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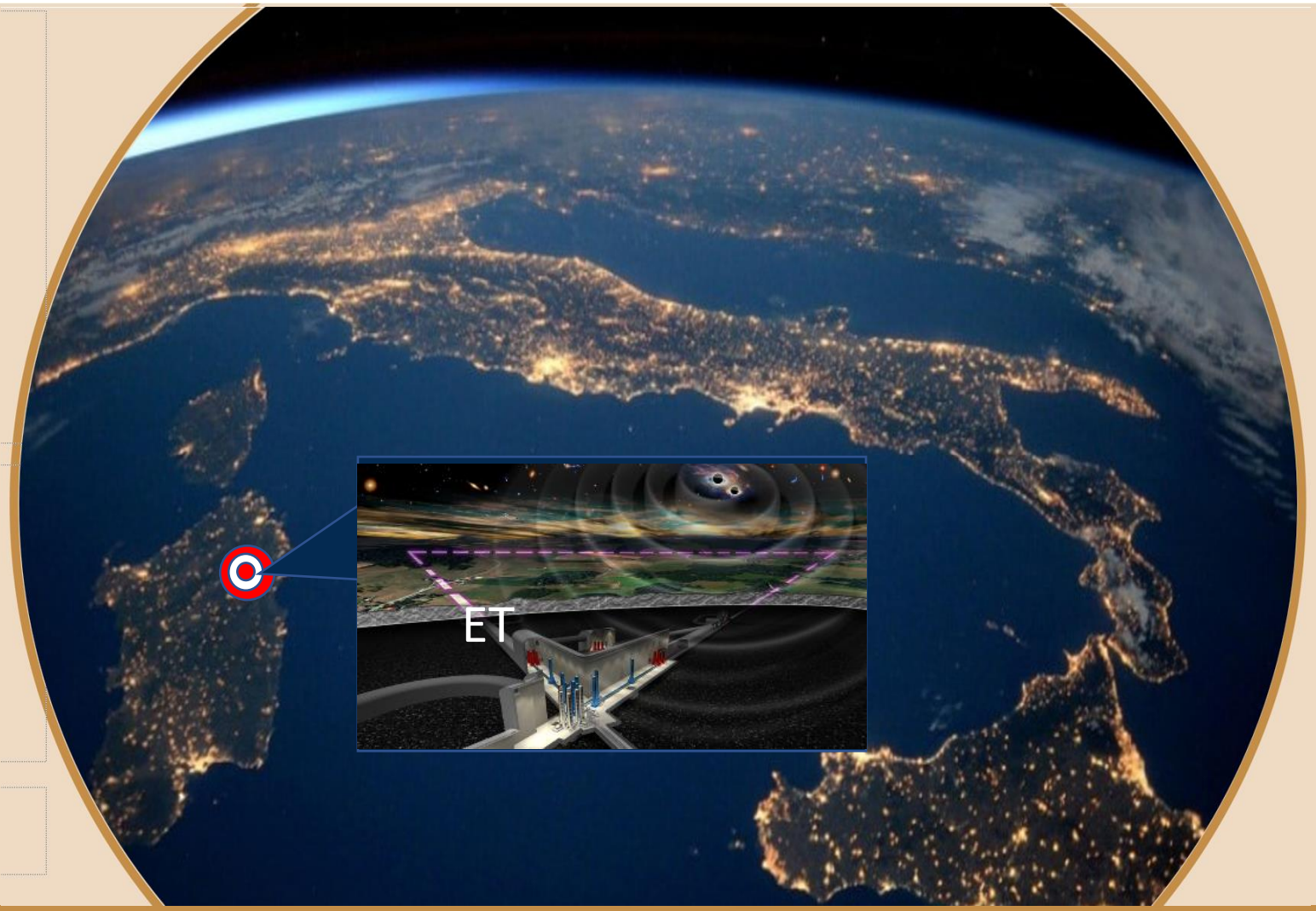
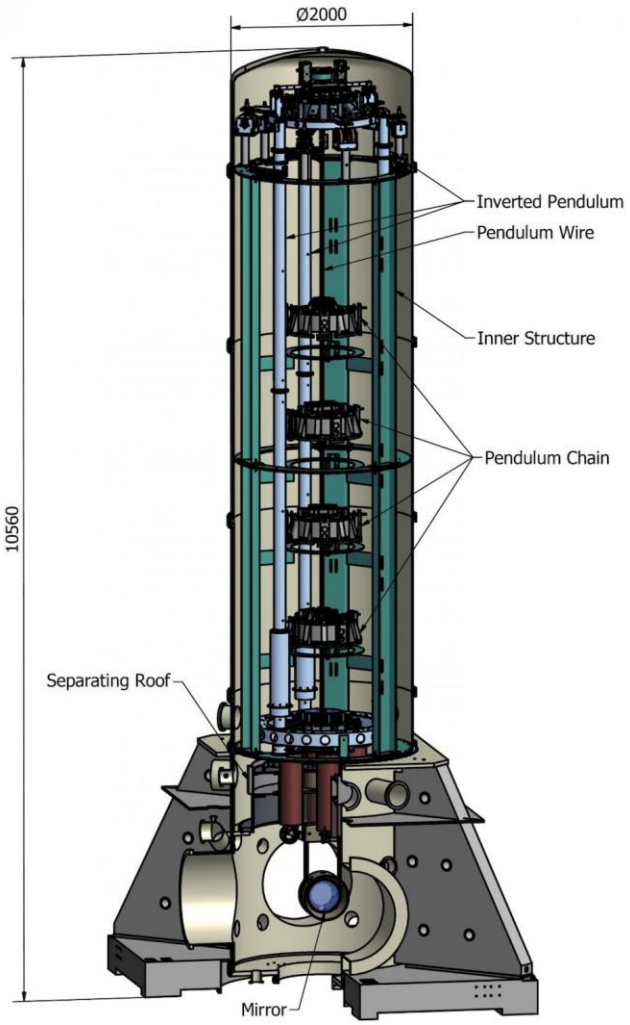
INFN

