

3rd SPB Workshop

6–7 Dec 2023 @Nikhef science park, Amsterdam, Netherlands

Active Noise Mitigation division status and perspectives

Luca Naticchioni

ET-0491A-23

ANM Division updates

The division experienced some “dynamics” in the last months:

- Jan Harms, appointed new co-chair of the ISB → stepped down from ANM co-chair;
- Luca Naticchioni appointed new co-chair of the ANM division → stepped down from Newtonian Noise WP co-chair;
- Conor Mow-Lowry stepped down from LF control noise WP co-chair;
- Francesca Badaracco stepped down from Newtonian Noise WP;
- Andrea Chincarini stepped down from Magnetic Noise WP;
- Soumen Koley and Maria C. Tringali appointed new co-chairs of Newtonian Noise WP;
- Artem Basalaeu appointed new co-chair of LF control noise WP;
- Barbara Garaventa appointed new co-chair of the Magnetic Noise WP;
- Changed division meeting time, now scheduled on second and/or fourth Friday of the month at 4pm (CET/CEST); **[due to Christmas break, next one will be on Dec.15]**
- Division info available on the ANM wikipage:

<https://wiki.et-gw.eu/ISB/ActiveNoiseMitigation/WebHome>

ANM Division structure

ISB-ANM

Active Noise Mitigation

Conor Mow-Lowry
Luca Naticchioni

WP 1 – Newtonian Noise Cancellation

Chairs: M.C. Tringali & S. Koley

WP 2 – Environmental Sensors

Chairs: R. De Rosa & M. Suchenek

WP 3 – Magnetic Noise

Chairs: I. Fiori & B. Garaventa

WP 4 – Inter-Platform Motion

Chairs: P. Ruggi & S. Koehlenbeck

WP 5 – Low Frequency Control Noise

Chairs: K. Dooley & A. Basalaev

ET – Low Frequency challenge

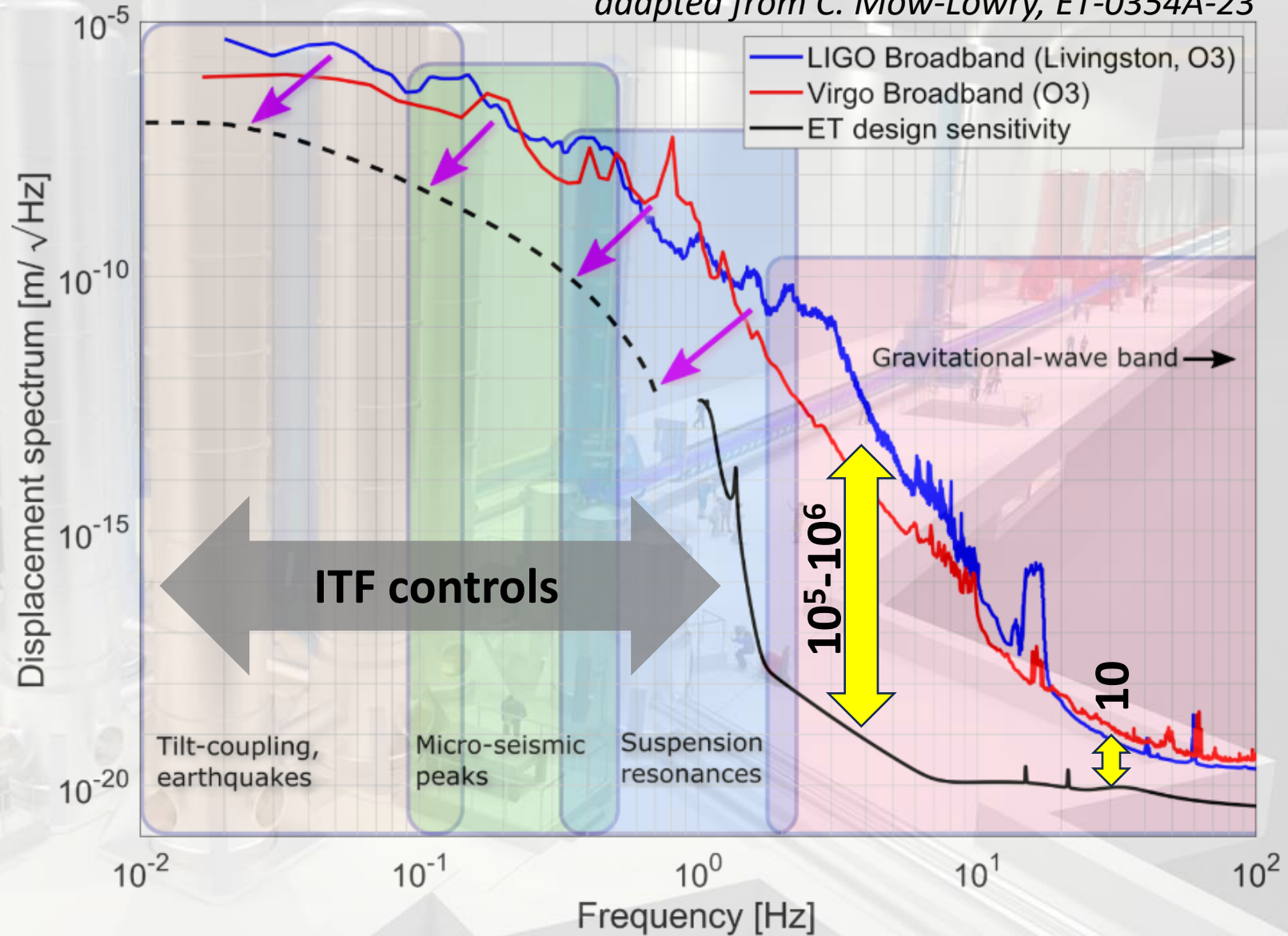
adapted from C. Mow-Lowry, ET-0354A-23

ET target sensitivity will be on average 10x wrt to current GW detectors.

BUT

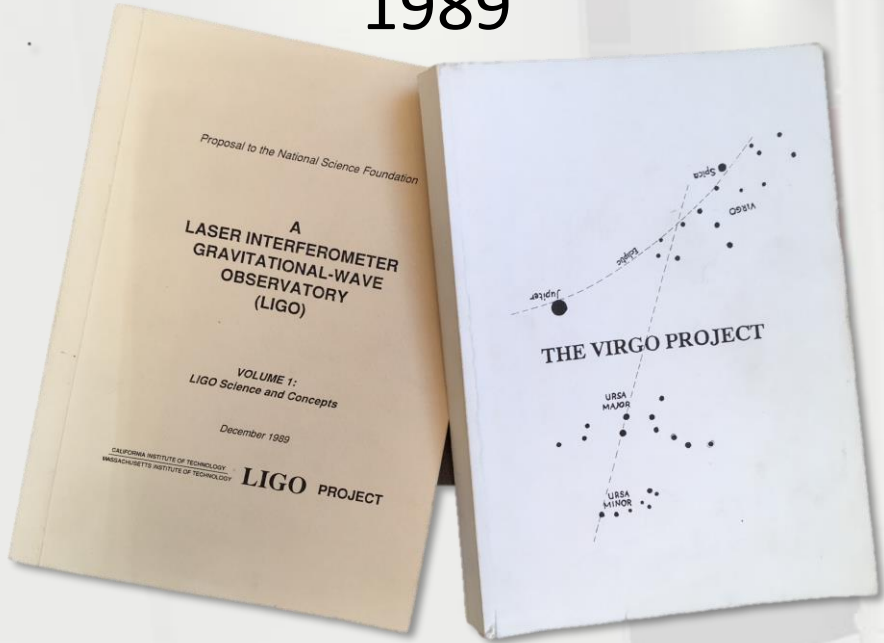
2-10 Hz band, that is crucial for ET, requires a dramatic improvement: $10^5 - 10^6$!

