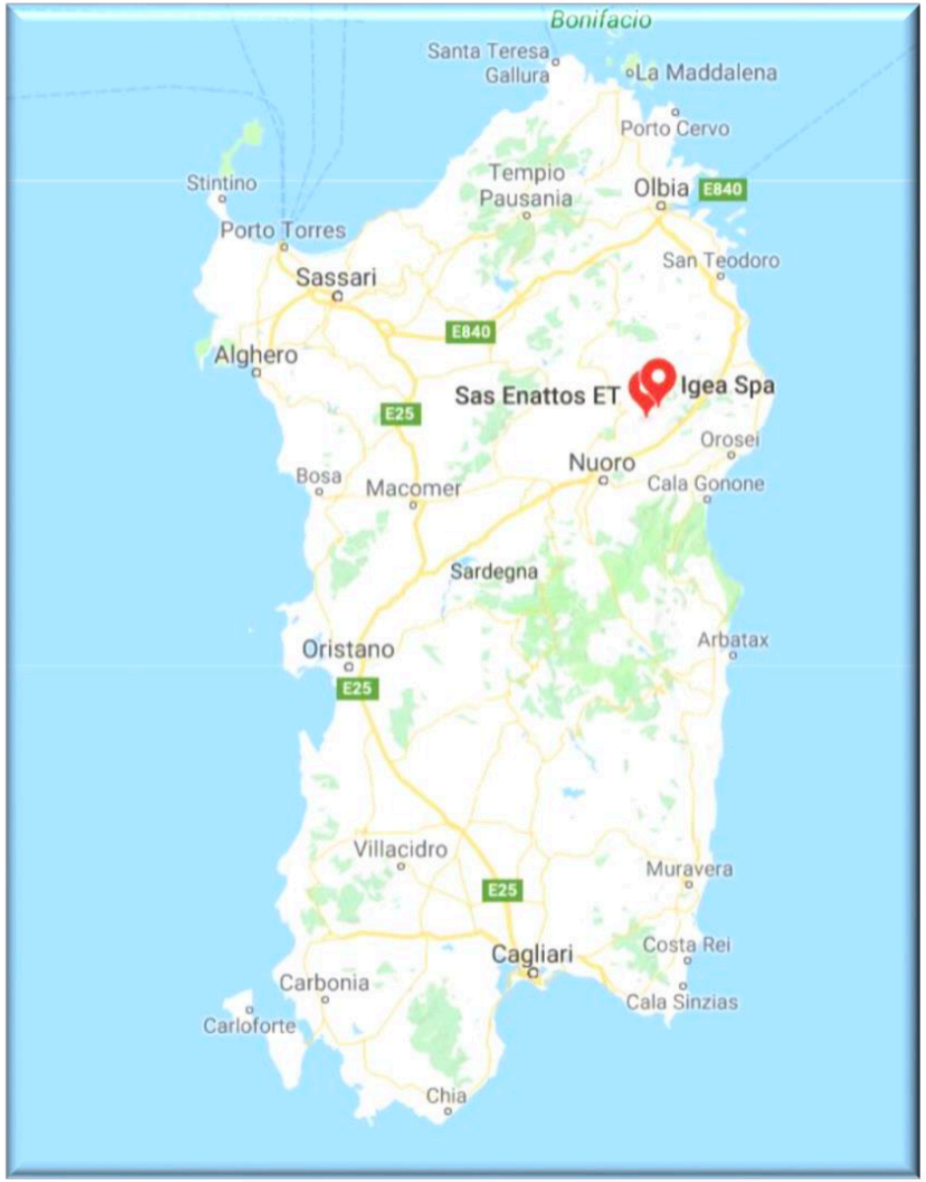
The Life @ Sos Enattos : current activities and future perspectives

ET Workshop 11-12 April 2019 Orosei

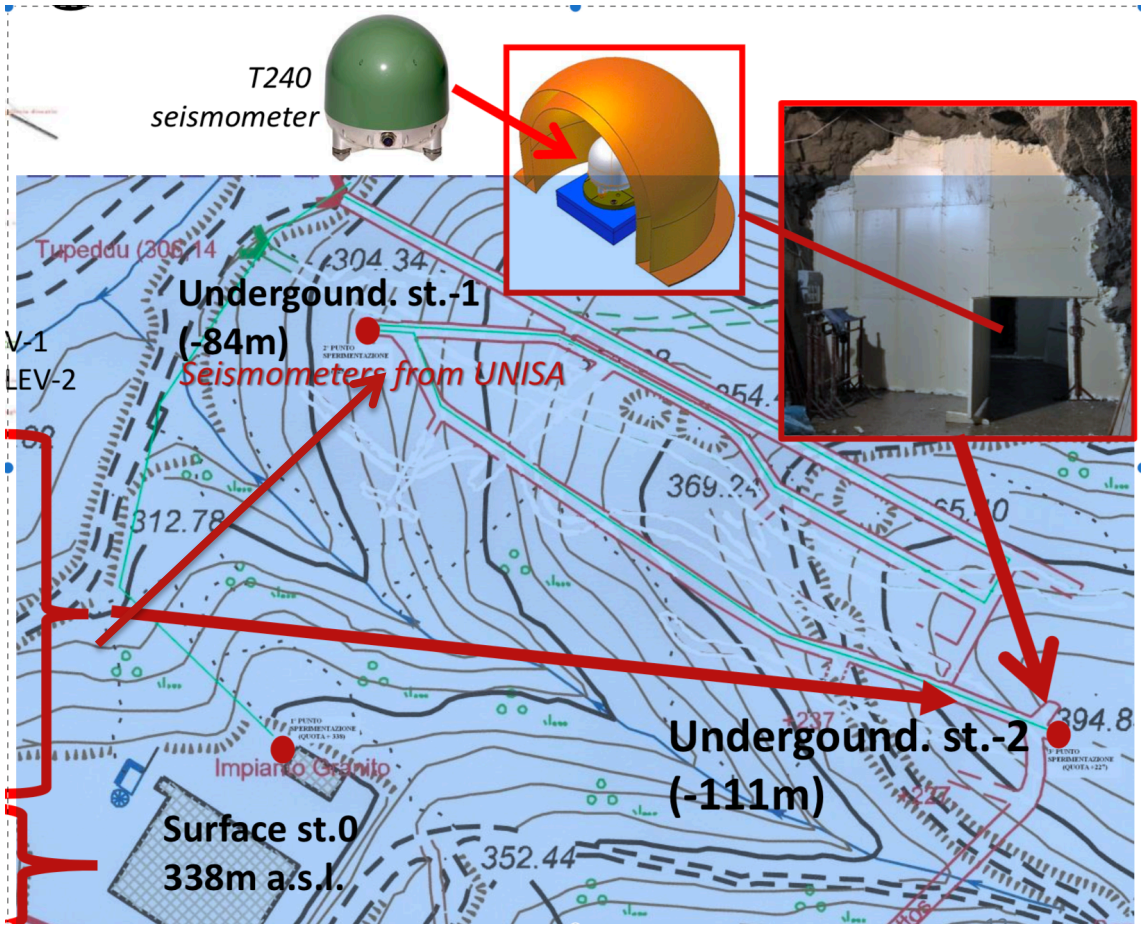
Historical hints

- Mining exploitation of the area started more then 2000 years ago
- From 1996 the mine infrastructure is maintained by IGEA s.p.a
- Since 2010 several underground measurement campaigns have been carried out to characterize the site in terms of environmental noise
- In 2017 was chosen as the site for Sar-Grav Laboratory hosting high precision gravitational experiments operating in underground site
- In 2018 was selected as one of the candidates site to host the future Einstein Telescope



Measurement and monitoring systems

- Seismic sensor array (see Saccorotti's talk)
- Magnetometers
- Multi-parameter environmental nsunderground stations
- Tiltmeters
- ….



Geology and Rock Mechanics Studies

- Rock characterization by means of measurements of physical mechanical parameters of lithotypes (uniaxial compressive strength, porosity, hardness, microstructural features etc.)
- Measurements of groundwater paths, occurrence of deep and perched aquifers, chemical features of groundwater.
- Measurement of radioactivity of the different lithotypes
- Crustal velocities and ground deformations

see poster Oggiano-Cuccuru's poster

Sar-Grav Consortium

- SAR-GRAV is a consortium among INFN, University of Sassari, Regione Sardegna, IGEA spa, INGV for the construction at Sos Enattos of an underground lab to host Gravitational Experiments
- UNICA joints the effort
- Open to new partners

REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA

uniss
UNIVERSITÀ DEGLI STUDI DI SASSARI

IGEA SpA
INTERVENTI GEO AMBIENTALI

INFN
Istituto Nazionale di Fisica Nucleare

INGV

Sar-Grav Laboratory

- It will host experiments requiring low seismic environment

  - ✓ The first approved experiment is Archimedes experiment and for which is on-going the design phase based on scientific apparatus
  - ✓ Other experiments are under discussions
  - ✓ A dedicated workshop to the relation of vacuum fluctuations and gravitation will be held in Orosei, from April 28th to May 3rd, to promote future collaborations that can benefit of a low seismic underground site

- Thanks to its geological and geophysical characteristics and site studies currently carried on, the Sar-Grav underground infrastructure can be exploited as test-bed for the R&D of technologies for the 3° generation GW detectors and as a first ET seed

A feasibility study to design the underground facility hosting the Archimedes experiment (seed for future SAR-GRAV experiments): engineering challenges and key solutions

