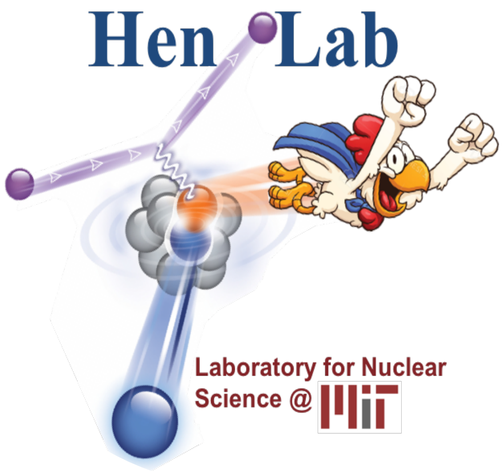
SRC Probe Universality with ρ^- Photoproduction

Jackson Pybus



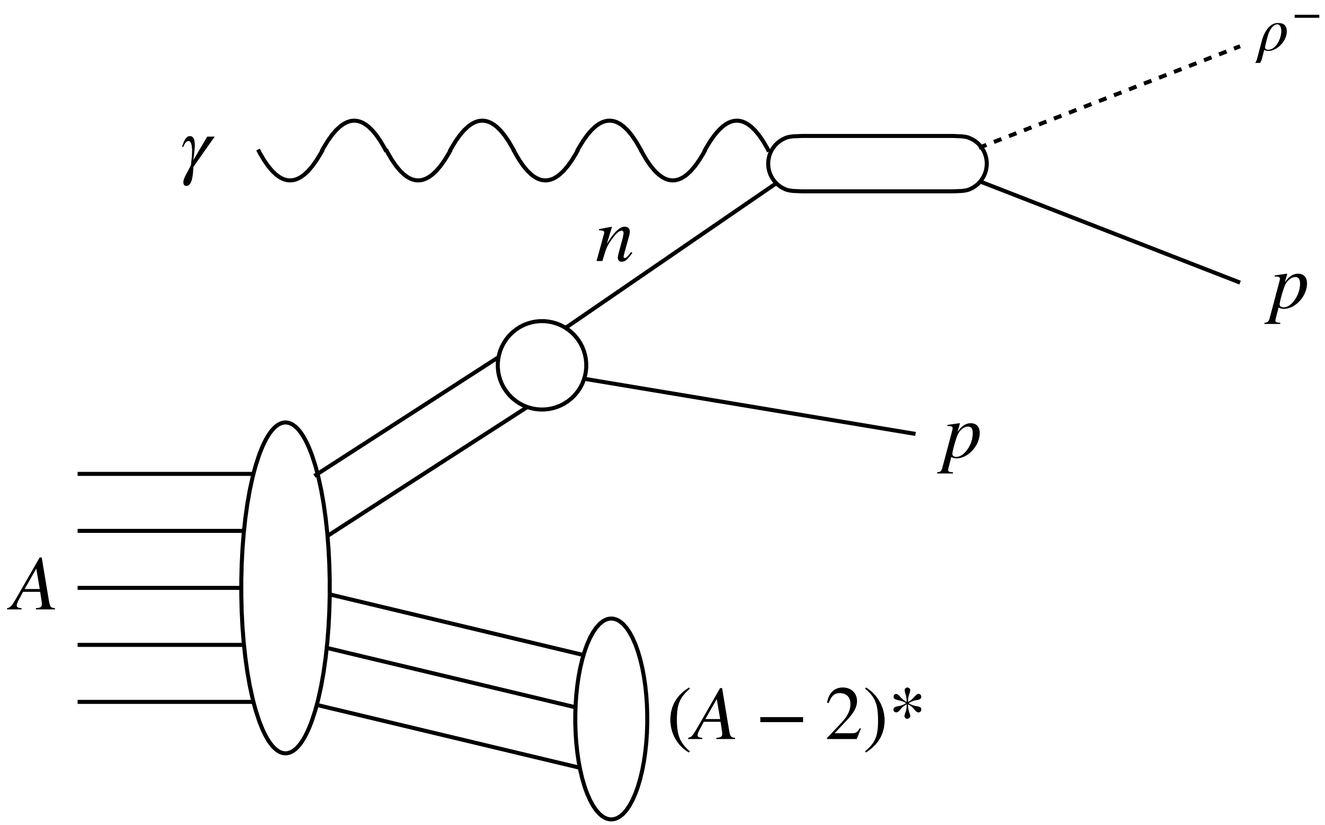
Objectives and Motivation

- Establish the observation of nuclear Short-Range Correlations via meson photoproduction from correlated nucleons

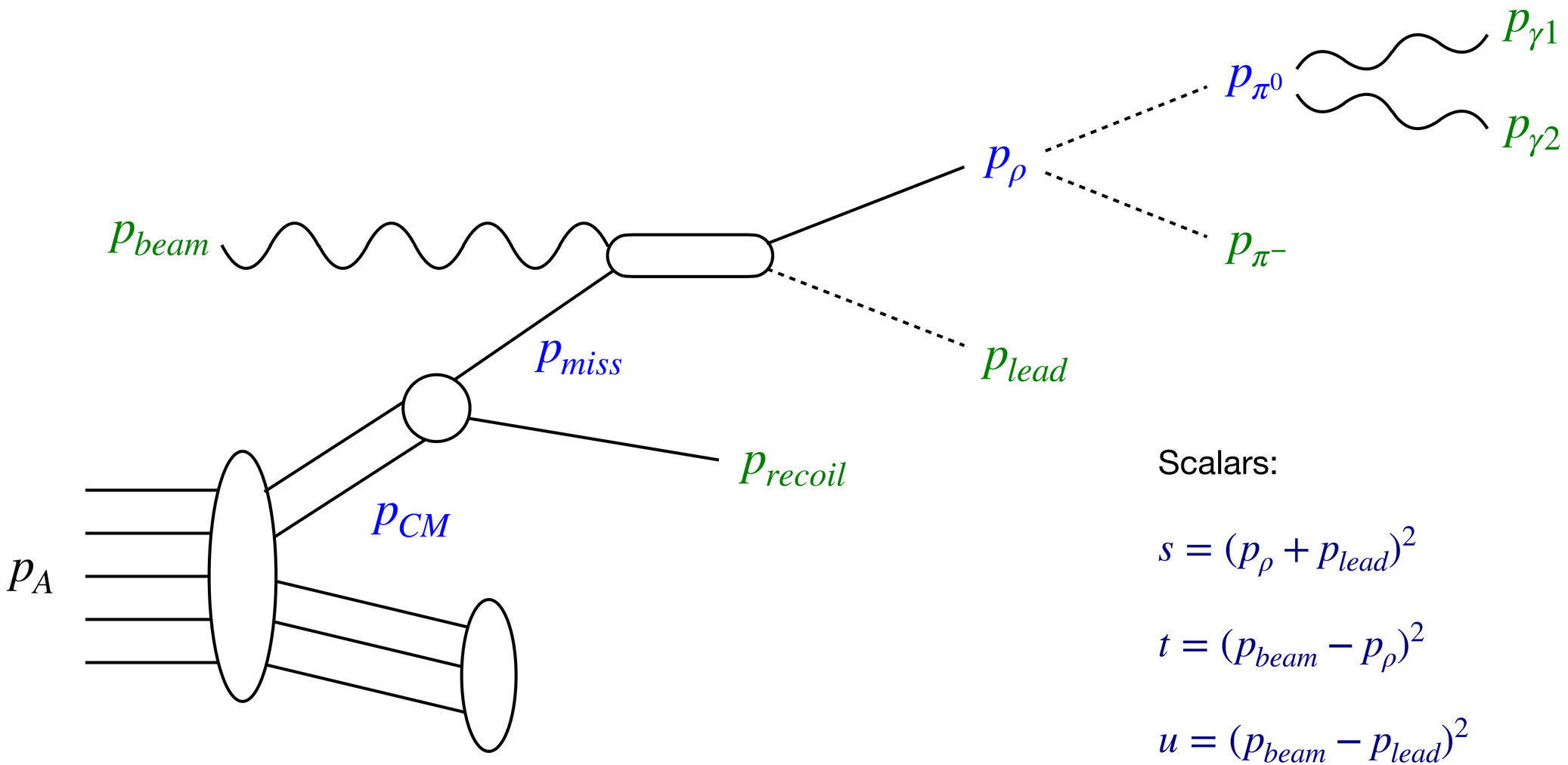
- Characterize the level of agreement between the measured data and predictions of the factorized Generalized Contact Formalism model

Clean SRC Channel: A($\gamma, \rho^- pp$)

- Vertex interaction $\gamma n \rightarrow \rho^- p$ from correlated neutron
  - Decay $\rho^- \rightarrow \pi^- \pi^0$, $\pi^0 \rightarrow \gamma\gamma$
- Final-state measures 2 positive charged tracks, 1 negative charged track, 2 “neutral” showers
- Resolution improved by kinematic fitting:
  - Common vertex
  - $(p_{\gamma 1} + p_{\gamma 2})^2 = m_{\pi^0}^2$
- Sensitive to abundant proton-neutron pairs



Measured Quantities



Scalars:

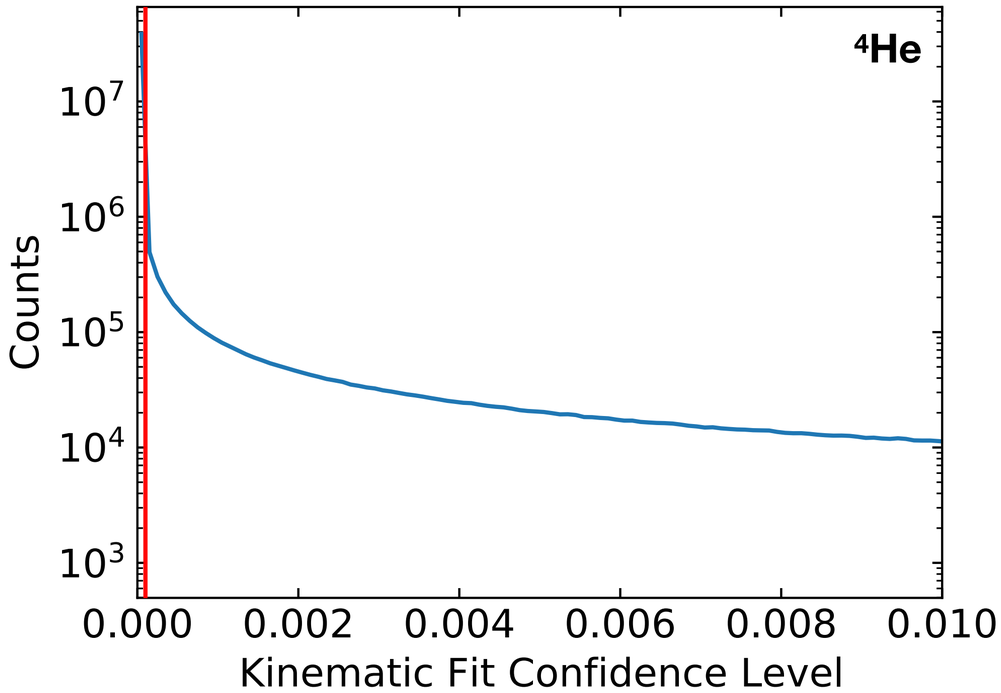
$s = (p_\rho + p_{lead})^2$

$t = (p_{beam} - p_\rho)^2$

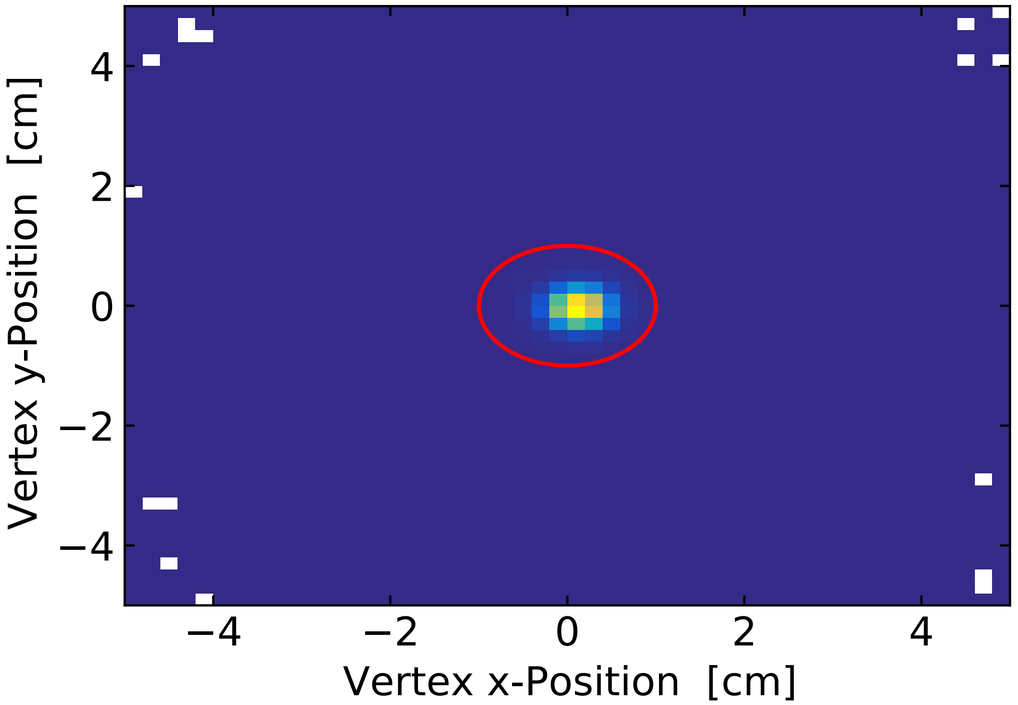
$u = (p_{beam} - p_{lead})^2$

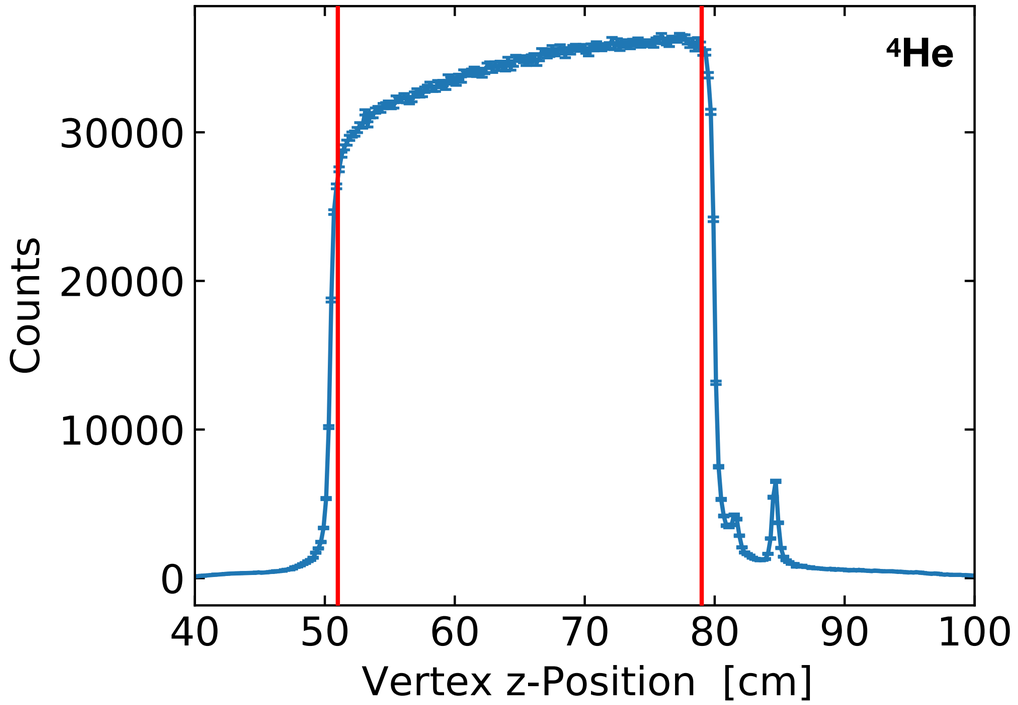
Event Selection Cuts

- Basic selection criteria
  - 2 positive tracks
  - 1 negative track
  - 2 neutral (photon) showers
  - No extra particles
- **Very loose cut on Kinematic Fit Confidence Level > 0.0001**
- Basic dE/dx and timing PID cuts applied



