Experiment and Physics Overview

Axel Schmidt

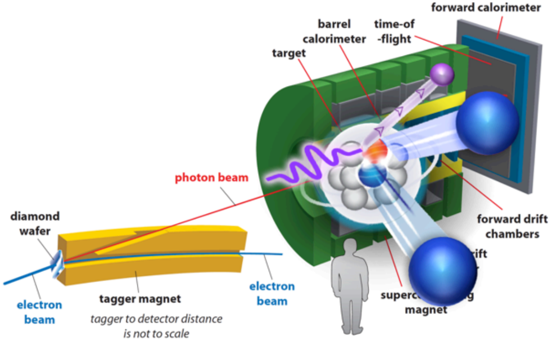
ERR: E12-19-003

May 7, 2020

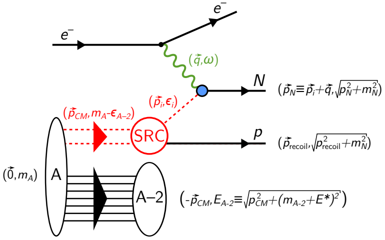
E12-19-003: Studying Short-Range Correlations with Real Photon Beams at GlueX

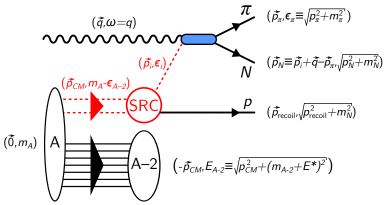
Spokespersons

- Or Hen (MIT)
- Eli Piazetsky (Tel Aviv)
- Maria Patsyuk (JINR)
- Axel Schmidt (GW)
- Alexander Somov (JLab)
- Lawrence Weinstein (ODU)



This experiment tests foundational assumptions about short-range correlations.





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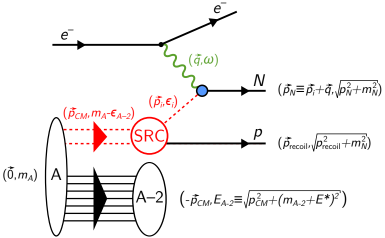
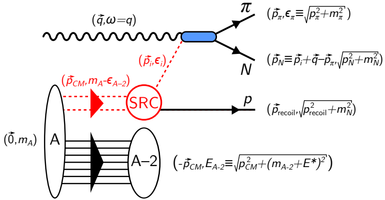
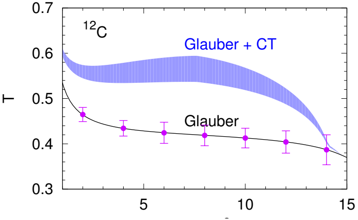


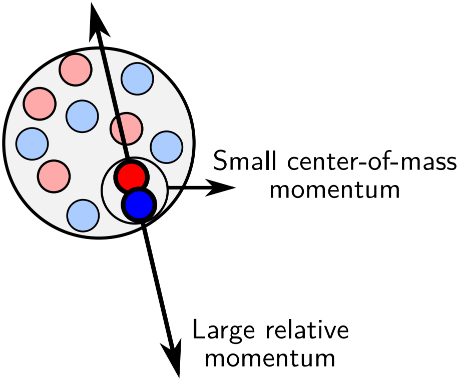


And lots of other physics too!

- Charged probes of neutrons
- Color Transparency
- BR Modification
- Photon structure



Short-range correlated (SRC) nucleons are found in all nuclei.



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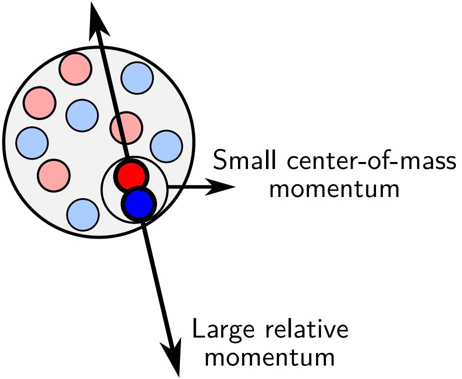

