Istituto Nazionale di Fisica Nucleare
Sezione di PISA

New Generation SuperAttenuator (NGSA) for seismic noise suppression

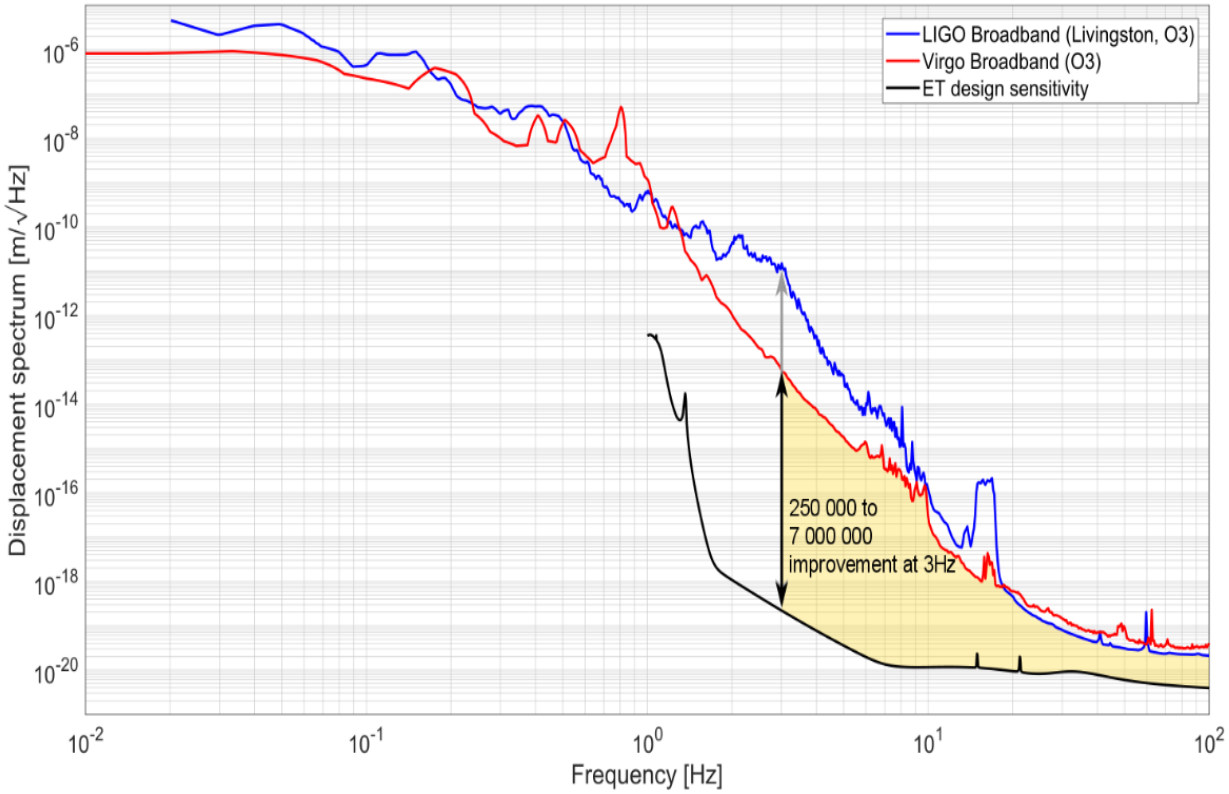
"Open Call" CSN5 for R&D Program on Third Generation Gravitational Wave Detector Einstein Telescope (ET) – Giant Laboratory

F. Frasconi – INFN Pisa

July 1st, 2022

NGSA goal: **Improvement of vibration isolation performance** for 3rd generation detectors of GW – Einstein Telescope (ET) underground giant laboratory: improve the current sensitivity by a factor 10 and extending the observation bandwidth in the low frequency region around 2 Hz

- Displacement sensitivity of the 2nd generation detetcors (O3 - Observation run 3) and ET design sensitivity
- Extending the bandwidth in the low frequency region around 2 Hz, requires an improvement with respect to the present experimental limits of more than 5 order of magnitude



