Measurements of Pion and Muon Nuclear Capture at Rest on Argon in the LArIAT Test Beam Experiment

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Motivation

- DUNE (Deep Underground Neutrino Experiment) will be the largest neutrino LArTPC in the world.
- Identification of mu/pi would improve the understanding of BSM events, like decay of heavy neutral leptons with unusual topologies as final state with $\mu^+\mu^-/\pi^+\pi^-$ [2]. This is *difficult* using standard track-based dE/dx methods due to the similar masses and energy deposition profiles in argon.

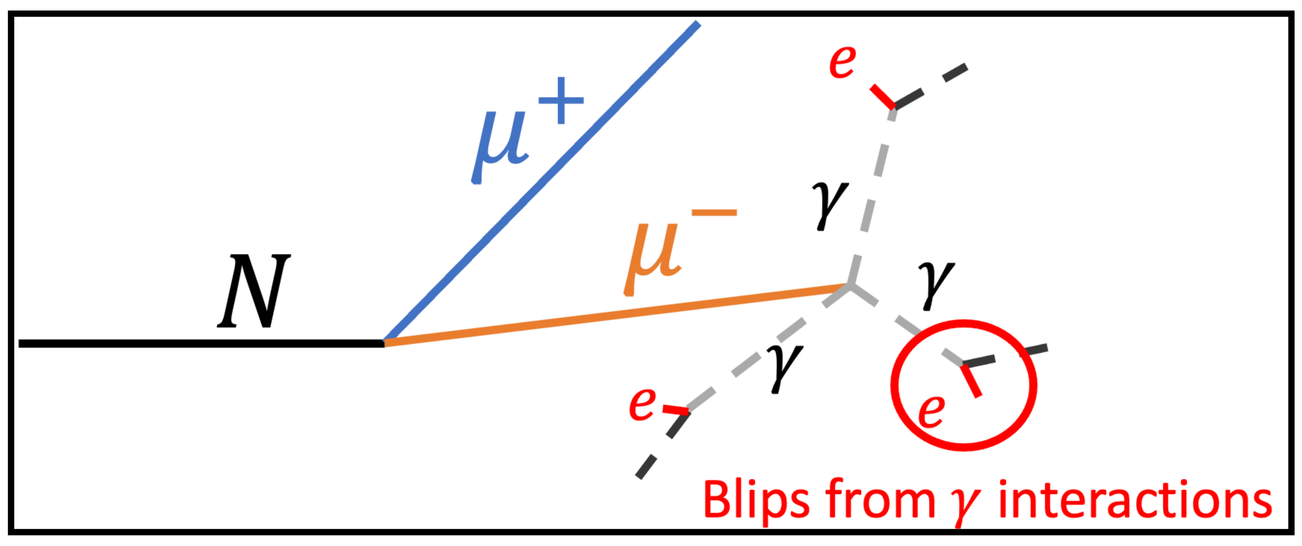
Missing energy !!!

$\mu^- + p \rightarrow n + \nu_\mu$ $\qquad$ $\pi^- + p \rightarrow n$

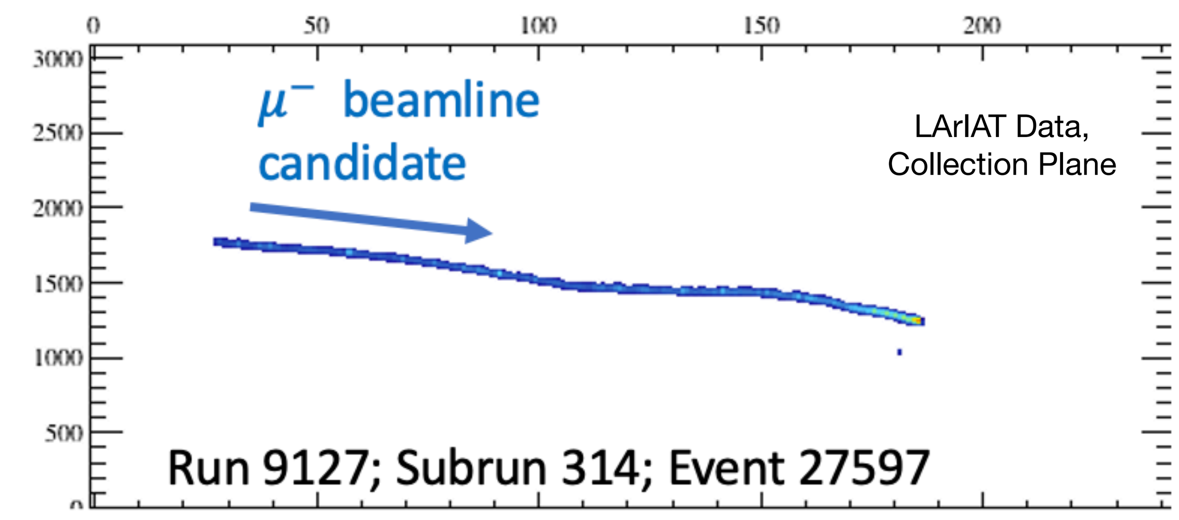
All energy to the nucleus !!!

