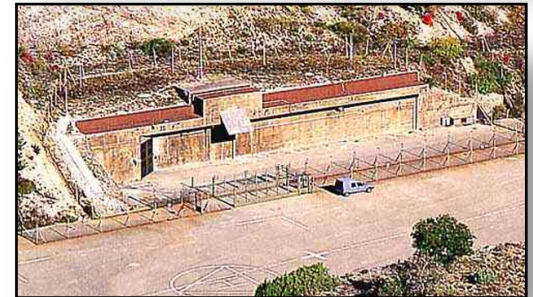
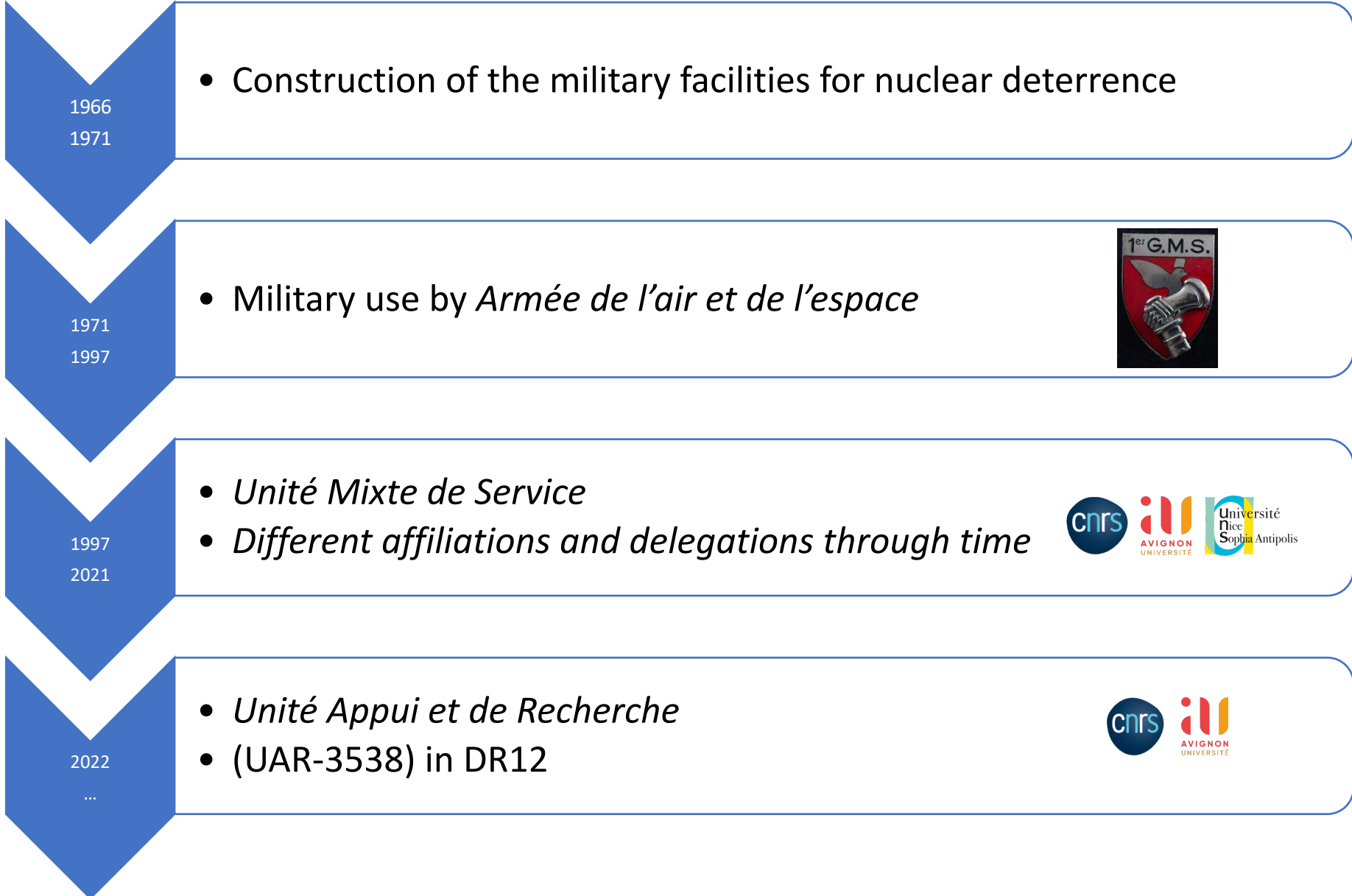
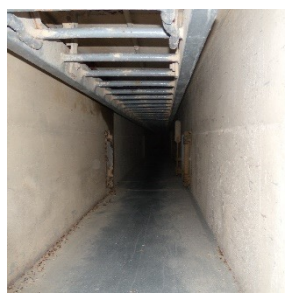




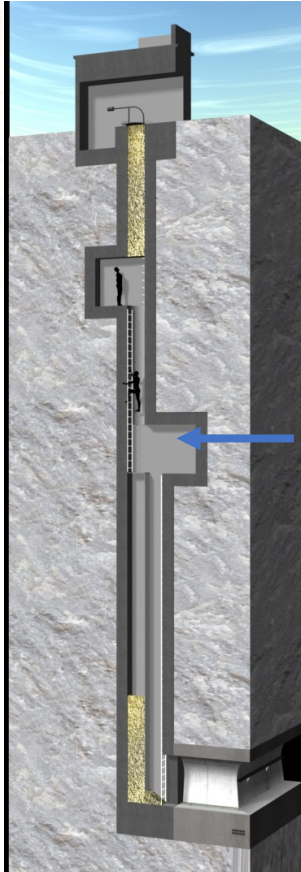
Low background noise underground research laboratory of Rustrel



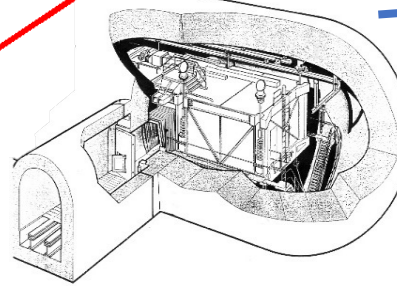
Conceived to resist a nuclear attack... and strike back



Safety exit well
(-30m)



EM shielded capsule
 $\text{Ø}8 \times 28 \text{ m}^3$
(-500m)



Two antiblast
galleries



Surface antenna on
the top of the
mountain
(1.016 mast)



Generator room
500 m², 7m height (-64m)

- Underground **and** surface unique facilities
 - 4.3km of galleries
 - 53 ha of surface



- Permanent network of detectors
- Periodical campaigns
- >20 years of environmental data
- Over 60 PhD thesis



