

Final joint report on potential European sites

Deliverable 2.8

WP2 Deliverable 2.8

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BULLETS

Template-based summaries

3. Summary of deliverables (template)

- General information
- Geology and background conditions
- Political and legal status
- Engineering evaluation
- Conclusions

2. EXECUTIVE SUMMARY

- 2.1 Pyhäsalmi
- 2.2 Fréjus
- 2.3 Boulby
- 2.4 Umbria
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BULLETS

General remarks

– common to all sites

- Impressive competence of the industrial partners
- Huge amount of R&D
- The final reports contain comprehensive evaluation of the sites
- Present state of technology allows, providing sufficient time and funding, to build the required caverns at every site
- Cavern construction is not the dominant cost
- Very positive attitude of the local governments
- No environmental problems; good accessibility
- Seismology is not an obstacle

Physics factors

- **Distance from CERN**
 - LBNO
- **Reactor neutrino background**
 - Relevant only to LENA (geo-neutrinos, diffuse SN)
- **Overburden** , in general – the more the better
 - Must meet the criteria required by the detector
 - GLACIER ≥ 2500 m.w.e (900 m of rock)
 - LENA ≥ 4000 m.w.e (1400 m of rock)
 - MEMPHYS ≥ 3000 m.w.e (1100 m of rock)

investigated
sites



SITE STUDY

Candidate Sites

- Boulby, UK
- Canfranc, Spain
- Fréjus, France
- Pyhäsalmi, Finland
- SUNLAB, Poland
- Slanic, Romania
- Umbria, Italy

LAGUNA Collaboration

100 scientists
more than 20 institutes
10 European countries



<http://www.laguna-science.eu/>

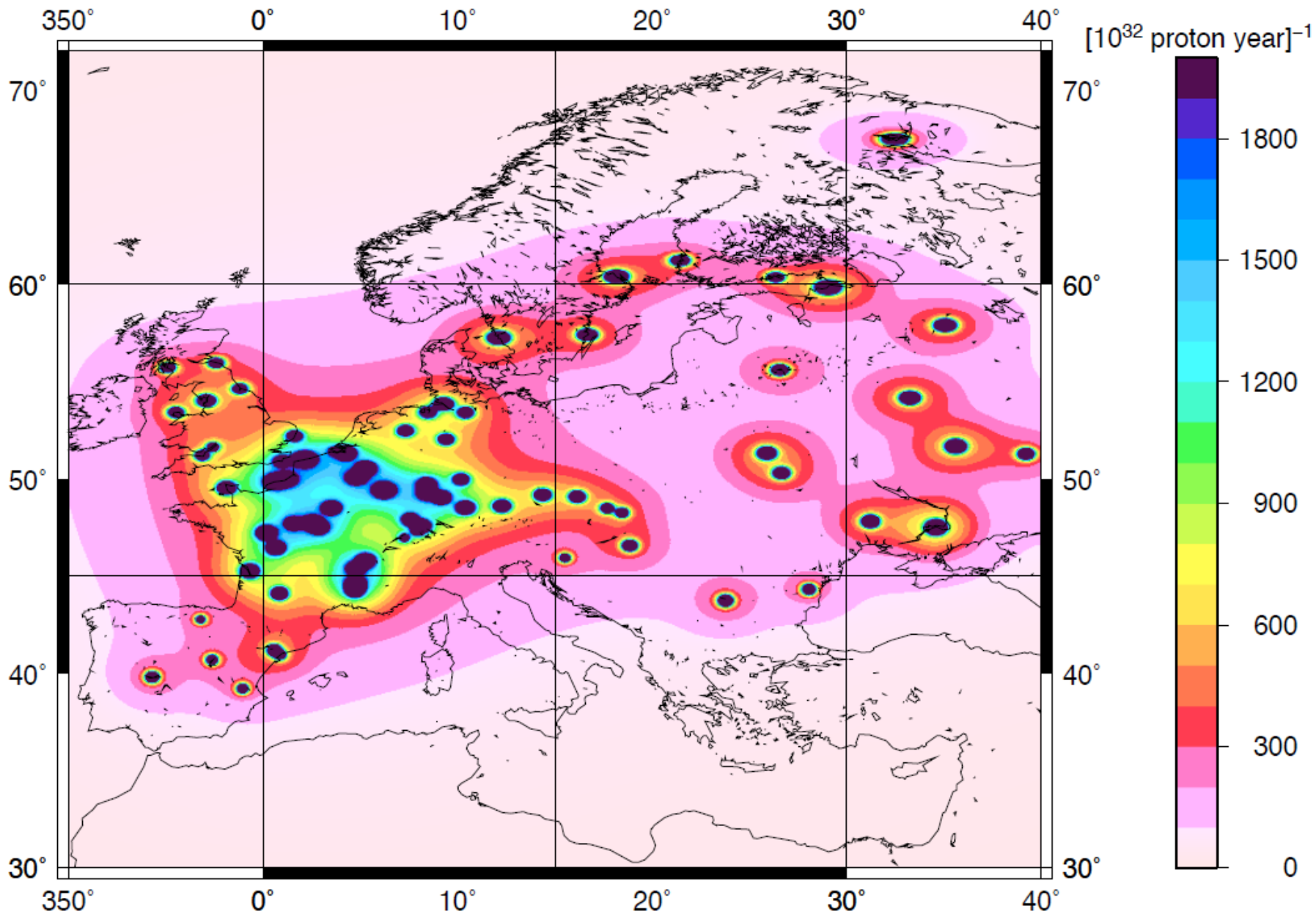
2540 km – bimagic value (feasible)

