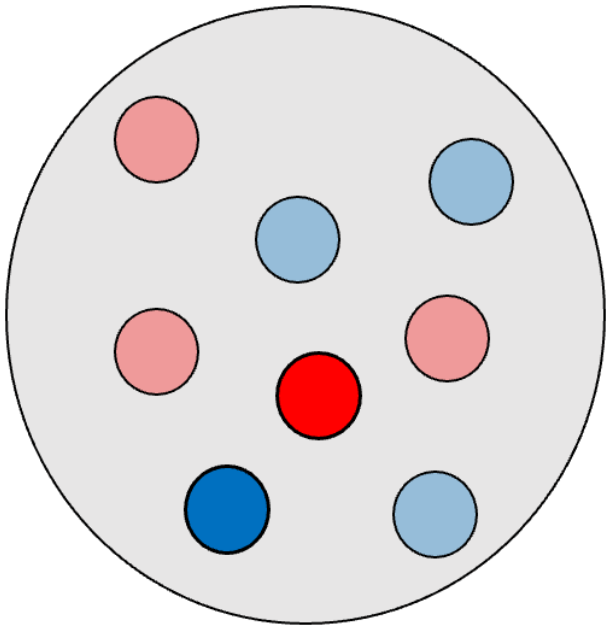
What are Short Range Correlations?

And how do we find them?

Phoebe Sharp — psharp15@gwu.edu

The nucleus is a complicated, many-body problem.

The Problem of Nuclear Structure



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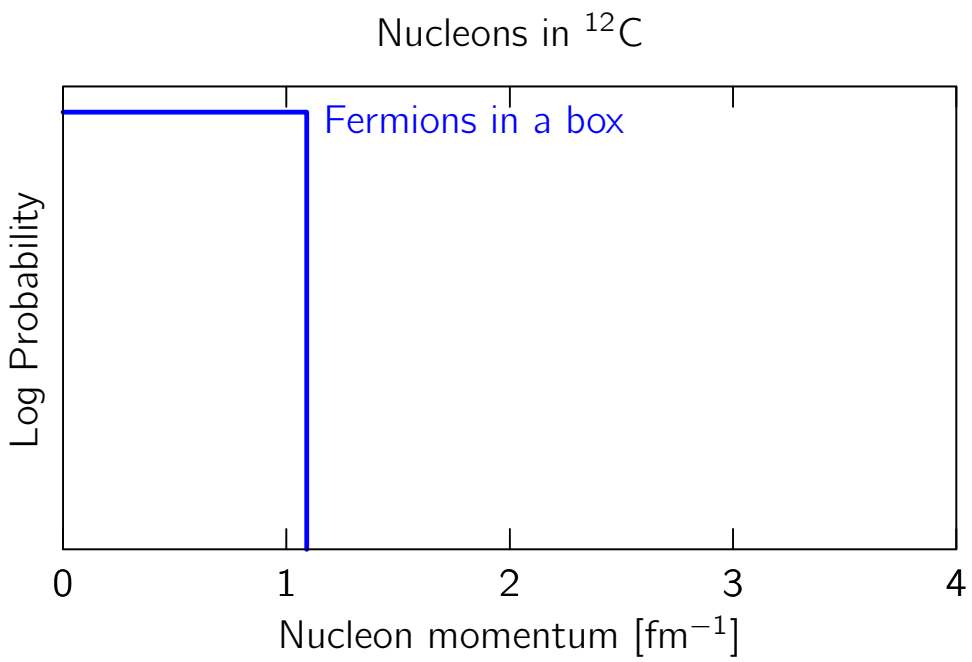

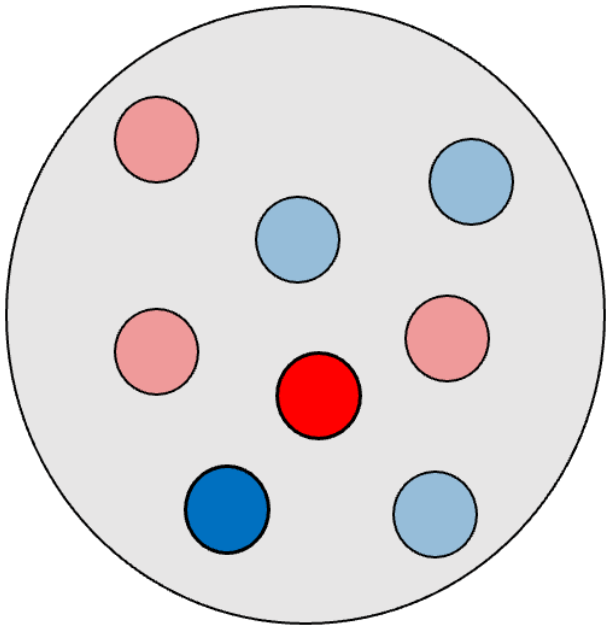

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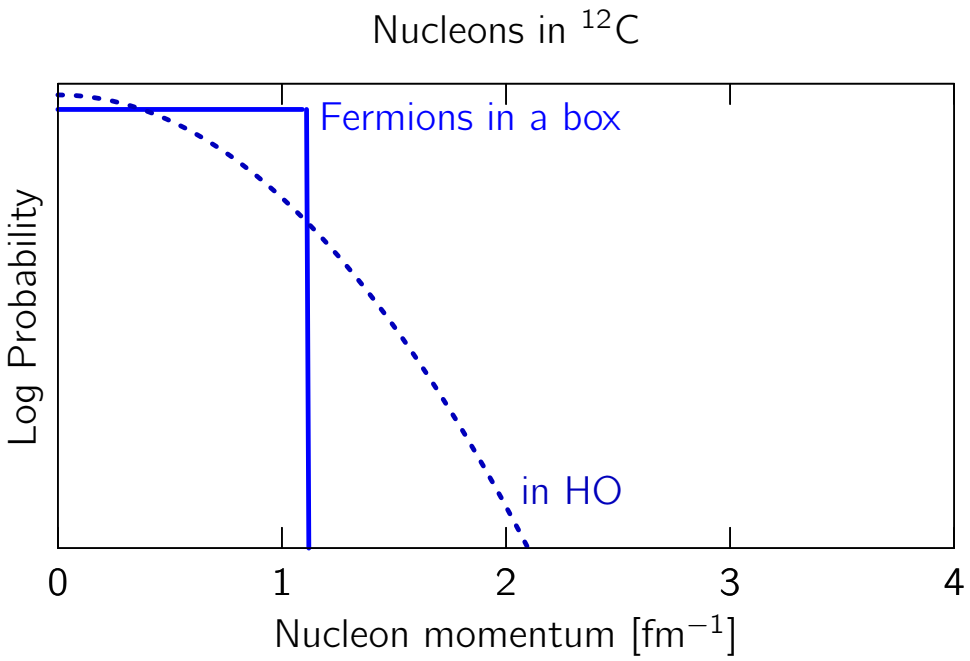

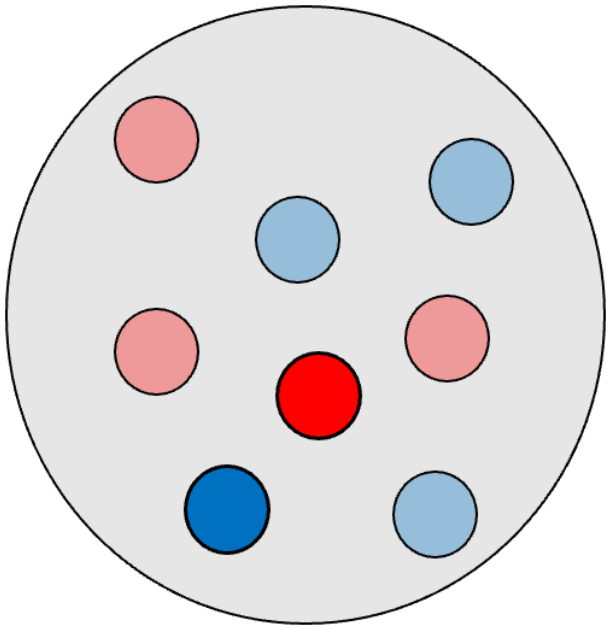

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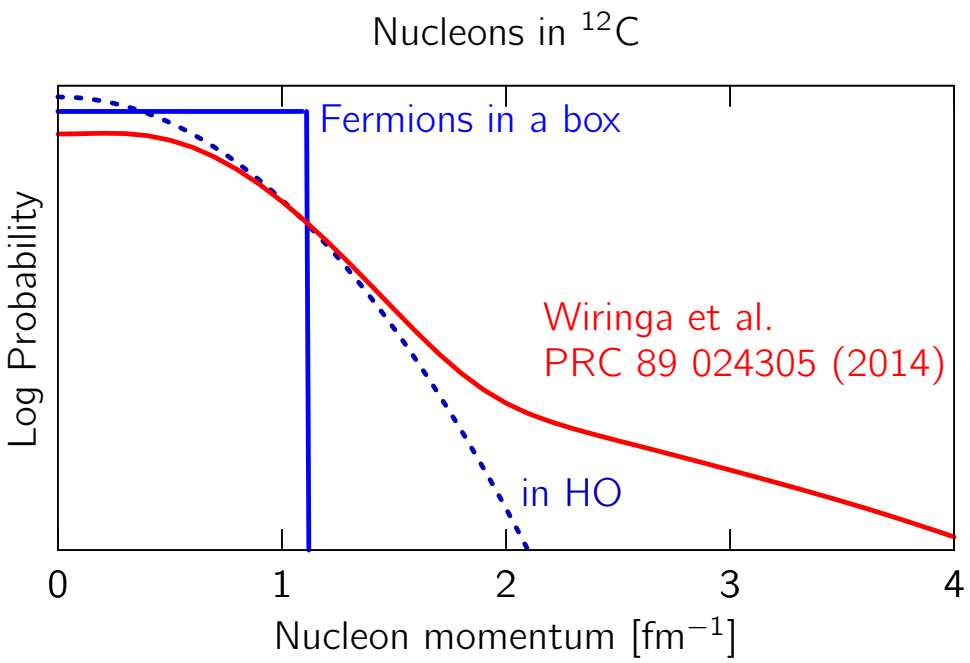

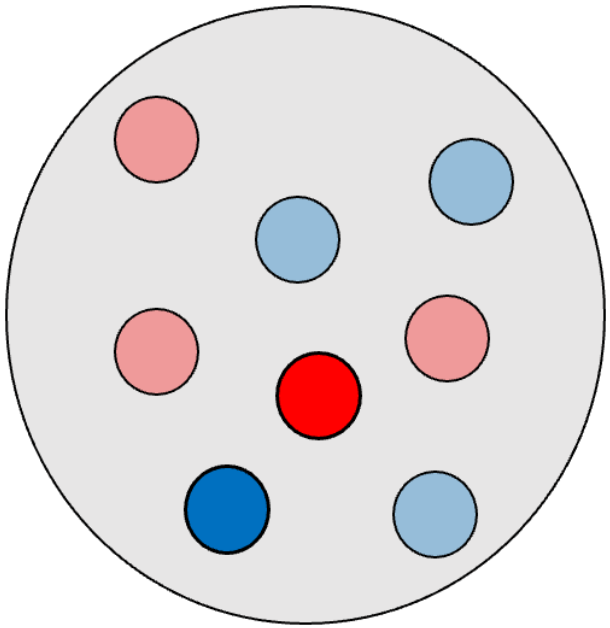

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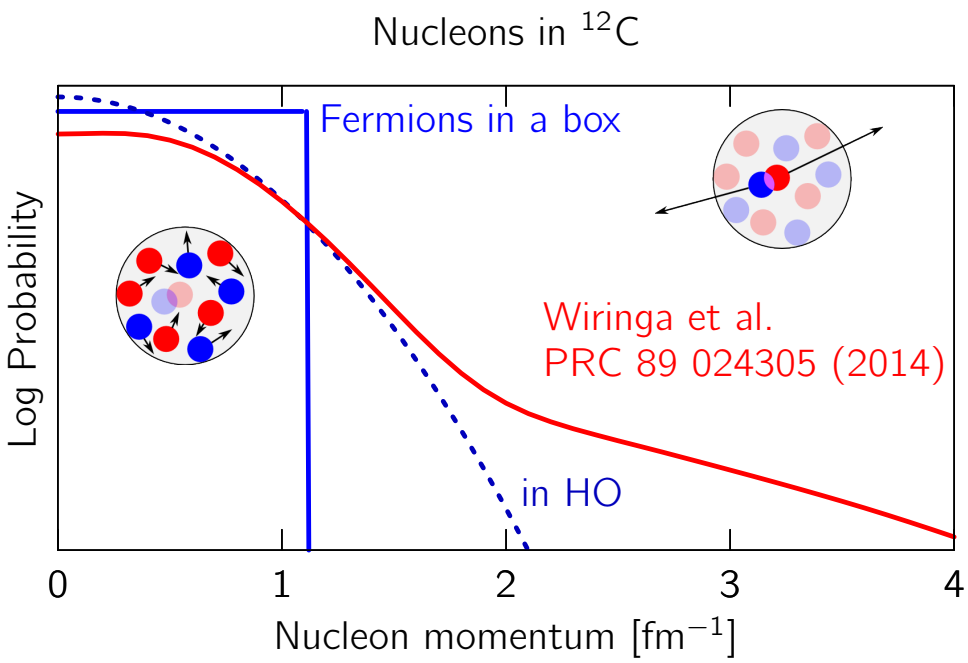
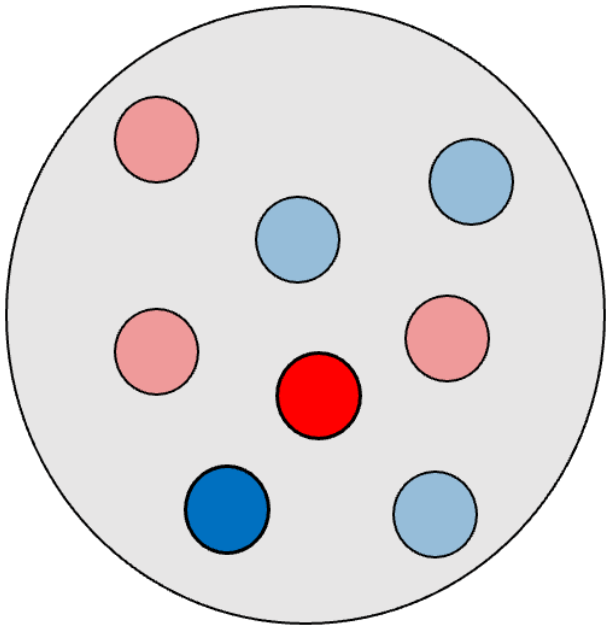
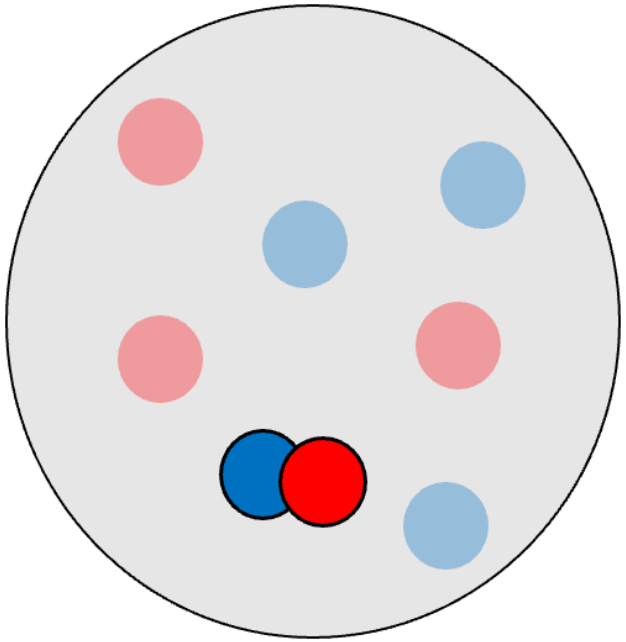




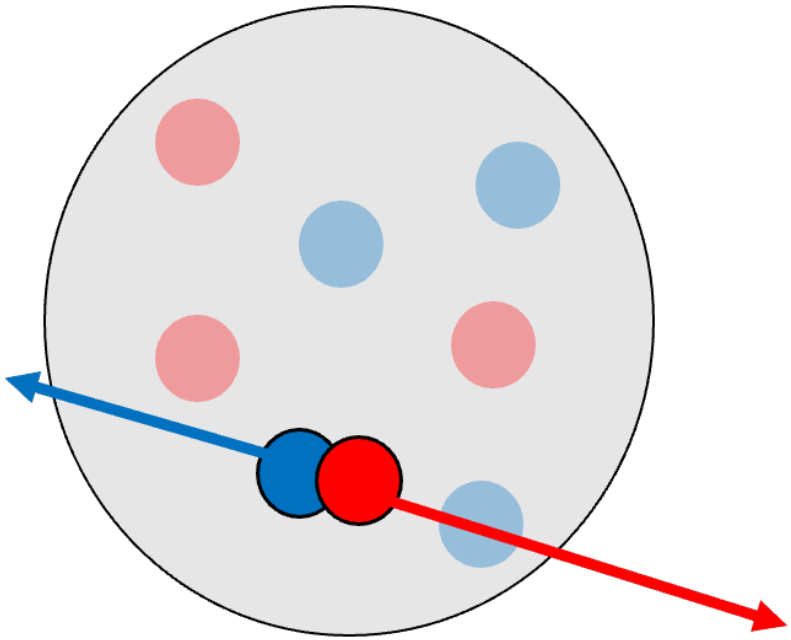
Short Range Correlations are when:

- 2 nucleons are overlapping.



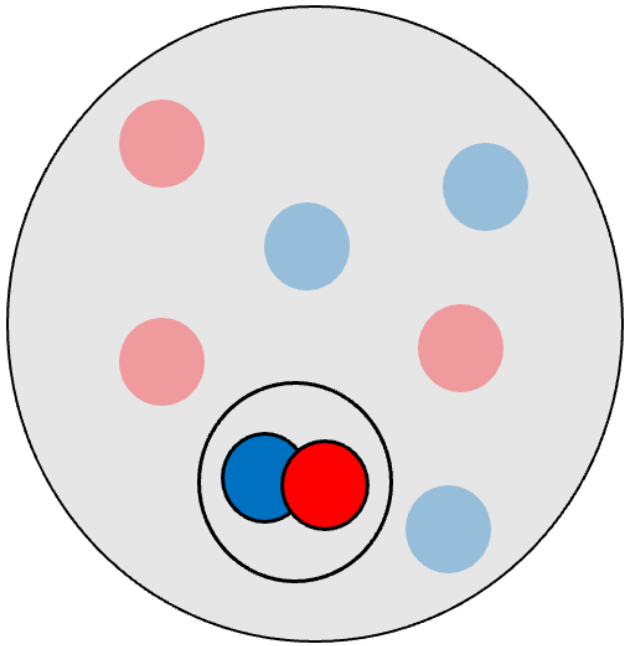
Short Range Correlations are when:

- 2 nucleons are overlapping.
- They have a large relative momentum, compared to the Fermi-momentum.



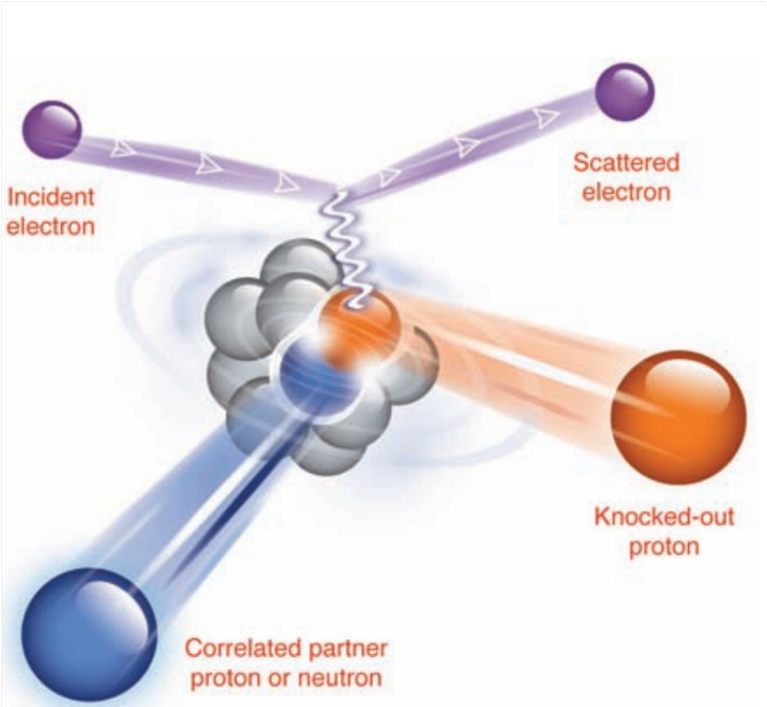
Short Range Correlations are when:

- 2 nucleons are overlapping.
- They have a large relative momentum, compared to the Fermi-momentum.
- The force between the nucleons is stronger than the interactions between the rest of the nucleus.



