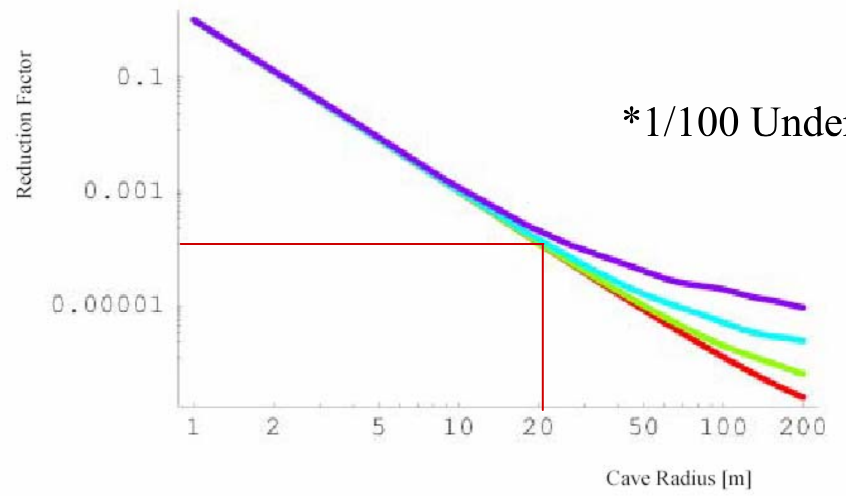
Seismic attenuation from LIGO to CEGO, and back

Riccardo DeSalvo

The CEGO LF-GW-ID seismic attenuation developments

Cella Suppression of Newtonian Noise



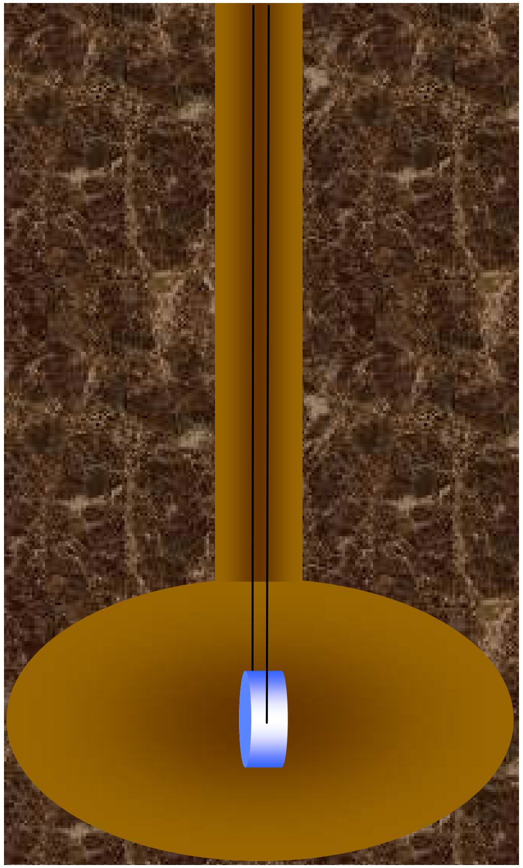
*1/100 Underground Seismic Amplitude

Giancarlo Cella Draft

Suppression of NN by a Factor of 10^{-6} in Amplitude, 30 in Frequency
Seismic Attenuation Must be Redesigned to Match the New Limit

Horizontal Achievable with Inverted Pendula and Longer Wires in Wells

Vertical Attenuation Requires New Development



LIGO

Shaker shaking tower

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

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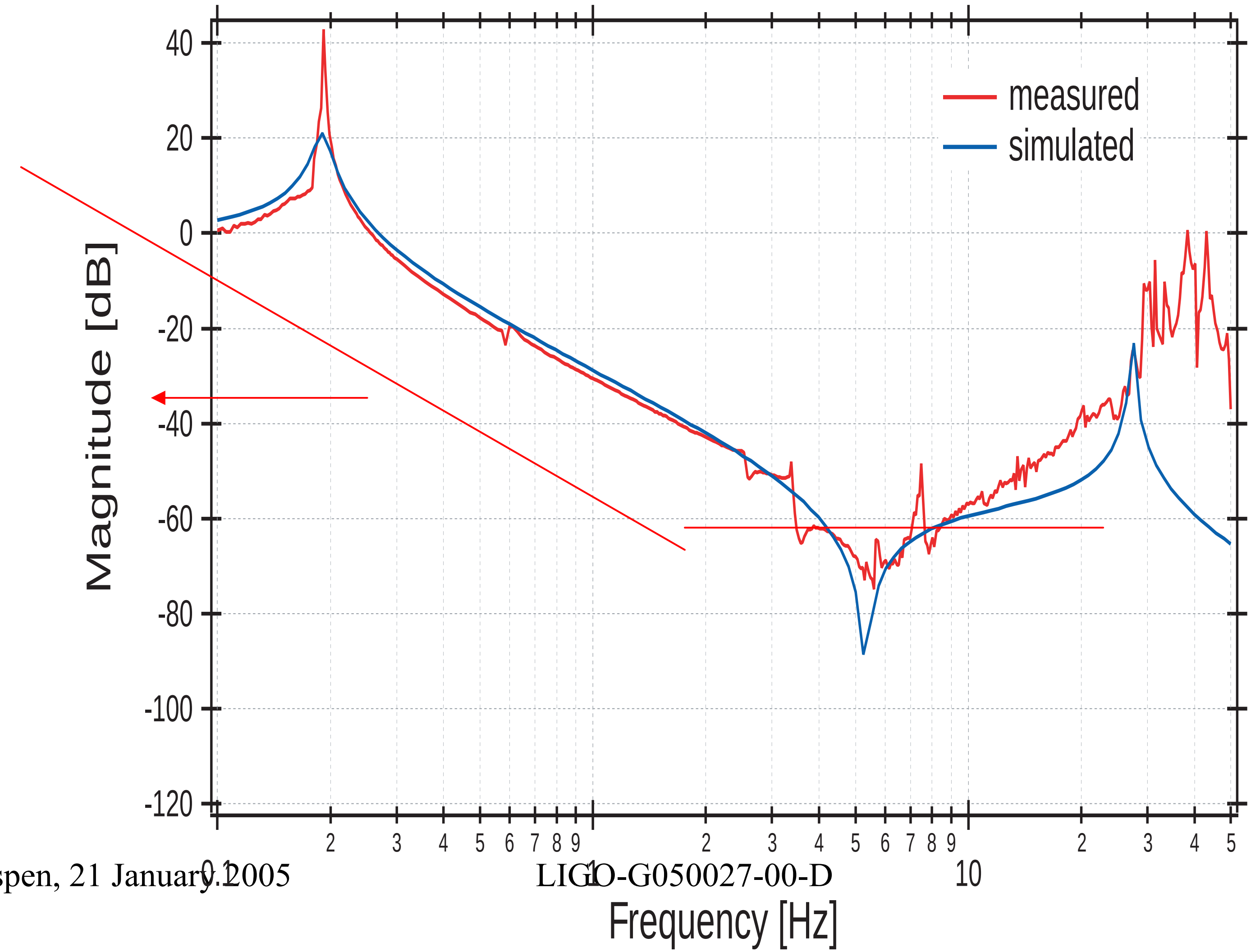
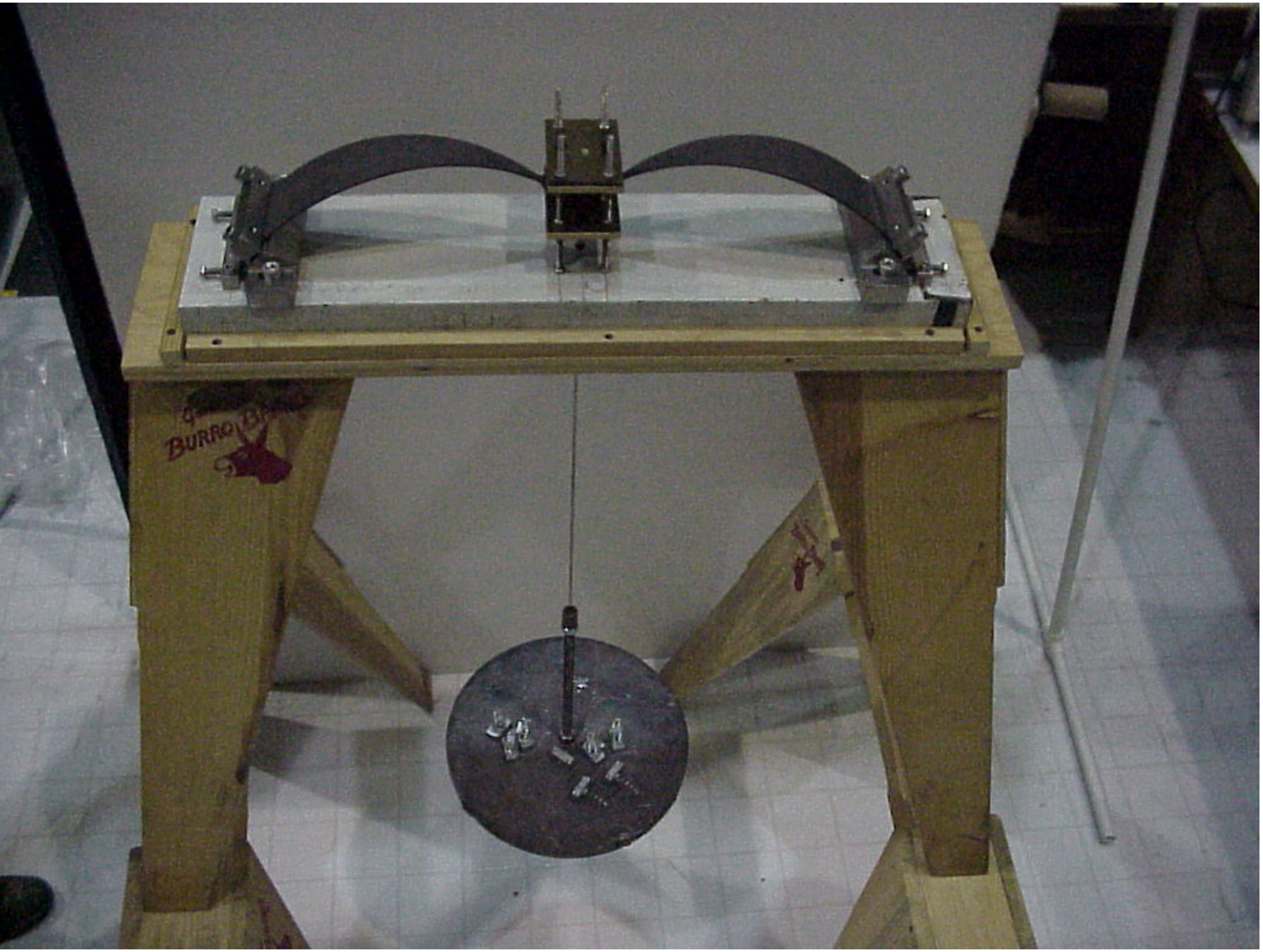
SAS Horizontal performance



