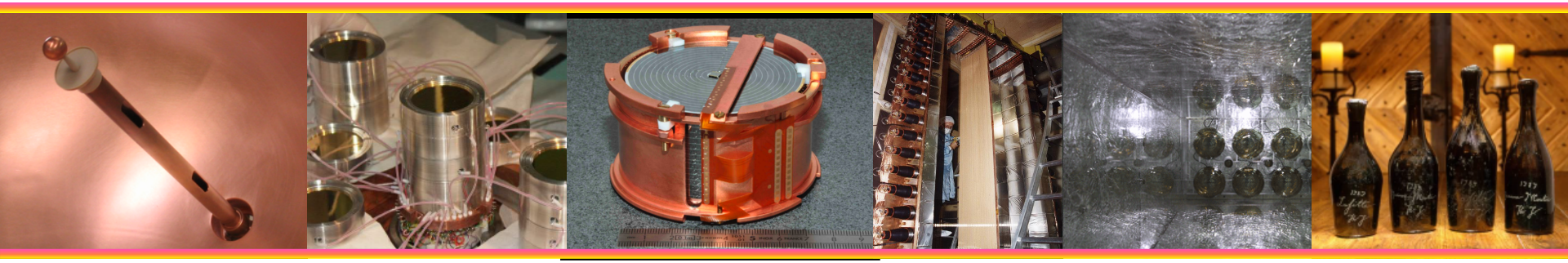
Activities at Modane Underground Laboratory

Fabrice Piquemal

Modane Underground Laboratory (CNRS)

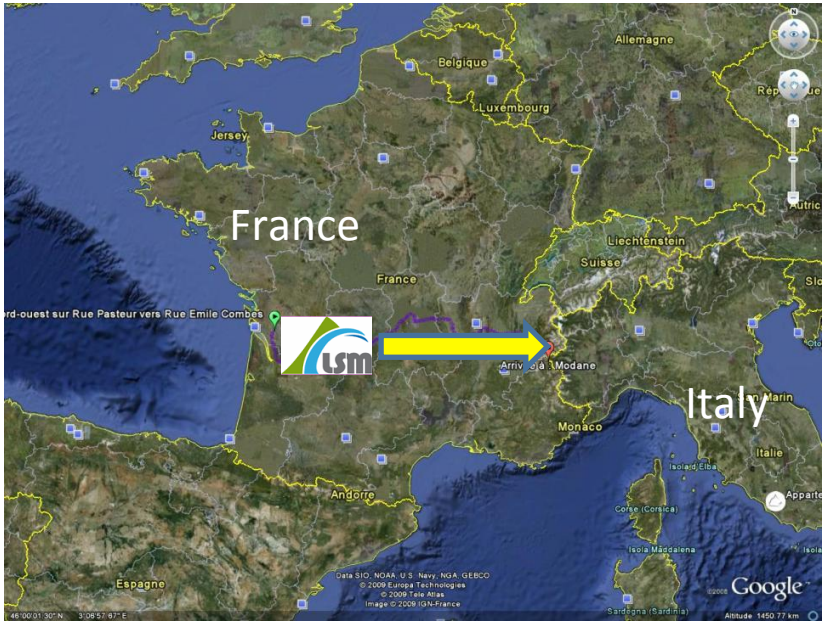


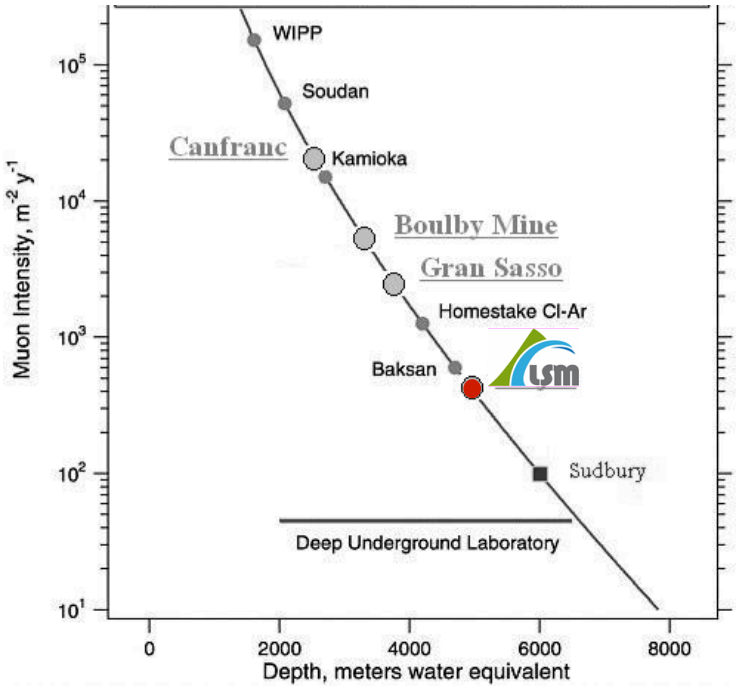
Taup 2013, September, 2013, Asilomar CA

Plan

- Presentation of LSM
- Experiments running at LSM
  - Particle physics
  - Nuclear physics
  - Environmental researches and surveys
  - Micro/nano-electronics
  - Biology
- LSM extension project

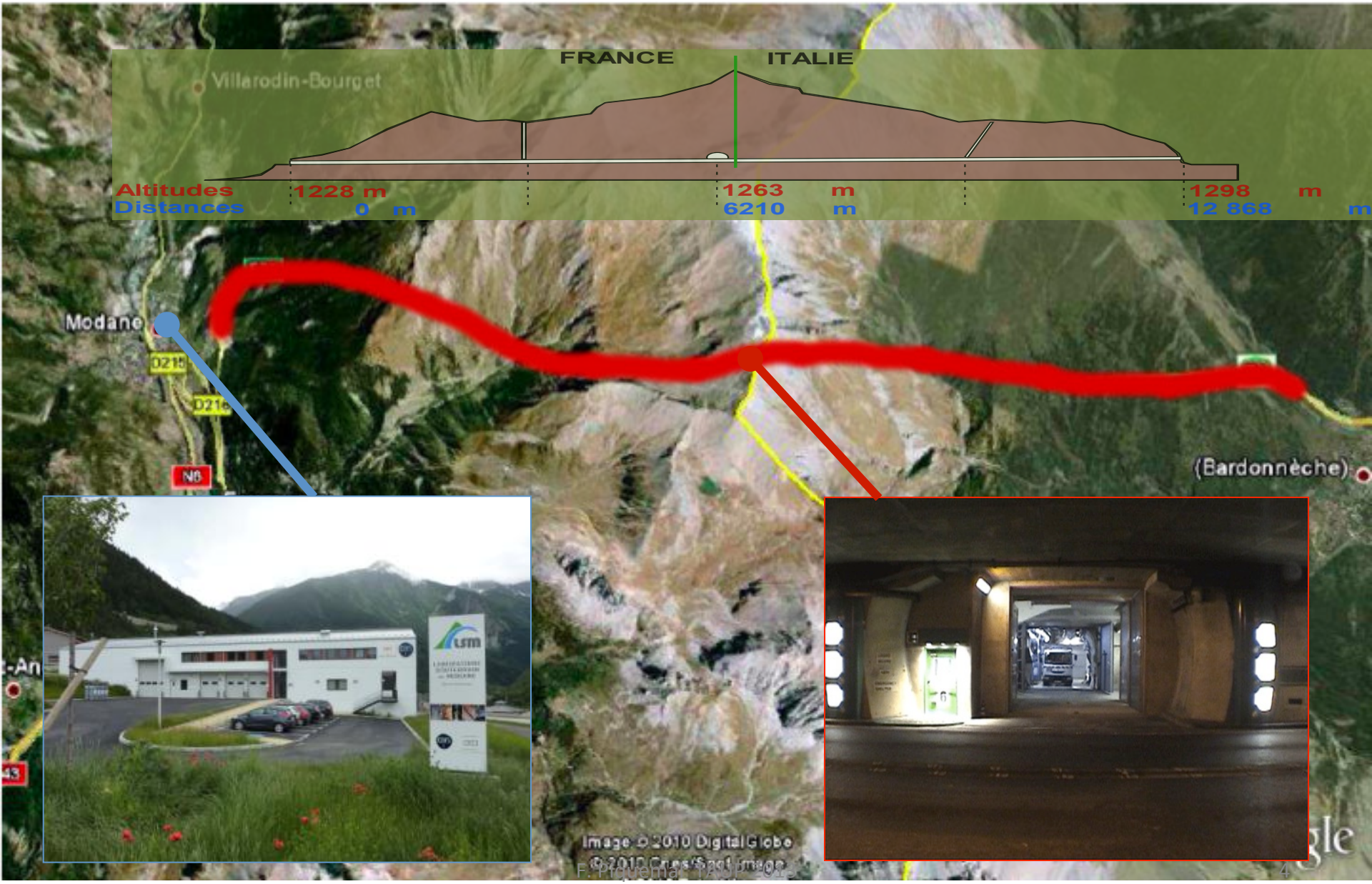
Laboratoire Souterrain de Modane





Operated by CNRS and CEA

Laboratoire Souterrain de Modane



Surface building

Offices, workshop, outreach space and guest rooms

Permanent exhibition for general public

3 000 visitors/year

LSM history

From a particle physics experiment to a multi-science plateform

1979 - 1981 | **1982- 1990** | **1990- 2000** | **2000 - ….**

Construction | **τ_p Experiment** | **Prototypes** → **Experiments**

Fundamental physics:

- **Proton decay**
- **Neutrino**
- **Dark matter**
- **Nuclear structure**

Multidisciplinary activities

- **Ultra low radioactivity measurements**
  - Material selection
  - Environmental researches and surveys
  - Applications
- **nano/micro-électronics**
- **Biology**

Laboratoire Souterrain de Modane

Depth: 4800 m.w.e.

