



LSM

The laboratory

The Science program



IN2P3
Les deux infinis



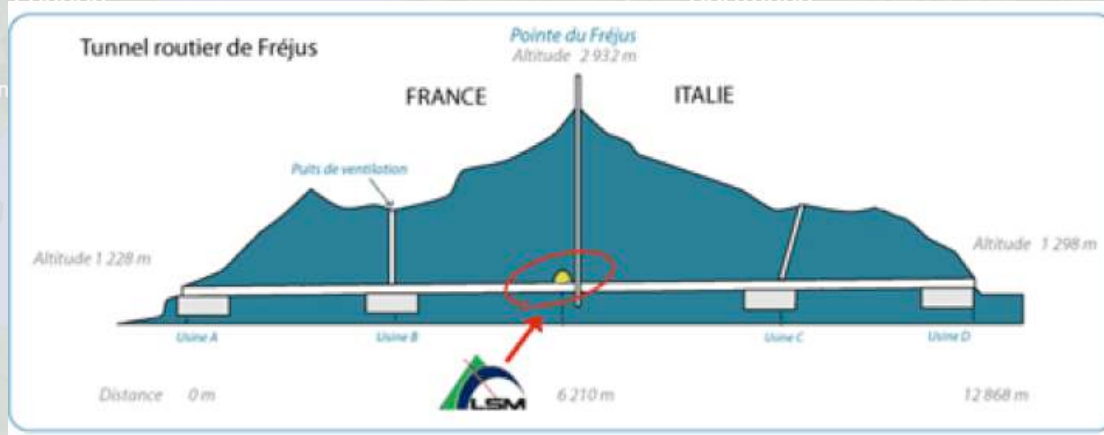
Scientific Director: Jules Gascon
(Université Lyon 1 + CNRS/IN2P3)

Director of Operations: Christophe Vescovi
(CNRS/IN2P3/LPSC)

Where are we?



Where are we?



Modane :

- 130 km from Grenoble
- 180 km from Geneva
- 1100 km from Prague

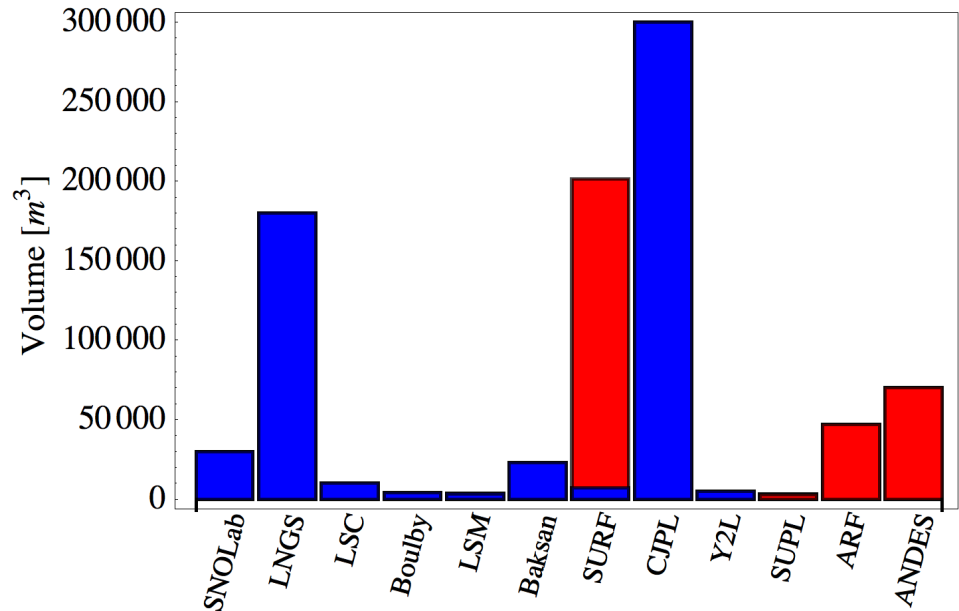
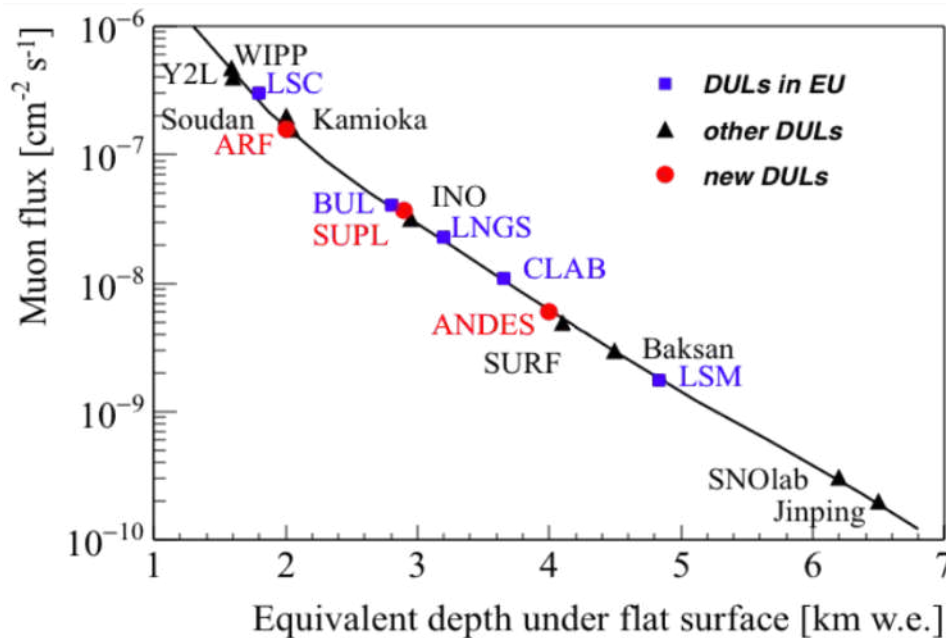
■ Experimental site midway in the 12km France/Italy road tunnel

