



LOW BACKGROUND NOISE UNDERGROUND RESEARCH LABORATORY OF RUSTREL

Ignacio LÁZARO ROCHE

LSBB delegate for Deep Underground Laboratories workshop

LNGS 2022

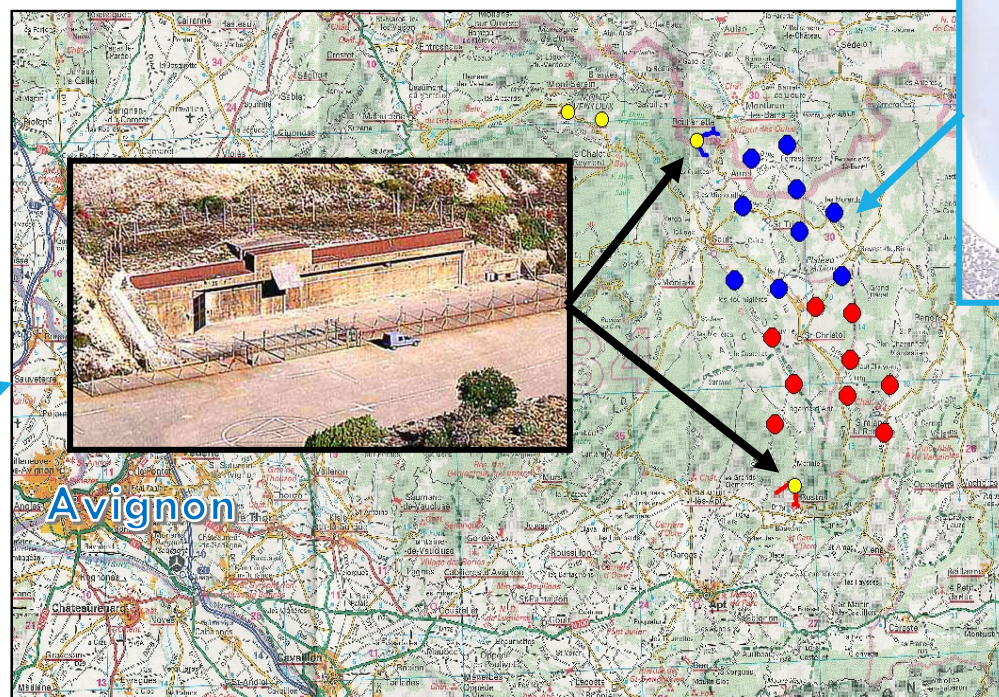


NUCLEAR DETERRENCE TO KEEP THE PEACE



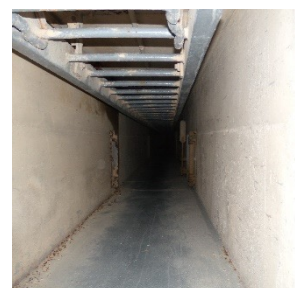
Figure from MODIS project by NASA.

- Creation of Strategic Missile Groupe *ALBION* in 1965
- Operational since 1971

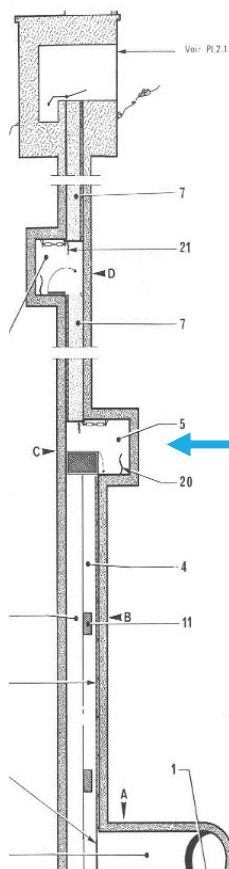


- 18 Ground-Ground Strategic Ballistic Missiles
- 1Mt each, 3.000 km reach
- 2 twin launching sites

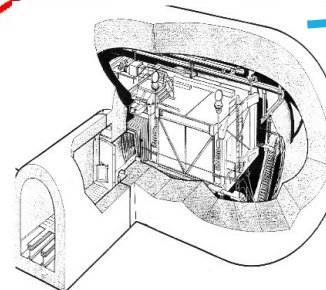
CONCEIVED TO RESIST A NUCLEAR ATTACK... AND STRIKE BACK



Safety exit well
(-30m)



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



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



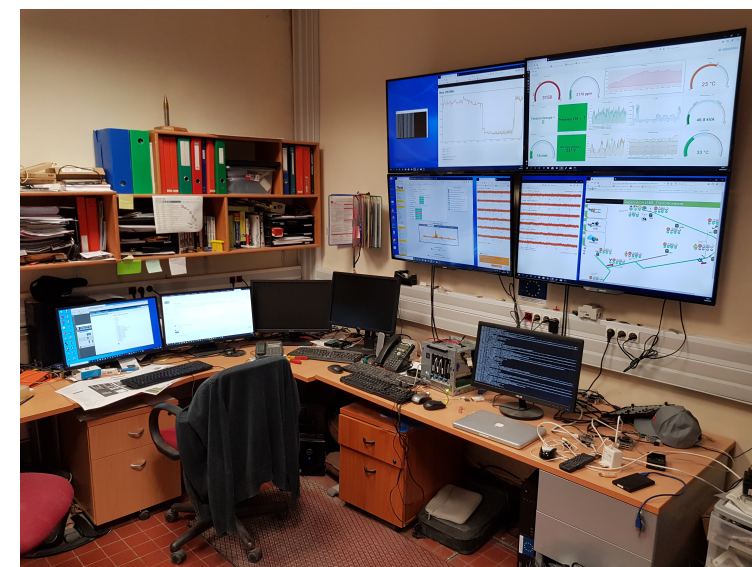
Two antiblast
galleries



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

FROM MILITARY BUNKER TO RESEARCH LABORATORY

- The end of the cold war and the use of nuclear submarines to carry the nuclear missiles lead to the dismantling decision in 1996
- Conversion in a research laboratory in 1997
 - Involved institutions:
 - French Defense & Research Ministries
 - French research structures CEA and CNRS
 - Universities of Nice, Avignon and Marseille
 - Local and regional political institutions
- Partial dismantling completed in 1998

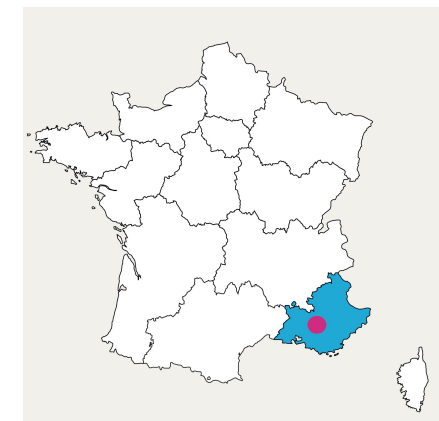
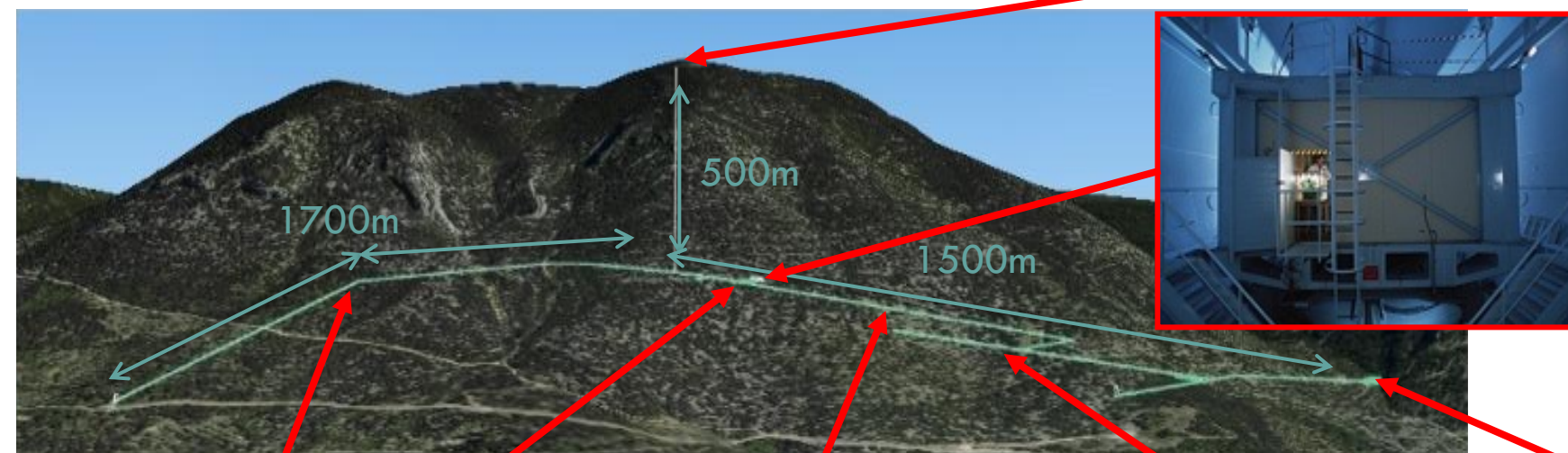


