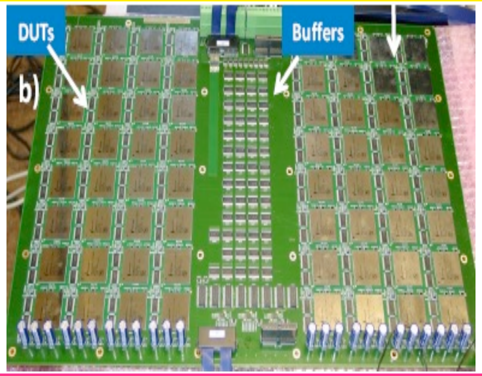
Science at Underground Laboratory of Modane (LSM)


Ali DASTGHEIBI FARD

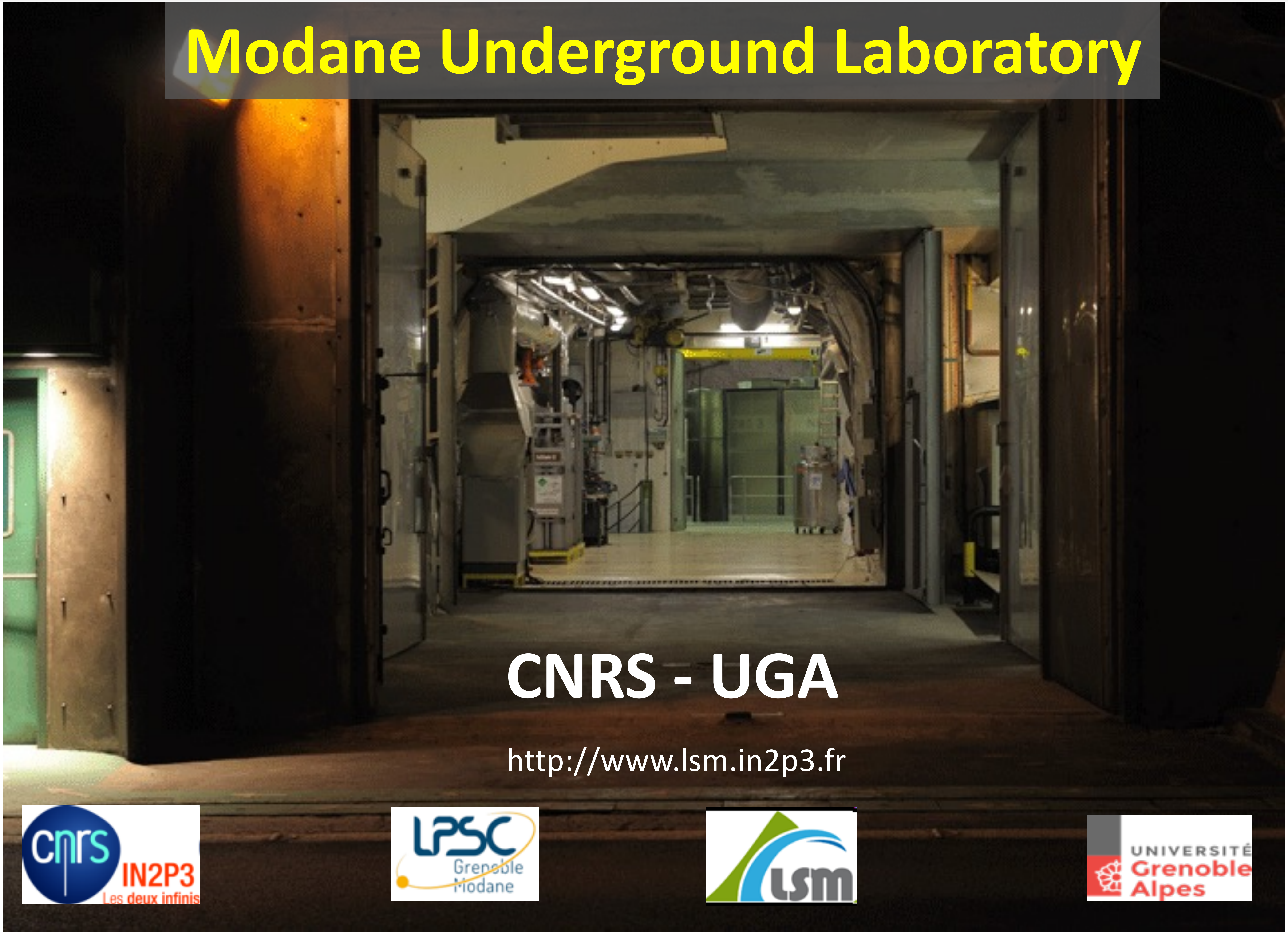
Symposium on Science at PAUL (Paarl Africa Underground Laboratory)