- Surface lab constructed in 2009: office, garage, museum



LSM: a deep underground lab in Europe

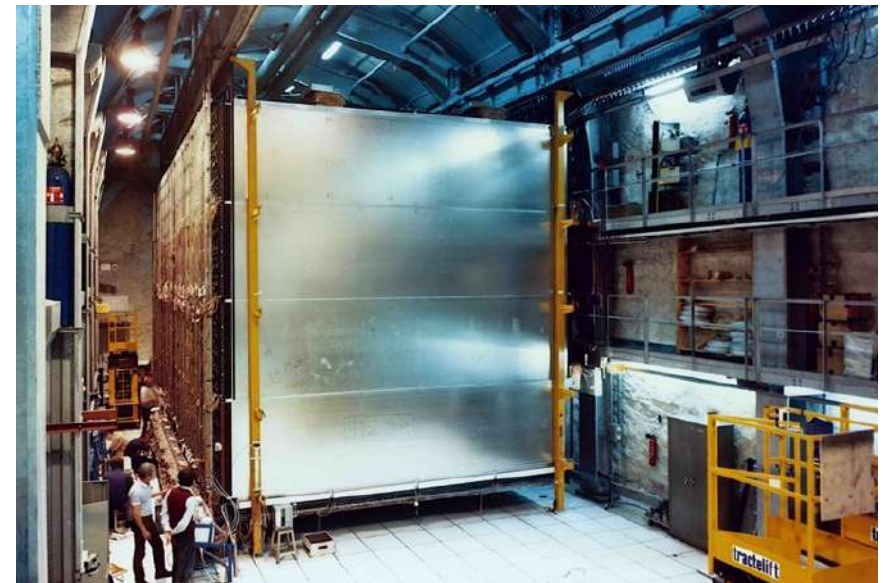
- *Deepest* site in Europe dedicated to Astropart., Nuclear & Particle Physics
- 4800 m.w.e: Muon Flux reduced by $>10^6$ relative to surface (/5.5 LNGS)
- *Flexible access* (hall accessible to trucks up to 9m);
- *Small* experimental surface: 400 m²
cf: Canfranc 600 m², Boulby 1700 m², SNOLAB 5350 m², Gran Sasso 180000 m²
- Natural radioactivity due to Radon <5 less than LNGS et LSC



Construction (1979-82) and first experiment



- Cavern dug out during the construction of the Fréjus Tunnel
- 1st experiment (1983-1989): proton lifetime



1990- onward: diversification

- Installation of an increasing number of germanium detectors for ultra-low radioactivity assays
- Installation in main hall of detector prototypes, followed by larger experiments
- Main themes: *neutrinoless double-beta decay* and *dark matter* searches



