Active Noise Mitigation

Division 5 of the ET Instrument Science Board
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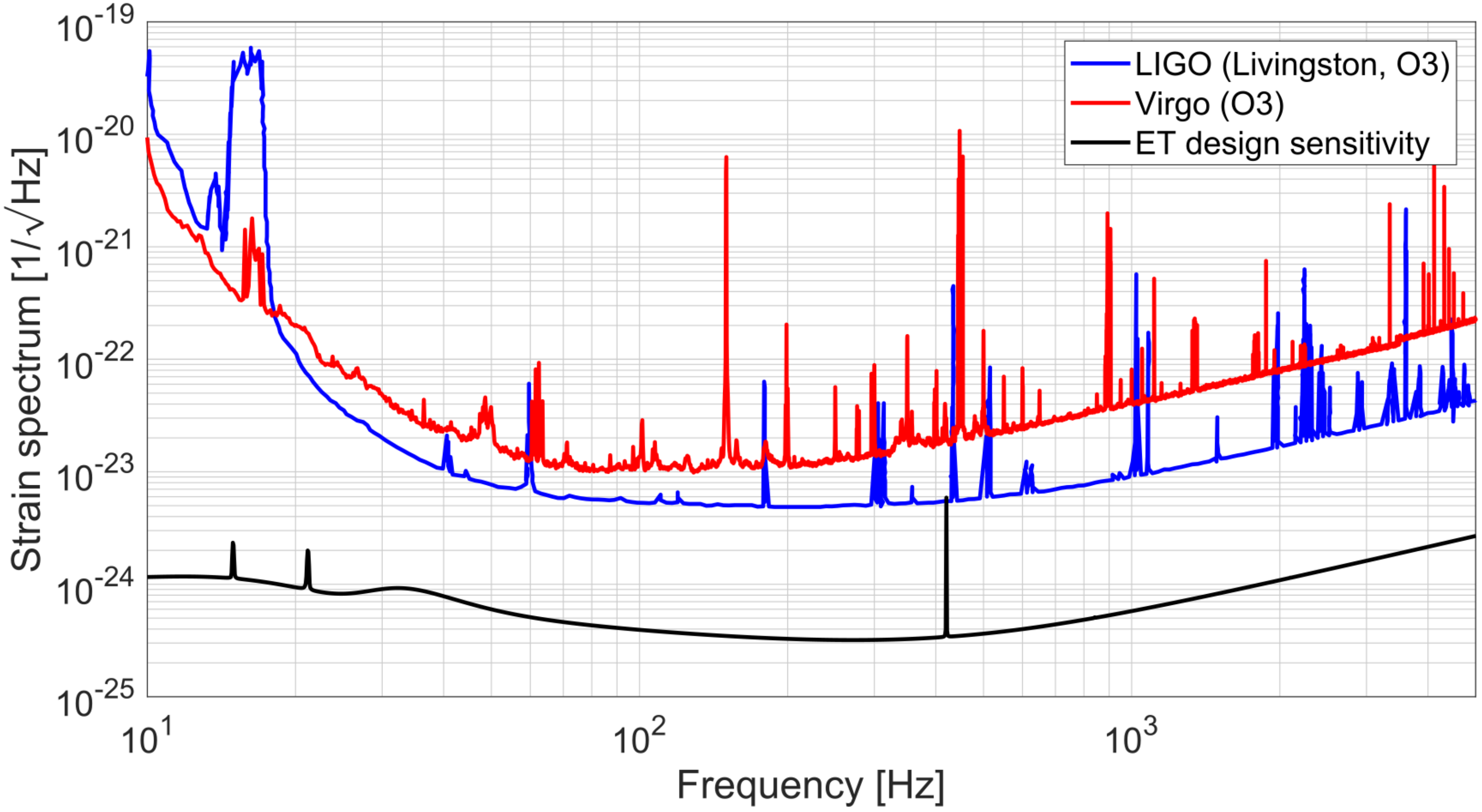
Active Noise Mitigation

There are several known issues that will affect the performance of current and future detectors, especially at low frequencies.

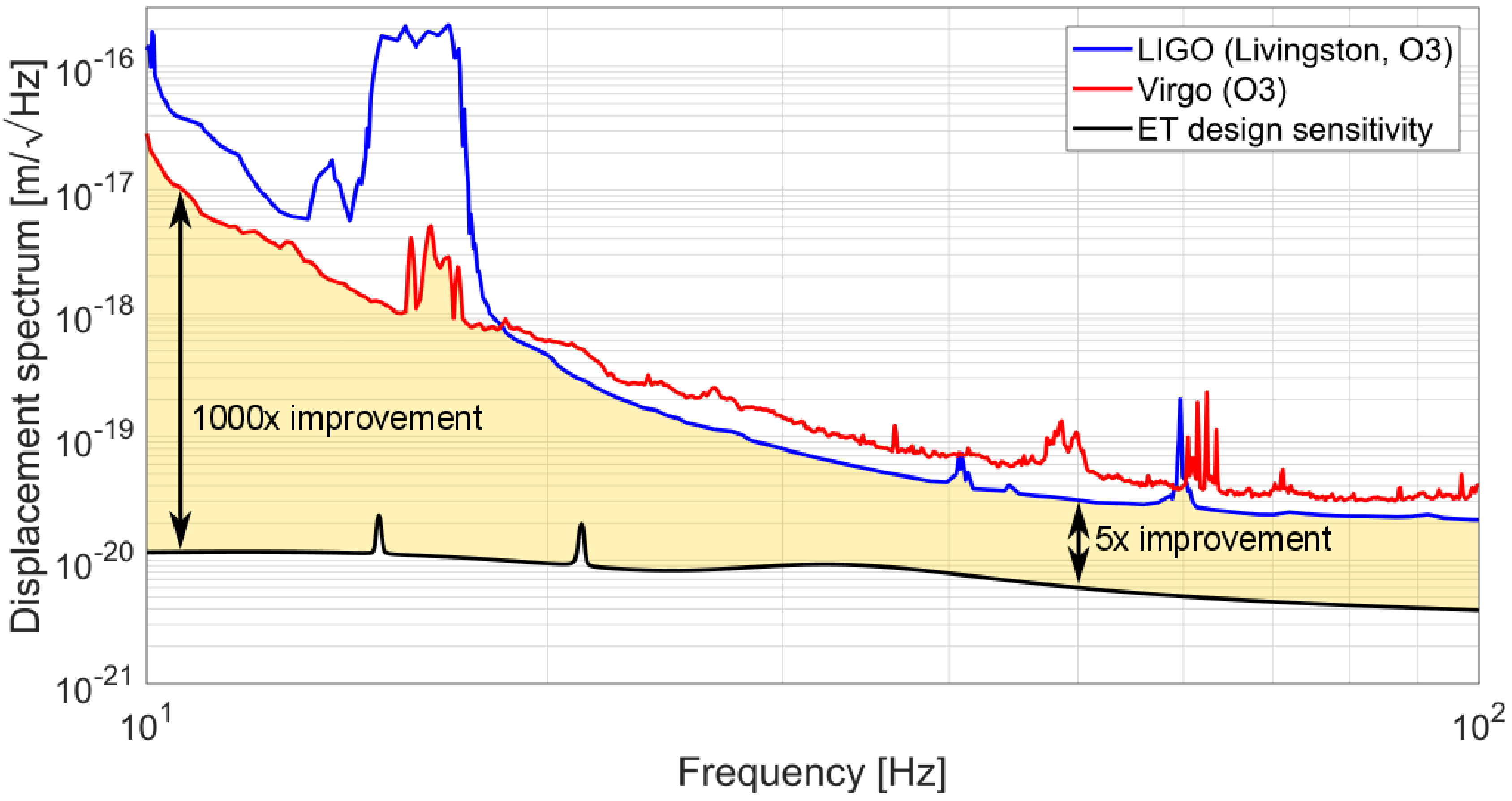
We will work to address the largest known issues by design and with realistic inputs from the current LVK Advanced and A+ instruments.

