Einstein Telescope: sfide tecnologiche e opportunità per l'industria

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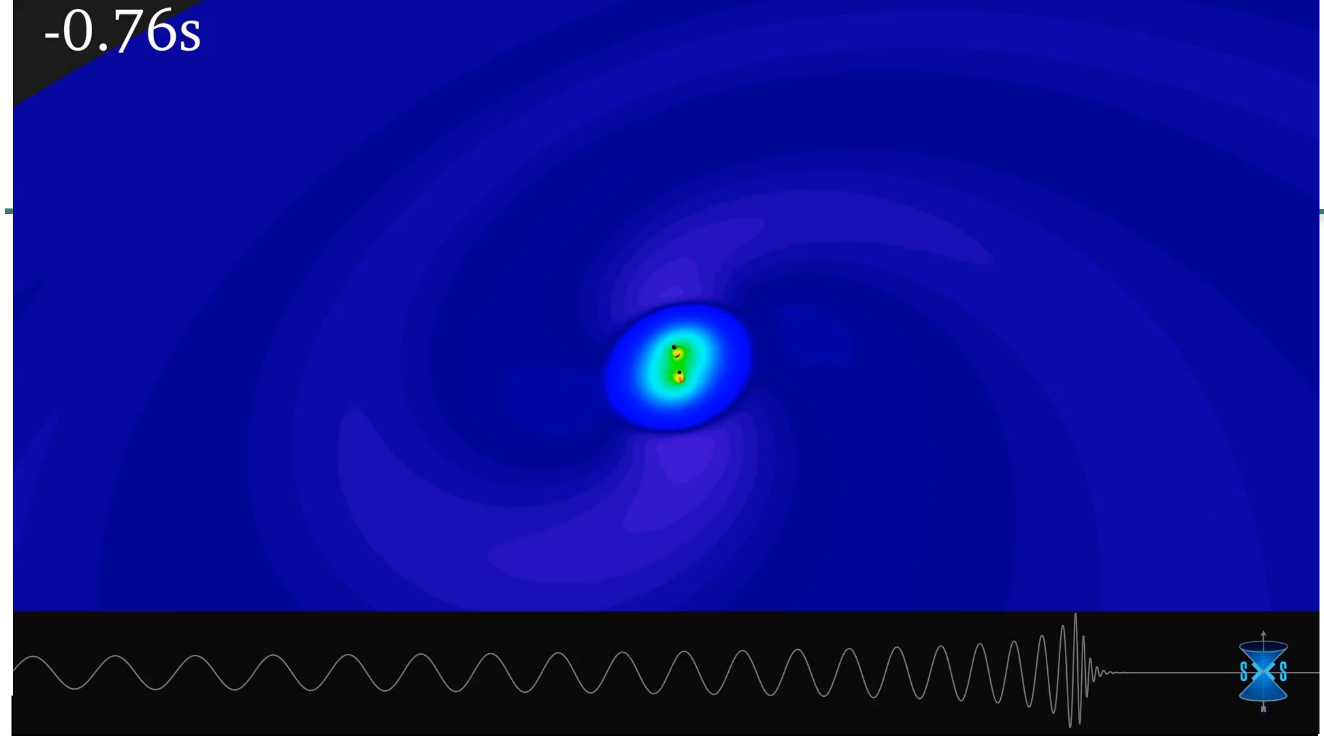
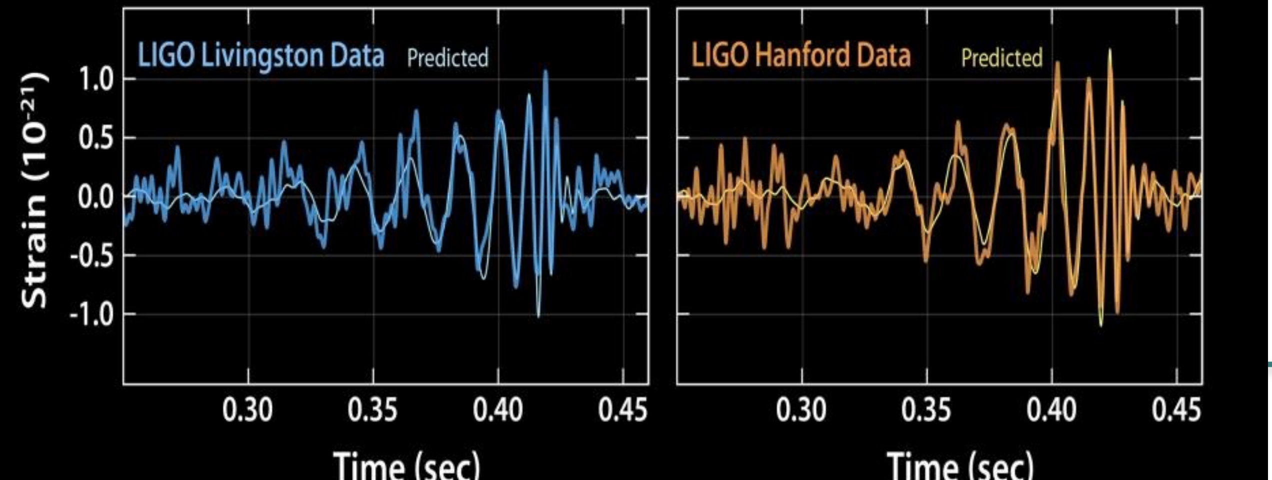
Traditional astronomy (electromagnetic observation) is no longer the only way of exploring the Universe



First GW Observation **Sept. 14th 2015**



Aug.17th 2017:

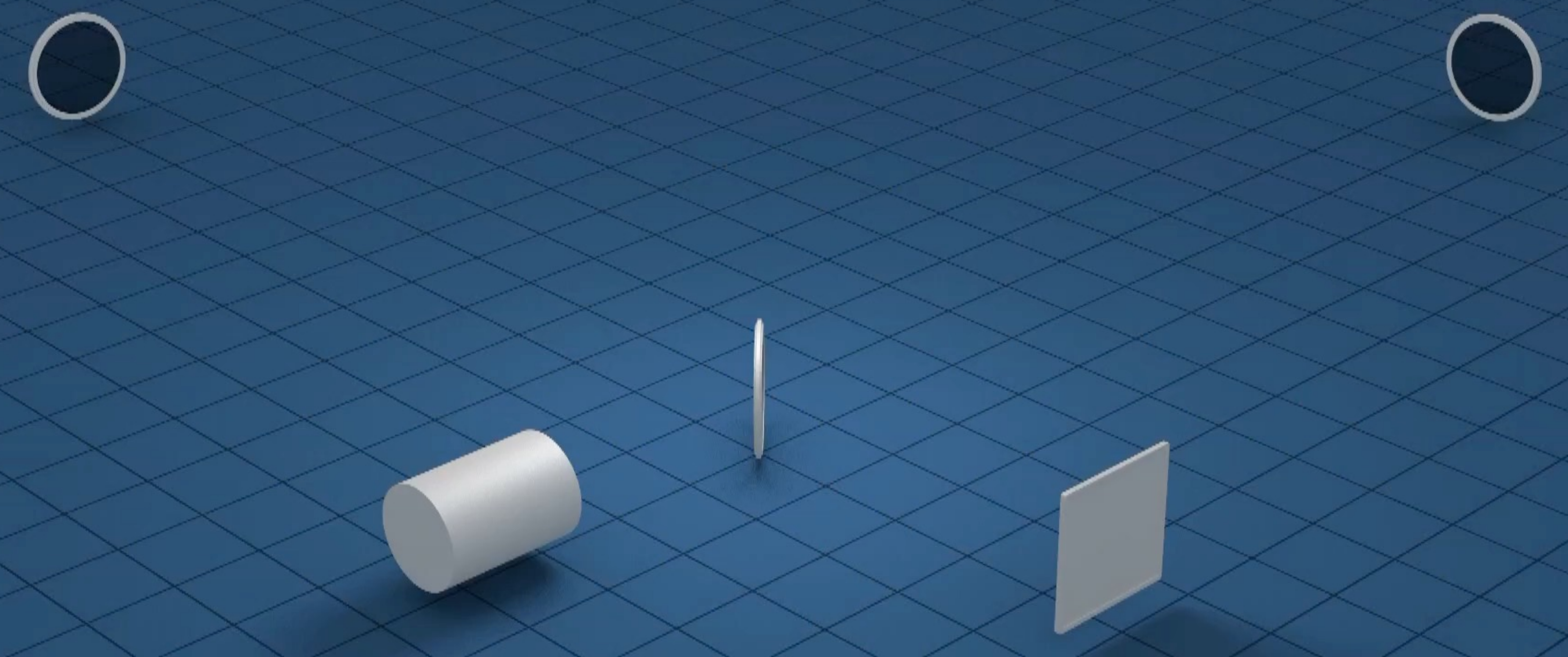
Birth of the MultiMessenger ERA

$$\Delta L = hL$$

ΔL displacement

h GW amplitude

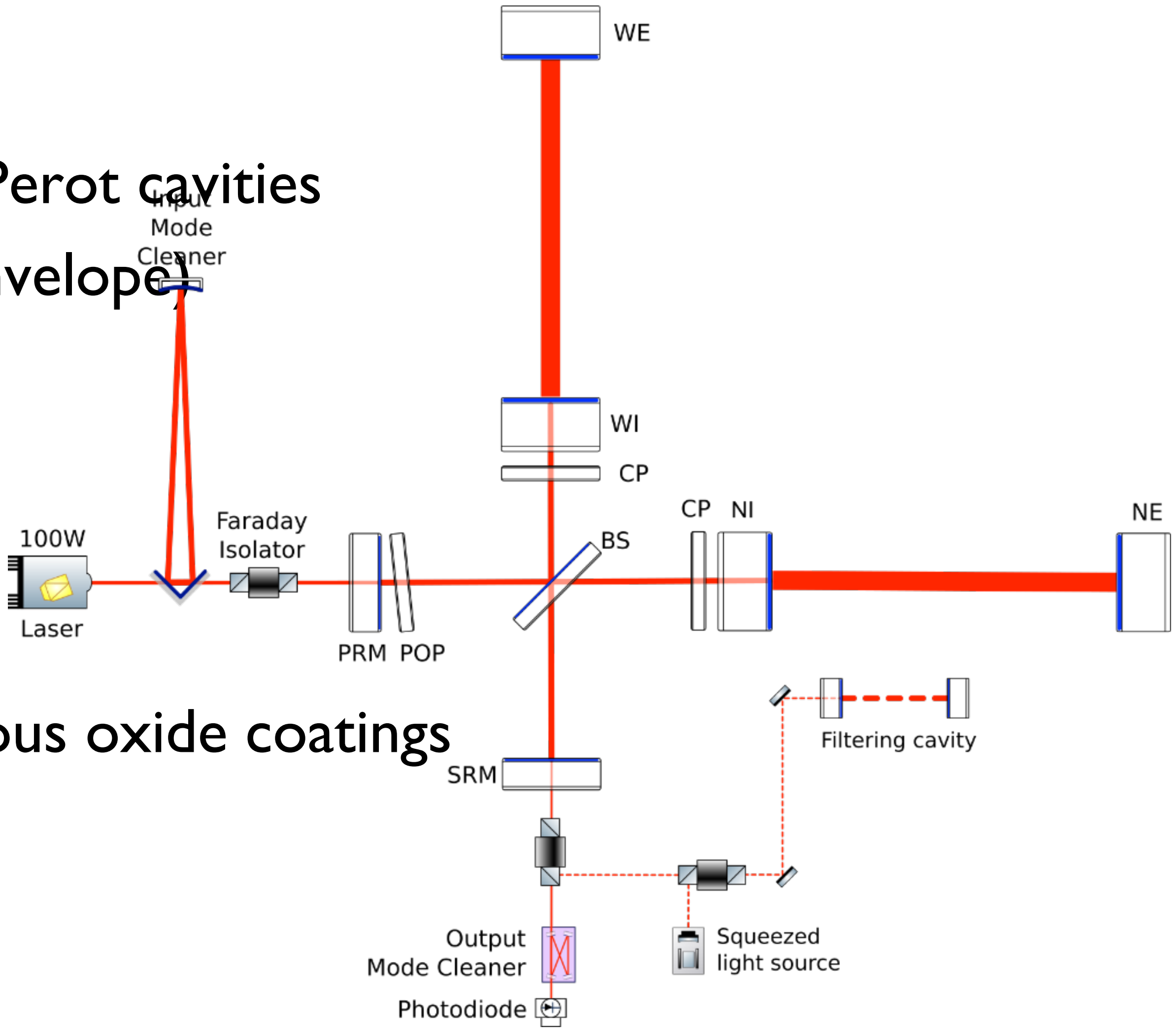
L distance under observation (arm length)



