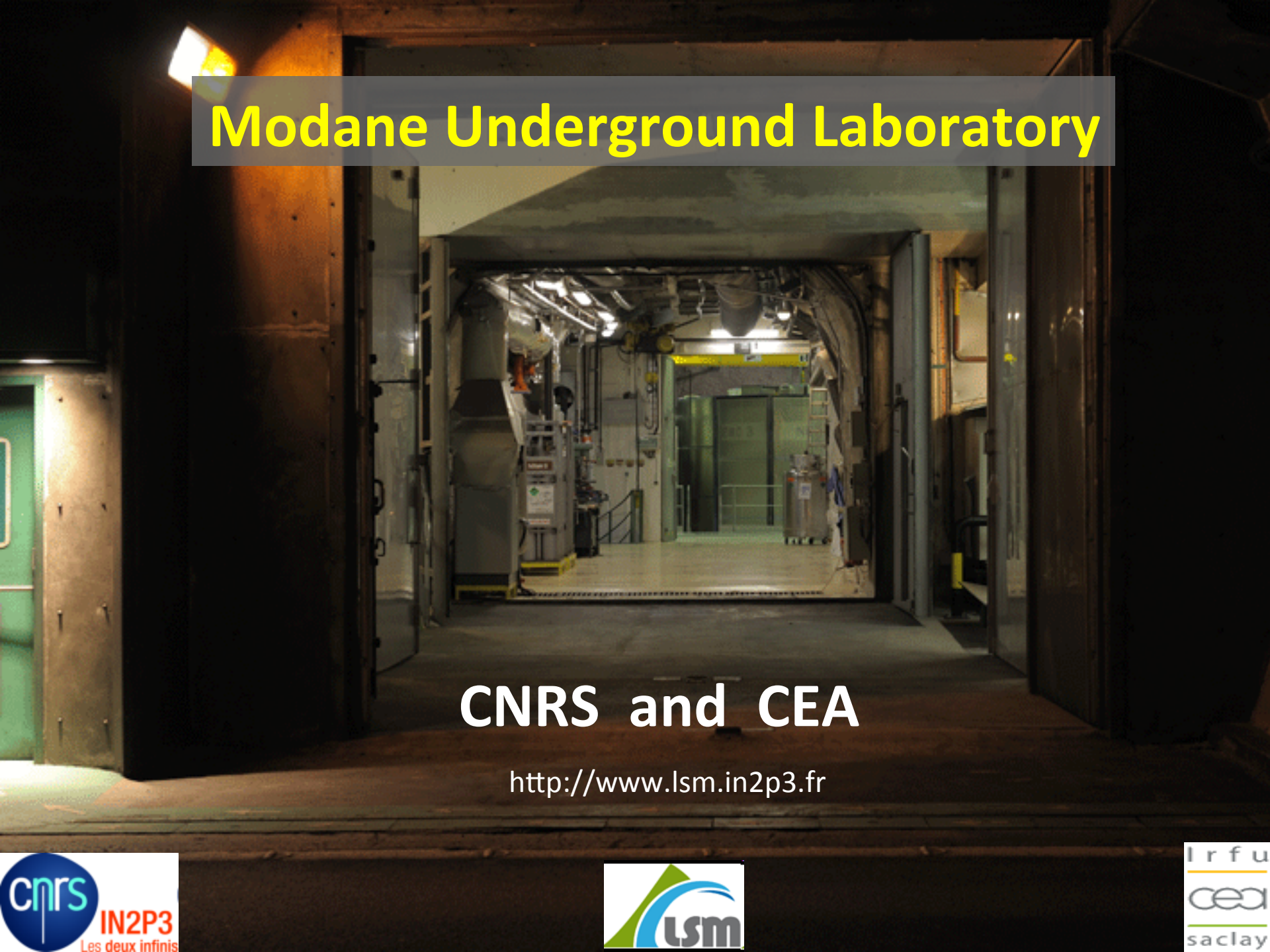
Modane Underground Laboratory

F. Piquemal (CNRS/IN2P3)

Laboratoire Souterrain de Modane (CNRS and CEA)

Aspera Interdisciplinary workshop
December,19 2012
Durham



Modane Underground Laboratory

CNRS and CEA

http://www.lsm.in2p3.fr

cnrs IN2P3 Les deux infinis

lsm

Irfu cea saclay

Modane Underground Laboratory

Laboratoire Souterrain de Modane

Laboratoire Souterrain de Modane

Depth: **4800 m.w.e.**

Surface:: **400 m2**

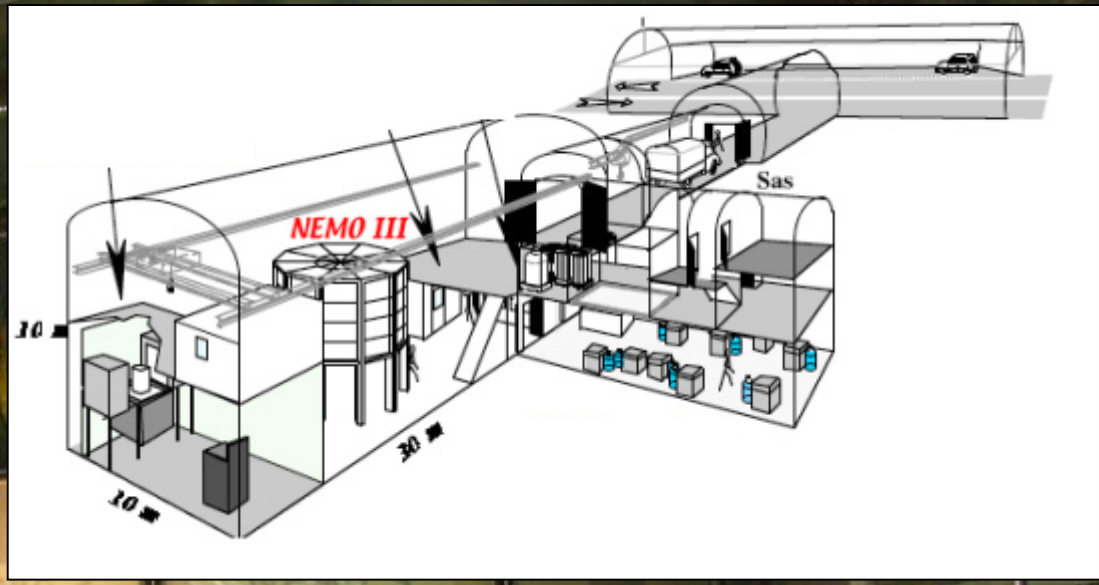
Volume : **3500 m^3**

Muon flux: **4 10^{-5} $\mu.m^{-2}.s^{-1}$**

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

Radon: **15 Bq/m^3**

Access : **horizontal**



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

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

LSM: external facility

Offices, workshop, outreach space and guest rooms

Permanent exhibition for general public

2 000 visitors/year

Laboratoire Souterrain de Modane

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:

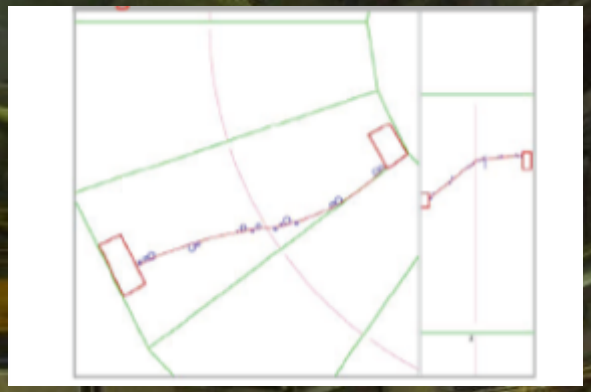
- Proton decay
- Neutrino: double beta decay, double EC
- Dark matter
- Nuclear structure

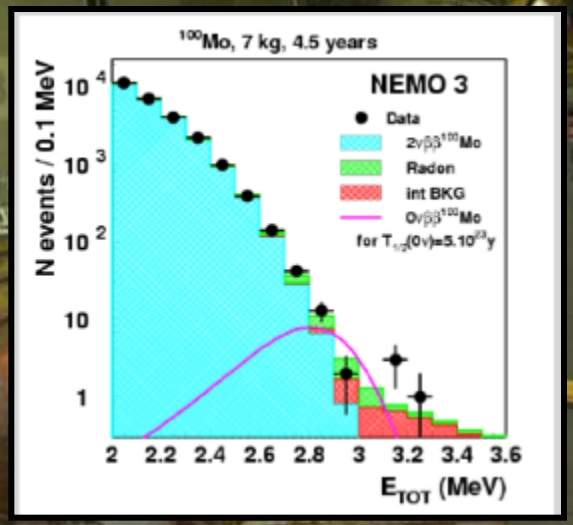
Multidisciplinary activities

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

Neutrino physics: NEMO -3

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





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

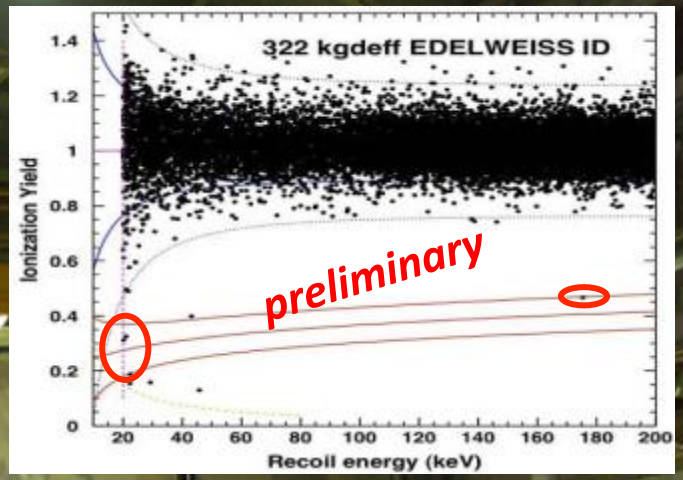
Stopped in January 2011

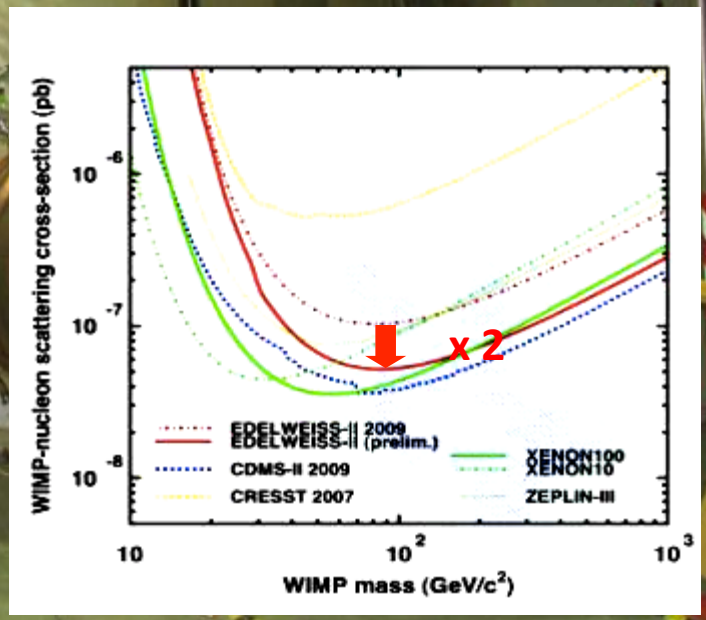
^{100}Mo $T_{1/2}$ ($\beta\beta0\nu$) > 1.0 10^{24} y (90% C.L.)

