

Study and mitigation of the Virgo air conditioning system noise

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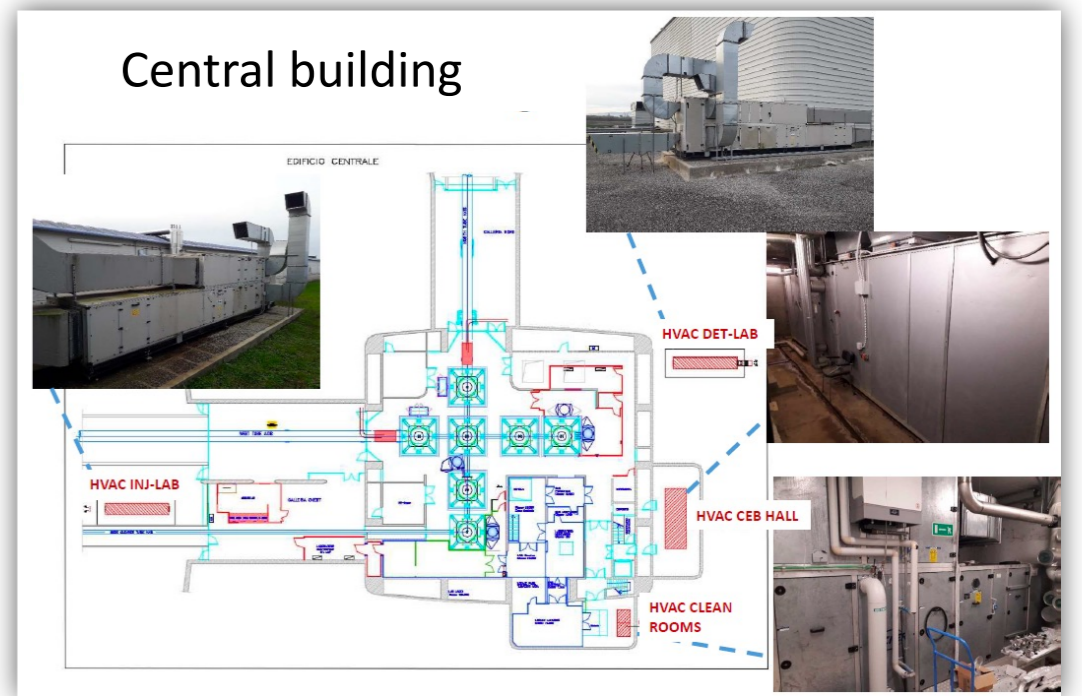
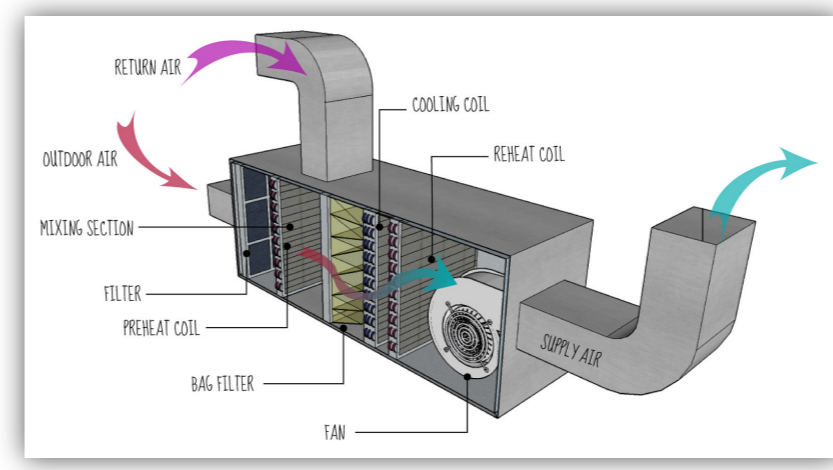
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Abstract - The heating, ventilation and air conditioning (HVAC) systems for the experimental halls of the Virgo interferometer generate considerable low-frequency noise of seismic, acoustic and electromagnetic nature that could affect detector sensitivity. This was experienced several times in the Virgo detector lifetime and most recently during the third science run. In preparation for the fourth run, we carried out an extensive study to identify critical noise components and noise pathways. We have designed and implemented several interventions to reduce the noise produced by the HVAC plants inside the experimental areas achieving significant improvements. In this poster, we describe the main solutions adopted, their implementation and the results obtained. Overall, we would like to propose a few technical solutions and rules of good practice that may be useful for the design of future interferometer air conditioning plants.