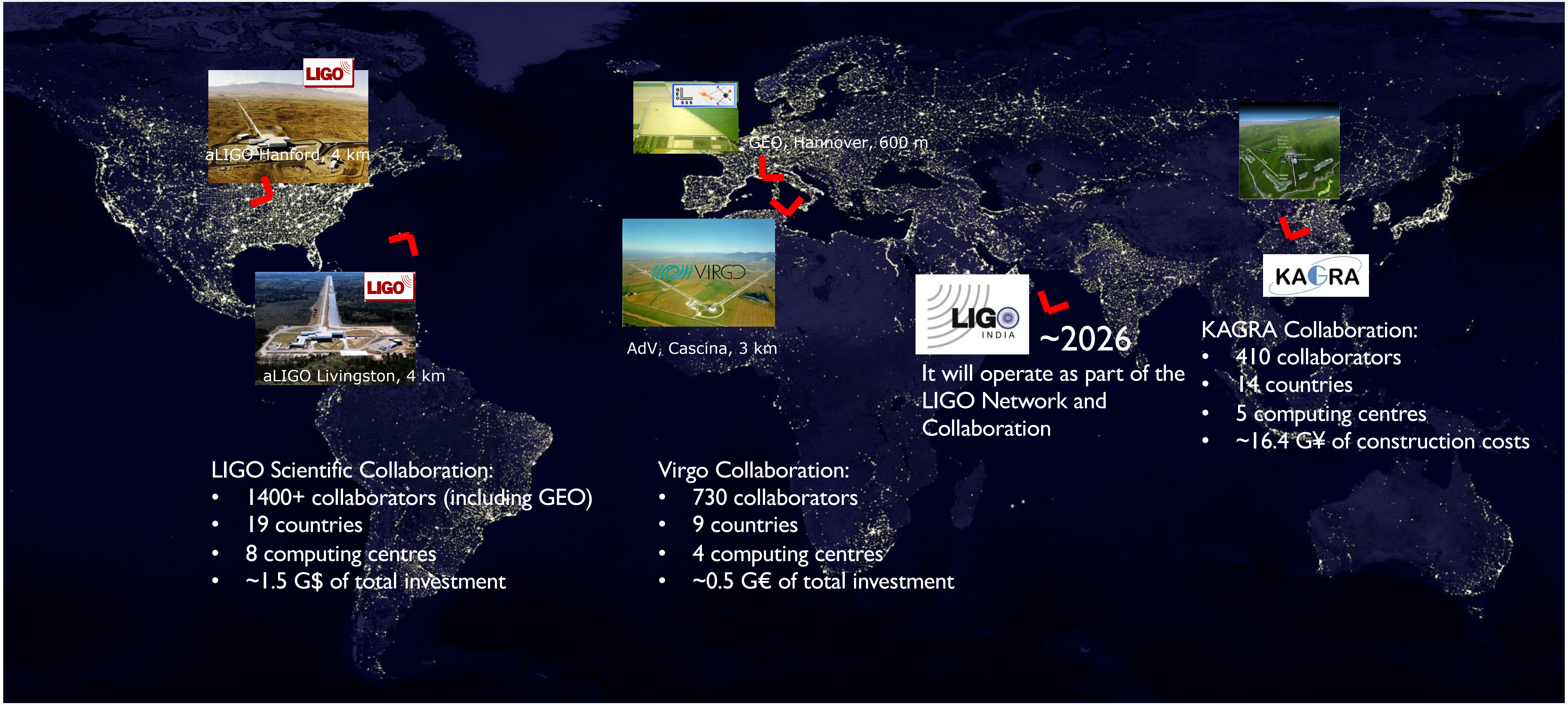
GW Detector Scheme

High sensitivity laser interferometer

- Michelson Interferometer with Fabry-Perot cavities
- km-length arm cavities (and vacuum envelope)
- Power and signal recycling
- Frequency dependent squeezing
- 100w light source @1064 nm
- Monolithic suspensions
- Large fused silica mirrors and amorphous oxide coatings
- Thermal compensation
- Sensing and control system
- Seismic isolation and suspensions



GW world wide Network



What's the Einstein Telescope (ET)

- **3rd generation GW observatory** Sensitivity at least one order of magnitude better with respect to the nominal sensitivity of advanced detectors in all the detection frequency band
- **Precision measurement and a new discovery project.** A wide frequency band observatory
- **Special focus on massive (or intermediate mass) black holes.** Extraordinary sensitivity at low frequency (few Hz)
- **High reliability.** High observation duty cycle
- **Lifetime of several decades.** 50 years

Requirements → Design specifications

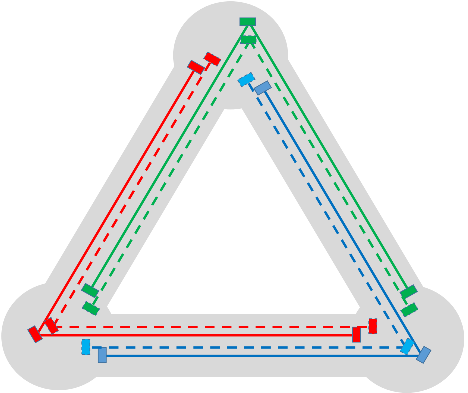
- **Underground infrastructure**, (~-200m) to reduce the impact of seismic noise, gravity gradient noise wind and acoustic disturbances impacting on the low frequency range
- **Longer arms**, to increase the signal-to-noise (SNR) ratio with respect to all the displacement noises limiting the sensitivity of the current detectors. In the ET reference design ET has 10km long arms

- **Multiple Interferometers per Detector (MIPD) or Xylophone design,**
  - low frequency band, **ET-LF**, from 3Hz to about 30-40 Hz
  - high frequency band, **ET-HF**, from 30 Hz to10 kHz

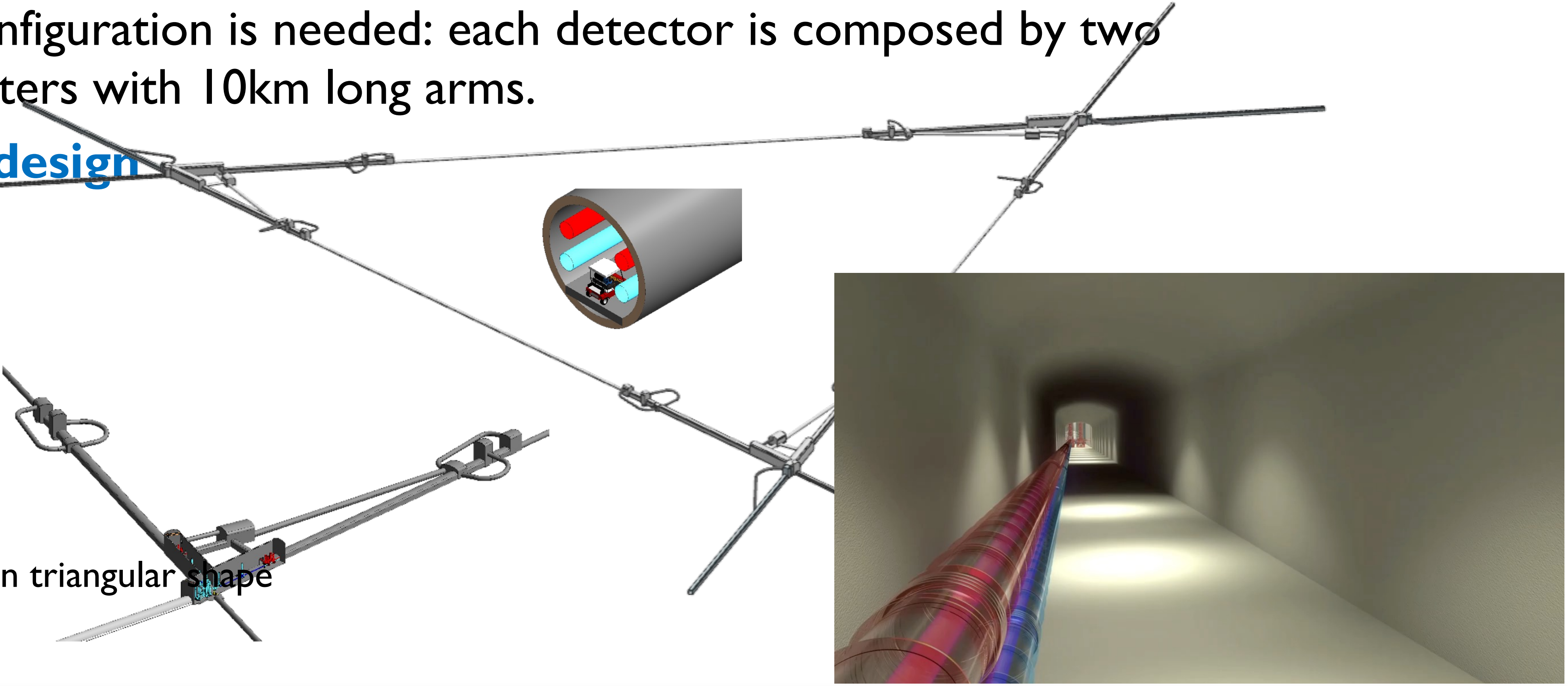
Requirements → Design specifications

- **Triangular geometry:** to satisfy the localisation capability, the polarisation disentanglement, the sky coverage and the high reliability requirements, a multiple detector configuration is needed: each detector is composed by two interferometers with 10km long arms.

ET reference design



6 interferometers arranged in triangular shape
3 HF + 3 LF



ET in the ESFRI Roadmap (2021)

Proposal submitted by:

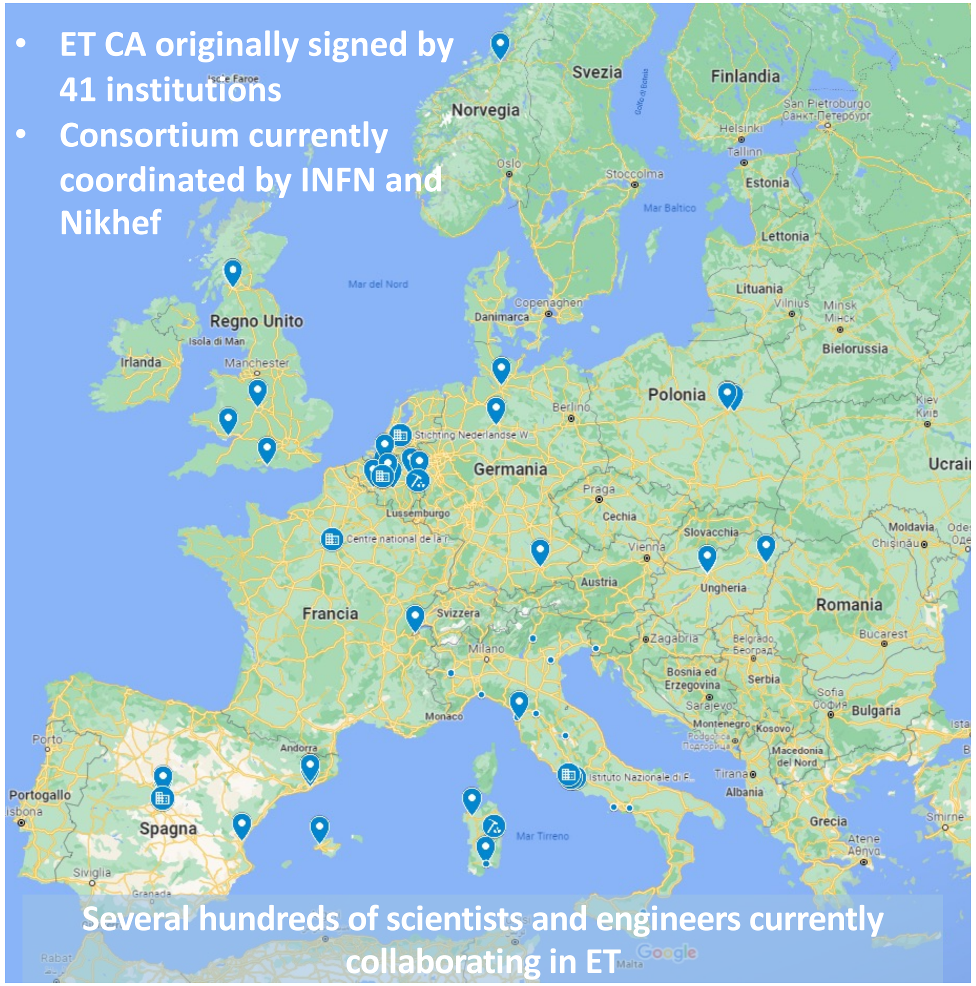
- **Italy**
- Belgium
- Netherlands
- Poland
- Spain

