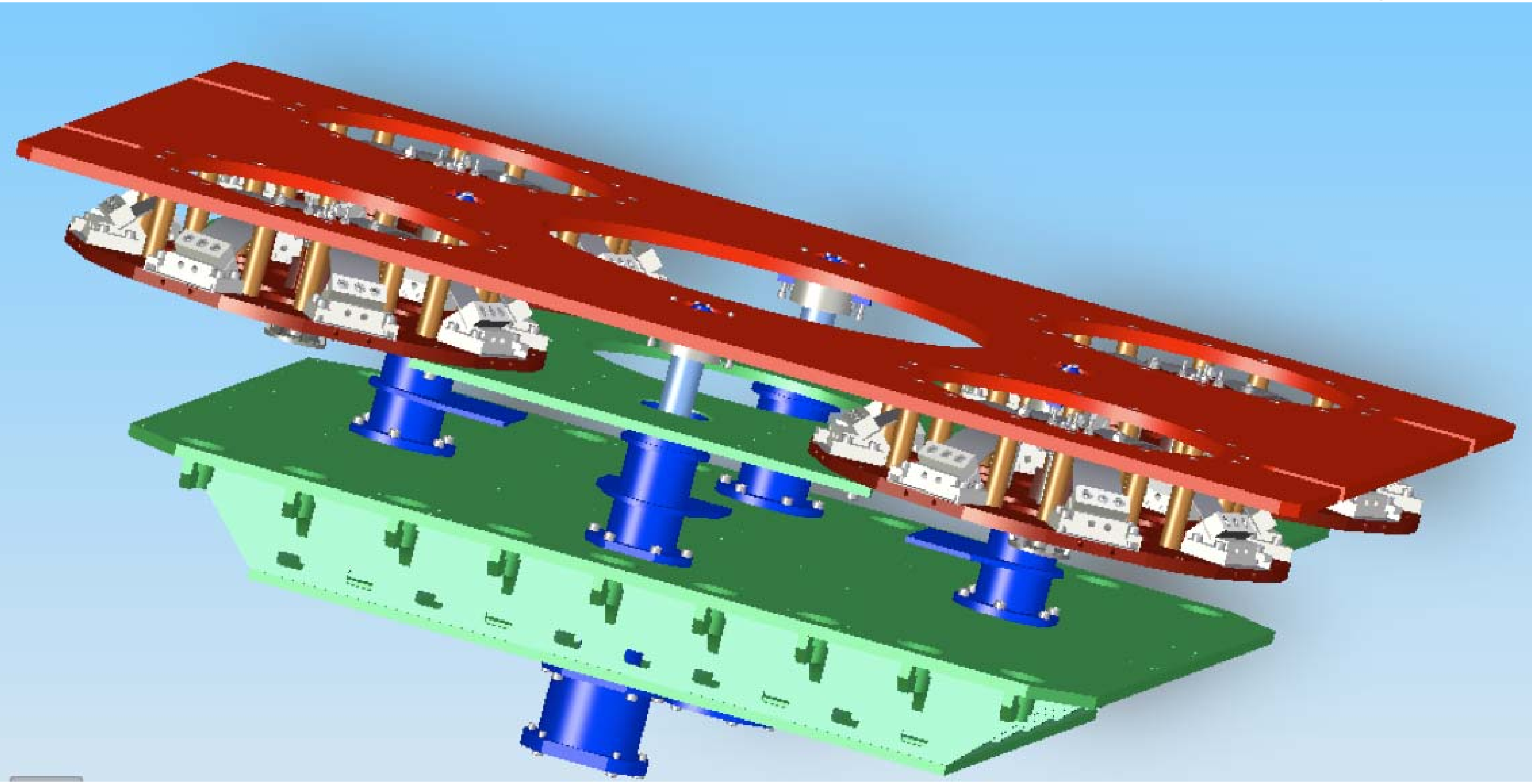
HAM SAS Passive Seismic Attenuation System

Fabrication, Assembly, Installation, Commissioning

Ben Abbott, Yoichi Aso, Mark Barton, Valerio Boschi, Dennis Coyne,
Riccardo DeSalvo, Michael Forte, Carlo Galli, Gianni Gennaro,
Yumei Huang, David Ottaway, Virginio Sannibale,
Alberto Stochino, Chiara Vanni

LIGO Gravitational Wave Observatories
California Institute of Technology
Massachusetts Institute of Technology

HAM SAS is a seismic isolator for the optical benches of HAM chambers (designed to include HEPI LF capabilities)



Construction summary

- The HAM SAS design was presented at the Amaldi-6 in 2005
- HAM SAS production started April 2006
  - Both a prototype and first production item

LIGO

Seism Busters

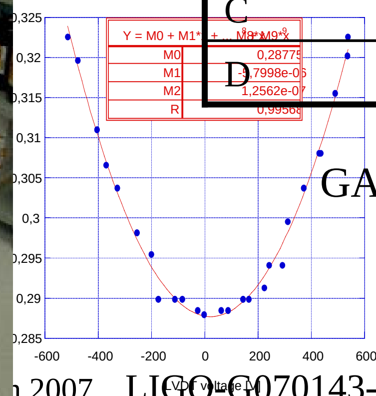
Construction summary

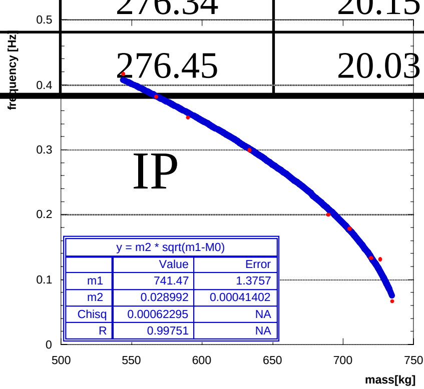
- Developed Clean in-factory assembly procedure
  - Sparing precious LIGO manpower and premises for better use

Construction summary

- Developed a in-factory tuning procedure
  - Some tuning was done in LASTI this time (HAM bench not available at G&M)
  - Production items all in-factory tuning

Filter	Frequency [mHz]	Optimal Load [Kg]	Height [mm]
A	192	276.21	19.46
B	180	275.42	19.95
C	188	276.34	20.15
D	180	276.45	20.03





Construction summary

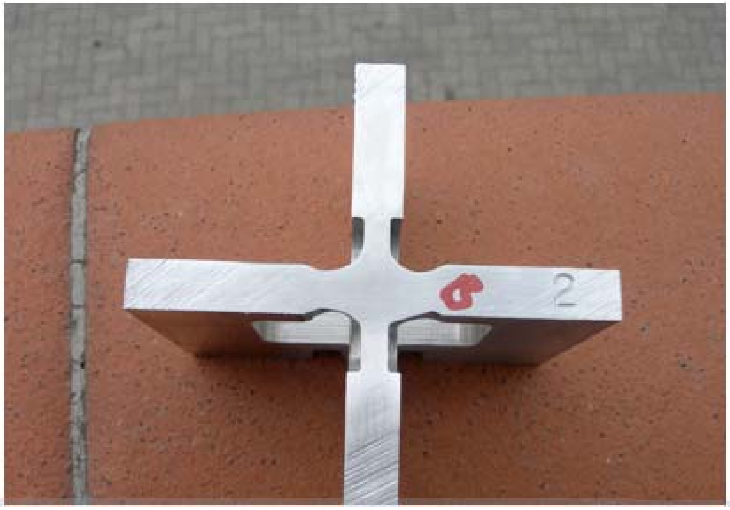
- Aluminum Welding problems

- Developed heat-flow optimized geometries to reliably avoiding cavities
- Developed counter-stressing and annealing techniques to avoid warping

