Observation of Radon Mitigation in MicroBooNE by a Liquid Argon Filtration System

Joseph Zennamo (Fermilab),
on behalf of the MicroBooNE Collaboration

Low Radioactivity Techniques 2022
June 16th, 2022

Based on: "Observation of Radon Mitigation in MicroBooNE by a Liquid Argon Filtration System", arxiv.org:2203.10147, ***submitted to JINST***

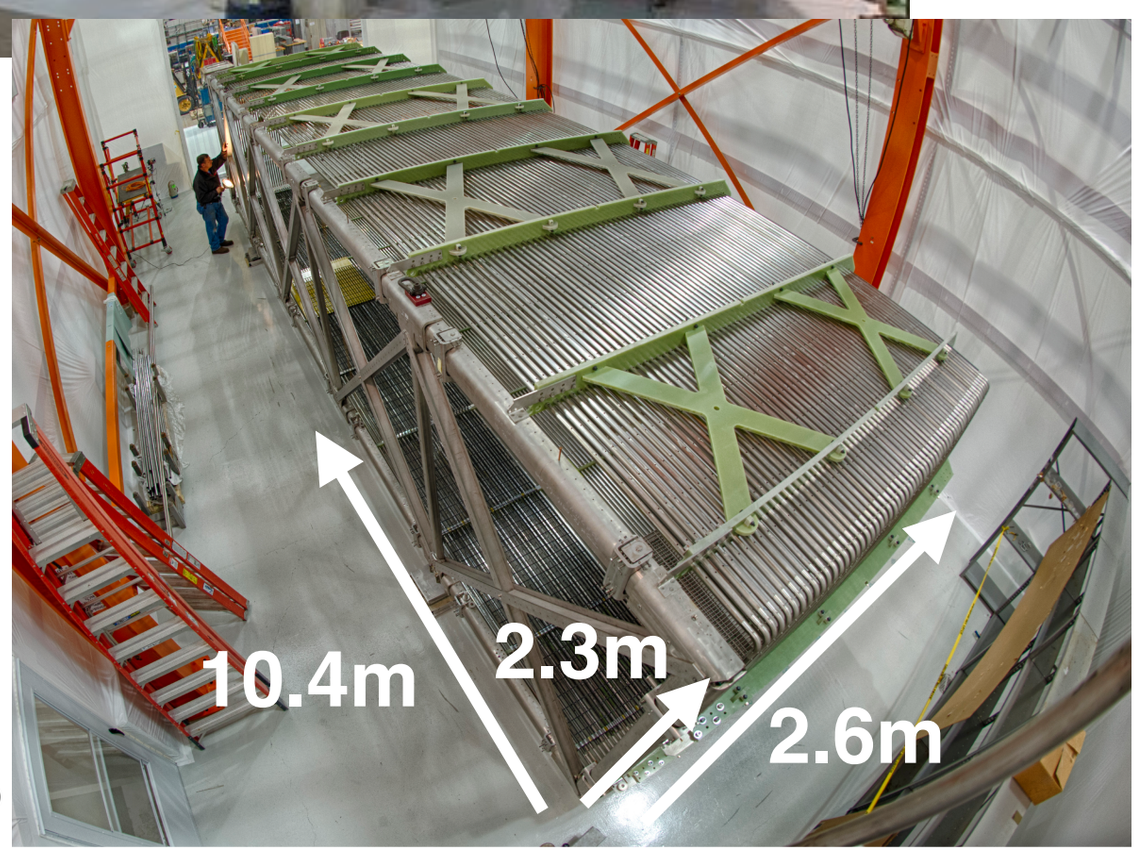
Fermilab

MicroBooNE

89-ton active mass liquid argon TPC

Studied GeV-scale neutrino interactions in data from 2014-2020

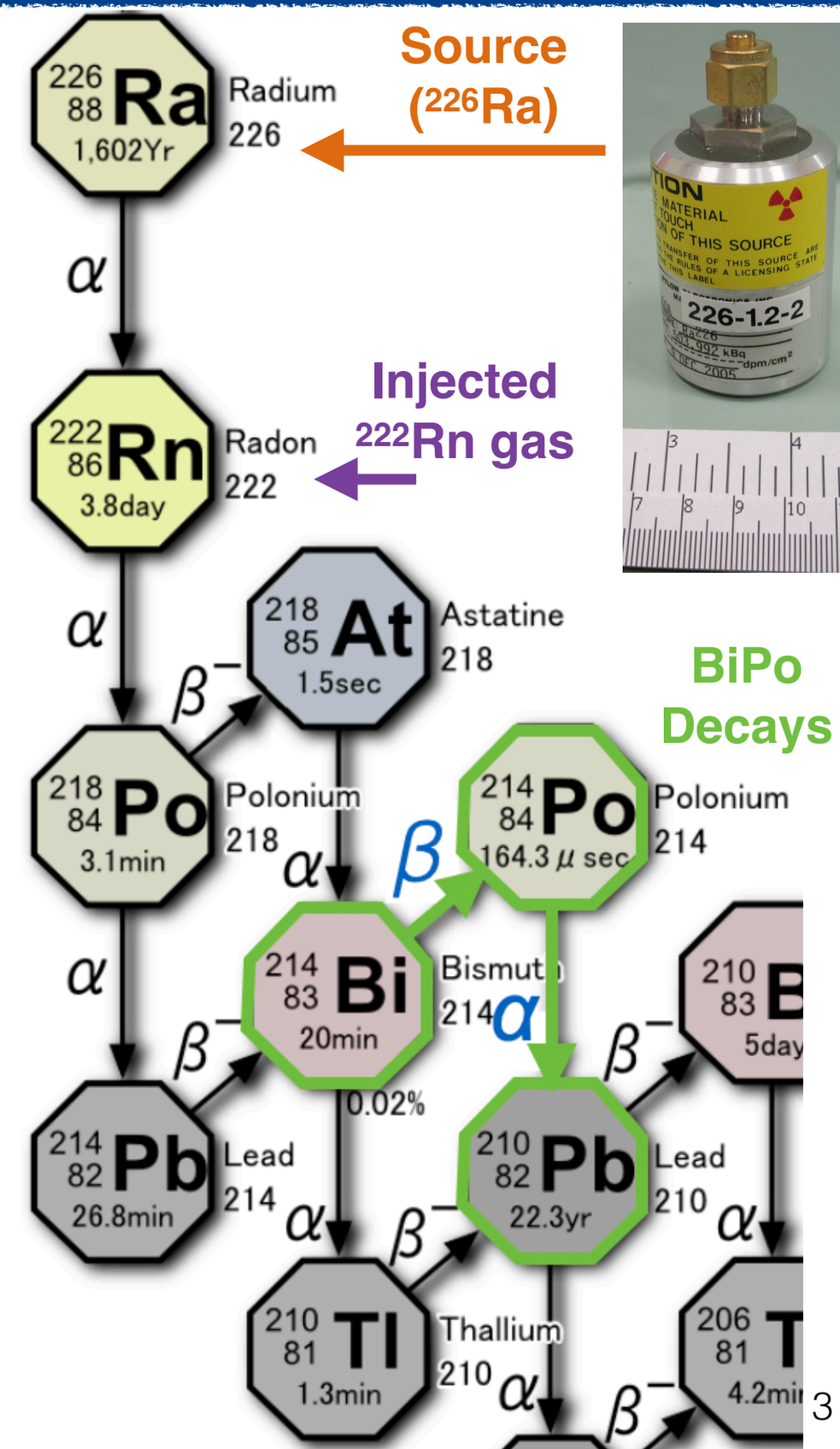
(not primarily targeting low energy signals)