The project and the collaboration activities now also include agencies and institutions belonging to:

- **Austria**
- **France**
- **Germany**
- **Hungary**
- **Switzerland**
- **UK**

Large preparatory funds available in some country (IT, NL, …), an EU INFRA-DEV proposal just approved with a grant of 3.45M€ and an EU INFRA-TECH proposal has been just submitted

- **ET CA originally signed by 41 institutions**
- **Consortium currently coordinated by INFN and Nikhef**



Several hundreds of scientists and engineers currently collaborating in ET

The ET Technological Challenge

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- ET science targets require two parallel tech developments
  - Brute force approach to innovate ET-HF technologies
  - Breakthrough technologies to design and realize ET-LF
- Many challenges in a wide multidisciplinary scenario:
  - Optics, material science, surface science
  - Laser and photonics
  - Cryocooling, vacuum technology (See A. Grado Presentation)
  - Seismic filtering and precision mechanics
  - Sensing actuation, sensing, actuation and control systems
  - Civil and underground infrastructures engineering (**See M. Marsella Presentation**)

Computing Challenges

- **Low-latency** (Candidate search, Sky localization, parameter estimation, Alert generation and distribution) : greater automation of data conditioning than is currently taking place with the second-generation detectors
  - LIGO and Virgo will be focusing on this during the coming years

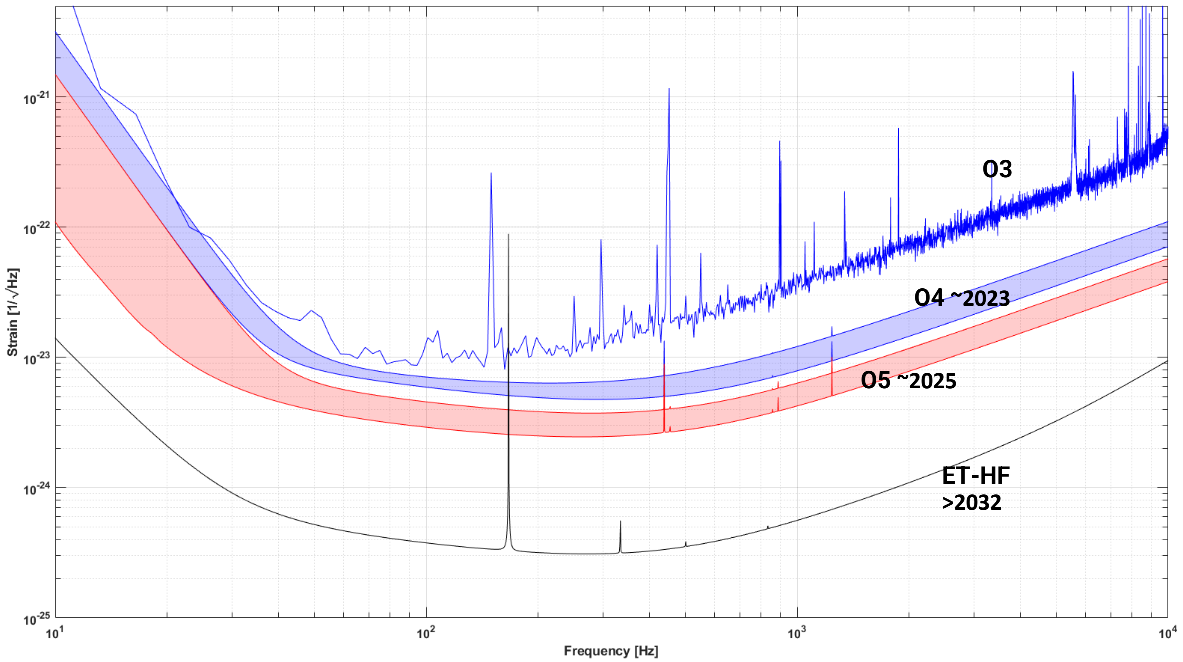
- **Offline**: data size ~tens of Pb/year, much more science in there - **10^4-10^6 GW candidate events per year**

- To properly analyze the data, progress will be needed in waveform generation and parameter estimation
- Follow the technology updates in the coming years

The HF Detector

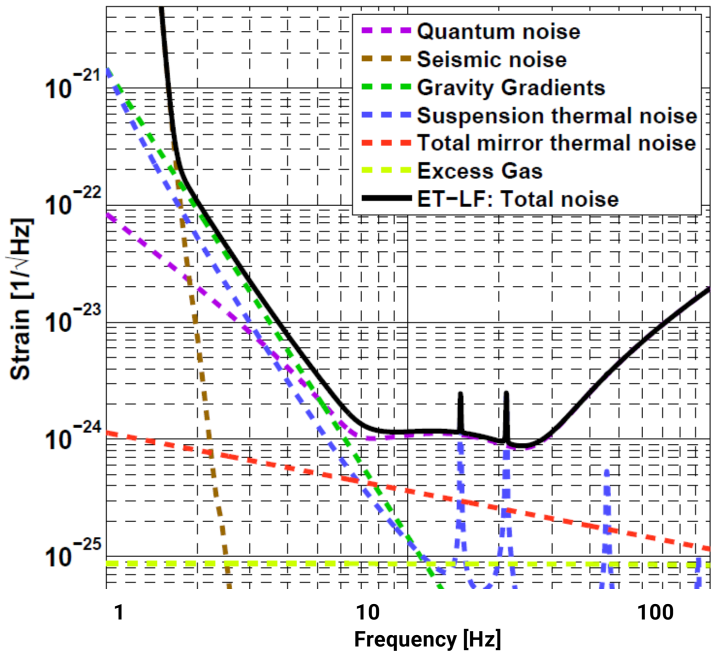
- Room temperature
- Laser wavelength 1064 nm
- High-power
  - Input power: 500 W (AdV+ 40-80W)
  - Arm power: 3 MW (AdV+120-400 KW)
- Thermal compensation
- Mitigation of parametric instabilities
- Large test masses 200 kg (AdV+100 kg)
- Improved coatings (loss reduced by a factor of ~7 – optical absorption <1ppm)
- Frequency dependent squeezing: 10db (AdV+ 3-6db)

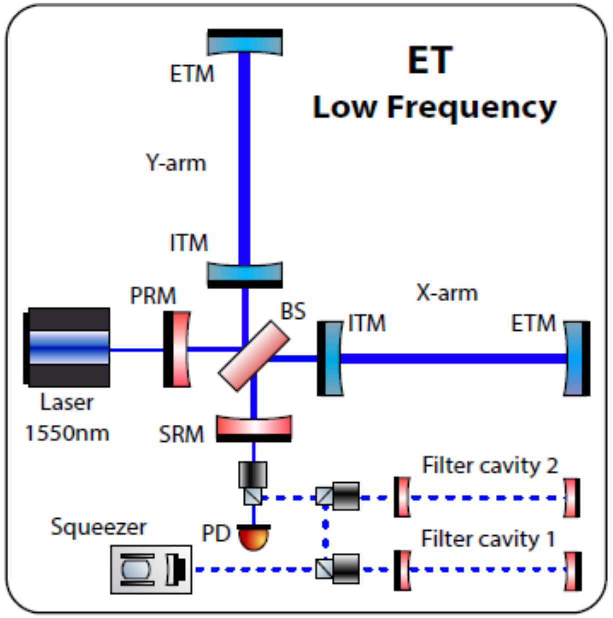
most OF these technology challenges will be addressed as part of the virgo post-o5 development (after 2025)



The LF Detector

- Cryogenics (10-20 K)
- Seismic isolation
- Newtonian noise cancellation
- Suspension thermal noise
- Large test masses
- New coatings
- Laser wavelength 1550-2000 nm
- Silicon (sapphire) test masses
- Frequency dependent squeezing, filter cavities





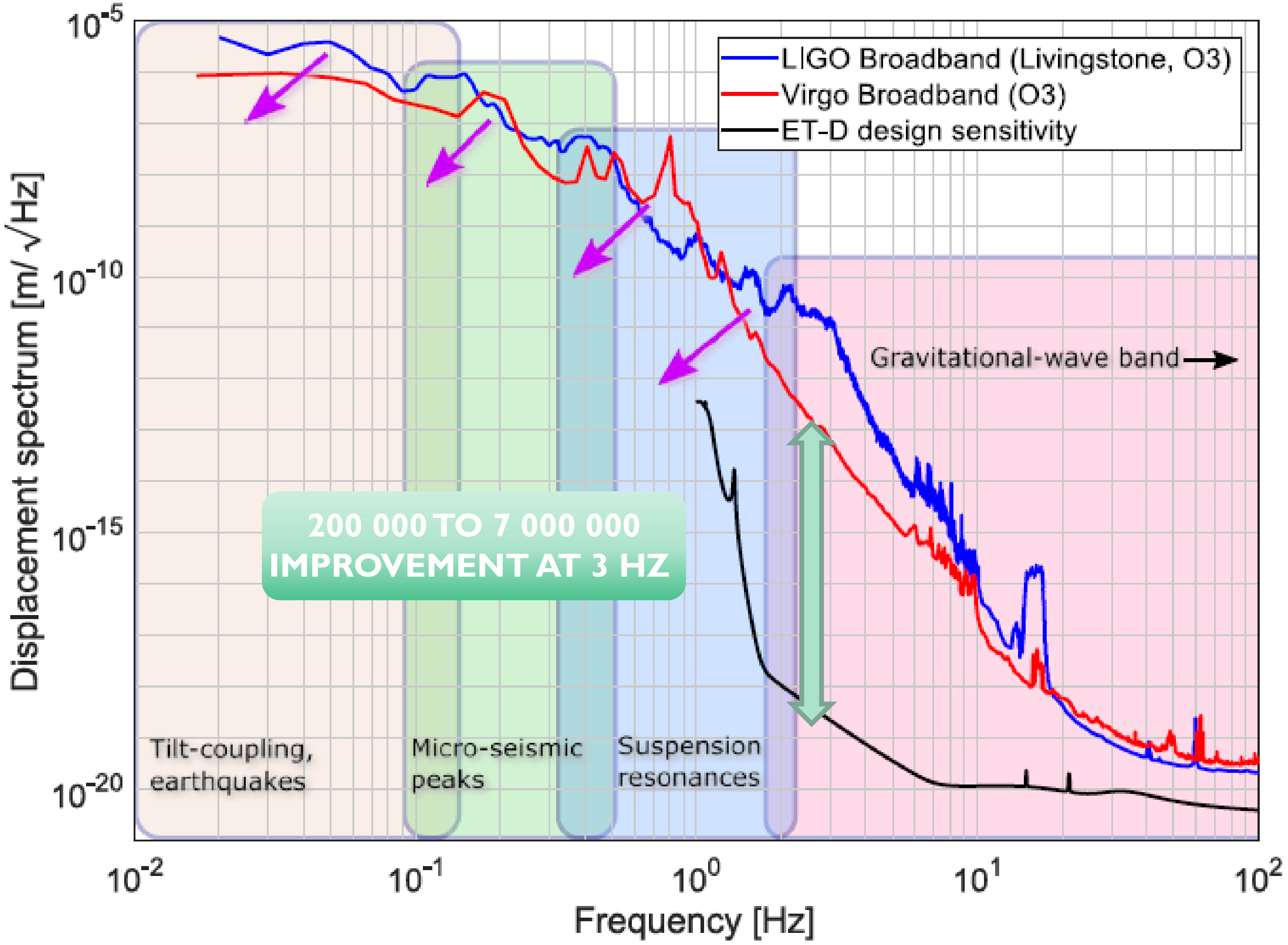
LF: Low frequency noise

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

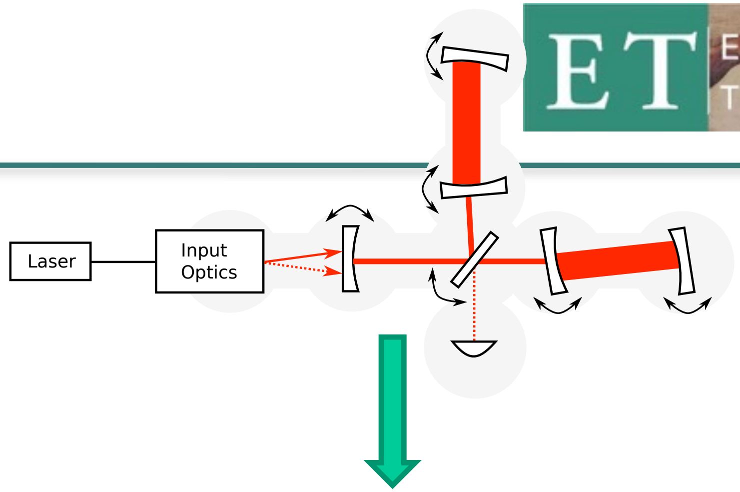
…and no gravitational wave detector to date has reached its design sensitivity at low frequencies

