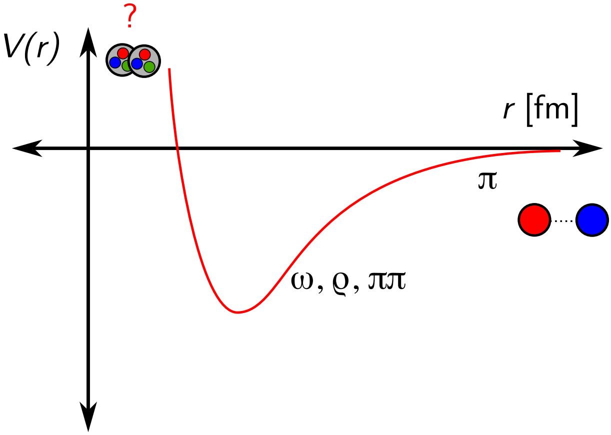
NN Core Studies in $A(e, e'NN)$

Axel Schmidt

2021 SRC/EMC Workshop

March 22, 2021

My understanding of the *NN* potential



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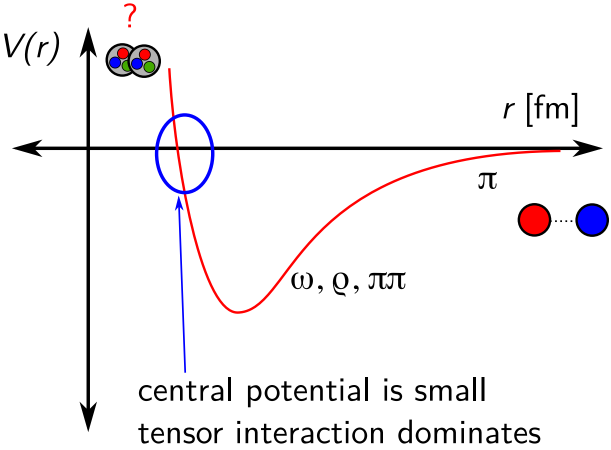
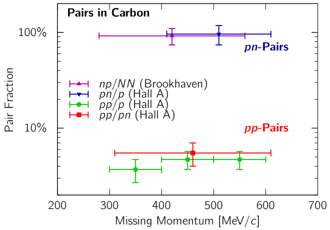
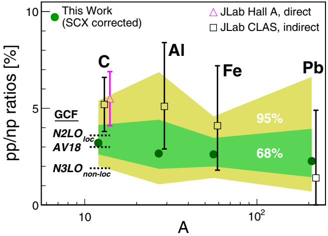


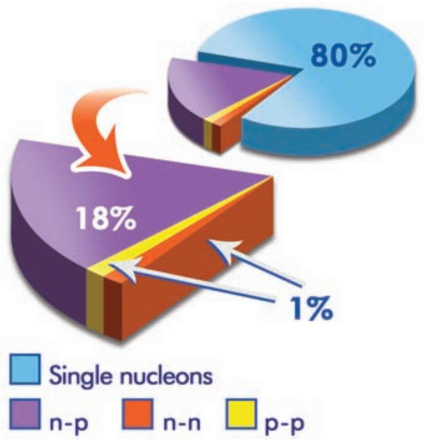
The tensor force causes the predominance of *np* short-range correlations.

Subedi et al., Science 320 p. 1476 (2008)

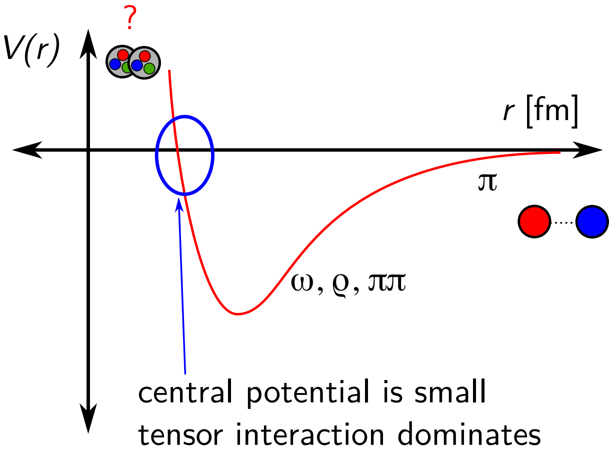


Duer et al., PRL 122, 172502 (2019)





Does *np*-dominance erode at even shorter distances, higher momenta?



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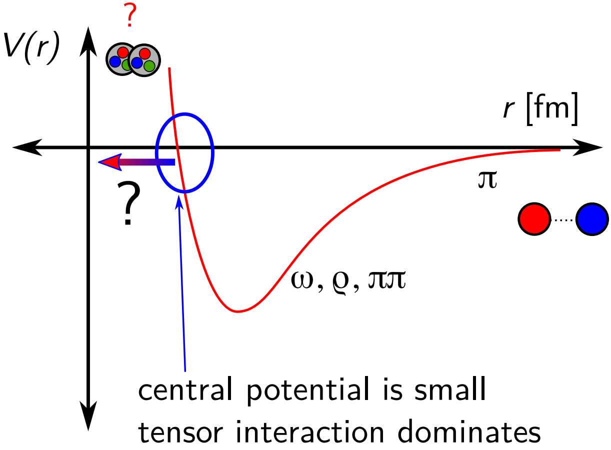
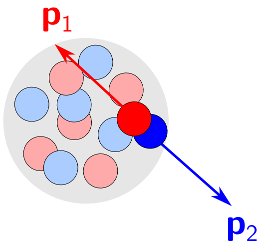


Studying SRC pairs through the $A(e, e'NN)$ reaction



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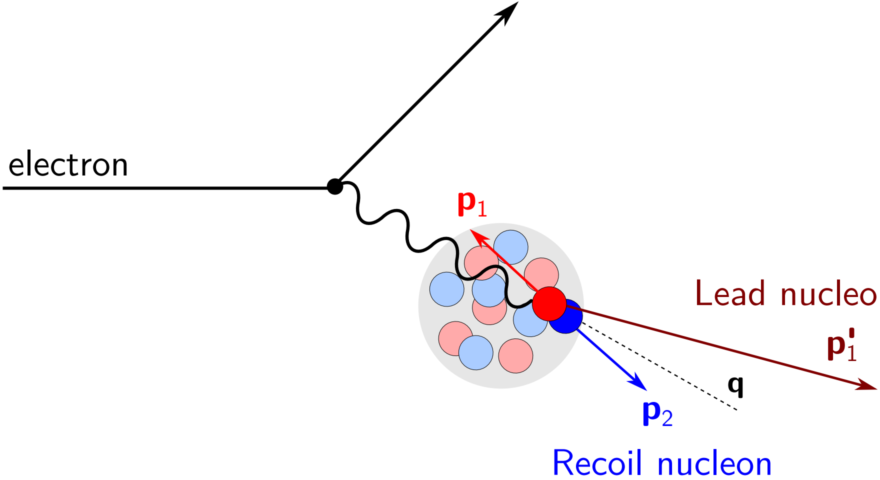

