

Cross Section Measurements with PDSP

Introduction

Motivations

Neutron Cross Section

Charged Hadron Cross sections

- Styles (Thin-Slice, Modified Thin-Slice, Fitting)
- Ongoing measurements

Systematic Uncertainties

Motivation

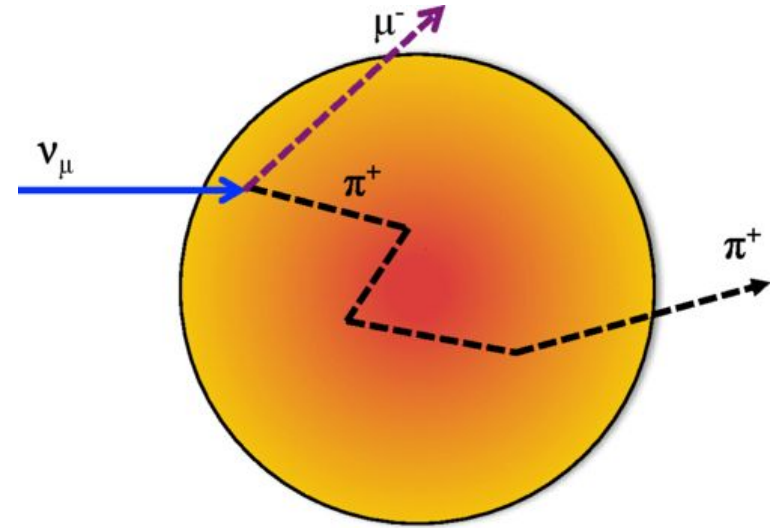
DUNE relies on signatures from particles emitted from nu-Ar interactions

Complications:

- Pions from primary interaction can undergo Final State Interactions (FSI)
- Can also be produced after primary interaction as a result of FSI

Need well-informed models

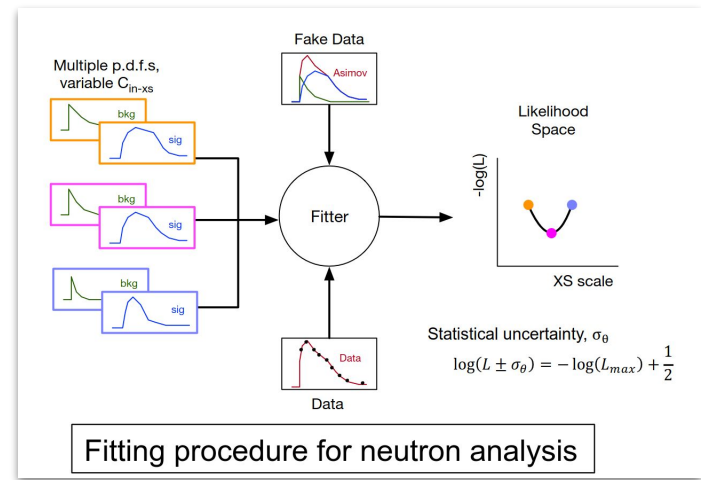
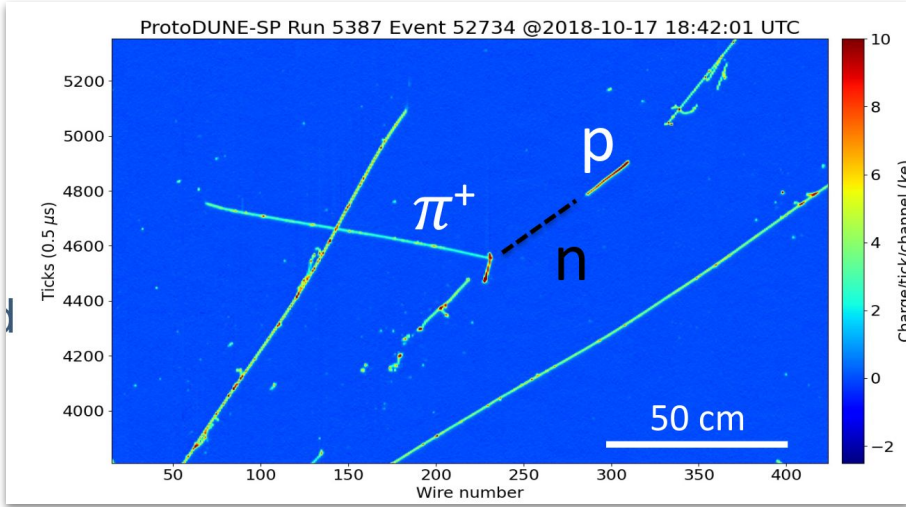
- Pion-Ar scattering data from PDSP can help!