Ge room, ca. 1990

Main Hall, 1990



October 17th, 2022



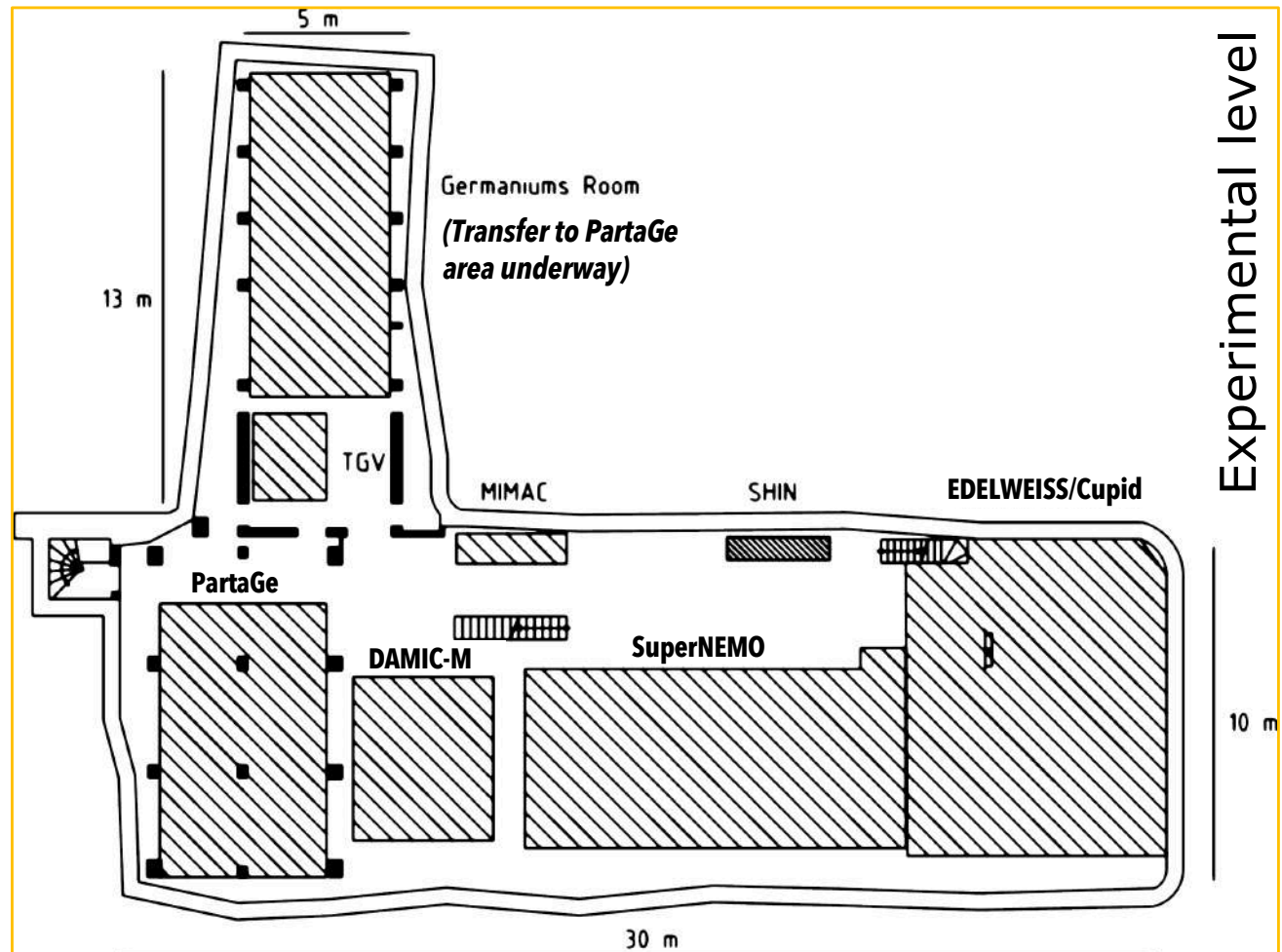
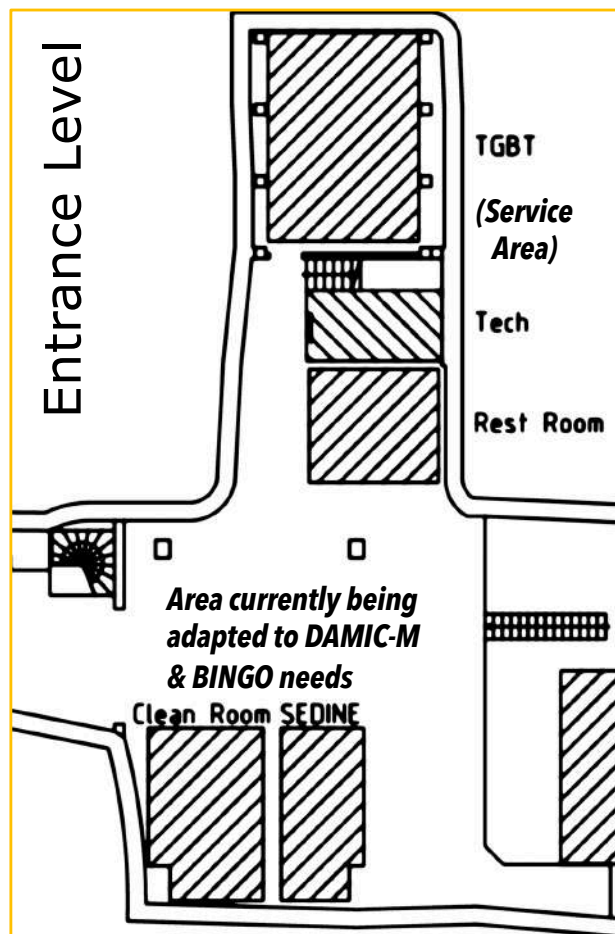
LSM presentation



Main Hall, 2000

LSM Floor plan (ca 2020)