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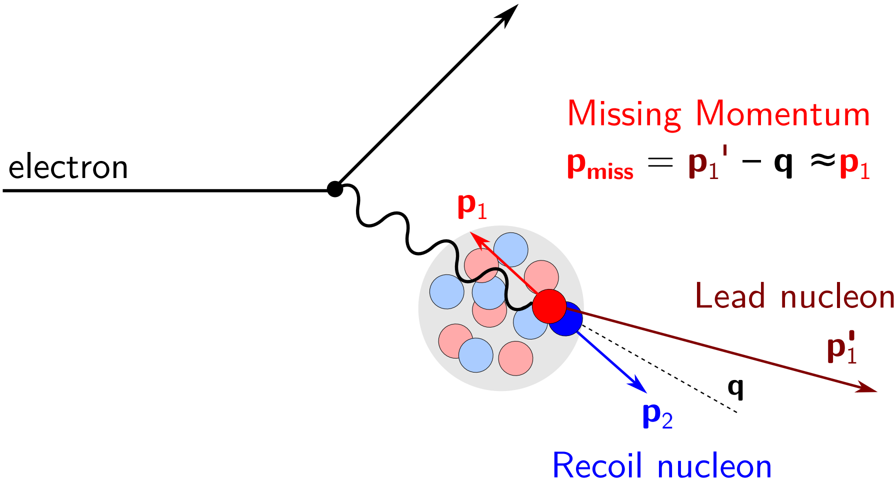

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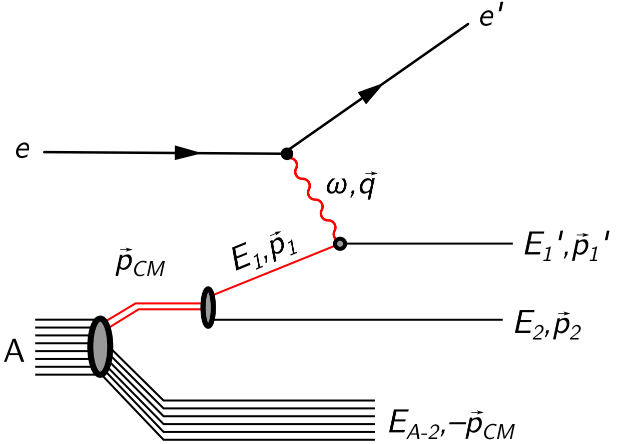


In my talk today:

- **Probing the core of the strong nuclear interaction**
  A. Schmidt et al., Nature 578, pp. 540–544 (2020)
  arXiv:2004.11221 [nucl-ex]

- **Tensor-to-Scalar Transition in the Nucleon-Nucleon Interaction Mapped by $^{12}\mathbf{C}(\mathbf{e},\mathbf{e}'\mathbf{pn})$ Measurements**
  I. Korover et al., under peer review, (2020)
  arXiv:2004.07304 [nucl-ex]

Hard work was done by:

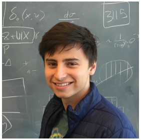
Jackson Pybus

Igor Korover

Efrain Segarra

Ronen Weiss

Adin Hrnjic

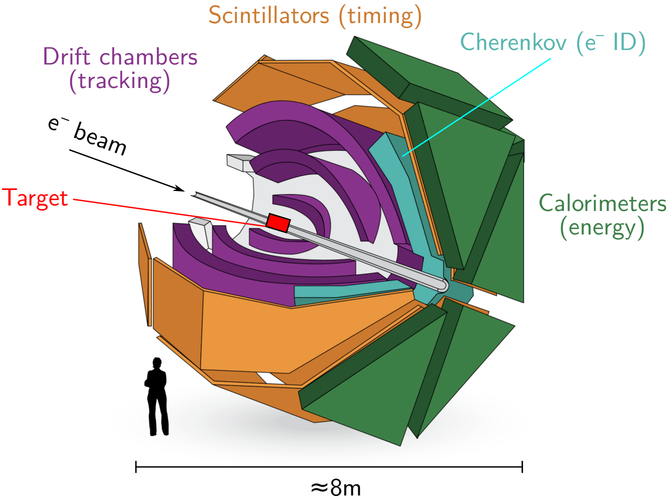


Andrew Denniston

The game-plan:

1. Analyze CLAS data to identify $A(e,e'p)$ and $A(e,e'pN)$ events from the break-up of an SRC pair.
2. Simulate the experiment using Generalized Contact Formalism.
3. Compare results at the event level.

JLab's CLAS Detector (1999–2012) was well-suited for data mining.



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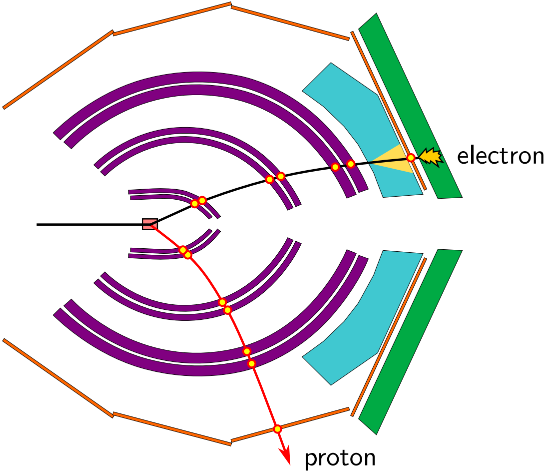
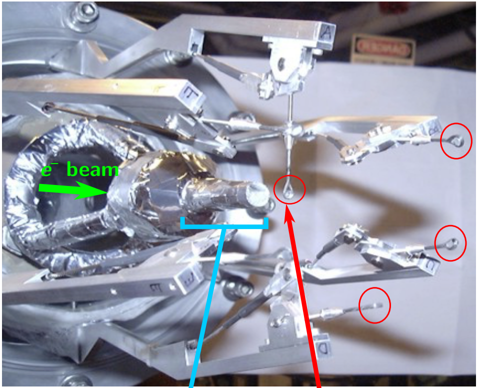


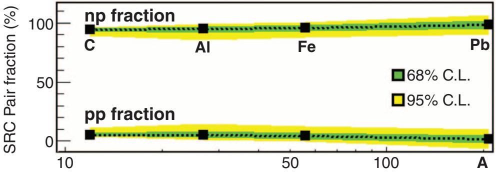
The EG2 Experiment (2004) collected data on multiple nuclear targets.



Liquid d_2 C, Al, Fe, or Pb

Highlights from EG2 Data Mining

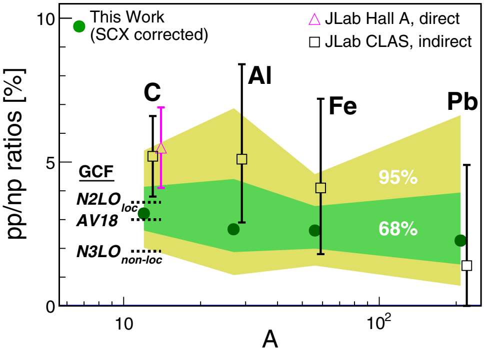
- *np* dominance persists in asymmetric nuclei.



