Measurements of interactions with argon

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Outline

- Interactions of pions with Ar
  - LADS (Large Acceptance Detector System)
  - LArIAT
- Interactions of nucleons with Ar
  - Comparisons to GEANT predictions

$$\sigma_{total}=\sigma_{abs}+\sigma_{cex}+\sigma_{inel}+\sigma_{elas}$$

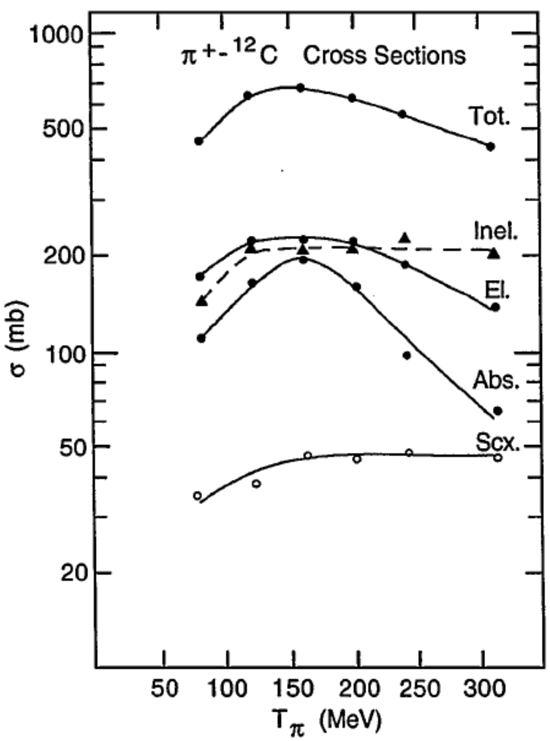
Cross section of pion-nucleus

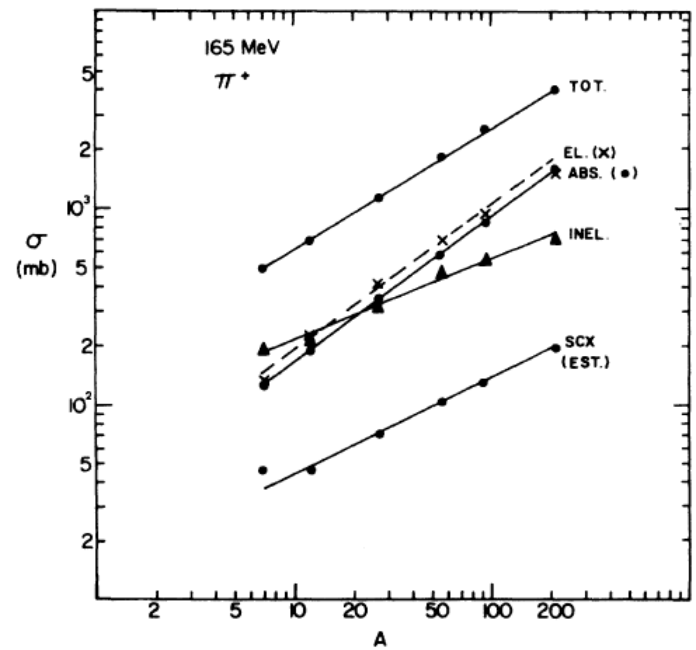
- **Total** - attenuation of initial beam
- **Elastic** (nucleus in ground state) differential cross section integrated
- **Inelastic** (nucleus in excited state or broken up) need to measure to zero energy
- **Charge Exchange** (π^+,π^0), (π^+,π^-)
  - Single charge exchange - need to detect neutral pion
  - Double charge exchange –but very small
- **Absorption** (no pion in final state)
  - need to confirm no pion in final state, or subtract all other cross sections.

Ann. Rev. Nucl. Sci, 52, 23 (2002)

Measurements of argon

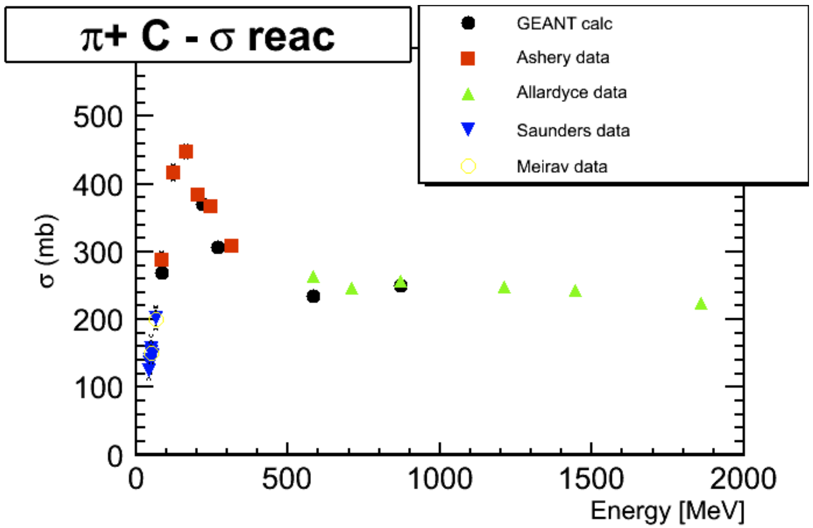
The Monte Carlo models are based on data from scattering on other nuclei. Cross sections scale with power of A (2/3 for absorption and 0.8 for total)