LOW BACKGROUND NOISE UNDERGROUND LABORATORY

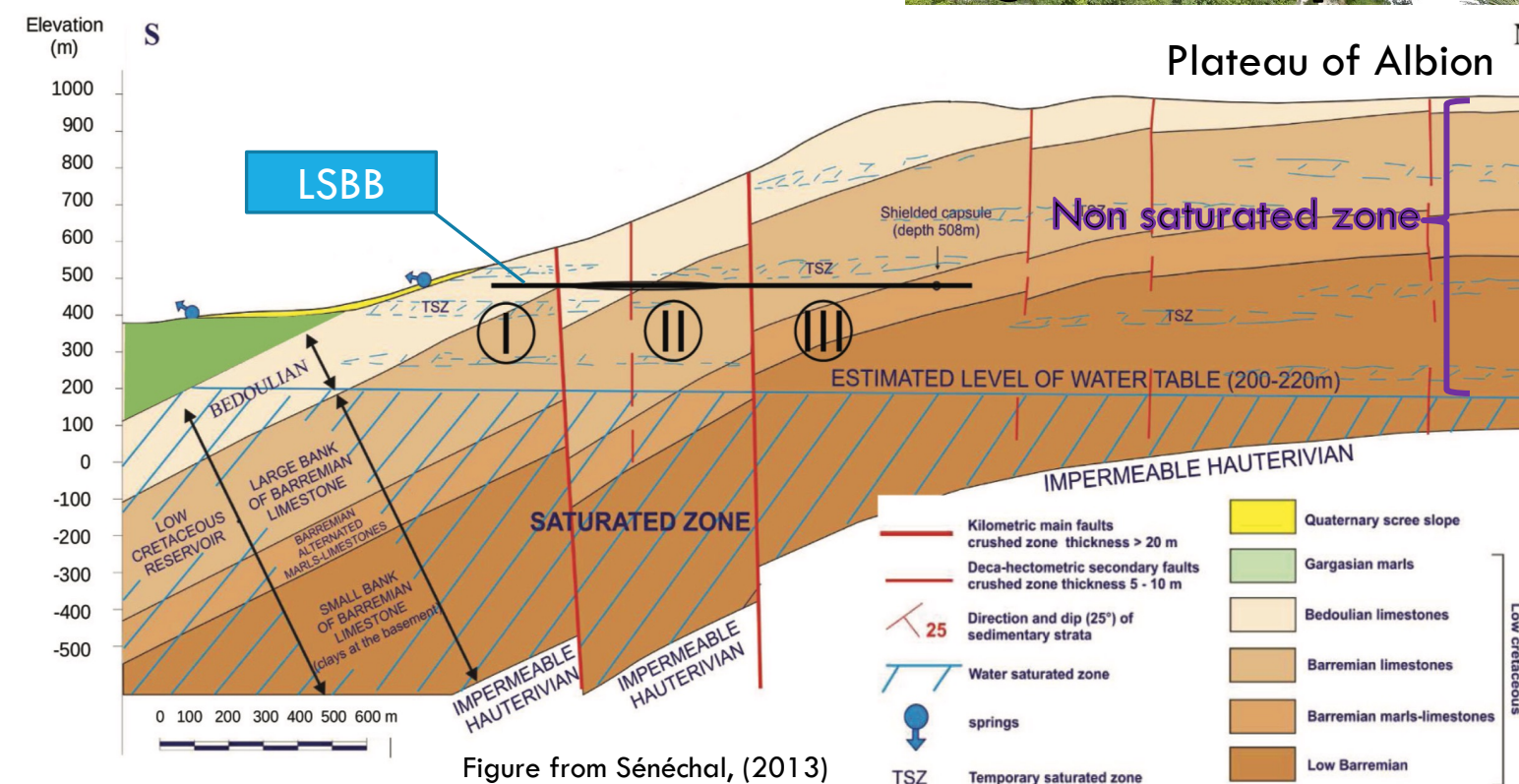
- Underground **and** surface unique facilities
 - 4.3km of galleries
 - 53 ha of surface



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

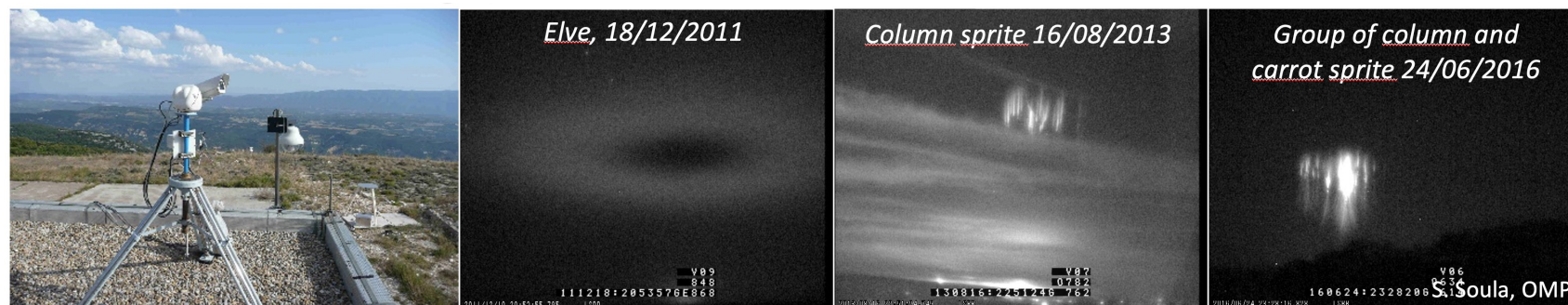
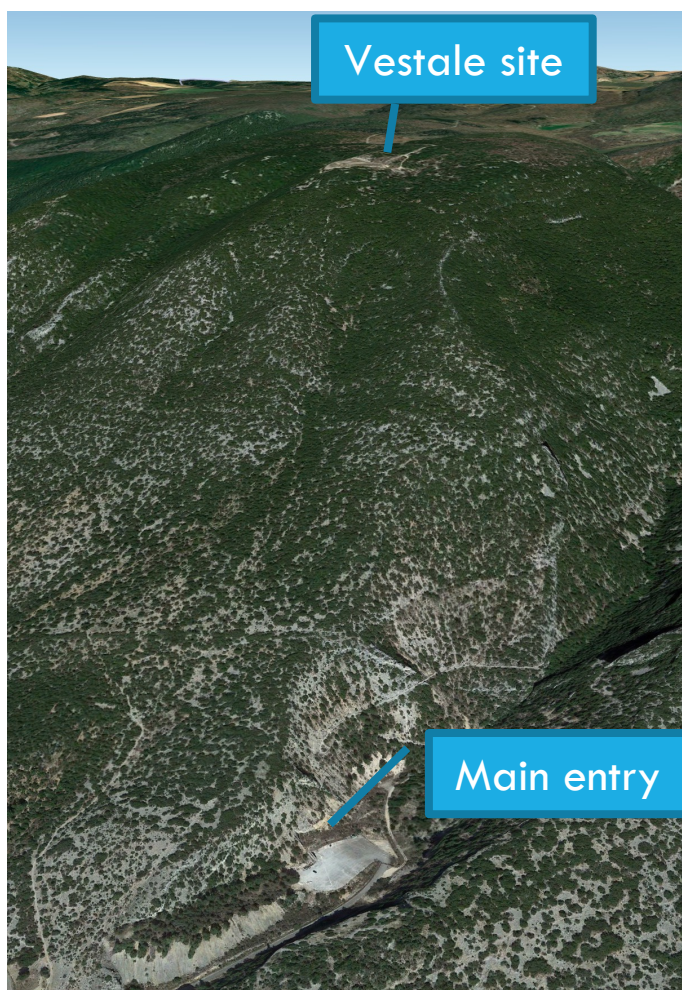


A CONVENIENT LOCATION



- 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

ATMOSPHERIC ELECTROMAGNETIC EVENTS

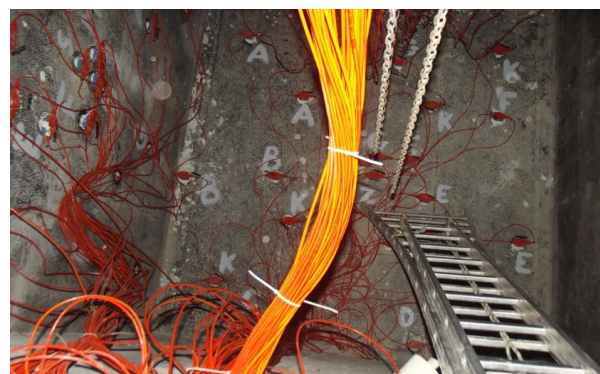
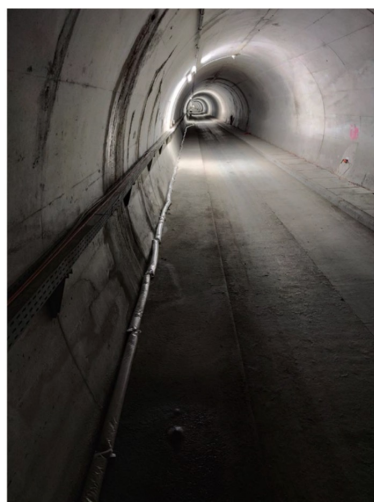


