Testing the universality of short-range correlations using electron and photon probes at Jefferson Lab

Phoebe Sharp

George Washington University

APS April Meeting

Sacramento, CA

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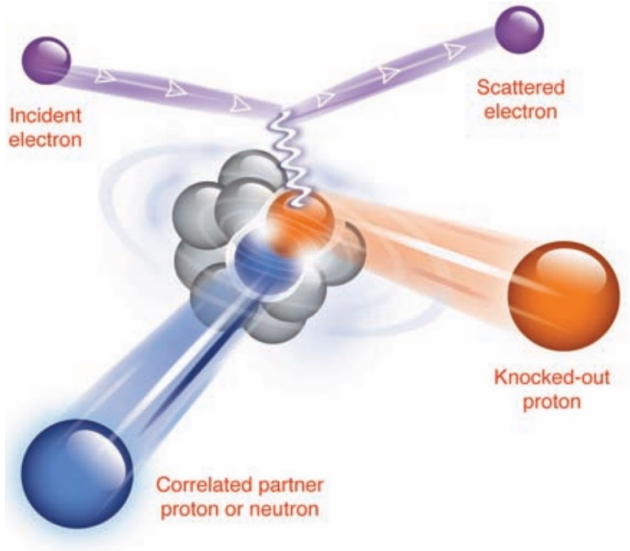
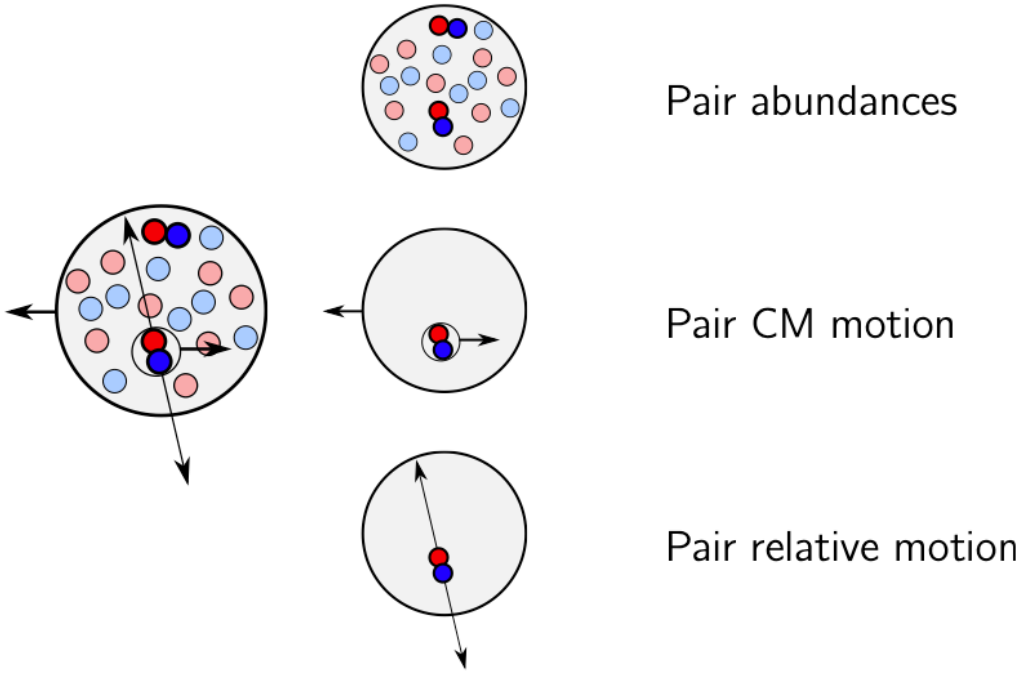
The Playbook on detecting SRCs from nucleon knockout with electrons

- Work in anti-parallel kinematics
  - $x_B > 1$
  - Reduce FSI
- High momentum transfer
  - Reduce MEC
- Large missing momentum
  - Hit nucleons above Fermi momentum



- Detect a correlated spectator nucleon?

Generalized Contact Formalism
Scale separated approach to Short Range Correlations



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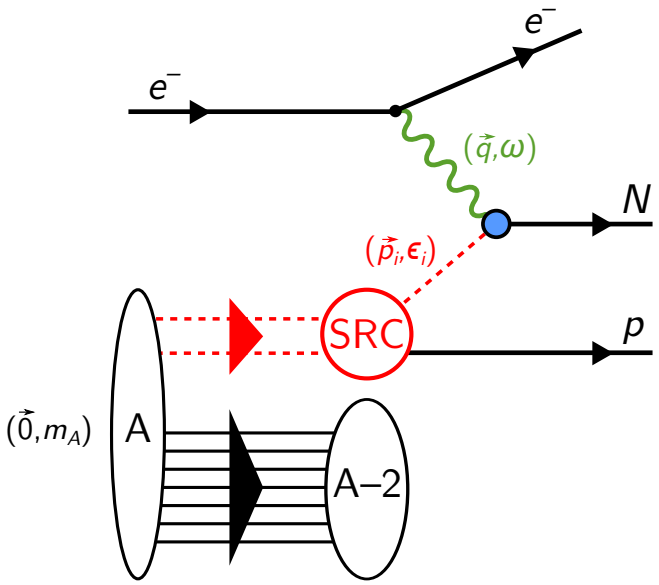
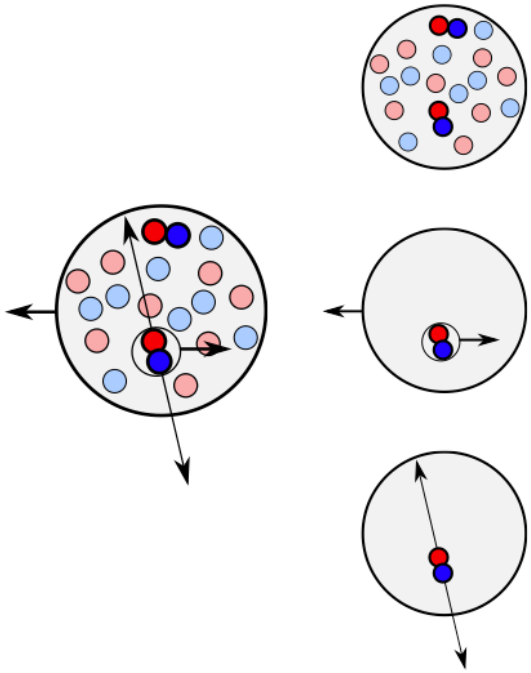




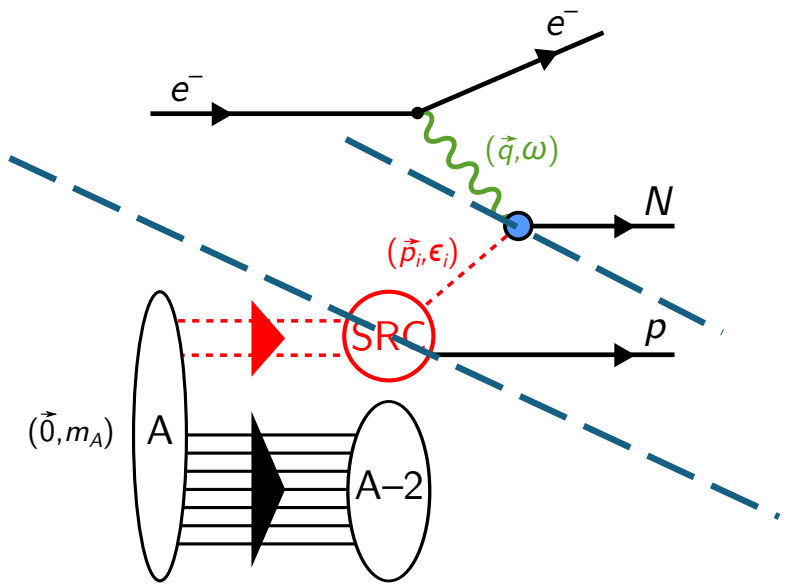
Pair abundances

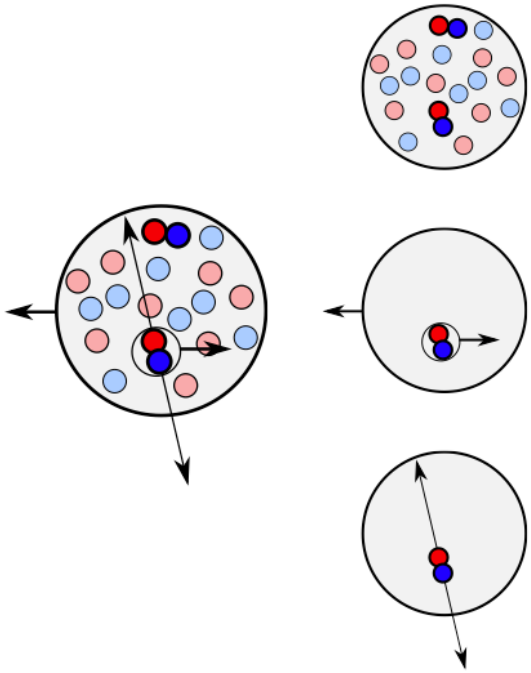
Pair CM motion

Pair relative motion

Generalized Contact Formalism

Scale separated approach to Short Range Correlations





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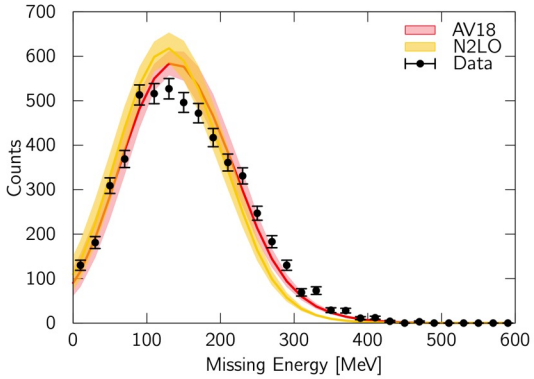

Schmidt, A., et.al. (CLAS) Nature *578* (2020).

