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

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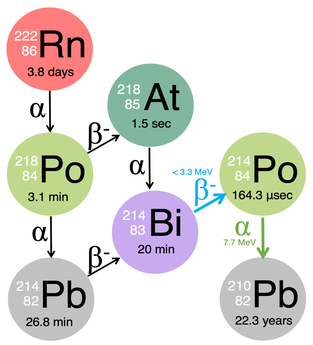
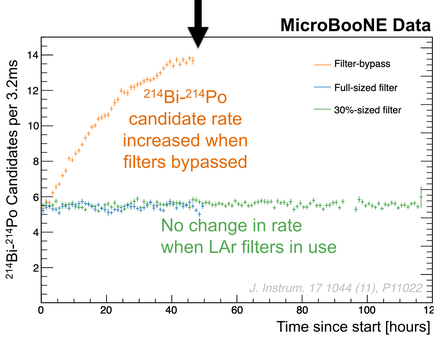
Introduction

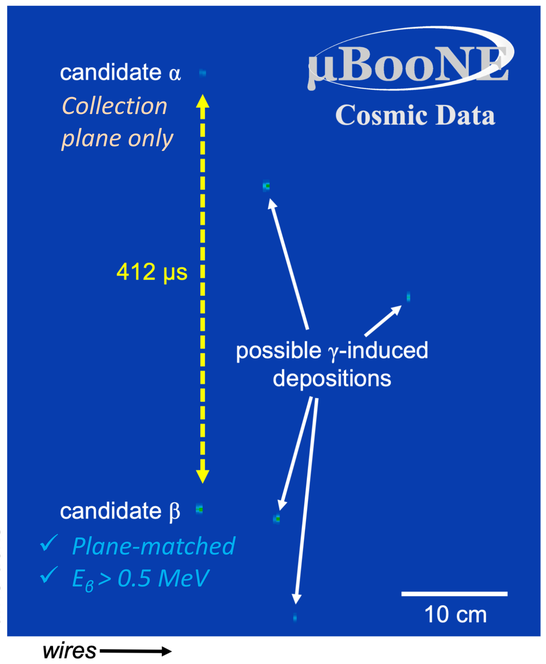
- Radon (^{222}Rn) is a major source of backgrounds for low-energy signals like supernova and solar ν's in future large LArTPCs like DUNE.
- Previous MicroBooNE result [1] showed removal of doped Rn by LAr filtration, but unknown backgrounds prevented measurement of absolute rate.

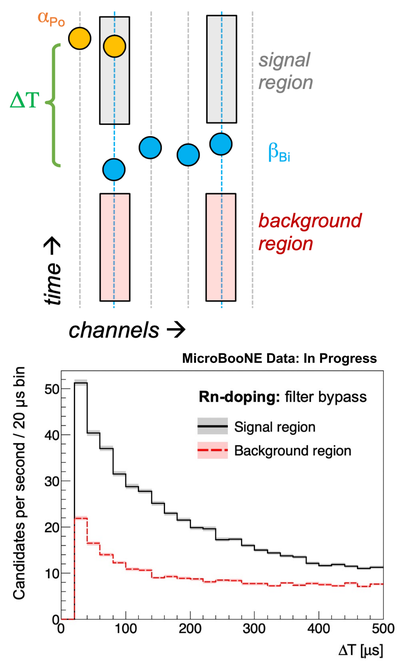




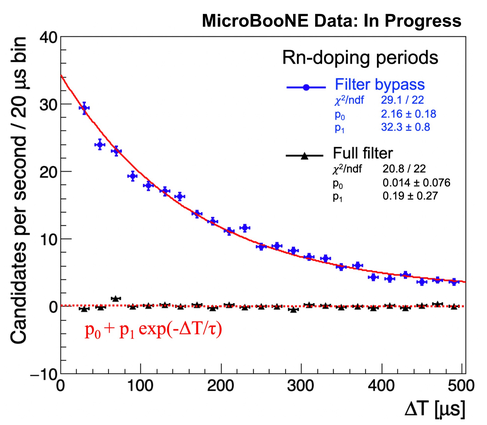
- Here we report a measurement of ambient Rn activity in the bulk LAr during standard data-taking periods, using novel low-energy reconstruction tools and background removal.
- We also demonstrate calorimetry at lowest energy ranges ever achieved in a large single-phase LArTPC.