A convenient location

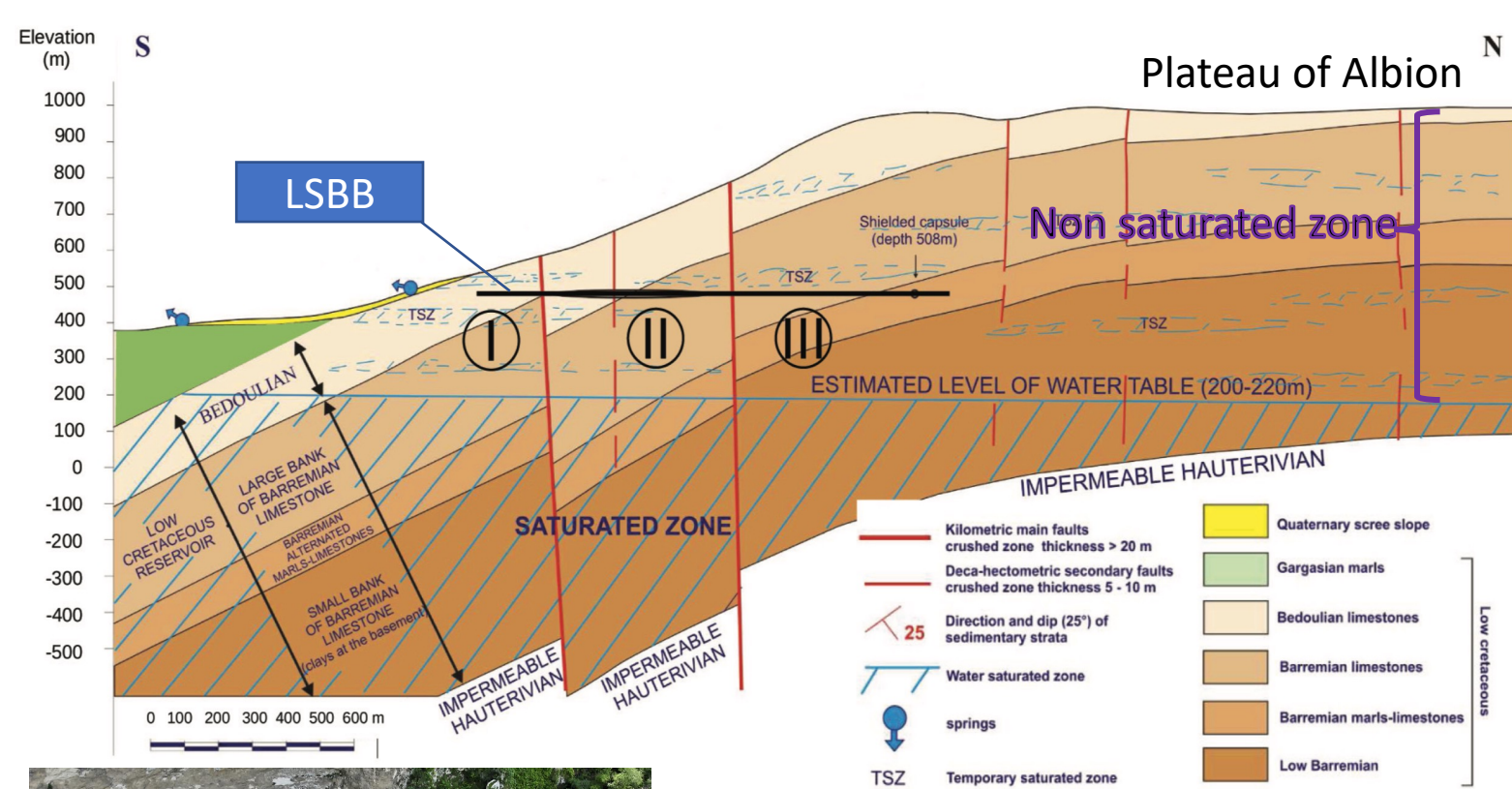
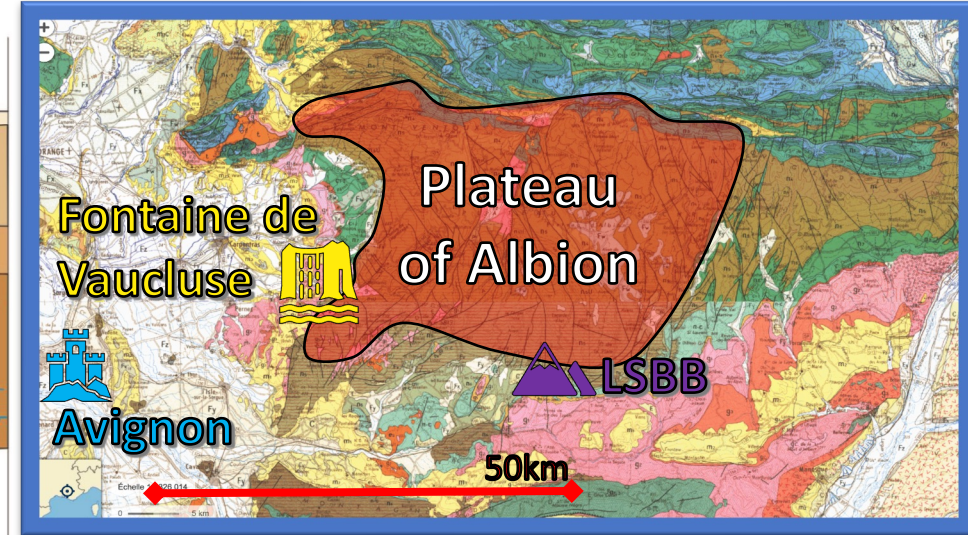


Figure from Sénéchal, (2013)



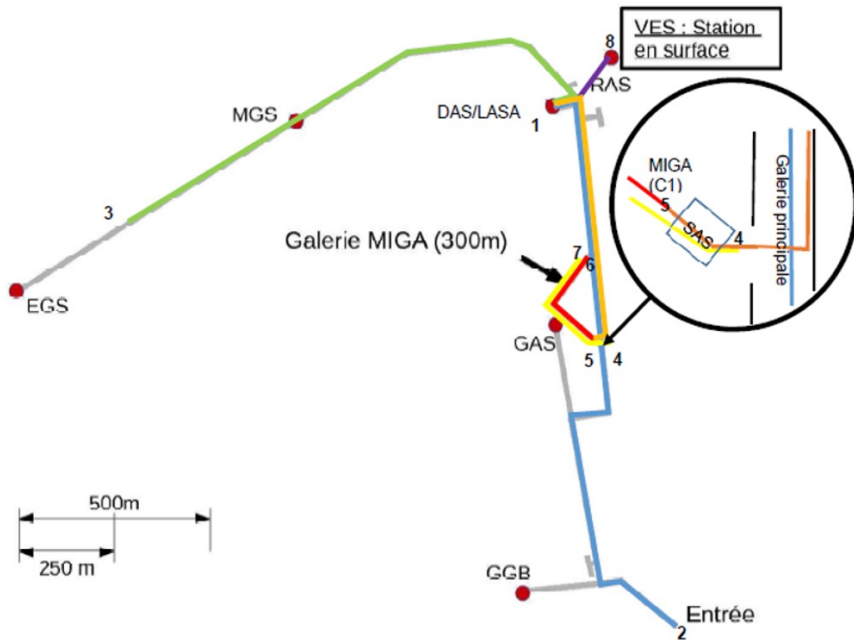
- Experimental site: carbonate reservoir
- 140 years of flow measurements at Fontaine-de-Vaucluse water catchment
- 17 years of hydrochemical simultaneous measurements at both LSBB and Fontaine-de-Vaucluse
- Easy and « random » access to LSBB flows in the unsaturated area of the karstic aquifer and within the saturated zone towards boreholes



