Constraining the Neutral Current π^0 Background for MicroBooNE's Single-Photon Low-Energy Excess Search

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On Behalf of the MicroBooNE Collaboration

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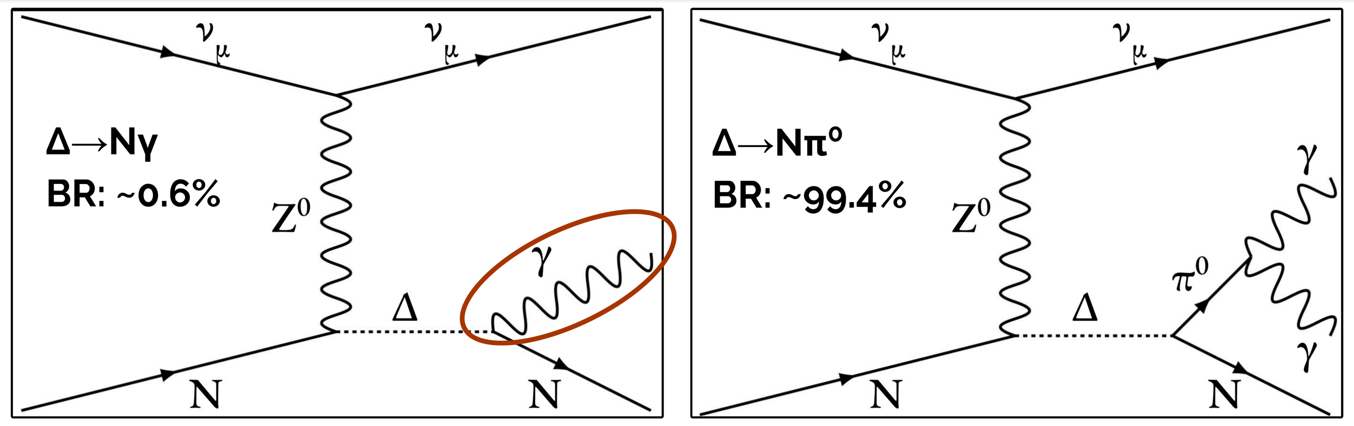
1. NC Δ Radiative Decay



- Possible source of low-energy excess (LEE) events in MiniBooNE [1]
- Dominant source of **single-photon events** in MicroBooNE [2]
- **~80% of single-photon backgrounds are neutral current (NC) π^0s**

2. Analysis Flow

1. Select Signal Topology

- Take Pandora [3] reconstructed tracks and showers
- Select events with **two shower (2γ) and either one or zero tracks (1p or 0p)**

