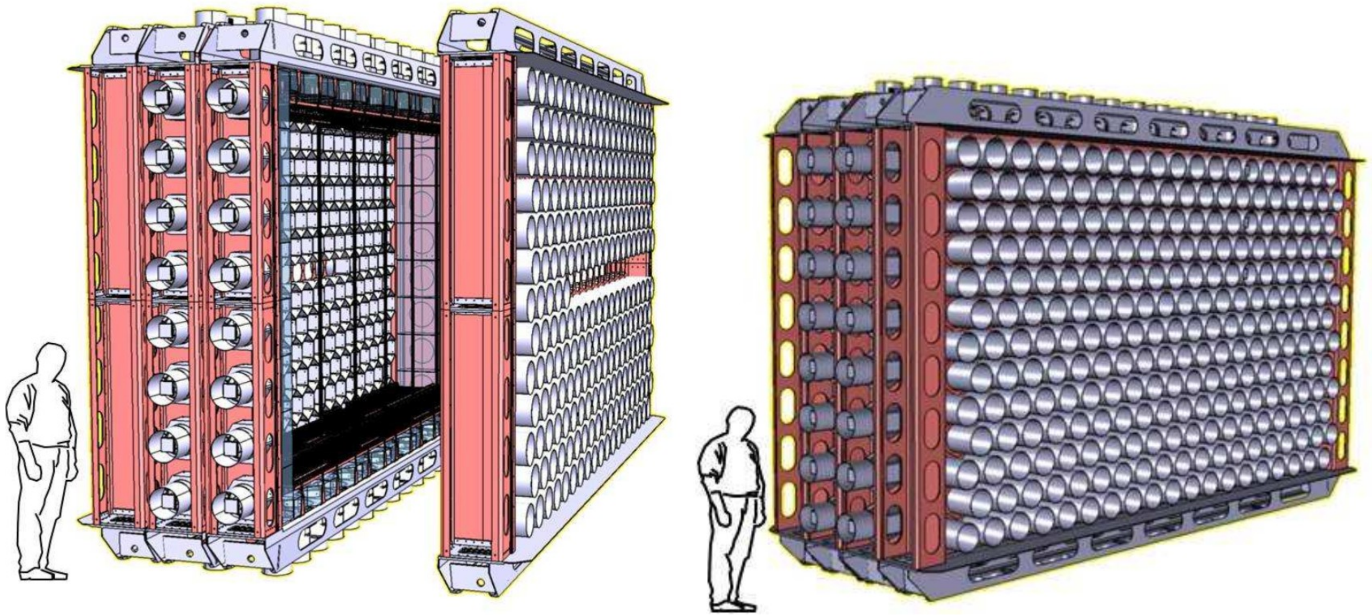
The SuperNEMO experiment



Hugon Christophe
Université Aix-Marseille, CPPM, IN2P3/CNRS
on behalf of the SuperNEMO collaboration

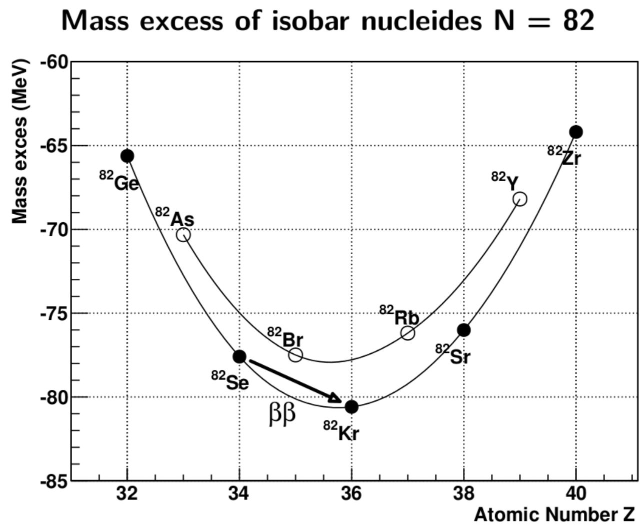
supernemo collaboration

cnrs advancing the frontiers

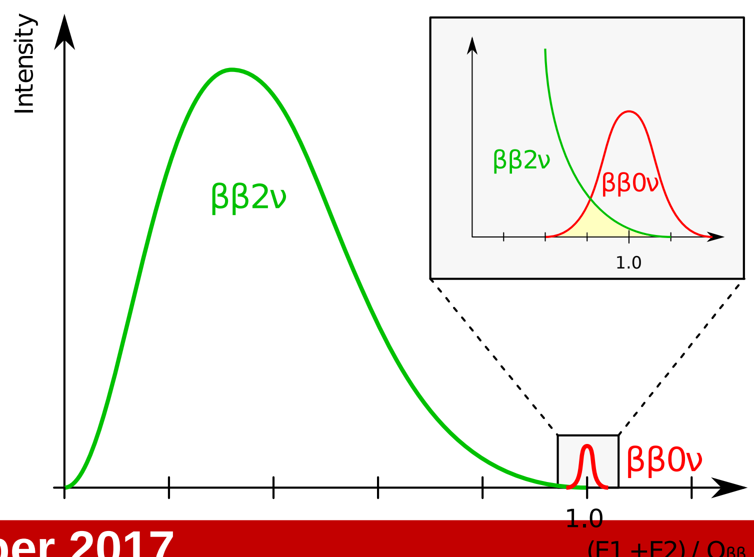
Aix*Marseille université

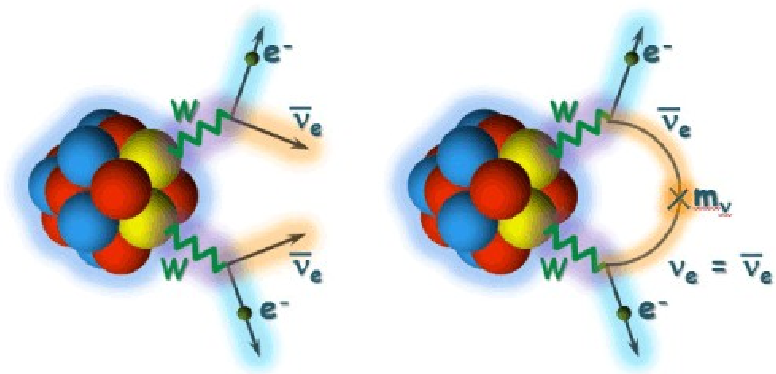
CENTRE DE PHYSIQUE DES PARTICULES DE MARSEILLE CPPM

The double beta decay



For some isotopes as the ^{82}Se only the ββ decay is allowed





Gives an access to 3 fundamental informations

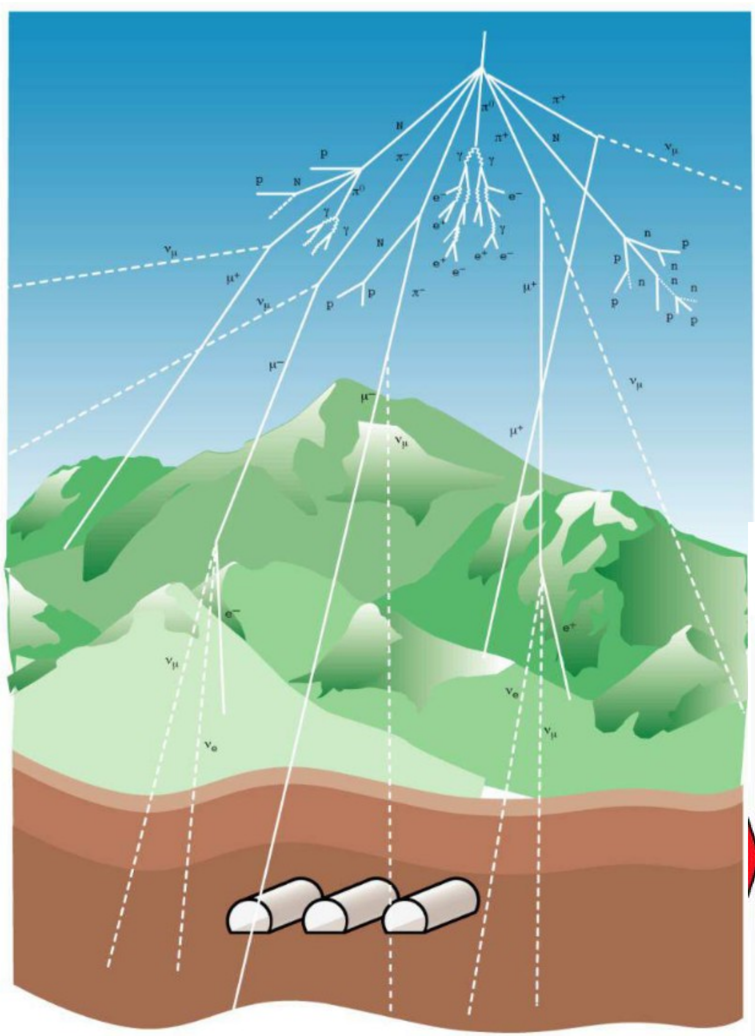
- Neutrino nature (Dirac or Majorana)
- Effective mass ν_{ee}
- Neutrino mass hierarchy