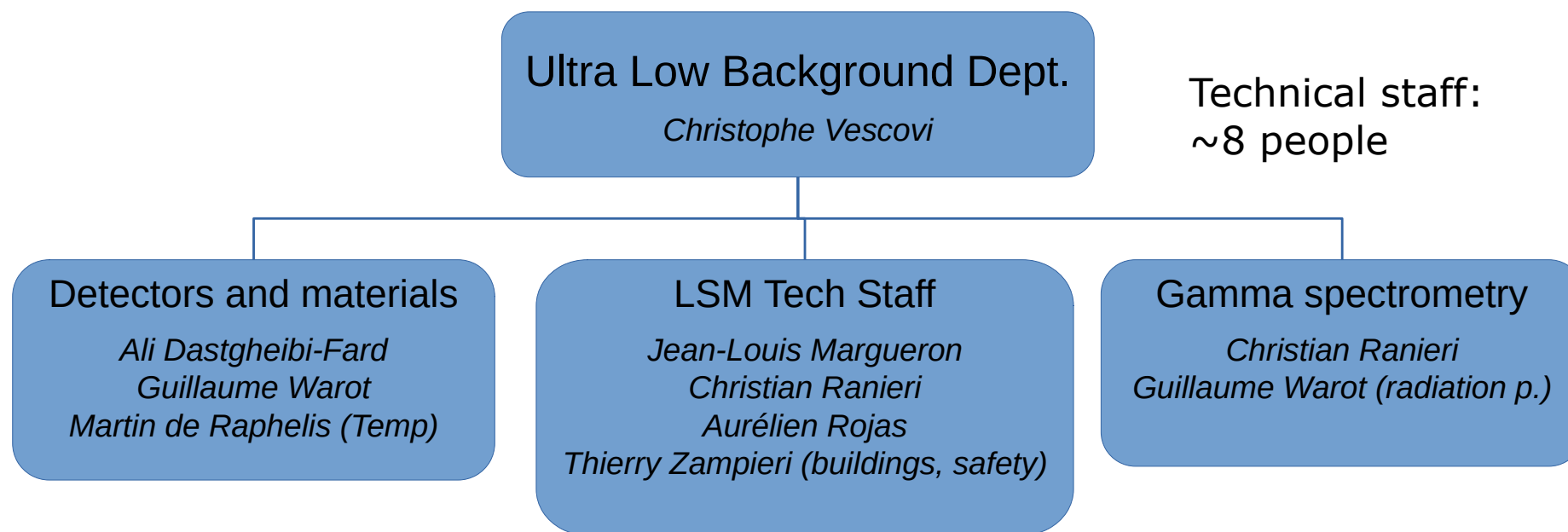
- Tight occupation of available 400 m²
- Plans to install 180 m² mezzanine level (over the crane access) above expt. level



LSM Status and Missions

- Since 2019: national platform of the French CNRS/IN2P3, hosted by the LPSC laboratory (CNRS + Grenoble-Alpes University)
 - Merging LSM (~10 personnel) with LPSC (~200 personnel) improved administrative & technical support, and improved link with Grenoble University (*infrastructure support*)
 - National status of LSM ensured by nomination of Scientific Director by French IN2P3
 - LSM included 2022 by French Ministry on its national list of Research Infrastructures
- **Platform for Subatomic/Astroparticle physics**
 - 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 generation experiments, with larger detector arrays being deployed in larger DUL
 - Provide technical support to experiments
- **Germanium detector platform**
 - Very low radioactivity measurements + associated technology developments
- **Opening to multidisciplinary applications**
 - Host small experiments that can benefit from the exceptional low-radioactivity environment and the staff expertise in this domain (*ex: biology, earth sciences..*)
- **Coordination with networks of European underground laboratory**

LSM Organization

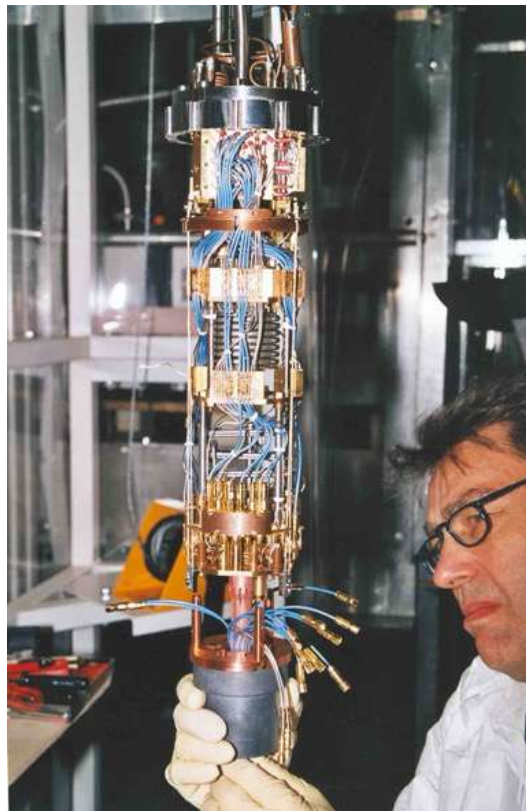


- Director of operation (C. Vescovi, LPSC)
- Scientific director (J. Gascon, Lyon University + CNRS/IN2P3)
- LSM Steering committee includes CNRS/IN2P3 & Université Grenoble Alpes
- LSM External Strategic Council: A. Iani (LNGS), S. Paling (Boulby), S. Schönert (TUM), N. Smith (Triumpf) ... *importance of DUL coordination in strategy discussion*
- *Scientific coordination of French efforts in Deep Underground Physics via DUPhy "Groupe de Recherche" (GDR): (<https://gdrduphy.in2p3.fr/>)*

Dark Matter searches: EDELWEISS (1995-...)

