LPSC

PLATEFORME NATIONALE LSM

LSM

LSM

The Laboratoire Souterrain de Modane

The laboratory

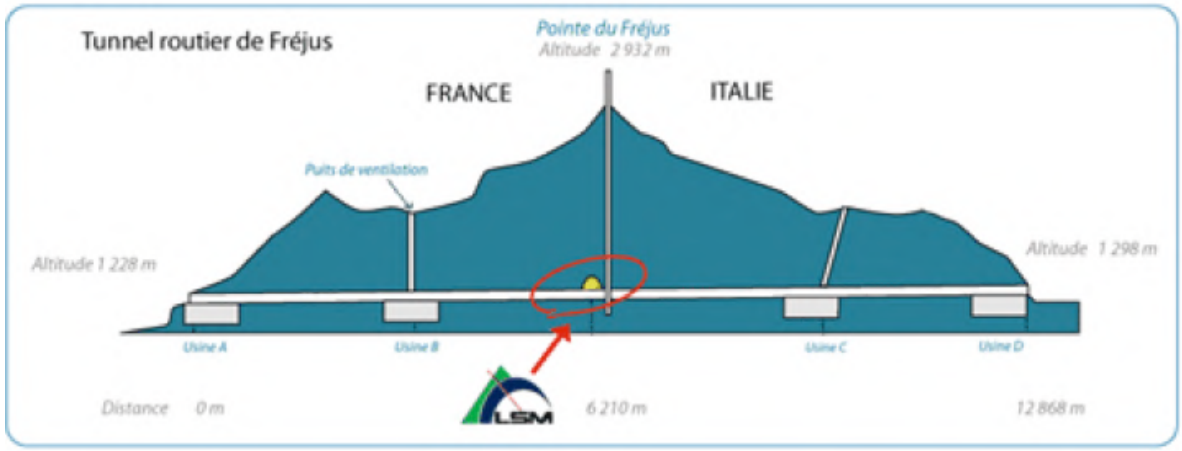
The science program

Jules Gascon
(Université Lyon 1 and CNRS/IN2P3)

Where is LSM?


Experimental platform of France IN2P3
attached to LPSC/Grenoble
(CNRS + Université Grenoble Alpes)
Laboratoire
Souterrain Modane
Google

The location



- Modane :
  - 130 km from Grenoble
  - 200 km from Lyon
  - 100 km from Torino
- Experimental site midway in the 12km France/Italy road tunnel
- Surface lab (*office, garage, small museum)*
- *French National Research Infrastructure*

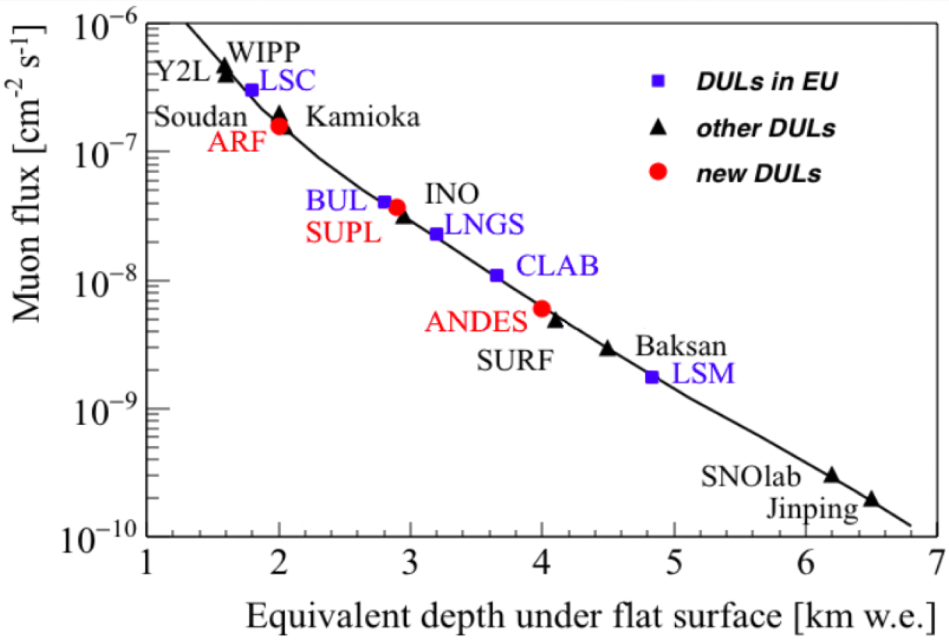

6
Grenoble 130 km
E70
Torino 100 km

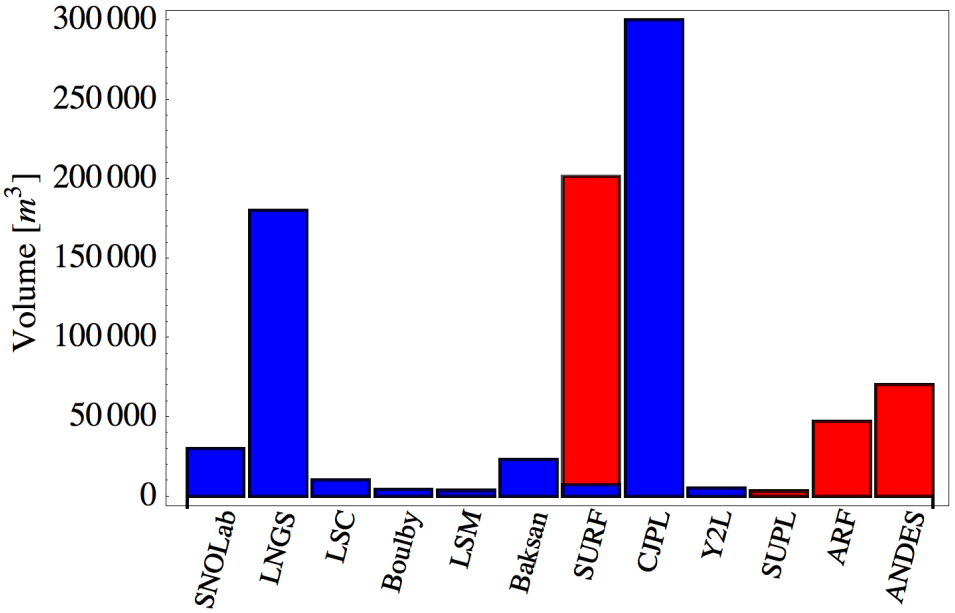
LSM: a deep underground lab in Europe

- **Deepest site in Europe** dedicated to Astropart., Nucl. & Part. Physics
- 4800 m.w.e: **4.5 μ/m²/day** (/5.5 LNGS); fast neutron = **1.6x10⁻⁶ n/cm²/s**
- ***Flexible access*** (hall accessible to trucks up to 9m);
- ***Small*** experimental surface: 400 m² (3500 m³)

  cf: Canfranc 600 m², Boulby 1700 m², SNOLAB 5350 m², Gran Sasso 180000 m²

- ***Natural radioactivity due to Radon : 15 Bq/m³*** (<5 less than LNGS et LSC)