SAS Horizontal performance

- Can tune IP down to 20 mHz resonant frequency
- => good attenuation starting at 1 Hz
- Then vertical pendula can be as long as needed in a well above a cave
- OK for LF-GW-interferometric detectors

Vertical direction SAS



QuickTime™ and a
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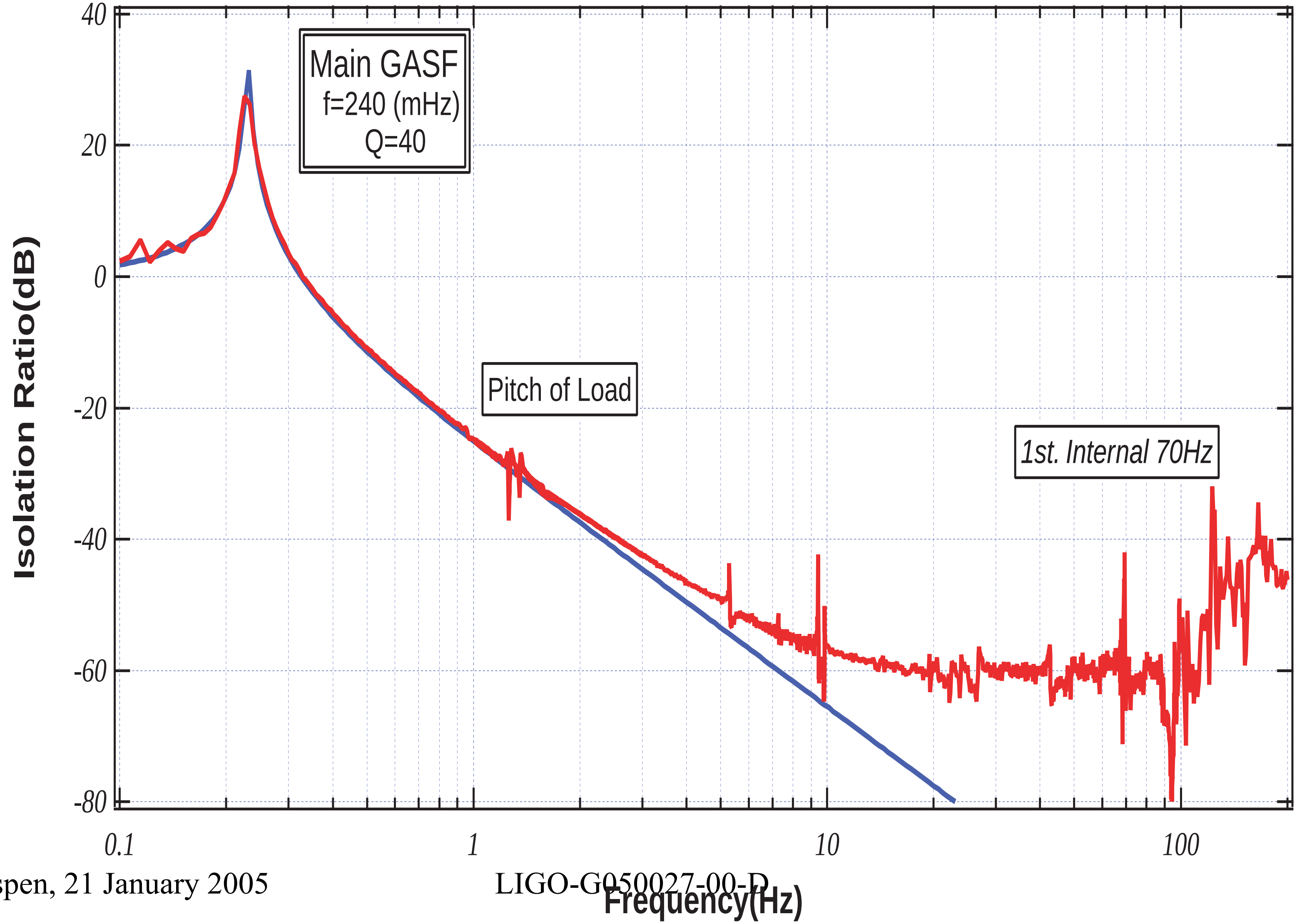
Passive vertical performance