- Now assisting SUS for their external structures

Some weld quality control

shaping parts worked well



LIGO- T060095-00-E → LIGO → May 12th 2006

Procedure to expose possible cracks in aluminum welds

Riccardo DeSalvo, Yumei Huang

LIGO- LIGO-T060108-00-D → LIGO → 25th May 2006

T-Weld Tests performed May 25th 2006

Stefano Molesti, Marcello Berchiolli, Riccardo DeSalvo

LIGO- T060110-00-D → LIGO → 25th May 2006

Successful plug welds

Stefano Molesti, Marcello Berchiolli, Riccardo DeSalvo

LIGO- T060111-00-D → LIGO → 24th May 2006

Failed plug welds

Stefano Molesti, Marcello Berchiolli, Riccardo DeSalvo

LIGO- LIGO-T060109-00-D → LIGO →

Preliminary Weld Tests, mid May 2

Stefano Molesti, Marcello Berchiolli, Yumei Huang, Riccardo

LIGO- T060128-00-D → LIGO → 27th May 2006

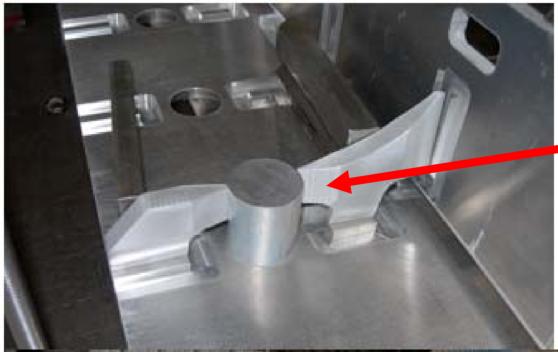
Cross weld tests

Stefano Molesti, Marcello Berchiolli, Chiara Vanni, Riccardo DeSalvo

LIGO

Weldments details

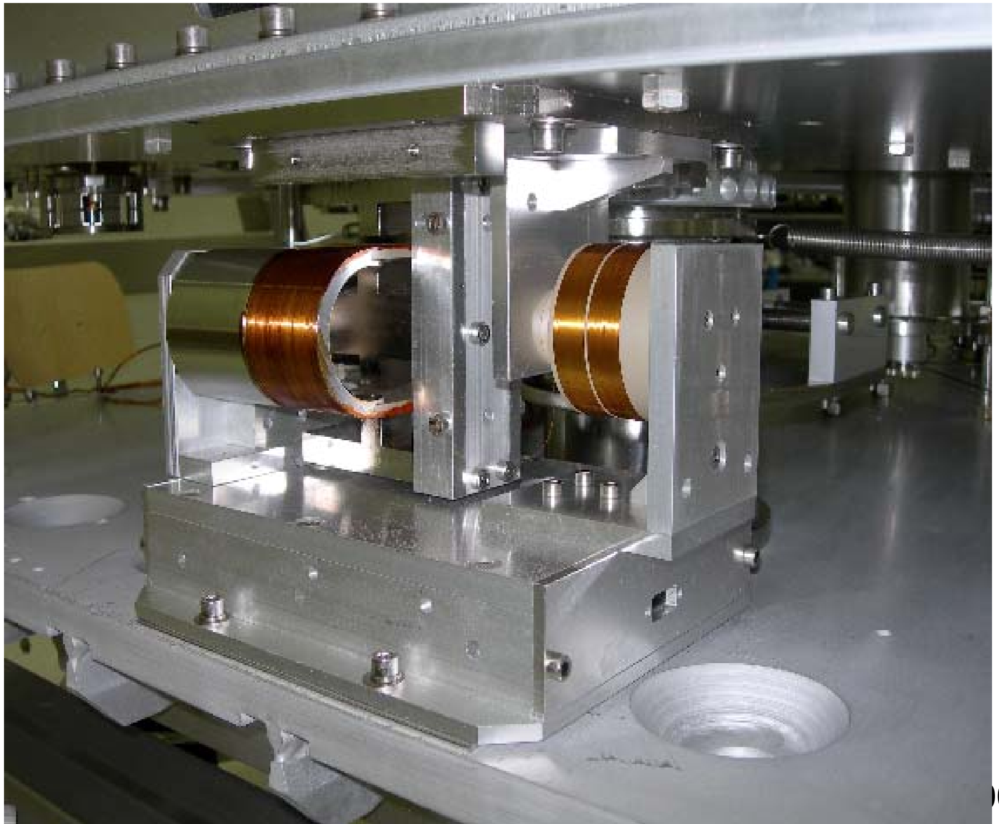
Weld shrinkage effect



Cross pipe supports

Construction summary

- Vacuum compatibility problems
  - Eliminated and re-built all UHV dubious elements



All parts built to our specs

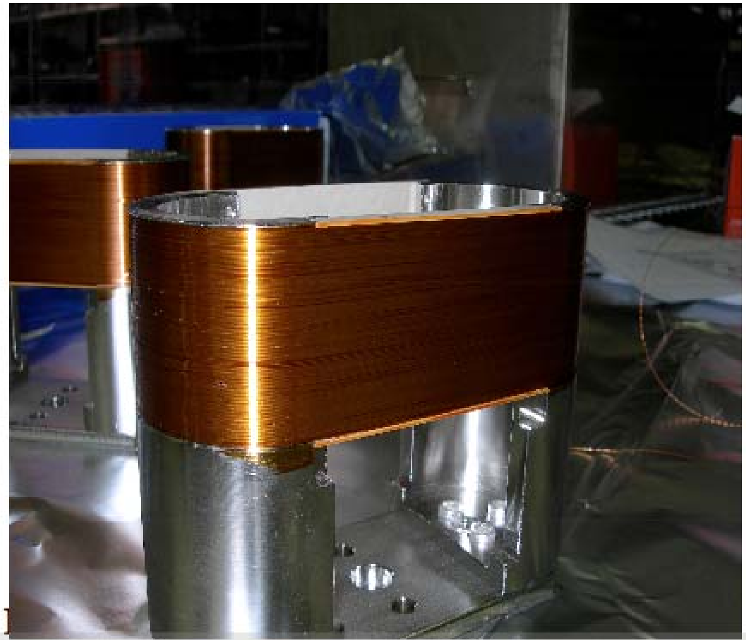
All parts fully dismountable

Only kapton and peek allowed

No risky sealed gas volumes

Construction summary

- Kapton coil UHV compatibility questions
  - Tendency of kapton resin to “foam” during baking
  - Common problem to all Ad-LIGO
  - Temporarily solved with pre-baking procedure
  - Developing a safe procedure for all Ad-LIGO

