Advanced Virgo: the magnetic coupling to the payloads and its impact on the low frequency sensitivity of the detector

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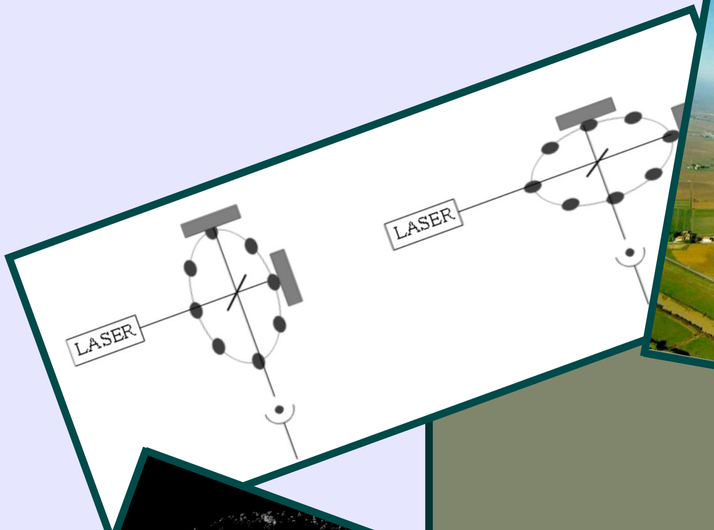
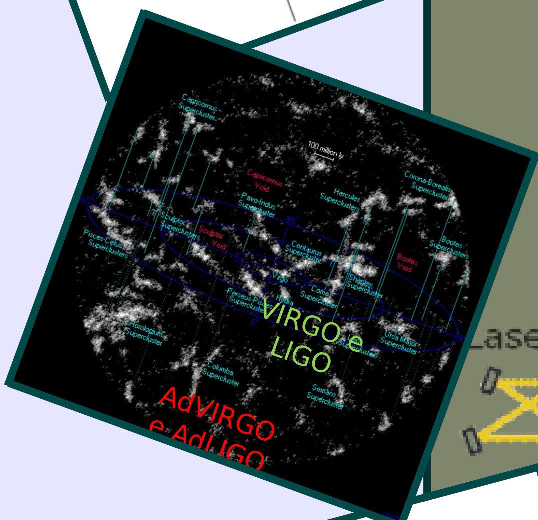
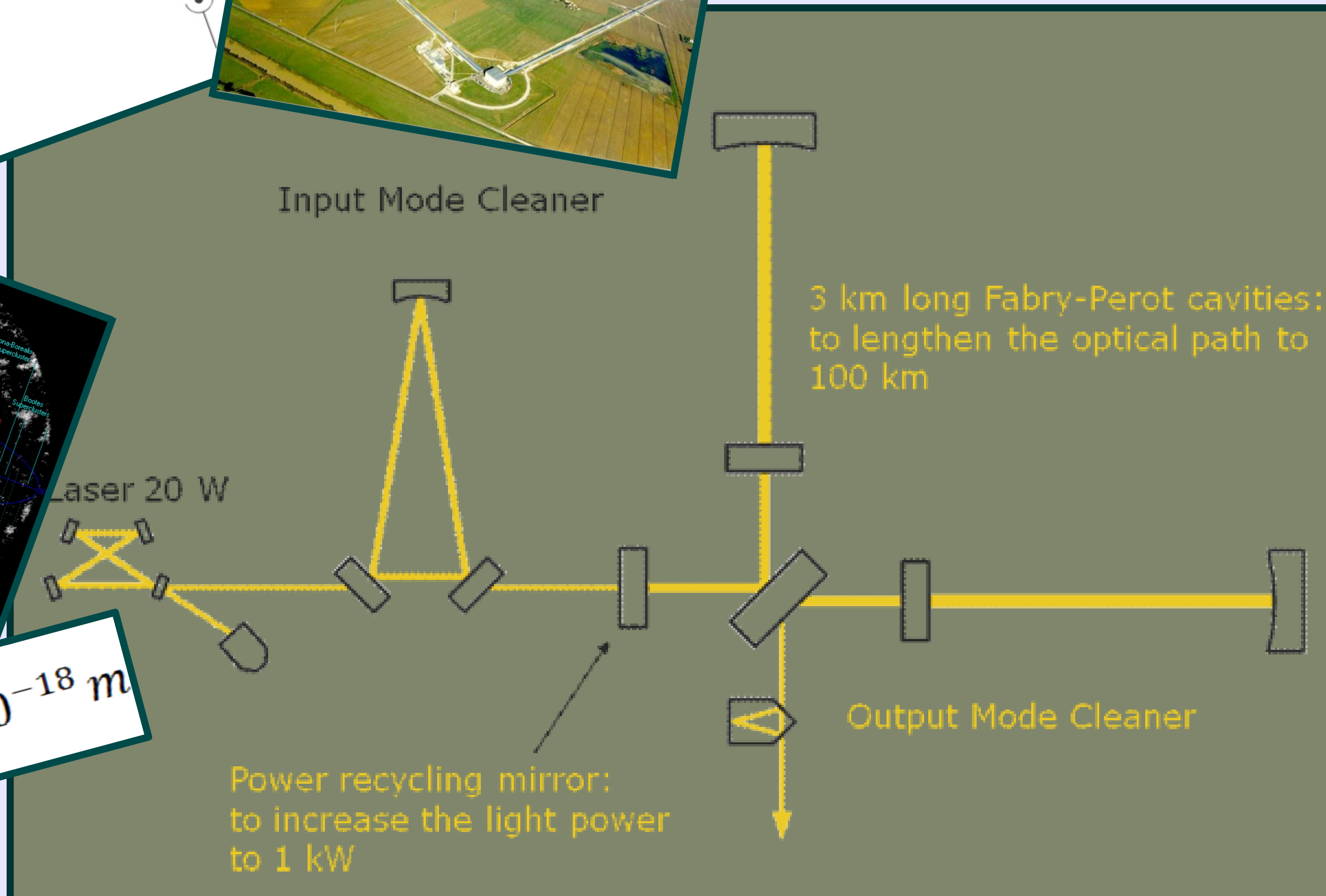
Advanced Virgo: a gravitational interferometer



