Jitter stability requirements and stabilization schemes for Warm / Cold LC

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IP jitter and its control in Warm LC

- Sources of IP beam jitter
  - linac quad jitter; BDS quad jitter; FD jitter, …
- IP beam stability is provided when
  - ground motion is sufficiently small
  - linac and BDS quads are engineered to be stable and local noise sources (cooling water, etc.) are controlled
  - the FD is actively stabilized
  - (or) efforts are made to make detector more “quiet”
  - train-to-train feedback fixes “slower” IP jitter
- Measures listed above should allow achieving nominal luminosity
  - as additional line of defense, FONT is being developed that would recover most (~70-80%) of luminosity if other systems work less than perfect

FONT = Feedback On Nanosecond Time scale

IP jitter and its control in Cold LC

- Sources of IP beam jitter
  - linac quad jitter; BDS quad jitter; FD jitter, …
- Approach to IP jitter control is different :
  - fast intra-train feedback can in principle recover almost all luminosity and was considered the only needed system
- Consequently, requirements to
  - ground motion; linac and BDS quads jitter and FD

will be determined not from IP jitter, but from diagnostic performance and emittance preservation

Warm LC: Jitter requirements

- Require total vertical jitter at the IP be less than 50% of beam size, with contribution
  - roughly 30% from each Linac, BDS and FD
- Main linac: 30% of jitter would be caused by 12nm jitter of linac quads
  - below will see feasibility studies and prototyping ...
- BDS quad jitter stability requirement is similar: 5nm or 12nm with 2nm on a few quads
  - can be achieved naturally ...
- FD jitter stability needed is about 0.5nm
  - active stabilization needed and being developed ...

Cold LC: Jitter requirements

- In spite of large capture range (10s of σ) of fast feedback, require that vertical jitter at the linac exit is < 100% of σ
  - Needed to minimize $\Delta\varepsilon/\varepsilon$ due to collimator wake-fields (see PT's talk)
  - and to provide acceptable conditions for beam diagnostics
- This 100 % jitter in the Main linac would correspond to about 80nm jitter of linac quads
  - below will see feasibility studies and prototyping ...
- BDS quad jitter requirement is similar to that of Warm LC
  - More discussion in the following Tor's talk ...
- FD jitter is much less relevant, ~100nm should be OK
  - No active stabilization is needed

Next we will discuss:

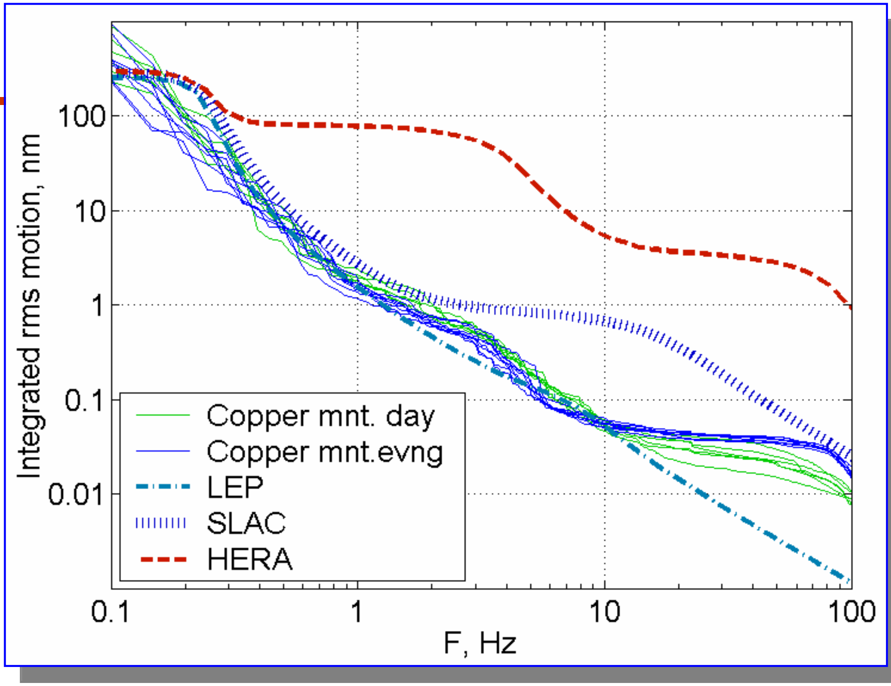
- In the following slides, will discuss
  - sources of jitter and methods of jitter control in Warm LC
  - sources of jitter in Cold LC linac
  - Scenarios “something does not work” in Warm LC
- The following
  - FONT (warm LC intratrain Feedback On Nanosecond Time)
  - The Cold LC intratrain feedback, and its feasibility