We need to systematically identify and mitigate LF noise

- ➢ RMS motion
- ➢ Achievable isolation
- ➢ LIGHT scattering
- ➢ Angular controls
- ➢ Seismic platform and suspensions
- ➢ Environmental noise



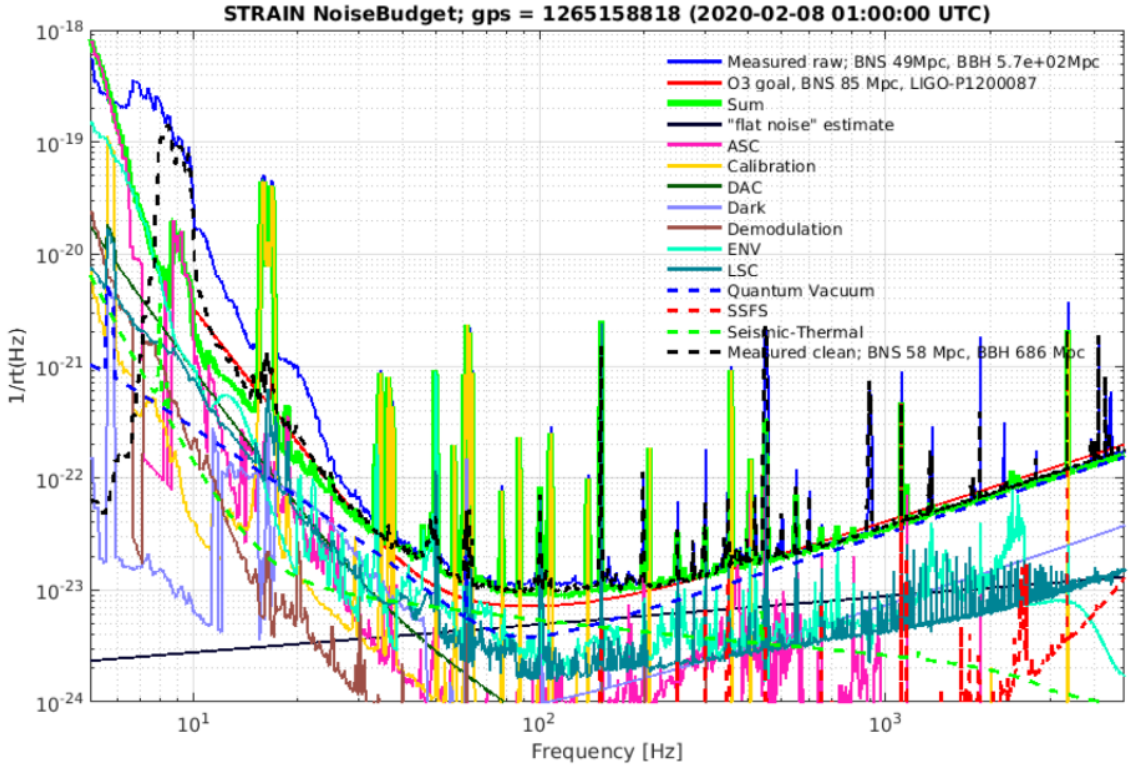
LF: Technical Noises



- site location → reduce mirror motions

- control systems → deal with residual motion
  - **Sensing**: lower noise sensors
  - **feedback optimization** : noise subtraction, automatic filter design, supervised machine learning, neural networks
  - **Actuation**: design and modeling of actuation mechanisms for guaranteed dynamic range and low noise

HIGH PRIORITY IN VIRGO POST-O5 DEVELOPMENTS



LF: Suspensions and seismic isolation systems

- the requirements of the suspension and isolation systems are set by the **target low end of the operating frequency band**, as well as by the **intrinsic seismic levels** of the chosen sites
- for detectors operating at ~10° K, silicon or sapphire
- A significant challenge is the need to extract any deposited power via the fibers, which in turn drives their cross-sectional area and vertical stiffness, and requires knowledge of their thermal properties
- Suspending heavy mirrors with thick fibers/ribbons will need a smart design to soften the vertical and horizontal modes
- monolithic assembly process
- excess losses like clamping or bonding losses

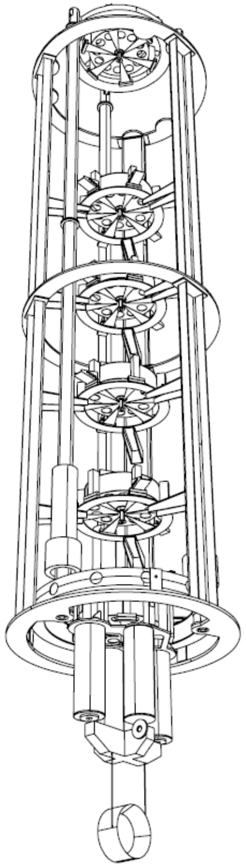
Seismic platforms and suspension

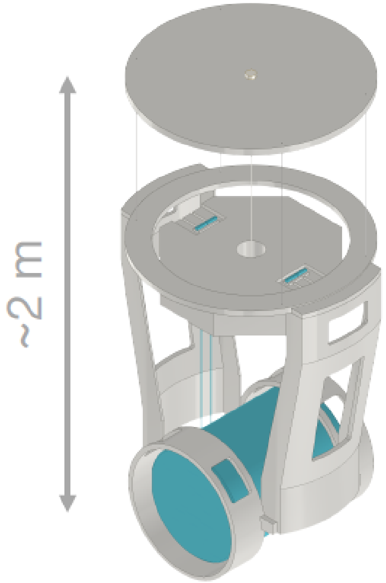
12 m suspensions sufficient?

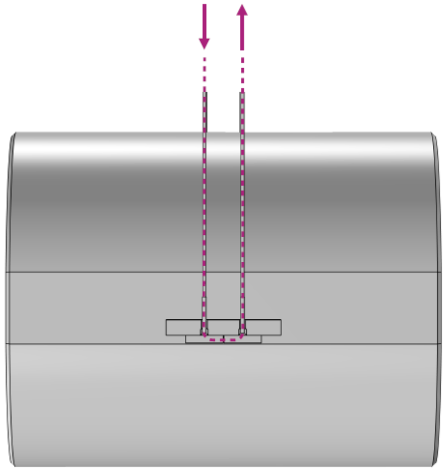
- Need to establish a detailed baseline for the suspensions and address:
  - R&D on sensors, noise+tilt/translation coupling
  - R&D on structure for rigidity
  - Additional filtering before inverted pendulum

Very important: **coupling with cryogenics**

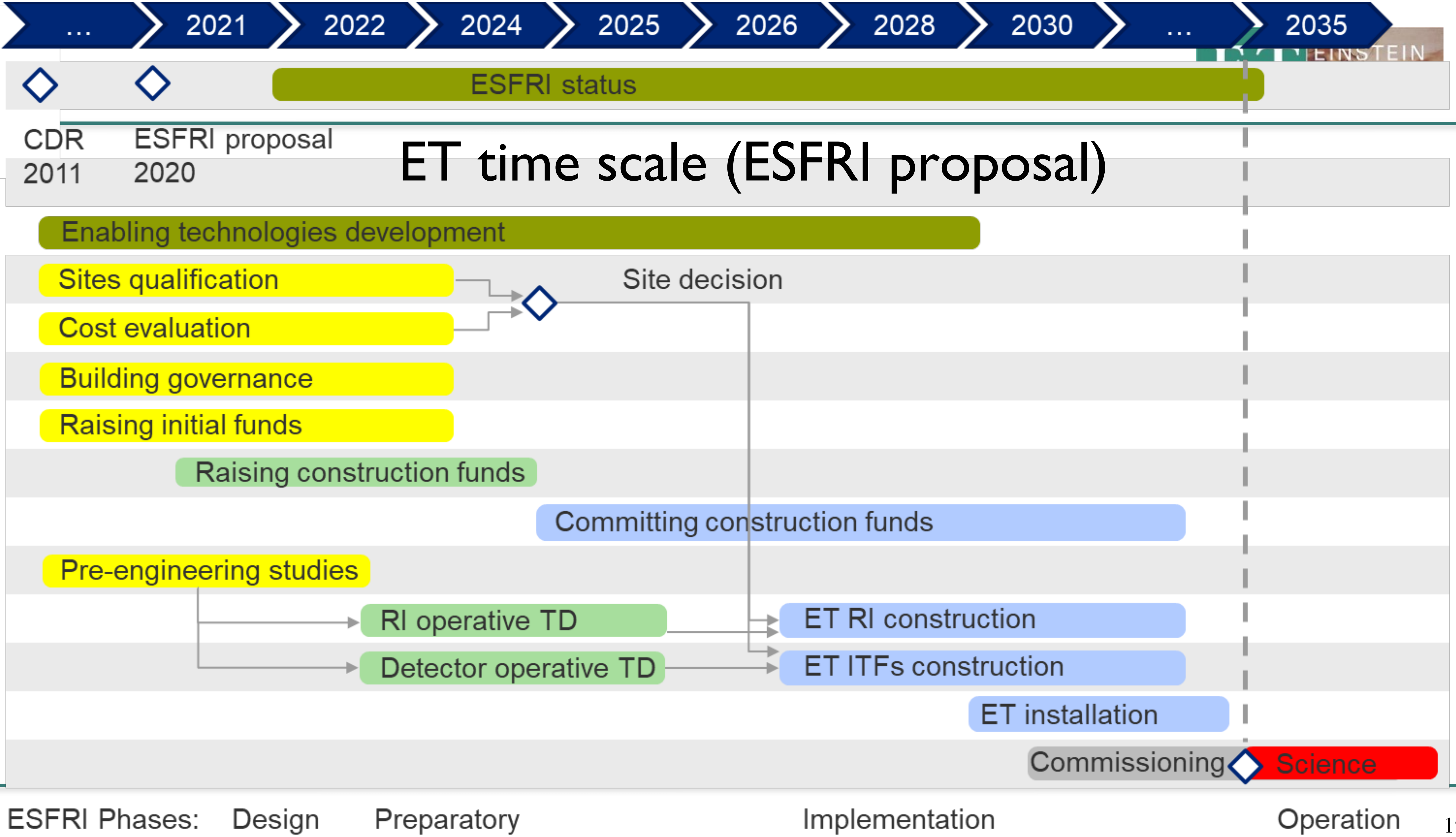
- Platform below cryostat being tested







ET time scale (ESFRI proposal)