- Permanent network of detectors with 6 different teams/technologies
 - CEA/DASE
 - Czech academy of sciences
 - Denmark technical university
 - Toulouse University
 - Bath University
 - AGH University of Science and Technology in Krakow

SEISMIC –PREMISE EXPERIMENT (LSBB+CEA-DAM+FEBUS+SERCEL)



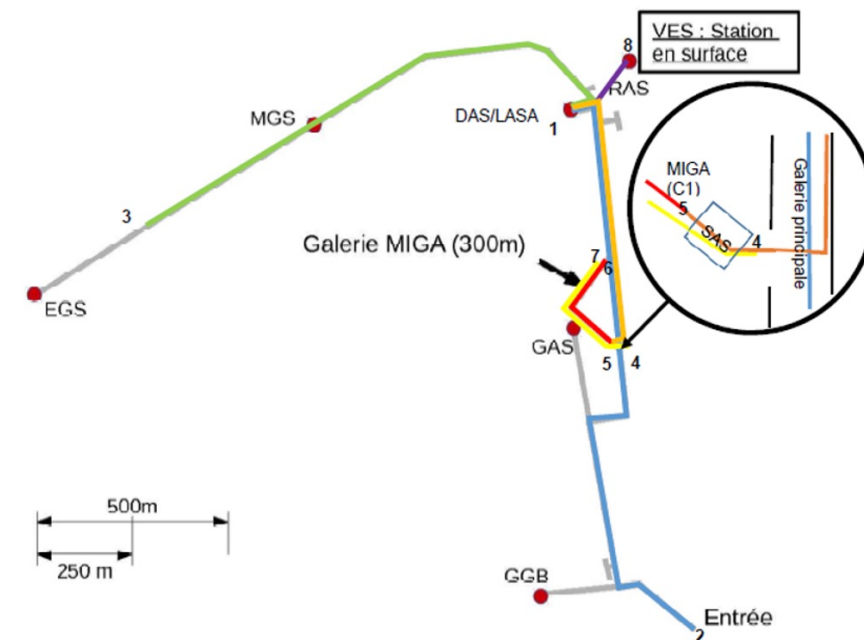
- ▶ **Seismometer 3C - surface : 105 sensors**
- ▶ **Accelerometers 3C – galleries : 200 sensors**
- ▶ **3km fiber - galleries**
- ▶ **Shot zone : depth 10 - 500m**
- ★ - Inside and outside galleries



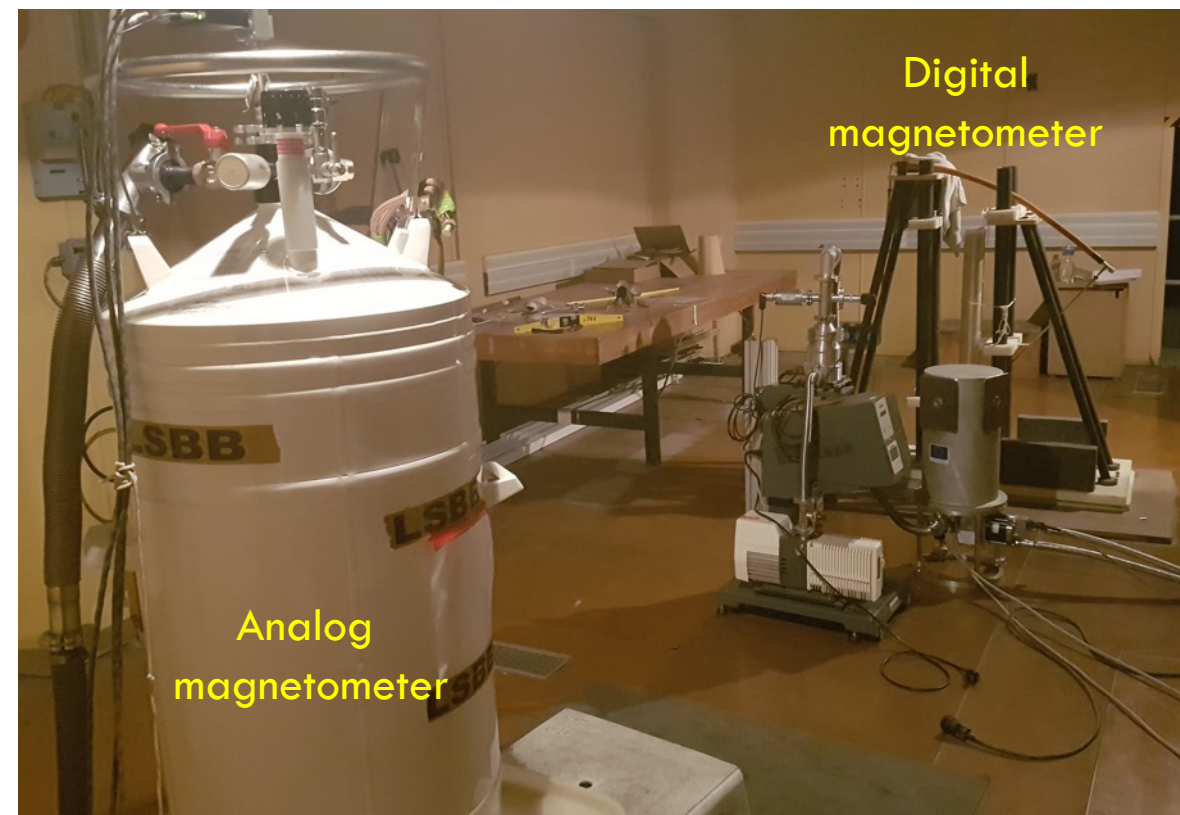
Done in 2020

Data analysis in progress

- 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)

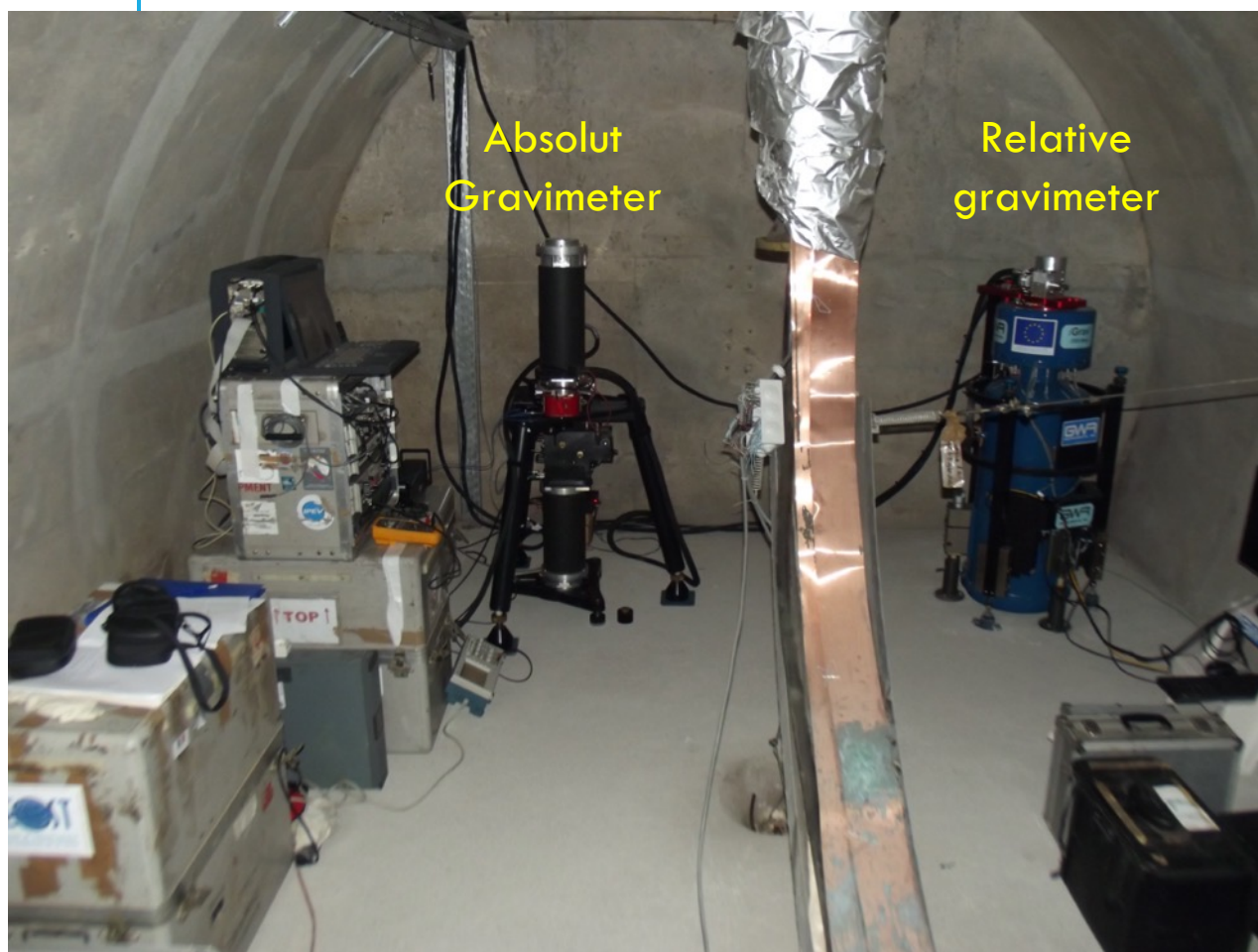


MAGNETOMETRY (LSBB + AU + USMB)



