The Modane Underground Laboratory

Silvia Scorza (CNRS-LPSC)

GRENOBLE

UGA



Université **Grenoble Alpes**

The LSM Underground Laboratory



The LSM is a French National Research Infrastructure

- Experimental site midway in the 13km France/Italy highway road tunnel
 - Surface lab (office, garage, small museum)

Modane:

- 130 km from Grenoble
- 200 km from Lyon
- 100 km from Torino
- Deepest site in Europe dedicated to astroparticle, nuclear & particle physics
- 4800 m.w.e: muon flux reduced by >10⁶ relative to surface
- Flexible access (hall accessible to trucks up to 9m);
- Natural radioactivity due to radon of about
 10-15 Bq/m³
 2025 Future Project Workshop 2025 04 29









- Spacious entrance level, providing horizontal access even for truck
- Hoists, forklifts and open the big double doors if needed 2025 Future Project Workshop - 2025 04 29

LSM Background Measurements

Since 1983, large corpus of measurements of various LSM backgrounds by experiments

• Muons: total flux (4.5 μ /m²/d), and angular

map

[Rhode, PhD Thesis (Ruppertal, 1993) + Schmidt et al, Astrop. Phys. 44 (2013) 28]

- High-energy gamma rays. [Ohsumi et al, NIMA 482 (2002) 832]
- Fast neutrons (1.6x10-6 n/cm²/s) [Armengaud et al, Astrop. Phys. 47 (2013) 1]
- Thermal neutrons [Rozov et al, BRAS 74 (2012) 464; arXiv:1001.4383]
- Radon (~15 Bq/m3)
 [Hodak et al, J. Phys. G 46 (2019) 11 + E. Armengaud et al, JINST 12 (2017) P08010]



LSM Science Programme

Science programme adapted to LSM size:

- Low-mass Dark Matter Experiments
- 0vBB demonstrators & technologies
- HPGe array for low-radioactivity

Experiment	Focus	Technology	Activities in 2024	
SuperNEMO	Ονββ	Tracking- calorimeter	Iron shielding installation. Water walls matter. Commissioning of the detector without neutron shielding. Installation of the Gas mixture recycling system Start of the commissioning	
BINGO	Ονββ	Cryogenic	Cryostat validation. Detector installation. Vibration study. Lead shield delivery. Ongoing contract, through a hosting convention.	
Obelix 82Se	ECEC2v	Ge ionisation	Counting of 6kg enriched 82Se sample from LNGS started in January 2022: ECEC2v to excited states. Transfer Material agreement signed. MoU to be done.	
TGV	Ονββ	Ge ionisation	Detector upgrade delayed - Collaboration frozen	
DAMIC-M	DM	Si CCD	Continuing test chamber (LBC) Physics run in 2024. Relocation of LBC in a "LSM-detector" cleanroom. MoU to be done, agreement letter <i>in-fieri</i> . 2025: Ongoing relocation of the LBC.	
MIMAC	DM	TPC	Detector upgrades with commissioning planned in 2025. Convention d'accueil to be done as soon as an EOI is received.	



Tight occupation of the available 640m²

Perspective: design study to possibly install ~150m² mezzanine level (over the crane access) above experimental level (CPER project)

LSM Layout 2025



SuperNEMO: a fully topological tracking detector for OVBB





Measured ßβ-candidate event (March 2024)



98.4% of tracker, 97.4% of calorimeter operational!

- Excellent background rejection
- Background measurement (dedicated channels)
- Golden-event signature
- Individual energy
- Angular correlation



Key to probing and understanding *0νββ* mechanism if it's discovered



SuperNEMO Demonstrator has rich physics potential with ⁸²Se

- 0νββ V-A
- 0vββ V+A (λ and η)
- 0νββ with Majoron
- 2νββ and 0νββ to excited states
- Nuclear structure effects via 2νββ spectrum
- BSM decay searches: sterile neutrinos, Lorentz violation, bosonic neutrinos...

Currently taking physics data at LSM, France

BINGO: Bi-Isotope 0vbb Next Generation Observatory

Technical demonstrator for radioactive background mitigation for the future phase of the experiment on double beta decay without neutrinos.