SSP

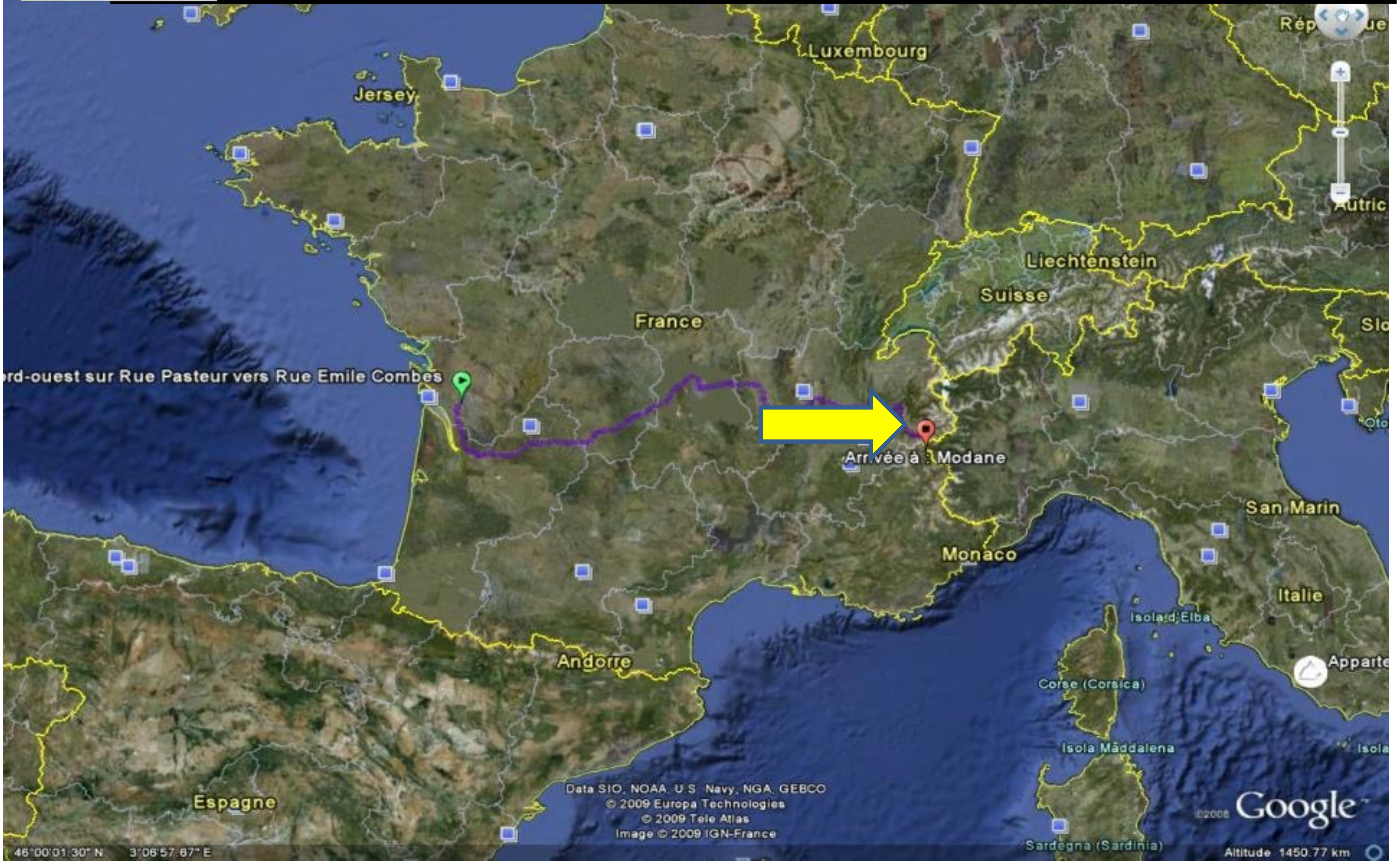
LPSC

Laboratoire Souterrain de Modane

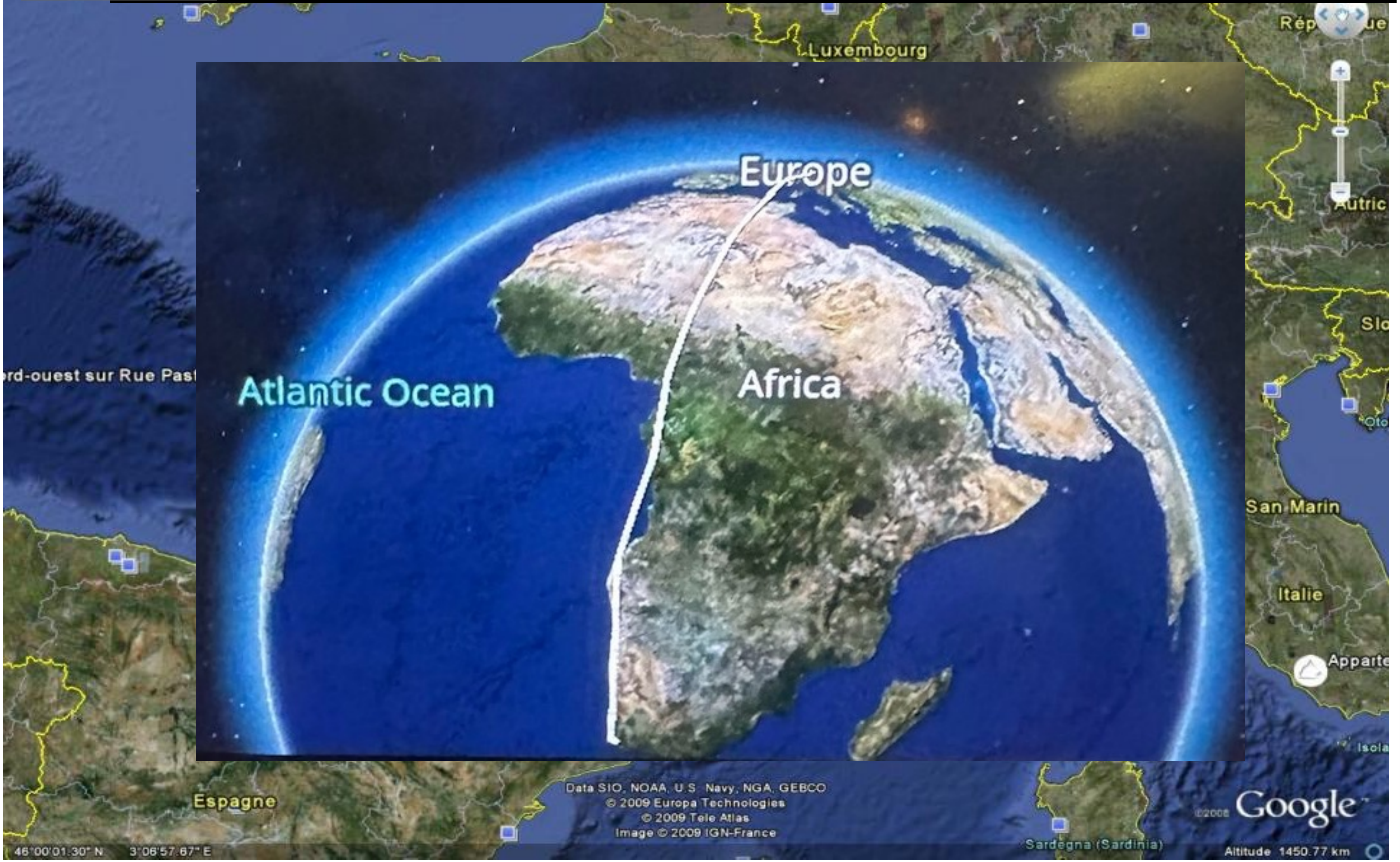
CNRS/UGA FRANCE


Modane Underground Laboratory
CNRS - UGA
http://www.lsm.in2p3.fr
IN2P3
Les deux infinis
Grenoble
Modane
UNIVERSITÉ
Grenoble
Alpes

