First Measurement of Charged-Current Muon-Neutrino-Induced K^+ Production on Argon Using the MicroBooNE Detector

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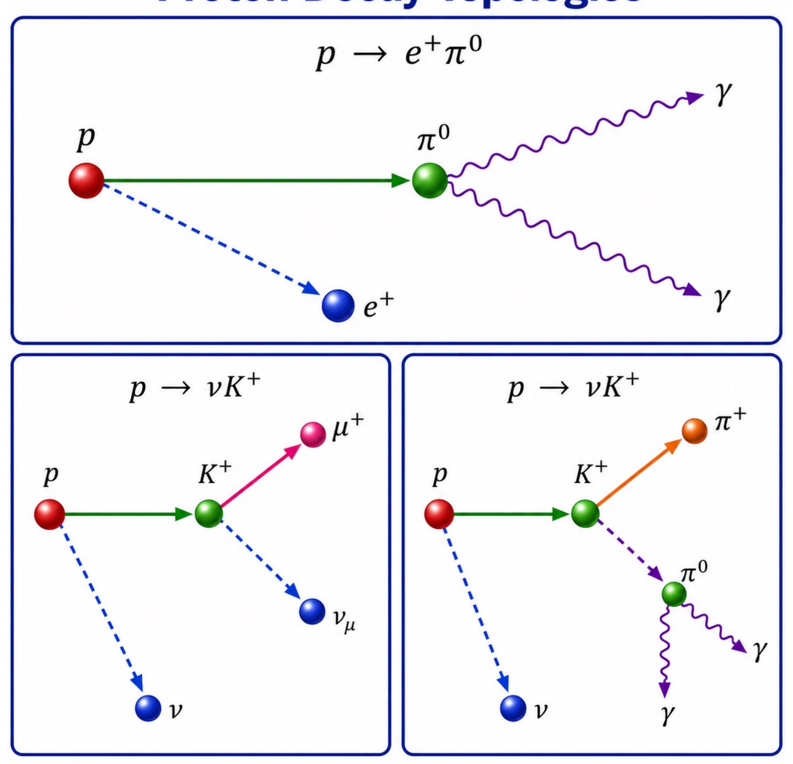
Motivation

Why Study Kaon Production?

- Proton decay searches are one of the major goals of future neutrino experiments such as DUNE or Hyper-Kamiokande.
- Many SUSY GUT models predict proton decay with a kaon in the final state $p \to \nu K^+$.
- Atmospheric-neutrino interactions can generate kaons and mimic proton decay signals.
- Measuring K^+ production provides key constraints for mitigating proton decay backgrounds in next-generation LArTPC experiments.
- MicroBooNE provides the first measurement of neutrino-induced K^+ production on argon, the same target used by DUNE.

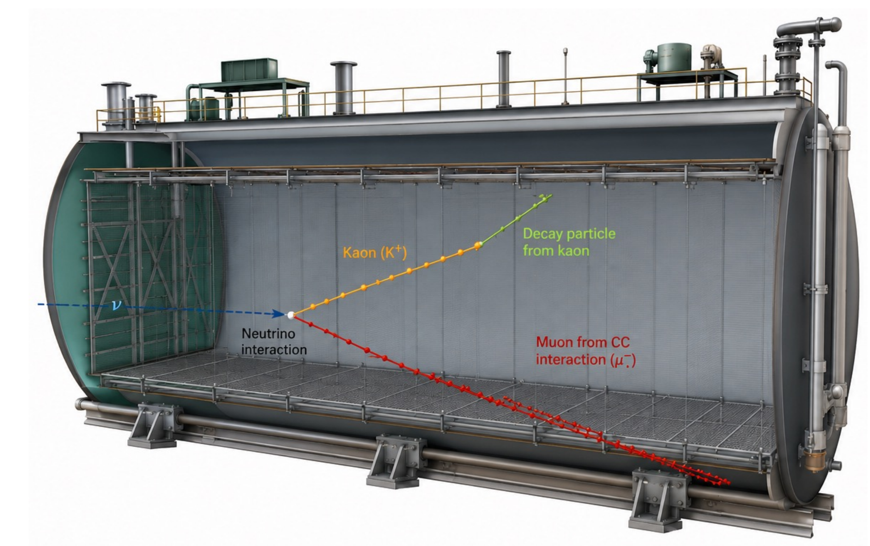
Proton Decay Topologies



MicroBooNE Detector

Liquid Argon TPC in the Booster Neutrino Beam

- 85-tonne active mass LArTPC located at Fermilab. [1]
- Exposed to the Booster Neutrino Beam (BNB).
- Collected 1.2 × 10^{21} protons on target (POT).
- High-resolution imaging with 3 mm wire spacing.
- Excellent capability for reconstructing kaon decay topologies.

