

# The SuperNEMO Demonstrator double beta experiment

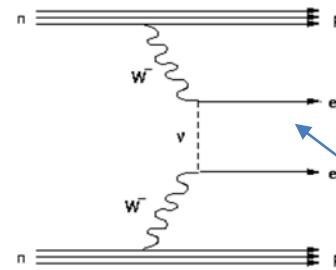
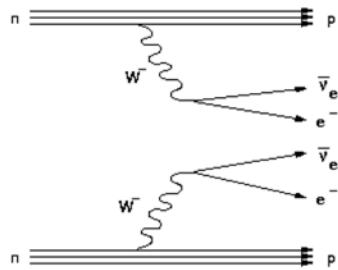
A.Jeremie (on behalf of the SuperNEMO collaboration)

February 21, 2019

<http://supernemo.org>



- Introduction
- From NEMO-3 to SuperNEMO
  - $\beta\beta$  sources
  - Tracker
  - Calorimeter
  - Background reduction
  - Calibration
- Current status and first results
- Future and Conclusion



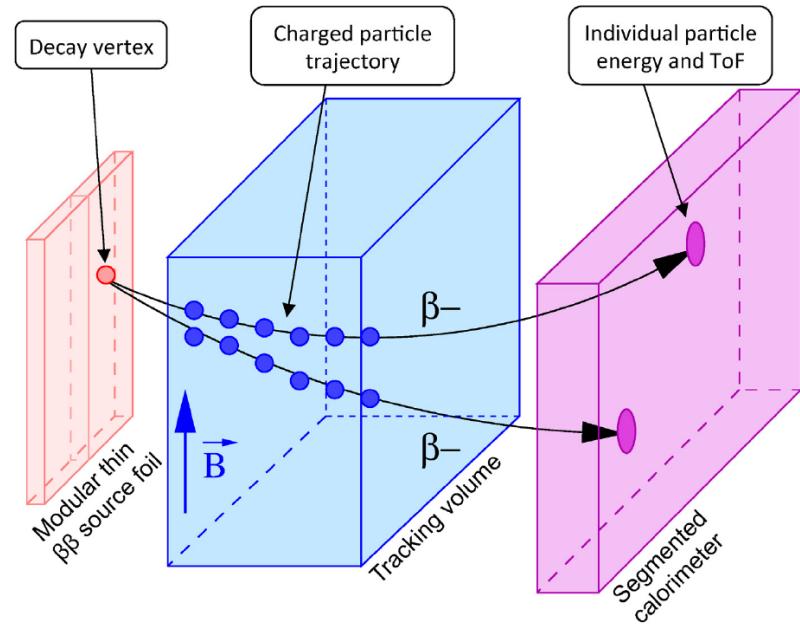
Majorana ν:  
particle and anti-particle are the same

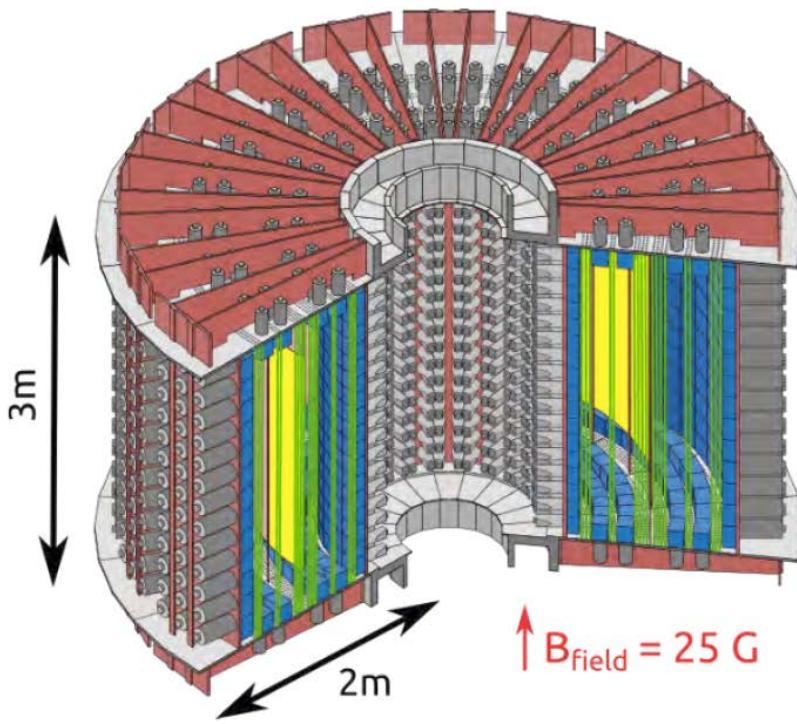
Looking for these events => New physics

$2\nu\beta\beta$

$0\nu\beta\beta$

NEMO detection principle





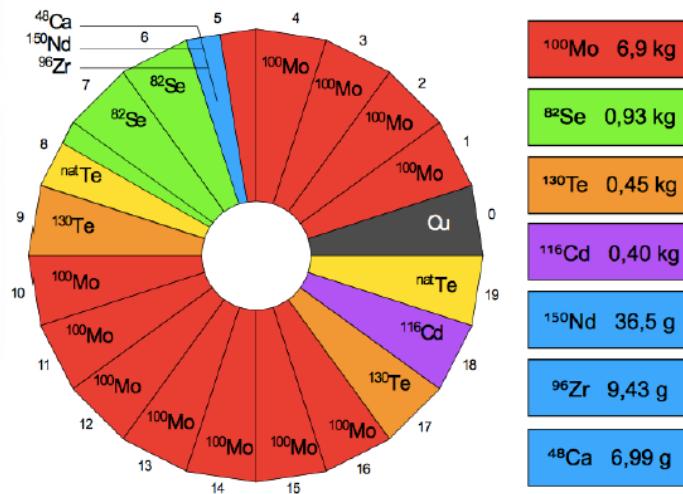
**sources**  
60 mg/cm<sup>2</sup> Foils  
10 kg of  $\beta\beta$  isotopes

**tracker**  
6180 Geiger cells  
vertex resolution :  
 $\sigma_{xy} \sim 3 \text{ mm}$   $\sigma_z \sim 10 \text{ mm}$

**calorimeter**  
1940 optical modules :  
polystyren scintillators  
+ 3" and 5" PMTs  
 $\text{FWHM}_E \sim 15\% / \sqrt{E_{\text{MeV}}}$   
 $\sigma_t \sim 250 \text{ ps}$

NEMO-3 (2003-2011)

NEMO-3 "camembert" (source top view)