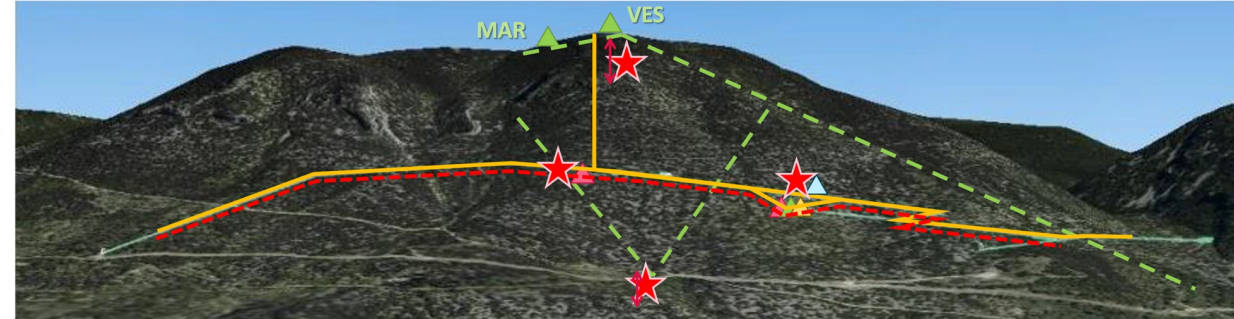
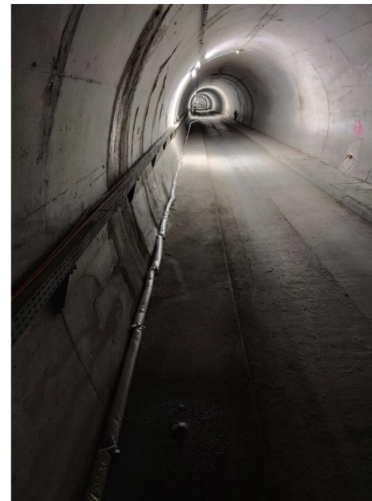
World 5th
 largest karst aquifer

Seismic -Premise experiment (LSBB+CEA-DASE+Febus+SERCEL)

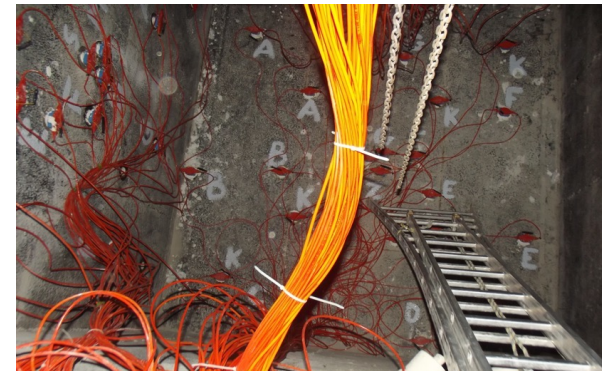
- FO Galerie principale (1.5km)
- FO Galerie de secours (1.5km)
- FO Télécom liaison LASA MIGA (0.7km)
- FO rainure MIGA (0.3km)
- FO multisens MIGA (0.325km)
- FO Verticale (0.675km)

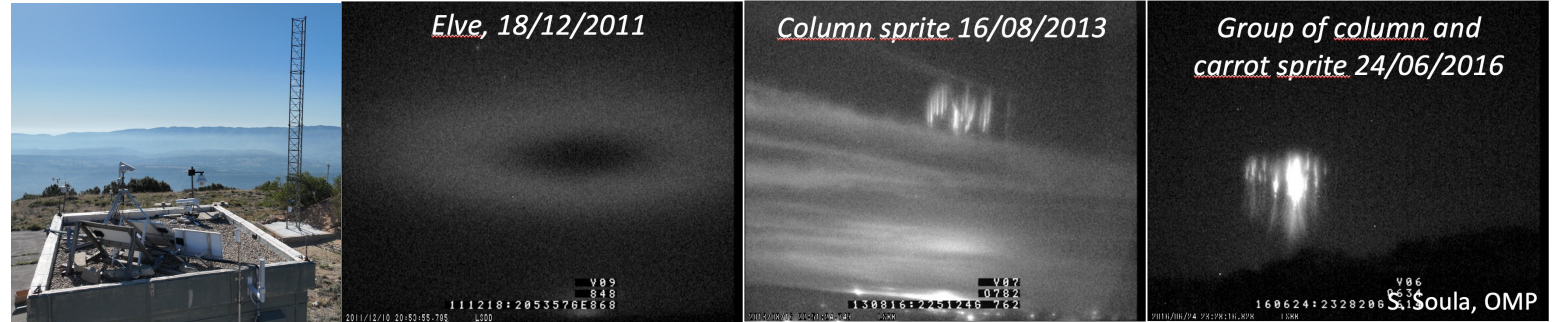
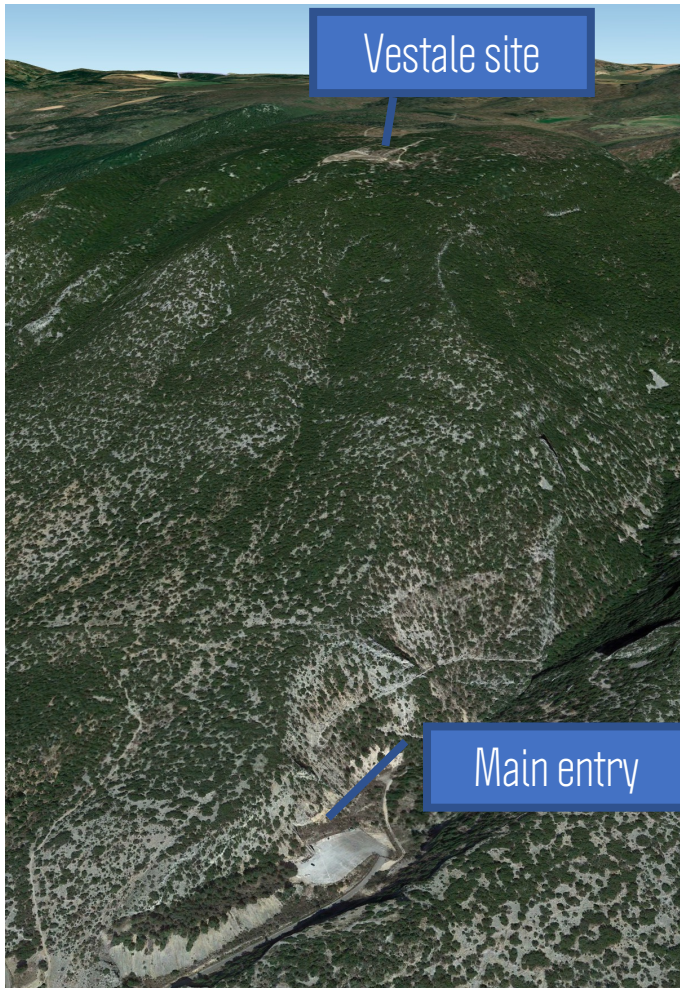


Done in 2020
Data analysis in progress



- ▶ Seismometer 3C - surface : 105 sensors
- ▶ Accelerometers 3C – galleries : 200 sensors
- ▶ 3km fiber - galleries
- ▶ Shot zone : depth 10 - 500m
- ★ - Inside and outside galleries





