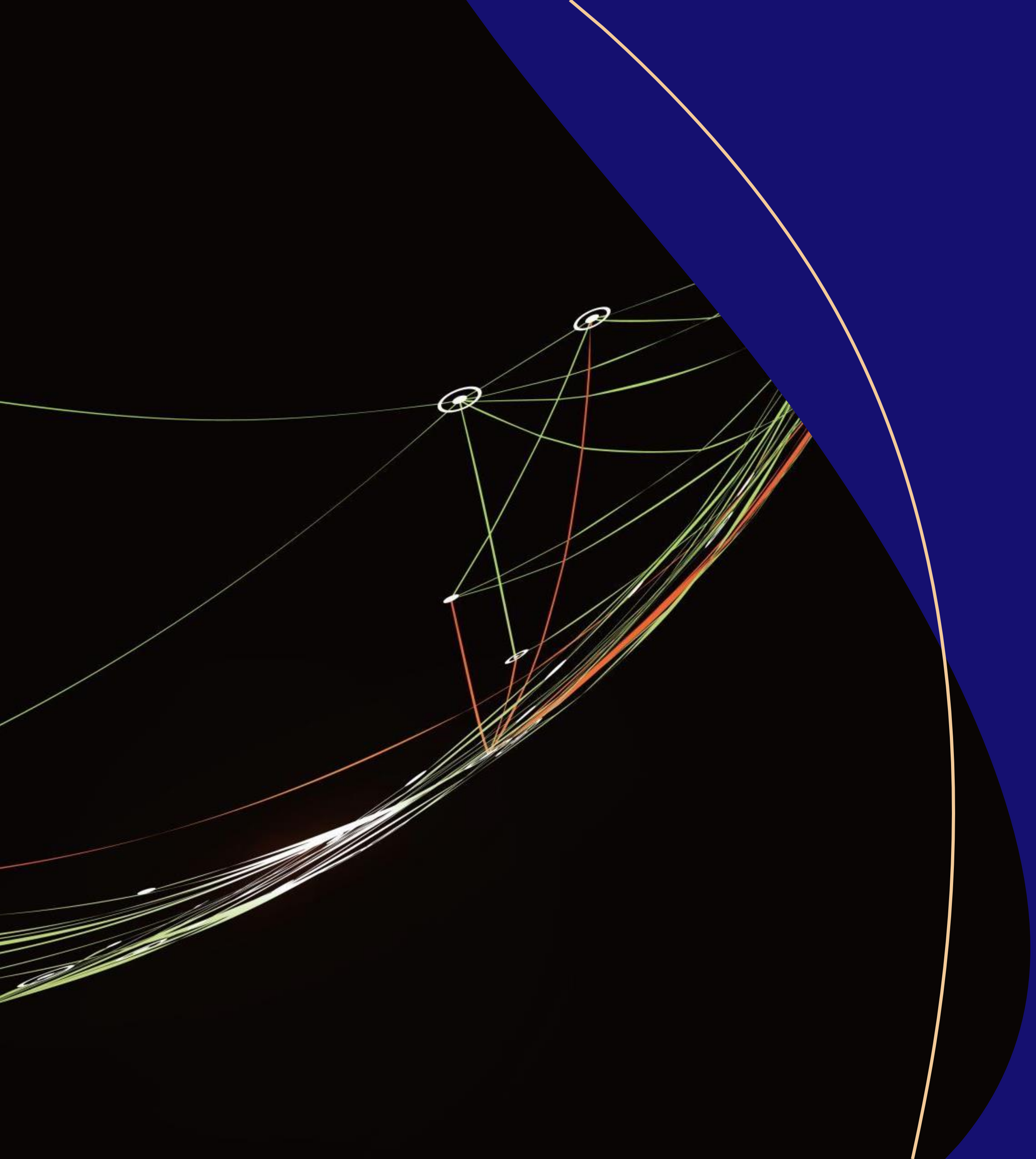
XV ET Symposium



Magnetic Noise and Mitigation Strategies for the Einstein Telescope

B. Garaventa

on behalf of ET-MN team

Contents

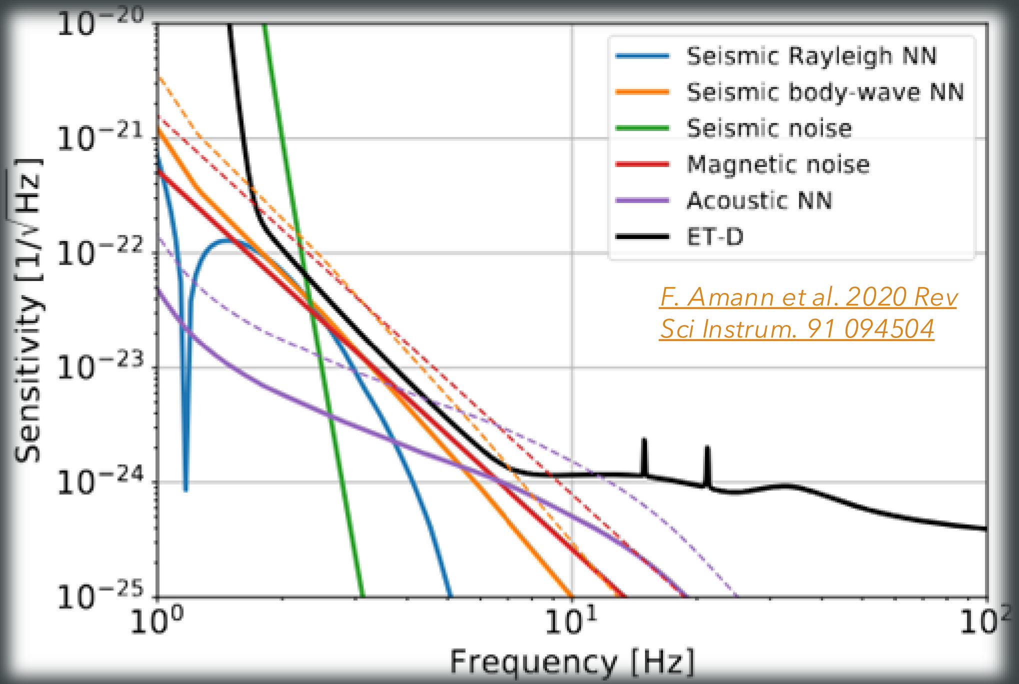
Magnetic Noise Introduction

Limits from few Hz up to 100 Hz in the Einstein Telescope detector

MN source 1
Natural terrestrial component (Schumann Resonances pT/√Hz)

