Integrated simulations of ground motion mitigation techniques for the CLIC ML and BDS

Jochem Snuverink
Jürgen Pfingstner

21st of March 2011

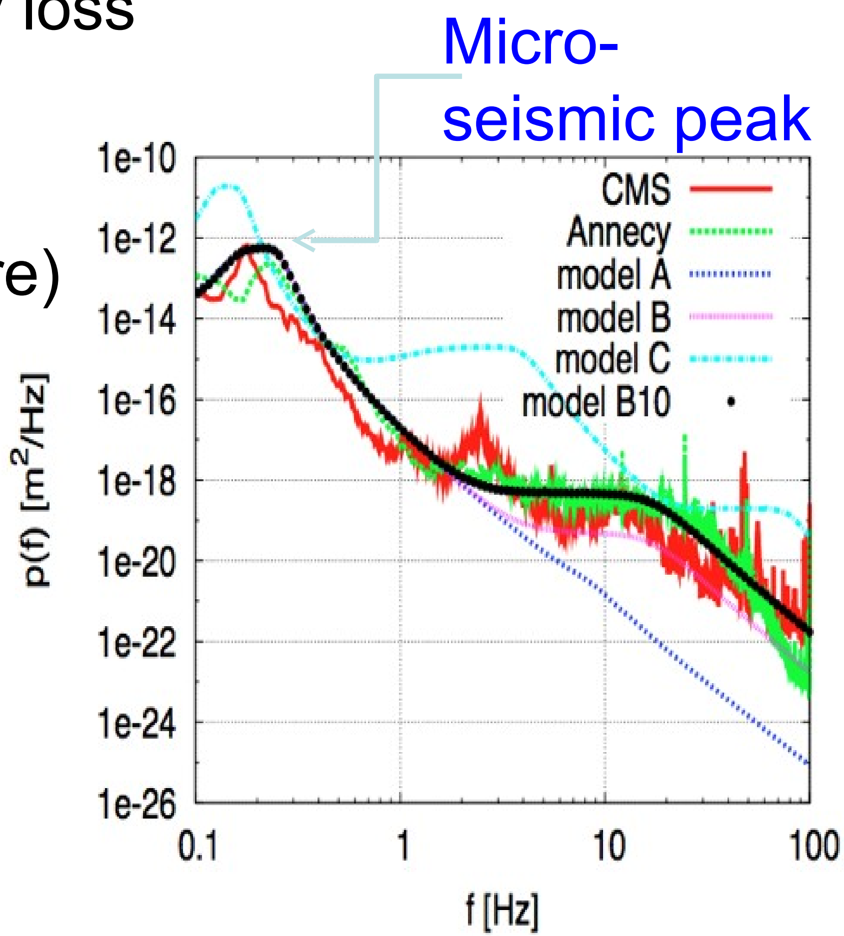
Outline

1. Introduction
   - Ground Motion
   - Stabilization & Feedback systems
   - Framework
2. Long term simulations
3. Pulse to pulse simulations
4. Conclusions

1. Introduction

Ground Motion

- Main dynamic cause for luminosity loss
- Slowly drifting element positions
- Short time scales (< 10 s)
  - A. Seryi models [1] (see figure)
- Long time scales
  - ATL law:
  - <(Δy)2> = A*t*L
- Model A, B and B10 used

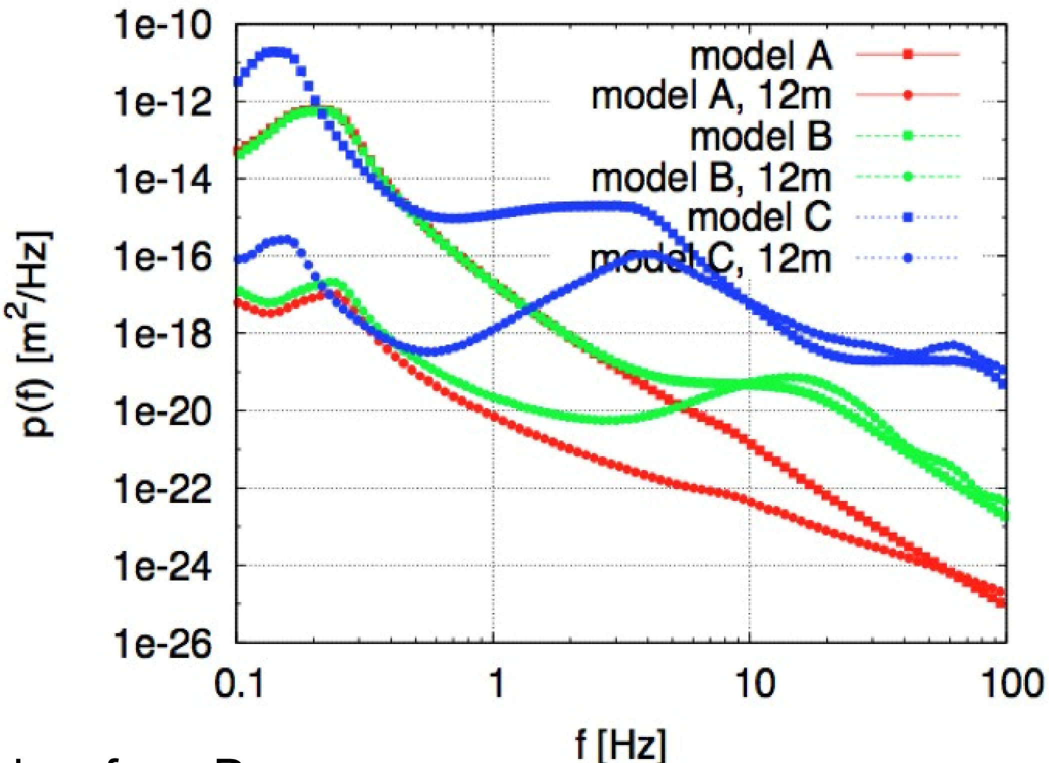


Ground Motion

Ground Motion Correlation

- Ground motion is correlated
- Correlation has an impact on the luminosity performance
  - e.g. relative offsets of final quadrupoles is important (relevant distance $\approx 12\,\mathrm{m}$)

