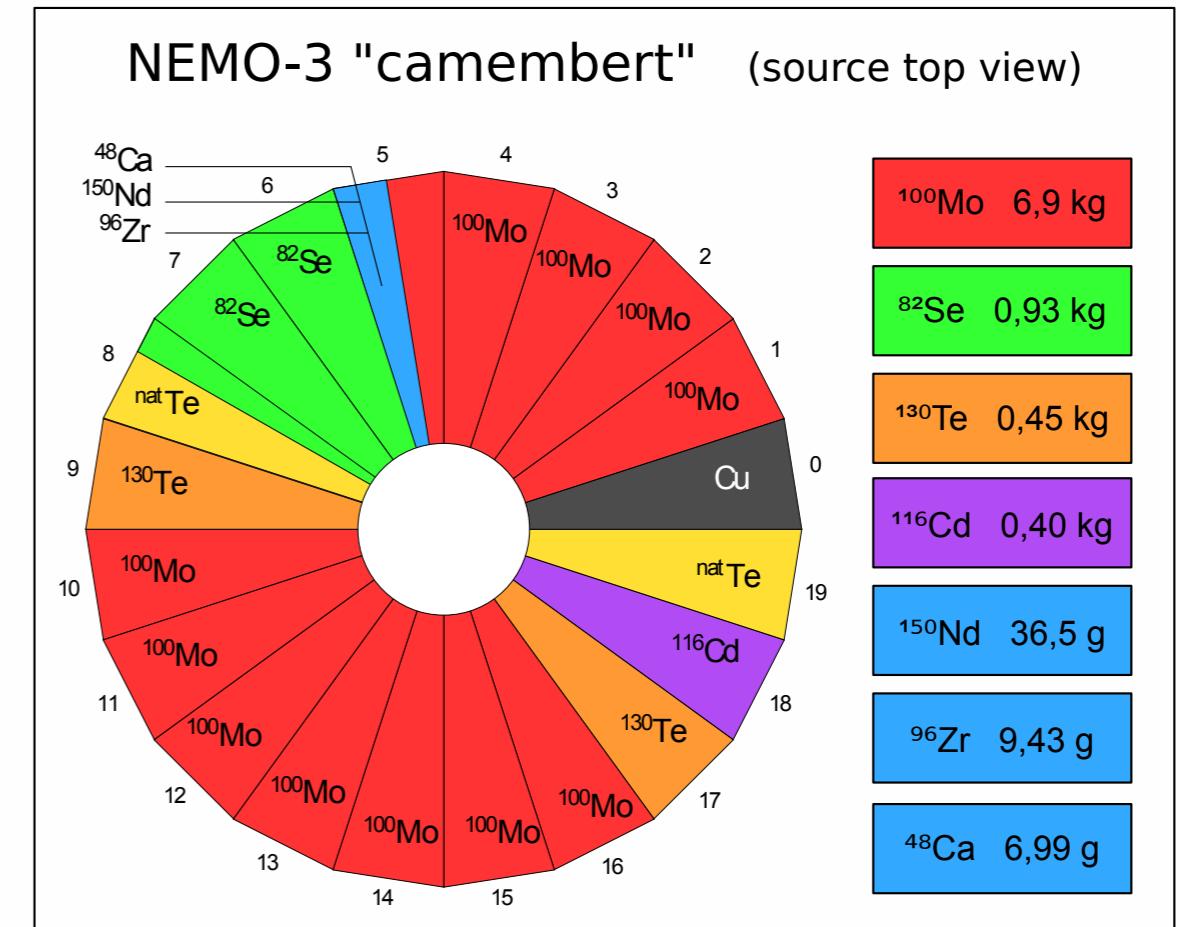
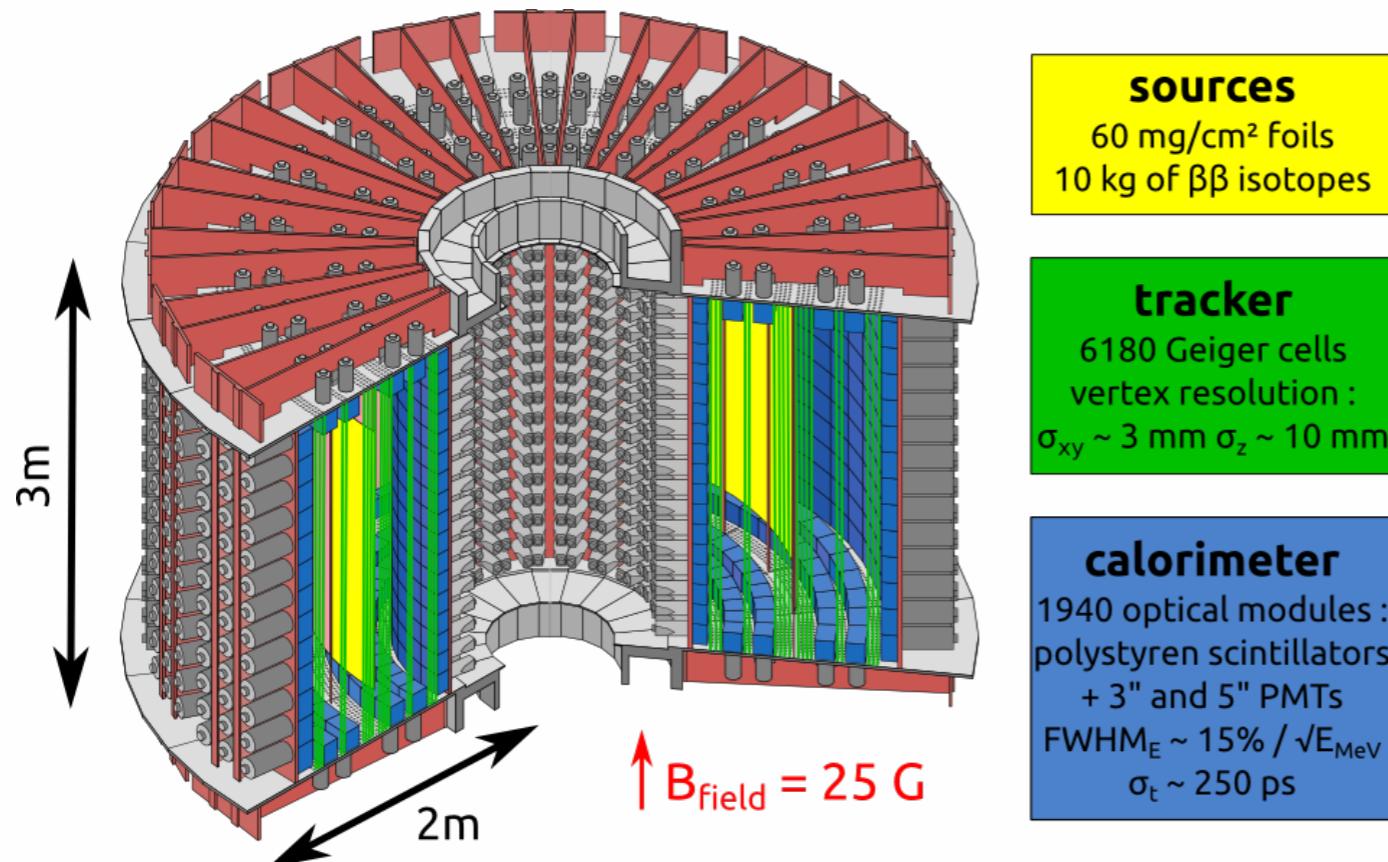


