Laguna

and the LSC

Luis Labarga, University Autónoma Madrid

Epiphany 2010 Conference, Cracow

20100108

What is LAGUNA ?

- The current European approach to the next generation, liquid [Mt-like], p-decay and neutrino detectors

- It considers seven candidate sites:

CUPP @ Pyhäsalmi mine, Finland
IUS @ Boulby mine, UK
SUNLAB @ Sieroszowice mine, Poland
IFIN-HH @ Unirea mine, Romania
LSM @ Frejus tunnel, France
New-Italian-Site @ CNGS beam halo, Italy
LSC @ Canfranc RW tunnel, Spain

- It considers three different detector technologies:
  - Water-Cherenkov: ~ 1 Mt
  - Liquid-Argon TPC: ~ 0.1 Mt
  - Liquid-Scintillator: ~ 0.05 Mt

What is LAGUNA ? (II)

- a pre-Collaboration is formed. It did apply for 5 M€ funding to the EU within the program FP7-INFRASTRUCTUES-2007
- Only 1.7 M€ were granted. The explicit request by the EU was to focus in the Feasibility Study (FS), mainly Geotechnic, of the 7 candidate sites.

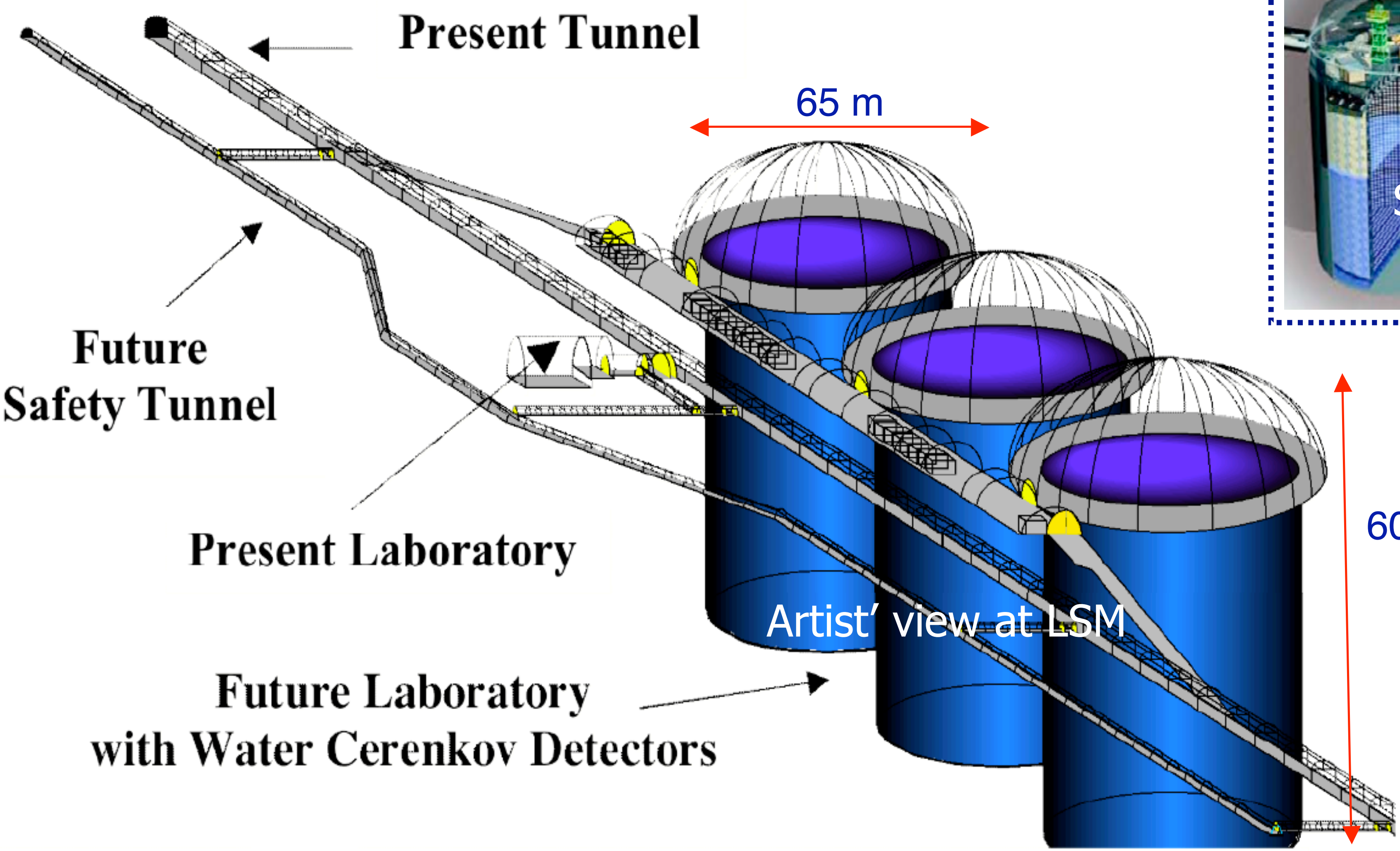
LAGUNA Governance structure **v2.0 / 14/10/08**

Coordinator		A. Rubbia
Deputy-Coordinator		??
Governing Board		
Coordinator		A. Rubbia
Deputy-coordinator		??
Administrator		F. Petrolo
WG2 coordinator		F. von Feilitzsch
WG3 coordinator		N. Spooner
WG4 coordinator		A. Zalewska
Academic partners' representatives		
	ETH Zurich	A. Marchionni
	U-Bern	A. Ereditato
	U-Jyväskylä	J. Maalampi
	UOULU	T. Enqvist
	CEA	M. Zito
	IN2P3	Th. Patzak
	MPG	M. Lindner
	TUM	L. Oberaurer
	IFJ PAN	Jan Kisiel - US (for IFJ PAN)
	LSC	A. Bettini ←
	UAM	L. Labarga ←
	UDUR	S. Pascoli
	USFD	P. Lightfoot
	AU	H. Fynbo
	IFIN-HH	R. Margineanu
Industrial partners' representatives (ex-officio)		
	Rockplan	G. Nuijten
	KGHM CUPRUM	W. Pytel
	IGSMiE PAN	K. Slizowski
	Technodyne	J. Thompson
	AGT	M. Temussi
	Lombardi	P.F. Bertola

The **LAGUNA** detector-technology approaches

Water-Cherenkov ⇨ MEMPHYS

Precursor:

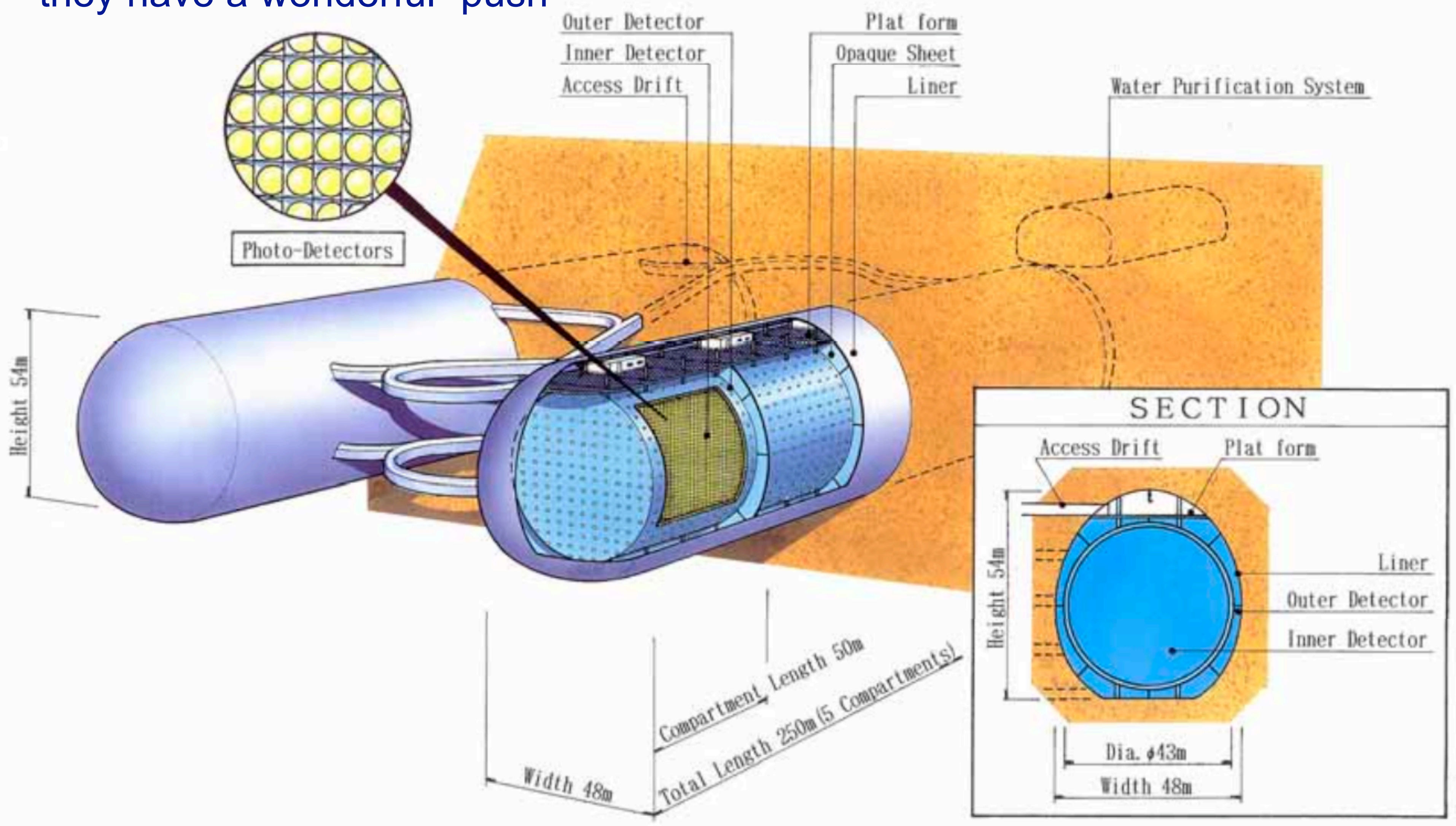


- tank size limited by light attenuation length (λ ~ 80m) and pressure on PMTs
- readout : ~3 x 81K 12" PMTs, 30% geom. cover

See talk by Michela Marafini

LAGUNA (MEMPHIS) is the European "competitor" of SuperKamiokande's successor: HyperKamiokande

- they have the expertise
- they have a powerful ν beam
- they have a wonderful "push"



Liquid Scintillator ⇨ LENA

DETECTOR LAYOUT

~ 50 kt Liquid Scintillator

Cavern
height: 115 m, diameter: 50 m
shielding from cosmic rays: ~4,000 m.w

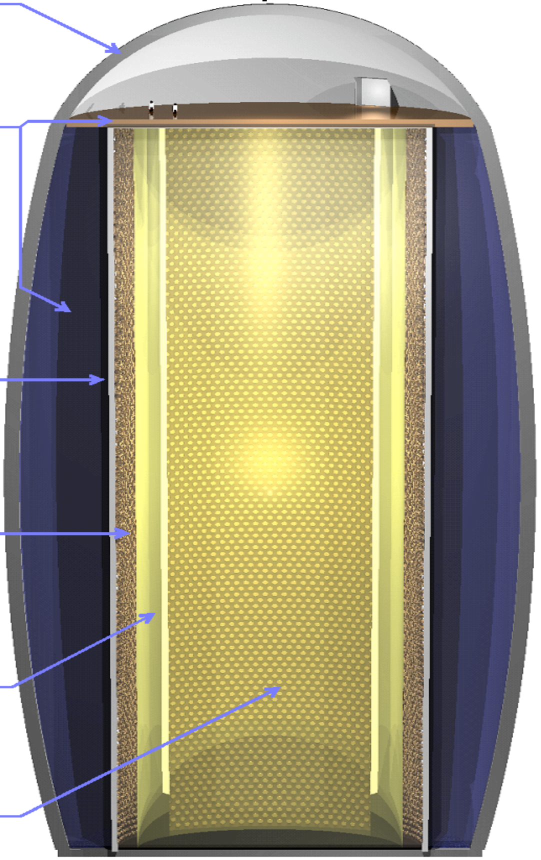
Muon Veto
plastic scintillator panels (on top)
Water Cherenkov Detector
1,500 phototubes
100 kt of water
reduction of fast
neutron background

Steel Cylinder
height: 100 m, diameter: 30 m
70 kt of organic liquid
13,500 phototubes

Buffer
thickness: 2 m
non-scintillating organic liquid
shielding external radioactivity

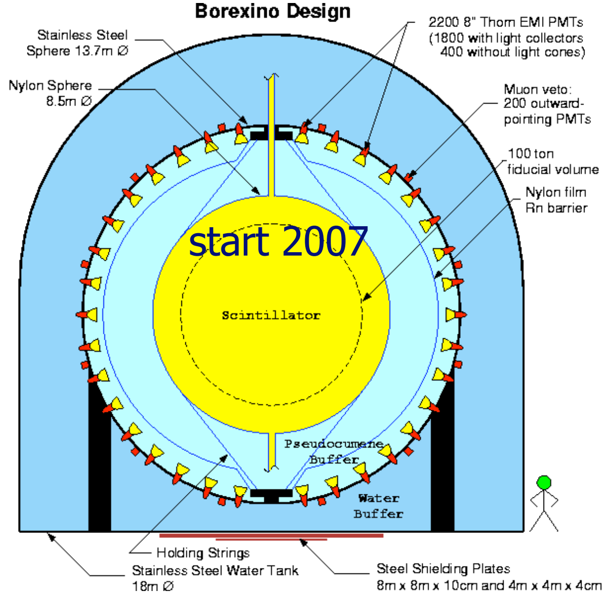
Nylon Vessel
parting buffer liquid
from liquid scintillator

Target Volume
height: 100 m, diameter: 26 m
50 kt of liquid scintillator

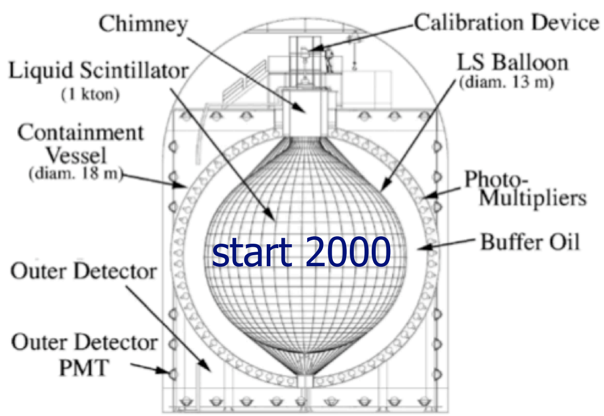


vertical design is favourable in terms of rock pressure and buoyancy forces

Borexino (LNGS):
LSci fiducial/tot vol.: 100/300 t
Buffer UP-org/water: 1k/2.4k t