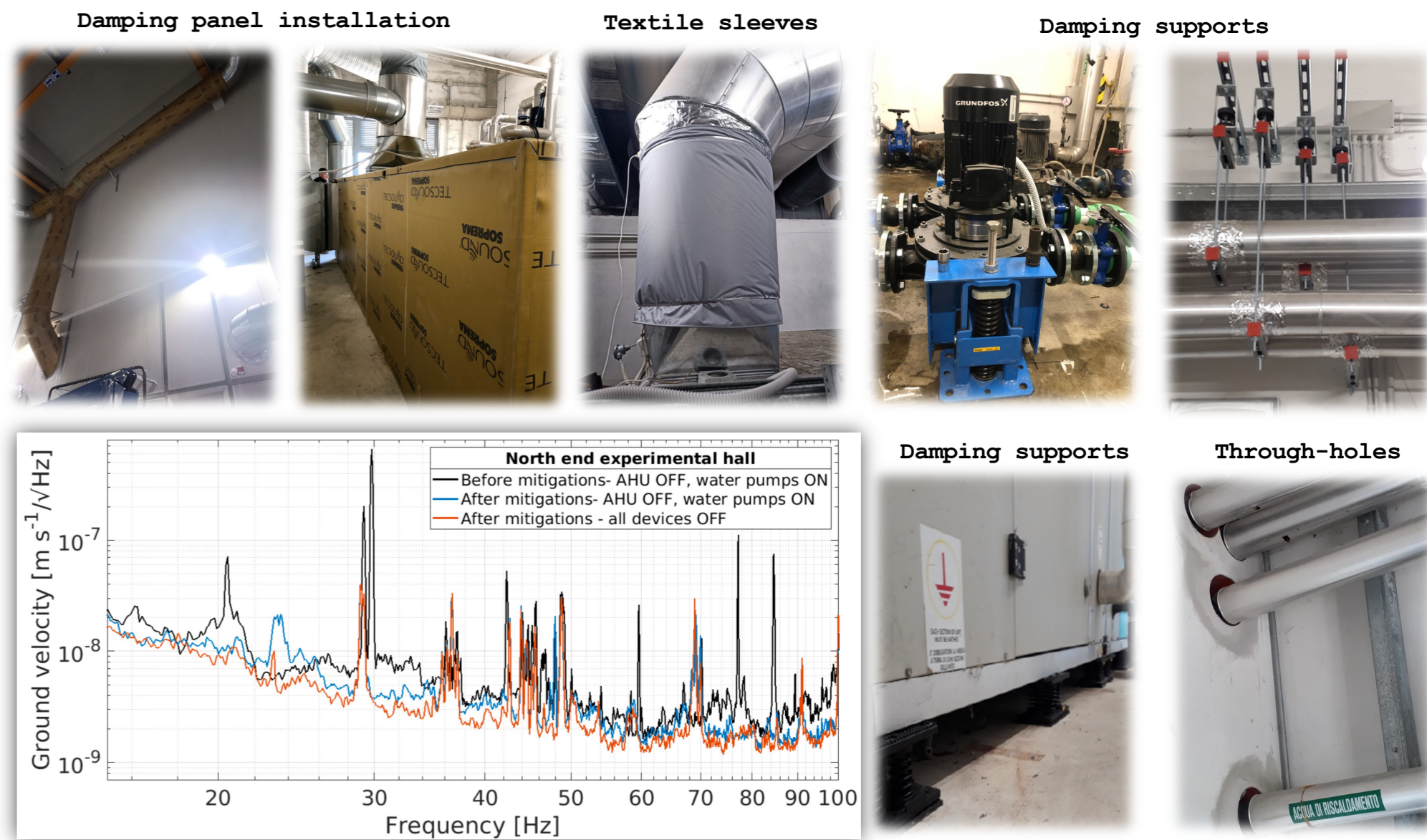
HVAC SYSTEM OVERVIEW

- For Virgo, the HVAC plant noise impacted on the interferometer sensitivity mainly through back-scattered light [1,2,3]. Several studies and mitigation actions were performed. With the improved design sensitivity of AdV+, the seismic and acoustic noise generated by HVAC systems could also contribute to Newtonian Noise [4], both from seismic ground vibration and from sound pressure noise within the experimental areas near the test mass.
- Noise investigations of the HVAC systems are complex because of the extension of the apparatus and the difficulty in identifying the main culprits among the multiplicity of noise couplings with the Virgo interferometer.
- The HVAC infrastructure components involved in the mitigation actions are:
 - air handling unit (AHU)
 - air circulator (fan);
 - air distribution (ducts);
 - cold and hot water production (chillers and heaters);
 - water distribution system (pumps and pipes).
- The HVAC plants contribute to seismic noise of Virgo building floors and acoustic noise of experimental halls in the region roughly from 1 Hz to 100 Hz. The produced noise has a broadband spectrum plus some monochromatic peaks at the fans, engines and water pumps rotation frequencies and harmonics.