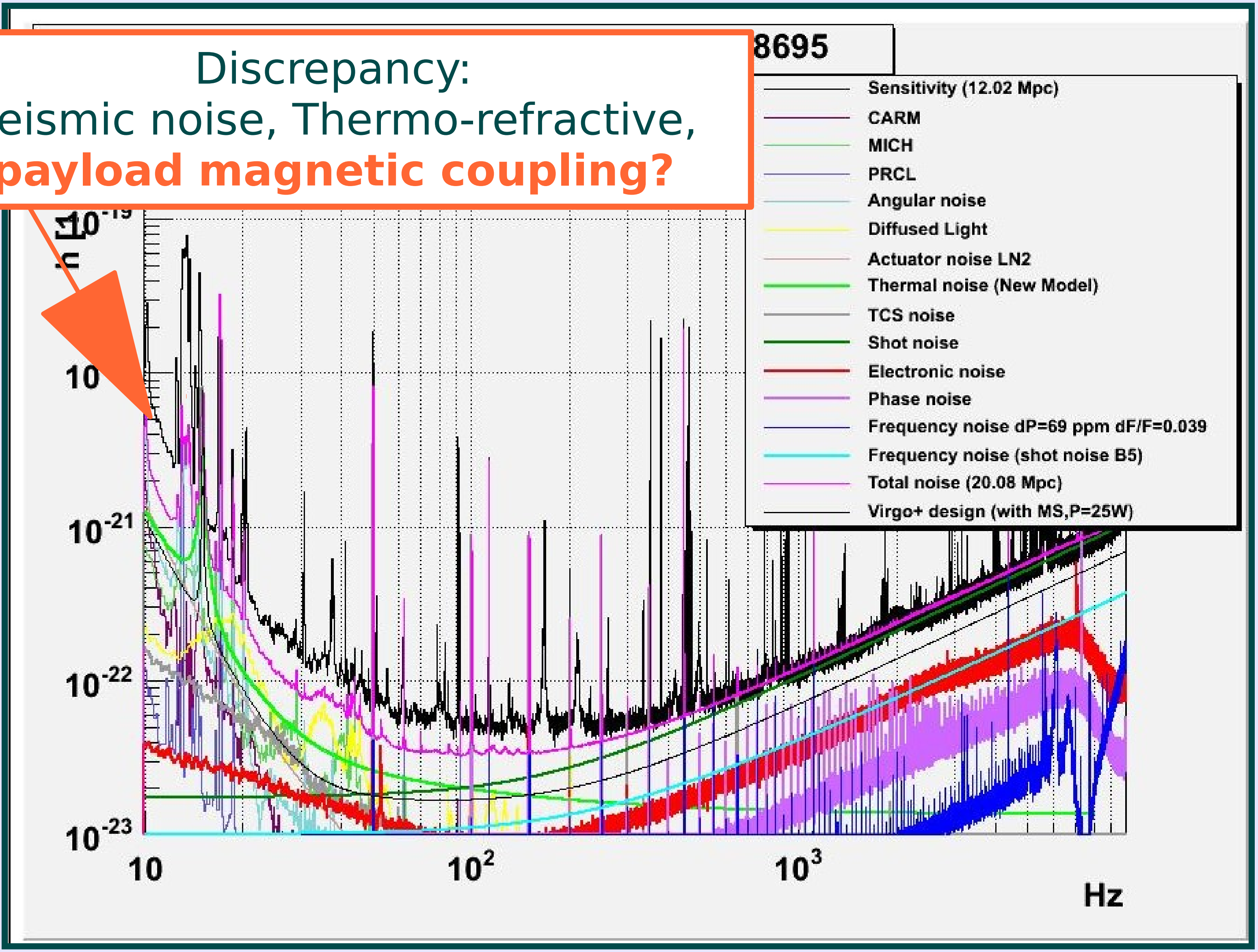


$$\Delta L = \frac{1}{2} h L \approx 10^{-18}\, m$$



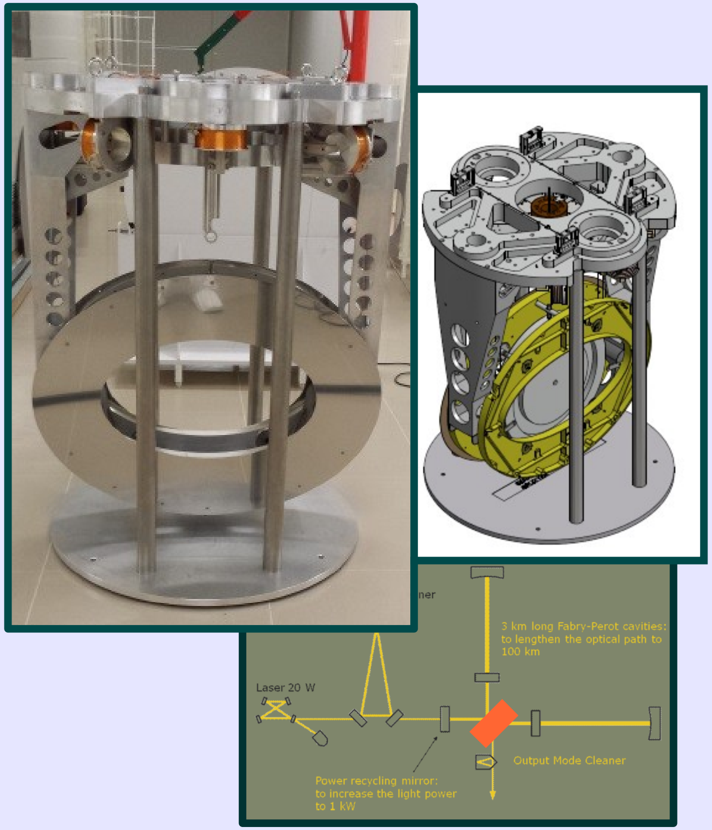
Sensitivity curve

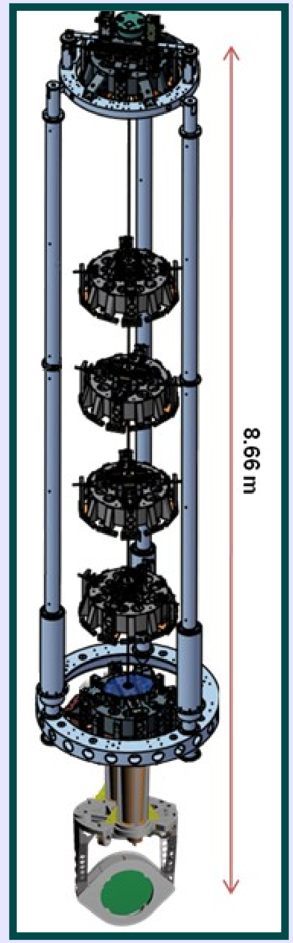
Discrepancy:
Seismic noise, Thermo-refractive,
payload magnetic coupling?