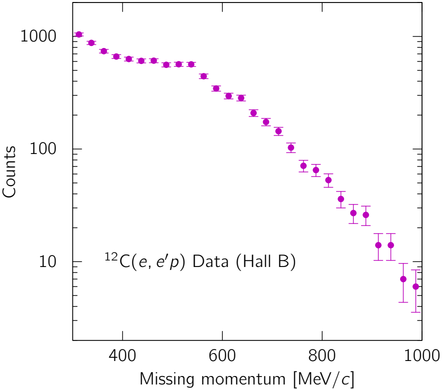

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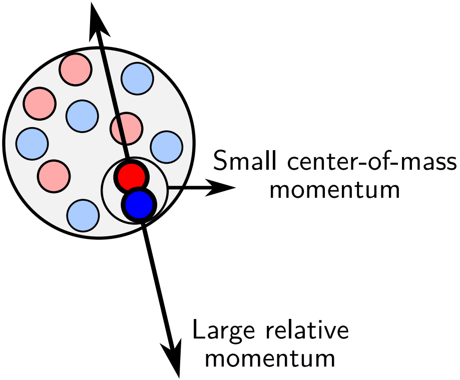
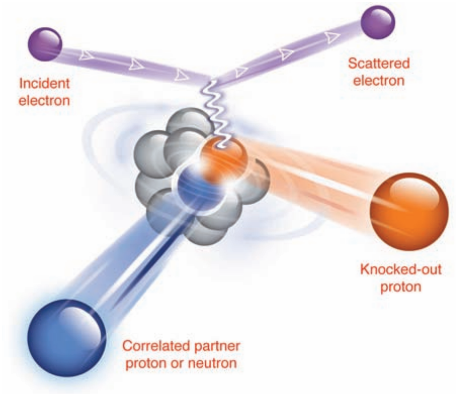
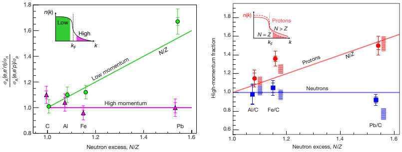


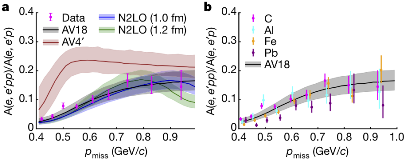


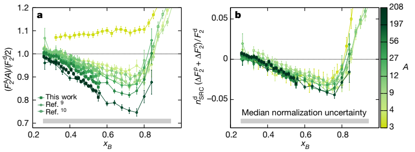
e^- scattering at Jefferson Lab has led to high-impact discoveries.

- Shneor et al., PRL 99, 072501 (2007)
- Subedi et al., Science 320, 1476 (2008)
- Hen et al., PLB 722, 63 (2013)
- Korover et al., PRL 113, 022501 (2014)
- Hen et al., Science 346, 614 (2014)
- Duer et al., Nature 560, 617 (2018)
- Cohen et al., PRL 121, 092501 (2018)
- Duer et al., PRL 122, 172502 (2019)
- Schmookler et al., Nature 566, 354 (2019)
- Duer et al., PLB 797, 134792 (2019)
- Cruz-Torres et al., PLB 797, 134890 (2019)
- Schmidt et al., Nature 578, 541 (2020)

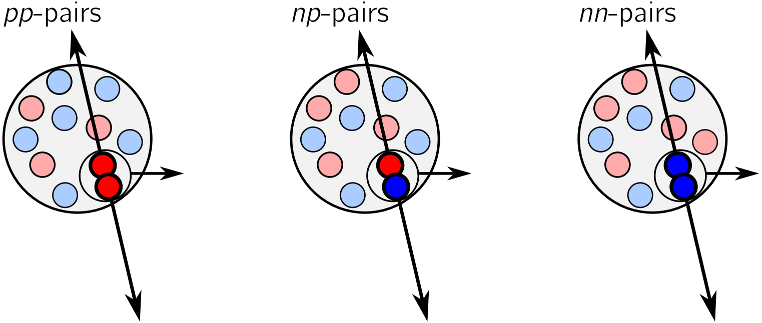
. . . and others!







Neutron-proton pairing dominates, even in asymmetric nuclei.



