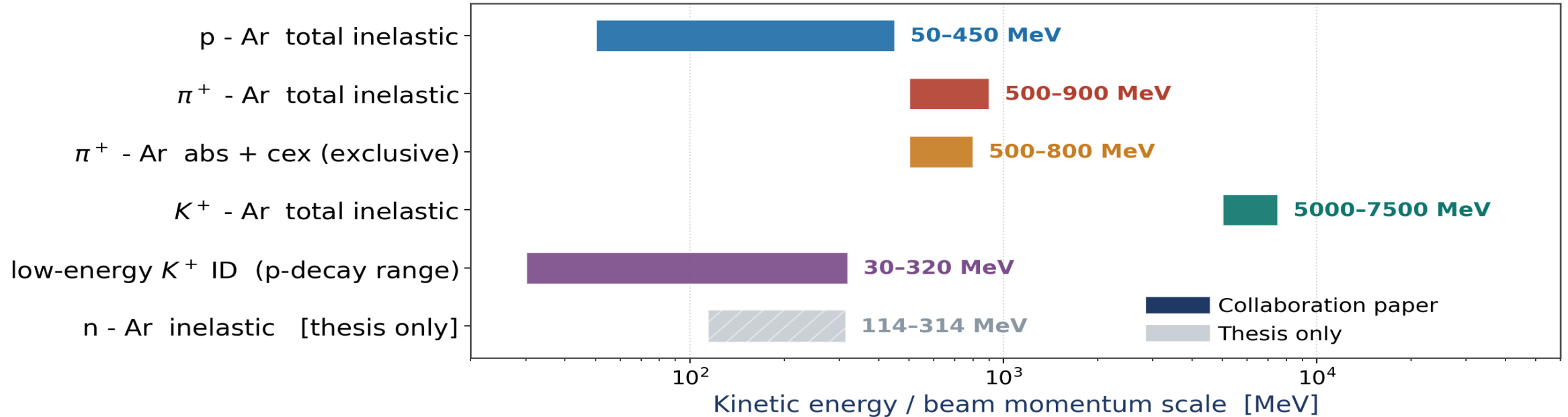


# **ProtoDUNE physics measurements so far (Could still be an incomplete list...)**

Jay Hyun Jo

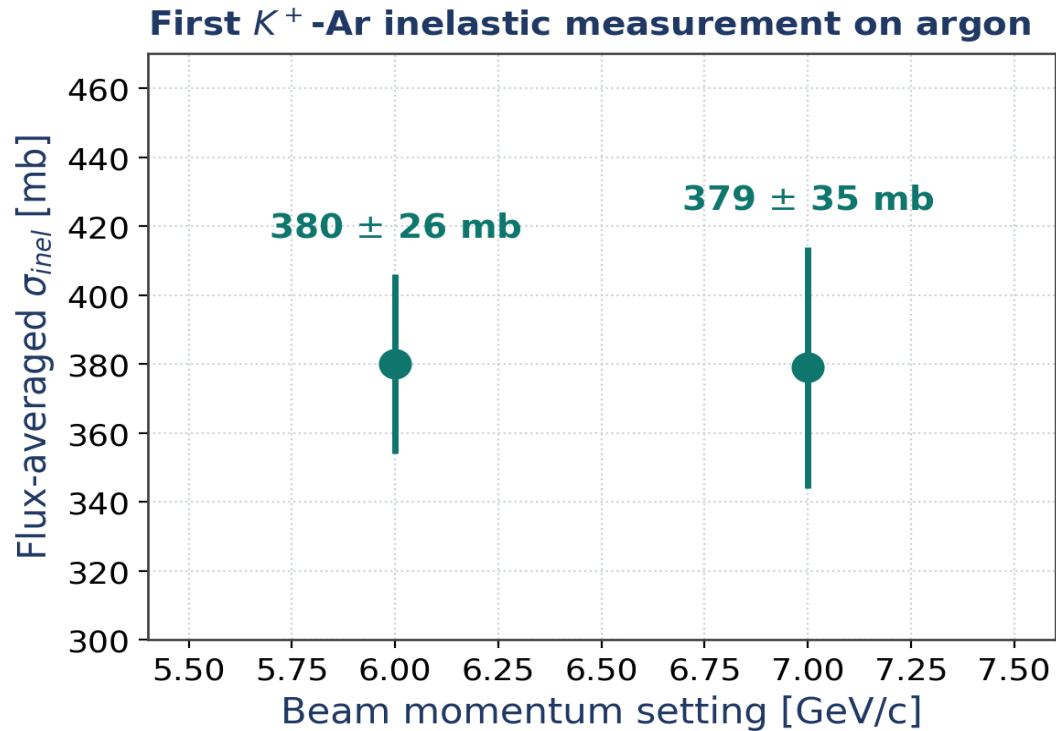
BNL ProtoDUNE Meeting  
September 9, 2026