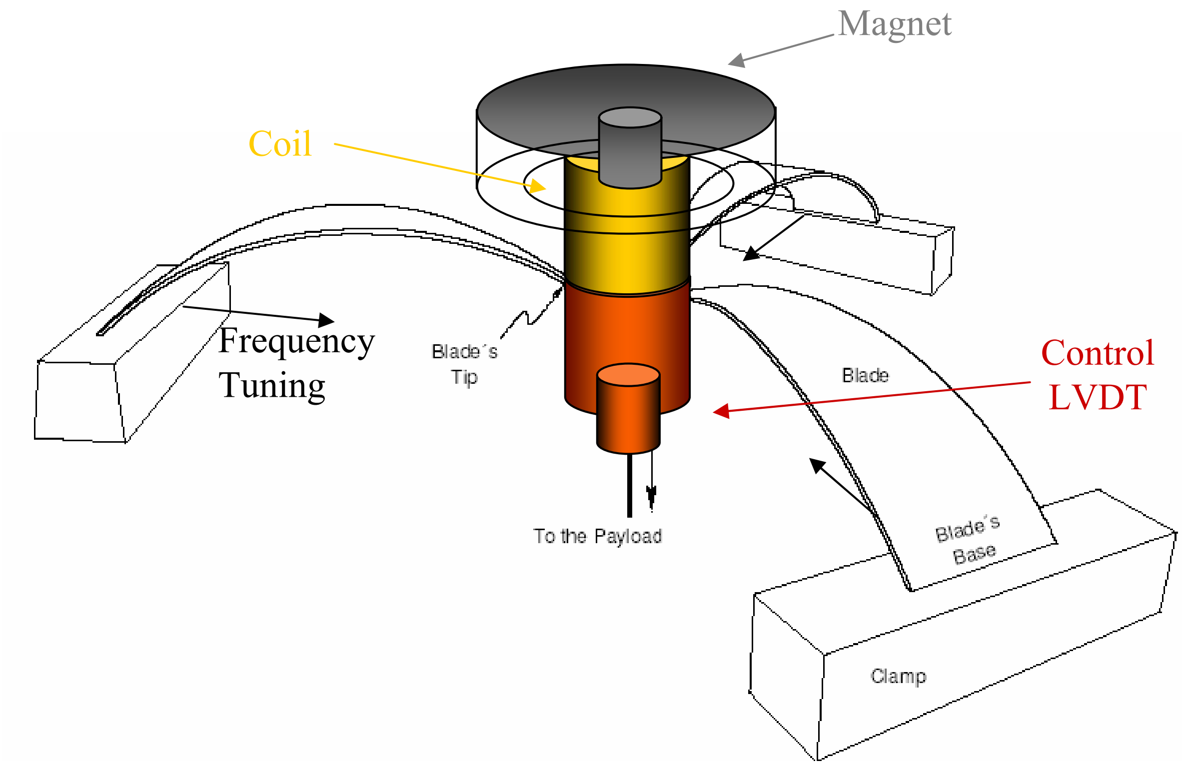


Passive vertical performance

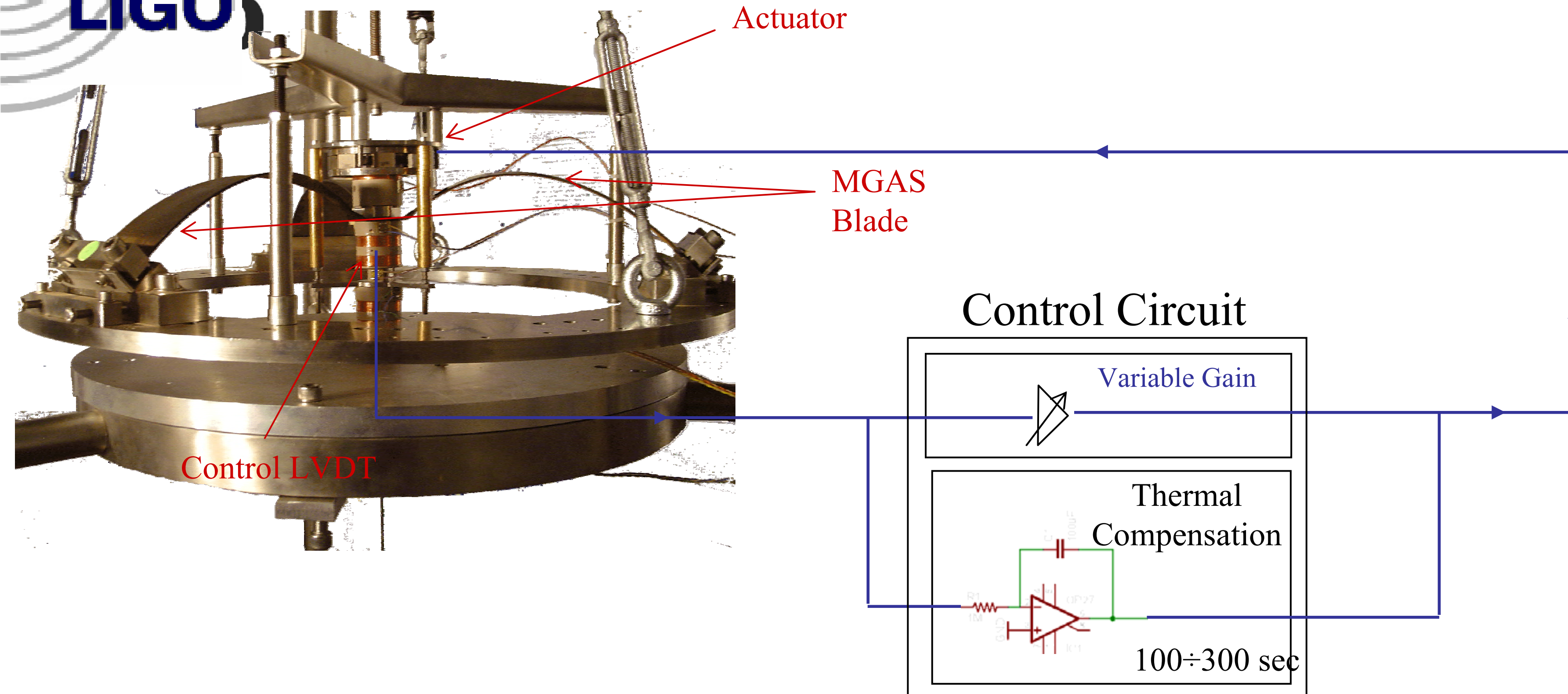
- There is a practical low frequency limit of the IP resonance due to material properties

- The limit is ≥ 0.1 Hz resonance frequency

Existing MGAS Spring



Method to Lower the Resonant Frequency below the Mechanical Limitations



- LVDT
- Variable Gain
- Amplificator-Voice Coil

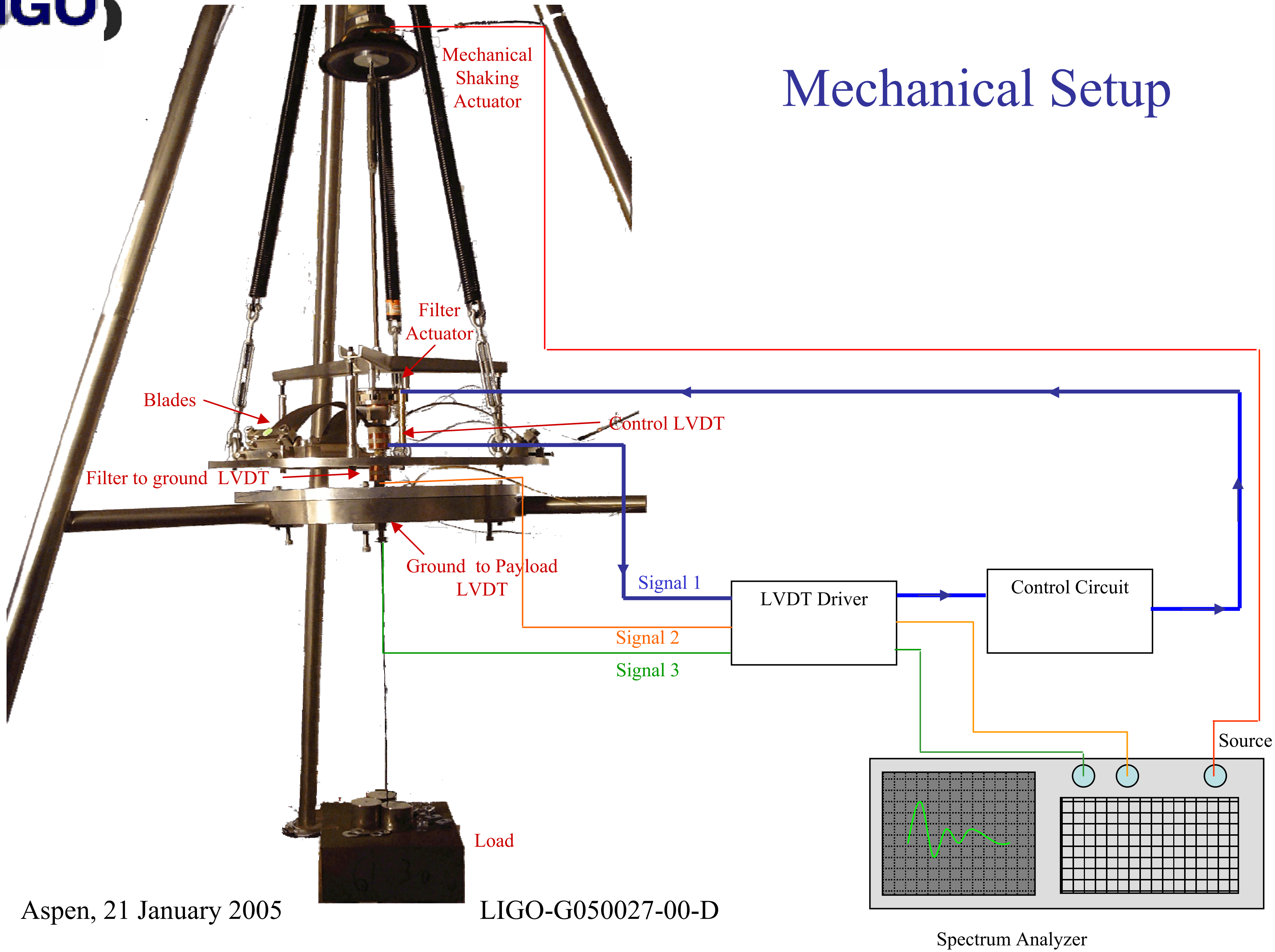
→ Tunable spring in parallel with MGAS spring

(Set Point Integrator → Thermal Drift Correction)