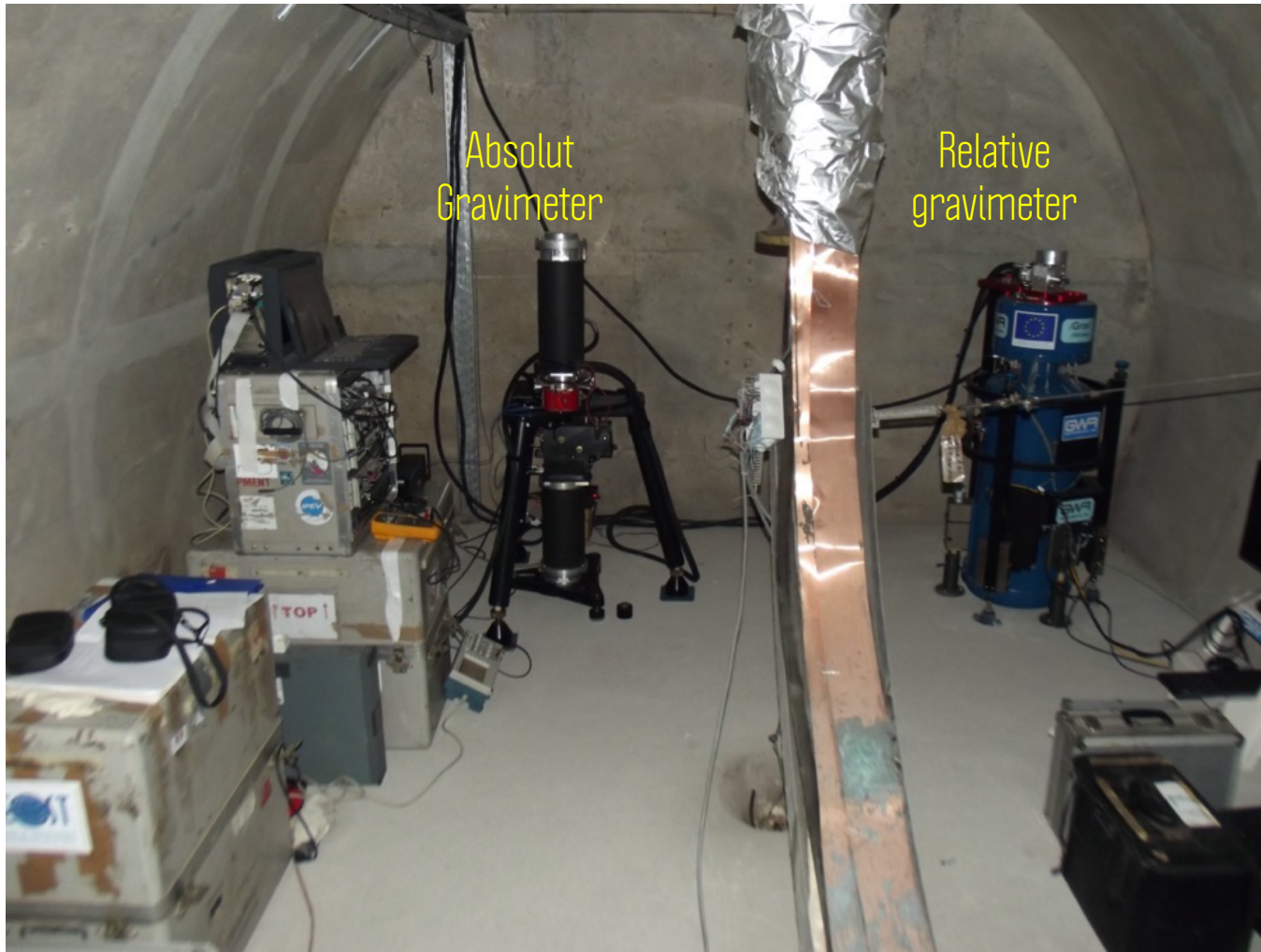
- Permanent network of detectors with 6 different teams/technologies
 - CEA/DASE
 - Czech academy of sciences
 - Denmark technical university
 - Toulouse University
 - Bath University
 - AGH University of Science and Technology in Krakow

Magnetometry (LSBB + AU + USMB)



- Main applications :
 - -Magneto-hydro-seismic coupling
 - -Earth/ionosphere coupling
 - -Monitoring of atmospheric and spatial phenomena
- Why at the LSBB ?
 - -The underground shielded vault acts as a 40Hz low pass filter. Extremely low background noise.

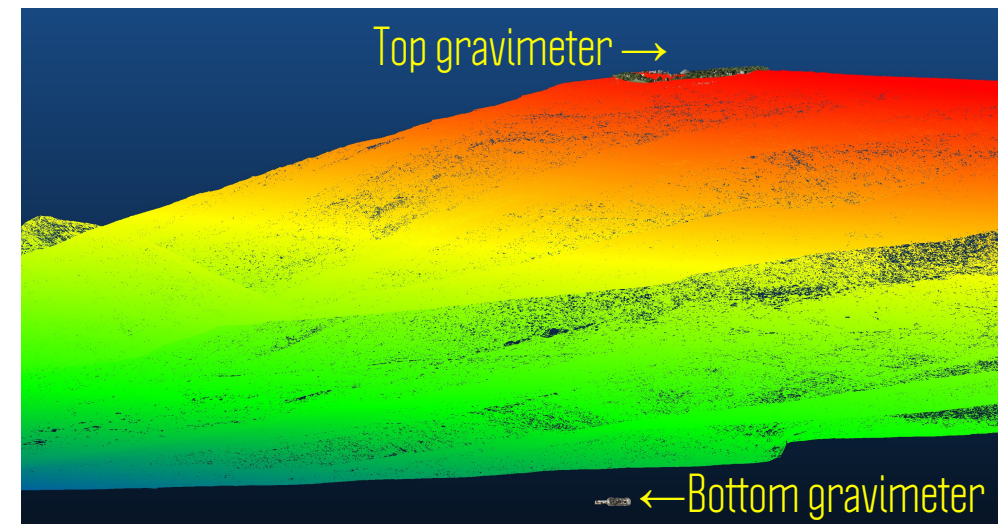
Gravimetry (LSBB +ITES)



Main applications : background gravimetric measurements for MIGA

Why at LSBB ?

- Outstanding S/N and accuracy
- Ultra low data drift
- 3D setup (surface underground)