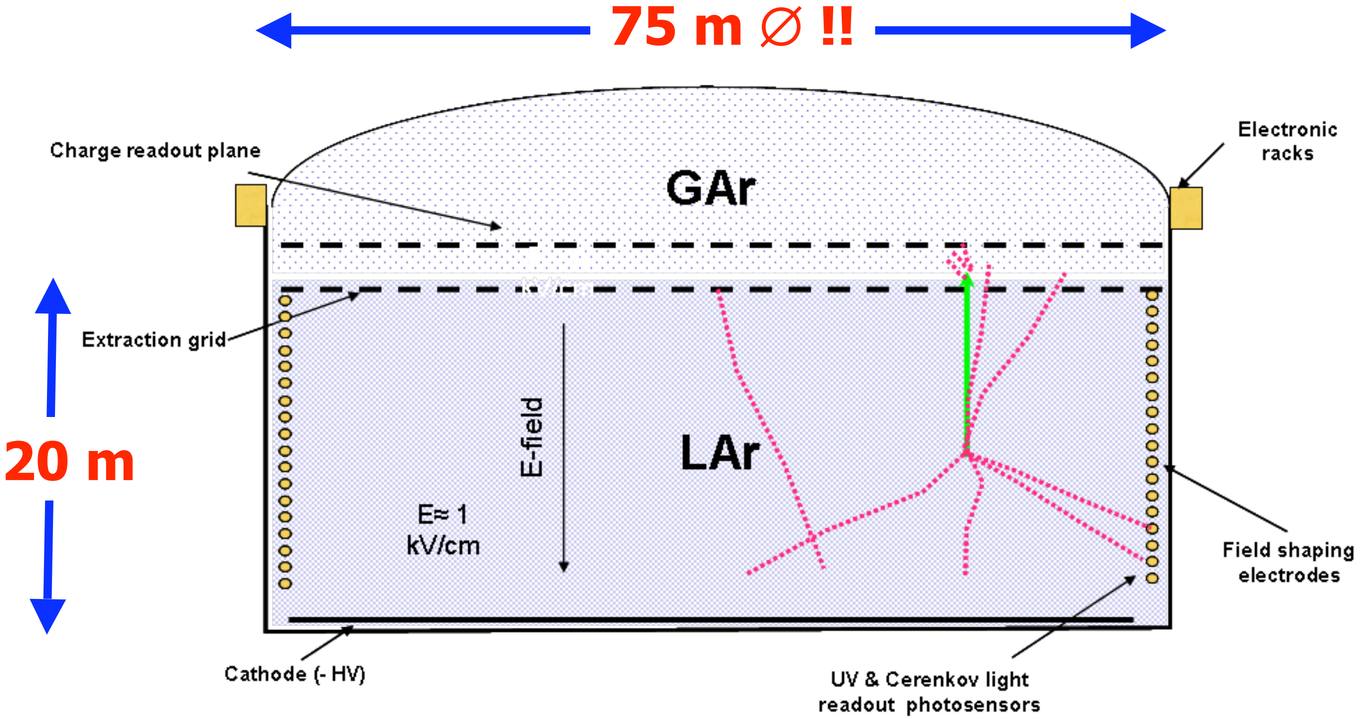
KamLand (Kamioka):
LSci fiducial/tot vol.: 400/1k t
Buffer UP-org/water: 2k/3k t



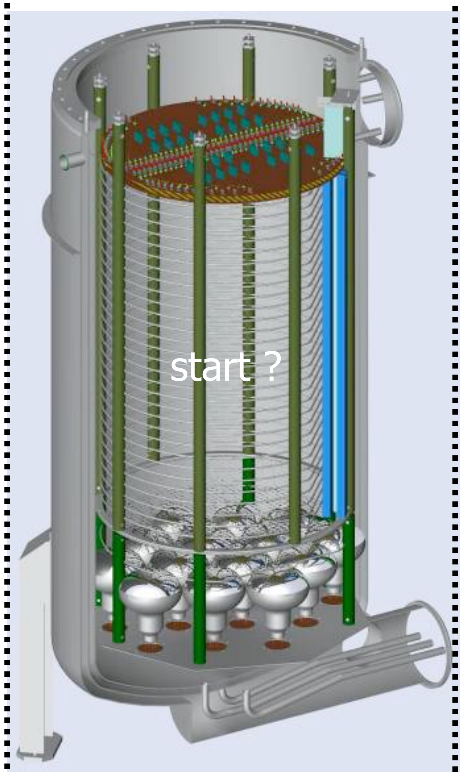
See talk by Michael Wurm

Liquid Argon ⇨ GLACIER

- LAr storage based on LNG tank tech.
- Double - Phase LEM readout (gain ~ 10^4)
- Cockroft-Walton (Greinacher) Voltage Multiplier (~ 1 kV/cm)
- Very Long drift distances (~ 20 m)



"Precursor"
ArDM (LSC ?)
1 t LArg



Comparison of potentialities:

Table 12. Summary of the physics potential of the proposed detectors for astro-particle physics topics. The (*) stands for the case where gadolinium salt is added to the water of one of the MEMPHYS shafts.

D. Autiero et al.; JCAP11(2007)011

Topics	GLACIER 100 kton	LENA 50 kton	MEMPHYS 440 kton
Proton decay			
$e^+\pi^0$	0.5×10^{35}	—	1.0×10^{35}
$\bar{\nu}K^+$	1.1×10^{35}	0.4×10^{35}	0.2×10^{35}
SN ν (10 kpc)			
CC or inverse β	$2.5 \times 10^4 (\nu_e)$	$9.0 \times 10^3 (\bar{\nu}_e)$	$2.0 \times 10^5 (\bar{\nu}_e)$ (*)
NC	3.0×10^4	3.0×10^3	—
ES	$1.0 \times 10^3 (e)$	$7.0 \times 10^3 (p)$	$1.0 \times 10^3 (e)$
DSNB ν (S/B 5 yr)	40–60/30	9–110/7	43–109/47 (*)
Solar ν (evts. 1 yr)			
^{8}B ES	4.5×10^4	1.6×10^4	1.1×10^5
^{8}B CC	—	360	—
^{7}Be	—	2.0×10^6	—
pep	—	7.7×10^4	—
Atmospheric ν (evts. 1 yr)	1.1×10^4	—	4.0×10^4 (1 ring only)
Geo ν (evts. 1 yr)	Below threshold	≈1000	Need 2 MeV threshold
Reactor ν (evts. 1 yr)	—	1.7×10^4	6.0×10^4 (*)

⇨ "~ similar" physics output in "~ similar" periods of time

See talks by Marafini & Wurm

The current

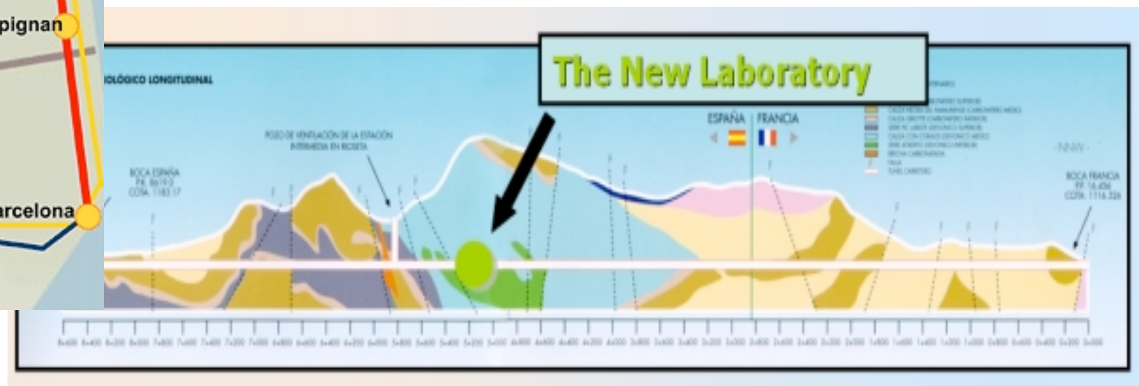
Underground Canfranc Laboratory

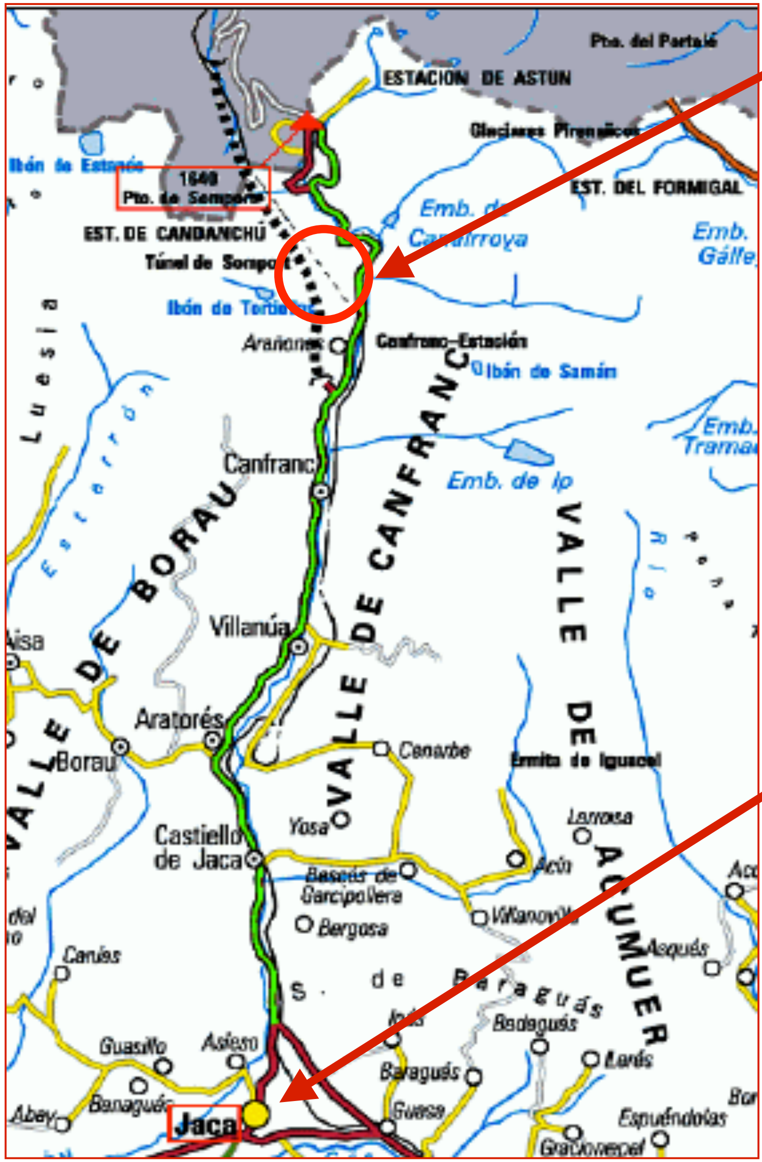
LSC

***L**aboratorio **S**ubterráneo de **C**anfranc*


El Tobazo


Bayona
Pau
Tarbes
Toulouse
San Sebastián
Bilbao
Olorón
Vitoria
Túnel de Somport
CANFRANC
Pamplona
Perpignan
JACA
Sabiñánigo
L' Aínsa
Huesca
Barbastro
Lleida
Barcelona
Zaragoza
AUTOVÍA
CTRA. NACIONAL
TÚNEL DEL SOMPORT
AUTOPISTA

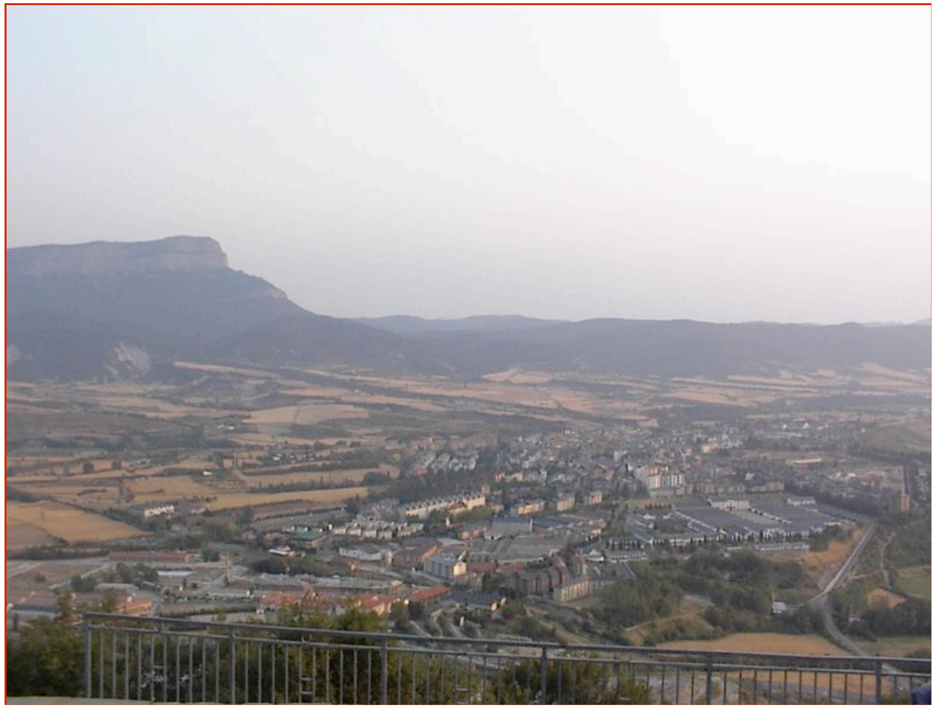

The New Laboratory
ESPAÑA
FRANCIA



Town of Canfranc:
LSC, candidate LAGUNA site

at 21 Km from the

City of Jaca:
Old (1097) but lively (~15000 inhab.).
It provides all living services / needs.



also …

technicians, admin. personnel, engineers, scientists, etc. may relax after duty in the two excellent nearby (< 3 Km) sky resorts **Candanchú** and **Astún**

