Thermal Noise in Initial and Enhanced LIGO

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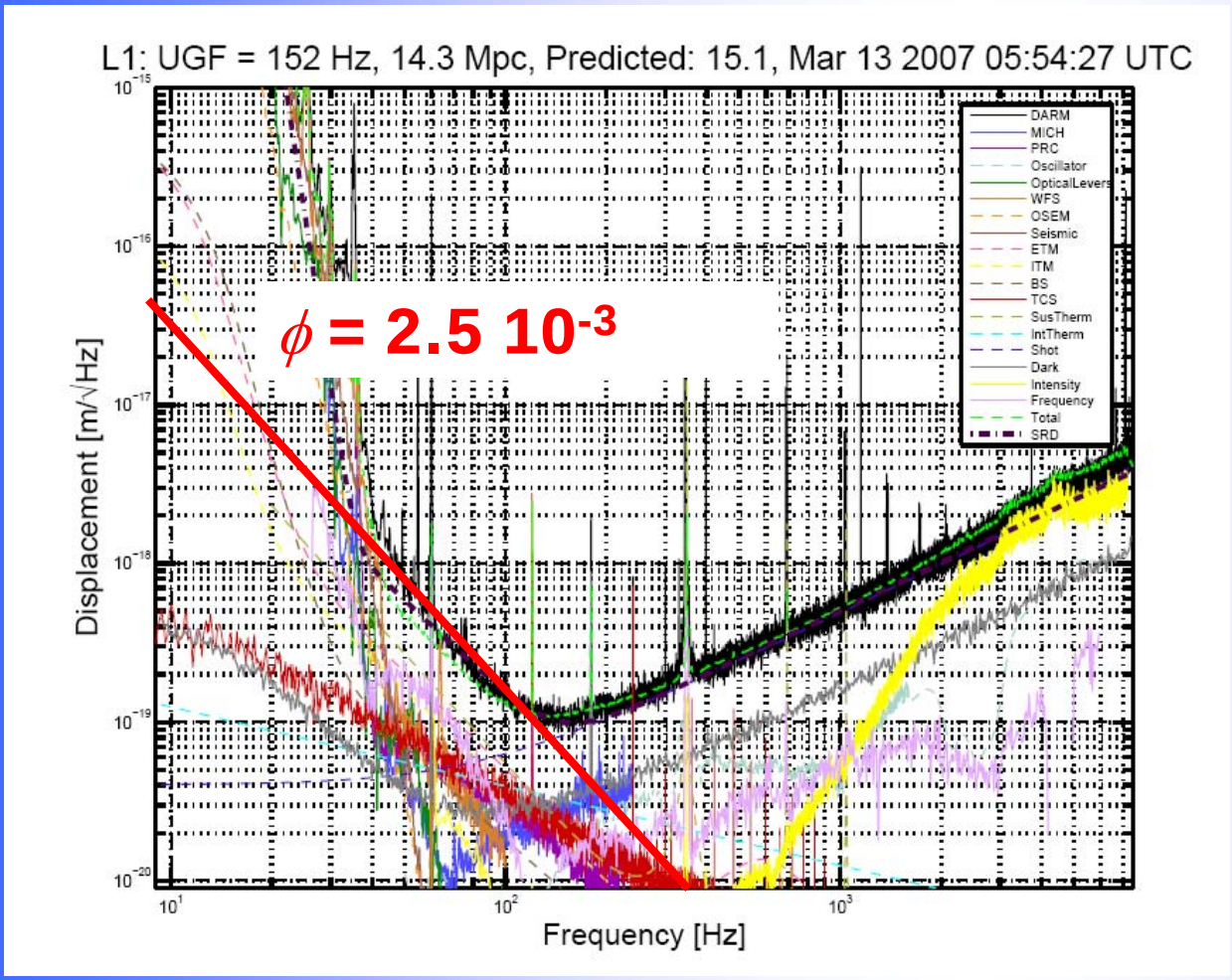
Suspension Thermal Noise

- **Limiting noise source in Initial LIGO 40 Hz – 100 Hz**
- **S5 value worse than expected from violin mode Q's, and much worse than material limit**



- **"Typical" Violin Q**
  $Q \approx 7\ 10^{4}$
  $\phi \approx 1\ 10^{-3}$
  Inconsistent between lock stretches

