Search for neutrinoless double-beta decay with the **SuperNEMO** demonstrator

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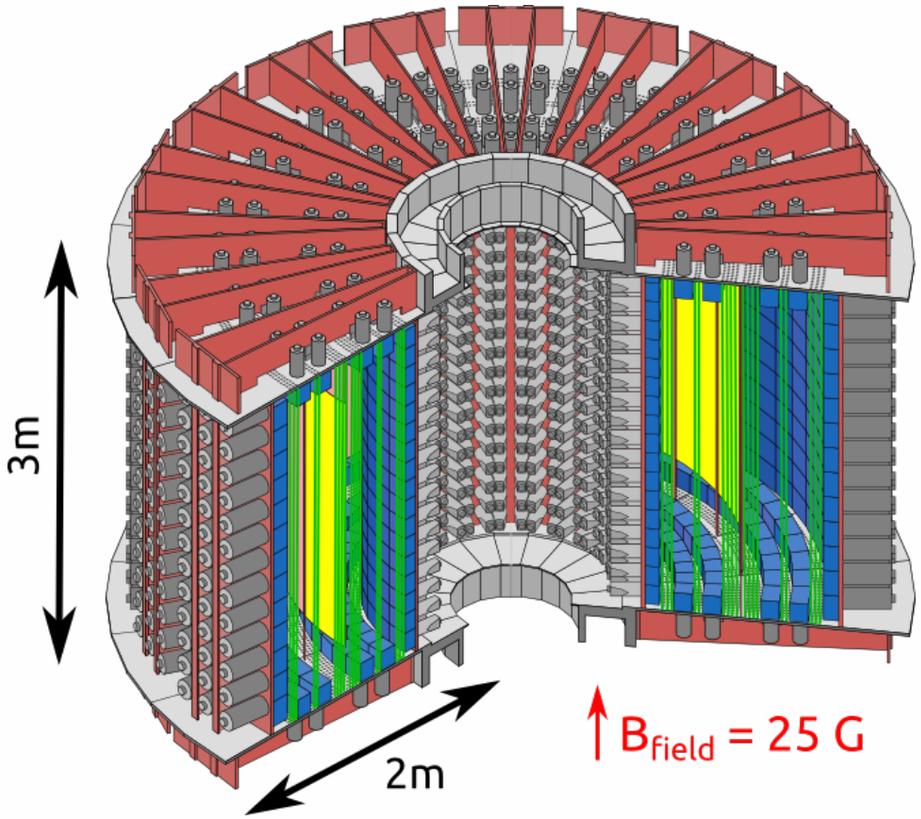
on behalf of the SuperNEMO collaboration