Experiment entered R&D period in 2021

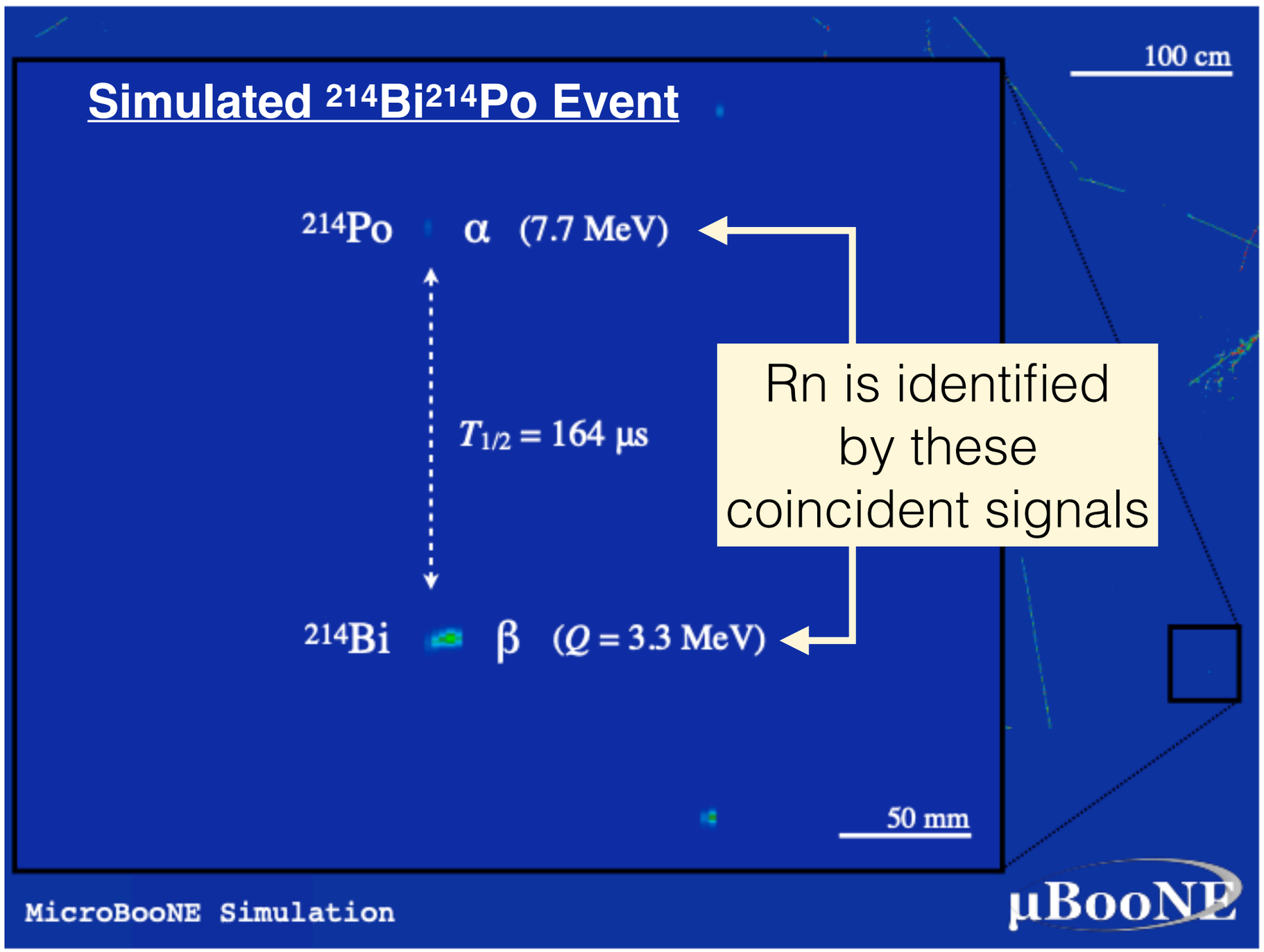
Doping LAr with Radon

- 500-kBq 226-radium source used to perform a spike-test
- 222-radon is interesting for MicroBooNE:
  - **222-radon has a 3.8-day half-life**
    - Mixes throughout cryostat
  - **214-polonium's short 164 μs half-life**
    - Tag the 214-bismuth β-signal with the trailing 214-polonium α-signal



MicroBooNE's MeV-Scale Capability

- LArTPCs are capable of reconstructing low-energy signals
  - MicroBooNE has shown the ability to reconstruct 100 keV β-decays