$C(e,e'p)$

Generalized Contact Formalism

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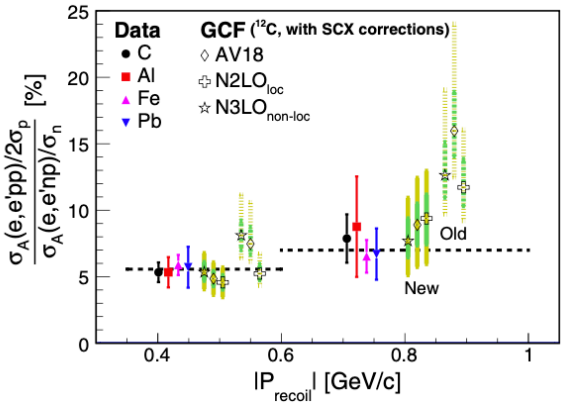
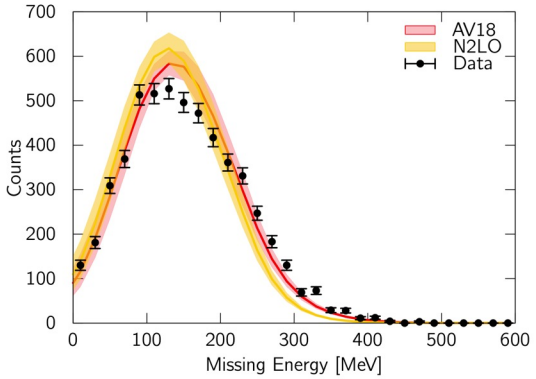


M. Duer et al., (CLAS)
PRL 122 172502 (2019)

A(e , e ‘ N p)



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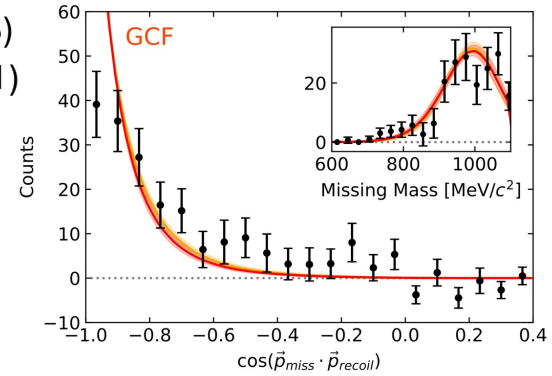
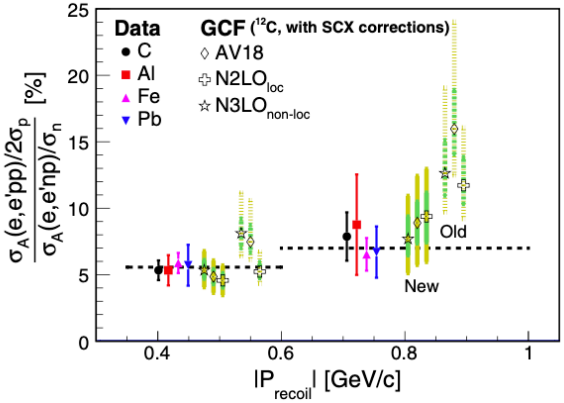
Korover, I., et. al, (CLAS)
PLB, *820*. 136523 (2021)

C (e , e ’p n)





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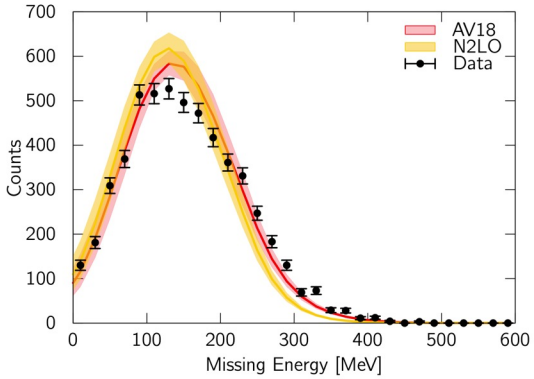

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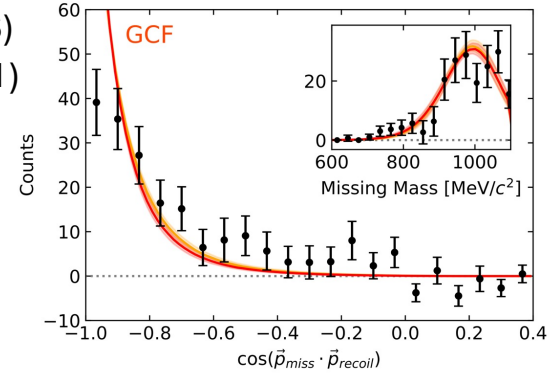
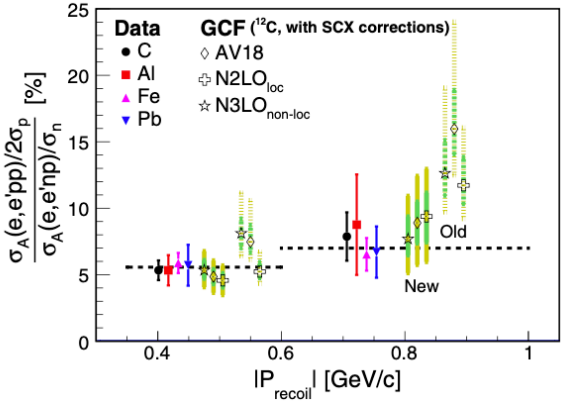


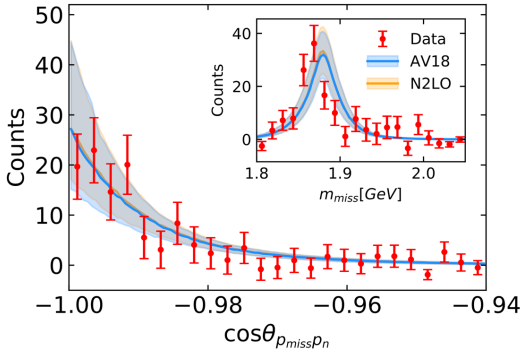


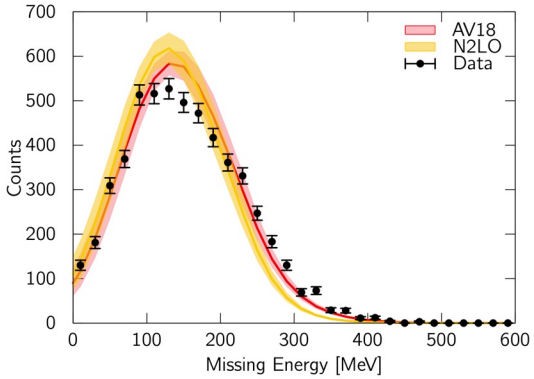
M. Duer et al., (CLAS)
PRL 122 172502 (2019)

A(e , e ‘ N p)