Search for neutrinoless double-beta decay with the **SuperNEMO** demonstrator

Carla Macolino (LAL-Orsay CNRS)
on behalf of the SuperNEMO collaboration

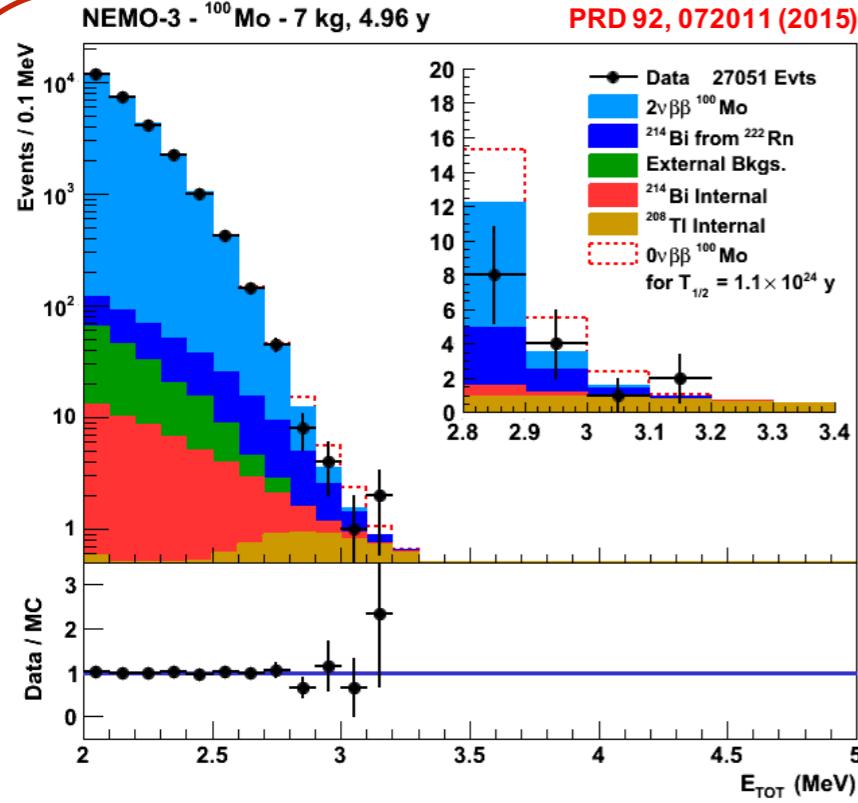
EPS-HEP2017 Venezia Lido
July, 7th 2017

From NEMO-3 to SuperNEMO



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

NEMO-3 results



$$T_{1/2}^{0\nu\beta\beta} > 1.1 \times 10^{24} \text{ yr (90% C.L.)}$$

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

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

Many results with different isotopes
and on different mechanisms

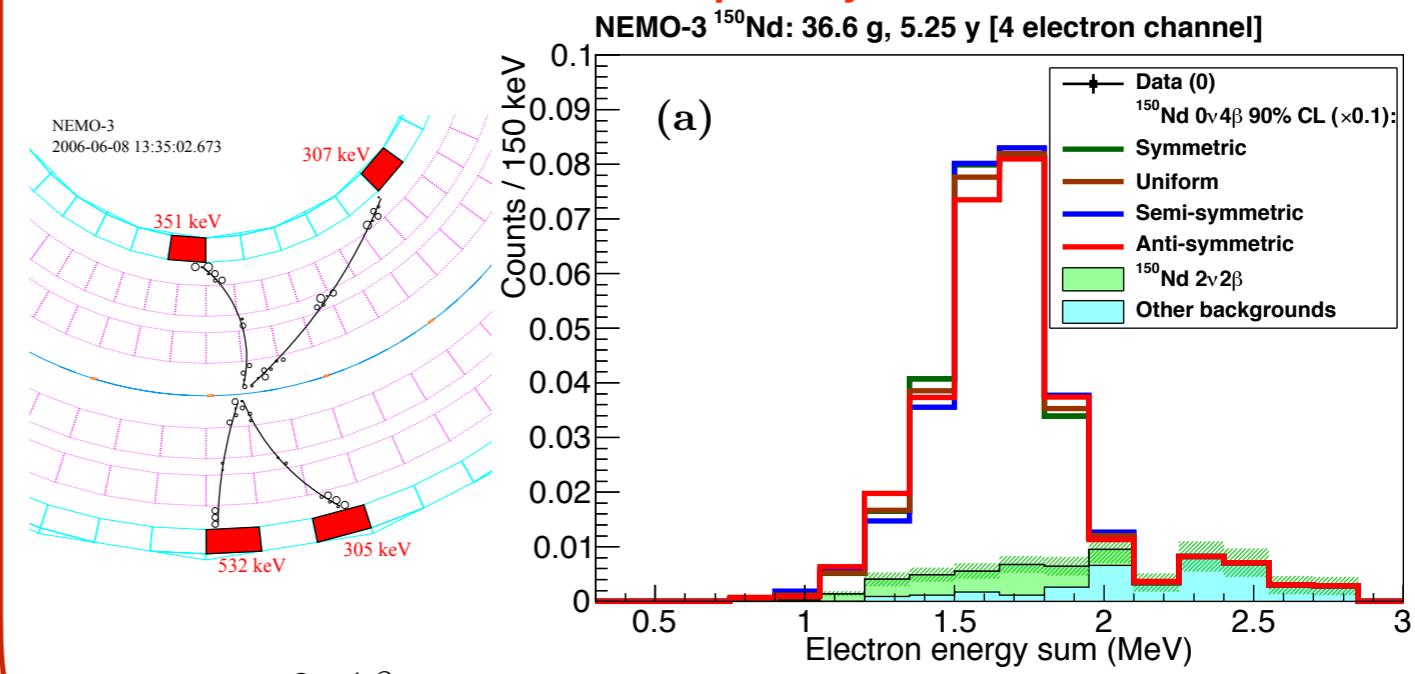
0 $\nu 4\beta$ of ^{150}Nd

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



$$T_{1/2}^{0\nu 4\beta} > 3.2 \times 10^{21} \text{ yr (90% C.L.)}$$

and others:

