supernemo collaboration

Status of the SuperNEMO Demonstrator and Analysis of First Data

THE UNIVERSITY of EDINBURGH

Xalbat Aguerre

SuperNEMO collaboration

~100 collaborators over 8 countries

Imperial College London

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

COMENIUS UNIVERSITY BRATISLAVA

INSTITUTE OF EXPERIMENTAL AND APPLIED PHYSICS CTU IN PRAGUE

LP2i Bordeaux

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

lpc caen Laboratoire de physique corpusculaire

WARWICK THE UNIVERSITY OF WARWICK

UCL

TEXAS The University of Texas at Austin

THE UNIVERSITY of EDINBURGH

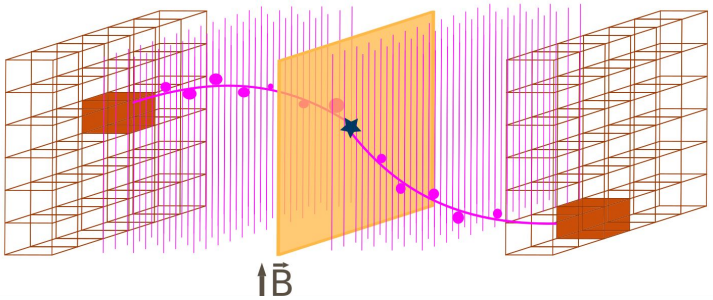
MANCHESTER 1824 The University of Manchester

Collaboration meeting in Marseille in February

Collaboration meeting in Edinburgh last July

SuperNEMO double beta decay experiment

Unique tracker/calorimeter approach



1. **ββ source foil:** free choice of solid **isotopes**
2. **Tracker**: charged particles' **trajectory**
3. **Calorimeter :** particle's **individual energy** **and** **time of flight**

SuperNEMO double beta decay experiment

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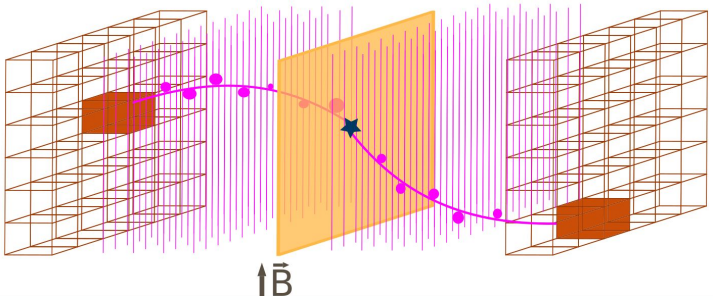

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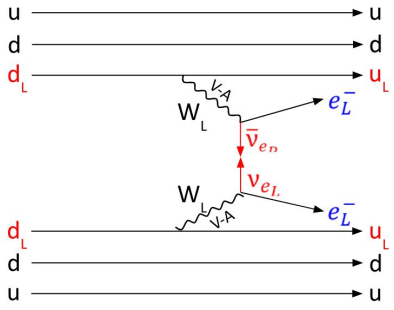
Full topology of the decay

New Physics with SuperNEMO

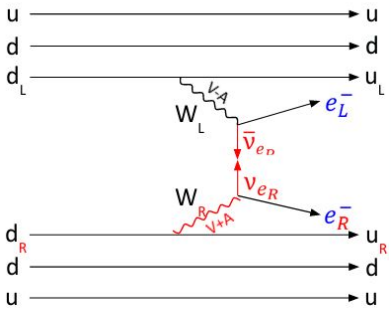
Ovββ mechanism discrimination

$^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^-$



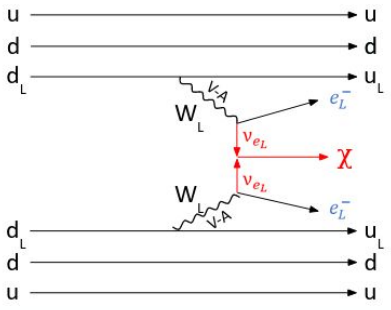
V-A current

$^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^-$



V+A current

$^{A}_{Z}X \rightarrow {}^{A}_{Z+2}Y + 2e^- + \chi$



Majoron emission

. . .

Mechanisms distinguishable by:

- e^- individual energy
- e^- angular distribution

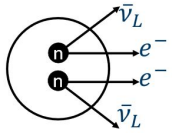
SuperNEMO is the only experiment able to study these mechanisms!

R. Arnold et al. "Probing New Physics Models of Neutrinoless Double Beta Decay with SuperNEMO" [Eur. Phys. J. C70:927-943, 2010]

New Physics with SuperNEMO

Standard and exotic 2νββ

Poster # 851



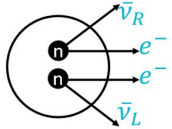
Improved description of $2\nu\beta\beta$ spectrum shape

› Precise shape analysis can constrain g_A[1]

› Shape parameters: ξ_{31}, ξ_{51}

Where to look:

› **Single-electron energy spectrum**



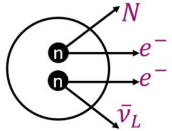
Decay with right-handed neutrino

› $\nu_R\nu_L\beta\beta$

› Constrains on the RH neutrino interactions $(V+A)$[2]

Where to look:

› **Angular distribution**



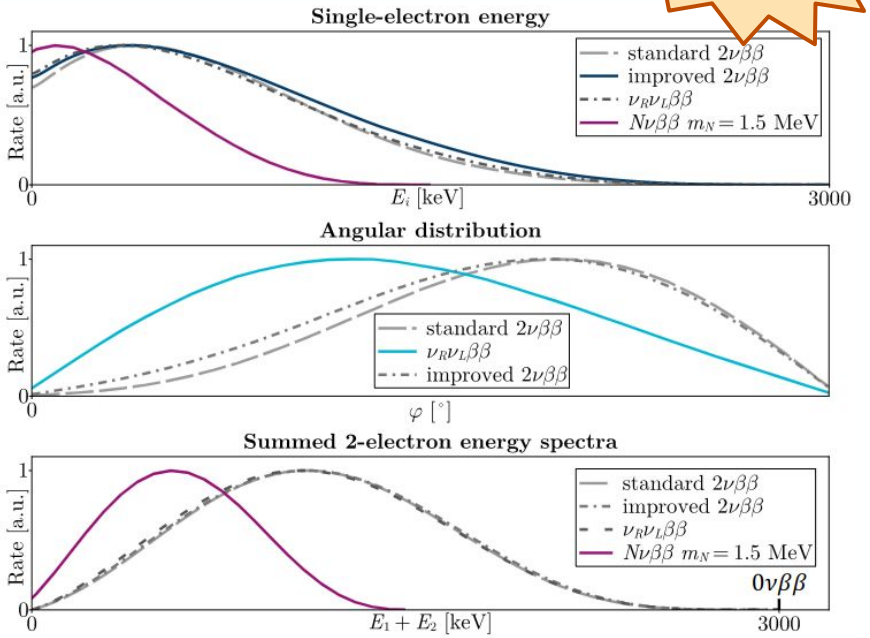
Decay with sterile neutrino

› $N\nu\beta\beta$

› Shape depends on m_N[3]

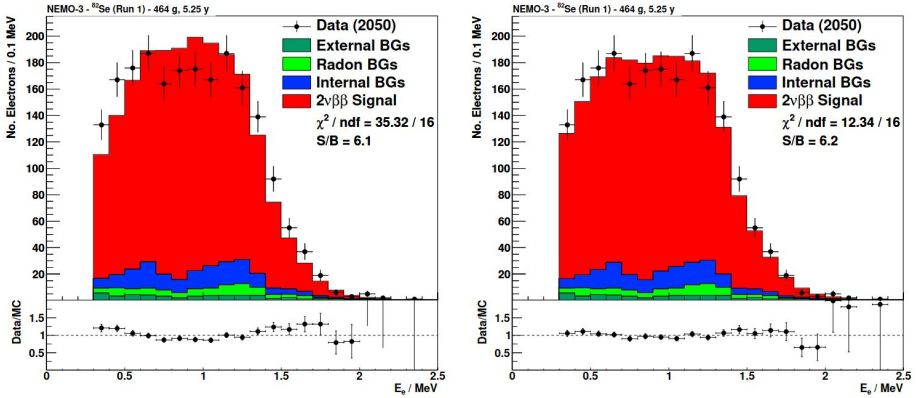
Where to look:

› **Single-electron energy and Summed energy spectra**



New Physics with SuperNEMO

NEMO-3 : 3σ preference for SSD decays in ^{82}Se

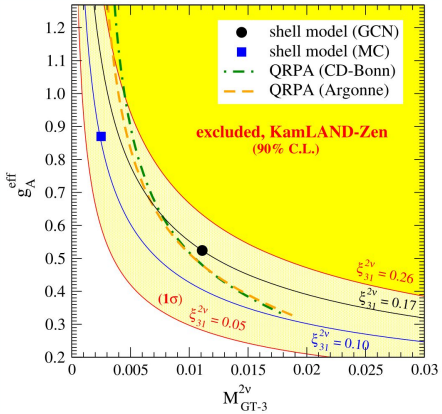


(a) Higher-state Dominated (HSD) (b) Single-state Dominated (SSD)

SuperNEMO : 5σ SSD/HSD sensitivity in < 2.5 years

Eur. Phys. J. C (2018) 78: 821

Quenching of g_A



SuperNEMO's individual e^- spectrum is more sensitive to g_A

Phys Rev Lett 122, 192501 (2019)

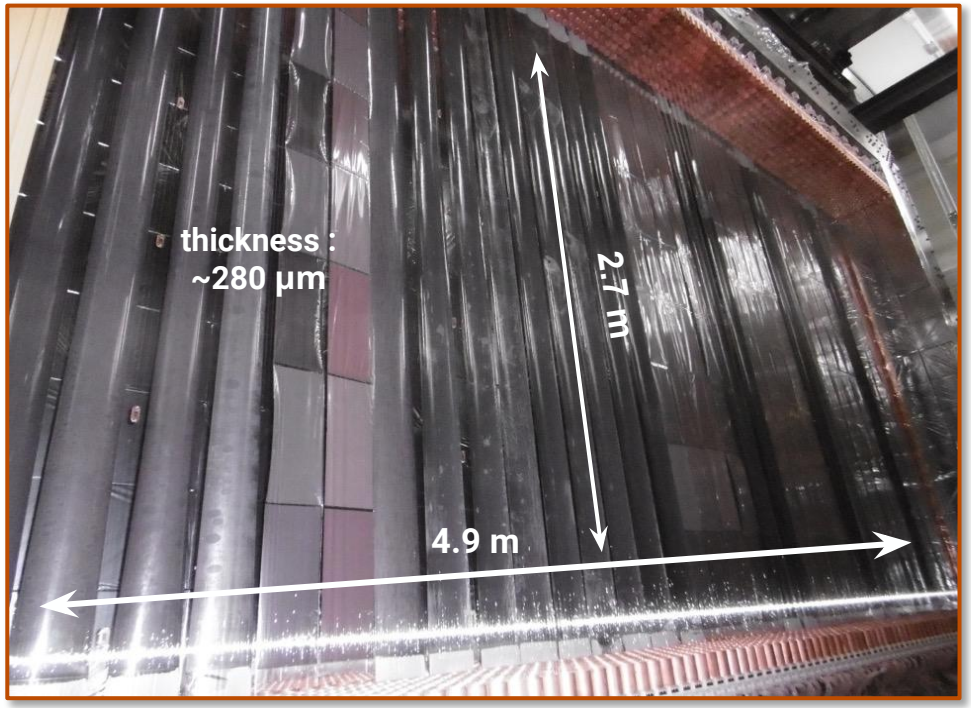
SuperNEMO demonstrator

Demonstrator construction is currently being finalised

Demonstrator **objectives**:

- Proof of **feasibility** of a large-scale detector.
- Precision measurement of the **2νββ decay kinematics**
- Background-free experiment in the ROI for 0νββ

^{82}Se source foils

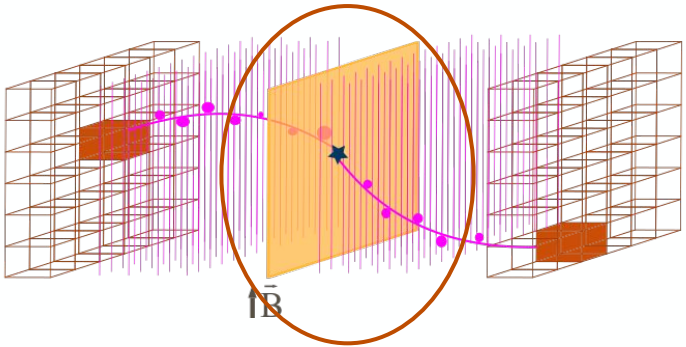


34 ^{82}Se foils, i.e **6.11 kg** (90-99% enriched)

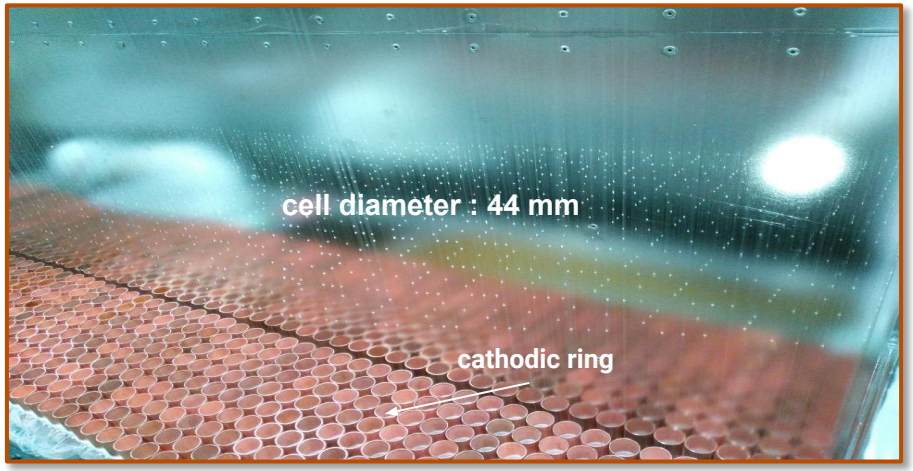
High $Q_{\beta\beta}$ = 2.998 MeV

High $T^{2\nu}_{1/2}$ = 9.4 10^{19} years

Article being finalised



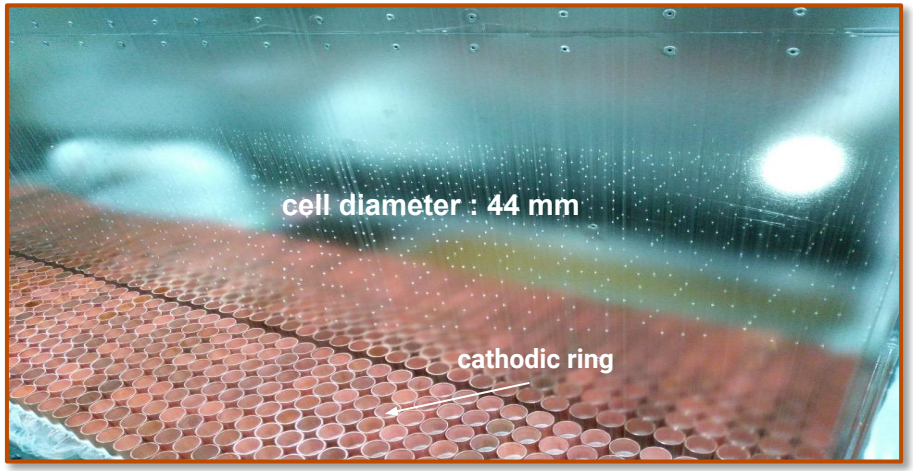
Tracker



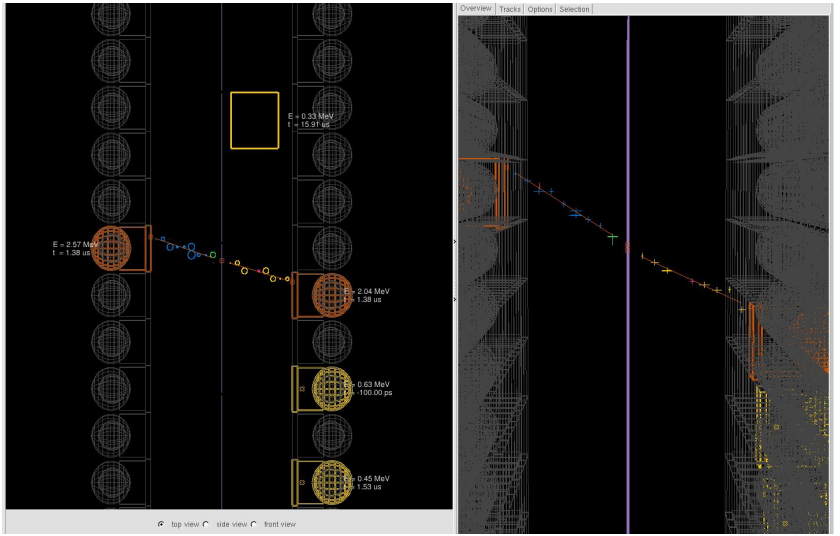
2034 cells (14970 wires) in Geiger mode (99% working)
Helium based ionisable gas mixture
3D track reconstruction