- start from a low-noise site
- apply mitigation strategies
- learn from 2G detectors

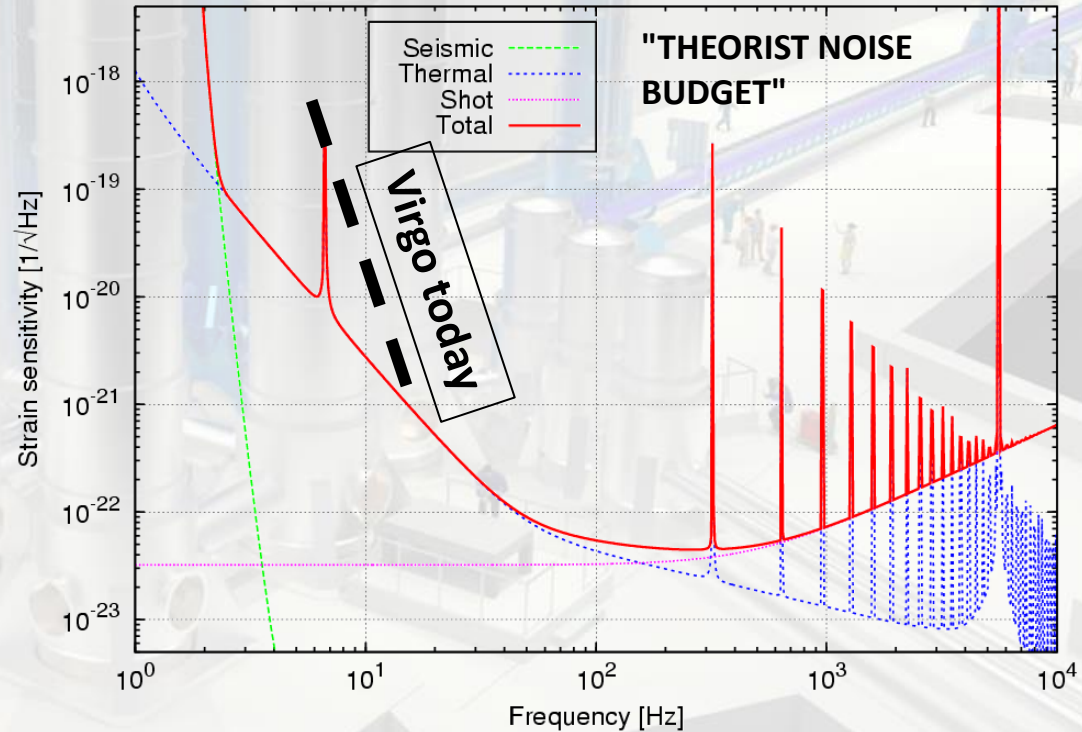


ET – Low Frequency challenge

1989

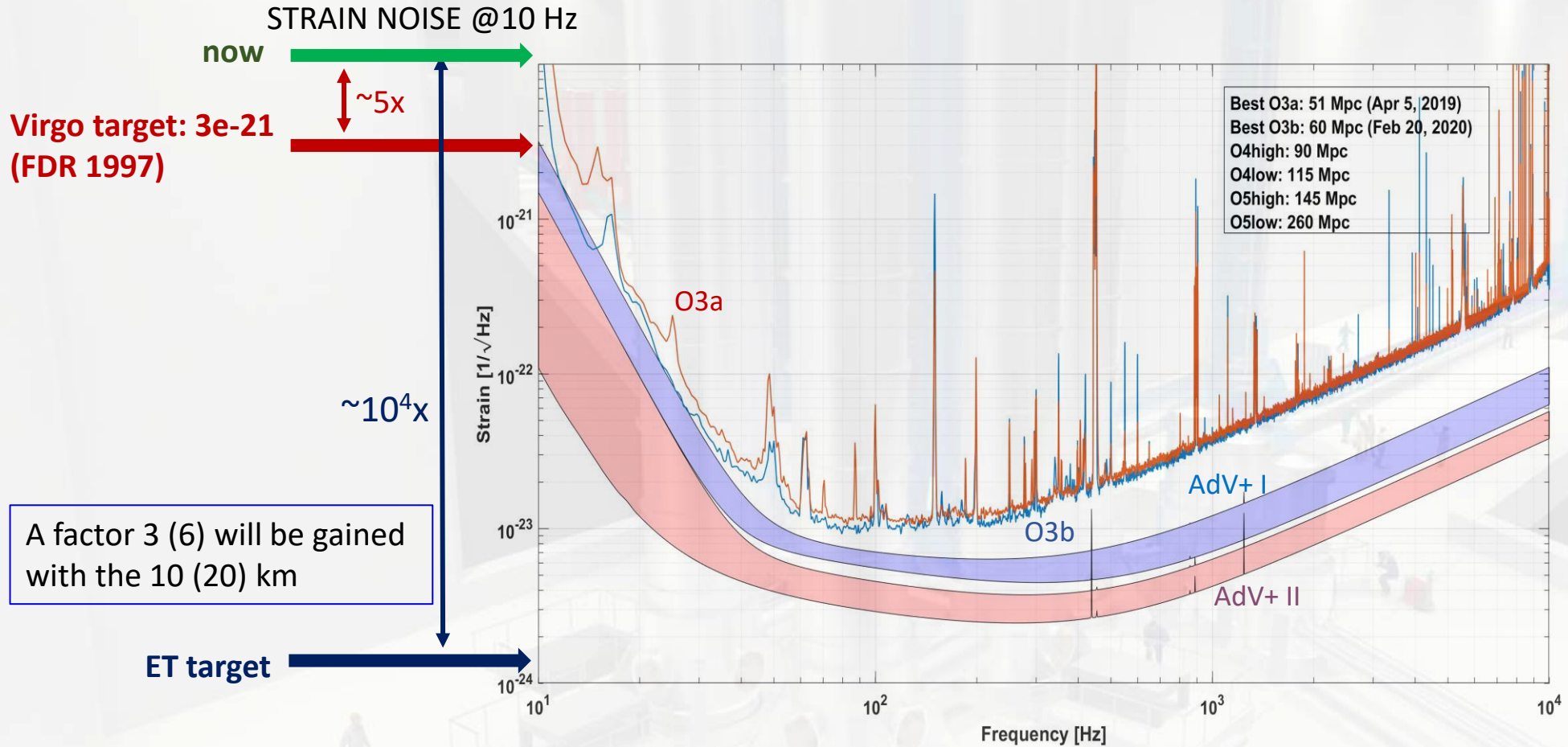


Initial Virgo Target (~30yr ago)