Surface :: 400 m^2

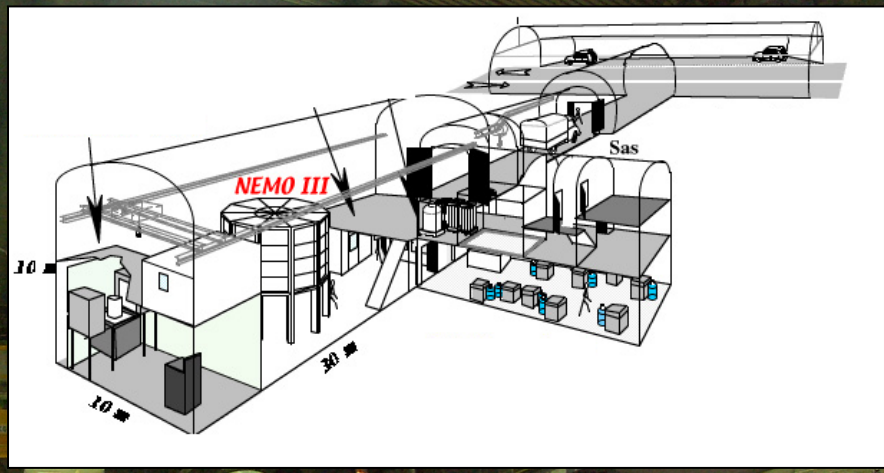
Volume : 3500 m^3

Muon flux :: 4 $\mu.m^{-2}.d^{-1}$

Neutrons:
Fast flux: 4 10^{-6} $n.cm^{-2}.s^{-1}$
Thermal flux: 1.6 10^{-6} $n.cm^{-2}.s^{-1}$

Radon: 15 Bq/m^3

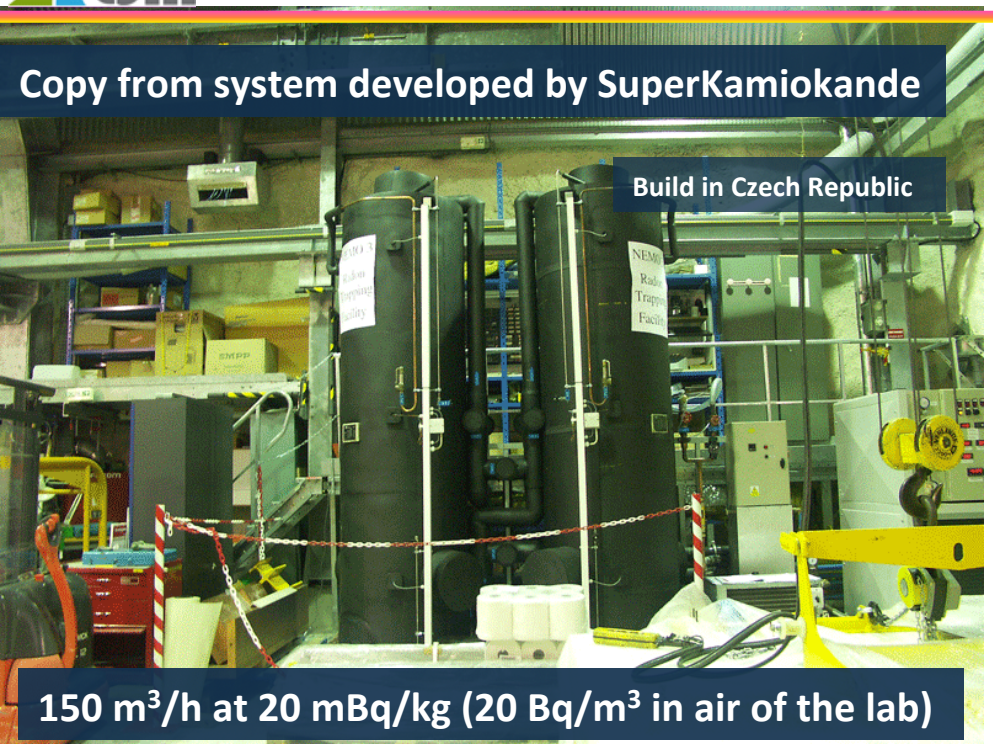
Access : direct by roadway



Budget (full cost): 1 M€/yr
Staff: 3 Physicists
3 Engineers
7 Technicians
Users: > 150

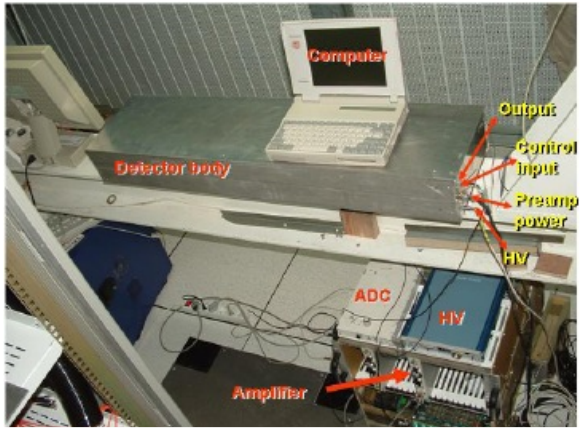
International associated laboratory agreement with JINR Dubna (Russia) and CTU Prague (Czech Republic)

Radon free air factory



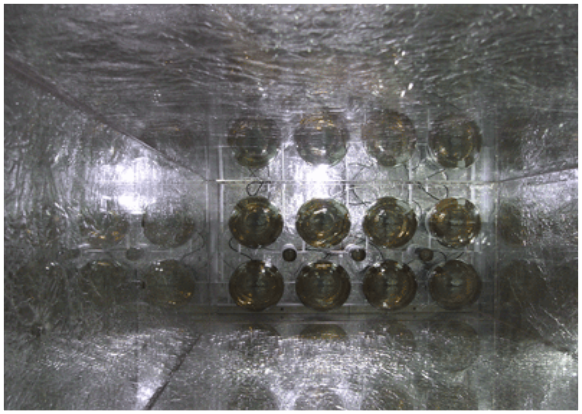
Radon detectors – ~1 mBq/kg
Saga University (Japan)
and Dubna (Russia))

Neutron detectors



^{3}He counters (JINR Dubna)

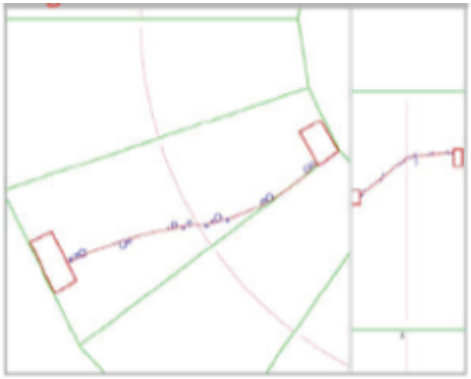
Sphere TPC (CEA)

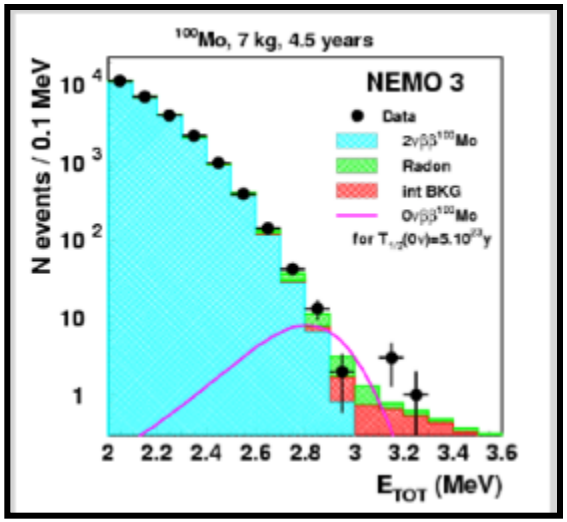


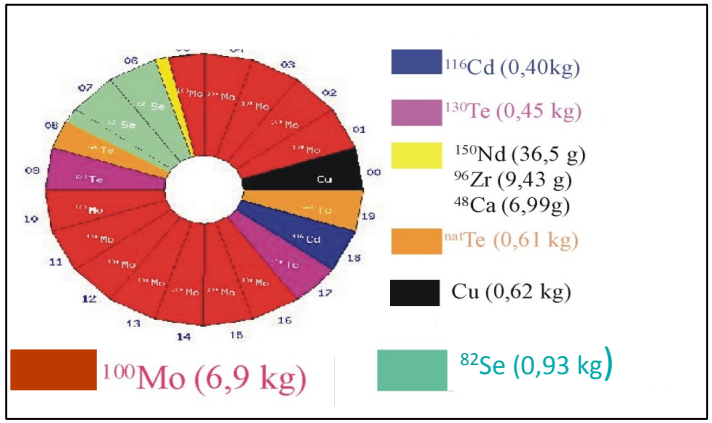
Gd loaded liquid scintillator (KIT)

NEMO 3

Double beta decay : Tracking + calorimeter - ^{100}Mo 7 kg







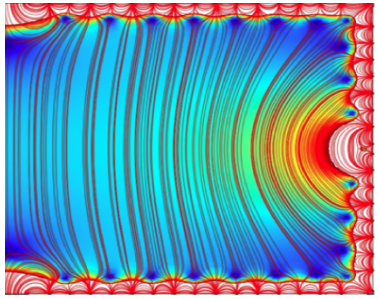
M. Bongrand talk

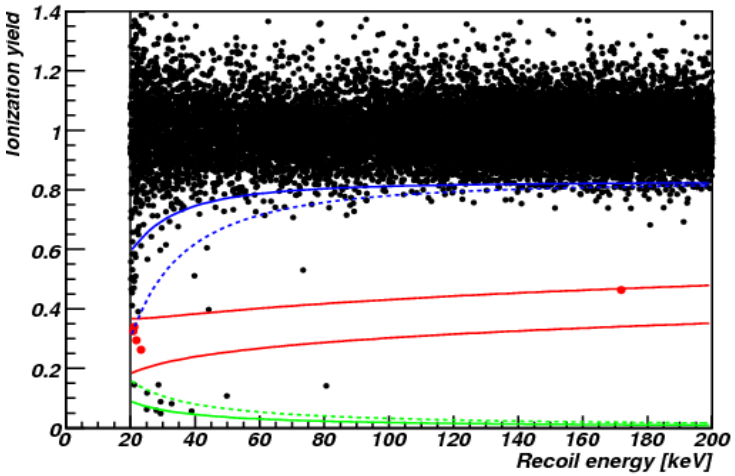
[2.8 – 3.2] MeV 18 observed events, 16.4 ± 1.3 expected

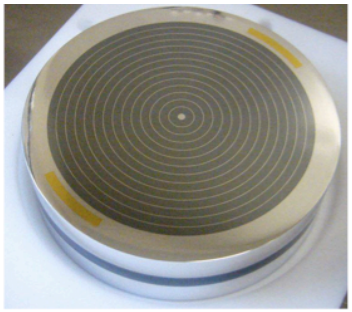
^{100}Mo $T_{1/2}$ (ββ0ν) > 1.0 10^{24} y (90% C.L.)

