Demande post-doc ENIGMASS

Construction, commissionning and data analysis of SuperNEMO demonstrator

Porteur du projet : Dominique Duchesneau

Acteurs d'ENIGMASS concernés (LAPP, LSM et Lapth)

- Fabrice Piquemal, LSM
- Dominique Duchesneau, , LAPP
- Guillaume Warot, LSM
- Pasquale Serpico, LAPTh
- Julien Lesgourgues, LAPTh
- Support technique du LAPP et LSM

Enigmass
The enigma of mass

Réunion postdoc
10/10/12

Pole neutrino in ENIGMASS

Collaboration: LAPP, LPSC, LSM, and LAPTh

The ENIGMASS neutrino program cover all the present reseach on the neutrino physics

- Mass hierarchy and absolute mass
- CP violation search
- Neutrino nature
- Sterile neutrinos ?
- Supernovae neutrinos

This program is in adequation with the national and international raodmaps. It will be performed using close infrastructures : CERN, LSM, ILL

Short term(2012 -2015): oscillation CNGS/OPERA
sterile neutrinos and anomalies (réacteur ILL, SEDINE, STEREO)

Middle term (2012 – 2020) : Double beta decay (SuperNEMO)
Long Baseline studies (LSM is candidate for the site)

Long term (2020 and beyond): Long Baseline

Support from theoritical groups of LAPTh and LPSC

Double beta decay physics case

- Leptonic number violation

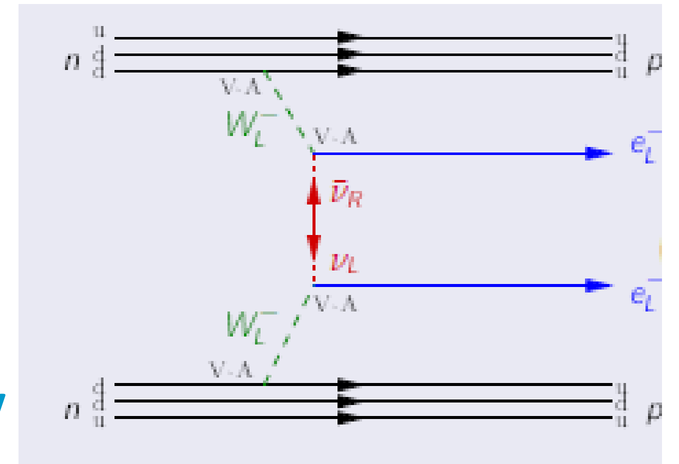
- Nature of neutrino : Dirac ($\nu \neq \bar{\nu}$) or Majorana ($\nu = \bar{\nu}$)

- Absolute neutrino mass and neutrino mass hierarchy

- Right-handed current interaction

- CP violation in leptonic sector

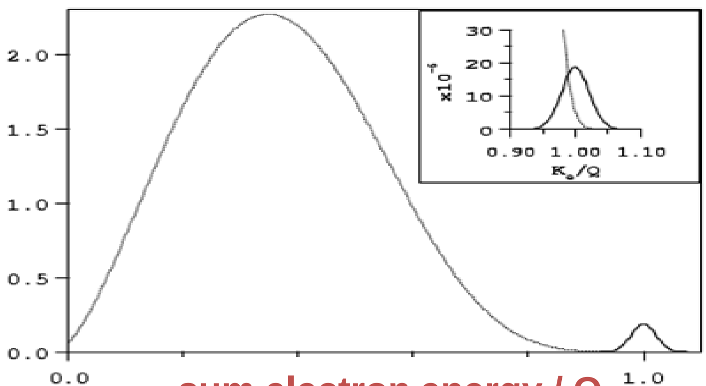
- Search of Supersymmetry and new particles