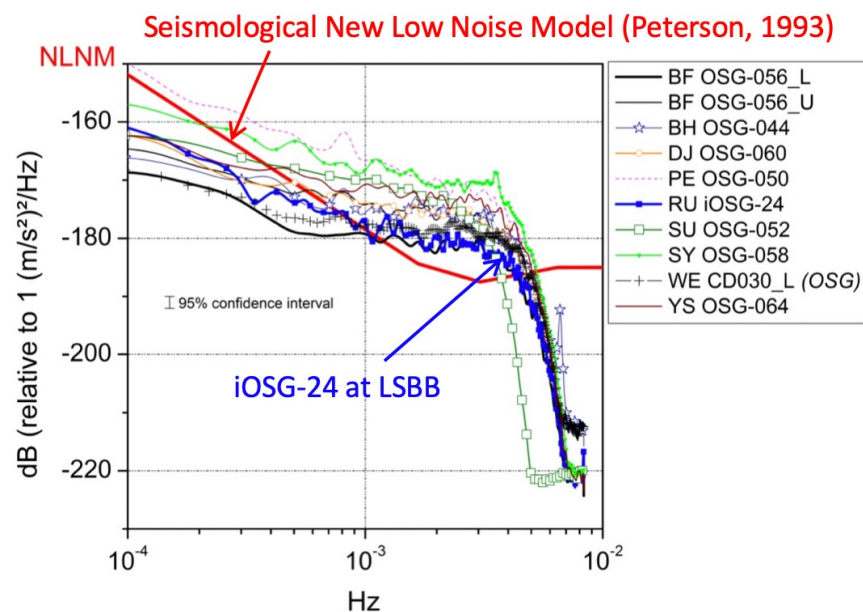
- Main applications :
 - Magneto-hydro-seismic coupling
 - Earth/ionosphere coupling
 - Monitoring of atmospheric and spatial phenomena
- Why at the LSBB ?
 - The underground shielded vault acts as a 40Hz low pass filter. Extremely low background noise.

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)

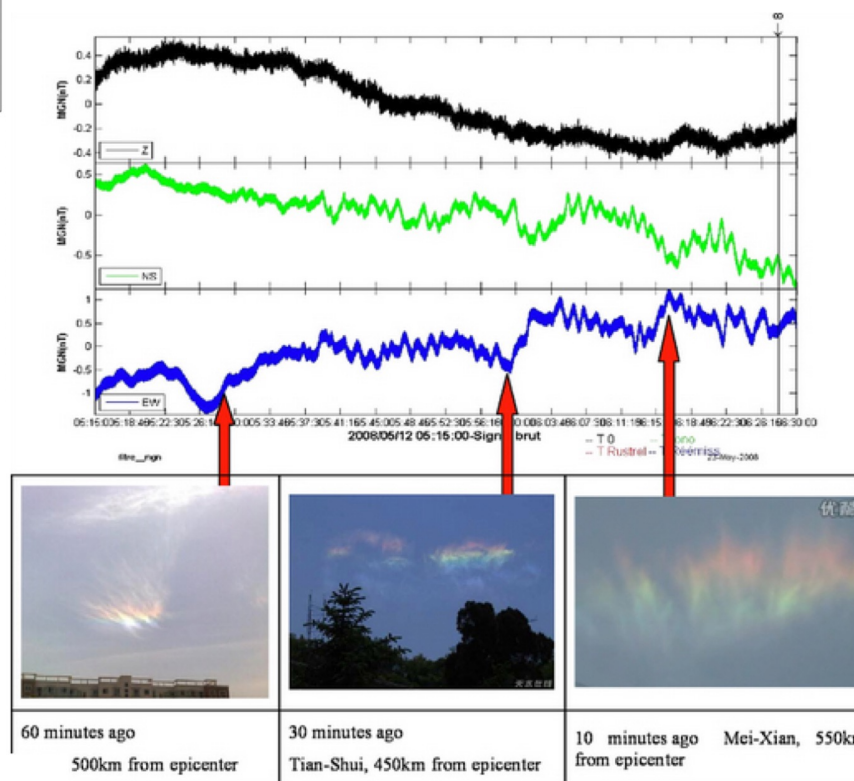


Superconducting gravimetry

One of the quietest sites in the world

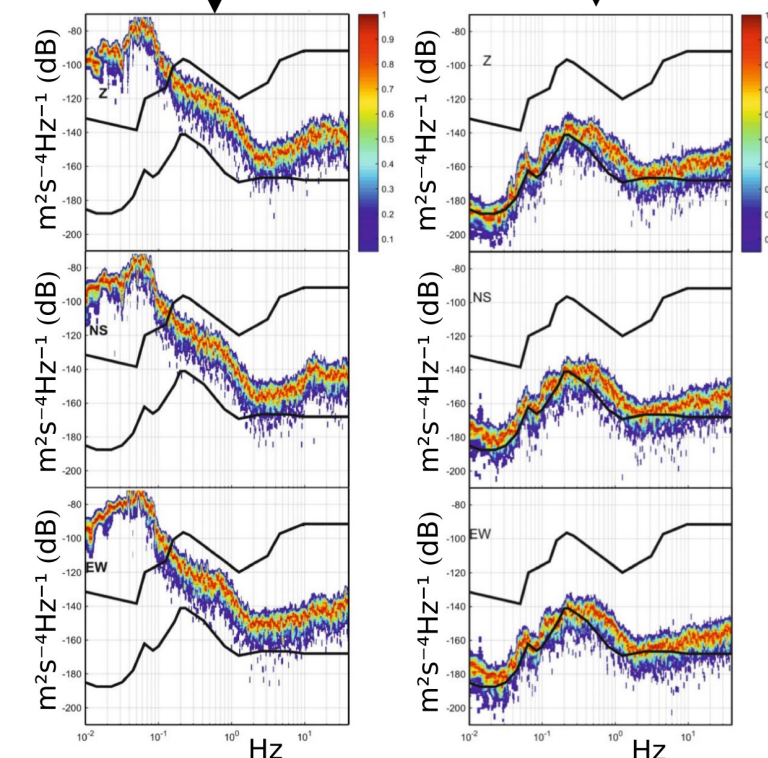
Ultra-sensitive magnetometry

Earth/ionosphere couplings



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

Quiet day



Low-noise seismic properties

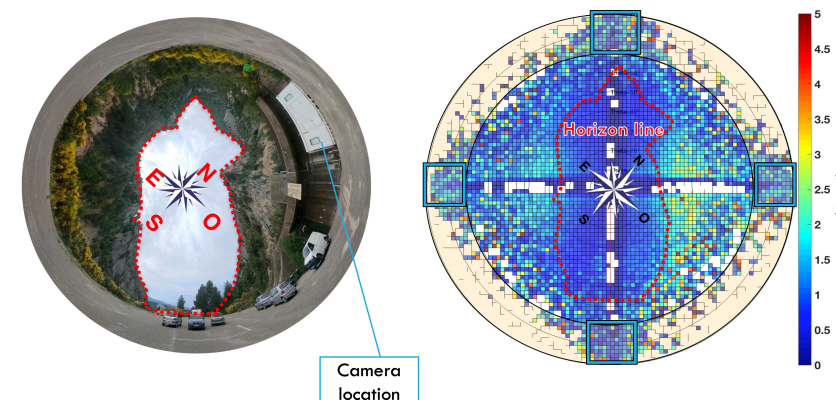
Seismic noise PSD for three components (top, Z; middle, NS; bottom, EW) compared to Peterson's high and low noise models (black lines).