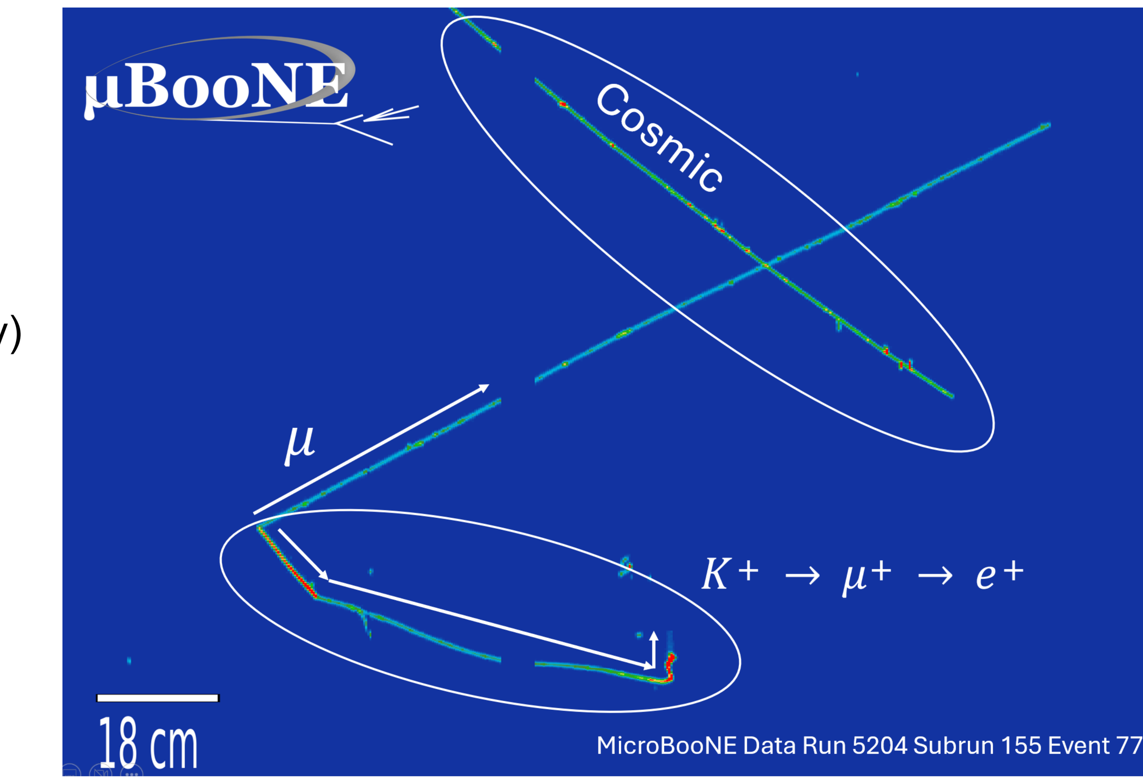


Pre-Selection

- Start with an inclusive charged-current neutrino sample.
- Fiducial containment of candidate and daughter tracks.
- Single charged daughter track at the candidate endpoint. (kaon-like topology)
- Analysis targeting the two dominant kaon decay modes.

