A Measurement of the Ambient Radon Rate and MeV-Scale Calorimetry in the MicroBooNE LArTPC

Will Foreman (Illinois Institute of Technology) representing the MicroBooNE Collaboration

Introduction

• Radon ($^{222}\text{Rn}$) is a major source of backgrounds for low-energy signals like supernova and solar $\nu$'s in future large LArTPCs like DUNE.

• Previous MicroBooNE result [1] showed removal of doped Rn by LAr filtration, but unknown backgrounds prevented measurement of absolute rate.

• Here we report a measurement of ambient Rn activity in the bulk LAr during standard data-taking periods, using novel low-energy reconstruction tools and background removal.

• We also demonstrate calorimetry at lowest energy ranges ever achieved in a large single-phase LArTPC.

MeV-Scale Blip Reconstruction


• Wire readout signals processed using lowered hit-finding thresholds for this analysis to enhance sensitivity to signals $\lesssim 1$ MeV.

• Energy reconstructed assuming electron-like recombination ($dE/dx \sim 2.8$ for 1 MeV $e^-$)

Signal Topology and Analysis Method

• $^{214}\text{Bi} \rightarrow ^{214}\text{Po}$ (BiPo) decay produces distinct 'two-blip' topology due to short Po lifetime of $164\mu$s

• $\Delta T$ 'decay time' distribution background -subtracted & fit to exponential function

• Function integrated to extract BiPo rate

• We also demonstrate calorimetry at lowest energy ranges ever achieved in a large single-phase LArTPC.

Calorimetric Validation of Monte Carlo

• R&D doping data used to validate the simulation at the MeV-scale by reconstructing BG-subtracted energy spectra.

• $p_{\text{Bi}}$ plane-matched; spectrum sculpted by thresholding effects at $E \lesssim 0.5$ MeV

• $p_{\text{Po}}$ signal reconstructed only in collection plane (lower thresh)

• Uncertainties in $\alpha$ charge-yield and quenching in LAr dominate systematic uncertainty

• MC efficiency for measuring BiPo rate: $\varepsilon_{\text{nom}} = (6 \pm 3\%)$

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Ambient Radon Rate Results

• R&D doping data used to validate the simulation at the MeV-scale by reconstructing BG-subtracted energy spectra.

• Measured $^{222}\text{Rn}$ activity from 46 days of data-taking: $(0.04 \pm 0.17)$ mBq/kg

• Set limit: $< 0.38$ mBq/kg at 95% confidence level

• Result is below the DUNE collaboration's low-energy physics target of $\lesssim 1$ mBq/kg [4], and was achieved with standard LAr liquid filtration techniques.

• This in-situ measurement is the first of its kind for a noble element detector with liquid-phase purification.

References

[1] P. Abratenko et al. (MicroBooNE), J. Instrum. 17 1044 (11), P11022