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Thèse de doctorat

Search of the $0\nu\beta\beta$ decay with the SuperNEMO demonstrator

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Contents

Contents **3**

Introduction **7**

1 Phenomenology of particle physics **9**
- 1.1 The Standard Model of particle physics . . . 9
  - 1.1.1 Bosons . . . 9
  - 1.1.2 Fermions . . . 9
  - 1.1.3 $2\nu\beta\beta$ decay . . . 9
  - 1.1.4 Where the Standard Model ends . . . 9
- 1.2 Going beyond the Standard Model with neutrinos . . . 9
  - 1.2.1 Neutrino flavors and oscillations . . . 9
  - 1.2.2 Neutrino masses and nature . . . 9
  - 1.2.3 Other searches beyond the Standard Model with neutrinos . . . 9

2 $0\nu\beta\beta$ experiment status **11**
- 2.1 Experimental design criteria . . . 11
  - 2.1.1 Aspects of the nuclear matrix elements . . . 12
  - 2.1.2 Quenching . . . 12
- 2.2 $0\nu\beta\beta$ direct search experiments . . . 12
  - 2.2.1 Semiconductors . . . 12
  - 2.2.2 Bolometers . . . 14
  - 2.2.3 Time projection chambers . . . 14
  - 2.2.4 Scintillators . . . 16
  - 2.2.5 Tracking calorimeters . . . 16

3 The SuperNemo demonstrator **18**
- 3.1 The SuperNemo demonstrator . . . 18
  - 3.1.1 Comparison with Nemo3 experiment . . . 18
  - 3.1.2 Expermimental design . . . 18
  - 3.1.3 Sources . . . 18
  - 3.1.4 Tracker . . . 18
  - 3.1.5 Calorimeter . . . 18
    - 3.1.5.1 Scintillator . . . 18
    - 3.1.5.2 Photomultiplier . . . 18
  - 3.1.6 Calibration systems . . . 18
  - 3.1.7 Control Monitoring system . . . 18

3.1.8 Electronics 18
3.2 The backgroung of SuperNEMO 18
3.2.1 Internal background 18
3.2.2 External background 18
3.2.3 Background specifications 18
3.2.4 Measured demonstrator background levels 18
3.3 The SuperNemo software 18
3.3.1 Simulation 18
3.3.2 Reconstruction 19

4 Analysis tools 21
4.0.1 Internal probability 21
4.1 Simulations 22
4.1.1 Modifications of simulation software 22
4.1.2 Internal background simulations 22
4.1.3 $0\nu\beta\beta$ simulations 22

5 Time difference 23
5.1 Principle and goal 23
5.1.1 Internal conversion 23
5.2 Analysis 24
5.2.1 Topological cuts 24
5.2.2 Exponentially modified Gaussian 24
5.2.3 Results 24
5.3 Conclusion 24

6 Sensitivity of the SuperNEMO demonstrator to the $0\nu\beta\beta$ 27
6.1 Signal and backgrounds considered 27
6.2 Optimisation of event selection 29
6.3 Expected number of background events 29
6.4 Demonstrator sensitivity 29
6.4.1 avec B 30
6.4.2 sans B 30
6.4.3 Champ mappé 30
6.5 HyperNEMO 30
6.6 Other isotopes 30
6.7 Conclusion 30

7 Detector commissioning 31
7.1 Reflectometry analysis 31
7.1.1 Goal of the reflectometry analysis 31
7.1.2 Pulse timing: controlling cable lengths 32
7.1.3 Signal attenuation 37
7.1.4 Pulse shape analysis 39
7.1.5 Comparison with ^{60}Co 39
7.1.6 Conclusion 39
7.2 Calibrating the electronic boards 39

7.2.1 Principle . . . 39
7.2.2 Measuring the time offset of front end boards . . . 39
7.2.3 Results . . . 39
7.3 Energy calibration of optical modules . . . 39
7.4 Baseline studies . . . 39
7.5 Light Injection System . . . 39

8 Characterisation of the calorimeter time resolution **41**
8.1 Interaction of particles in the SuperNEMO scintillators . . . 42
8.1.1 Interaction of electrons . . . 42
8.1.2 Interaction of photons . . . 42
8.2 Measurement of the time resolution with a ^{60}Co source . . . 43
8.2.1 Description of Cobalt 60 nucleus . . . 44
8.2.2 Time response of optical modules . . . 44
8.2.3 Final experimental design . . . 47
8.2.4 Signal events selection . . . 49
8.2.5 Background estimation . . . 51
8.2.6 Detector efficiency . . . 55
8.2.7 Determination of the individual timing resolution of each optical module . . . 56
8.2.8 Conclusion . . . 60
8.3 The Light Injection System . . . 60
8.3.1 Light injection system commissioning . . . 61
8.3.2 Time resolution of optical modules . . . 61