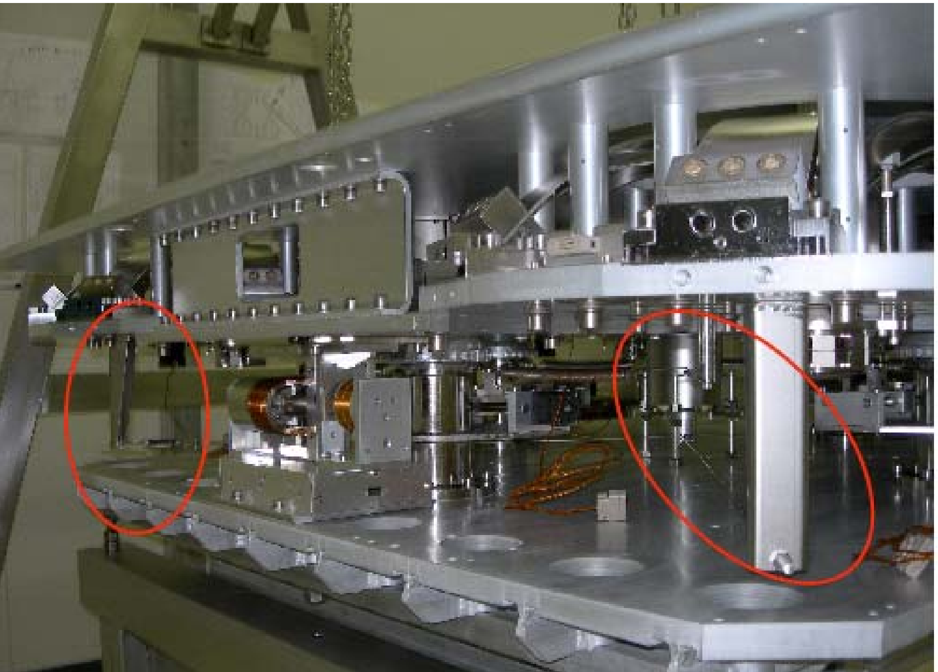


Construction summary

- Cleaning and Baking problems
  - built a baking facility and develop cleaning procedure
    - Facility now in use for cleaning and baking ISI
  - Fully assembled and tuned unit undergoes final re-bake for added cleanliness before packaging and shipping

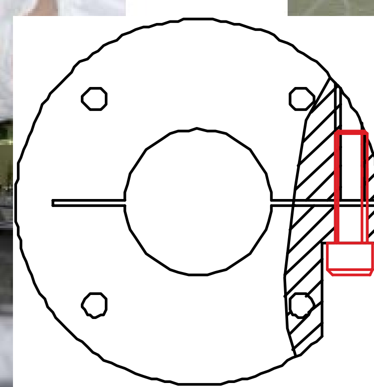
Construction summary

- Tilt instability problems
  - Remember the quad pendulum flipping intermediate mass?
  - They put the effective flexing point below the c.o.m.
  - We put the c.o.m. above the effective flexing point
  - The simulations missed the problem
- Solved with introduction of a roll bar.



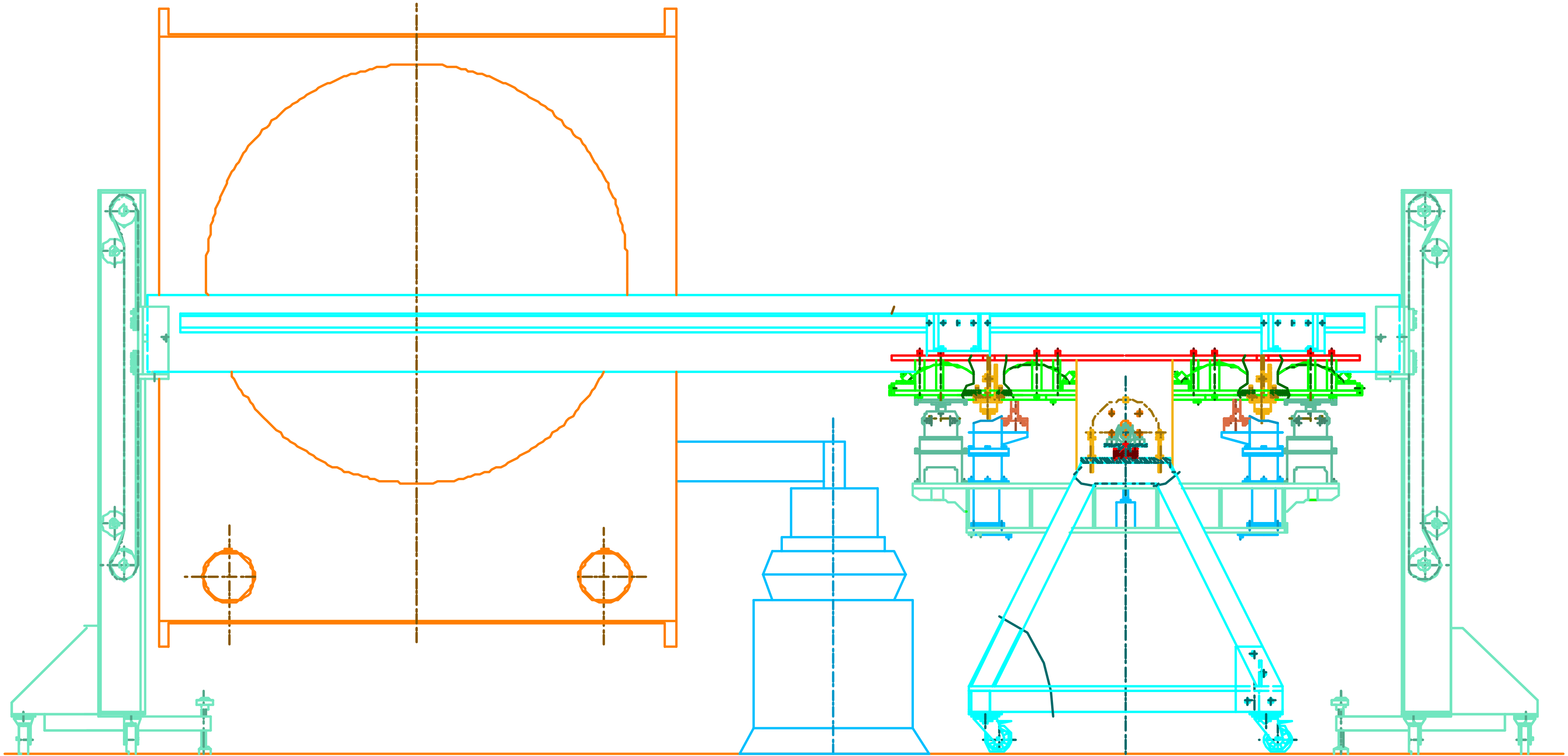
Construction summary

- Additional problem
- Roll bar bolt was not properly tightened
  - Long time puzzled, changed many springs before correct diagnosis
  - A show stopper if not solved Lost three weeks on this
  - The roll bar encased in a set of witness LVDTs is almost unreachable
  - Finally solved with a “long” and “sneaky” wrench