- Germanium detectors cooled down to 20 mK
- Particle identification using phonon and ionization signals

EDELWEISS-I 1998
3x300g
Best limits @50 GeV (2001)

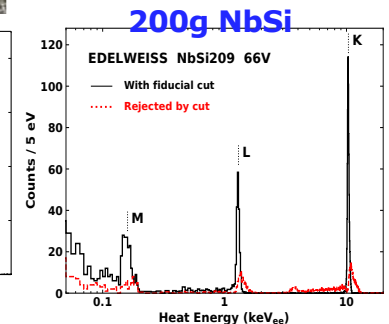
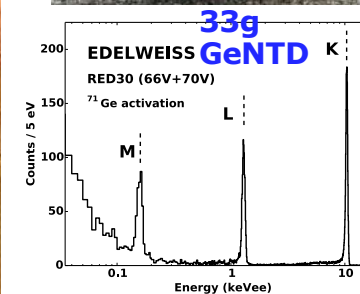
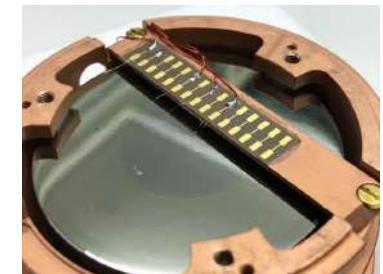
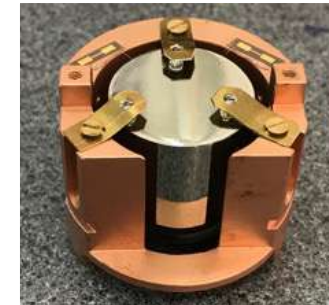


EDELWEISS-II-III 2005-2017
10x300g -> 24x870g
Best limits @ 50 GeV (2009)
& axions @ keV (2017)

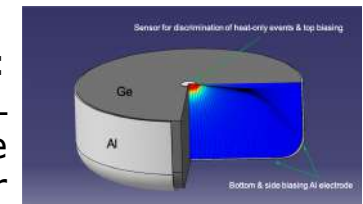


Largest cryoGe array

EDELWEISS-SubGeV (2018-...)
Scaling 870g -> 33 g: eV-scale thresholds
Best Dark Photons limits @6 eV (2019)
& first Ge limits < 35 MeV/c²



2022-2024:
CRYOSEL
40 g Ge, tag of single
electron-hole pair



Light Dark Matter: NEWS-G and DAMIC-M

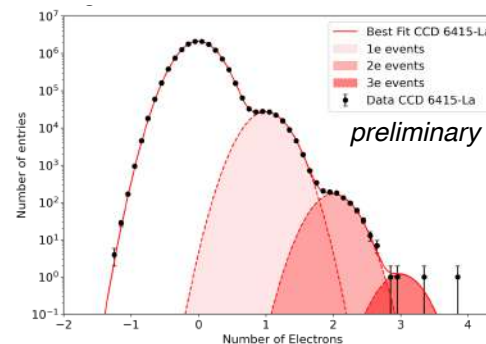
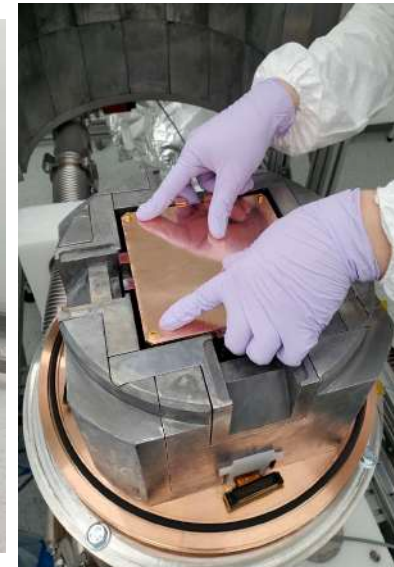
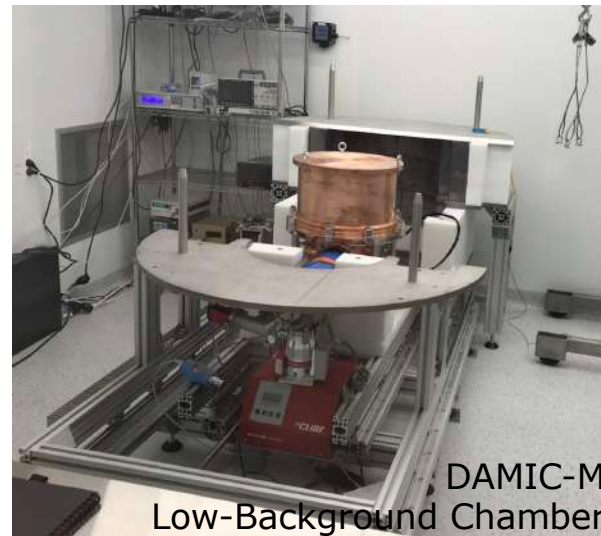
- **NEWS-G** (2015-2020): large gaseous volume with single-anode readout (expt moved to SNOLAB since 2020)