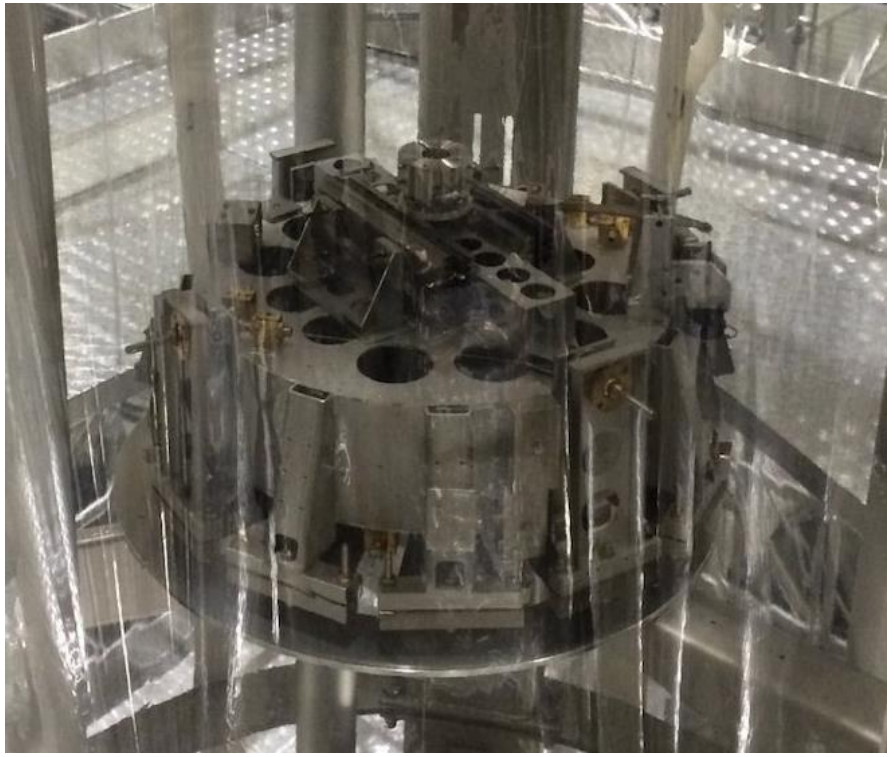
Sospensioni in ETIC (programma Pisa-Napoli)





The seismic noise reduction has been one of the major effort and success of the Virgo experiment, especially of the Italian community, and one of the most important heritage left toward the third generation observatories

On the left the so-called **SuperAttenuato**r a chain of seismic isolations system and on the right a **single element** of the chain



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We will focus on seismic isolation, starting from the Virgo heritage

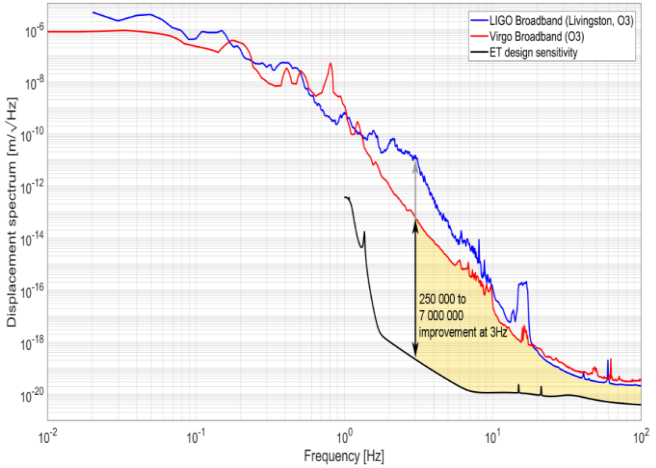
The Virgo Super-Attenuator is the best seismic isolator in the world. It is the result of years of R&D in INFN and was crucial to allow the extension of the antenna detection band down to 10 Hz.

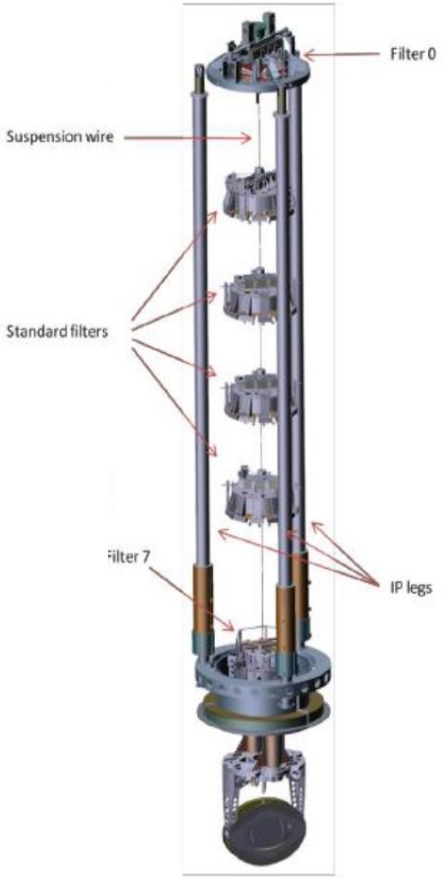
The SA is made by a pre-isolator (inverted-pendulum), a passive filter chain and a Payload (mirror and control elements). The total length is about 9 m.

The ET-LF design sensitivity requires an improvement by a factor 10^5 around 2-3 Hz with respect to the present Virgo sensitivity

INFN holds a consolidated leadership on this subject

Keeping this leadership will be essential for role of INFN in the development of ET.





