ET – Site Studies and Characterization Workshop – Nuoro, Nov. 8-11, 2021

Preliminary results from the boreholes at the ET corners in Sardinia

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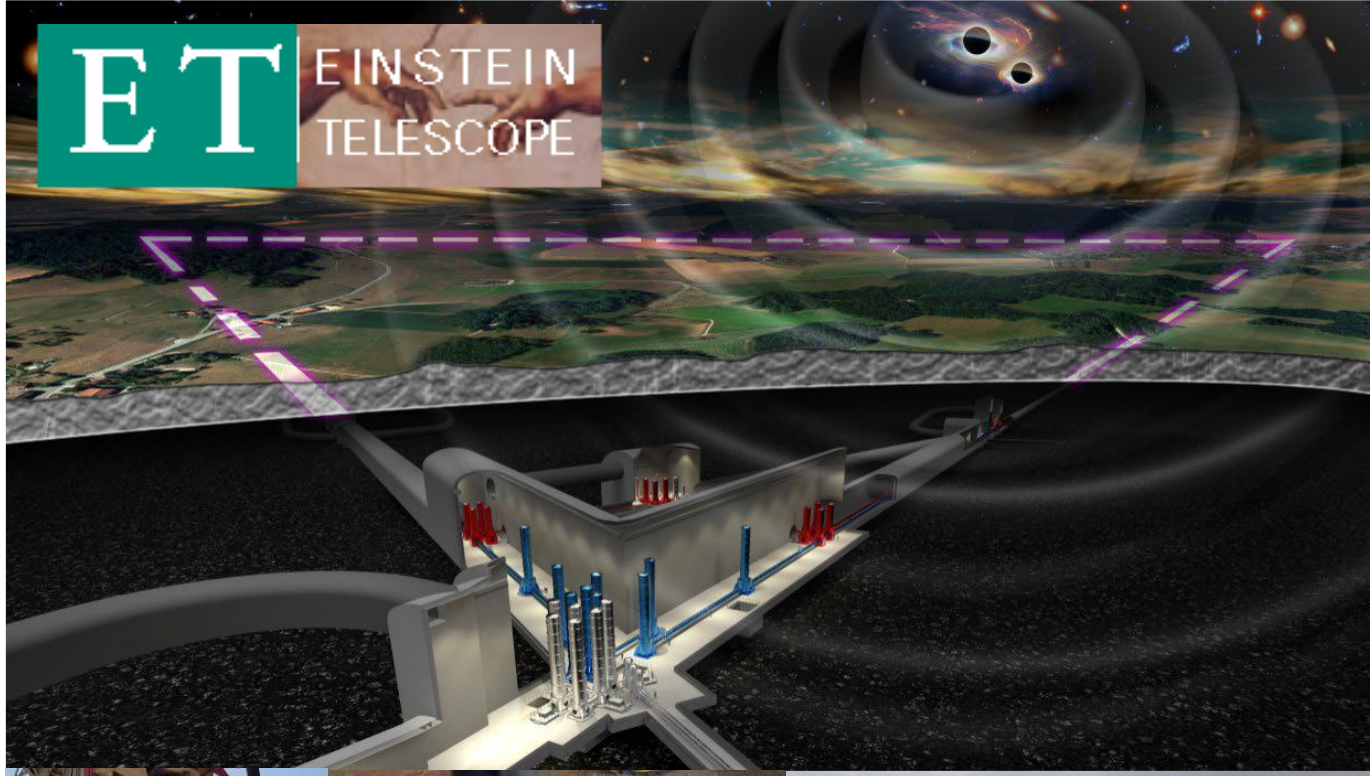
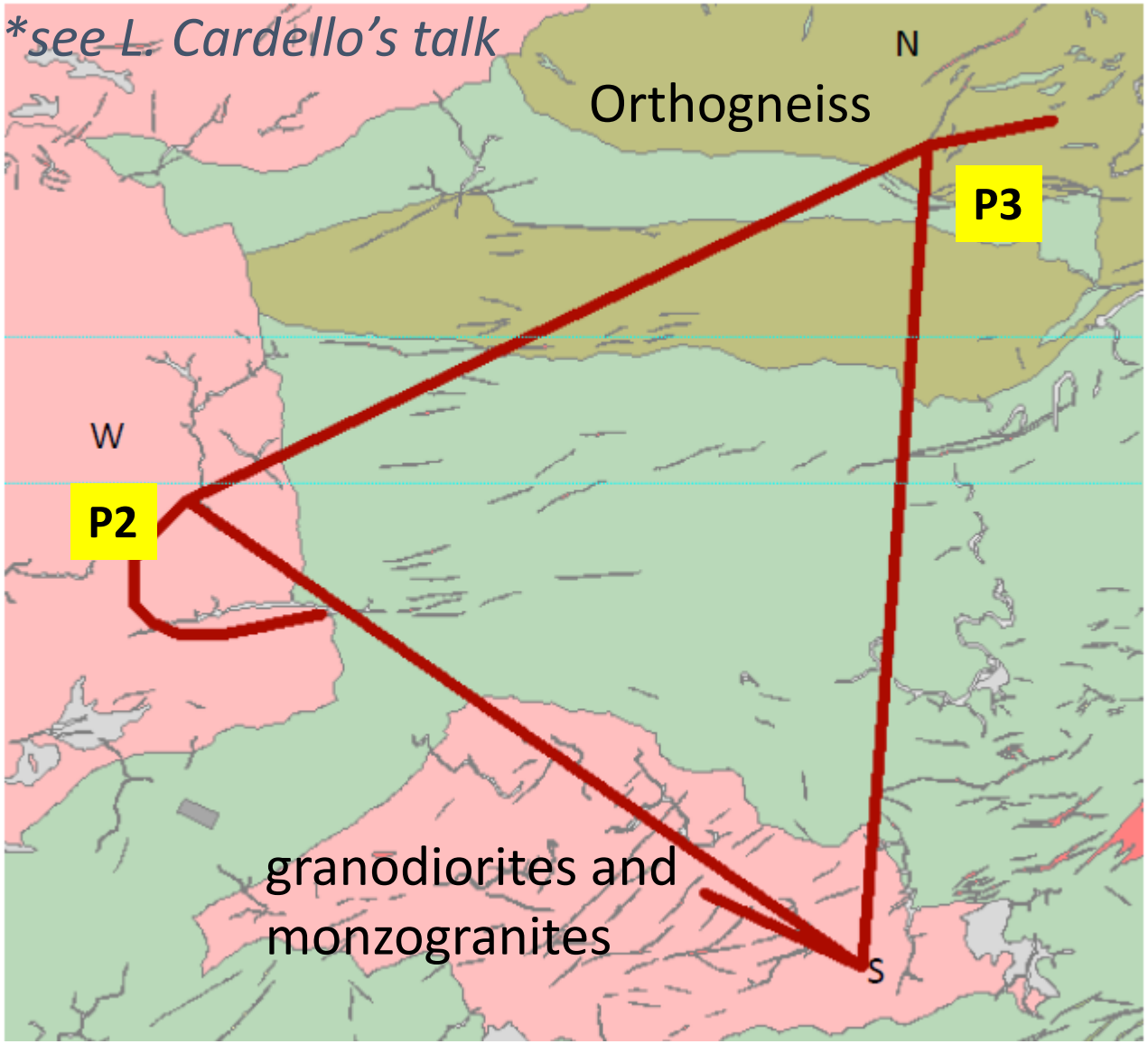


Outline

Summary:

- ❑ **P2 and P3 sites**
- ❑ Experimental setup
- ❑ Borehole preparation
- ❑ Geophysical logs
- ❑ Seismometers installation
- ❑ Preliminary results

P2 and P3 sites

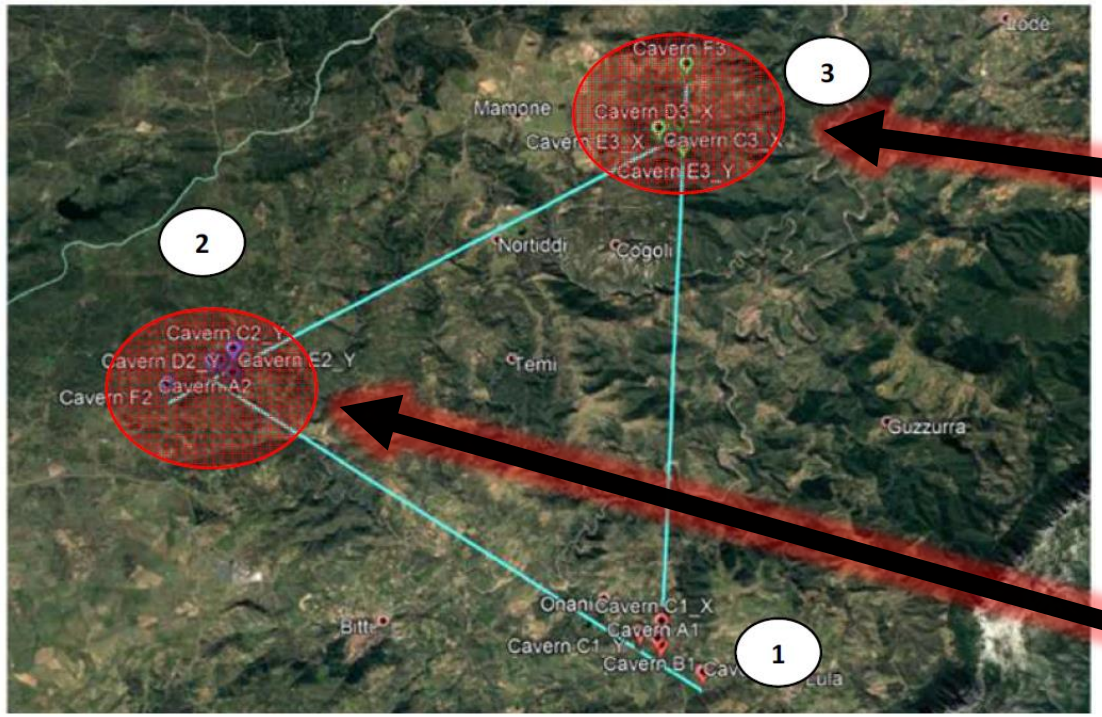


ET Δ layout (10km):

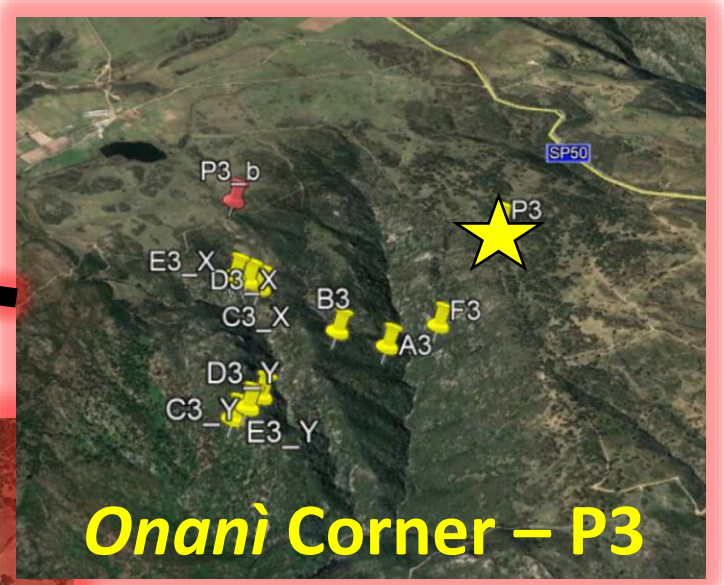
- One corner is close to the Sos Enattos area (Lula)
- The other two corners are located in rocks with good geomechanical properties (granites and orthogneiss)
- Two boreholes have been excavated at these two corners (P2, P3, *see C. Rossini's talk in this session*)

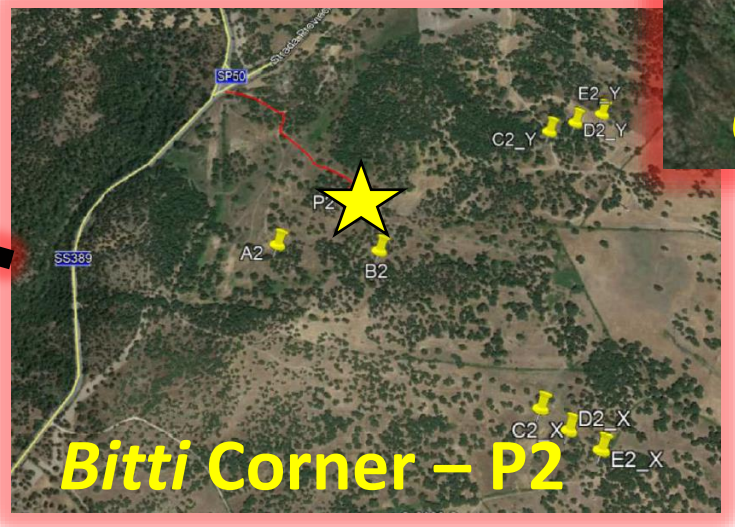
P2 and P3 sites

In July 2021 we started the surface and underground seismic, geophisical and environmental measurements at the other two corners (named after the local municipalities of *Bitti* and *Onanì*).



