Gamma spectrometry at LSM

Laboratoire Souterrain de Modane

From digging to modern experiments

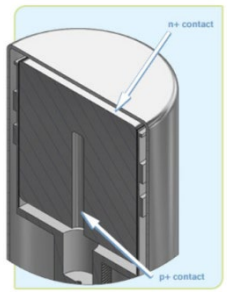
Low radioactivity constraints

- Requirement on material below mBq
- Strong pressure on analytical capabilities
- Increased number of pieces and longer time
- Main measurement performed by gamma ray spectrometry
- Constant effort took place in LSM to develop ultra low background germanium
- Hosting 22 HPGe by 2020
- 19 effectively in shield

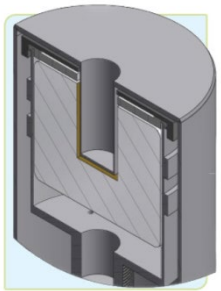
High purity germanium

- Semi conductor crystal cooled down to 77 K
- Sample at room temperature
- Sensitive to gammas from 20keV up to 3MeV
- Non destructive measurement
- Sensitive to muons and cosmic activation
- Different detectors adapted to samples shape

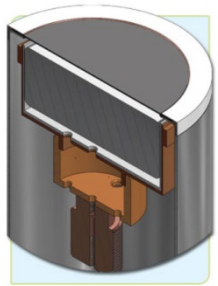
Coax

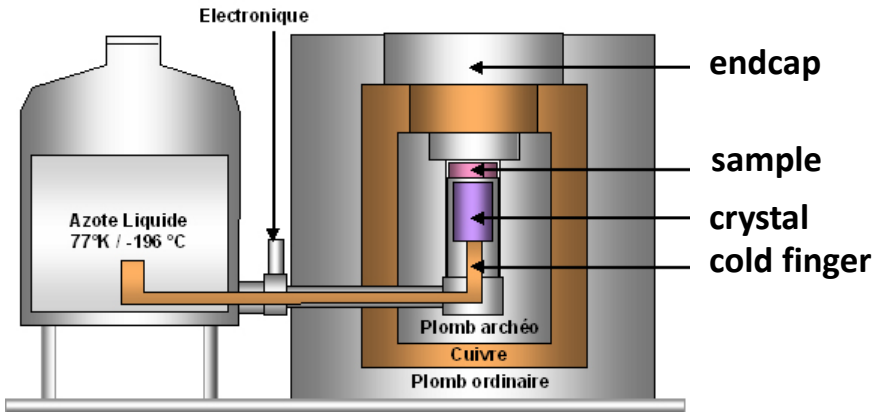


Well



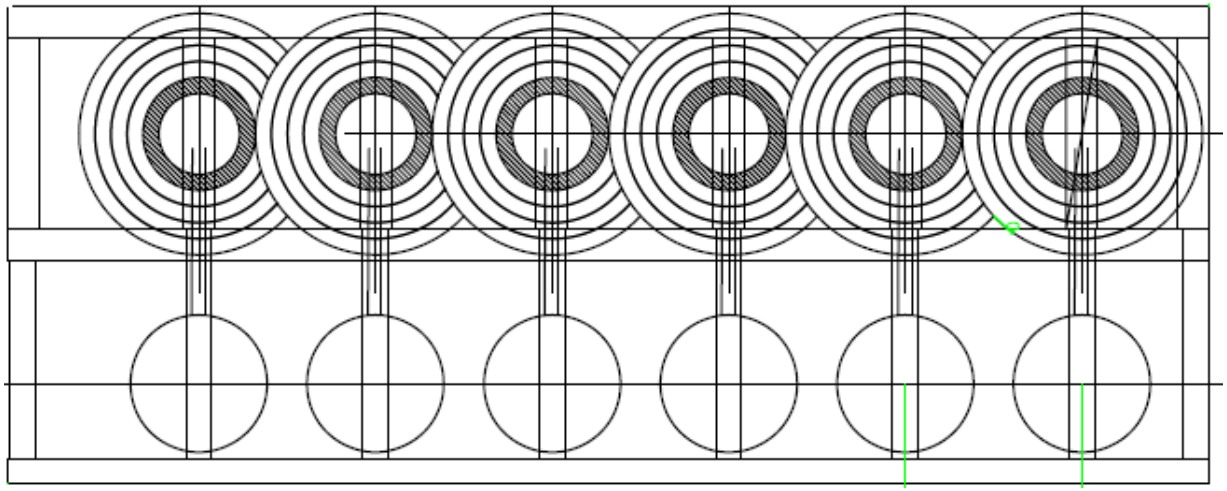
Planar





Future of measurement at LSM

- PARTAGe project
  - Combining shields in common walls

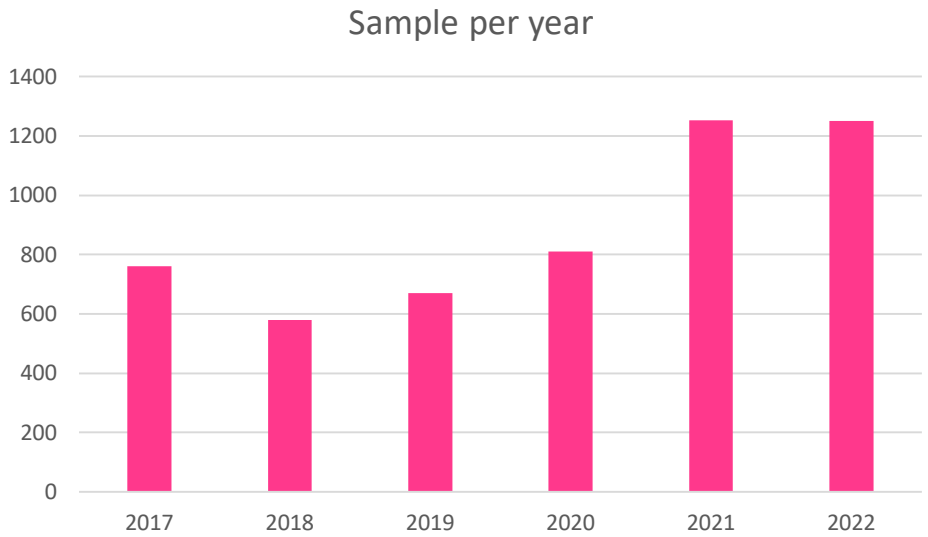


- Robotisation