Quasi-elastic Electron Scattering

Hard breakup of an SRC pair

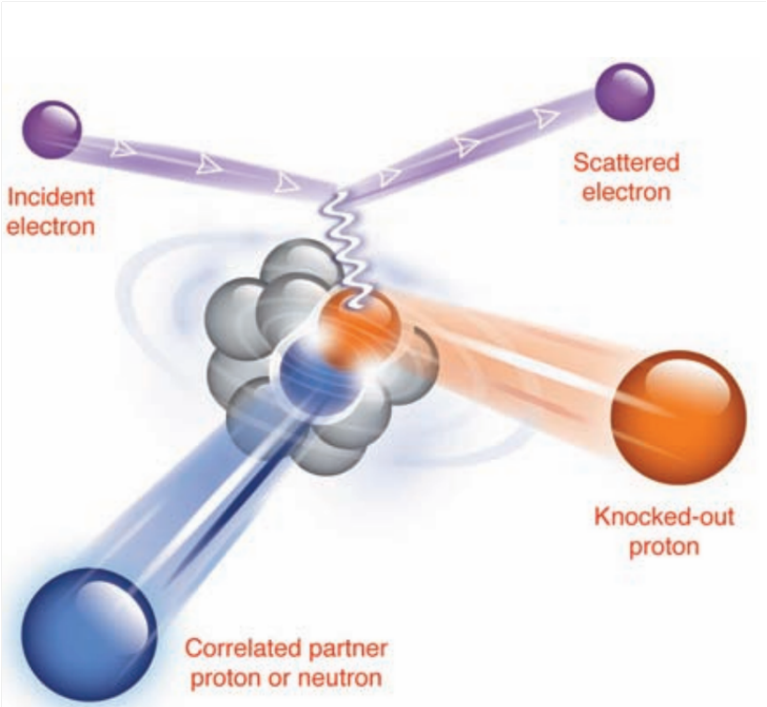


R. Subedi, R. Shneor, P. Monaghan, B.D. Anderson, K. Aniol, J. Annand et al., *Probing cold dense nuclear matter*, *Science* **320** (2008) 1476.

Quasi-elastic Electron Scattering

3 kinds of SRC experiments

- Inclusive
- Semi-inclusive
- Exclusive



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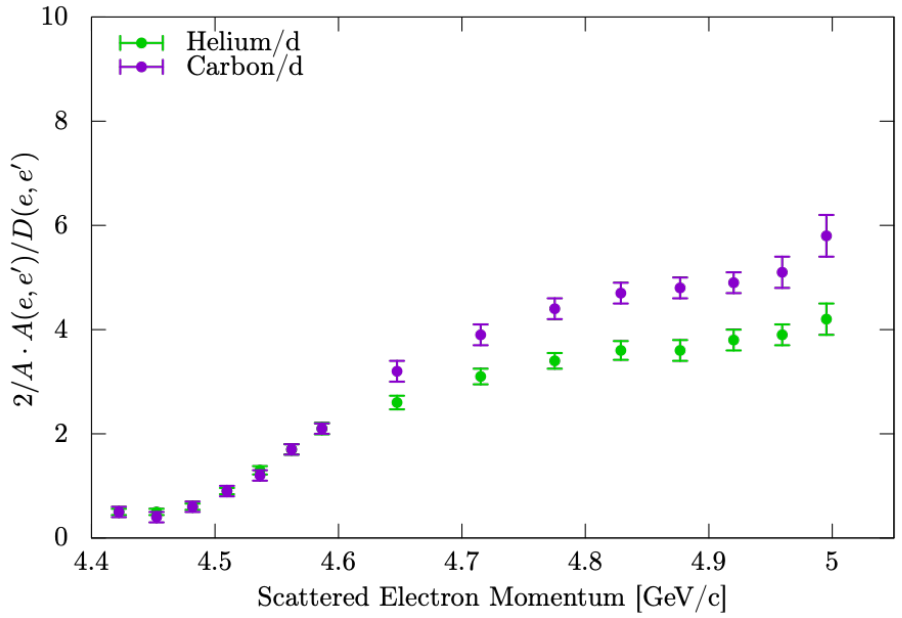
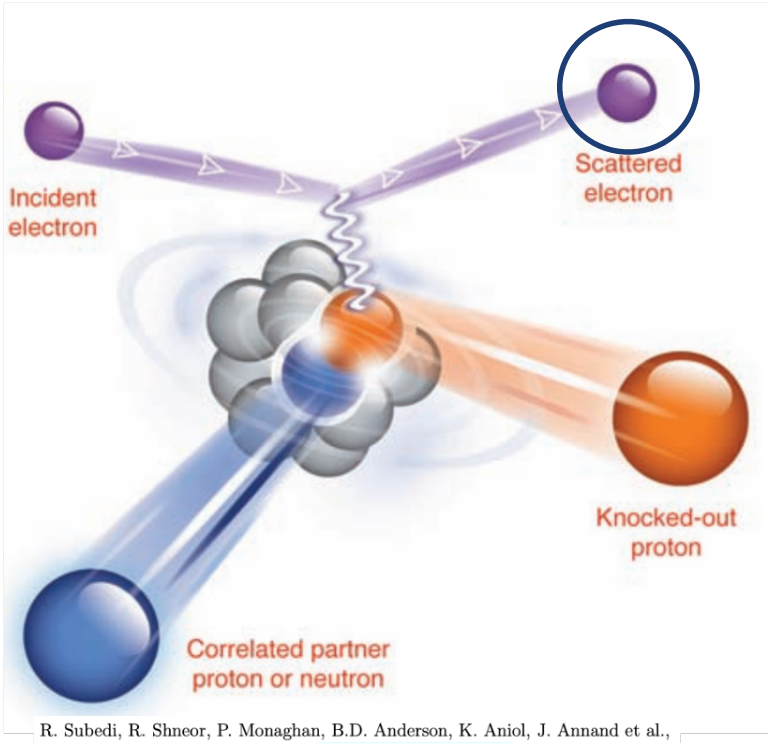
Quasi-elastic Electron Scattering

Inclusive



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.



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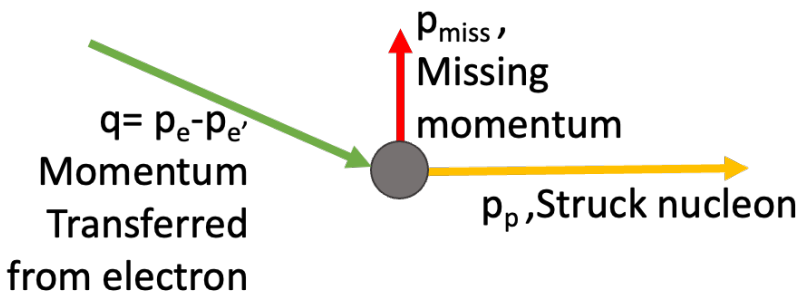
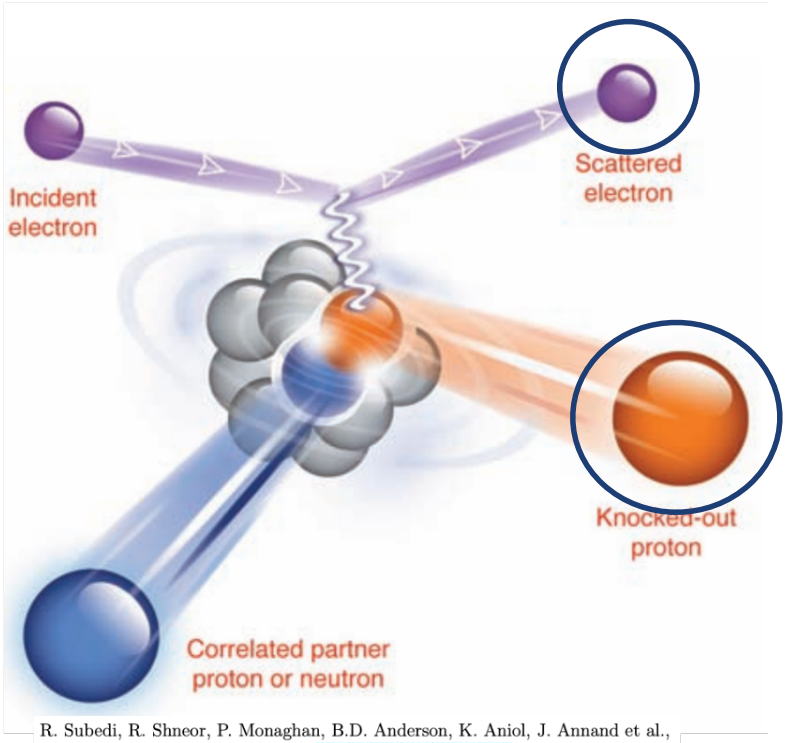
Quasi-elastic Electron Scattering

Semi-Inclusive

$P_{miss} = p_p - (p_e - p_{e'})$





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Quasi-elastic Electron Scattering

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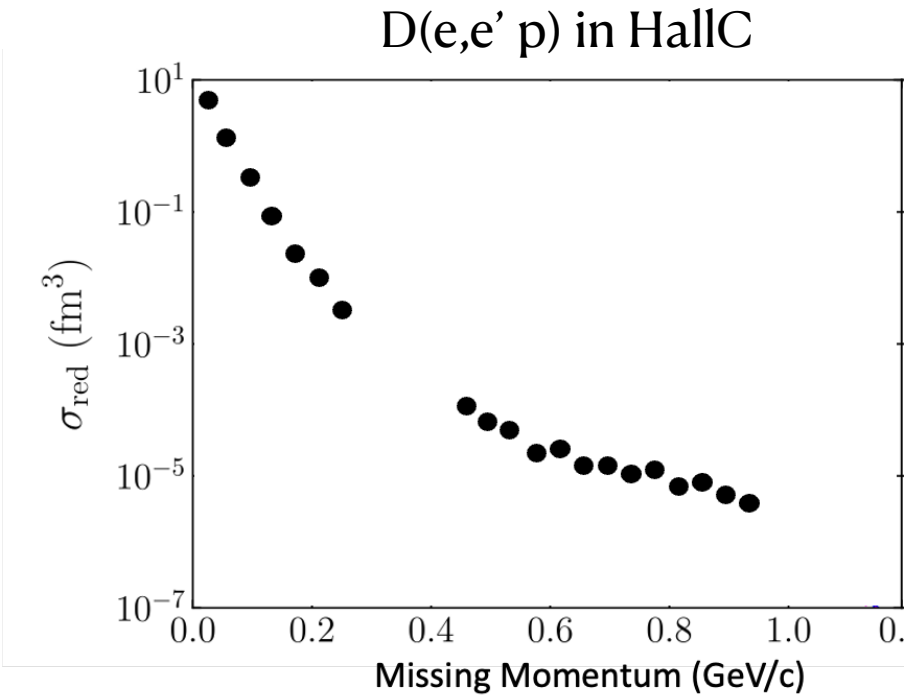
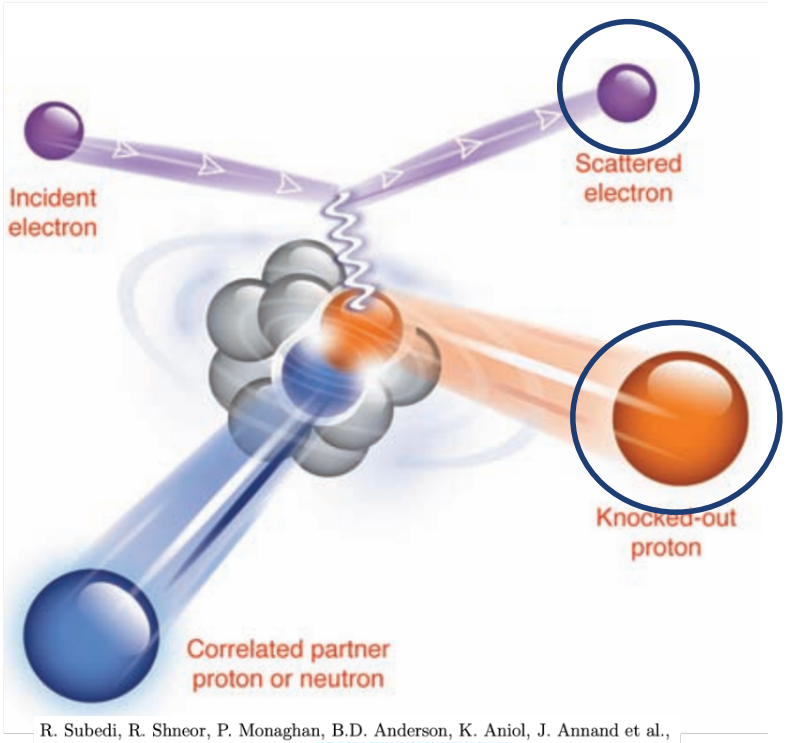


C. Yero, D. Abrams, Z. Ahmed, A. Ahmidouch, B. Aljawrneh, S. Alsalmi et al., *Probing the Deuteron at Very Large Internal Momenta*, *Physical Review Letters* **125** (2020) [2008.08058].



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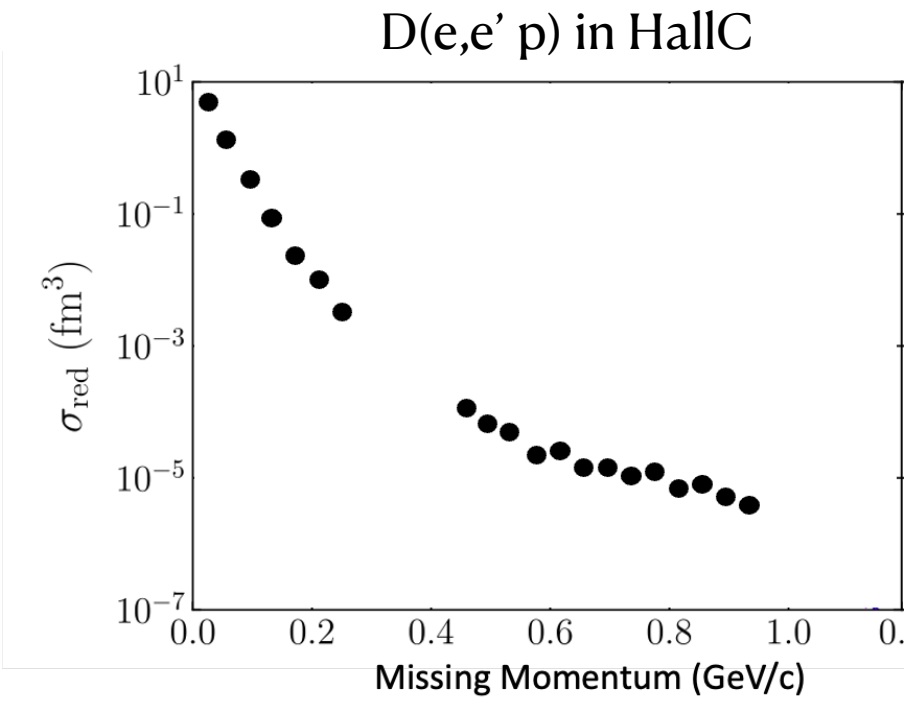

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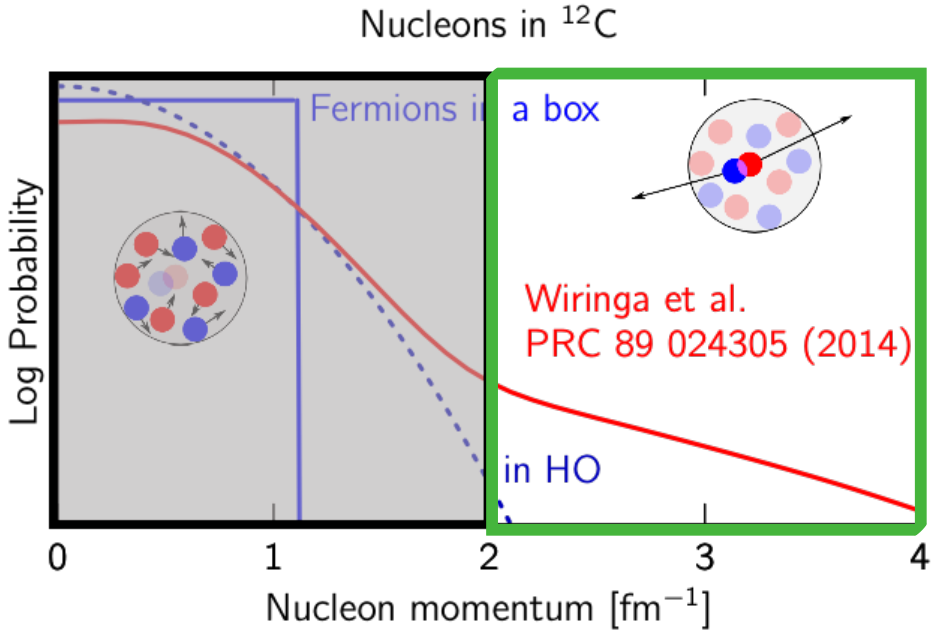

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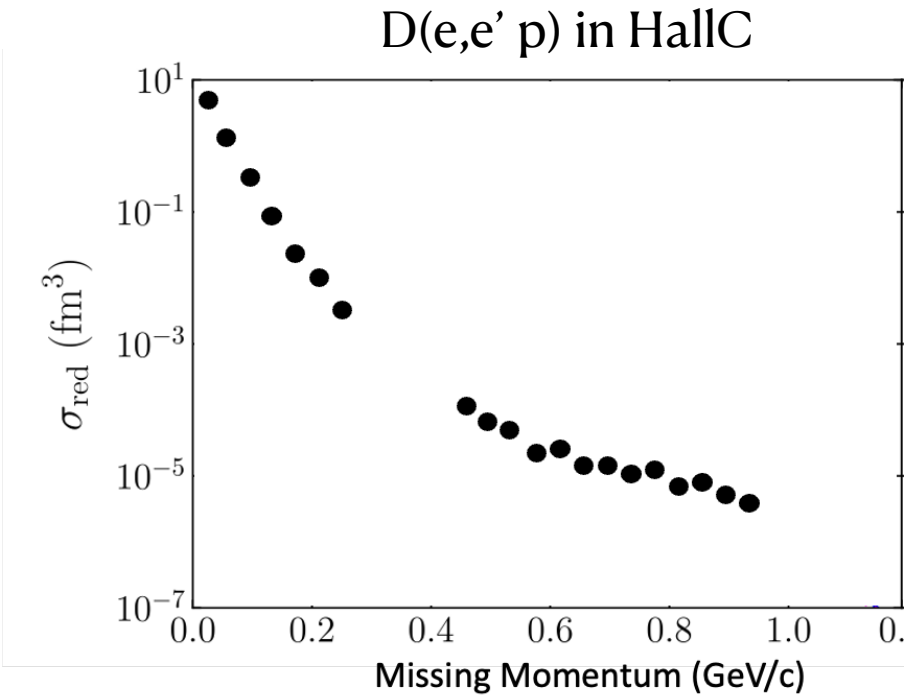

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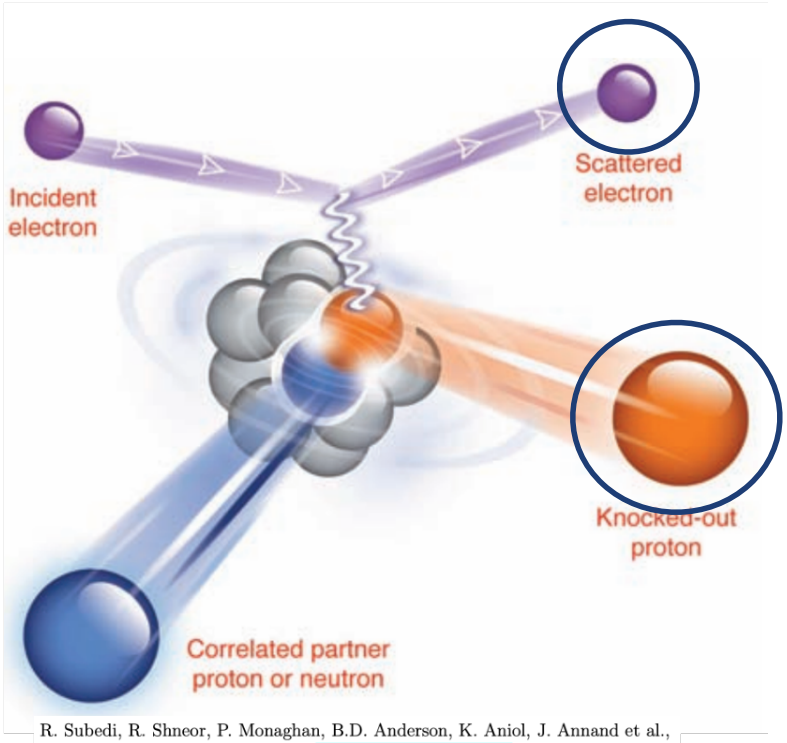