P1 - *Lula* Corner – *Sos Enattos*



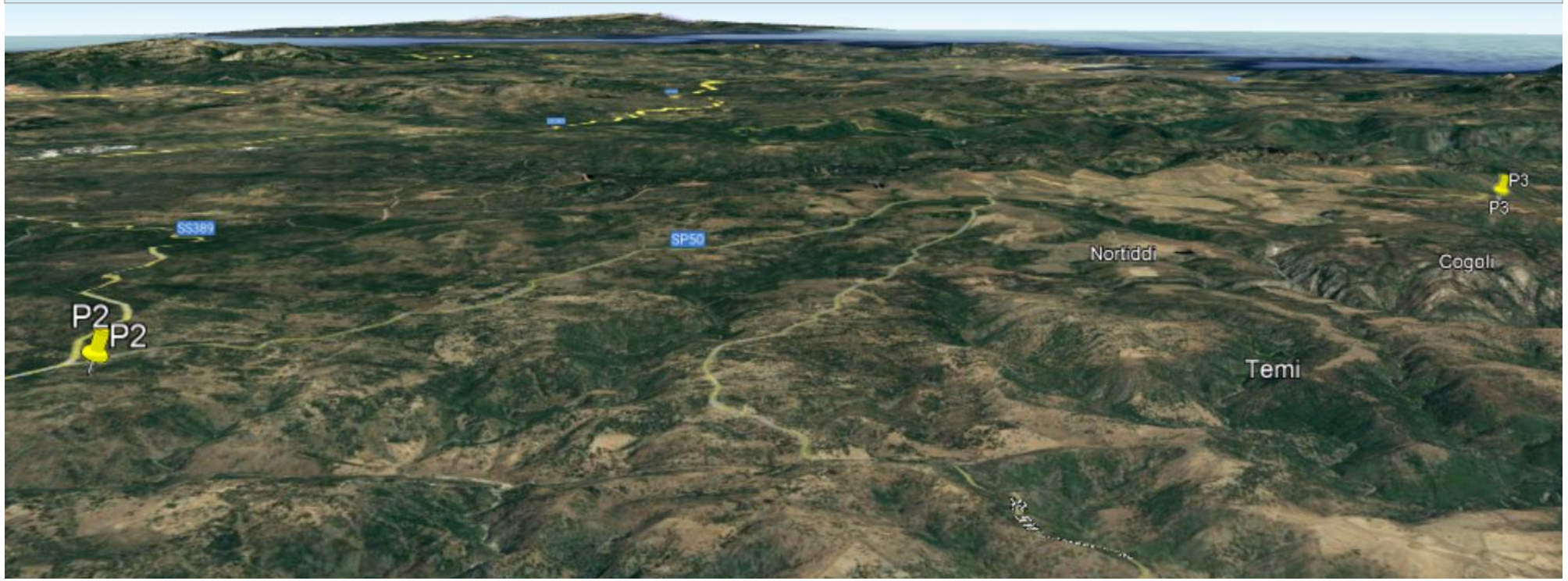


★ : Borehole area

: proposed locations for ET Δ main caverns

P2 and P3 sites

SITE	COORDINATES		ALTITUDE AMSL
P2	40°31’24’’N	9°20’55.7’’E	767 *m*
P3	40°34’38.7’’N	9°27’55.8’’E	720 *m*



P2 and P3 sites

Bitti corner, borehole area *before excavation*

Onanì corner, borehole area *before excavation*

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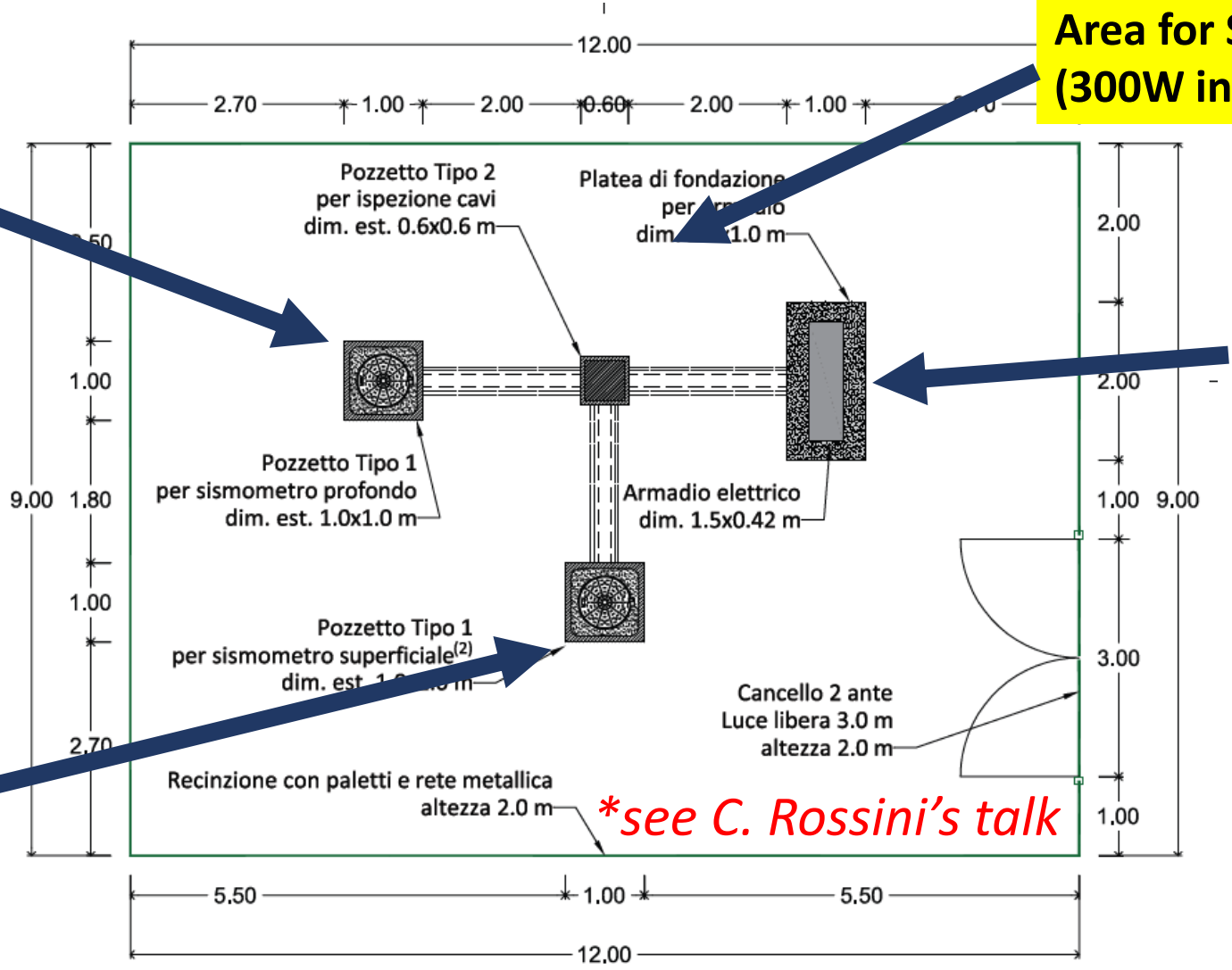
- ❑ Seismometers installation
- ❑ Preliminary results

Experimental setup

General plan of the borehole area

Borehole access (inside a manhole):
- Borehole broadband triaxial seismometer (Nanometrics Trillium 120 BH Slim)

Vault access (inside a manhole):
- Broadband triaxial seismometer (Nanometrics Trillium 120 Horizon)

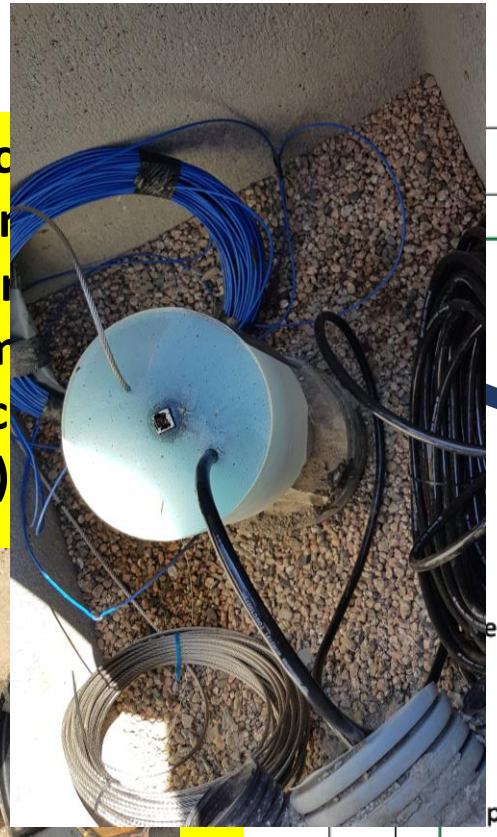


Area for Solar Panels (300W installed)

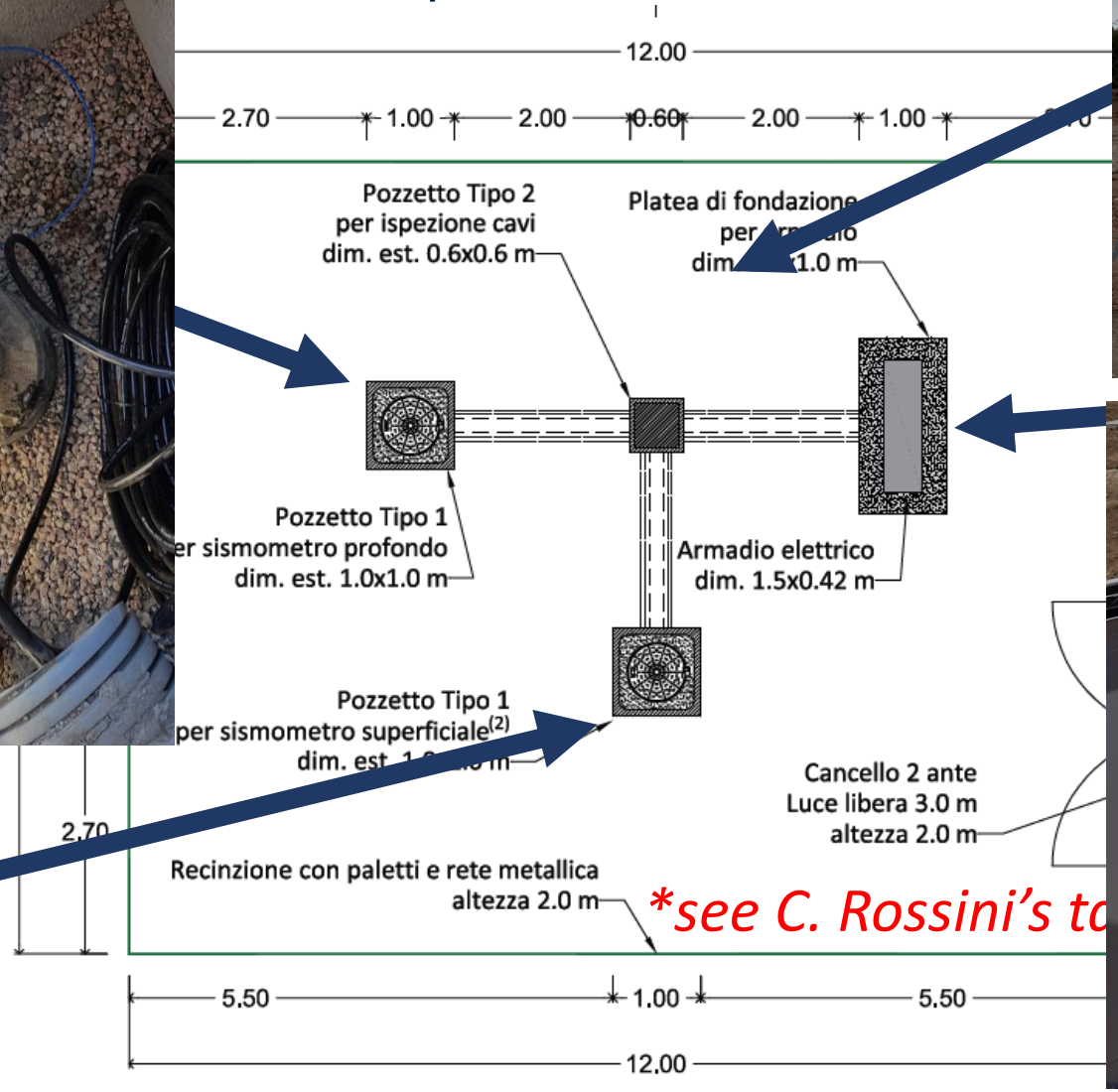
Electrical Cabinet:
- **DAQ (Nanometrics Centaur 6ch. 24bit)**
- **12V Battery pack**
- **UMTS modem, GPS receiver, solar charge controller**
- **DAQ for magnetometers**
- **Opt. Fiber strainmeter connection**