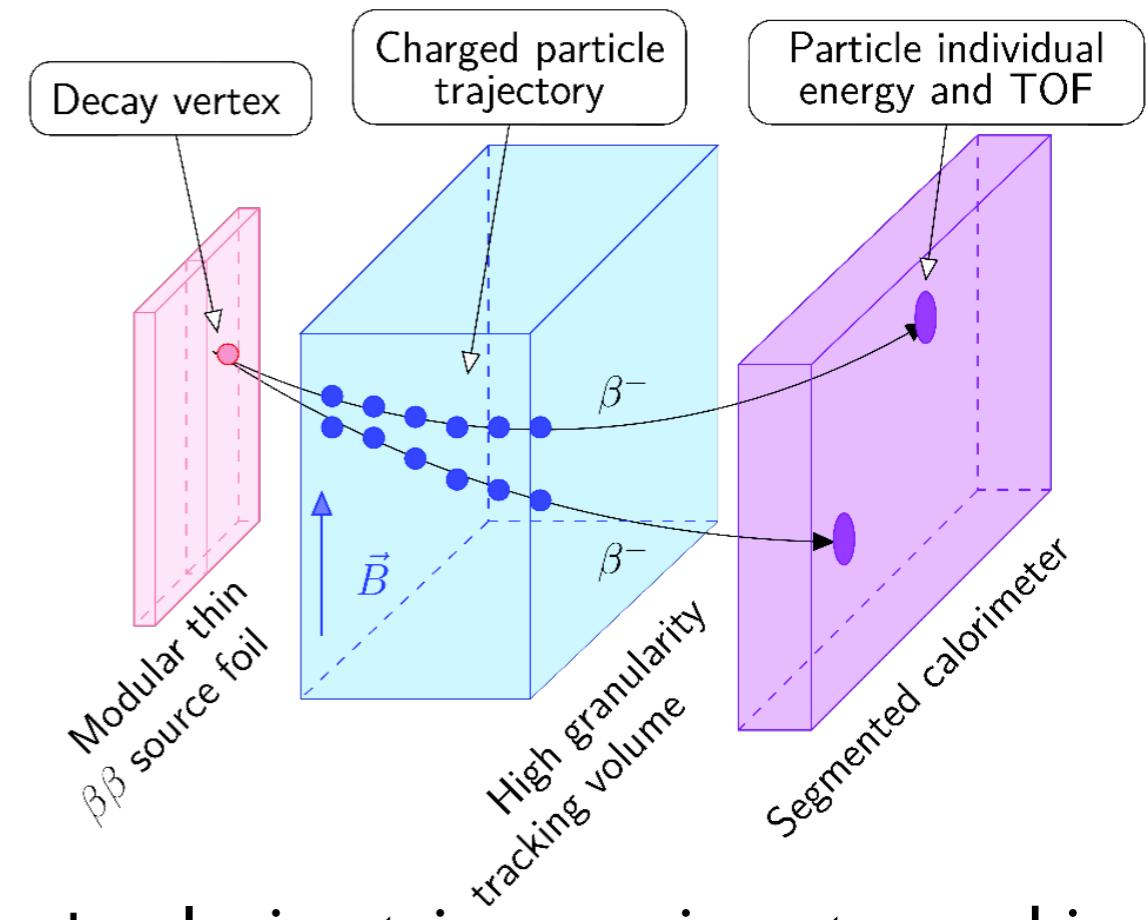
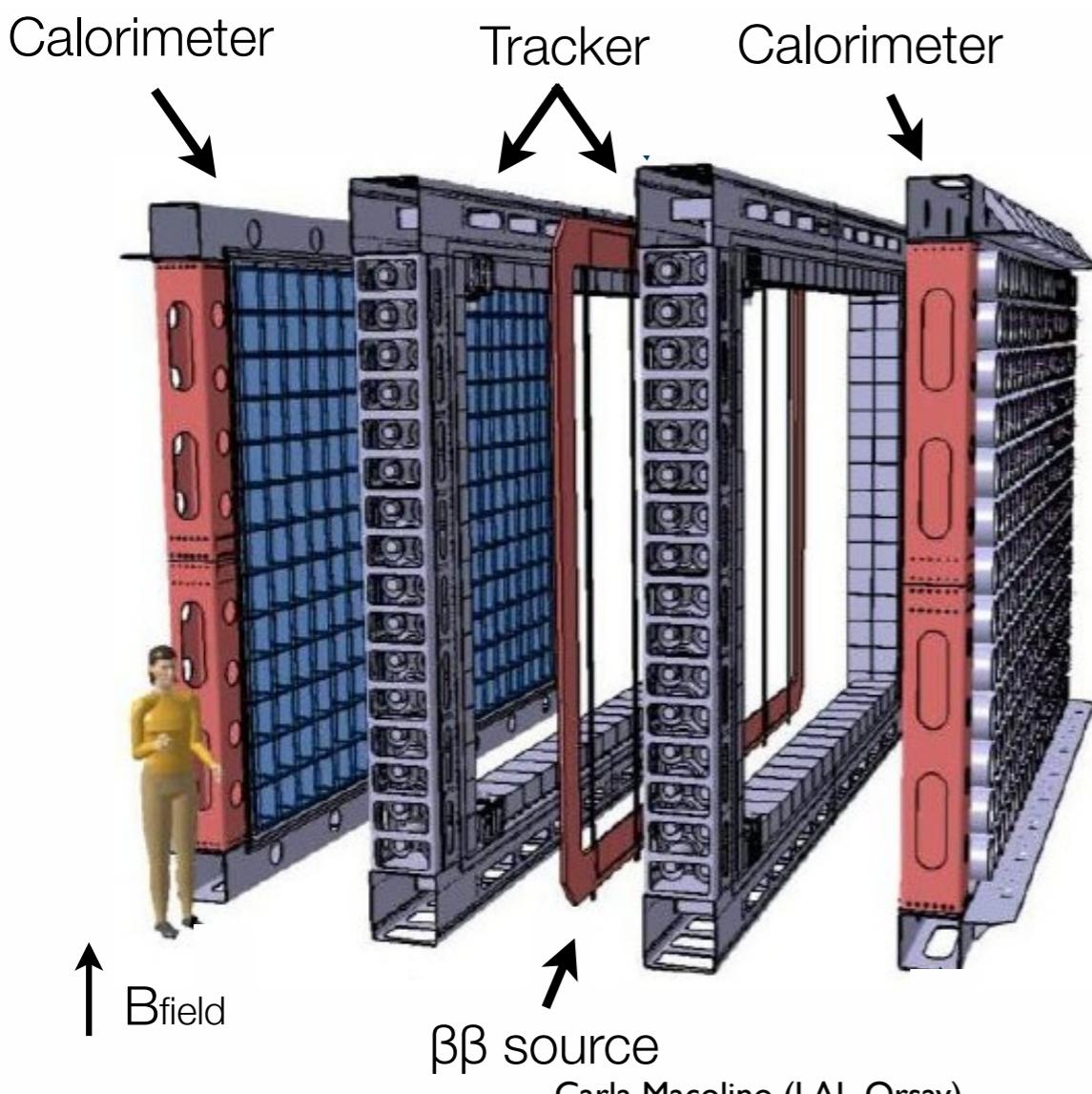
- $2\nu\beta\beta$ (meas.) and $0\nu\beta\beta$ of ^{82}Se
- $2\nu\beta\beta$ (meas.) of ^{48}Ca
- $2\nu\beta\beta$ (meas.) and $0\nu\beta\beta$ of ^{150}Nd
- $2\nu\beta\beta$ (meas.) of ^{116}Cd
- decays to excited states