M. Carpinelli[1,2], S. Cuccuru[1,2], D. D'Urso[1,2], G. Oggiano[1,2], V. Sipala [1,2]
E. Calloni[3,4]
F. Ricci[5,6], P. Rapagnani[5,6], P. Puppo[6], M. Perciballi[6], E. Majorana[6], L. Naticchioni[6]
M. Marsella[7], Napoleoni[7] ,, A. Celauro[7], P.J.V.Daranno[7], L. Lipparini[7], J. A. Palenzuela Baena[7]
A. Paoli[8], L. Paoli[8], C. Fabozzi[8]
G. Loddo [9]
M. Punturo[10]
G. Losurdo[11]

[1]*Dipartimento di Chimica e Farmacia, Università di Sassari, Sassari, Italy*
[2] *INFN LNS, Catania, Italy*
[3] *Dipartimento di Fisica, Università di Napoli Federico II, Napoli, Italy*
[4] *INFN Sezione di Napoli, Napoli, Italy*
[5] *Dipartimento di Fisica, Università di Roma Sapienza, Roma, Italy*
[6] *INFN Sezione di Roma, Roma, Italy*
[7] *Dipartimento di Ingegneria Civile e Ambientale, Università di Roma Sapienza, Roma, Italy*
[8] *European Gravitational Observatory (EGO), Cascina (Pisa), Italy*
[9] *IGEA spa, Italy*
[10] *INFN Sezione di Perugia, Perugia, Italy*
[11] *INFN Sezione di Pisa, Italy*

Archimedes underground lab

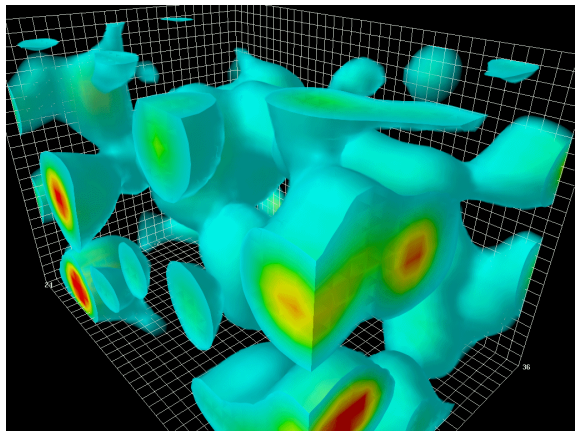
- SOS Enattos area is a potential vertex ET in Sardinia
- Hosting site for the SAR-GRAV experiments starting from Archimedes
- Surface lab – control room
- Underground labs for cryostat lab and subsidiary ones to control seismic and environmental noises

- This work is authored by a multi-disciplinary team composed by
  - ✓ GW physicists
  - ✓ Geologists, geophysicists, and mining archeologists
  - ✓ Engineers with expertise in infrastructure for interferometers
  - ✓ Engineers with expertise in civil and underground infrastructure
  - ✓ Engineers and technicians from the Sardinian mining company

Archimedes Experiment

- Why the universe exhibits a vacuum energy density much smaller than the one resulting from application of quantum mechanics and equivalence principle?

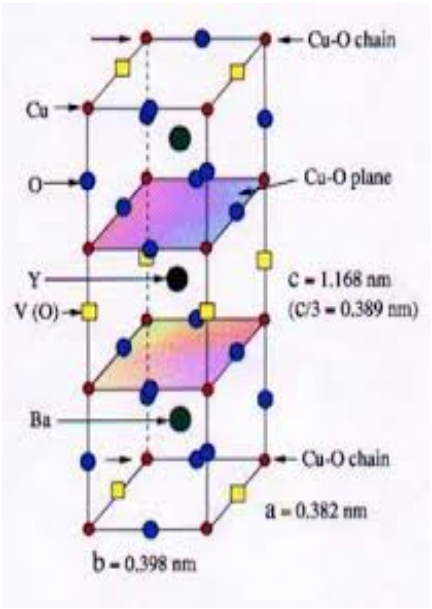
Does vacuum fluctuations interact with gravity ?
Does vacuum weigths ?



- To better understand we can measure

$$F = (E_c/c^2)\, g$$

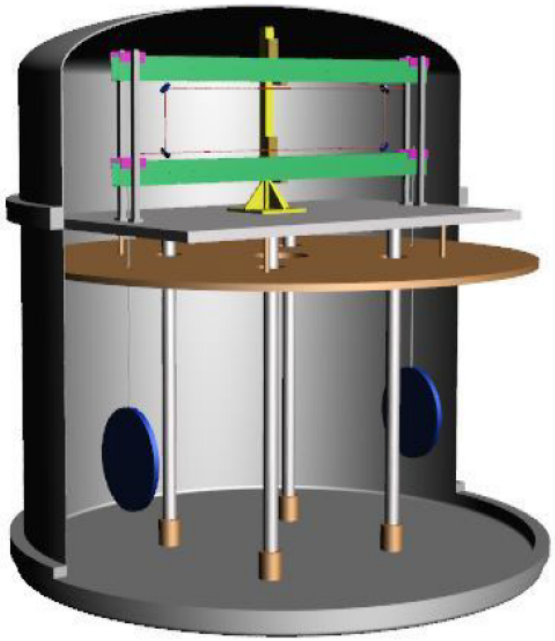
where E_c is the Casimir (negative) vacuum energy

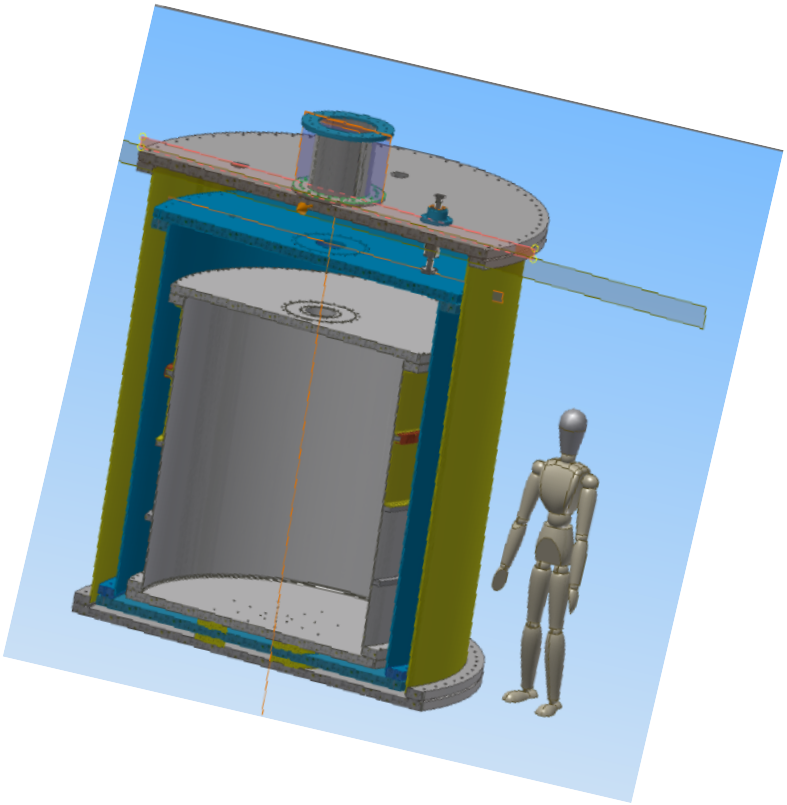


- Using high Tc layered superconductors (modulated in temperature) as natural multi Casimir-cavities

Expected upward force 10^{-16} N

Archimedes Experiment





- High sensitivity cryogenic balance
- Interferometric read-out of arm rotation

- Quiet environment: low human activity(newtonian noise) and low seismic noise

- cryostat to host the balance (3m diameter, 3.5 m height)

INFN Istituto Nazionale di Fisica Nucleare

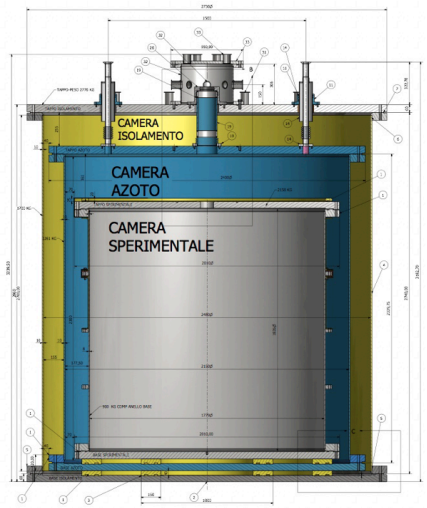
Università degli Studi di Napoli Federico II