Cartoon depicting ν_μ -nucleus scattering and Pion FSI¹

1. <https://doi.org/10.1103/PhysRevD.99.052007>

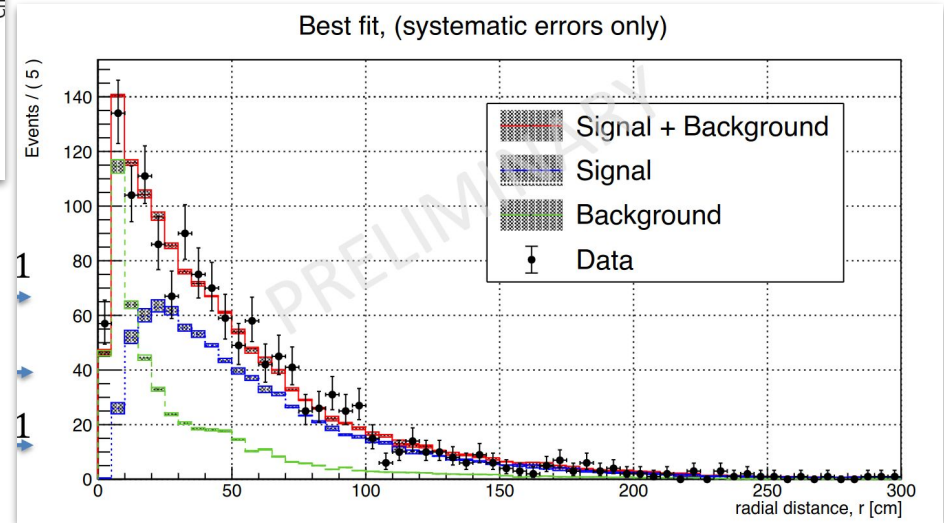
Neutron Cross Section



Vary geant4 n cross section
 → Different radial distance distributions

Fit to data

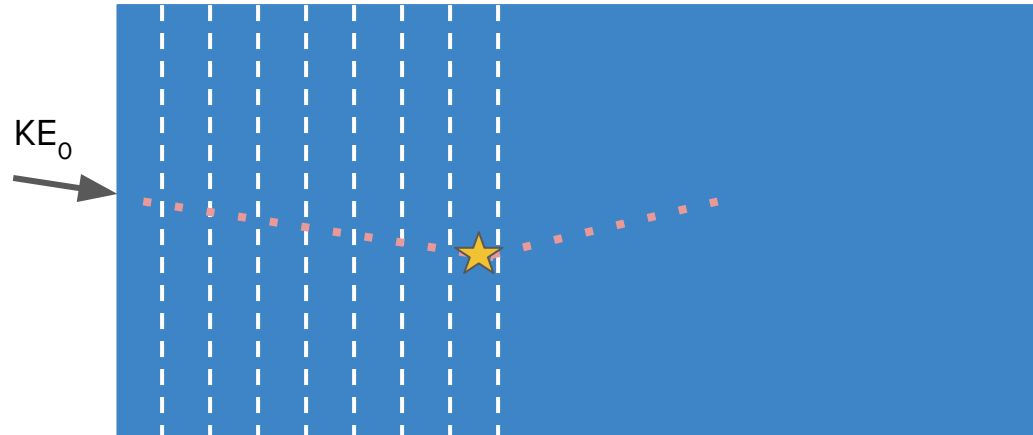
Unsure of current status



Charged Hadron Cross Section Styles – Thin-Slice

Based off of LArIAT technique

- Slice up volume by some number of wires (thickness t)
- This forms multiple thin-target experiments
 - Hadron has a chance to interact in each slice it passes through
 $p \propto \sigma/t$