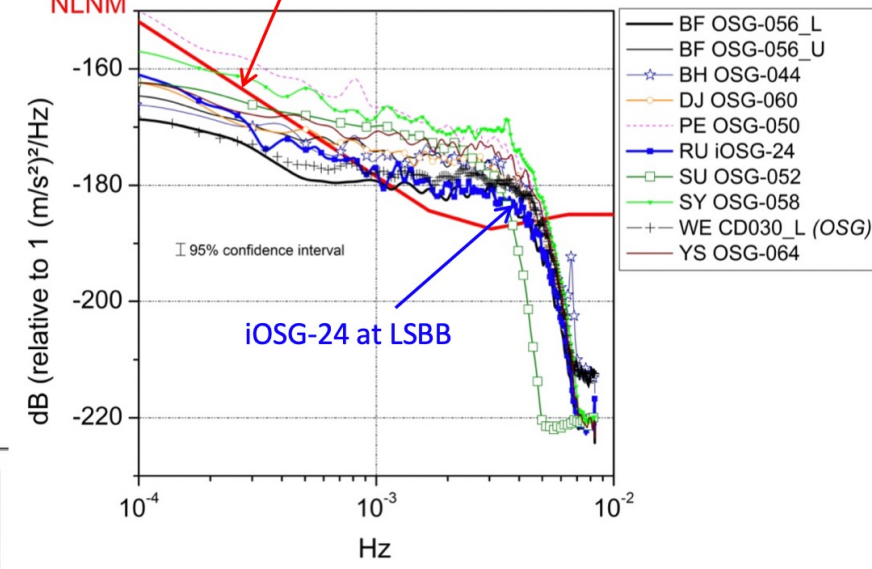
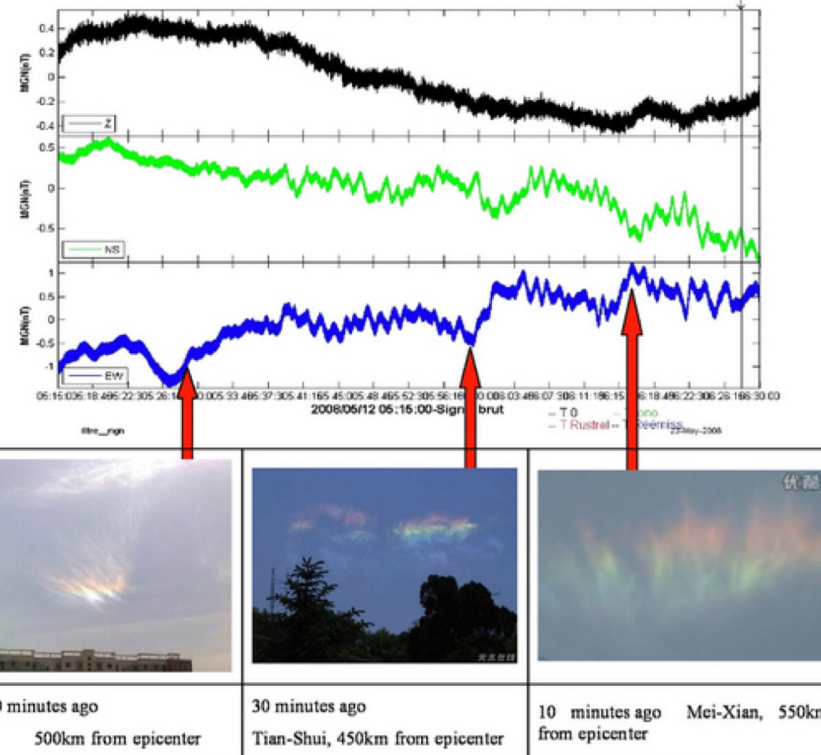
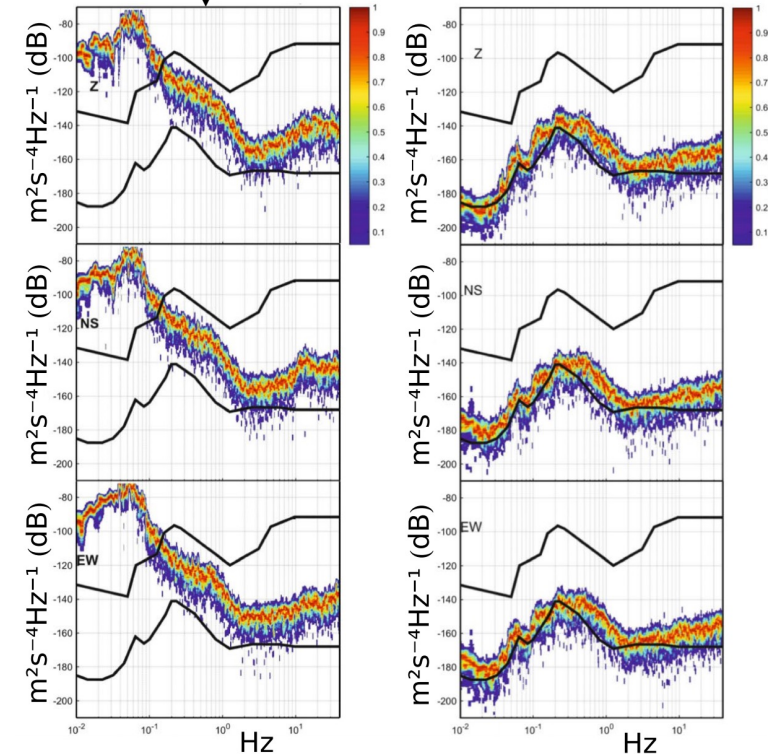


Tohoku-Oki
earthquake
(11/3/11)

Quiet day

Ultra-sensitive magnetometry
Earth/ionosphere couplings

Seismological New Low Noise Model (Peterson, 1993)

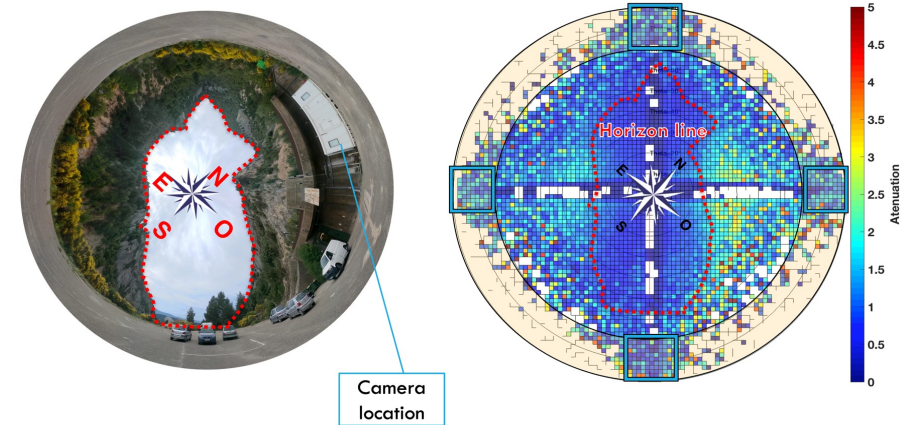
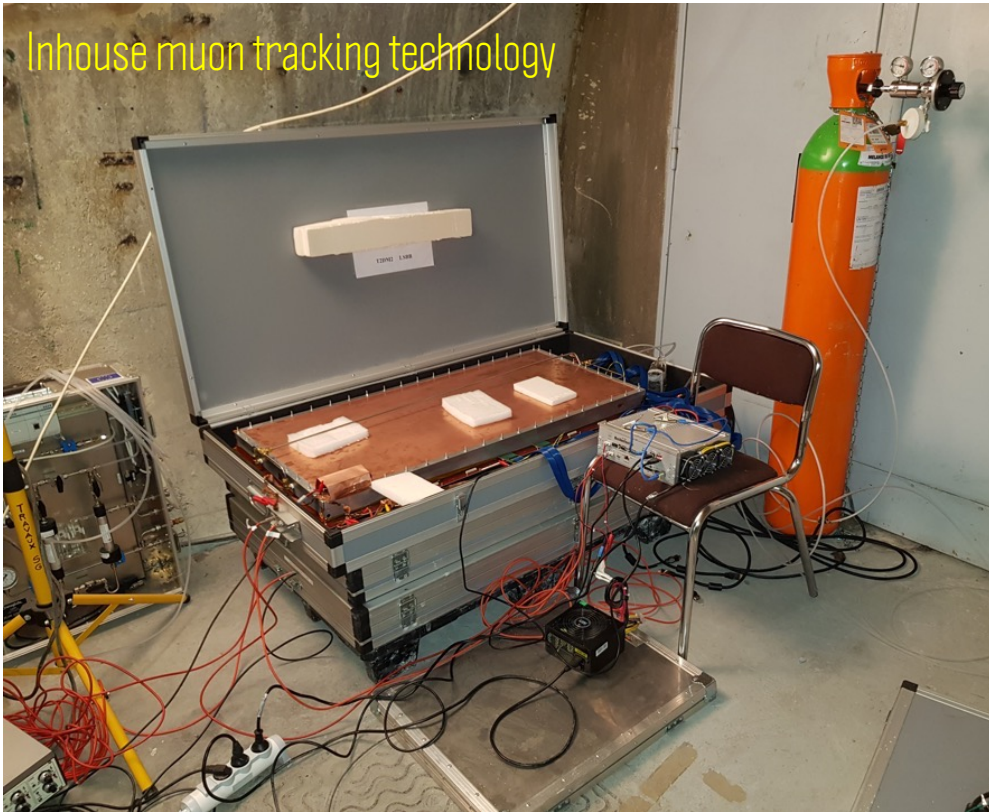