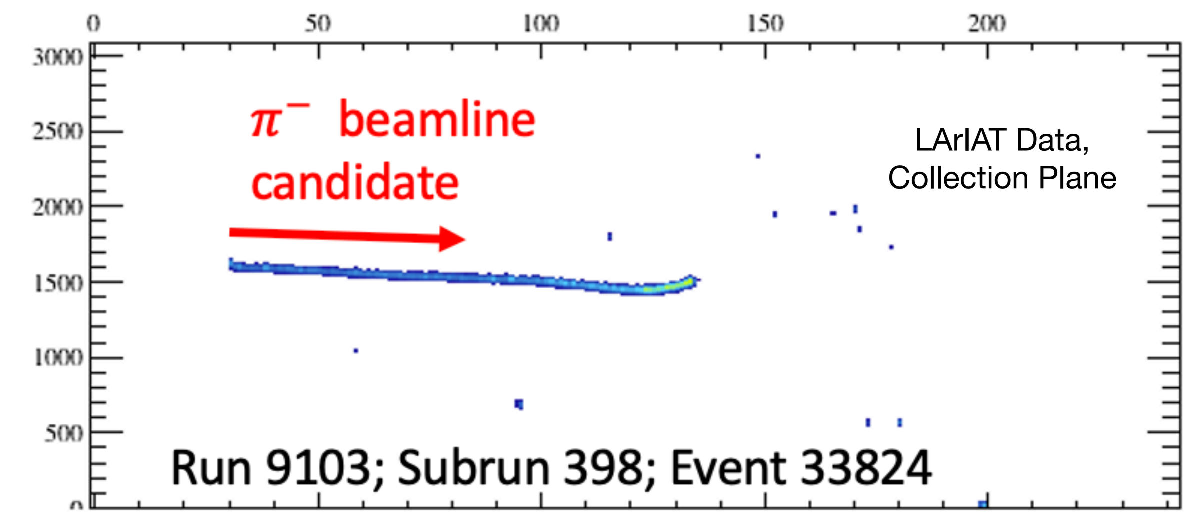
Muon capture at rest process | Pion capture at rest process

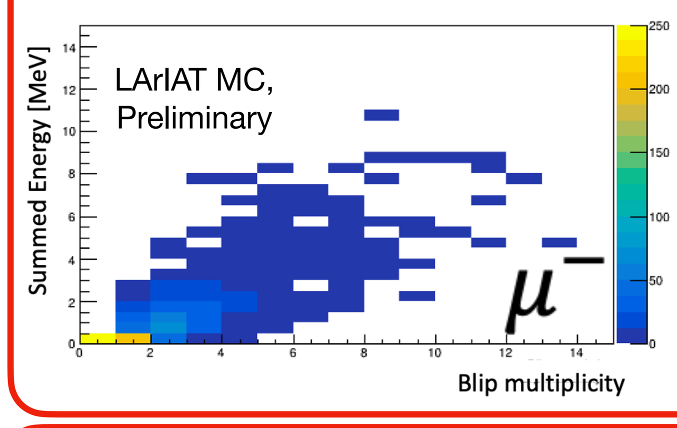
- Reconstruction of gammas from nuclear capture (Blips) can help with this!

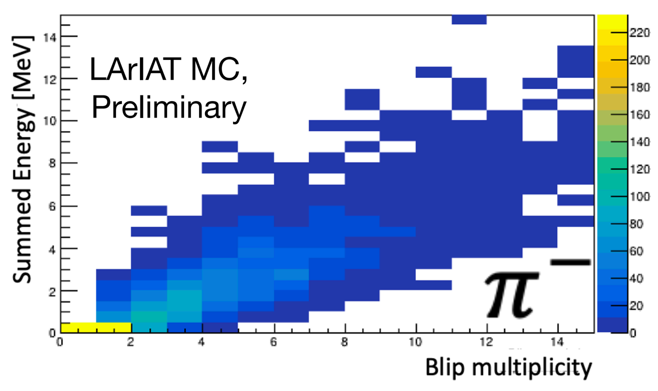


Unusual topologies $\mu^+\mu^-/\pi^+\pi^-$ for BSM. Gammas produced by muon/pion capture, these gammas produce electrons (Blips) from induced interactions.