7250 km – magic value (not yet)

Location Baseline (km)	CERN 2540	J-PARC 7250	Fermilab 7250
Pyhäsalmi	2290 (90%)	7090 (98%)	6630 (91%)
Boulby	1050 (41%)	8480 (117%)	5980 (82%)
Canfranc	650 (26%)	9280 (128%)	6550 (90%)
Frejus	130 (5%)	8900 (123%)	6840 (94%)
Sieroszowice	940 (37%)	8180 (113%)	6960 (96%)
Slanic	1540 (61%)	8150 (112%)	7780 (107%)
Umbria	670 (26%)	8850 (122%)	7300 (101%)

Calculated reactor neutrino rates

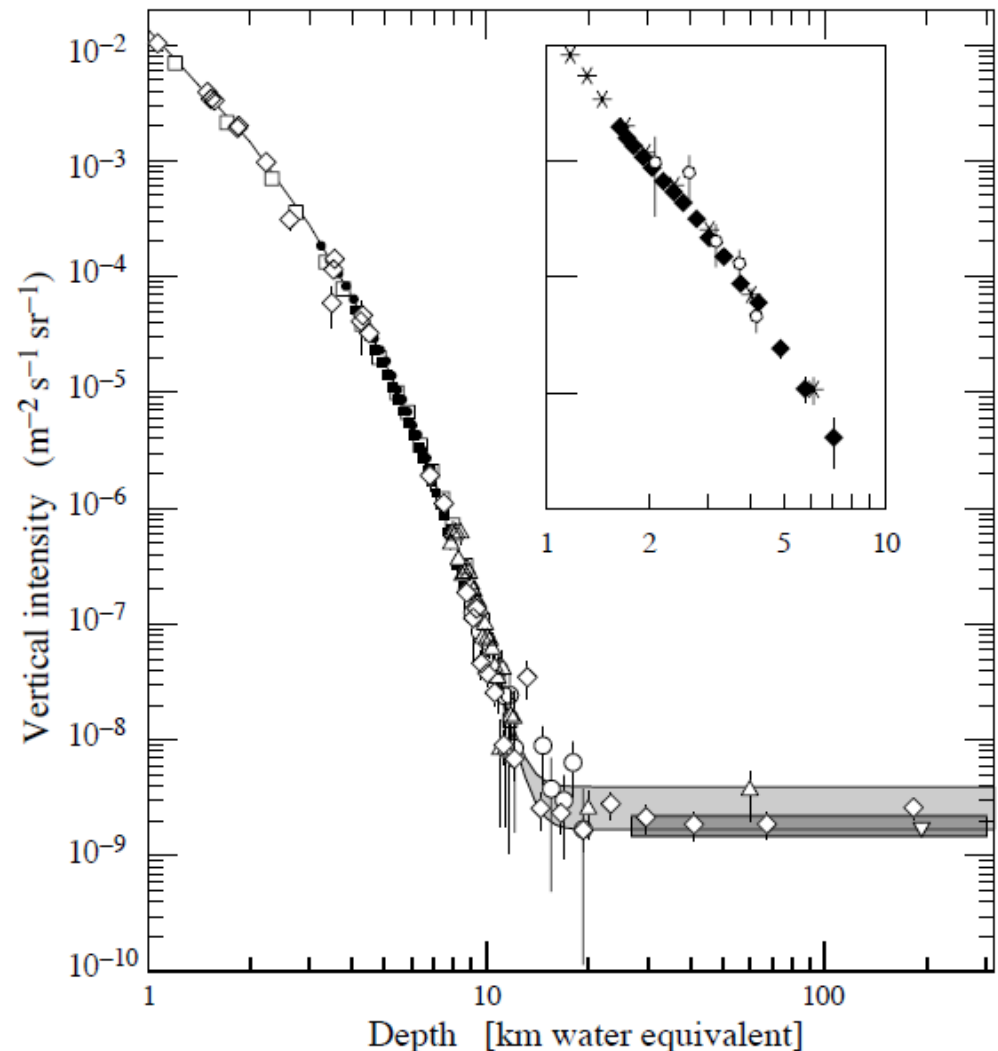
Proposed site	Counts per 10^{32} per year [TNU]
Pyhäsalmi (FIN)	~ 78
Pyhäsalmi after 2012	~ 86
Caso (ITA)	~ 110
Slanic (ROM)	~ 130
Sieroszowice (POL)	~ 200
Canfranc (ESP)	~ 300
Frejus (FRA)	~ 700
Boulby (GBR)	~ 1600
Boulby w/o Hartlepool	~ 280



