Monte Carlo Studies
Exclusive Cross Sections

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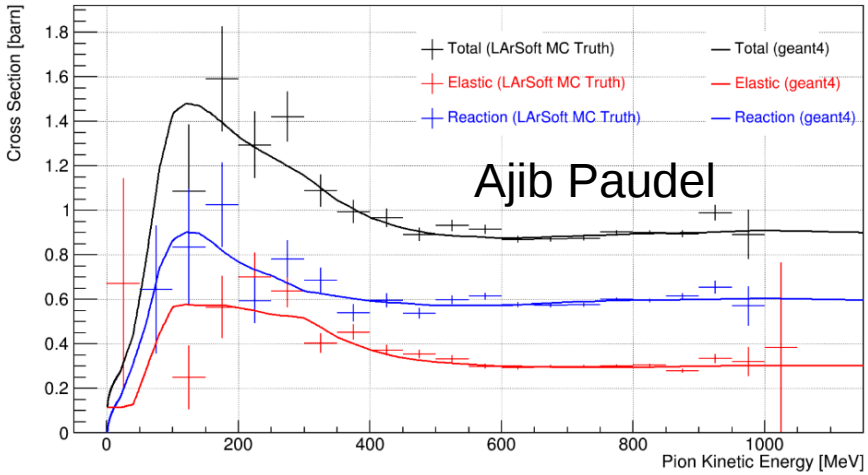
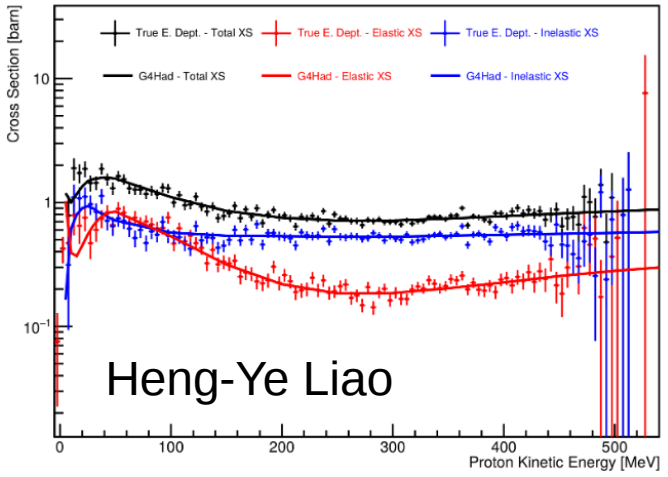
Introduction

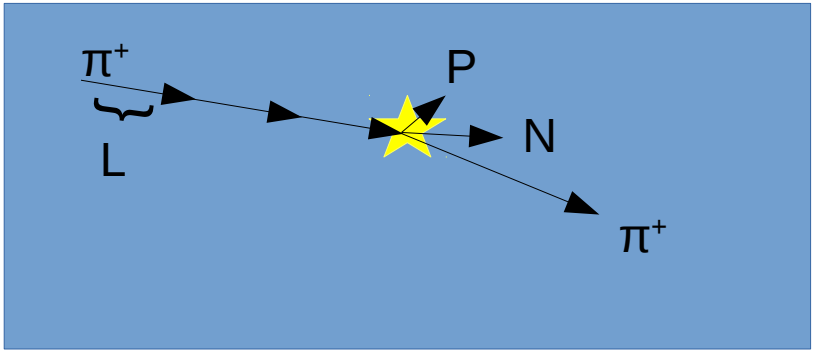
- Ajib and Heng-Ye presented MC studies last week at the Wednesday meeting
  - Looked into total inelastic/elastic cross sections for pions and protons
  - Compared LArG4 thin-slice to Geant4 toy scattering experiment (G4HadStudies from Hans Wenzel)
- I've extended a similar study to exclusive pion interactions
  - Also developed my own code to extract Geant4 cross sections
    - Total inelastic/elastic and exclusive