# Energy coverage of the hadron-Ar measurements



- All published measurements are positive polarity — PD-HD/VD runs both, so  $\pi^-$ ,  $K^-$  and  $p^-$  are open

# $K^+$ – Ar total inelastic cross section



Plot built from the published flux-averaged values. For the energy-dependent result see the paper's own figures.

## First measurement on argon

- Flux-averaged  $\sigma = 380 \pm 26$  mb (6 GeV/c setting) and  $379 \pm 35$  mb (7 GeV/c)
- Energy range 5.0 – 7.5 GeV; never before measured as a function of energy on argon
- Motivated by  $p \rightarrow K^+ \bar{\nu}$  modelling

*DUNE Collab., Phys. Rev. D 110, 092011 (2024)*

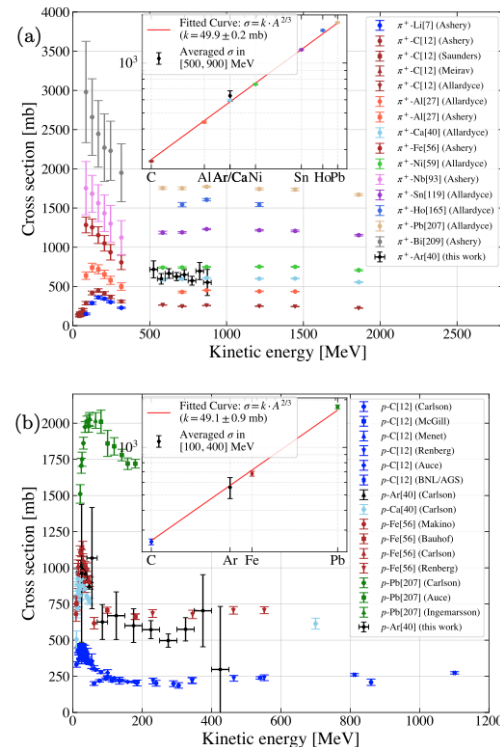
<https://arxiv.org/abs/2408.00582>

# $\pi^+$ – Ar and p – Ar total inelastic

## First measurements in these ranges

- $\pi^+$  – Ar total inelastic, 500 – 900 MeV kinetic energy
- p – Ar total inelastic, below 450 MeV
- Uses the energy-slicing (thin-slice) method on the 2018 beam data
- Preprint appeared November 2025

