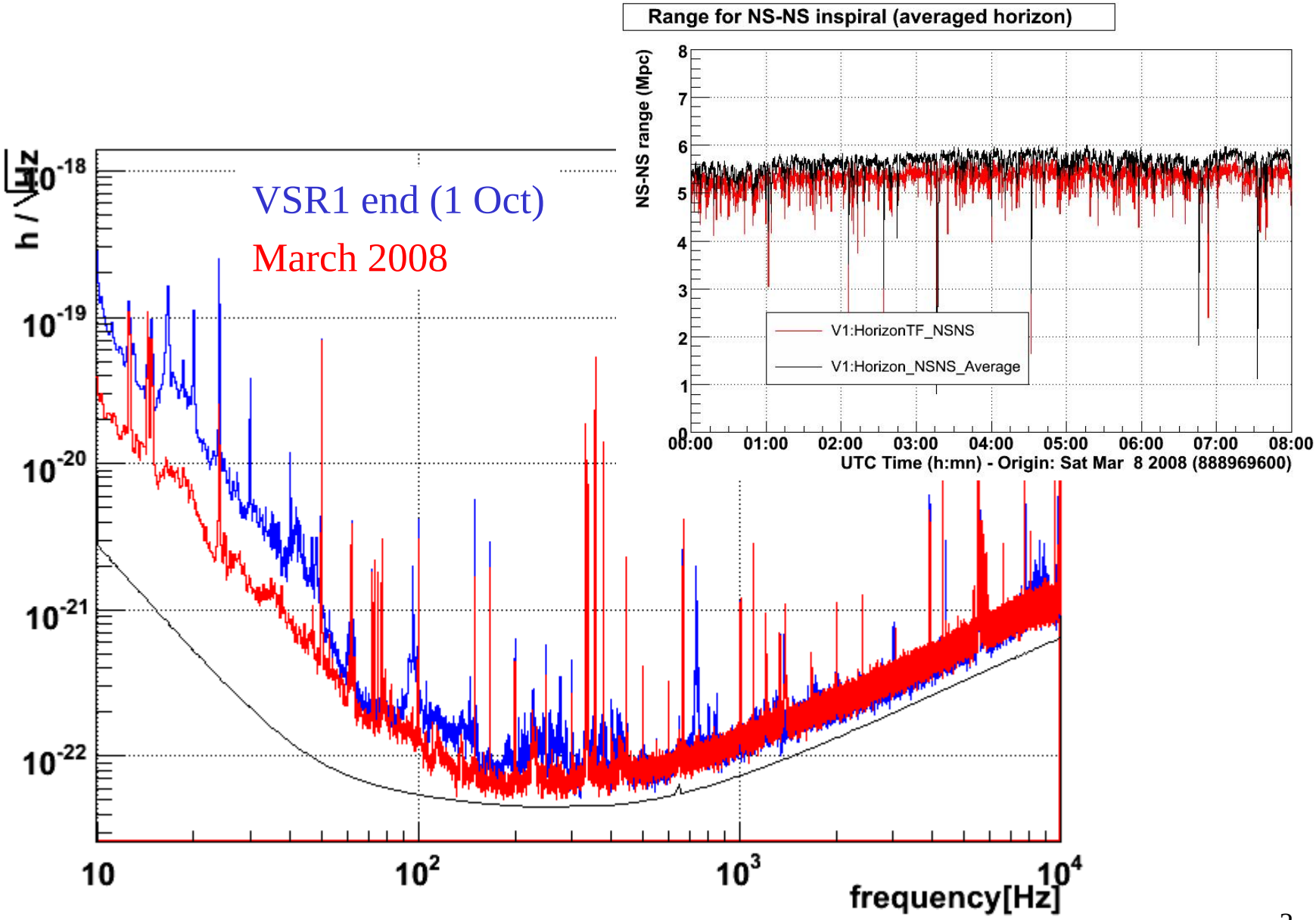
# Virgo commissioning highlights and plans

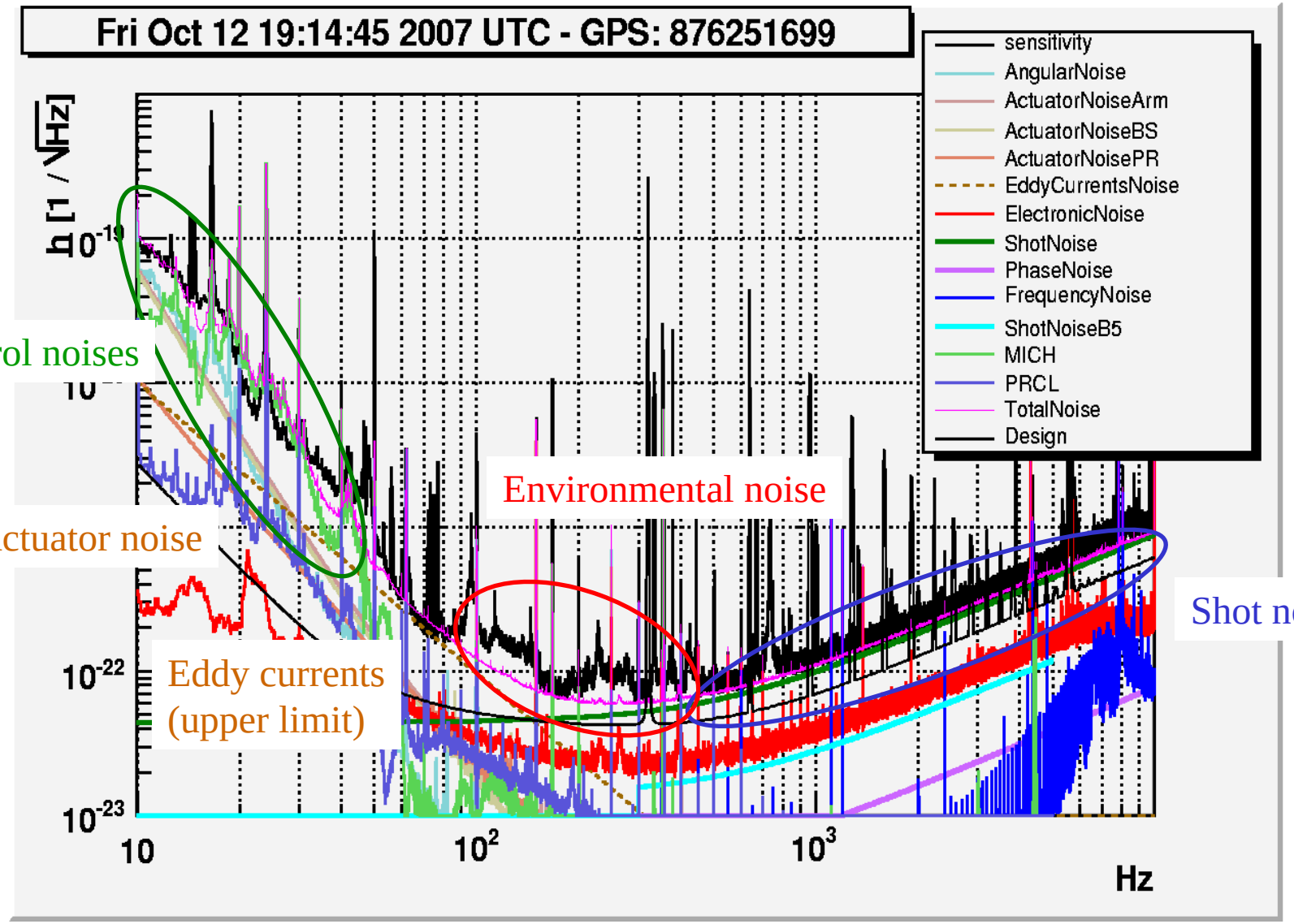
E. Tournefier

LSC-Virgo meeting, Caltech
March 17th ,2008

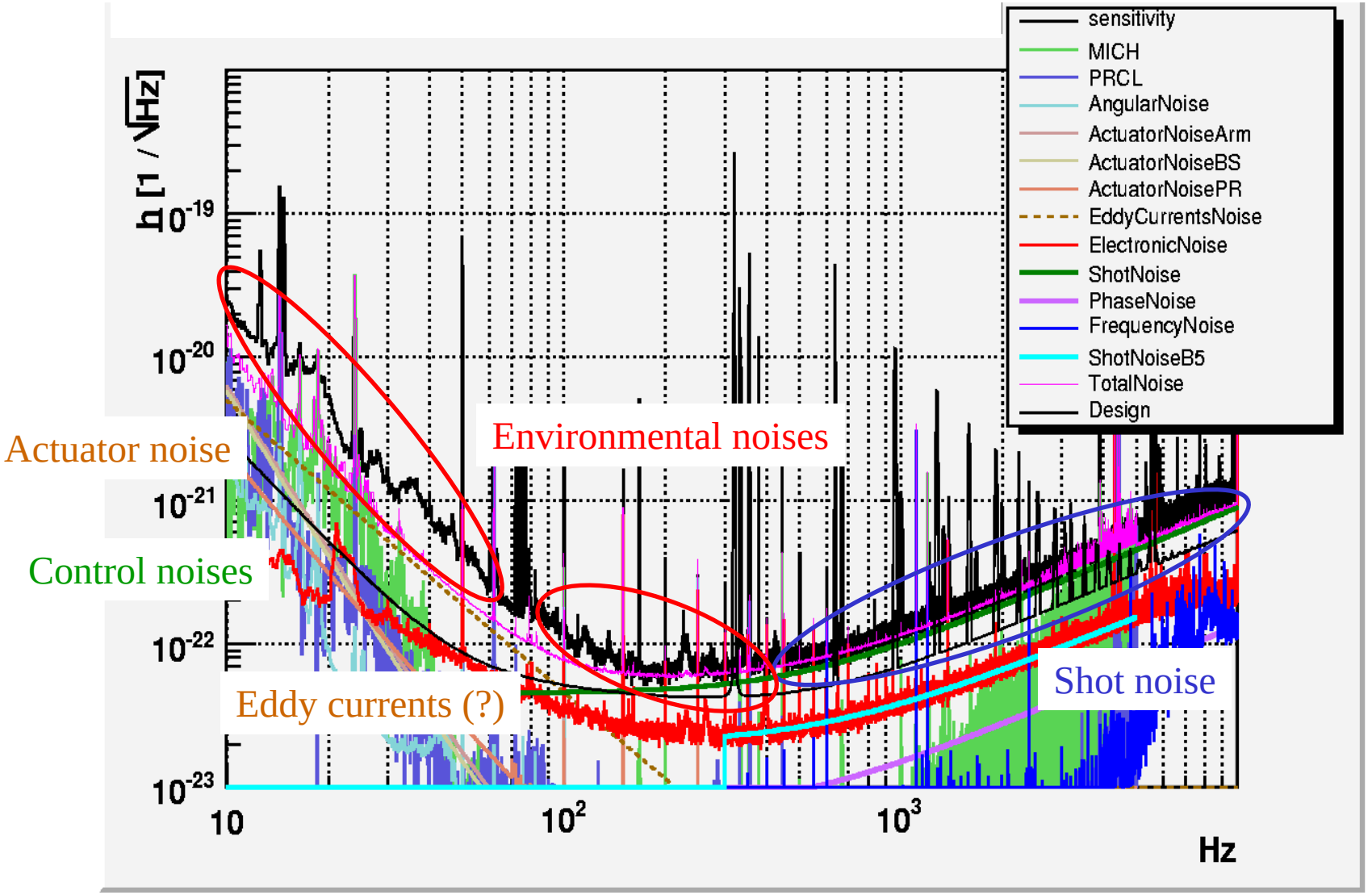
# VSR1 to now


Range for NS-NS inspiral (averaged horizon)
NS-NS range (Mpc)
V1:HorizonTF_NSNS
V1:Horizon_NSNS_Average
UTC Time (h:mn) - Origin: Sat Mar 8 2008 (888969600)
VSR1 end (1 Oct)
March 2008
h / √Hz
frequency[Hz]