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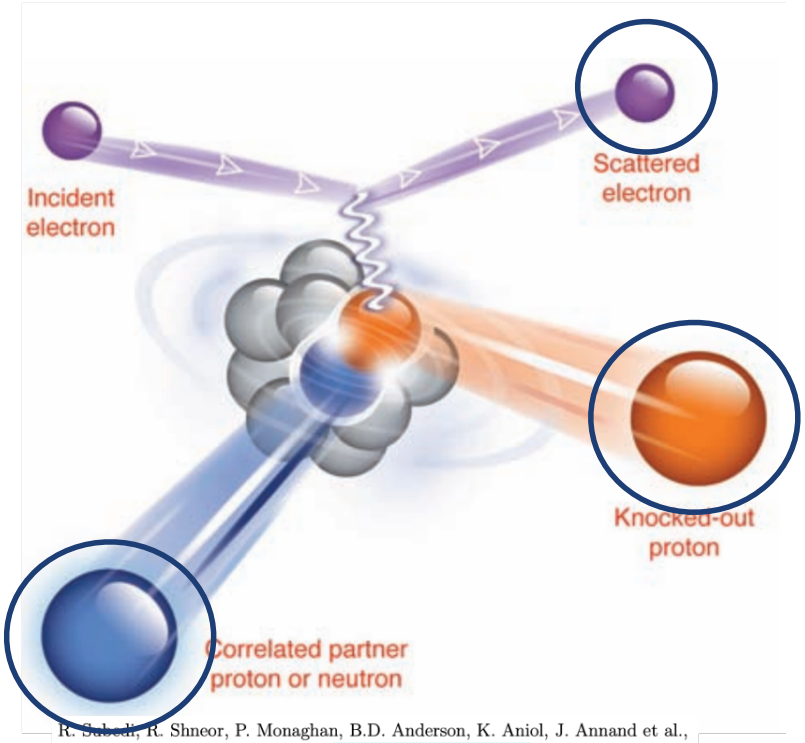
Quasi-elastic Electron Scattering

Exclusive



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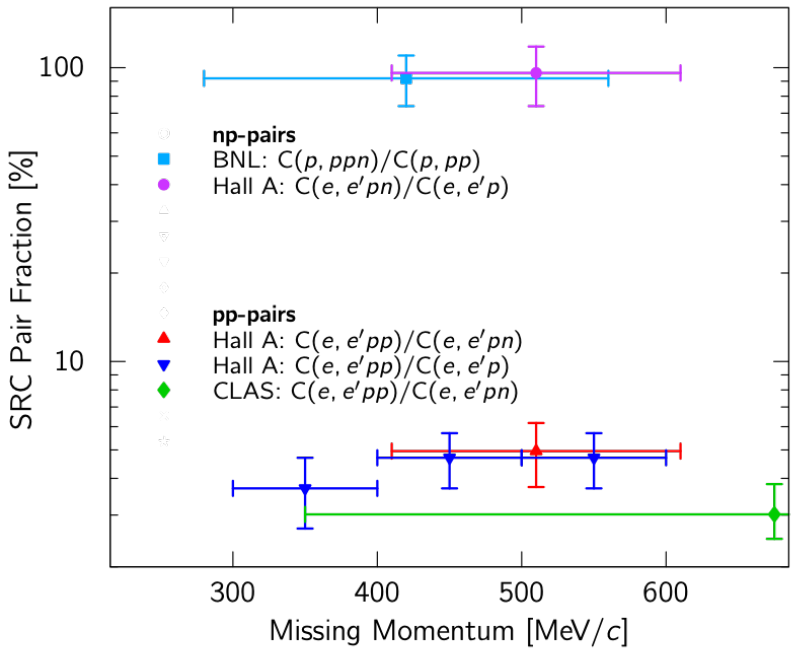

CLAS Collaboration collaboration, *Direct observation of proton-neutron short-range correlation dominance in heavy nuclei*, *Phys. Rev. Lett.* **122** (2019) 172502.

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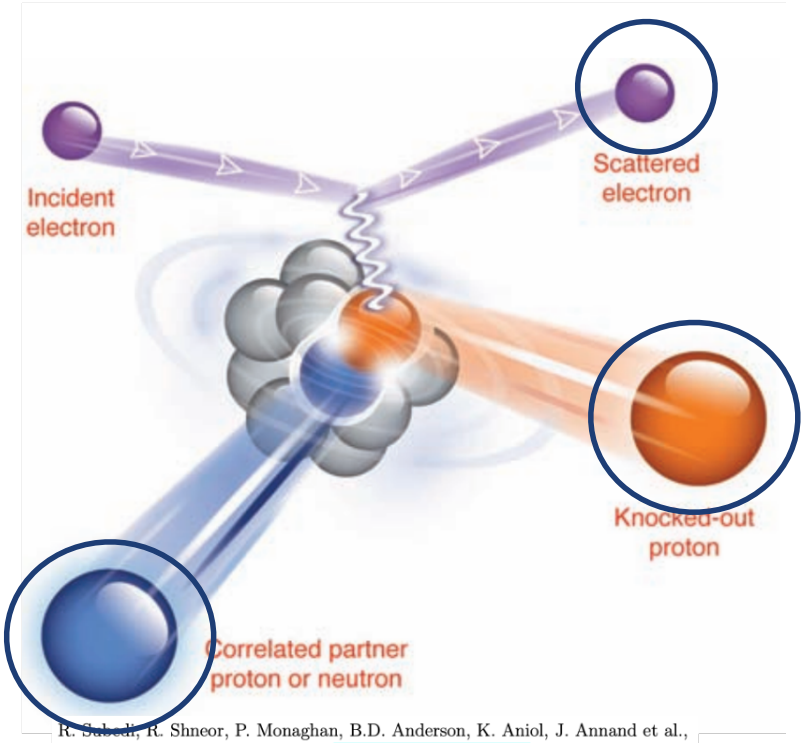

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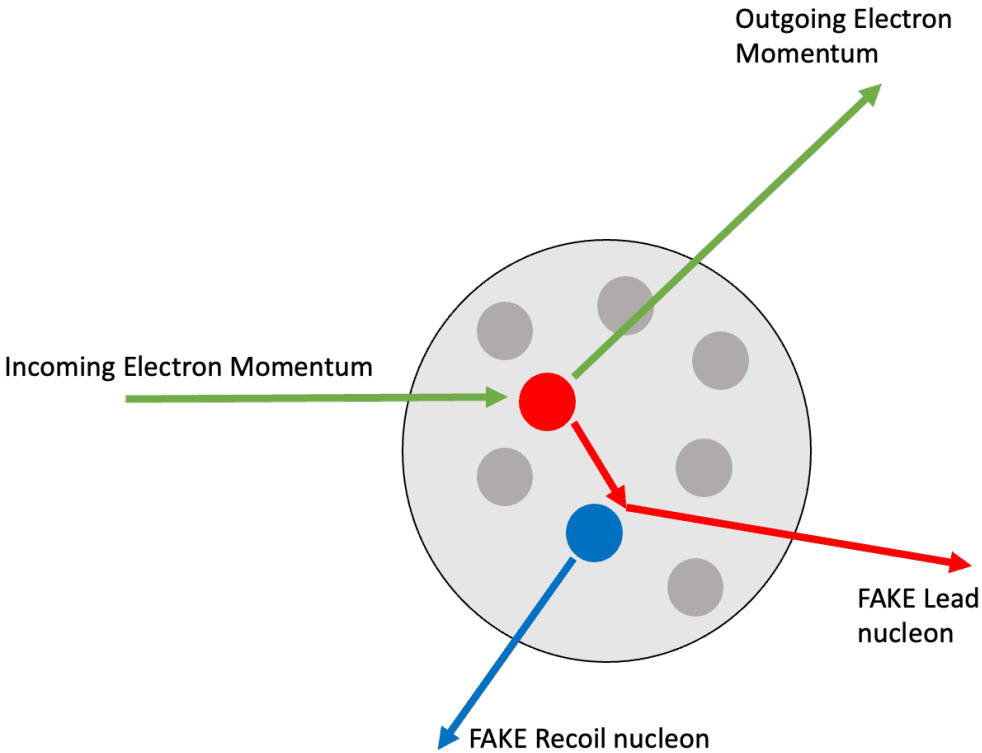
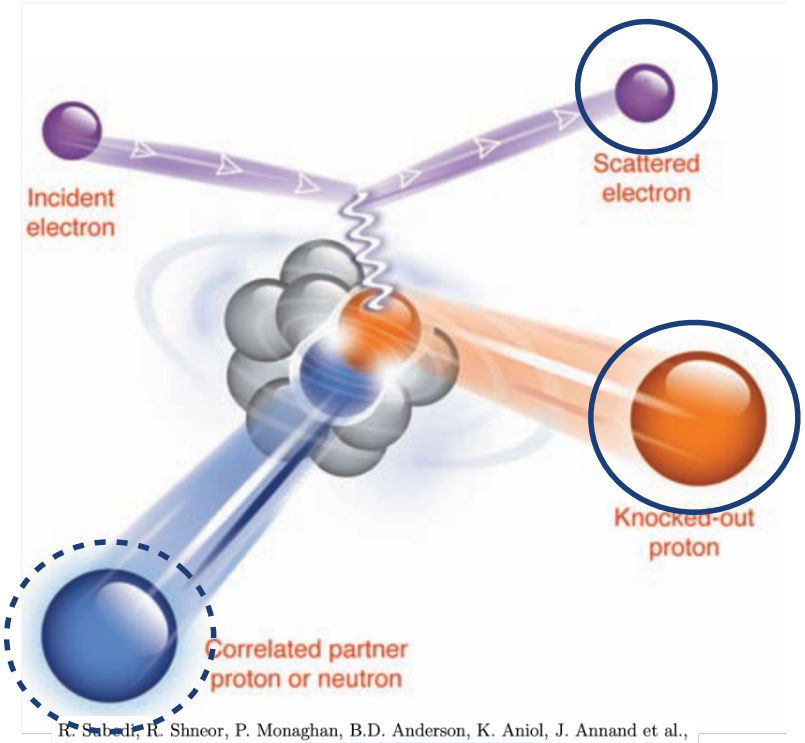
SRCs from nucleon knock-out have an additional concern.

Final State Interactions





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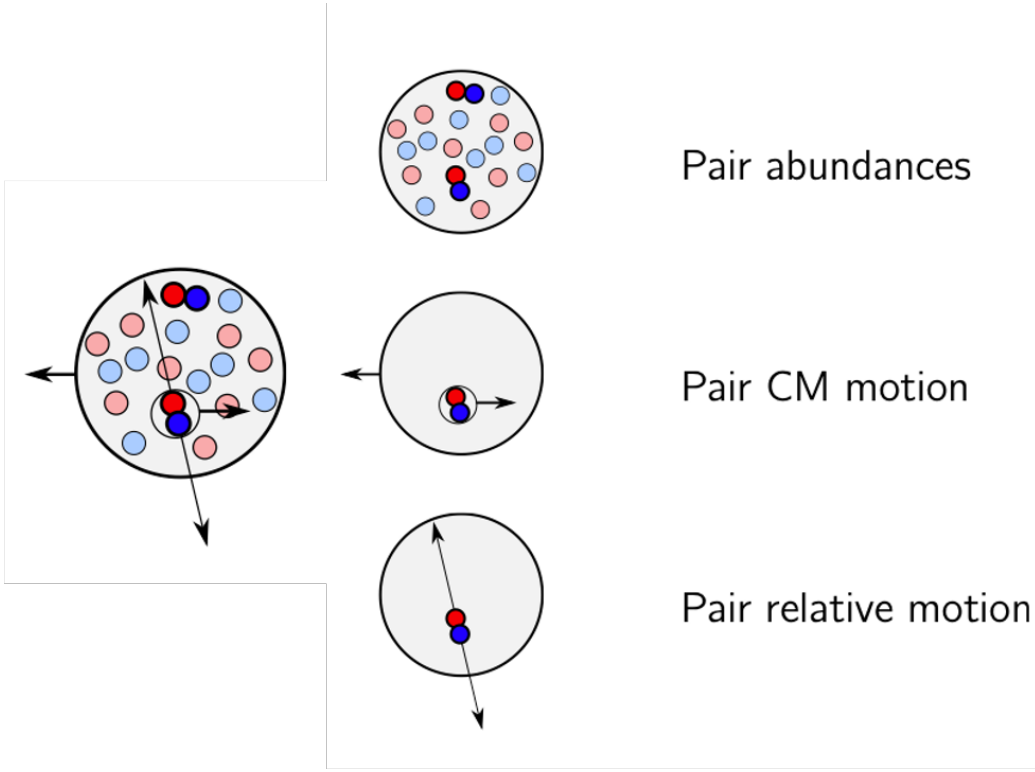
We've been able to model SRCs well.

Generalized Contact Formalism (GCF)



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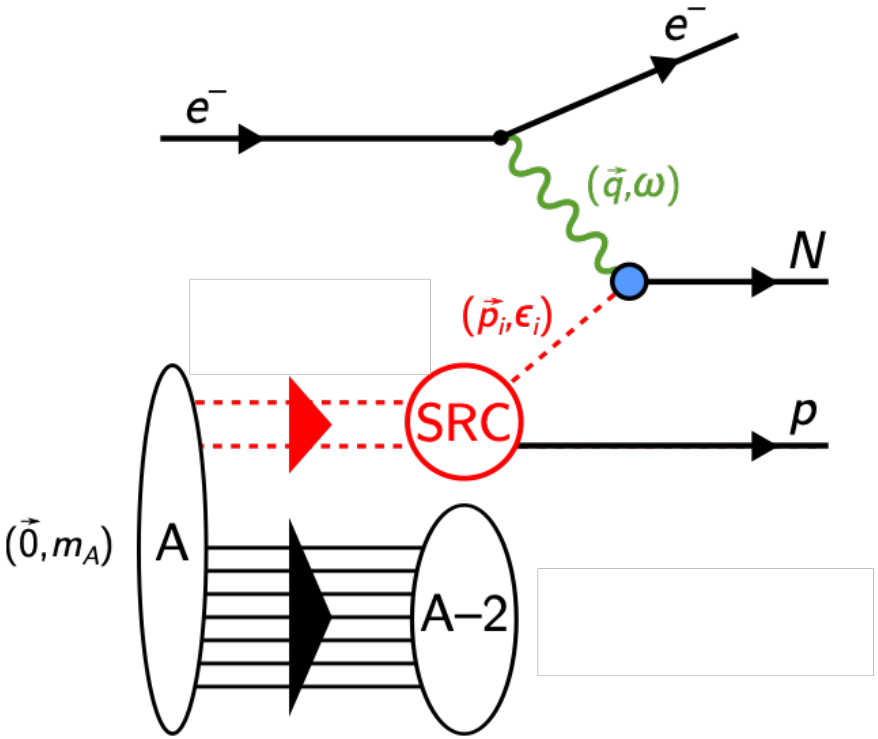

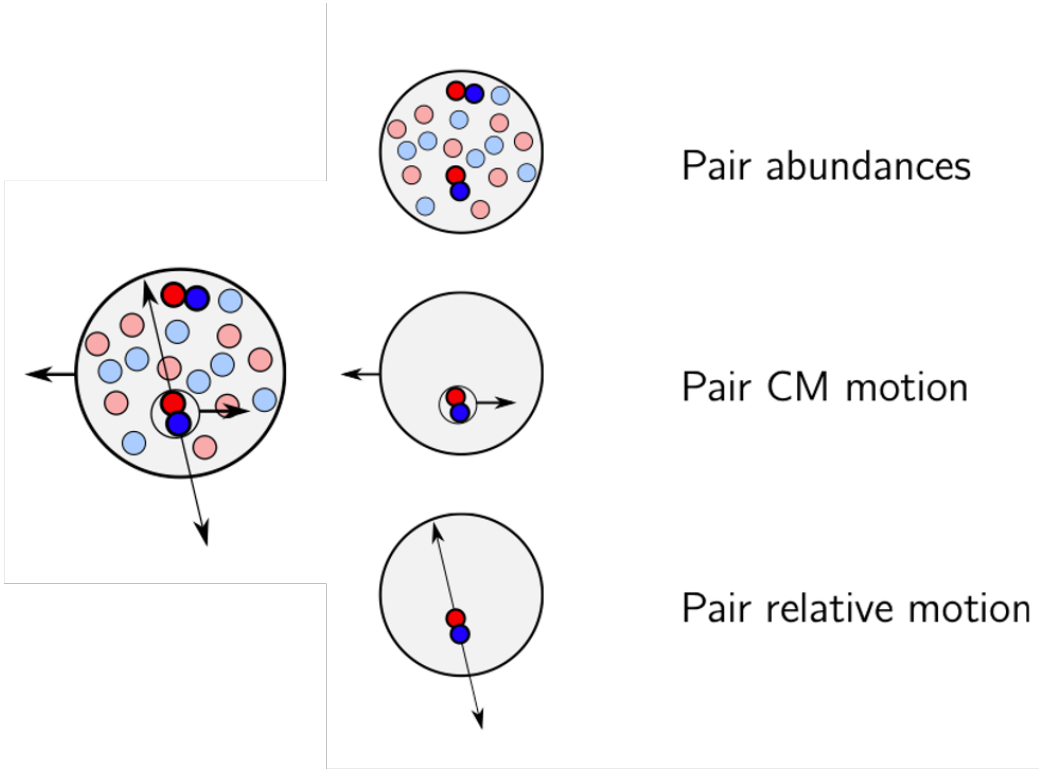

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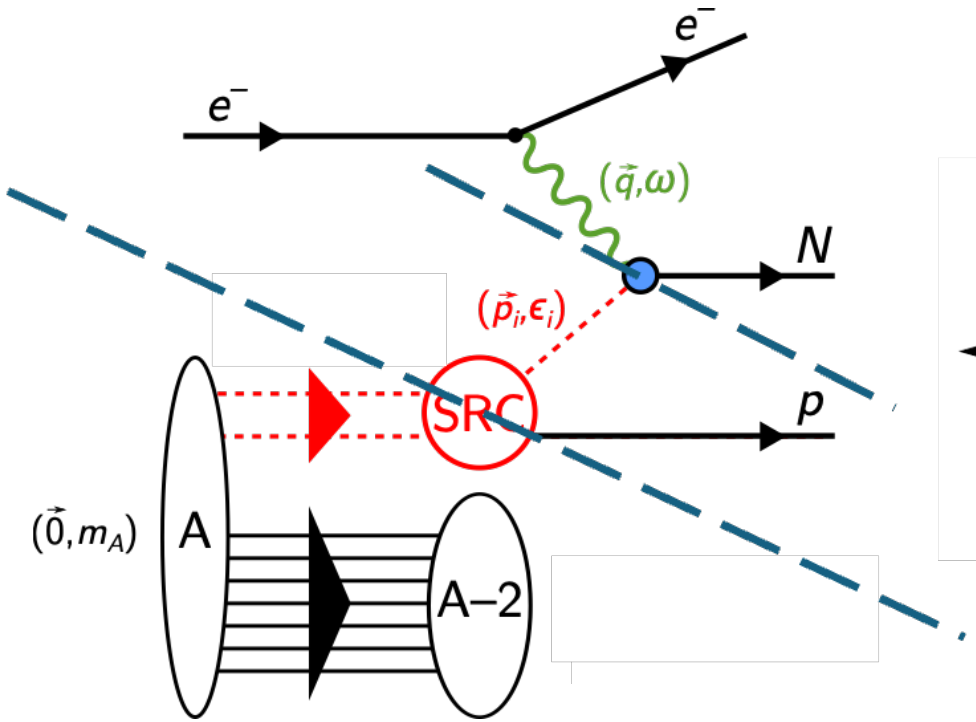