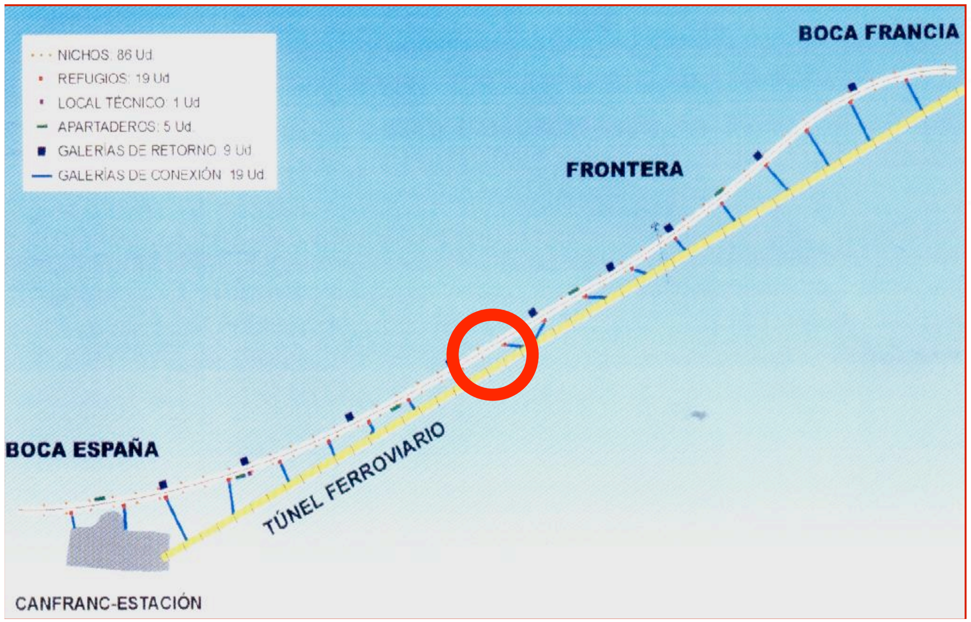
LSC lies physically in between:

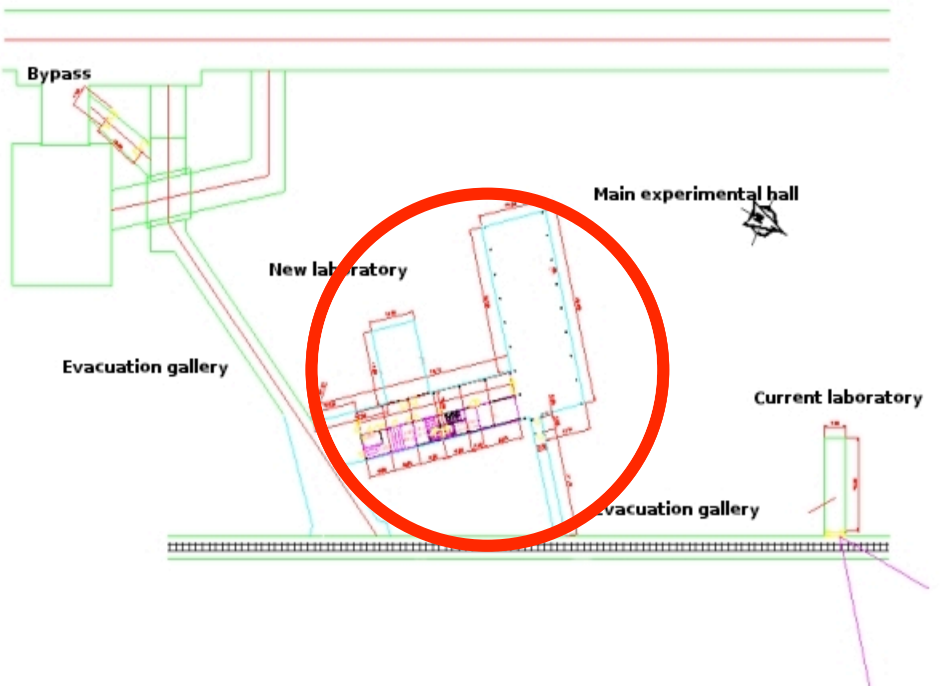
New Road Tunnel (Somport tunnel, opened 2003)

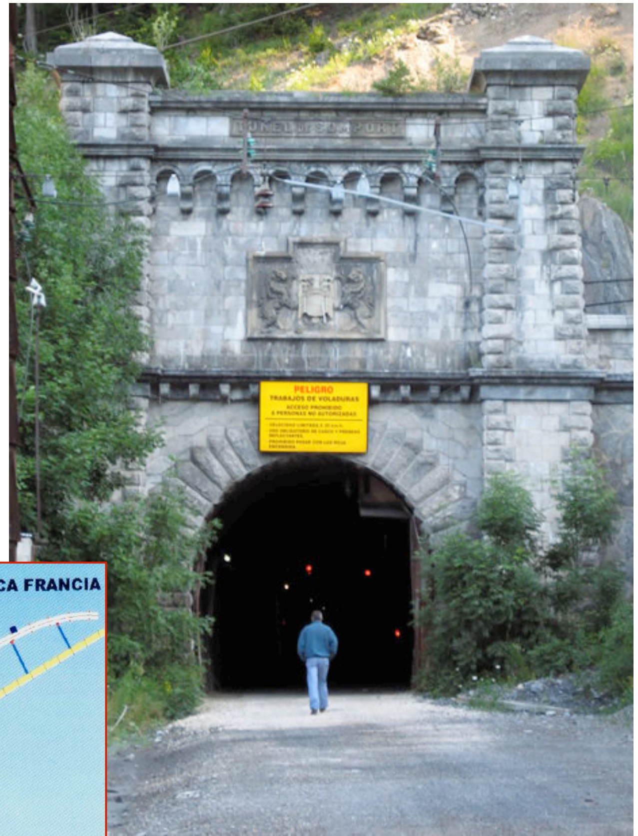
- binational: Spain (Jaca) - France (Pau)
- Length: 8,6 Km (5,7 in Spain + 2,9 in France)
- State of the art on safety features (EU directive 2004)

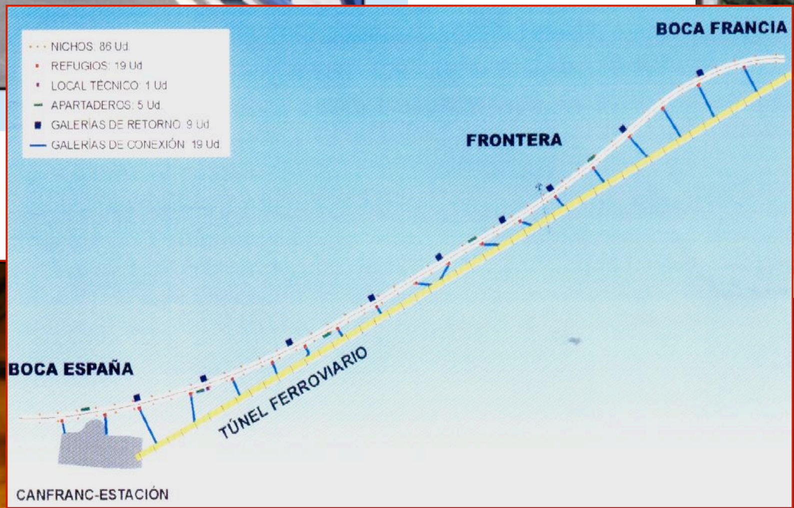
Old Railway Tunnel

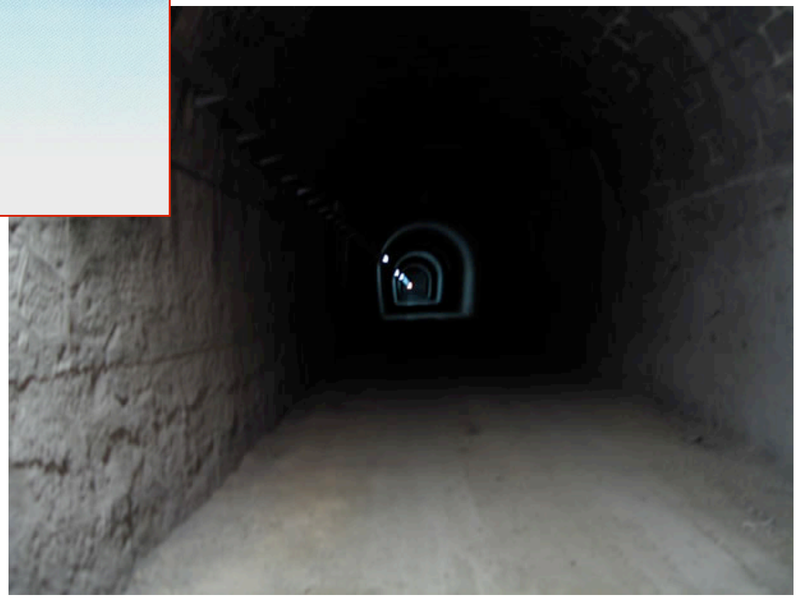
- Now used as service and emergency exit of Road Tunnel
- Safety galleries connecting both tunnels every 400 m
- Current Access for Laboratory



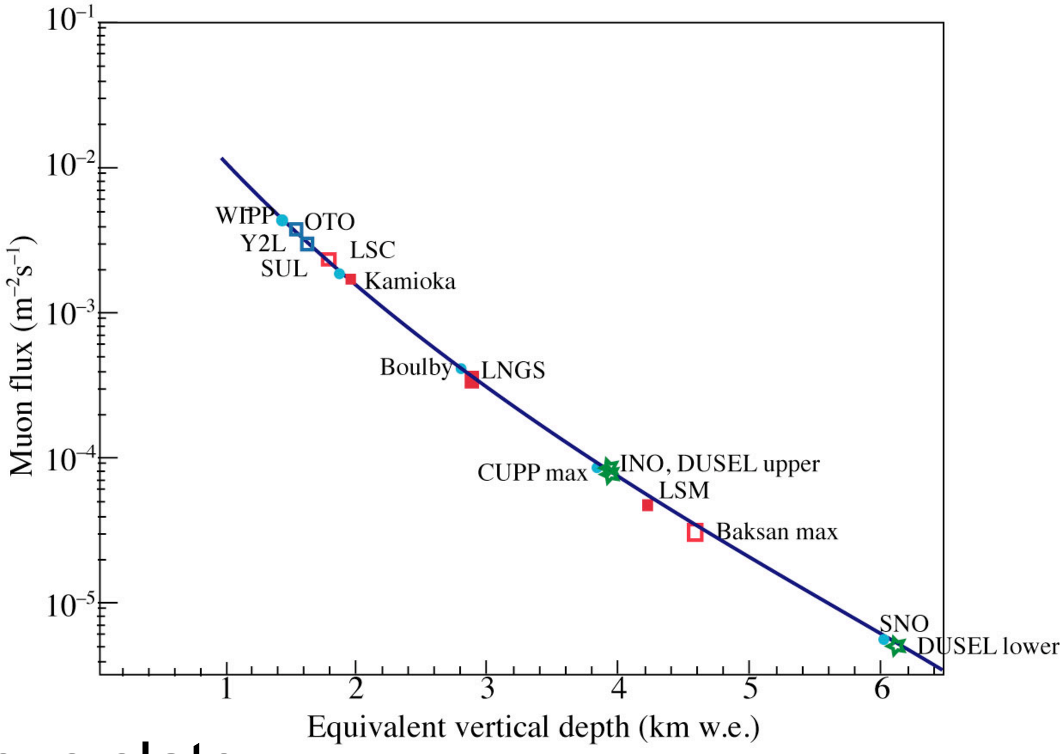



PELIGRO
TRABAJOS DE VOLADURAS


NICHOS: 86 Ud
REFUGIOS: 19 Ud
LOCAL TÉCNICO: 1 Ud
APARTADEROS: 5 Ud
GALERÍAS DE RETORNO: 9 Ud
GALERÍAS DE CONEXIÓN: 19 Ud
BOCA FRANCIA
FRONTERA
BOCA ESPAÑA
TÚNEL FERROVIARIO
CANFRANC-ESTACIÓN



Some characteristics:



- Depth: ~ 2.500 m.w.e.
- Rock composition: Calcareous slate
  - Limestone, filosilicates, some quartz
  - ρ = 2,7 g/cm^3
- Radon: 50 - 80 Bq/m^3
- Muon flux: ~ 3 x 10 μ /(m^{-2} s^{-1})
- Neutrons: ~ 2 x 10^{-2} n /(m^{-2} s^{-1})

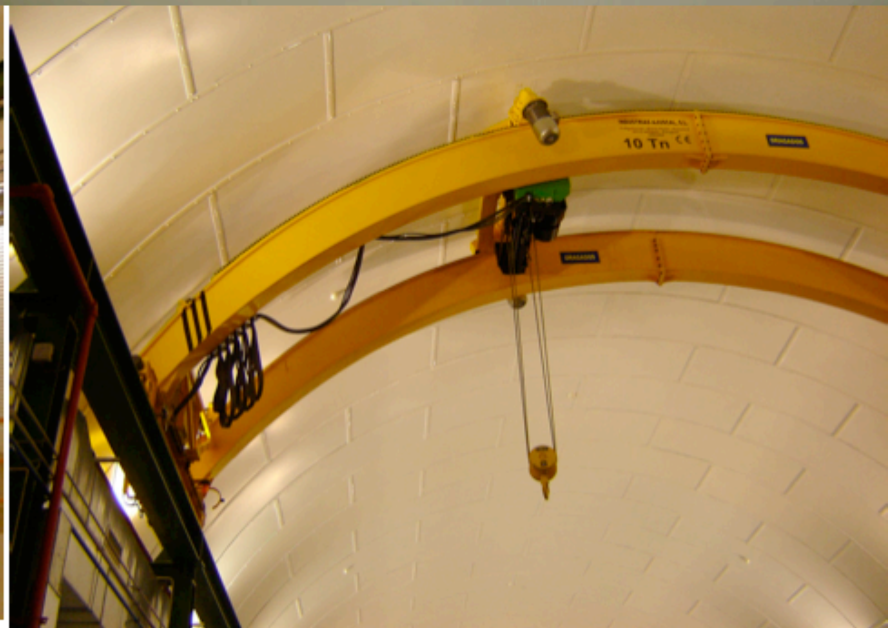
[from A.Bettini, "The World Underground Scientific Facilities, a compendium", hep-exp:0712.1051]

Some Pictures and Plans of the LSC

the pictures were taken before the falls' incident; but the laboratory looks identical after the reinforcement / reconstruction is fully finished (this spring)

