Project: 101079696 — ET-PP — HORIZON-INFRA-2021-DEV-02

Horizon Europe:
Coordination and Support Actions

ET-PP WP4
2nd review meeting (RP2)

15/05/2025

Grant agreement: № 101079696

WP 4: Introduction and objectives

Duration: M1-M48
WPL: NIKHEF.
WP4 chairs: Domenico D'Urso (INFN), Wim Walk (NIKHEF), Andreas Rietbrock (KIT)

General Objective: The general objective of WP4 is to facilitate the site selection process by collecting – and wherever possible quantifying – all relevant site-specific aspects entering the ET site selection process.

Objectives for this period:

- Report on site-specific characteristics that impact ET sensitivity and its duty cycle
- Report on a common methodology to estimate impact of site characteristics on ET performance
- Inventory of Legal Procedures to be taken prior starting excavation
- Update of socio-economic impact of ET infrastructure

WP 4: Tasks

Three sites candidate to host ET:

- The Sardinia site, close to the Sos Enattos mine
- The EU Regio Rhine-Meuse site, at the NL-B-D border
- Lausitz, Saxony (D)
- Site selection and the optimal geometrical configuration (1 triangle or 2L in two different sites) is still under discussion.

Overall site evaluation is a complex task depending on:

- Detector performance
- Geophysical and environmental quality
- Financial and organization aspects
- Services, infrastructures

WP 4: Tasks

Tasks and activities are leading by Site Host Teams, by the ET Collaboration and coordinated by the Site Preparation and Characterization Board of ET

- Measurement campaign and data analysis of environmental sensors to understand relevant site characteristics for ET detector performance. Data analysis of environmental data.
- Meetings to discuss results and methodology.
- Produce intermediate ET Collaboration papers and presentations.
- Develop geological and hydrogeological models for ET positioning
- Study of legal scenario of candidate country
- Update overall costs

WP 4: Critical risks, deviations from Annex I, contingency plans

Critical risks

- WP4 is the responsible for collecting and processing all the required information necessary for site qualification. Activities are **managed directly by site Host Teams**, which are implementing different organizational strategies, constrained by the national and regional fundings conditions (in 2022-2023 **42M€ for the EMR** team and **50M€ for the Sardinia** team, **22M€ for the Lausitz** and additional funds have been allocated in 2024-2025).

- **Host Teams have different timelines.**

- ET Collaboration is working on the definition of detector specification and on a common definition of standards for site characteristics measurements and of standard modelling and interpretation

- Site selection criteria and the optimal geometrical configuration still to be set

WP 4: Critical risks, deviations from Annex I, contingency plans

Deviations from Annex 1

M2 Document detailing the site-specific characteristics that impact ET sensitivity and its duty cycle – **Resubmitted (Initially Rejected)**

M3 Common methodology to estimate the impact of site characteristics on ET sensitivity and operation and, if required a scheme to compensate it – **Delivered in April 2025 (Expected in Jun 2023)**

D4.1 Scan of legal procedures, permitting and land acquisitions – **Delivered**

D4.2 Updated socio-economic impact studies. Scan of accessibility, quality of life etc. –**Delivered in April 2025 (Expected in Nov. 2023)**

WP 4: Critical risks, deviations from Annex I, contingency plans

Deviations from Annex 1

D4.3 – M47: Complete quantification of all the aspects impacting the ET performance for each site (Exp. in M28/Dec24)

D4.4 – M42: Report on 3D geology, hydrology, etc. model with localisation of the ET infrastructure (Exp. in M30/Feb25)

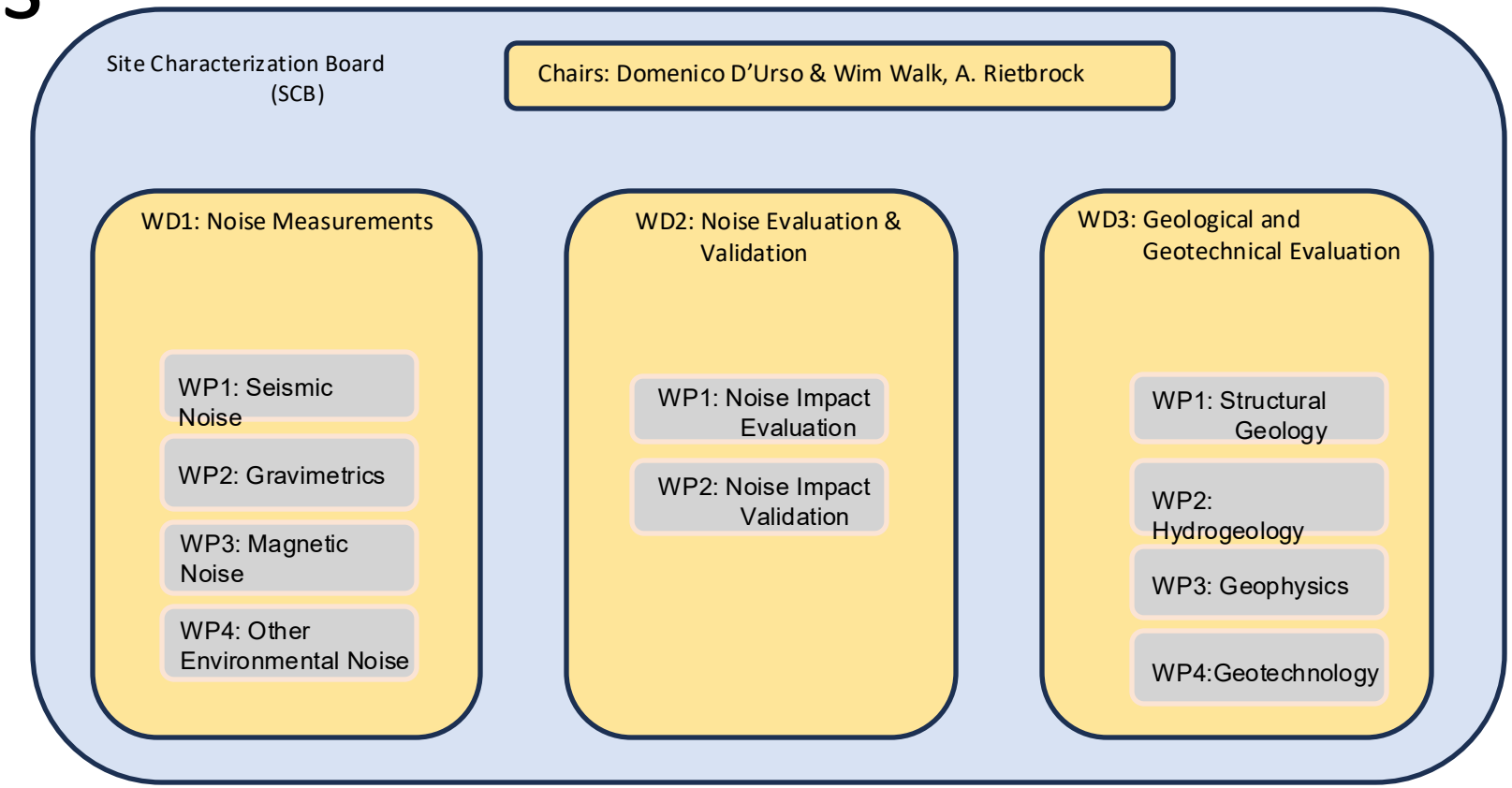
D4.5 - M47: Updated cost and schedule estimates of the excavations, including, if necessary: instrumentation for Newtonian Noise cancellation; costs of debris removal; costs of land acquisition, permitting, etc. (Exp. in M42/Feb26)

WP 4: Critical risks, deviations from Annex I, contingency plans

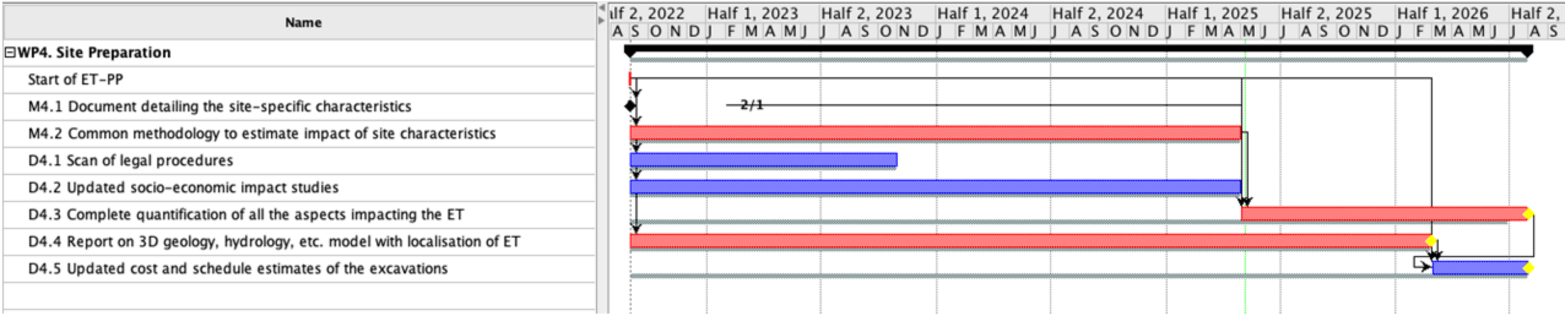
Contingency:

- **New SCB Organization**

- **ETC Task Force for Noise Impact Evaluation**



WP 4: Deliverables and milestones



Code	Milestone Name	Expected date
M2 (M4.1)	Document detailing the site-specific characteristics that impact ET sensitivity and its duty cycle	M6/Feb23 M25/Oct24
M3 (M4.2)	Common methodology to estimate impact of site characteristics	M33/April25

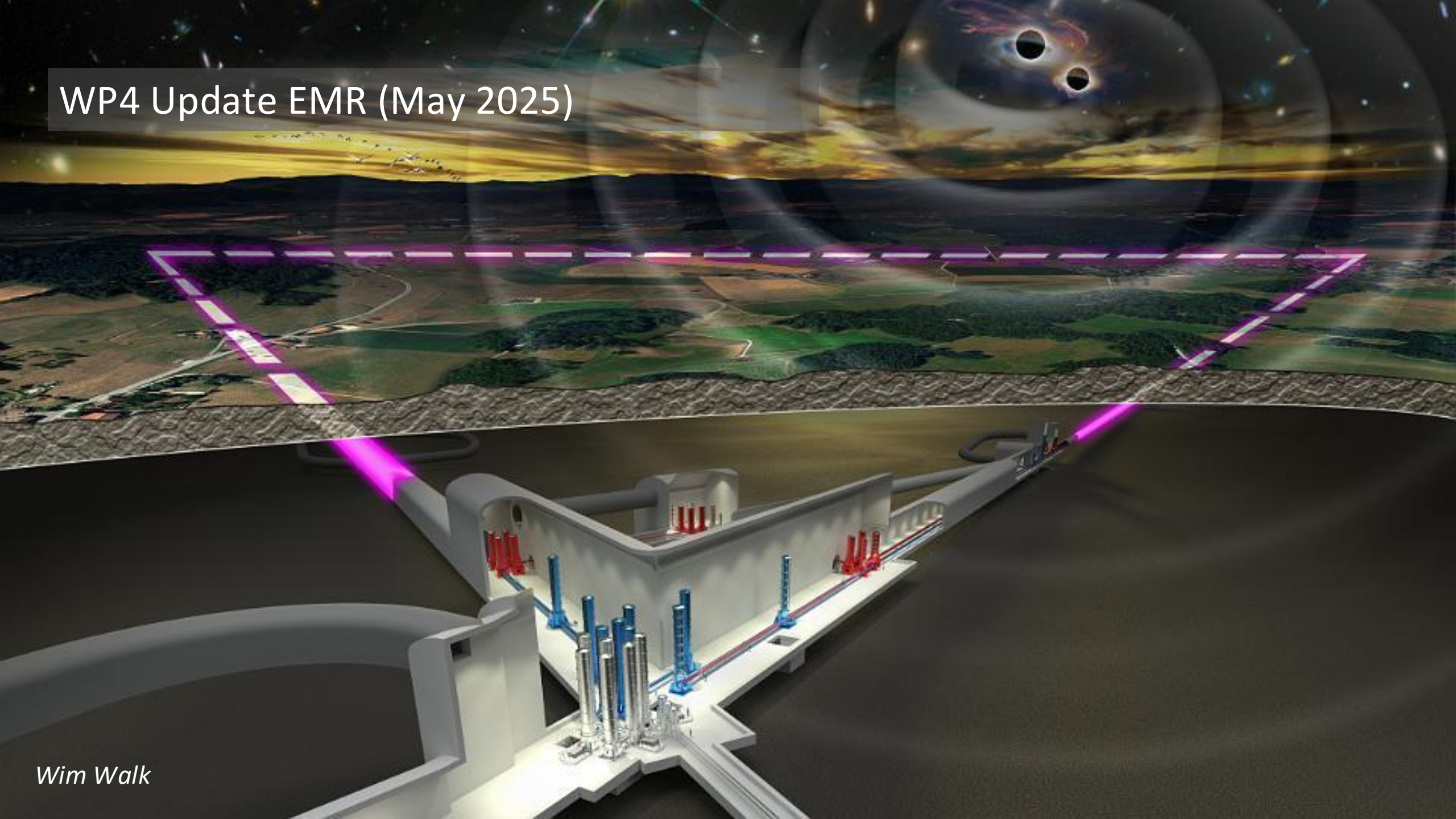
4.1	Scan of legal procedures	M18/Oct.23
4.2	Updated socio-economic impact studies	M31/Apr25
4.3	Complete quantification of all the aspects impacting the ET performance for each site	M47/Jul26
4.4	Report on 3D geology, hydrology, etc. model with localization of the ET infrastructure	M42/Feb26
4.5	Updated cost and schedule estimates of the excavations	M47/Jul26

WP 4: Contribution from each partner

- PM affected by the limitations in the declarations from Beneficiaries [INFN - affiliated not included**] (some of our WP coordinators time is not counted here)

INSTITUTION		PM as per Annex I	PM in RP2 the period	PM in the RP1 period
INFN	CONTRIBUTIVES	10	0	0
	REQUESTED EC	0	0	0
UW	CONTRIBUTIVES	12	3,43	0,9
	REQUESTED EC	0	0	0
NIKHEF	CONTRIBUTIVES	10	24,64	2,74
	REQUESTED EC	0	0	0
WIGNER RCP	CONTRIBUTIVES	13,2	3,8	3,3
	REQUESTED EC	0	0	0
Total Person Months	**CONTRIBUTIVES**	**45,2**	**31,87**	**6,94**
Total Person Months	**REQUESTED EC**	**0**	**0**	**0**
		45,2	**31,87**	**6,94**

WP4 Update EMR (May 2025)