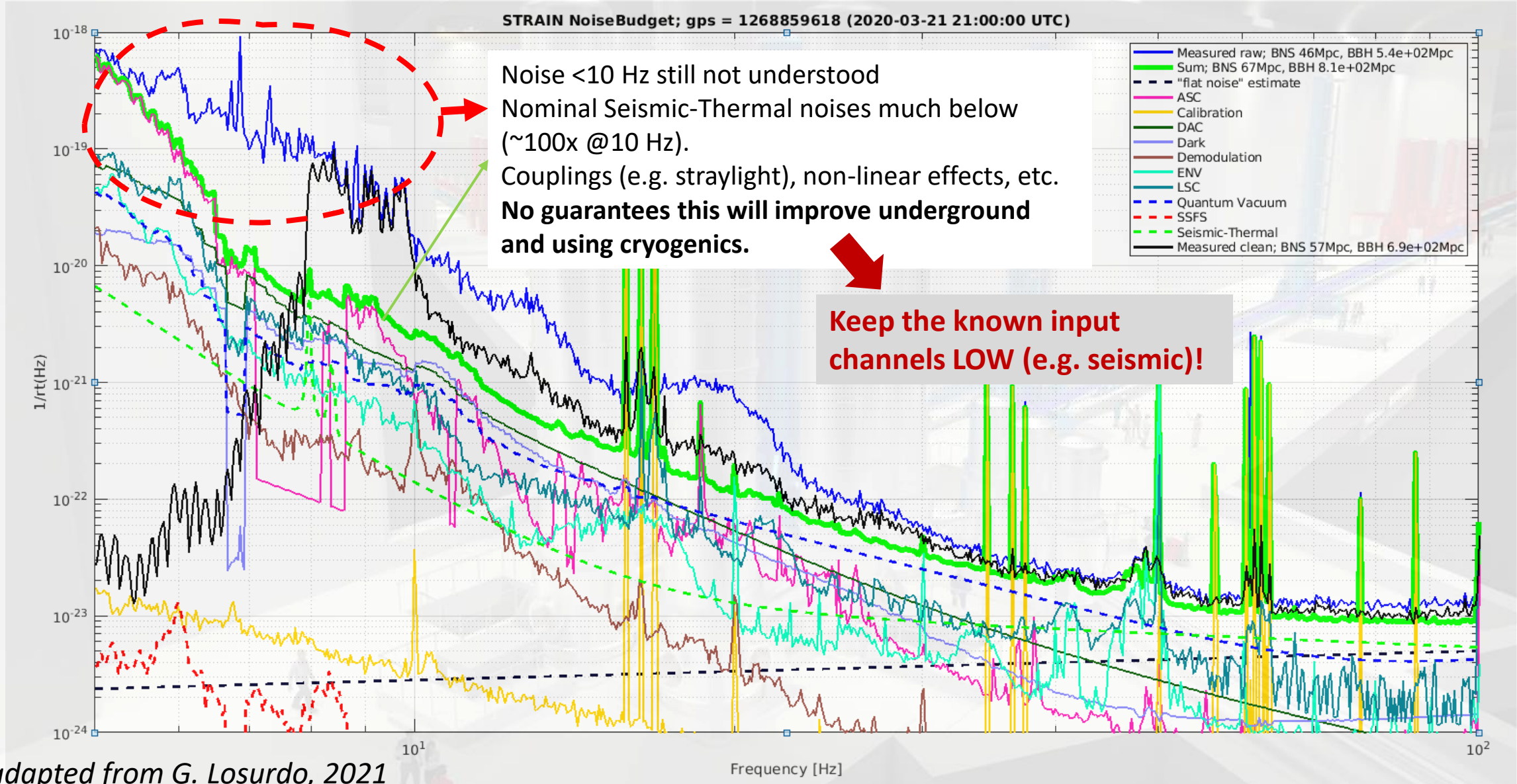
adapted from G. Losurdo, 2021

ET – Low Frequency challenge



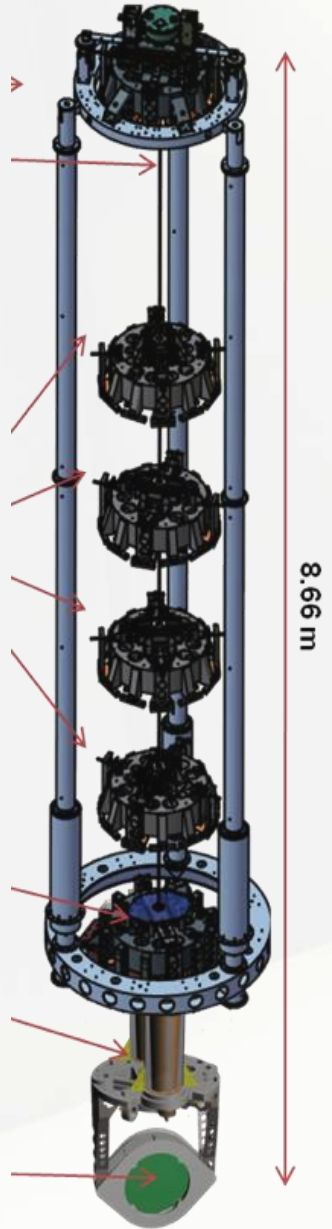
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ET – Low Frequency challenge

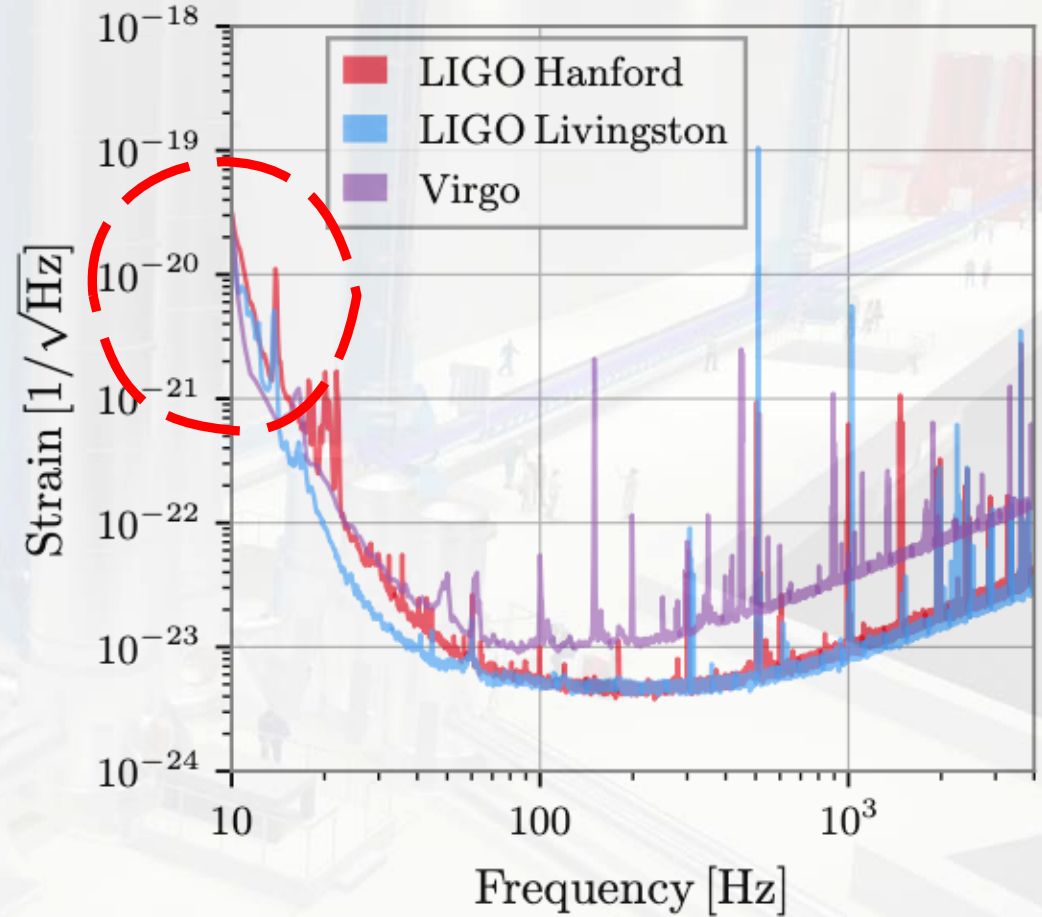
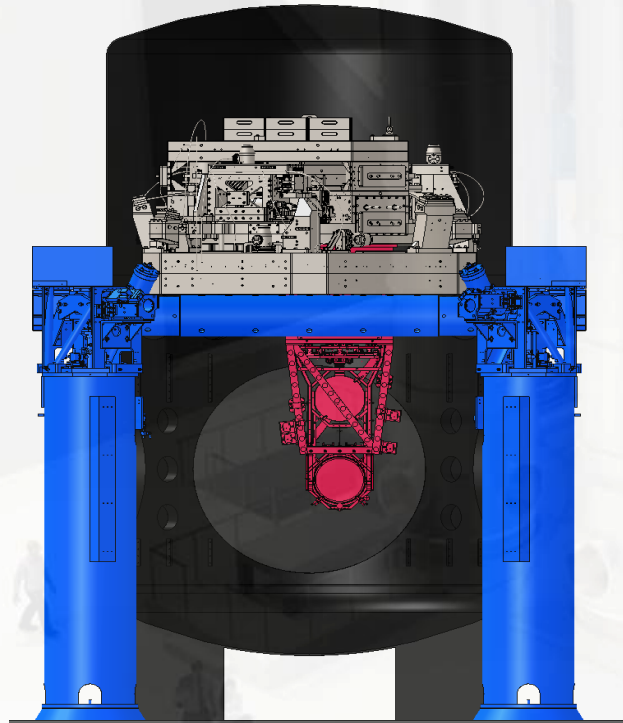


adapted from G. Losurdo, 2021

ET – Low Frequency challenge



Advanced LIGO/Virgo:
different vibration isolation
technologies,
comparable LF sensitivity