# Noise budget at the end of VSR1



# Noise budget now



# Longitudinal noise reduction

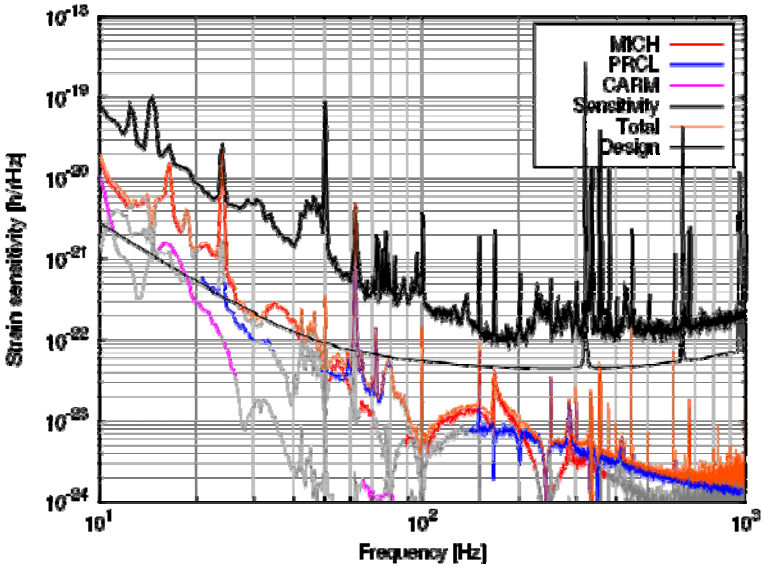
Improvement of the controls:

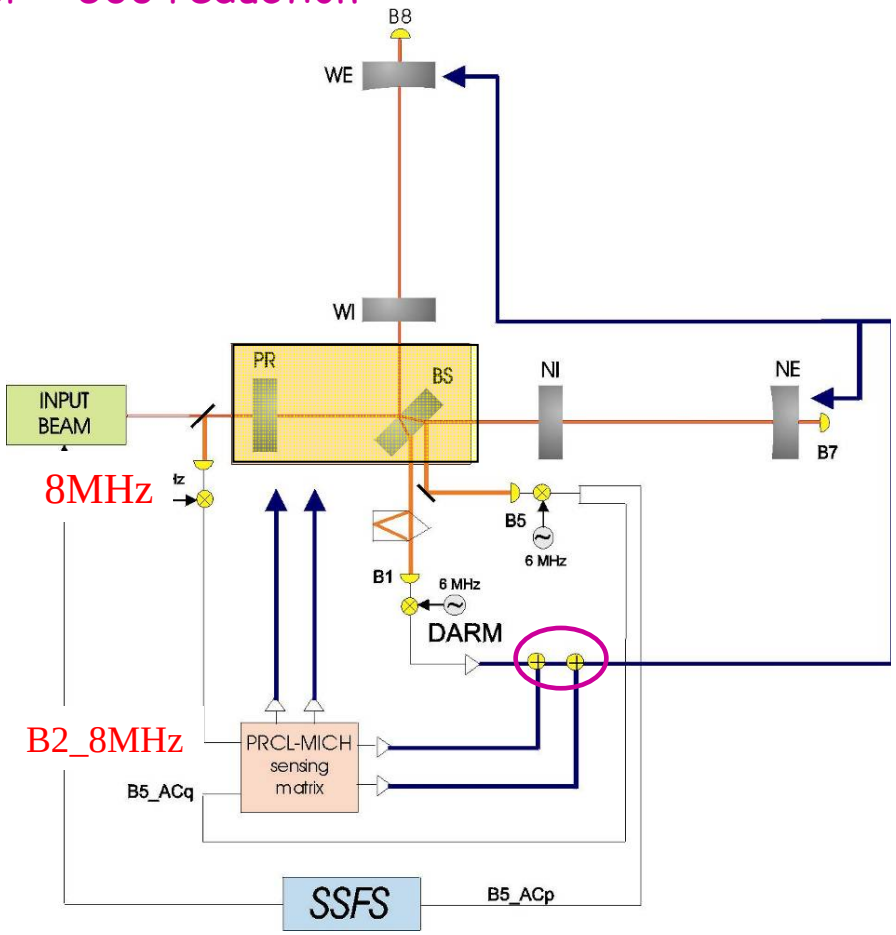
See G. Vajente's talk

- improve filters and driving/sensing matrices
- more flexible Global Control algorithm
- use signal at second modulation frequency (8MHz): cleaner signal for MICH control
- improve noise subtraction: now reach a factor ~ 500 reduction