LSM Geographic position #1



LSM Geographic position #1

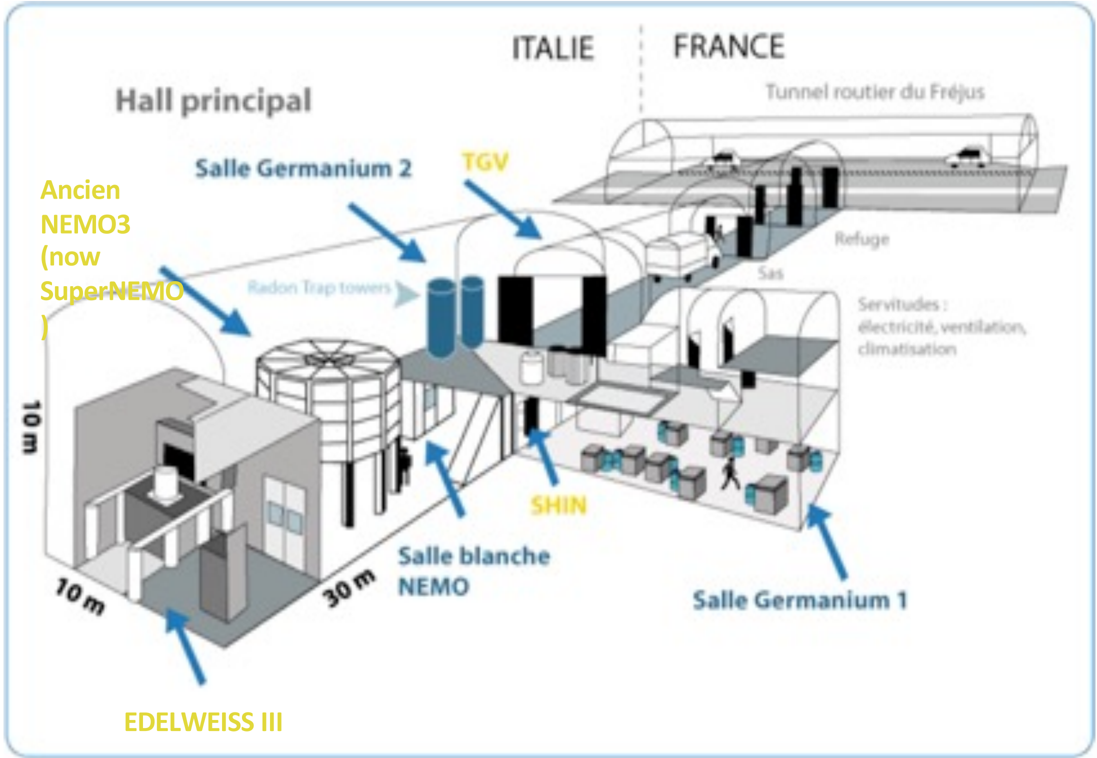


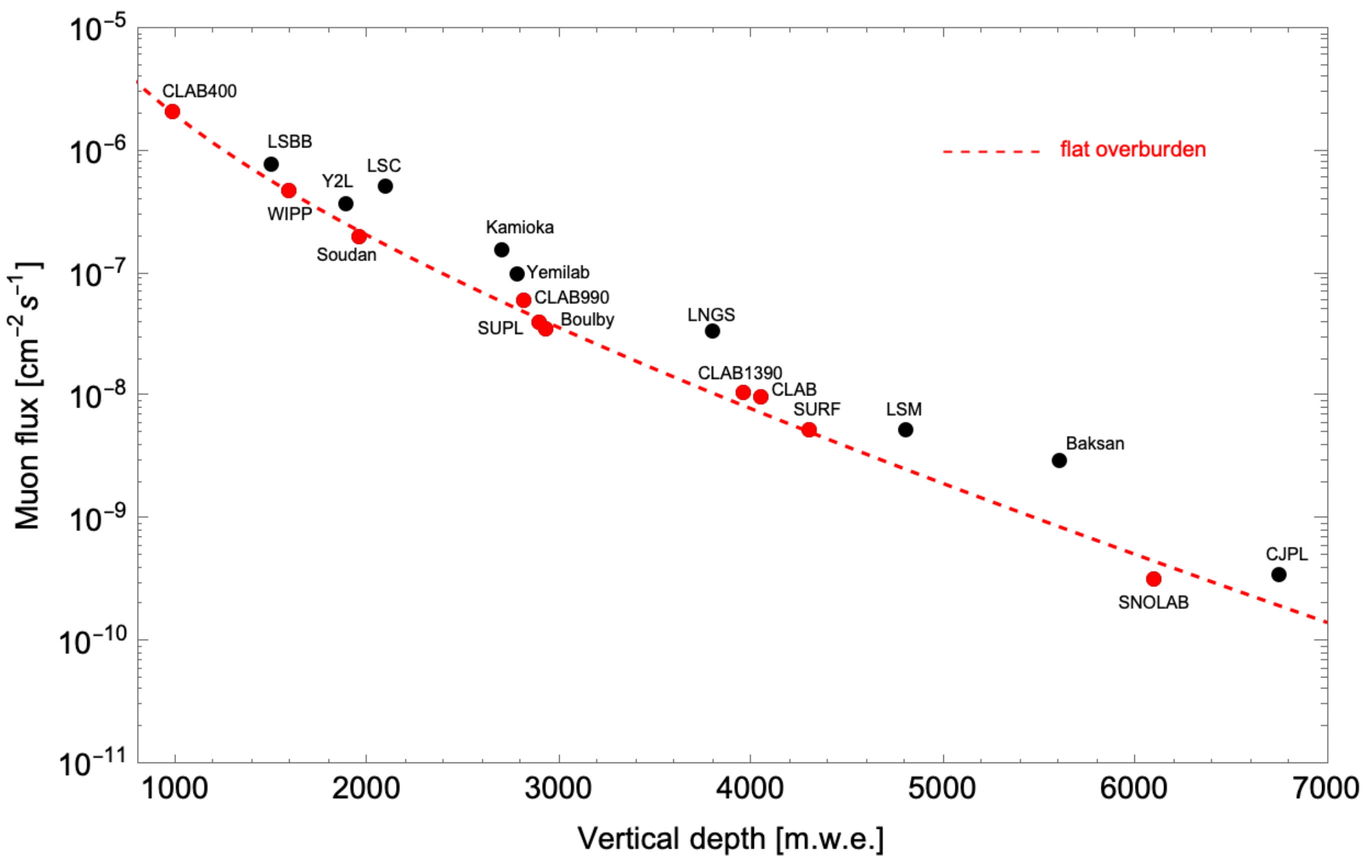
LSM Geographic position #2

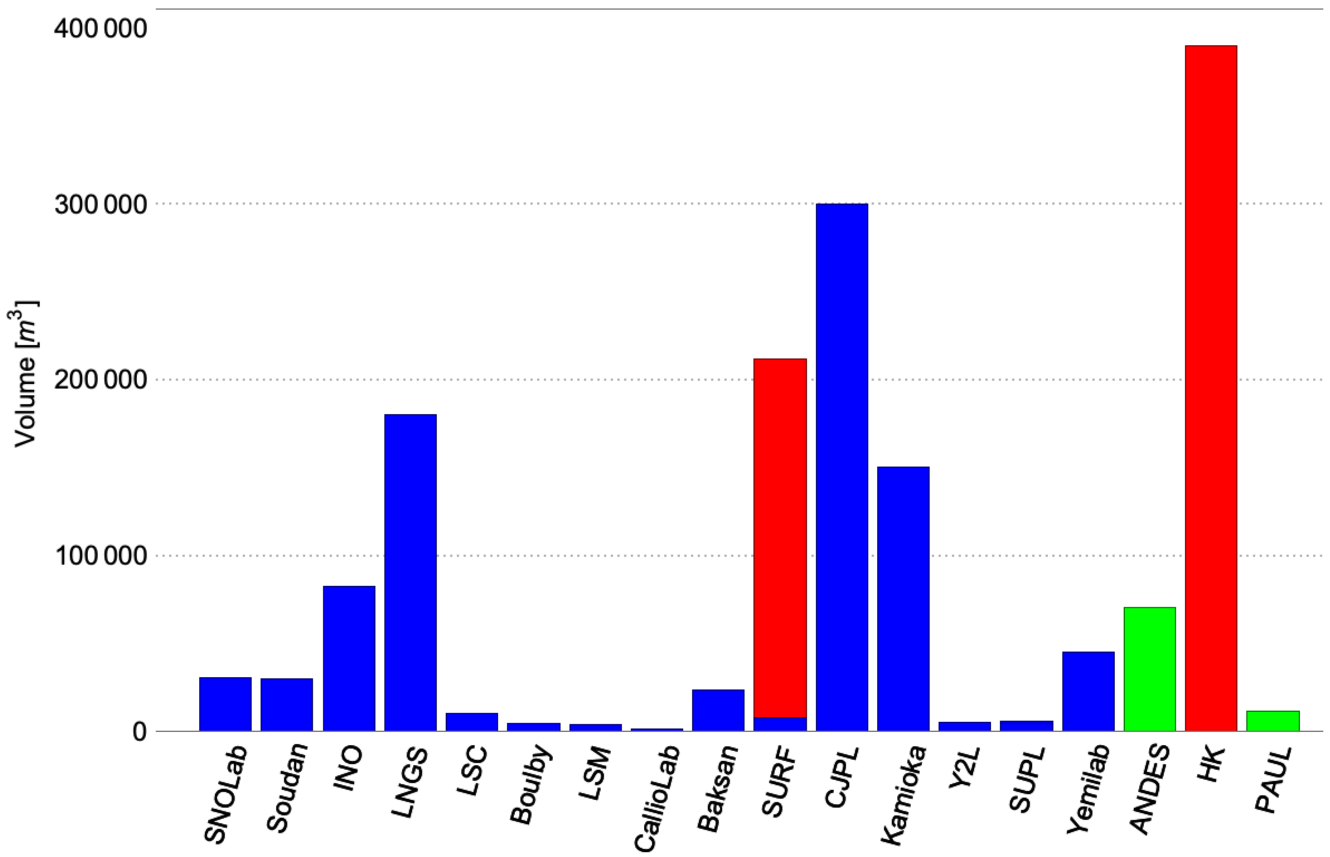
LSM a deep underground lab in Europe

- **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)







LSM History

From a particle physic experiment to a multi-science platform

1979 - 1981

Construction

1982- 1990

τ_p Experiment
Proton decay

1990- 2000

Prototypes ⟶

2000 - ….

Experiments

Fundamental physics:

- **Proton decay**
- **Neutrino: double beta decay, double EC**
- **Dark matter**
- **Nuclear structure**

Multidisciplinary activities

- **Ultra low radioactivity measurements**
  Environmental sciences, applications, expertises
- **Logical test failures in nano/micro-electronics**
- **Biology**

Facilities @ LSM

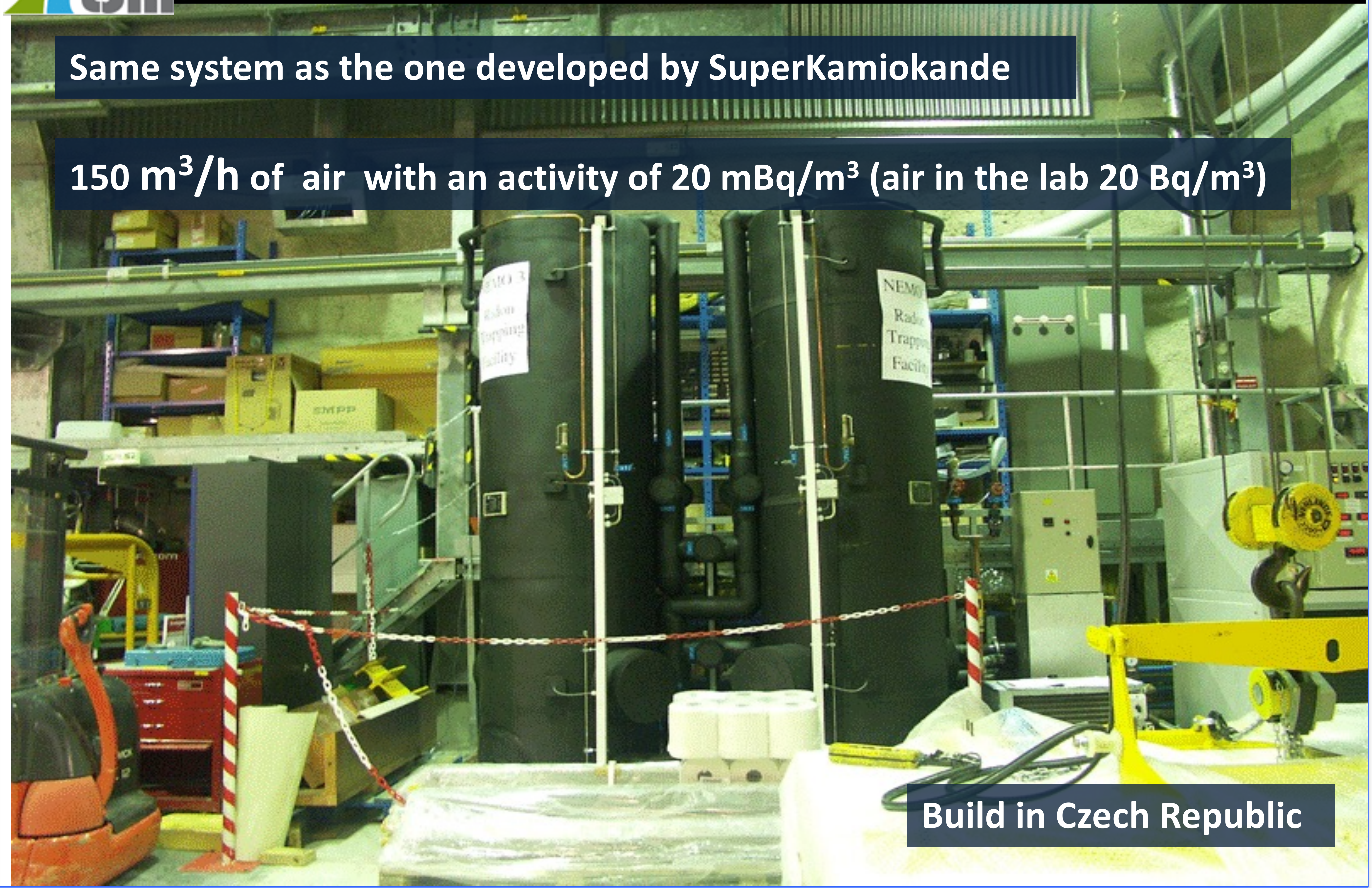
CNRS - UGA

http://www.lsm.in2p3.fr

Radon mitigation system

Same system as the one developed by SuperKamiokande

150 m^3/h of air with an activity of 20 mBq/m^3 (air in the lab 20 Bq/m^3)



Build in Czech Republic

Gamma ray spectroscopy @ LSM

22 HPGe from 7 different laboratories of CNRS , CEA, JINR DUBNA and CTU Prague are available at LSM

- Material selection for astroparticle physics,
- Environmental research (oceanography, climatology, retro-observation,….)
- Environmental survey
- Applications (wine datation, salt origin,…)
- Developments of Ge detector (ILIAS European project)

Obelix Ge @ LSM

PARTAGe project

- Combining shields in common walls

Robotisation

- Optimisation of measurement time based on the radiopurity objectives

Interdisciplinary @ LSM

ulta-low level gamma-ray spectroscopy

- Radio-isotopes are used as tracers in the environment or as chronometers for dating of glacial or sedimentary layers.
- They are used also for archaeological objects which sometimes require non-destructive measurements

Some examples:

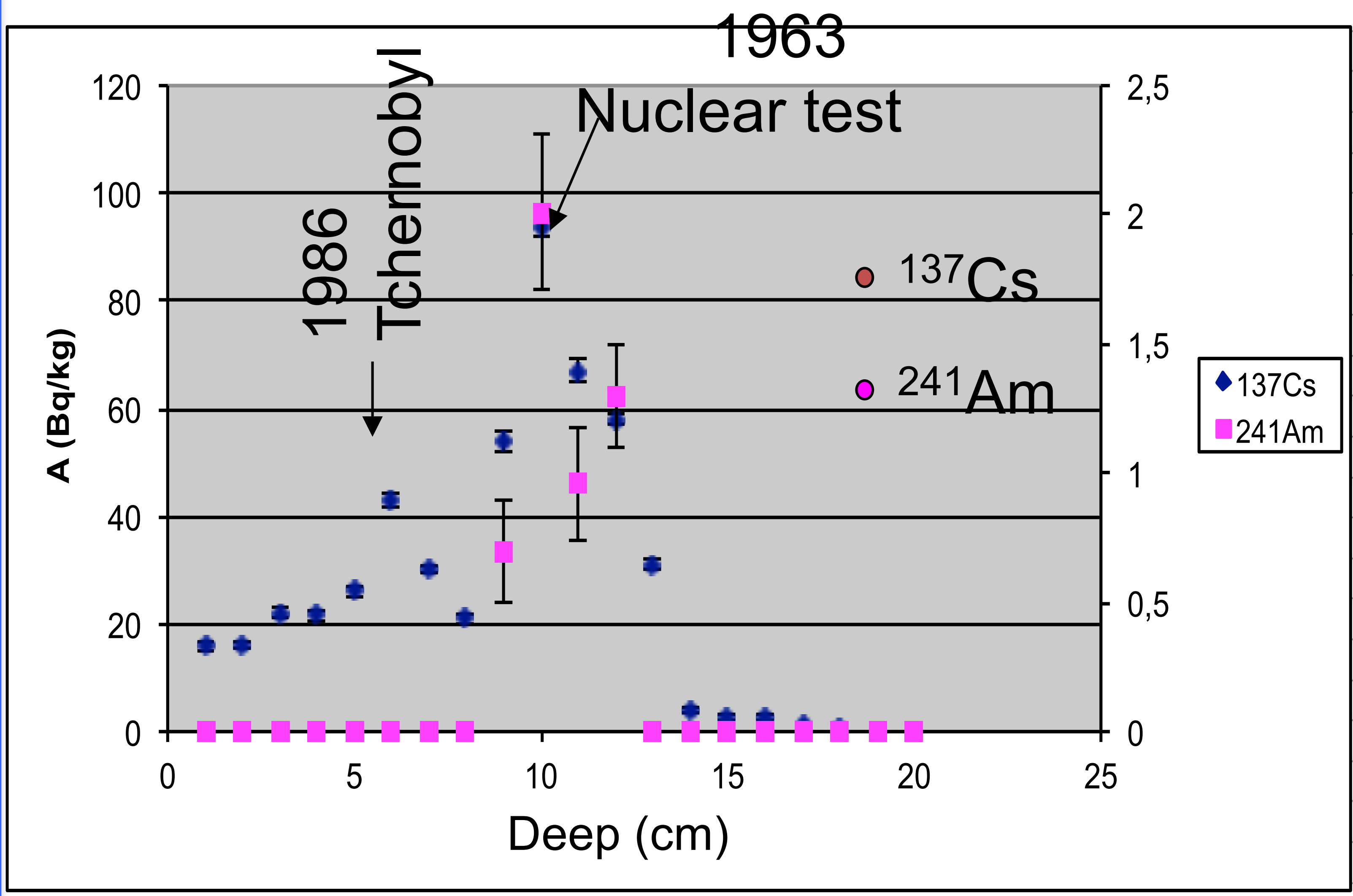
- Environmental survey
- Characterization the age of the suspended solids and pollutants associated with them in rivers
- Marine and continental geochemistry
- Characterization of water masses, their origin and age in the ocean
- Retro-observation (effects on human activities on the environment)
- Radioactivity in the atmosphere

