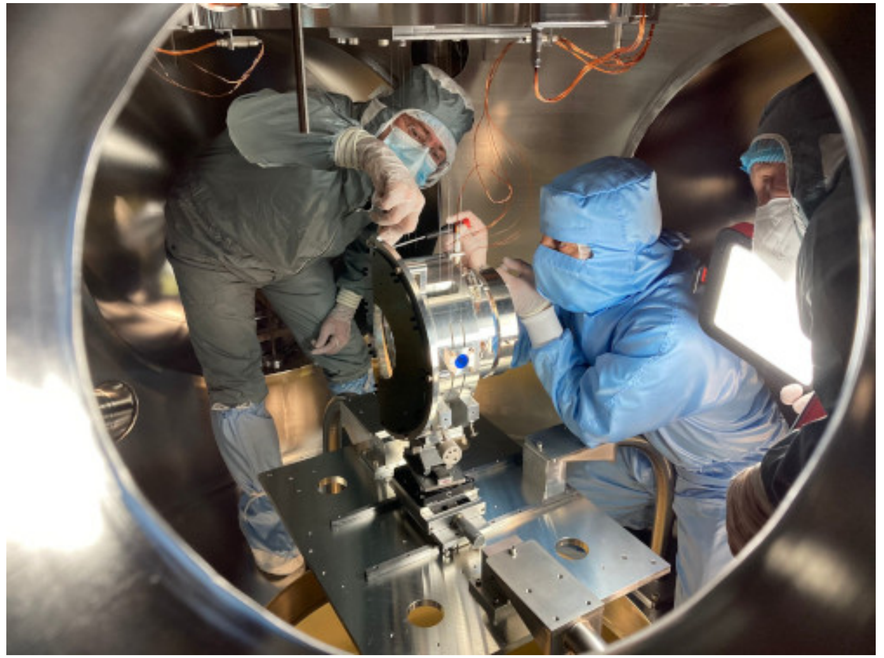
The Einstein Telescope Project

M. Martínez

Plan Complementario, Zaragoza, June 2024

Outline

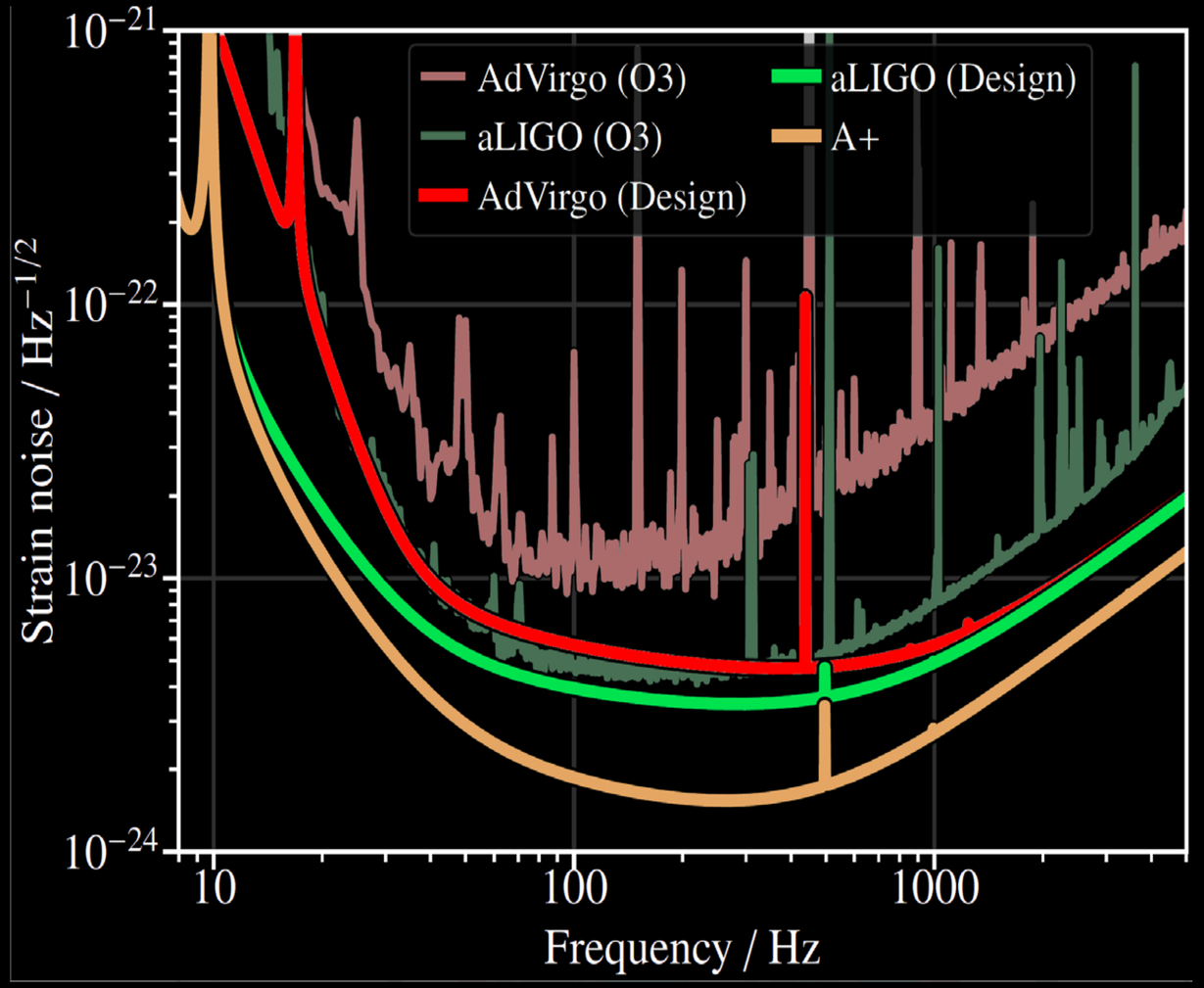
- The Einstein Telescope
  - Conceptual Design
  - Physics Potential
  - Time Scales, costs, location
  - R&D for its realization
- ET @ ESFRI 2021 roadmap
  - Preparatory Phase
  - Organization
  - Political Support
  - ET@CERN activities
  - Ongoing geometry discussions
  - ET-Spain
- Final notes

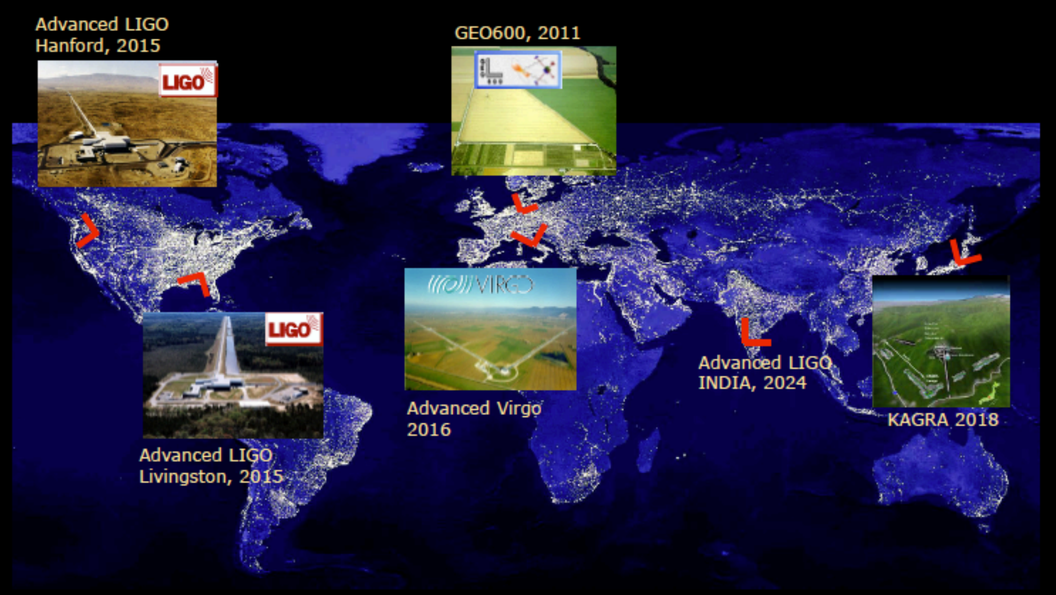


IFAE engineers installing instrumented baffle at Virgo

(A demonstrator of the novel technology… not for this talk)

LVK sensitivity

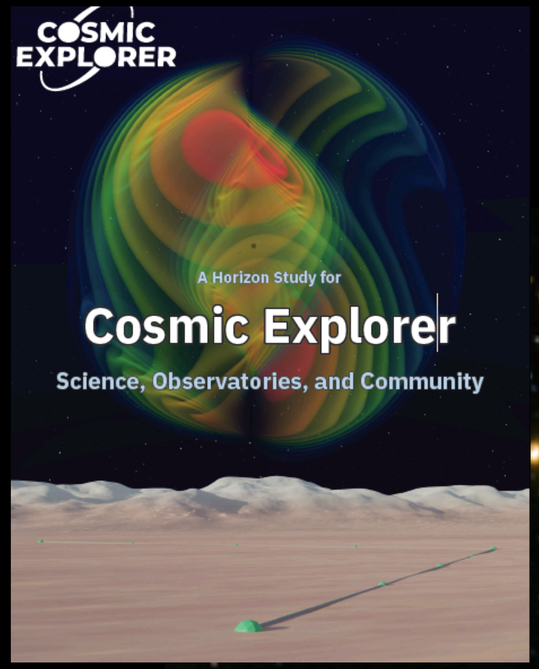


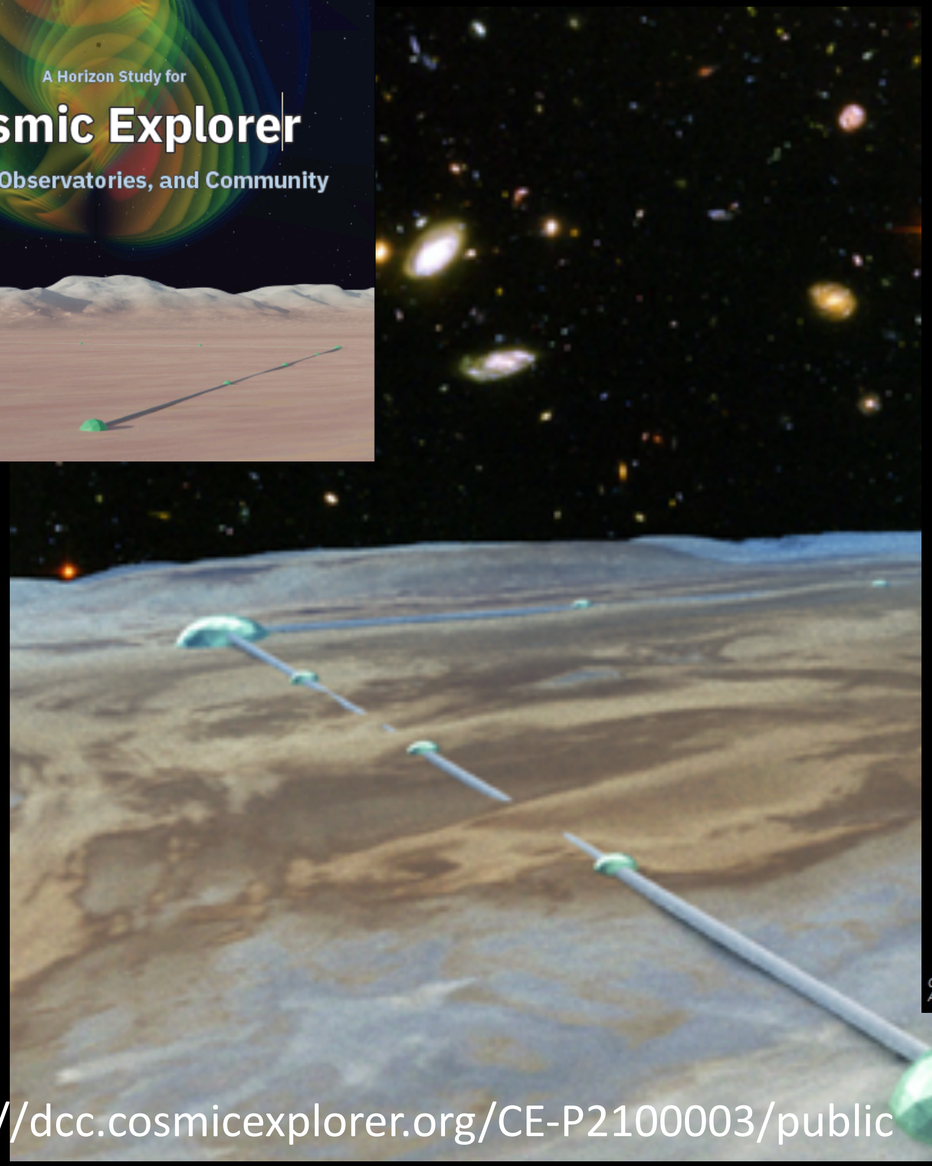


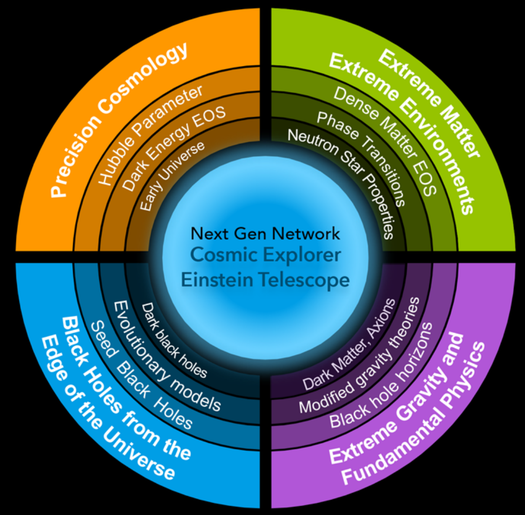
In the next 6 years the current Interferometers will reach their design sensitivity…

Cosmic Explorer (USA)

https://cosmicexplorer.org/







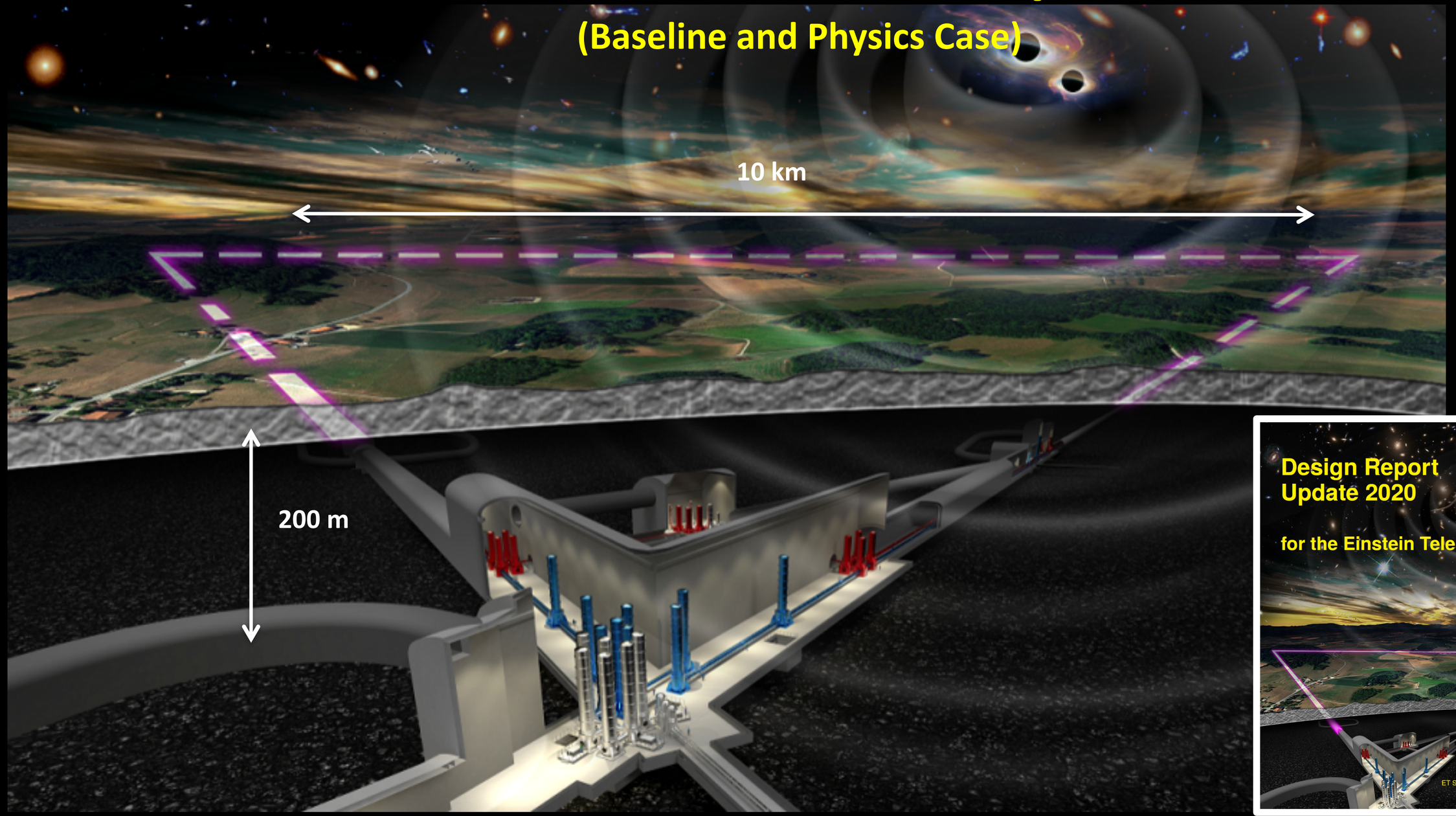
http://dcc.cosmicexplorer.org/CE-P2100003/public

http://www.et-gw.eu/

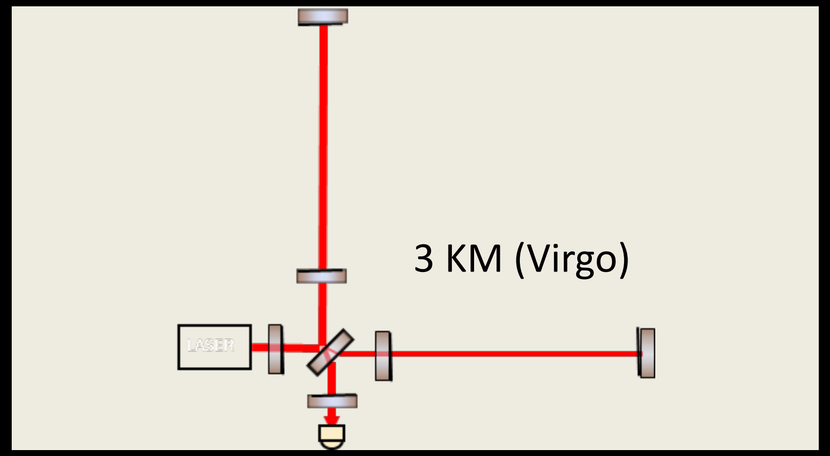
The Einstein Telescope

(Baseline and Physics Case)