Hen et al., Science 346, p. 614 (2014)

Highlights from EG2 Data Mining

- *np* dominance persists in asymmetric nuclei.
- Direct confirmation through neutron detection



Duer et al., Nature 560, p. 617 (2018)
Duer et al., PRL 122, 172502 (2019)

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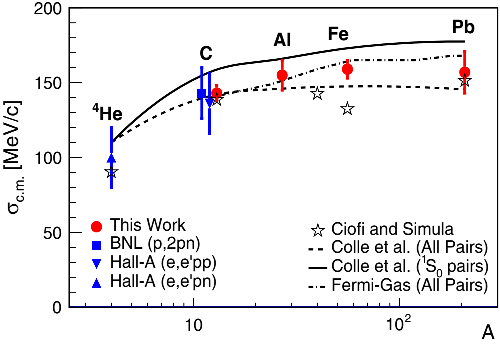
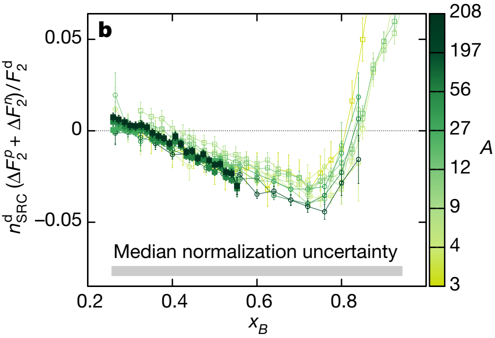


Cohen et al., PRL 121, 092501 (2018)

Highlights from EG2 Data Mining

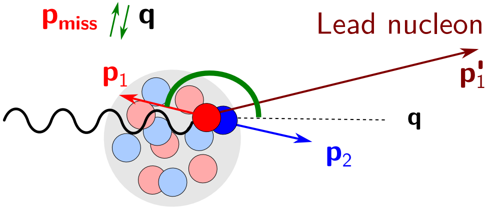
- *np* dominance persists in asymmetric nuclei.
- Direct confirmation through neutron detection
- Center-of-mass motion of *pp* pairs
- Universal modification of SRC pairs



Schmookler et al., Nature 566 p. 354 (2019)

We identify SRC $A(e, e'p)$ events in anti-parallel kinematics.

Missing Momentum



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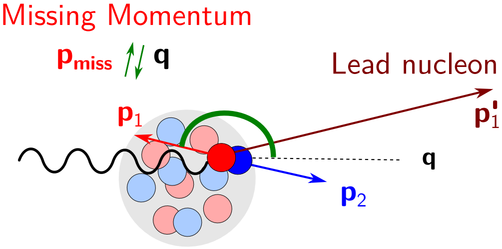

- Reduces inelastic contamination
- Simplifies final-state rescattering
  - Transparency factor

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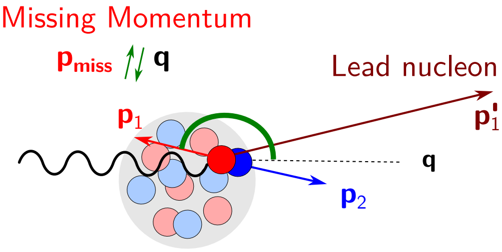

Event Selection

- $300 < p_{\text{miss}} < 1000$ MeV

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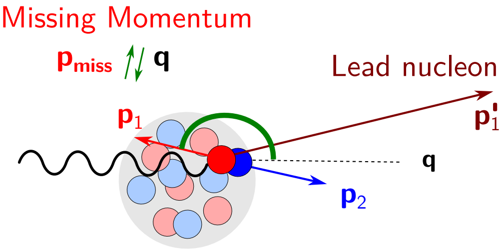

- Reduces inelastic contamination
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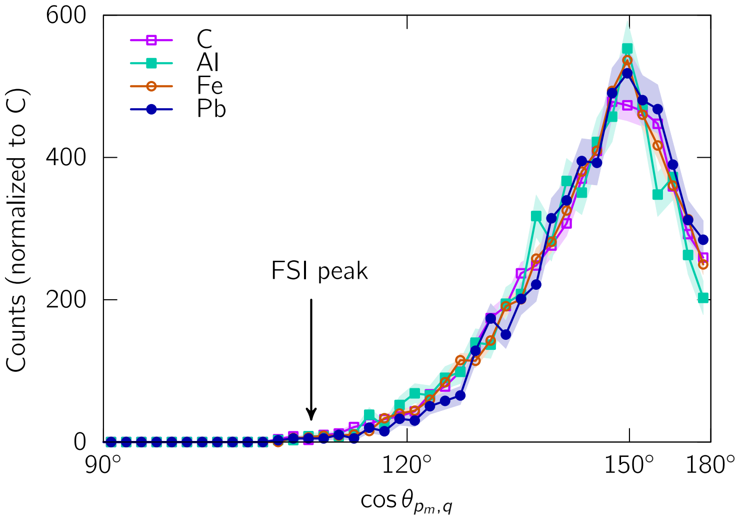
  - Transparency factor

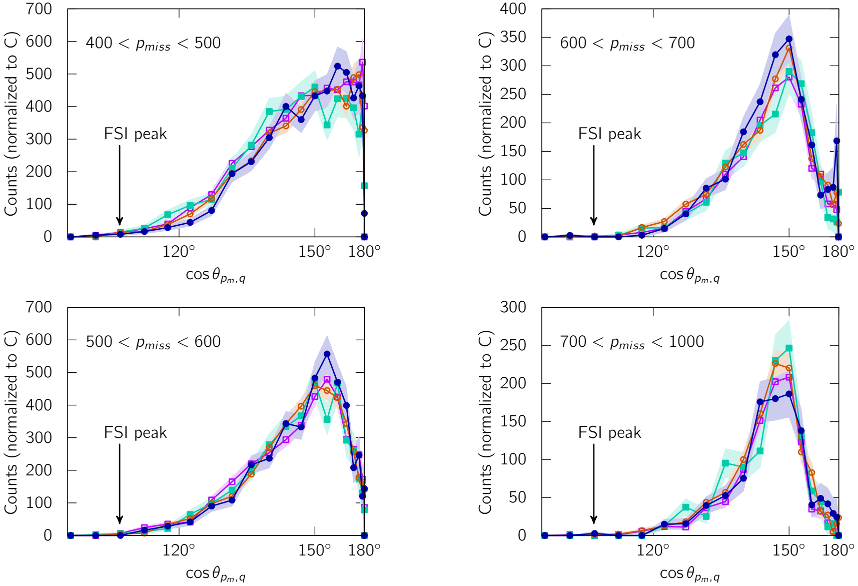
Event Selection

- $300 < p_{\text{miss}} < 1000$ MeV
- $x_B > 1.2$
- $0.62 < |p'_1|/|q| < 0.96$
- $\theta_{p'_1 q} < 25^\circ$
- $M_{\text{miss}} < 1.1$ GeV

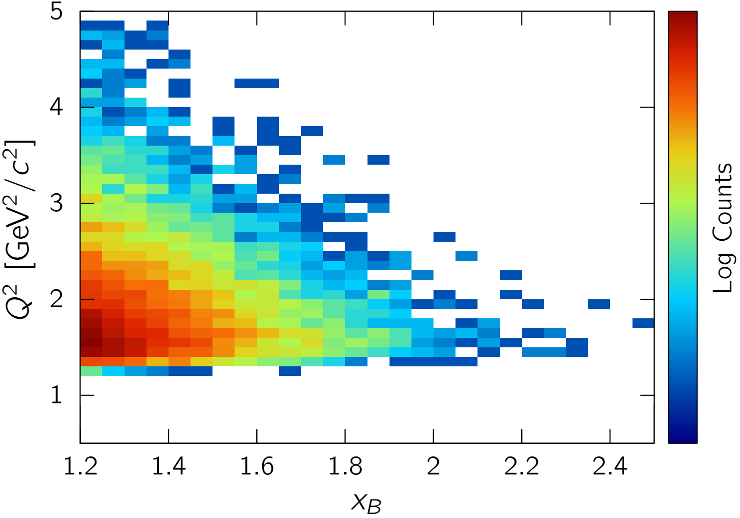
No evidence of excess due to rescattering



No sign of rescattering over entire p_{miss} range.