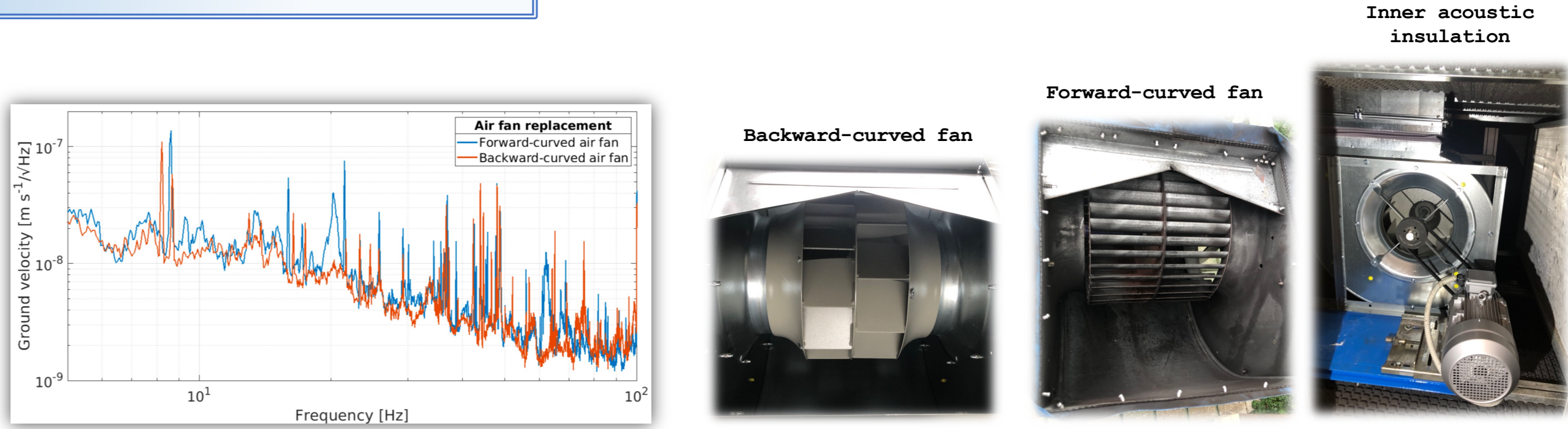
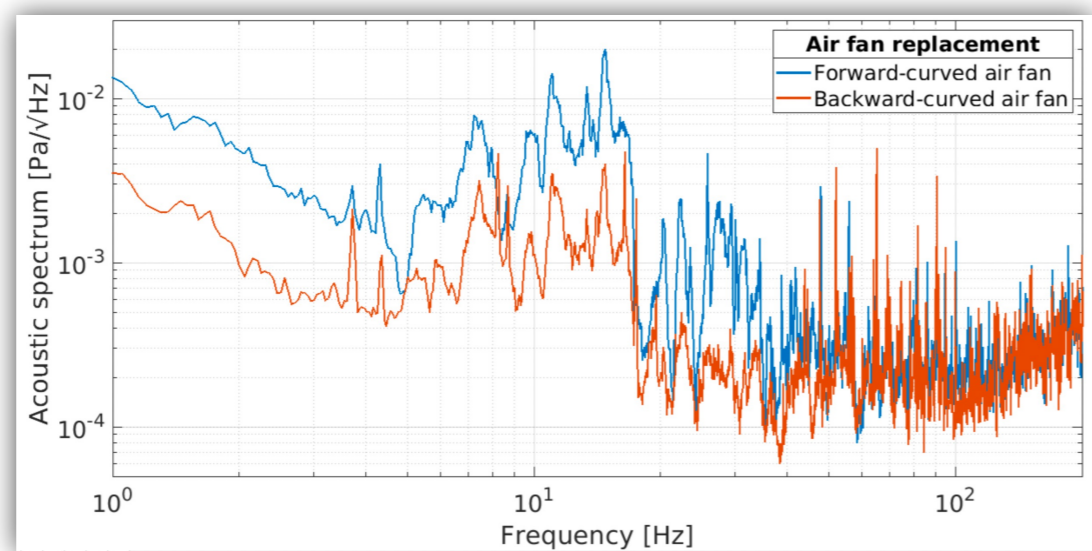
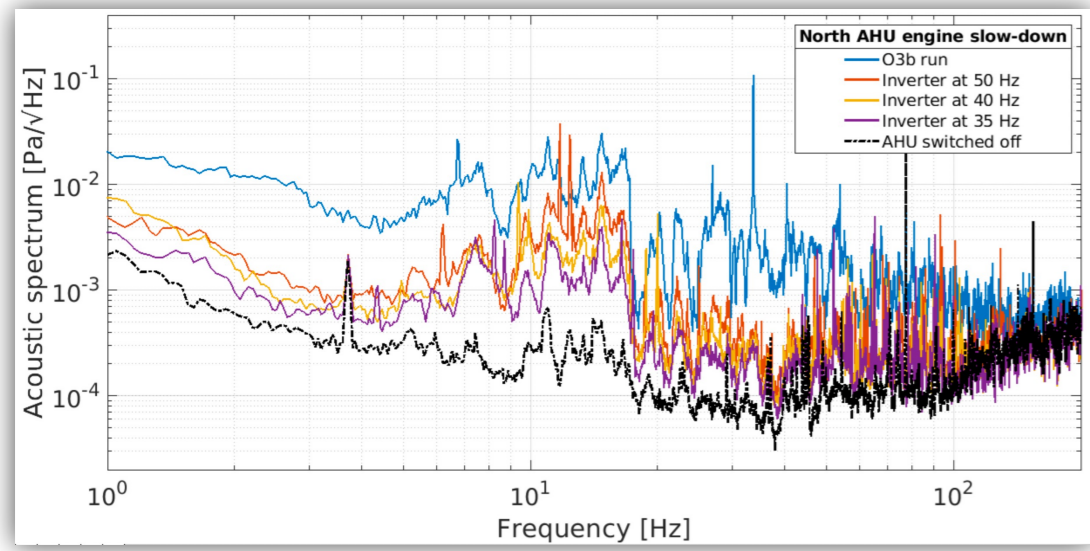
SEISMIC NOISE