- **"Material Limit" (HWS)**
  $\phi = 1.5\ 10^{-4}$

Lab Experiments at MIT and HWS

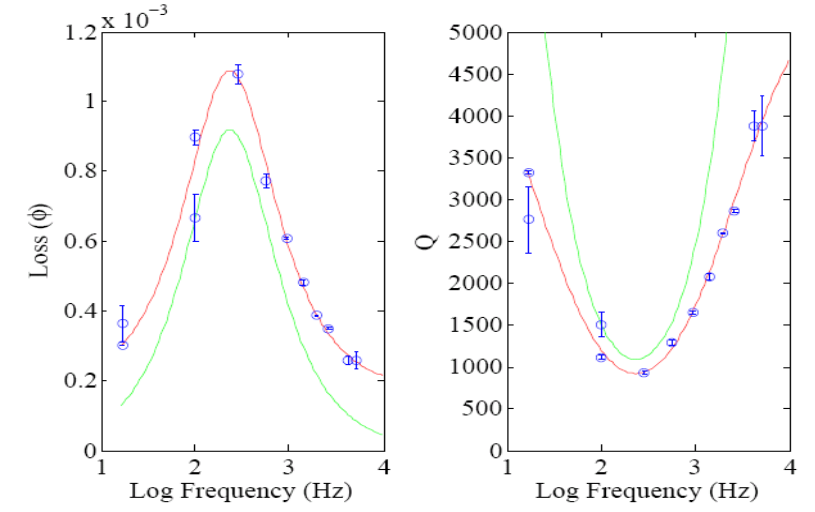
HWS

Single wire from sites either free,
or tensioned with 5 kg

MIT

Initial LIGO Pathfinder Optic hung
In spare frame with wire from sites

Review of Previous Results

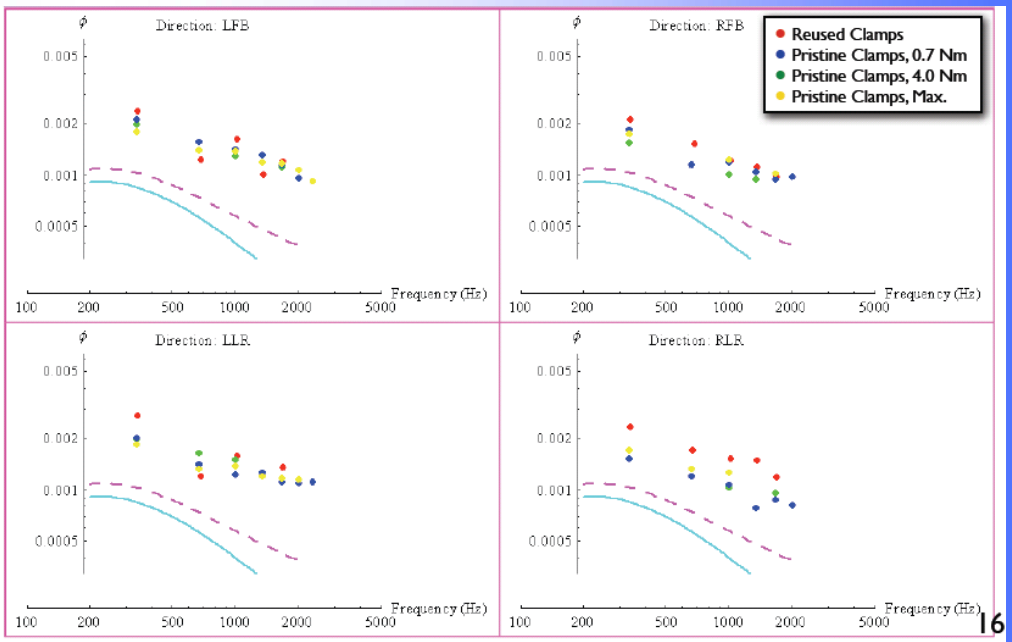


Free Wire Mechanical Loss

- Clear Thermoelastic Peak at ≈ 400 Hz
- Material Limit $\phi = 1.5\ 10^{-4}$

Violin Mode Q's

- Well above material limit
- Reuse of clamps does not effect mechanical loss
- Torque on clamps does not effect mechanical loss