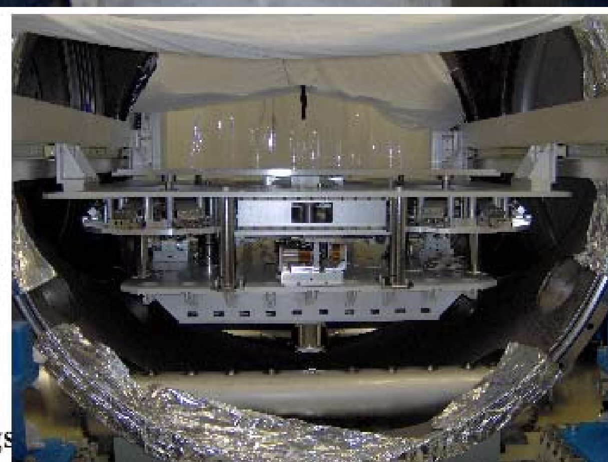
Construction summary

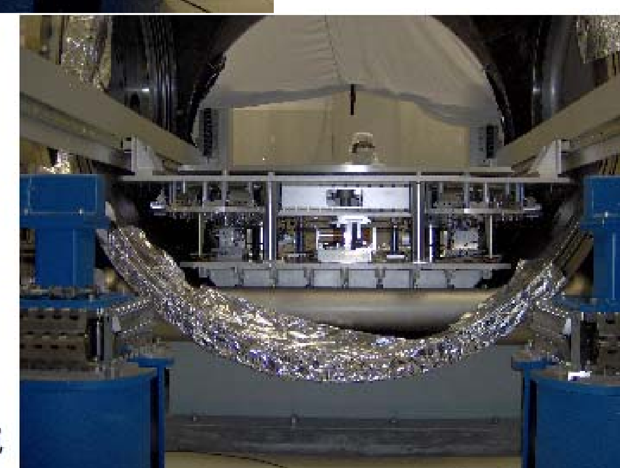
- Developed a fully-assembled-unit HAM chamber installation procedure
- Successfully inserted SAS and optical bench into HAM chamber.



LIGO

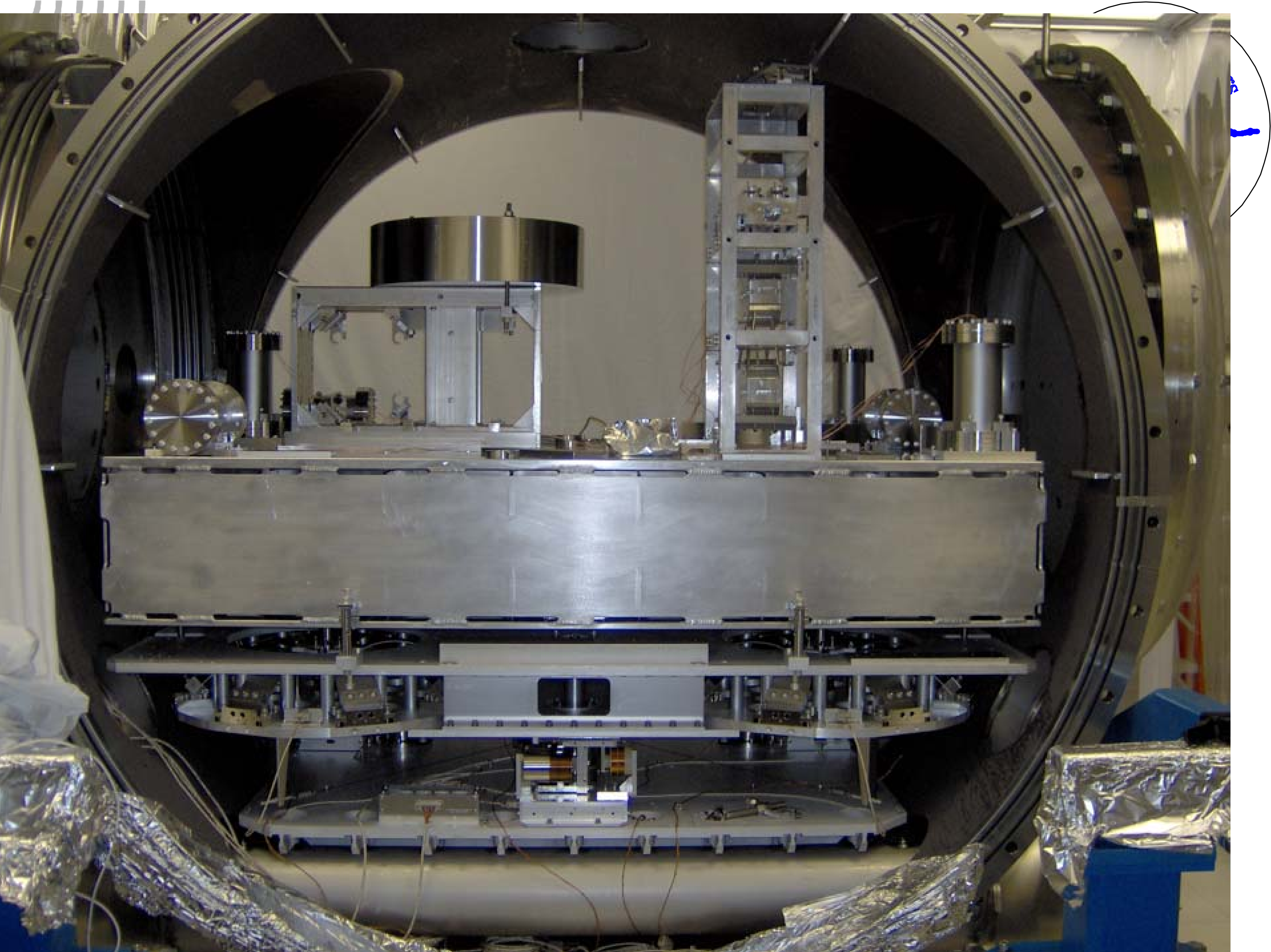
Seism Busters





Construction summary

- The optical bench can be inserted fully populated.



Construction summary

- At present the HAM optical table loaded with a triple pendulum (presently locked) is floating in the HAM chamber at LASTI

- Taking stability damping and attenuation data

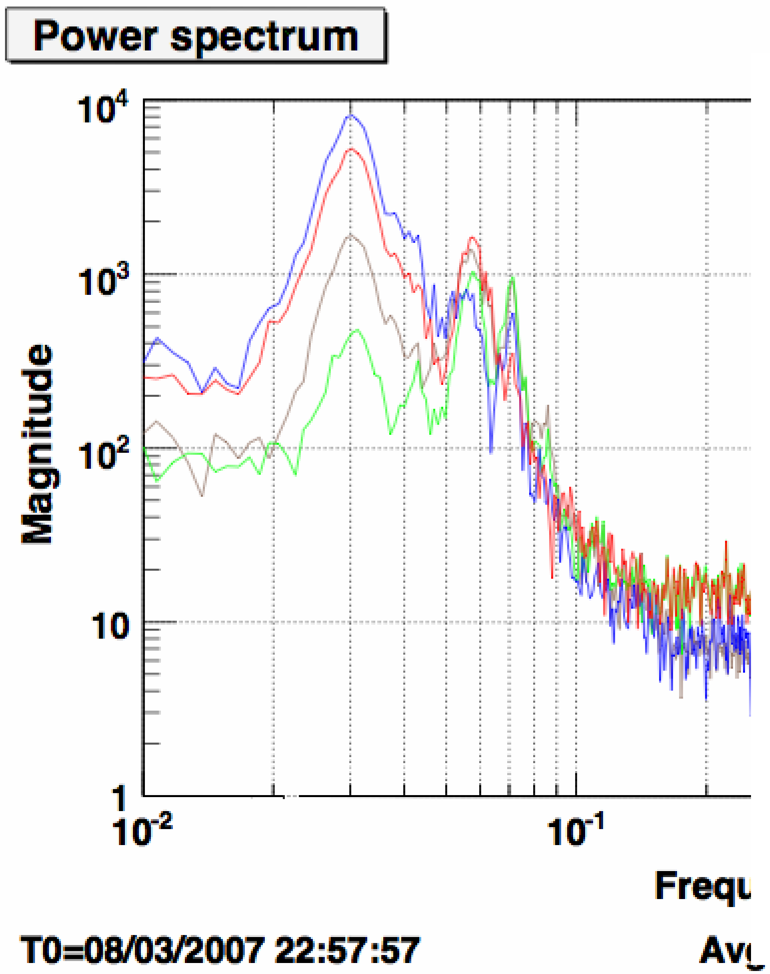
Control work and strategies

- Use electromagnetic springs to lower resonant frequencies
- DC controls to compensate thermal, tidal and slow tilt drifts
- Resonance damping to reduce the r.m.s. residual motion