⇒ Noise reduction

⇒ More robust lock acquisition

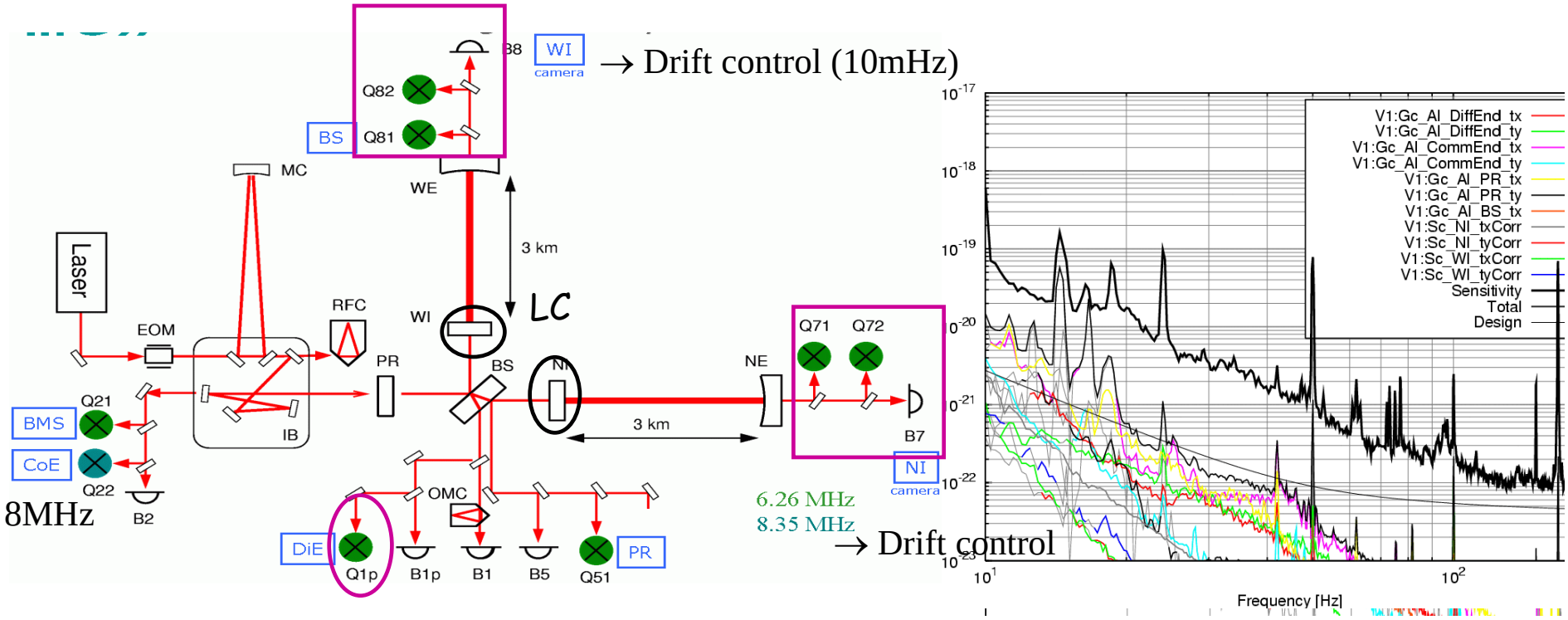


See G. Vajente's talk

# Alignment noise reduction

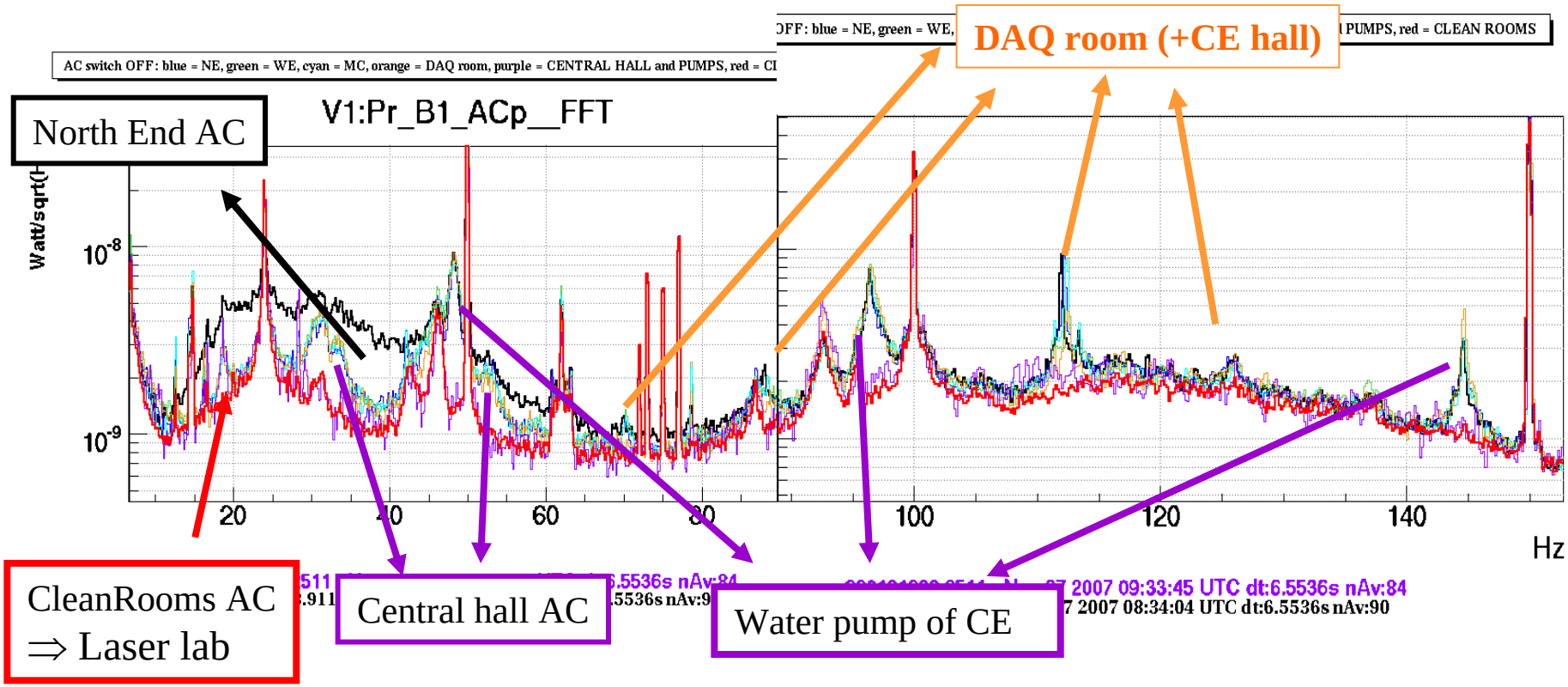
- Post VSR1 alignment noise reductions:
  - More efficient filters + noise from the local controls reduced
  - Mirror centering improved
  - ⇒ The alignment noise is below V+ design above 20 Hz
  - More accurate controls ⇒ coupling of noises above 100Hz reduced
- Ongoing improvements:
  - Find cleaner signals for BS and input mirrors (under drift control)
  - ⇒ New end benches and new quadrant (on DF) have been installed



# Environmental noises studies

- Test: switch OFF the air conditioning in ALL buildings

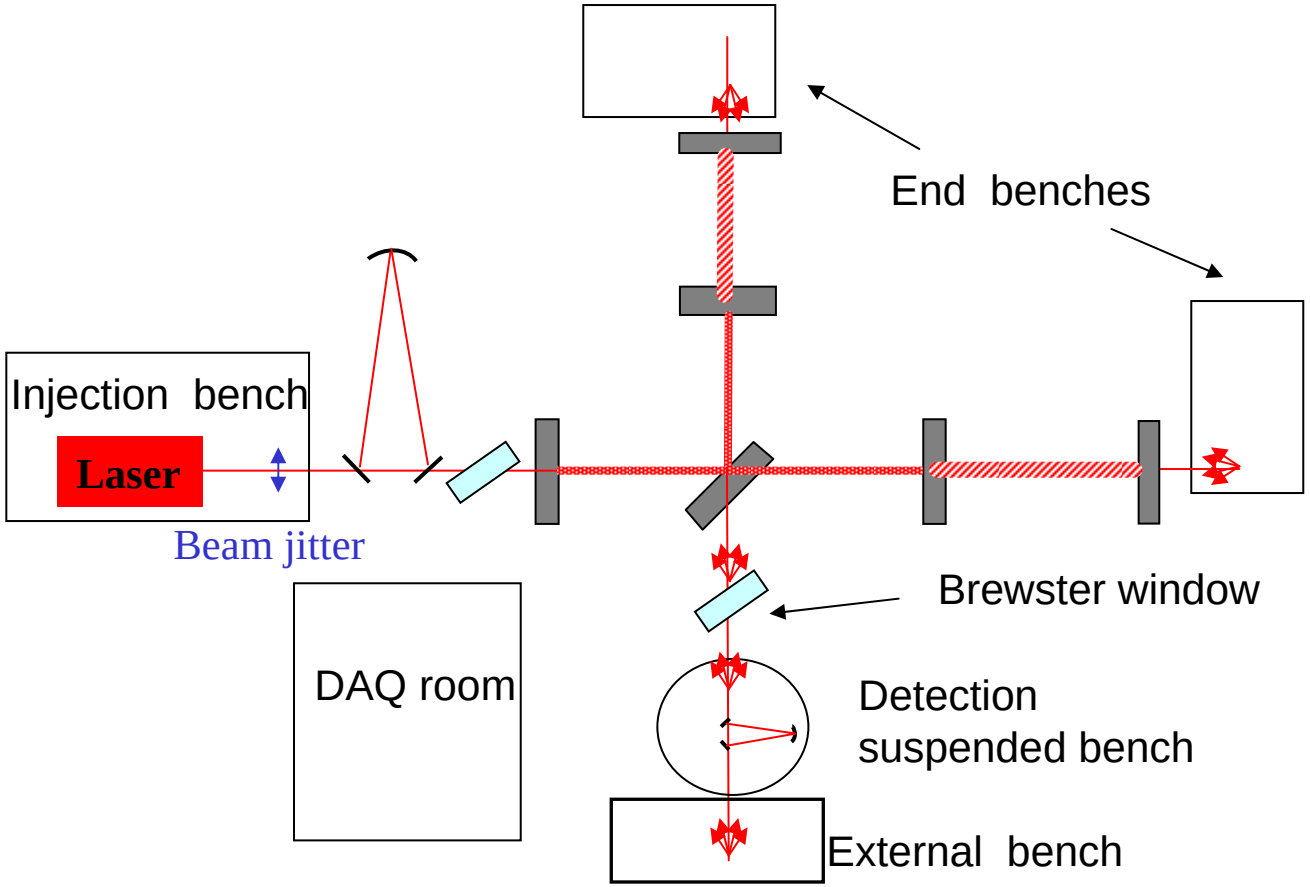
⇒ Identify sources and path to dark fringe



# Environmental noises studies

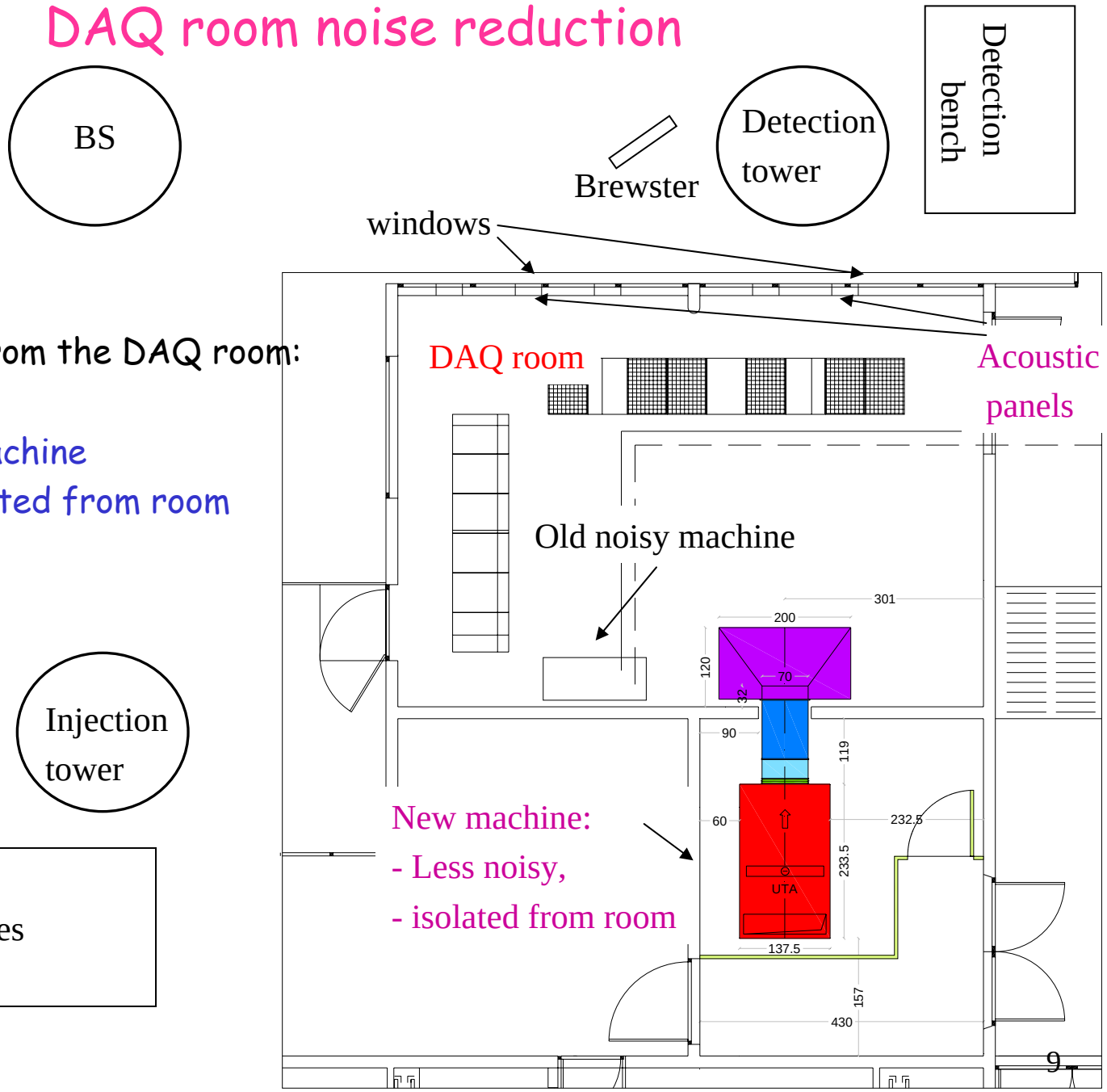
⇒ Identify sources and path to dark fringe

- diffused light from end benches (now almost completely cured)
- diffused light from Brewster/detection induced by Central hall + DAQ room AC
- beam jitter induced by air conditioning in laser lab



# DAQ room noise reduction

- Reduction of noise from the DAQ room:
  - Acoustic panels
  - Less noisy AC machine
  - AC machine isolated from room