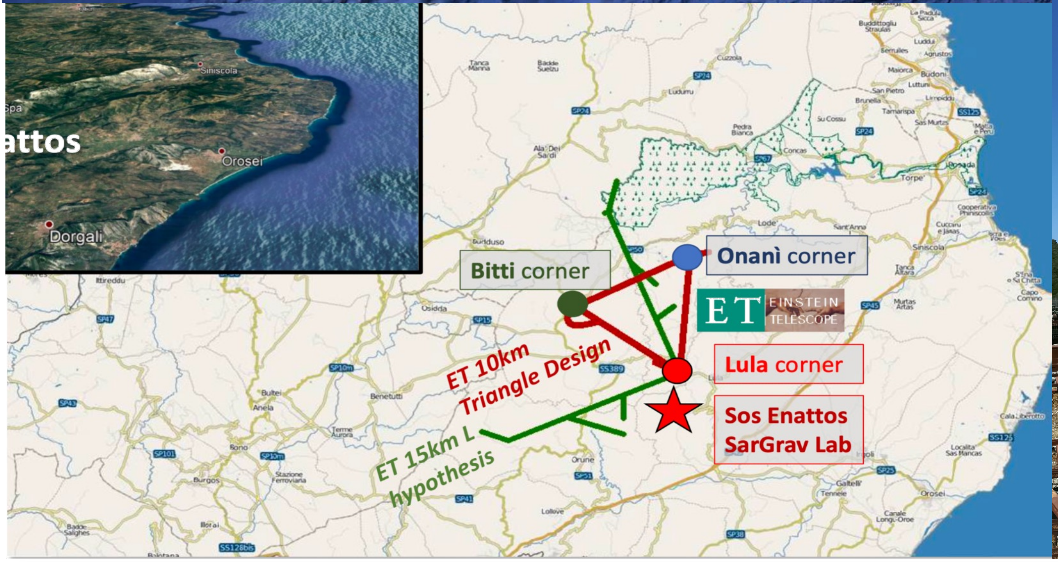
EMR site

Saxony site

Sos
Ennatos site

Sos Enattos Candidate Site

Sos Enattos area among Bitti, Lula and Onanì

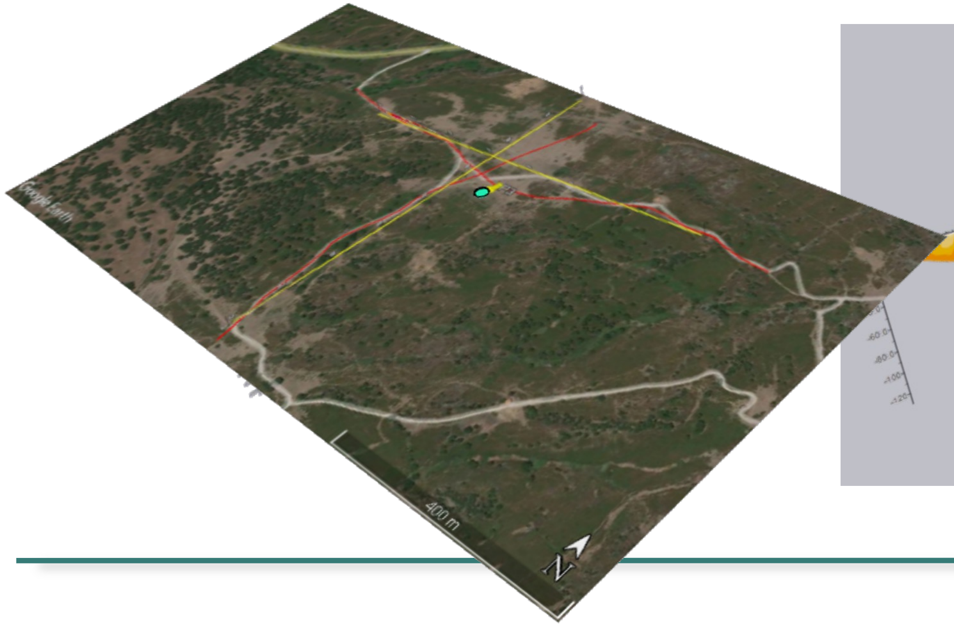


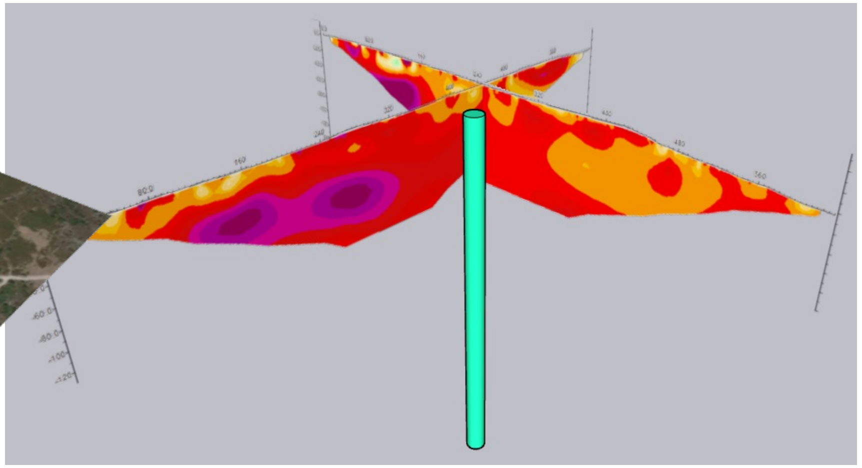
Works already on going (Sardinia)

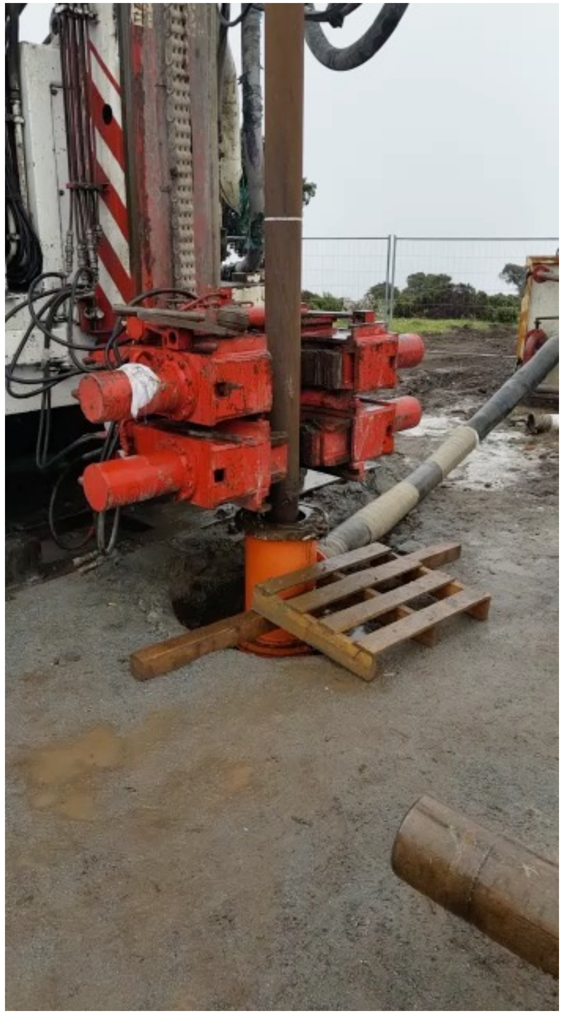
- Long standing characterisation of Sos Enattos mine, nearby one of the corners
  - Seismic, magnetic and acoustic noise characterisation ongoing at different depth in the mine
- Surface laboratory operative, underground laboratory under preparation (SarGrav Lab)
- Geological and geophysical investigations

Works already on going (Sardinia)

- Two ~290m boreholes have been excavated, equipped and data taking is ongoing. **Call for tenders of 410 k€ on 2021**
- A set of other boreholes expected in 2022
- Intense surface investigations programme ongoing
- Characterisation funded on regional and national funds
- Large proposal for technology development and engineering design submitted to the Italian government







ET Costs and fundings

EMR: 2 INTRREG projects ~ 30 M€

Italy:

- 2018: 16,5/17,0M€ from MIUR for ET/Virgo
- 3,5M€ from Regione Autonoma della Sardegna to realize the SarGrav Laboratory within the Sos Enattos mine
- 1 project founded by PRIN 2017 (~1M€) on site characterization
- 3 projects financed by PRIN 2020 ~3 M€

Activity	Cost [M€]	Start	End	Note
Infrastructure costs	932			
Excavation	781	2027	2033	Excavation of the underground tunnels with TBMs and of the caverns. Cost based on the evaluation by two independent external companies.
Direction of the civil works	9	2026	2034	Evaluation based on the 1% of the underground and surface infrastructures realisation cost.
Civil works on the surface	98	2028	2033	Realisation of the technical and civil infrastructures on the surface. Cost evaluation based on the Conceptual Design study.
Services underground (ventilation …)	44	2030	2033	Technical infrastructures serving the underground facilities and apparatuses.
Detector costs	804			
Vacuum system	566	2026	2032	Vacuum plant, pumps and pipes.
Optics and Laser	125	2027	2032	Main mirrors, auxiliary optics and lasers.
Suspension system	48	2027	2032	Filtering and suspension systems.
Cryogenics	45	2026	2032	Cryogenic plants.
ET installation	20	2032	2035	Contracts and activities for the installation of the ET components.
Total	1736			

ET IN EUREGIO MEUSE-RHINE (EMR)

Dutch National Growth Fund for ET

- 42 ME (conditionally) awarded now
  - Money can flow from 2023
  - 19 ME: connections to industry for research and innovation: ‘the aim of this programme is to optimally position […] in particular Dutch industry, for R&D and orders related to Einstein Telescope’
  - 23 ME: ‘for the preparation toward the realisation of the underground infrastructure […]’, project organisation and management
- 870 ME have been reserved for the construction of the ET infrastructure

Het Nationaal Groeifonds
Resultaten tweede ronde

Onderzoek, ontwikkeling en Innovatie	
De revolutie van de zelfdenkende moleculaire systemen	97
Duurzame MaterialenNL	220
Einstein Telescope	42 & (870)
NXTGEN HIGHTECH	450
Photondelta	471
Cellulaire agricultuur	60
CropXR	43
Groeiplan Watertechnologie	(135)
NL2120, het groene verdienvermogen van Nederland	(110)
Werklandschappen van de toekomst	(26)
Biotech Booster	246
Oncode-PACT	325
PharmaNL	80
Toekomstbestendige leefomgeving	(100)
Groenvermogen II	500
Nieuwe Warmte Nu!	200
Digitaal Ecosysteem Mobiliteit en Smart City	(85)
Digitale Infrastructuur en Logistiek	51
Luchtvaart in Transitie	383
Zero-emissie binnenvaart batterij-elektrisch	50
Totaal	€ 4.544 mln

(100) : bedrag tussen haakjes = reservering

Kennisontwikkeling	
Digitaal Onderwijs Goed Geregeld	34
Digitaliseringsimpuls onderwijs NL	560
Impuls Open Leermateriaal	78
Ontwikkelkracht	332
Collectief laagopgeleiden en laaggeletterden	51
Nationale LLO Katalysator	392
Opschaling publiek private samenwerking in het beroepsonderwijs	210
Totaal	€ 1.657 mln

Infrastructuur	
Rail Gent-Terneuzen	105
Totaal	€ 105 mln

Toegekend:	€ 1.317 miljoen
Voorwaardelijk toegekend:	€ 3.663 miljoen
Gereserveerd:	€ 1.326 miljoen
Totaal NGF:	€ 6.305 miljoen

Welvaart van morgen begint vandaag

ETIC – Einstein Telescope Infrastructure Consortium

Next Generation EU
Investment proposed 100M€ focused on ET enabling technology and Sardinian site candidature support

- 8% Human Resources
- 30% Scientific apparatuses
- 12% Distributed Infrastructures
- 28% ET design
- 12% Training

Additional 5M€ funding on the same framework for the site characterization

Feedback expected in June 2022

Discussion ongoing on an Italian share toward ET realization

Conclusions

- ET is a 2 Billion project recently entered the ESFRI roadmap
  - Precision measurement and a new discovery project
  - Science Operation since 2035
- Many Challenging and multidisciplinary technology developments
  - Breakthrough technologies to design and realize ET-LF
  - Go to the limit of current technologies to realize ET-HF
  - R&D on going on many different aspects
- Sardinia is one of the two sites candidates to host the ET infrastructure
  - Site Characterization activities on going
- A project for ET within the PNRR has been approved. Negotiations for the real budget will start next week