NGSA: EXPERIMENTAL PROGRAM

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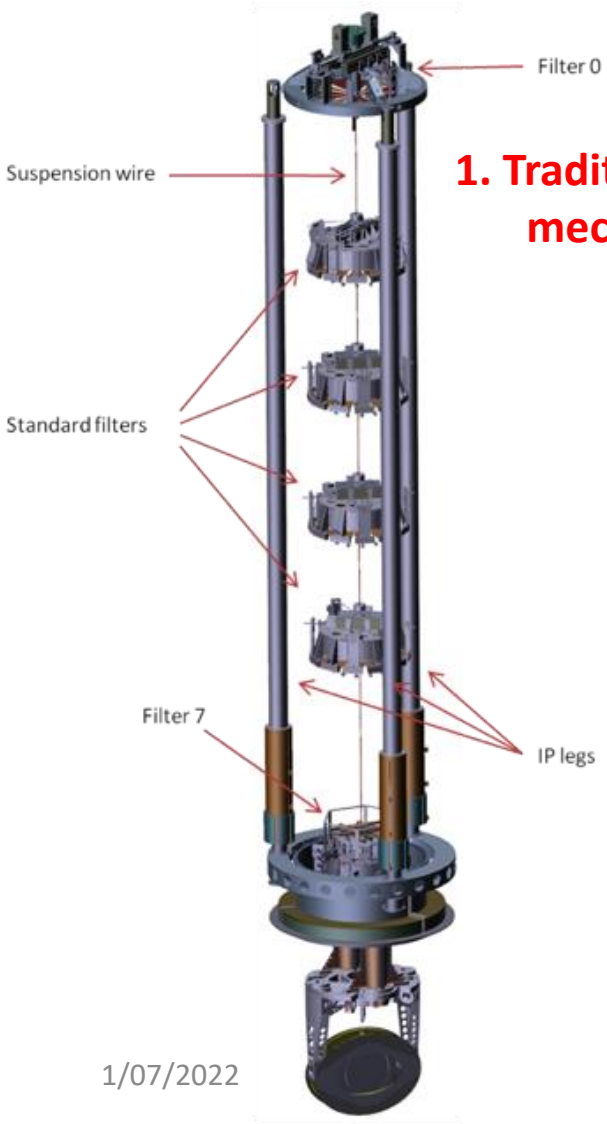
- Define guidelines for future seismic isolation systems to be extended down to 2 Hz: seismic noise is the dominant noise source in the low frequency region
- **Two different experimental lines:**

1. Based on the **AdV mechanical structure** (Inverted Pendulum, Filters chain, heavy/cryogenic payload) with the intent to better distribute the mass all along the suspension chain, improving vertical attenuation performance and keeping the total length of the structure around 12 m
2. Based on the use of a **two-stage Nested Inverted Pendulum (NIP)**: evident advantages from the point of view of the horizontal pre-isolation stages but never put in operation with many open questions (stability, automatic control, cross coupling of different d.o.f., vertical and tilt noise at ground level, …)