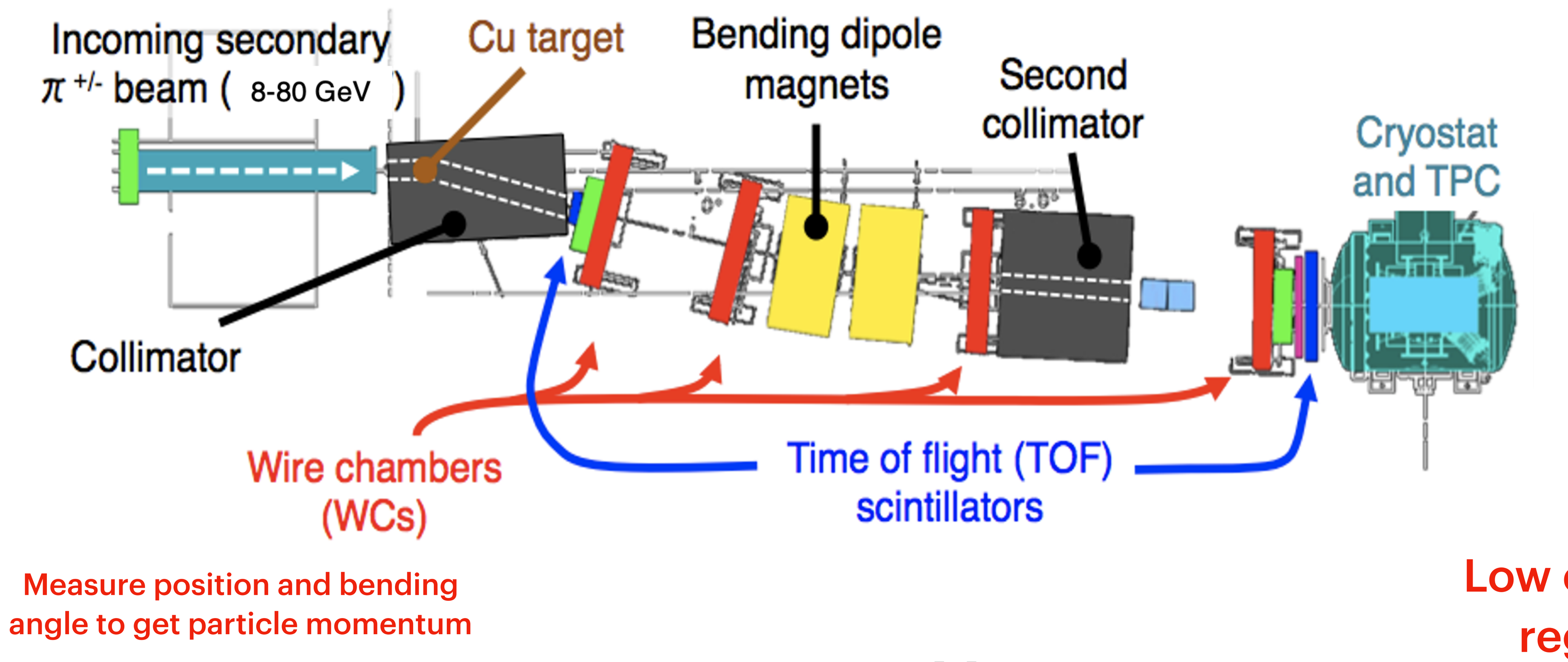






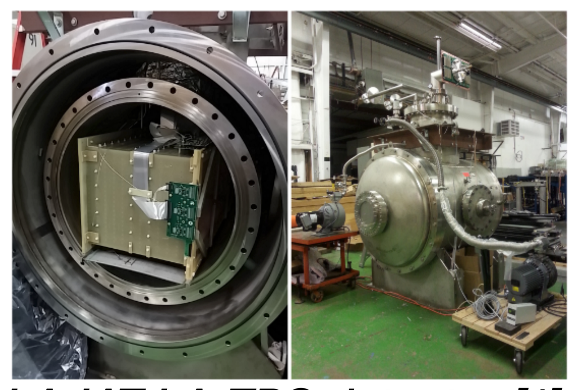


Why LArIAT?

