Low Radioactivity and Multidisciplinary Underground Laboratory of Modane (LSM)

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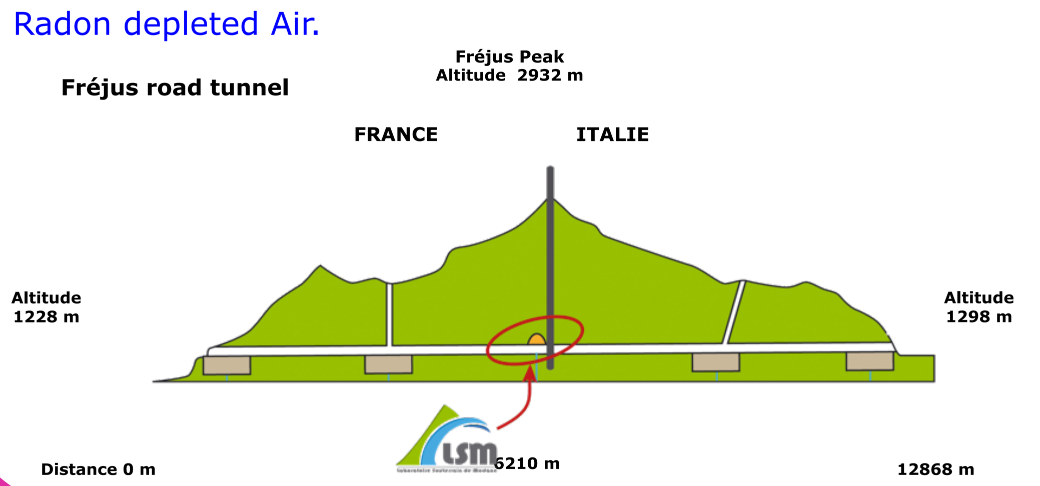
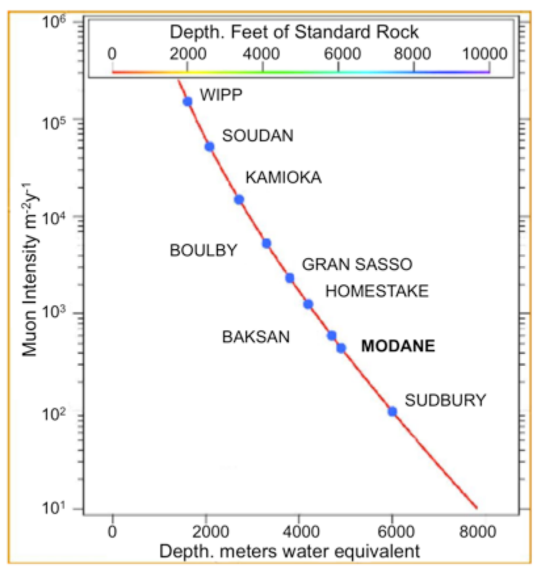
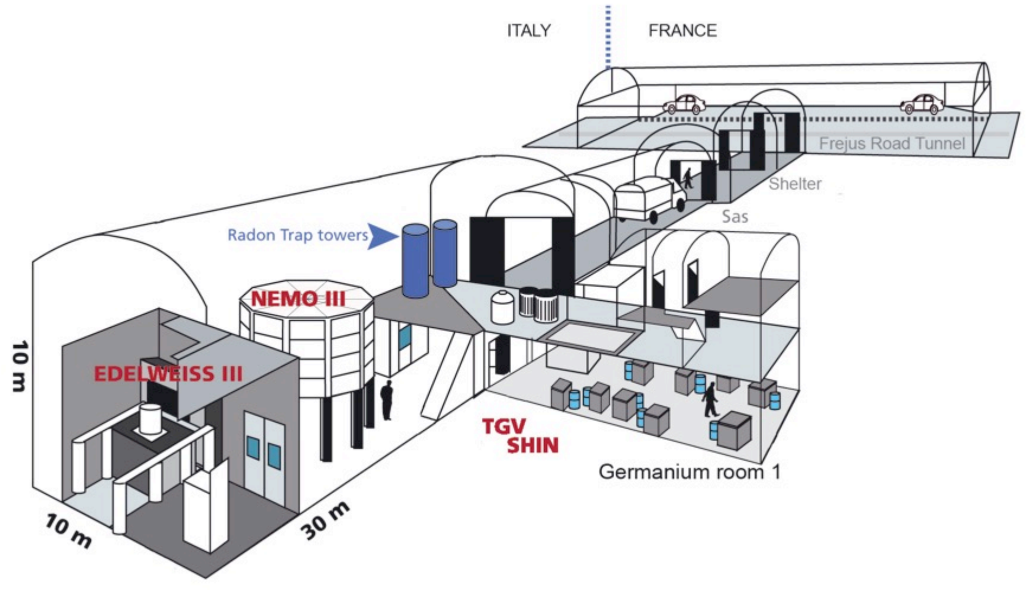
Underground Laboratory of Modane