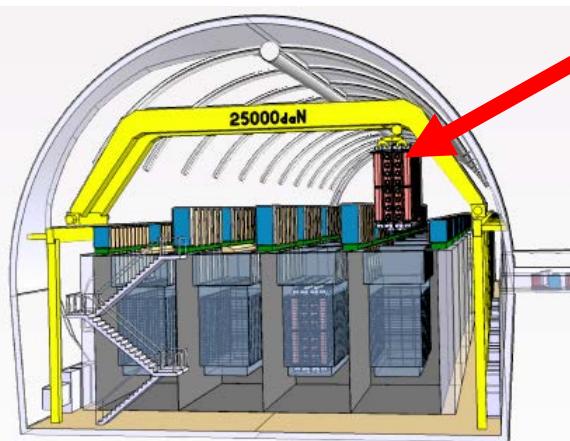
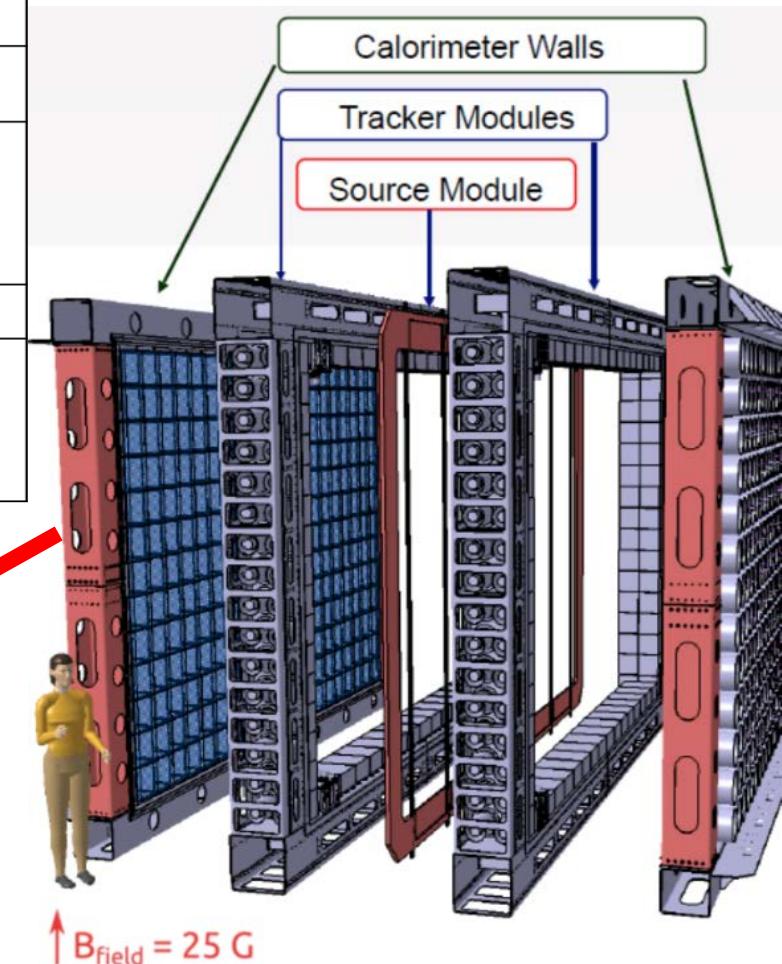


- Source separated from detector
- Full topological reconstruction, particle identification
- Powerful background suppression
- Ability to discriminate different transition mechanisms
- Modular



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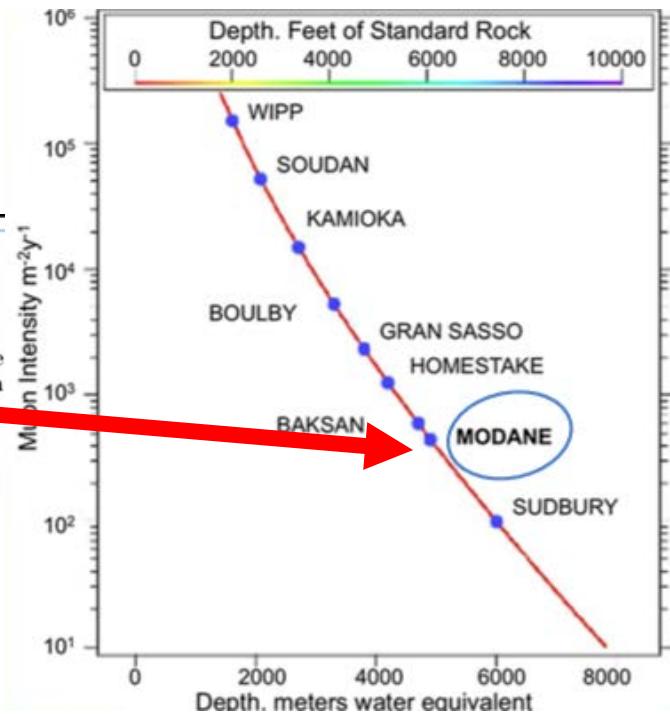
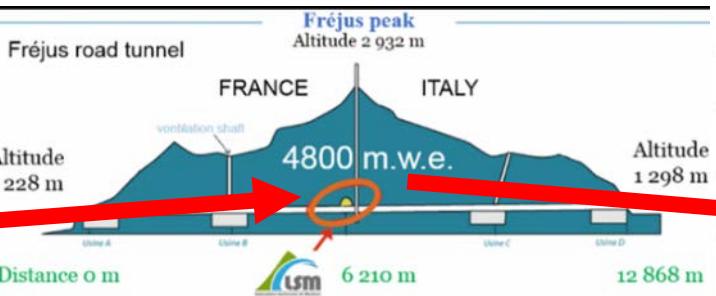
	NEMO-3	SuperNEMO	
		Demonstrator	Complete
Isotope	$^{100}\text{Mo}$	$^{82}\text{Se}$	
Mass (kg)	7	7	100
$T_{1/2}^{2\nu}$	$6,8 \cdot 10^{18} \text{ y}$	$9,4 \cdot 10^{18} \text{ y}$	
Energy resolution (FWHM @ 1 MeV)	15%	8%	
Source radiopurity			
A ( $^{208}\text{Tl}$ )	$\sim 100 \mu\text{Bq/kg}$	$< 2 \mu\text{Bq/kg}$	
A ( $^{214}\text{Bi}$ )	$< 300 \mu\text{Bq/kg}$	$< 10 \mu\text{Bq/kg}$	
A ( $^{222}\text{Rn}$ )	$\sim 5 \text{ mBq/m}^3$	$< 0,15 \text{ mBq/m}^3$	
Exposure	5y	2,5y	5y
Sensitivity $T_{1/2}^{0\nu}$	$> 10^{24} \text{ y}$	$> 5 \cdot 10^{24} \text{ y}$	$> 5 \cdot 10^{25} \text{ y}$
$m_{\beta\beta}$	$< 330\text{-}620 \text{ meV}$	$< 260\text{-}500 \text{ meV}$	$< 82\text{-}160 \text{ meV}$







## LSM, Modane, France



- $\beta\beta$  source =>  $^{82}\text{Se}$  ~50mg/cm<sup>2</sup>
- Tracker => ~2000 cell drift chamber (Geiger mode) with 95% He+4%  $\text{C}_2\text{H}_5\text{OH}$ +1% Ar
- Calorimeter => 712 Optical modules (Scintillator + PMT)
- 25G Magnetic field
- Passive shielding => iron + PE/water
- Anti-radon system

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Six different purification batches for radiopure  $^{82}\text{Se}$  production (distillation, chromatography, chemical precipitation)

=> Good opportunity to validate purification techniques

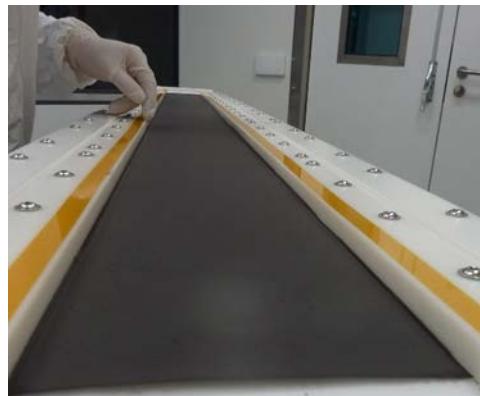
Novel purification process « reverse chromatography » (publ. in prep.)

