Short Range Nuclear Structure Investigated Through ρ^0 meson Photoproduction

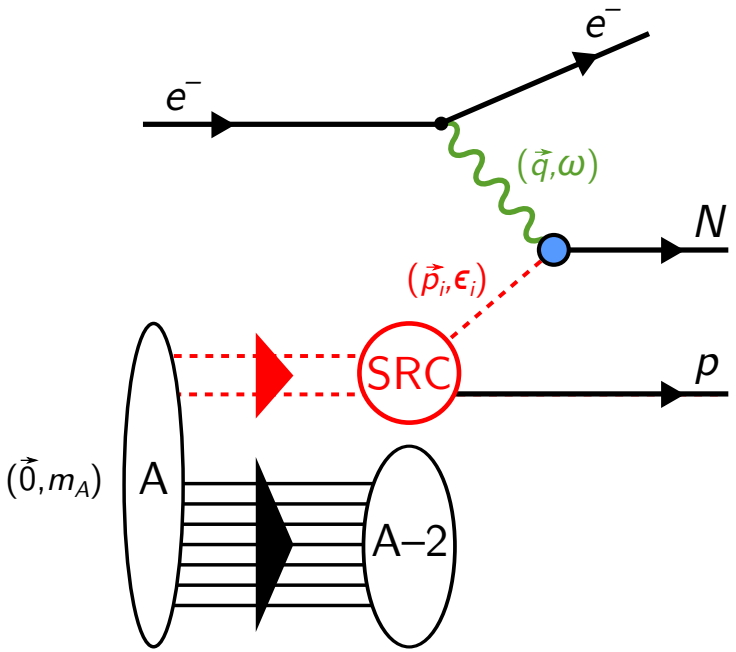
Phoebe Sharp

Tuesday, August 2

SRC Collaboration Meeting 2022

A primary goal of this experiment:
Validate Scale Separation Observed in e^- scattering

A primary goal of this experiment: Validate Scale Separation Observed in e⁻ scattering



High Momentum
- Probe

Medium Momentum
- Relative Motion

Low Momentum
- CM Motion

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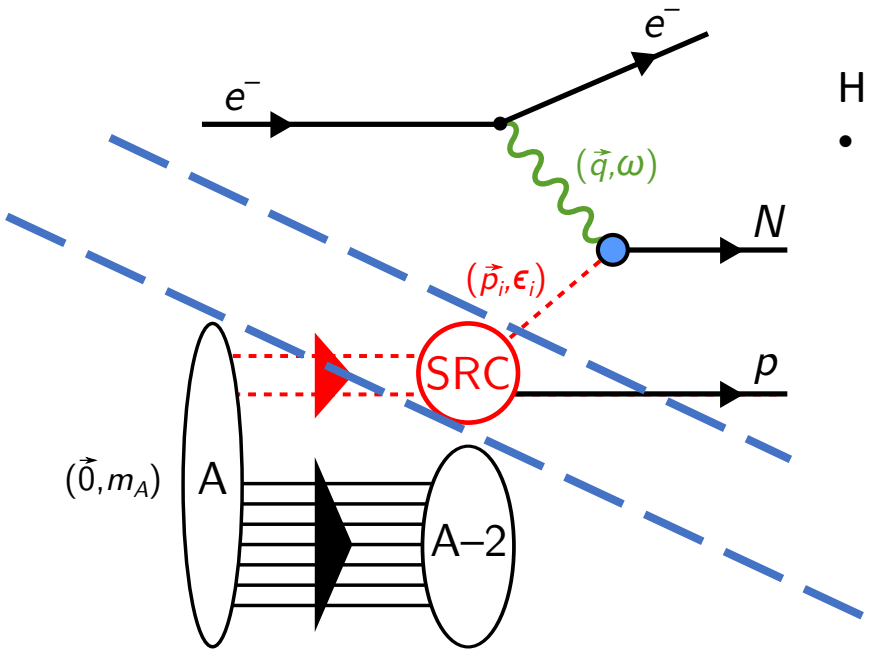

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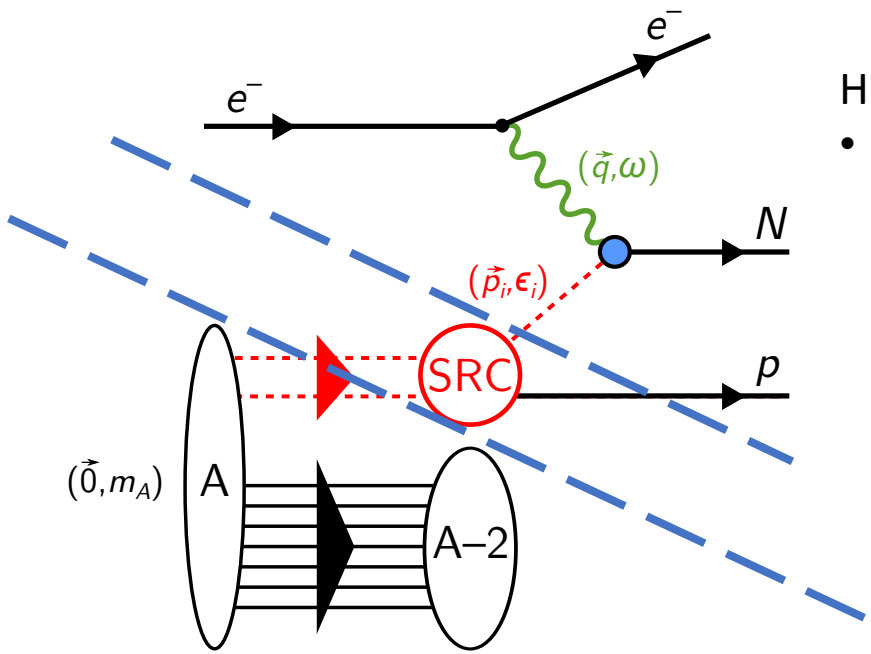

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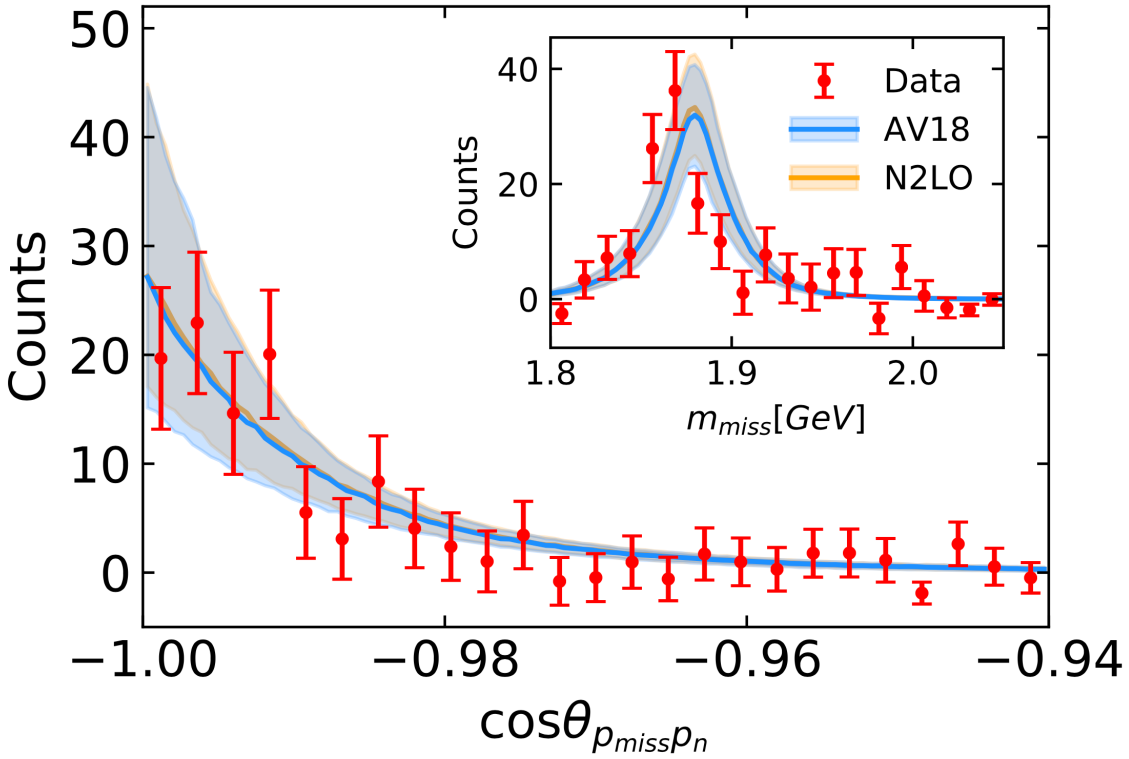
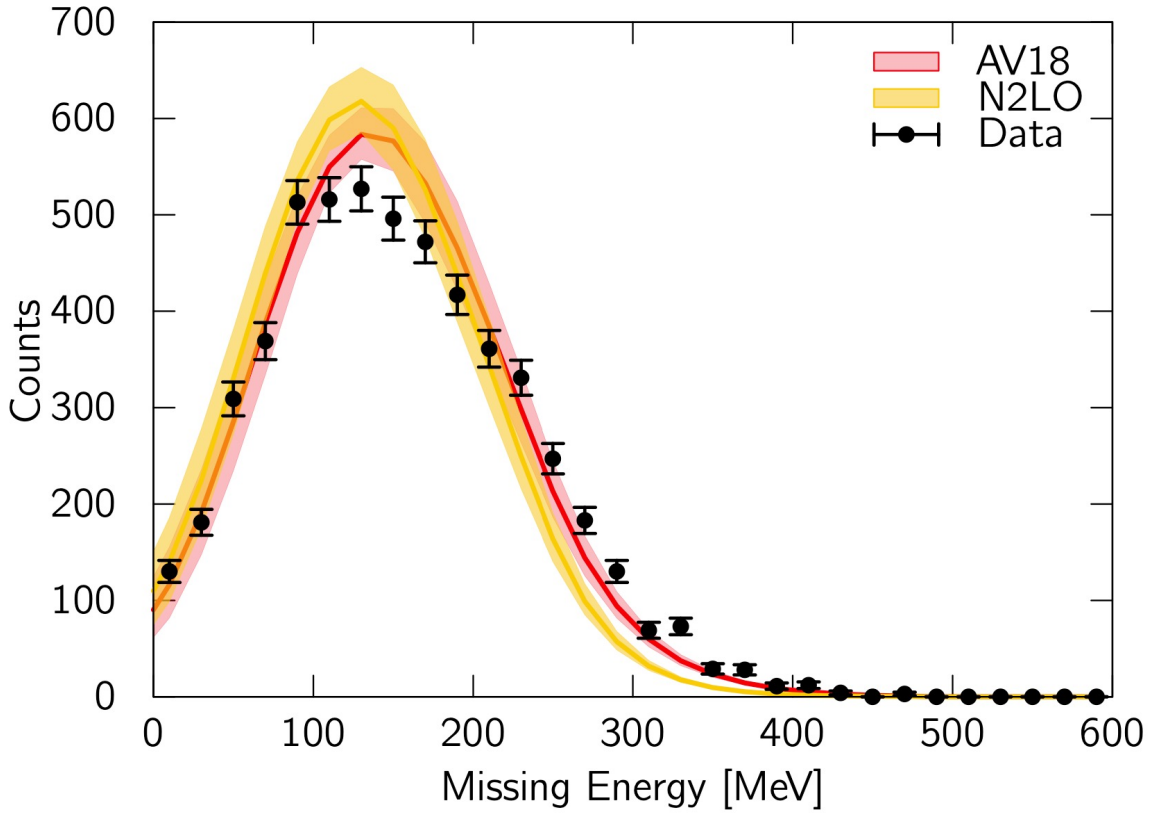
$$d\,\sigma \sim \sigma_{eN} \cdot \Sigma_\alpha\, C_\alpha \cdot P_\alpha(k_{cm}) \cdot \left|\tilde{\phi}(k_{rel})\right|^2$$

- σ_{eN}: single nucleon cross section
- C_α: Pair abundances (contacts)
- $P_\alpha(k_{cm})$: CM motion (Gaussian)
- $\left|\tilde{\phi}(k_{rel})\right|$: Rel. Motion (2-body)

Leads to Factorized Approximation!