EPS-HEP2017 Venezia Lido
July,7th 2017

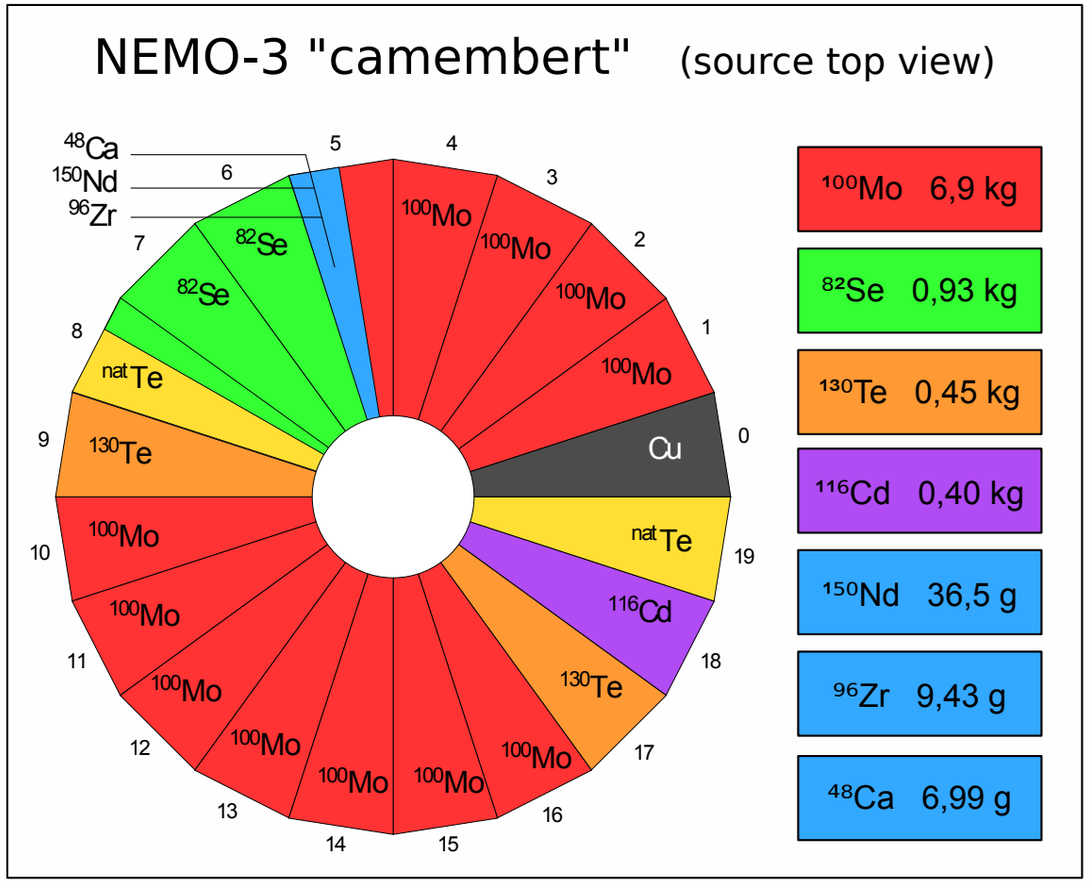
From NEMO-3 to SuperNEMO



sources
60 mg/cm² foils
10 kg of ββ isotopes

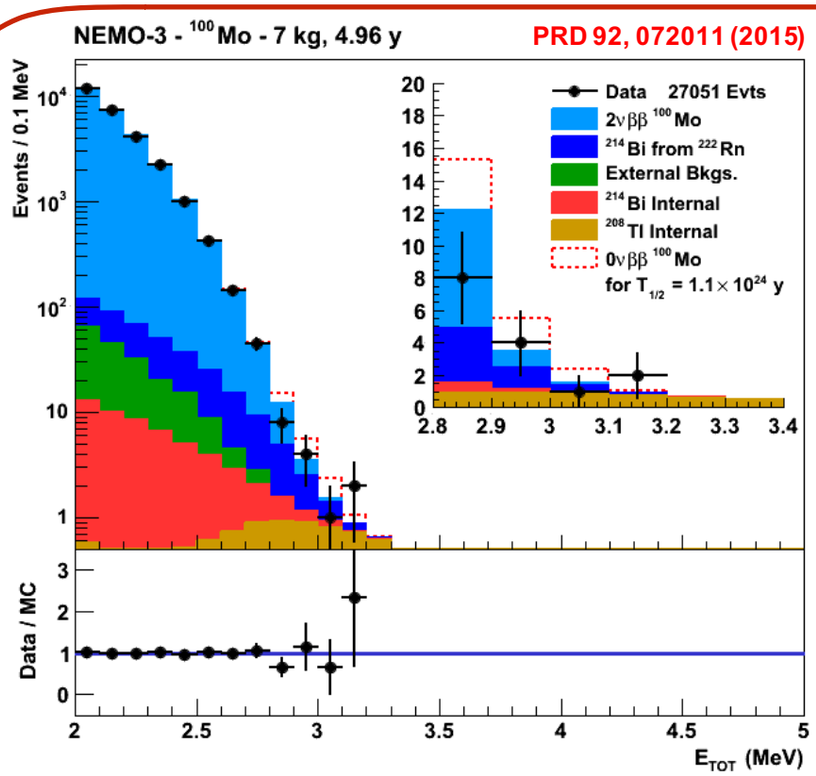
tracker
6180 Geiger cells
vertex resolution :
σ_{xy} ~ 3 mm σ_z ~ 10 mm

calorimeter
1940 optical modules :
polystyren scintillators
+ 3" and 5" PMTs
$FWHM_E$ ~ 15% / $\sqrt{E_{MeV}}$
σ_t ~ 250 ps