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 $0\nu\beta\beta$ 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

$0\nu\beta\beta$ event topology

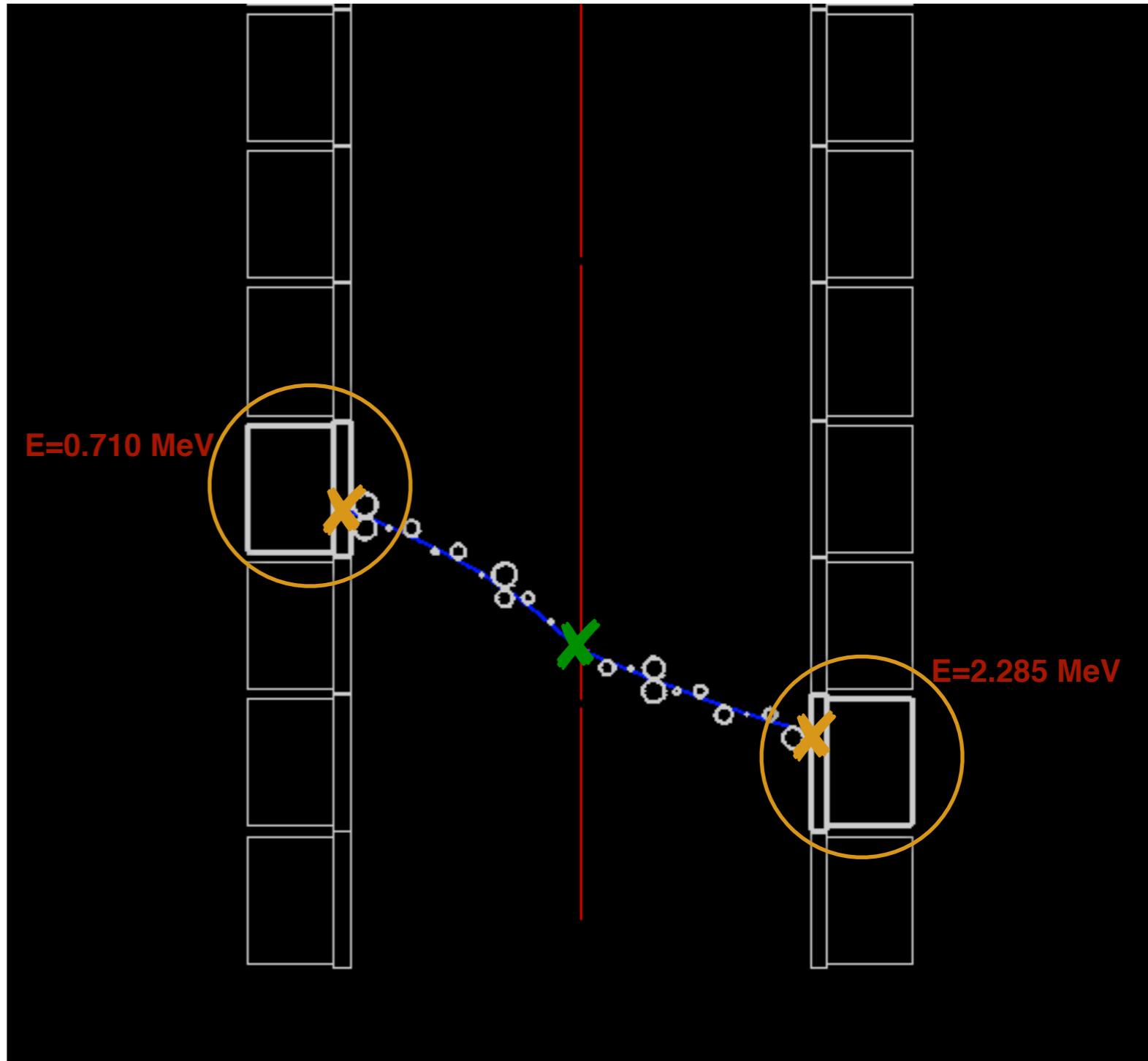
Unique double beta decay experiment with the direct reconstruction of the two electrons

Full signature of $0\nu\beta\beta$ events and

powerful background rejection

Basic selection criteria:

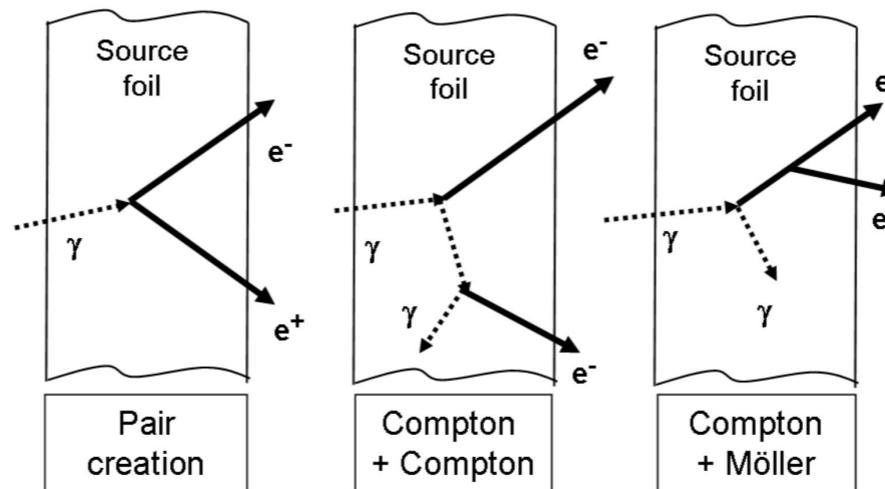
- 2 tracks with negative curvature
- common vertex
- 2 PMT hits with sum $E > 200$ keV
- PMT-track association