DUAL ROLE: TEST SITE & DEVELOPER FOR MUOGRAPHY

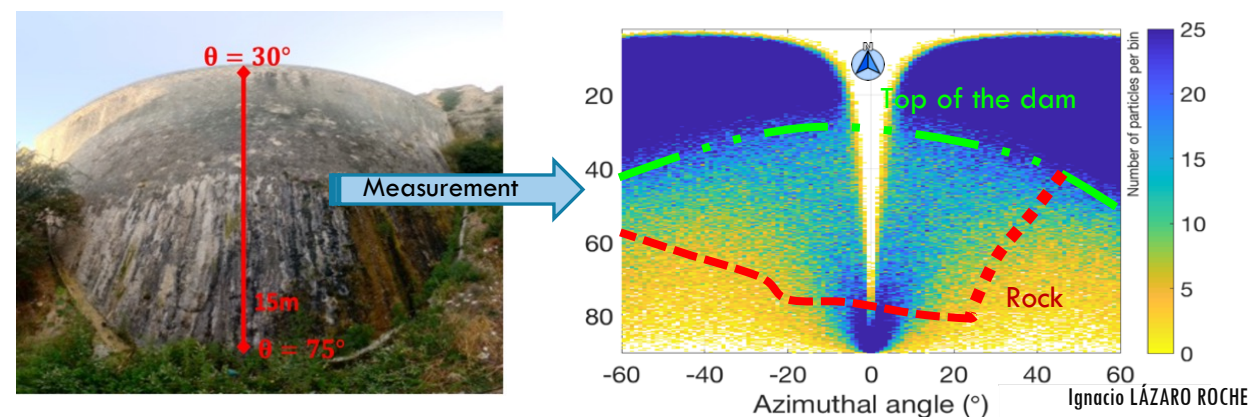
Inhouse muon tracking technology



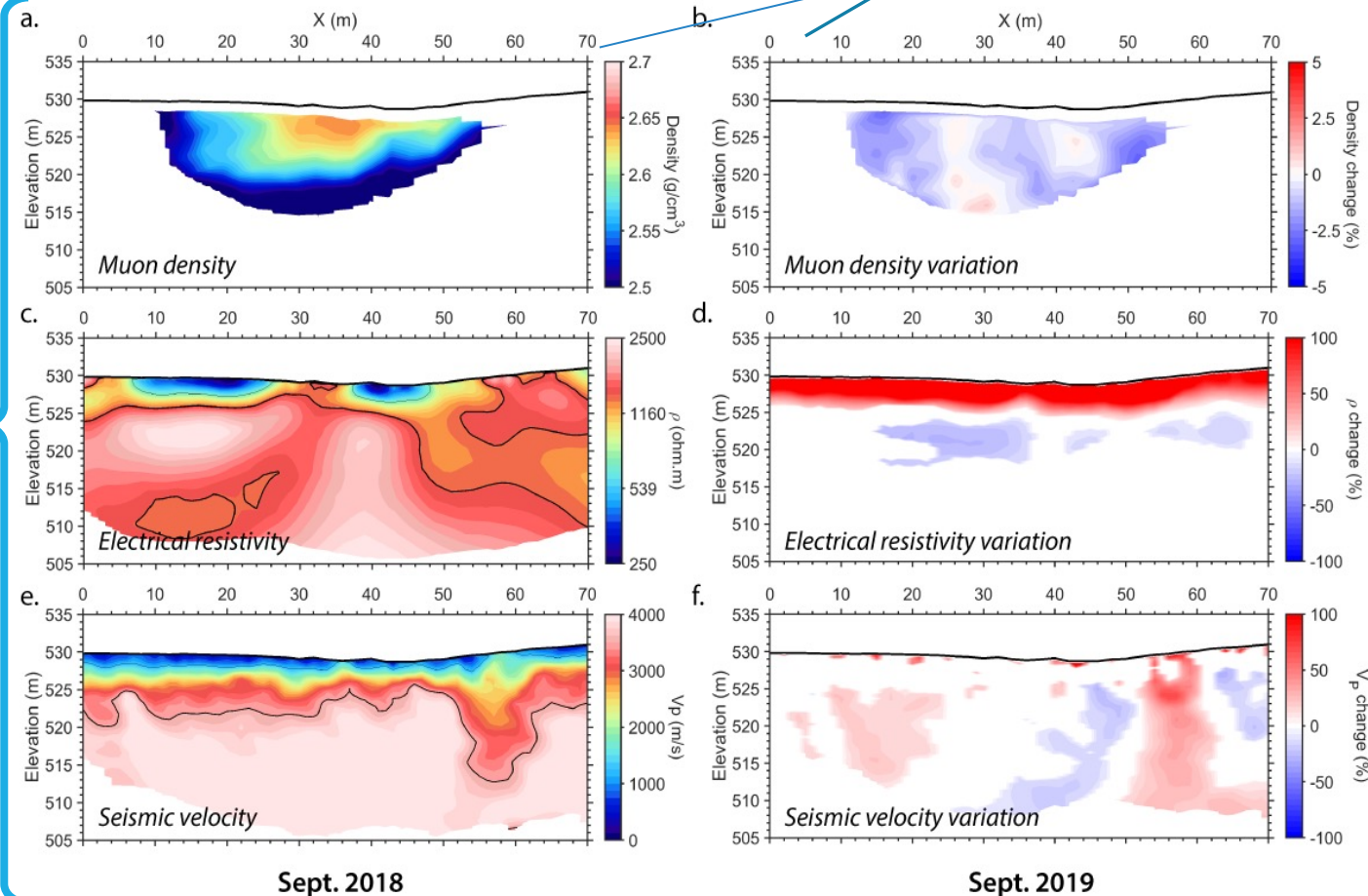
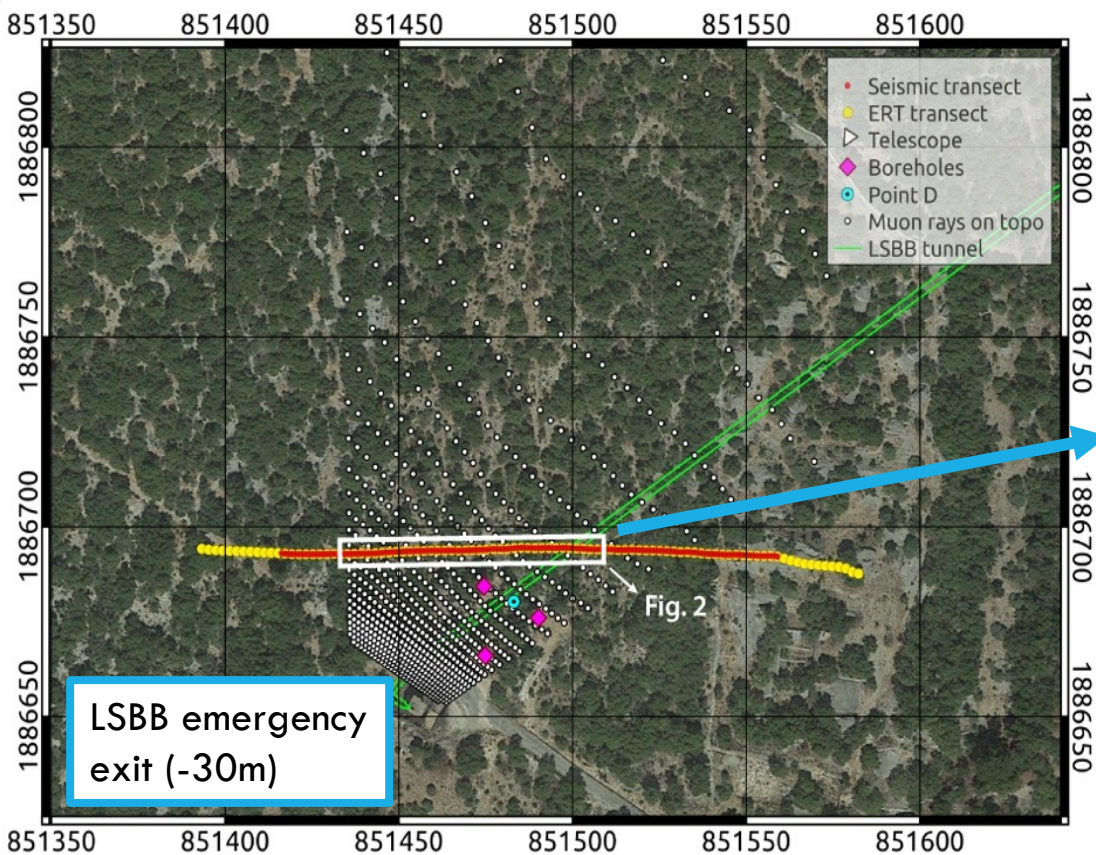
Ref. Lázaro Roche, I. A Compact Muon Tracker for Dynamic Tomography of Density Based on a Thin Time Projection Chamber with Micromegas Readout. **2021**. Particles. 4, 333-342.



- 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.