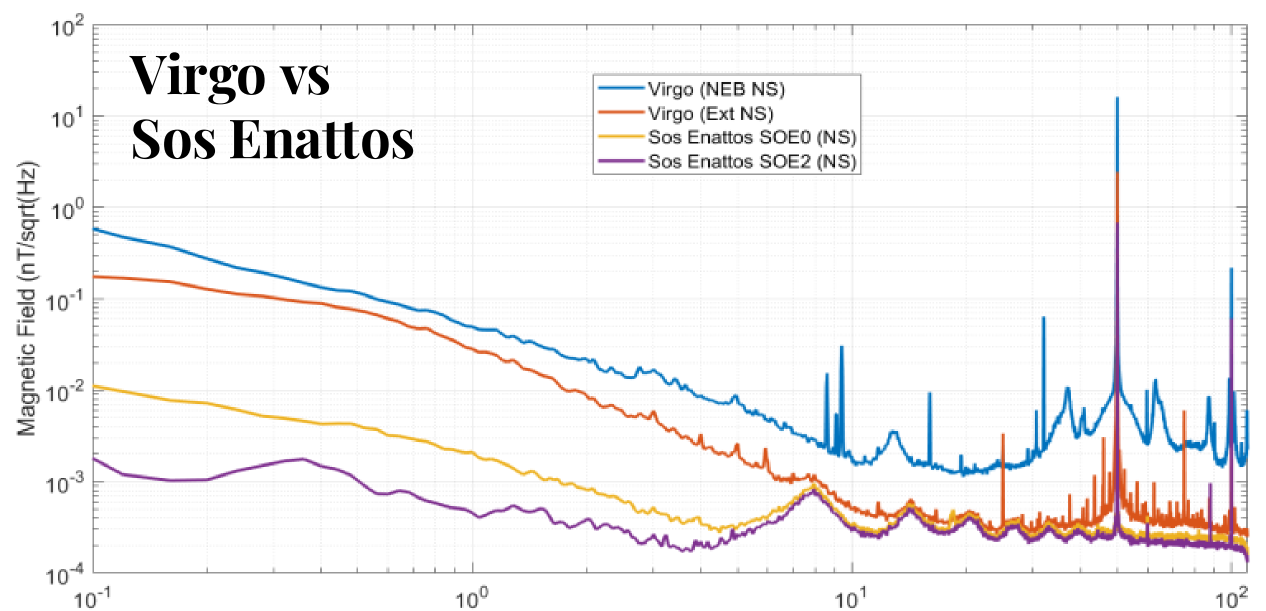
MN source 2
Environmental noise component of the interferometer (self-inflicted noise)

ET environmental-noise budget



→ Low-frequency sensitivity improved compared to current GW detectors: specific noise sources reduced (fluctuations of EM field, vibrations and deformations..)