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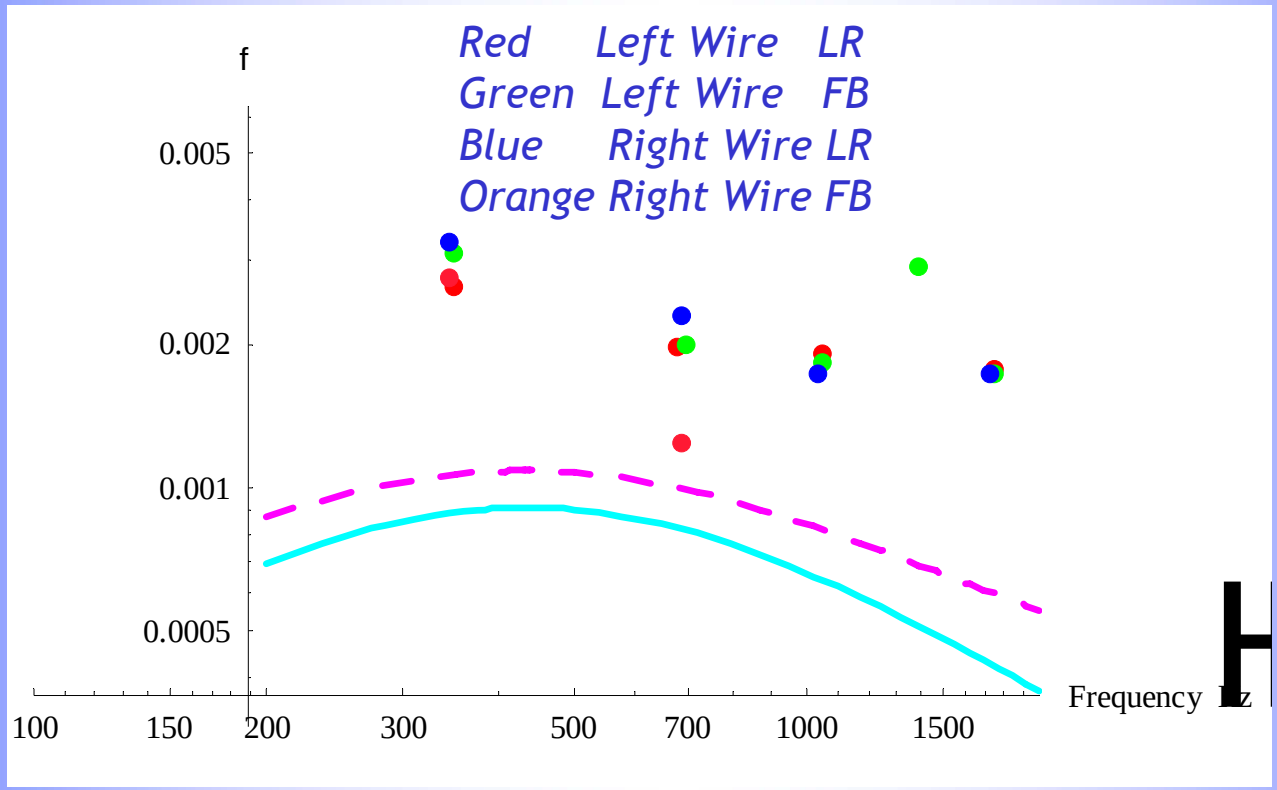
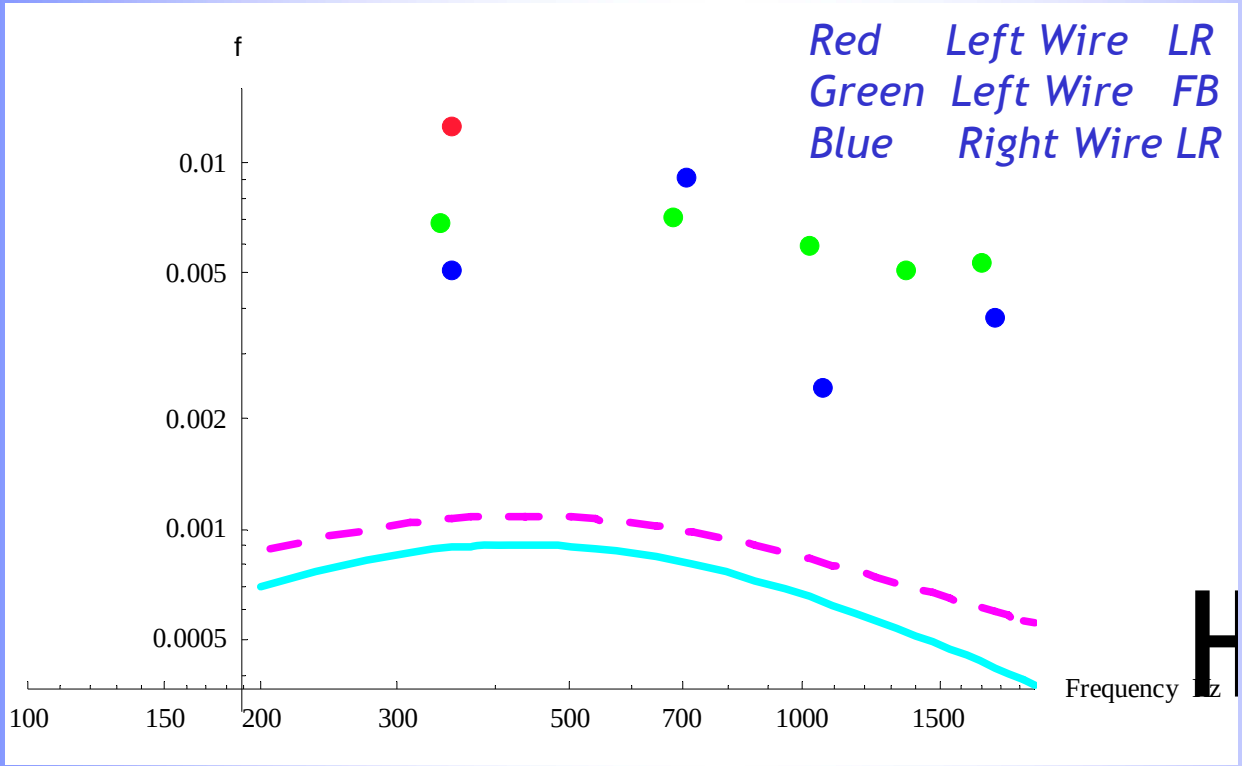
Virgo Inspired Clamps