$\Rightarrow$ high frequency part is uncorrelated

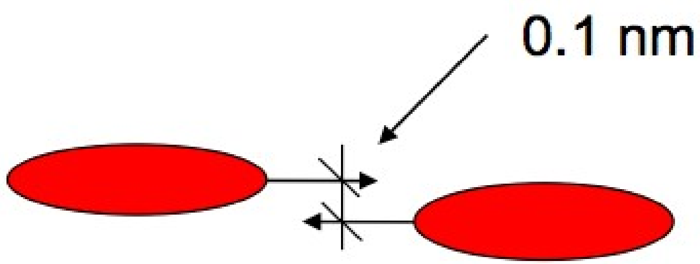


Taken from D. Schulte

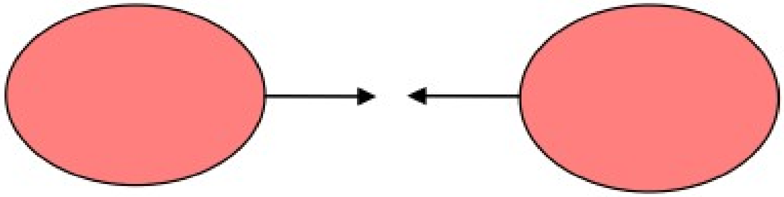
Stabilization & Feedback systems

- Two tasks

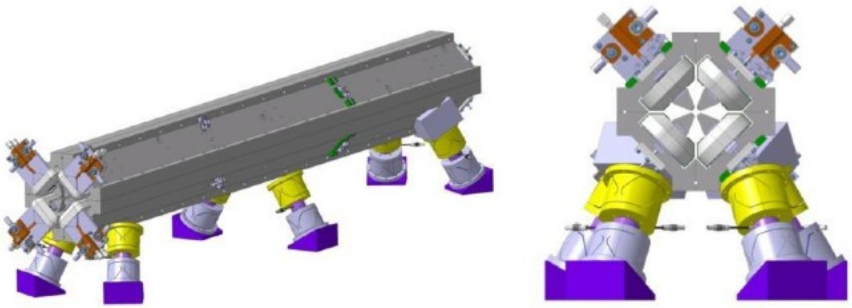
1.) Beam steering

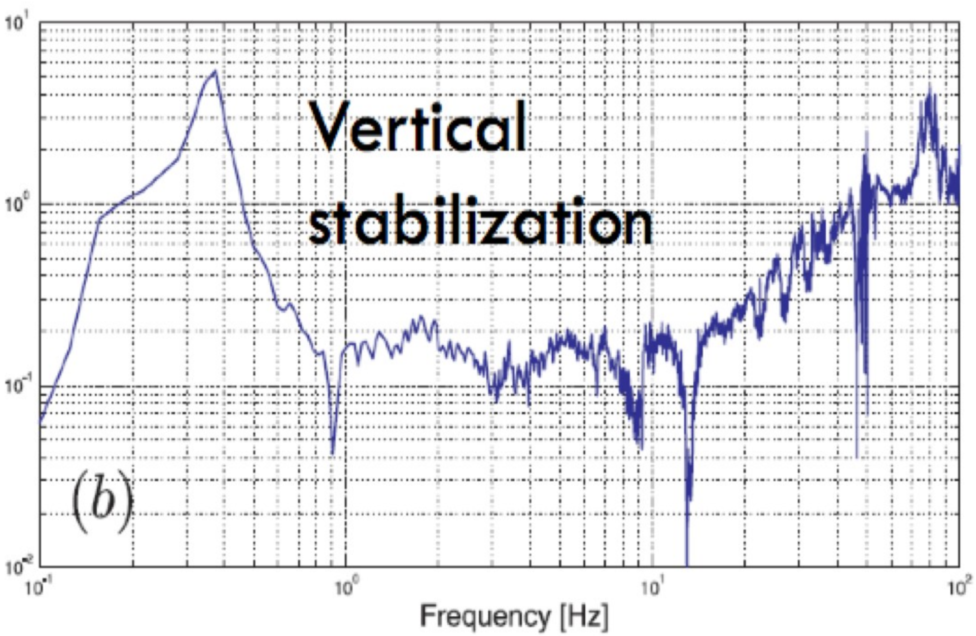


