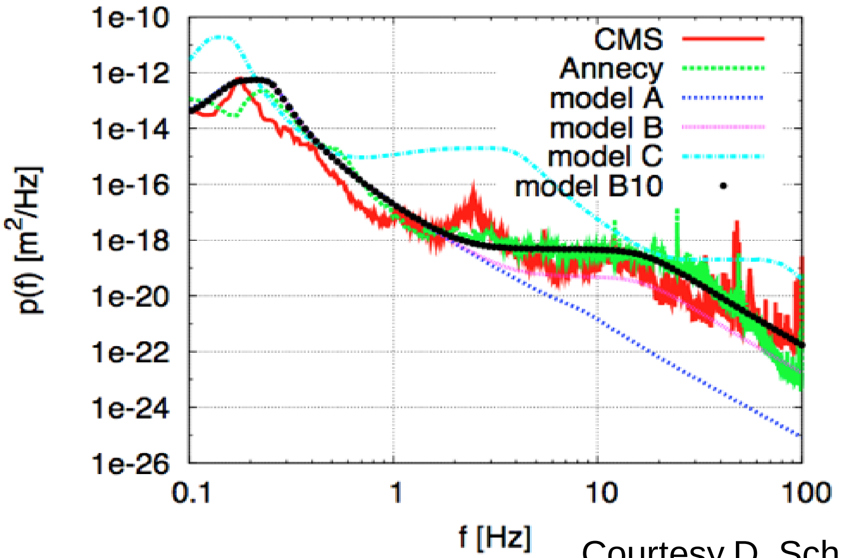
Taken from Ch. Collette et al. (see [6])

1. Introduction
2. Stabilization and pre-isolator
3. IP feedback
4. Beam based Feedback
5. Conclusions & Outlook

1. Introduction

The problem of ground motion

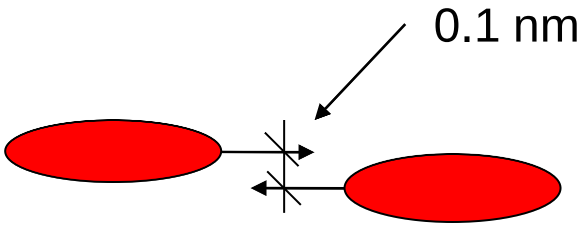
- Ground motion is a major source of beam offset and beams size growth at the IP
- <u>Mechanism:</u>
  - Ground motion misaligns magnets
  - Therefore beam is kicked from its ideal orbit => quality decrease.



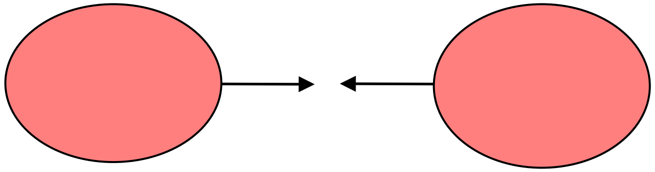
Courtesy D. Schulte

- Two tasks

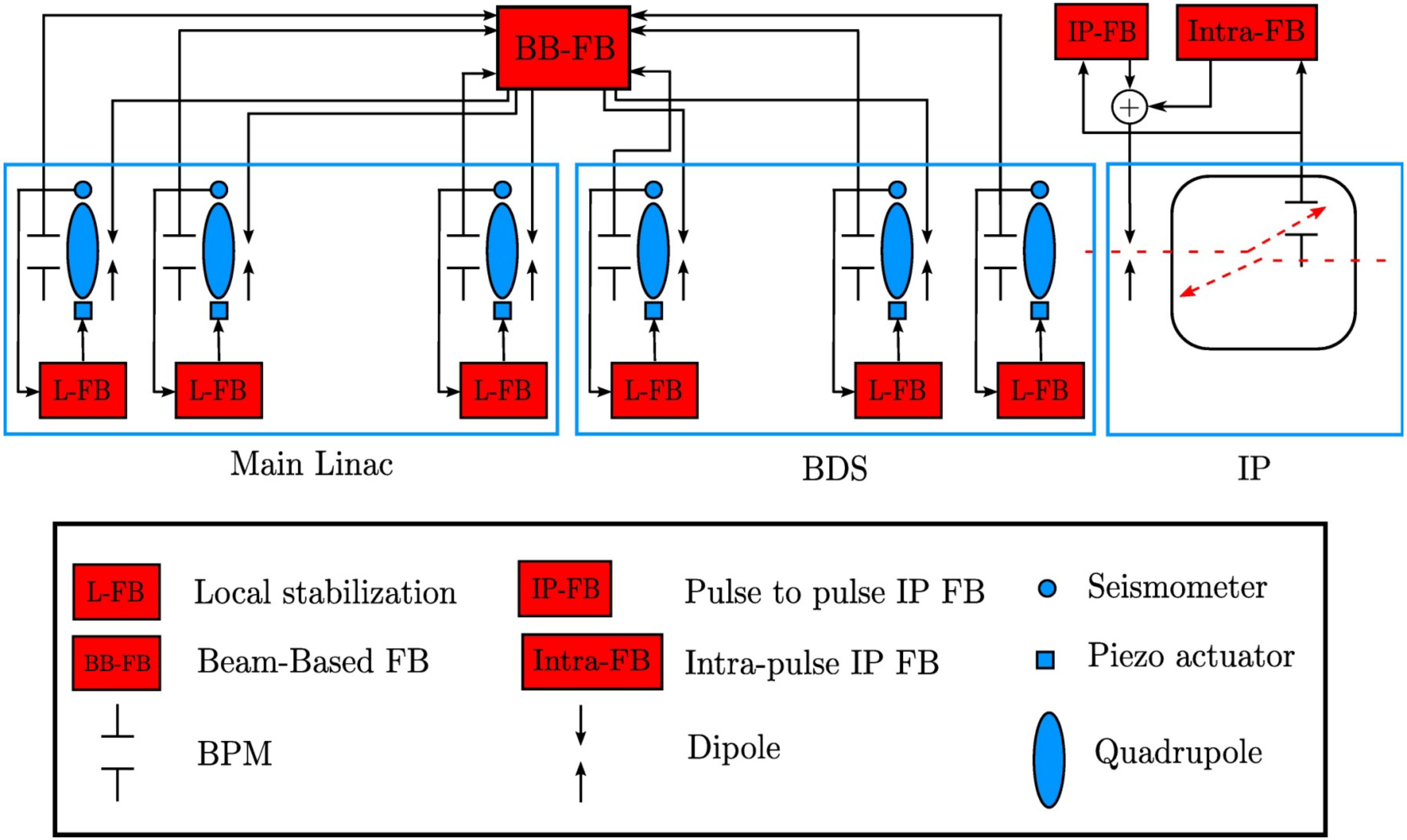
1.) Beam steering



2.) Beam quality preservation



Countermeasures



General about the design procedure

See talk J. Snuverink, Thu 14:00 WG6

- For the feedback design we us in general two types of tools

1. Simplified models

- Separate models for:
    - Beam offset and IP feedback
    - Luminosity growth due to beam size growth
    - Dispersive effect in final doublet
- No single big model available yet
- Used for design