INO-CNR Istituto Nazionale di Ottica

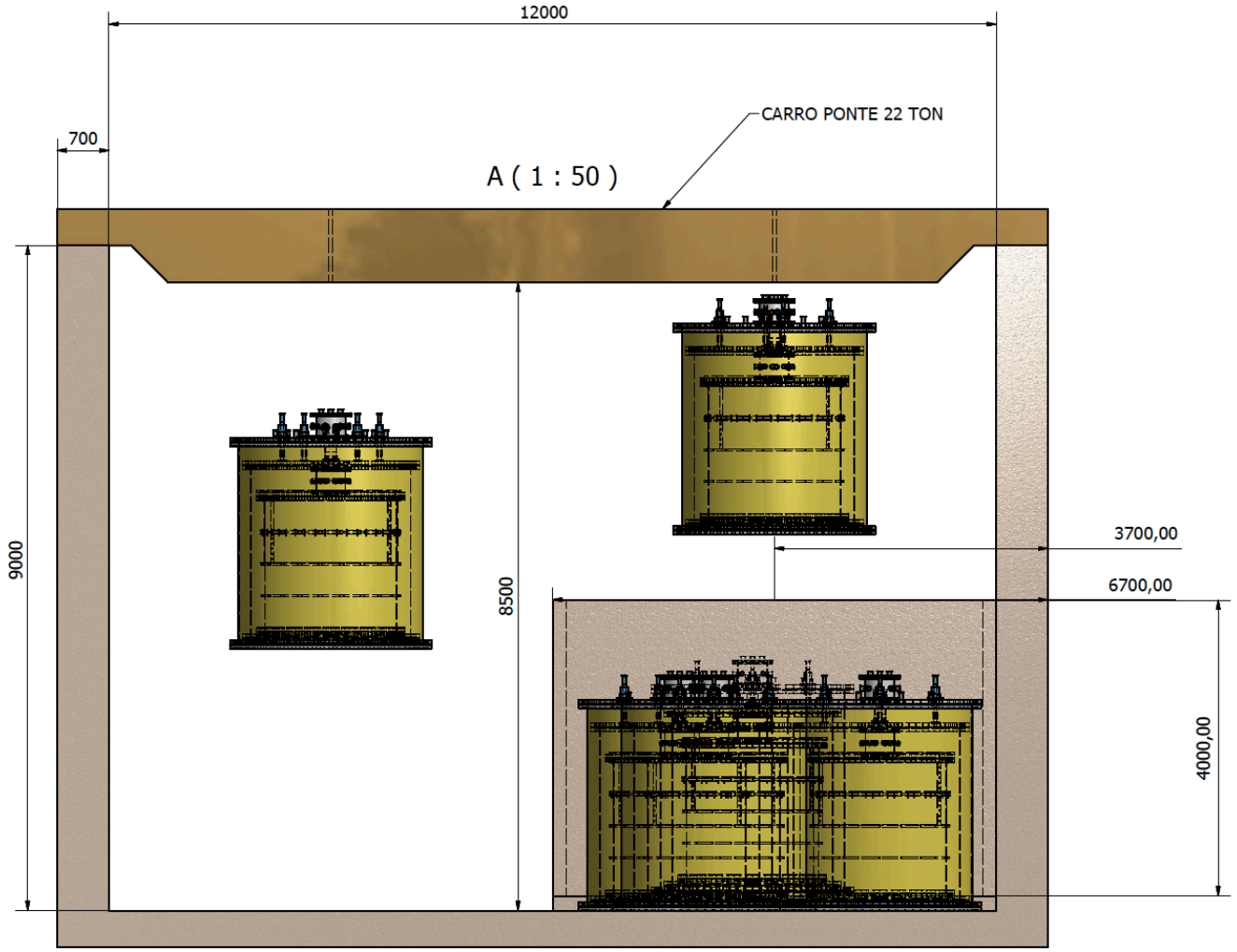
Aix*Marseille université

Sapienza Università di Roma

Archimedes underground lab



- W 2.5 m x h 3 m
- 3000 l of nitrogen
- Load of 20 ton



Archimedes underground lab: initial stage

- ❑ Starting condition

Access gallery

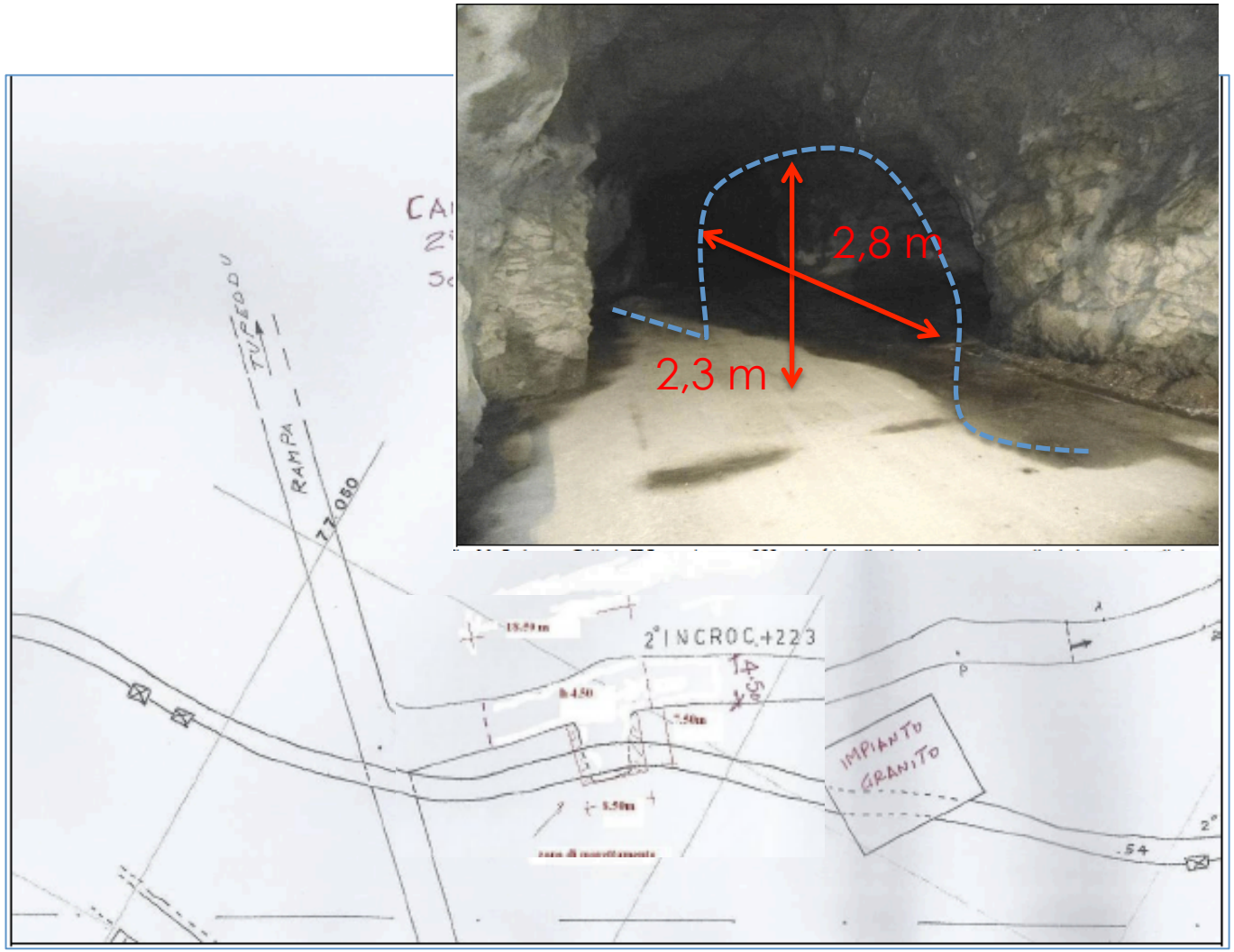
- ✓ Width 4,5 m
- ✓ Height 4,5 m

Cavern

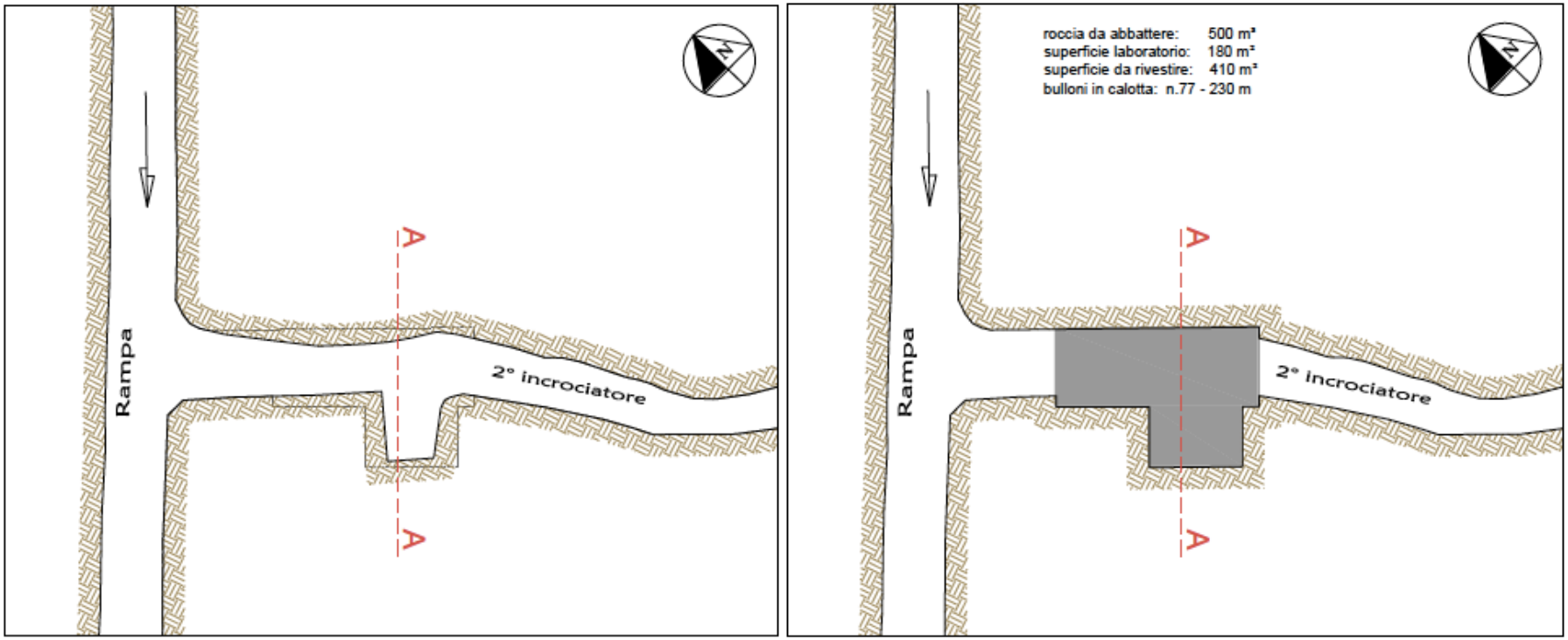
- ✓ Width 2,8 m
- ✓ Height 2,3 m
- ✓ Length 7,5 m