- 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

NEMO-3 results



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

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

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

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

Many results with different isotopes and on different mechanisms

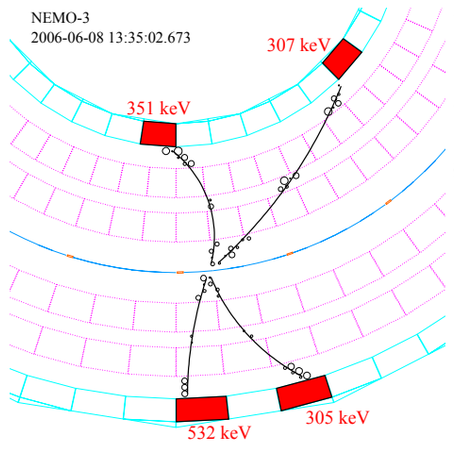
$0\nu4\beta$ of ^{150}Nd

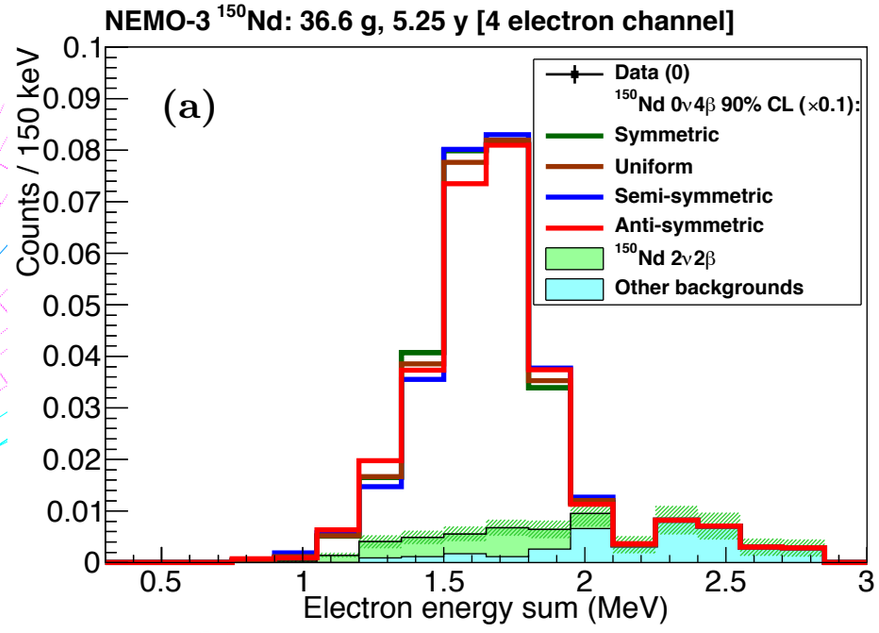
Possible with Dirac Neutrinos

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

First measurement ever

accepted by PRL arXiv: 1705.08847





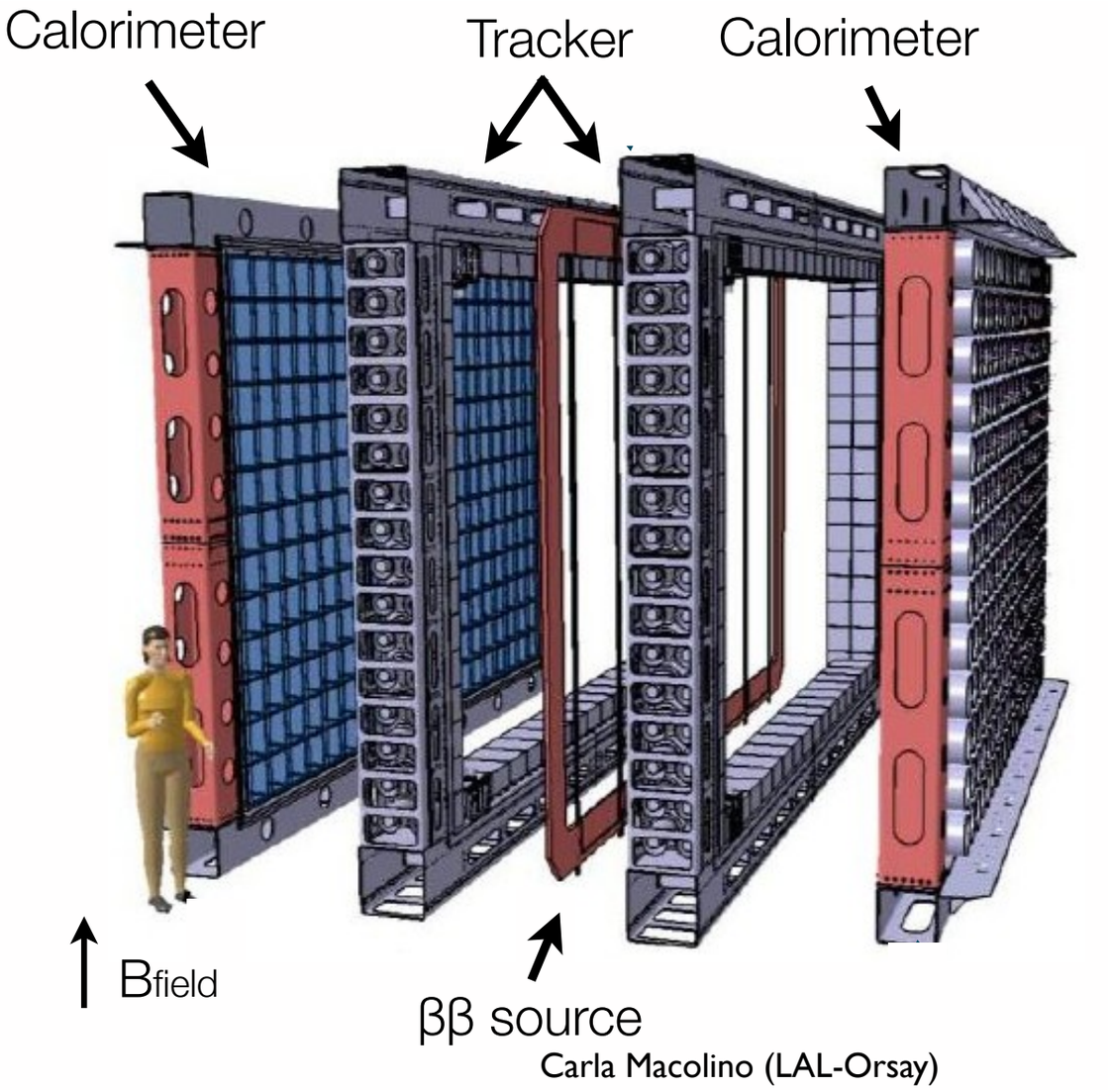
$$T_{1/2}^{0\nu4\beta} > 3.2 \times 10^{21}\ \text{yr (90\% C.L.)}$$

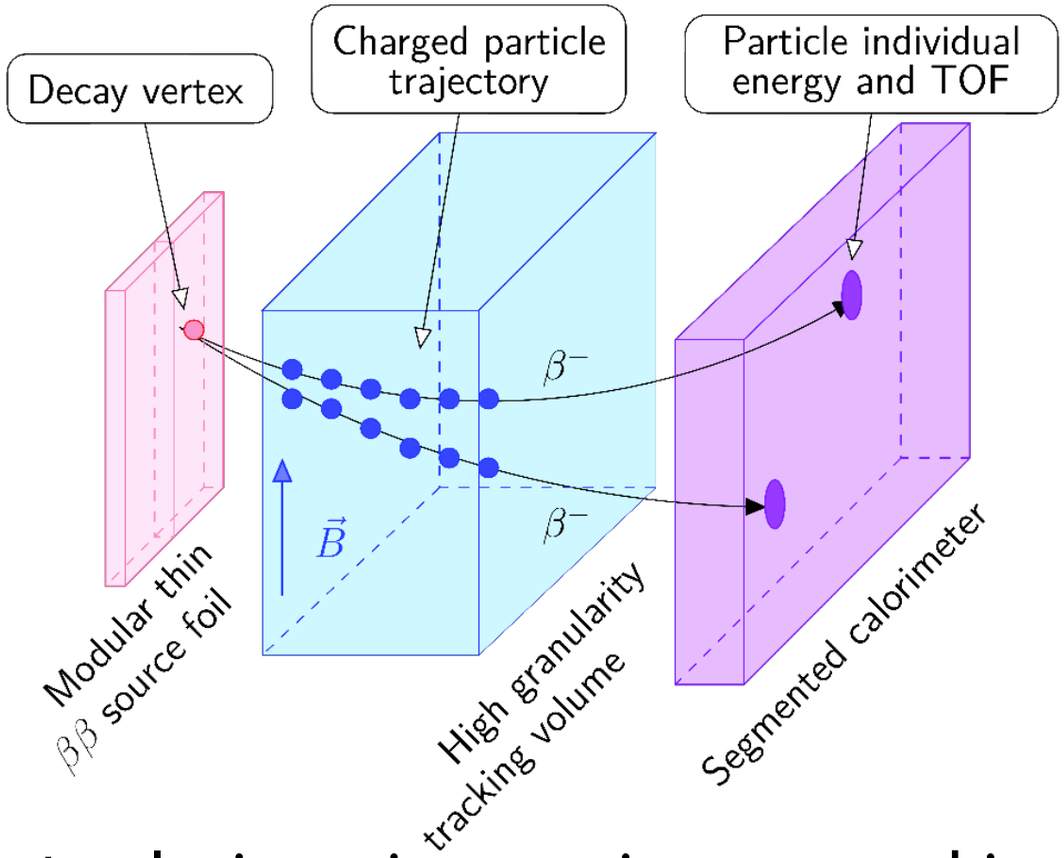
SuperNEMO technique

NEMO-3/SuperNEMO unique features

- Full topological event reconstruction
- Source separated from detector (can host any isotope)

Strong background suppression by particle identification, event characterisation and timing





- Tracker + calorimetric experiment searching for 0νββ decay at Modane underground lab. (France)
- Modular design (20 modules) with total mass of 100 kg
- Demonstrator module currently being installed at Modane
- Demonstrator: 7 kg of ^{82}Se running for 2.5 yr