Double check

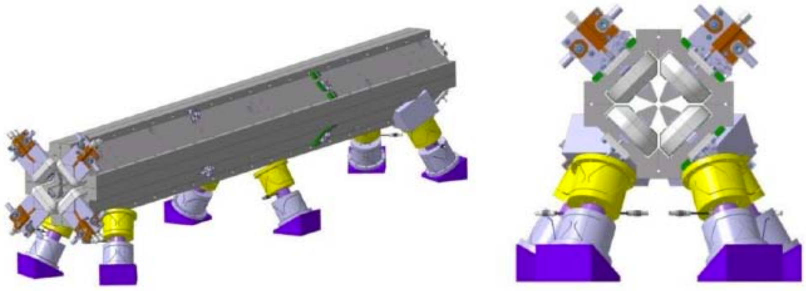
2. Full-scale simulation

- Includes
    - Beam tracking: PLACET
    - Beam-beam: GUINEAPIG
    - Ground motion generator (Sery)
    - Controller in Octave
- Pre-Isolator and stabilization is added via a modification of the ground motion generator
- IP and orbit feedback implemented in Octave
- Used to verify the design made with simple models

2. Stabilization and Pre-isolator

How do they look like?

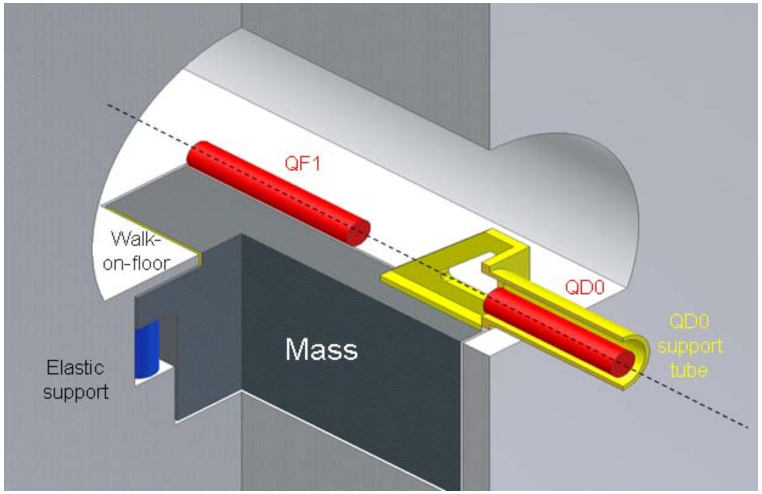
Quadrupole stabilization:



Taken from CERN stabilization group (see [2])

- Elements of the Tripod:
  - Sensor: Guralp seismometer
  - Actuator: Piezo-electric actuator legs
  - Feedback controller
- Purpose: reduces high frequency motion of the QPs, which results in less beam offset at the IP and less beam size growth (due to high frequencies)

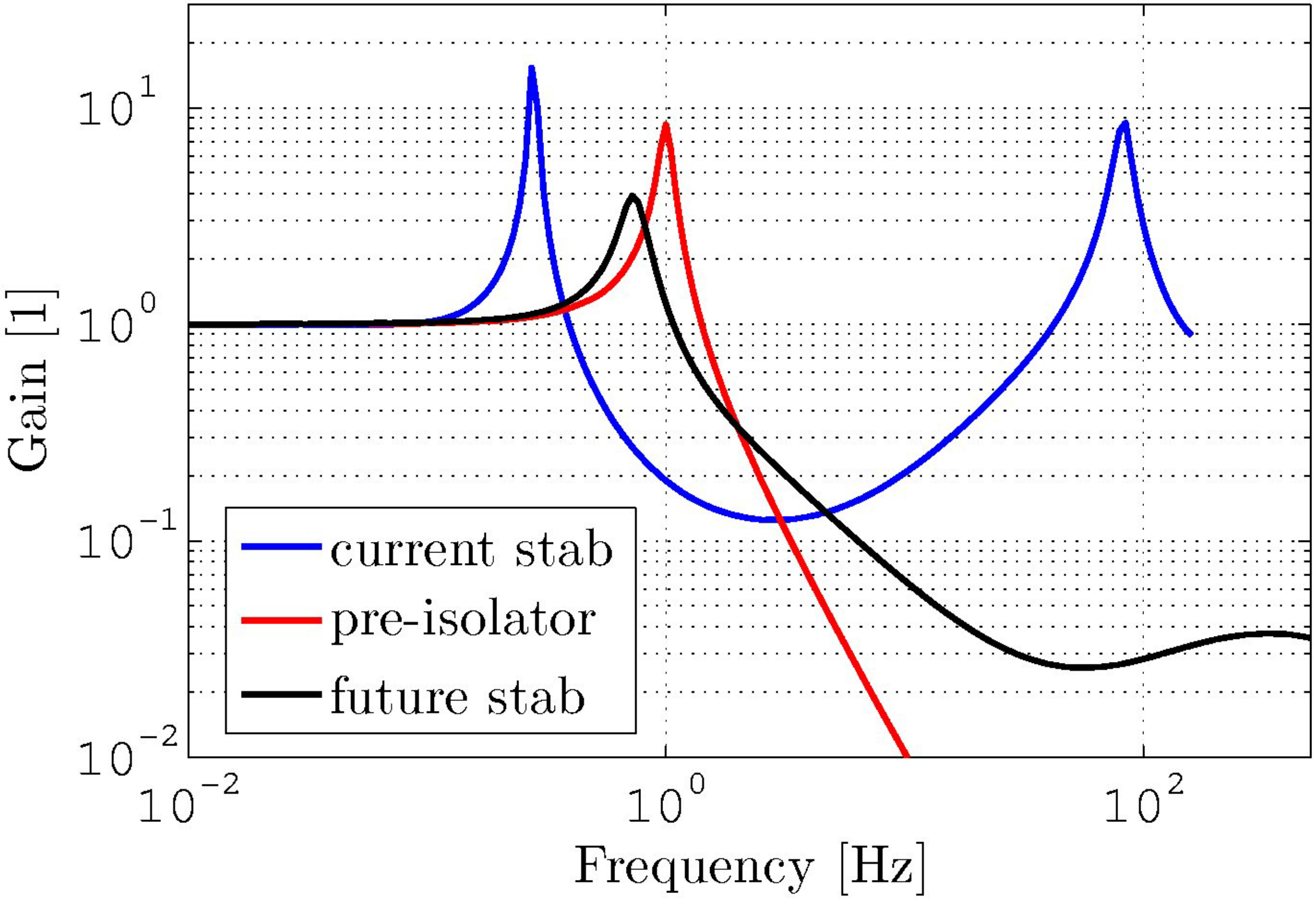
Pre-isolator:



Taken from A. Gaddi et al. (see [3])

- Elements:
  - Mass: concrete block (50-100 tons)
  - Springs: structural beams
- Purpose: Beam offset at IP is very sensitive to final doublet offset. Pre-isolator damps high-frequency ground motion very efficiently

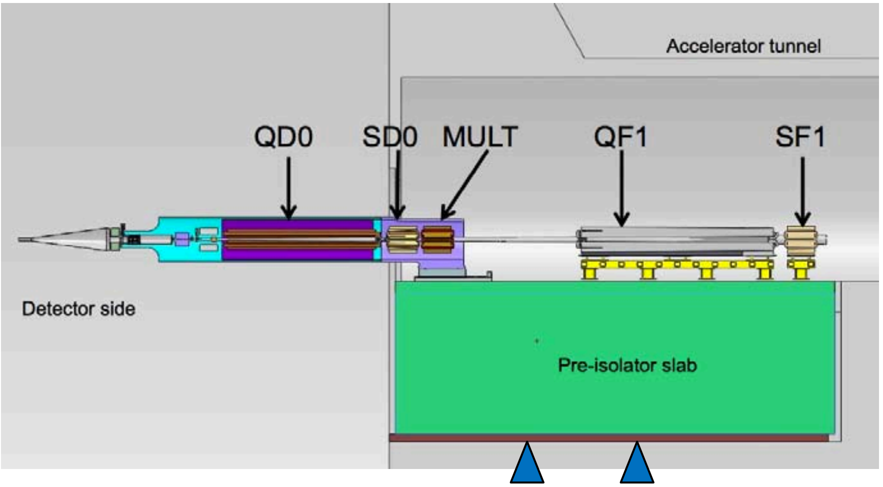
Transfer functions



3. IP feedback

Simple model of beam offset

- Main effect for beam offset is the final doublet, which can be calculated as:



Taken from A. Gaddi et al. (see [3])

δy	… beam-beam offset at IP
$P(\omega, k)$	… PSD of ground motion
$G_o(\omega, k)$	… beam-beam offset due to a sine wave of amp=1
$G_{FB}(\omega)$	IP-FB transfer function

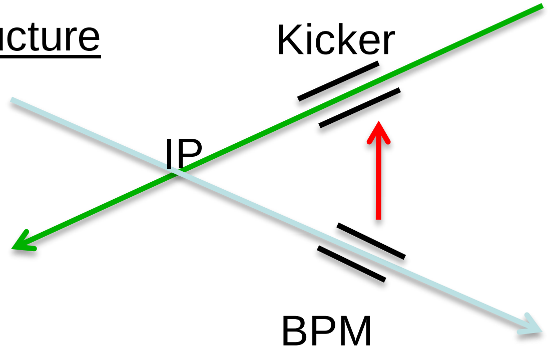
$$E\{\delta y^2\} = \iint\limits_{-\infty}^{+\infty} P(\omega,k)|G_o(\omega,k)|^2|G_{FB}(\omega)|^2 d\omega dk$$

$$\begin{aligned} G_o(\omega,k) = 2\big[r_{QD0}\big(&T_{P1\rightarrow QD0}\sin(k * s_{P1}) \\ &+ T_{P2\rightarrow QD0}\sin(k * s_{P2})\big) \\ &+ r_{QF1}\big(T_{P1\rightarrow QF1}\sin(k * s_{P1}) \\ &+ T_{P2\rightarrow QF1}\sin(k * s_{P2})\big)\big] \end{aligned}$$

$P1, P2$	… support points
s_{P1}	… distance of P1 from IP
k	… $2\pi/\lambda$ … wavelength
ω	… $2\pi f$ … frequency
r_{QD0}	… beam offset change at IP due to a QD0 y position chance
$T_{P1\rightarrow QD0}$	… Transfer function between support point and QD0 offset

IP feedbacks used

- Structure



Taken from J. Resta-Lopez (see also e.g. [5])

- Simple feedbacks
  => easy to design
  => can be changed quickly

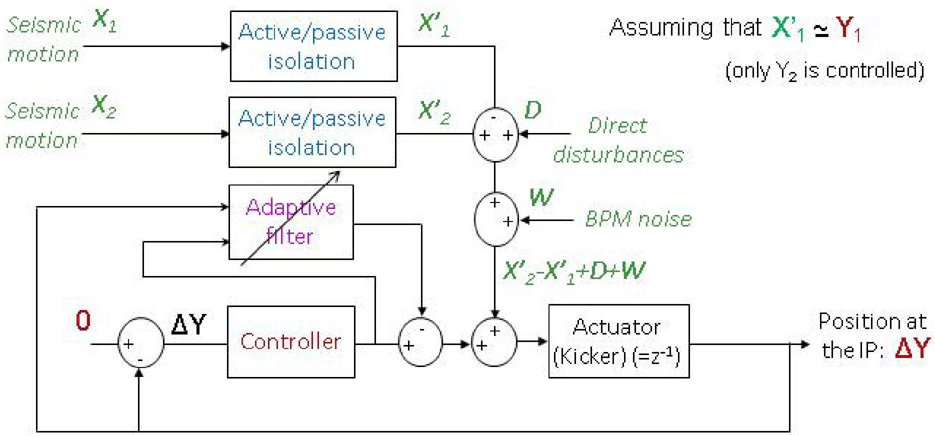
Variant 1 (integrator): 1 param.

$$u_k = u_{k-1} - g\delta y$$

Variant 2 (double integrator): 2 param.