Rn is identified by these coincident signals

^{39}Ar Beta Decays at MicroBooNE
MicroBooNE Public Note 1050

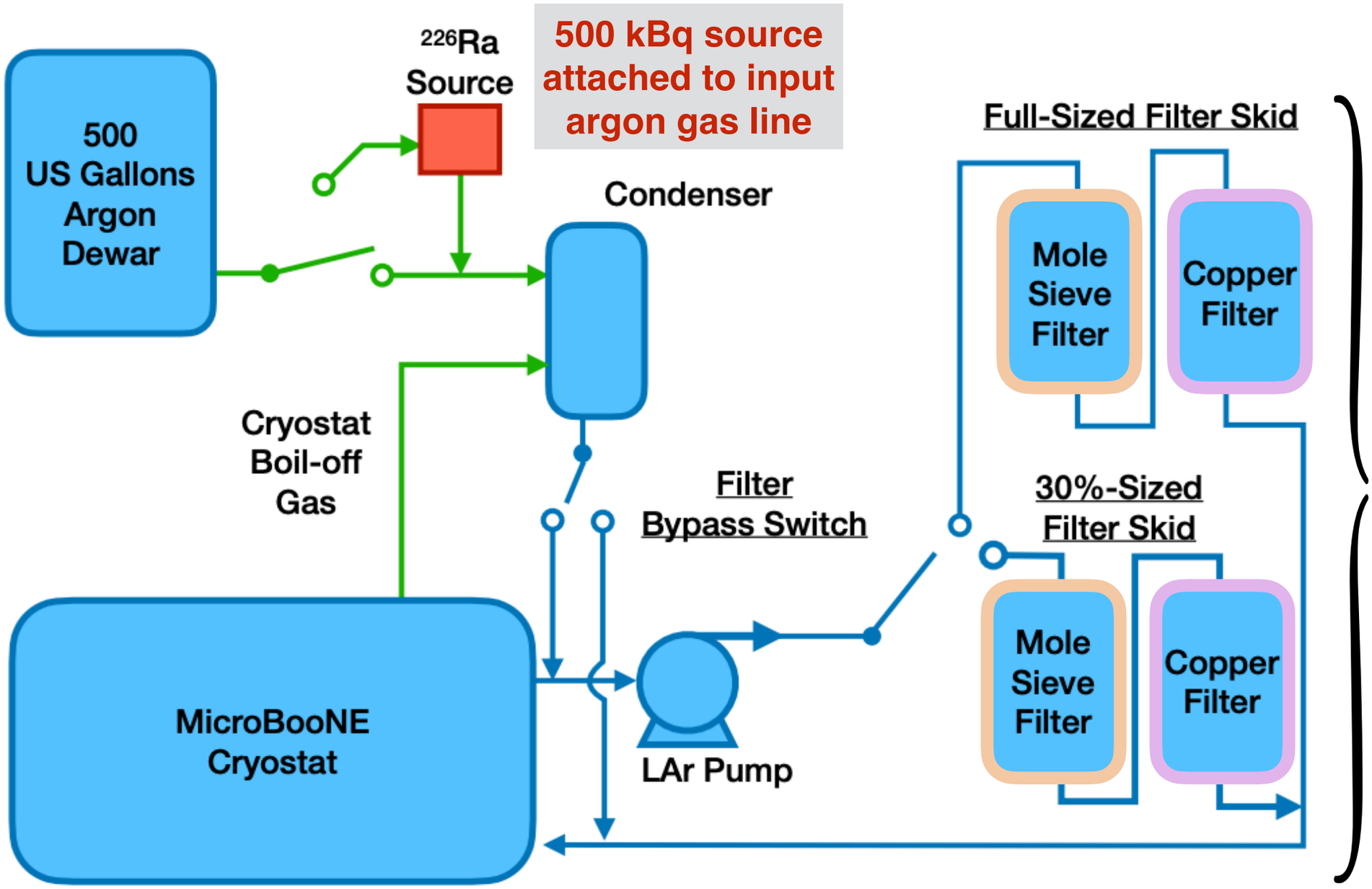
MeV Physics in MicroBooNE
MicroBooNE Public Note 1076

MeV Physics in ArgoNeuT
Phys. Rev. D 99, 012002

Benefits of MeV Reco In LArTPCs
W. Castiglioni, et al.
Phys. Rev. D 102, 092010

Path Towards 0νββ with LArTPCs
A. Mastbaum, F. Psihas, J. Zennamo
arxiv:2203.14700

MicroBooNE Cryogenic System



Two filters aim to remove electronegative contaminants from the liquid argon

No filter targets radioactivity

First,

4Å Molecular Sieve

1.6-2.6 mm beads

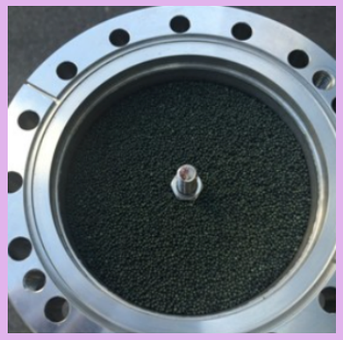
Removes water!

