Suspension Thermal Noise in Initial LIGO

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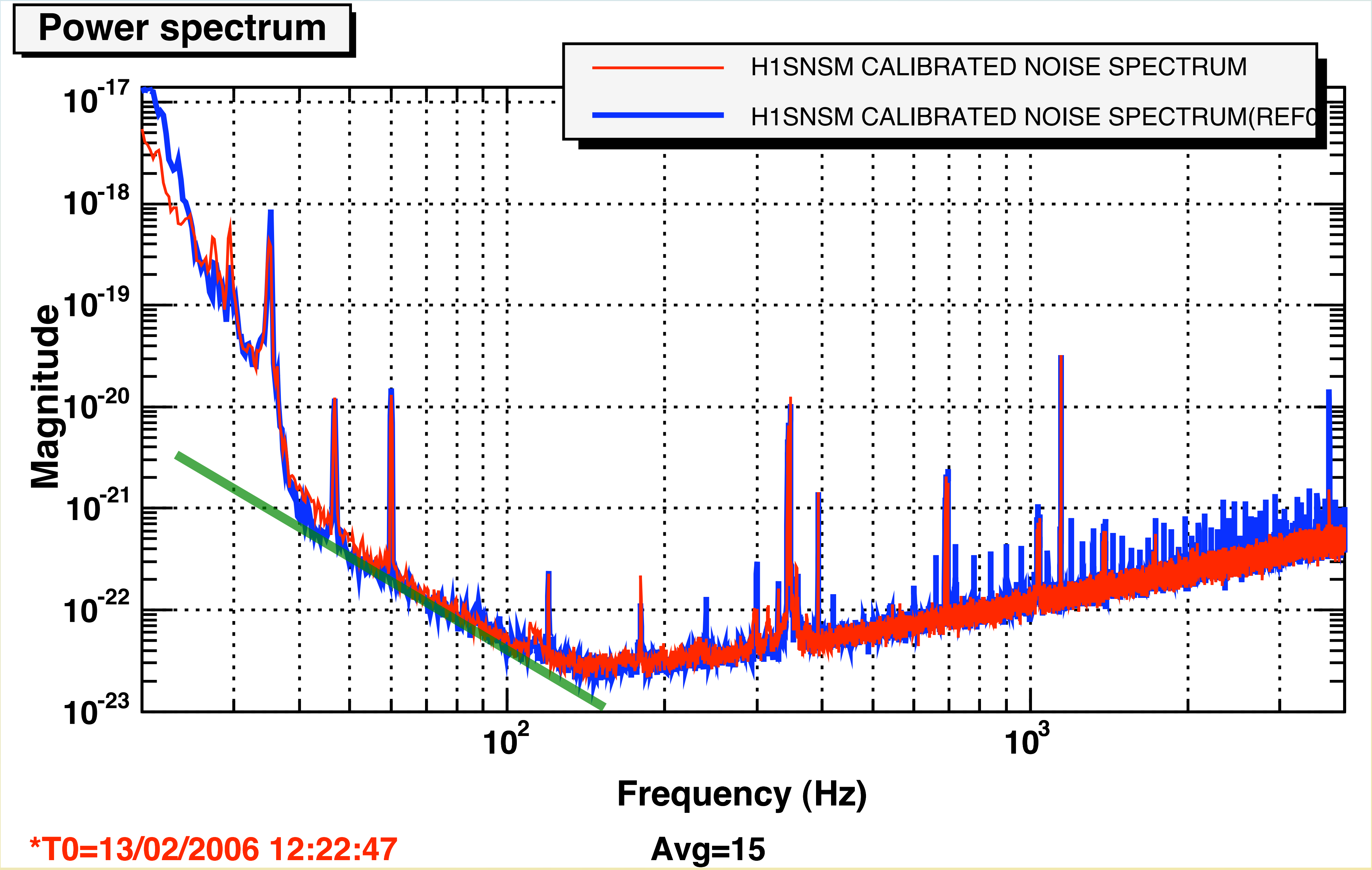
- Suspension Working Group -

March 21, 2006
LSC Meeting - LHO

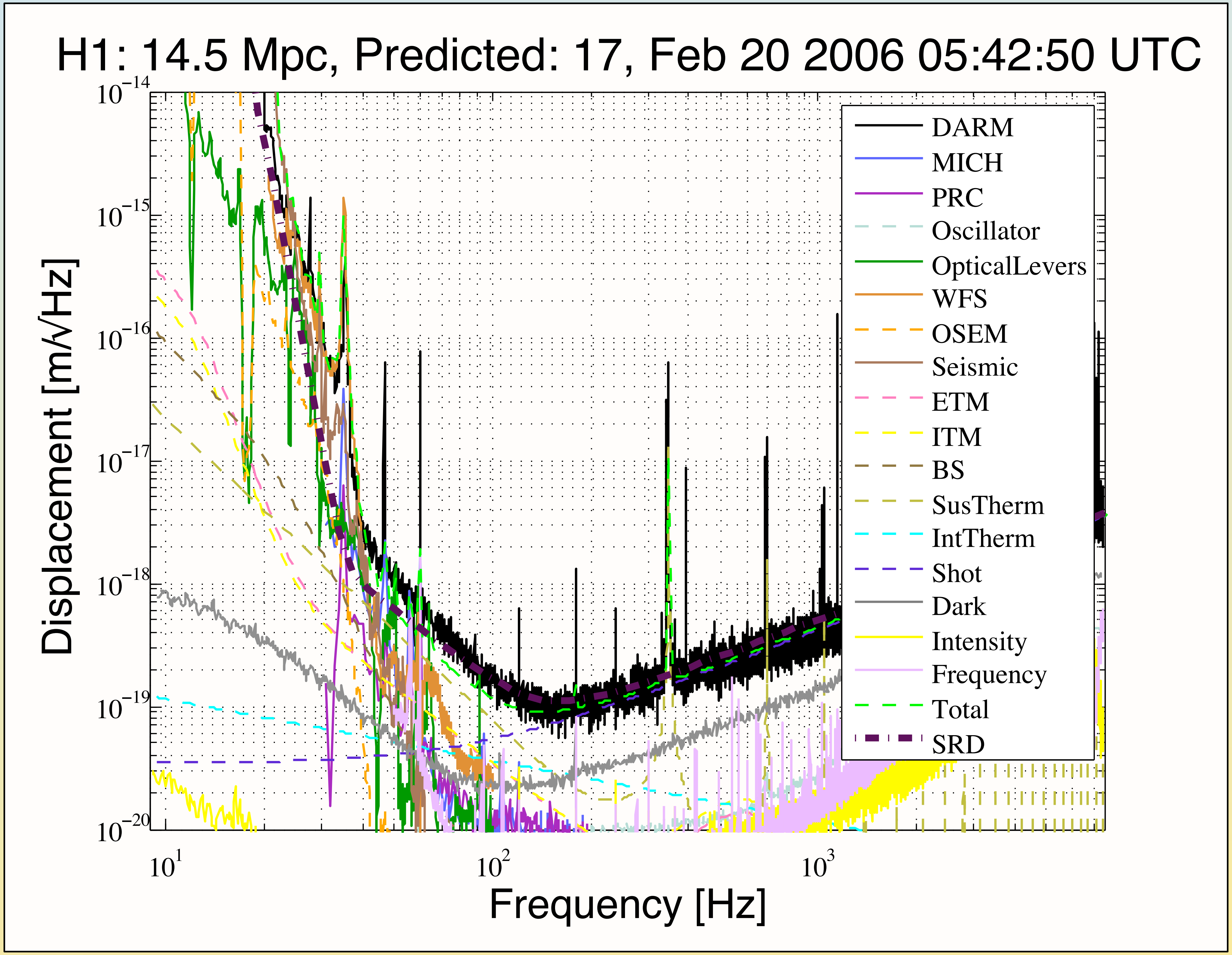
LIGO DCC LIGO-G060144-00-Z

The Problem



- Noise between 40 Hz and 150 Hz has slope near 5/2
- Level is high, but not impossibly high, to be suspension thermal noise
- Very similar level in all three interferometers