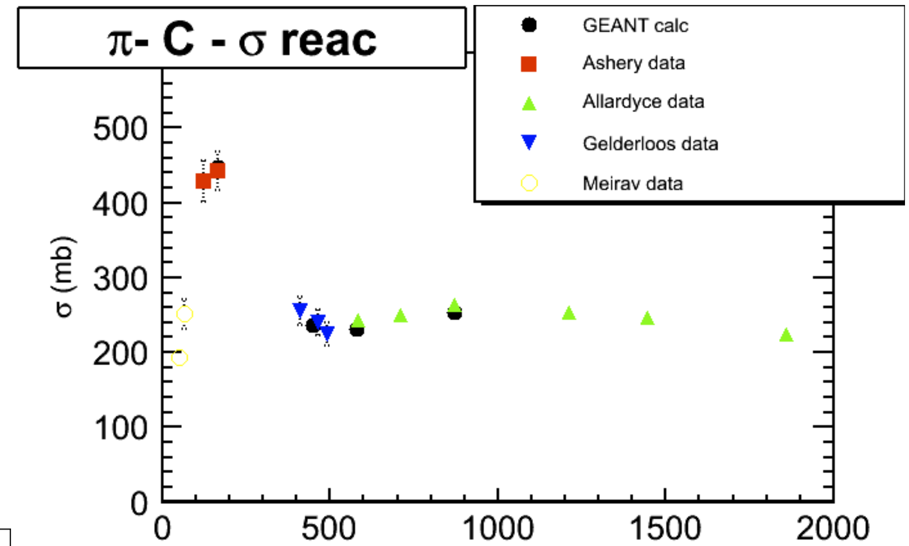


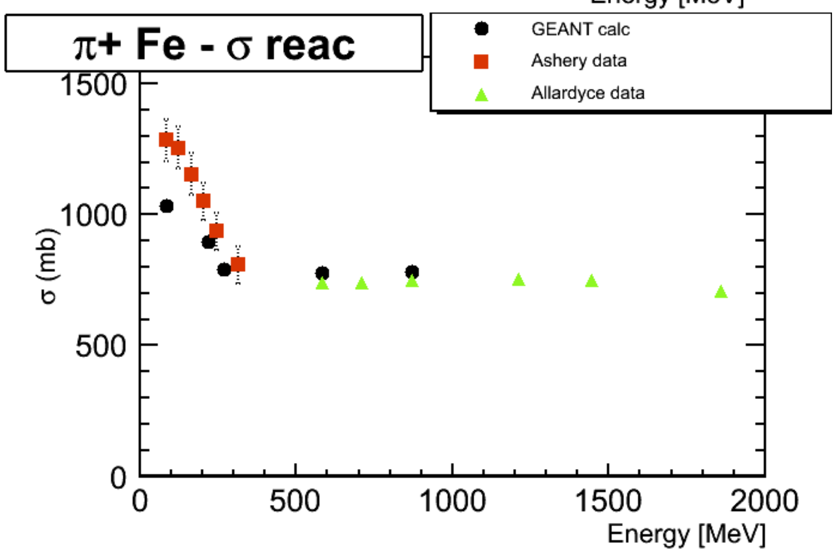


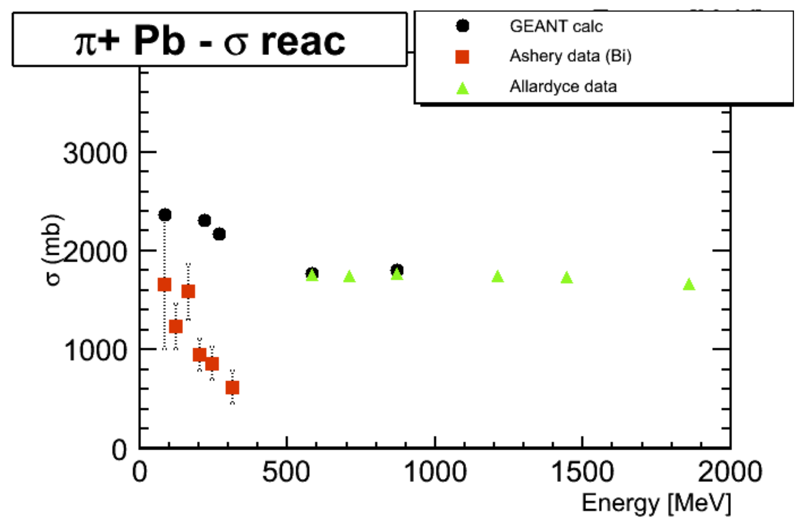
Ashery, PRC 23, 2173 (1981)