adapted from G. Losurdo, 2021

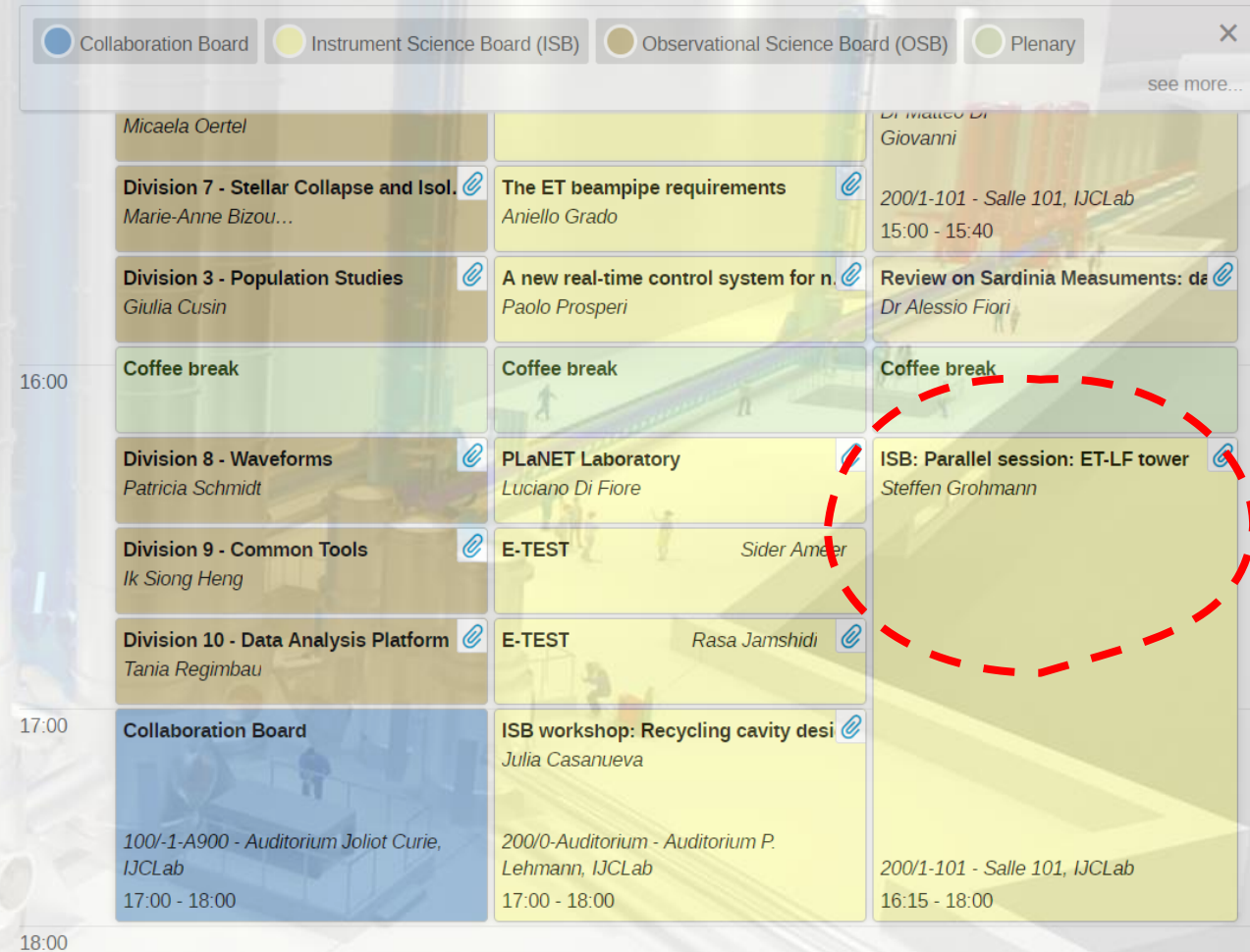
ET – Low Frequency challenge

Reaching the ET target sensitivity at LF requires also a careful design of the detectors:

A ***cross-divisional team*** inside the ISB, composed of members of *Vacuum&Cryogenics, Suspensions and Active Noise Mitigation divisions*, working together to in the design of the **ET-LF towers**.

First meeting at the dedicated parallel session of the ET annual meeting in Paris-Saclay last month:

<https://indico.ijclab.in2p3.fr/event/9686/timetable/#20231114.detailed>

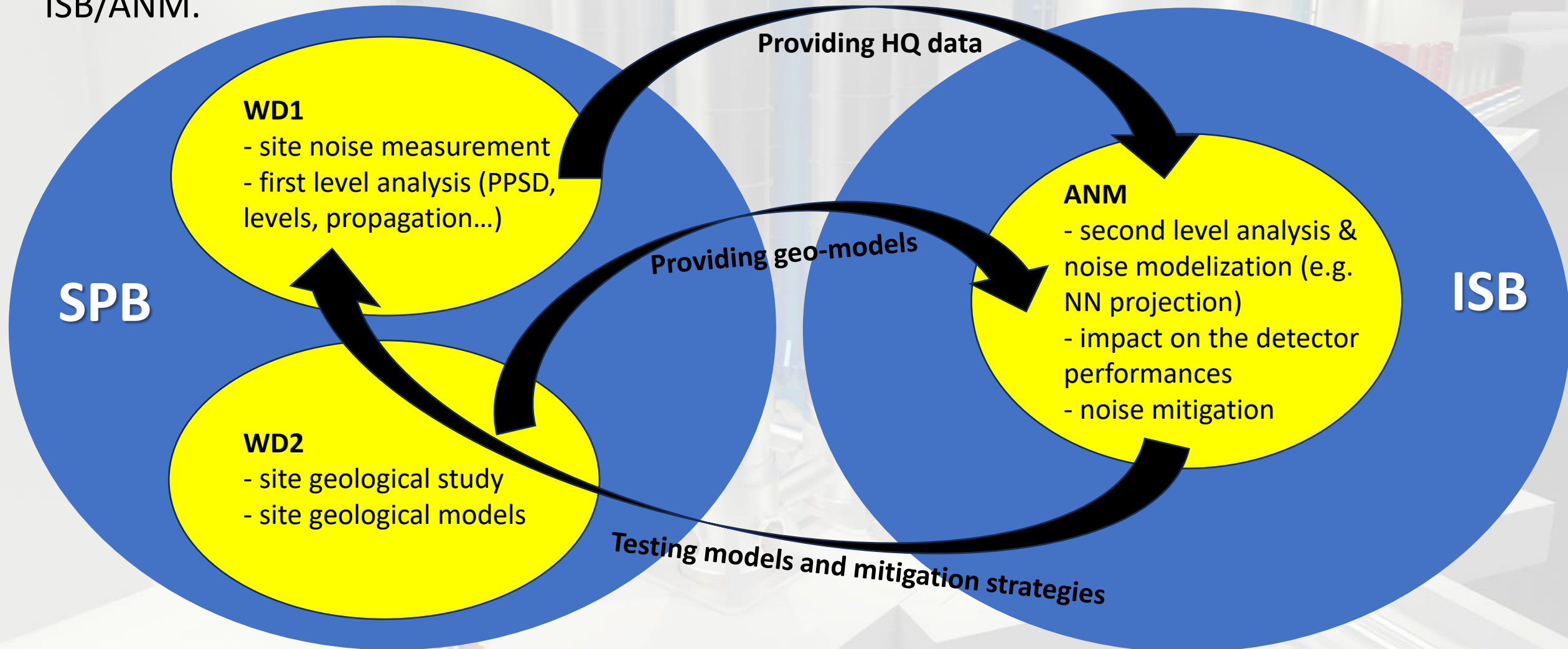


What's going on now

- The ANM division (and the whole ISB) is now working on the **Project Breakdown Structure (PBS)**, a “hierarchy backbone” and the first step towards the TDR (→ design, parameters, costs).
 - 798 lines (items) for ET-HF detectors, 955 lines for ET-LF! O(2k) items!
 - Contact persons designed for each item (division/WP duty);
 - Contact persons are now defining the functional and integration parameters for each item (deadline January 15). Currently this is the main task of the whole ISB.
- *Modelling Einstein Telescope low-frequency controls and inter-platform motion workshop in Hamburg, 4-6 March 2023 (<https://indico.desy.de/event/42127/>)*

ISB/ANM & SPB

We must strengthen the synergy between the SPB (in particular, WD1 & WD2) and the ISB/ANM.



Newtonian Noise WP

Soumen Koley & Maria C. Tringali

ANM Division – NN WP

Soumen Koley & Maria C. Tringali

- Sos Enattos: Seismic characterization → NN projection with analytical models.
- Sos Enattos: **missing NN simulation.**
- Terziet: Seismic characterization → NN projection with analytical models.
- Terziet: NN simulation (simplified geological model, **results not compatible with analytical projections**).
- Seismic **glitchiness** study → NN impact (*R. De Rosa's talk*).
- NN **correlation** studies (one preliminary work published, one ongoing).
- **Accelerometers optimization** preliminary studies (isotropic/homogeneous seismic field): **work in progress.**
- **Strainmeters optimization** preliminary studies (isotropic/homogeneous seismic field): **work in progress.**
- **Atmospheric NN** model improvement.

ANM Division – NN WP

Soumen Koley & Maria C. Tringali

Critical issues/mailing list discussions

- Discussion about shear wave contribution (3 documents + emails).
- Discussion about Wiener Filter vs Neural Network (ANM email exchanges)
- Discussion about cavern shape impact (1 document + emails)
- Limit to NN cancellation (1 document + emails)

***Defining a common, shared agreement on methods and models to calculate NN is a goal of this WP, discussions must happen here!
Methods and models must be reviewed/published/open source.
The collaboration should then follow the defined “standards” when there is a consensus on them.***

ANM Division – NN WP

Soumen Koley & Maria C. Tringali

NN talks at this workshop today:

- Seismic NN evaluation – J. Harms.
- Seismic NN glitches: impact on ET sensitivity and duty cycle – R. De Rosa.
- NN modeling and cancellation methods – F. Badaracco.

