Broadband seismometer deployment in boreholes

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

Borehole

Borehole for a broadband seismometer deployment

From our experience in Sardinia:

drilling, pipes, consolidation, assuming a final inner diameter of 119mm:

- **Cost***: ~50k€/100m
- **Time****: ~1 month for drilling (~250m), 1 week for consolidation with steel pipes + concrete

**Here we did not take into account the post-covid19 cost increase of materials*

***: if no major issues are encountered*

NB: cost for increasing diameter scales with the volume of the steel of the pipes used for the consolidation.

COST SENSITIVITY ANALYSIS

A cost sensitivity analysis is carried out as a support for the feasibility study of the sensor network for the ET infrastructure.

Main assumptions:

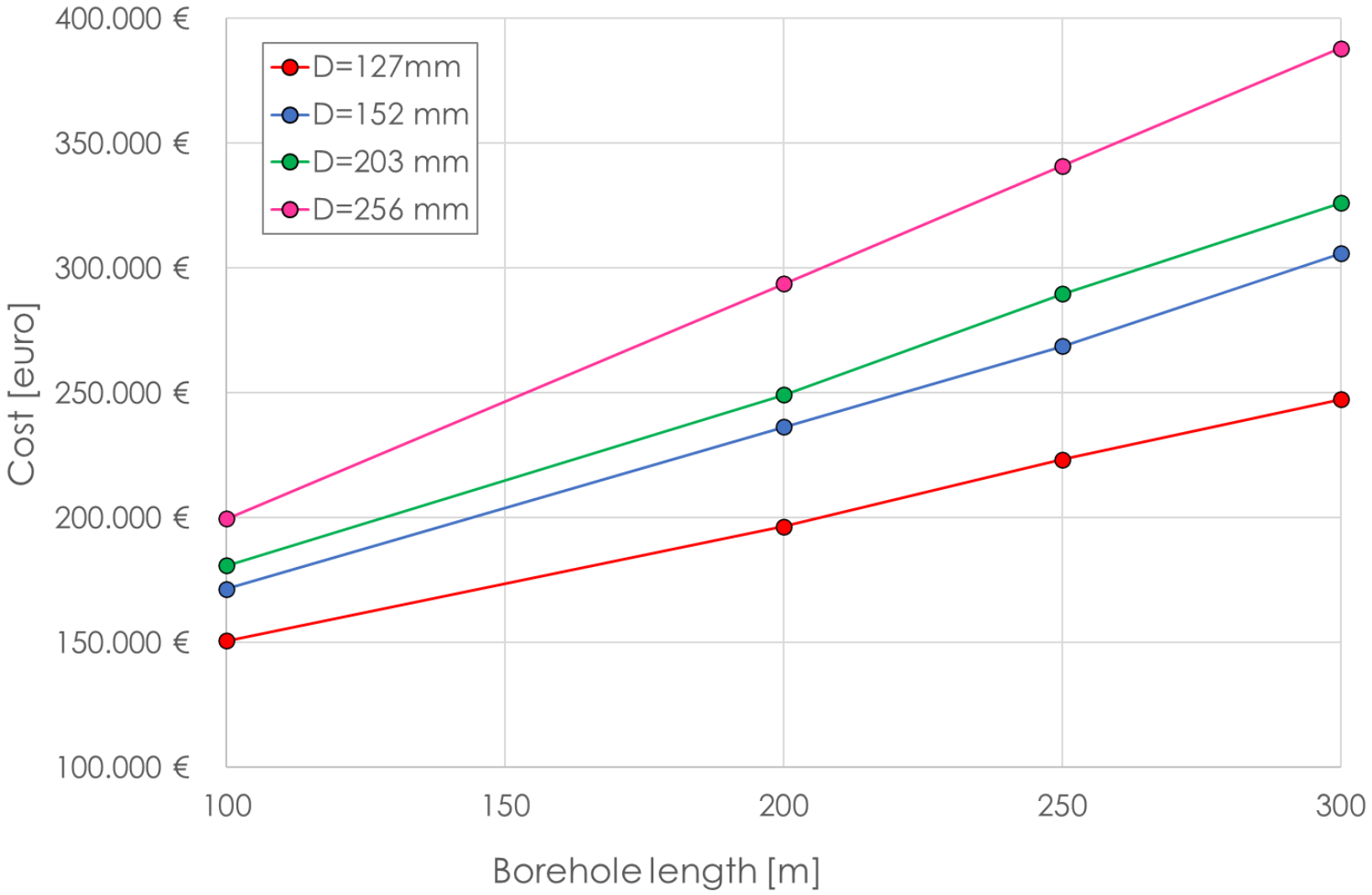
- Boreholes depth: 100, 200, 250, 300 m
- Steel lining external diameter: from 114,3 mm (4.5 inch) to 254 mm (10 inch)
- unit prices from the regional or national reference price list
- Included in the cost: site installation, borehole drilling and completion, surface infrastructures, safety
- Not included in the cost: instrumentation and sensors, solar panels, electrical equipment