Selected $C(e, e'p)$ Events



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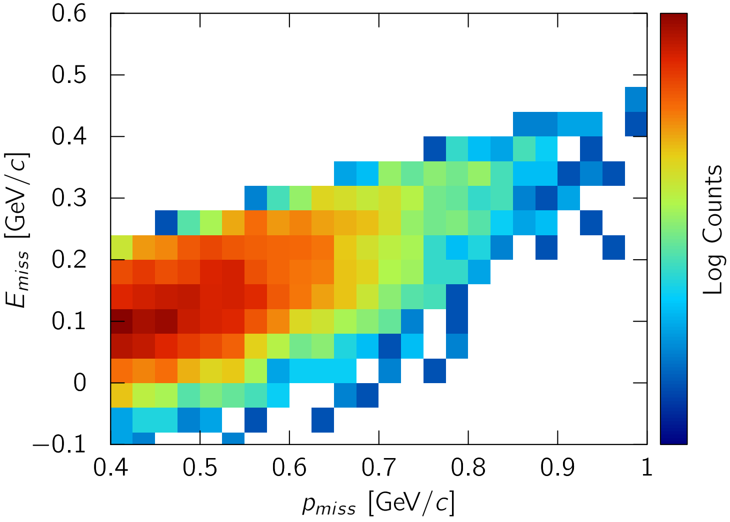

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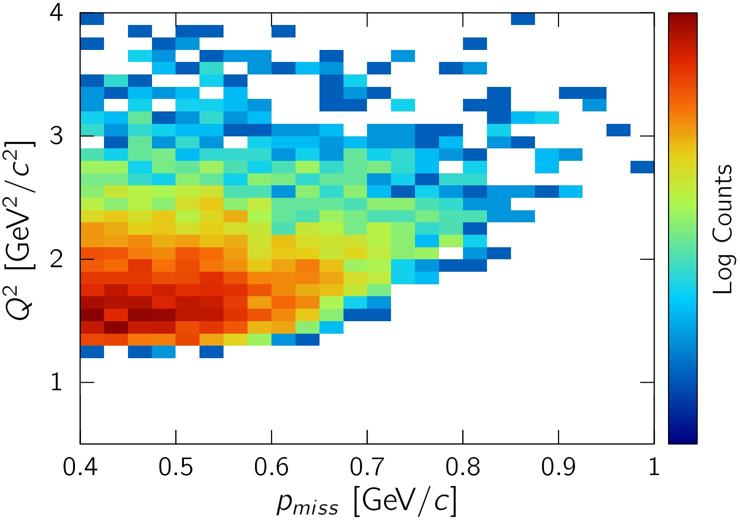
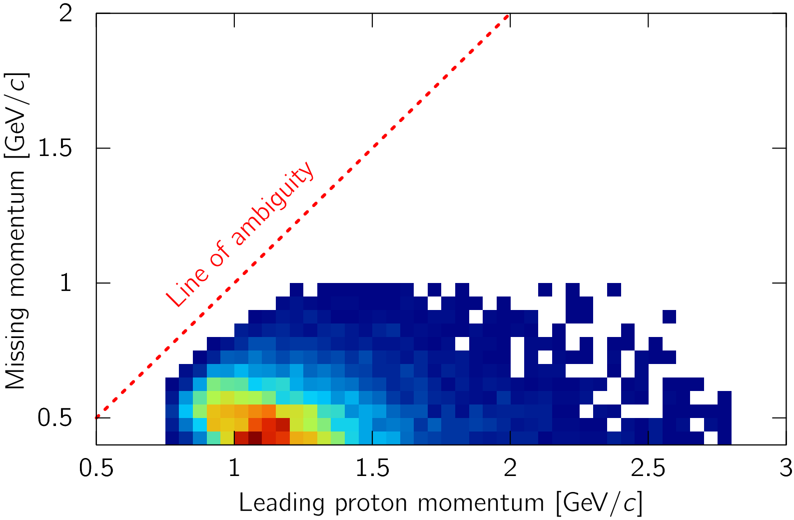
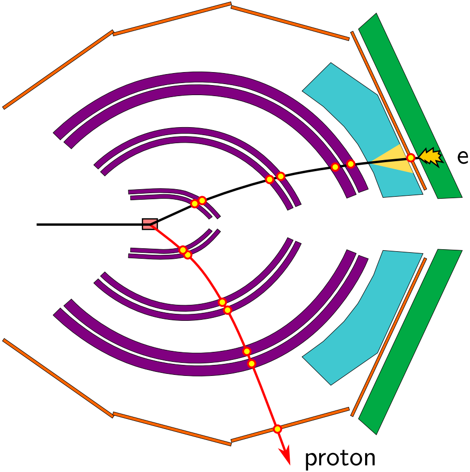


Leading and recoil protons are distinct.



Detecting a recoil proton confirms we broke up *pp*-SRC pair.



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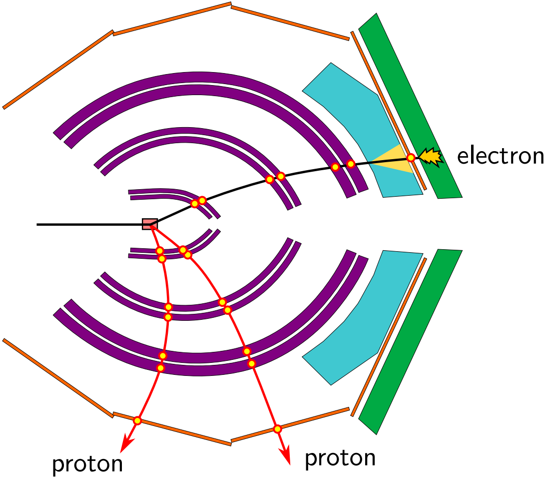

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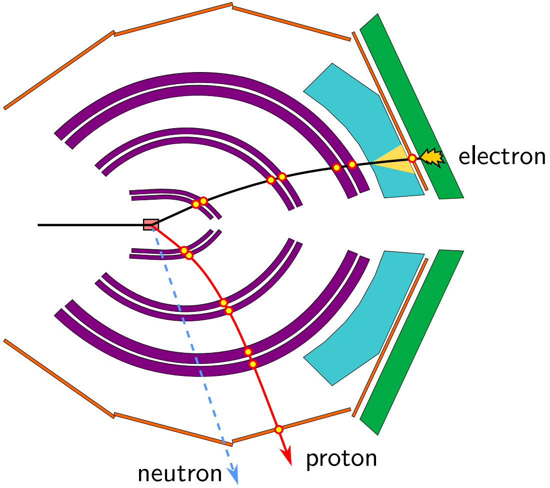