0νββ event topology

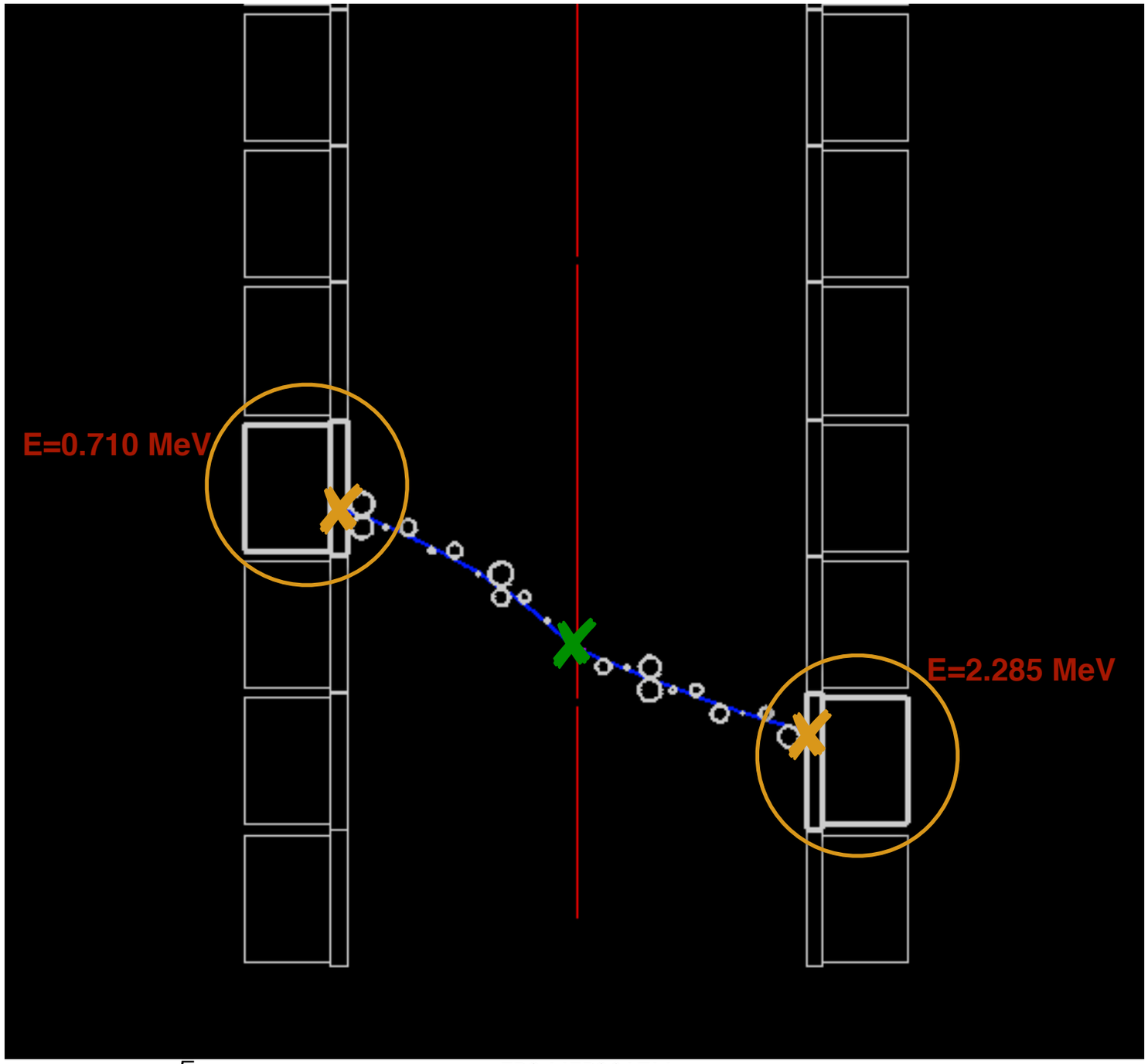
Unique double beta decay experiment with the direct reconstruction of the two electrons

Full signature of 0νββ events and

powerful background rejection

Basic selection criteria:

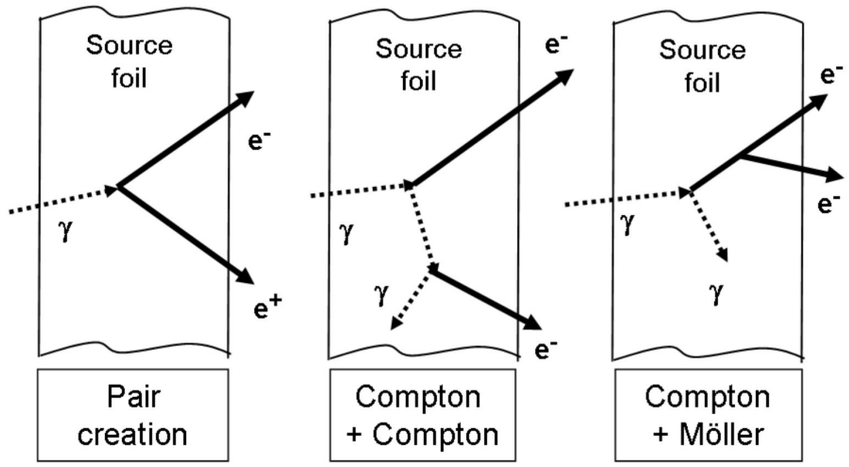
- 2 tracks with negative curvature
- common vertex
- 2 PMT hits with sum E > 200 keV
- PMT-track association



SuperNEMO background

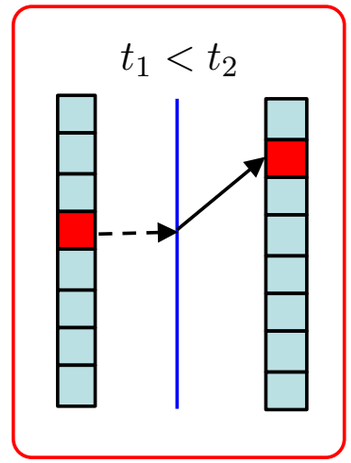
External background

- Natural radioactivity (γ,n) from the detector components or its surroundings
- Cosmic rays
- Neutrons



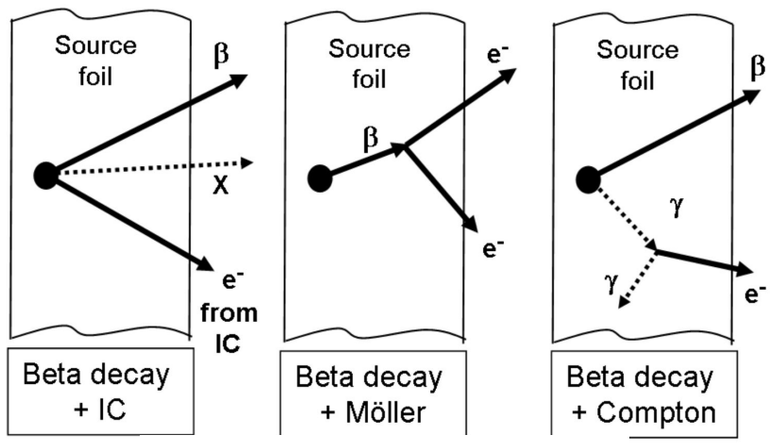
$0\nu2\beta$:
^{208}Tl γ 2.6 MeV
(n,γ) up to ~10 MeV

