Ongoing Measurement of Pion Absorption Cross Section in Liquid Argon with LArIAT

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Measuring the pion absorption cross section will reduce uncertainty in neutrino events with multiple proton emission from the target nucleus.

Thanks to:
Elena Gramellini
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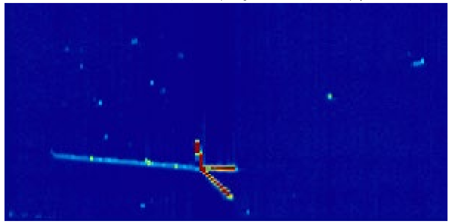
Jen Raaf
LArIAT Collaboration

What is Pion Absorption?

Pion absorption occurs when a charged pion impinges on a target nucleus, causing the nucleus to emit protons or neutrons. The event display shown below shows a pion absorption candidate in LArIAT data. The light blue track represents a pion, and the three red, heavily ionizing tracks represent three final state protons.

Acciarri, R. et. al. (2020). The Liquid Argon In A Testbeam (LArIAT) experiment. *JINST 15 P04026*

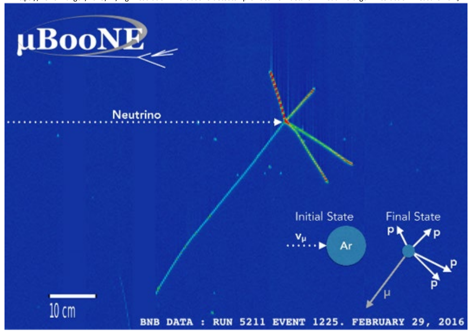


Pion Absorption Candidate in LArIAT

Relevance to Neutrino Physics:

There are some neutrino events where the existence of final state protons indicates a pion absorption interaction in the nucleus. When the neutrino collides, it creates a pion in the nucleus which transfers energy to the nucleons, ejecting them. This being an inelastic interaction, the energy lost can create a large uncertainty in the energy of the incident neutrino. **Effectively modeling the pion absorption in the absence of neutrinos will allow us to reduce the uncertainty on this neutrino measurement.**

https://news.fnal.gov/2019/12/high-resolution-microboone-detector-provides-new-details-in-neutrino-argon-interaction-measurement/



Pion Absorption Candidate in MicroBooNE

The LArIAT Experiment:

LArIAT (Liquid Argon in a Testbeam) is a **Liquid Argon Time Projection Chamber** (LArTPC) that measured a beam of known particles, including pions, kaons, muons, protons, and electrons in the momentum range of 0.3 to 1.4 GeV/c in three runs from April 2015 to July 2017 in the Test Beam Facility at Fermilab.

The beamline technology (collimators, time-of-flight (TOF) paddles, electromagnets, and four multiwire proportional chambers) allows us to measure the **mass and momentum** of particles before they reach the TPC.

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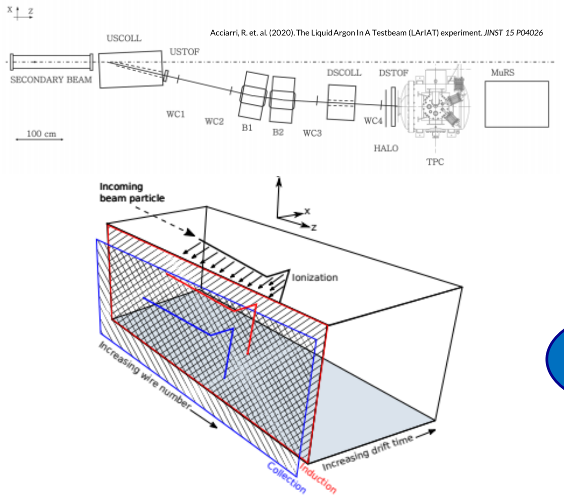


LArIAT Beamline and TPC Diagrams

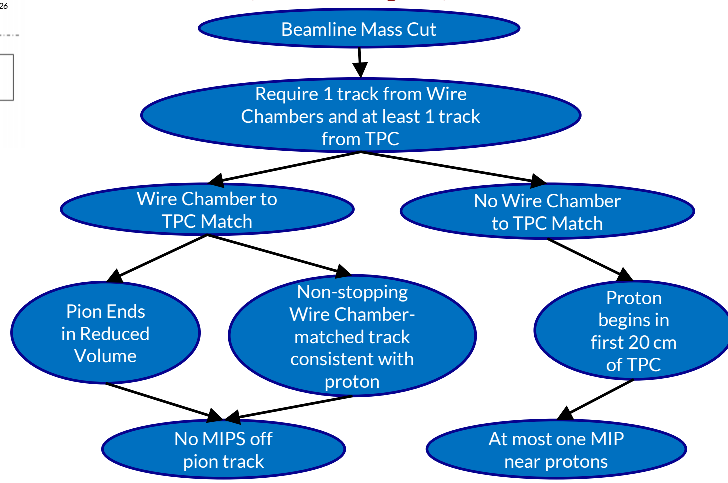
Signal Definition:

I require the simulated particle events to satisfy the following properties:

- Incident particle is a π^-
- Interaction vertex inside TPC volume
- At least one proton or neutron in final state
- No pions, kaons, or muons in final state

The final requirement is to distinguish this interaction from other inelastic nuclear processes that pions can undergo, such as charge exchange, pion production, and inelastic scattering. It also disallows pion decays into muons.

Selection Criteria (Work in Progress):



Selection Criteria Flowchart For Pion Absorption in Data

Selection Criteria Discussion:

The beamline mass cut disallows kaons and protons. Crucially, only protons may emerge from the pion vertex in an absorption event. Sometimes, a final state proton and the incident pion are reconstructed into the same TPC track, and I recover these events by identifying the proton at the end. **PID** is determined by a cut on the mean dE/dx over the last ~6cm of the particle track. If there is no Wire Chamber to TPC match, I recover signal events by finding tracks consistent with protons early in the TPC and demanding at most one MIP near them.

Efficiency and Purity:

The selection algorithm, run on the simulated signal events, has an efficiency of 73.6%. The greatest hits to the **efficiency** are:

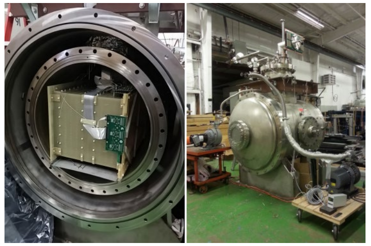
- Misidentifying protons after the incident pion vertex as pions
- Lack of Wire Chamber to TPC match in an event.

Hits to the selection **purity** in data include:

- Electron matched with Wire Chamber
- Electron not matched with Wire Chamber (small shower tracks masquerade as protons)
- Single Pion Charge Exchange is a background for 0 proton absorption

Prognosis:

The next step in this measurement is improving the purity with high-efficiency electron cuts. After this, I will make a preliminary cross section measurement, running over the full LArIAT dataset. My goal is to finish the project and publish by the end of 2021.



The LArIAT Detector in Cryostat

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