- ❑ Excavation to enlarge the cavern up to 140 m^2

- ✓ Width 8,5 m
- ✓ Height 4,5 m
- ✓ Length 7,5 m



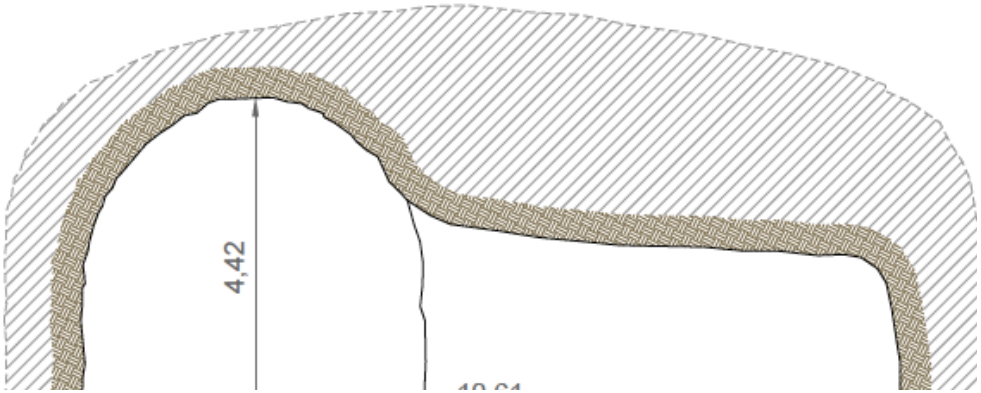
Archimedes underground lab: first design