- Optimisation of measurement time based on the radiopurity objectives

Shielding in progress

Measurement

- Increasing number of sample through years
- Sample coming from 9 different institutions



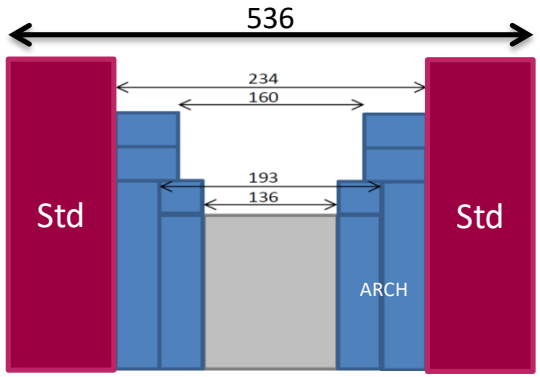
Germanium facility

- Example of detection limits

Mafalda : (our swiss army knife)

- Size 150 cc – 43,1%
  - Φ 80mm h 31,7mm
- Resolution
  - 122 keV 920 eV
  - 1,33MeV 1,97keV
- Background
  - Integral 115±3,5 count/day
  - 133 c/kg
  - Peaks
  - 46,5 keV 1,49 ± 0,37 c/d [210Pb]
  - 75 keV 3,6 ± 0,62c/d [Pb]

Shielding

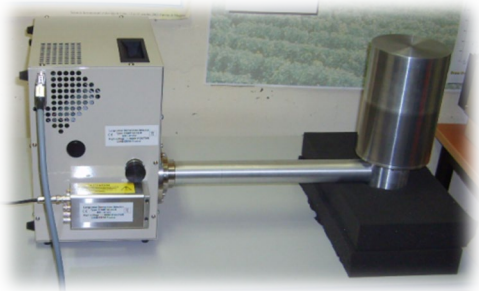


Silicon wafer measurement
700 000s 650g

Nucleide		Bq/kg
210Pb	<	1,58E-02
^{226}Ra	<	1,27E-03
238U	<	6,27E-03
228Ra	<	3,82E-03
228Th	<	8,66E-04

$$\text{limit (Bq)} = \frac{1{,}43 + 2{,}36\sqrt{1{,}36 + bdf \times t}}{\varepsilon(m)\, m\, t}$$

$$\varepsilon = \frac{detected}{emitted}$$



Germanium facility

- Improving detection limit :
  - Imply choices :

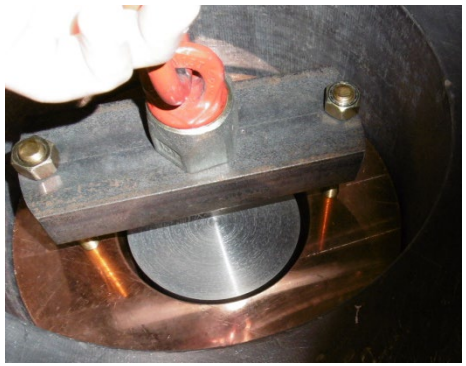
This detector can welcome much bigger sample but the low energy gamma are stopped by the dead layer around the detector.

