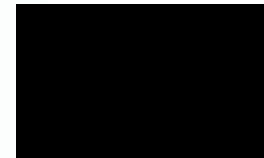


The Modane Underground Laboratory

LPSC Scientific Council

Silvia Scorza



1979 - 1981

1982- 1990

1990- 2000

2000 -



Construction

τ_p Experiment

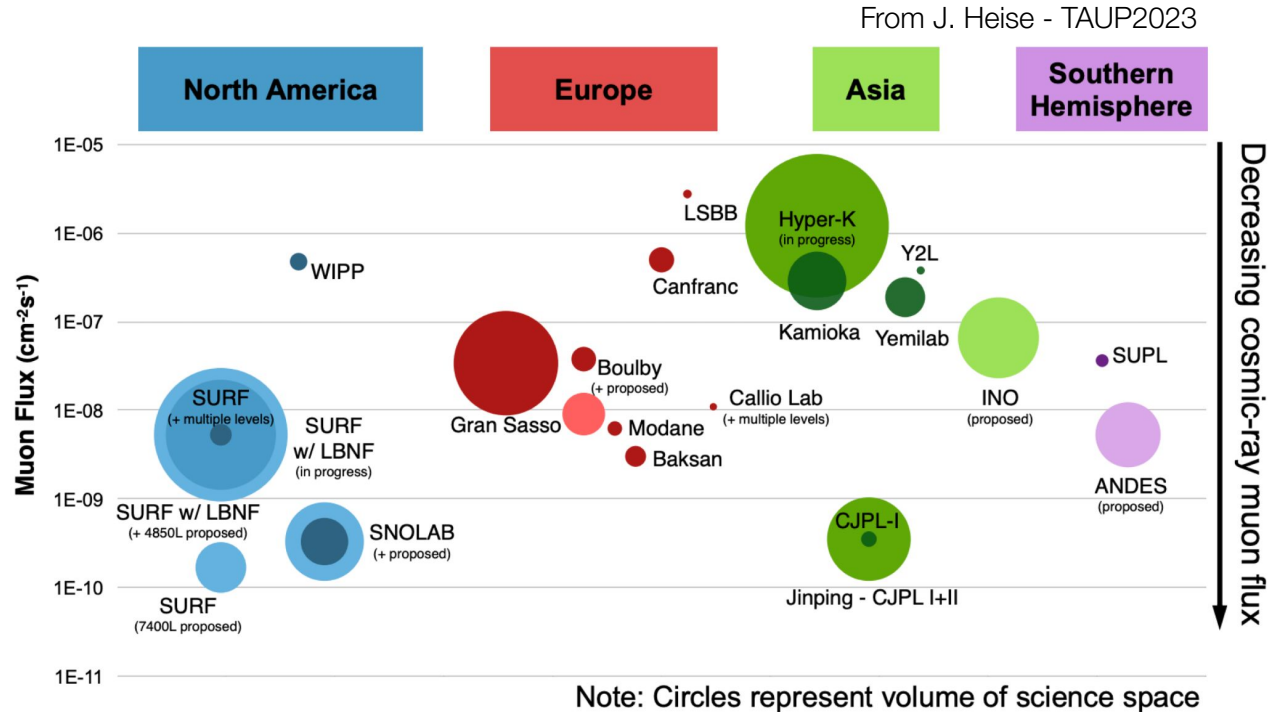
Prototypes



Experiments

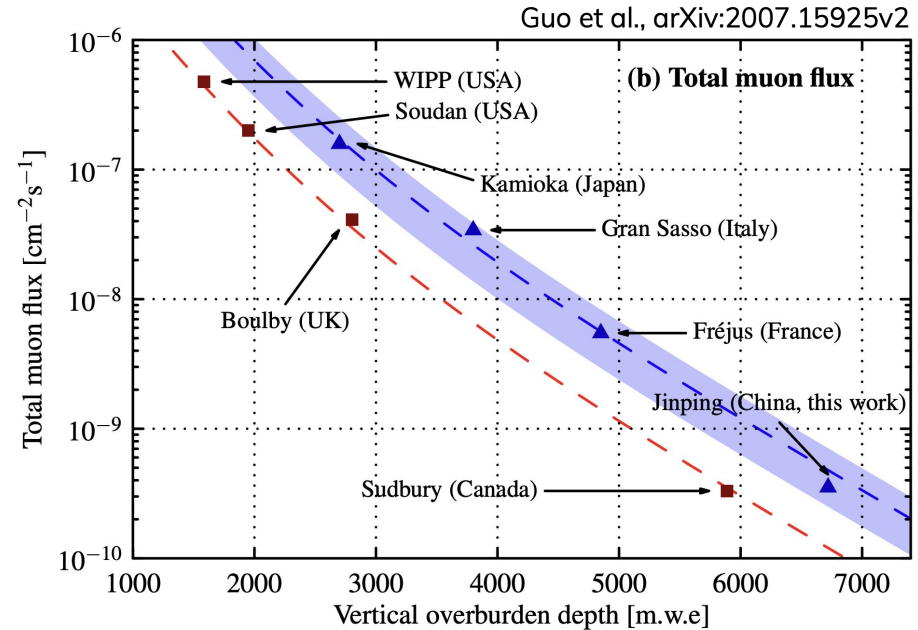
Worldwide Underground Laboratory Community