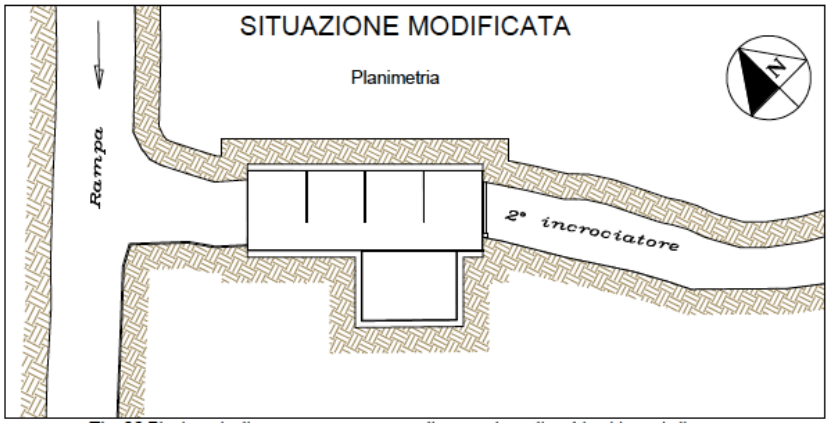


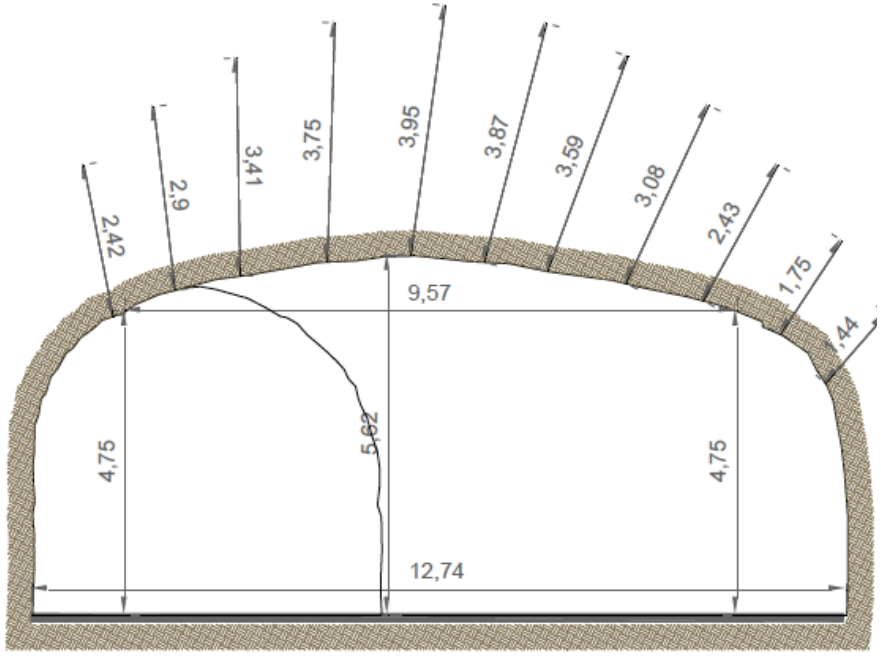
From Technical report Nov. 2017

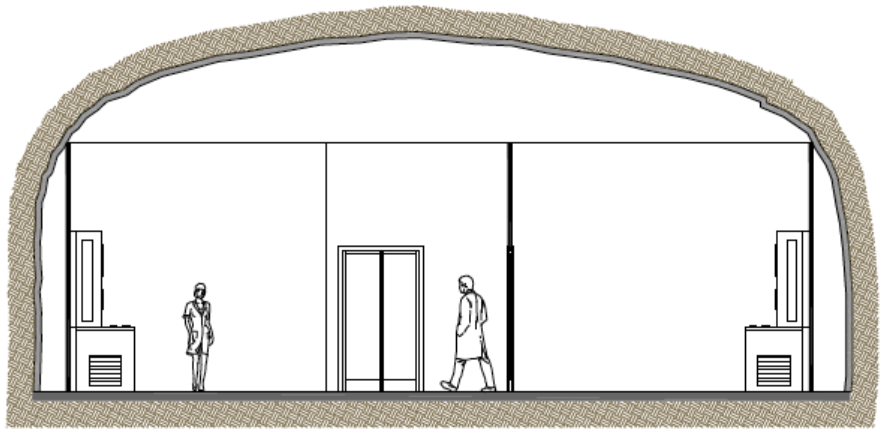
IGEA SPA
INTERVENTI GEO AMBIENTALI

Archimedes underground lab: first design





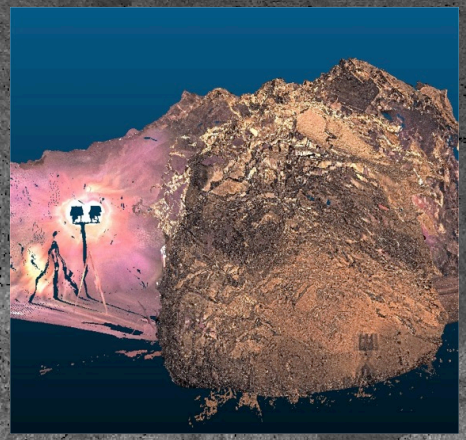




From Technical report Nov. 2017

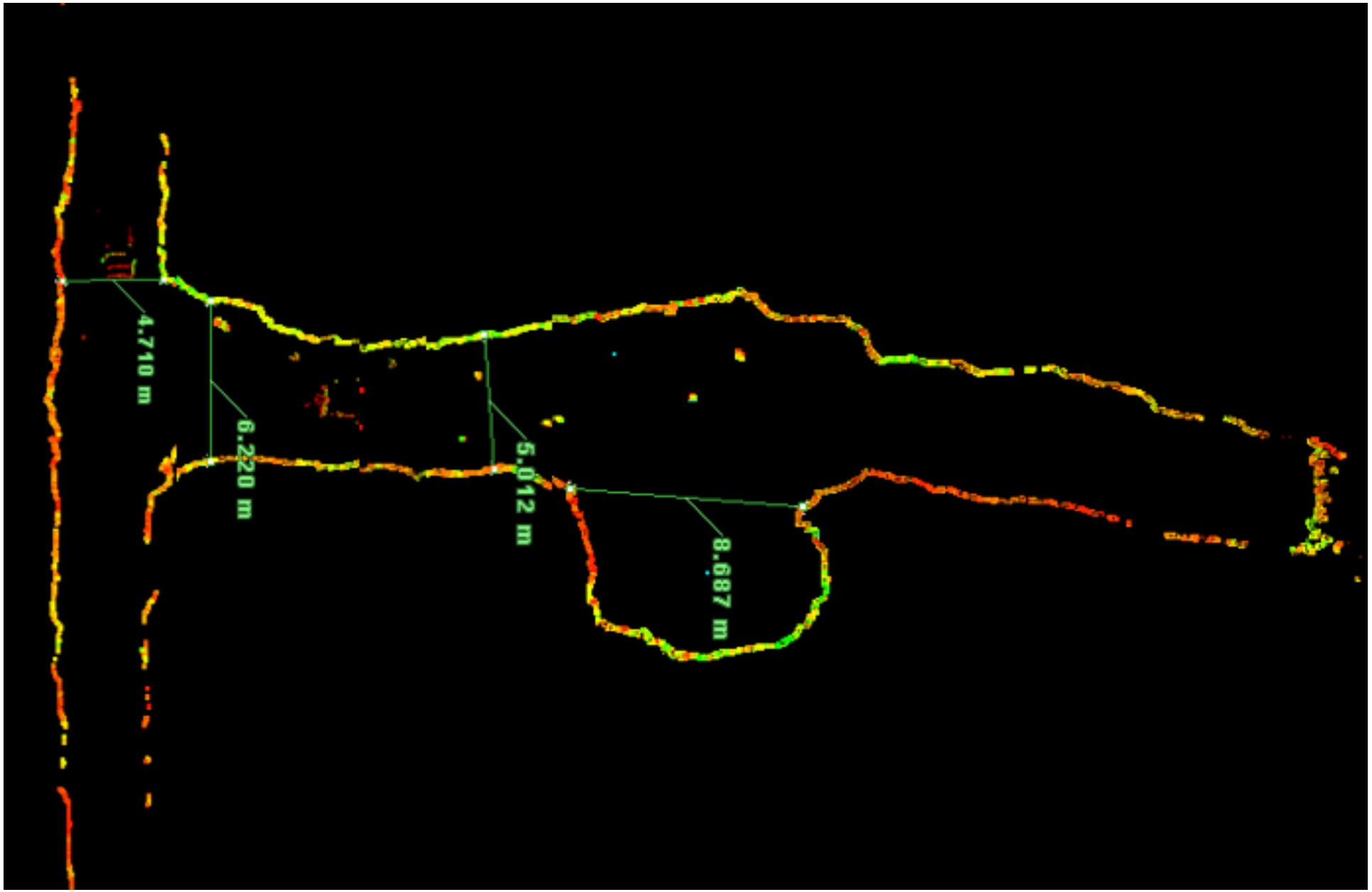
IGEA SPA
INTERVENTI GEO AMBIENTALI

Archimedes underground lab: present stage

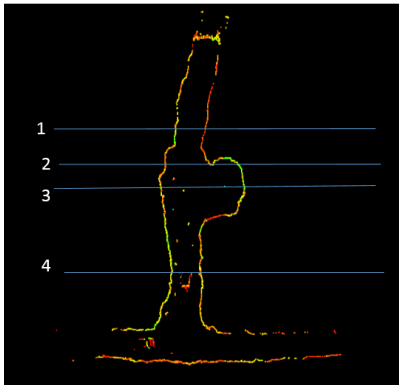


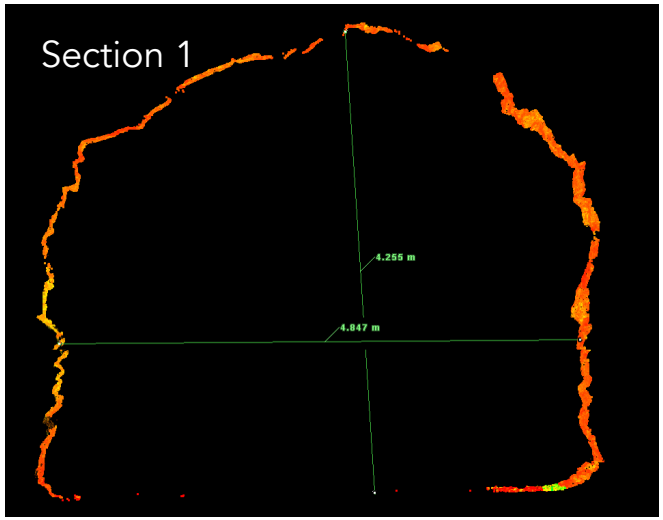
- physical Characterization – Mechanics Structural analysis of and fracturing (UNISS)
- laser scanning surveying to define the optimal geometry of the hosting rock cavity and to evaluate the accessibility through the existing tunnels.

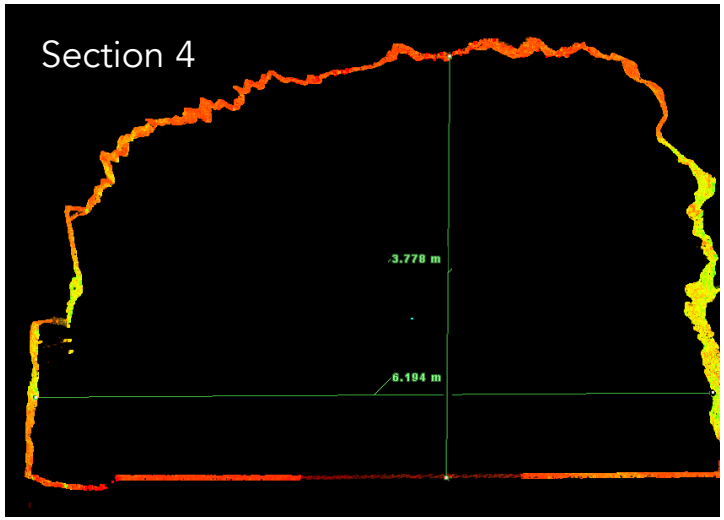
Archimedes underground lab: present stage