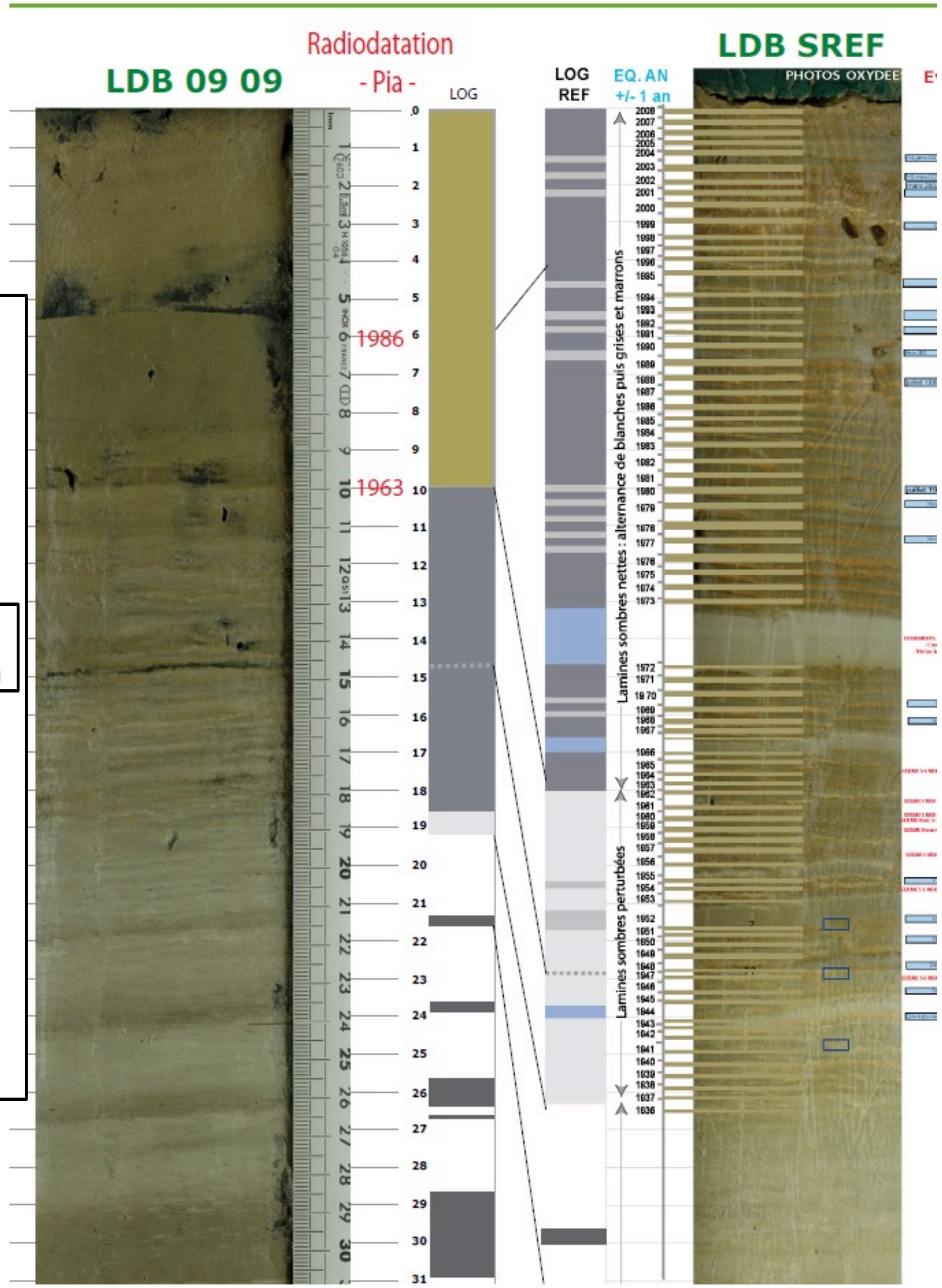
Oct 2023
Interdisciplinary workshop @ LSM

Dec 2023
Interdisciplinary strategy plan was send to in2P3

Environmental applications

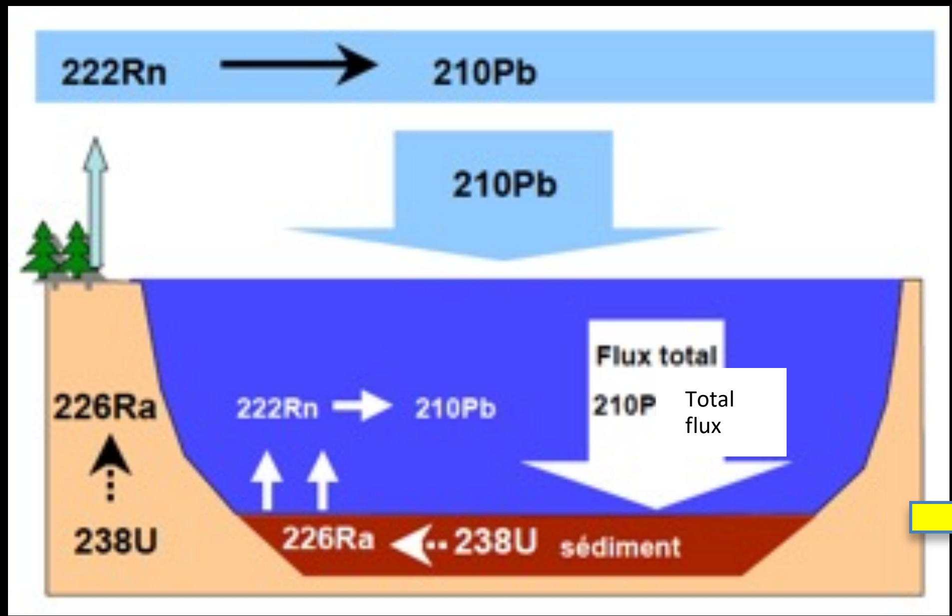
Datation of a carot from Bourget lake :



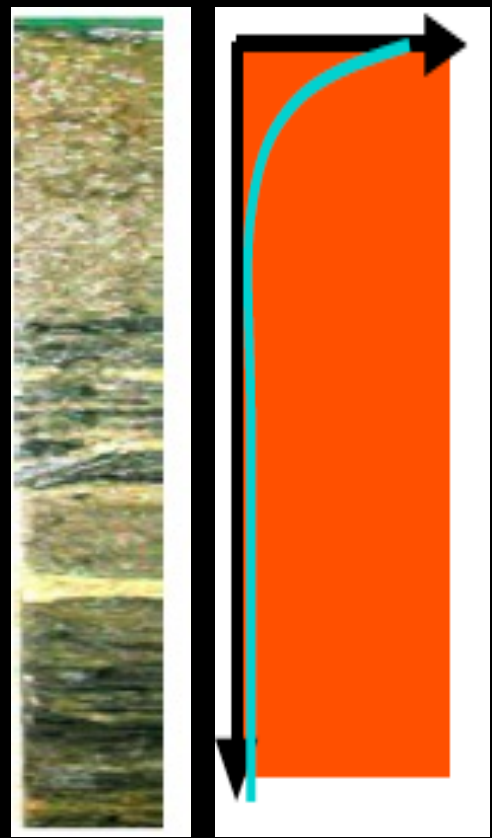


Radioactivity measurements for environmental sciences

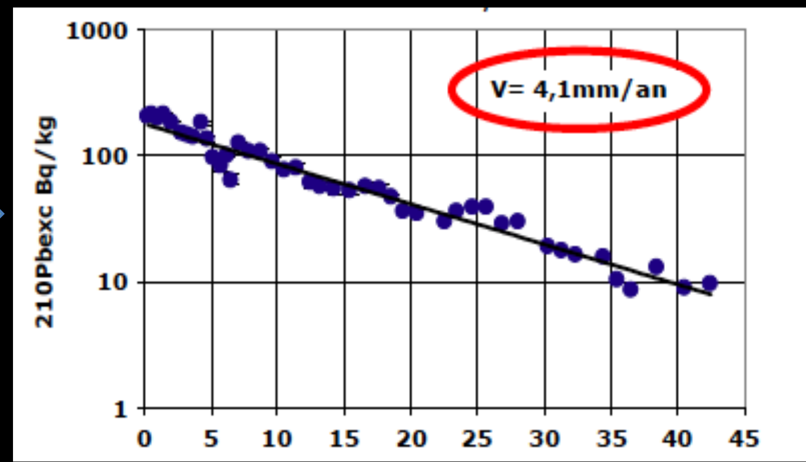
Exemple with core samples
from Bourget lake