Underground facilities provide unique environments for astroparticle and multidisciplinary research with the main feature to be the overburden protection from cosmic-ray muons



The Modane Underground Laboratory

- Deepest site in Europe dedicated to astroparticle, nuclear & particle physics
- 4800 m.w.e: muon flux reduced by $>10^6$ relative to surface
- Flexible access (hall accessible to trucks up to 9m);
- Small experimental surface: 400m^2
- Natural radioactivity due to radon <5 less than LNGS et LSC



LSM Background Measurements

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

- **Muons:** total flux ($4.5 \mu\text{m}^2/\text{d}$), 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** ($1.6 \times 10^{-6} \text{ n/cm}^2/\text{s}$)

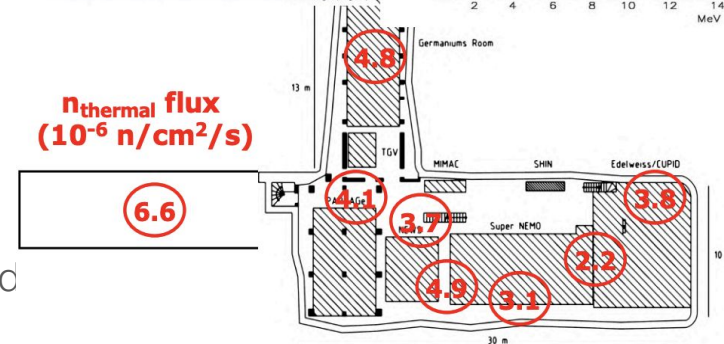
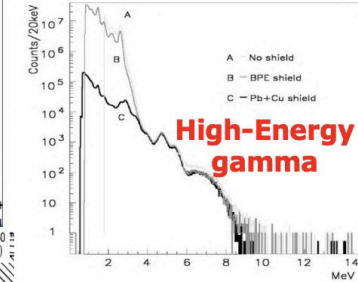
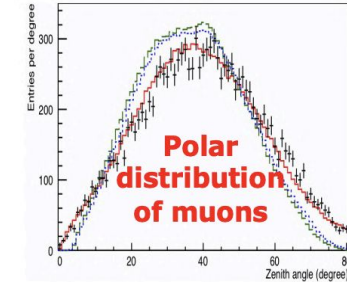
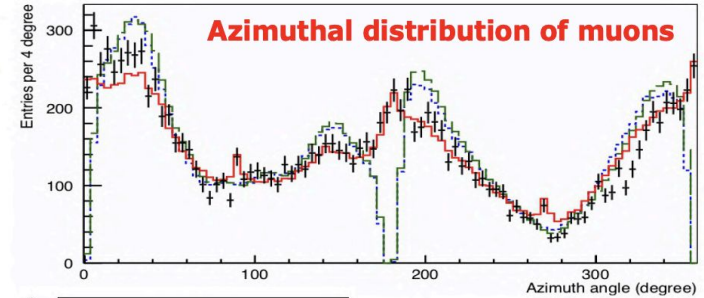
[Armengaud et al, Astrop. Phys. 47 (2013) 1]

- **Thermal neutrons**

[Rozov et al, BRAS 74 (2012) 464; arXiv:1001.4383]

- **Radon** ($\sim 15 \text{ Bq/m}^3$)