MULTI-TECHNIQUE APPROACH – THE BUISSONNIÈRE EXPERIMENT



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; Olah, L., Tanaka, H., Varga, D., Eds. American Geophysical Union, USA. DOI:10.1002/9781119722748.ch10

MULTIDISCIPLINARY AND WELCOMING

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

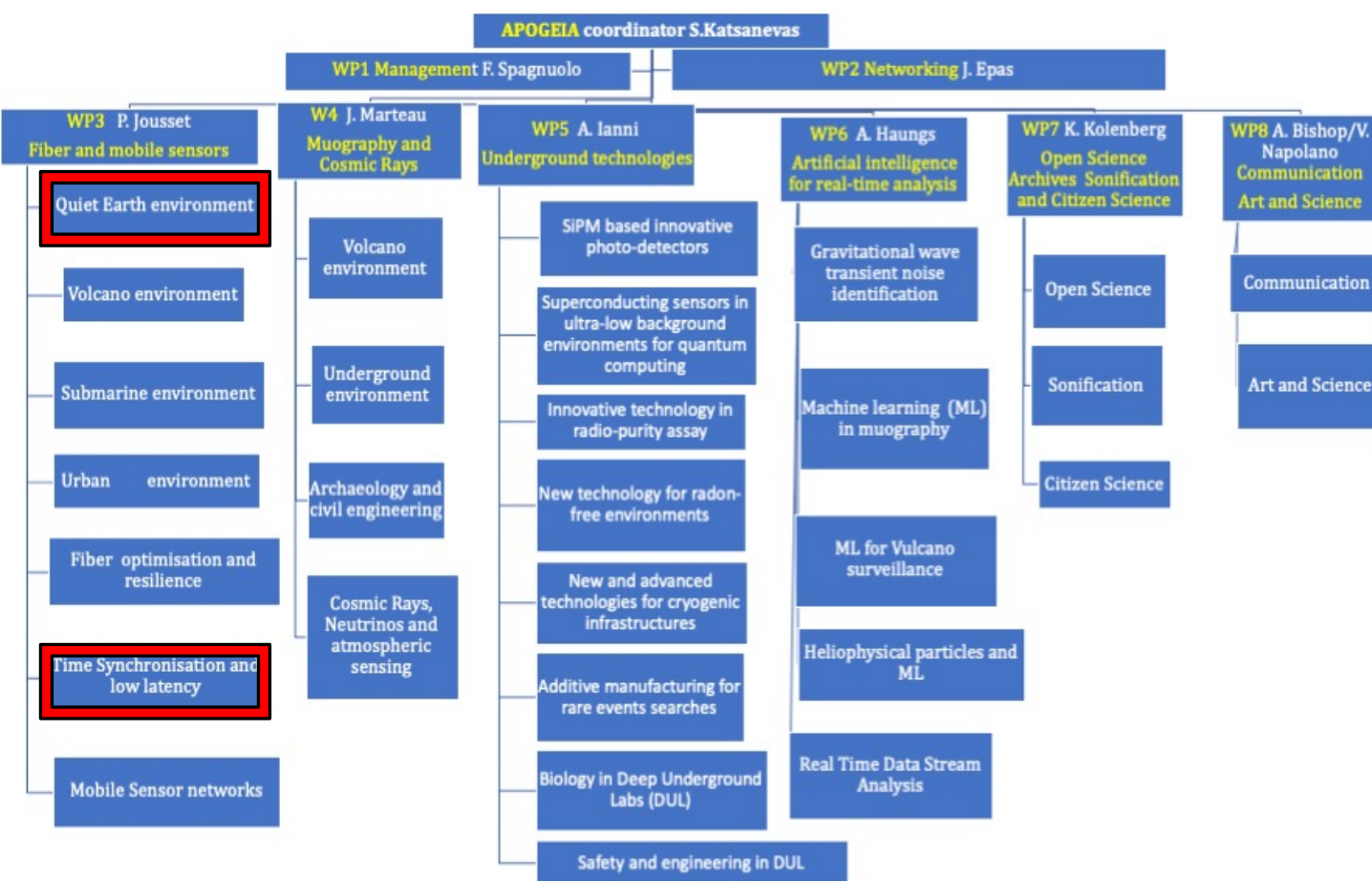
- Contemporary History vs Cold War
- Anthropization vs Global Changes

Open to everyone

APART, BUT NOT ISOLATED

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 Consortium	ECCSEL	European Research Infrastructure for CO ₂ Capture, Utilisation, 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
International organization	Muographers	Development of Muographic techniques and applications
International network	SQUID	Superconducting magnetometer measurements
Eu. Infrastructure	APOGEIA	AstroParticle Observatories and GEoscience

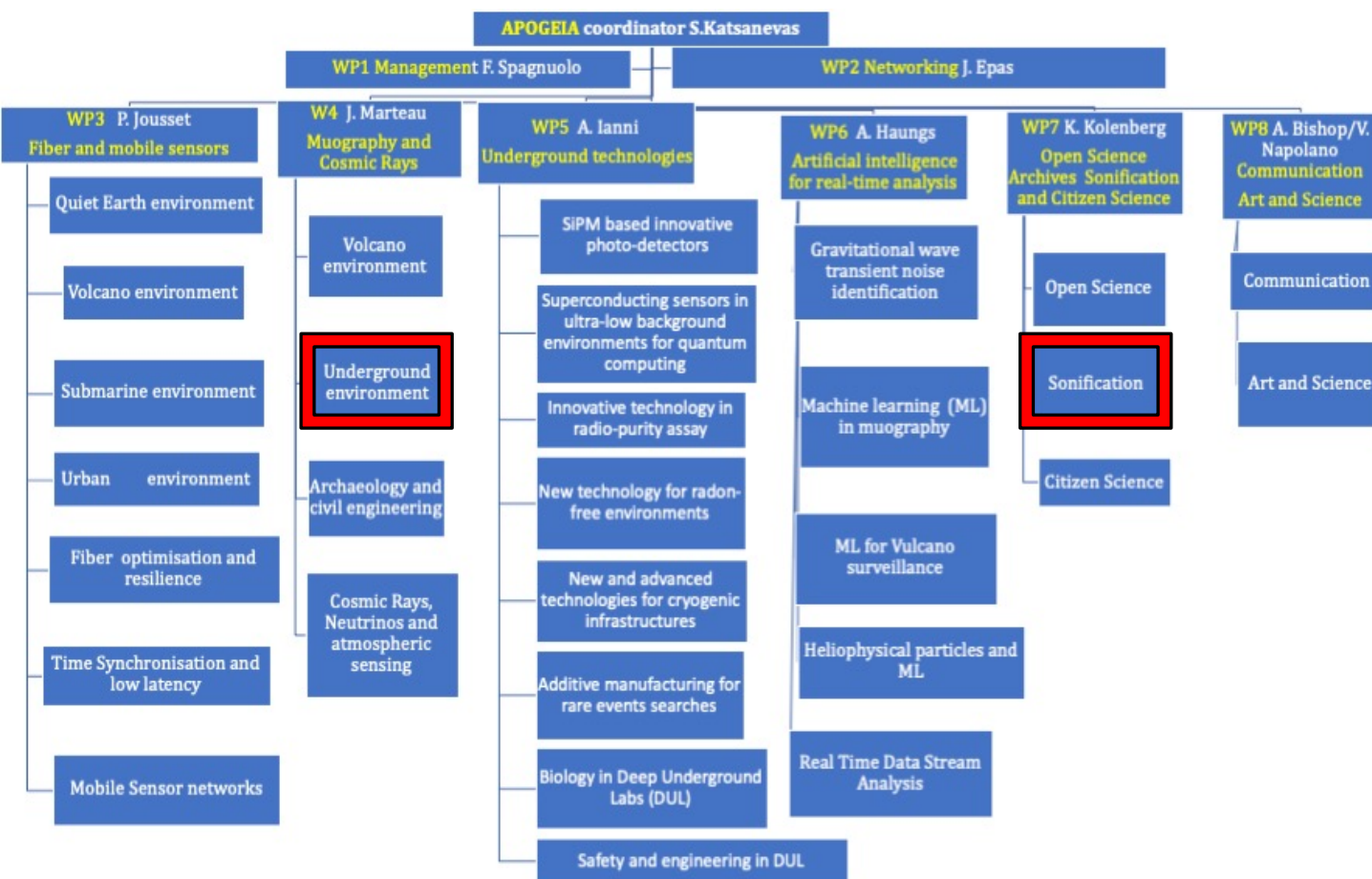
APOGEIA - LSBB CONTRIBUTION



■ WP3.