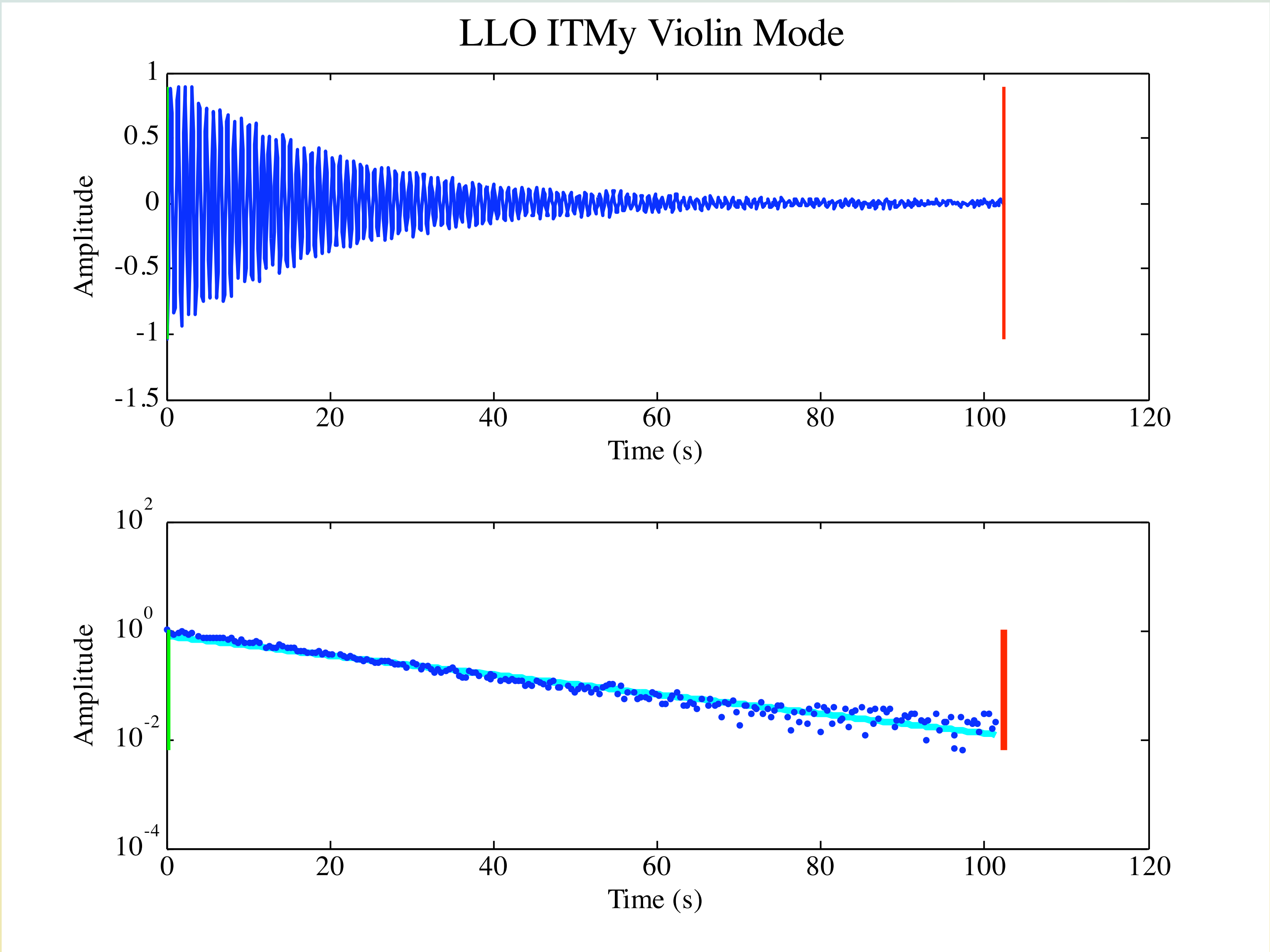
The Problem



H1: 14.5 Mpc, Predicted: 17, Feb 20 2006 05:42:50 UTC
Displacement [m/√Hz]
Frequency [Hz]
DARM
MICH
PRC
Oscillator
OpticalLevers
WFS
OSEM
Seismic
ETM
ITM
BS
SusTherm
IntTherm
Shot
Dark
Intensity
Frequency
Total
SRD

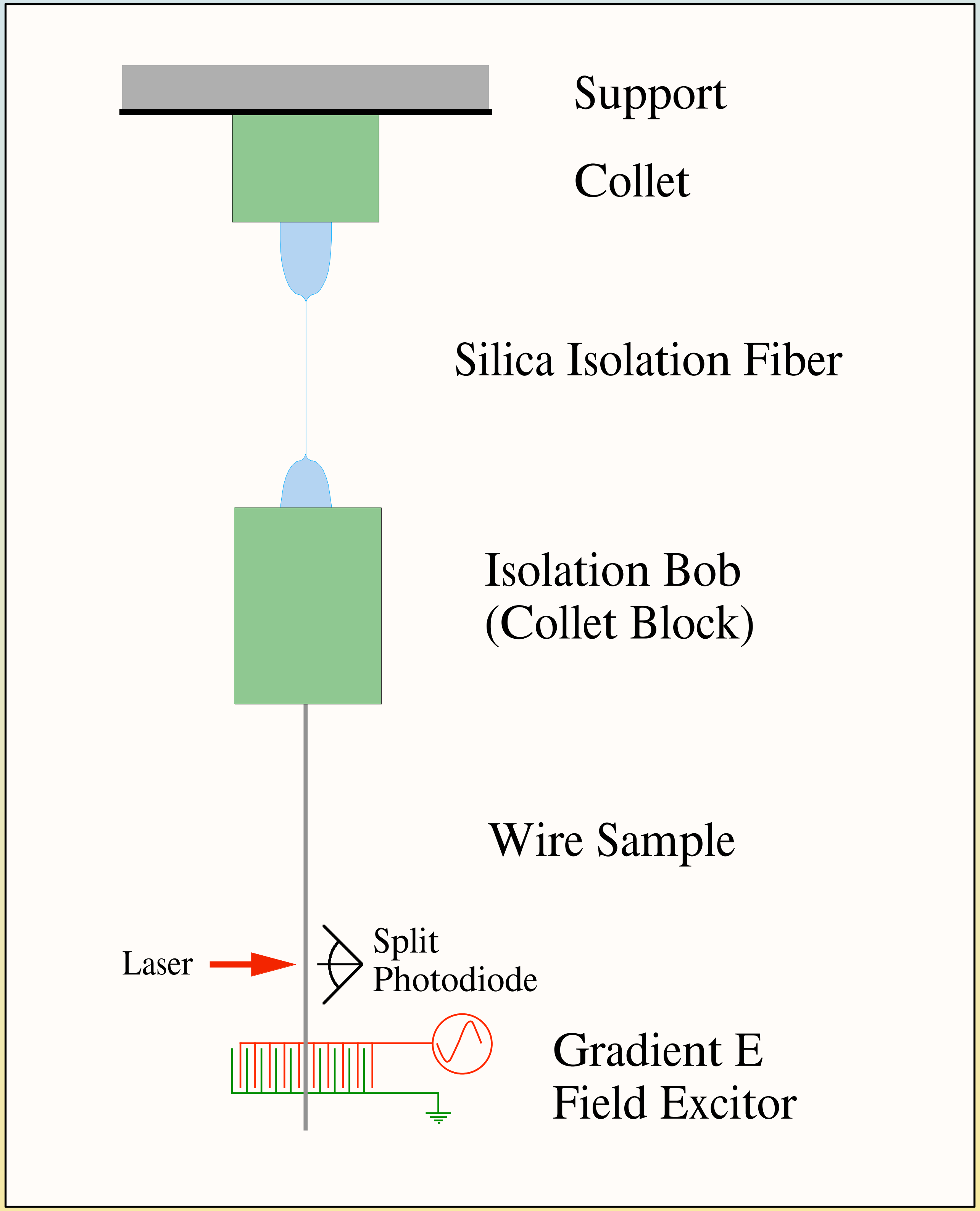
Measurement of Violin Modes at Sites

- Q's typically lower than expected Q due to mechanical loss (thermoelastic damping and structural loss)
- No agreement between optics
- Mysterious changes in Q
    - Consistent within lock stretch
    - Feedback effects, however no dependence on optical power
    - Possible losses
        - Recoil damping
        - Temperature drifts
        - Clamp losses