Low-noise seismic properties

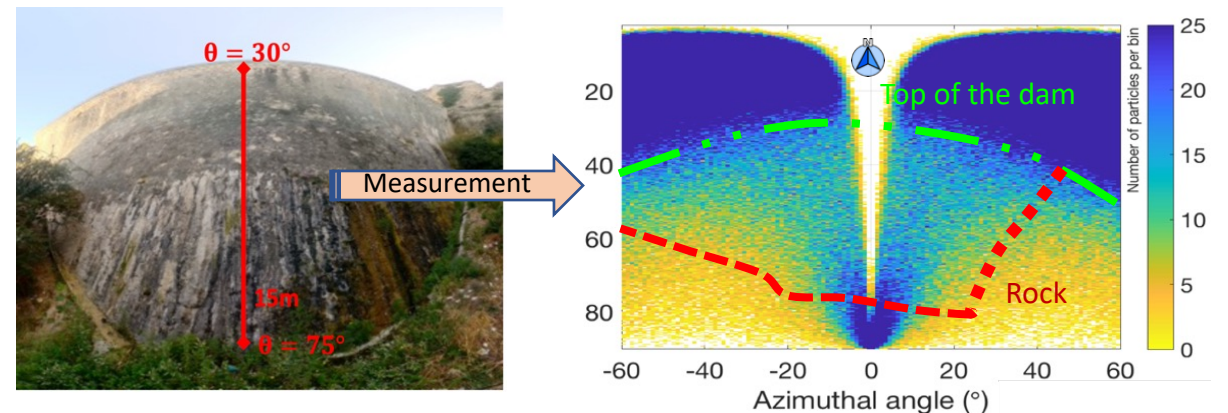
Seismic noise PSD for three components
(top, Z; middle, NS; bottom, EW)
compared to Peterson's high and low noise models
(black lines).

Sichuan-Wenchuan Earth Quake, May 12, 2008 (Mw 8.1)

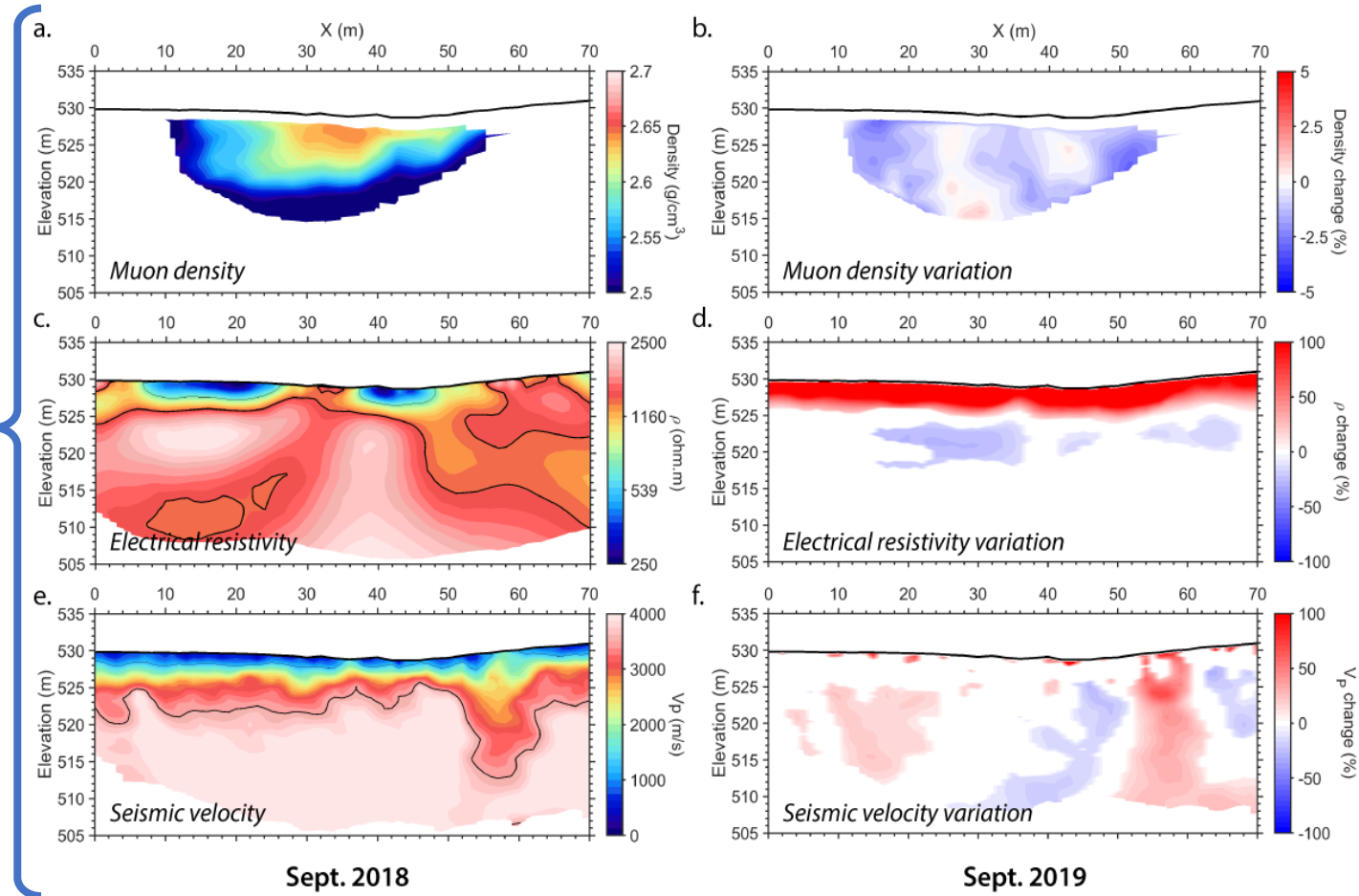
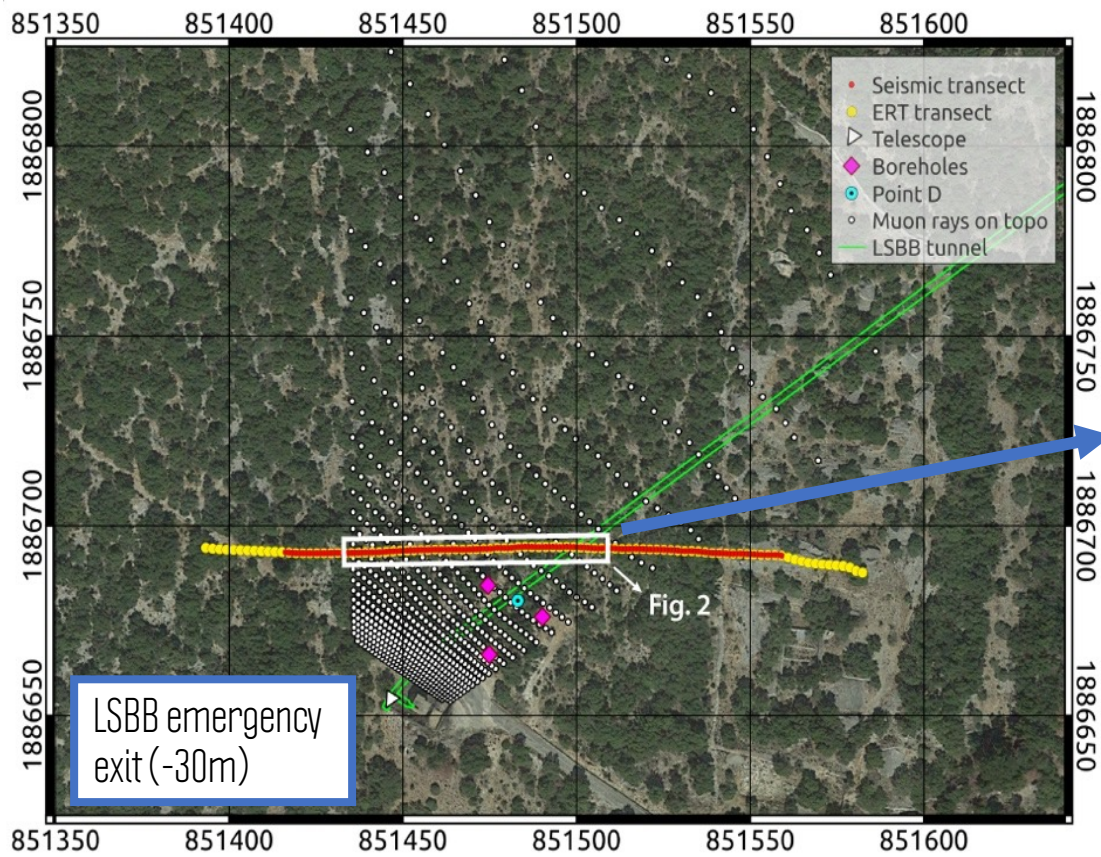
Superconducting gravimetry
One of the quietest sites in the world