The both decays have a different energy spectrum and a very long lifetime, for ^{82}Se:

- $T_{1/2}(2\beta 2\nu) = 10^{19}$ years
- $T_{1/2}(2\beta 0\nu) > 10^{24}$ years

$$T^{1/2}(2\beta 0\nu) \propto \frac{1}{|M|^2 |m_{\beta\beta}|^2}$$

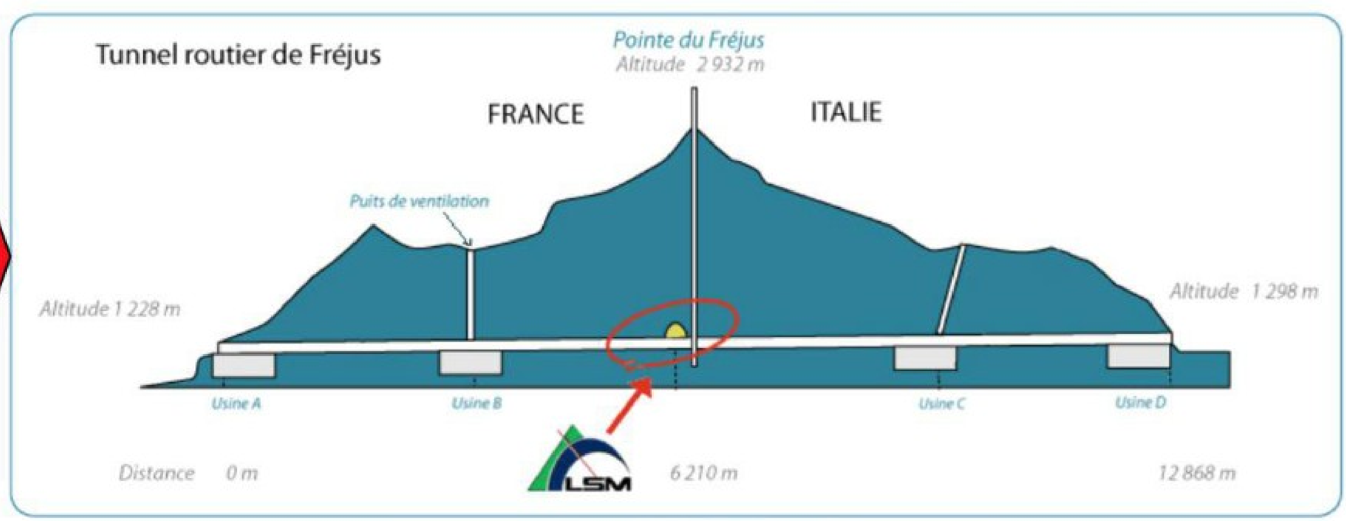
Underground laboratories and muon flux



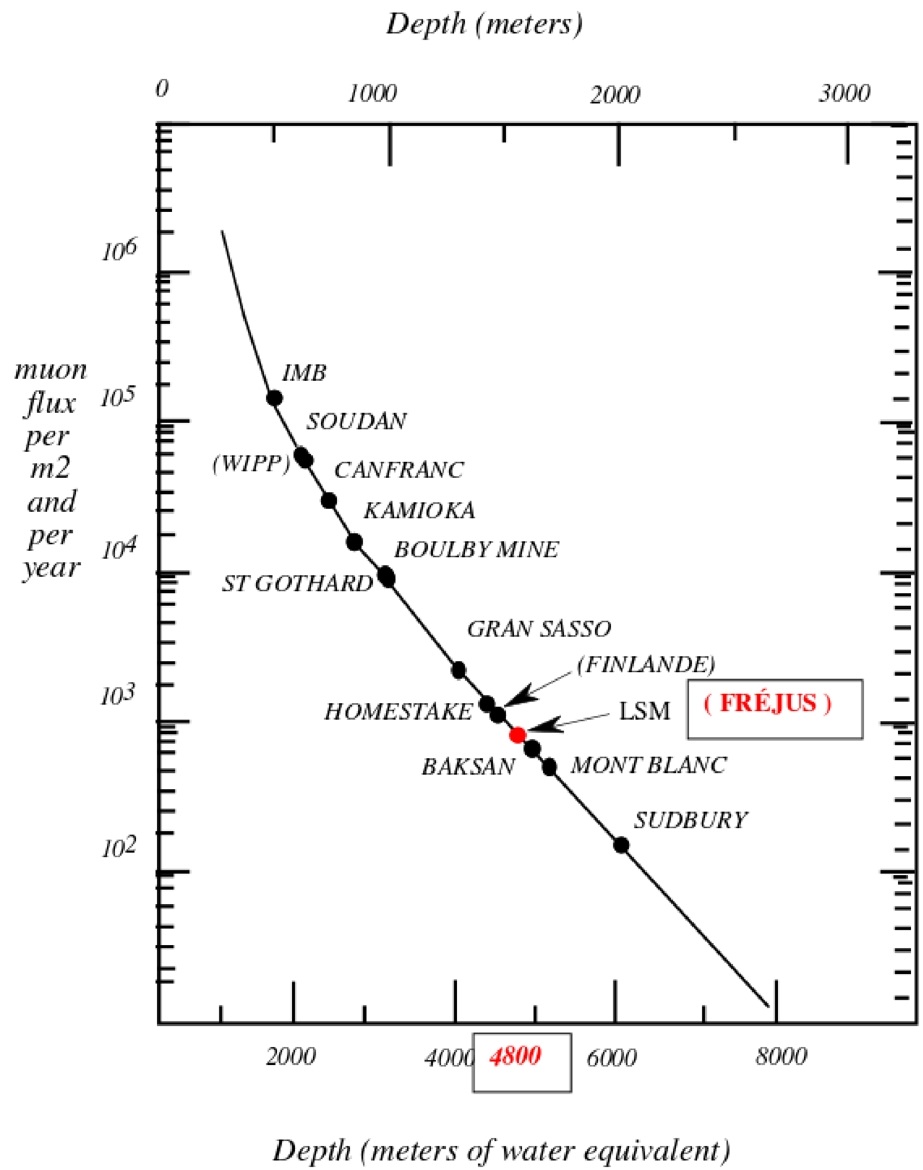
- Very rare events → needs a very low background
- “Laboratoire souterrain de Modane”
  - In the frejus tunnel
  - Dug in 1983 for the proton decay research
  - 1700 m underground, 4800 m MWE

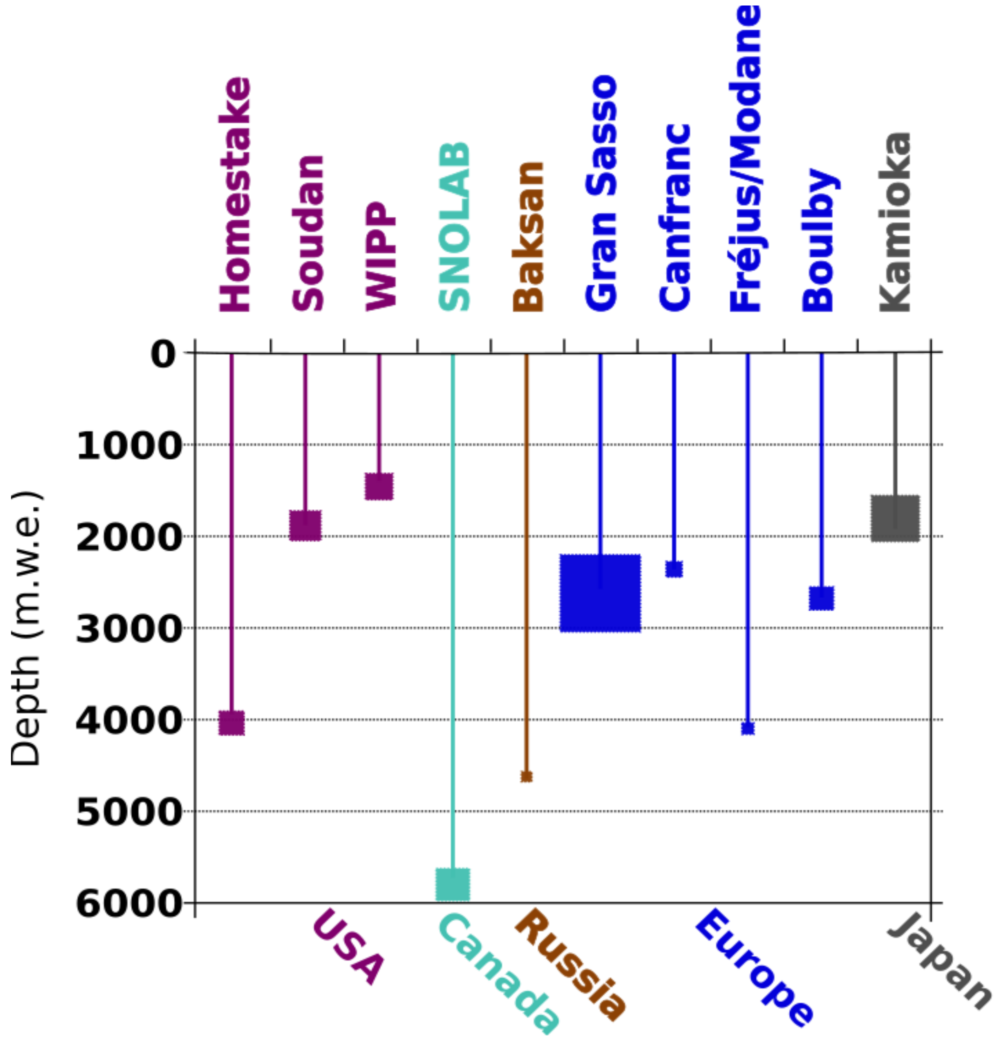
Reduction of muon flux by a factor of 10^6

Laboratoire Souterrain de Modane (LSM) : 4800 M.W.E.