Magnetic Noise in ET



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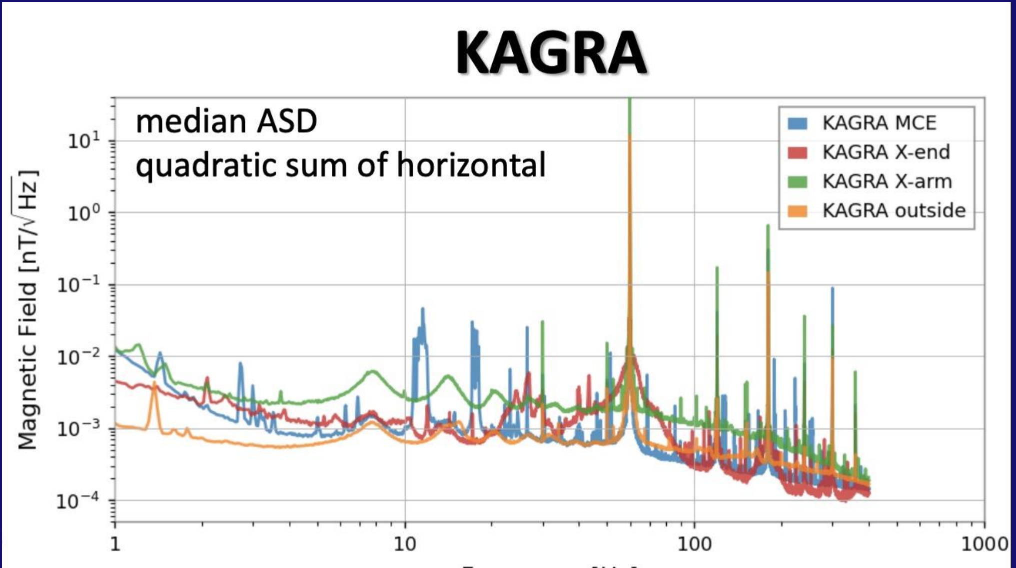
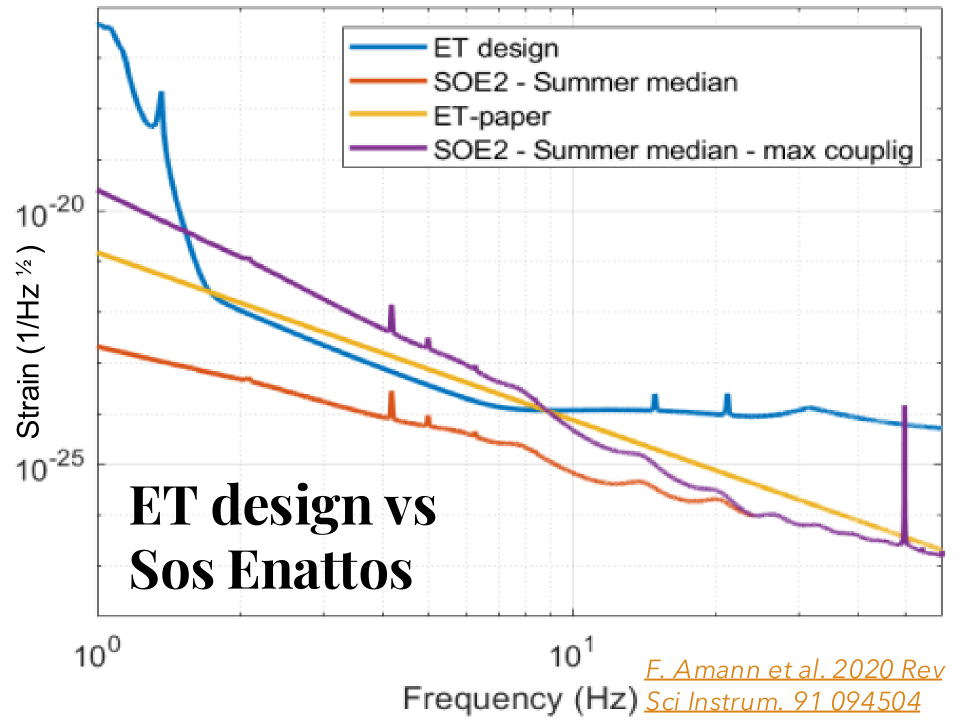
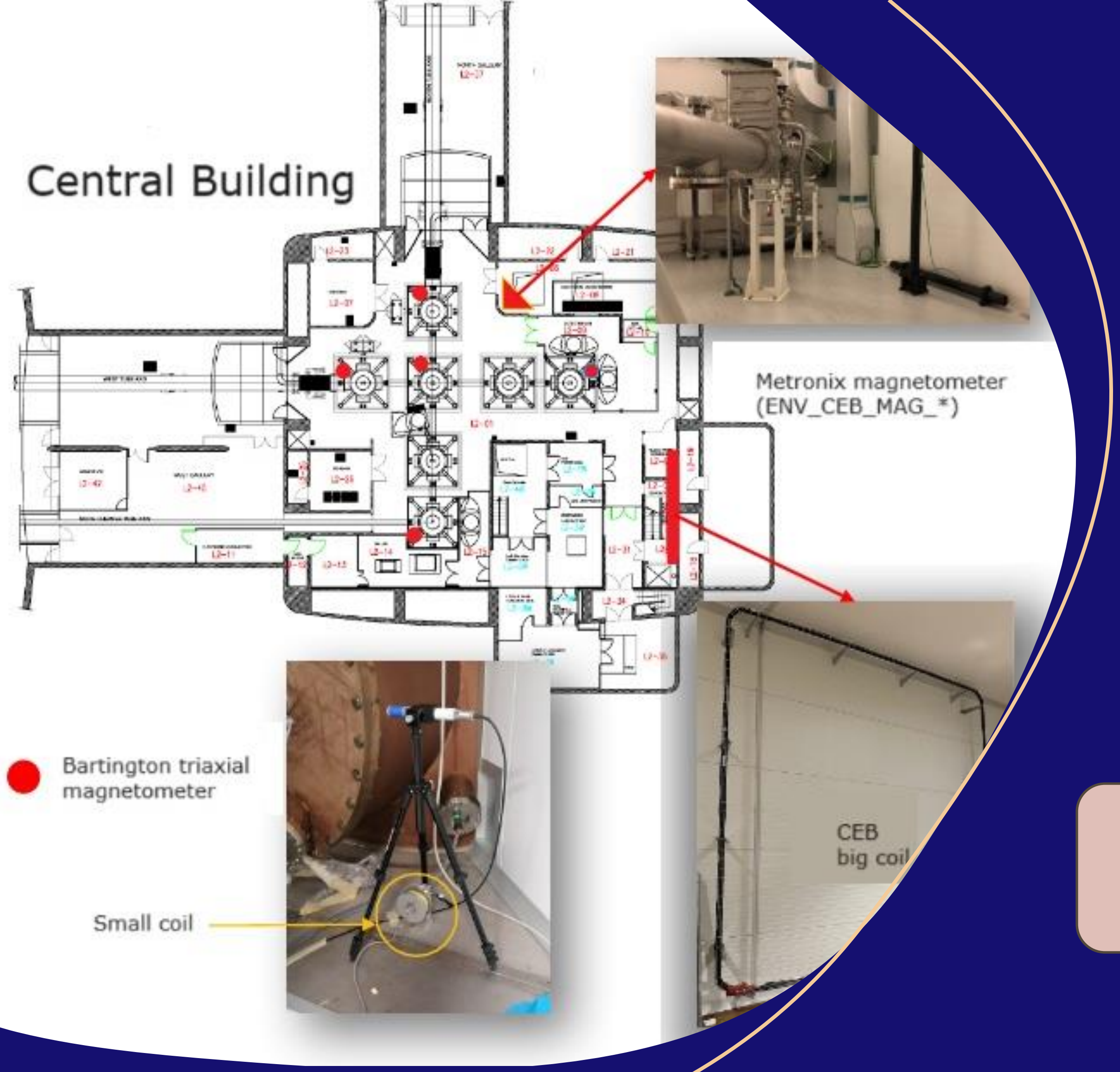


Tatsuki Washimi - ET-0165A-22



F. Amann et al. 2020 Rev Sci Instrum. 91 094504



https://doi.org/10.3390/galaxies8040082.