Interactions in Geant4

- Geant4 simulates particles by “tracking” them through material
  - The particle takes a series of steps
  - Multiple processes “active” each step
    - Active: has a chance to occur
  - Different types of processes
    - “AlongStep” - Transportation, ionization
    - “AtRest” - Decay at rest, capture
    - “PostStep” - **Elastic, Inelastic hadronic interactions**

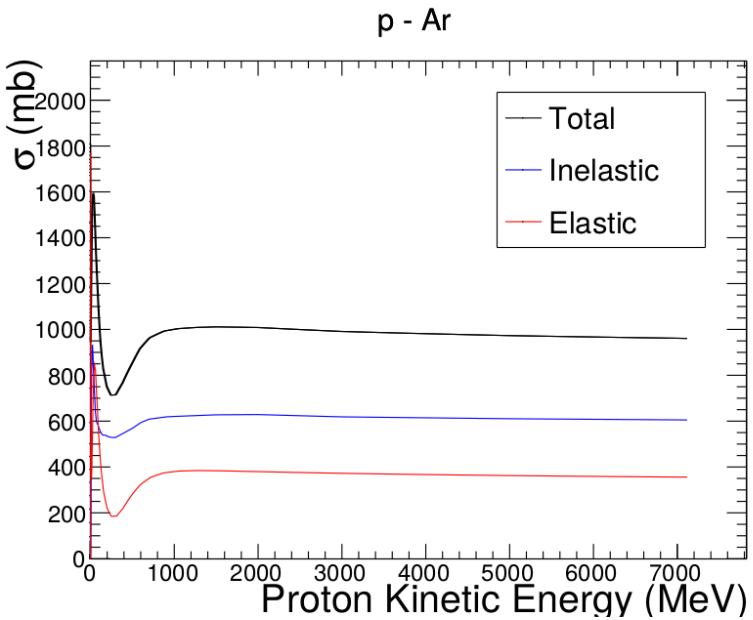


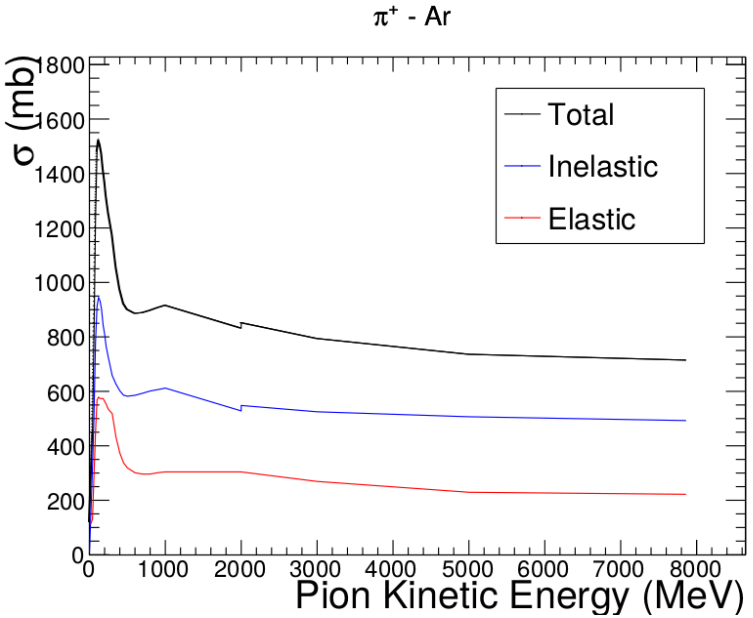
Interactions in Geant4

- Each process has a chance of occurring during a step
  - Hadronic (in)elastic interactions: based on the **cross section**
- After a process is chosen to occur, its interaction **model** is invoked
- You can mix and match **cross sections** and **models**
  - Using pre-defined physics lists or creating your own
- 2 separate concepts
  - When will a process occur? → Cross Section
  - What happens when a process occurs? → Model