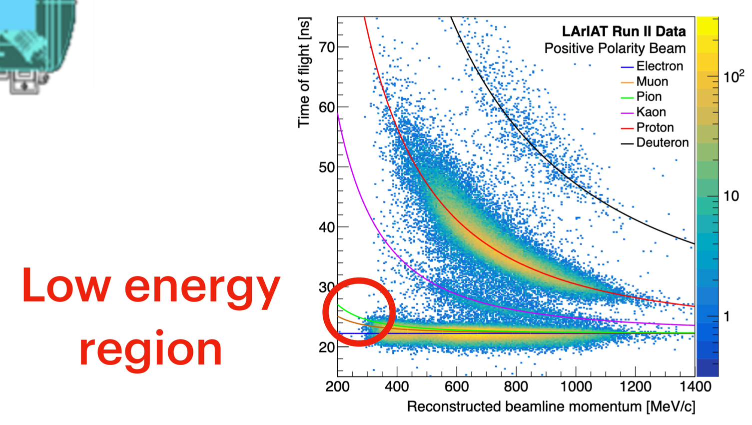


Fermilab test beamline [1].

LArIAT: Liquid Argon In A Testbeam

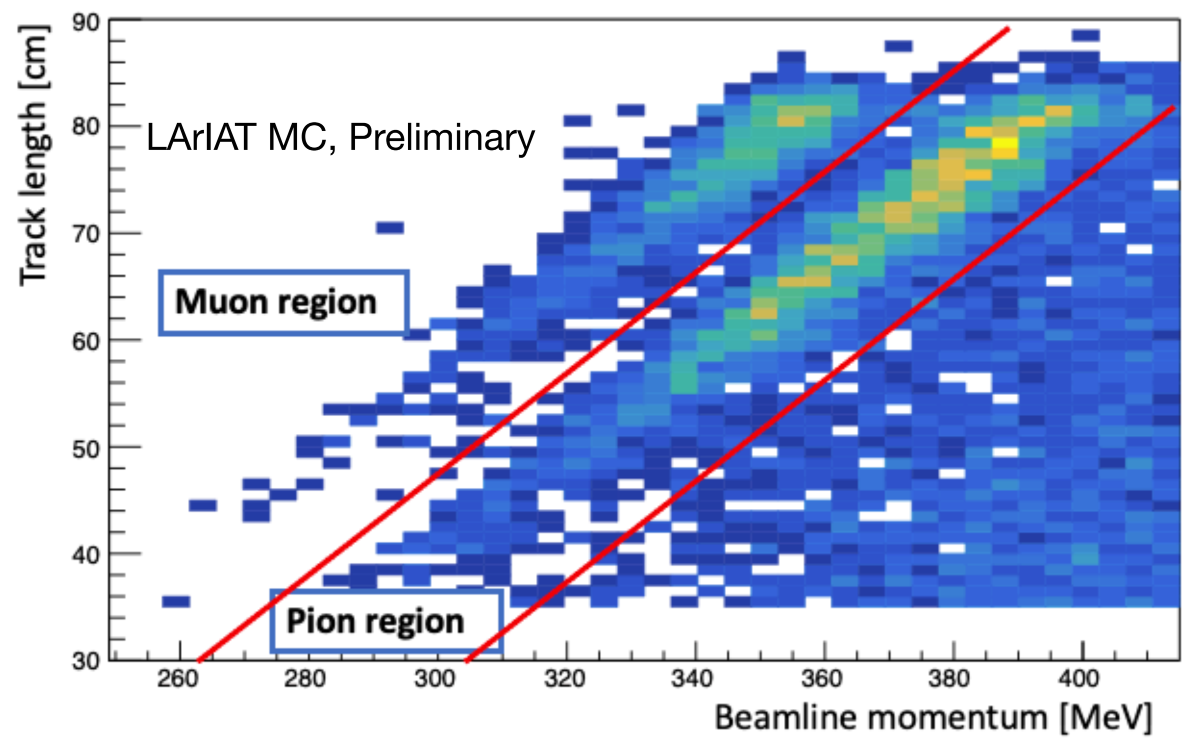


LArIAT LArTPC detector [1].



TOF vs reconstructed momentum [1].