2 types of  $^{82}\text{Se}$  foils (40-60mg/cm<sup>2</sup> ~300μm thick, enrichment: 96%-99.9%) :

- same as for NEMO-3 : in one piece poured into perforated Mylar (12μm)
- new method with standalone pads in raw Mylar (12μm)

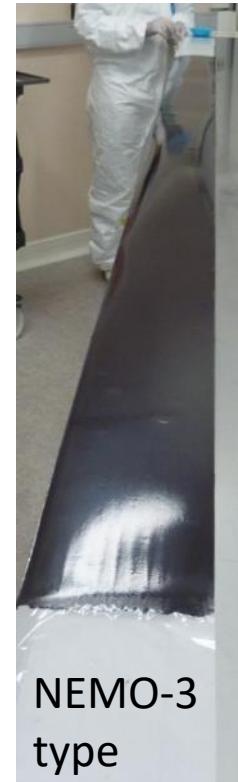


Mix  $^{82}\text{Se}$  powder with  
PVA (90%/10%)

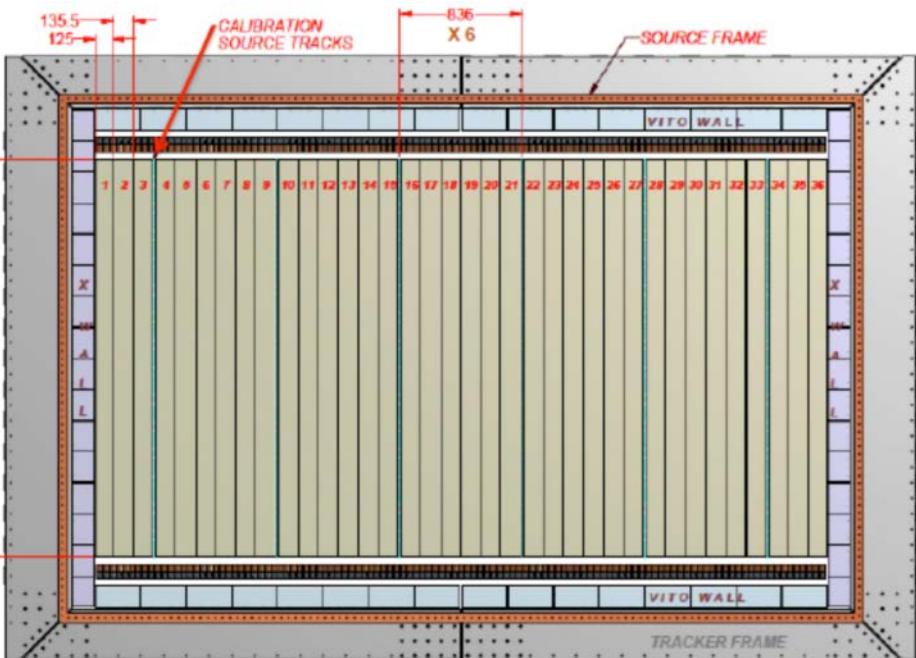


Pour mixture

Prepared in an ISO 6 clean room



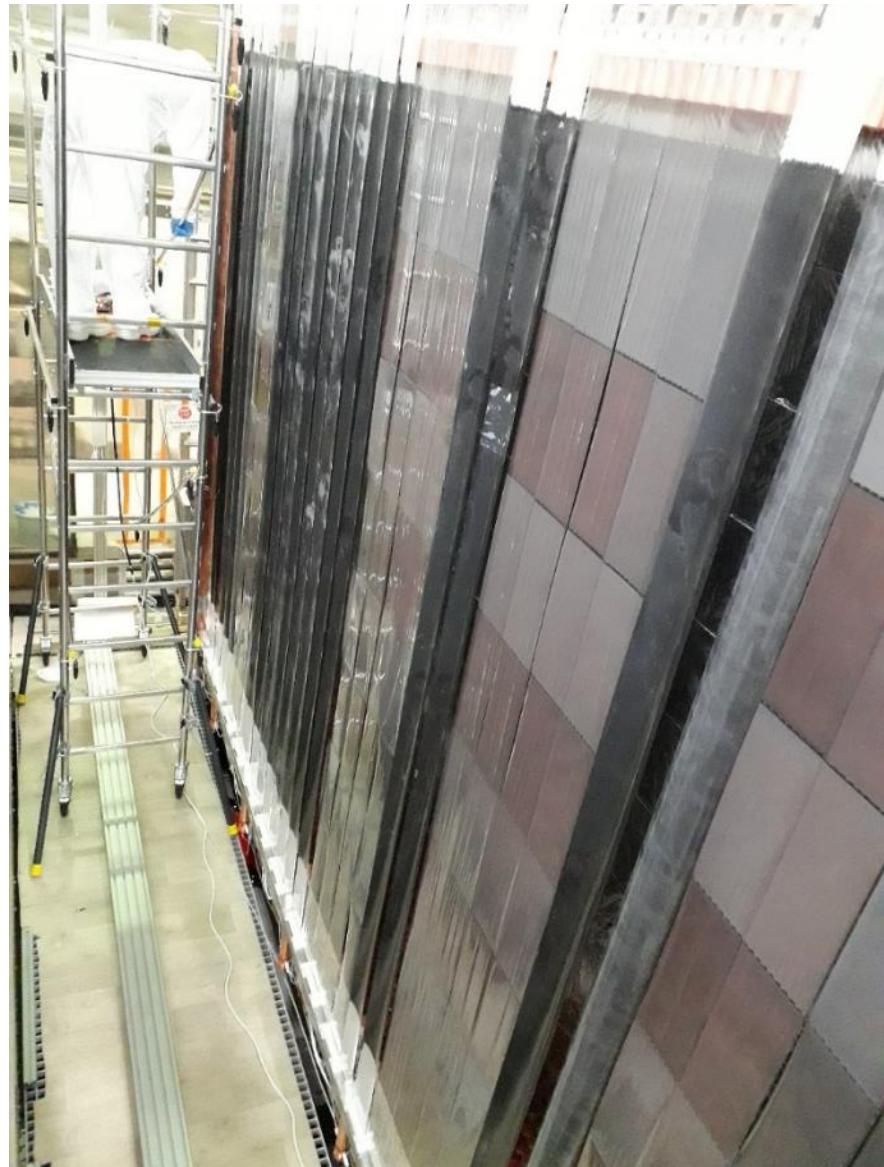
36 foils : 34  $^{82}\text{Se}$  (6.3kg) + 2 Cu (0,4kg)