$\langle m_\nu \rangle$ < 0.31– 0.79 eV

Dark matter: EDELWEISS

Bolometric technique: Heat + Ionization Ge crystals - 40 kg





Other experiments

Neutrino physics

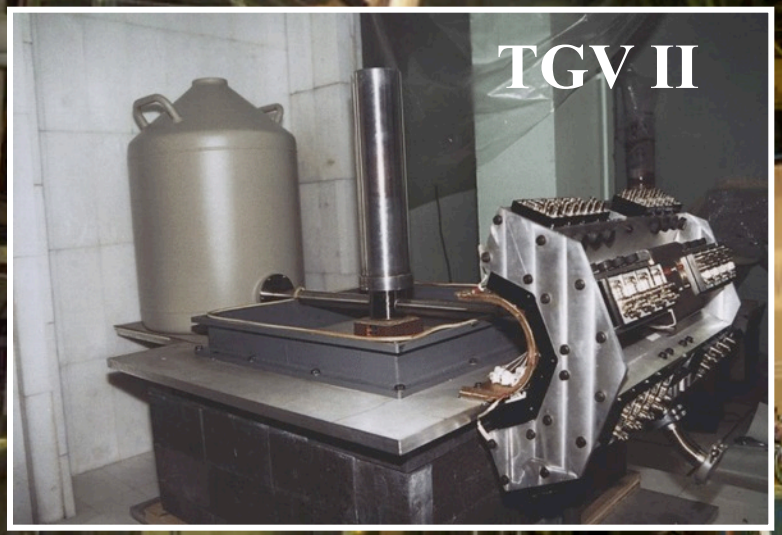
Double EC search (^{106}Cd)

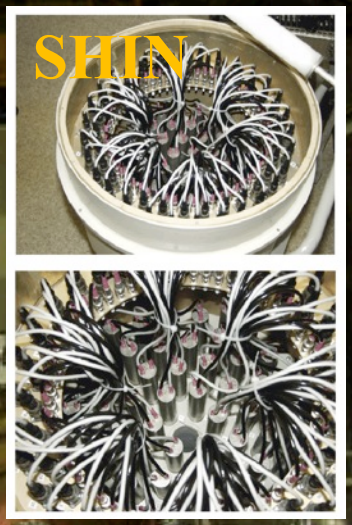
TGV-II (Ge with sheets of Double EC candidates)

Nuclear physics

Super Heavy Element In nature

SHIN (osmium ore surrounded by 3He neutron detectors)



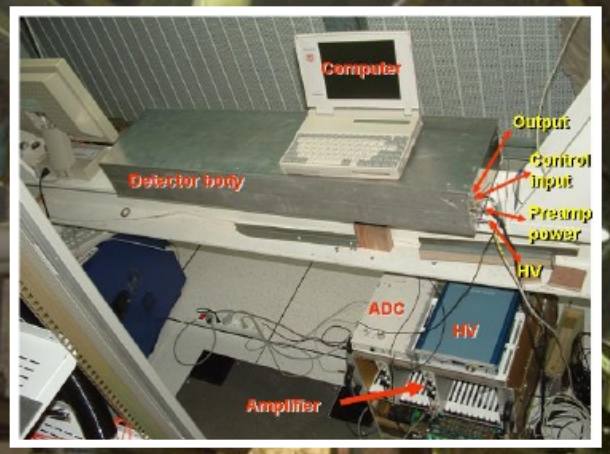


MIMAC prototype : Dark matter low pressure TPC for DM directional detection

SEDINE Spherical high pressure TPC for supernovae neutrino detection

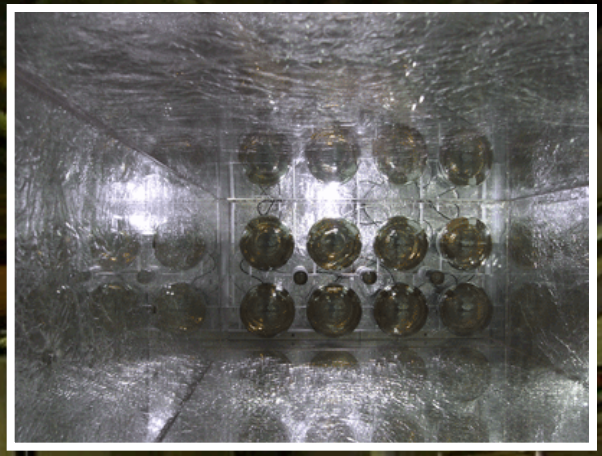
Scientific activities @ LSM

Neutron detectors at LSM



^{3}He counters

Sphere TPC



Gd loaded liquid scintillator

Support from ILIAS TARI for the 3 detectors

Radon detectors – sensitivity ~1 mBq/kg
(electrostatic collection of radon daughters)
Saga University (Japan) and Dubna (Russia))

Radon free air factory

Gamma ray spectroscopy @ LSM

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

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

Interdisciplinary @ LSM

Use of the ulta-low 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 exemples:

- 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

The scientific and societal usefulness of recent (< 250 years) Alpine lake sediment studies

An overview on LSM – Université de Savoie joint scientific progresses in paleolimnology

Fabien Arnaud
Charline Giguet-Covex
Bruno Wilhelm

Jean-Louis Reyss

Marie-Elodie Perga

The concept of “retro-observatory”

Having a look on yesterday to manage tomorrow challenges

An underestimated tool to
make natural areas management policies better
and to evaluate the impact of current global changes

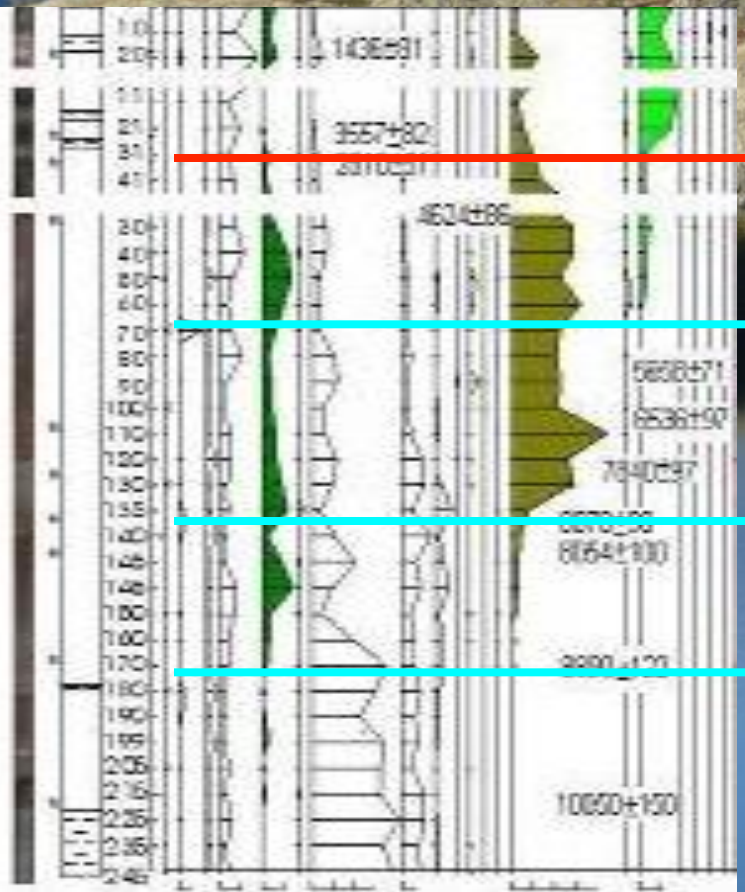
In Europe, even remote mountain landscapes are man-made

Chalets d'Ecuelle, 1872 m, commune de Passy (Haute Savoie)

In Europe, even remote mountain landscapes are man-made

Noisetier Epicéa
Pin cembro Sapin

Pollen data, Villy, Haute Savoie, 2250m asl



Epicéa

3600 cal. BP

Pin cembro
Epicéa Sapin

5600 cal. BP

Pin cembro
Sapin

8000 cal. BP

Pin cembro

8900 cal. BP

Noisetier

Open space: deforestation

First forest opening (human or climate?)

Closing of the forest space

Forest reconquest

Interdisciplinary @ LSM

Use of the gamma-ray spectroscopy

Applications :

- Charaterisation of water (lake, river, underground water) EU directive

-For drug and food administration ex. wine dating, marine salt origin

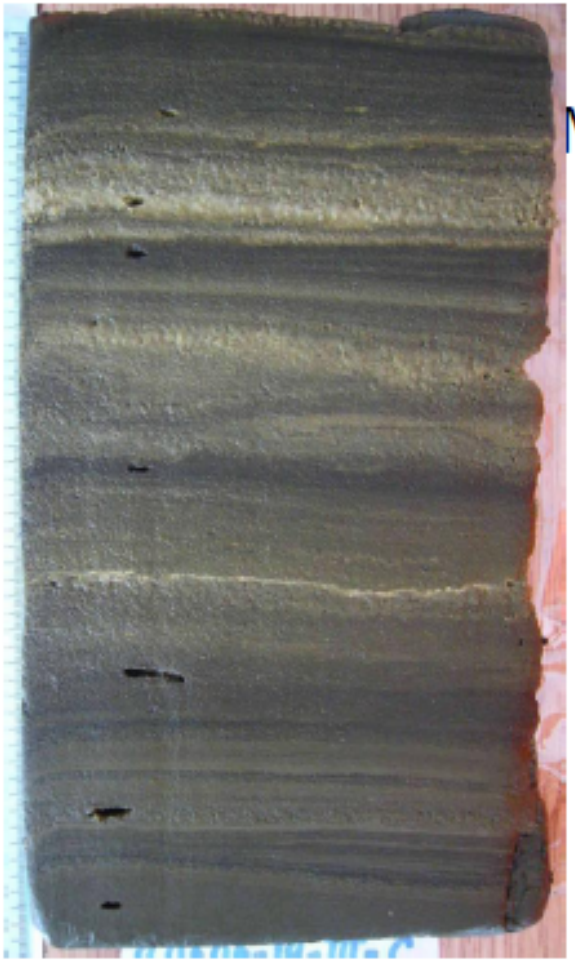
- Judicial expertises

- Mean age of crustacean livestock for fishing regulation

- ……

Development of a national ultra-low radioactivity platform measurements with

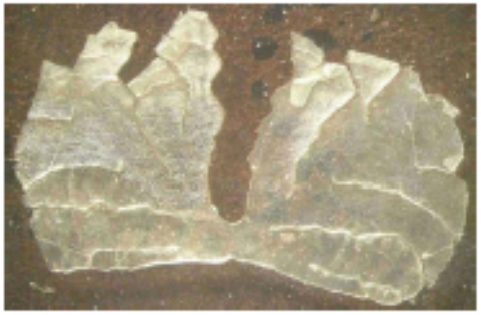
EDYTEM (University of Savoie/CNRS), LGGE (University of Grenoble / CNRS), LSCE (CNRS/CEA), LPSC (University of Grenoble / CNRS) and LSM



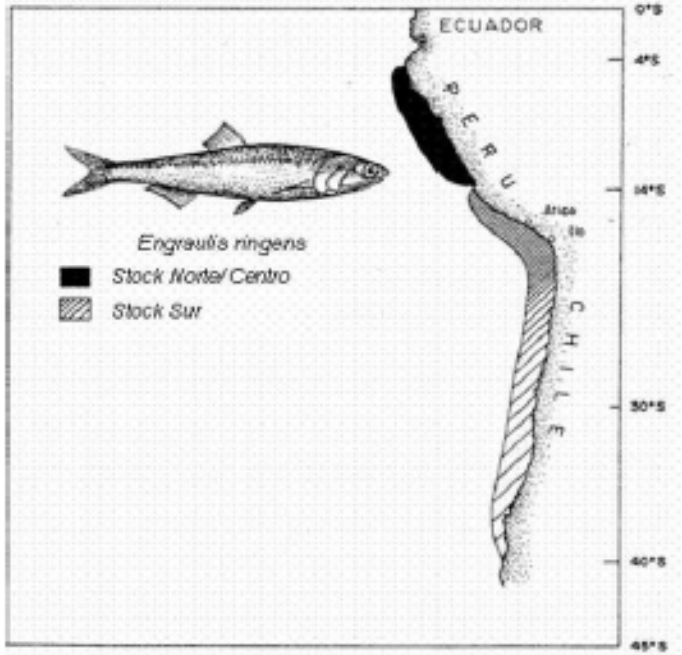
Multi-decadal to centennial scale variability in fish scale preservation and burial from marine laminated sediments off Pisco, Peru during the late Holocene

Salvatteci, R.

