

Neutrinoless Double Beta Decay

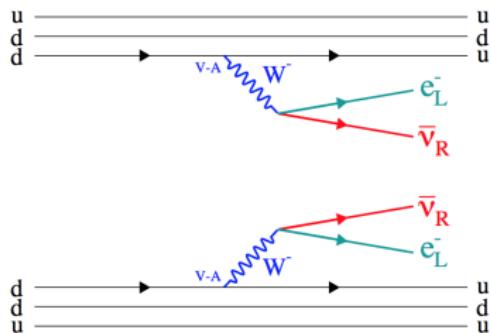
The SuperNEMO Project

Jen's group

September 3, 2013

Double Beta Decay

2 Neutrino Double Beta Decay



Lepton number conservation :

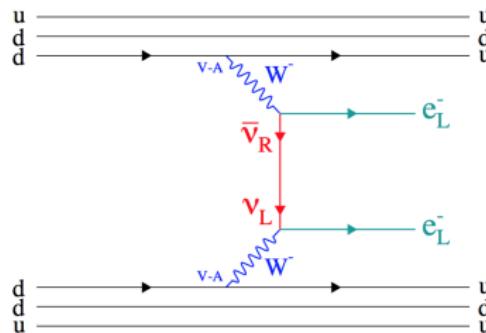
$$\Delta L = 0$$

Order of magnitude of half-lives:

$$T_{2\nu 2\beta}^{1/2} \sim 10^{18} - 10^{21} \text{ y}$$

No information on neutrino nature

Neutrinoless Double Beta Decay



Lepton number violation :

$$\Delta L = 2$$

Order of magnitude of half-lives:

$$T_{0\nu 2\beta}^{1/2} > 10^{24} - 10^{25} \text{ y}$$

Constraints on neutrino mass:

$$(T_{0\nu 2\beta}^{1/2})^{-1} = G^{0\nu} |M_{0\nu}|^2 |< m_{\beta\beta} >|^2$$

$0\nu\beta\beta$ Physical Implications

The most sensitive method to answer the nature of the neutrino is the search of neutrinoless double beta decay.

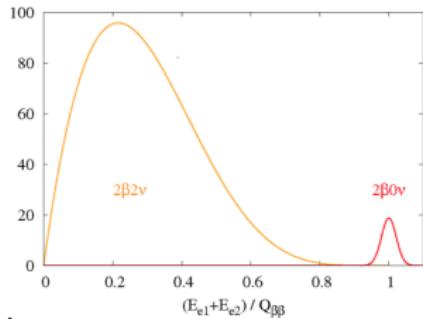
- ν 's are Majorana particles
- Lepton Number Violation, $\Delta L = 2$ (LVN)
- See-Saw mechanism → existence of a heavy sterile neutrino (excellent candidate for dark matter)
- Leptogenesis requires LVN → asymmetry between matter and antimatter explained

IF $0\nu\beta\beta$ EXISTS then ⇒

Experimental Principle

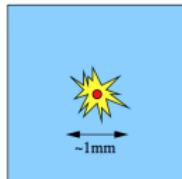
Ideally one $0\nu2\beta$ experiment should:

- measure the energy of the 2 electrons with a very good energy resolution
- identify individually the 2 electrons emitted ($E_{e1}, E_{e2}, \Delta t$ & $\cos \theta$)
- identify the daughter isotope after the decay



Two experimental techniques:

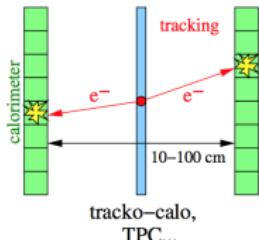
Active sources



semiconductors,
bolometers,
scintillators...

- high efficiency (~90%)
- very good energy resolution (fwhm < 1% @ 1 MeV)
- no tracking
- small background rejection

Passive sources



tracko-calco,
TPC...

- lower efficiency (~30%)
- less good energy resolution (fwhm few % @ 1 MeV)
- tracking & particles identification
- backgrounds measurements

Why funding the SuperNEMO project?

Possible
detectors:

- Tracko-calorimeters (NEMO3, SuperNEMO)
- Germanium detectors (GERDA, IGEX, Heidelberg-Moscou)
- Bolometer detectors (CUORICINO, CUORE)
- Xe TPC experiments (EXO-200)
- Liquid scintillators (KamLAND-Zen, SNO+)

but only tracko-calorimeter experiments have the tracker!

We need a tracker for:

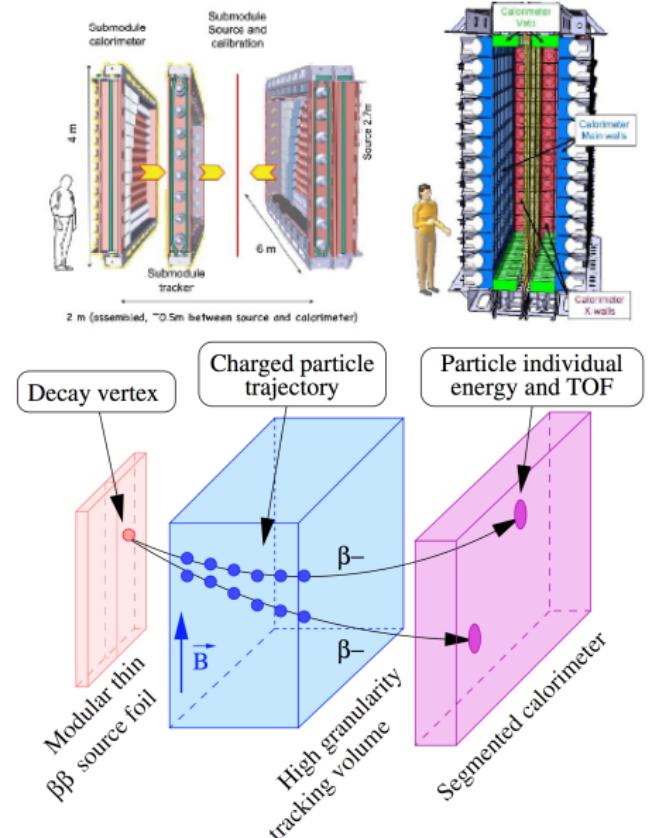
- measure the angular distribution between the two e^- → understand the mechanism behind $0\nu\beta\beta$
- strong background rejection
- particle ID (e^-, α, γ)