Underground laboratories and muon flux



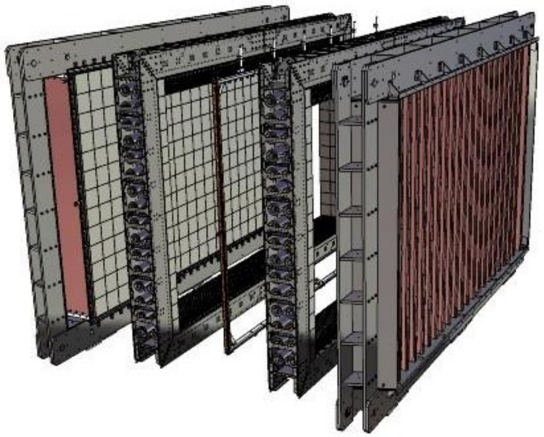


Deepest in Europe

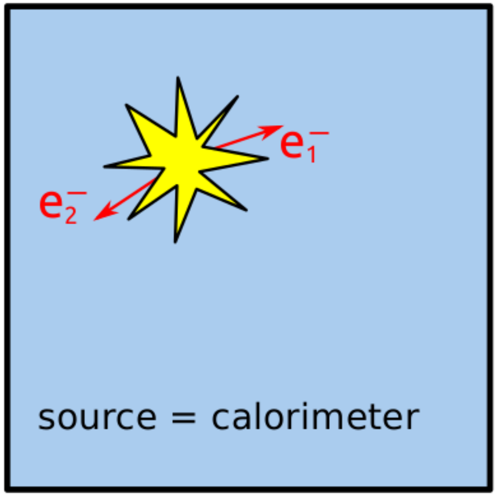
The SuperNEMO international collaboration

The calorimetry/tracking technology From NEMO-3 to SuperNEMO

NEMO-3 (2003 - 2011)



SuperNEMO démonstrateur (≥ 2016)



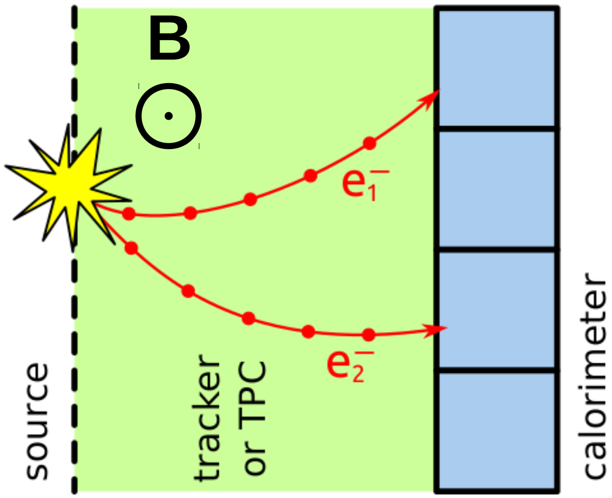
→ GERDA, KamLAND-Zen, CUORE, ...

The calorimetry/tracking technology

- Has a lower efficiency
- Poor energy resolution (8%@1MeV for SuperNEMO)

But

- It has a good electron identification and ββ kinematics
- It can identify other particles ($\alpha, \gamma, \beta^+, \beta^-$)
- It can be multi-sources
- Background identification an rejection
- Multi-channel study ββ0ν, ββ2ν, ββ*, ...



→ EXO, NEMO-3, SuperNEMO

Background identification

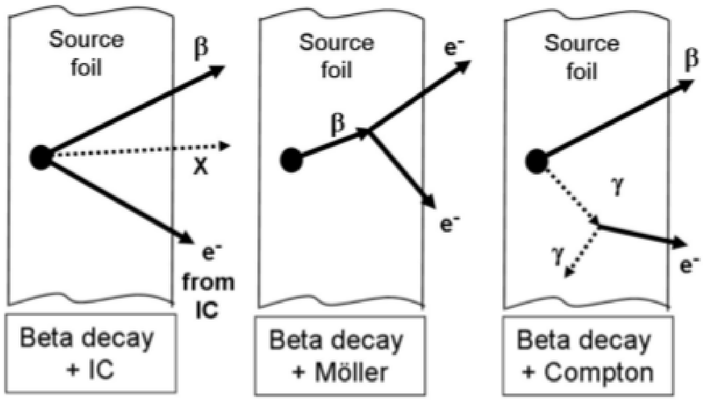
The Background noise: Internal background

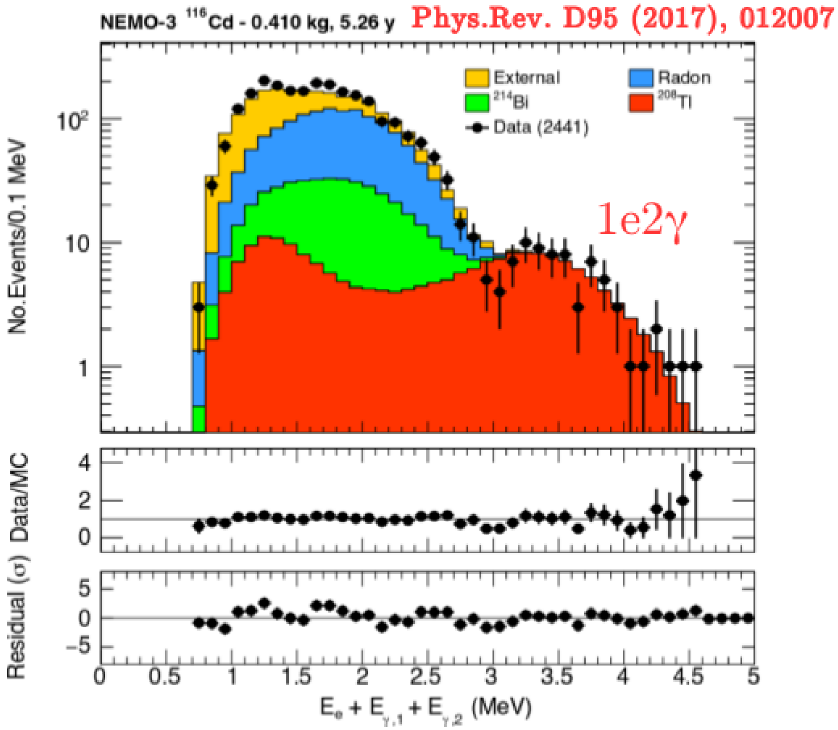
Regroups the backgrounds coming from the source foil, mainly come from :

- Radio-impurities inside the source foil
  - ^{208}Tl (from ^{232}Th), ^{214}Bi (from ^{238}U)
  - Single beta emitter (^{40}K, ^{234m}Pa, ^{210}Bi)
- ^{214}Bi from radon decay in tracker volume

Backgrounds are measured through different background channels using event topologies

- ^{208}Tl in 1e1γ, 1e2γ and 1e3γ
- ^{40}K, ^{210}Bi, ^{234m}Pa in 1e channel
- ^{210}Bi, ^{222}Rn in 1e1α and 1e1γ channel





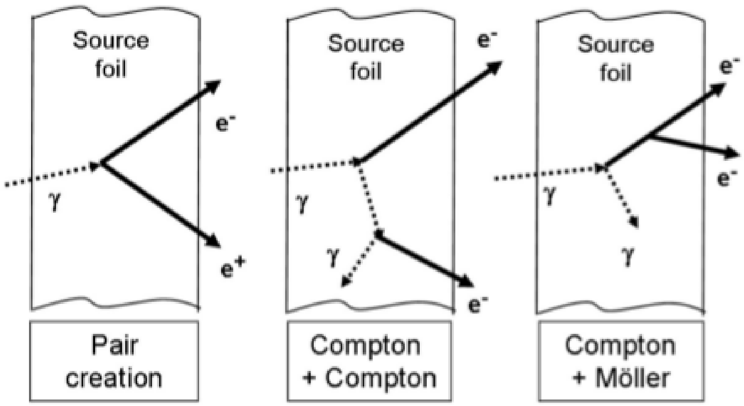
Example: Internal Background from NEMO-3 (^{116}Cd)