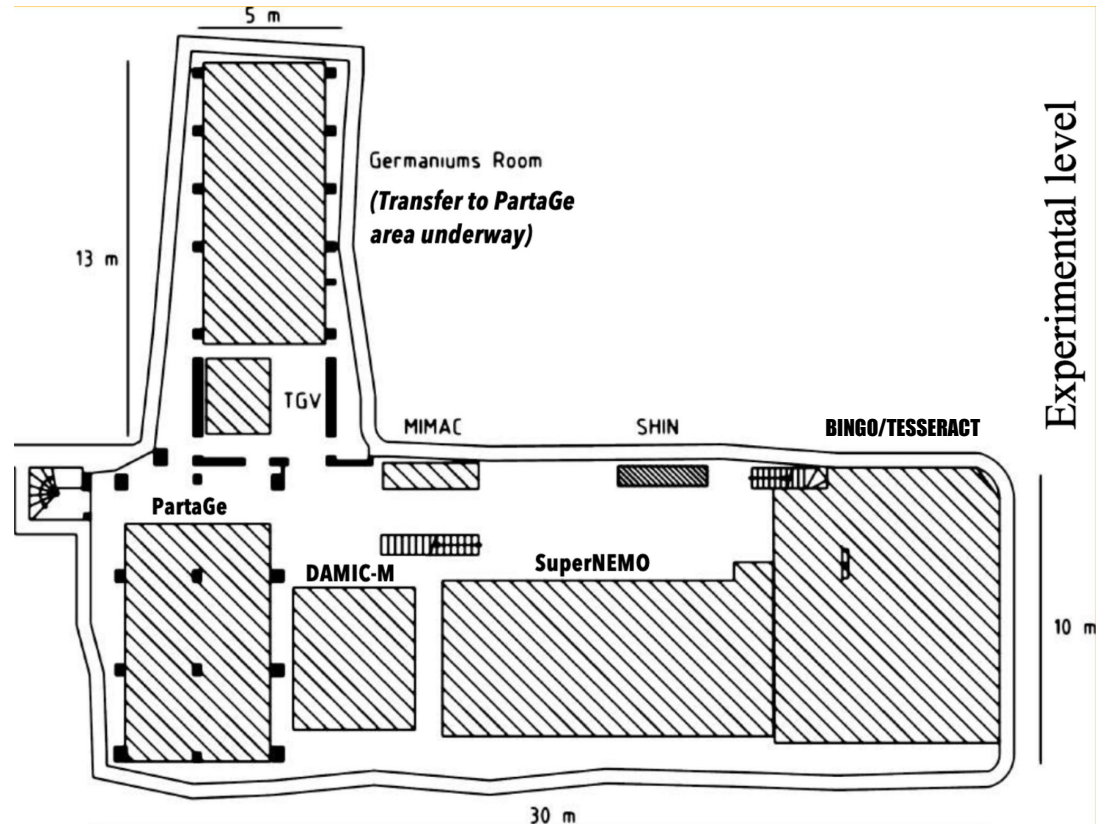
[Hodak et al, J. Phys. G 46 (2019) 11 + E. Armengaud et al, JINST 12 (2017) P08010]



LSM Floor Plan

Tight occupation of the available 400m²

Design study to possibly install 180m² mezzanine level (over the crane access) above experimental level



LSM Science Programme

Subatomic/Astroparticle physics Platform

Hosting fundamental physics experiments, in particular those supported by IN2P3, with international, bi-national or national collaborations.

Host R&D and detector physics for future experiments (larger detector deployed in larger DUL).

Provide technical support to experiments as agreed upon.

Priority topics (well-adapted to depth+size): Light Dark Matter, R&D for $0\nu\beta\beta$.

Improve infrastructure to develop hosting opportunities.

Develop R&D around underground physics.

Germanium gamma-ray material assaying

Very low radioactivity measurements.

Associated technology developments.

Opening to interdisciplinary applications

Host small experiments that can benefit from the exceptional low-radioactivity environment and the staff expertise in this domain (ex: biology, earth sciences..).

Communicate and promote the infrastructure

New website developed and will be published soon.

LSM Scientific Policy

Up to 2018: independent laboratory of IN2P3

Since 2019: « National platform of IN2P3 ».

- LSM administratively attached to LPSC, with activities, budget and resources annually reviewed by a « comité de direction » (IN2P3, University and LPSC).
- Scientific director directly nominated by IN2P3 (in concertation with LPSC) in order to ensure that the LSM scientific program conforms with the IN2P3 objectives at the national and international level.
- IN2P3 has mandated an international Strategic Council to advise annually on the scientific program and global strategy of the LSM.

LSM in the French Ecosystem

Since 2022, to improve the visibility of the LSM at the national level, it has been included in the list of Research Infrastructure of the French Ministry.