2 Source Foils 125mm x 2700mm (1&36)

34 Source Foils 135.5mm x 2700mm (2-35)

**TOTAL SOURCE SURFACE = 131139cm<sup>2</sup>**



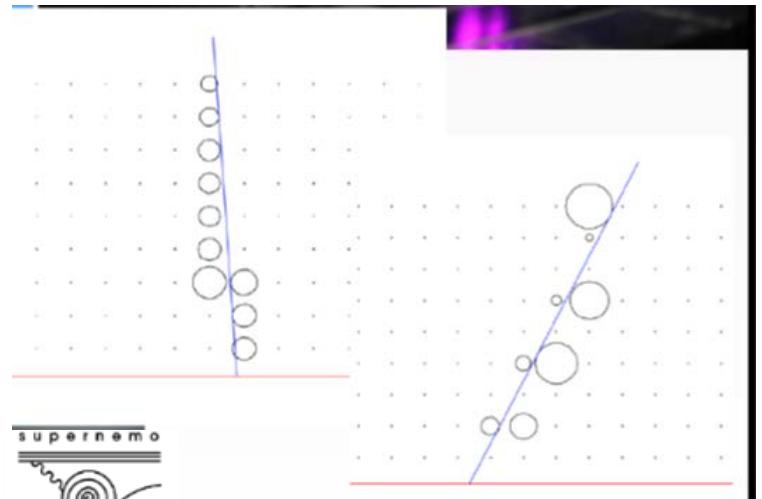
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Tracker Cell Production  
2034 cells, ~13,000 wires



4 C-sections assembly



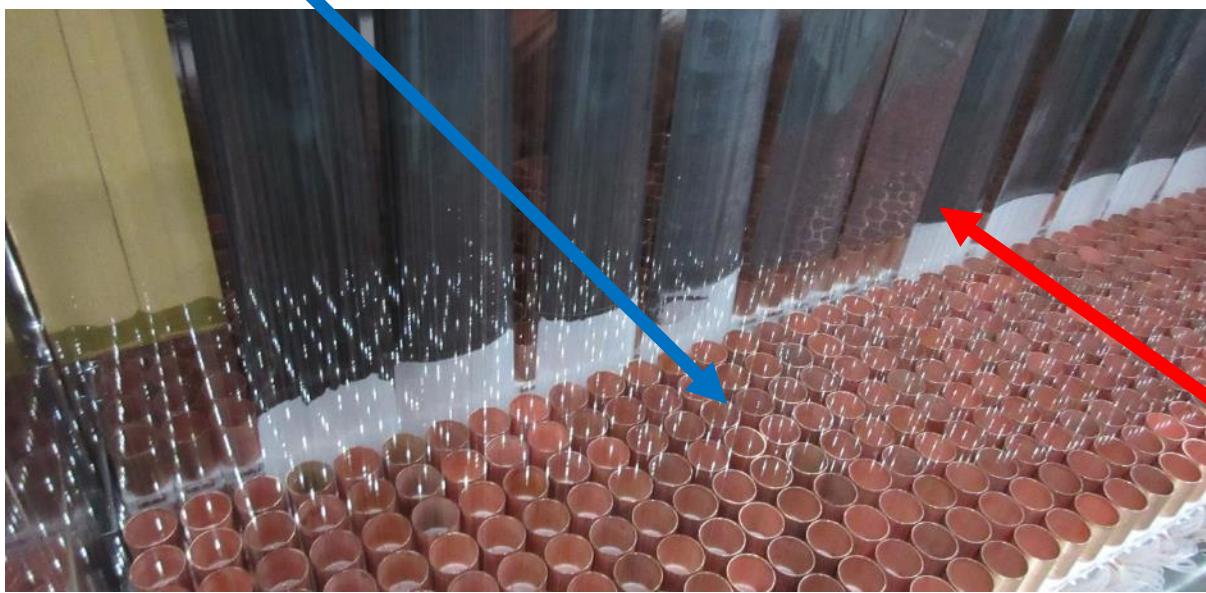
Rn emanation from fully assembled tracker  
Target ( $150 \mu\text{Bq}/\text{m}^3$ ) reached

Commissioned with cosmic rays before installation

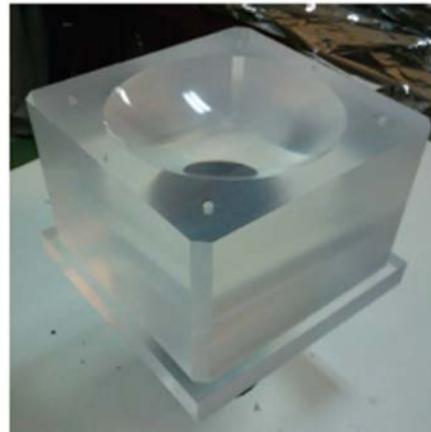
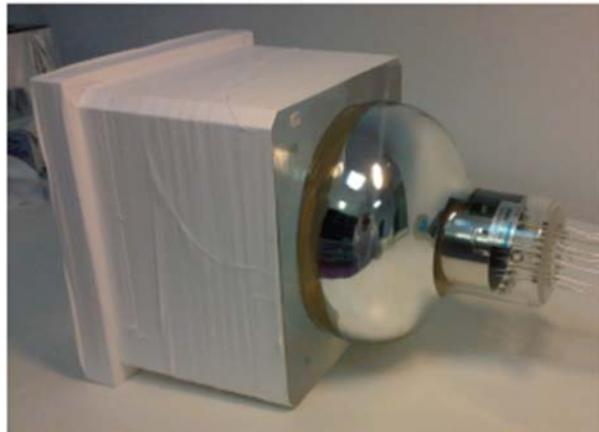


