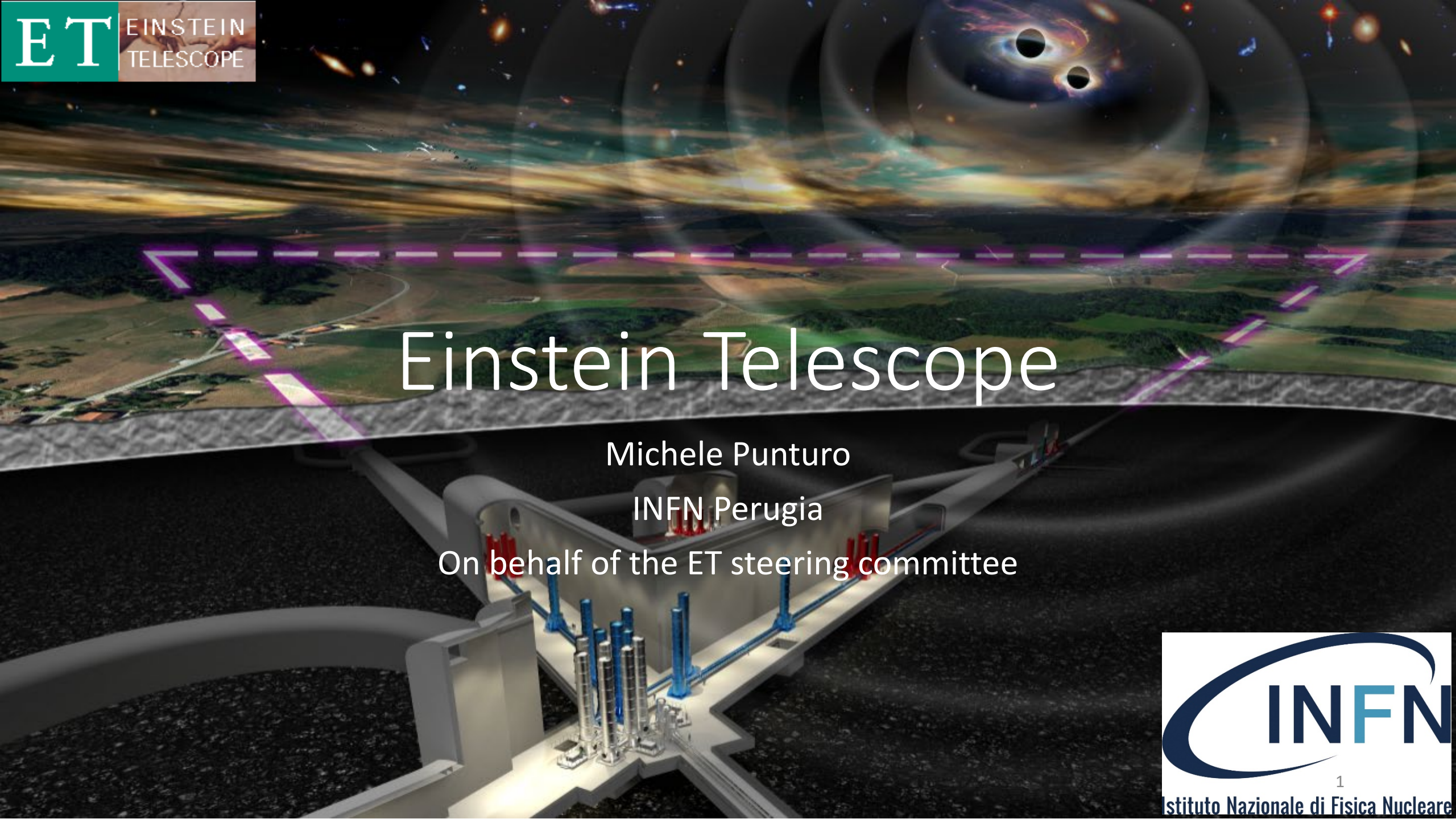


Einstein Telescope

Michele Punturo

INFN Perugia

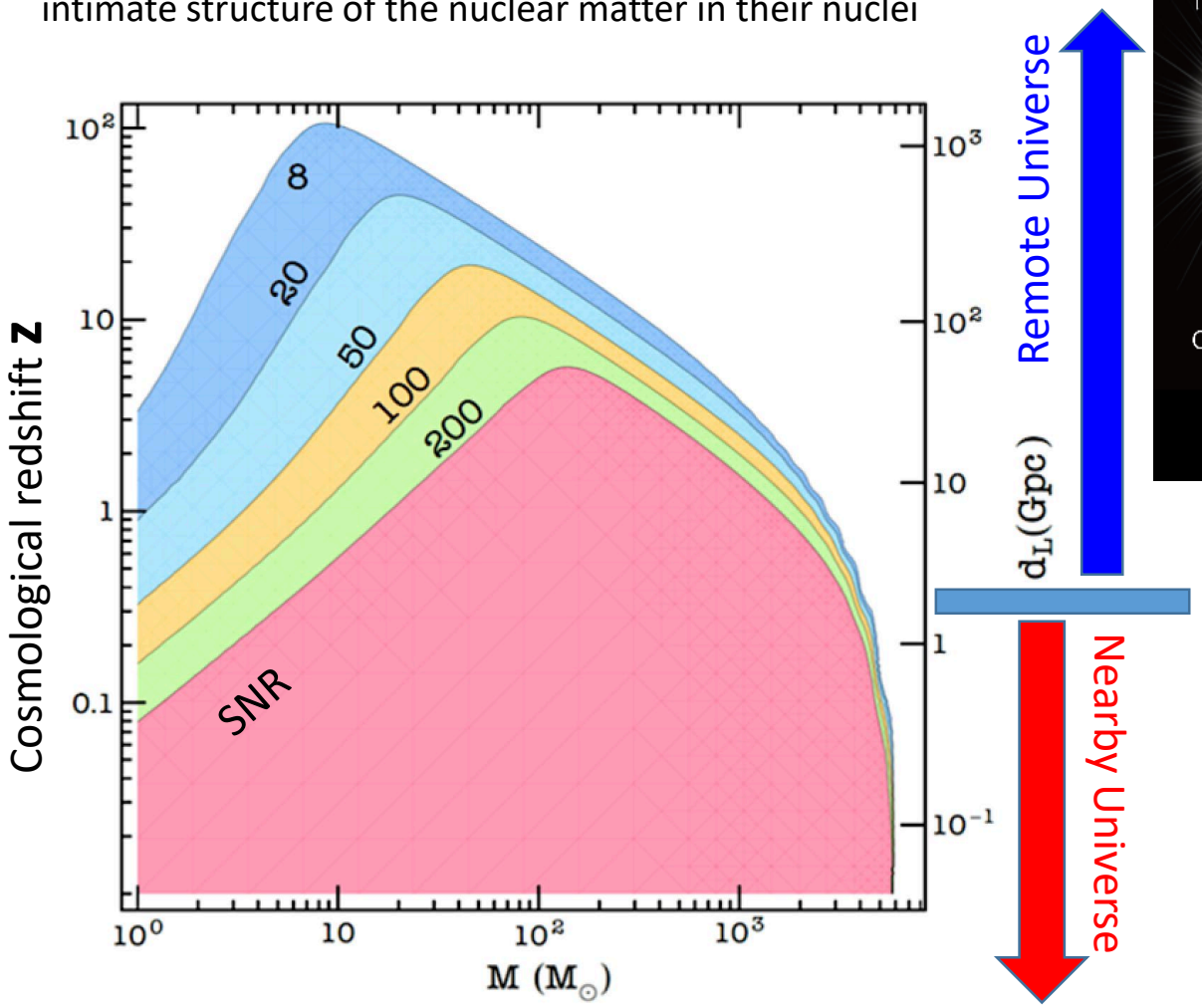
On behalf of the ET steering committee

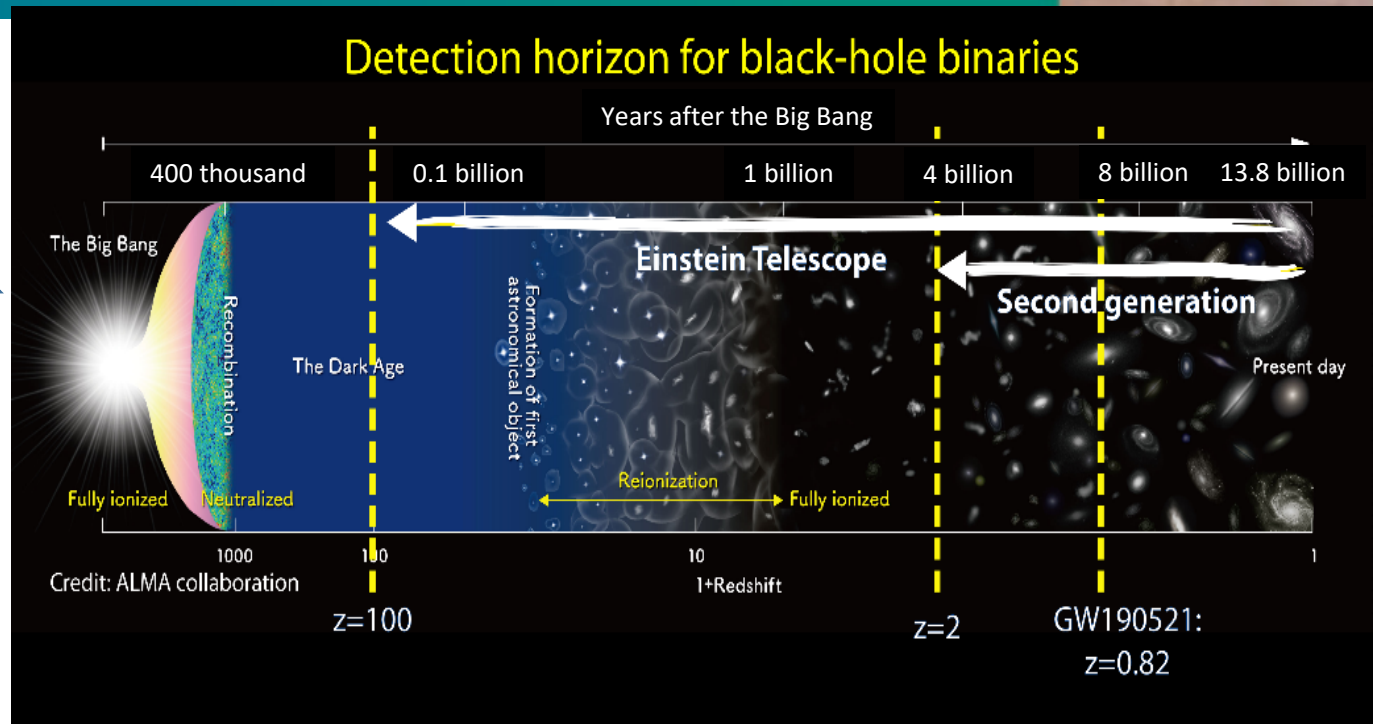
What is Einstein Telescope (ET)?

- ET is the project aiming to realise the European 3rd Generation Gravitational Wave observatory
- ET has been a pioneer idea that defined the concept of 3rd generation GW observatory:
  - A sensitivity at least 10 times better than the (nominal) advanced detectors on a large fraction of the (detection) frequency band
  - A dramatic improvement in sensitivity in the low frequency (few Hz – 10Hz) range
  - High reliability and improved observation capability
- ET has a long and important history through the ET community and now the ET project
- ET is now going to form a (formal) scientific collaboration

ET Science in a nutshell

- ET will explore almost the entire Universe listening the gravitational waves emitted by black hole, back to the dark ages after the Big Bang
- 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





ET will contribute to solve the enigma of the dark matter and dark energy in the Universe testing the Einstein General Relativity and possible alternative gravitation theories with unprecedented precision

ET will explore the gravity near the horizon of events of intermediate mass black holes