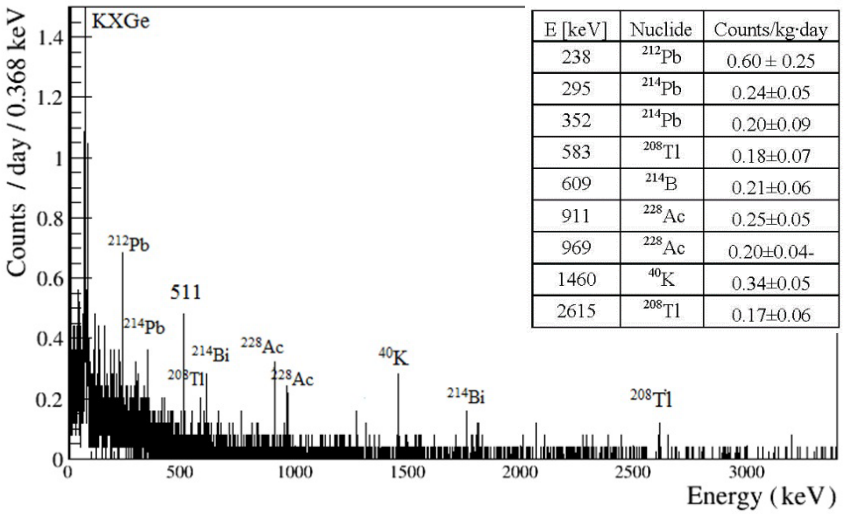
Theoretical sample of 1kg for 500000s

Nucleide		Bq/kg
210Pb		NA
^{226}Ra	<	4,96^{E}-4
238U		NA
228Ra	<	1,78E-03
228Th	<	4,37E-04

Obélix :

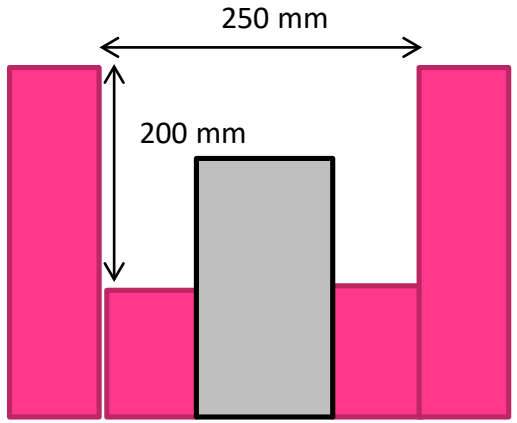
- Size
  - 600cc-160%
- Background
  - 95 counts/kg.d
- Resolution
  - 122 keV 1,1 keV
  - 1,33MeV 2keV