$<m_\nu>$ < 0.31– 0.79 eV

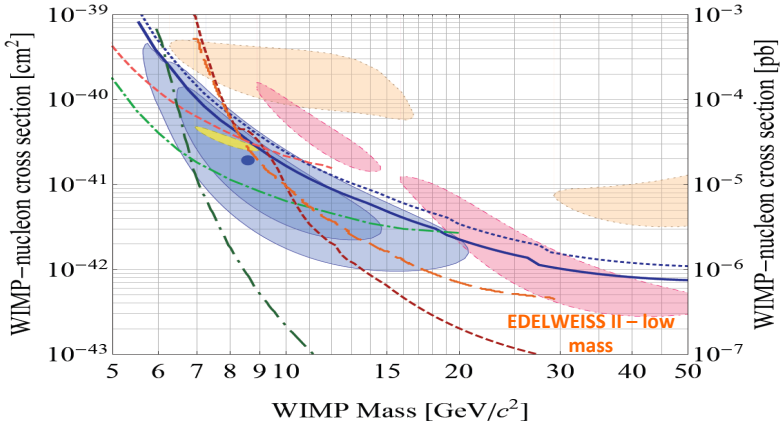
Bolometric technique: Heat + Ionization Ge crystals - 40 kg





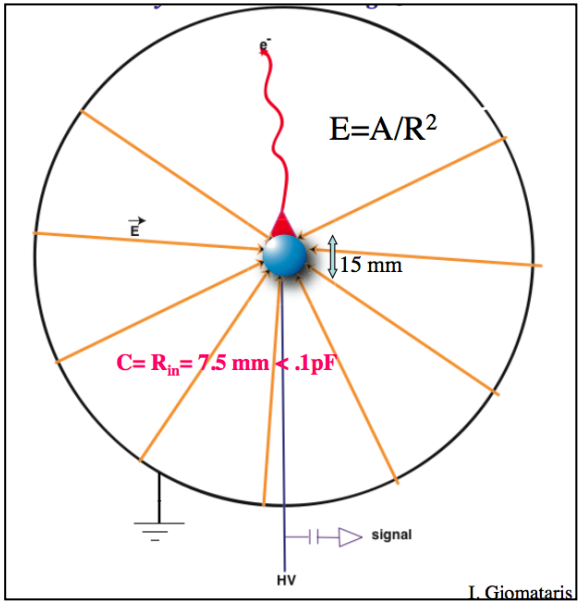


K. Eittel talk

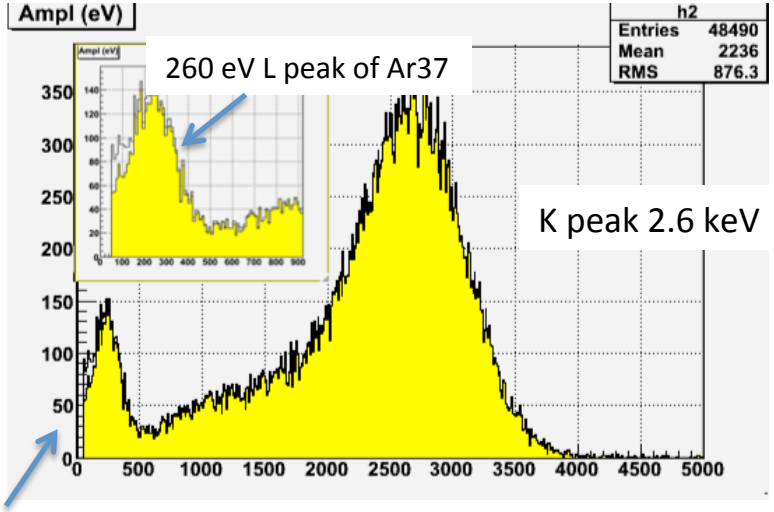


Spherical proportionnal counter: SEDINE

G. Gerbier talk



- Sphere cavity + spherical sensor + HT
- => Low threshold (low C), does not depend on size
- Fiducial volume selection by pulse risetime
- Flexible (P, gaz)
- Works in sealed mode
- Large volume => 10's kg possible
- 2 LEP cavity 130 cm Ø tested
- Digitisation at 2 MHz + soft trigger
- 1 low activity 60 cm Ø in operation @ LSM



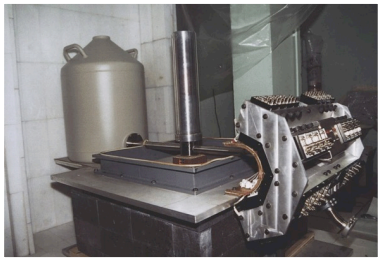
Threshold 50 eV

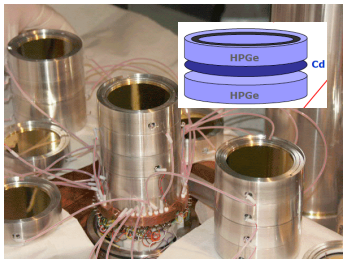
Experiments @ LSM

Neutrino physics

Double EC search (^{106}Cd)

TGV-II (Ge detectors)





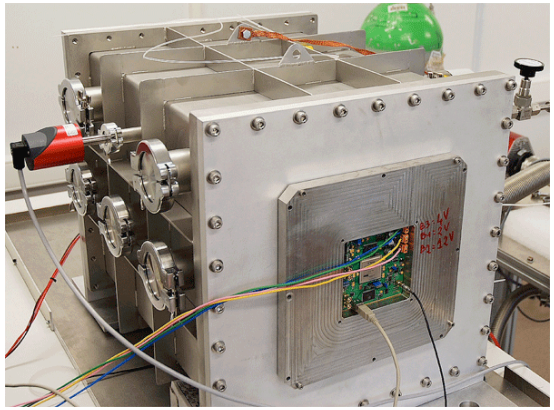
$T_{1/2}$(^{106}Cd 2νEC/EC (g.s.)) > 3.6 ×10^{20} years

Dark matter

MIMAC prototype tests

low pressure TPC

for DM directional detection



Nuclear physics

Super Heavy Element In nature

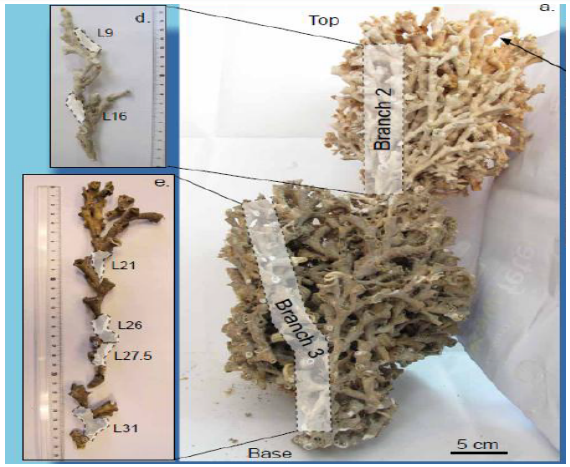
SHIN (osmium ore surrounded by 3He neutron detectors)

Ultra Low Background Gamma-Ray Spectroscopy

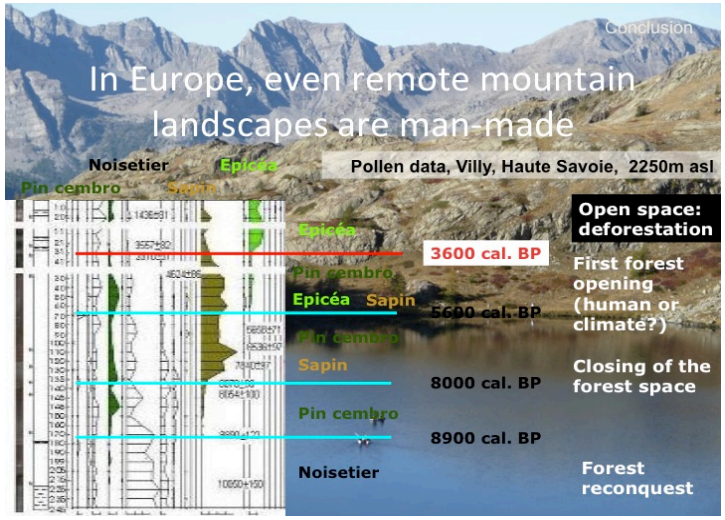
16 HPGe (CNRS , CEA, JINR Dubna, CTU Prague, NRPI Prague, LSM)

- Material selection for astroparticle physics,
- Environnemental researches (oceanography, climat, retro-observation,….)
- Environmental surveys
- Applications (wine dating, salt origin,…)
- Developements of Ge detector (ILIAS)