^{210}Pb



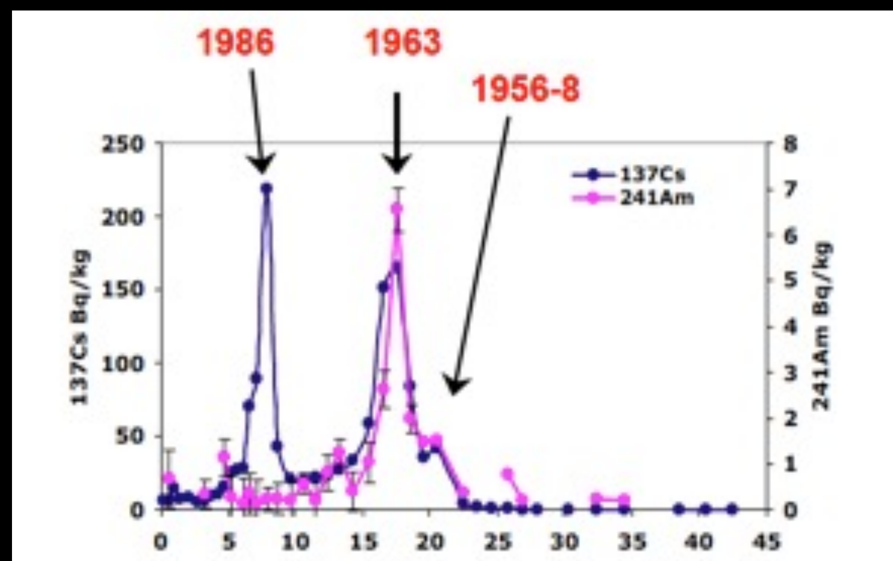
Sedimentation rate



Depth (cm)

Use of anthropic isotopes

From A. Gougiotis and J.L. Reyss LSCE)



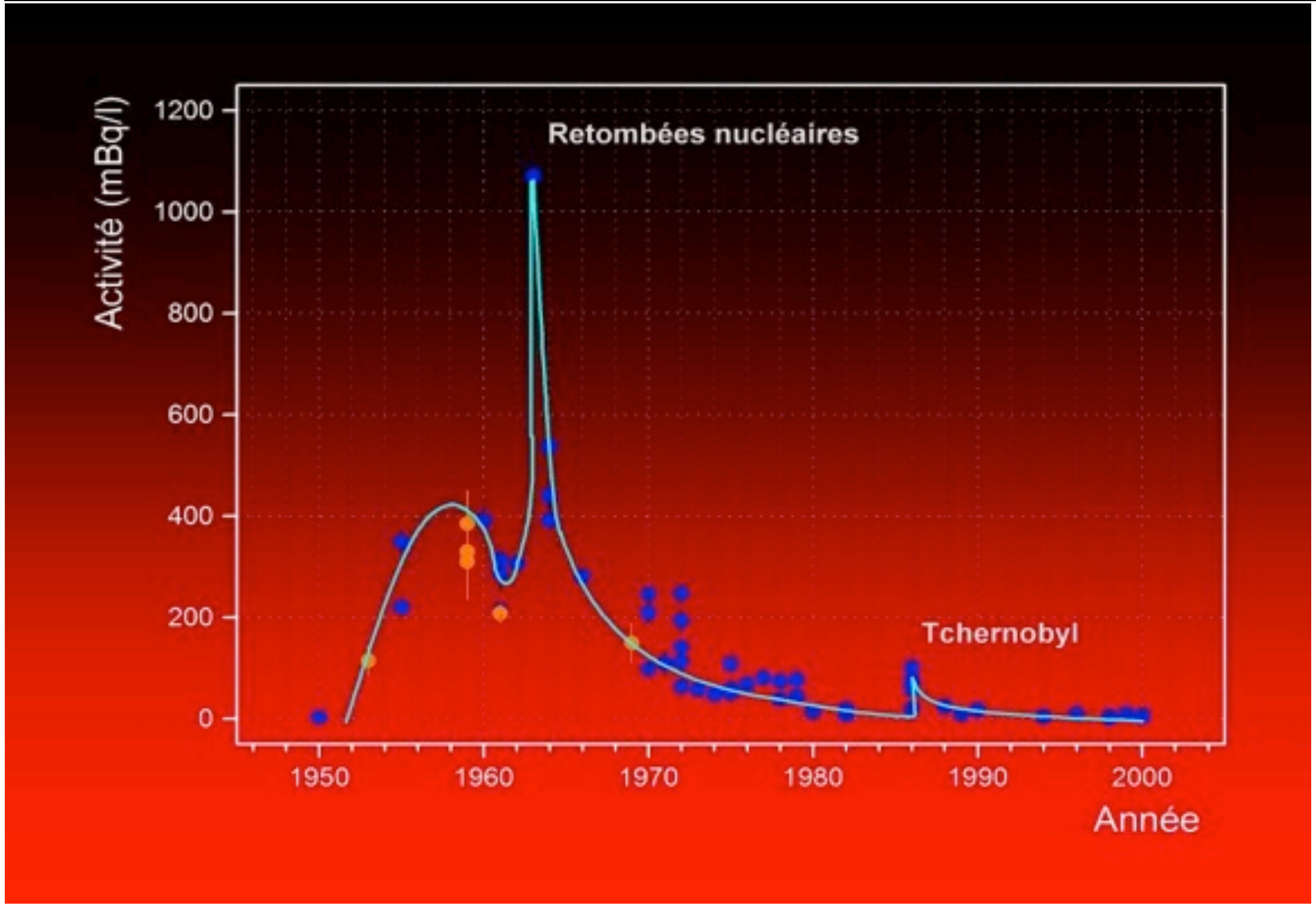
Depth (cm)

Wine dating by ^{137}Cs measurement

Bottles appeared on the market in 2000

Châteaux “Lafite” “Margaux” 1900 ?

Drug and food administration:
True or fake bottles; Wine taster: beginning of 60’s
Scientific proof ?



Developed by Ph. Hubert (Centre d ‘Etudes Nucleaires de Bordeaux-Gradignan)

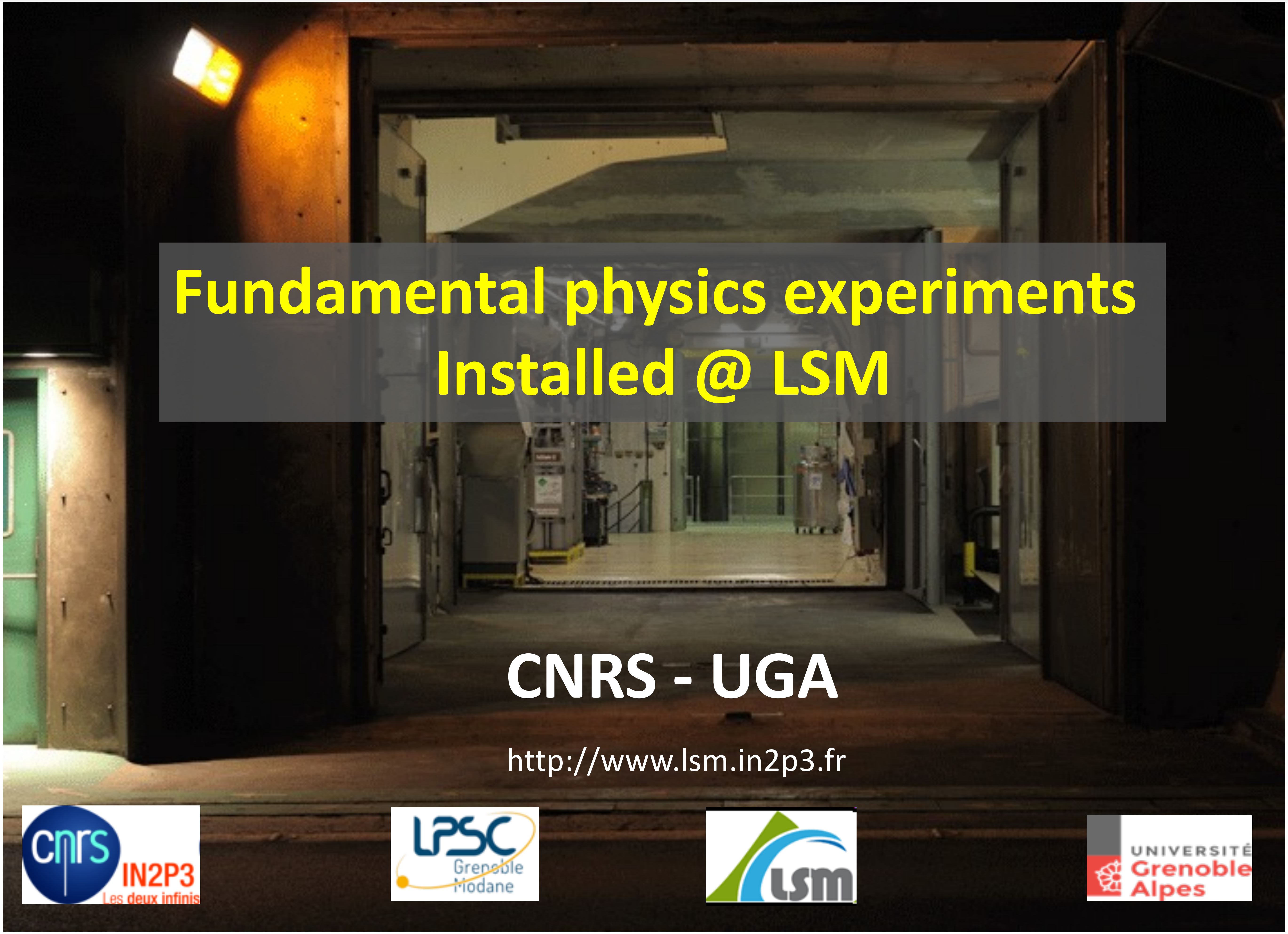
Biology

- Natural radioactivity impact to the Bacteria

More details: see
F. Piquemal talk tomorrow

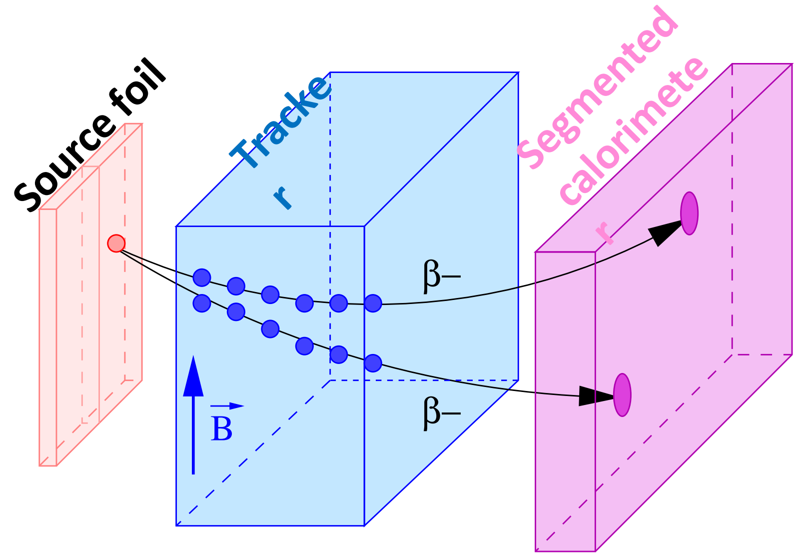
Comparison between Surface and underground result