ESFRI

ET Science in a nutshell

ET EINSTEIN TELESCOPE

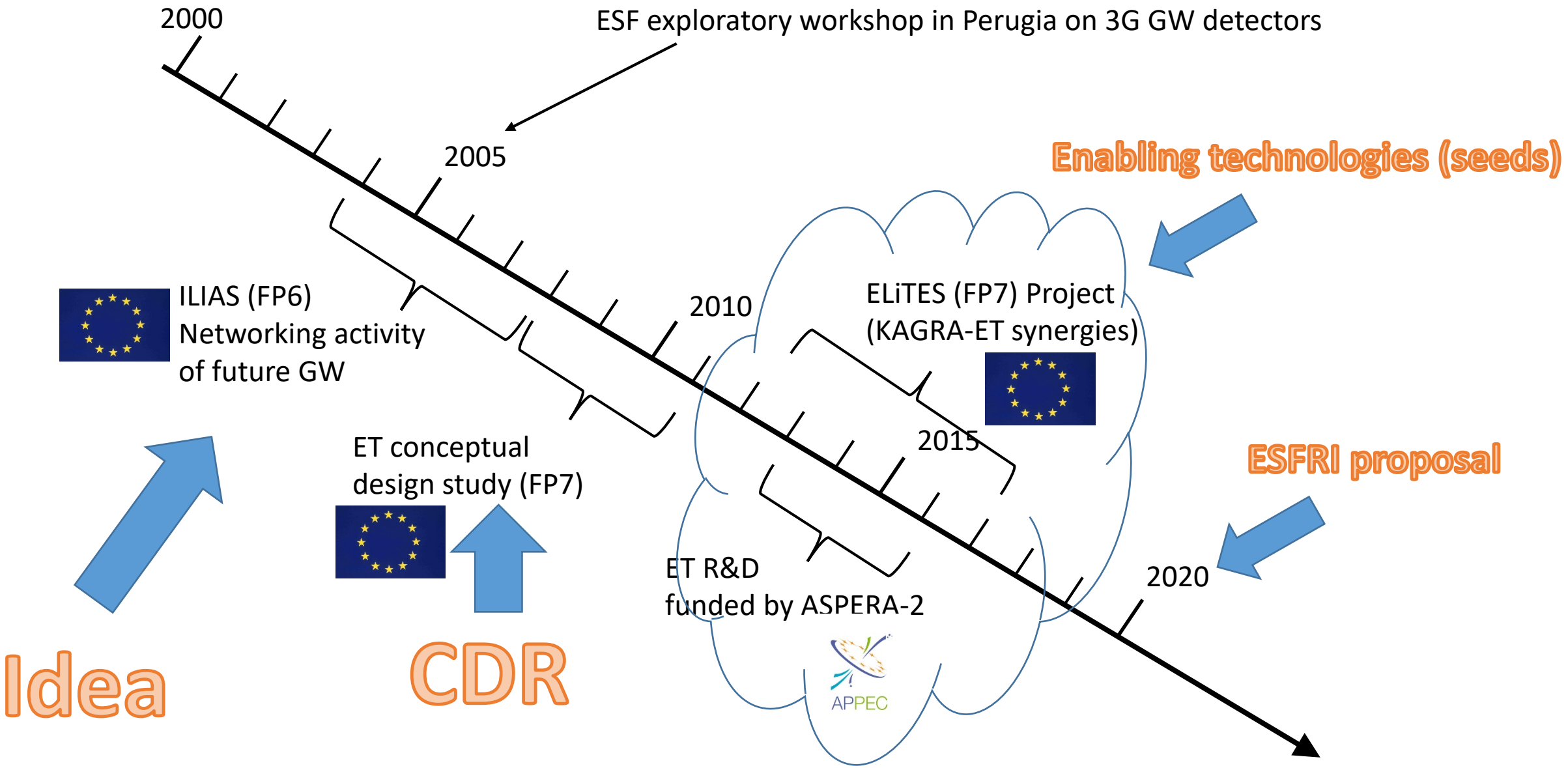
ASTROPHYSICS

- **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 long path


2000
ESF exploratory workshop in Perugia on 3G GW detectors
2005
Enabling technologies (seeds)
ILIAS (FP6)
Networking activity
of future GW
2010
ELiTES (FP7) Project
(KAGRA-ET synergies)
2015
ET conceptual
design study (FP7)
ESFRI proposal
ET R&D
funded by ASPERA-2
2020
APPEC
Idea
CDR

European Strategy Forum on Research Infrastructures

ESFRI Roadmap

ET EINSTEIN TELESCOPE

Proposal submitted by:

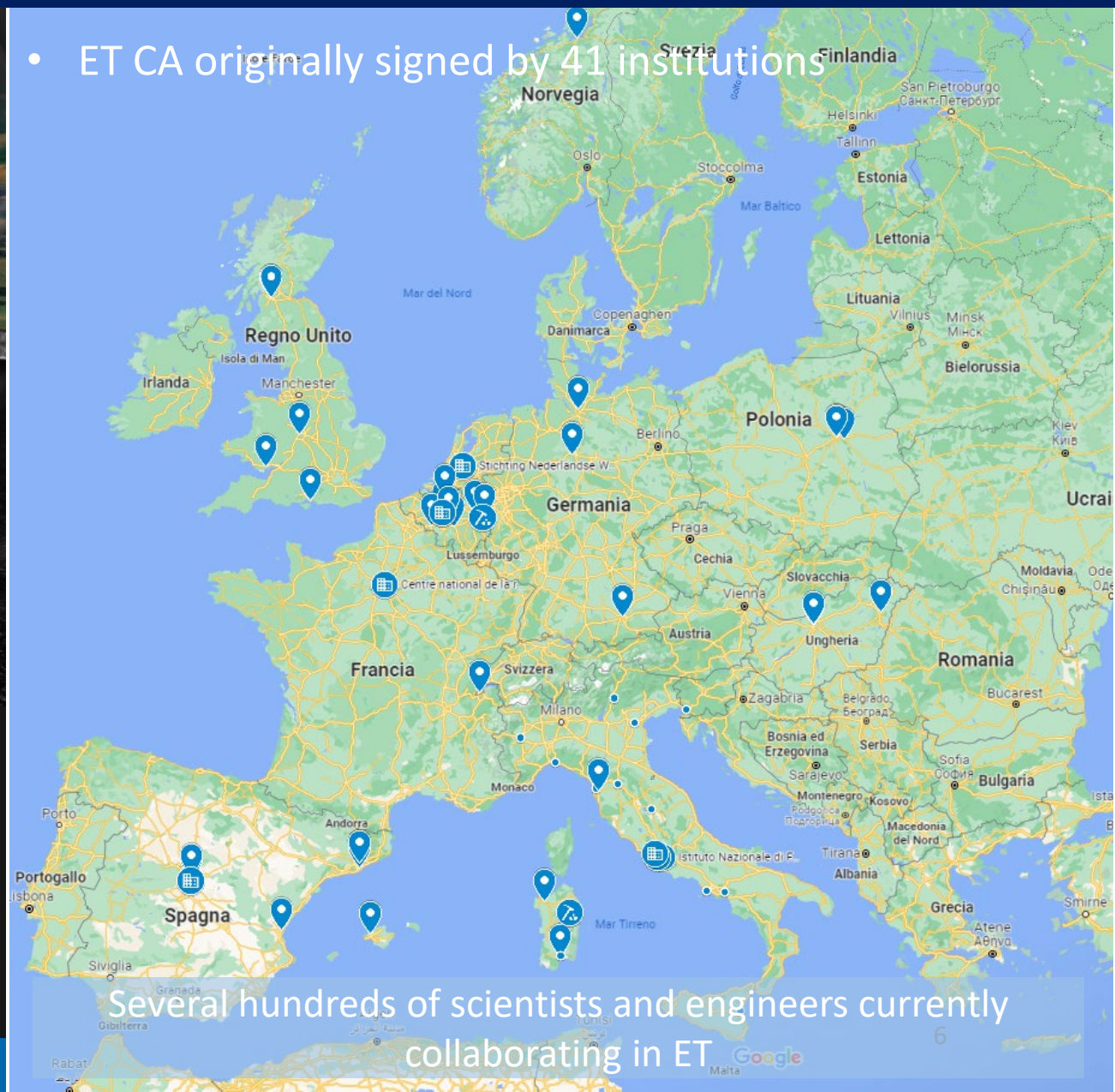
- **Italy** (Lead Country)
- Belgium
- Netherlands
- Poland
- Spain