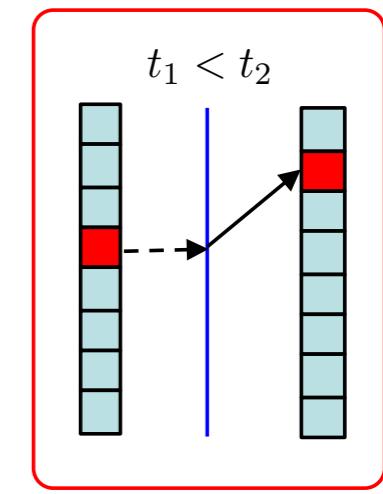
SuperNEMO background

External background

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



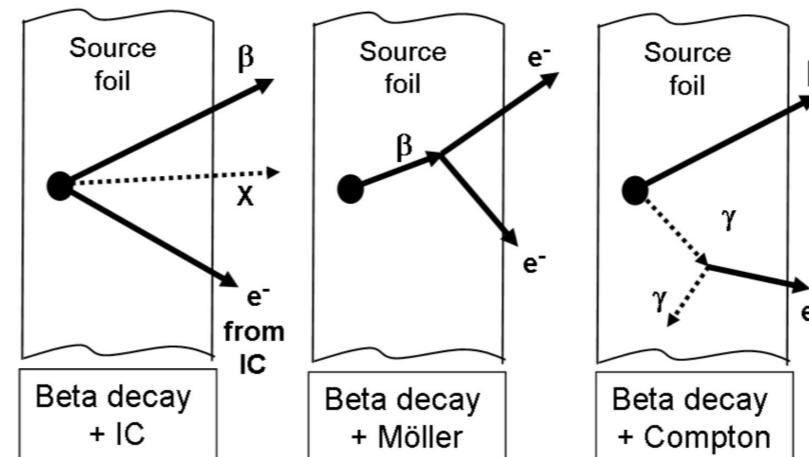
Measure



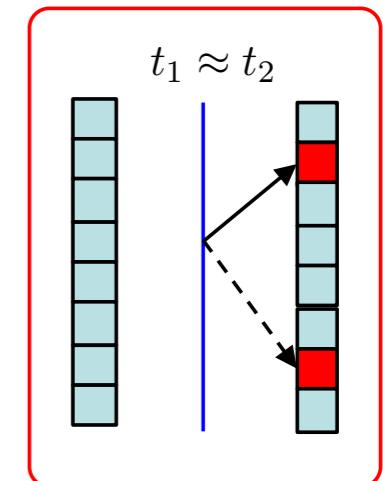
$0\nu2\beta$:
 ^{208}TI γ 2.6 MeV
(n, γ) up to ~ 10 MeV

Internal background

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



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



SuperNEMO background

- ^{214}Bi important background with $Q_\beta=3.27 \text{ MeV}$
- Can originate from internal ^{238}U -chain contamination or from ^{222}Rn emanation/diffusion

- Ultra-pure material selection
- Radon tent
- alpha tagging: $\text{l} \rightarrow \alpha$ channel



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

Nucl.Instrum.Meth. A845 (2017)



Bordeaux emanation setup



London concentration line

SuperNEMO tracker



Nucl.Instrum.Meth. A824 (2016)

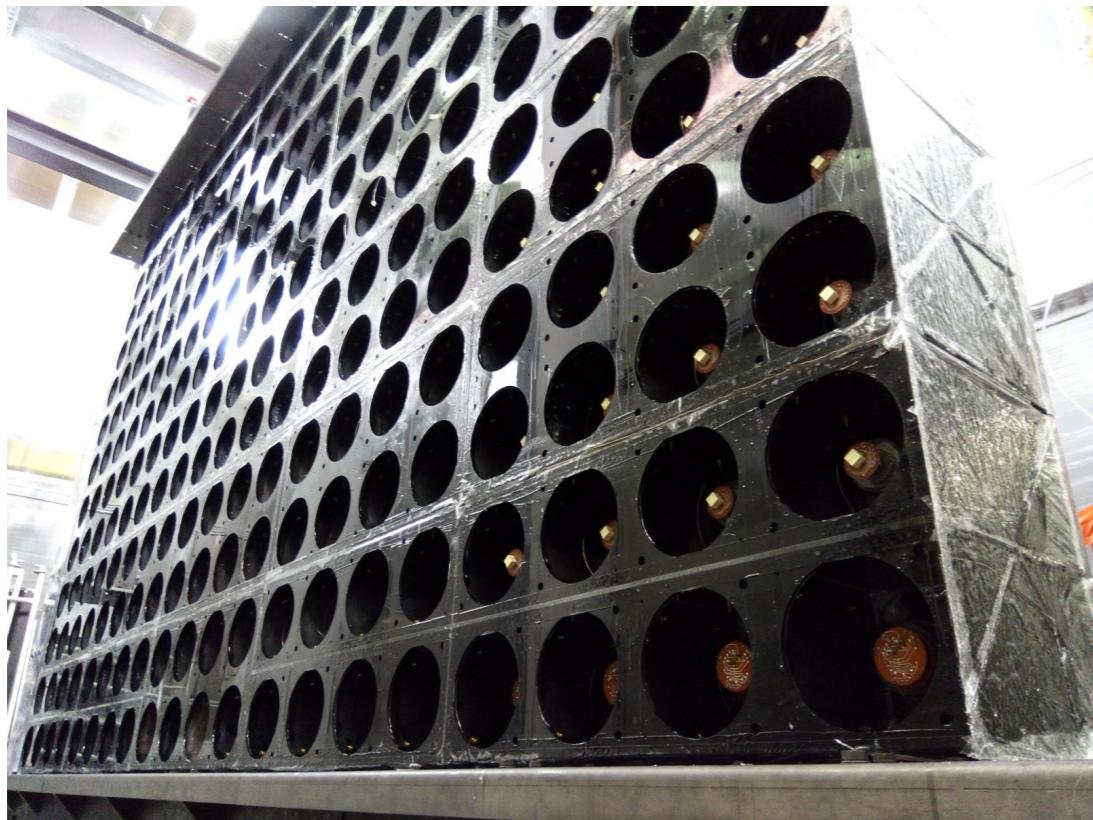
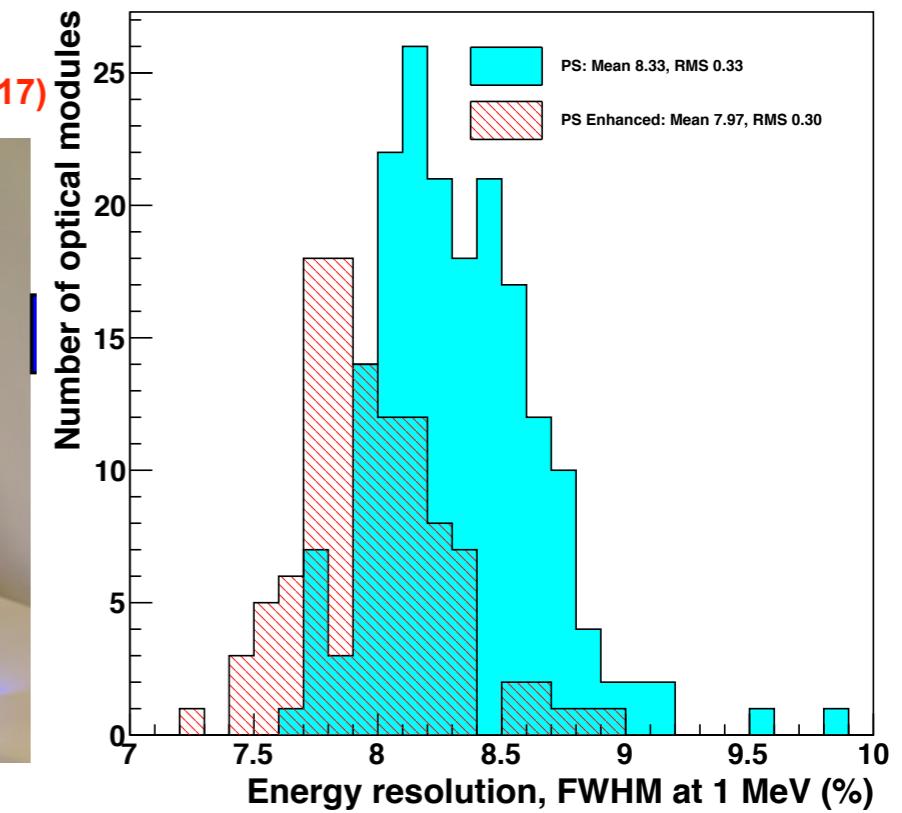
- Multi-wire drift chamber in Geiger mode
- Ultrapure materials: copper, steel, duracon
- Robotic production of 2034 drift cells
- Radiopure gas flow, anti-radon sealing
- <1% dead channels