(A,Z) → (A,Z+2) + 2 e^-

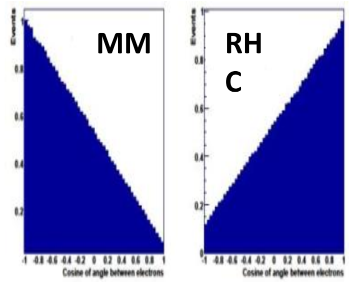
Double beta decay observables

$(A,Z) \longrightarrow (A,Z+2) + 2\,e^-$

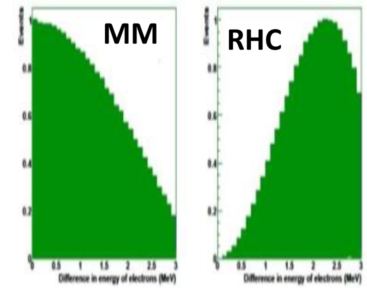


sum electron energy / Q

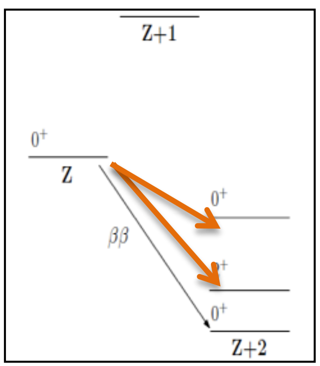
Angular distribution



$Ee_1 - Ee_2$ distribution



Mass vs Right-Handed Current mechanism



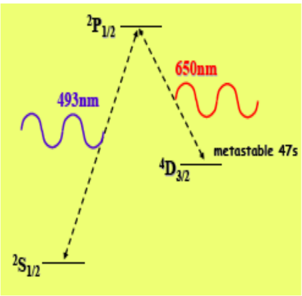
Decay to Excited States

$(A,Z) \rightarrow (A, Z+2) + 2\,e^- + 1,2\,\gamma$

1 or 2 additonnal γ-rays

Identification of daugther nucleus :