- The seismic mitigation was attempted through mechanical isolation and damping the rotating component (pumps, fans), while avoiding any seismic shortcuts.
- Seismic noise mitigations**
 - Air handling unit:**
 - insertion of the dumping supports under AHU feet and case;
 - seismic decoupling of the supply and return air ducts from the vibrating case by means of textile sleeves;
 - damping panel installation on AHU external case and on the supply and return air ducts.
 - Water distribution system:**
 - seismic isolation of pumps and pipes from floors and walls;
 - elimination of seismic shortcuts (pipes through-holes);
 - valves and bellows installations to reduce the transmission of water-borne vibrations carried by unused pipe sections.
- The noise mitigations of the HVAC water distribution produced a reduction of seismic noise (blue curve) in the frequency range \sim (15-80) Hz.



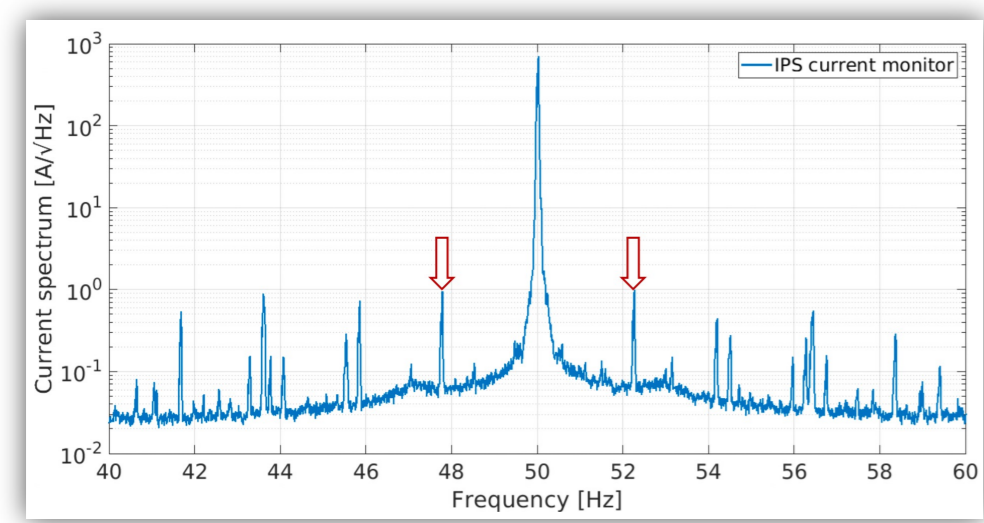
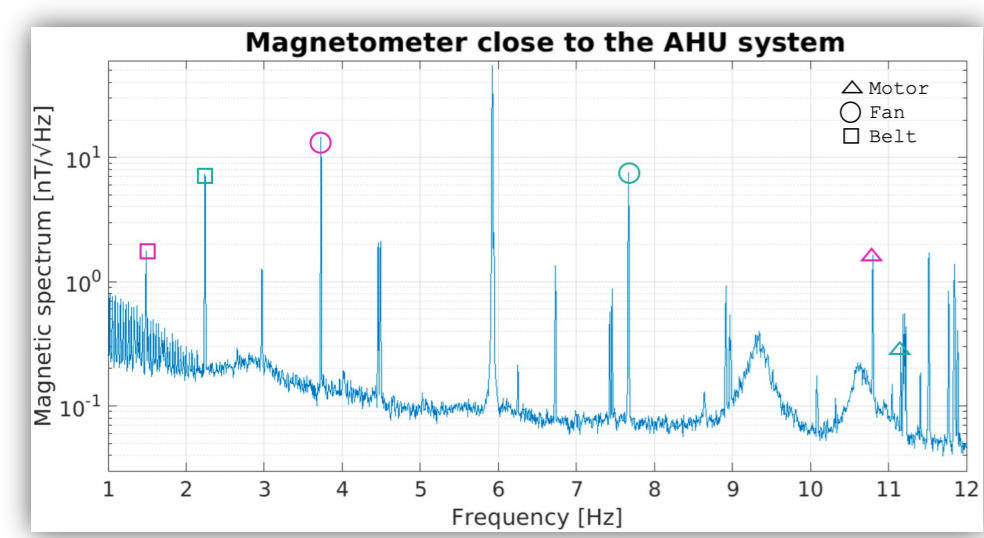
ACOUSTIC NOISE

- The main contribution of HVAC system to acoustic noise comes from air turbulence at the fan outlet or within the air ducts. A more laminar air flux may reduce the acoustic noise inside the experimental rooms.
- Acoustic noise mitigations**
 - Air handling unit:**
 - replacement of forward-curved air fan with backward-curved air fan;
 - inner acoustic insulation of AHU fan-engine enclosure;
 - slow-down of the AHU motor driving fan by acting on the inverter.



- The air fan replacement and the optimization of the air fan speed allowed to obtain a significant reduction of the acoustic noise in the infrasound frequency band (1-50) Hz.