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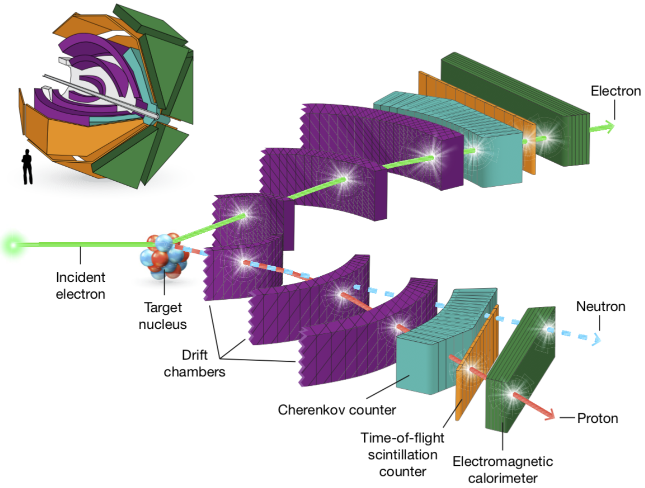

M. Duer et al, Nature 560 pp. 617–621 (2018)

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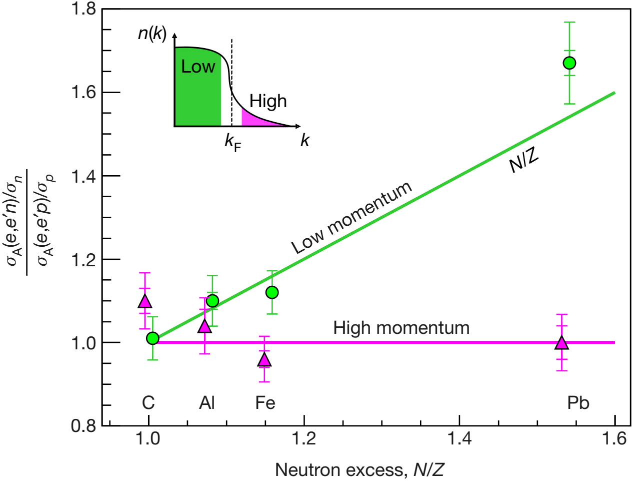

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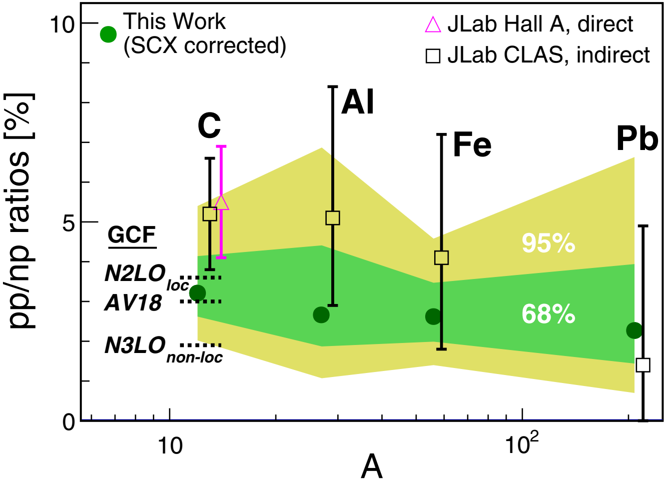
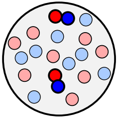
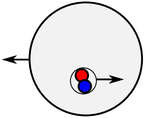


M. Duer et al, PRL 122, 172502 (2019)

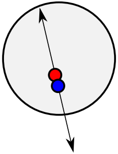
We can understand short-distance structure using scale separation.



Pair abundances



Pair CM motion



Pair relative motion

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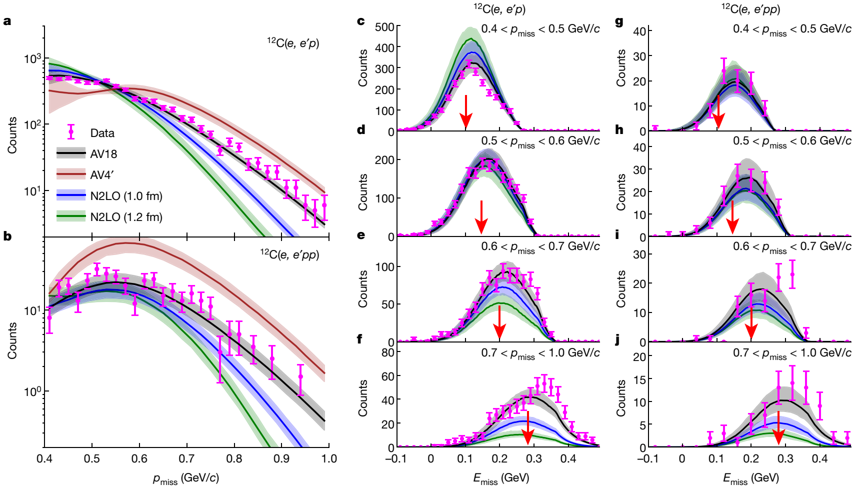