Second,

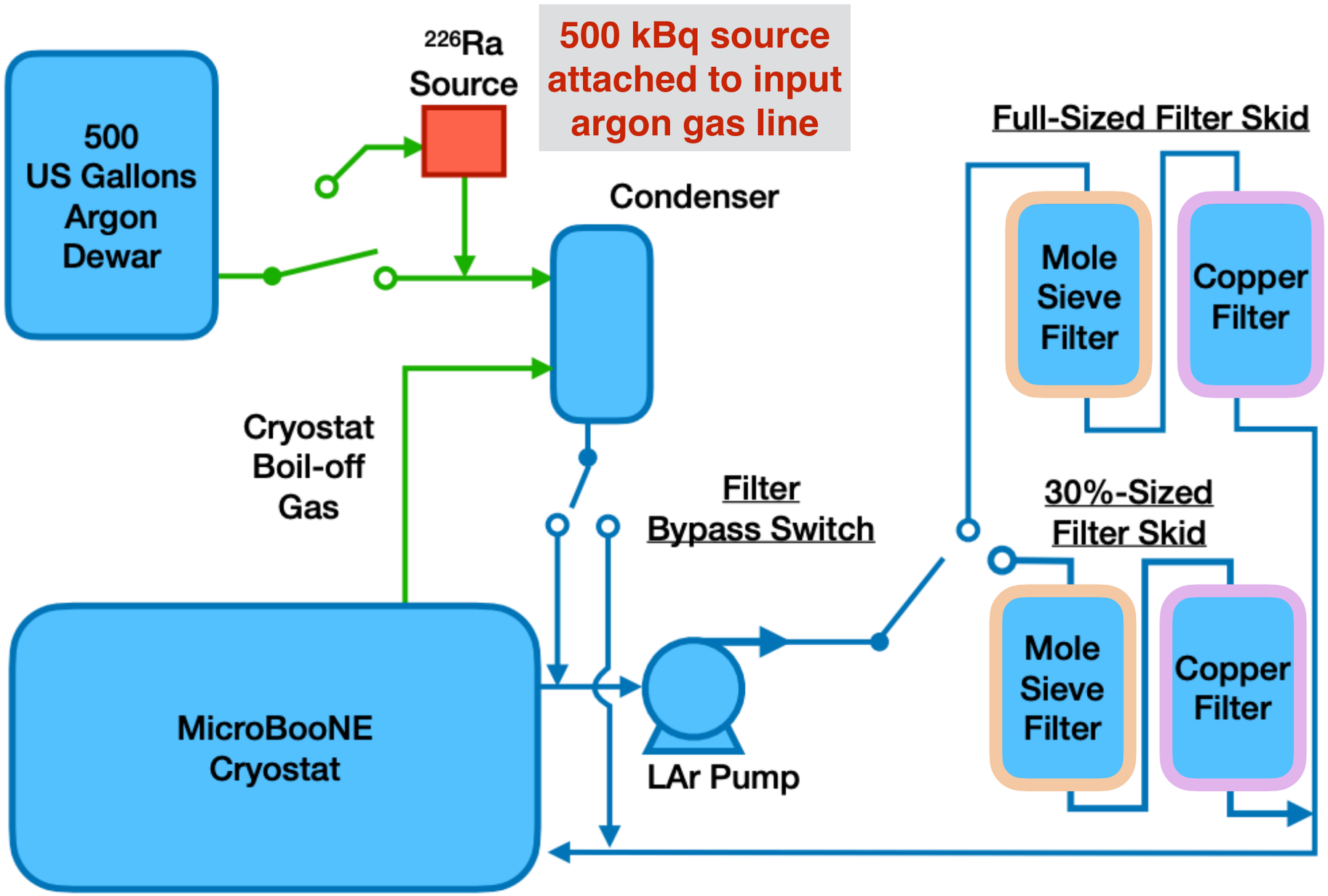
Copper Filter

Cu-0226 S

Removes O_2!



MicroBooNE Cryogenic System



System can be run in 3 modes

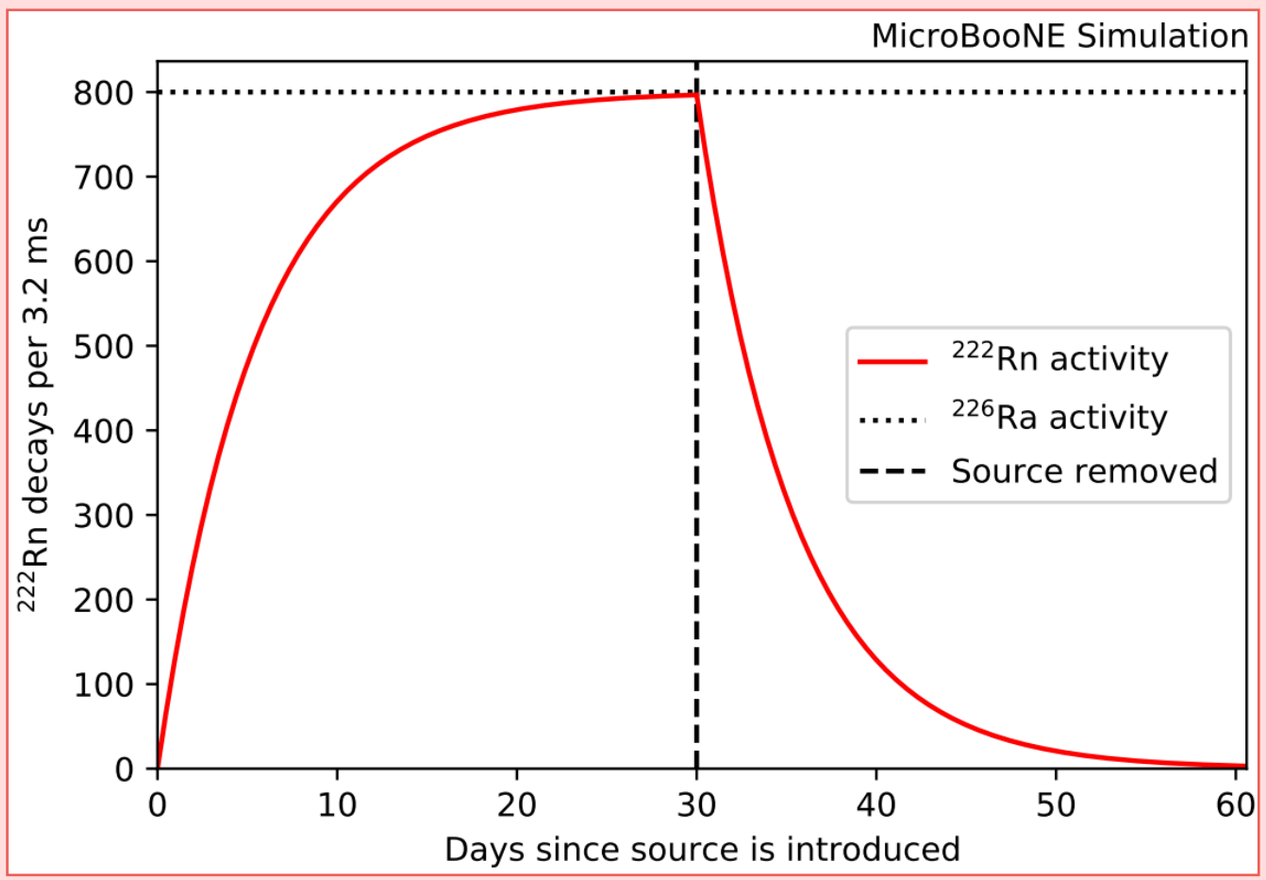
1. **Flow LAr & GAr through the full-sized filter**
(Nominal mode)

2. **Flow LAr & GAr through the 30%-sized filter**

3. **Recondensed GAr bypasses the filters**
(Reduces electron lifetimes)

