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Impact of wrapping materials and bonding adhesives on light transfer efficiency (LTE) and light transfer time spread (LTTS) in scintillation detectors

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The light output from high-aspect ratio scintillators used in Positron Emission Tomography (PET) detectors is a critical factor to achieve good energy and time resolution. However, only a fraction of the light generated in the crystals is actually extracted from these scintillators, hence raising the need to identify the predominant causes of signal loss.

As a first step, in order to identify the key factors affecting the light transfer efficiency (LTE) in high-aspect ratio LYSO scintillators, various combinations of crystal geometry and wrapping conditions were investigated with Monte Carlo simulations through a full factorial design. It was concluded that the highly reflective material must be carefully selected along with the high-transmittance optical adhesive used to bond the reflector, since both factors were found to be strongly interrelated when optimizing LTE.

As a second step, the unexpectedly high light crosstalk (˜30%) measured in crystal arrays assembled with the 3M-ESR reflector was investigated. Analytical modelling of the ESR reflector showed that the film becomes highly transparent to light impinging at large angles when surrounded on both sides by materials of refractive index (RI) higher than air. Monte Carlo simulations indicate that a large fraction (˜25–35%) of scintillation photons is incident at these leaking angles in high-aspect ratio LYSO crystals. The film transparency was confirmed experimentally as significant light leakage, up to nearly 30%, measured through the reflector when coated on both sides with optical grease. The angular dependence of the reflector transparency was also confirmed experimentally for angles of incidence larger than ˜60°. The major cause of light crosstalk in ESR-bonded arrays was thus elucidated.

Light crosstalk in bonded scintillator arrays is also dependent on the transmittance of the adhesive used to bond the reflector to the crystals. Simulations showed that high transmittance adhesives yield higher LTE, but results in higher light crosstalk (+15-20%). Moreover, the combined effects of high adhesive transmittance and ESR reflectivity quenching at large incident angles result in even higher light crosstalk (+25-30%). One thus has to seek low-RI adhesives approaching an air-coupling condition to eliminate the reflectivity quenching effect, in combination with high transmittance for optimum results.

The ultimate goal in scintillation detectors nowadays is to achieve ultra-fast time resolution, allowing accurate time-of-flight measurements. All aforementioned light collection factors enhancing LTE will contribute to improve time resolution, but the time fluctuation between production and detection of scintillation photons, the light transfer time spread (LTTS), must also be enhanced. The variance in optical path length becomes prominent in long crystal elements and must be taken into account in estimating the achievable time resolution. This was done by calculating a probability distribution function (PDF) representing the photons travel time in crystals. Wrapping conditions, including adhesive and reflector optical characteristics, were found to alter the scintillation light propagation. The influence on both LTE and LTTS, thus on the achievable timing resolution, will be discussed.

Has accepted

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