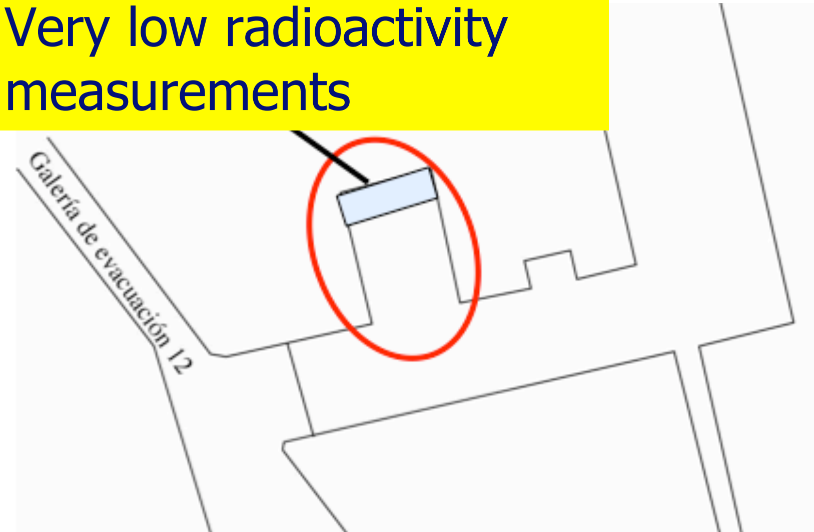
Hall A

40x15x12 600 m²



Halls B and C

Hall C:
Very low radioactivity measurements



$15x10x8\ m^3$ $100+50\ m^2$

Gallery: clean room & services

IN

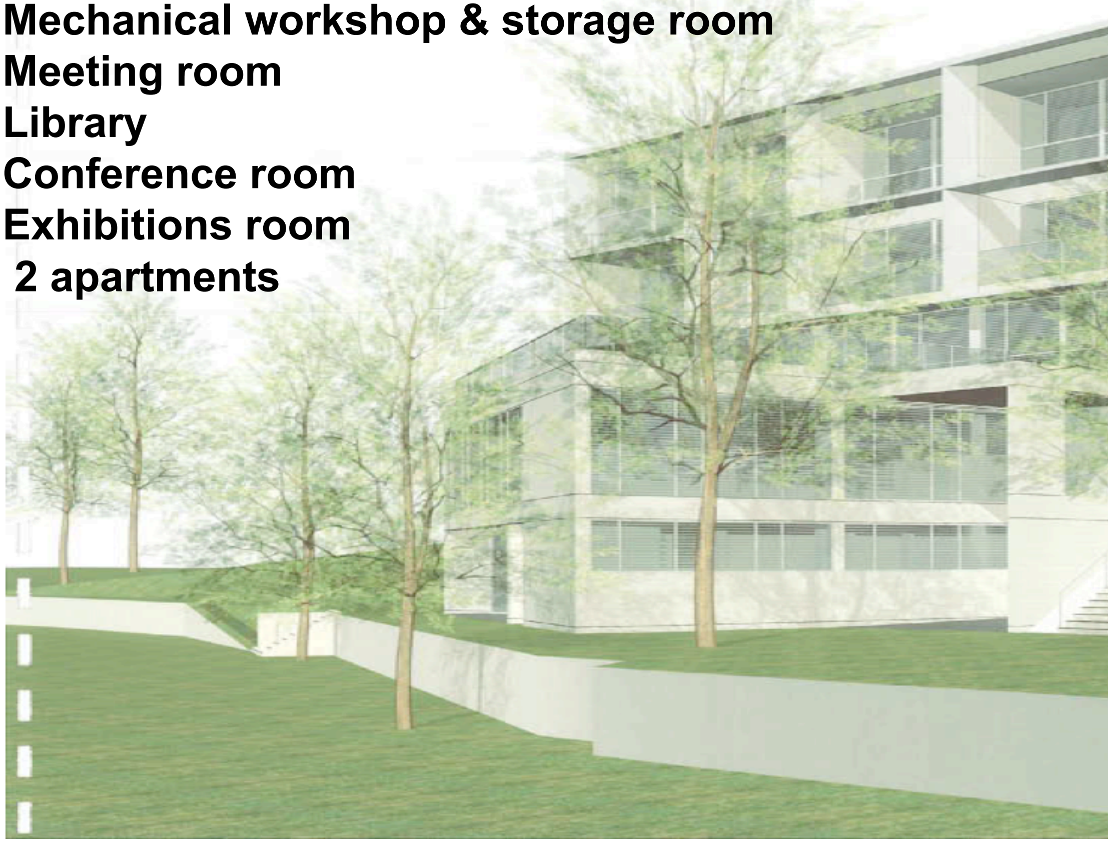
Emergency exit

Connection to the safety (railway) gallery and bay area

External building

Headquarters & Administration
Safety and Quality Assurance
16 offices for scientific users
7 offices for LSC personnel
4 specialised laboratories
Mechanical workshop & storage room
Meeting room
Library
Conference room
Exhibitions room
2 apartments

Surface:	1.821 m^2 (2.115 m^2 built)
Project completed:	December 2008
Construction begins:	July 8 2009
Building completed:	December 2010
Cost of the building:	2.003.974,32 € (+IVA)



The following **experimental proposals** have been submitted or shown interest and are being discussed and followed by the Scientific Committee:

Approved:

- ***ANAIS***: experiment to search for annual modulation of Cold Dark-Matter
- the ***ROSEBUD*** test facility for bolometer R&D to support European cryogenic detectors
- the ***BiPo*** test series in view of the super-NEMO program for $0\nu2\beta$
- ***NEXT***: time-projection-chamber experiment for $0\nu2\beta$
- ***ULTIMA***: ultra cold prototype detector for the search the super-fluid phase of a 3He-4He mixture.
- ***SUPERKGD***: "mass production" of very low background measurements for the Super-Kamiokande R&D program on neutron tagging by dissolving Gadolinium in its water

Under study:

- the ArDM Dark-Matter search with a liquid Argon TPC

⇨ An enlargement of the laboratory to host next-generation nuclear astrophysics experiments and the potentiality of the underground environment for geological and biological sciences are under study

Laguna

at the **LSC**

Some items about this first period LAGUNA-LSC

- The coordinator of the Feasibility Study (FS) for the LSC is L. Labarga (UAM); he has the help of LSC staff

- LAGUNA-EU has assigned ~145 K€ for the FS of the LSC, the LSC has contributed with ~ 100 K€

- The LSC has not Geotechnic Dept.; technical part had to be subcontracted

- July 2008 --> March 2009
  - Contact, discussions and (private) pre-selection of Geotechnic Companies candidate to carry out the FS for the LSC
  - Administrative and legal procedure to select the Company.
  - Select Company (got a *"dream team"*, see next slide), sign contract, Company starts working

- December 2009: The Company delivers the main document basis of WP2's *"Interim Report for the LSC"* (almost final version, yet preliminary, is at http://www.lsc-canfranc.es/ links *activity* → *LAGUNA*)

Main work
Help work

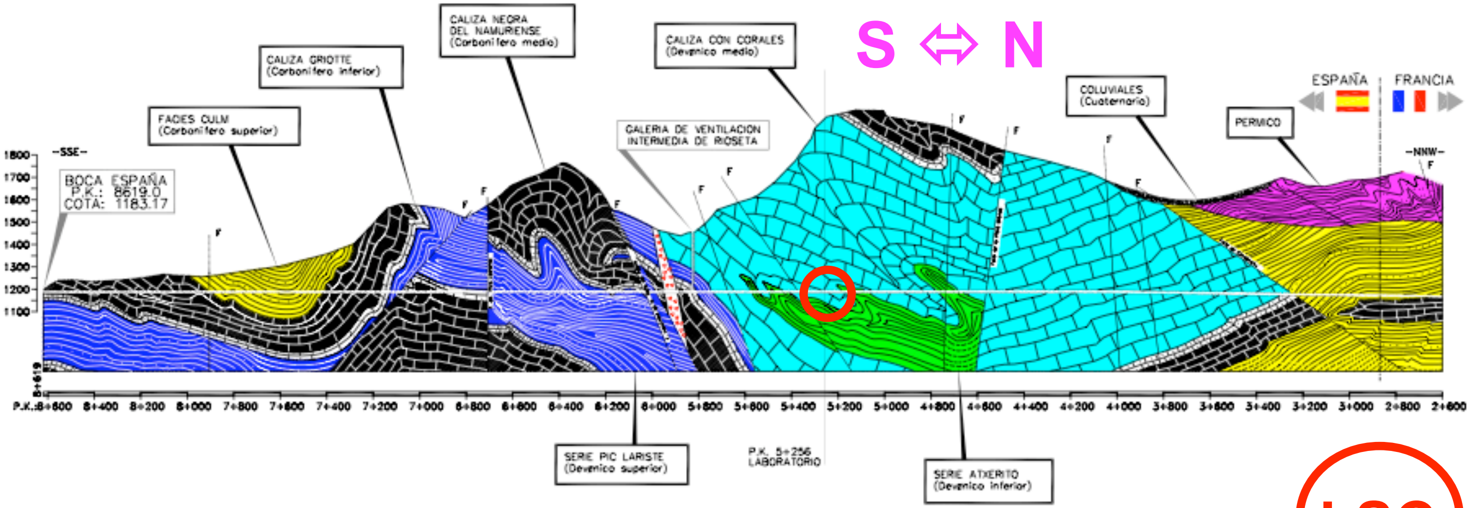
PROJECT TEAM

leader: *Manuel Romana* (STMR)
co-leader: *Clemente Saenz* (Iberinsa)
Companies involved:

LAGUNA Canfranc feasibility study

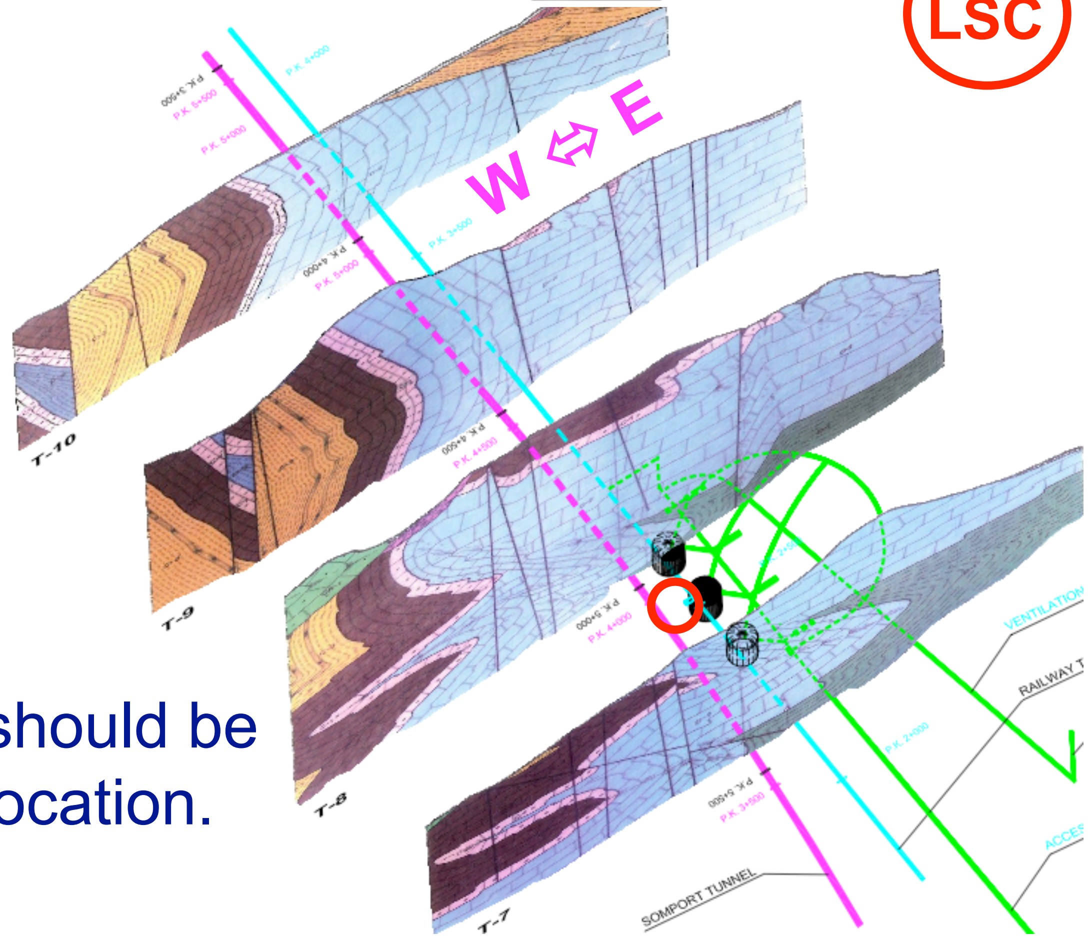
- **Iberinsa: big Spanish consulting firm**
  - Geological-geotechnical work (General)
  - Numerical modelling
  - Environmental questions
  - Auxiliary installations. Buildings
  - Cost estimates
- **STMR: small Spanish geotechnical and tunnelling firm**
  - Project managing and coordination
  - Geologic-geotechnical work (Rock Mechanics problems)
  - Construction processes and work methods
- Obras Subterraneas (OSSA): Biggest Spanish firm for underground works contruction
  - Construction processes and work methods
  - Cost estimates
- Itasca Spain: Local branch of Itasca network of firms
  - Numerical modelling
- Individual consultants
  - Site knowledge (project and construction Manager for Somport Tunnel)
  - Tectonic stresses and seismicity (Madrid Geology Faculty Professor)

General I:



LSC

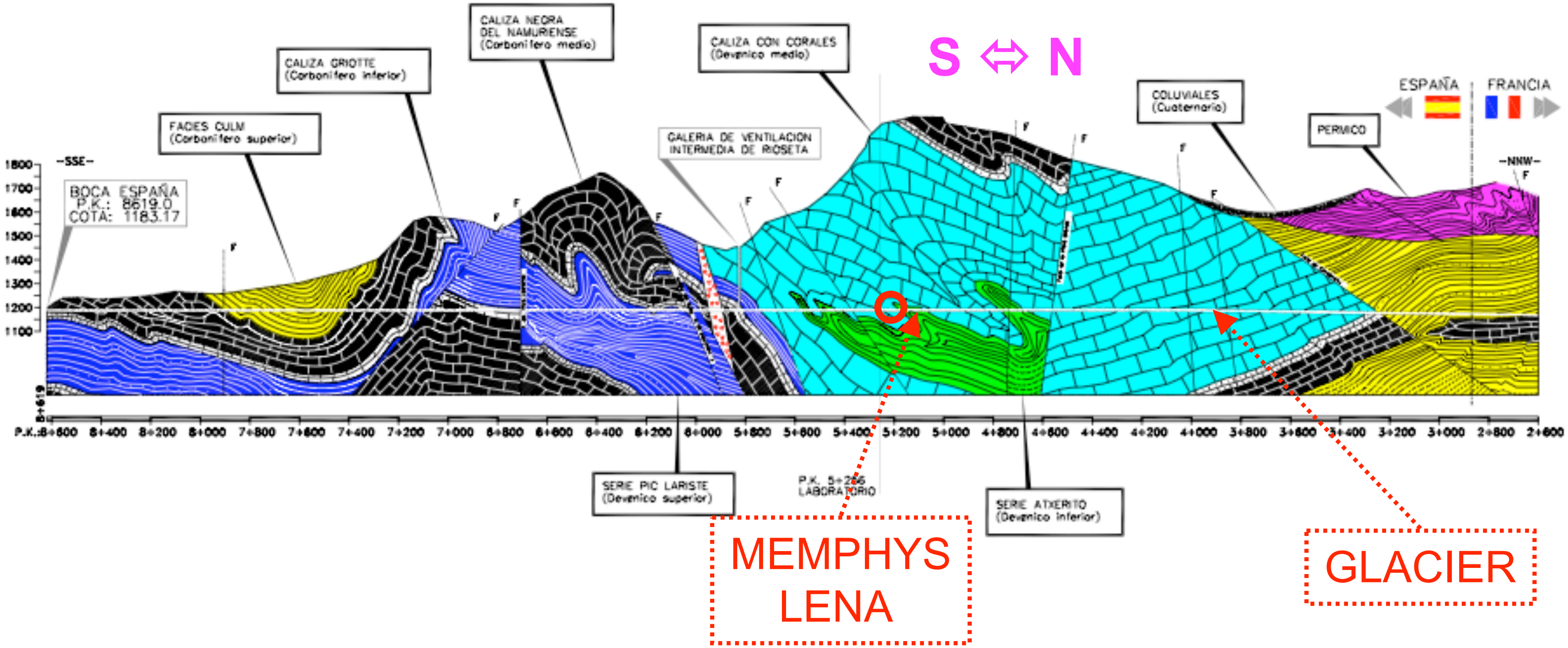
best compromise between overburden, rock quality, knowledge (within FS) and expectations of rock quality, centralization of services ... :



⇨ the LAGUNA experiment should be close to the current LSC location.