GCF describes multidimensional kinematics.





Pybus, J. R., et. al, (2020). Generalized contact formalism analysis of the 4 He (e , e pN) reaction. *Physics Letters B*, *805*, 135429.

Schmidt, A., et.al. *Probing the core of the strong nuclear interaction*. Nature *578*(February 2020).

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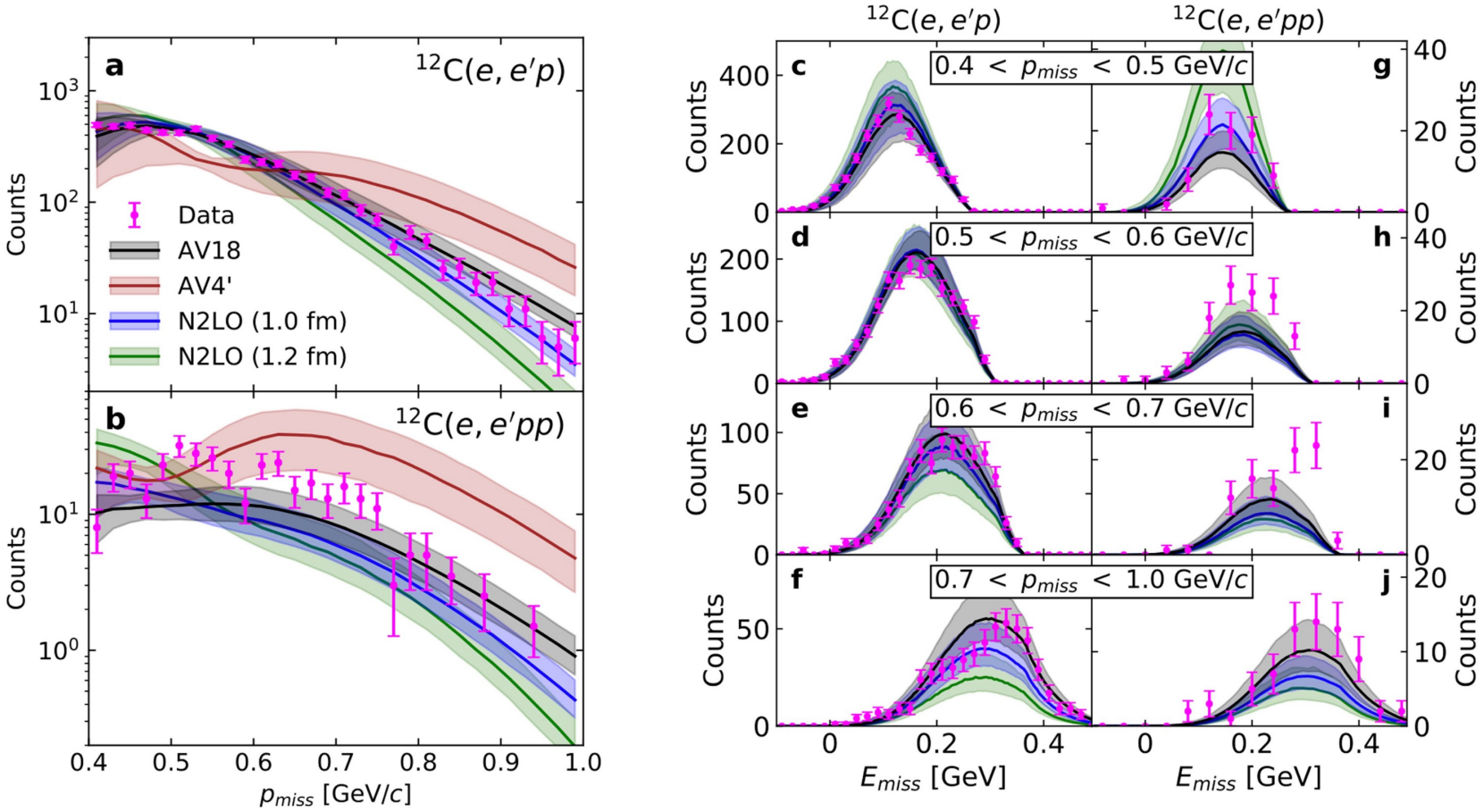

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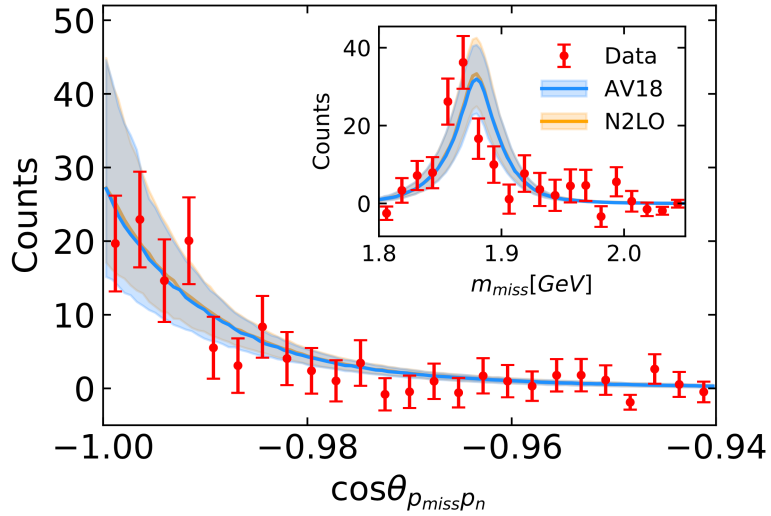
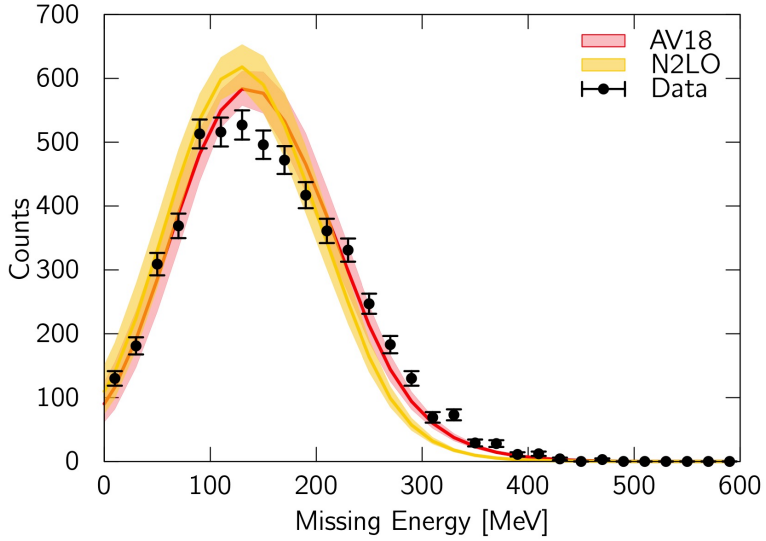
GCF in Electron Scattering SRC Papers





List of papers:

- Duer PRL 2019
- Schmidt Nature 2020
- Pybus PLB 2020
- Korover PLB 2021
- Weiss PRC 2021
- *Under Review:*
  - *Wright 2021, with PLB*
  - *Korover 2021, with Science*

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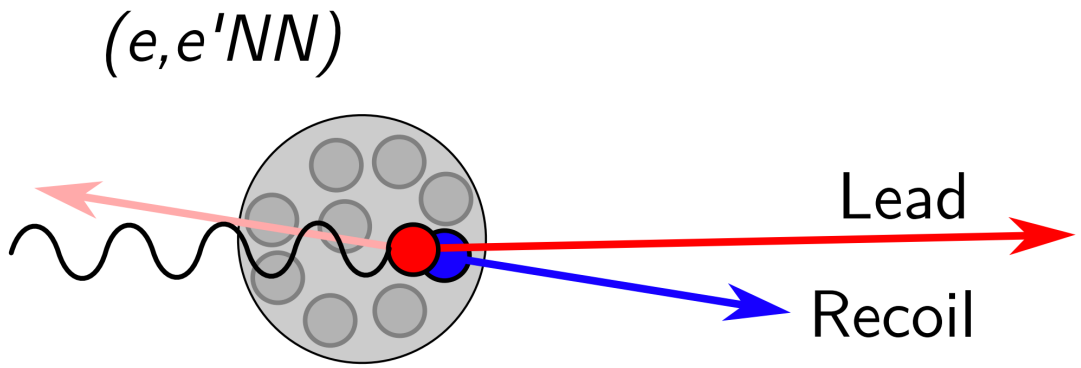
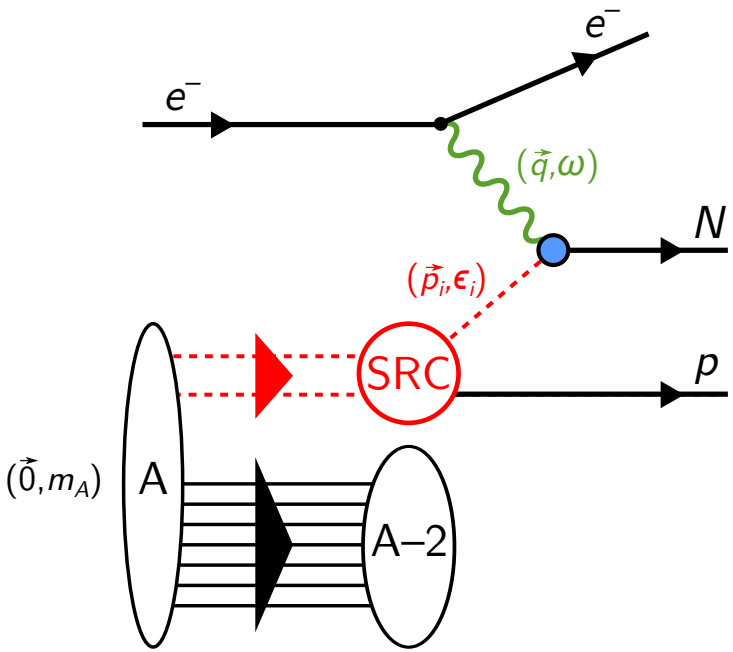
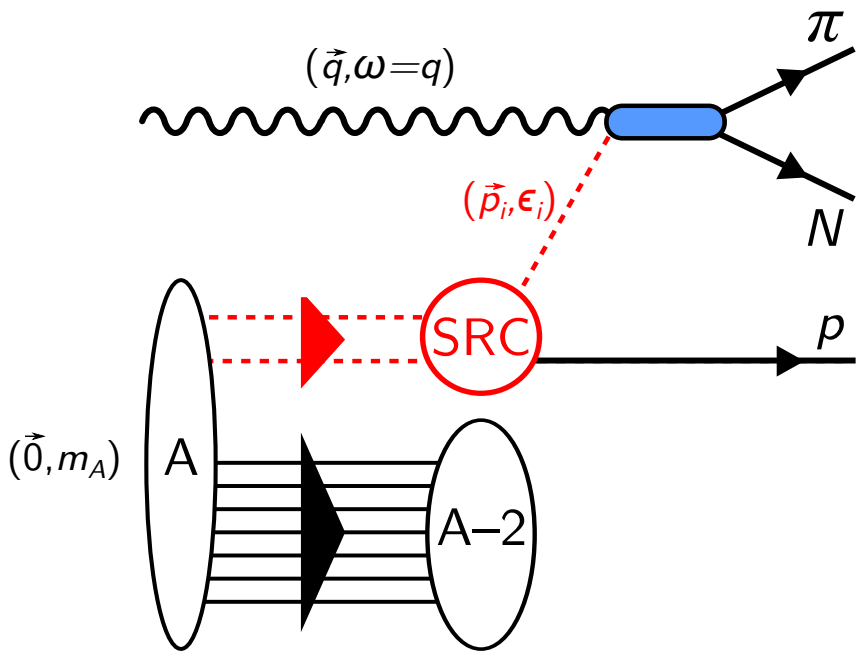
Caveat: These results work in a narrow wedge of anti-parallel kinematics.