Work packages

V.1	Newtonian Noise
V.2	Environmental sensors
V.3	Magnetic Noise
V.4	Inter-platform Motion
V.5	Low-frequency control noise



LIGO (Livingston, O3)
Virgo (O3)
ET design sensitivity
Strain spectrum [1/√Hz]
Frequency [Hz]
10^{-19}
10^{-20}
10^{-21}
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{1}
10^{2}
10^{3}

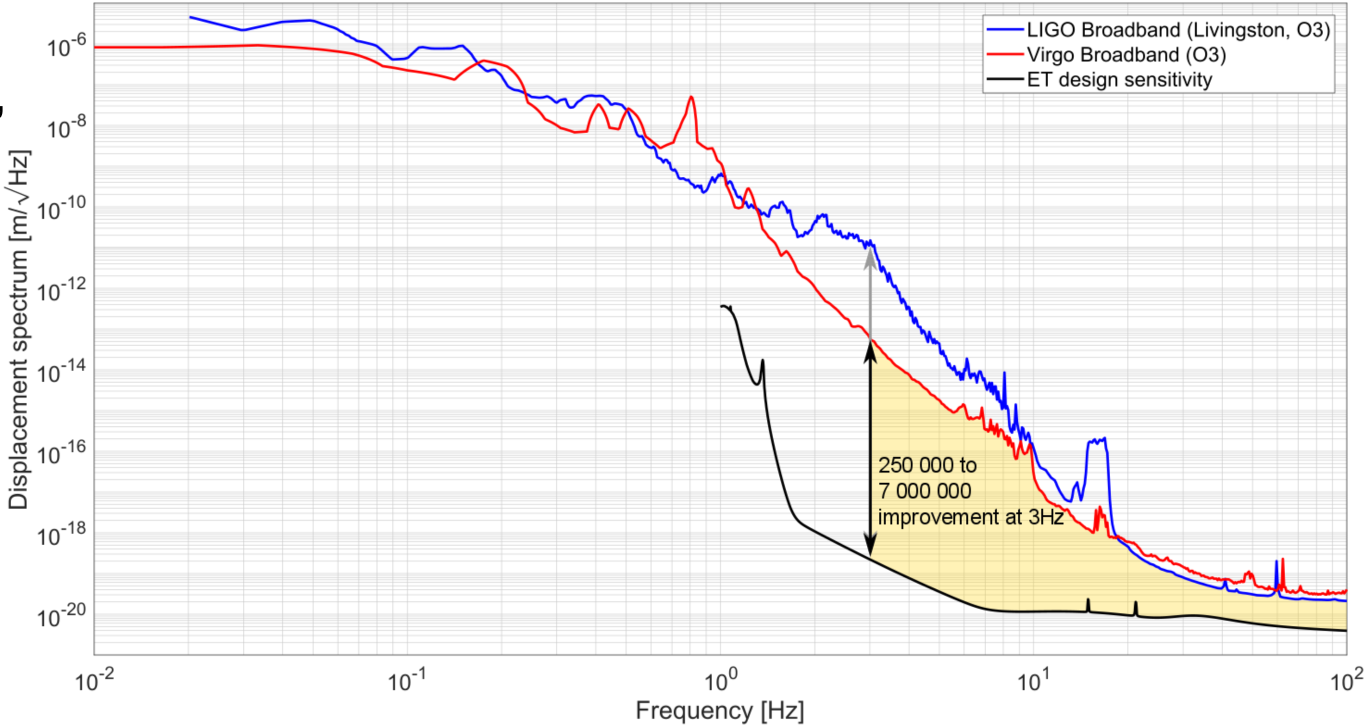


LIGO (Livingston, O3)
Virgo (O3)
ET design sensitivity
1000x improvement
5x improvement
Displacement spectrum [m/√Hz]
Frequency [Hz]
10^{-16}
10^{-17}
10^{-18}
10^{-19}
10^{-20}
10^{-21}
10^{1}
10^{2}

Active Noise Mitigation Example 1, LF noise

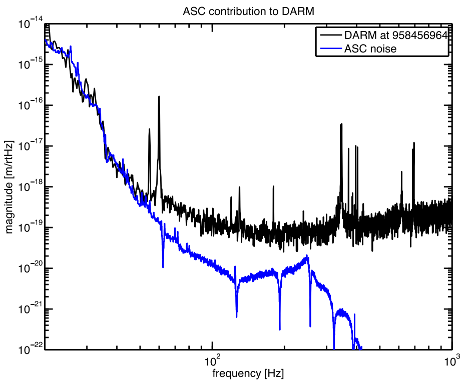
ET is not 10x better than 2nd gen detectors, it is a million times better at 3Hz.