Review of pion scattering data









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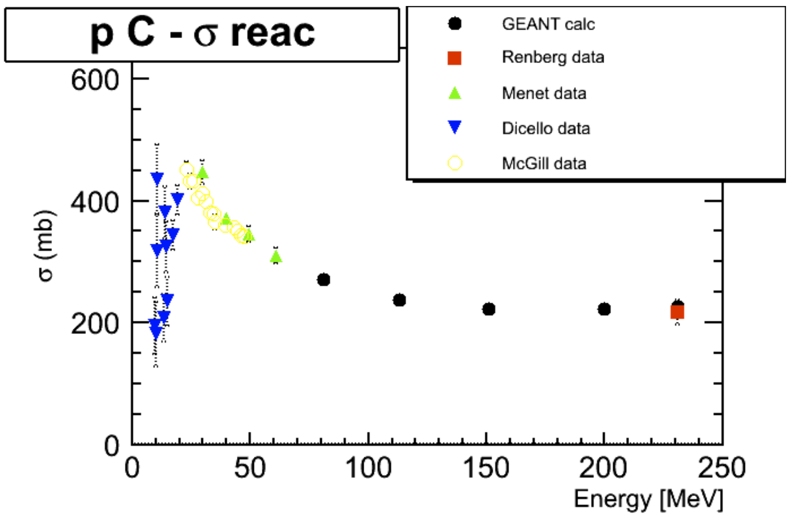
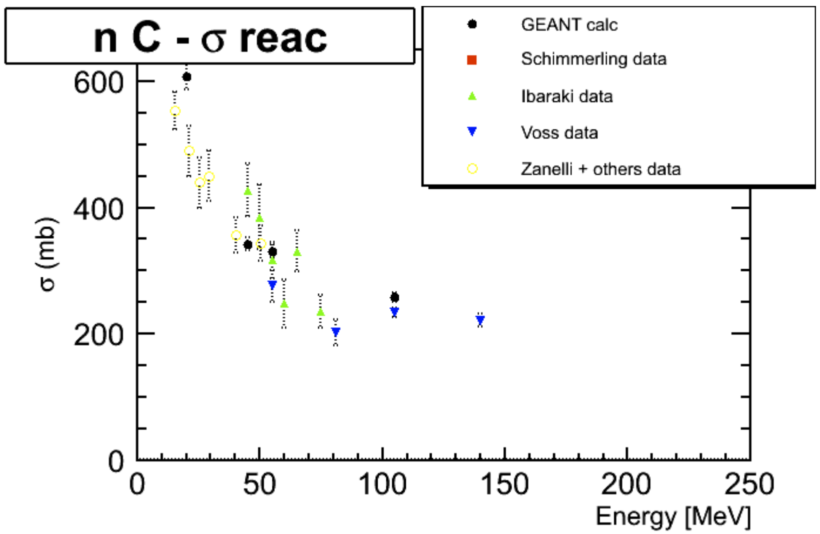
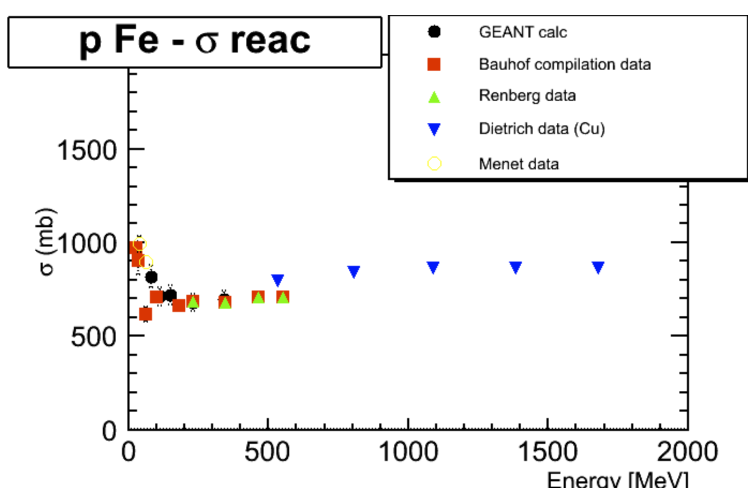
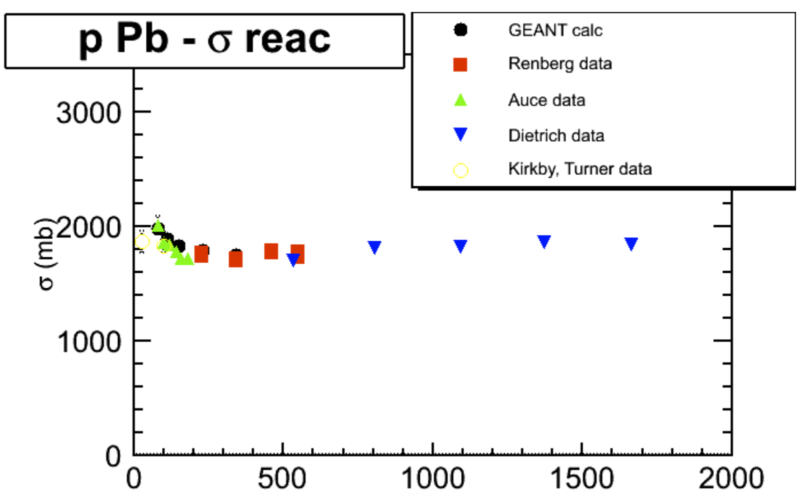
GEANT: QGSP_BERT