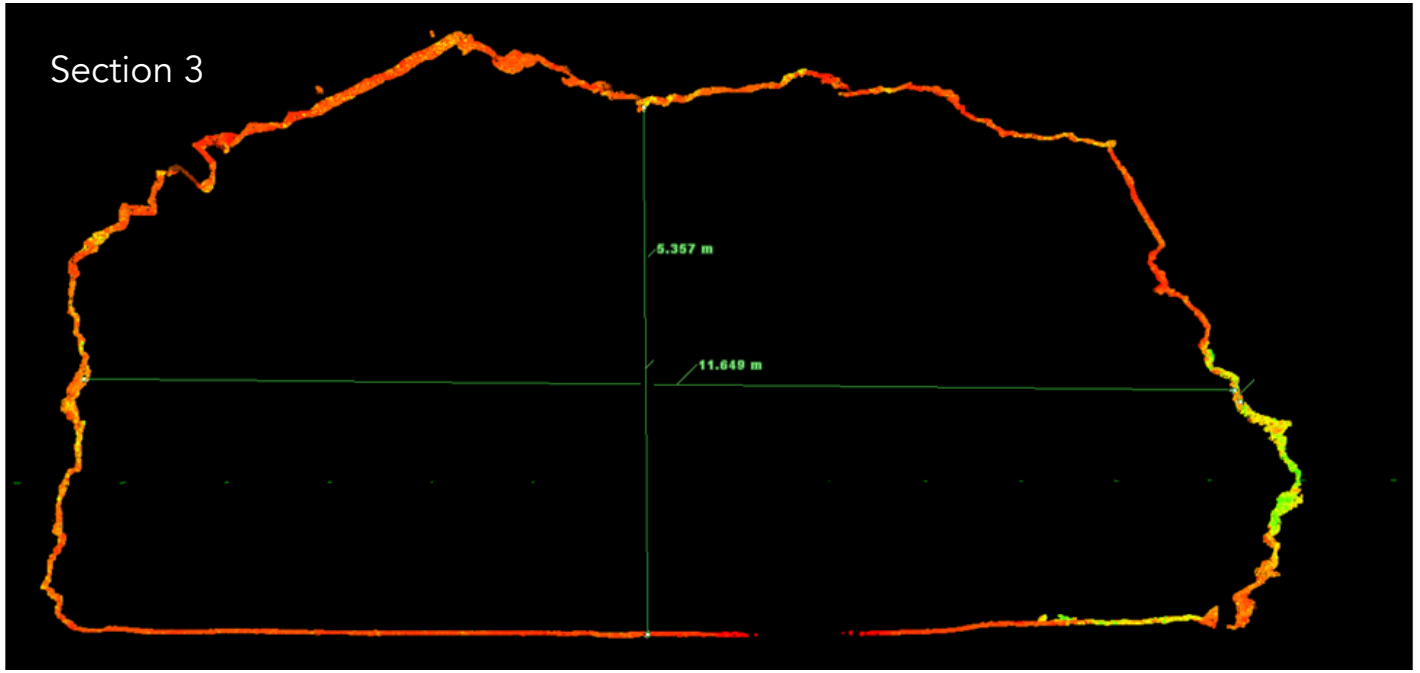


Archimedes underground lab: present stage

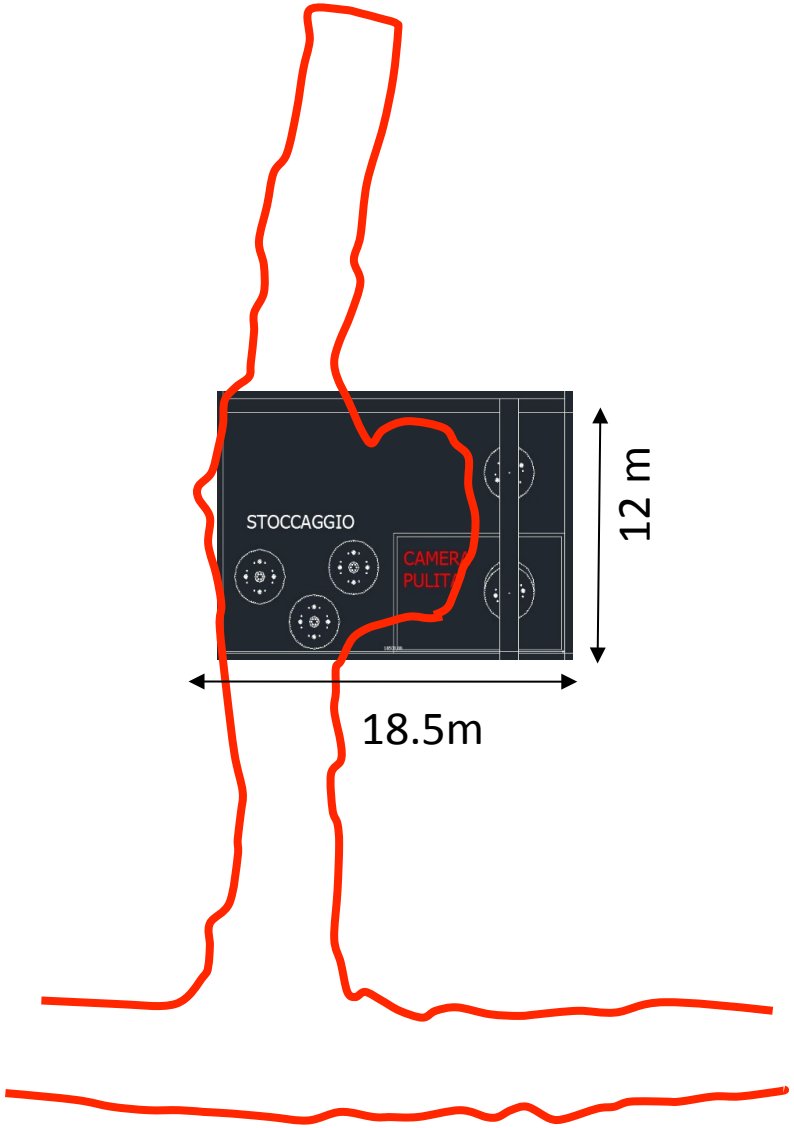


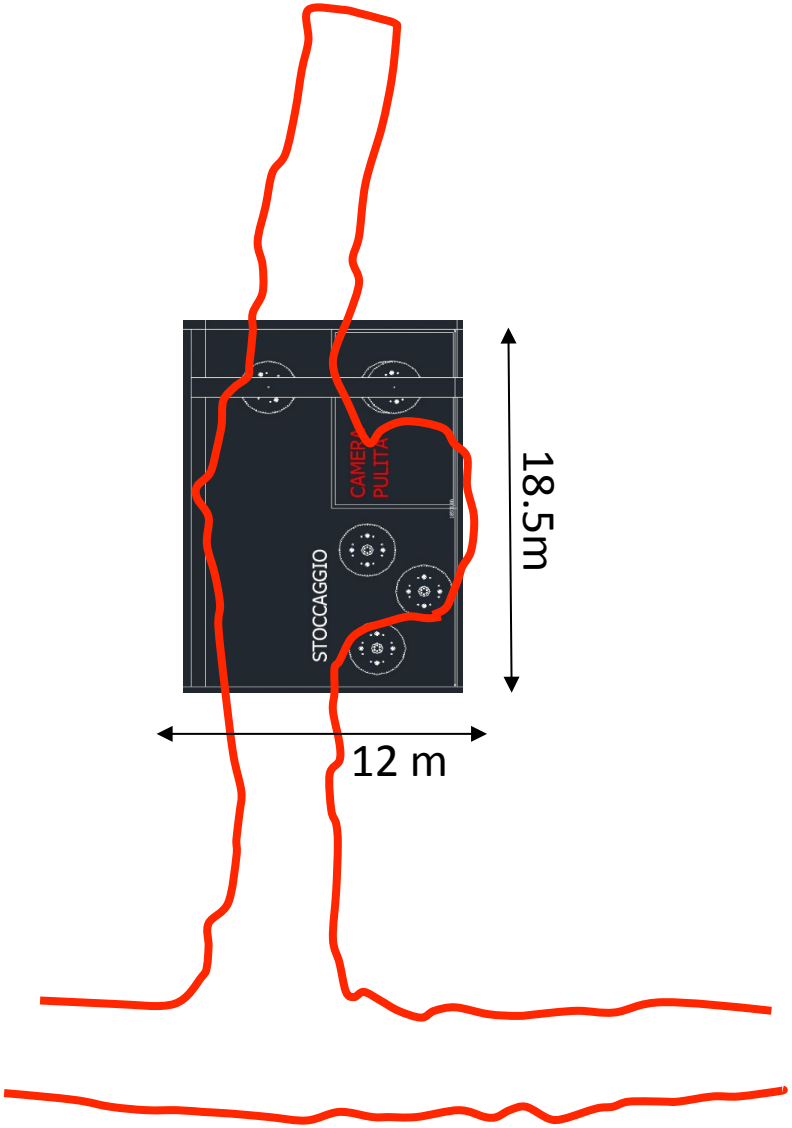




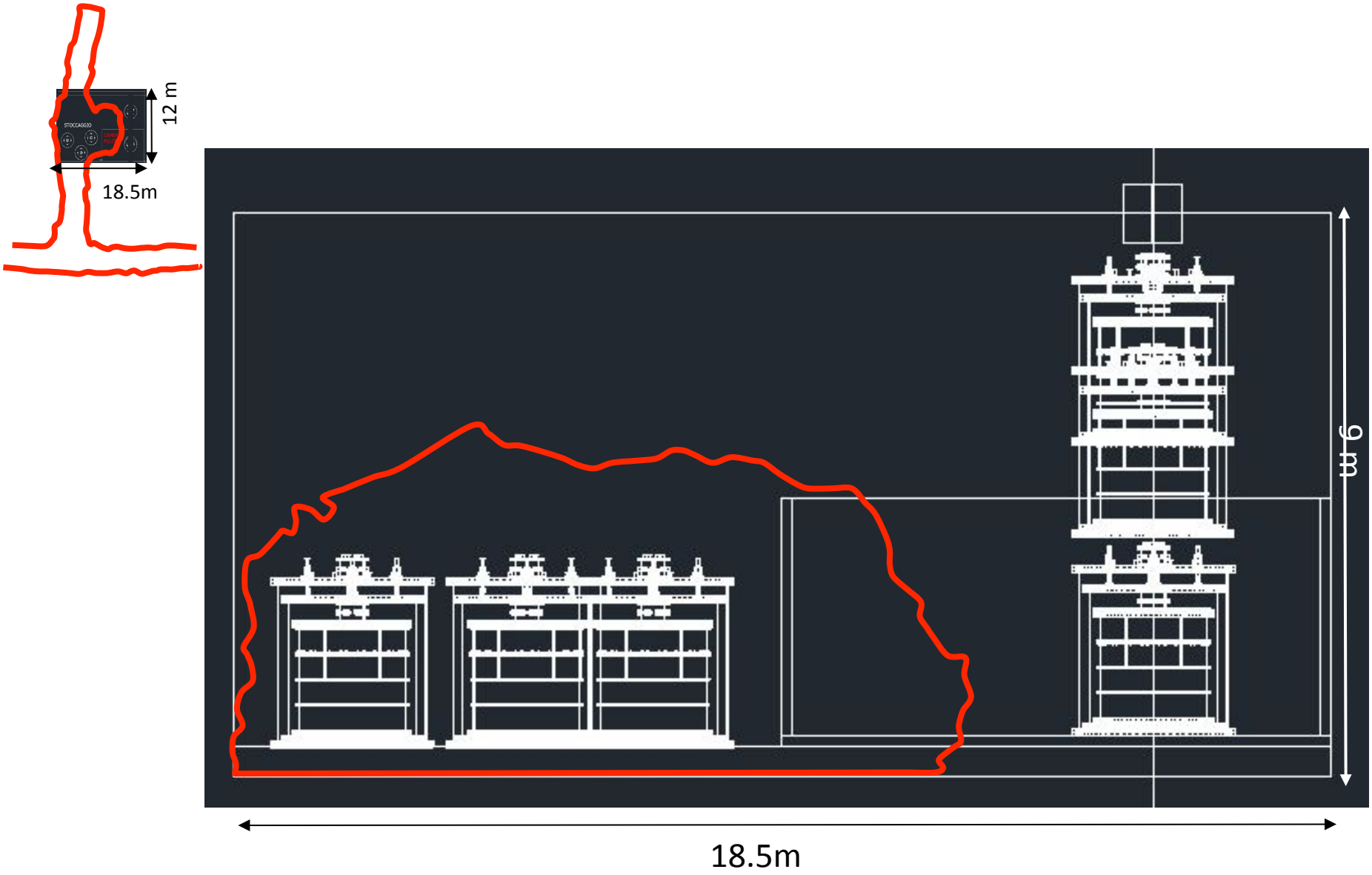


Archimedes underground lab: future configuration

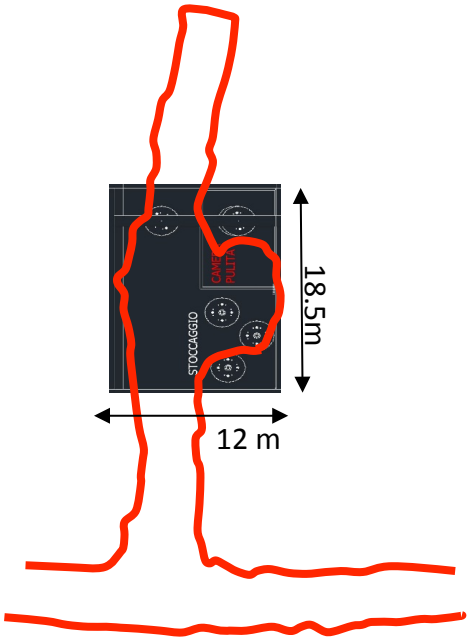


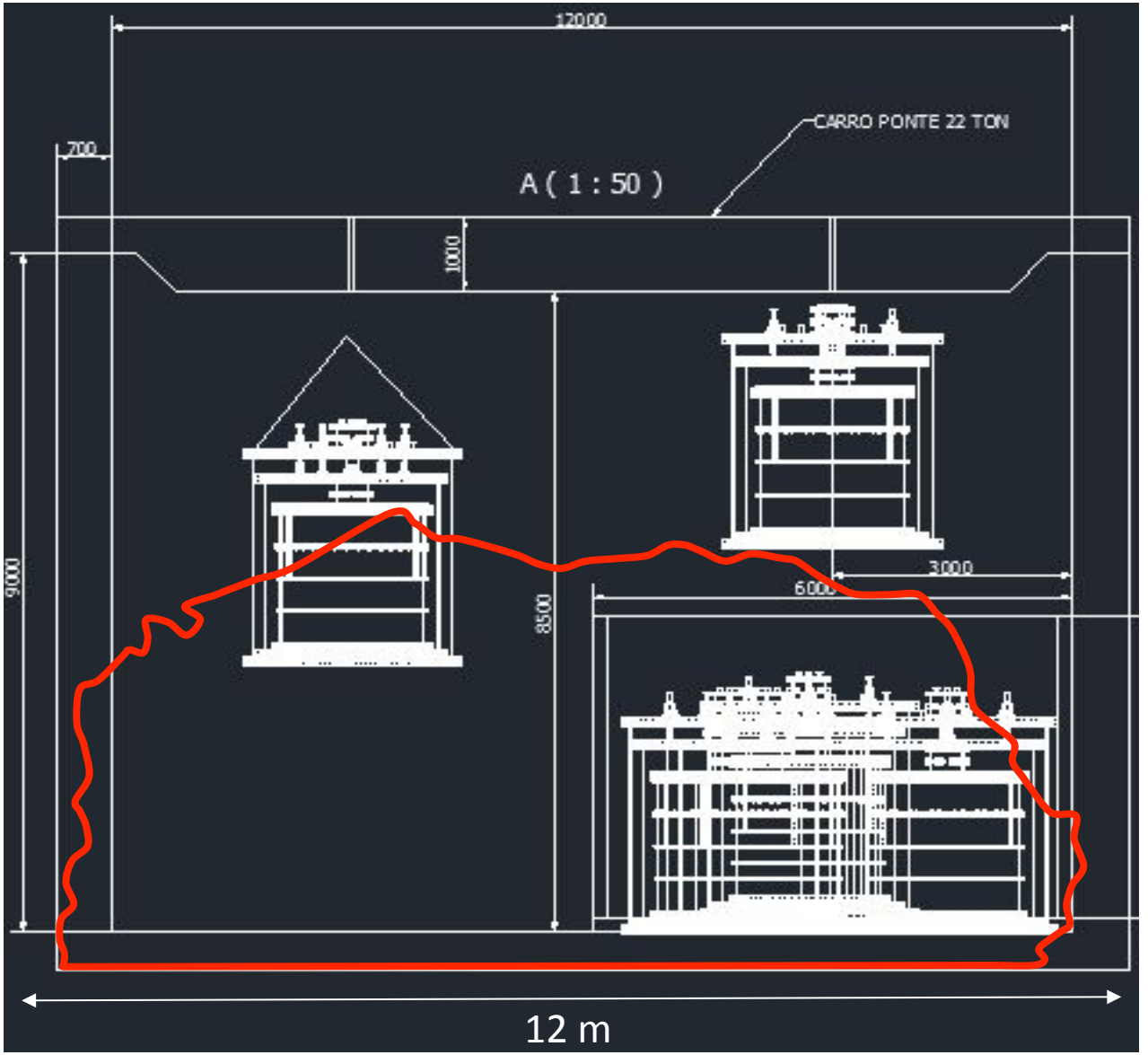


Archimedes underground lab: future configuration

