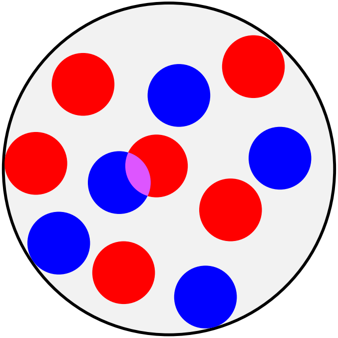
Highlights and Recent Developments in Short Range Correlations

Axel Schmidt

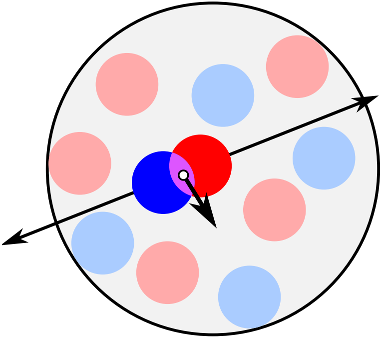
MIT

July 26, 2017

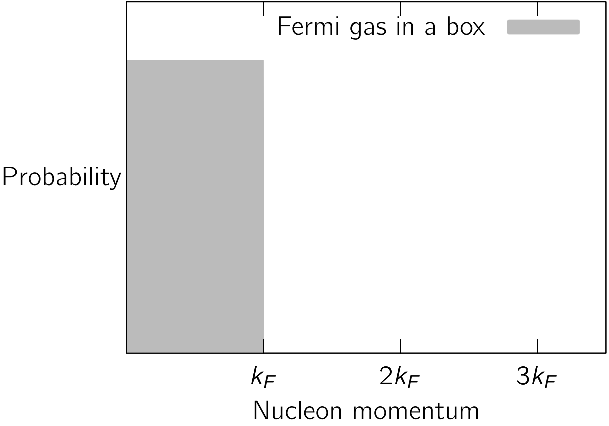
20% of the nuclear wave function



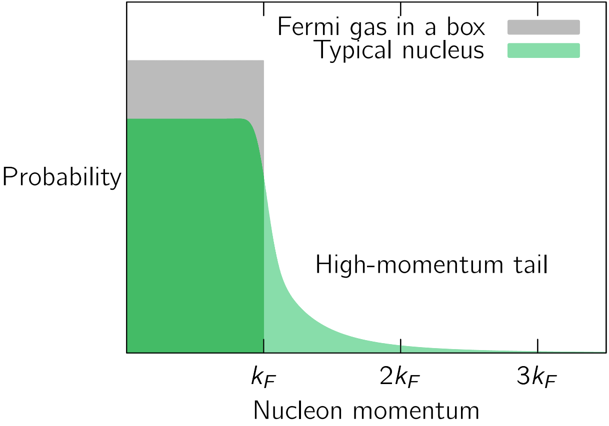
20% of the nuclear wave function



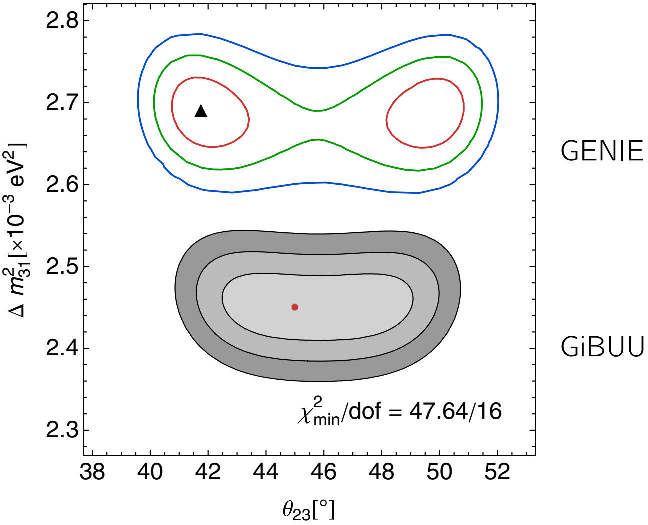
SRCs produce a high-momentum tail.



SRCs produce a high-momentum tail.