I. Korover et al., (Hall A)
PRL 113 022501 (2014)
Pybus, J. R., et. al, *PLB*, *805*, 135429. (2020).

4 He (e , e’ p n)





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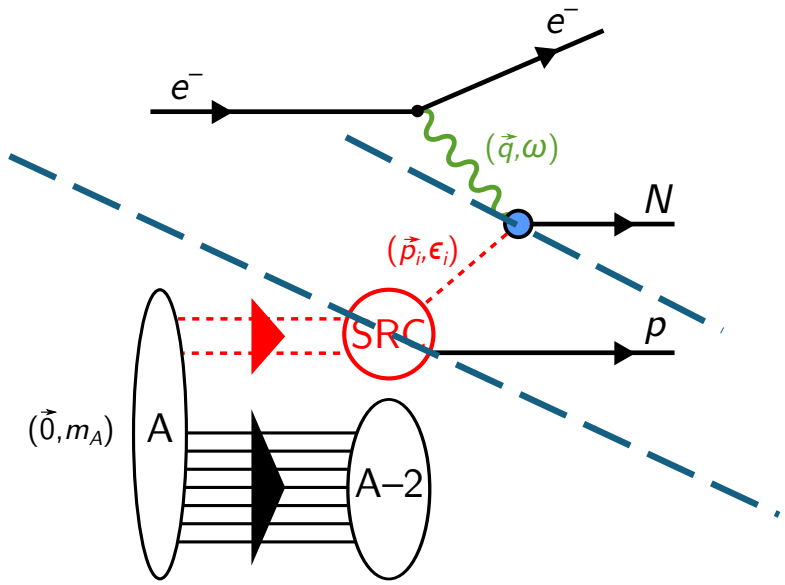
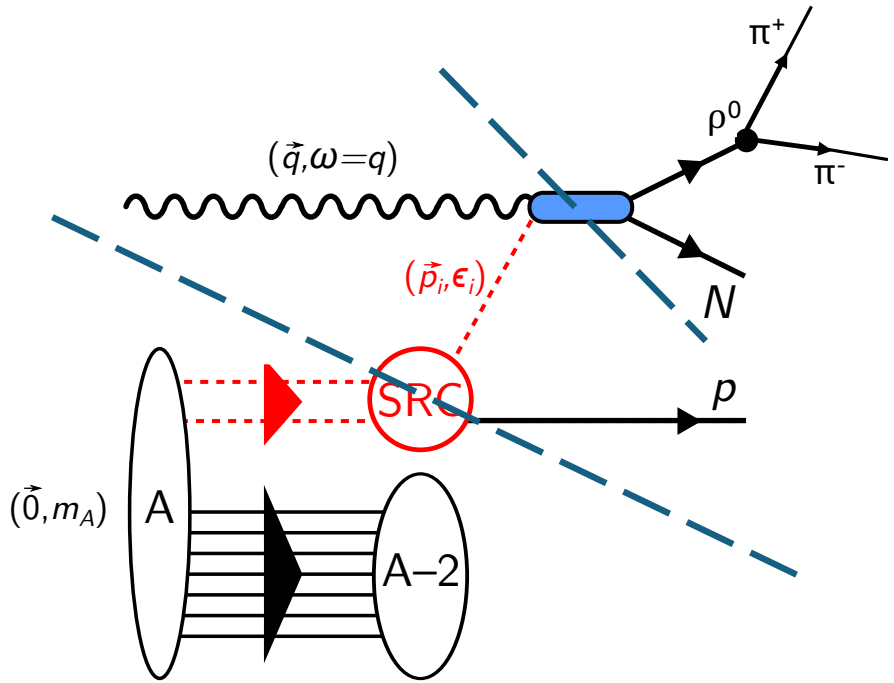
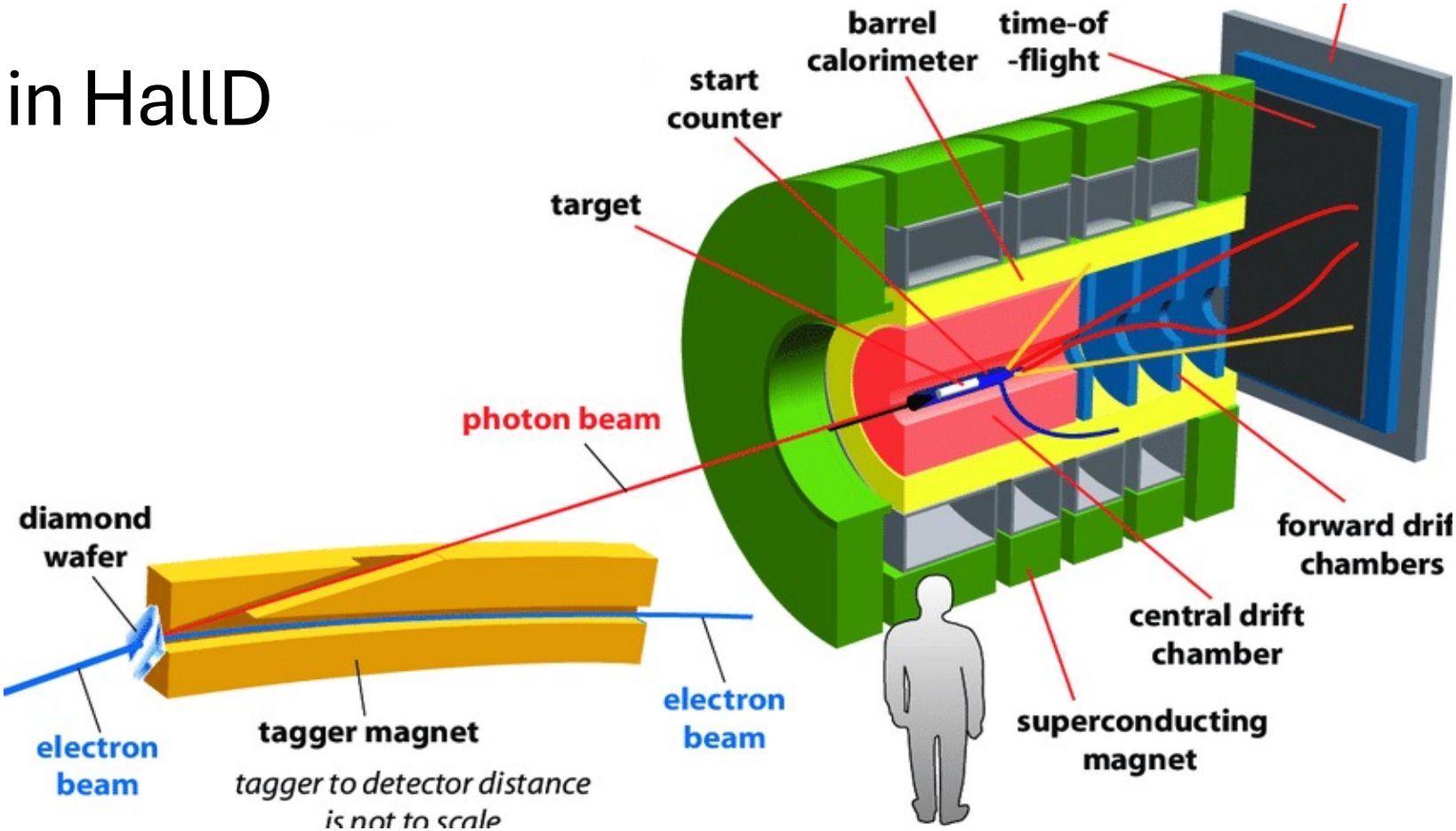
C (e , e ’p)

Testing Probe Universality of SRCs





GlueX in HallD



GlueX Collaboration, et al. *First Results from The GlueX Experiment*. Dec. 2015. *ResearchGate*, doi:10.1063/1.4949369.

SRC @ GlueX: Experimental Details

- November - December 2021
- 43 days
- Collaboration at GW, MIT, Duke, MSU, Tel Aviv, ODU, and Jlab
- Analysis Status:
  - Dark Matter Search – *in peer review*
  - **Preliminary Short Range Correlations Results**

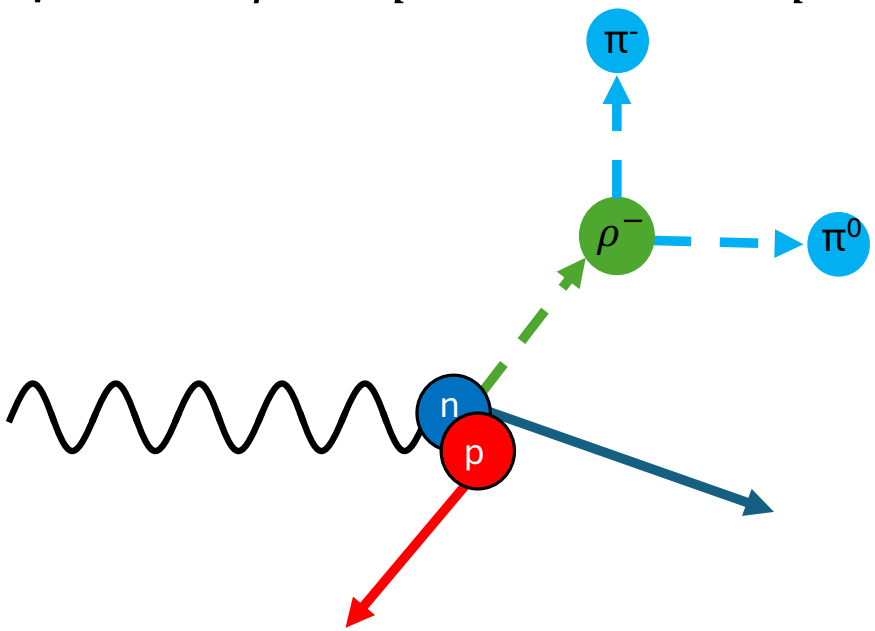
Target	Days on Beam
Liquid Helium 4	10
Liquid Deuterium	4
Carbon Multi-Foil	14

GlueX allows us to learn about multiple reaction channels.

p reactions	n reactions
$\gamma p \to \pi^0 p$	$\gamma n \to \pi^- p$
$\gamma p \to \pi^- \Delta^{++}$	$\gamma n \to \pi^- \Delta^+$
$\gamma p \to \rho^0 p$	$\gamma n \to \rho^- p$
$\gamma p \to K^+ \Lambda$	$\gamma n \to K^0 \Lambda$
$\gamma p \to K^+ \Sigma^0$	$\gamma n \to K^0 \Sigma^0$
$\gamma p \to \omega p$	$\gamma n \to K^+ \Sigma^-$
$\gamma p \to \phi p$	$\gamma n \to K^- \Sigma^+$
$\vdots$	$\vdots$

GlueX allows us to learn about multiple reaction channels.

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



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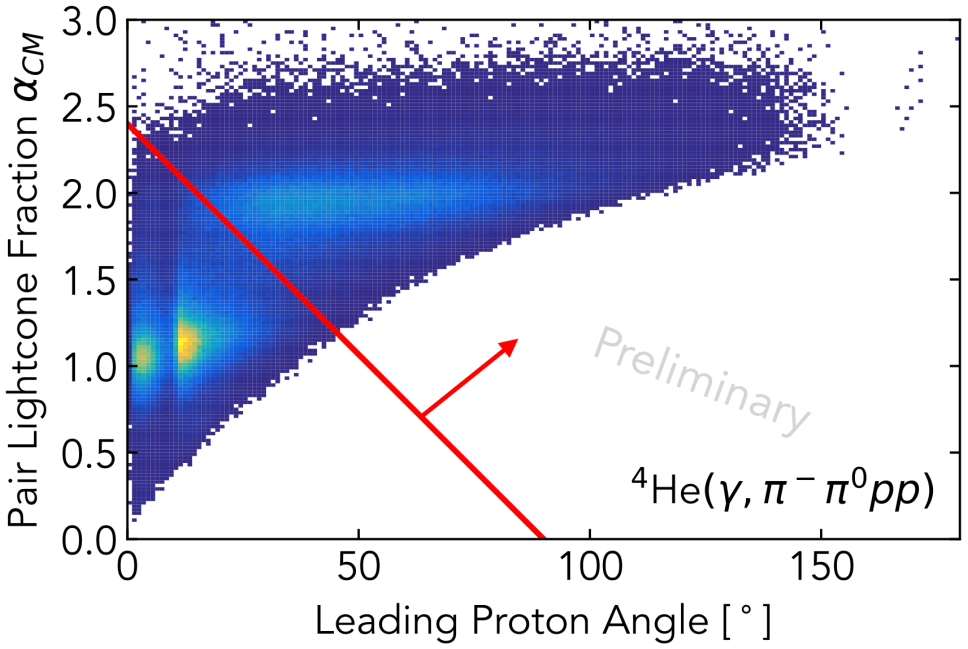
$\vdots$	$\vdots$

GlueX is very different from CLAS.

CLAS	Property	GlueX
< 1% Forward, < 3% Central	Momentum Resolution	3-10% (Measures $p_\perp$, θ)
Very Good	Particle ID	Poor
Limited Coverage	Gamma Detection	Nearly 4 π

We need to isolate the ρ^- photoproduction signal.