IN2P3 SuperNEMO project review (Oct. 2022)

IN2P3 Scientific Committee for Dark Matter (Oct 2023)

IN2P3 Scientific Council Oct 2023 - Dark Matter Experiments

GDR DUPhy community

Special session for future experiments at LSM - Oct 2022

Next general meeting 9-11 October 2024

International Network of Deep Underground Laboratories (DULs)

- Stronger collaboration between underground laboratories to improve support for the scientific community
 - LSM Visit of SNOLAB executive and research directors (September 2023)
 - LSM Visit of SURF director and SNOLAB Research Manager (October 2023)
 - LSM Visit of PAUL lab (June 2024)
- DUL Directors meeting in Vienna in September 2023 as part of the international TAUP conference, with the creation of joint working groups
 - Sharing of good practices
 - Development in operational matters, Health and Safety, experience management, etc.
 - Low background counting/analysis (“Low Radioactivity Techniques” workshop series), shared databases
 - Workload sharing for low-background measurements
- Coordination of the response of underground laboratories to European calls for tenders
 - e-COST in October 2023 (Project not retained)
 - EU INFRADEV in March 2024 (Evaluation Feedback, Summer 2024)

LSM Organization Updates Over Last Year

LSM management as of February 2024:

LSM DP: Silvia Scorza

LSM RO: Nadine Sauzet

LSM Ultra Low-Background Service (SUBR)

Team manager: Guillaume Warot

7 agents on-site at LSM

Non-SUBR staff

Administrative and financial service

Valérie Favre, on-site manager in Modane (~0.3 FTE)

Procurement, finance and HR support from LPSC (~0.2 FTE)

IT Department

Support on the Grenoble site (~0.3 FTE)

Technical Departments (mechanical, electronic, etc.)

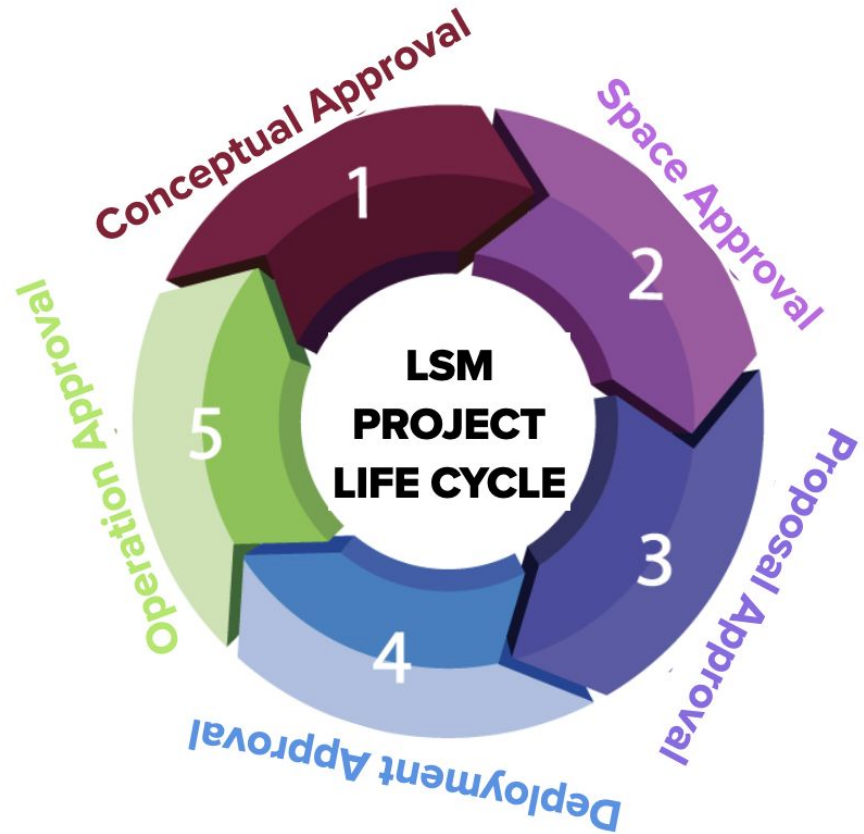
Design and production for SKID anti-radon (SERM ~0.3 FTE)

Update security automation (SE ~0.5 FTE)

LSM Project Life Cycle

- |

- Formalisation of the Experiment Life Cycle
- Clearer definition of the LSM responsibilities
- Clearer definition of the Experiment responsibilities
- Agreement on the occupied footprint and LSM facility needs (timeline, m2)



LSM Project Life Cycle

- II

Need to interact with LSM direction (Scorza/Sauzet) to define schedule & space constraints

EOI <https://forms.gle/bh9hR3e13qBhYQG5A>

Setting up one expt affects (+/-) all others : optimization of use of volume, required investment by LSM (+ support from funding agencies)

Approval process

Contact LSM direction to present your project

Discuss with LSM to optimize (experiments needs vs integration constraints):

Preparation of agreement

Approval of resource uses by funding agencies (IN2P3+University)

Signature of agreement

Experiments at LSM - 2023 Status

Only one mail hall experiment taking physics run in 2023/2024 : DAMIC-M LBC (+82Se long Ge measurement) (+SuperNEMO commissioning run)