  will be discussed in the next talks

Warm LC: Jitter control demonstrations and R&D

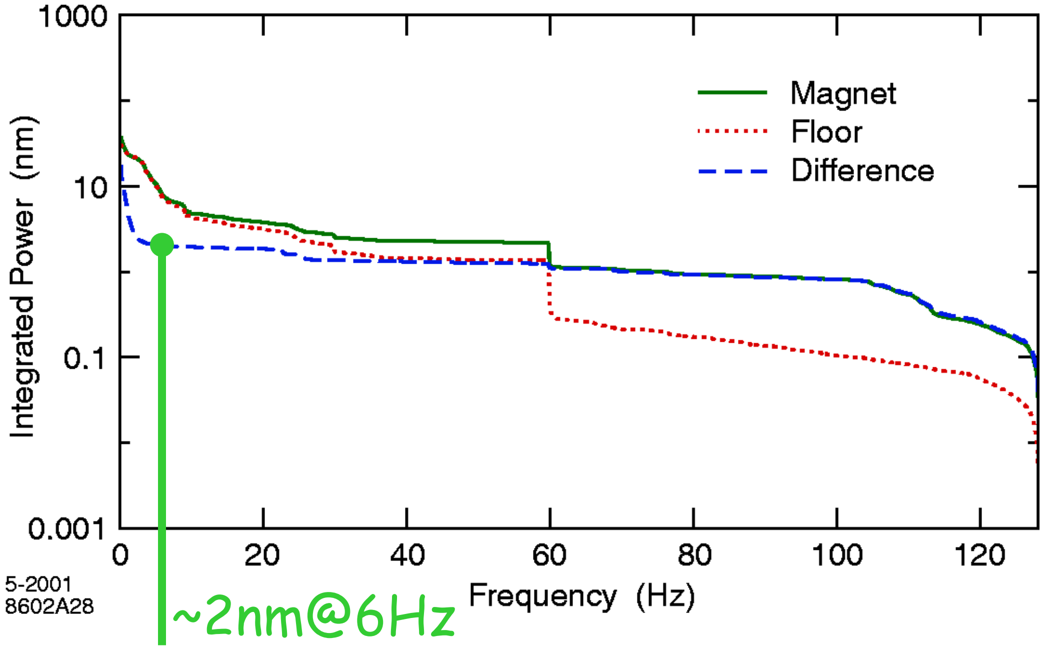
Quiet Sites

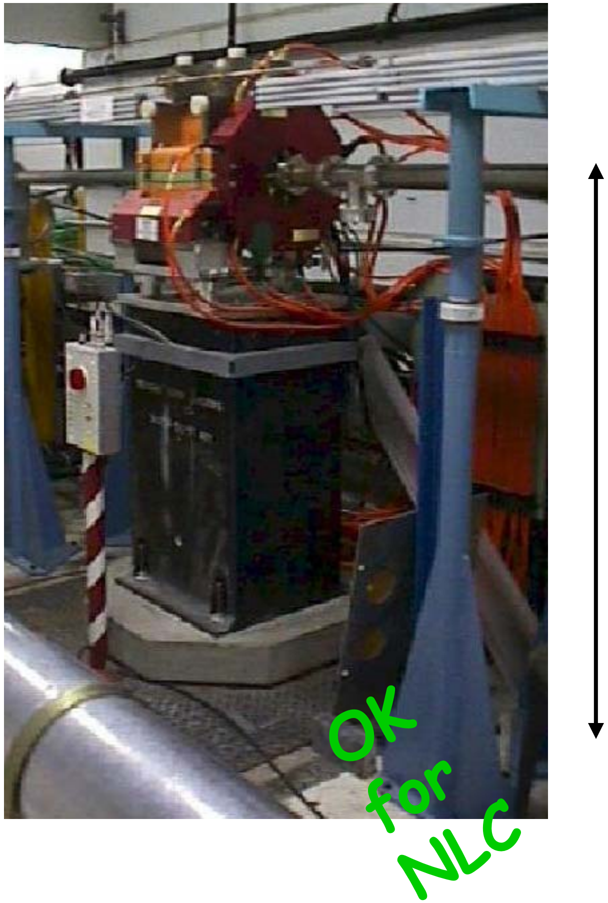
- Many sites have been identified and studied that exceed Warm LC stability requirements
  - ❖ e.g. sites in vicinity of SLAC and Fermilab
- These sites also possibly satisfy future multi TeV LC (tighter) stability requirements



DESY and SLAC colleagues on the way to Copper mountain site, CA (historical TESLA town is on the background)

Warm LC: Jitter control demonstrations and R&D
Stability of BDS and BC quads

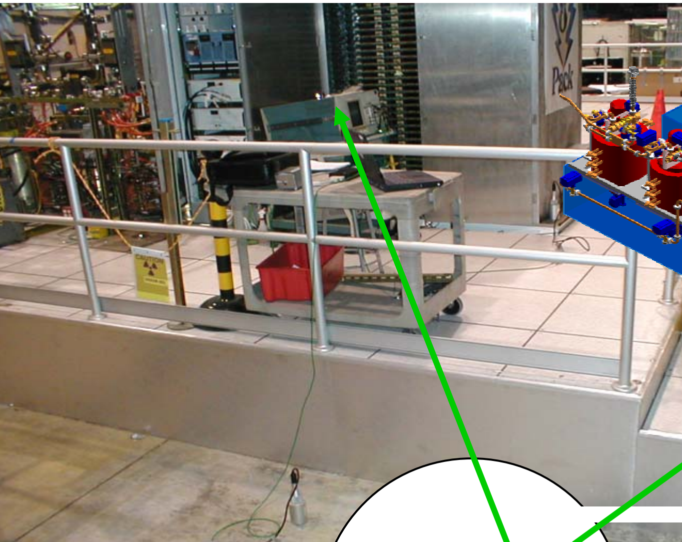


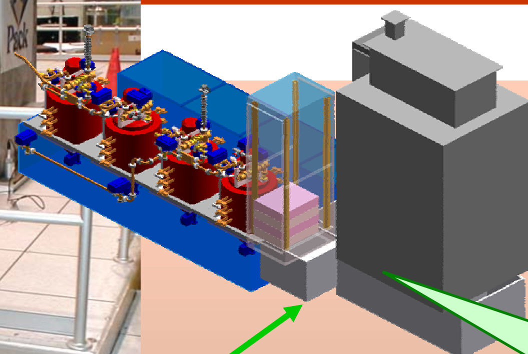


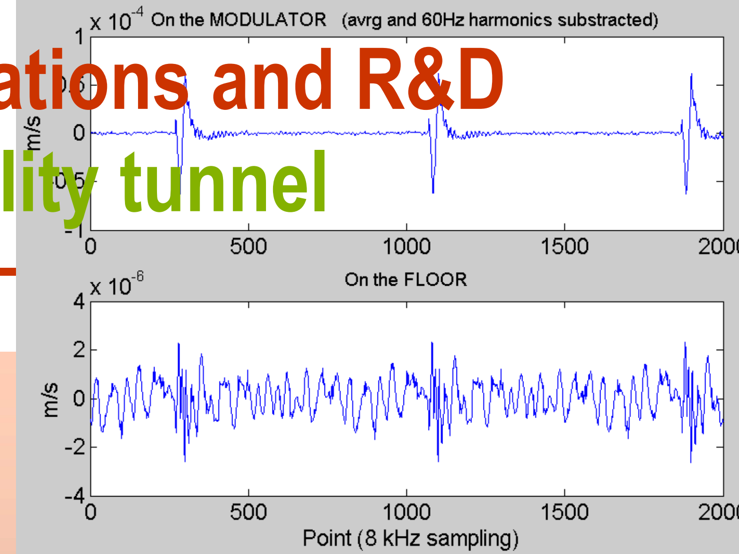
- FFTB quad
  - Only ~2nm difference to ground (on movers, with water flow, etc.)
  - Note that even absolute ~8nm in poor FFTB tunnel is OK
  - Applicable to most of BDS and BC quads in Warm (and Cold) LC