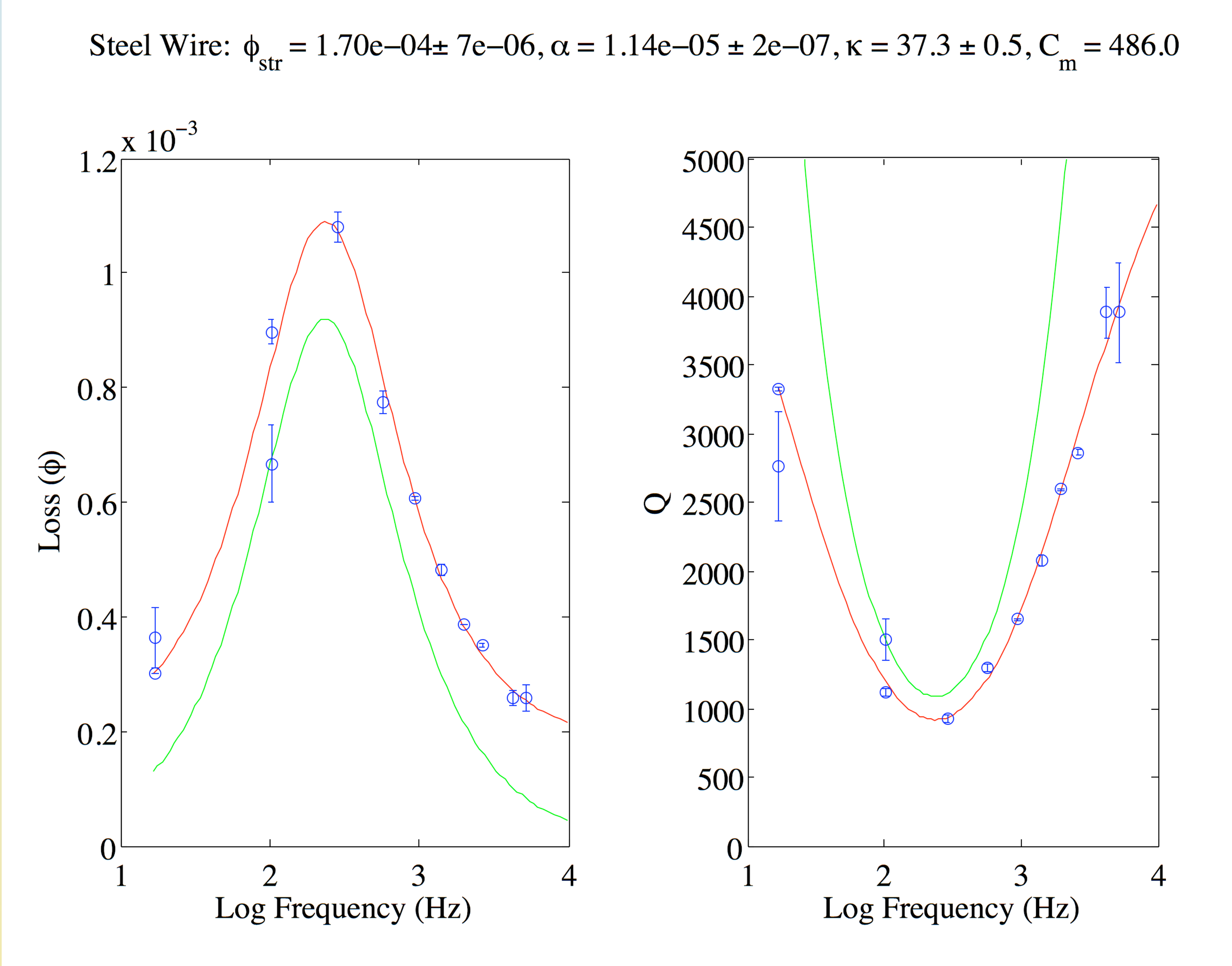


Violin Mode Q's are inconsistent and much lower than fundamental mechanical loss limit.

Mechanical Loss in Wires



Mechanical Loss in Wires



Structural loss about half of the previously accepted value.

MIT Experiment

Pathfinder Optic hung in spare frame with wire from the sites. Each wire monitored by eight shadow sensors.