Calculations by Kai Loo

Overburden

- **Fréjus** – 4800 mwe
- **Pyhäsalmi, Boulby** – 4000 mwe
- **SUNLab** – 3300 mwe
 - GLACIER
 - LENA horizontal
- **Canfranc** – 2700 mwe
- **Umbria** – 1900 mwe
 - GLACIER only
- **Slanic** – 1000 mwe
 - GLACIER only



GLACIER \geq 2500 m.w.e (900 m of rock)
LENA \geq 4000 m.w.e (1400 m of rock)
MEMPHYS \geq 3000 m.w.e (1100 m of rock)



Site specific remarks

Pyhäsalmi

Deepest mine in Europe: copper, zinc and pyrite



Pyhäsalmi (operating mine 63° 39' N, 26° 02' E)

- **Excellent rock conditions** allow hosting of all options (GLACIER, MEMPHYS, LENA), possibly at once, each at the required depth. Rock temperature: cool, less than 22° C.
- **The most modern and efficient mine of its type** with uniquely **small footprint** of the excavation area. The fact that the ore is surrounded by high quality rock **eliminates the need for extended network of tunnels**.
- **Offers two modes of access:** via a vertical shaft leading directly from the loading zone to the detector, and via a decline access tunnel. No other site offers this feature.
- **Has excellent safety record.**
- **The mine owner has signed the memorandum of understanding** concerning LAGUNA.
- **Centre for Underground Physics in Pyhäsalmi (CUPP)** has a decade of experience in conducting scientific experiments in the mine.



250 m long tunnel and a cavern at 1400m excavated for LAGUNA R&D



Cafeteria, meeting room and sauna at 1400 m below ground



Mobile phones work and internet available also at 1400 m



Cosmic Ray experiment EMMA at shallow depth

Fréjus road tunnel

Laboratoire Souterrain de Modane



Fréjus (road tunnel 45°08' N, 6°41' E)

- **The most viable location for the MEMPHYS detector**, although the other two proposed options GLACIER and LENA can also be considered, pending safety approval.
- **Known rock conditions** thanks to the existence of the highway and railway tunnel excavations. Rock temperature: warm, more than 25°C.
- **Dedicated, horizontal access:** The Fréjus safety tunnel, presently under construction (8 meters in diameter), will provide an dedicated and optimal access to the LAGUNA site.
- **Lifetime access:** expected with the roadway tunnel operation for decades.
- **The present underground laboratory (LSM)**, with the collaboration of about 100 physicists, is recognized worldwide for nearly thirty years. In addition the scientific and technological environment is at the top level (CERN-Lyon-Grenoble-Chambery-Annecy-Torino-etc)