Experimental setup

Borehole acc
(inside a mar
- Borehole br
triaxial seism
(Nanometric
120 BH Slim)



General plan of the borehole area



net:
metrics
. 24bit)
12V Battery pack
S

*see C. Rossini's to

Outline

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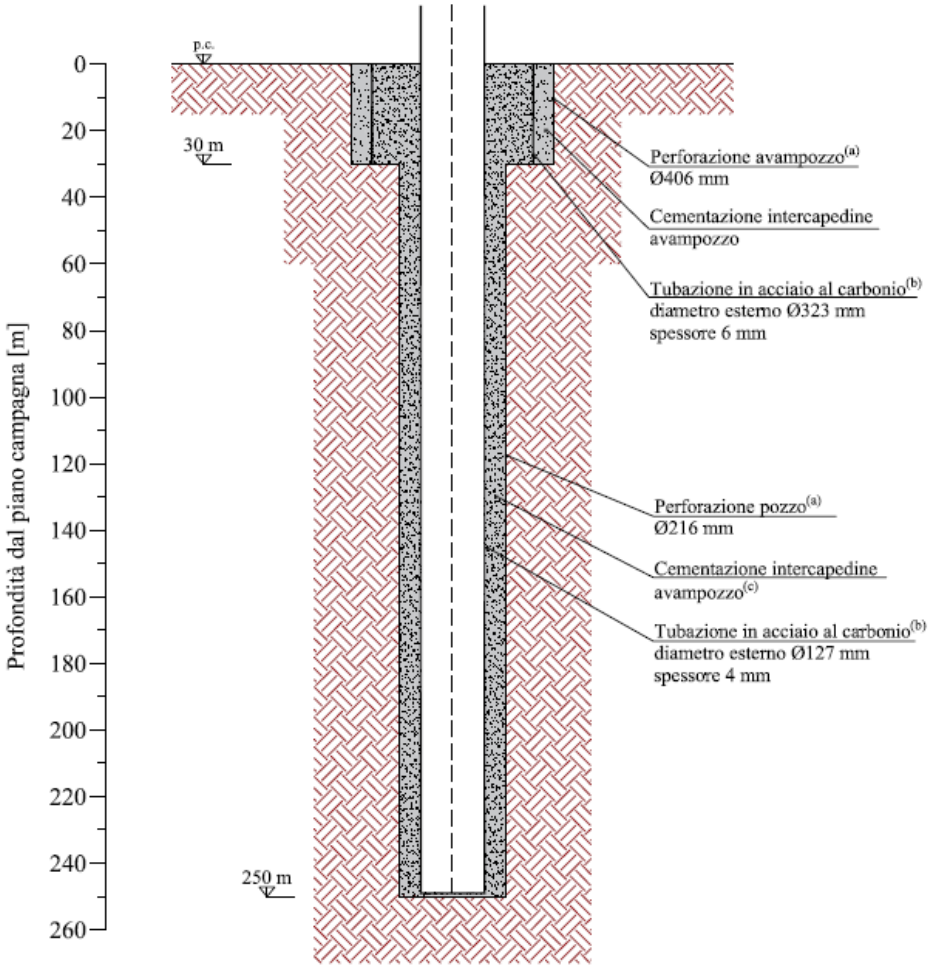
Borehole preparation

- Excavation of two boreholes at the corner points P2 (-270m) and P3 (-260m). The drilling and consolidation of the boreholes has been started in April 2021 and completed in July 2021.

- A steel pipe was inserted into the borehole and cemented to the surrounding rocks. An optical fiber strainmeter was fixed inside the concrete (*see A. Rietbrock's talk*).

- Final inner diameter: 119mm.

- Pressure test passed in both cases.



*see C. Rossini's talk

Borehole preparation

Outline

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Geophysical logs

PROS

✓ **continuous logging of geophysical parameters** and comparison with litostratigraphic information;

✓ **reliability and repeatability** because are based on standard probes and automated processes;

✓ **continuous coring is not required** and destructive perforation for less **time consuming and cost-effective** field activities;

CONS

✓ **don't substitute totally continuous coring** that can be necessary in unexplorated areas based on the aim of the field surveys;

✓ **not unique response** and require litostratigraphic characterization of the soil cutting;

✓ **limited volume of rock investigated**;

***From GEOexplorer reports RT Bitti and RT Onanì**: S. Bernardinetti, S. Berti, T. Colonna, P. Conti, E. Guastaldi, N. Lopane*

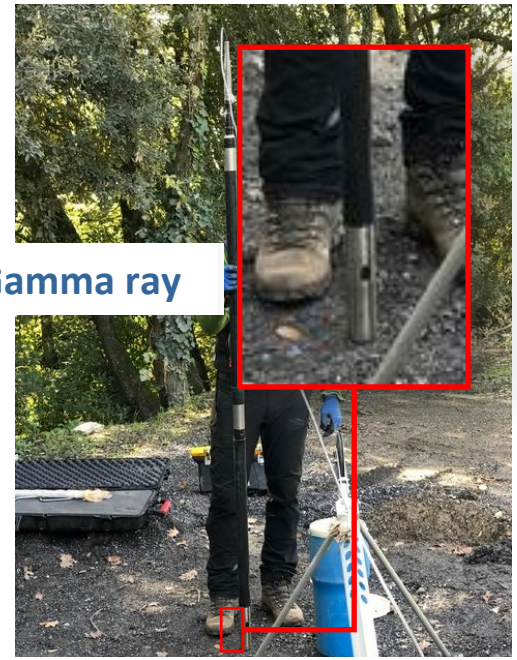
Geophysical logs

Logs were made right after the drilling and before the consolidation of the borehole with the steel pipes.

Probes:

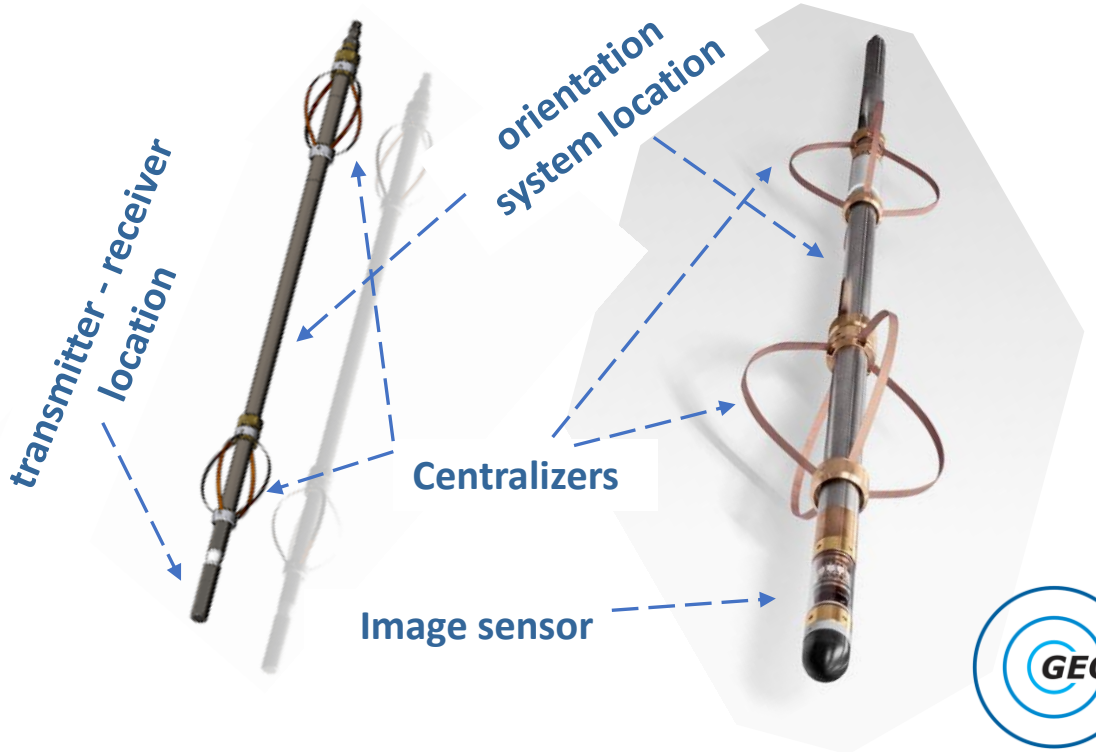
QL40 Caliper

QL40 Gamma and FTC stacked



Fluid temperature/conductivity

QL40 ABI 2G (acoustic) **QL40 OBI 2G (image)**

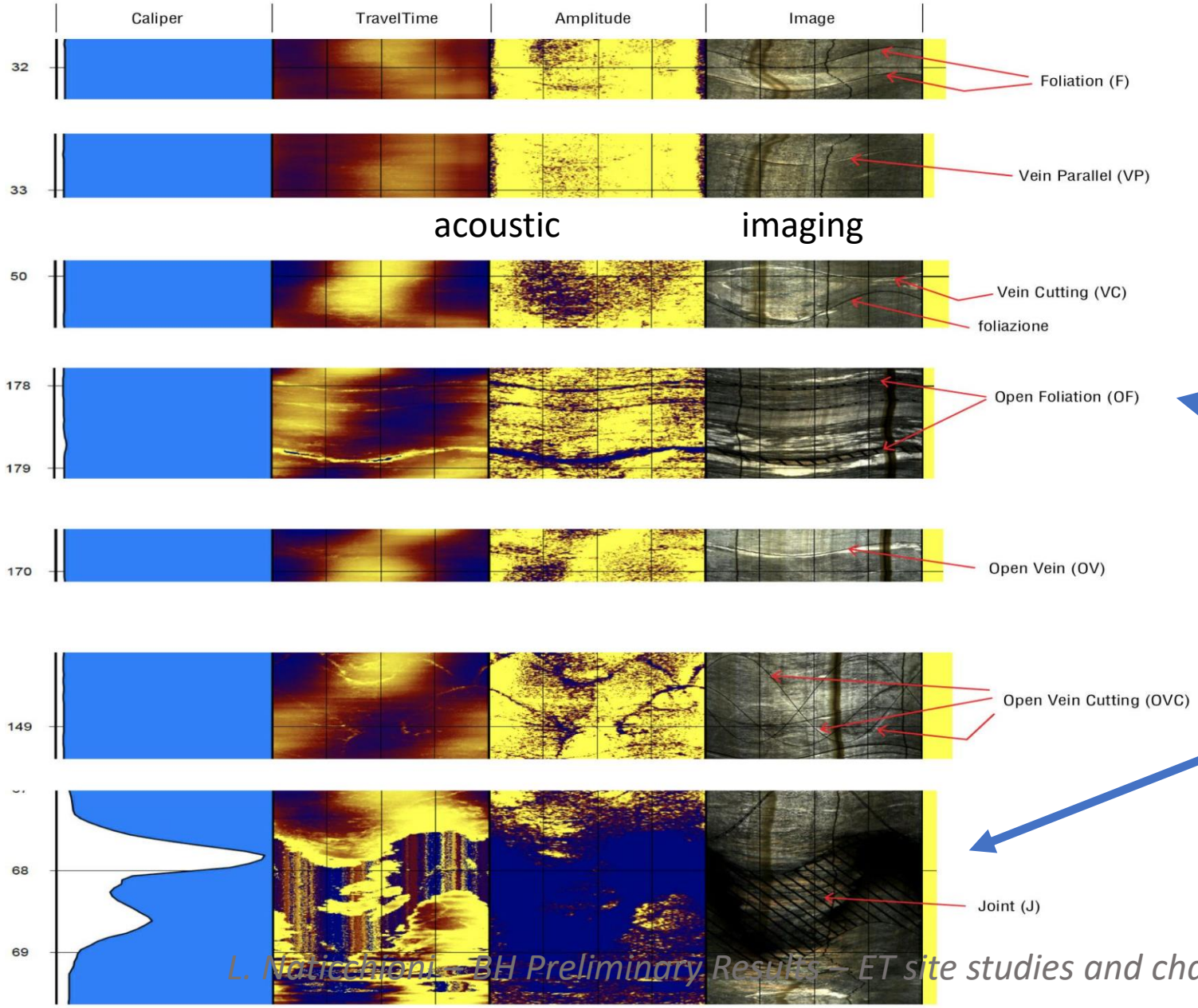


Geophysical logs

Geophysical Logs	
Temperature & Conductivity	Incoming water flow; Geothermal gradient
Self-potential	Lithological local variation; Incoming water flow with different salinity
Natural Gamma Ray	Clay content variation
Normal Resistivity	Lithology and water content variation
Caliper	Well diameter; Discontinuities mapping

Structural Logs	
Acoustic	Discontinuities in water: orientation, spacing, frequency, aperture
Optical	RGB image of the well; Discontinuities in dry or clean water: orientation, spacing, frequency, aperture

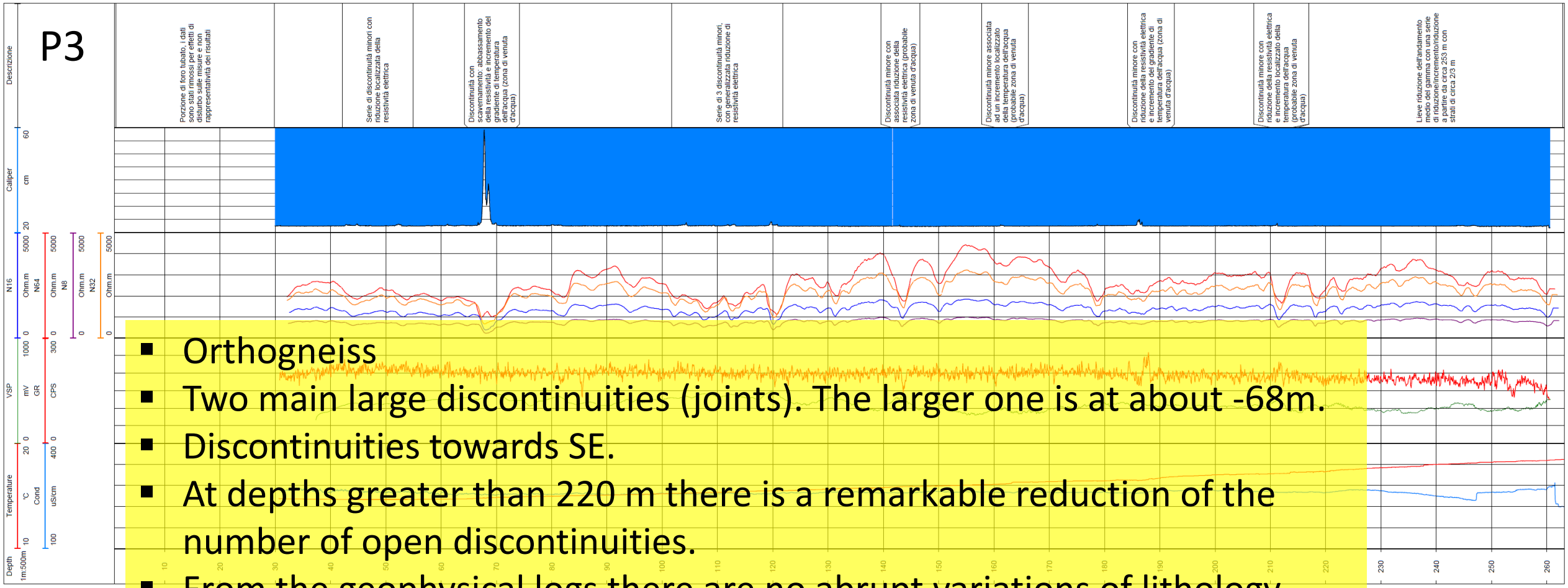
Geophysical logs



Example of discontinuities encountered in the P3 borehole and interpretation:

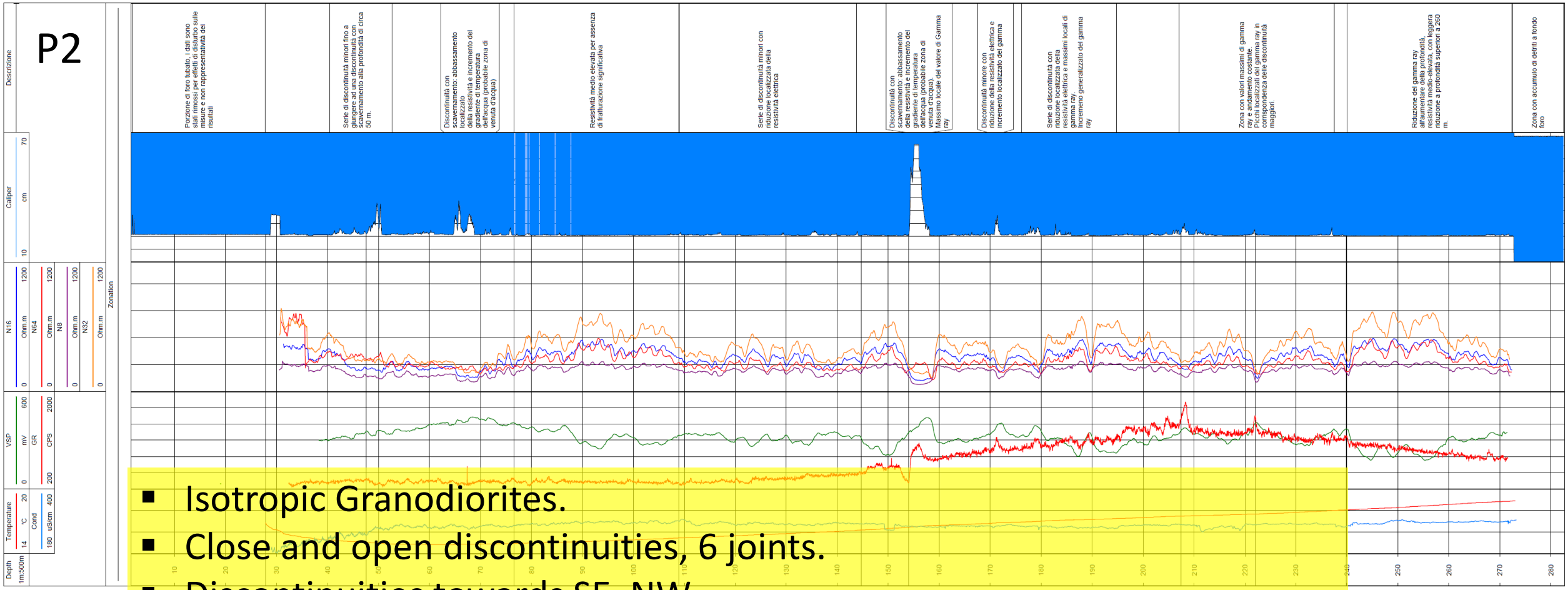
- Small-aperture discontinuities
- Large-aperture discontinuities

Geophysical logs



- Orthogneiss
- Two main large discontinuities (joints). The larger one is at about -68m.
- Discontinuities towards SE.
- At depths greater than 220 m there is a remarkable reduction of the number of open discontinuities.
- From the geophysical logs there are no abrupt variations of lithology, and the borehole looks drilled into the same geological formation.

Geophysical logs



- Isotropic Granodiorites.
- Close and open discontinuities, 6 joints.
- Discontinuities towards SE, NW
- Main discontinuity at -154m

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BH Seismometer installation

Surface and borehole seismometers have been installed @P2 and P3 in the first half of September 2021 with the assistance of Nanometrics and Codevintec technicians.