General II:

⇨ place MEMPHYS and LENA where overburden is largest



- GLACIER can work at shallower locations.
- Its 75 m ∅ dome (!) is a geotechnic challenge; less overburden and best rock quality will be of big help.
- There is a region along the tunnel shallower and of better rock

⇨ place GLACIER there

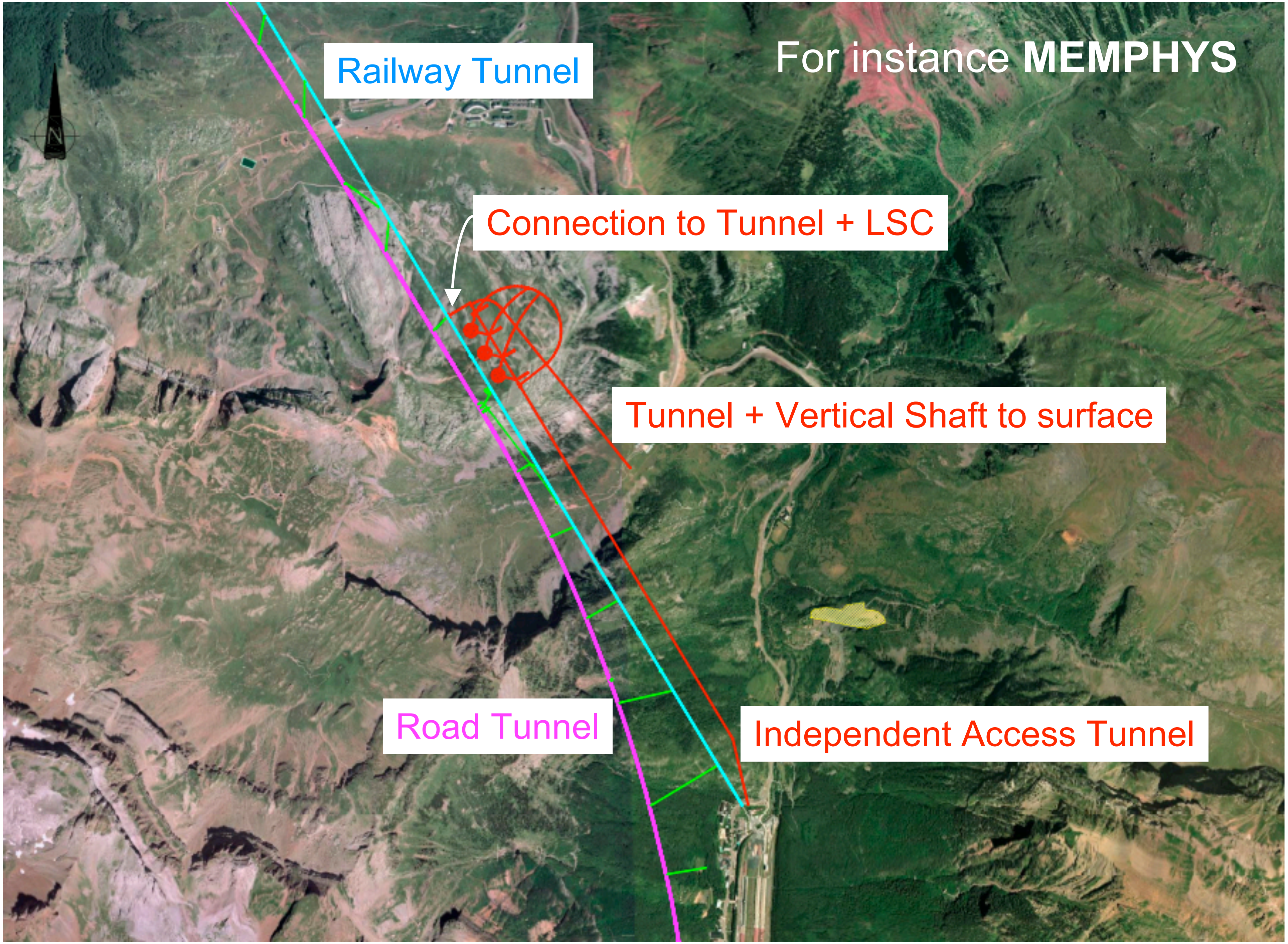
General III:

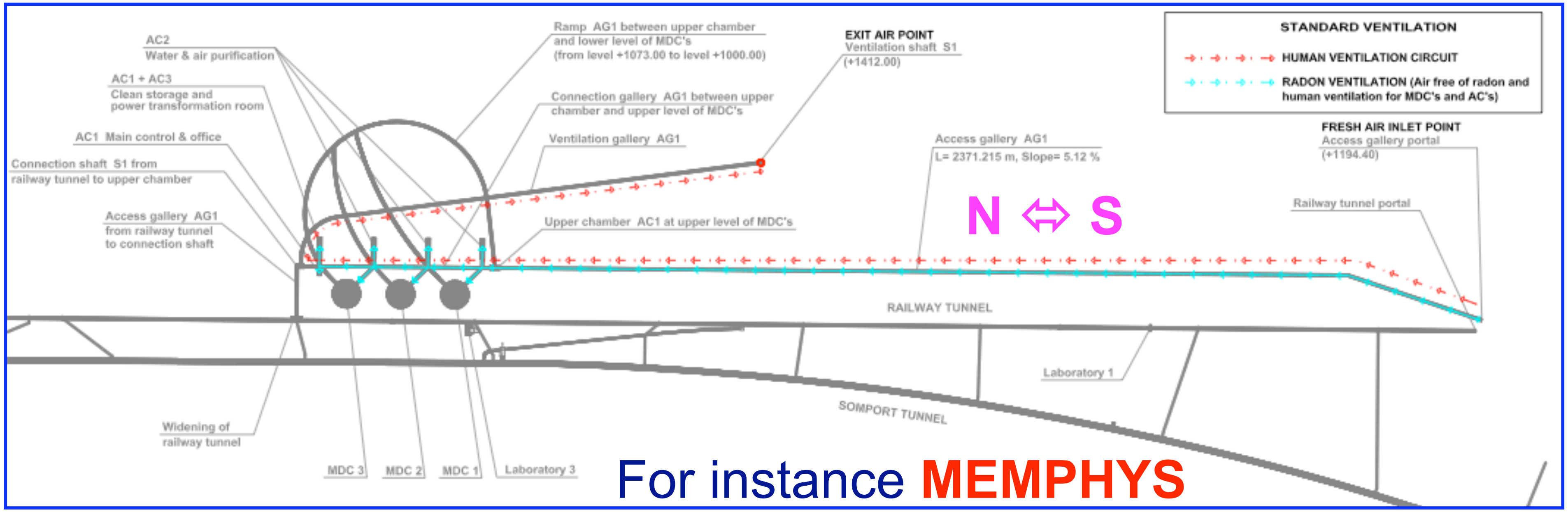
• The main layouts in the three experiments have been designed neither to interfere with the regular running of Road Tunnel nor with the emergency and service purposes of Railway Tunnel.
• Of course they try to take the maximum profit of them, but at the same time they are thought to operate independently if necessary.

⇨ An independent access tunnel (2 - 3 Km long, ~ 4 - 7% downwards) almost parallel to existing ones
  - For construction access (!)
  - For regular operation/running and maintenance access
  - For radon-free air conduction
  - For supplies: energy, water, others
  - For Liquid Scintillator .OR. Liquid Argon supply by truck
  - For ventilation: regular operation/running and fire

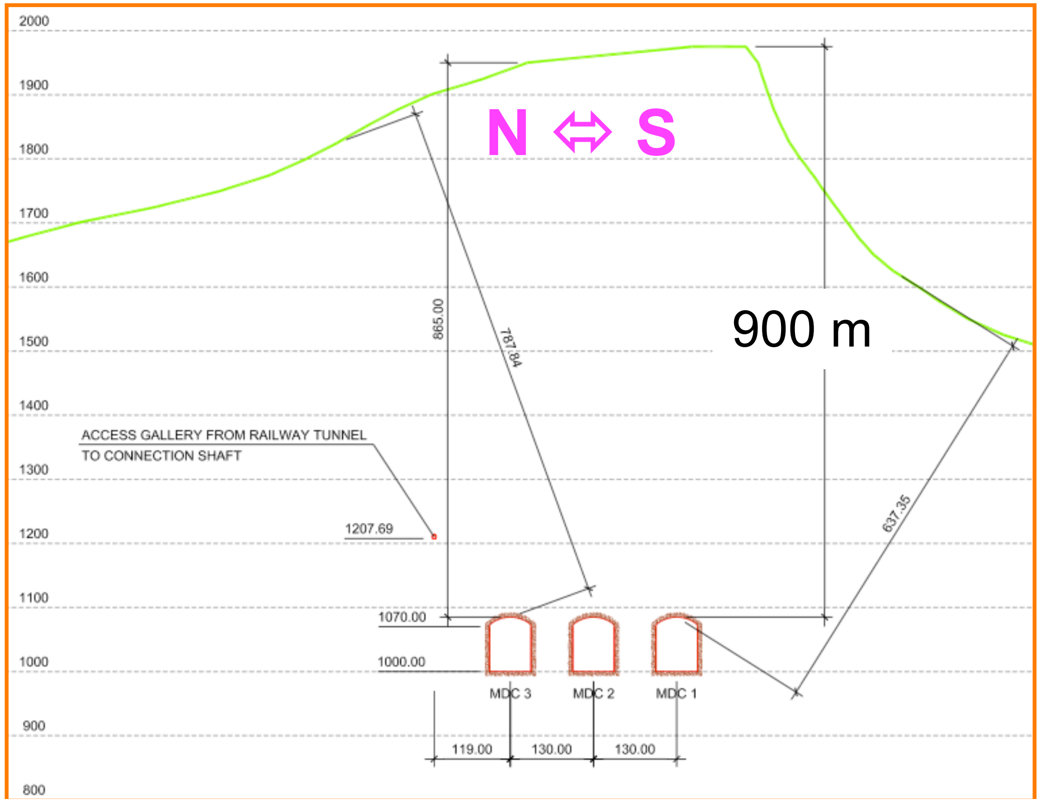
⇨ A permanent connection with the Road and Railway tunnels and the LSC
  - For normal operation (connection to LSC)
  - As an emergency escape way

⇨ Another tunnel + vertical shaft to the surface
  - For ventilation: regular operation/running and fire

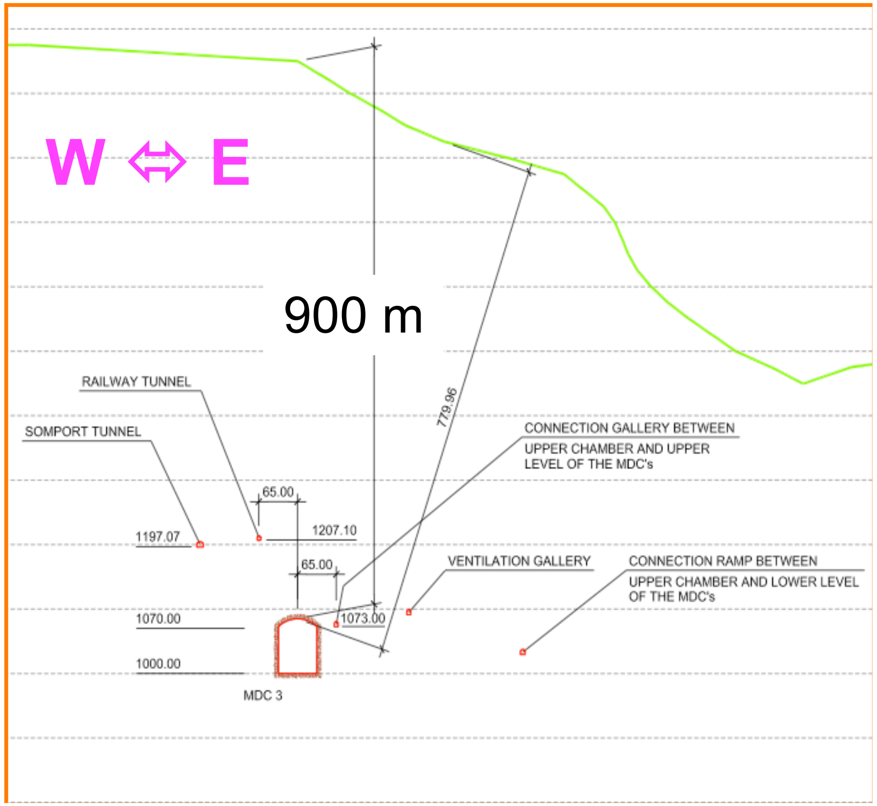

For instance **MEMPHYS**
Railway Tunnel
Connection to Tunnel + LSC
Tunnel + Vertical Shaft to surface
Road Tunnel
Independent Access Tunnel



