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COLLIDING NANOBEAMS in CLIC with MAGNETS STABILIZED to the SUB-NANOMETER LEVEL

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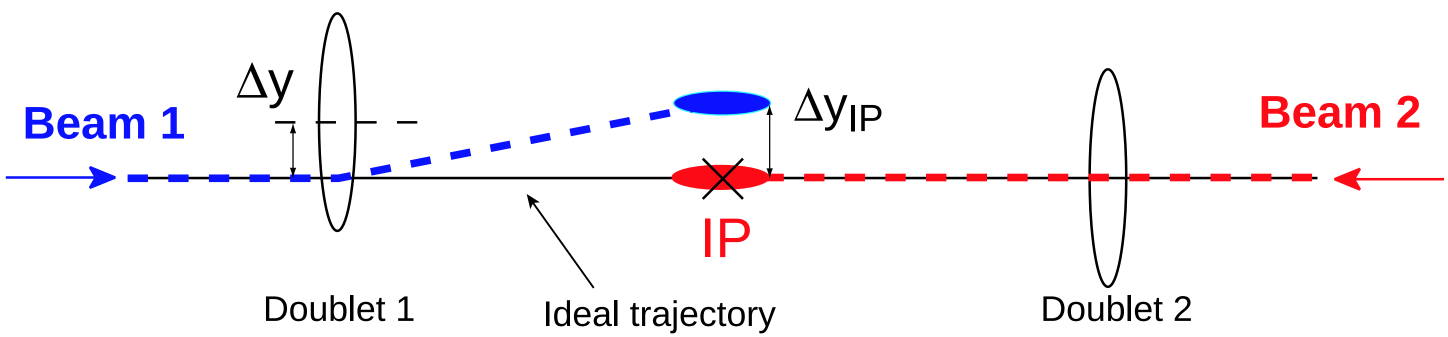
Overview of my talk:

1. **Introduction**
2. **How to measure with sub-nanometer accuracy?**
3. **How good can we stabilize accelerator magnets?**
4. **What luminosity is predicted for CLIC?**
5. **Conclusions**

1. Introduction

CLIC: Collide 1.5 TeV beams (e^+e^-) with transverse spot sizes of **55 nm x 0.7 nm**

- **Sub-nm spot size vertically!**
- **Final doublets must be stable to ~ 0.2 nm.**



$$L \approx L_0 e^{-\frac{\Delta y_{\mathrm{IP}}^2}{4\sigma_y^2}}$$

If the stability goal is not achieved, there is a **loss in the luminosity reach**!

… these tolerances seem extremely tough (we are usually fighting against μm vibrations…)

CLIC Stability Study:

Bring **modern stabilization technology** to the accelerator field.

Successfully used in other field (e.g. TEM’s, microchip production…).

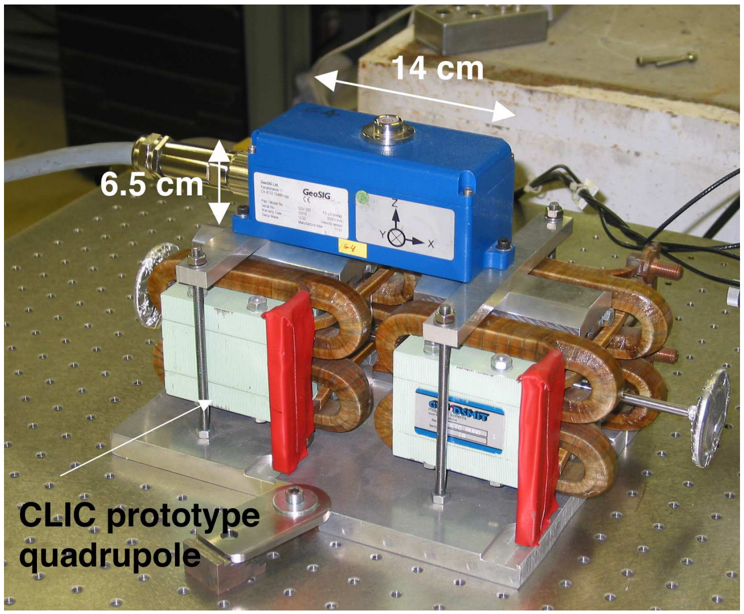
Goals of the 1st phase of our study:

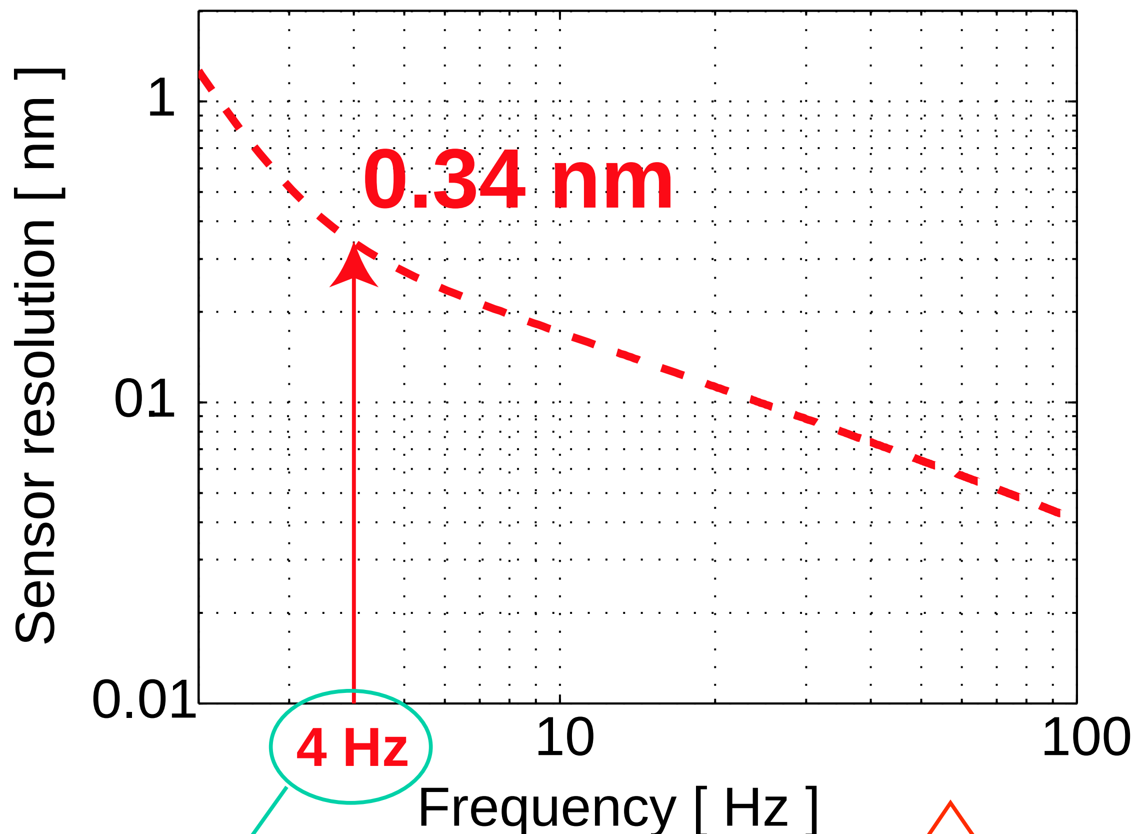
- Establish vibration measurements with sub-nanometer accuracy.
- Investigate modern techniques for the stabilization of accelerator magnets.
- Predict the time-dependent luminosity performance of CLIC with the measured quadrupole stability.

2. How can we measure with sub-nanometer accuracy?

Triaxial **geophones**

(Measure velocities in the 4Hz - 315 Hz frequency range)





4 Hz is an important frequency for us!

Motion of the quadrupole **ABOVE 4 Hz** must be **stabilized mechanically**.