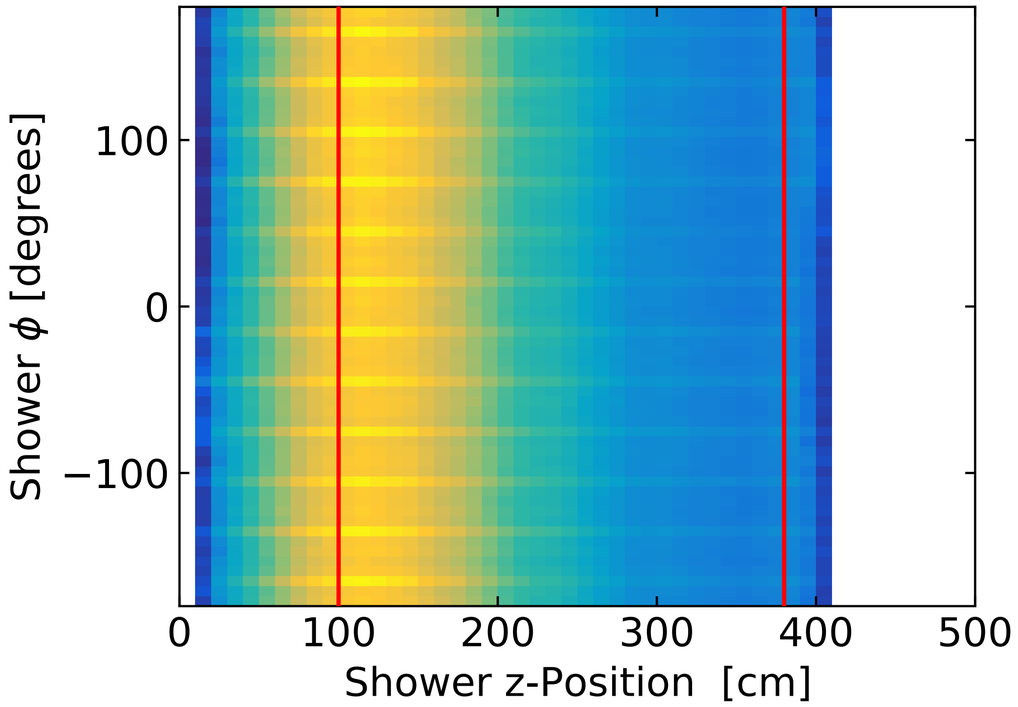
Vertex Cuts


Vertex y-Position [cm]
Vertex x-Position [cm]
4
2
0
−2
−4
−4
−2
0
2
4

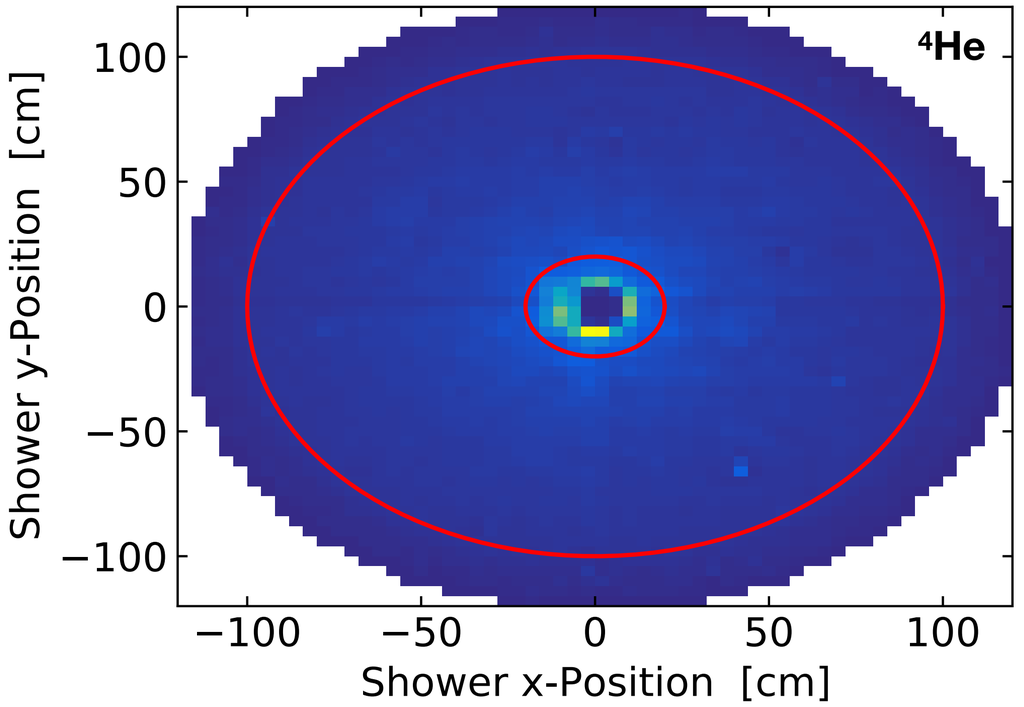

^{4}He
Counts
Vertex z-Position [cm]
30000
20000
10000
0
40
50
60
70
80
90
100

Calorimeter Shower Position Cuts

Barrel Calorimeter

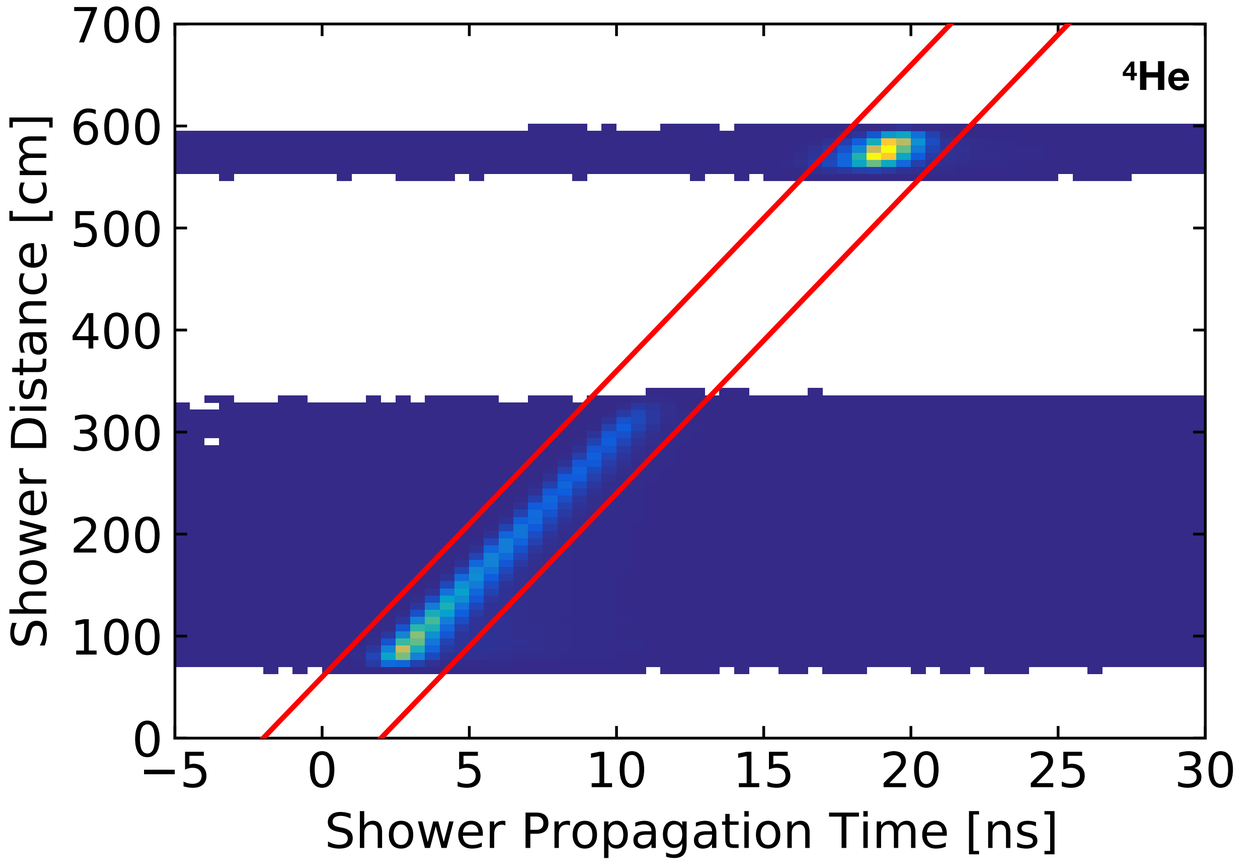


Forward Calorimeter



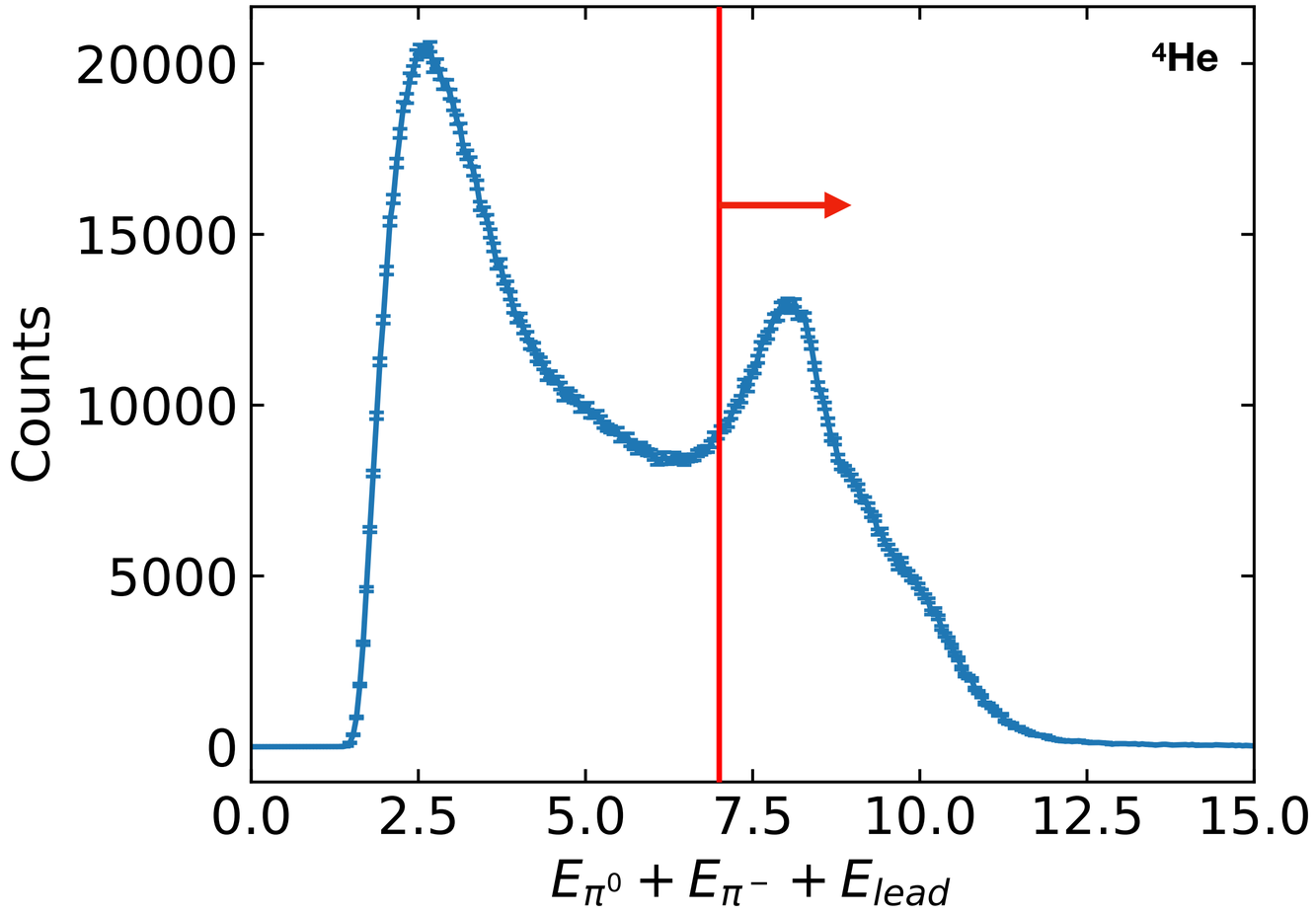
Calorimeter Timing

- Final-state selection
- CL cut
- PID cuts
- Shower position cuts
- **Shower timing within 2 ns of** d/c

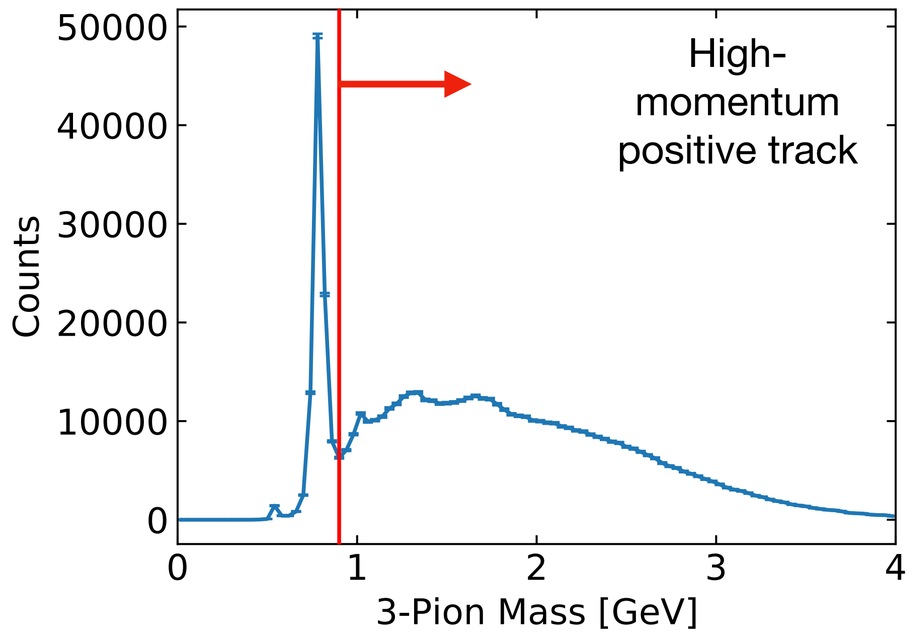


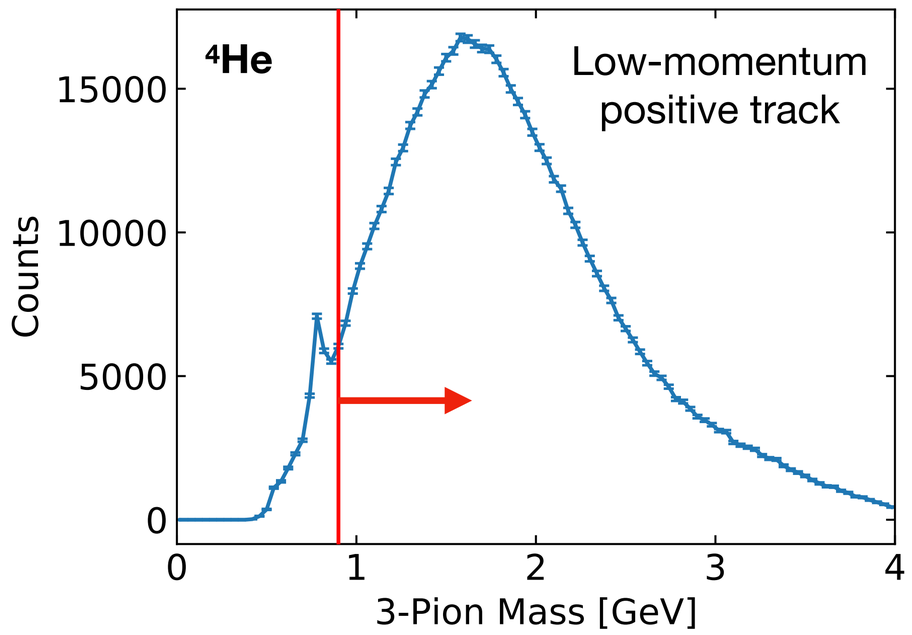
Leading Particle Energy

- Final-state selection
- CL cut
- PID cuts
- Shower position cuts
- Shower timing cuts
- **Leading particle energy > 7 GeV**



$\omega \rightarrow \pi^+\pi^-\pi^0$ Background Cut





Positive track may be misidentified π^+

Invariant mass can be recalculated assuming different mass of positive particle

Defining some analysis variables

- Longitudinal momentum poorly measured
  - "Minus" component $p^- = E - p_Z$
  - Linear combination cancels resolution effects
- Transverse components of momentum well-measured
- Light-cone fraction $\alpha = \dfrac{p^-}{m_A/A}$ denotes fraction of "minus" momentum carried by nucleon, normalized to A
- For SRCs we expect $\alpha_{CM} \sim 2$; the pair carries $2/A$ of the minus-momentum of the nucleus

Defining some analysis variables

- “Proxy” for missing momentum can be defined by assuming breakup of a standing pair, and calculating the momentum using the well-measured components:

$$p_{miss} = p_{\pi^0} + p_{\pi^-} + p_{lead} - p_{beam}$$

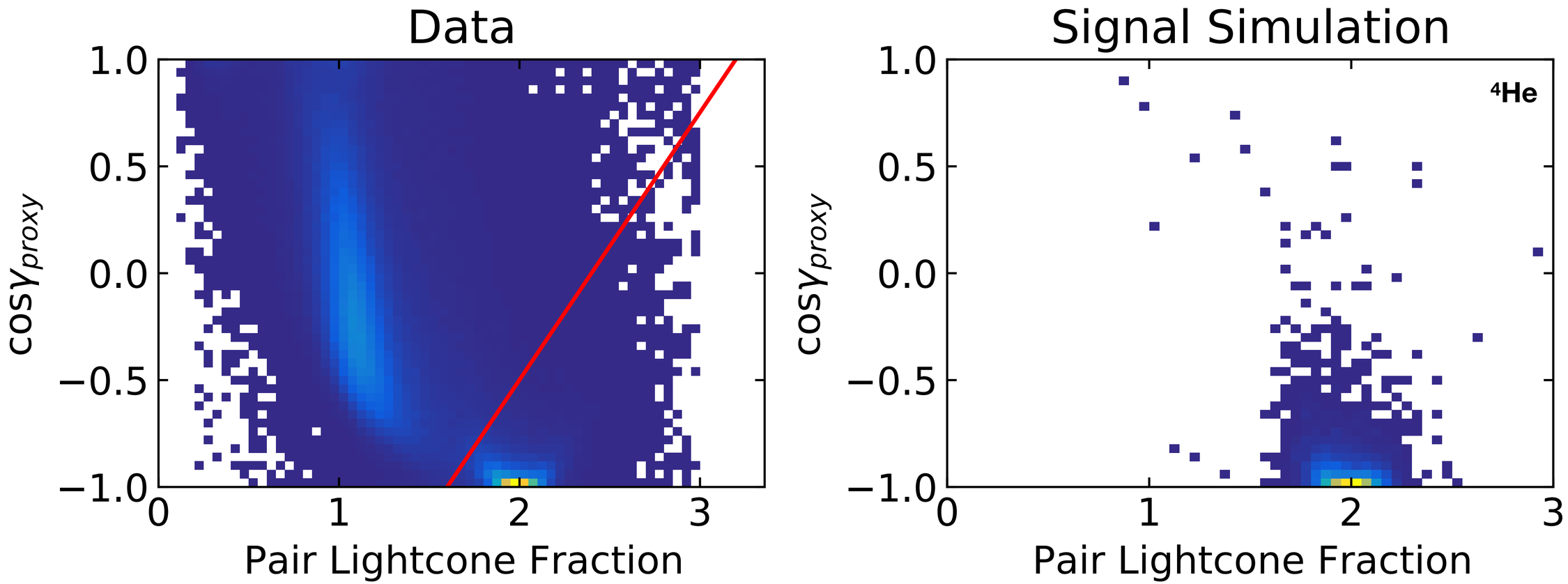
$$p^{+}_{proxy} = 2m_N - \frac{m_N^2 + p^2_{miss,\perp}}{2m_N - p^{-}_{miss}}$$

$$p_{proxy,z} = \frac{1}{2}\left(p^{+}_{proxy} - p^{-}_{miss}\right)$$

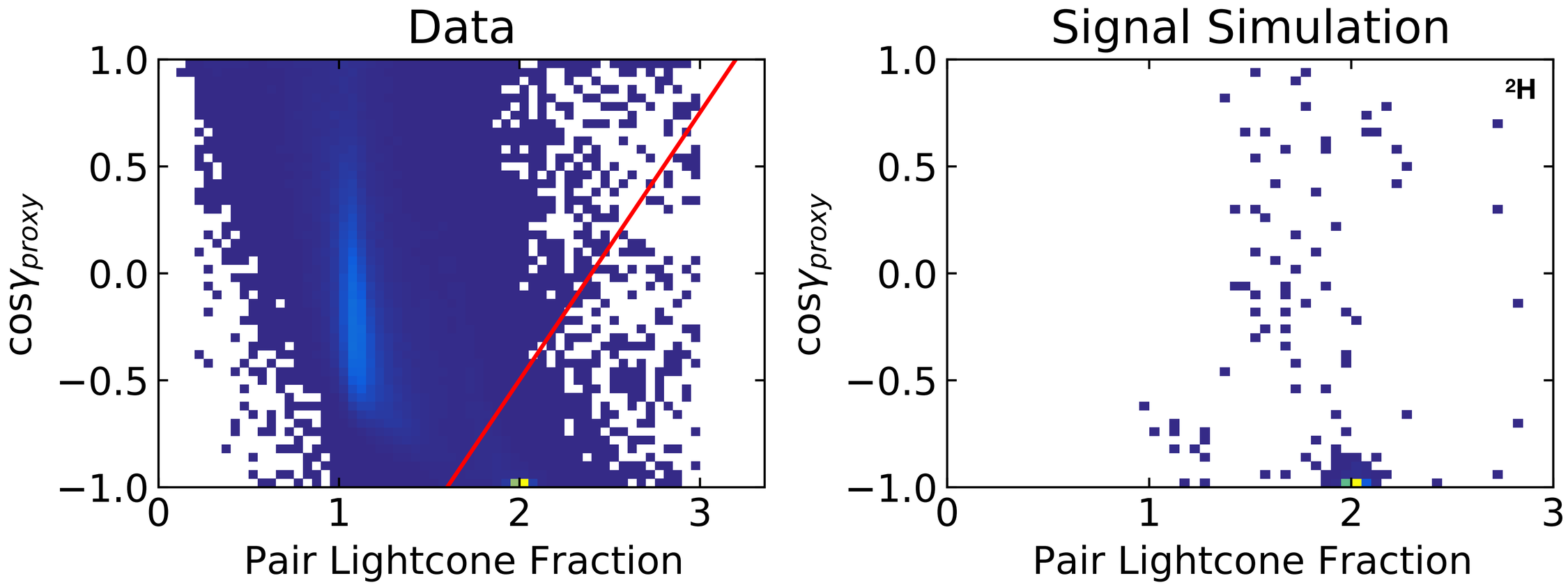
- “Proxy” momentum vector can be used to calculate pair opening angle $\cos\gamma_{proxy}$

