Selection of charged-current neutrino-induced K^+ production interactions in MicroBooNE

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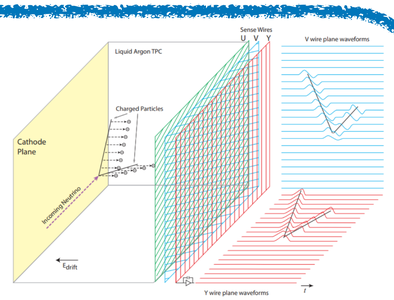
Motivation

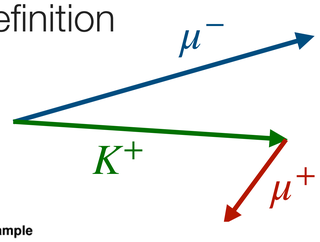
Improve background estimates for future proton decay experiments looking for the $p \rightarrow K^+\bar{\nu}$ channel on argon such as DUNE
This is the first step toward a charged-current kaon production cross section measurement in argon

The MicroBooNE experiment

- 85 ton active mass LArTPC
- Exposed to BNB & NUMI beams at Fermilab
- 3 anode planes, ~8k wires 3 mm spaced

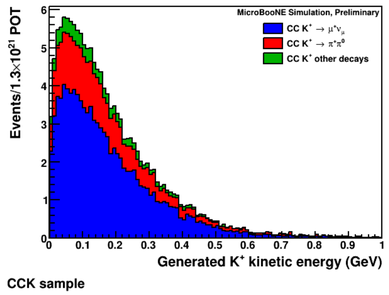


Simulation and signal definition

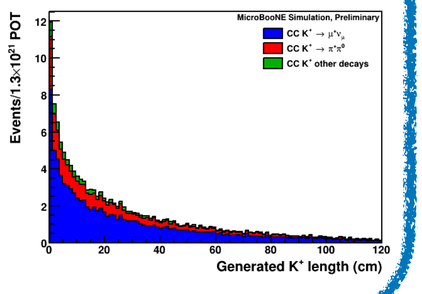


- The analysis uses GENIE 3.0.6 to simulate neutrino interactions in the MicroBooNE detector
- Particle propagation in the detector is done by GEANT4 and drift simulation by LArSoft/ Wirecell [1]
- Signal: $\nu_\mu CCK^+$ interactions inside the TPC where the K^+ decays into $\mu^+\nu_\mu$ (K^+ and μ^+ are contained in TPC)
- Two MicroBooNE simulation samples are used for this analysis. One includes all neutrino interactions types with the BNB neutrino flux, the other includes only $\nu_\mu CCK^+$
- Both samples are scaled to 1.3×10^{21} POT

CCK sample



CCK sample



K^+ candidate selection

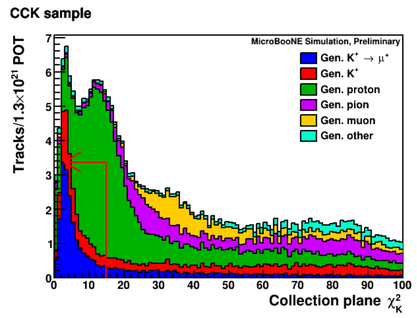
All track reconstruction uses the Pandora framework [2] for pattern recognition

Particle identification based on collection plane calorimetry: Particle's track dE/dx profile is compared against templates created for different particle hypothesis to create a χ^2 value

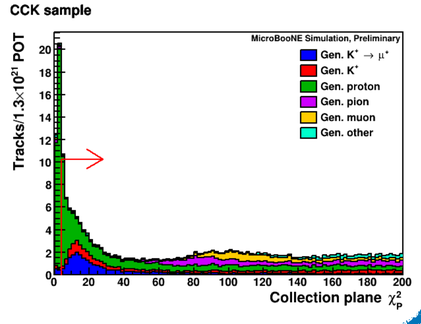
χ^2 values under Kaon and Proton hypothesis (χ^2_K and χ^2_P) are used to isolate K^+ track candidates:

- χ^2_K<15
- χ^2_P>4

CCK sample



CCK sample

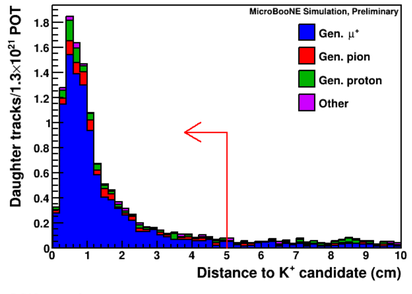


μ^+ candidate selection

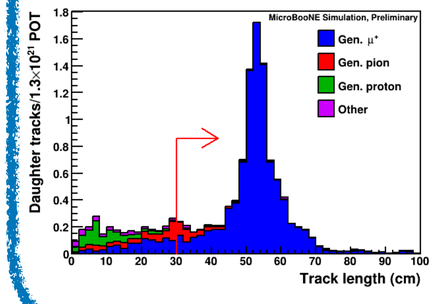
The cuts used to isolate μ^+ track candidates:

- Distance to K^+ candidate < 5 cm
- Track length > 30 cm
- χ^2_P>50

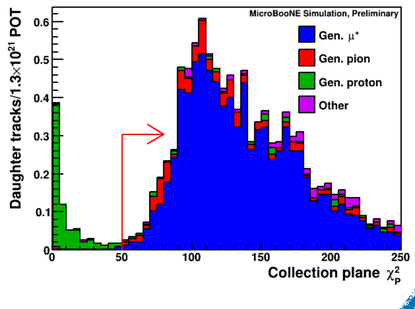
CCK sample



CCK sample

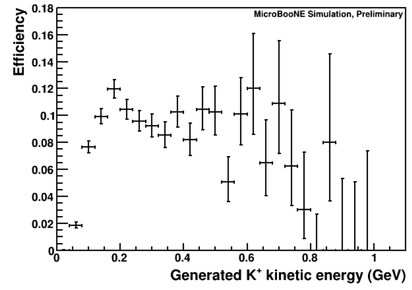


CCK sample



Event selection

- 1 μ^- track candidate from the neutrino interaction vertex, including cosmic rejection based on topology and timing and light information
- 1 K^+ track candidate
- 1 μ^+ track candidate starting at the end of K^+ track candidate



Selection criteria	BNB (total)	BNB (signal)	CCK (total)	CCK (signal)	Eff. (%)	Purity (%)
0) All events	1042798	103	444.0	99.8	100.0	0.01
1) CC inclusive pre-selection	153425	46	147.7	46.1	46.2	0.03
2) Track multiplicity >= 2	124505	45	142.7	44.8	44.9	0.04
3) # of K^+ cand. >= 1	25641	21	47.92	19.9	20.0	0.08
4) # of K^+ cand. w/ μ^+ cand.=1	12	8	8.36	7.01	7.02	66.7

BNB: MicroBooNE BNB simulation
CCK: Dedicated $\nu_\mu CCK^+$ sample

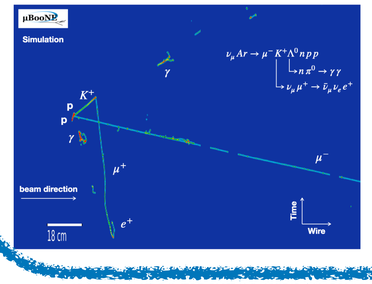
Selected candidates

After the event selection is run over the MicroBooNE BNB simulation, 12 $\nu_\mu CCK^+ \rightarrow \mu^+$ event candidates were found in a exposure of 1.3×10^{21} POT:

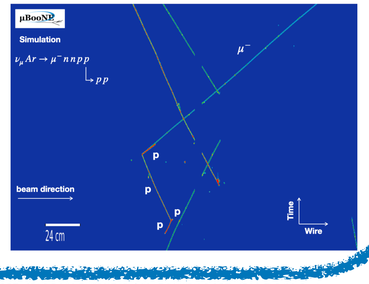
- 8 signal events
- 4 background events

Cand. #	Interaction
1	CC RES, ν_μ Ar $\rightarrow \mu^-$ Λ^0 K^+ n 2p
2	CC RES, ν_μ Ar $\rightarrow \mu^-$ Λ^0 K^+
3	CC DIS, ν_μ Ar $\rightarrow \mu^-$ Σ^+ K^+ π^+ π^-
4	CC DIS, ν_μ Ar $\rightarrow \mu^-$ Σ^+ K^+ π^+ n
5	CC RES, ν_μ Ar $\rightarrow \mu^-$ Σ^+ K^+ n
6	CC DIS, ν_μ Ar $\rightarrow \mu^-$ Λ^0 K^+ p
7	CC DIS, ν_μ Ar $\rightarrow \mu^-$ Λ^0 K^+ n p
8	CC RES, ν_μ Ar $\rightarrow \mu^-$ Λ^0 K^+
9	CC RES, ν_μ Ar $\rightarrow \mu^-$ π^+ p
10	CC MEC, ν_μ Ar $\rightarrow \mu^-$ 2n 2p
11	CC RES, ν_μ Ar $\rightarrow \mu^-$ π^+ 3p 2n
12	CC RES, ν_μ Ar $\rightarrow \mu^-$ π^+ π^- π^0 n p

Candidate #1 (signal)



Candidate #10 (background)



References

[1] MicroBooNE collaboration, "Tomographic Event Reconstruction with MicroBooNE data", MICROBOONE-NOTE-1040-PUB.
[2] MicroBooNE collaboration, "The Pandora Multi-Algorithm Approach to Automated Pattern Recognition of Cosmic Ray Muon and Neutrino Events in the MicroBooNE Detector", Eur. Phys. J. C78, 1, 82 (2018).