Environmental sensors WP

Rosario De Rosa & Mariusz Suchenek

**Obvious link with SPB WP1.3 (Magnetic Noise)
and WP1.4 (other environmental noises)**

ANM Division – Env. sensors WP

Rosario De Rosa & Mariusz Suchenek

Recent activities:

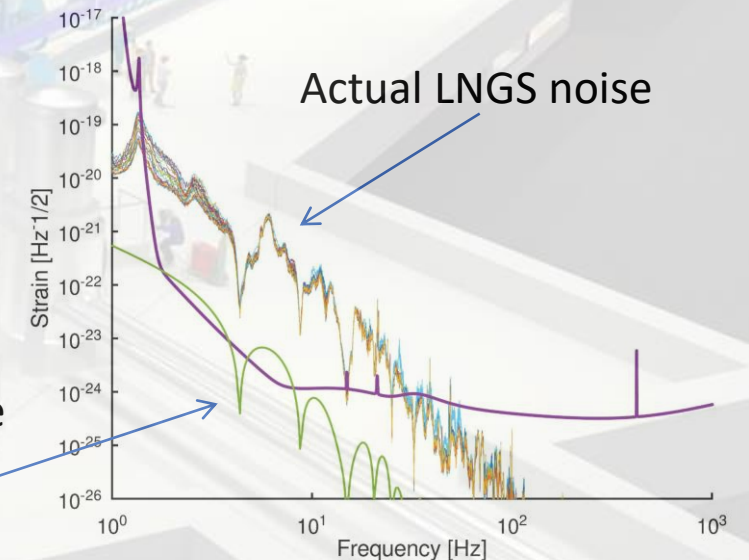
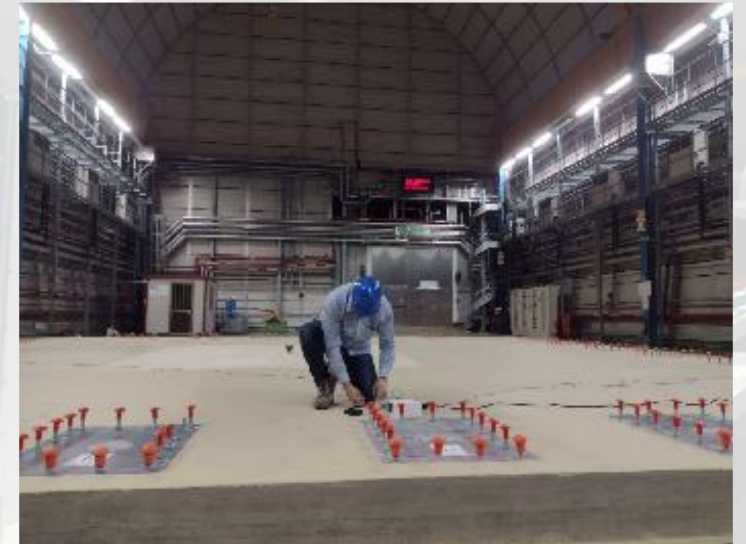
- Infrasound campaign in Sardinia (Sos Enattos) - done
- Acoustic Newtonian (ENV+NN WPs) noise based on LNGS - done
- Magnetic noise campaign in Sardinia (Sos Enattos and P2) in progress.
- New prototype of tiltmeter installed at Virgo site – commissioning in progress.

Plans:

- Seismic and infrasonic network installation at the ET Pathfinder in Maastricht.
- New prototype of an infrasonic microphone (microphone head design) - end of 2023.
- Acoustic measurement campaign at P2 & P3 borehole areas in Sardinia.

Newtonian noise based on LNGS measurements

- **Acoustic NN is not negligible**
- Assume a geometry of detector: hall 100m x 20m x 25 m;
- Calculations in Fiorucci et al. 2018;
- LNGS measurement can be considered as upper limit;
- Noise level in tunnels is too high;
- Lower limit - from ambient noise can also affect ET sensitivity;
- **Possible actions to lower this noise:**
 - silence all equipment;
 - differential pressure?;
 - build ET in several smaller halls.

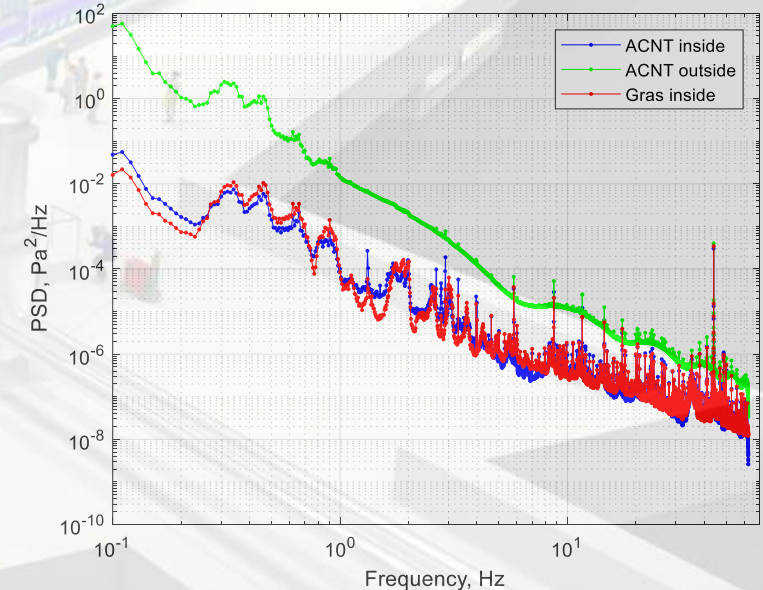
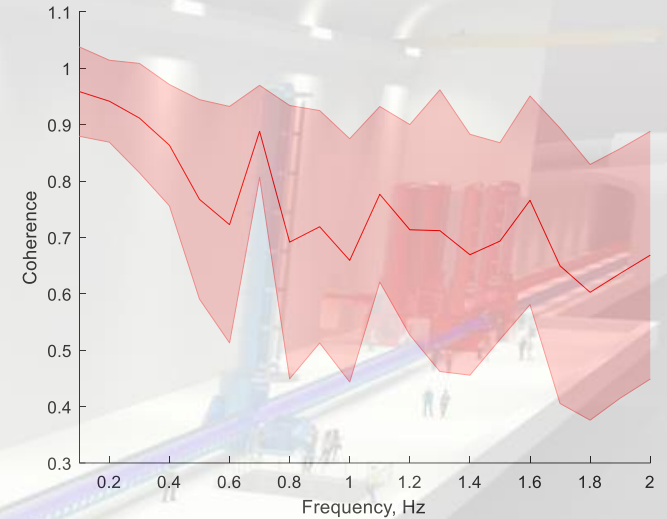


ANM Division – Env. sensors WP

Rosario De Rosa & Mariusz Suchenek

Infrasound campaign in Sardinia

- Characterization of the infrasound field in the mine, a place similar to the destination site for the ET.
- We placed infrasound microphones inside the mine, in three locations, and also outside of the mine;
- noise inside in the mine is almost same (from sensor to sensor);
- high coherence between sensors outside the mine and inside, especially for very low frequencies below 0.5 Hz;
- damping of the wall between the tunnel and the cavern about factor 10x (amplitude, 100x PSD)

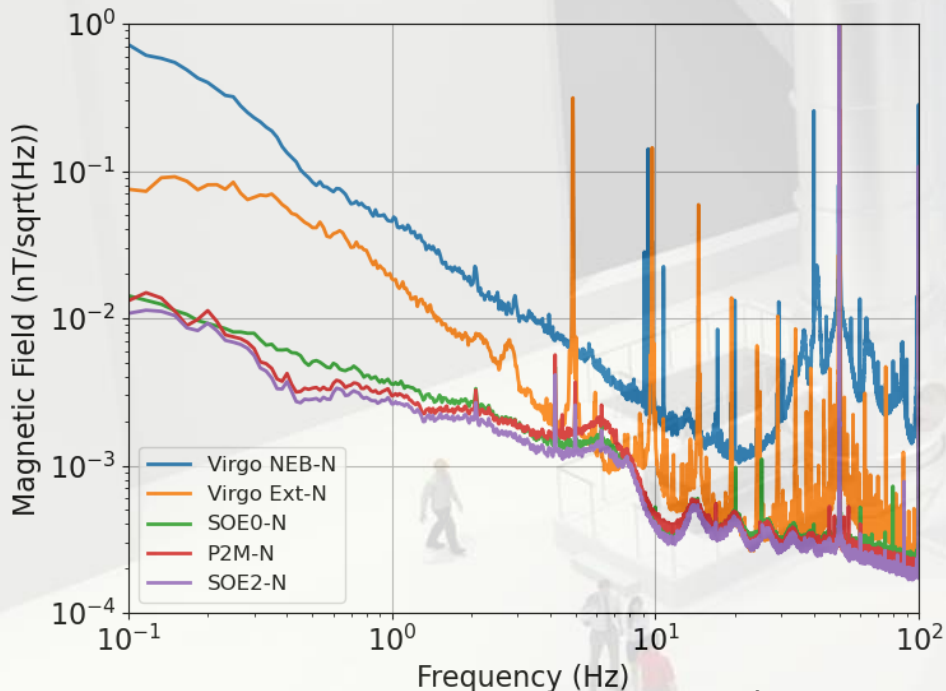


ANM Division – Env. sensors WP

Rosario De Rosa & Mariusz Suchenek

Magnetic Noise campaigning in Sardinia

- Magnetometers in Sos Enattos (surface and underground) and P2 (surface).
- Magnetic noise is strongly dependent on the location, mainly for the impact of the anthropogenic contribution.
- An example of magnetic noise spectrum for the same time, at different locations (Virgo, Sos Enattos, P2).