Paris, October 2010



The Humboldt Upwelling Ecosystem is characterized by strong ENSO variability and the highest pelagic fish productivity



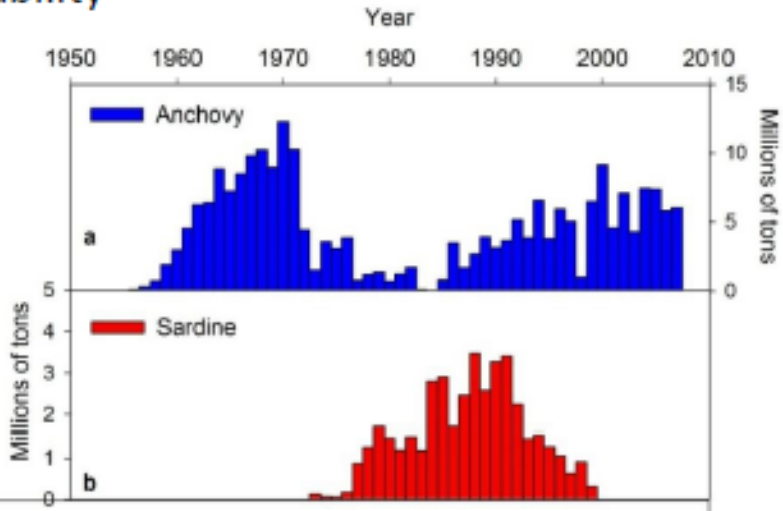
-Continuous coastal upwelling throughout the year

-The northern Humboldt Current System off Peru presently produces about 10% of the world fish catch based primarily on anchovy.

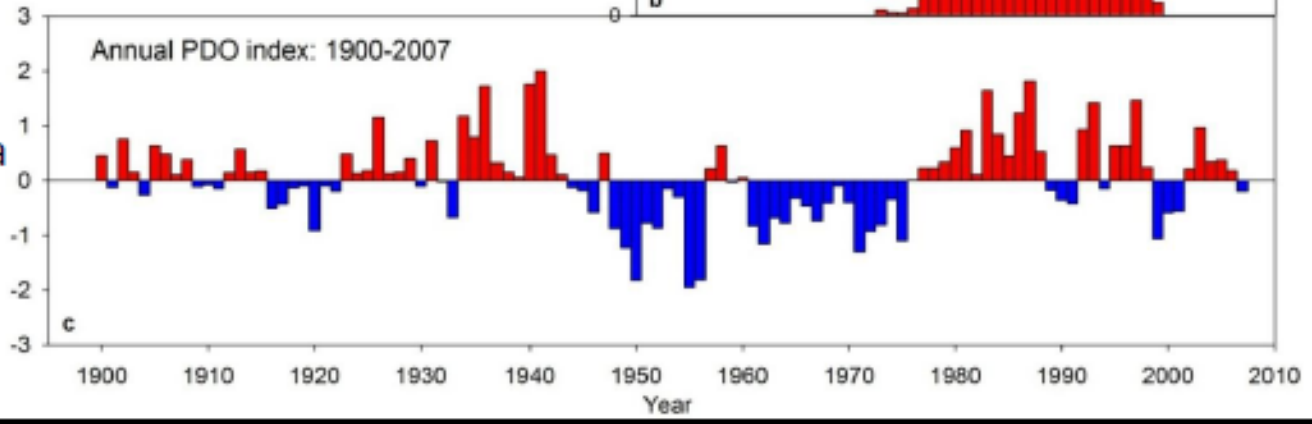
-Anchovy and sardine landings show strong annual and decadal biomass variability


Engraulis ringens


Sardinops sagax sagax



The Pacific Decadal Oscillation (PDO) Index is defined as the leading principal component of North Pacific monthly sea surface temperature variability (poleward of 20N for the 1900-93 period).



Questions regarding the variability in abundance of these 2 species:

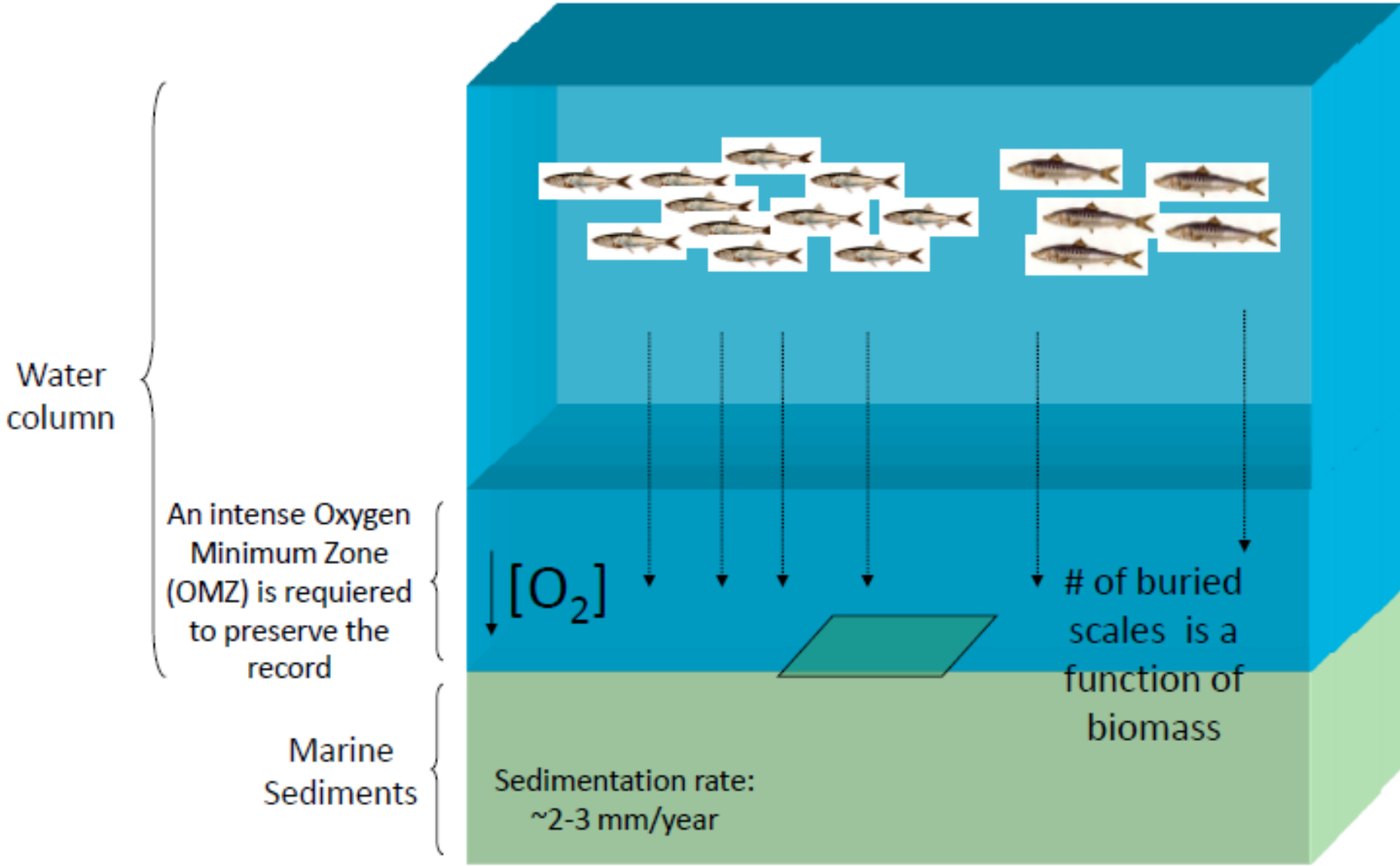
Are changes in populations anchovy and sardine linked or related to climate change?

Global Warming: More upwelling and thus more anchovy??? (Bakun)

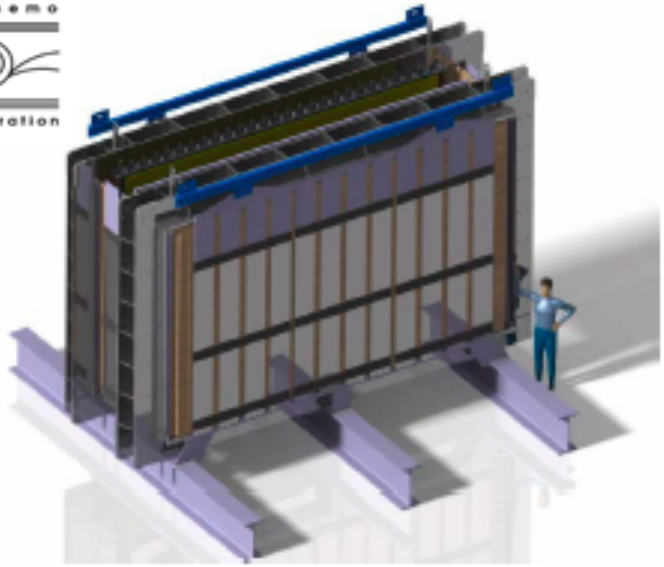
Periods of climate instability favors sardine? (Bakun 2008 PO)

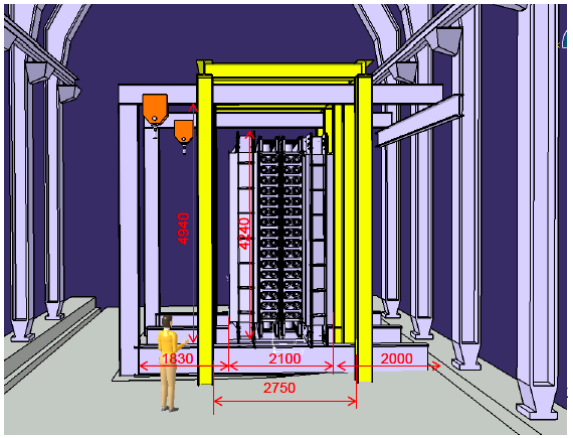
Rapid changes will favor anchovy or sardine?