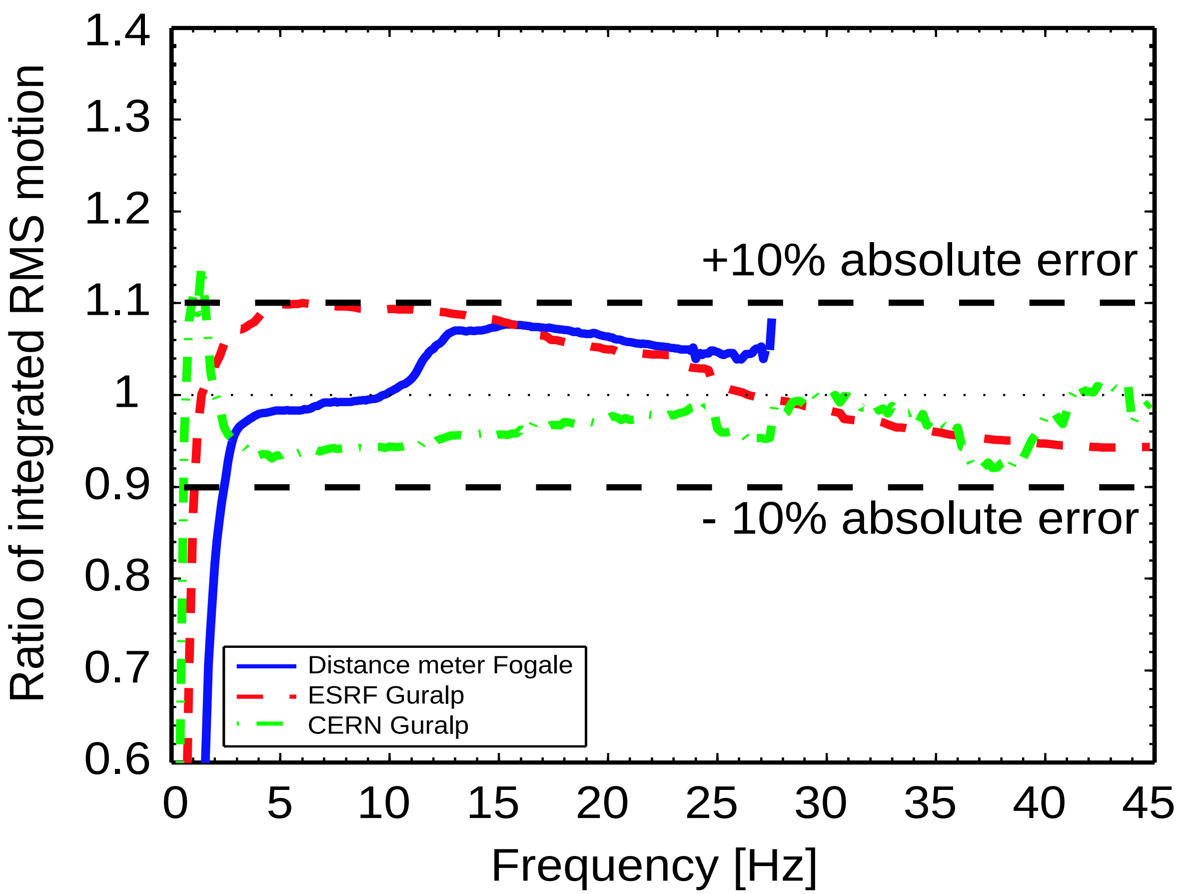
(slower motion is efficiently corrected by beam-based feedback systems).

Resolution measured as difference between two sensors placed side-by-side.

Why do we believe that 1 nm is *really* 1 nm?

Our geophones **compared** with other sensors for vibration measurements:

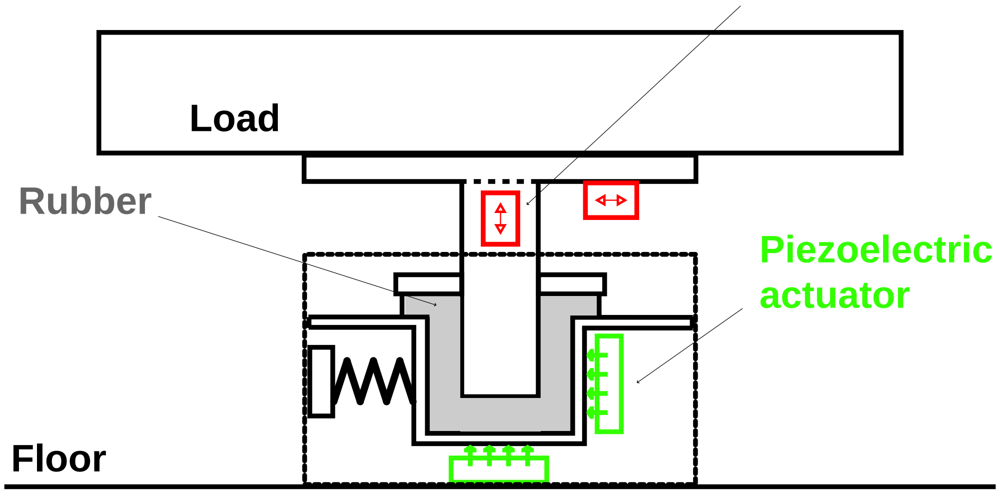
- Geophones from other manufacturers.
- Geophones used in other laboratories (in collaboration with L. Zhang, ESRF).
- Capacitive distance meter.



* Comparison also with sensors from **Desy** - No results here. (Collaboration with W. Bialowons, H. Ehrlichmann)

We believe that 1 nm is 1 nm within 10 %!