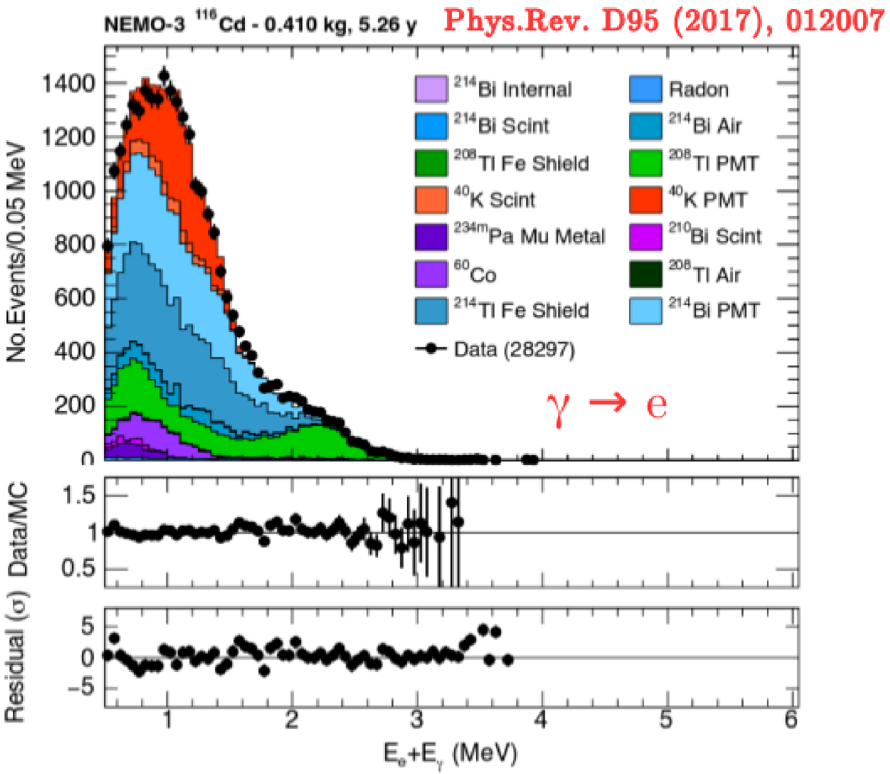
The background noise: External background

- Regroups the backgrounds not coming from the source foil, come from :
- Radio-impurities in detector material (208 Tl, 214 Bi)

- γ from (n,γ) reactions
- μ from Bremsstrahlung

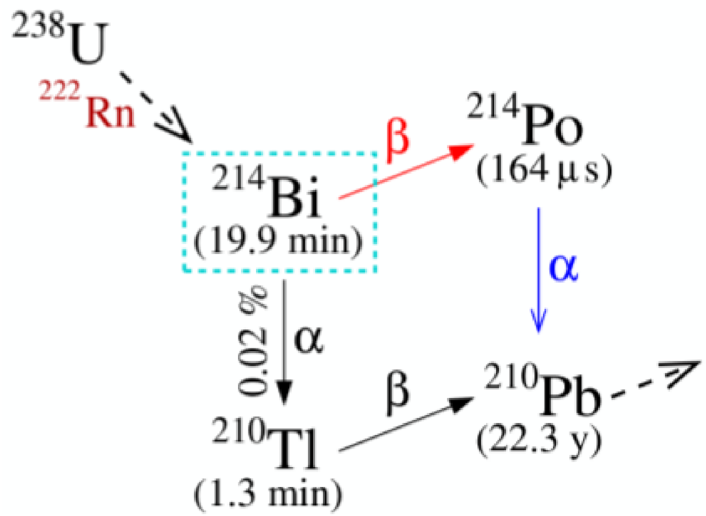
- Are measured in 2 main channels, requiring the timing informations :
  - external crossing electron
  - external γ → e



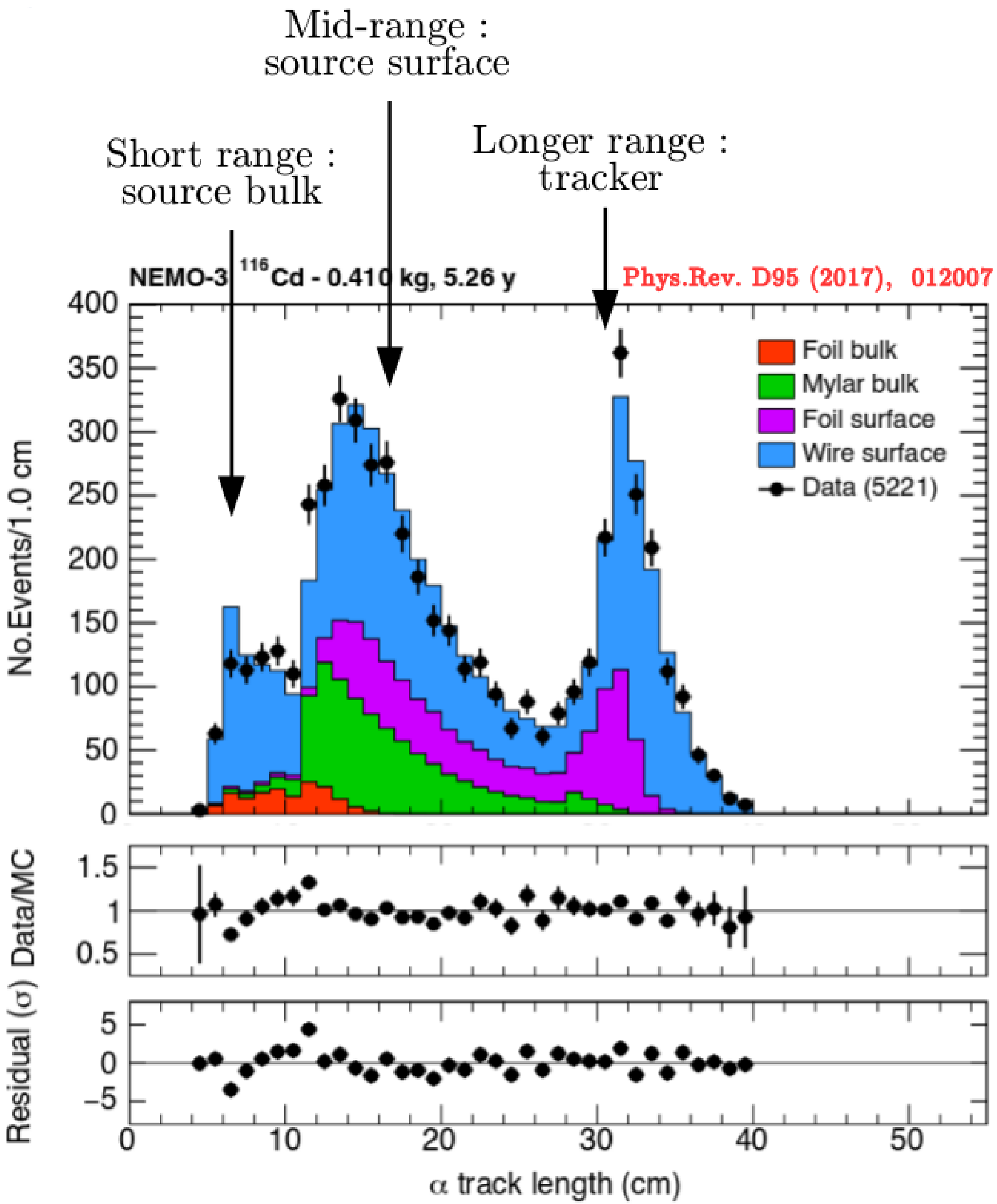


Example: External background from NEMO-3 (^{116}Cd)

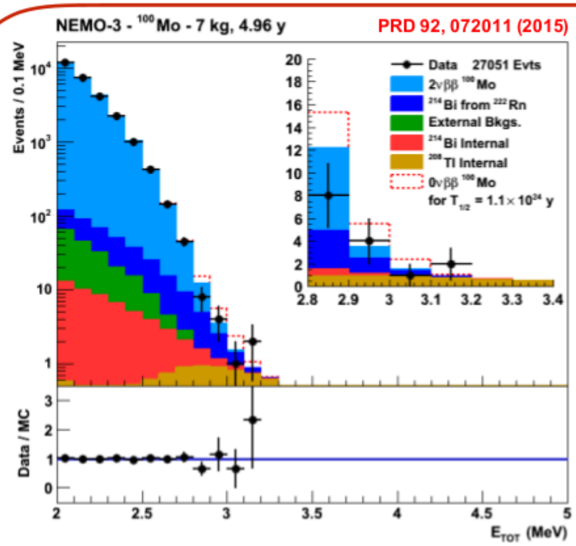
The background noise:
The radon in the wire chamber



- ^{214}Bi is an important background with a Q_β=3,3 MeV
- Arise from ^{238}U chain or ^{222}Rn emanation
- Measured in 1e1α channel
  →Background free measurement
- Alpha track length provide information on contamination origins