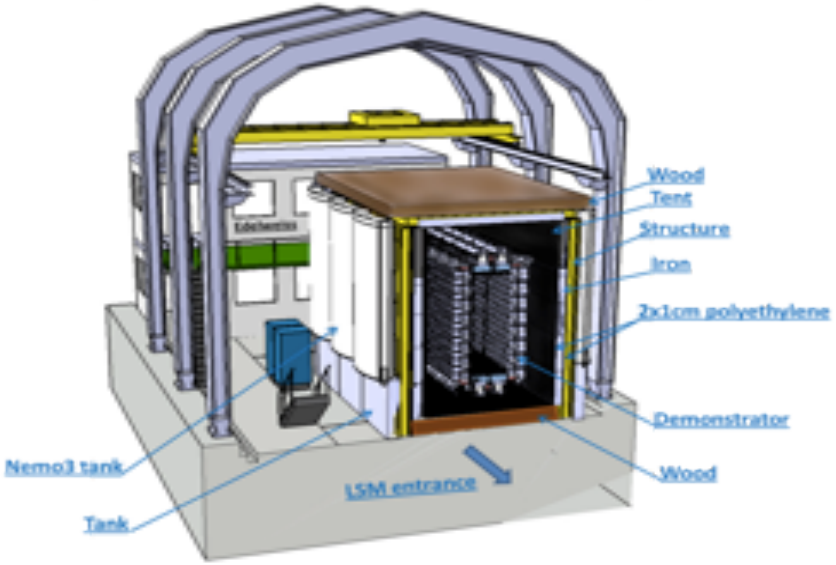
Fish scales buried in marine laminated sediments can provide a record of population variability of small pelagic fishes prior to the development of the fisheries



SuperNEMO demonstrator @ LSM







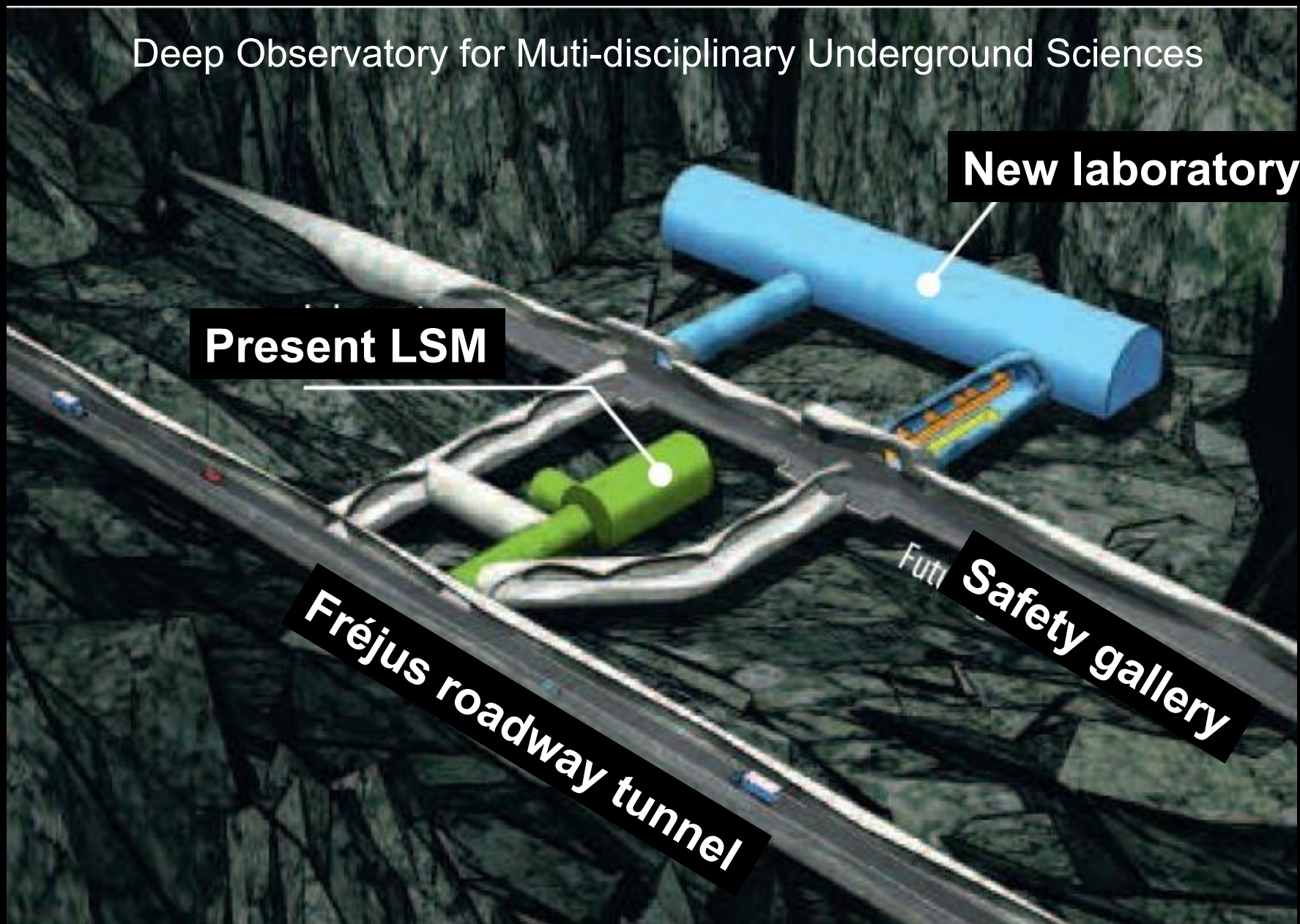
SuperNEMO Demonstrator:
Double beta decay