Why and R&D for ET

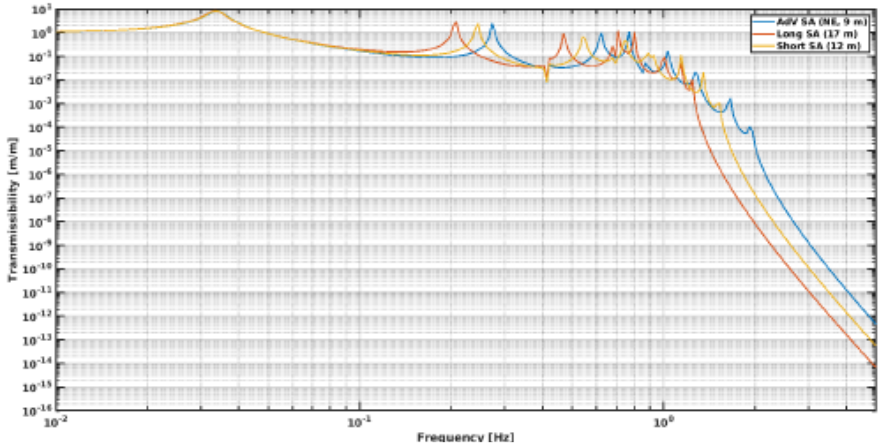
In the current ET design a SA with a total length of 17 m is assumed.

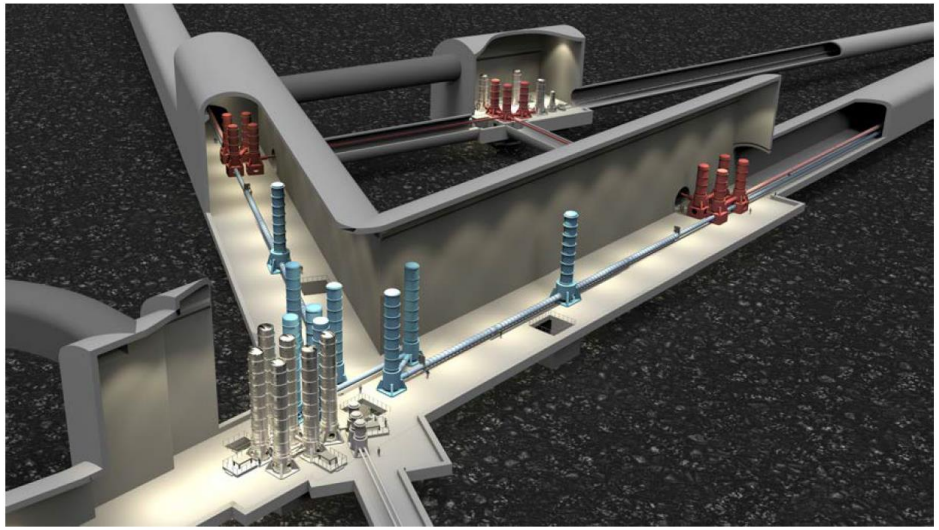
This implies very large caverns (up to 30 meter in height) with big cost and complexity.

Further difficulties come form the need to hang a cryogenic payload with a total mass of about 600 kg.

In order to fulfill the ET requirements, while keeping the total SA length around 12 m, a detailed R&D program is needed

The final goal is to demonstrate the possibility of using the new SuperAttenuator and use it in the almost 100 towers to be build in ET





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Present R&D on suspensions

PRIN "**Toward high mass and high Z black holes at Sos Enattos, the Sardinian site for the Einstein Telescope"** - F. Fidecaro - Università di Pisa – Università Federico II Napoli – Università di Sassari - Università di Urbino – INFN

CALL_INFN "**NGSA New Generation Super Attenuator"** - L. Di Fiore – INFN (Sezioni di Napoli – Pisa - LNS/Sassari)

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NGSA (New Generation Super-Attenuator) – similar project for the PRIN

The main ideas are organized in two research lines:

1) Traditional solution (optimized SA)

- Starting form the Advanced Virgo SA architecture, we will study the optimization of the mass distribution along the isolation chain and the improvement of the performance of the Magnetic Anti-Springs (MAS) of the single filters.
- The goal is to keep the total length around 12 m.
- If necessary, an active pre-isolator platforms, at the base of the IP, will be considered.

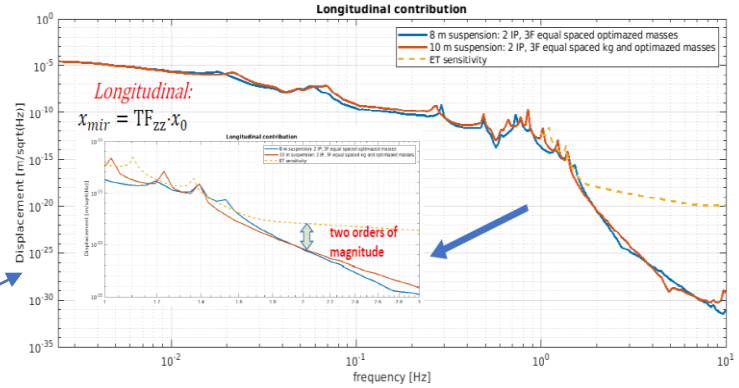
2) *Alternative solution* (Nested inverted pendulum pre-isolator)

- Study of an innovative solution, based on a two-stage Nested Inverted Pendulum (NIP)
- This solution allows a better horizontal attenuation of the pre-isolator but has never been experimentally demonstrated.
- Open questions to be addressed: reliability, stability, control systems, cross talks and vertical and angular noise suppression.

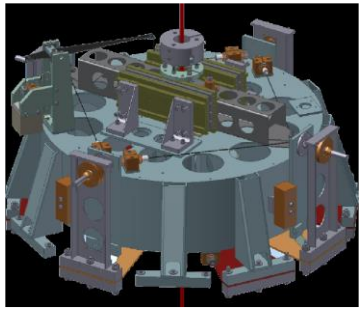
Final goal, after comparison of the two alternatives, will be the definition of the Conceptual Design of the SA for the ET Antenna.

