# Measurement of Pion-Argon Inclusive Cross-Section on ProtoDUNE-Single Phase(SP) at CERN

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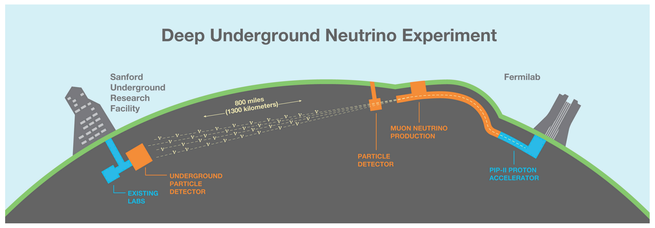
## Introduction



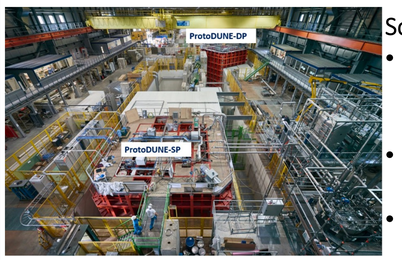

DUNE is a leading-edge, international neutrino experiment that addresses fundamental questions about matter and the universe [1].

DUNE Objectives:

- Search for CP violation in neutrino oscillations
- Nucleon decay
- Search for supernova (SNe) burst neutrinos

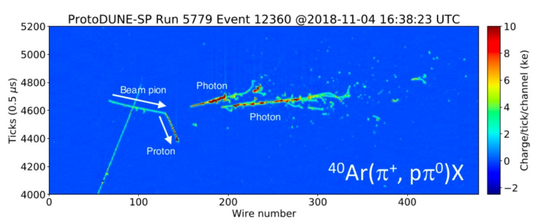
DUNE comprises 1300 collaborations over 30+ countries and 300+ institutions [2].

## ProtoDUNE-SP




Scientific goals of ProtoDUNE-SP:

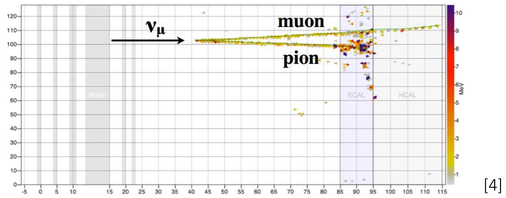
- Prototype the production and installation procedures for single phase FD design.
- Validate the design for the detector performance.
- Accumulate test-beam data to understand the detector response for different particles.




[1] Paudel, A. (2021). A pion-argon cross section measurement in the ProtoDUNE-SP experiment with cosmogenic muon calibration (Doctoral dissertation, Kansas State University).
[2] Home. Deep Underground Neutrino Experiment. (n.d.). Retrieved January 18, 2023, from https://www.dunescience.org/
[3] Calcutt, J., & DUNE Collaboration. (2021). Measurement of Pion-Argon Absorption and Charge Exchange using ProtoDUNE-SP. In APS April Meeting Abstracts (Vol. 2021, pp. H13-004).
[4] Leah. (2016, March 8). Pion on the break shot. News. Retrieved January 19, 2023, from https://news.fnal.gov/2014/08/pion-on-the-break-shot/
[5] Oh S., & FNAL DUNE Group. (2022). Status Report. Retrieved Jan 18, 2023, from shorturl.at/fijQ6

## 2 GeV/c Pion Beam Cross-Section

- Pions are the common final product that helps to reveal neutrino energies and flavors.
- Pion-Argon cross-section measurements provide constraints within DUNE's oscillation analysis and reduce DUNE's systematic uncertainty [3].

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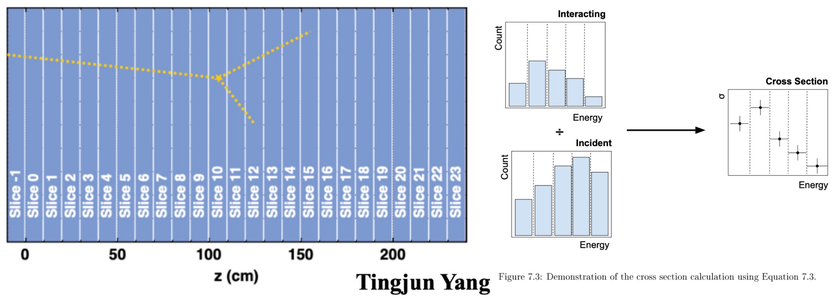
## Thin Slice Method




Tingjun Yang Figure 7.3: Demonstration of the cross section calculation using Equation 7.3.

Cross-section calculation based on Thin Slice Method developed by LArIAT: [3]

- Treat collection plane wires as "thin-slab" targets in an extended LAr volume.
- Each slab is an independent measurement.
- Cross-section (XS) formula:

$$\frac{N_{Inter}}{\Phi A} = \frac{N_{Inter}}{N_{Inc}} = 1 - e^{-nt\sigma}$$

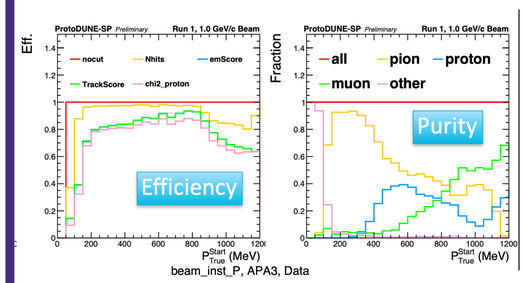
$$\frac{N_{Inter}(E)}{N_{Inc}(E)} = nt\sigma(E)$$

$\sigma$: cross-section
$N_{Inter}$: # of interacting pions
$N_{Inc}$: # of incident pions
$n$: number density of atoms
$t$: width of the wire spacings

$\sigma$ is proportional to the ratio of number of interacting events to incident events as a function of energy.

## Current Status*

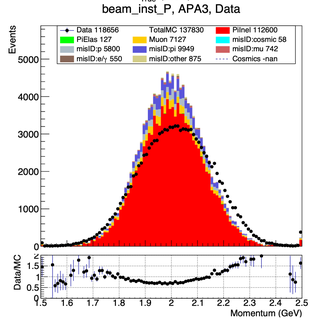
*These plots are parts of XS study. We are still in the analysis progress.



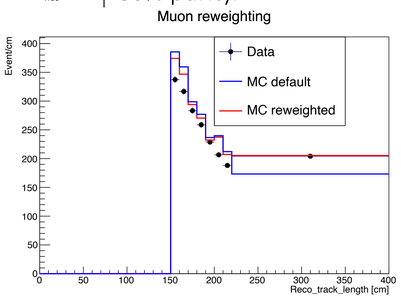

[5]

for 1 GeV/c $\pi's$

For 2GeV/c sample, we obtained 65% efficiency for pion inelastic scatterings and 80% purity.




Muon reweighting




- Try to understand differences in data and MC distribution of beam momentum.
- We find a weight of of 1.56 ± 0.02* at minimum $\chi$^2
- This weight is used to reweight muon fraction

## Prospects

- 2 GeV/c pion-Argon interaction analysis is one of ProtoDUNE-SP's first measurements of pion inclusive cross-sections.
- Similar analysis at various momentum ranges will allow further exploration of this region.
- As a result of such analysis, the data can be properly compared to interaction models within detector simulations for upcoming experiments, including SBN and DUNE [3].

## Acknowledgements

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