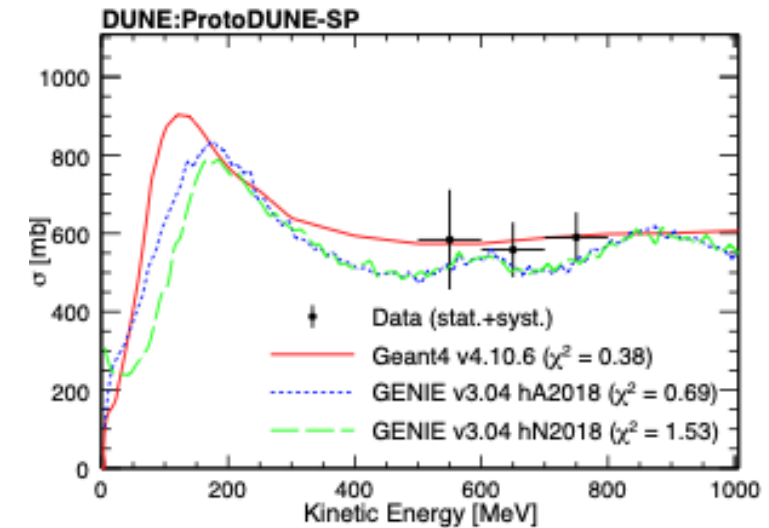
<https://arxiv.org/abs/2511.11925>



## $\pi^+$ – Ar exclusive channels

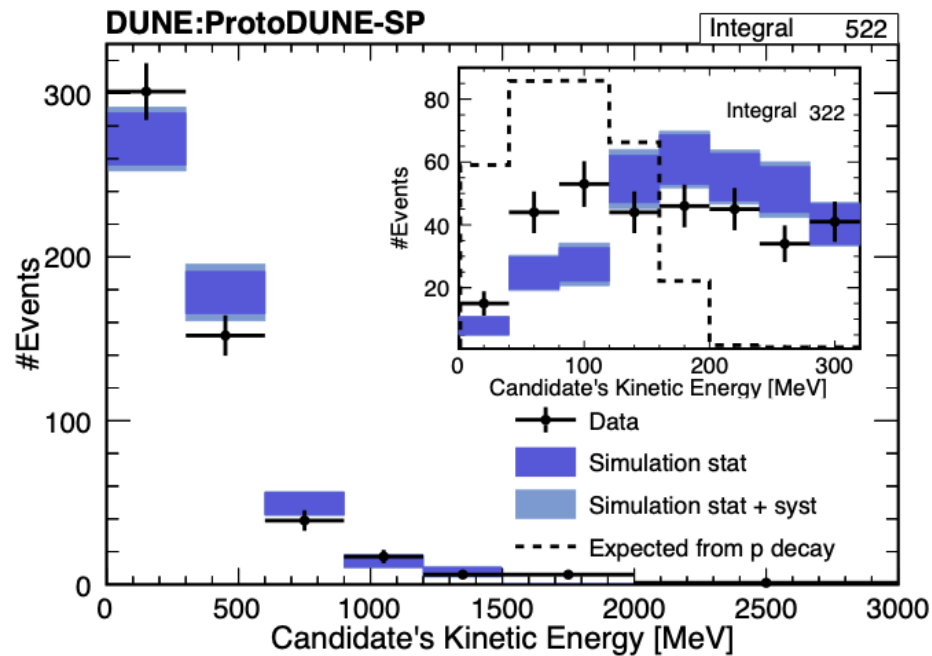
- Absorption, charge exchange, and remaining inelastic, 500 – 800 MeV
- First  $\pi^+$ -Ar absorption measurement in this range
- First-ever  $\pi^+$ -Ar charge exchange measurement
- The exclusive channels are  $\pi^0$ -reconstruction limited

<https://arxiv.org/abs/2511.13462>



(a) Total Inelastic Cross Section

# Low-energy $K^+$ identification

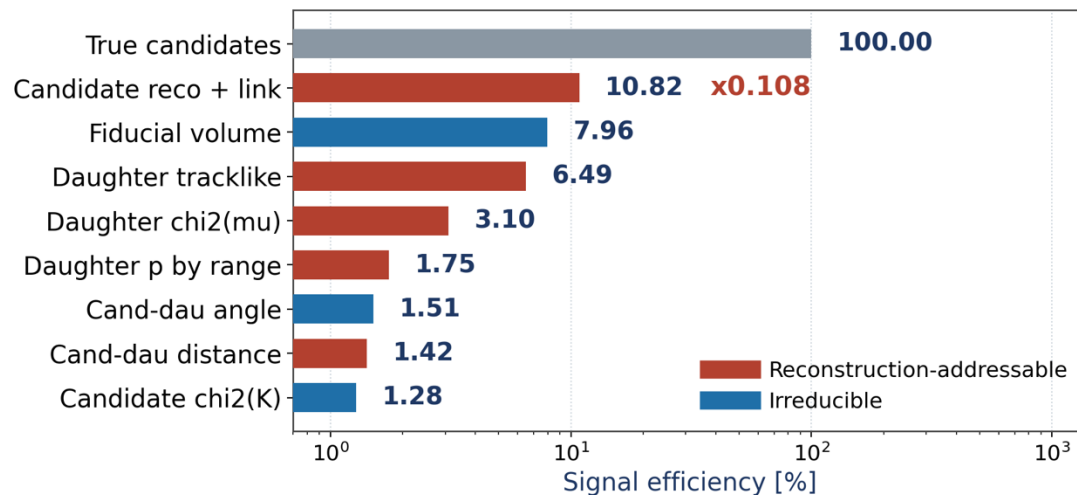


## Toward $p \rightarrow K^+ \bar{\nu}$ at DUNE

- 522 stopping- $K^+$  candidates at 92% purity, 1% selection efficiency
- 322 candidates in the 0 – 320 MeV proton-decay range
- First detailed  $K^+$  dE/dx vs residual range in LAr
- No kaons selected below 50 MeV — 25% of the p-decay signal