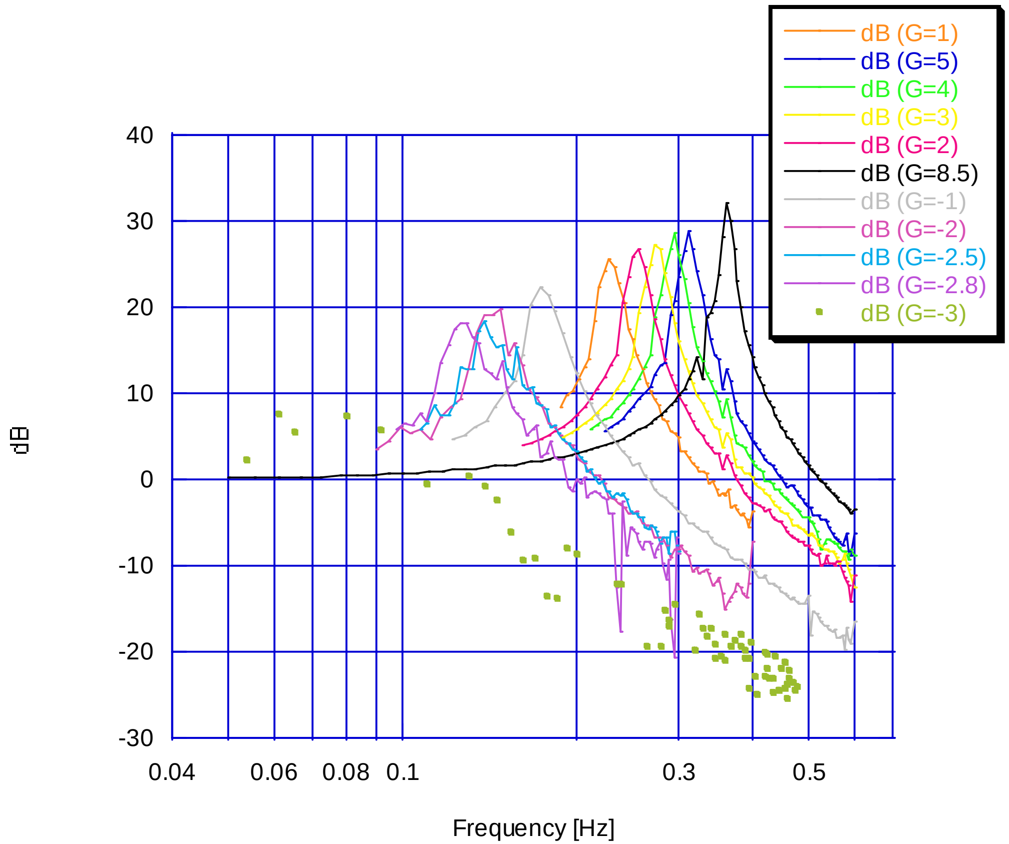
MGAS already neutralize > 90% of cantilever spring stiffness

Circuit corrects the last few per cent of stiffness and stabilizes performance

Mechanical Setup



Transfer Function with Different Gain values



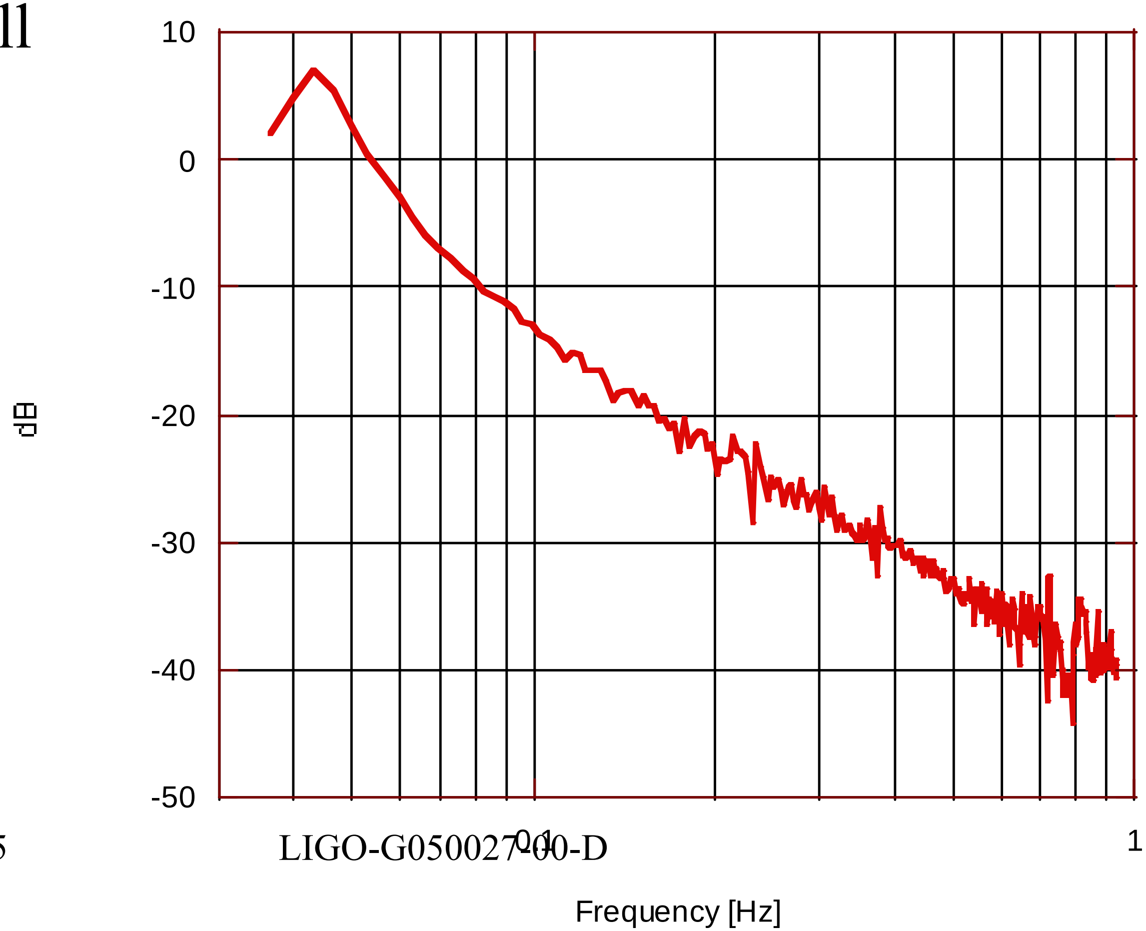
Lowering the system stiffness

As the Transfer Function is shifted to lower frequencies,

The Q factor decreases

CEGO Conclusions

- This technology allows the introduction of attenuation factors as large as one thousand for frequencies above 1 Hertz for LF-GW-ID
- Sizeable attenuation at the micro seismic peak at 150 mHz can be obtained as well

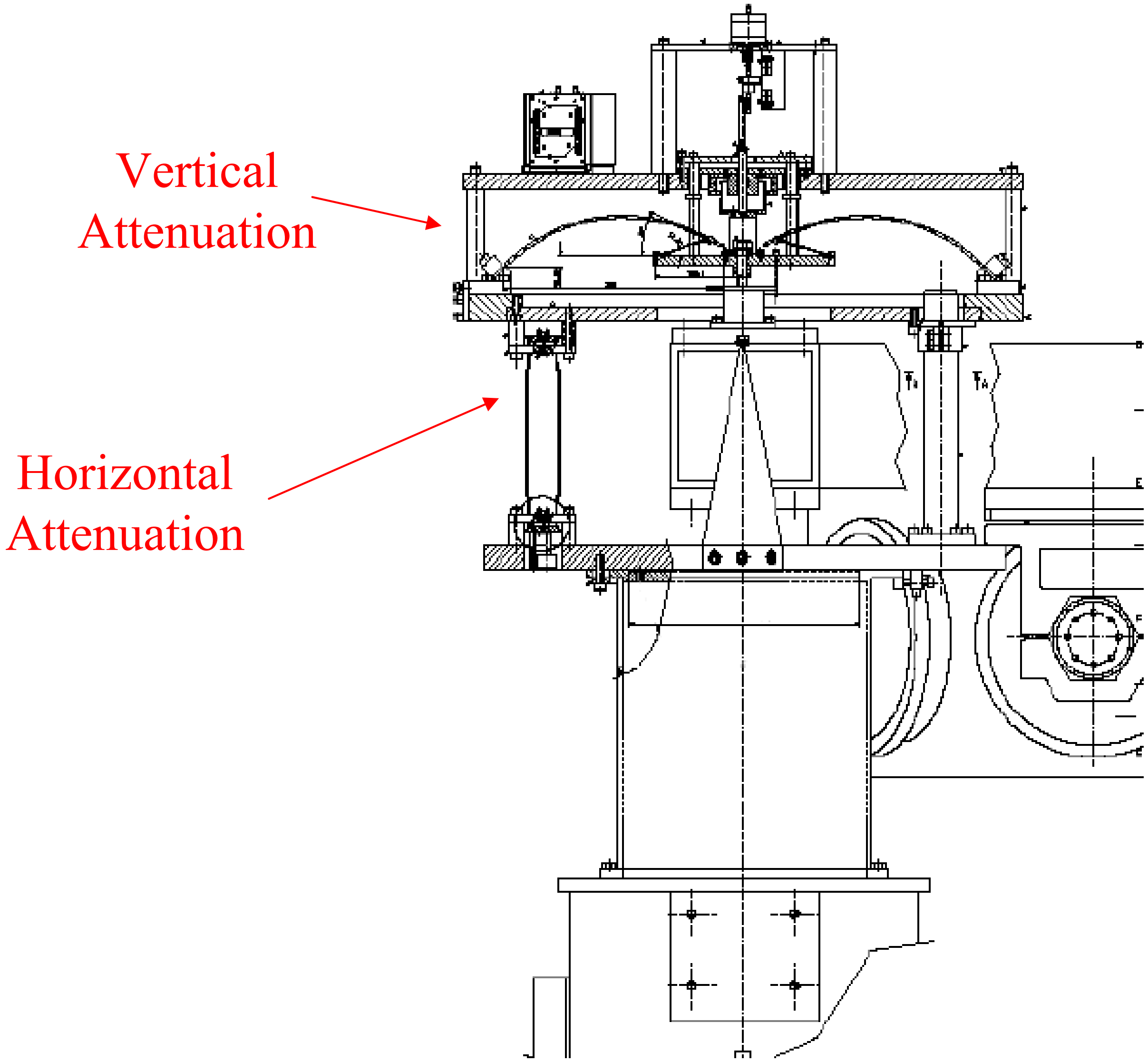


Back to LIGO

- How are these development profiting LIGO?

