A voice from the grave.

Lessons learned from ALLEGRO,

1970 - 2007

R.I.P.

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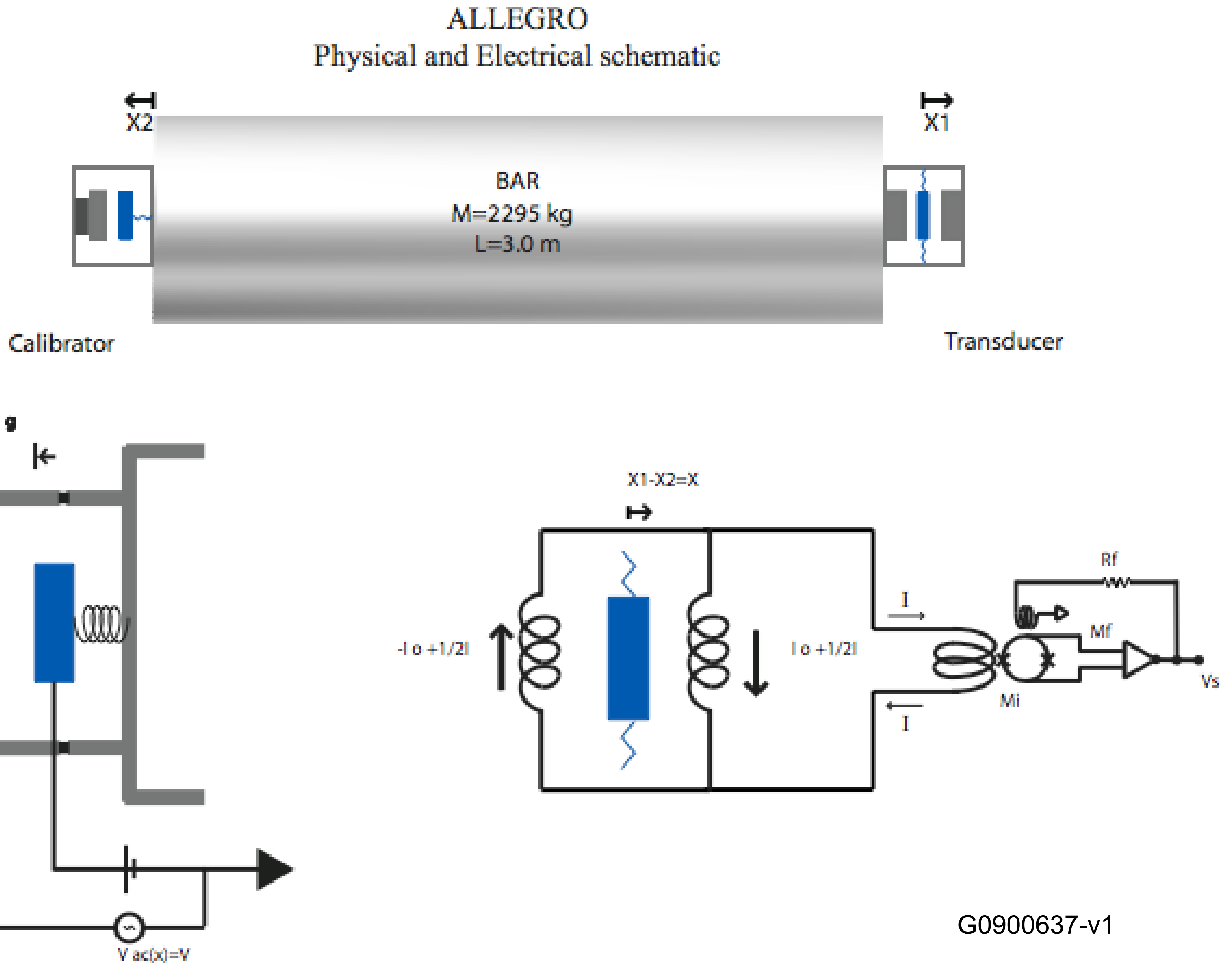
ALLEGRO cryogenic bar antenna