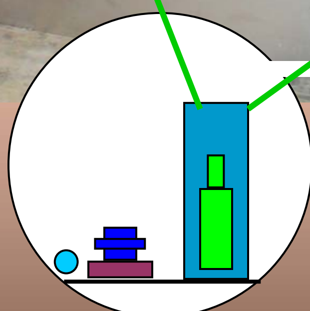
Warm LC: Jitter control demonstrations and R&D

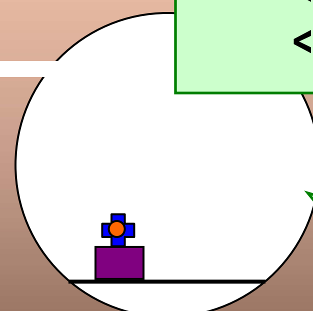
Stability with noises from utility tunnel





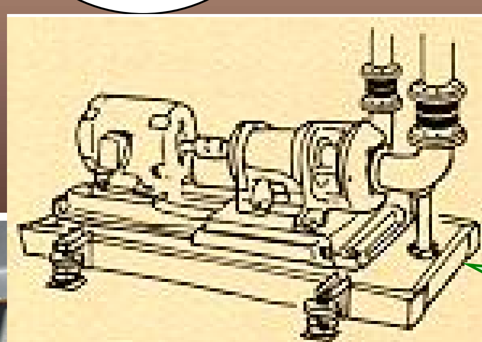






Measured vibration due to modulator pulses:
< 120nm on the modulator
< 2 nm on the floor, peak to peak

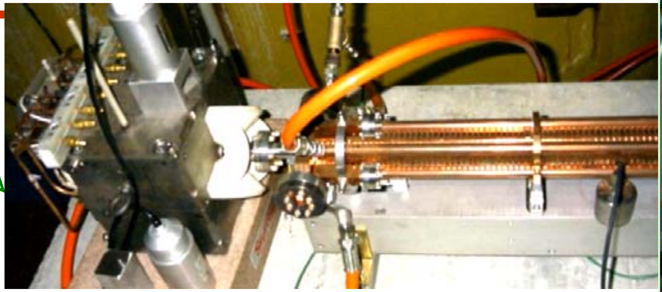
Transmission between tunnels was measured in LA metro in similar twin tunnel configuration

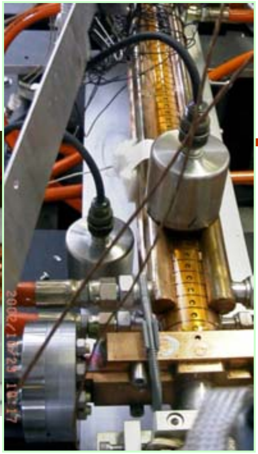


Estimation of mechanical nose due to cooling systems: 1-3nm if placed on 3Hz spring supports (common practice, e.g. successfully used at LIGO) will be further modeled and experimentally tested

Warm LC: Jitter control demonstrations and R&D

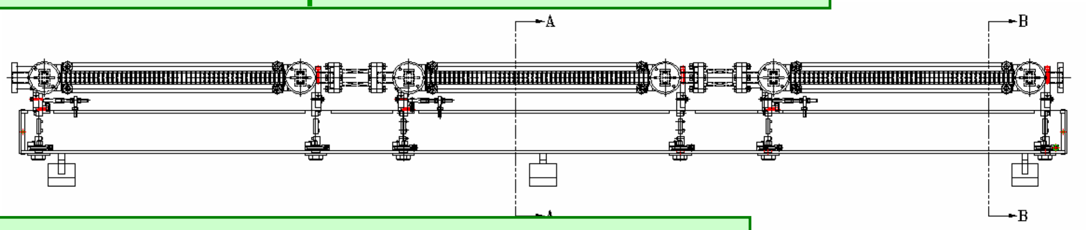
Stability with on-girder noises

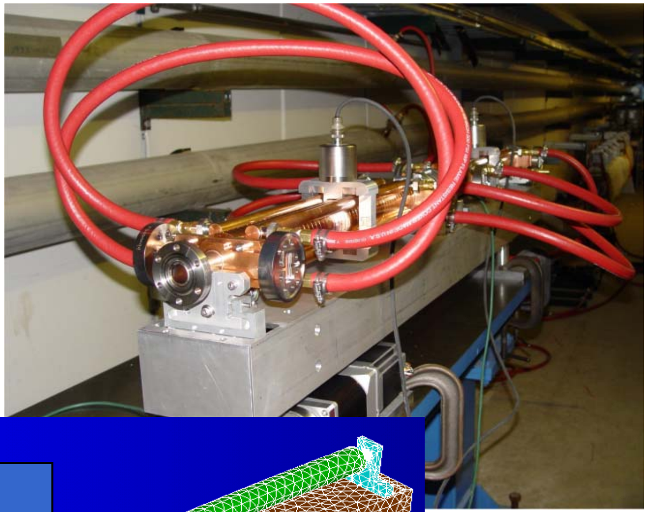




Structure vibration (feasibility studies at SLAC):

- **50 to 300 nm** depending on flow, length and water quietness
- coupling to the quad is small: **2-3%** (i.e. **<10nm** in worst case)
- vibration due to RF pulse is small

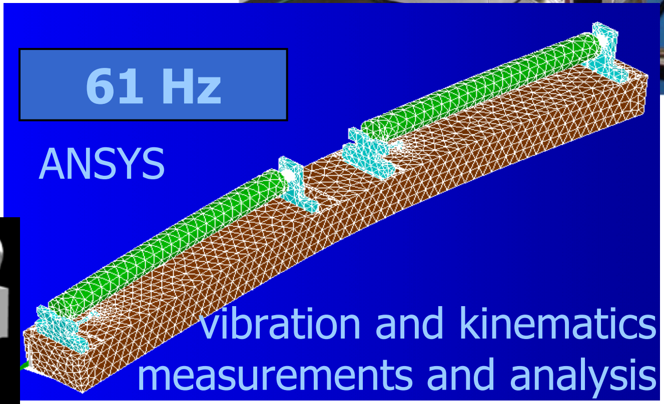


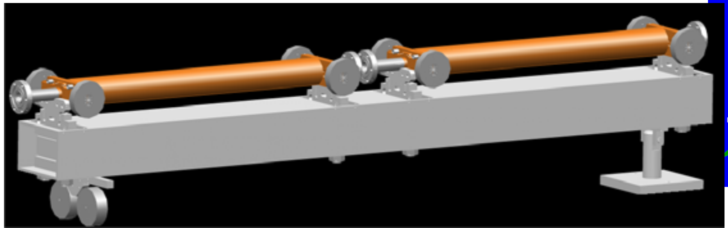


Development of more realistic NLC-like girder

- including mechanical, thermal, modal analysis, satisfying short and long term stability requirements, with movers and fiducials, etc.