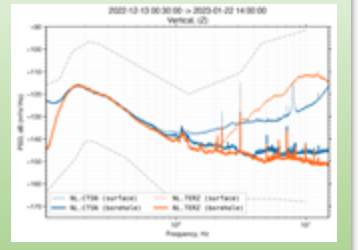


Wim Walk

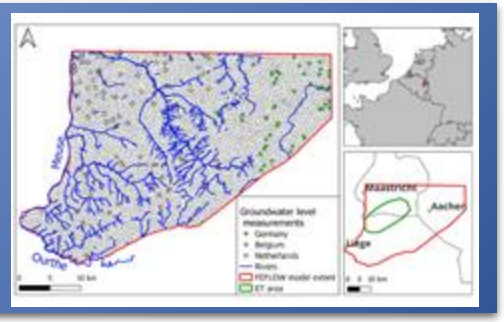
Current Status (May 2025):

- 11 new boreholes completed 300-400m deep
- Total of 16 boreholes being evaluated
- 2nd borehole campaign starting May 19th evaluating geo-mechanics at potential vertices to correct depth, and also equipped with seismometers

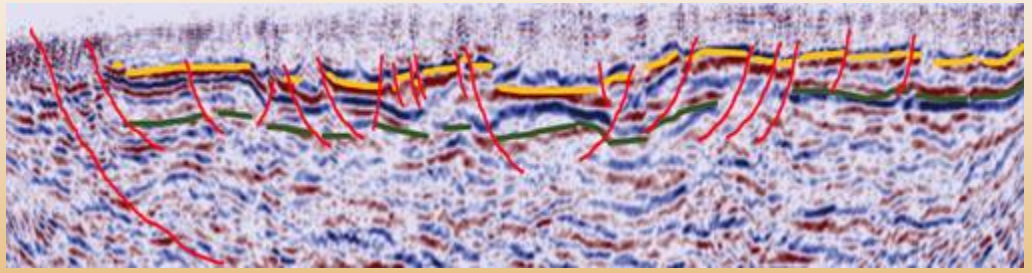
- Noise measurements at surface ongoing
- Subsurface noise network being installed for 10 boreholes, results Q2-Q3
- All seismometer boreholes also equipped with DAS and VSP
- More sophisticated noise modeling being developed by dedicated team
- Noise mitigation schemes starting to be addressed



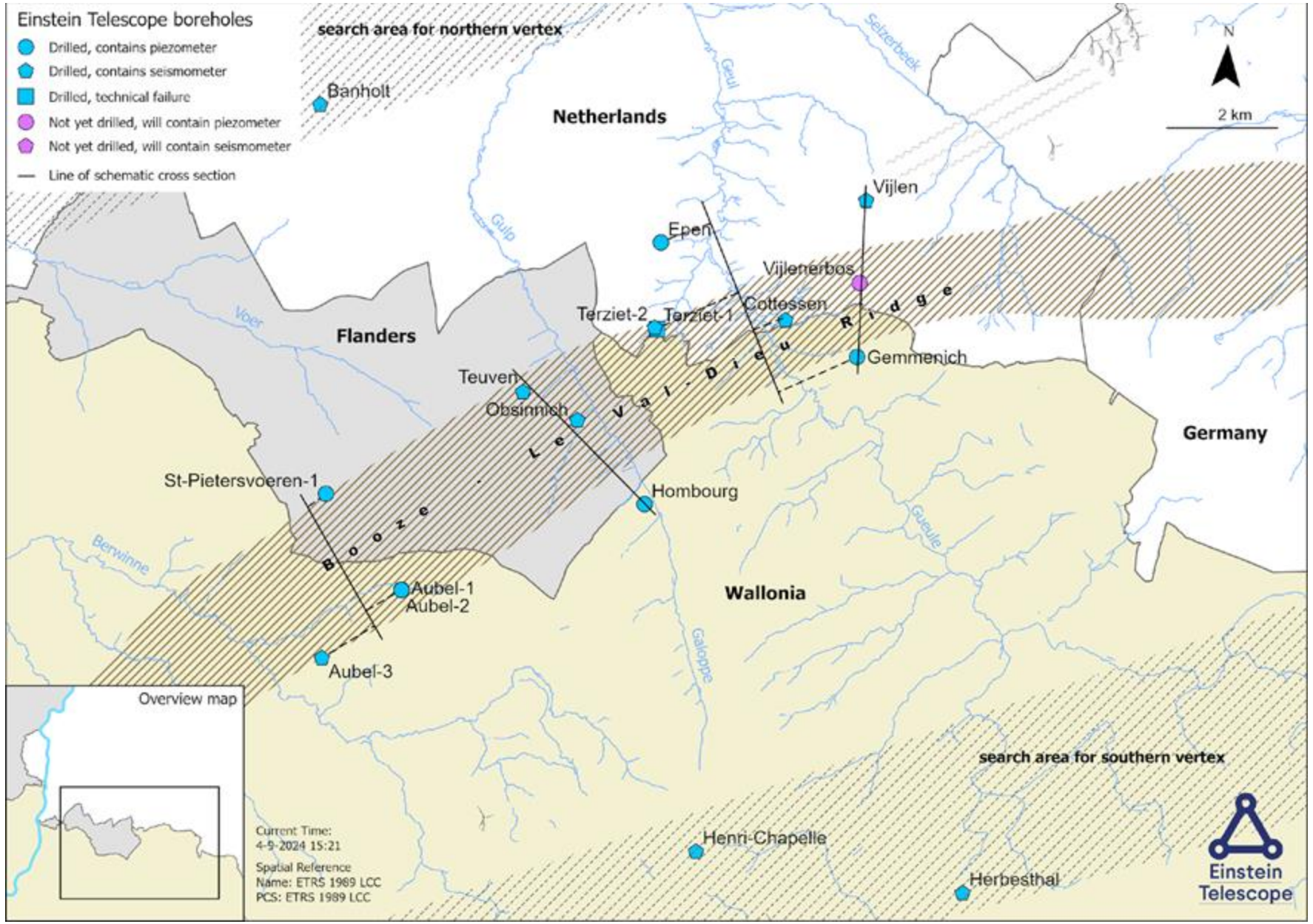
- In total 6 boreholes have been equipped for hydro measurements
- Another 2 will be added during 2nd borehole campaign
- 3D Subsurface Hydro-geological model being constructed
  First significant version ready Q3



- 100 km seismic completed in April, confirming nice resolution with updated receiver topology
- Seismic being processed and input into 3D subsurface model
- Wind turbine experiments ongoing



Map of completed boreholes

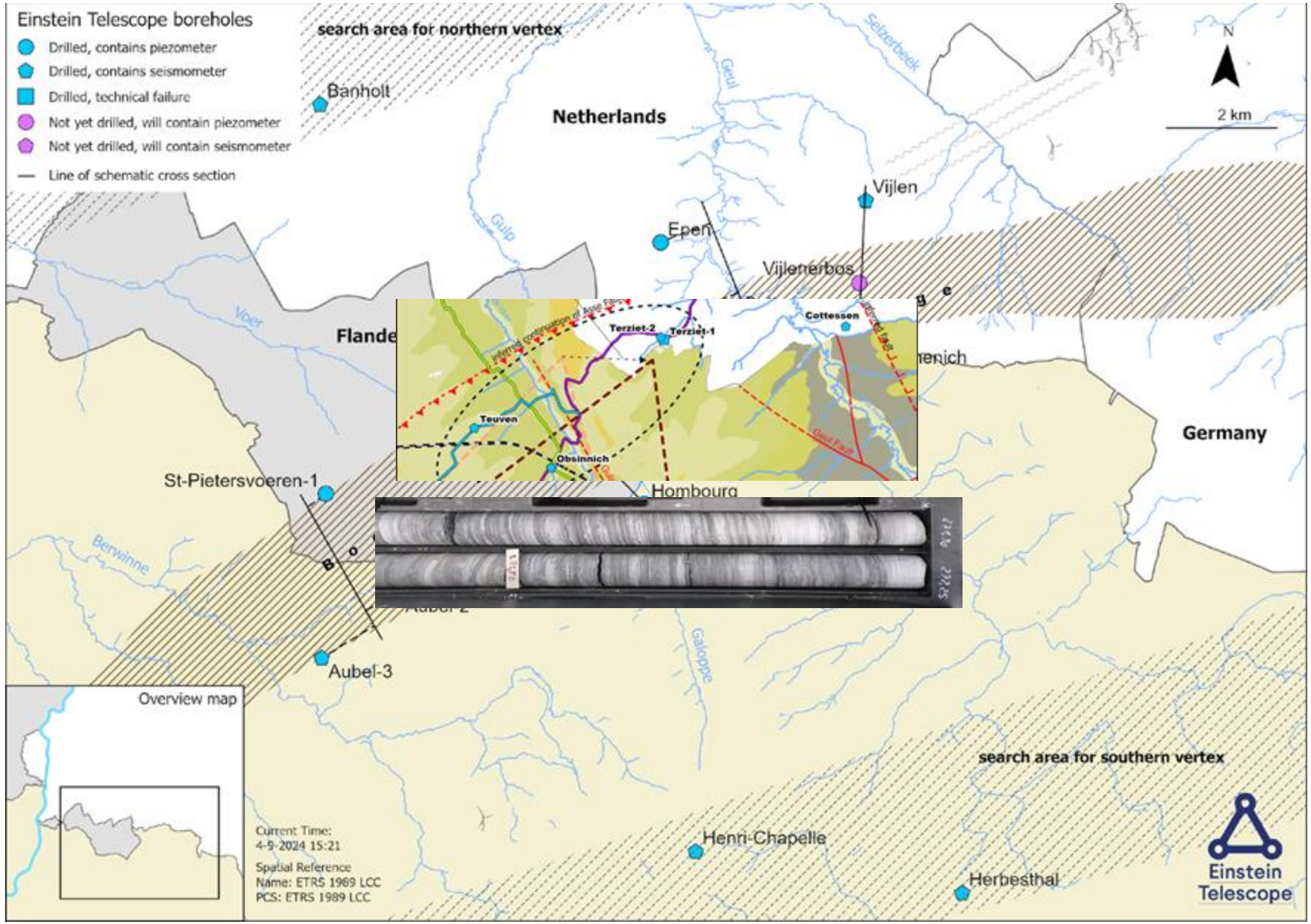


11 new boreholes in 2024

- Flanders: 3 locations in Voeren
- Wallonia: 5 locations: Plombières (2), Aubel, Welkenraedt and Lontzen
- Dutch Limburg: 3 locations in Vijlen (2) and Epen
- Extremely low impact on Environment
- Communication

EINSTEIN TELESCOPE

Map of completed boreholes



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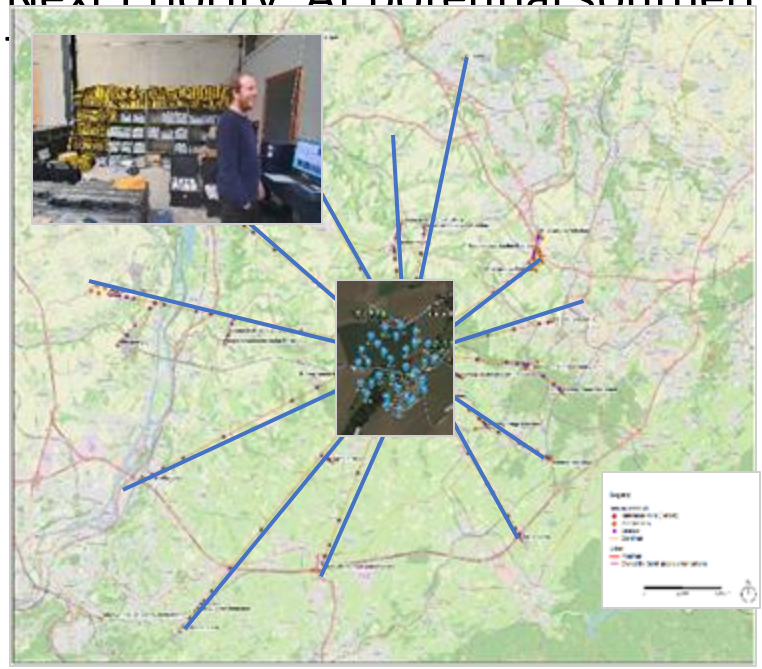
EINSTEIN TELESCOPE

Seismic & Noise Measurements:

- **Surface noise measurements**
  (example below Terziet)

- Starting at identified noise sources geophone were placed along scan-lines:
  - Airport, quarries, wind-turbines, tunnels, pipelines, Mijnwater geothermal site, …
- Next Priority: At potential southern vertex of



- **Source function of a wind turbine recorded**

- Fully instrumented windturbines
  - 4 towers for meterological data
  - Eddy covariance (vert. turbulent flux)
  - Lidar (wind monitoring, etc.)
  - Ceilometer (cloud height, etc.)
  - Tower movements
    - Bending moments
    - Torsional moments
    - Acceleration
    - ***
  - Broadband seismometer (0.05-45Hz)
  - Rotational geophones on foundation
  - Dense grid of geophones around the foundation (Nikhef et al.)
  - Acquired from 20.12.24-21.01.25

- Data to be collected at a common site for sharing

Seismic & Noise Measurements (2):

6 DAS-Fiber installations completed, VSP and 2D acquisition starting

- Example DAS installation at Obsinnich:

DAS-bottom hole assembly

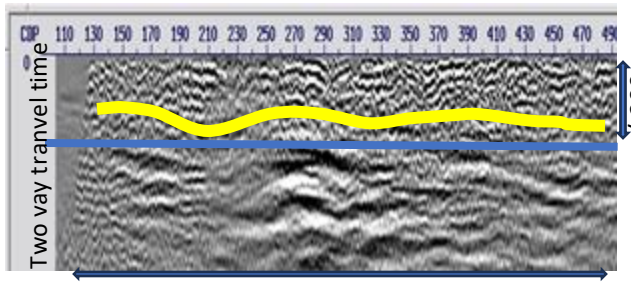
Centralizer

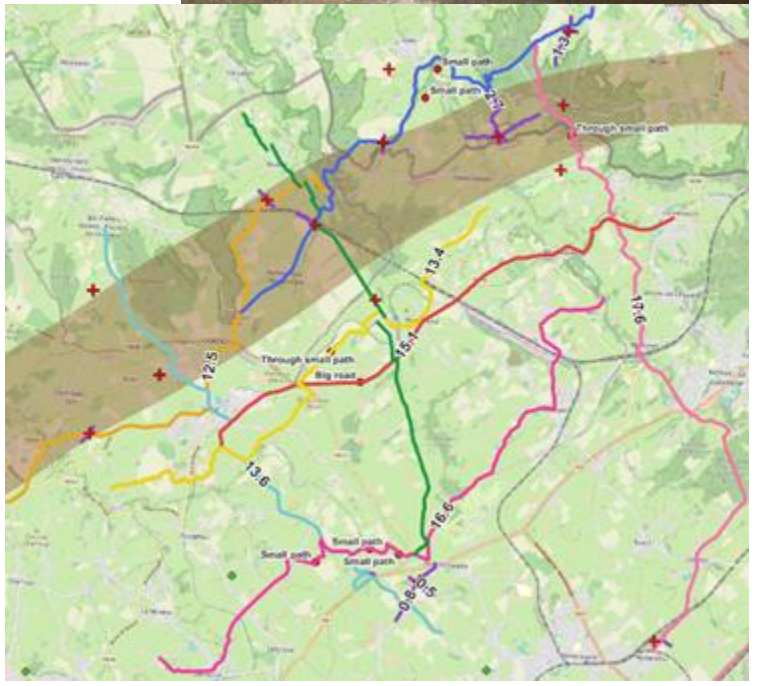
DAS- and DSS-cables

Checking every ~20m for loss of signal (OTDR)