Introduction

The LSM, **deepest European underground laboratory,** is located 1700 m (4800 m.w.e) below Fréjus peak (Alps chain) in the middle of the Fréjus tunnel between France and Italy. The LSM is a multidisciplinary platform for the experiments requiring low radioactivity environment and cosmic ray free background. Several experiments in Particle and Astroparticle Physics, low-level of High Purity Germanium gamma ray spectrometry, biology and home land security hosted in the LSM. It's equipped by Anti-Radon facility where all of the detectors are flashed by Radon depleted Air.







The sketch of the LSM and emplacement of the different experiments:

- Dark Matter research: EDELWEISS, SEDINE, MIMAC
- Neutrino Double Beta Decay: SuperNEMO, TGV, Lumineu
- Gamma Spectrometry: 14 HPGe detectors
- Multidisciplinary: Microelectronics, Biology

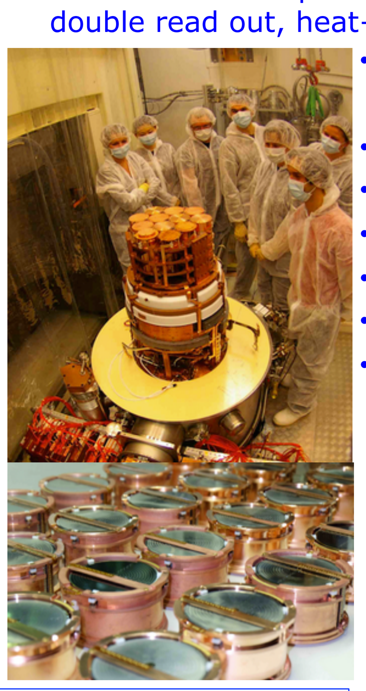
LSM and the numbers

- Depth: 4800 m.w.e.
- Surface: 400 m²
- Volume: 3500 m³
- Muon flux: 4 10^{-5} μ.m^{-2}.s^{-1}
- Neutrons:
  - Fast flux: 4 x 10^{-2} n.m^{-2}.s^{-1}
  - Thermal flux: 1.6 10^{-2} n.m^{-2}.s^{-1}
- Radon: 15 Bq/m³ => anti-radon, facility installation at LSM which produce 120 m³/h
- 4 Physicists
- 2 Engineers
- 7 Technicians
- Budget 1M€/year

Dark Matter research

EDELWEISS EXPERIMENT

- The Edelweiss experiment, a direct search for Dark Matter experiment, is located at the LSM and is based on double read out, heat+ionization, detectors working at very low temperatures.