Selecting Radon Decays

Expected *hundreds* of signals per readout

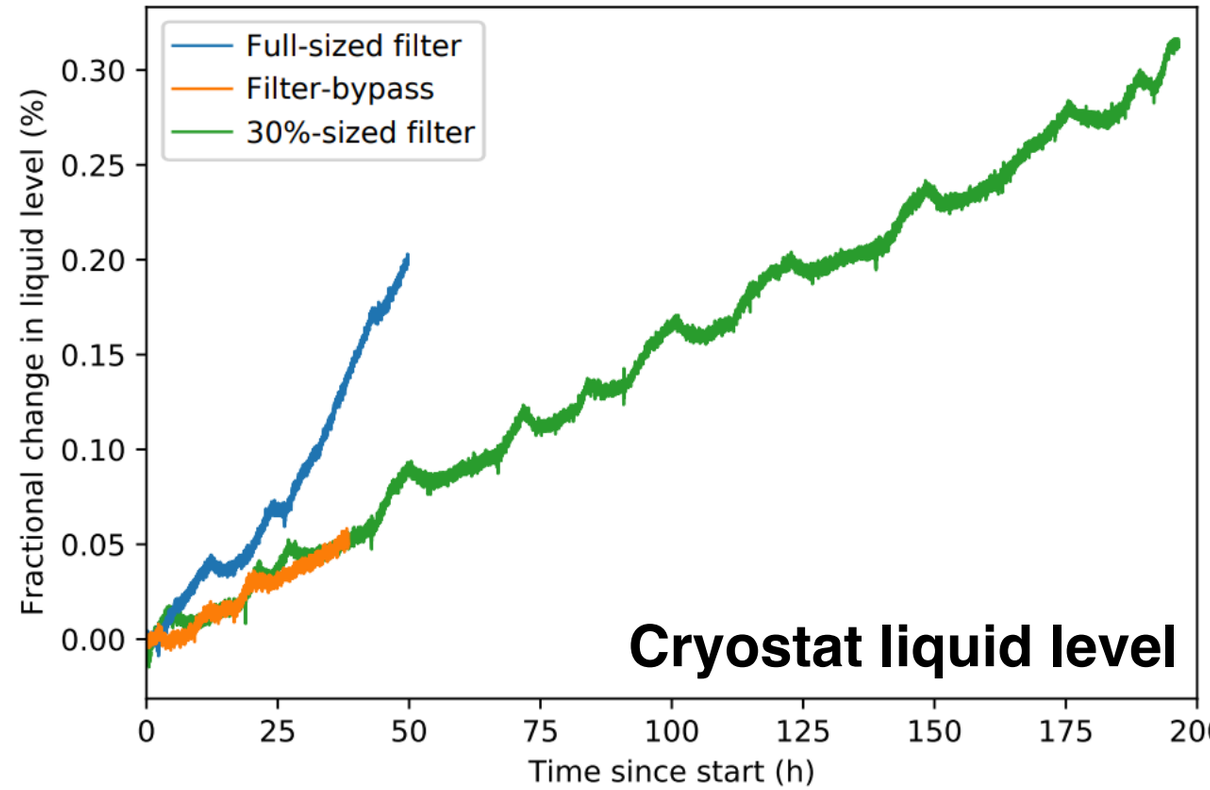


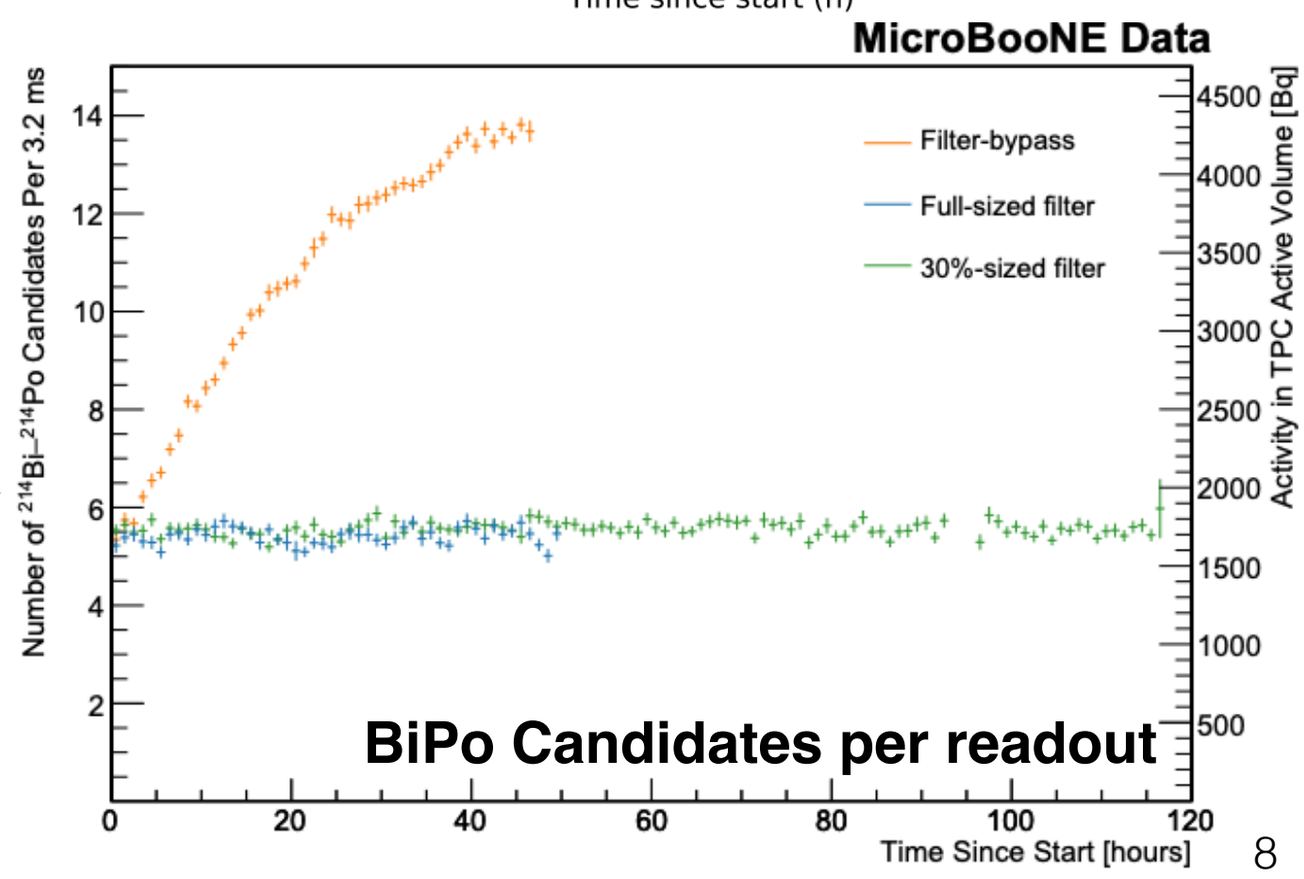
Assumes cryostat comes into secular equilibrium with source and filter removes no radon