A. Schmidt et al, Nature 578 pp. 540–544 (2020)

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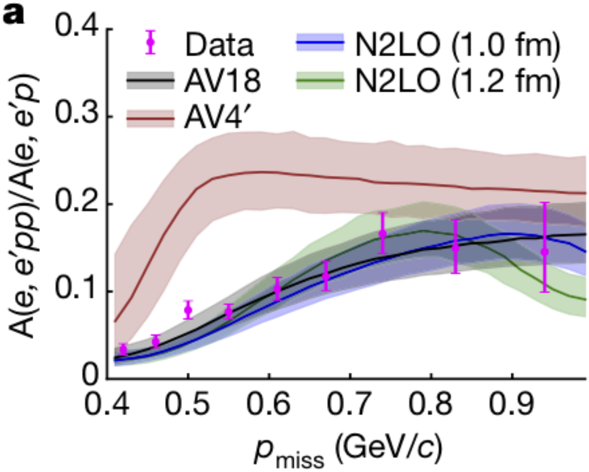

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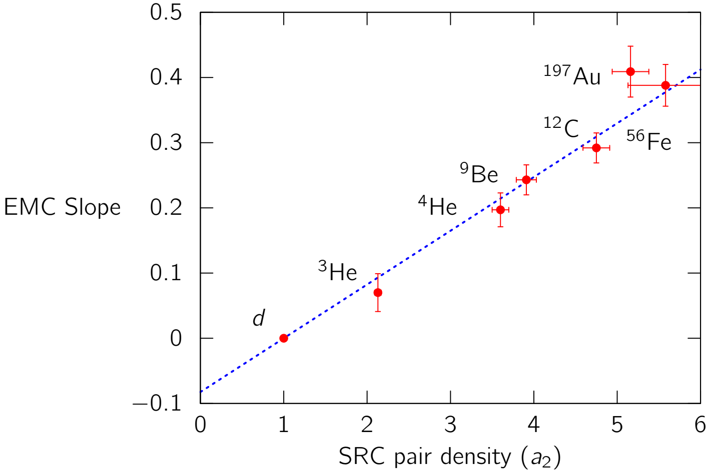
We have uncovered a connection between the EMC Effect and SRC nucleons.



Adapted from Hen et al., PRC 85, 047301 (2012)

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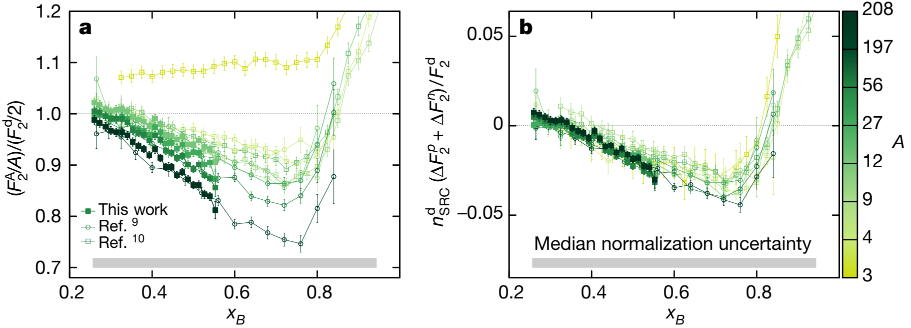
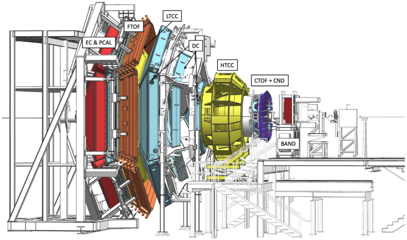


Schmookler et al., Nature 566 pp. 354–358 (2019)

