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Development of an Organic Plastic Scintillator based Muon Veto Operating at Sub-Kelvin Temperatures for the NUCLEUS Experiment

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The NUCLEUS experiment aims to measure coherent elastic neutrino nucleus scattering of reactor anti-neutrinos using cryogenic calorimeters. Operating at an overburden of 3m.w.e., muon-induced backgrounds are expected to be dominant. For this reason, an efficient muon veto with a muon detection efficiency of more than 99% is indispensable and shall be achieved in NUCLEUS with a compact cube assembly of plastic scintillator panels. In order to prevent a large unshielded area where the cryostat enters the shielding arrangement without unnecessarily increasing the induced detector dead time, a novel concept has been investigated, consisting of a plastic scintillator based disc-shape active muon veto operating inside the NUCLEUS cryostat at sub-Kelvin temperatures. The required verification of the key physical aspects of the intended cryogenic muon veto detector concept by investigating its low temperature behavior led to the first reported measurements of organic plastic scintillators at sub-Kelvin temperatures. The functionality of the principal scintillation process of organic plastic scintillators at sub-Kelvin temperatures has been confirmed. On the basis of these findings, a disc-shape plastic scintillator based muon veto equipped with wavelength shifting fibers and a silicon photomultiplier to guide and detect the scintillation light has been developed. The NUCLEUS cryogenic muon veto will be the first of its kind to be operated at sub-Kelvin temperatures.

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