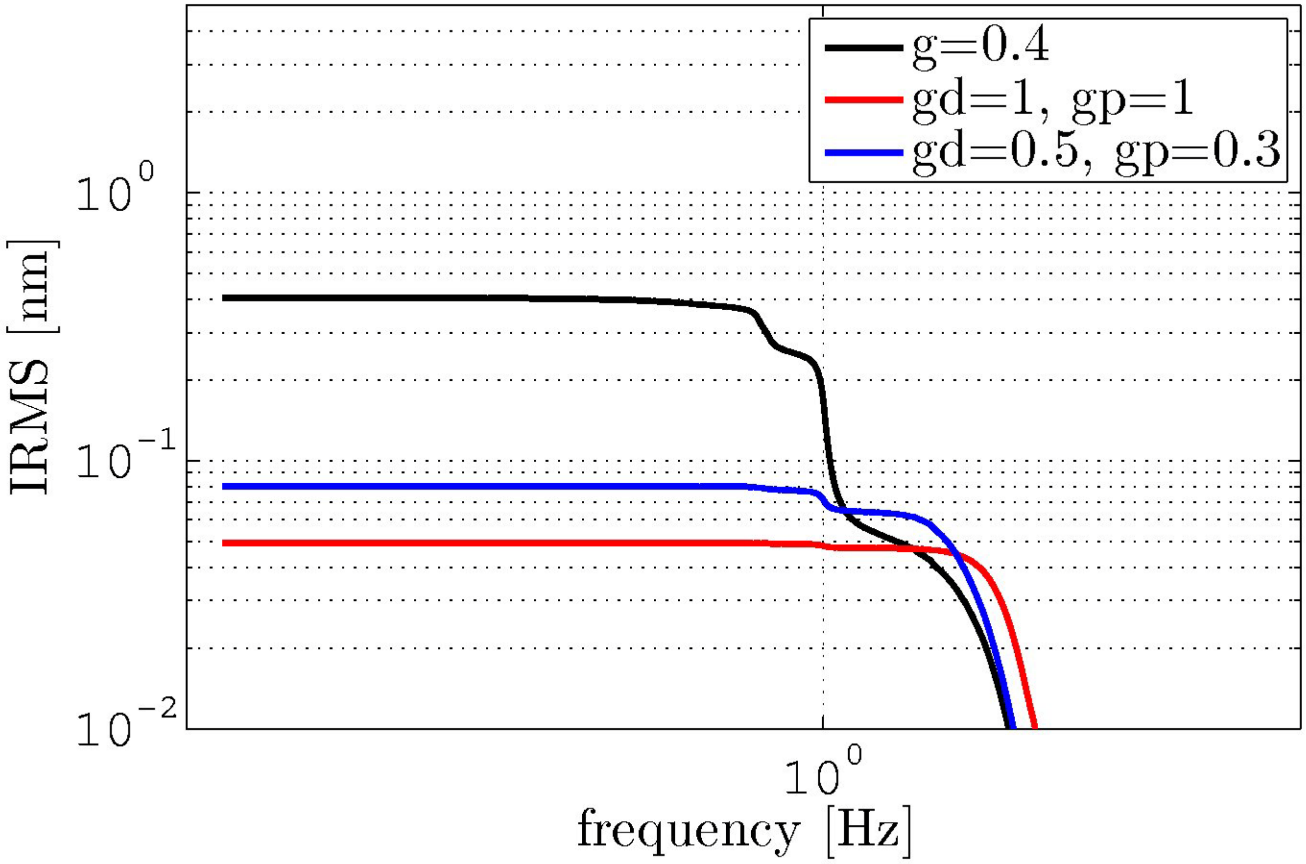
$$u_k = 2u_{k-1} - u_{k-2} + (g_p - g_d)\delta y_k - g_d \delta y_k$$

- Sophisticated feedback designed by LAViSta
  $\Rightarrow$ better performance
  $\Rightarrow$ more difficult to design