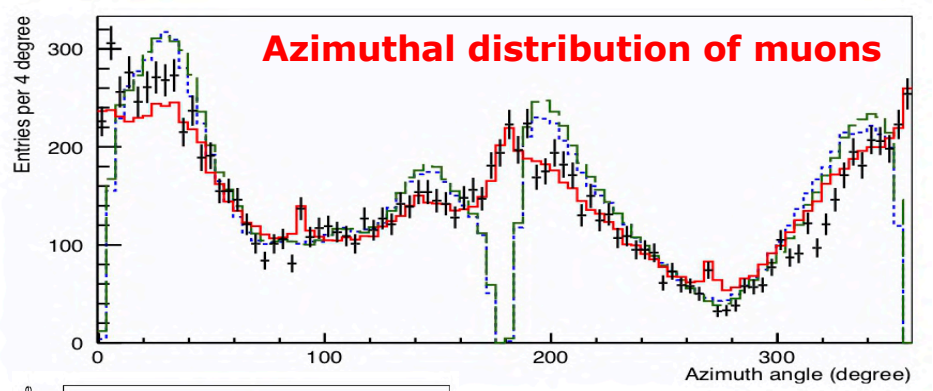


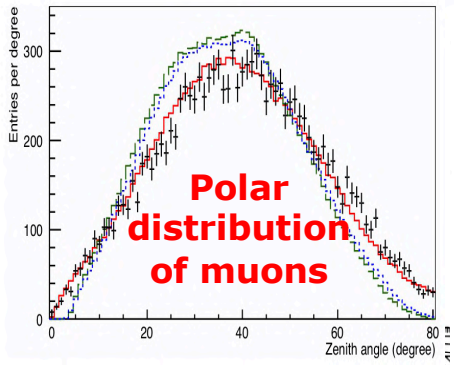


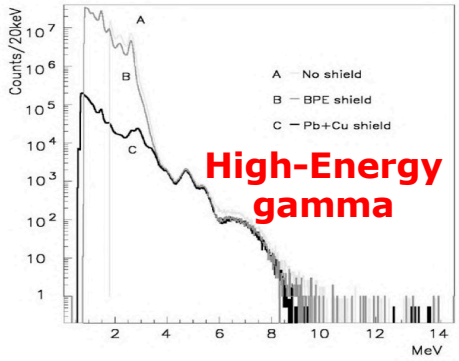
Background level measurements

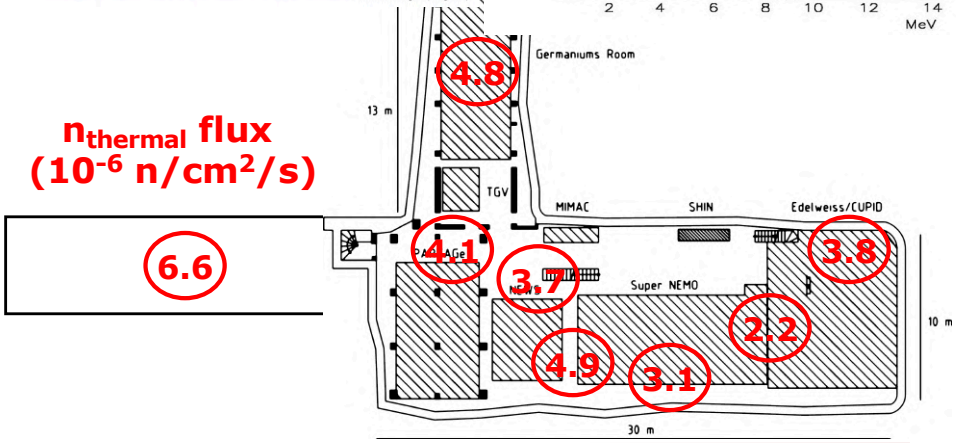
Since 1983, large corpus of measurements of various LSM backgrounds by experiments

- Muons: total flux (4.5 μ/m^2/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/cm^2/s)
  [Armengaud et al, Astrop. Phys. 47 (2013) 1]
- Thermal neutrons
  [Rozov et al, BRAS 74 (2012) 464; arXiv:1001.4383]
- Radon (~15 Bq/m^3)
  [Hodak et al, J. Phys. G 46 (2019) 11, E. Armengaud et al, JINST 12 (2017) P08010]