Now in the project and in the collaboration activities also agencies or institutions belonging to:

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

ET is the pioneer project for a 3rd generation Gravitational Wave Observatory in Europe

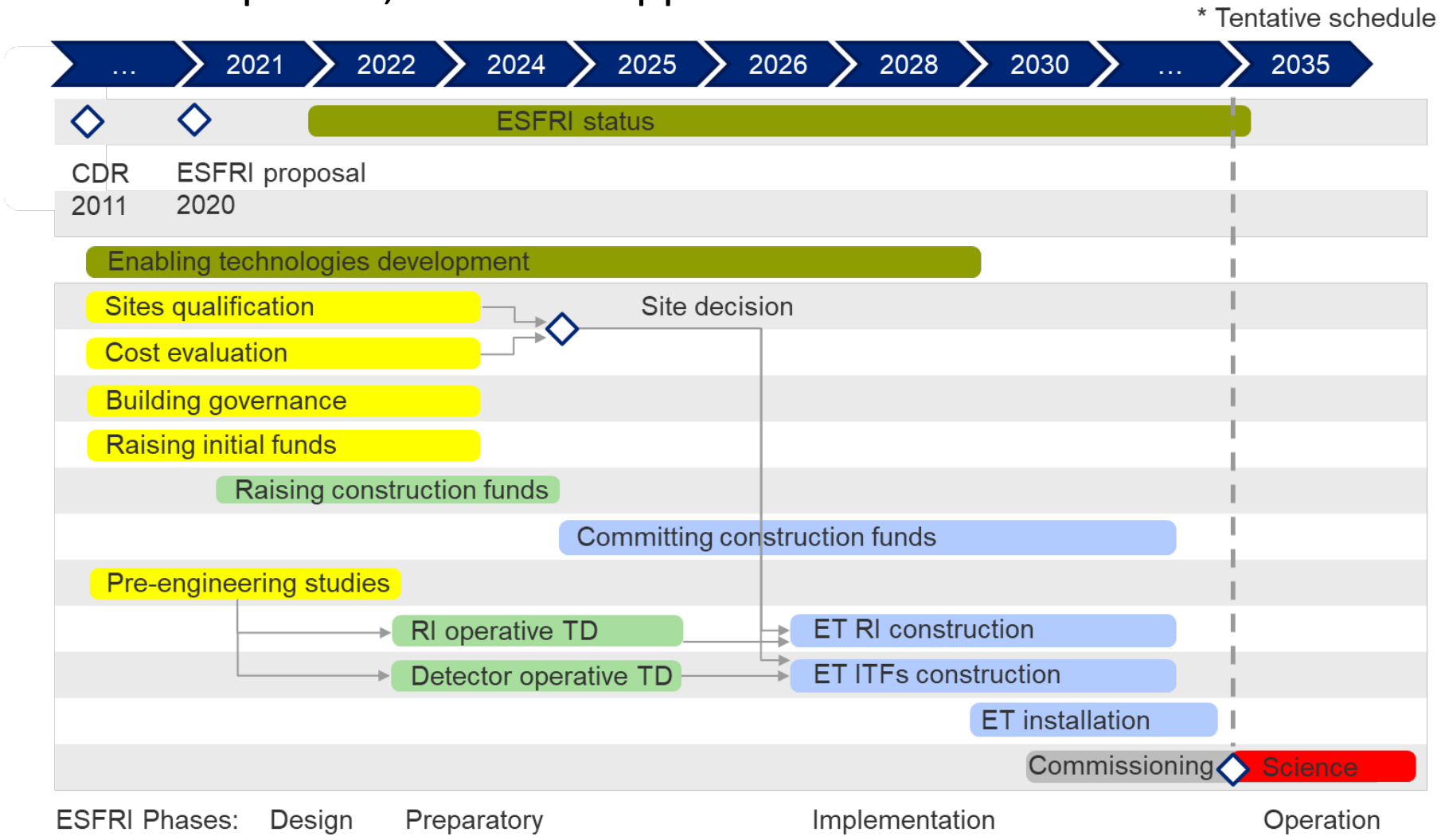
- ET CA originally signed by 41 institutions