Nucleon Total reaction cross sections









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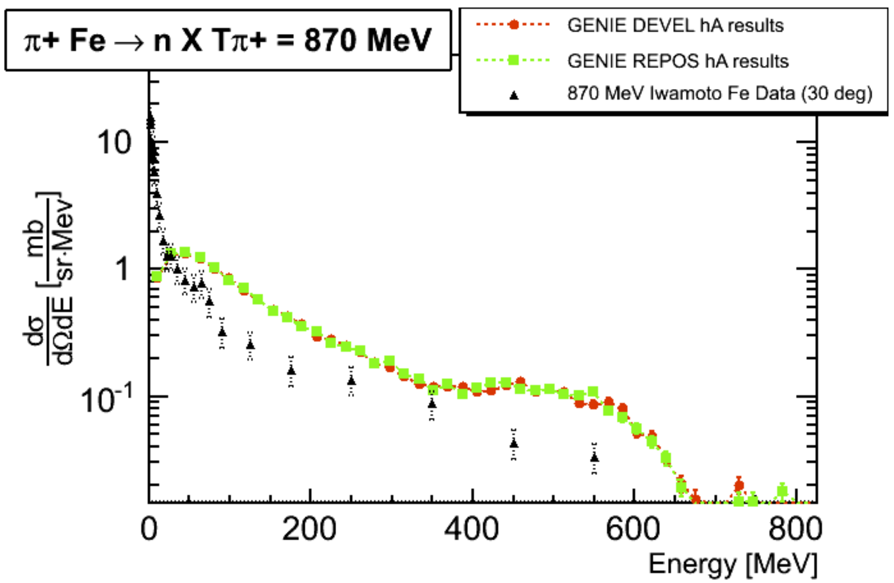
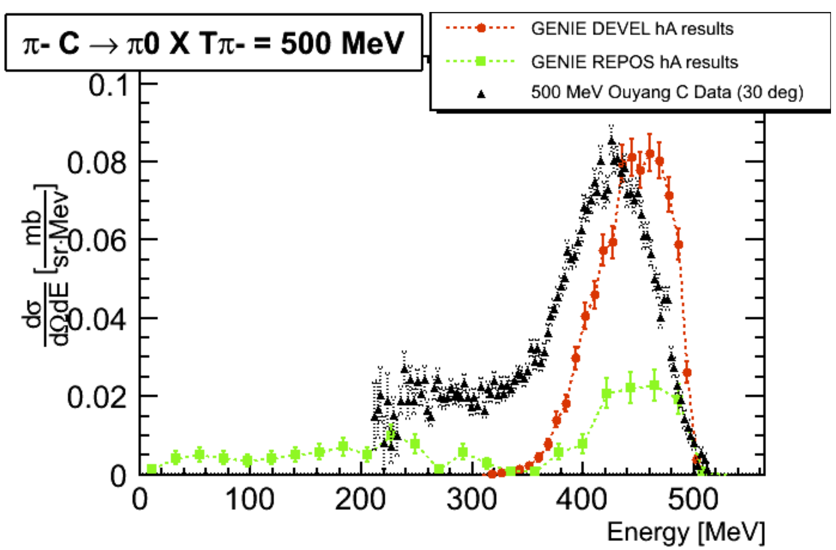
Pions T_π>~500 MeV

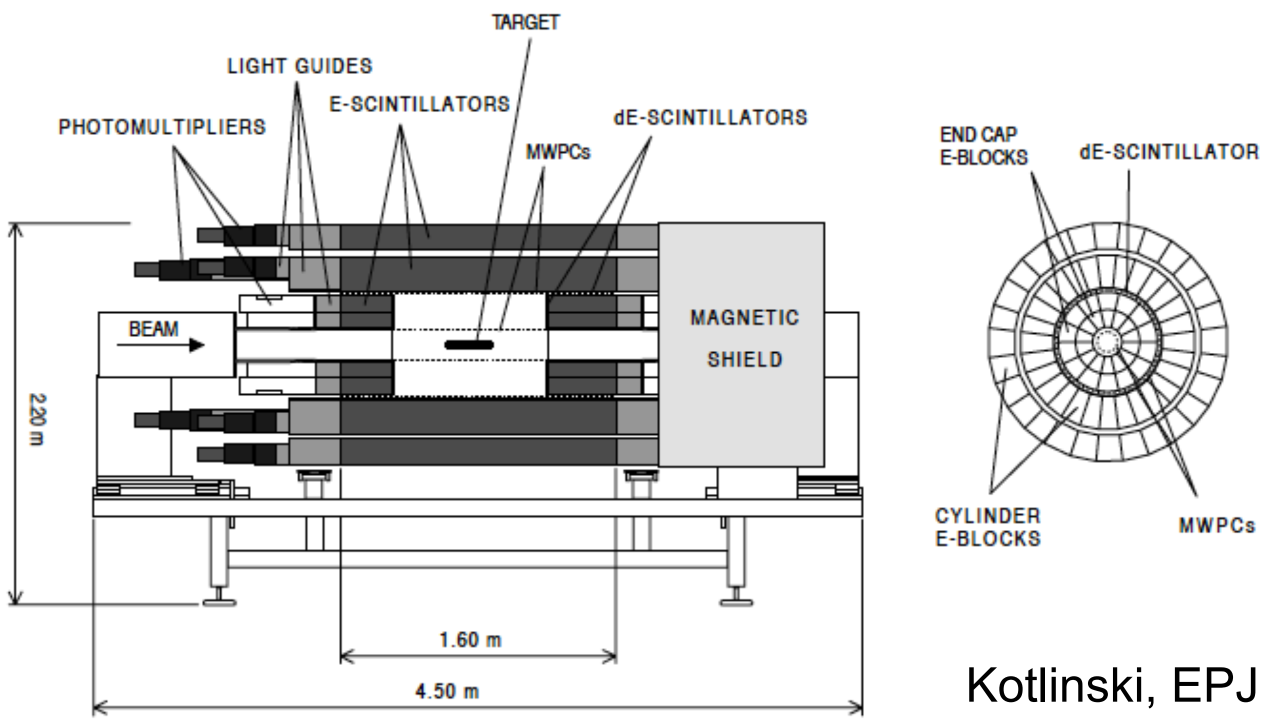
- There is limited data for interactions of pions with T_π> 500MeV for other nuclei
- Not obvious how to extrapolate to Ar





Description of the LADS experiment

LADS was a wire chamber/plastic scintillator experiment covering ~98% of 4π. Experiments studied gas targets (3He, 4He, N, Ar, Xe).



Kotlinski, EPJ 9, 537 (2000)

Fig. 1. Side view and end view of the LADS detector.