Tracker with wires

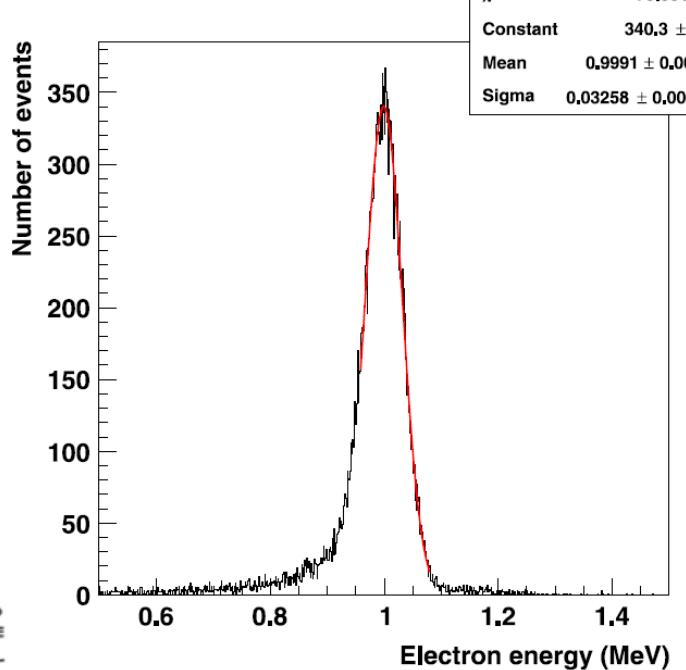
Calorimeter blocks



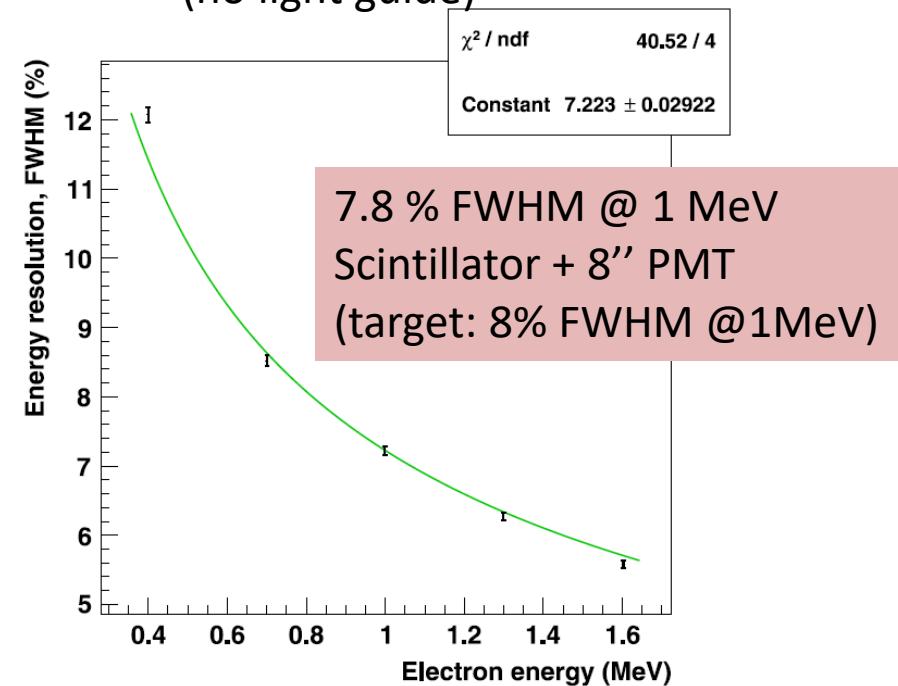
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Each block characterized



- 712 Optical Modules
- Polystyrene-based scintillator
- Hamamatsu 8" PMT (some 5" PMT outer rows)
- Teflon and Mylar wrapping
- Individual pure iron magnetic shields (25 G)
- PMT directly coupled to scintillator (no light guide)





Front of Main Wall

Back of Main Wall



Nucl.Inst.Meth. A 868 98-108

15th VCI 2019

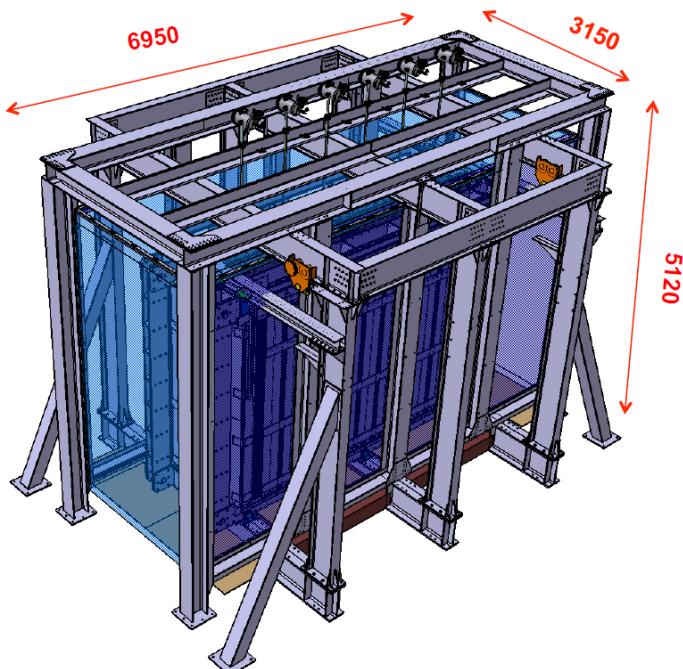
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SuperNEMO  $^{222}\text{Rn}$  target:  $\leq 150 \mu\text{Bq}/\text{m}^3$

## Remove Radon from experiment

Anti-radon tent:

- Black polycarbonate (shown in blue)
- Flushed with radon free air (dedicated facility with radon trap)

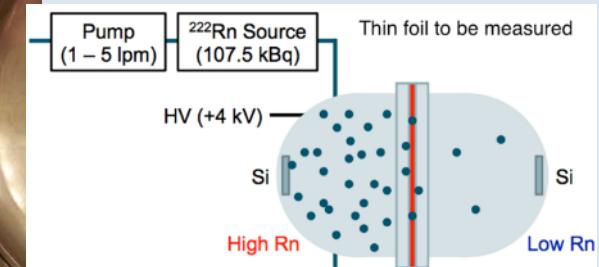


## Measure Radon before installation

### Rn emanation setup



### Rn permeability setup



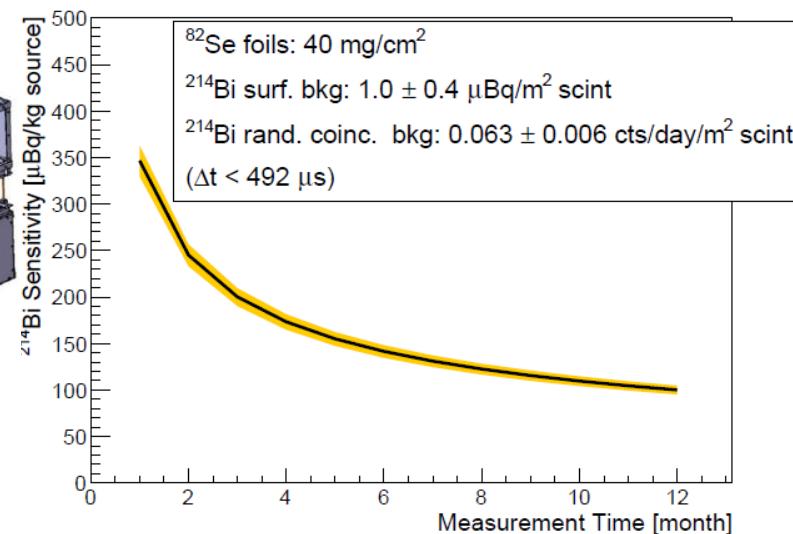
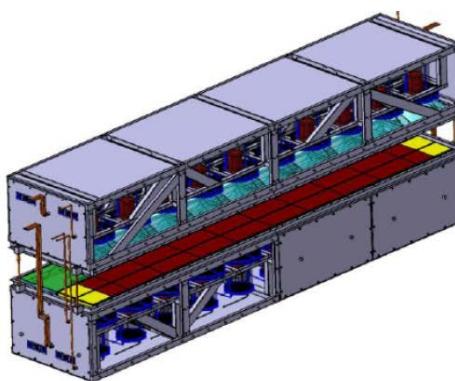
Rn concentration line for Rn measurements