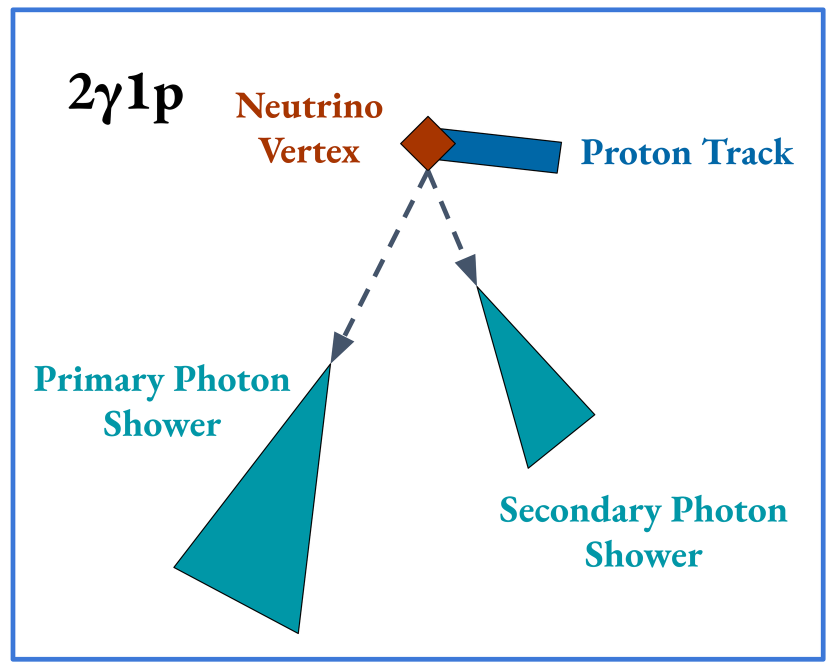
2. Background Rejection

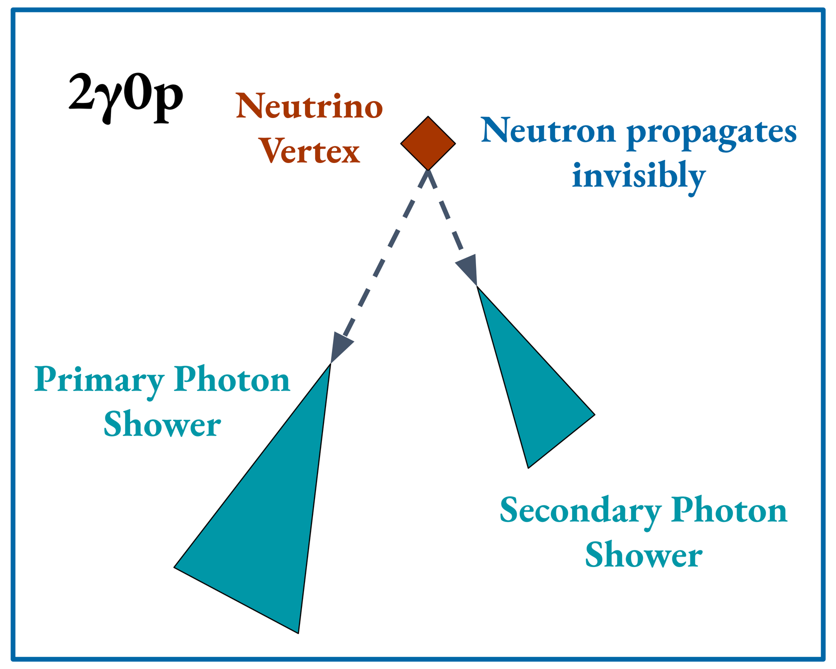
- Use tailored **Boosted Decision Tree (BDT)** trained on background events
- Reject backgrounds by cutting on BDT response
  - See Box 6

3. High-Stats NC π^0 Selection

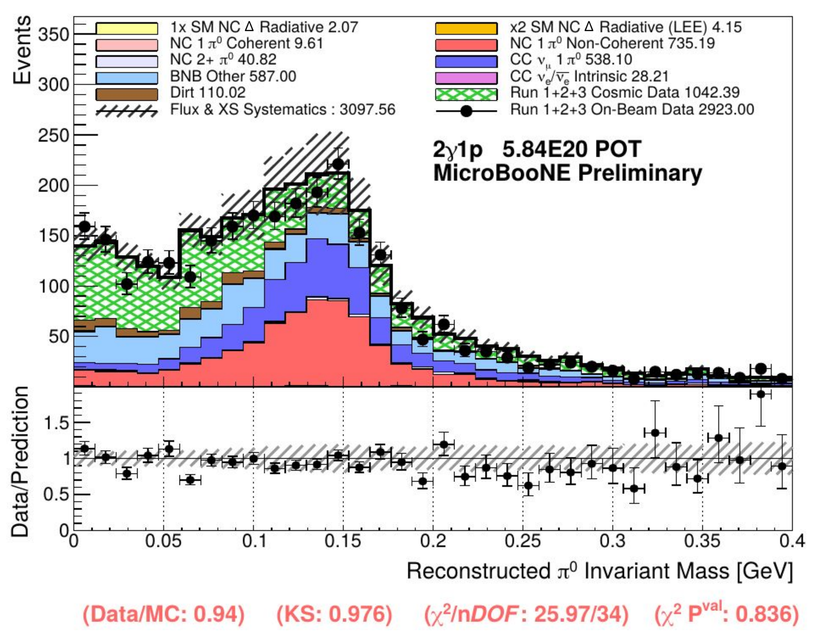
- Result is the **world's highest-stats NC π^0 selection on Argon**
- **Constrain single-photon NC π^0 background**
  - See poster by G. Yarbrough