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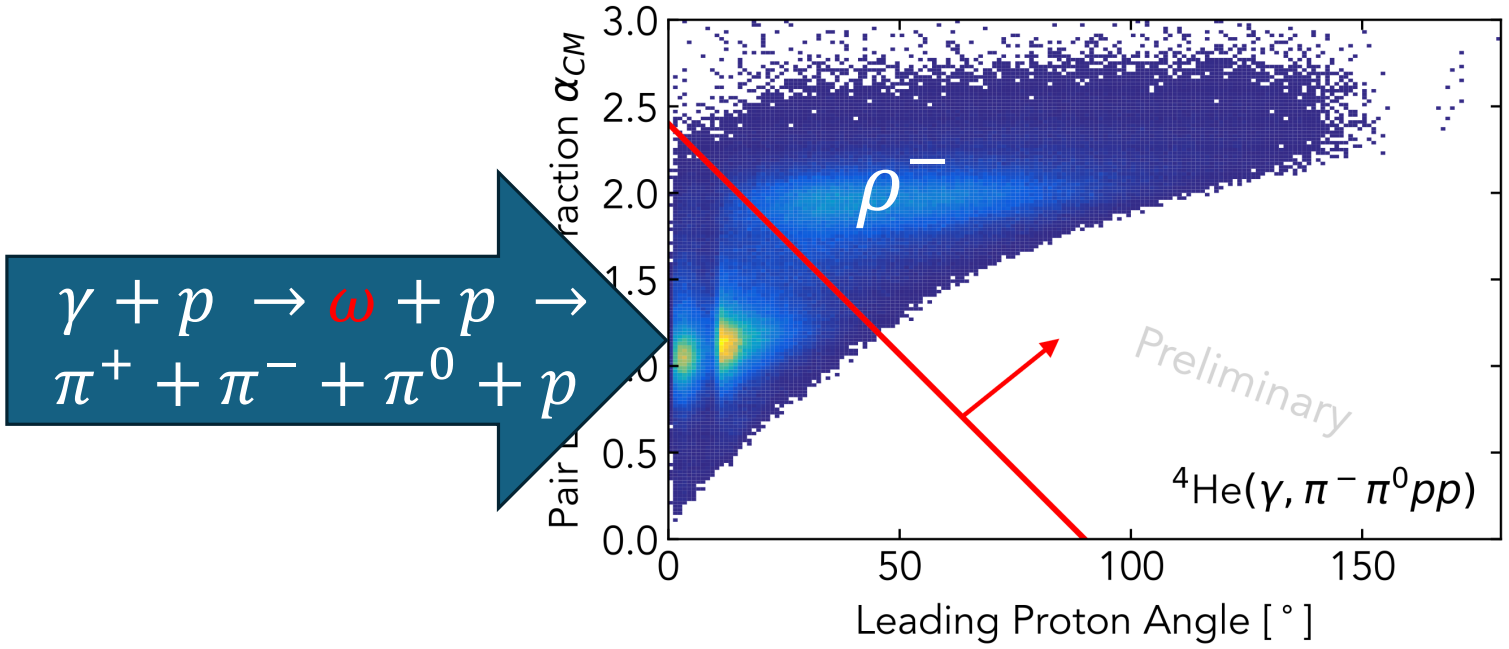
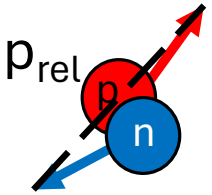


We need to select high momentum nucleons.

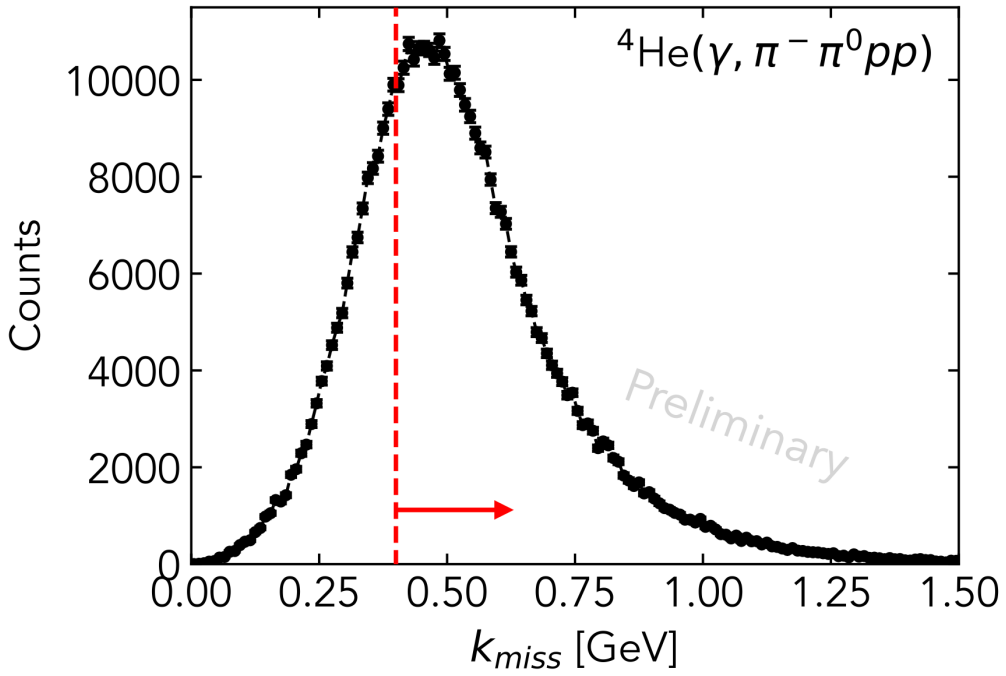


Traditionally

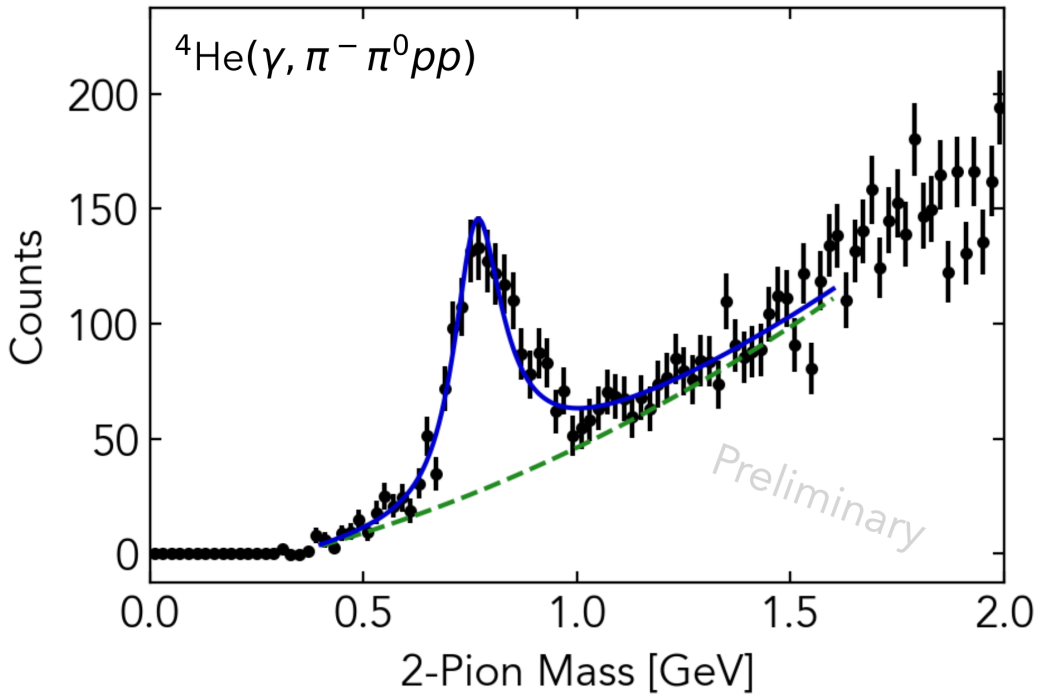
$$p_{\mathrm{miss}} = \overrightarrow{p_N} - \vec{q}$$

In our experiment

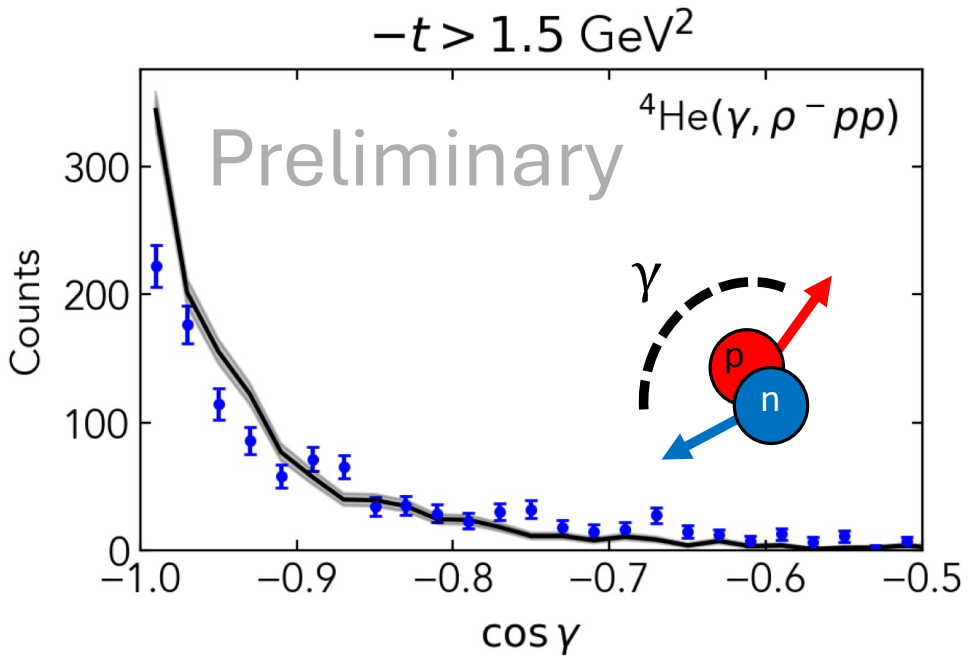
$$k_{\mathrm{miss}} = m_N \sqrt{\frac{m_N^2 + p_{miss\perp}^2}{p_{miss}^-\left(2m_N - p_{miss}^-\right)}} - 1$$