SuperNEMO calorimeter

- 520 main optical modules
- 8" high QE radiopure PMTs
- $\sigma_t = 400$ ps at 1 MeV
- Energy resolution $7.2\%/\sqrt{E(\text{MeV})}$
- Calibration system allows stability to < 1%

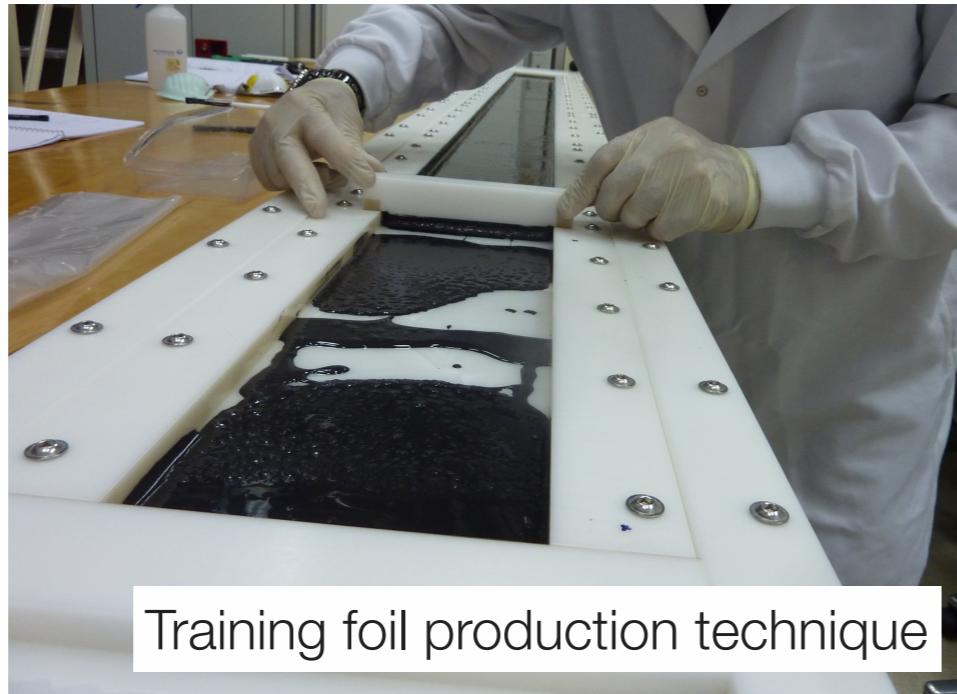
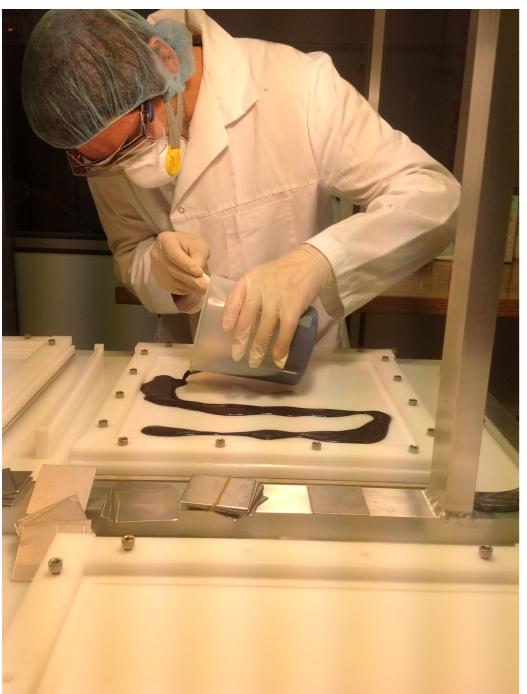
Nucl.Instrum.Meth. under publication (2017)



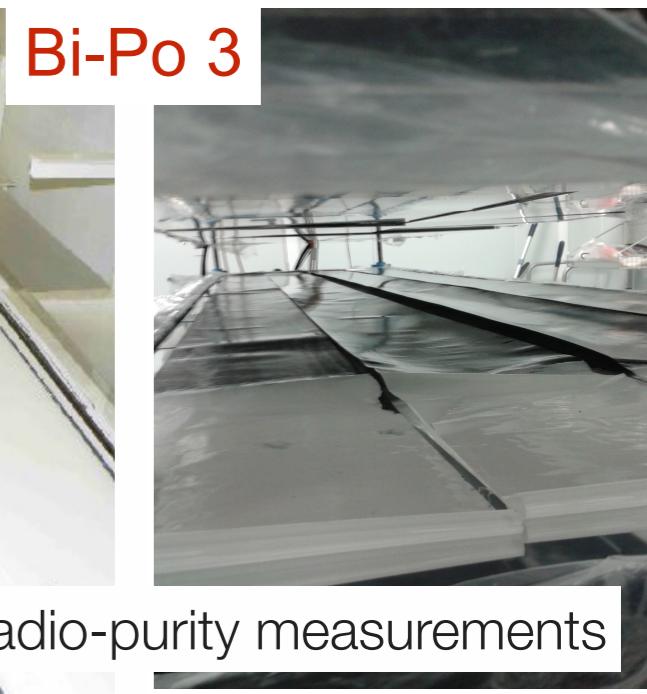
SuperNEMO source foils

- 36 foils made of ^{82}Se powder mixed with PVA glue + mylar mechanical support (200 um thick)
- 7 kg of ^{82}Se ($Q_{\beta\beta}=2.996 \text{ MeV}$)
- Target limits (challenging) on foil contamination:
 $^{208}\text{TI} \leq 2 \mu\text{Bq/kg}$
 $^{214}\text{Bi} \leq 10 \mu\text{Bq/kg}$
- BiPo detector in Canfranc laboratory to measure source foil contamination: preliminary results indicate levels of ^{208}TI [10-30] $\mu\text{Bq/kg}$ (90% C.L.)

