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Simulation of the background from ^{13}C(α, n)^{16}O reaction in the JUNO scintillator

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The Jiangmen Underground Neutrino Observatory (JUNO), a large-scale organic liquid scintillator detector, will begin data collection this year. JUNO's primary and ultimate goal is to determine the neutrino mass ordering. To answer this fundamental question, the fine structure in the oscillated reactor antineutrino energy spectrum must be resolved. This experimental approach requires serious efforts in background reduction of the target liquid scintillator and then precise monitoring of its residual radioactivity. Antineutrinos are detected through the inverse beta decay reaction, so one possibly significant background is the (α, n) reaction, which occurs on ^{13}C nuclei. The sources of the α particles are the decays of intrinsic contaminants such as ^{238}U, ^{232}Th, ^{210}Pb/^{210}Po and their daughters. The (α, n) background evaluation was performed in two steps, namely ^{13}C(α, n)^{16}O reaction modelling and simulation of the detector response. The open source Geant4-based software SaG4n was used for the first step, calculating the expected energy depositions from the neutron, associated de-excitation products and the α particle propagating in the medium until the (α, n) interaction occurs. This data was the input for the second step of the calculation, when all the produced particles were run with a new event generator and tracked in the JUNO detector within a dedicated Monte Carlo simulation package. Expected (α, n) background event rates and respective energy spectra have been obtained for all α particle sources (^{238}U and ^{232}Th chains and ^{210}Pb/^{210}Po), considering JUNO's predicted radioactivity concentration. Corresponding uncertainties were also evaluated. Finally, it is important to note that the simulation pipeline and its outcomes are applicable and relevant to other organic liquid scintillator neutrino detectors and may be useful in direct detection dark matter experiments.

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