Towards an Inelastic Cross Section Measurement of 6 GeV Kaons on Argon at ProtoDUNE Single-Phase

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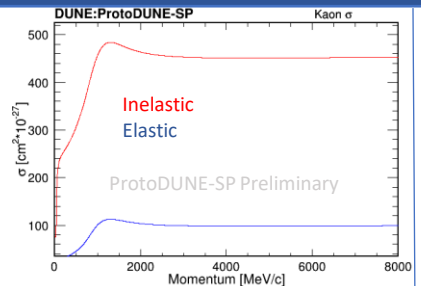
DEEP UNDERGROUND NEUTRINO EXPERIMENT

1. ProtoDUNE Single-Phase (ProtoDUNE-SP)

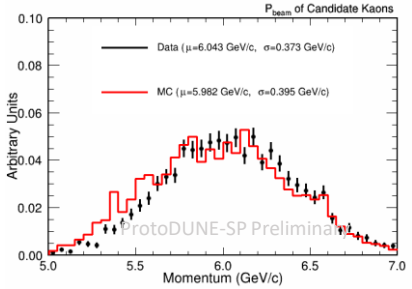
- Detector is a 700-ton liquid argon time-projection-chamber with two drift volumes.
- Prototypes DUNE Far Detector and evaluates hadron passage in argon.
- Uses the CERN Super Proton Synchotron 0.3-7 GeV/c test beam.
- Kaons are final-state particle in neutrino interactions and predicted in proton decay.
  - Use kaons at high momentum to understand passage in argon.
- Beamline monitor uses Cherenkov detectors to select candidate kaons.

P (GeV/c)	Pion-like (k)	Proton-like (k)	Electron-like (k)	Kaon-like (k)
0.3	0	0	242.5	0
0.5	1.5	1.5	296.3	0
1	381.8	420.8	262.7	0
2	333	128.1	173.5	5.4
3	284.1	107.5	113.2	15.6
6	394.5	70.1	197	**27.9**
7	343.7	58.4	112.9	**28.3**

Total cumulative candidate triggers from test beam.



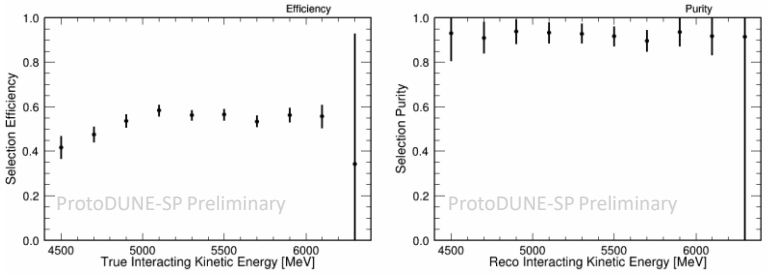
Cross section in Geant4 [1]



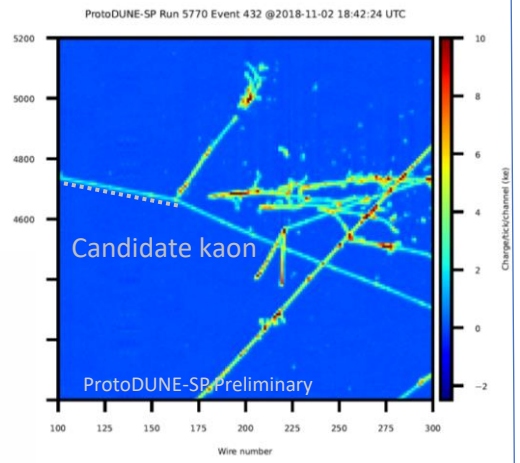
Momentum distribution of candidate kaons.

2. Selection of Candidate Inelastic Scatters

- Candidate kaons are selected if a beamline particle:
  - Passes a quality check using the beamline monitor data.
  - Contains reconstructed track calorimetry information.
  - Ends in the first APA to prevent broken tracks being mis-identified.