AC2
Water & air purification
AC1 + AC3
Clean storage and power transformation room
AC1 Main control & office
Connection shaft S1 from railway tunnel to upper chamber
Access gallery AG1 from railway tunnel to connection shaft
Ramp AG1 between upper chamber and lower level of MDC's (from level +1073.00 to level +1000.00)
Connection gallery AG1 between upper chamber and upper level of MDC's
Ventilation gallery AG1
Upper chamber AC1 at upper level of MDC's
EXIT AIR POINT
Ventilation shaft S1
(+1412.00)
Access gallery AG1
L= 2371.215 m, Slope= 5.12 %
STANDARD VENTILATION
HUMAN VENTILATION CIRCUIT
RADON VENTILATION (Air free of radon and human ventilation for MDC's and AC's)
FRESH AIR INLET POINT
Access gallery portal
(+1194.40)
Railway tunnel portal
N ⇔ S
RAILWAY TUNNEL
Laboratory 1
SOMPORT TUNNEL
Widening of railway tunnel
MDC 3
MDC 2
MDC 1
Laboratory 3
For instance MEMPHYS

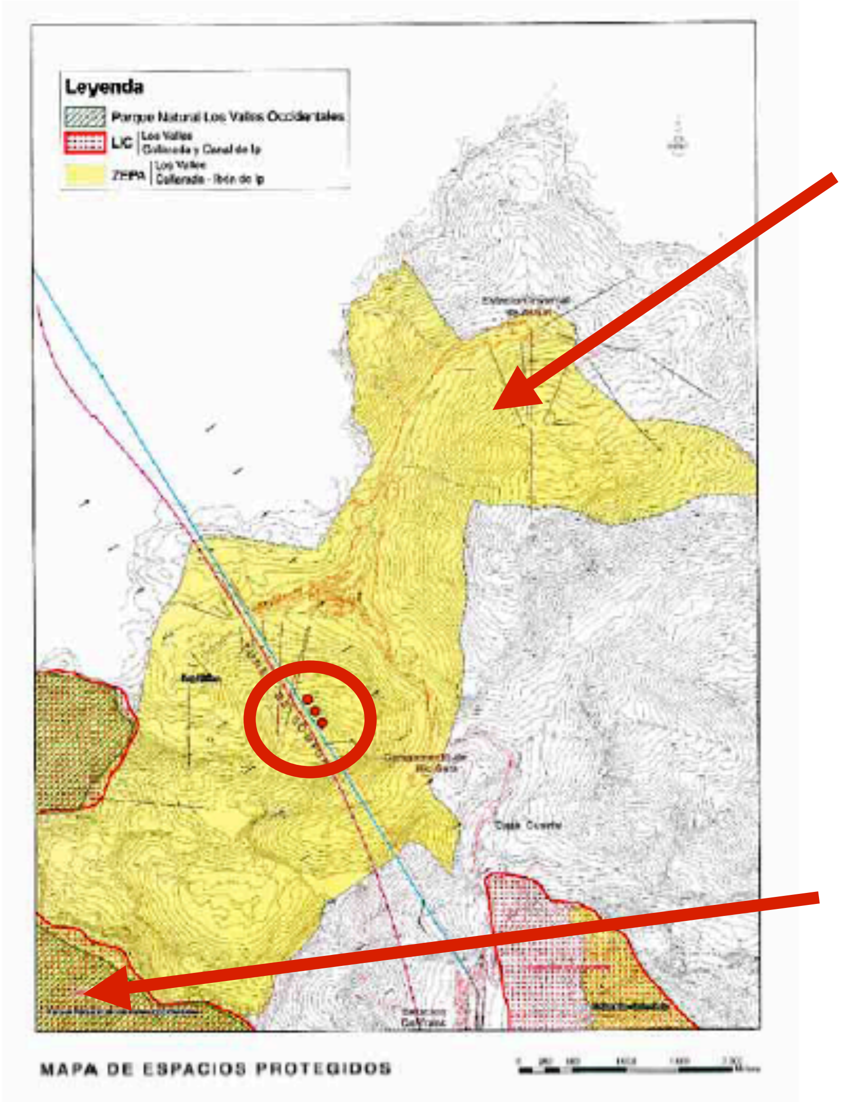


2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
N ⇔ S
900 m
865.00
787.84
637.35
ACCESS GALLERY FROM RAILWAY TUNNEL TO CONNECTION SHAFT
1207.69
1070.00
1000.00
MDC 3
MDC 2
MDC 1
119.00
130.00
130.00



W ⇔ E
900 m
779.96
RAILWAY TUNNEL
SOMPORT TUNNEL
CONNECTION GALLERY BETWEEN UPPER CHAMBER AND UPPER LEVEL OF THE MDC's
65.00
1197.07
1207.10
65.00
VENTILATION GALLERY
CONNECTION RAMP BETWEEN UPPER CHAMBER AND LOWER LEVEL OF THE MDC's
1070.00
1073.00
1000.00
MDC 3

Environmental I:

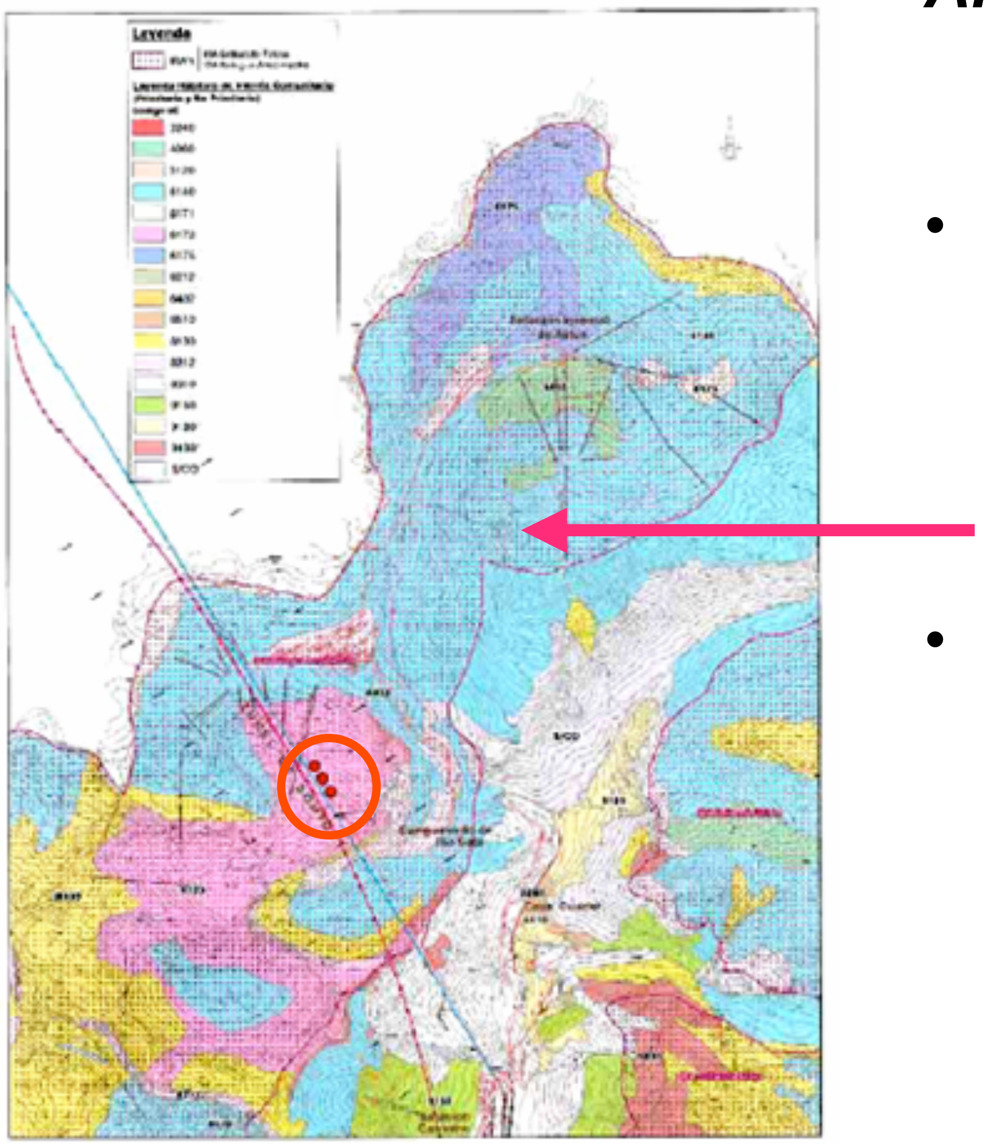


LIC ≡ SCI, Spaces of Community Importance; ZEPA ≡ SPA, Special Protection Areas (Birds); Parque Natural ≡ Nature Park

Nearby protected sites

- Special protected area for birds (ZEPA)
  - Includes site
  - There is a rare vulture protected species
  - No influence for underground works
  - Regulations for surface works during birds nesting period
- Nature Park
  - Far away from the site

Environmental II:



MAPA DE HÁBITATS

Animals habitats network

- Maps for animal and vegetal habitats network around the site have been drawn
- There is no special problem at the site for underground works

Environmental III:

Places for waste rock

Waste rock quantities are big

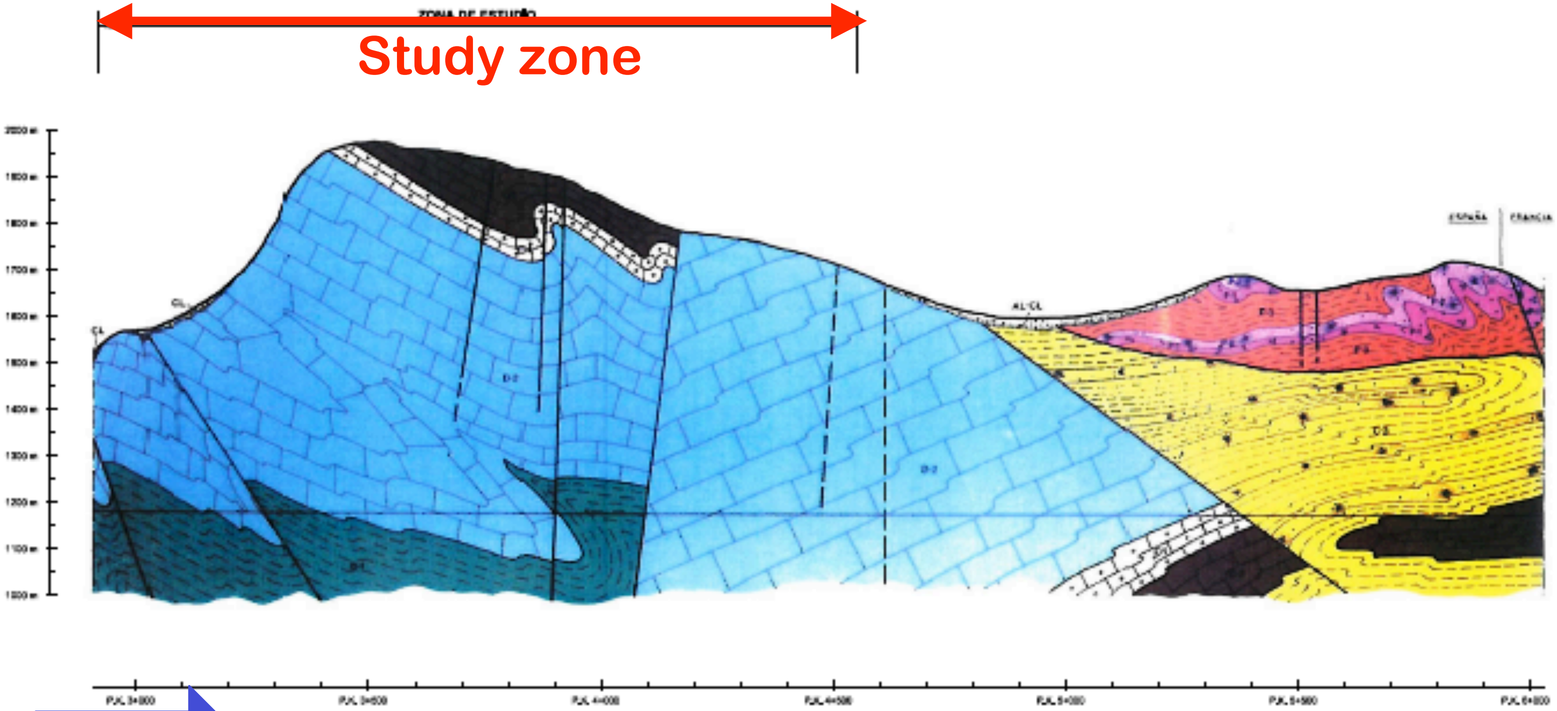
MEMPHYS ~1.000.000 m^3

GLACIER ~200.000 m^3

Two sites are selected closer than 20 Km. with no environmental problems

The places would be reforested like it was done fo Road Tunnel waste rock sites

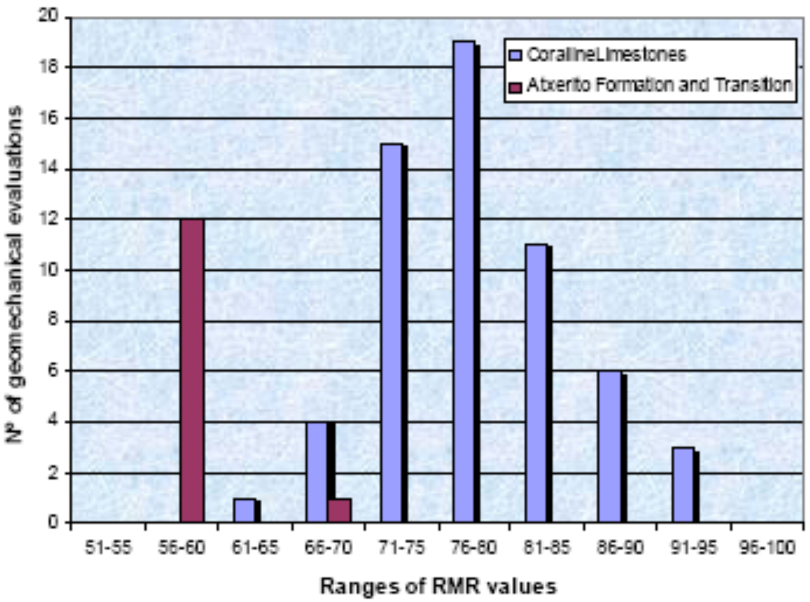
Geology I: profile at site from Road Tunnel studies



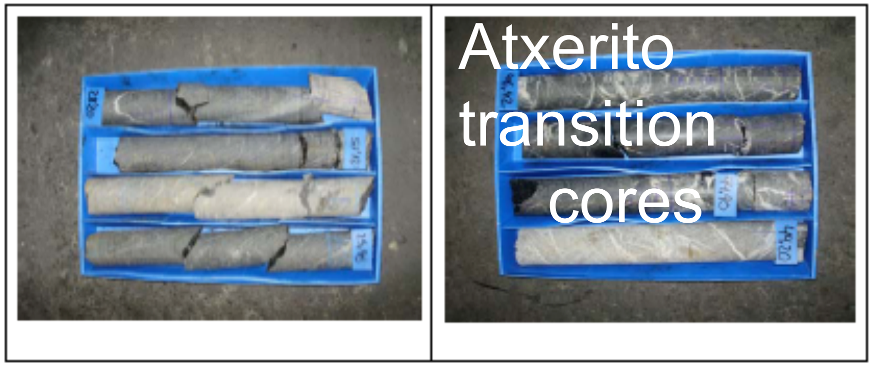
- Calcareous slate (Atxerito series) LSC
  - Metamorphic (low grade)
  - Schistose texture
- Limestone (Coralline limestone Series)
  - Sedimentary
  - Bedded texture

Geology II: geological studies in this FS

- Retrospective analysis of falls in the current LSC in order to check the real rock parameters around the laboratory
- Revision and analysis of geological data gathered at Road Tunnel excavation fases
- Two probing boreholes (40 and 70m long) in key locations
- Laboratory tests



Two boxes of S-1. At left, from 11,00 to 13,25 meters deep. At right, from 37,00 to 39,20.