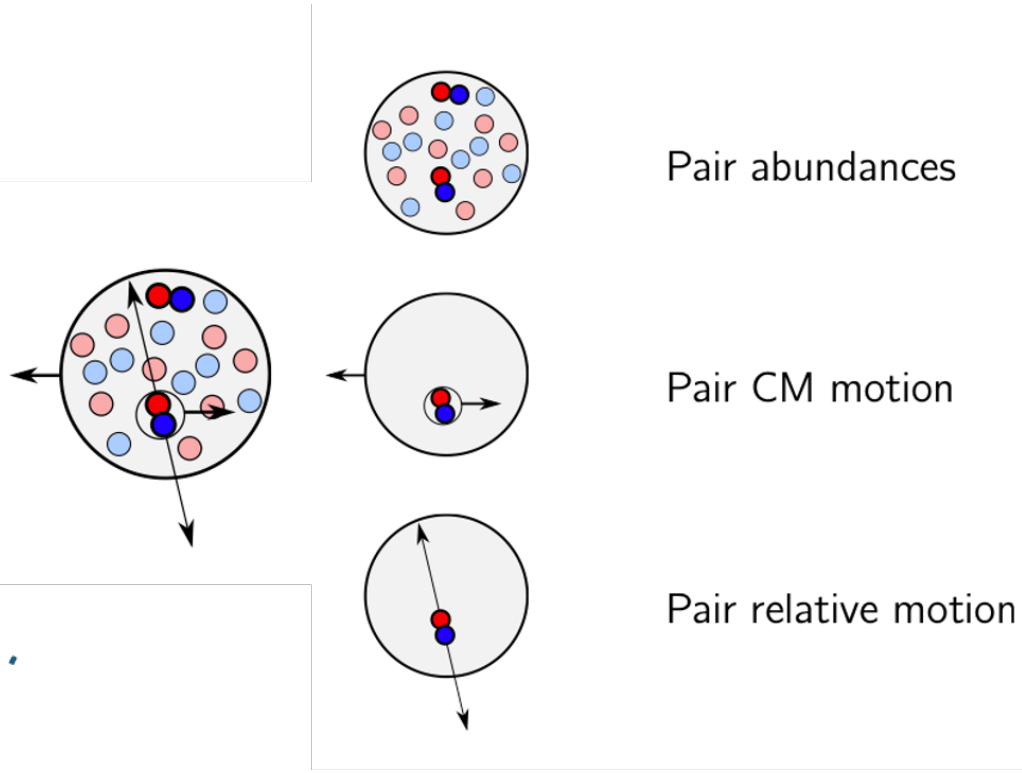

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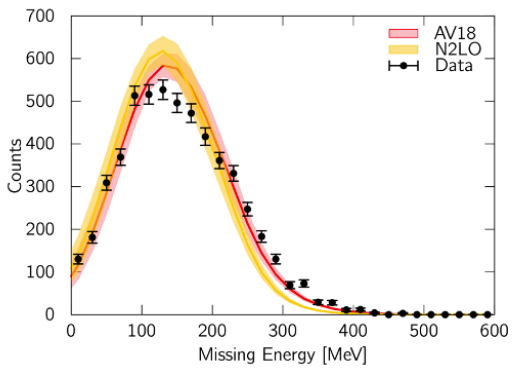
Generalized Contact Formalism and electron scattering results



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

$C(e,e'p)$

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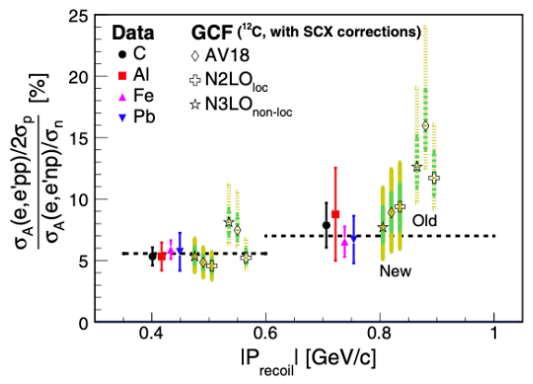
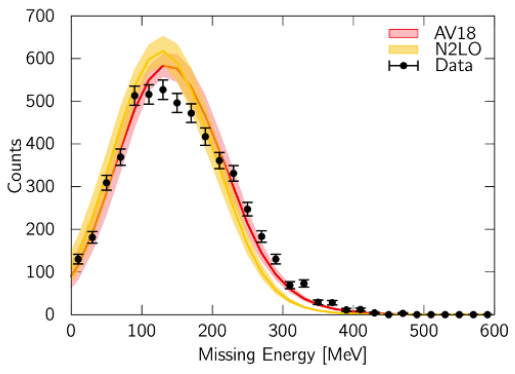


M. Duer et al., (CLAS)
PRL 122 172502 (2019)

A(e , e ' N p)



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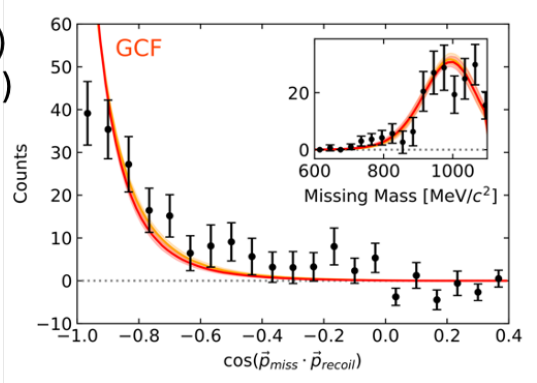
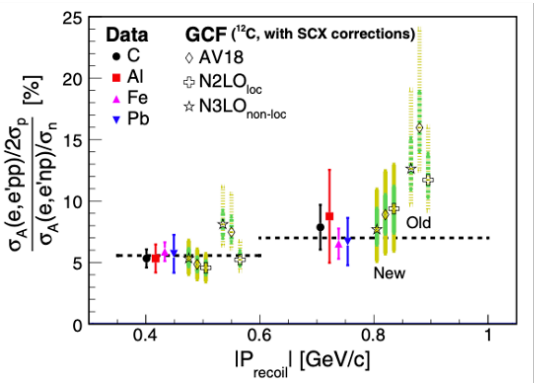
Generalized Contact Formalism and electron scattering results

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

C (e , e ' p n)





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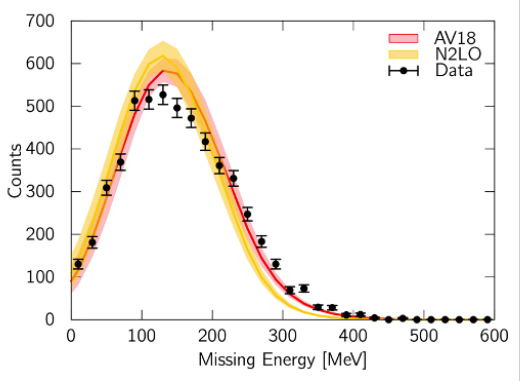

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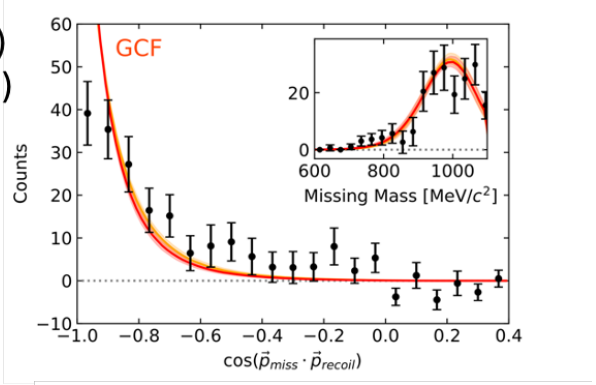
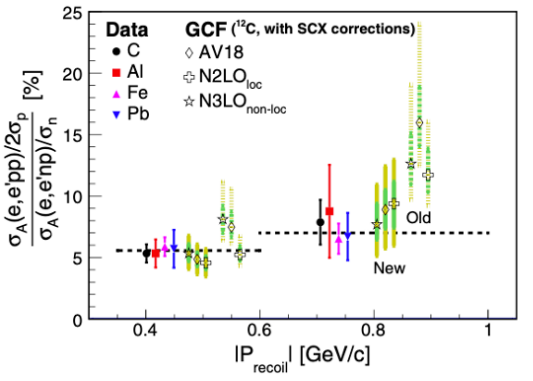


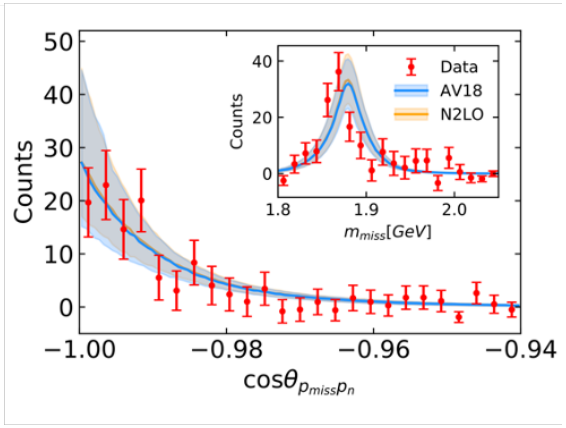


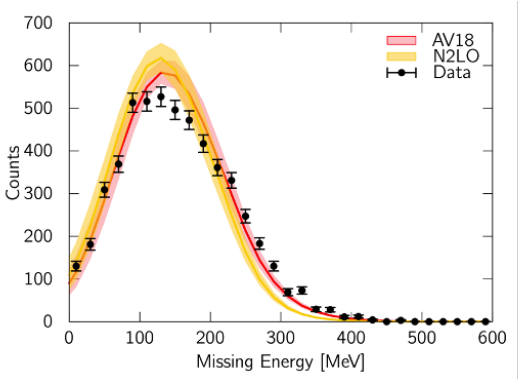
M. Duer et al., (CLAS) PRL 122 172502 (2019)

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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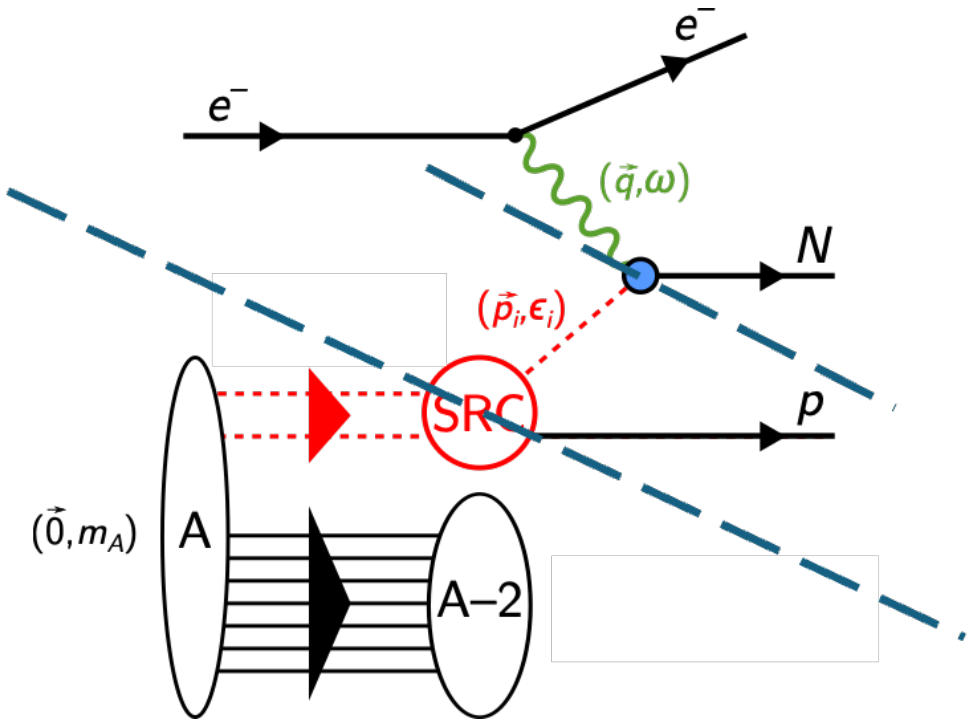
C (e , e ' p)

Testing SRC hypothesis with new probe

Real Photon Beam



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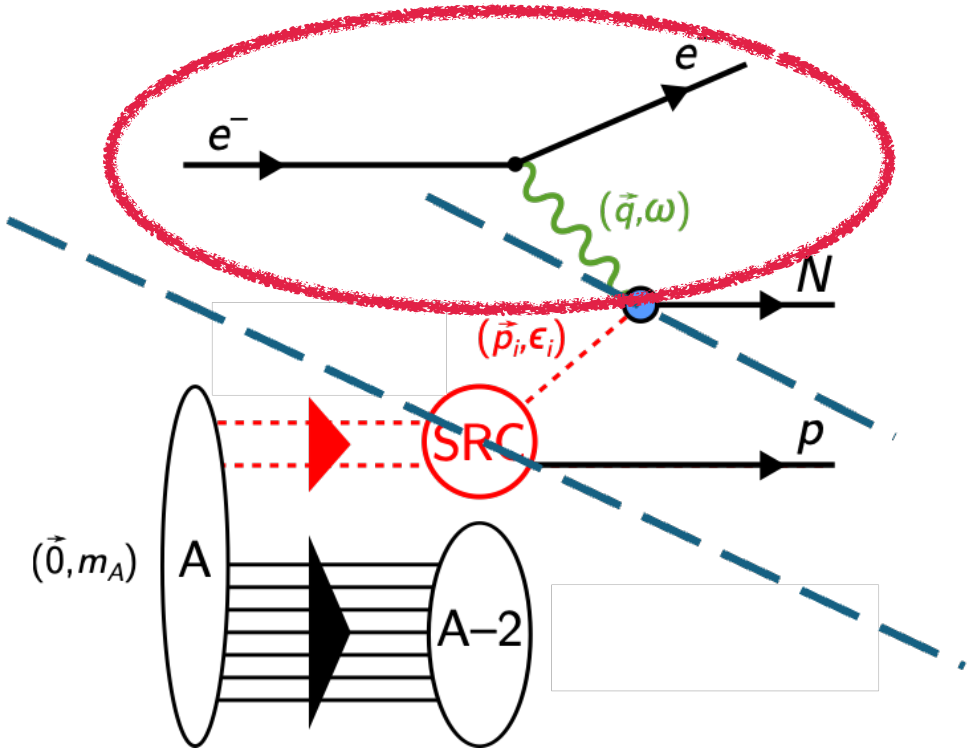

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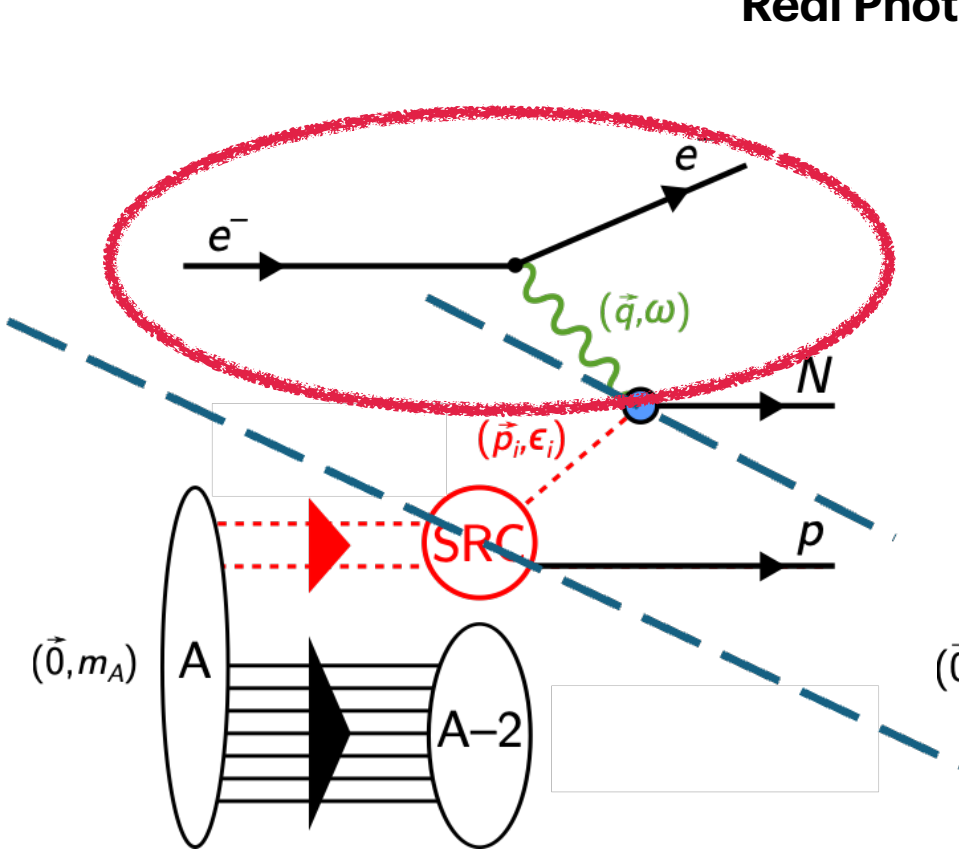
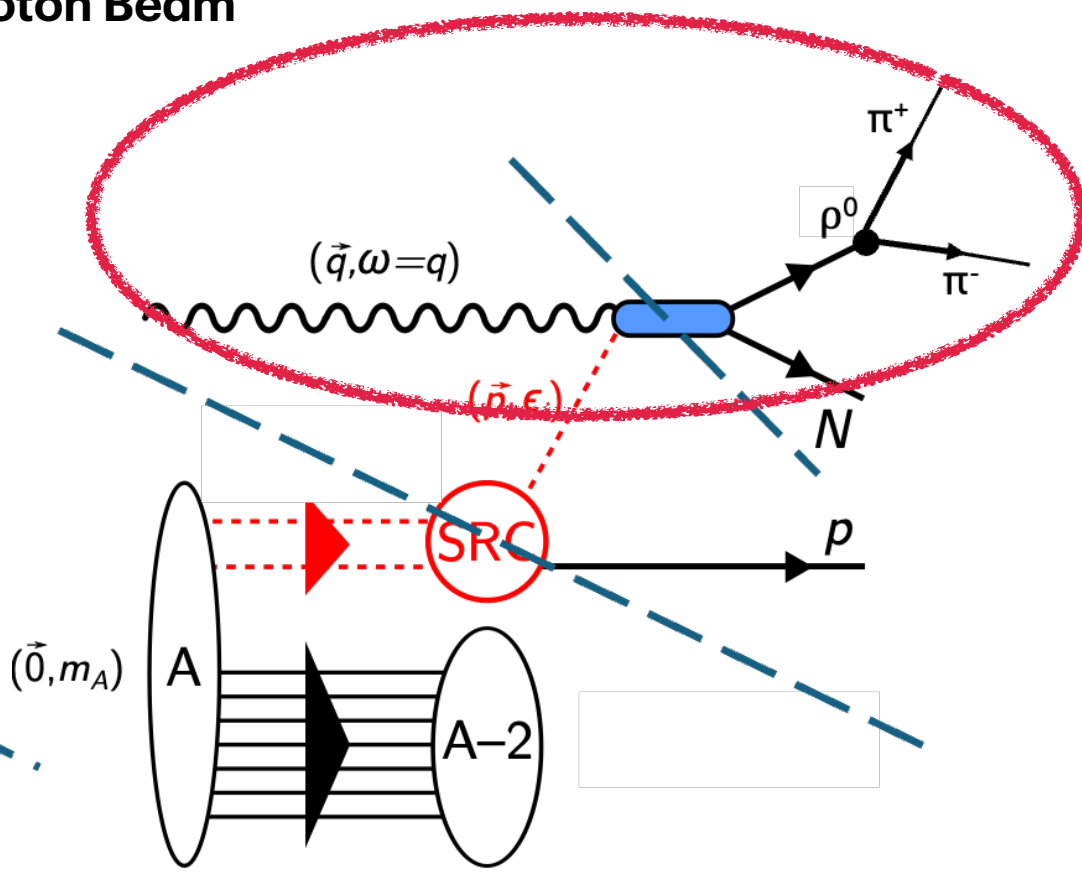
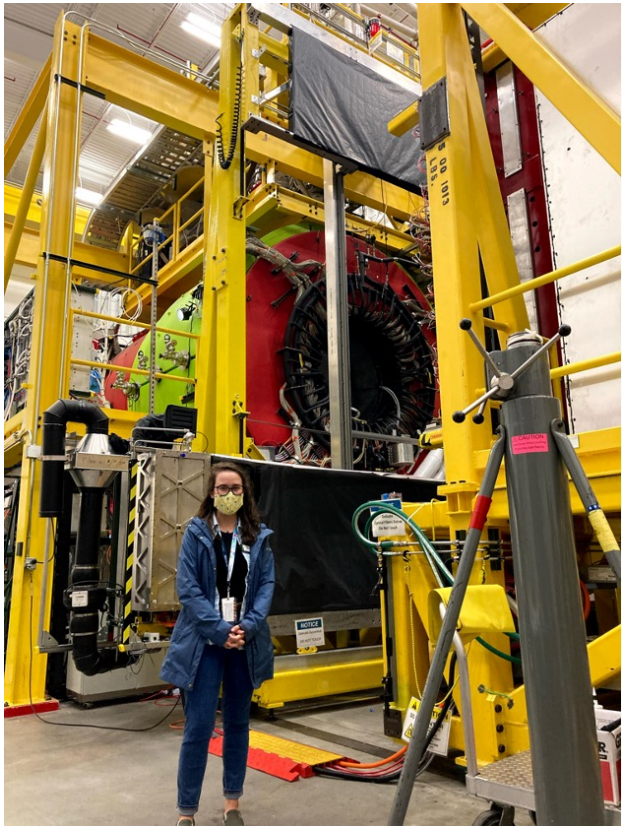




The Rest of this Talk

Hi, I'm Phoebe!



