Commissioning of LIGO Detectors

5th EDOARDO AMALDI CONFERENCE

July 7, 2003

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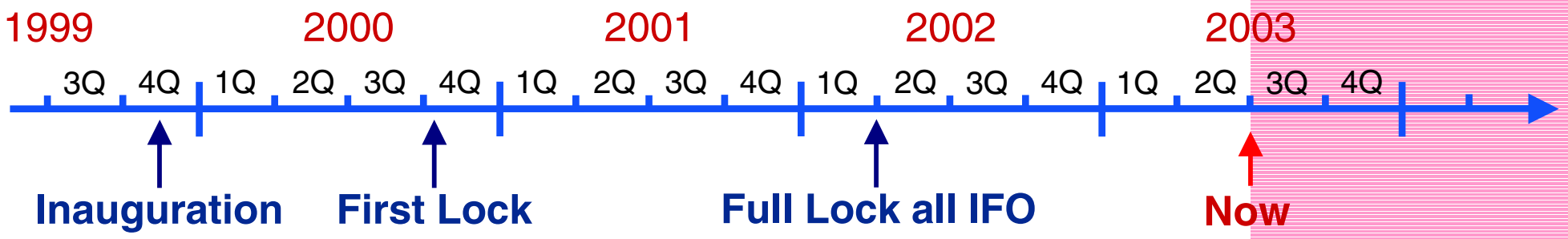
LIGO-G030304-00-D

Arial View of the LIGO Sites

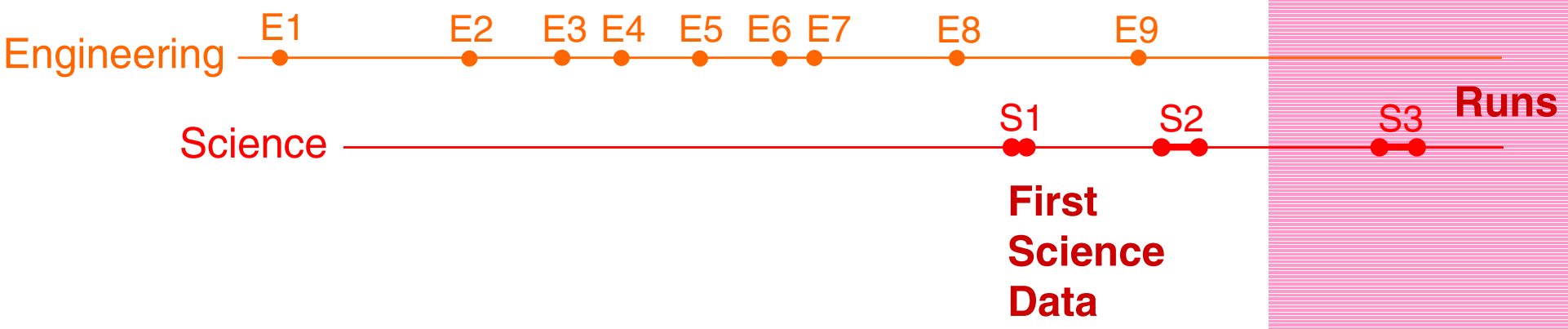
LIGO Hanford Observatory

LIGO Livingston Observatory

Time Line



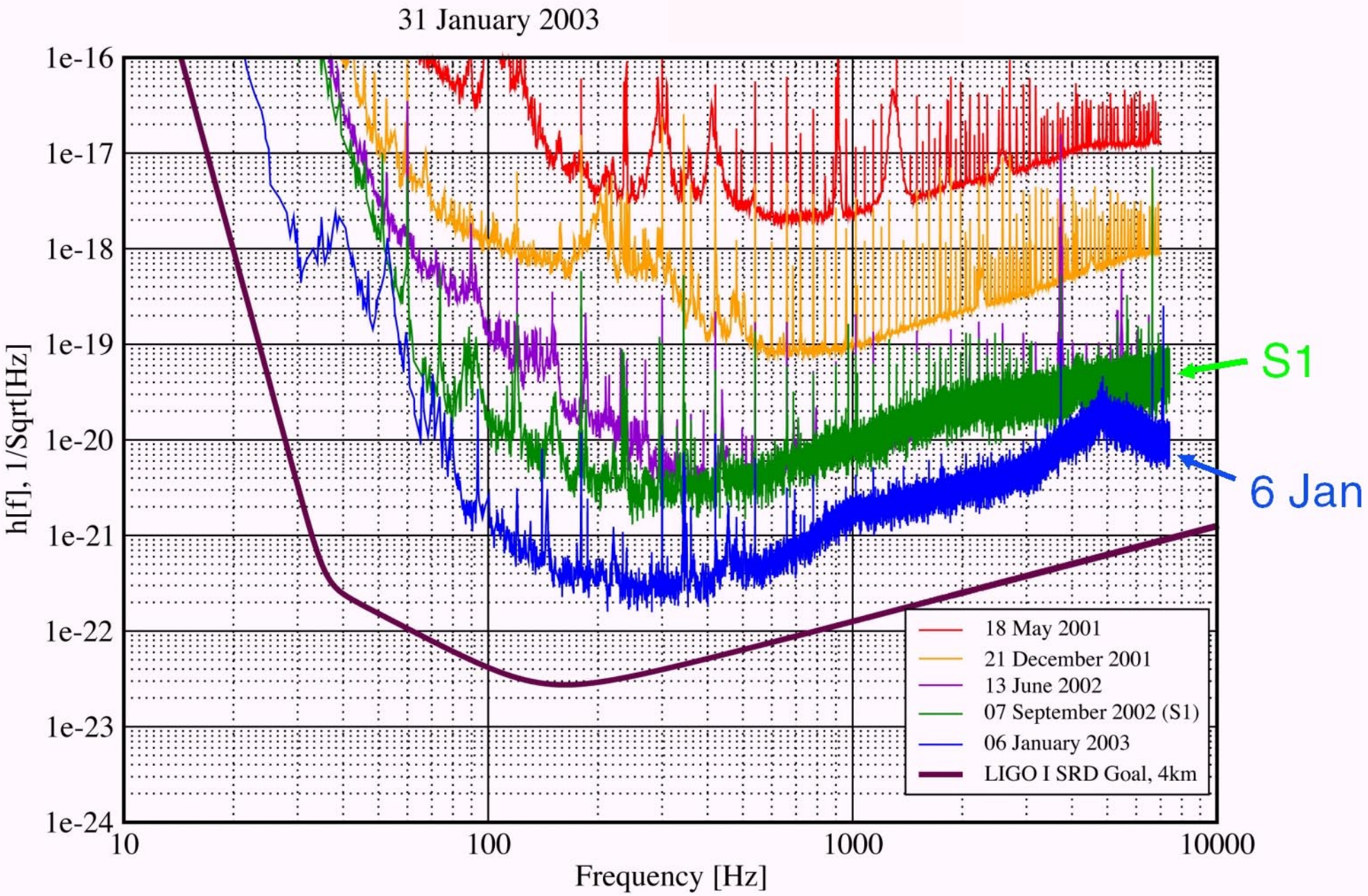
L4K strain noise @ 150 Hz [$Hz^{-1/2}$] 10^{-17} 10^{-18} 10^{-19} 10^{-20} 10^{-21}