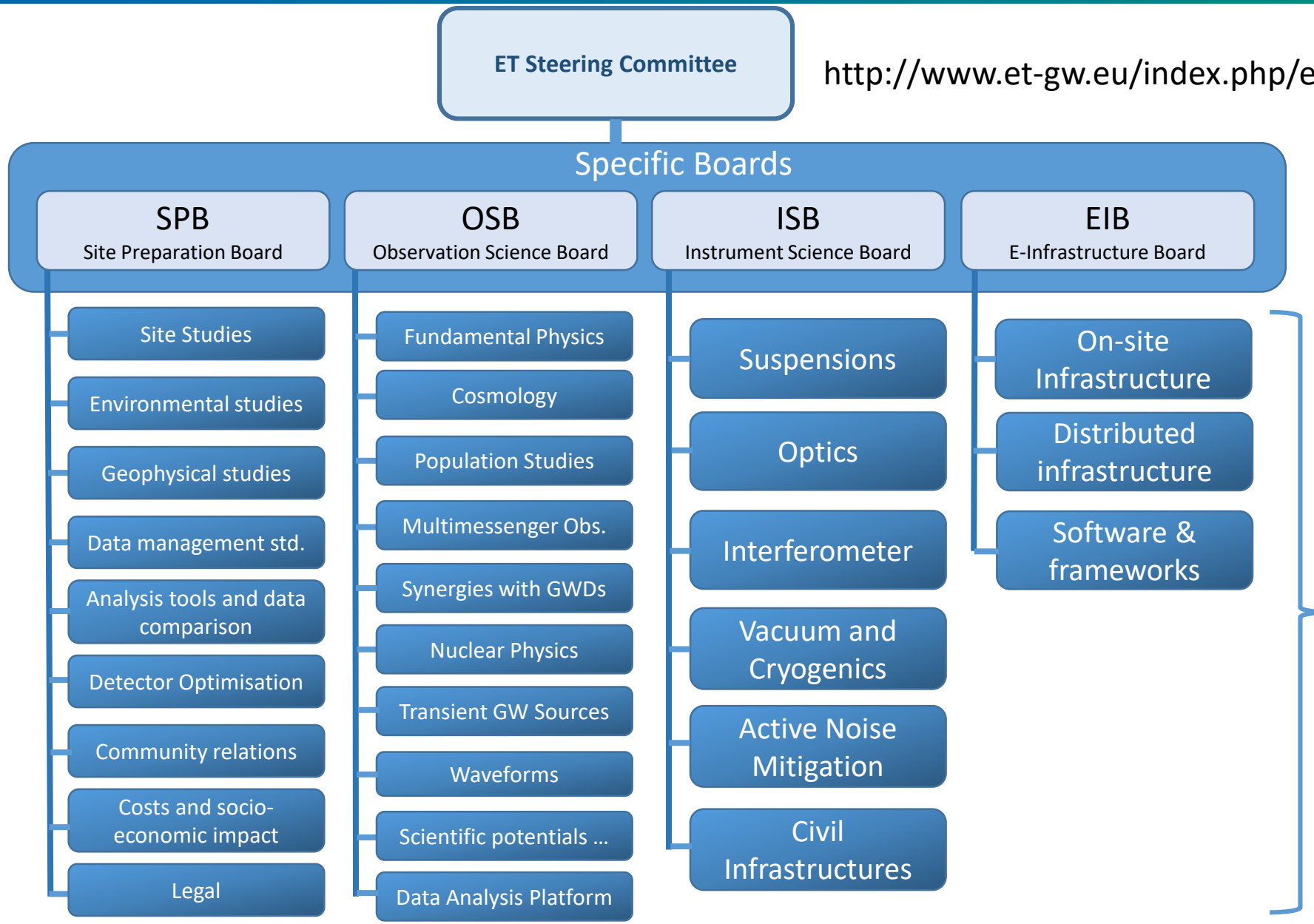
Several hundreds of scientists and engineers currently collaborating in ET

ET timeline

- ET timeline presented to ESFRI
  - As expected, the ESFRI approval boosted the activities at all the levels:
    - Scientists
    - Agencies
    - Governments



ET collaboration current organisation



http://www.et-gw.eu/index.php/et-steering-committee

The proto-collaboration is currently the most organised component of the ET project

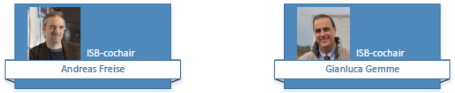
Divisions

ISB: Instrument Science Board

ESFRI

ET EINSTEIN TELESCOPE

ET Instrument Science Board (ISB) Organigram (ET-0033A-21)



ET EINSTEIN TELESCOPE

The ISB mandate (from ET-085A-20)

Boosted by financial availabilities at national level

- The first objective of the team is to deliver the ET Technical Design Report (ET-TDR) of the infrastructure and of the detectors starting from the ET Conceptual Design Report (ET-CDR). The ET TDR production will be an iterative process and will go through intermediate steps:
  - **Q3 2022: Pre-engineering definition of the Research Infrastructure** (including an updated costs evaluation).
  - **Q4 2022: Pre-engineering definition of the detector** (including an updated costs evaluation).
- The level of detail of the design must be sufficient to allow the customization of the design for the two different sites, in order to prepare the site bids.
  - **Q4 2025: RI operative TDR full engineering** (including costs evaluation). This activity will probably be transferred to (or shared with) an external company.
  - **Q2 2026**: **Detector operative TDR** (including costs evaluations).
- Further intermediate internal release of the TDR will be needed in order, for example, to inform external agencies or committees.
- The second objective of the whole team is to identify the missing technologies and suggest a plan for R&D activities. This must be a living plan, regularly updated.
  - The first delivering of this plan is expected in **early 2022**.

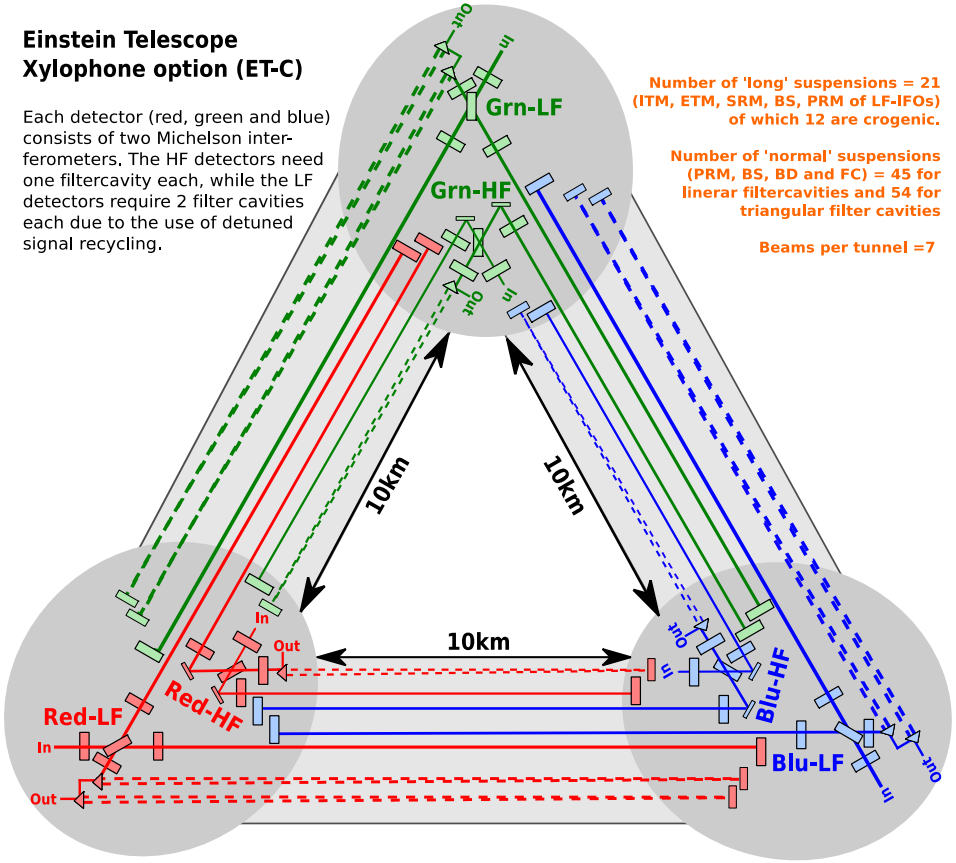
Boosted by grant possibilities at European level in 2022