- Stem Cell cryogenic conservation (CNRS patent)


Fundamental physics experiments
Installed @ LSM
CNRS - UGA
http://www.lsm.in2p3.fr

Neutrino physics: SuperNEMO

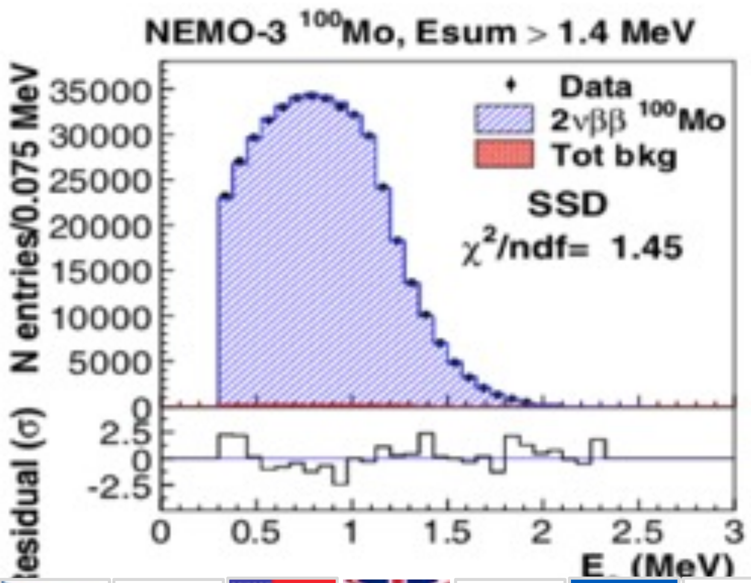
Tracking + calorimeter – ^{82}Se 7 kg



- Foils can be made of any *ββ* isotope (SuperNEMO uses ^{82}Se)
- Identification of e^-, e^+, γ and α
- Full *ββ* kinematics and topology: E_{single}, E_{sum}, x, y, z, t, $\cos\vartheta$
- Full event reconstruction can be used to disentangle different mechanisms contributing to *0νββ* (V+A, SUSY…)
- Nuclear physics: constrain g_A in *2νββ* (NEMO-3 analysis in progress)
- *e-γ* separation can probe decays to excited states

Double-Beta Decay Physics with NEMO-3:

0.5M *2νββ* ^{100}Mo events (Signal/Background ~ 80)



Recent results:

- New physics constraints **Eur.Phys.J.C 79 (2019) 440**
- Search for decay-rate time variation: **arXiv: 2011.07657**
- Decays to excited states: **Nucl.Phys.A 996 (2021) 121701**
- g_A vectorial axial coupling constant quenching constraints (in preparation).

SuperNEMO Collaboration

SuperNEMO Demonstrator:

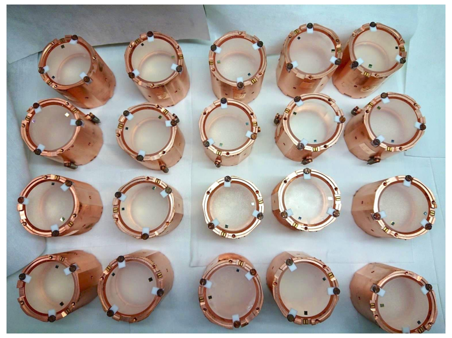
- Final commissioning in progress!
- First data taking at the end 2021

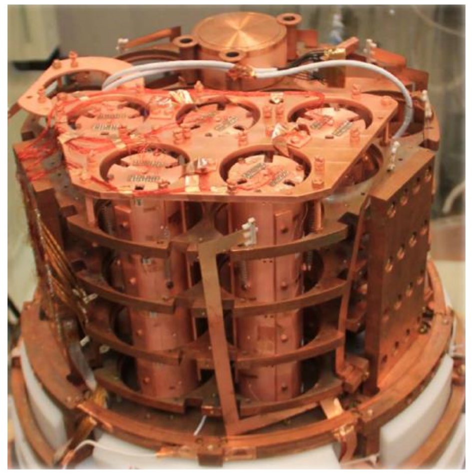
Neutrino physics: CUPID-Mo & BINGO

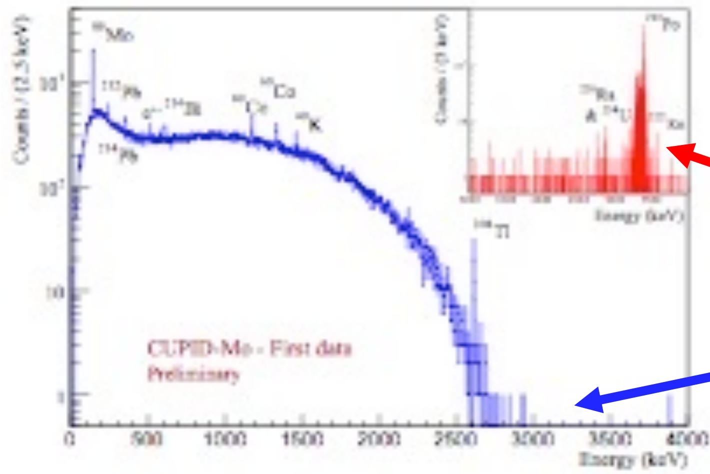
20 $Li_2{}^{100}MoO_4$ scintillating bolometers

7 countries, 15 institutions
~90 scientists

- 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:
  - $T_{1/2}$>1.8×10^{24}year
  - ⟨mββ⟩ < (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)*

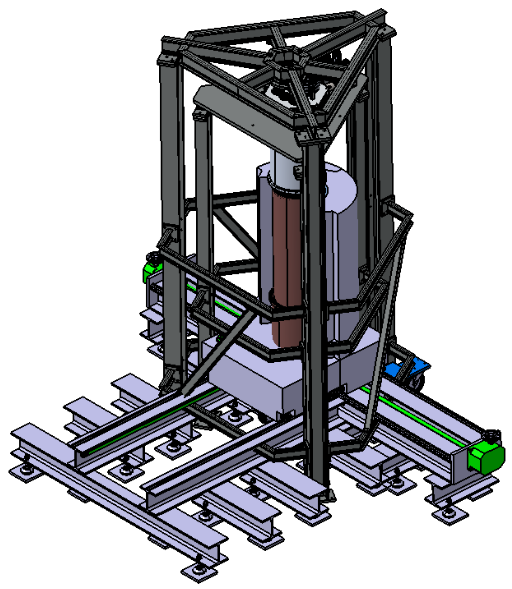


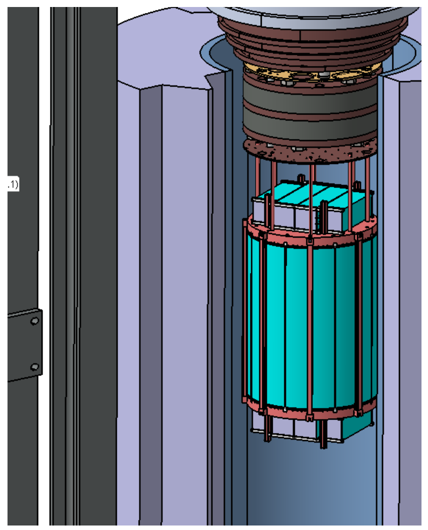




Rejected background (light detector)

Region of interest: 3034 ±10 keV





BINGO cryostat @LSM

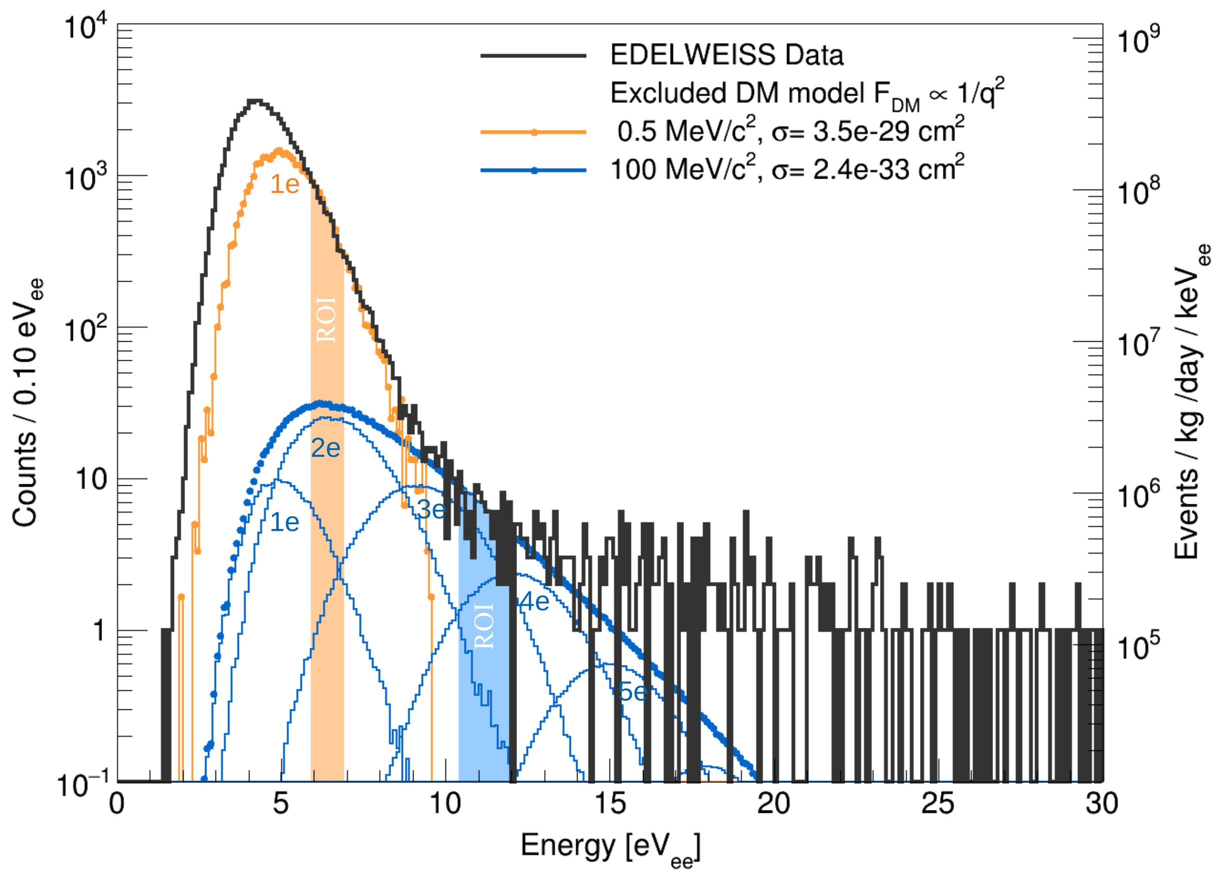
^{100}Mo + ^{130}Te scintillating targets