- t_{anodic} (0-10 µs) ⟶ radial distance (X,Y)
- $t_{cathodic}$ (0-80 µs) ⟶ longitudinal distance (Z)

Tracker



Real data 3D track reconstruction



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Calorimeter

One of the calorimeter walls prior to the detector's closure

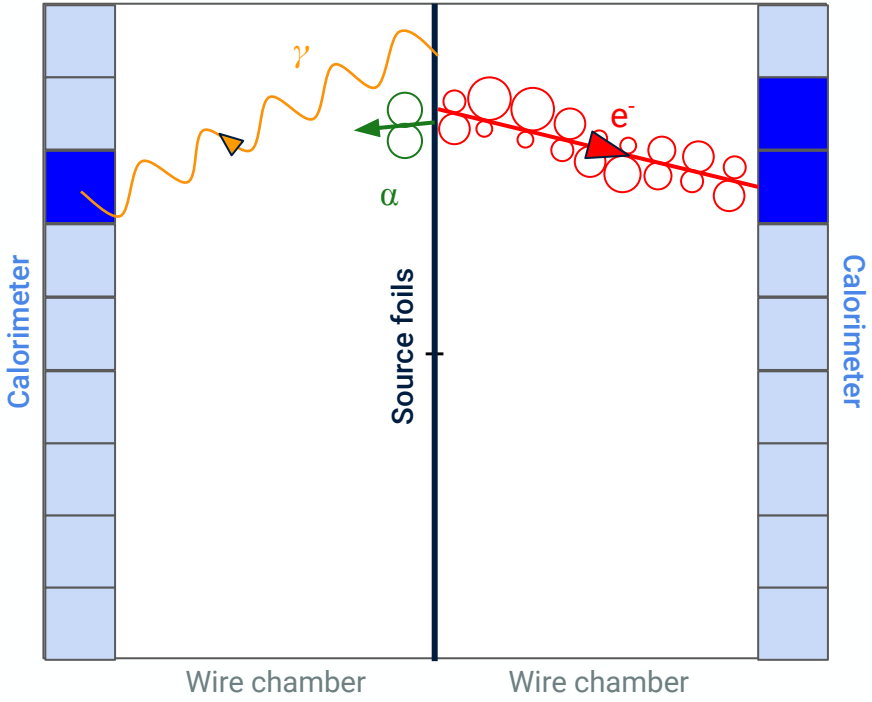
712 Optical Modules (scintillator + photomultiplier)