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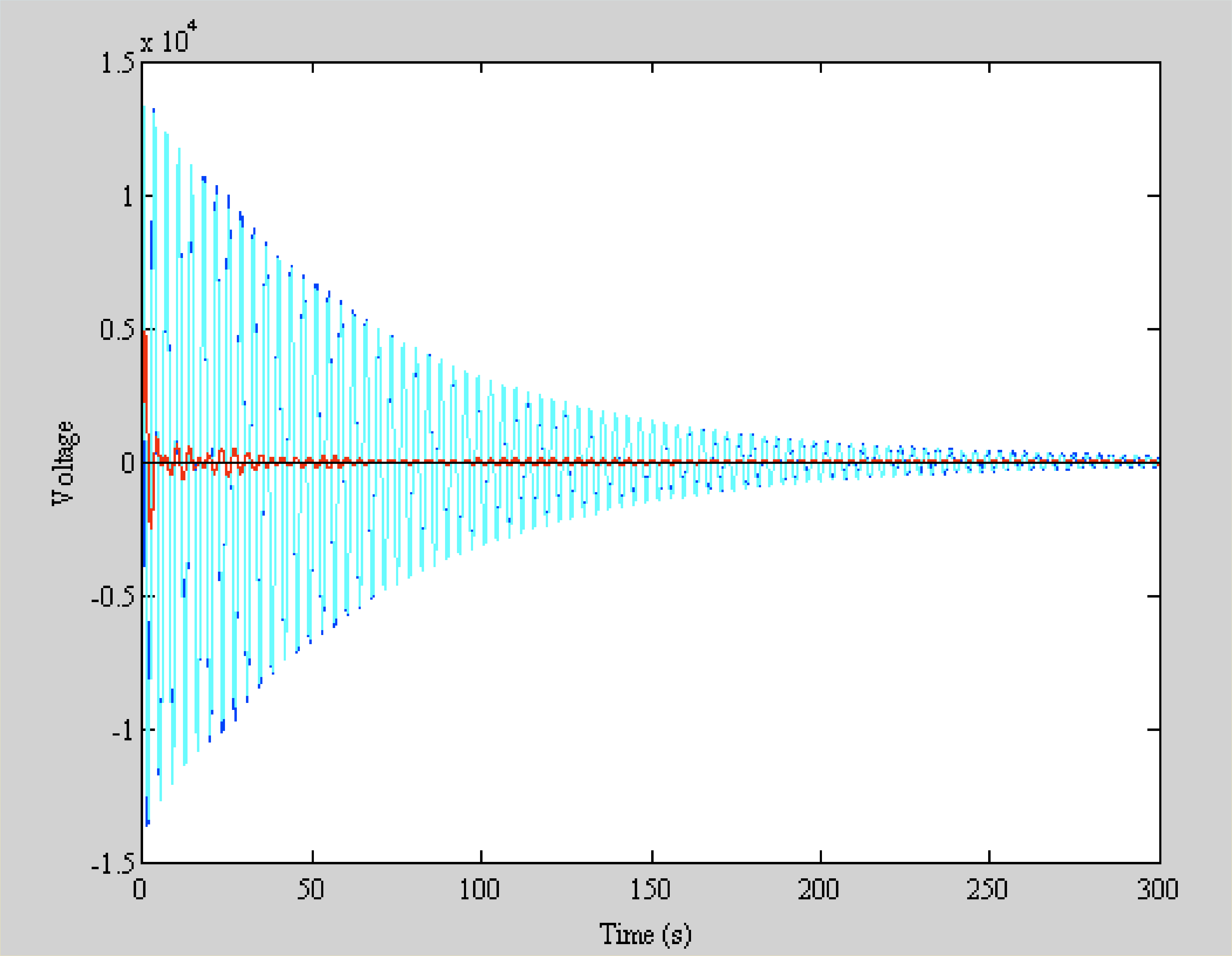
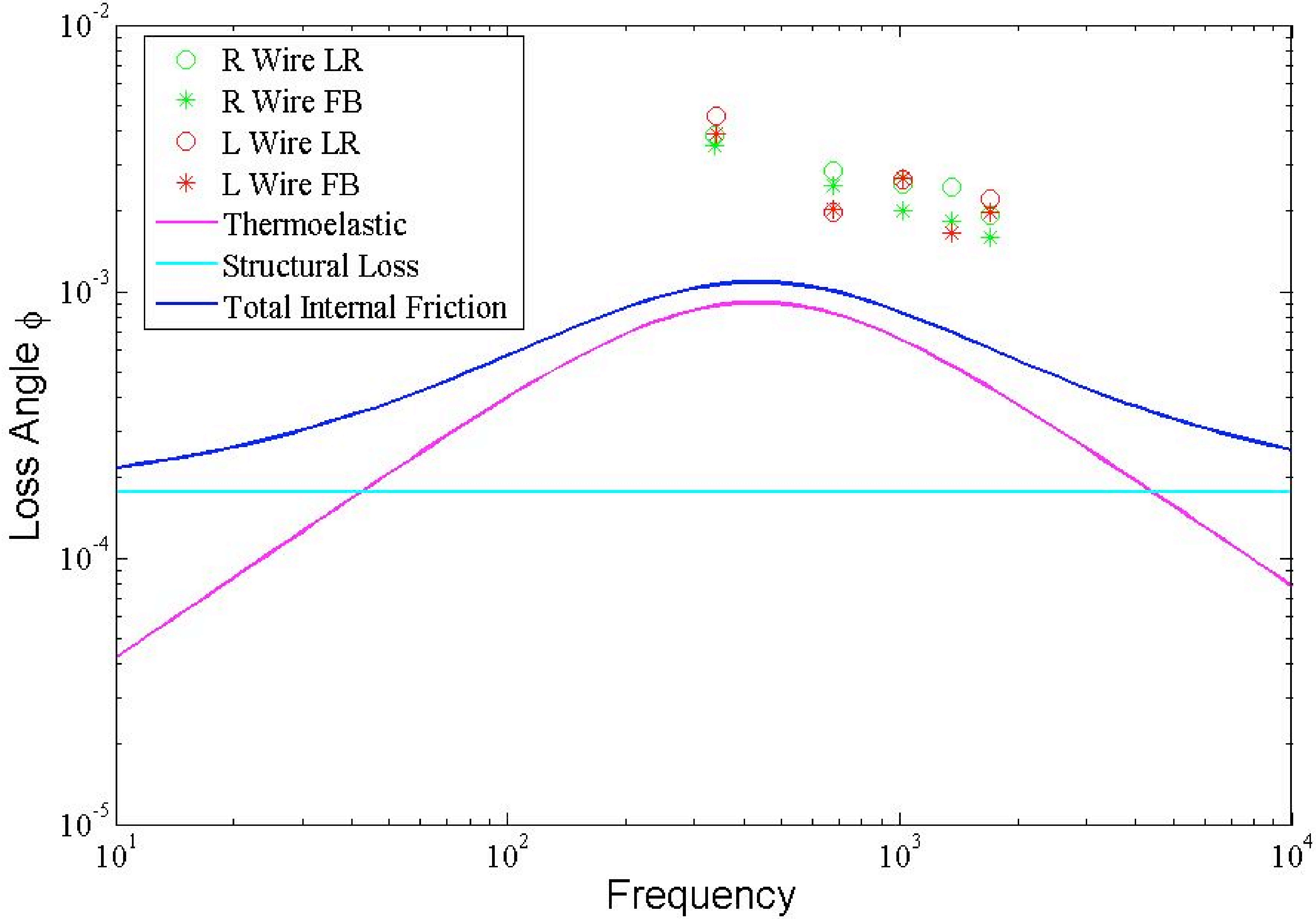
Violin Mode Loss