2.) Beam quality preservation



Quadrupole Stabilisation





Reduces quad movements above 1 Hz

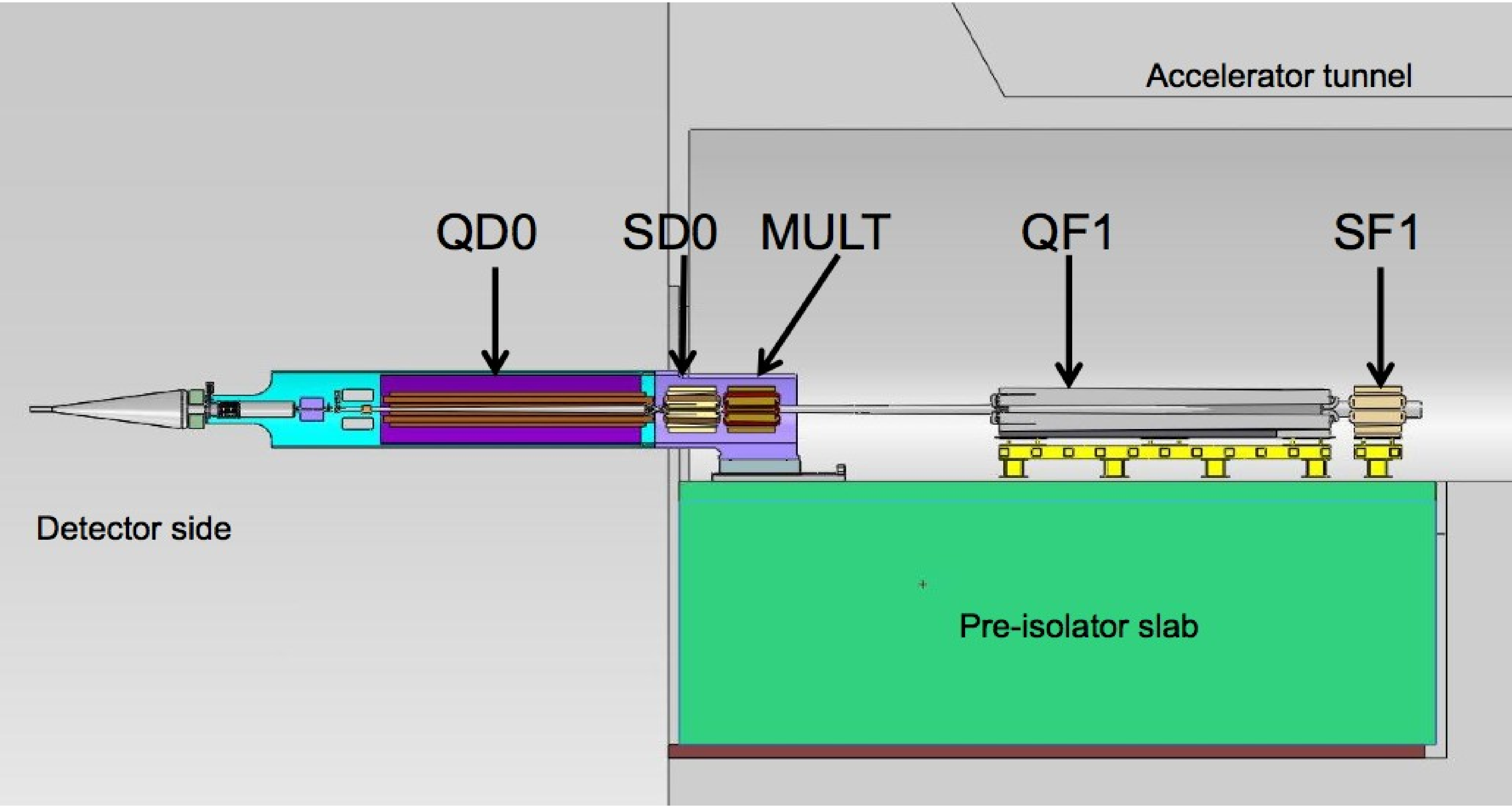
(int. rms 1 nm)

Reduces emittance growth and beam jitter for high frequencies

Taken from CERN stabilisation group (see [2])