Isolating ρ^- above background



A signature of ρ^- tagged SRC events on He4



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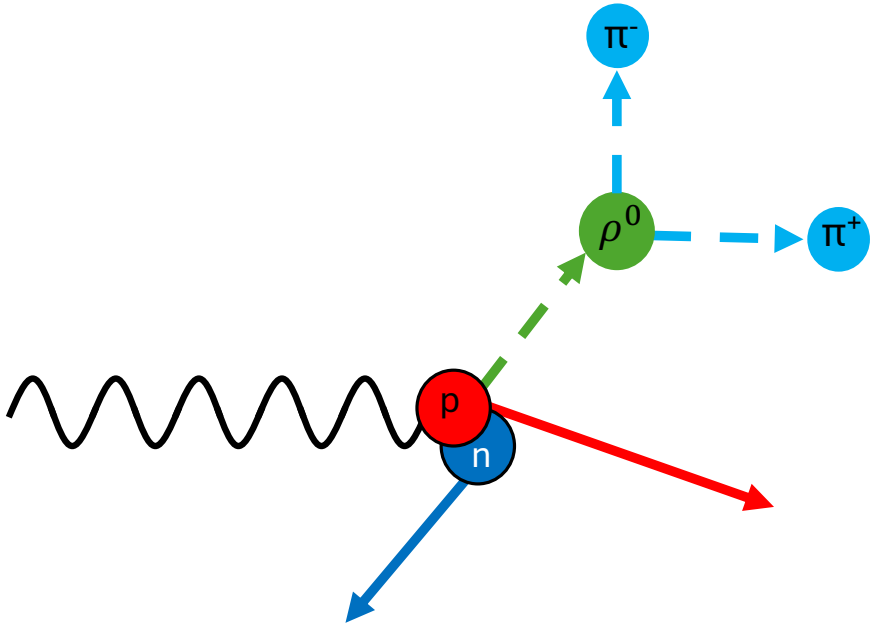

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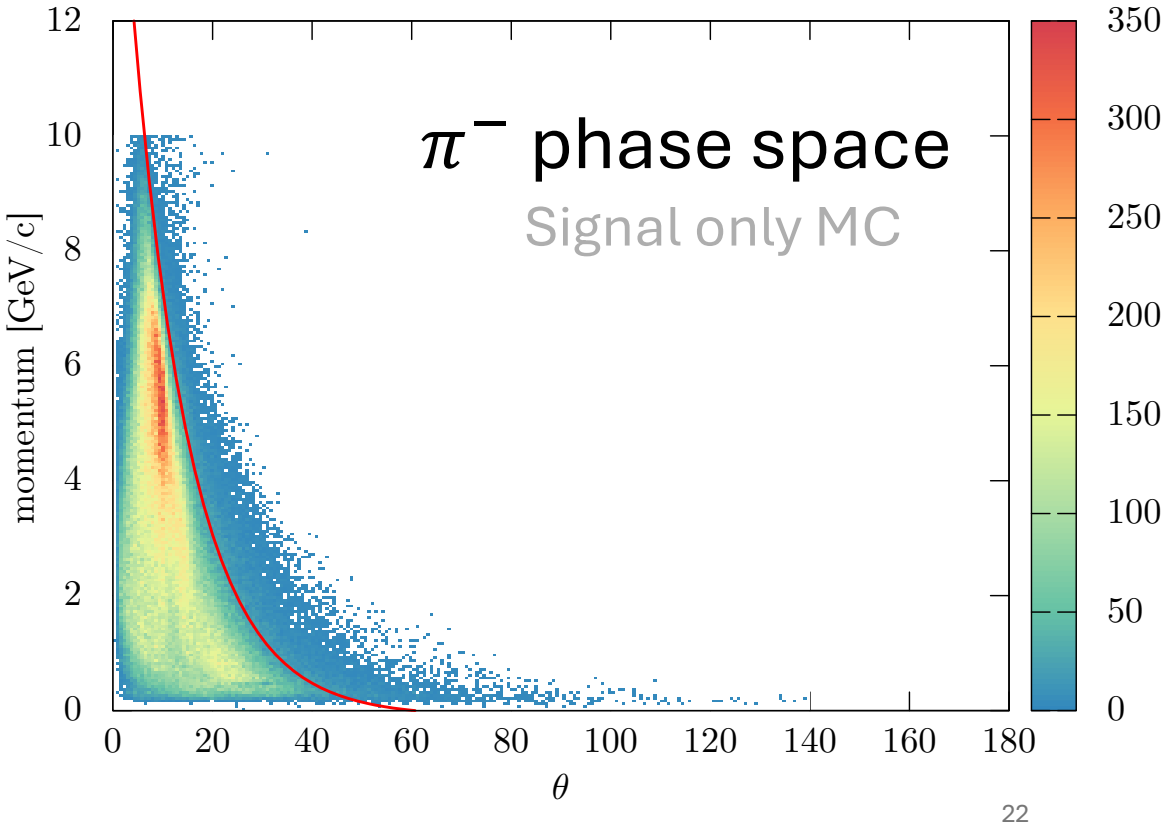
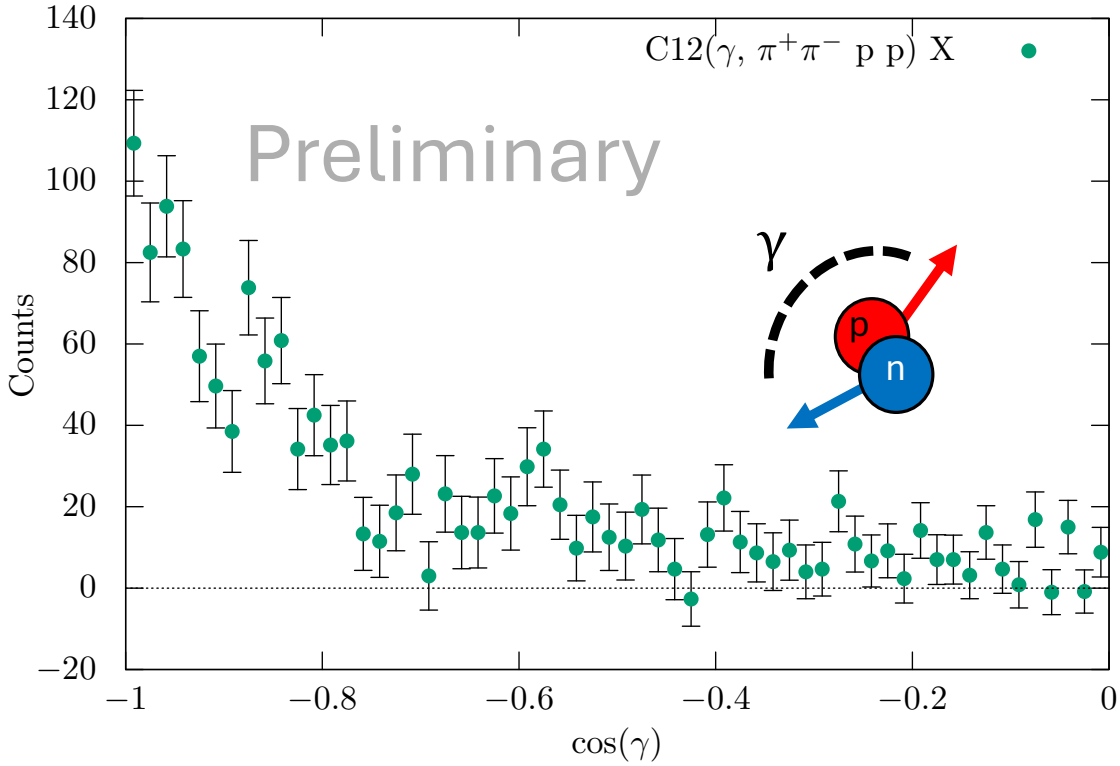
⋮	⋮

π^+ / Proton confusion: π^- can help.

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



A signature of ρ^0 tagged SRC events on C12



ρ^0 photoproduction can be used to test neutron-proton pair dominance.

Photoproduction

Observable

$$\frac{\sigma(\rho^0 + p + p)}{\sigma(\rho^0 + p) + n/p}$$

ρ^0 photoproduction can be used to test neutron-proton pair dominance.