Cross Sections

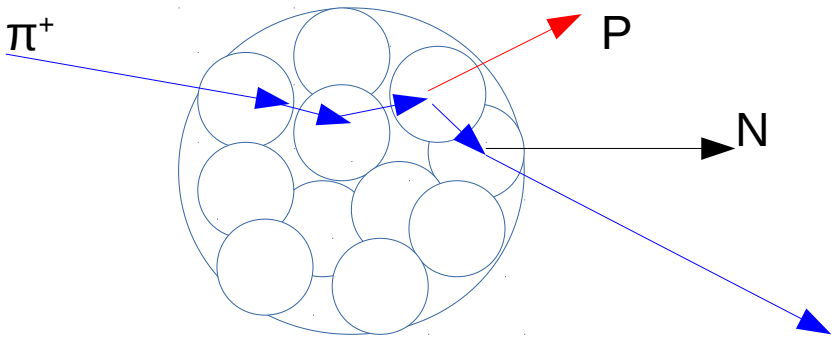
- Wrote my own code to extract the cross sections from Geant4
  - Gets the inelastic, elastic, and total (their sum)
  - Material is configurable (for this study – Ar)
  - Works for protons, charged pions





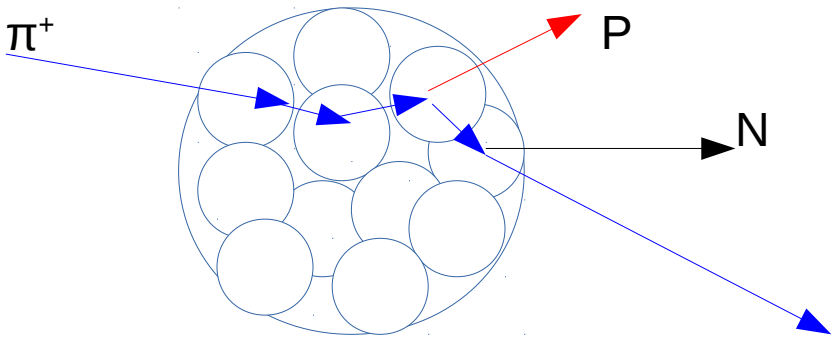
Inelastic Interactions

- The usual model in Geant4 for inelastic hadronic interactions is the **Bertini Cascade**
  - The hadron enters the nucleus, steps through the nuclear medium, and possibly interacts with nucleons
    - The targeted nucleons step through the nucleus similary
      - Creates a “cascade” of particles/interactions in the nucleus



Inelastic Interactions

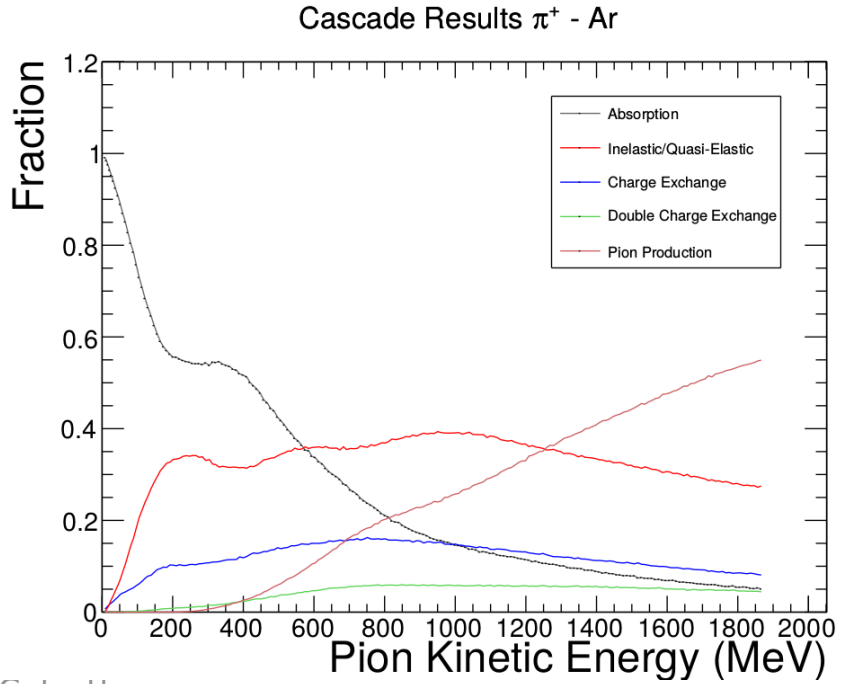
- When all cascading particles leave the nucleus or are absorbed by the medium, the cascade ends
  - The results/observables are the outgoing particles