Final installation of the EDELWEISS III

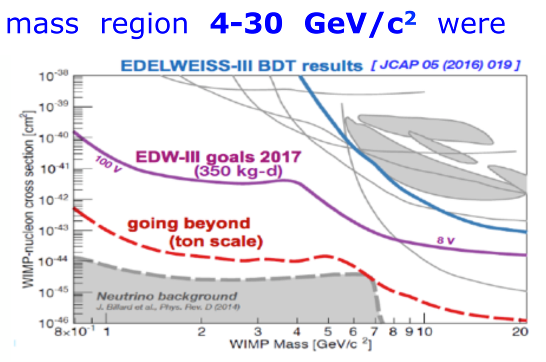
- Specific massive Germanium bolometer technology
  Low background facility @ LSM
- Active muon veto: 97.7% geometric coverage
- External Polyethylene shielding: 50 cm
- External Lead shielding: 18 cm + 2 cm Roman Lead
- Reversed Dilution fridge, 50 l volume
- Extra polyethylene and Roman Lead inside the cryostat
- Dedicated low-noise cold electronics and wires.

New results in the search for low mass WIMPs

- Low mass WIMPs: M ~ 4-20 GeV → low energy
  nuclear recoils: ~ keV
- Fiducial exposure 582 kg.d from 8 detectors (2014-2015)
- Analysis threshold @ 1-1.5 keV_{ee}

Perspectives: Competitive results in the WIMP mass region **4-30 GeV/c²** were recently extracted from data acquired in a long exposure campaign (**582 kg x days**).

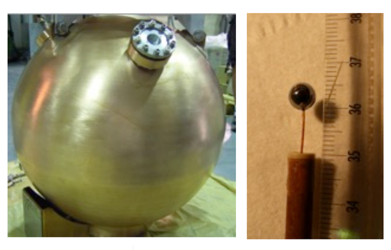
- **R&D** is ongoing on background sources, rejection techniques and detector upgrade
- Long-term prospects: international collaboration with SuperCDMS for a ton-scale setup.



New results in the search for low mass WIMPs [JCAP 05 (2016) 019]

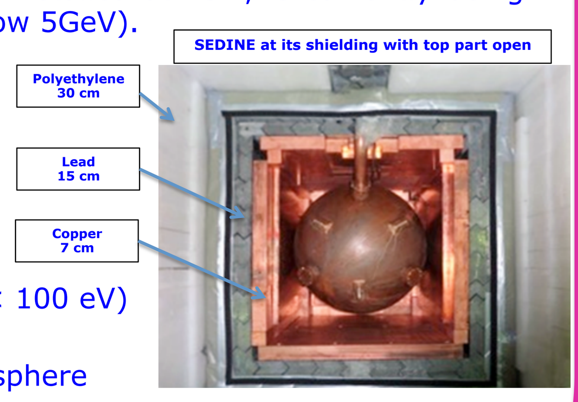
SEDINE/NEWS-G_LSM

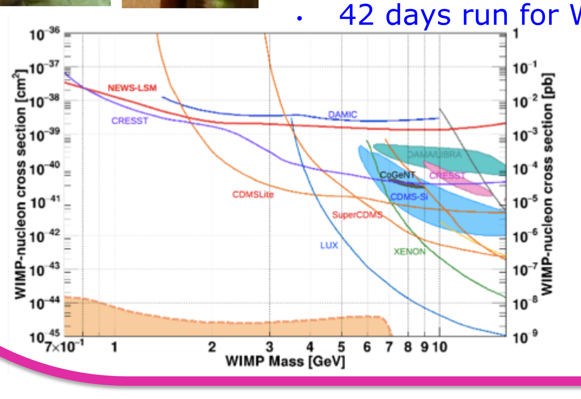
The Spherical gaseous detector (or Spherical Proportional Counter, SPC) is a novel type of particle detector, with a broad range of applications. SEDINE, (*Φ=60cm)* a low background detector installed at LSM, is currently being operated and its aims is dark matter searches, in particular Light WIMP's (below 5GeV).