ALLEGRO

- Project started about 1970
- First long data run in 1991
- Longest run was ~5 years
- Last long data run in 2005-7
- Other cryogenic bars
  - Stanford
  - Perth - NIOBE
  - Rome - EXPLORER
  - Frascati - NAUTILUS
  - Padova - AURIGA

Test mass tradeoffs (early 80's)

Material \ Parameter:	Sapphire	Silicon	Aluminum
Q_{best} (4 K)	200 x 10^6	~1000 x 10^6	100 x 10^6
Mass	~ 10 kg	~ 20 kg	2000 kg

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Inside - shells, cold suspension, bar

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Why cryogenics?

- Many ***material properties improve*** by orders of magnitude
  - Mechanical loss Q^{-1} in metals and some crystals
  - Conductor loss R -> ~0 (superconductors)
  - Superb vacuum is free [no bakeout ?] (except for helium)
  - ? Creep (Ricardo's stress-induced noise)
  - Thermal conductivity of crystals and pure metals
  - Thermal expansivity of crystals and metals

Bad behavior, cryogenic division

Plastics and glasses have very poor thermal conductivity

--> slow heat exchange

Substantial differences in thermal contraction

--> induced stress when

Q_m of glasses (e.g., fused silica) get worse at lower T

Coating noise gets worse (?) at low T ?

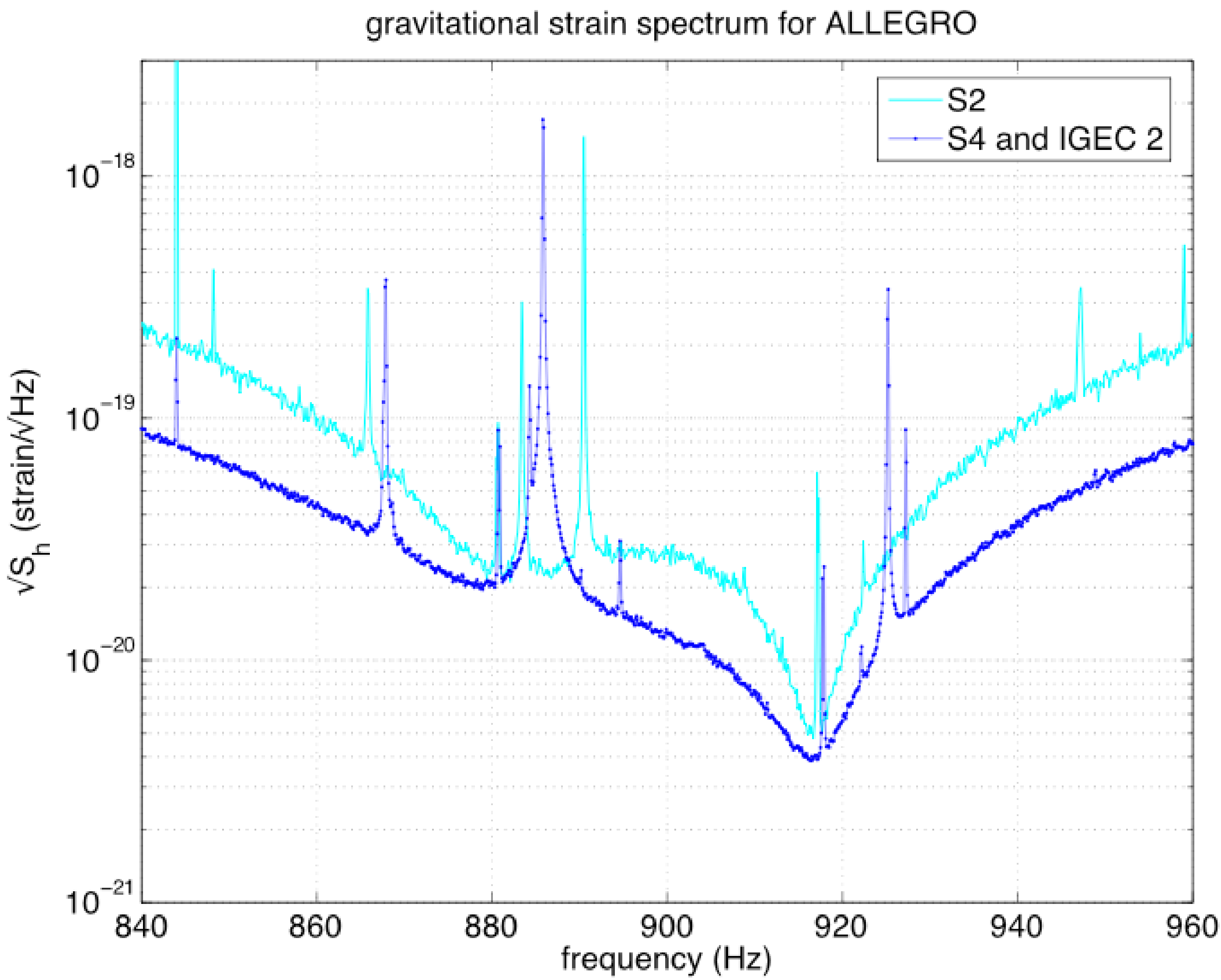
Soft springs have large contraction with lower T