First CDR in 2010 - 2011



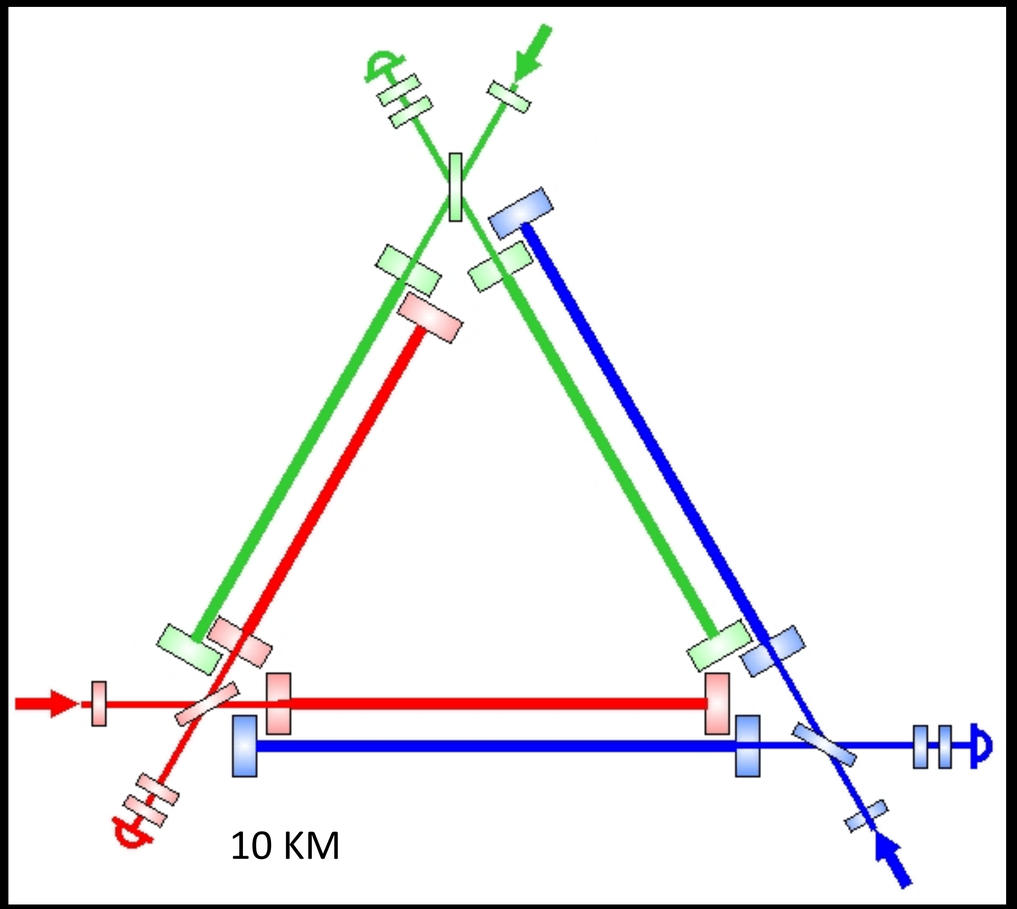
2nd Gen → 3rd Gen

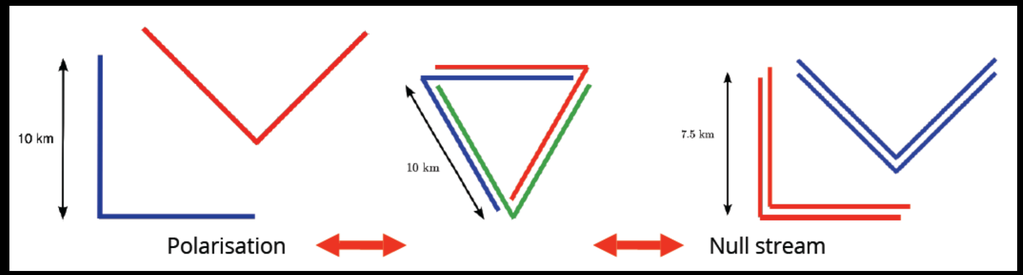


- Underground to suppress seismic and Newtonian noise at low frequencies

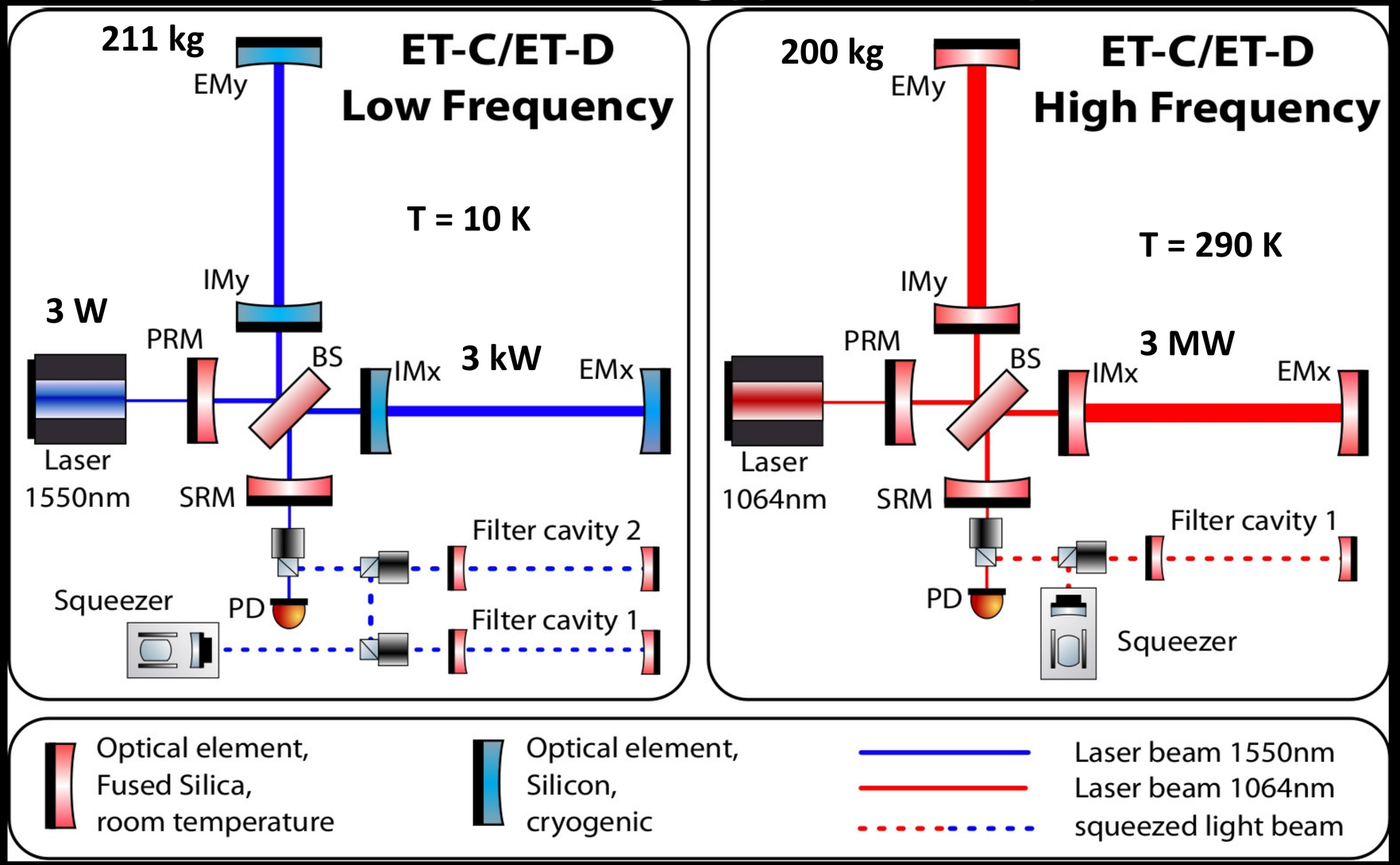
- Longer arms to increase sensitivity

- Triangular ITF configuration to
  - Measure polarization
  - Auto-calibration / null-stream
  - Redundancy
  - One single big infrastructure (optimization of costs)





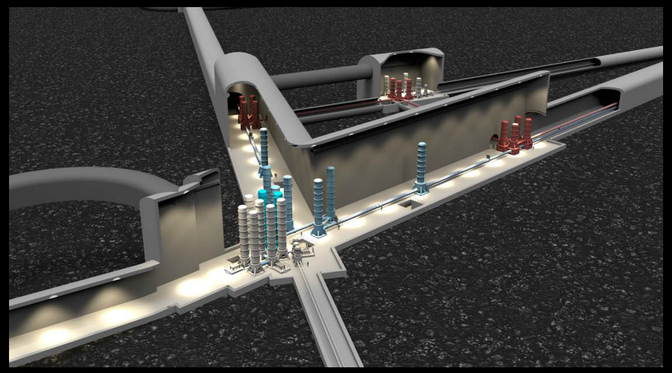
2nd Gen → ET

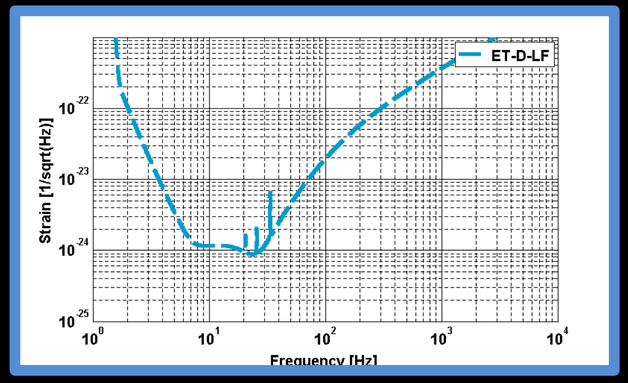


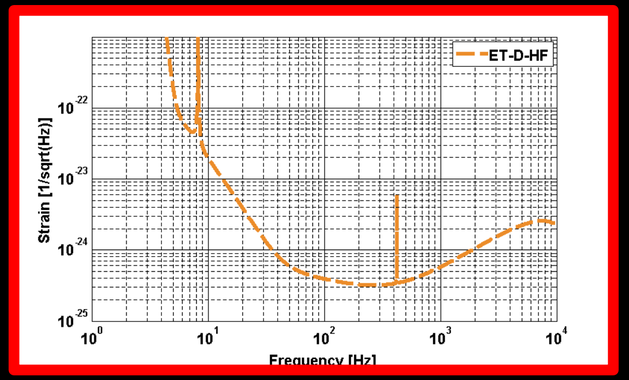
Underground
Cryogenic
Silicon mirrors
1550 nm (Si transparent)
New optical coatings
New suspensions / seismic controls

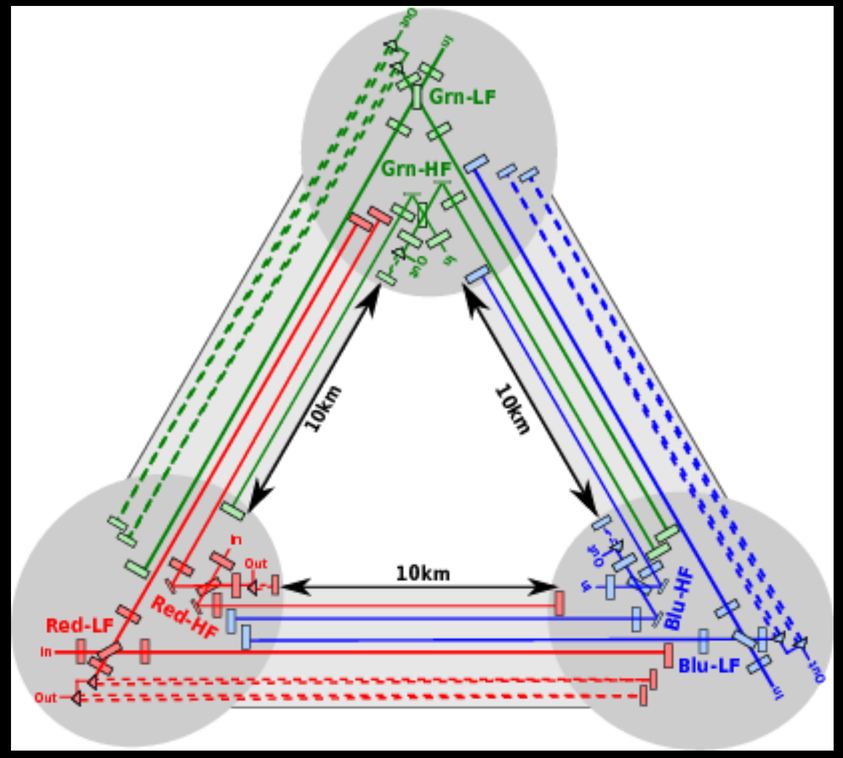
More powerful lasers
Larger fused silica mirrors
1064 nm (silica transparent)
New optical coatings
New thermal compensation systems

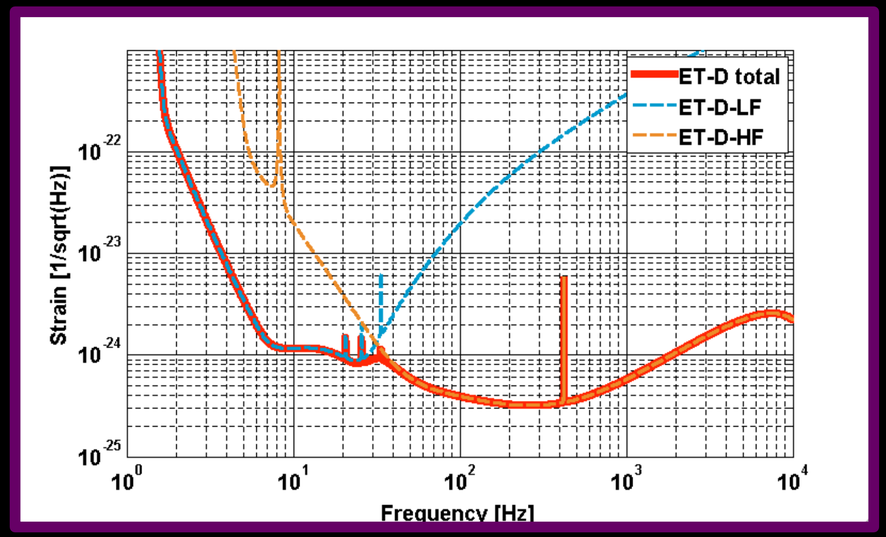
Einstein Telescope (6 in 1) Xylophone











Each interferometer decoupled into 2 devices independent for the best sensitivity to low and high frequency

ET Science

arXiv:1912.02622

ET Science Blue Book will be ready by September 2024

Astrophysics

- **Black hole properties**

– origin (stellar vs. primordial)

– evolution, demography

- **Neutron star properties**

– demography, equation of state

- **Multi-messenger astronomy**

– joint GW/EM observations (GRB, kilonova,…)

– multiband GW detection (LISA)

- **Detection of new astrophysical sources**

– core collapse supernovae

– isolated neutron stars

– stochastic background of astrophysical origin

Fundamental Physics, Cosmology, HEP

- **Testing the nature of gravity**

– perturbative regime: inspiral phase of BBH, post-Newtonian expansion

– strong field regime: physics near BH horizon

exotic compact objects

- **QCD**

— interior structure of neutron stars probe ultra-high temperatures and densities