- Typical Event Selection Criteria:
  - $x_B > 1.2$
  - $Q^2 > 1$
  - $\theta_{p_{miss},q} > 120^\circ$
  - $0.62 < \frac{|p|}{|q|} < 0.96$
  - $\theta_{p,q} < 25^\circ$



Scale separation: hard reaction factorizes





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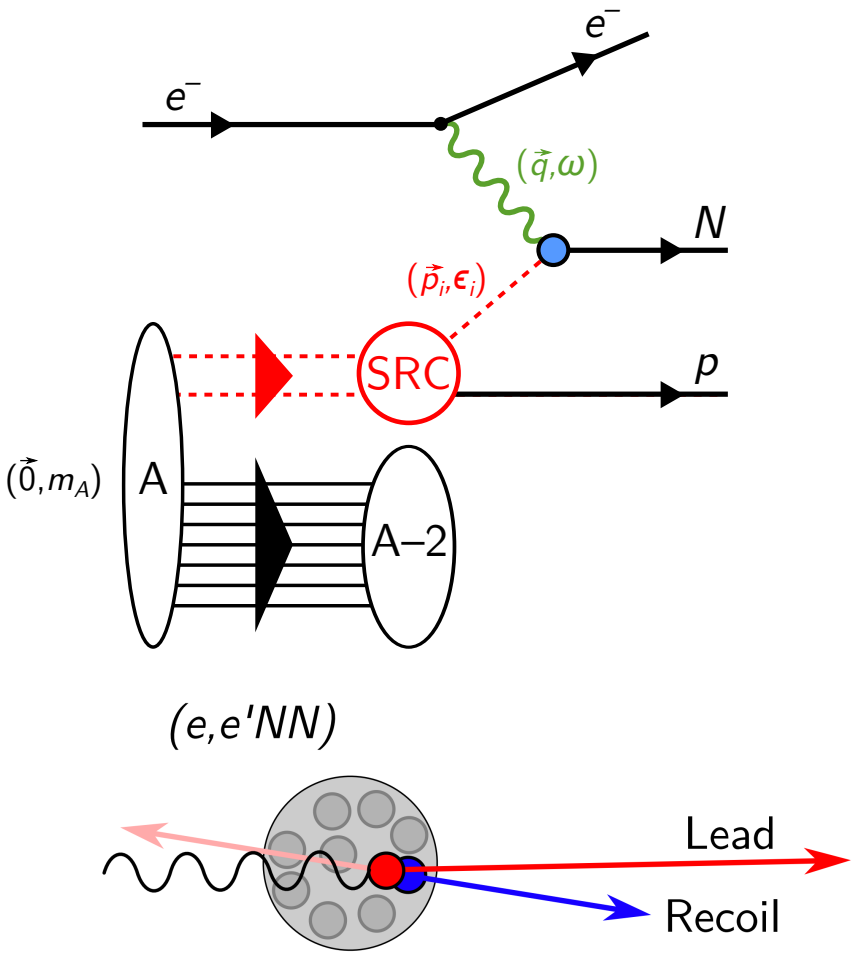
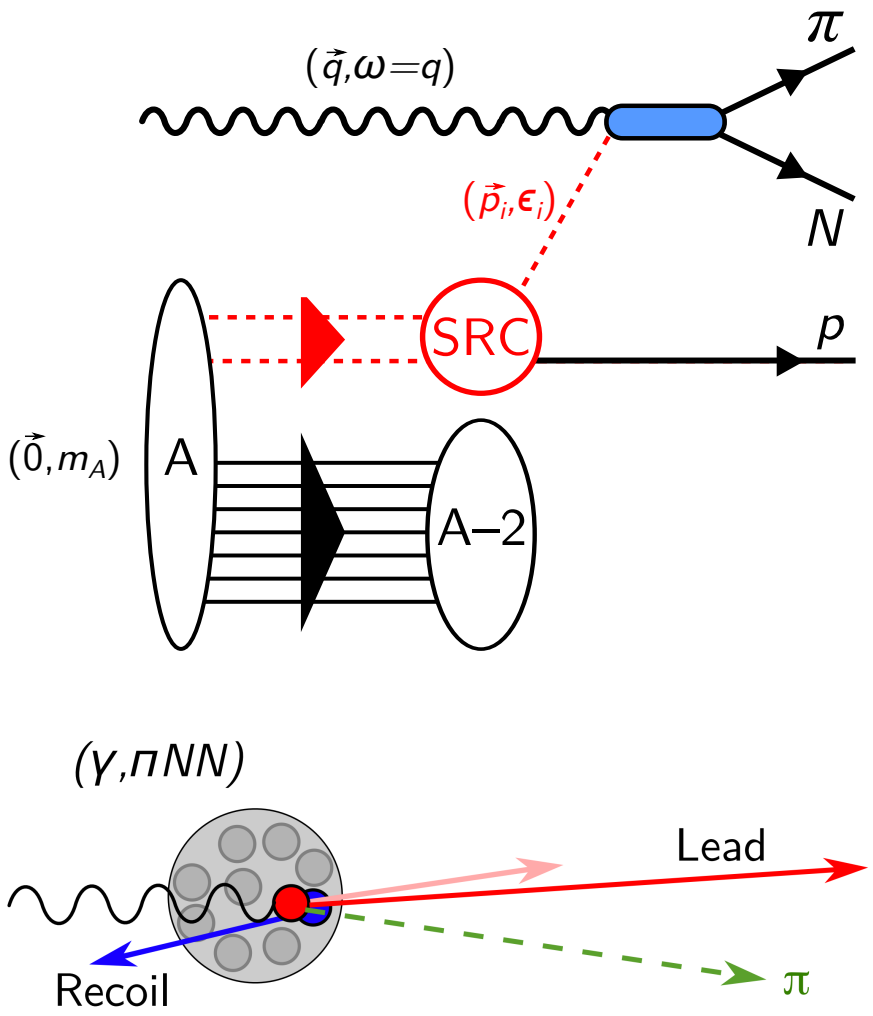
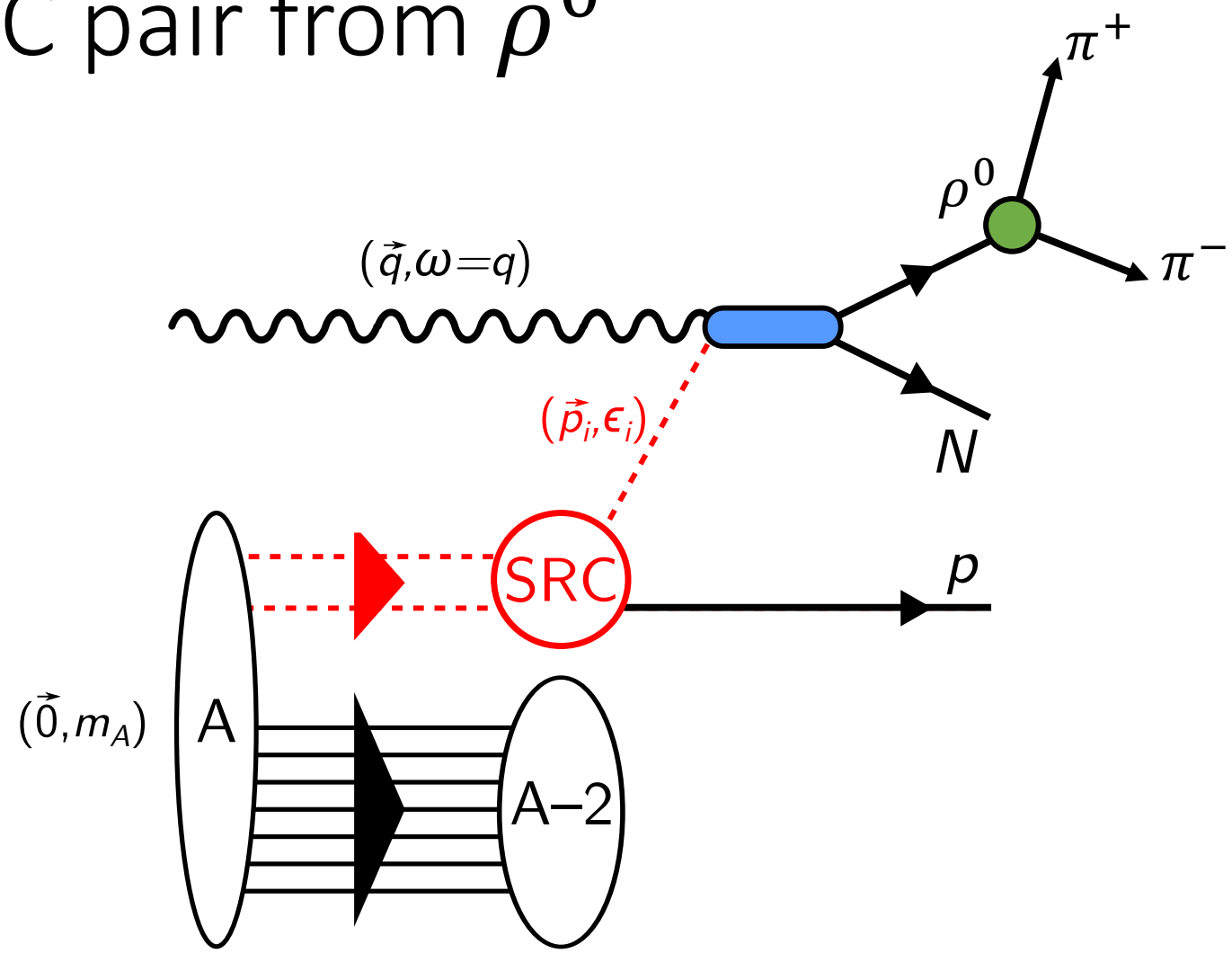
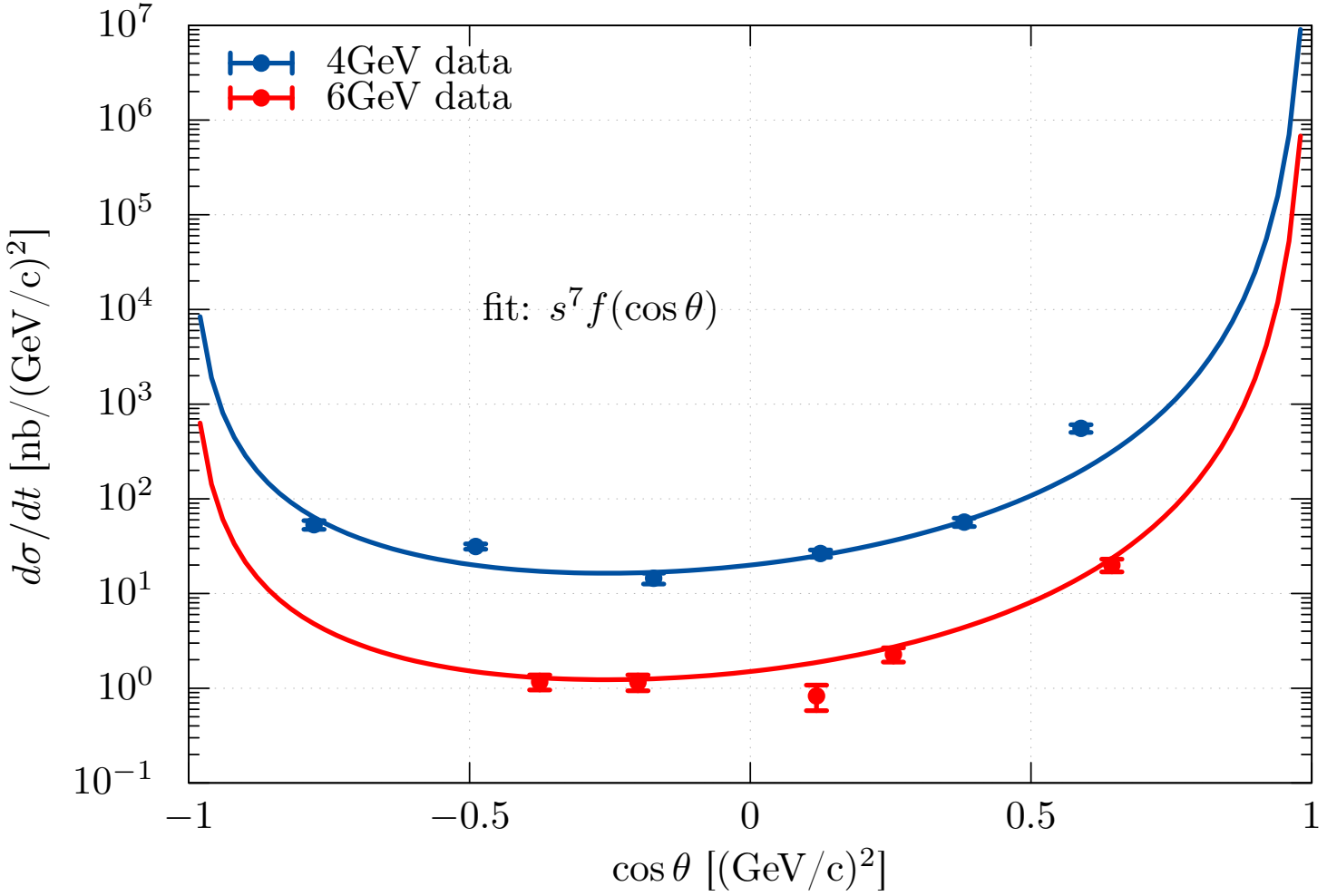