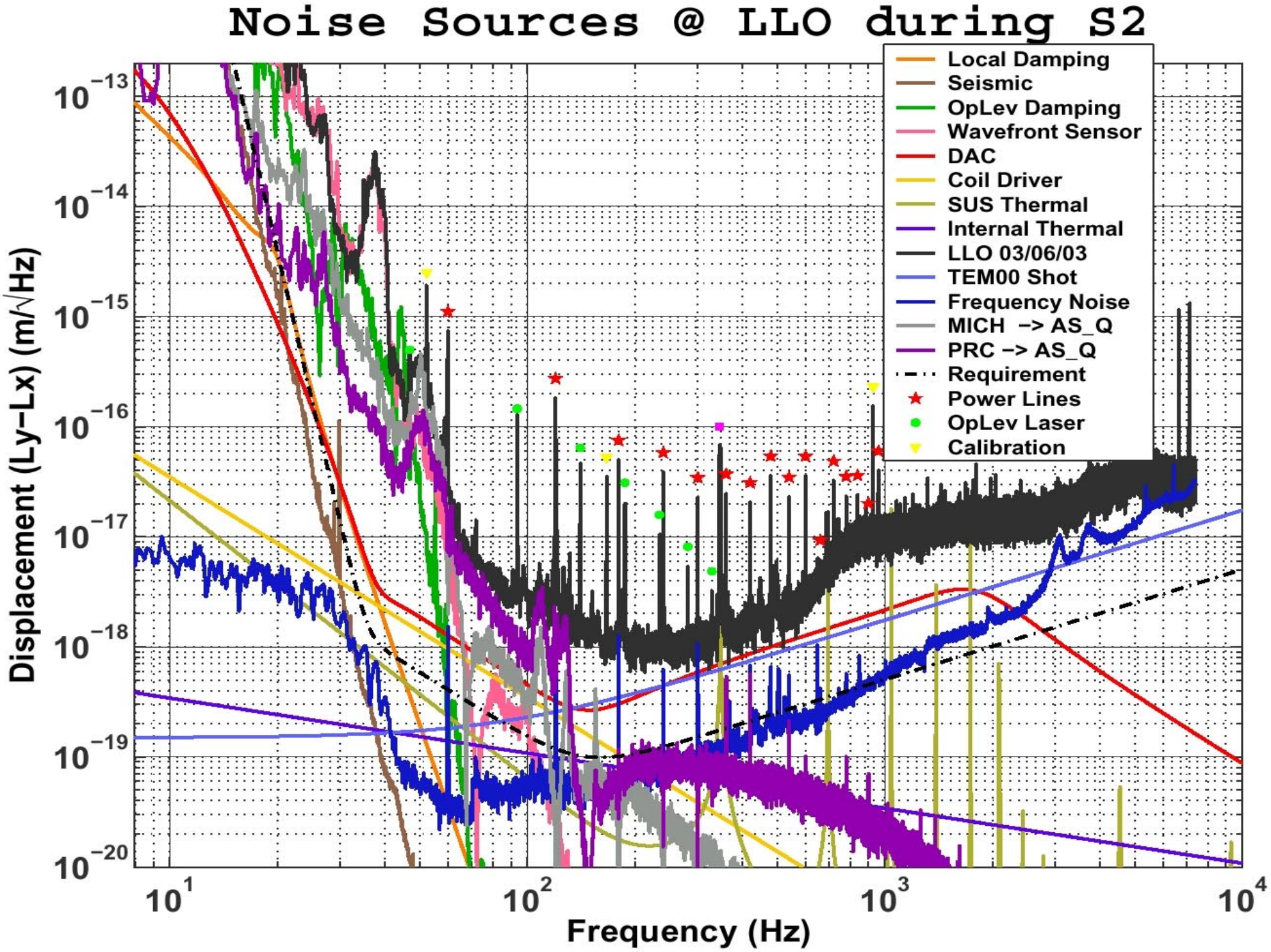


Major Achievements Since Last Amaldi

- Four orders of magnitude improvement in sensitivity (at 150Hz)
- All 3 interferometers operate routinely in power-recycled mode
  - Kilowatts in the arm cavities
  - Common mode control to the laser
  - Auto-alignment system / Optical levers for local damping
  - Great improvements in digital controls
    - Digital suspension controller
- First science data

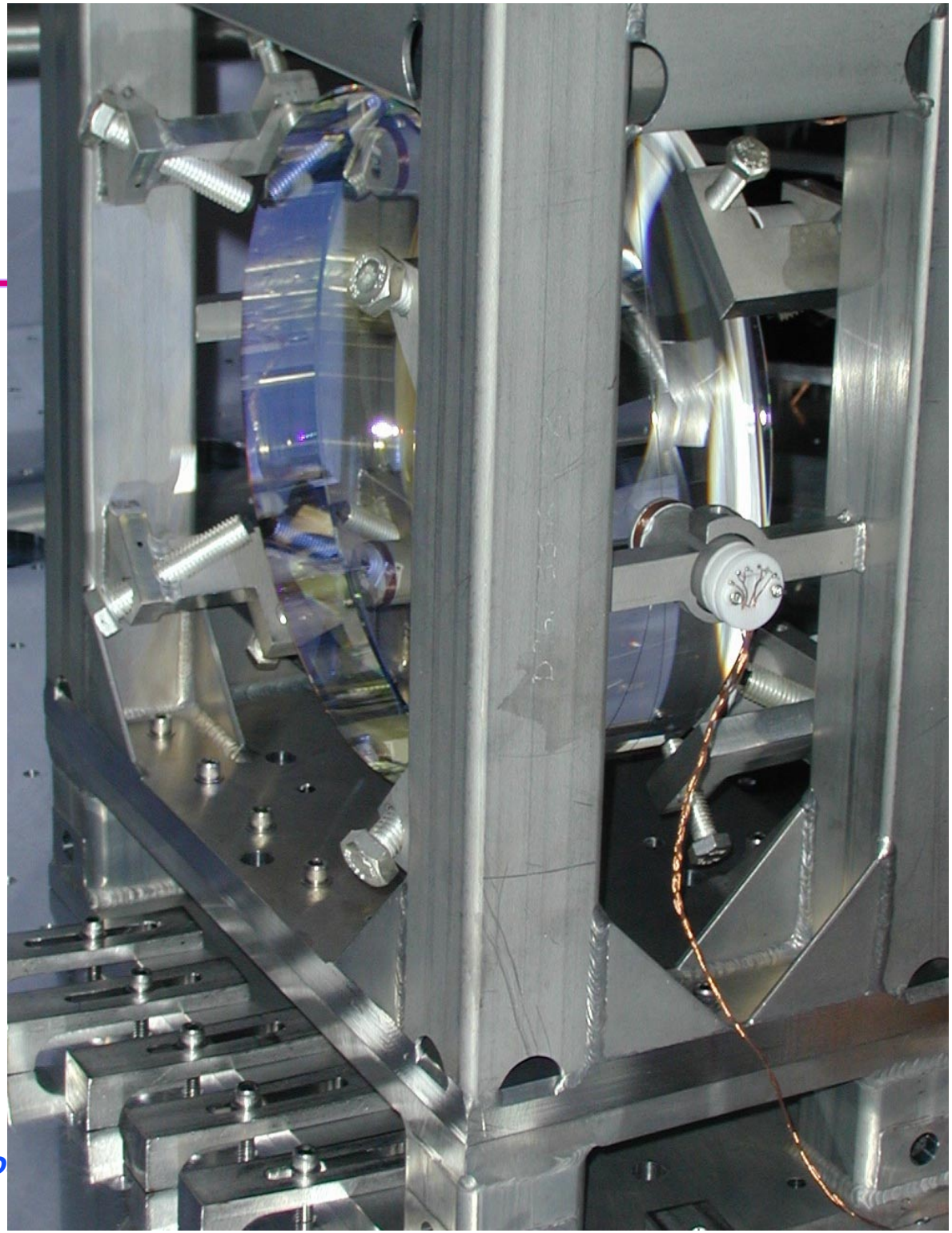
Strain Sensitivity for the LLO 4km Interferometer