JINST 12 (2017) no.06



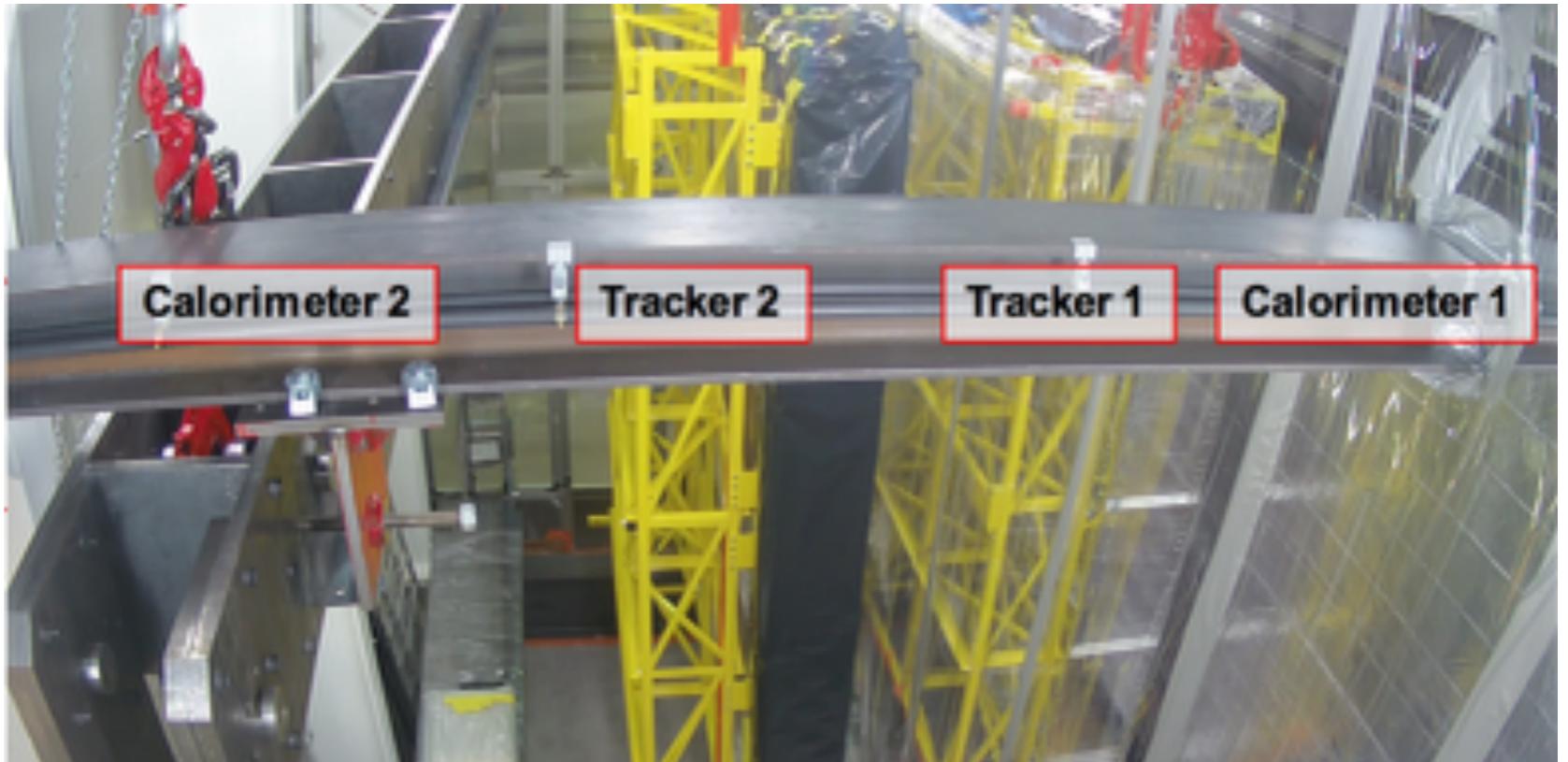
Carla Macolino (LAL-Orsay)



Installation status



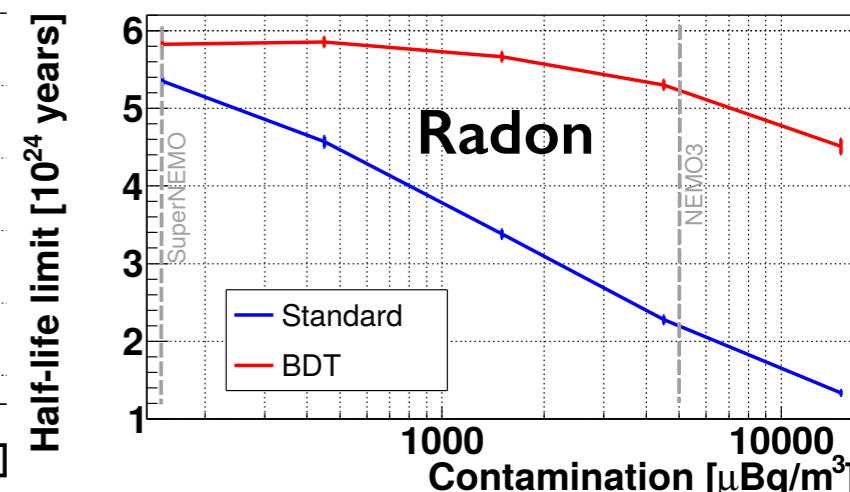
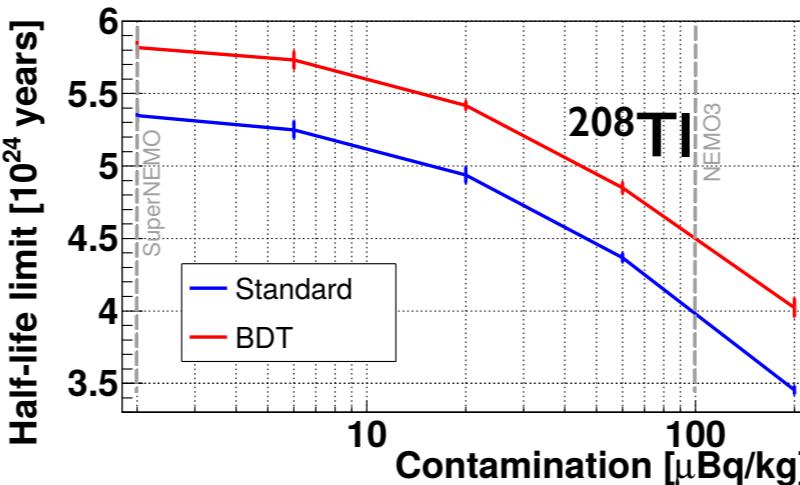
- Half-detector already installed, other half currently under installation at LSM
- Source foils under measurement with BiPo at Canfranc
- Demonstrator running by end of 2017