is ongoing at Fermilab addressing TRC R2



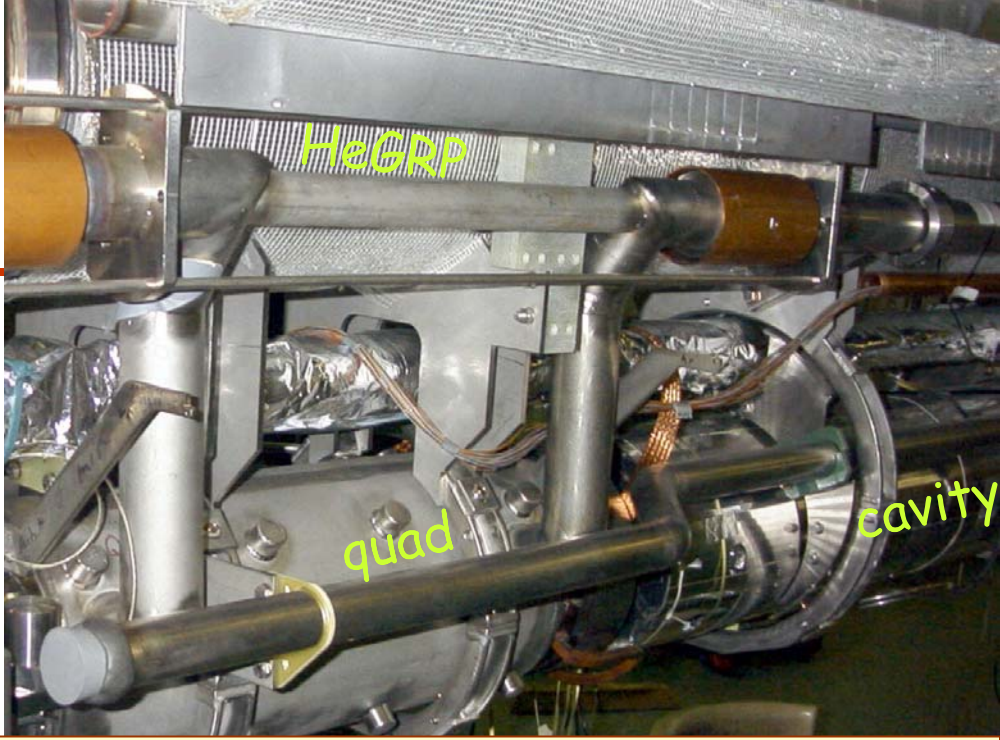


Cold LC: linac quad stability
What has been demonstrated?

TTF cryomodules, since ~1995, were equipped with vibration sensors.

Studies at TTF were ongoing in September 2002 [1]. At that time there was still big uncertainty in the measured data, due to not well determined calibration at cold temperature, issues with sensor grounding, measured spectrum being limited to <100Hz, etc.

[1] Private communication with DESY engineers Heiner Brueck and Erwin Gadwinkel.



TRC R2 :
"A sufficiently detailed prototype of the main linac module (girder or cryomodule with quadrupole) must be developed to provide information about on-girder sources of vibration."

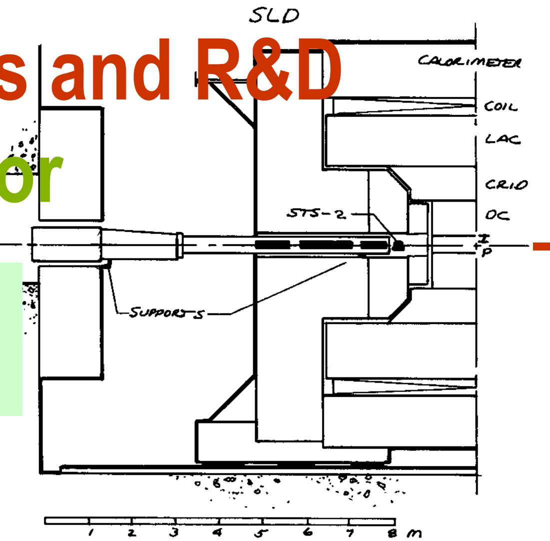
- XFEL will have to solve the cryomodule stability issue by both using fast feedback and improving module stability:

" Beam jitter stability requirements: 0.1σ (or somewhat better)...
With 70 nm (rms) quad movement about 0.05σ at linac end...
1:1 transfer ground to quad assumed, may need redesign of present quad mounting in cryostat...
Measurements of quad vibration in cryostat not yet conclusive "

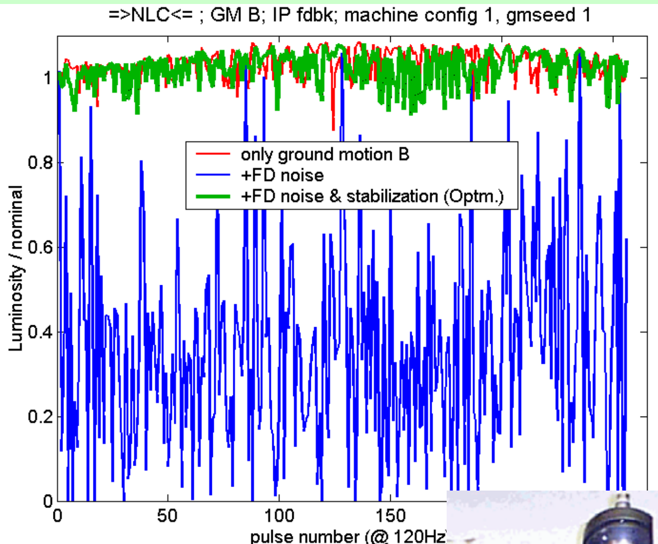
[XFEL WG-Minutes, Oct.2003, http://xfel.desy.de/xfel/content/e154/upload/upload_file/Meetings/WG-Minutes]