8" optical module

Time resolution < 400 ps for e^- at 1 MeV

Article in preparation

Particle identification

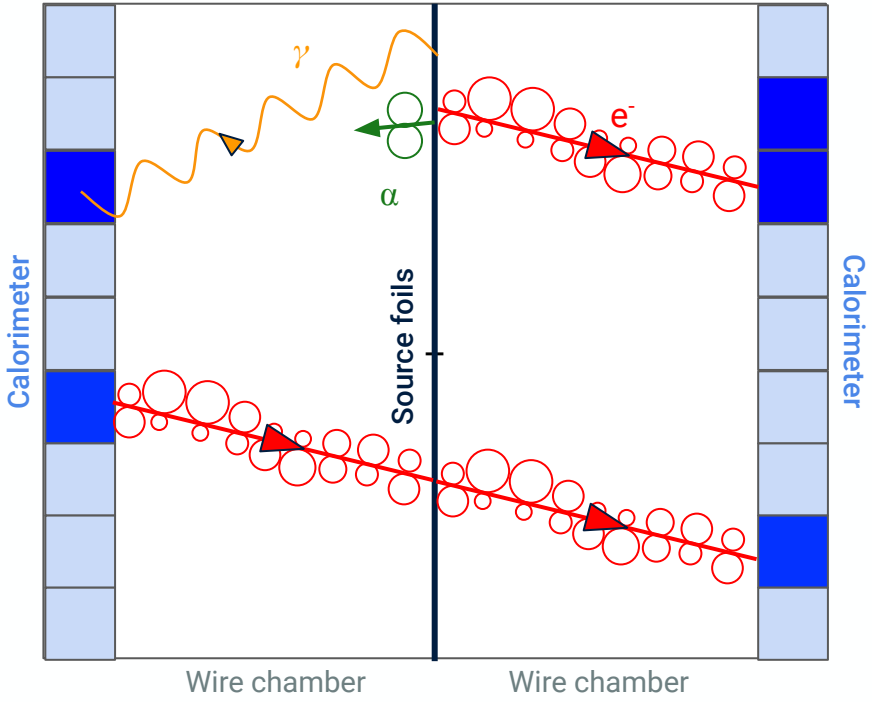


γ : **no track**, only calo hit

α : **short track**, no calo hit

e^- : **track and calo hit**

Particle identification



γ : **no track**, only calo hit

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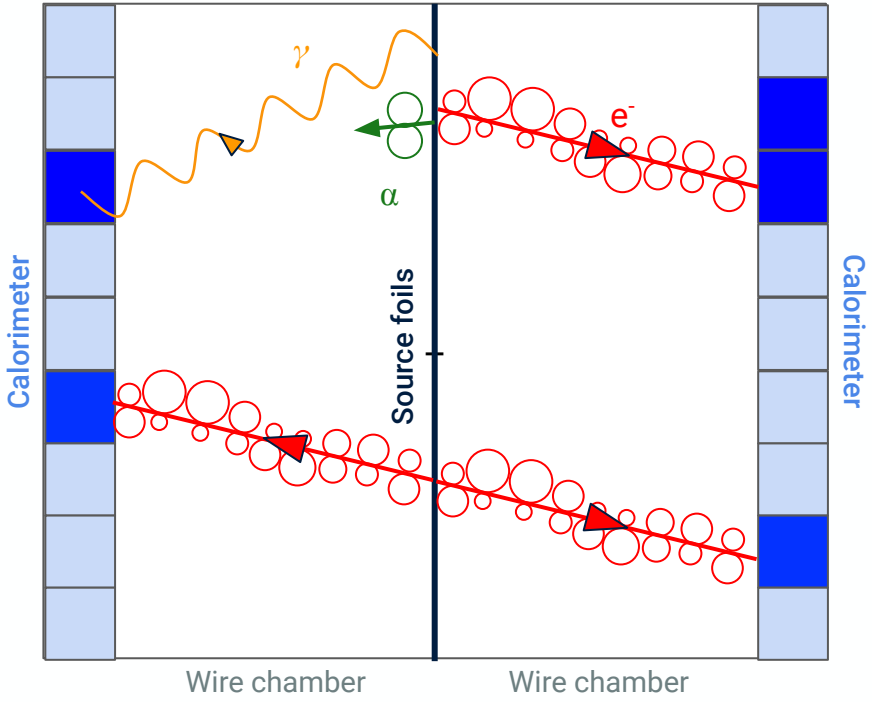
e^- : **track and calo hit**

Crossing electron distinguishable by time of flight

Particle identification



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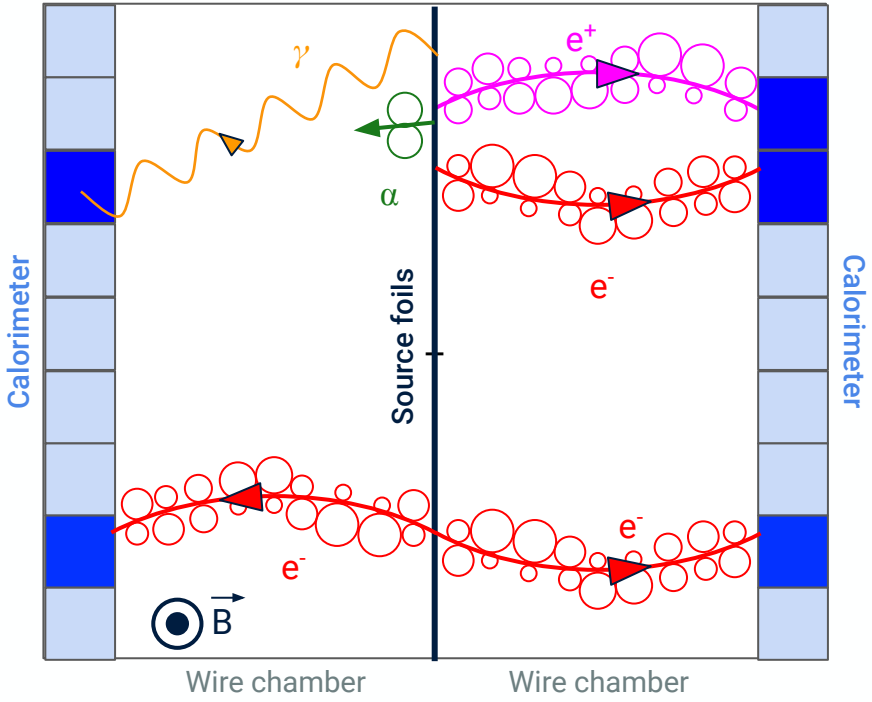
α : **short track**, no calo hit

e^- : **track and calo hit**

Golden ββ event

Particle identification

Magnetic field can identify pair production background



γ : **no track**, only calo hit

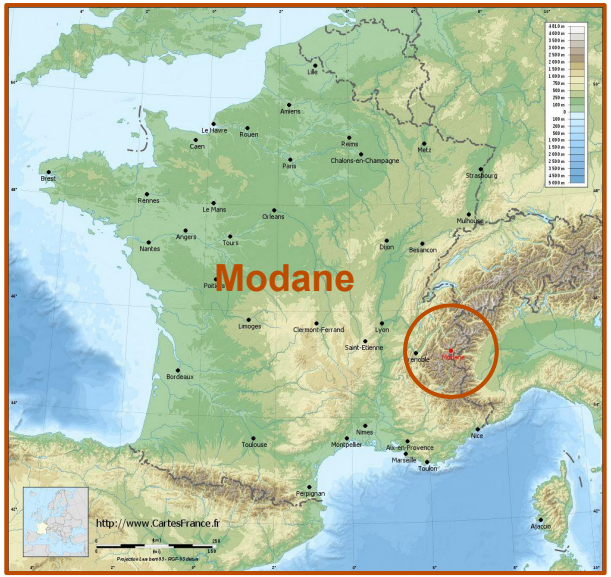
α : **short track**, no calo hit

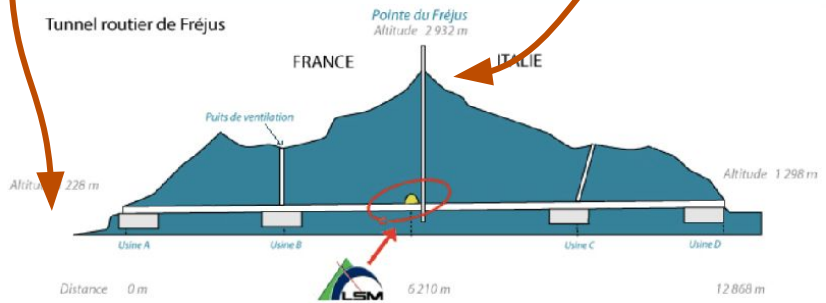
e^- and e^+ : **track and calo hit,** distinction by magnetic field