SuperNEMO sensitivity

From S. Calvez, talk at Moriond 2017

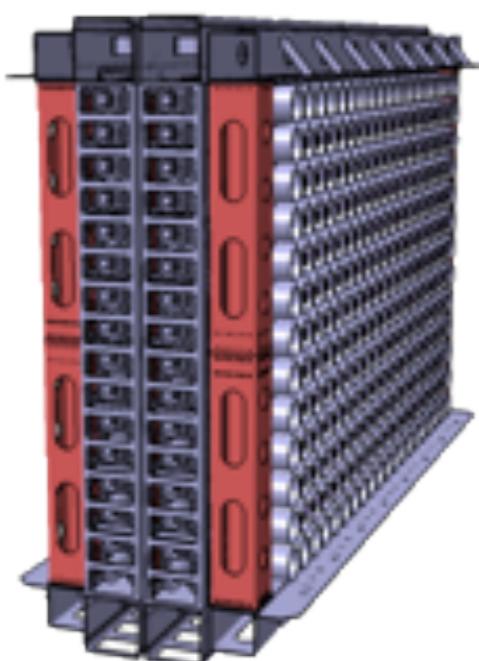
	SuperNEMO	Status
isotope	^{82}Se (or other, e.g. ^{150}Nd)	✓ (7 kg)
isotope mass	$7 \rightarrow 100 \text{ kg}$	✓
radon	0.15 mBq/m^3	in progress
internal contamination	$^{208}\text{TI} \leq 2 \mu\text{Bq/kg}$ $^{214}\text{Bi} \leq 10 \mu\text{Bq/kg}$	in progress
σ_E (FWHM)	8% @ 1 MeV	✓



From S. Calvez
PhD Thesis 2017

In [2.8-3.2] MeV:

- Efficiency: 27.5%
- Total n. of bkg events: 0.21
- Background index: $3 \times 10^{-5} \text{ cts}/(\text{keV kg yr})$



1 module

Demonstrator Module

17.5 kg.yr :

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

$$\langle m_\nu \rangle < 0.20 - 0.55 \text{ eV}$$

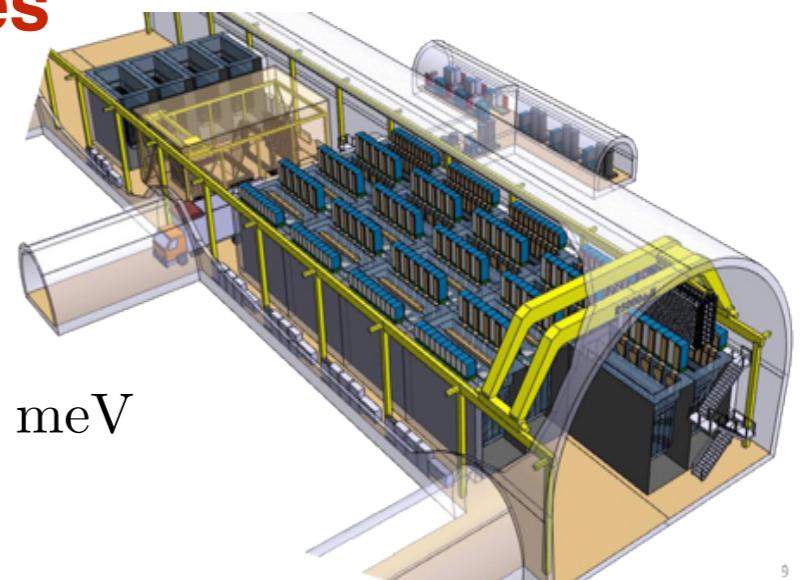
20 modules

Full SuperNEMO

500 kg.yr :

$$T_{1/2}^{0\nu} > 10^{26} \text{ yr}$$

$$\langle m_\nu \rangle < 40 - 110 \text{ meV}$$



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 50-100 meV

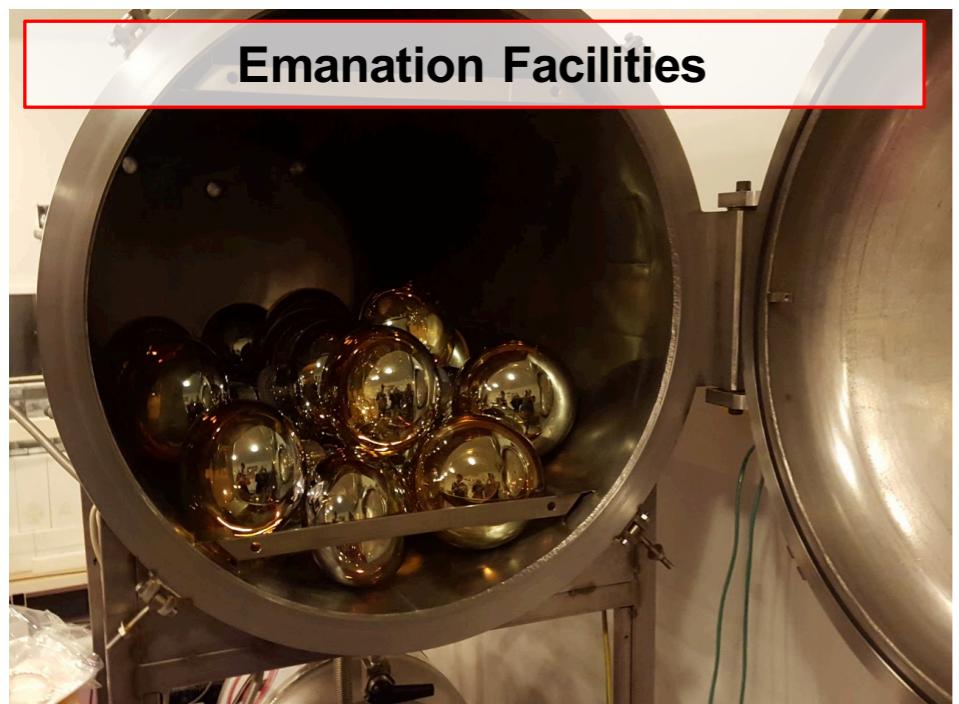
Backup

Backup slides

Radon

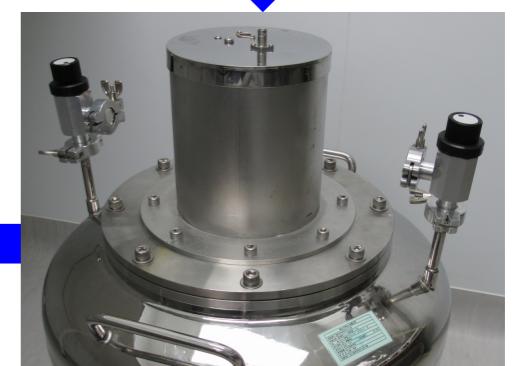


2. Flow through cooled carbon trap.



70 atoms per m^3
30 times better than NEMO-3

3. Release into electrostatic detector.



4. For reasonable gas-flow rates :
 $A(^{222}\text{Rn}) = 150 \mu\text{Bq}/\text{m}^3$

The Bi-Po 3 detector

- HPGe spectroscopy not sensitive enough to reach few $\mu\text{Bq}/\text{Kg}$: BiPo-3 dedicated setup at Canfranc underground lab
- 2 modules of $3.0 \times 0.6 \text{ m}^2$ can measure up to 1.4 kg of ^{82}Se foil with thickness of 40 mg/cm^2
- ^{214}Bi and ^{208}Tl measured through process from natural radioactivity chain
- Thin radiopure plastic scintillators coupled to lightguides and low radioactivity PMTs