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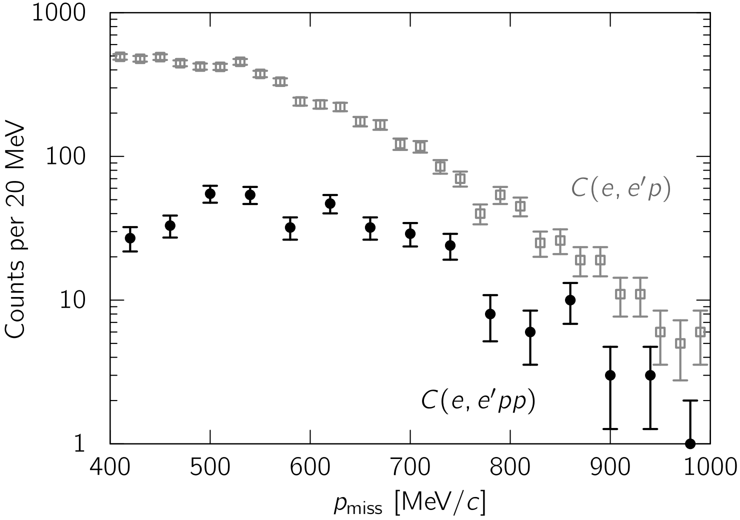

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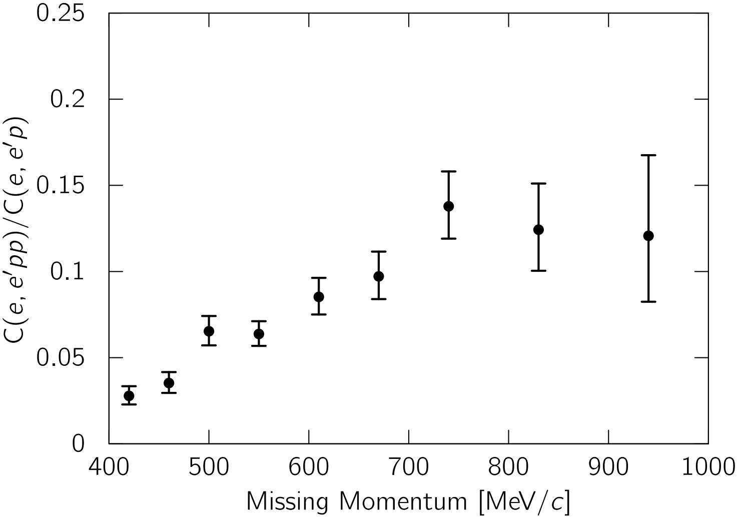
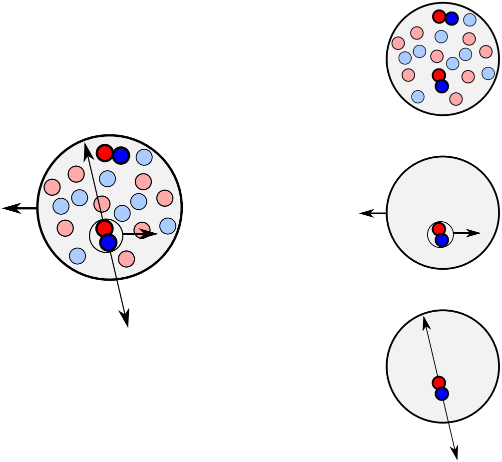


Generalized contact formalism factorizes SRCs from the nucleus.



Pair abundances

Pair CM motion

Pair relative motion

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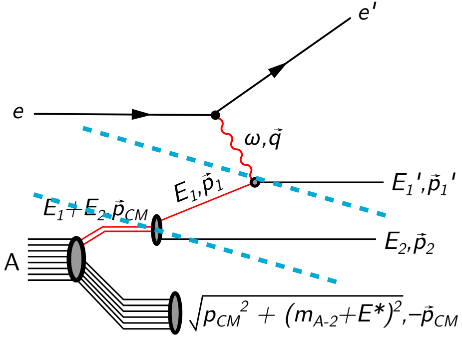

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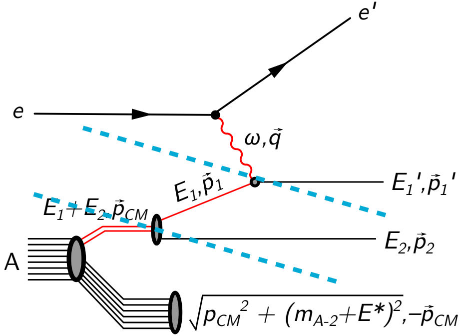

$$d\sigma \sim \sigma_{eN} \cdot \sum_{\alpha} C_{\alpha} \cdot P_{\alpha}(k_{\text{cm}}) \cdot |\tilde{\phi}(k_{\text{rel.}})|^2$$

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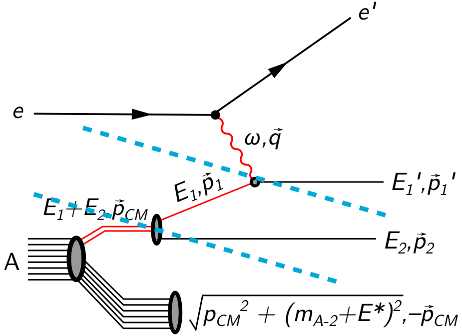

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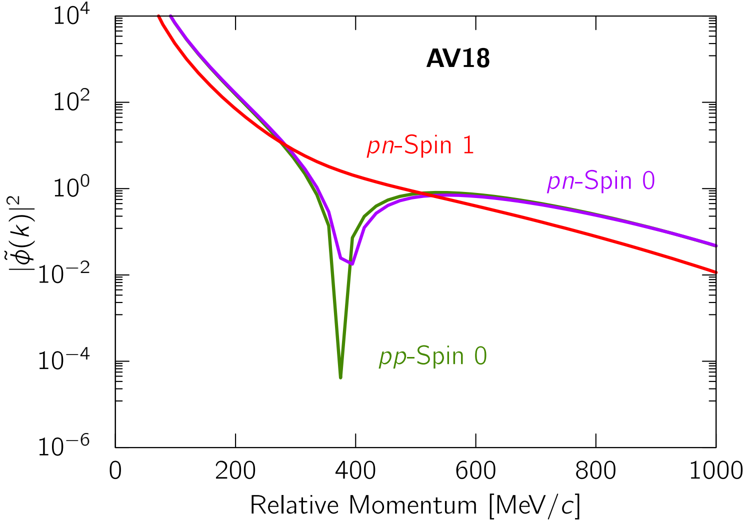

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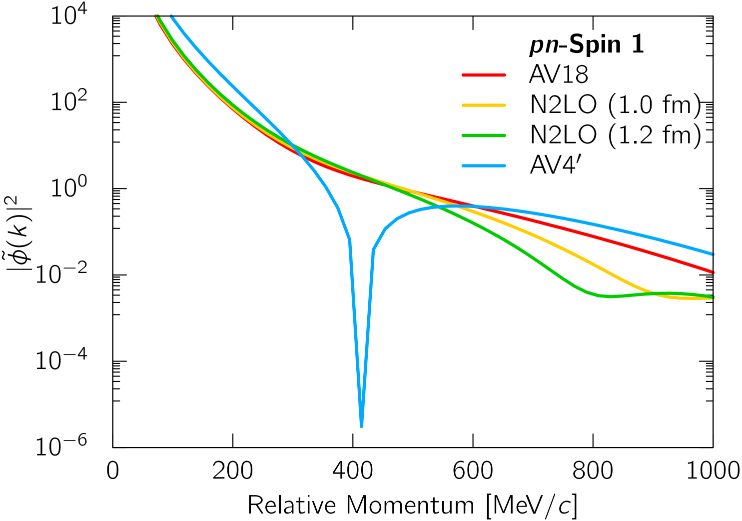
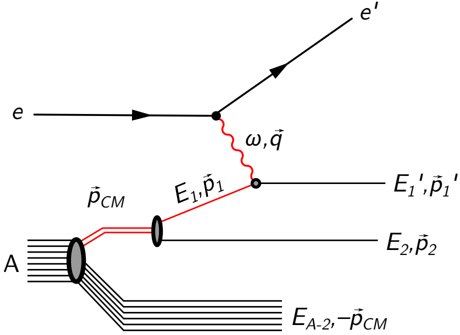


We use GCF to simulate the experiment for direct comparison with data.