- The seismic noise of the building floor reduced at several pikes at frequency range (10-100) Hz.
- The environmental parameter of the experimental room such as temperature and overpressure are preserved.

MAGNETIC NOISE



- Magnetic lines are observed at motor-fan-belt frequencies (supply and return AHU systems of the Central building).
- The metallic component vibrations (e.g., fan) of AHU system modulate Earth magnetic field or any other magnetic field.
- The sidebands around 50 Hz main due to the belts of the supply AHU system are well visible in the current probes.
- The mains sidebands are emitted by the current flowing in the cables from the mains to the AHU inverter.

- These sidebands were close to limit the Virgo detector sensitivity during the O3 science run [1].

CONCLUSIONS

- This work collected the results of the planned noise mitigation based on the past experience, the implementations of technical solutions and good practice rules.
- A detailed characterization of the HVAC systems was performed identifying all the sources of the acoustic and seismic peaks.
- A significant reduction of the acoustic noise has been achieved:
 - a factor of about 8 (inverter set to 35 Hz) less than during the O3 run.
- The experience gained from first and second generation of gravitational wave detectors may be useful for future generations of detectors.

References

- [1] *The Hunt for Environmental Noise in Virgo during the Third Observing Run*, I. Fiori et al, *Galaxies* 2020, 8(4).
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- [4] *Terrestrial gravity fluctuations*, J. Harms *Living Rev Relativ* 22, 6 (2019).