Golden ββ event

Ultra-low background experiment

Modane Underground Laboratory (LSM)



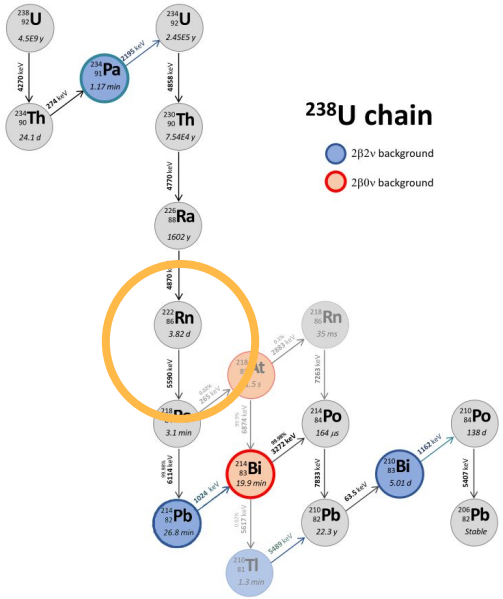


4800 m.w.e

Ultra-low background experiment

Poster # 632

Radon



Ultra-low background experiment

Poster # 632

Radon

SuperNEMO goal: <150 μBq·m^{-3}

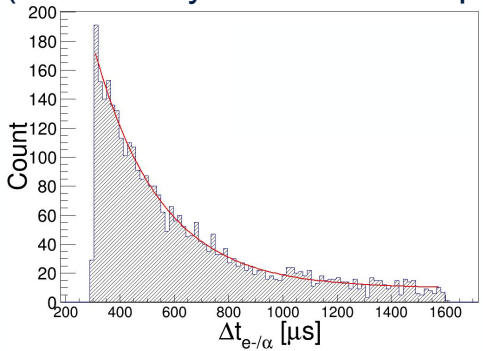
Ultra-low background experiment

Poster # 632

Radon

SuperNEMO goal: <150 μBq·m^{-3}

First Radon measurement : 10-15 mBq·m^{-3}
(without any anti-Rn technique)



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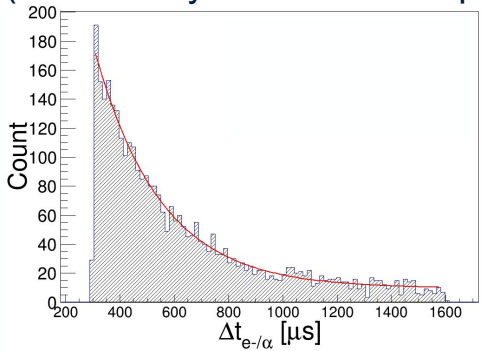

➔ Tracker gas cleaning (J-trap)
- Rn capture by charcoal

J-Trap 2
-80 C°
6 x 500 cm3 charcoal
⇒ Radon capture
→ Need very pure gaz

J-Trap 1
-50 C°
2 x 500 cm3 charcoal
⇒ pre-cooling the gas
⇒ Carture traces of vapours

Ultra-low background experiment

Poster # 632

Radon

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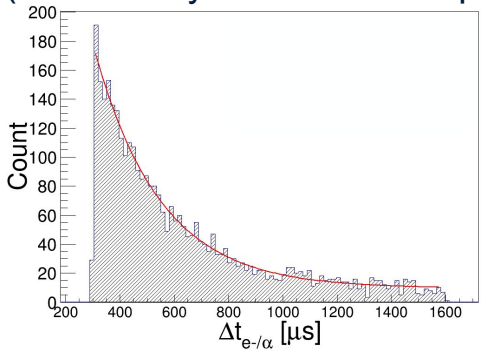
First Radon measurement : 10-15 mBq·m^{-3}
(without any anti-Rn technique)



Ethanol removing cartridge

- ➔ Tracker gas cleaning (J-trap)
- ➔ Gas flux control: He recycling
  - Bigger flux for less Rn
  - He purification and reinsertion
  - Installation ongoing

Ultra-low background experiment

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Radon

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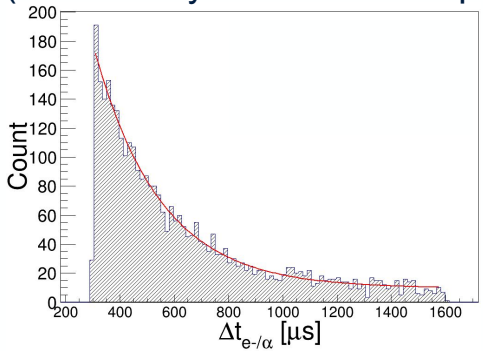
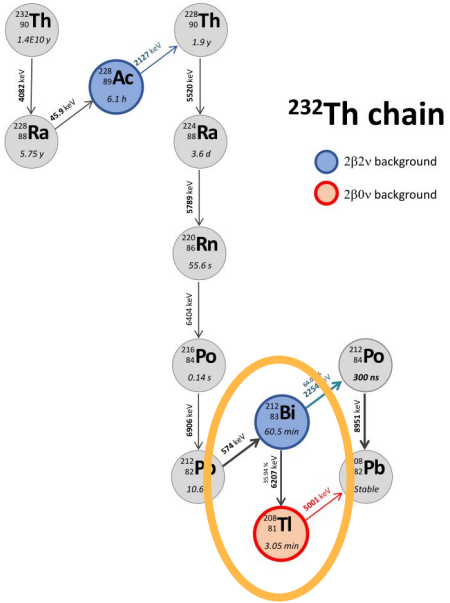
First Radon measurement : 10-15 mBq·m^{-3}
(without any anti-Rn technique)

