Quasielastic Scattering in Pion+ Liquid Argon Interactions

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Introduction

Elastic scattering results when a particle interacts with another particle. Both particles will retain their identity. There is only one instance of energy transfer in this interaction, and therefore the kinematics are defined by two particles.

In contrast, quasielastic scattering is a type of interaction in which the incoming particle interacts with a single nucleon (p+ or n) in the target particle. There are interactions between the outgoing pion and the spectating nuclei. Because there are many particles involved in quasielastic scattering, this type of interaction is not easily modeled in Geant4, a particle collision simulation.

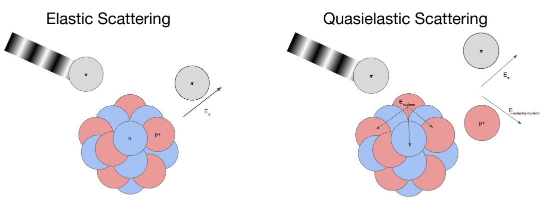

Fig 1: A representation of elastic scattering and quasielastic scattering, respectively.

Statement of Purpose

This project serves to analyze interactions between pions and liquid argon and determine to what extent the quasielastic processes are included in Geant4.

Method:

The data used in this analysis are Geant4 simulations of Pi+ at a momentum of 1 GeV/c interacting on a thin (1cm) liquid argon target. The model used in this case is the Bertini cascade model (Geant4 provides various models that can be selected). The data was kept as a ROOT TTree. Only events labeled by Geant4 as inelastic were kept. This inelastic process contains various subprocesses (pi absorption, pion charge exchange, quasielastic scattering, etc). We were especially interested in quasielastic processes and to what extent they were included in the Geant4 simulation. We used kinematic quantities to distinguish between quasielastic and the other processes.
To calculate energy loss, the following formula was used:

$$E_{lost} = E_{incoming} - E_{outgoing} \qquad (1)$$

To calculate the incoming pion energy from the quantity of the outgoing particles, the following equation which is valid only for the quasielastic process was used:

$$E_{\pi}^{QE} = \frac{m_p^2 - (m_n - E_b)^2 - m_\pi^2 + 2(m_n - E_b)E_\pi}{2(m_n - E_b - E_\pi + |\vec{p_\pi}| cos\theta)} \qquad (2)$$

Results and Discussion

The first quantity measured to ensure that quasielastic scattering is occurring is to find the energy loss of outgoing pions. Quasielastic scattering gives the lowest amount of energy loss, as shown in the following figure:

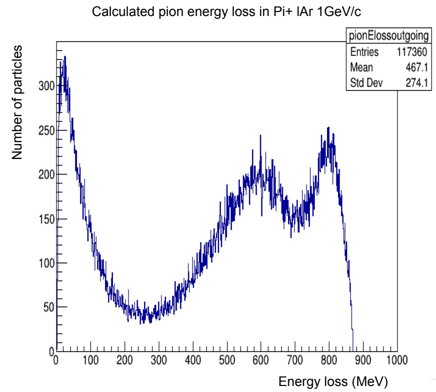

Fig 2: A histogram showing the number of particles in an energy loss distribution.

This histogram was created by running a script that plotted the number of particles in a bin size 1 MeV for the energy calculated using equation 1. This distribution shows a peak at a low energy (4 MeV).

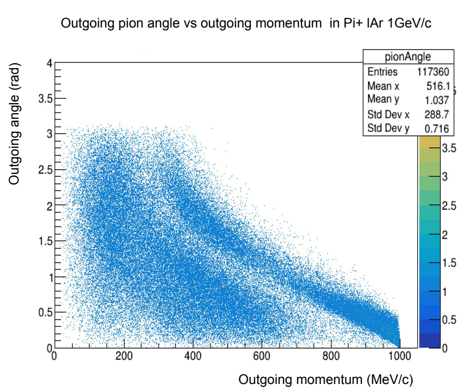

Fig 3: A 2D histogram of outgoing pion angle vs outgoing momentum.

Figure 3 shows a distribution of angle out the outgoing particle vs. outgoing momentum. Because this graph shows two significant bands, there must be at least two processes occurring in this run, where the band to the right is evidence of quasielastic scattering.
The final proof of quasielastic scattering is through inverse kinematics. By using equation 2, it is possible to reconstruct the energy of the incoming pions, as shown in Figure 4.

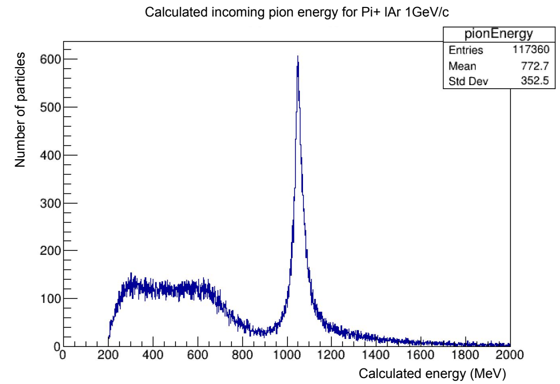

Fig 4: A histogram of the incoming pion energy

We observe a clear peak at the energy expected for quasielastic scattering on top of the combinatorial background. The background results from the fact that not all interactions shown in the plot stem from quasielastic interactions, but also interactions for which equation 2 is not valid. The peak is centered at the expected energy for quasielastic scattering. Thus, it should be assumed that there are substantial quasielastic processes. It should be noted that there is various information included in this peak. First, the number of events can be translated to the total cross section for nuclear quasielastic pi+ liquid argon interactions Furthermore, the exact position and the width of the peak can be used to extract other nuclear properties.

Conclusion

As demonstrated throughout this poster, there are quasielastic processes occurring in the 1 GeV/c Pi+ lAr interaction. The next step is to calculate the quasielastic cross section for this interaction using the number of events under the peak as well as peak position and width in Figure 4. The next step would be to compare to different cascade models included in Geant4 and compare the simulation with available experimental data for different targets.

Acknowledgments

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