PROCEEDINGS OF SCIENCE

Gamma-tracking and sensitivity to gamma-emitting backgrounds in SuperNEMO

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SuperNEMO, successor to the NEMO3 experiment [1], is looking for the neutrinoless double beta decay. Its unique design [2], combining both tracking and calorimetry techniques, provides essential topological informations. Indeed, fully reconstructing the event kinematics : allows a powerful background discrimination, would discriminate between the several hypothesized underlying mechanisms, but also gives access to a variety of event topologies which can be used to measure the different background contributions. The SuperNEMO software relies on a range of algorithms to ensure a faithful event reconstruction. The improved detector performance for γ detection coupled to new γ-reconstruction algorithms, based on geometrical and Time-of-Flight criteria, will not only improve the measurements of the γ-emitter backgrounds (^{208}Tl, ^{214}Bi...) but also increase the sensitivity for the search of $\beta\beta$-decays to the excited states.

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1. The SuperNEMO demonstrator

The first SuperNEMO module (*Cf* Fig. 1), or demonstrator, is under construction at Laboratoire Souterrain de Modane (LSM) and should start taking data in 2017 [2]. Each module can hold 5 kg (7 kg for the demonstrator) of any $\beta\beta$-isotope, provided it can be manufactured into thin foils. The demonstrator will mainly be studying ^{82}Se but also ^{150}Nd in a second phase. The source foil is surrounded by a tracking chamber, composed of 2034 drift cells operating in Geiger regime, itself surrounded by a calorimeter. The latter is composed of 712 optical modules consisting in a polystyrene scintillator coupled to low-radioactivity photomultiplers. The whole detector is immersed in a 25 G magnetic field allowing a particle charge identification. The SuperNEMO demonstrator aims for a background-free energy region of interest which would translate in a sensitivity on the $0\nu\beta\beta$ process for the full scale experiment, i.e. 500 kg.y, of $T^{0\nu}_{1/2} > 10^{26}$ y or in terms of effective neutrino mass $\langle m_{\beta\beta}\rangle < 0.04-0.10$ eV (assuming the light Majorana exchange mechanism).

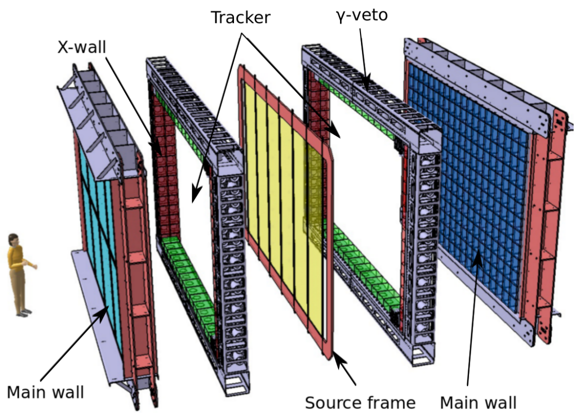

Figure 1: SuperNEMO demonstrator module overview

2. The γ-tracking algorithm

The NEMO principle [1] provides an efficient particle identification and thus a powerful background rejection power. An electron (resp. a positron) will be reconstructed as a long negatively (resp. positively) curved track in the wire chamber while alpha particles will consist in short straight delayed tracks. The γ particles will not leave tracks, their signature will then be one or more triggered calorimeter blocks to which no track is associated. The calorimeter scintillator blocks size was increased compared to NEMO3 in order to reach a 50-80% detection efficiency for gamma particles (depending on their energy). However, the latter may not be contained in a single calorimeter block and can interact with several ones, hence the need for a dedicated reconstruction procedure called γ-tracking. The γ-tracking algorithm will consider all the unassociated calorimeter blocks in the event and, first, gather the neighbouring calorimeter blocks into clusters, provided their time difference is not too large (optimized at Δt <2.5 ns). The tracking istelf consists in computing the χ^2 (later translated into a probability) of the hypothesis that a single γ triggered two distant calorimeter blocks based on the Time-Of-Flight and taking into account the various experimental uncertainties (time resolution, track length and interaction point uncertainty, etc...). Before applying the tracking to the potentially multiple clusters in the event, a quality cut on the individual hits is applied. Indeed, with a low energy deposit (typically right above the low energy threshold of 50 keV) comes a large time uncertainty, which, should it be taken into account in the hypothesis probability calculation, would artificially increase its value and consequently decrease the reconstruction efficiency by linking clusters too often. Actually, the tracking is applied between clusters, taking the last 'good' calorimeter hit from a chronologically first cluster and the first 'good' from a second cluster. If this hypothesis probability matches our criteria (typically $P > 4\%$) the two clusters are considered as belonging to the same gamma.