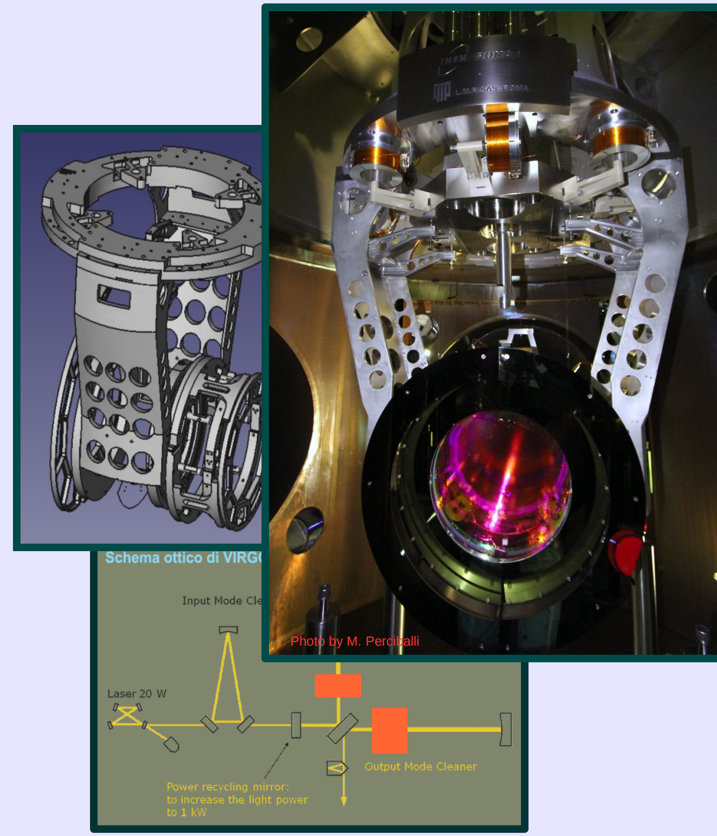
Advanced Virgo payloads

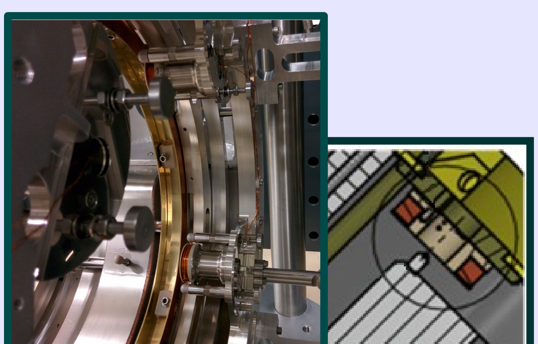
Beam Splitter





Input Mirror

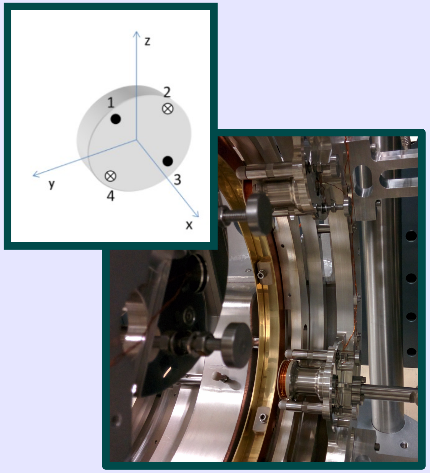




Magnetic actuators for the fine positioning of the mirrors!

Payloads & magnetic coupling

Problem → does the magnetic actuation impact on the Virgo Noise Budget?



Magnetic actuation system in a metallic frame : interaction with stray magnetic fields yielding potential gradient noise in the region of interest

$$\vec{F} = \nabla \left(\vec{m} \cdot \vec{B} \right)$$

- different magnetic field gradients;
- error in the positioning of the magnets;
- uncertainties on the magnetic moment value.

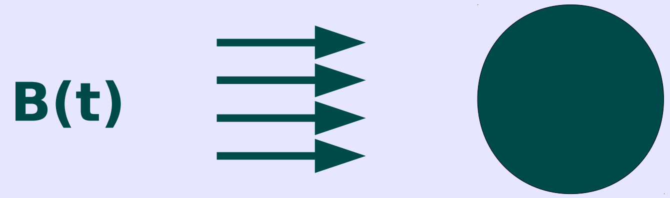
→

$$h = \frac{\sum \vec{F}}{MLo \left(2 \pi f \right)^2}$$

Magnetic characterization of the whole Payload: estimate and minimization of the magnetic noise.

Procedure

What is the magnetic response of the Pay?
How a metallic and composite object behaves in a B(t)?



- Geometrical complexity
- Impractical to measure the complet magnetic field map
- Impractical to measure the magnetic gradient