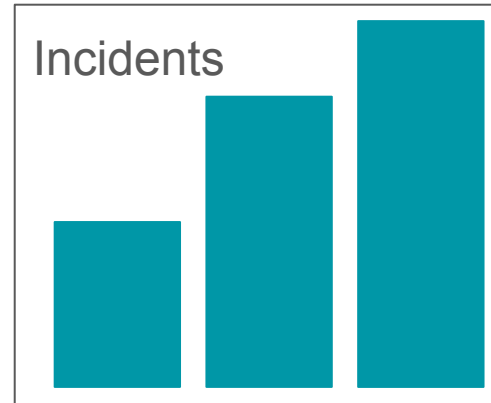
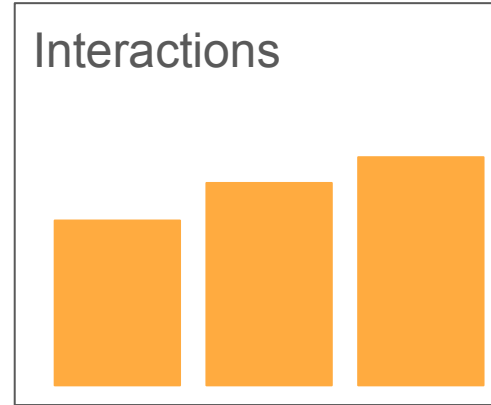
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Count interactions & “incidents”
(flux)

$$\sigma = f(N_{Int}, N_{Inc})$$

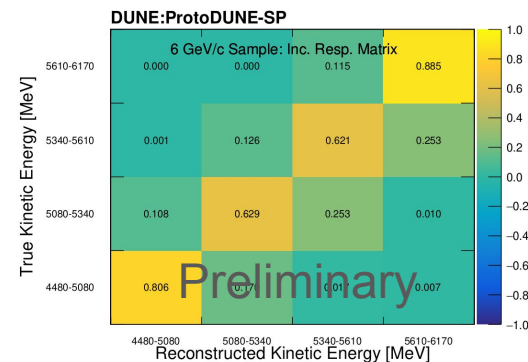
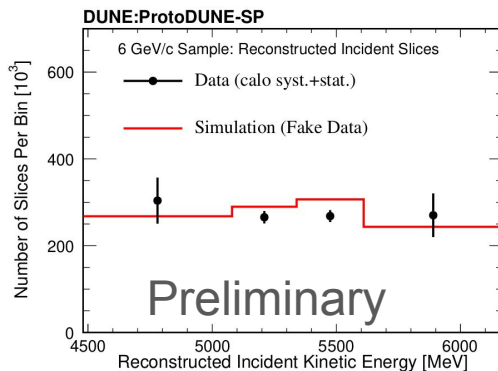
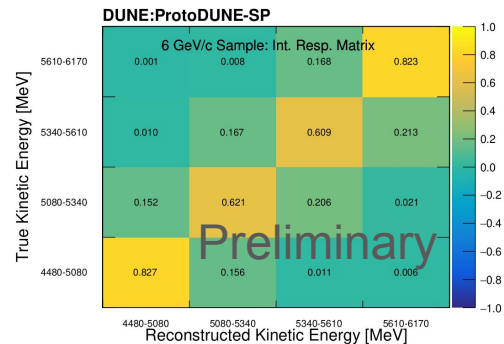
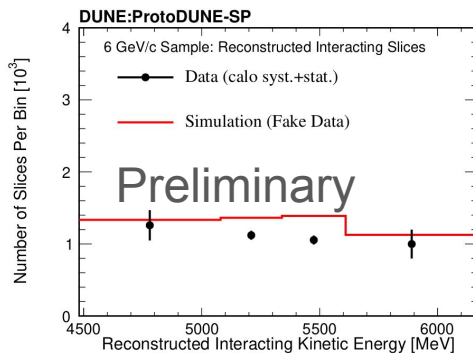