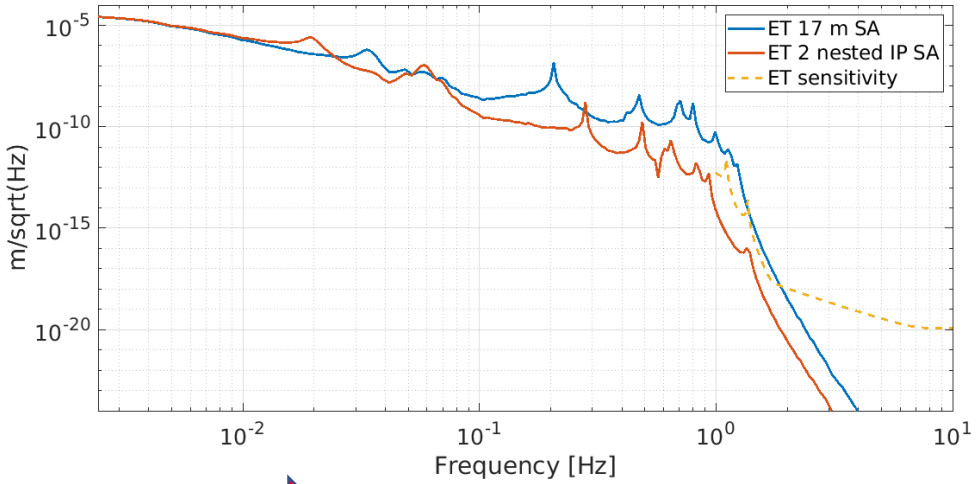
- **Present mechanical system of the SA (2nd generation) is considered compliant with 3rd generation detector (see ET Conceptual Design)**

NGSA: TWO EXPERIMENTAL LINES



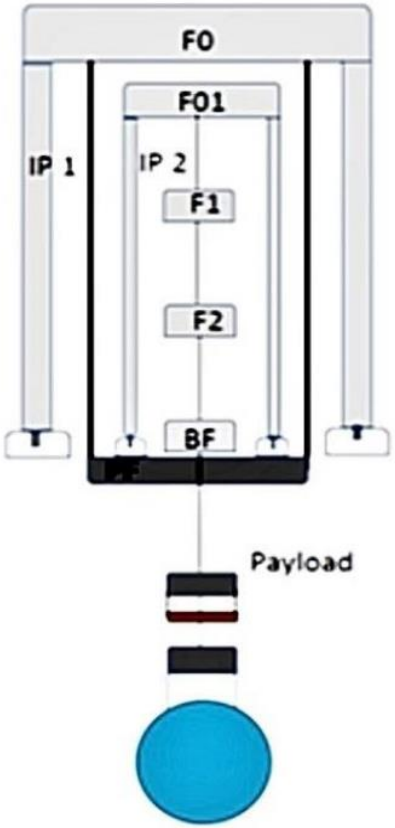
1. Traditional: based on AdV mechanical structure

Common Goal: fulfil the ET attenuation requirements keeping the whole length of the mechanical structure around 12 m



Great impact on the excavation cost of the cavern

2. Based on two-stage NIP



NGSA: PRESENT STATUS and FUTURE

- **Collaboration Project:** INFN Pi, INFN Na, LNS/SS; **Resp. Naz.**: L. Di fiore (INFN Na)

- **WP1 Simulation & Optimization of the Superattenuator (SIM)**
- Simulation in well advanced status: ready for the preliminary design of the prototype
- Iterative process to finalize NIP and new MAS designs (WP2)
- **WP2 Mechanical Filter with new Magneti Anti-Spring (MAS)**
- Good indication from SIM on improvements: reduced load of the movable apparatus (cross-bar)
- Rare-earth magnets selected (SmCo, NdFeB): material procurement in progress
- Vacuum compatibility test to be performed soon; Magnetic field measurements to be done
- **WP3 Development and test of a Nested Inverted Pendulum (NIP)**
- Clear indication from SIM for a preliminary design of a prototype in reduced scale
- Vacuum tank @ INFN Na equipped with gasket and minor components. Pumping system to be purchased
- INFN Pisa contribution to the NIP design: well defined
- **WP4 Sensing & Control (S&C)**
- Devices selection for a station test of a feedback control system concluded. Preliminary list for sensors/actuators channels done
- Purchase process in progress (LabView based) for a test station
- Preliminary set-up/configuration test in view of feedback control system use on NIP to be done

NGSA: WP1 details

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- **WP1 Simulation & Optimization of the Superattenuator (SIM) - L. Trozzo (Na)**

- Simulation in well advanced status: ready for the preliminary design of the prototype
- Iterative process to finalize NIP and new MAS designs (WP2)

See also:

- L. Trozzo et al., «New Generation Super Attenuator for Einstein Telescope: preliminary studies», presentation at GWADW 2022, 24 May 2022.