Hardened Tool Steel at Clamp Interfaces
EDM cut Groove for Wire Through Clamp
Larger Bolts holding Clamp Together

Tool Steel Pitted by Cleaning in Liquinox
Sanded Down – Some Pitting Remained, Groove Reduced

Glued Standoffs

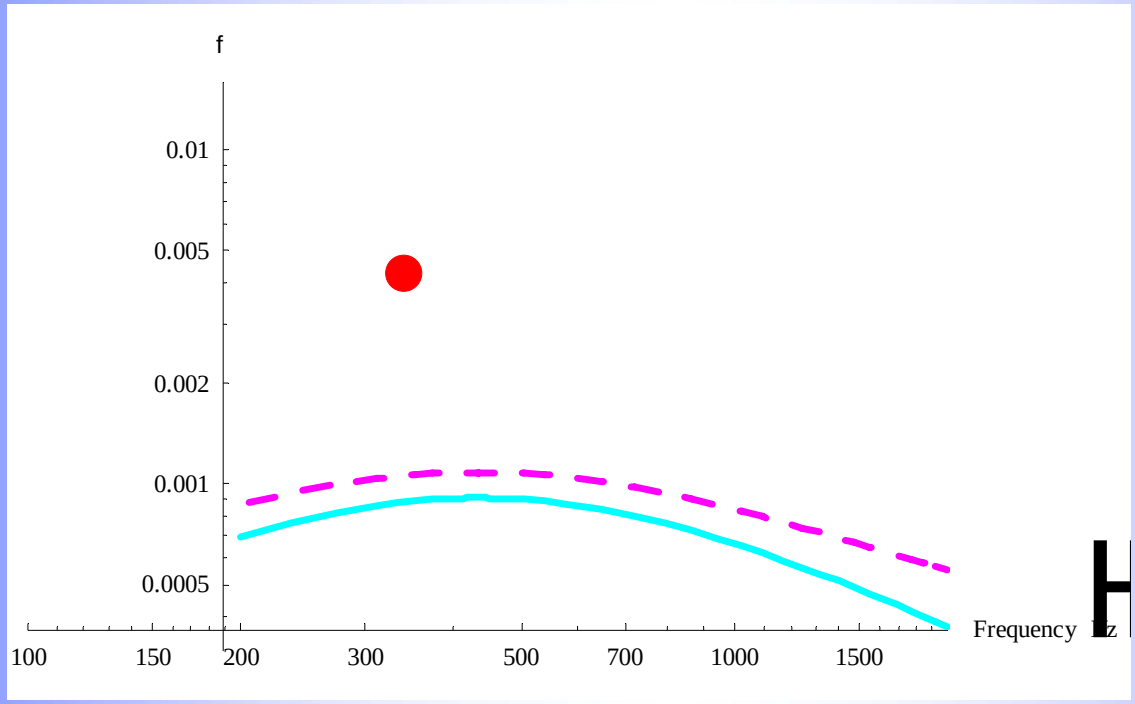


Reused LIGO Clamp

Wire Held to Glass Standoff at Bottom with Glue

- Right Wire – Vac Seal
- Left Wire – Commercial Krazy Glue