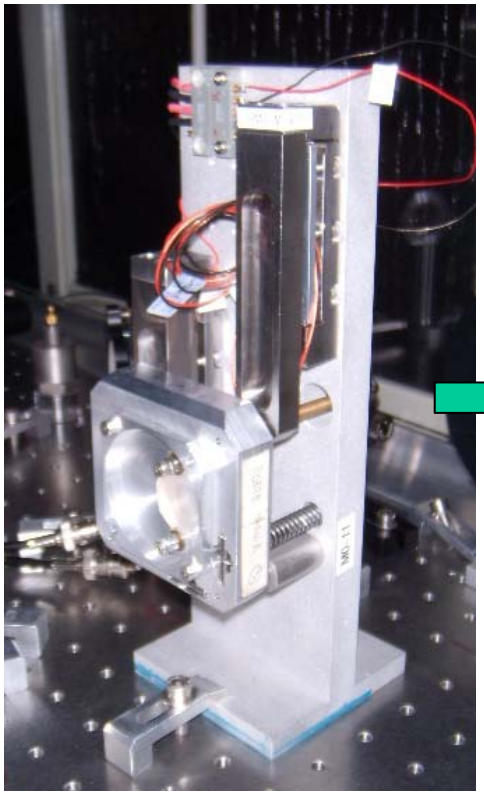


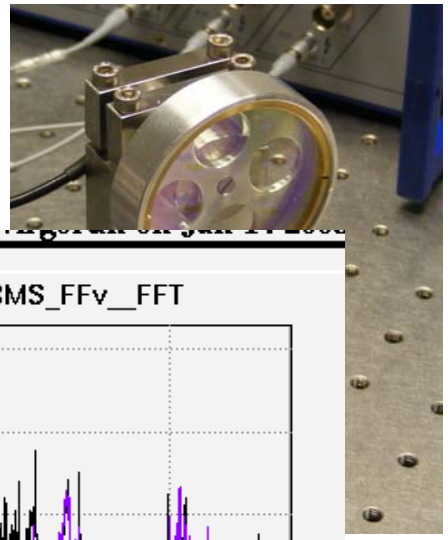
# Beam jitter at the injection

- Mechanical resonances of the Beam Monitoring System (mount+ PZT) seen in dark fringe

⇒ Mount + PZT replaced with better one:

Move resonances at higher frequencies + they are less easily excited








- Identified vertical/horizontal resonance (~45/18Hz) of the injection bench ⇒ beam jitter

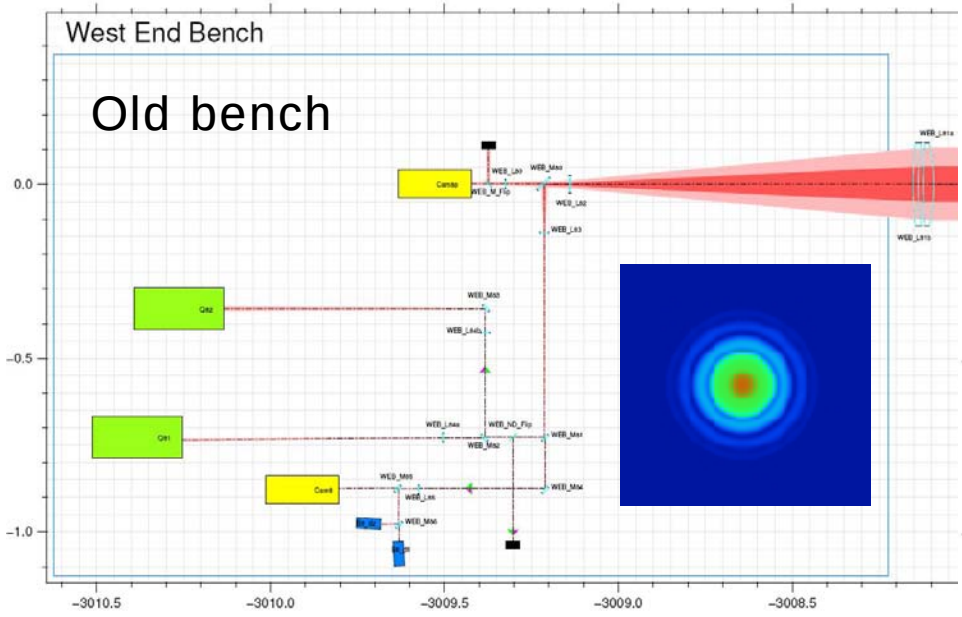
⇒ Damping of these resonances under study

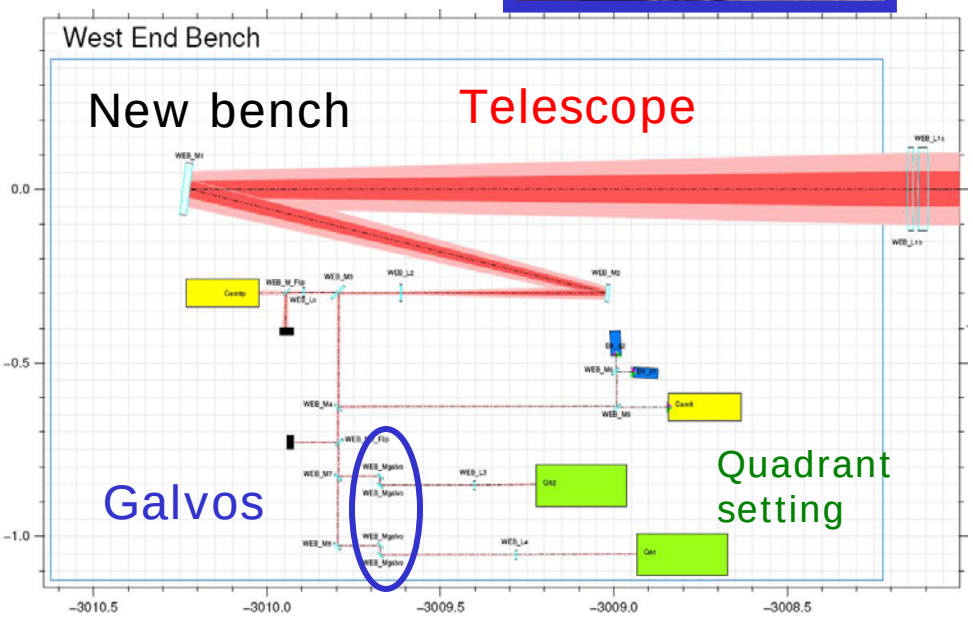
# End benches upgrade

- New end benches recently installed:
  - Better telescope: helps to reduce diffused light and aberrations
  - Quadrants Gouy phase optimized: better signals for alignment
  - Galvanometers installed: quadrants centering

Remaining problem:

quadrant signals polluted by air flux and bench motion

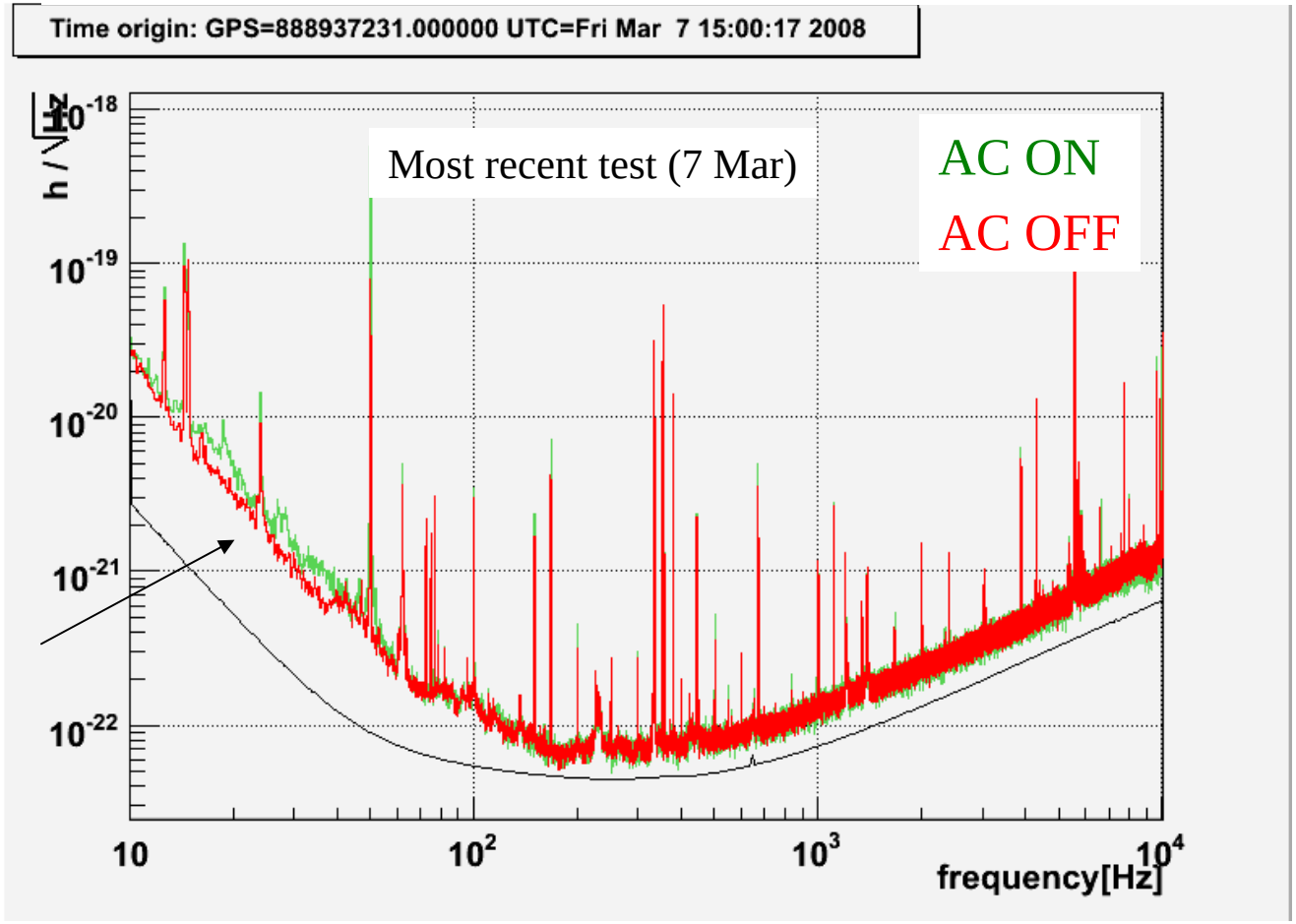



# Effect of air conditioning now

- Impact of AC reduced thanks to:
  - Diffused light reduction (new end benches)
  - Input beam jitter reduction
  - Improved AC in DAQ room
  - More accurate alignment: diffused light coupling reduced

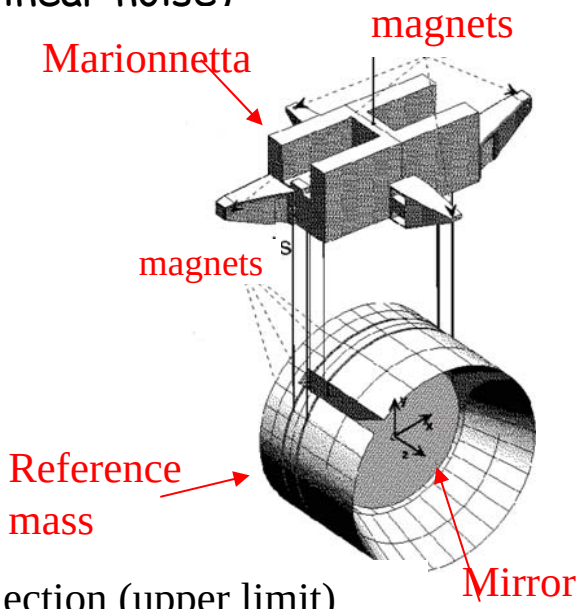
?