Muon and Pion selection



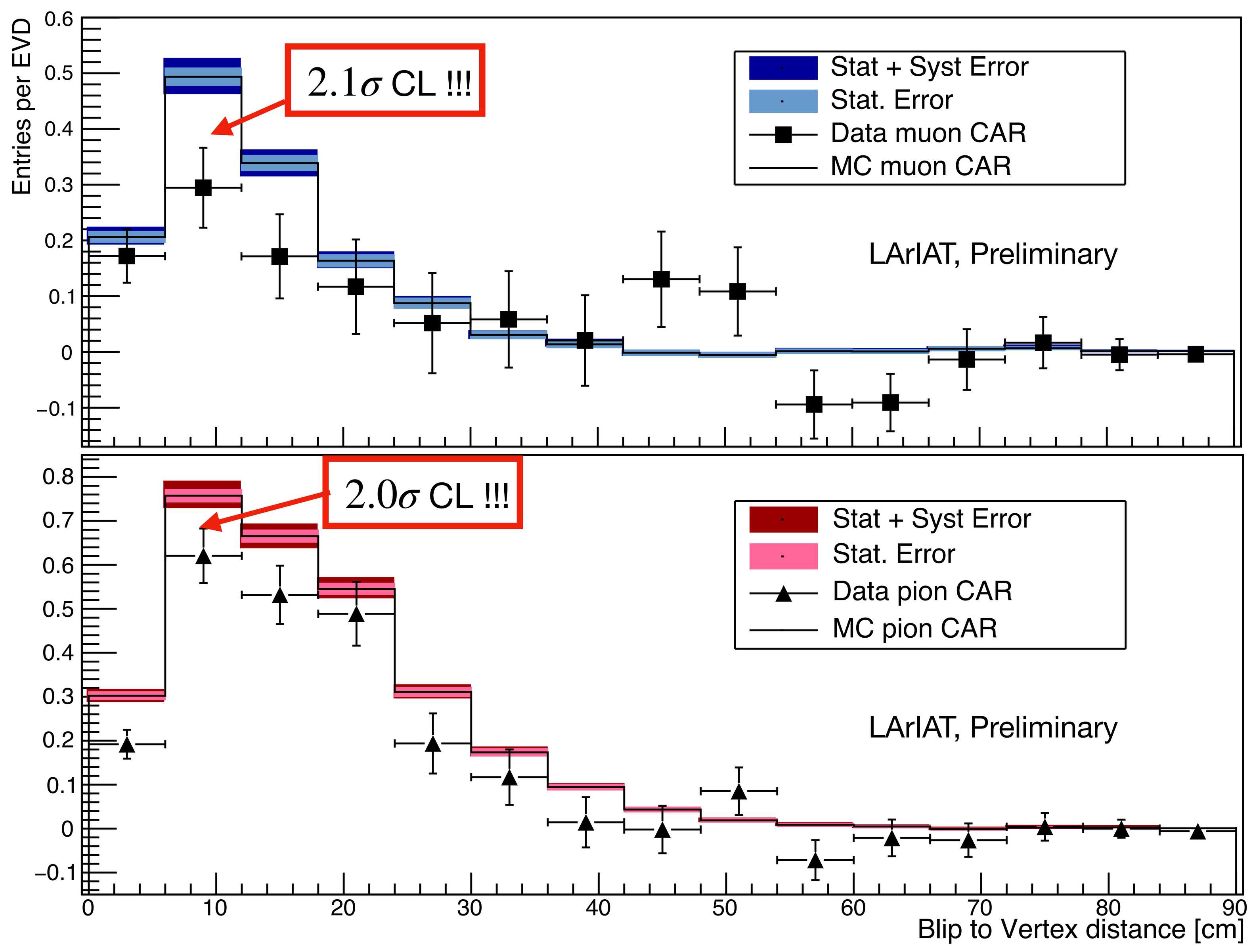
Initial precuts on beam momentum, Bragg peak, start and end positions of the primary particle.

Using beam momentum and track stopping point inside of the TPC we separate stopping muons from stoping pions.

With a MC sample of 500k (G4 QGSP_Bert_HP Physics list) events a final selection of
2132 muon captured-at-rest events (79% purity)
3931 pion captured-at-rest events (76% purity)

Data has 87 muon captured at rest and 209 pion captured at rest candidates.