Exclusive Cross Sections

- "Exclusive cross sections" do not actually exist in Geant4
  - But we can categorize the results of the cascade and multiply the fractions to the extracted inelastic cross section
  - Wrote code to run only the cascade

Channel	Definition
Absorption	No pions
Charge Exchange	1 π^0
Inelastic	1 same-charge π
Double Charge Exch.	1 opposite-charge π
Production	>1 pions



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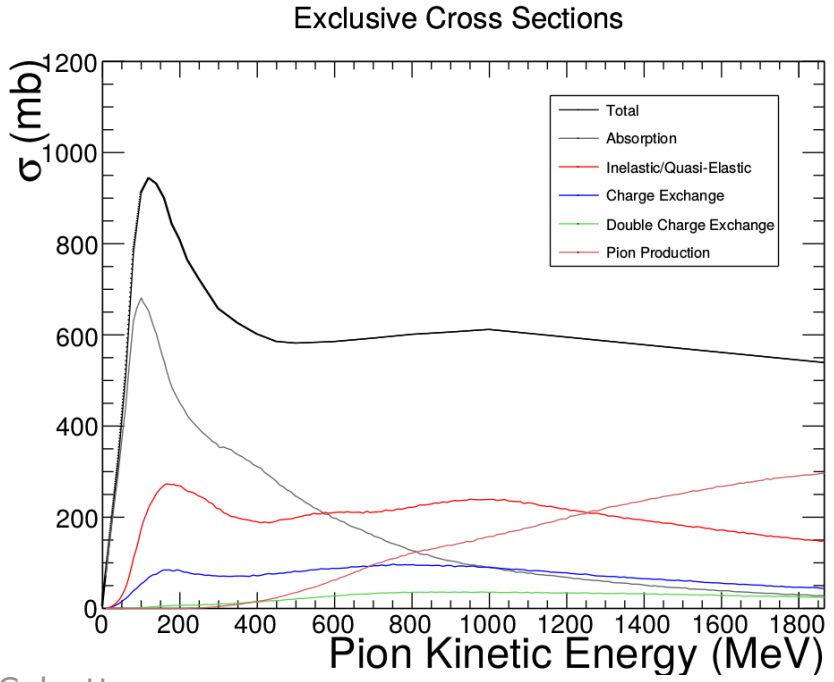
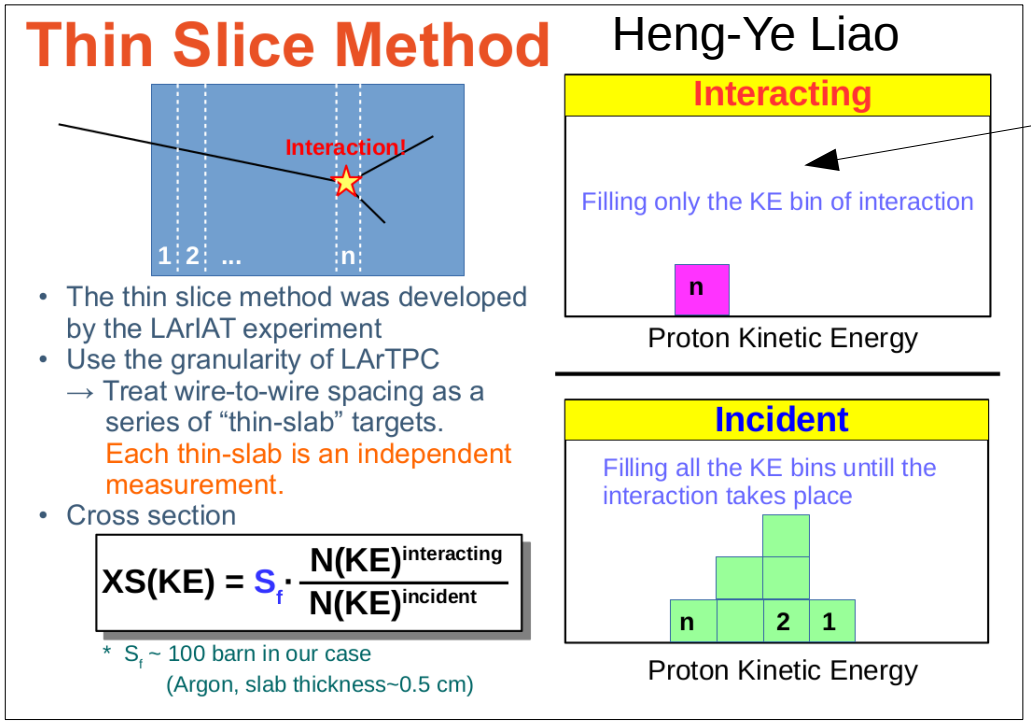