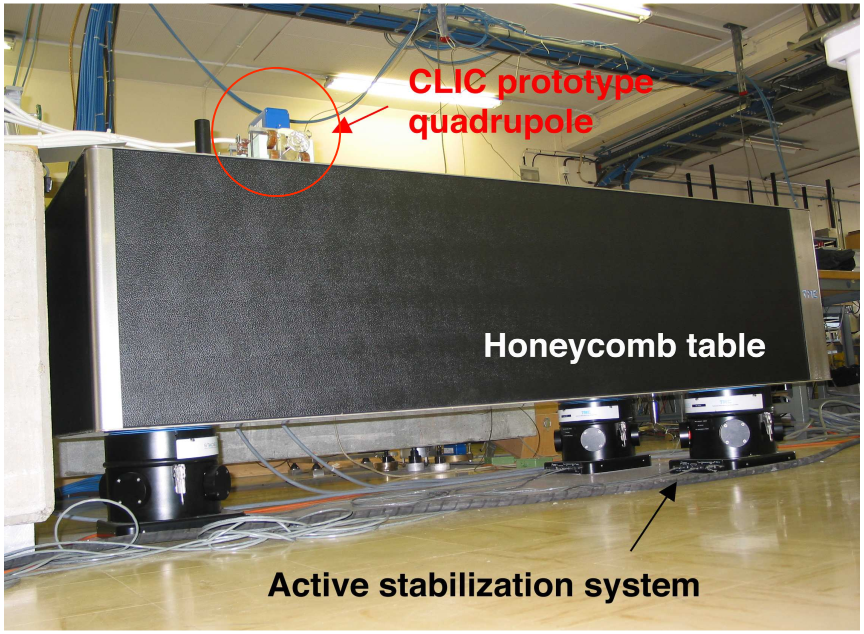
3. How do we stabilize accelerator magnets?

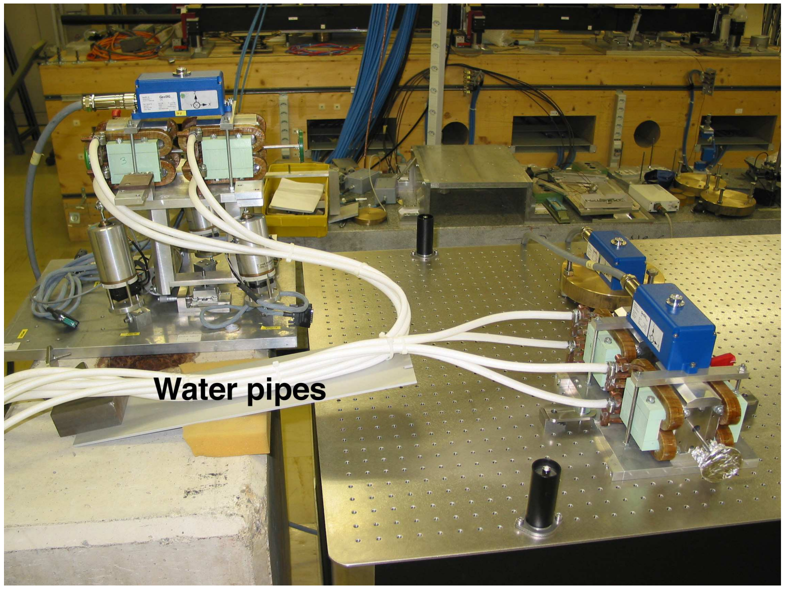


Stacis2000 by TMC:

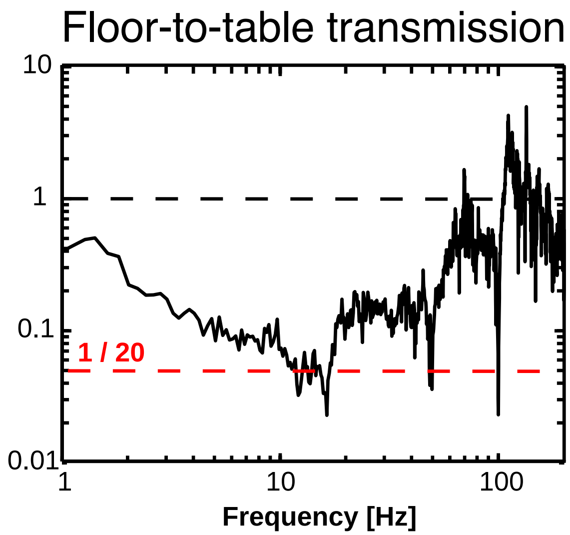
Passive+active stabilization system based on **geophones** to measure vibrations and on **piezoelectric actuators** to correct them.

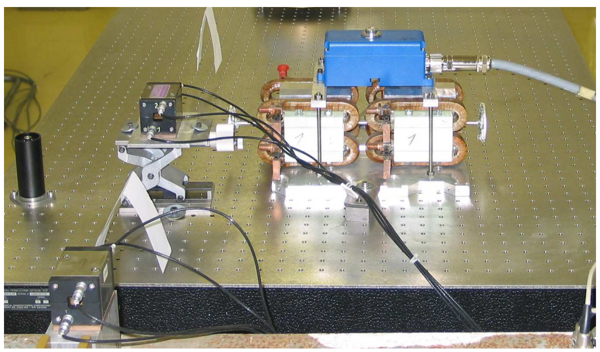
4 independent feet stabilize an honeycomb table.