A faithful gamma reconstruction is not only useful for the study of background events but also for the search of other rare processes such as the double beta decay to an excited state of the daughter nuclei where one or more γ particles are emitted along with the electrons.

3. Demonstrator sensitivity to γ-emitting backgrounds

In addition to providing a strong background rejection power, the NEMO technique also gives acces to a variety of channels which can be used to measure the different background contributions both internal (from the source foil) and external. The most harmful backgrounds for the $0\nu\beta\beta$ search in SuperNEMO will be, beside the irreducible $2\nu\beta\beta$ process, a contamination of the source foils in ^{208}Tl and ^{214}Bi. Both isotopes decay emitting one electron and up to 3 gamma particles, as illustrated in Figure 2.

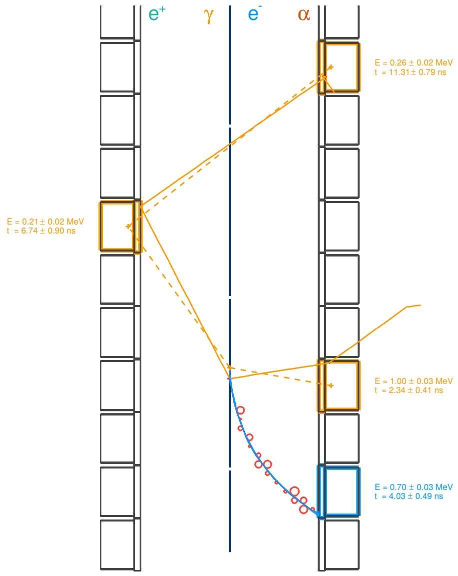

Figure 2: Top view simulation display : a ^{208}Tl event reconstructed in the $1e2\gamma$ channel

These γ's (up to 2.6 MeV for ^{208}Tl) can undergo a Compton scattering, thus mimicking a $\beta\beta$ event, among other possible processes. But these isotopes contamination can be measured in channels where $\beta\beta$ events are not expected, like the $1e1\gamma$ channel for instance. Each channel provides a diversity of discriminating variables and a fit of the different background contributions can then be performed on several of these variables and in several channels simultaneously. A special care during the source production is taken to keep very stringent background levels : A(^{208}Tl)<2μBq/kg and A(^{214}Bi)<10μBq/kg. The Radon level inside the tracking chamber is required to be lower than 0.15 mBq/m^3. Figure 3 shows the result of a fit on the total energy in the 1e1γ channel for a demonstrator pseudo-experience, considering the background contaminations aforementioned.

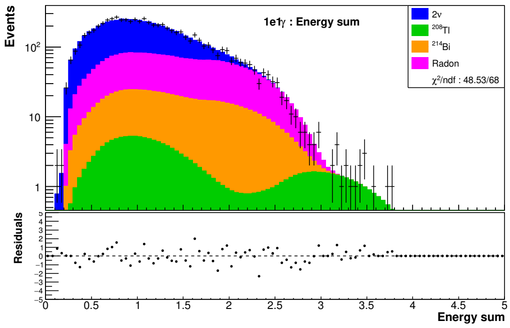

Figure 3: Electron and gamma energy sum fitted for a demonstrator pseudo-experiment i.e. 17.5 kg.y of ^{82}Se and A(^{208}Tl) = 2 μBq/kg, A(^{214}Bi) = 10 μBq/kg and A(Radon) = 150 μBq/m^3

Generating and fitting a large number of pseudo-experiments gives the distributions of the individual contamination levels around their expected values. Thus, a 10 μBq/kg contamination of the demonstrator source in ^{214}Bi is expected to be measured with a 10 % uncertainty after 2 months while a 2 μBq/kg ^{208}Tl source contamination should be measured at 10 % after 8 months.

4. Conclusion

A gamma reconstruction algorithm based on Time-Of-Flight analysis was developed. Such an algorithm is not only important for the search of double beta decays to the excited states but also for the background characterization. Indeed, the NEMO technique allows a full topology and kinematics reconstruction, thus giving access to several analysis channels in which the different background contributions can be measured.

References

[1] R. Arnold et al., *Result of the search for neutrinoless double-β decay in ^{100}Mo with the NEMO-3 experiment. Phys. Rev. D* 92 (2015) 072011F

[2] F. Perrot, *Status of SuperNEMO demonstrator*, 38th International Conference on High Energy Physics (ICHEP 2016), Chicago, USA, August 3-10, 2016

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