Tagged SRC pair from ρ^0



ρ^0 photoproduction cross sections have been measured, obey scaling laws



R.L. Anderson, D.B. Gustavson, D.M. Ritson, G.A. Weitsch, H.J. Halpern, R. Prepost et al.,
Measurements of exclusive photoproduction processes at large values of t and u from 4 to 7.5 gev,
Phys. Rev. D 14 (1976) 679.

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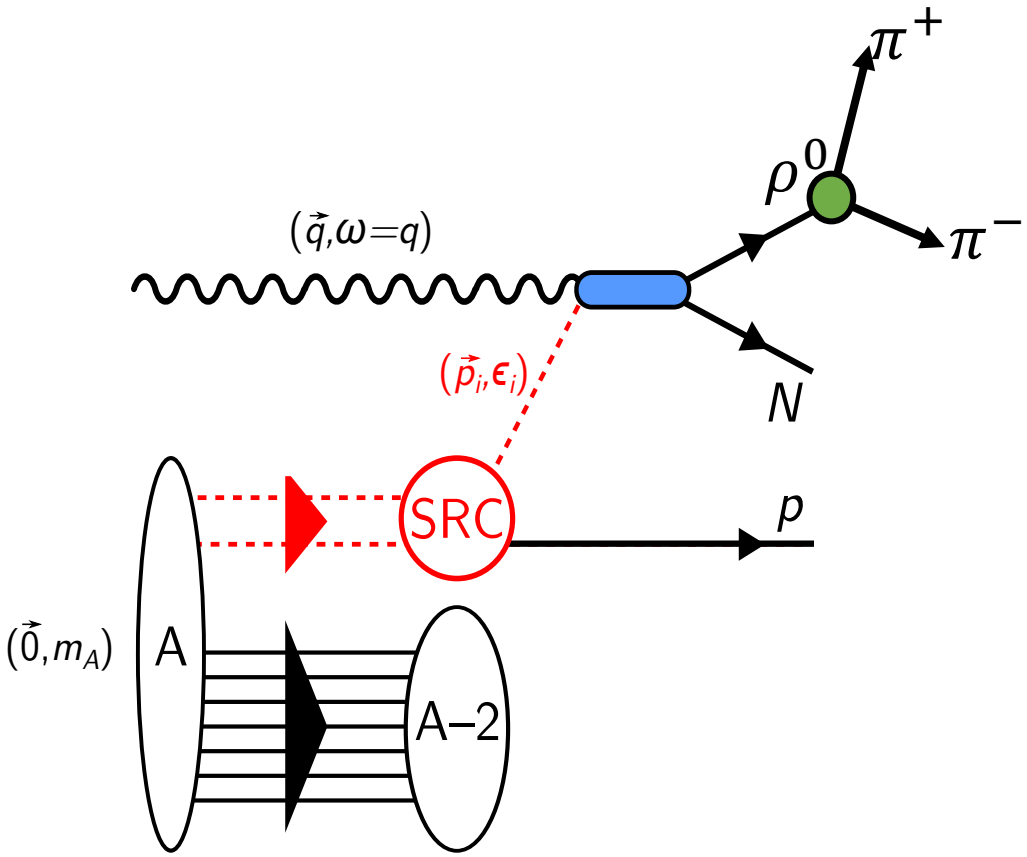
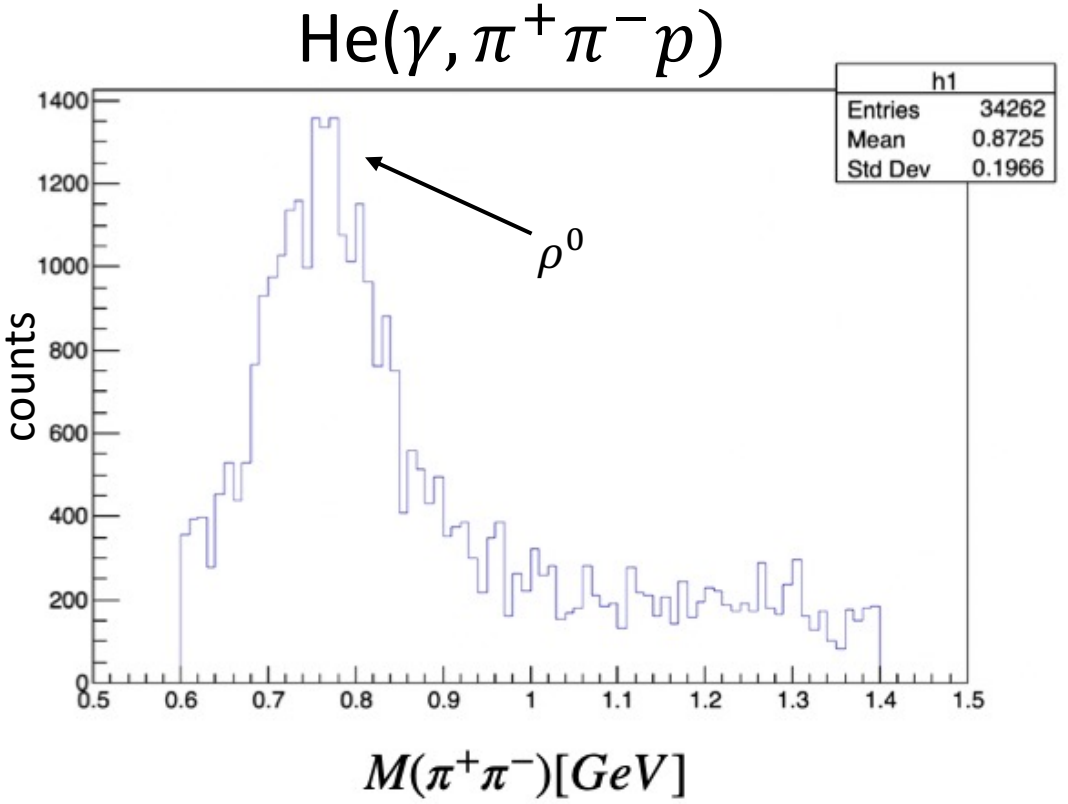


$$d\,\sigma \sim \boldsymbol{\sigma_{\rho^0}} \cdot \Sigma_\alpha\, C_\alpha \cdot P_\alpha(k_{cm}) \cdot \left|\tilde{\phi}(k_{rel})\right|^2$$

The ρ^0 meson is a great for identifying SRC pair breakup.