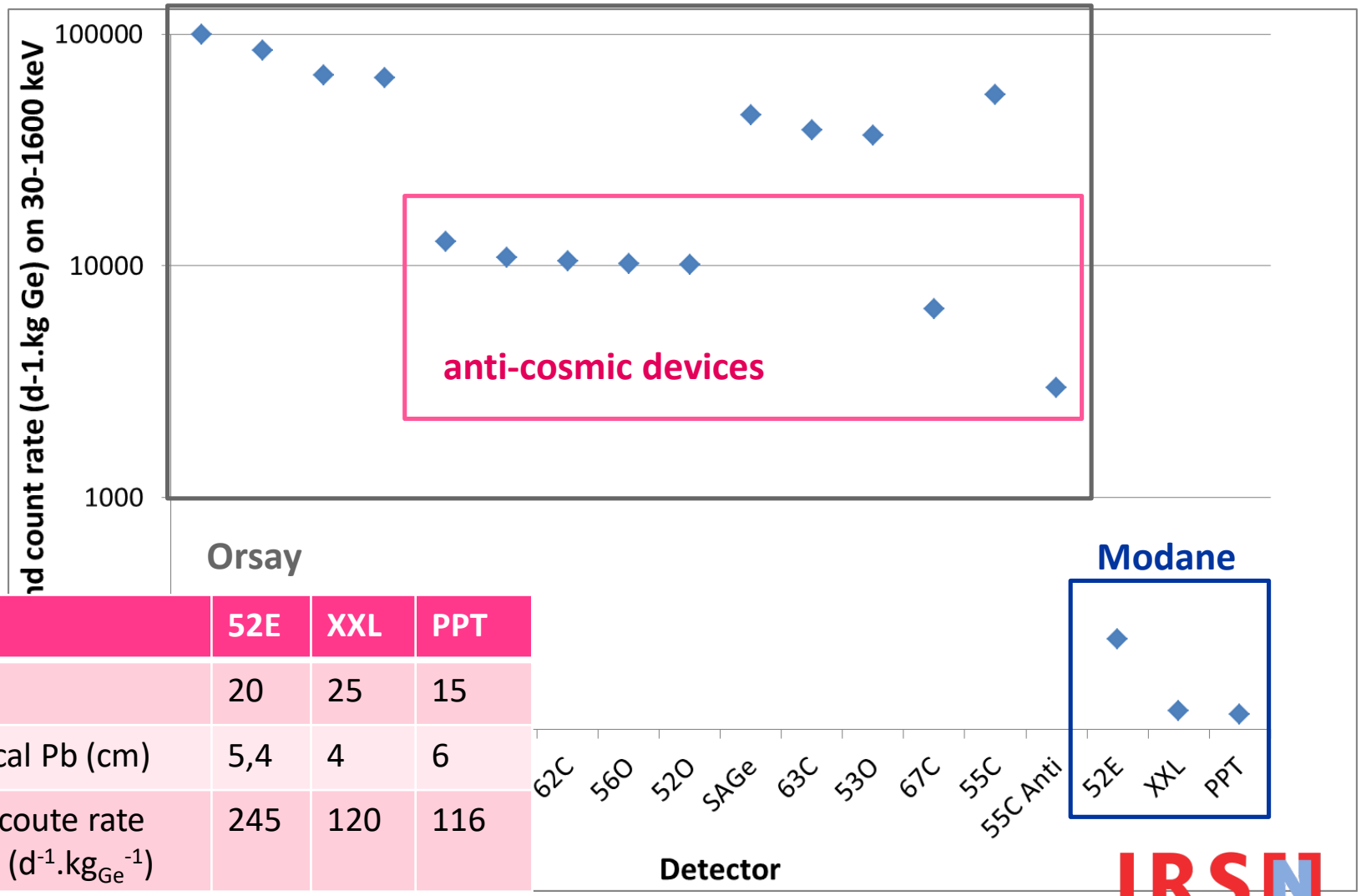


E [keV]	Nuclide	Counts/kg·day
238	^{212}Pb	0.60 ± 0.25
295	^{214}Pb	0.24±0.05
352	^{214}Pb	0.20±0.09
583	^{208}Tl	0.18±0.07
609	^{214}B	0.21±0.06
911	^{228}Ac	0.25±0.05
969	^{228}Ac	0.20±0.04-
1460	^{40}K	0.34±0.05
2615	^{208}Tl	0.17±0.06

Sample Chamber



IRSN



	52E	XXL	PPT
Pb (cm)	20	25	15
Archeologiocal Pb (cm)	5,4	4	6
Background coute rate 30-1600 keV ($d^{-1}.kg_{Ge}^{-1}$)	245	120	116

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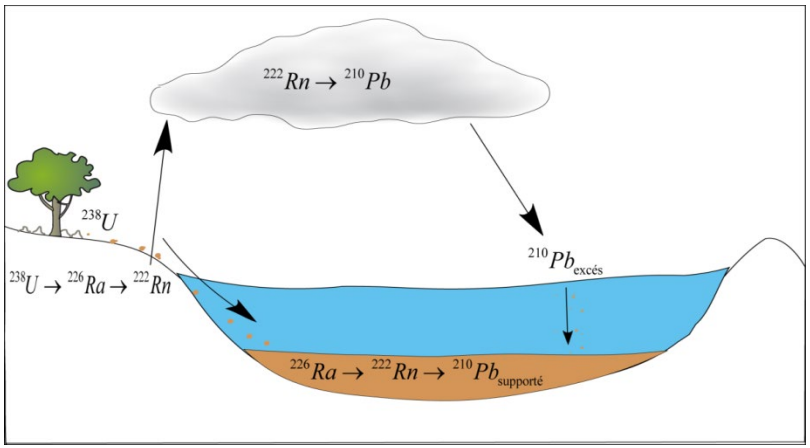
Analitycal power for interdiciplinarity

- High counting statistic 1 sample/day
- Used in many environmental datation

Relative datation



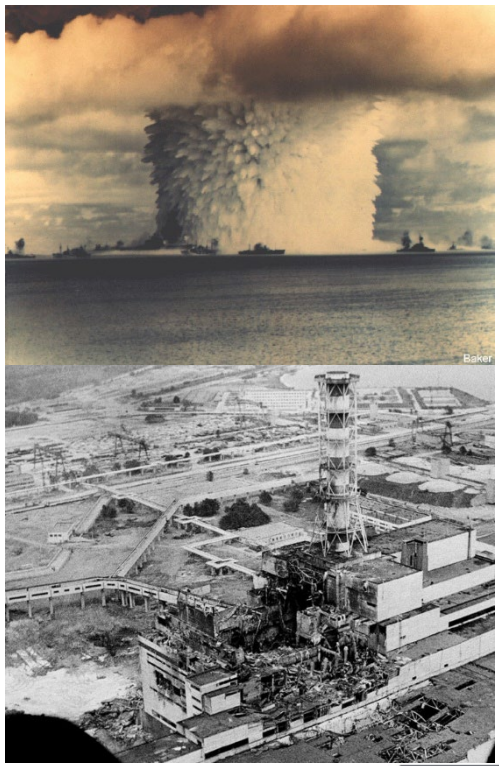
$$(^{210}Pb)^{t}_{ex} = (^{210}Pb)^{0}_{ex} \times e^{-\lambda t}$$