Courtesy of C. Rossini, see related talk

COST SENSITIVITY ANALYSIS

Courtesy of C. Rossini, see related talk

COST SENSITIVITY ANALYSIS



Courtesy of C. Rossini, see related talk

Borehole

Borehole for a broadband seismometer deployment

From our experience in Sardinia:

- Slim borehole sensor choice is a *cost-saving* solution for the borehole excavation/consolidation.
- 119mm diameter is ok for a Trillium 120 slim-class broadband seismometer (which can be installed in a 114-241mm range, depending on the holelock used).
- A “slim” broadband seismometer **has more stringent requirements for the vertical tilt**. E.g.: the T120BH slim must be installed with a tilt < 4° (*i.e. the verticality of the borehole is crucial. To be monitored during the drilling*).


Mechanical clamping system

Sensor installation

Broadband seismometers for boreholes

Costs:

- A Trillium120-class sensor: ~15-20k€
- 300m-long data cable: ~20k€
- DAQ: ~8k€
- Accessories: ~4k€

Total: ~52k€

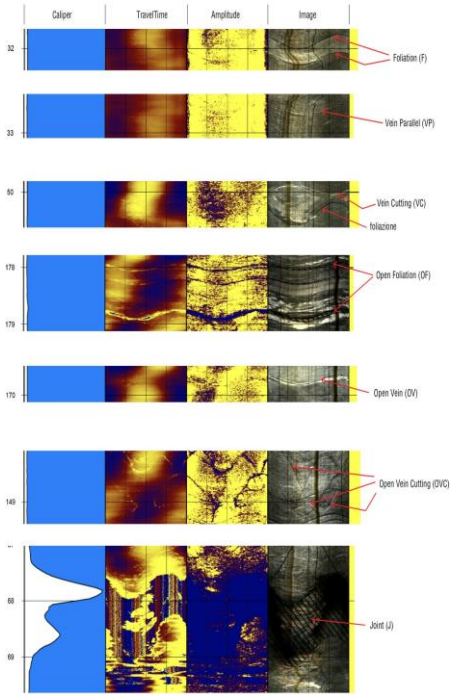
- Assistance, e.g. from Nanometrics (or authorised local company) for a state-of-art installation (including tools): ~10k€/installation

Sensor installation

Broadband seismometers for boreholes

Installation:

- **Good mechanical contact** with the surrounding rock mass is crucial: a well-done borehole consolidation (good concrete injection) is required.
- *Before the consolidation*: **logs** are important to identify the most important discontinuities in the borehole walls.
- **The seismometer should be installed avoiding fractured sectors of the borehole**.
- Surface structures/setup: avoid to inject additional vibration noise (e.g. support structures of solar panels vs wind)