- High Cross Section
  - Vector Meson Dominance
  - $J^{\pi C}_{\rho^0} = 1^{--}$



N. Santiesteban. Fall 2021

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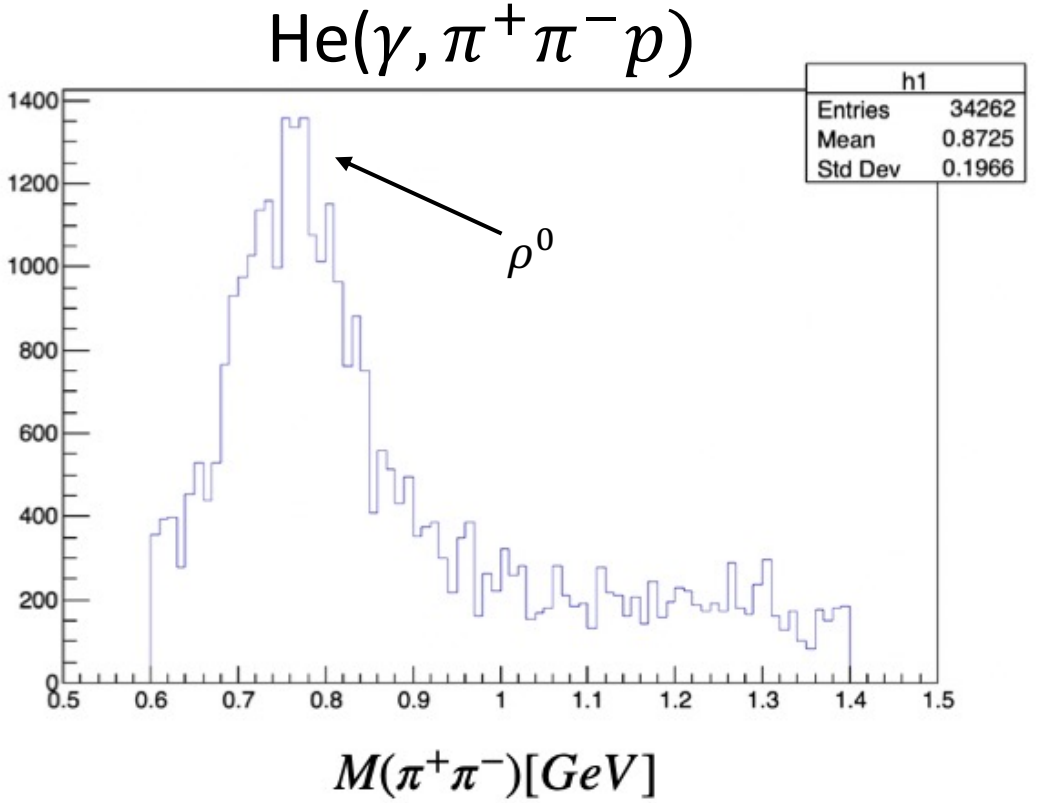
  - ρ^0 lifetime: ~4.5×10^{-24} s



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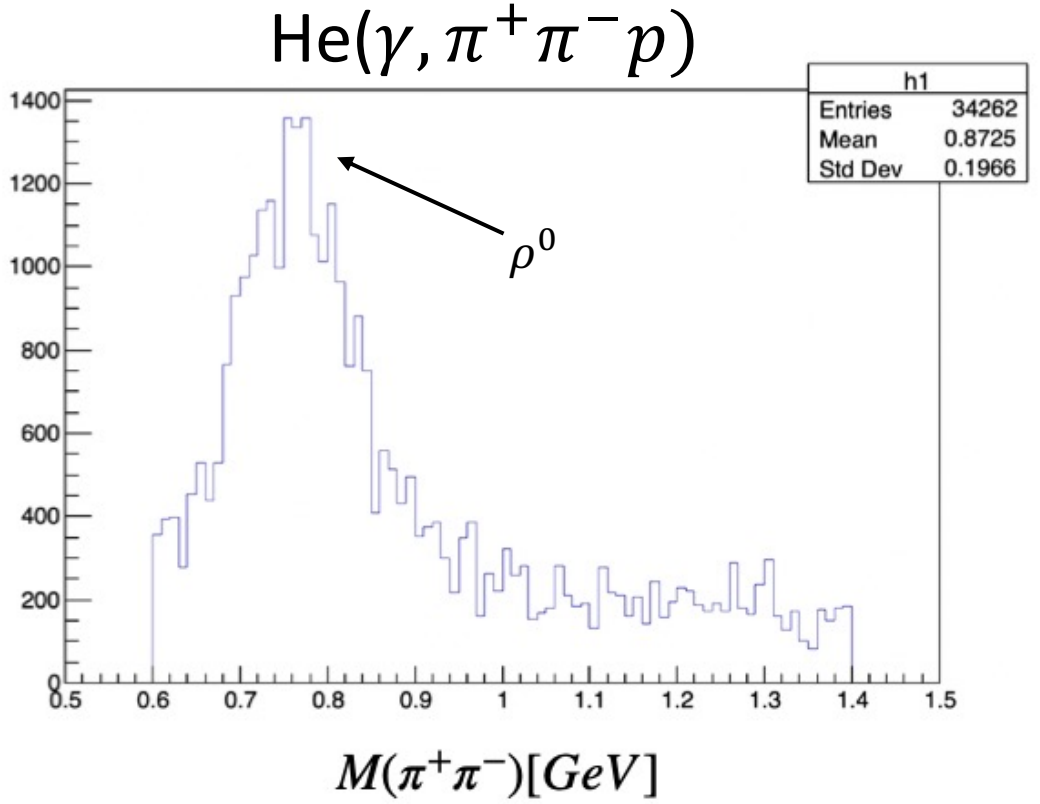
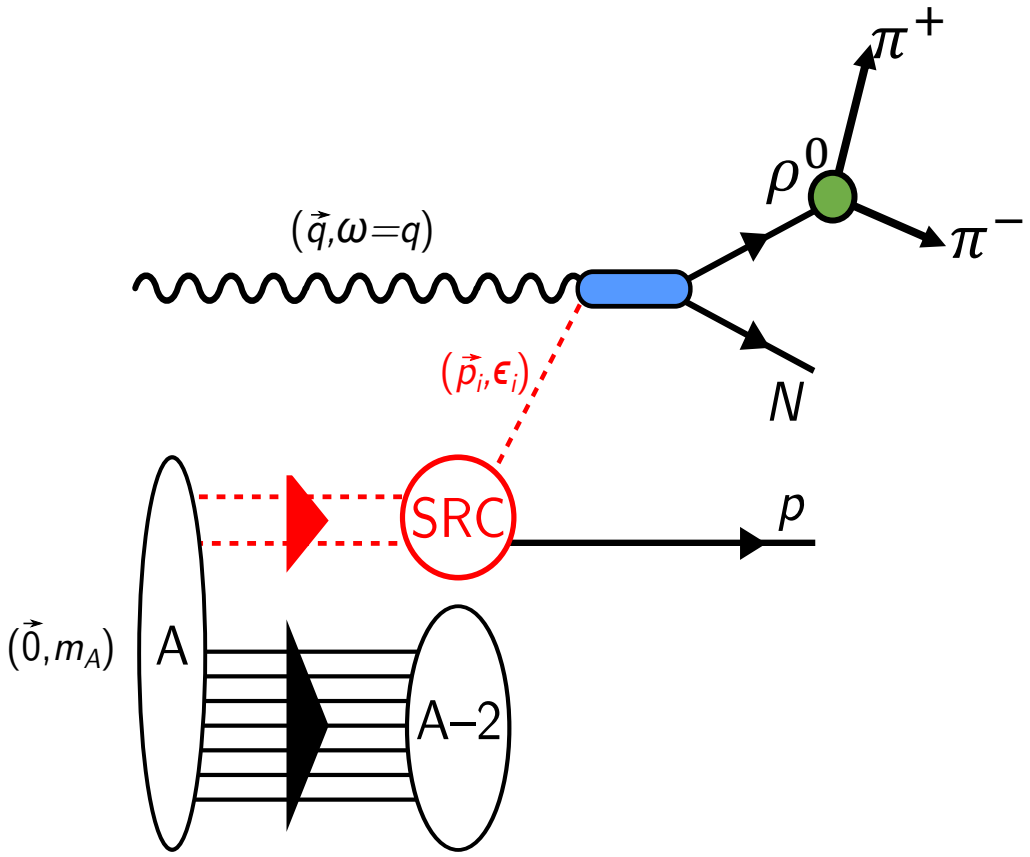
- Identified by invariant mass
  - ρ^0 mass: 0.775 GeV/c^2



Plot Credit: N. Santiesteban. Fall 2021

Using the ρ^0 reaction channel, I want to answer these question:

$$\gamma + p \rightarrow \rho^0 + p \rightarrow \pi^+ + \pi^- + p$$



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2. Can photoproduction confirm the abundances of SRC pairs?

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To do this, I will look at:

- $\gamma + p + (n) \rightarrow \rho^0 + p$
- $\gamma + p + (p) \rightarrow \rho^0 + p + p$
- $$\frac{\sigma(\rho^0 + p + p)}{\sigma(\rho^0 + p)}$$

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To do this, I will look at:

- $\frac{A(\rho^0 p)}{d(\rho^0 p)}$ for C12 and He4

1. Can np-dominance be verified with photon scattering?
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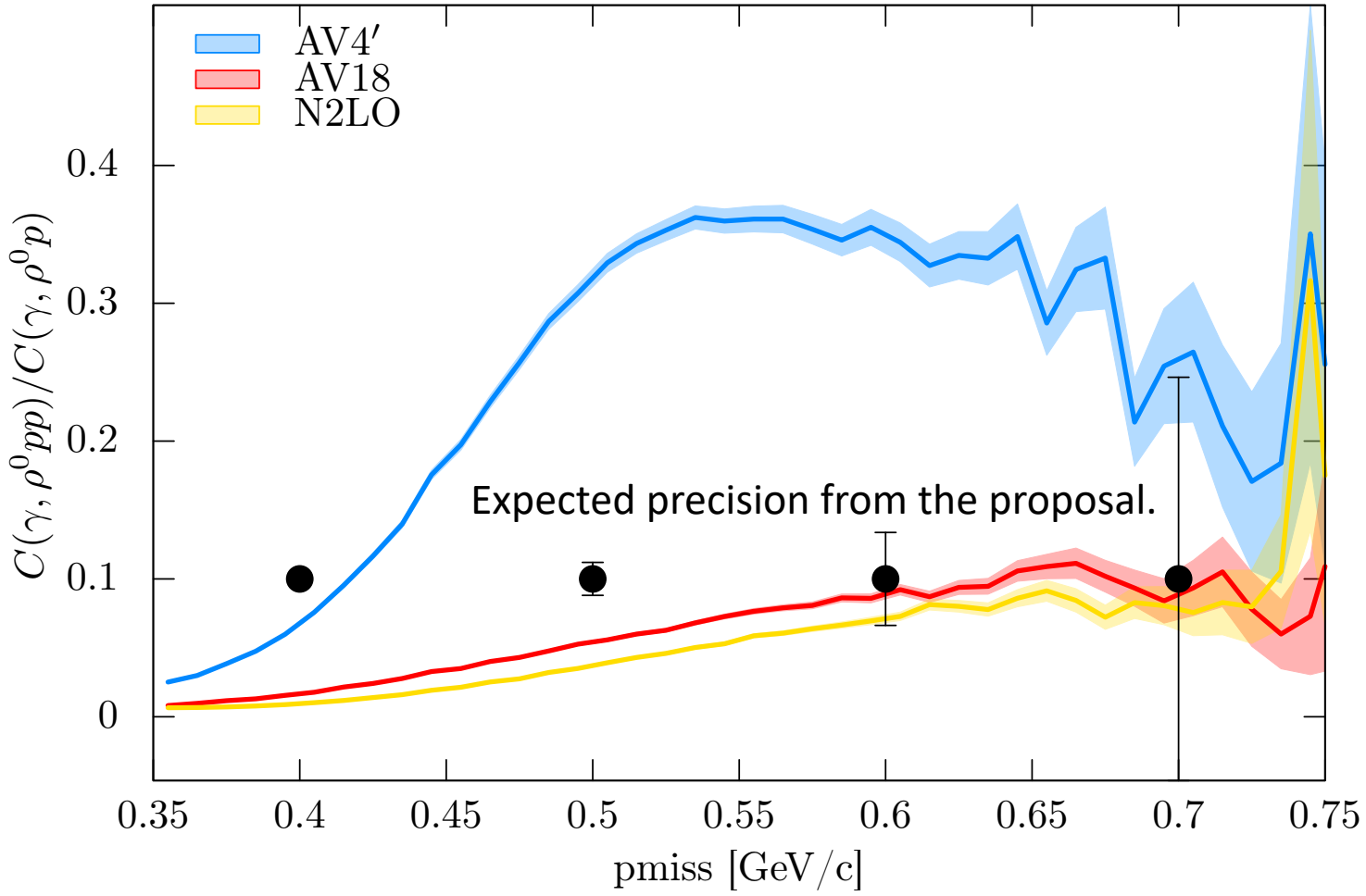
GCF predictions