We need to systematically identify and mitigate LF noise by reducing
- RMS motion
- Actuation forces
- A2L couplings
- … and many more



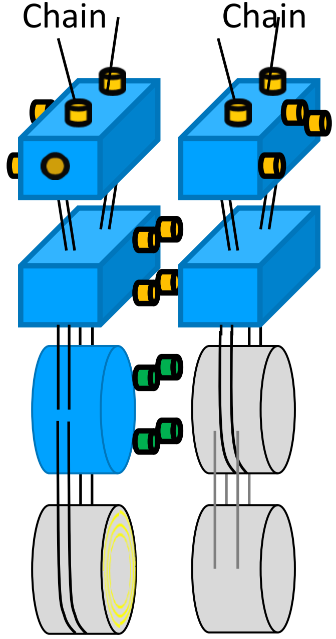
An example problem

1. Angular control is a limiting noise source

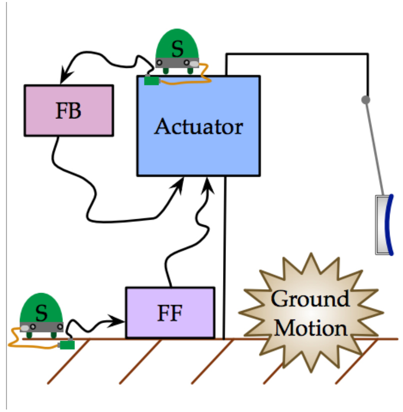


Dooley, P1100125

2. Coupling mechanisms, including suspension coupling from length drive to angle, and back to DARM

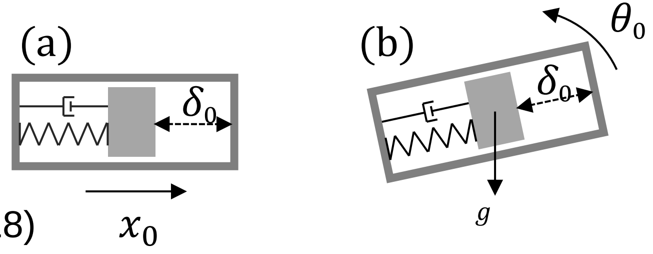


3. The length drive is necessary because the isolation tables aren't perfectly quiet…

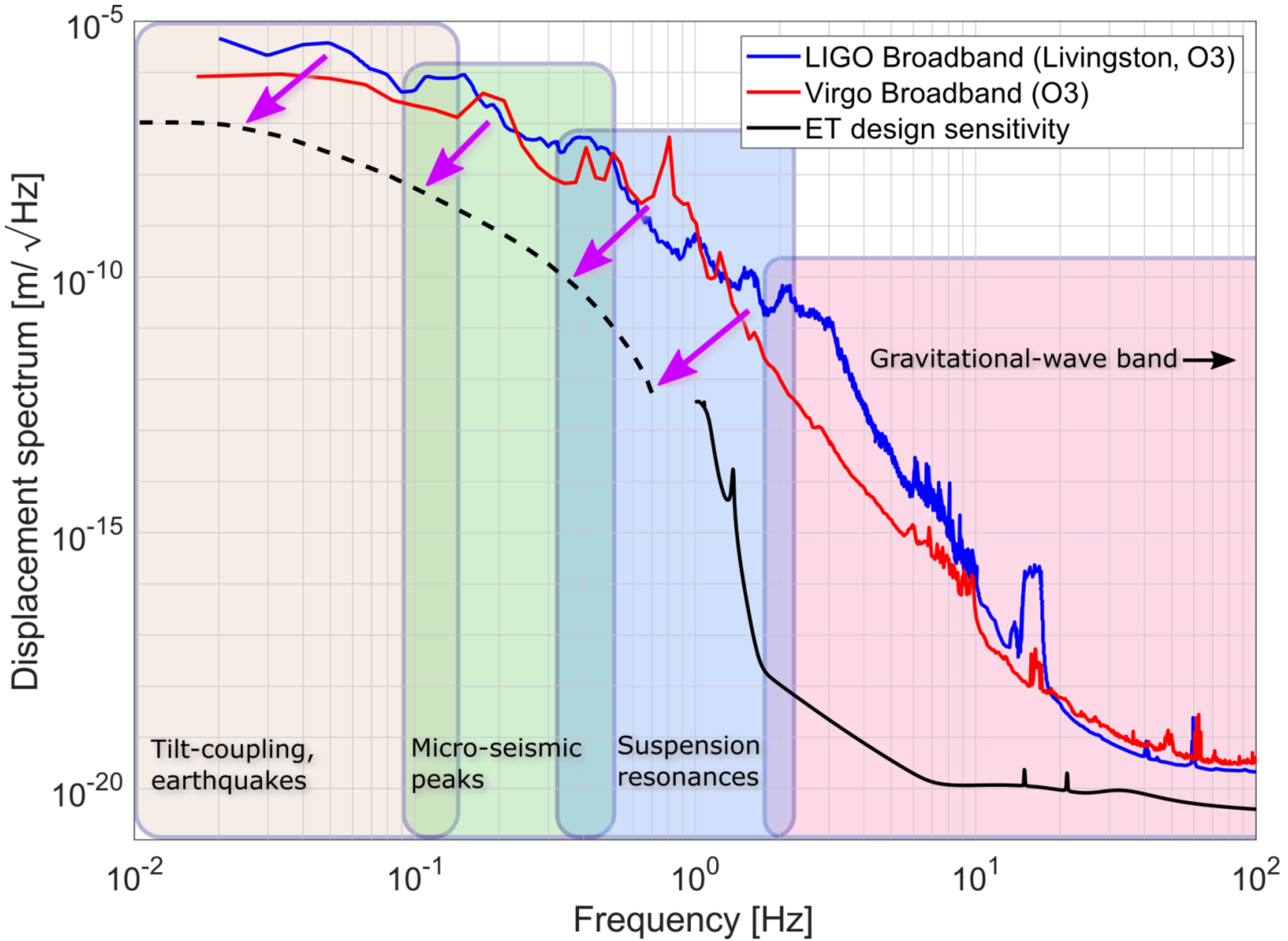


Driggers, G1500001

4. Due in part to tilt-to-translation coupling in seismometers



(UoB workshop on low-frequency noise, 2018)
https://dcc.ligo.org/LIGO-G1801755



LIGO Broadband (Livingston, O3)
Virgo Broadband (O3)
ET design sensitivity
Gravitational-wave band
Tilt-coupling, earthquakes
Micro-seismic peaks
Suspension resonances
Displacement spectrum [m/√Hz]
Frequency [Hz]