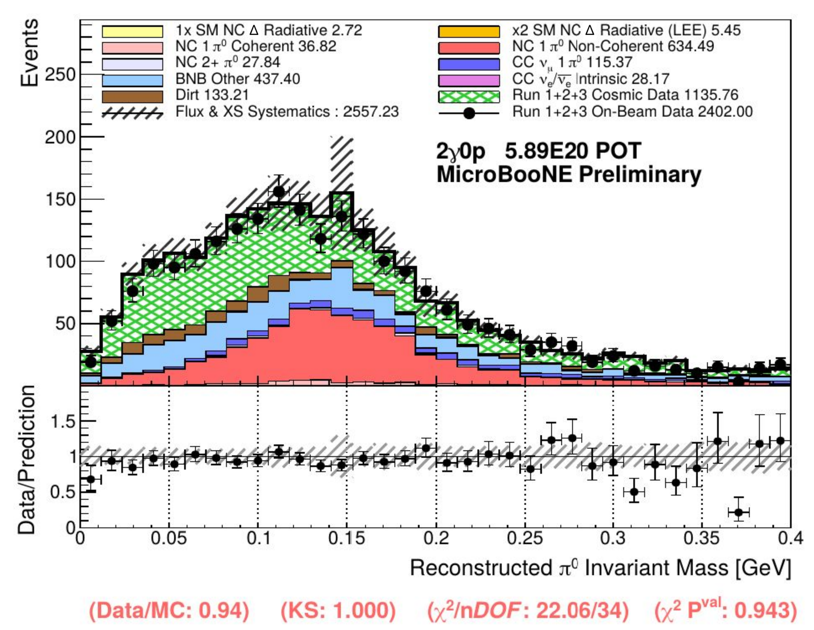
3. Signal Topologies





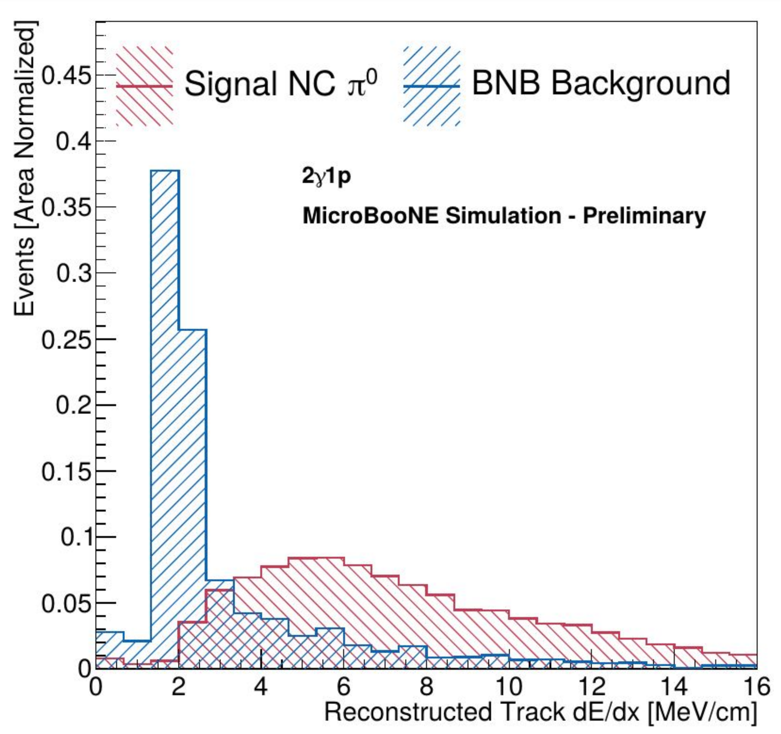
4. Initial Selection





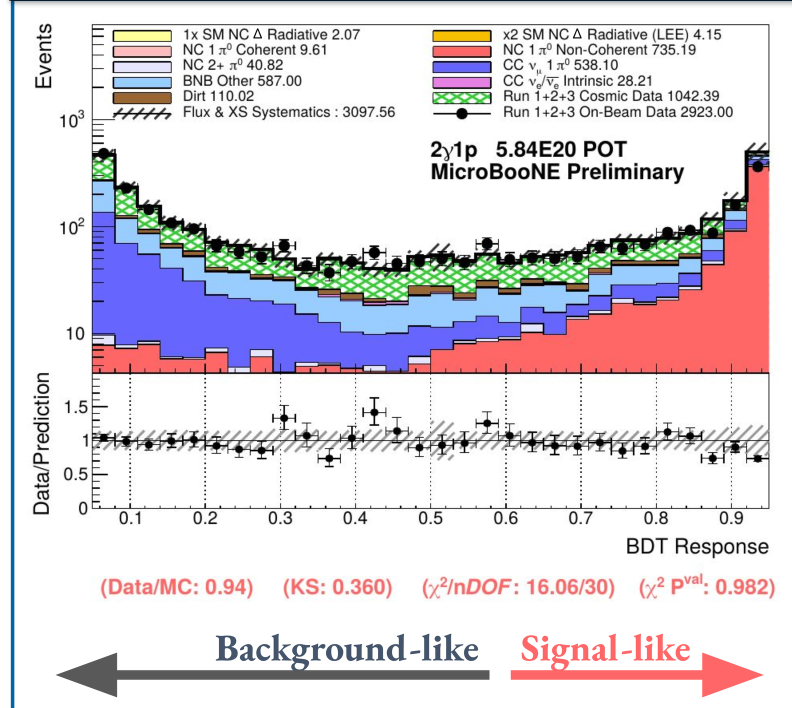
- Signal (red) dominated by cosmic and on-beam backgrounds
- Pre-selection cuts: vertex containment, shower energy thresholds, conversion distances

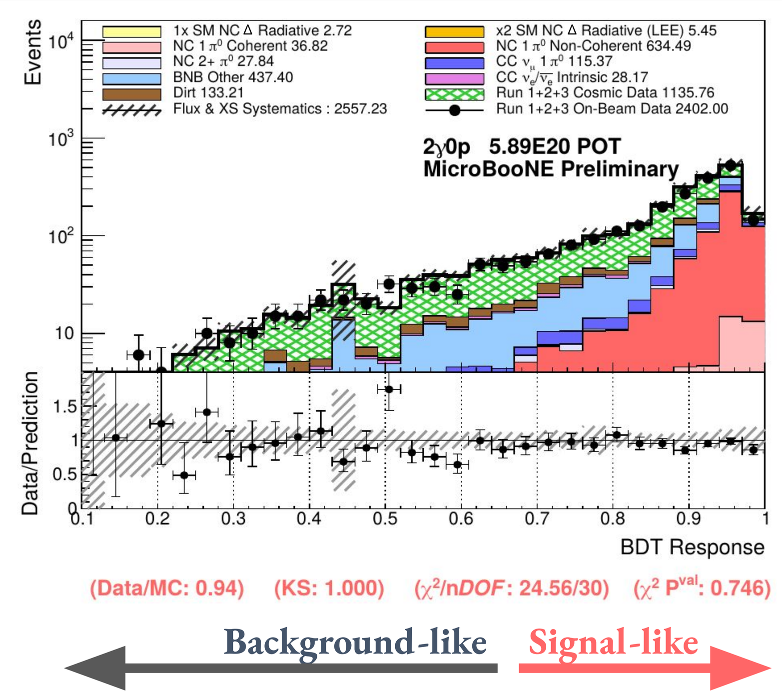
5. BDT Training



- Train BDT on 10 various kinematic and calorimetric variables in simulation
- Choose variables with high separation power between signal and background
- Example: track dE/dx (left)
  - dE/dx: Energy deposition per unit length
  - Isolates events with proton tracks (higher dE/dx) for 2γ1p selection
  - Peak at 2 MeV/cm mostly from minimally-ionizing muon tracks