Remachined Virgo Clamps and Metal Standoff

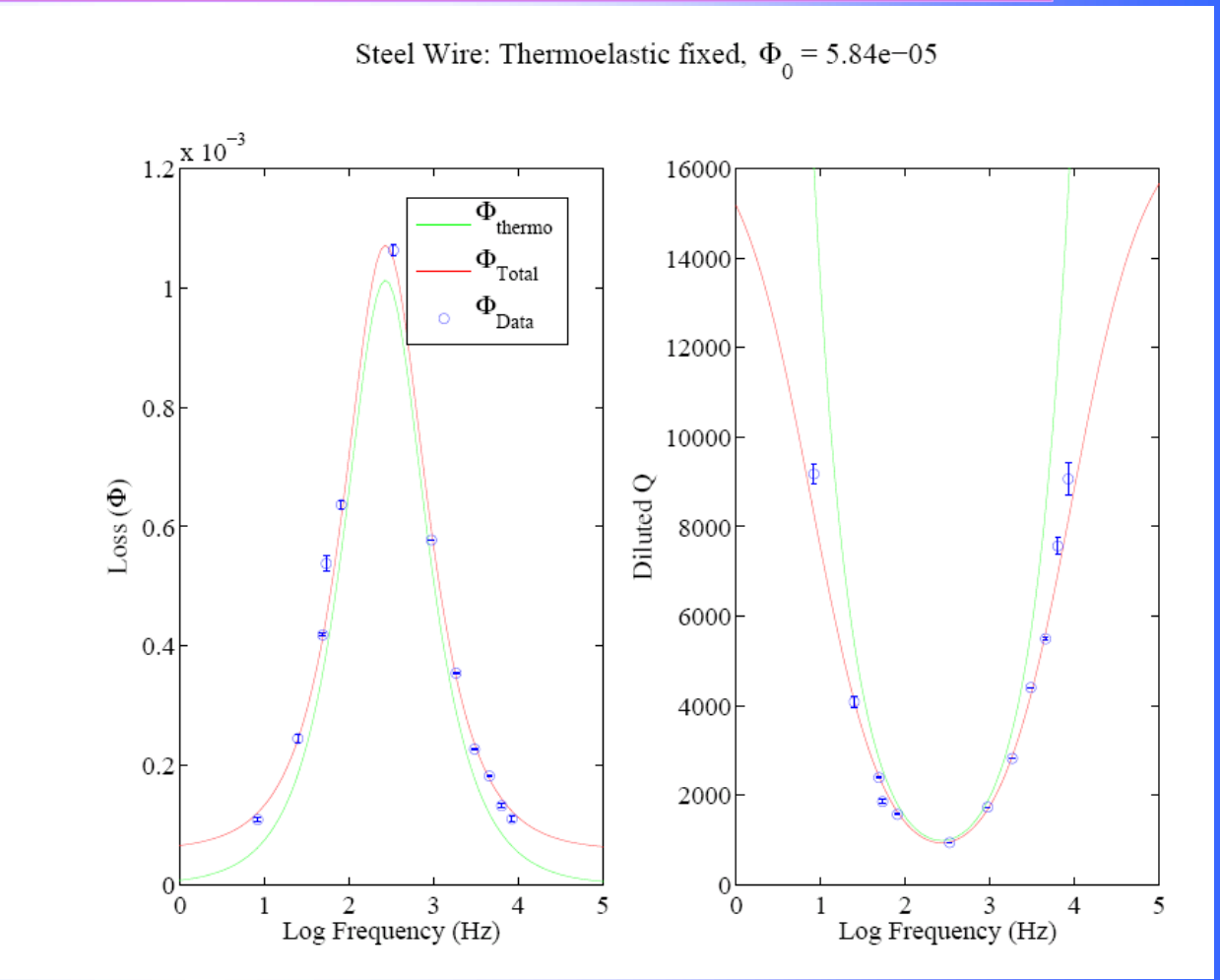


One Q measured last week
Right wire = metal standoff
Very poor mechanical loss

Further hints that it is the standoffs that dominate loss?

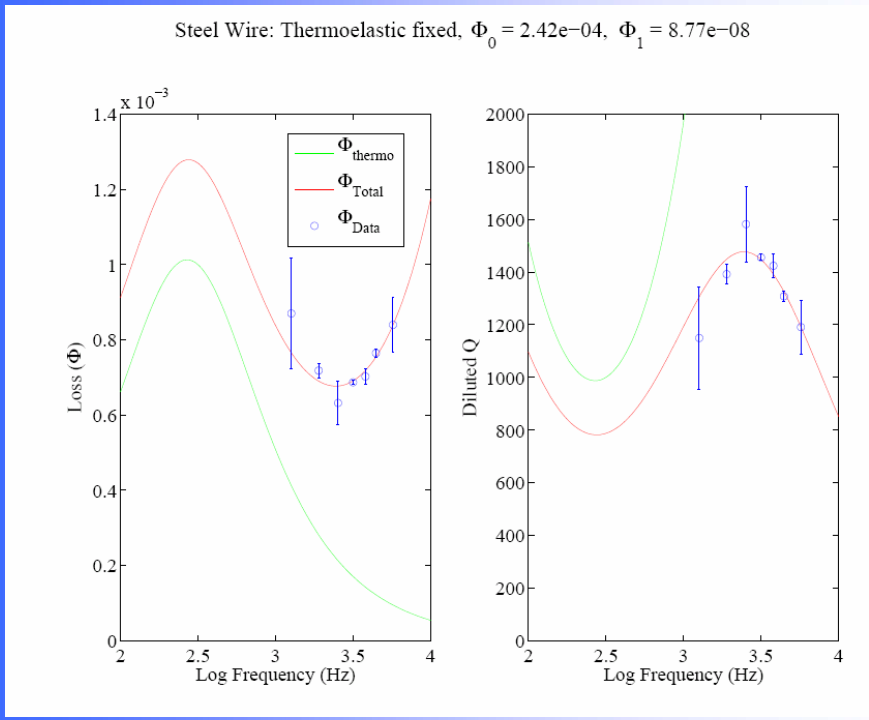
Free Wire Q Measurement at HWS

- Virgo-style clamps
- Much lower structural phi
  5.8×10^{-5}
- Excellent agreement with thermoelastic theory