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

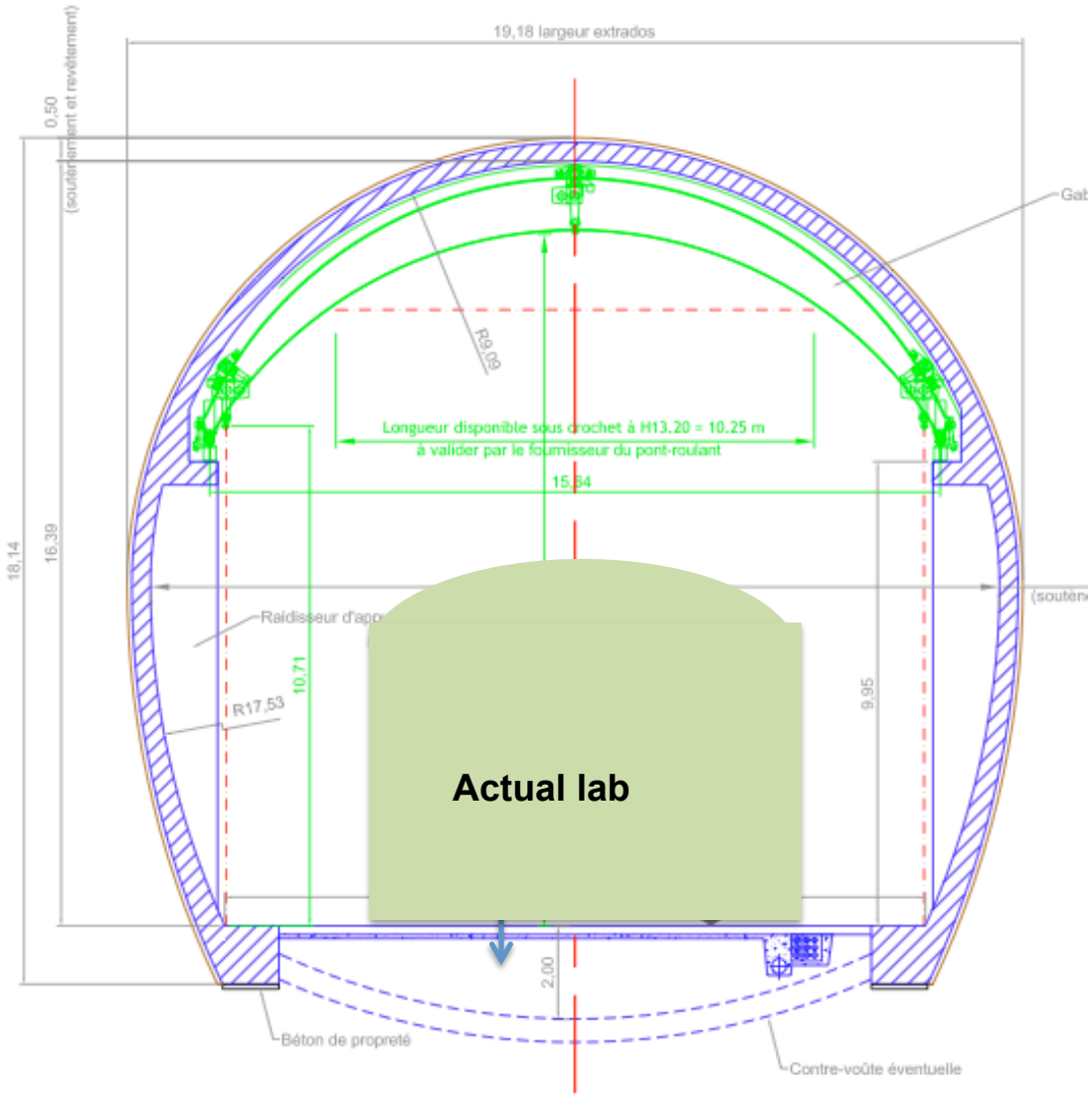
No background for 2.5 yr of data

Sensitivity on m_ν: 200 – 400 meV

DOMUS: LSM extension

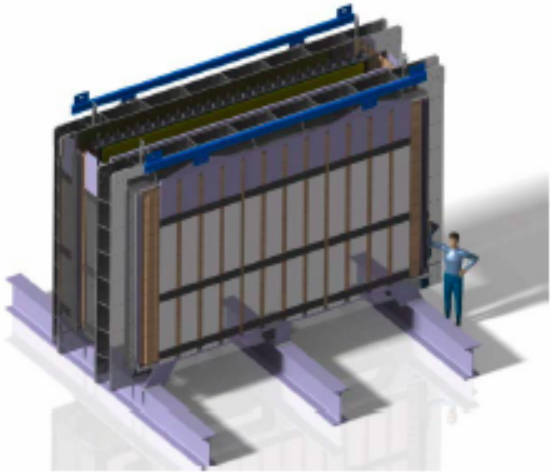


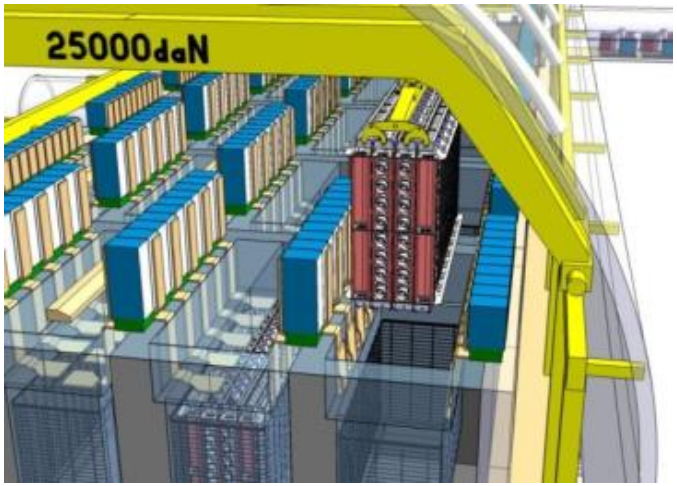
DOMUS project

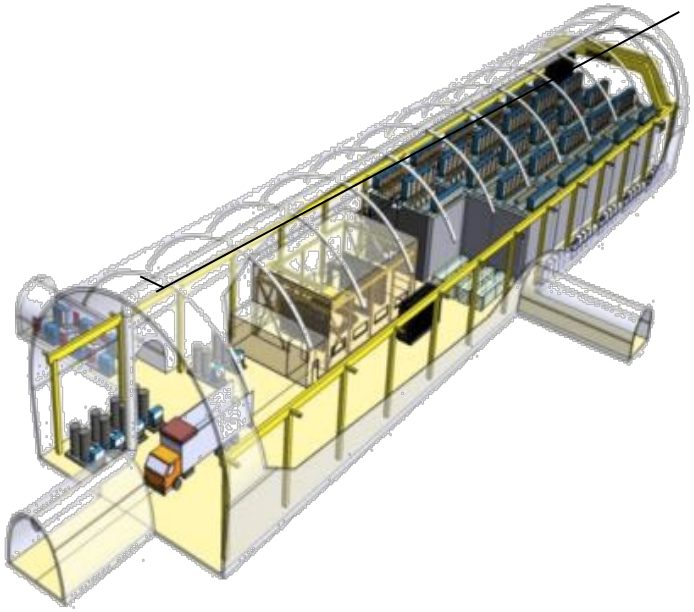


COUPE AA ech : 1/100

SuperNEMO @ DOMUS







SuperNEMO: Double beta decay

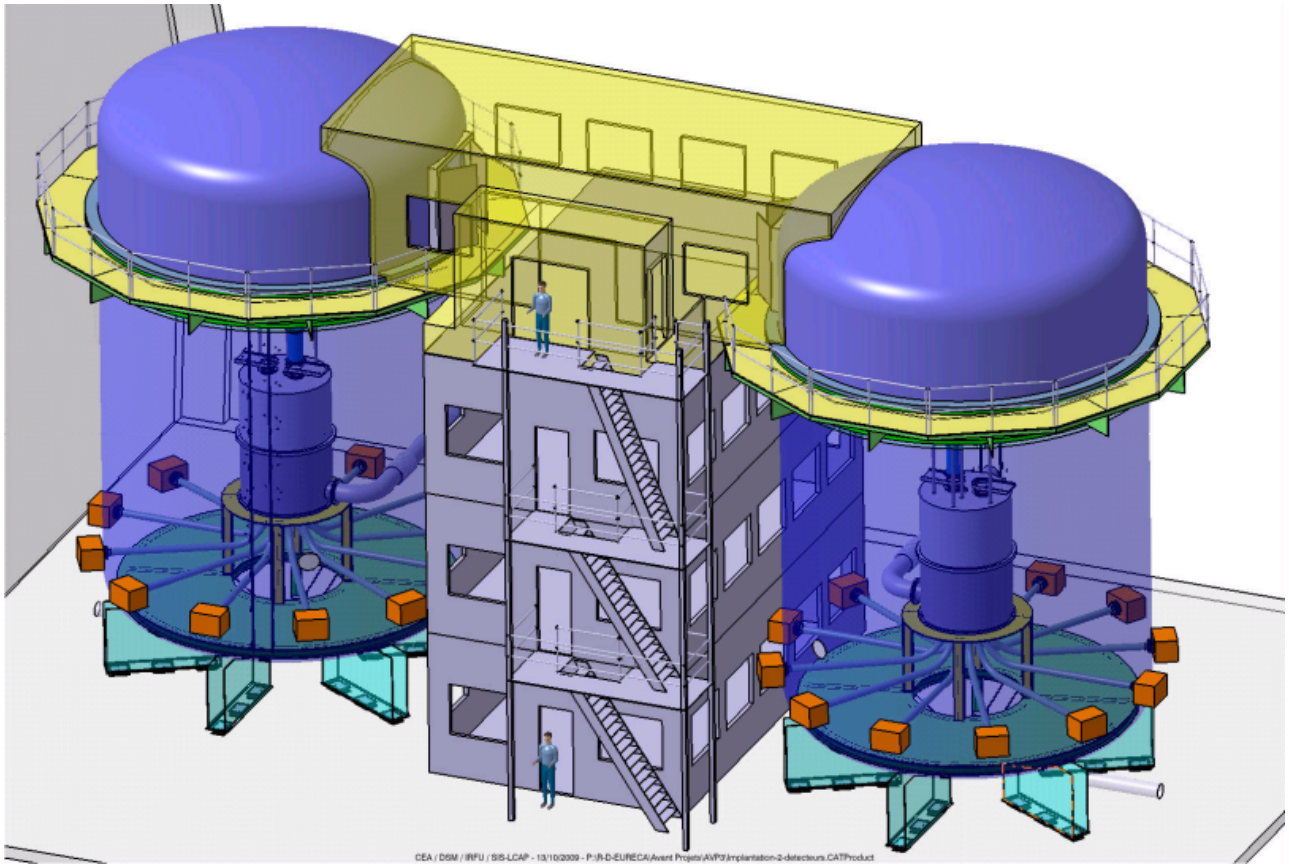
20 modules

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

Sensitivity on m_ν: 40 – 100 meV

LSM ULISSE
Un autre regard sur l'Univers

EURECA @LSM

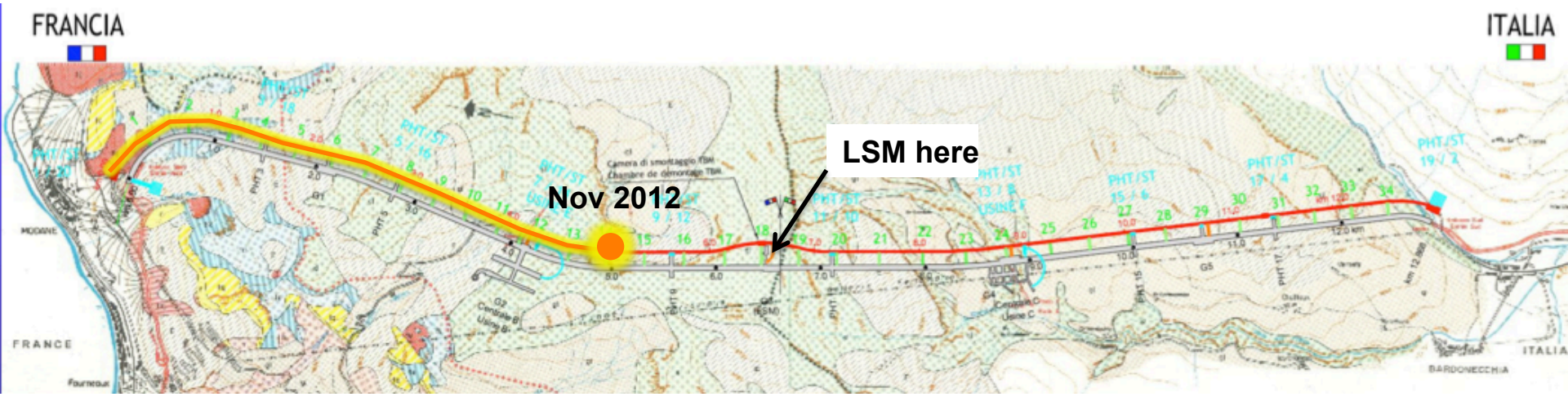


Cryogenic facility

1 ton of Ge bolometers

DOMUS project

- Current status of safety gallery
  - About 5.8 km from French entrance
  - Digging at 1 km/month => January at LSM level
  - TBM will go to Italy ?

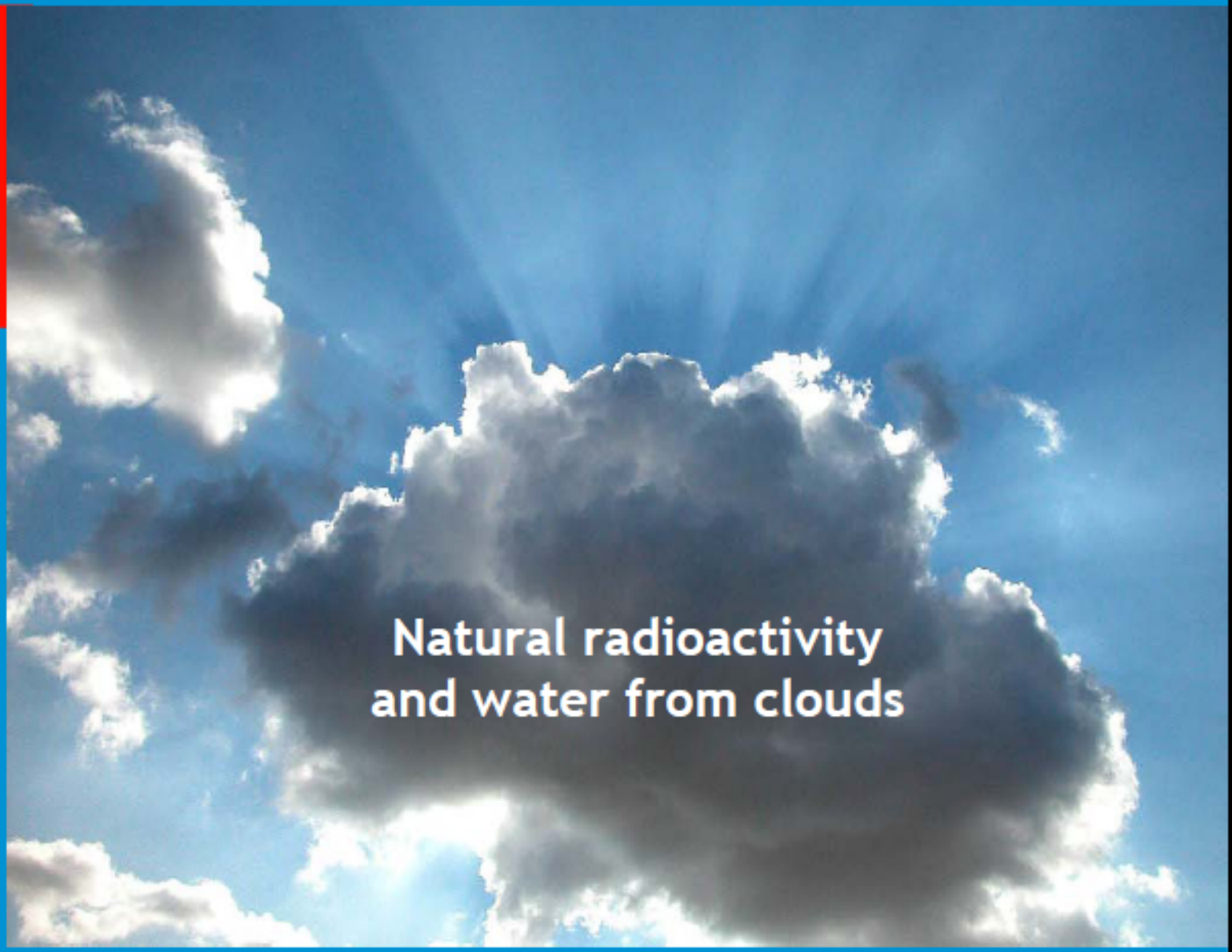


LSM Extension project

- Safety galery work started in September 2009
- Excavation of the extension 2014 or 2015.
- In operation in 2016.
- Detailed studies funded by Savoie departement and Rhone-Alpes Region
- Agreement from Ministery and CNRS for the project
- Funding almost secured (85% already obtained CNRS, Region Rhone-Alpes, FEDER funds)
- Technical discussion in progress