- Selection takes overlapping small clusters where the cluster at higher-drift distance has less charge
- $(46^{+31}_{-29})\%$ ^{214}Bi^{214}Po selection efficiency
  - The uncertainty comes from a data-driven comparison
  - Uncertainty covers source efficiency, simulation differences, reconstruction differences

Radon Candidates in Different Modes

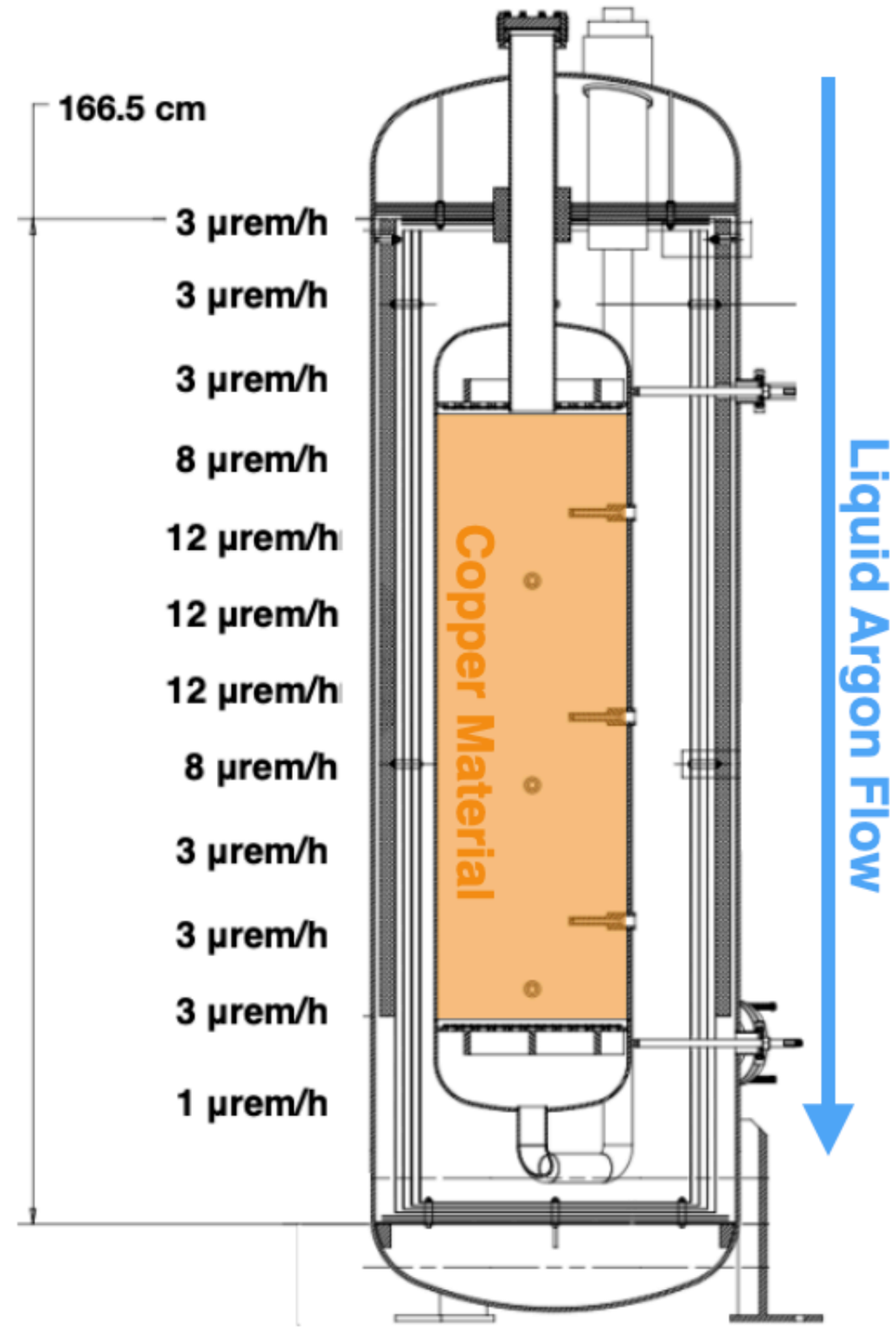
- Three modes we ran in:
  - **Full-sized filter:** recondensed GAr goes through 77 L mole sieve + 77 L copper
  - **30%-sized filter:** recondensed GAr goes through 25 L mole sieve + 24 L copper
  - **Filter-bypass:** recondensed GAr bypasses filters
- **Only filter-bypass led to an increase in the ^{214}Bi^{214}Po rate**





Radiological Survey

- Performed radiological survey of the complete cryogenic system
- Background rates (1-5 μrem/h) **expect near the source and the copper filter** (12-16 μrem/h)
  - Stratification stable over 8-months
- The mole sieve (first in line) has a larger surface area per gram compared to the copper filter but read at background levels
  - 900 m^2/g compared to 200 m^2/g