Lots of tools to check radiopurity of demonstrator components

Materials screening using HPGe in LSM,  
Bordeaux,  
Boulby  
0.1-1mBq/kg



Dedicated BiPo detector to measure  $\beta\beta$  source foil contamination,  
10 $\mu$ Bq/kg for  $^{214}\text{Bi}$ , 2  $\mu$ Bq/kg for  $^{208}\text{Tl}$  — operating since 2013 at LSC (Canfranc, Spain)

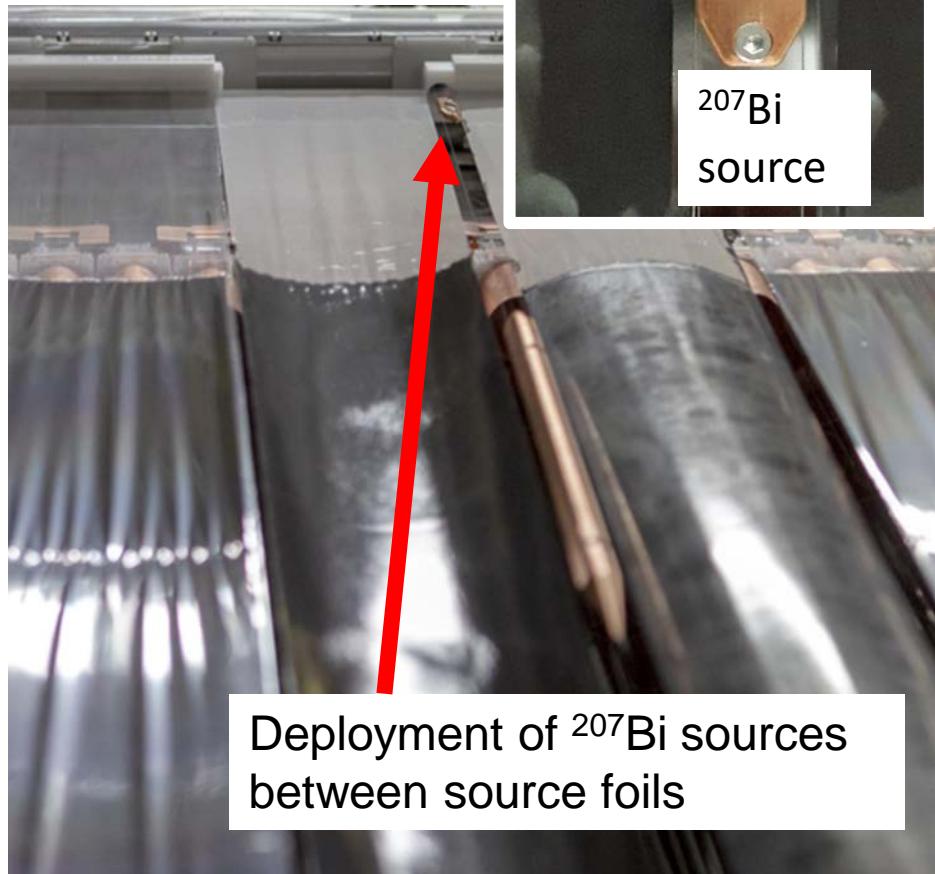
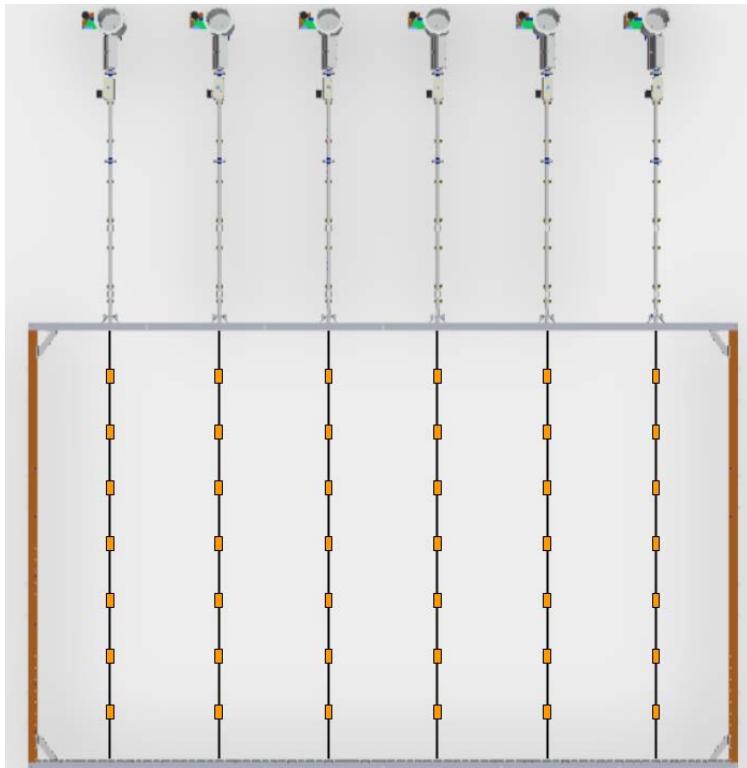