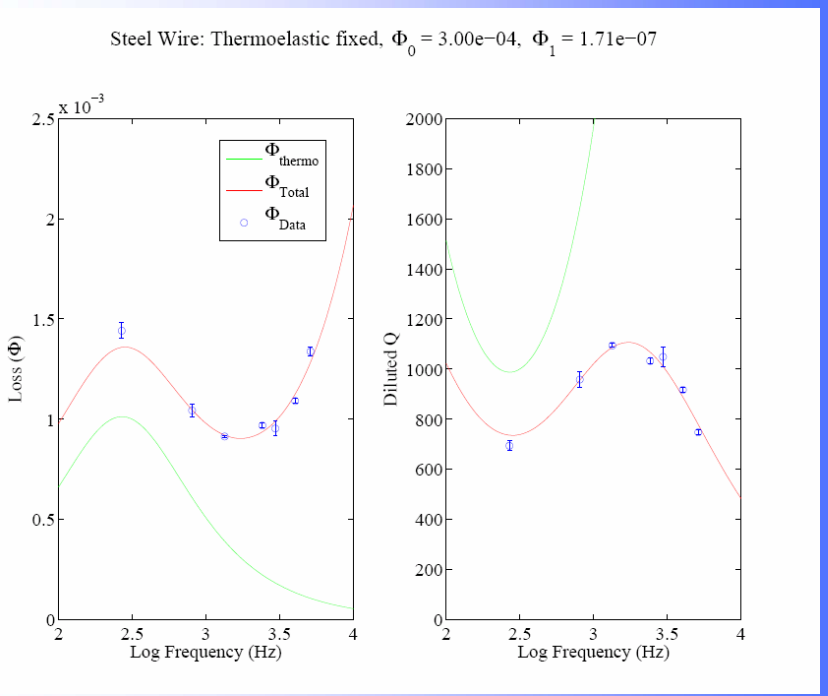


Tensioned Wire Q Measurements at HWS

Viscous damping rising at high (> 1 kHz) frequencies
Evidence of rubbing friction in clamps?
    Why only bottom clamp?
Tension dependant loss?
High frequency independent phi



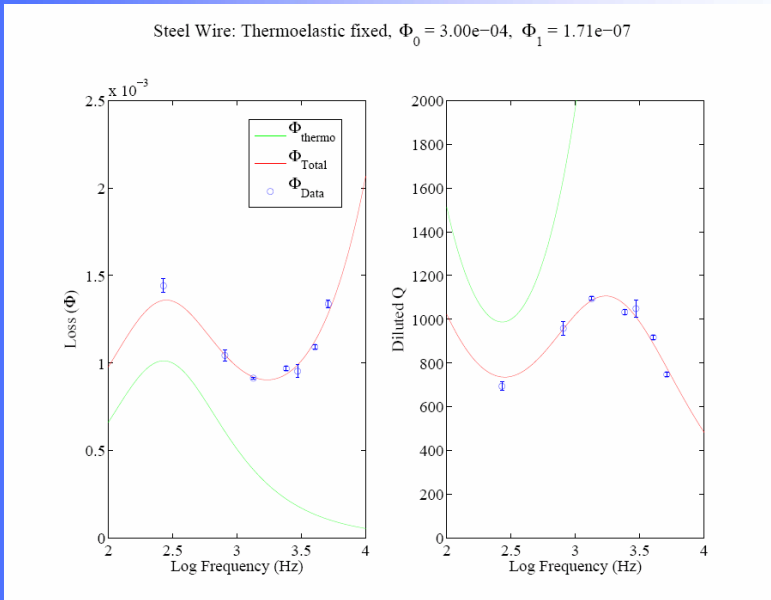
Collet



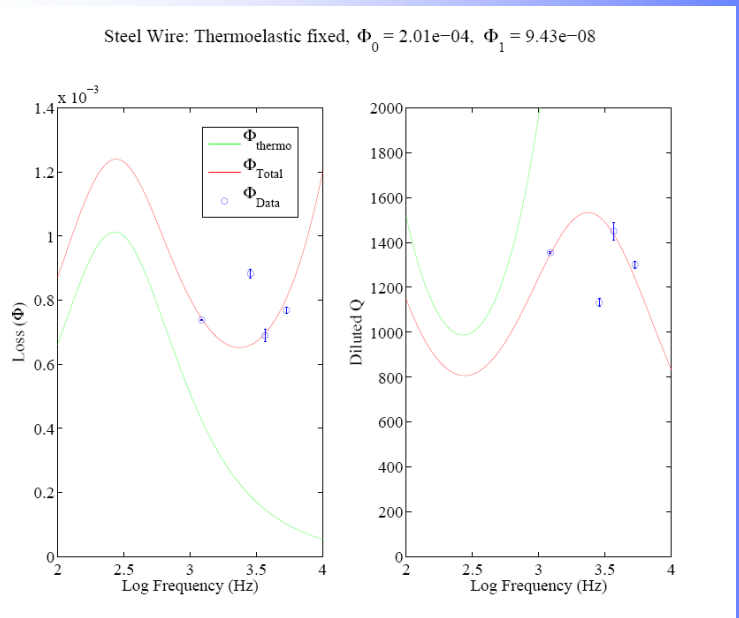
Virgo-style Clamp

Heat Treated Wire Q Measurements at HWS

Heat Treated as suggested by Virgo colleagues
Improves both structural and viscous loss
Structural loss still not at level of free wire