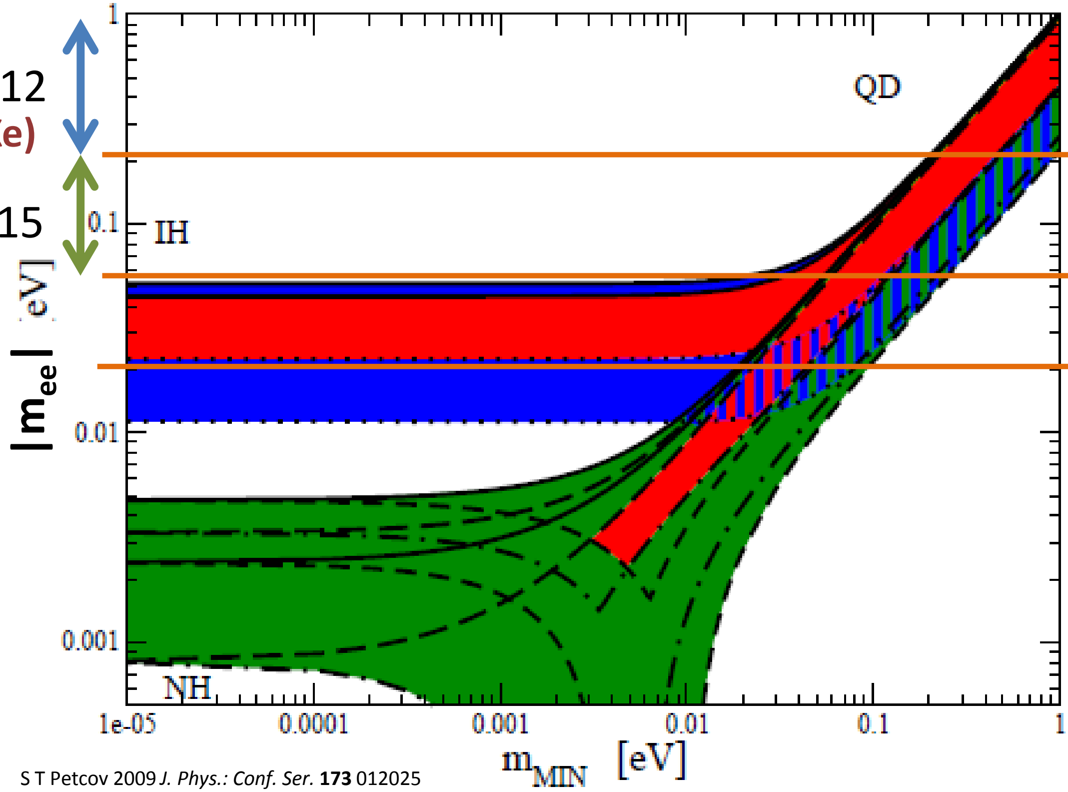
$Xe \rightarrow Ba^{++} + 2\,e^-$



Goal of the next generation

$$m_{\beta\beta} = \left|\sum_i U_{ei}^2 m_i\right| = \left|c_{13}^2 c_{12}^2 m_1 + c_{13}^2 s_{12}^2 m_2 e^{i\phi_2} + s_{13}^2 m_3 e^{i\phi_3}\right|$$

Isotope mass		Required background level in the ROI
~ 10 kg (200 – 400kg ^{136}Xe)	2012	100 – 1000 cts/yr/ton
~ 100 kg	2015	1 – 10 cts/yr/ton
~ 1000 kg		0.1 – 1 cts/yr/ton