Thin-Slice Kaon Total Inel. @ 6 & 7 GeV/c

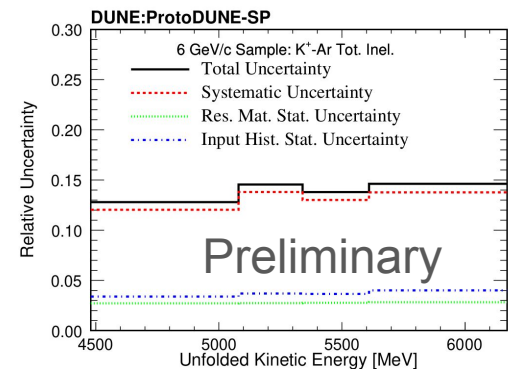
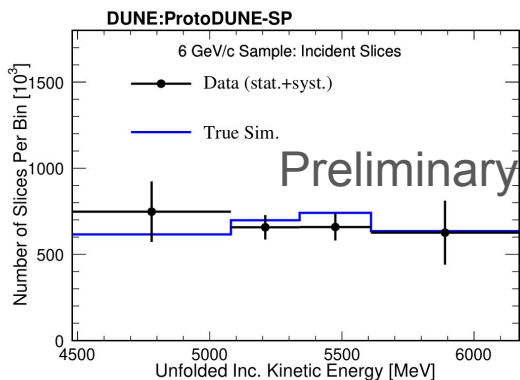
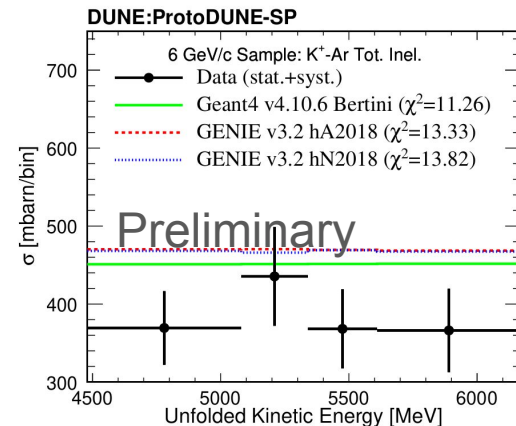
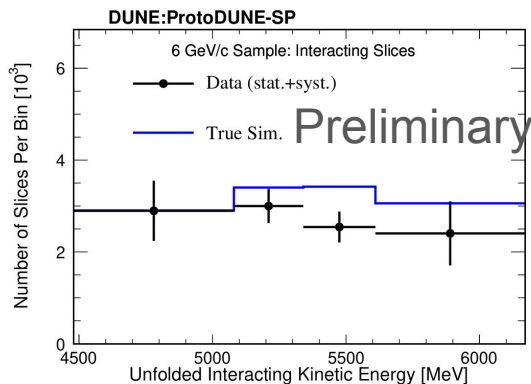
Methodology

- Use RooUnfold to unfold both interacting and incident dists. separately
 - Takes into account purity & efficiency corrections
 - Iterative Bayesian/D'Agostini unfolding

Systematics encoded in response matrices (multisim)



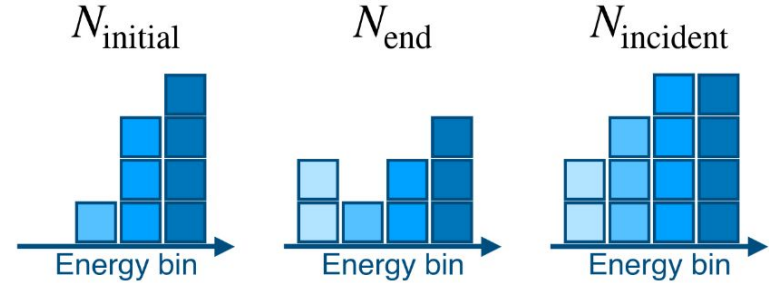
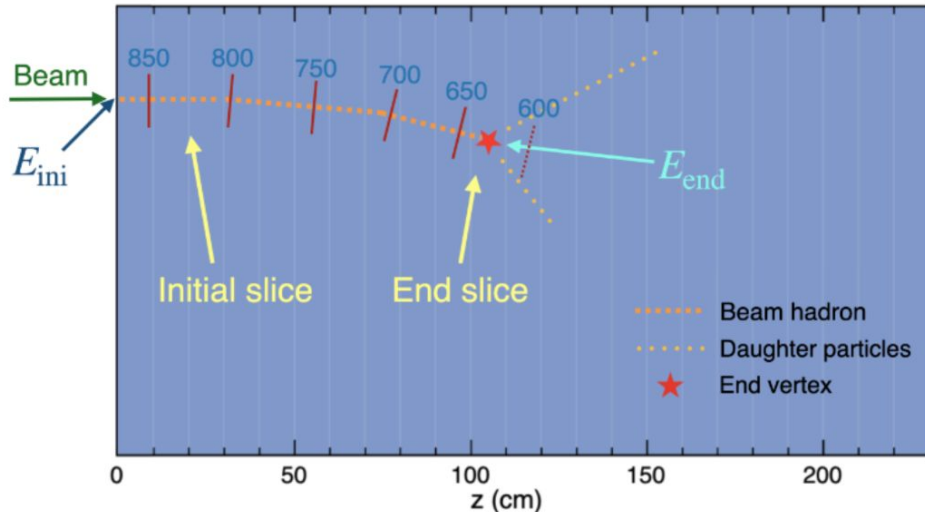
Thin-Slice Kaon Total Inel. @ 6 & 7 GeV/c