Finite Element Model

- Complex geometry: simplification

Validation

- Task: estimate of the magnetic gradient

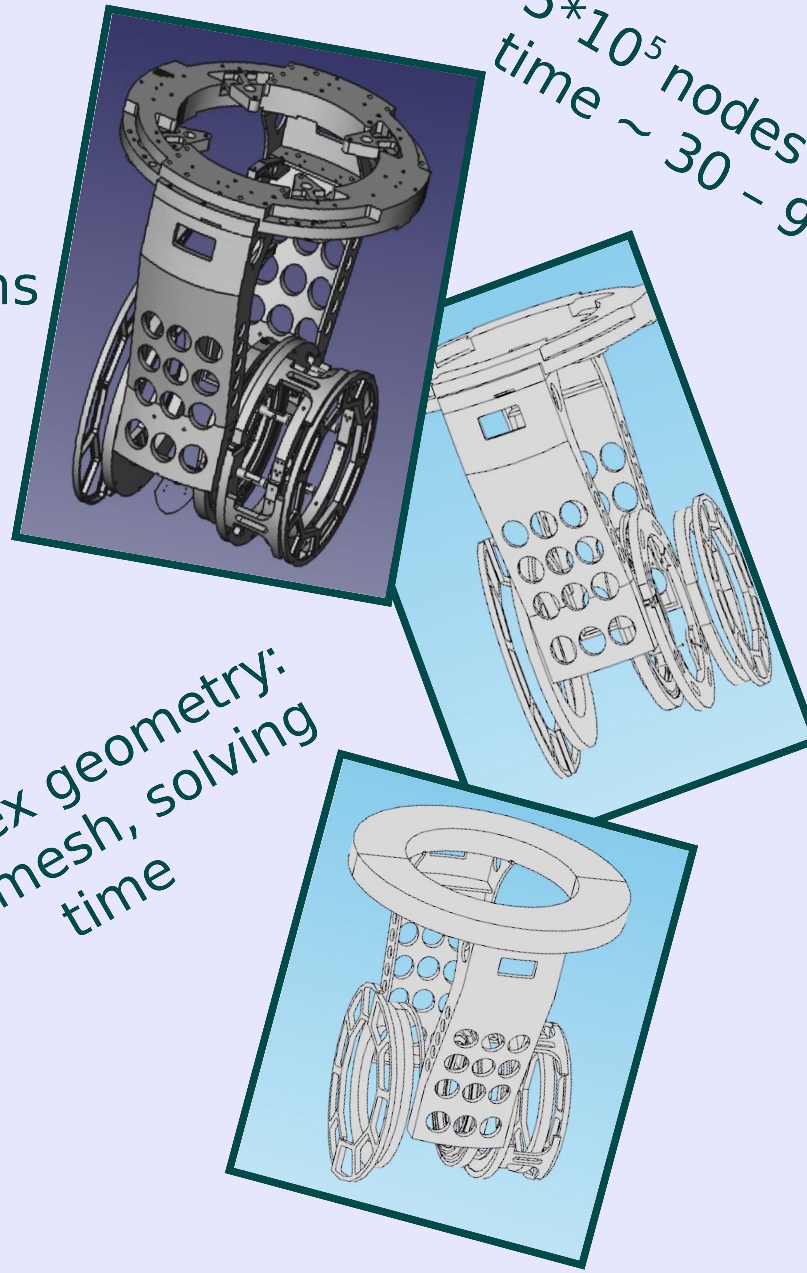
FES+Analysis

Finite Element Model

Tool: Comsol Multiphysics®

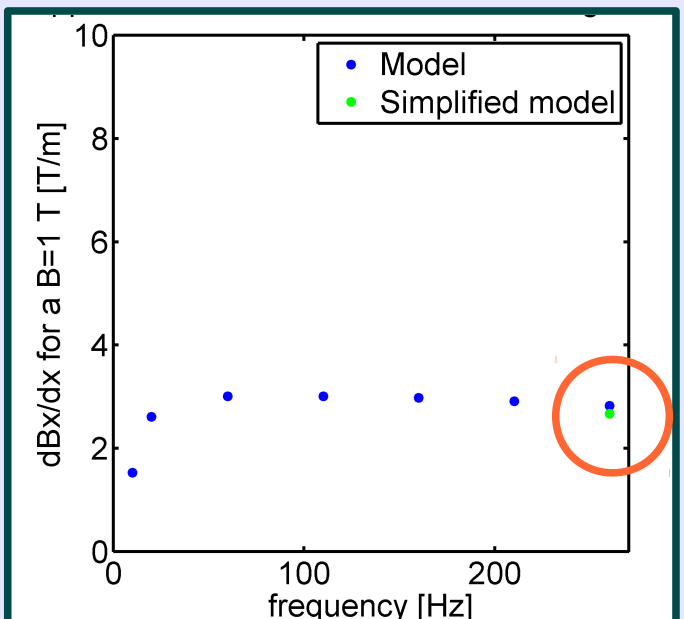
Electro-Magnetic field simulations
frequency domain