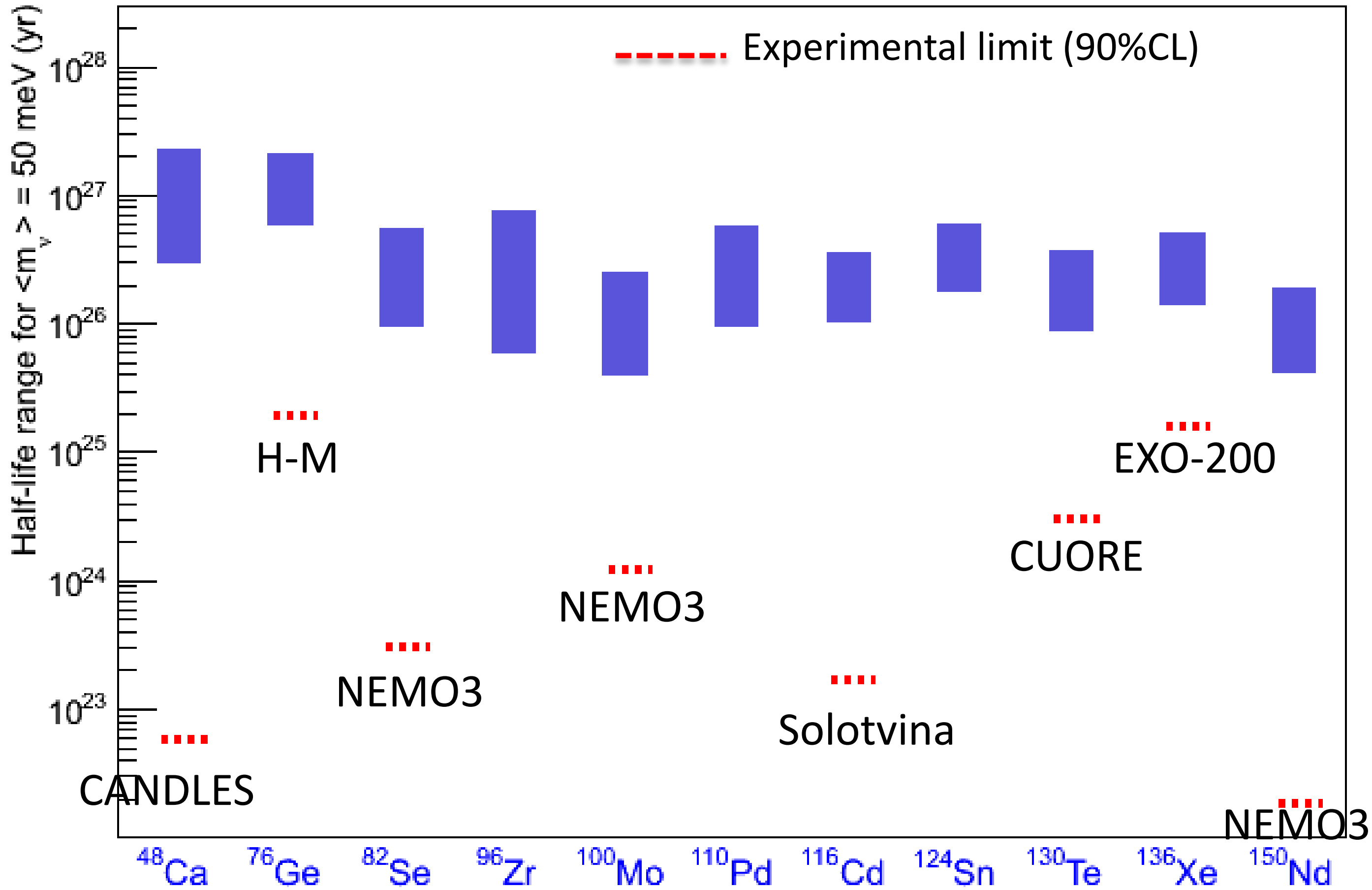


S T Petcov 2009 *J. Phys.: Conf. Ser.* **173** 012025

Next generation will use ≥ 100 kg (started with Xe experiments)

Improvements of background needed

Present limits and half-live to reach for $<m_\nu> = 50$ meV



Next generation of experiments

Calorimeter

- **Ge diode** — ε, ΔE — ^{76}Ge → GERDA, MAJORANA
- **Bolometers** — ε, ΔE — ^{130}Te, ^{82}Se, ^{100}Mo → CUORE, LUCIFER, ZnMo4
- **Liquid Xe** — ε, M, (N_{bckd}) — ^{136}Xe → EXO
- **Scintillator** — ε, M — ^{136}Xe, ,^{48}Ca, ^{150}Nd, ^{100}Mo → KamLAND-Zen, CANDLES, SNO+, Borexino, CdWO4, AMoRE

Tracker

- **Tracko-calo** — N_{Bckg}, isotopes — ^{82}Se (^{150}Nd, ^{48}Ca) → SuperNEMO
- **Pixellized CdZnTe** — ε, N_{Bckd} — ^{116}Cd → COBRA
- **TPC** — ε, N_{Bckd} — ^{136}Xe, ^{150}Nd → MTD, EXO-gas, NEXT

Avantages of Tracko-calo technique

The NEMO collaboration develop since 20 years a unique method to look for double beta decay : tracking + calorimeter

- Identification of the electron
- Full measurement of kinematic parameters (angular distribution, single energy)
- Choice of the isotope
- Drastic reduction of background and cross-check by different channels
- Probe the background origin

NEMO3 proved the feasibility of the technique for large mass

The SuperNEMO demonstrator will prove the ability to measure 100 kg

NEMO 3

Tracking detector: drift chambers (6180 Geiger cells)
σ_t = 5 mm, σ_z = 1 cm (vertex)

Calorimeter (1940 plastic scintillators and PMTs)
Energy Resolution FWHM=8 % (3 MeV)