Modified Thin-Slice – Binning Directly in Energy

“Slice” in energy: See initial (~from beam) and ending (including deposits)

- (Ideally) know the hadron did not interact between, so intermediary bins are filled → Can calculate the number of interactions & incident entries



The cross section is calculated by

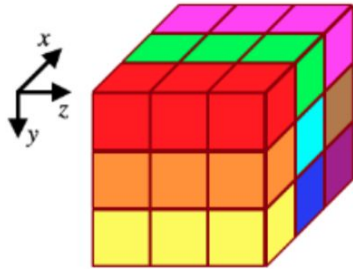
$$\sigma(E) = \frac{N_{\text{int}}(E)}{nN_{\text{end}}(E)\delta E} \frac{dE}{dx}(E) \ln \left(\frac{N_{\text{inc}}(E)}{N_{\text{inc}}(E) - N_{\text{end}}(E)} \right)$$

Modified Thin-Slice – “Quasi-3D Unfolding”

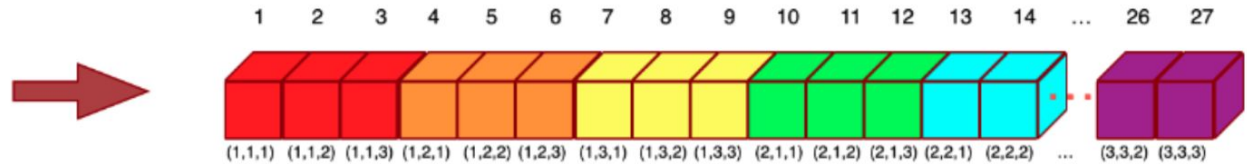
3D distribution

- N events at some initial energy (N_{Ini})
- N events at some initial energy (N_{End})
- N events of some specific interaction (N_{Int})

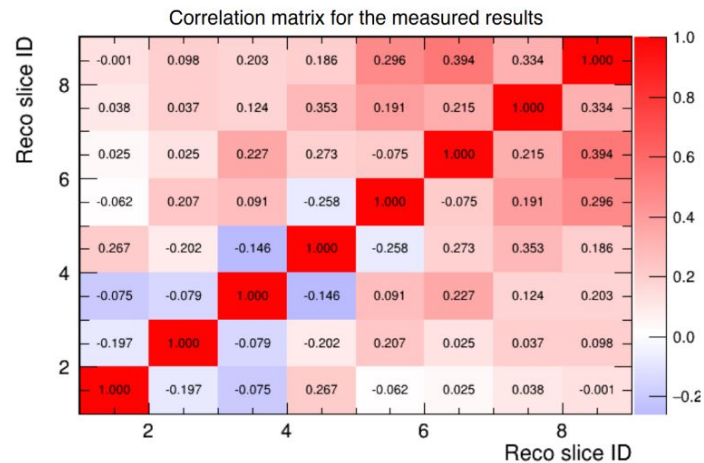
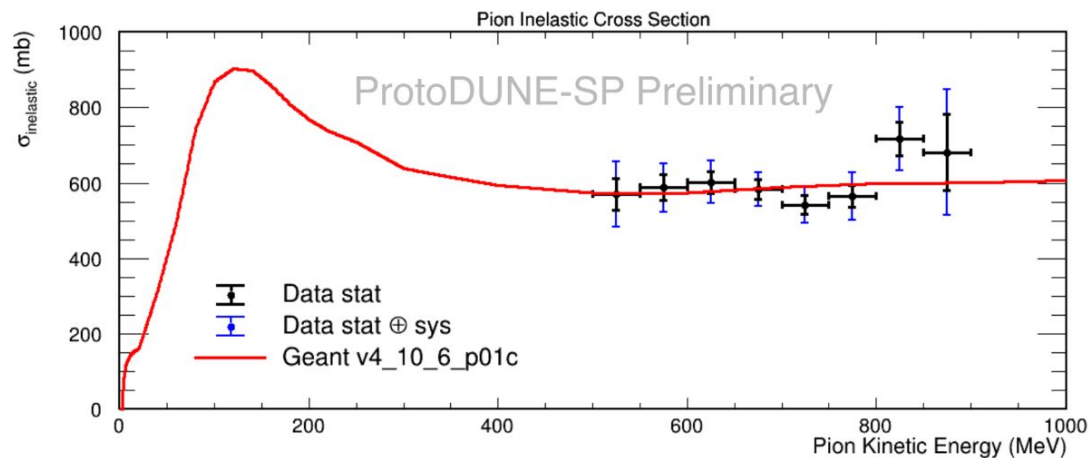
Convert to 1D, unfold together: $P(A, B, C) \neq P(A)P(B)P(C)$