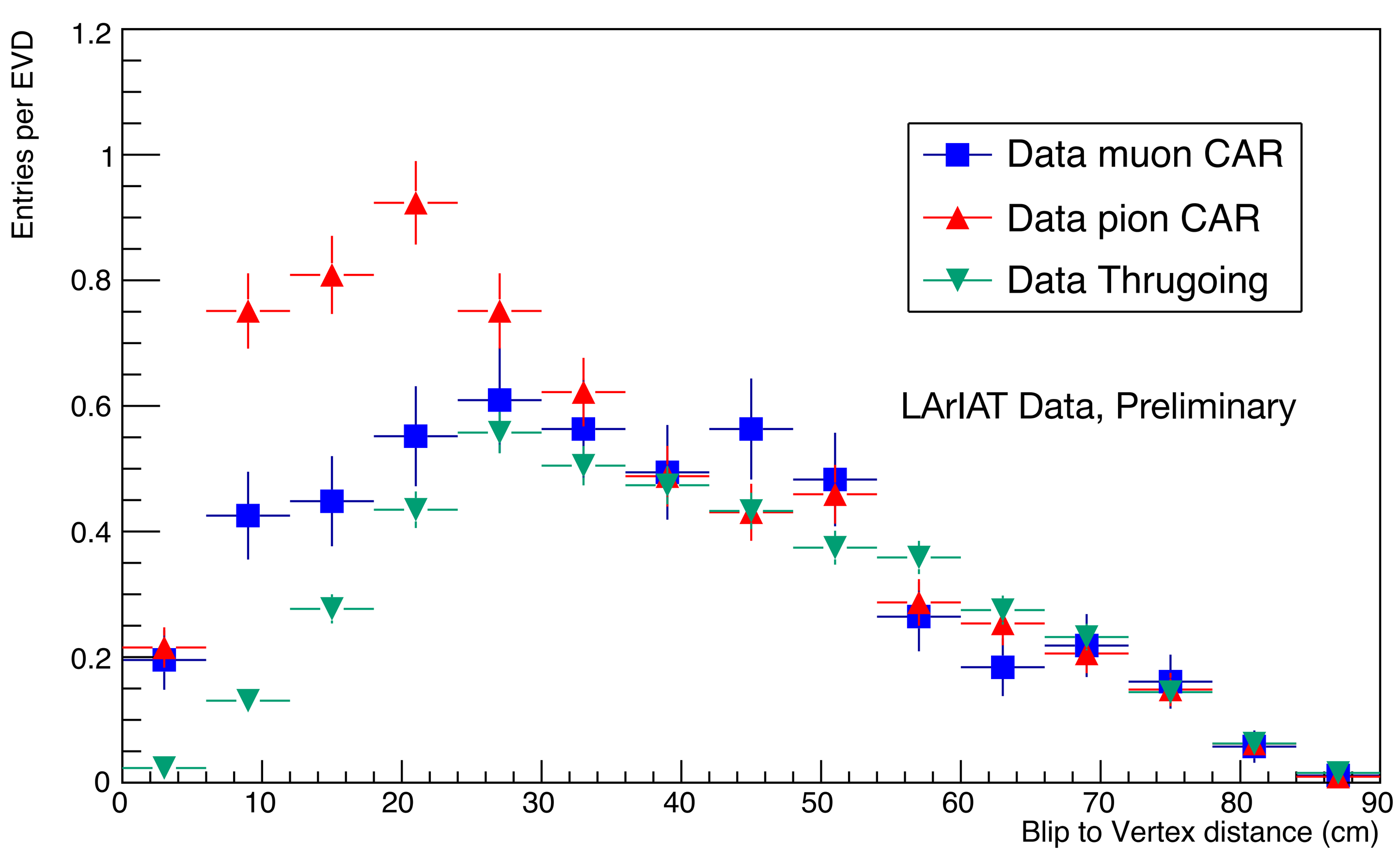
Data-MC comparison



Dataset	Blips per EVD
Muon Data	0.74 ± 0.19
Muon MC	1.22 ± 0.08

Dataset	Blips per EVD
Pion Data	1.86 ± 0.17
Pion MC	2.34 ± 0.09

Data based observations



- Muon Captured at rest to through-going 4.2σ CL of statistical incompatibility
- Pion Captured at rest to through-going $\gg 5\sigma$ CL of statistical incompatibility
- Muon to pion captured at rest 3.6σ CL of statistical incompatibility

We have provided the first observation of the products of stopped pion and muon nuclear capture on argon, and have shown that capture products of the two particle types are clearly distinguishable from one another in neutrino LArTPC data (arXiv posting coming soon)

References

[1] Acciarri, R. et al. (2020). The Liquid Argon In A Testbeam (LArIAT) experiment. Journal of Instrumentation, 15(04), P04026.
[2] Abratenko, P. et al. (2022). Search for long-lived heavy neutral leptons and Higgs portal scalars decaying in the MicroBooNE detector. American Physics Society, PhysRevD.106.092006