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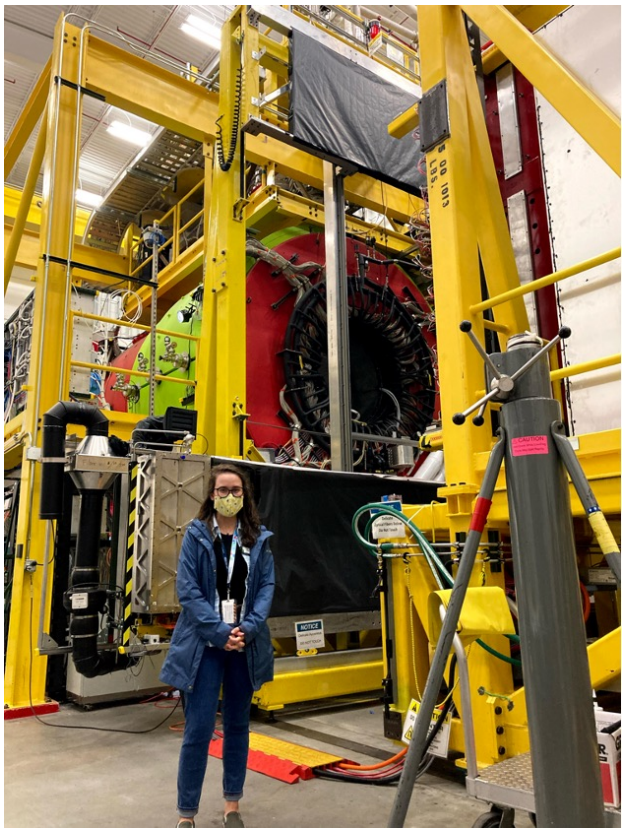
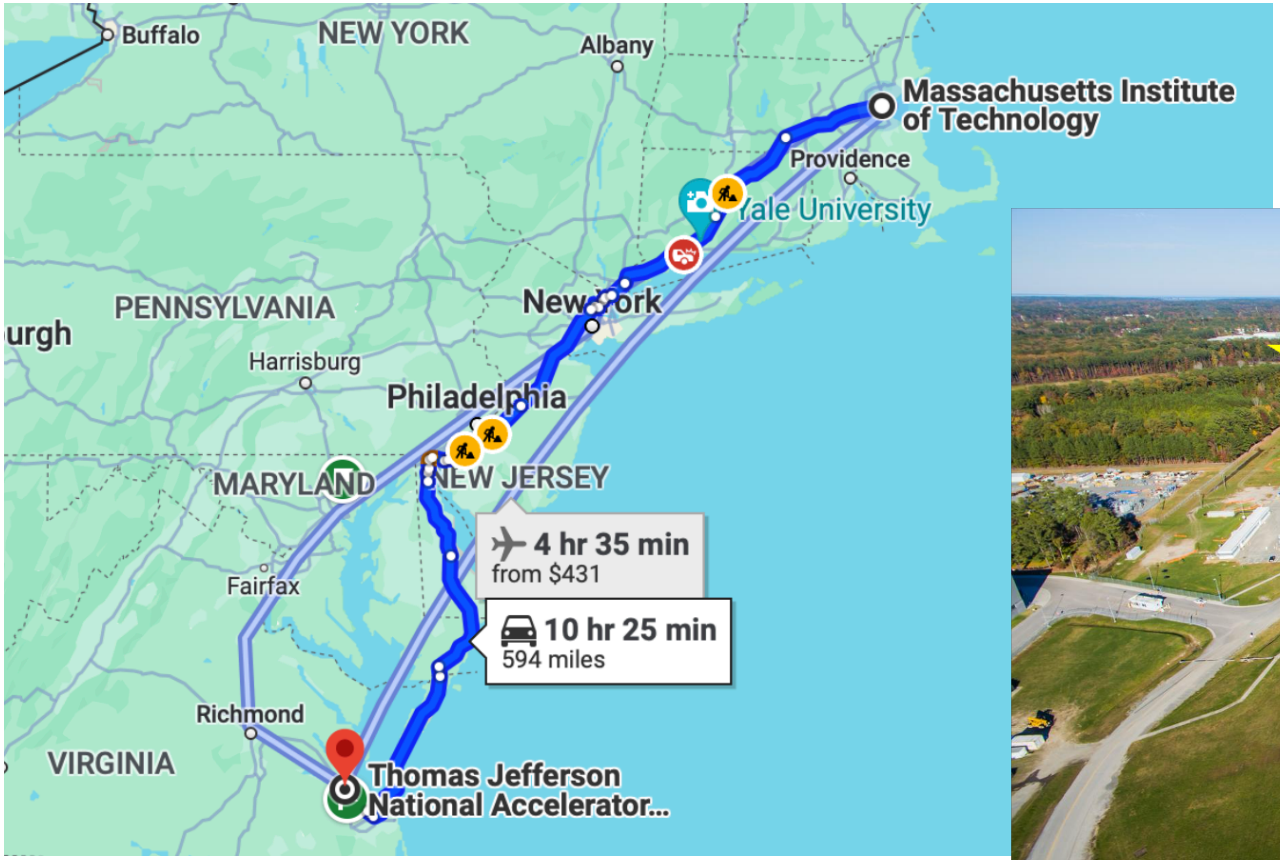
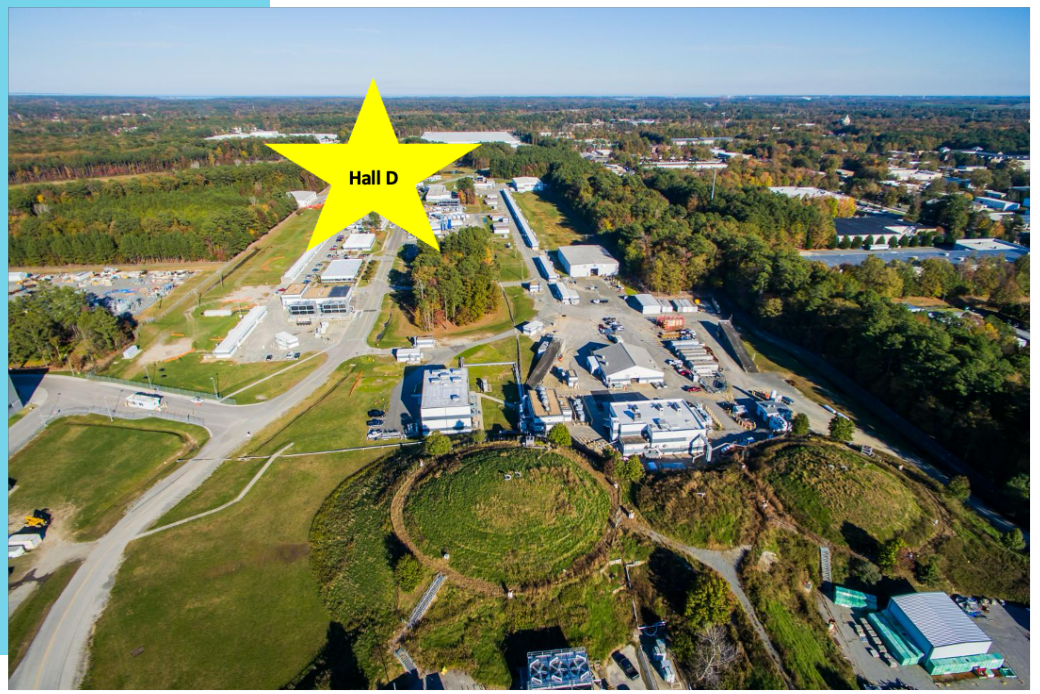
- Analysis update
- GCF Predictions

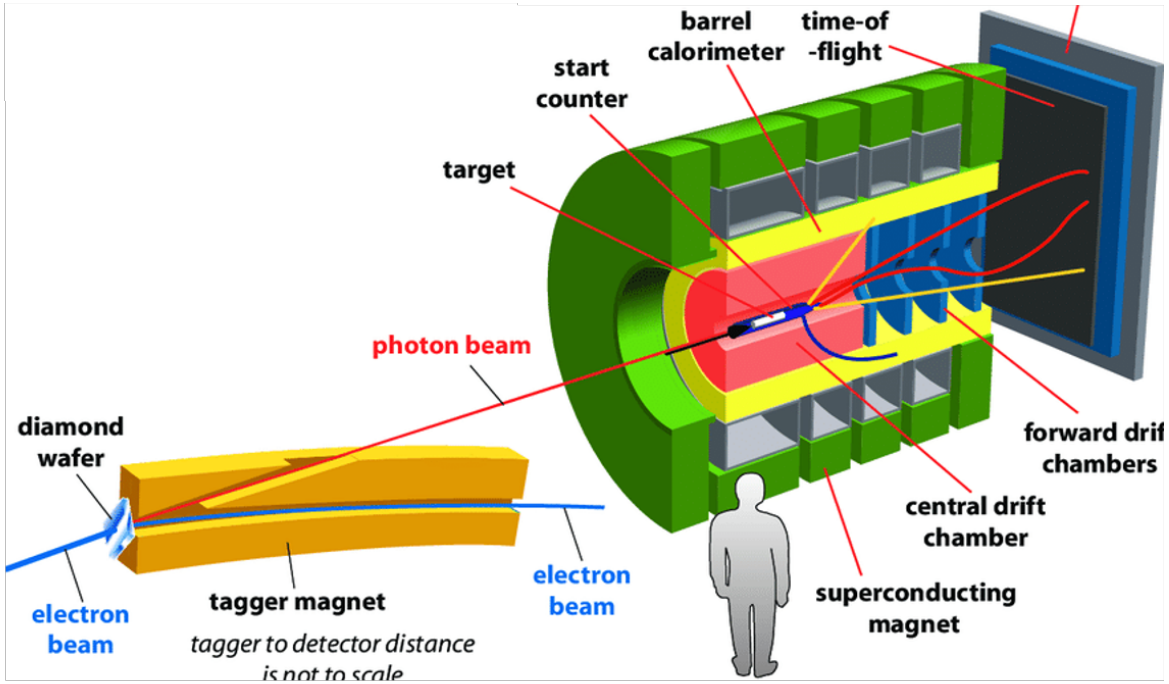


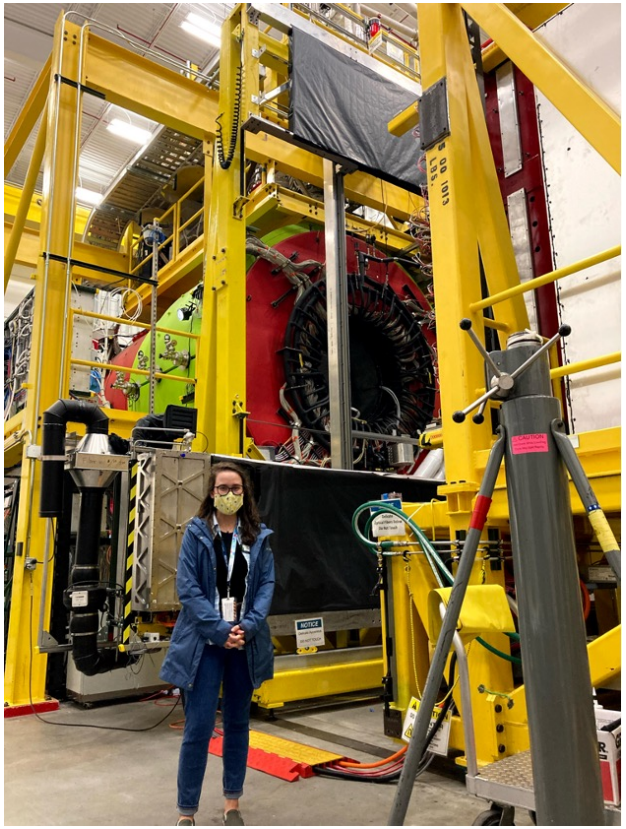
Jefferson Lab





Real Photons from GlueX in Hall D





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

Hall D SRC/CT Experiment

- November - December 2021
- 43 days
- Collaboration at GW, MIT, Duke, MSU, Tel Aviv, ODU, and Jlab
- Analysis Status:
  - Dark Matter Search - PUBLISHED
  - J/ ψ Production - Arxiv soon!
  - Preliminary Short Range Correlations Results

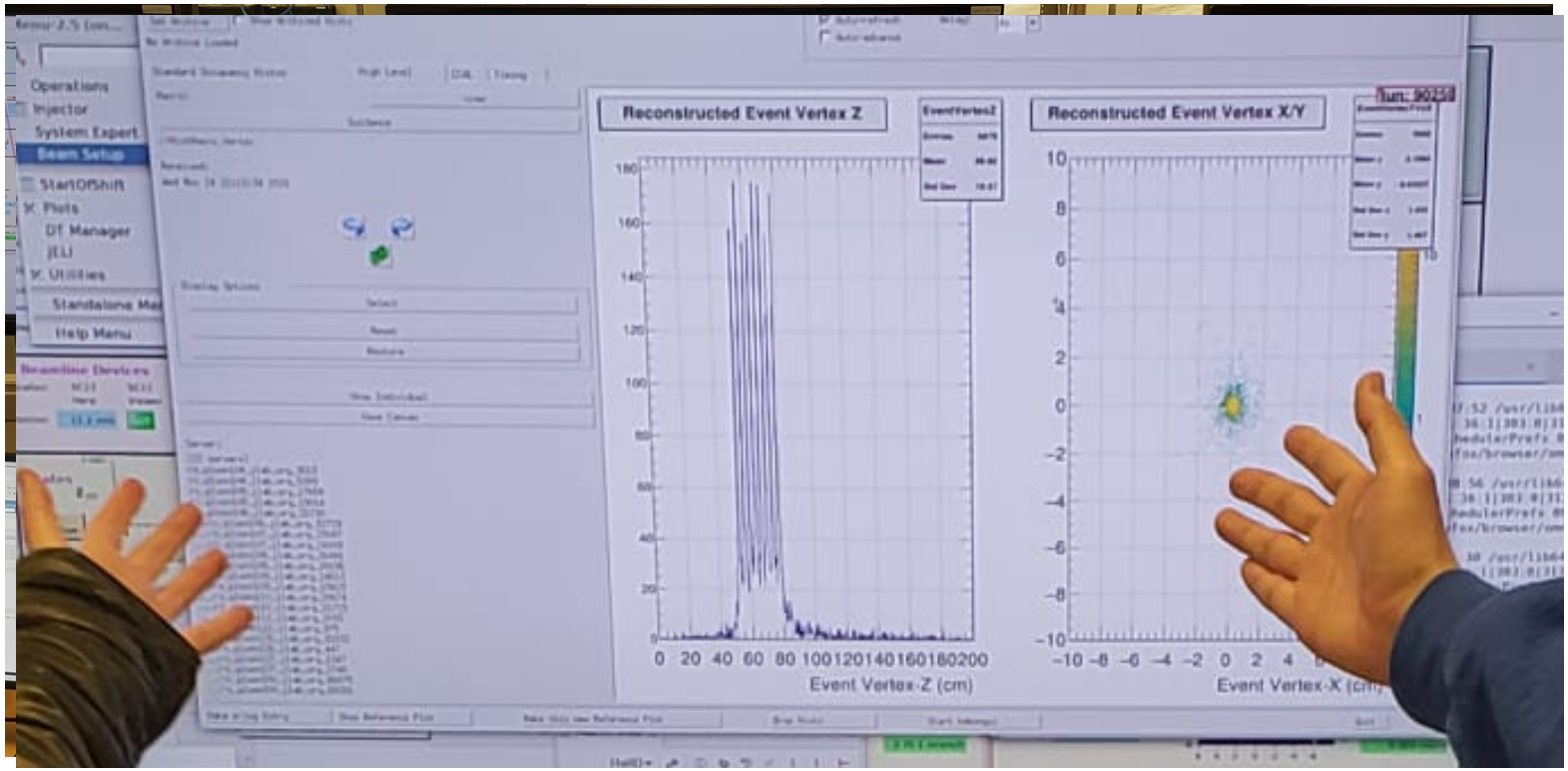
Target	Days on Beam
Liquid Helium 4	10
Liquid Deuterium	4
Carbon Multi-Foil	14

The Multi-foil Carbon Target

A first for us all

The Multi-foil Carbon Target

A first for us all



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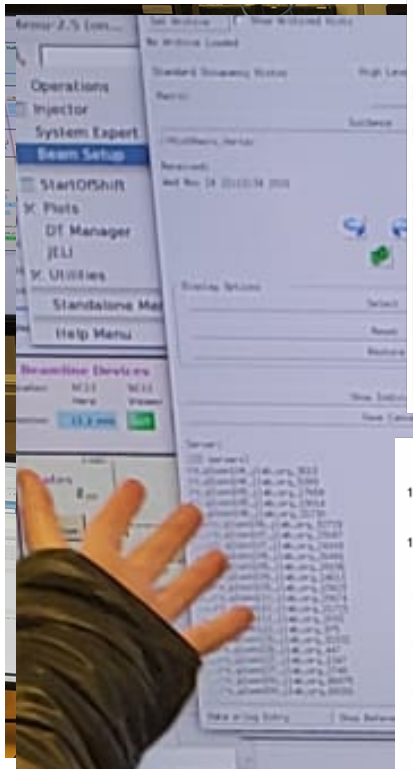
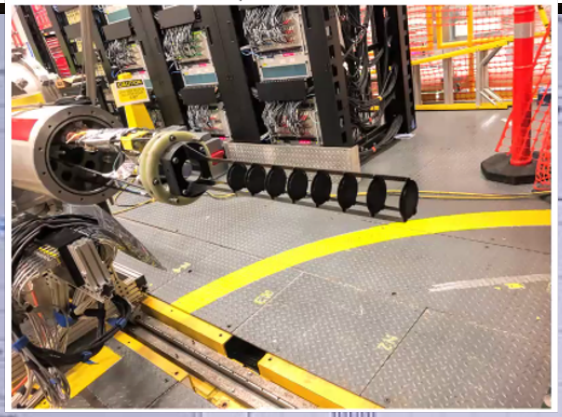
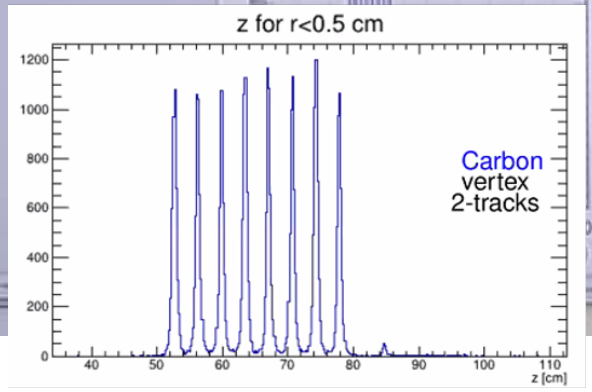
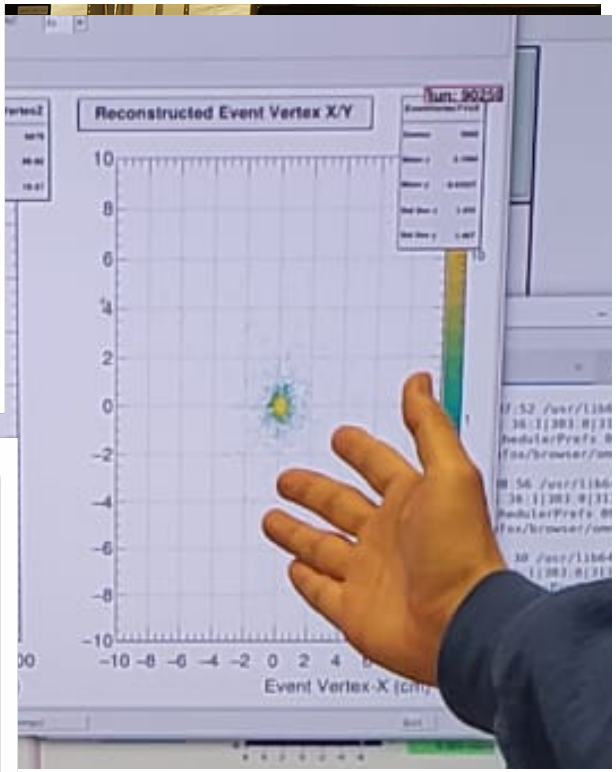