- DFBS
- HAM-SAS
- BSC-SAS

The DFBS pre-isolator design



the LIGO Deep Fall Back solution prototype for on-pier pre-attenuator

The DFBS task and principle

- Negative stiffness GAS springs and Inverted pendula offload the LIGO weight on piers and neutralize the bellow stiffness with negative K

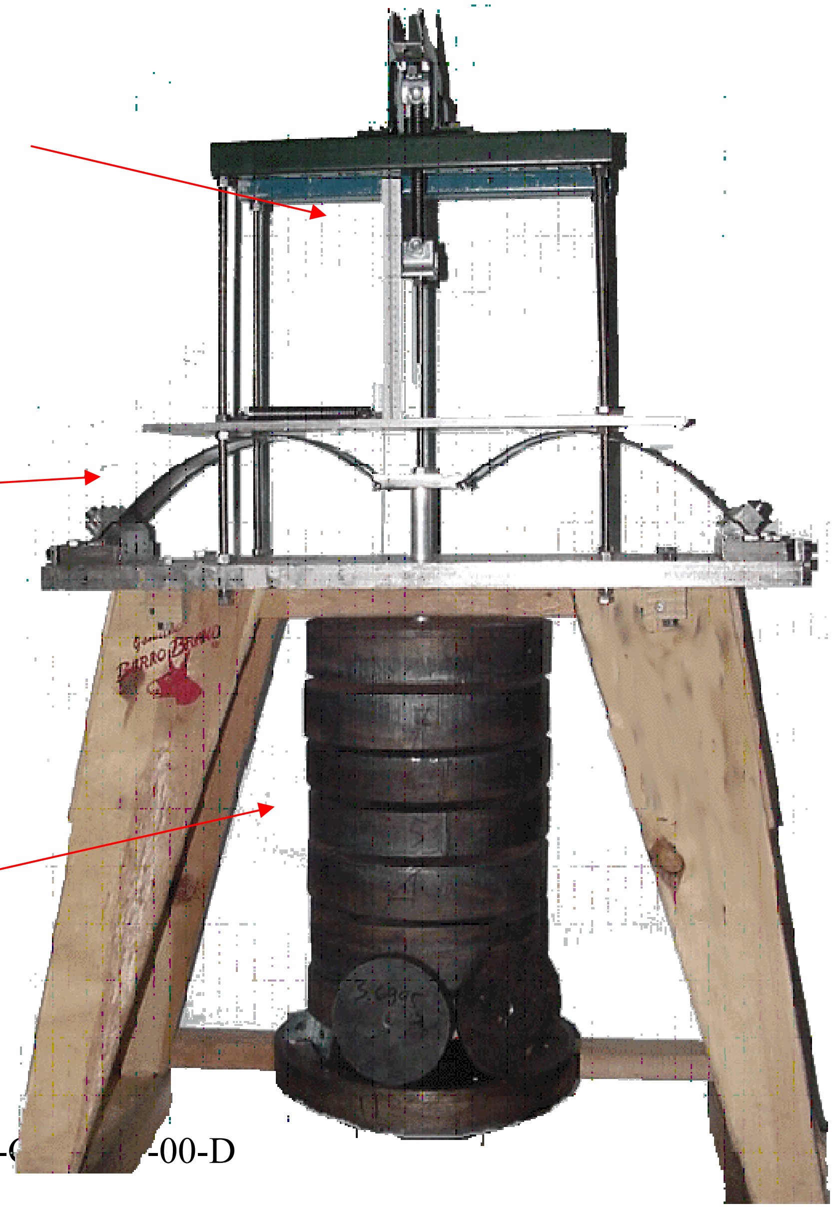
- The DFBS was designed to provide pre-isolation just after S2, while waiting for HEPI to be developed

DFBS prototype

Bellow equivalent springs
(neutralized by GAS)

Cantilevers
GAS springs

350 Kg Payload



DFBS Prototype

driven down the additional springs to 120mHz resonance in fully passive configuration

Can tune to ≤ 30mHz if tuned with e.m. anti-springs

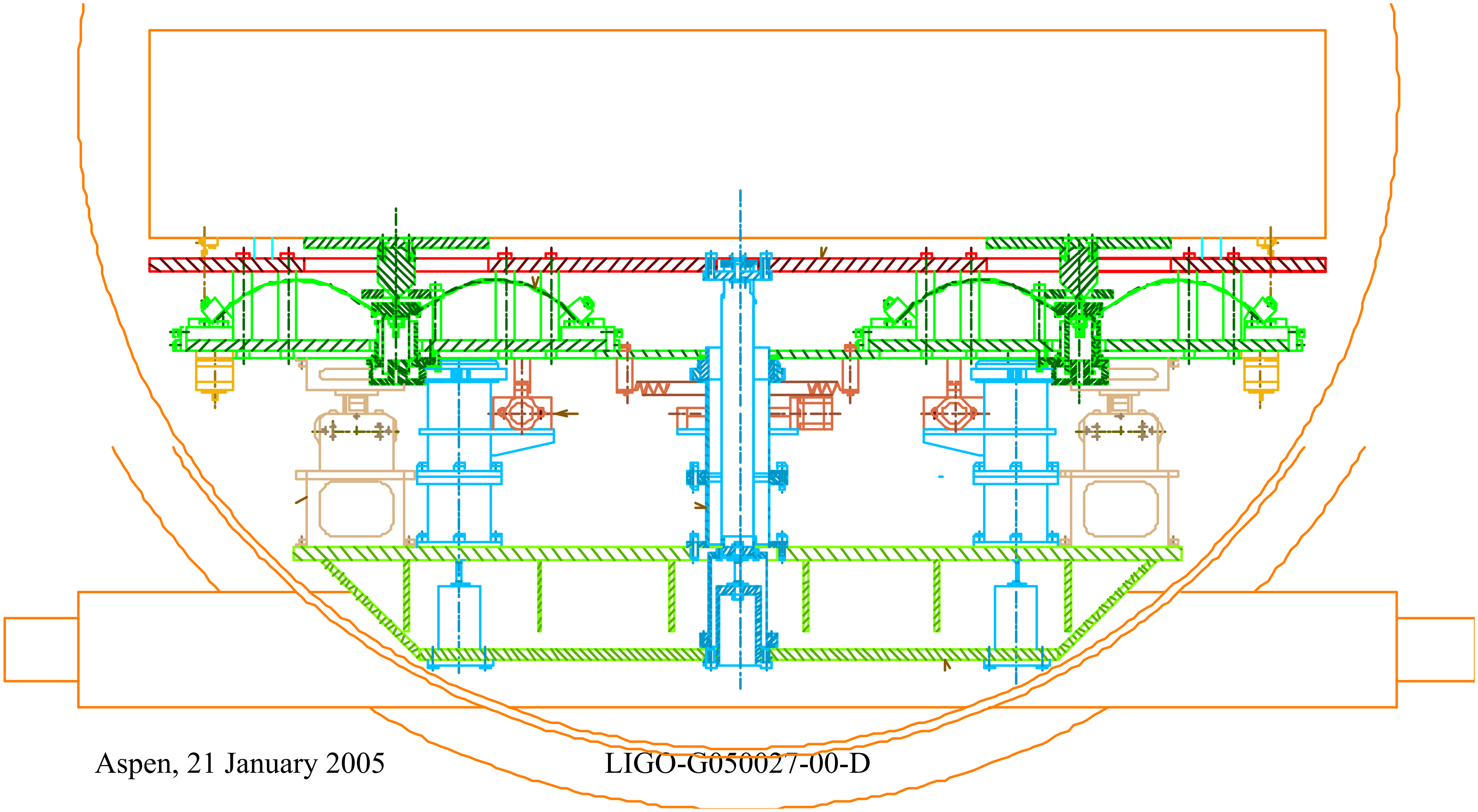
Pre-attenuation 40 to 60 dB in all directions possible above 1 Hz

Shelved

The In-vacuum Seismic Isolation

- Design initially made for the Output Mode Cleaner HAM optical benches
- Found to be applicable to any HAM or BSC adv-LIGO optical bench
- Capable, in passive mode, to produce the cumulative performance of all three active stages of the baseline adv-LIGO S.I.