- Test site to assess the capability of various fibre optic instrumentation (interrogators) in quiet environments in order to reach the ultimate performance of OF technologies
- Perform and benchmark DAS (acoustic), DSS (strain) and DTS (temperature) continuous measurements of the ground noise
- Characterize the ground noise in quiet environments
- Network Synchronisation and time/frequency distribution

APOGEIA - LSBB CONTRIBUTION



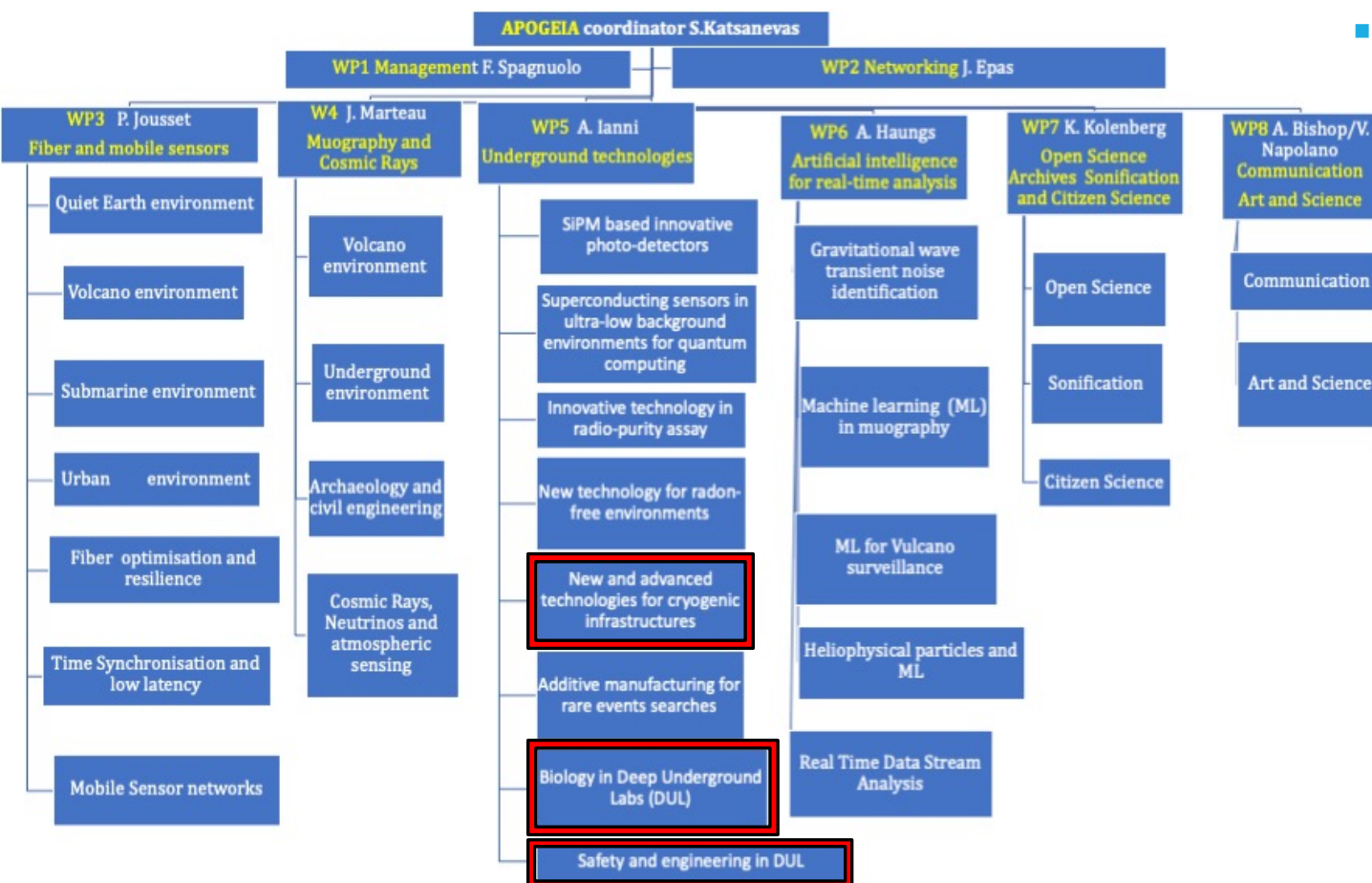
■ WP4.

- Benchmarking site for critical-zone muographic measurements.
- Multi- technique/technology/scale experiment

■ WP7.

- Data from Muographic acquisition will be sonificated

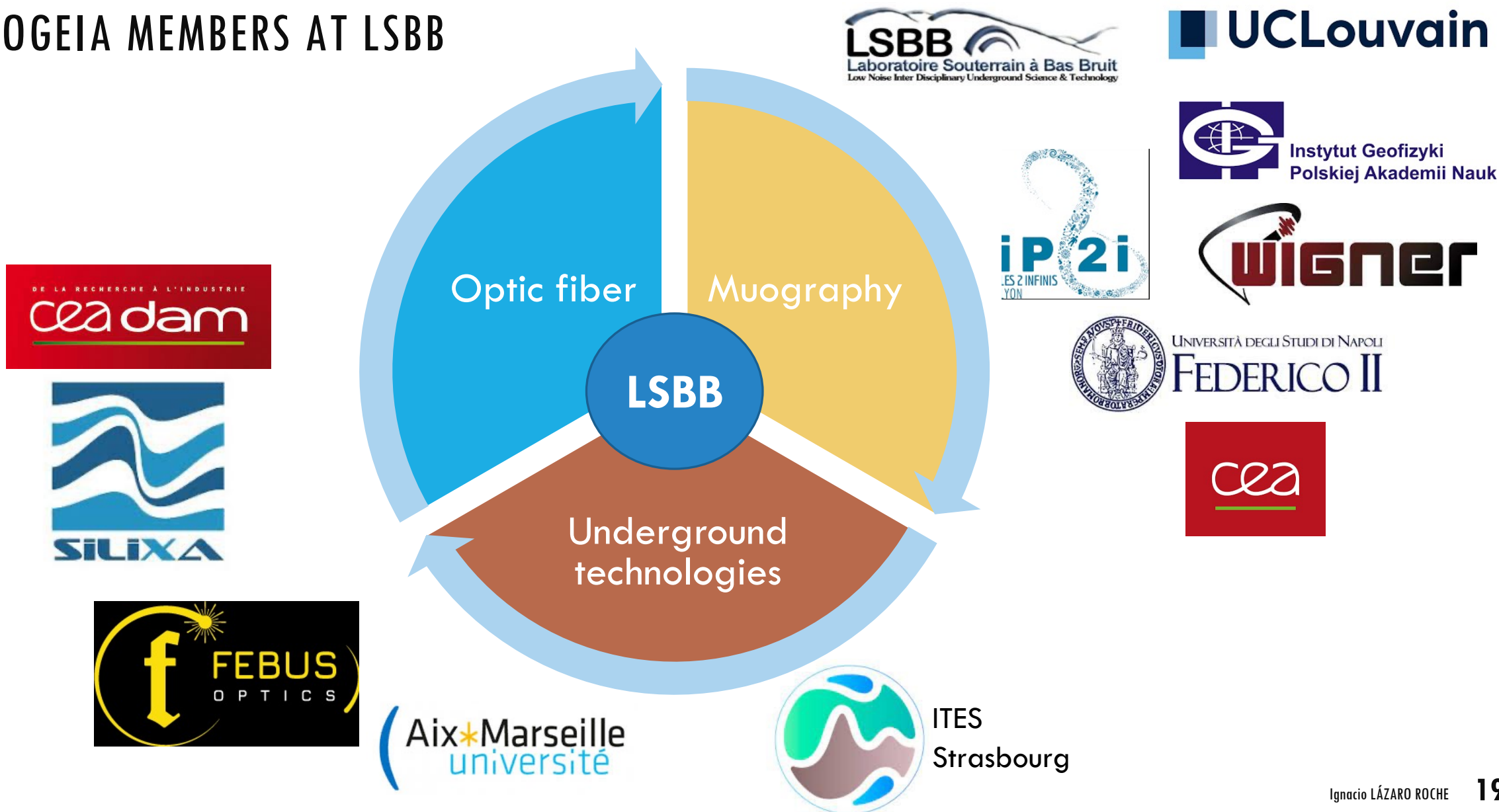
APOGEIA - LSBB CONTRIBUTION



■ WP5.

- The LSBB is equipped with two superconducting gravimeters, vertical to each other, and separated by 520 meters of rock.
- This unique configuration makes it possible to measure mass fluctuations with twice the sensitivity of a single gravimeter and provides sensitivity to lateral variations.
- Strong synergies with muographic measurements
- Characterization of microbiological material in karstic environment for water quality control
- Part of the European network for improving UL safety solutions.

APOGEIA MEMBERS AT LSBB



FOSTERING SYNERGIES

9TH EDITION OF THE INTER-DISCIPLINARY UNDERGROUND SCIENCE & TECHNOLOGY INTERNATIONAL CONFERENCE

Avignon, on June 7-9, 2022

Important deadlines

**Deadline extended
May 9th**

- ~~April 22, 2022~~ 300 words abstracts submission
- **July 1st, 2022** Full paper for publication on Web of Conferences (EDP Sciences)

Visit of the LSBB new facilities
June 7th in the morning

Invited talks

"AstroParticle Observatories and GEoscience Innovative Actions (APOGEIA)"

Stavros Katsanevas, APOGEIA consortium

"MIGA, a large scale gravity antenna using quantum technology" (<http://miga-project.org/>)

Benjamin Canuel, MIGA consortium

"Winlight System upcoming underground operations" (<https://www.winlight-system.com/>)