– exotic states of matter

- **Dark Matter / New Particles**

– primordial BHs

– axions, dark matter accreting on compact objects

- **Modified Cosmology**

– Dark Energy equation of state

– modified GW propagation @ cosmological scales

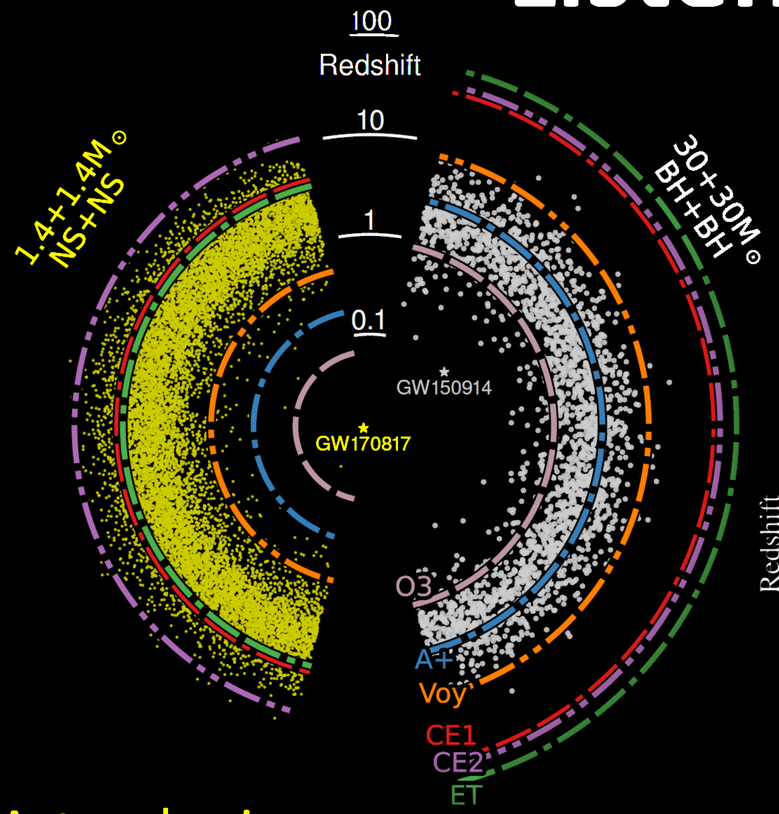
- **Stochastic backgrounds of cosmological origin and HEP**

– inflation, first-order phase transitions

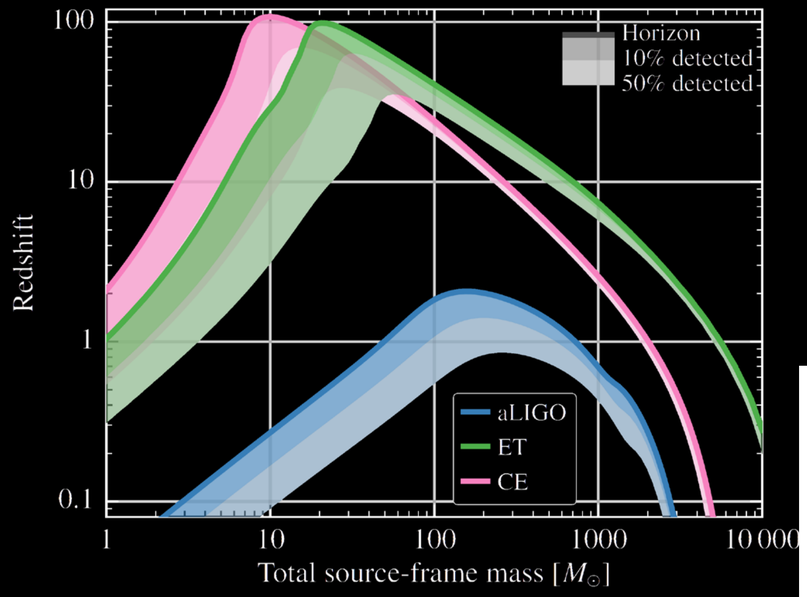
– cosmic strings, domain walls..

Listening the whole Universe

Iacovelli et al. 2022

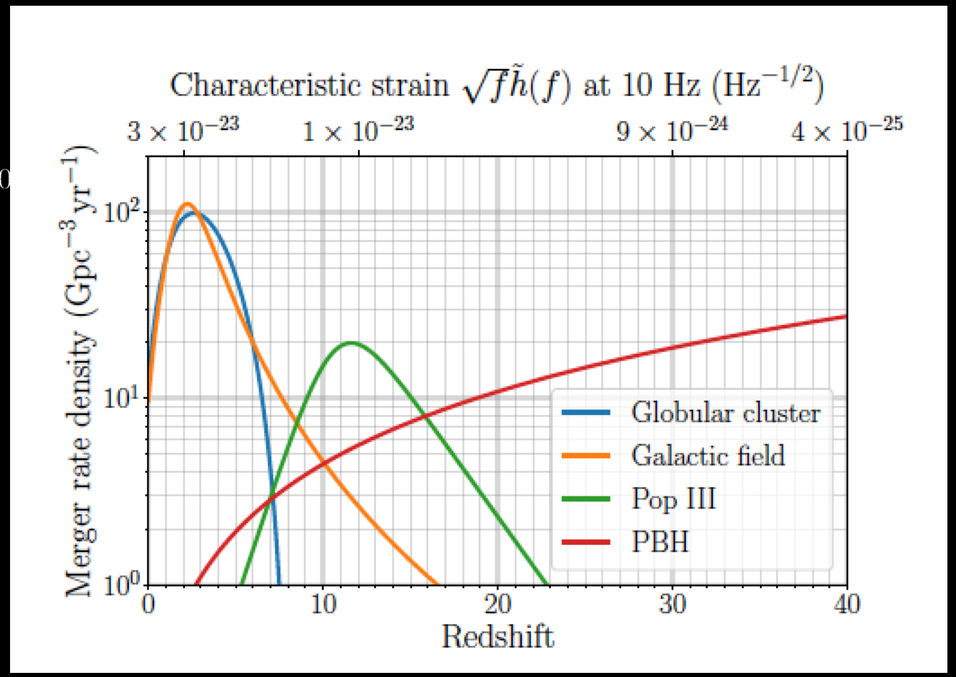


- 10^6 BH-BH / year up to z ~20 (230 Gpcs) and 10^3 M_{sun}
- 10^5 NS-NS / year up to z~2
- O(10^2 – 10^3) GW events with EM counterparts

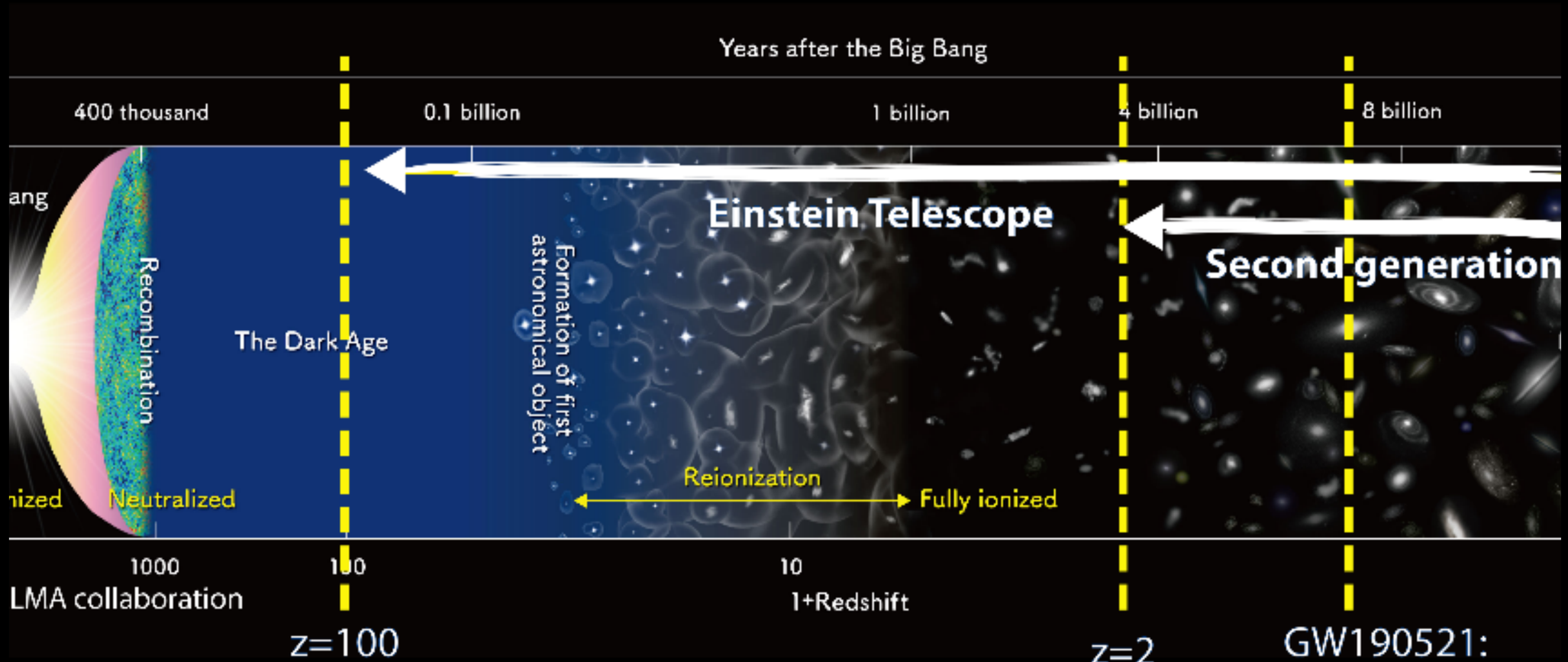


Astrophysics

- BH demography and evolution
- Primordials? Stellar?
- Are BHs part of the dark matter?
- Supernovae, Pulsars, Stochastic signals
- Properties of neutron stars
- Multi Messenger: Optical, Neutrinos, Gamma Rays



Detection horizon for black-hole binaries

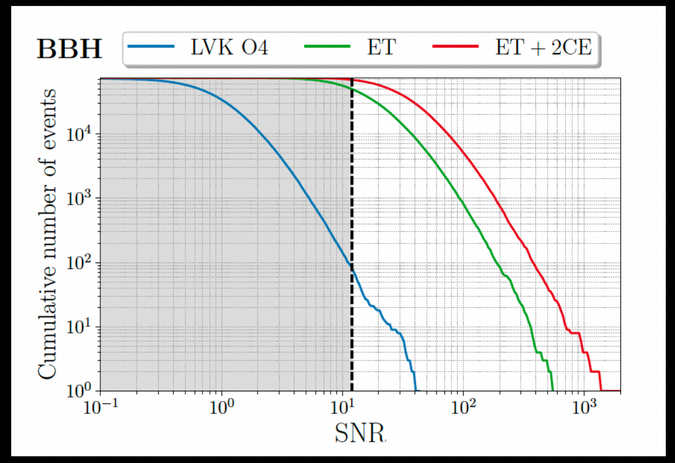


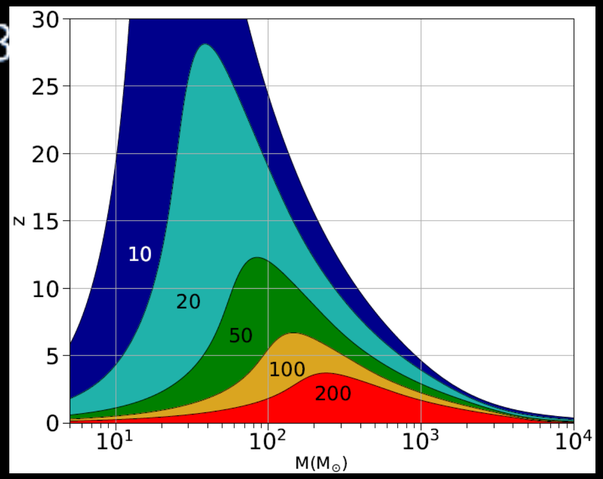
Huge rate of detections (about 1 per minute)
Extended redshift coverage up to the Dark Age

- Test for primordial BH origin
- Cosmology & Cosmography

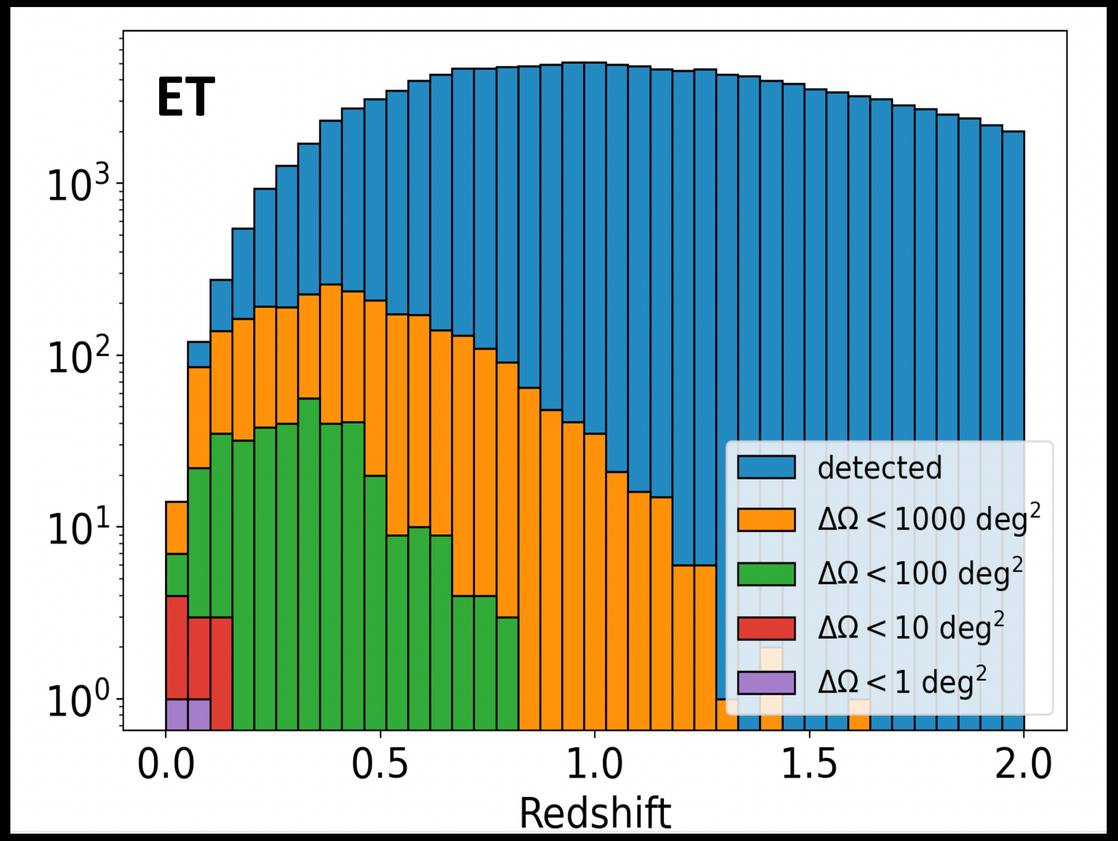
Many events with very large Signal-to-Noise ratios

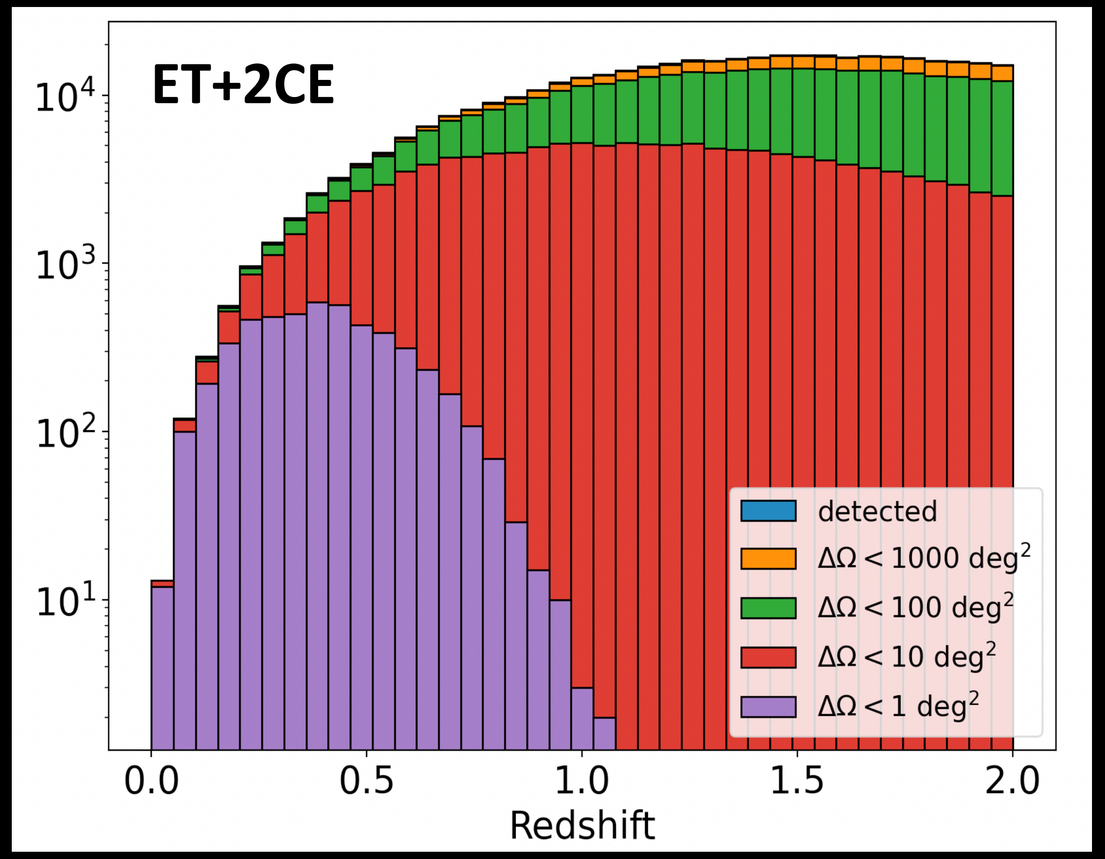
- Precision tests of GR predictions and detailed BH studies





