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LUCIFER: Scintillating bolometers for the search of Neutrinoless Double Beta Decay

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Abstract

The nature of neutrino mass is one of the frontier problems of particle physics. Neutrinoless Double Beta Decay (0νDBD) is a powerful tool to measure the neutrino mass and to test possible extensions of the Standard Model. Bolometers are excellent detectors to search for this rare decay, thanks to their good energy resolution and to the low background conditions in which they can operate. The current challenge consists in the reduction of the background, represented by environmental γ's and α's, in view of a zero background experiment. We present the LUCIFER R&D, funded by an European grant, in which the background can be reduced by an order of magnitude with respect to the present generation experiments. The technique is based on the simultaneous bolometric measurement of the heat and of the scintillation light produced by a particle, that allows to discriminate between β and α particles. The γ background is reduced by choosing 0νDBD candidate isotopes with transition energy above the environmental γ's spectrum. The prospect of this R&D are discussed.

Keywords: Neutrino mass, neutrinoless double beta decay, scintillating bolometers.

The search for the 0νDBD is a challenge. This decay has never been observed, and present limits on the half-lifes of candidate isotopes are higher than 10^{24} years. The effective neutrino mass that mediates the process ($m_{\beta\beta}$) is constrained to be less than 500 meV. Upcoming experiments aim to reach a sensitivity on the effective neutrino mass in the range of 50-100 meV. The high sensitivity required implies excellent energy resolution (O[keV]), low background O(10^{-2} – 10^{-3} counts/keV/kg/y) and high mass O(100-1000 kg) . Experiments based on bolometric detectors are able to reach the needed resolution and mass, but the background seems to be not reducible below 10^{-2} counts/keV/kg/y. A 1 ton bolometric experiment, with zero background, could have a sensitivity on $m_{\beta\beta}$ as low as 20 meV. Presently the main source of background seems to be constituted by α particles, which originates from the materials surrounding the detectors. Since the 0νDBD is detected by the emission of two electrons, experiments able to discriminate between β (and γ) particles from α particles will gain in higher signal to background ratio. The LUCIFER group is developing bolometers made of ZnSe crystals to search the 0νDBD of ^{82}Se. The ZnSe crystal has good bolometric properties, and also emits scintillation light when particles release in it their energy. By facing a Germanium light detector to the bolometer we are able to discriminate α particles from β/γ particles, thanks to the different amount of light emitted by these particles. Also, the discrimination is enhanced by the dependence of the shape of the scintillation signal on the nature of the impinging particle. Preliminary studies shows that the background in the 0νDBD region could be less than 10^{-3} counts/keV/kg/y, making this technique very promising. Studies are being done to improve the performances of light detectors. A pilot experiment will be prepared. With a ^{82}Se mass of only $\sim$ 18 kg, it could reach a sensitivity on $m_{\beta\beta}$ of order 60 meV, competing with the leading experiments of the field.