Some results from NEMO-3



$0\nu\beta\beta$ of ^{100}Mo

$$T_{1/2}^{0\nu\beta\beta} > 1.1\times10^{24} \text{ yr (90\% C.L.)}$$

$$\langle m_\nu \rangle < 0.3 - 0.6 \text{ eV}$$

Many results with different isotopes and on different mechanisms

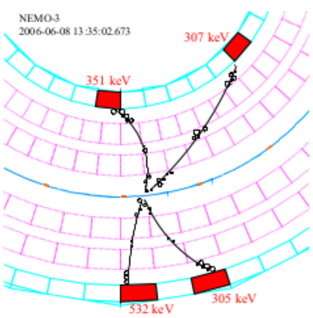
$0\nu4\beta$ of ^{150}Nd

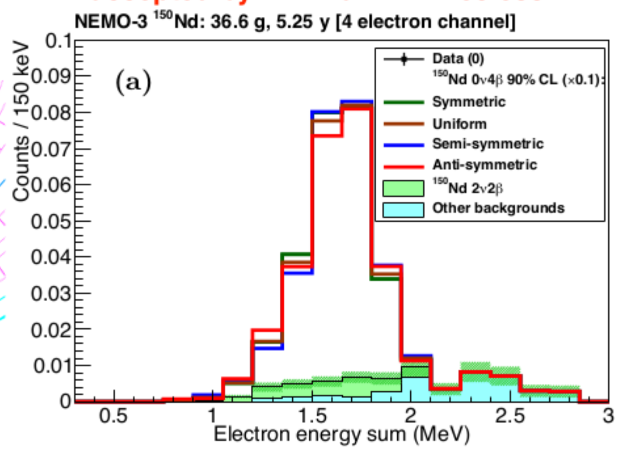
Possible with Dirac Neutrinos

Best candidate $^{150}\text{Nd} \xrightarrow{2.079 \text{ MeV}} {}^{150}\text{Gd} + 4e^-$

First measurement ever

accepted by PRL arXiv: 1705.08847





$$T_{1/2}^{0\nu4\beta} > 3.2 \times 10^{21} \text{ yr (90\% C.L.)}$$

and others:

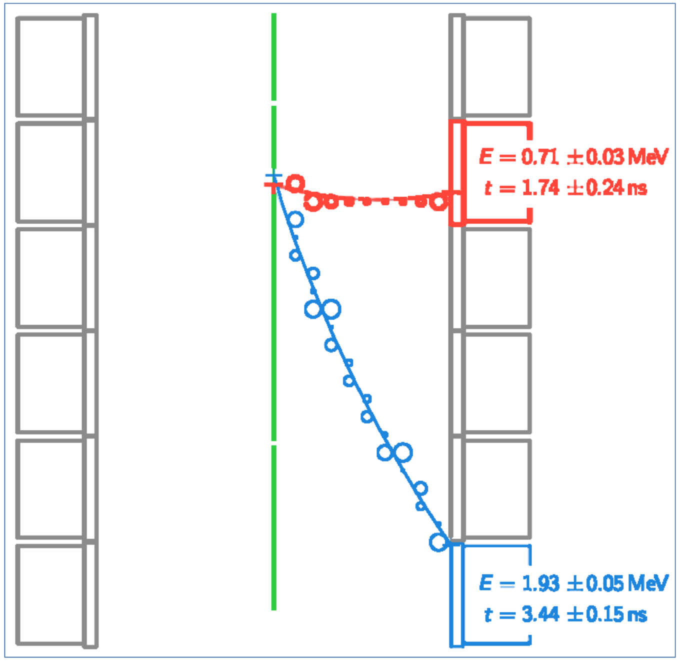
- $2\nu\beta\beta$(meas.) and $0\nu\beta\beta$ of ^{82}Se
- $2\nu\beta\beta$(meas.) of ^{48}Ca
- $2\nu\beta\beta$(meas.) and $0\nu\beta\beta$ of ^{150}Nd
- $2\nu\beta\beta$ (meas.) of ^{116}Cd
- decays to excited states

Assembling and status of SuperNEMO

SuperNEMO demonstrator sources

- Source
  - 7 kg of ^{82}Se ⇄ 17.5 kg.yr
  - ~40 mg/cm^2
  - $T_{1/2}(2\nu\beta\beta) = 10.3 \pm 0.3$ (stat) $\pm$ 0.7 (syst) 10^{19} y
  - $Q_{\beta\beta}$ = 2,966 MeV

SuperNEMO demonstrator tracker



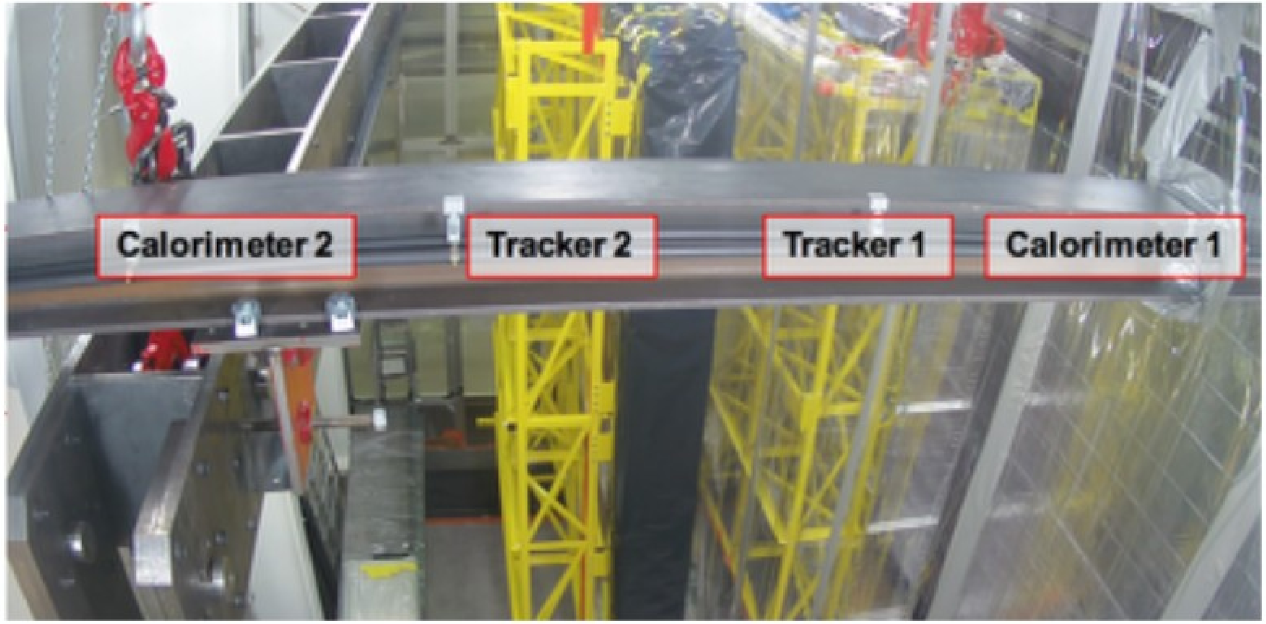
- 2034 wires in Geiger mode in each module (~45 km of wires)
- Ultra pure material (copper, steel, duracon, HPGe tested)
- 3d track reconstruction

SuperNEMO demonstrator calorimeter walls

- Calorimeter
  - 520 x 8” PM + 192 x 5” PMs coupled with polystyrene scintillators
  - Energy resolution:
    8% FWHM @ 1 MeV
  - Time resolution:
    σ = 400 ps @ 1MeV