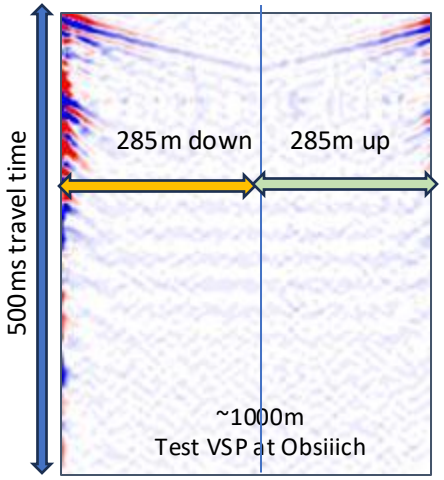
DAS / DSS

- ~100km 2D seismic with e-Vib's

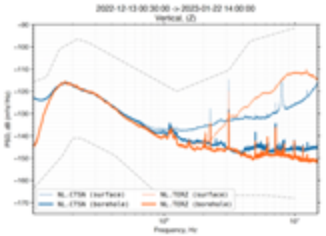




- 6 VSP's



Noise for EMR



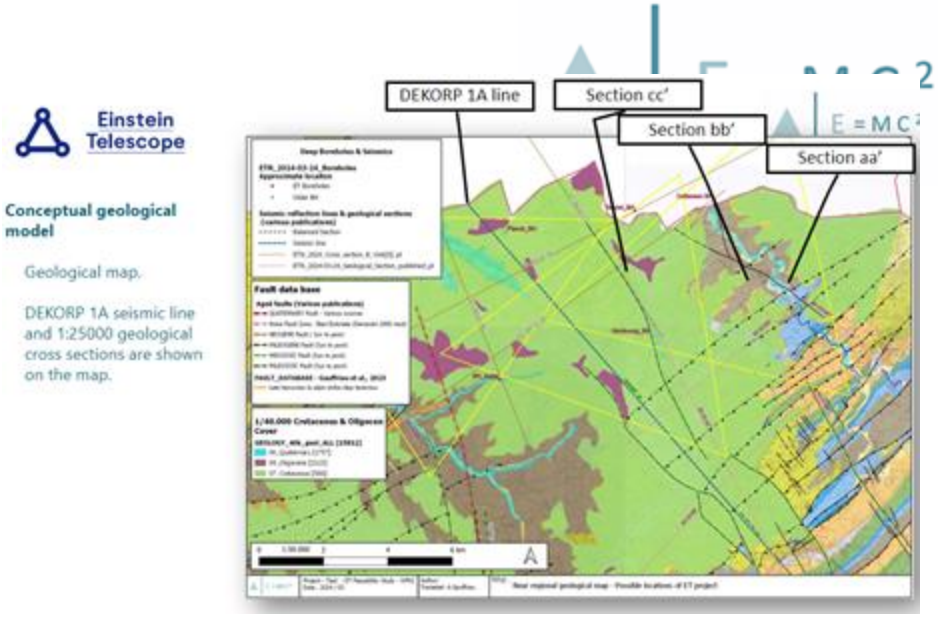
- Measuring the noise
  - Replacing preliminary Terziet data by EMR representative data from noise network at target depth
  - Sensor network being implemented, expect first results this Summer

- Modeling the noise
  - Structured geology provides (additional) opportunity for noise mitigation
  - Requires careful and approved NN modeling for the EMR region
    - Measuring the noise at surface and subsurface
      - Dampening effect for subsurface
    - Propagation to the corners of the triangle
      - Propagation of seismic waves depend on the geology structure and lithology
      - EMR has complex geology with softer top-layers that dampen
    - Effect of the residual PSD noise on the ET instrument
      - Calculation of NN contribution, using adequate models for geology and sources
      - Requires careful and approved NN modeling for the EMR region
  - Specialists team put in place to develop modeling

- Mitigating the noise
  - Active and passive mitigation (e.g. geometry of the caverns)

Civil Engineering EMR

- Review of the geological and geotechnical data
- Dedicated geo-mechanical / civil-engineering team
- Facilities and Infrastructure
- Developing alternative construction scenarios
- Estimating building cost most likely triangle construction scenario



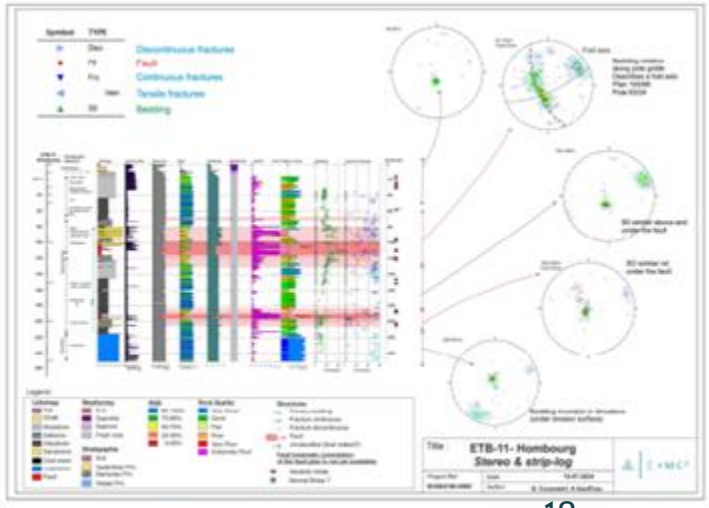
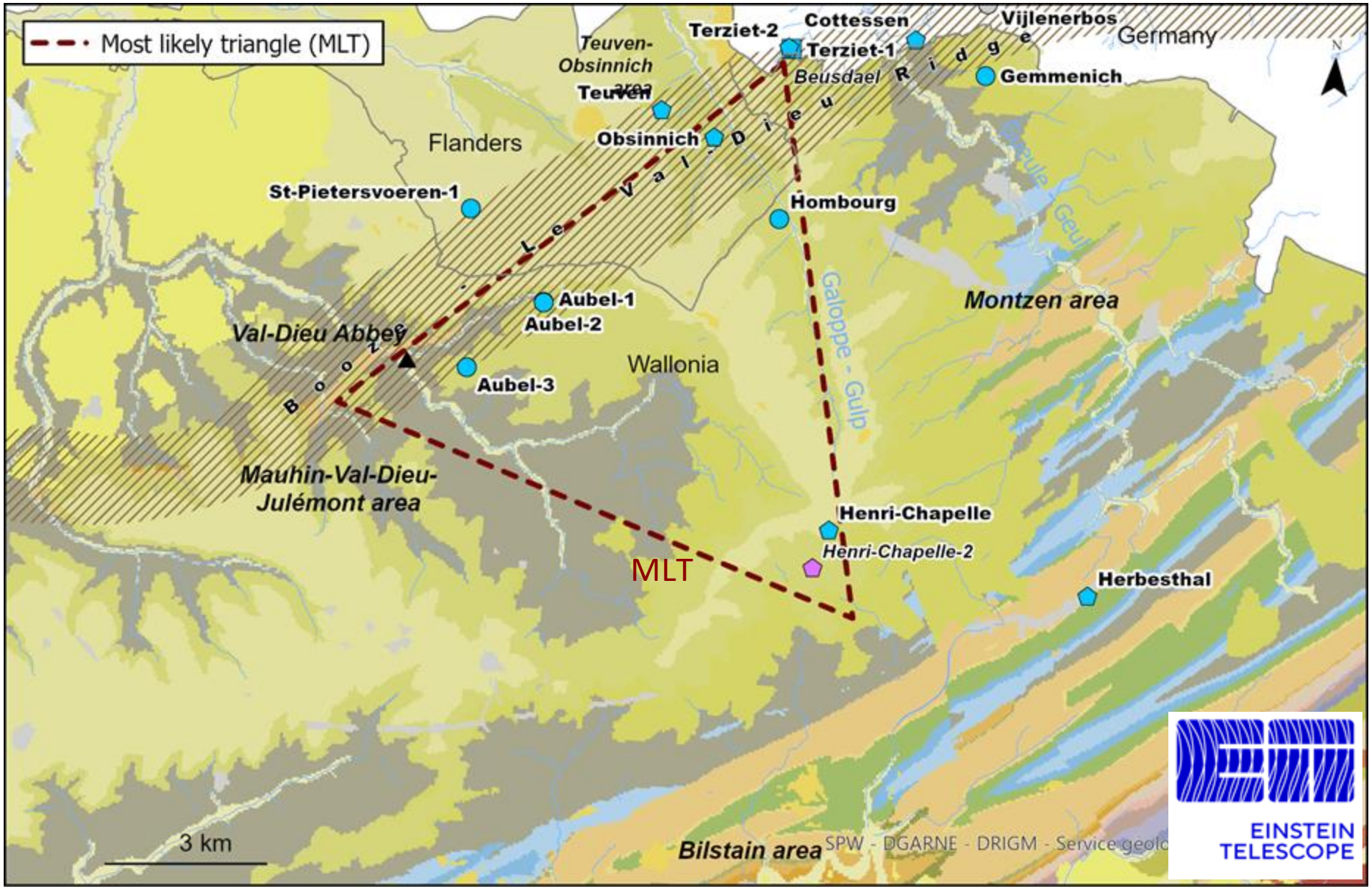


Figure 5 : Structural patterns of each tectonic domains toward [illegible]

Most Likely Triangle – based on current knowledge



MLT location convergence based on:

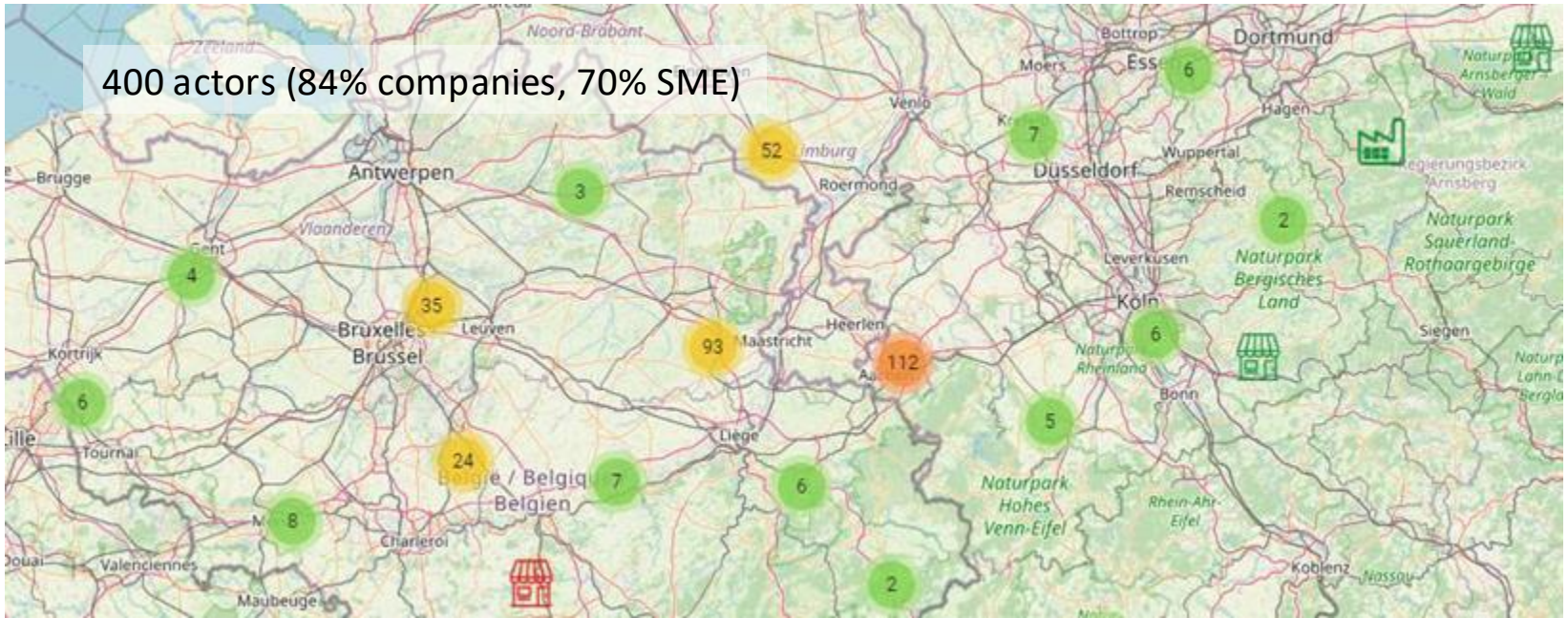
- Structural geology model
- Geomechanical core evaluation
- Available seismic and ERT data

2nd borehole campaign:

- Confirm vertices
- Use recently completed seismic campaign data
- Refine hydro-geological model
- Investigate L (boreholes pending approval)

Socio-economics

See details in updated study



The Sardinian Candidate Site

Action lines

- Two Geometrical Options: Δ vs 2L
- Legal Framework and authorization (D4.1)
- Socio-economic impact (D4.2)
- Site monitoring (M4.1)
- Noise impact Evaluation (M4.2, D4.3)
- Geological studies (D4.4)
- Engineering studies (D.4.5)
  - cost and time estimation

Why Δ vs 2L ? Optimize Science return

The 2L 15 km geometry shows, wrt 10km Δ shape, an improved science return in the majority of science targets

1. All the triangular and 2L geometries that we have investigated can be the baseline for a superb 3G detector, that will allow us to improve by orders of magnitudes compared to 2G detectors, and allow us to penetrate deeply into unknown territories.

2a. The 2L-15km-45° configuration in general offers better scientific return with respect to the 10 km triangle, improving on most figures of merits and scientific cases, by factors typically of order 2-3 on the errors of the relevant parameters.

2b. The 2L-15km-45° configuration and the 15 km triangle have very similar performances on all parameters both for BBHs and BNSs, except for luminosity distance, where the 2L-15km-45° configuration is better by a factor ~ 3 in the number events with accurately measured distance.

3. A single L-shaped detector is not a viable alternative, independently of arm length. If a single-site solution should be preferred for ET, the detector must necessarily have the triangular geometry.