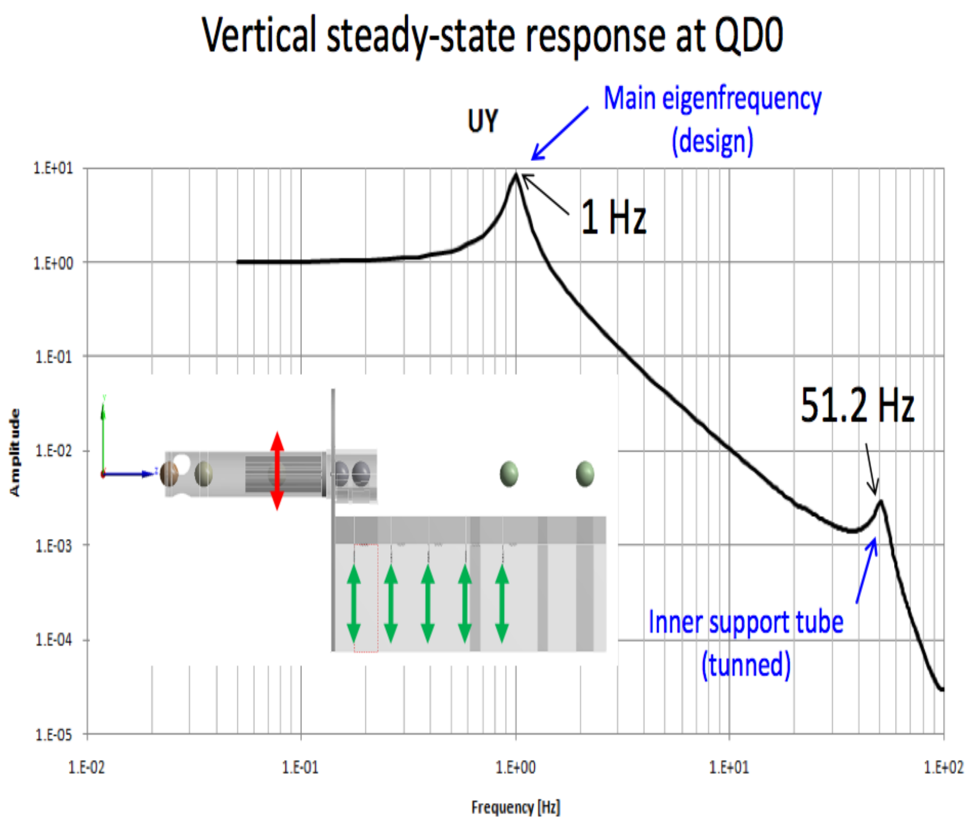
Pre-isolator

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



Pre-isolator

Harmonic excitation in the vertical direction

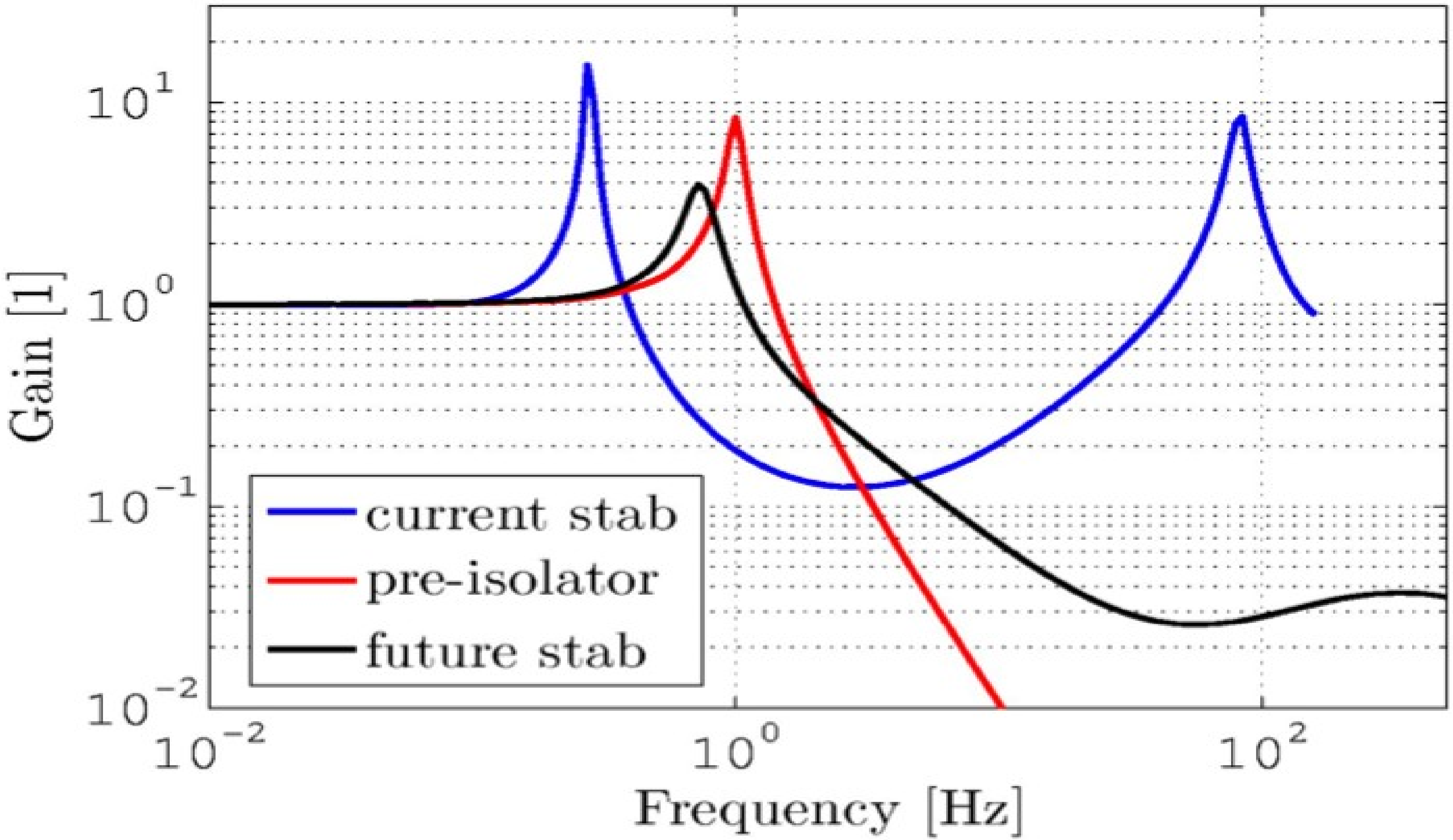


- Reduces movements of the Final Focus magnets above several Hz

  (int. rms 0.13 nm)

- Reduces beam jitter (offset) at IP for high frequencies

Transfer functions



Orbit feedback

Orbit correction

2010 quads and BPMs per beamline

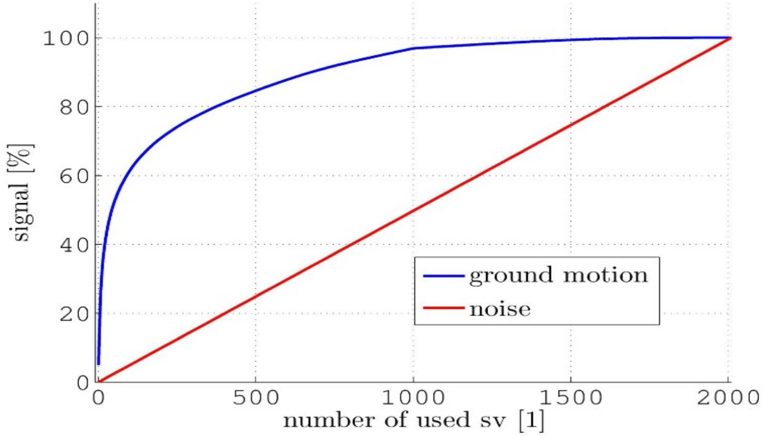
Weighted SVD controller [4]