*Phys. Rev. D 113, 052004 (2026)*

<https://arxiv.org/abs/2510.08380>



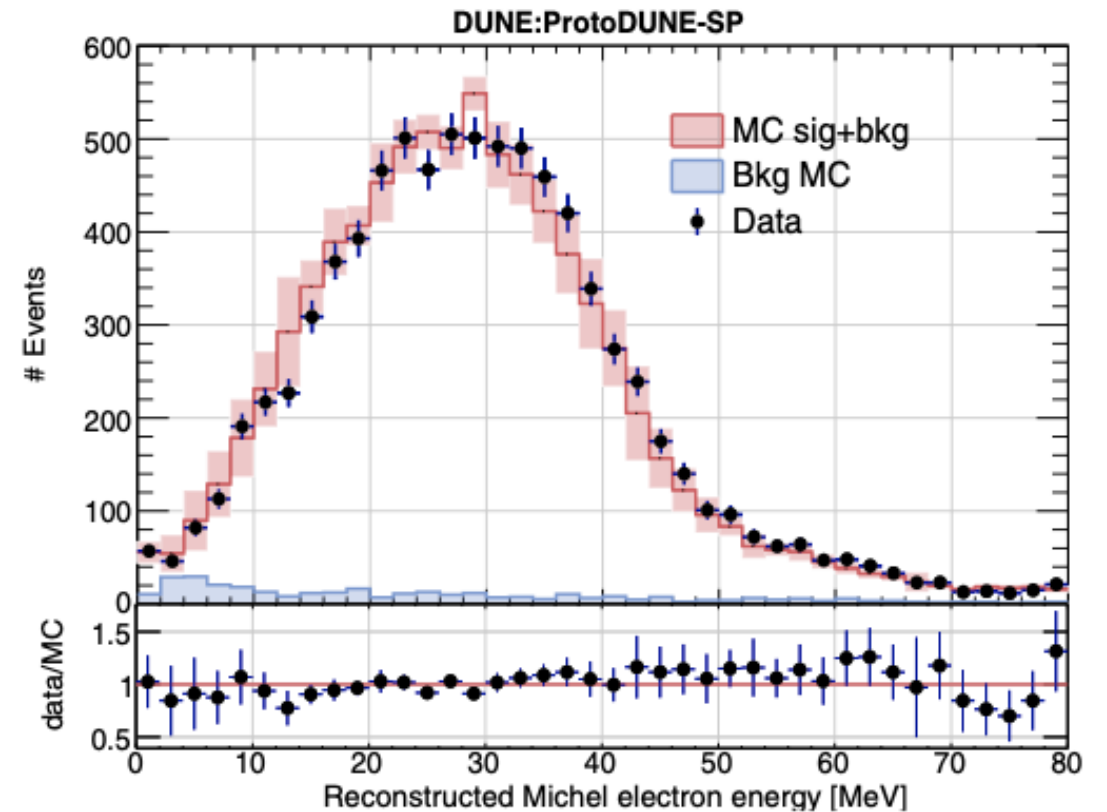
# Low-energy electrons (Michel)

## Identification and reconstruction

- Michel electrons from cosmic-muon decay, selected at 95% purity
- Used to calibrate the low-energy electron energy scale

*Phys. Rev. D* 107, 092012 (2023)