Measure

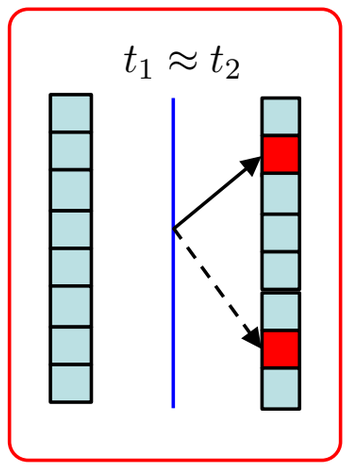


Internal background

Radioactive contaminations in the source foil or Radon daughters depositions on the foil or tracking wires



$0\nu2\beta$:
^{208}Tl $Q_\beta = 5.0$ MeV
^{214}Bi $Q_\beta = 3.27$ MeV

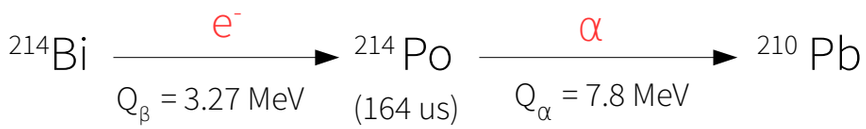


SuperNEMO background

- ^{214}Bi important background with Q_β=3.27 MeV

- Can originate from internal ^{238}U-chain contamination or from ^{222}Rn emanation/diffusion

- Ultra-pure material selection
- Radon tent
- alpha tagging: 1e1α channel



$\mathcal{A}(^{222}\mathrm{Rn}) = 0.15$ mBq/m^3

Nucl.Instrum.Meth. A845 (2017)

Bordeaux emanation setup

London concentration line

SuperNEMO tracker

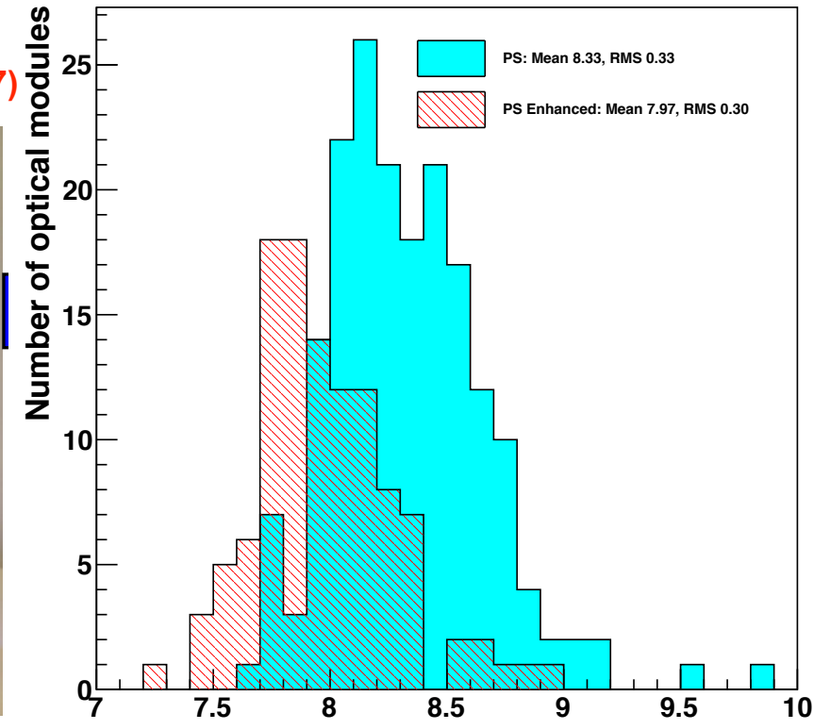
Nucl.Instrum.Meth. A824 (2016)

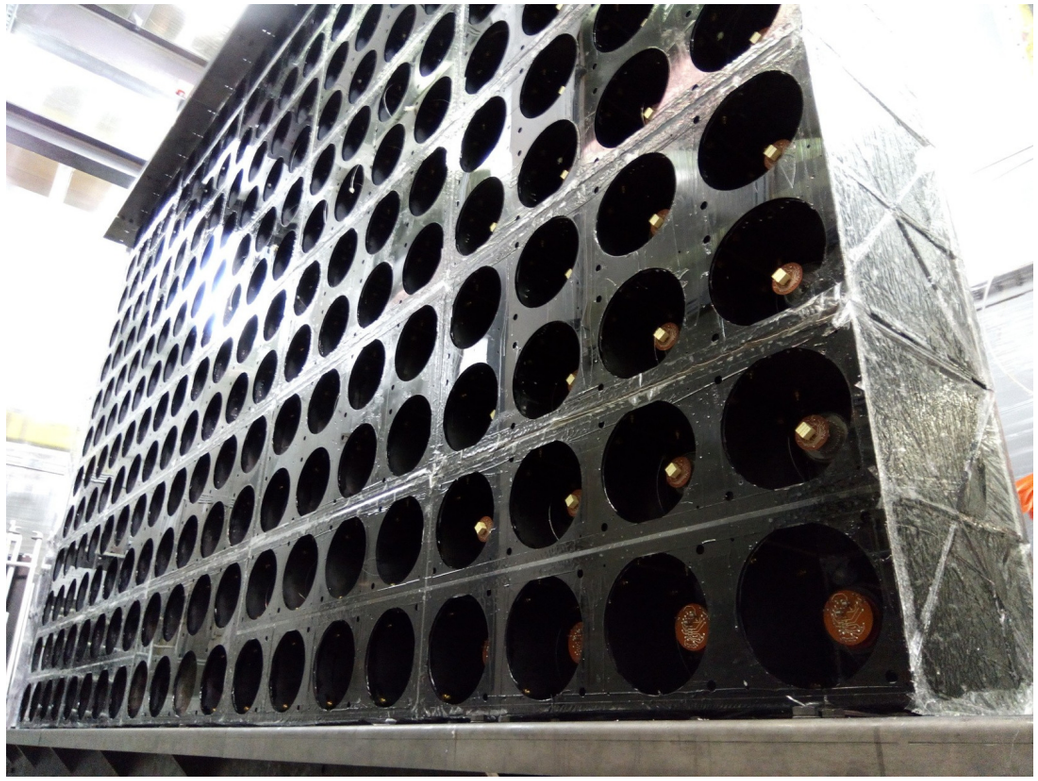
- Multi-wire drift chamber in Geiger mode
- Ultrapure materials: copper, steel, duracon
- Robotic production of 2034 drift cells
- Radiopure gas flow, anti-radon sealing
- <1% dead channels

SuperNEMO calorimeter

- 520 main optical modules
- 8” high QE radiopure PMTs
- σ_t = 400 ps at 1 MeV
- Calibration system allows stability to < 1%

Nucl.Instrum.Meth. under publication (2017)





SuperNEMO source foils

- 36 foils made of ^{82}Se powder mixed with PVA glue + mylar mechanical support (200 um thick)

- 7 kg of ^{82}Se ($Q_{\beta\beta}$=2.996 MeV)

- Target limits (challenging) on foil contamination:
  ^{208}Tl ≤ 2 μBq/kg
  ^{214}Bi ≤ 10 μBq/kg

- BiPo detector in Canfranc laboratory to measure source foil contamination: preliminary results indicate levels of ^{208}Tl [10-30] uBq/kg (90% C.L.)