- One large response matrix
- Smaller singular values downweighted

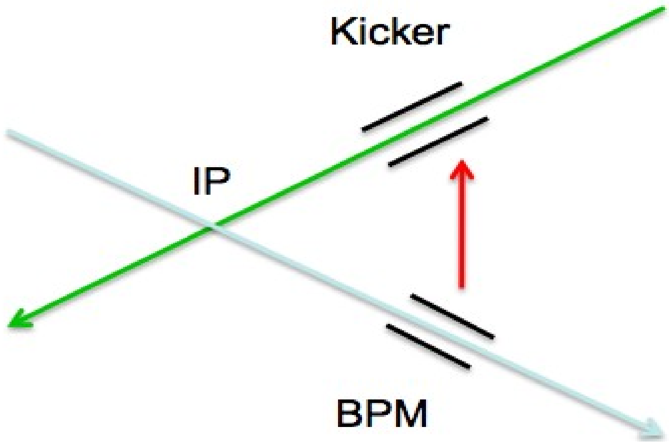
Robust against noise

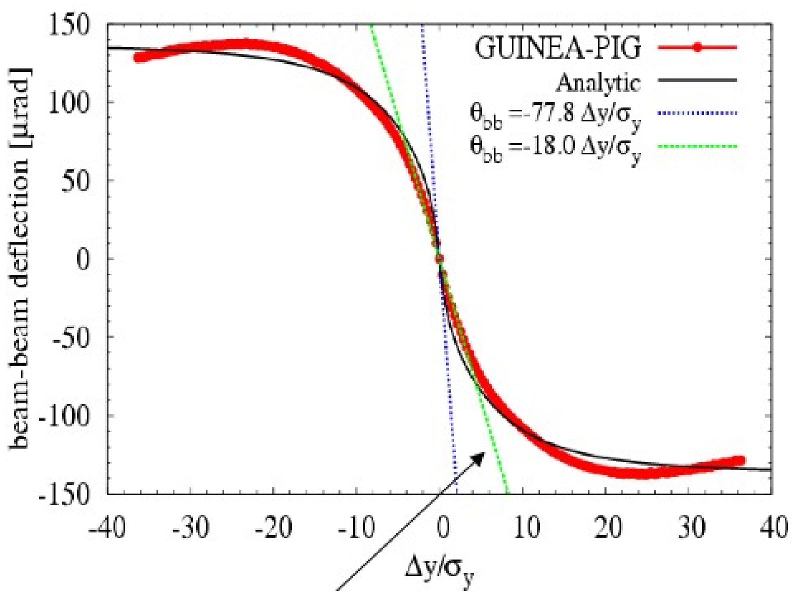
Reduces emittance growth for low frequencies

See talk J. Pfingstner, Tue 8:30 WG6



IP feedback





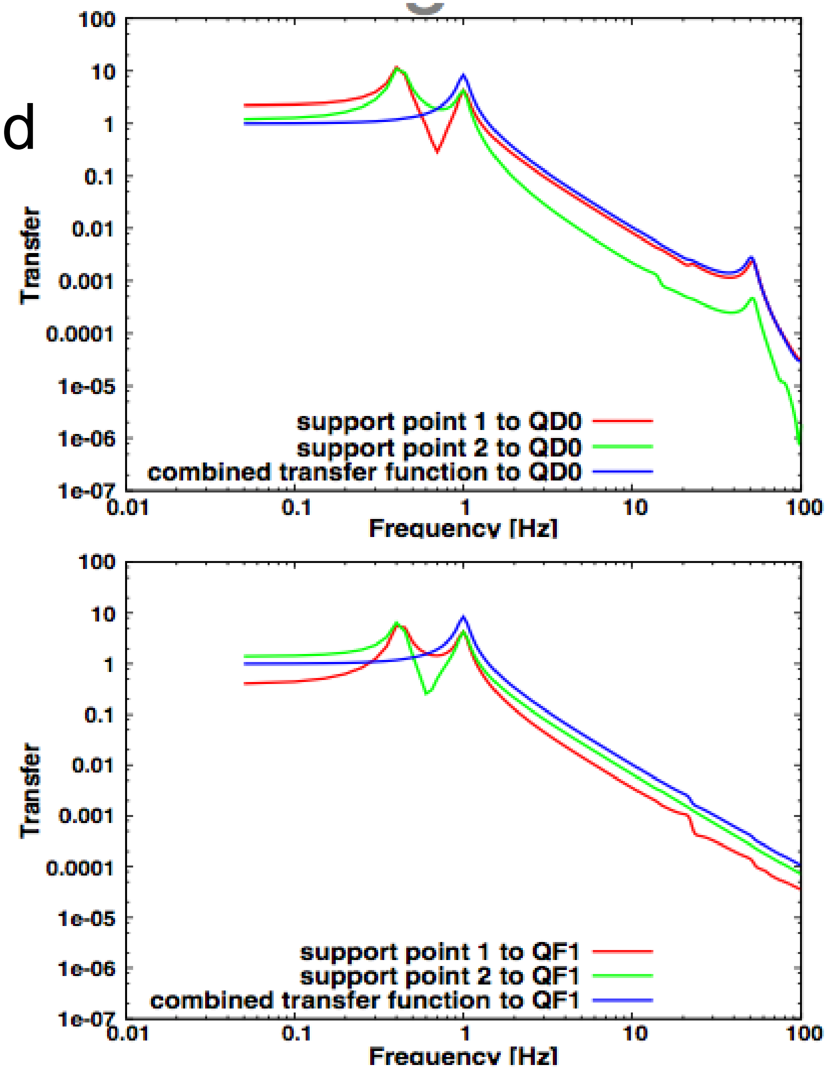
- Feedback based on the deflection angle of the colliding beams
- Pulse to pulse (intrapulse possible, but not used here)
- Reduces beam offset at IP for low frequencies
- Non-linear effect
- In collaboration with LAPP-Annecy

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

Ground Motion: Preisolator

Preisolator tilt has been implemented

- 4 different transfer functions
- Tilts at 0.4 - 1 Hz and 50 Hz
- New PLACET command AddPreisolator
- Kink between preisolator and rest of beamline will be important.