SuperNEMO demonstrator status

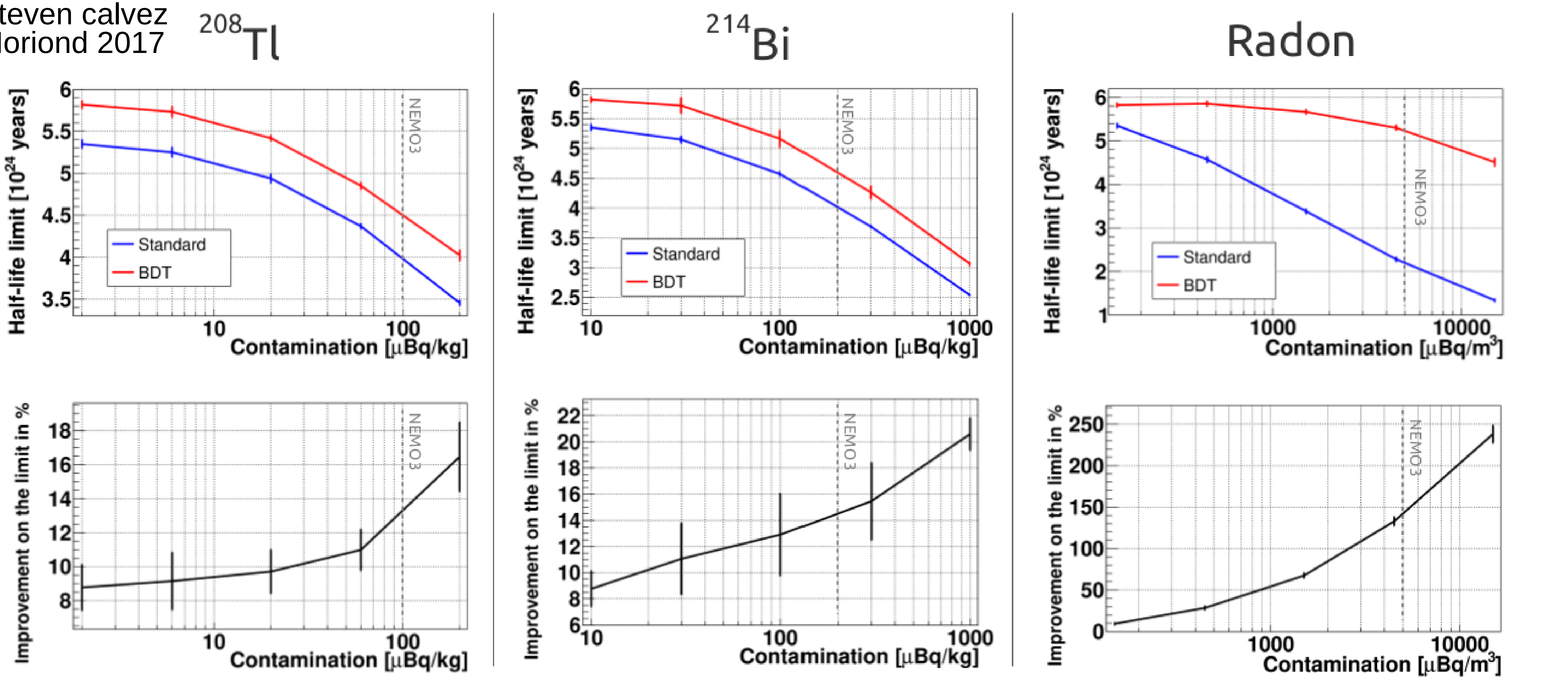
- Calorimeter on site, under commissioning
- Source foils radiopurity test ongoing at Canfranc (BiPo detector)
- The demonstrator data taking will start by the end of 2017



SuperNEMO demonstrator sensitivity

- Train BDTs to discriminate signal events from background events
- Radiopurity requirements : A(^{208}Tl) = 2 µBq/kg, A(^{214}Bi) = 10 µBq/kg
- and A(Radon) = 150 µBq/m^3
- Half-life limit as a function of the background contamination levels :

Steven calvez
Moriond 2017



Conclusions

- SuperNEMO detector
  - Very low background experiment
    - 4800 MWE underground laboratory
    - Very good background reconstruction and exclusion
  - Calorimeter/tracking technology validated by NEMO-3 (new limits on 2β0ν), used by SuperNEMO
  - The data taking should start by the end of the year
  - Sensitivity $T_{1/2}^{0v} \sim 10^{24}$ years ($T_{1/2}^{0v} \sim 10^{26}$ years for full detector)

backup

The Double beta decay and the mass hierarchy

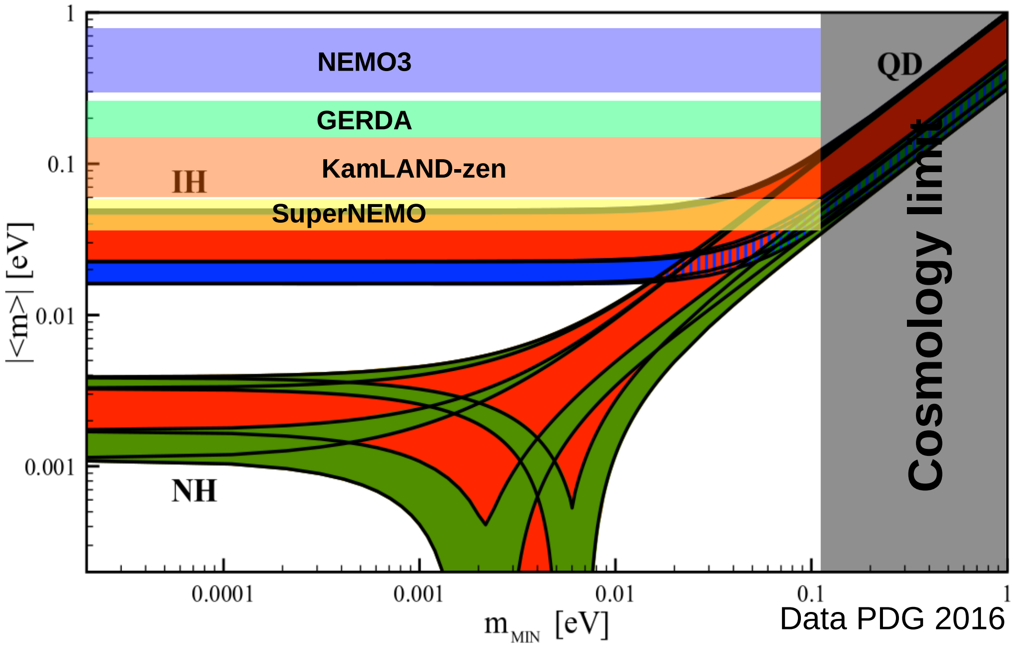
$$(T^{0\nu}_{1/2})^{-1} = G_{0\nu}(Q_{\beta\beta}, Z)|M_{0\nu}|^2\langle m_{\beta\beta}\rangle^2$$

$$\langle m_{\beta\beta}\rangle \equiv |\sum_k m_k U^2_{ek}|$$

$$m_{\nu_e} = \left(\sum_i |V^2_{ei}|\, m_i^2\right)^{1/2}$$

The measurement of the double beta decay lifetime and the PMNS angle values gives an access to the hierarchy:

- NH: $<m_{ee}>$ = [4;0] meV
- IH: $<m_{ee}>$ = [60;15] meV & m_{ve} ~ 40 meV



Data PDG 2016

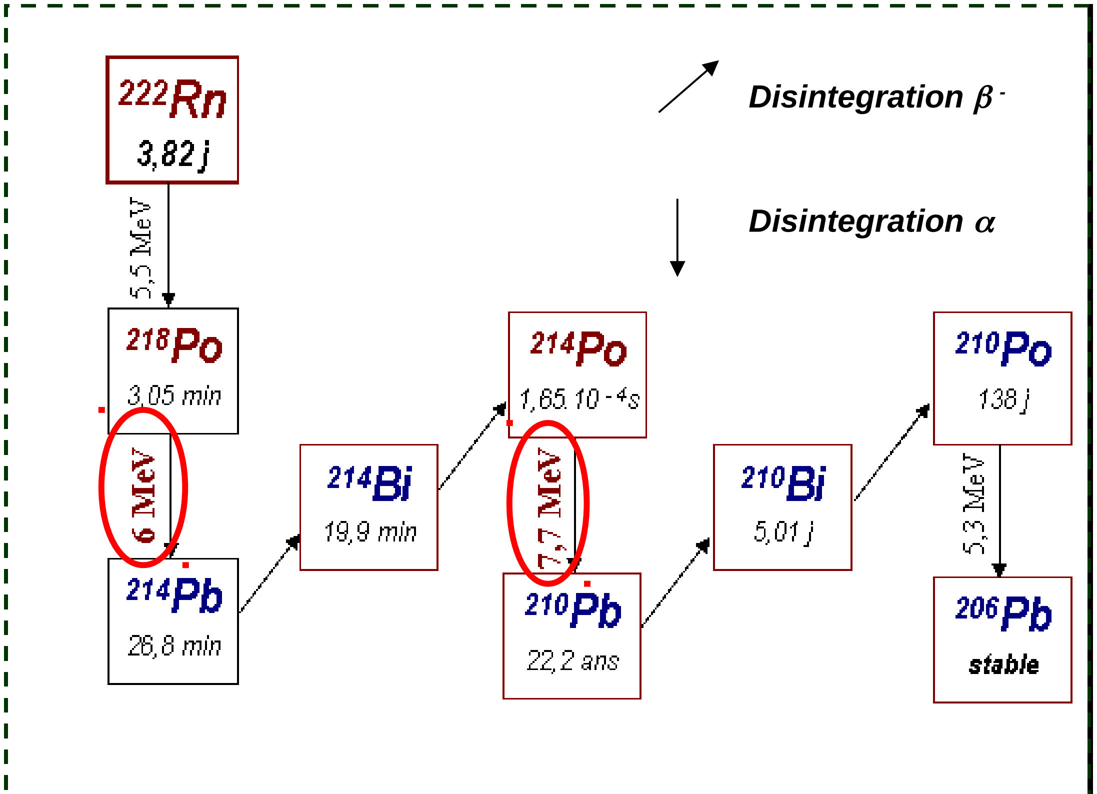
Nemo-3 ^{100}Mo result: 300-900 meV

SuperNEMO goal: 50-100 meV

Radon and thoron decay chains

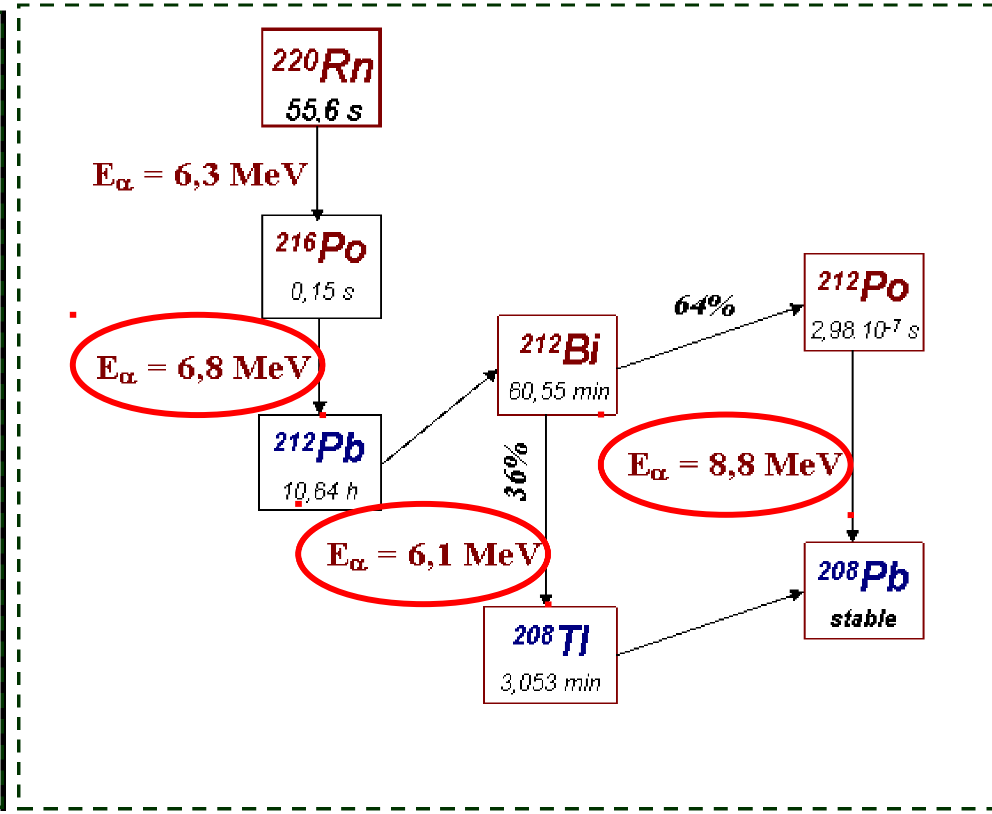
Radon

(Chain of l'^{238}U)



Thoron

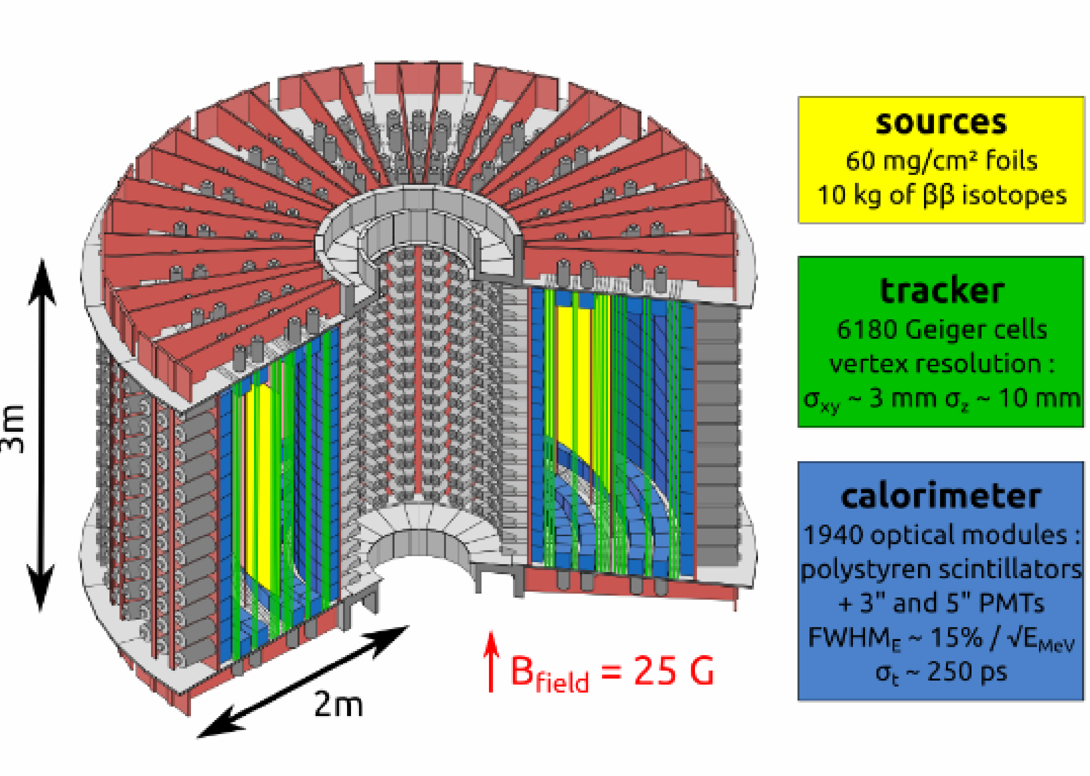
(Chain of ^{232}Th)

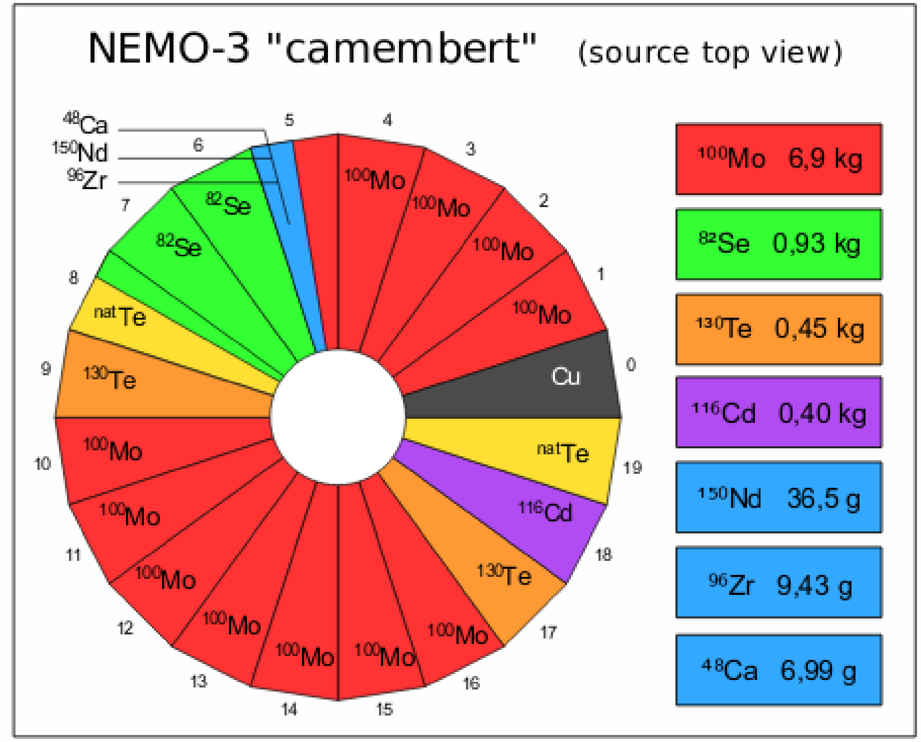


- Remarks :

- The two decay chains are identical in the chemical point of view
- The main difference comes from the periods : 56 seconds for the thoron
  3.8 days for the radon