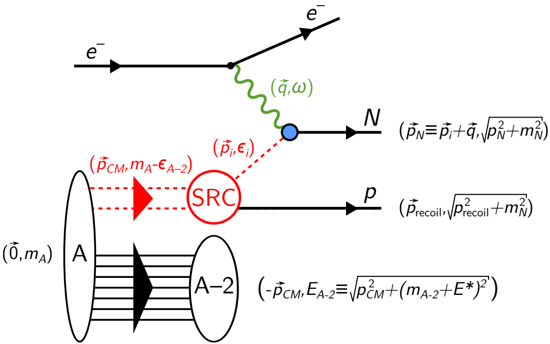
E12-17-006A: A new high-statistics campaign to study SRCs with CLAS-12

- 45 days, 'A'-rating from PAC 46
- CLAS-12 Run Group M
- 10 nuclei, multiple beam energies
- Size and asymmetry dependence
- 10×–100× statistics from 6 GeV Era



The e^--scattering program is built on a set of common assumptions.

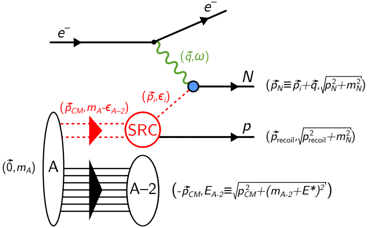
- Scale separation
- Relativistic effects
- Reaction mechanisms
- Final state interactions



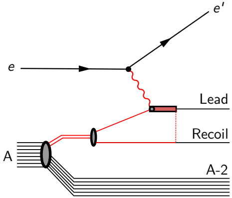
R. Weiss et al., PLB 791 pp. 242–248 (2019)
A. Schmidt et al., Nature 578 pp. 540–544 (2020)
J. R. Pybus et al., PLB 805 135429 (2020)
and others. . .

These assumptions need to be proven.

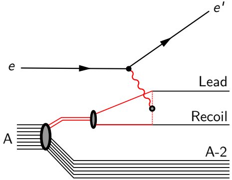
Plane-Wave



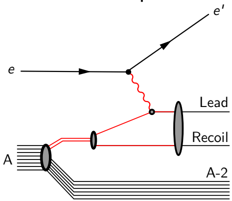
Isobar Config.



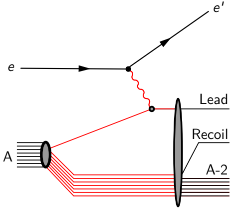
Meson-exchange curr.



FSI within pair



FSI with nucleus



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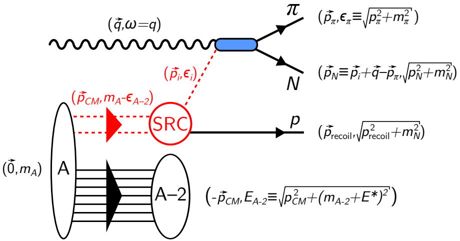

- Scale separation

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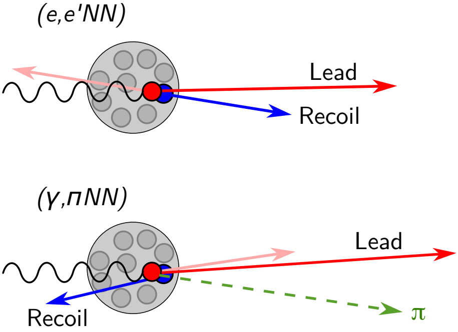
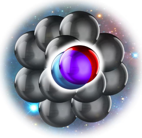


- Scale separation
- Reaction mechanisms
    - Final state interactions
    - Meson-exchange currents
    - Relativitistic effects

There's lots of other photon-nucleus physics too!

- Branching ratio modification

$$|p\rangle_{\text{free}} = \alpha_{PLC}|PLC\rangle + \alpha_{3qg}|3q+g\rangle + \alpha_{3q\pi}|3q+\pi\rangle + \ldots$$

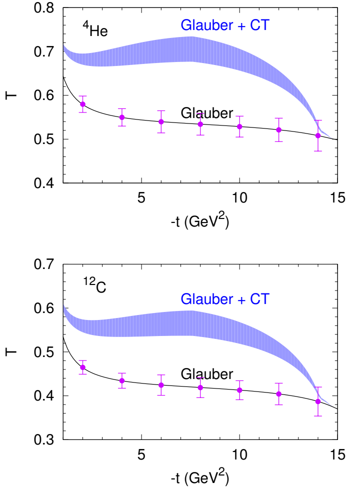


$$|p\rangle_{\text{bound}} = \alpha_{PLC}^{bound}|PLC\rangle + \alpha_{3qg}^{bound}|3q+g\rangle + \alpha_{3q\pi}^{bound}|3q+\pi\rangle + \ldots$$