Reducing ‘technical’ low-frequency noise

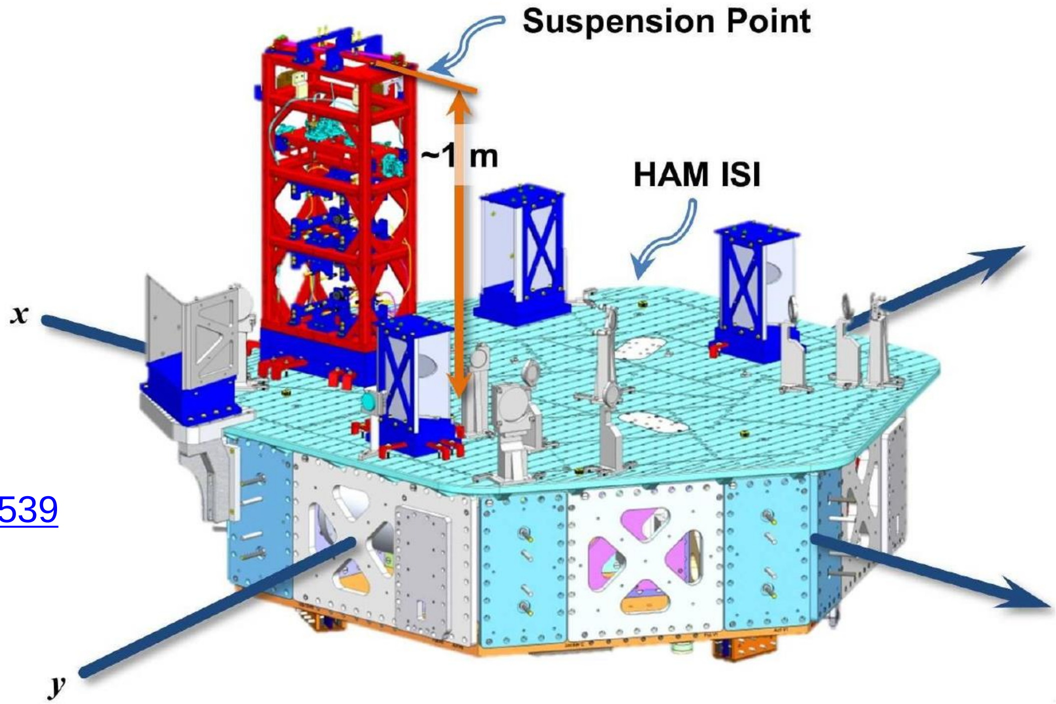
The solution will span several divisions, and we will need to

- Reduce dynamic range and input motion through Inter-Platform Motion (overlap with Division 1)
- Reduce noise couplings from auxiliary systems through LF Controls (overlap with Division 3)
- Develop more consistent models for converting input motion via auxiliary controllers into h(t)

- Better understand how the requirement for h(t) at 3Hz flows into system and sub-system requirements.

This is not a system

“Systems” considerations in GWDs

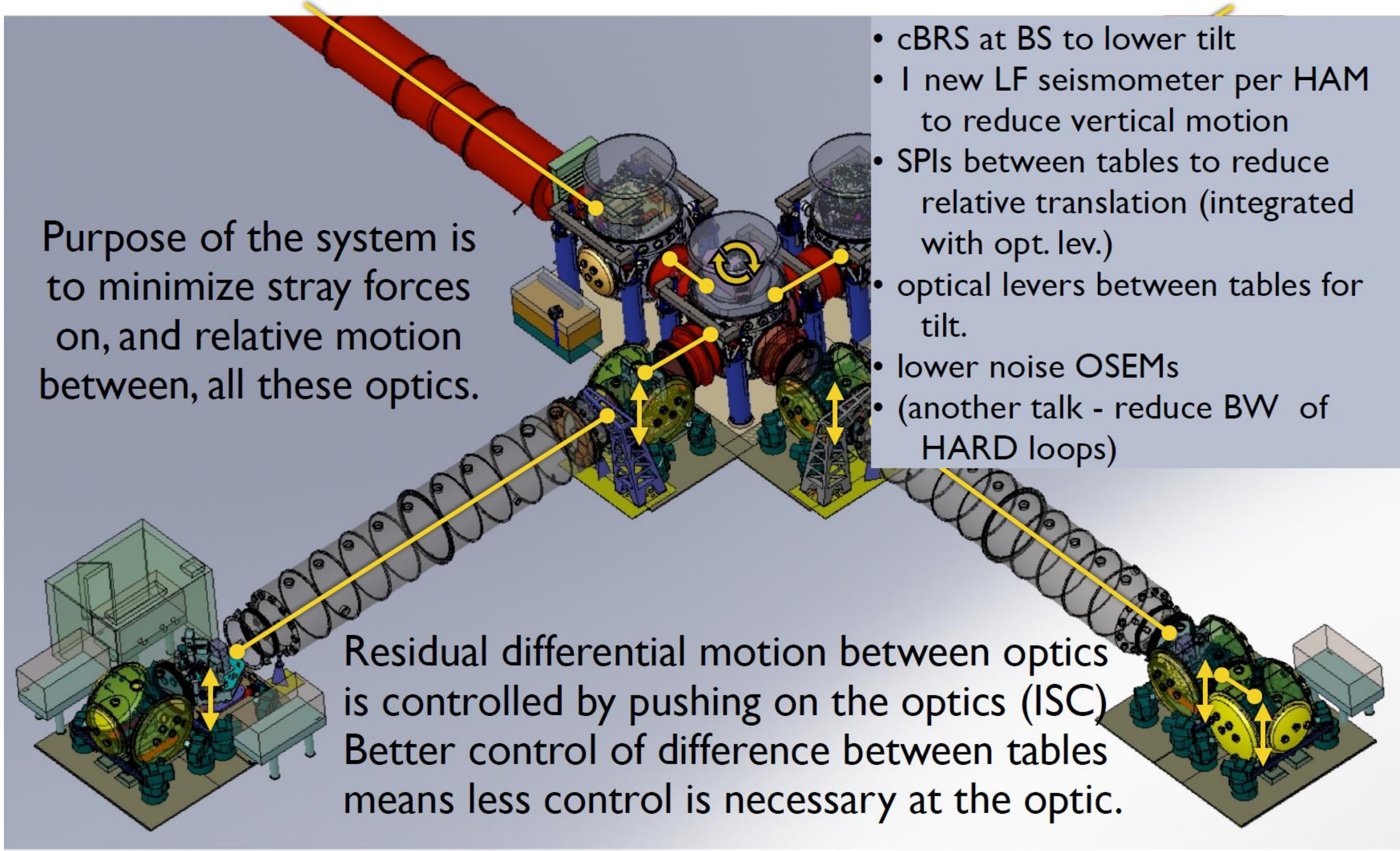


Taken from Brian Lantz’s recent LVK talk at:

https://dcc.ligo.org/LIGO-G2001539

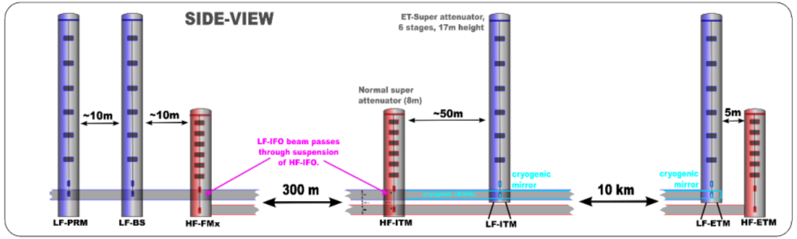
For ET we need to plan, from the beginning, to deal with the auxiliary controls, dynamic range, and realistic considerations of non-linearities.