SuperNEMO will be unique among the next generation $0\nu\beta\beta$ experiments

Detector Particularities

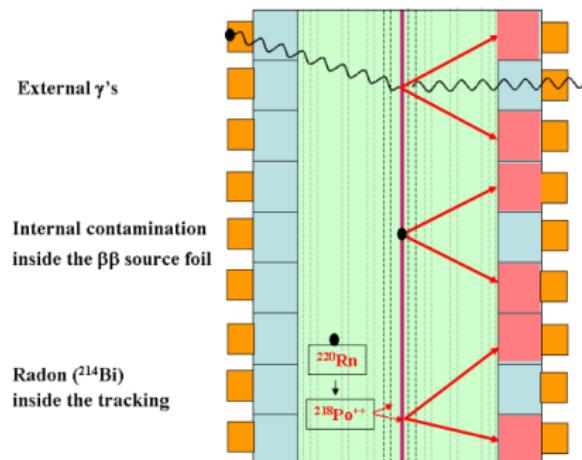
Underground laboratory in Modane (France) at 1700 m below the mountain

- source: ^{82}Se (high $Q_{\beta\beta}$, proven enrichment technique)
- tracker (drift tubes)
→ track + vertices
- calorimeter (scintillators)
- → excellent resolution down to the MeV
- veto and magnetic field to reject the background



Signal - Background

- Signal is a peak in the $2e^-$ energy distribution
- Background:
 - ① $2\beta 2\nu$ (normal double beta)
 - ② impurities inside the source
 - ③ gamma rays from inside the detector
 - ④ Radon inside the drift tubes



SuperNEMO vs NEMO-3

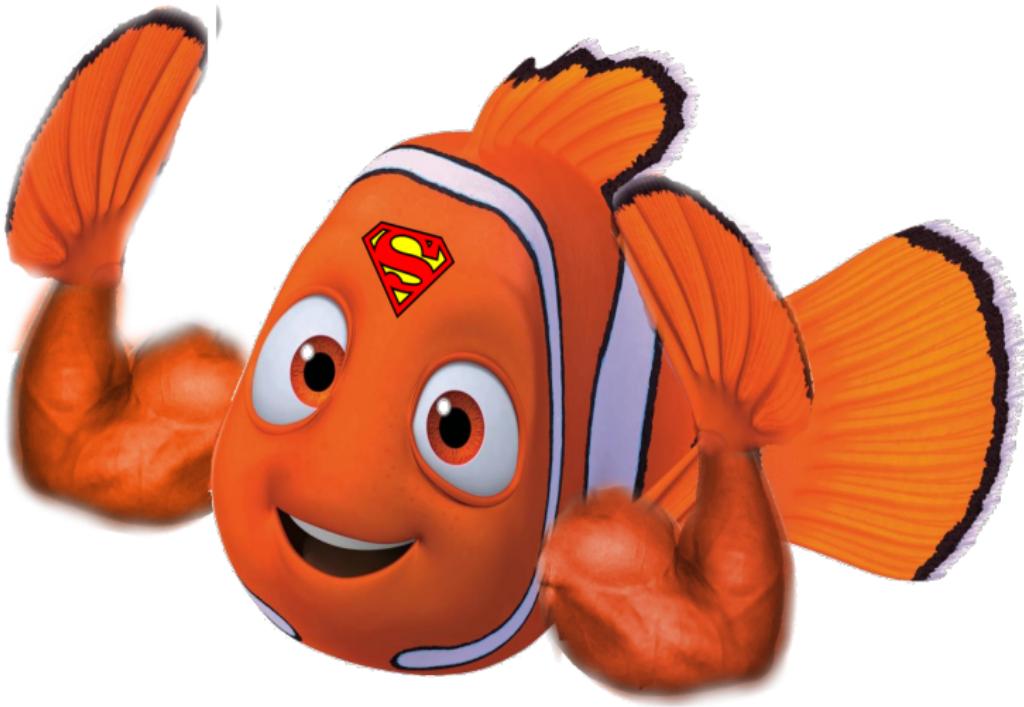
The SuperNEMO experiment is an **extension** and **improvement** of the experimental techniques used in NEMO-3,
by combining calorimetry and tracking.

	NEMO-3	SuperNEMO
Half-life sensitivity	10^{24} years	10^{26} years
Isotope mass	7 kg	100 kg
Energy resolution	15%	7%
Source radiopurity:		
^{208}Ti	100 mBq/kg	2 mBq/kg
^{214}Bi	300 mBq/kg	10 mBq/kg
Radon	5 mBq/m ³	0.1 mBq/m ³

Timeline and practical aspects

- Same cavern as NEMO-3
- Demonstrator module
 - ① demonstration of the feasibility
 - ② measurement and validation of the Radon background
 - ③ measurement and validation of the background contribution from the detector components
 - ④ finalization of the technical choices





Funding SuperNEMO
gives you SuperPOWERS!