ET-0426A-21, https://apps.et-gw.eu/tds/?content=3&r=17710

BH Seismometer installation

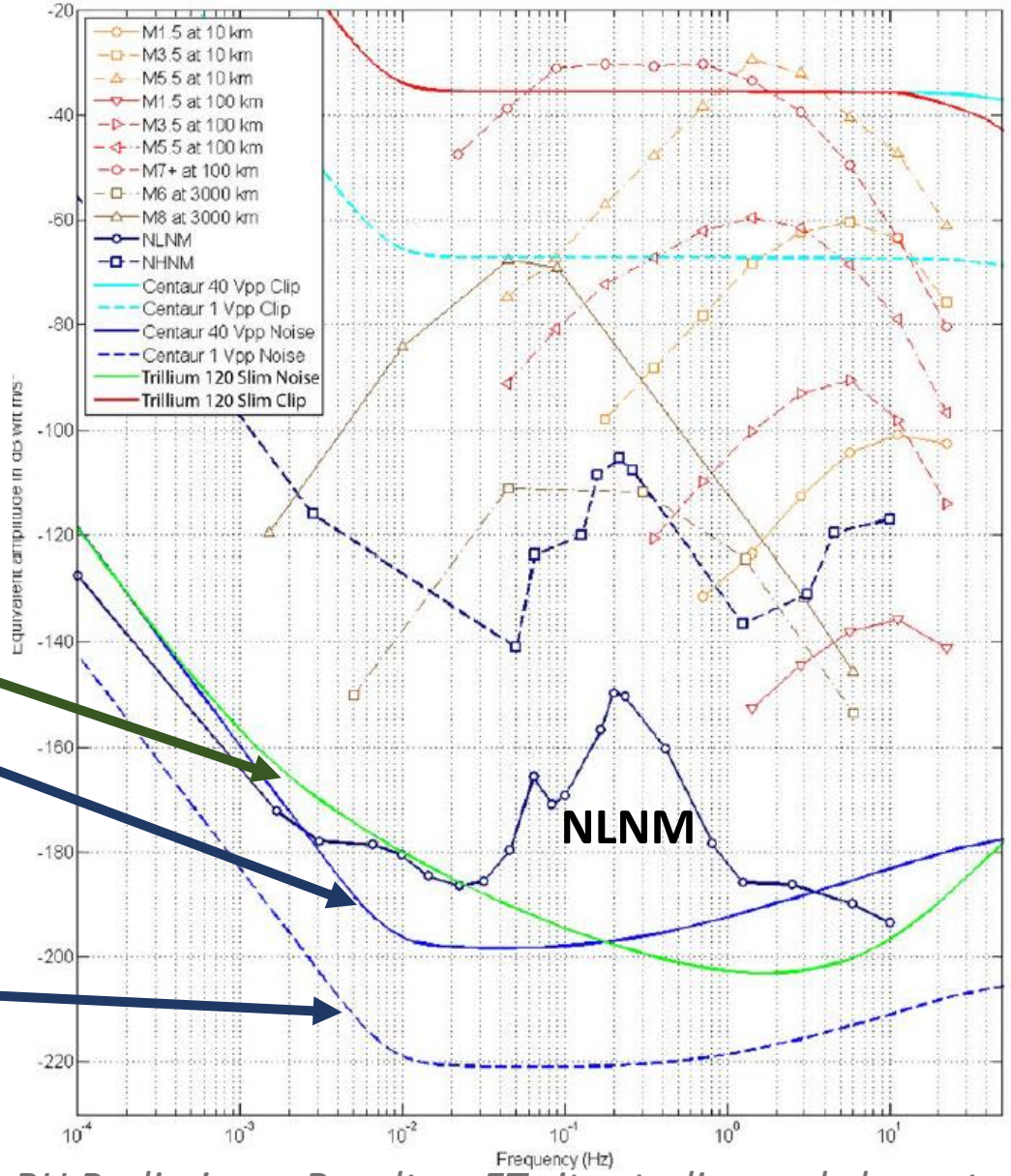
Trillium 120-SPH2

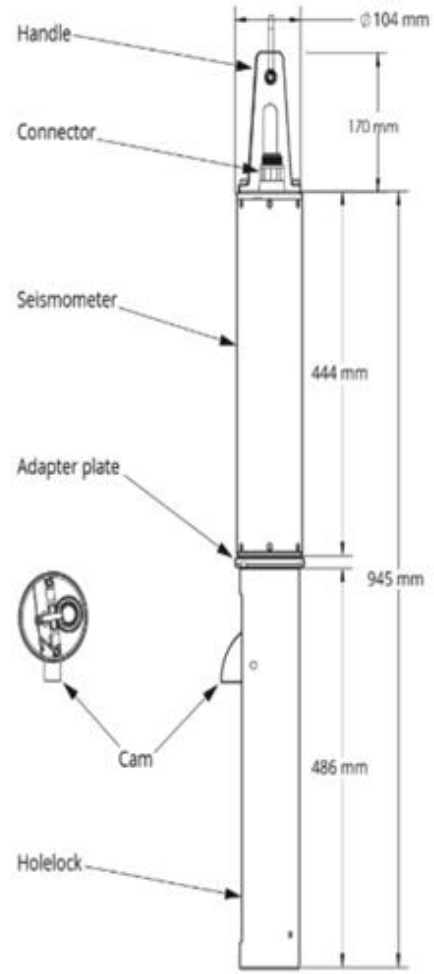
Broadband triaxial seismometer

Sensor self-noise

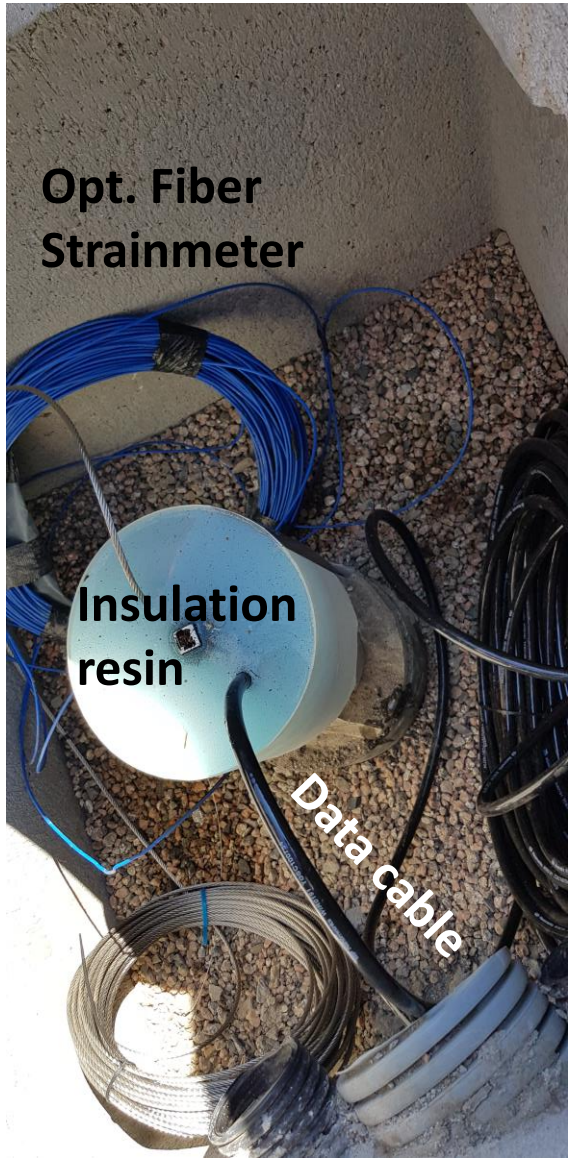
DAQ 40V self-noise

DAQ 1V (max gain) self-noise





BH Seismometer installation



BH Sensor	P2	P3
Depth	-264 m	-252 m
Tilt	1°	3.5°
Digitizer input range	1Vpp	2Vpp

NS – EW rotation have to be corrected with rotation matrix to be calculated observing teleseisms.

BH Seismometer installation

As surface reference we deployed two **Trillium 120 Horizon** in a vault installation. In both cases, the digitizers are running with an input range of 4Vpp.

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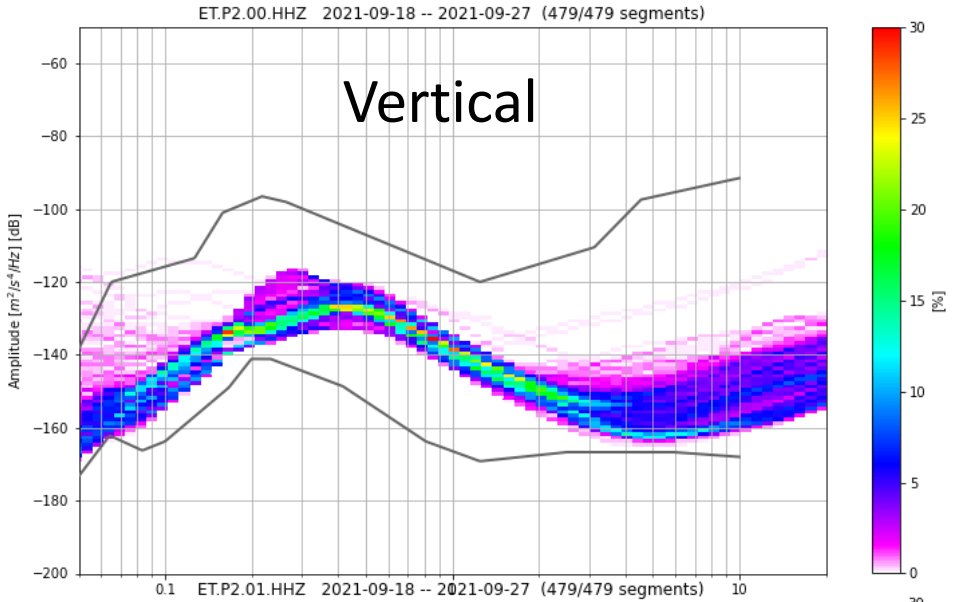
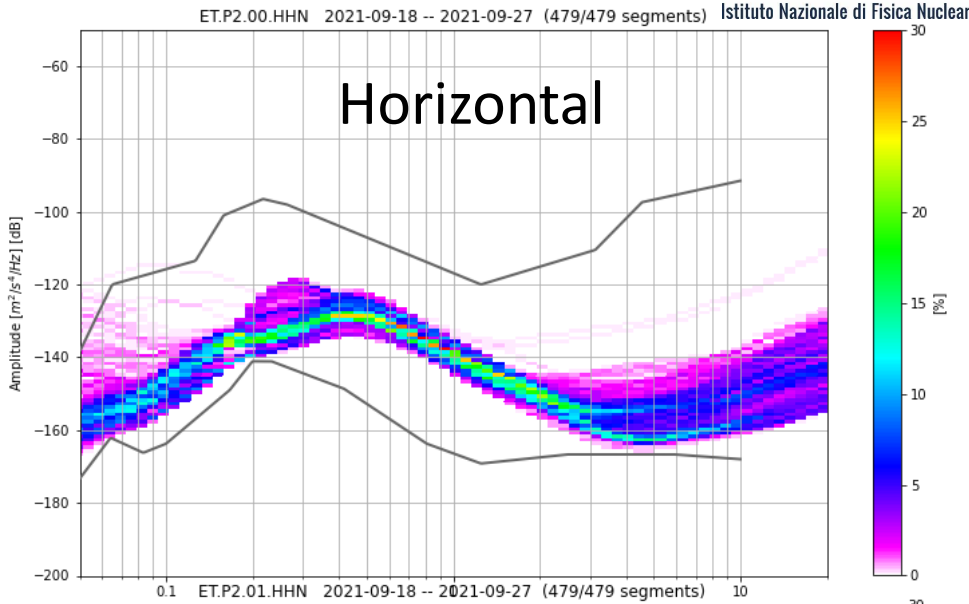
- ❑ **Preliminary results**

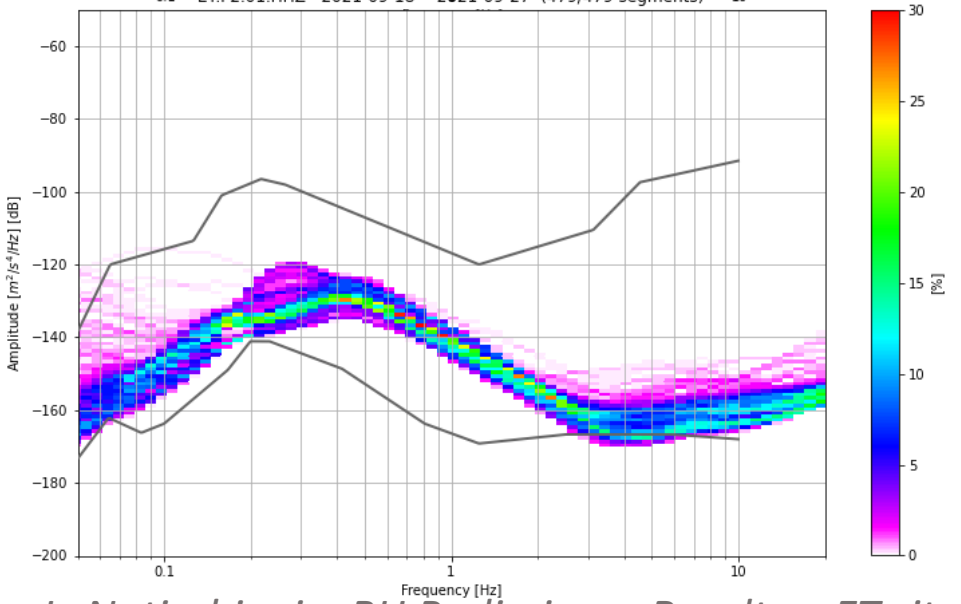
Preliminary Results

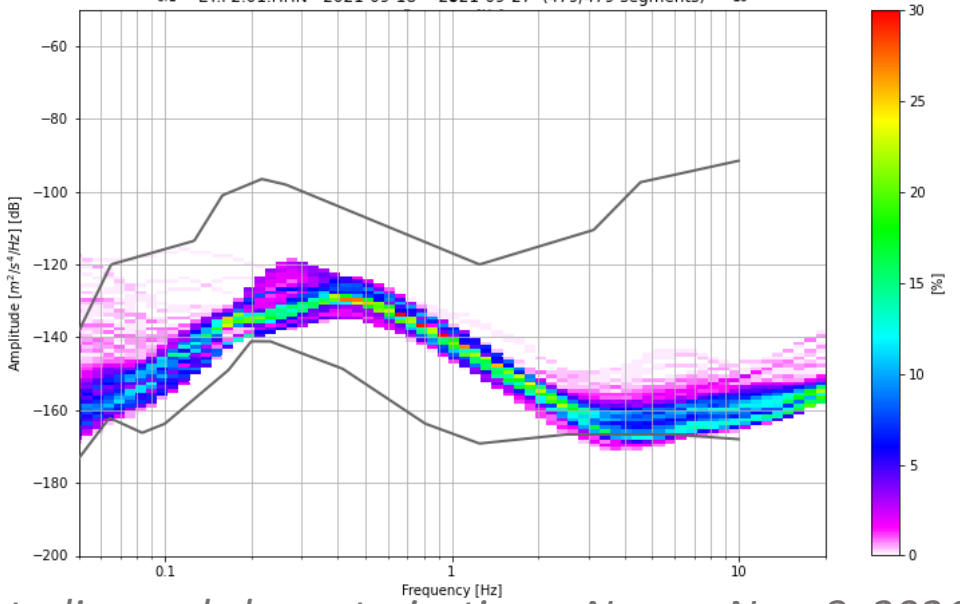
P2

First 10 days (2nd half September)