Identification e^-, e^+, γ, α
Very high efficiency for background rejection

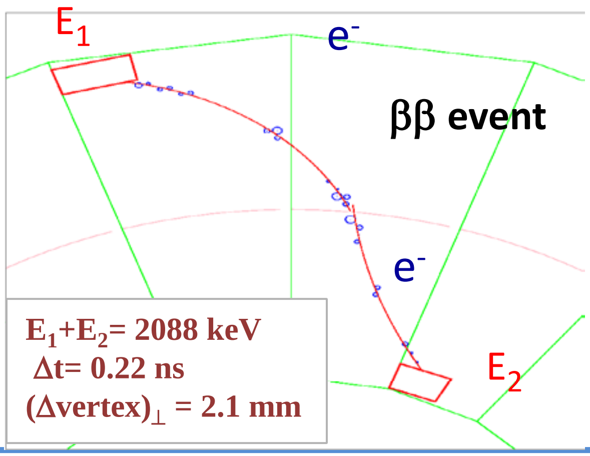
Background level @ $Q_{\beta\beta}$ [2.8 – 3.2 MeV] : 1.2 10^{-3} cts/keV/kg/y

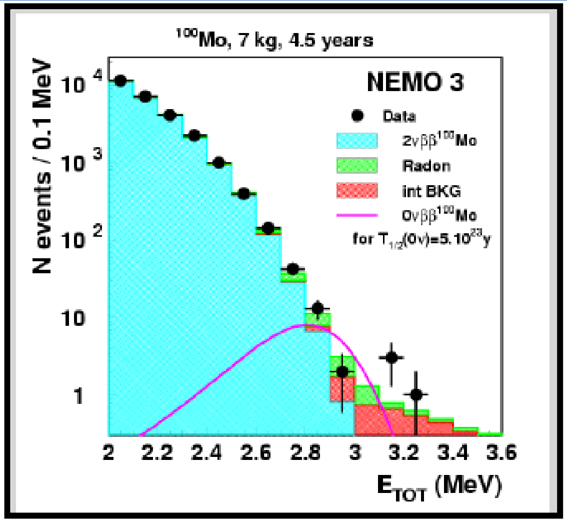
Multi-isotope (7 measured at the same time)

Running at Modane underground laboratory (2003 - 2011)

Unique feature

Measurement of all kinematic parameters: individual energies and angular distribution