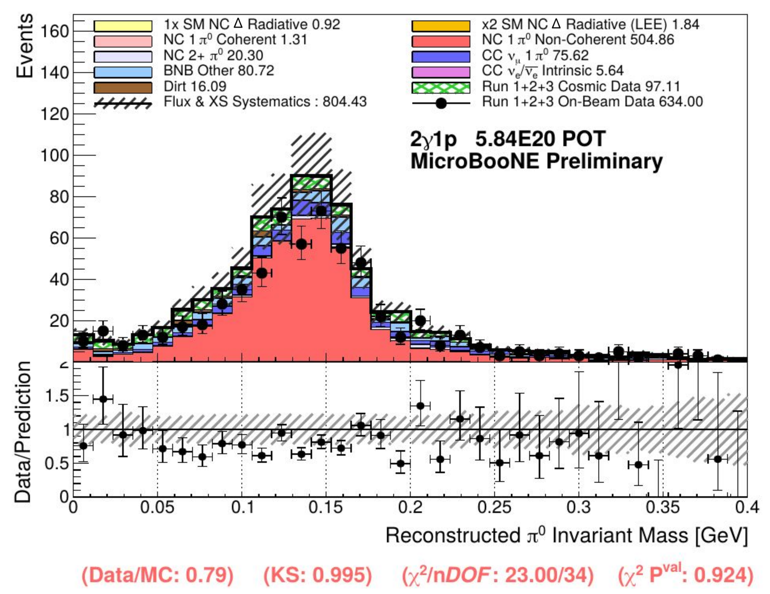
6. BDT Response





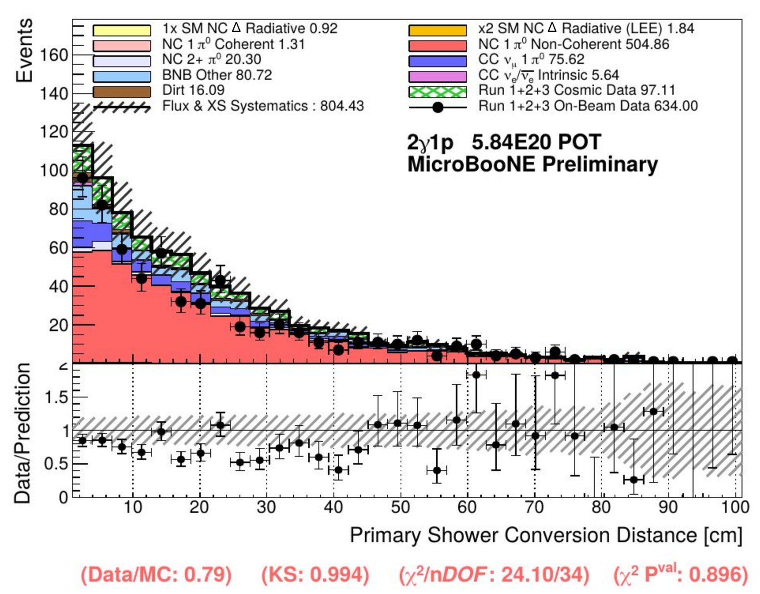
- Cut on BDT response to **maximize efficiency times purity** in final selection