Similar idea to flattening a 3D array into a 1D array



Modified Thin-Slice – Pion-Ar



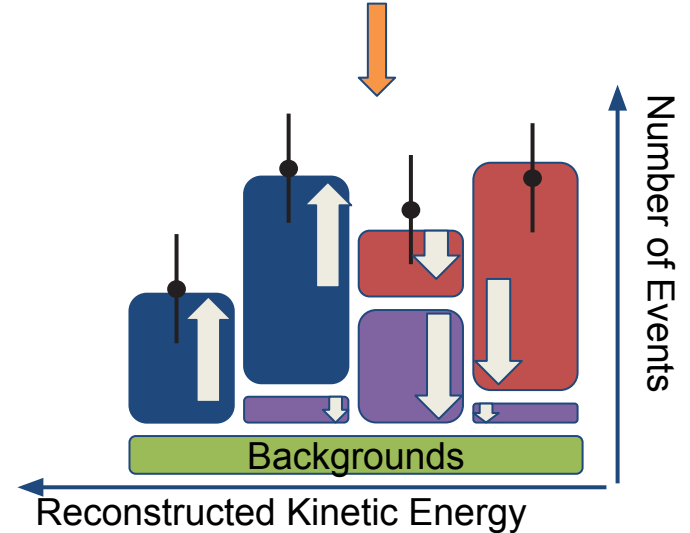
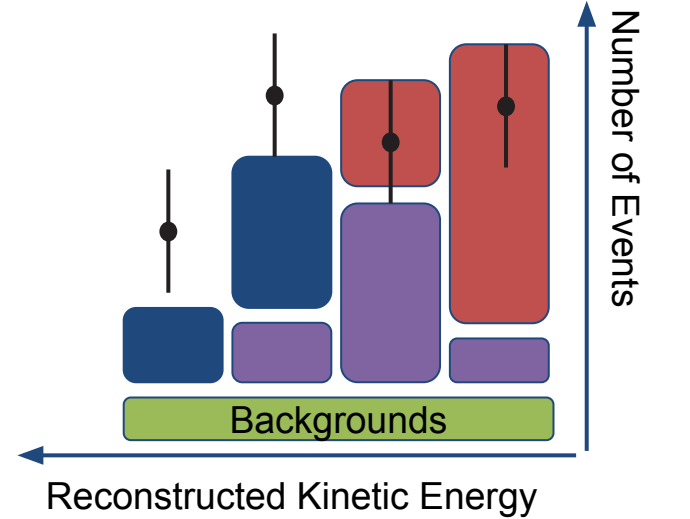
Systematics encoded in response matrices
(multisim) – Need to double check this...