The optimization studies make use of different tools:

- A simplified analytical model that, once fixed total mass, payload mass and suspension length, allows to define an optimal distribution of masses and length along the chain (Europhys. Lett. 40 (1997) 601-606);
- A software tool, based on the impedance matrix formalism (Octopus), already developed, validated and tested,on AdV Superattenuators. It allows to compute the system mechanical TF by:
  - defining the impedence matrix of each single SA element (mass, blade spring, wire, IP flex joint and legs,….)
  - evaluation of the mechanical TF from/to any stage of the SA in 6DOF
  - taking into account servo loops for controlling and damping the SA

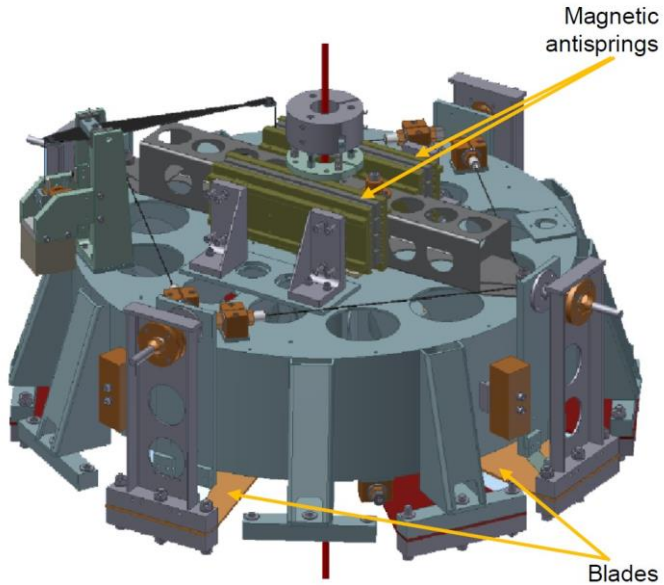
NGSA: WP2 details

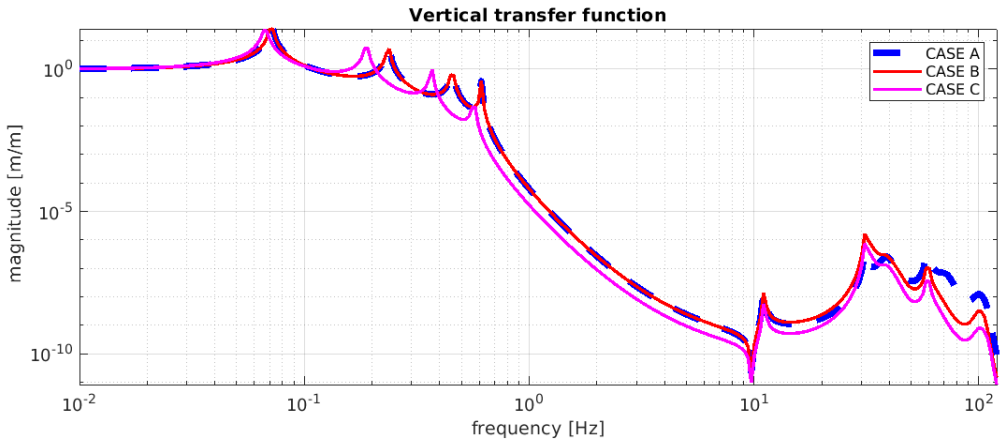
- **WP2 Mechanical Filter with new Magneti Anti-Spring (MAS) – F. Frasconi (Pi)**

- Good indication from SIM on improvements: reduced load of the movable apparatus (cross-bar)
- Rare-earth magnets selected (SmCo, NdFeB): material procurement in progress
- Vacuum compatibility test to be performed soon; Magnetic field measurements to be done

The mechanical filters of AdV SA are equipped with blade springs to support the load of the next stages. The Magnetic Anti-Springs (permanent magnets) mounted in repulsive configuration are used to decrease the vertical oscillation frequency of each stage at the level of the horizontal one.