^{12}C $8 \times \varnothing 20 \times 2.3$ mm







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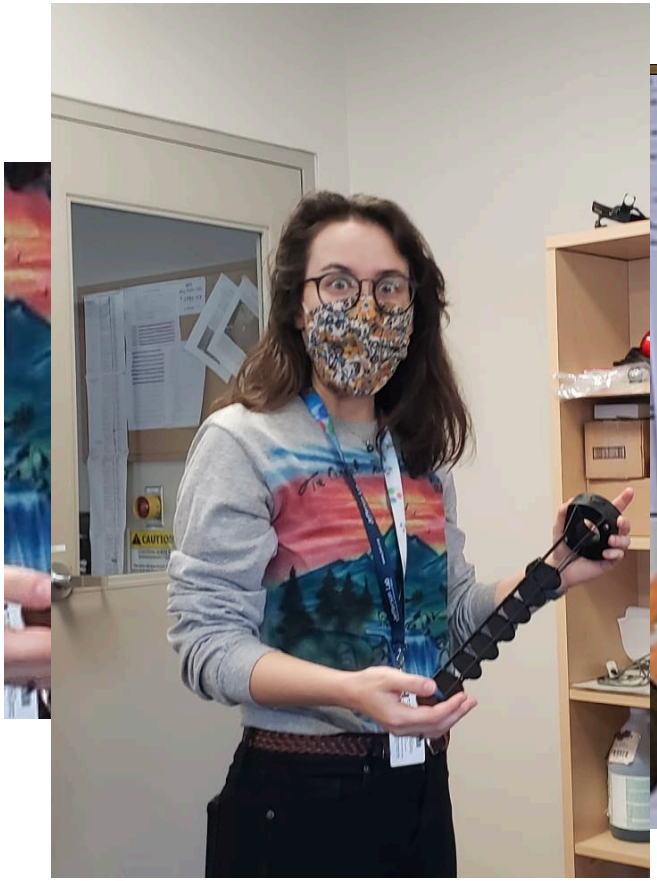

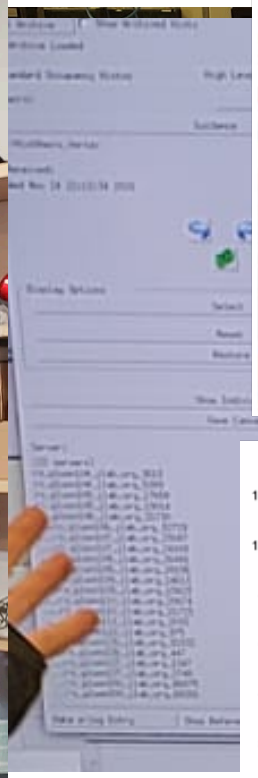

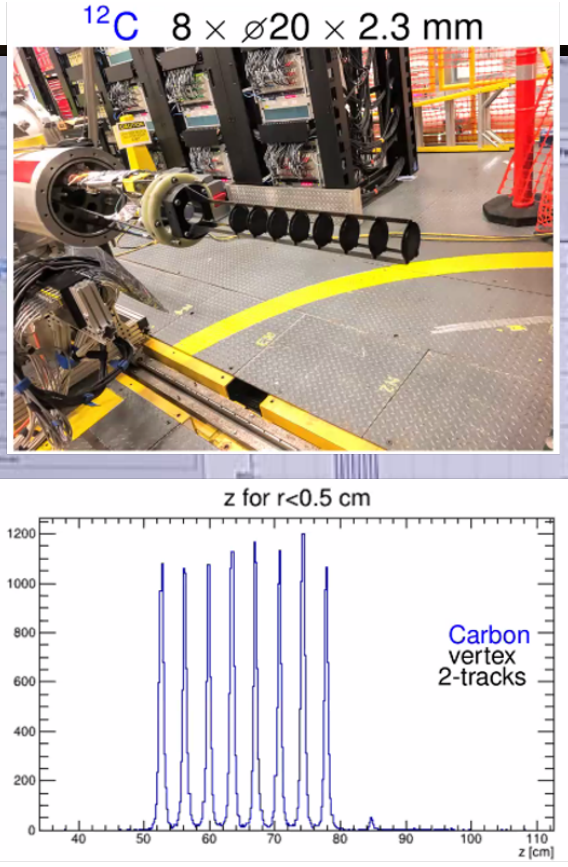

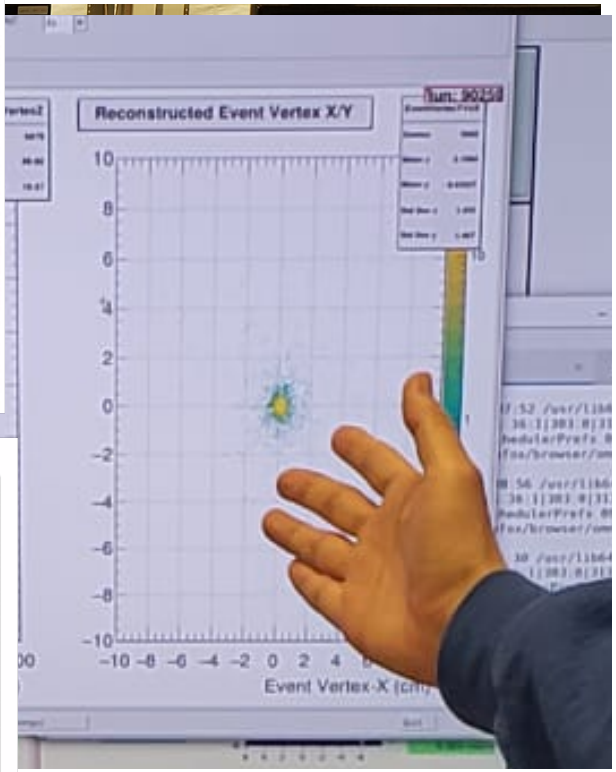

Lots of great data for lots of great physics

Lots of great data for lots of great physics

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

The Rest of this Talk

- Hall D SRC/CT Experimental Details
- **Analysis update**
- GCF Predictions

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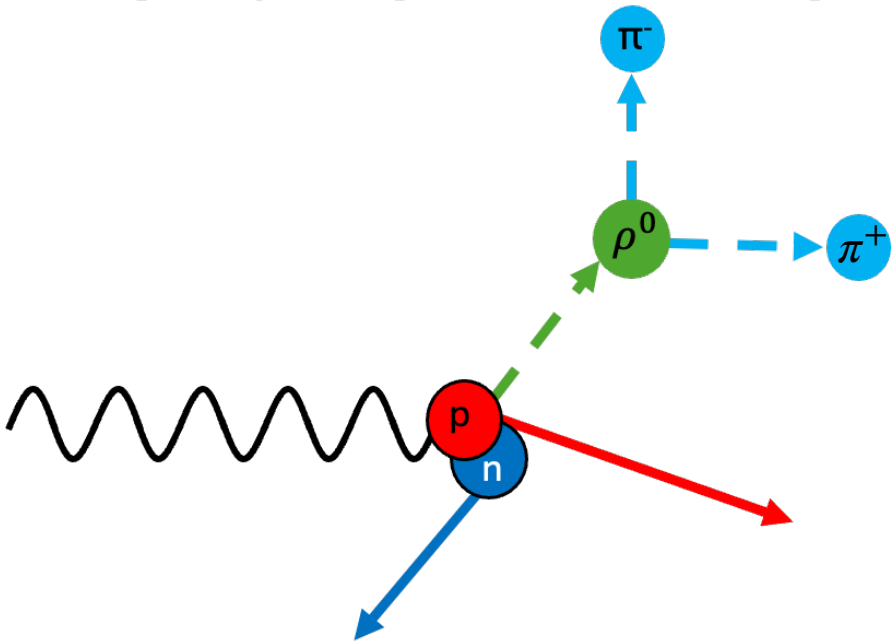
Lots of great data for lots of great physics

ρ^0 photo production: Tagging SRC events

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



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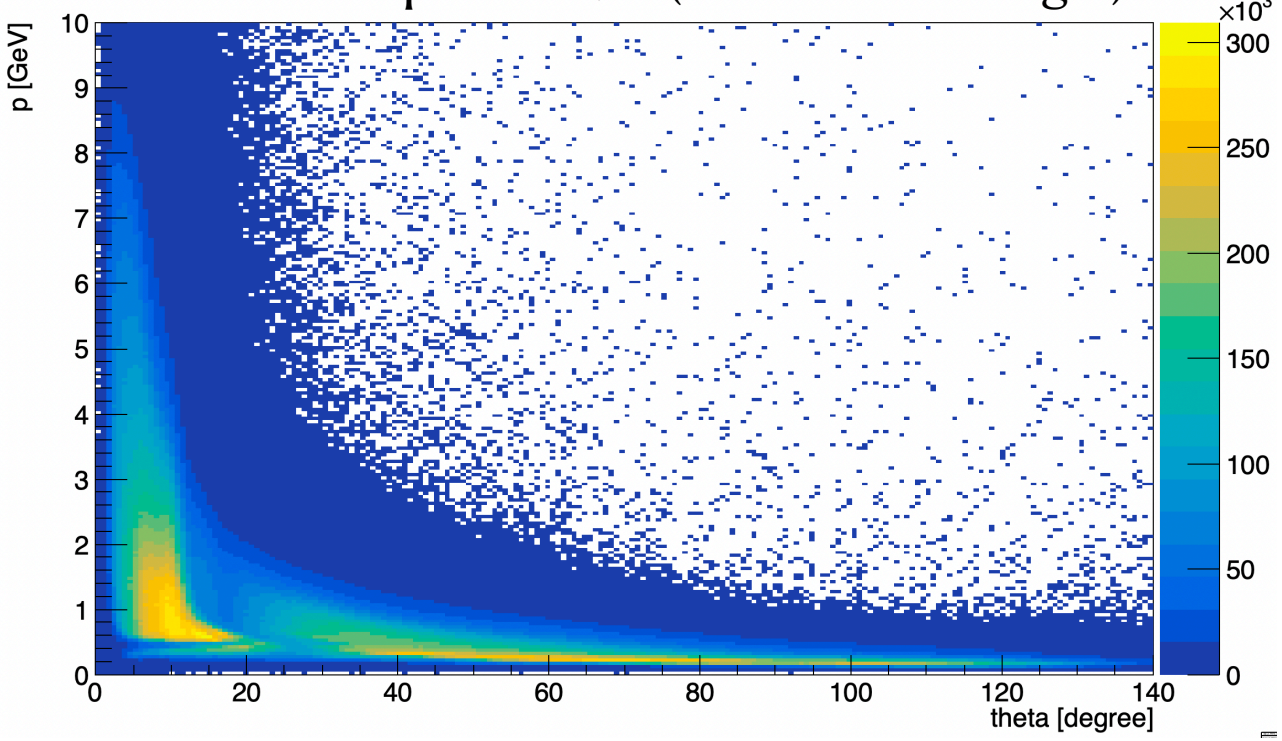
ρ^0 photo production: Tagging SRC events

π^+ proton confusion — π^- can help!

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



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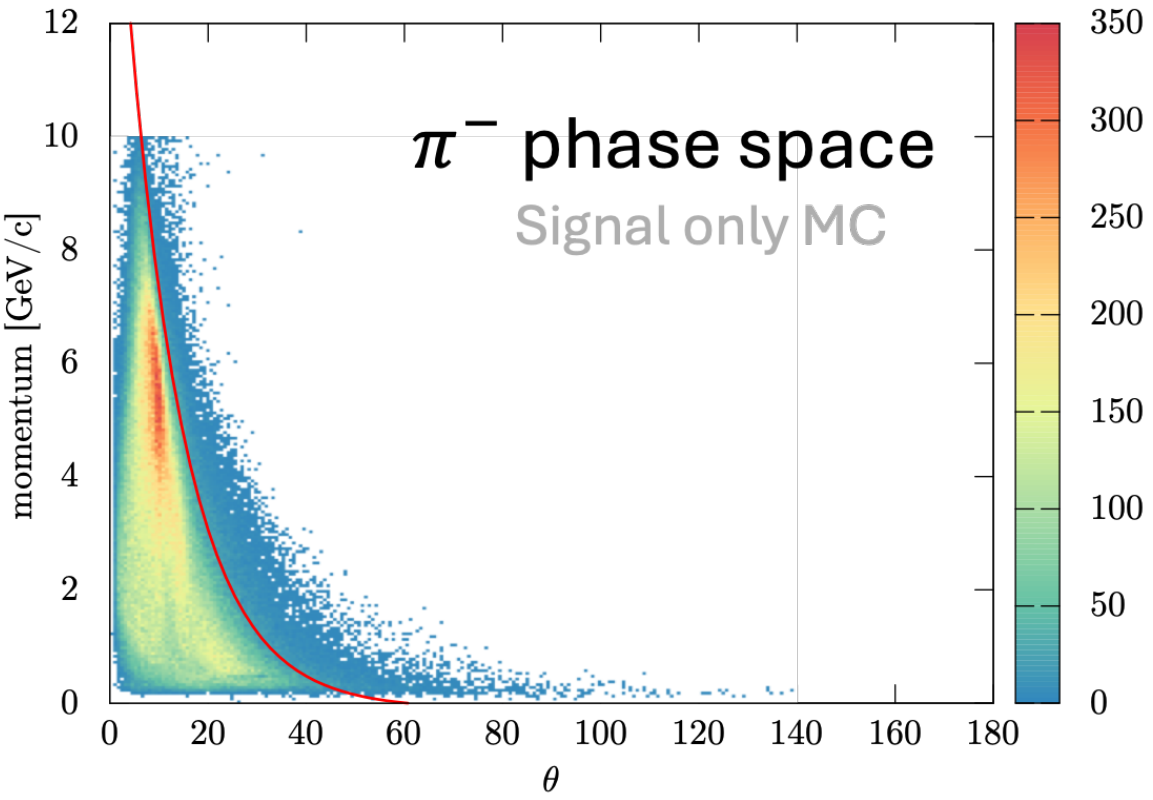
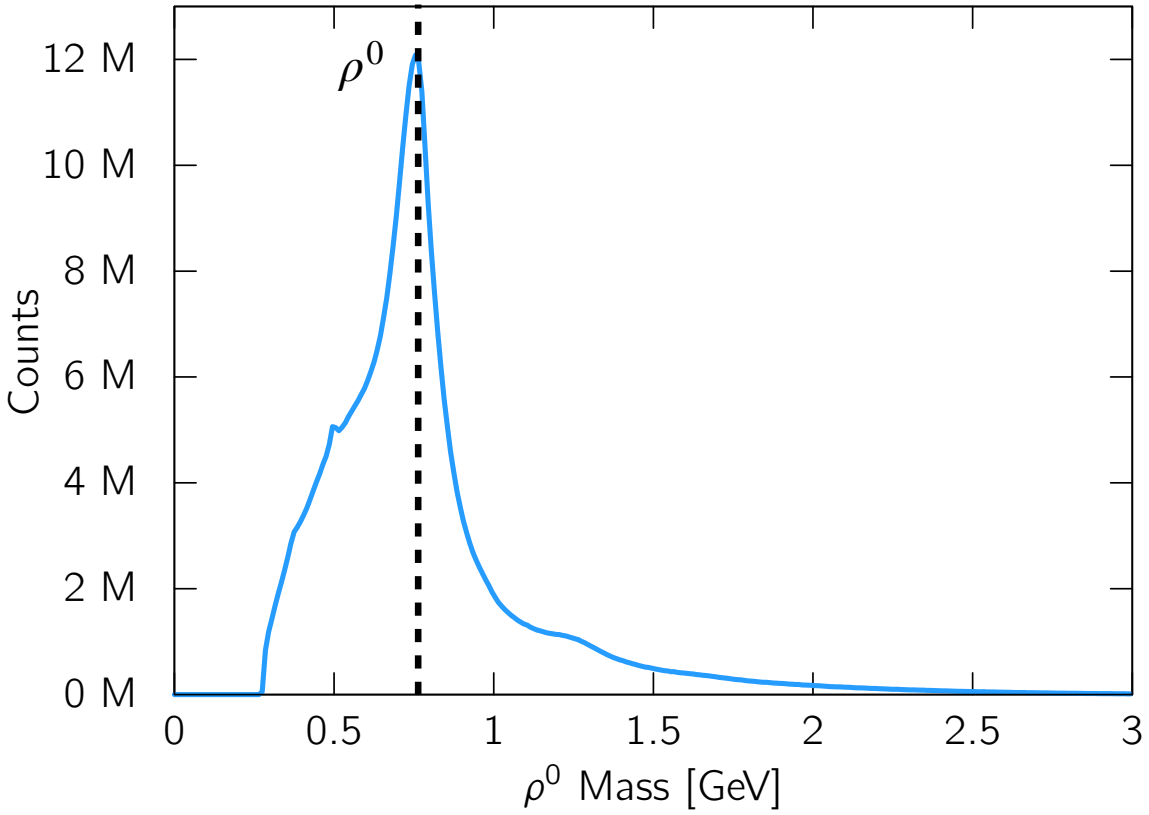


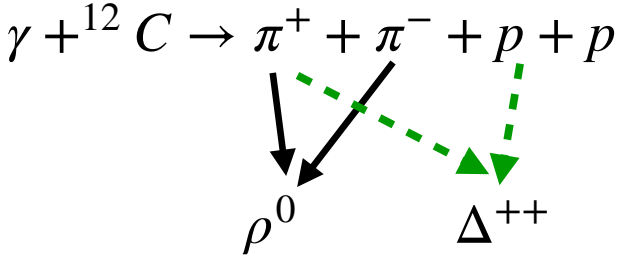
ρ^0 photo production: Tagging SRC events

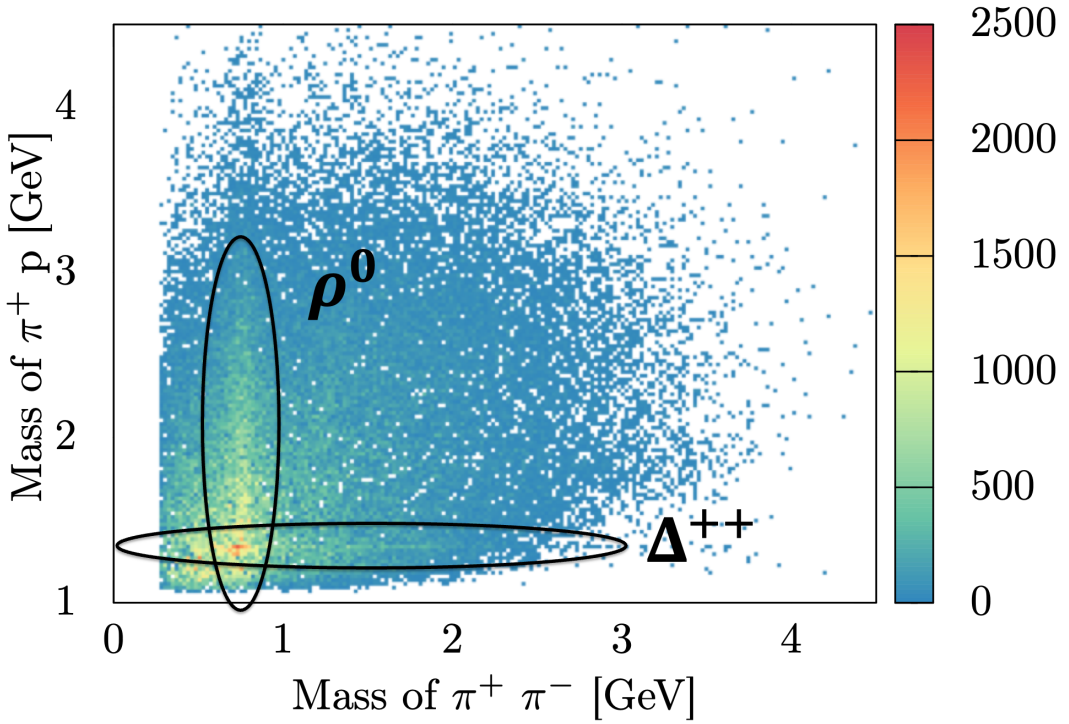
We see ρ^0 events!