Violin Mode Loss



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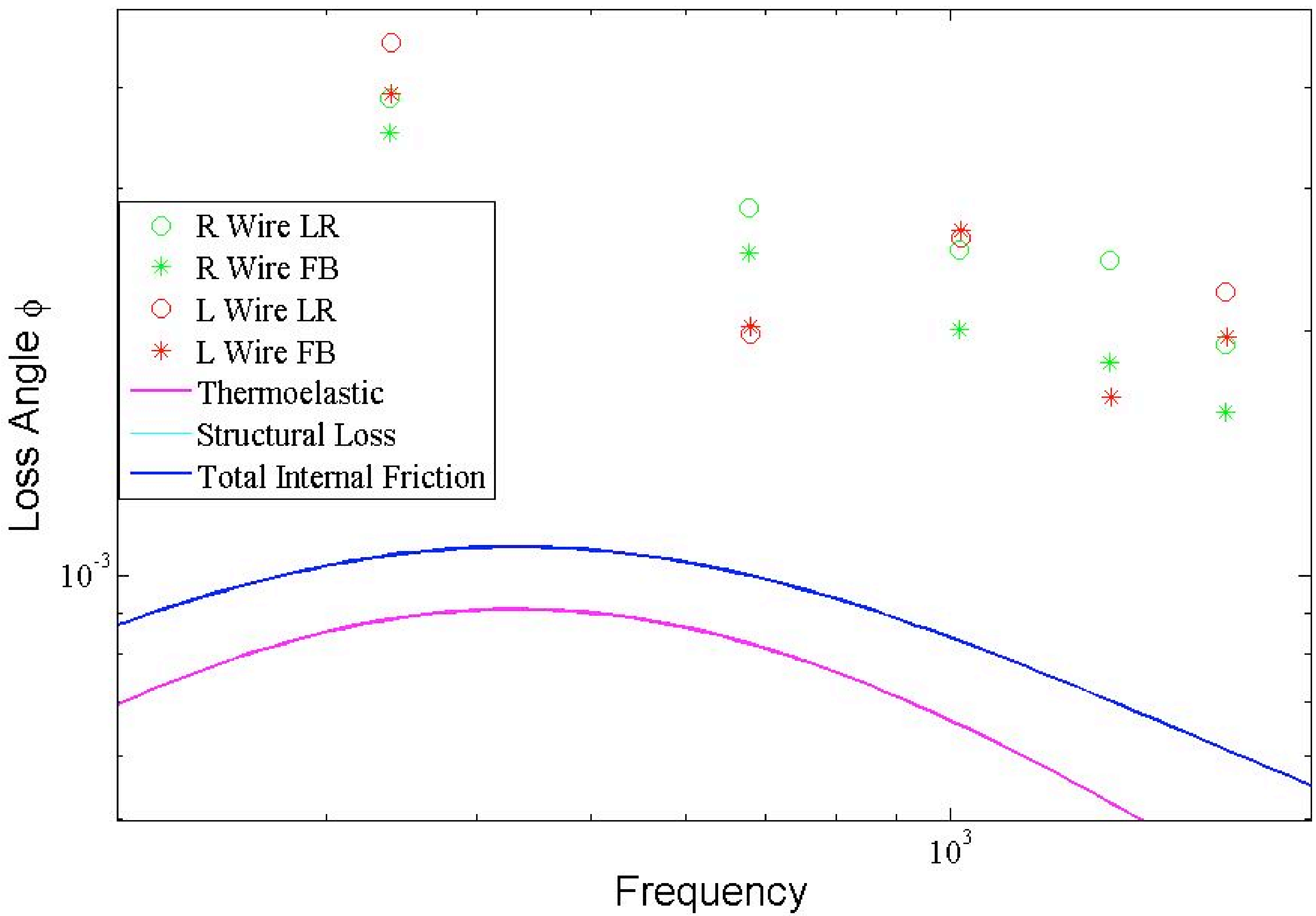
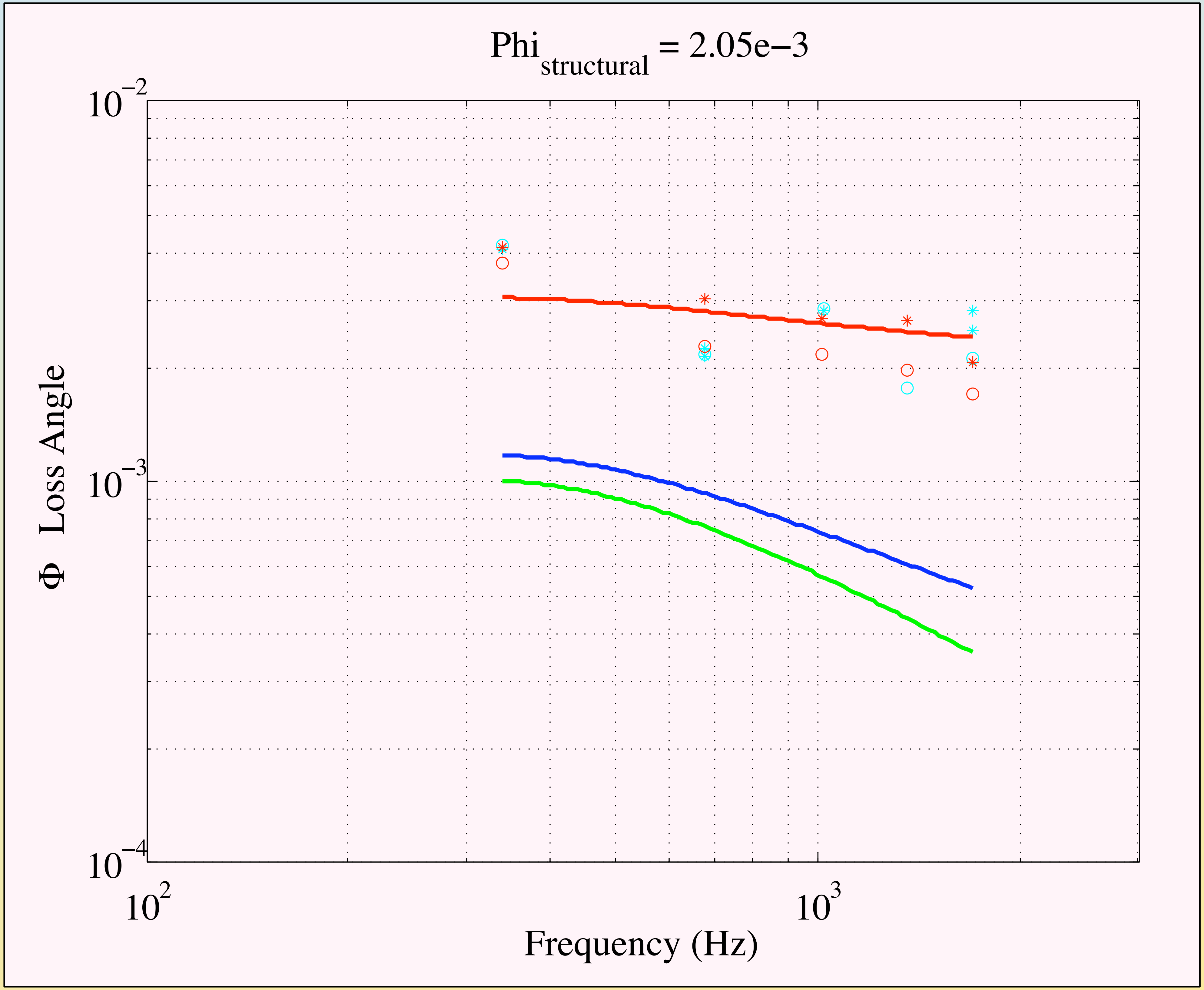
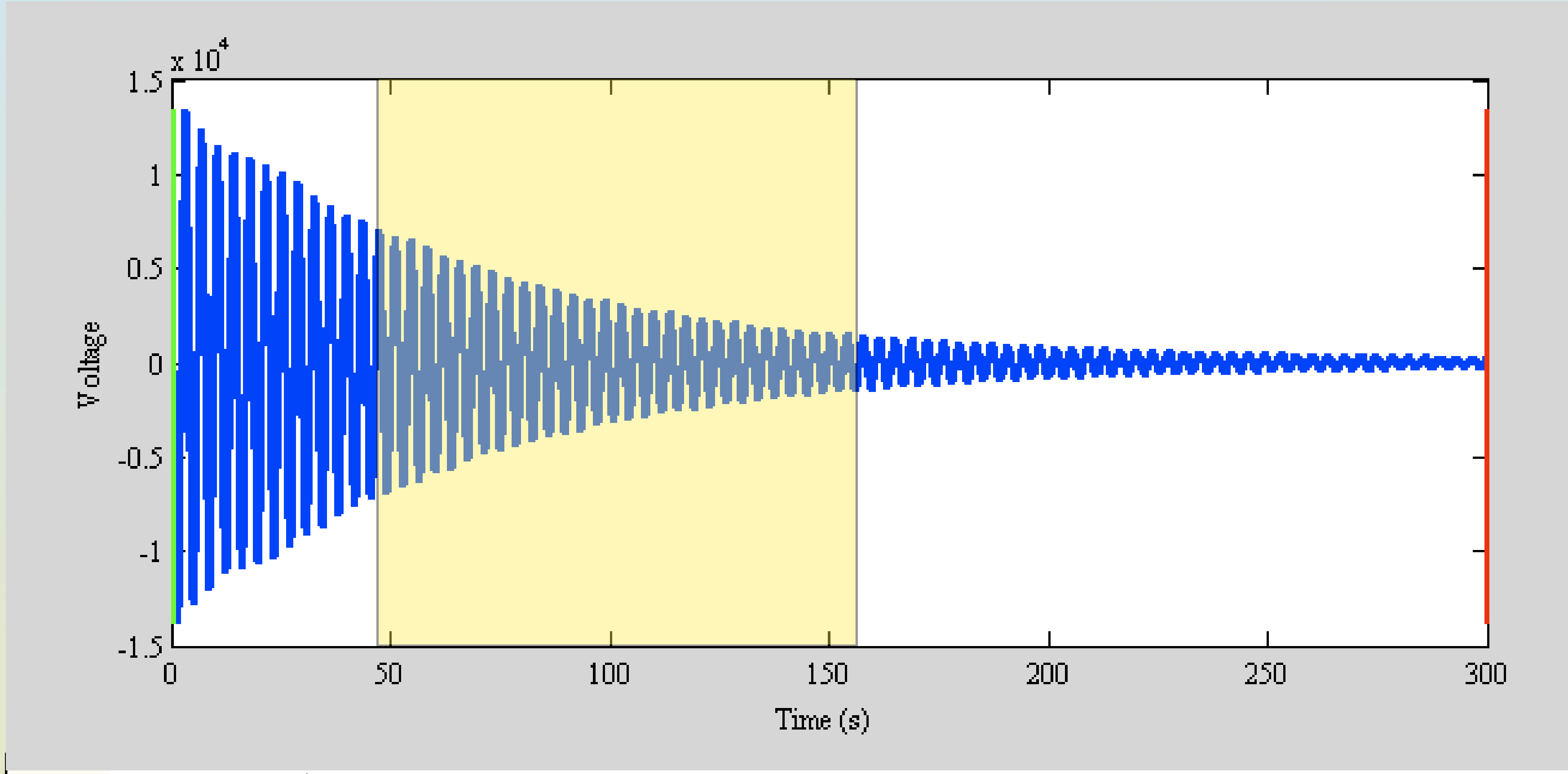
Violin Mode Loss