Virgo Investigation strategy

MN coupling and "self-inflicted noise" sources

Coupling to Interferometer

Power distribution system

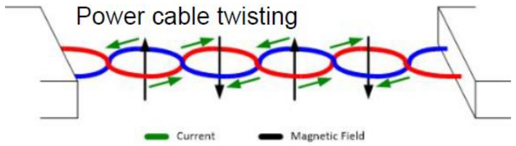
Anthropogenic

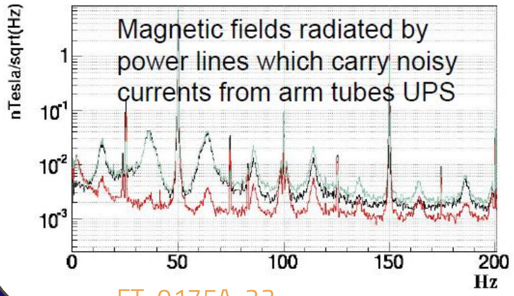
Electric and electronic devices

Virgo: Self-inflicted sources

Power Distribution System

EM fields radiated by cables/wires (e.g. HVAC, UPS,..)





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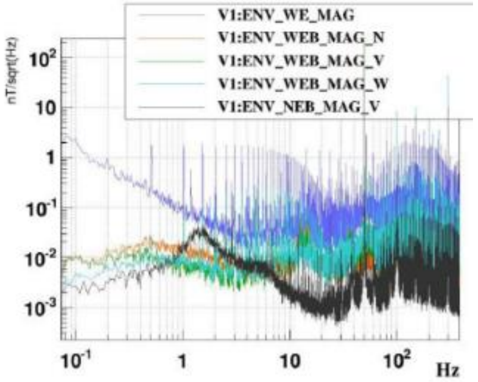
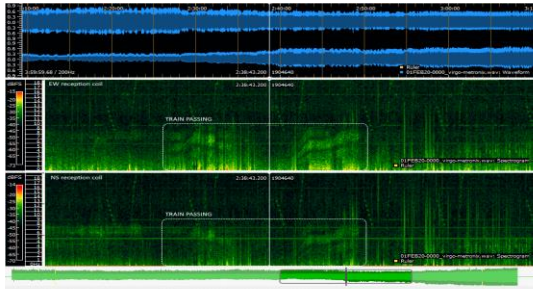
Devices

Magnetic fields from electric and electronic devices



Anthropogenic

- Trains (sitewide magnetic glitches from 2-3 km far railways)
- Galvanic currents from methan gas pipes



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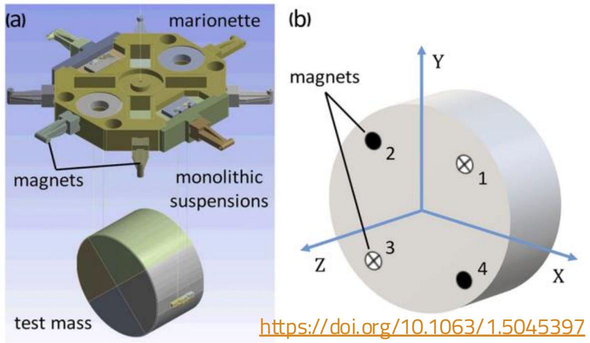
Coupling to Interferometer

Results from Virgo and Sos Enattos

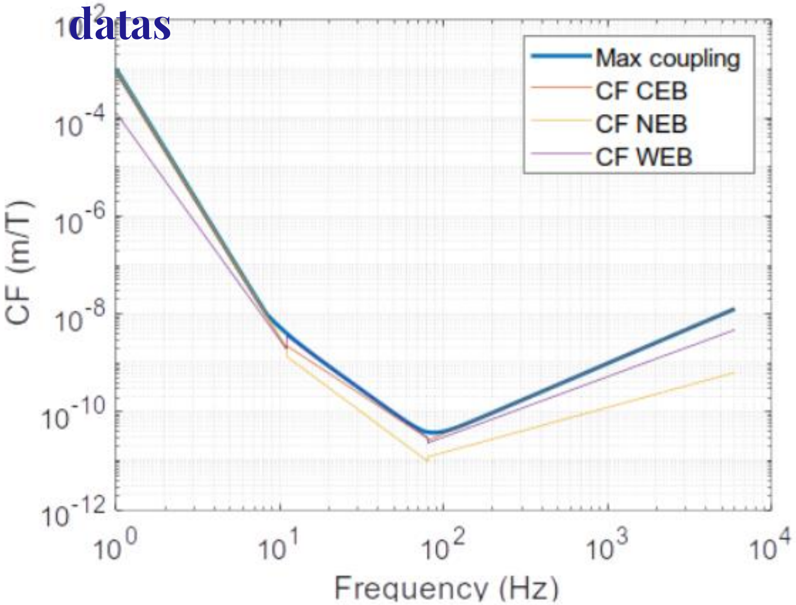


https://doi.org/10.1063/1.5045397

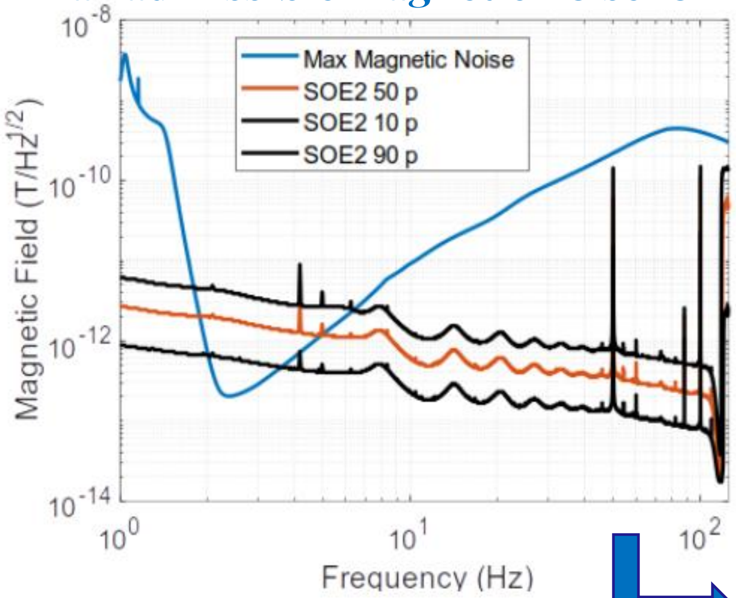
https://git.ligo.org/virgo/environmental/couplingfunctions/-/tree/main/O4/Magnetic?ref_type=heads

https://doi.org/10.3390/galaxies8040082.

