The LArIAT Experiment

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Abstract. A short overview of the Liquid Argon In A Testbeam (LArIAT) experiment hosted at Fermilab is reported. This program supports the Liquid Argon Time Projection Chamber (LArTPC) Neutrino Experiments at Fermilab. The LArIAT program consists of a calibration of a LArTPC in a dedicated charged particle beamline. The first total pion interaction cross section measurement ever made on argon is presented here (preliminary result).

1. Introduction

The LArIAT experiment is part of the international US neutrino program [1, 2]. The experiment aims to characterize LArTPC performance in the energy range relevant to both the Short-Baseline (MicroBooNE, SBND, ICARUS) and Long-Baseline (DUNE) Neutrino experiments. The LArIAT experiment is a 0.26 ton active mass Liquid Argon Time Projection Chamber (LArTPC) located at the Fermilab Test Beam Facility (FTBF). The TPC is exposed to a tertiary charged particles beam comprised of pions ($\pi^\pm$) along with a mix of muons ($\mu^\pm$), protons (p), kaons ($K^\pm$) and electrons ($e^\pm$) in the range 200 MeV to 2 GeV. The beamline is instrumented with detectors that aid in identification and selection of particle species and momenta in order to characterize the response of the LArTPC to known incoming particle type and momentum. These results can then be used to tune simulation and reconstruction algorithms for future LArTPC experiments. Figure 1 shows a schematic overview of the LArIAT experiment.

![Figure 1. LArIAT beamline detectors and TPC.](image-url)
2. LArIAT Detector features and goals
The LArIAT detector combines the “traditional” LArTPC design for the ionization track imaging [3] with a new scintillation light collection system (LCS) providing enhanced light collection efficiency and uniformity [4].

The LArIAT experiment uses preexisting components from the ArgoNeuT experiment [5], such as the double-wall, vacuum-jacketed cryostat. The inner vessel hosts the 550 liters of liquid argon and the outer vessel serves as the vacuum insulation. The LArIAT TPC has an active volume of 90 cm × 47 cm × 40 cm (length × width × height) with the width serving as the drift direction. There are three planes of wires (Shield, Induction and Collection) of which two are instrumented with dedicated cold electronics to collect the ionization electrons created during a charged particle interaction in the argon. Each of the two planes consists of 240 wires oriented at ±60° relative to the beam axis, with 4 mm anode wire spacing. Pulse signals on the wires are processed and analyzed through LArSoft, a dedicated framework for LArTPC tracks reconstruction.

The LArIAT light collection system consists of an array of two high quantum efficiency cryogenic photomultiplier tubes (PMT) and three Silicon PhotoMultiplier Detectors (SiPM), which are deployed in liquid argon and mounted behind the wire planes of the TPC.

LArIAT main analysis on the collected data are: measurement of charged hadron-Ar interaction cross sections and study of exclusive channels, kaon identification and interaction topology, e/γ shower identification, µ sign determination in the absence of a magnetic field, study of nuclear effects in argon, and Geant4 validation for hadrons interaction models. Regarding the detector technical characterization, other studies are ongoing: optimization of LArTPC fully-automated event reconstruction and particle ID techniques, light collection system characterization, and combined study of ionization and scintillation light.

3. Total π± - Ar cross section measurement in LArIAT
One of the goals of the LArIAT experiment is the experimental measurement of charged pion cross section on Ar in the (0.2 - 2.0) GeV energy range. Prior to this analyses, no experimental measurement of this cross section on argon had been performed.

The total \(\pi^-\)-Ar interaction cross section \(\sigma_{\text{tot}}\) measured in this analysis is defined as the one related to single strong interactions (including both elastic and reaction channels). In case of the “thin target” approximation, the measured rate of interactions for a given slab can be used to calculate the total cross section as a function of energy (see Eq.1).

\[
\sigma_{\text{tot}}(E) \simeq \frac{1}{n z} \frac{N_{\text{interacting}}(E)}{N_{\text{incident}}(E)}
\]

where \(z\) is the target thickness (in cm) along the incident pion direction, and \(n\) is the scattering center density in the target, \(n = \frac{\rho N_A}{2}\) (in cm\(^{-3}\)).

A new technique called the “sliced TPC” method was developed which makes possible an accurate measurement of the pion cross section dependence on energy in the “thick target” LArTPC environment [6]. The fine-grained tracking of the LArIAT TPC allows the treatment of the 90-cm thick LAr volume as a sequence of many adjacent thin slices of \(\Delta z \approx 4.5\) mm thickness along the \(z\) axis, i.e., direction of the incident particles (pions), as shown in Figure 2. Each slice can be considered as a “thin target” and it is possible apply the cross section calculation from Eq.1 iteratively, evaluating the actual kinetic energy of the pion as it enters each slice, utilizing the precise calorimetric reconstruction along the track.

This analysis uses data collected during LArIAT’s initial run, which lasted from May 2015 to July 2015. Selection criteria on beamline detectors response and on TPC events topology were applied to select \(\pi^-\) candidate events. The preliminary result for the inclusive cross section...
Figure 2. Representation of the analysis of reconstructed tracks with “sliced TPC” technique.

section presented below in Figure 3 currently includes the traditional strong processes as well as background processes. The background processes involve: pion capture at rest and pion decay events. The systematic uncertainties on the cross section are related to: calibration of the energy deposition (dE/dx) in the TPC, energy loss prior to entering the TPC, through-going muons contamination, and wire chamber (initial) momentum reconstruction [7].

Figure 3. Interacting ($N_{\text{interacting}}(E)$) and Incident ($N_{\text{incident}}(E)$) energy distributions [left] and total $\pi^-$ - Ar cross section [right] (LArIAT Preliminary)[7].

4. Conclusions
The data sample from LArIAT’s initial run is utilized to make the first measurement of the $\pi^-$ - Ar cross section and is compared to the expectation from Monte Carlo. Further studies to remove intrinsic backgrounds such as $\pi^-$ capture and $\pi^-$ decay are currently underway. More analyses are forthcoming from the LArIAT collaboration utilizing additional data collected in the second beam run which took place between February and August 2016.

References
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