- Copper vessel equipped with 6 mm Ø sensor
- Runs with **Neon**+0.7%CH_4 @ 3.1 bars
  => 310 g sensitive mass
- Several internal cleanings for radon
  deposit removal
- 42 days run for WIMP search (Phy-threshold < 100 eV)

SEDINE at its shielding with top part open





Perspectives: Go to bigger sphere and optimised management of radioactive contaminants => **NEWS-G_SNOLAB** project. This new detector (Ø=140 cm) will be fabricated by the end of this year. After blank assembly at LSM, it will undergo a chemical cleaning to remove the deposited Radon daughter from surface before final installation at SNOLAB.

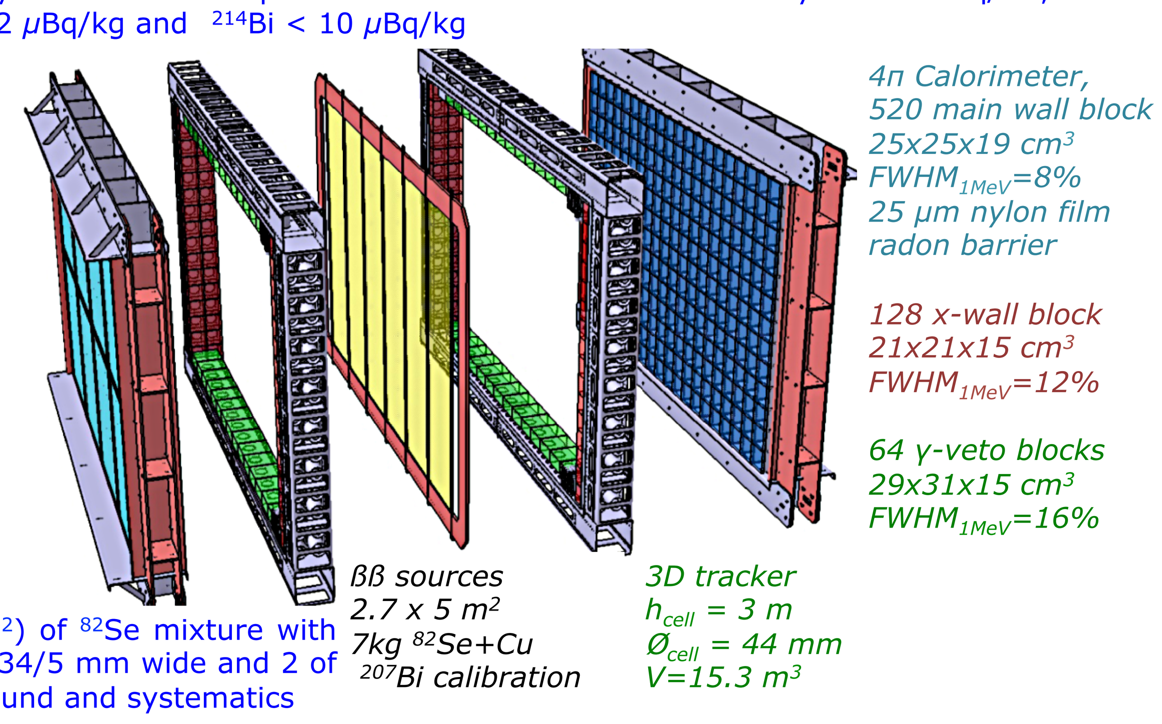
Neutrino

SuperNEMO EXPERIMENT

- SuperNEMO is the next generation ββ-decay experiment combining a tracker and a segmented calorimeter. It is the successor of the NEMO-3 experiment which reached a sensitivity on the 0ν2β search with 34.3 kg.y exposure of 100 Mo: $T^{0\nu}_{1/2}$ > 1.1 x 10^{24} y → <m_ν> < 0.33 -0.62 (90% CL)
- Goal: 20 detectors and 100 kg of ^{82}Se
- Sensitivity: $T^{0\nu}_{1/2}$ > 1 x 10^{26} y and <m_ν> < 0.04 -0.10 eV
- Background: 5 x 10-5 keV^{-1} kg^{-1}y^{-1} with severe requirements for internal radon activity <0.15 mBq/m³, *ββ* source contaminations is ^{208}Tl < 2 μBq/kg and ^{214}Bi < 10 μBq/kg