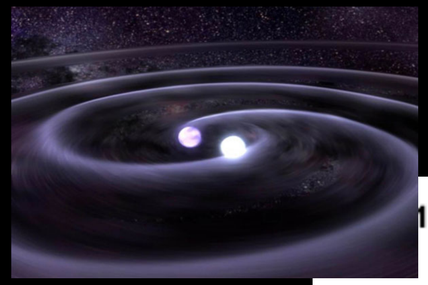
Sky localization





ET only configuration would allow for O(100) events / year with a sky-localizations (90% CL) < 100 deg^2

ET + 2 CE configuration would allow for O(1000) events / year with a sky-localizations (90% CL) < 1 deg^2



Complementarity

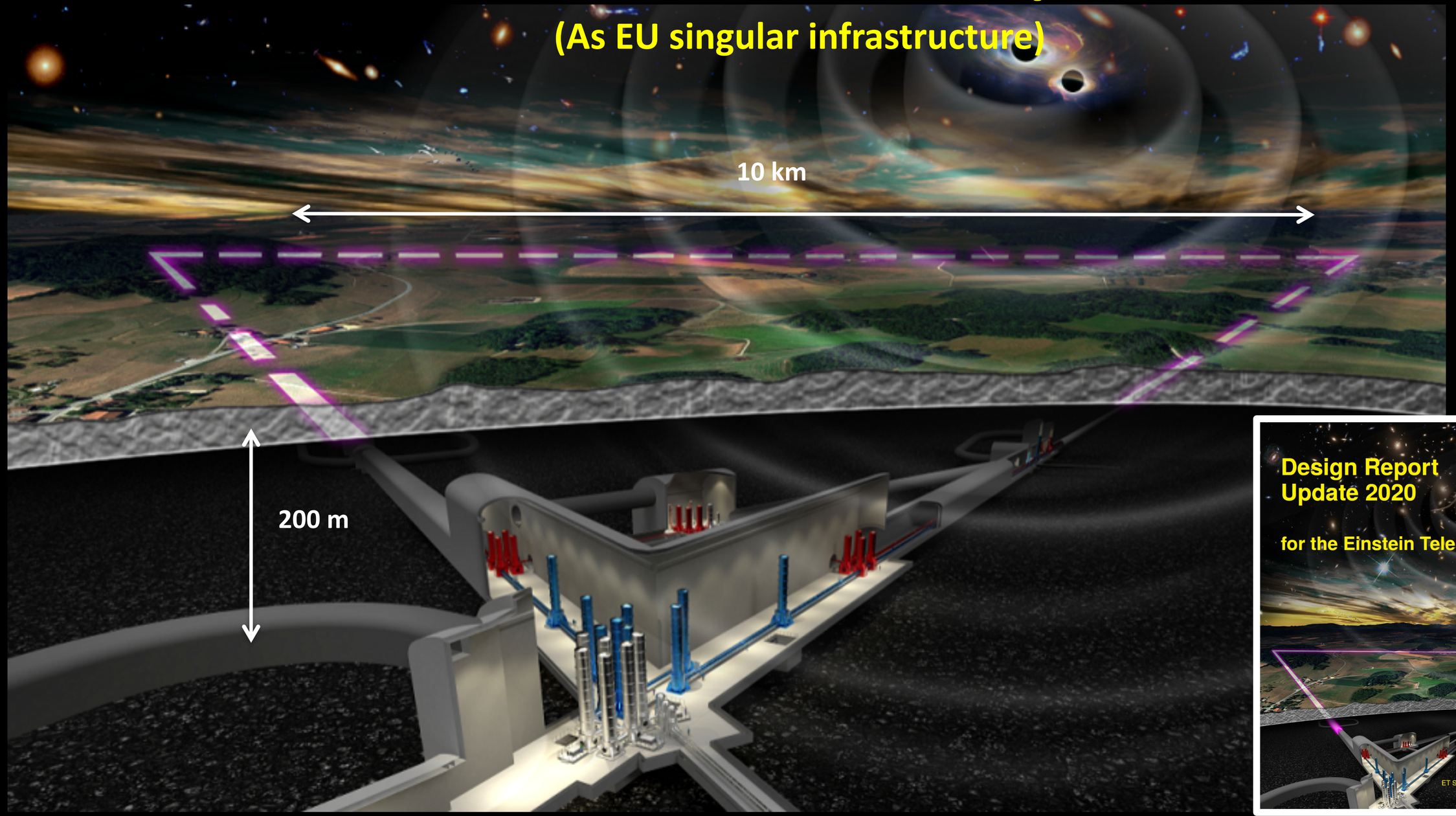
LISA and ET become complementary now
that the same signal can be followed
by LISA and ET in different Hz ranges

LISA pre-warns ET

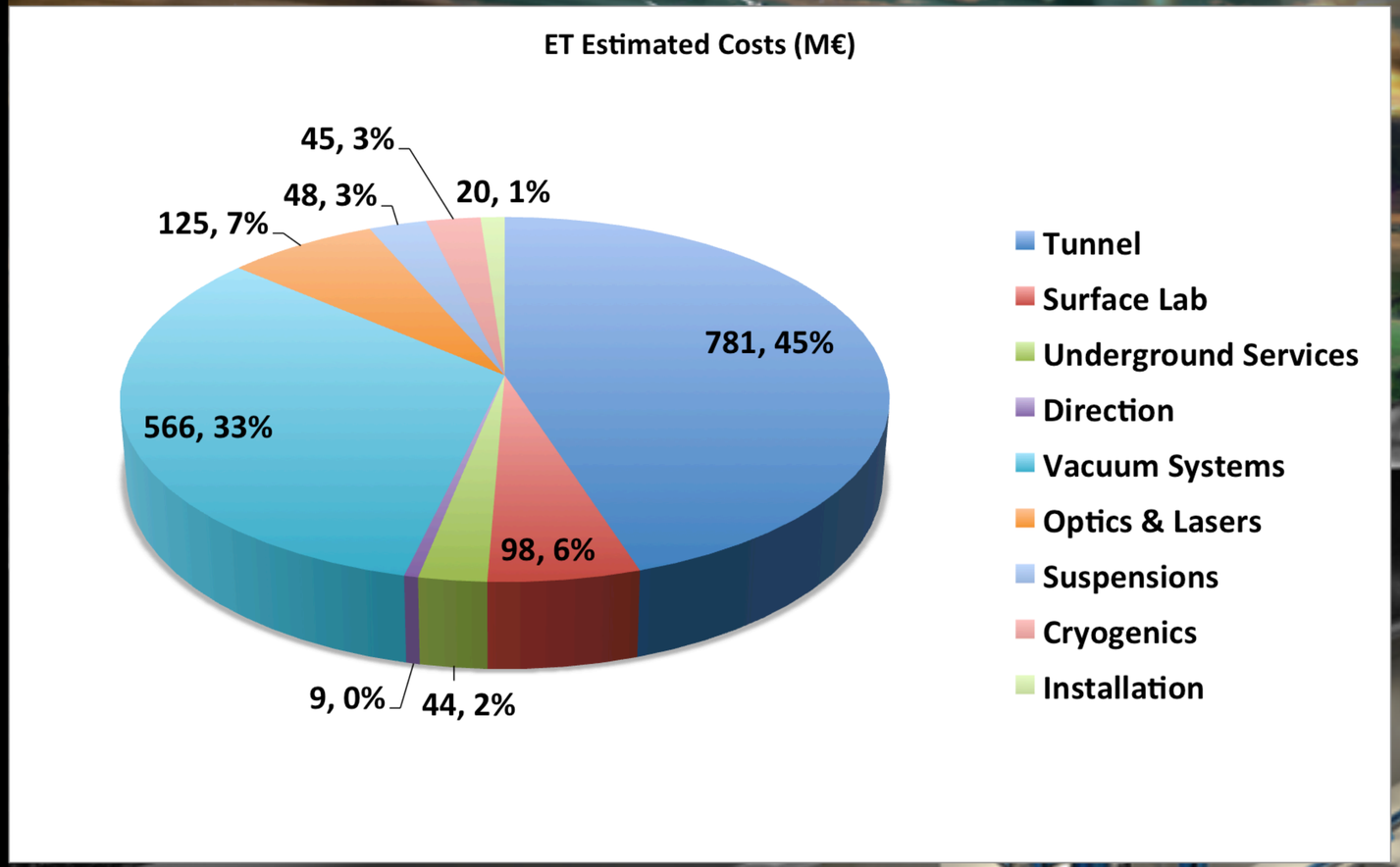
http://www.et-gw.eu/

The Einstein Telescope

(As EU singular infrastructure)



Estimated cost (EU accounting)



Preparatory phase (170M€)

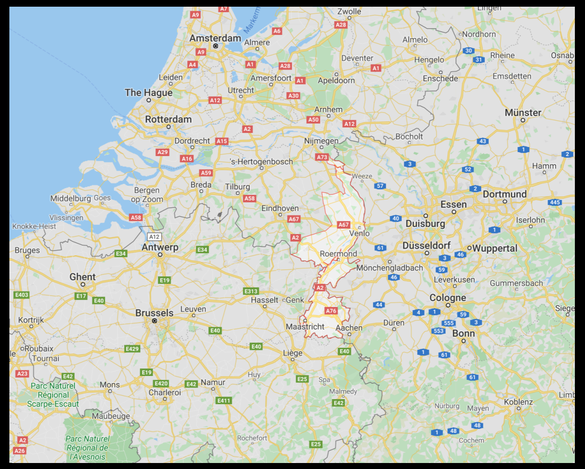
1. Site qualification (funded)
2. Site preparation (50 – 60 M€)
   Covered by host country
3. R&D on technology (95 M€) (funded)

Construction : 1900 M€ (in 10 years)
M&O : 37M€ /year

Host country is expected to contribute with > 50% of the total cost

Locations ?

O(50 M€) investment
Lab in construction



@ Limburg area (border NL-B-D)
→ Promoted by Nikhef

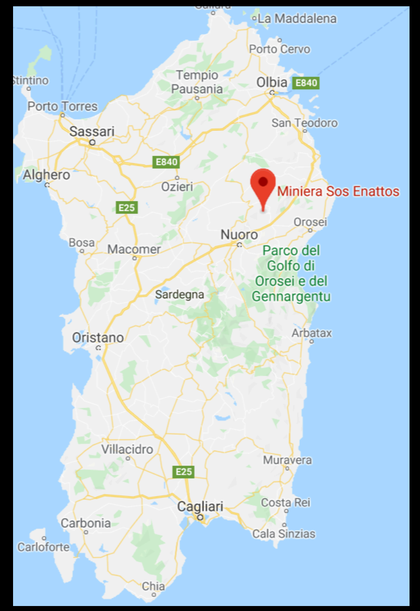
30 M€ investment
ETparthfinder

Intensive studies
@ Limburg,
@ Sardinia
@ Saxony
For characterize seismic, environmental noise, etc ...

@ Germany is very present in ET and ETpathfinder
They foresee a large investment in the following years

→Exploring Saxony as a possibility
→ Ongoing geological characterization of the site

O(50 M€) investment
Lab in construction



@ Sardinia
→ Promoted by INFN

?

Rising Construction Funds

In the Netherlands a formal request of 900M€ for ET@ Maastricht **has been approved** by the Science Minister to the NL Government

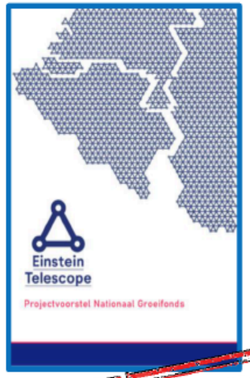
Italy approved a 50M€ project for enabling technologies and additional 950M€ for supporting ET@ Italy **has been secured**

Time to discuss the level of financial involvement by other EU countries in ET for the following decade

Einstein Telescope in Euregio Meuse-Rhine (EMR)

Connected institutions in:
Belgium,
Germany &
the Netherlands

Nationaal Groeifonds (the Netherlands)



Emphasis on potential socio-economic Impact

Submitted by OCW Ministry
(EZK Ministry support)

Supported by ~70 Dutch Industrial Institutions

APPROVED

In October 2021 the Netherlands Minister large funding proposal within context of the '*Nationaal Groeifonds*'. Decision in April 2022.

Includes 42 M€ for geology, R&D & organization as well as possible Dutch share towards ET realization

27

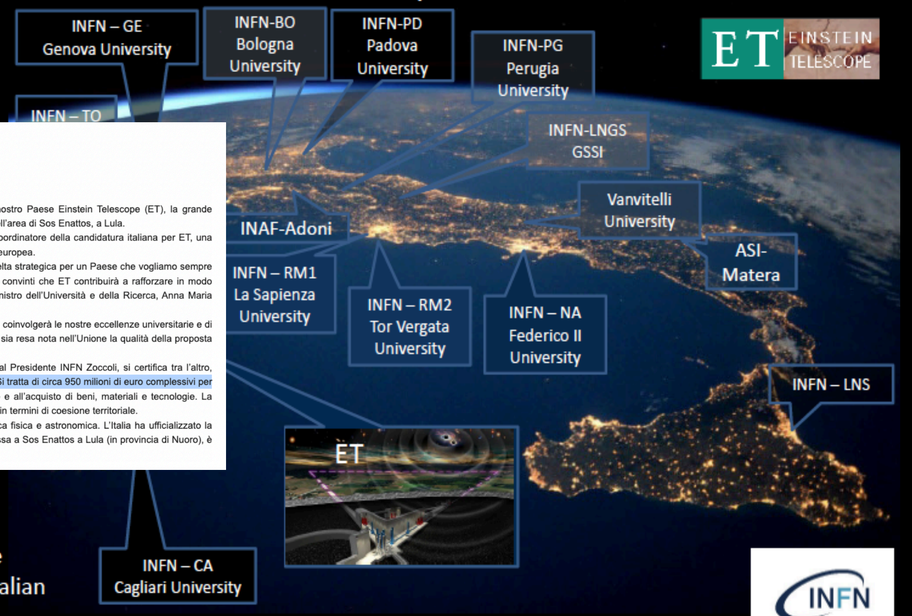
Next Generation EU Investment focused on ET enabling technology and Sardinian site candidature

COMUNICATO STAMPA
Ricerca, Governo rafforza candidatura Einstein Telescope
Il Ministro Bernini: "Scelta strategica per Paese ambizioso"

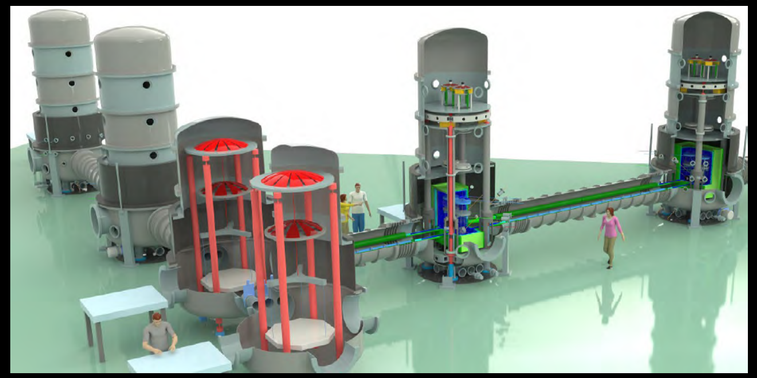
ROMA, 13 dicembre 2023 – Il Governo italiano è pronto a sostenere l'impegno finanziario per ospitare nel nostro Paese Einstein Telescope (ET), la grande infrastruttura di ricerca per lo studio delle onde gravitazionali che l'Italia si è candidata a realizzare in Sardegna, nell'area di Sos Enattos, a Lula.
Il Governo ha indirizzato ad Antonio Zoccoli, Presidente dell'Istituto Nazionale di Fisica Nucleare (INFN), ente coordinatore della candidatura italiana per ET, una lettera con la quale conferma l'impegno, istituzionale e economico, perché la proposta sia quella vincente in sede europea.
"La volontà di realizzare Einstein Telescope in Italia è stata fortemente sostenuta dal Governo. Si tratta di una scelta strategica per un Paese che vogliamo sempre più ambizioso. L'Italia è leader in Europa per la fisica, con la presenza di molte eccellenze scientifiche. Siamo convinti che ET contribuirà a rafforzare in modo decisivo la realizzazione di un ecosistema della ricerca e dell'innovazione sempre più attrattivo", ha detto il Ministro dell'Università e della Ricerca, Anna Maria Bernini.
Per ottenere l'assegnazione europea, il Governo ha deciso di programmare un piano di 'diplomazia scientifica' che coinvolgerà le nostre eccellenze universitarie e di ricerca, tra cui il Premio Nobel Giorgio Parisi. Sarà affidato loro un ruolo di coordinamento e divulgazione, perché sia resa nota nell'Unione la qualità della proposta italiana e quanto questa sappia rappresentare al meglio gli interessi comunitari.
Nella lettera del Sottosegretario di Stato alla Presidenza del Consiglio dei Ministri, Alfredo Mantovano, inviata al Presidente INFN Zoccoli, si certifica tra l'altro, l'importante impegno finanziario che il Governo è pronto ad assumere in caso di assegnazione dell'infrastruttura. Si tratta di circa 950 milioni di euro complessivi per i nove anni previsti per la costruzione (dal 2026 al 2035). In particolare, le spese serviranno alla realizzazione e all'acquisto di beni, materiali e tecnologie. La dotazione è stata prevista tenendo conto anche dell'elevato impatto occupazionale e di indotto atteso e del ritorno in termini di coesione territoriale.
Einstein Telescope sarà un osservatorio internazionale di terza generazione all'avanguardia assoluta nella ricerca fisica e astronomica. L'Italia ha ufficializzato la sua candidatura nello scorso mese di giugno. Il sito scelto per l'infrastruttura, e cioè nell'area della miniera dismessa a Sos Enattos a Lula (in provincia di Nuoro), è considerata ottimale per le eccellenti condizioni geologiche e ambientali che può garantire.