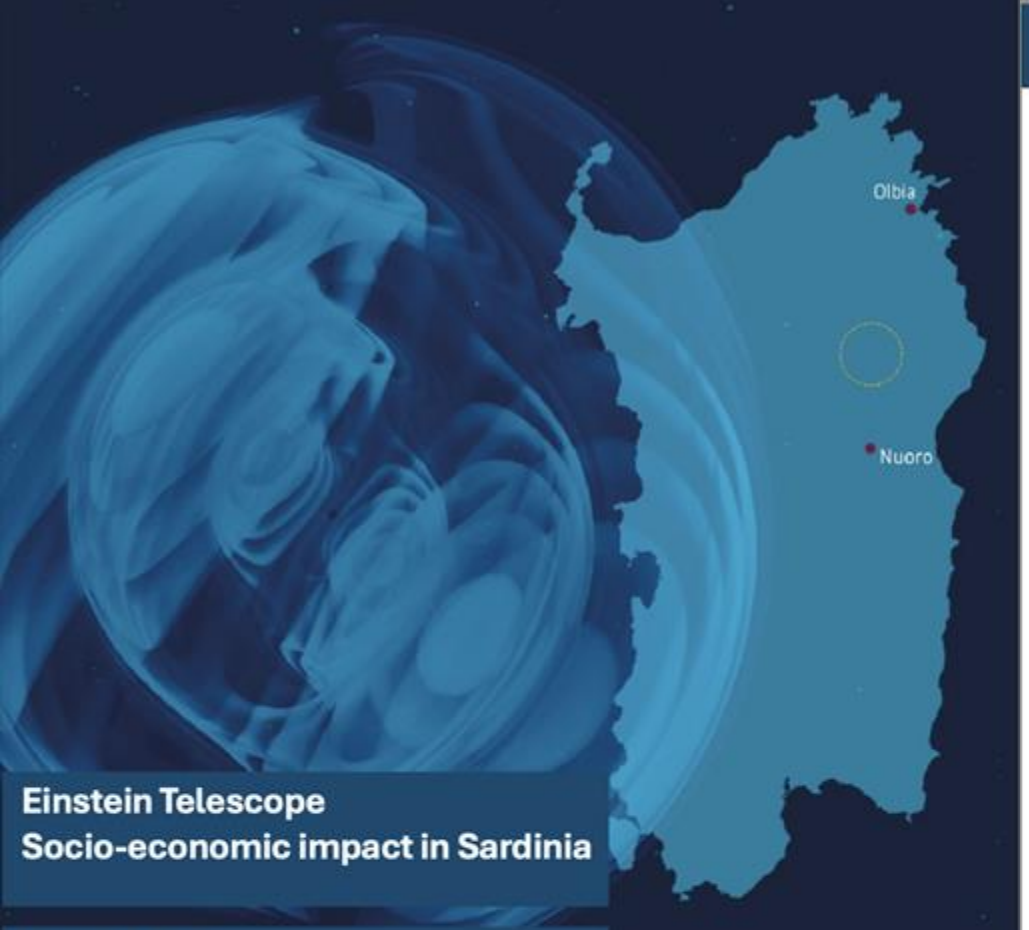
4. The low-frequency sensitivity is crucial for exploiting the full scientific potential of ET. In the HF-only configuration, independently of the geometry chosen, several crucial scientific targets of the science case would be lost or significantly diminished.

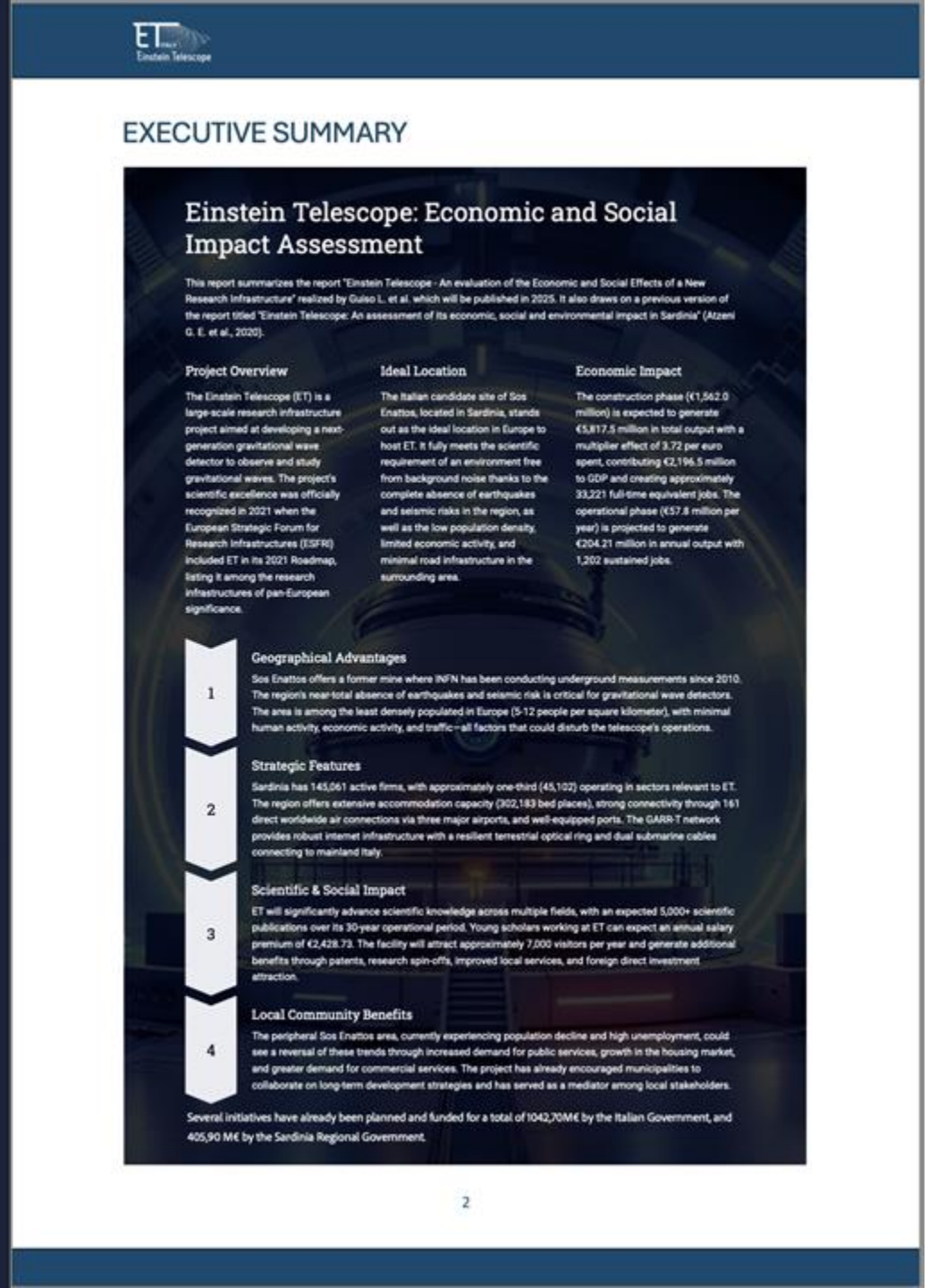
5. There are some important targets of the Science Case that depend only on the HF sensitivity, and that could be fully reached with an HF-only instrument.

6. For some important aspects of the Science Case, the 2L with 15 km arms at 45°, already in the HF-only configuration, is comparable the 10 km triangle in a full HFLF-cryo configuration.

Marica Branchesi *et al* JCAP07(2023)068
https://doi.org/10.1088/1475-7516/2023/07/068

Socio Economic Impact





ET Einstein Telescope

EXECUTIVE SUMMARY

Einstein Telescope: Economic and Social Impact Assessment

This report summarizes the report "Einstein Telescope - An evaluation of the Economic and Social Effects of a New Research Infrastructure" realized by Guiso L. et al. which will be published in 2025. It also draws on a previous version of the report titled "Einstein Telescope: An assessment of its economic, social and environmental impact in Sardinia" (Atzeni G. E. et al., 2020).

Project Overview

The Einstein Telescope (ET) is a large-scale research infrastructure project aimed at developing a next-generation gravitational wave detector to observe and study gravitational waves. The project's scientific excellence was officially recognized in 2021 when the European Strategic Forum for Research Infrastructures (ESFRI) included ET in its 2021 Roadmap, listing it among the research infrastructures of pan-European significance.

Ideal Location

The Italian candidate site of Sos Enattos, located in Sardinia, stands out as the ideal location in Europe to host ET. It fully meets the scientific requirement of an environment free from background noise thanks to the complete absence of earthquakes and seismic risks in the region, as well as the low population density, limited economic activity, and minimal road infrastructure in the surrounding area.

Economic Impact

The construction phase (€1,562.0 million) is expected to generate €5,817.5 million in total output with a multiplier effect of 3.72 per euro spent, contributing €2,196.5 million to GDP and creating approximately 33,221 full-time equivalent jobs. The operational phase (€57.8 million per year) is projected to generate €204.21 million in annual output with 1,202 sustained jobs.

1 **Geographical Advantages**

Sos Enattos offers a former mine where INFN has been conducting underground measurements since 2010. The region's near-total absence of earthquakes and seismic risk is critical for gravitational wave detectors. The area is among the least densely populated in Europe (5-12 people per square kilometer), with minimal human activity, economic activity, and traffic—all factors that could disturb the telescope's operations.

2 **Strategic Features**

Sardinia has 145,061 active firms, with approximately one-third (45,102) operating in sectors relevant to ET. The region offers extensive accommodation capacity (302,183 bed places), strong connectivity through 161 direct worldwide air connections via three major airports, and well-equipped ports. The GARR-T network provides robust internet infrastructure with a resilient terrestrial optical ring and dual submarine cables connecting to mainland Italy.

3 **Scientific & Social Impact**

ET will significantly advance scientific knowledge across multiple fields, with an expected 5,000+ scientific publications over its 30-year operational period. Young scholars working at ET can expect an annual salary premium of €2,428.73. The facility will attract approximately 7,000 visitors per year and generate additional benefits through patents, research spin-offs, improved local services, and foreign direct investment attraction.

4 **Local Community Benefits**

The peripheral Sos Enattos area, currently experiencing population decline and high unemployment, could see a reversal of these trends through increased demand for public services, growth in the housing market, and greater demand for commercial services. The project has already encouraged municipalities to collaborate on long-term development strategies and has served as a mediator among local stakeholders.

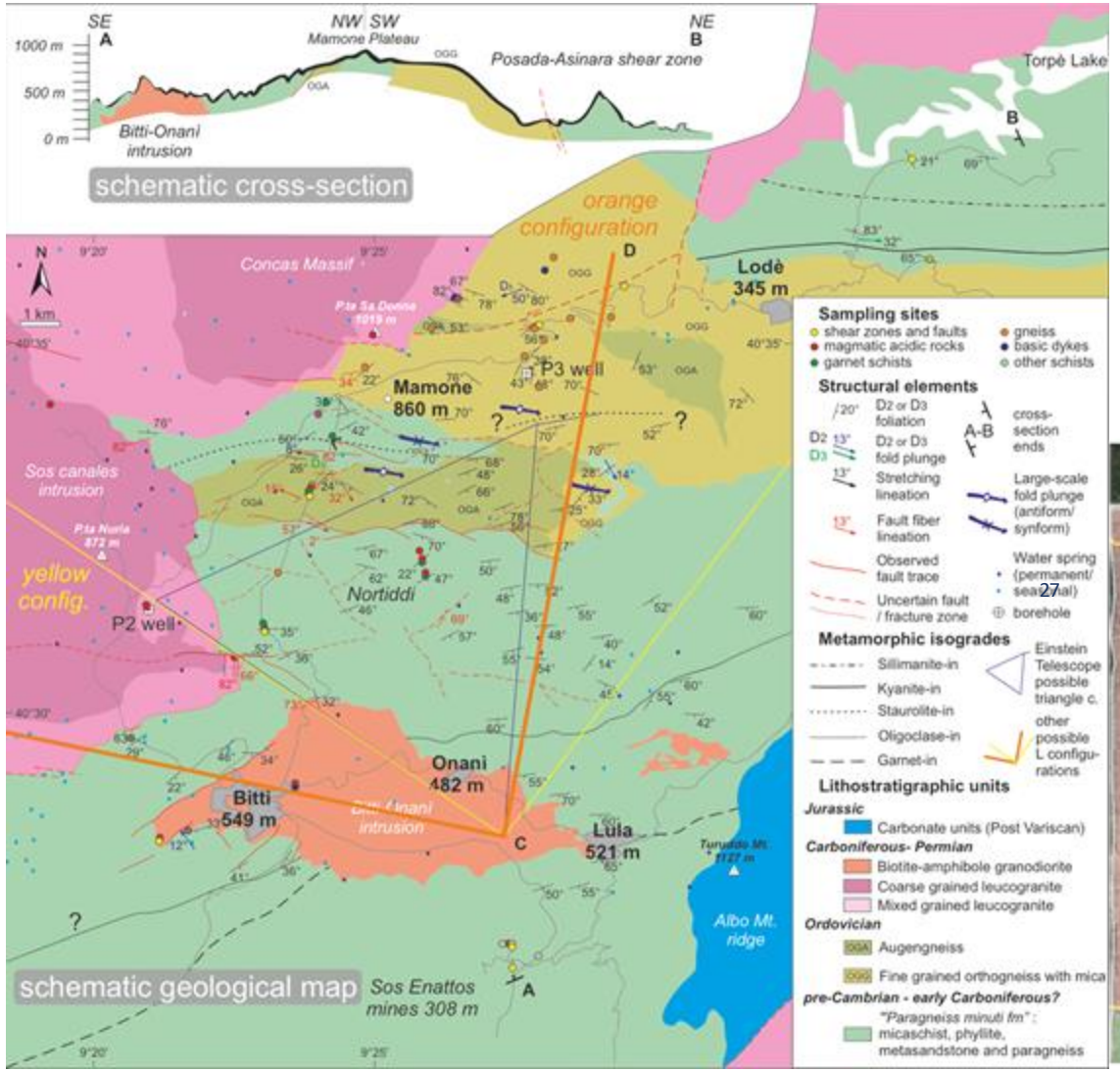
Several initiatives have already been planned and funded for a total of 1042,70M€ by the Italian Government, and 405,90 M€ by the Sardinia Regional Government.