CAD intrerface



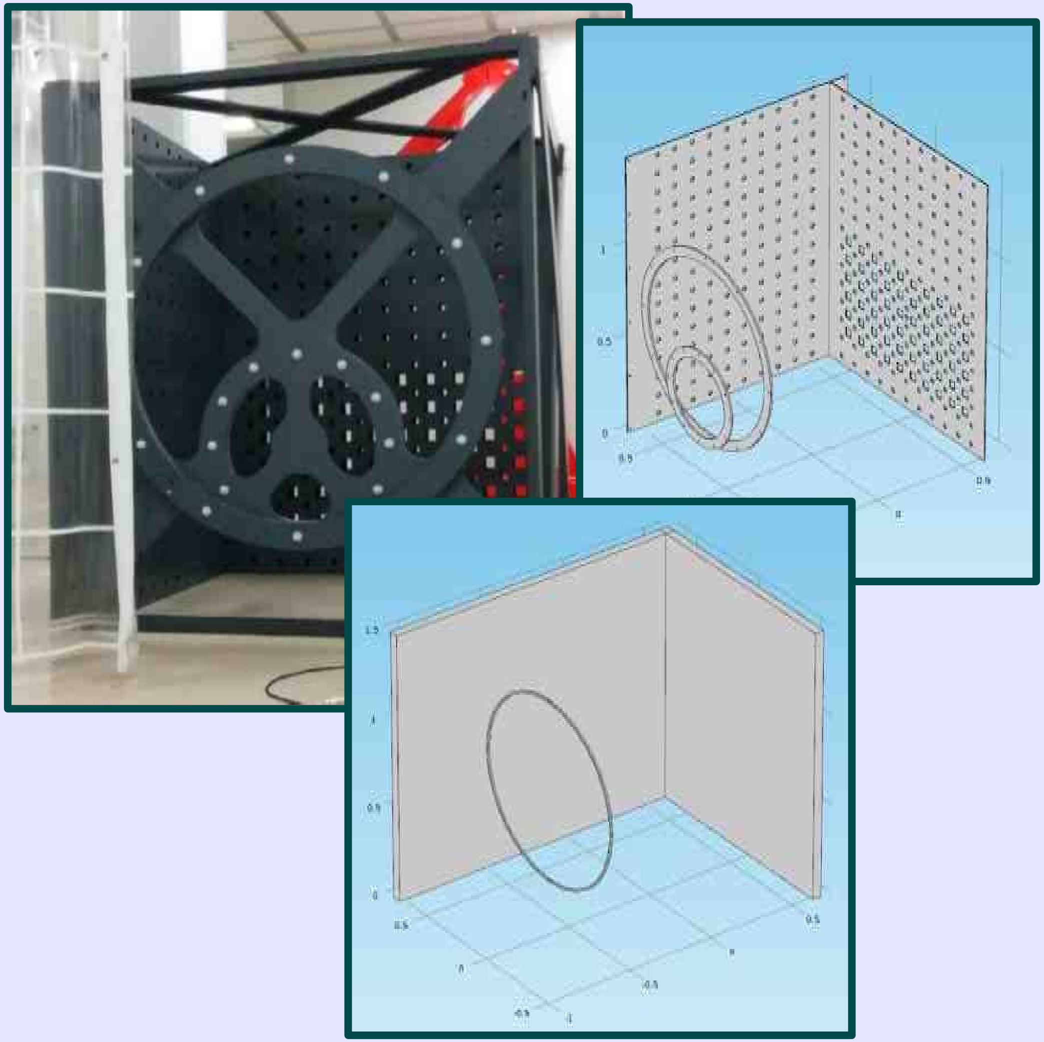
$5*10^5$ nodes
time ~ 30 – 90 min

Complex geometry:
CAD, mesh, solving
time

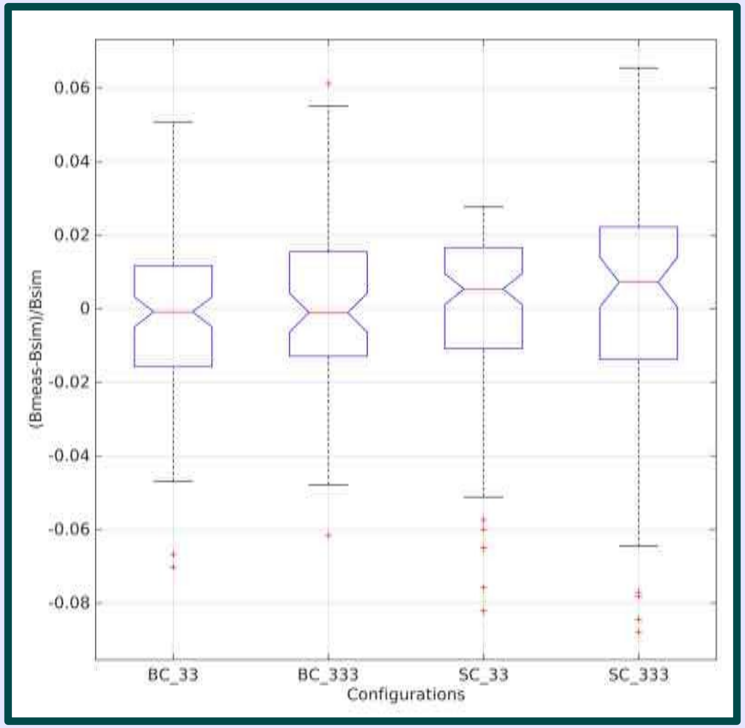


Model validation

Reference measurements



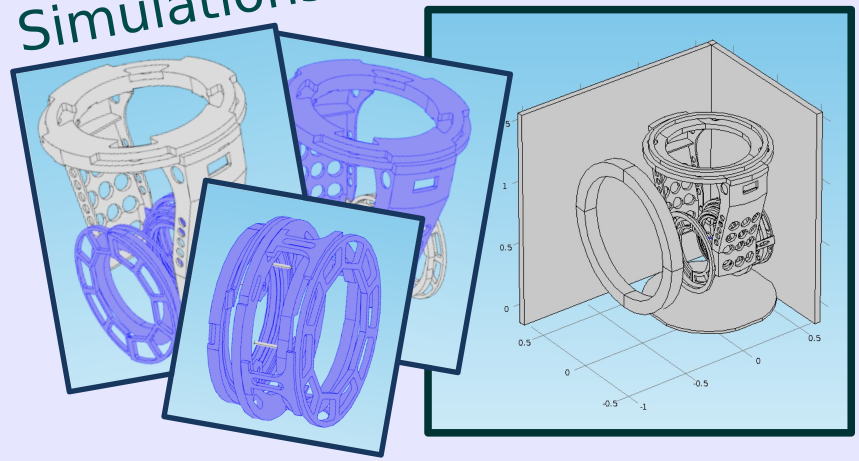
Big Coil @ 33 Hz
Big Coil @ 333 Hz
Small Coil @ 33 Hz
Small Coil @ 333 Hz



Model validation