Photoproduction Observable

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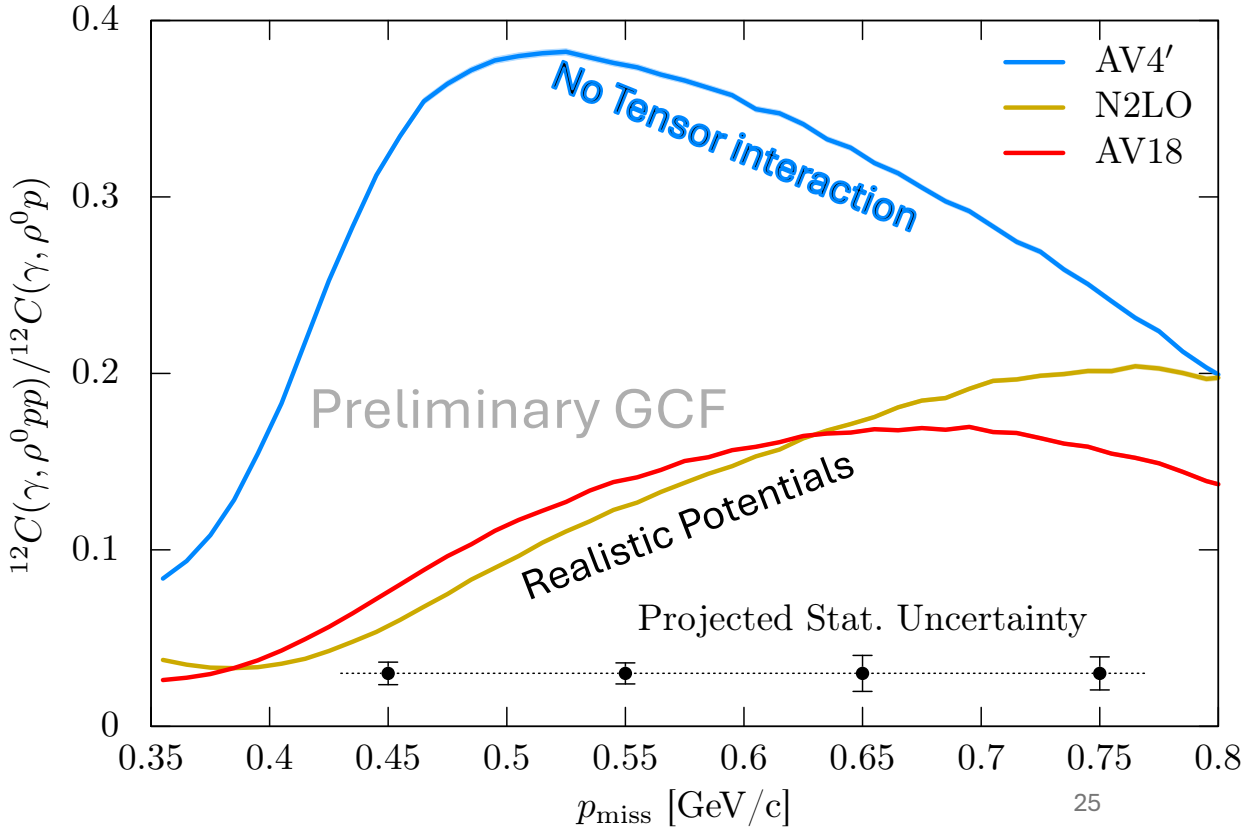
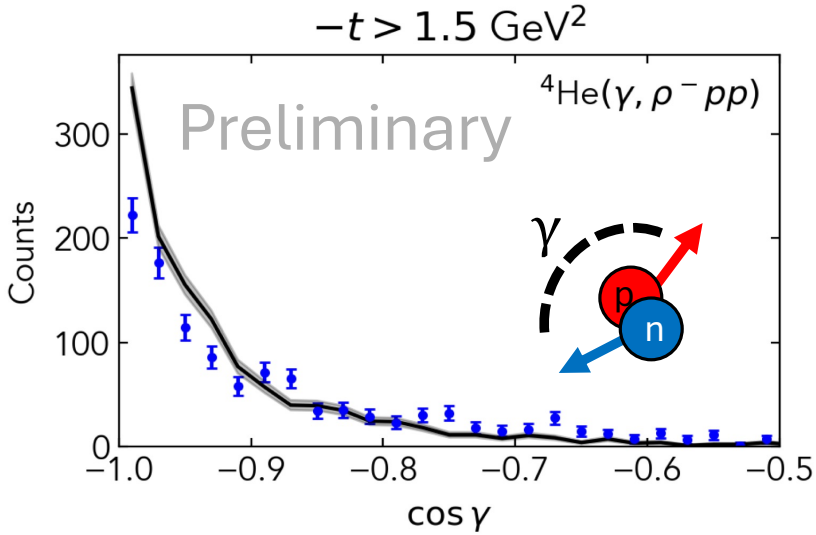
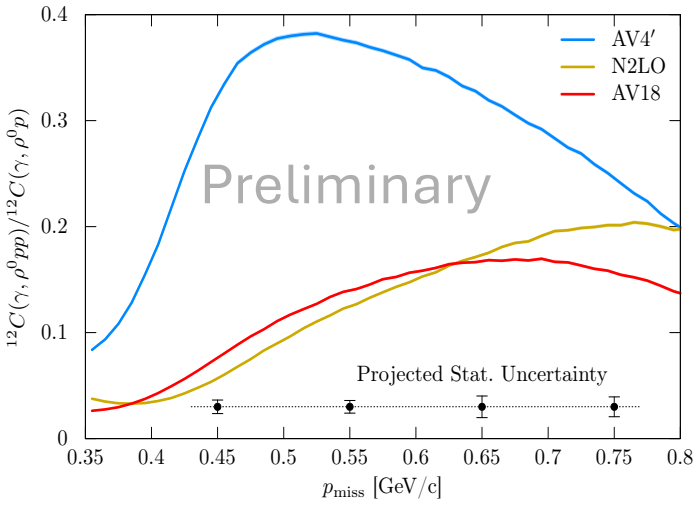
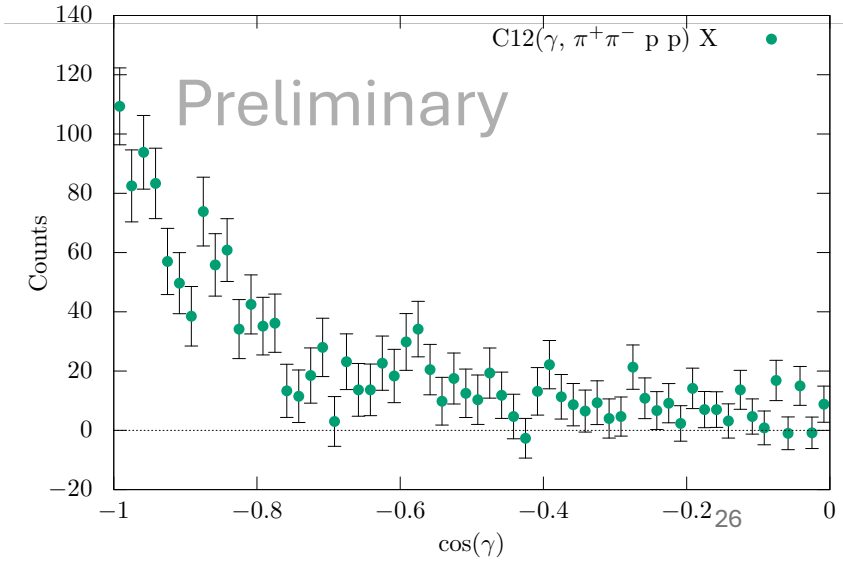


Conclusion

- We do see (preliminary) evidence of SRC's in photoproduction data.
- Further analysis is needed, and more results will be available soon.
- Other talks:







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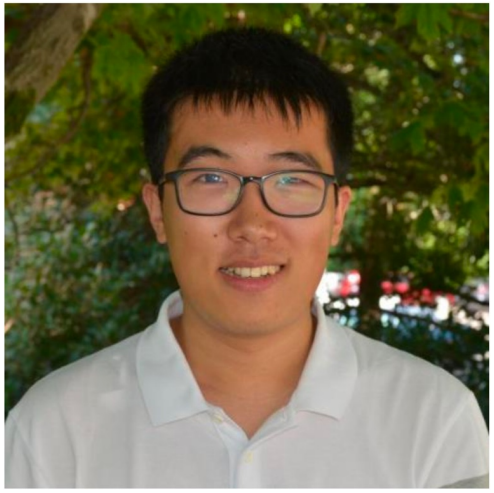


Bo Yu
Talk: Saturday, 1:30, S03

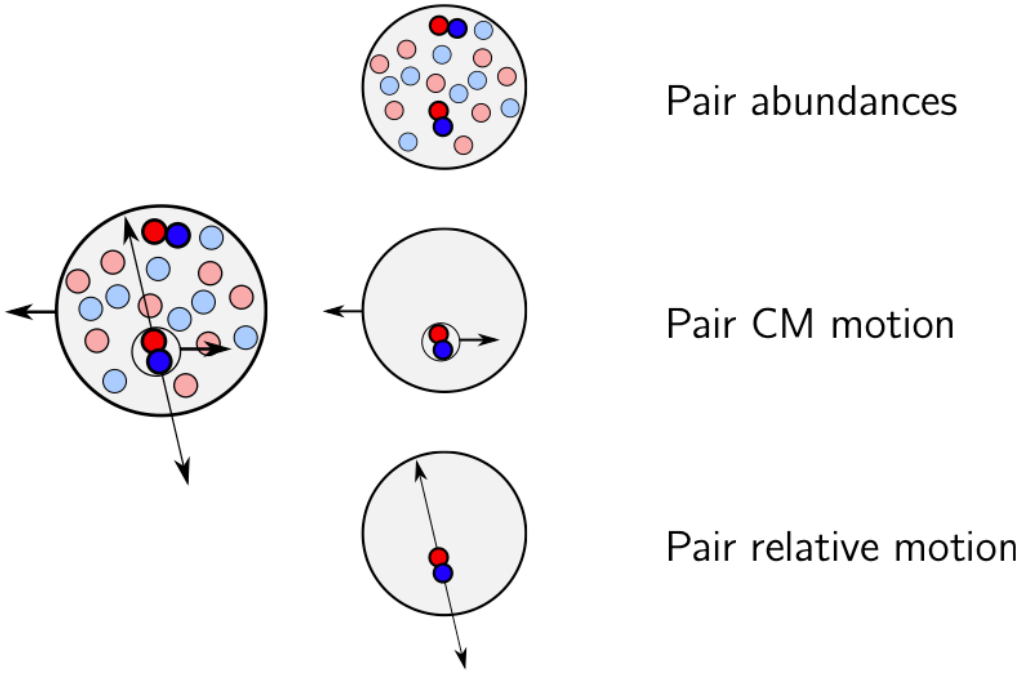
Jackson Pybus
Talk: Wednesday, 3:45, D17

Bhesha Devkota
Talk: Friday, 3:45, P03

BACKUP

Generalized Contact Formalism
Scale separated approach to Short Range Correlations

- Extension of work on cold Fermi gases
- N. Barnea / R. Weiss at the Hebrew University of Jerusalem applied it to nuclear physics
- Leverages separation of scales