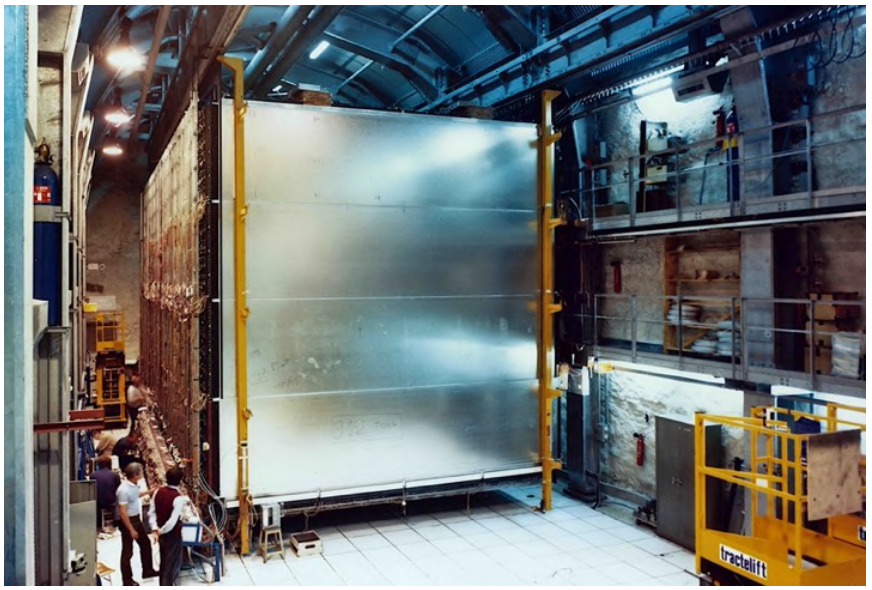






Construction (1979-82) and first experiment

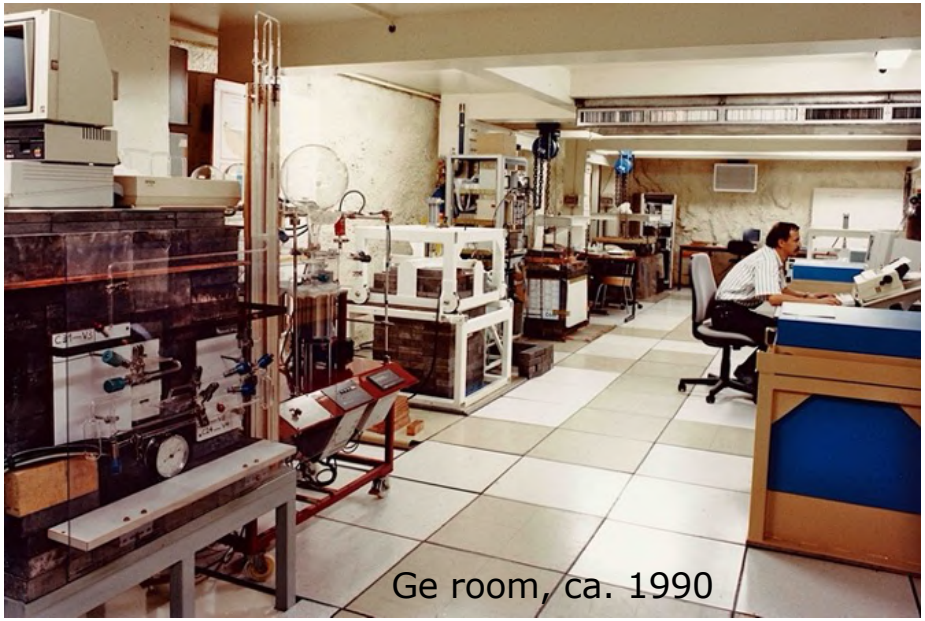
- Cavern dug out during the construction of the Fréjus Tunnel



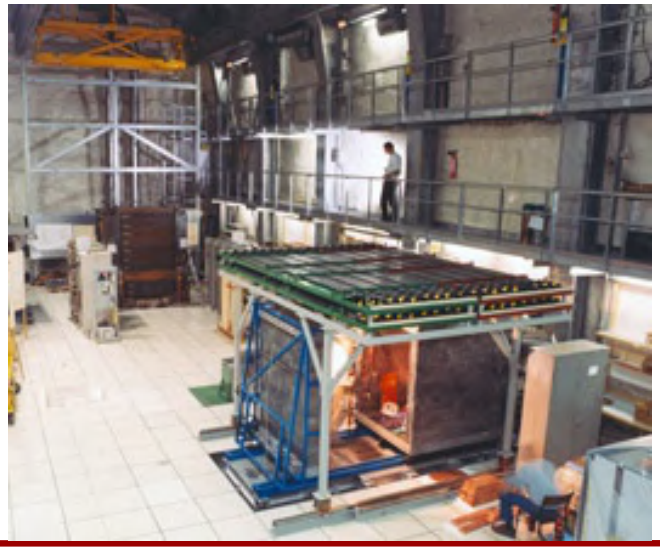
- 1st experiment (1983-1989): proton lifetime

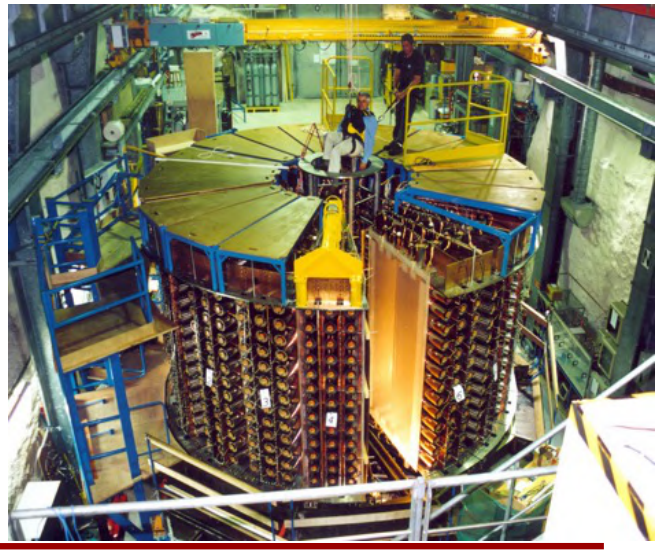
1990- onward: diversification

- Installation of an increasing number of germanium detectors for ultra-low radioactivity assays
- Installation in main hall of detector prototypes, followed by larger expts
- **Main themes: *ν-less double-β decay* and *dark matter* searches**
- **~400 users, 50% outside France**