Simulation Framework & Settings

- A simulation framework has been setup
  - Placet-CVS: /clic-integrated-simulations/linac-bds/dynamic
  - Main Linac and BDS, Placet for tracking
  - GuineaPig for luminosity calculation
- Ground motion generation for all models
- Including all feedback systems mentioned
- One settings file
- BPM resolution
  - ML: 50 nm
  - BDS: 10 nm

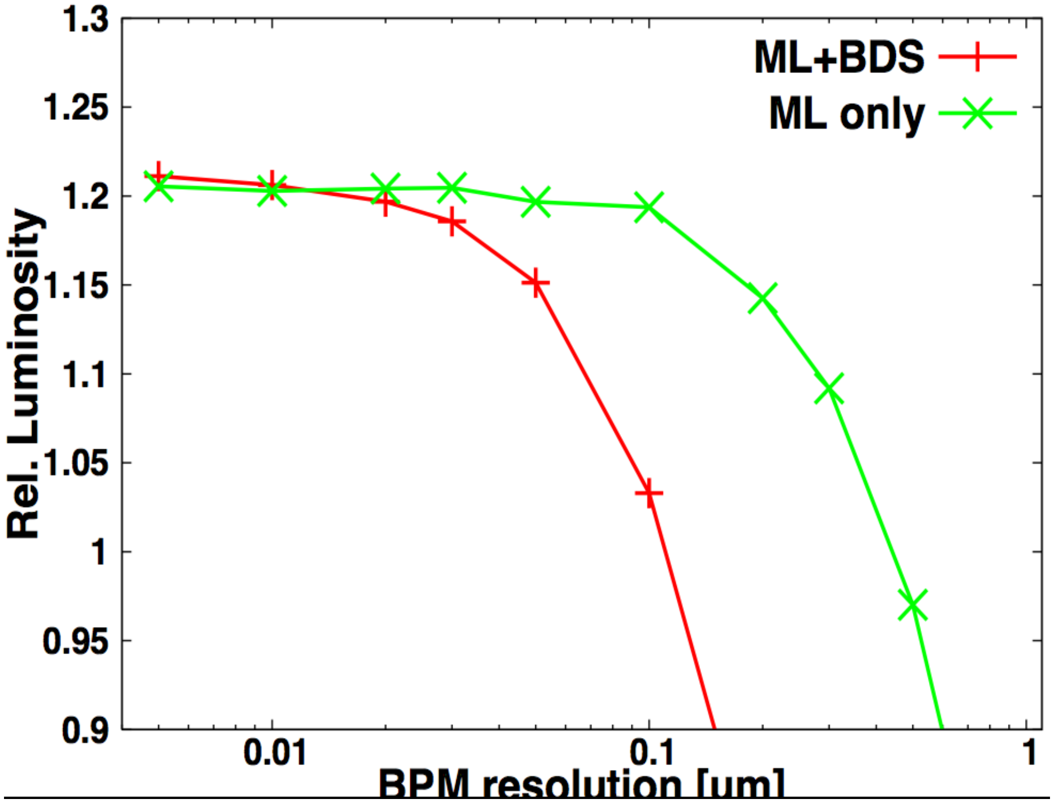
Static imperfection treatment

- The rel. peak luminosity is calculated wrt the nominal peak luminosity of $2*10^{34}$ $cm^{-2}s^{-1}$
- Static imperfections have been accounted for by a 20nm vertical emittance at the ML start
- Dynamic Imperfection budget is about 20% (perfect beamline = 121%)

2. Long term simulations

BPM Resolution

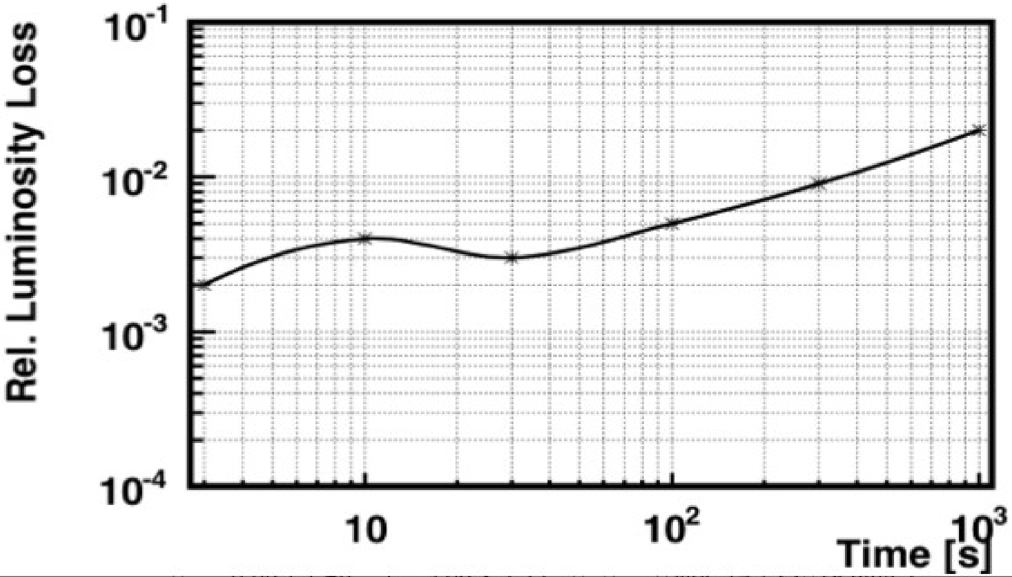
- Let the feedback run at full speed
  - no ground motion, only BPM errors
- BDS most sensitive
- ML BPMs less sensitive