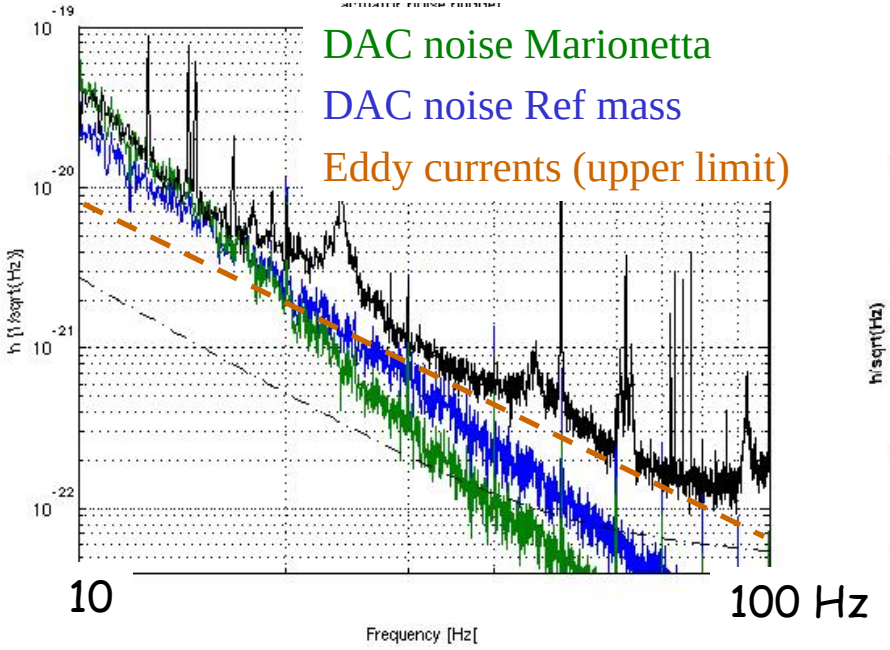
# Actuator and magnetic noise

- Actuator noise: dominated by electronic noise of DACs (non linear noise)
  - Reference mass and marionetta controls

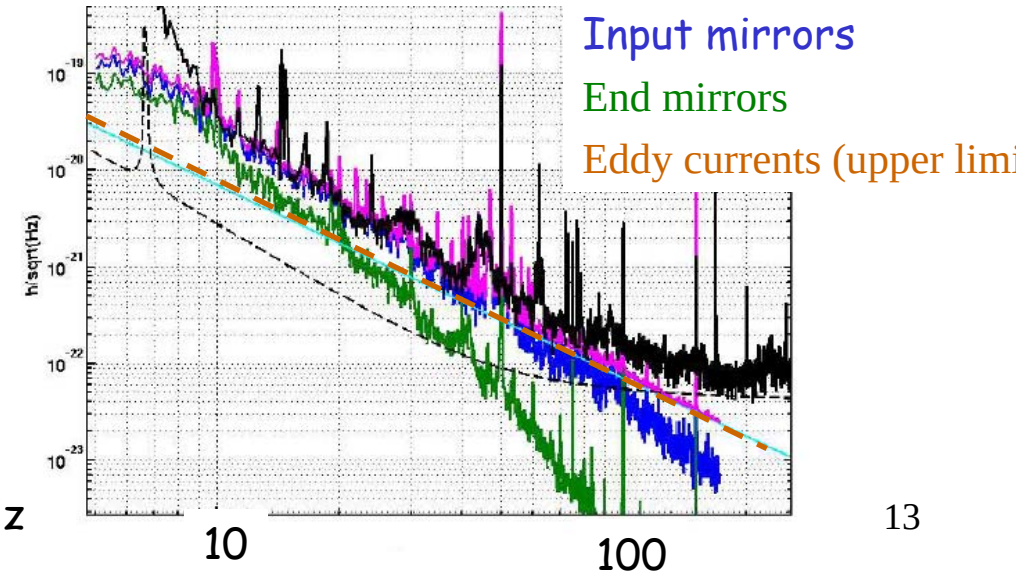
- Magnetic noise:
  - Magnet of input mirrors mounted parallel
    ⇒ Direct coupling of external magnetic noise
  - Eddy currents in Reference Mass




Actuator noise projection (Dec 21st)




Magnetic noise projection (upper limit)



# Actuator and magnetic noise reduction

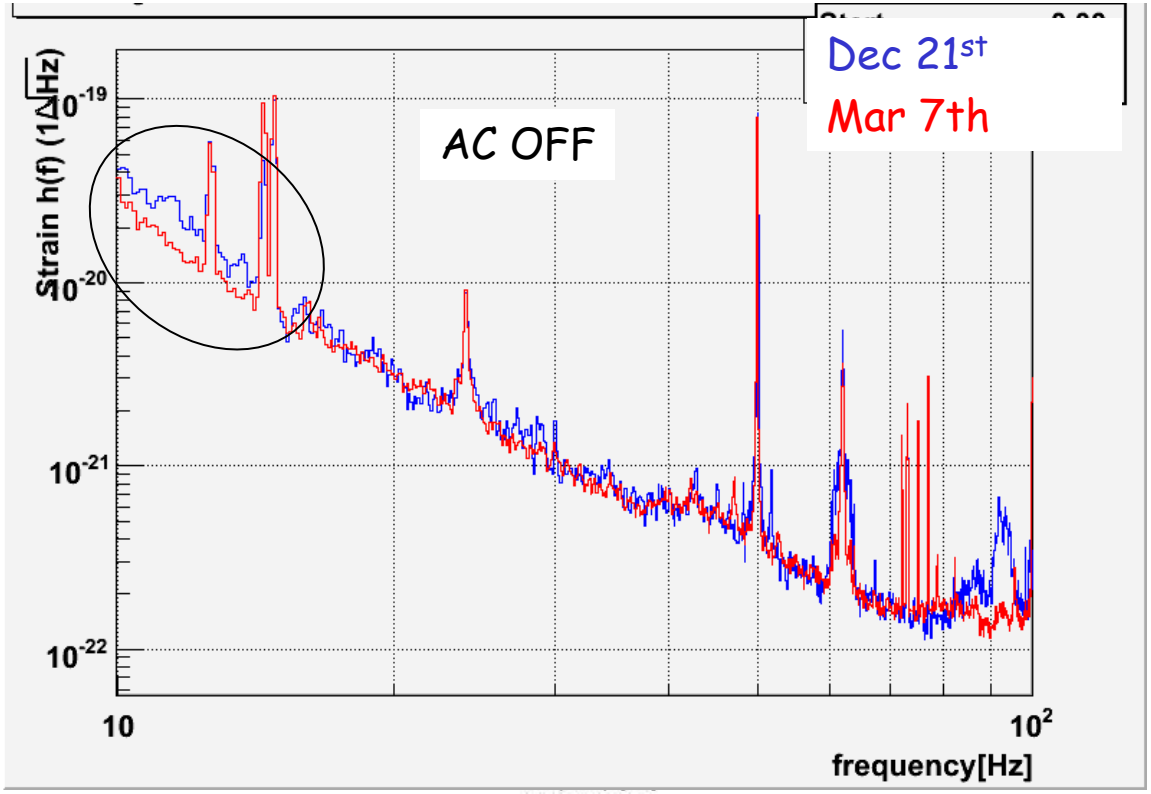
Actions:

1/ Actuator electronic noise reduced: Reference mass + Marionetta (shaping filters)

2/ Magnet of the input mirrors replaced: weaker (/5.5) + anti-parallel

Result:

- improvement below 20 Hz: expected from Marionetta actuator noise



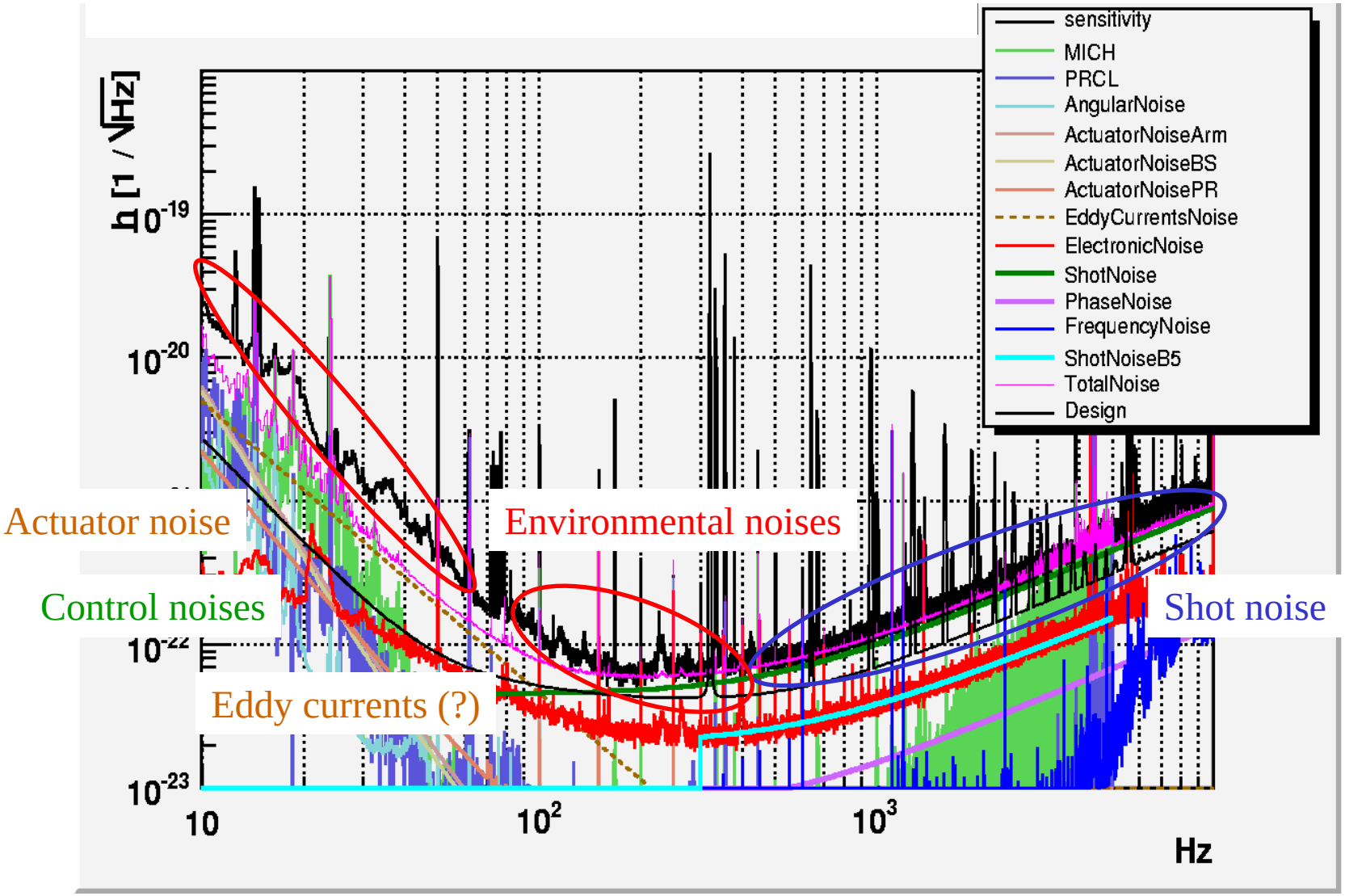

Remaining noise under investigation
(lateral magnets?,…)

