tolerance on LHC orbit stability is tight:

- 16 μm IP spot size
- random jitter tolerance for beam-beam offset (from turn to turn) ~0.6 nm! for 1%/hr emittance growth

quadrupole motion creates beam-beam offset

- 2 separate rings with asymmetric IR optics

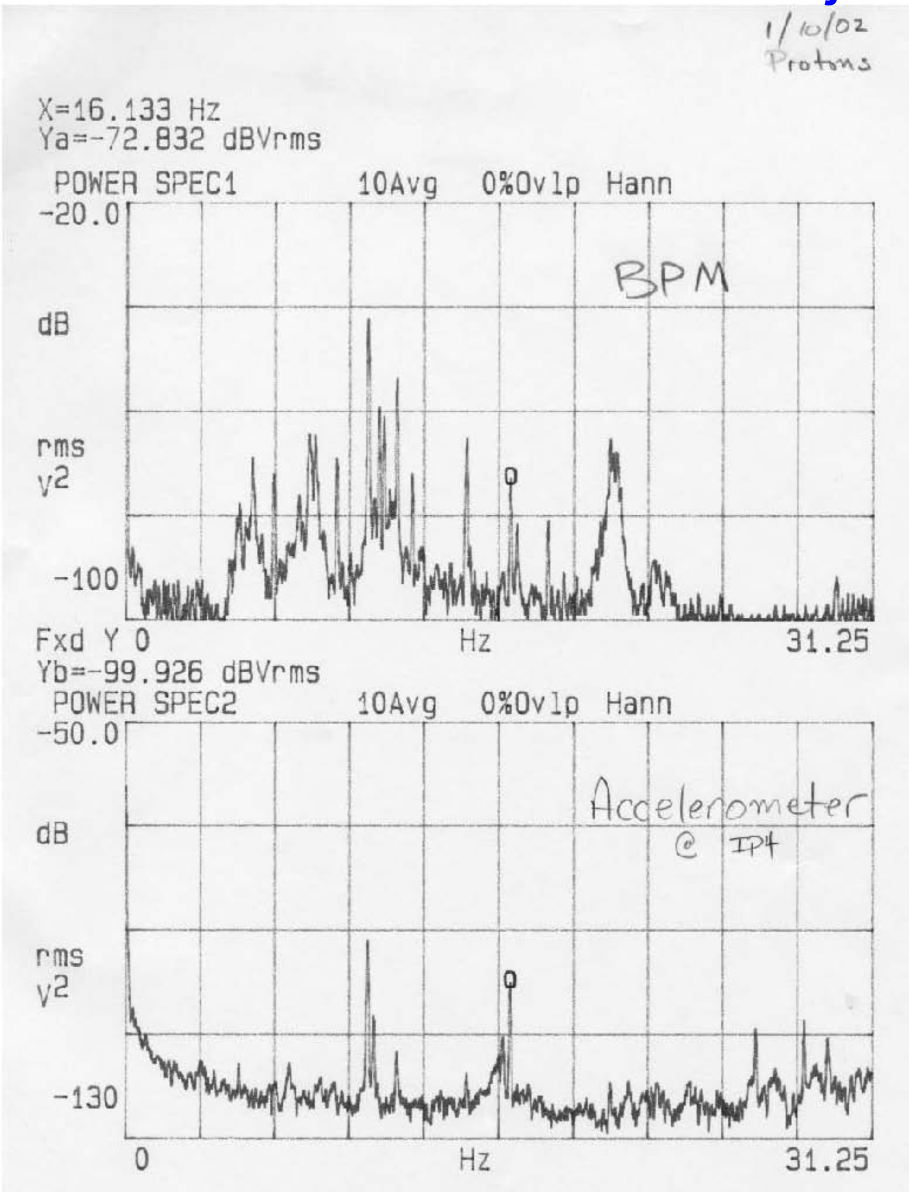
typically, amplitude of beam motion
> 10 x amplitude of quadrupole motion

estimate of emittance growth would require (even rough) data on quadrupole motion amplitude & frequency spectrum

Christoph Montag

RHIC beam jitter & magnet vibrations

Spectra of horizontal beam and triplet motion (IP 4 triplet):