2

Einstein Telescope –
An evaluation of the Economic and Social Effects of a New Research Infrastructure
(Guiso L. et al., 2025, to be published)

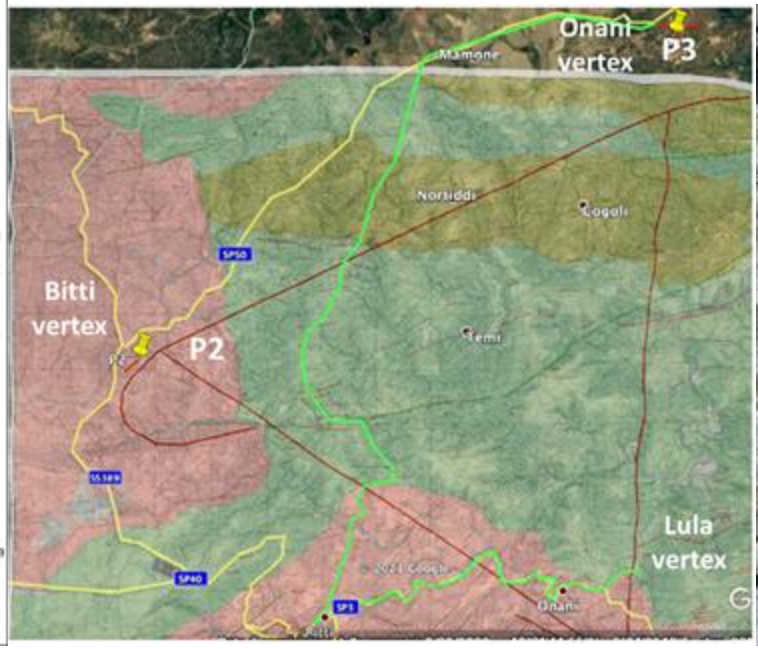
Geological Studies

The ET Italian candidate site is located in the stable **VARISCAN BASEMENT OF SARDINIA**

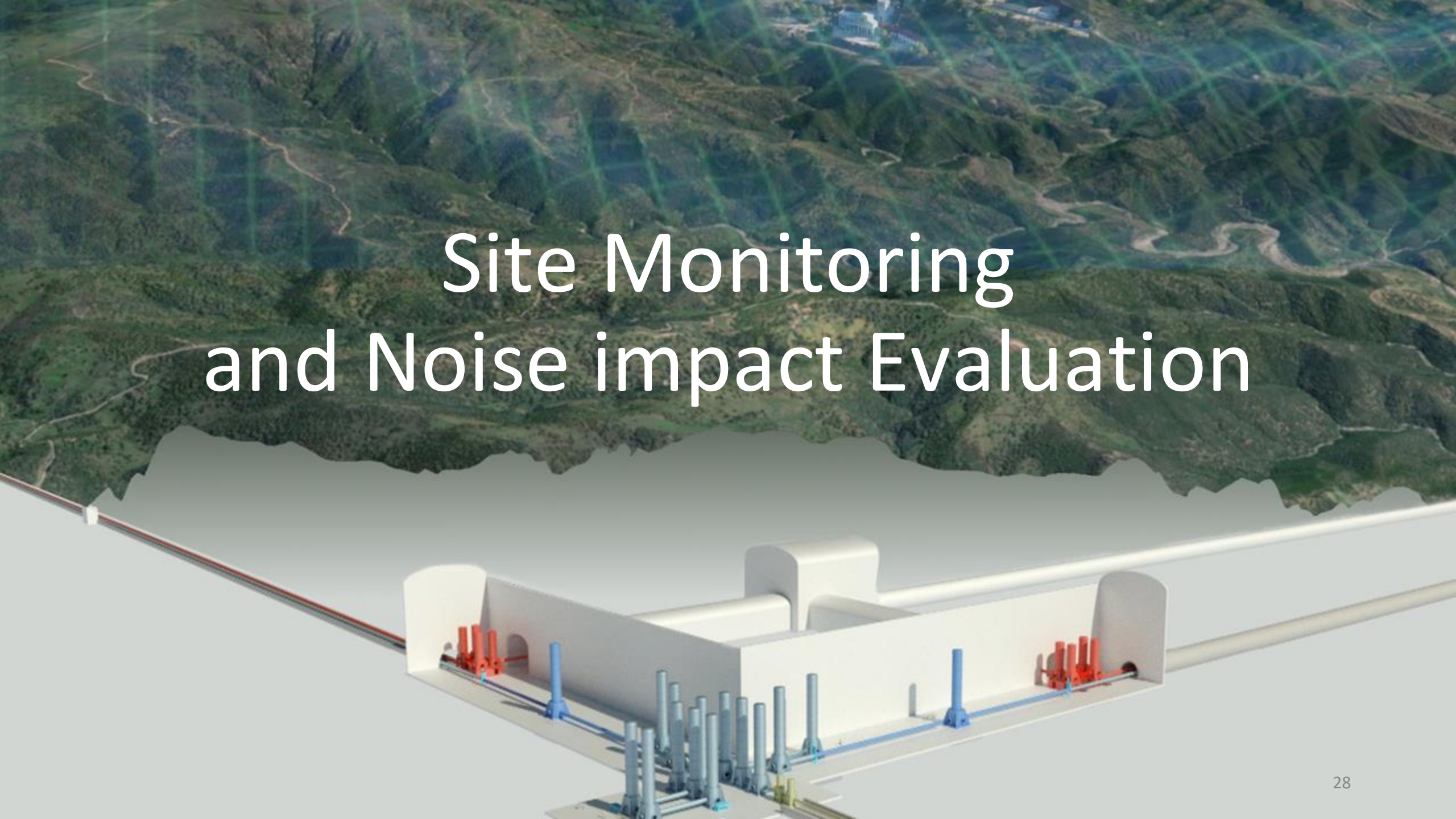


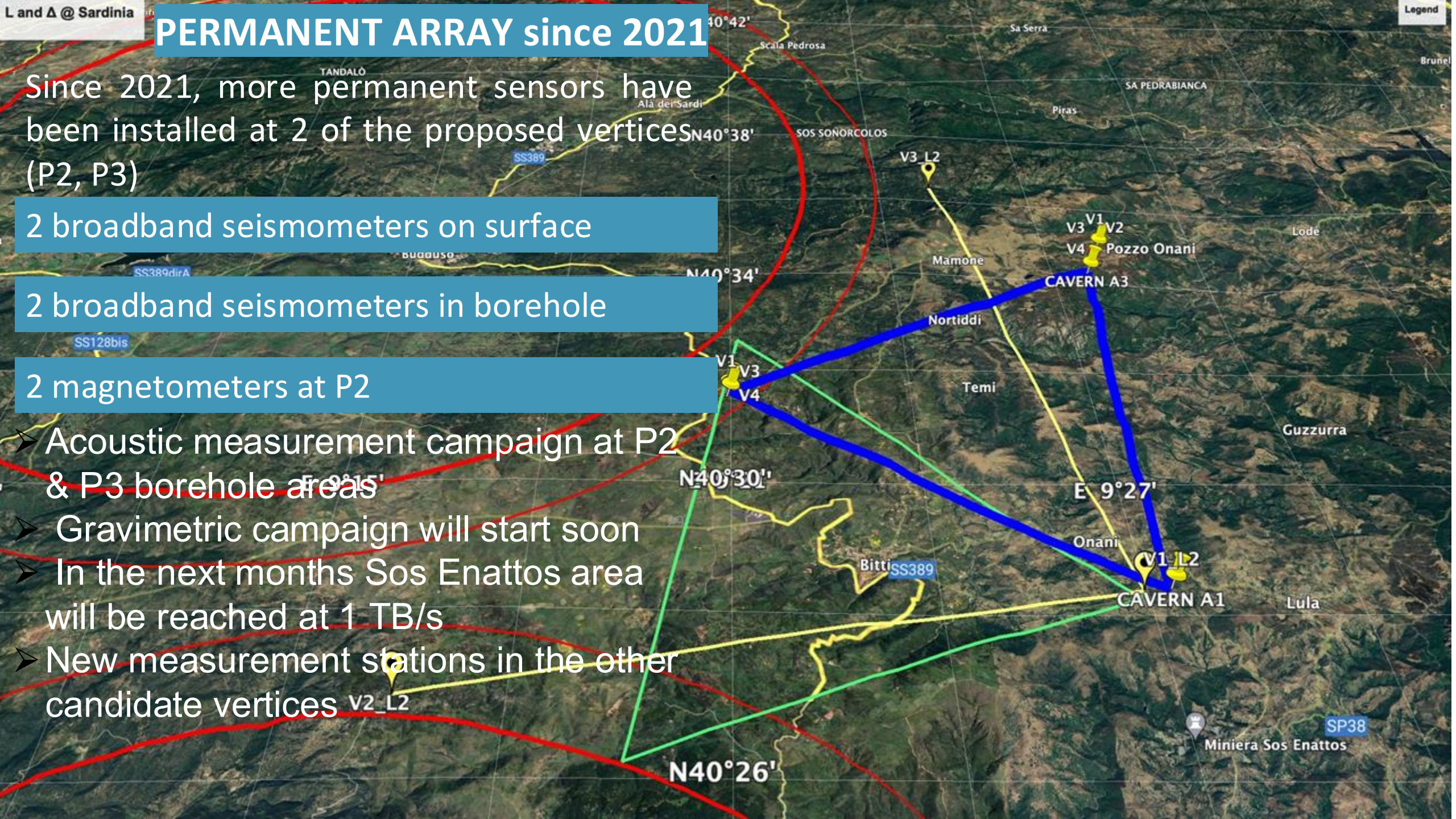
LITHOLOGIES: Orthogneiss, granitoids, micaschists.

P2 and P3 are the borehole locations optimization is ongoing.

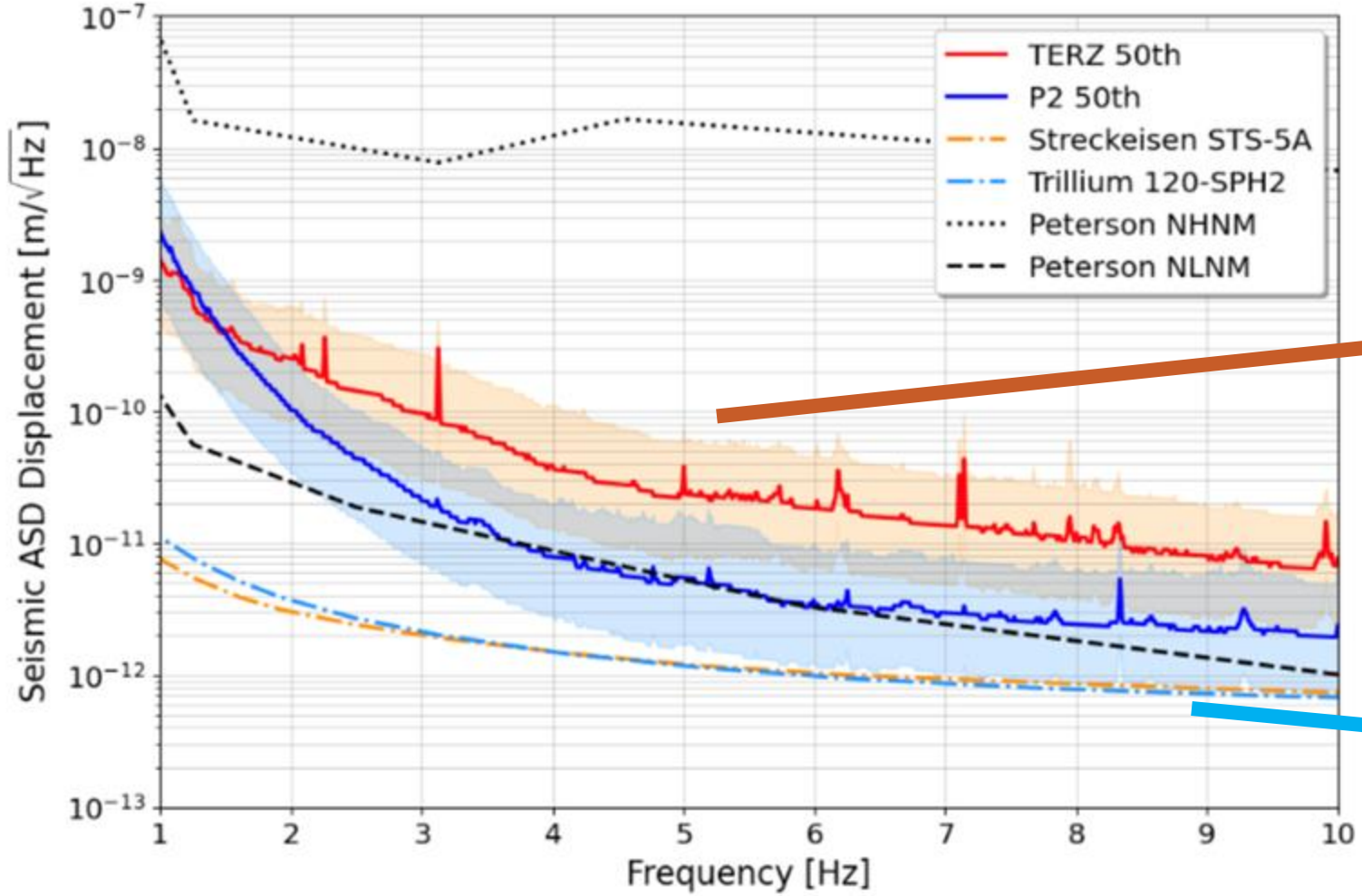


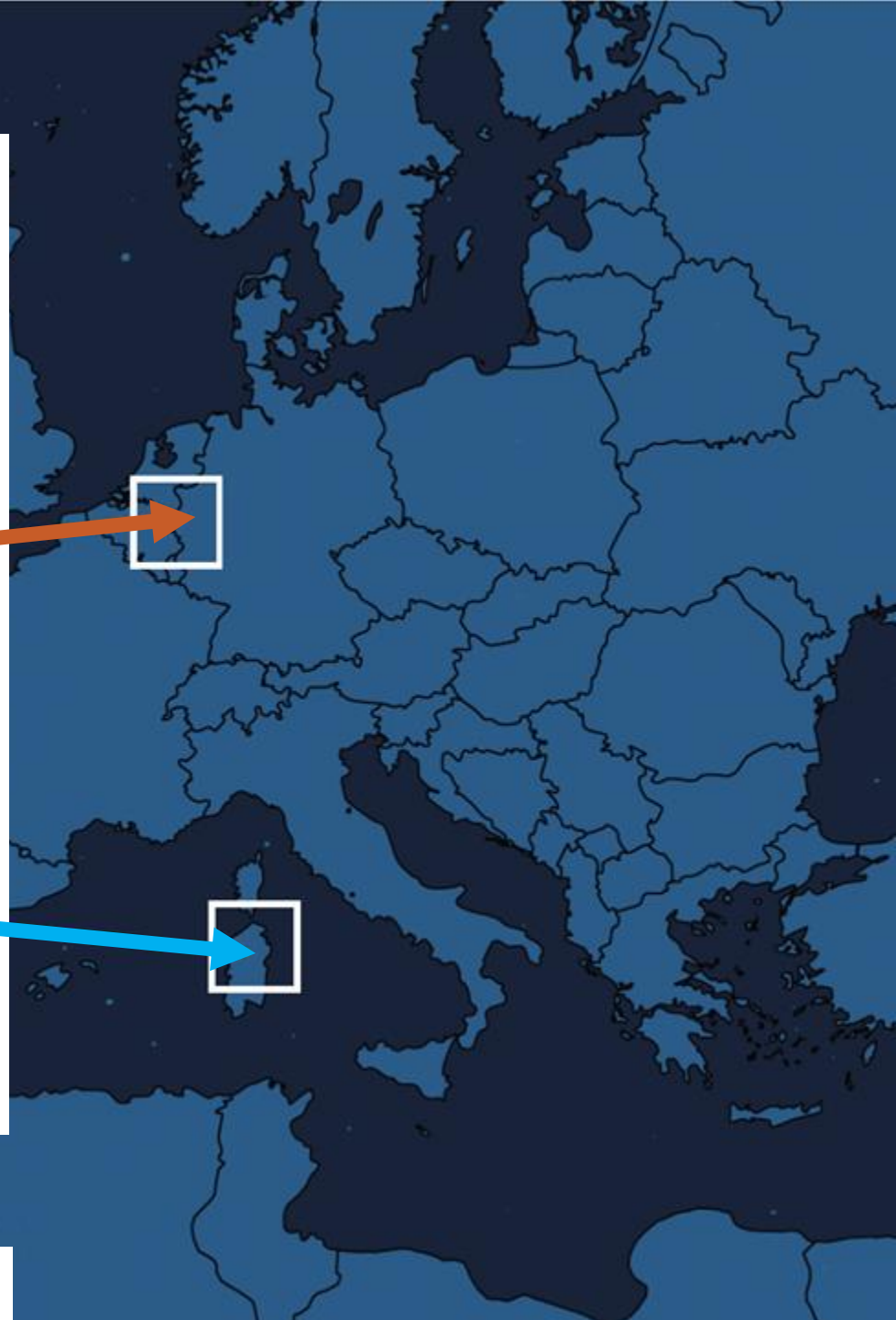
Site Monitoring and Noise impact Evaluation