All(?) soft materials get stiff, e.g. rubber

Special engineering needed

- For cooldown of cryogenic enclosures (cryostats)
- For mechanical and thermal design of suspensions and test masses
- (For removal of heat deposited in test masses)

Performance



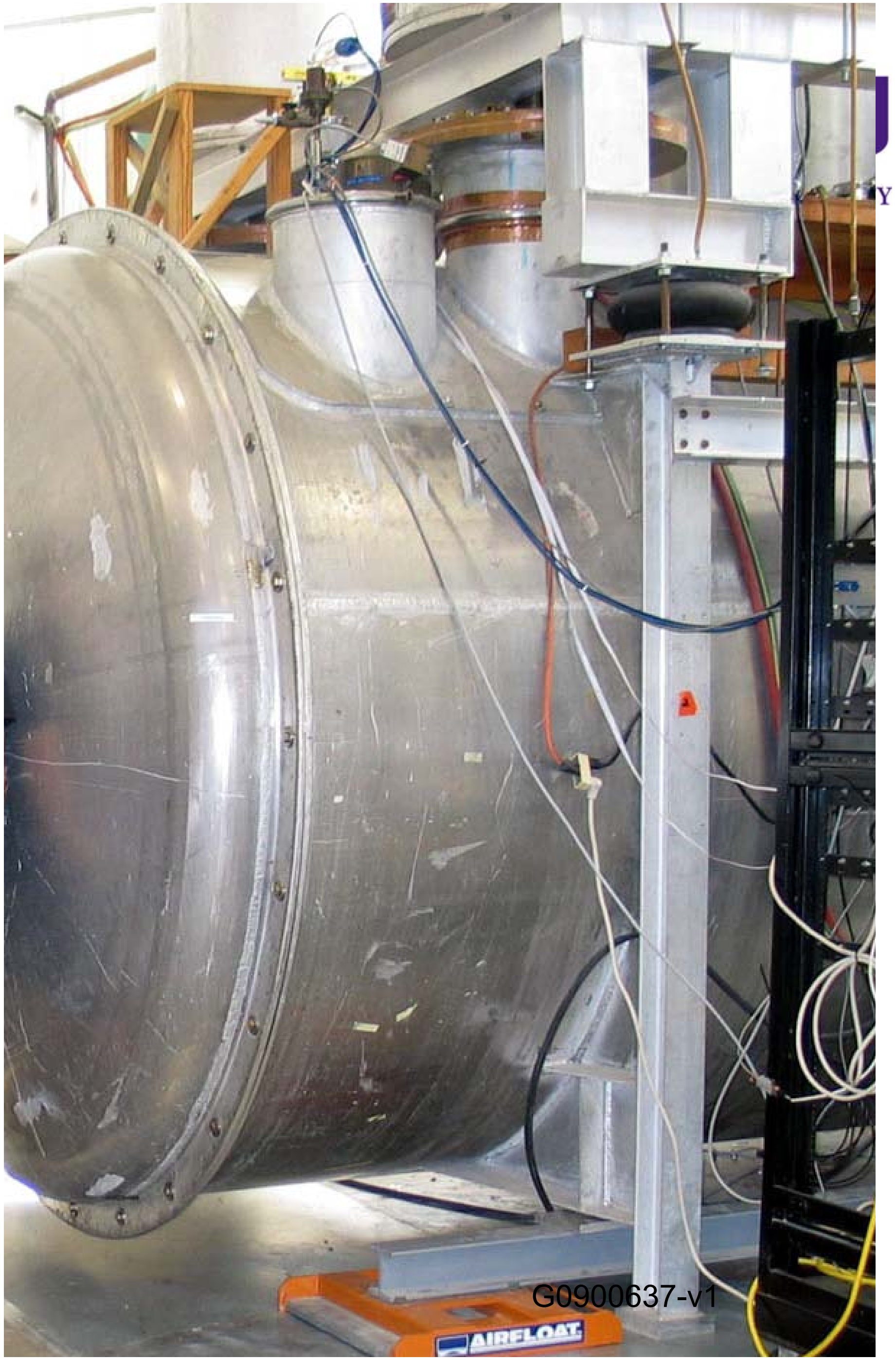
Biggest initial problem: Suspension Noise