Long term ground motion

- Beam-based orbit feedback can only maintain luminosity for limited time
- Simulation of long term ground motion
  – Apply long term motion using model B/B10
    - Feedback is not active during this period
  – Run the feedback until it converges
    - Running during the ground motion could yield better results

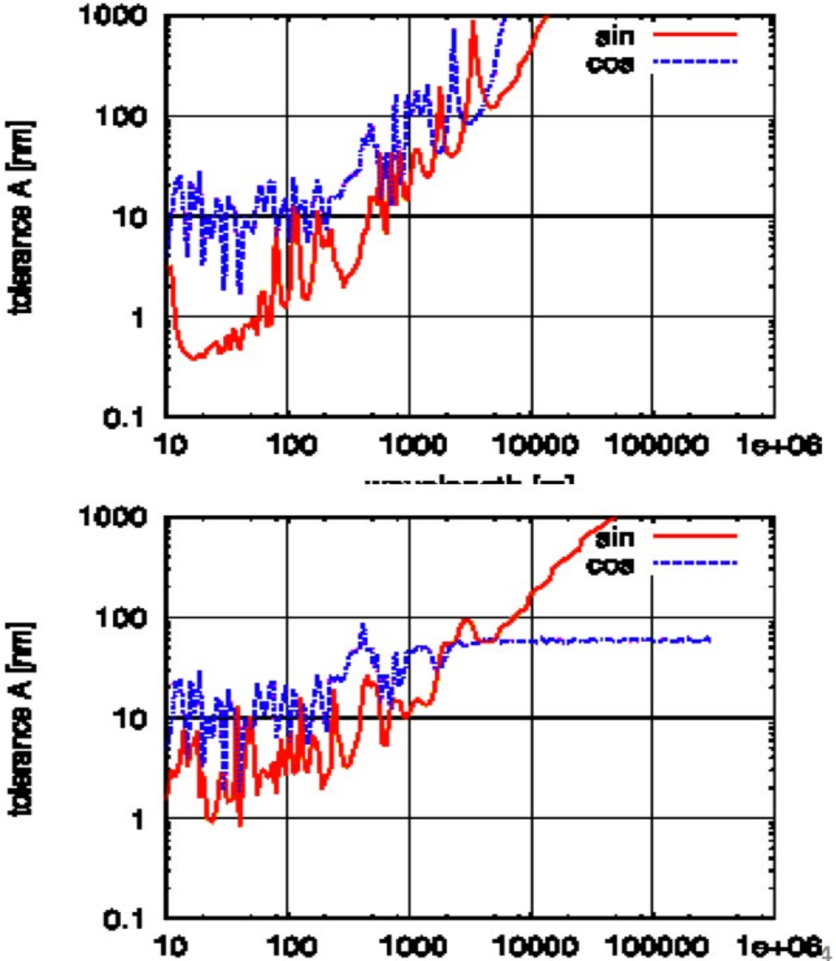
- Can probably be improved by optimizing beam-based feedback
- Can use tuning knobs to further improve



3. Pulse to pulse simulations

Note: simplified calculation

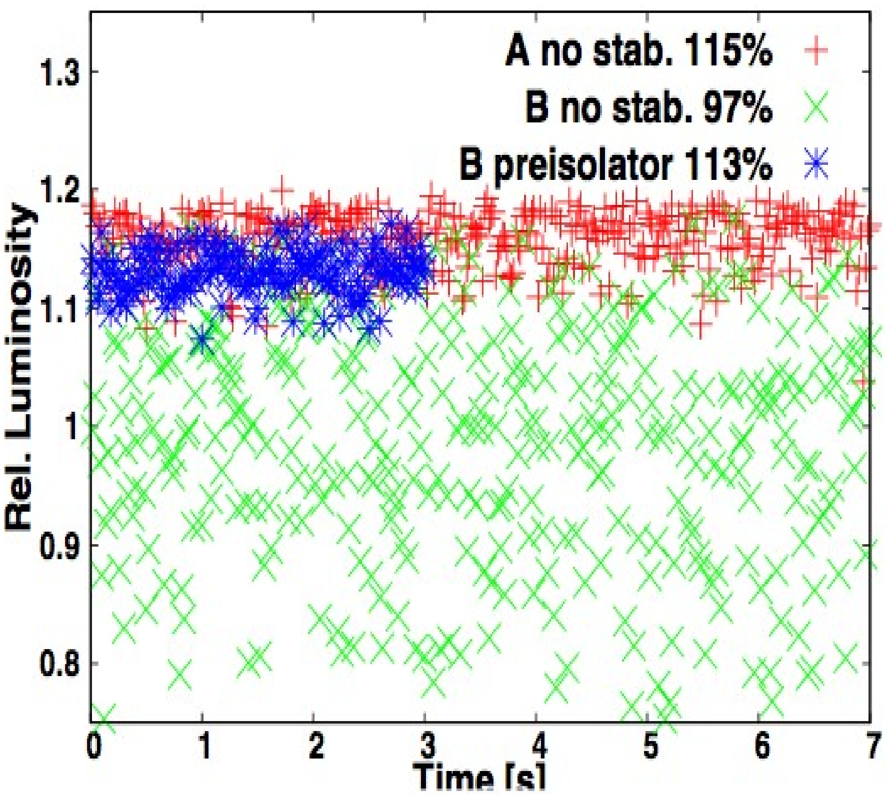
- Simplified calculation allows to determine impact of each ground motion mode as function of
  - Wavelength
  - Frequency
- Tolerance shown
  - ΔL/L=10%
  - sinus/cosinus with respect to IP
- Upper plot has no stabilisation
- Lower plot has air hook final doublet stabilisation



Results (no local stab.)