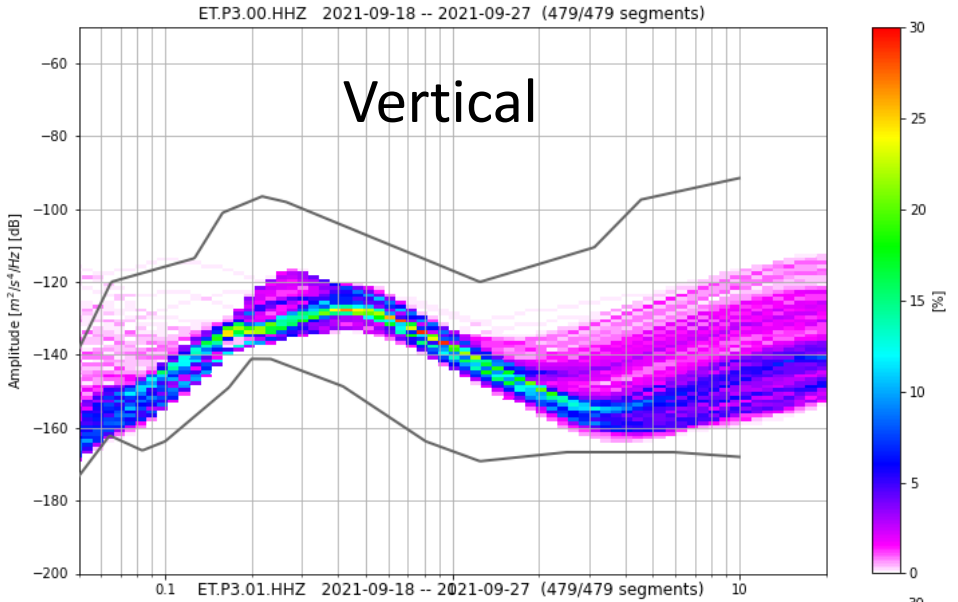
Surface

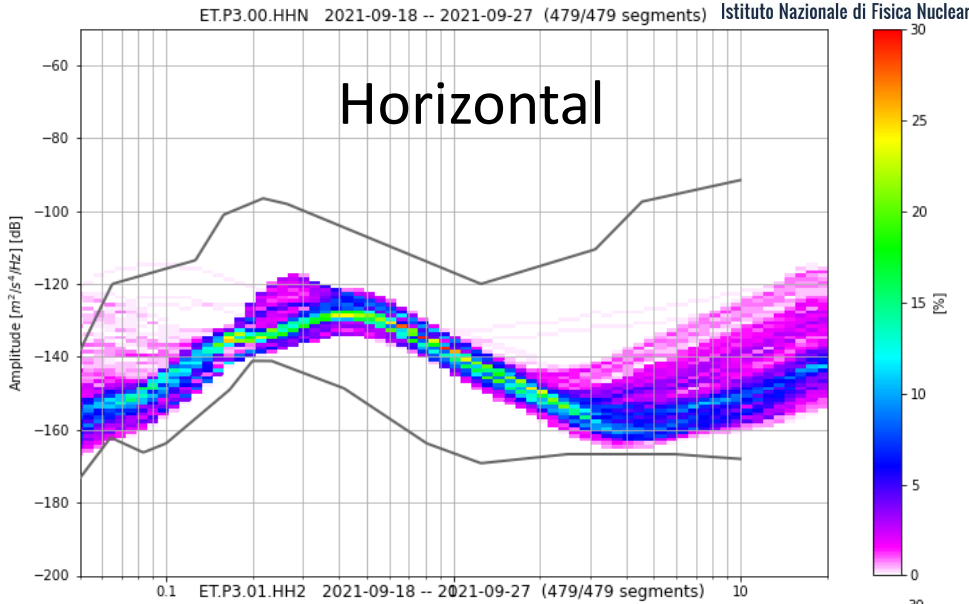
Underground (-264m)

Preliminary Results

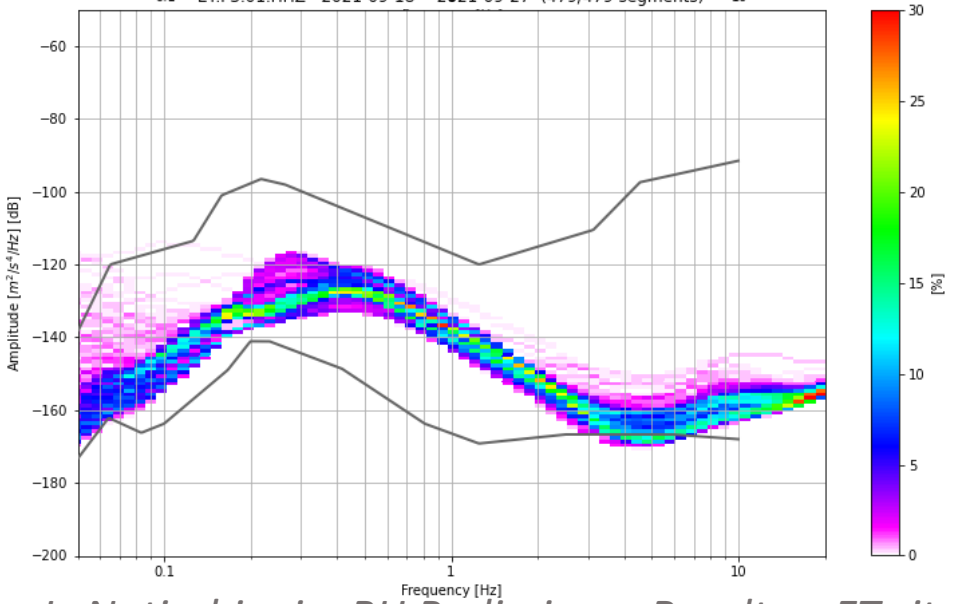
P3

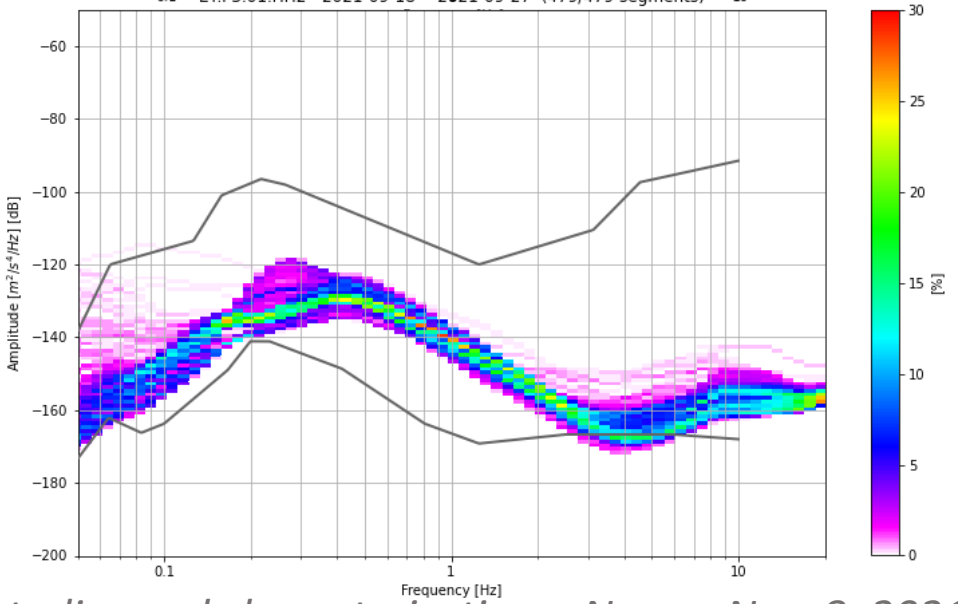
First 10 days (2nd half September)





Surface



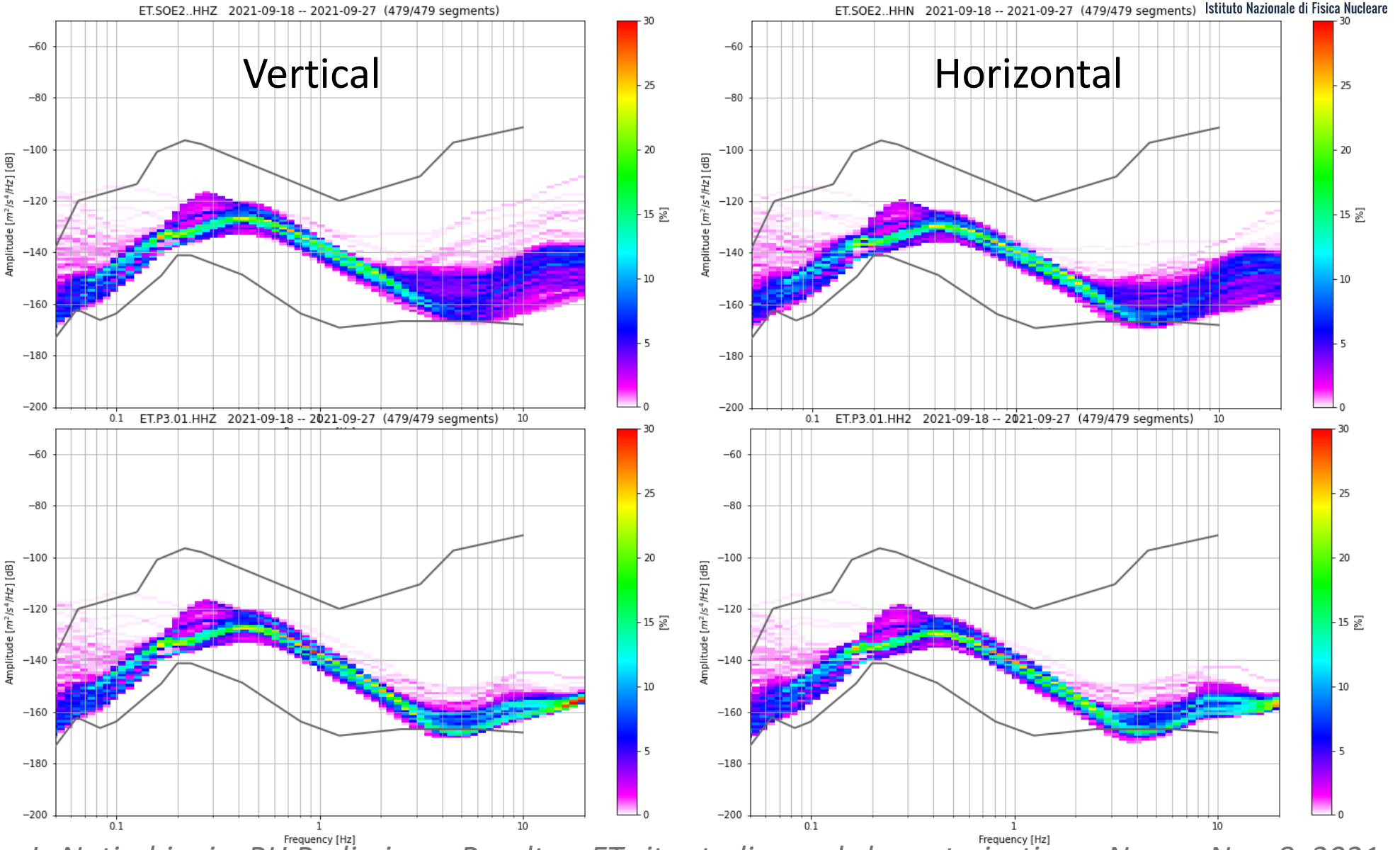


Underground (-252m)