ρ^0 photo production: Tagging SRC events

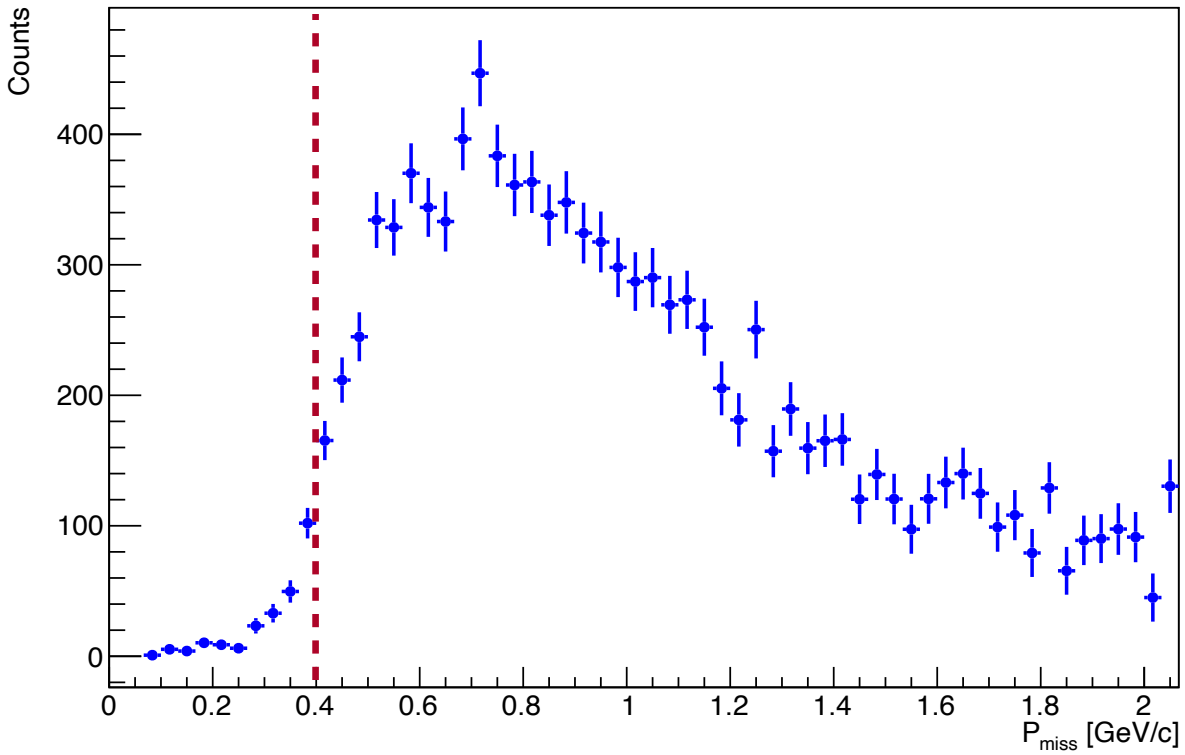
Baryonic Sources of Background





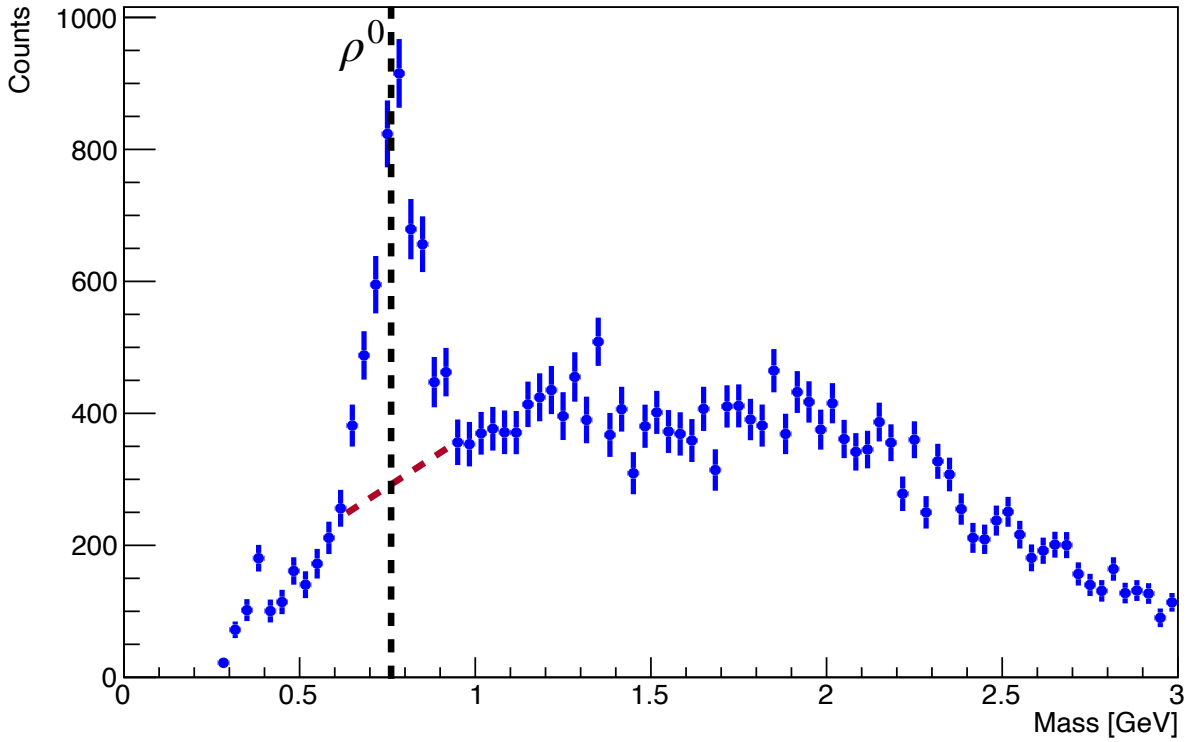
ρ^0 photo production: Tagging SRC events

Missing Momentum Cut



ρ^0 photo production: Tagging SRC events

Great ρ^0 signal definition!



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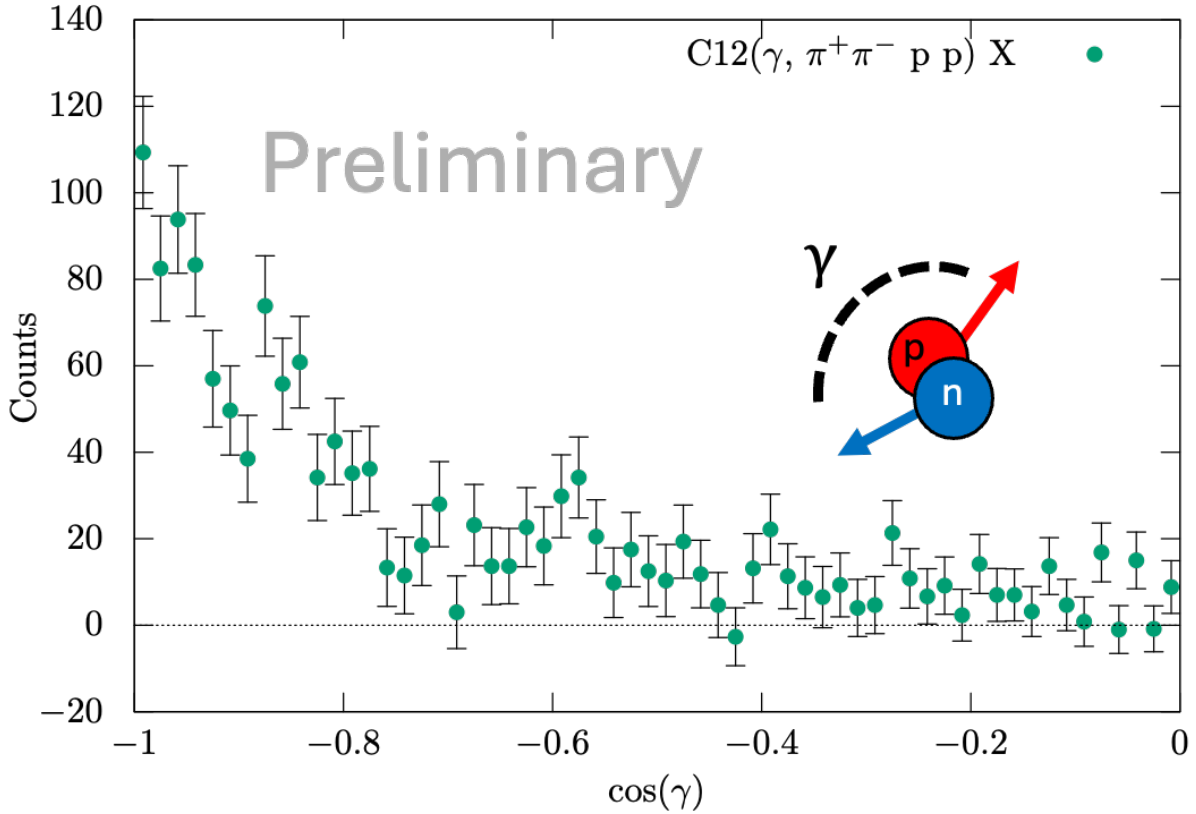
We see SRC events!



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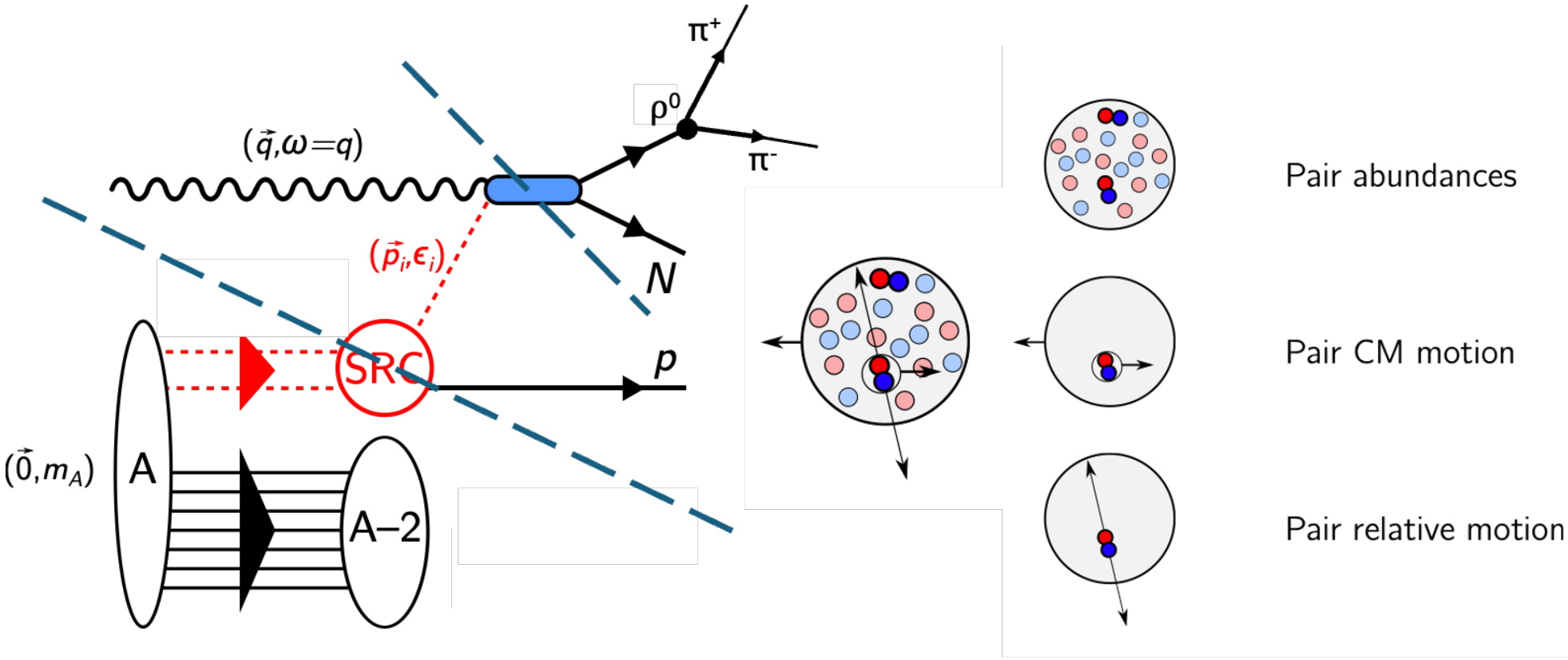
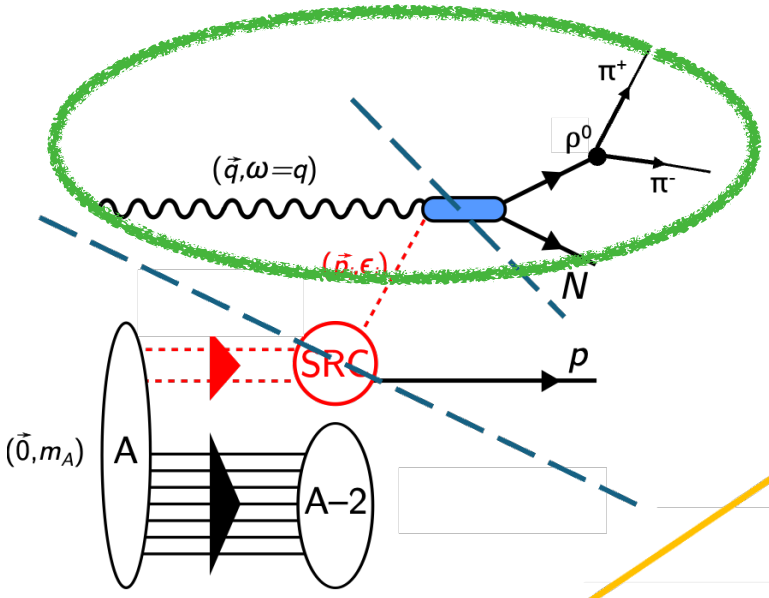
Comparing the events to our predictions:

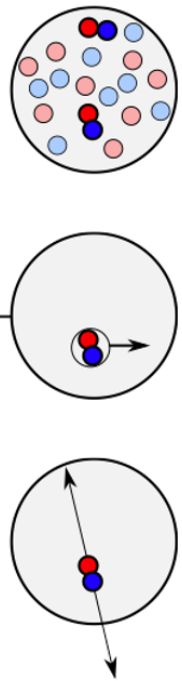
Generalized Contact Formalism



We've been able to model SRCs well.

Generalized Contact Formalism





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

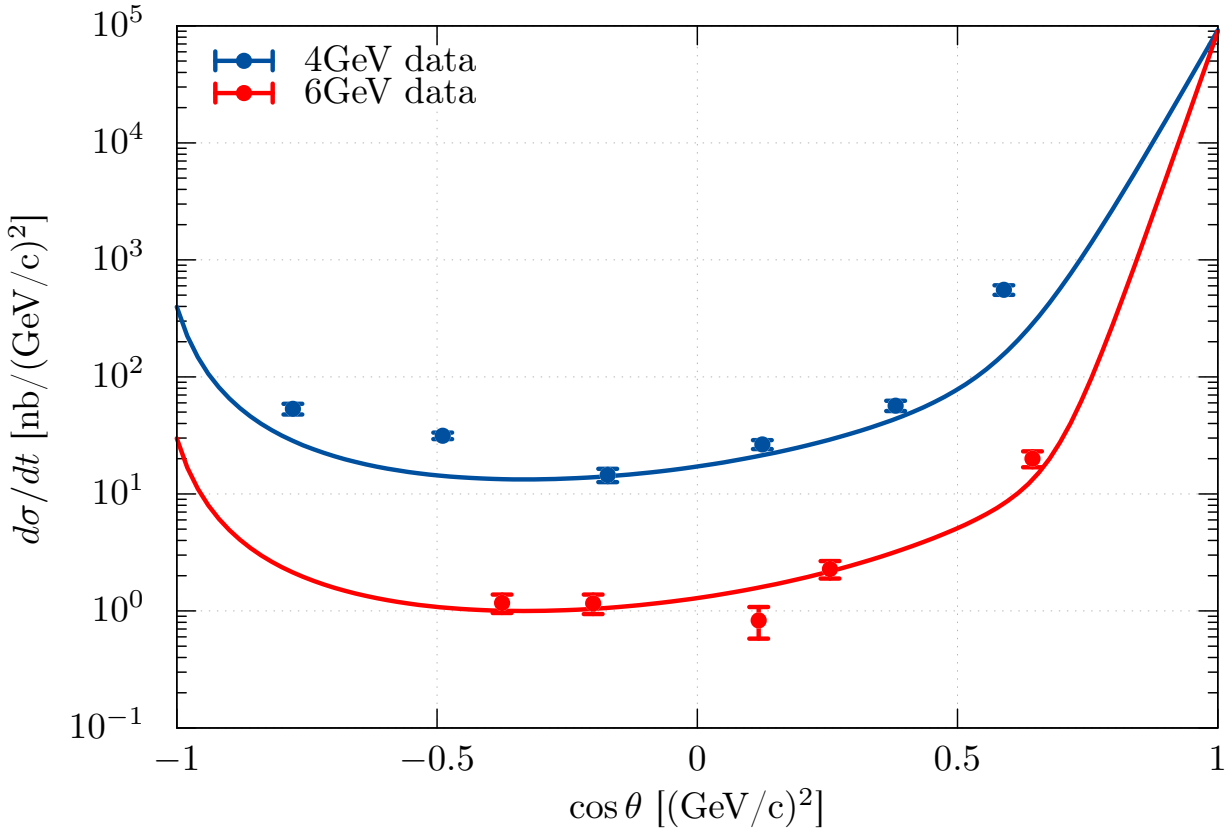
Pair abundances
Contacts from
Ab initio
calculations

Pair CM motion
Gaussian, width
from CLAS data

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

We have a ρ^0 cross section to add to GCF.

ρ^0 photo production: Anderson, et.al, SLAC 1976



Testing characteristics of SRC with ρ^0 photo production

Neutron-Proton Pair Dominance

Photo production Observable

$$\frac{\sigma(\rho^0 pp)}{\sigma(\rho^0 p) + N}$$

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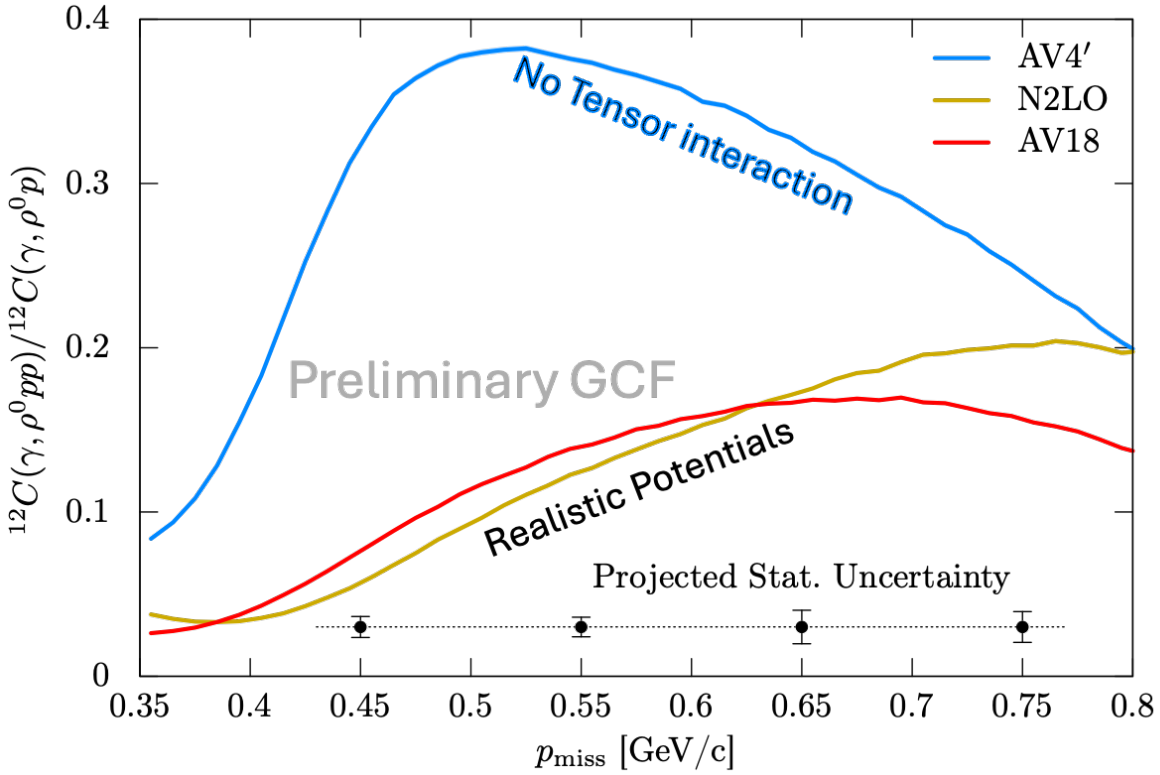
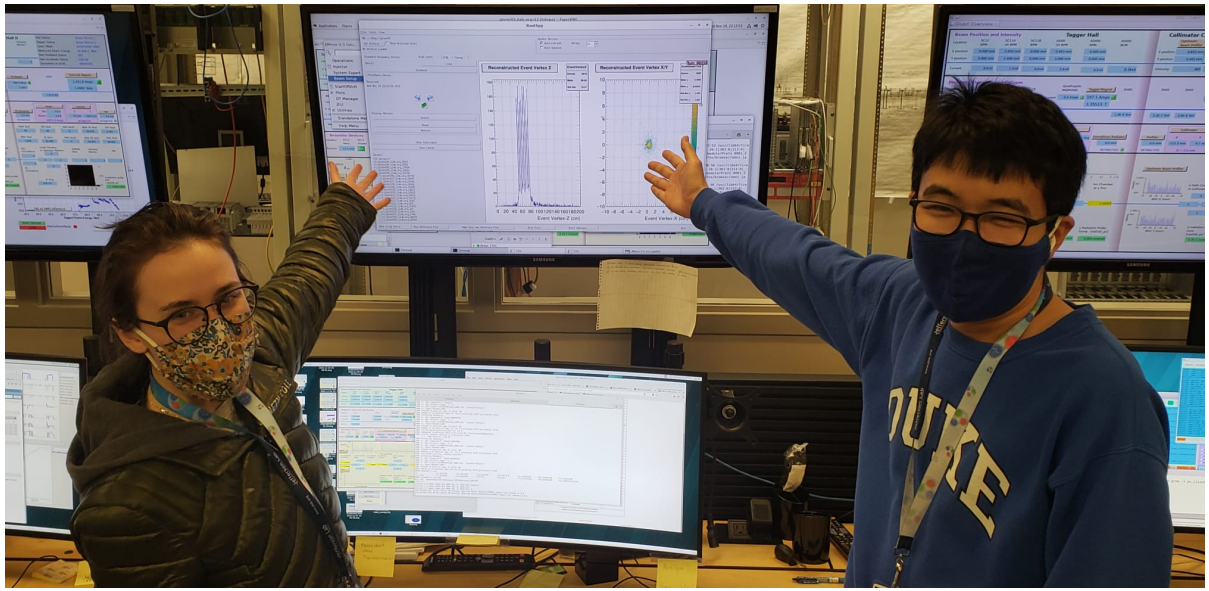