:

LSM Experiment	Domain	Technique	Collaboration	Activities
CUPID-Mo	$\beta\beta 0\nu$	Cryogenic LiMoO	France, Russia, Germany, Italy, USA, Chine, Ukraine	Data exploitation. Dismantling completed
SuperNEMO	$\beta\beta 0\nu$	Tracko-Calo	France, UK, Russia, Japan, USA, Czech Rep., Slovakia	Commissioning ongoing. Delays in the shield installation
BINGO	$\beta\beta 0\nu$	Cryogenic	France	Installation of cryostat in summer 2024
Obelix 82Se	ECEC2v	Ge ionisation	France, Italy, Russia, Czech Rep.	Counting of 6 kg enriched 82Se sample from LNGS started in january 2022: ECEC2v to excited states
TGV	$\beta\beta 0\nu$	Ge ionisation	Russia	Detector upgrade delayed
DAMIC-M	DM	Si CCD	France, USA, Canada, Switzerland, Denmark, Spain, Brasil, Argentina	Test chamber physics run in 2022, installation of kg-stage in 2024
EDELWEISS	DM	Ge Cryogenic	France, Russia, Germany	Data exploitation. Dismantling completed

Scientific Production - 2023

TAUP2023 Conference: Eight talks connected with LSM

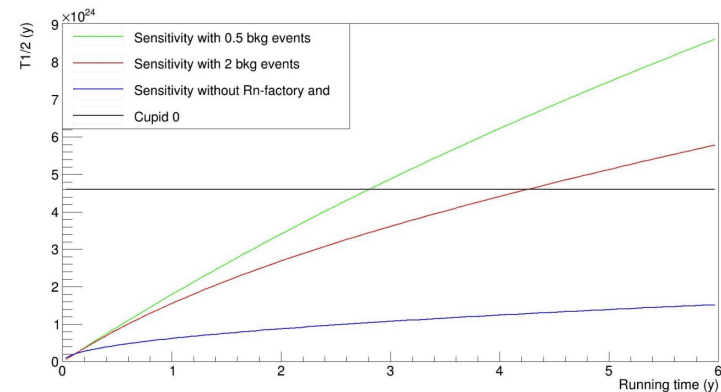
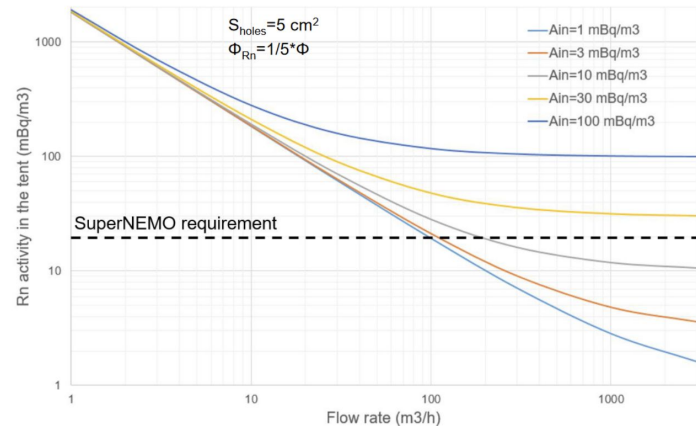
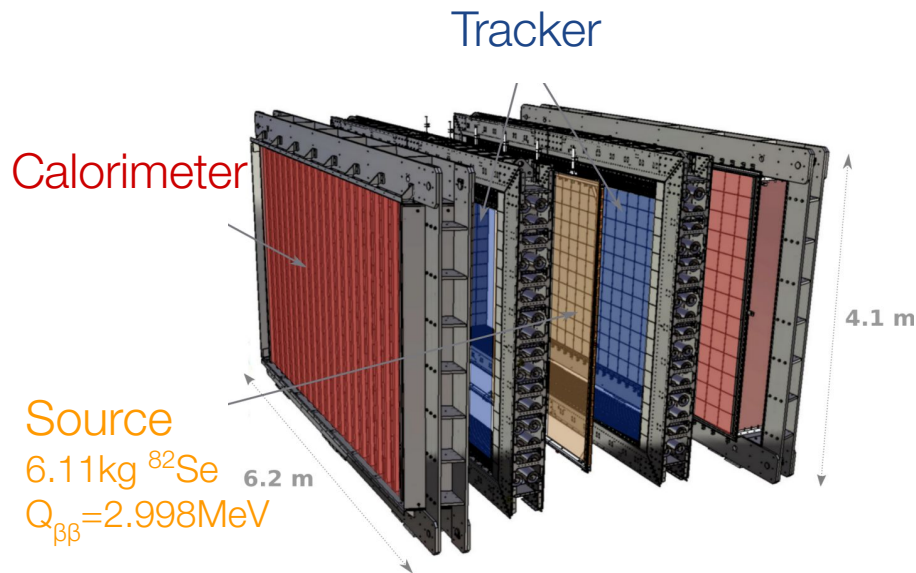
[LSM review, radon reduction, 2xDAMIC-M, CUPID-Mo, BINGO, EDELWEISS/CRYOSEL, SuperNEMO]