- For SRCs we expect the pair back-to-back, with $\cos\gamma \sim -1$

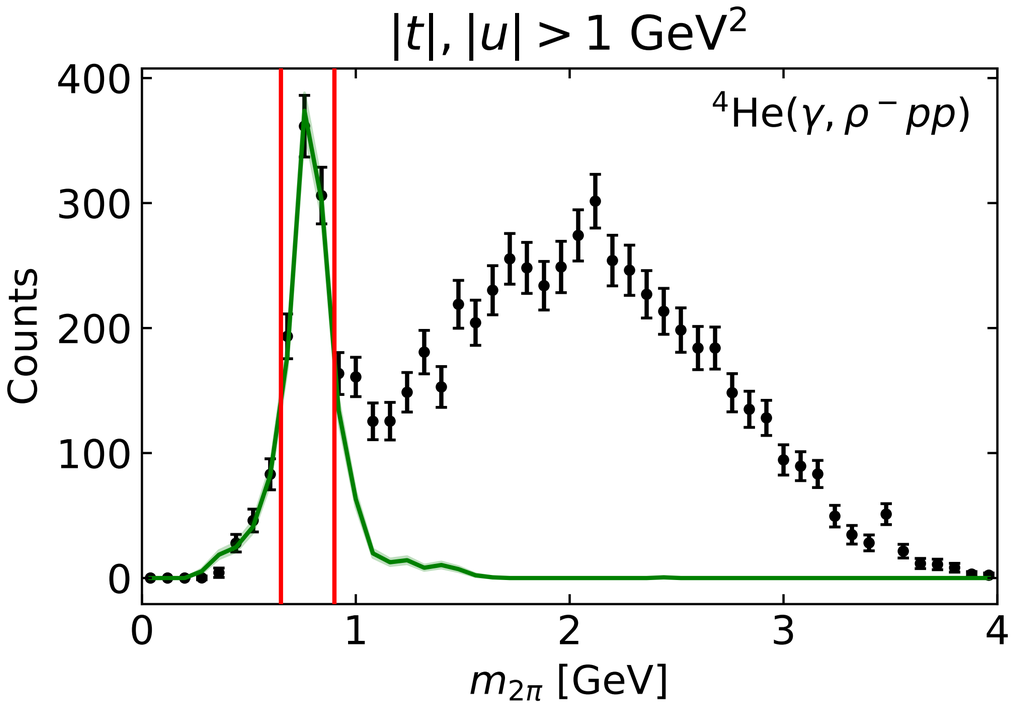
SRC signal localized with $\alpha_{CM} \sim 2$, back-to-back

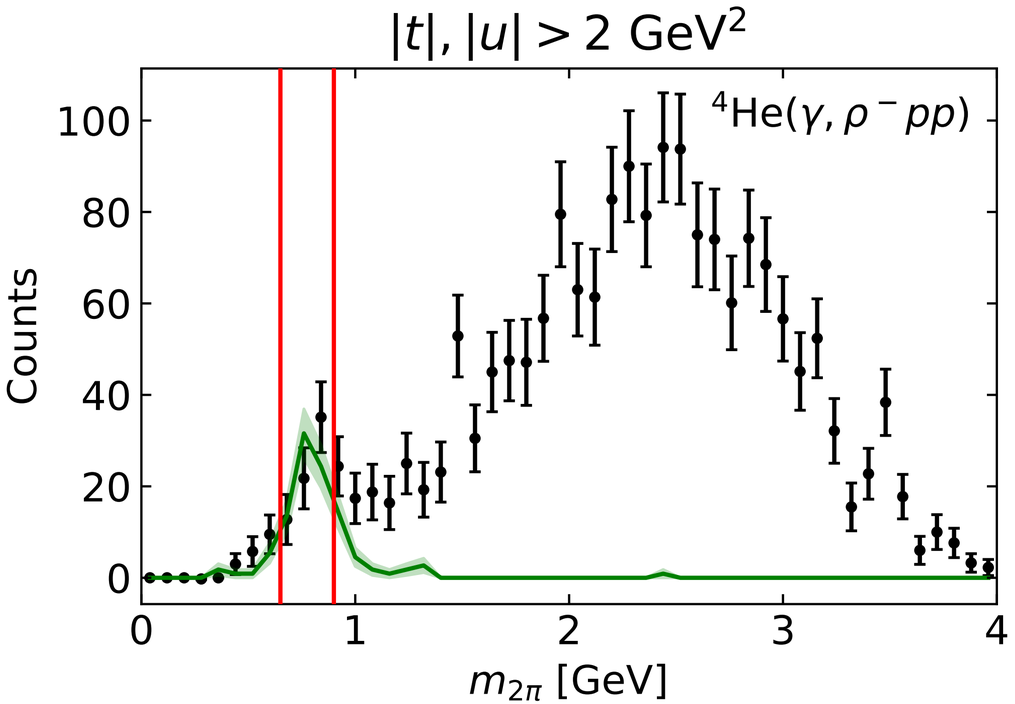


Signal more contained in deuterium



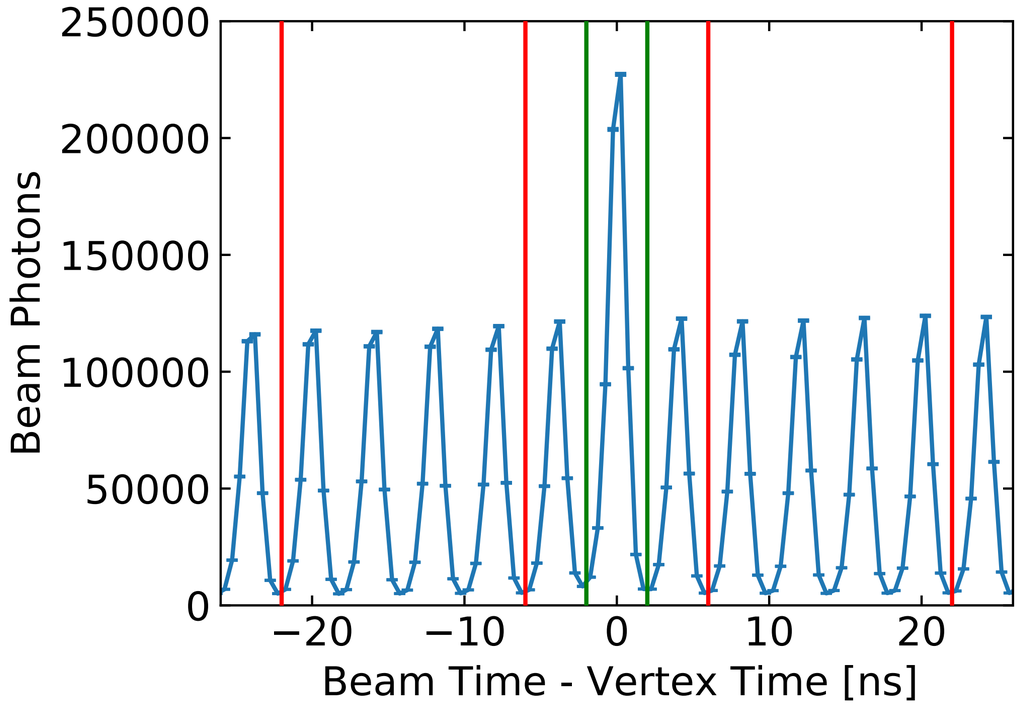
Cut on ρ^- meson mass



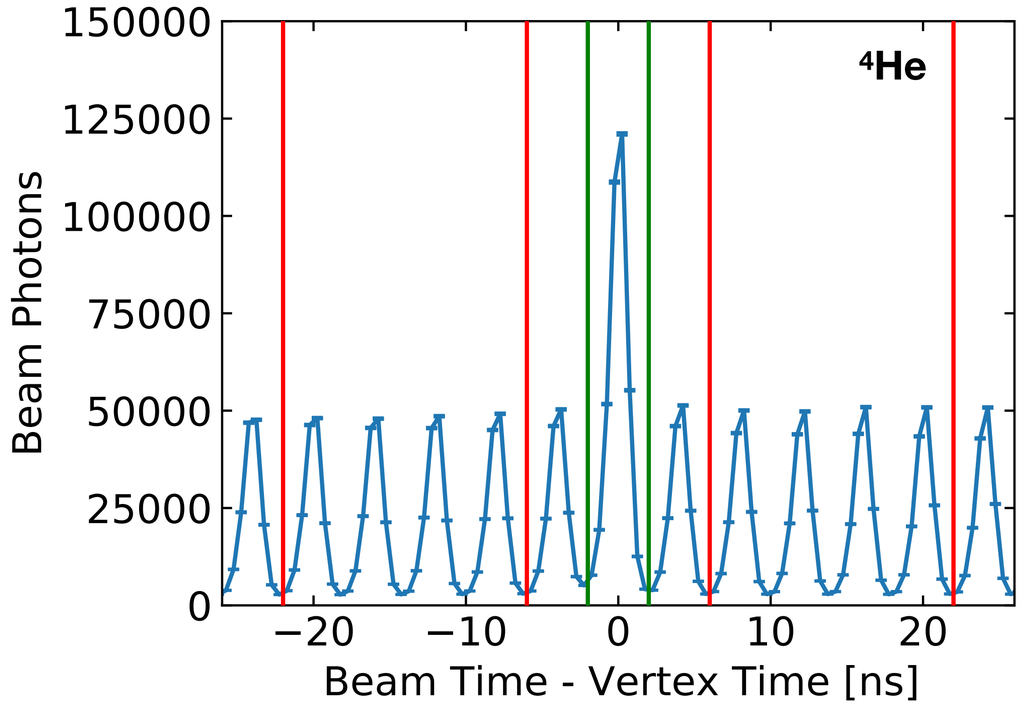


Incorporating photon information requires accidental subtraction

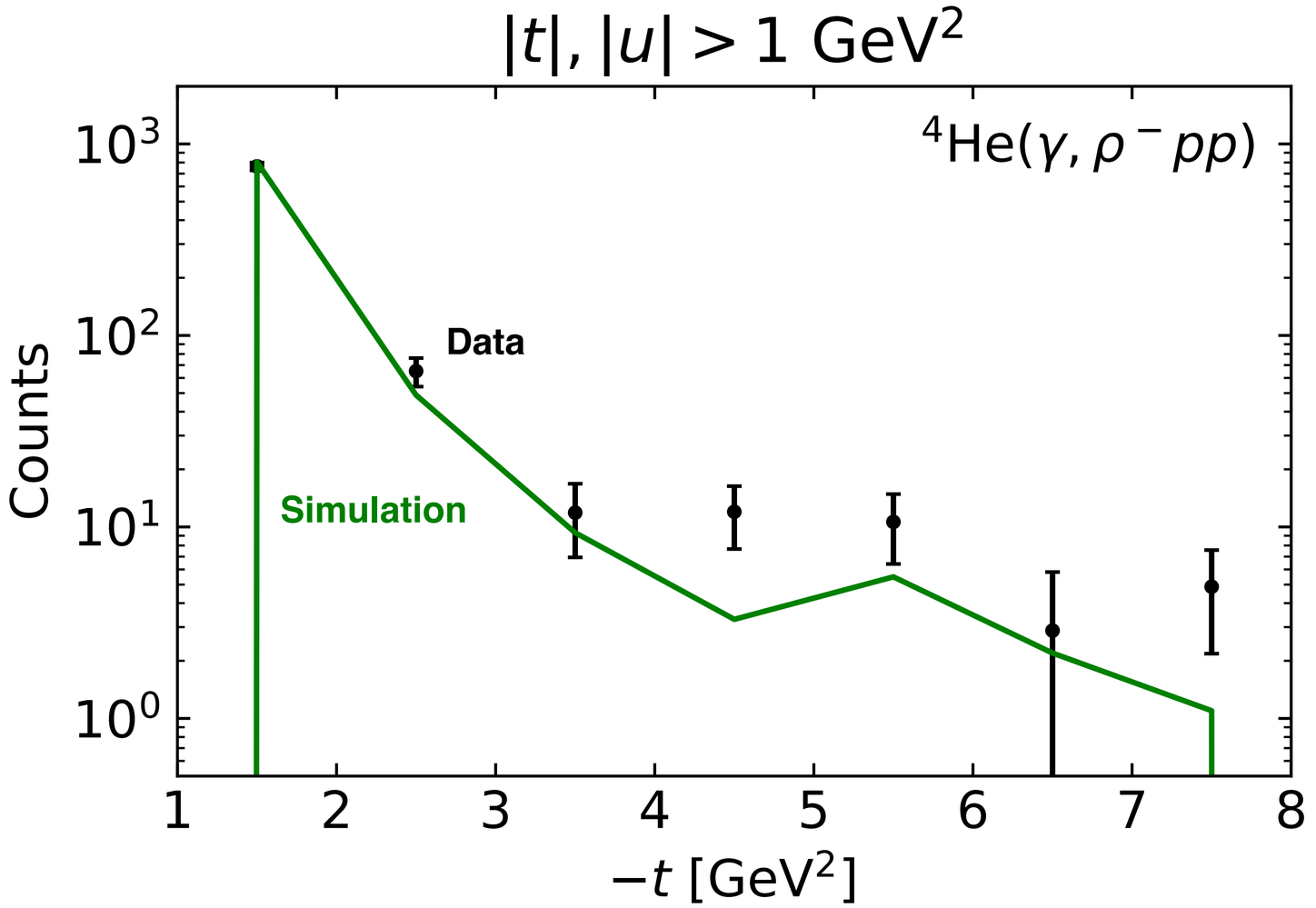
All Beam Photons $E_{beam} > 6$ GeV



Beam Photons $E_{beam} > 6$ GeV and
$|E_{beam} + 2m_N - E_{\pi^0} - E_{\pi^-} - E_{lead} - E_{rec}| < 1$ GeV



Cut requiring high momentum-transfer $|t|$



“Internal” missing momentum k_{miss}

- “Internal” momentum defined in Frankfurt & Strikman 1981 Phys Rep.

$$k = \sqrt{\frac{m^2 + k_\perp^2}{\alpha(2-\alpha)} - m^2} \qquad \alpha = 1 + k_3/\sqrt{m^2 + k^2}\,.$$

- In the light-front deuteron model this variable controls the magnitude of the NN interaction between the nucleons