Ge room, ca. 1990

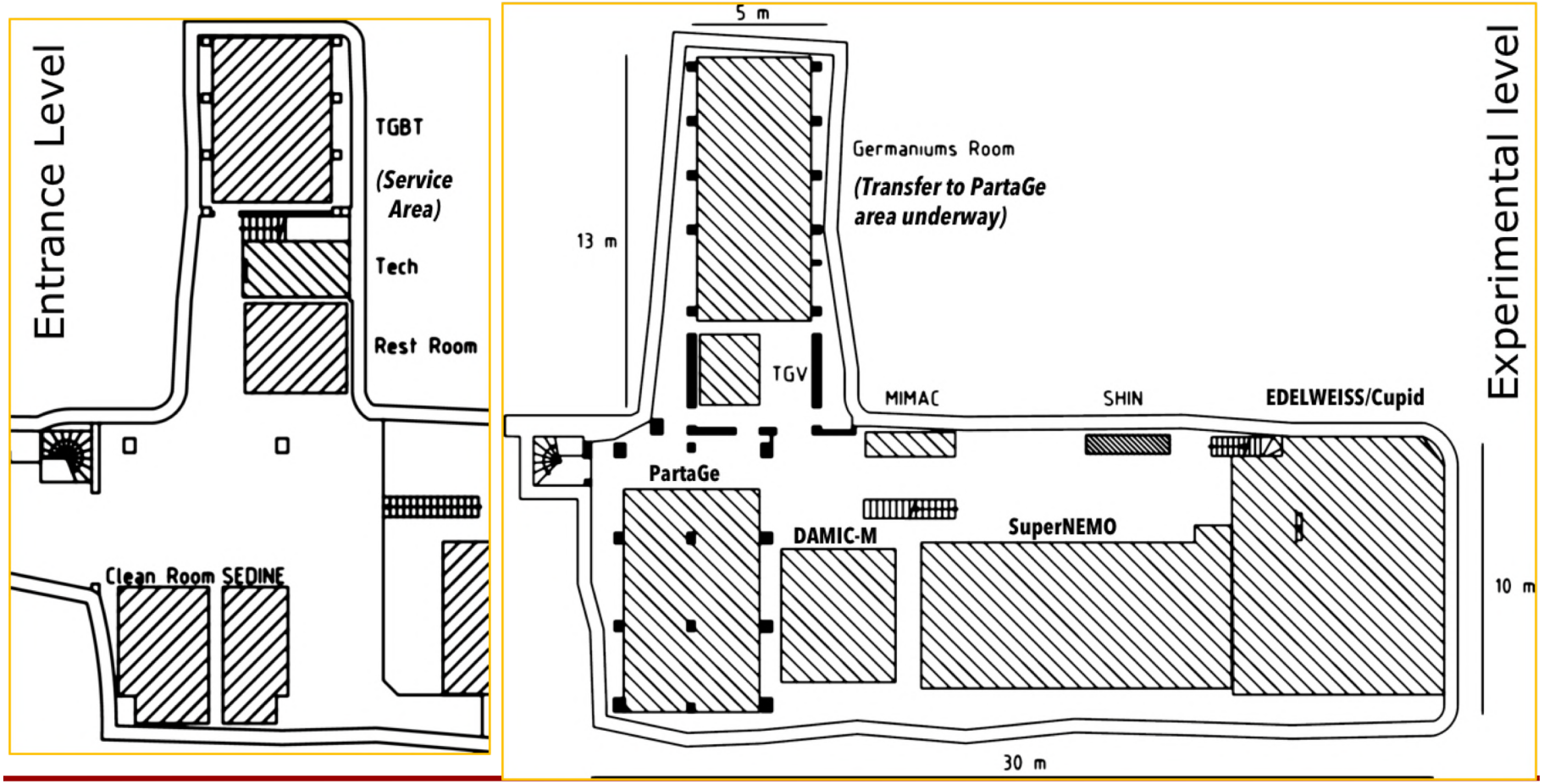
Main Hall, 1990




Main Hall, 2000

LSM Floor plan *(ca 2020)*

- Tight occupation of available 400 m^2
- Plans to install 180 m^2 mezzanine level (over the crane access) above expt. Level
- *Current conversion of EDELWEISS area for BINGO + DAMIC-M + future expts*



LSM Missions

- **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 expts (larger detector deployed in larger DUL)
  - Provide technical support to experiments
  - ***Priority topics (well-adapted to depth+size): Light Dark Matter, R&D for $\beta\beta0\nu$***

- **Germanium γ-ray assaying**
  - 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**
  - Request by APPEC
  - Common working groups in preparation

LSM Organization

Dedicated technical staff: ~8 people

Ultra Low Background Dept.
Christophe Vescovi

Integrated to LPSC
(admin. + technical support from large IN2P3/UGA laboratory in Grenoble)

Detectors and materials
Ali Dastgheibi-Fard
Guillaume Warot
Martin de Raphelis (Temp)

LSM Tech Staff
Jean-Louis Margueron
Christian Ranieri
Aurélien Rojas
Thierry Zampieri (buildings, safety)

Gamma spectrometry
Christian Ranieri
Guillaume Warot (radiation p.)

Safety & basic tunnel infrastructure: STRF

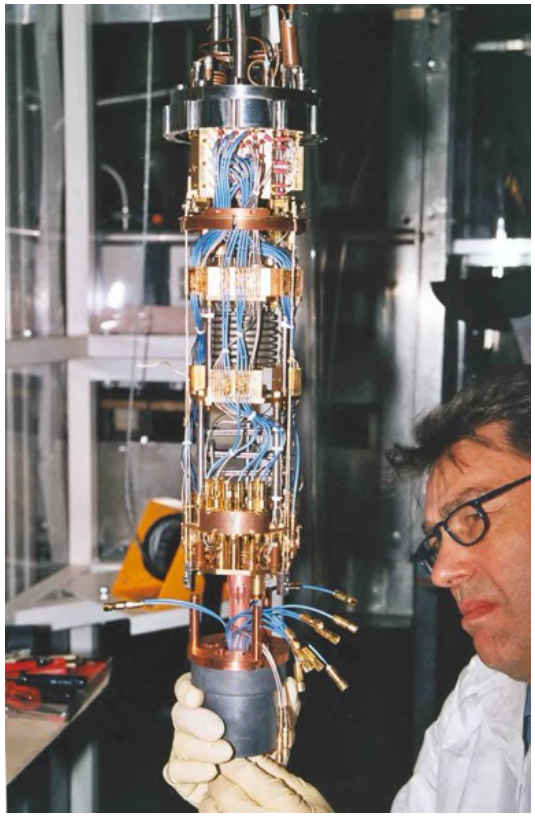
- Director of operation (C. Vescovi, LPSC)
- Scientific director (J. Gascon, Lyon University + CNRS/IN2P3)
- LSM Steering committee includes CNRS/IN2P3 & Université Grenoble Alpes
- LSM External Strategic Council: A. Iani (LNGS), S. Paling (Boulby), S. Schönert (TUM), N. Smith (Triumf) ... *importance 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

See E. Guy talk

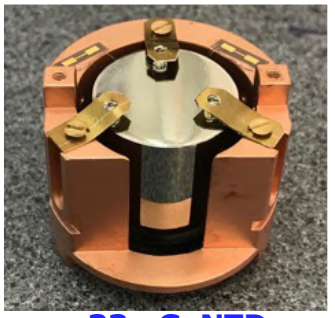
EDELWEISS-I 1998
3x300g
Best limits @50 GeV (2001)