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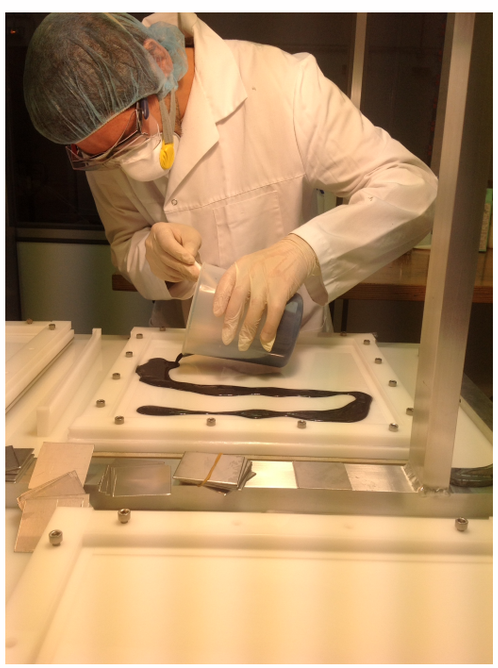
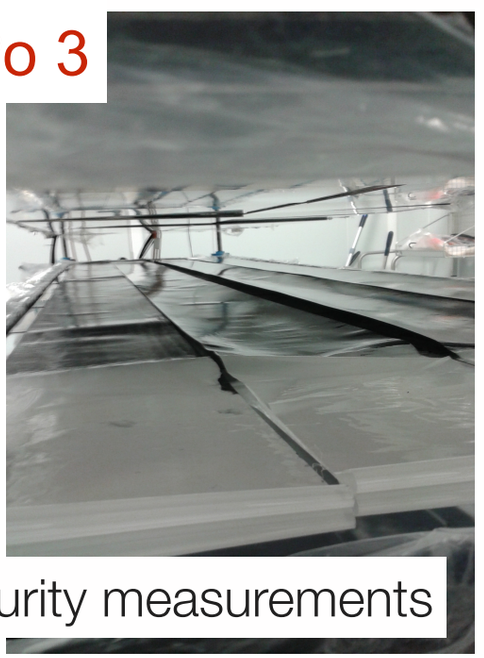