For ET we need to suspend large masses (up to 600 kg payload) improving the Vertical Attenuation performance: rare-earth permanent magnets (SmCo, NdFeB) to reduce the load of cross-bar.

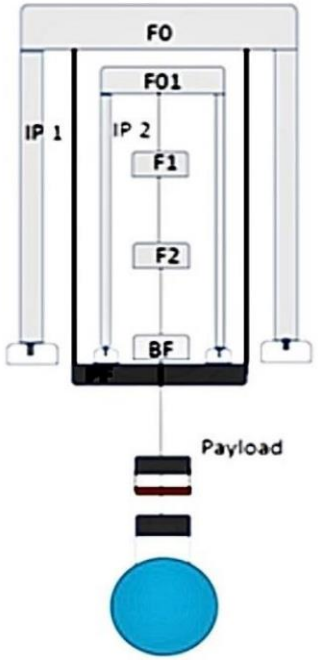




NGSA: WP3 details

- **WP3 Development and test of a Nested Inverted Pendulum (NIP) – R. De Rosa (Na)**

- Clear indication from SIM for a preliminary design of a prototype in reduced scale
- Vacuum tank @ INFN Na equipped with gasket and minor components. Pumping system to be purchased
- INFN Pisa contribution to the NIP design: well defined



The NIP prototype will be assembled at INFN Na
Due to the limited space in the laboratory and to the available vacuum chamber it will represents a prototype on scale 1:2 with:

- NIP legs length about 2m
- Dummy load 600 kg (representing filter chain and payload)
- Total mass about 1200 kg

Assembling and operration of the prototype in collaboration with LNS/SS and INFN Pi personnel

NGSA: WP4 details

- **WP4 Sensing & Control (S&C) – A. Gennai (Pi)**

- Devices selection for a station test of a feedback control system concluded. Preliminary list of sensors/actuators channels done
- Purchase process in progress (LabView based) for a test station
- Preliminary set-up/configuration test in view of feedback control system use on NIP to be done

- In a seismic isolation soppression a feedback control system play a fondamental role;
- The main purpose of this Work Packadge is providing a control system for the NIP prototype commissioning and test;
- Another fondamental outcome of this WP is represented by the definition of requirements and architectural design of a control system in future GW detectors for both hardware and software.

NGSA: PERSONNEL & Services Requests

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Name	Research Unit	FTE	Contribution to Work Packages
Franco Frasconi	INFN Pisa	0.4	WP1, WP2, WP4
Alberto Gennai	INFN Pisa	0.4	WP1, WP3, WP4
Federico Pilo	INFN Pisa	0.1	WP2
AdR#2 (*)	INFN Pisa	1.0	WP2, WP4
Total	INFN Pisa	1.9	

(*) Competition Notice for AdR#2 to be published soon

Services Request

- Standard support from “Alte Tecnologie People” for Laboratory daily life
- Mechanical workshop for construction of small mechanical parts for MAS (WP2) prototype support to be tested [1mU/year]

NGSA: Budget for 2023 - PRELIMINARY

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- **Budget so far (2022)**

- Licenze Software: 14 kEuro (sj) DA SBLOCCCARE
- Impianti (Costruzioni Apparati): 76 kEuro (sj) DA SBLOCCARE 49 kEuro SBLOCCATO
- Inventariabile: 14 kEuro (sj) SBLOCCATO e USATO
- Personale: 31kEuro DISPONIBILE Bando AdR (1 anno) da emettere prossimamente

- **Budget Request for 2023 – VERY PRELIMINARY**

- Consumi: 15 kEuro
- Licenze Software: 5 kEuro
- Impianti (Costruzioni Apparati): 15 kEuro
- Missioni: 8 kEuro
- Personale: 31 kEuro - Bando AdR (Secondo anno)

TOTALE: **74 kEuro**