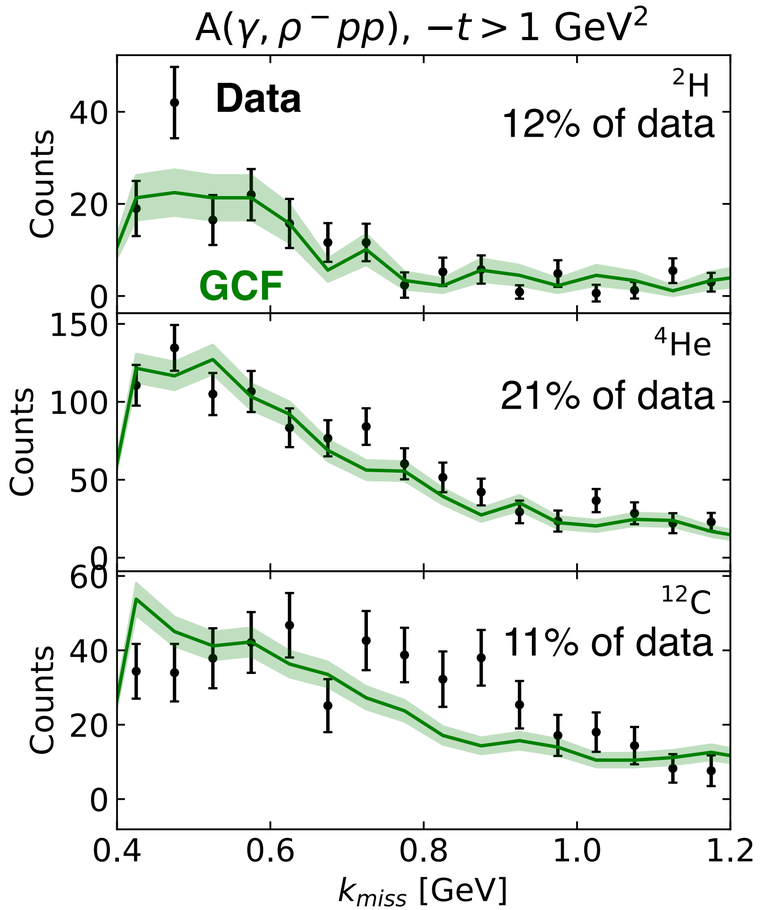
“Internal” missing momentum k_{miss}

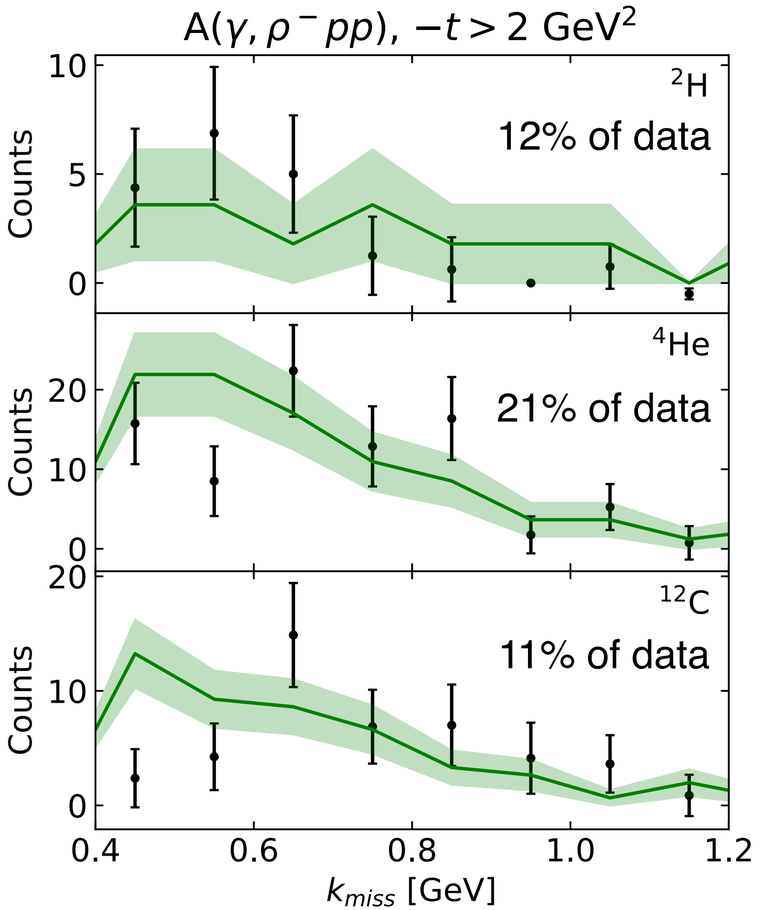
- Internal momentum can be calculated assuming a standing pair approximation, defining k_{miss}:

$$k_{miss} = m_N \sqrt{\frac{m_N^2 + p_{miss,\perp}^2}{p_{miss}^- \left(2m_N - p_{miss}^-\right)} - 1}$$

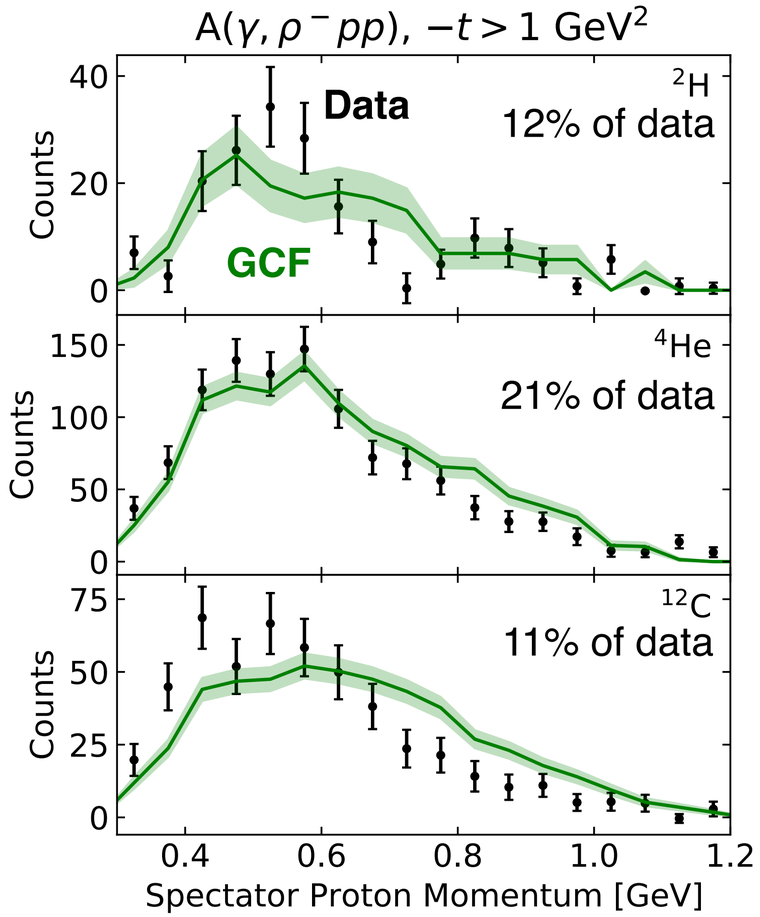
- This variable can be calculated using only quantities well-measured in the GlueX detector

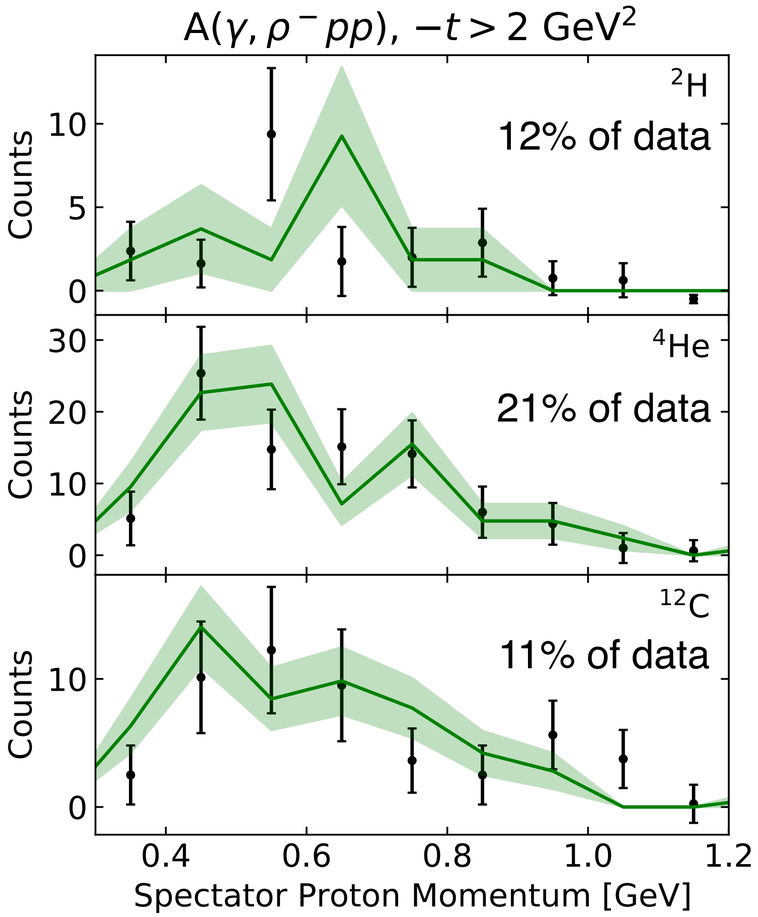
“Internal” missing momentum k_{miss}



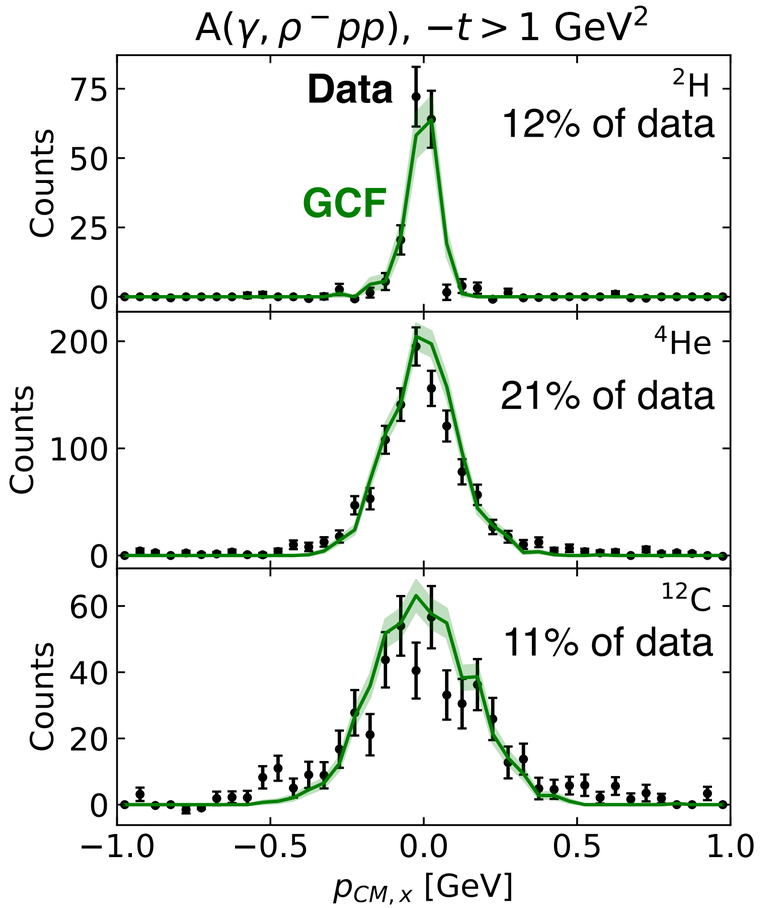


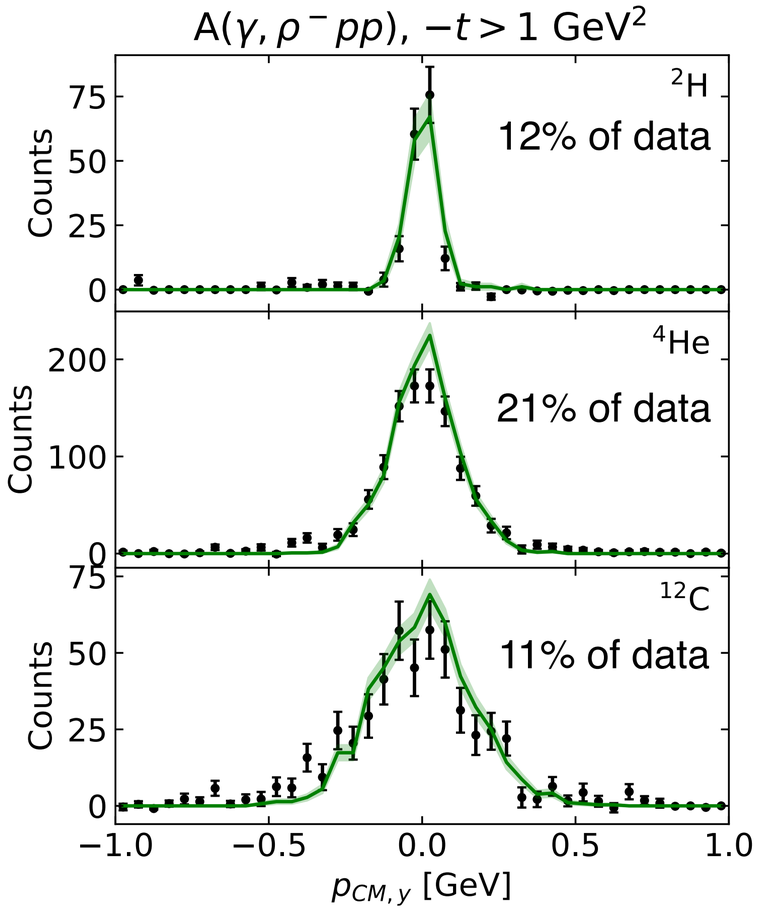
Recoil proton momentum



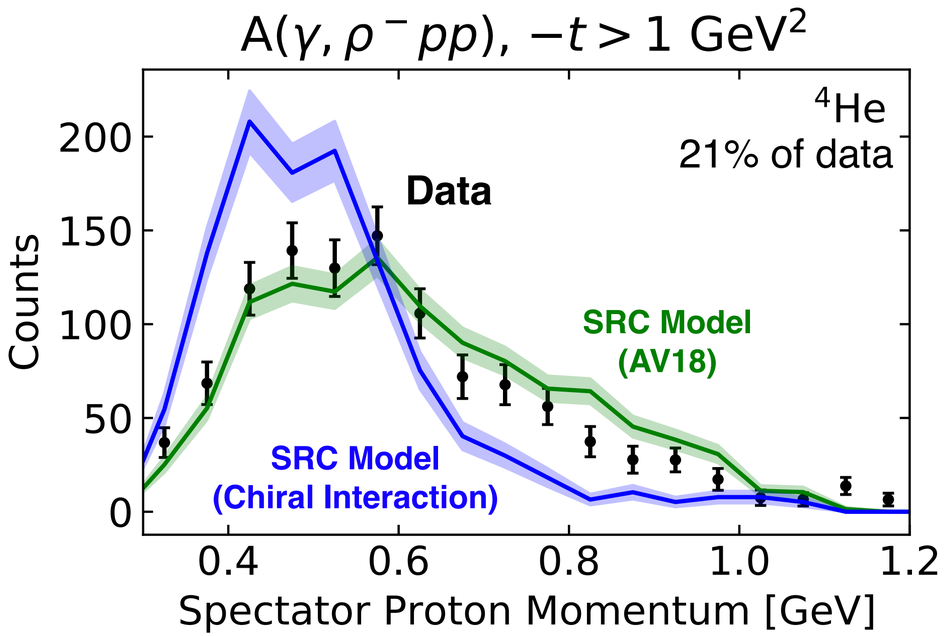


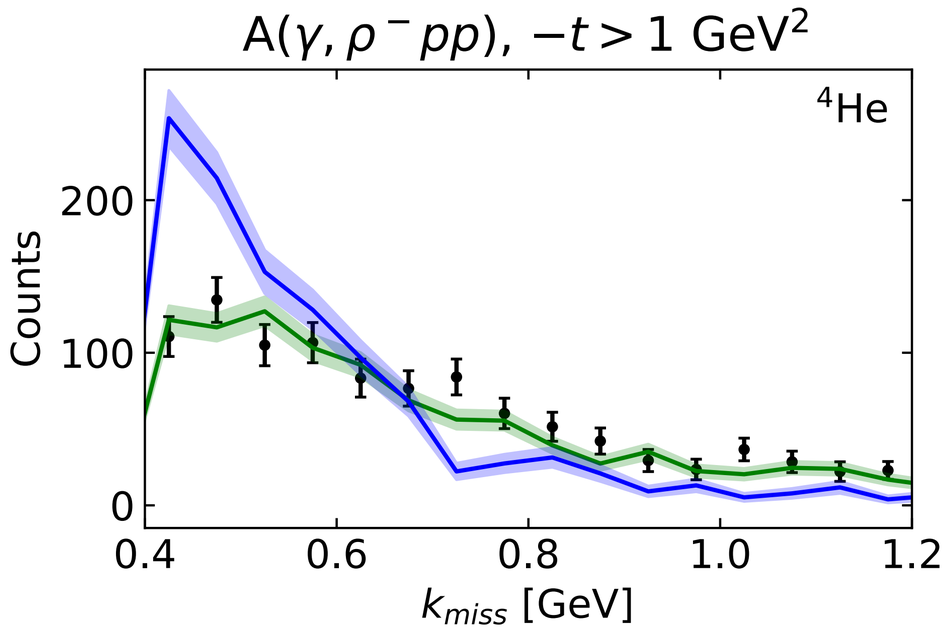
Center-of-mass width matches electron-scattering





Statistics sufficient to distinguish NN interaction models + other GCF inputs

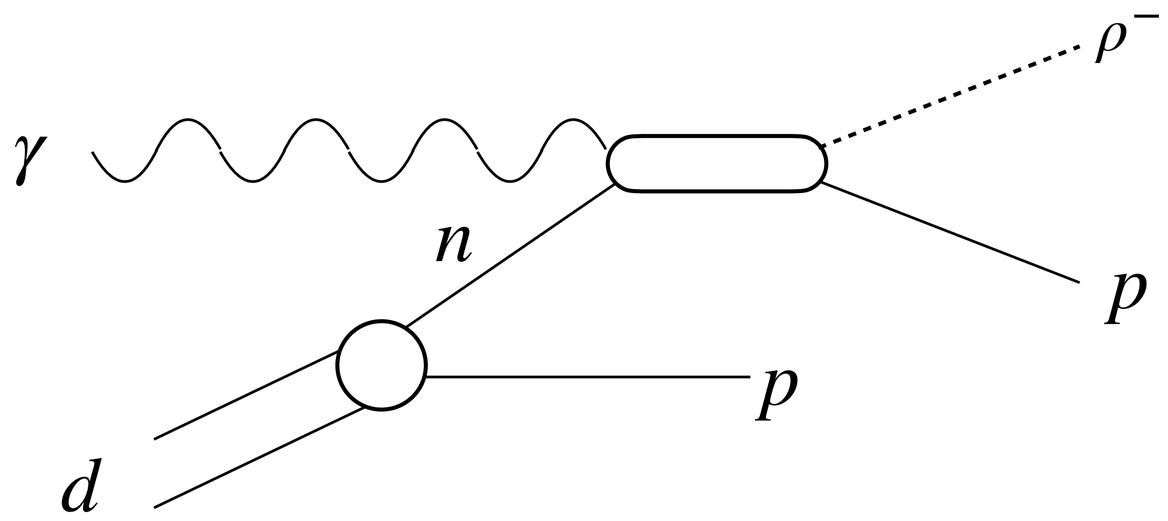




Measurement of $\gamma n \rightarrow \rho^{-} p$ Cross Section

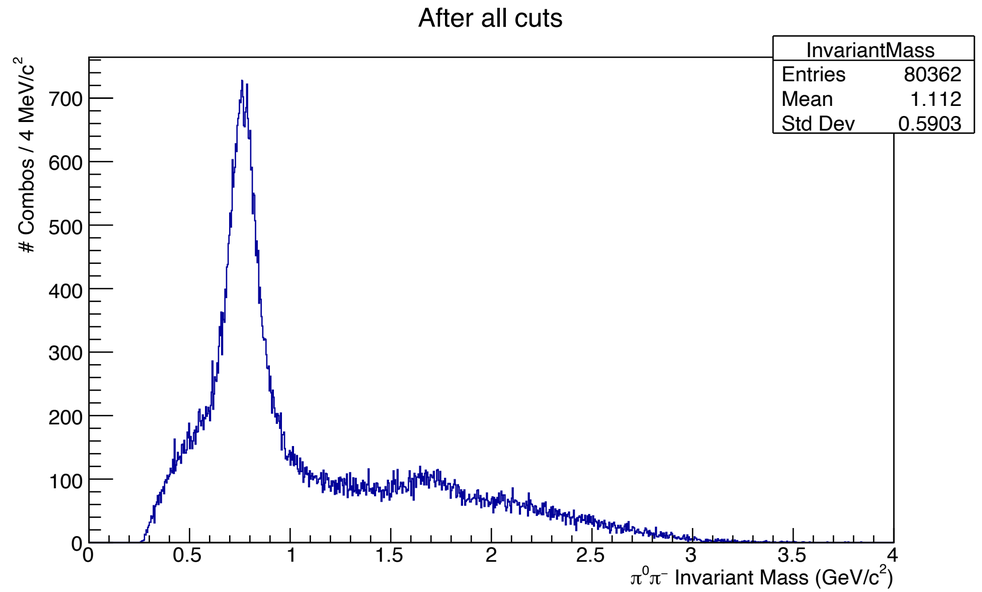
Cross Section Measurement

- Measurement channel: $\gamma d \rightarrow \pi^{-}\pi^{0}p(p)$
- Using ReactionFilter plugin to specify final-state
- Final state of 1 proton, 1 π^{-}, 2 γ
- Constraints:
  - Common Vertex
  - $m_{\gamma\gamma} = m_{\pi^0}$
  - $m^2_{miss} = m^2_p$
- (Missing proton because low-momentum protons are not detected)