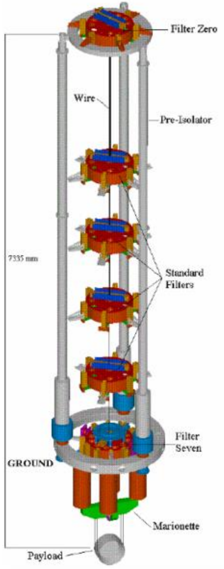
This is (most of) a system

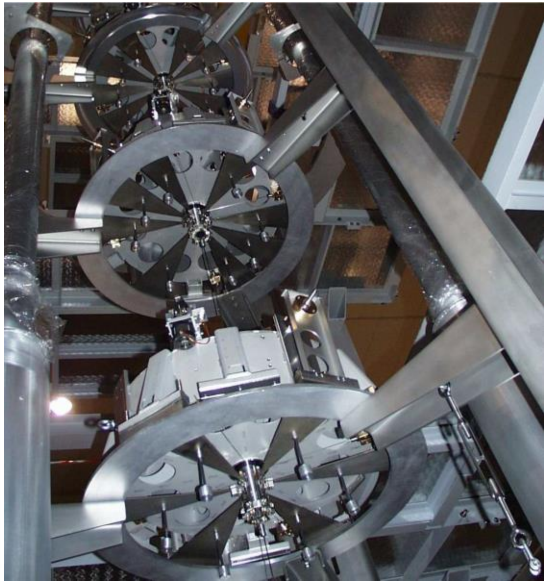


Suspension point stabilization

See Sina's talk, tomorrow at 15:20







Arm cavities:

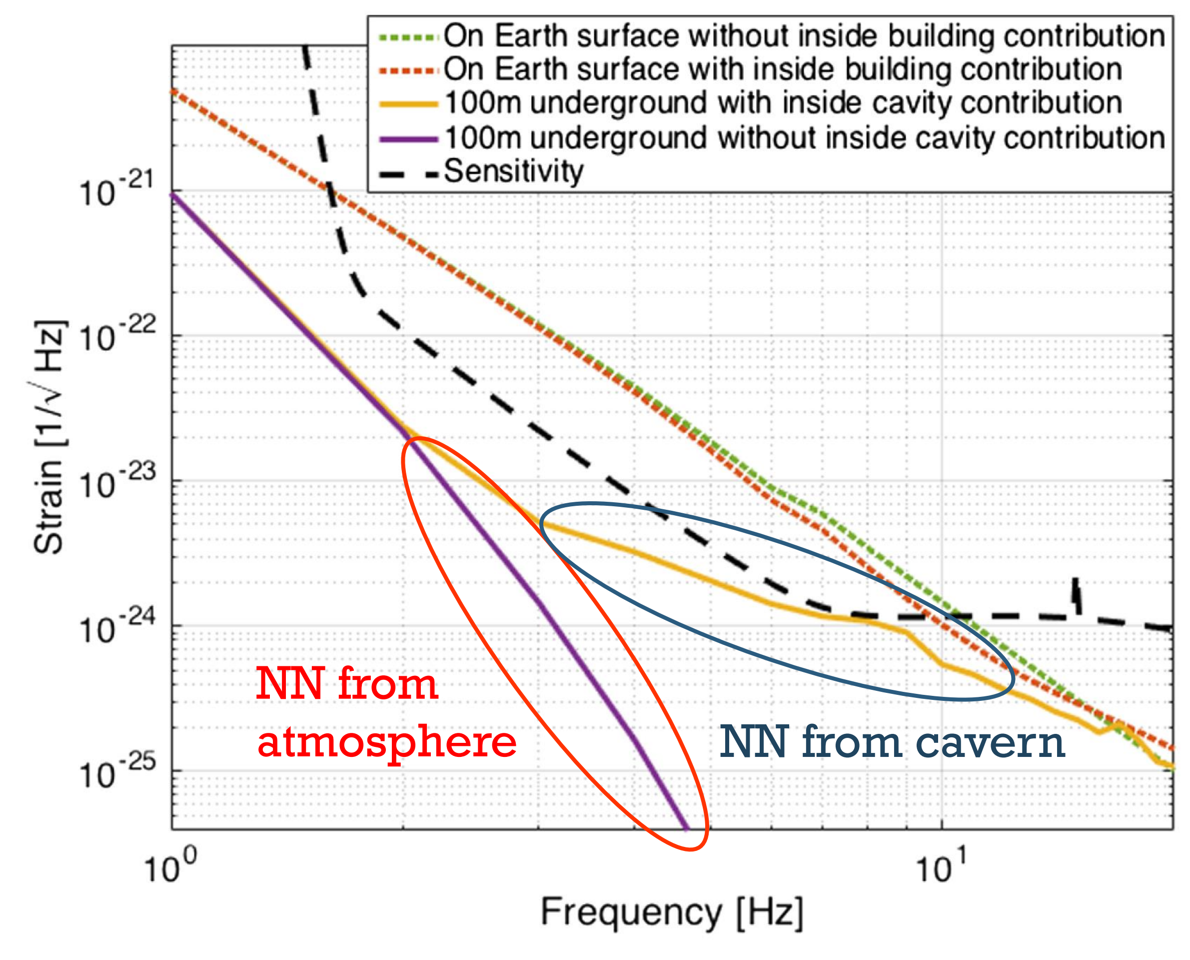
- No clear line of view
- Need to get near the beam line
- Periscope at inner structure, but
  - Cryogenic-shield in the way
  - Tilt read-out required

- Angular stabilization to reduce control bandwidth on angular interferometer control loops