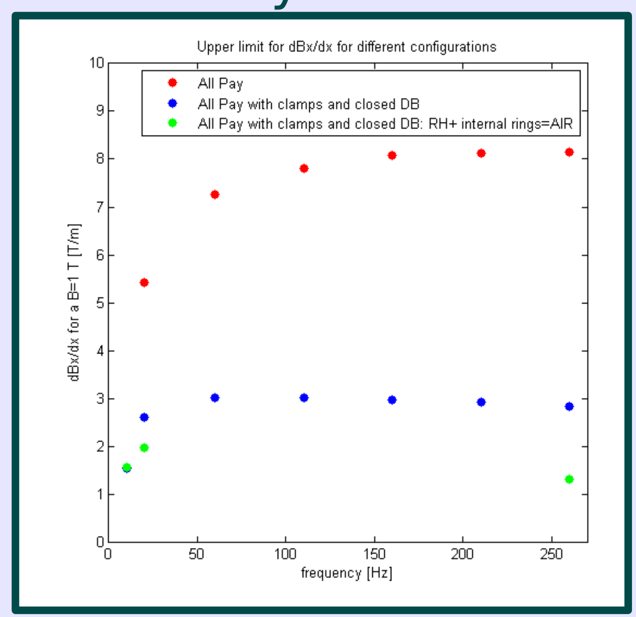
Measurements

Simulations



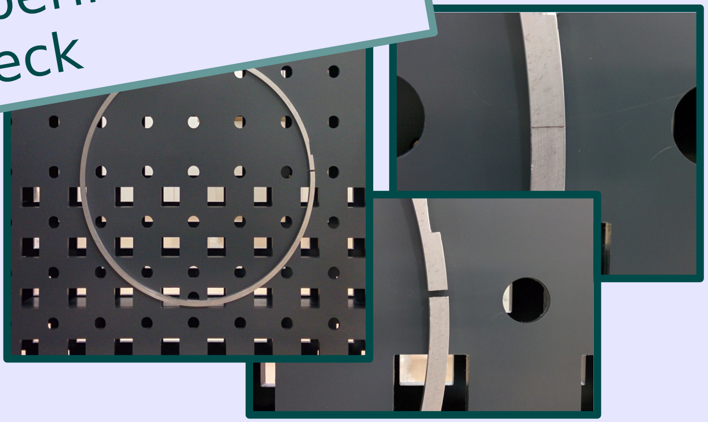
Connections

Preliminary simulations:

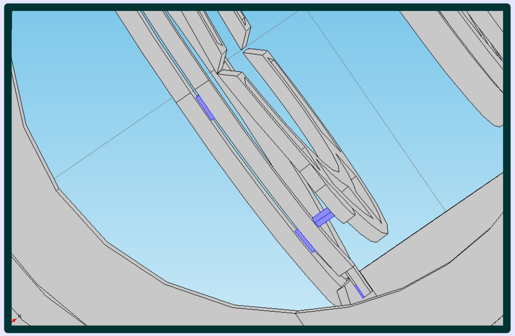


Model validation: DoE

Experimental check

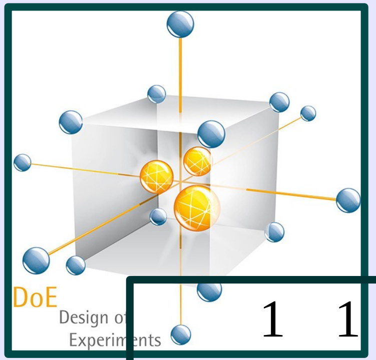


- Physical connection does not guarantee “eddy current” connection



- Model: connection volumes (Al or air)