Past Experiments:

- CUPID-Mo
 - *Measurement of the $2\nu\beta\beta$ decay rate and spectral shape of ^{100}Mo from the CUPID-Mo experiment* [Phys. Rev. Lett. 131 (2023) 162501]
 - *The background model of the CUPID-Mo $0\nu\beta\beta$ experiment* [EPJC 83 (2023) 675]
 - *New measurement of double- β decays of ^{100}Mo to excited states of ^{100}Ru with the CUPID-Mo experiment* [PRC 107 (2023) 025503]
- EDELWEISS
 - *Tagging and localisation of ionizing events using NbSi transition edge phonon sensors for Dark Matter searches* [PRD 108 (2023) 022006]
- NEMO-3
 - *Measurement of double- β decay of ^{150}Nd to the 0^{+1} excited state of ^{150}Sm in NEMO-3* [EPJC 83 (2023) 12]

SuperNEMO

Unique combination of tracking + calorimetry
Full reconstruction of both electron tracks

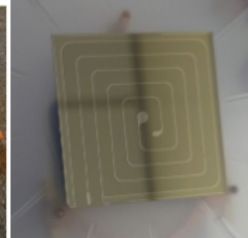
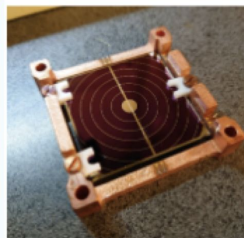
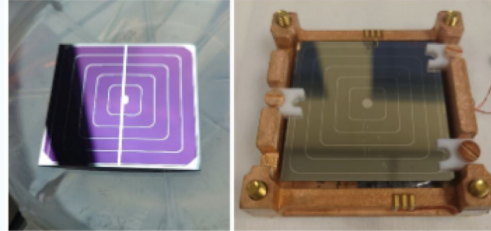
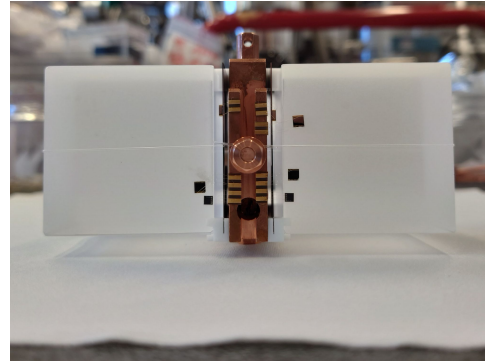


BINGO

R&D program 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:

- **Compact assembly** with fewer materials
- Rejection of events coincident with a **veto** in BGO or ZnWO₄
- **Light detector** with signal-to-noise amplification using the Luke-Neganov technique



BINGO



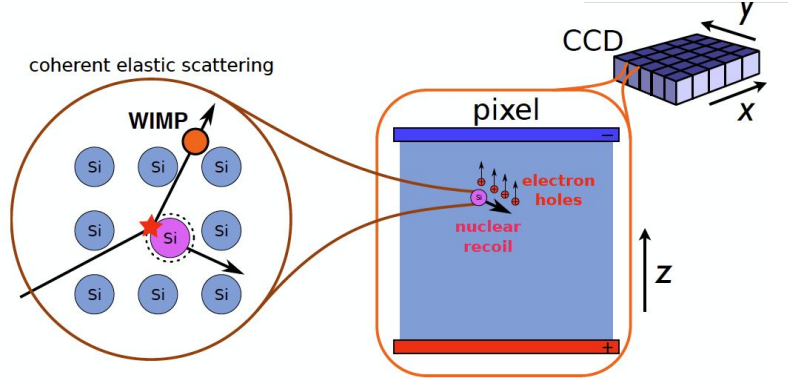
New technologies will allow $<10^{-5}$ events/(keV kg year)

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

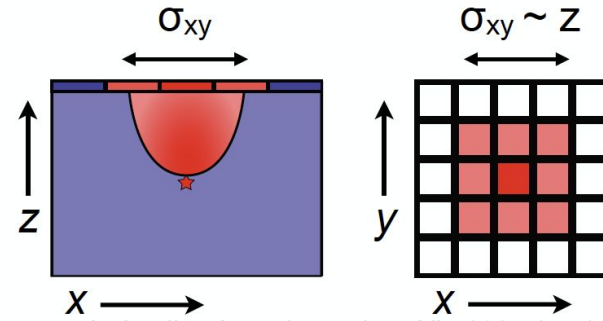
The very weak cosmic flux at LSM makes it an interesting site for future experiments