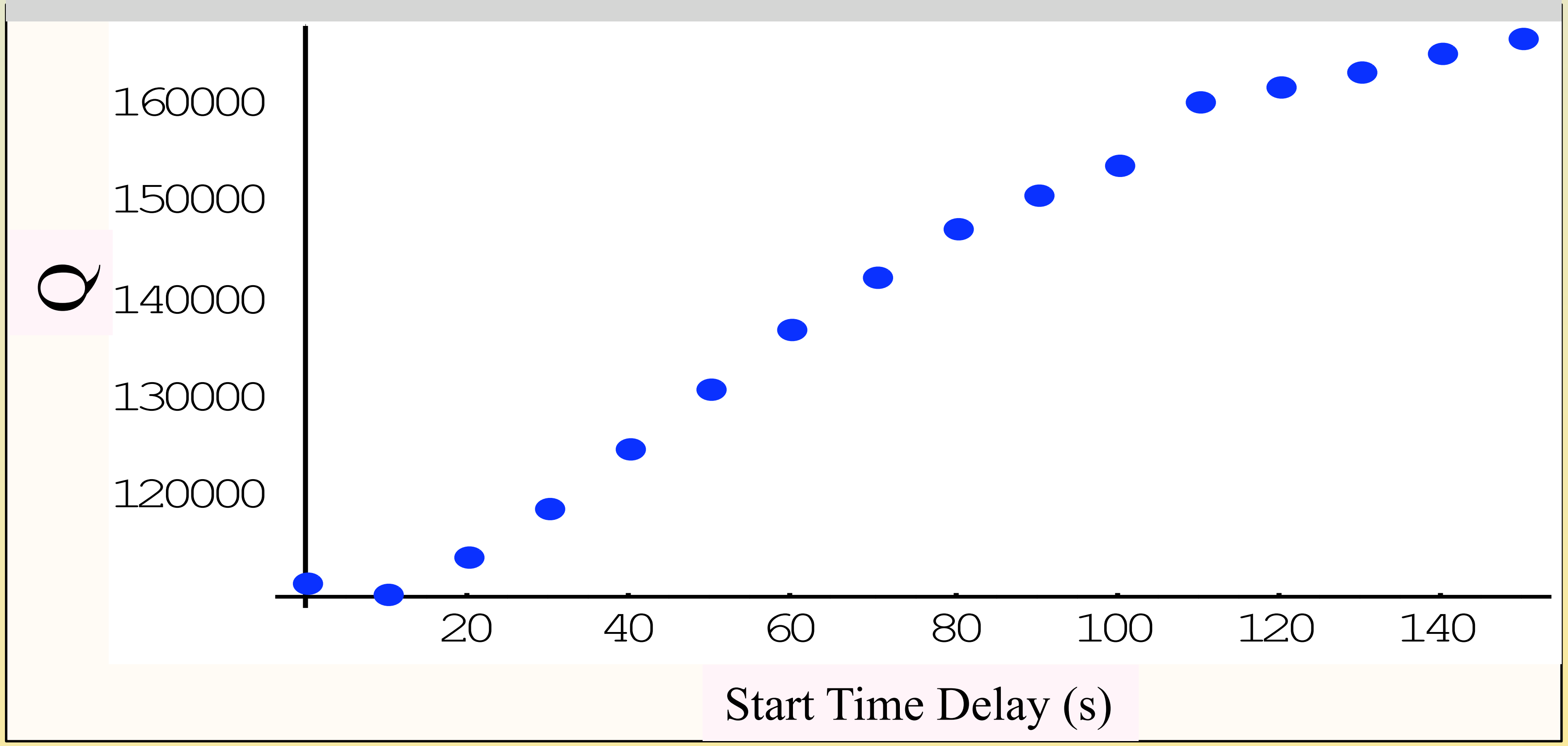


Violin Mode Loss



Q vs. Amplitude





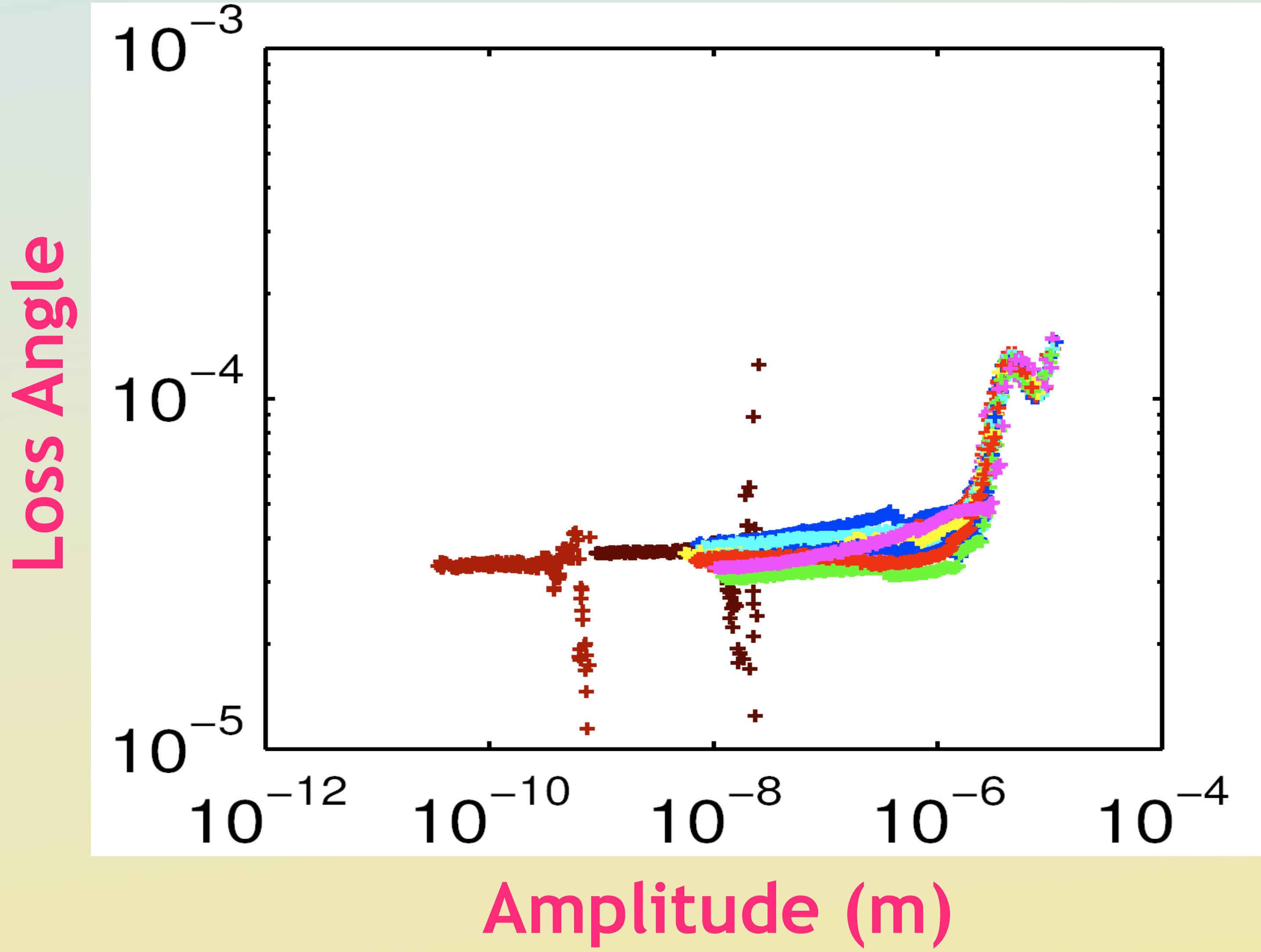
Amplitude Dependence of Loss Angle

Clamp Friction losses

- Rubbing friction at high amplitude
  - Higher loss
  - Amplitude & frequency dependent
- Partial slip (slip-stick) at lower amplitude
  - Nearly frequency independent
  - Degrades with multiple measurements

Proper Clamping

- Clamp should not cause plastic deformation in clamp or fiber
  - Repeatability
  - No time variability
- No Clamp slippage
  - Hardened uniform clamping (collet)
  - Taper fiber ends



Data from Gretarsson thesis

W wire in Al clamps. Loss is 100 x internal loss.

Noise Budget

Estimate for thermal noise assuming the suspension noise for all test mass is the same as our result.