- Optimal configuration: Design of Experiment with hadamard matrix



$$H4 = \begin{matrix} 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 \end{matrix}$$

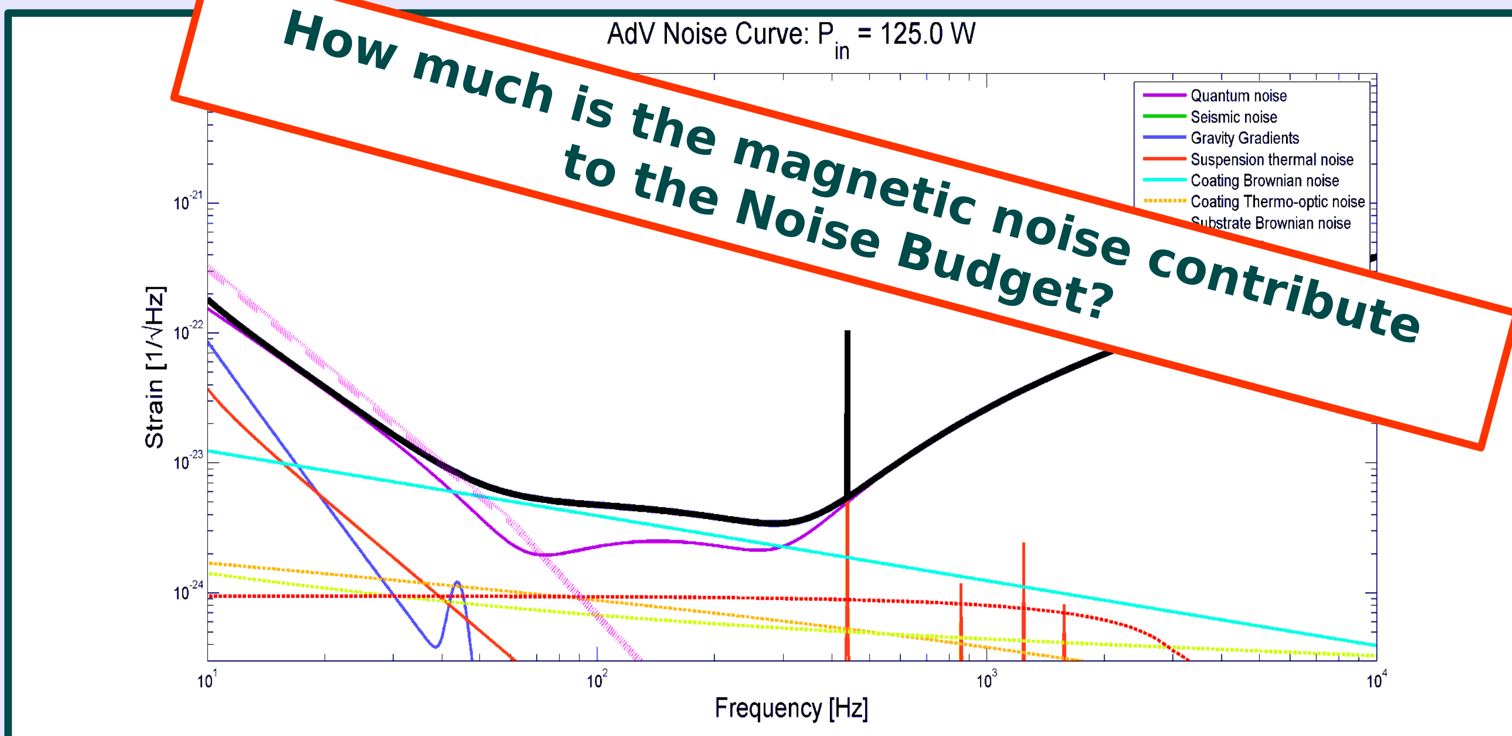
↓

Optimal configuration → validated model

h noise projection

- Validated model: study of the Pay magnetic response
- Estimate of the magnetic gradient in the volume of the magnets
- MonteCarlo simulation: magnetic moment tolerance & positioning errors
- Estimate of the h contribute

How much is the magnetic noise contribute to the Noise Budget?



Conclusions

- Low frequency magnetic noise has to be estimated

- Low frequency magnetic noise due to the magnetic coupling with the Payloads

- Payloads are complex and composite objects: we need FES

- Development of a procedure to simulate the Payloads:
  - Measurements
  - Model creation
  - Parameters: electrical connections
  - DoE for optimal configuration
  - Model validation

- Study of the magnetic response of the Payload
- Estimate of the magnetic gradient in the magnet volume
- Estimate of the h contribution