[2.8 – 3.2] MeV 18 observed events, 16.4 ± 1.3 expected

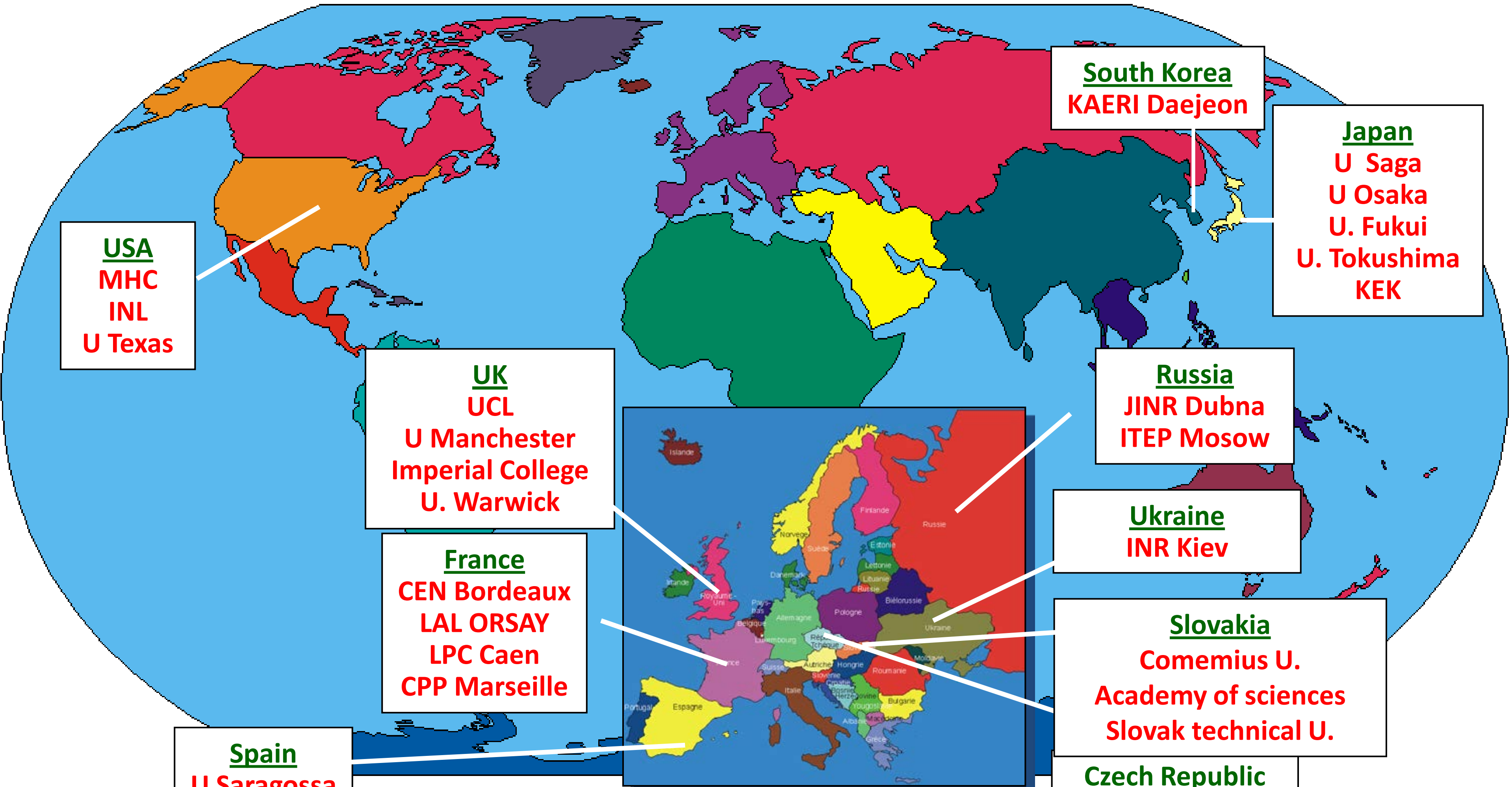
^{100}Mo $T_{1/2}$ ($\beta\beta0\nu$) > 1.0 10^{24} y (90% C.L.)

$\langle m_\nu \rangle$ < 0.31– 0.79 eV

Measurement of 7 isotopes $\beta\beta(2\nu)$ half-lifes
Excited states, Majoron limits for $\beta\beta(0\nu)$

SuperNEMO collaboration

~ 100 physicists, 10 countries, 27 laboratories



USA
MHC
INL
U Texas

UK
UCL
U Manchester
Imperial College
U. Warwick

France
CEN Bordeaux
LAL ORSAY
LPC Caen
CPP Marseille

Spain
U Saragossa

South Korea
KAERI Daejeon

Japan
U Saga
U Osaka
U. Fukui
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Russia
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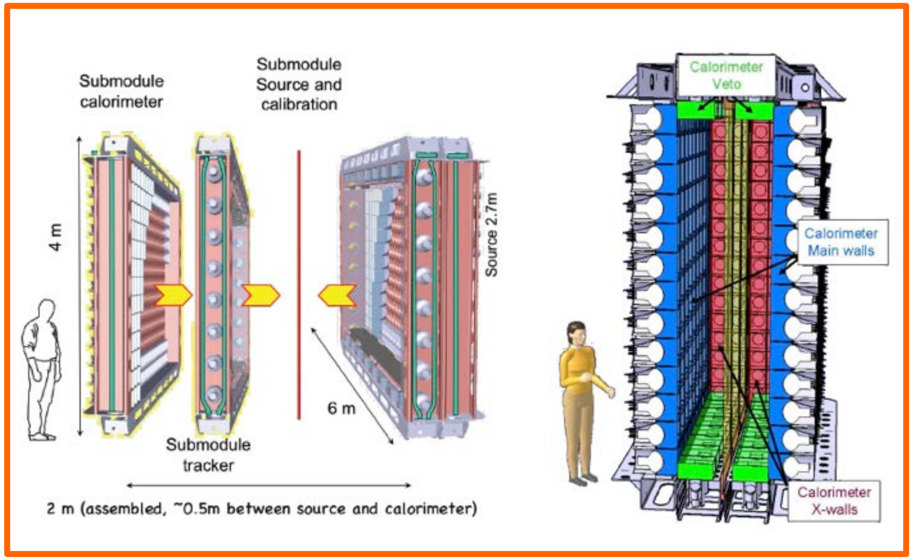
SuperNEMO