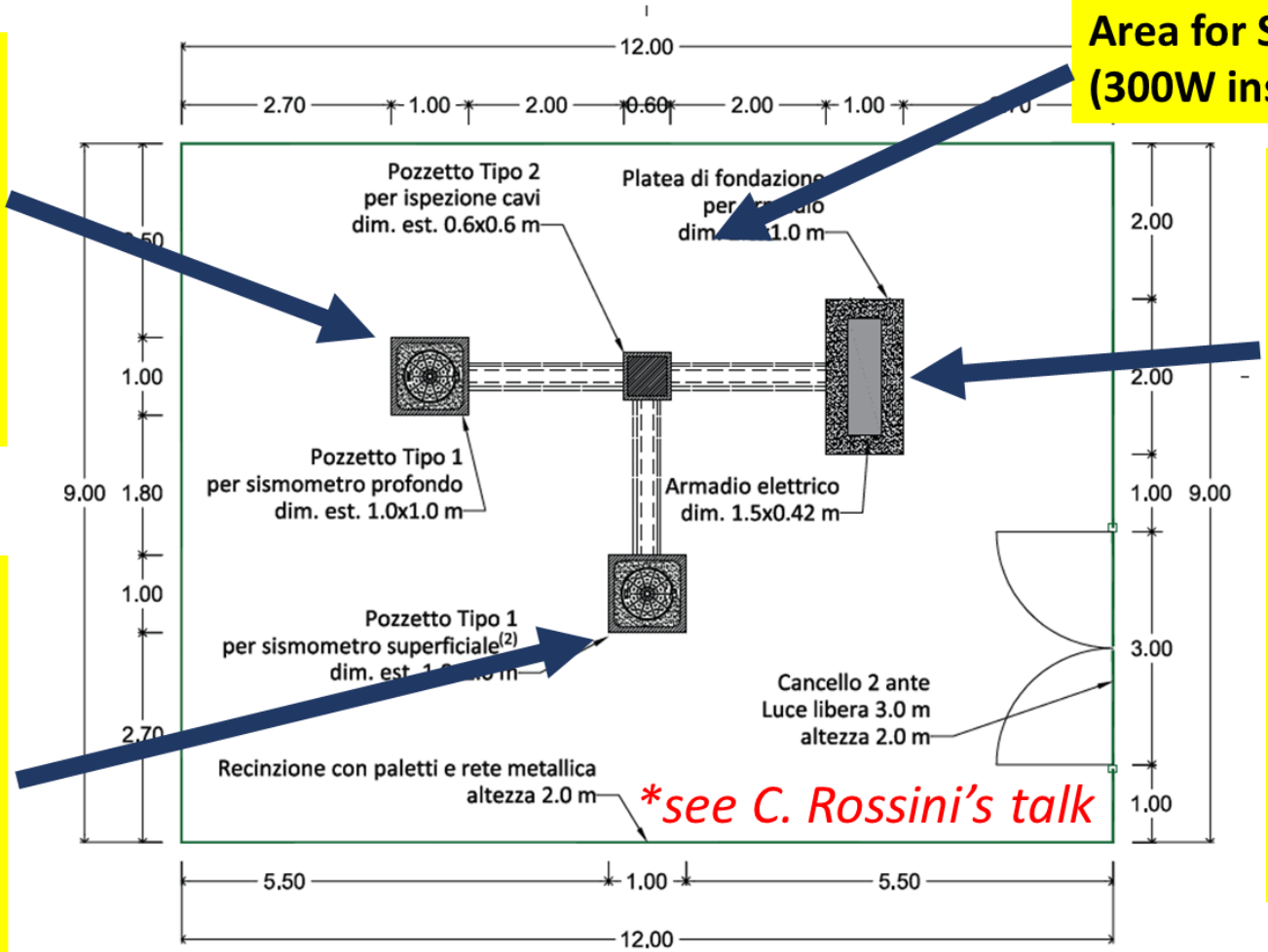
Sensor installation

Example: BH seismometer installation in Sardinia for seismic study at the corners P2, P3

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**

Sensor installation

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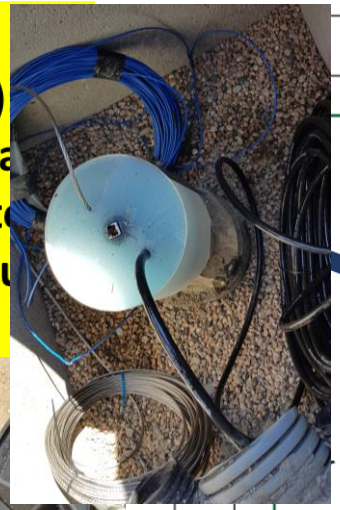