L and Δ @ Sardinia
PERMANENT ARRAY since 2021
Since 2021, more permanent sensors have been installed at 2 of the proposed vertices (P2, P3)
2 broadband seismometers on surface
2 broadband seismometers in borehole
2 magnetometers at P2
Acoustic measurement campaign at P2 & P3 borehole areas
Gravimetric campaign will start soon
In the next months Sos Enattos area will be reached at 1 TB/s
New measurement stations in the other candidate vertices
Legend
Sa Serra
Scala Pedrosa
TANDALÒ
SA PEDRABIANCA
Piras
Alà dei Sardi
SOS SONORCOLOS
N40°38'
SS389
V3_L2
V3
V1
V2
V4
Pozzo Onani
Lode
Mamone
CAVERN A3
N40°34'
Nortiddi
SS128bis
V1
V3
V4
Temi
Guzzurra
N40°30'
E 9°27'
Onani
Bitti
SS389
V1_L2
CAVERN A1
Lula
V2_L2
SP38
Miniera Sos Enattos
N40°26'

Preliminary Site comparison





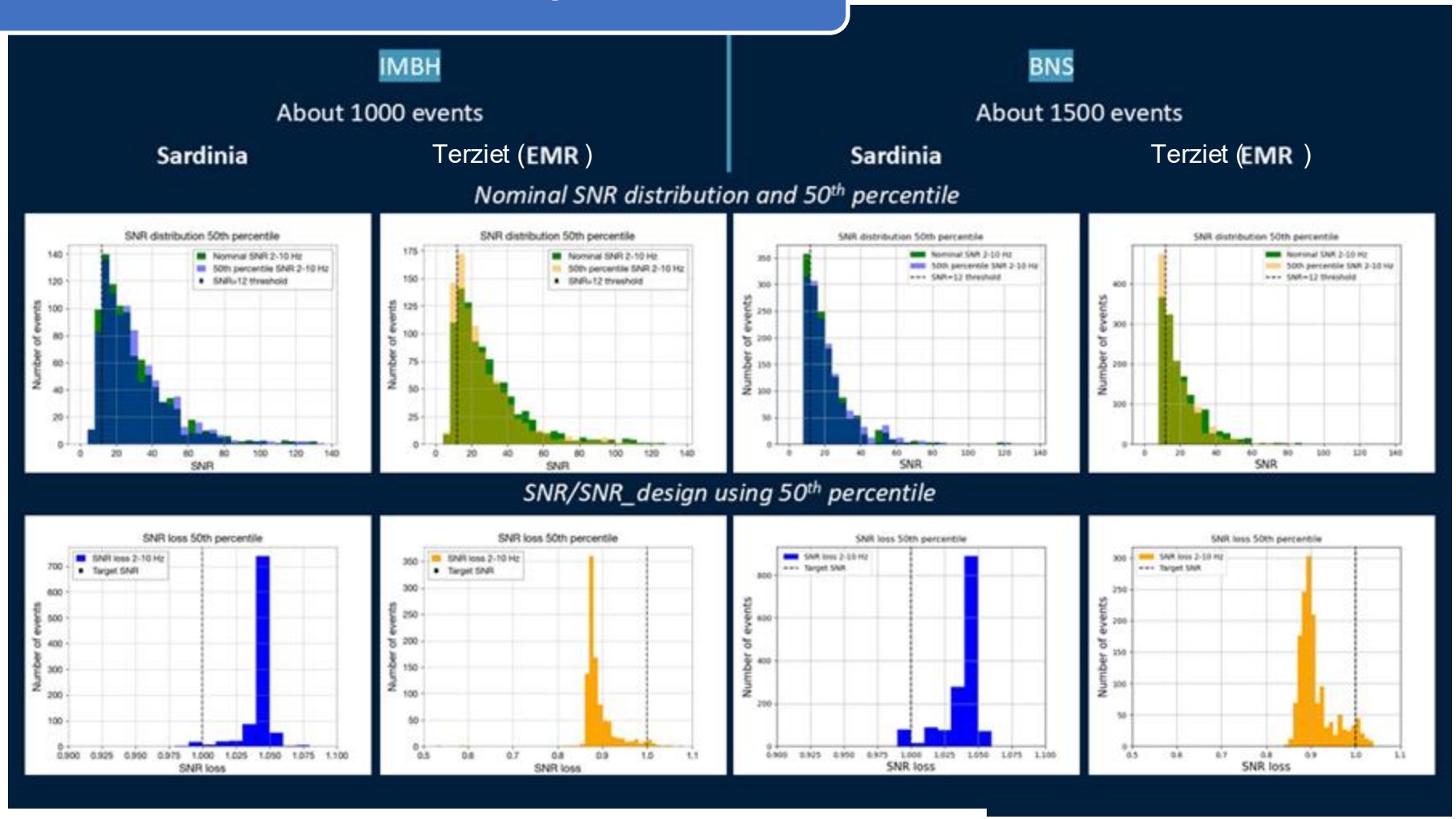
Seismic noise / frequency

Manuscript available at https://arxiv.org/abs/2503.02166

Preliminary Site comparison

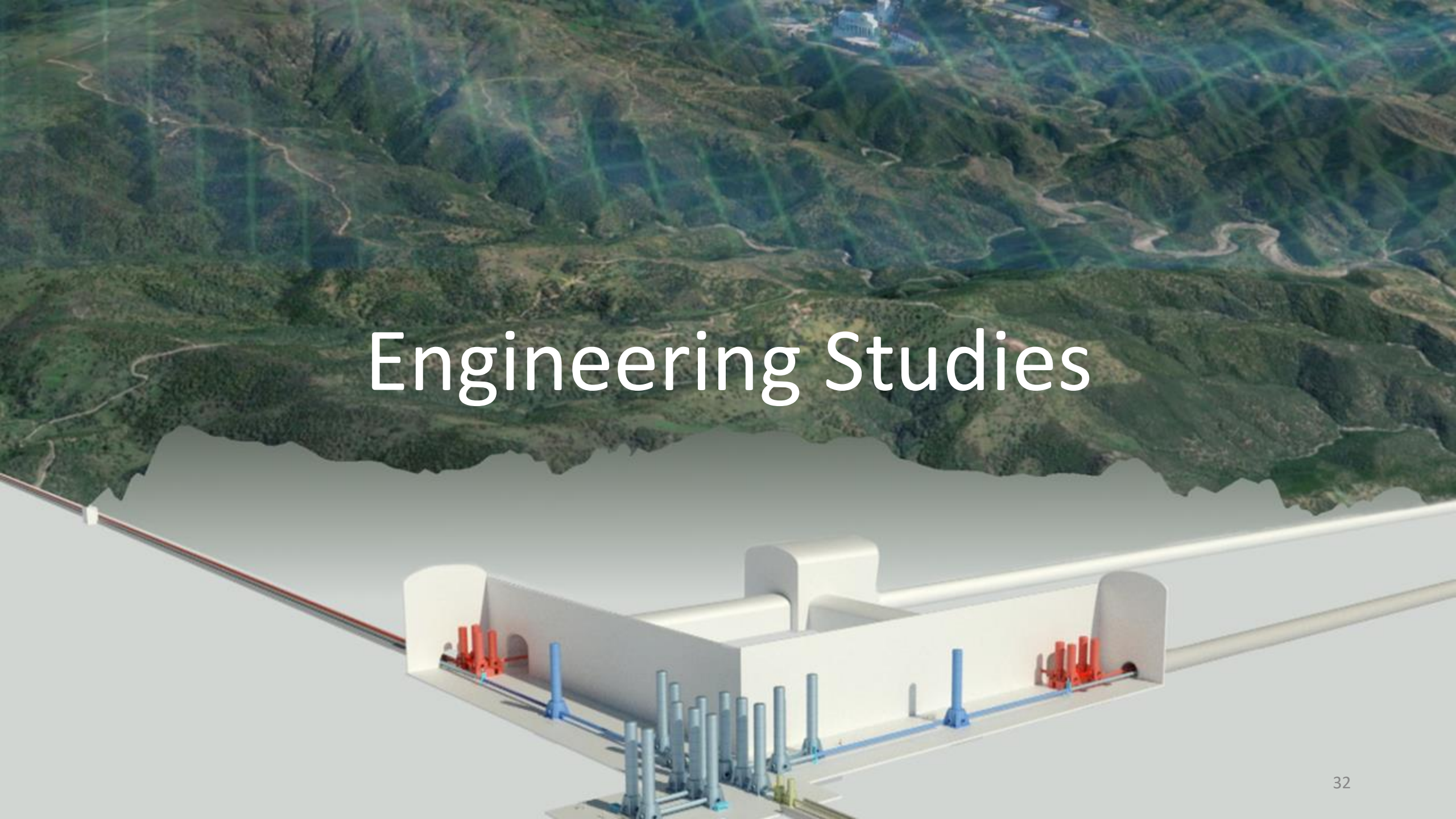
Seismic Newtonian Noise effect on GW signal detection

Results:



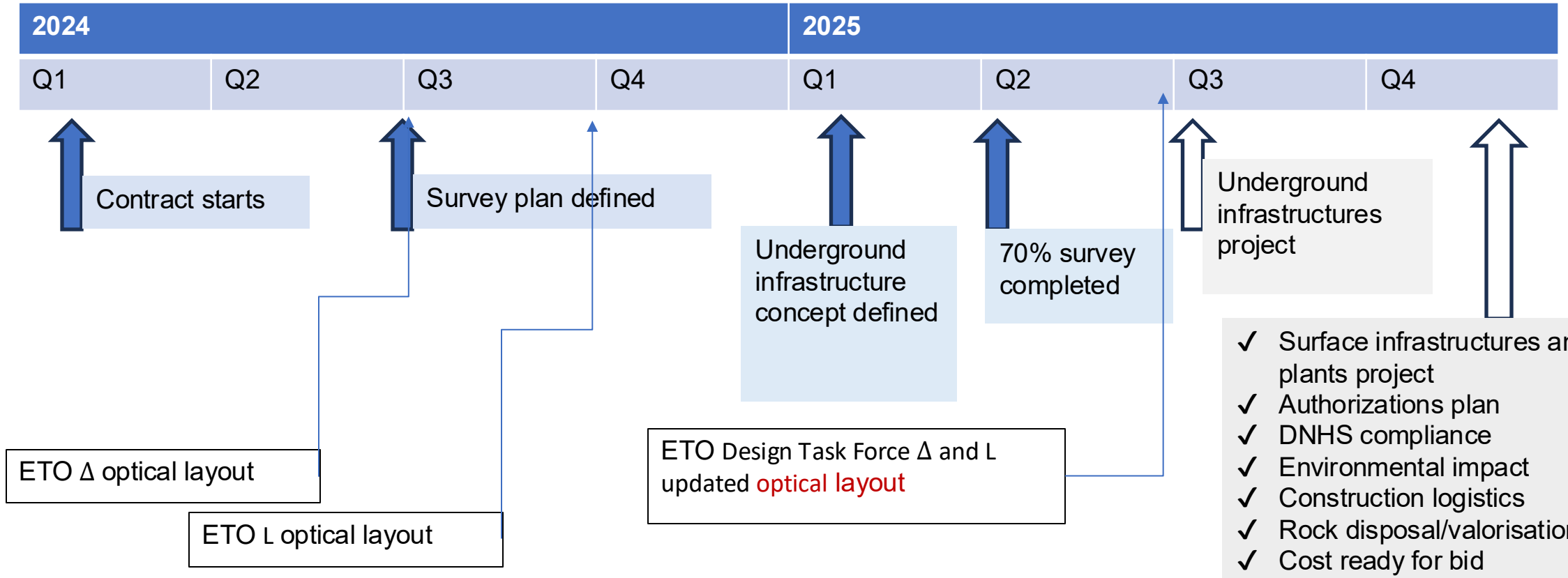
Manuscript available at https://arxiv.org/abs/2503.02166

Engineering Studies



Feasibility and engineering study completed by 2025, ready-to-tender

Carried out by a consortium of 7 highly professional companies, led by Rocksoil, and funded by MUR/INFN with NextGenEU (PNRR)



All the needed information for D4.4 and D4.5 will be available by the end of 2025

Official web page https://www.einstein-telescope.it

ET Italian Community

Contacts
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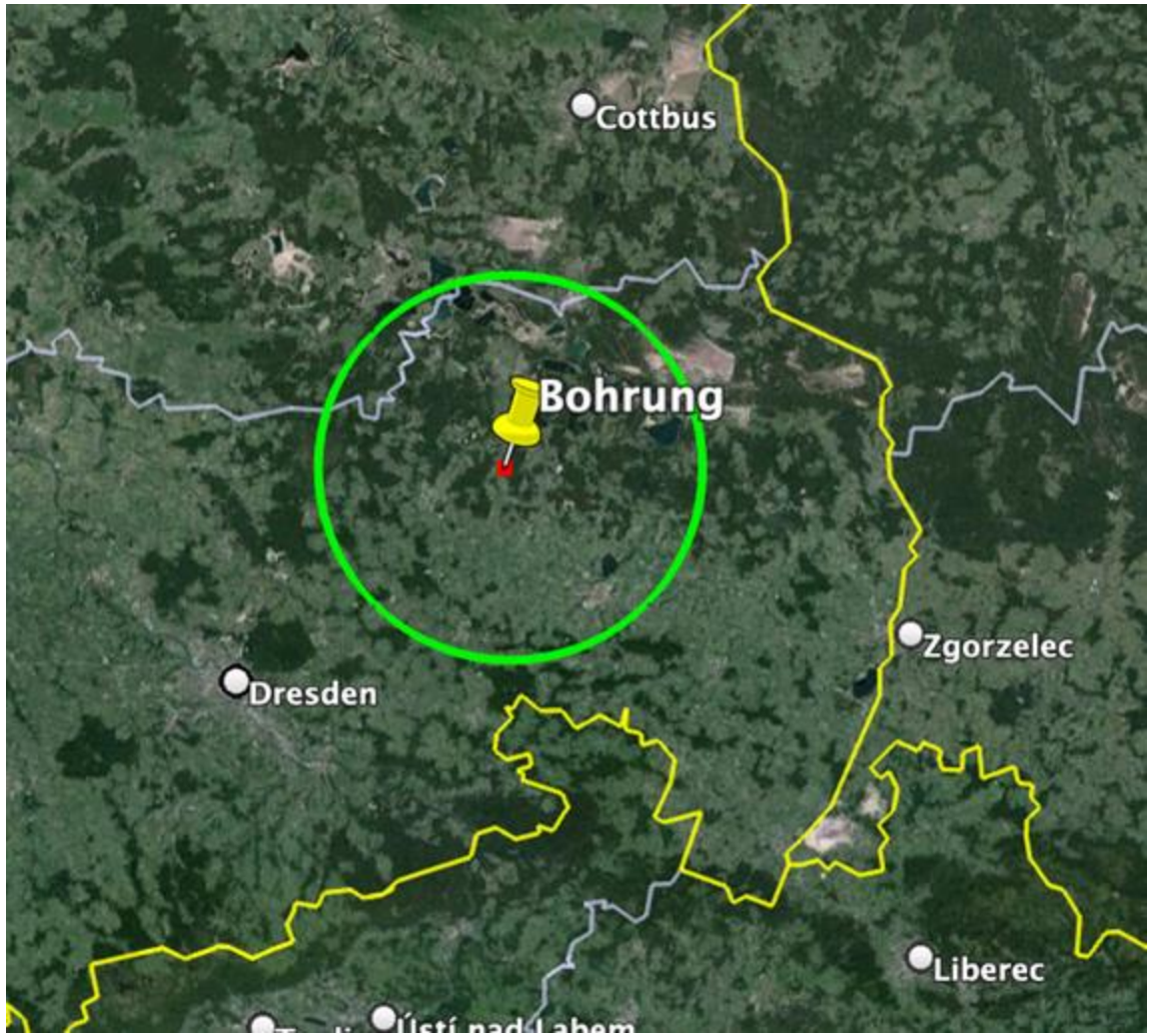
Projects: Etic, ETpp/Infra-Dev, Sar-Grav, Terabit

nel progetto Etic	nel progetto Terabit	nel progetto ETpp/Infra-Dev	nel progetto Terabit	nel progetto Etic	nel progetto Etic
nei progetti Meet/Faber, Sar-Grav	nel progetto Terabit	nel progetto Etic	nei progetti Etic, Sar-Grav	nel progetto Etic	nel progetto Etic	nel progetto Etic
nel progetto Etic	nel progetto Etic	nel progetto Etic	nel progetto Etic	nel progetto Etic	nel progetto Sar-Grav