Max coupling curve from Virgo datas



Max admissible magnetic noise for ET



M.C. Tringali et al., Magnetic injections: overview and plans, VIR-0300A-24

How to do:

$$CF(f) = \sqrt{\frac{Y_{inj}^2 - Y_{bkg}^2}{X_{inj}^2 - X_{bkg}^2}}$$

$$r = \frac{m_V}{m_{ET}} \qquad CF_{ET}(f) = r\, CF_V(f)$$

$$CF_{V,max}(f) = \max_{j=1,2,3} CF_{V,j}(f)$$

$$h_{ET} = s_{MAG}\, h_{MAG}$$

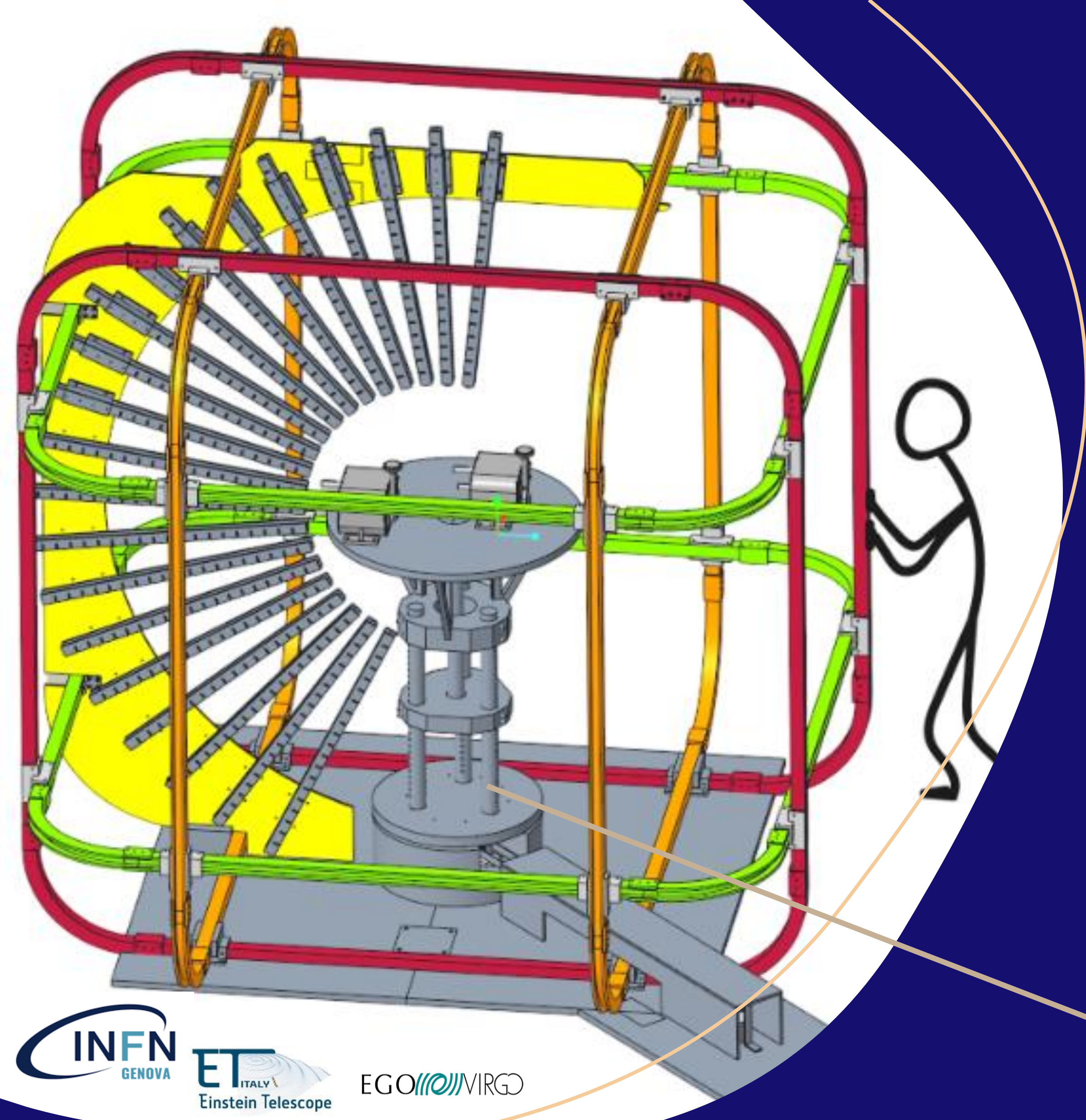
$$X_{C,max} = \frac{1}{s_{MAG}} \frac{L}{2CF_{ET}(f)\, z_{MAG}(f)} h_{ET}$$

Safety factor

Shielding function

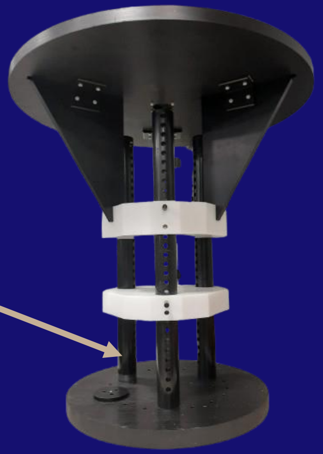
Assumptions:

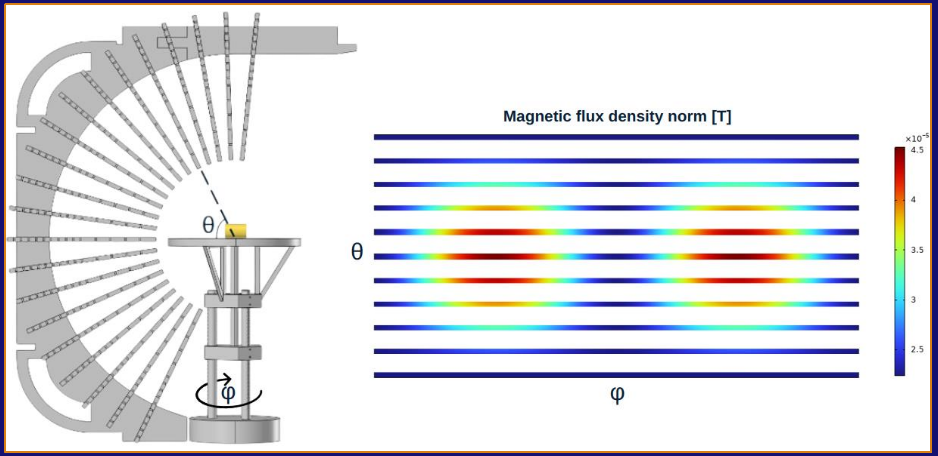
- $s=3$, $z_{MAG}=0.2$
- Only natural magnetic noise for ET



MANET facility

MAgnetic **N**oise facility for **ET**:
characterization of the magnetic noise emissions of various devices, analyzing their response to external magnetic fields, and evaluating magnetic mitigation strategies





See Poster

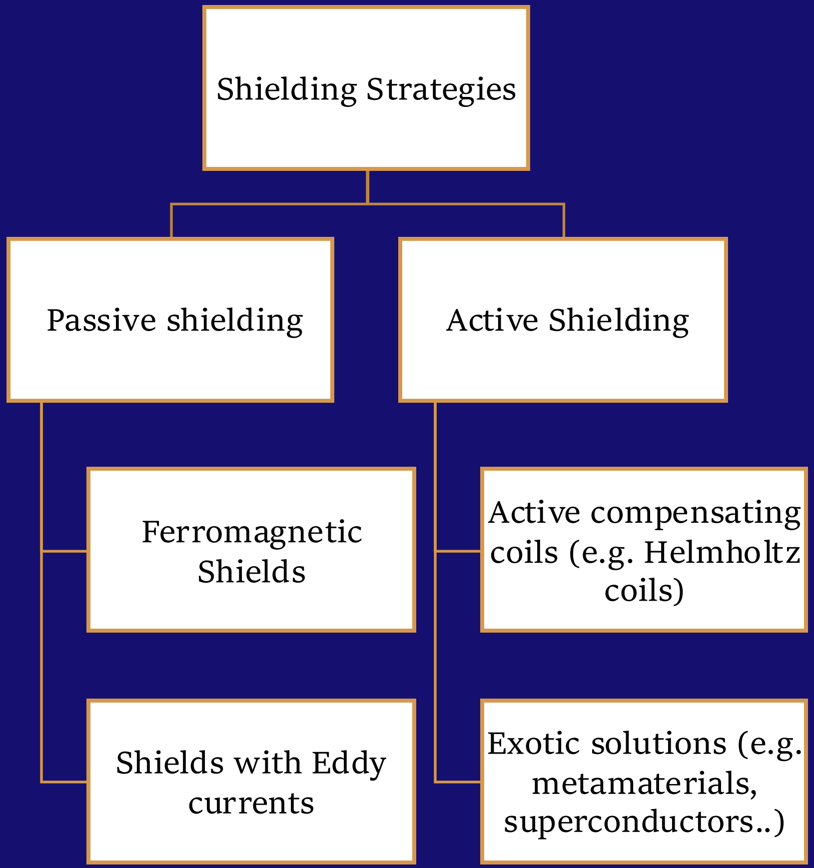
GALILEO Infrastructures for Einstein Telescope: Advanced Quantum Optics Technologies and Magnetic Emission Characterizations – B.-Garaventa

INFN GENOVA
ET ITALY Einstein Telescope
EGO VIRGO

[ET-0212A-25](ET-0212A-25)

https://doi.org/10.3390/galaxies13010009

Mitigation Strategies



- **Passive shields:** simplicity, safer, operational stability, cheaper, less effective (or use multilayers shields)
- **Active shields:** more effective, only for ad hoc implementations

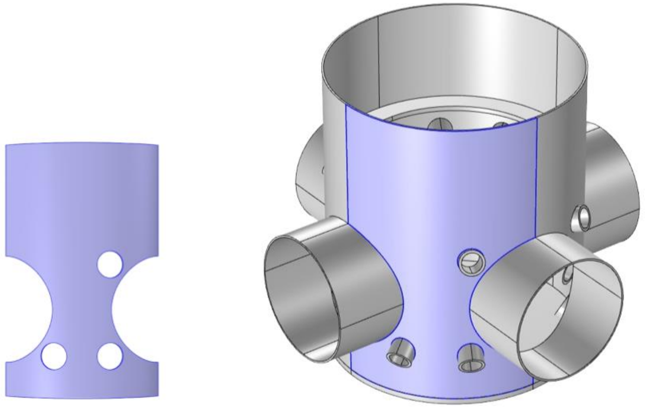
Shielding factor:

$S(x,y,z)=|B_{without\_shield}|/|B_{with\_shield}|$

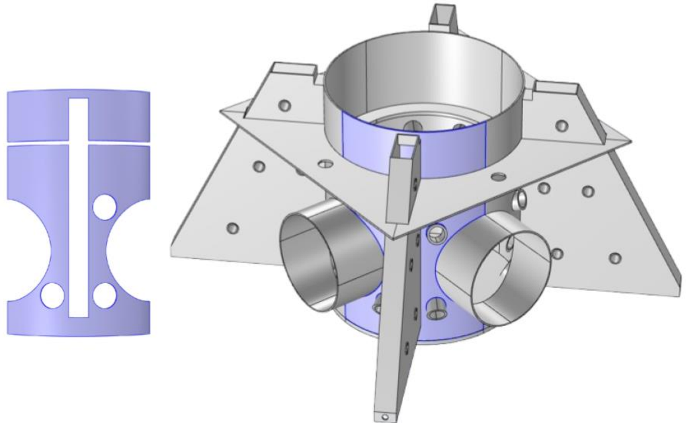
Simulations ongoing

1. Passive Shielding - TM TOWERS- Ferromagnetic Shields (Virgo as reference)

- Test Mass Tower: one of the most sensitive component (Virgo as reference)
- Strategy: High magnetic permeability layer (mu-metal has an hysteresis loop) to attract and move magnetic field lines away from the area



Frequency [Hz]	Relative Permeability	Shielding Factor width=1 mm	Shielding Factor width=2 mm
0	57 000	9.89	13.85
10	48 000	8.95	12.87
100	40 000	8.02	11.82
1000	15 000	4.19	6.67



Frequency [Hz]	Relative Permeability	Shielding Factor width=1 mm	Shielding Factor width=2 mm
0	57 000	4.07	6.10
10	48 000	3.69	5.51
100	40 000	3.34	4.95
1000	15 000	2.10	2.88

See Poster

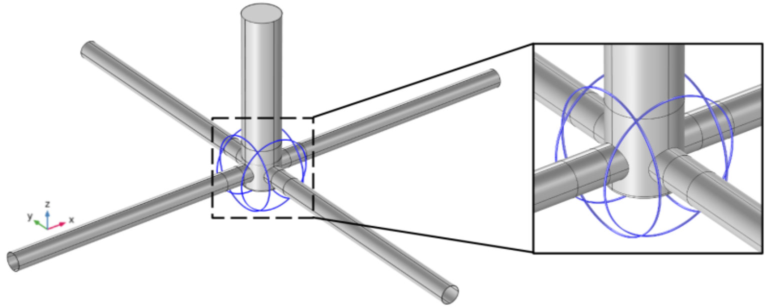
Magnetic noise mitigation for the Einstein Telescope: optimization of ferromagnetic shielding – F. Armato, B.-Garaventa, A. Chincarini

Simulations ongoing

2. Passive Shielding - TM TOWERS- Shields with Eddy currents (Virgo as reference)

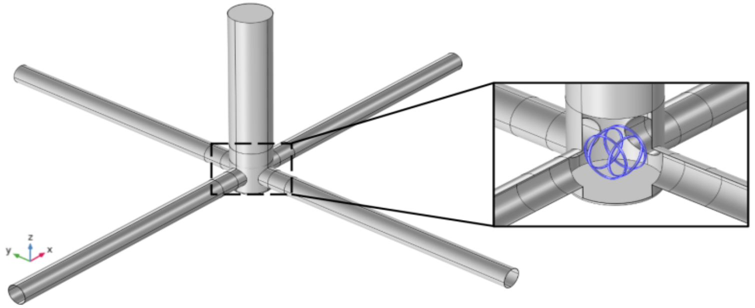
- Strategy: as described by Faraday's law, generate an induced magnetic field to partially cancel the one coming from the source. By enclosing the arms at their intersection with hollow cylinder (conductive material) in an Helmholtz configuration

Outside the tower



Frequency (Hz)	Thickness (cm)	Height (cm)	SF (B_ext along one arm)	SF (B_ext at 45°)
1000	2.0	5.0	1.8	1.8

Inside the tower



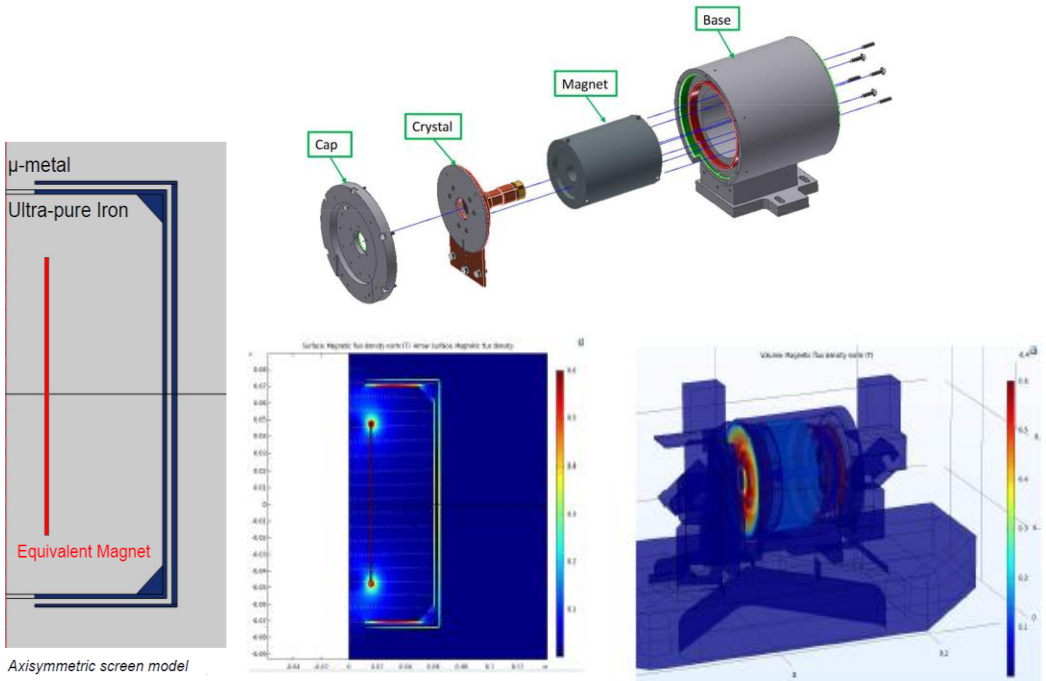
Frequency (Hz)	Thickness (cm)	Height (cm)	SF (B_ext along one arm)	SF (B_ext at 45°)
500	2.0	5.0	2.4	2.5