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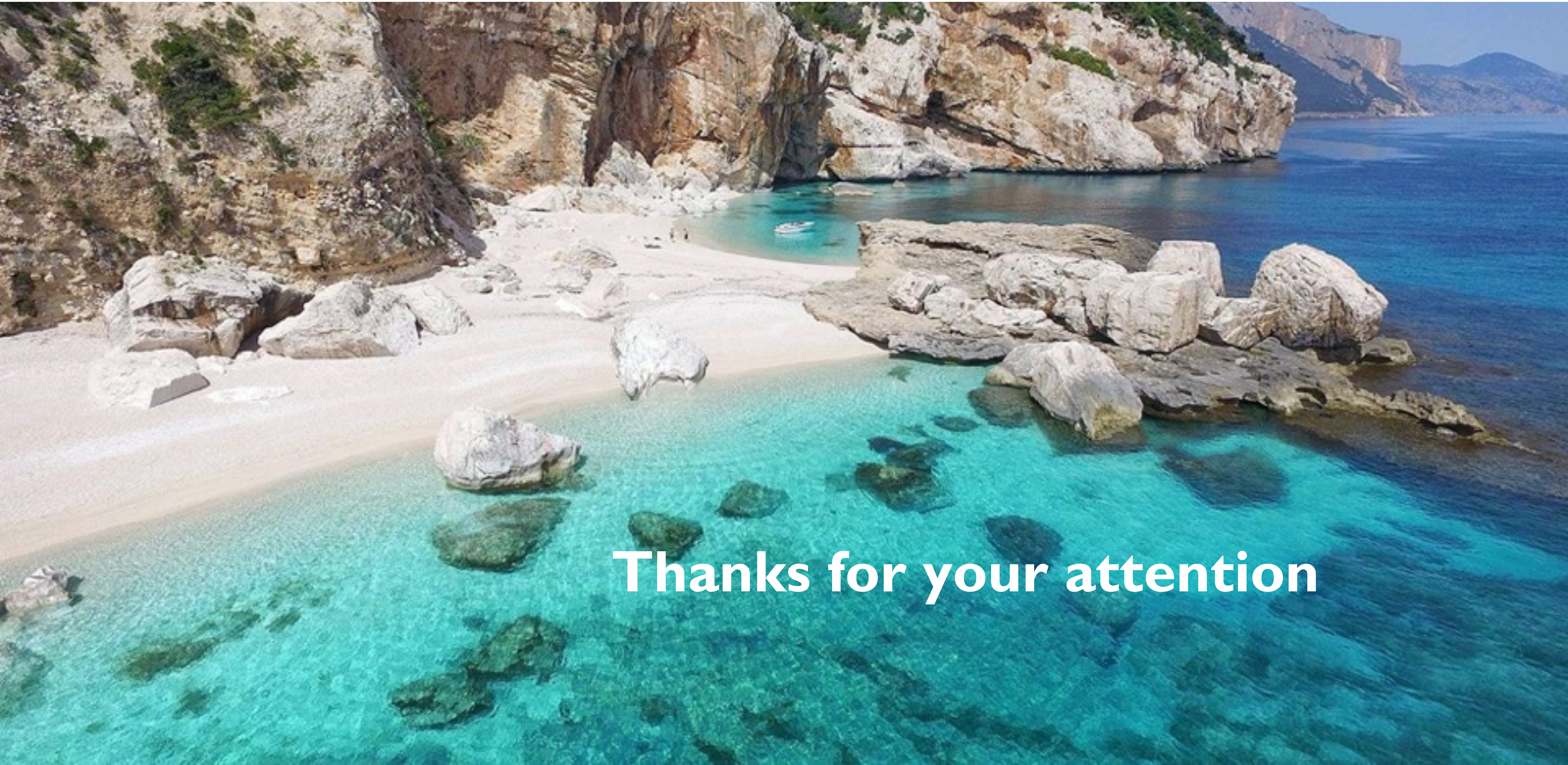
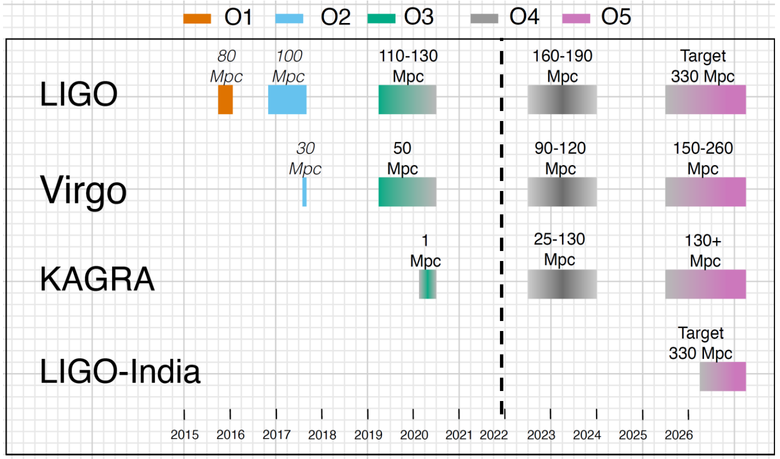
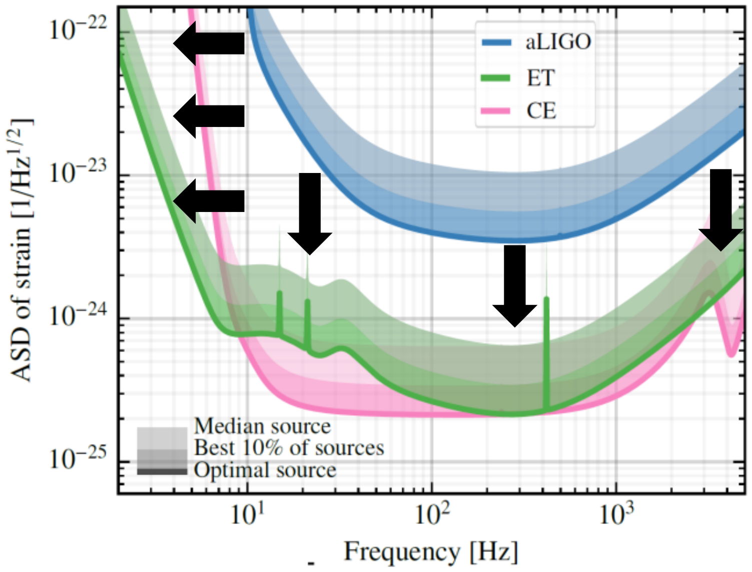


Thanks for your attention

Current GW Scenario and future prospects

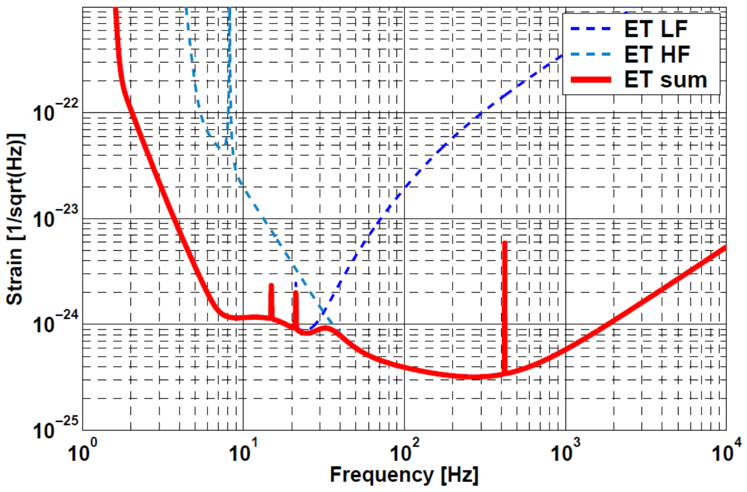
- Currently Gravitational Wave Detectors (Advanced LIGO and Advanced Virgo) have completed the third observing run and are being upgraded toward LIGO A+ and AdV+ operations (o4: ~2023-2024 – O5: ~2026-2028)
- Further upgrades are being planned for post-o5
- The first instruments to be installed in the new third generation Observatories will be **>10X sensitive** than the design sensitivity of current instruments and **will extend the bandwidth below 10 hz**
- The third-generation facilities are being designed with **lifetimes on the order of 50 years** in order to house detectors with far more sensitivity than the initially proposed designs

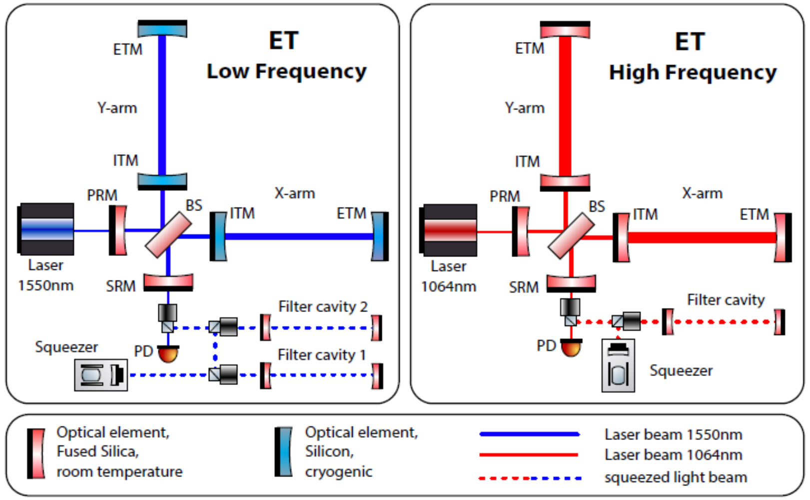




The Xylophone

Parameter	ET-HF	ET-LF
Arm length	10 km	10 km
Input power (after IMC)	500 W	3 W
Arm power	3 MW	18 kW
Temperature	290 K	10-20 K
Mirror material	fused silica	silicon
Mirror diameter / thickness	62 cm / 30 cm	45 cm/ 57 cm
Mirror masses	200 kg	211 kg
Laser wavelength	1064 nm	1550 nm
SR-phase (rad)	tuned (0.0)	detuned (0.6)
SR transmittance	10 %	20 %
Quantum noise suppression	freq. dep. squeez.	freq. dep. squeez.
Filter cavities	1×300 m	2×1.0 km
Squeezing level	10 dB (effective)	10 dB (effective)
Beam shape	TEM_{00}	TEM_{00}
Beam radius	12.0 cm	9 cm
Scatter loss per surface	37 ppm	37 ppm
Seismic isolation	SA, 8 m tall	mod SA, 17 m tall
Seismic (for $f > 1$ Hz)	$5 \cdot 10^{-10}\,m/f^2$	$5 \cdot 10^{-10}\,m/f^2$
Gravity gradient subtraction	none	factor of a few





ET Science Case in a nutshell

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ASTROPHYSICS

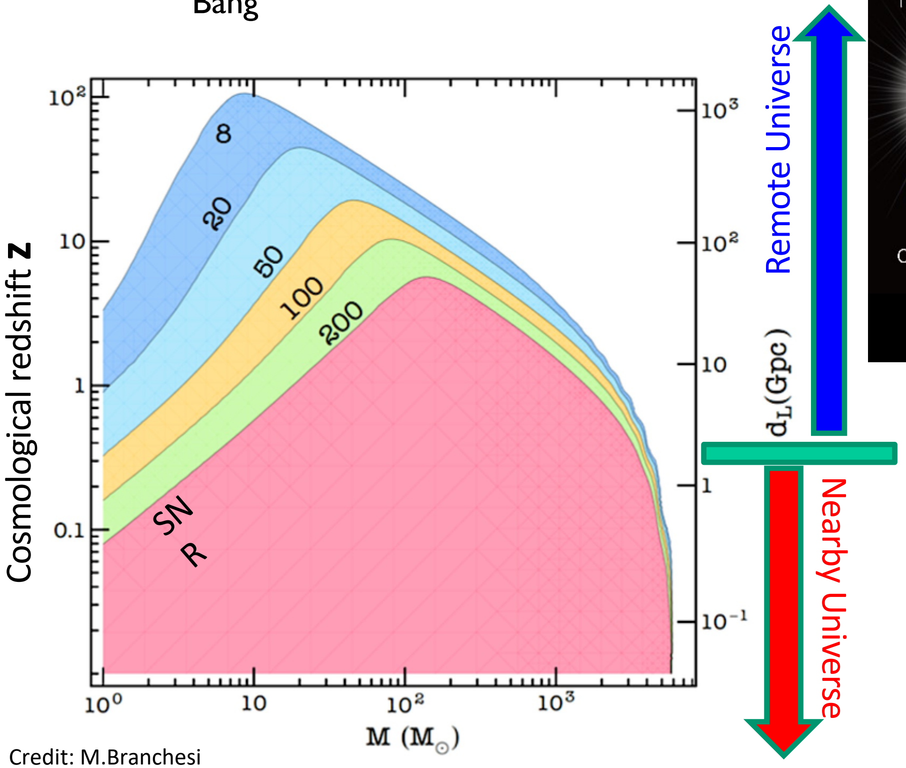
- **Black hole properties**
  - origin (stellar vs. primordial)
  - evolution, demography
- **Neutron star properties**
  - interior structure (QCD at ultra-high densities, exotic states of matter)
  - demography
- **Multi-band and -messenger astronomy**
  - joint GW/EM observations (GRB, kilonova,...)
  - multiband GW detection (LISA)
  - neutrinos
- **Detection of new astrophysical sources**
  - core collapse supernovae
  - isolated neutron stars
  - stochastic background of astrophysical origin

FUNDAMENTAL PHYSICS AND COSMOLOGY

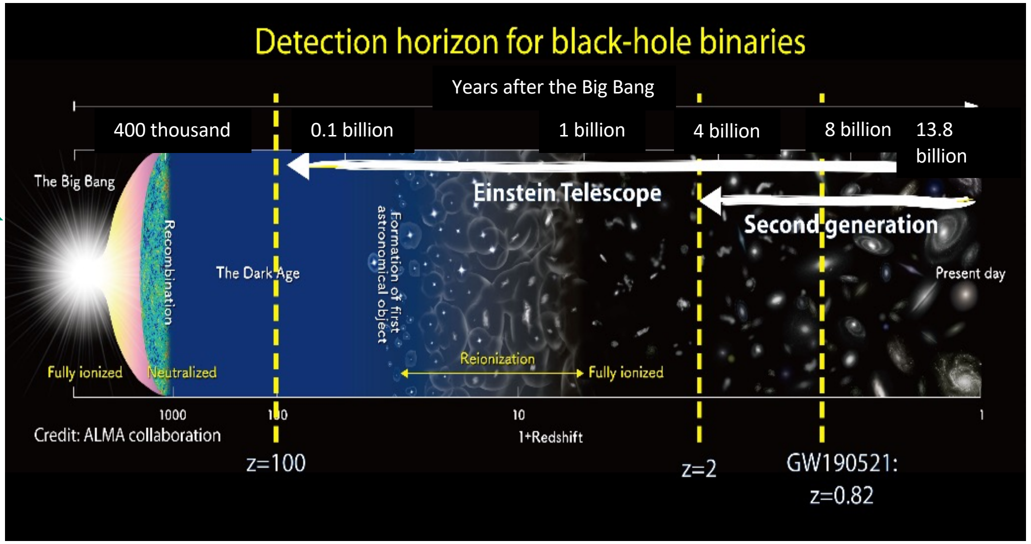
- **The nature of compact objects**
  - near-horizon physics
  - tests of no-hair theorem
  - exotic compact objects
- **Tests of General Relativity**
  - post-Newtonian expansion
  - strong field regime
- **Dark matter**
  - primordial BHs
  - axion clouds, dark matter accreting on compact objects
- **Dark energy and modifications of gravity on cosmological scales**
  - dark energy equation of state
  - modified GW propagation
- **Stochastic backgrounds of cosmological origin**
  - inflation, phase transitions, cosmic strings