The WP lines of NSGA : these are the typical research activities developed in Suspension design, Project, Test

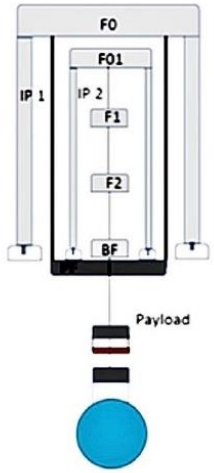
WP1 – Simulation and optimization of the Superattenuator Responsabile: L. Trozzo (INFN-NA)



WP2 – Mechanical filter with improved Magnetic Anti-Spring (MAS) Responsabile: F. Frasconi (INFN-PI)



WP3 – Development and test of a Nested Inverted Pendulum (NIP) Responsabile: R. De Rosa (INFN-NA)



WP4 – Sensing and Control (S&C) Responsabile: A. Gennai (INFN PI)

Simulations and mechanical filter improvements

- Use of commercial packages like Ansys, Comsol (both for mechanical and thermal simulations) and also home-made programs like Octopus, developed in EGO
- Filter improvements: search of new materials particularly for permanent magnets – new filter design especially improving the mass of each filter towards few hundreds kg each

Inverted pendulums and sensors and controls

- Inverted pendulum is a mechanical system, few meter tall that support the platform that suspends the filer chains – the main attempt is to design a double inverted pendulum so that the passive attenuation is increased succeeding in realizing a controllable system
- Sensors: a quite large activity, historically important in Virgo, that spans from home made accelerometers, speedmeters, tiltmeters to use of commercial systems when possible.

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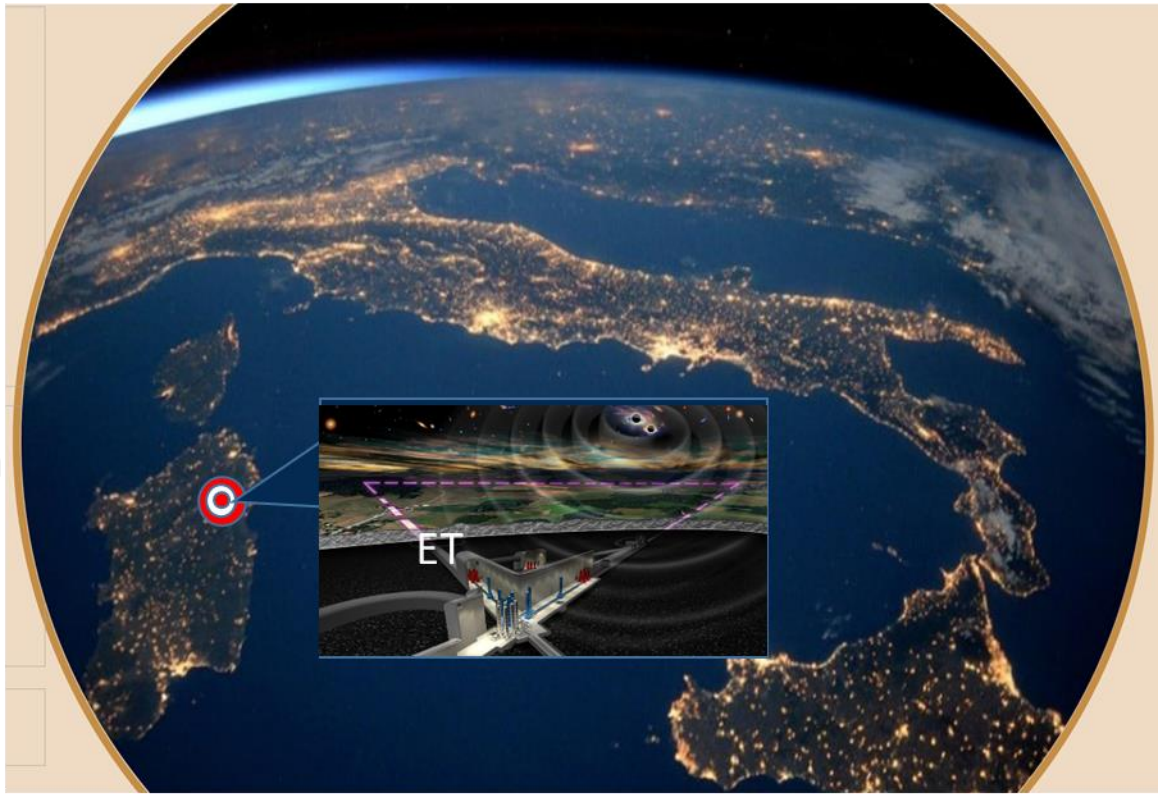
BACk to ETIC: PISA

Breve Resoconto del Progetto ET-ETIC



Unità di Ricerca – INFN Pisa

SAMaNET

F. Frasconi

15 Febbraio, 2023

SAMaNET

Unità di Ricerca – INFN Pisa

Nell'ambito del Progetto ET-ETIC, presso i Laboratori della Sezione **INFN Pisa** queste le attività previste:

- **Allestimento di set-up sperimentali** con nuova strumentazione da laboratorio per sviluppo, test, validazione e caratterizzazione di nuove tecnologie per la progettazione/prototipizzazione della nuova generazione di Superattenuatori (SA) dell'iterferometro ET
- **Studi di ottimizzazione delle performance passive dei filtri meccanici** basati su nuove anti-molle magnetiche
- **Studio e sviluppo di nuovi materiali tecnologicamente avanzati** per la progettazione di elementi elastici
- **Studi di compatibilità** di elementi meccanici usati in ambiente di Ultra Alto Vuoto e/o a temperature Criogeniche