<https://doi.org/10.1103/PhysRevD.107.092012>

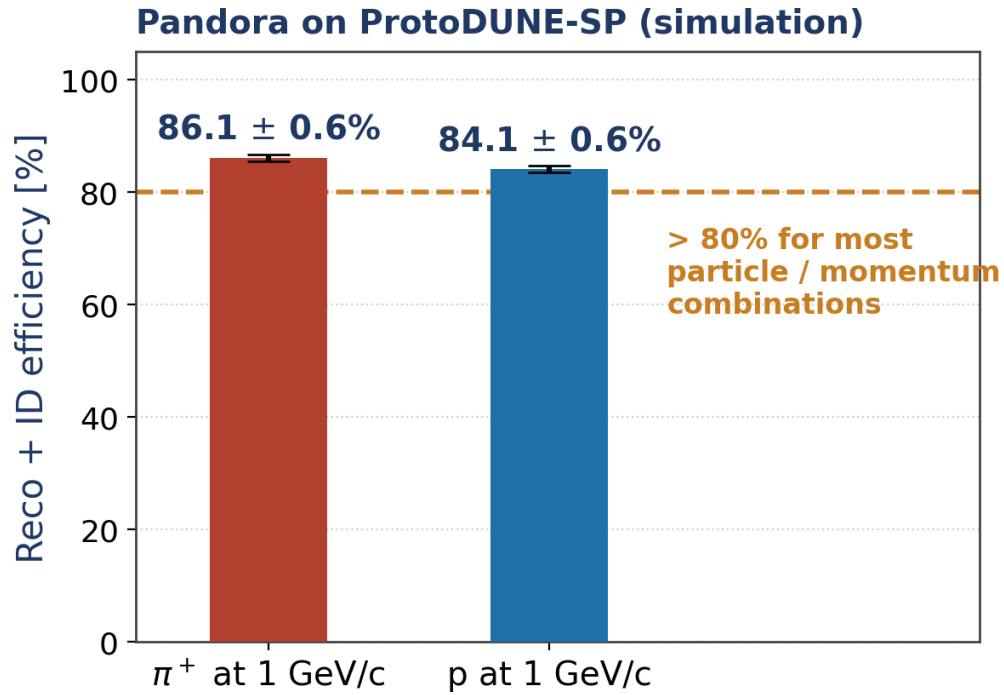


# Backup slides

# ProtoDUNE-HD and ProtoDUNE-VD

- **ProtoDUNE-HD — one paper (CE)**
  - Charge readout electronics design and performance, arXiv:2604.23966 (April 2026)
  - States explicitly that other subsystems and analysis of the test-beam data will be described in future work
  - Took beam and cosmic data April – November 2024, both polarities, 0.3 – 7 GeV/c
- **ProtoDUNE-VD — nothing published yet**
- **I was told that there will be a centralized information with list of on-going results in ProtoDUNEs (Jake)**

# Reconstruction and performance papers (all PD-SP)



## Pandora reconstruction of interactions

*Eur. Phys. J. C* 83, 618 (2023)

[link](#)

## Track / shower separation with a CNN

*Eur. Phys. J. C* 82, 903 (2022)

[link](#)

## Track-length extension fitting for energy

*JINST* 20, P02021 (2025)

[link](#)

## First results on TPC performance

*JINST* 15, P12004 (2020)

[link](#)

## Design, construction and operation

*JINST* 17, P01005 (2022)

[link](#)

# In progress: other works

- **$^{207}\text{Bi}$  source calibration in PD-HD**
  - Two  $^{207}\text{Bi}$  sources deployed; energy reconstruction evaluated from raw data and from Trigger Primitives, on late-2024 data
  - A. Oranday for DUNE, JINST 21, C01030 (2026)
- **PD-HD photon detection system**
  - ~30 million beam and cosmic interactions collected; preliminary slow-component lifetime and light-vs-beam-energy linearity agree with expectation (arXiv:2412.15154)
- **New ProtoDUNE-II calibration hardware**
  - Laser calibration system and pulsed neutron source — both new relative to PD-SP, implying calibration analyses with no SP counterpart
- **What is not publicly visible**
  - DocDB, analysis-group agendas, and 2025–26 conference agendas where PD-HD preliminary results would first appear
  - Highest-value next step is not another search: contact Wenqiang (WCT PD-HD data prep) and Calcutt (hadron-analysis status)

## At a glance

|                     | Physics<br>measurements | Reconstruction /<br>performance | Detector /<br>technical |
|---------------------|-------------------------|---------------------------------|-------------------------|
| <b>ProtoDUNE-SP</b> | 5                       | 3                               | 3                       |
| <b>ProtoDUNE-HD</b> | 0                       | 0                               | 1                       |
| <b>ProtoDUNE-VD</b> | 0                       | 0                               | 0                       |

Counts are refereed collaboration papers. Theses excluded.

- All ProtoDUNE physics output to date is ProtoDUNE-SP, and all of it is hadron-argon or low-energy particle ID