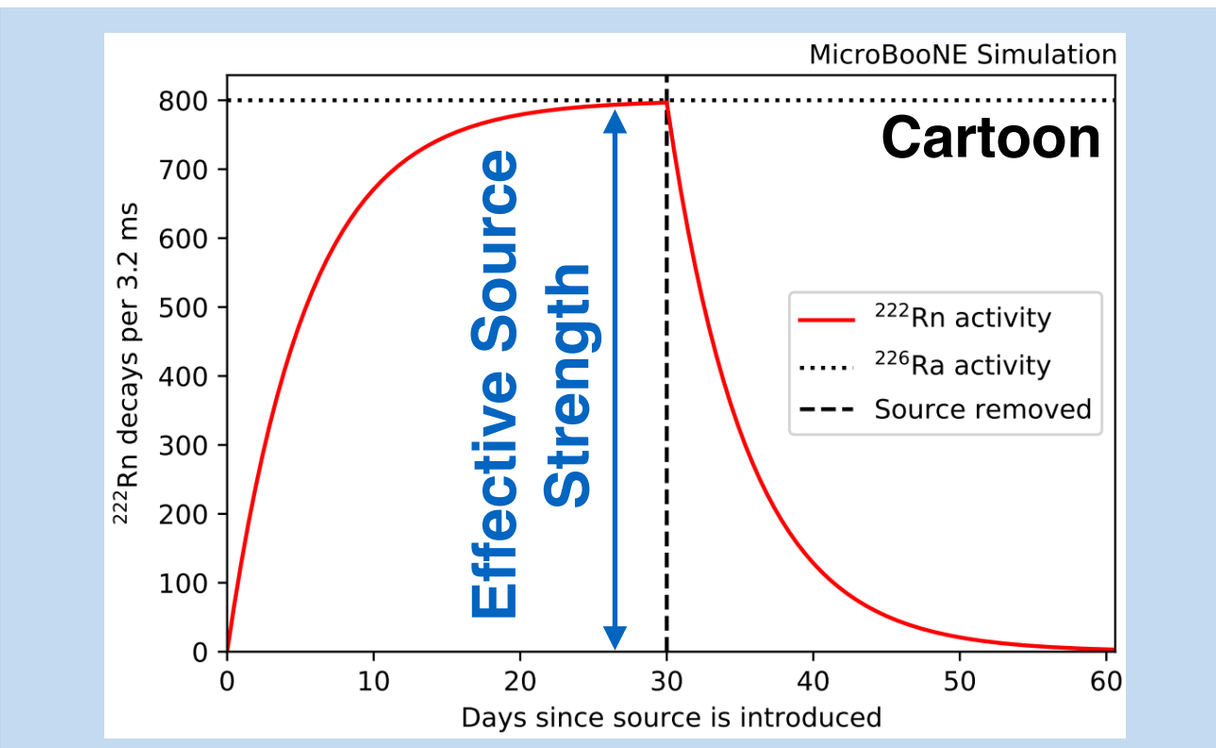
Radon Mitigation Models

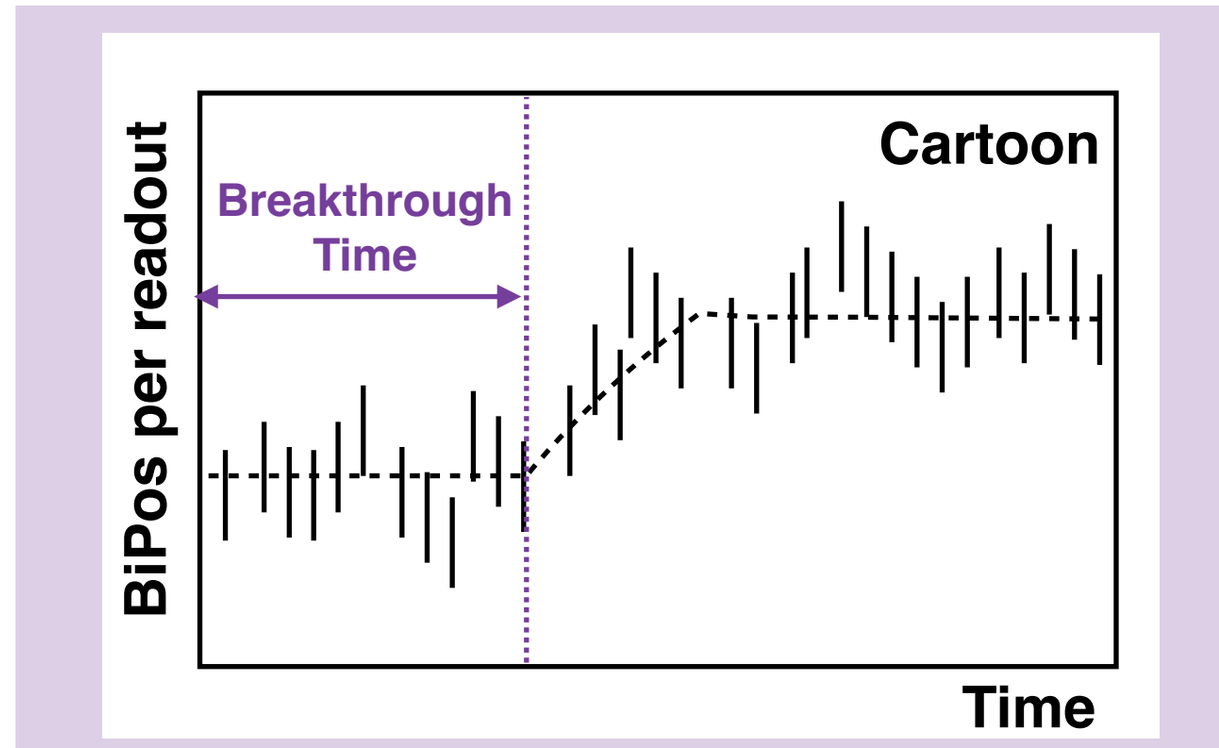
Trapping: the filter captures and holds onto the radon, similar to electronegative contaminants

Measure **effective source strength**, compare that to 500-kBq injected

Slowing: the filter material slows the radon which then decays as it traverses the filter material