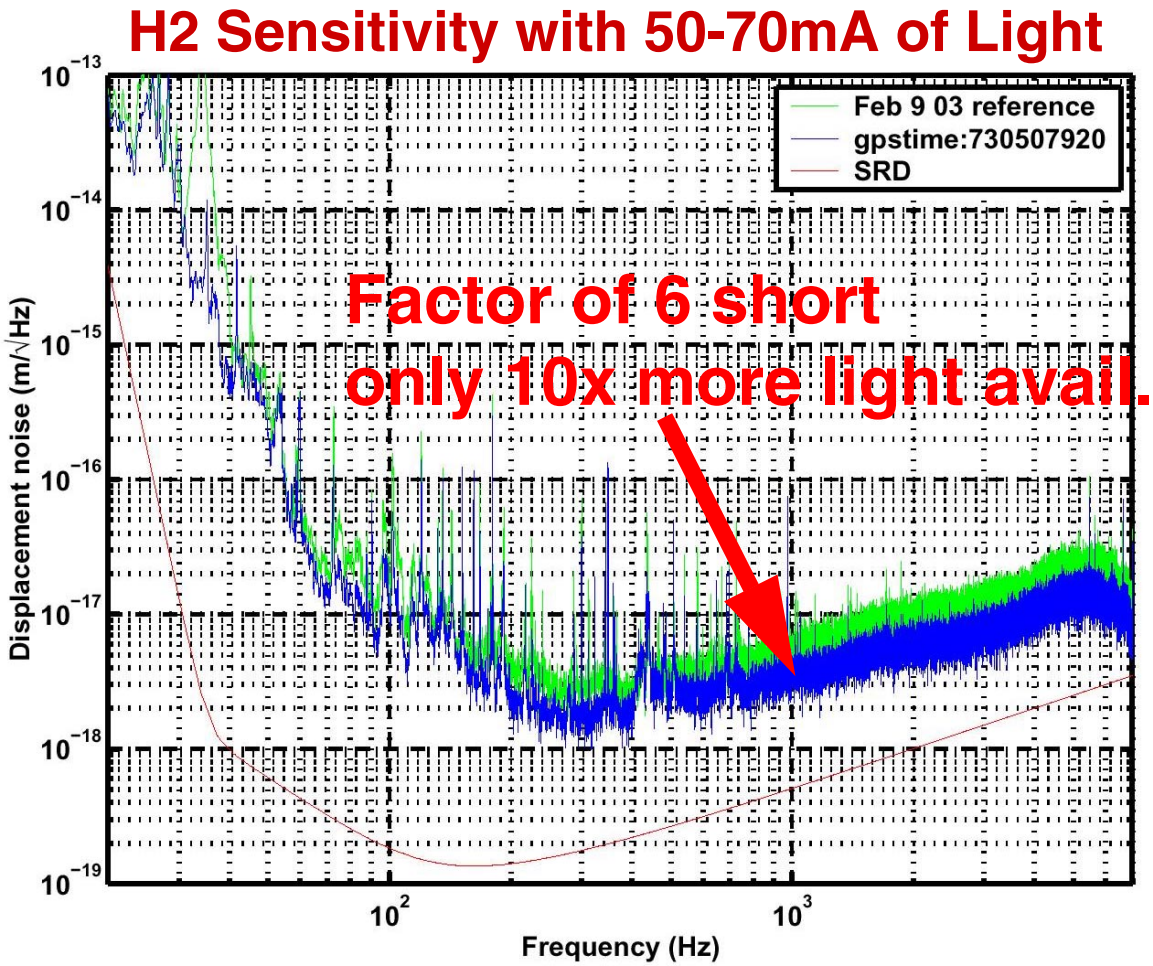

Noise Sources @ LLO during S2
Local Damping
Seismic
OpLev Damping
Wavefront Sensor
DAC
Coil Driver
SUS Thermal
Internal Thermal
LLO 03/06/03
TEM00 Shot
Frequency Noise
MICH -> AS_Q
PRC -> AS_Q
Requirement
Power Lines
OpLev Laser
Calibration
Displacement (Ly-Lx) (m/√Hz)
Frequency (Hz)
10^-13
10^-14
10^-15
10^-16
10^-17
10^-18
10^-19
10^-20
10^1
10^2
10^3
10^4

Optics

- Optics quality is (almost all) good
- Recycling gain meets or exceeds goals
  - L1: Gain of 45- 50 seen
  - H1: Gain of 40-45
  - H2: Cause of low recycling gain (20) found and fixed
- Contrast defect meets or exceeds goals
  - L1: $P_{as}/ P_{bs} = 3 \times 10^{-5}$
  - H1: $P_{as}/ P_{bs} = 6 \times 10^{-4}$