- Patented technology and ongoing valorization
- Network of 20 inhouse, autonomous, detectors
- Permanent setup for groundwater monitoring and mobile muon trackers for large civil structures survey.



Ref. Lázaro Roche, I. A Compact Muon Tracker for Dynamic Tomography of Density Based on a Thin Time Projection Chamber with Micromegas Readout. **2021**. Particles. 4, 333-342.



Ref: Lázaro Roche, I.; Pasquet, S.; Chalikakis, K.; Mazzilli, N.; Rosas-Carbajal, M.; Decitre, J.B.; Batiot-Guilhe, C.; Emblanch, C.; Marteau, J.; et al.

 Water resource management: The multi-technique approach of the Low Background Noise Underground Research Laboratory of Rustrel, France, and its muon detection projects.

 In Muography: Exploring Earth's Subsurface with Elementary Particles. **2021**, Geophysical Monograph Series; Oláh, L., Tanaka, H., Varga, D., Eds. American Geophysical Union, USA. DOI:10.1002/9781119722748.ch10

Resources

- Karst
- Underground Water Resources
- Carbonated platform

Environment/ fluid interactions

- Processes and thermo-hydro-mechanical couplings
- Poroelasticity
- Geomechanics

Waves, radiation and astrophysics

- Seismology
- Magnetism
- Gamma
- Neutrons
- Muons
- WIMPs (DM)
- Atmospheric electrical phenomena

Instrumentation and metrology

- Magnetometry
- Gravimetry
- Densitometry
- Seismometry
- Rotation
- Clinometry
- Optic fiber
- Electronics characterization
- New tools development

Life

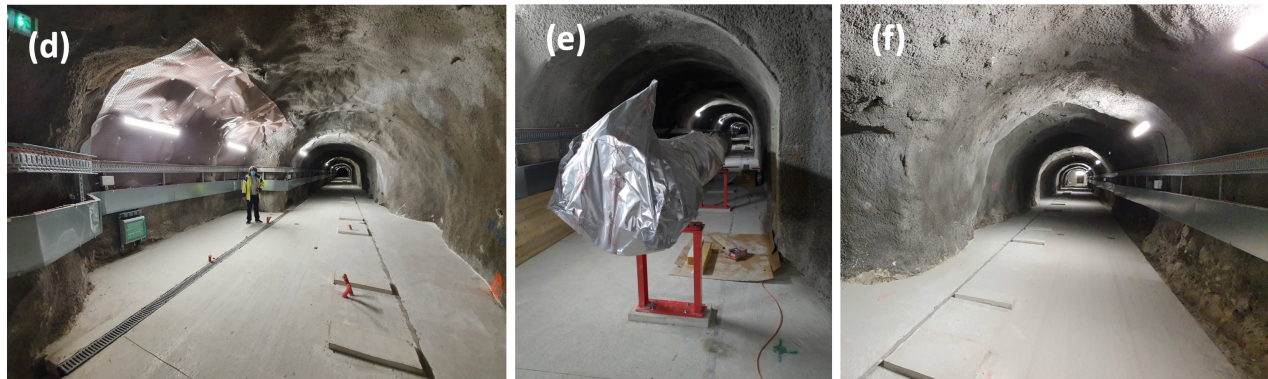
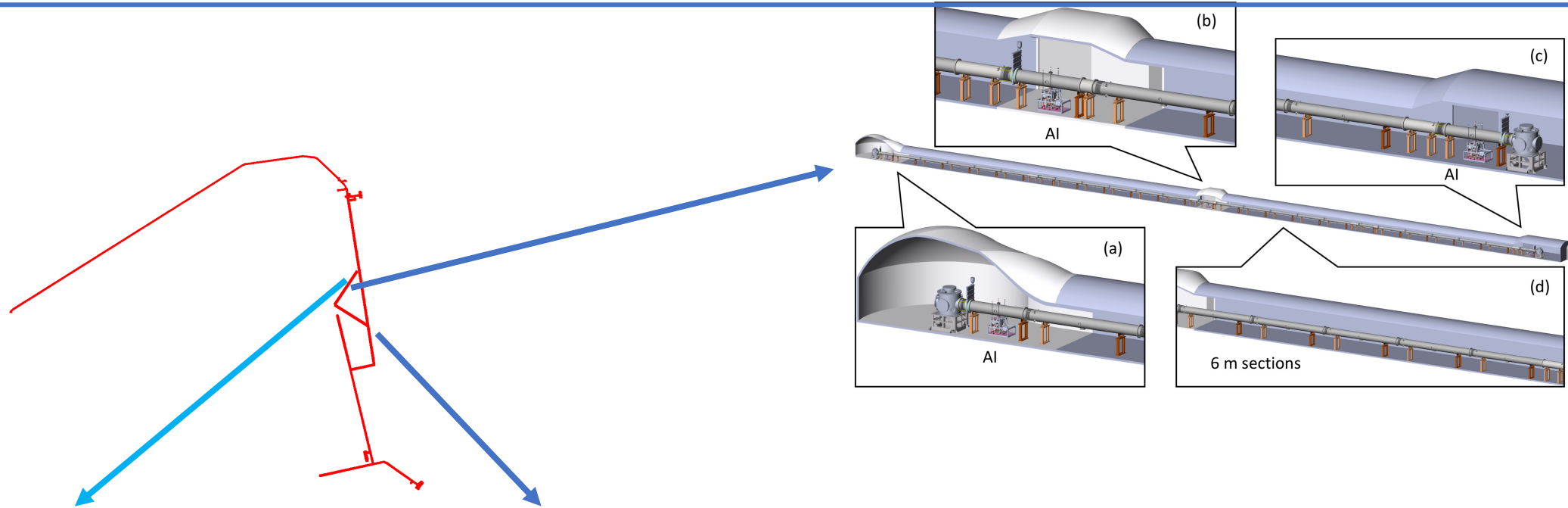
- Geobiology
- Brain imaging