There's lots of other photon-nucleus physics too!

$$T \equiv \sigma(\gamma A \to \pi^- p)/\sigma(\gamma d \to \pi^- p)$$

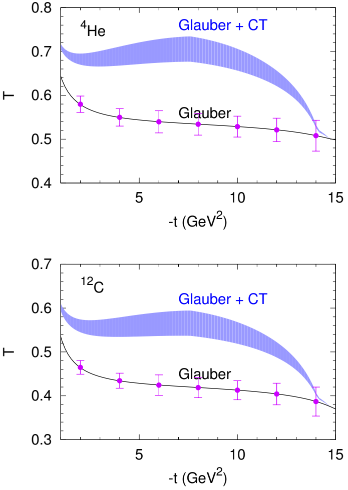
- Branching ratio modification
- Probing color transparency



There's lots of other photon-nucleus physics too!

$$T \equiv \sigma(\gamma A \to \pi^- p)/\sigma(\gamma d \to \pi^- p)$$

- Branching ratio modification
- Probing color transparency
- Probing neutrons via charged final states
- Photon structure
- ...



The plan for this experiment:

- Nuclear targets
- GlueX detector in standard configuration
- Measure many photo-production channels on SRC nucleons

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

- Extract cross-section ratios
  - C/d
  - Channel 1 / Channel 2
  - Double ratios

Road to first publication

Testing SRC Scaling and Abundances with Photon Probes

$$\sigma_A(\gamma n \to p\pi^-)/\sigma_D(\gamma n \to p\pi^-)$$

dependence on t, missing momentum.

- First publication based on simplest observable
- Fully-charged final state
- Clear theory predictions

- *First publication anticipated within 1 year*

Our 12 GeV track record

Hall A Tritium Program

- April 12–30, 2018
  Data Taking

Our 12 GeV track record

Hall A Tritium Program

- April 12–30, 2018
  Data Taking
- Feb. 18, 2019
  arXiv:1902.06358

ELSEVIER

Physics Letters B
Volume 797, 10 October 2019, 134890

Comparing proton momentum distributions in A=2 and 3 nuclei via ^{2}H ^{3}H and ^{3}He $(e,e'p)$ measurements

Jefferson Lab Hall A Tritium Collaboration

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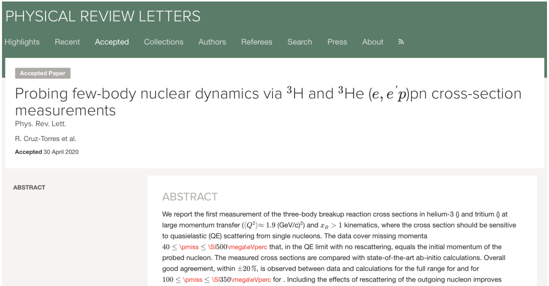
Abstract

We report the first measurement of the $(e,e'p)$ reaction cross-section ratios for Helium-3 (^{3}He), Tritium (^{3}H), and Deuterium (d). The measurement covered a missing momentum range of $40 \le p_{miss} \le 550$ MeV/c, at large momentum transfer ($\langle Q^2 \rangle \approx 1.9$ (GeV/c)^2) and $x_B > 1$, which minimized contributions from non quasi-elastic (QE) reaction mechanisms. The data is

Our 12 GeV track record

Hall A Tritium Program

- April 12–30, 2018
  Data Taking
- Feb. 18, 2019
  arXiv:1902.06358
- Jan. 20, 2020
  arXiv:2001.07230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Accepted Paper

Probing few-body nuclear dynamics via ^{3}H and ^{3}He $(e, e'p)$pn cross-section measurements

Phys. Rev. Lett.