- Silicon CCD technology highly advanced thanks to utility in astronomical and satellite-based imaging
- DM particles scatter coherently off of Si nuclei, which recoil and yield detectable ionization signals
- CCDs are “exposed”, i.e. collect charge, for $\mathcal{O}(1 \text{ day})$ and images are then read out for analysis



A. Aguilar-Arevalo et al., arXiv:1506.02562



A. Aguilar-Arevalo et al., arXiv:1607.07410

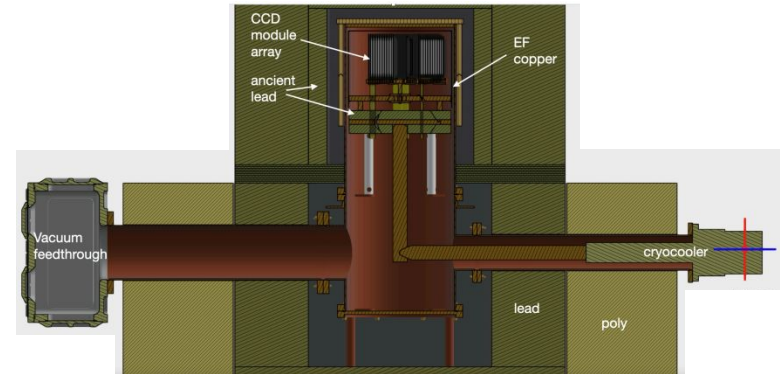
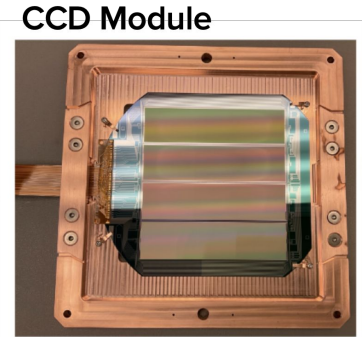
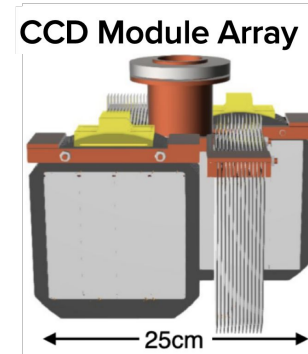
DAMIC-M

52 CCD module (208 CCDs) (~0.7 kg silicon) read in 'skipper' mode: multiple rereading to achieve a resolution of less than 0.1 electron-hole pair.

Preliminary results already obtained in 2023 at LSM with two CCDs in the LBC device ([world record sensitivity](#))

DAMIC-M is gradually progressing towards its installation objective, and commissioning at the end of 2024.

Future: LBC and DAMIC-M for R&D program for OSCURA (10-kg skipper-CCD)



Screening and Material Assay Programme

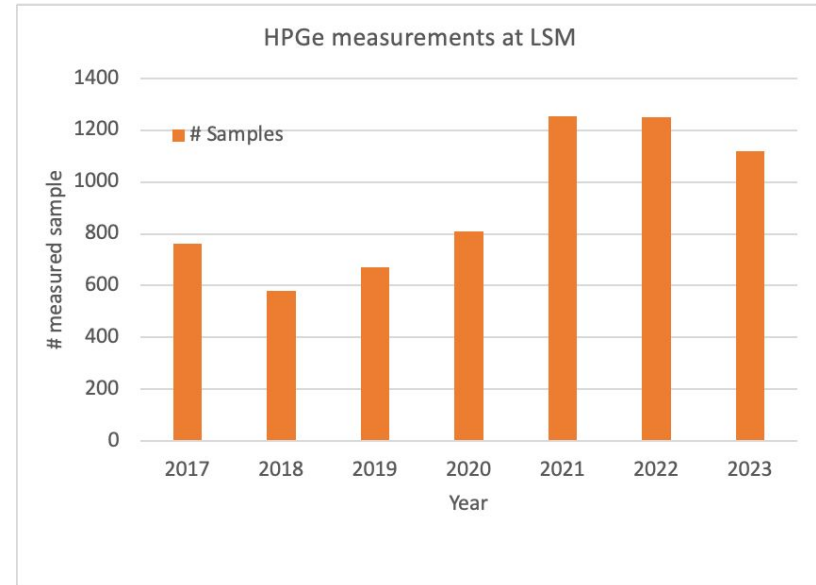
Gamma bulk (HPGe):