High Power Operations

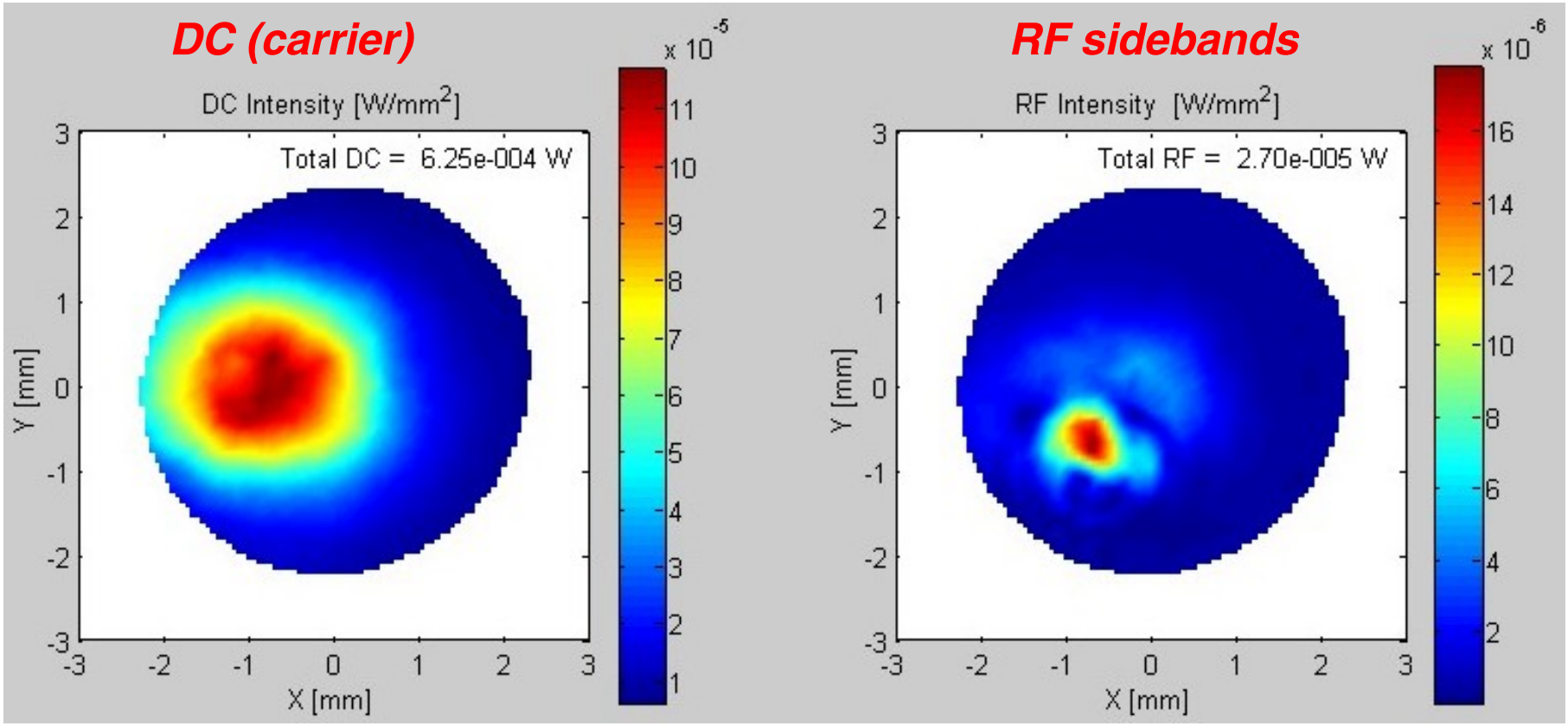


- Dynamic range problem: 1000x
- Signal in wrong quadrature dominant!
- Use multiple detectors at anti-symmetric port
- Need protection for photodetectors
- Need protection for suspension wires!

Recycling Cavity Degeneracy

- RF sideband efficiency is very low
  - H1 efficiency: ~6% (anti-symmetric port relative to input)
  - lack of ITM thermal lens makes $g_1 \cdot g_2 > 1$ (unstable resonator)

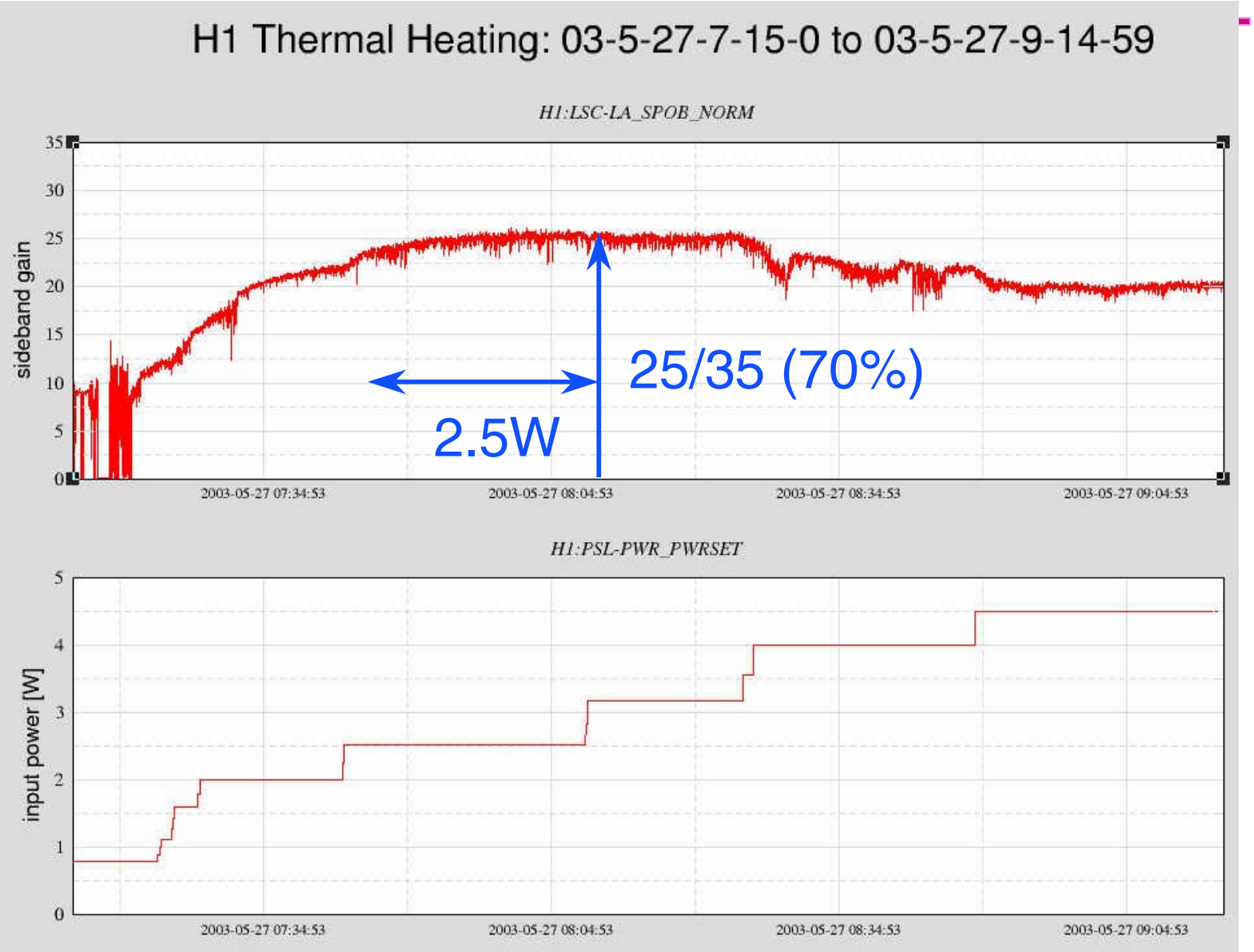
Bad mode overlap!