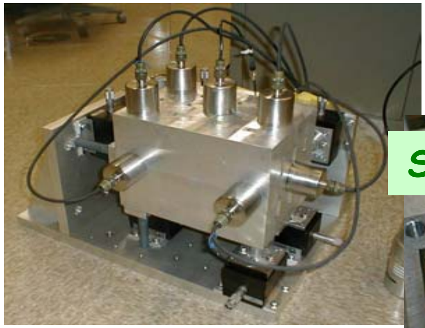
Warm LC: Jitter control demonstrations and R&D

Stability of FD on noisy detector

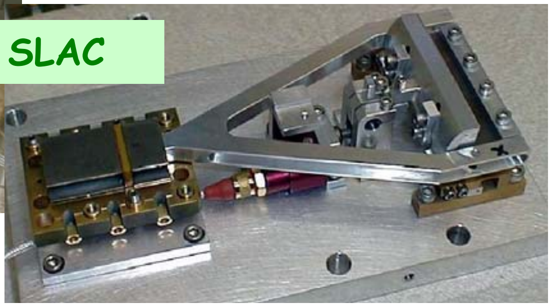


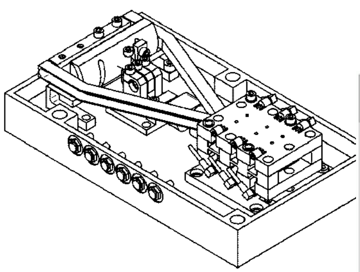
Taking conservative approach and assume that vibration of FD can be as large as measured at SLD: (~20nm of each FDs above 3Hz, i.e. 30nm relative motion) **=> Develop active techniques to counteract FD vibrations**

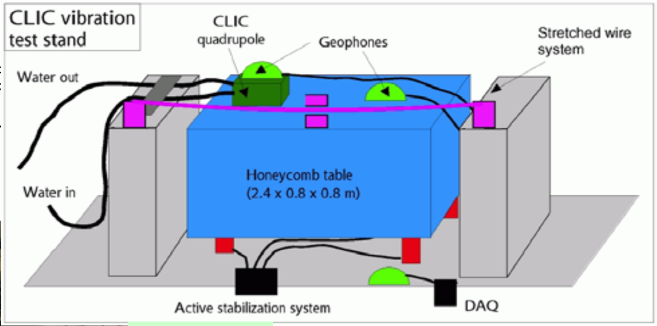




SLAC

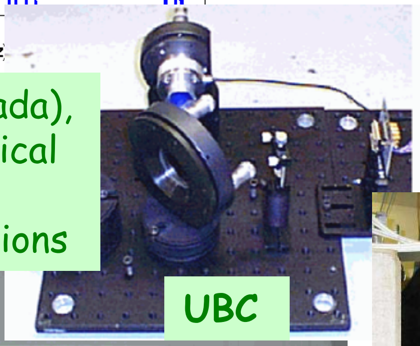






CERN

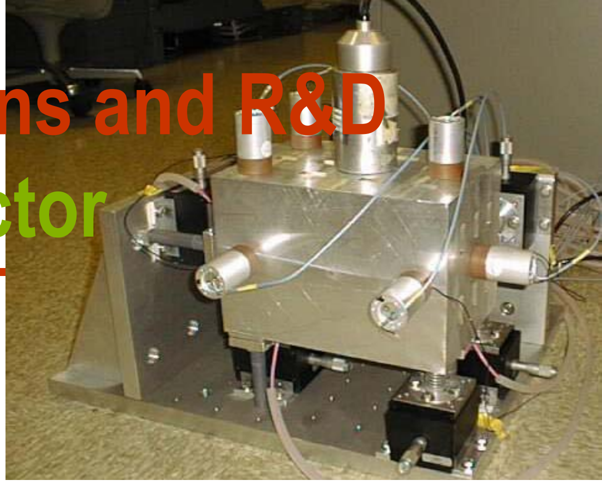
SLAC, CERN, UBC (Canada), develop inertial and optical methods of sensing and correction of FD vibrations