Lusatia Site Characterization

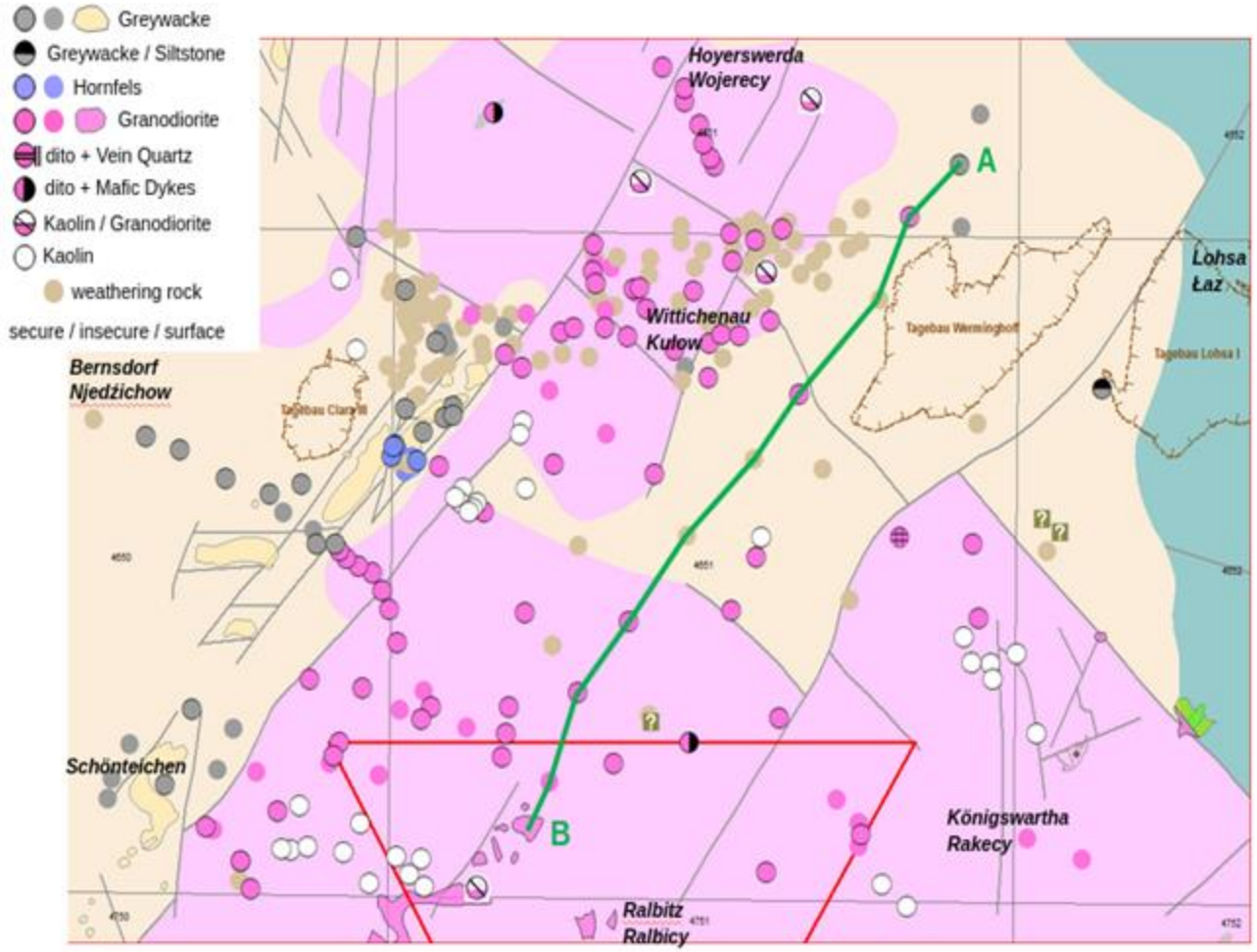
Location and site characterisation

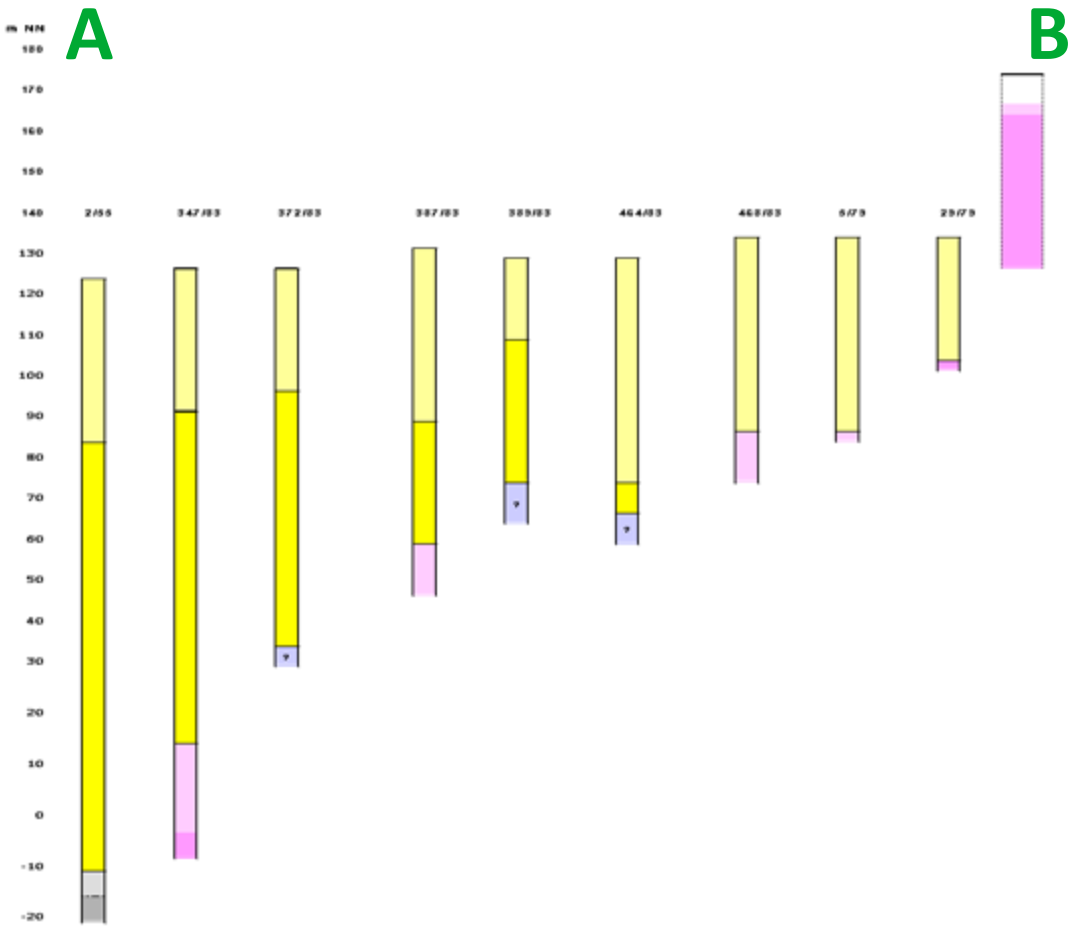


Starting in 2023:

- Re-evaluation geological model and faulting structure of granodiorite massif
- 2 borehole seismometers running (170m and 250m depth); 1 surface station
- Dense deployment of 200 seismic stations for 6 week period (central region, April 2024)
- Dense deployment of 100 3C seismic stations for a one year period (running since Dec. 2024)
- 10km of active shallow seismics to characterise the velocity model
- Dense deployment of 200 seismic stations for 6 week period (south-east region, June 2025)
- Rock mechanics studies to estimate elastic moduli and permeability

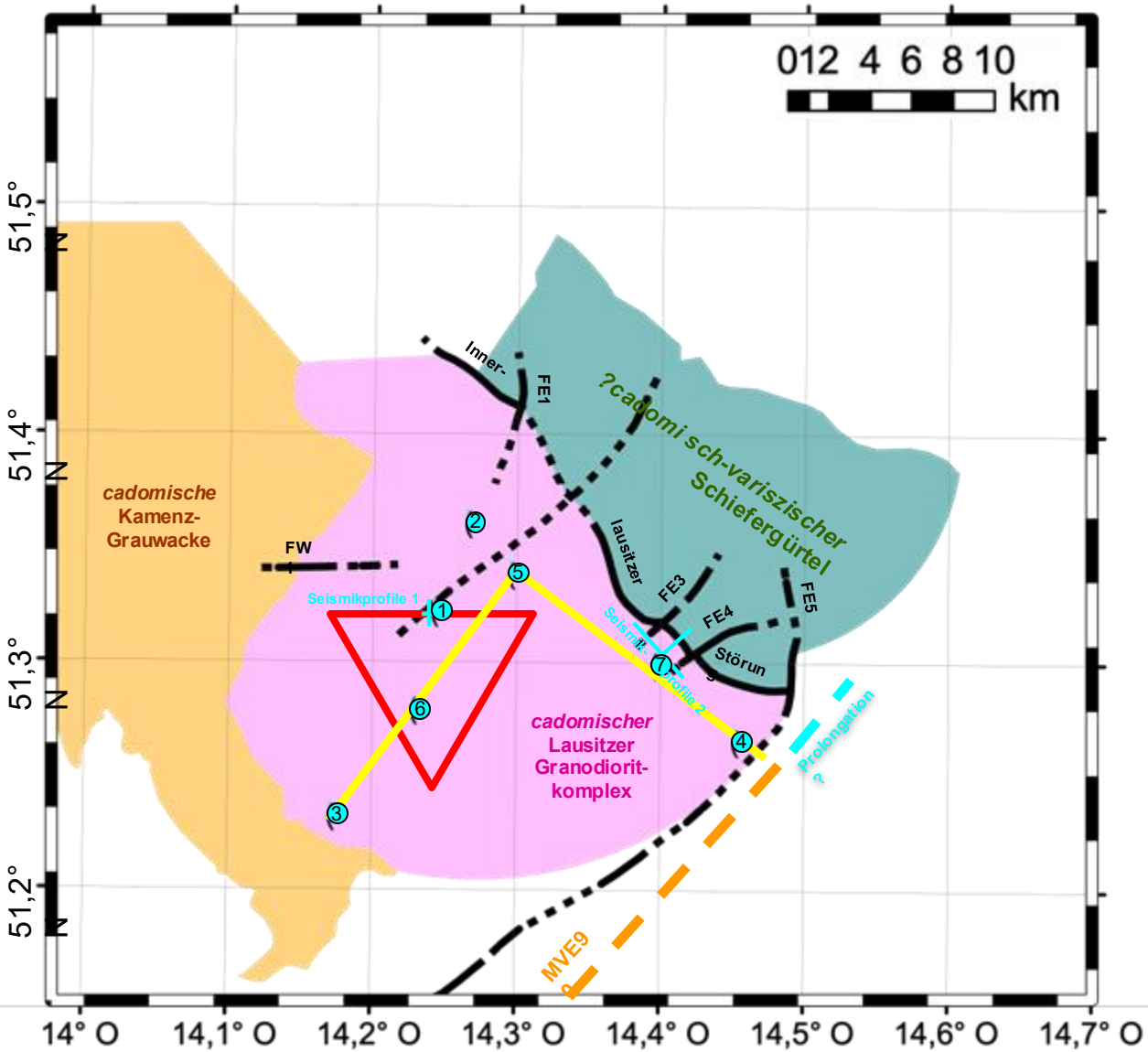
Re-evaluation of historical Boreholes





Re-evaluation of over 4000 historical boreholes down to the granodiorite.