Human science & society

- Contemporary History vs Cold War
- Anthropization vs Global Changes

Open to everyone

Kind of network/Consortium	Name	Description
International Laboratory	IRP Maxwell Berger Lab.	(With U. of British Columbia) Focused on high sensitivity EEG, GPR and MEMS
Eu. Research Infrastructure Con.	ECCSEL	European Research Infrastructure for CO ₂ Capture, Utilization, Transport and Storage
Eu. Plate Observing System	Résif	European research infrastructure in solid Earth sciences
Innovative Training Network	SPIN	Seismological Parameters and INstrumentation
National observatory	H ⁺	Network of hydrogeology experimental sites
	FORKARST	Karst hydrogeology
	TELERAY	Network for radioactivity alert for national security
Equipex	MIGA	Laser based Interferometer Gravitation Antenna
	OZCAR	Critical zone instrumentation
	REFIMEVE	Ultra-stable optical frequency on Internet over long-distances (Ongoing connection)
CERN collaboration	RD51	Development of advanced gas-avalanche detector technologies
	DRD1	Gaseous detector technologies
International organization	Muographers	Development of Muographic techniques and applications
International network	SQUID	Superconducting magnetometer measurements
	ELGAR	European Laboratory for Gravitation and Atom-interferometric Research
	Einstein telescope	Gravitational-wave observatory



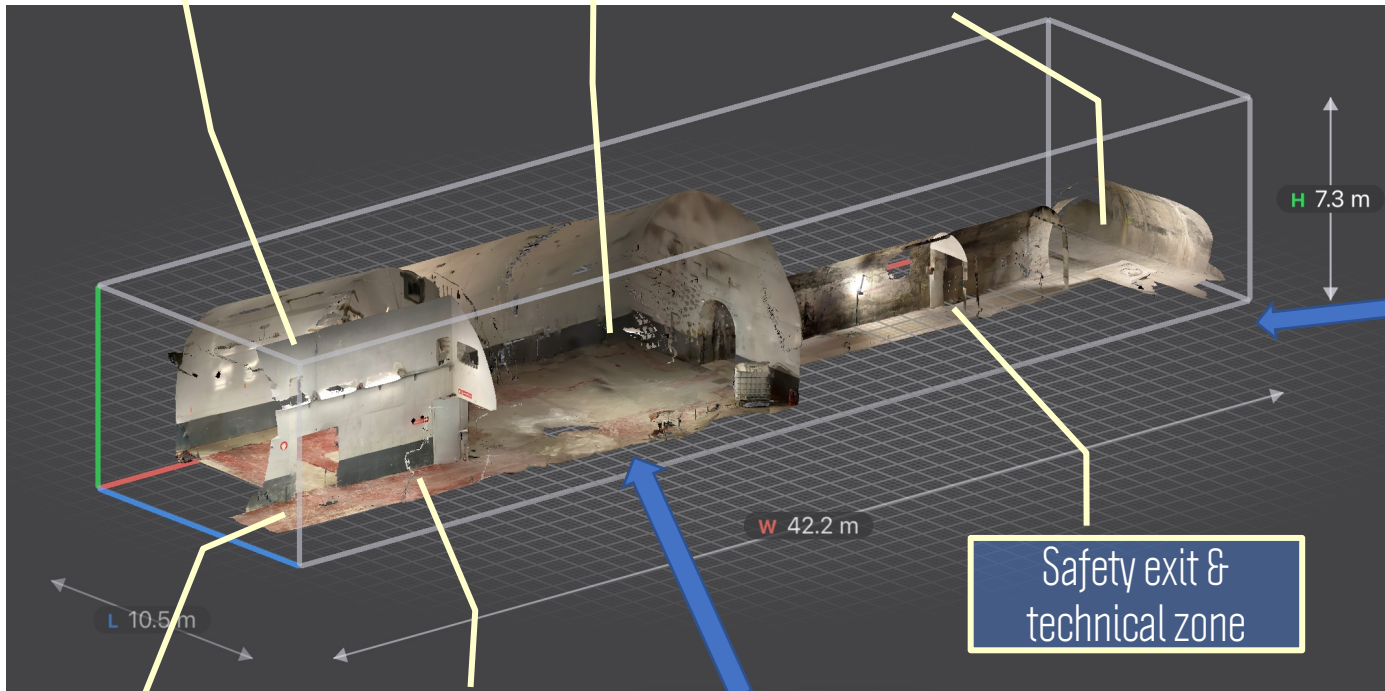
- 2X150m new horizontal ad-hoc galleries
- To host an underground long baseline atom interferometer to study gravity at large scale (MIGA)
- Fully equipped (airlock, high voltage, HS internet, OpFib. for seismic, high-resolution clock...)
- Civil engineering works finished after 2y operations
- **The instrument is being deployed as we speak**

Ref. Canuel et al., Sci. Rep. 8 (1), 14064 (2018)

Monitoring room

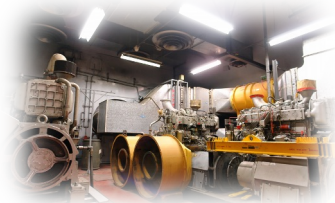
Metrology room

Secondary gallery

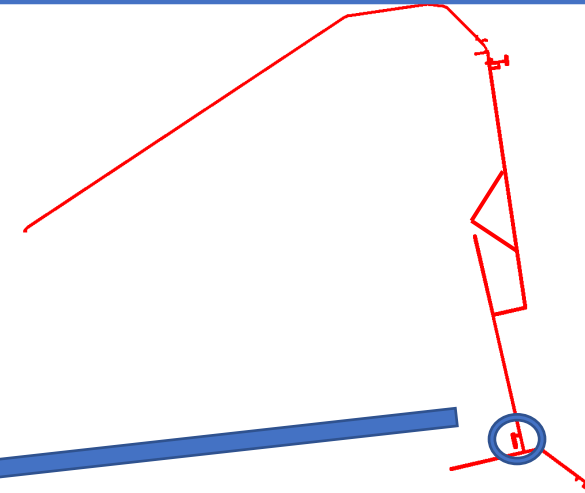


To main gallery

Airlock



Room that used to host the power generators



- Remarkably low thermal amplitude $\sim 0.02^{\circ}\text{C}/\text{day}$
- Located at $\sim 60\text{m}$ depth
- Multipurpose high-sensitivity/resolution metrology room ($\sim 1000\text{m}^3$)
- Different workspaces for research and industrial projects
- Conversion in progress

The LSBB is...

- A **multidisciplinary** platform
 - with **unique infrastructure**
 - in a remarkable and **well-known environment**
- **Highly equipped** for terrestrial, atmospheric and astrophysical observation
- **Contributing** to several observatories
- Leading multiple **research** projects
- Capable of **hosting multi scale projects** for fundamental research and industry
- Currently **expanding and enhancing** its facilities
- **Open for collaborations**

Thank you for your attention