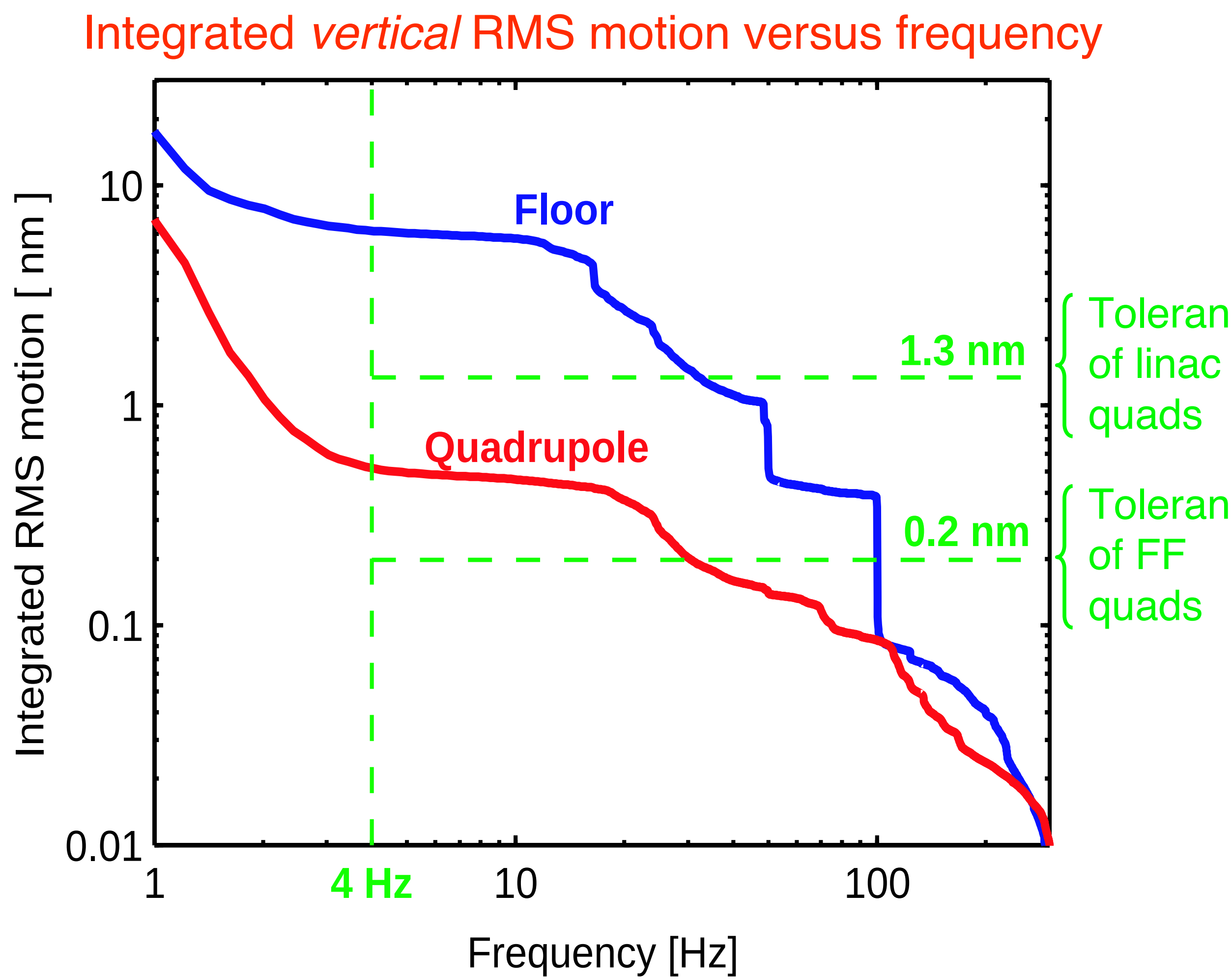




Vertical stabilization of a CLIC prototype quadrupole





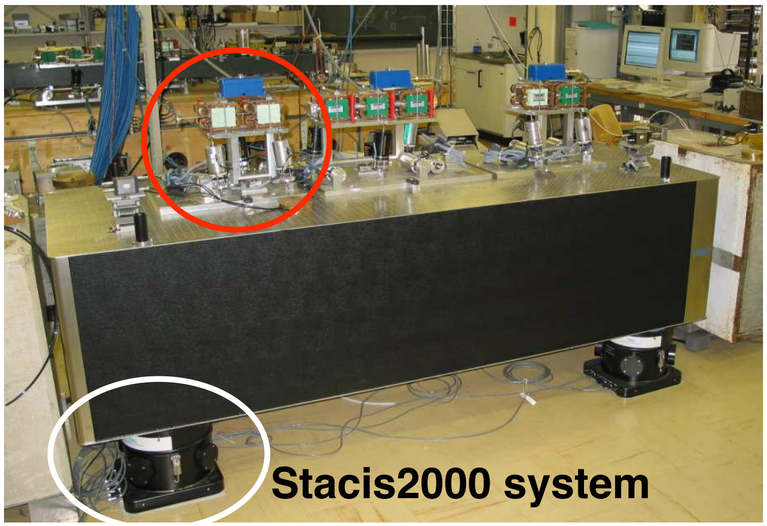


CLIC prototype magnets stabilized to the sub-nanometer level !!

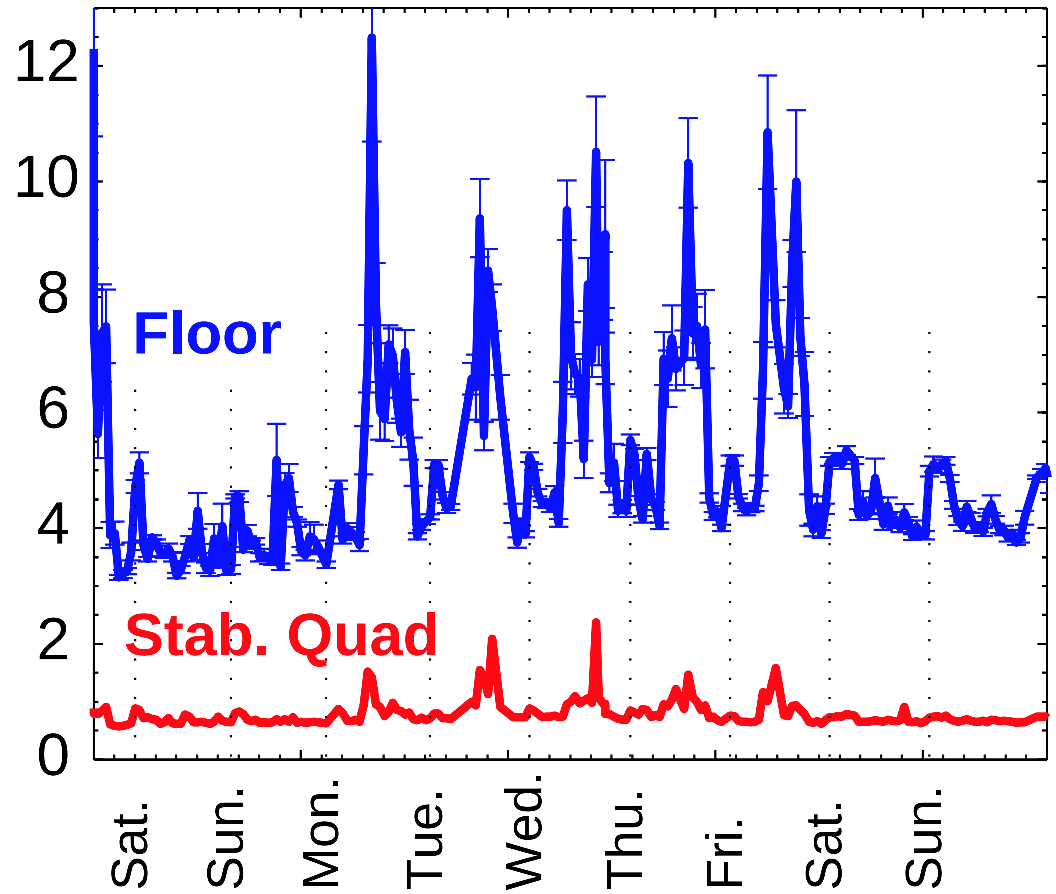
Above 4Hz: **0.52 nm** on the quadrupole instead of **6.20 nm** of the ground.

Ok, this is good. But is it ***stable***?

Honeycomb table used as a girder to support three prototype quadrupoles on their alignment support structure



Integrated RMS motion **above 4 Hz** [nm]



Note: Results on not-optimized CLIC alignment support structure.