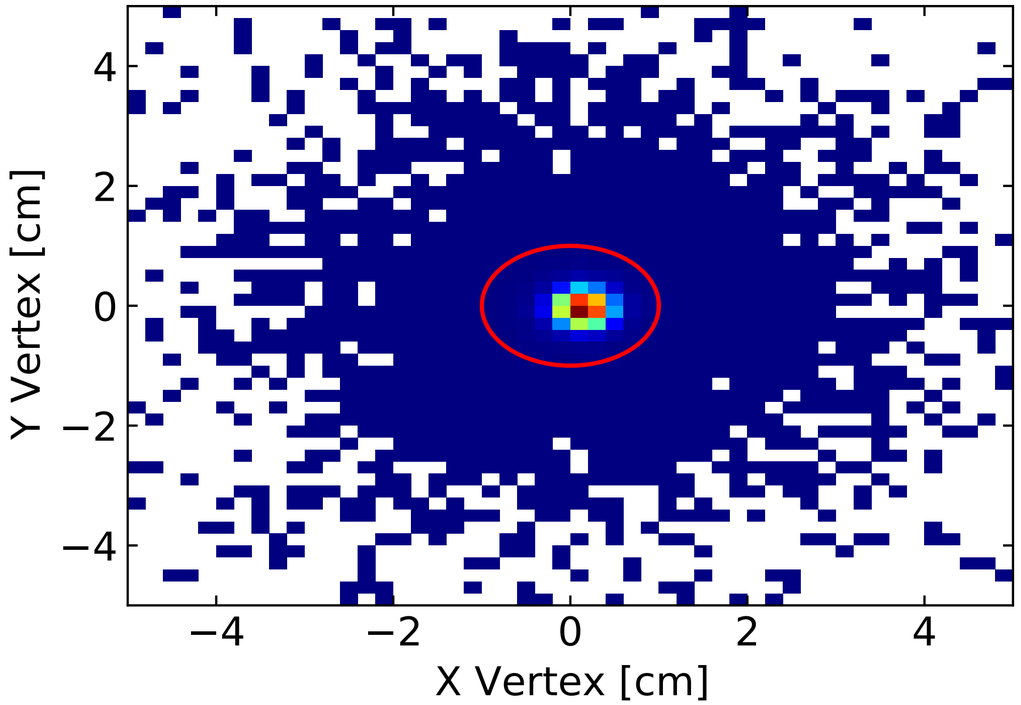


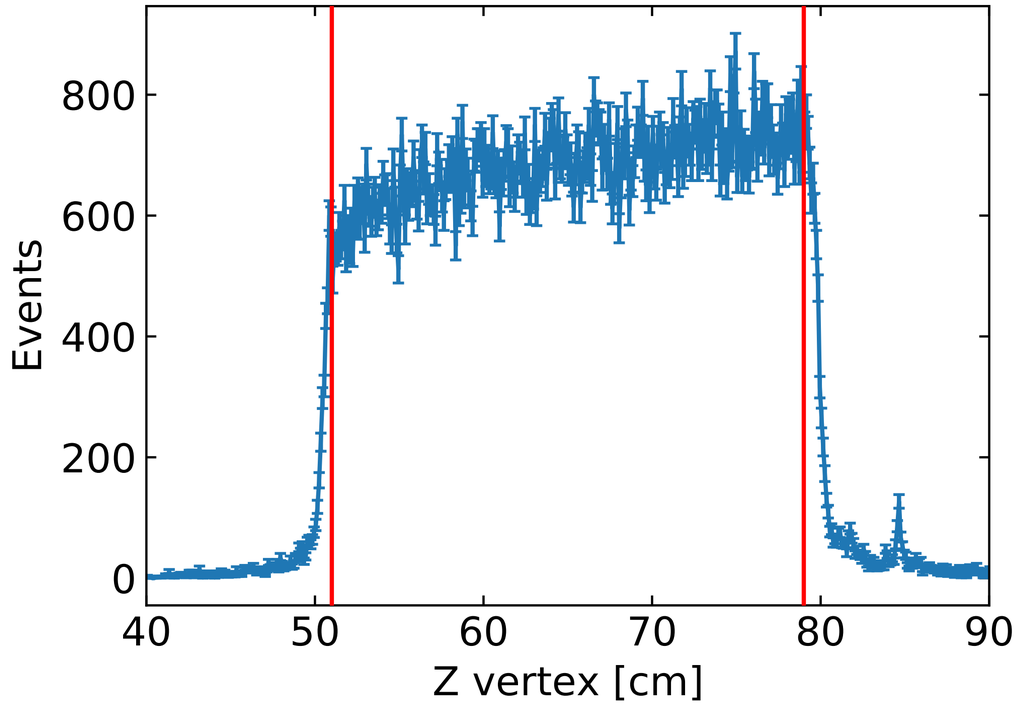
Event Selection

- Basic selection cuts applied initially
  - 0 unused charged tracks
  - 0 unused shower energy
  - PID CL > 0.1 for all particles
  - KinFit CL > 0.01 for the event
  - FCAL shower quality > 0.5
  - 6 < Beam Energy < 10.8 GeV