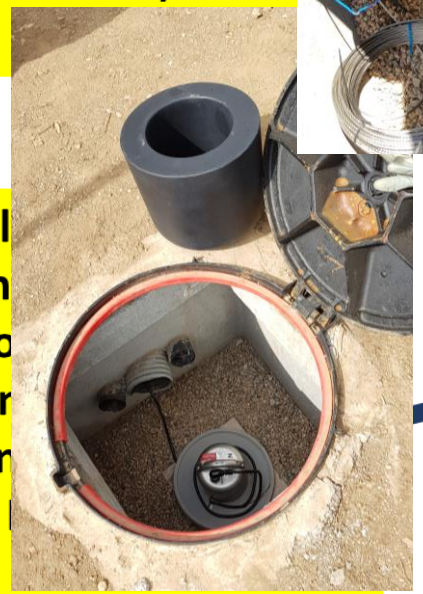

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Electrical Cabinet:
- **DAQ (Nanometrics**
Centaur 6ch, 24bit)

*see C. Rossini's talk

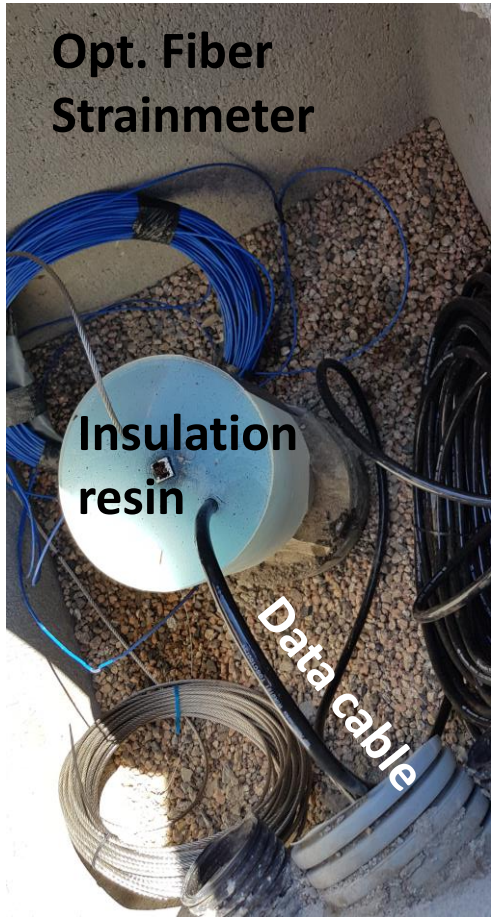
Sensor installation

Example: BH seismometer installation in Sardinia for seismic study at the corners P2, P3

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

Sensor installation

Example: BH seismometer installation in Sardinia for seismic study at the corners P2, P3



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.