Recap

- **Hall D SRC/CT Experimental Details**
- Analysis update
- GCF Predictions



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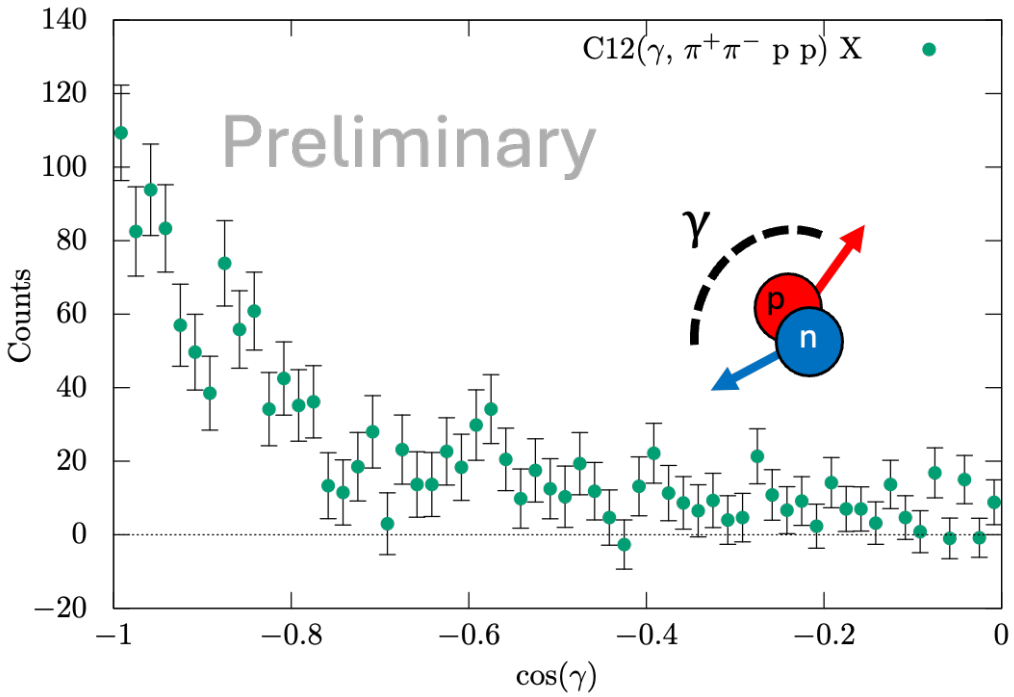

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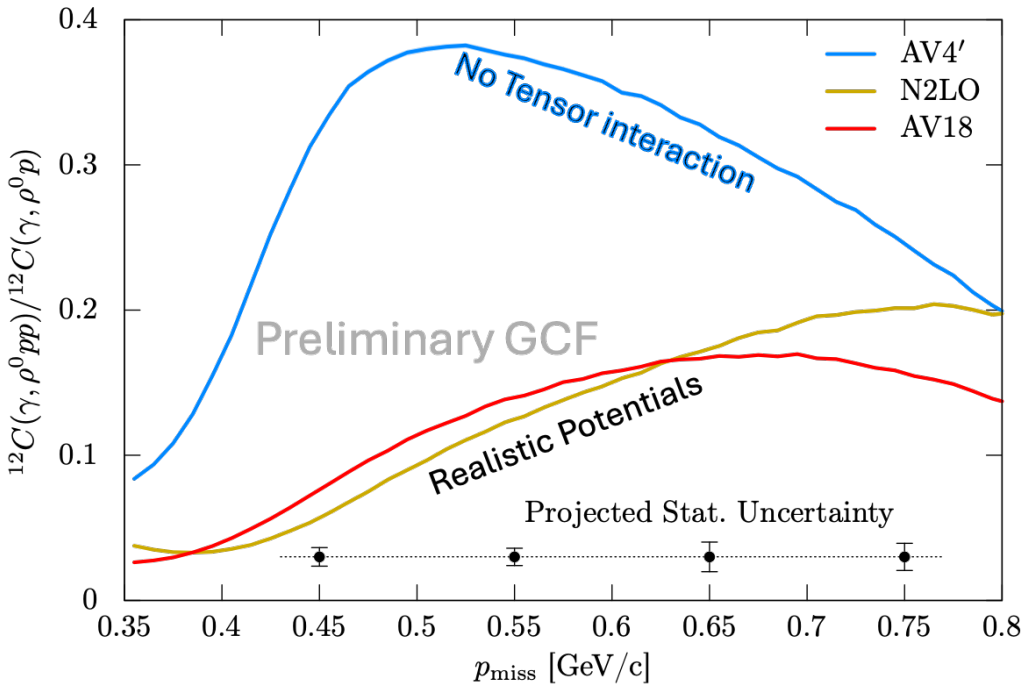

Conclusions

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- Further analysis is needed, and more results will be available soon.
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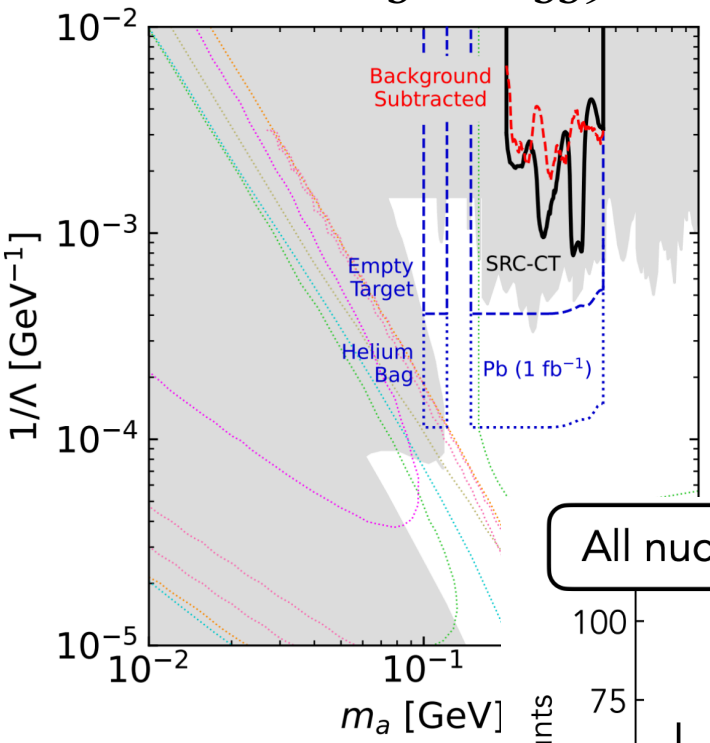
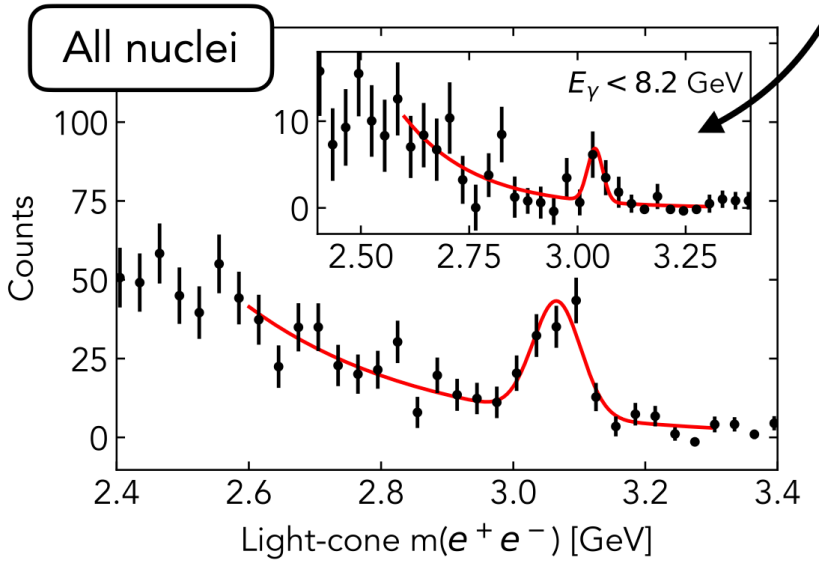
arxiv:2308.06339



J/ψ (Coming Soon)



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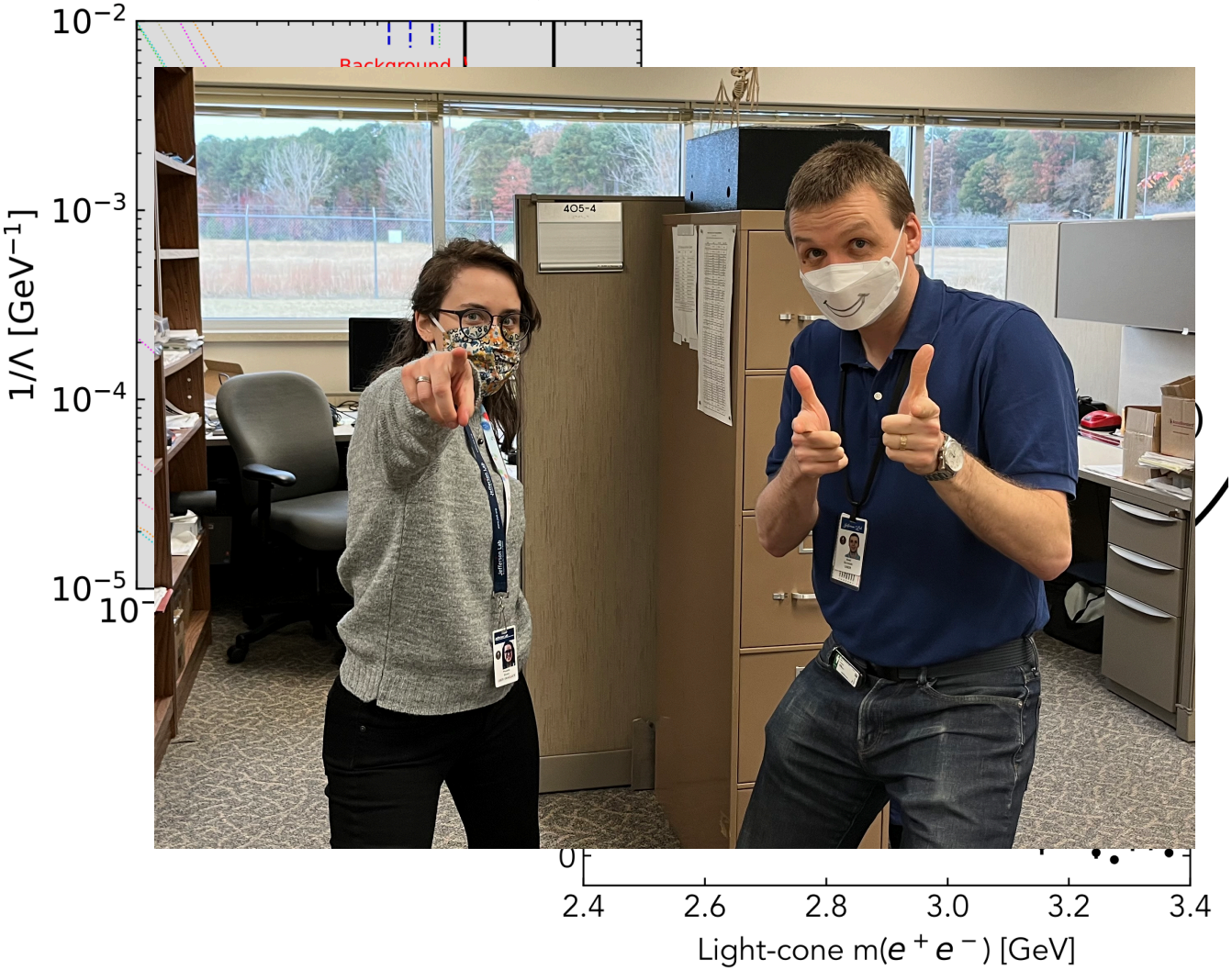
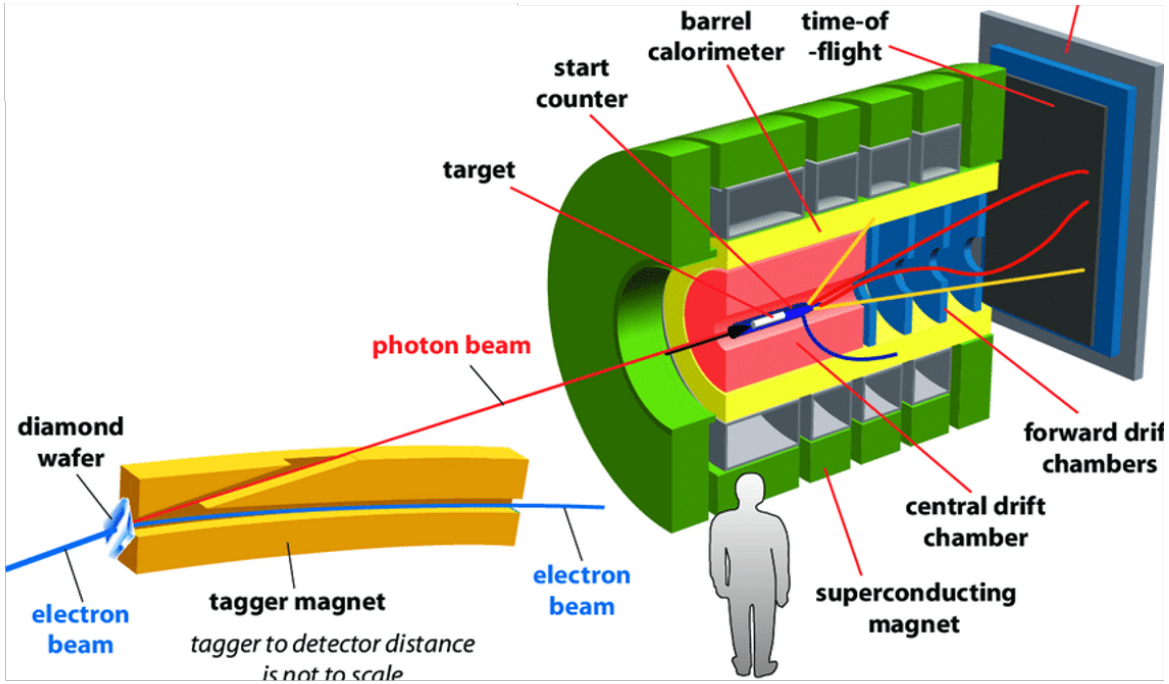
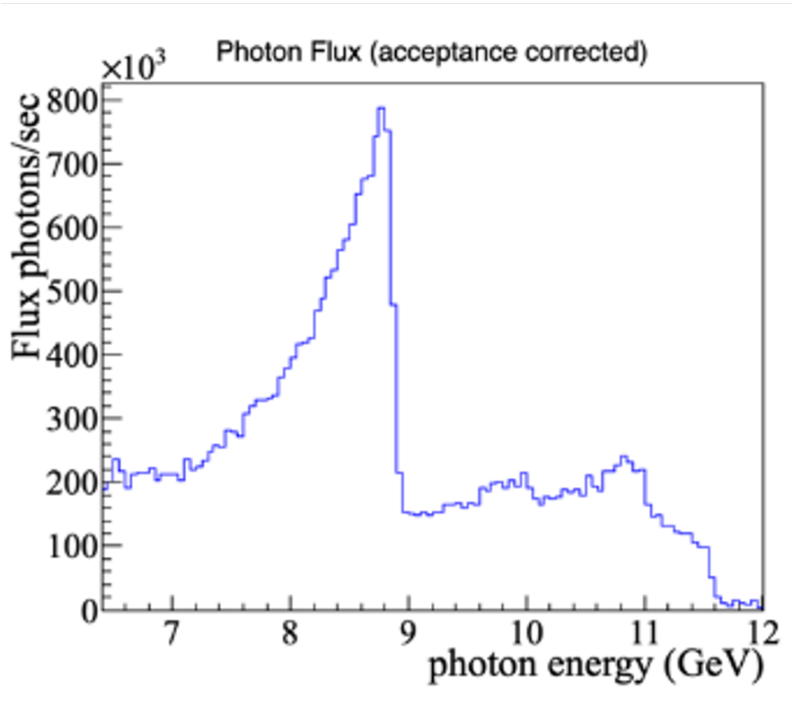


Back ups

Real Photons from GlueX in Hall D

FlueZ





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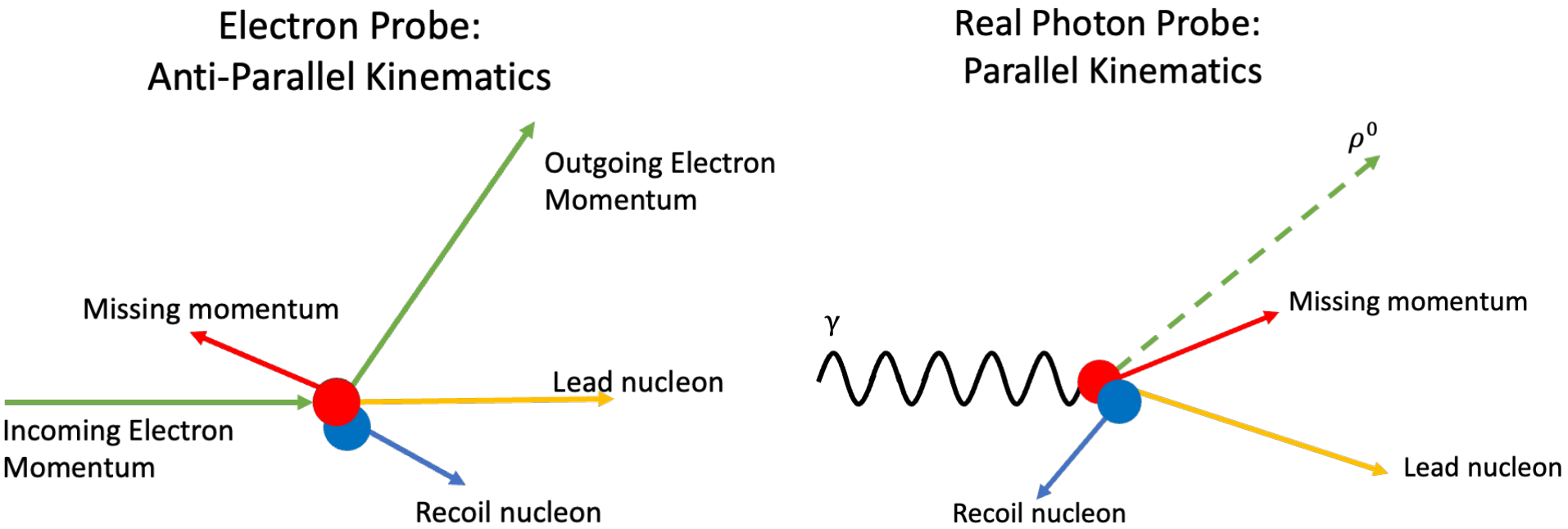
But, SRCs from nucleon knock-out have an additional concern.



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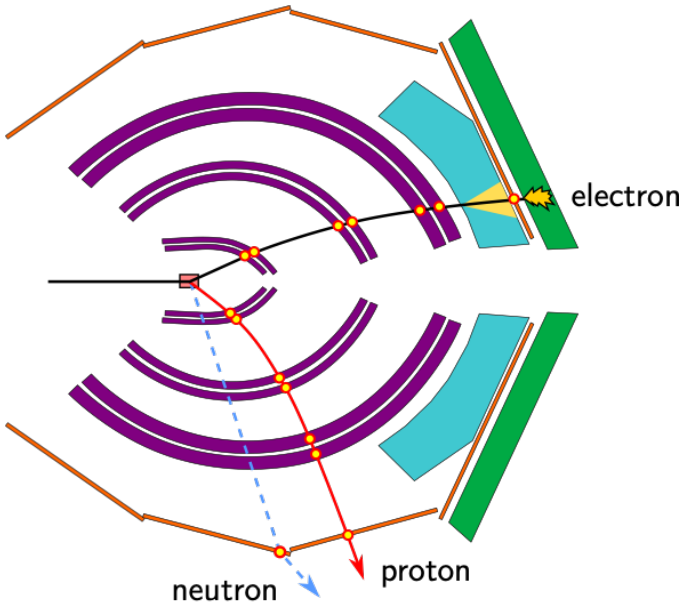
CLAS

Electron Probe:
Anti-Parallel Kinematics



GlueX

Real Photon Probe:
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