Fitting Analysis

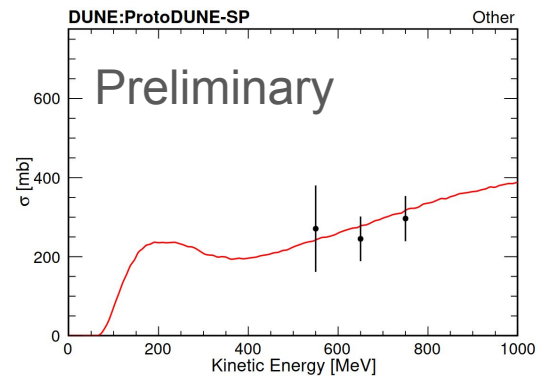
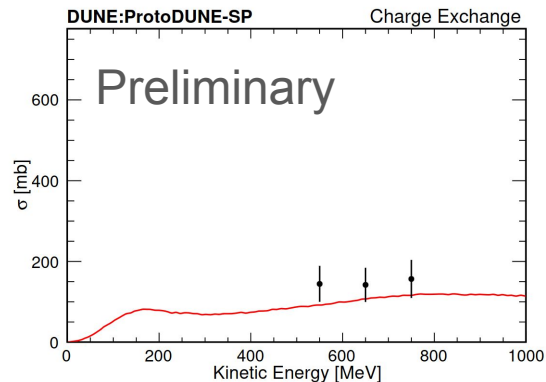
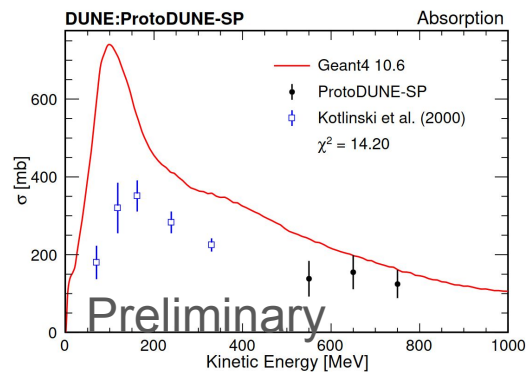
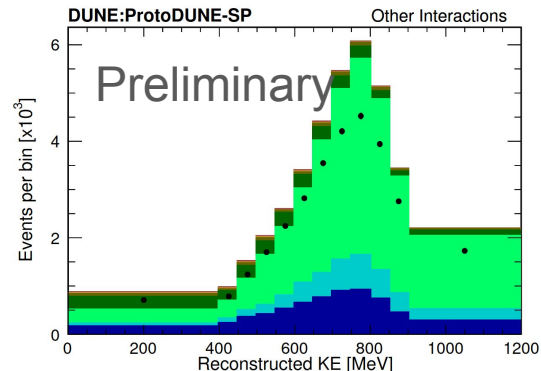
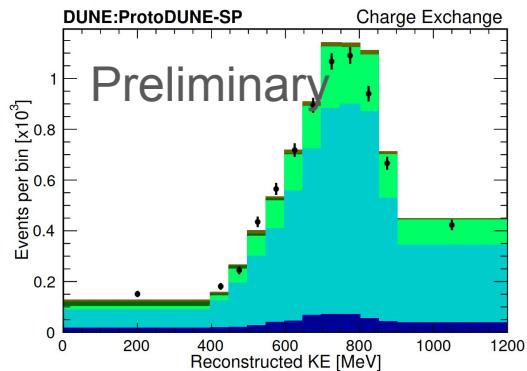
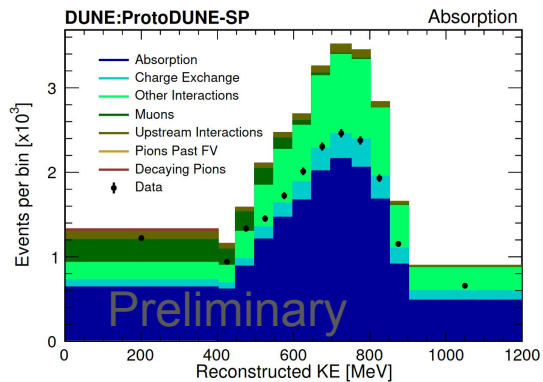
Instead of D'Agostini Unfolding, modify collections of true events (i.e. interaction type, energy) as distributions in reco space

Use *Thin-Slice on MC truth info* to calculate the cross section using the varied MC

Systematics implemented as changes to input MC used in fit to data (essentially a multisim approach)



Fitting Analysis – Exclusive 1 GeV/c Pion



Other Ongoing Analyses

1 GeV/c Proton Total Inelastic

2 GeV/c Exclusive Pion

1 GeV/c Differential Ch. Exch. Pion

3 GeV/c Proton

Freestyle on Systematic Uncertainties

Thank You