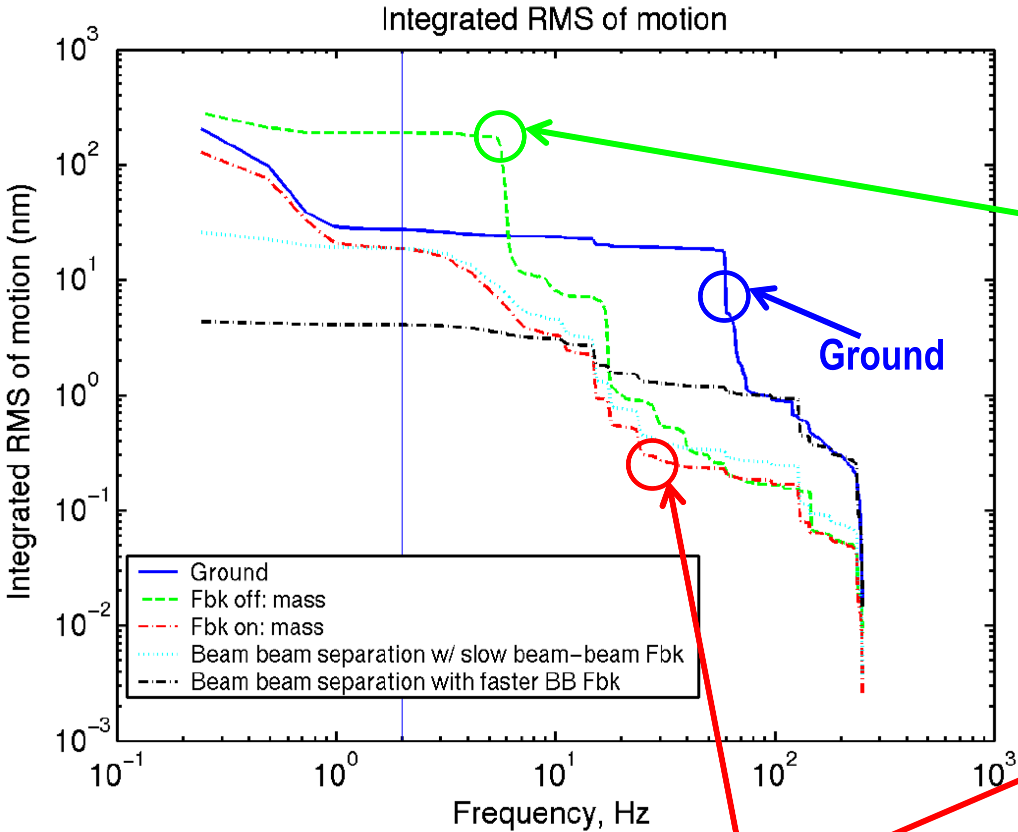


UBC

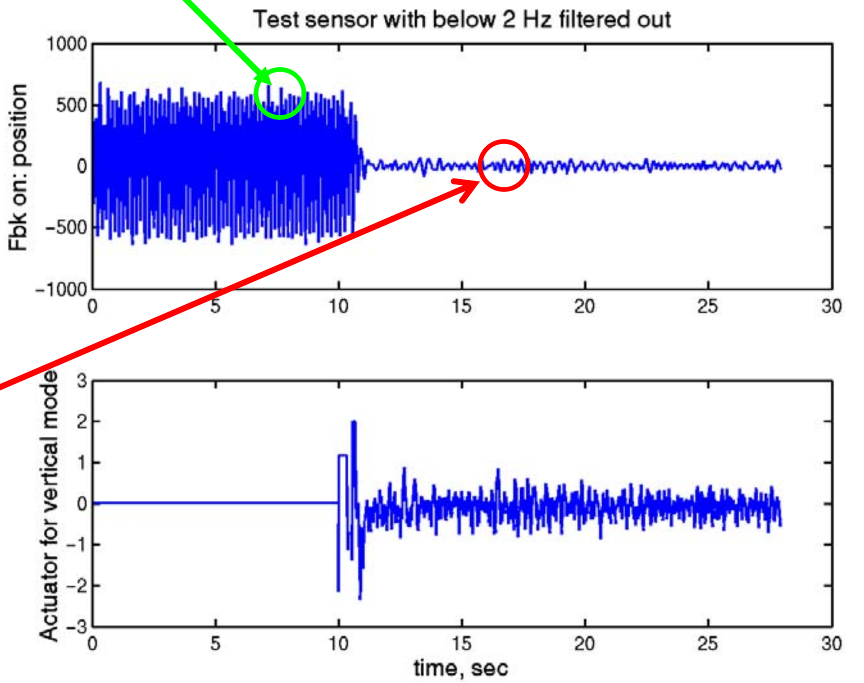
Warm LC: Jitter control demonstrations and R&D

Stability of FD on noisy detector





Feedback OFF, motion is amplified at resonance, attenuated above



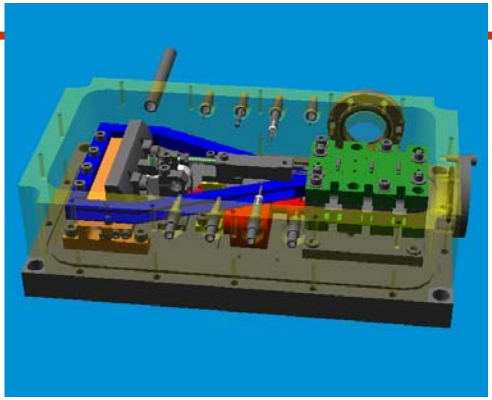
Feedback ON, motion is attenuated for all frequencies (performance is limited by sensor noises)

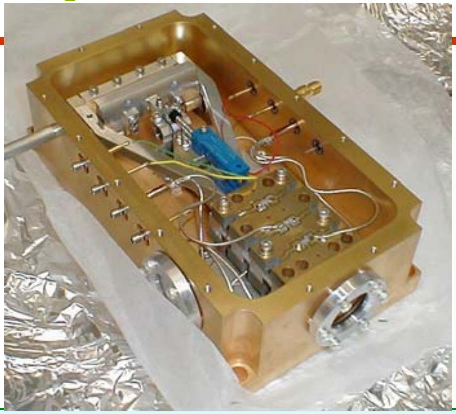
⇒ develop compact nonmagnetic sensor

⇒ stabilize large object

Warm LC: Jitter control demonstrations and R&D

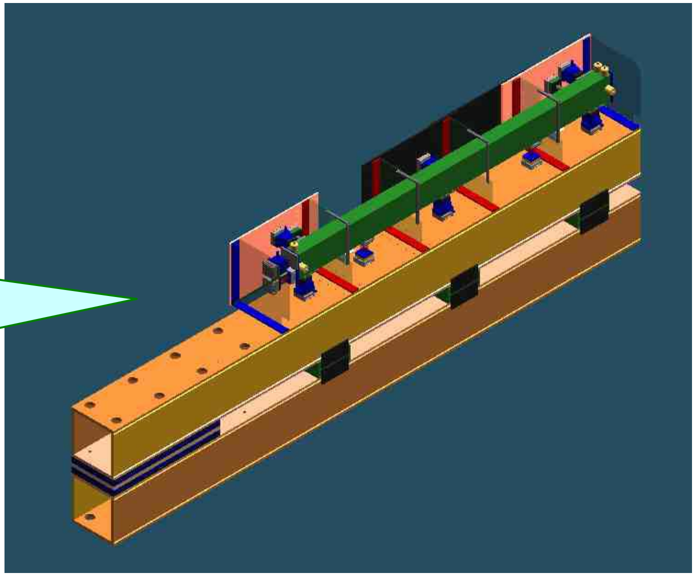
Stability of FD on noisy detector





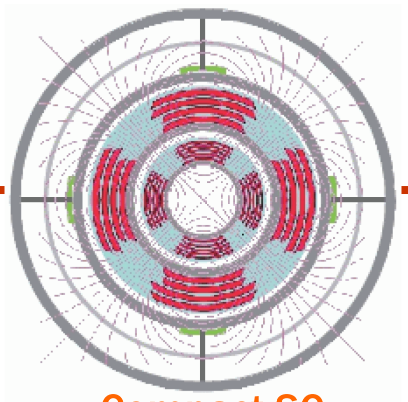
Nonmagnetic inertial sensor development at SLAC:
Recently achieved good results: noise level is small, ~noise of 1Hz Mark-4 geophones and is ~OK for stabilization