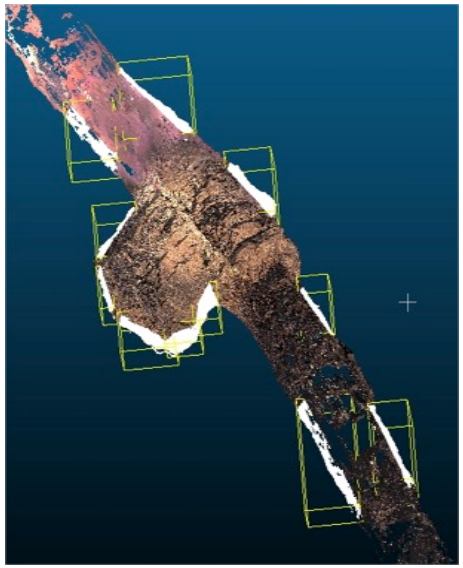


Archimedes underground lab: future configuration



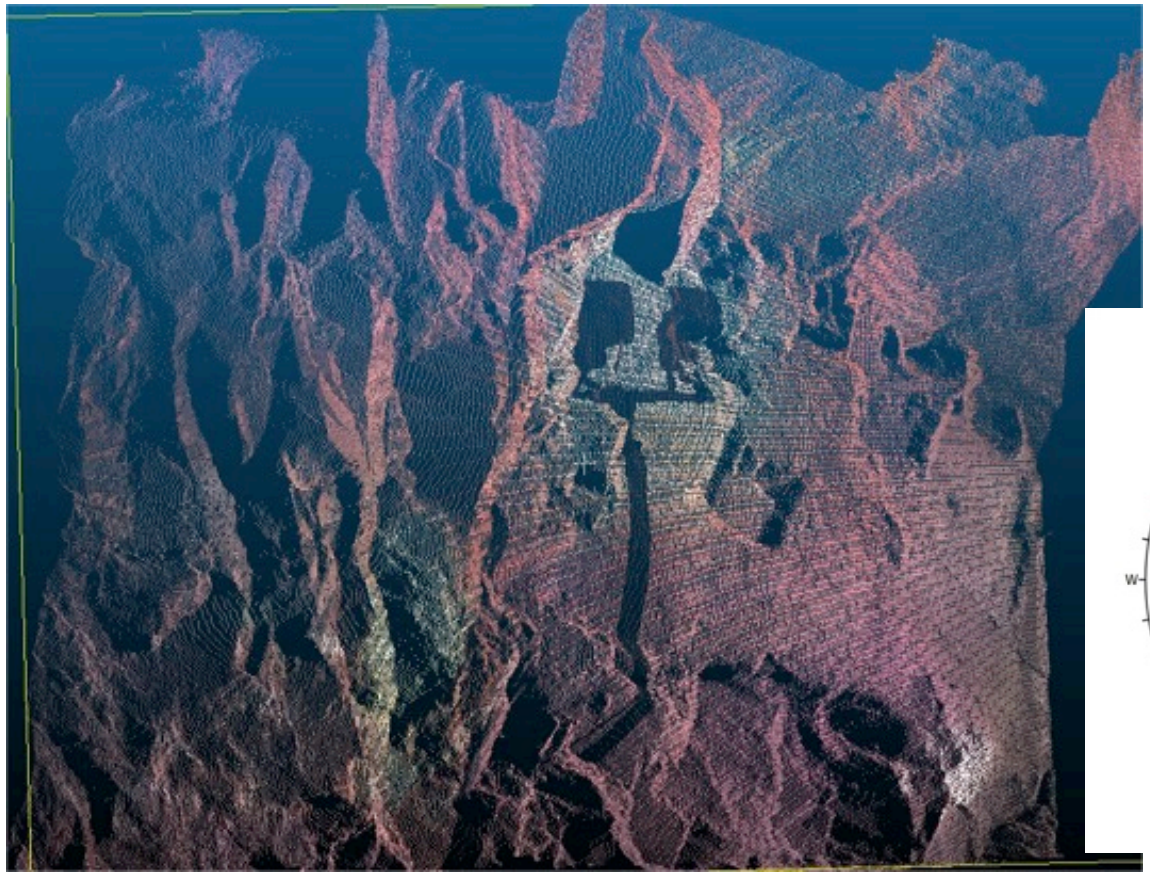


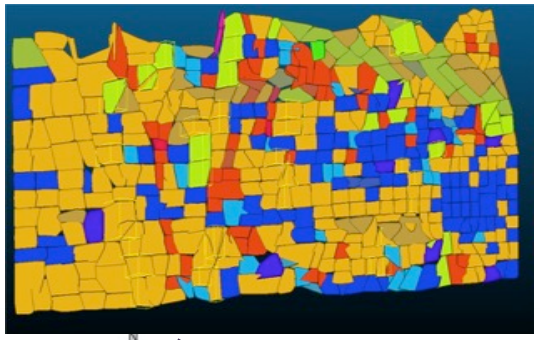
Laser scanning for geo-structural surveying

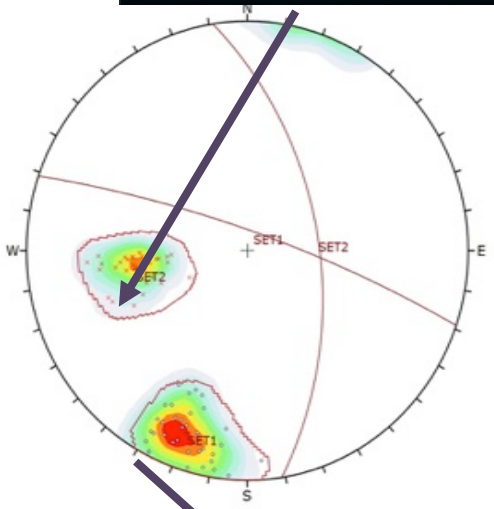


- Rock discontinuities identified by the dense laser point cloud
- Laser scans at different orientations and position along the galleries