BGO internal shelding

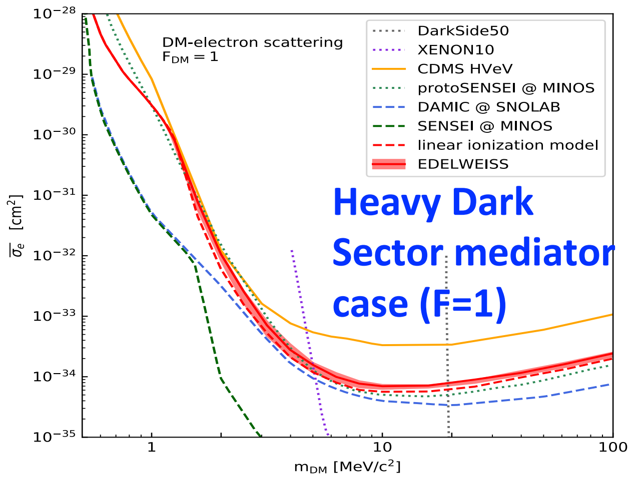
Dark matter search: EDELWEISS

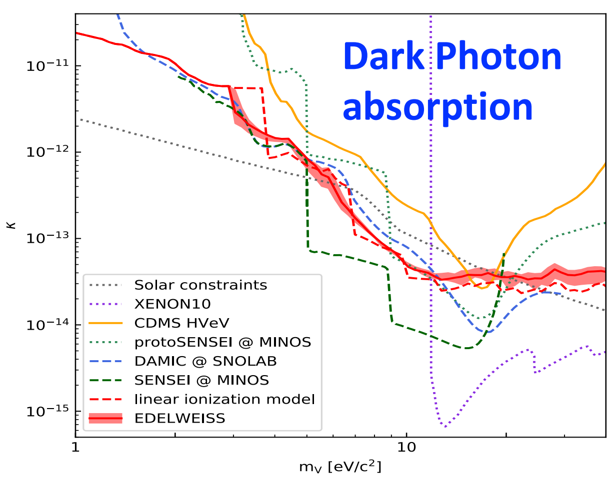
largest mass of cryogenic Ge (30 kg) : Heat + Ionization
EDELWEISS SubGeV Dark Matter Searches

- 2019-2020 breakthrough: **successful run at LSM of 33 g Ge detector** biased at 78V, **with single-electron sensitivity**
- First Ge cryogenic detector with **sub-electron resolution (σ = 0.53 electron-hole pair)**
- First Ge detector sensitive to **sub-MeV DM particles interacting with electrons** and 1-eV Dark Photons



[PRL 125, 141401 (2020)]





Ongoing development of EDELWEISS-SubGeV kg-scale array, with evt-by-evt nuclear recoil ID down to 50 eV (in synergy with Ricochet R&D) in addition to <1 eV_{ee} resolution for electron recoils

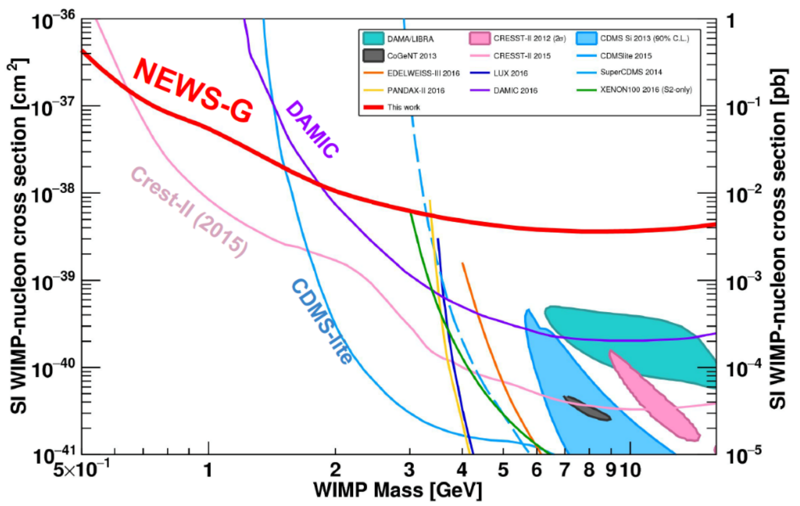
Light WIMP: SEDINE => NEWS-G

Gaseous detector: Spherical Proportional Counter

NEWS-G_LSM (SEDINE) => NEWS-G_SNO

^{226}Ra et ^{228}Th

< à qq 0.1 à qq 10 mBq/kg



Q. Arnaud et al, Phys. Rev. D 99 (2019) 102003

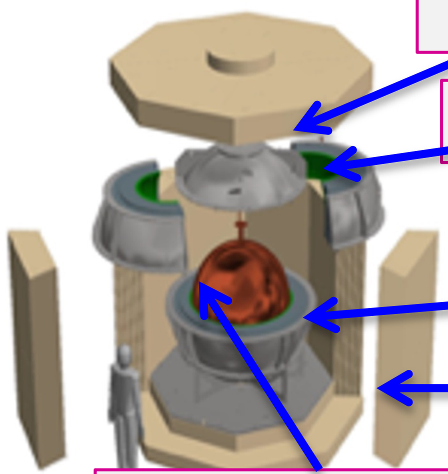
Spinning

Electropolishing/ Electroplating

Sulfuric acid solution in

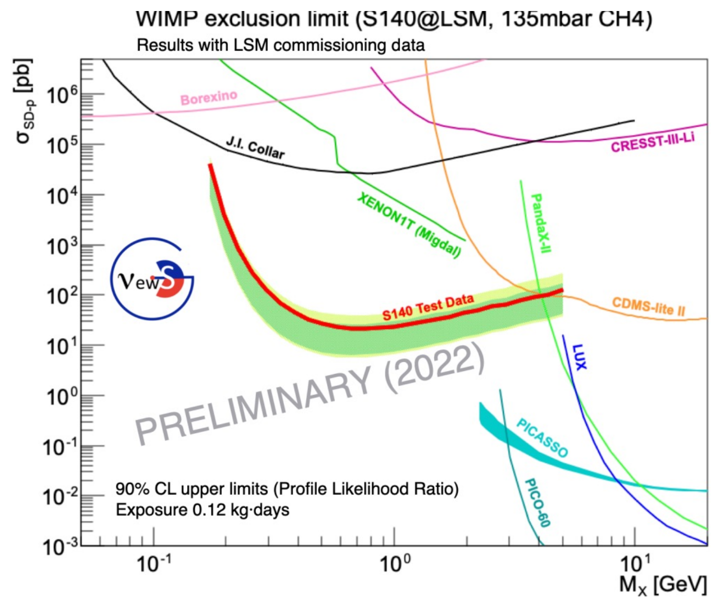
Anode & Cathode

A. Dastgheibi-Fard et al, [NIMA_162390] in Nuclear Inst



- 3 cm Archeological lead
- 23 cm Low activity lead
- Stainless steal skin
- 40 cm HDPE

- φ=140 cm Cu sphere / Thickness=12mm copper » 36 ± 13 mBq/kg of ^{210} / »7 - 25 µBq/kg of ^{232}Th / » 1 - 5 µBq/kg ^{238}U



Expected to be sensitive to WIMP Masses ≈ 100 MeV using H-rich gas and an energy threshold < 50 eV_{nr}

NEWS-G

+ ECuME DarkSPHERE

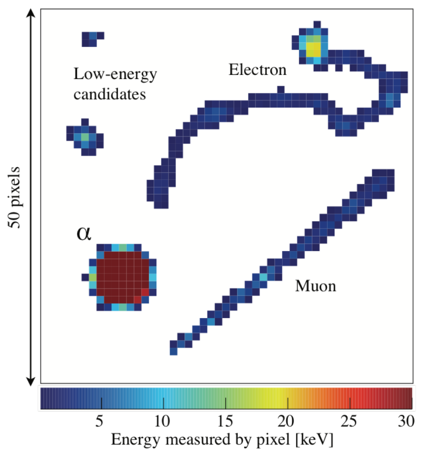
Light WIMP: DAMIC-M LBC

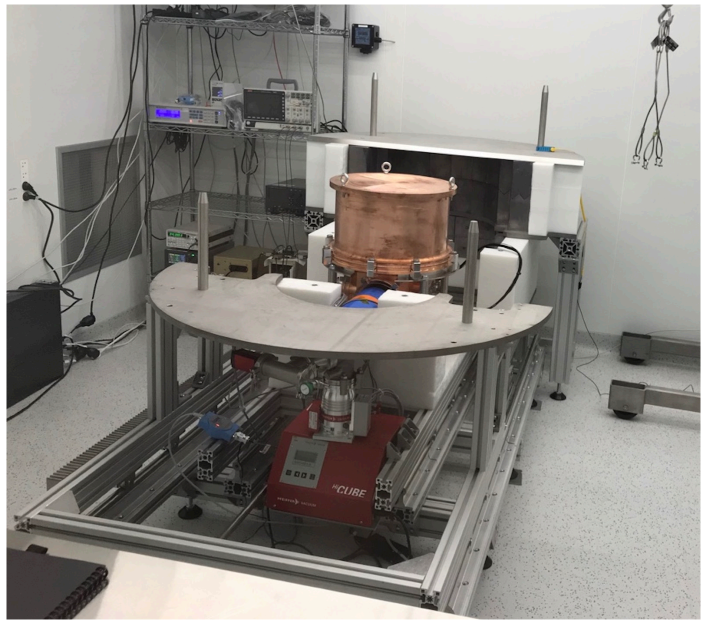
CCD detector

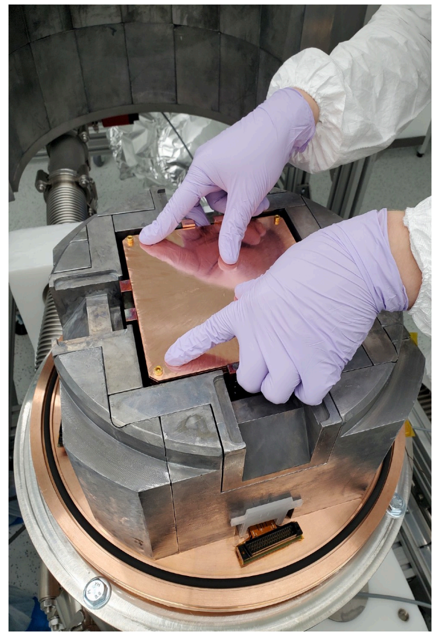
- **LBC :** Low-Background Chamber with 2 CCDs
- Target mass 18 g
- Polyethylene and lead shield (+ roman lead)
- Operated in clean room
- 85.2 g.day exposure acquired in 2022
- 0.2 e^- resolution (N_{skip}=650)
- **Best limits on e^--DM interactions via light mediator between 1.6 MeV/c² and 1 GeV/c²;**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