$$Ln(^{210}Pb)^{t}_{ex} = -\lambda \frac{z}{V} + Ln(^{210}Pb)^{0}_{ex}$$

Absolute datation

^{137}Cs + ^{241}Am
1963

^{137}Cs only
1986



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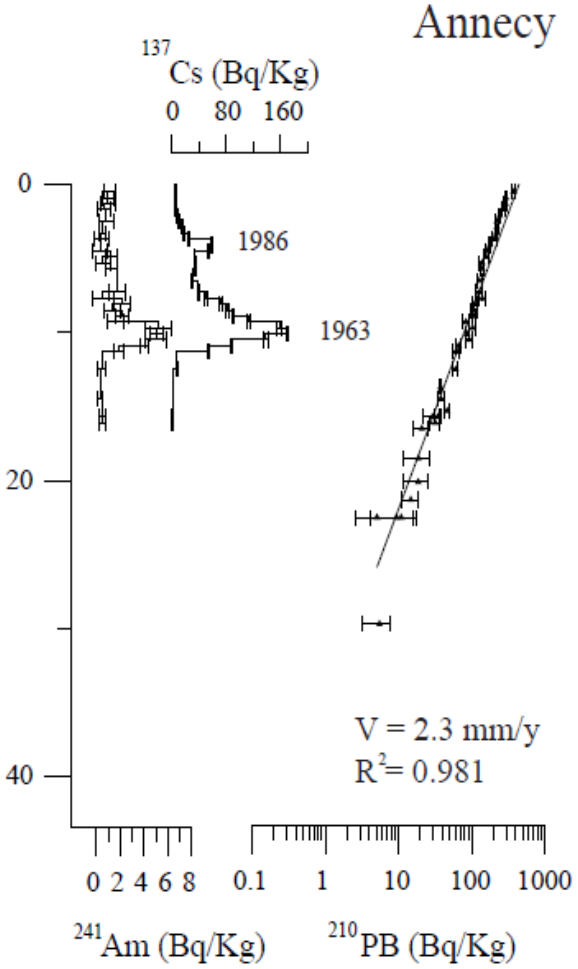
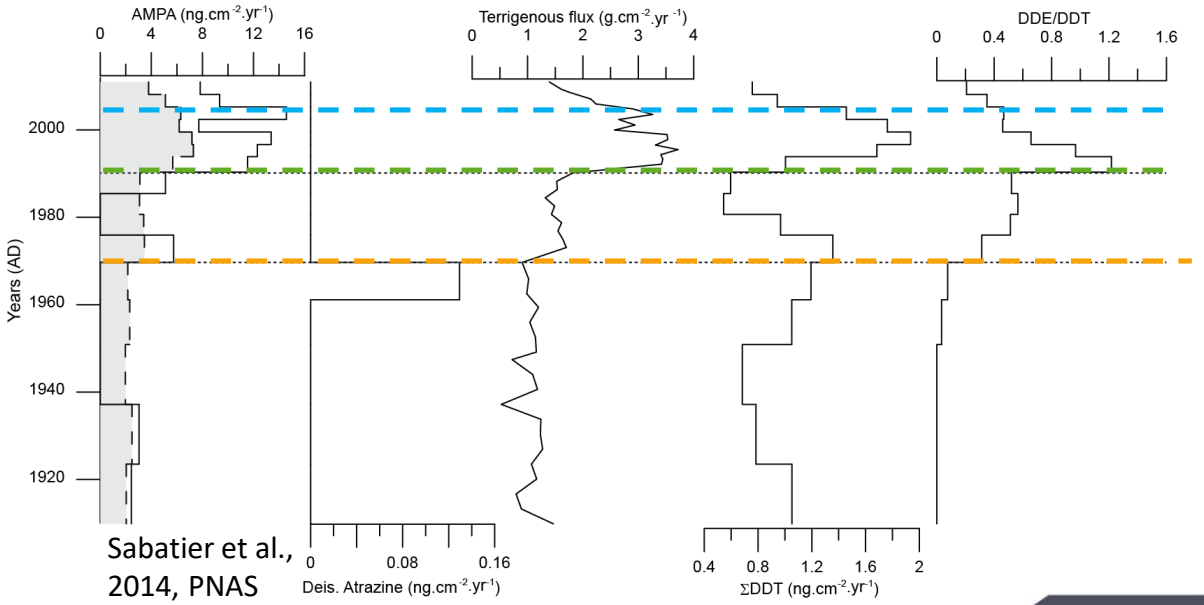
Lake survey