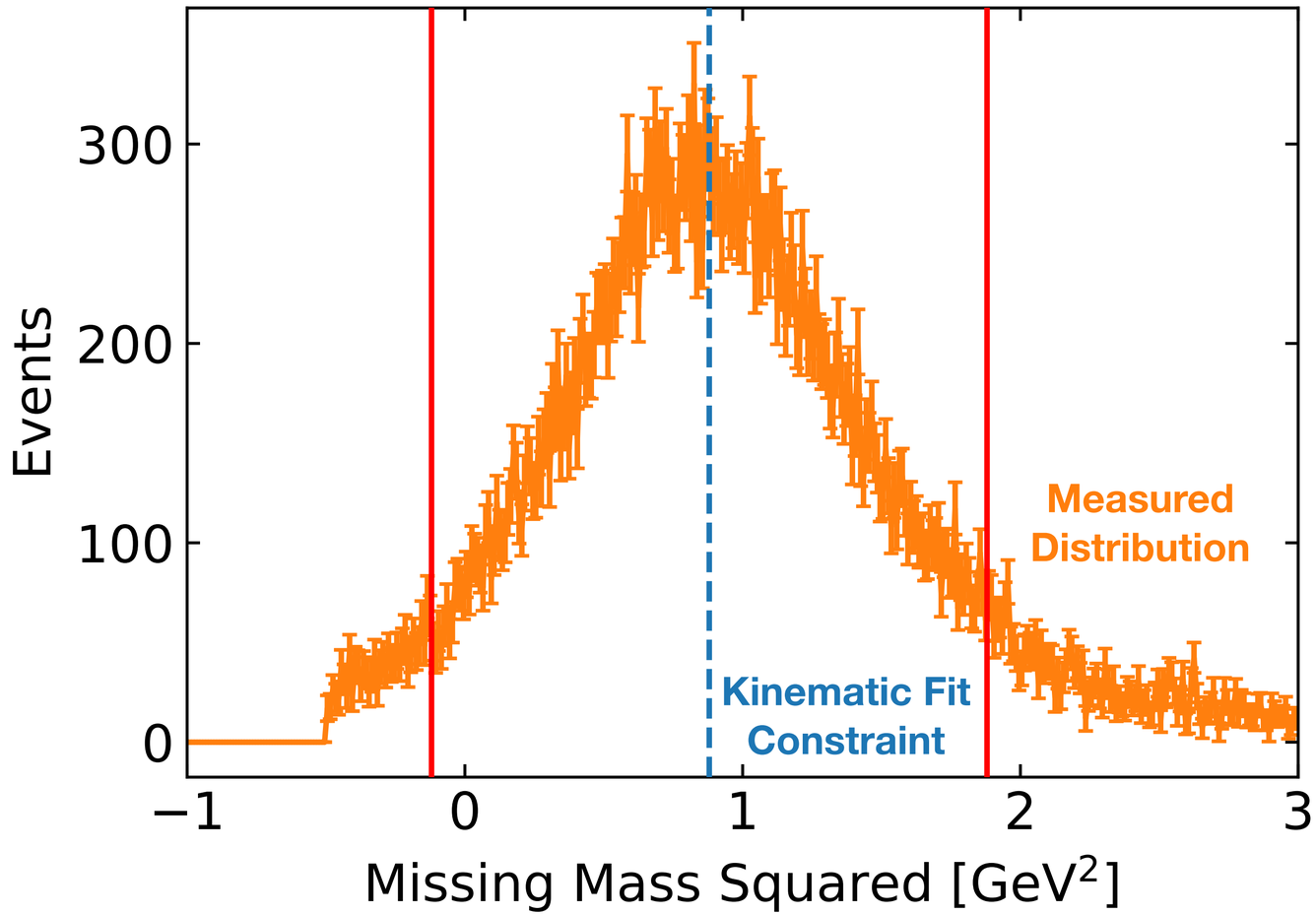


Vertex Cuts

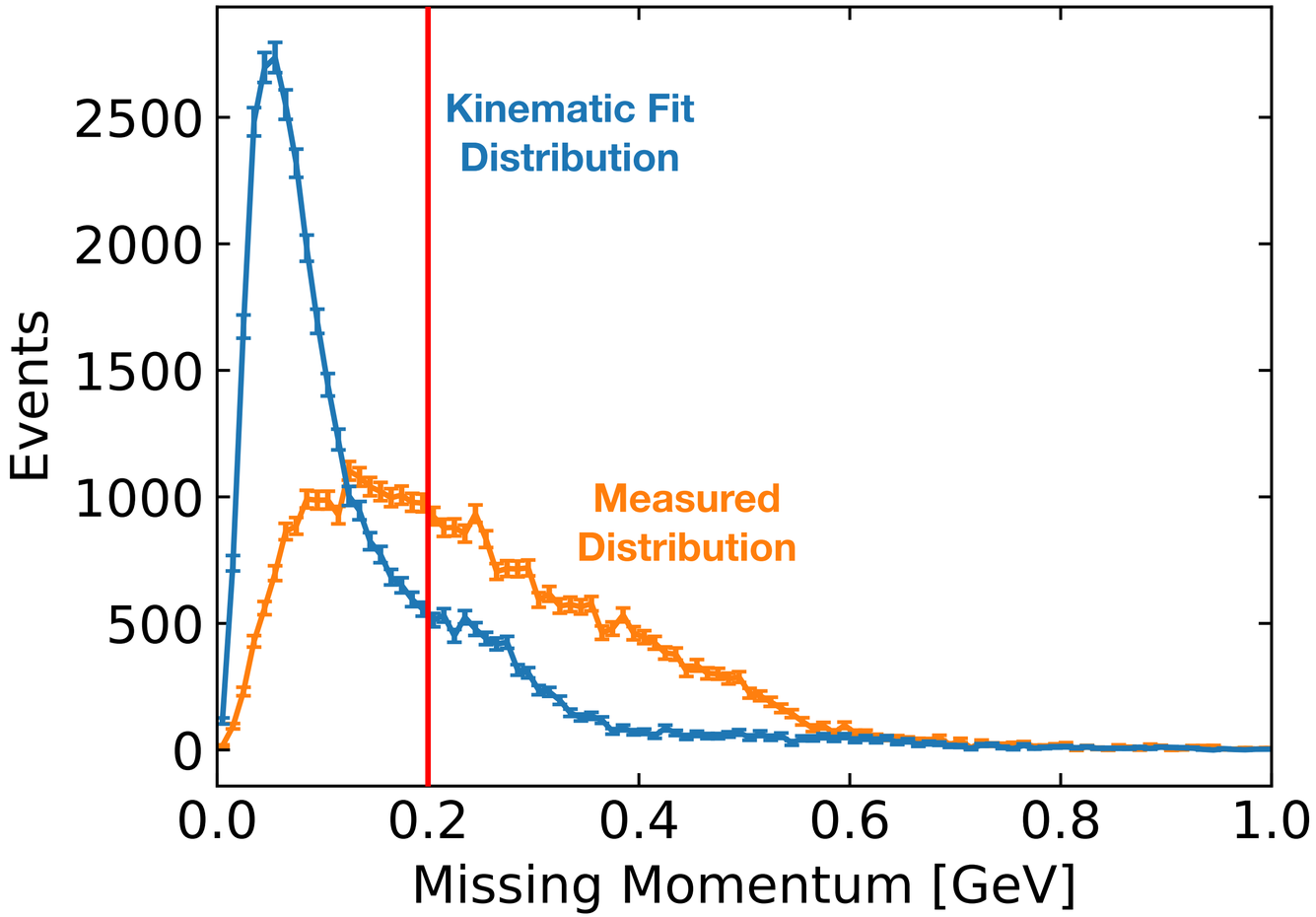

Y Vertex [cm]
X Vertex [cm]
4
2
0
−2
−4
−4
−2
0
2
4


Events
Z vertex [cm]
800
600
400
200
0
40
50
60
70
80
90

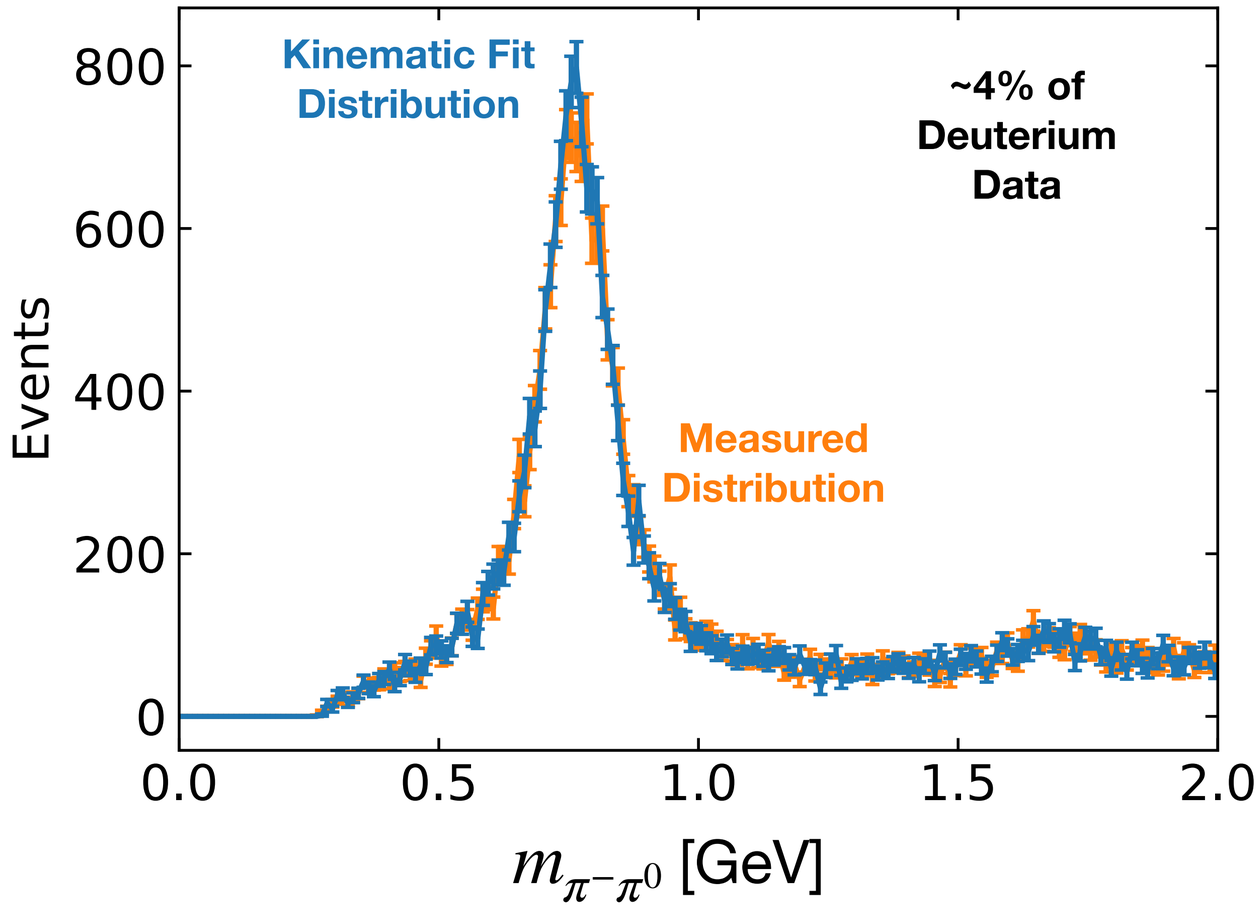
Measured Missing Mass ~ m_p



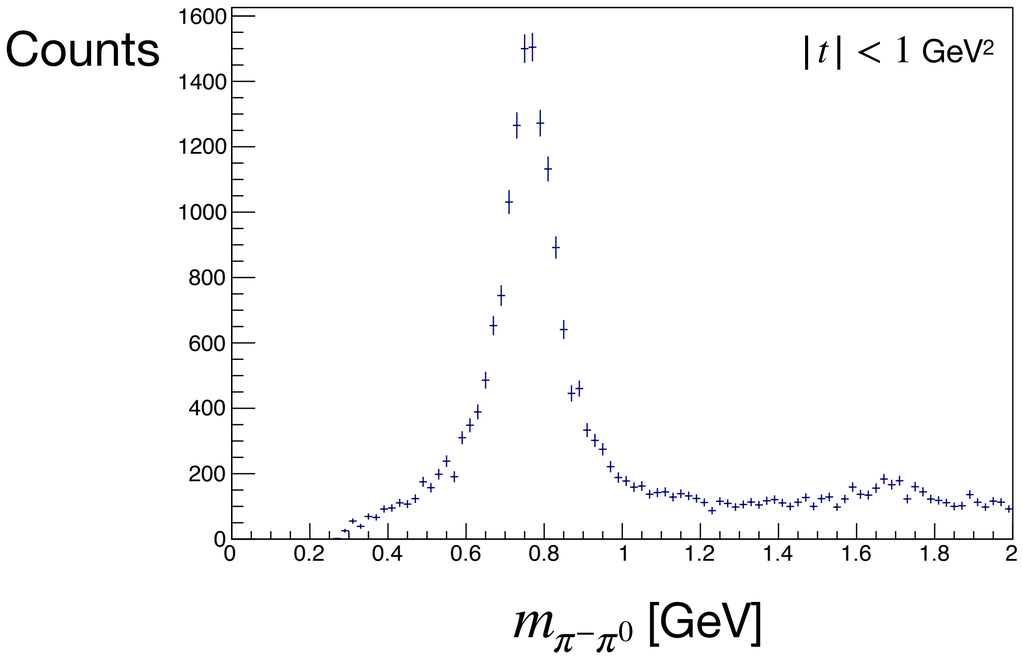
KinFit Missing Momentum Low

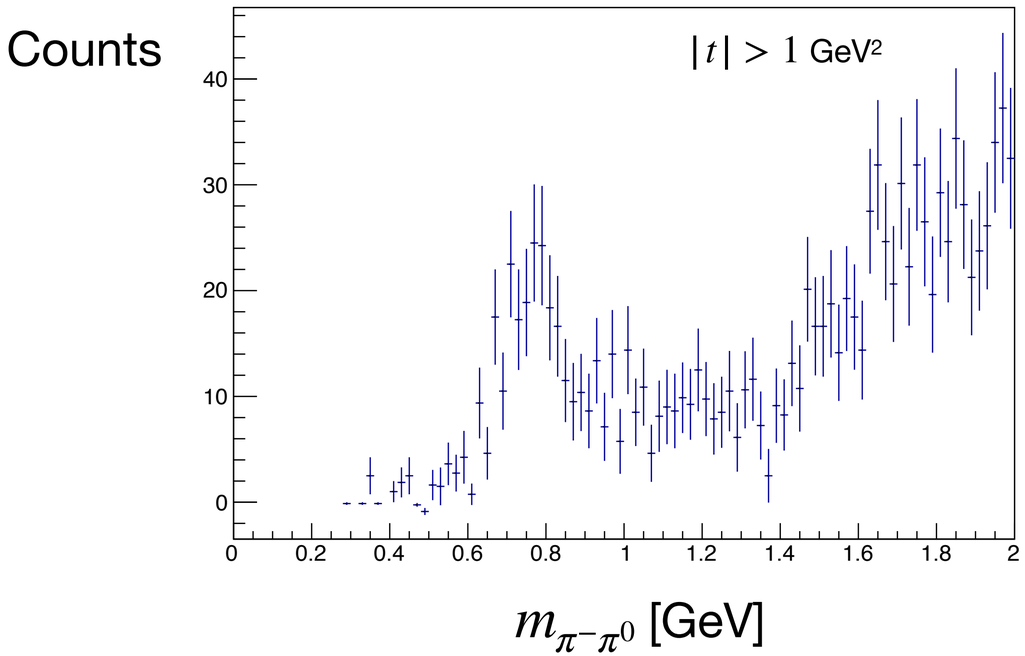


Event selection results in prominent ρ^- mass peak over background

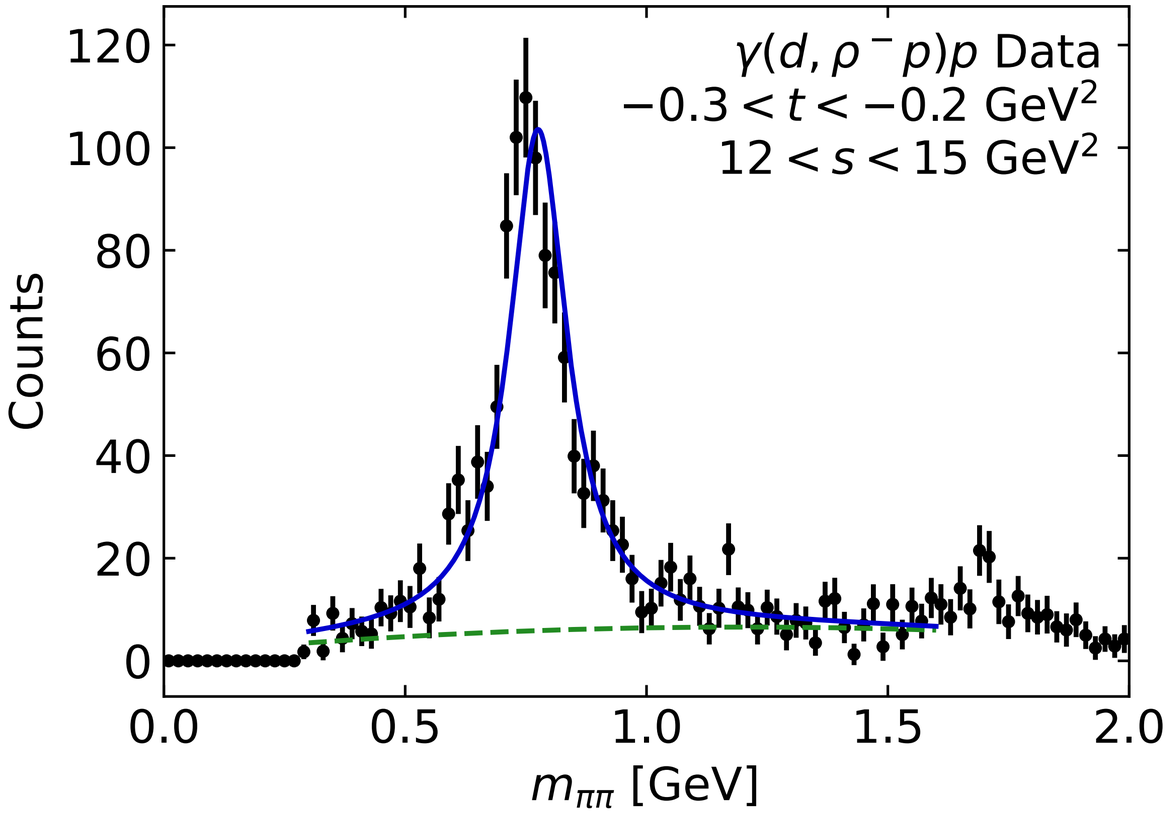


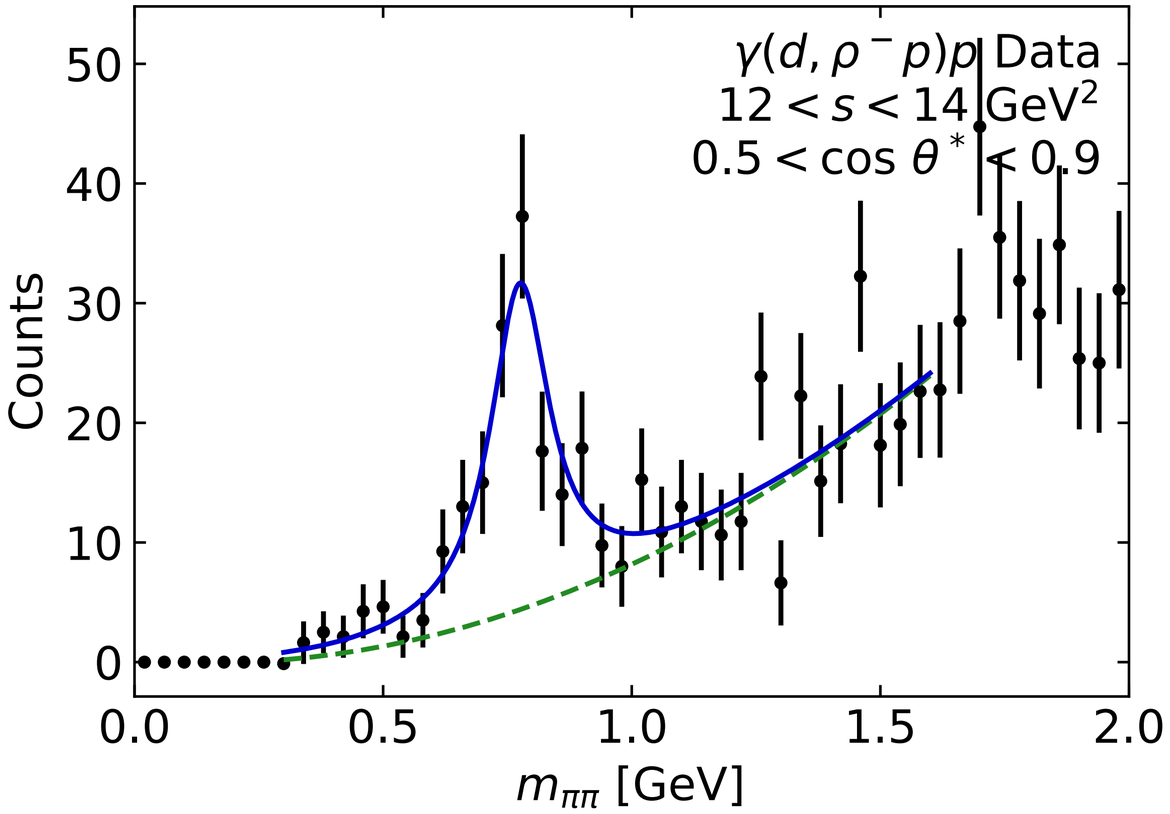
Background level is not constant over all kinematics





ρ^- yield estimated by fitting Breit-Wigner curve + polynomial background in each kinematic bin

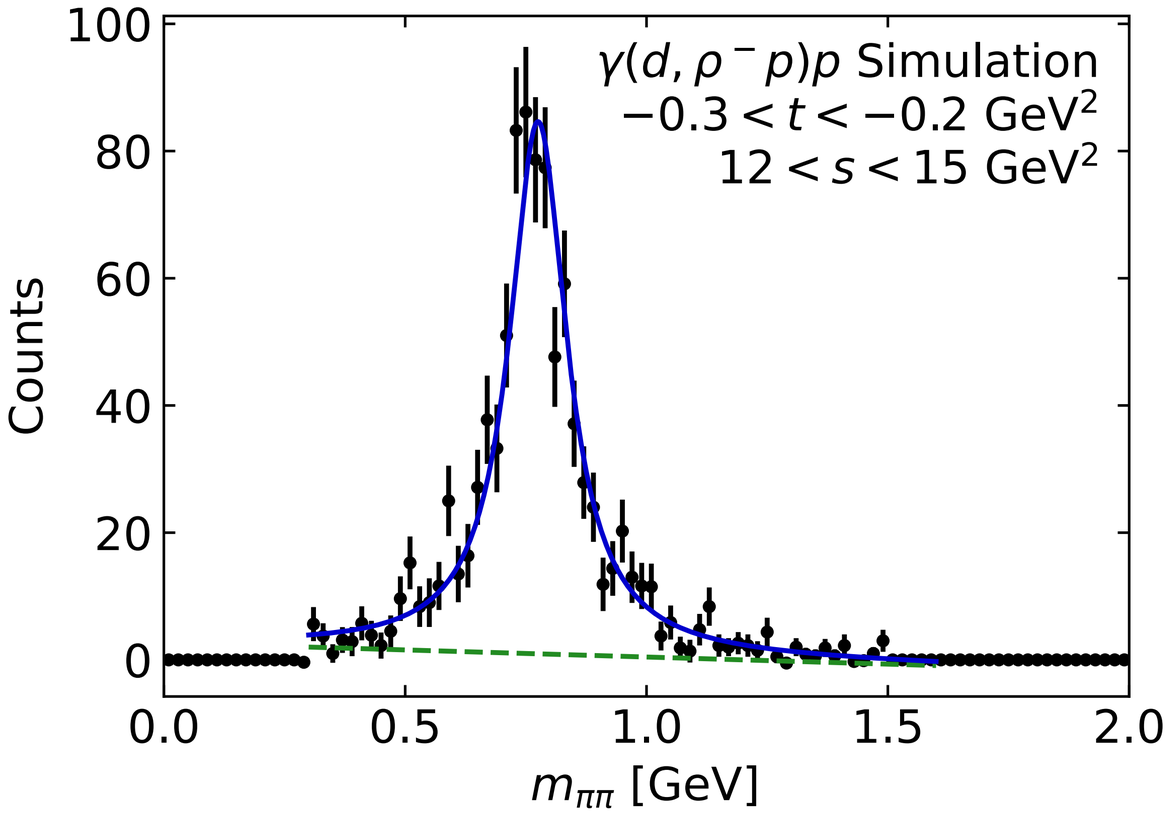


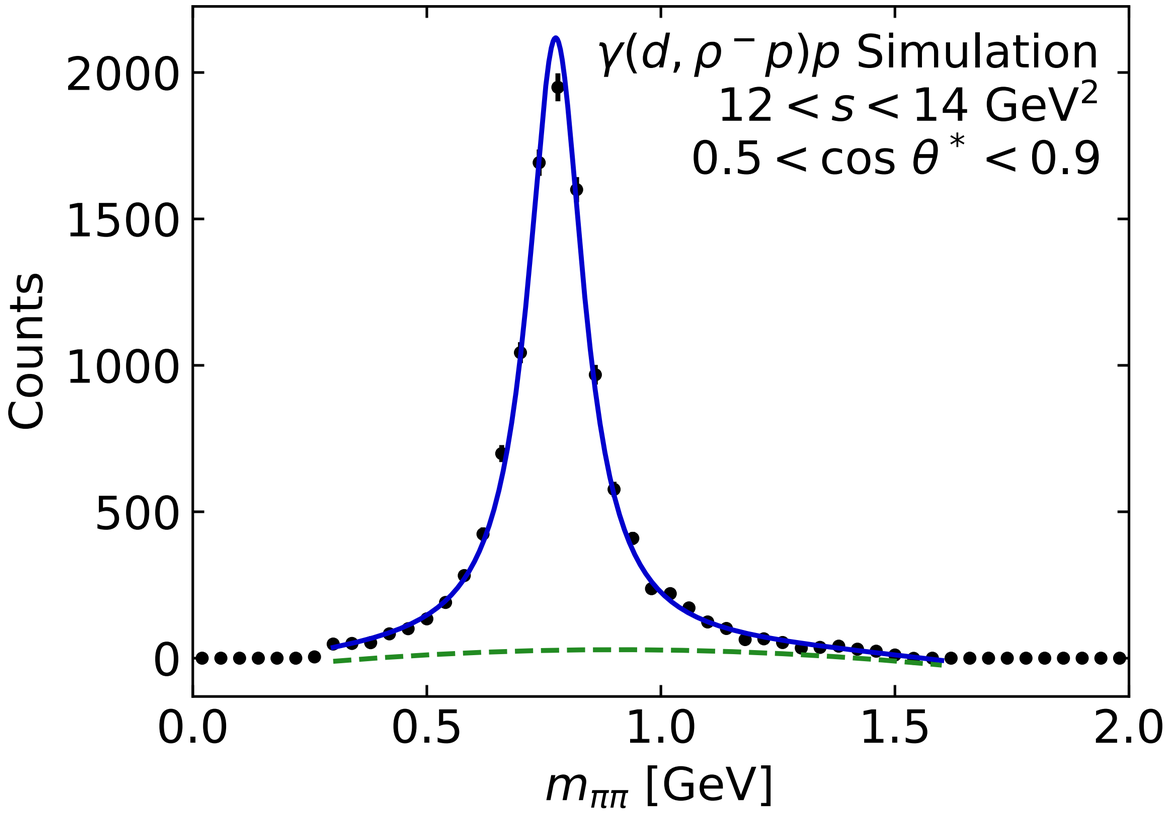


Conversion to cross section

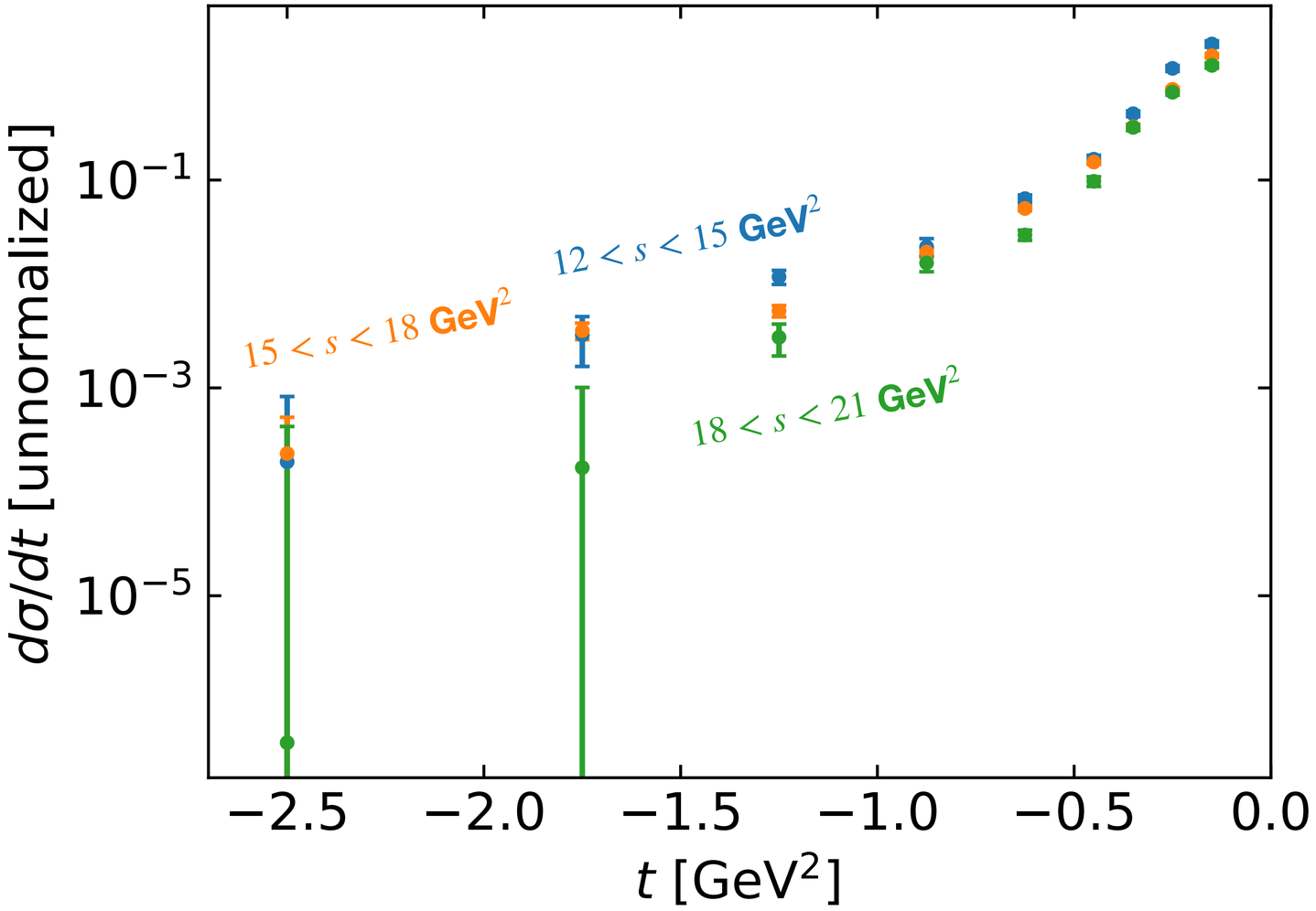
- Yield in each kinematic bin is a function of cross section, acceptance, efficiency, and phase space
- Simulation allows us to account for acceptance, efficiency, and phase space to extract the cross section
- Simulated $\gamma d \to \rho^- pp$ events, assuming a flat cross section of $\frac{d\sigma}{dt}(\gamma n \to \rho^- p) = 1$ nb GeV^{-2}
  - This allows for event reweighting to test cross section models
- Passed events through GEANT and event selection and examined same mass histograms