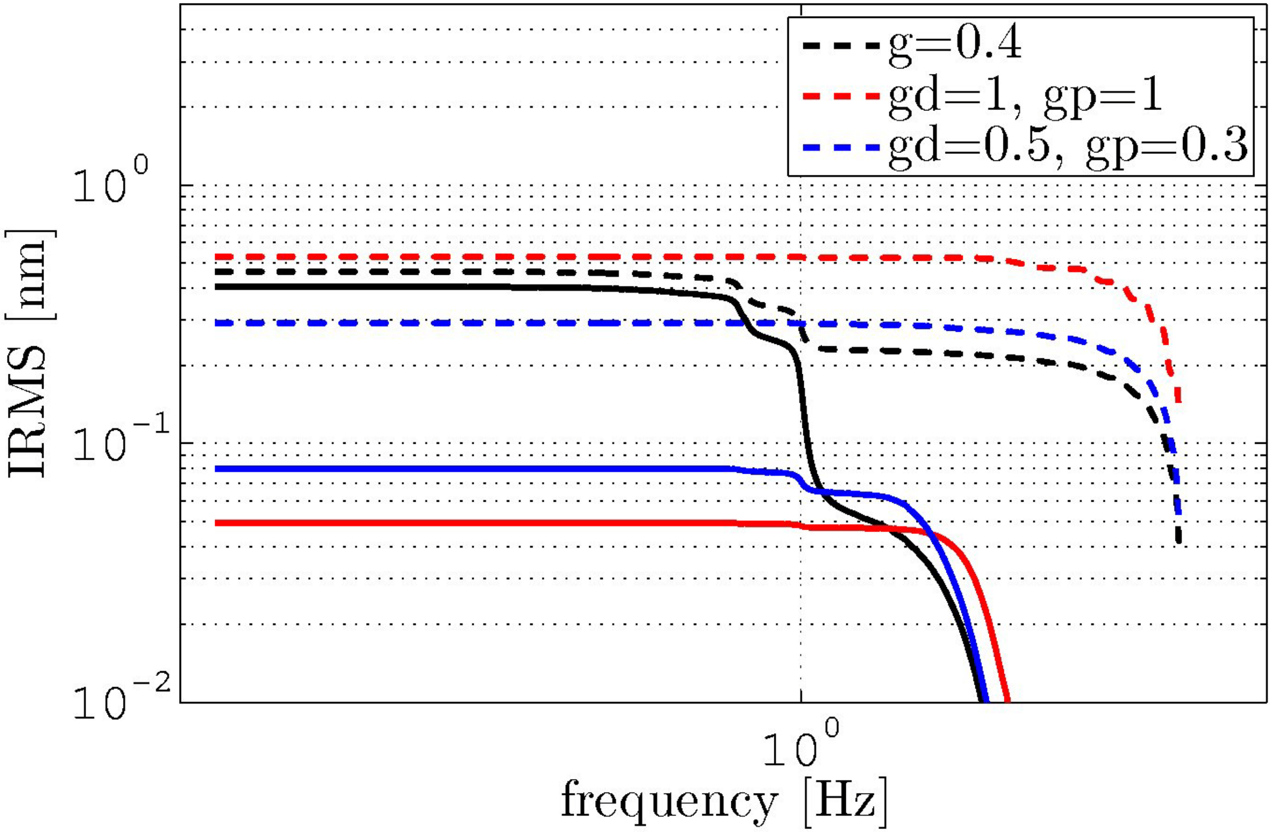


Taken from Gaël Balik (see [5])

IP feedback optimization (simple) no noise



IP feedback optimization (simple) with noise



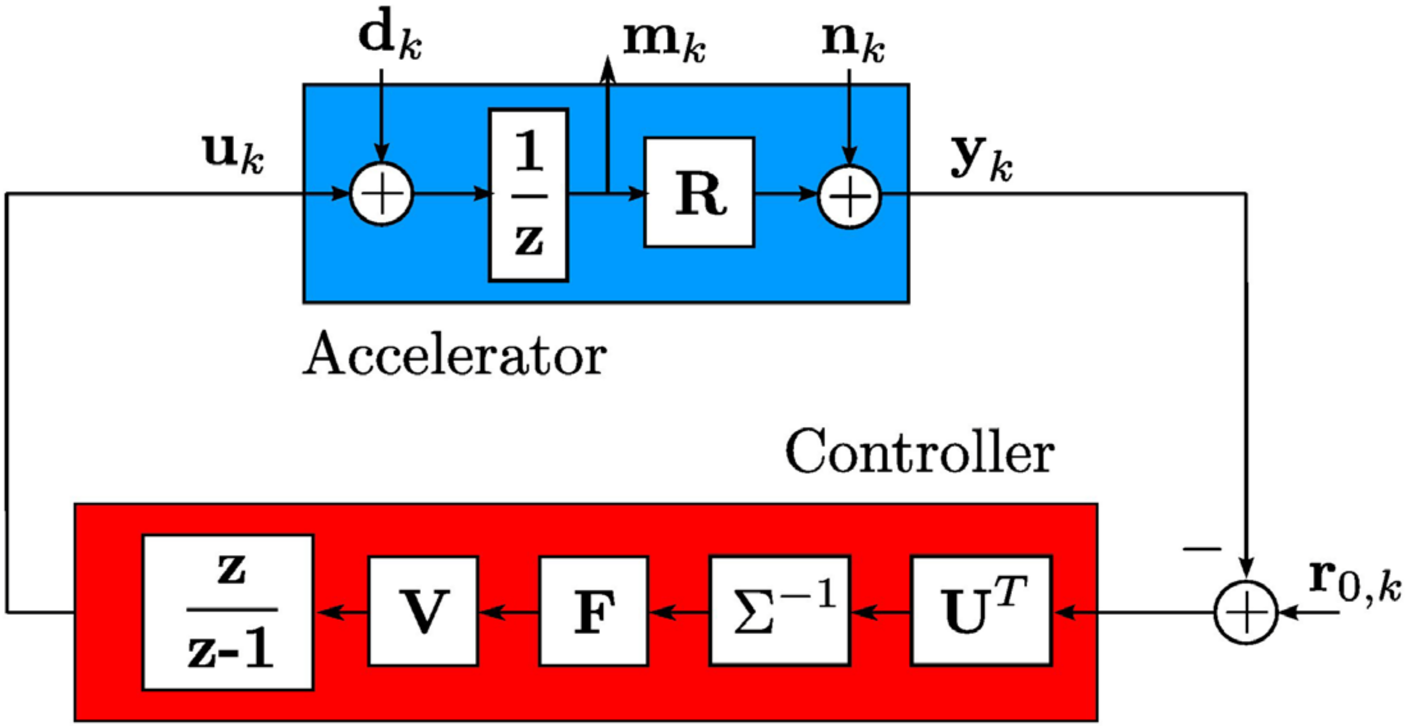
Used noise model: 0.2nm beam jitter (white) from upstream and 20pm BPM noise

4. Orbit feedback

Reasoning for the design choice

1. Decoupling of the inputs and outputs
2. Spatial filtering to reduce the influence of noise
3. Frequency filtering is based on ATL motion assumption. This will be improved in future designs