Laser scanning for geo-structural surveying

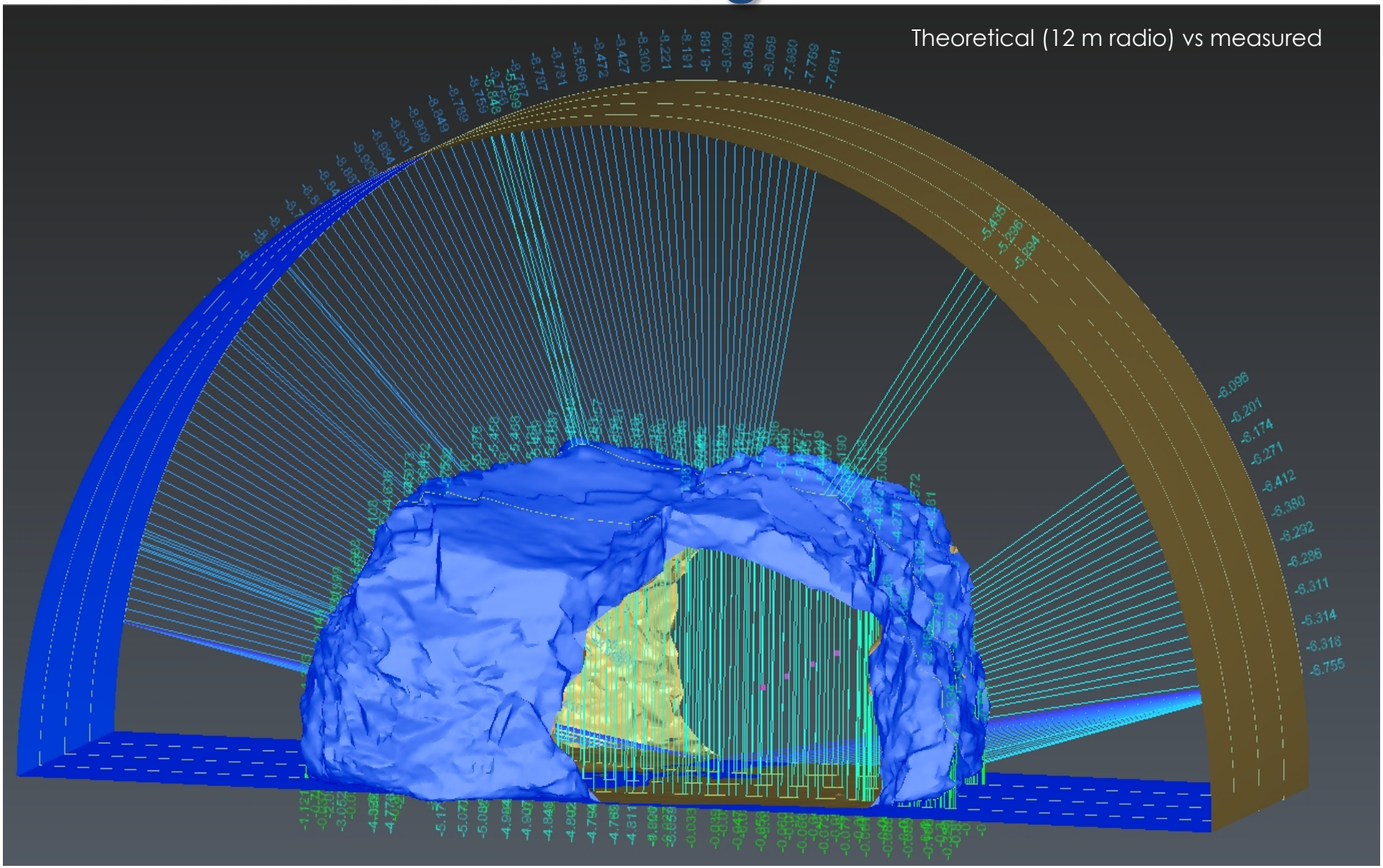






- segmentation
- Semi automatic (supervised) plane extraction
- Set parameters for rock kinematic stability analysis

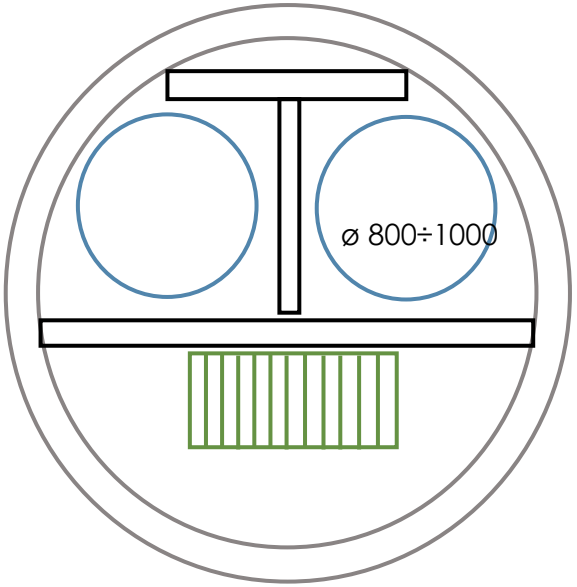
Toward the cavern design



Design of the service well (tbd)

- 100 m long and at least 1.5 m widht
- direct and indirect survey methodologies (through geophysical surveys and exploration drilling) for characterization properties of rocks
- in-depth quantitative knowledge of the fracture system

volume	V [m^3]	2442
surface	S_U [m^2]	222
Clean Room	V [m^3]	216
ISO 7/8 (20 exchange/h)	G_{CR} [m^3/h]	4320
UTA, GF e PdC at surface	DH [m]	170÷180
Preliminary dimension		
UTA	G [m^3/h]	12000
UTA+ausiliari	P [kW_{el}]	10
GF	P [kW_{el}]	40
PdC	P [kW_{el}]	40
Bivalente (100% redundancy)	P [kW_{el}]	40
Overlapping coefficients	P [kW_{el}]	74

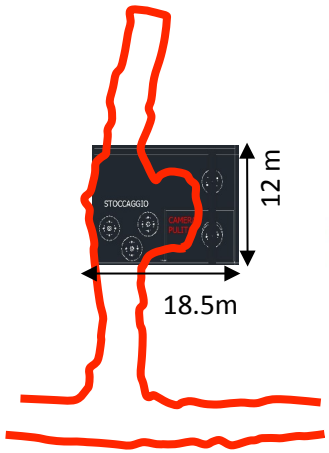


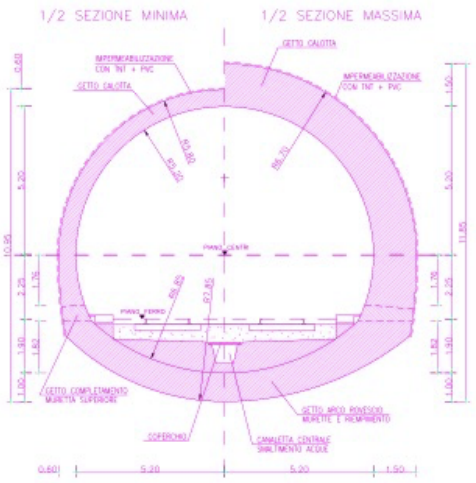
Challenges: lessons learnt from KAGRA

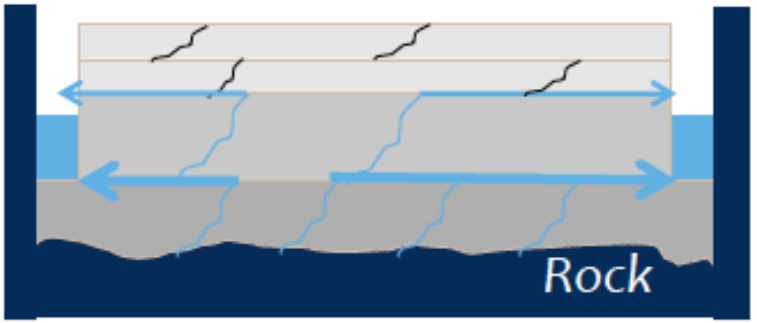
- Suitable methods and materials to reinforce the rock cavity and build up the experimental room
- Safe operational conditions for accessing the site and installation of the experimental apparatus
- Efficient drainage and ventilation systems for controlling dripping
- Implementing a cost-effective approach and adjusting and adapting to scientific requirements (iterative approach)

Next steps

- Geometry of lab and service area
- Requirements for the technological and safety infrastructure
- Rock characterization, testing and monitoring
- Radon monitoring
- modelling excavation and consolidation works
- design water drainage system
- define ante/sin/post- opera monitoring approach
- Geophysical prospections to detect ground water paths and cataclastic belt (necessary to design the well)







Ideal Floor Design

From kagra pres.

Archimedes vs other underground facilities

	Volume [m^3]	Depth [m]	Length [m]	Width [m]	Height [m]	Realization Time [y]
CERN - ATLAS	61600	92	55	32	35	4.5 (1998-2003)
CERN - CMS	35775	20	53	27	25	6.5 (1998-2004)
LNGS (tot 3 caverns)	95000	1400	100	20	18	3 (1982-1985)
KAGRA Japan	21500	200				(2012 -2014)
Super-K dome Japan	69000	1000	Ø 42		58	(1991-1994)
HERA-DESY Germany (x2)	34400	25-28	43	25	16	(1984-1990)
LSM France (Domus ext.)	14000	1700	40	18	16	
LSC Spain	10500		40	15	12	(2006-2009)
LBNF-DUNE USA (CDR)	80000	1500	150	20	28	(2017-2023)
Archimedes LAB	**2500**	**> 100**	**19**	**12**	**12**	**(2020-….)**
ET	**?????**	**?????**	**?????**	**?????**	**?????**	**?????**