New safety tunnel is being constructed



Traffic is stopped to allow access to the lab



Impressive range of ongoing experiments



Dedicated area for parking and services

Boulby

Salt, potash and other minerals mine



Boulby (operating mine 54°33' N, 0°49' W)

- **Local experience in underground research in an operating mine:** More than 20 yrs of science with a surface facility (John Barton Lab offering electronics, chemical and mechanical workshop, offices, conference room, stores, internet, fibre-optic link underground) and existing underground lab (Palmer Lab) of ~1000m². Lab has achieved high safety standard.
- **Known rock conditions** via extensive boreholes and mining over 400 km² to 1500m depth. New ramp allowed in-situ rock studies. Construction in indurated, predominantly Permian dolomite rock at 1400-1500m or 1200m with some anhydrite. Rock temperature: warm, 25°-40°C.
- **Cavern excavation:** Mine infrastructure can handle megatons/yr rock. Mine has 40 years experience - all the major legal, planning permission, environmental, commercial and visual issues are well in control, no major risks envisaged.
- **Liquid procurement:** Air Products/Linde/BOC argon production at Tees, Hull and Carington. Boulby is used to handling liquids underground with established cryogenic safety and experience of liquid pipelines down shafts of 200,000 litres/hr.
- **Interference with mining activities:** Boulby operates 3 shifts per day, 24 hrs/day, 365 days/yr. Owned by Cleveland Potash Ltd. (CPL), ~400 km² with >1000 km of underground road (partly under sea). ~1000 staff. The maximum rock removal capacity is ~5 Mton/yr. Based on LAGUNA timescales this would require rock removal at ~3% of maximum capacity. The proposed site has good separation from mine workings. Power and ventilation requirements are within capacity.



DARK

MATTER

John Bart
Dark Matter

NU57 AVP

Visitors : no pictures allowed!





Impressive accommodation possibilities

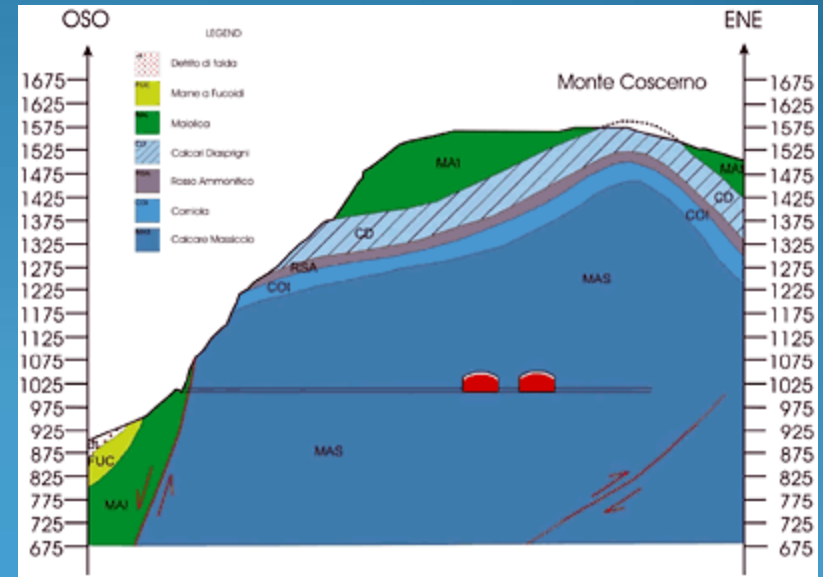


John Marshall

Terry Jamieson

Umbria

Virgin site – a tunnel into a mountain



Umbria (green field 42.7o N, 12.9o E)

- **Green-field:** no preceding human or working activities to interfere with. The 5 possible sites have similar geological/geotechnical characteristics, which allow the construction of the required main cavern and access paths. Scientific requirements and environmental features will be conclusive in the choice. Main differences are: location, environmental features, length of access tunnel, access (→ length of existing roads which must be developed or new roads).
- **Sub-horizontal access tunnel is a strong point**
- **Geology and rock conditions:** well-known geological context of the area and of the selected positions: formazione di calcare massiccio (→ Platform Limestone), with excellent mechanical characteristics. More detailed investigations of in-situ rock are foreseen to improve geological knowledge, including the excavation of a “pilot-bore”. Rock temperature: unknown, expect 15°C.
- **Layout:** due to environmental needs, external installations must be reduced as much as possible. The layout design considers “ancillary caverns”, needed for LAr storage/recirculation.
- **Accessibility & services:** a development of the existing infrastructures is needed. For the access to work-yard and to laboratory short connection roads (<2km) must be made with local roads.