Reduction of surface and external radioactive background with:

- Innovative assembly with fewer materials
- Rejection of gamma and alpha events with an active cryogenic veto based on BGO crystals
- Light detector with signal-to-noise amplification using the Luke-Neganov technique



BINGO

erc

C22

BINGO: Bi-Isotope 0vbb Next Generation Observatory

New technologies will allow <10⁻⁵ events/(keV kg year)

The technologies offered by BINGO are likely candidates for the next generation of bolometric detectors

The devoted cryogenic infrastructure is installed at LSM and data-taking on prototypes is ongoing

The very weak cosmic flux at LSM makes it an interesting site for future experiments





DAMIC-M



0

0.5

200

- Pixelated silicon detectors: Charge-Coupled Devices (CCD).
- Skipper readout: single eresolution and 2-3e- threshold.





1.5

2 Charge [e-]

• Excellent *xy* resolution: $15 \mu m \times 15 \mu m$.

z-reconstruction with distribution of charge in pixel clusters.

DAMIC-M CCD module: 4x 9-Mpixel CCDs (13.2 g total Si mass).

DAMIC-M

- DAMIC-M prototype (LBC) at LSM probes benchmark hidden sector dark-matter models!
 - o <u>arXiv:2503.14617</u>
 - o <u>arXiv:2407.17872</u>
- 52 CCD modules to deploy in LSM (0.7 kg sensitive mass)
- Background rates: a fraction of a DRU (events per keV-kg-day)
- Commissioning by the end of 2025!





TESSERACT: Detector Technologies

[<u>Transition Edge Sensors with Sub-Ev Resolution And Cryogenic Targets</u>]

aims at extending the Dark Matter mass search window from meV-to-GeV with ultra low-threshold cryogenic detectors with multiple targets and particle identification capabilities

All detector technologies will be featuring:

- 1. athermal phonon TES with sub-eV energy thresholds,
- 2. drastically mitigated LEE (under intense investigation),
- 3. payloads between 10g to 100g

	Target	Search type	Mass range	LEE rejection	Particle ID
SPICE Polar crystals	AI_2O_3 , SiO_2	ERDM	100 meV - MeV	Dual TES channel	None
SPICE Scintillator	GaAs	NRDM/ ERDM	eV - MeV MeV - GeV	Phonon/ photon coïncidence	Dual Phonon- photon readout
HeRALD LHe	He	NRDM	MeV - GeV	Multiple He4/ photon	Pulse shape discrimination
Semicon. High V	Ge, Si	ERDM	eV - MeV	SSED	None
Semicon. Low V	Ge, Si, C	NRDM	MeV - GeV	Phonon/ lonization coincidence	Dual phonon- ionisation readout



TESSERACT

- Two copies of the setup, for enabling both:
 - Underground R&D and detector optimisation
 - DM science data taking
- Each detector technologies is designed to achieve major breakthrough in short time scales (few months) hence allowing fast turnarounds
- Unique opportunity to build the next leading cryogenic light DM experiment at LSM, featuring French bolometer technology, benefiting from decades of experience from EDELWEISS, CUPID, and Ricochet





Screening and Material Assay Platform

Wide-range program for Astroparticles, Earth Sciences (sediment and ice core sample datation), environmental safety (CEA), biology, etc...

- HPGe gamma spectroscopy
- Alpha surface contamination via the XIA-UltraLo1800 counter
 - Commissioning at LPSC (surface cleanroom)
- Material assays for experiments based at LSM (SuperNEMO, EDELWEISS, CUPID-Mo, DAMIC-M, DarkSide), and also for other experiments (ex: JUNO, RICOCHET, Q-BITS Canada)
- Agreement with LNGS for long term (~ year) measurement of ECEC decay of ⁸²Se (6 kg) to excited state on large (600 cc) Obelix HPGe.

HPGe Obelix at LSM





Footprint optimization for HPGe screening detectors



More efficient use of space Shielding optimisation Ease of operation (LN2 refill)





XIA - UltraLo1800

Alpha spectrometer for large surface screening: specialized ionization counter comprising an active volume filled with boiled-off argon, a lower grounded electrode that is a conductive tray (holds sample), and an upper pair of positively charged electrodes.



- Empty tray monitoring (in-fieri)
- Detector characterization via electroformed Cu tray (courtesy of SNOLAB) (*in-fieri*)
- First sample: Rn implanted copper lids of Ge semiconductor detectors to study the background discrimination power.
- Commissioning of gas recycling system (developed by CPPM Marseille)
- Relocation underground at LSM (summer/fall 2025)



Thank You!

Additional Utilities

- Underground flushing toilets and shower
- Underground kitchen and coffee machine
- 8-ton crane at the underground main hall experiment
- 3.2-ton crane at the underground laboratory SAS
- LN2: surface 6000L, underground 1000L, 650L and 450L
- Upgraded Anti-Radon Facility
 - commissioning in the Summer 2025
 - nominal flux 120m³/h