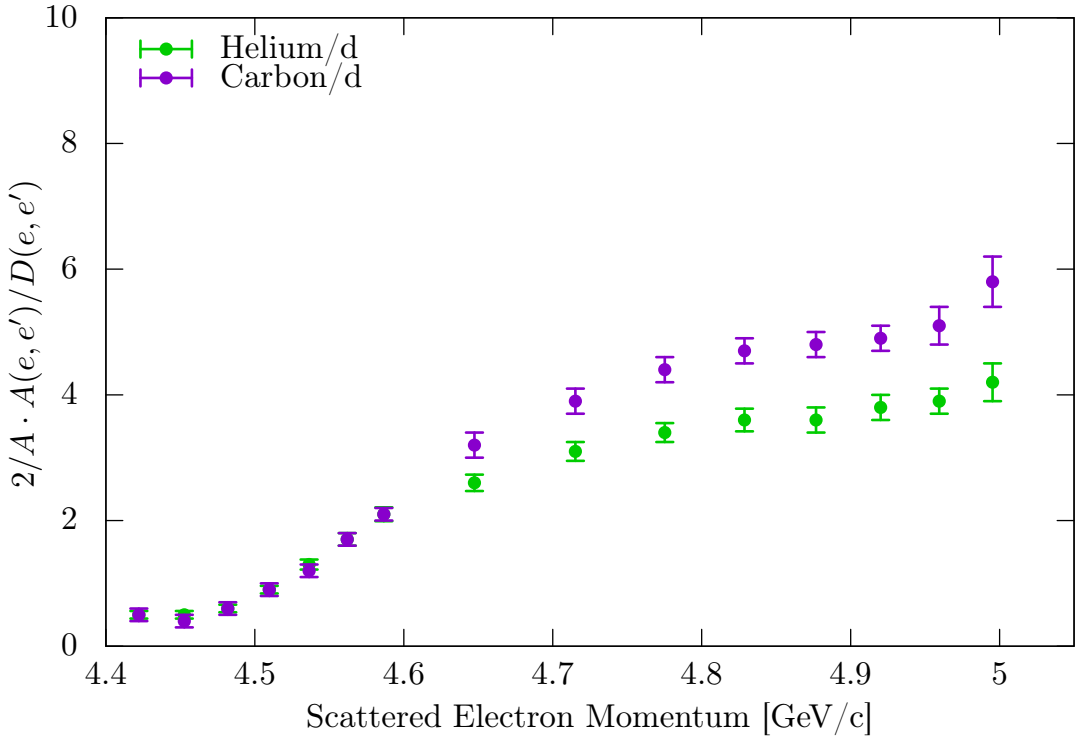
- |u| and |t| > 2
- For lead proton:
  - $\theta_{baryon} > 1.5°$, $|p_{miss}| > 0.350$ GeV, and $\theta_{p_{miss}} < 45°$
- For recoil proton:
  - $\theta_{baryon} > 1.5°$, $|p_{miss}| > 0.350$ GeV, and $\theta_{p_{miss}} < 45°$
  - $\theta_{recoil} > 1.5°$, and $|p_{recoil}| > 0.350$ GeV

- No Geant yet

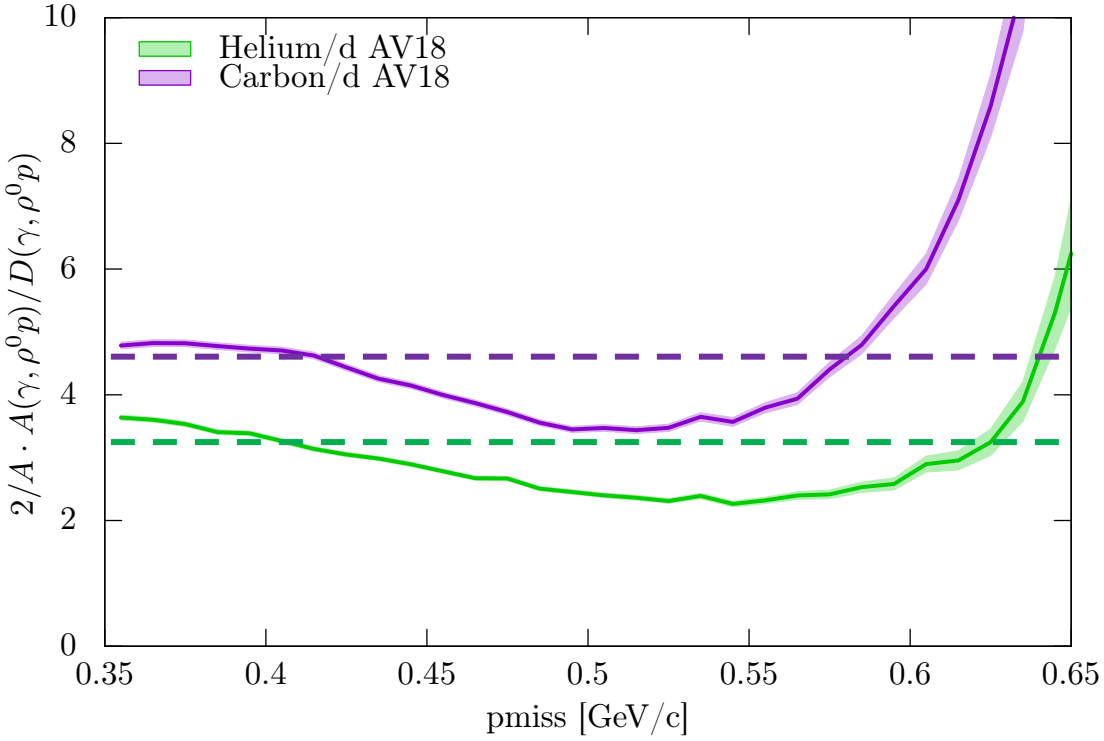
GCF Predictions of np-pair dominance using ρ^0 photoproduction.



GCF Predictions of pair abundances using ρ^0 photoproduction.



Previous electron scattering data



Photoproduction prediction

N. Fomin, J. Arrington, R. Asaturyan, F. Benmokhtar, W. Boeglin, P. Bosted et al., *New measurements of high-momentum nucleons and short-range structures in nuclei*, *Phys. Rev. Lett.* **108** (2012) 092502.

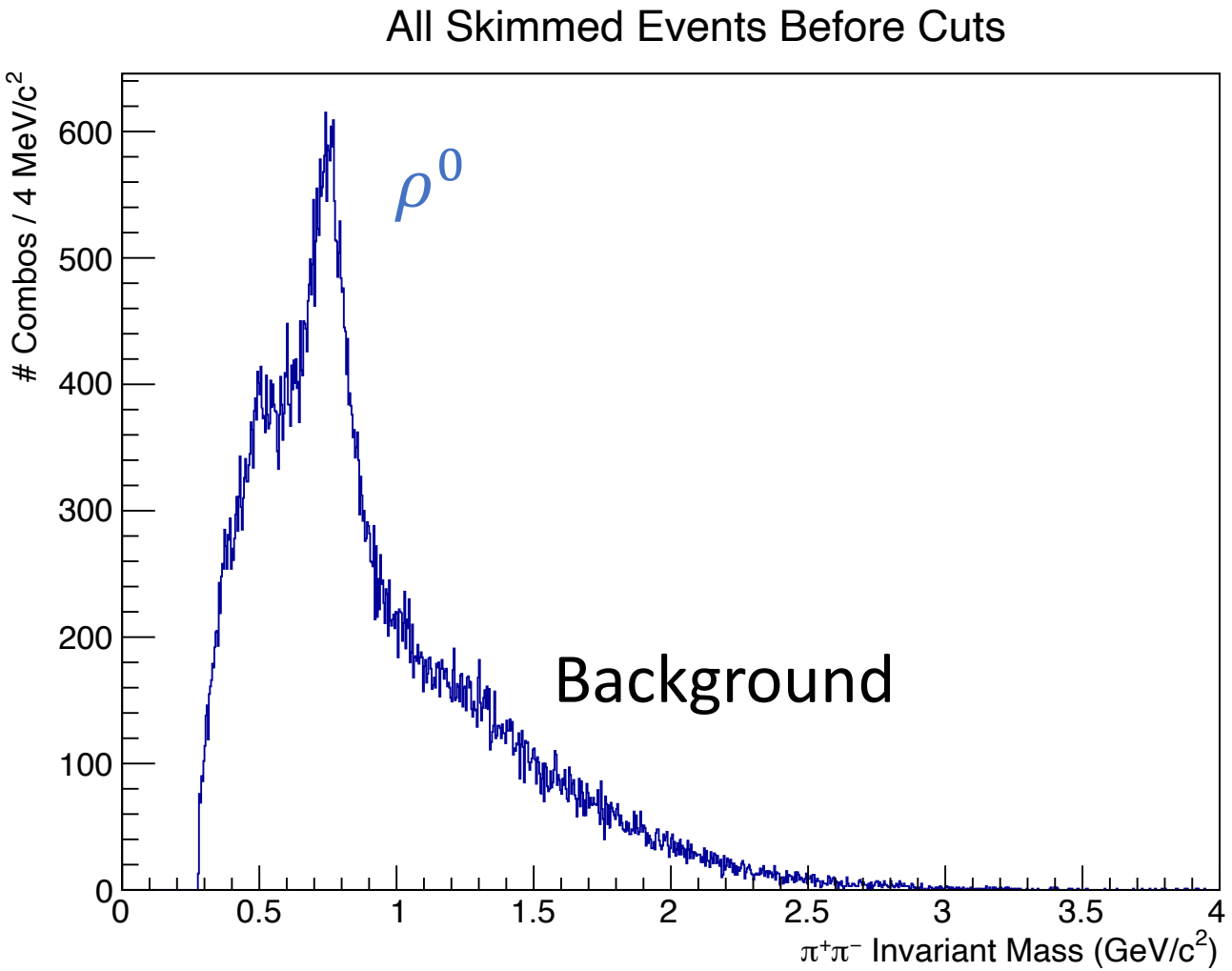
Add prelim stuff from work flow

- Skim for $\gamma\ d\ \rightarrow \pi^{+}\pi^{-}p(n)$
- Kinematic Fit constraining vertices, missing neutron mass
  - Confidence Level Cut
- Event Selection Criteria
  - Fiducial Cuts
  - Remove contaminates ($\phi, \Delta^{0}, \Delta^{++}, \ldots$)
  - Select SRC events using p_{miss}, or p_{proxy}
  - Fit signal, background using $M_{\pi^{+}\pi^{-}}$