Weighted SVD controller

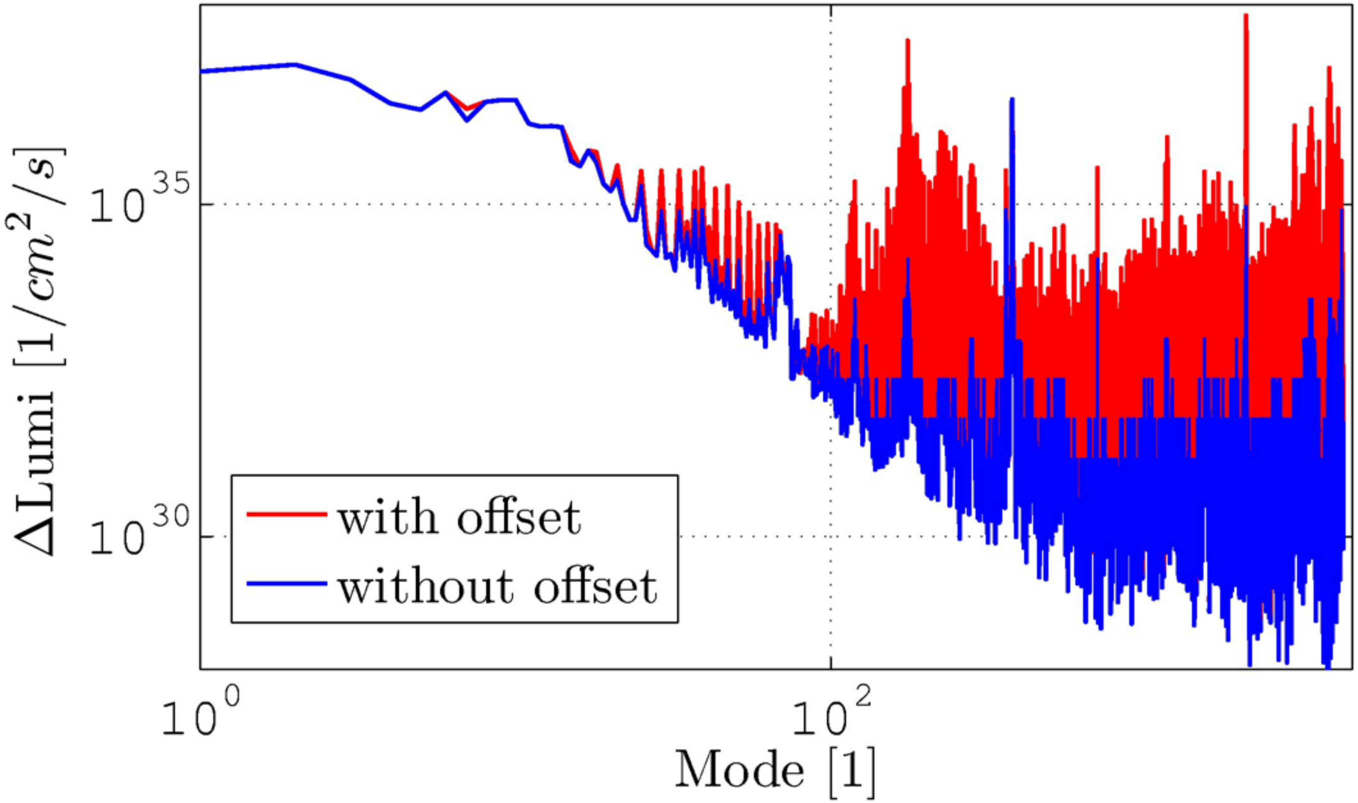


$\mathbf{d}_k \ldots$ ground motion
$\mathbf{n}_k \ldots$ BPM noise
$\mathbf{y}_k \ldots$ BPM measur.

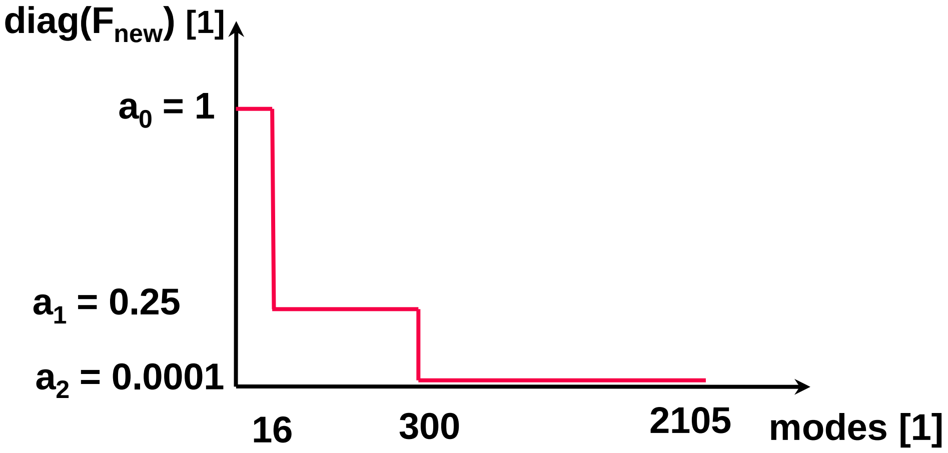
$\mathbf{R} \ldots$ response matr.
$\mathbf{R} = \mathbf{U}\Sigma\mathbf{V}^T$
$\mathbf{R}^{-1} = \mathbf{V}\Sigma^{-1}\mathbf{U}^T$

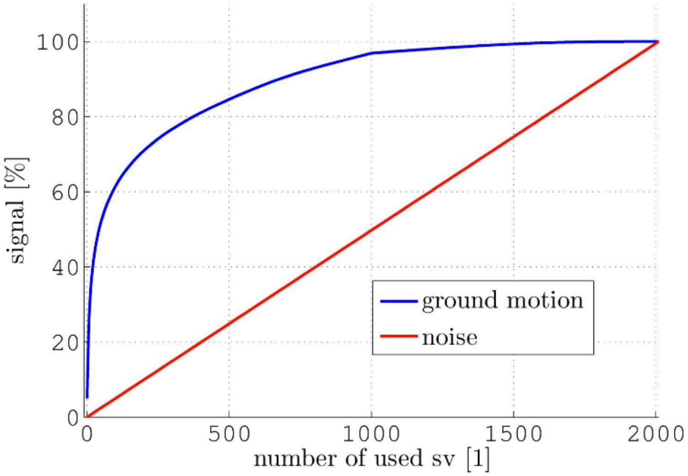
$\mathbf{m}_k \ldots$ mag. center
$\mathbf{r}_k \ldots$ BPM set point
$\mathbf{F} = \mathrm{diag}\left(\mathbf{f}\right)$