https://doi.org/10.3390/galaxies13010009

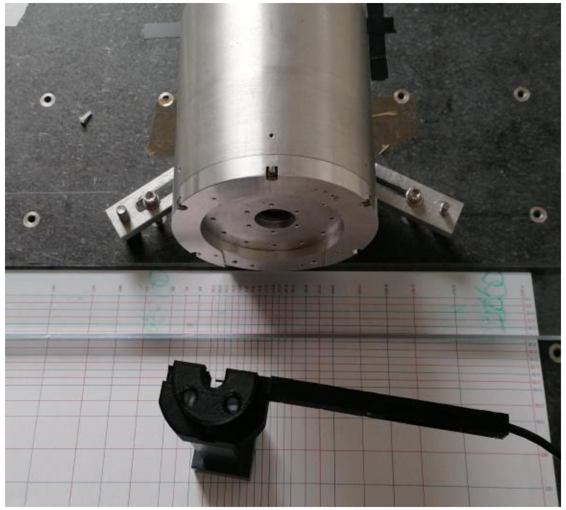
Simulations ongoing

3. Passive Shielding – Faraday Isolator Shielding

- 1 layer of mu-metal and 1 layer of soft iron
- Shielding factor in simulation around 100
- Shielding factor with prototype around 20



COMSOL simulation



Prototype

Activities ongoing:
Cagliari INFN and UniCa

Team:
Prof. Giuseppe Muscas
Dr. Francesco Congiu
Prof. Giorgio Concas

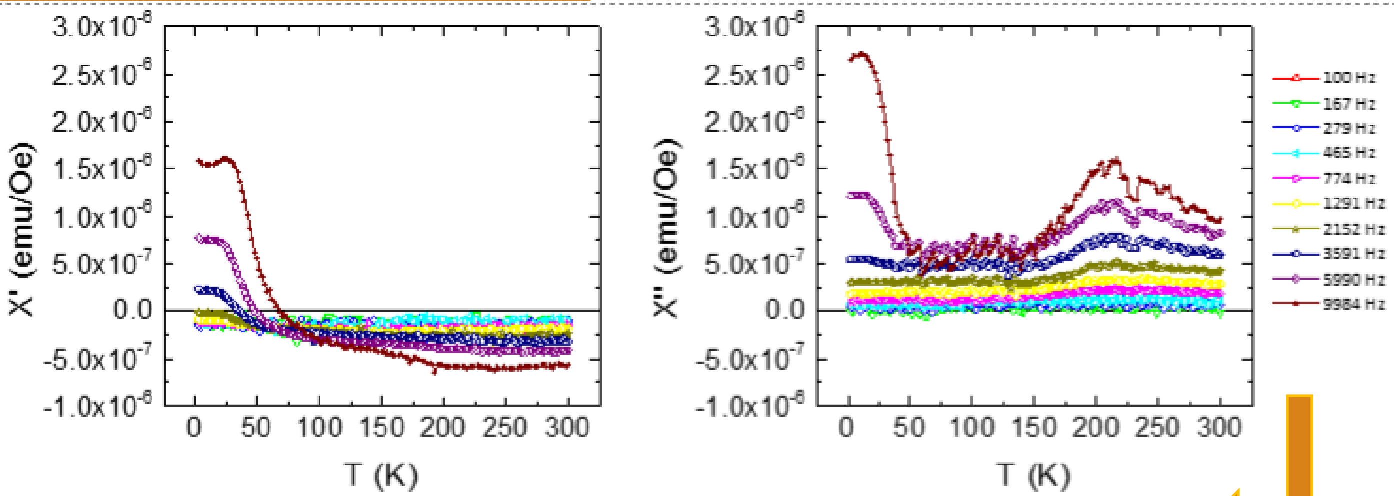
Running activities

- Prototype coatings magnetic characterization (collaboration with Core-Optics activities)
- Characterization of magnetic properties of steel for structural components
- Investigation of materials for magnetic noise shielding

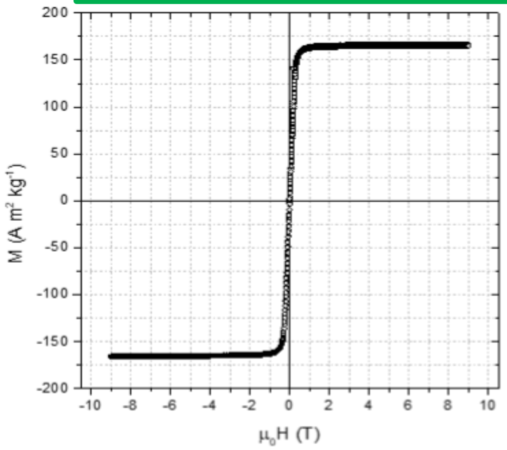
Characterization setup:

Physical Property Measurement System (Dynacool)

- DC Magnetization vs Temperature (2-400 K)
- Magnetization vs field (up to 9 T)
- AC magnetic susceptibility vs frequency up to 10’000 Hz



AC susceptibility of a prototype coating evidencing a significant low- temperature high frequency contribution



M(H) curve at 2 K of 444 commercial steel

Conclusions

Many MN activities ongoing

MN requirements for ET:

- Using the coupling functions measured at Virgo, and assuming the self-inflicted noise of the ET site negligible, it will be necessary to mitigate magnetic noise coupling by a factor of 100 in the low frequency range below 10 Hz -> It's not enough to use only passive shielding -> Reduce the coupling at the magnets.
- Based on the experience of Virgo and KAGRA, the site anthropogenic noise and infrastructure noise can contribute significantly.
- Need to implement mitigation strategies (shielding) and an intrinsic quiet anthropogenic noise.

Thanks for the attention!

You can find us at:
barbara.garaventa@ge.infn.it irene.fiori@ego-gw.it