The first module SuperNEMO demonstrator is under construction at the LSM

- This demonstrator will reach the NEMO-3 sensitivity in only 5 months.
- No background is expected in the 0*ν*2*β* region in 2.5 years for 7 kg of ^{82}Se (to be demonstrated).
- The final sensitivity after 17.5 kg y exposure (90 % CL) is: $T^{0\nu}_{1/2}$ > 1 x 10^{24} y
- *ββ* source: Thin foil (50 mg.cm^{-2}) of ^{82}Se mixture with glue in 12 μm mylar. 34 strips 134/5 mm wide and 2 of 125 mm. Copper foil for background and systematics

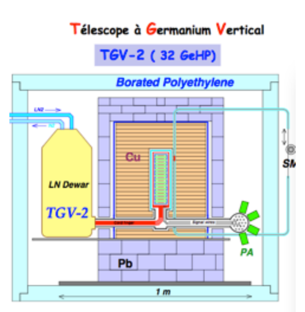


- Tracker: 4 C-sections drift chamber with ~2000 vertical cells. The tracking gas is a mixture of helium, ethanol and argon. All materials have been selected for radiopurity and low radon emanation levels.
- Calorimeter: 712 plastic scintillators coupled to 5" or 8" Hamamatsu PMTs and wrapped with PTFE on the sides and 6 μm aluminized mylar on the front. The main wall is covered by 25 μm radon tight nylon film. The PMTs are protected from the magnetic field by mu-metal or by pure iron shields. The latter serves also as supporting structure.
- Surroundings: a copper coil around the detector provide a vertical 25 G magnetic field. An air-tight tent flushed with radon-free air (< 15 mBq m−3) closes the detector volume. The remaining radon will be stopped by radon tight glue seals between sub-detectors. The shielding will consist of 20 cm of pure iron and 30 cm of borated water.

TGV EXPERIMENT

Telescope Germanium Vertical: is another experiment for double beta decay (*ββ*) using 32 Germanium planar detectors (Ø=60mm).

- Double *β*: Enriched ^{48}Ca
- Double E-Capture: Enriched ^{106}Cd



Phase1 Results:

Decay of the 2*ν*Ec/Ec (0^+ → 0^+) measurement with 10g of enriched ^{106}Cd since 1 year:

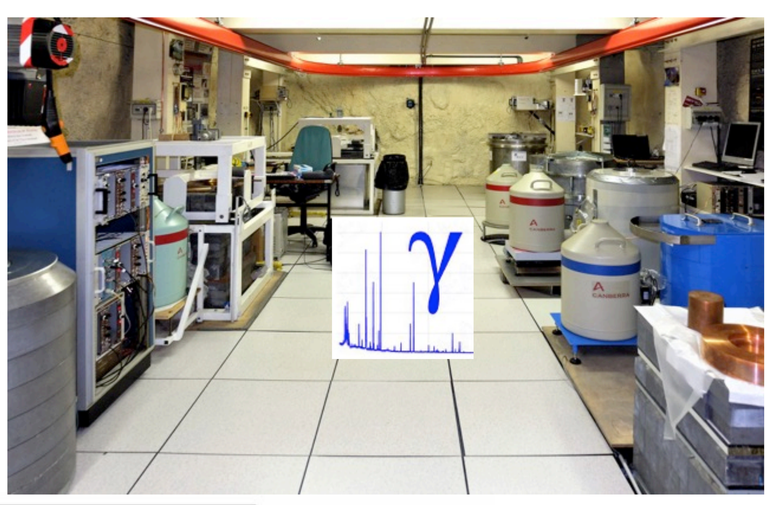
$T_{1/2}$ (0^+ → 0^+) ≥ 3.2 x 10^{20} y (90% CL)