Also ICP-MS at UCL

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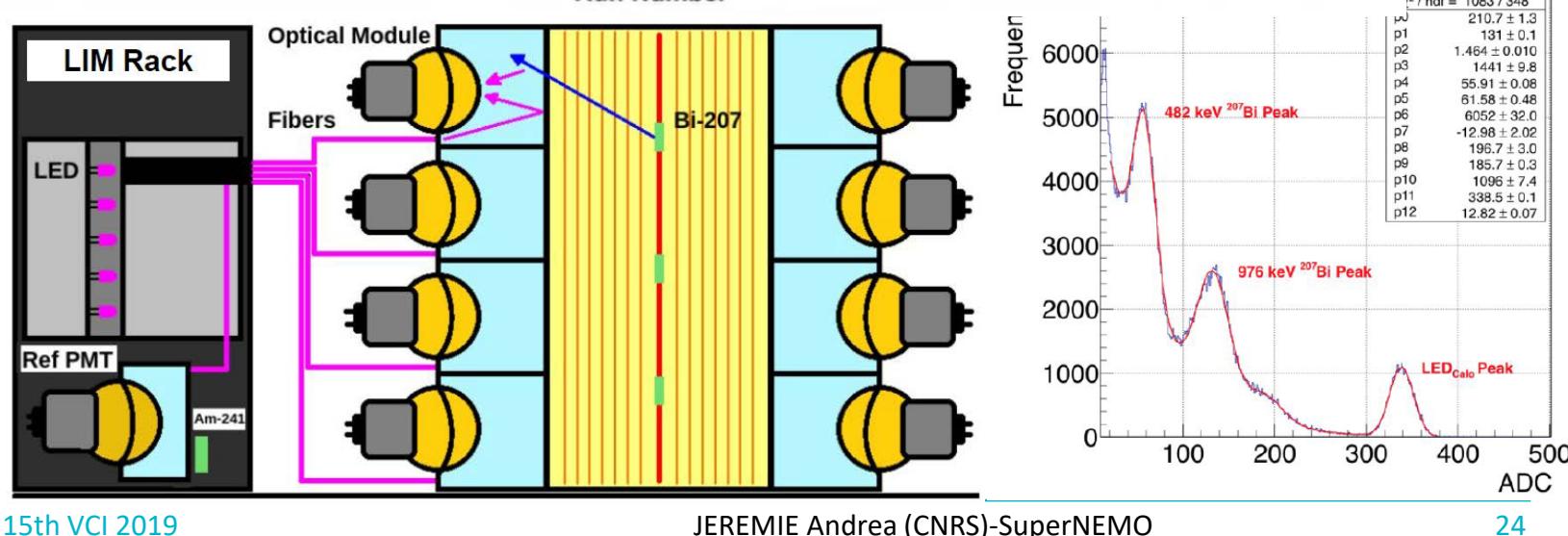
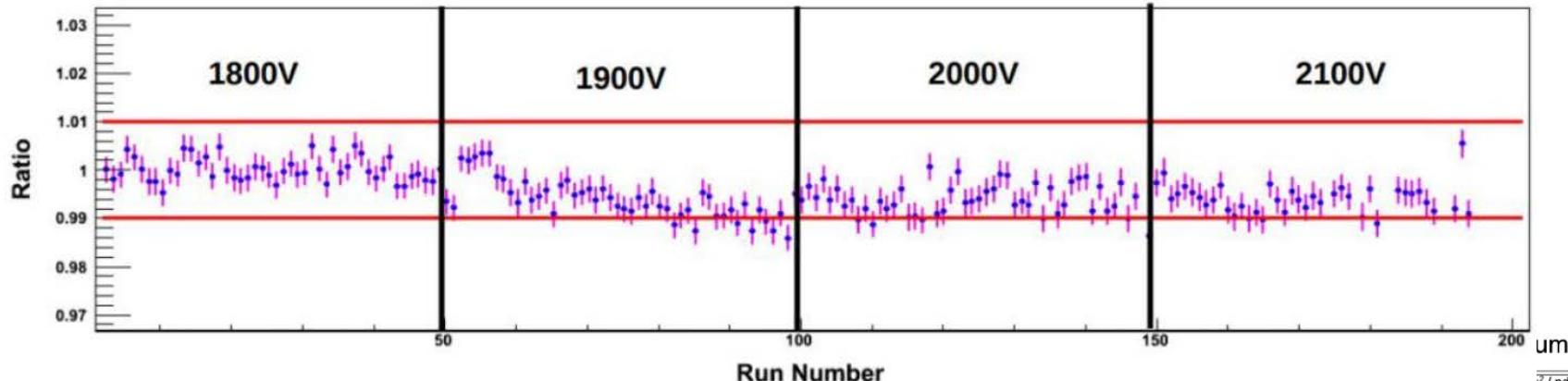
- Rn tight automatic deployment system of  $^{207}\text{Bi}$  sources
- To be periodically deployed for calibration

Spatial distribution of calibration sources

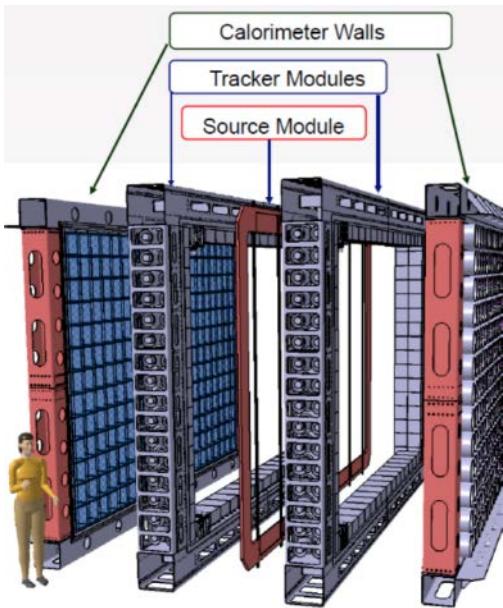


- Monitor the calorimeter response with a precision of 1%.
- 20 pulsed UV LEDs => inject light into calorimeter modules via fiber optics
- Reference OM with  $^{241}\text{Am}$  for LED stability monitoring

Ratio of Predicted to Measured  $^{207}\text{Bi}$  Peak (1 MeV)



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Demonstrator (active part) assembled at LSM  
November 2018