Backup

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE



Natural radioactivity and water from clouds

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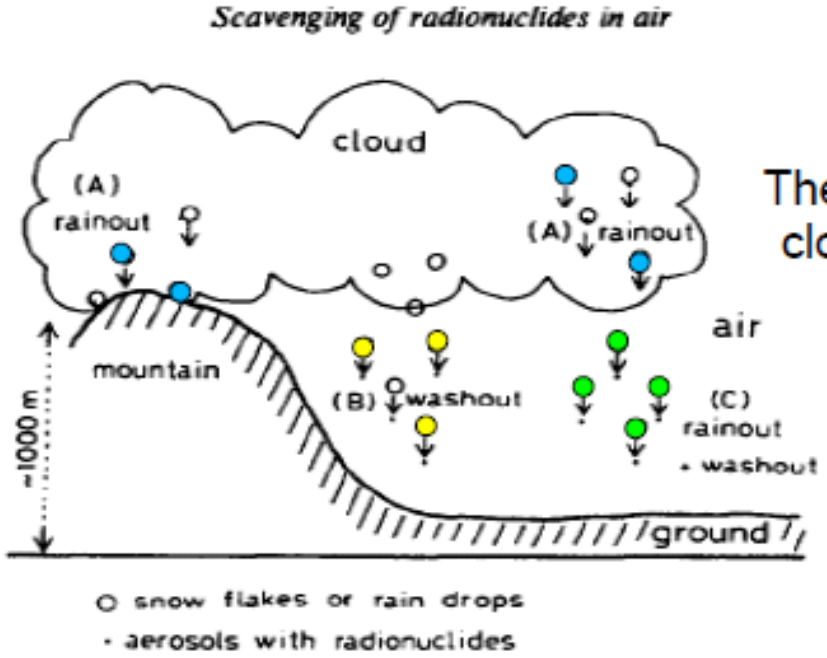
rodolfo.gurriaran@irsn.fr

As part of its mission of environmental monitoring, IRSN carries out studies on the environmental processes that can explain the transfer and the evolution in time of natural and artificial radionuclides present in the atmosphere

The process of leaching of aerosols can explain 90% deposition of radionuclides in the event of accidental release into the atmosphere



These processes are carried out under the cloud but also in the cloud and are called the wash ("rainout")

Given their size, collection efficiency is 10 to 100 times greater for droplets in the cloud as raindrops that precipitate,

Intra-cloud washing accounts for 25% of total wet deposition from an altitude> 800 m (Lange, 2003)

The IRSN has instruments to collect cloud water at the station's scientific study of the atmosphere at the summit of the Puy de Dome
(OPGC / Laboratoire de Météorologie Physique)


Active collector


Passive collector
(Cloud harp)

Optical measurement of the
contains in liquid water
of the cloud

The volumes collected are very low (few tens of milliliters or less).

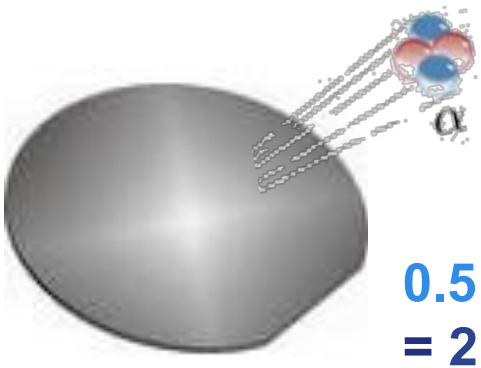
After evaporation, the solids content is set for a measurement geometry XXL long in the detector wells installed at the IRSN LSM

The level of artificial radionuclides in the water droplets in clouds are sampled equivalents (a few mBq / l) to those obtained in rainwater collected in plain

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

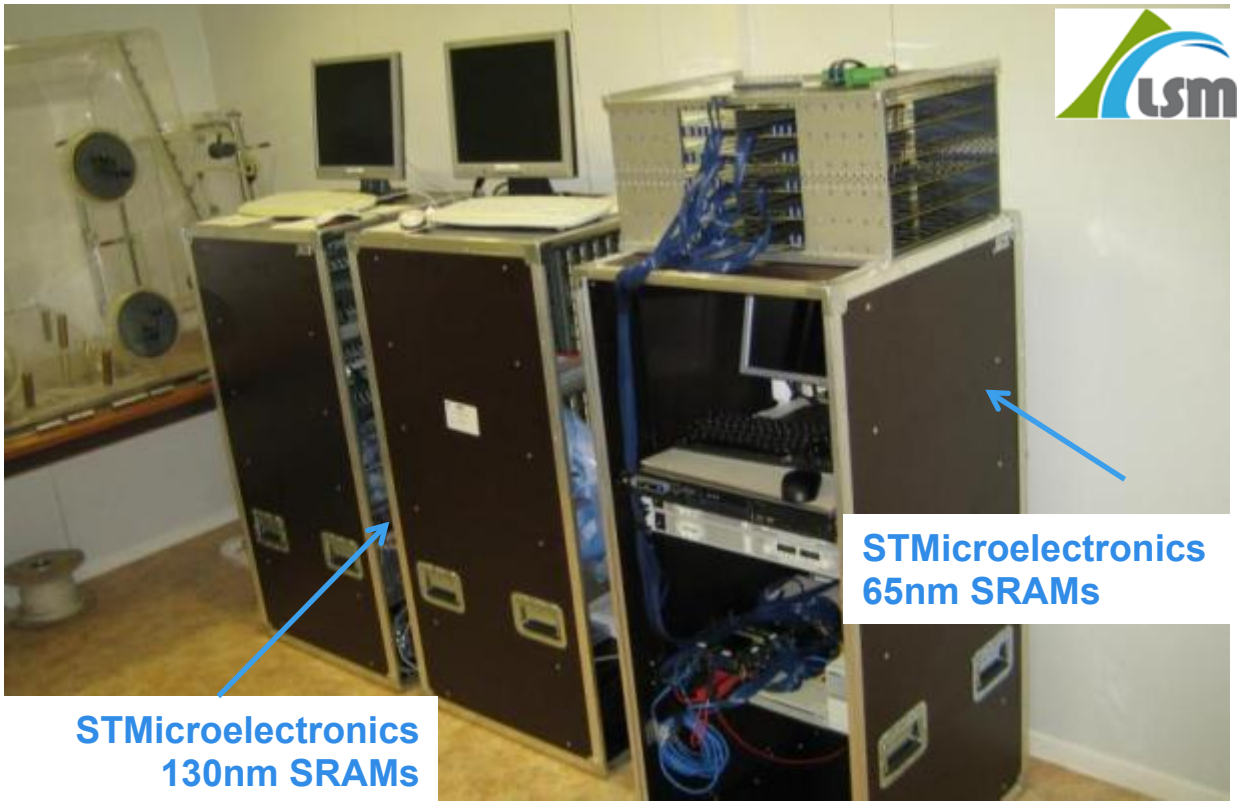
Silicon wafers, ceramic packages and contact bumps are contaminated with Uranium and Thorium elements at ppb concentration levels



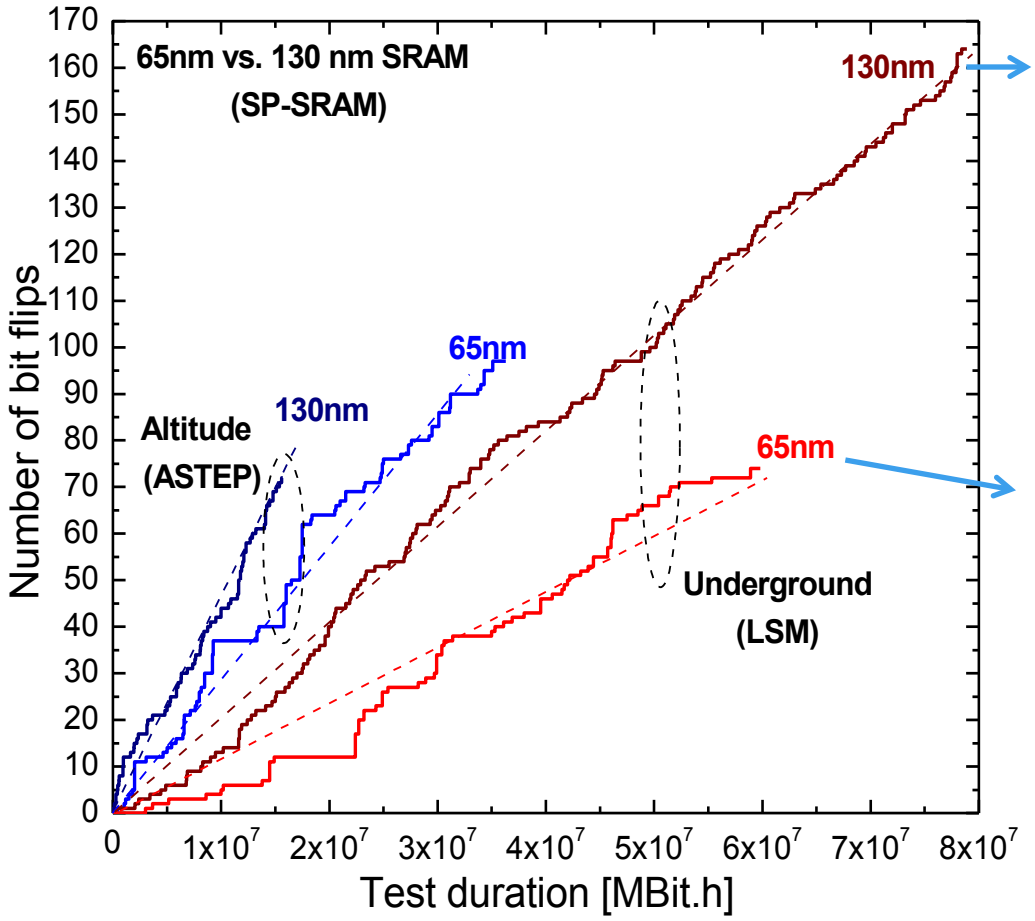
0.5 ppb of ^{238}U in Silicon
= 425 Bq/m^3
= 0.18 Bq/kg