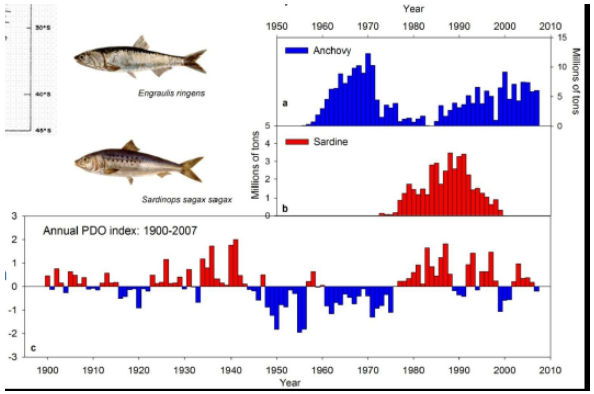
Examples of gamma-ray spectroscopy studies



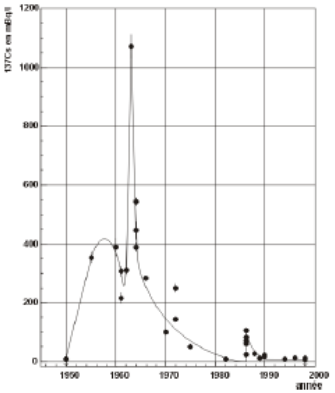
Deep see Coral use as archives to study seasonnal, annual, decadal paleoclimate changes ^{210}Pb, ^{226}Ra, ^{230}Th, ^{14}C



Alpin lake sediment measurements to study the effects of human activity on landscape

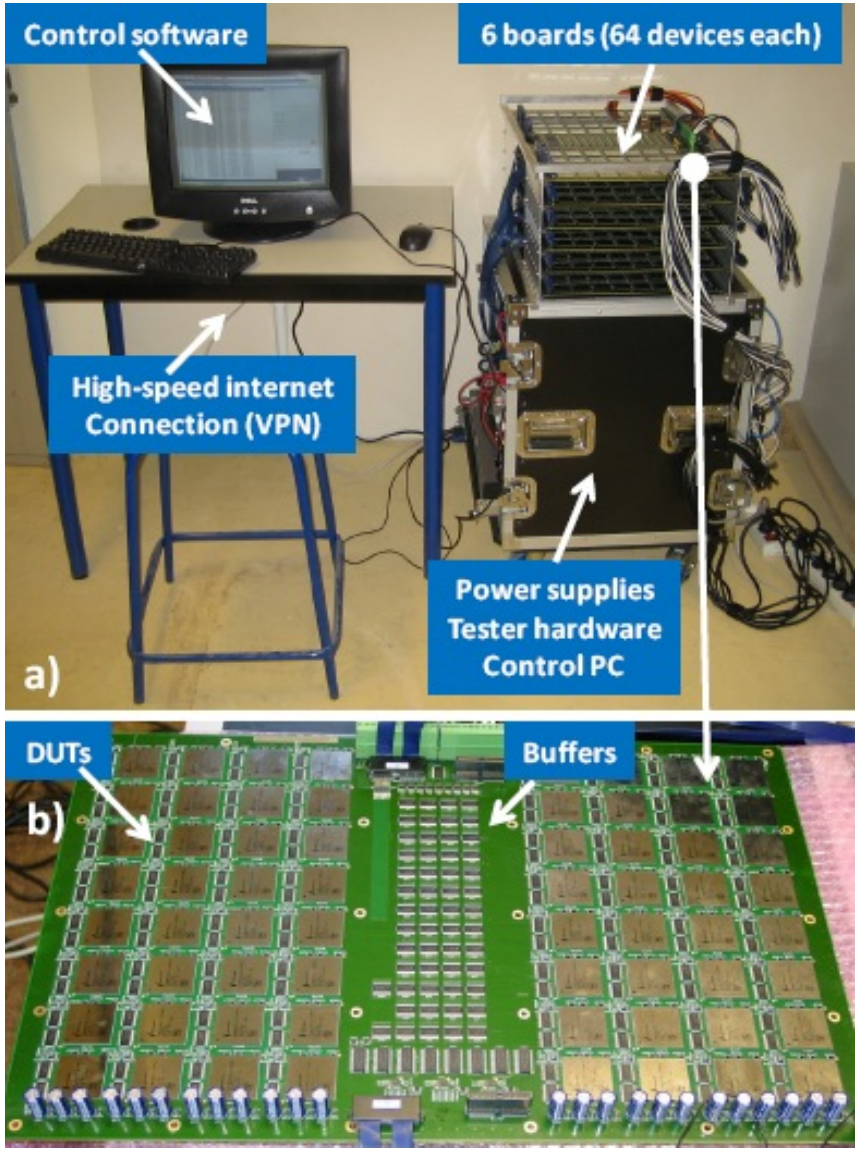


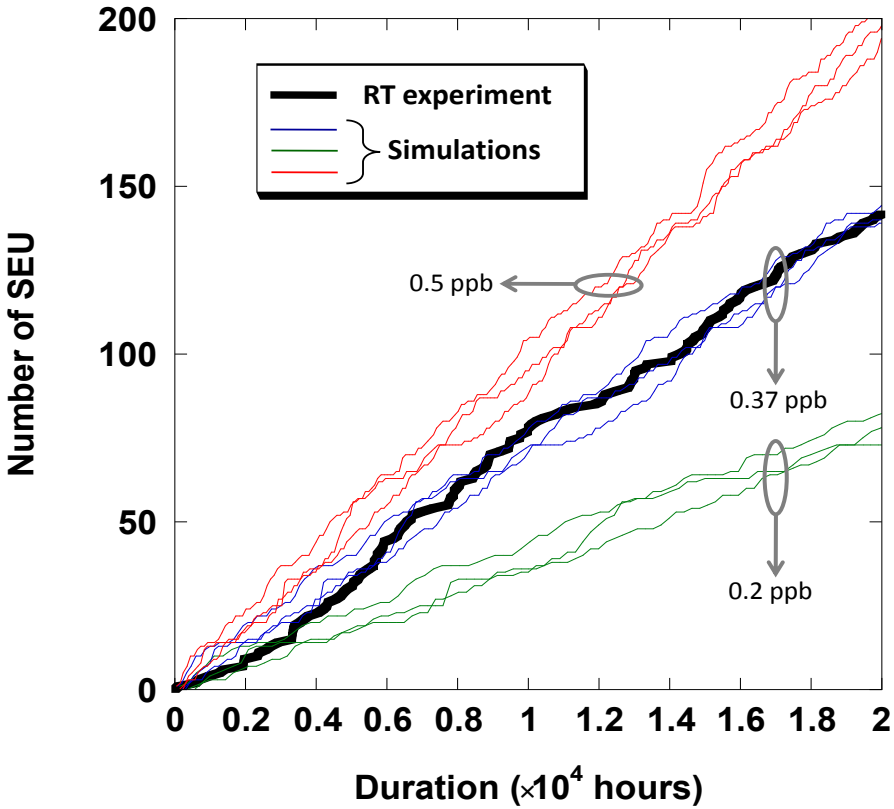
Study of multi-decadal or centennial variability of anchovy and sardins population off Peru