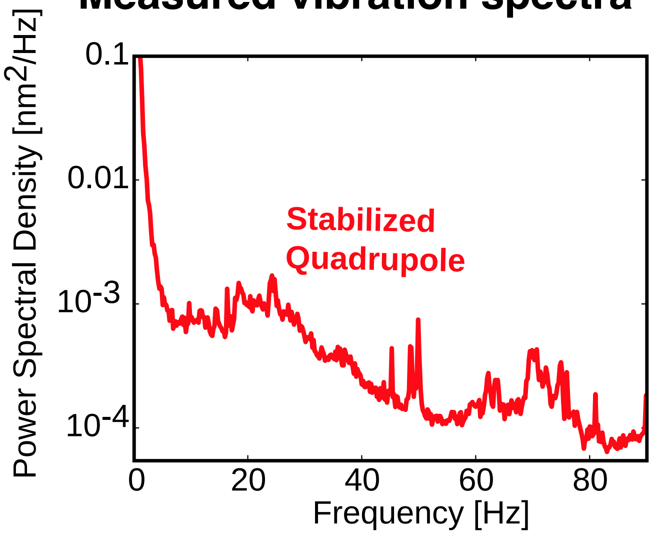
Average: **0.7 nm** instead of 0.5 nm.

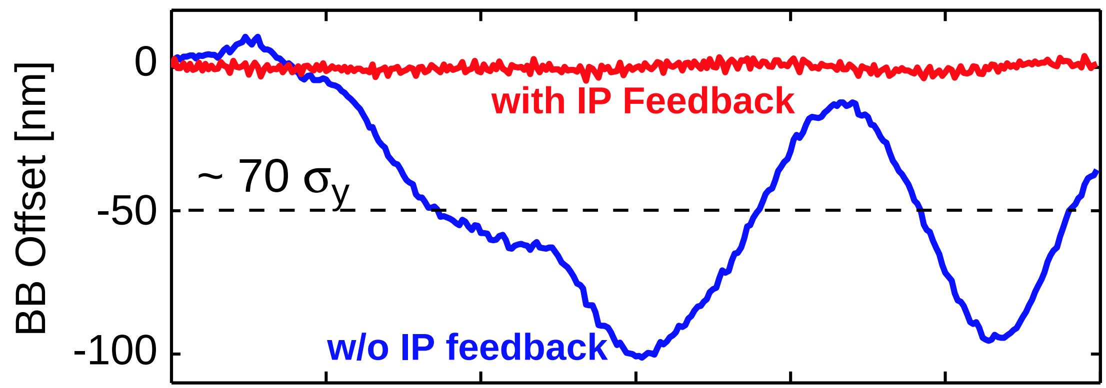
Cultural noise greatly reduced!!

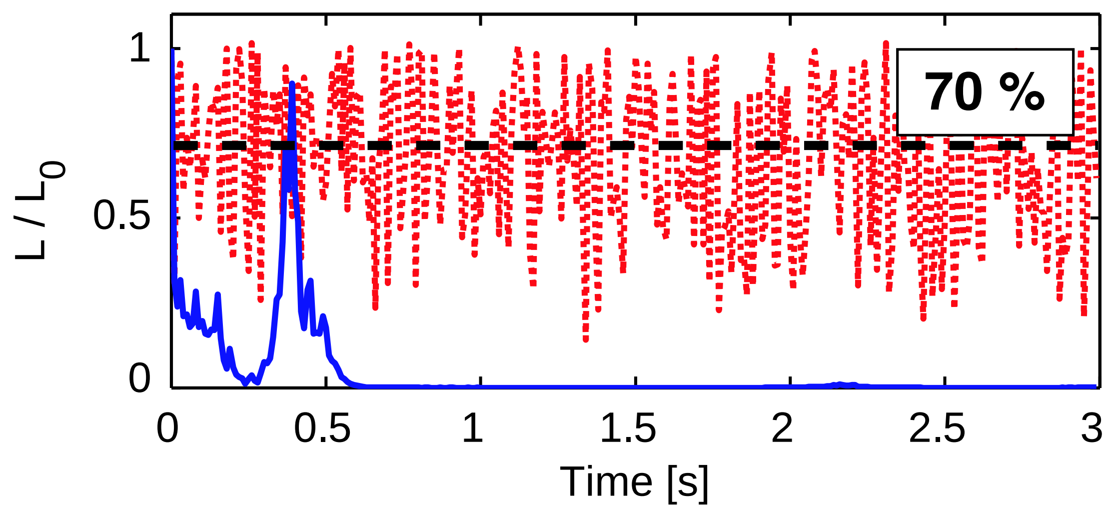
(Normal CERN working area on the ground floor of a multistore building.)