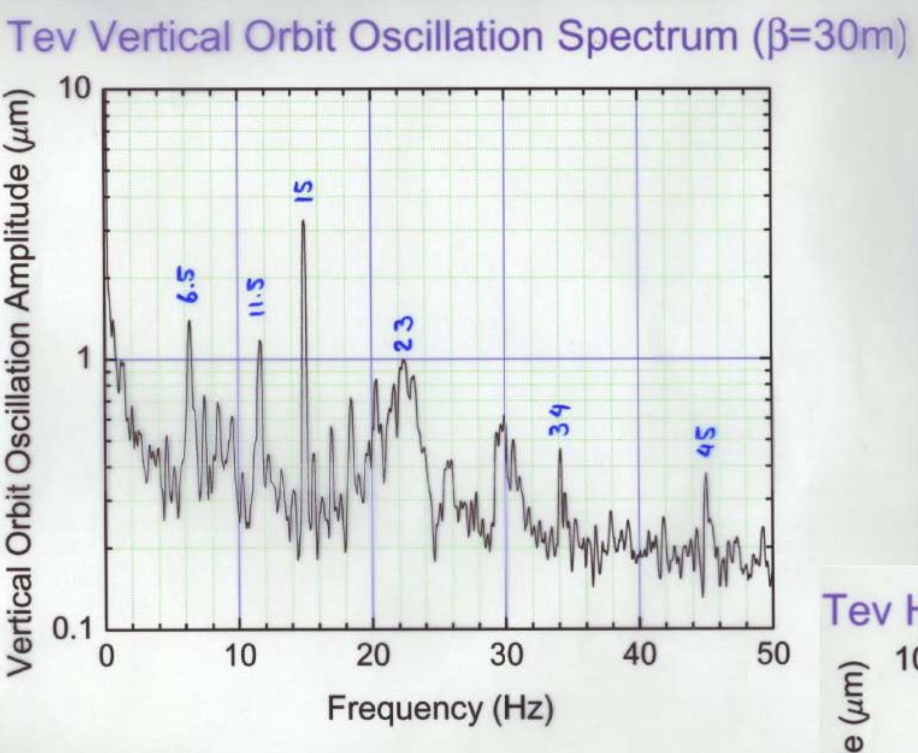


IR triplet vibrations have been identified as source of beam motion around 10 Hz

vibration of cold masses within the cryostat at ~10 μm level rather than vibration of triplet as a whole

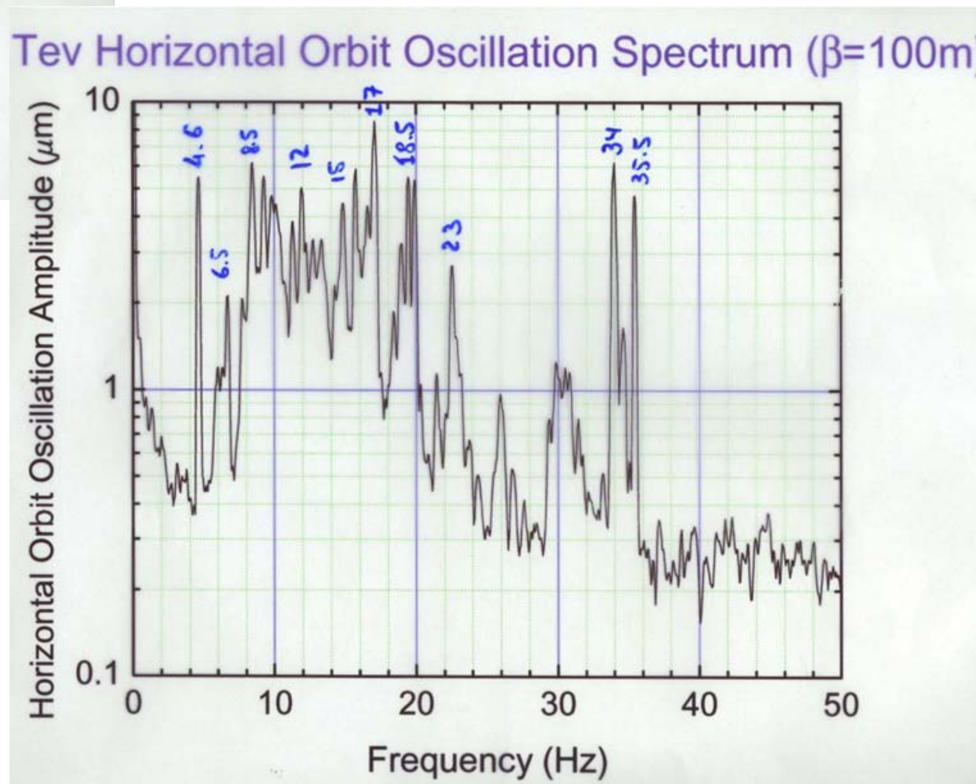
modulated beam-beam interaction causes emittance growth at start of each store