Thermal Lensing

No mode overlap improvements seen at AS port!?

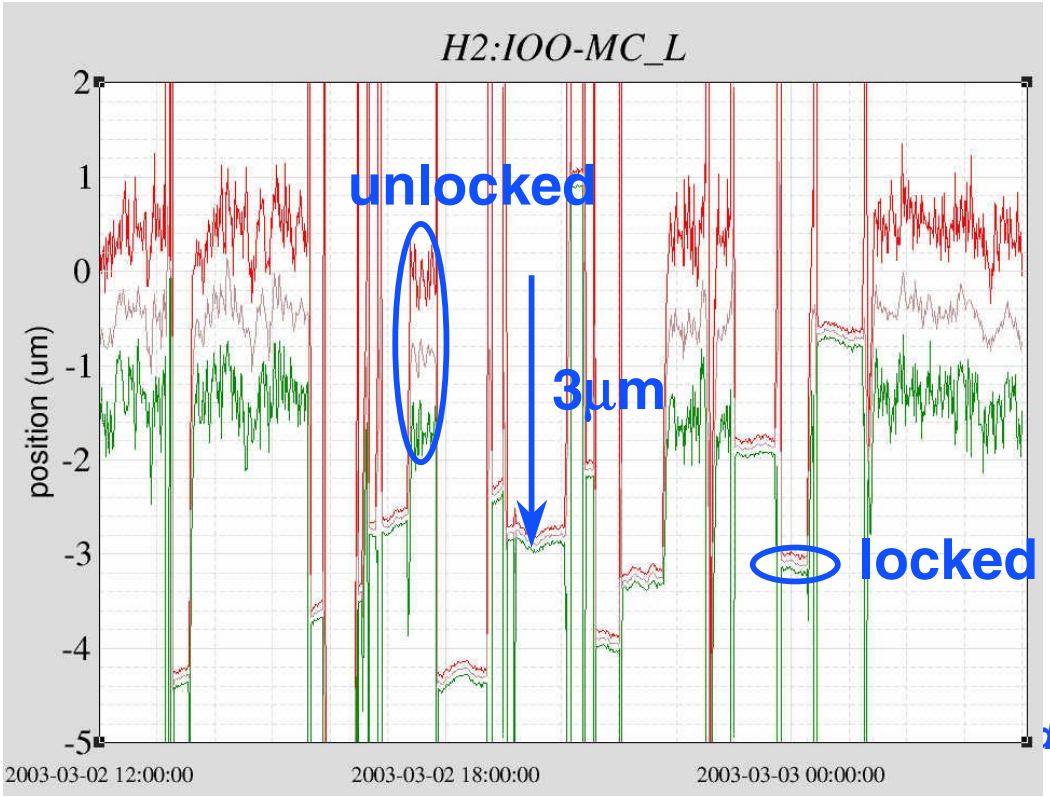
H2/L1: Thermal Compensation

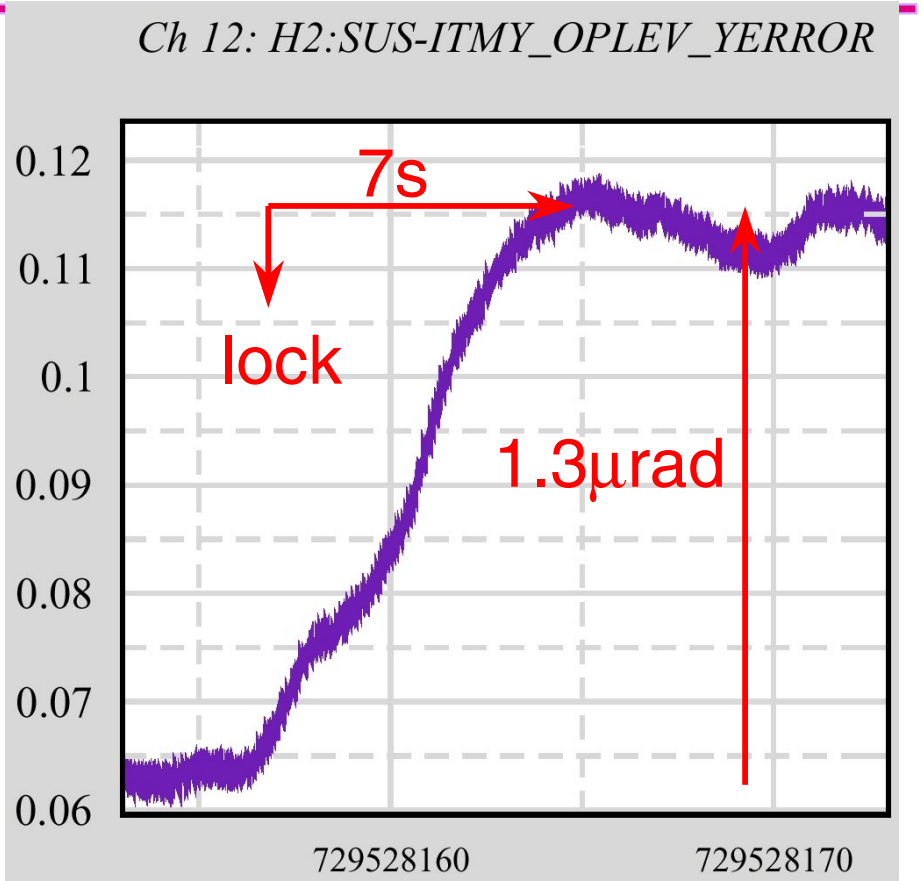


Radiation Pressure

- Not a small effect!

Mode cleaner length shift (2kW)