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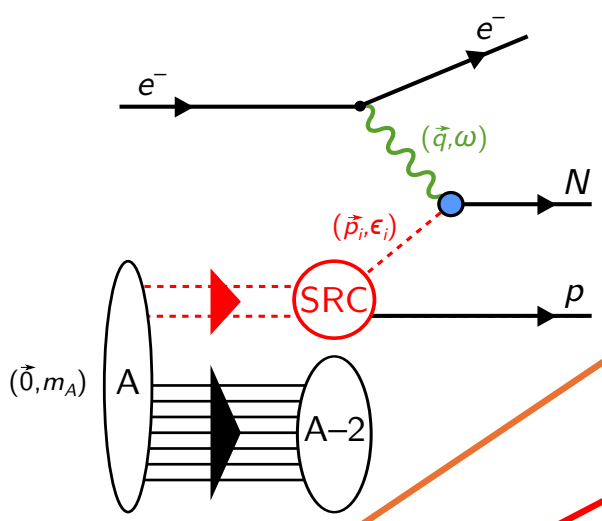
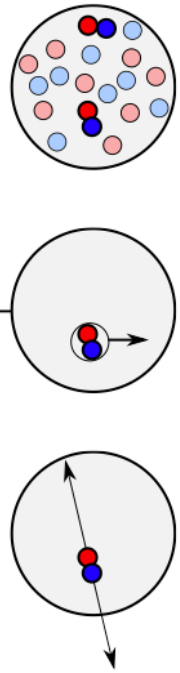


$$d\,\sigma \sim \sigma_{probe} \cdot \Sigma_{\alpha} C_{\alpha} P_{\alpha}(k_{cm}) \left|\tilde{\phi}(k_{rel})\right|^2$$

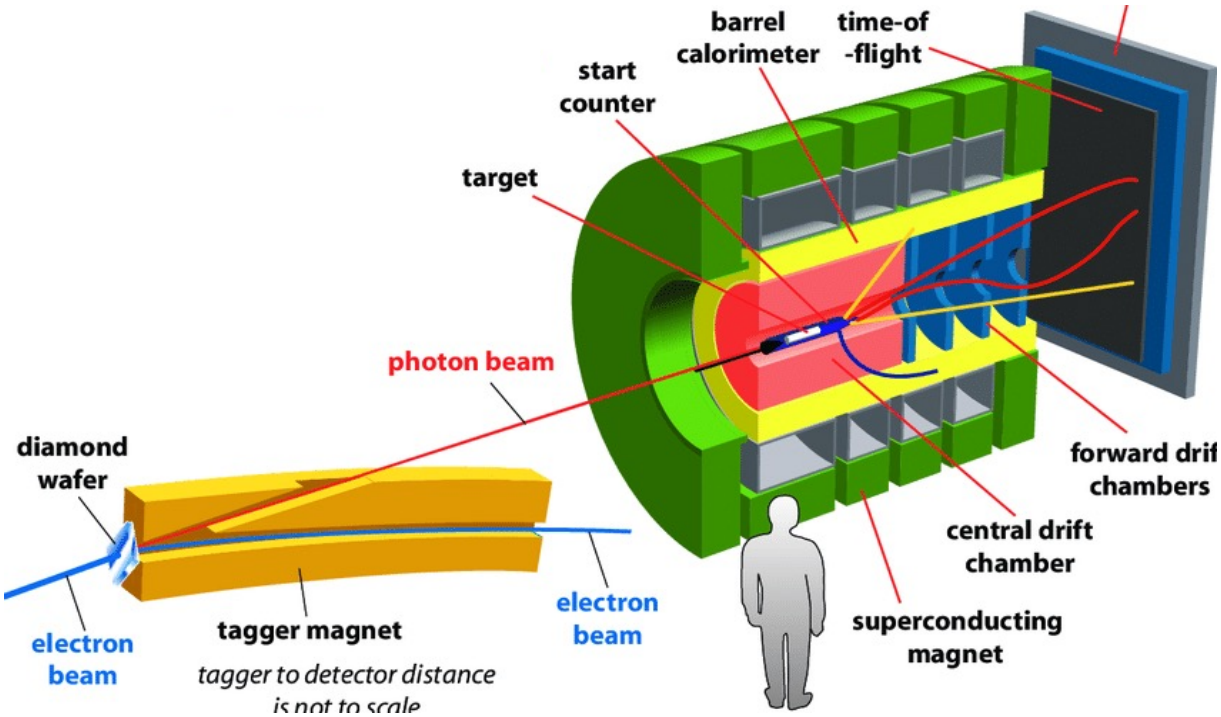


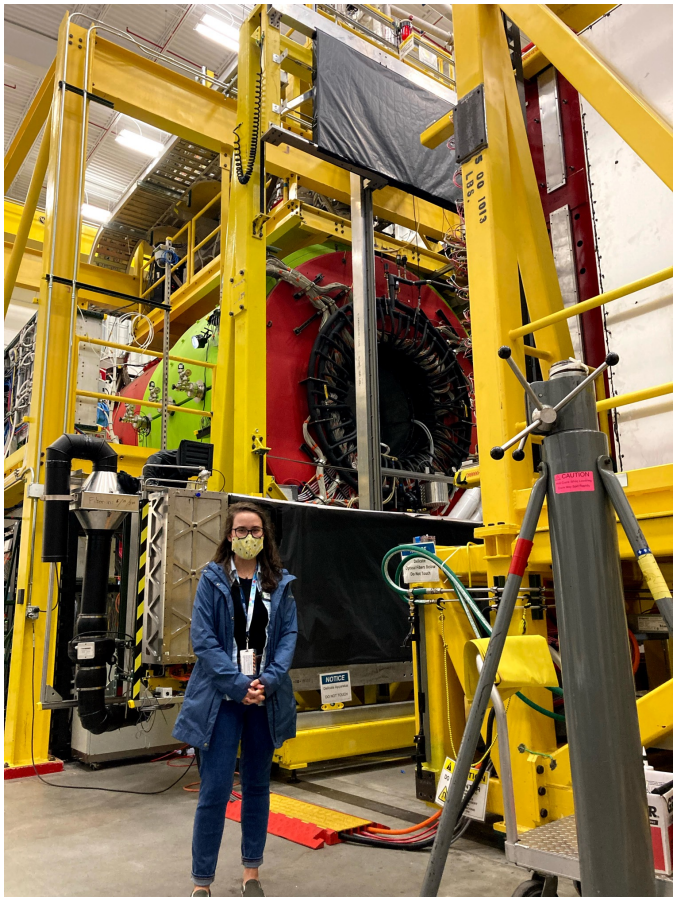
Pair abundances
Contacts from
CLAS 6 EG2

Pair CM motion
Gaussian

Pair relative motion
2-body potentials
AV18, N2LO, AV4'

GlueX: Glossy Schematic





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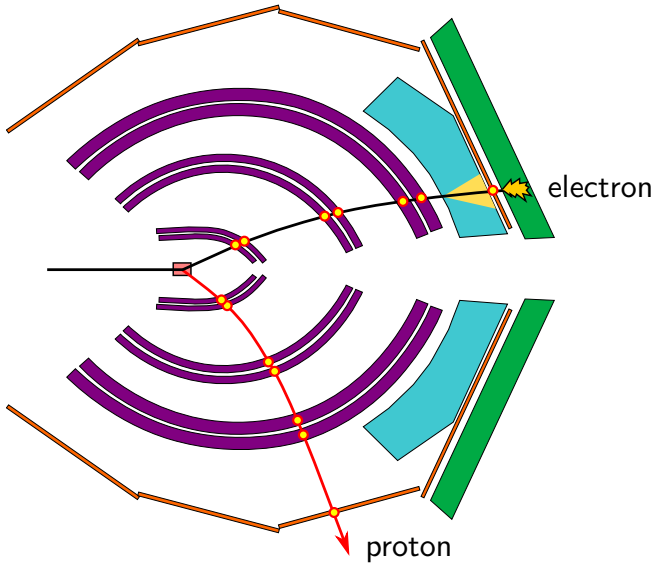
Brief Summary of Electron Scattering Experiments

Electron Beam: CLAS 6 of Hall B



- Carbon target
- 5 GeV beam
- Strict event selection
- Isolate protons in an SRC pair
- Missing momentum >400 MeV/c

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

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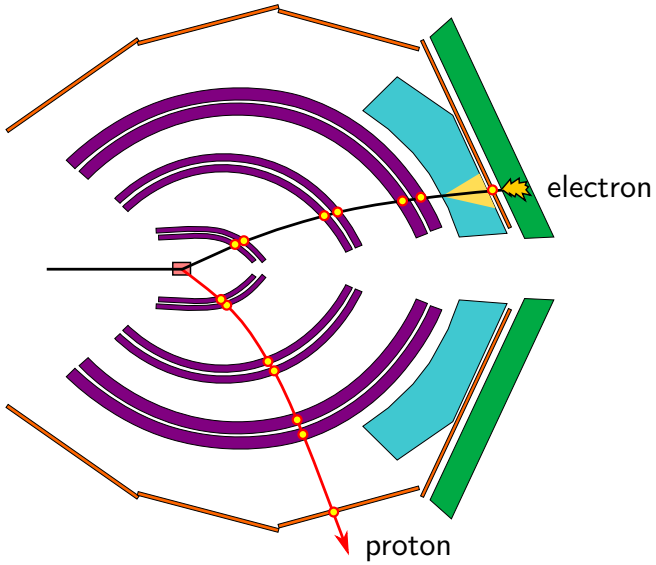