Signal Topology and Analysis Method



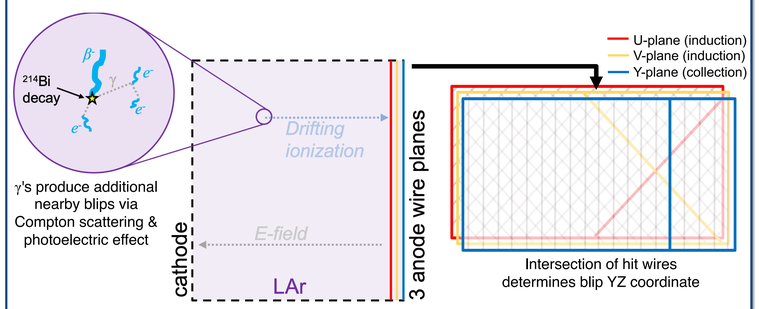


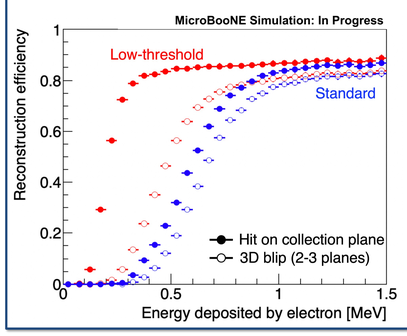
- ^{214}Bi → ^{214}Po ('BiPo') decay produces distinct 'two-blip' topology due to short Po lifetime of 164μs.
- ΔT 'decay time' distribution background-subtracted & fit to exponential function.
- Function integrated to extract BiPo rate.

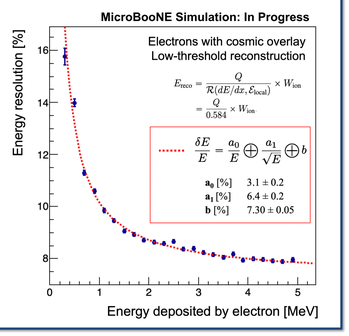


MeV-Scale Blip Reconstruction

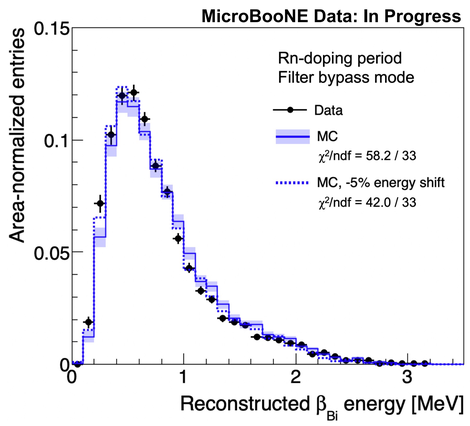
- Tools adapted from techniques pioneered by the ArgoNeuT [2] and MicroBooNE [3] collaborations.
- Wire readout signals processed using lowered hit-finding thresholds to enhance sensitivity to signals $\lesssim$ 1 MeV.
- Energy reconstructed with electron-equivalent e$^-$/ion recombination (dE/dx ~ 2.8 MeV/cm for 1 MeV β).

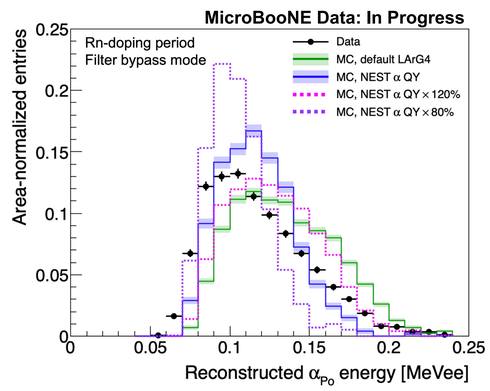






Calorimetric Validation of Monte Carlo

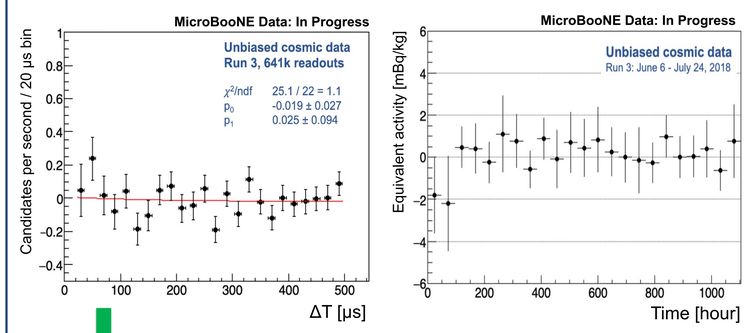




- R&D doping data used to validate the simulation at the MeV-scale by reconstructing BG-subtracted energy spectra.
- β_{Bi} is plane-matched; spectrum sculpted by thresholding effects at E $\lesssim$ 0.5 MeV.
- α_{Po} signal reconstructed only in collection plane (lower thresh)
  - Uncertainties in α charge-yield and quenching in LAr dominate systematic uncertainty
- MC efficiency for measuring BiPo rate: ε_{nom} = (6 ± 3)%

Systematic	$(\delta\varepsilon / \varepsilon_{nom})$ Uncertainty
Alpha QY	±43%
Electron diffusion	+26%, -17%
Energy scale	±15%
Recombination modeling	±1.9%
Total	+52%, -49%

Ambient Radon Rate Results



Measured ^{222}Rn activity from 46 days of data-taking: **(0.04 ± 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
[2] R. Acciarri *et al.* (ArgoNeuT), Phys. Rev. D 99, 012002 (2019)
[3] A. Bhat, PhD Thesis, Syracuse Univ., FERMILAB-THESIS-2021-14
[4] A. Avasthi et al., Snowmass 2022, arXiv:2203.08821

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