- Model A:
  no stab. needed
- Model B:
  needs FD stab.
- Model B10 or worse:
  needs ML quad stabilisation

Averaged over 20 seeds

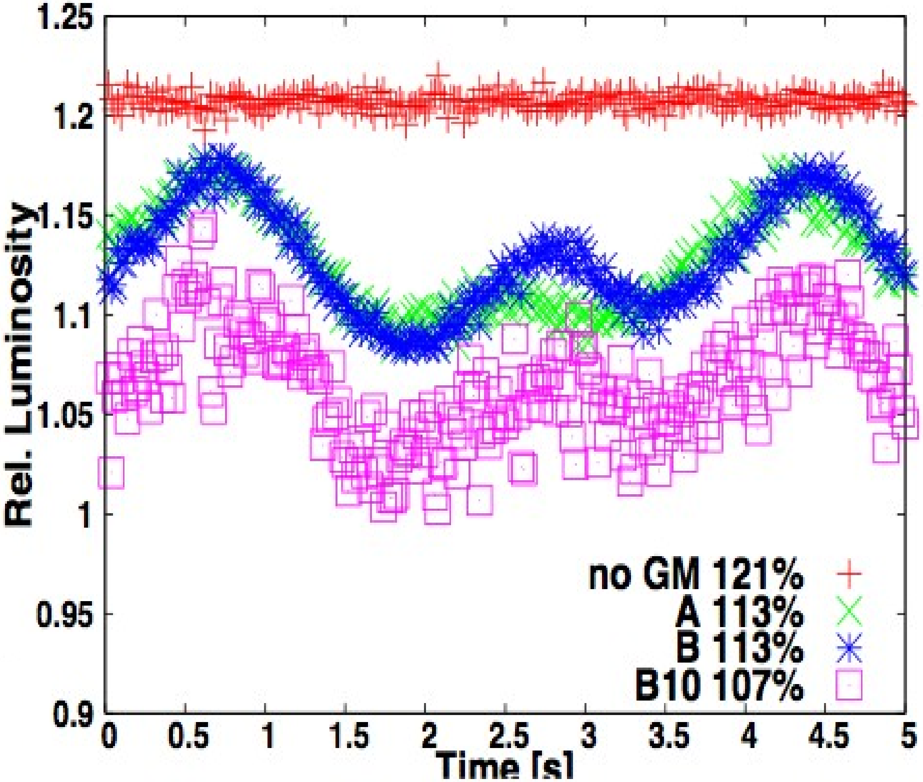


Results (stab.)

- Model A gets worse
- Model B about the same
- Model B10 acceptable

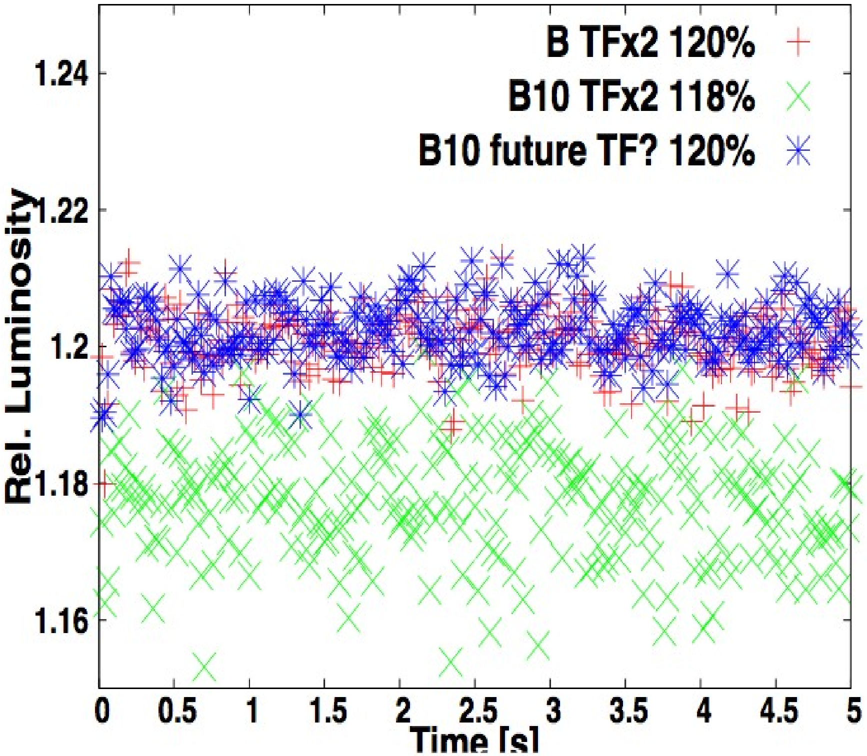
- Loss in A and B might be recovered by tuning the stabilisation and/or controller.

Averaged over 20 seeds



Future transfer function

- Large gains can be made by:
- moving away from the microseismic peak (TFx2)
- matching better with the preisolator (future TF)
  - no kink between FD and rest of BDS



4. Conclusions

Conclusions

- Models and full-scale simulations of the ground motion effects have been developed
- Fruitful collaboration with the stabilisation team
- Orbit and IP feedback has been designed
- The luminosity preservation for short time-scales has been shown. Luminosity loss stays within the budget

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

Thank you for your attention!