Exclusive Cross Sections

- Expanded on Heng-Ye's code for Thin-Slice cross section
  - Separated out by final states
  - Code available in branch feature/calcuttj_pion_analysis_abscex
    - @ dunetpc/dune/Protodune/Analysis/PionCrossSectionAnalyzer_module.cc



One "interacting" histogram per channel

Exclusive Cross Sections

- Analyzed 50000 ~1GeV Pions generated by Ajib
  - Compared to the extracted exclusive cross sections

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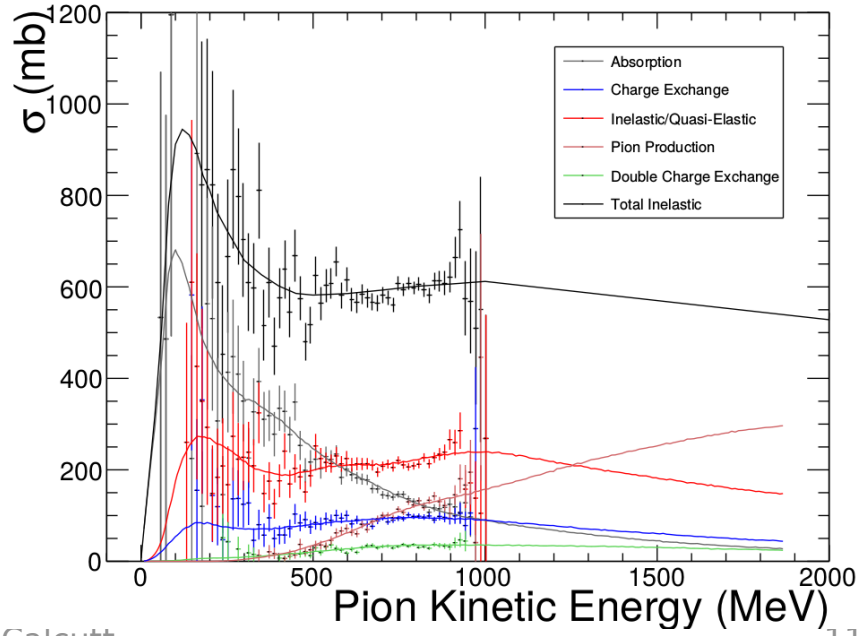

Summary

- Expanded MC cross section studies to exclusive final states
- Have code to extract exclusive cross sections of user-defined final states
- Sanity check: matches thin slice method for exclusive channels