HAM-SAS



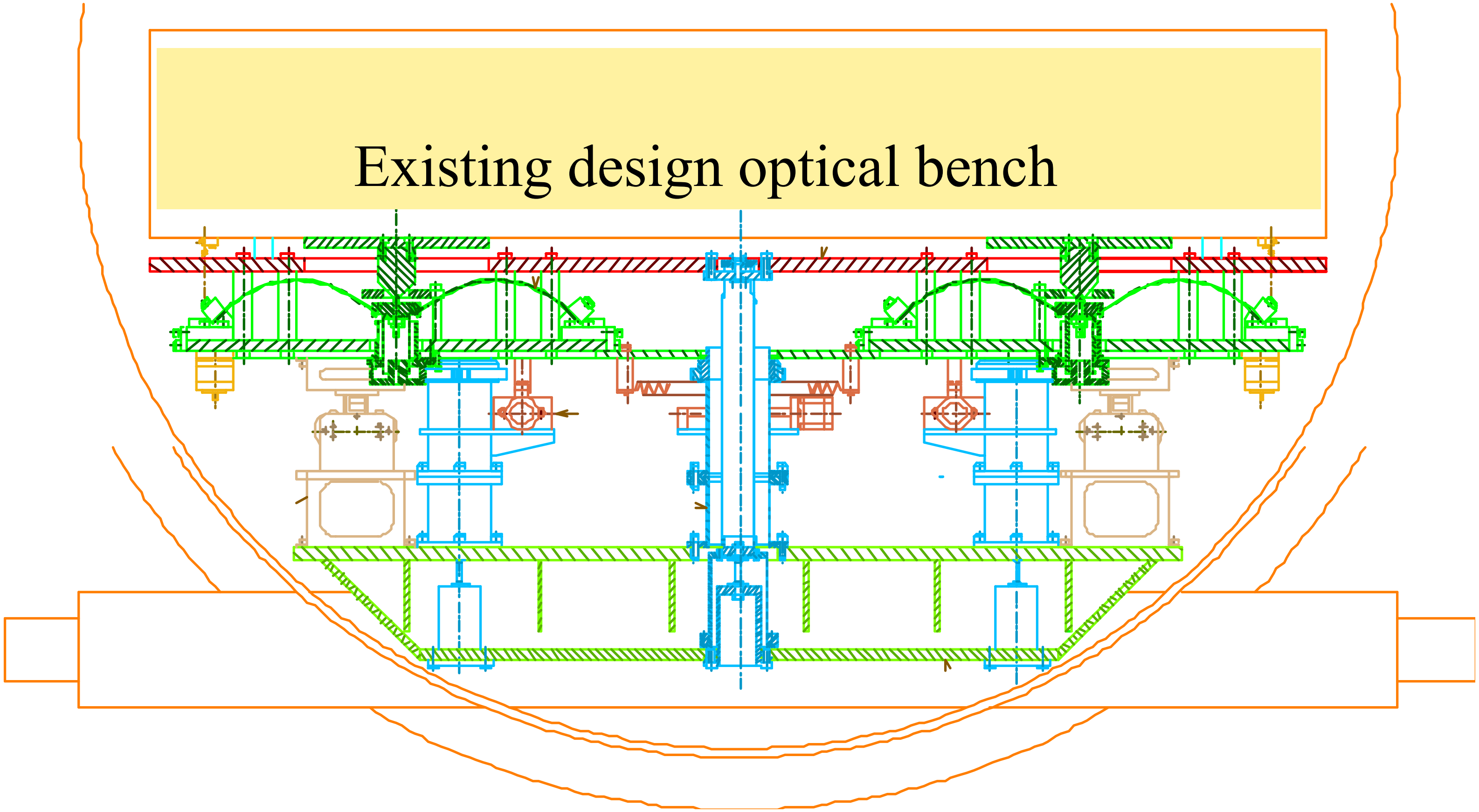
In-vacuum Seismic Isolation SAS

- A HAM SAS design has been initially developed on the following assumptions
  - Passively providing up to 60dB attenuation in the GW frequency region, 10 at the Micro Seismic Peak
  - The seismic attenuation must protect optics from 10 mm earthquakes
  - The optical bench must be easily aligned, and return to the original alignment after interventions and must be able to track tidal movements.
  - It should be immune from thermal drifts

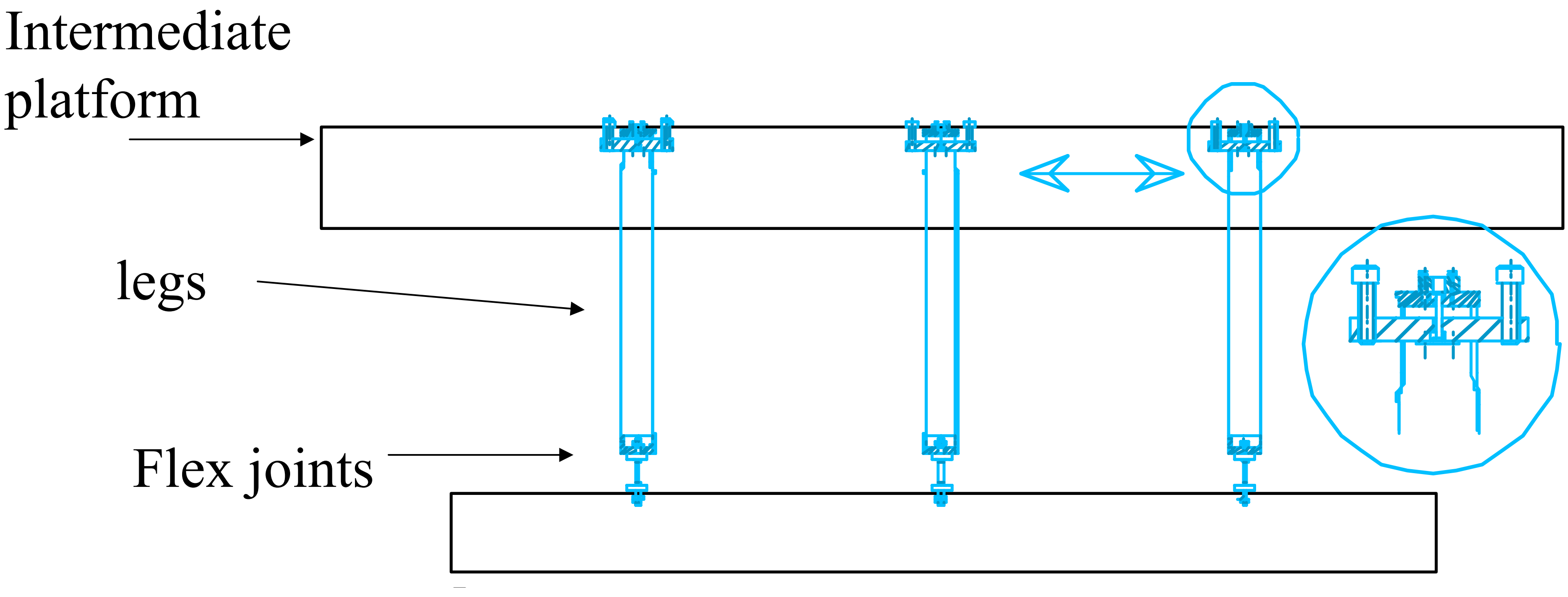
OMC SAS

- The requirement of guaranteeing easy return of the alignment after interventions requires a set of suitable UHV compatible sensors and actuators
- The sensors will read the changes of position after interventions and either suggest changes of ballast to regenerate the previous balance, or use the actuators to return to the original table alignment
- A set of LVDT, nanometer resolution, cm range, UHV compatible position sensors are adequate for the use.
- Low power, UHV compatible voice coils are suitable actuators to deal with tidal and thermal position changes
- These sensors and actuators are available for active attenuation