Effect of different controller directions on luminosity



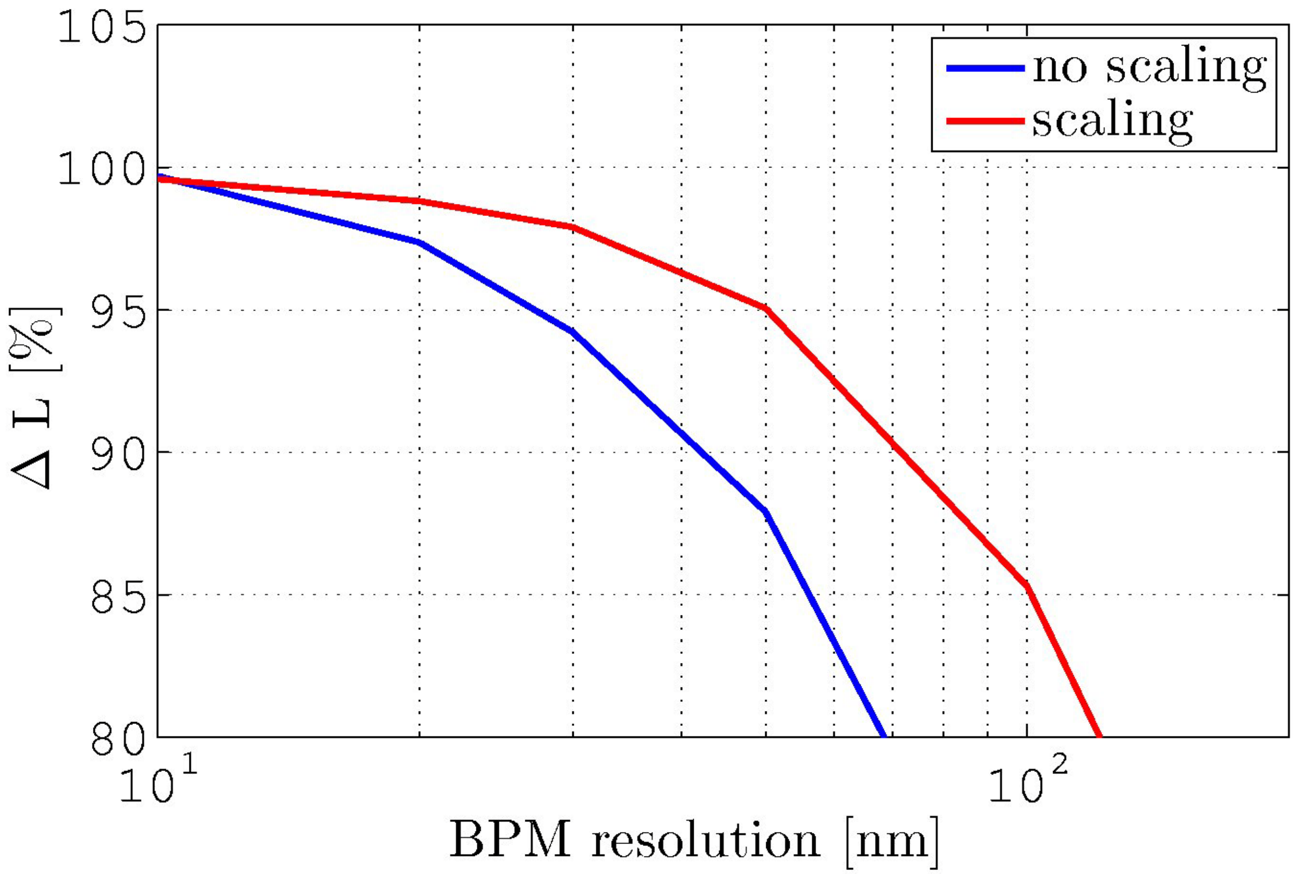
High-/low-frequency balancing



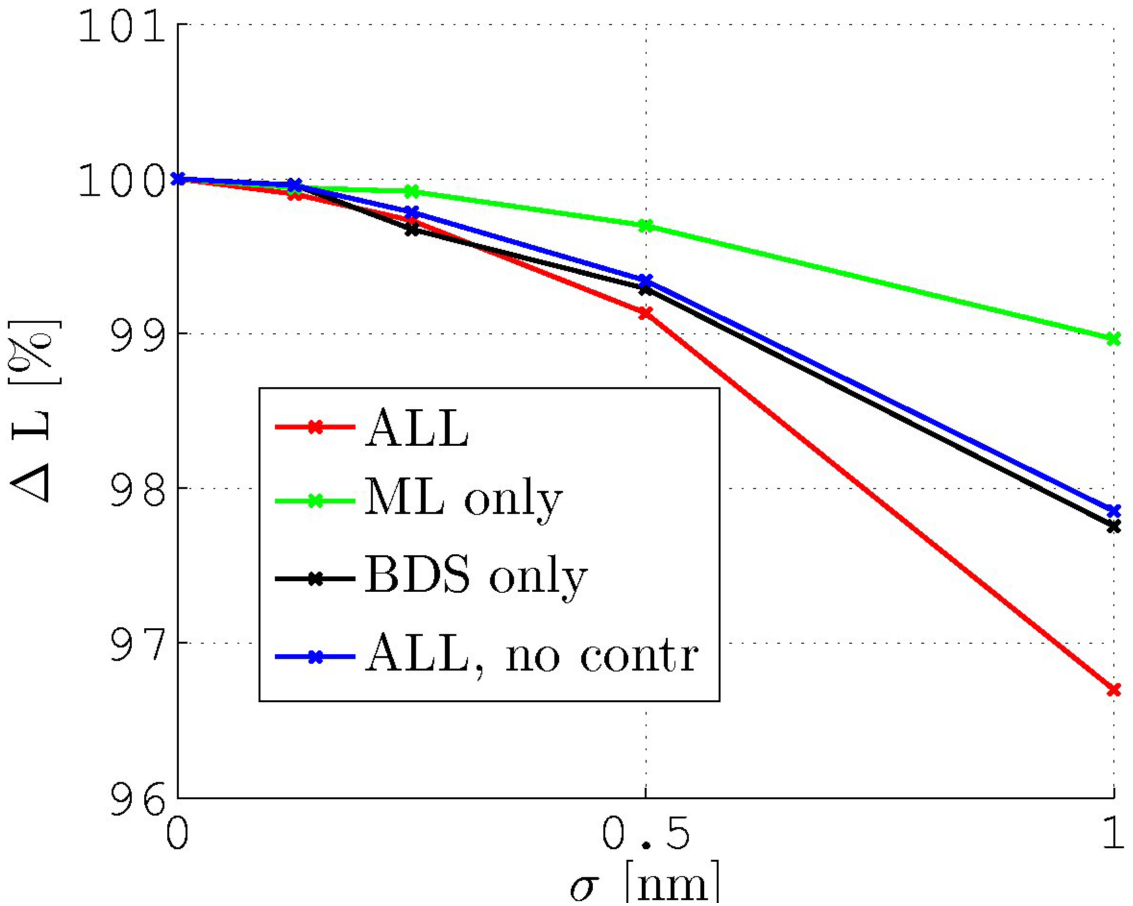


- If a_1 is too small:
  => Low frequency lumi. decrease, due to beam size growth
- If a_1 is too big:
  $\Rightarrow$ High frequency lumi. decrease, due to offset, beam size growth and nosie
- Best value found: a_1=0.25
- Further controller optimization possible

BPM sensitivity

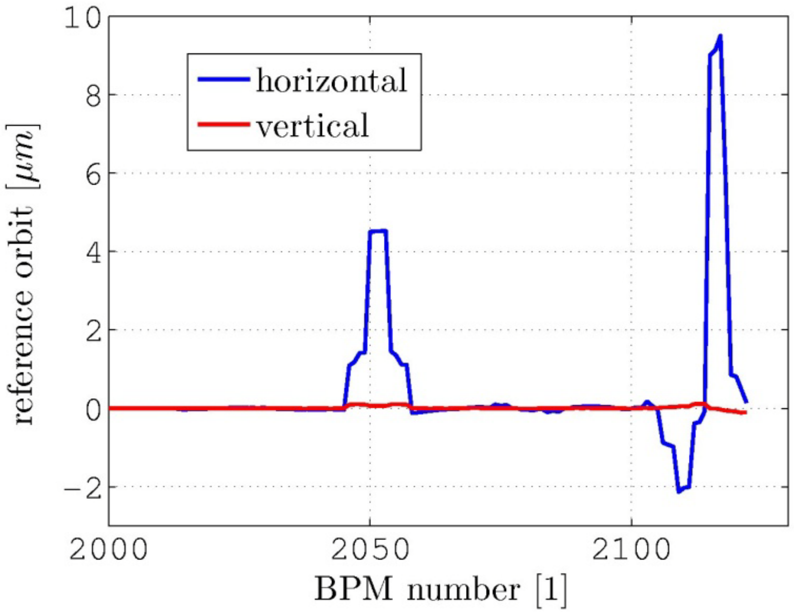


Sensitivity to corrector noise



Reference orbit and energy jitter

- Dipoles in x direction create a dispersive reference orbit.
- Can be also recognized in y direction due to coupling in sextupoles
- This has to be taken into account by specifying a reference orbit $r_{0,k}$
- Otherwise FB acts on the BPM readings and destroys luminosity.



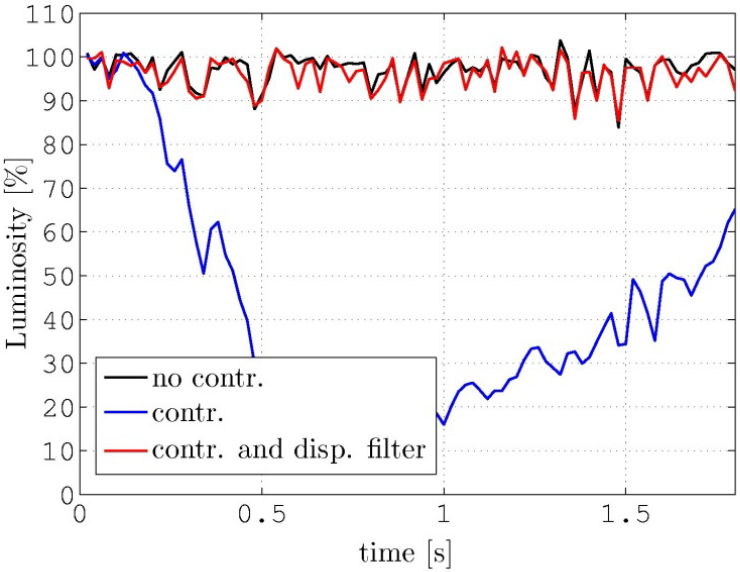
Energy jitter

- Jitter in acceleration gradient leads energy variations of the beam
- Due to the dispersion, this results in large BPM readings, which are used by the orbit FB.
- Solution: the according BPM readings all have the same dispersive pattern, just scaled with the energy variation
- This pattern can be filtered out by

$$y_1 = y_0 - y_0 * d_y$$

y … BPM readings

d_y … dispersion pattern



- Resulting luminosity loss (large RF jitter):

  => no controller: 2.62%