7. Final Selection



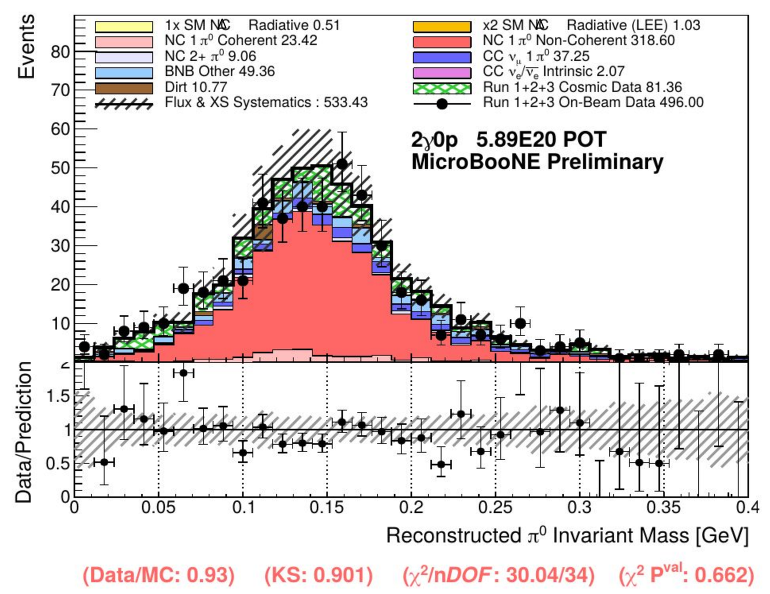
2γ1p π^0 Invariant Mass

- ~20% normalization difference between data/MC
  - Within systematic uncertainties
- Gaussian fit to data:
  - **Mean: 137.6 ± 2.1 MeV**
  - Width: 44.1 ± 1.8 MeV



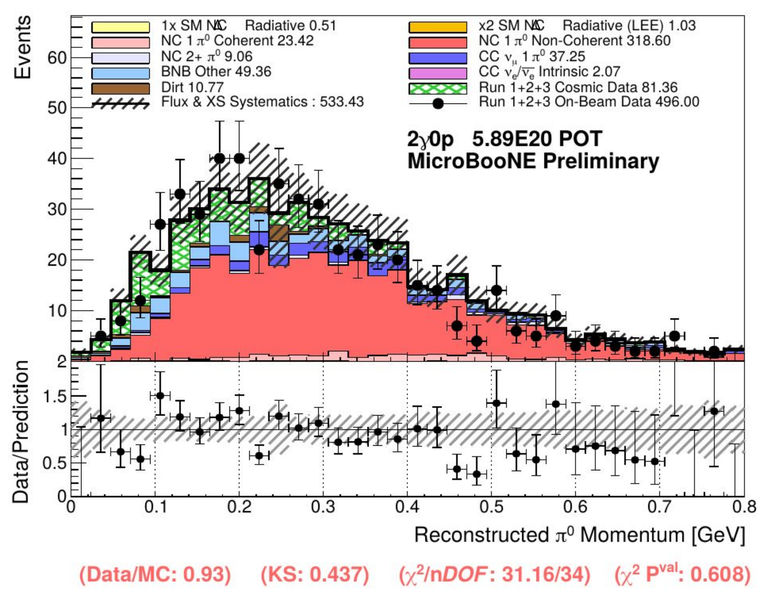
Primary Photon Conversion Distance

- Exponential shape, as expected
- 2γ1p selection **62.9% pure** and **68.0% efficient** (relative to initial selection)
- Full expected dataset **12.25E20 POT**