Sos Enattos (underground)



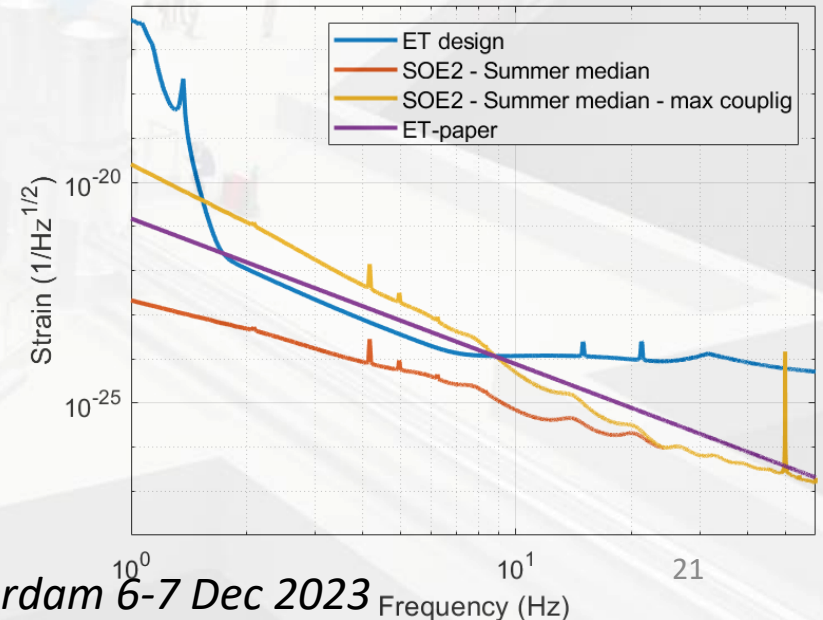
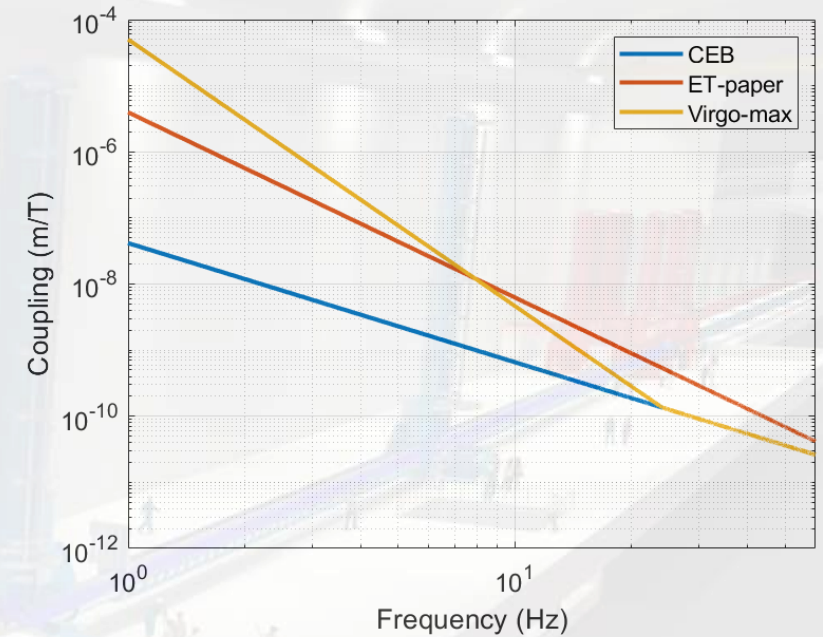
P2 (surface)

ANM Division – Env. sensors WP

Rosario De Rosa & Mariusz Suchenek

Magnetic Noise projection on ET sensitivity

- The magnetic noise projections with different assumptions, compared to the published projection.
- The **noise coupling** as measured at Virgo, including only the contribution measured at CEB, or the full contribution (CEB+NEB+WEB) is compared with the coupling used in the ET paper
- The measured coupling was used with the measurements performed in Sos Enattos to project the impact of magnetic noise on sensitivity (Coupling measured from 10Hz, extrapolated for lower frequencies)
- Need for Magnetic Noise mitigation...



ANM Division status

Magnetic noise WP

Barbara Garaventa & Irene Fiori

→ Barbara's talk today!

Inter-platform motion WP

Paolo Ruggi & Sina Koehlenbeck

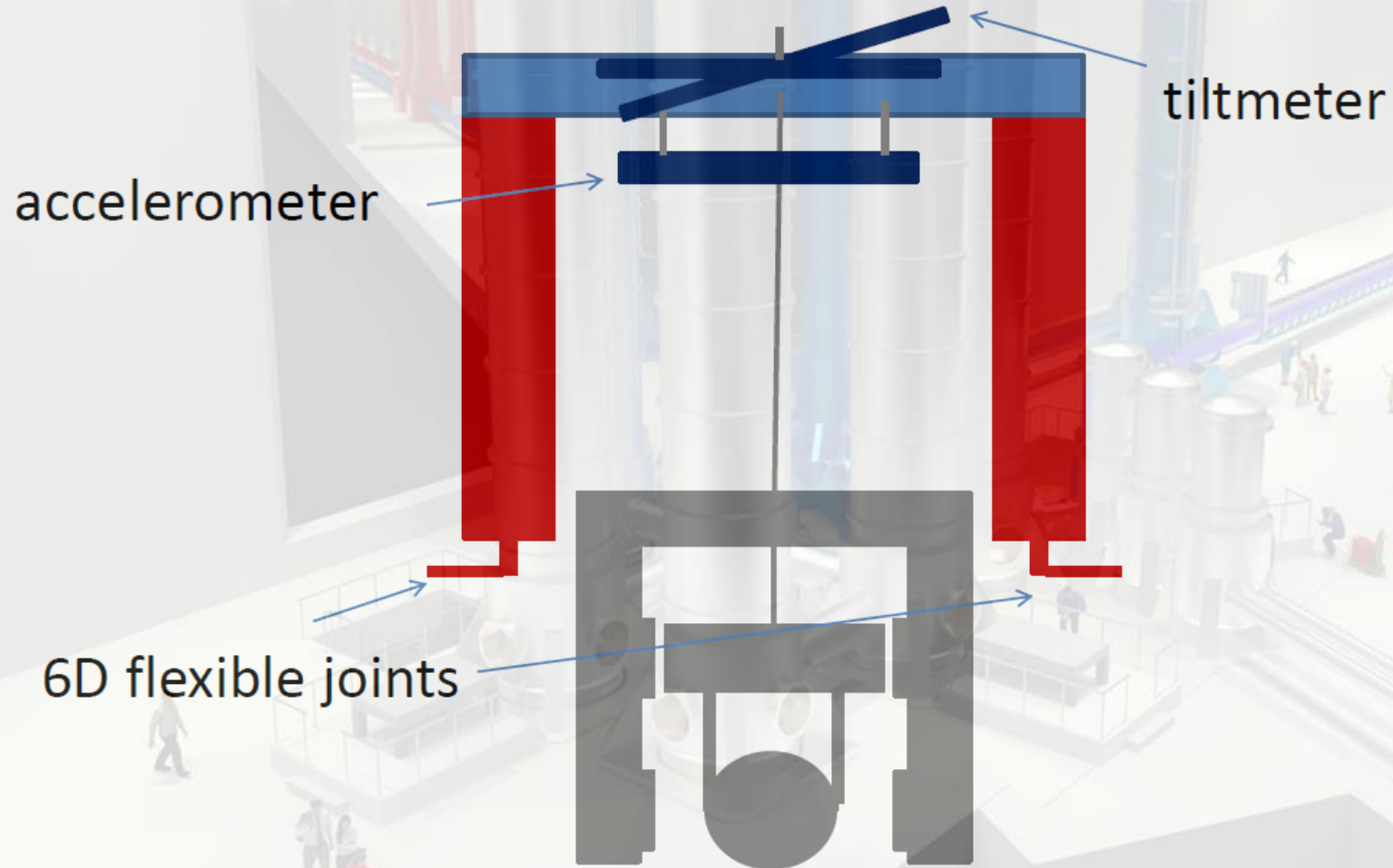
Status

- At low frequency one fundamental limitation of the sensitivity is the test mass **MECHANICAL NOISE**, a combination of **thermal noise**, **seismic noise** and **control noise**.
- The different sources need to be faced all together, by a correct design of suspension, sensors, control electronics and control strategy.
- Currently, an integrated design of a new generation suspension does not exist.
- We should work soon on the development of a suspension conceptual design, comparing different options.
- We need a modeling method, able to provide the residual motion of the test mass for given inputs. The model must include controls. The model should allow to tune parameter, find optimal solution and see if the requirements are matched.