- 25 detectors in hands at LSM
- 15 installed in PARTAGE
- 5 detectors belonging to LSM
- ~1000 samples/year

Year	# Samples	# Detectors in PARTAGE
2017	761	0
2018	579	0
2019	669	0
2020	810	0
2021	1253	5
2022	1251	12
2023	1119	15

Alpha Surface:

- New capabilities: surface contamination
- XIA-UltraLo1800
- Commissioning at LPSC (surface cleanroom)



PARTAGe



Robotell outer lead shield



First PARTAGe detector row ready

PARTAGe

March 18, 2024: meeting with users of HPGe detectors. Clear feedback from users: need to improve detector performances.

<https://lpsc-indico.in2p3.fr/event/3591/>

From Feb 2024: continuous performance improvement

- Ongoing tests on purging - first promising results
- Updated cleanliness protocols
- Updated sample change protocols
- Staff training in the coming months
- Systematic tests on all detectors

MoU/agreement to be written/updated for all the HPGe users



Evaporation of dewar 2.3 L/day leading to 1.1L/min of N2 Gas

BACKGROUND RATES

ROI	2021	PARTAGe 2023	PARTAGe 2024
^{222}Rn (609keV)	5.0 ± 0.9	44.0 ± 6.6	7.0 ± 1.3
Thres - 3MeV	540.0 ± 9.1	1400.0 ± 14.2	583 ± 9.5

All rates are in counts

Interdisciplinary Activities

LSM hosts small experiments that can benefit from the exceptional low-radioactivity environment and the staff expertise in this domain (ex: biology, earth sciences..)

Stem cells storage underground

- LSM-pasteur institute collaboration
- Funded by CNRS interdisciplinary mission
- Allowed to test a stem cell storage shielded from natural radioactivity and terrestrial cosmic rays
- Patented cryostat

RAMURe project

- Funded by CNRS interdisciplinary mission
- Study of the long-term impact of natural radioactivity on living organisms, in particular those inhabiting aquatic ecosystems (three species of diatoms).
- Reduced radiation levels lead to various physiological consequences, such as growth inhibition and increased sensitivity to chemical mutagens.

Interdisciplinary Activities

International interdisciplinary workshop hosted at LSM in October 2023. Goal to promote and enhance interdisciplinary activities at the Underground laboratory of Modane Foreign underground lab representative Boulby^r, LNGS^r, LSBB, LSC^r, SNOLAB et SURF.

Workshop Committee in place
➔ Recommendations document centered on a strategic plan for the development of interdisciplinarity at LSM sent to IN2P3.

	Introduction	<i>Silvia Scorza</i>	14:00	Bio at LSM	<i>Vincent Breton</i>
		09:30 - 09:45		13:45 - 14:02	
	LSM	<i>Jules Gascon</i>		Medicine al LSM	<i>Fabrice Piquemal</i>
		09:45 - 10:00		14:02 - 14:19	
10:00	SURF	<i>Jaret Heise</i>		GDR MI2B - LabEx PRIMES	<i>Denis Dauvergne</i>
		10:00 - 10:20		14:19 - 14:36	
	SNOLAB	<i>Sekula Steve</i>		EDYTEM, INSU and INEE	<i>Fabien Arnaud</i>
		10:20 - 10:40	15:00	14:36 - 14:53	
	Boulby	<i>Sean Paling</i>		Radon &Co.	<i>José Busto</i>
		10:40 - 11:00		14:53 - 15:10	
11:00	Coffee Break			Gamma Spectroscopy	<i>Guillaume Warot</i>
		11:00 - 11:15		15:10 - 15:27	
	LSBB	<i>Ignacio Lazaro</i>		Qbits @underground	<i>Silvia Scorza</i>
		11:15 - 11:35		15:27 - 15:44	
	LSC	<i>Carlos Pena Garay</i>		Coffee Break	
		11:35 - 11:55	16:00	15:45 - 16:00	
12:00	LNGS	<i>Gaetano De Luca et al.</i>		Discussion	<i>Jules Gascon</i>
		11:55 - 12:15	17:00	16:00 - 18:00	
			18:00		

LSM Strategic Plan

- *Enhance the laboratory visibility at the forefront of nuclear and astroparticle physics by delivering world-class science and boosting its scientific leadership;*
- *Maintain a strong focus on the delivery of science, and support to the continued progress of current and future experiments; and*
- *Strengthen its global partnerships with European and international laboratories to further consolidate the role of France and IN2P3 in world-class physics research in the domain of deep underground physics.*

THE END

Thank You!