ET Key ingredients

Factor 10 better sensitivity in a wide range of frequency
with a specific attention to low frequency (<10Hz)

- Einstein Telescope is a 3rd generation Gravitational Wave Observatory
  - It is, first of all, a new Research Infrastructure

- Capable to host ET and its upgrades
- Capable to host 4G, …



Observation (rather than detection) is the core business:

Requirements	Design Specifications
• Wide frequency range	• Xylophone (multi-interferometer) Design
• Massive black holes (LF focus)	• Underground
• Localisation capability	• Cryogenic
• (more) Uniform sky coverage	• Triangular shape
• Polarisation disentanglement	• Multi-detector design
• High Reliability (high duty cycle)	• Longer arms
• High SNR	

Q1: Enabling Technologies

Challenging engineering

New technology in cryo-cooling

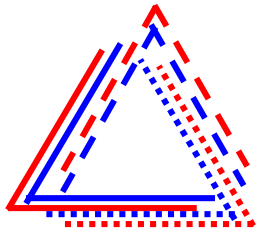
New technology in optics

New laser technology

High precision mechanics and low noise controls

High quality opto-electronics and new controls

- The multi-interferometer approach asks for two parallel technology developments:



- **ET-LF:**
  - Underground
  - Cryogenics
  - Silicon (Sapphire) test masses
  - Large test masses
  - New coatings
  - New laser wavelength
  - Seismic suspensions
  - Frequency dependent squeezing

- **ET-HF:**
  - High power laser
  - Large test masses
  - New coatings
  - Thermal compensation
  - Frequency dependent squeezing

Evolved laser technology

Evolved technology in optics

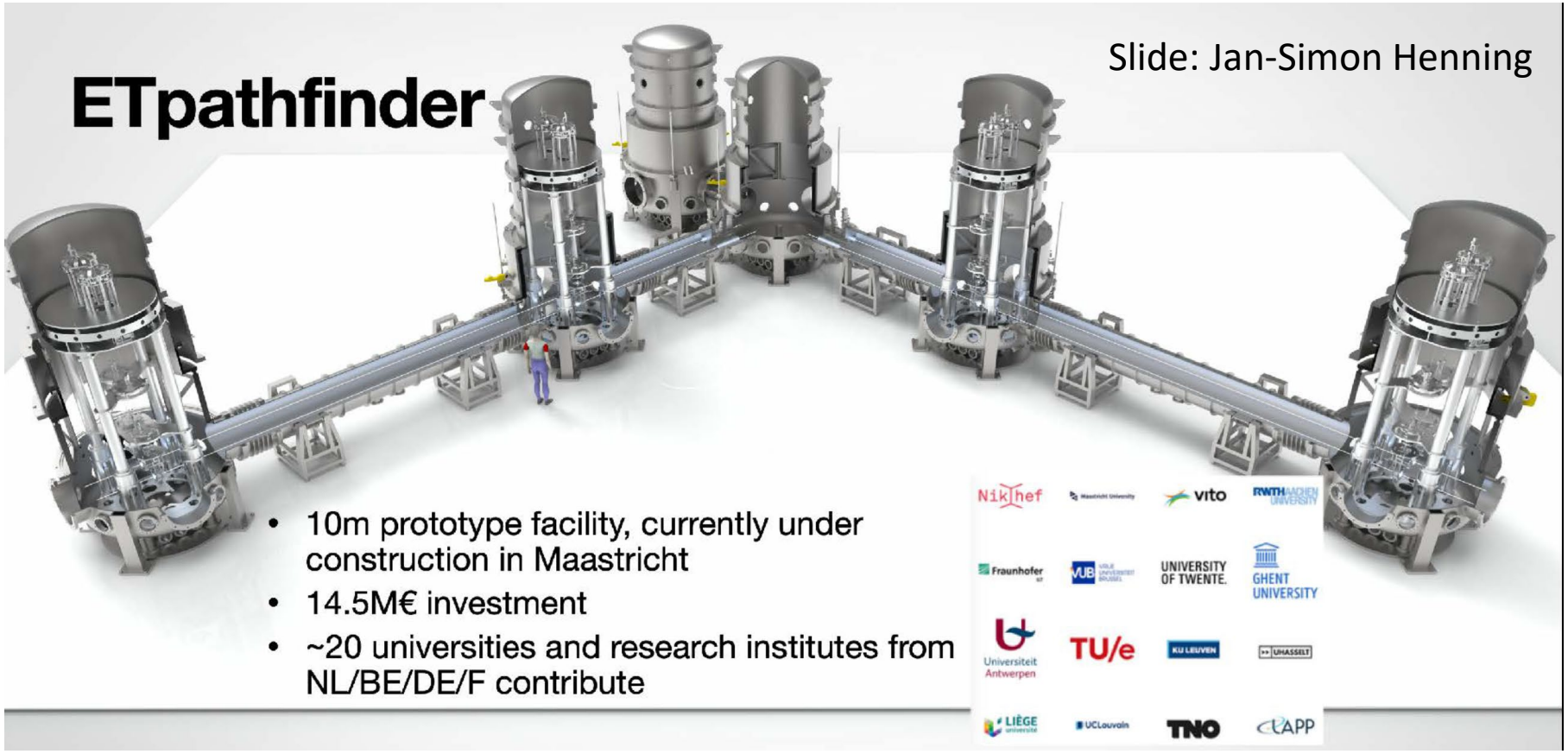
Highly innovative adaptive optics

High quality opto-electronics and new controls

Advanced detectors and their development programmes are a crucial de-risking factor for ET-HF