Vladimir Shiltsev



Tevatron fast beam motion

low-β quad vibration frequencies
-CHL compressors
-stand resonances
beam/quad amplitude >10

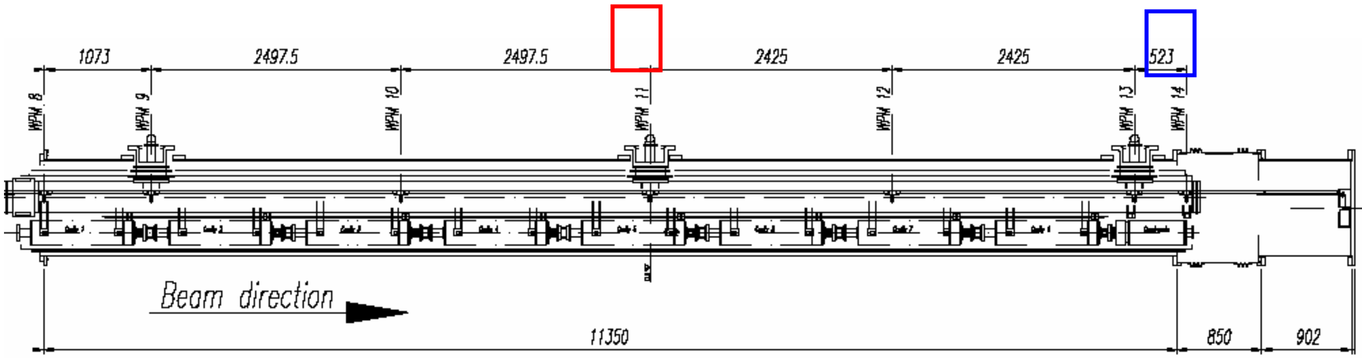


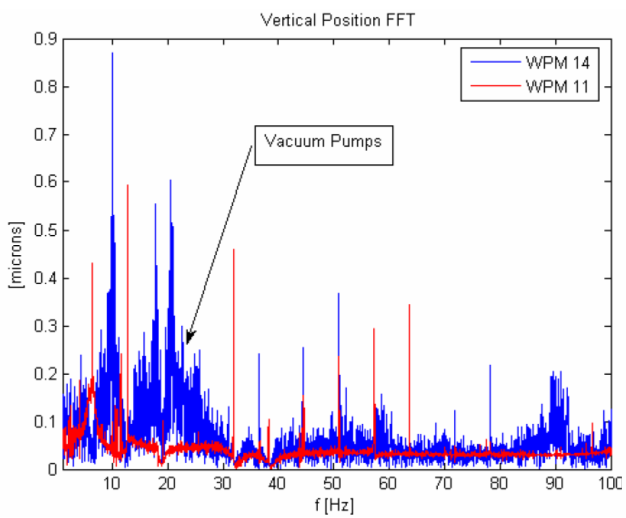
should we initiate a measurement of vibration levels in an LHC (e.g., low-β) quadrupole?

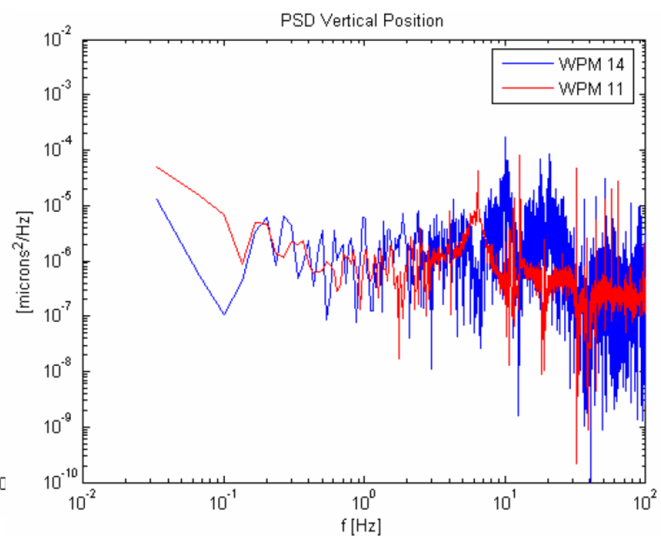
measurements of cold-quadrupole vibrations were done for ILC by three teams using three different instruments

WPM to measure ILC cryomodule vibration

- A. Bosotti et al. [PAC2005]: use of WPM (wire position monitors)
  - difficult task, complicated by vibration of wire
  - Qualitatively, observed less motion near the support post
  - Data are preliminary
  - Normalization?
    - e.g. blue at 10Hz 0.9 μm left plot ~14nm right plot