- Noise transmitted through suspension from
  - Outside: acoustic and ‘seismic’ noise, and
  - Inside: boiling noise.
  - **Mechanical upconversion** of low frequency ground motion, to high frequency bar excitation.
    - ‘Crinkling’ plastic tape
    - ‘Rubbing’ of two surfaces
    - Many more ? ?
- Sound transmission through gas if $P_{RT} > 10^{-5}$ torr
- Required several complete redesigns and rebuilds of suspension system.
- BAD CHOICE: **~2- 3 months** thermal cycle time! Better: **1 week**

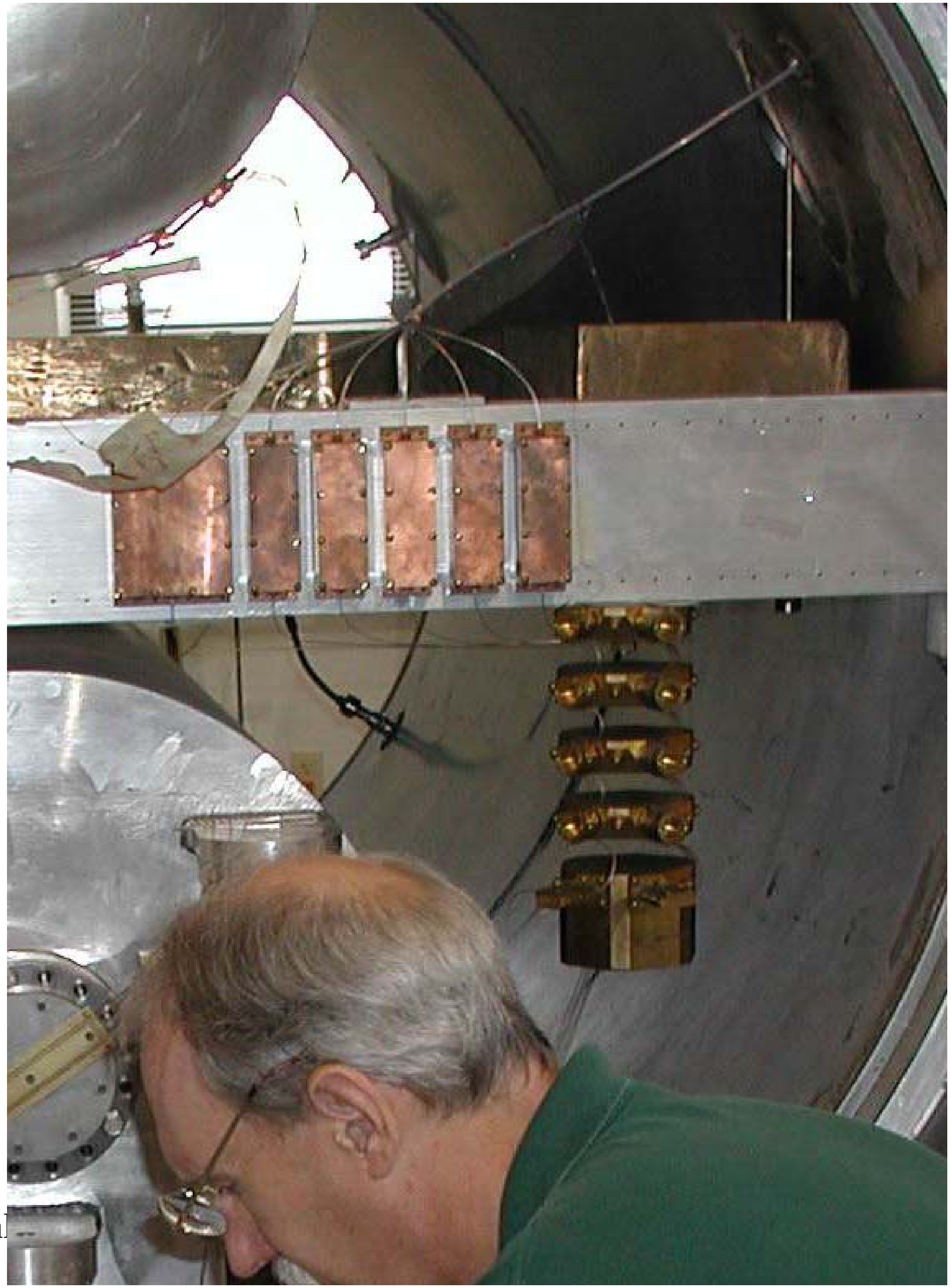
  The “MOONSHOT EXPERIMENTs” should have made it ~ **1 week**