1. Generate events using GCF



We use GCF to simulate the experiment for direct comparison with data.

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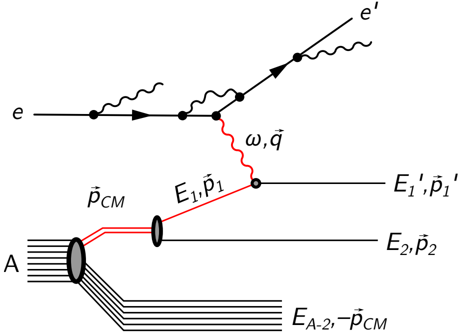
2. Model radiative effects



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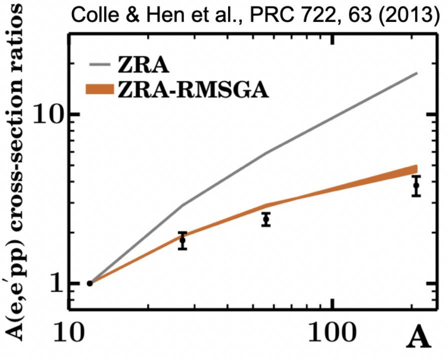
1. Generate events using GCF
2. Model radiative effects
3. Model FSI effects with Glauber as SCX + transparency

Colle & Hen et al., PRC 722, 63 (2013)



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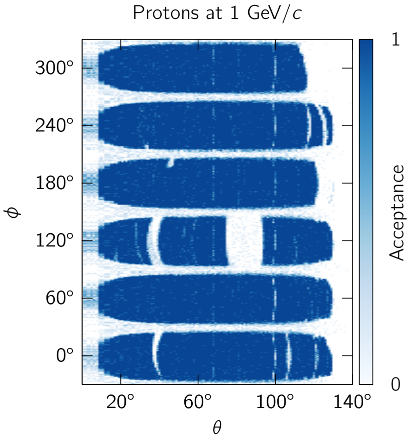
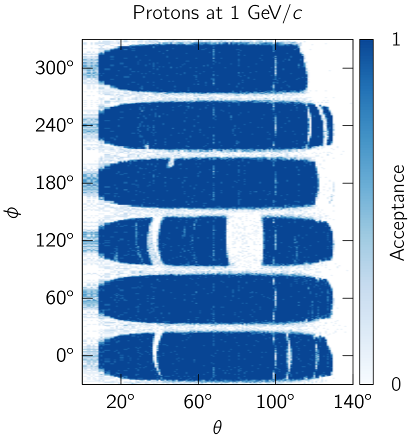
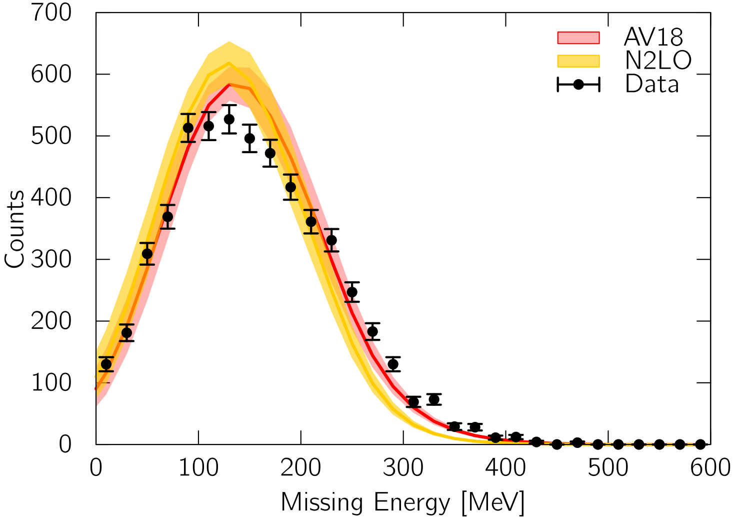


We use GCF to simulate the experiment for direct comparison with data.

1. Generate events using GCF
2. Model radiative effects
3. Model FSI effects with Glauber as SCX + transparency
4. CLAS detector acceptance
5. Same event selection criteria



GCF describes kinematic distributions extremely well.



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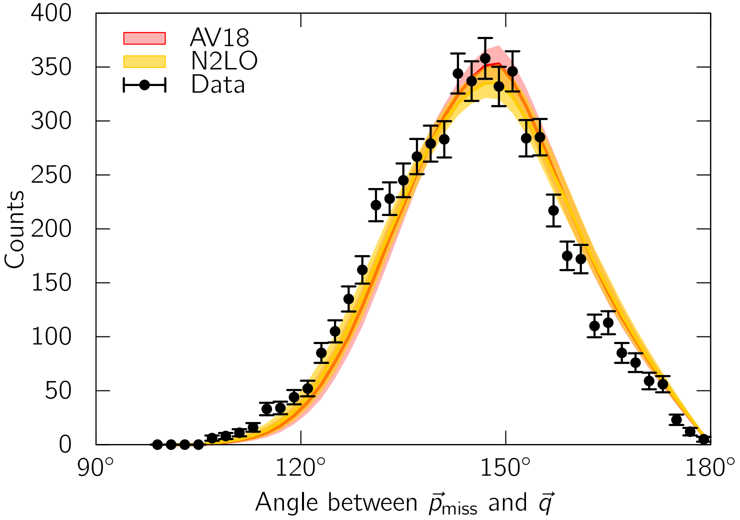
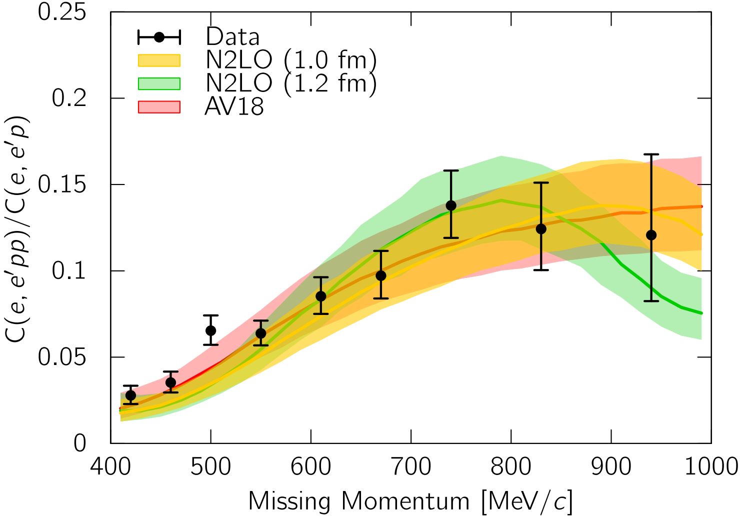


The C$(e, e'pp)$/C$(e, e'p)$ ratio shows a tensor-to-scalar transition.