Off Spool



Heat Treated Wire

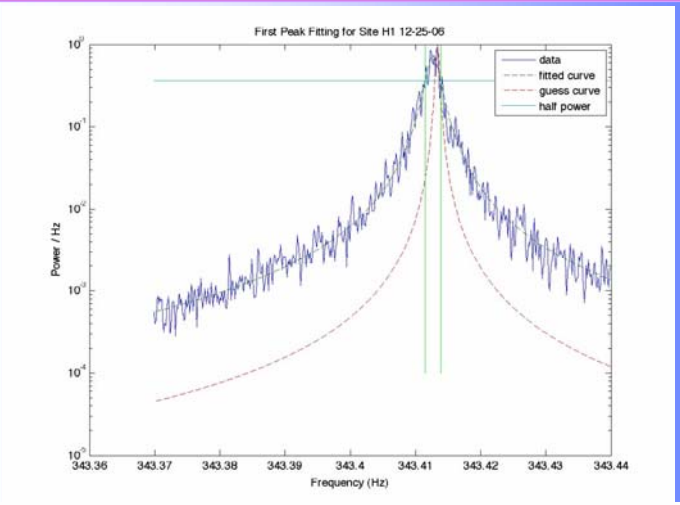
Fitting S5 Violin Modes at Syracuse

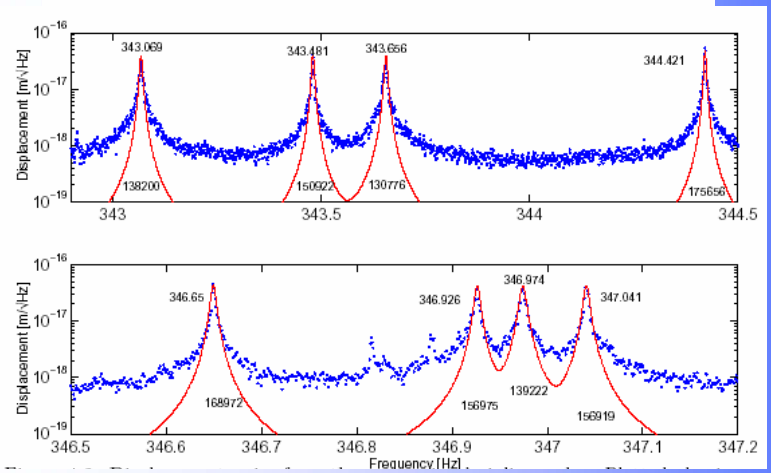
H1 Data

343.0 Hz	1.5×10^5
344.7 Hz	1.6×10^5
344.8 Hz	1.2×10^5
343.9 Hz	1.3×10^5

Much more at

www.syr.edu/~dmalling/suspq





Q's very high, most at or near "material" limit

Some seem to be beyond thermoelastic limit?

Much better fits than older science data (Rana's thesis)

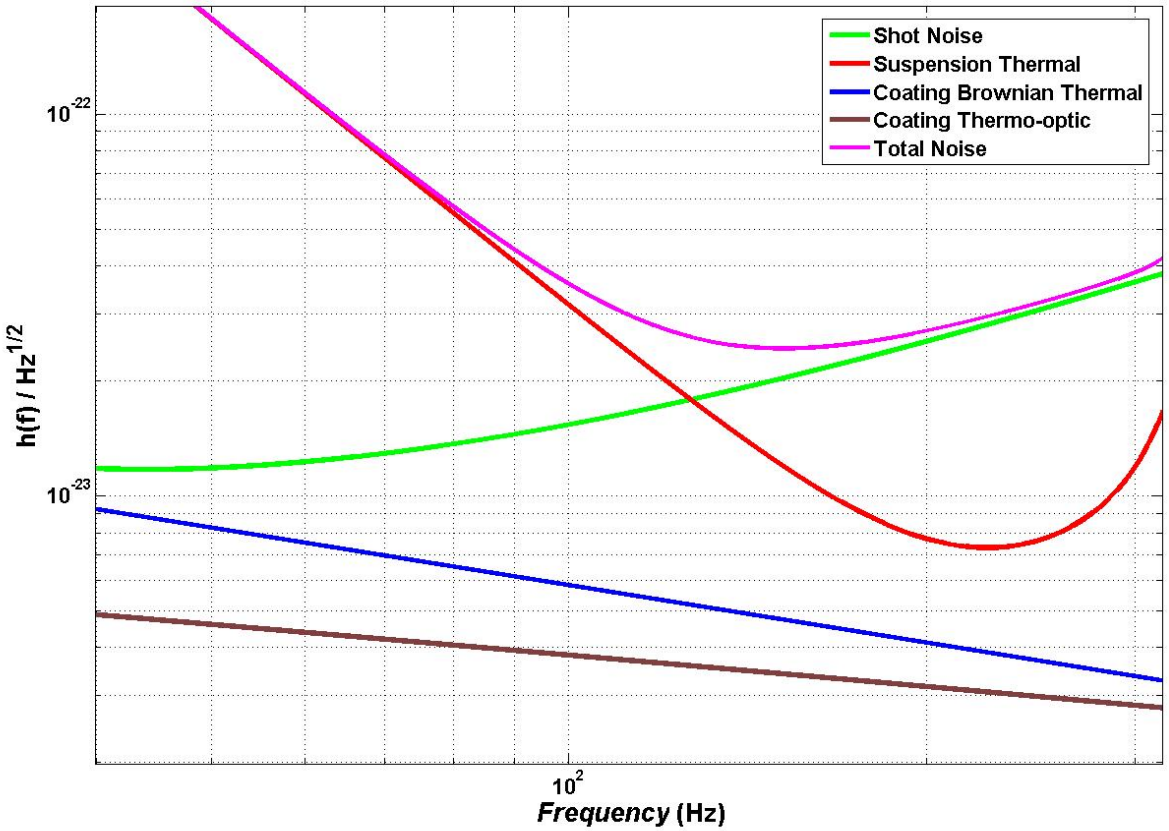
Possible evidence for amplitude dependence in t domain Q's?