Sensor installation

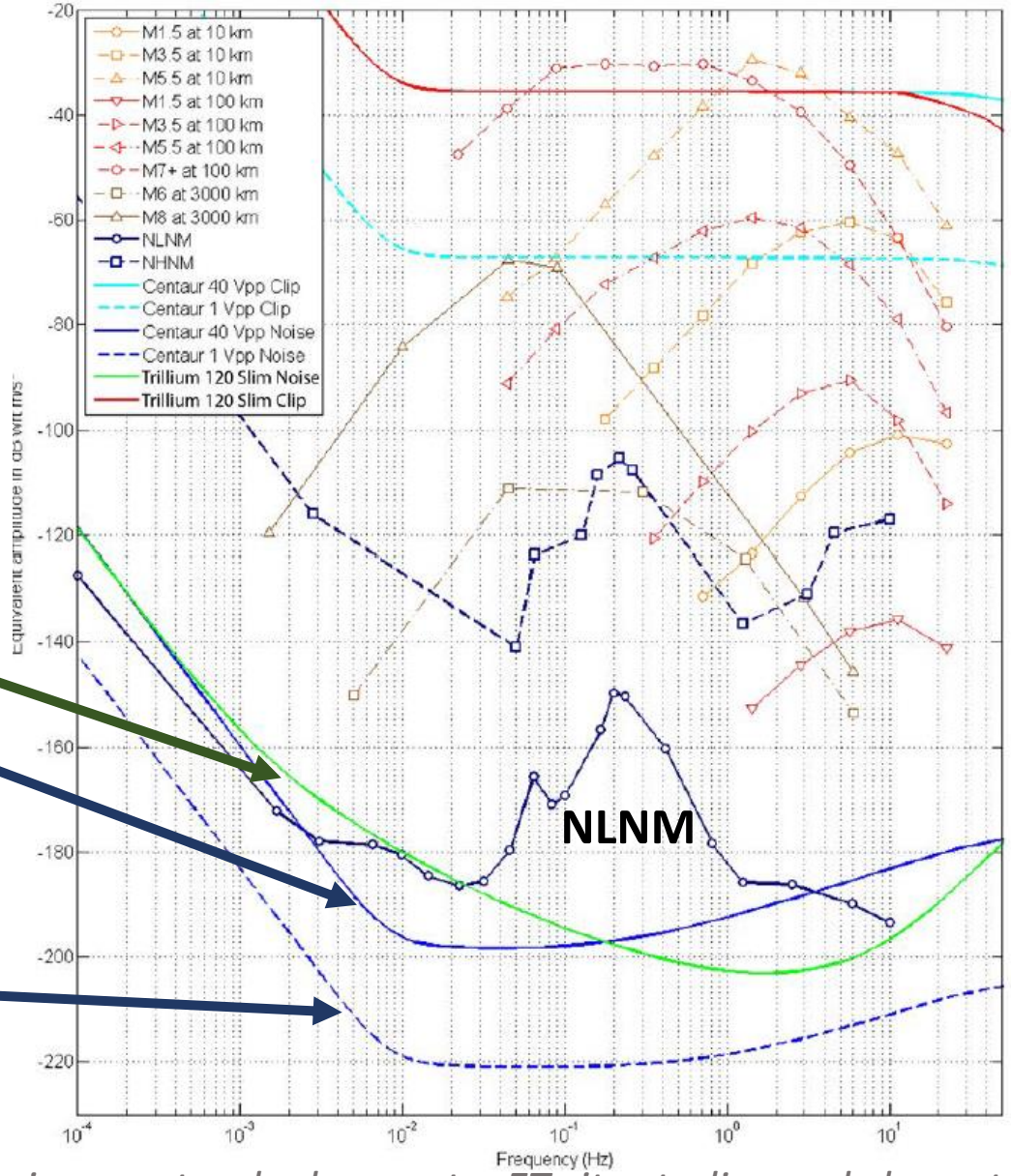
Trillium 120-SPH2

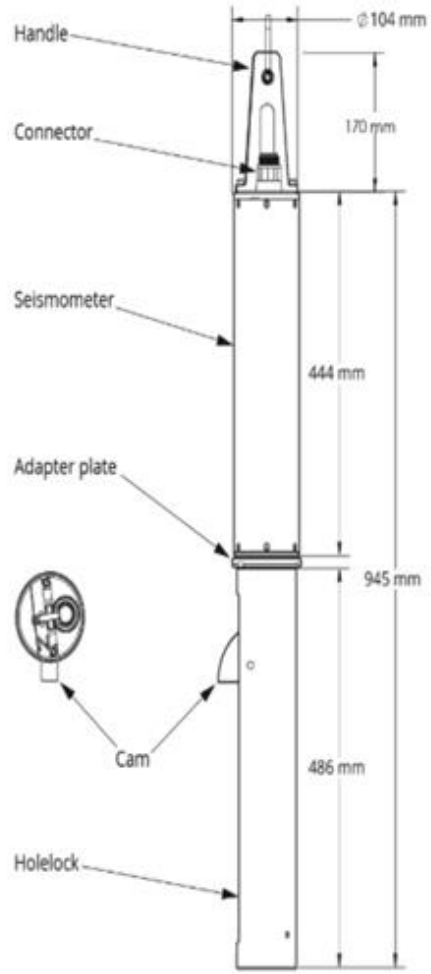
Broadband triaxial seismometer

Sensor self-noise

DAQ 40V self-noise

DAQ 1V (max gain) self-noise





Sensor installation

Multi-seismometer chain in a borehole (e.g. 3 seismometers, 100m spaced)

- Not currently available on the market, but **feasible** as future development (*private communication from Nanometrics*).
- Compatible passing data cables to be engineered.
- Single seismometers of the chain will require (remote) electromechanical clamping system → *larger* BH final inner diameter (>122mm).
- Up to 500m-long cable is ok, higher possible (→increase voltage)
- **Cost optimization required** (main parameters: number of sensors/BH, BH depth, BH diameter, steel volume of pipes, number of BHs)
- Possible to have such a BH seismometers chain on the market in a **5-year timescale**, interest from the producing companies. *Need to keep in contact with them & stimulate this development*.