Discussion ongoing with the Italian Government on an Italian share toward ET realization

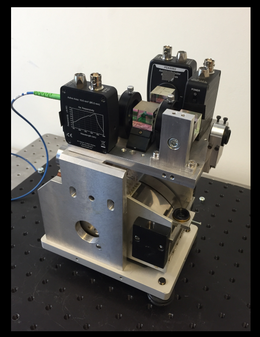
ETIC – Einstein Telescope Infrastructure Consortium

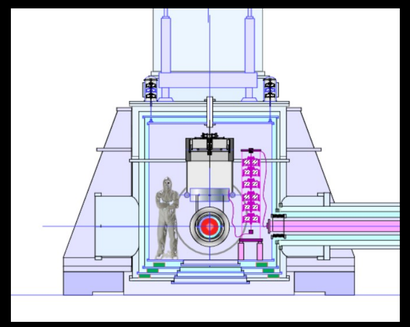


Ongoing R&D for ET (examples)



@ Maastricht small-scale prototype
in order to study the operations in
cryogenics with silicon optics at 1550 nm
and with mirrors up to 100 kg (relevant for ET-LF)



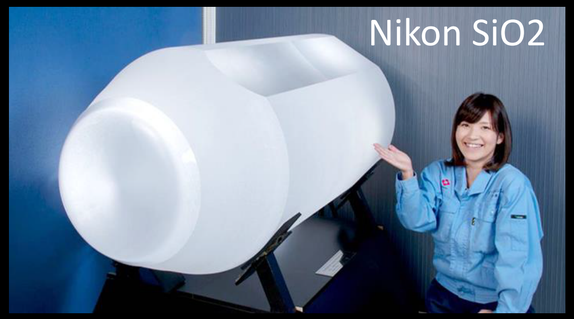


R&D in active mitigation
of seismic / Newtonian noise

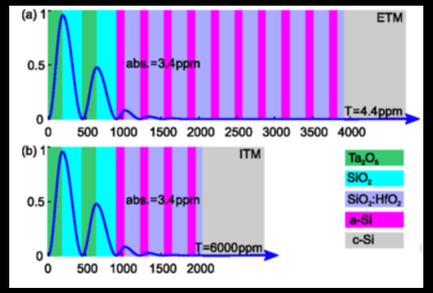
R&D on IR photo sensors

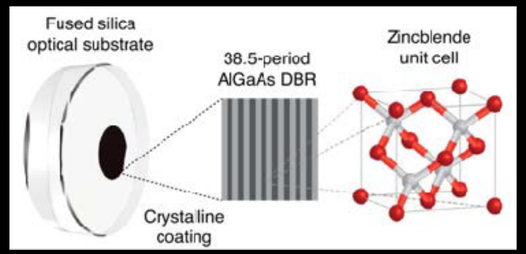
@ Rome and other R&D places
in cryogenic suspension

R&D for the production of mirrors up to
200kg based on silica or silicon of
high purity and homogeneity.



R&D in optical coatings reflective
with low absorption and reduced
thermal noise.





AlGaAs crystalline coatings

Major R&D Facilities in ET (incomplete)

From the XIII ET symposium, an incomplete selection of thepresented large facilities

VATIGrav and Compact Laser Interferometry

Main goals:
- test DFMI-based compact displacement sensors on suspensions to reduce control noise
- test inertial sensors with highly sensitive interferometric displacement sensors
- study new suspension control and seismic isolation schemes

DFMI metrology

Optical head (COBRI)

Readout algorithm

Readout system and electronics

System-level testing

OmniSense at Nikhef

- Interferometric sensing (HoQI), compact and proven
- Fused-silica suspension
- Closed-loop control
- Careful shielding for thermal fluctuations, acoustics, and E-M
- Mechanical simplicity, no cables or magnets.

Etpathfinder in Maastricht

Interreg Vlaanderen-Nederland

2 FPMI interferometers:
1) 1550nm @ 18K
2) 2090nm @ 123K

Main target:
provide a testbed for ET technol
concepts and qualify them in lo
environment.

The AEI 10 m Prototype Facility

Main goal: Sub-SQL interferometry
Studies of vibration isolation / control

Fused-silica welding

∅ = 3 m

∅ = 1.5 m

= 3 m

= 10 m

See Monday talk by David Wu

On solid ground

DZA The German Centre for Astrophysics (DZA)

a centre for research, technology, and application

DZA concept : the challenges of astrophysics today

E-TEST : Einstein Telescope EMR Site and Technology

Radiative cooling

Vibration isolation

E-TEST objectives

- Large mirror (100 Kg)
- Cryogenic temperature (10-20 K)
- Isolated at low frequency (0.1-10 Hz)
- Compact suspension (4.5 meters)

Test facility for experimental investigations of the He-II based ET-LF payload cooling concept

Suspension and cooling concept studied for ET-LF

He-I: Cool-down process

He-II: Stationary-state operation

See Monday talk by Xhesika Koroveshi

CoMET - Coating Materials for Einstein Telescope

Goals:
- Capability to deposit virtually all the (amorphous) materials of interest for the GW community with the needed level of control.
- Ability to explore different process ranges (energies, growth kinetics etc.)
- Study of the physical processes occurring durign deposition

Coating deposition (samples)
- Ion beam
- Magnetron

Characterization facilities

LMA - Laboratoire des Materiaux Avances

New large optics coater facility

2.2 x 2.2 x 2 m³

Also investing into substrate growth and polishing

Aim: produce ET cryo-compatible substrates in sapphire

Existing LMA building

Extension

1 optic Ø1.5 m/600 kg
2 optics Ø0.8 m/300 kg

CAOS: Centro per Applicazioni sulle Onde gravitazionali e la Sismologia

New facility at the University of Perugia

Development of specific technology for the third- generation GW detectors, and

GEMINI at LNGS

Goals
- Test the limits of active seismic isolation in an underground environment
- Inter-platform motion control
- Underground environmental monitoring
- Test new approaches to controls optimization
- Test new inertial sensors

Vibration target

GEMINI

SAR-GRAV Laboratory

SAR-GRAV hosts ET activities as well as Geophysics and Fundamental Physics activities

PNRR project "Monitoring Earth Evolution and Tectonics" (MEET)
Principal Investigator: Giulio Selvaggi, INGV

Cavern that should host the Archimedes experiment

It is planned to test at least partially a preliminary version of the double-suspended inverted pendulum in a quiet underground environment.

See Monday talk by Enrico Calloni

Amaldi Research Center at Roma La Sapienza

Facility dedicated to cryogenics development for ET.

Build prototype payload

See Monday talk by Ettore Majorana

Glasgow
Amsterdam
Maastricht
Louvain
Hamburg
Hannover
Görlitz
Karlsruhe
Lyon
Padova
LNGS
Rom
Sos Enatos

Landsat / Copernicus
U.S. Navy, NGA, GEBCO

Google Earth

ETpathfinder(s)

A collaboration established with Etpathfinder @ Maastricht

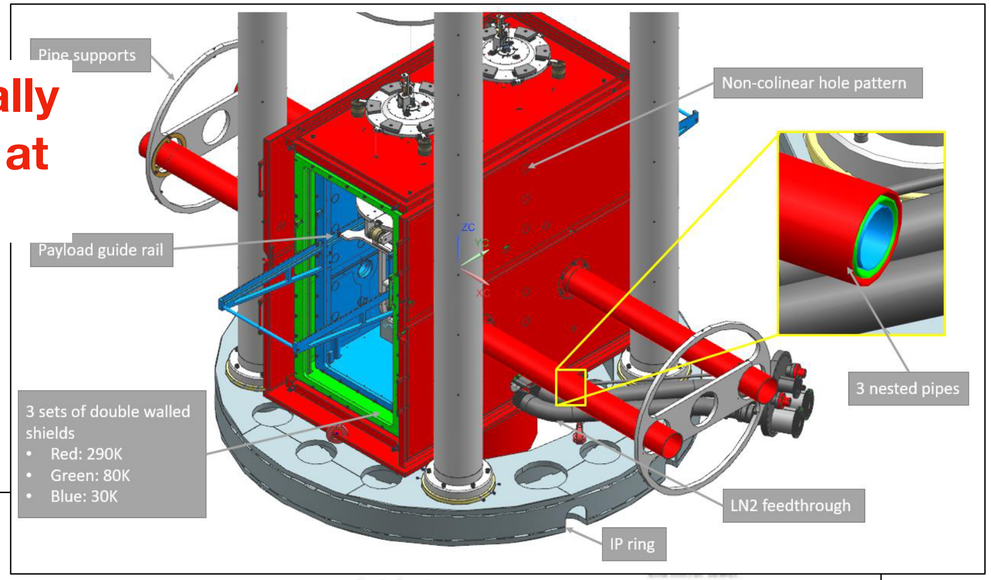
PC will cover partially the hardware cost at ETparthfinder

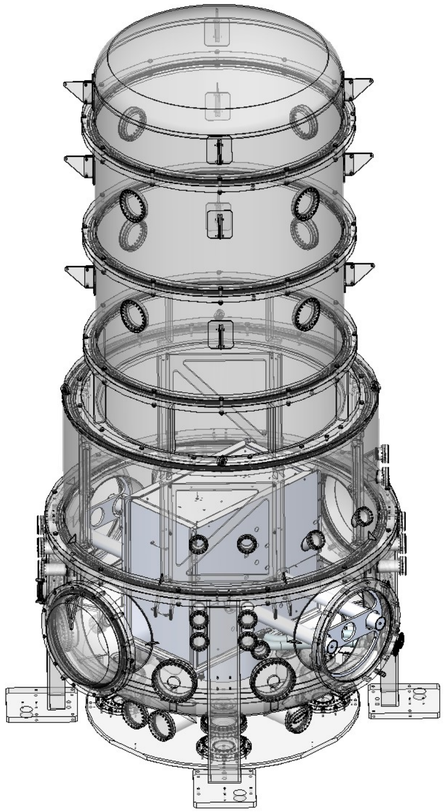
à IFAE redesigned the cryo-shielding [paid by Nikhef]

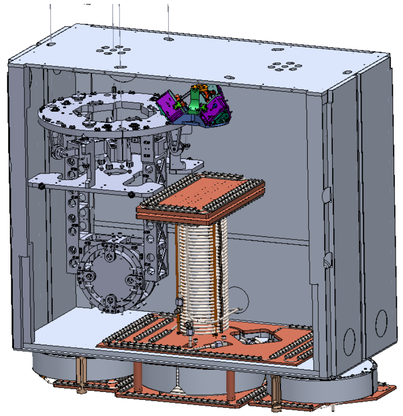
à IFAE will contribute to its installation in 2024

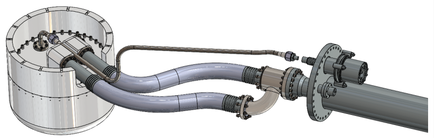
à Pre-alignment & monitoring of the mirror surface at 80 - 290 K (instrumented baffle with sensors for λ = 1550 nm)

→ R&D on InGaAs photosensors with AR-coatings will start soon





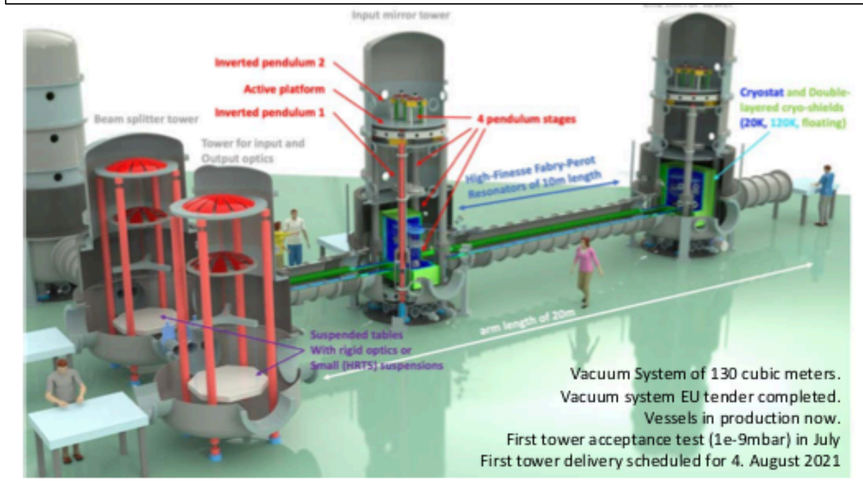




ETpathfinder

- **New facility for testing 3G technology in a low-noise, full-interferometer setup.**
- Key aspects: **Silicon mirrors** (3 to 100+kg), **cryogenics** (cryogenic liquids and sorption coolers, water/ice management), **"new" wavelengths** (1550 and 2090nm), new coatings …
- Start with 2 FPMI, one 120K and one 15K.
- **16 official partners from NL/B/G/FR** + a few more involved, but not yet official partners (like AEI, KIT, Bham, Cardiff, Barcelona etc).
- **Initial capital funding of 14.5 Meuro (no personpower).**
- Detailed **Design Report** available at apps.et-gw.eu/tds/?content=3&r=17177
- **Open for everyone interested to join.**
- www.etpathfinder.eu

Nikhef SAC, 2021-05-26 [S.Hild]



Slide from Nikhef SAC Meeting

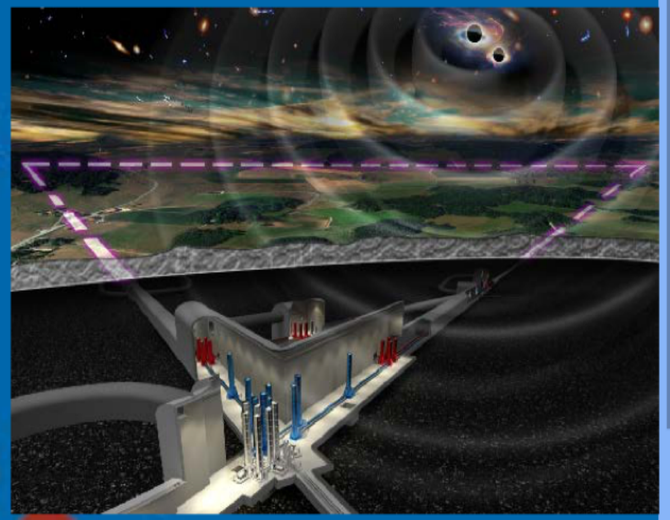
European Strategy Forum on Research Infrastructures

ET on the ESFRI roadmap

ET EINSTEIN TELESCOPE

ESFRI ROADMAP 2021

https://www.et-gw.eu/



Project submitted by:

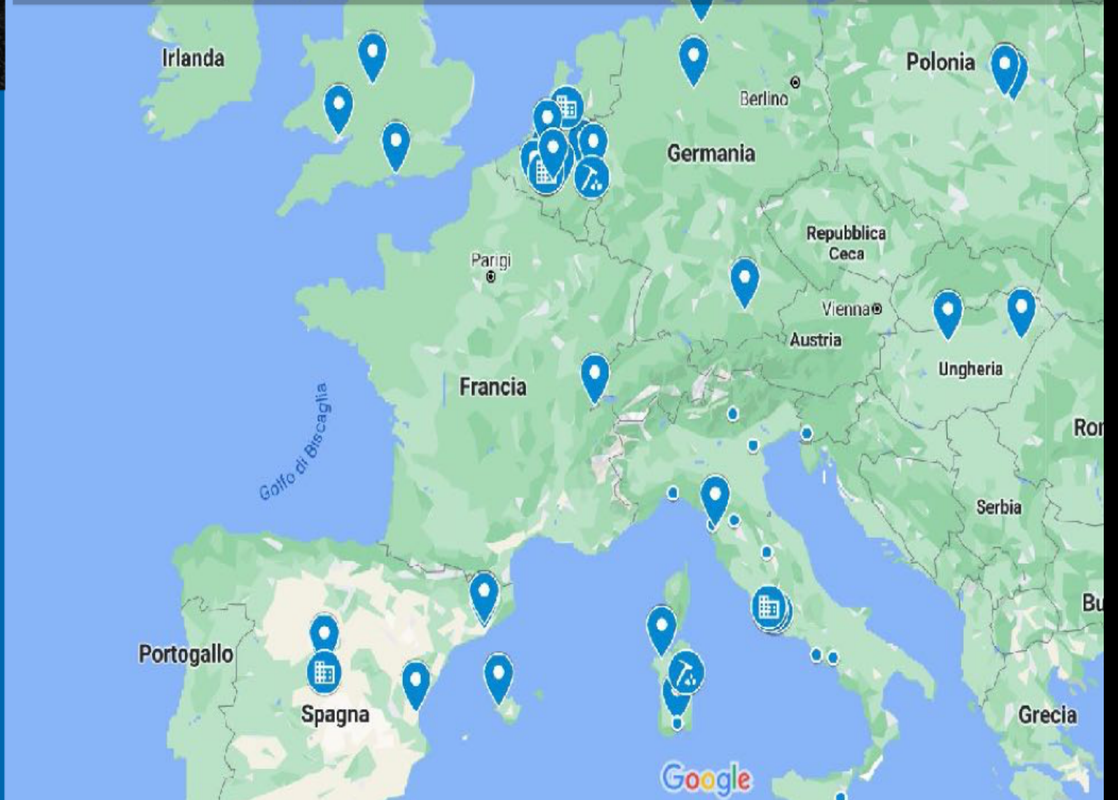
- **Italy** (Lead Country)
- Netherlands
- Belgium
- Spain
- Poland

30/06/2021:

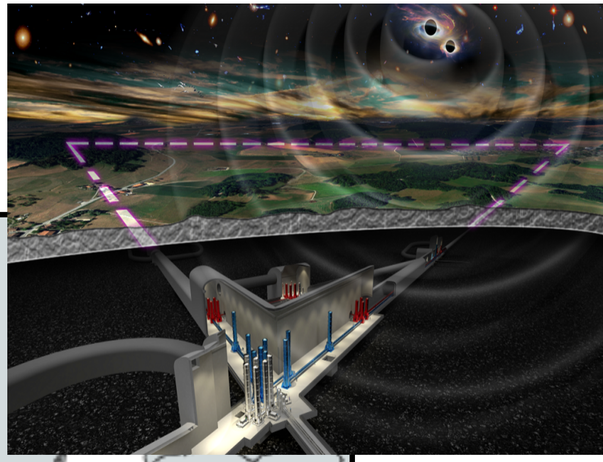
ET is on the ESFRI roadmap!