Tests of inertial stabilization of extended object are ongoing



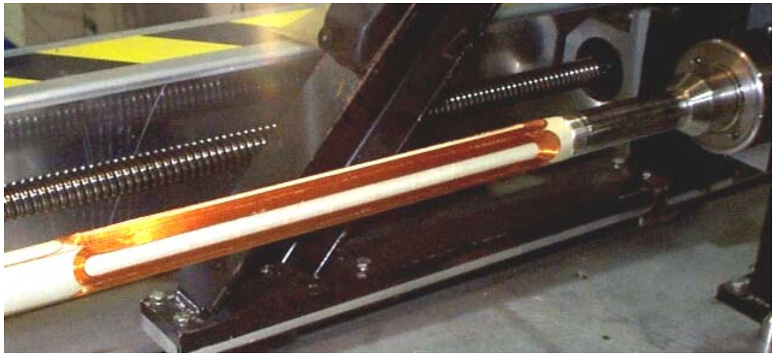
Compact SC final quad

R&D on prototyping and vibration R&D at BNL

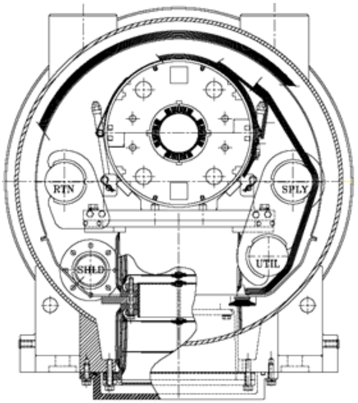


Compact SC FD quad

- BNL designed compact SC quad for LC
- Working on its prototyping



- Starting work on stability study of such quad
- First, will develop capabilities to measure vibration at cryo temperatures
- To gain experience, will first measure relative motion of a RHIC CQS, warm and cold both with and without cryogenic flow.



RHIC CQS

Warm LC: Scenarios
"something does not work"

Case 1
Stabilization works,
FONT failed

Detector is pessimistically noisy

Achieve full luminosity

Case 2
Stabilization failed,
FONT failed

Need well engineered detector and nominal 120Hz feedback

Achieve full to ~80% luminosity

Case 3
Stabilization failed
FONT works

Detector is pessimistically noisy

Achieve ~70 – 80% luminosity

Case 4
Stabilization works
FONT failed

Detector is pessimistically noisy

Linac jitter is x2

Achieve ~70% luminosity

Case 5
Stabilization and FONT failed

Detector is pessimistically noisy

May achieve ~20% luminosity

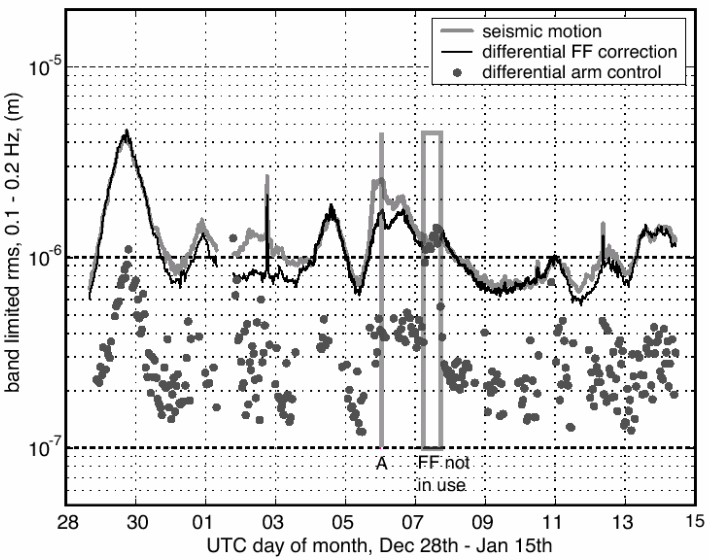
Warm LC: how bad is the worst case?

- Most of reduction in case of noisy detector and failure of either stabilization or FONT
  - However, this is single item, and can be rebuild
- More difficult to fix would be excessive jitter coming from the linac
  - not surprising, TRC ranked it R2 (in Warm or Cold)
- Nevertheless, if we manage to have jitter larger than expected, are there anything that can be done?

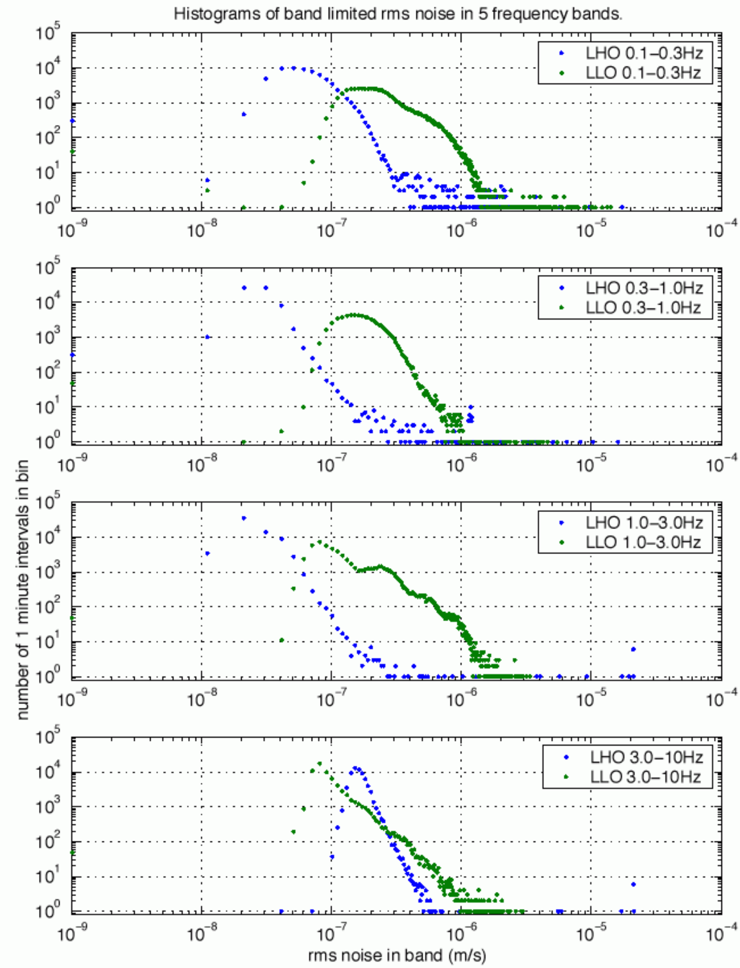
Warm LC: if linac jitter is large? Encouraging LIGO example

- Gravitational wave observations require suppression of ground motion by many orders
- After start, certainly, there were things which were different from what was expected
  - E.g. larger 1-3Hz noise at Livingston (LLO)
  - Larger and more varying 7s hum at Hanford (LHO)

Microseismic feedforward correction



Seismometer signals from each building used to correct arm lengths for ocean-wave-produced, 7 s surface waves.