- Use feed-forward from ground seismometers to further reduce residual motion
  - (feed-back an additional option)

  - Thanks to our stiff colleagues for their useful advice

Horizontal degrees of freedom
Preliminary control results

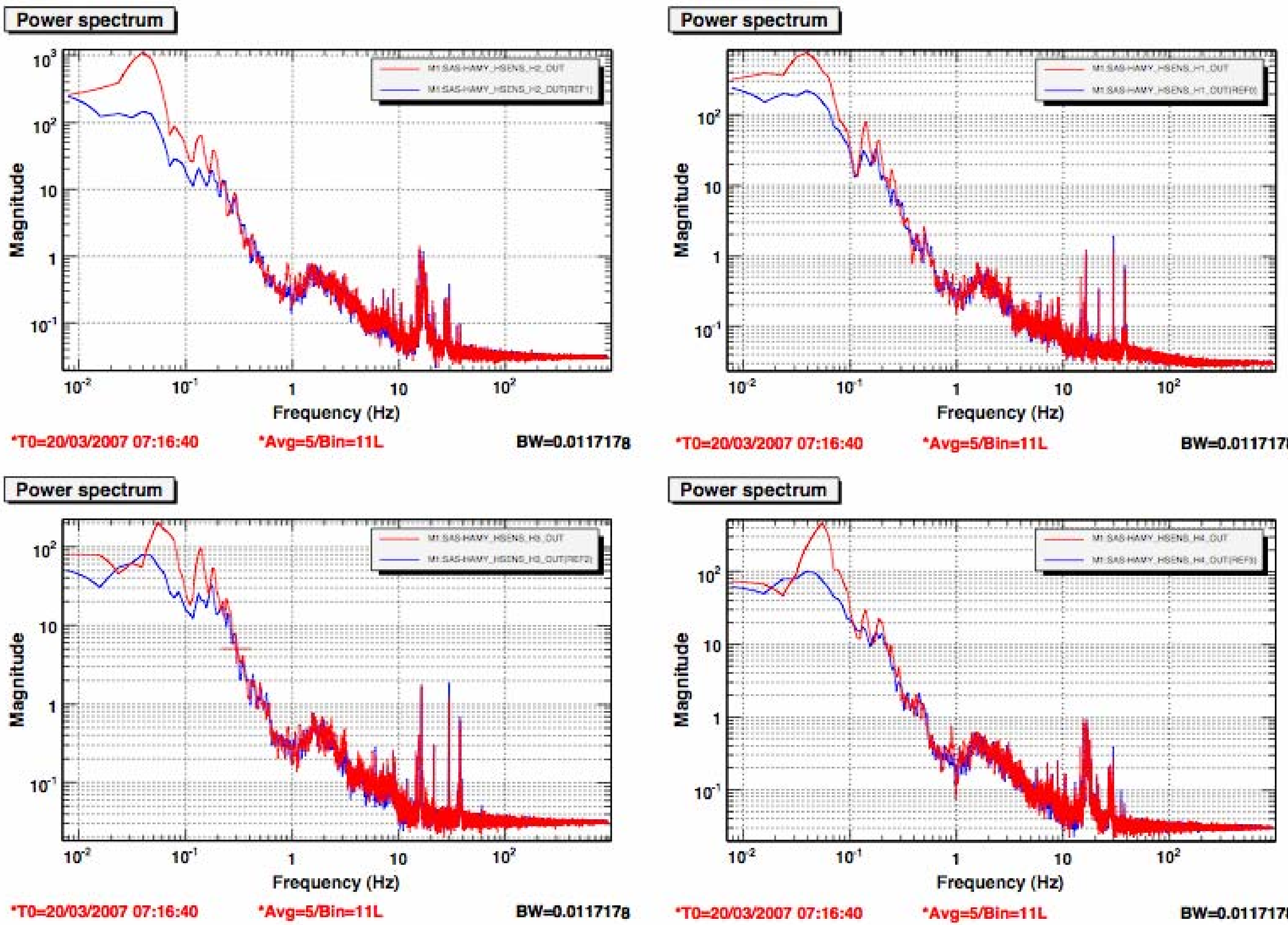


- 30 mHz resonance easily achieved with mechanical plant only

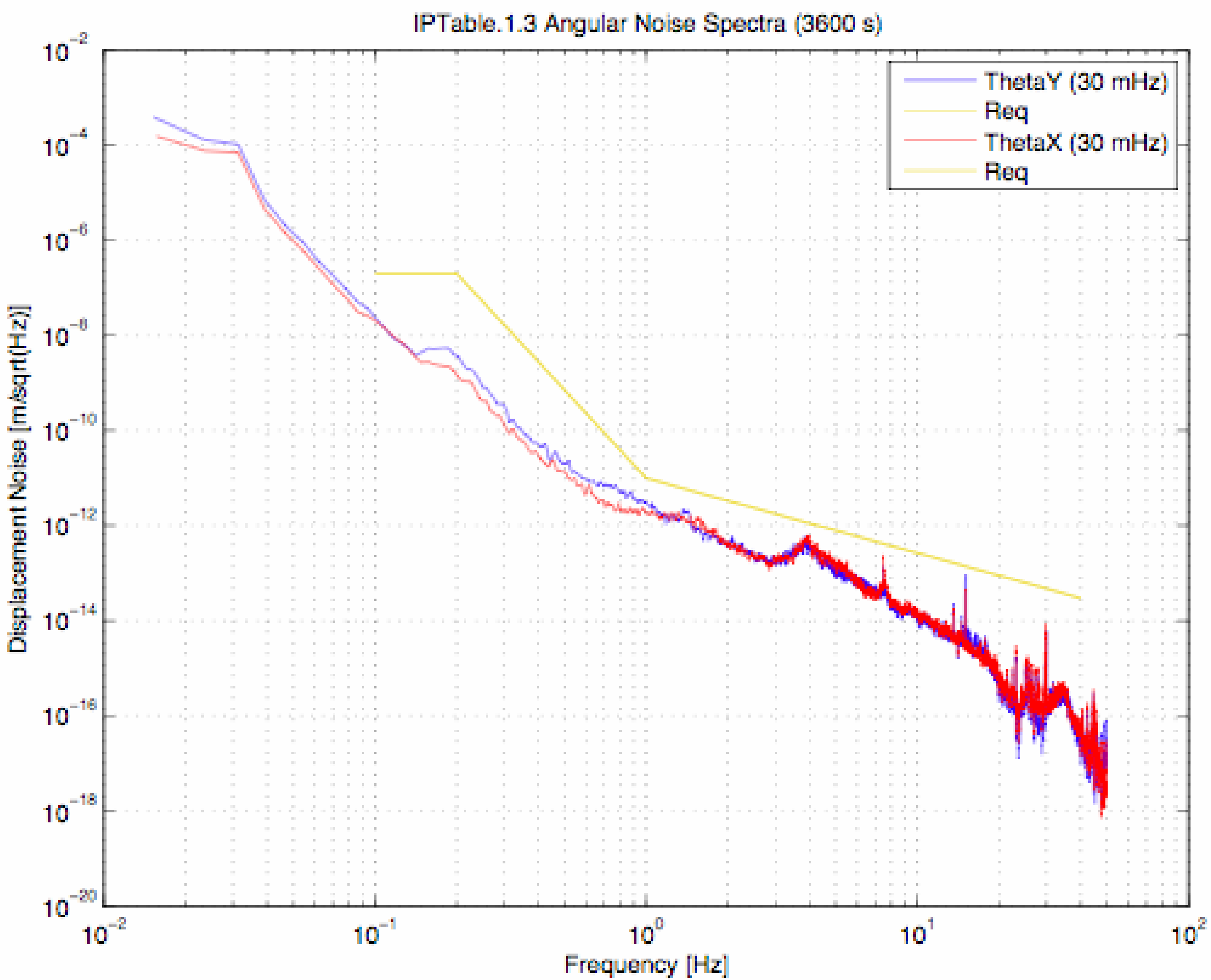
- Need damping to reduce r.m.s. motion

  (or need to tune resonance below <5 mHz)

IP resonance damping very preliminary