ANM Division – Inter-platform motion WP

Paolo Ruggi & Sina Koehlenbeck

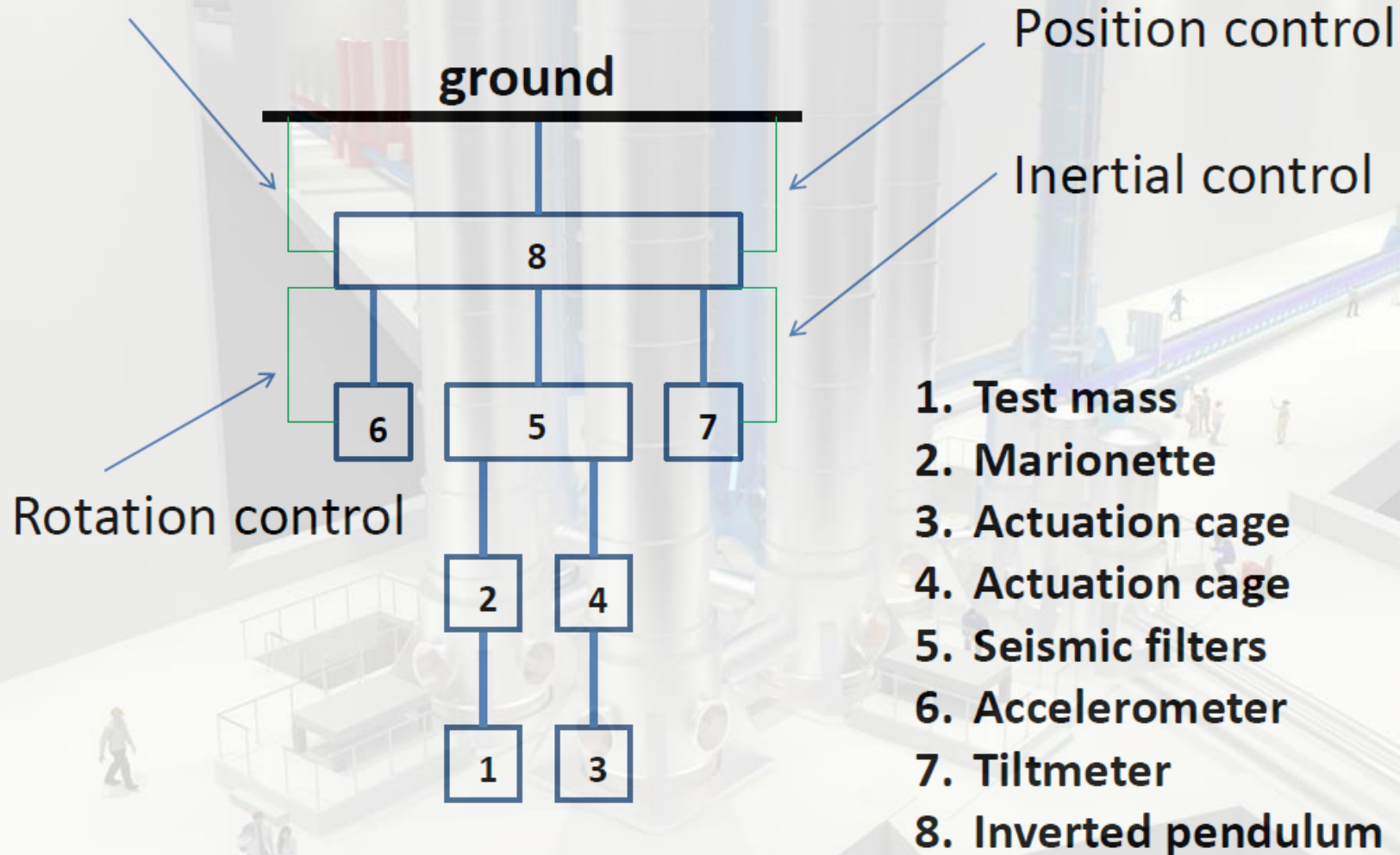
Option 1: SAT (single 6D controlled stage)



ANM Division – Inter-platform motion WP

Paolo Ruggi & Sina Koehlenbeck

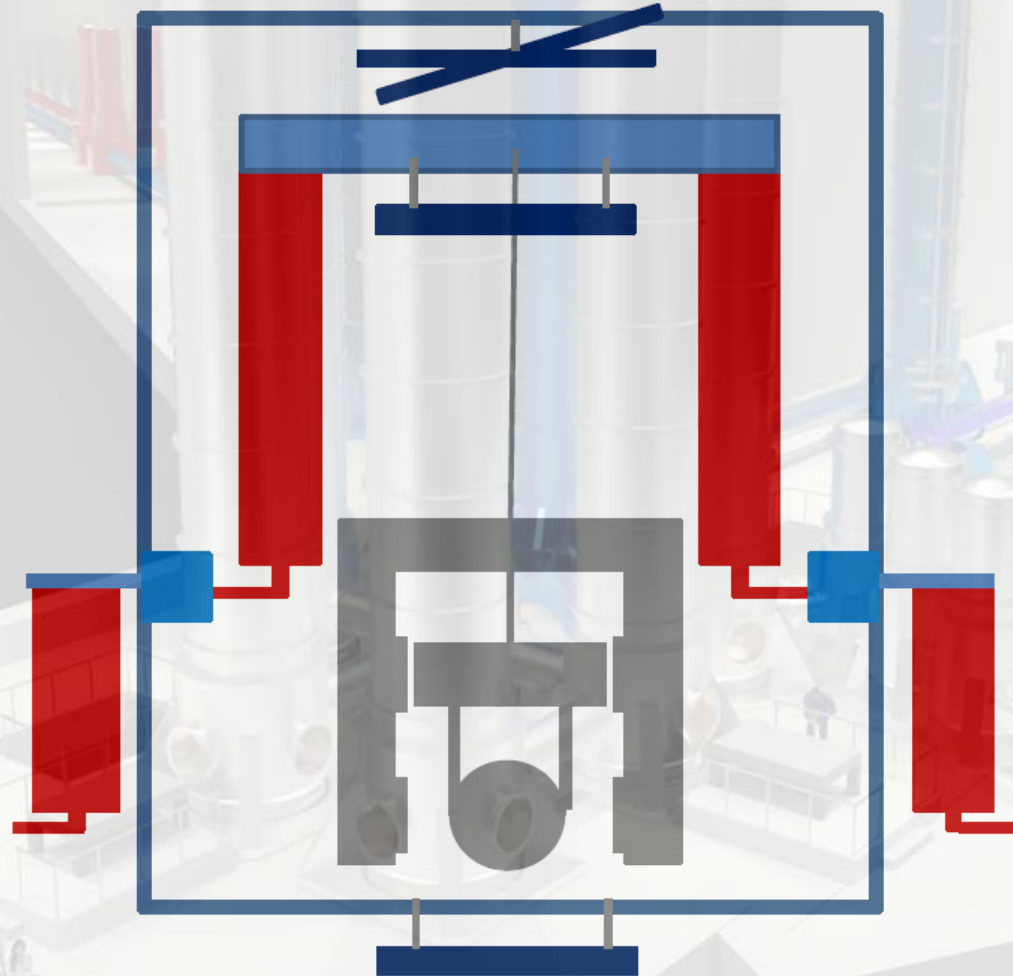
Inclination control



ANM Division – Inter-platform motion WP

Paolo Ruggi & Sina Koehlenbeck

Option 2: adding a controlled box



Modeling method

- Frequency domain: OCTOPUS now it includes the possibility to implement controls, with some limitation. Almost ready to be published and put in a gitlab repository. A model of controlled SAT is already available, and it can be used to produce noise projections.
- Time domain: needed for the development of stable and optimal controls.