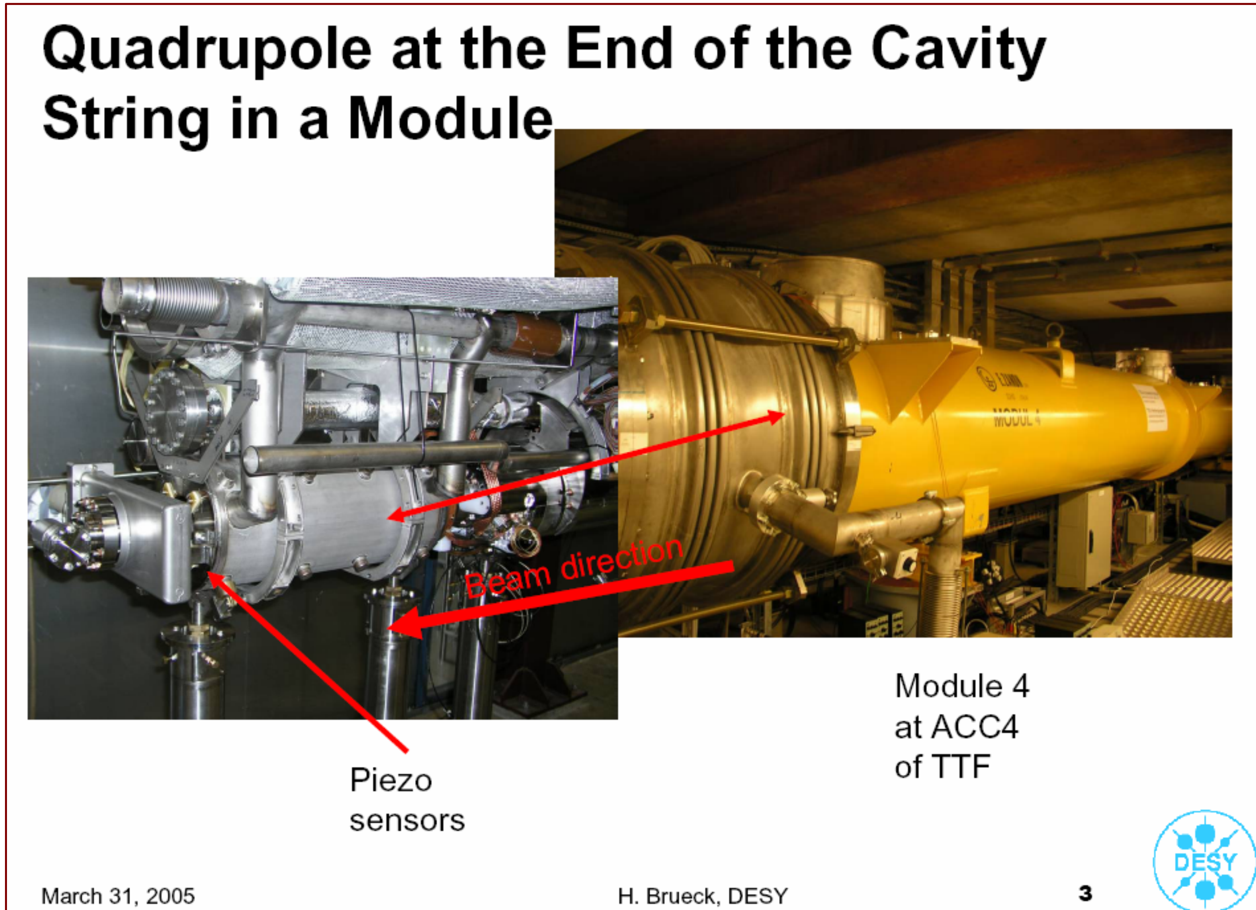




A.Bosotti et al., PAC2005

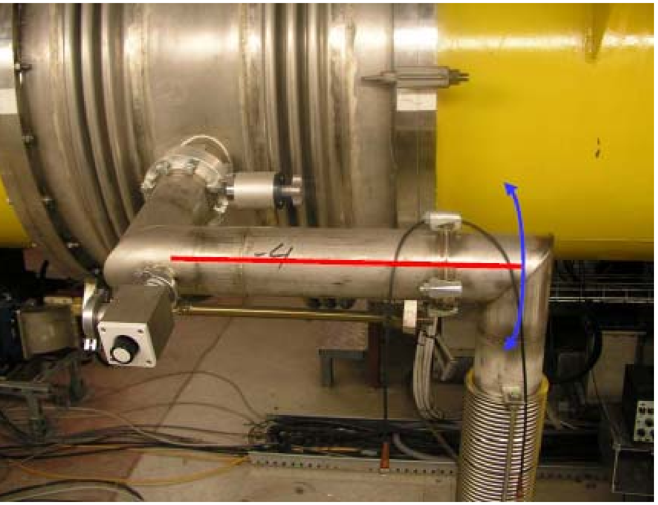
Vibration study at TTF in cold

- Heiner Brueck et al., TESLA Meeting, Hamburg 03/31/2005
  - Piezo sensors (cold) at the quad, in X and Y directions
  - Sensors on top of the module, on ground, support, +geophone



Heiner Brueck, et al.

TTF vibration study – pump modification



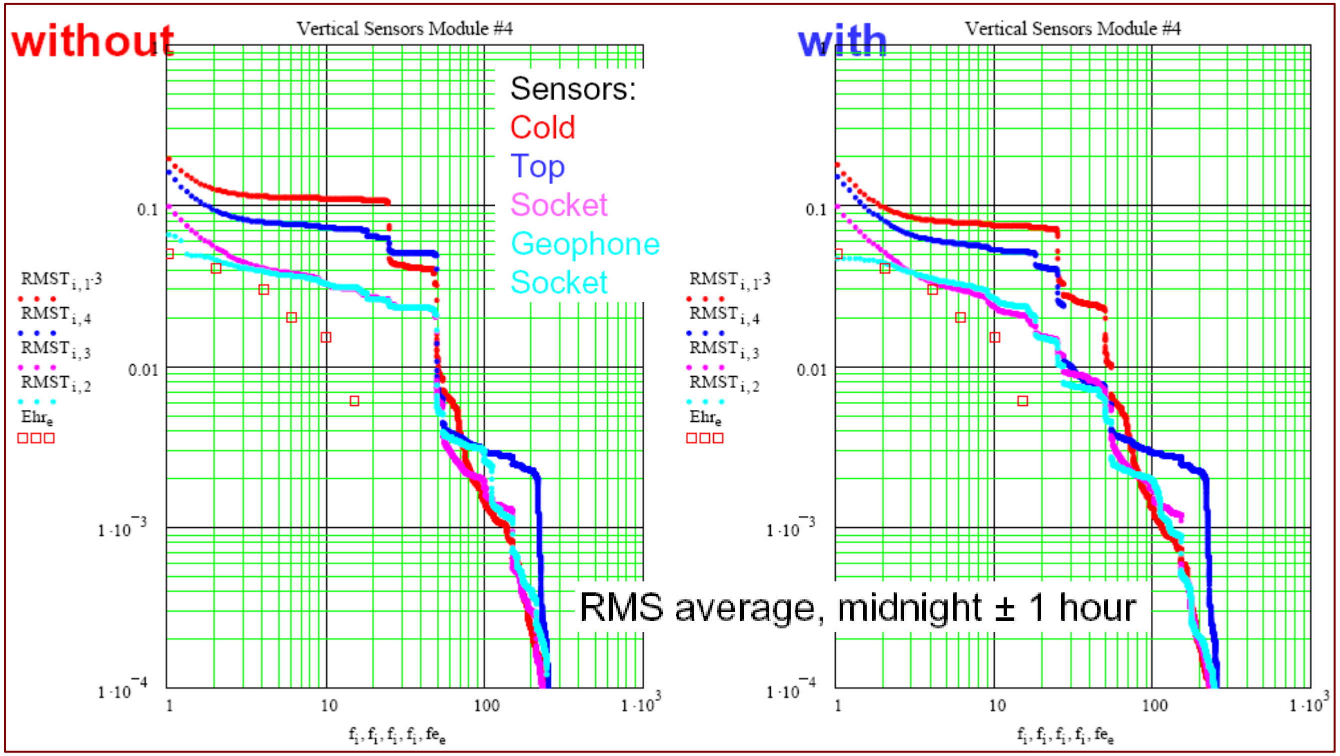
- Decouple pump from cryomodule, use flexible pipe and fo
pump

Heiner Brueck, et al.

Nanobeam'05 ***Andrei Seryi***

TTF vibration study – vertical

- With or without pump modification => improvement
- Quad vibration about 3 * tunnel
- Low f – noise of electronics
- Horizontal motion about twice larger
- Also studies forced vibration of HERA dipole cryostat – observed strong (*10) resonance at 14.5 Hz



Heiner Brueck, et al.