LADS pion abs data for Argon

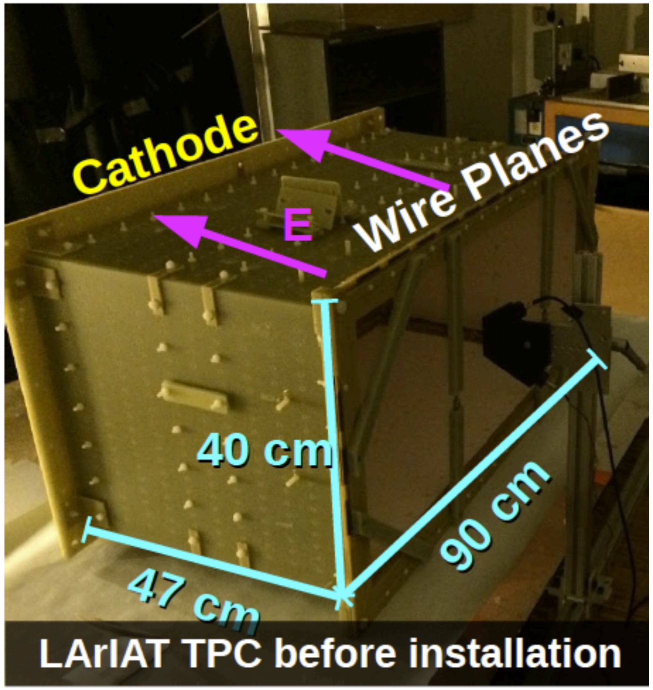
- Lots of data for several energies
- Many possible final states
- Note significant corrections for data below threshold.

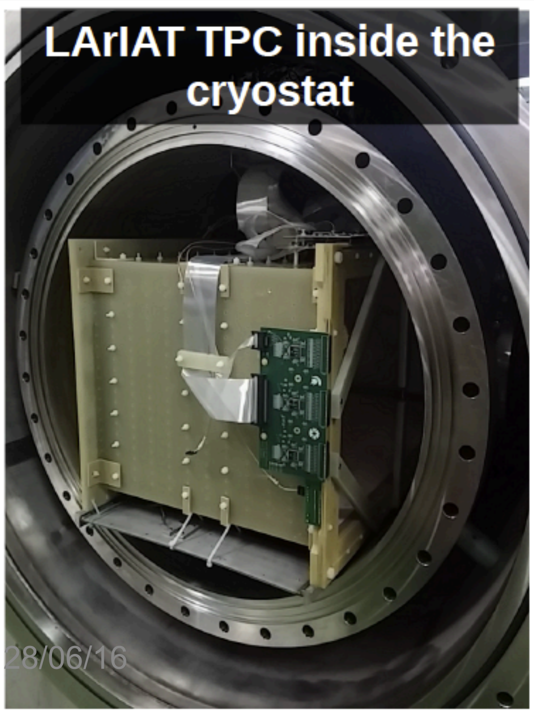
	Raw Data	30 MeV Threshold	Extrapolated to 0 MeV
5p	0.013 ± 0.001	0.04 ± 0.01	0.64 ± 0.13
4p	1.11 ± 0.10	2.0 ± 0.2	5.1 ± 1.0
3p	19.9 ± 1.2	26.8 ± 2.5	28.4 ± 4.0 →
3pn	2.0 ± 0.2	11.9 ± 1.3	33.2 ± 7.5
2p	69.8 ± 4.2	72.9 ± 5.8	43.6 ± 5.2
2p1n	11.9 ± 0.9	62.9 ± 6.6	$75. \pm 10.$
2p2n	0.67 ± 0.05	5.6 ± 1.0	$21. \pm 8.$
2pd	9.2 ± 1.0	10.3 ± 1.2	7.9 ± 1.4
pd	14.6 ± 2.3	9.8 ± 1.7	4.2 ± 1.0
pdn	3.0 ± 0.4	13.8 ± 2.4	10.6 ± 2.5

Table 4. Error contributions (in mb) to the Ar(π^+,3p) pion absorption reaction cross-section. See text for the row label explanation.

	T_π (MeV)				
	70	118	162	239	330
Statistical	0.12	0.09	0.08	0.05	0.02
Normalisation	2.35	3.9	3.6	1.5	1.0
Fit	0.56	0.18	0.16	0.06	0.03
MC model	1.76	5.3	7.1	3.4	1.6
Excitation energy	1.88	4.6	6.2	1.1	1.8
SCX subtraction	0.11	0.35	0.47	0.28	0.15
Pion contamination	0.22	0.71	0.94	0.56	0.30
PID mis-identification	0.18	0.59	0.52	0.40	0.22
Final error	3.6	8.1	10.	4.0	2.6
Cross-section	11.8	35.3	47.	28.4	14.5

Eur. Phys. J. A 9, 537–552 (2000)