K^+ decay modes

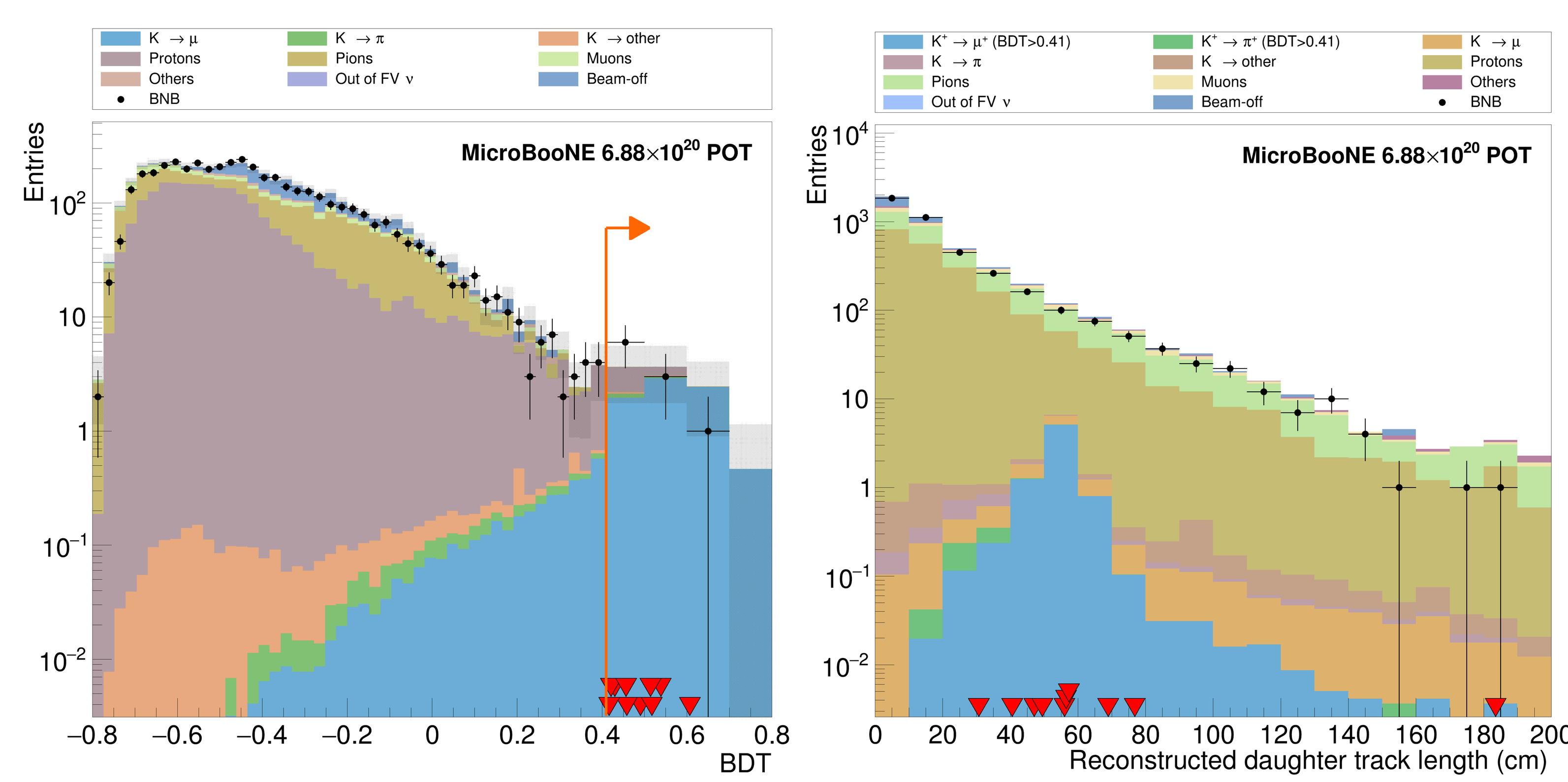
$K^+ \to \mu^+\nu_\mu$,	BR = 63.55%
$K^+ \to \pi^0\pi^+$,	BR = 20.66%



BDT Selection

Identifying Kaon Signals

- BDT trained using MC signal and background samples.
- Inputs include
  - dE/dx χ^2 goodness of fit PID score.
  - Log-Likelihood Ratio PID score. [2]
  - Daughter track length.
- Selection threshold:
  - BDT > 0.41.
- Achieved:
  - 3.95% efficiency.
  - 79% purity.
  - 10.3 events were predicted, of which 2.2 are expected to be background.

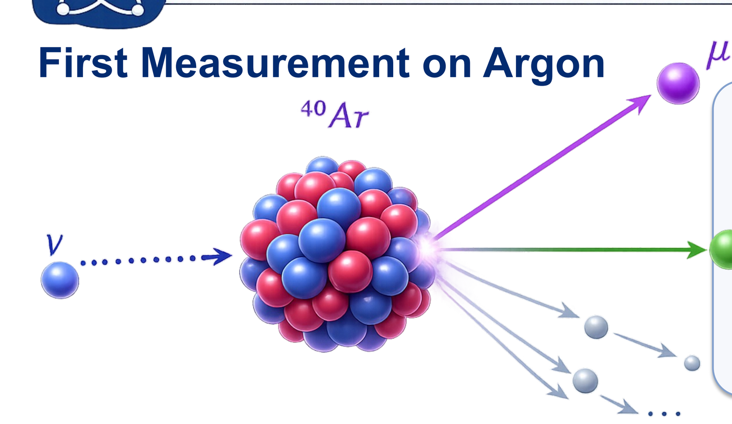


Black points: MicroBooNE data. Gray band: MC prediction uncertainty. Orange arrow: BDT score cut. Red triangles: selected K^+ candidates.