Tilt to horizontal contribution revisited



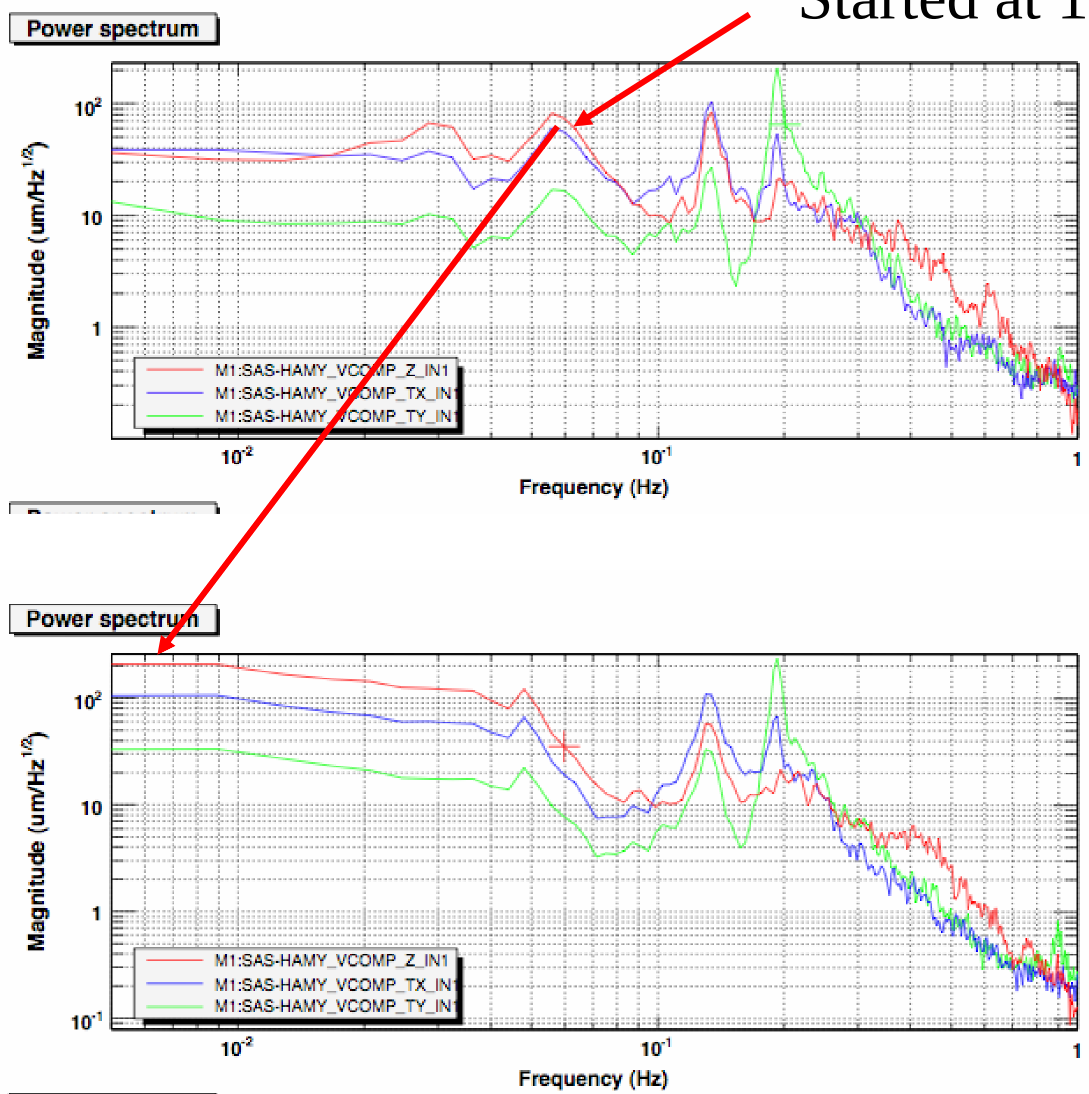
- Excess ground tilt contribution was overlooked
- No problem expected by simulations to satisfy the specifications

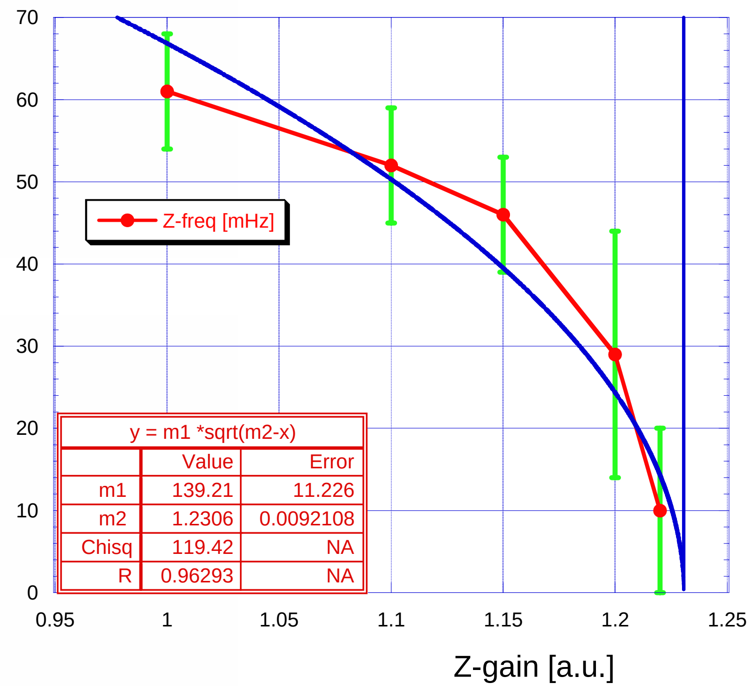
Vertical degrees of freedom preliminary

- Preliminary control results
- Vertical and tilt resonances below 200 mHz from mechanical plant only
- Resonances tuned at LF with e.m. springs
- Need better diagonalization for further progress