SNOglobe test @LSM (2019)

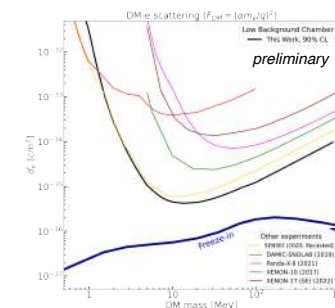


- Also: **MIMAC** gaseous TPC for directional searches

- **DAMIC-M** (ERC, 2018-...): CCD with skipper read-out for sub- e^- resolution
- 200 CCD (1 kg Si) array for 2023-2024
- **2-CCD tests & physics run in 2022**



DAMIC-M results, IDM 2022



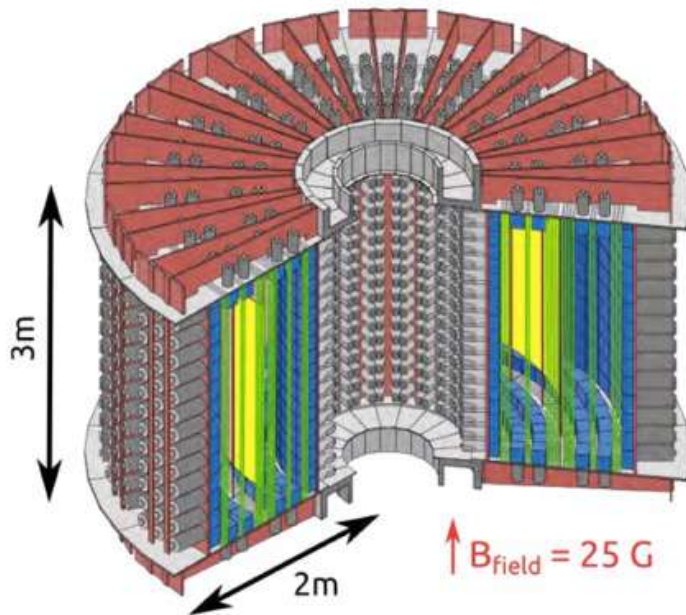
$\beta\beta 0\nu$ searches: NEMO and SuperNEMO

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

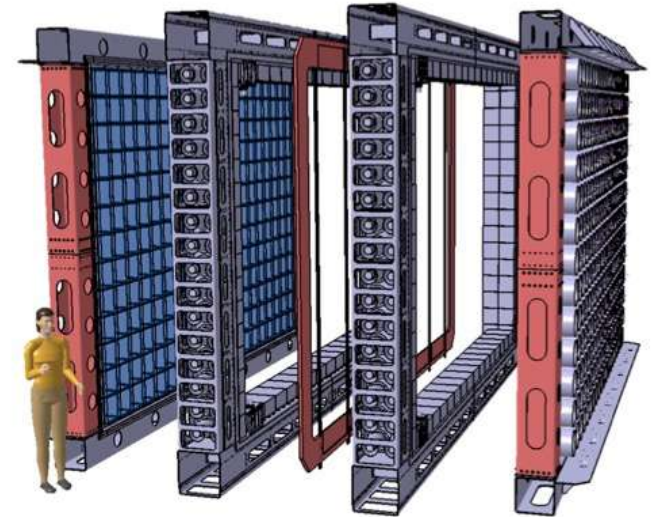


NEMO-1
1989

NEMO-3 : 2000-2011



2015-... :
SuperNEMO
demonstrator

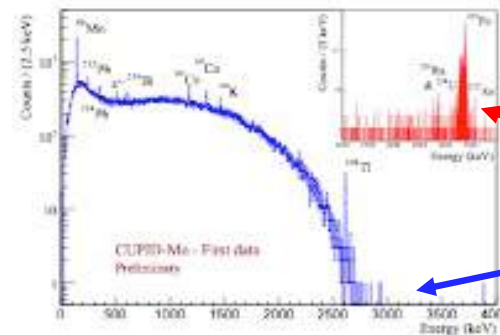
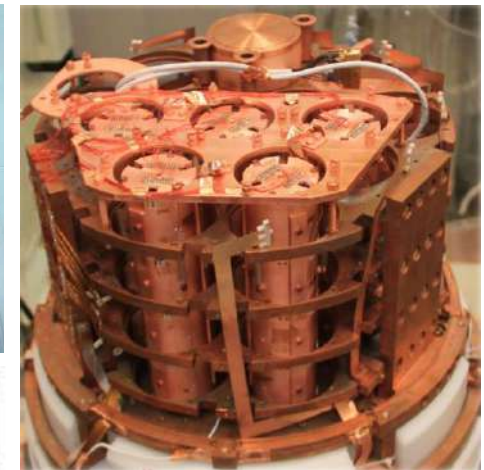