Preliminary Results

SOE2 vs P3

First 10 days (2nd half September)



Sos Enattos

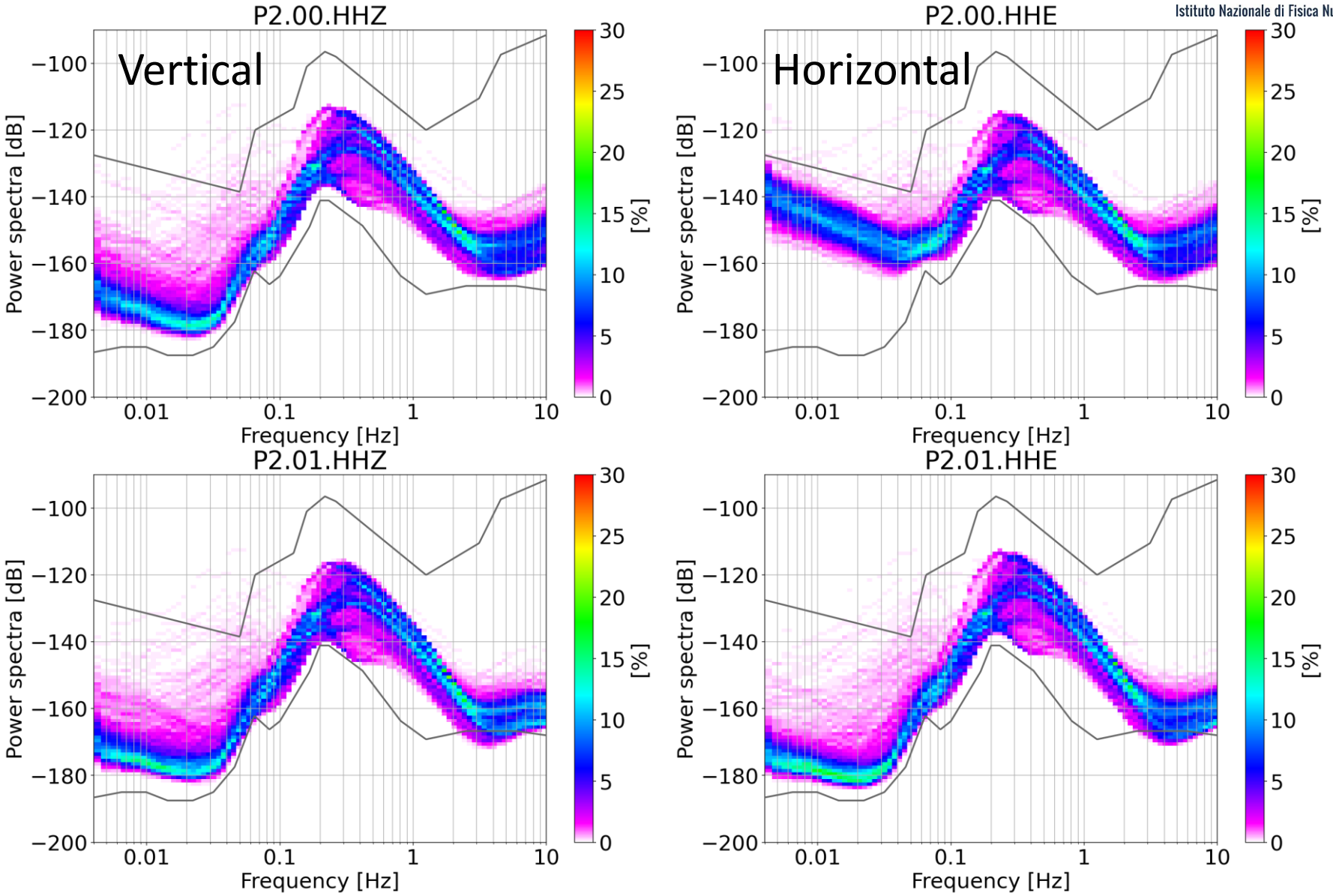
SOE2 (-111m)

P3 (-252m)

Preliminary Results

P2

October 2021

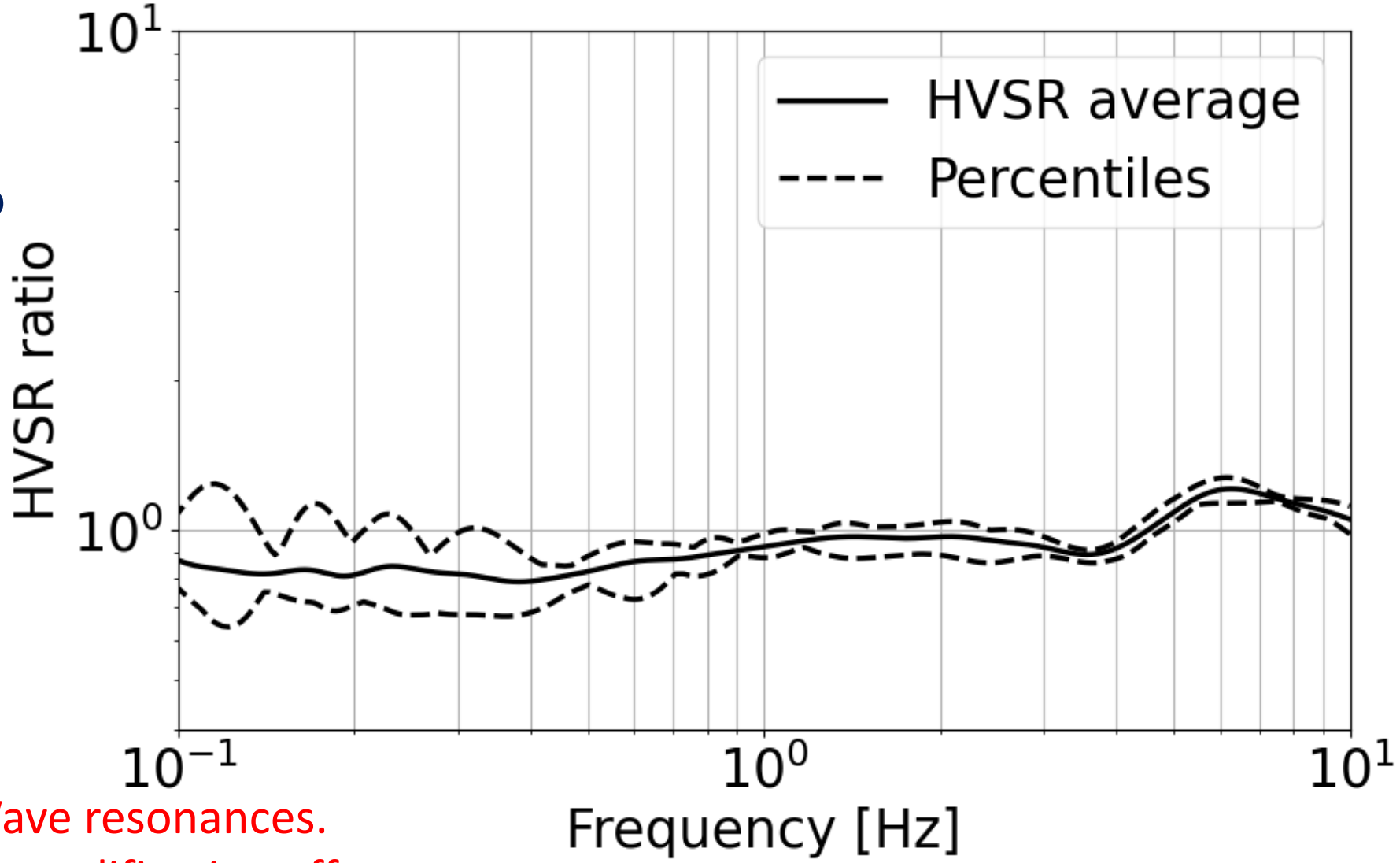


Preliminary Results

P2

October 2021

Horizontal to Vertical Ratio



Peaks ↔ S-Wave resonances.

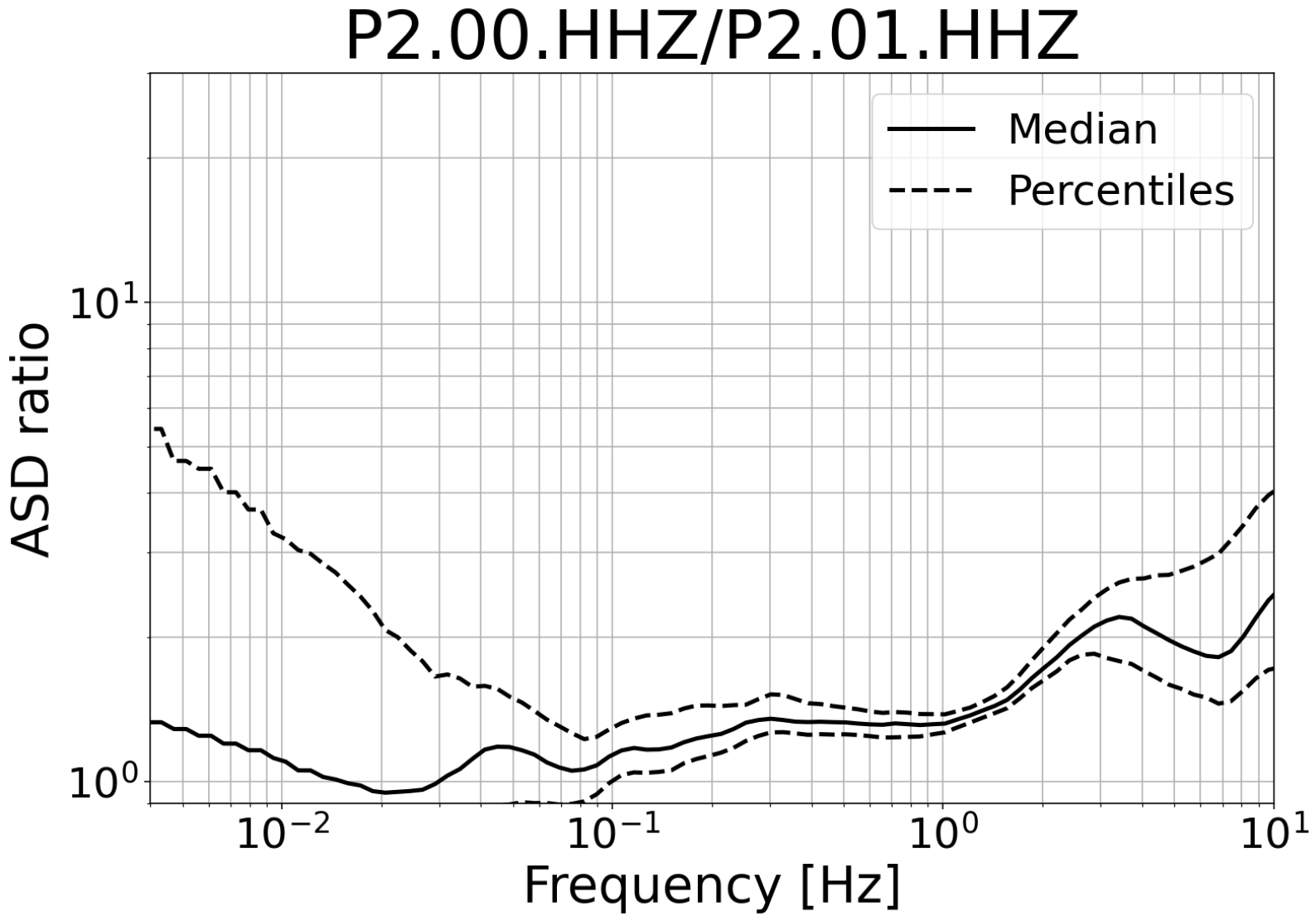
No significant amplification effects.