Updated geological model and drilling campaigns

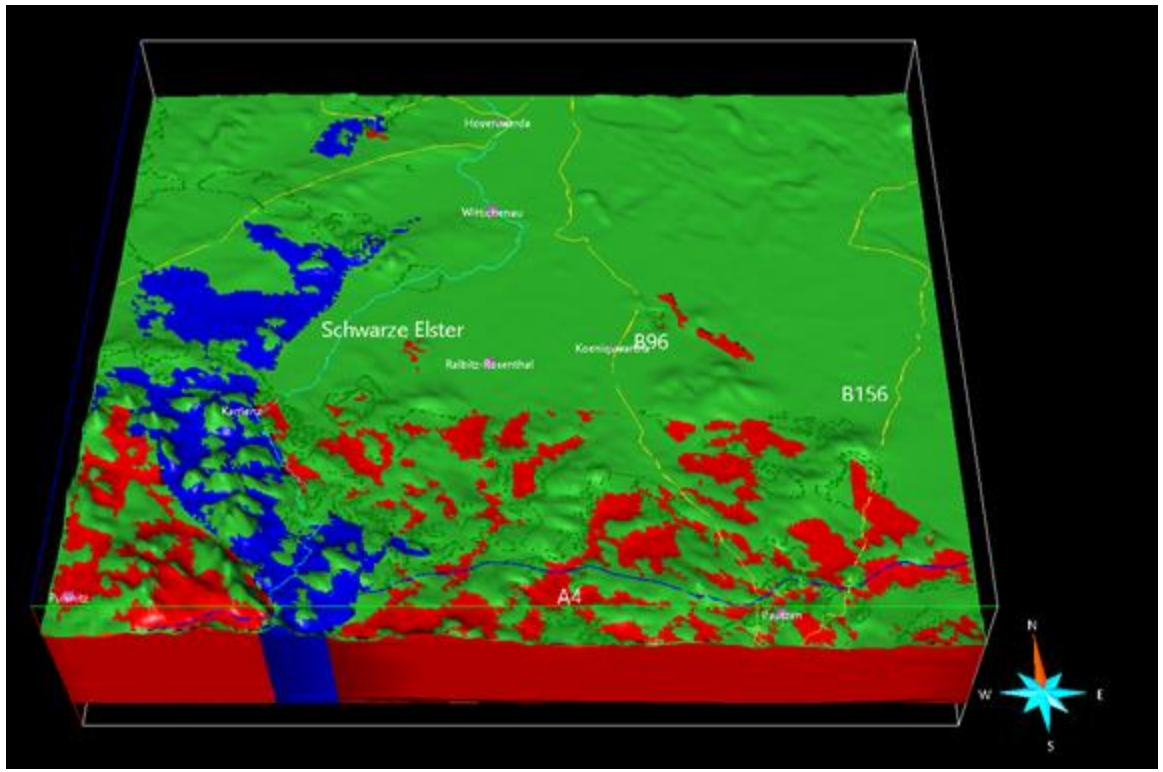


DZA1: up and running
DZA2: drilling started
DZA4: permit granted
DZA6: permit granted
DZA5: permit granted
DZA3: permit applied
DZA7: deliberation
DZA8: scouting

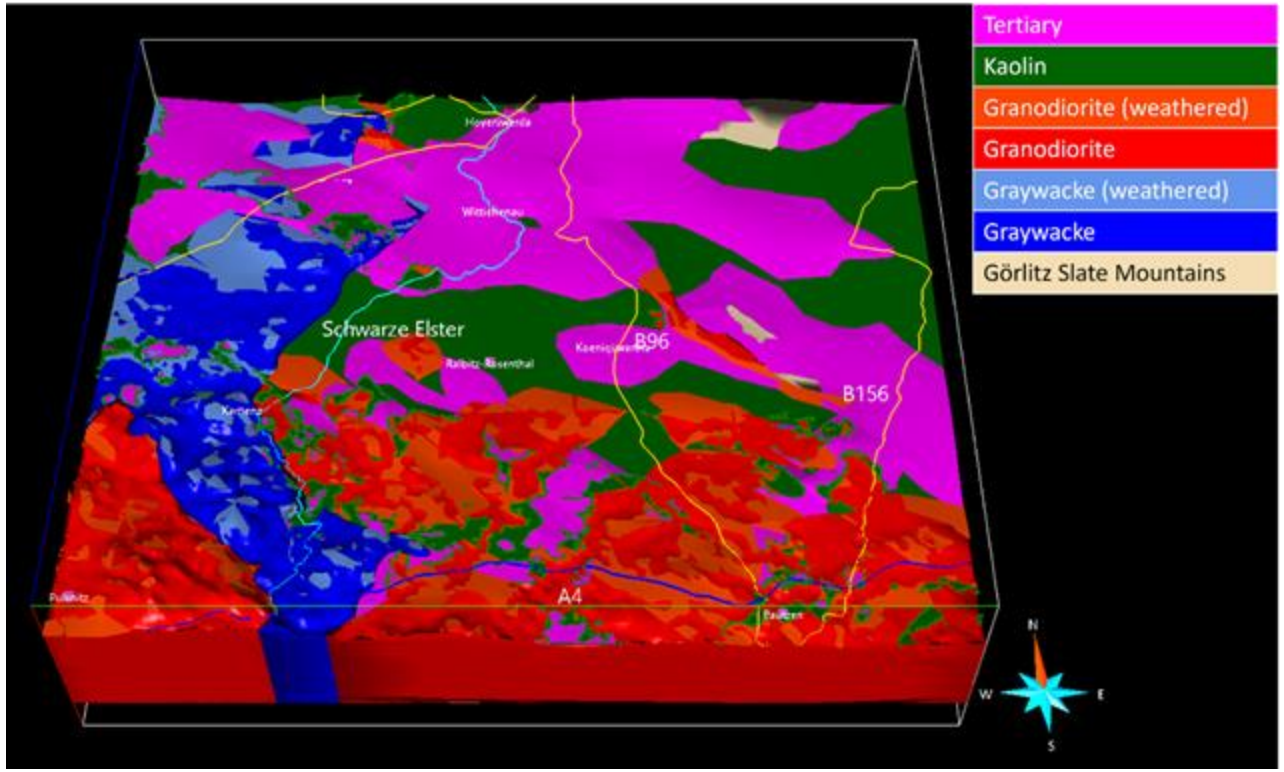
Triangle location as outlined but can be still rotated

L-shape configuration rotated by 45 degrees in respect to Sardinia to maximise detection capabilities of the two Ls (close contact with Sardinia)

Integrated Geological Model: Base for noise evaluation

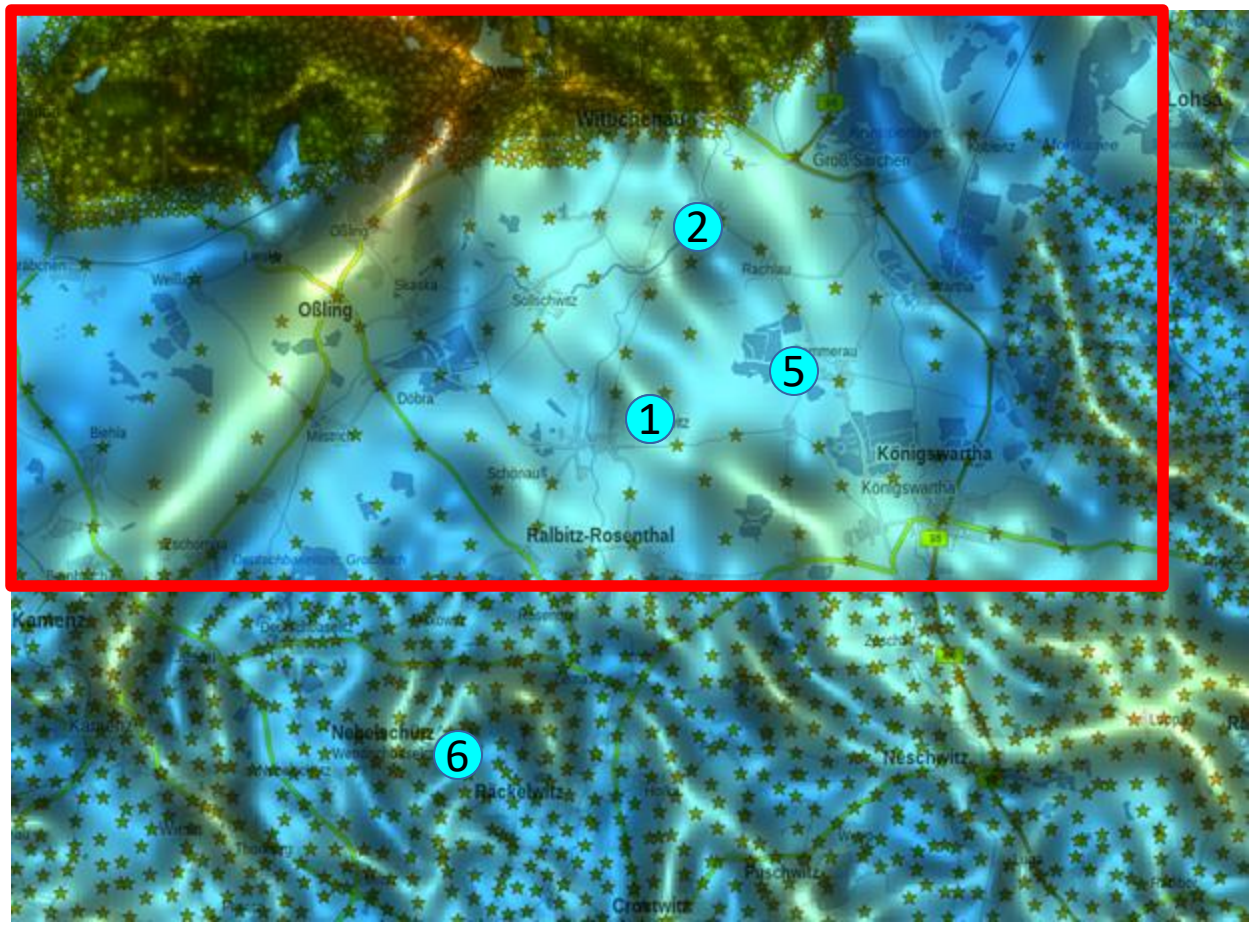


Surface expression

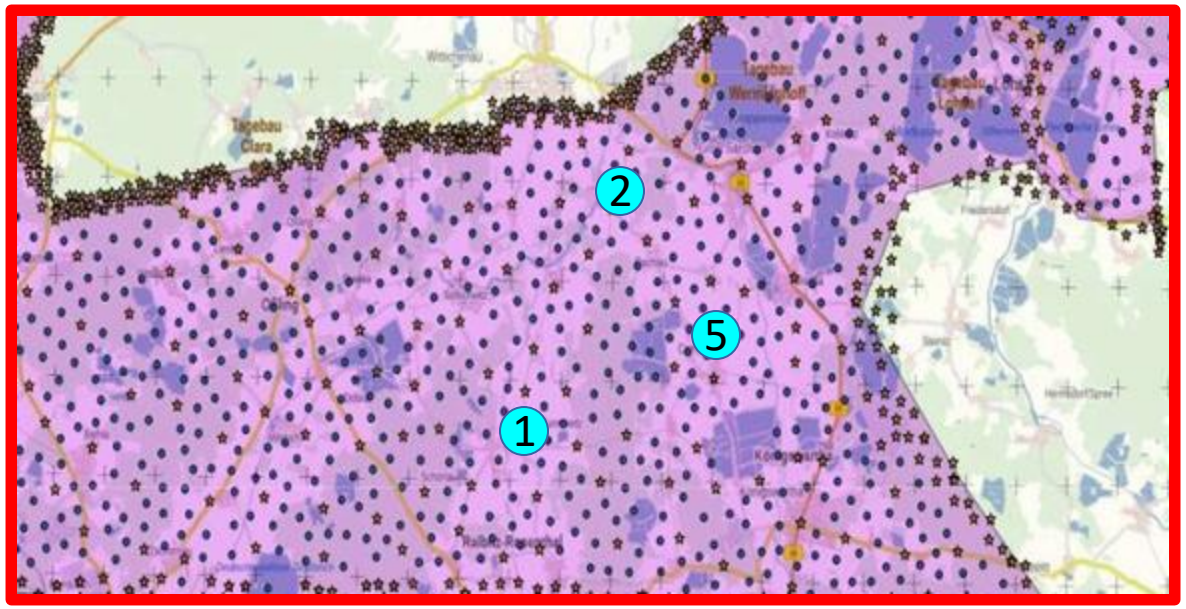


Quaternary cover stripped

Gravimetry Measurements

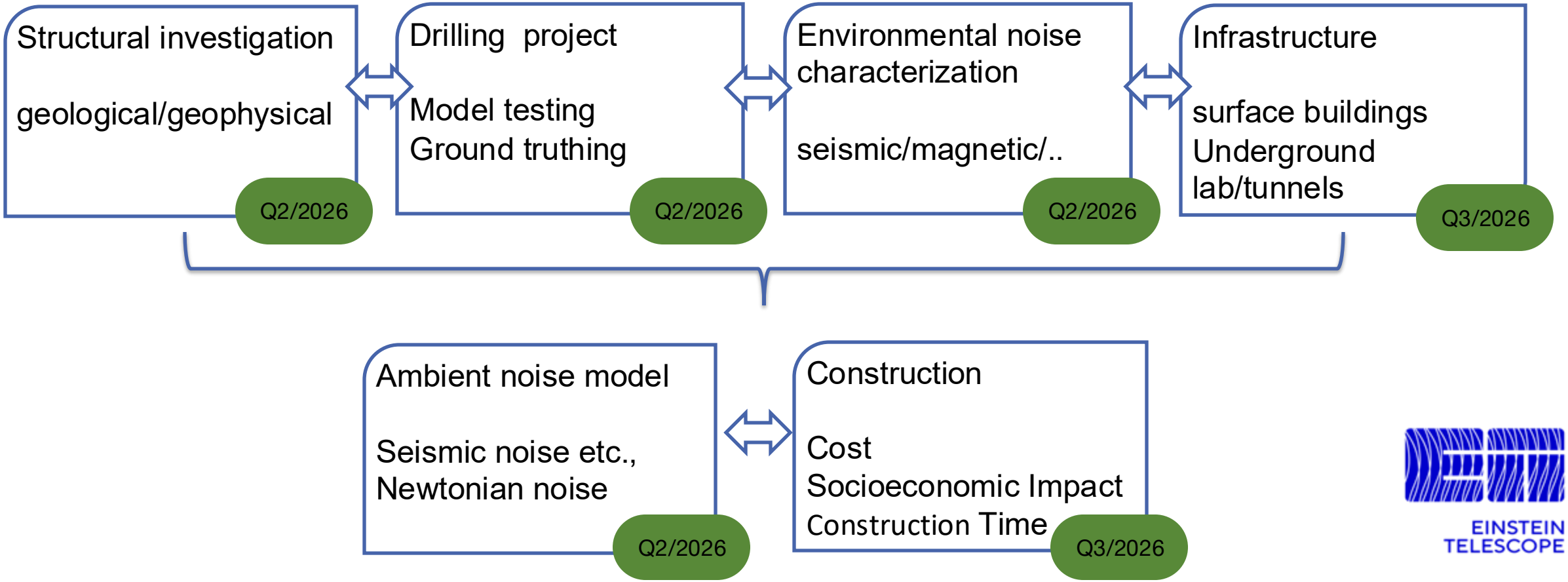


Gravimetry with different point resolution
(2 km, 400 m and up to 10 m)



Re-measurement of area will low point resolution (2 km) is currently in process

Timeline and (inter)dependencies



WP 4: Outlook and perspectives

Continue measurement campaign and data analysis of environmental sensors to understand relevant site characteristics for ET detector performance.

- EMR measurements for ET-PP Deliverable will end by Q1 2026
- General Tender procedure in Sardinia will give the results by Oct 2025
- Lausitz measurements for ET-PP Deliverable will end by Q1 2026

Initially estimated timeline not easy to follow.

Activities are managed directly by Site Host Teams which are implementing different organizational strategies constrained by the national and regional fundings conditions. Not always easy to uniform and harmonize results, products and timeline.

WP 4: Outlook and perspectives

D4.3 Complete quantification of all the aspects impacting the ET performance for each site **Exp. 07/2026** (application of the methodology describe in M3)

D4.4 3D Geology, hydro-geology and modeling **Exp. 02/2026**

Local site funding and contracting result in different timeline

- EMR investigations will be completed by the end of 2025, data will be available by the beginning of 26
- Investigations in Sardinia are expected to be completed by Oct 2025

D4.5 3D Updated cost and schedule estimates of the excavations **Exp. 07/2026**

Based on the outcome of D4.1 (legal permits), D4.3 (mitigation systems) and D4.4 (local geology)

Project: 101079696 — ET-PP — HORIZON-INFRA-2021-DEV-02

Horizon Europe:
Coordination and Support Actions

ET-PP (WPX)
2nd review meeting (RP2)

15/05/2025

Grant agreement: № 101079696