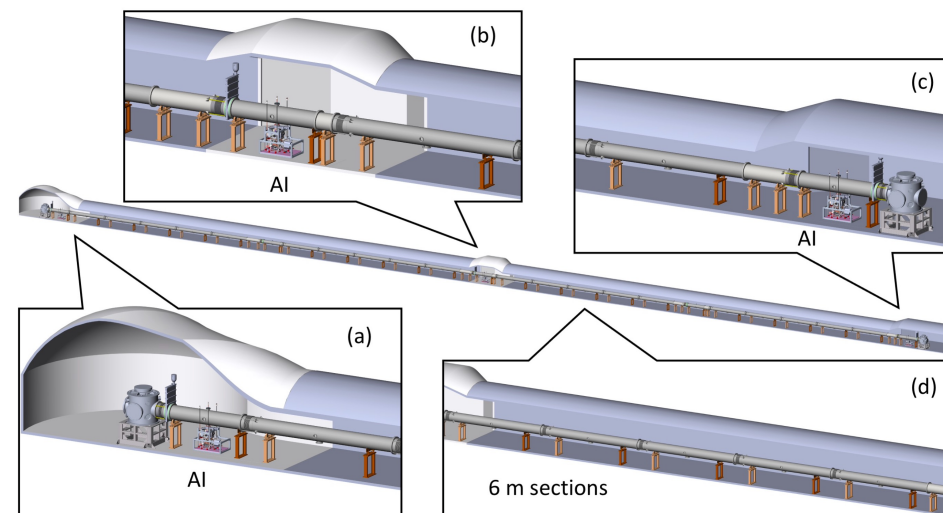
contact.idust2022@lsbb.eu

i-DUST website: <https://indico.cern.ch/event/idust2022/>

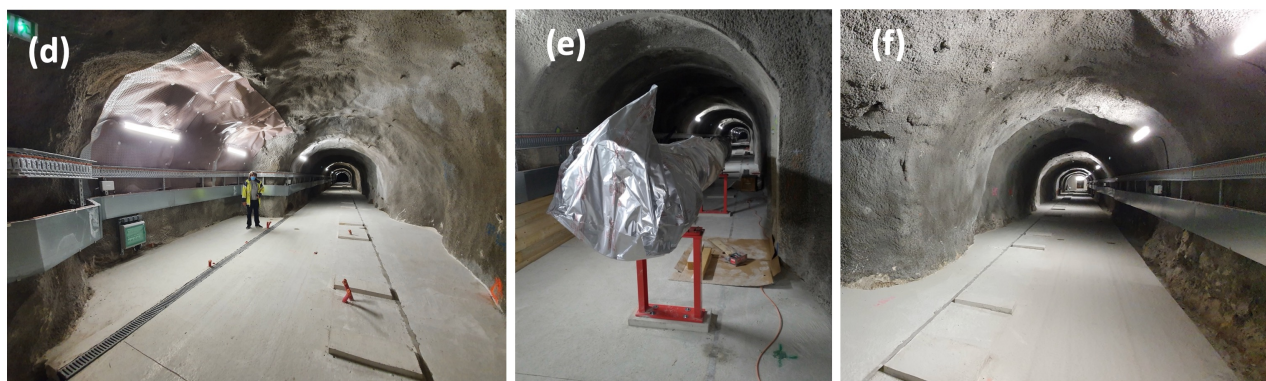
Scientific program:

- Critical Zone
- Geological reservoirs
- Couplings: Earth, solid, atmosphere, universe
- Astrophysical measurements in the terrestrial env.
- Noise as signal, advanced metrology
- Living
- Industrial development in low background noise env.

NEW 2021 UNDERGROUND FACILITIES



- 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**



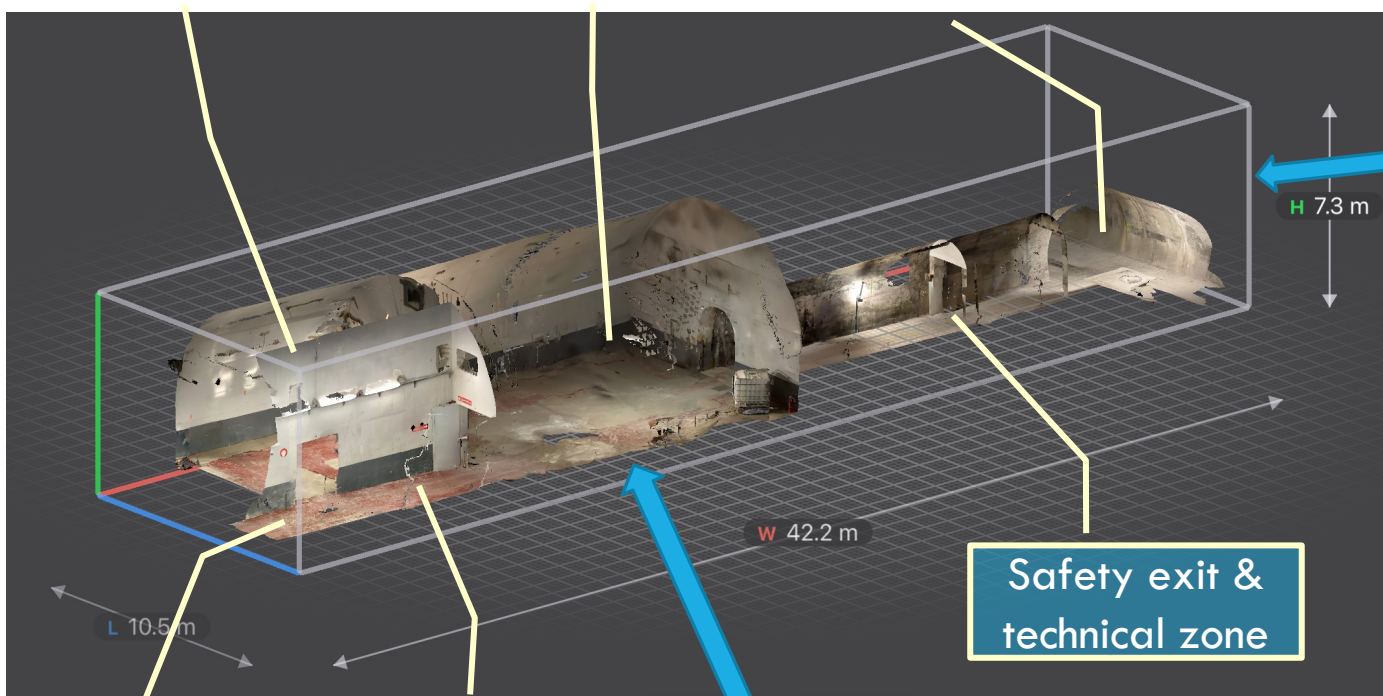
Ref. Canuel et al., Sci. Rep. 8 (1), 14064 (2018)

NEW 2022 UNDERGROUND FACILITIES

Monitoring room

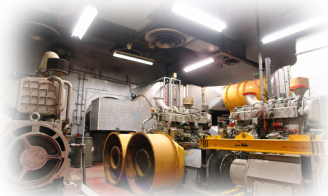
Metrology room

Secondary gallery

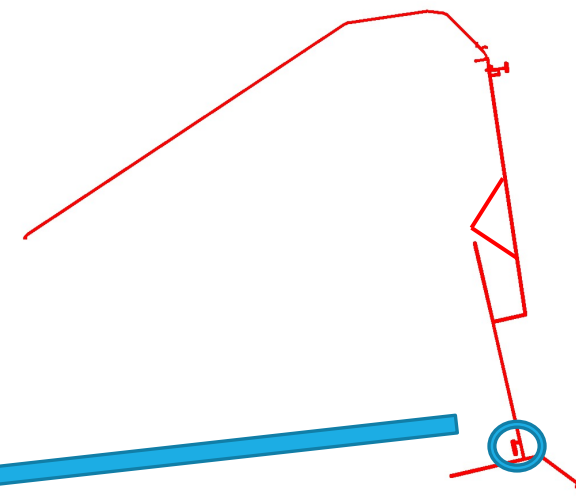


To main gallery

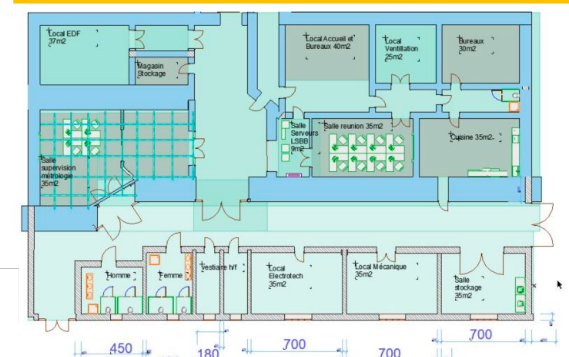
Airlock



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, finished this year



- Current building ($\sim 400\text{m}^2$)
 - Designed originally for a different purpose
 - Classed as XXth century historical monument
-
- Phase 1 ($+360\text{m}^2$)
 - Building extension.
 - New clean rooms
 - Separation between technical zones and offices.
-
- Phase 2 ($+330\text{m}^2$), 2027
 - New surface building
 - New conference, monitoring, and outreaching zones

CONCLUSIONS

The Low Background Noise Laboratory of Rustrel :

- ❑ Is a **multidisciplinary** platform with **unique infrastructure** in a remarkable and **well-know environment**
- ❑ Is heavily instrumented for Earth and Universe observation
- ❑ Fosters synergies thanks to its well-stablished and organized transdisciplinary user community
- ❑ Its new facilities and equipment allow to welcome new partners and projects from different scales and kinds
- ❑ Is **open** for collaborations

Thank you for your attention