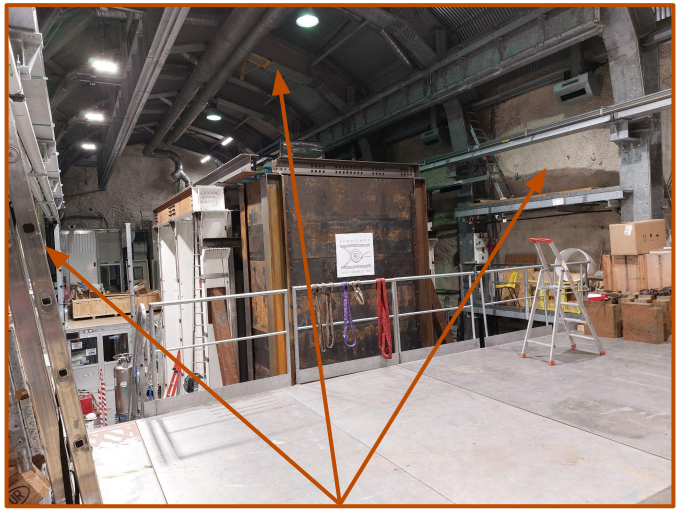


- ➔ Tracker gas cleaning (J-trap)
- ➔ Gas flux control: He recycling
- ➔ Anti-Rn tent
  - Plastic panels on metal frame
  - Filled with radon-reduced air
  - Already installed

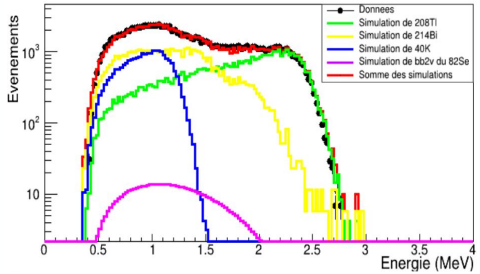
Ultra-low background experiment

Gamma shielding for ambient background





Gammas naturally generated by lab's rock wall

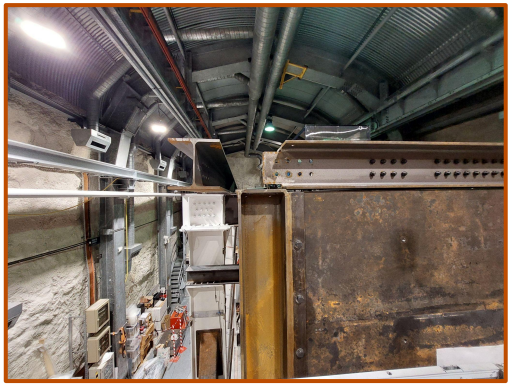


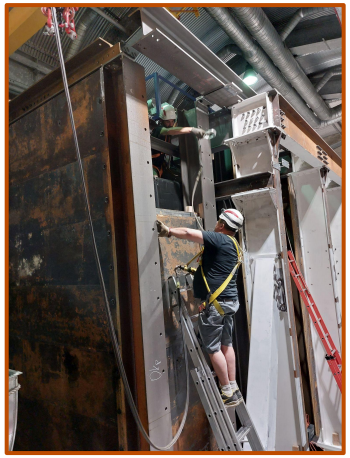
Ambient γ background measurement

Ultra-low background experiment

Gamma shielding for ambient background

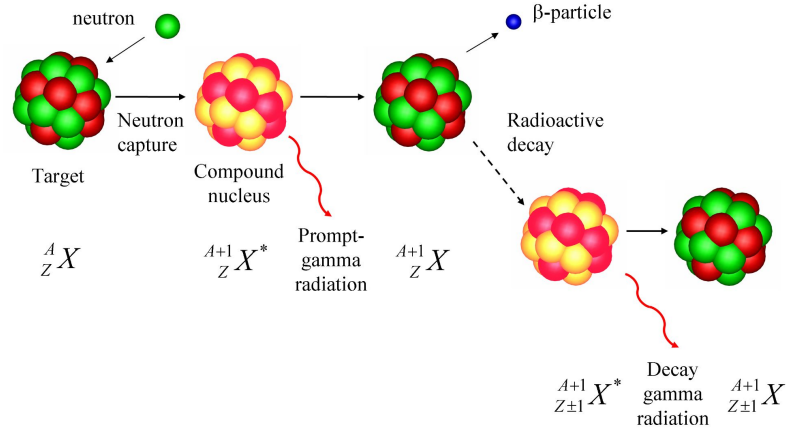
18 cm width iron shielding (320 tonnes of iron)
Installation ongoing