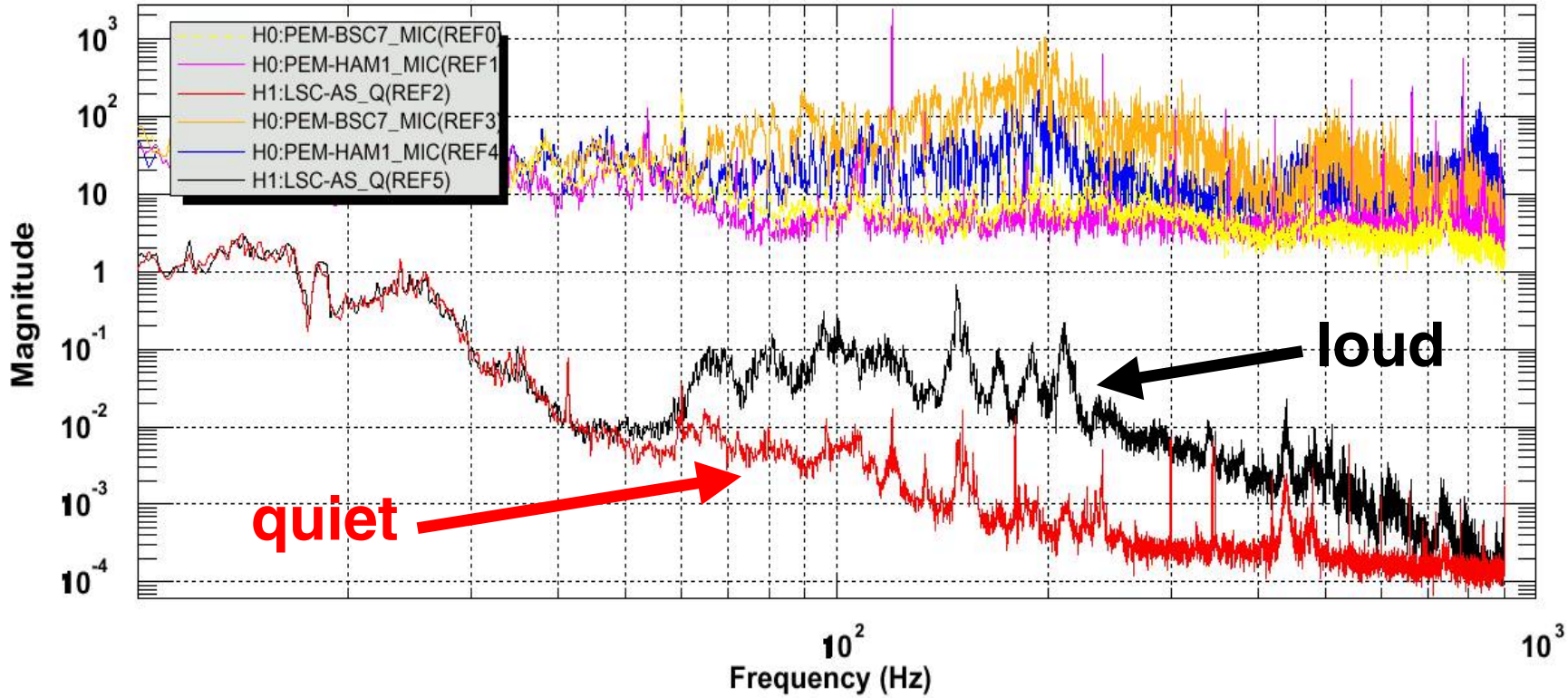


Arm cavity angular shift
2cm de-centering at 5kW

Acoustic Noise Coupling

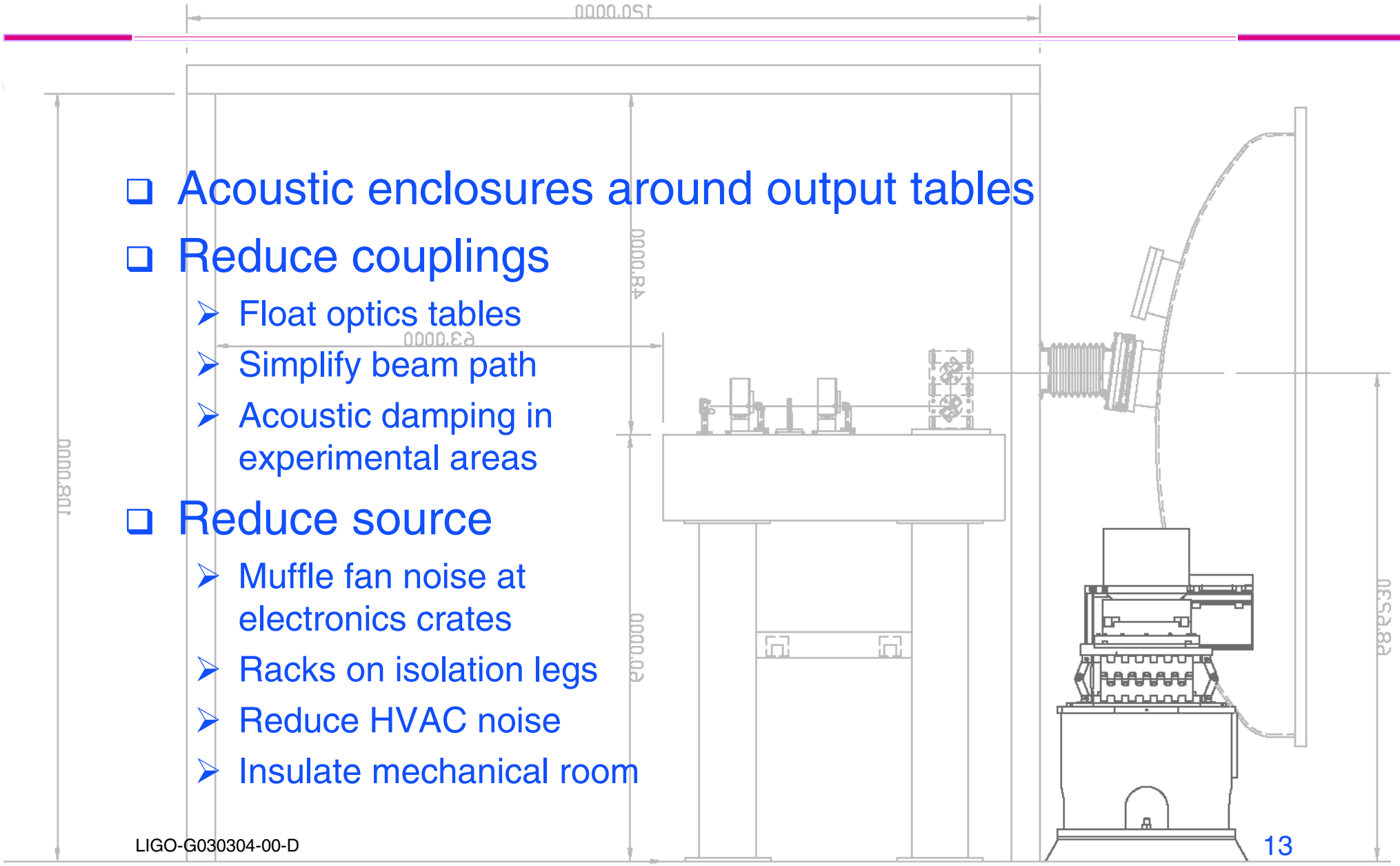
- Peaks occur in 80-1000 Hz band, at a level 10-100x the design sensitivity
- Source for H1/H2 coincidences(?)