A module



20 modules

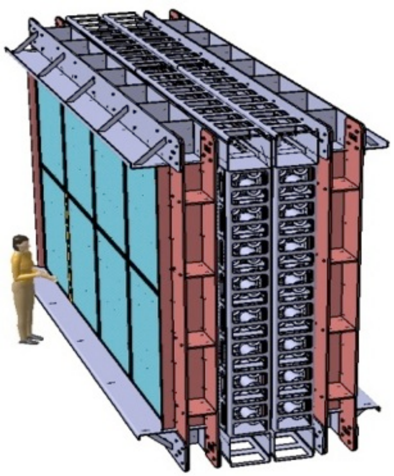
	Demonstrator module	20 Modules
Source : ^{82}Se	7 kg	100 kg
Drift chambers for tracking	2 000	40 000
Electron calorimeter	500	10 000
γ veto (up and down)	100	2 000
$T_{1/2}$ sensitivity	$6.6\ 10^{24}$ y (No background)	$1.\ 10^{26}$ y (after 5years)
$<m_\nu>$ sensitivity	200 – 400 meV	40 – 100 meV

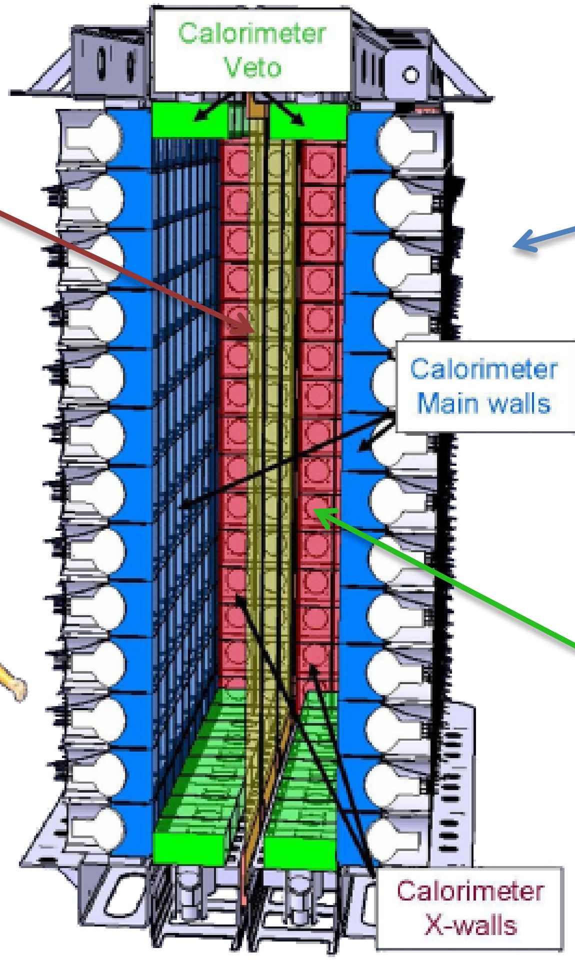
SuperNEMO Demonstrator

Objective: to reach the background level for 100 kg
to perform a no background experiment with 7 kg isotope of ^{82}Se in 2 yr

Source

$^{214}Bi < 10\ \mu Bq/kg$
($NEMO3\ 100\ \mu Bq/kg$)
208Tl < 2 $\mu Bq/kg$
($NEMO3\ 100\ \mu Bq/kg$)