ET Science in a nutshell: double nature

- ET will be a new discovery machine:
  - ET will explore almost the entire Universe listening the gravitational waves emitted by black hole, back to the dark ages after the Big Bang



Credit: M.Branchesi



- ET will be a precision measurement observatory:
  - ET will detect, with high SNR, hundreds of thousands coalescences of binary systems of Neutron Stars per year, revealing the most intimate structure of the nuclear matter in their nuclei

Economic Impact: Construction Phase

Estimation of the Total Output effect of the construction

- Estimation of construction costs obtained by
  - Experts' opinion
  - ET Conceptual Design Study
  - Annual costs for 5 macro systems: (i) Site; (ii) Vacuum; (iii) Cryogenics; (iv) Suspensions, and; (v) Optics
  - Estimation of I-O multipliers based on I-O data by ISTAT
- Combining estimates for construction costs and industry total output multipliers we obtain the total economic impact

Source of Impact	Overall output impact*	Present Value at 2025**
Direct	1,106	901
Induced	2,572	2,301
Total	3,588	3,211

Table 1: Estimation of the Total Output effect of the construction phase – millions of €

* Obtained by summing annual flows without discounting
** Obtained by discounting to year 2025 the annual flows before adding them up. Discount rate, 2.73%

Value Added from the construction phase

- The total output effect captures the volume of economic activity, i.e. value of economic transactions, triggered by the construction of ET
- However, not all these economic transactions add value: some of them correspond to a cost for some firm and to a revenue for some other firm/worker ⇒ Duplication effect
- Accordingly, the total output effect overestimates the value generated by the construction of ET
- For this reason we estimate the value added associated with such output effect
- In order to do so we estimate Value added multipliers using the I-O tables provided by ISTAT
- Estimates of the value added are as follows

Source of value added	Value Added	Present Value (2, 73%)
Demand of Labor	177	159
Demand of goods and services	1,132	1,011
Total	1,309	1,171

Economic Impact: Operating Phase

Economic Impact at operating stage

- Sources of impact
  - Direct impact: Demand of goods and services by employees and visitors of ET
  - Induced impact: Demand of goods and services induced by the (a) Labor income; (b) Demand of intermediate goods and services along the supply chain related to ET operation
- Estimation approach
  - Information on large research infrastructure that share some features with ET: i) European Gravitational Observatory (EGO); ii) Laboratori Nazionali Gran Sasso (LNGS)
  - Expert's opinion
- Estimation of direct and induced effects to determine
  - Total Output effect
  - Value added
  - Employment effect
- We estimate the annual flows associated with these effects
- We also evaluate the present value of these effects by assuming an operating life-span of 30 years

Economic impact at operating stage: Annual flows

- Annual total output effect (M €)

Source of impact	Value
Direct impact	36.2
Induced impact	91.3
Total	127.5

- Annual Value added (M €)

Source of impact	Value
Direct impact	9.6
Induced impact	35.7
Total	45.3

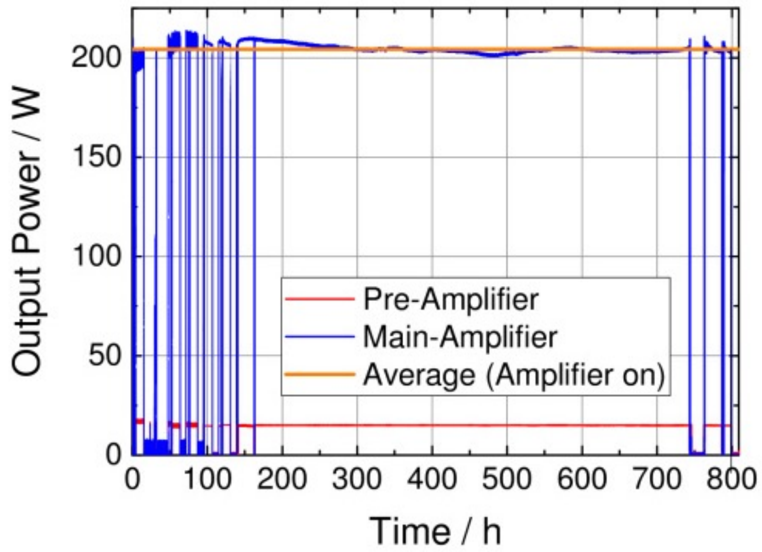
- Annual Employment (people)

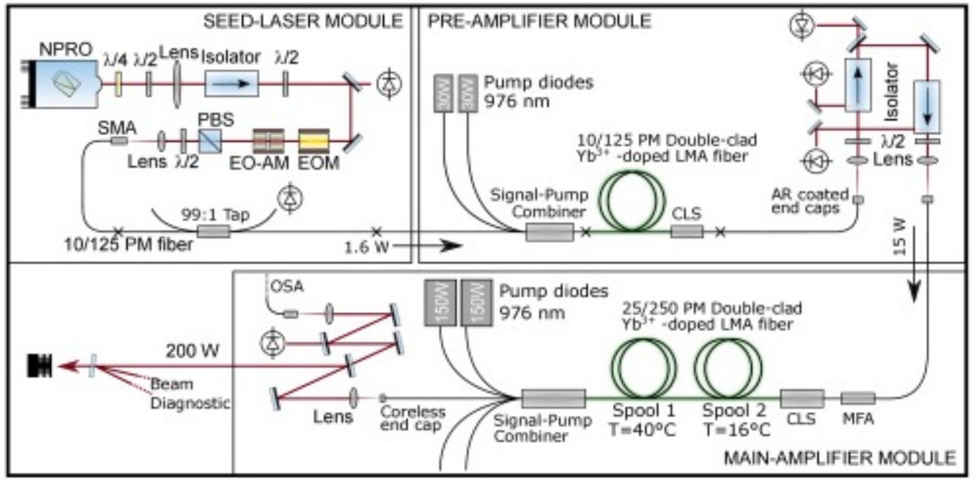
Source of impact	Value
Direct impact	143
Induced impact	570
Total	713

HF: High power light sources

ET-HF Baseline: 700W laser power will be generated by a **coherent combination** of several **high-power laser-amplifier** stages

- Monolithic Fiber amplifier with outpower of 200W at 1064 nm was demonstrated @LZH
  - Yb^{3+}-doped Polarization-maintaining large-mode-area fiber
  - No sign of stimulated Brillouin scattering @ 200W
  - 94.8% fractional power in TEM_{00} mode
  - Long-term test of more than 695 hours

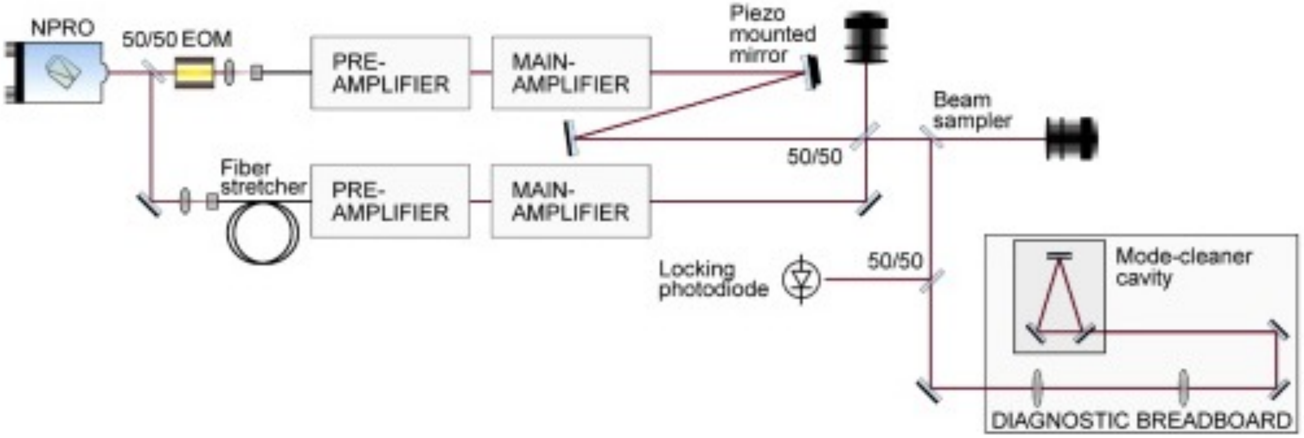


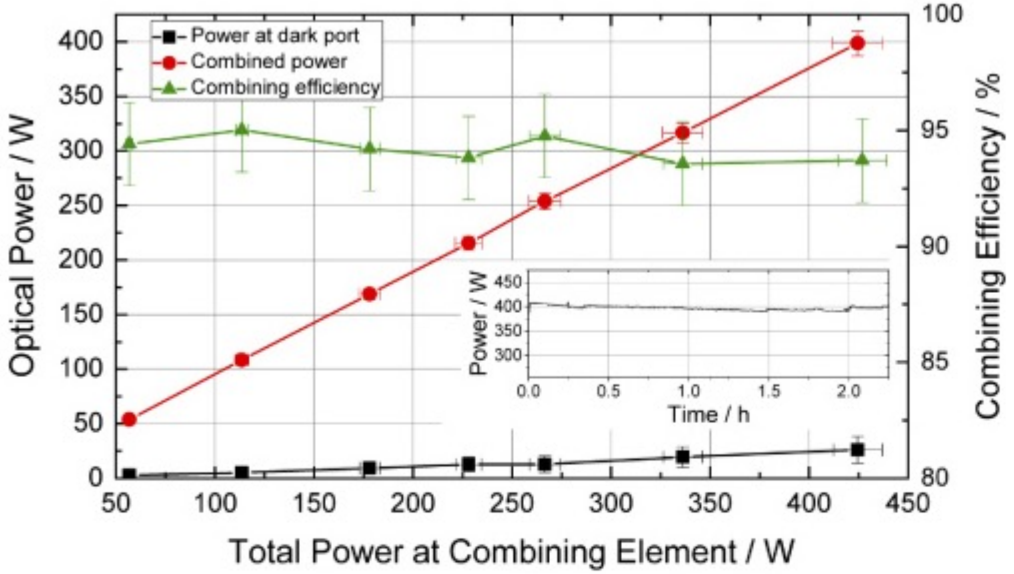


https://doi.org/10.1364/OE.27.028523

HF: High power light sources

- Coherent beam combining of two fiber amplifiers
  - 370W in TEM_{00} mode with combining efficiency >93%
  - The noise performance of the combined beam is comparable to the single amplifier noise

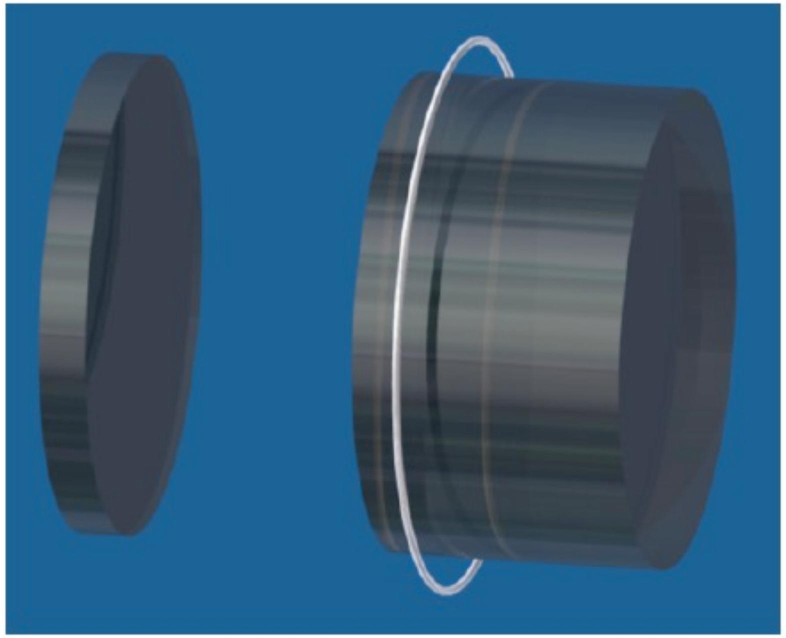




https://doi.org/10.1364/OE.420350

HF: Thermal compensation

- Considering 3 MW of optical power and 0.6ppm of absorption the total absorbed power amounts to 1.8 W (3x AdV)
- It should be possible to apply the same thermal compensation strategy as in AdV detectors:
  - compensation plates + C02 laser to correct lensing
  - Ring heaters to correct roc
- R&d for third generation detectors is expected to focus on:
  - Adaptive optics
  - sensors
    - ✓ radio frequency bullseye wavefront sensors
    - ✓ improved Hartmann wavefront sensors
  - actuators