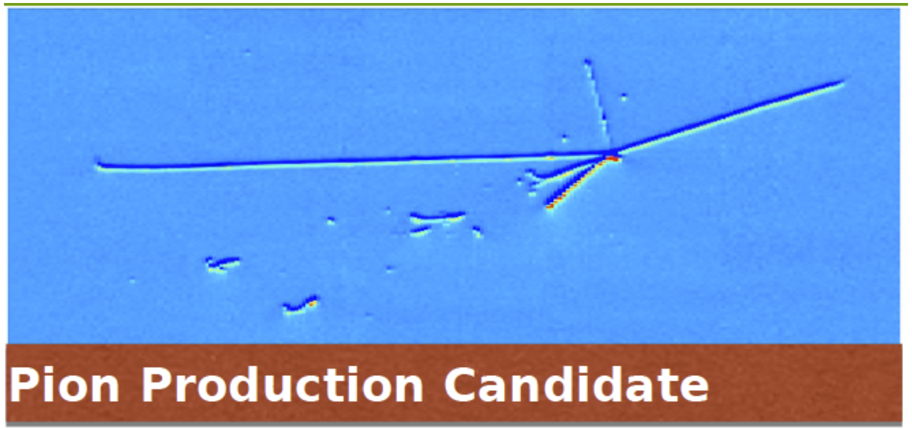


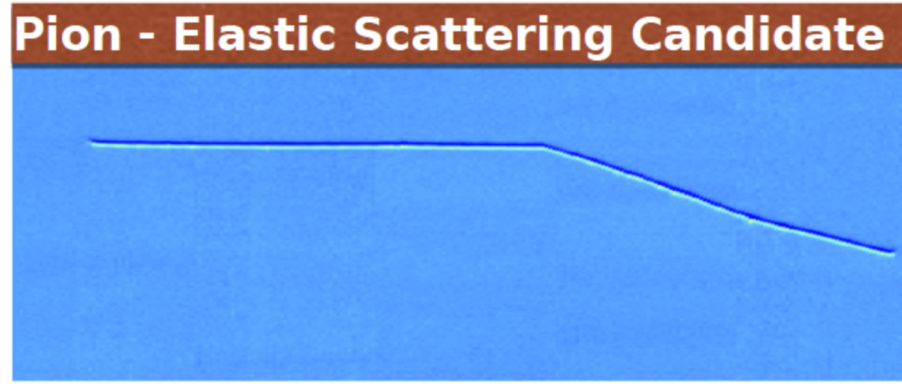


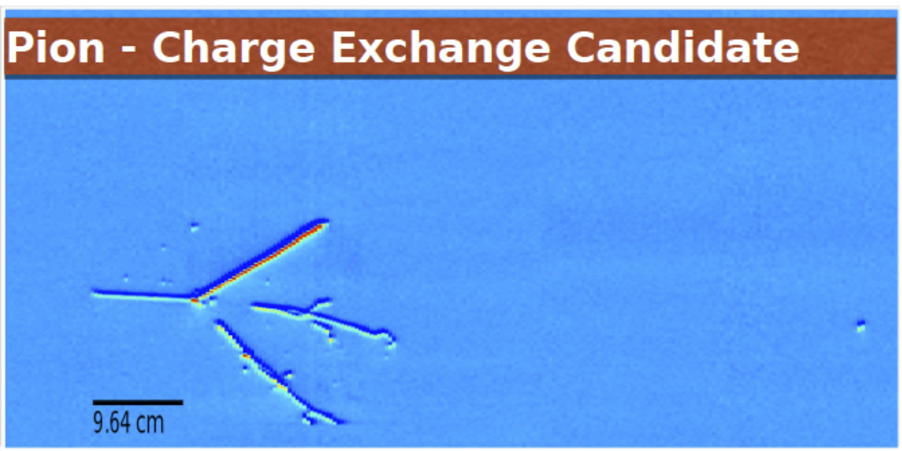
LArIAT

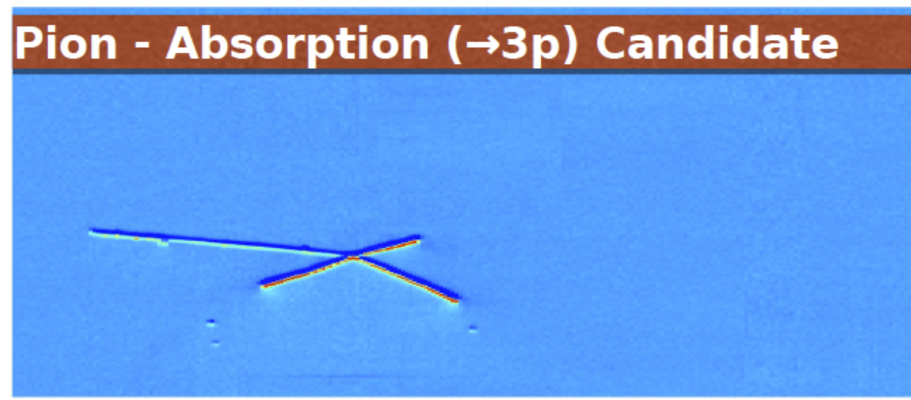
- LArIAT is small 0.25 tons of Ar LArTPC designed for calibrating detector response in a charged particle beam
- Physics Goals
  - Hadron-Ar interaction cross sections
  - Study of nuclear effects in Ar
  - e/γ shower identification
  - Particle sign determination in the absence of a magnetic field, utilizing topology e.g. decay vs capture
  - Geant4 validation
- R&D programme

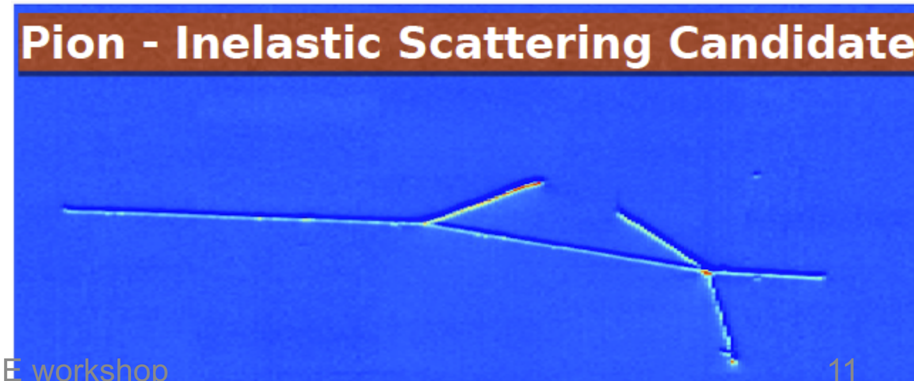
Topologies for pion interactions from LArIAT data