Acoustic Excitations

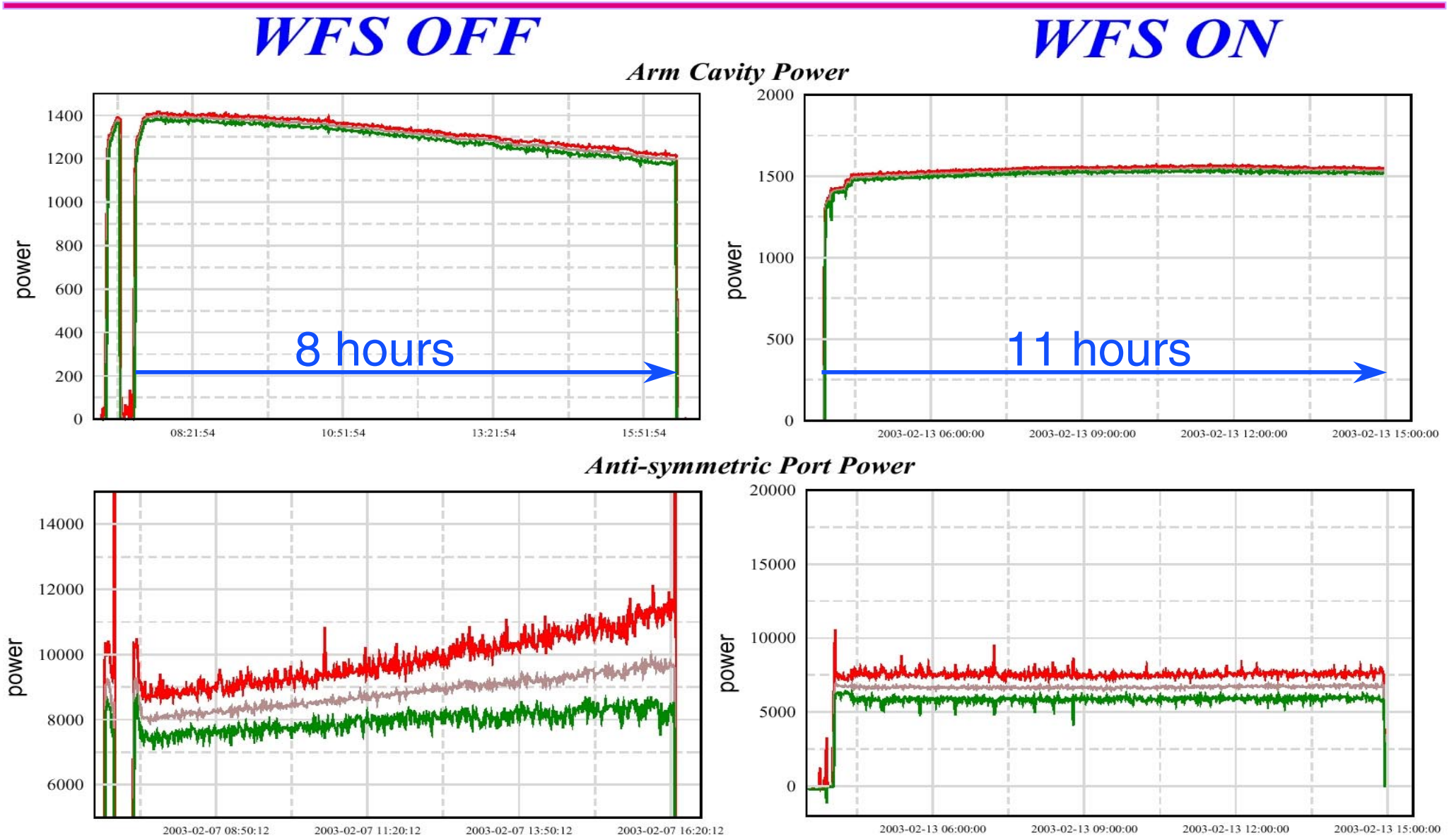


Acoustic Mitigation

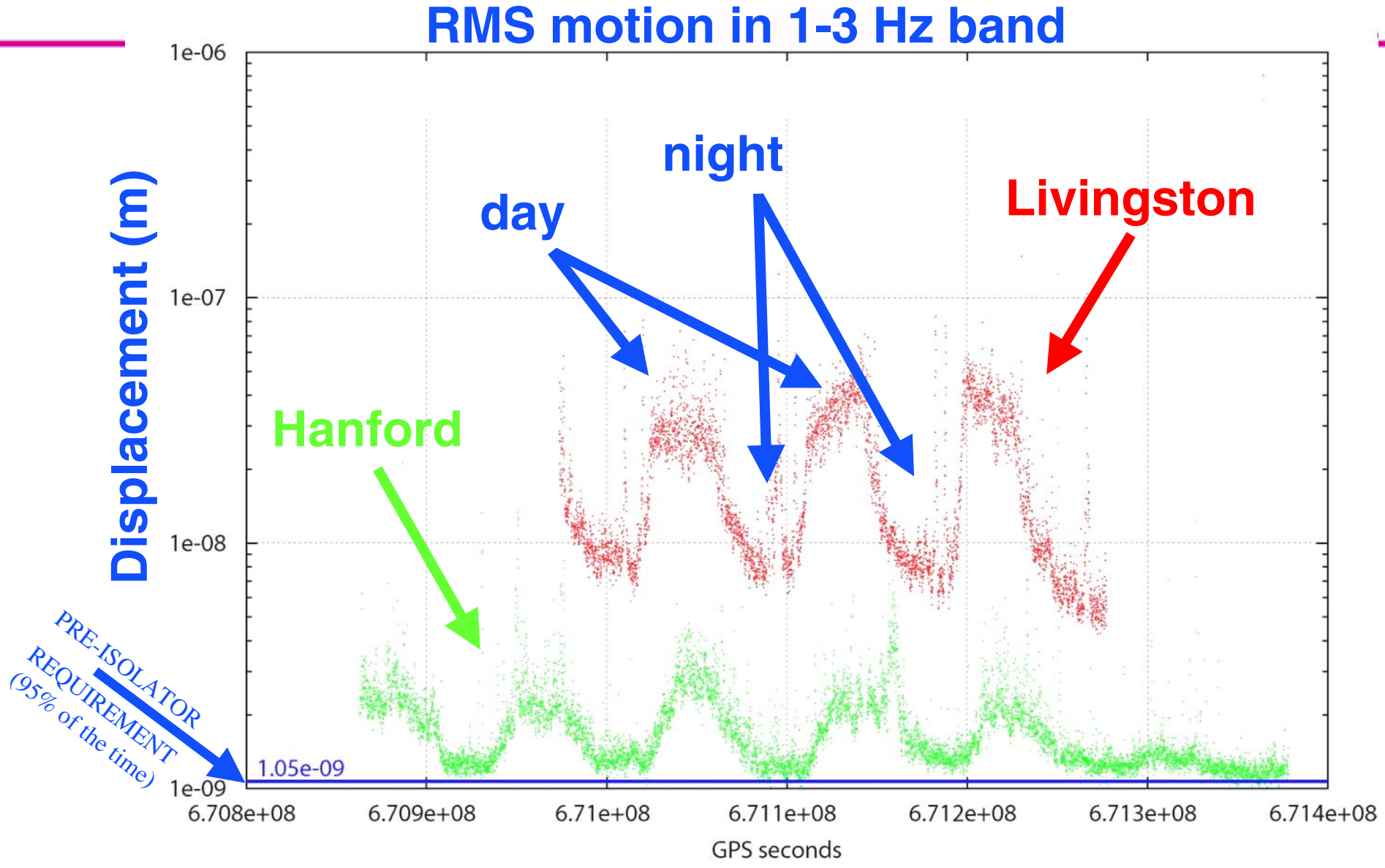
- Acoustic enclosures around output tables
- Reduce couplings
  - Float optics tables
  - Simplify beam path
  - Acoustic damping in experimental areas
- Reduce source
  - Muffle fan noise at electronics crates
  - Racks on isolation legs
  - Reduce HVAC noise
  - Insulate mechanical room