SUNLAB

Sieroszowice UNderground LABoratory



SUNLAB (operating mine 51° 33' N - 16° 2' E)

- **Tectonically stable and good quality hard rock** consisting of dolomites and anhydrites, and locally of rock-salt. Non seismic regions.
- **Known rock conditions:** Anhydrite layers provide excellent conditions for locating the LAGUNA laboratory, ideally for GLACIER (three locations at different depths were found acceptable) and possibly for LENA placed horizontally. Rock temperature: warm, 25°-40°C.
- **Mine operation guaranteed:** The mine belongs to the holding KGHM Polska Miedź S.A., referred to as the European copper giant. The mine has been under continuous operation for almost 30 years. Its present lifetime is estimated more than 40 years.
- **Vast existing mine infrastructure:** available, includes a number of large access shafts, an extended network of underground roads, ventilation system, machines for fully mechanized extraction work and cars for underground transport.
- **Near term plan for research in the operating mine:** A small laboratory SUNLAB₁, which will benefit from the exceptionally low background of the salt-rock natural radioactivity and from a relatively low background of antineutrinos from nuclear power stations, is on the Polish roadmap for research infrastructures.



1580 dm³

TEAM Marek Pasierbski
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WROCLAW/DŁUGOLEKA
tel. 071 315 31 10
www.team.pl



Huge cavern in salt layer





Canfranc

Laboratorio Subterráneo de Canfranc



Canfranc (road tunnel 42°42'N, 0° 31'W)

- **Well-understood geology:** Excellent rock for GLACIER [massive coralline limestone]. Good at the lower part of LENA and MEMPHYS caverns [formation “Atxerito”: interbedded layers of mudstones slates and limestone, slightly rough rock joints]. No spalling or creep effect recorded. Rock temperature: 10-12° C.
- **Elastic-modelling** of three cavern options with positive results. Full elasto-plastic modelling, assuming worst case of one MEMPHYS cavern: ~12 cm displacement at vault, ~14 cm at wall, ~27 cm invert at bottom. The vaults of GLACIER and MEMPHYS will be sustained by a reinforced concrete “crown” in order to ensure long-term stability.
- **Horizontal and dedicated tunnel access:** located between the Somport road tunnel and its emergency escape tunnel (old dismissed railway), both providing the current access to the laboratory. A new tunnel will be built. It will provide access to the experiment for construction and running; all major piping and cabling connecting to surface will be laid on it. In the case of GLACIER and LENA the liquid procurement will be by lorry transport thorough this tunnel down to the tank area. The network of shafts and auxiliary galleries and the main detector cavern(s) will be connected to the existing facilities for regular access, emergency escape and ventilation (regular and emergency).



PELIGRO
TRABAJOS DE VOLADURAS
ACCESO PROHIBIDO
A PERSONAS NO AUTORIZADAS
- VELOCIDAD LIMITADA A 30 km/h
- USO OBLIGATORIO DE CASCO Y PNEUMOS
HIBRISTANTES.
PREMIERE PESAR CON LUZ ROJA
ENCENDIDA

!
**SALIDA DE
CAMIONES**

20

303



Ample parking and storage available



The laboratory is nearly complete



Lab has access also from the new road tunnel



GR
65.3



Canfranc
Estación



Slanic

Unirea salt mine



Slanic (salt mine 45.230 N, 25.940 E)

- **Well-understood geology:** Huge excavations already performed. A cavern up to 91 m width and 45 m height at a depth of 350 m could be excavated without any reinforcement. Due to spalling, reinforcement of walls and roof is necessary. Constant temperature: 12.0 - 13.0°C and humidity practically zero. Rock mechanics calculations confirm stability of large cavern.
- **liquid procurement:** Liquid Argon can be handled by LINDE GAS Romania.
- **Excavated salt:** sold on market (salt is a valuable resource.)





A maze of impressive cathedral-sized caverns in salt



Low-background laboratory



Underground sanatorium



and a museum