Two boxes of S-2. At left, from 25,90 to 28,20 meters deep. At right, from 44,20 to 46,420.

Geology III: conclusions and assumptions for calculations

- The rock in most of the site is good quality marine coraline limestone
- There is a transition between the limestone and medium quality folded Atxerito beds
- The distribution of both rocks is well known at the Road Tunnel elevation (both from tunnel excavation and further studies for LAGUNA project)
- To know the exact distribution of both rocks at larger depths it is necessary a further campaign of geological-geotechnical boreholing

The rock assumptions for the calculations of this study are:

- MEMPHYS and LENA are assumed to lie in the worst possible situation (the Atxerito beds)
- GLACIER is known to lie in good quality limestones beds

Conceptual support design I: MEMPHYS and GLACIER

There are ***no precedents***

Their big spans cannot be supported by conventional methods (cables < 20 m, bolts, shotcrete):

- Able to cope with rock stresses near excavation limits
- Able to cope with "minor" wedges (relative to big spans)
- Not able to cope with "major" wedges

A complete concrete roof vault is not considered

⇨ Go for a partial concrete structure to cope with eventual big wedges

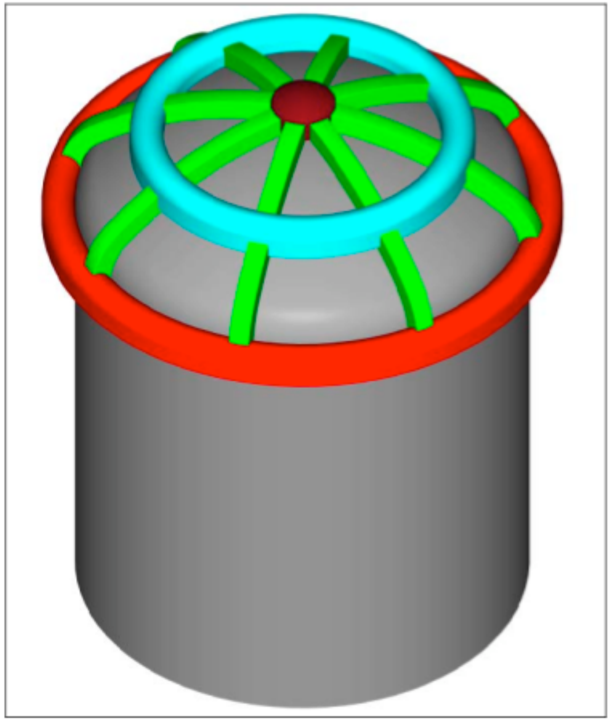


Figure 7.3-2. Perspective view of the vault system.

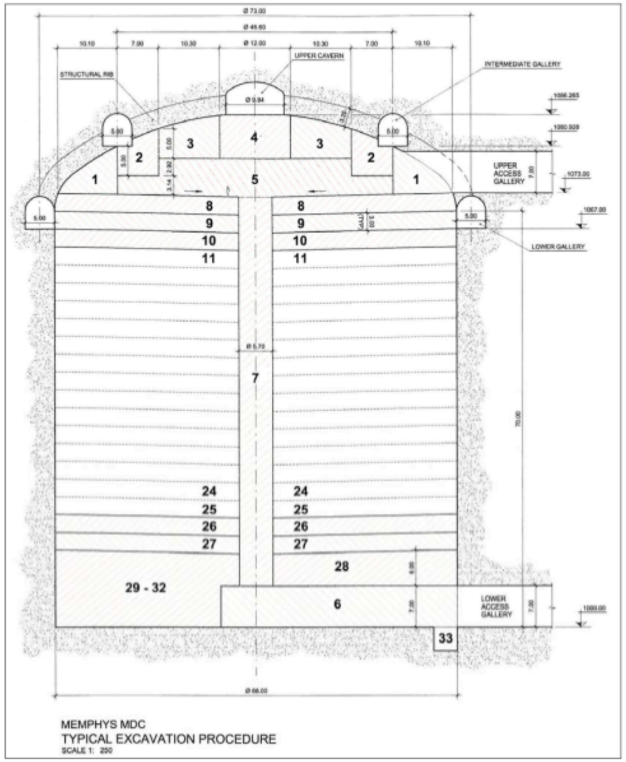


Figure 7.3-3. Excavation sequence for the MEMPHYS caverns.

Conceptual support design II: LENA

There are precedents: Mingtan cavern in weak rock (by *Hoek*)

1. Preliminary circular gallery excavated over the cavern

2. Support cables installed from the gallery before cavern excavation

3. Support completed with more cables, bolts and shotcrete during excavation

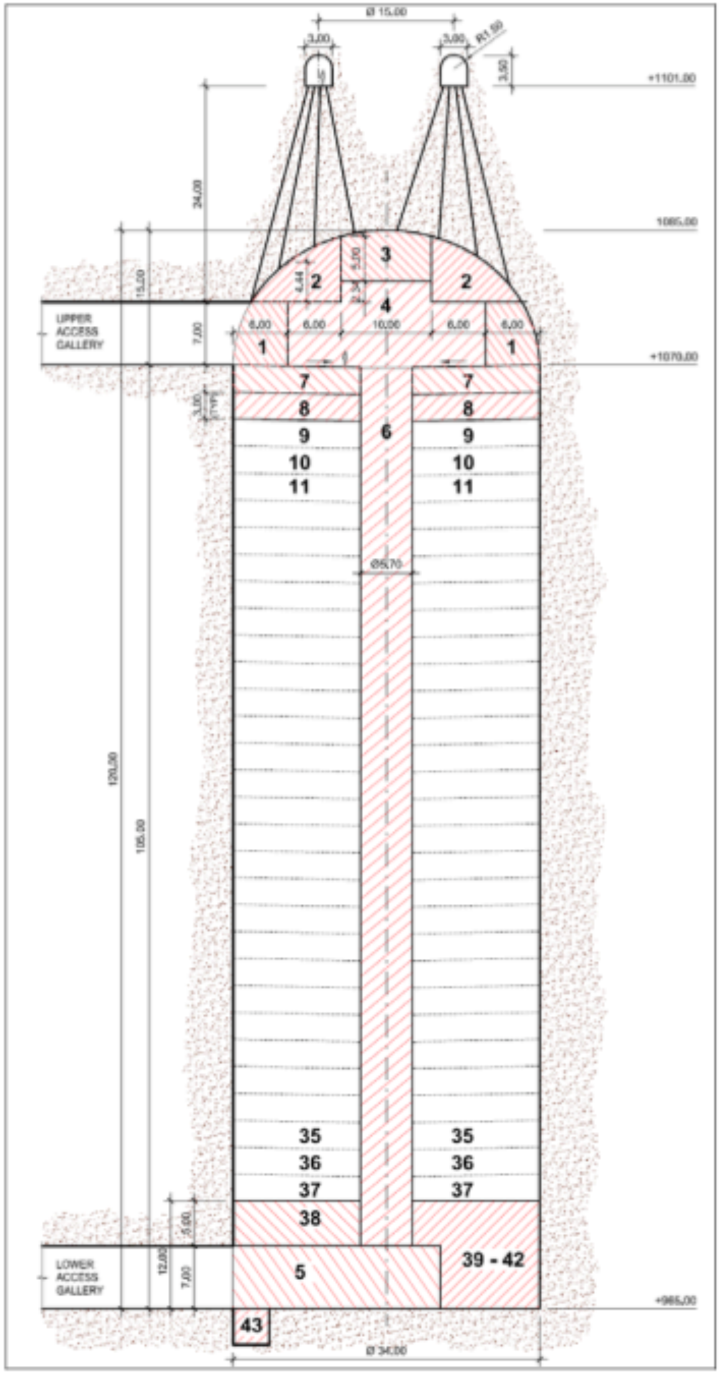
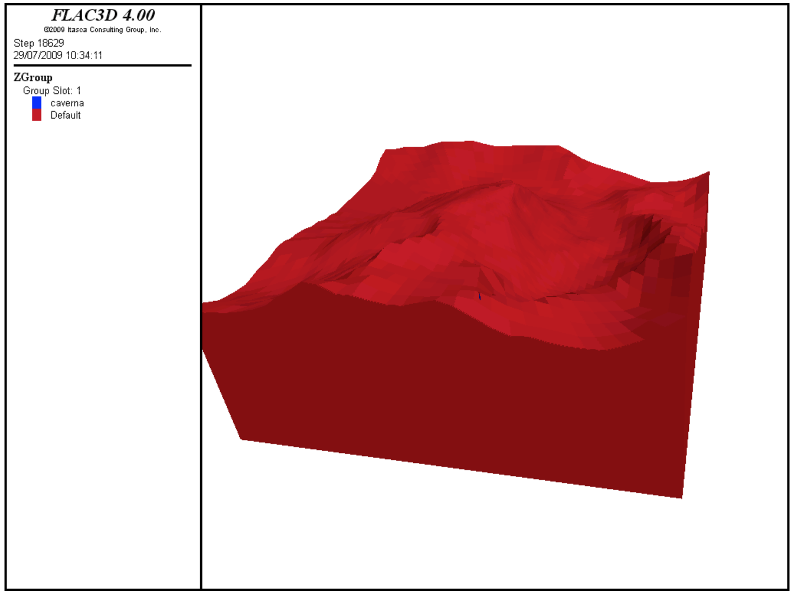
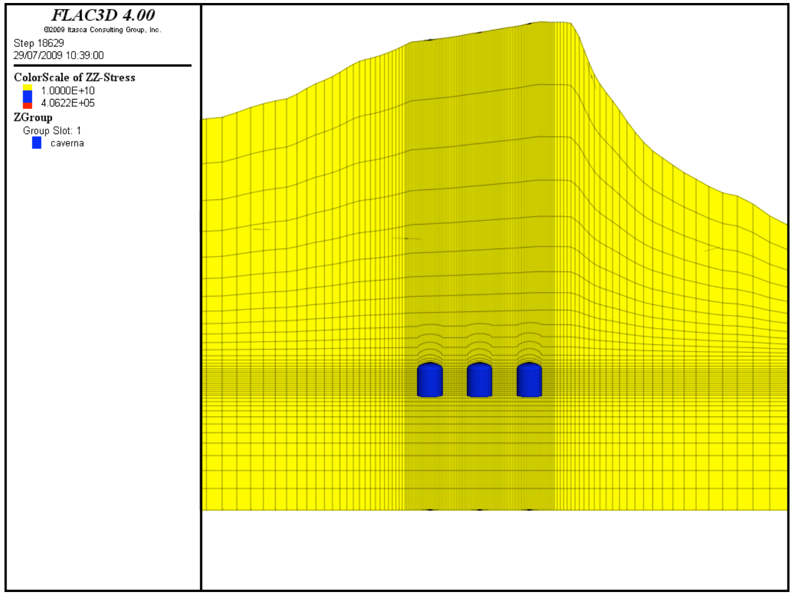


Figure 8.3-3. Excavation sequence for the LENA cavern.