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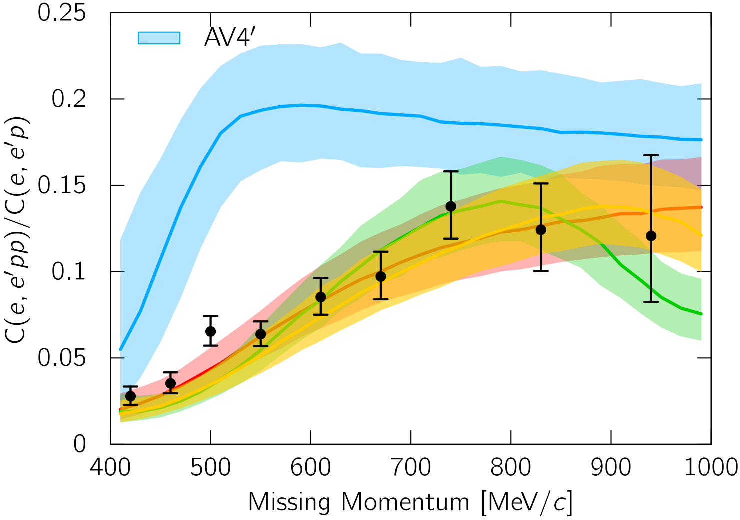

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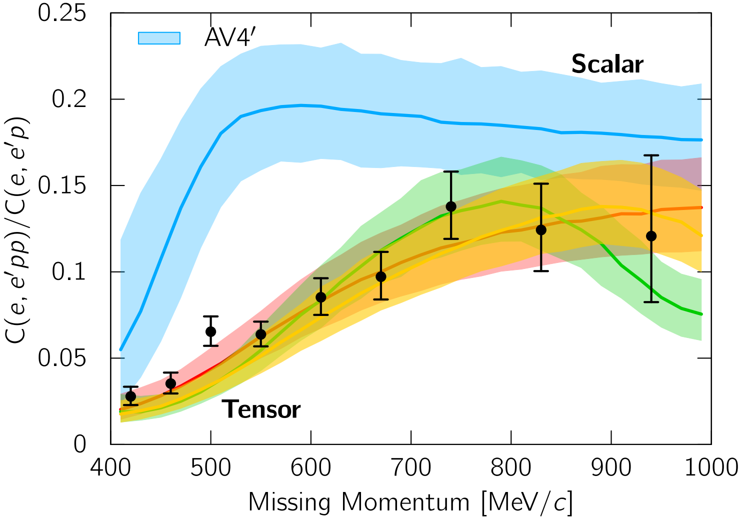
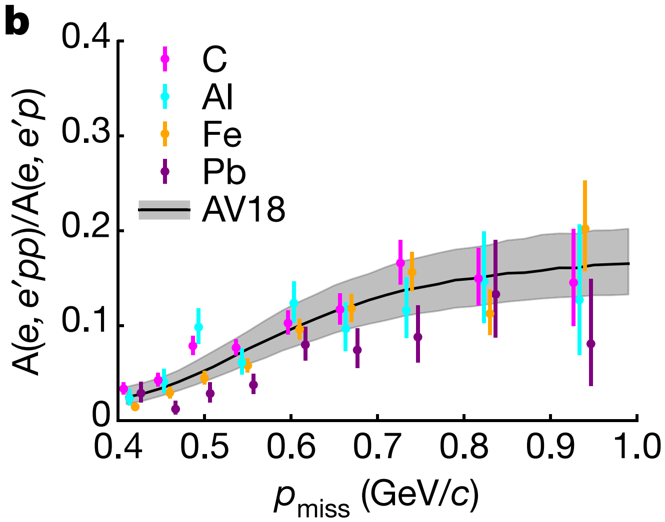
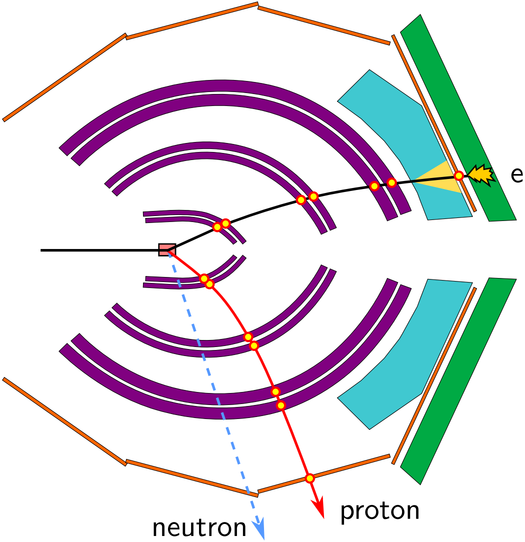


Heavier nuclei show the same transition.



We've identified neutron candidate hits in the CLAS ToF scintillators.



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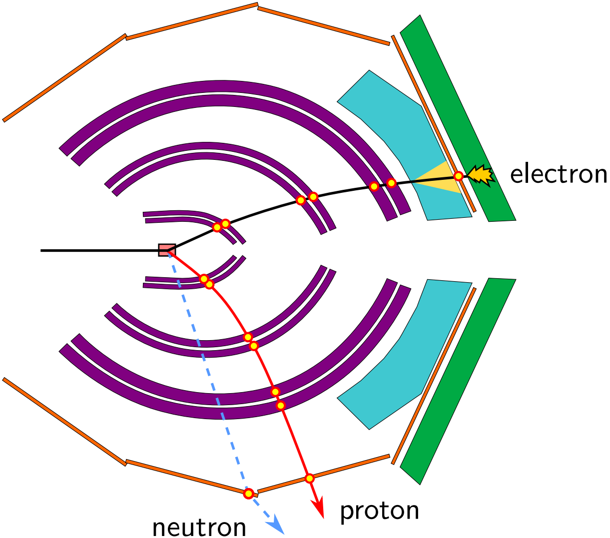
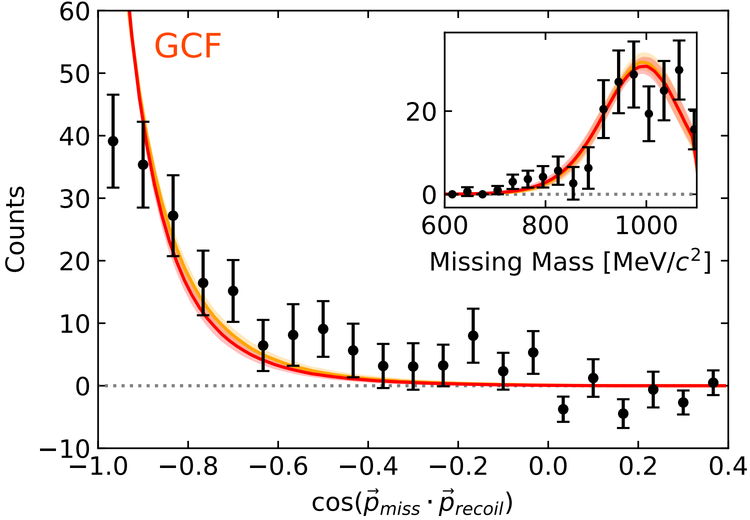
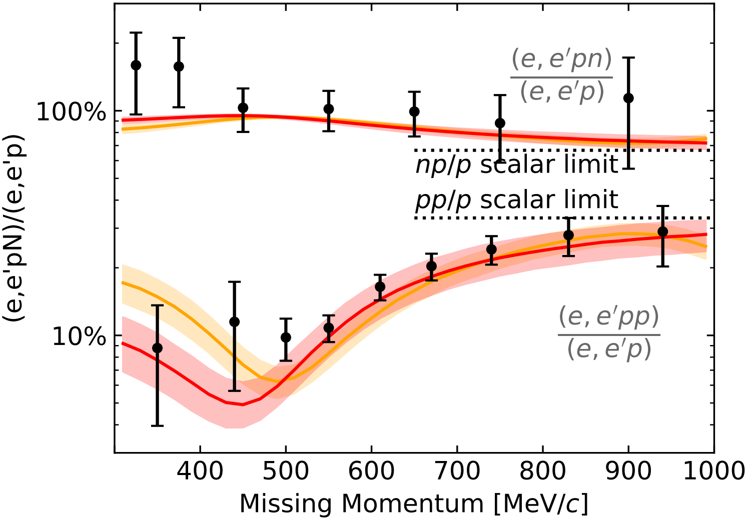