- 210Pb gives the sedimentation rate

tificials nucleides

nstruct the history of a lake without archives





Sabatier et al., 2014, PNAS

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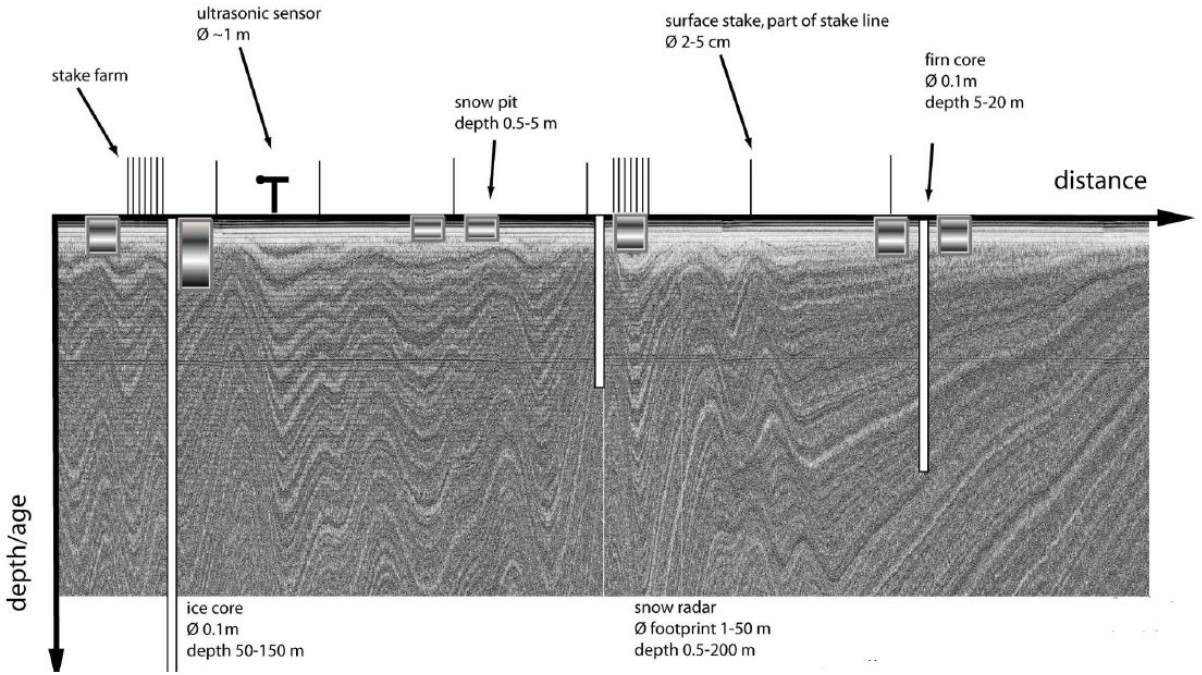
laboratoire edytem environnements dynamiques territoires montagnes

Ice survey

- Datation of ice core in antartica
- Calibration of radar
- Temporal marker for climate change
- 2 days measure needed in underground lab



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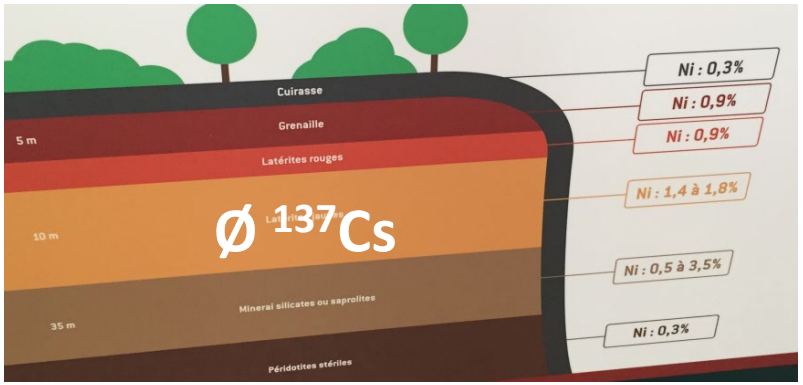
Erosion survey

Sources of sediment in mining catchments of New Caledonia

Two main sources of sediment to the main river

Non-mining tributaries

Mining tributaries



- Discrimination of contributions of both types of tributaries based on their activities in natural/artificial radionuclides
- Quantification using mixing models
- Analysis of sediment cores collected in the delta to reconstruct changes in source contributions with time