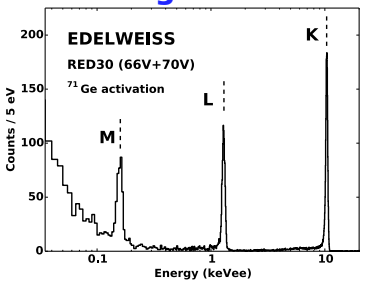
EDELWEISS-II-III 2005-2017
10x300g -> 24x870g
Best limits @ 50 GeV (2009)
& axions @ keV (2017)

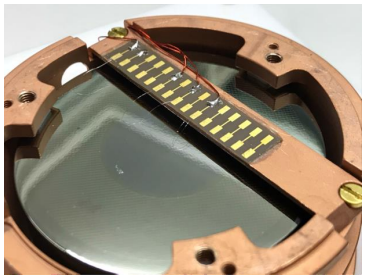
Largest cryoGe array

EDELWEISS-SubGeV (2018-...)
Scaling 870g -> 33 g: eV-scale thresholds
Best Dark Photons limits @6 eV (2019)
& first Ge limits < 35 MeV/c^2

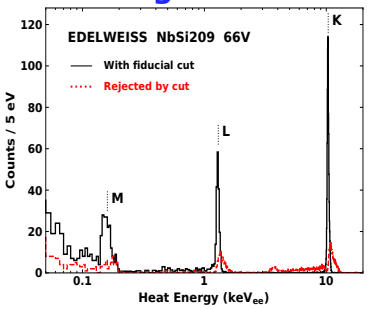


33g GeNTD

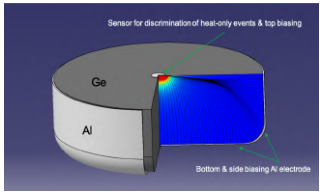




200g NbSi



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



Future: TESSERACT @ LSM?

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)

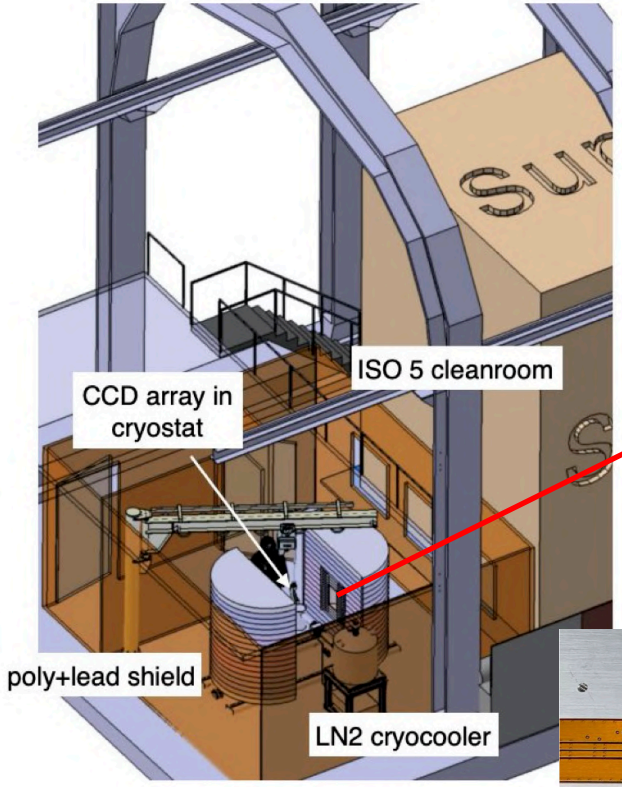
SNOglobe test @LSM (2019)

See JM Coquilat talk

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

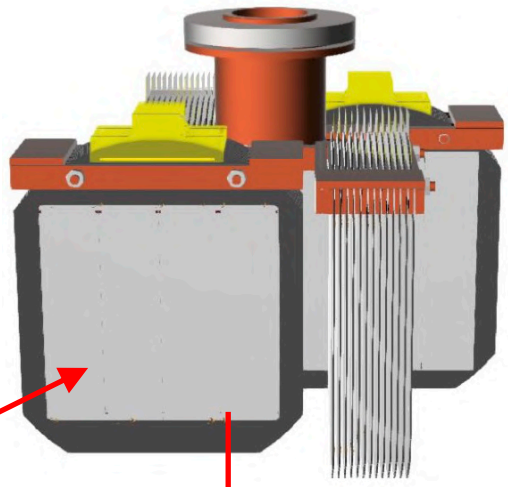
- **DAMIC-M** (ERC, 2018-...): **CCD with skipper read-out** for sub-e^- resolution
- 200 CCD (1 kg Si) array run starting 2024

See R. Simda and P. Privitera talks

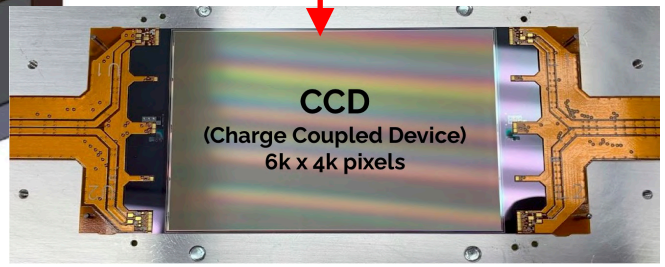


DAMIC-M@LSM
(conceptual design)