Training foil production technique

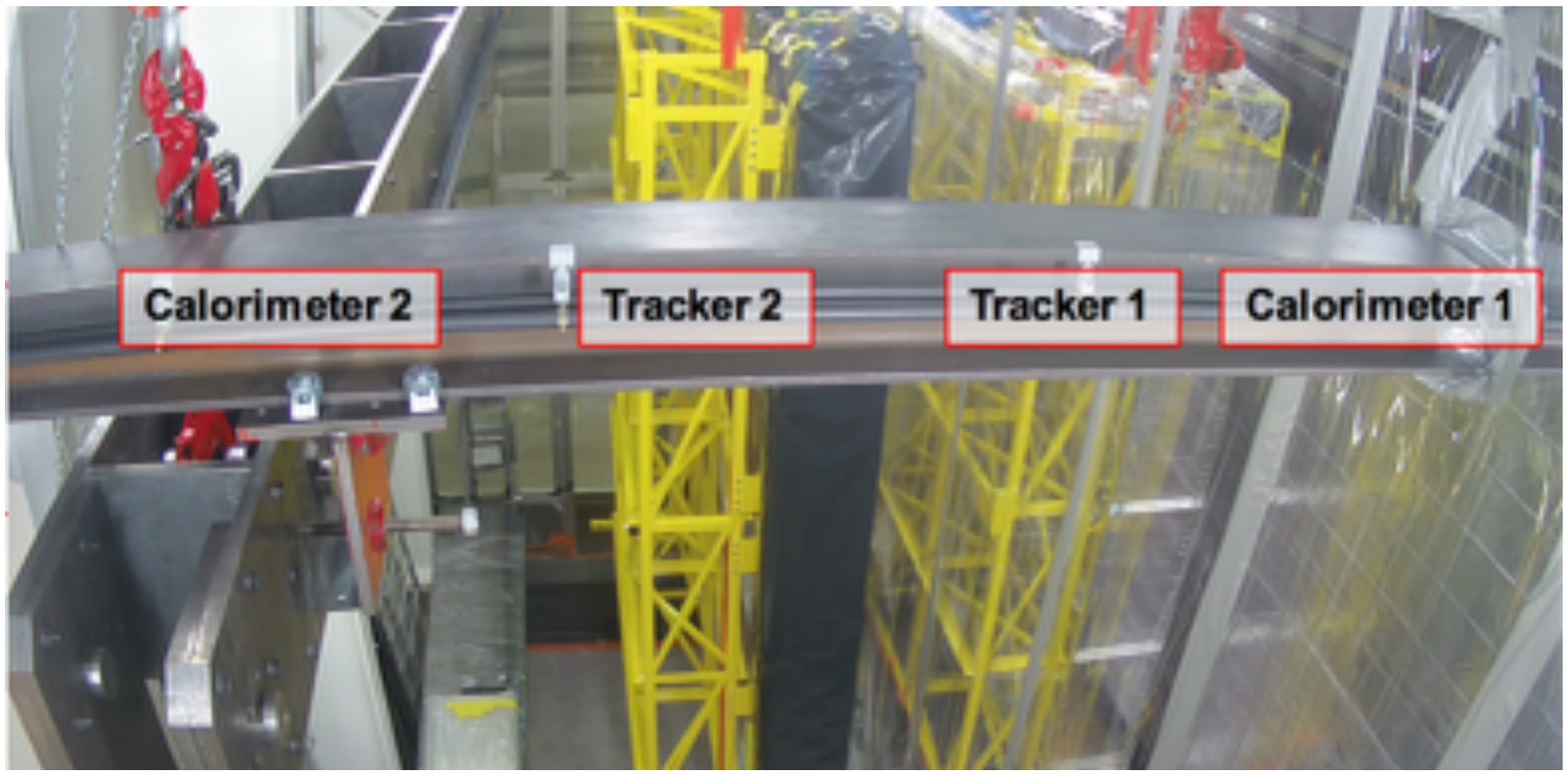
Bi-Po 3



^{82}Se foils radio-purity measurements

Installation status

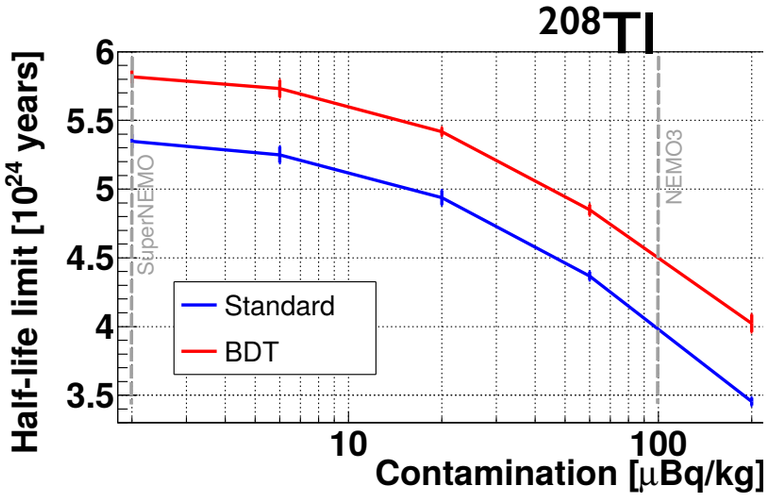
- Half-detector already installed, other half currently under installation at LSM
- Source foils under measurement with BiPo at Canfranc
- Demonstrator running by end of 2017

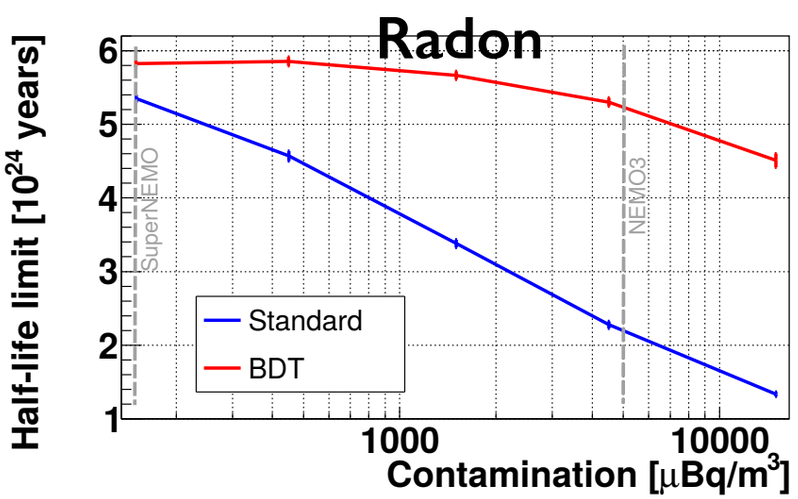


SuperNEMO sensitivity

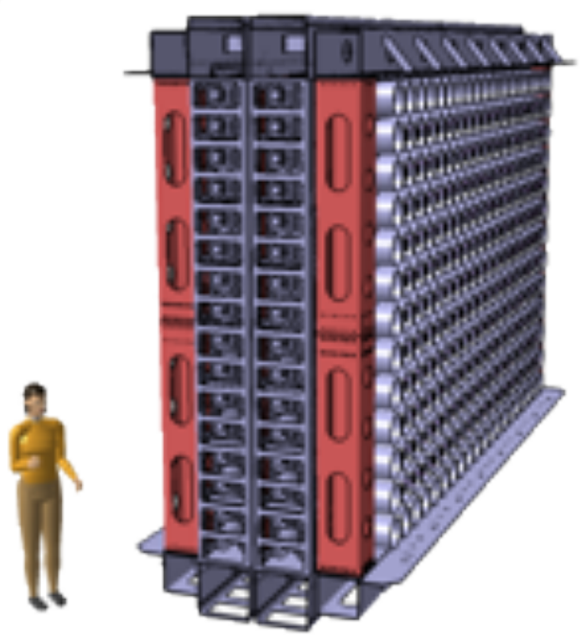
	SuperNEMO	Status
isotope	^{82}Se (or other, e.g. ^{150}Nd)	✓ (7 kg)
isotope mass	7 ➔ 100 kg	✓
radon	0.15 mBq/m^3	in progress
internal contamination	^{208}Tl ≤ 2 μBq/kg ^{214}Bi ≤ 10 μBq/kg	in progress
σ_E (FWHM)	8% @ 1 MeV	✓

From S. Calvez, talk at Moriond 2017





1 module



Demonstrator Module

17.5 kg.yr :

$T^{0\nu}_{1/2} > 5.9 \times 10^{24}$ yr

$\langle m_\nu \rangle <$ 0.20 - 0.55 eV

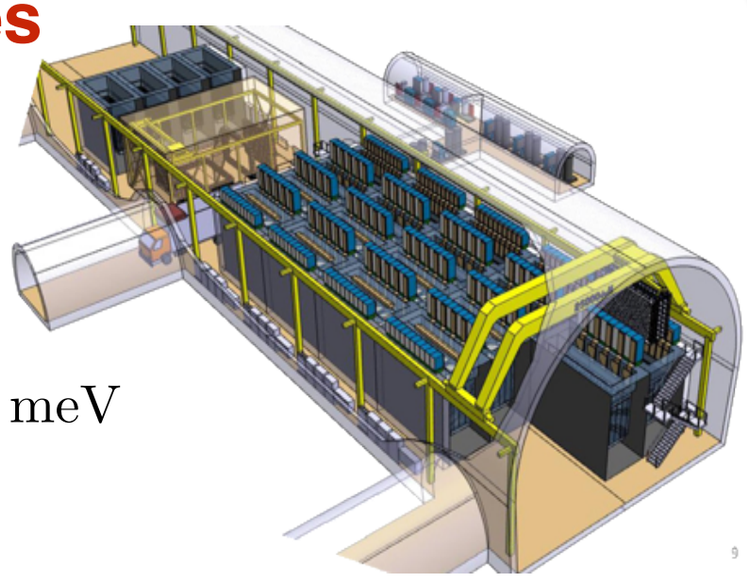
20 modules

Full SuperNEMO

500 kg.yr :