First estimation of the caverns feasibility I:

Modelling / Calculations [elastic]



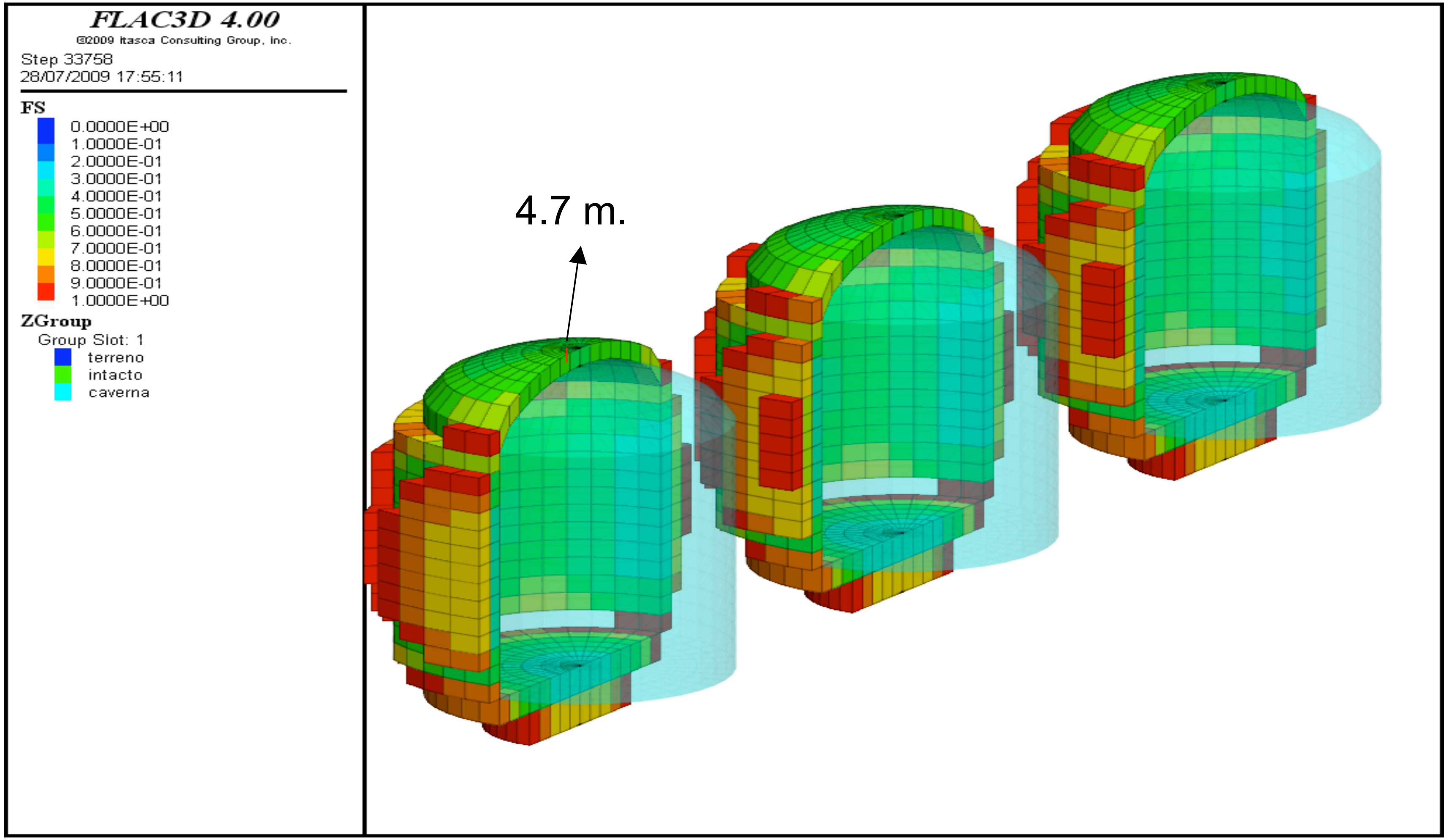


- Check the effect of real topographic features
- Result: no practical effect

First estimation of the caverns feasibility II:

Modelling / Calculations [elastic]

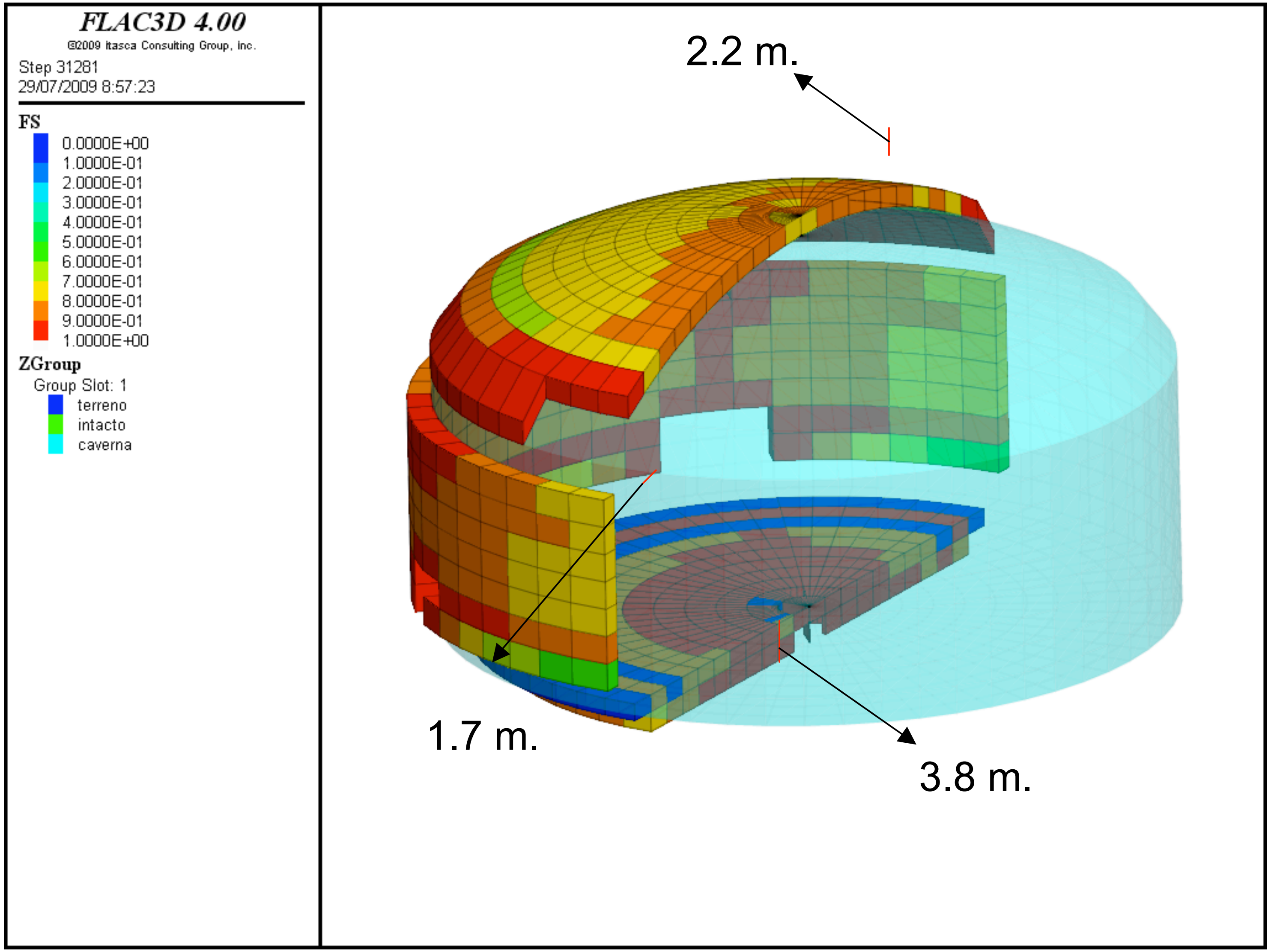
Three MENPHYS caverns; Plasticity Indicators ⇨ OK



First estimation of the caverns feasibility III:

Modelling / Calculations [elastic]

GLACIER cavern; Plasticity Indicators ⇨ OK



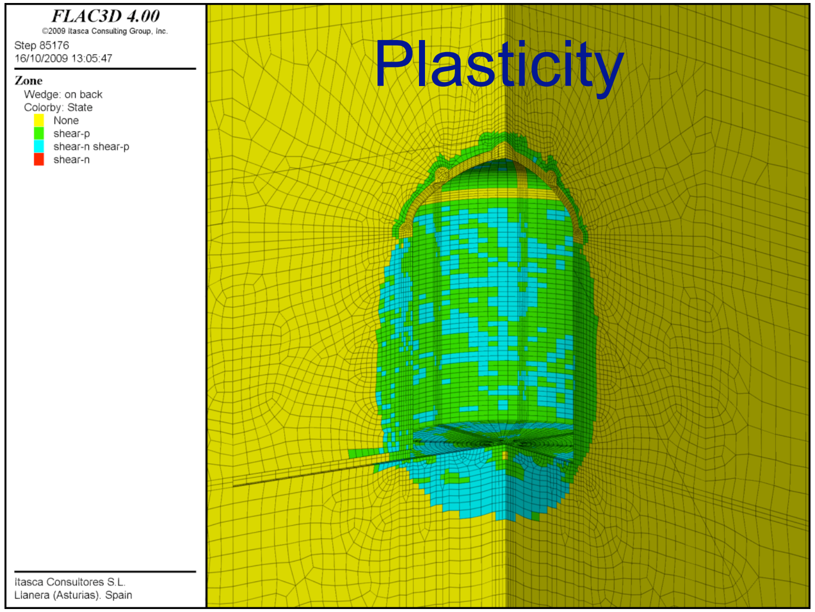
Realistic Calculation: MENPHYS elasto-plastic modelling

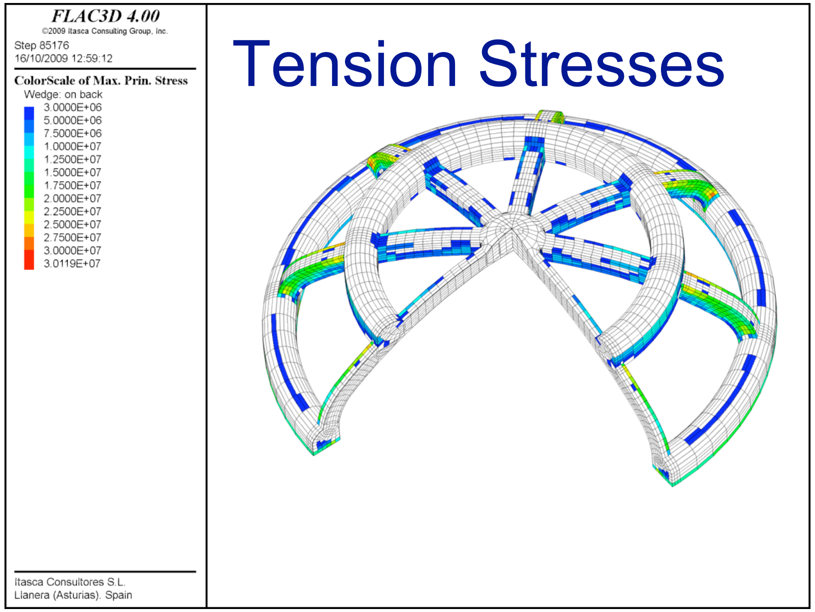
- Assumed worst rock conditions
- Almost all construction stages (slightly simplified)
- Three different behaviour laws for concrete
  - Elastoplastic
  - Brittle failure
  - Softening
- Two different concrete sequences
  - Prior to cavern excavation
  - By stages with cavern excavation
- Concrete needs some reinforcement in the roof lower gallery

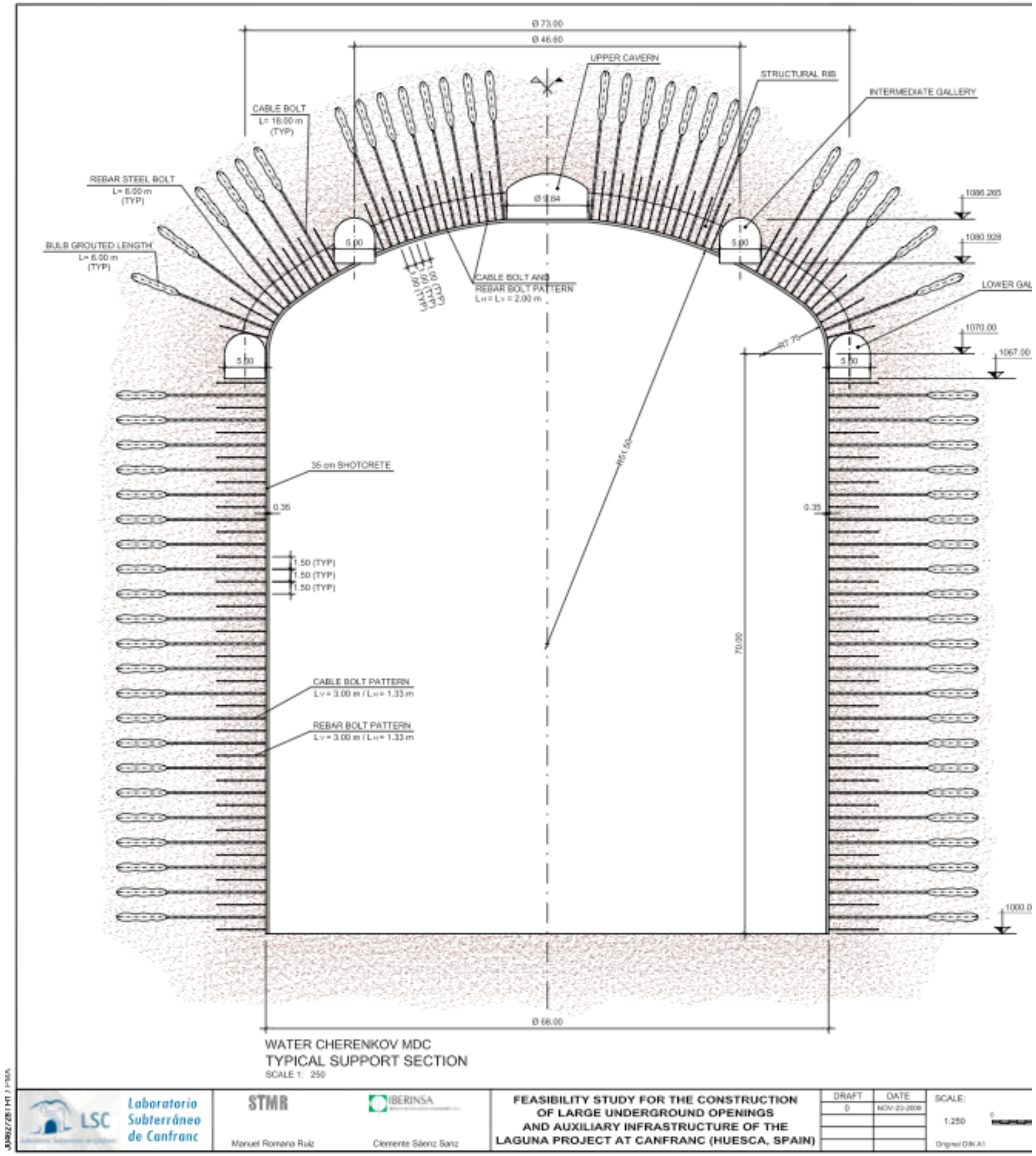
Elastic modelling studies allows us to extrapolate valid conclusions for LENA and GLACIER pre-designs

Example for illustration follows:

Pre-design after elasto-plastic structural calculations of one of the three MENPHYS detector' caverns







Summary / Conclusions

- A very detailed feasibility study for LAGUNA at the LSC has been performed. It is documented in the yet preliminary LAGUNA-WP2's *"Interim Report for the LSC"* (http://www.lsc-canfranc.es/ links *activity* → *LAGUNA*)
- Many items have not been presented here due to lack of time (in particular installations and auxiliary infrastructures). Please have a look to the above page.

- The Canfranc area is excellent to provide the social / living needs of the people forming a large Collaboration like LAGUNA
- The LSC is found to be very well suited to place any of the LAGUNA experiments

- However much work is yet to be done to solve the equation
  technology + location + beam = excellent_physics
- The UAM and LSC are working hard to solve it.