DAMIC-M CCD stack



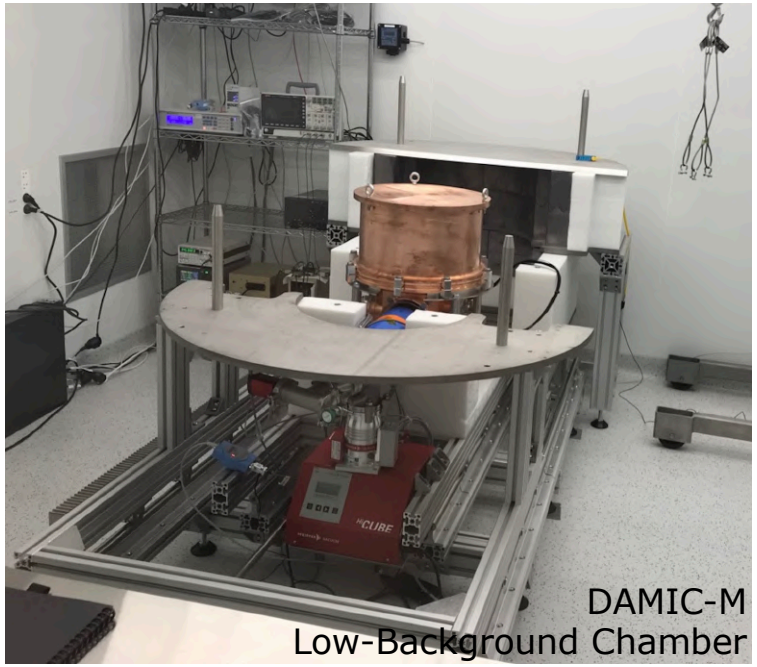
~200 SKIPPER CCDs

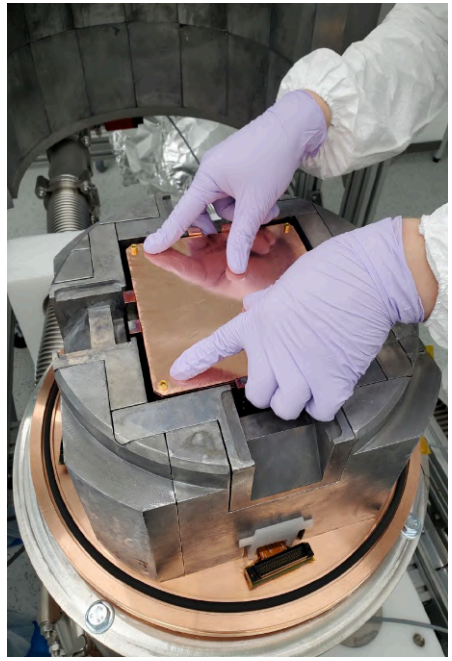


Most recent physics results: DAMIC-M LBC

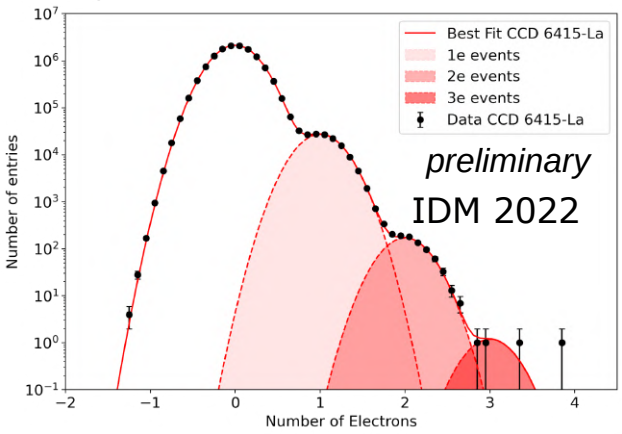
- **LBC :** Low-Background Chamber with 2 CCDs
- Target mass 18 g
- Polyethylene and lead shield (+ roman lead)
- Operated in clean room
- 85.2 g.day exposure acquired in 2022
- 0.2 e^- resolution (N_{skip}=650)
- **Best limits on e^--DM interactions via light mediator between 1.6 MeV/c² and 1 GeV/c²;**
- **Best limits for heavy mediator (1-15 MeV/c²)**

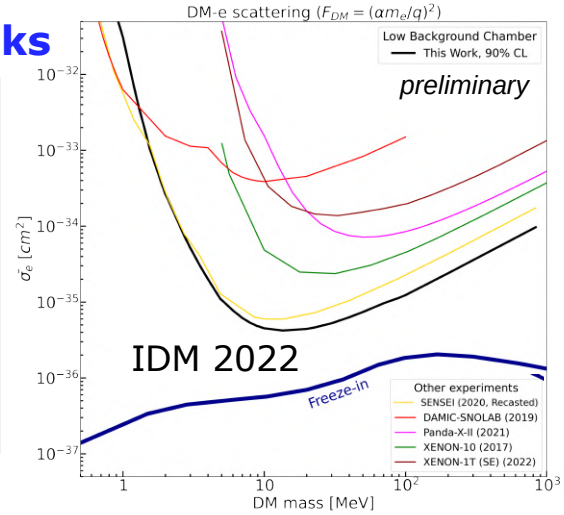
PRL 130 (2023) 171003





See R. Simda, P. Privitera talks





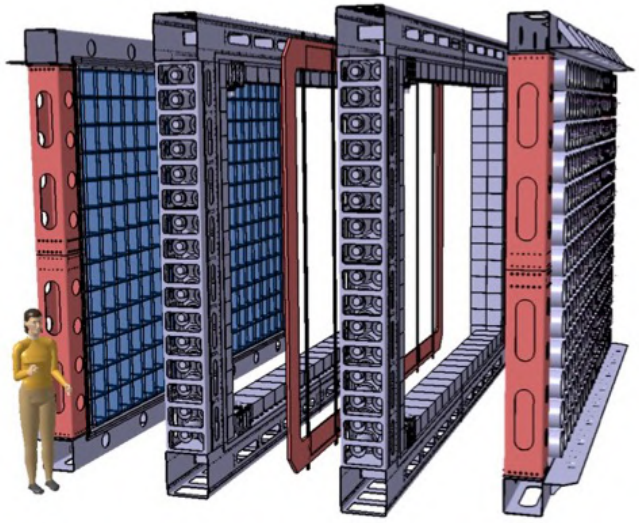
$\beta\beta0\nu$ searches: NEMO and SuperNEMO