ANM Division – Inter-platform motion WP

Paolo Ruggi & Sina Koehlenbeck

Plans

- Continue the development of modeling methods and tools;
- Use the existing methods and tools to produce drawings of ‘conceptual’ suspensions and configure models;
- Define a set of input variables needed to define the status of the system and make a model of them;
- Define the set of interesting output variables, compute them for the given input and define the expectation levels or the requirements;
- Modify physical quantities or control parameters to improve the outputs;
- Compare different options and select the best.

Low Frequency control noise WP

Kate Dooley & Artem Basalaev

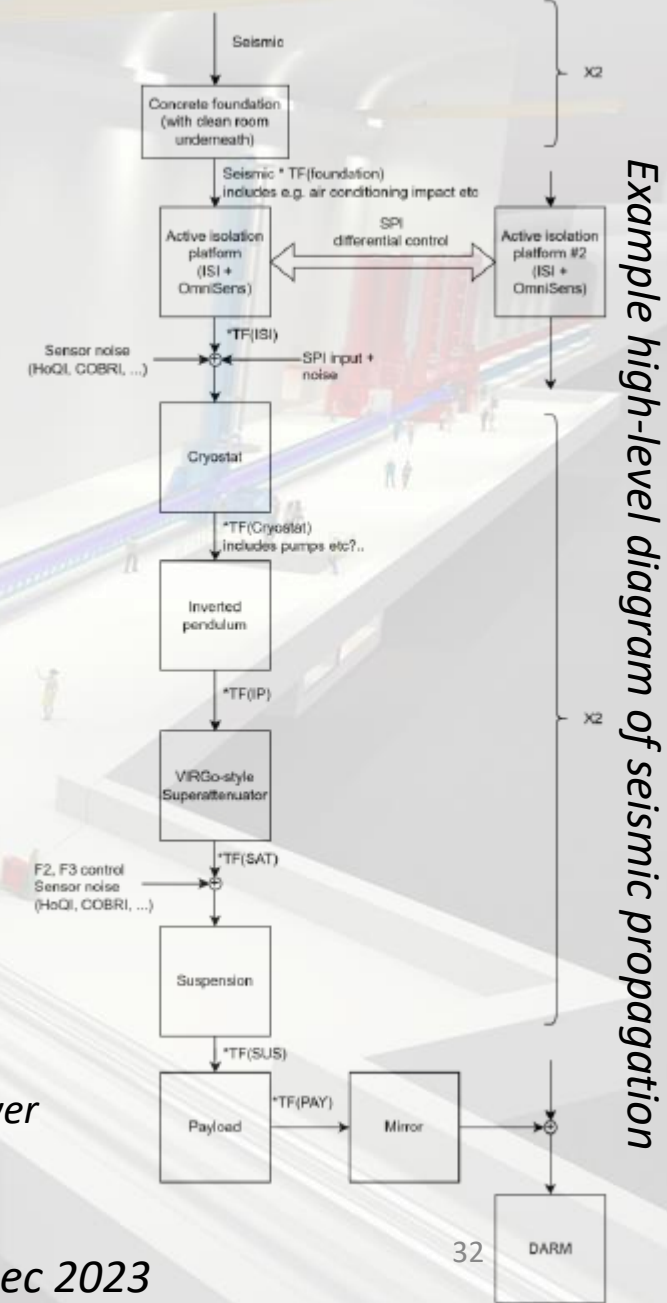
ANM Division – LF control noise WP

Kate Dooley & Artem Basalaev

Current status and Plans

- Had very productive in-person interactions at ET Symposium and GWADW this spring.
- We decided to work together with Inter-Platform Motion WP chairs and other experts in suspension platform interferometer, 6D interferometric sensors, suspension modelling, controls*
- To **produce an improved** (relative to 2020 Design Report Update) **estimate of RMS of motion and impact on ET performance** (DARM but also ASC, MICH, PRC, etc). In particular, the new model would incorporate following key design features:
 - **Differential motion** between isolated platforms controlled with SPI
 - **6D interferometric sensors** for isolated platforms
 - **Optimized local and global control**

** Team currently includes: Conor Mow-Lowry, Artem Basalaev, Katherine Dooley, Jesse van Dongen, Oliver Gerberding, Nathan Holland, Sina Koehlenbeck, Paolo Ruggi. We certainly need more people and expertise! (see next slide)*

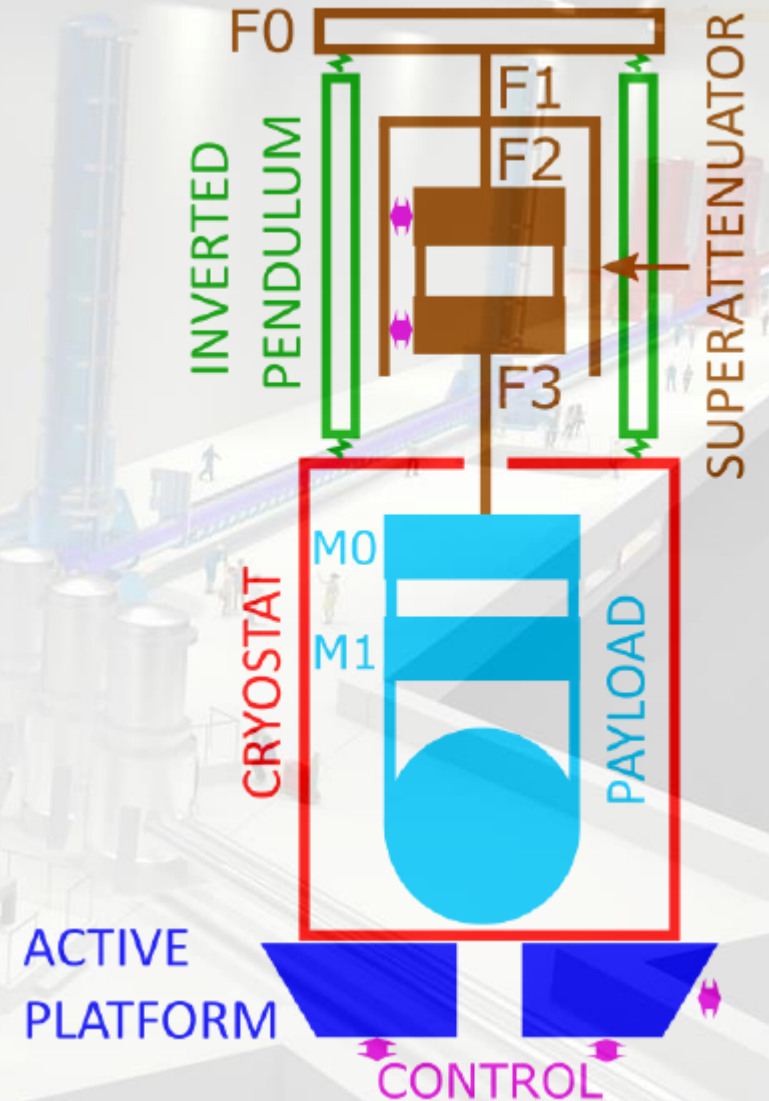


ANM Division – LF control noise WP

Kate Dooley & Artem Basalae

Current status and Plans

- Since then, we had several follow up meetings (see meeting notes on the ANM wiki page).
- We started an Overleaf document with a paper draft. Current main goal is to come up with a **rough structure**, **assign roles**, and identify areas where we are currently **missing expertise** and need to establish interactions. For example:
 - Suspension (esp. thermal noise), scattered light, cryostat and payload design...
- Dedicated workshop in Hamburg (March 2023, <https://indico.desy.de/event/42127/>).



A simplified schematic of possible isolation system model

Conclusions & take-away messages

- We need to support the **information flow between SPB/WD1&WD2 and ISB/ANM.**
- **SPB duty is to provide quality data and geological model. Noise modelization, evaluation** (also impact on detector sensitivity/duty cycle) **and mitigation is a duty of ANM**, where these aspects should be discussed.
- **Reaching ET LF sensitivity is a challenging task! 1&2G GW detector lessons...**
 Wise choice: **keep every known input noise as low as possible!**
- **Newtonian Noise modelling and cancellation must be discussed in the dedicated WP.**
- Many activities ongoing in all the other WPs (Environmental sensors, Magnetic Noise, IPM, LF control noise).
- Everyone in the collaboration interested in noise and noise mitigation should join the ANM WPs!