O. Evrard et al; Geophysical Research Abstracts. Vol. 18, EGU2016-7155, 2016

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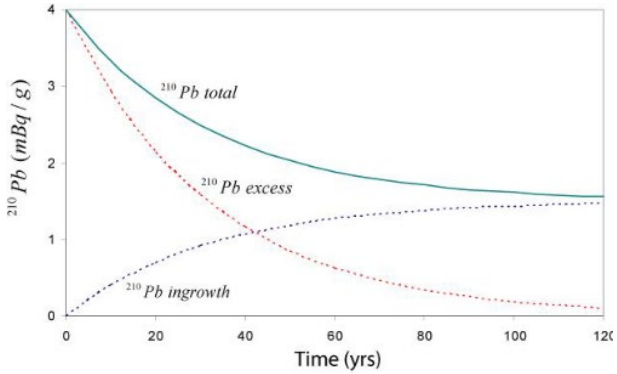
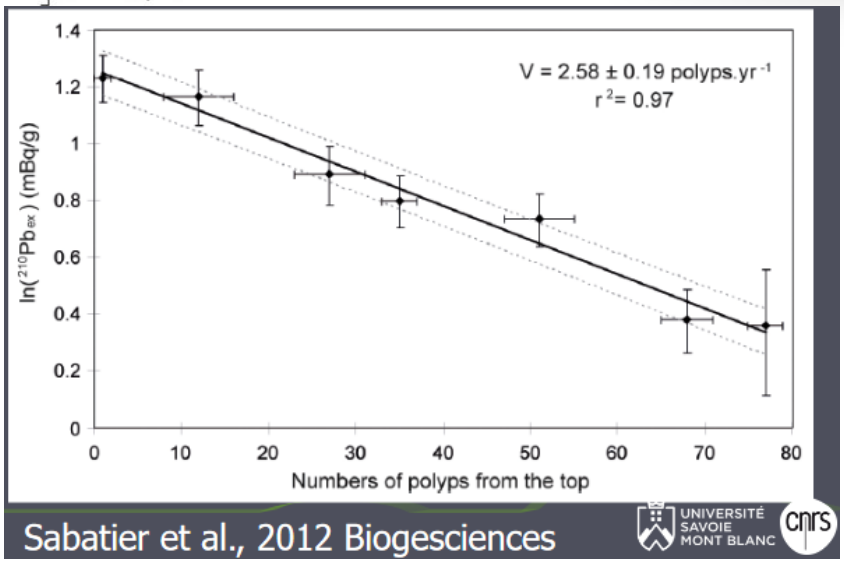
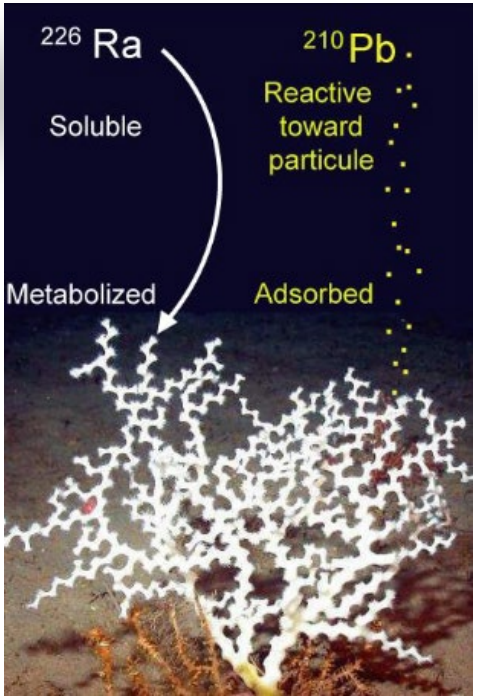
Coral datation

- Datation through 210Pb excess



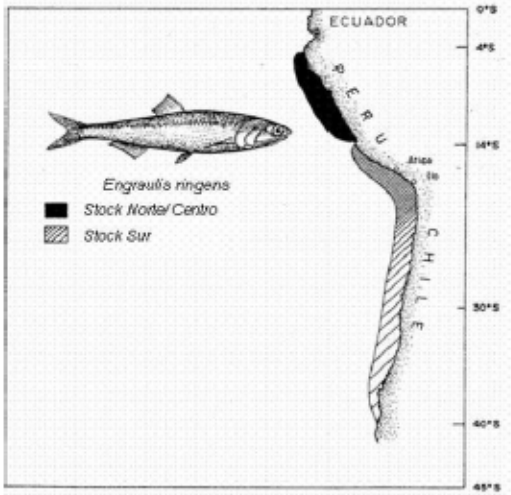
$$(^{210}Pb)_{total} = (^{226}Ra)\left[1 - e^{-\lambda_{210} * t}\right] + (^{210}Pb)_0 \times e^{-\lambda_{210} * t}$$





Anchovy/Sardine population recorded in carots

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



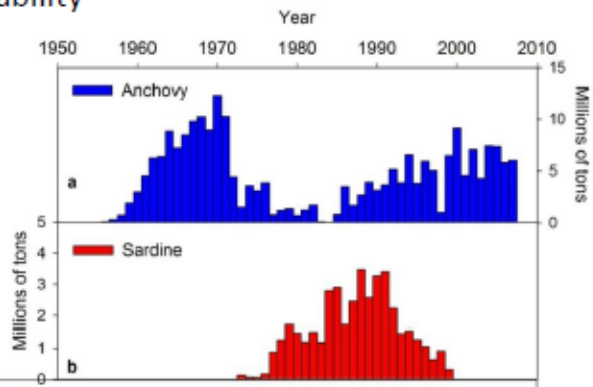
-Continuous coastal upwelling throughout the year

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

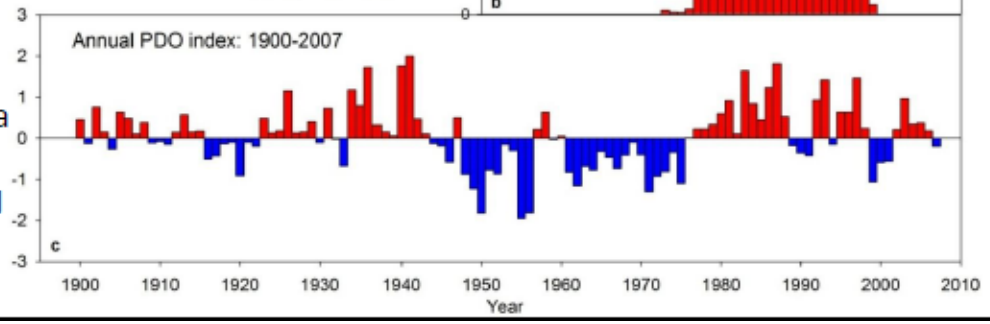
-Anchovy and sardine landings show strong annual and decadal biomass variability

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).