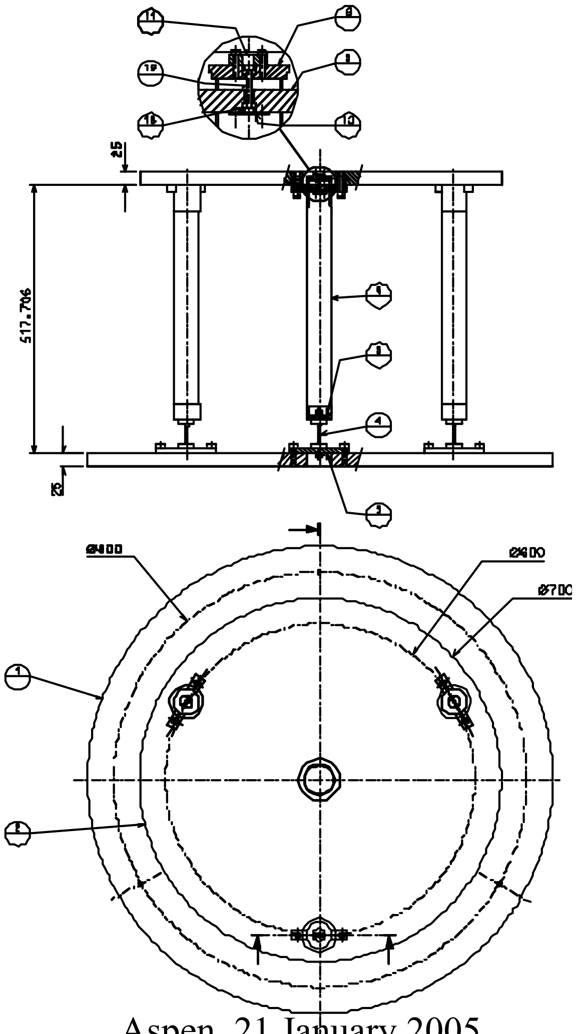
HAM implementation



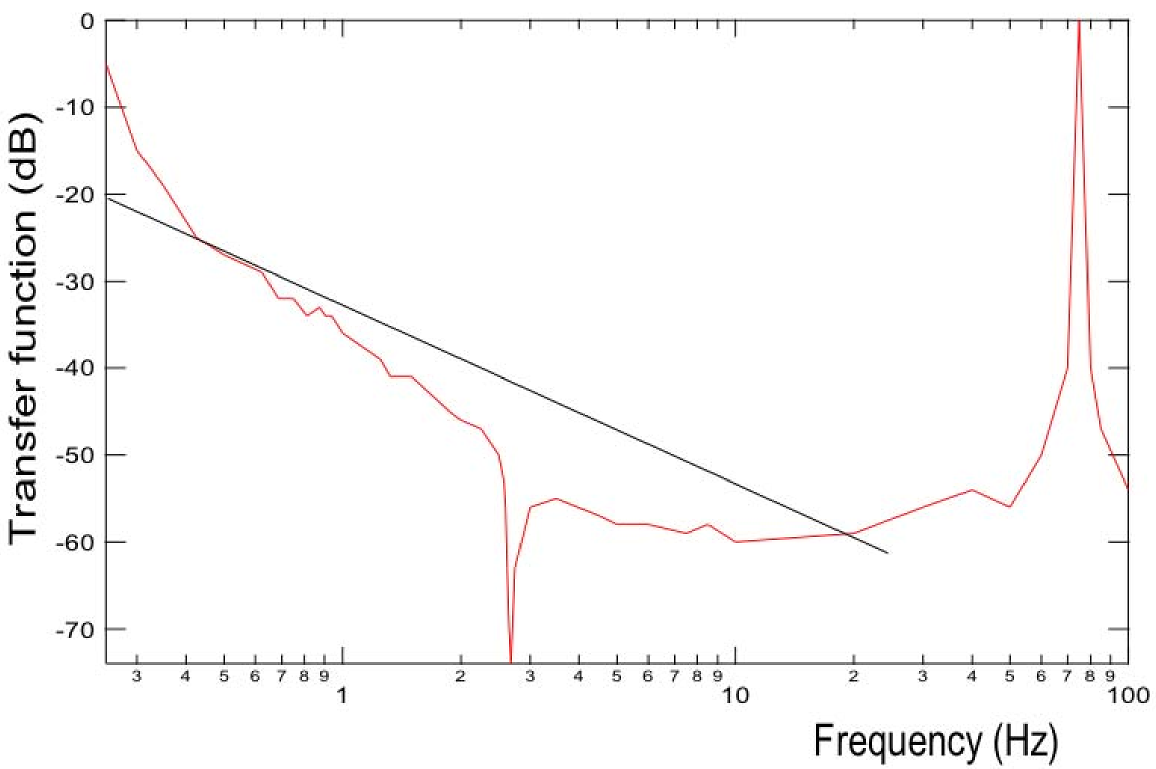
Horizontal direction, x, y, phi the IPs



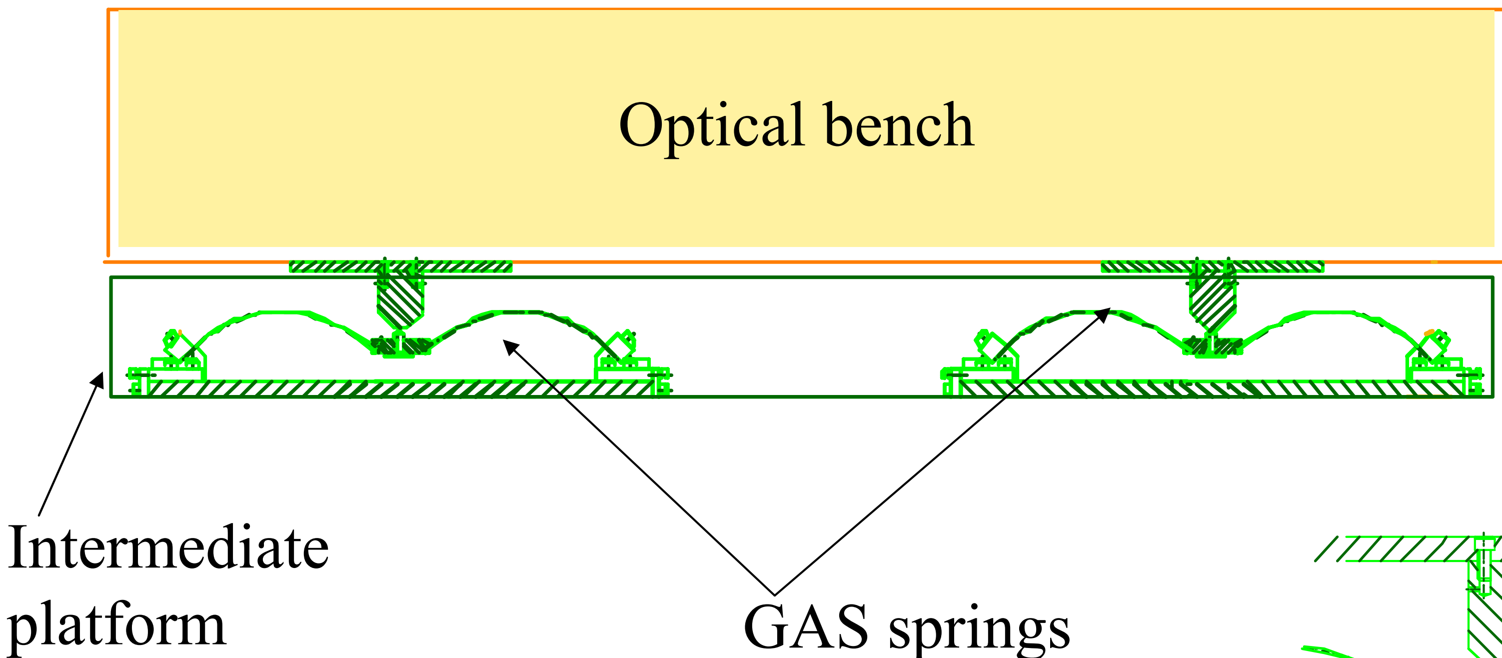
HAM IP first tests

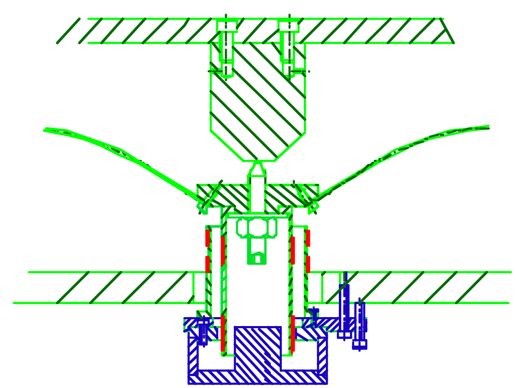


- Preliminary test results
- 60 dB achieved without CounterWeight
- 1/8 payload (8 times better at full payload)
- Further improvement with CW