Measure **breakthrough time,** sets fraction of radon that decayed





Measured Radon Removal

Trapping

Fit for effective source strengths

No appreciable increase in BiPo rates

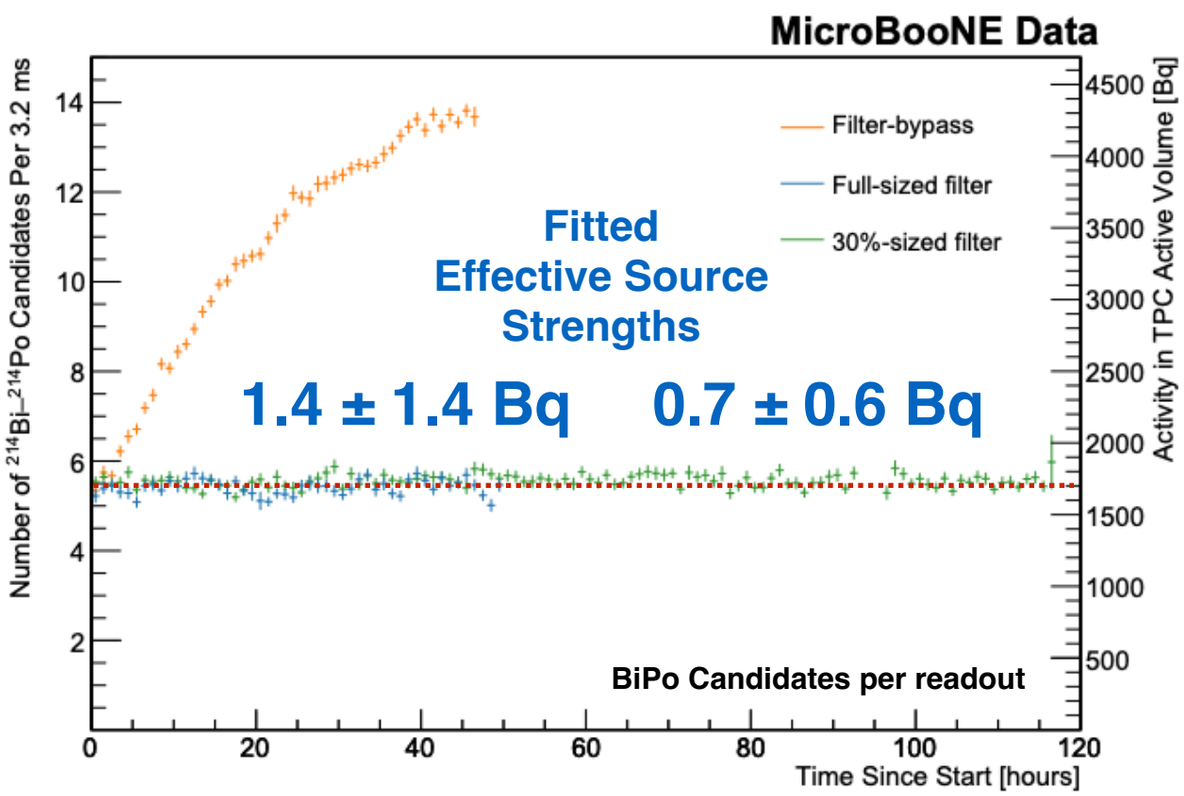
Correct selection efficiency and LAr mass

Compare to input source strength (500 kBq)

Fraction of radon removed:

Full-sized filter: (99.9997±0.0003)%

30%-sized filter: (99.9999±0.0001)%



Slowing

Search for a delayed baseline shift

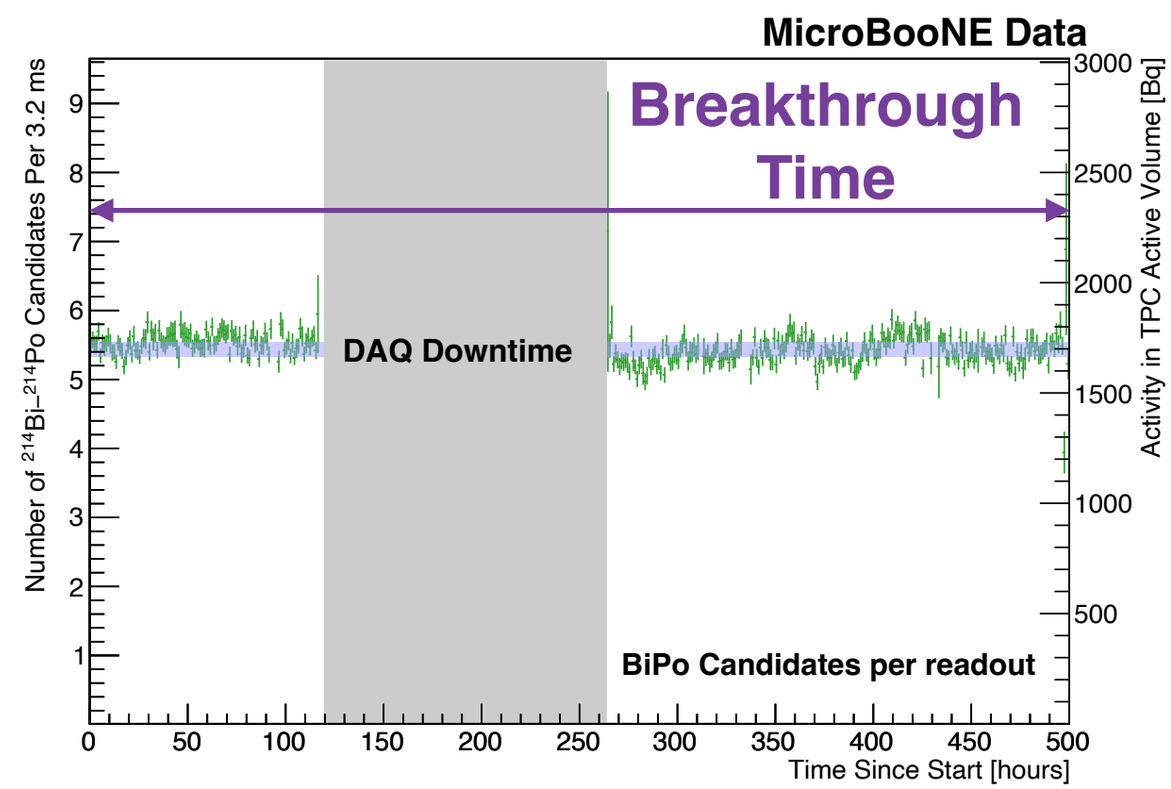
2% uncertainty on background level

Observed no baseline shift over 500 hrs

Places limit on fraction of ^{222}Rn decayed

Lower limit of fraction of radon removed:

30%-sized filter: 97.7%



Conclusions

- MicroBooNE has observed that its copper filter material is highly efficient at sequestering 222-radon from liquid argon
  - Analyses performed for radon being trapped or slowed by copper filter
- This work shows that 222-radon can be mitigated via liquid-phase filtration in liquid argon
  - **Could enable scaling MeV-scale LAr detectors to very large masses**

Trapped Radon Removal Efficiency

Full-sized filter: (99.9997±0.0003)%

30%-sized filter: (99.9999±0.0001)%

Slowed Radon Removal Efficiency

30%-sized filter: >97.7%

No radon punch through observed for 500 hours

Based on: "Observation of Radon Mitigation in MicroBooNE by a Liquid Argon Filtration System", arxiv.org:2203.10147, ***submitted to JINST***