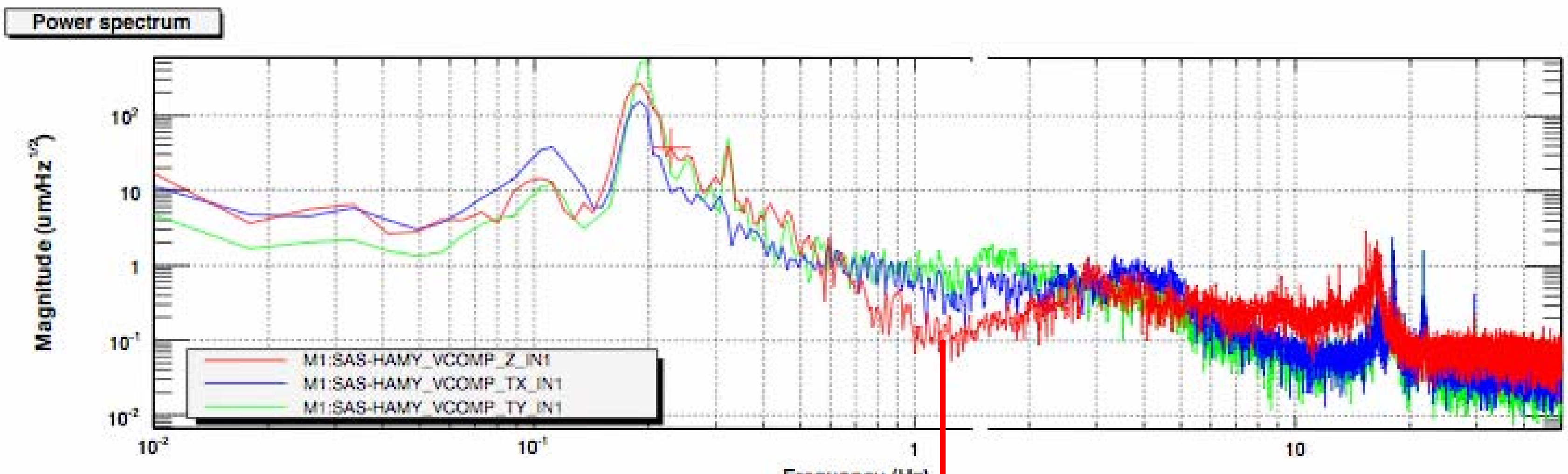
Tuning down the vertical resonance frequency