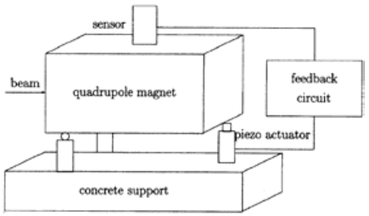


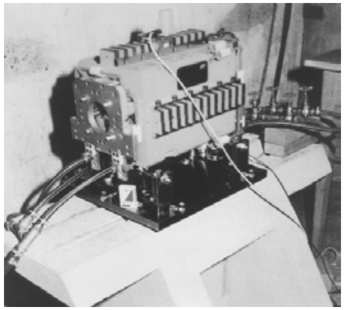
"A study of transient noise sources in LIGO", J. Giaime, 2002
http://www.ligo.caltech.edu/docs/G/G020549-00.pdf

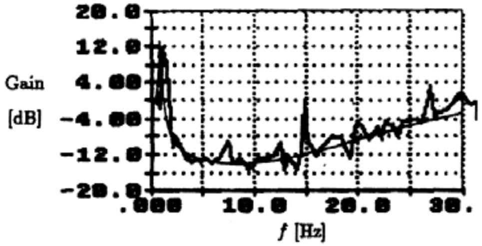
- Still, people are finding ways around, and presently the "interferometer locked time" (~time of luminosity integration for LC) is up to 20-40% at LLO and 80% at LHO and improving
[Ricardo De Salvo, private communication, 2004]

Warm LC: what if linac jitter is too large?

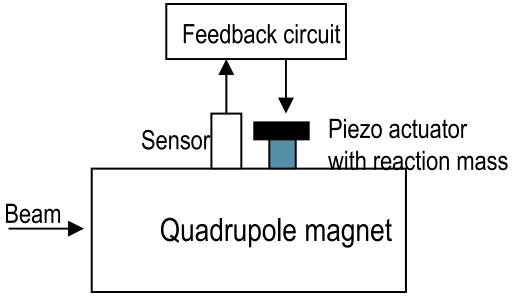
- Examples from the past: too large quad jitter was observed at SLAC and ALS at the start, but then fixed with simple modifications of quad supports
- Example from S-Band LC:
  - Developed and tested inexpensive quad stabilization scheme that gave 3 times reduction for <10K$/quad [C.Montag, DESY 1995]

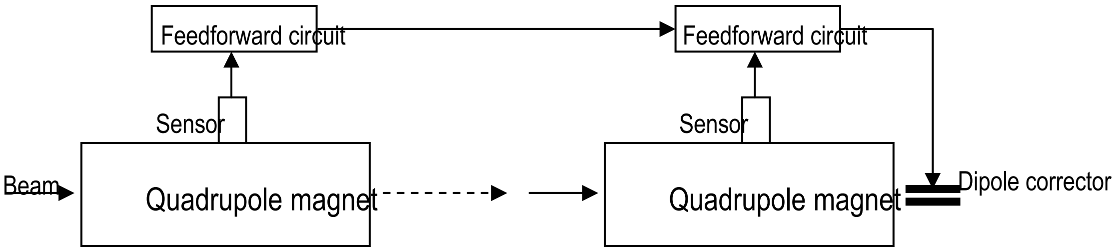






- Similar and simpler schemes can be imagined, that even would not require modification of supports, and could be applied ad hoc
  - Reaction mass stabilization (SBIR-II topic by Energen Inc.)
  - Feedforward correction of the beam (may be soon tested at ATF)
- Warm LC quads are accessible, in contrast to Cold LC quads which are inside of cryostats





NLC Stability: Collaborative efforts

SLAC, FNAL, KEK, Northern Illinois University, LLNL, BNL, Northwestern University, Queen Mary University of London, Daresbury Laboratory, University of British Columbia, Oxford University, BINP, CERN, DESY, …

Fred Asiri, Cristian Boffo, Philip Carpenter, Clay Corwin, Jeff Gronberg, Vic Kuchler, Tom Markiewicz, Brett Parker, Tom Mattison, Russ Greenall, Parry Fung, Andrei Seryi, Jeff Sims, Michal Szleper, Philip Burrows, Glen White, Stephen Molloy, Shah Hussain, Alexander Kalinine, Colin Perry, Gerald Myatt, Simon Jolly, Gavin Nesom, Joe Frisch, Linda Hendrickson, Marc Ross, Chris Adolphsen, Keith Jobe, Doug McCormick, Janice Nelson, Tonee Smith, Mark Woodley, Peter Tenenbaum,Gordon Bowden, Rainer Pitthan, Steve Smith, Jastin May, M. Cooke, Yuri Kolomensky, Evgenii Borissov, Harry Carter, Robert Ruland, Frederic Le Pimpec, Chris Adolphsen, Andrei Chupira, Anatoly Medvedko, Vladimir Shiltsev, Shavkat Singatulin, Rainer Soika, Paul Kovash, George Ganetis, Jesse Schmalzle, Christoph Montag, Animesh Jain, Mike Anerella, Ralph Assmann, Stefano Redaelli, Toshiaki Tauchi, Kiyoshi Kubo, Takeshi Matsuda, Alexander Erokhin, Mikhail Kondaurov, Vasili Parkhomchuk, Evgeny Shubin, Fulvia Pilat, Joe Lach, Chris Laughton, Duane Plant, Mayda Velasco, Jerry Aarons, Domenico Dell'Orco, Eric Doyle, Wilhelm Bialowons, Heiko Ehrlichmann, …

Conclusion

- Warm LC jitter requirements are more tight
  - But based on prototype measurements
  - Stability is provided by several systems
  - Each of systems allowed to work not perfectly
  - Accessible quads make ad-hoc fixes easy
- Cold LC jitter requirements are less tight
  - Stability of quads in cryomodules was not demonstrated
  - Collision stability provided solely by intratrain feedback
  - This single system is not allowed to fail
  - Quads hidden in cryostats make ad-hoc fixes difficult