Magnetic studies:

- magnetic injections and modelling

⇒ See B. Swinkels's talk on Wednesday

# What about high frequency?



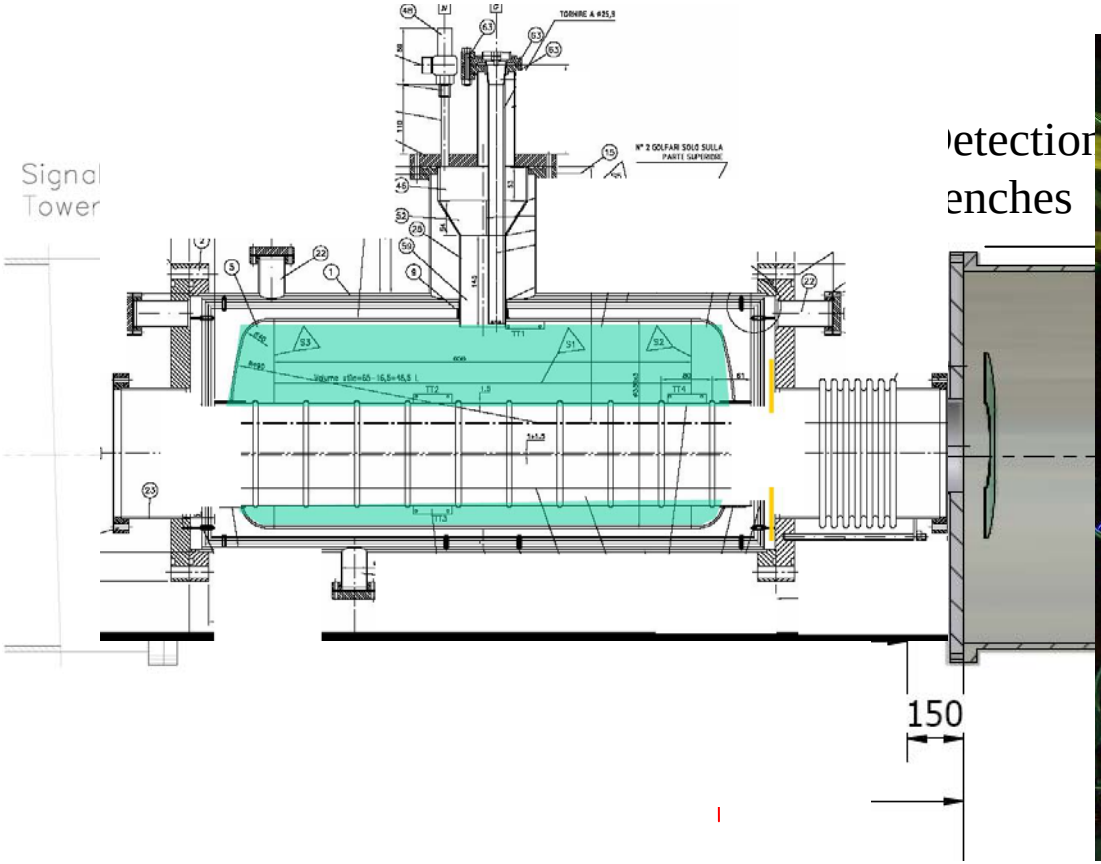

Diffused light at detection port above ~100 Hz?

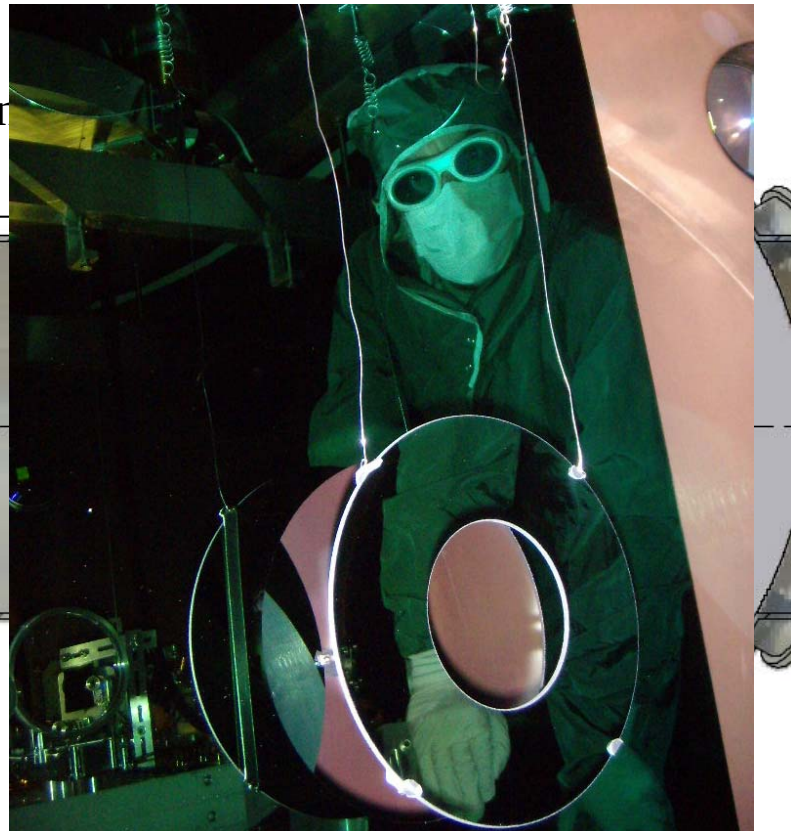
# Diffused light at detection port

Many structures above ~100 Hz are coherent with the motion of the Brewster window

Investigate the path for diffused light

- Diffused light on the tower walls or inside the Brewster link?
  ⇒ baffles installed – no visible/clear effect
- Coupling through the Brewster window?
  ⇒ replaced it with cryogenic trap last week – just restarting



# Thermal effects

- Cleaning of the input mirrors was performed at the end of November
  - Some visual improvement was observed for both

**WI mirror** :

❑ Observation before cleaning : with an halogen lamp coupled to a fiber
some large particules on the coatings
center part : a little bit 'opaque' (~ Ø1 cm)
a lot of condensation points but not on the coating

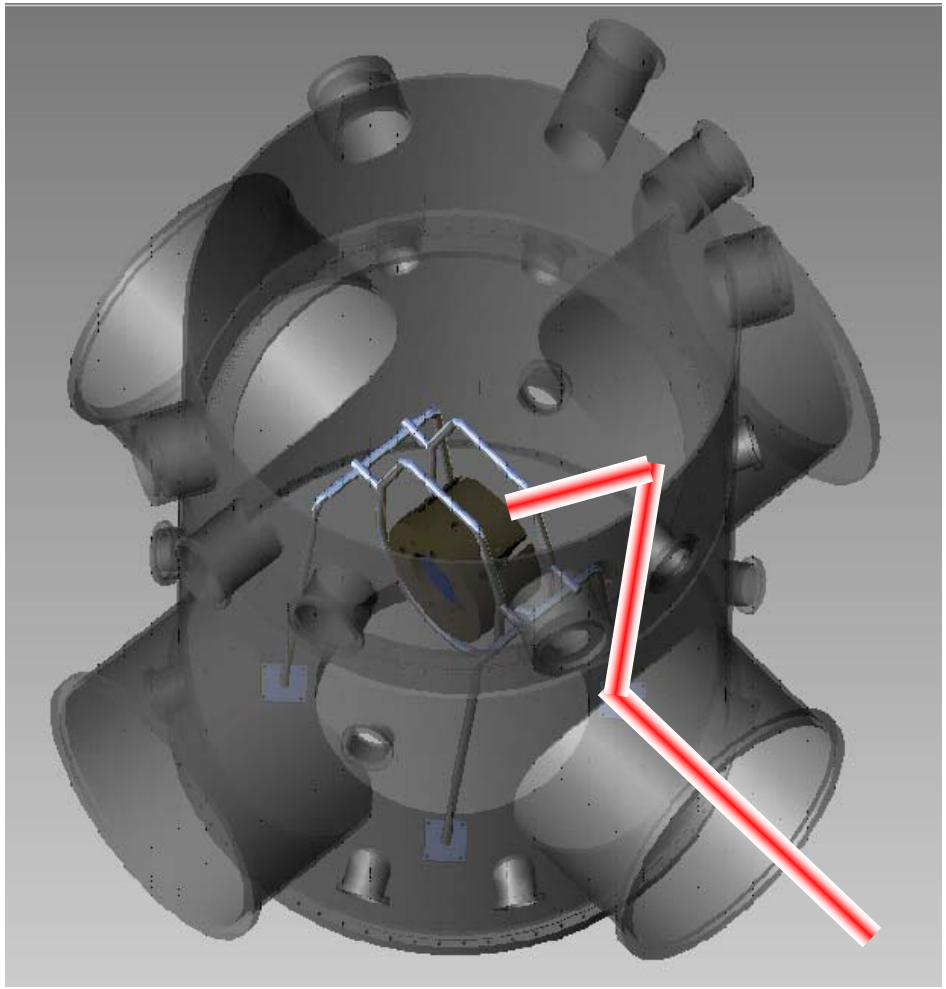
❑ Observation after cleaning : no more large particles
center part : clearer(# Ø1 cm)
visual aspect better than before cleaning

- But no clear improvement in the thermal effects:
  - thermal transient similar to before
  - increase of the sidebands power ~ 25% only

⇒ The thermal compensation system will have to do a good job

# Thermal compensation system

- TCS based on $CO_2$ laser with annular profile
- Installation: end of March/ early April



Power needed for compensation

| | |
|---|---|
| Virgo on WI mirror (absorption 7.7ppm) | ~1.8 W |
| Virgo (nominal absorption) | ~0.4 W |
| Virgo+ on WI mirror (absorption 7.7ppm, $P_{las}$=25W) | ~6.2 W |
| Virgo+ on NI mirror (absorption 2.3ppm, $P_{las}$=25W) | ~2.1 W |

# Plans for next months

Next 2 months commissioning:

- Understand sensitivity without Brewster / with cryogenic trap
- Thermal Compensation System installation: end of March - early April
  - TCS commissioning
- Understand effect of the magnets replacement (magnetic noise, Eddy currents)
  - Remove the lateral magnets
  - Also replace those of the end mirrors?
- Further investigate / reduce the environmental noises

Virgo+ shutdown (June): ~ 1.5-2 months

- Injection system:
  - Laser amplifier
  - New injection bench optics
  - New mode cleaner mirror
- New control electronics

Then: restart commissioning

END

# Summary

- Control noise reduction:
  - Longitudinal controls: use a second modulation frequency, noise subtraction,…
  - Angular controls: more efficient filters, mirrors centering,…

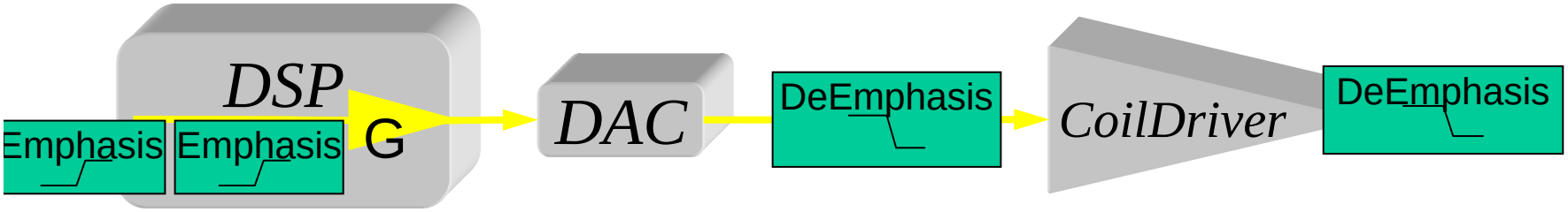
- Actuator noise:
  - DAC noise filtering
  - Magnetic noise: replaced magnets on input mirrors (strength/5.5 + good polarity)

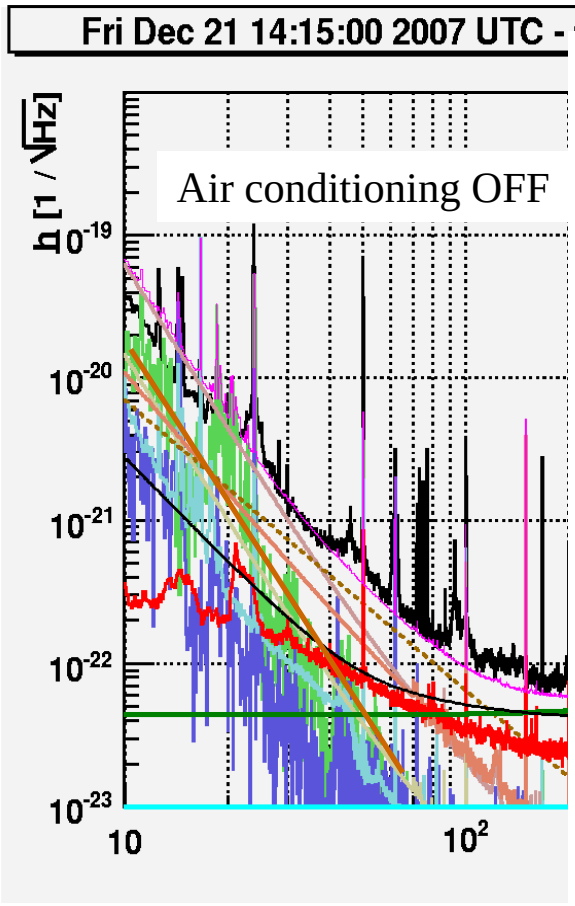
- Environmental noise investigations
  - Noise sources: air conditioning (<150 Hz), electronic racks
  - Path to dark fringe:
    injection beam jitter, diffused light on benches, detection/Brewster

- Environmental noise reduction:
  - Beam jitter reduced
  - Diffused light mitigation on end benches, improved telescopes
  - Air conditioning improvement started
  - ~~Brewster~~ => cryogenic trap

# Actuator noise reduction

- Reduction of the mirror actuator electronics noise ('non linear' noise)




Impact of DAC noise reduced:

- BS and arm towers (NI,WI,NE,WE):
  - gain decreased by factor 4 (reduced dynamic)
  + new coil driver with several (switchable) low noise sections

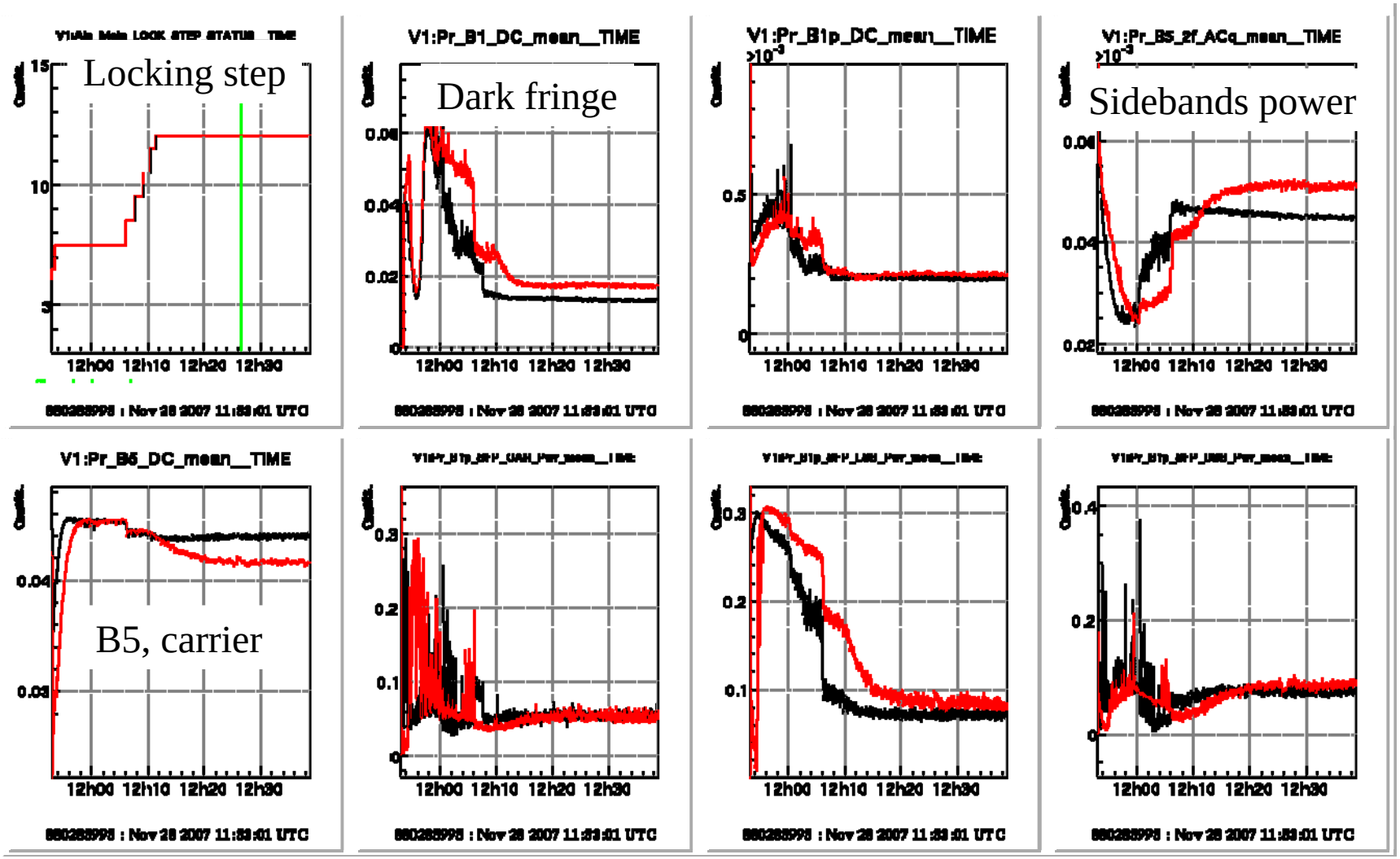
- Marionetta DAC noise (arm towers):
  - Installed emphasis-deemphasis filters

Result:

- Noise reduced below 20 Hz: marionetta DAC noise
- no clear reduction above 20 Hz (RM DAC noise)...

# Thermal effects

- Before / after cleaning

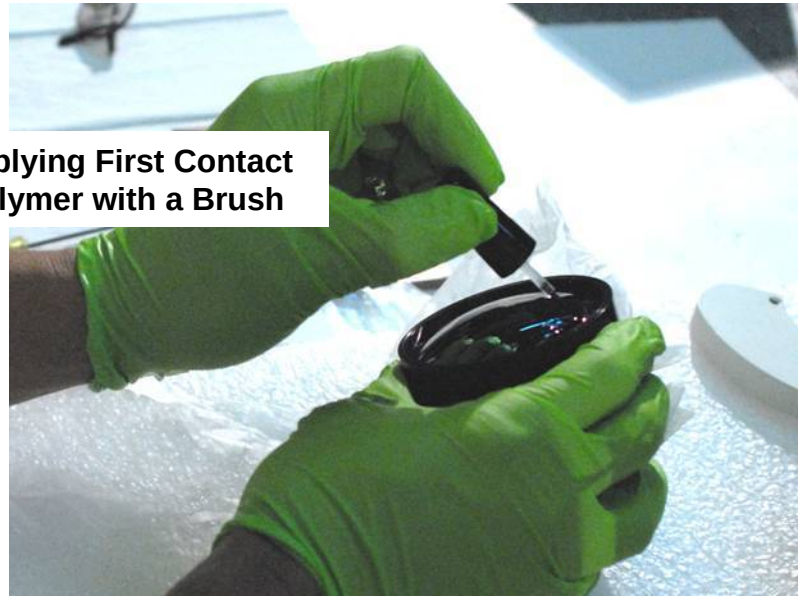


# How to clean the mirrors?

- The "natural" way should be to dismount the mirrors
  - Rejected, because we cannot accept the dead time (~1 month) for the commissioning
- First contact polymer
  - http://www.photoniccleaning.com/

Credit to L.Pinard (LMA)