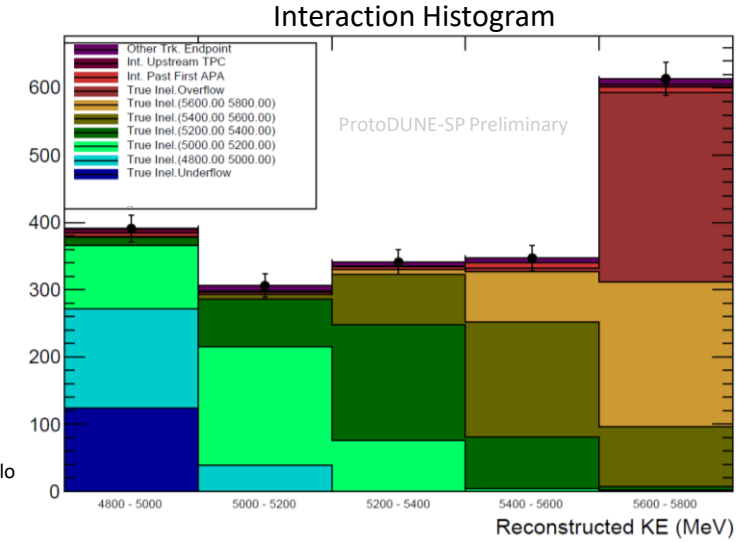
Efficiency and purity using the candidate kaon selection in simulation.



Candidate inelastic kaon scatter in data. The interaction creates a messy spread of hadronic activity.

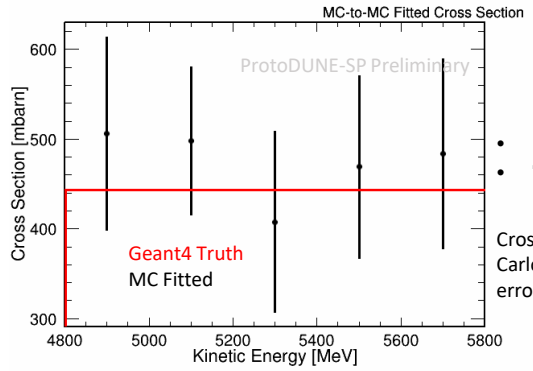
3. Fit of Kaon Inelastic Interaction Points using Monte Carlo as Fake Data

- An interaction point is an inelastic scatter candidate found through the track endpoint.
- An incident point is a slice of the track where no interaction candidate occurred.
- Uses a template fit of interacting kinetic energy bins with multinomial statistics [2].



Interacting histogram for kaon candidate events of a Monte Carlo fit. Sorted by truth information.

4. Extraction of Cross Section using Monte Carlo-to-Monte Carlo Fit



$$\sigma(\mathrm{KE}) = \frac{\mathrm{M_{atomic}}}{\mathrm{N_{avo.} r_{pitch} \rho_{Ar}}} \ln\left[\frac{\mathrm{N_{inc.}(KE)}}{\mathrm{N_{inc.}(KE) - N_{int.}(KE)}}\right]$$

$d_{\text{wire to wire}}/\cos(\theta_{\text{track}})$

- Cross section calculated using post fit incident and interacting histograms.
- The uncertainties extracted from correlated throws from covariance matrix.

Cross section measured using Mote Carlo-to-Mote Carlo fit. Statistical errors only are shown.

- Focus on implementing systematic uncertainties related to beam performance and detector physics.
- The dataset will then be unblinded to reveal the result from ProtoDUNE-SP.

References

1. S. Agostinelli, et al. *Geant4-a simulation toolkit, Nuclear Instruments and Methods A,* **506** (2003) 250-303.
2. S. Baker and R. D. Cousins, *Clarification of the use of chi-square and likelihood functions in fits to histograms, Nuclear Instruments and Methods* **221** (1984) 437-442.