Sviluppo di sensori/attuatori a basso rumore:

- Test di nuovi devices, caratterizzazione per compatibilità e.m. e misure di alta precisione

Sviluppo di nuove schede di elettronica per il controllo in retroazione dei SA

- Studio e implementazione di nuove strategie di controllo in retroazione
- Sviluppo e prototipizzazione di piattaforme per la compensazione dei micromovimenti di rotazione

SAMaNET

Investimenti PNRR – INFN Pisa

Il Progetto ET-ETIC per la Research Unit **INFN Pisa** prevede l'ammodernamento della strumentazione di laboratorio nonchè l'acquisizione di nuove apparecchiature per lo sviluppo e i test delle tecnologie che verranno introdotte nella progettazione dei **Superattenuatori**: **la struttura meccanica controllata in feedback che ha permesso l'osservazione del flebile segnale gravitazionale con l'interferometro Advance VIRGO.** Per questo equipaggeremo il nostro laboratorio con:

Investimenti

- Sensori magnetici e relativa elettronica di alimentazione e calibrazione (studi di compatibilità e.m.)
- Sistema di acquisizione dati e controllo AD/DA da laboratorio
- Microscopio elettronico di precision per studi di materiali e diagnostica
- Analizzatore di spettri a 4ch per studio e caratterizzazione Superattenuatori di Nuova Generazione
- Sistemi di pompaggio e sensori di monitoring per test di compatibilità in Alto Vuoto e temperature Criogeniche
- Sistema di cancellazione del rumore magnetico triassiale e relativa sensoristica
- Workstation dedicata ad acquisizione dati per studi di compatibilità e.m. con relativi upgrade di sistemi già esistenti

Programma ETIC NAPOLI

- Adattamento di un nuovo laboratorio (che in passato ospitava un acceleratore) di circa 200 m2
- Ammodernamento del laboratorio di «Fisica della Gravitazione»
- Acquisto di materiale di elettronica, sensoristica, acquisizione dati, sistemi di controllo, componentistica per sistemi da vuoto

Programma acquisti INFN Napoli

1	**Attrezzature**			**Impianti**	
2	Lathe and accessories	180327,9		Other mixed electronics	28688,52
3	Ultra High Vacuum Kelvin Probe System and optomechanical sensors	31868		Mechanic equipment	16393
4	ion beam gun with power control unit	34320		Sensors and electronics	40983
5	Workstations	6557,377		Actuators and electronics	49180,33
6	Control System	90163		Electronics (misc equipments, UPS)	77868,85
7	Server and Storage	24590,16		Vacuum chambers	98360,66
8	Cleaning equipments	40983,61		Accessories	24590
9	Clean boxes for optical benches	49180,33		Acoustic Isolation	8196,72
10	Optical Bench	40983		High speed Detectors	32786
11	Lasers	81967,21		Precision Actuators	40983,61
12	DAQ System	40983,61		Components	6000
13	AHU system	49180			
14	Pumping system	40983			
15	Spectrum Analyzer	49180,33			
16	Server and Storage	24590,16			
17	Control System	70163			
18					

Programma acquisti UNINA

	A	B
1	**Infrastructure works**	
2	Refurbishment of lab section 1	24590
3	Refurbishment of lab section 2	24590
4	Design	32786,89
5	Laboratory Infrastructure	69672,13
6	Plinths	200819,7
7	Support room	73770
8	Services (electrics, network, safety, plumbing)	146721,3
9	Crane Refurbishment	20491
10	Clean Area Equipments	208195
11		

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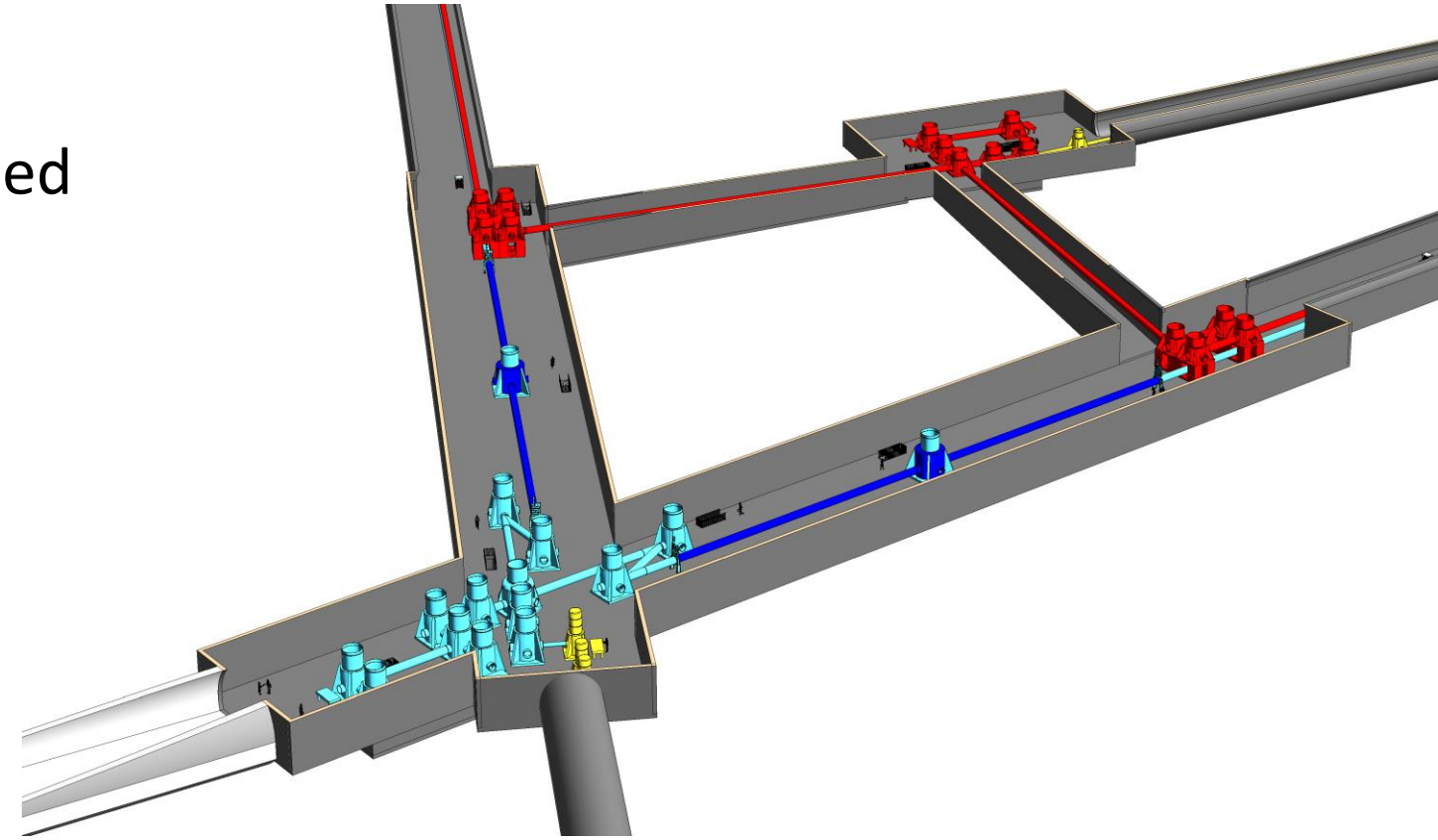
Conclusions