Ongoing installation and
commissioning @LSM



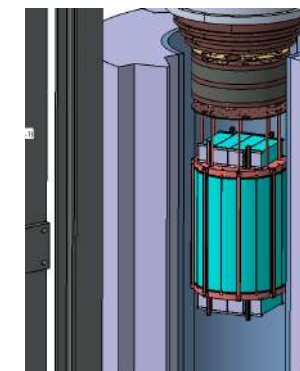
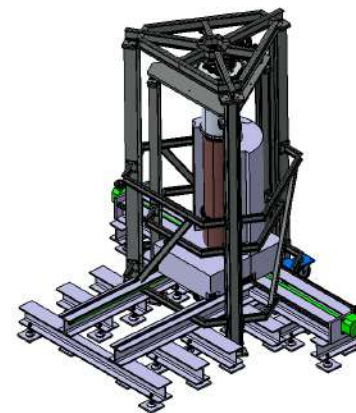
$\beta\beta 0\nu$ searches: CUPID-Mo and BINGO

- 20 Li₂MoO₄ scintillating crystals, 4 kg total
- Shared cooled-down at 20 mK with EDELWEISS
- 19 months physics run
- Best limit for ¹⁰⁰Mo since NEMO-3:
 - $T_{1/2} > 1.8 \times 10^{24}$ year
 - $\langle m\beta\beta \rangle < (0.28-0.49)$ eV
- Key result for the design of the CUPID experiment @ Gran Sasso
- *R&D for next generation of cryogenic detectors: BINGO (ERC, 2022-2026)*



Rejected background (light detector)

Region of interest: 3034 ± 10 keV



BINGO cryostat

¹⁰⁰Mo + ¹³⁰Te scintillating targets

BGO internal shielding

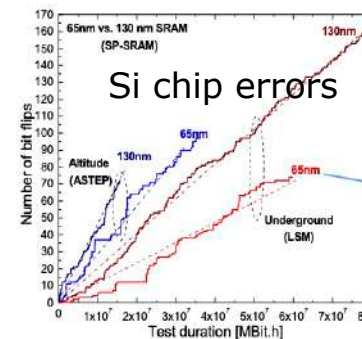
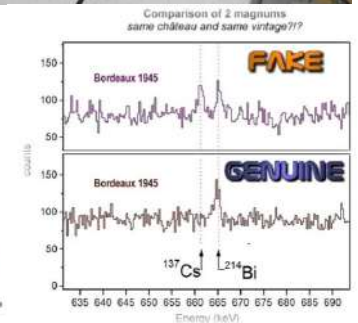
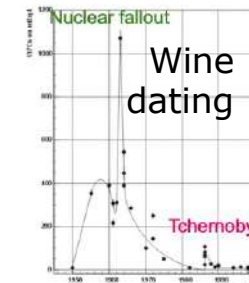
Germanium platform

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

- ~16 Ge for very-low background material assays
 - For experiments based at LSM (SuperNEMO, EDELWEISS, CUPID-Mo) or for other experiments (ex: JUNO)
 - Agreement with LNGS for measurement of ECEC decay of ^{82}Se (6 kg) to excited state on large (600 cc) Obelix Ge

- Academic and industrial partners
 - France: IRSN, CEA, CENBG, IP2I, LSCE (Université Paris-Saclay, CEA, CNRS), EDYTEM (CNRS, Université Savoie Mont-Blanc),
 - International: JINR Dubna (Russia), UTEF Prague and SURO (Czech Republic)