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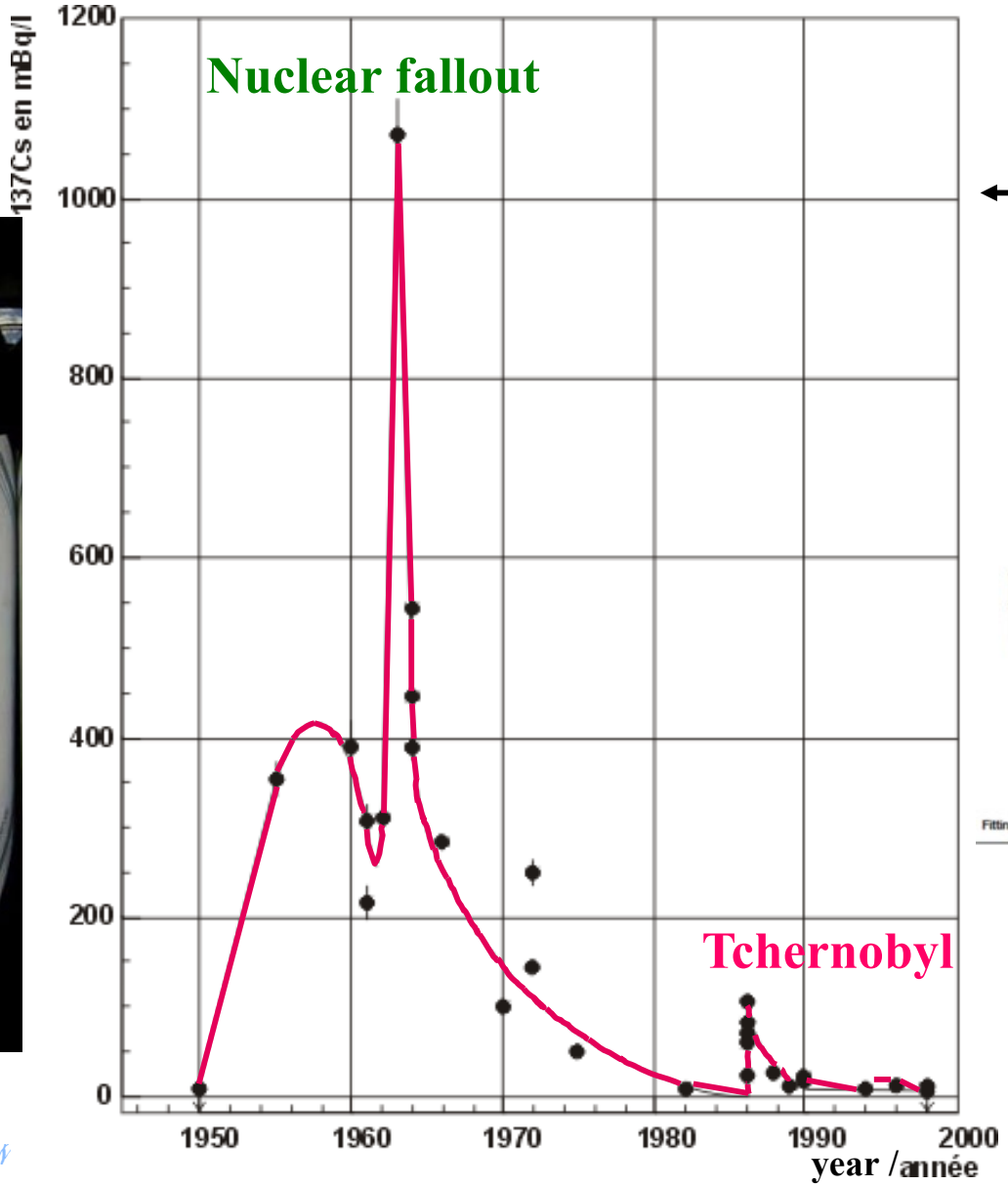
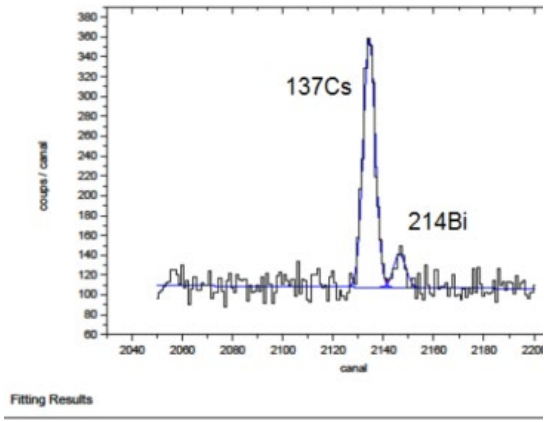
Millesime identification



← **1 Bq/l**

Margaux 1900
?



Guillaume W

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Possibility of interdisciplinary research

Conclusion

- LSM was designed for large scale fundamental physics
- Leaves room for interdisciplinary program at moderate cost
- New fields and discoveries made possible by the access to low level radiation environment