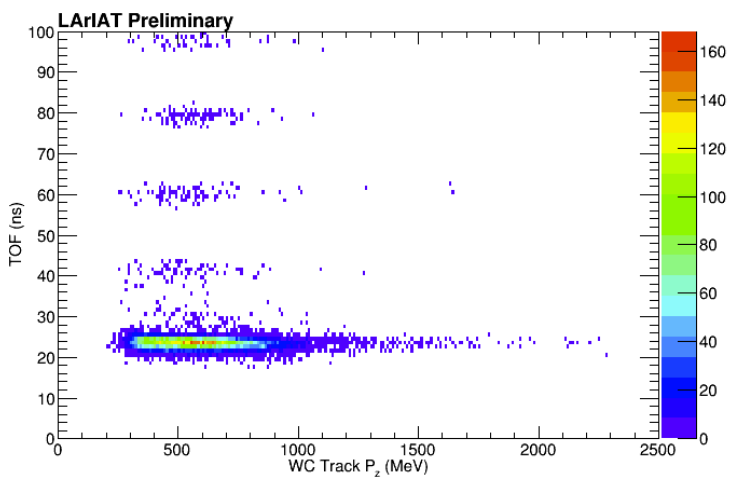


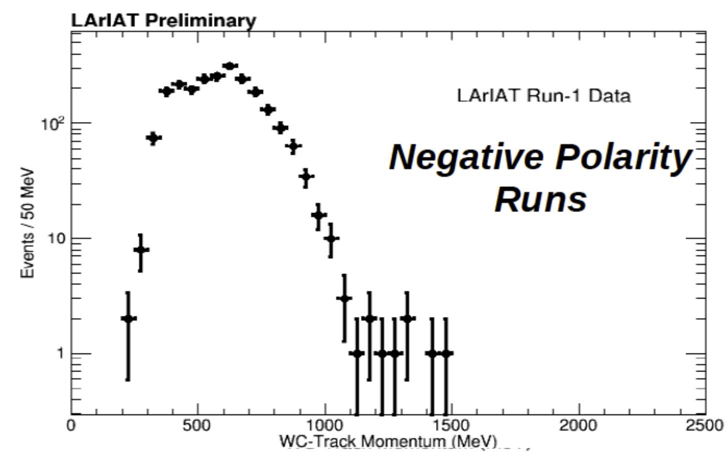


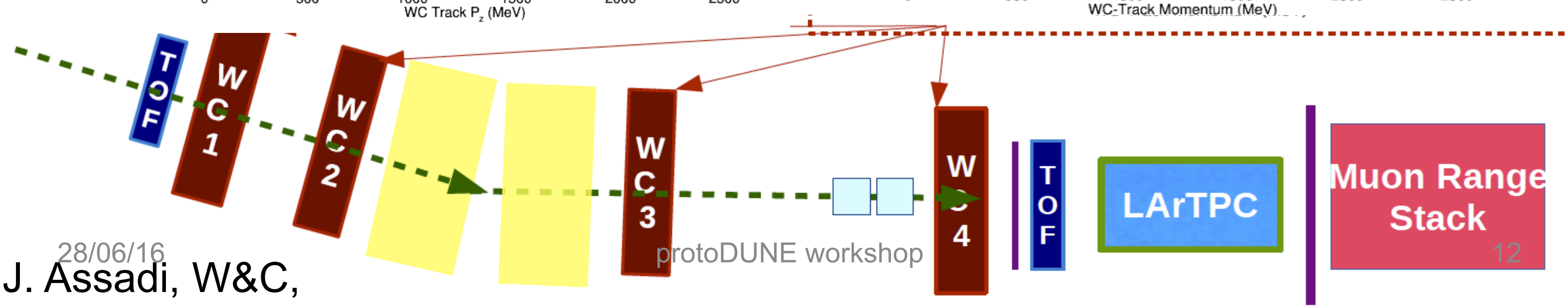
J. Assadi, W&C,

Pion energy measurement

- The beamline instrumentations is used to
  - measure momentum of the pions (Wire Chambers)
  - separate particle types (ToF and Muon Range Stack)
  - Remove halo events by matching WC and TPC tracks



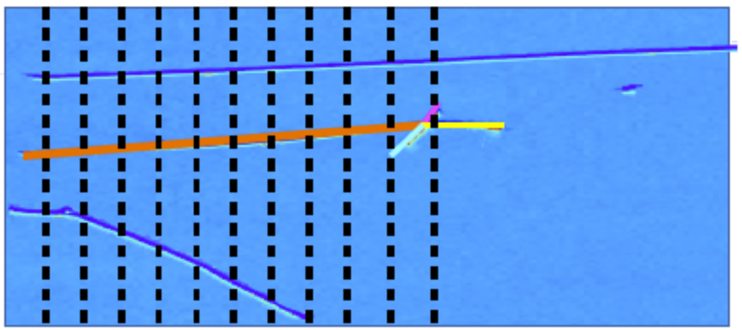


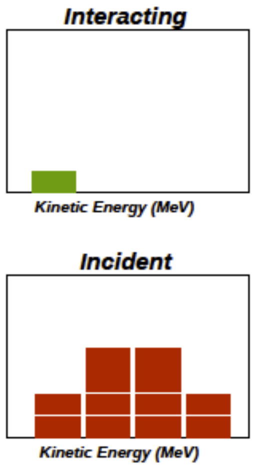


LArIAT analysis

- For each wire chamber track (with an initial kinetic energy) matched to a TPC track, they follow that TPC track in slices
  - The slice represents the distance between each 3D point in the track
  - For each slice they ask: “Is this the end of the track?”
    - NO: Calculate the kinetic energy at this point and put that in our “non-interacting” histogram
    - Yes: Calculate the kinetic energy at this point and put that in our “interacting” histogram
    - This is kinetic energy is put in both the interacting and incident histograms