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)*



Underground results for 130nm and 65nm SRAM technologies



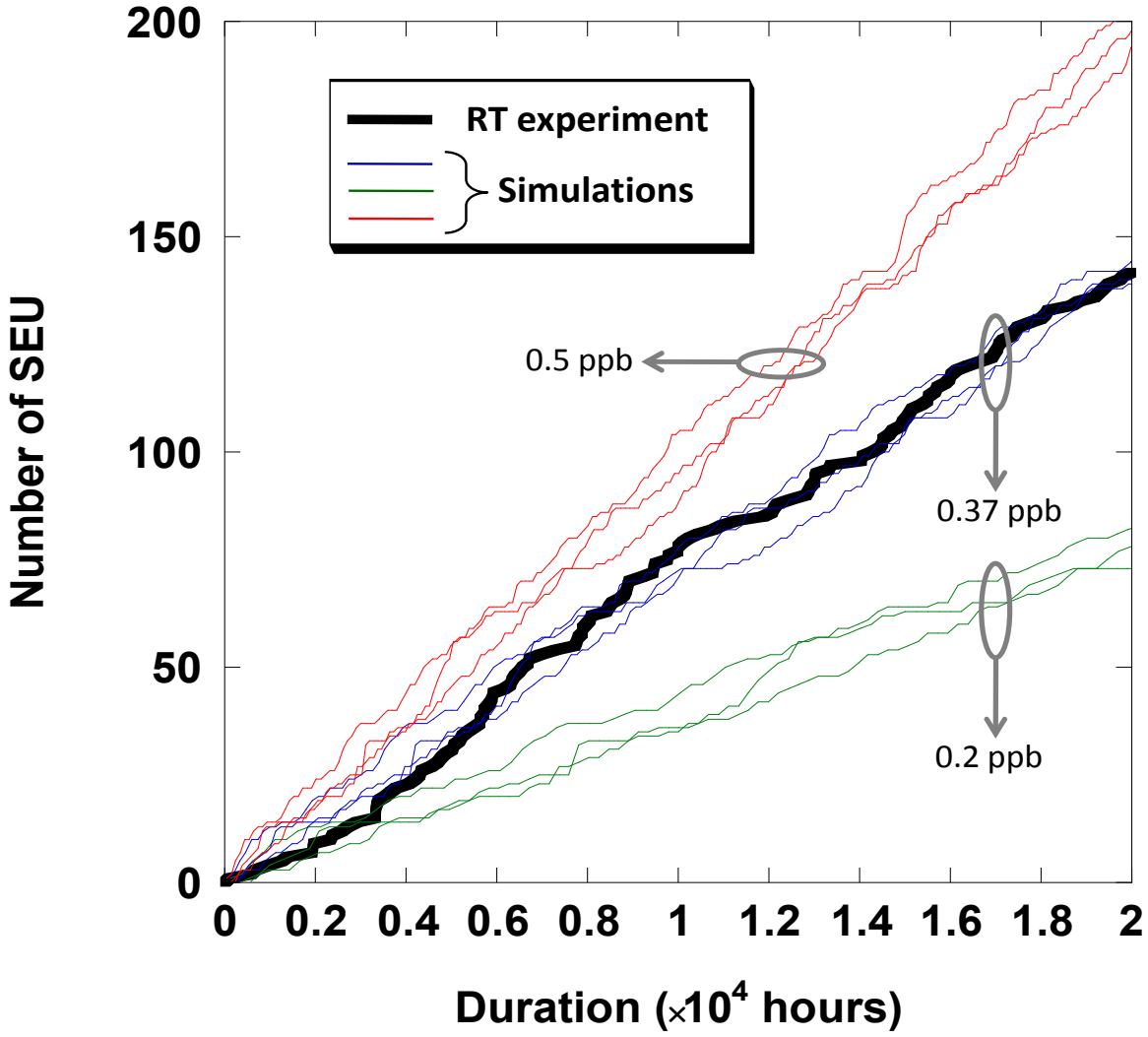
4×10^{-3} $\alpha/cm^2/h$

9×10^{-4} $\alpha/cm^2/h$

= result of a substantive work performed at technological process integration level (elimination of some materials subjected to alpha emitter contamination).

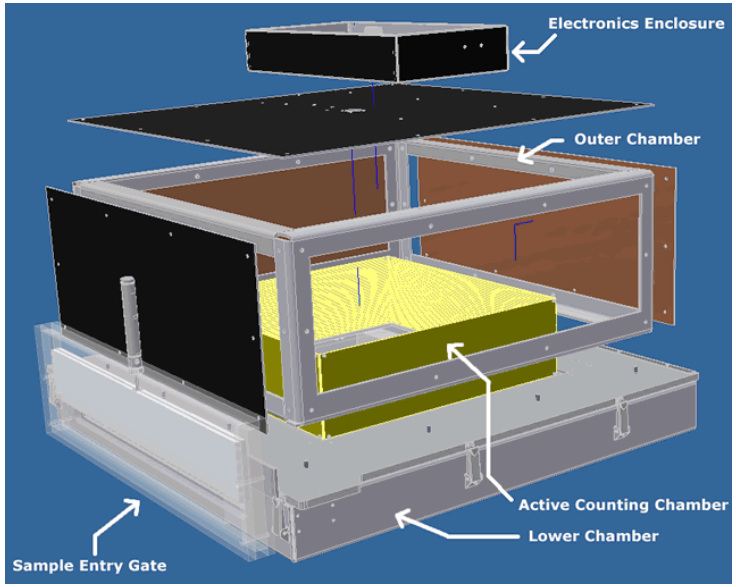
Monte-Carlo Simulation of Underground Experiments

- Up to 20,000 h of cave characterization
- α-SER reevaluated to 2079 FIT/MBit
- Monte-Carlo simulation gives a contamination level by ^{238}U impurities of 0.37 ppb
- Very good agreement with wafer-level characterization (alpha emissivity) in the range [0.2-0.5] ppb



Metrologic characterization of alpha-particle emissivity

❑ **In collaboration with XIA LLC (CA, USA), underground measurements at wafer-level using an ultra-low alpha-particle counter developed by XIA**



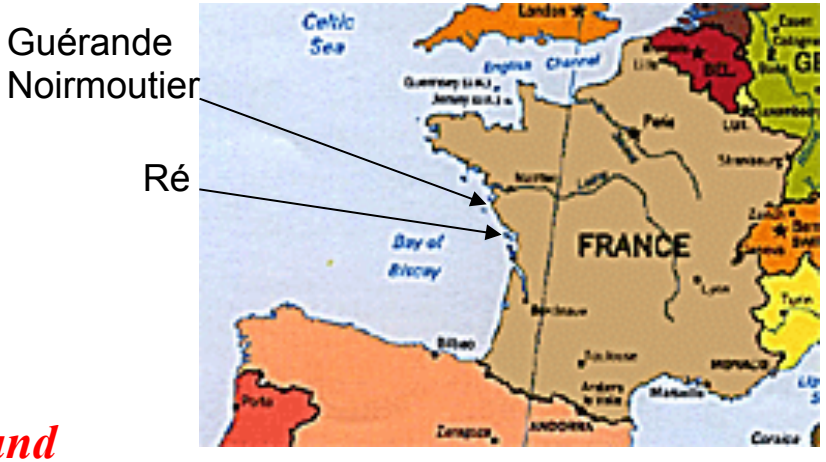
- Measure sample emissivities to **0.0001 /cm²/h** and below
- Large sample area - accepting samples up to **1800 cm²**

Applications of low-background gamma spectrometry techniques to sign the geographical origin of food-products

Frédéric PERROT, CENBG

First example: marine salts

Economical context:
french atlantic salts (Ré, Guérande, Noirmoutier) are protected by a quality control label



Question from the DGCCRF laboratory:

How to discriminate between french atlantic salts and others salts (mine, Mediterranean, Spain, Portugal…)?

Analysis of the mineral elements (Na, K, Ca, Mg…) done by the DGCCRF lab.

➡ No enough informations to discriminate between all the salts!

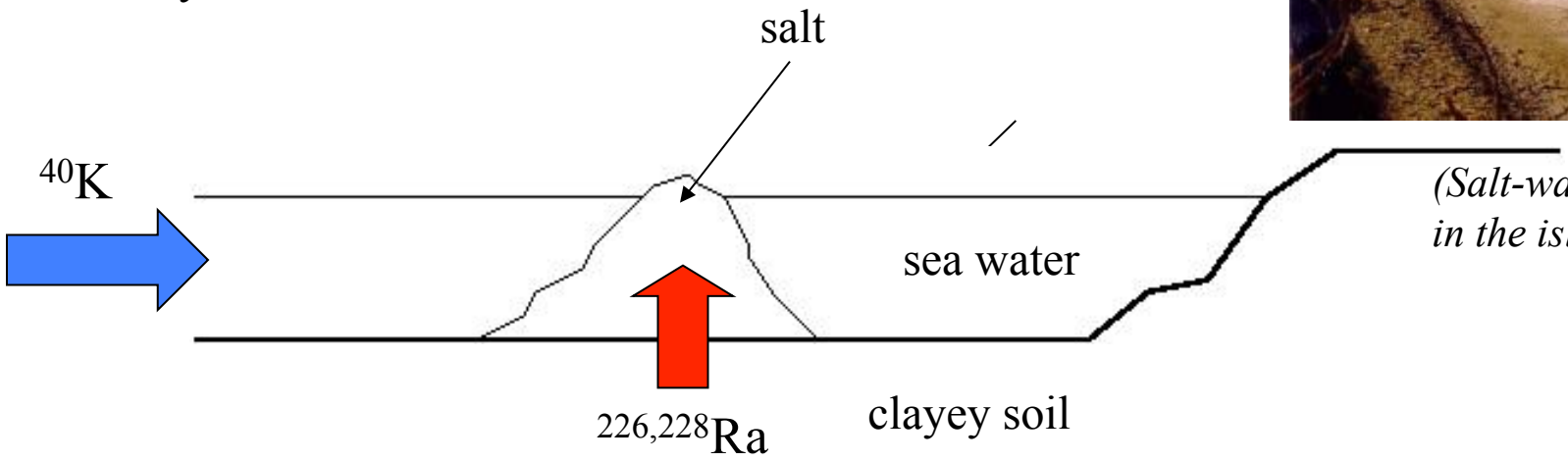
Could gamma radioactivity measurements bring complementary informations?

Possible origins of the radioactivity in the salts

(Salt-water fields in the island of Ré)

In sea water:

- 0.4 g/l for K^+ ions gives 13 Bq/l of ^{40}K: enough to explain the level of ^{40}K activity
- 1 or 2 mBq/l of ^{226}Ra: not enough to explain the level of ^{226}Ra activity

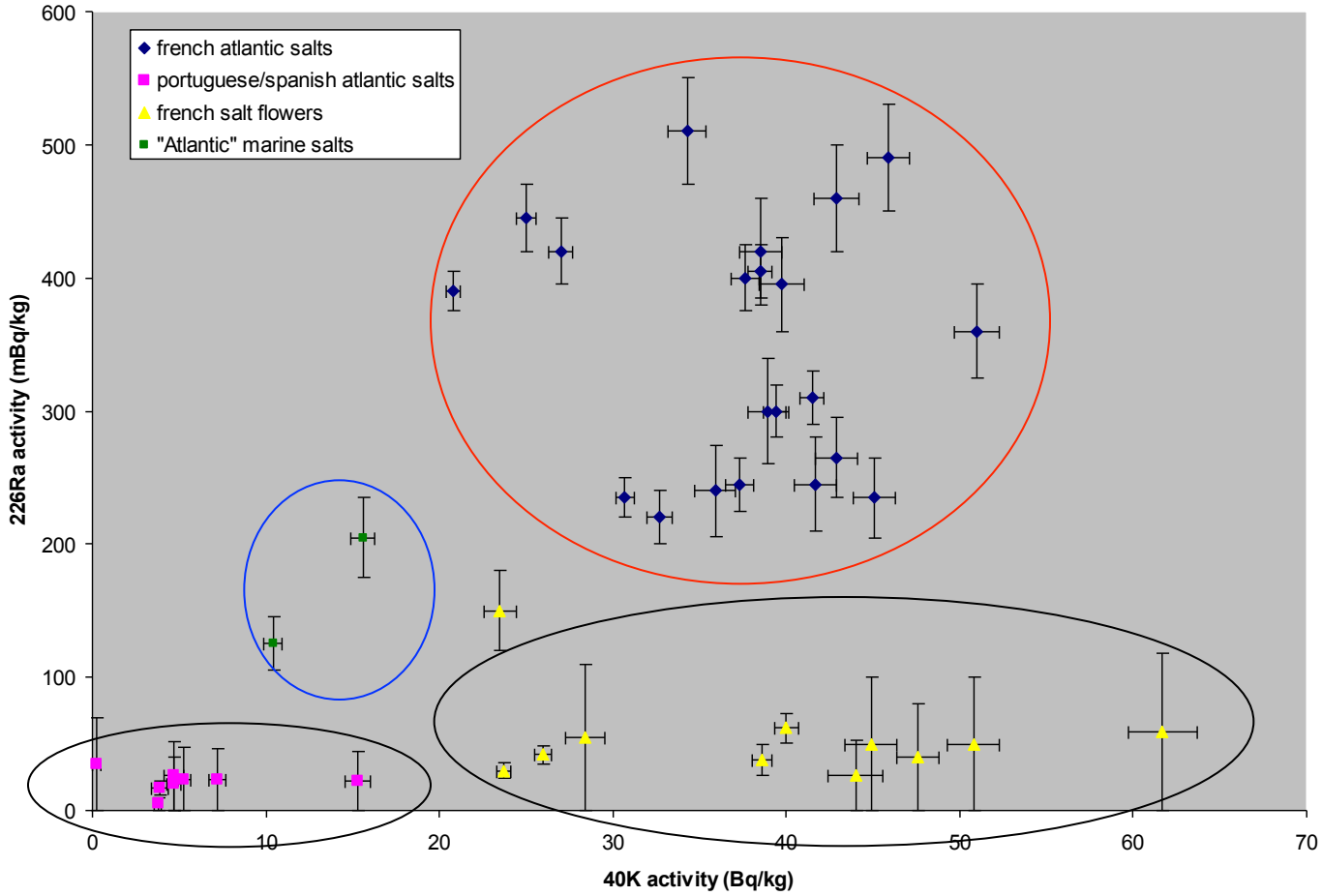


presence of radium isotopes in salts due to diffusion of $^{226,228}Ra$ from the soil to the salt

possible difference of level of radioactivity in clay from France to Portugal

In marine salts: « salt flowers » are most expensive and better taste for cooking