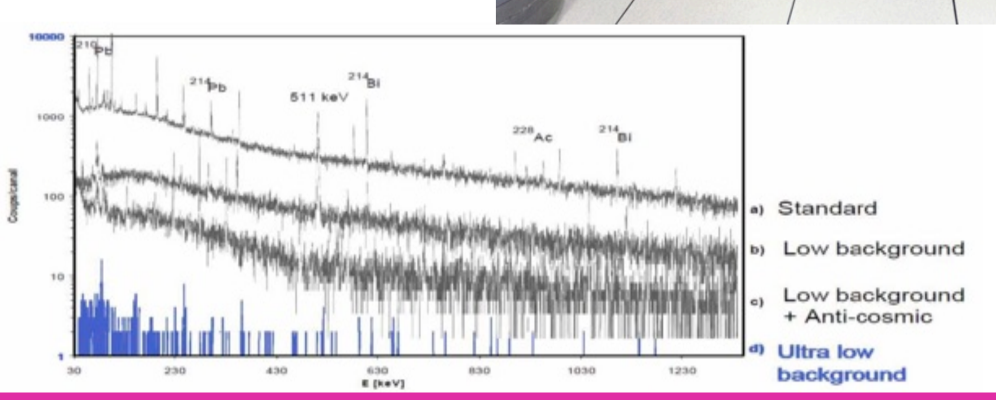
Phase2 under run

Multidisciplinary

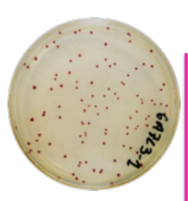
HPGe Gamma Spectrometry

- 16 HPGe from 7 different laboratories of CNRS, CEA, JINR DUBNA and CTU Prague are available at LSM
- Gamma spectrometry with very low levels of radioactivity : measurements for sediments or ice core dating, environmental studies for climate evolution
- Material selection for astroparticle physics
  Environmental research (oceanography, climate, retro-observation,….)
- Applications (wine dating, salt origin,…)
- Environmental survey
- Developments of Ge (Mafalda detector)



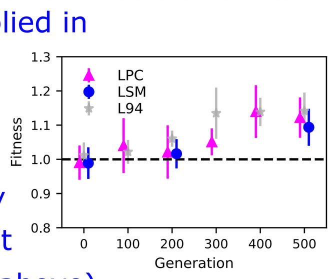


BIOLOGY



Low background biological research has consistently shown that despite the natural radiation background already being incredibly small, it is nevertheless significant enough for living systems to sense it and respond to it. The adaptive and hormetic effects that are noticed at low background are not yet well understood, and significant experimental work is needed to better clarify them. Experimental approaches that draw from evolutionary biology are well adapted to this task, as epigenetic and genetic changes may occur at low radiation backgrounds. Whole sequence genotyping, proteomics, multi-generational studies, and long term evolution experiments are some of the mechanisms that may be applied in approaching this problem.

Lampe, N et al, D. G. Understanding Low Radiation Background Biology Through Controlled Evolution Experiments. Evolutionary Applications.

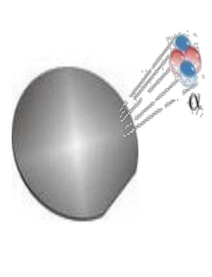


More experiment is necessary to improve this result (against right) and to reach our goal (above)

MicroElectronics

Due to miniaturization, the electronic sensitive to neutrons, at ground level, from cosmic ray and internal alpha particles contamination. The LSM is a unique test field for alpha contamination because cosmic neutrons are reduced to zero (JEDEC 2007).

- IM2NP laboratory has conducted since 2007 a series of underground experiments to quantify the importance of alpha-particle emitter contamination in advanced SRAM memories



0.5 ppb of ^{238}U in Silicon = 2.28×10^{-3} α/cm²/h

0.5 ppb of ^{238}U in Silicon = 425 Bq/m³ = 0.18 Bq/kg