$$KE_{Interaction} = KE_i - \sum_{i=0}^{nSpts} dE/dX_i \times Pitch_i$$





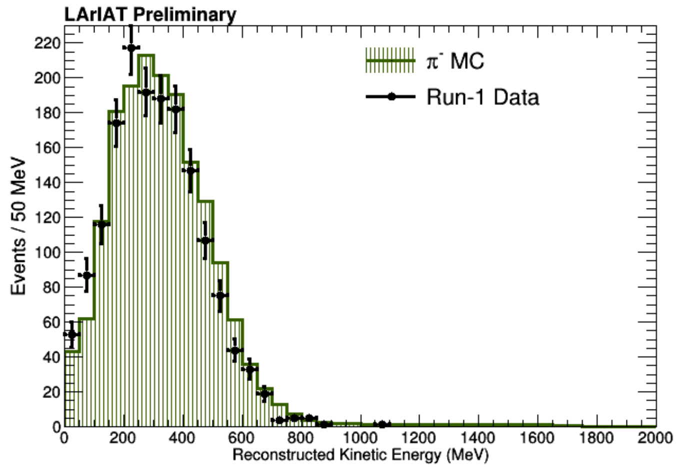
LArIAT analysis

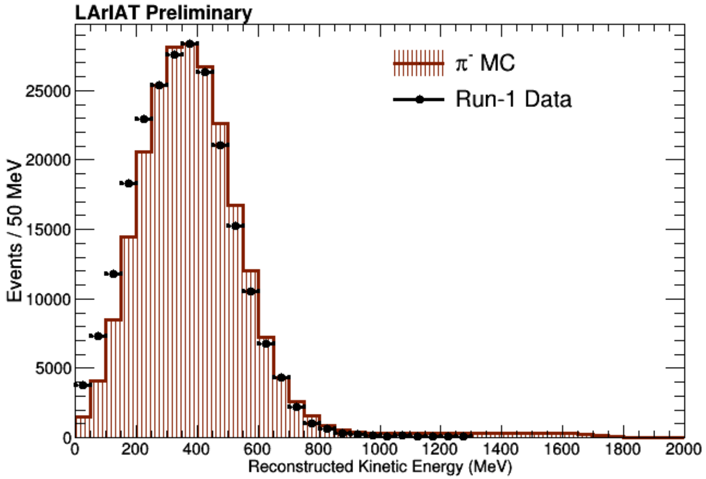
$$\sigma(E) \approx \frac{1}{nz} P_{\text{Interacting}} = \frac{1}{nz} \frac{N_{\text{interacting}}}{N_{\text{Incident}}}$$

- z is the depth of the slab and n is the density

- NB: Cross section still contains capture and decay processes.

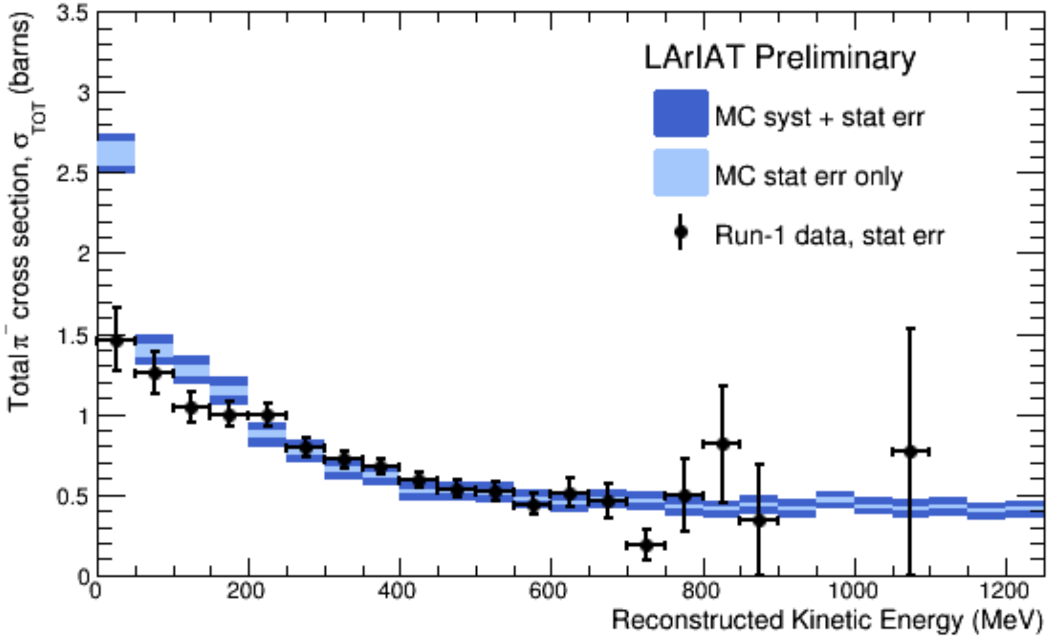
- There is work being done to utilize in situ approach as well as MC to estimate the relative fraction of abs/decay to remove this from our sample





Total π-Ar Cross-Section from LArIAT

- The first cross section results for LAr
- The first cross section for T > 400 MeV



Systematics Considered Here
dE/dx Calibration: 5%
Energy Loss Prior to entering the TPC: 3.5%
Through Going Muon Contamination: 3%
Wire Chamber Momentum Uncertainty: 3%

About 7% systematics error

Not official err, but
my estimation!!!

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Summary and action items for the workshop

- Precise cross section measurements are difficult due to complicated final states
- Systematic uncertainties from previous experiments are high and difficult to apply for Ar – usually we overestimate them
- During the workshop we need to start analysis of the pion/kaon scattering following LArIAT example with focus on the beamline instrumentation requirements