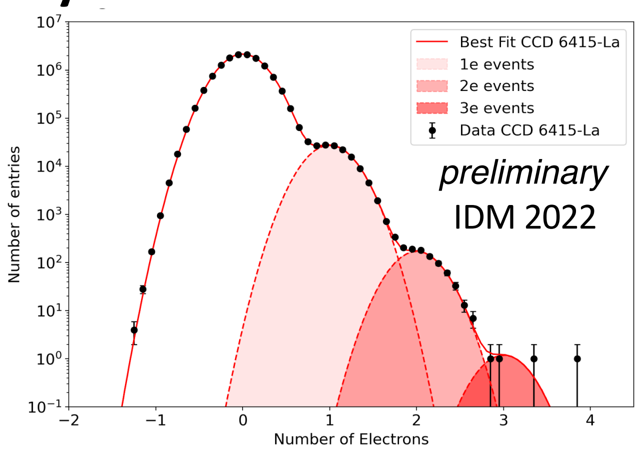
PRL 130 (2023) 171003

exquisite spatial resolution

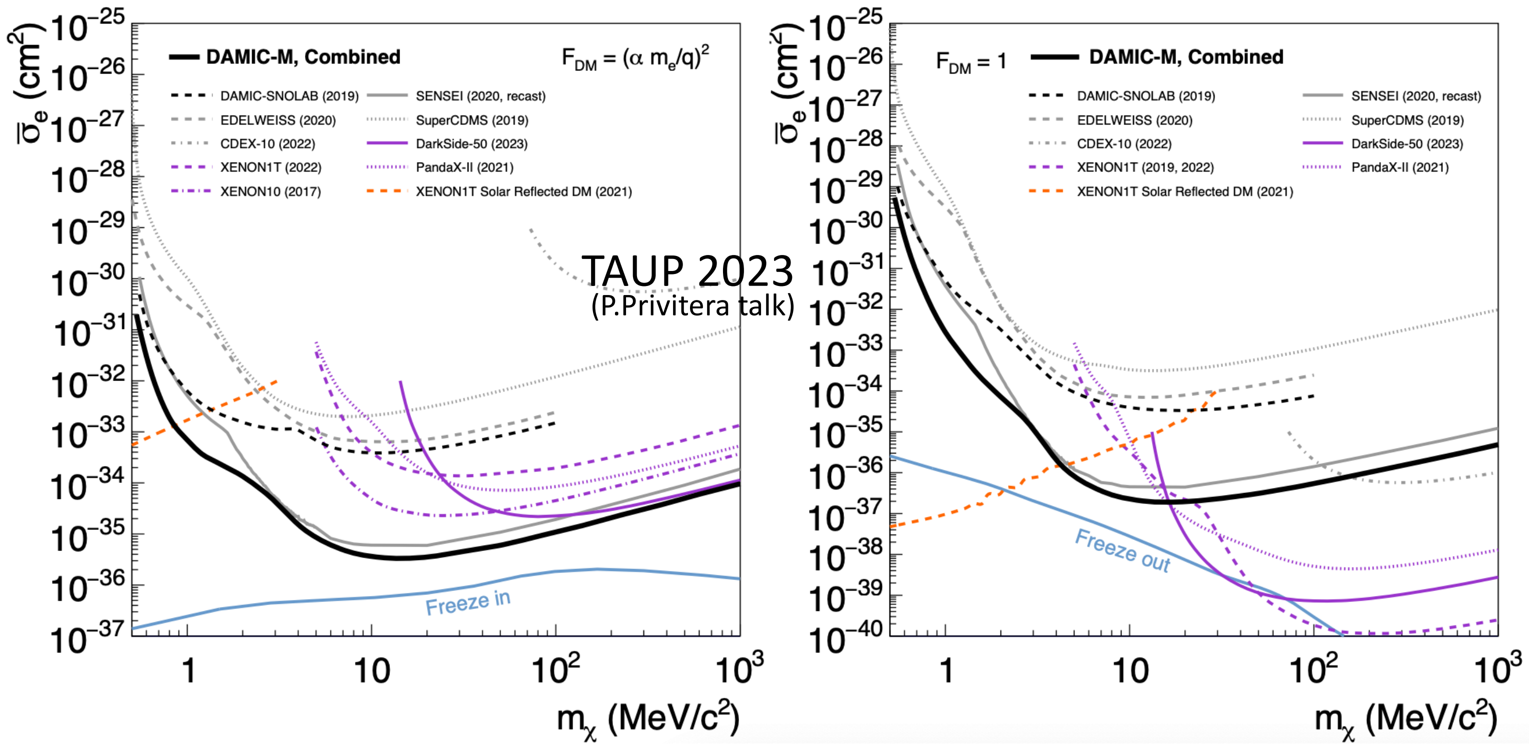








DAMIC-M constraints on DM-e scattering

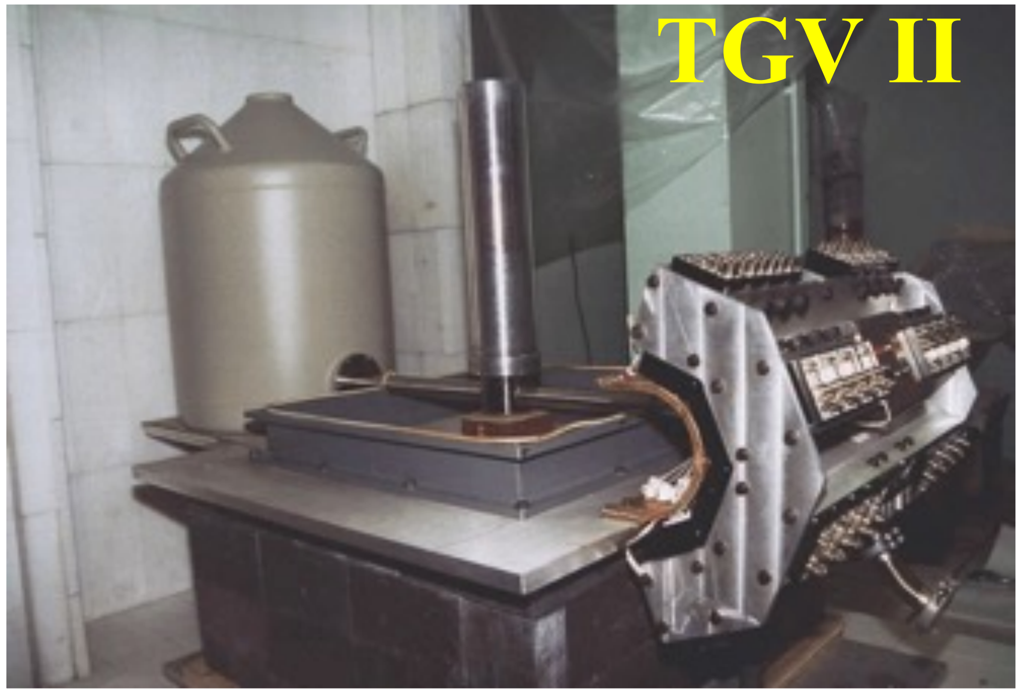


Other experiments

Neutrino physics

Double EC search (^{106}Cd)

TGV-II (Ge with sheets of Double EC candidates)



Nuclear physics

Super Heavy Element In nature

SHIN (osmium ore surrounded by 3He neutron detectors)

SHIN

MIMAC (prototype) Dark matter TPC for DM directional detection

Summary and outlook

Ultra-low gamma-ray spectrometry has a lot of potential for environmental Research and survey

Improvements for material selection for particle physics or astroparticle allows to improve also the sensitivity for the other science and to open new methods

Interest for science like micro/nano microelectronics

Discussion in progress with biologists and geophysicists for the extension

There is not so many labs where you can perform research on particle physics, oceanography, retro-observation, logical failure from natural radioactivity, wine datation,….

Deep Underground Infrastructures are rather new (~40 years), certainly a large potential to welcome other **Labs (PAUL), and science** sciences

In LSM,
More projects in the future : biology, EF Copper production, Quantum computing ...

DANKIE

(Africaans)

谢谢

Gracias

سپاس

Sépâsse

(Persan)

謝謝

Merci

Danke

Thanks

Grazie

“Mési"

(Créol)

धन्यवाद

شكرا

Shokran

(Arab)

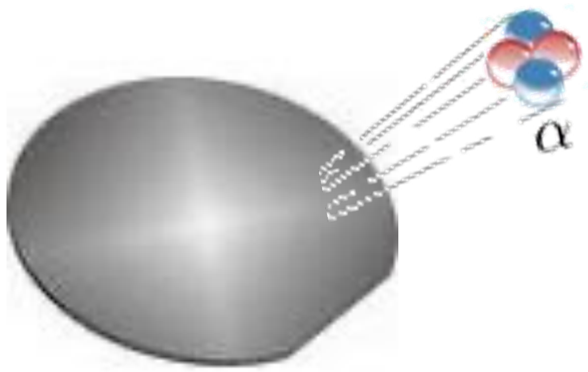

Enjoy your stay

Soft-Error Rate (SER) Characterization of SRAM circuits induced by alpha-particle emitter contamination

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

Silicon wafers, ceramic packages and contact bumps are contaminated with Uranium and Thorium elements at ppb concentration levels

0.5 ppb of ^{238}U in Silicon
= 425 Bq/m^3
= 0.18 Bq/kg



0.5 ppb of ^{238}U in Silicon
= 2.28×10^{-3} α/cm^2/h

- ***Real-time experiments*** **:** ***long-term (several months) exposure of a large amount (Gbits) of circuits to the natural radiation environment***
- ***Underground: to remove the atmospheric neutron contribution (observed soft-errors are expected to be due to alpha particles)***