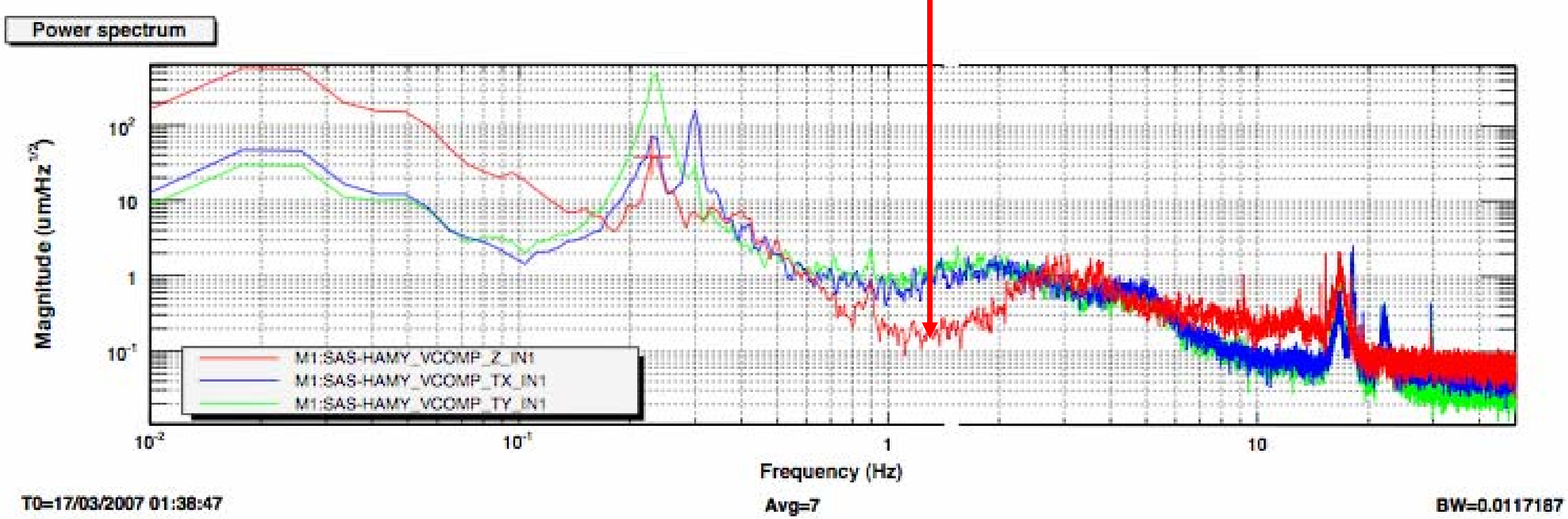
Started at 180 mHz



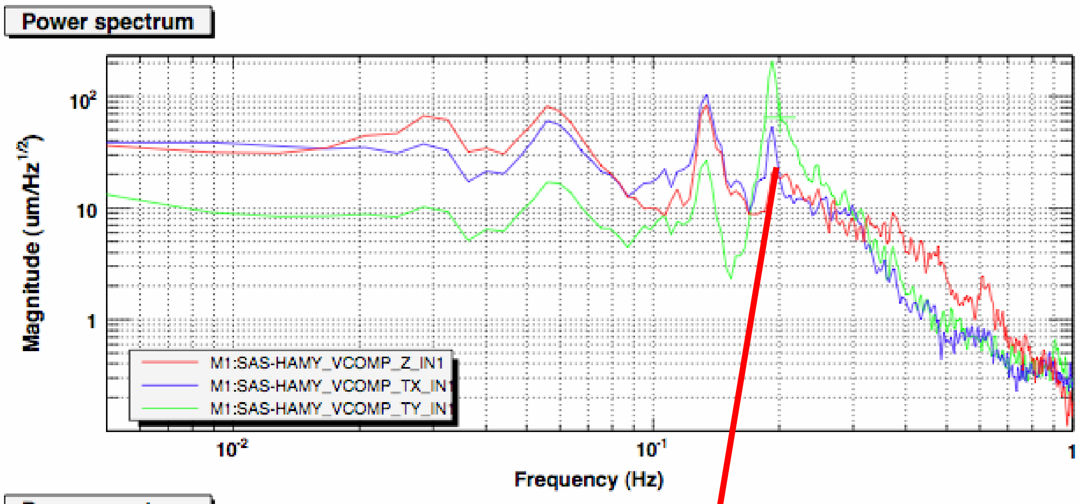


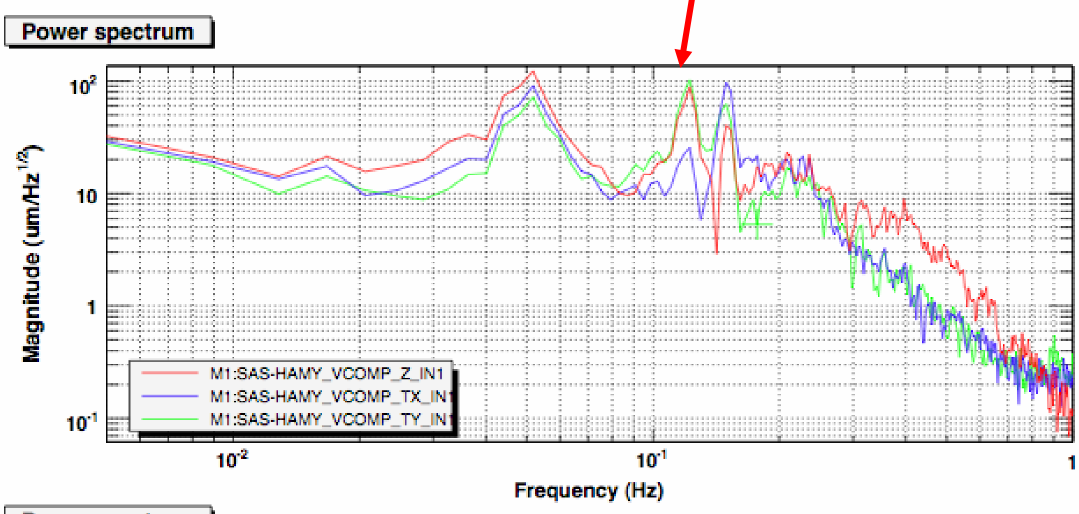
No noise injected at high frequency

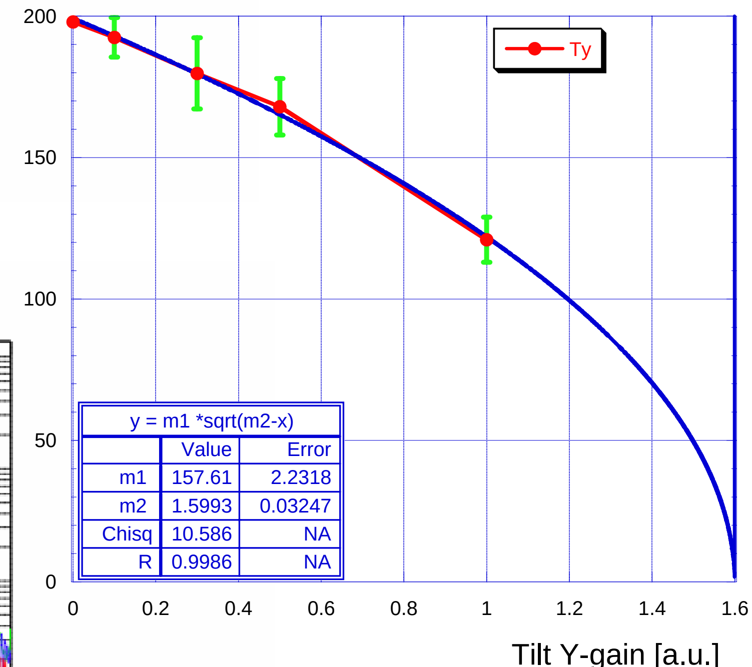




Tuning down tilt modes



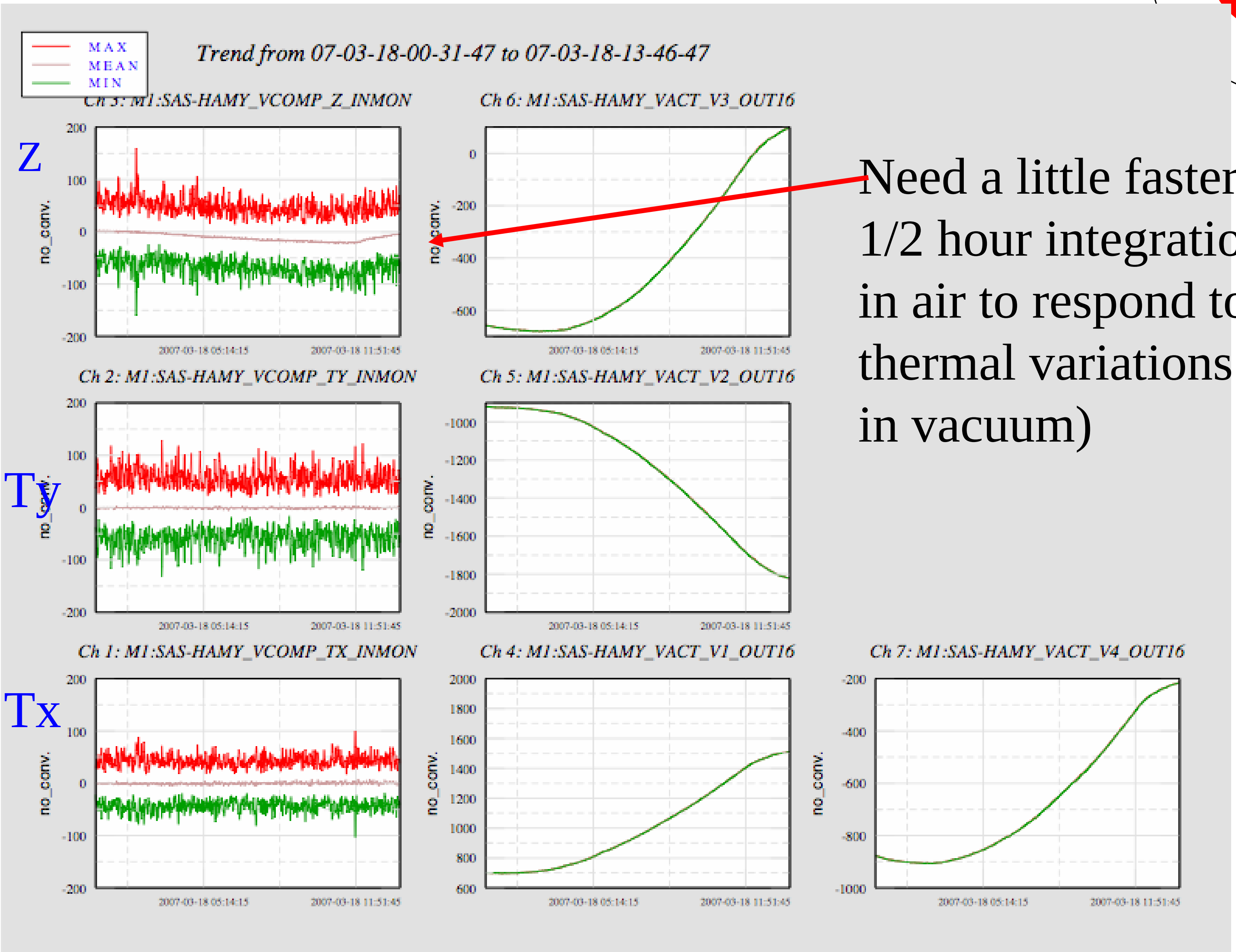




- No need for damping in the vertical direction

- Probably some damping needed for tilt modes

Stability tests



Need a little faster than 1/2 hour integration time in air to respond to thermal variations (plenty in vacuum)

Summary

- The mechanics had problems but now works as expected
- Controls are being implemented
- Presently closing the doors for vacuum ops
- Problems with geophone readout
- Should get preliminary attenuation data shortly

Summary (2006)

- <u>**We are going slower that we expected but**</u>
  by next LSC meeting

  we will have a first class seismic attenuator:

1. Single stage including the functionality of HEPI
2. Passive attenuation:
   - No active components in vacuum (only coils)
     - No chance of electronics failures in vacuum ! ! !
     - Virtually no power dissipation under vacuum ! !
       - (From elimination of active components and from Low Frequency mechanics)
   - No sealed gas volumes in vacuum
     - No chance of crippling virtual leaks ! ! !
   - Immunity from power failures
   - Earthquake immunity