- The Seismic isolation is an important Italian research line also in ET
- The R&D activities are presently funded with investments on laboratory scale
- The ETIC programme is a great infrastructural support
- The main goal is to arrive at the final design and use in ET scale, where about 100 towers equipped with SuperAttenuators will be build



Thank you for your attention

Spares

WP1 – Simulation and optimization of the Superattenuator

The optimization study will make use of different tools:

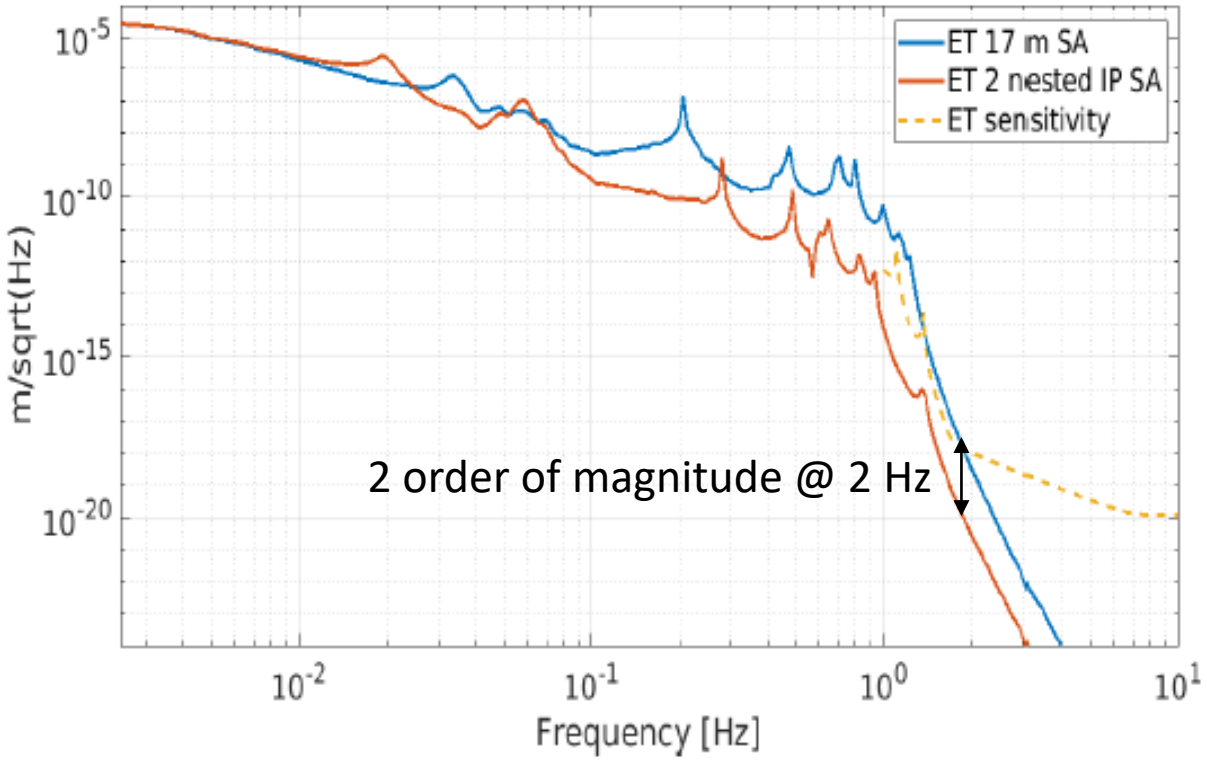
- A simplified analytical model that, once fixed total mass, payload mass and suspension length, allows to define an optimal distribution of masses and length along the chain[1].

