Introduction

The study of pion absorption in nuclei remains a subject of considerable interest in medium-energy physics. All the measurements of pion absorption and charge exchange are below 300 MeV/c, as shown in figure 1. Besides the lack of cross-section measurements at high momentum (>300 MeV/c), there are still some opened questions related to pion absorptions. For example, two-nucleon absorption has been observed to be important, but multi-nucleon absorption also plays an important role in pion nucleus reaction; Searching for the signature of Initial State Interactions(ISI) Final State Interactions (FSI), Multi-nucleon process involved in pion absorptions have become an important topic in pion analysis.

Cross Section Measurement and Systematic Evaluation Scheme

In previous experiments [1], a low momentum threshold to the pions in signal and Any number of neutral pions Pion Reaction : No neutral pions No charged pions above

Figure 4 shows the distribution of reconstructed efficiency of charged pions from pion events with beam momentum = 1 GeV/c

H4-VLE Test Beam [2]

H4-VLE test beam comes from an extension of secondary 80 GeV/c pions beam line, coming in from a turn from a first extension of the 400 GeV/c primary beam from BNL. It consists of tertiary e, p, μ, K beam with momenta range from 0.5 to 7 GeV/c. Large amount of data to study hadron-Ar interactions (Over 4 million beam events collected).

ProtoDUNE Single Phase (SP) Detector[2] (Shown in Figure 2)

- Active volume: 6m high, 7m wide and 7.2 m deep (along drift direction)
- Scientific goals of protoDUNE
  ○ Prototype the production and installation procedures for the single phase far detector design
  ○ Validate the design from the perspective of basic detector performance.
  ○ Accumulate test-beam data for the study of detector response, calibration, particle identification etc.[3]

Research Scheme of Pion Analysis Group with pion beam events (1 GeV/c)

- Shower and particle identification
- Cross section measurement of pion absorption and charge exchange process
- Characterize the kinematic distributions of pion absorption including
  ○ Proton’s momentum, kinetic energy and angular distribution
  ○ Missing energy and missing momentum distribution
- Nuclear effect study
  ○ Searching for signature of FSI, nucleon-nucleon correlations
  ○ Transverse Kinematic imbalance study (TKI)

Figure 5. Track score distribution of all particle flow objects in LArTPC.

Particle Identification Purity

Pion - Proton Separation

To select the pion absorption and charge exchange processes, protons needs to be identified and separated from all the track-like objects in TPC based on two calculated variables as a function of energy loss dEdx

- Truncated Mean dEdx (Figure 7)
  ○ Calculated from energy loss dEdx in collection plane
  ○ Hits at the beginning and end of the track excluded in calculation
  ○ Proton Region: Truncated Mean dEdx > 3.4; Pion Region: 0.6 < Truncated Mean dEdx < 2.8

Transition Region: Truncated Mean dEdx < 0.6 and 2.8 < Truncated Mean dEdx < 3.4 → Further proton-pion separation (chi2/ndof > 70) performed in transition region

- Chi2 per degree of freedom(Figure 8):
  \[ \chi^2 = \frac{N_{	ext{obs}} - N_{	ext{exp}}}{N_{	ext{exp}}} \]

Where:
- number of hits in collection plane

Figure 6. Distribution of Shower - Interaction distance.

Figure 7. Distribution of truncated mean dEdx

Figure 8. Distribution of chi2 calculated from dEdx on collection plane.

Figure 9. Distributions of momentum (Left) and cosθ (Right) of all the proton candidates of selected pion absorption events.

Figure 10. Distributions of missing energy (Left) and missing momentum (Right) of all the proton candidates of selected pion absorption events.

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