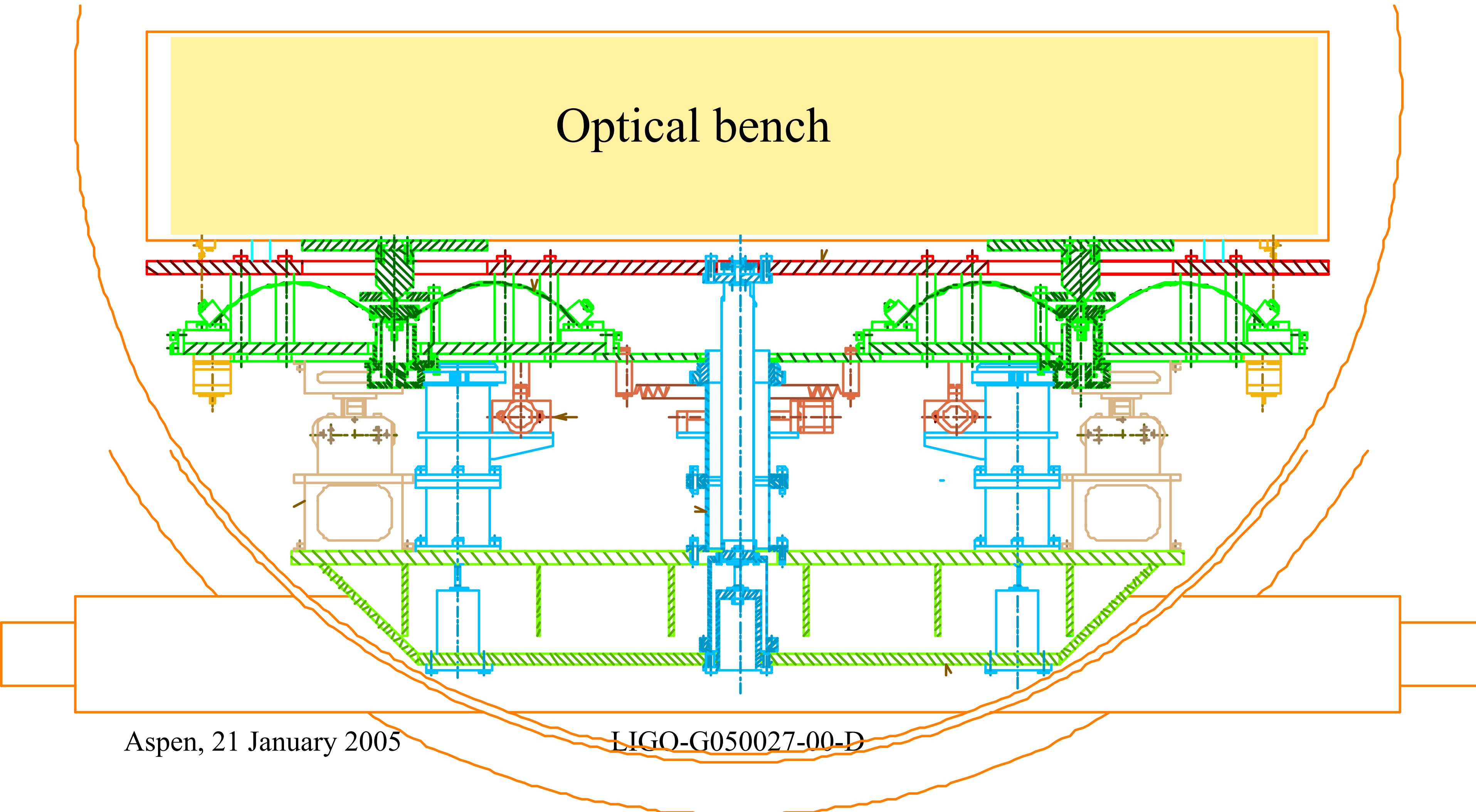


vertical direction, the GAS springs





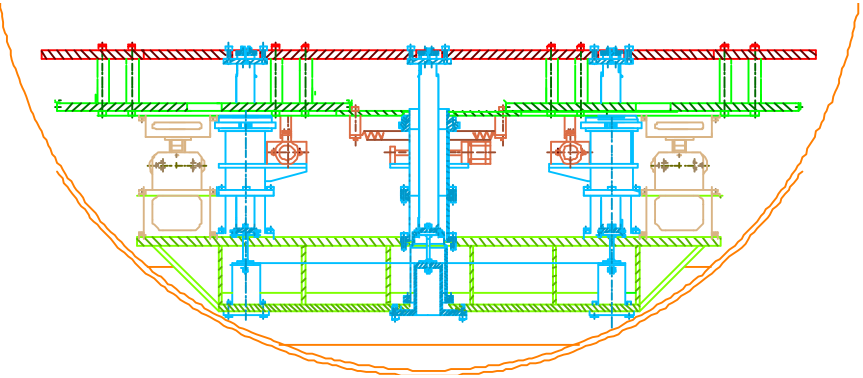
Complete ISI SAS design for HAMs

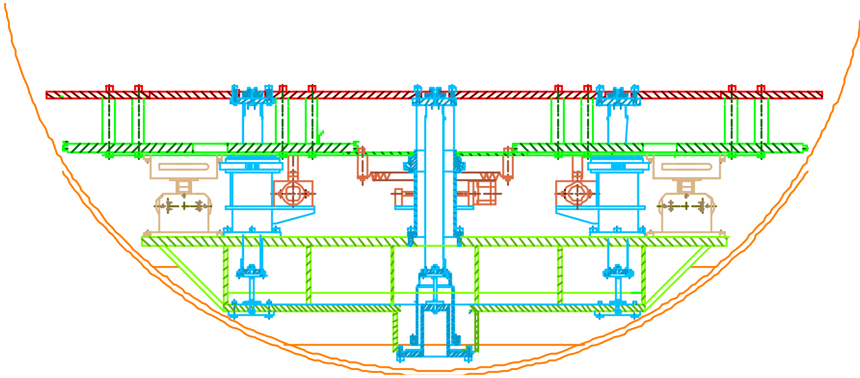


Transition from LIGO-I to Adv-LIGO

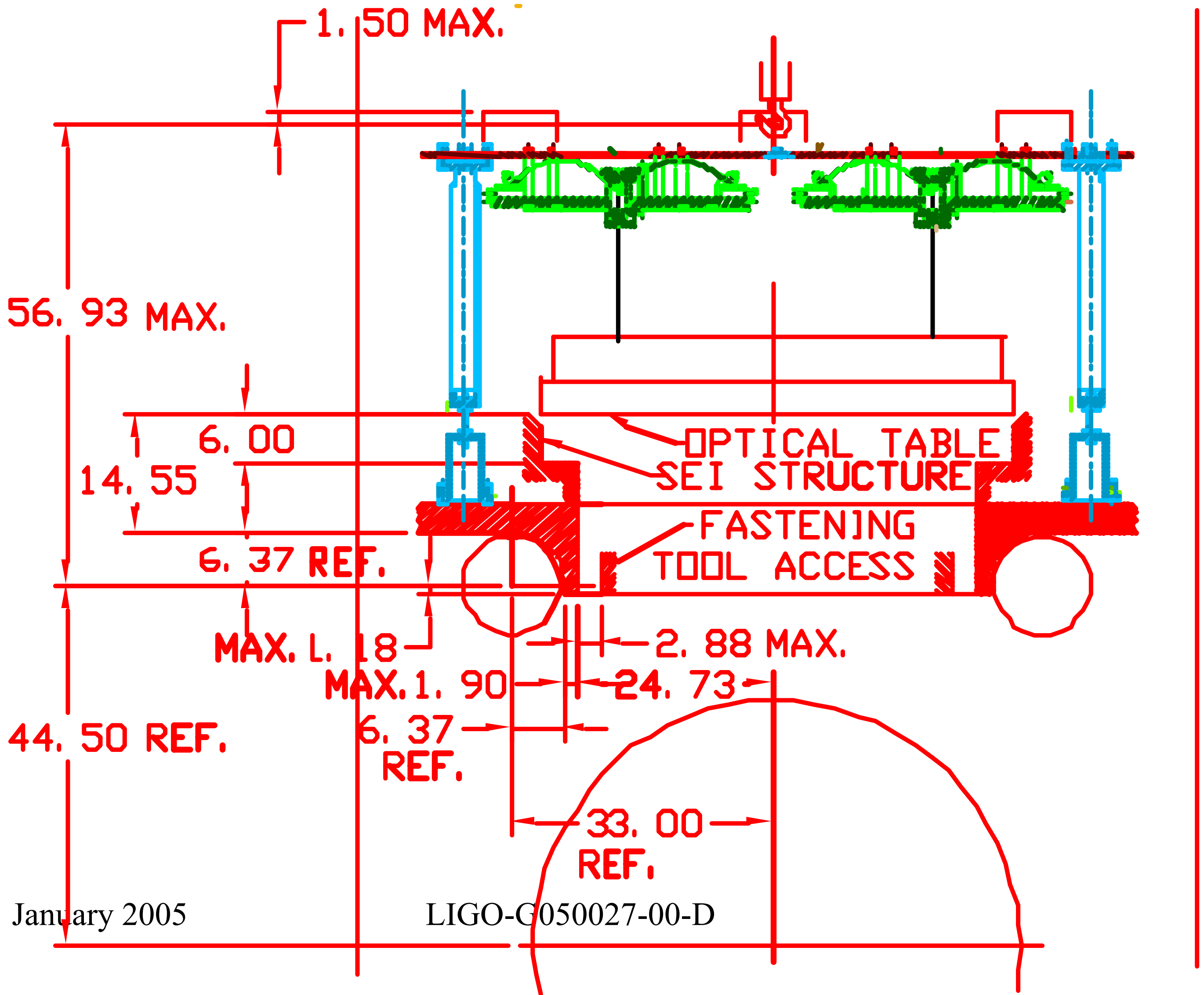
- The transition between

  LIGO and Advanced LIGO is obtained by simply eliminating a number of spacers





ISI SAS design for BSCs



BSC SAS

- The HAM-SAS design fits in the BSC and is capable to offload the entire weight
- An additional pendulum stage, needed to reach the (lower) level required by the quad suspensions, gives a redundant safety factor in horizontal isolation

ISI SAS features

- The sensors and actuators are used to lower the resonant frequency, to viscously damp resonances, to satisfy the positioning, tidal and thermal stability requirements
- The expected passive attenuation performance should exceed 40 dB above 1 Hz and 60dB above 6-10 Hz
- The performance of HAM-SAS can be complemented with one stage of active attenuation, thus providing a reserve of attenuation power

Ham and BSC SAS features

- SAS is a viable and inexpensive in-vacuum seismic attenuation candidate for Adv-LIGO
- Can potentially replace all three stages of stiff SEI
- is fully compatible with the SUS system
- In case of attenuation shortfalls (possible example, the power recycle triple pendulum) one could fall back on HEPI or, if that is not sufficient, on the DFBS

ISI SAS design status

- A complete HAM SAS design is ready for production, it can be found in

  http://www.ligo.caltech.edu/~desalvo/HAM-SAS and

  http://www.ligo.caltech.edu/~desalvo/HAM-SAS.doc
- Preliminary bidding indicate a mechanical components cost of ~ 150K$ and production times of the order of three months
- Prototyping will be made shortly, to validate the design in LASTI
- Scaling of the design is possible for BSC