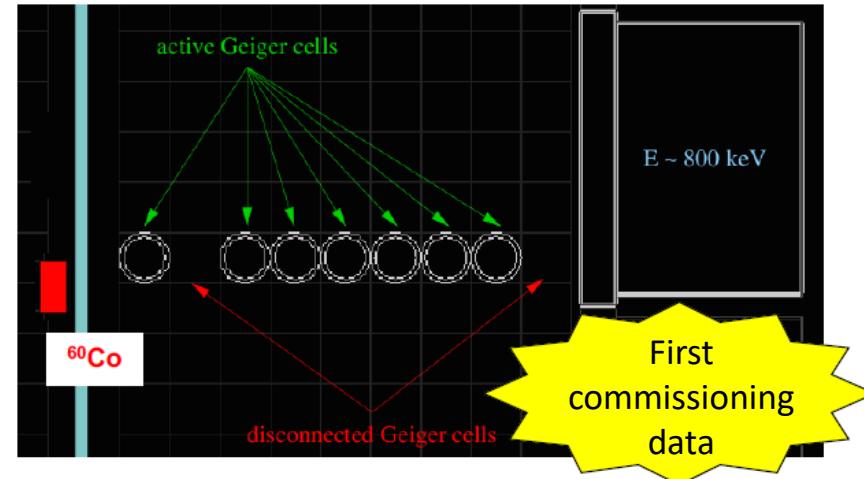


Source frame

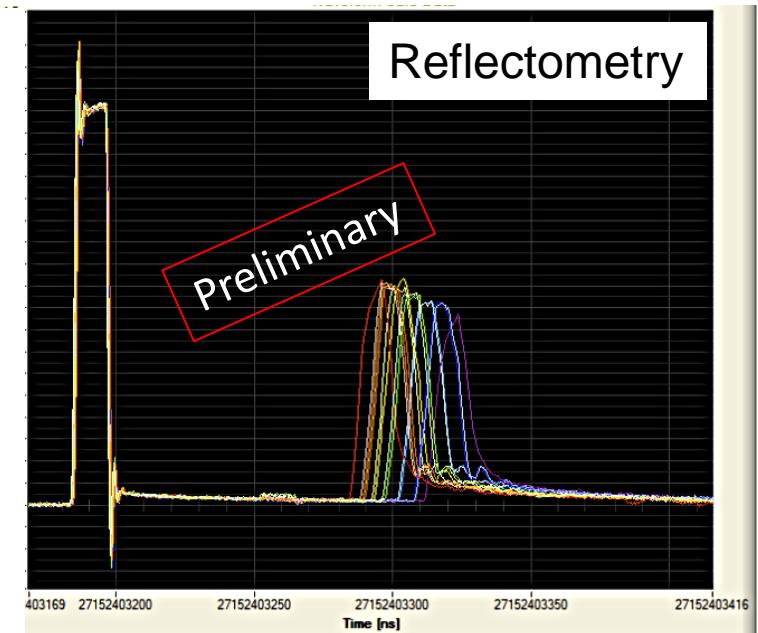
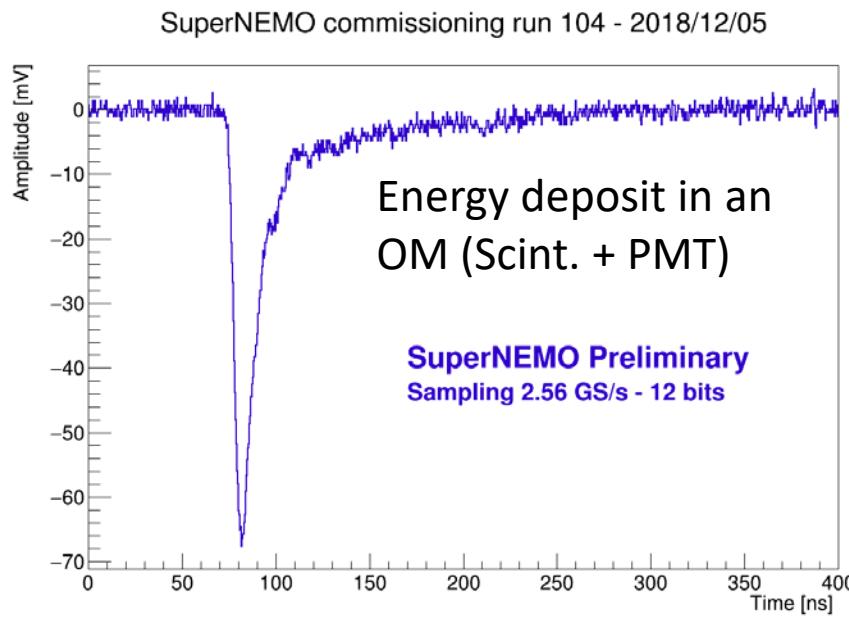
Tracker + side OMs

Calorimeter main walls

## Half-detector commissioning with Argon



Commissioning on one assembled calorimeter main wall (December 2018)



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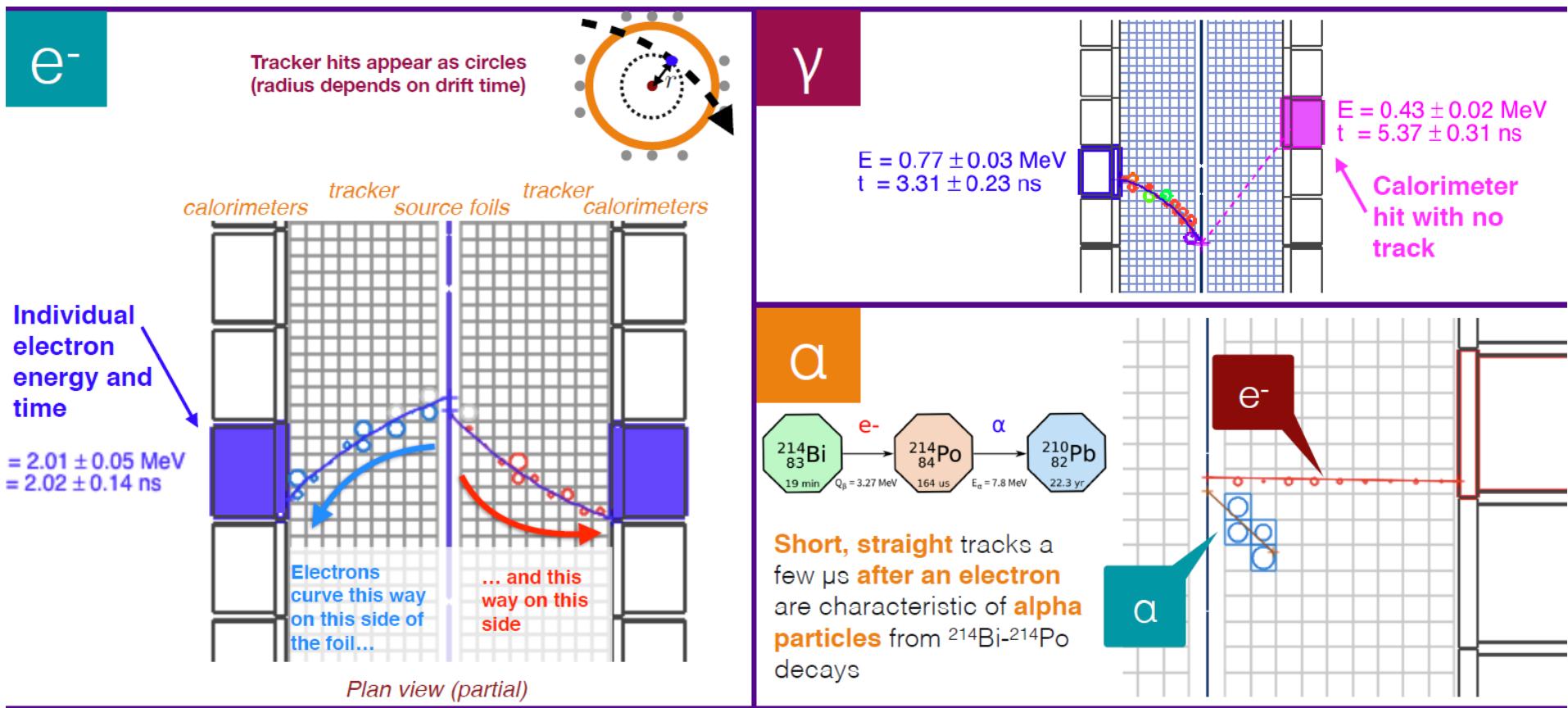
- Progressive start-up of remaining demonstrator components
  - Coil installation
    - Anti-radon tent installation
    - Passive shielding installation

...Data taking throughout...

- SuperNEMO tracker-calorimeter technique  
=>multi-observable signal identification + background rejection
- Detector construction challenging
- Optical Modules with exceptional performances : 7.8 % FWHM @ 1 MeV
- Radiopure tracker construction: 150  $\mu\text{Bq}/\text{m}^3$  reached
- Novel source foil production : ~7kg of  $^{82}\text{Se}$
- Possibility for other isotopes :  $^{150}\text{Nd}$  and  $^{48}\text{Ca}$  for example
- Calibration within 1% : Light Injection and  $^{207}\text{Bi}$  sources







## How To Build a $\beta\beta$ -Experiment

maximise efficiency ( $\varepsilon$ ) & isotope abundance ( $a$ )

maximise exposure = mass ( $M$ )  $\times$  time ( $t$ )

$$T_{1/2}^{0\nu} \text{ (90% C.L.)} = 2.54 \times 10^{26} \text{ y} \left( \frac{\varepsilon \times a}{W} \right) \sqrt{\frac{M \times t}{b \times \Delta E}}$$

$W$  = atomic weight

minimise background ( $b$ ) & energy resolution ( $\Delta E$ )

Dedicated BiPo detector to measure  $\beta\beta$  source foil contamination,  
10  $\mu\text{Bq}/\text{kg}$  for  $^{214}\text{Bi}$ , 2  $\mu\text{Bq}/\text{kg}$  for  $^{208}\text{TI}$  — operating since 2013 at LSC (Canfranc, Spain)