→ Stabilize at the 'Seismic platform' level

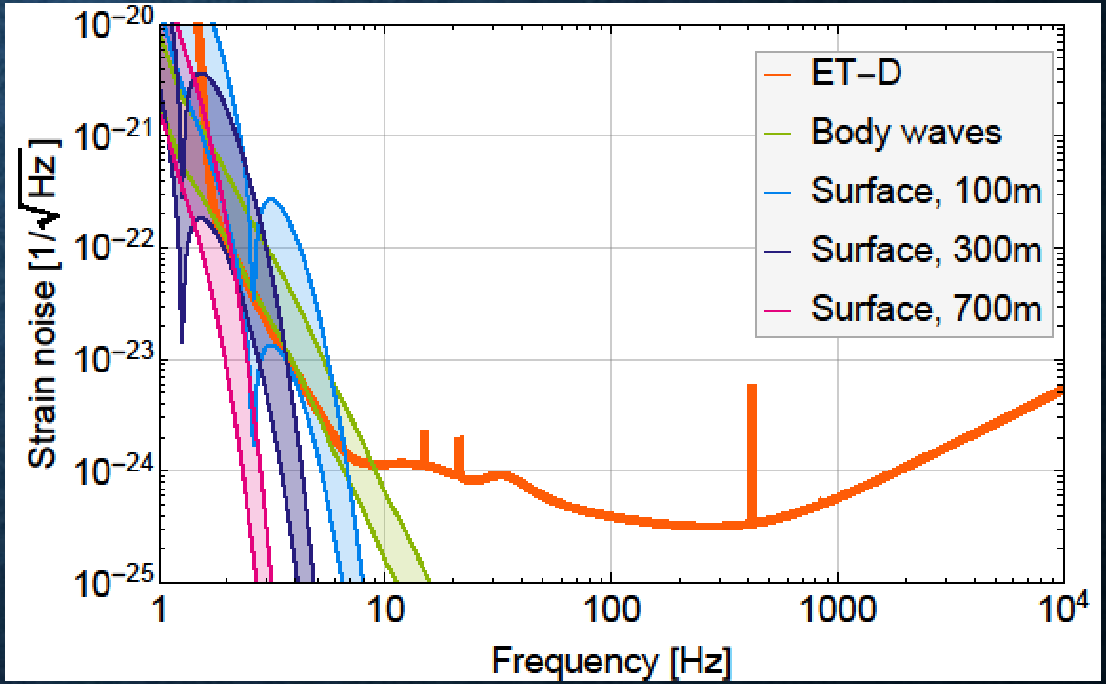
ET Newtonian-noise models

Acoustic NN underground



Fiorucci et al (2016)

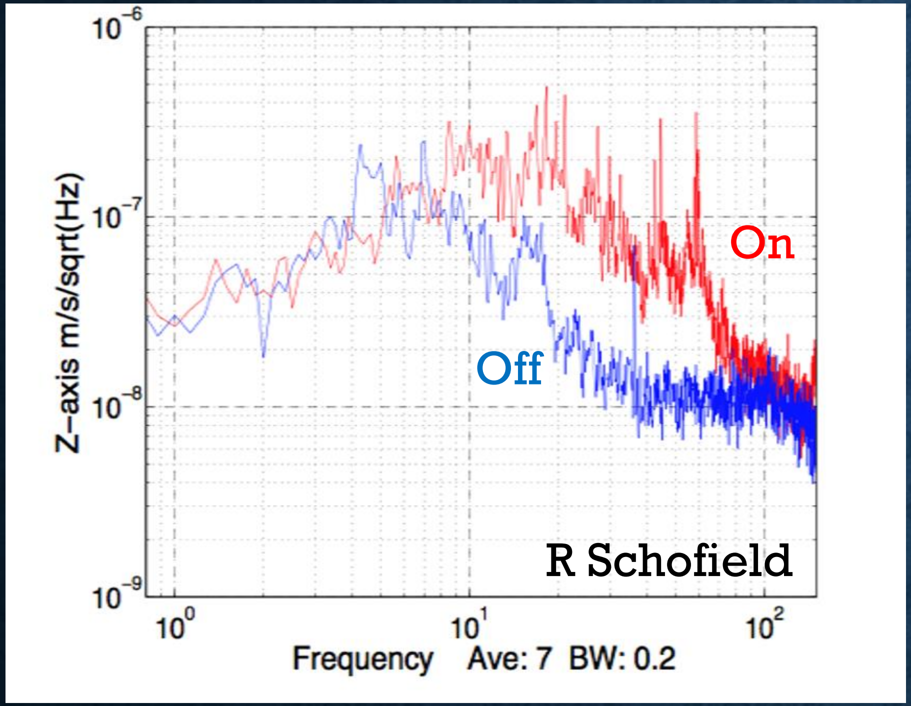
Seismic NN underground



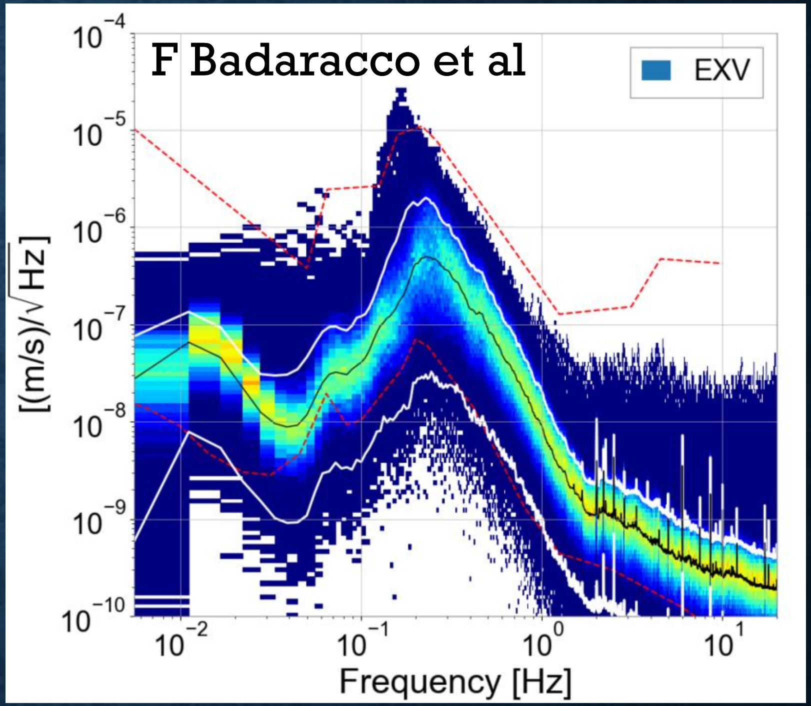
Badaracco/Harms (2019)