4. What luminosity can we get with measured quad vibrations?

Measured vibration spectra







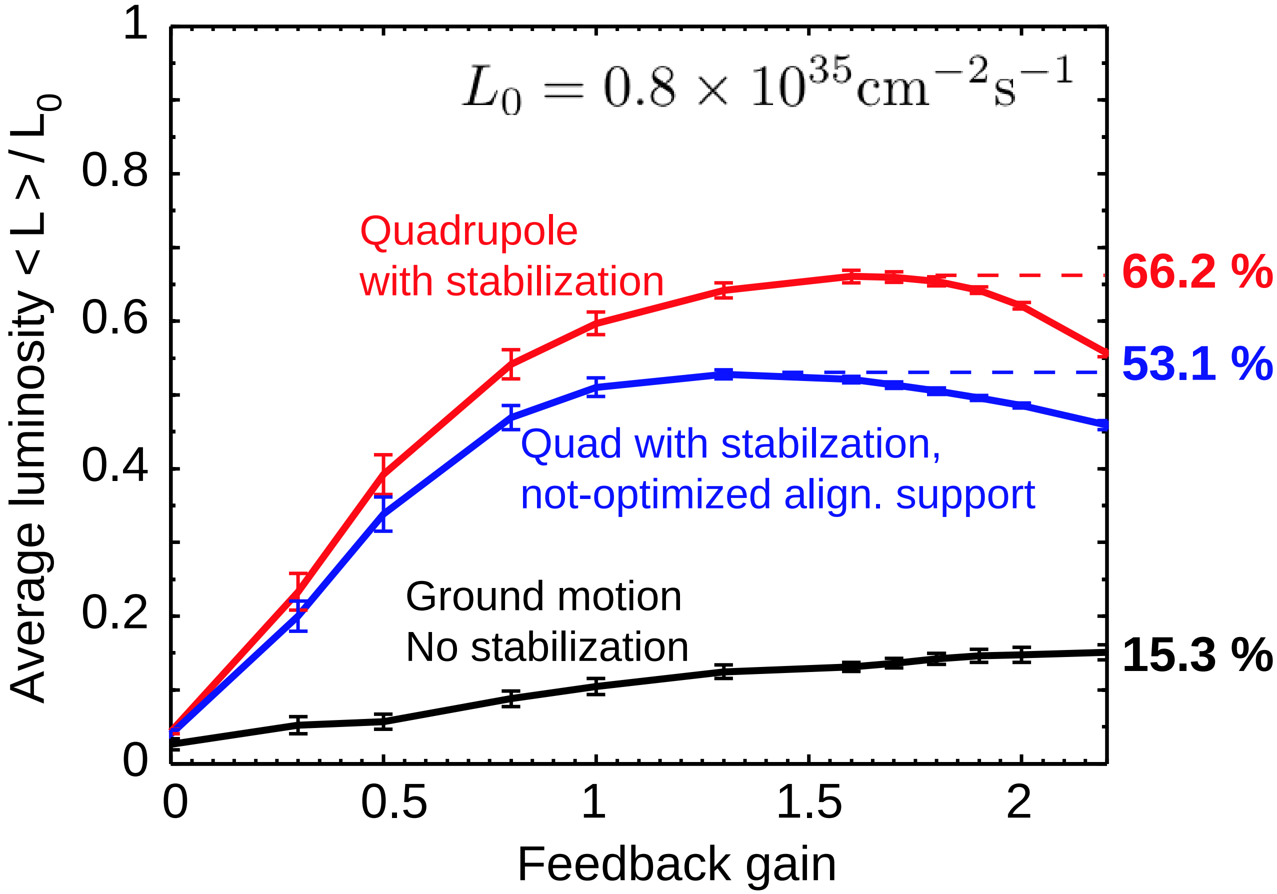
- **Measured spectra to move quads.**
- Two-beam simulations.
- Tracking with **`Merlin`**.
- BB with **`GuineaPig`** (lumi and angle).
- Feedback for correction of IP offset.
- Horizontal direction not critical.

~ 70 % of the luminosity maintained

with stabilization + IP feedback!

Luminosity performance with / w/o stabilization and feedback

- Average luminosity over three seconds of CLIC operation (300 pulses).
- Uncorrelated motion of the Final Doublets (left and right of IP).
- Scan of feedback gain to obtain the best luminosity performance.



Large improvement with respect to the floor motion if quad is stabilized!

(66 % of the design luminosity instead of 15 %).

5. Conclusions

- **Basic feasibility of colliding nanobeams for CLIC demonstrated!**

  1. CLIC prototype quadrupoles stabilized vertically to the **0.5 nm level** in a normal CERN environment.
  2. Vibrations in horizontal plane acceptable - Luminosity ≥ 95 %
  3. Some further improvements are required (water induce vibr., support, …)
  4. *However:* already **70 %** of the design CLIC luminosity can be obtained with the present technology (in CERN working environment!!).

- **Outlook**

  Proper design of the quadrupole alignment support structure.

  Further optimization of stabilization system performance.

  Integrated the installation into the detector region.

Members of the CLIC Stability Study Group:

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