Bordeaux wine dating using ^{137}Cs

Micro-electronics test failures

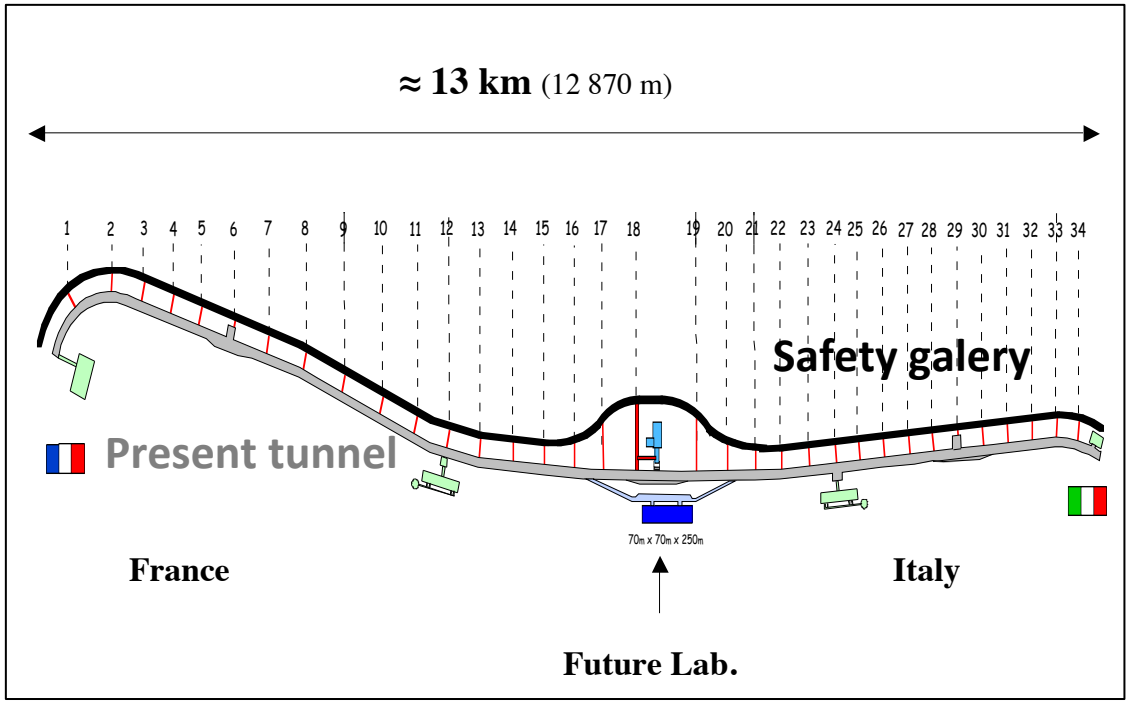


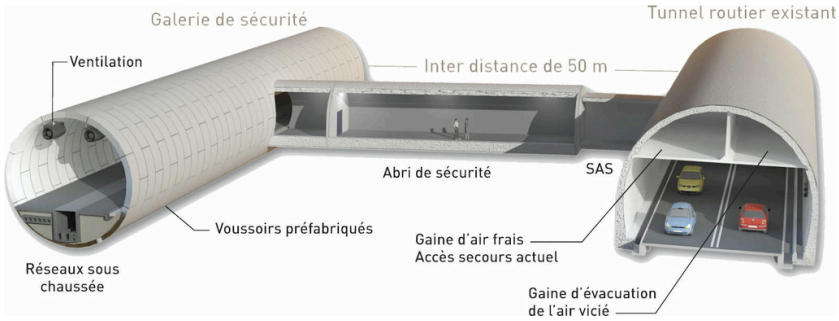


Comparaison experiments - simulations

Extension of LSM : DOMUS

Deep **O**bservatory for **M**ultidisciplinary **U**nderground **S**ciences





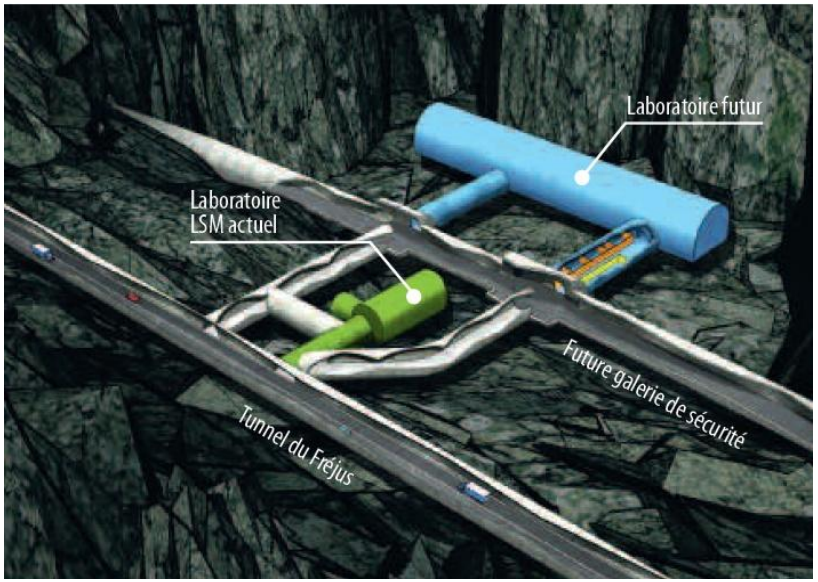
In 2006, the decision to dig a safety galery at the Frejus roadway tunnel was taken

Extension of LSM : DOMUS

An unique opportunity to extend the lab to host next generation of astroparticle experiments and to develop multidisciplinary activities

- **Deepest site in Europe (4800 mwe)**
- **Known and « good » site (low convergence, dry, stiff rock)**
- **Central location in Europe, easy access (plane, train, car)**
- **23 years experience in running such platform**
- **Convenient, safe, horizontal access**
- **European Roadmap new projects**
- **Integration in the project of the tunnel company planning and constraints**
- **Performed pre study : moderate cost**

LSM extension: DOMUS



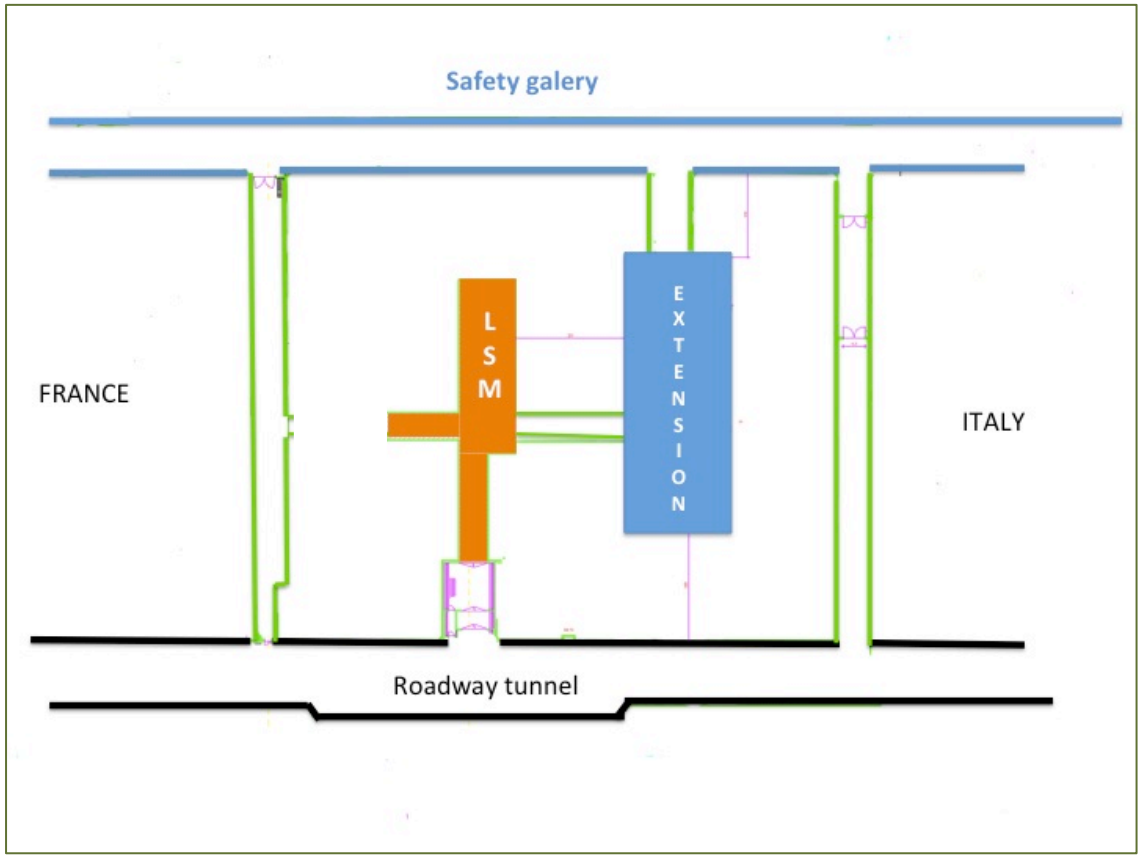
The project has been revisited several times taking into account constraints from:

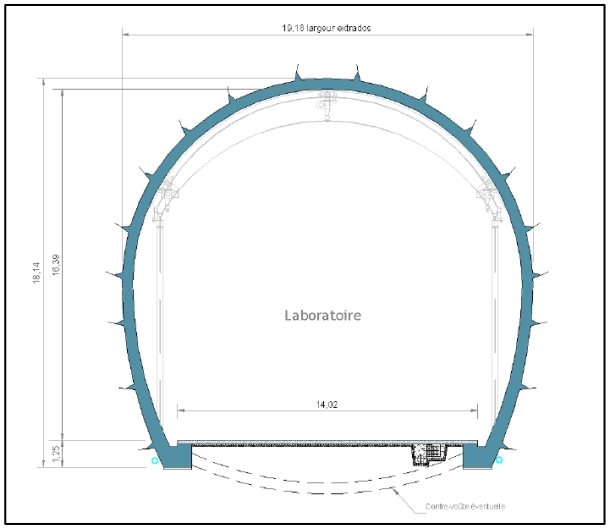
- Geology
- Safety galery work design (schedule, time slot for excavation)
- Safety
- Tunnel company (safety galery → new roadway tunnel, Change of the design of the safety galery, deadline for safety galery opening)
- ……

…….AND MONEY ……..

LSM extension: DOMUS

Final Design





Length : 40 m

High : 16 m

Width : 19 m

Volume : 12 000 m^3

Total volume 17 000 m^3

Many avantages to operate both labs, safety, cost,….

LSM extension: DOMUS

International call for letter of interest June 2008
12 LoI received and one Expression of Interest

Neutrino (DBD)
SuperNEMO (tracko-calo method)
COBRA (solid TPC)

Dark matter:
EURECA (Bolometers)
DARWIN (noble liquid) EoI
MIMAC (TPC)
ULTIMA (Superfluid 3He)