ET Consortium

- ET CA signed by 41 institutions
- INFN and Nikhef are the coordinators of the consortium
- Funding expected in the next months by the governments in the frontline
- EU funding for the Preparatory Phase in 2022



Einstein Telescope as ESFRI



European Commission | Funding & tender opportunities
Single Electronic Data Interchange Area (SEDIA)

SEARCH FUNDING & TENDERS | HOW TO PARTICIPATE | PROJECTS & RESULTS | WORK AS AN EXPERT

Preparatory phase of new ESFRI research infrastructure projects

TOPIC ID: HORIZON-INFRA-2021-DEV-02-01

Grant

General

Topic de

Destinati

Conditio

Partner s

Submiss

Topic rel

Get supp

Goals for ET Preparatory Phase

- Governance
- Financial architecture/plan/framework
- ET legal entity
- Final ET design and cost evaluation
- Site or sites selection
- Construction funding
- User services
- Computing model
- Sustainability

3.45M€

uctures landscape, m

Type of

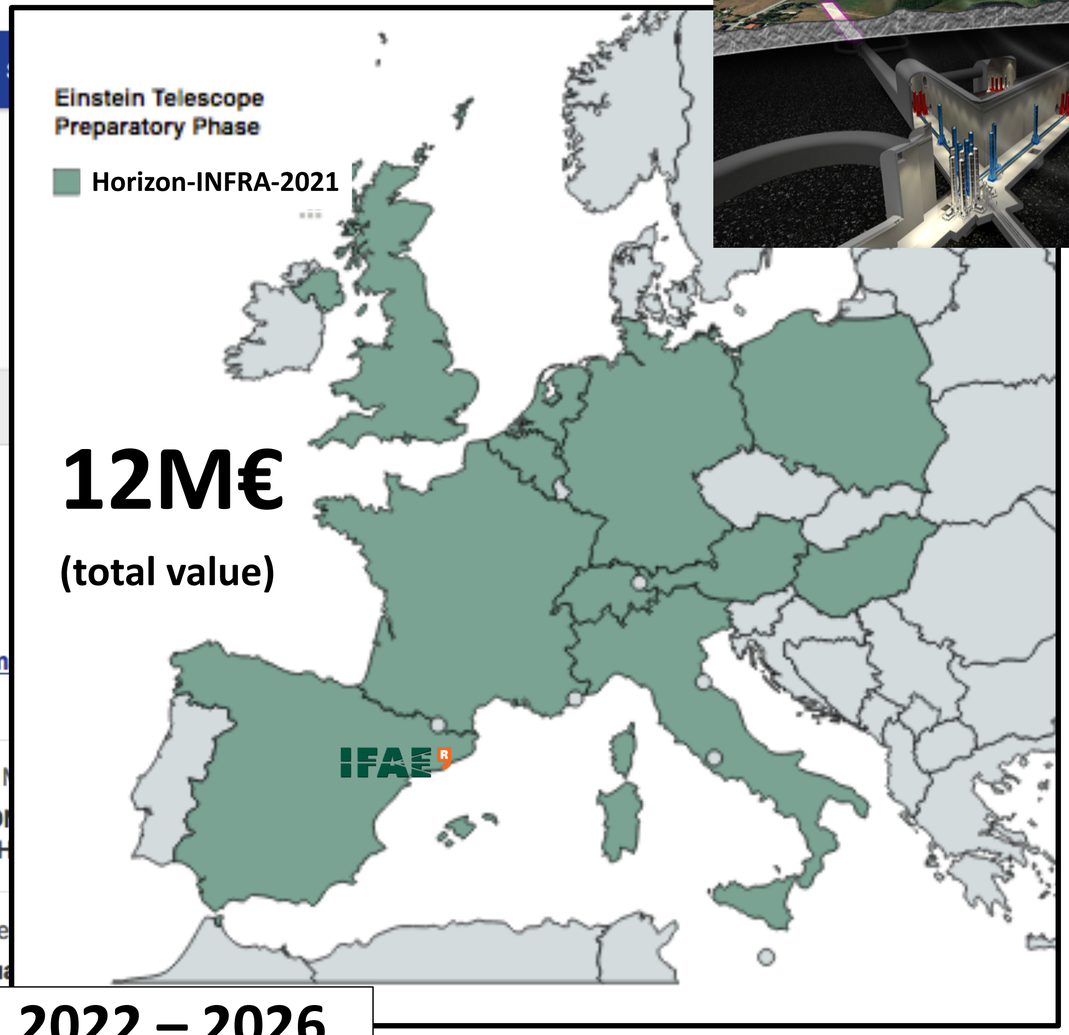
HORIZO

Based [H

Deadline model
single-stage

Planned opening date
30 September 2021

Deadline
20 Janu



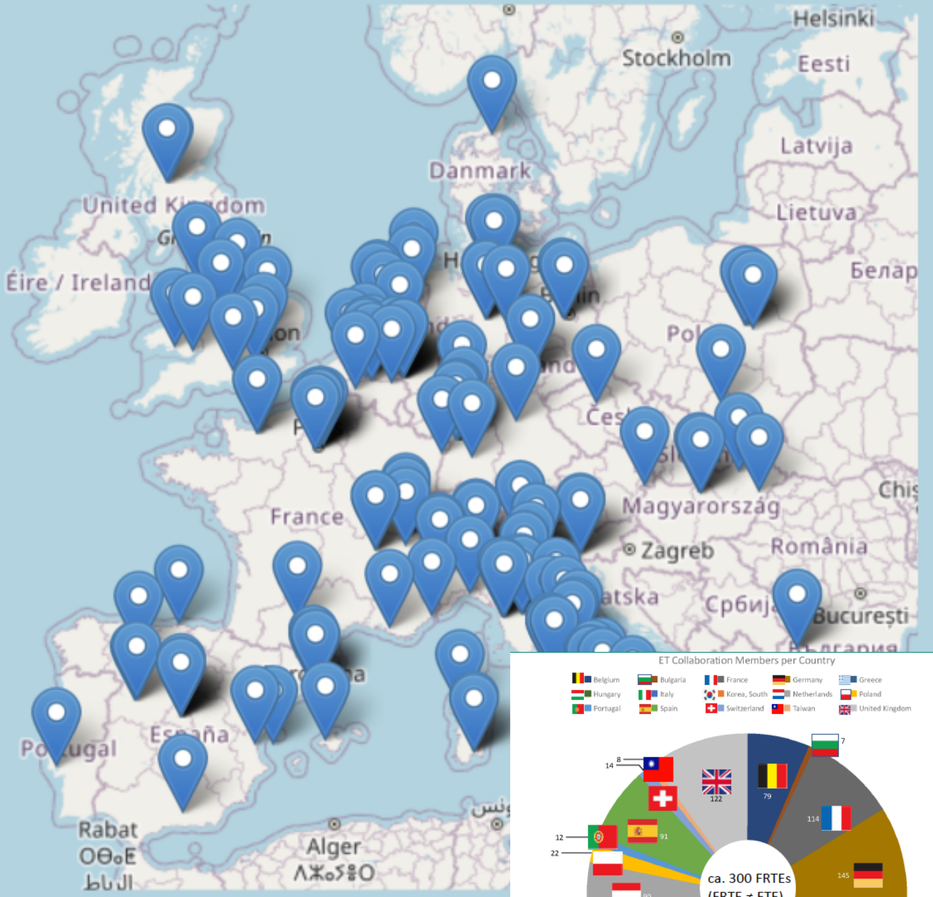
Einstein Telescope Preparatory Phase (ET-PP) in 2022 – 2026
HORIZON-INFRA-DEV EU Project coordinated by IFAE

→ **Project started 1st September 2022 (https://etpp.ifae.es)**

The Einstein Telescope Collaboration

- 85 Research Units (+1 request pending)
- 1568 members (24/11/2023 15:29)
- Total: 226 Institutions
  in 25 Countries

- ET member database



A Large Collaboration
(comparable to a LHC experiment)
Requires a proper Governance /Financial Model

- Internal organisation in place
- Bylaws already in place

ET experiment and ET Organization

ETO (ET Organisation)

- Board of governmental representatives
- Board of Scientific representatives
- Coordinators
- ET Directorate
- Project office
- Engineering department
- Administrative office
- ET-PP

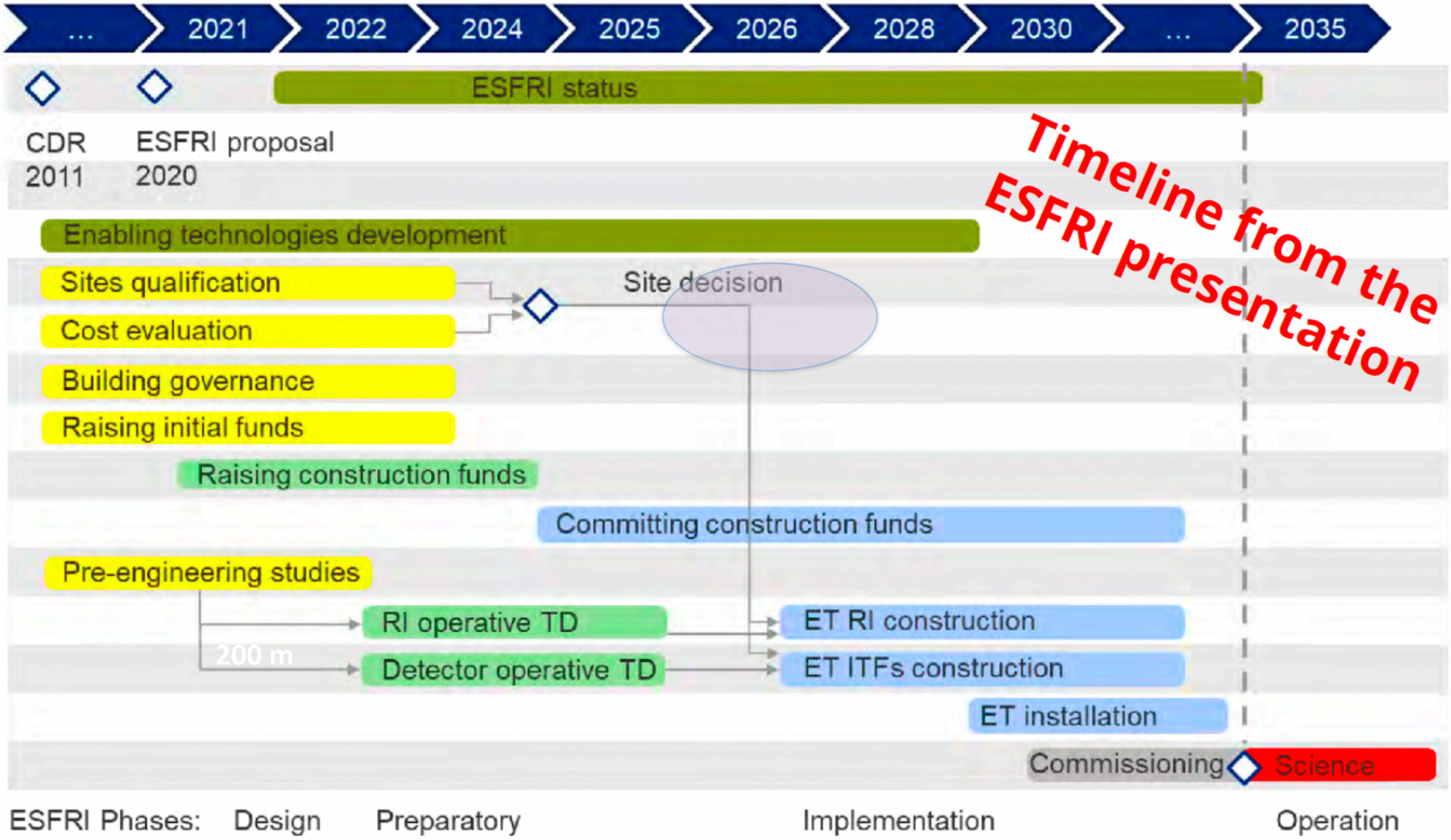
ET Collaboration

- Collaboration board
- Executive board
- Specific boards
  - ISB
  - OSB
  - EIB
  - SCB
  - SSB
  - ...

ET-PP is naturally framed inside ETO chart

ET research infrastructure, services, and vacuum system under ETO supervision

ET Scientific Collaboration dedicated to experiment design & scientific exploitation



ET project is now in the preparatory phase

—> We know already ESFRI roadmap schedule was too optimistic based on simplified assumptions

—> We are in the process to define a new schedule and roadmap —> to be ready by early 2025

EMR-TETI civil engineering - Timelines

Example 1: Civil engineering (with CERN)

Timeline / Activities	Dur (mon)	2023 Q1	Q2	Q3	Q4	2024 Q1	Q2	Q3	Q4	2025 Q1	Q2	Q3	Q4	2026 Q1	Q2	Q3	Q4
EMR																	
Technical studies subsurface	?																
1st Assessment subsurface	?																
Draft Bidbook	?																
Location Scenarios	?											?					
Structure Design	?																
Cost Estimate	?																
Tender Plan Construction Phase	?																
Logistics Plan Construction Phase	?																
Spatial Plan Corner Points	?																
Risk Register	?																
Implementation plan & tender dossier	?																
TETI																	
Performing Surveys & Drillings	12																
Positioning of Underground Structures (Triangle and 2L)	12																
Underground Service Plants	12																
Surface Buildings	7																
Construction of Underground Structures	16																
Cost and Time Estimation	2																
Permissions and opinions for construction	16																

EMR site

- *Underground investigations (surveys, drilling and testing)* — *Q2 2025*
- *Positioning and construction design* — *Q3 2025*
- Implementation plan & tender dossier (Bidbook. ?) — Q3 2026

Sardinia site

- *Underground investigations (drilling and testing)* — *Q1 2025*
- *Positioning and construction design* — *Q2 2025*

Preliminary dates that will still change!

BASELINE layout

Sardinia Site investigations

Sardinia design

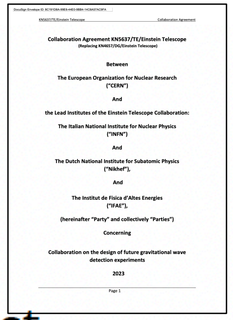
EMR Site investigations

EMR -design

EMR Implementation plan & tender dossier

Q4 2024 | Q1 2025 | Q2 2025 | Q3 2025 | Q4 2025 | Q1 2026 | Q2 2026 | Q3 2026 | Q4 2026

Working with CERN



The Einstein Telescope is a 'recognised experiment' at CERN. We can access support provided it is cost neutral to CERN.

- **Vacuum pipe**: governed by an MOU between CERN, INFN, Nikhef and IFAE, CERN has started a dedicated activity to deliver the technical design report for the vacuum pipe in 2025. Currently a prototyp station is being built at CERN, supported by a large and efficient team.

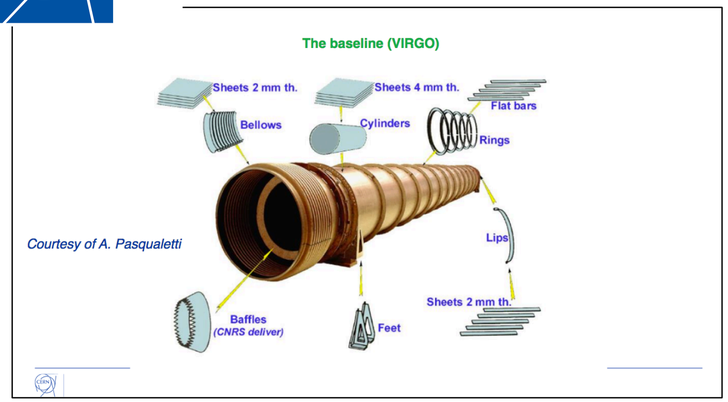
- **Civil engineering**: an extension to the MOU has been agreed: CERN will provide consultancy and technical support towards the creation of the TDR for the civil engineering and technical infrastructure for 2026.

- **Document management**: project management requires specific tools, we are investigating the use of the CERN tool EDMS. CERN is providing support for a pilot study which has now started.

- **Engineering support**: technical designs at CERN are usually done by a large interdisciplinary team, including for example the safety group. We have organised several discussions with the relevant teams and are now formulating a plan for dedicated support for the design of the technical infrastructure.