INFRASTRUCTURE NOISE

LIGO Hanford power outage



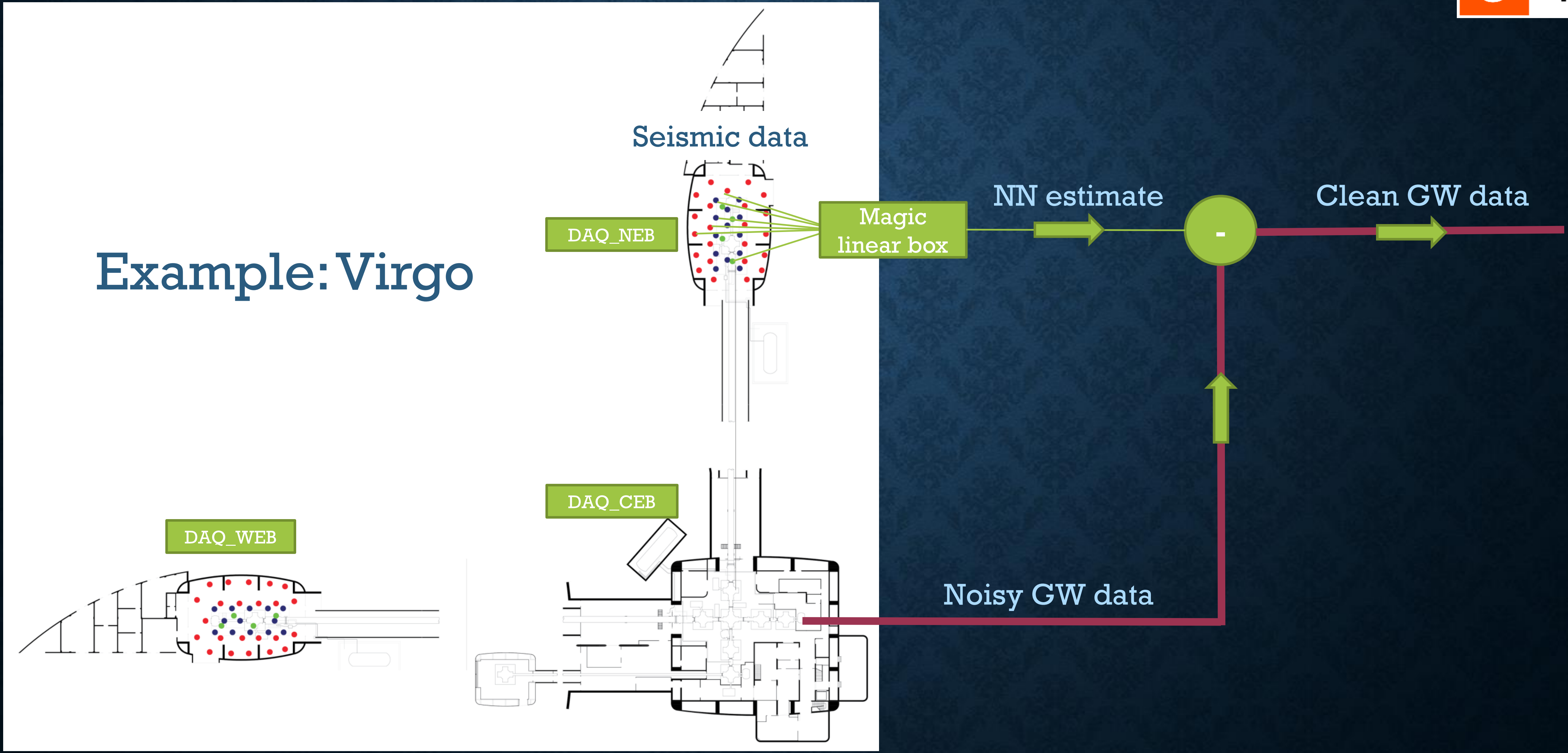
KAGRA end station
(corner station is a bit noisier)



Local (mostly infrastructural) seismic sources produce dominant perturbations above a few Hz at LIGO/Virgo

KAGRA has managed to preserve an almost prestine environment below 20Hz at least at the end stations

NN CANCELLATION



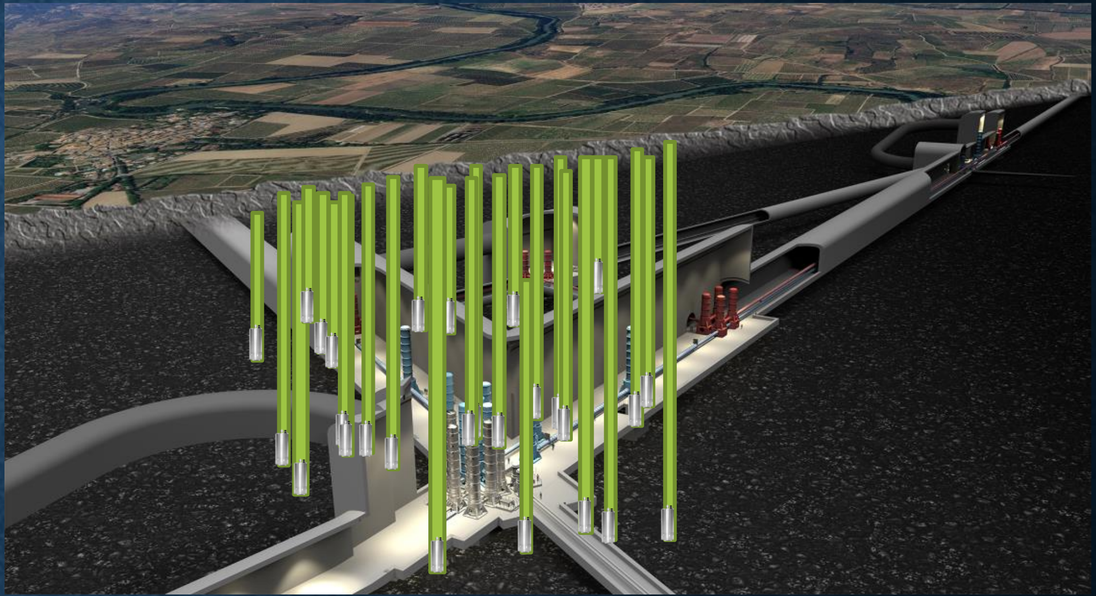
SENSOR DEVELOPMENT

Goals
- Increase sensitivity of environmental sensors
- Wind shields for microphones
- Make them easier to deploy and easier to operate large arrays
- Reduce cost of a NNC system

Acoustic sensors (wind shield)