R. Cruz-Torres et al.

Accepted 30 April 2020

ABSTRACT

ABSTRACT

We report the first measurement of the three-body breakup reaction cross sections in helium-3 () and tritium () at large momentum transfer ($\langle Q^2 \rangle \approx 1.9$ (GeV/c)^2) and $x_B > 1$ kinematics, where the cross section should be sensitive to quasielastic (QE) scattering from single nucleons. The data cover missing momenta $40 \le$ \pmiss $\le$ \SI$500$\mega\eVperc that, in the QE limit with no rescattering, equals the initial momentum of the probed nucleon. The measured cross sections are compared with state-of-the-art ab-initio calculations. Overall good agreement, within $\pm 20\%$, is observed between data and calculations for the full range for and for $100 \le$ \pmiss $\le$ \SI$350$\mega\eVperc for . Including the effects of rescattering of the outgoing nucleon improves

Collaboration

- Moskov Amaryan
- Arshak Asaturyan
- Adi Ashkenazi
- Alexander Austregesilo
- Arie Beck
- Vladimir Berdnikov
- Tim Black
- William Briscoe
- Thomas Britton
- Will Brooks
- Eugene Chudakov
- Olga Cortes
- Reynier Cruz-Torres
- Mark Dalton
- Andrew Denniston
- Alexandre Deur
- Sean Dobbs
- Hovanes Egiyan
- Paul Eugenio
- Cristiano Fanelli
- Stuart Fegan
- Caleb Fogler
- Sergey Furletov
- Liping Gan
- Lei Guo
- Florian Hauenstein
- Hayk Haykobyan
- Or Hen
- Douglas Higinbotham
- David Ireland
- Mark Ito
- Igal Jaegle
- Goran Johansson

Collaboration continued. . .

- Richard Jones
- Mahmoud Kamel
- Igor Korover
- Sergey Kuleshov
- Tyler Kutz
- Iliya Larin
- David Lawrence
- Ken Livingston
- David Mack
- Mike McCaughan
- Bryan McKinnon
- Sharon May-Tal Beck
- Keigo Mizutani
- Frank Nerline
- Dien Nguyen
- Afroditi Papadopoulou
- Zisis Papandreou
- Maria Patsyuk
- Peter Pauli
- Ron Pedroni
- Lubomir Pentchev
- Eli Piasetzky
- Jackson Pybus
- Sara Ratliff
- Dmitry Romanov
- Christian Romera
- Carlos Salgado
- Axel Schmidt
- Barak Schmookler
- Efrain Segarra
- Phoebe Sharpe
- Elton Smith

Collaboration continued...

- Sergey Somov
- Alexander Somov
- Igor Strakovski
- Noah Swan
- Holly Szumila-Vance
- Simon Taylor
- Annika Thiel
- Lawrence Weinstein
- Beni Zihlmann

Partial list...

Experiment Readiness Review

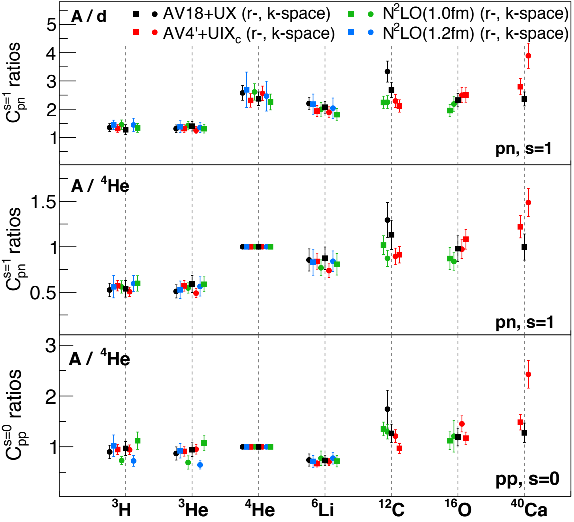
- Run plan, conditions, configuration — H. Szumila-Vance
  - Addressing charges 1, 3, & 5
- Status of the target system — C. Keith
  - Addressing charge 2
- Radiation and Beamline Commissioning — A. Somov
  - Addressing charges 4 & 7
- Documentation — L. Pentchev
  - Addressing charge 9
- Responsibilities for the experiment and analysis — O. Hen
  - Addressing charges 6 & 8

Back-up

Anticipated Rates

		$\gamma n \to \pi^- p$		$\gamma n \to \rho^- p$	
Target	PAC Days	MF	SRC	MF	SRC
D	4.5	12240	675	51300	2700
^{4}He	1.0	1600	84	6800	350
^{12}C	7.0	5192	1633	21583	6417

Scale/Scheme-independence and *k*-*r* equivalence



R. Cruz-Torres et al., arXiv:1907.03658