ET & CE vacuum pipe design

MoU signed with CERN



DocuSign Envelope ID: 8C1910BA-99E6-44E0-98B4-14C6A57AC9FA

KN5637/TE/Einstein Telescope Collaboration Agreement

Collaboration Agreement KN5637/TE/Einstein Telescope
(Replacing KN4657/DG/Einstein Telescope)

Between

The European Organization for Nuclear Research
("CERN")

And

the Lead Institutes of the Einstein Telescope Collaboration:

The Italian National Institute for Nuclear Physics
("INFN")

And

The Dutch National Institute for Subatomic Physics
("Nikhef"),

And

The Institut de Fisica d'Altes Energies
("IFAE"),

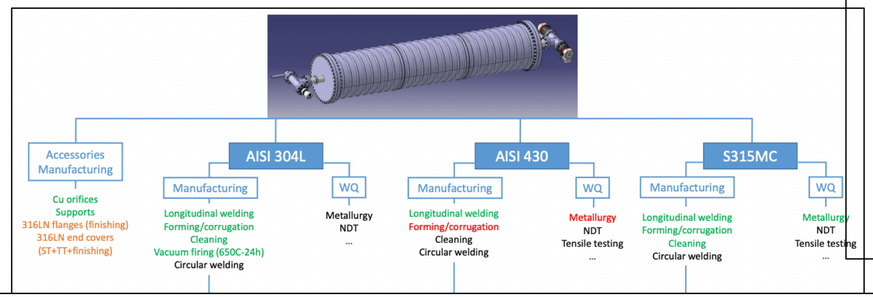
(hereinafter "Party" and collectively "Parties")

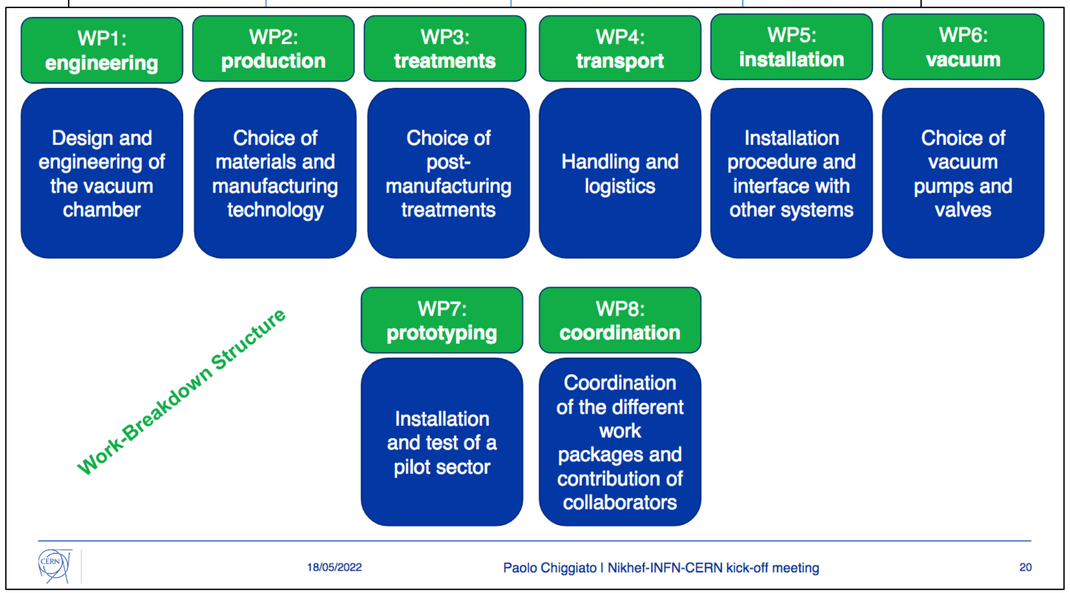
Concerning

Collaboration on the design of future gravitational wave detection experiments

2023

Page 1





Global planning 2025

	First year				Second year				Third year			
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Functional specifications												
Roles and agreement with Institutes												
Optimisation of baseline, including cost analysis												
Definition of alternative solutions												
Cost & performance of alternative solutions												
Optimisation of interfaces with services/infrastructures												
Decision about vacuum design for pilot sector at CERN.												
Prototyping of the selected solutions.												
Technical design report (ET vacuum system).												

18/05/2022 Paolo Chiggiato I Nikhef-INFN-CERN kick-off meeting 29

On-going effort led by CERN on the design of ET vacuum pipe

(1/3 of the total ET cost) —> Will deliver a TDR in 2 years

- Physics requirements
- Vacuum / Cryo Technology
- Civil Infra-structure
- Cost Reduction/Optimization
- Prototyping

PC will cover partially the cost of baffling strategy for the CERN prototype plus related simulation work

Peer Review of the ET pilot sector

Monday 22 Jan 2024, 14:00 → 18:30 Europe/Zurich

30/6-019 (CERN)

Paolo Chiggiato (CERN)

Videoconference — Peer Review of the ET pilot sector — Join

There are minutes attached to this event. Show them.

14:00 → 14:05 **Welcome** — 5m

Speaker: Jose Miguel Jimenez (CERN)

14:05 → 14:25 **Purpose and planning of the pilot sector.** — 20m

Speaker: Paolo Chiggiato (CERN)

Purpose and planni... | Purpose and planni...

14:25 → 14:45 **Notes on optical cavity at CERN: ET pilot sector after 2025**

Speaker: Mario Martinez-Perez (The Barcelona Institute of Science and Technol

CERN-FP-Cavity.pdf | CERN-FP-Cavity.pptx

14:45 → 15:15 **Design of the ET beampipe pilot sector, including baffle integra**

Speaker: Cedric Garion (CERN)

Design_CG.pdf | Design_CG.pptx | Design_CG_Rev1.pdf

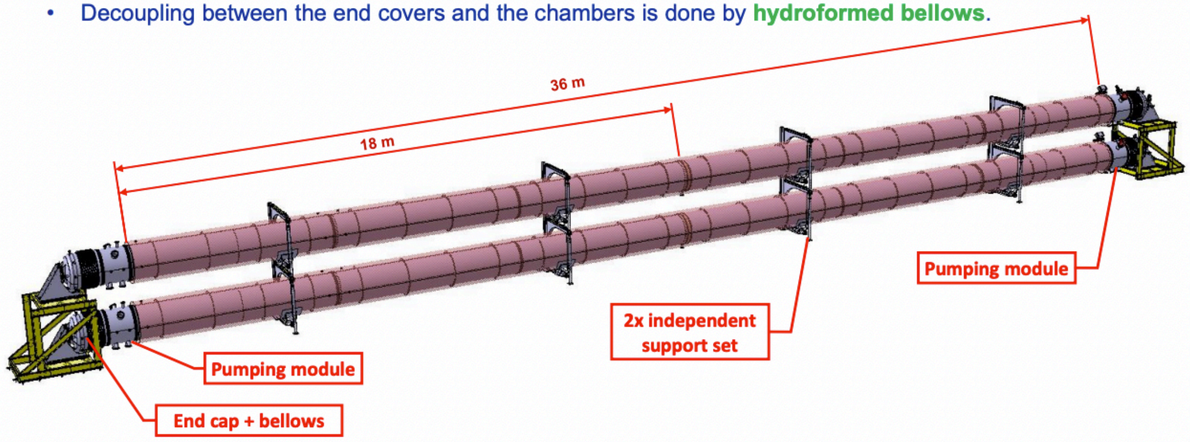
Big CERN vacuum Dept team working on ET aspects now

PC will cover partially the cost of baffling strategy for the CERN prototype plus related simulation work

https://indico.cern.ch/event/1360696/

Mechanical layout of the ET pilot sector at CERN

- **Two independent vacuum chambers** of around 18m will be transported and installed individually.
- Each pipe is **suspended** on independent supports and can be aligned vertically and laterally.
- Each **endcap** can be aligned laterally, vertically and longitudinally.
- Decoupling between the end covers and the chambers is done by **hydroformed bellows**.



Pilot sector : Choice of Material and

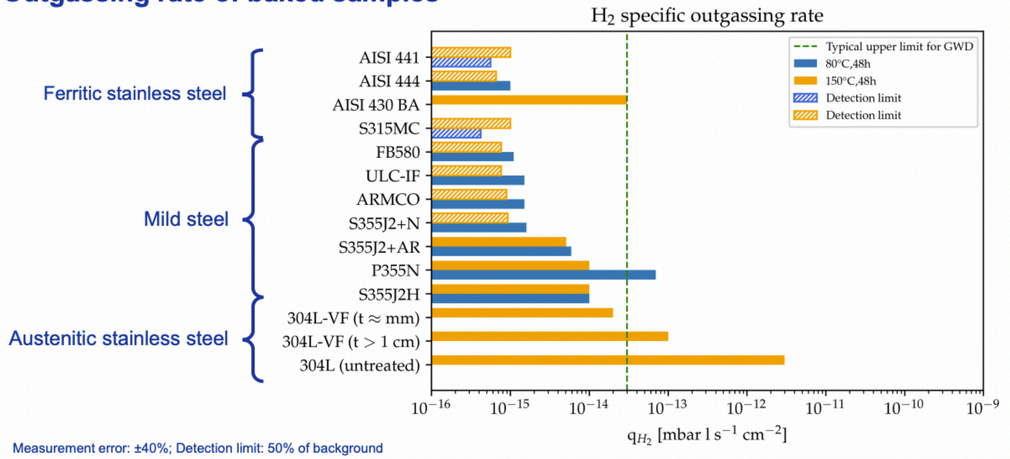
Materials	ET Vacuum requirements	Manufacturability (Welding and forming)	Corrosion resistance
AISI 304 L	Good	Good	High
S 315 MC	Good	Good	Low
AISI 441	Good	Good	High

Components	Material and dimensions (Procurement estimation)
Vacuum chamber and end caps	AISI 441, 2B surface,~ 4 mm thickness, width of coil ~1500 mm, quantity=12 tons**
Stiffeners	AISI 441 / 304L, 4-8 mm thickness, width 45-60 mm, length ~3.5m, 80-100 pieces
Sleeves	AISI 441, ~2mm thickness, standard width coil, 1 ton

** Quantity of material needed for two chambers

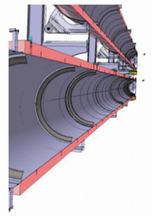
Vacuum characterization of ferritic alloys

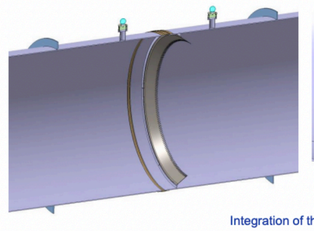
Outgassing rate of baked samples

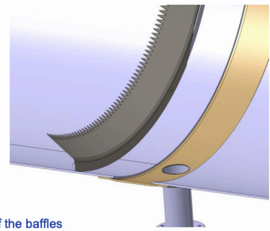


Measurement error: ±40%; Detection limit: 50% of background

Baffle integration





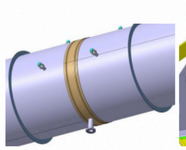


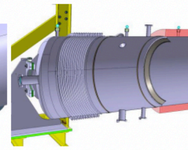
Integration of the baffles

…um chamber:
…ith M6 holes welded inside the chamber.
…ews, vacuum fired.

…ses: without and with black nickel coating.

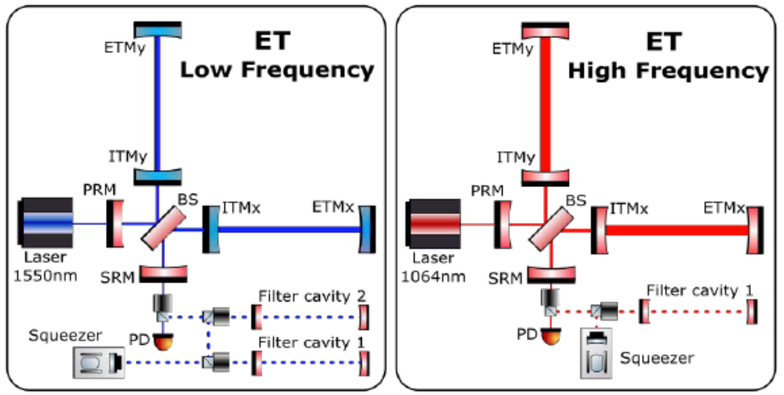
…arefully studied (cleanliness during assembly, weld).
…th silicon wafers for dust quantity assessment in the …ties.
… for witness samples to implement.





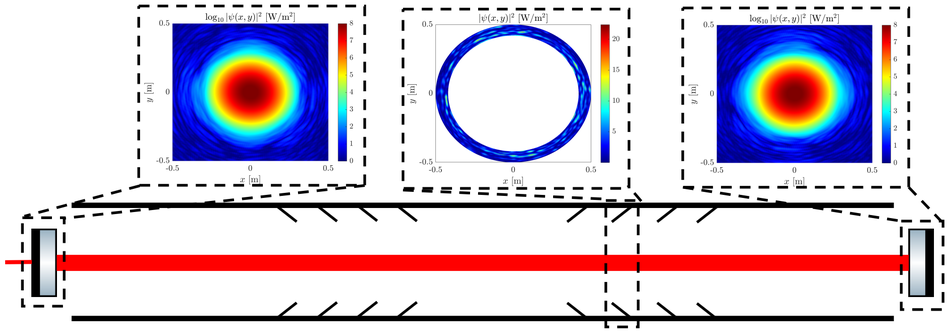
Dedicated ports for dust control assessment

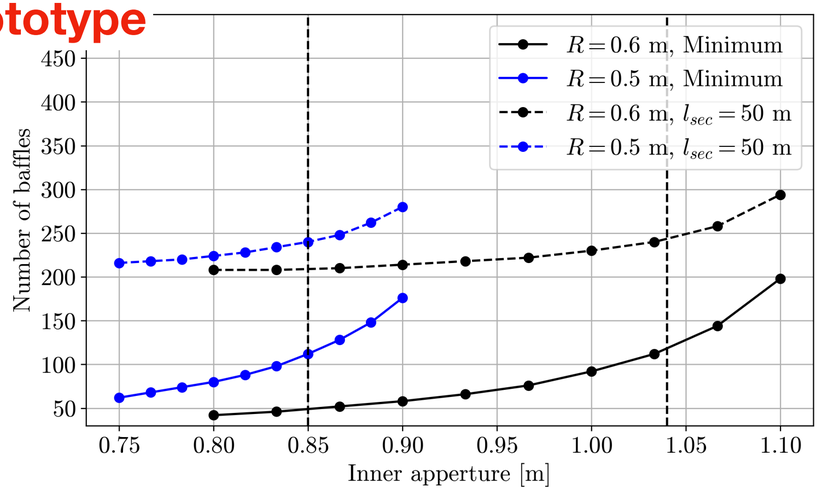
ET stray light simulations



IFO	λ	mode	mirror ⌀	R_C	w_0	z_0	w	$g-$factor
ET-HF	1064 nm	TEM_{00}	62 cm	5070 m	1.42 cm	5000 m	12.0 cm	0.95
ET-LF	1550 nm	TEM_{00}	45 cm	5580 m	2.9 cm	5000 m	9.0 cm	0.63

PC covered the cost of simulations for baffling strategy for the CERN prototype

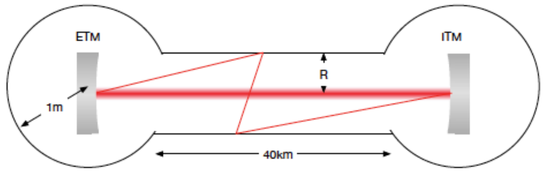


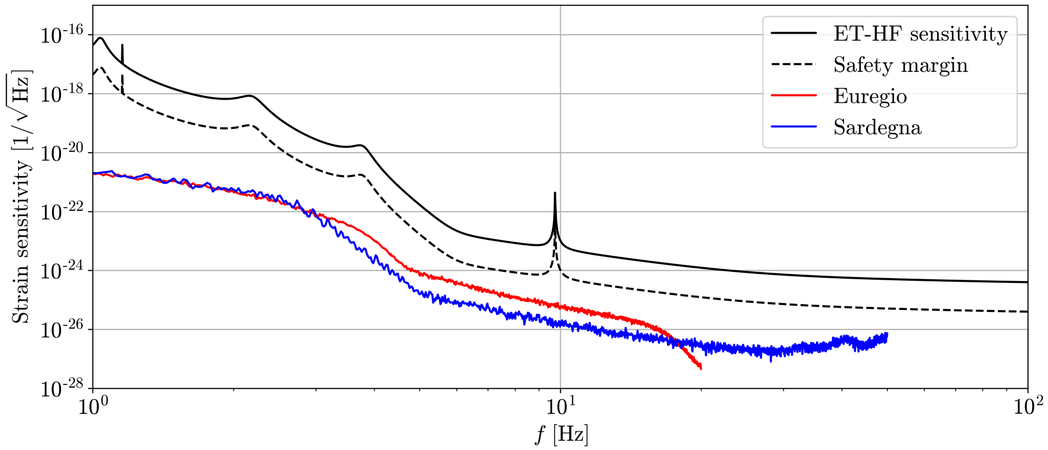


Running optical simulations to determine the best strategy for stray light mitigation in ET

—> Desire to extend it to CE

—> Running common ET/CE meetings





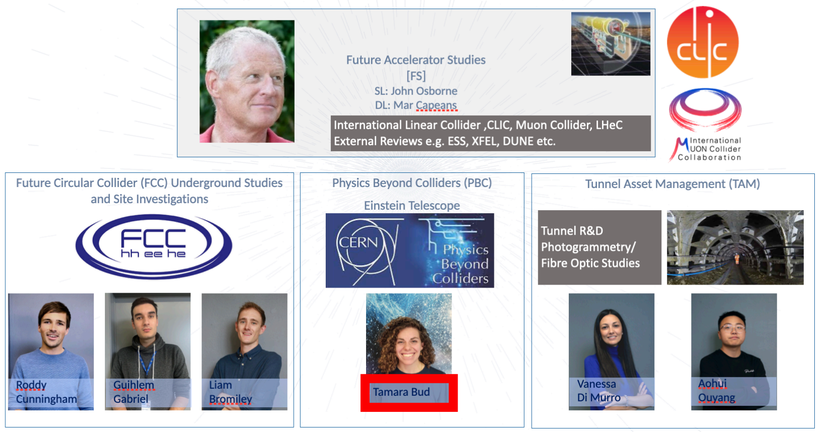
A joint effort with CERN on the very details of the vacuum pipe design and the baffling integration strategy, eventually including active monitoring inside the cavity