- A software tool, based on the impedance matrix formalism, already developed, validated and tested, for the simulation of the Virgo Suspension. It allows to compute the system mechanical TF by:
  1) defining the impedence matrix of each single SA element (mass, blade spring, wire, IP flex joint and legs,….)
  2) computing, in 6 DOF, the complete TF from/to any stage of the SA
  3) Taking into account servo loops for controlling and damping the SA

- CAD design tools for FEM analysis

1) *Optimization of multipendular seismic suspensions for interferometric gravitational-wave detectors,* A. Bove, L. Di Fiore, E. Calloni and A. Grado, ***Europhys. Lett.* 40** (1997) 601-606).

example of simulation(I): 17 m SA (1 IP) compared to a 10 m SA (2 NIP)



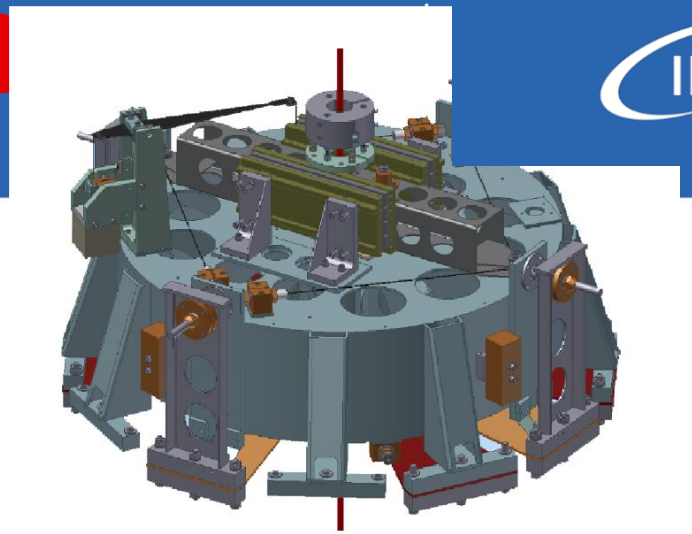
WP2 – Mechanical filter with improved Magnetic Anti-Spring (MAS)

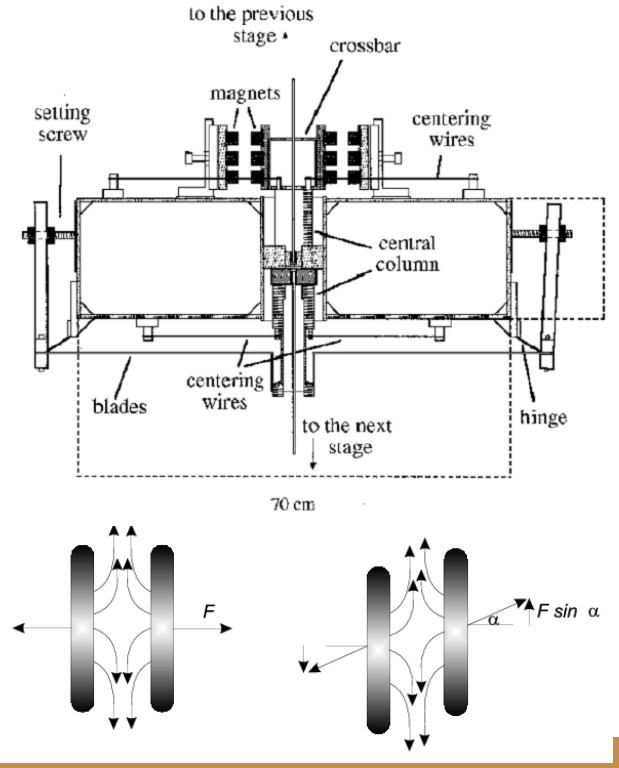
The filter of the Virgo SA are equipped with blade springs to support the weight so the subsequent stages, and magnetic anti-springs (made of ferrite magnets) to decrease the resonance frequency of the single filter.

The need to suspend much larger masses for ET, with a payload of about 600 kg, requires e complete revision of the design.
In particular:

- it will be studied a new geometry for the maraging alloy blades
- Rare earth magnets (SmCo or NdFeB) will be used for anti-spring that will allow larger repulsive forces keeping a limited volume.
- Issue like Barkhausen magnetic noise will be considered in selecting magnetic materials

A complete prototype filter will be assembled and tested in PISA Laboratory





WP3 – Development and test of a Nested Inverted Pendulum (NIP)

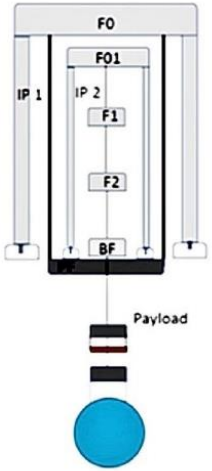
The prototype will be assembled in the Napoli Gravitational Physics laboratory.

The system should be representative of a full-size SA with a total length of 10 m, NIP legs of 4 m, a chain of passive filters and a payload of about 600 kg, for a total mass around 2600 kg.

Due to the limited space in the lab, and the size of the available vacuum chamber, we will build a scale 1:2 prototype:

- NIP legs length ~ 2 m
- Dummy mass of 600 kg (representing filters and payload)
- Total mass of ~ 1200 kg

The LNS/Sassari group will participate to construction, assembling and test. This will be a good opportunity for young scientist to acquire experience seismic isolation systems



WP4 – Sensing and Control (S&C)

In a seismic isolation system, control plays fundamental role.