Conclusion **63**

Bibliography **65**

Chapter 6

Sensitivity of the SuperNEMO demonstrator to the $0\nu\beta\beta$

In this chapter, we present the SuperNEMO sensitivity to the $0\nu\beta\beta$ decay half-life, and the corresponding effective neutrino masses, for several isotopes. The SuperNEMO final detector is expected to exclude $0\nu\beta\beta$ half-lives up to 1.2×10^{26} y (90% CL) if $0\nu\beta\beta$ decays through the mass mechanism, with a detector exposure of 500 kg.y [7]. The sensitivity is given as a limit, in case we do not observe the expected signal. In 2010 began the demonstrator installation at the Laboratoire Souterrain de Modane. With an exposure of 17.5 y, the demonstrator could set a limit on the $0\nu\beta\beta$ process of 5.35×10^{24} y (90% CL) [8].

This study aims to explore the impact on the sensitivity of the presence of a magnetic field, and will participate in the final decision on the installation of the coil. In a context of investigating the demonstrator and final detector capabilities, different internal source contamination levels are explored. The topology of interest is the two electrons topology, and we use the $2e$ energy sum to discriminate the signal from the background events. Thanks to SuperNEMO tracking capabilities, topological informations are exploited to improve the SuperNEMO sensitivity.

6.1 Signal and backgrounds considered

A full simulation for the SuperNEMO demonstrator was perfomed, in order to determine the longest $0\nu\beta\beta$ half-life that can be probed with SuperNEMO using the distribution of the sum of electron energies, in the case where the $0\nu\beta\beta$ decay were not observed. In the Tab. 6.1 is summarised the expected number of signal and background events, both for the SuperNEMO demonstrator and final detector, and we present the amount of simulated Monte-Carlo events for each considered decay.

The $0\nu\beta\beta$ signal

In the following, the assumed underlying mechanism for the $0\nu\beta\beta$ decay is the mass mechanism (MM), as it is the most natural and widespread mechanism. The hypotetical $0\nu\beta\beta$ signal would be detected as an excess of events in the region of interest, with respect to the predicted background contamination level. The 10^7 $0\nu\beta\beta$ Monte-Carlo events are generated using the DECAY0 software [9]. The simulations are normalised assuming a $T^{0\nu}_{1/2} = 6.0\,10^{24}$ y half-life [citation].

Internal backgrounds

As described in Sec. 3.2.1, source foils contaminations by isotopes such as ^{208}Tl or ^{214}Bi constitute the principal internal backgrounds with the $2\nu\beta\beta$ decay. These backgrounds are processed by the same detector simulation as the $0\nu\beta\beta$ signal, using DECAY0. Since internal backgrounds have very low efficiencies in the $2e$ topology, we simulated an important amount of Monte-Carlo events. The target background activities were defined so that each background has a similar contribution to that of the $2\nu\beta\beta$ in the region of interest [10].
The dominant two neutrino $2\nu\beta\beta$ background and the background due to foil contamination were normalised assuming a detector exposure of 500 kg.y.

Tracking volume background

External background

All external backgrounds from outside the foil, apart from ^{222}Rn in the tracking volume, are expected to be negligible and were not simulated.

Table 6.1: Expected and simulated decays for different processes, both for the demonstrator (17.5 kg.y) and for the final detector (500 kg.y).

	Expected decays		Simulated decays
	Demonstrator	Final detector	
$0\nu\beta\beta$ ($T^{0\nu}_{1/2} = 6.0\,10^{24}$ y)	$1.5\,10^1$	$2.7\,10^7$	$1.0\,10^7$
$2\nu\beta\beta$	$9.5\,10^5$	$4.2\,10^2$	$1.0\,10^7$
^{208}Tl	$5.5\,10^3$	$1.6\,10^5$	$1.0\,10^7$
^{214}Bi	$1.1\,10^3$	$3.1\,10^4$	$1.0\,10^7$
^{222}Rn	$1.8\,10^5$	$7.2\,10^6$	$1.0\,10^7$