This salt is collected at the surface of the salt-marine fields



Wine datation by 137Cs measurement

Developed by Ph. Hubert (Centre d'etudes Nucleaires de Bordeaux-Gradignan)

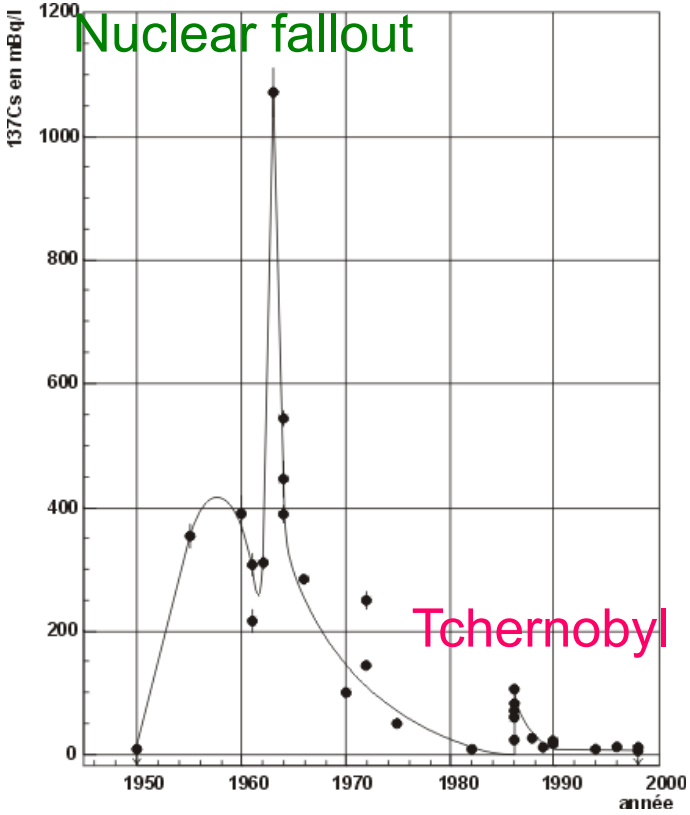
Châteaux

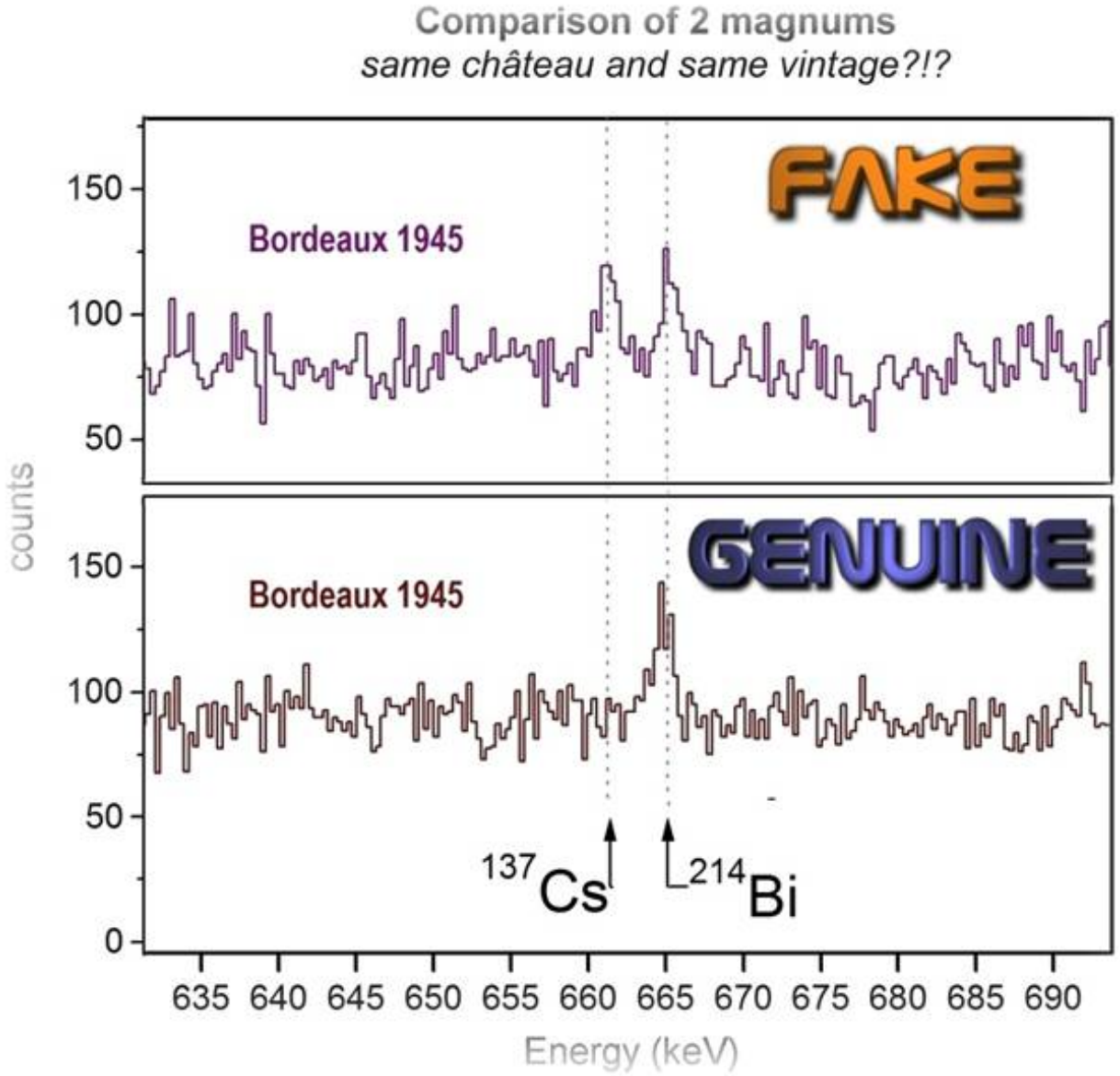
"Lafite"

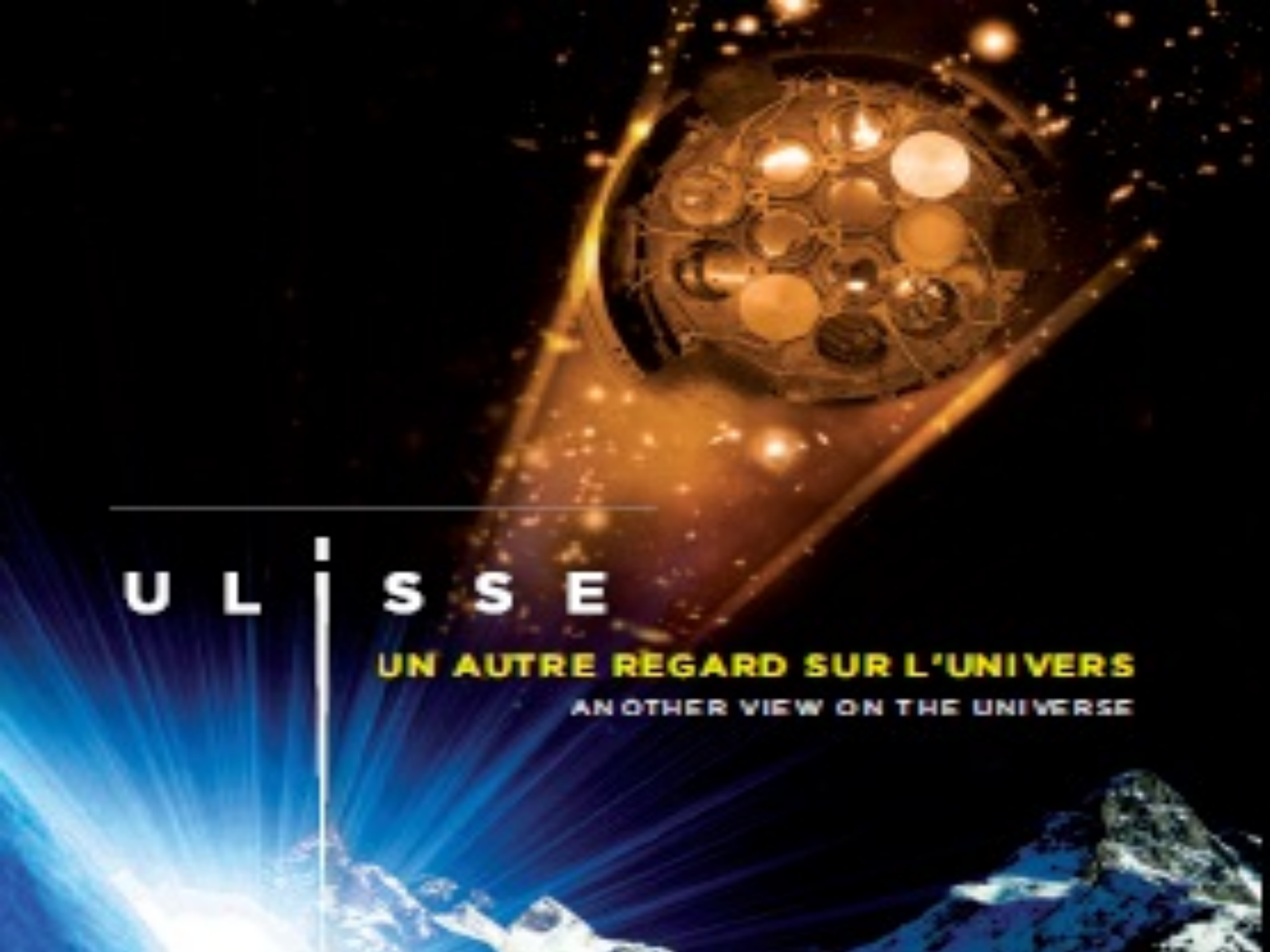
&

"Margaux"

1900 ?




Comparison of 2 magnums
same château and same vintage?!?
FAKE
Bordeaux 1945
GENUINE
Bordeaux 1945
counts
150
100
50
150
100
50
0
137Cs
214Bi
635 640 645 650 655 660 665 670 675 680 685 690
Energy (keV)


ULISSE
UN AUTRE REGARD SUR L'UNIVERS
ANOTHER VIEW ON THE UNIVERSE

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 (~30 years), certainly a large potential to welcome other sciences (How was able to predict at the time of Taup Experiement in LSM than 30 years later LSM will use to follow water columns in the ocean…)