Obelix Ge @ LSM

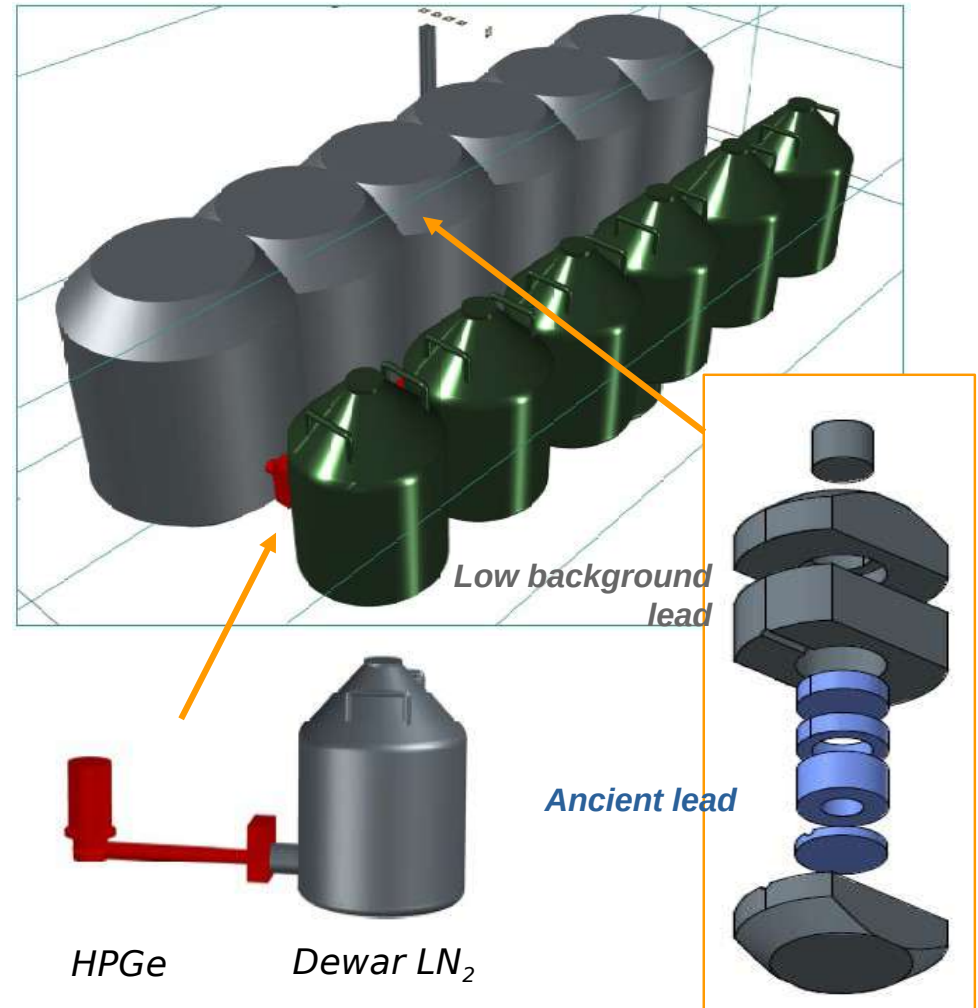


Sediment dating



Current Ge facility upgrade: PARTAGe

- More efficient use of space
- Can increase up to 22 HPGe
- Shielding optimisation
- Ease of LN₂ refill
- Common Rn-free air tent



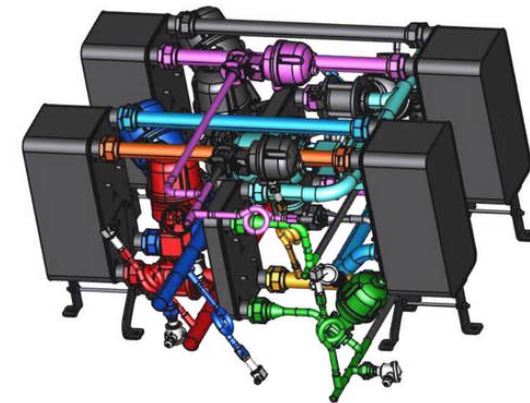
- 11 detectors transferred so far

Other facility upgrade: Radon trapping

- 2005: First Radon trapping facility installed in a DUL
 - Strong Czech contribution
- Initially, 120 m³/h flow of air with 15 mBq/m³ Rn concentration (~ /1000 ambient).
- Major upgrade of this aging facility under way

Upgrade:

- Staged approach to reach flow of 250 m³/h in time for SuperNEMO and DAMIC-M runs + reduce electricity & cooling needs



Design study for optimized refrigeration system

Conclusion

- LSM physics program focused on experiments requiring stringent low-radioactivity requirements + their associated technological developments.
- Also open to other applications that can benefit from its depth, its expertise and its European collaborations
 - Looking forward formalizing CR-LSM collaboration via a more formal bi-lateral agreement, to replace the formal JOULE agreement
- Physics program already linked with larger experiments in larger DUL

Summary of 2021 activities for experiments

- Program focused on development of new techniques (“demonstrator”) and low-mass WIMP searches: *well adapted to LSM constraints (small space) and strong point (lowest muon rate in EU, easy road/truck access, proximity to French labs)*
- *~400 users, including ~200 from 18 countries other than France*

LSM Experiment	Domain	Technique	Collaboration	Activities in 2020-2021
CUPID-Mo	$\beta\beta 0\nu$	Cryogenic LiMoO	France, Russia, Germany, Italy, USA, Chine, Ukraine	Physics exploitation. No futher runs in EDELWEISS-III cryostat.
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 to start end of 2022
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 by covid & war
DAMIC-M	DM	Si CCD	France, USA, Canada, Switzerland, Denmark, Spain, Brasil, Argentina	Installation started in 2020, Test chamber data started in 2022, physics in 2023
EDELWEISS	DM	Ge Cryogenic	France, Russia, Germany	Physics exploitation. No furter runs in EDELWEISS-III cryostat
CRYOSEL	DM	Ge Cryogenic	France	EDELWEISS detector R&D using BINGO cryostat
MIMAC	DM	TPC Direct.	France	No runs in 2021
NEWS-G	DM	Spherical gas detecor	France, Canada, USA, Greece, UK	Plans for SEDINE detector tests in new shielding