Justifier bdf externe avec article nemo3 (plus diff roi et meilleure eff) Activités bkg considérées à justifier, bkg interne: balek externe à justifier

Demies vies 2nu à jusifier

Se, Nd avec et sans champs
présentation du PID de Steven (peut être à bouger dans Tl selon développement du plan ou généralités)

Influence des quantités de contaminations sur la sensibilité

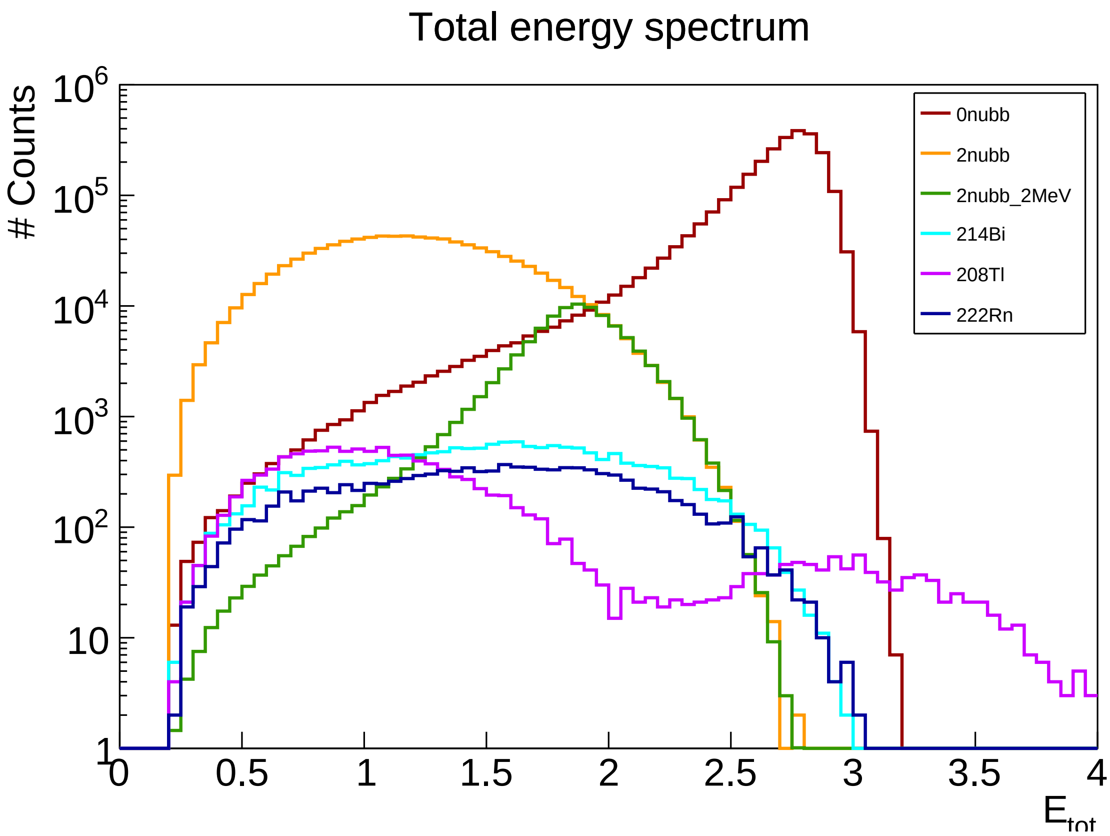

Figure 6.1

6.2 Optimisation of event selection

plot S/sqrt(B) en fonction E¿Emin

Quel est le signal qu'on cherche
présentation des cuts
efficacité des cuts/ signal + bkg
cuts premier et second ordre

6.3 Expected number of background events

plot energy tot plus dans région intéret

6.4 Demonstrator sensitivity

Résultats $B = 0$, avec activités nominales, puis avec activités caca
Efficiency spretra
Energy spectra

6.4.1 avec B

Parler du champ non uniforme/attenuation ROI optimization: avec variation coupure énergie

6.4.2 sans B

avec variation coupure énergie

6.4.3 Champ mappé

6.5 HyperNEMO

results for 500kg.y exposure

6.6 Other isotopes

bam bam le Nd

distribution t1/2 avec différents échantillons de simus (17.5 kg.y)

6.7 Conclusion

Faut arrêter SN
Etude plus générale avec bkg externe+lab (reprendre chiffres NEMO3) + neutrons (cf NEMO3)

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