EGO+Polgraw

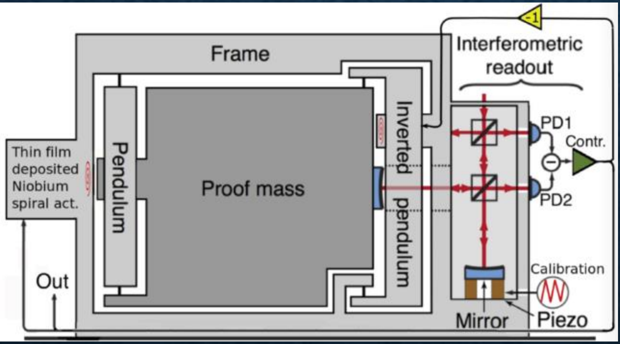
Borehole deployment



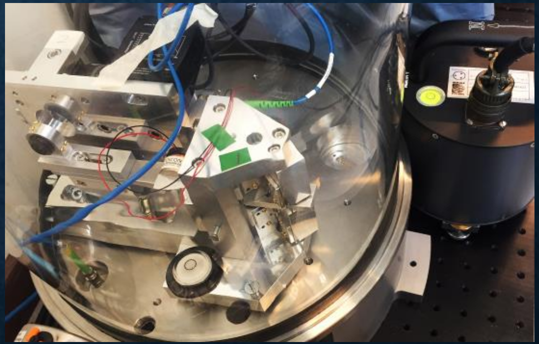
Distributed sensing

Polgraw+Nikhef @ EGO

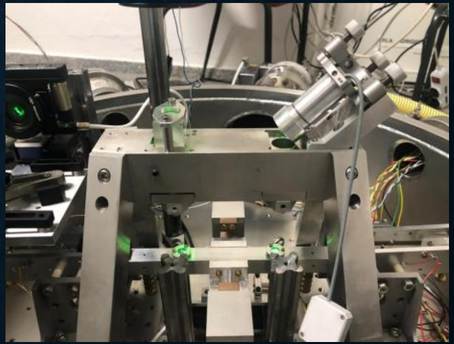
Beyond commerical sensitivity standards



J van Heijningen



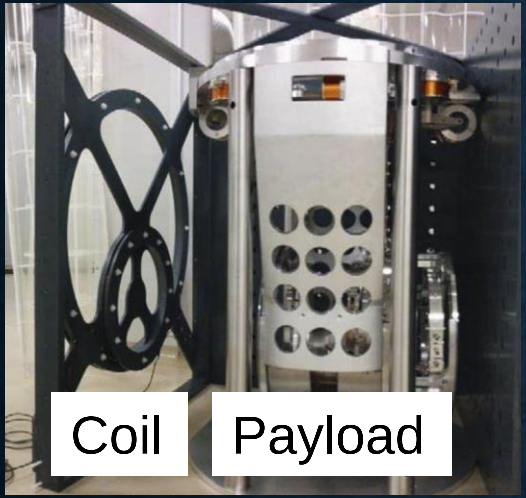
C Collette



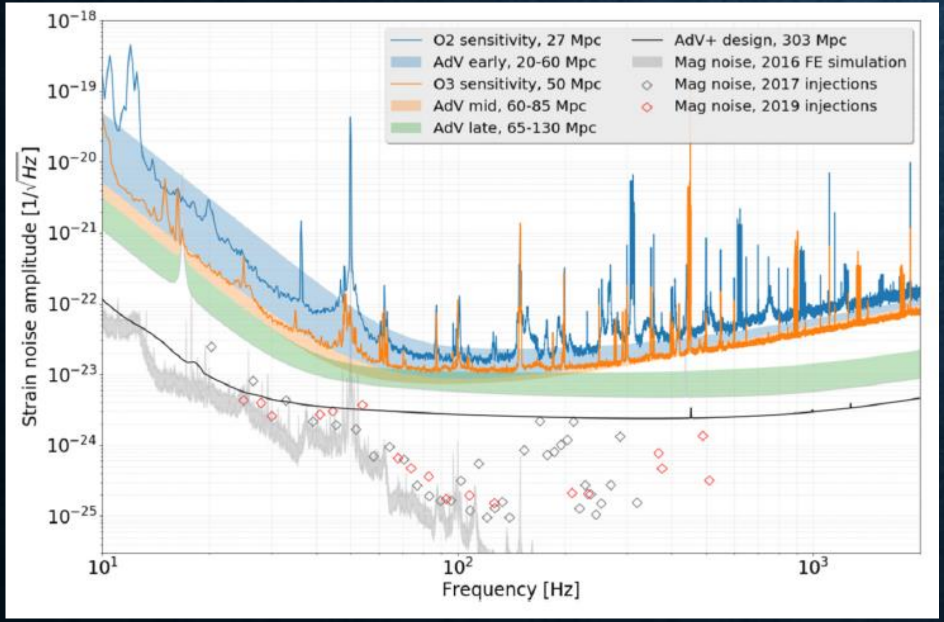
E Calloni et al

MAGNETIC NOISE

Coupling measurement



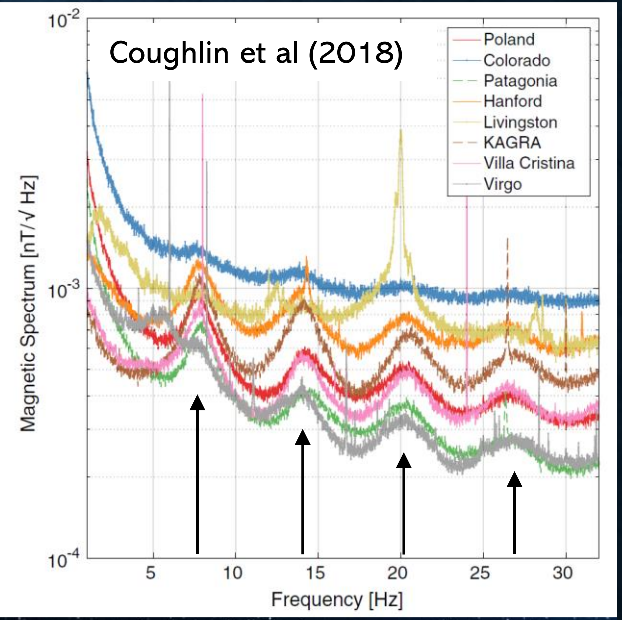
Virgo noise injections



Cirone et al (2019)

- Magnetic fluctuations are dominated by local sources (electronics).
- Schumann resonances are waves wrapping around the globe pumped by lightnings.
- Schumann resonances can cause correlated noise between any pair of GW detectors.

Natural magnetic fluctuations



Schumann resonances