Invariant Mass

$$\gamma\, d \rightarrow \pi^+\, \pi^-\, p$$

- Cuts Applied
  - KFCL > 0.01
  - PIDCL> 0.1
  - 6 < Ebeam < 10



From < 1% of available data

Time difference

$$\gamma\, d \rightarrow \pi^+\, \pi^-\, p$$

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  - KFCL > 0.01
  - PIDCL> 0.1
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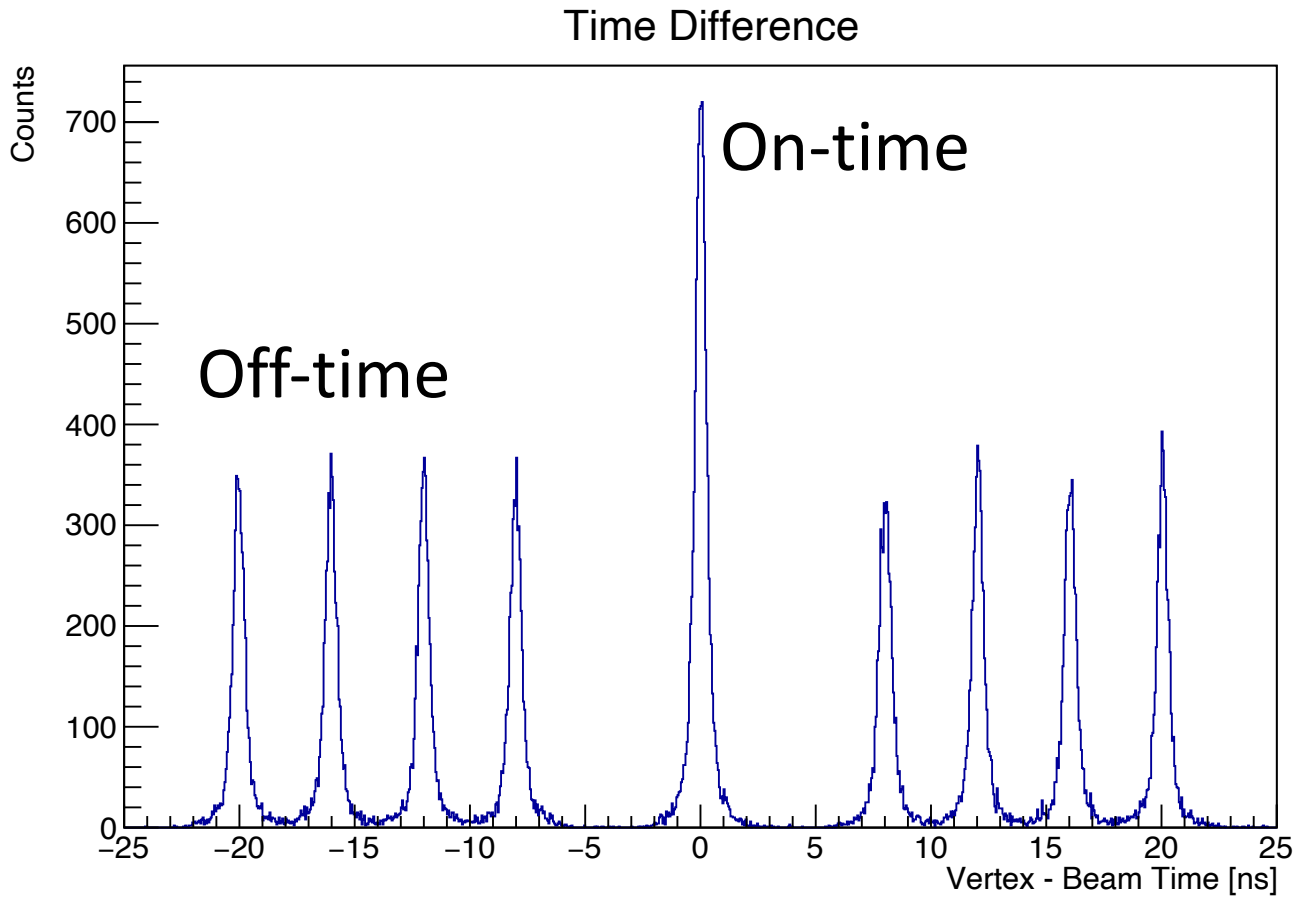

Vertex Cuts

$$\gamma\, d \rightarrow \pi^+\, \pi^-\, p$$

- Cuts Applied
  - KFCL > 0.01
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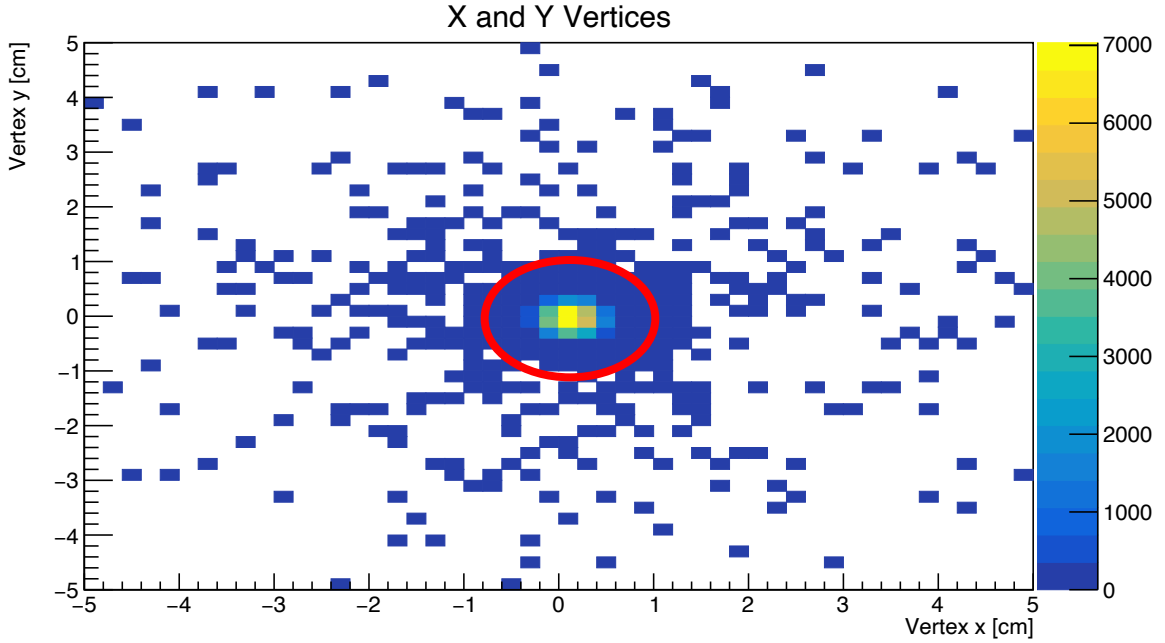
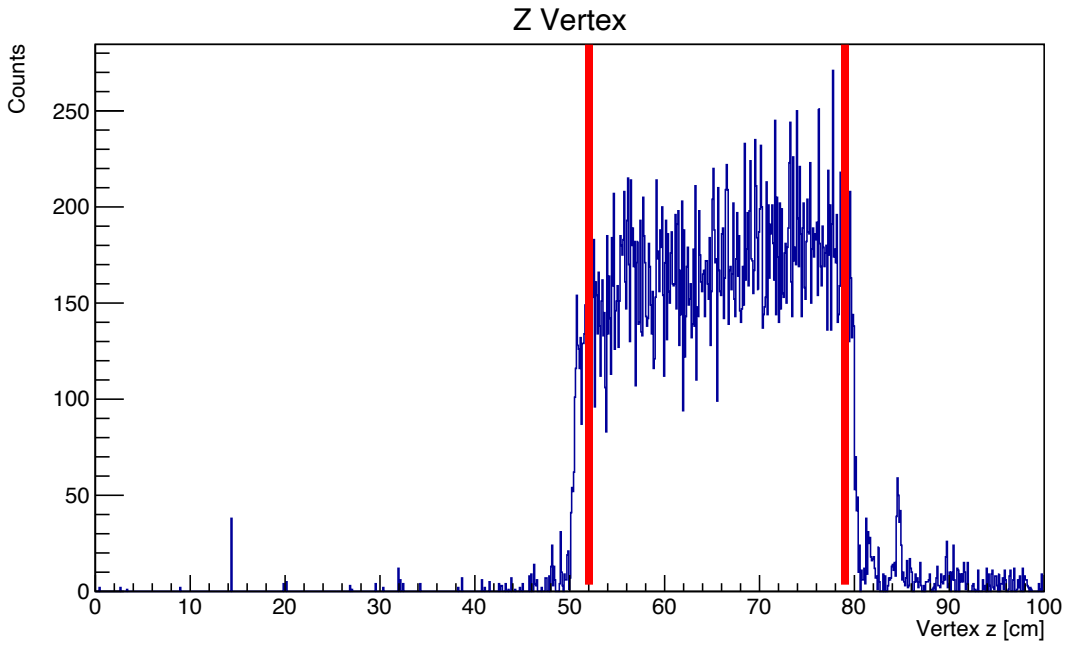
  - 6 < Ebeam < 10
  - OffTime Subtraction