—> IFAE will build baffle prototypes

M. Andrés-Carcasona et al., Phys. Rev. D 108, 102001 (2023)

ET Civil Eng. workshop at CERN 29-30th April 2024

SCE-SAM-Future Studies Section



- Successful workshop at CERN, hosting colleagues from ETO, INFN, Nikhef, IFAE, Local Teams, Amberg, Tractebel, Rocksoil.
- Seed questions from the local teams addressed, and hosted a lively discussion
- Identified challenges and considered next steps together
- Decided that a baseline report addressing some of the design complexities of the project would be a positive next step

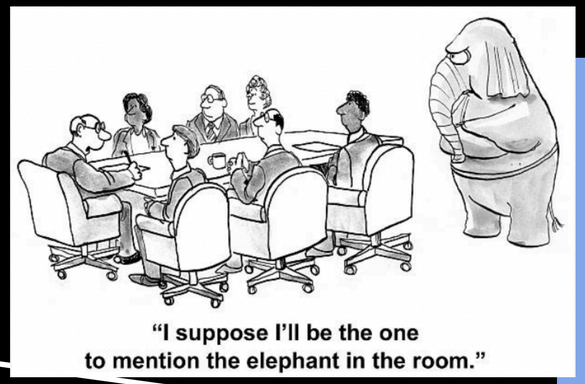
Ongoing layout discussion

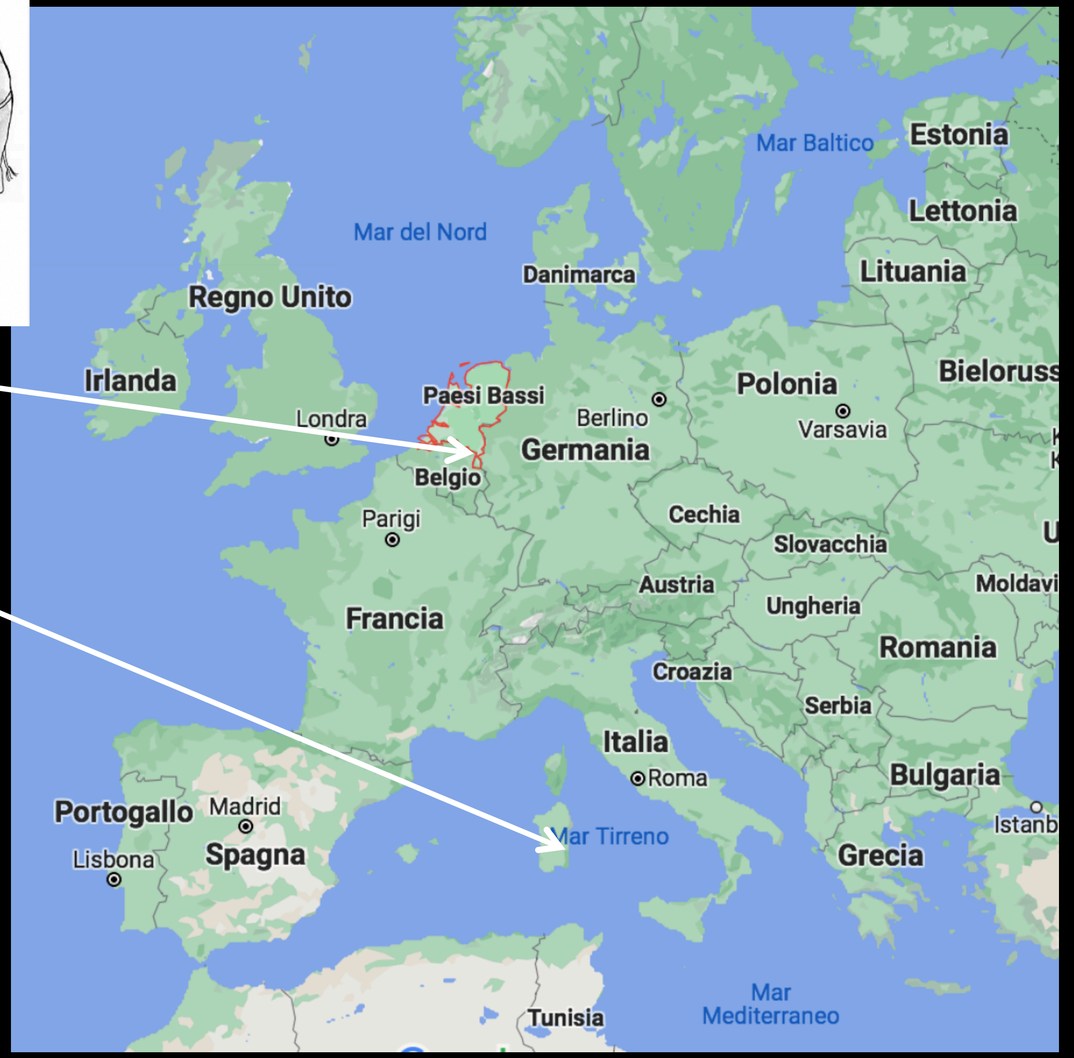
Branchesi, Maggiore et al. 2023

Two scenarios
- D of 10 km
- D of 15 km

Two scenarios
- 2L of 15 km
- 2L of 20 km

2L misaligned of 45˚





Full sensitivity: HF+LF

Only HF

Always underground

Scientific community made a study of physics potential comparing ET-baseline (triangle) vs 2L configurations

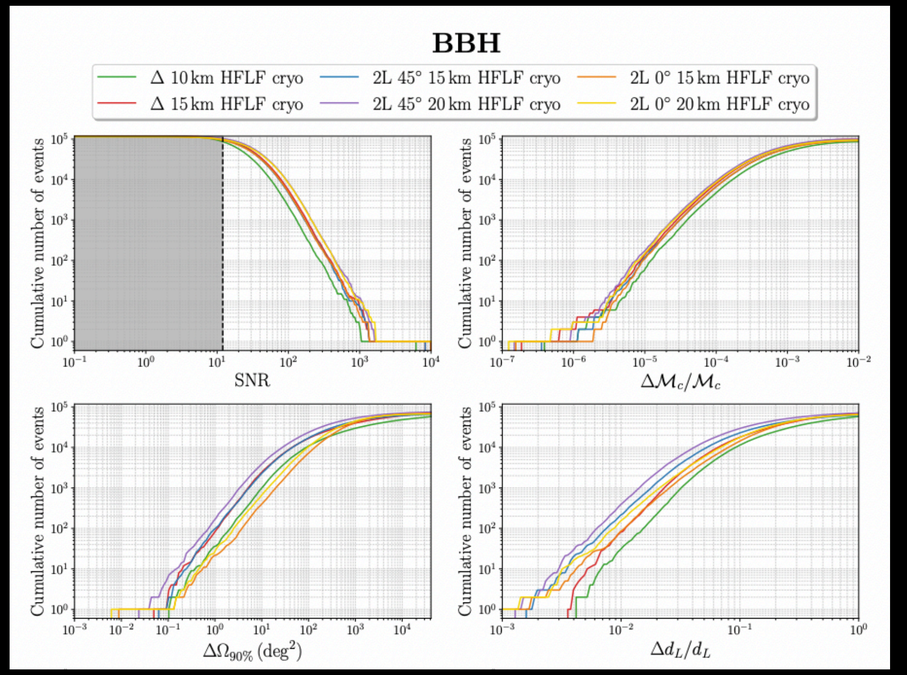
—> ETO received the mandate to present full cost of risk analysis

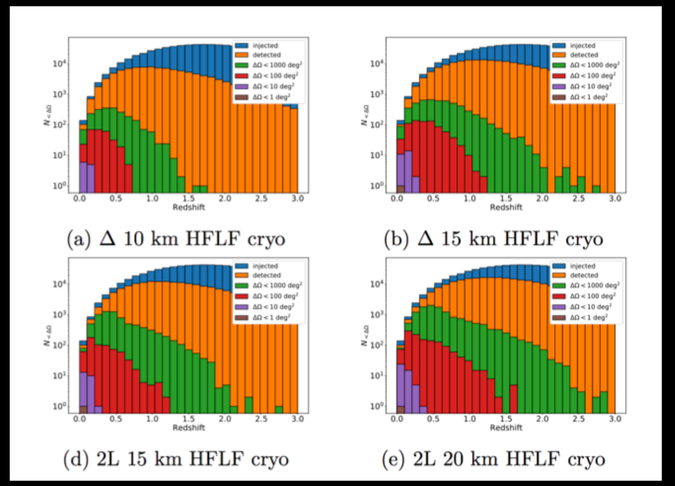
—> Will compare underground 10 km ET triangle vs underground 2L 15km

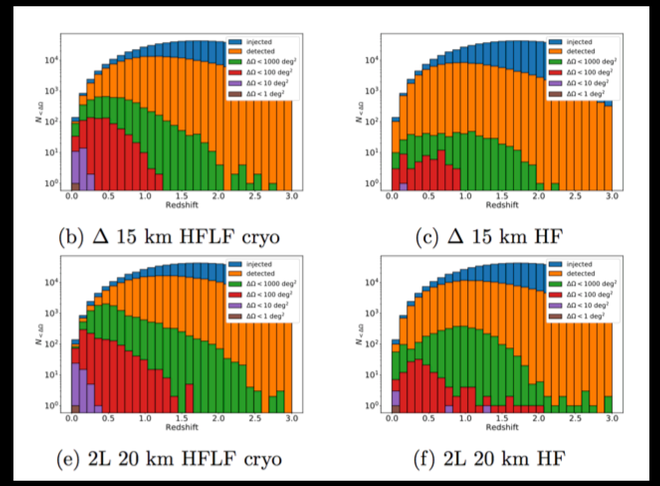
Comparative studies
(only physics potential)

arXiv:2303.15923 Branchesi, Maggiore et al. 2023

- The conclusions are the expected ones
  - Longer arms perform better
  - Only 1L is not an option (dependent on overall network)
    - Either one site Triangle or 2 sites L
- NO LF translates into reduction of well localised events (more severe for triangular configuration)
  - 2L HF 15 km comparable to HFLF Δ10km
- Only LF makes BNS pre-meger alerts possible —> impact on multi messenger
- Concerns about possible correlations in the Δ compromising stochastic searchers





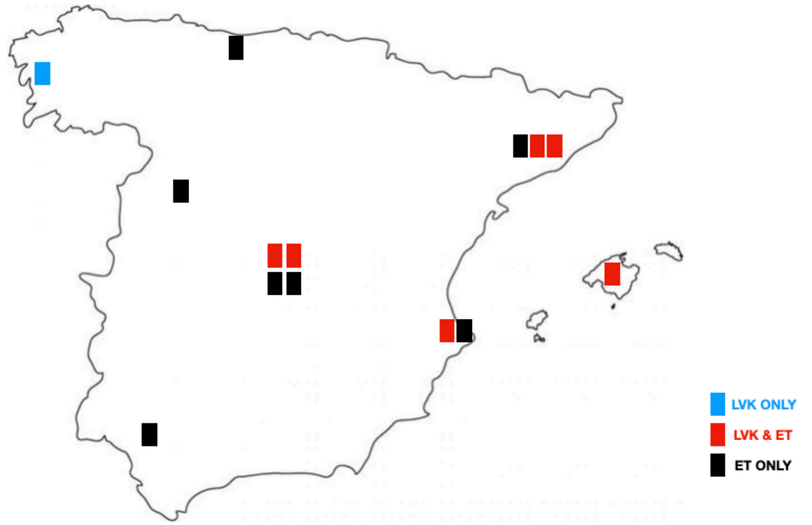


Map of Spanish involvement in LVK/ET

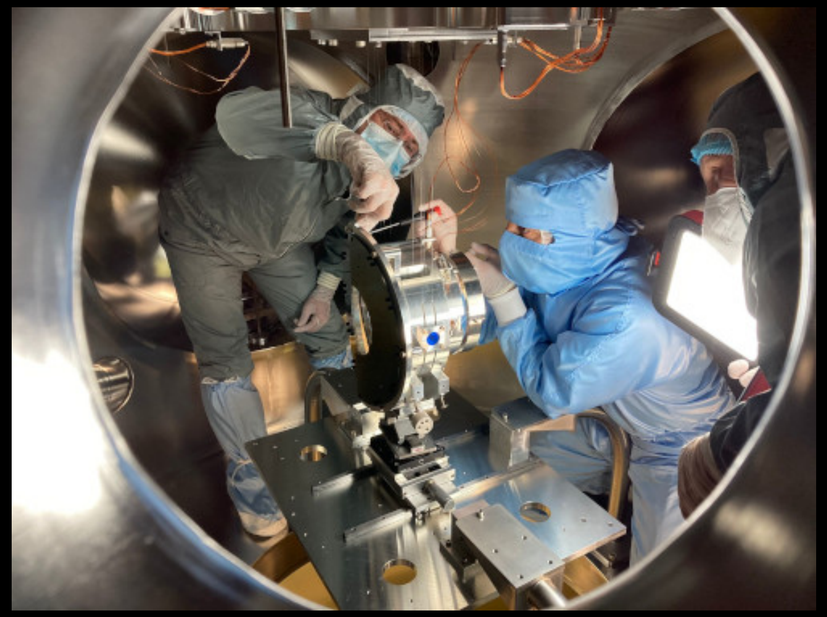
Group	LVK	ET	Hardware	Computing	Note
CIEMAT	Virgo	Y	Y	YY	Still qualifying in Virgo
ICE	LISA	Y	YY-LISA	N	Not allocated FTEs for HD
IFAE	Virgo	Y	YY	YY	
IFIC		Y			TH
UIB	LIGO	Y		Y	TH/Analysis
USC	LIGO	N			TH/Analysis
USAL		Y			TH
IFT	Virgo	Y			TH/Analysis
UCM		Y			TH
UCAN		Y			TH
ICCUB	Virgo	Y		Y	TH/Analysis
UV	Virgo	Y			TH/Analysis
IEM		Y			TH/Analysis
IAA		Y			TH/Analysis

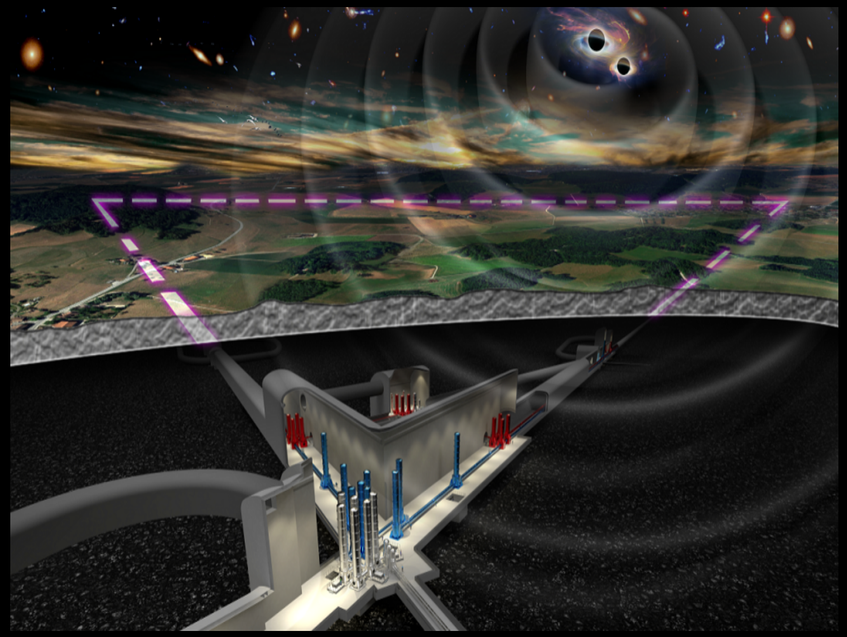
After a INFN-IFAE dedicated discussion in June 2023 of possible synergies… the message has been propagated to all the Spanish HEP community showing the R&D opportunities (including plenary talks in HEP all hands CPAN meetings)

We made the effort of visiting ICFO (x2) ; ICMAB ; ICREA… etc…
Scheduled a visit to CLPU (Pulsed Lasers) in Salamanca in 2 weeks



- There are many groups interested in ET, some of them from HEP, some of them detector builders
- A majority has no hardware capacities
- Most of them are Theory and GW analysis oriented
- As today there is no consolidated large enough experimental community in GW is Spain.
- We are actively exploring synergies with other research centers in Spain to improve the situation
- Close contact with UPC (Applied Optics)





Final notes

- ET is the leading EU 3G project today and is regarded as a flagship
- Together with CE will drive the GW field in 203X
- Strong proposals for hosting the ET infrastructure in place including already secured money for construction
- Intensive R&D activity in all fronts (somehow focused on LF)
- In the following years the ET project will progress towards a site selection(s) , final design and governance, costs and risk studies, aiming for starting construction before the end of the decade [?]
- ET-PP EU Preparatory Phase Project is a tool to build coherence in the process (never easy…) and to glue “competing teams”
- The re-discussion of ET geometry saga might slow down the progress as it is putting ET in a “non-projected quantum state of geometry and location(s)”
- ET-Spain needs to grow and get experimental community more involved.