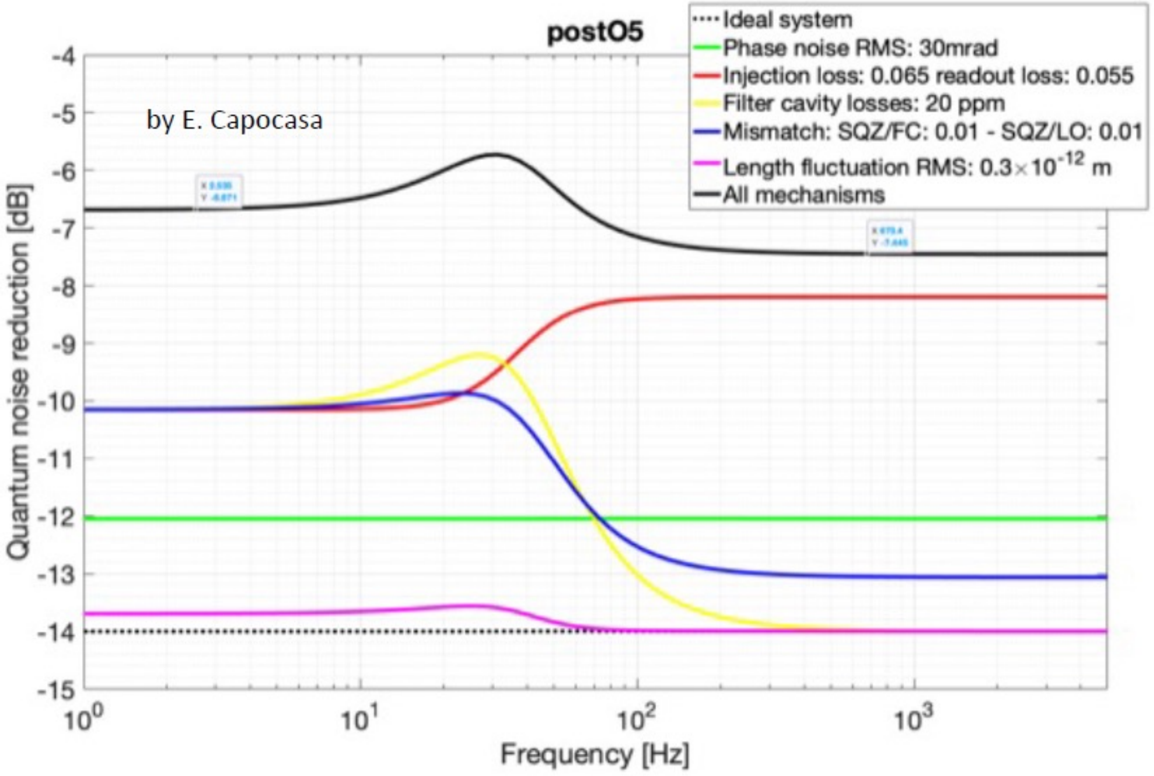


HF: Quantum noise reduction

- Baseline: Frequency dependent squeezing via a single filter cavity

- R&D to Improve optical losses:
  - ❑ Mode matching in FC and ITF arms
  - ❑ Filter cavity losses
  - ❑ SRC losses
  - ❑ Injection and readout losses

- Different topologies (epr, speedmeter,…)
  - ❑ Potential improvements
  - ❑ Less mature
  - ❑ Need large-scale prototypes



EU Fundings

- **ET INFRA-DEV (approved)**
  - ET-PP Einstein Telescope Preparatory Phase **- 3.45M€** with 4 years duration, mainly devoted to define the technical details of ET project
- ET INFRATECH (submitted)
  - M2TECH (Technologies for Multi-Messenger Astrophysics), call HORIZON-INFRA-2022-TECH-01-01 on"R&D for the next generation of scientific instrumentation, tools and methods"
  - Involved research infrastructures:
    - ✓ **CTAO and MAGIC** for gamma-ray astronomy,
    - ✓ **ET** and **Virgo** for gravitational wave interferometry
    - ✓ **KM3NeT** for neutrino astronomy
    - ✓ **ELI** for high power laser related technology
  - Total cost: 11.8 ME Duration: 48months

ET beam tubes requirements

- Tube diameter ~ 1m
- Total lenght 120 km

Surface: 3.8×10^5 m^2
Volume: 9.4×10^4 m^3

- Total residual pressure: H_2 10^{-10} mbar, H_2O 5×10^{-11} mbar, N_2 10^{-11} mbar (more stringent reqs comes from ET-HF)
- Hydrocarbon partial pressure < 10^{-14} mbar
- Material ?(2G detectors: SS 304L or 316L)
- Life time: 50 years

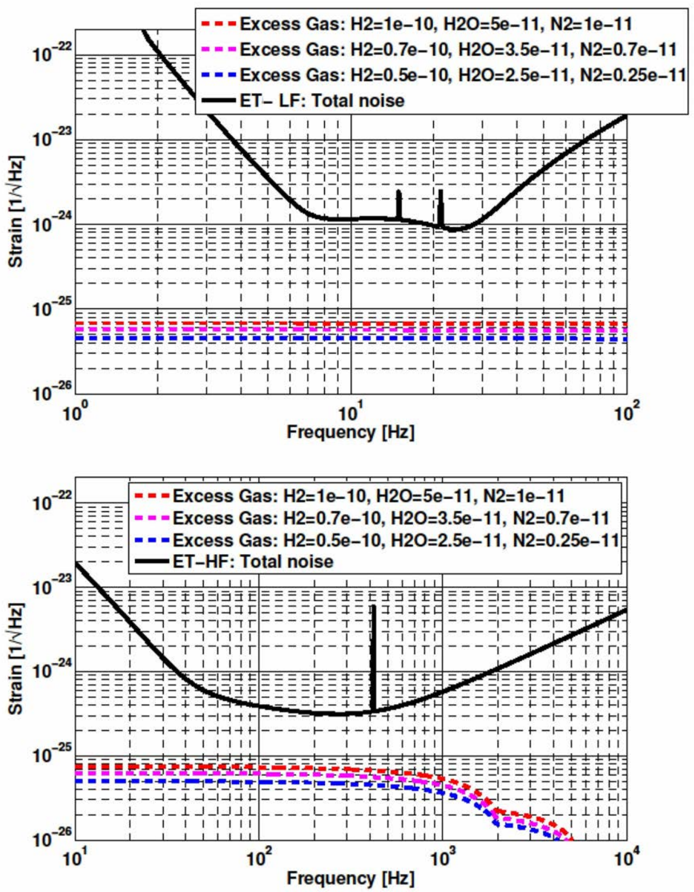


Figure 6.16: Phase noise given by the residual gases compared to the expected sensitivity, computed for the appropriate beam profile for different gas compositions. (Goal gas composition: Hydrogen [$1 \cdot 10^{-10}$ mbar], Water [$5 \cdot 10^{-11}$ mbar], Nitrogen [$1 \cdot 10^{-11}$ mbar])

See A. Grado Presentation

ET technical report 2020

ETIC Goals

ETIC project aims to support the qualification of Sos Enattos candidate site and to implement a network of research infrastructures and laboratories that will be the core framework to develop the enabling technologies for ET, grouped in the following five macro-areas:

1) *Optics, Electronics and Photonics*
2) *Vacuum and Cryogenics*
3) *Suspensions and Interferometry*
4) *Computing & DAQ*
5) *Civil and environmental engineering modelling and design*

ETIC WBS

The programme is organised in 7 work packages (WPs):

- *WP1-Management*
- *WP2-Optics, Electronics and Photonics*
- *WP3-Vacuum and Cryogenics*
- *WP4 -Suspension and Interferometric large facilities*
- *WP5-Computing & DAQ*
- *WP6-Sustainable Design*
- *WP7-Outreaching, dissemination, training*

ETIC Infrastructure Network

EINSTEIN TELESCOPE

1. GEMINI(WP4),located in the INFN-LNGS OU, aiming to the development of an active seismic-isolation system and an inter-platform motion control for Einstein Telescope in the low- noise underground environment of the National Laboratories of Gran Sasso
2. CAOS(WP4),located in the INFN-PG and UniPG OUs, targeting the realization of an international laboratory where to develop the technologies of future GW detectors, hosting a reduced scale prototype of the ET interferometer
3. SAMaNET(WP4),located in the INFN-PI OU, aiming to the realization of a well-equipped laboratory for the development, test, and validation of a full-scale Superattenuator (with passive and active components) for seismic noise and local disturbances suppression in ET
4. PLANET(WP2),located in the INFN-NA and UniNA OUs, rovide location and equipment for the development and test of: the ET environmental monitoring, the squeezing system for quantum noise reduction, the new suspension system for the ET test mass
5. CoMET(WP2),located in the INFN-PD OU, aiming to the production of high-quality thin film samples of varied materials to fulfil the global demand of the research groups working on new coatings for ET
6. BETIF(WP2-WP5),located in the INFN-BO OU, integrates resources for time synchronization, data processing and computing, prototyping an access point for testing and validating the ET telescope technologies
7. GALILEO (WP2), located in the INFN-GE and UniGE OUs, aiming to the production and characterization of advanced optical materials and development of quantum techniques for the mitigation of thermal and quantum noise in third generation gravitational wave detectors
8. ETiCO2 (WP2), located in the INFN-CA and UniCA-Fisica OUs, will develop, build and characterize custom optoelectronics devices to monitor and control the ET interferometer, and will also design, fabricate and test dielectric materials and multilayers for the ET mirror coatings
9. AiLOV-ET (WP2), located in the INFN-RM2 and UniRM2 OUs, targeting the development of innovative technologies for wavefront sensing and control, and production and characterization of advanced coating materials for third generation gravitational wave detectors
10. CALATIA (WP3), located in the UniVanvitelli OU, aiming to optimise vacuum system treatments and procedures in ET and to test and vacuum-qualify large ET components like the pipe section

ETIC Infrastructure Network

11. ARC-ETCRYO (WP3), located in the INFN-RM1 and UniSapienza-Fis OUs, aiming to pursue towards the target of developing a test facility for 1:1 cryogenic payload prototype and designing a full-scale cryostat design for ET
12. CTLab4ET (WP5), located in the INFN-TO OU, prototyping and testing the computing technologies for data analysis, waveform simulation, data management and low-latency services, aimed at the preparation of the ET Computing Model
13. DIFAET (WP2, WP5), located in the UniBO OU, enabling R&D for accelerated science in ET via a heterogeneous computing platform to support design and testing of innovative ET applications, and to find the best coating for ET mirrors
14. ADONI-ET (WP2), located at the INAF Arcetri Observatory, the mission of National Laboratory of Adaptive Optics, ADONI, is to advance and foster the technology of Adaptive Optics in ground- and space- based Astronomy, in industrial and medical application as well as in research, education and outreaching to the general public.
15. PisaET-IR@CISUP (WP2), located in UniPI, aiming to the production and mechanical characterization of low dissipation thin films for optical applications.
16. ET-3G LAB (WP6) located in the UniSapienza-Ing OU, propose the establishment of a multi- disciplinary lab focused on frontier research in civil and environmental engineering that will enable to obtain an optimized design for the civil works, to analyse innovative technical solution for the planning, construction and operation of ET.
17. AT-LAB (WP6) located in the UniCA-IngCiv OU, aiming to support for the definition of the spatial components of the research infrastructure and study of the effects on territorial, urban and landscape systems.

INFN-LNS OU, located in Catania, will collect the outcomes of the analysis, investigations and modelling performed by ET-3G LAB and AT-LAB to define specifications and requirements for activate an international tender to be assigned to a leader engineering company.