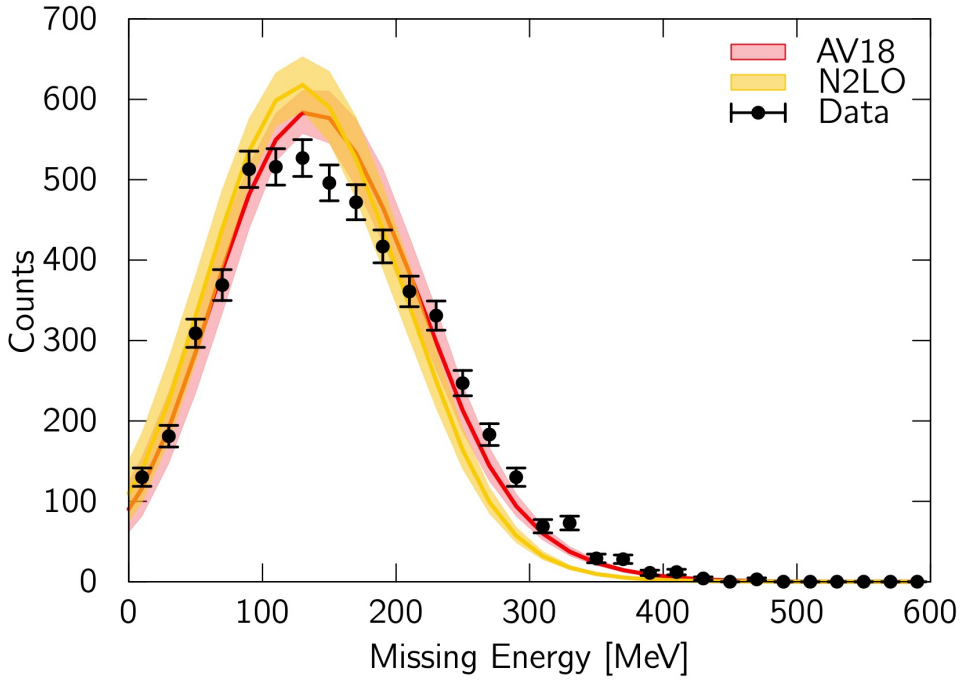

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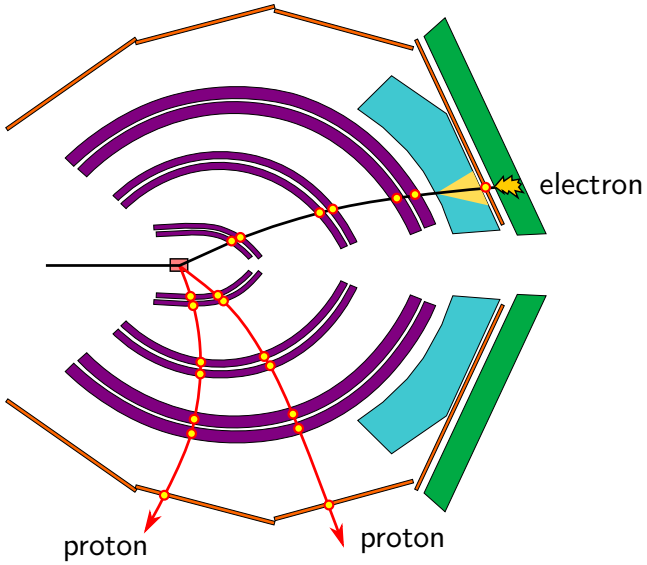
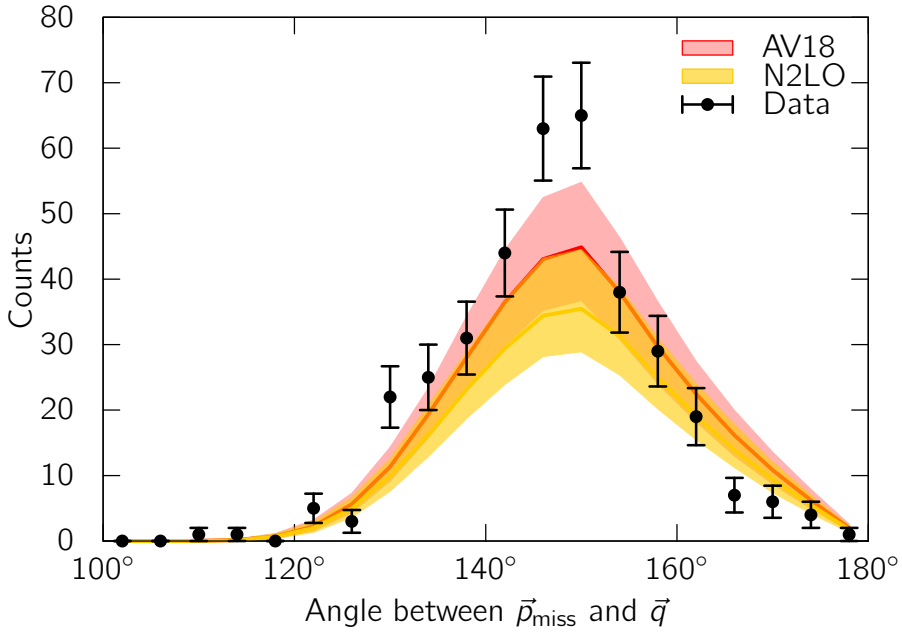
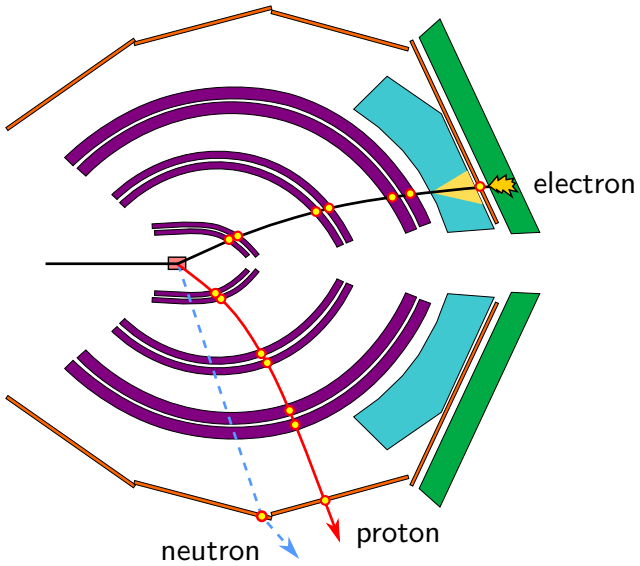
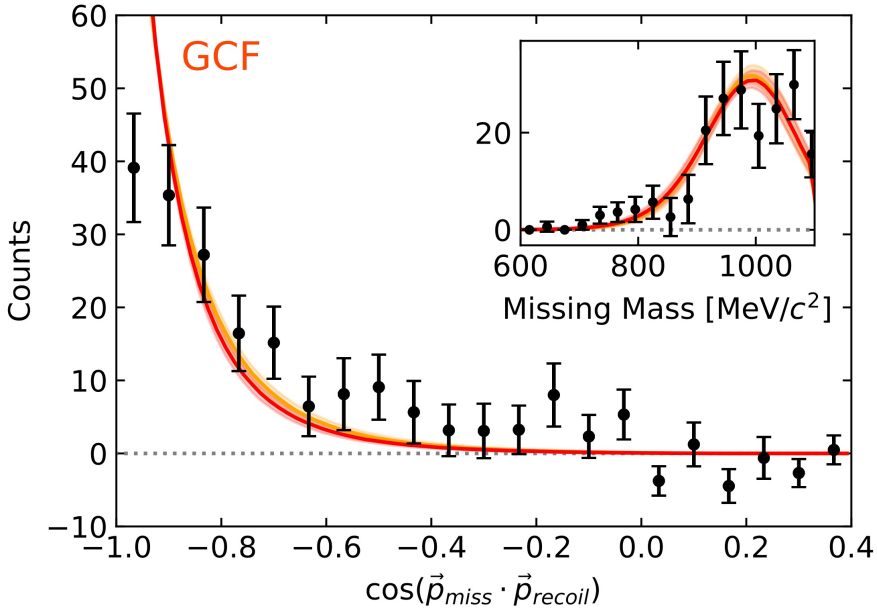




Brief Summary of Electron Scattering Experiments

Electron Beam: CLAS 6 of Hall B





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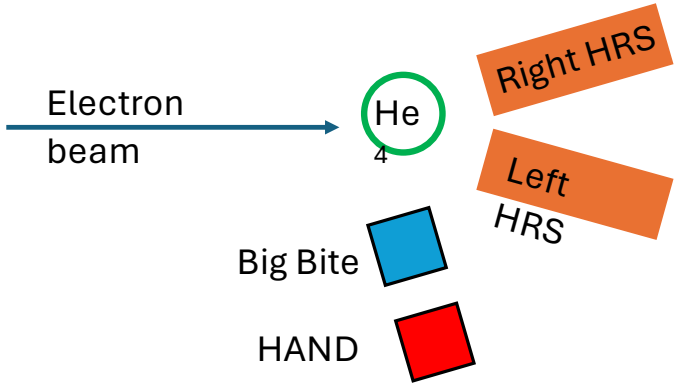
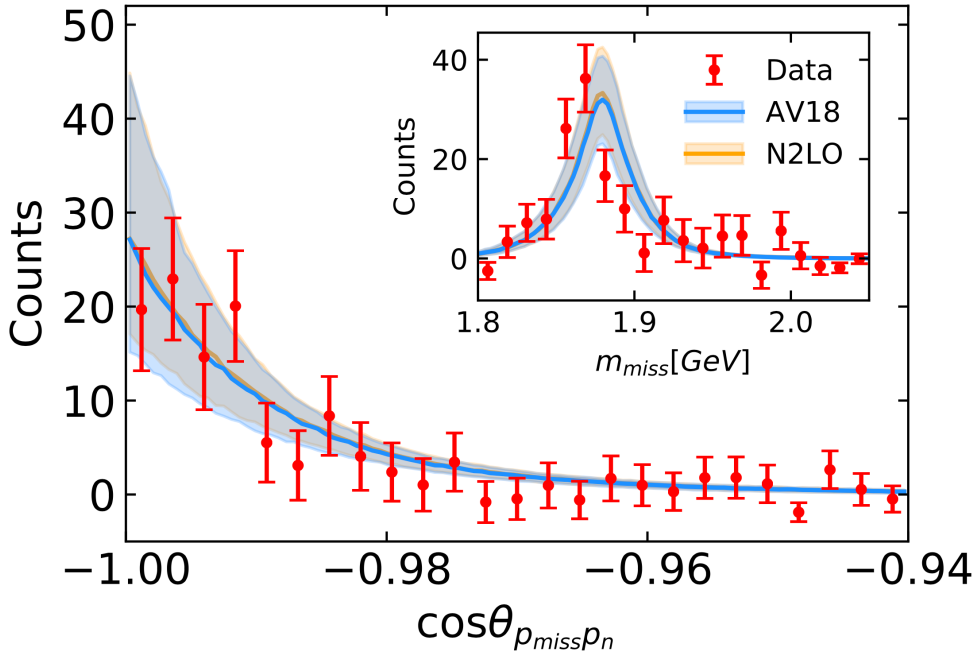
Brief Summary of Electron Scattering Experiments

Electron Beam: Hall A

- Helium target
- 4.5 GeV beam





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