A network of new R&D infrastructures

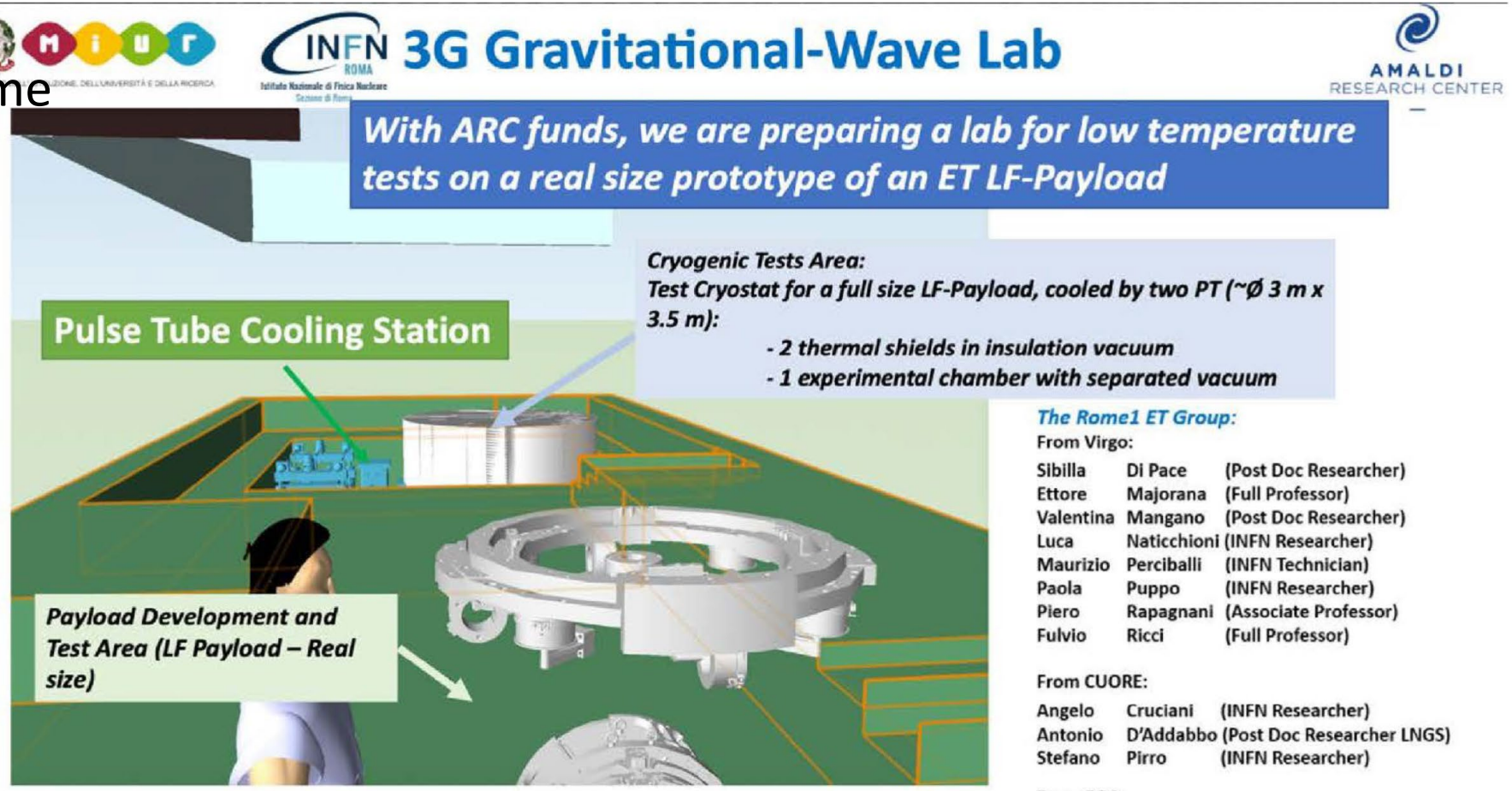
- The technological evolution requested by ET is stimulating the grown of a series of new facilities and infrastructures where ET R&D is performed:
  - ET pathfinder



A network of new R&D infrastructures

- The technological evolution requested by ET is stimulating the grown of a series of new facilities and infrastructures where ET R&D is performed:
  - ET pathfinder
  - Amaldi Centre, Rome

Grant: About 11M€



Slide P.Rapagnani

A network of new R&D infrastructures

- The technological evolution requested by ET is stimulating the grown of a series of new facilities and infrastructures where ET R&D is performed:
  - ET pathfinder
  - Amaldi Centre, Rome
  - Sar-Grav lab in Sardinia
  - Other sites under preparation

The SarGrav Laboratory

Founded with 3.5 M€ by the Regione Autonoma della Sardegna (RAS) to host low seismic noise underground experiments (low seismic noise experiments, cryogenic payloads, low frequency and cryogenic sensor development)

- ~ 900 m^2 surface Laboratory
- 3 Underground stations equipped for measurements at different depths
- ~ 50 m^2 underground area available
- planned a 250 m^2 underground Lab
- First experiment: Archimedes (founded by INFN)

ET site(s)

- Currently there are two sites, in Europe, candidate to host ET:
  - The Sardinia site, close to the Sos Enattos mine
  - The EU Regio Rhine-Meusse site, close to the NL-B-D border
- A third option in Saxony (Germany) is under discussion, ~~but still too preliminary to be a candidate~~

SPB: ET sites under characterisation

Euregio Meuse-Rhine

- A 250-m deep borehole has been excavated and equipped
  - Seismic data under acquisition and analysis
- 3-5 other boreholes expected
- Extensive active and passive site characterisation with sensor arrays in 2021
- Good seismic noise attenuation given by the particular geological structure
- Characterisation funded through Interreg grants

Sardinia

- Long standing characterisation of the mine in one of the corners continuing
  - Seismic, magnetic and acoustic noise characterisation ongoing at different depth in the mine
- Underground laboratory under construction (SarGrav)
- Two ~290m boreholes have been excavated, equipped and data taking is ongoing
- Intense & international surface investigations programme in Summer/Fall 2021
- Characterisation funded on regional and national funds