Preliminary Results

P2

October 2021

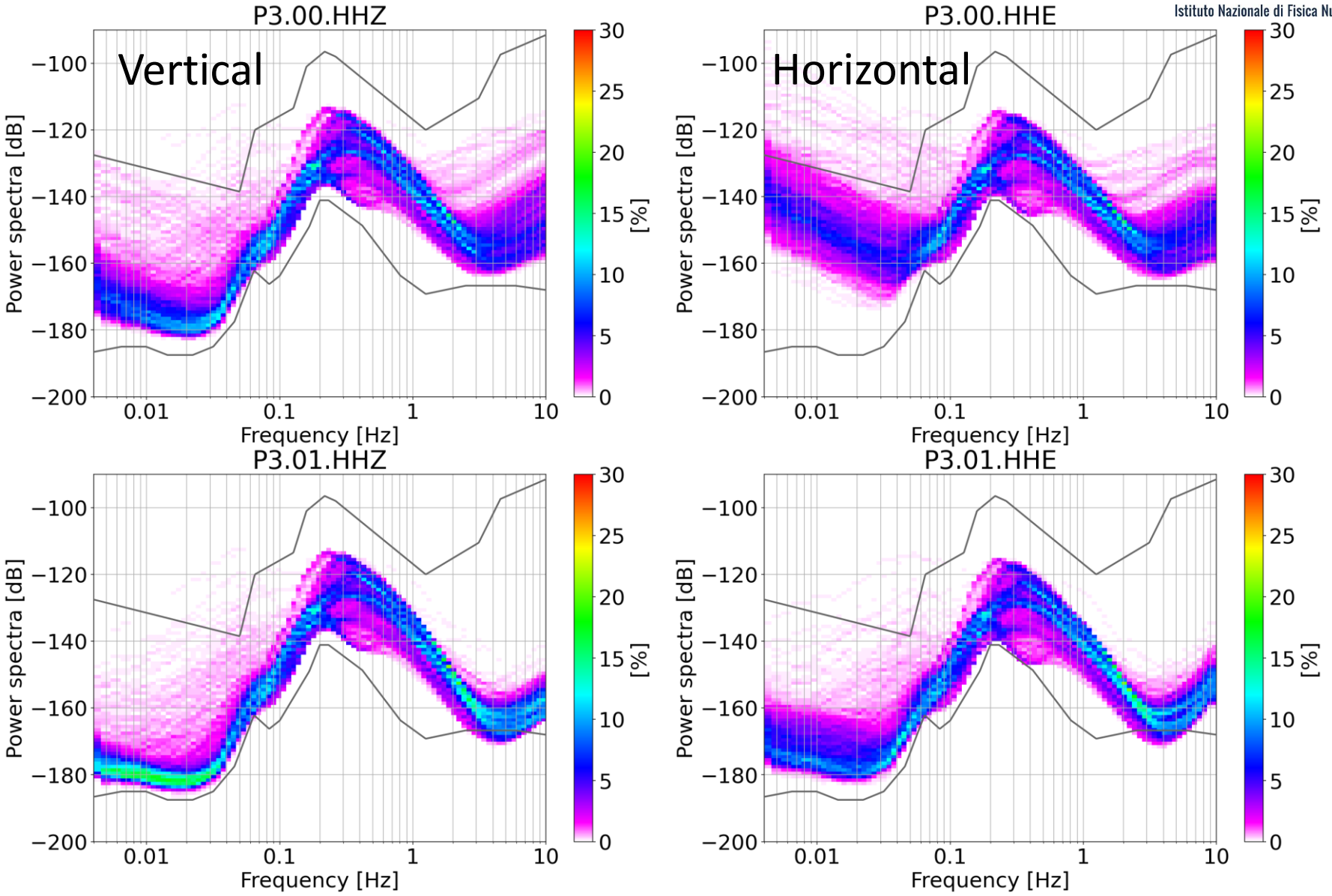
Attenuation



Preliminary Results

P3

October 2021

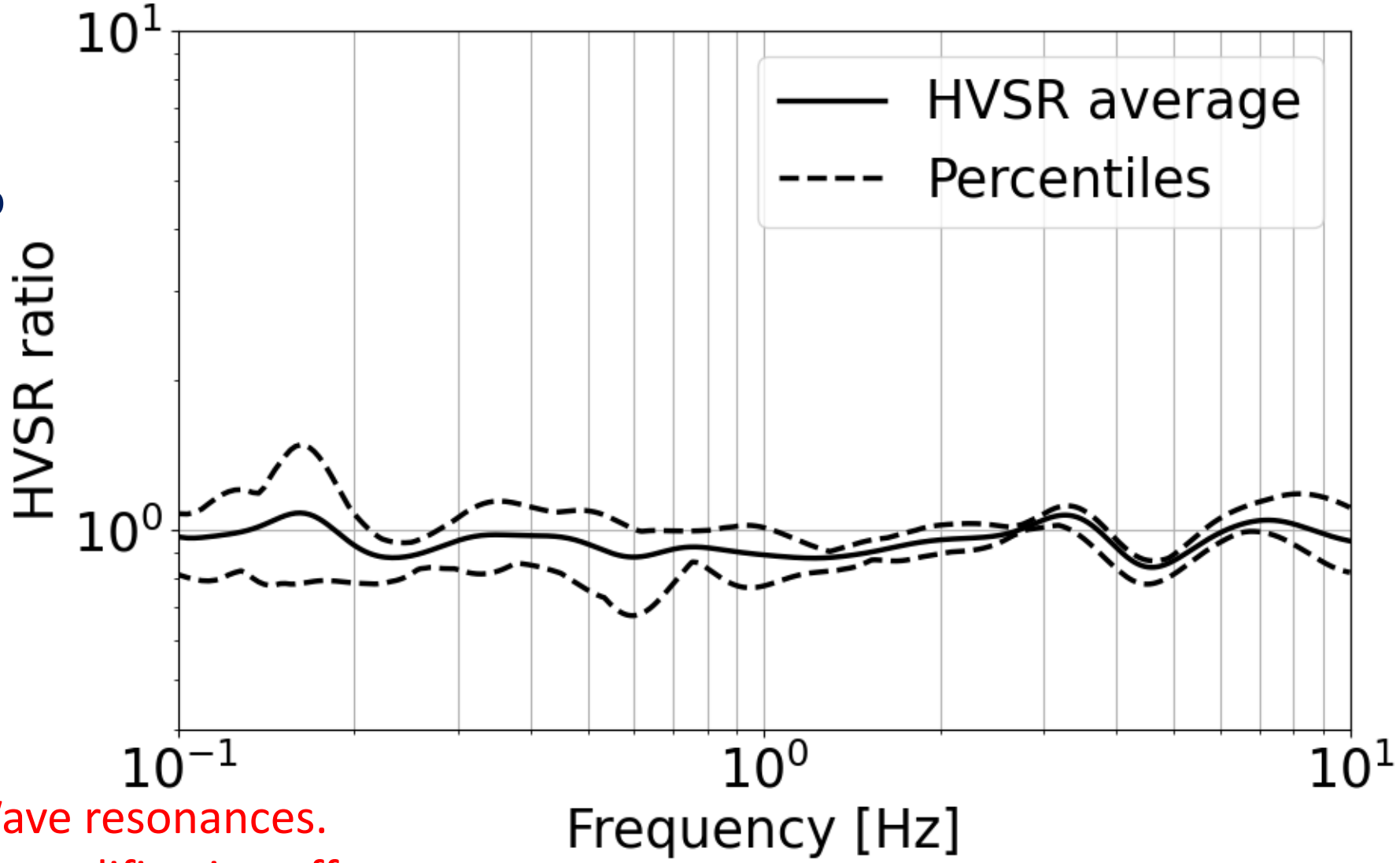


Preliminary Results

P3

October 2021

Horizontal to Vertical Ratio



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Preliminary Results

P3

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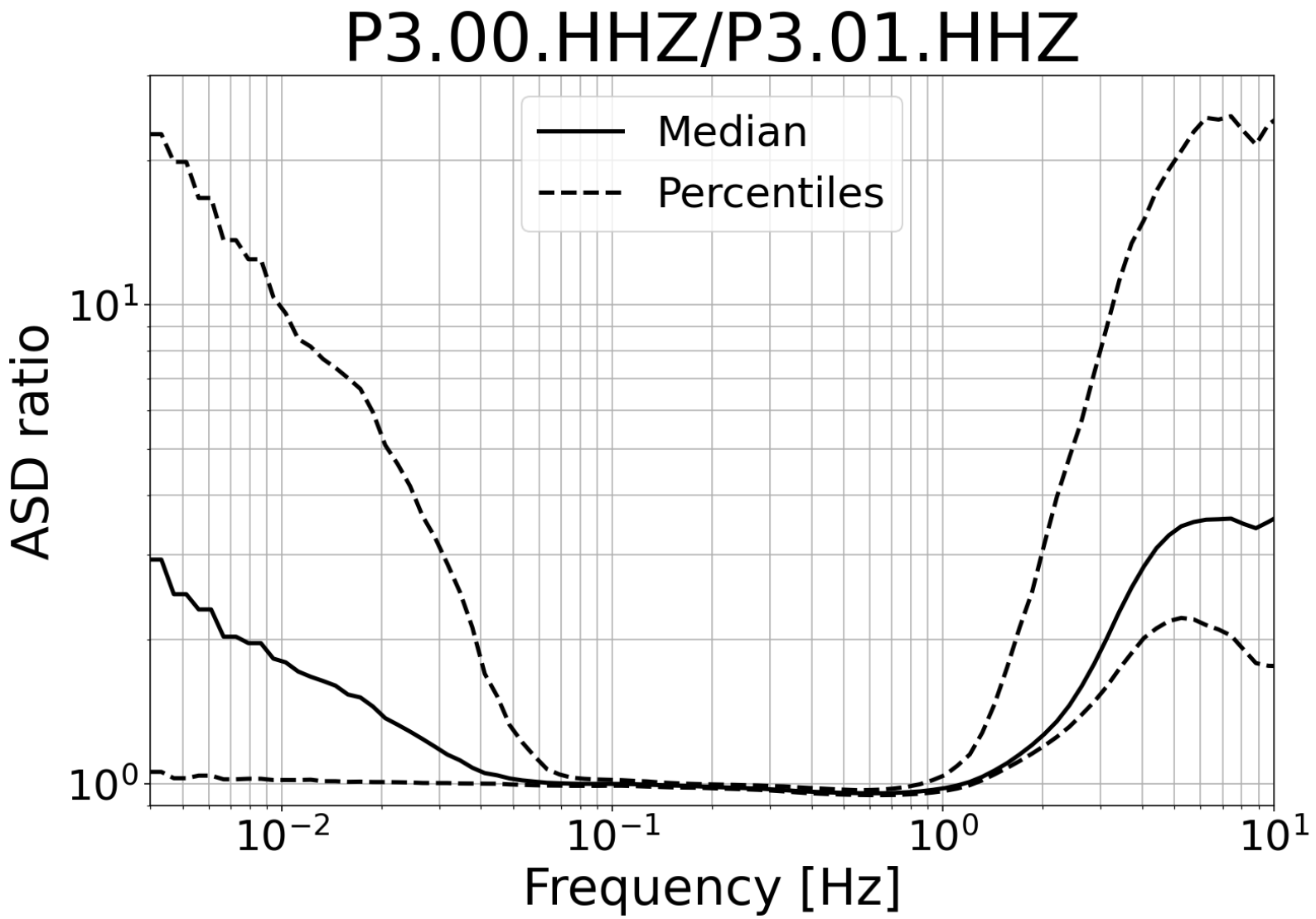

Conclusions

- On July 2021 the characterisation of the two other corners (P2,P3) of ET in Sardinia has begun.

- Two boreholes excavated (about 270m and 260m deep).

- Geophysical/structural logs done in granites (P2) and orthogneiss (P3).

- Borehole equipped with optical fiber strainmeters and broadband seismometers.

- First results are impressive: the attenuation of the seismic background measured with the borehole seismometer is evident above 1Hz, in particular in the band 2-7Hz, where the background noise crosses the Peterson's New Low Noise Model (NLNM).

Thanks for your attention!