- Midnight data may be close to XFEL goal, overall may need up to a factor of 2 improvement to reach 0.1σ stability goal at XFEL (not relying on feedback)
- For ILC would need factor of several improvement

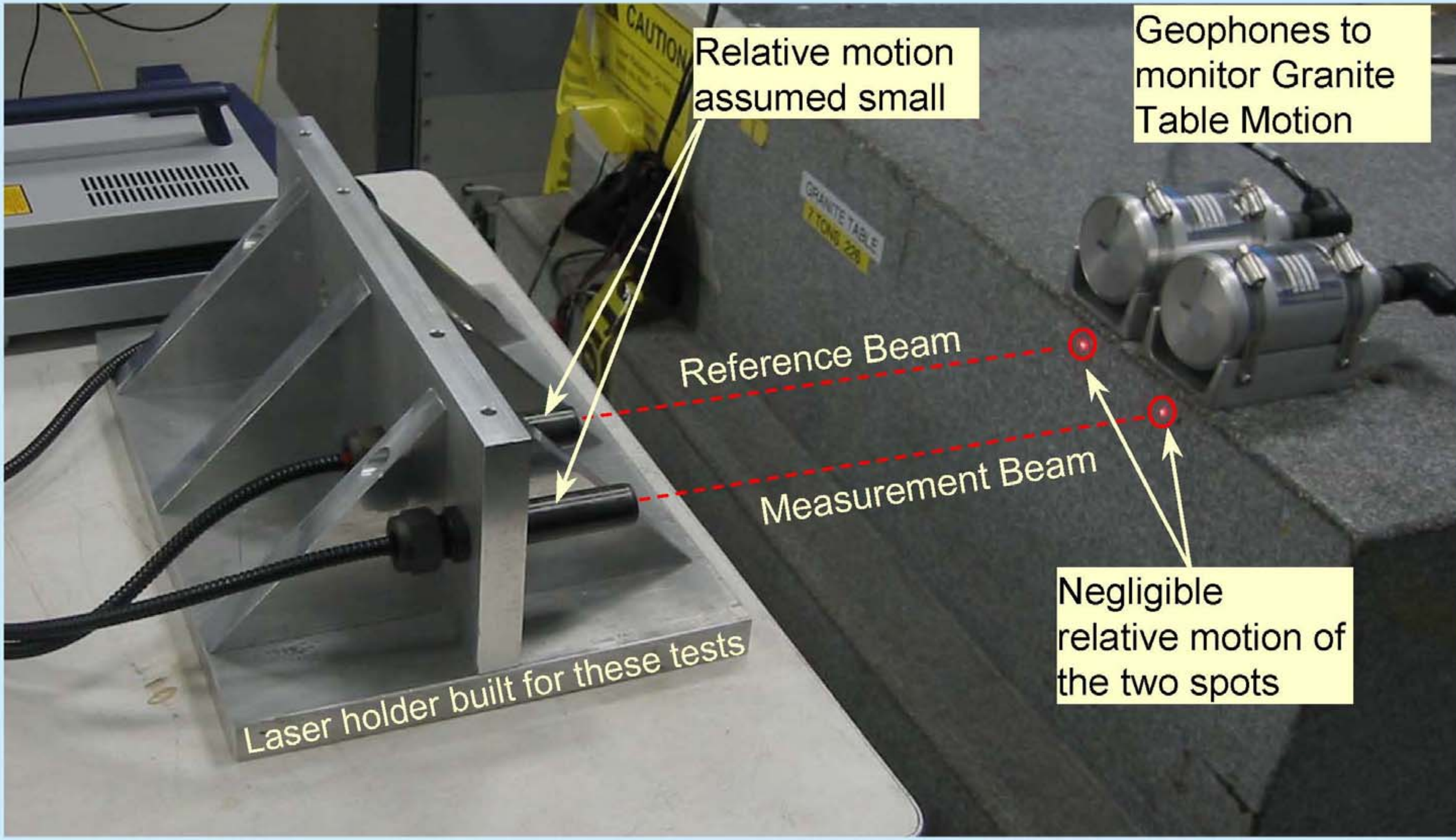
Andrei Seryi

Nanobeam'05

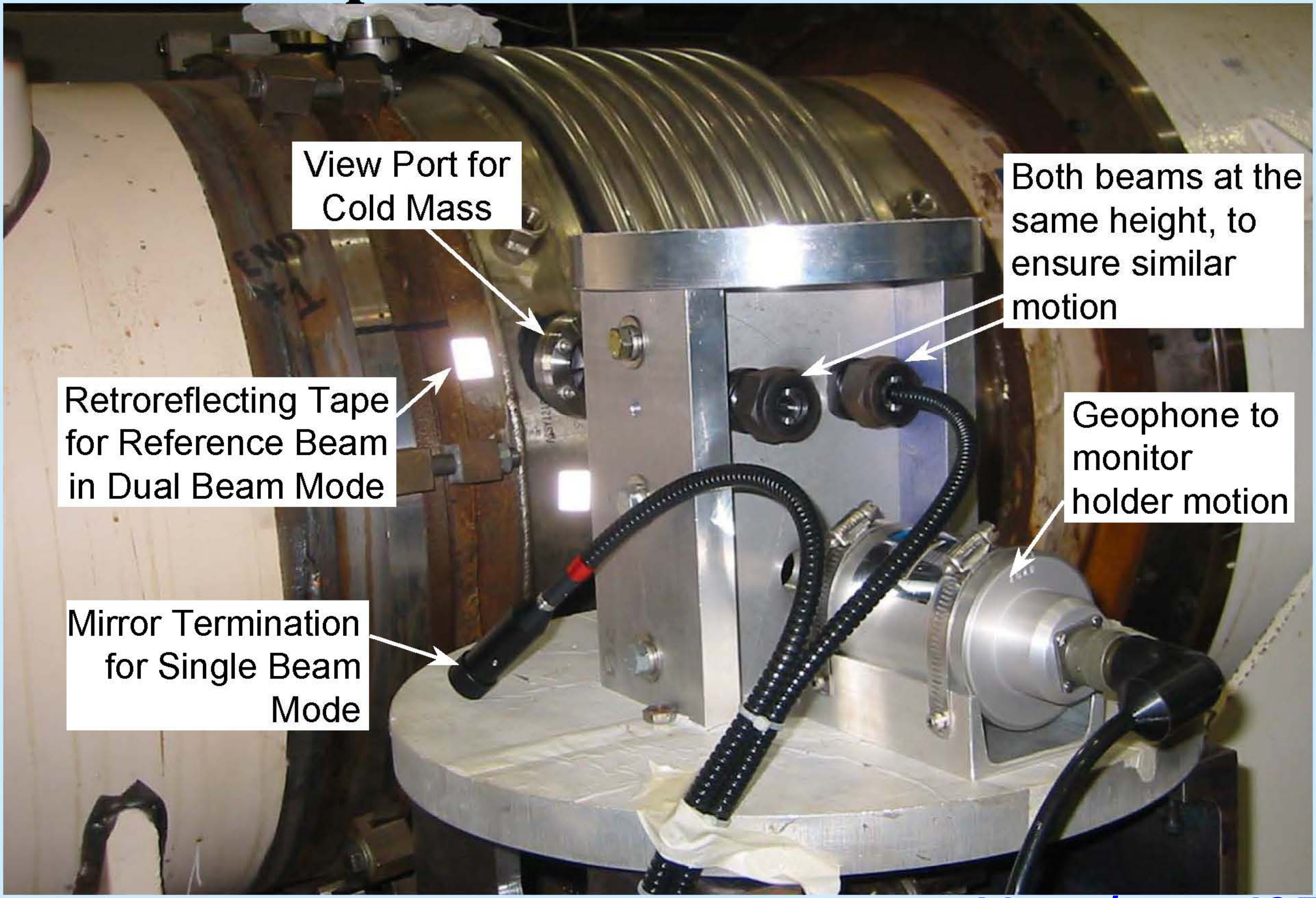
Suitability of Laser Vibrometer

- Motion is measured by the Doppler shift in frequency of a laser beam bounced back from the object.
- Non-contact method – suitable for tight spaces.
- No parts are installed on the object – suitable for cryogenic environment and in magnetic field.
- Has the necessary resolution ~ nm at low frequencies.
- Some drawbacks:
  - Requires "line of sight" to the object (add viewports)
  - Measurements are sensitive to the motion of the laser head itself:
    * Use a dual beam fiber optic laser head (diff. meas.)
    * Many iterations of the laser holder design.