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

NEMO-1
1989

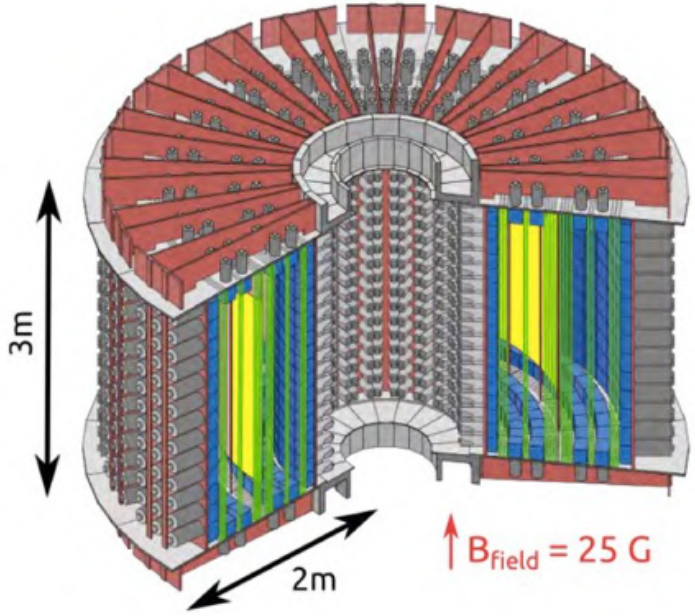
See C. Patrick talk

2015-... : SuperNEMO demonstrator



Ongoing installation and commissioning @LSM

NEMO-3 : 2000-2011



$\beta\beta0\nu$ searches: CUPID-Mo and BINGO

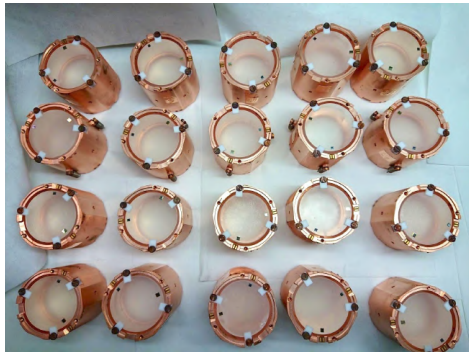
- 20 Li2MoO4 scintillating crystals, 4 kg total
- Shared cooled-down at 20 mK with EDELWEISS
- 19 months physics run
- Best limit for ^{100}Mo since NEMO-3:
  - $T_{1/2} > 1.8 \times 10^{24}$ year
  - $\langle m\beta\beta \rangle$ < (0.28-0.49) eV

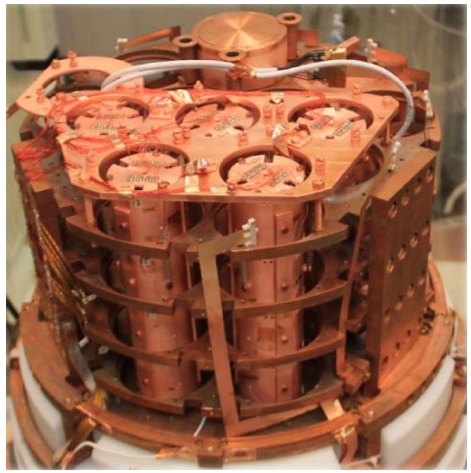
More recent results: see L. Imbert talk

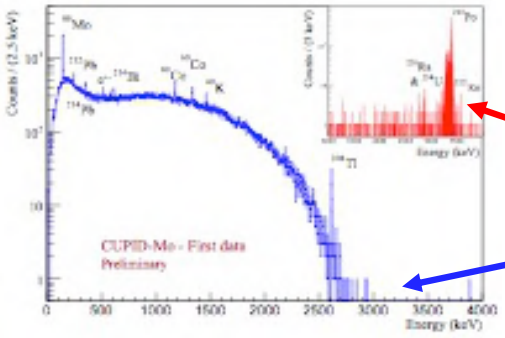
- ***Key result for the design of the CUPID experiment @ Gran Sasso***

- *R&D for next generation of cryogenic detectors: BINGO (ERC, 2022-2026)*

See V. Berest talk

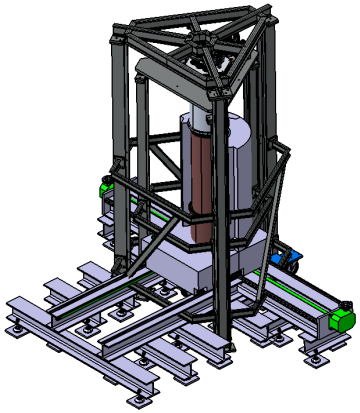


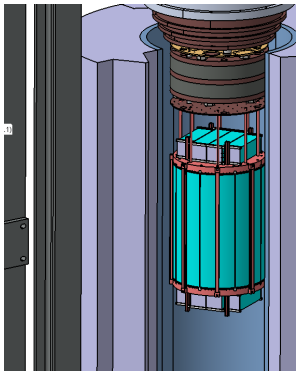




Rejected background (light detector)

Region of interest: 3034 ±10 keV





BINGO cryostat @LSM

^{100}Mo + ^{130}Te scintillating targets

BGO internal shelding

Germanium platform (1)

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

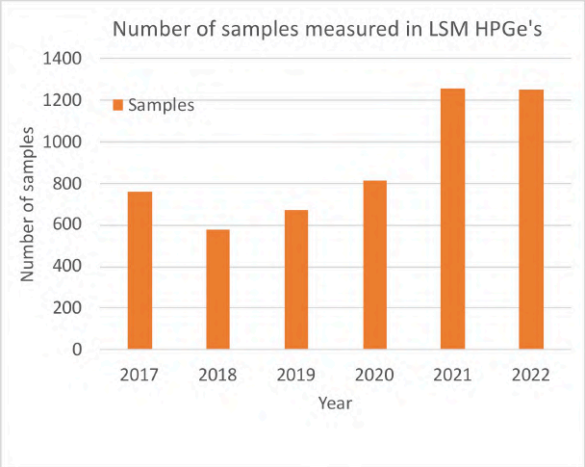
- Total of ~16 HPGe
- Astroparticle physics applications:
  - Material assays for experiments based at LSM (SuperNEMO, EDELWEISS, CUPID-Mo, ...), and also for other experiments (ex: JUNO)
  - *Agreement with LNGS for long term (~ year) measurement of ECEC decay of ^{82}Se (6 kg) to excited state on large (600 cc) Obelix HPGe*