Ultra-low background experiment

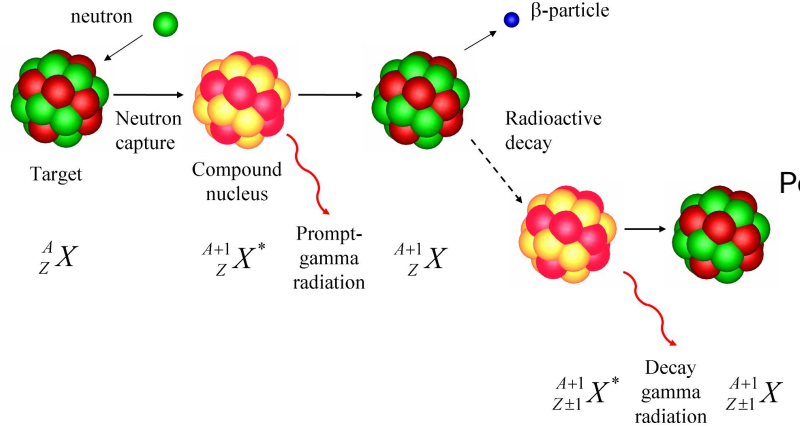
Neutron shielding



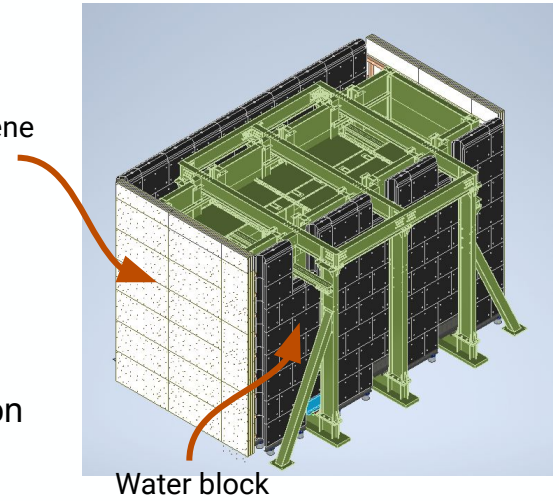
Neutron capture can produce gamma radiation, especially on iron

Ultra-low background experiment

Neutron shielding



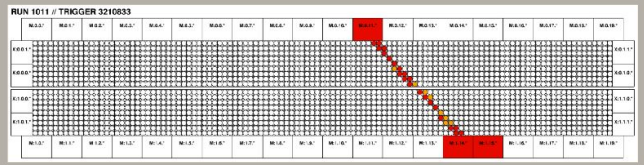
- 243 50 cm-thick water-filled polyethylene tanks
- 24 cm-thick PE plates
- Installation ongoing



Neutron capture can produce gamma radiation, especially on iron

Timeline

Taking calibration and background data - 99% of tracker & 98% of calorimeter channels live!



Install helium recycling system

2023-Feb 2024 | March-July 2024 | July -August 2024 | September 2024 - 2027

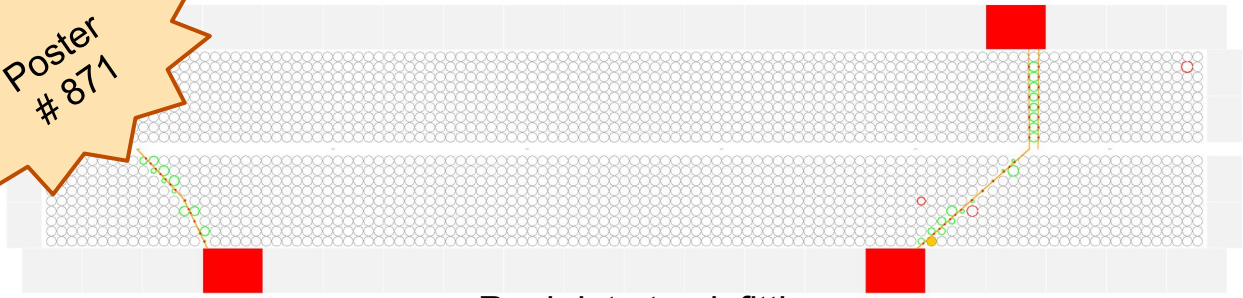
Gamma shielding (iron) currently being installed

Install neutron shielding (water / polyethylene)

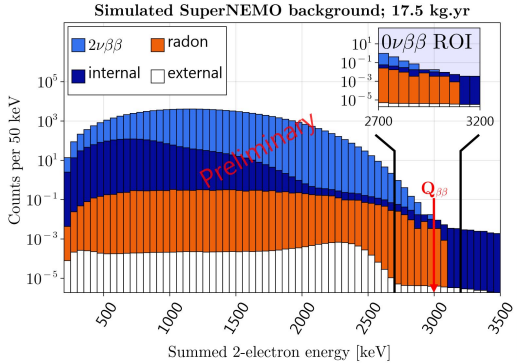
ββ data taking

Preparation for data-taking

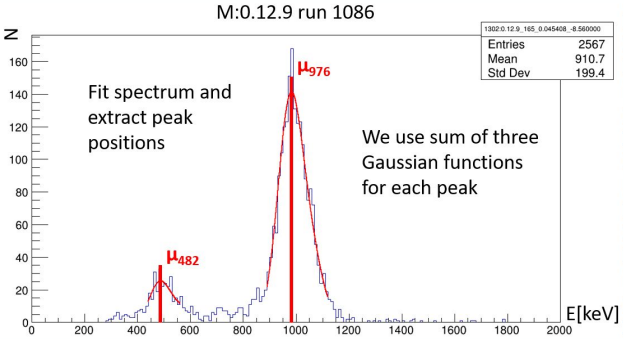
Poster # 871



Real data track fitting



Background estimation



Energy calibration

Conclusion

SuperNEMO is a unique 0νββ tracker/calorimeter experiment:

- ➔ Full kinematics of the decay
- ➔ Study of new physics only possible for SuperNEMO

Demonstrator currently being finalised:

- ➔ Source foils, calorimeter and tracker ready
- ➔ Gamma and neutron shielding and anti-radon system currently being installed
- ➔ Analysis tools in preparation
- ➔ Background analysis ongoing