Result: 10 candidate events observed in data.

Results

First Measurement on Argon

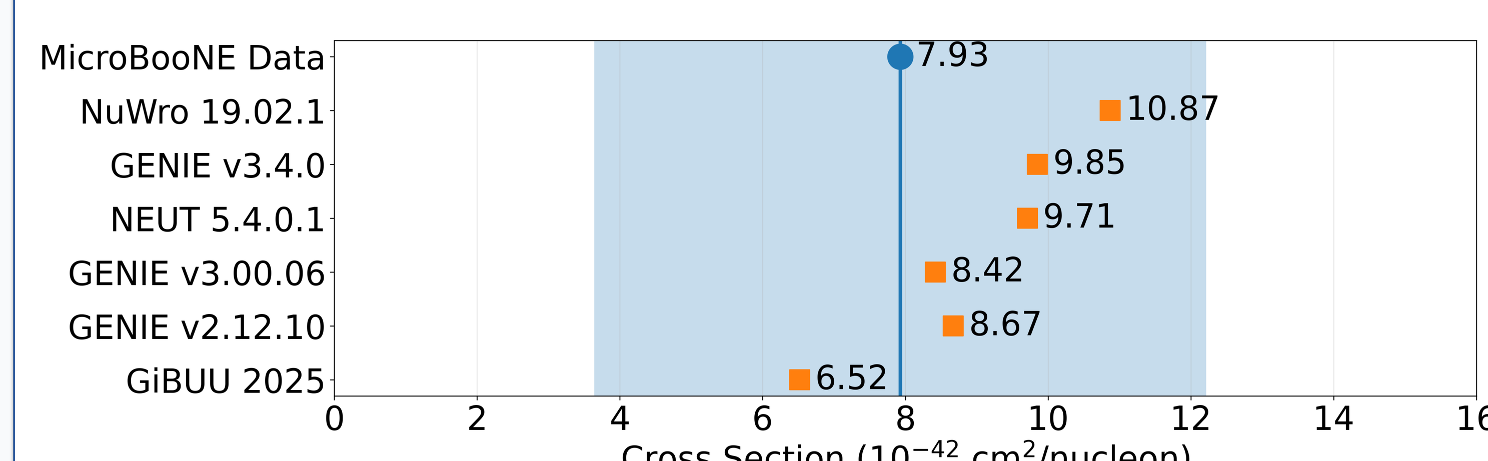


Measured Flux-Integrated Cross Section (6.88×10^{20} POT)

$$\sigma(\nu_\mu + {}^{40}Ar \to \mu^- + K^+ + X) =$$

$$7.93 \pm 3.22(stat) \pm 2.83(syst) \times 10^{-42} \text{ cm}^2\text{/nucleon [3]}$$

Consistent with current neutrino interaction model predictions.



Principal Uncertainty Sources (Fractional)

- Statistics (40.6%)
- Detector Response (30.3%)
  - Recombination effect.
- Flux (11.7%)
- Kaon Reinteractions (10.5%)

Statistics is the dominant uncertainty.

Impact for LArTPC Experiments

Why This Matters

- **First K^+ production measurement on argon.**
- **Measurement relevant to DUNE proton decay searches.**
- **Will help to develop strategies for background mitigation in proton decay searches**
- **Will help to constrain neutrino-interaction models involving kaons at final state.**
- **Provides a benchmark for future high-statistics measurements of kaon production on argon.**

Outlook

- We reported the first measurement of K^+ production on argon. This results was published in PRL. (see QR code)
- It will serve to improve strange-particle production modeling.
- It has direct applications to DUNE, SBND, ICARUS, since they share similar LArTPC technology as MicroBooNE.
- Larger samples from these current and future LArTPC experiments will expand this measurement with a potential first differential cross-section on argon.

References

[1] Design and Construction of the MicroBooNE Detector. JINST, 12(2), P02017.
[2] P. Abratenko et al. (MicroBooNE), J. High Energ. Phys. 2021, 153 (2021).
[3] P. Abratenko et al. (MicroBooNE), Phys. Rev. Lett. 135, 251804 (2025).

Acknowledgments

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