Amplitude of fitted mass peak in simulation give normalization factor for dividing simulation

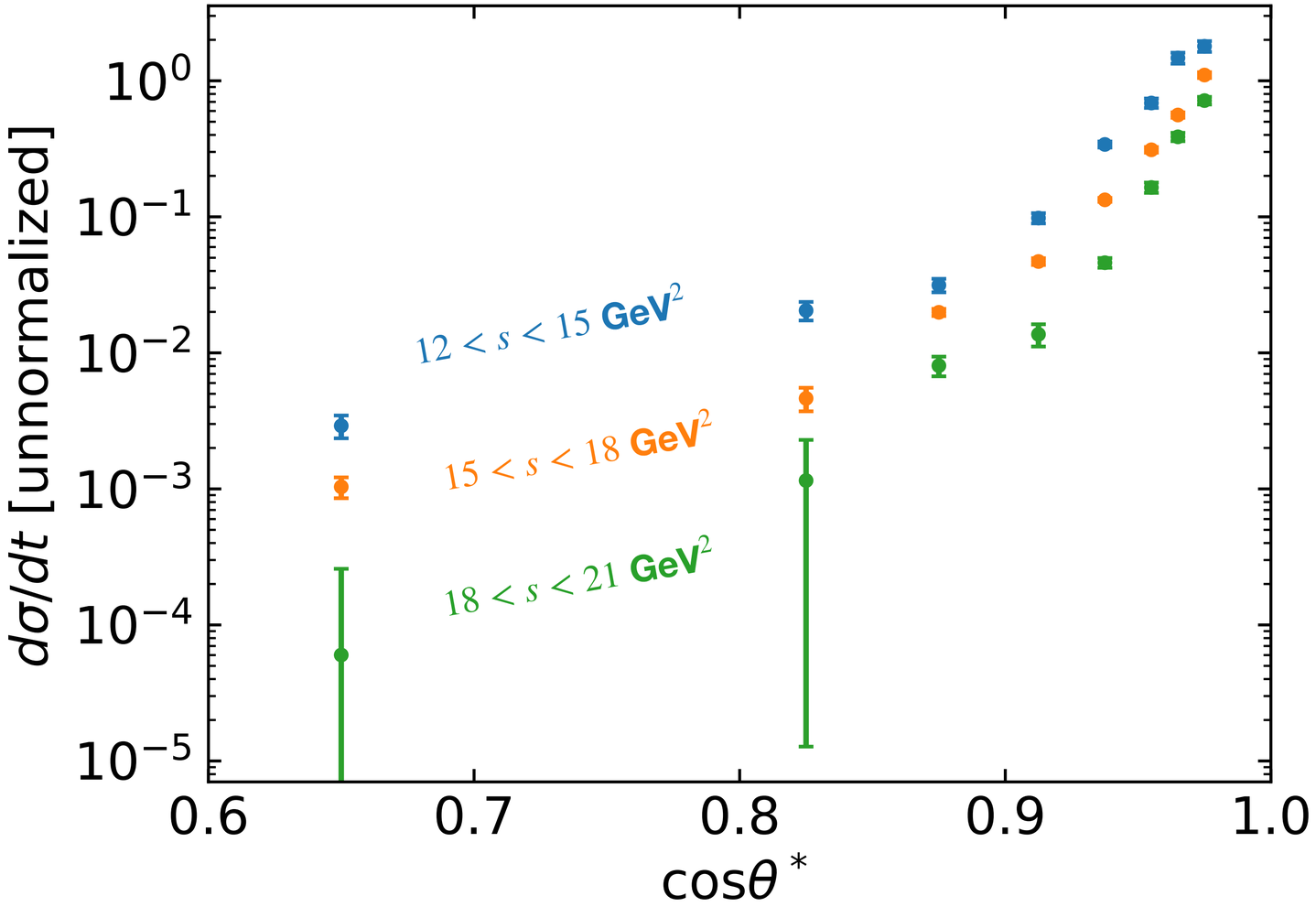




Cross Section Yields binned in $|t|$



Cross Section Yields binned in $\cos\theta^*$



Comparison to theory model

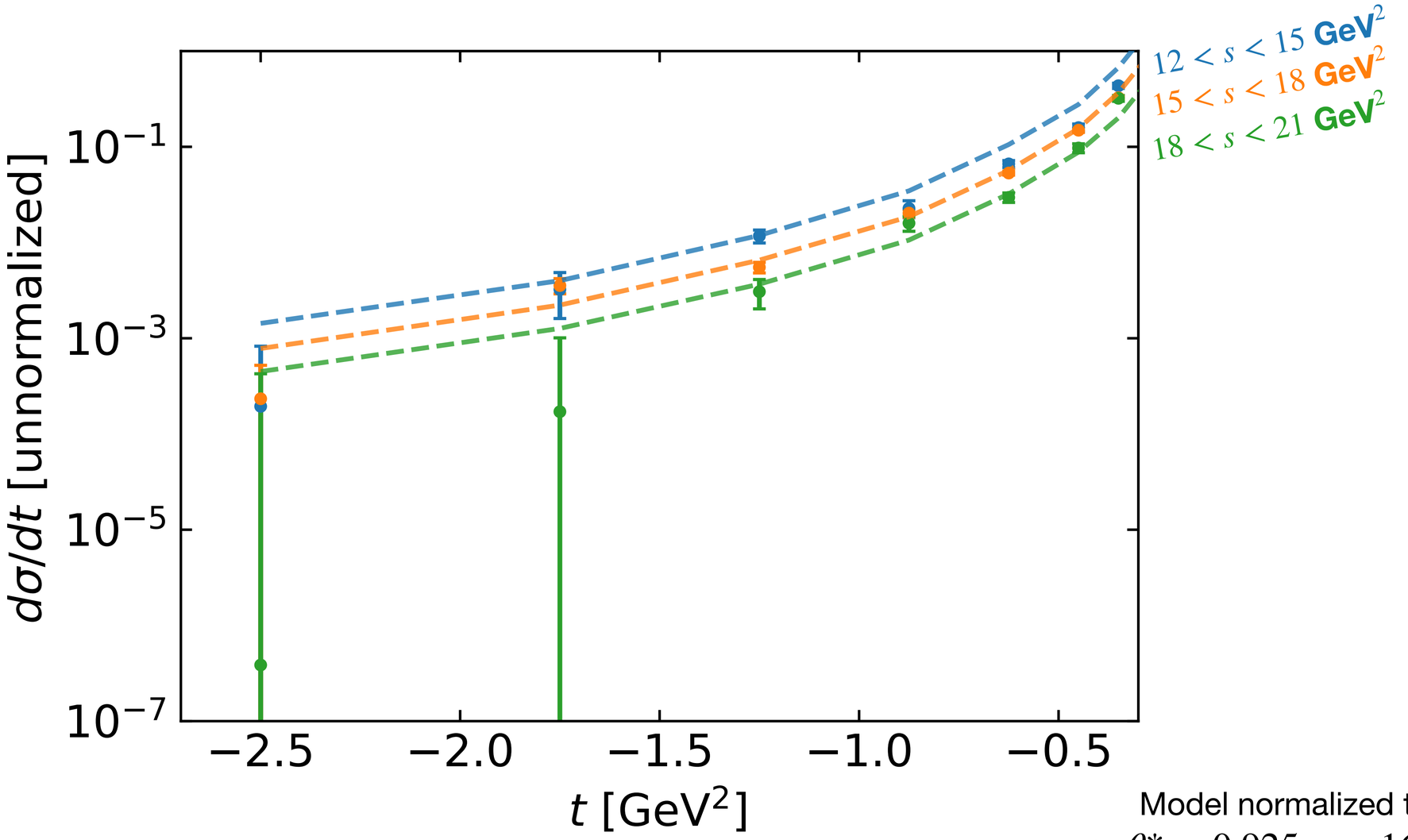
- Constituent scaling model predicts cross section scaling at large momentum transfer $|t|$ and $|u|$:

$$\frac{d\sigma}{dt}(\gamma n \to \rho^- p) = f(\theta^*)s^{-n},\ n = 7$$

- Different cross section models tested by taking flat simulation and reweighting events
  - This accounts for bin-centering and bin-migration
- Data compared to a model with functional form:

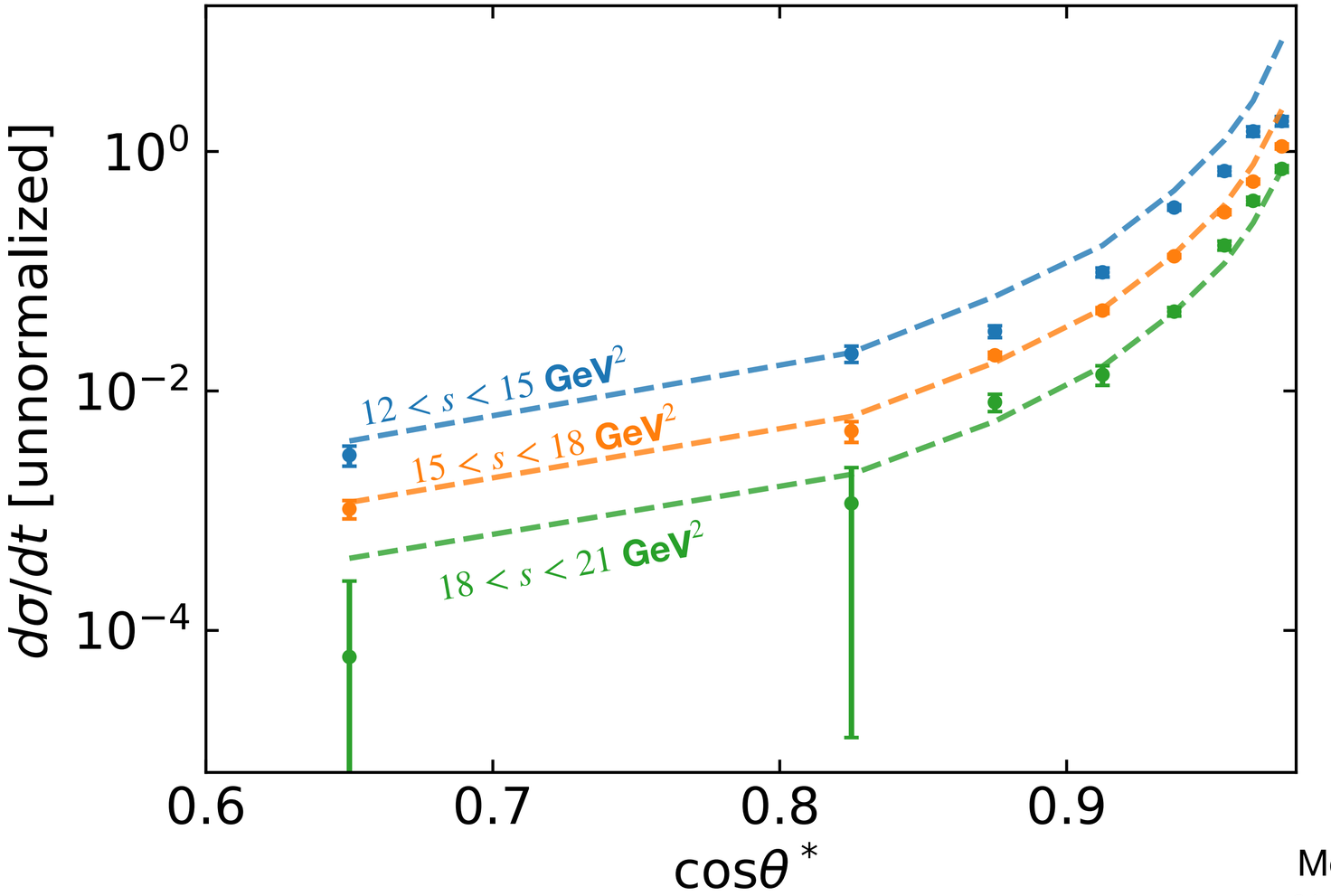
$$\frac{d\sigma}{dt}(\gamma n \to \rho^- p) \propto (1 - \cos\theta^*)^{-3}s^{-7}$$

Cross Section Yields binned in $|t|$



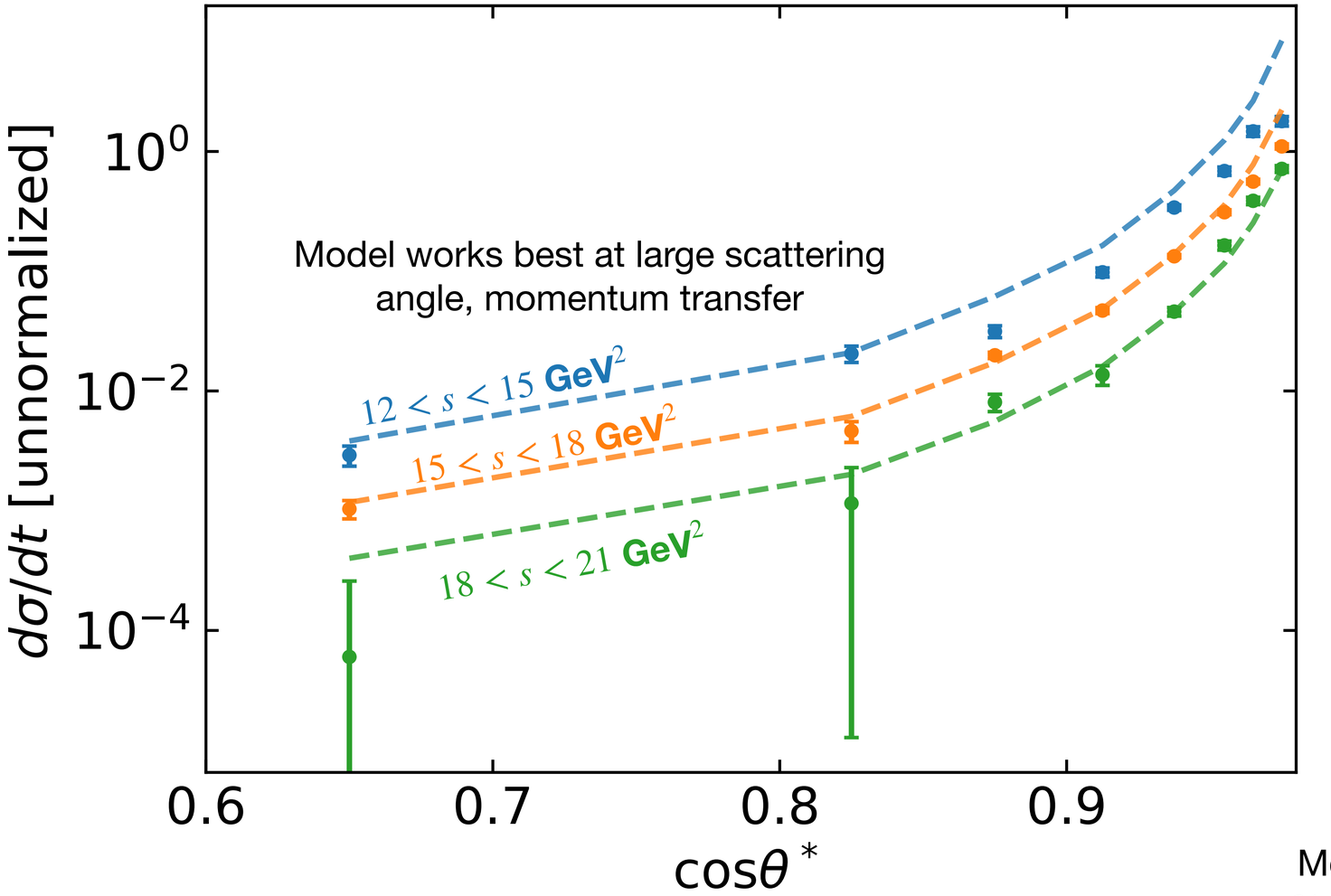
Model normalized to
$\cos\theta^* = 0.925$, $s = 16$ GeV^2