Calorimeter

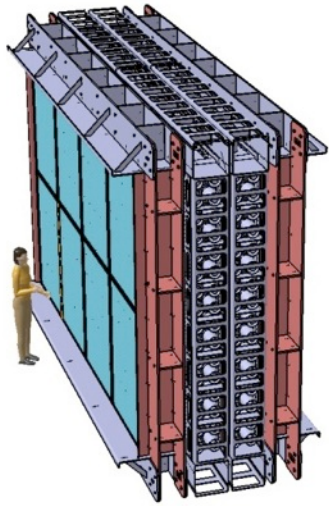
$\Delta E/E < 4\%$ @ 3 MeV
(NEMO3 8.6% at 3MeV)

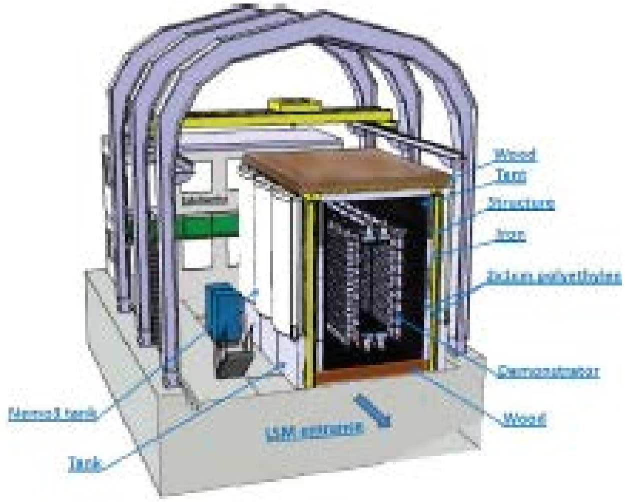
Tracker

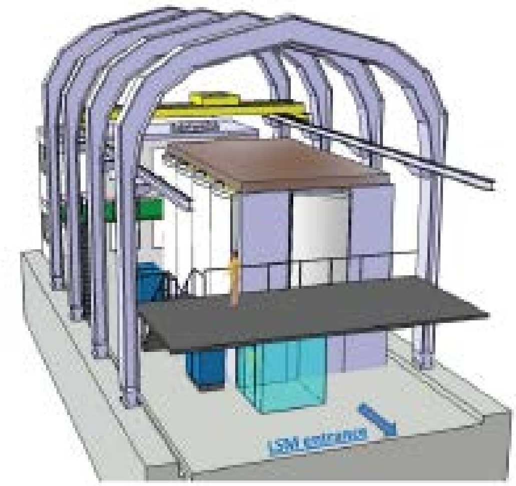
3.7 m long (NEMO3 2.7 m)
$\sigma_t = 5$ mm, $\sigma_z = 1$ cm
Radon < 0.15 mBq/m^3
(NEMO3 5 mBq/m^3)
Wiring robot

Global efficiency : 30 % (NEMO3 8%)

SuperNEMO demonstrator







- ❑ Construction started in the laboratories
- ❑ Installation and commissioning (2013 – 2014) @ Modane Underground Laboratory
- ❑ Data taking in 2014
- ❑ No background expected
- ❑ Sensitivity after 2 years : $T_{1/2} > 6.6\ 10^{24}$ y and $<m_{\nu}> < 0.2$ -0.4 eV

Role of the post-doc for double beta decay in ENIGMASS

- Development of an original method to produce and optimise the SuperNemo thin source foils in collaboration with LSM
- Simulation of the performance of the demonstrator
- Commissioning at LSM and data analysis of the demonstrator
- Interactions with LAPTh for implications of the results

  - Essential for the experiment
  - Visible contribution

Minimum requirements are: PhD degrees in Nuclear or Particle physics, experience in techniques for nuclear or particle detectors in particular on low radioactive techniques, Monte-Carlo simulations, scintillators, photo-detector and data analysis. Good hands-on skills are a benefit.

The end

Comparison of Current Techniques