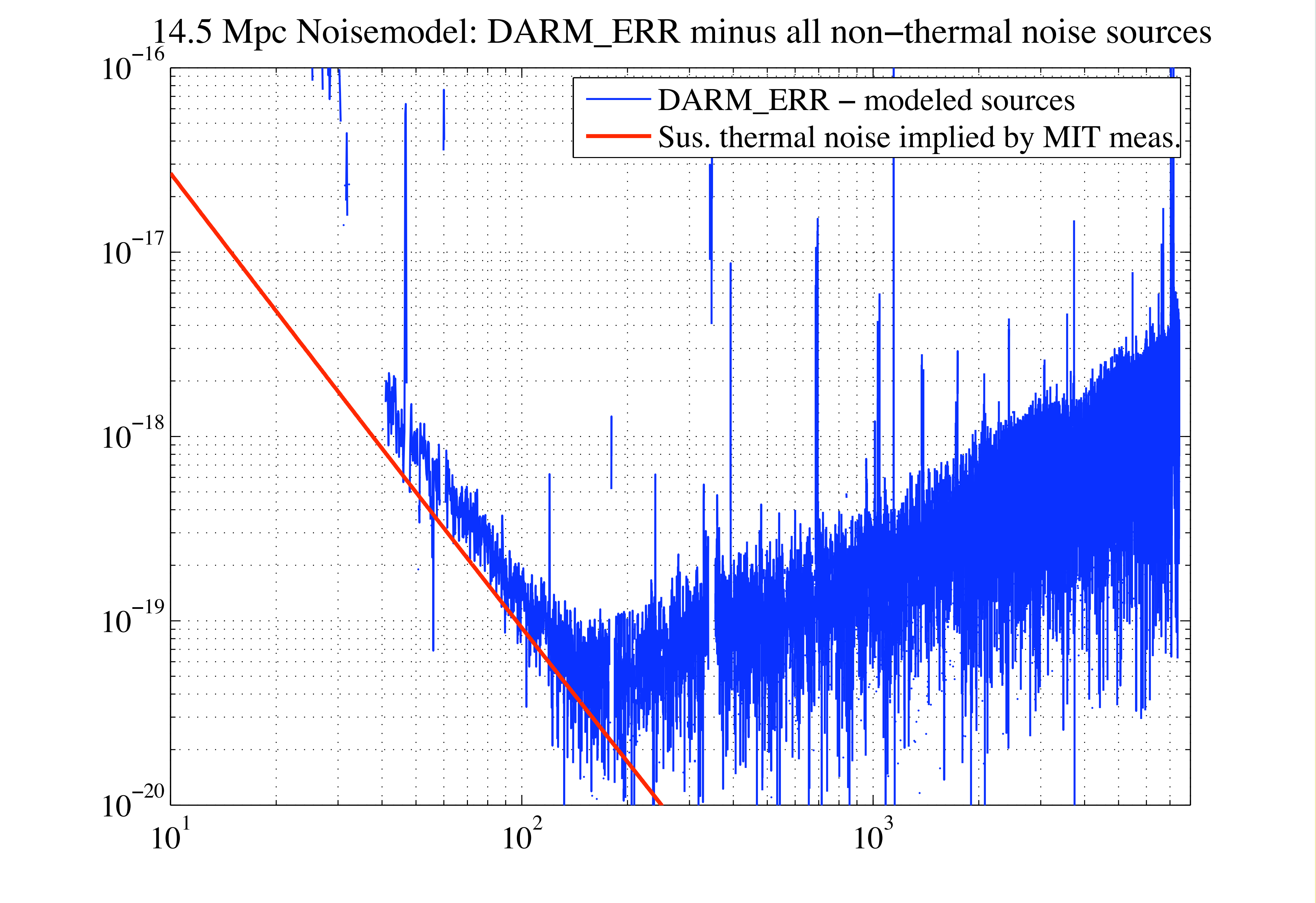
$\phi = 2 \times 10^{-3}$

Worst loss seen from measurements of violin mode at the sites is

$\phi = 1.1 \times 10^{-2}$

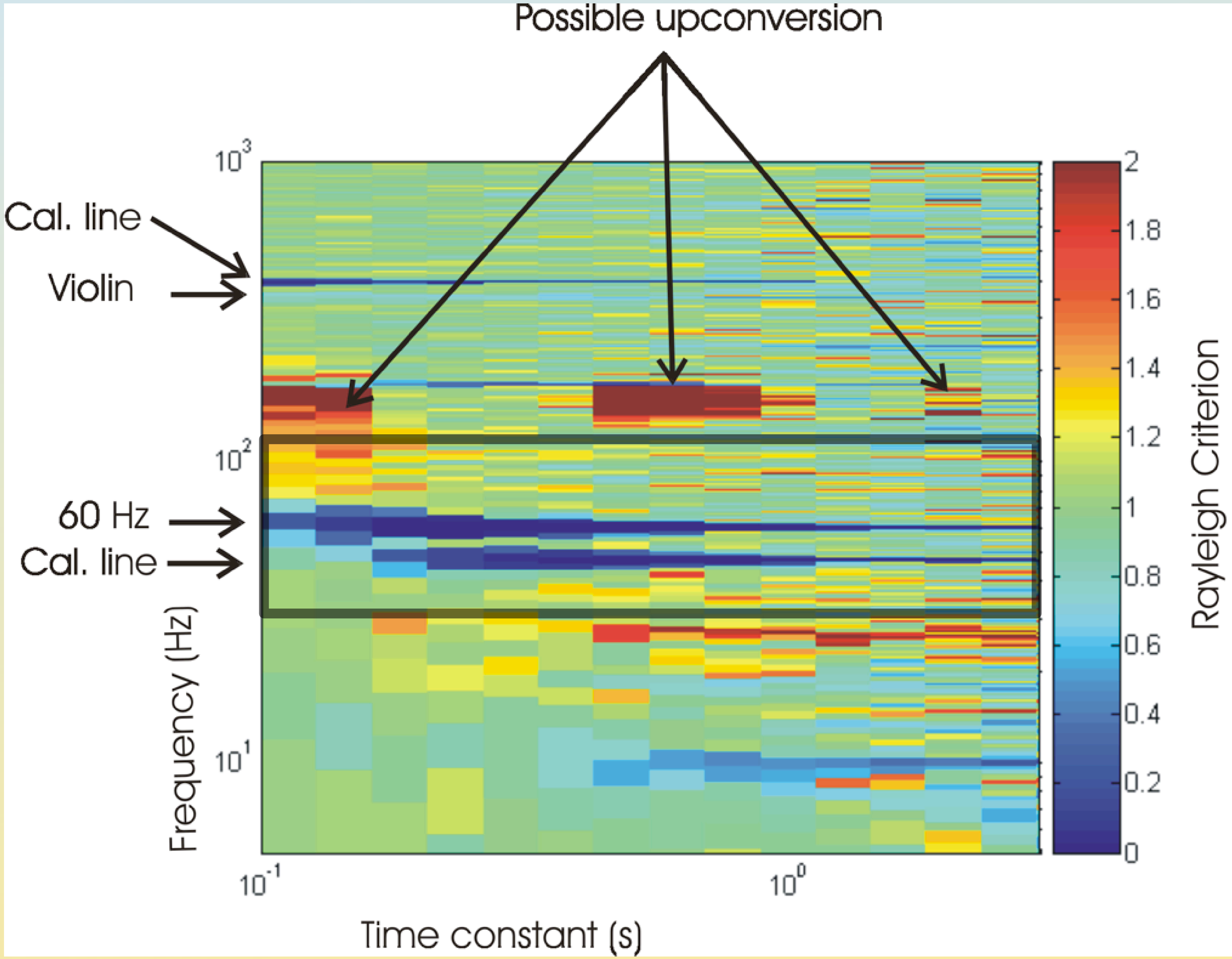
Best fit to observed 40-10 Hz noise is

$\phi \approx 7 \times 10^{-3}$



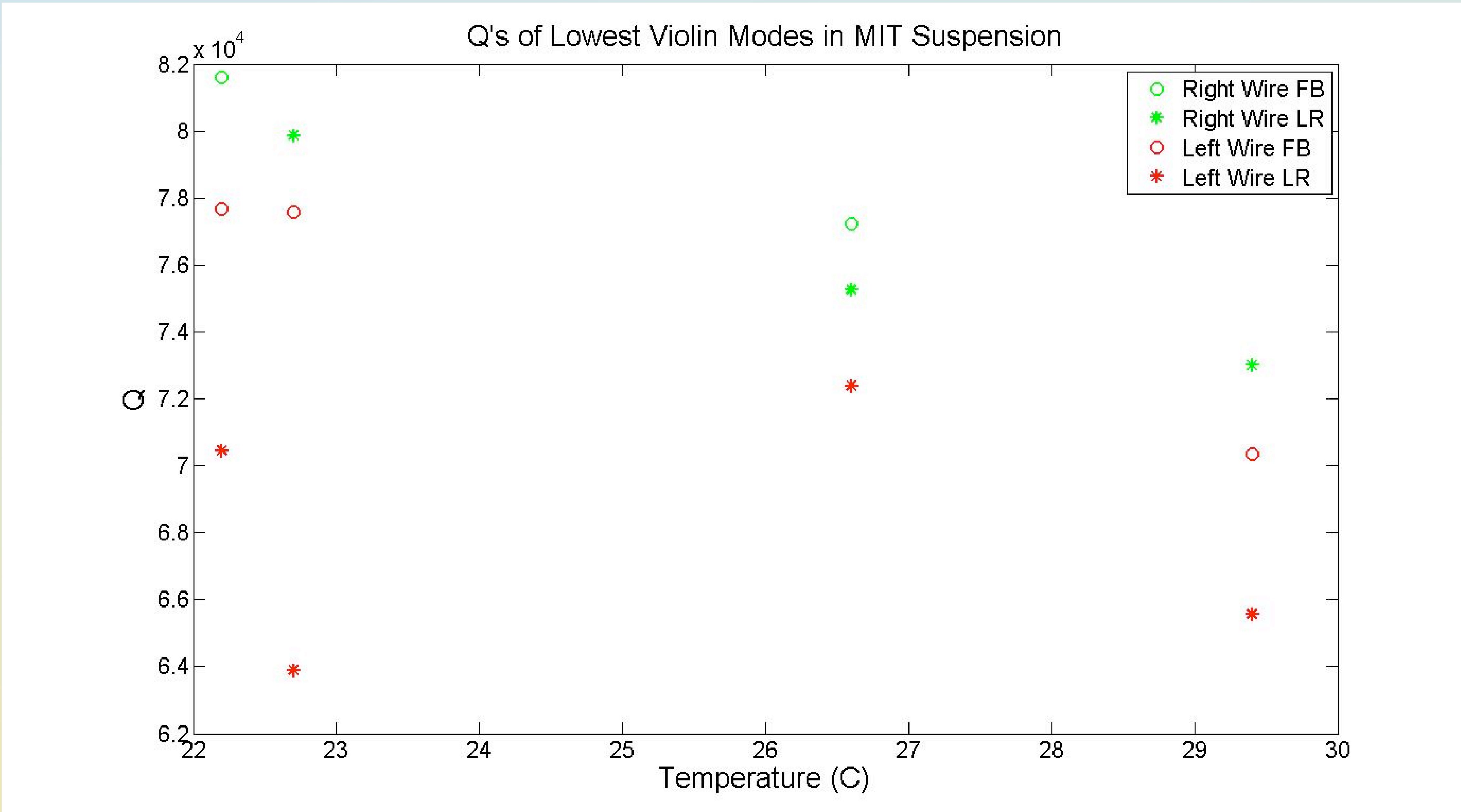
Strong indications that Suspension thermal noise is a major contributer to the 40–100 Hz excess noise.

Test for NonGaussian Noise



Rayleigh Monitor indicates no major departure from Gaussian noise in 40–100 Hz region.

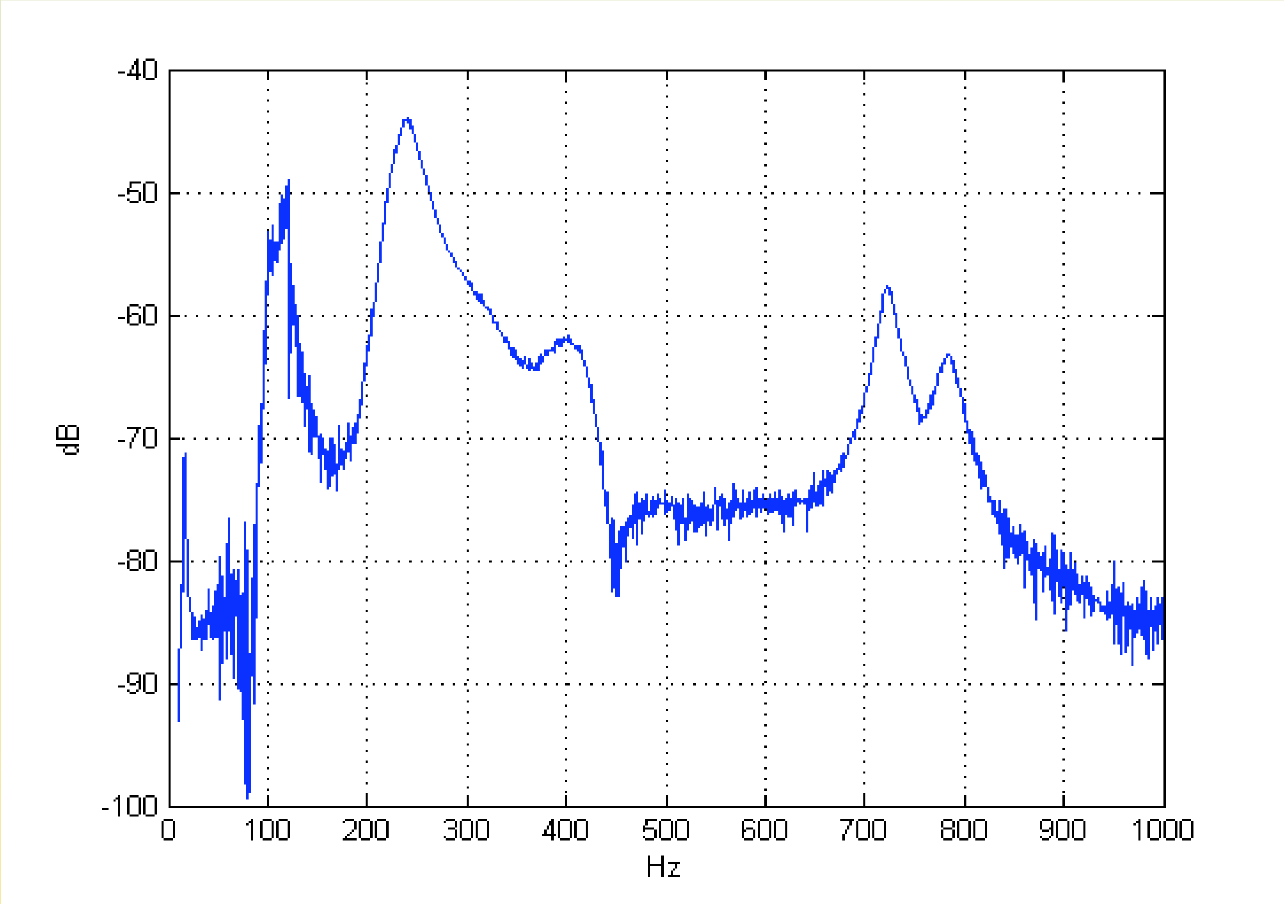
Q vs Temperature



- Does not seem to be a correlation with temperature
- Calls into question recoil damping model to explain Q variation at sites

Suspension Cage Frequency Measurements

- Measurements on spare cage at ERAU
- Transfer function on top plate
- Compare frequencies with model and measurements at Caltech
- Verify temperature dependance
- Will attempt to modify frequency structure by clamping mass on cage



New Directions

- Tests for recoil damping (Easy test. Unlikely source of problem.)
- Test Remachined clamps
- Test Redesigned Clamps
  - **Wire collets**
  - Ribbons
- Test of standoff rubbing friction
  - Change standoff system (HARD)
- Try new wire/ribbons