Auto-Alignment System

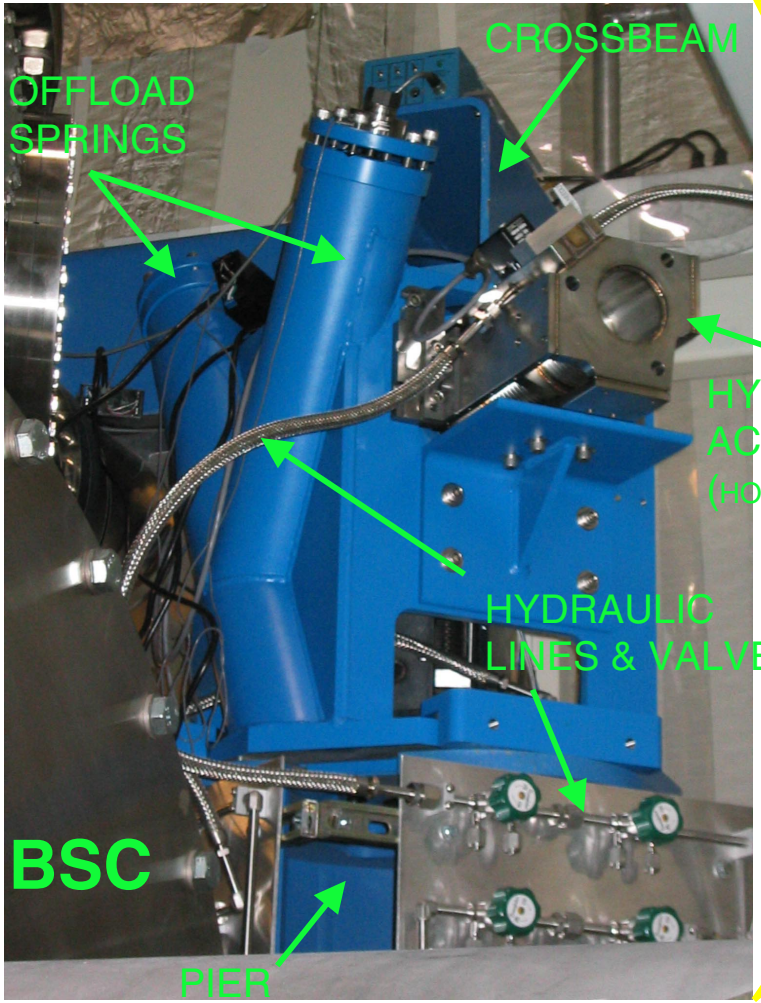


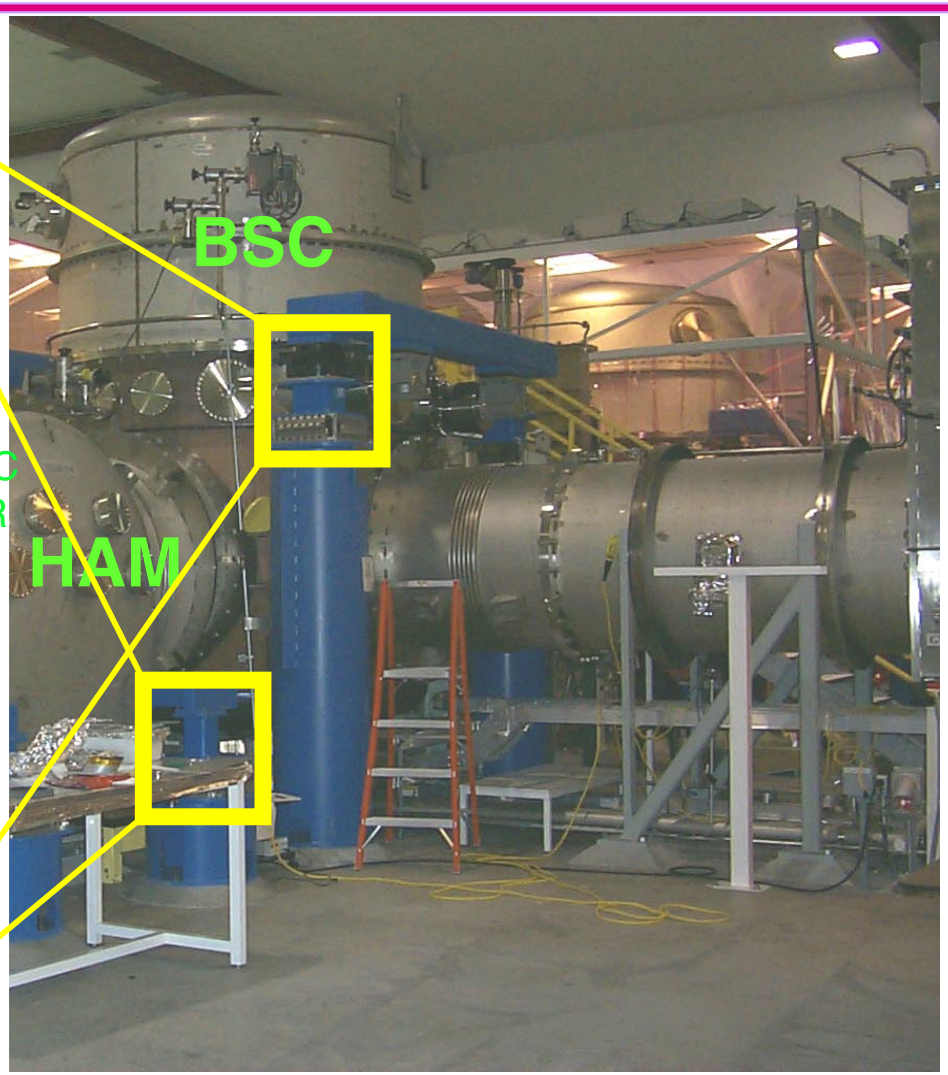
Daily Variability of Seismic Noise



Active Seismic Isolation

Hydraulic External Pre-Isolator (HEPI)





Science Runs

- First science run
  - August 23 – September 9, 2002 (2.5 weeks)
  - Inspiral range: 25 kpc for $1.4M_{sol}$
  - Duty cycle: H1 58%, H2 73%, L1 42%, triple 23%
  - Analysis for burst, inspiral, periodic and stochastic completed
  - Papers ready
- Second science run
  - February 14 – April 14, 2003 (8.5 weeks)
  - Inspiral range: up to 1 Mpc for $1.4M_{sol}$
- Third science run
  - Planned to start end of October, 2003 (2 months)