Missing Energy

$$\gamma\, d \rightarrow \pi^{+}\, \pi^{-}\, p$$

- Cuts Applied
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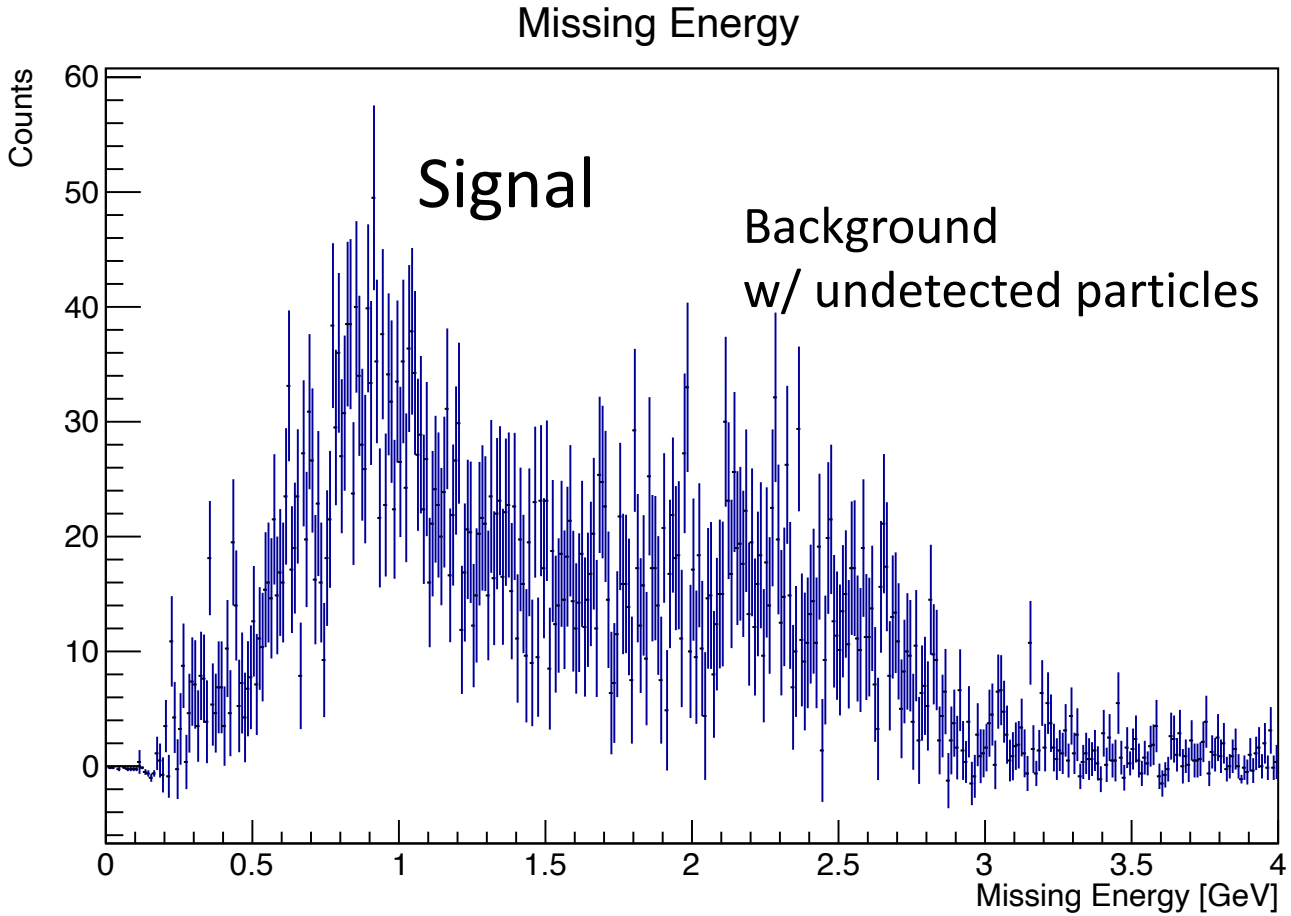

Missing Mass Squared

$$\gamma\, d \rightarrow \pi^{+}\, \pi^{-}\, p$$

- Cuts Applied
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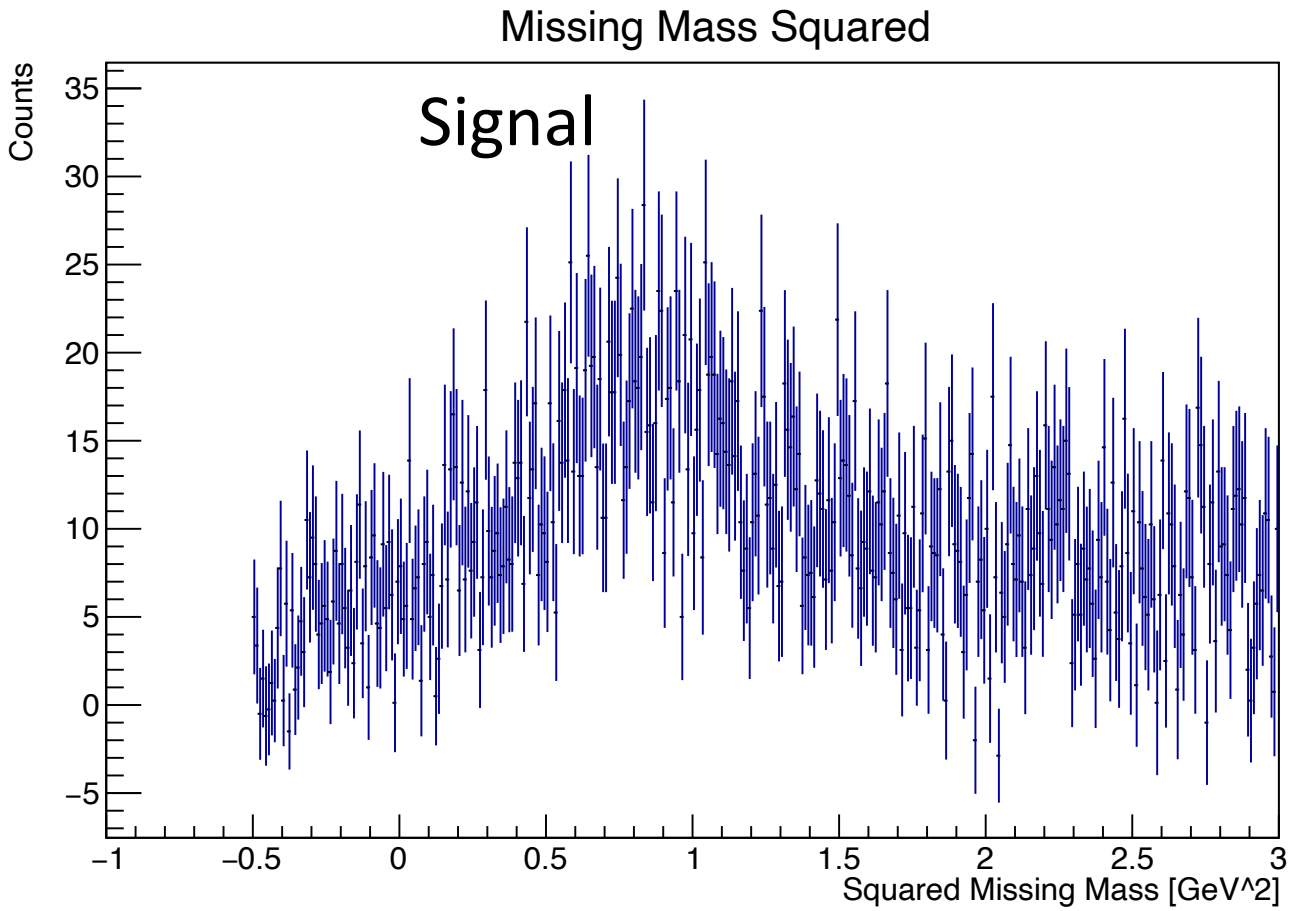

Missing Momentum

$$\gamma\, d \rightarrow \pi^{+}\, \pi^{-}\, p$$

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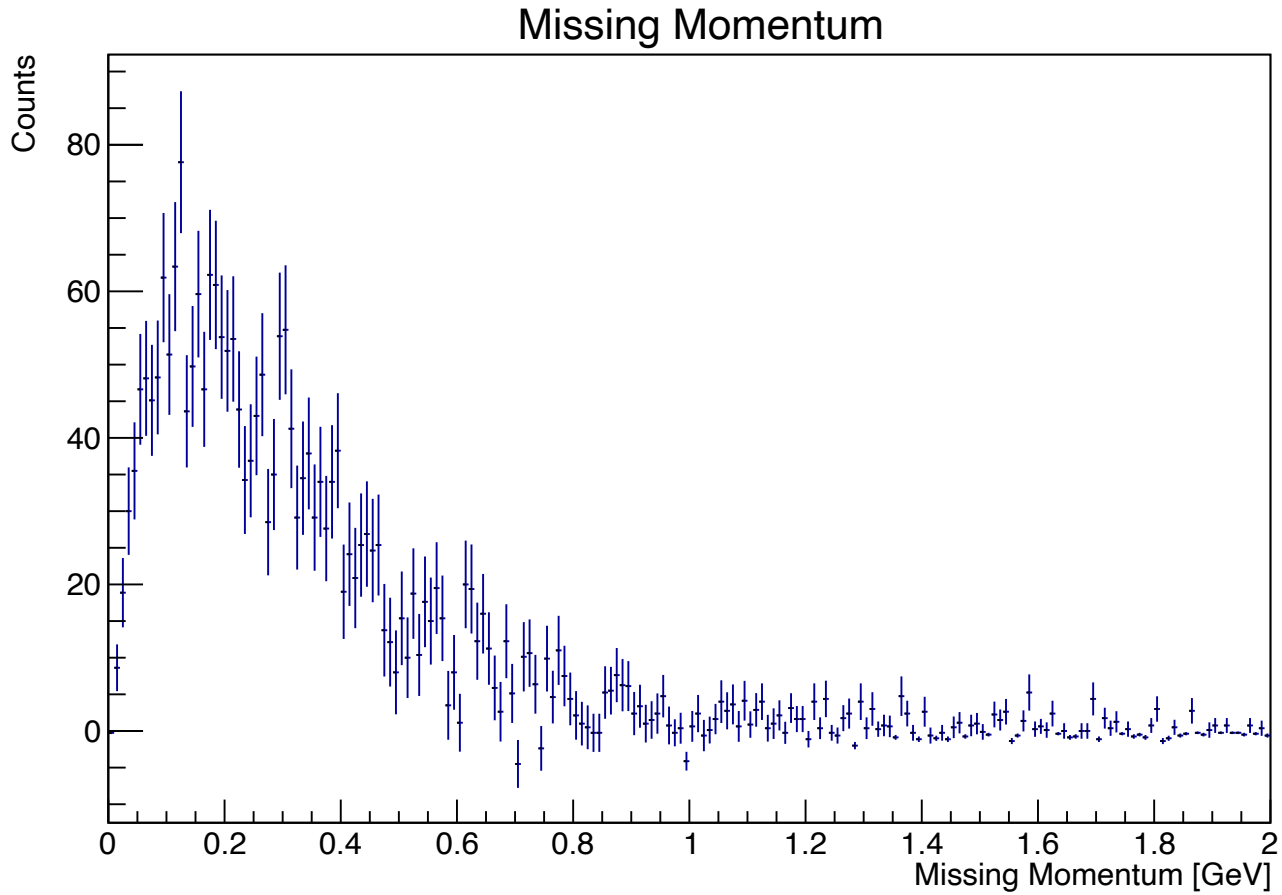

Conclusion

- The Hall D SRC/CT experiment will validate scale separation.
- Photoproduced ρ^0 mesons will be used to tag SRC pairs.
- Analysis is in preliminary stages.