Cross Section Yields binned in $\cos\theta^*$



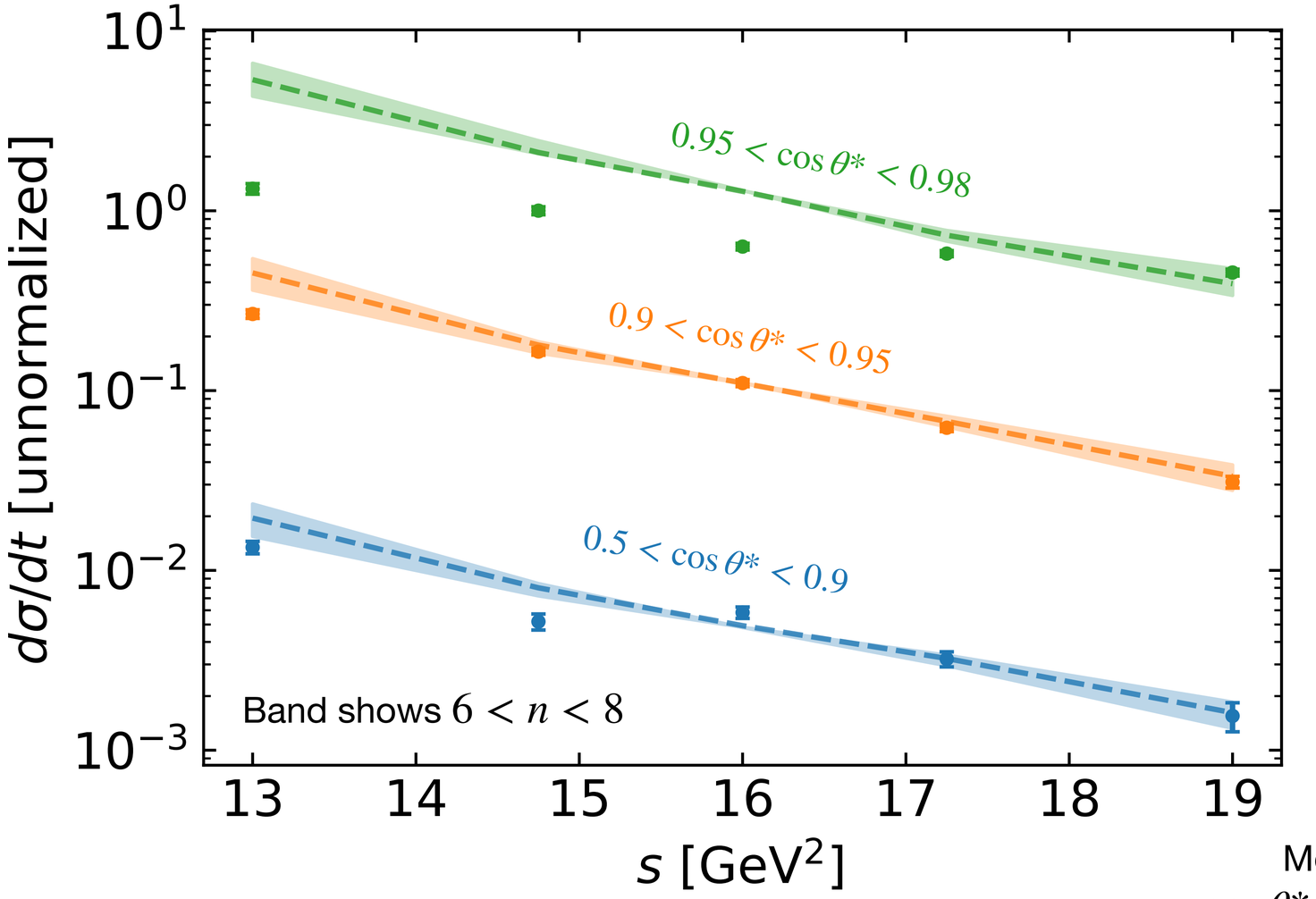
Model normalized to
$\cos\theta^* = 0.925$, $s = 16$ GeV^2

Cross Section Yields binned in $\cos\theta^*$



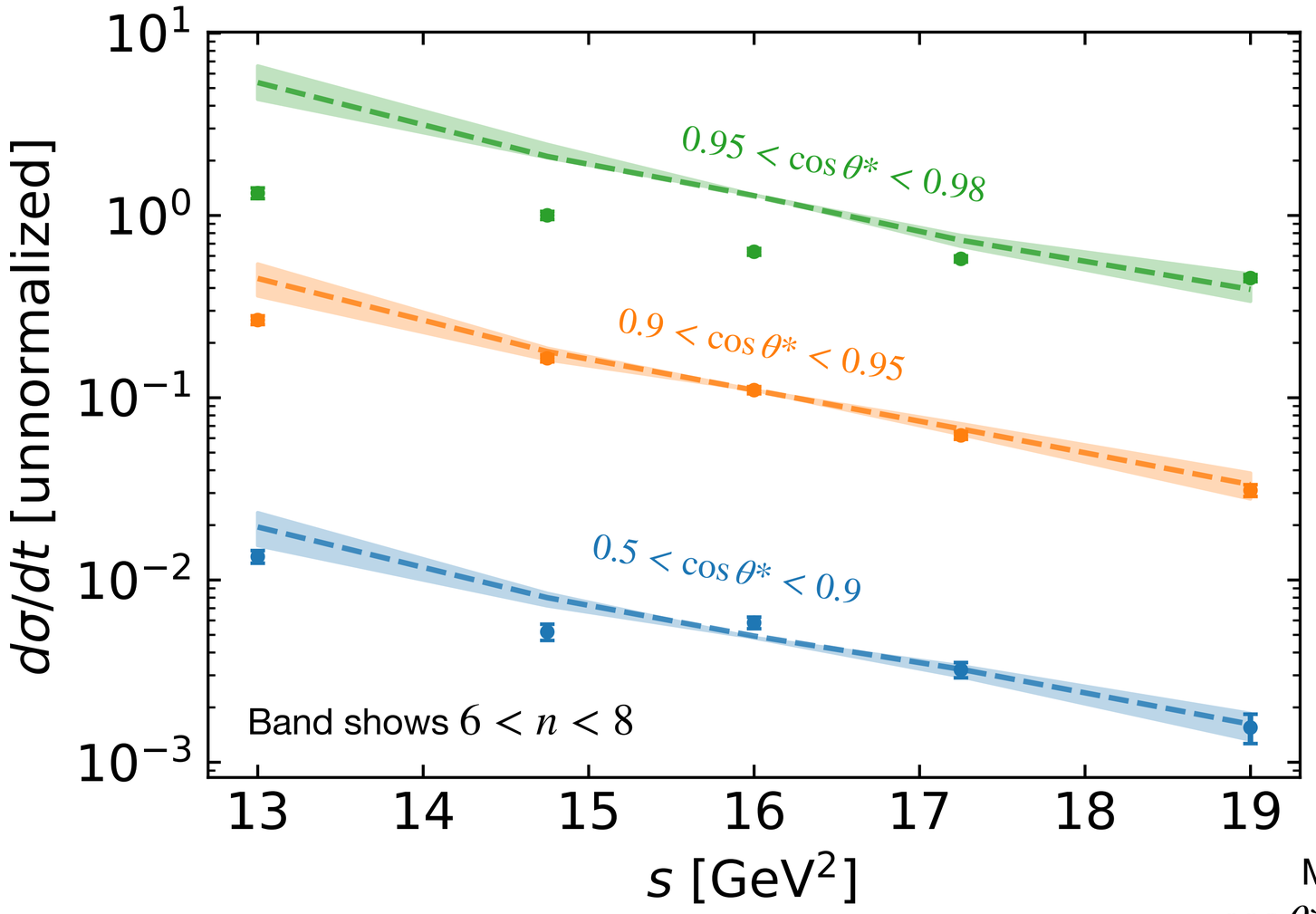
Model normalized to
$\cos\theta^* = 0.925$, $s = 16$ GeV^2

Examining constituent scaling as a function of s



Model normalized to
$\cos\theta^* = 0.925$, $s = 16$ GeV^2

Examining constituent scaling as a function of s



|t| ~ 0.25 GeV²

|t| ~ 0.5 GeV²

|t| ~ 1 GeV²

Model normalized to
$\cos\theta^* = 0.925$, $s = 16$ GeV^2

Conclusions

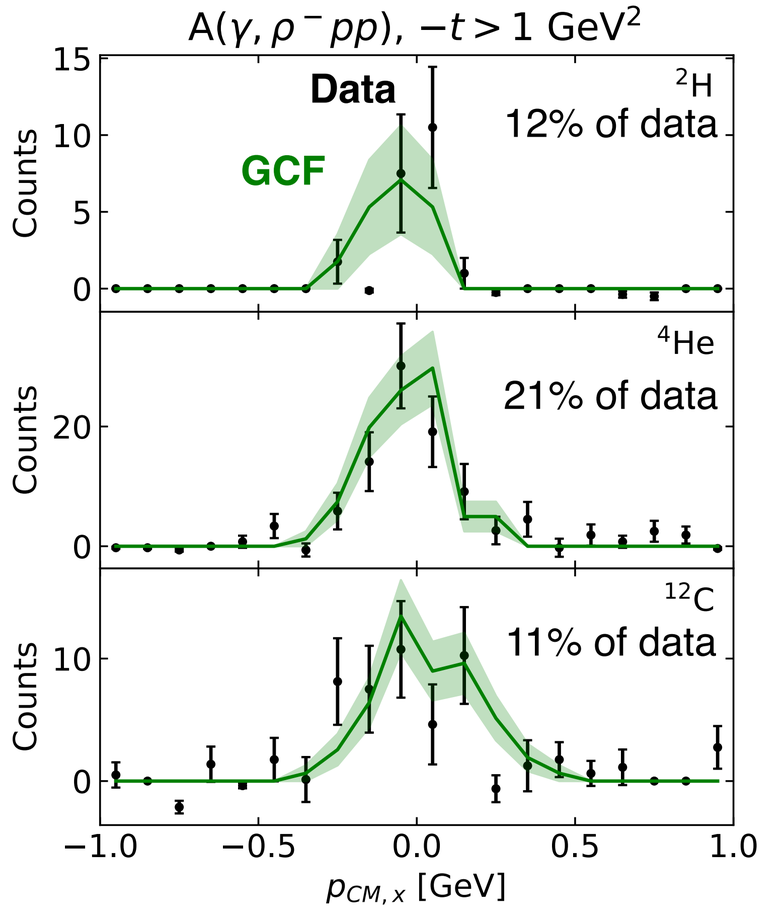
- Preliminary online analysis shows good indication of SRC signal in photonuclear data
- Deuterium data allows measurement of charged ρ^- meson photoproduction cross section
- Analysis of data will entail detailed comparison between measured SRC data and GCF predictions to test factorization model in photoproduction measurements

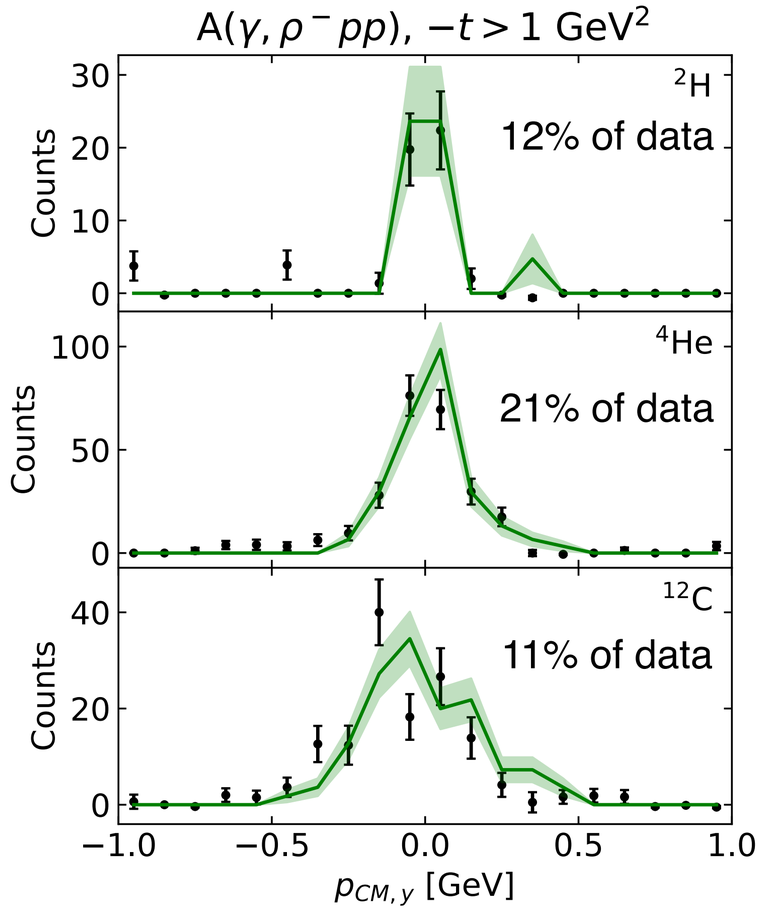
Backup

List of SRC Cuts

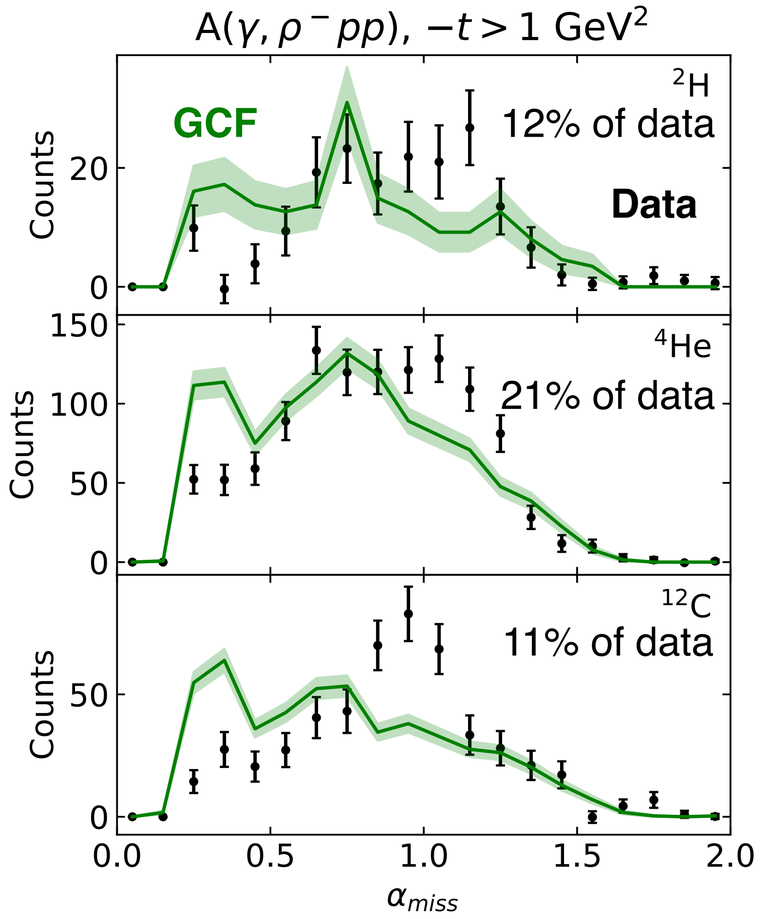
- KinFit CL > 0.0001
- PID cuts on dE/dx, β
- Vertex cuts
- Calorimeter fiducial cuts
- Calorimeter timing
- $E_{\pi^-} + E_{\pi^0} + E_{lead} > 7$ GeV
- ω meson background cut
- Cut in $\alpha_{CM} - \cos\gamma_{proxy}$
- $0.65 < m_{\pi^0\pi^-} < 0.9$ GeV
- $E_{beam} > 6$ GeV
- $|E_{beam} + 2m_N - E_{\pi^0} - E_{\pi^-} - E_{lead} - E_{rec}| < 1$ GeV
- $k_{miss} > 0.4$ GeV
- $p_{rec} > 0.3$ GeV
- $|t|, |u| > 1$ GeV^2

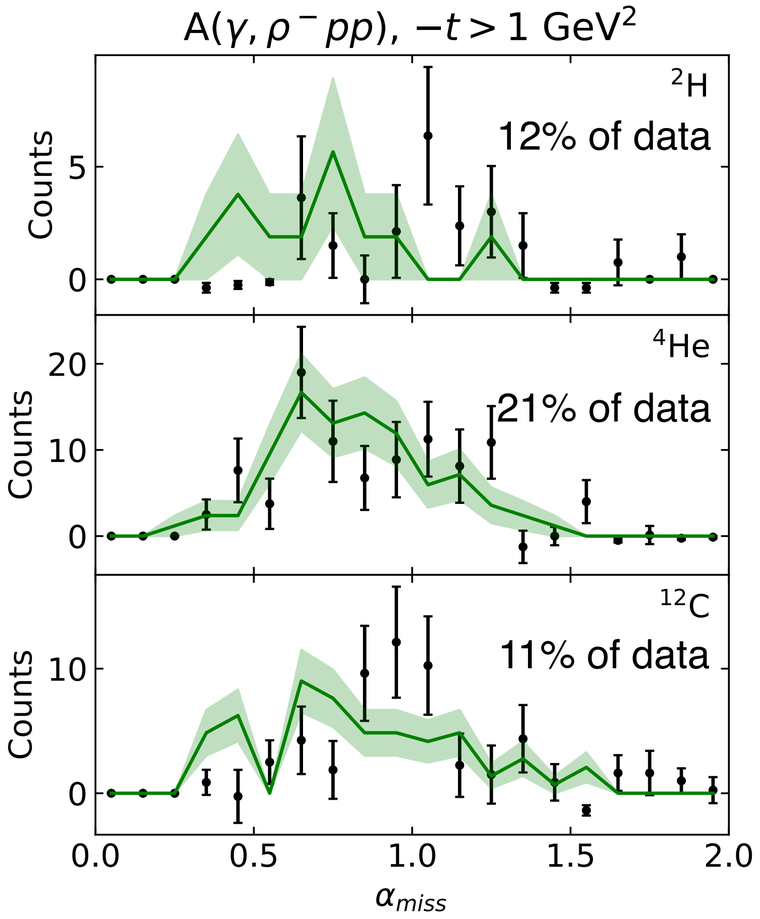
Center-of-mass width matches electron-scattering





Missing light-cone fraction α_{miss}





Recoil light-cone fraction α_{rec}