Double EC
TGVIII Double EC (pixellized detector)
Double EC with Ge detectors

R&D for proton decay and neutrino physics
MEMPHYNO

Supernovae neutrinos:
TPC sphere

Logical test failure

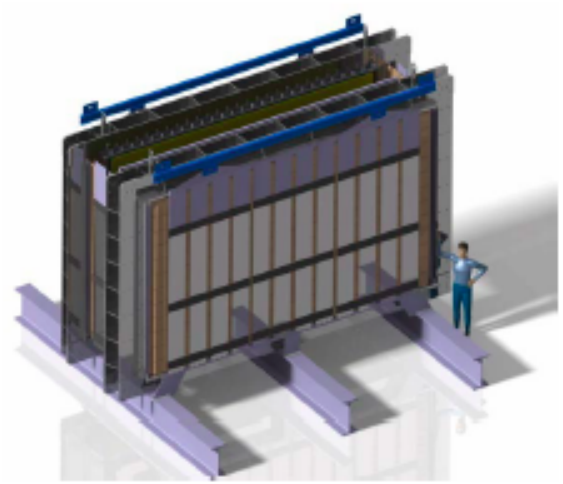
Low background techniqques

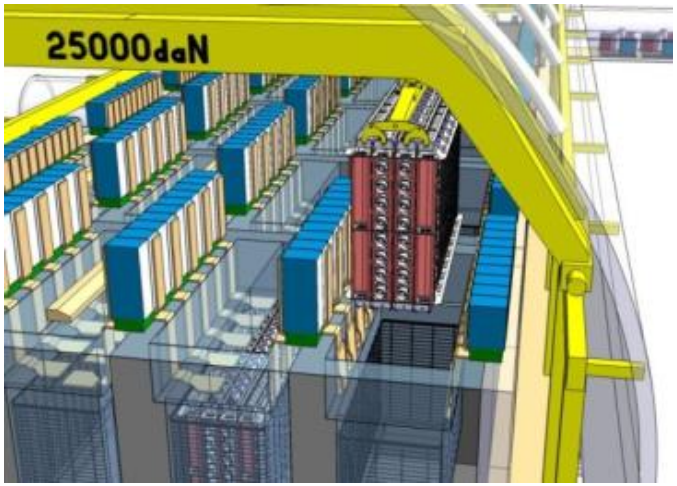
Environmental measurements

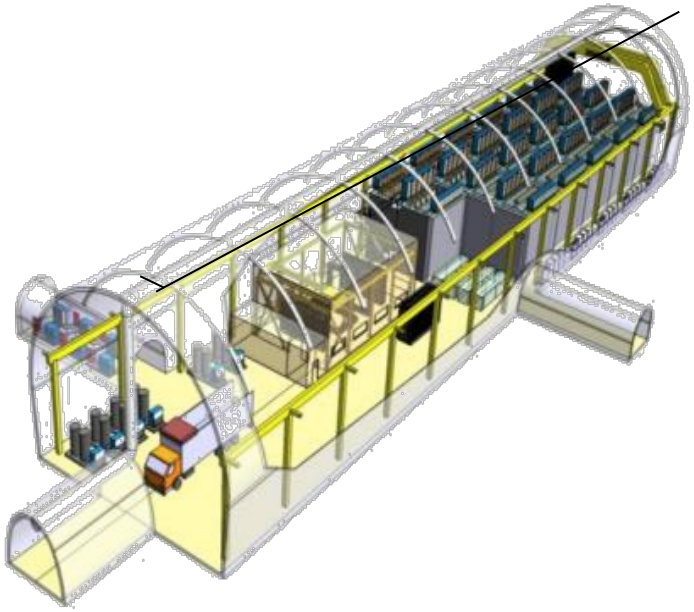
2 workshops to present projects

Reviewed by an International Scientific Advisory Committee

SuperNEMO @ DOMUS







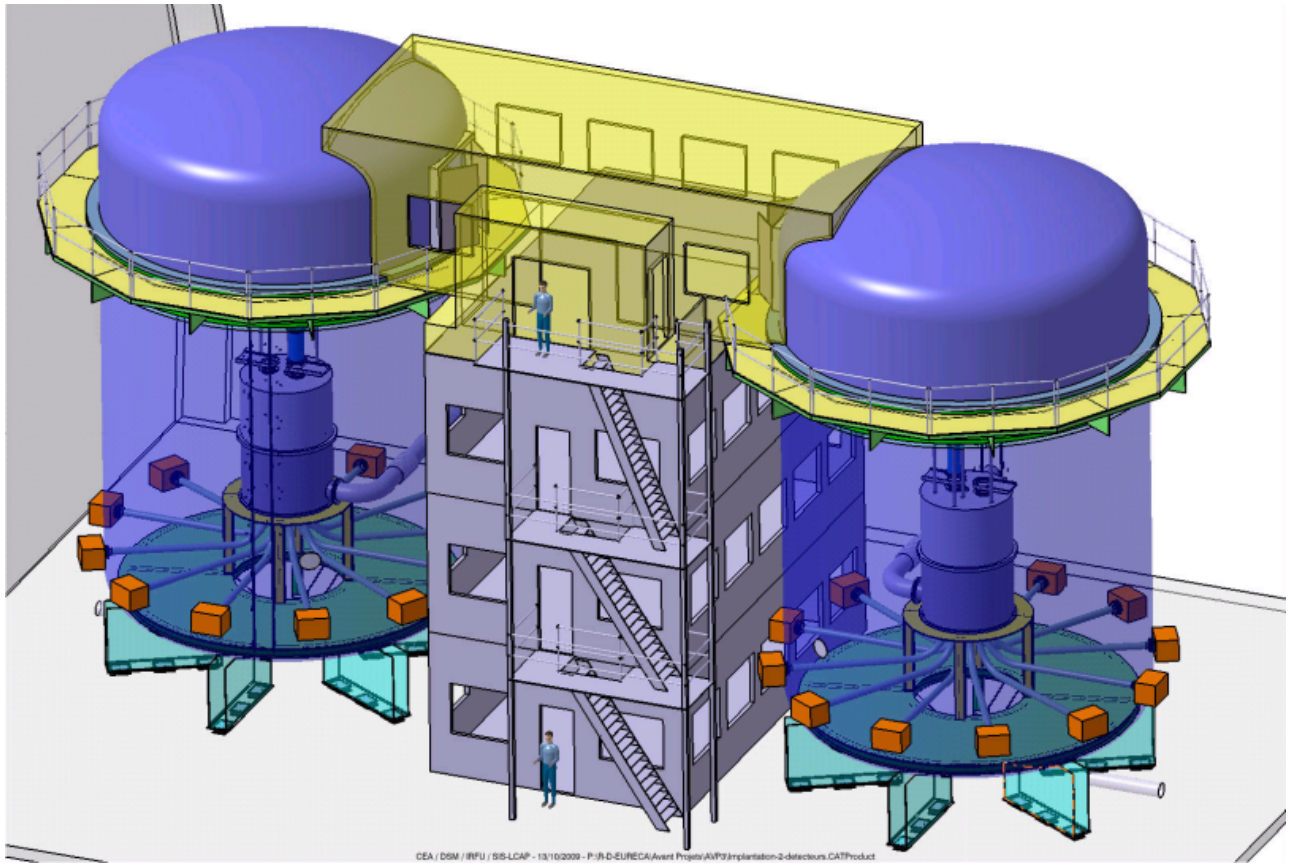
SuperNEMO: Double beta decay

20 modules

100 kg of ^{82}Se (or ^{150}Nd, ^{48}Ca)

Sensitivity on m_ν: 40 – 100 meV

EURECA @ DOMUS



Dark matter search

Cryogenic facility

1 ton of Ge bolometers

LSM extension: DOMUS

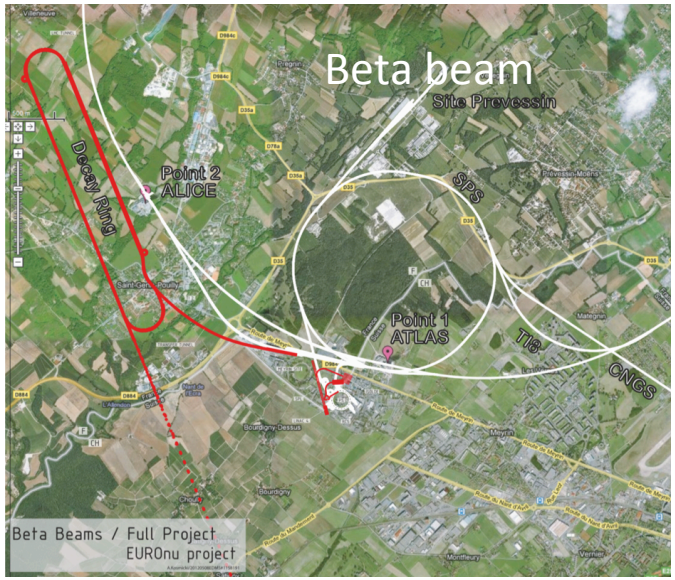
- **Project accepted by Ministery of Research and programmed by CNRS**
- **Cost estimated by project supervisor of safety galery :**
  7 M€ including 20% hazards
- **Funding secured from CNRS, Rhône-Alpes region, Savoie department, FEDER**
- **Technical studies completed**
- **Negociations with the civil work company in October**
- **Digging Spring 2014 or end 2015 depending of the company schedule**
- **6 months for excavation, 10 months for outfittings**
- **Extension in operation 2016 -2017**

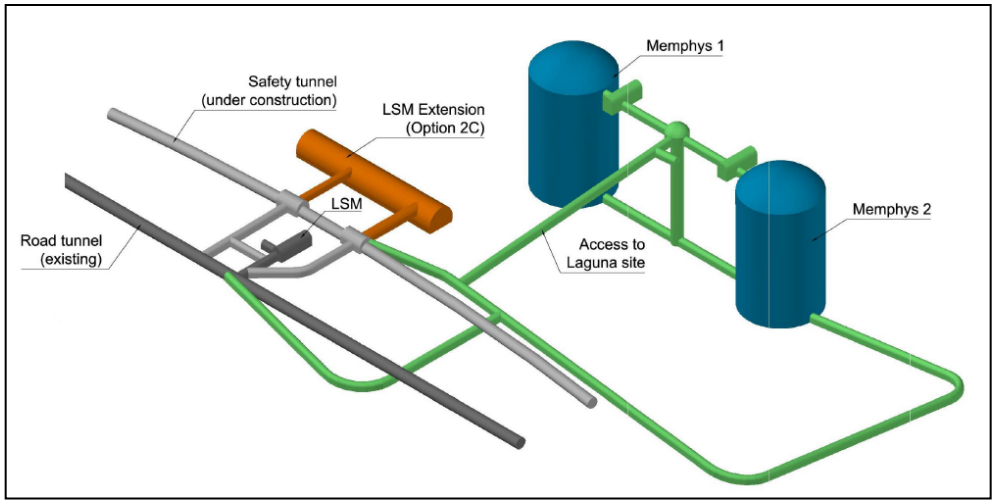
LAGUNA

MEMPHYS : project of large cherenkov detector

MEgaton Mass PHYSics:

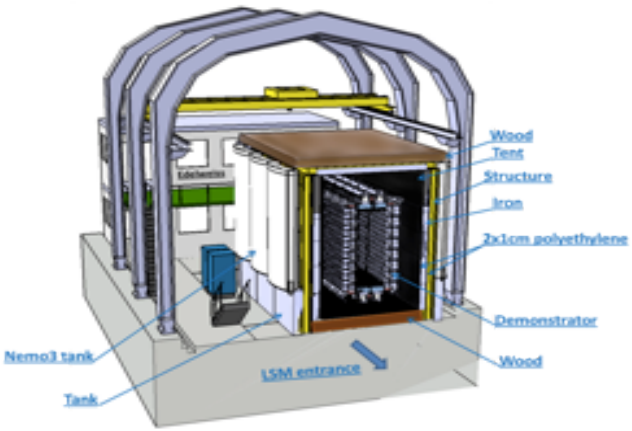
- Proton decay :
  - Explore models not yet excluded: push limits to 10^{34}-10^{35} y
- Astrophysics with neutrinos:
  - SuperNovae core collapse → investigate mechanism
  - Diffuse SN neutrinos → measure
  - Solar neutrinos → helioseismology, CNO rate
  - Atmospheric neutrinos
- Neutrino oscillations:
  - CP violation in lepton sector
  - Mass hierarchy
  - Precision on oscillation parameters





SUMMARY

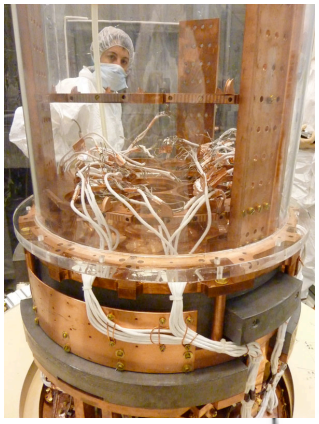
- Underground laboratories are now multidisciplinary science and this aspect has been developed at LSM since the last 20 years



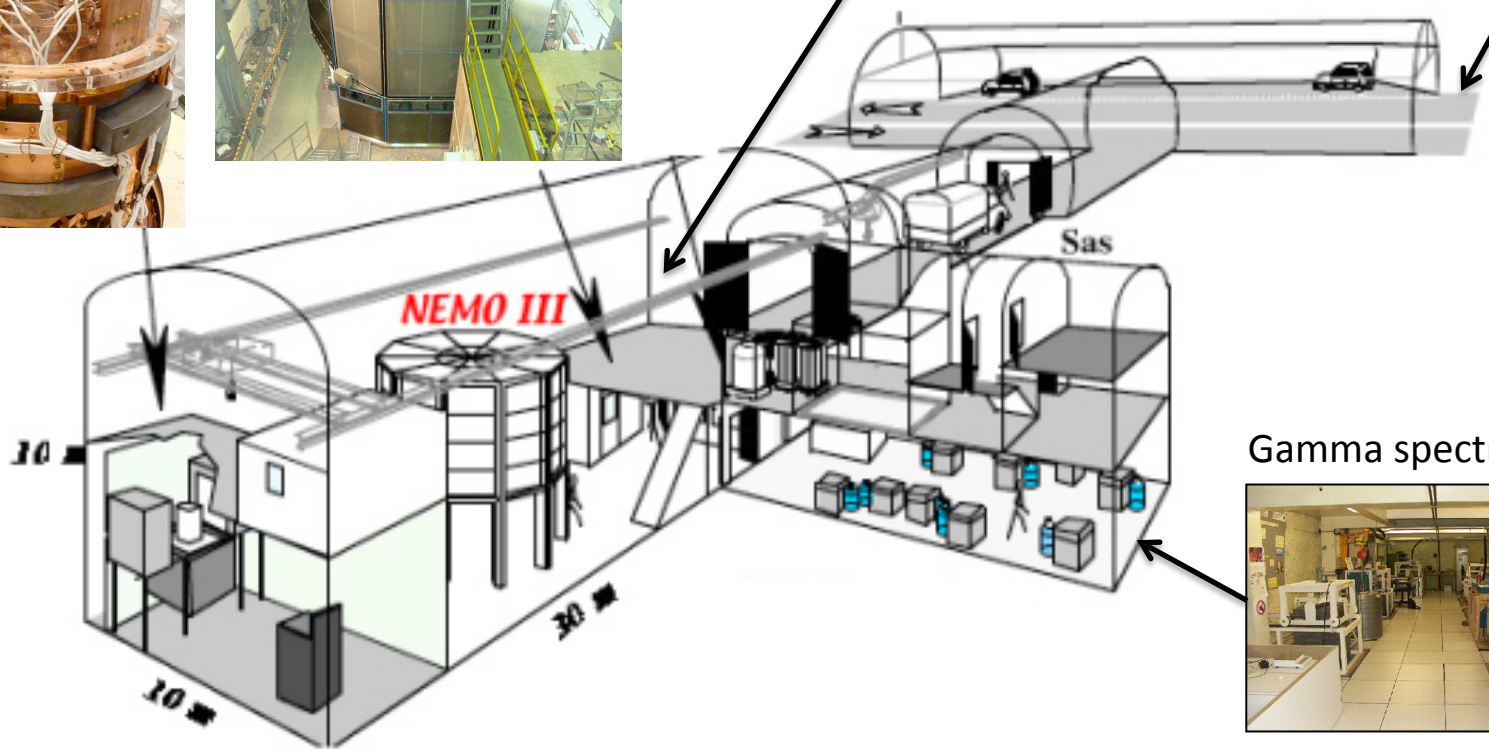
- Soon LSM will be again full with the installation of SuperNEMO demonstrator

- The end of the tunnel is close for the extension to give additonnal place to continue to develop activities

Edelweiss

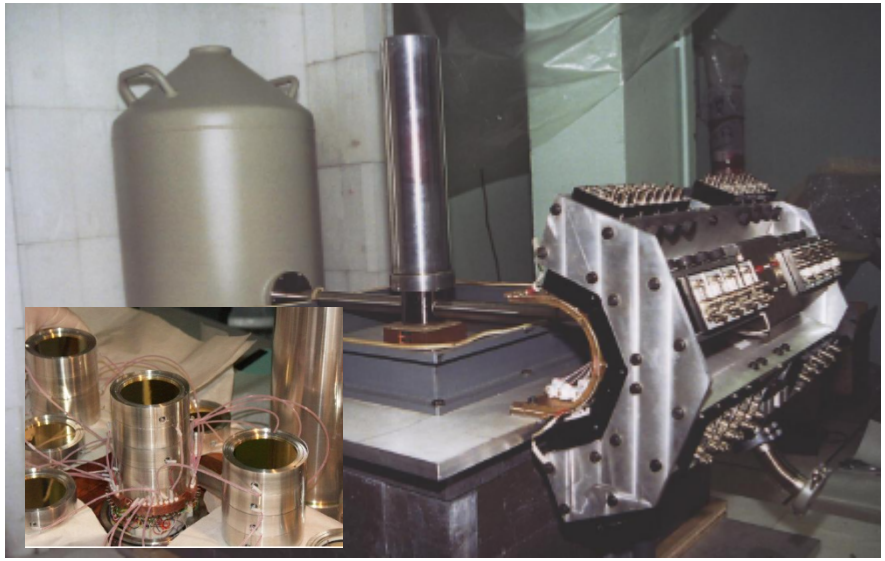


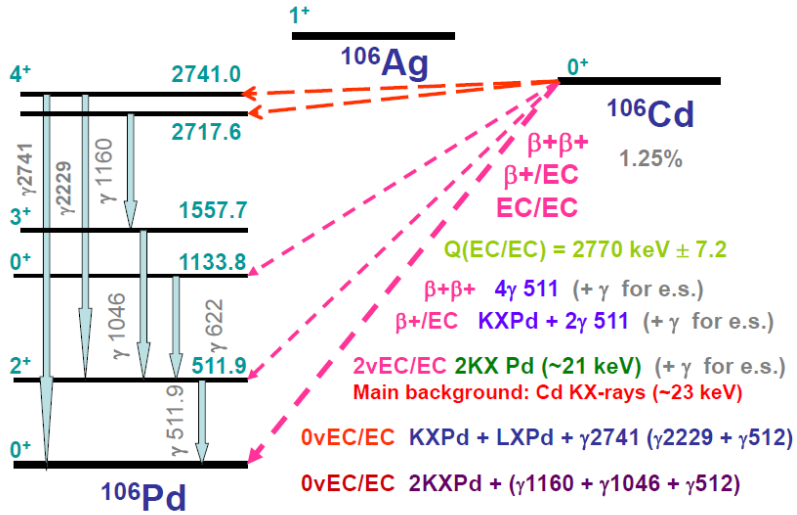
NEMO3



Gamma spectroscopy

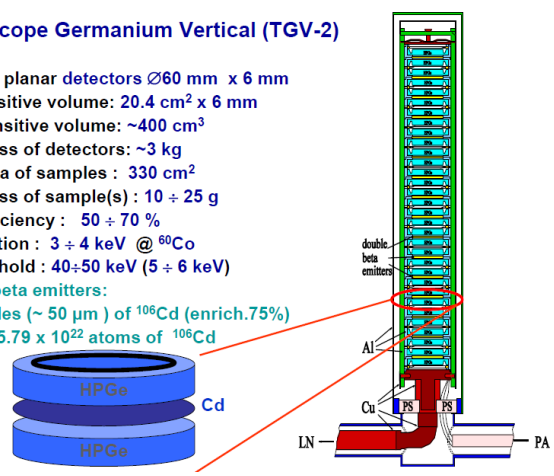
TGV II experiment

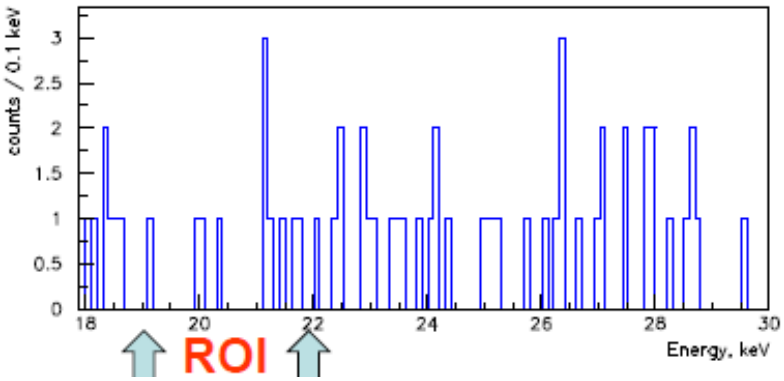




Telescope Germanium Vertical (TGV-2)