Further Thoughts and Plans on Suspensions

- Sapphire replacing hardened steel
  - Even harder clamp
  - Being machined
- Steel wire encased in glass on end
  - Will allow larger glass bob to be grasped (in collet?)
  - Wire in glass has been made at Syracuse glass shop
  - Q measurements in progress

- Triangular standoffs?
- Ribbons?
  - How would standoffs work?
- Other ideas?

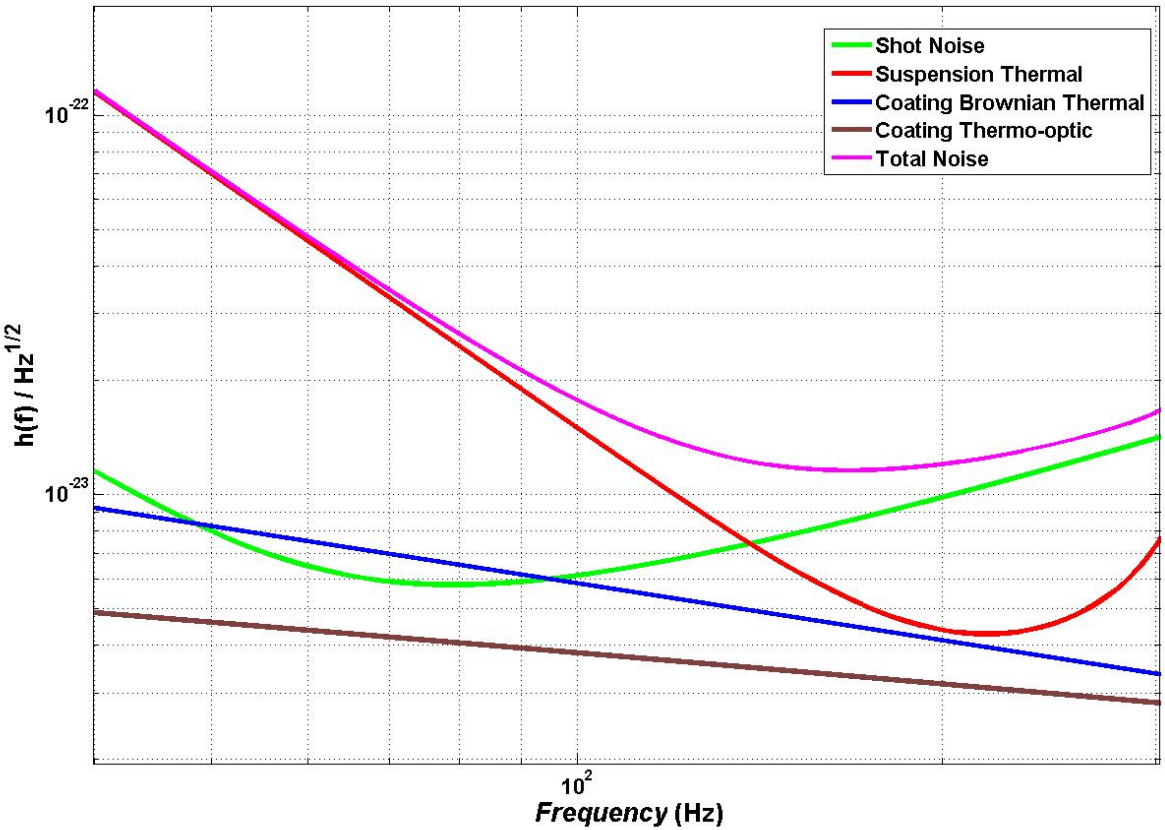
Coating Thermal Noise in Initial LIGO (S5)



≈ 15 Mpc BNS Range

- 10 W laser
- Suspension $\phi = 2.5\ 10^{-3}$
- Tantala $dn/dT = 5\ 10^{-5}$
- REO Tantala $\phi = 5.5\ 10^{-4}$

Coating Thermal Noise in Enhanced LIGO



≈ 30 Mpc BNS Range

- 30 W laser
- Suspension $\phi = 1.5\ 10^{-4}$
- Tantala $dn/dT = 5\ 10^{-5}$
- REO Tantala $\phi = 5.5\ 10^{-4}$