$T^{0\nu}_{1/2} > 10^{26}$ yr

$\langle m_\nu \rangle <$ 40 - 110 meV



Summary

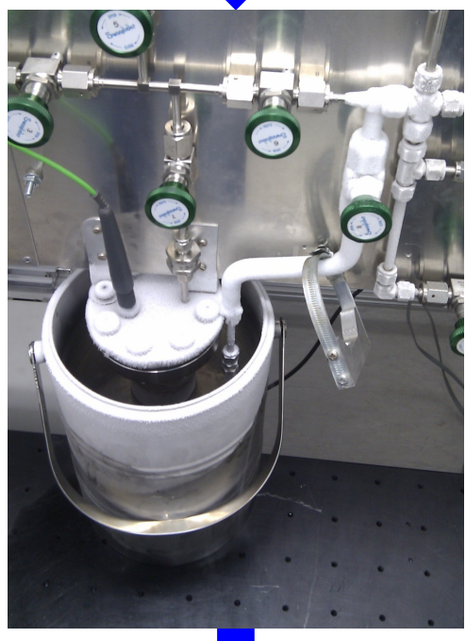
- Tracker + calorimetric experiment searching for $0\nu\beta\beta$ decay
- Demonstrator module under installation at Laboratoire Souterrain de Modane
- Demonstrator:
  - ✳7 kg of ^{82}Se running for 2.5 yr
  - ✳Sensitivity on effective mass 0.2-0.55 eV
- Challenges: low radioactivity source foil, extremely low levels of Radon
- Half-demonstrator module already installed. Data taking expected at the end of 2017
- Modular design (20 modules) with total mass of 100 kg - Ultimate sensitivity 40-110 meV

Backup

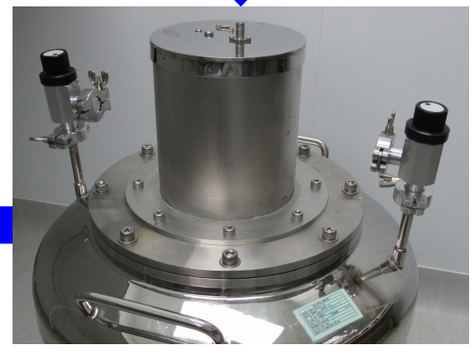
Backup slides

Radon

2. Flow through cooled carbon trap.



3. Release into electrostatic detector.

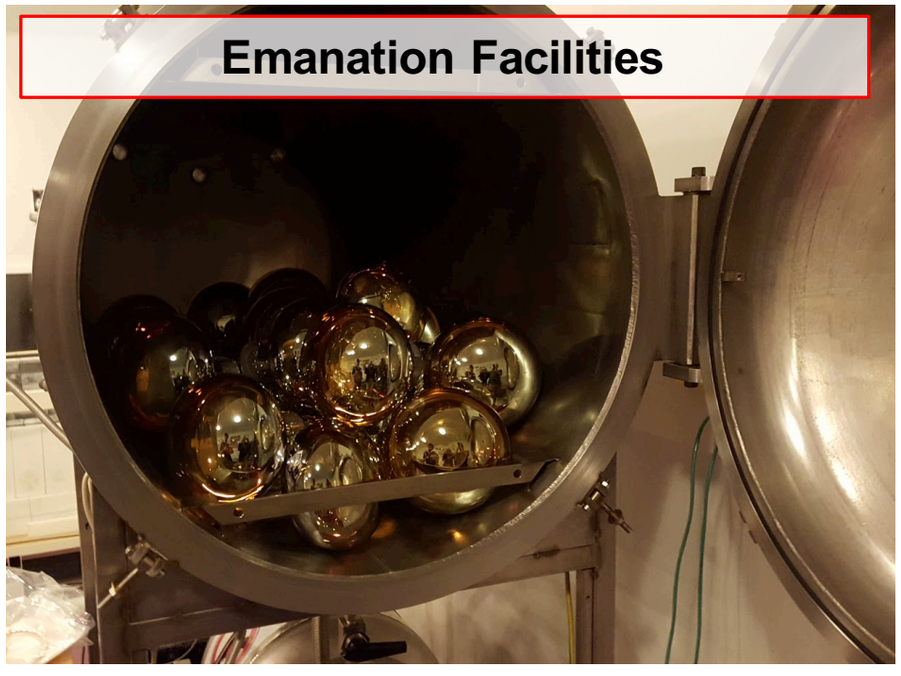


4. For reasonable gas-flow rates :

$$A(^{222}\mathrm{Rn}) = 150\,\mu\mathrm{Bq/m^3}$$

70 atoms per m^3

30 times better than NEMO-3

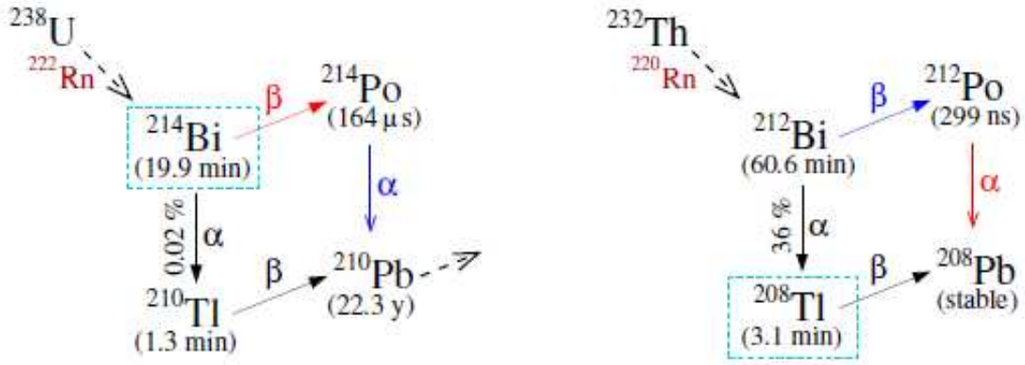


The Bi-Po 3 detector

- HPGe spectroscopy not sensitive enough to reach few μBq/Kg: BiPo-3 dedicated setup at Canfranc underground lab

- 2 modules of 3.0x0.6 m^2 can measure up to 1.4 kg of ^{82}Se foil with thickness of 40 mg/cm^2

- ^{214}Bi and ^{208}Tl measured trough process from natural radioactivity chain



- Thin radiopure plastic scintillators coupled to lightguides and low radioactivity PTMs