Performance Tests: Dual Beam Mode

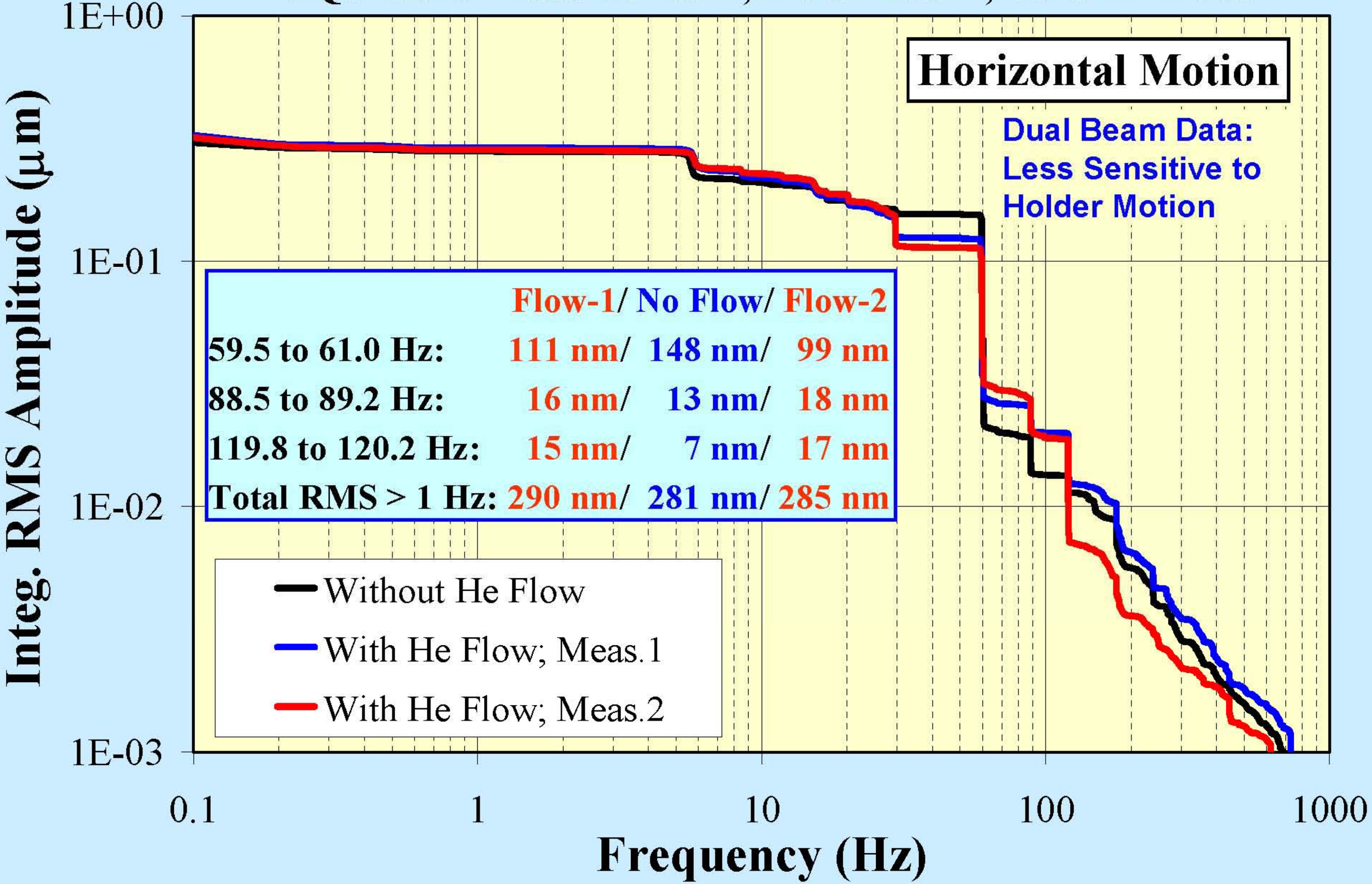


Laser Set up for Horizontal Measurements



Animesh Jain

CQS Cold Mass at 4.5K; Dual Beam; 08-SEP-2005



appendix:

formula for emittance growth with random beam-beam offset

emittance growth from noise

including decoherence & feedback (Y. Alexahin):

$$\frac{1}{\varepsilon}\frac{d\varepsilon}{dt} \approx f_{rev} \frac{1-s_0}{4} \frac{(\Delta x)^2}{\sigma_x^2} \frac{1}{\left(1+\frac{g}{2\pi|\xi|}\right)^2}$$

g~0.2 feedback gain, ξ~0.01 total beam-beam parameter, s_0~0.645 related to the fact that only a small fraction of the energy received from a kick is imparted on the continuum eigenmode spectrum

1% emittance growth per hour
↔ Δx=1.5 nm with feedback
↔ Δx=0.6 nm w/o feedback