  => with contr. and filter: 3.86%
- => influence of filter on gm performance O(0.1%)

5. Conclusions and outlook

Conclusions

- Models and a full-scale simulations of the ground motion effects have been developed
- Orbit- and IP-FP have been designed
- The luminosity preservation for short time-scales has been shown. Luminosity loss stays within the budget. See talk J. Snuverink, Thu 14:00 WG6
- Some imperfections have been studied and according modifications have been made

Future work

- Improvements in the orbit-FB to lower the BPM requirements
- More investigations on imperfections
- Improving and finalize the modeling
- Long-term studies, for first results see talk J. Snuverink, Thu 14:00 WG6

Further information and references

[1] A. Seryi, “Ground Motion Models for Future Linear Colliders”, EPAC2000, Vienna

[2] C. Collette et al., “Active quadrupole stabilization for future linear particle colliders”, Nuclear Instrumentation and Methods in Physics Research A, 2010

[3] A. Gaddi et al., "Passive Isolation", IWLC 2010, Geneva

[4] J. Pfingstner et al., “Adaptive Scheme for the CLIC Orbit Feedback”, IPAC10, Kyoto,

[5] G. Balik et al., "Non-linear feedback controller", IWLC 2010, Geneva

[6] C. Collette, K. Artoos, M. Guinchard and C. Hauviller, Seismic response of linear accelerators, Physical reviews special topics - accelerators and beams.

Thank you for your attention!