2γ0p π^0 Invariant Mass

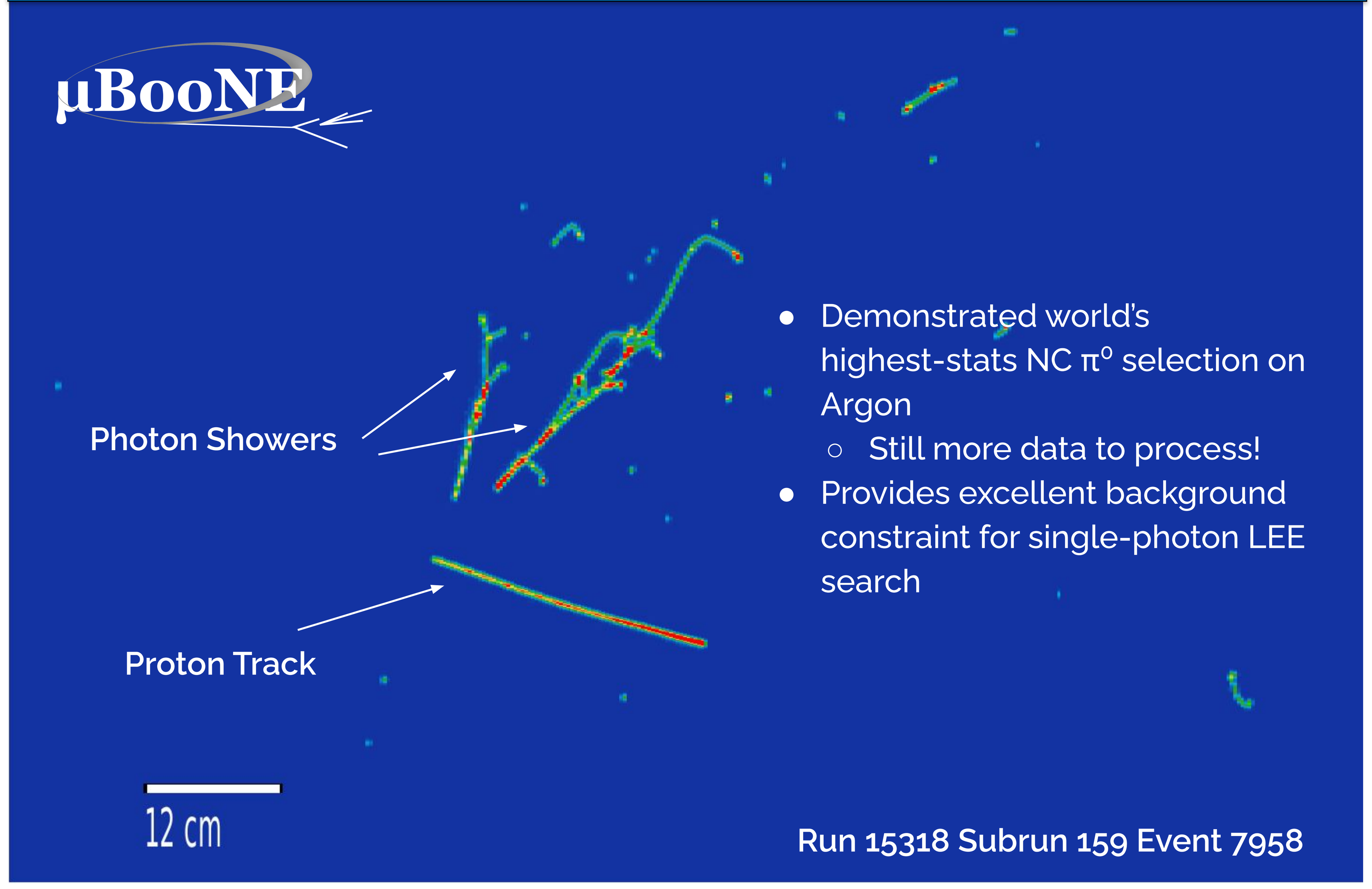
- Normalization difference < 10%
- Gaussian fit to data:
  - **Mean: 140.2 ± 2.8 MeV**
  - Width: 49.9 ± 2.7 MeV



π^0 Momentum

- 2γ0p selection **64.1% pure** and **41.6% efficient** (relative to initial selection)
- Generally good agreement between data and simulation

8. Summary



- Demonstrated world's highest-stats NC π^0 selection on Argon
  - Still more data to process!
- Provides excellent background constraint for single-photon LEE search

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References
[1] Aguilar-Arevalo et al., Phys. Rev. Lett., vol 121, p. 221801, 2018
[2] Wang et al., "Photon Emission in Neutral-Current Interactions at Intermediate Energies," PRC, vol. 89, p. 015503, 2014
[3] Acciacri et al., European Phys. C, vol. 78, p. 82, 2018