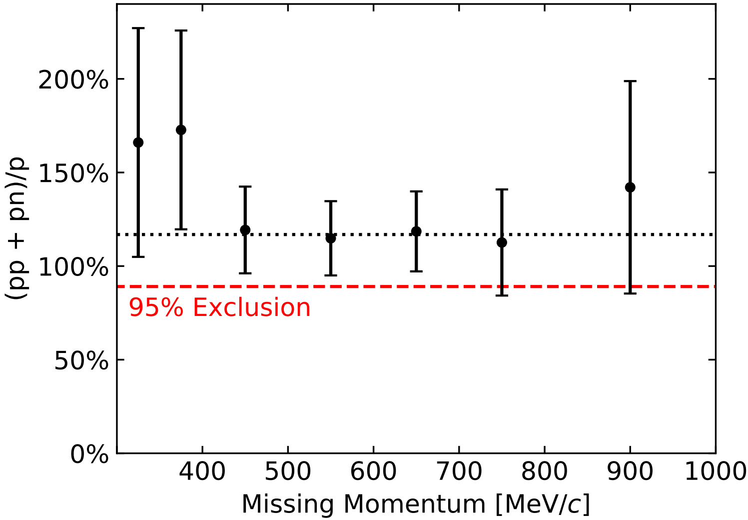
GCF describes neutron kinematic distributions as well.



Direct detection of recoil neutrons confirms the tensor-to-scalar transition.

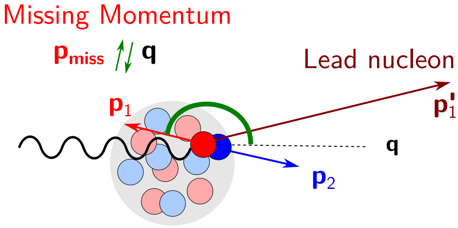


All high-momentum protons are correlated.



Summary

- SRC pairs tell us about the isospin structure of the *NN* interaction.



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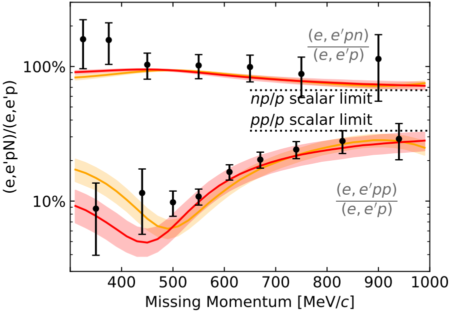
- We observe a tensor-to-scalar transition from 400–1000 MeV/c.



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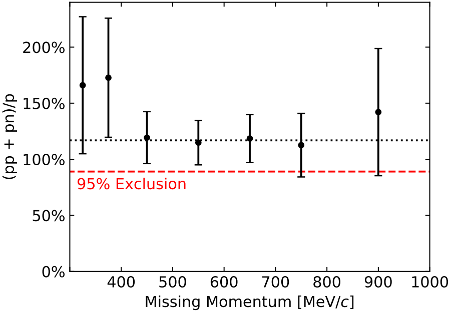

Outlook

- Benchmarking against FSI models

  See talk by Natalie Wright!

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- Extending this analysis to infer pairing properties in heavier nuclei

Outlook

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- Factor of 10–100$\times$ statistics on many nuclei coming 2021
  CLAS12 Run Group M

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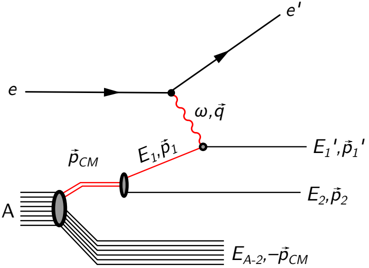
- Also in 2021: Nuclear target experiment with real photons.

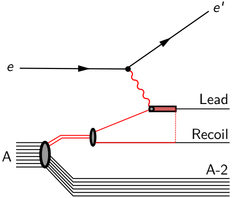
BACK-UP SLIDES

We've selected events to minimize competing reactions.

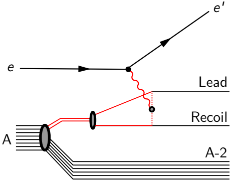
Plane-Wave



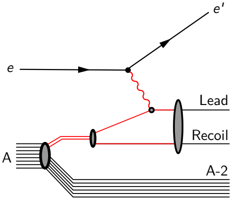
Isobar Config.



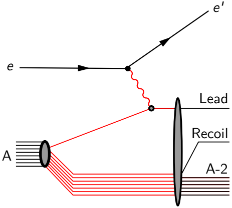
Meson-exchange curr.



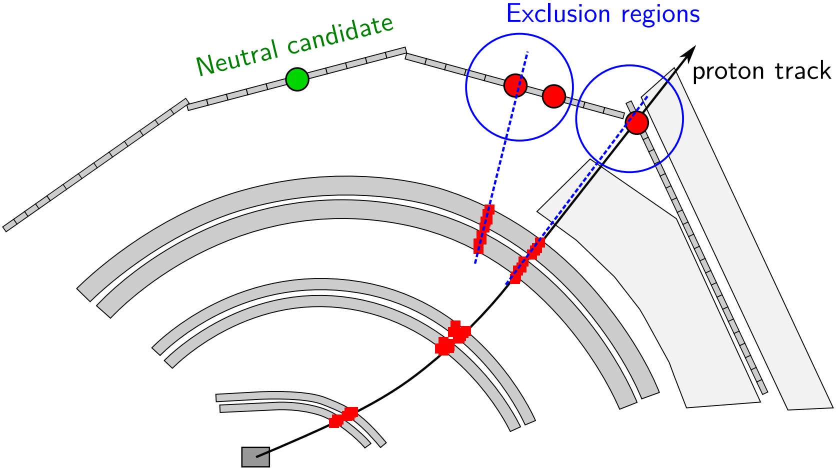
FSI within pair



FSI with nucleus



Neutral Particle Veto



Neutron time-of-flight