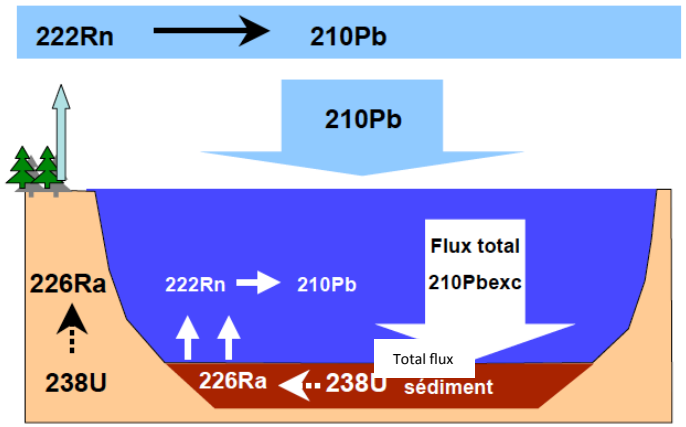
32 HPGe planar detectors ∅60 mm x 6 mm
with sensitive volume: 20.4 cm² x 6 mm
Total sensitive volume: ~400 cm³
Total mass of detectors: ~3 kg
Total area of samples : 330 cm²
Total mass of sample(s) : 10 ÷ 25 g
Total efficiency : 50 ÷ 70 %
E-resolution : 3 ÷ 4 keV @ ^{60}Co
LE-threshold : 40÷50 keV (5 ÷ 6 keV)
Double beta emitters:
16 samples (~ 50 µm) of ^{106}Cd (enrich.75%)
13.6 g ~ 5.79 x 10^{22} atoms of ^{106}Cd

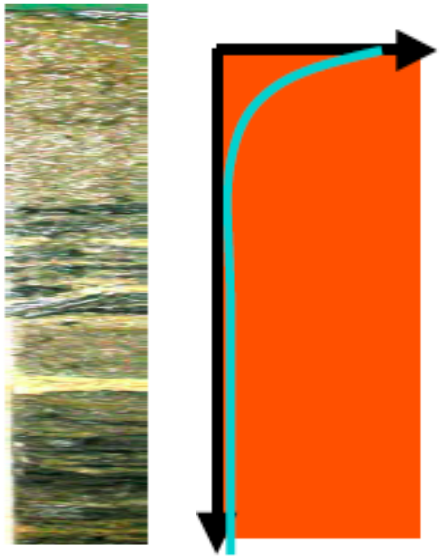




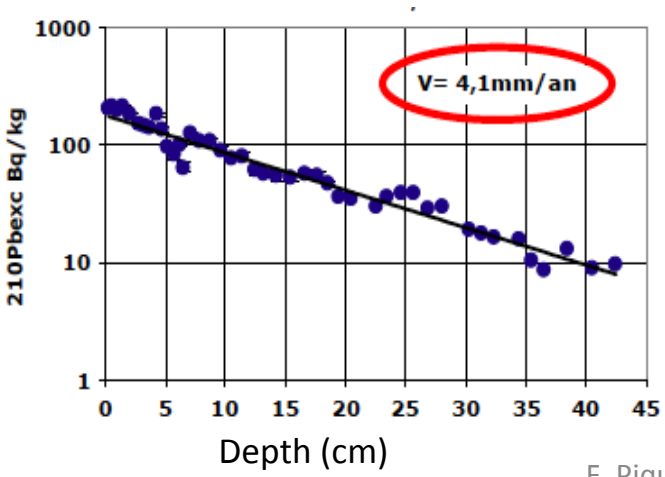
$$T_{1/2}^{2\nu EC/EC}(^{106}Cd) = 4.5\times10^{20}\ y\ (77\%\ C.L.)$$
$$T_{1/2}^{2\nu EC/EC}(^{106}Cd) > 4.2\times10^{20}\ y\ (90\%\ C.L.)$$

Environmental research

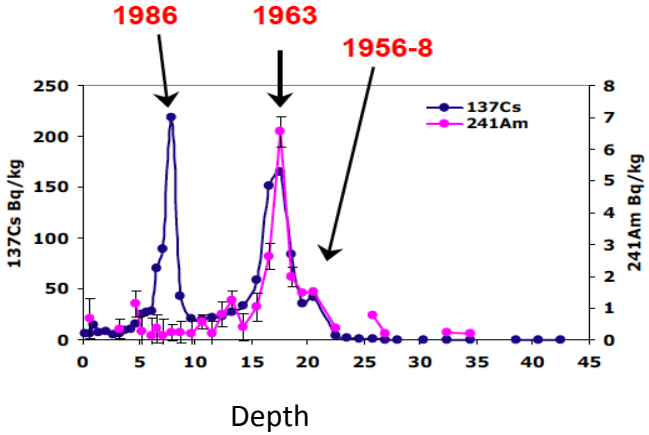




Sedimentation rate

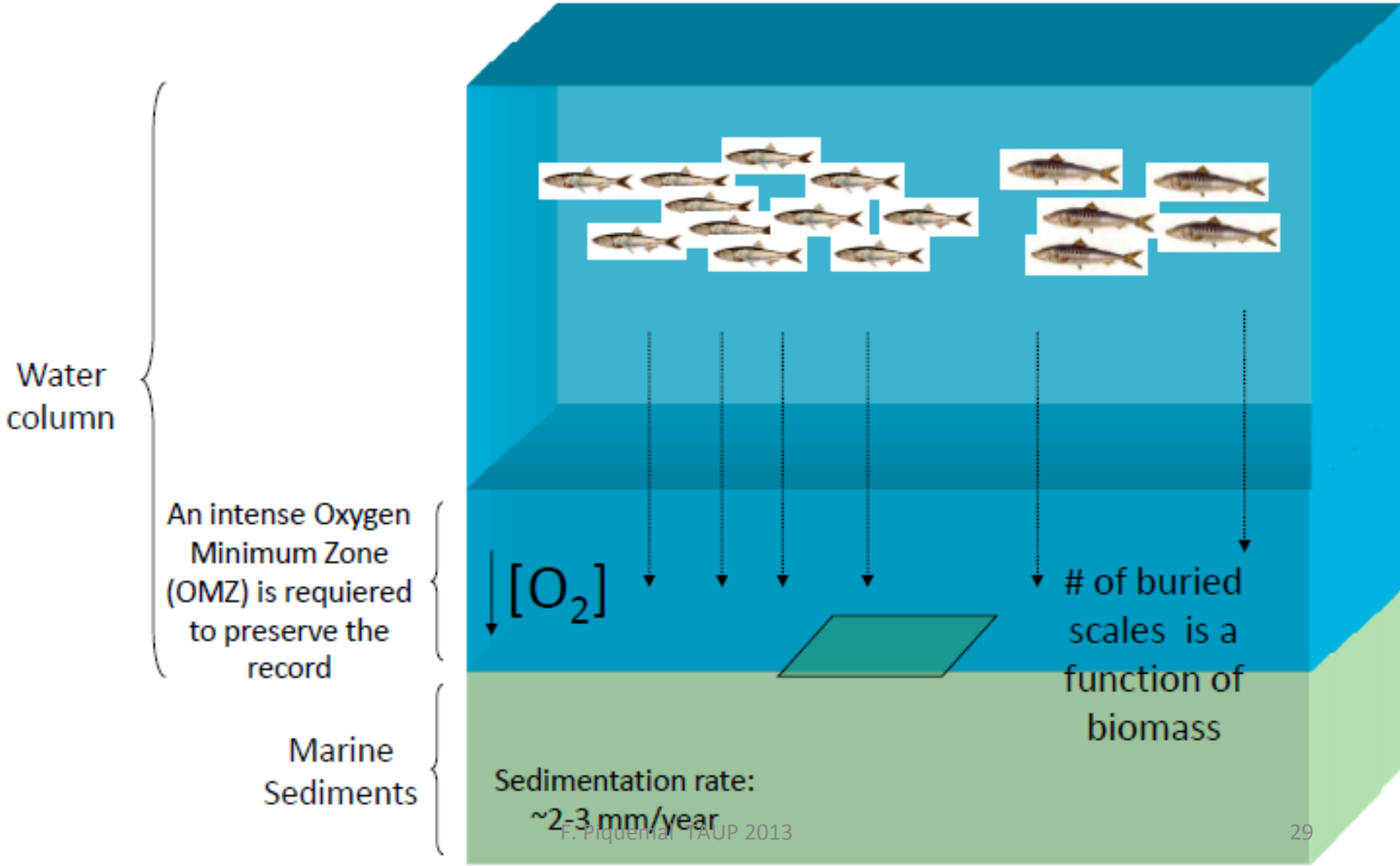


Anthropic isotopes



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

Fish scales buried in marine laminated sediments can provide a record of population variability of small pelagic fishes prior to the development of the fisheries



Planar detector developed @ LSM

- selection of all materials used for cryostat
- cool down by cryogenerator

Installed in LSM : april 2008

Funded by ILIAS program

Development made in collaboration with CANBERRA and Centre d'Etudes Nucléaires de Bordeaux Gradignan

Crystal dimensions:
ϕ = 80 mm
h = 30 mm
Vol = 150 cm^3
Mass=0.8 kg

→

Planar geometry adapted for E< 600 keV

Biology

- **Modeling the impact of radiation on living cells: Geant4 DNA**
- **Validation: need for relevant observables to characterize biological systems**
  - Cell survival rate
  - DNA single or double strain breaks
  - Molecular biology: genomic mutations, gene expression
- **Experimental protocol: compare observables after controlled radiation exposure**
  - In normal lab conditions
  - After beam irradiation (γ, e-, p, α)
  - Need for a reference point at zero-radiation: Modane

Biologists, computer scientists
Physicists, chemists

Geant4 DNA