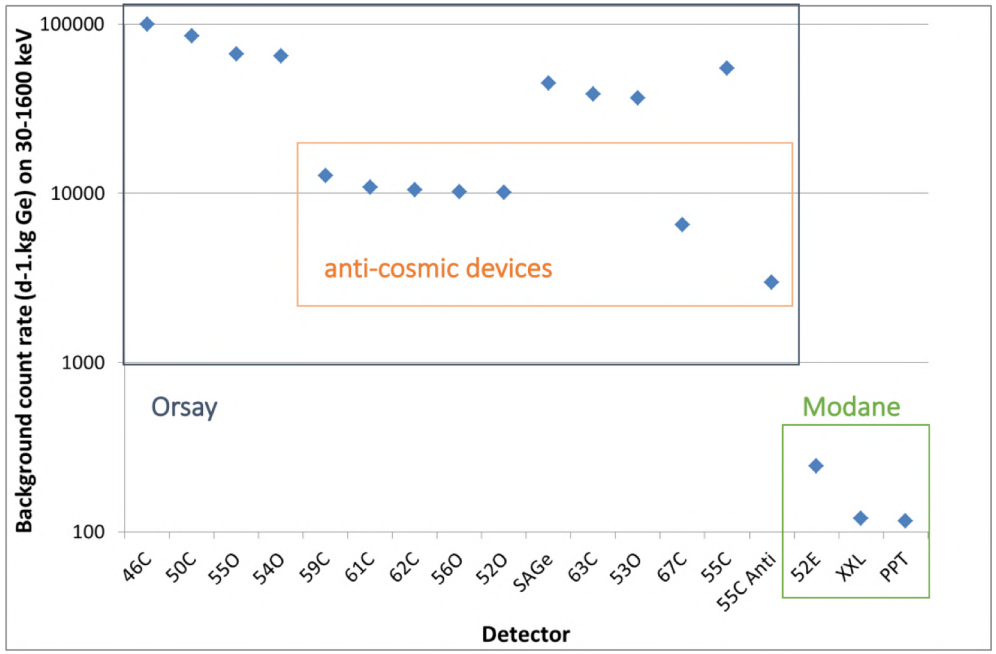
Obelix Ge @ LSM

Germanium platform (2)

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

- Pluri-disciplinary program open to academic and industrial users and partners
- *Covering very lowest-rate background end of their measurements*





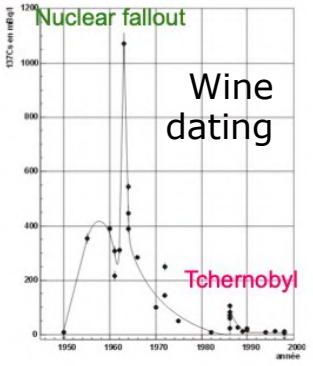
Source:

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

Germanium platform (3)

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

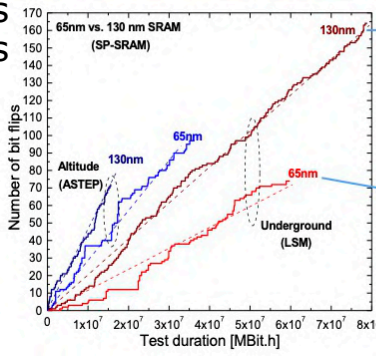
- Pluri-disciplinary program open to academic & industrial users + partners
  - *Covering very lowest-rate end of expts*
  - France: IRSN, CEA, CENBG, IP2I, LSCE (Université Paris-Saclay, CEA, CNRS), EDYTEM (CNRS, U. Savoie Mont-Blanc)
  - International: JINR Dubna (Russia), UTEF Prague and SURO (Czech Republic)
- Non-HPGe program: effect of radiation
  - Biology: seeds, bacteria, stem cells
  - Electronics (CMOS)



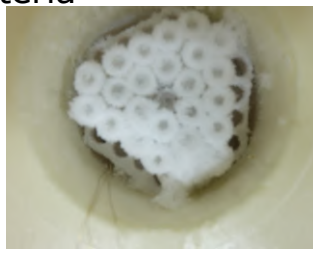
River sediment dating ^{137}Cs, ^{210}Pb

^{137}Cs in Sahara sand dust in Alps glaciers

Rate of errors in Si chips



Bacteria



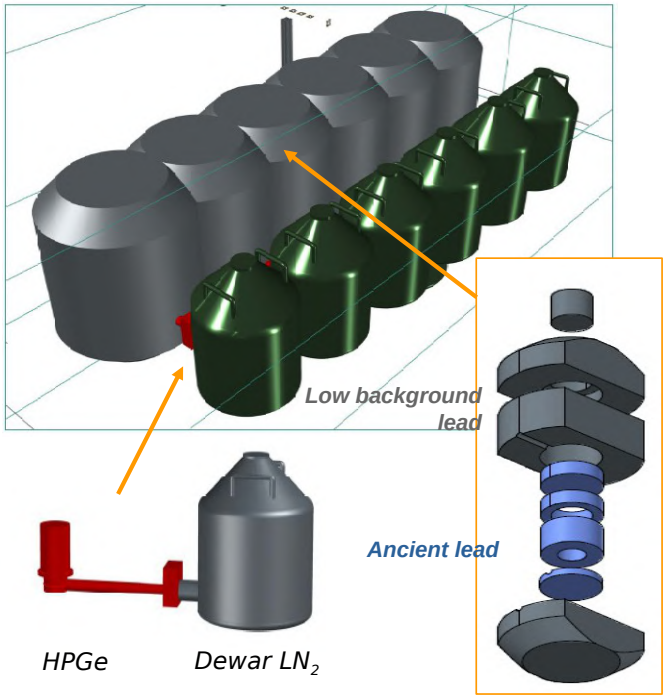
[Lampe et al., Nature Scient. Report 2019]

[Rocheteau et al., Cell Transplantation 2022]

[Autran et al., IEEE Nucl. Sc. 2009]

Current Ge facility upgrade: PARTAGe

- More efficient use of space (room for up to 22 HPGe)
- Shielding optimisation
- Ease of operation (LN_2 refill)



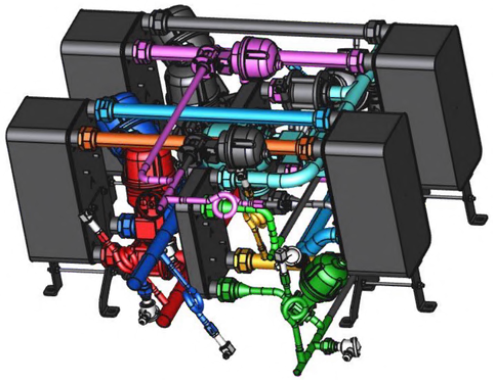
- **11 HPGe transferred so far**

Other facility upgrade: Radon trapping

- *2005: First Radon trapping facility installed in a DUL*
  - *Strong Czech contribution + Marseille*
- Initially, 120 m^3/h flow of air with 15 mBq/m^3 Rn concentration (~ /1000 ambient).
- Major upgrade of this aging facility under way

Upgrade:

- Staged approach to reach flow of 250 m^3/h in time for SuperNEMO and DAMIC-M runs + reduce electricity & cooling needs



Design study for optimized refrigeration system

Other work on Rn implatation: see G. Warot talk

Conclusion

- physics program focused on experiments requiring stringent low-radioactivity requirements, and on the associated technological developments. Also open to other applications that can benefit from its depth, its expertise and its position within the French and EU landscape
- *LSM physics program has already links with larger experiments in larger DUL*
- *Looking forward an increased partnership with the EU underground laboratories*