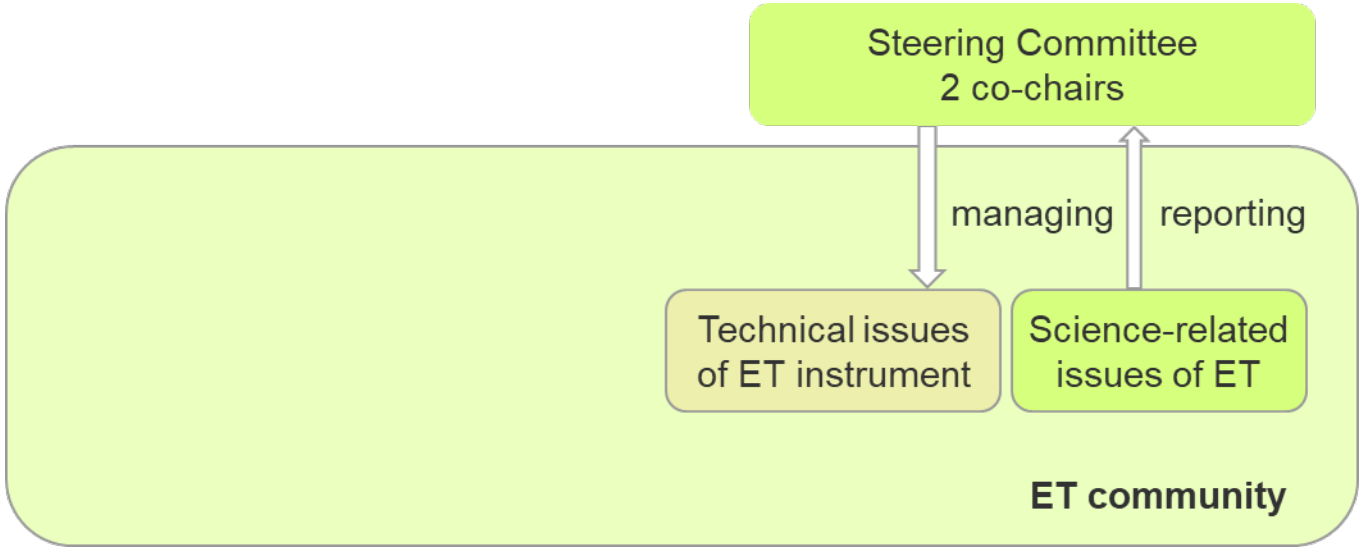
OSB: Observation Science Board

Marica Branchesi - Michele Maggiore - Ed Porter

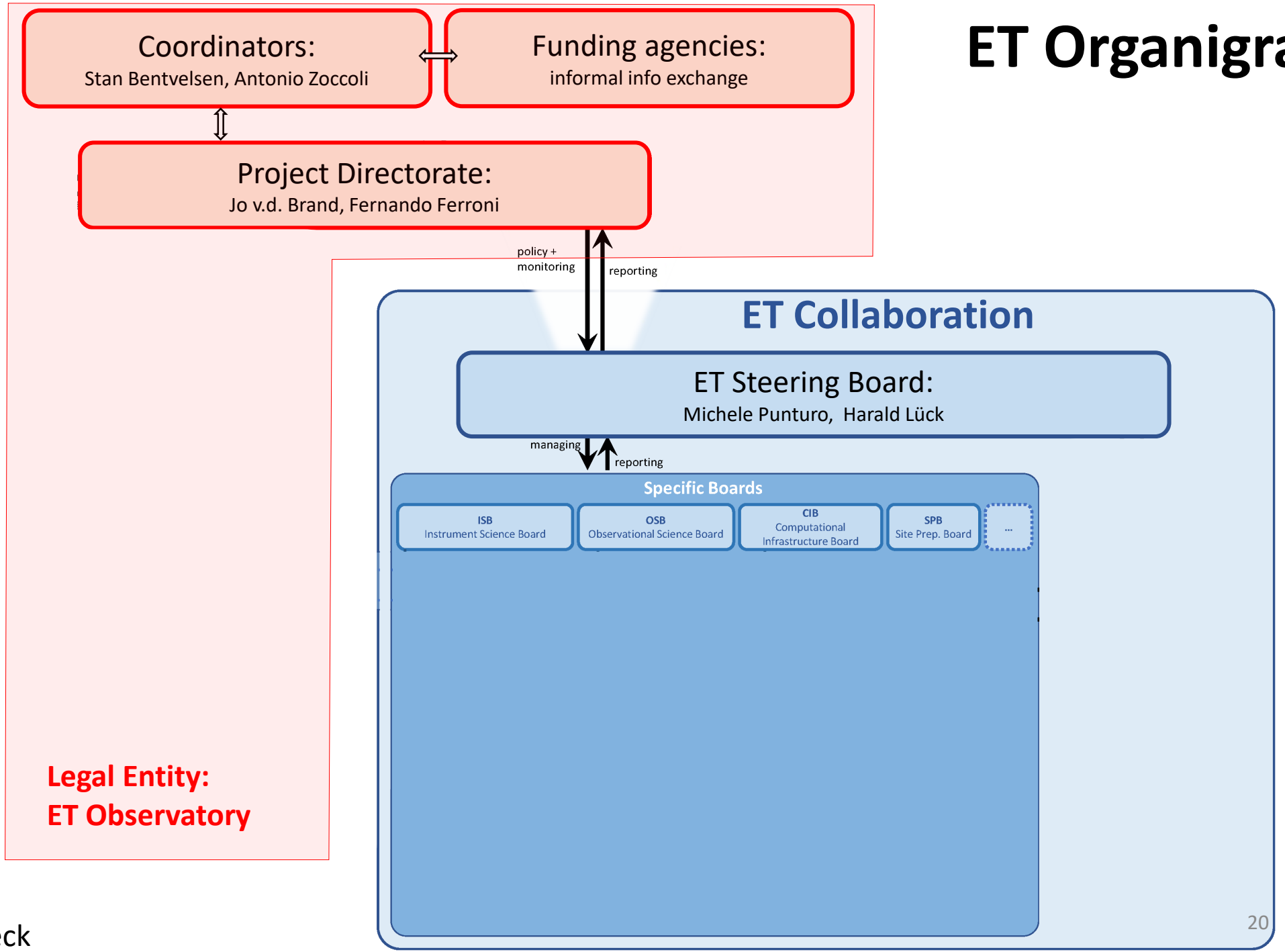
Fundamental physics	Cosmology	Population Studies	MM observations	Synergies w. other GW observ.	Nuclear physics	Transient GW Sources	Waveforms	Science Potential	DA platform
Physics near BH horizons	Dark Energy	Predictions of population of astrophysical origin	ET / high-energy	Synergies with 2G+ detector	EoS of NSs in isolated systems	Predictions for Supernovae	Waveforms relevant for ET	Science potential for various detector configurations	DA platform
Tests of GR	Dark matter	Predictions of primordial BHs	ET / optical	Synergies with CE, 3G	EoS in NSs in binary systems	Predictions for magnetars	Improvement of waveforms for BBH	Common tools	
Exotic compact objects	Estimation of cosmological parameters	Stochastic backgrounds of astrophysical origin	ET / radio	Synergies with LISA	Nucleo-synthesis in BNS mergers	Predictions for cosmic string bursts	Improvement of waveforms for NSBH		
	Modifications of gravity at cosmological scales		ET / neutrinos				Improvement of waveforms for BNS		
	Stochastic background of cosmological origin								

ET Structure - 2020

- **Before ESFRI approval: A broad ET scientific community;**



ET Organigram



Slide animation: H.Lueck

Summary

- ET is now an ESFRI project
  - Important and increasing support of national governments
    - Important funding possibility currently under discussion
  - Perspective of EU funding for specific activities
    - Specific ESFRI calls under preparation
- Agencies and institutions are working to define the ET project governance
  - INFRA-DEV EU proposal under preparation
- The ET collaboration is going toward its formalisation
  - ET wants to be open to all the scientific and technical contributions, but this so challenging effort needs commitment by its members
- Huge amount of technical, scientific, political and financial activities is progressing

What are you doing?

ET Wants You!