isolation chain

- Pillar
- Air spring
- Air table
- Iron disk and rubber stack - on compression
- Long titanium rod
  - (300 -> 4K)
- 2000 lb brass casting
- Another rod
- Bar



Covers for the iron and rubber isolation stacks



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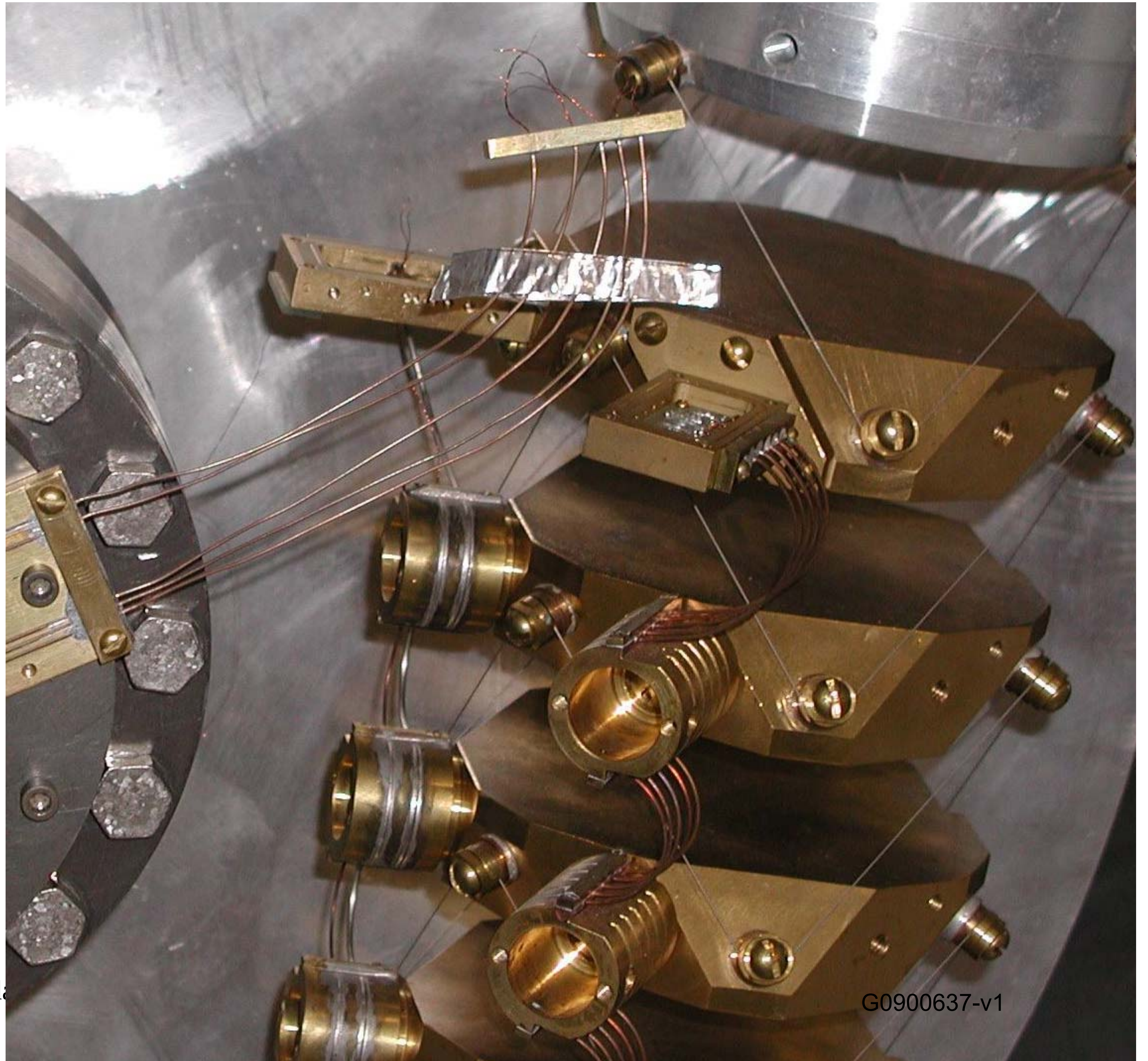
Vibration isolation stack for wiring



Biggest later problem

- Excessive loss in the transducer. [Dirt in narrow gap?]
  - We probably would have solved the problems with advanced detectors if we had done many tests to find and fix the ‘dirt’ problems.

Biggest lessons

- Do ***a lot*** of experiments on every piece of design.
- **Count on numerous failures in design and execution.** None of us was remotely smart enough.
- Now: **get professionals** to do your cryogenics, at least outside the detector. User-friendly.
- Want a ***cryo-optical-table*** (set-up *like a bell jar*) the temperature cycles 10-20 kg in < 2-3 hours, with fixed vacuum feedthroughs, etc. Fast cycle time. 2π of mechanical access. Fast extraction of low pressure (thermal exchange) gas. Testbed for eventual detector cryogenics.

Different universe of thin film coatings: MBE

Molecular Beam Epitaxy ('good crystalline thin films')

- Was / still(?) a MAJOR activity in applied condensed matter physics (IBM, Bell, etc, etc)
- Motivation was semiconductor devices of various kinds
  - e.g? heterostructure lasers?
- Have not yet found any connection between this universe and ours [optical (thin film) coating]

• Noise and loss in epitaxial optical coatings (at all temperatures) ***could be*** completely different from the coatings in our current universe.

Resuscitate magnetic levitation?

- I x B force in reasonable volumes can be
  - Big enough for suspending 100s of kg
  - Extremely stable (especially persistent super-currents)
  - Spring constant (dF/dx) easily adjusted (positive, zero, negative) (e.g., Ricardos magnetic anti-springs)
  - No contact, so potentially large isolation/stage at $f > f_0$
- So very soft-spring vibration isolation is conceivable.
  - 0.03Hz (30 s period) --> 60 dB at 1 Hz ?
  - 4 stages possible? --> 240 dB at 1 Hz ?
    - 4×10^{-21} m / 4×10^{-9} m = 10^{-12} == 240 dB

Don't forget big mass

Always helps

Big silicon - probably get 250 kg now

[300 kg crystal pullers]