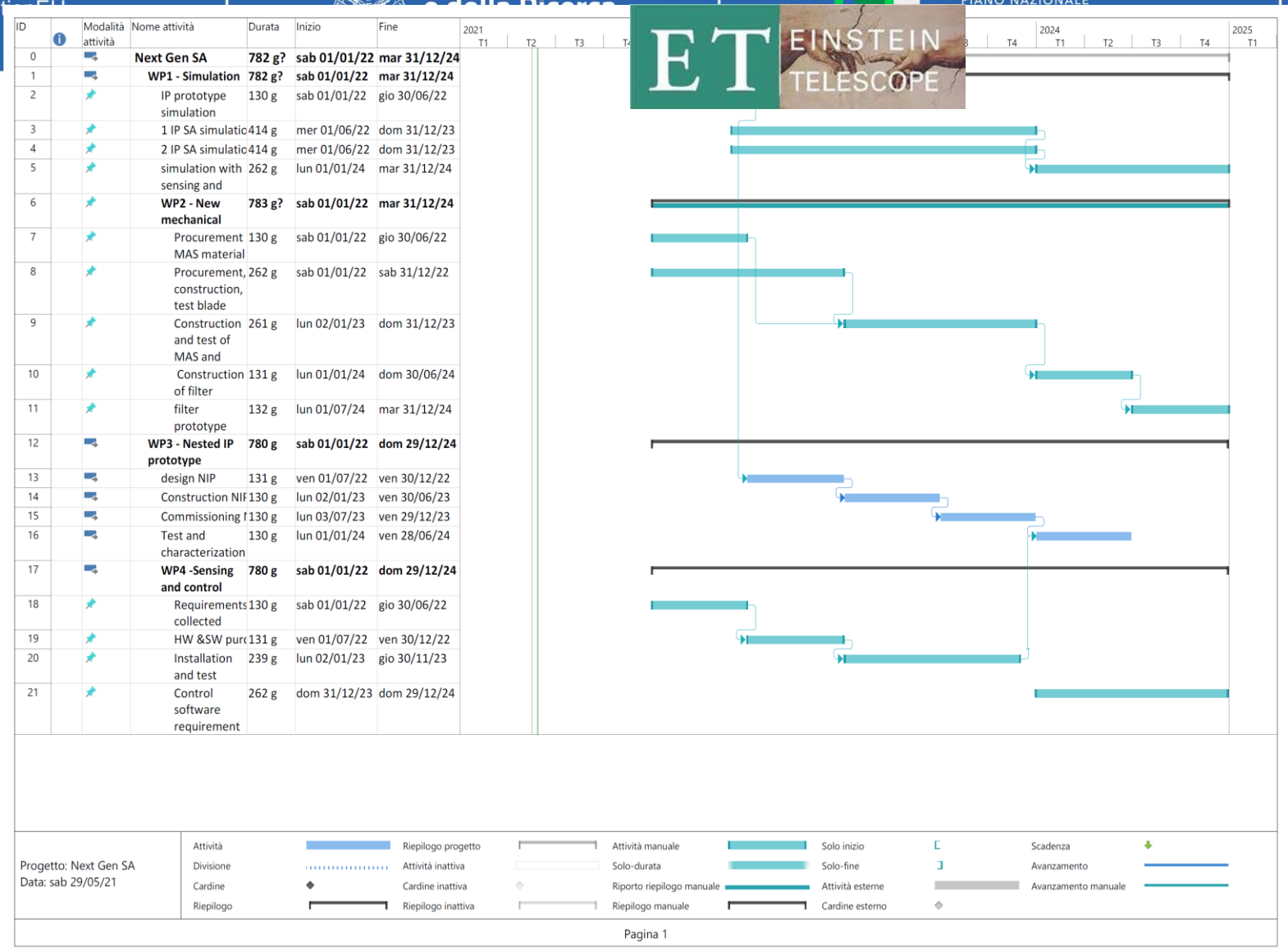
The main purpose of this Work Package is providing a control system for NIP commissioning and test.
Another import outcome will be the definitions of requirements and the architectural design of control system in future GW detectors for both hardware and software.

Preliminary list of hardware and software:

- One 3-axis seismometer to precisely measure ground movement.
- 8 accelerometers and 8 displacement sensors (one for each control axis)
- 8 optical lever sensors for sensing angular displacement
- 8 stepping motors
- 2 motor controllers
- 8 coil-magnet pair actuators

Control Unit: based on a PXI System from National Instruments, with a suitable number of I/O modules
Pre-selected PXI controller and processing unit is PXIe-8880 RT, an Intel Xeon 8-Core for PXI Express.
Control Software:
Most of control software can be developed using LabView. Specific tasks requiring higher performances could be handled by additional DSP-based processing unit

GANTT chart



ID	Modalità attività	Nome attività	Durata	Inizio	Fine
0		**Next Gen SA**	**782 g?**	**sab 01/01/22**	**mar 31/12/24**
1		**WP1 - Simulation**	**782 g?**	**sab 01/01/22**	**mar 31/12/24**
2		IP prototype simulation	130 g	sab 01/01/22	gio 30/06/22
3		1 IP SA simulatic	414 g	mer 01/06/22	dom 31/12/23
4		2 IP SA simulatic	414 g	mer 01/06/22	dom 31/12/23
5		simulation with sensing and	262 g	lun 01/01/24	mar 31/12/24
6		**WP2 - New mechanical**	**783 g?**	**sab 01/01/22**	**mar 31/12/24**
7		Procurement MAS material	130 g	sab 01/01/22	gio 30/06/22
8		Procurement, construction, test blade	262 g	sab 01/01/22	sab 31/12/22
9		Construction and test of MAS and	261 g	lun 02/01/23	dom 31/12/23
10		Construction of filter	131 g	lun 01/01/24	dom 30/06/24
11		filter prototype	132 g	lun 01/07/24	mar 31/12/24
12		**WP3 - Nested IP prototype**	**780 g**	**sab 01/01/22**	**dom 29/12/24**
13		design NIP	131 g	ven 01/07/22	ven 30/12/22
14		Construction NIF	130 g	lun 02/01/23	ven 30/06/23
15		Commissioning f	130 g	lun 03/07/23	ven 29/12/23
16		Test and characterization	130 g	lun 01/01/24	ven 28/06/24
17		**WP4 -Sensing and control**	**780 g**	**sab 01/01/22**	**dom 29/12/24**
18		Requirements collected	130 g	sab 01/01/22	gio 30/06/22
19		HW &SW pur	131 g	ven 01/07/22	ven 30/12/22
20		Installation and test	239 g	lun 02/01/23	gio 30/11/23
21		Control software requirement	262 g	dom 31/12/23	dom 29/12/24