From NEMO-3 to SuperNEMO

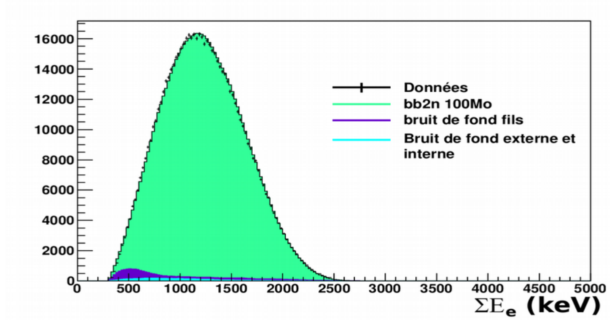


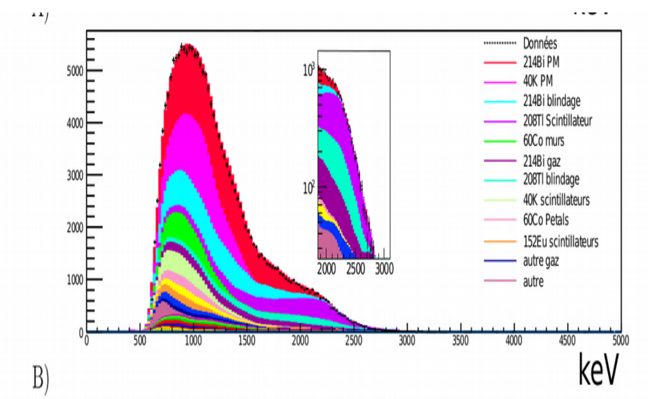


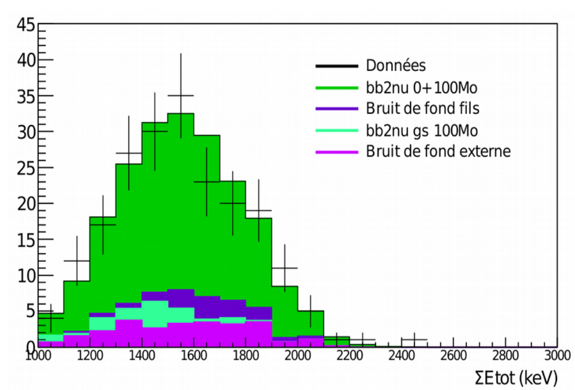
- Tracker + calorimetric experiment searching for 0νββ decay
- Located at Modane underground laboratory from Feb. 2003 to Jan. 2011
- 5 years of effective data taking
- 10 kg total of different ββ isotopes

reconstruction

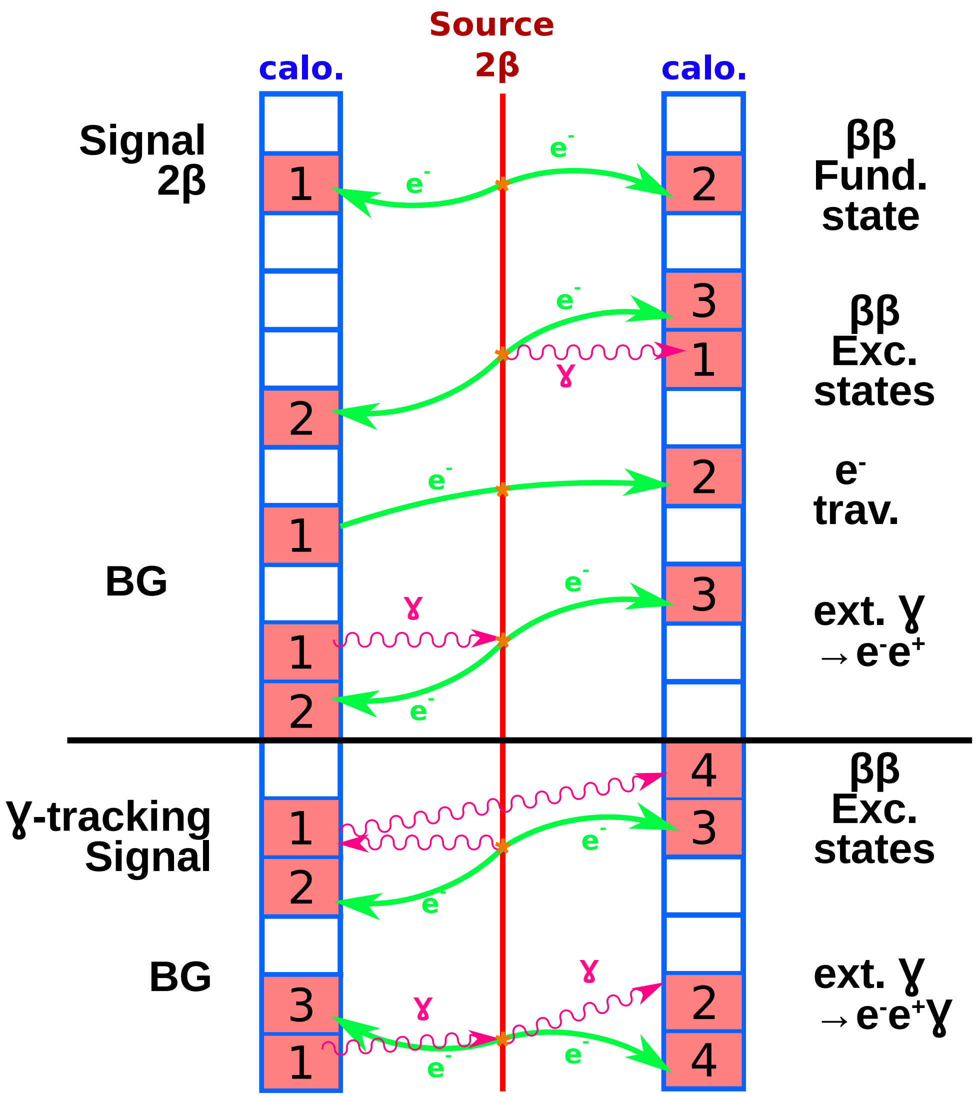
The reconstruction of the events and NEMO3 spectrums

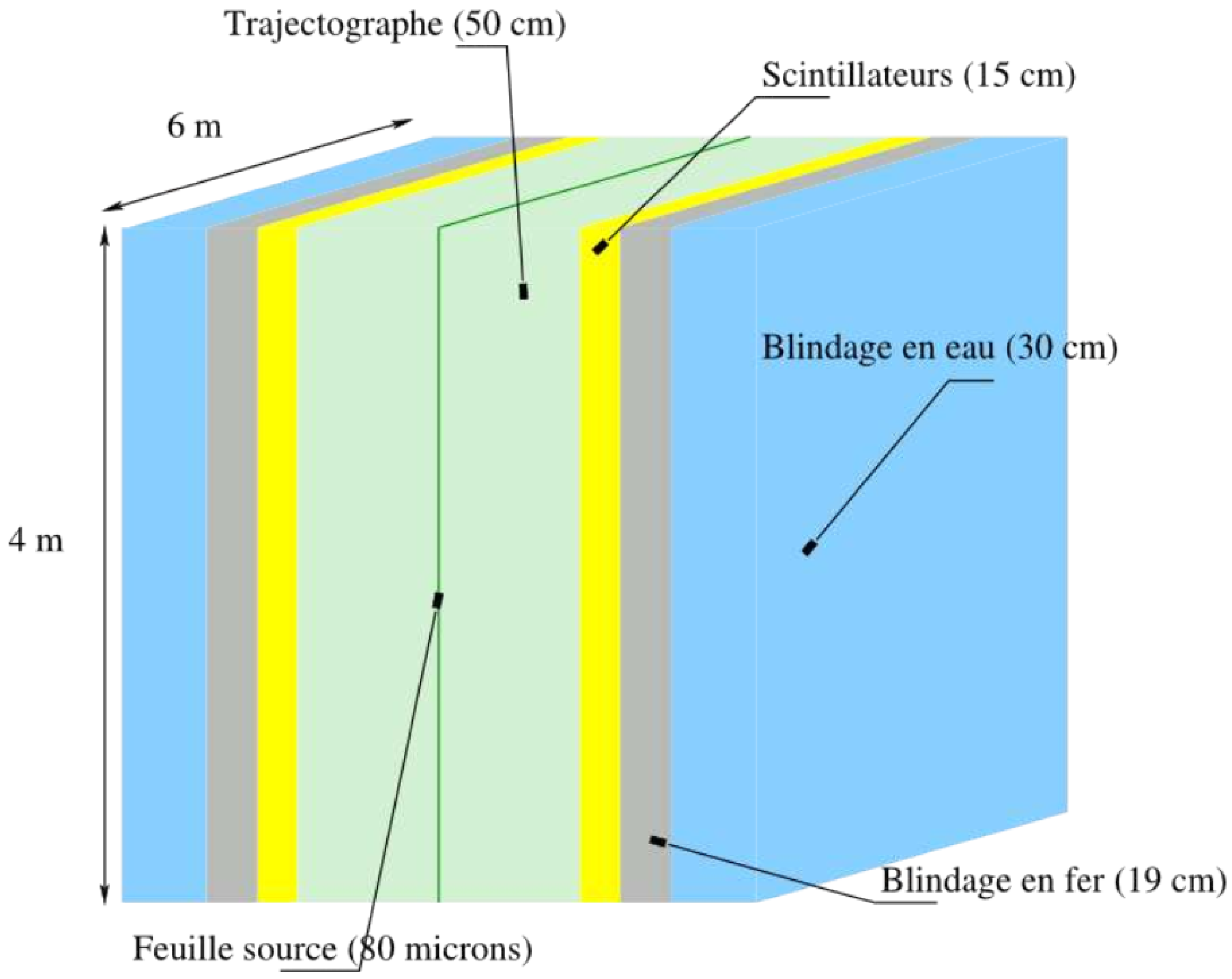






Event reconstruction
C. Hugon Ph.D (NAT++)




Trajectographe (50 cm)
Scintillateurs (15 cm)
6 m
4 m
Blindage en eau (30 cm)
Blindage en fer (19 cm)
Feuille source (80 microns)