**Clear Polymer Applied with A Pump Spray**

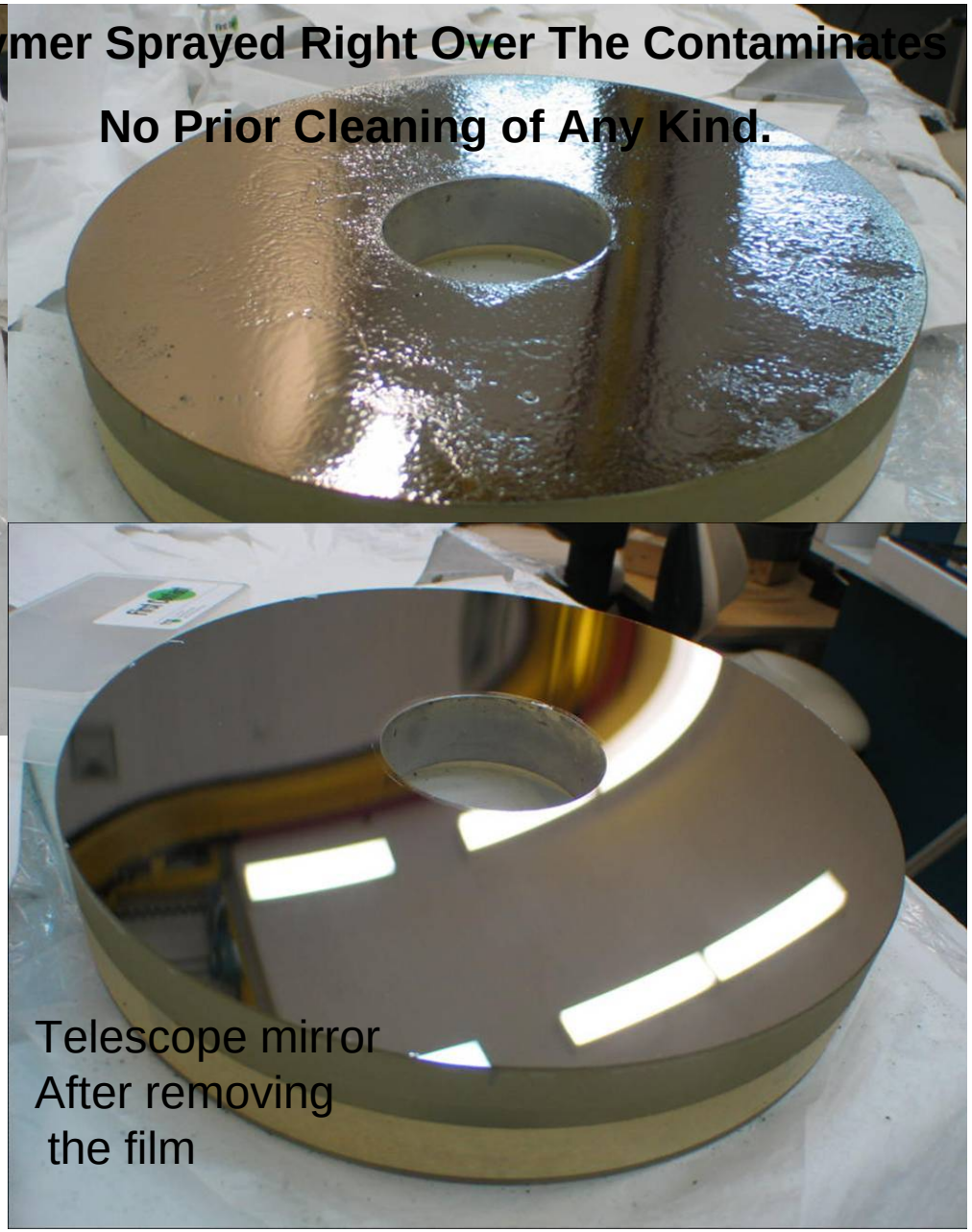


**Applying First Contact Polymer with a Brush**

# Cleaning performance demonstration


**Polymer Sprayed Right Over The Contaminates**

**No Prior Cleaning of Any Kind.**

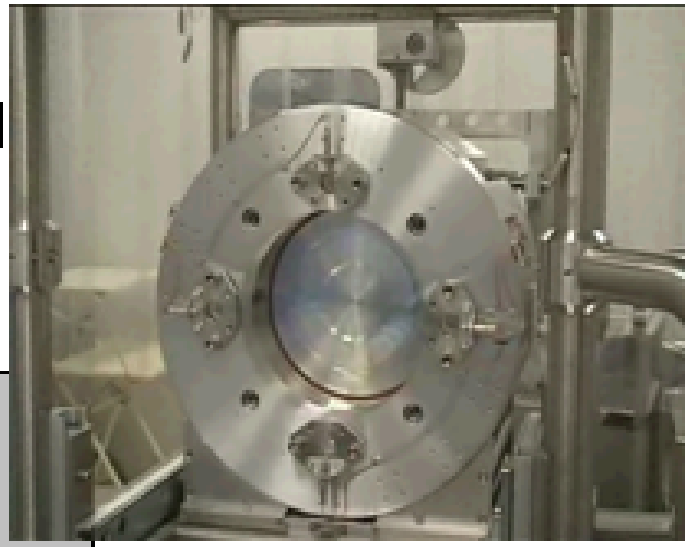


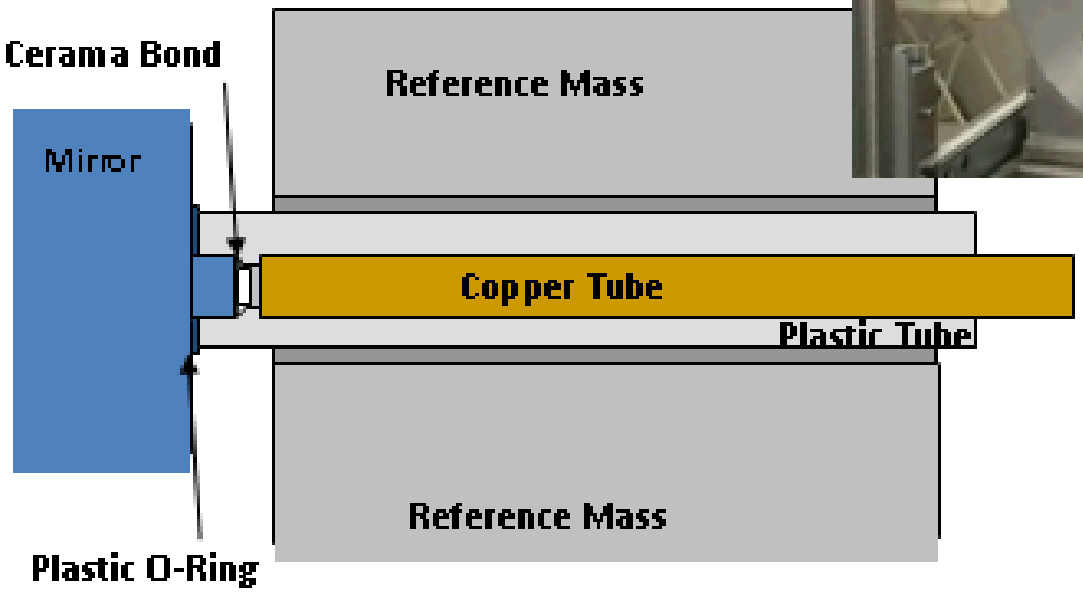

Credit to L.Pinard (LMA)

# Magnets replacement

## Replacement tools

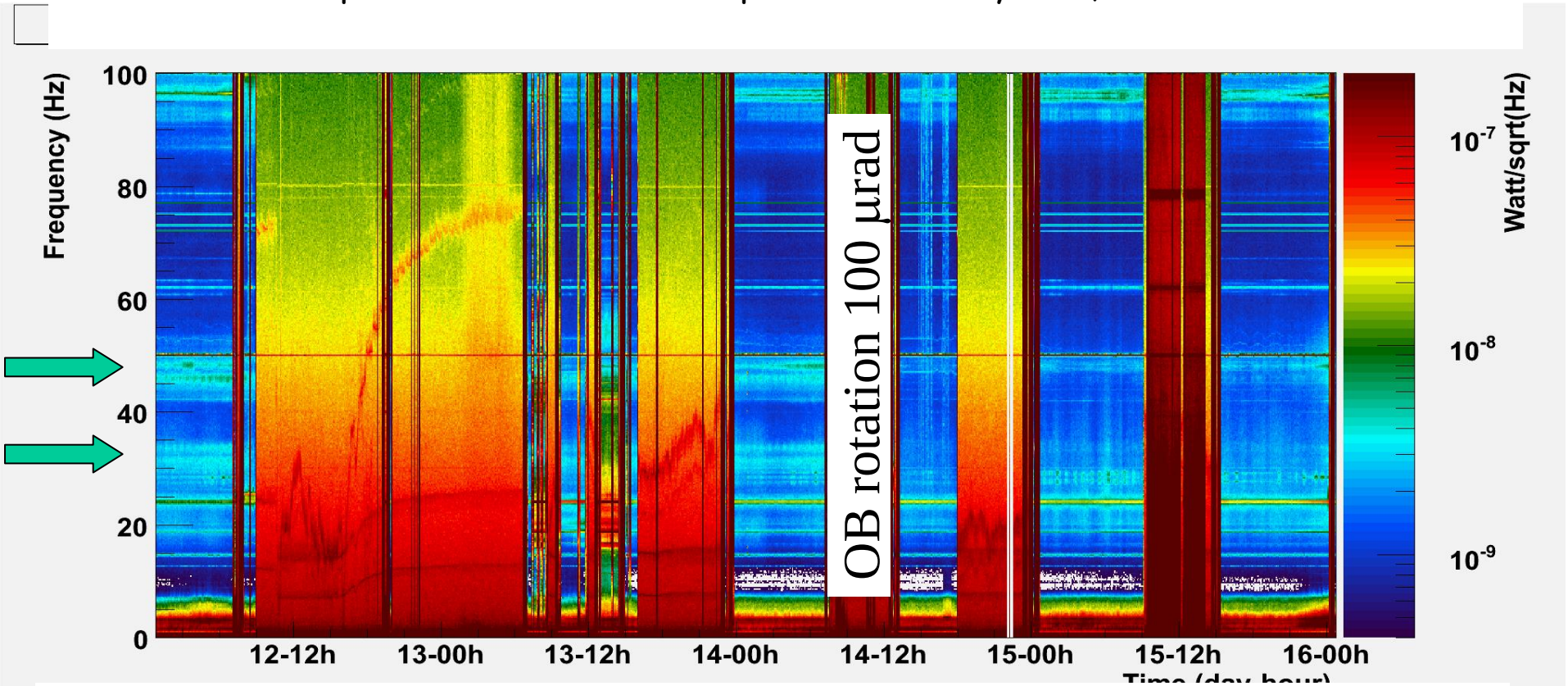
- The magnets are located in a place difficult to reach for any action
- Some tool has been developed to "operate in *endoscopy*"





# Diffused light reduction (?) at detection

- Indication of light reflected/diffused by the detection bench:
  Dedicated experiment: rotate the suspended bench by 100 μrad




⇒ 30 Hz and 45 Hz bumps disappeared (related to air conditioning noise in central hall)

⇒ No clear effect at higher frequencies

Other rotation experiments were not so clear (??)

Which is the mechanism?