SIMULATIONS OF OPTICAL PERFORMANCE OF LONG BGO SCINTILLATORS FOR PROTOTYPE CRYOGENIC ACTIVE VETO IN THE BINGO 2β PROJECT

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In the well-established two-neutrino double-beta decay (2ν2β), a nucleus (*A, Z*) decays into (*A, Z+2*) with the emission of two electrons and two antineutrinos. In contrast, the hypothetical neutrinoless mode (0ν2β) proceeds with the emission of only two electrons and no neutrinos in the final state: $(A, Z) \rightarrow (A, Z+2) + 2e^{-}$. Numerous experimental efforts are dedicated to the search for 0ν2β, as its observation would constitute a major breakthrough in understanding the fundamental nature of neutrinos [1].

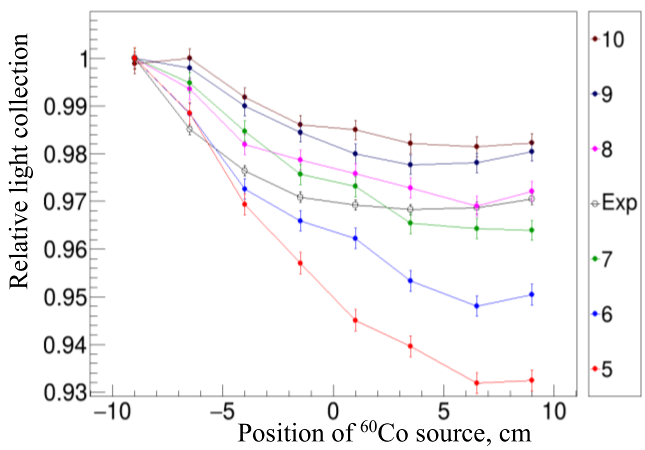

Fig. 1 Comparison of relative light collection efficiency: colored lines show simulations with different attenuation lengths (reference att. length curve [5] scaled by numerical factors from 5 to 10 in steps of 1); while unfilled points represent experimental data

The multi-isotope BINGO project [2] aims to advance the search for 0ν2β of ^{130}Te and ^{100}Mo by improving experimental sensitivity through innovative detector technologies. The isotopes of interest are embedded in low-temperature TeO_2 and Li_2MoO_4 bolometers, installed in a low-background cryogenic setup at the Modane Underground Laboratory. One of the approaches to reduce the background in the region of interest is the implementation of an active cryogenic veto system [3], that utilizes $Bi_4Ge_3O_{12}$ (BGO) scintillators to identify and reject gamma-induced background events. Registration of scintillation signals from BGO scintillators will be carried out using low-temperature germanium bolometric photosensors based on the Neganov–Luke effect.

In BINGO, specific challenges are related to light collection from the BGO active veto scintillators. Elongated shape of crystals (50–100)×5×5 cm^3 leads to position-dependent light collection and complicates scintillation signal readout. Defining BGO scintillator and photodetector parameters via photon propagation simulations requires the measurement of value of BGO optical transparency (photon absorption length). At the same time, determining the absorption length of long samples is difficult for highly transparent materials.

To experimentally determine the absorption length of BGO crystals, an indirect method was employed. Test samples (four trapezoidal crystals, 23 cm long with a cross-sectional area of about 19.4 cm^2) were optically coupled to a PMT on one side, while the rest of the surface was wrapped with ESR reflective film [4]. Then the full-energy peak position in the γ-ray spectrum was measured for different positions of a collimated ^{60}Co source along the crystals (from −9 to +9 cm in 2.5 cm steps).

These measurements yielded a relative light collection profiles, which were reproduced using optical Monte Carlo simulations by expressing the optical attenuation length as the product of reference value from [5] and a free scaling parameter (Fig. 1). The attenuation length at the emission spectrum maximum was determined to be 80 ± 8 cm, based on the measurements of four crystals of the same shape. This value was then used to estimate the energy threshold of a bolometric BGO active veto prototype (≈ 80 keV), in good agreement with the experimentally achieved value [3].

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3. A. Armatol et al. (BINGO Collaboration) BINGO: cryogenic scintillation veto for 0ν2β bolometric experiments, submitted to Eur. Phys. J C.
4. 3M Company, Application Guide for Enhanced Specular Reflector (ESR) Film.
5. E. Roncali et al., Biomed. Phys. Eng. Express 5(3) (2019) 035033.