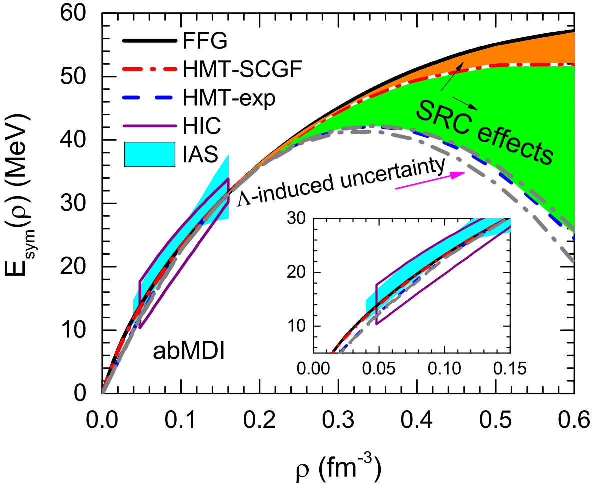


SRCs impact *NN*-Matrix Elements.



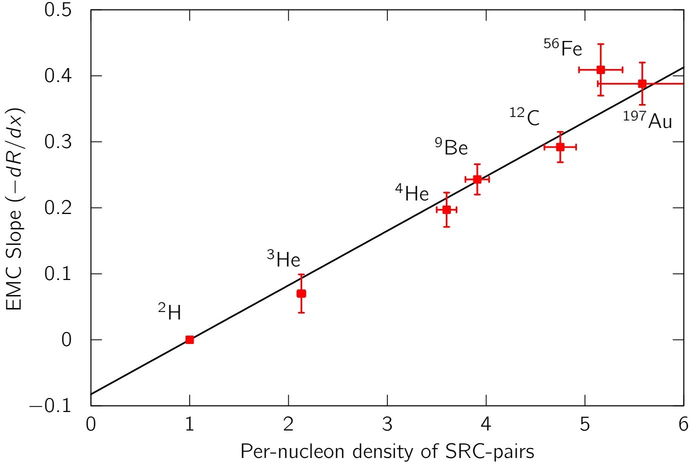
Coloma et al., PRD 89 073015 (2014)

SRCs alter the eq.-of-state for neutron stars.



B.-J. Cai, B.-A. Li, arXiv:1509.09290v2 (2016), arXiv:1703.08743v1 (2017)

SRCs may play a major role in the EMC effect.



L.B. Weinstein et al., PRL 106, 052301 (2011)

O. Hen et al., PRC 85, 047301 (2012)

Short Range Correlations Collaboration

Massachusetts Institute of Technology

- **Prof. Or Hen**
- Dr. Shalev Gilad
- Dr. Adi Ashkenazi
- Dr. George Laskaris
- Dr. Maria Patsyuk
- Dr. Axel Schmidt
- Barak Schmookler
- Rey Cruz-Torres
- Afro Papadopoulou
- Efrain Segarra

OLD DOMINION UNIVERSITY

- **Prof. Lawrence Weinstein**
- Dr. Florian Hauenstein
- Mariana Khachatryan

TEL AVIV UNIVERSITY

- **Prof. Eli Piasetzky**
- Dr. Igor Korover
- Erez Cohen
- Meytal Duer

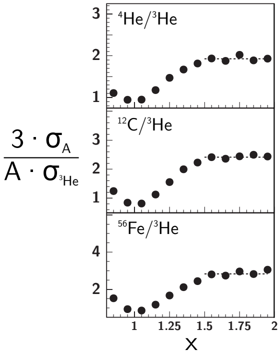
In my talk today:

1. Important past results
2. Recent developments
3. Future plans

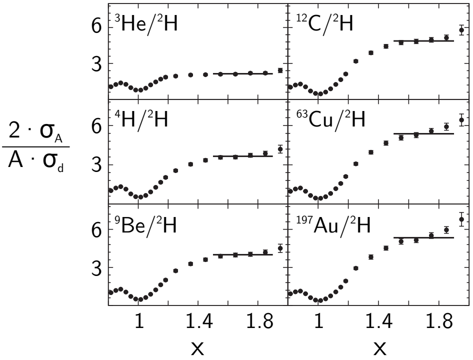
In my talk today:

1. **Important past results**
2. Recent developments
3. Future plans

Inclusive cross sections scale for $x > 1.5$.

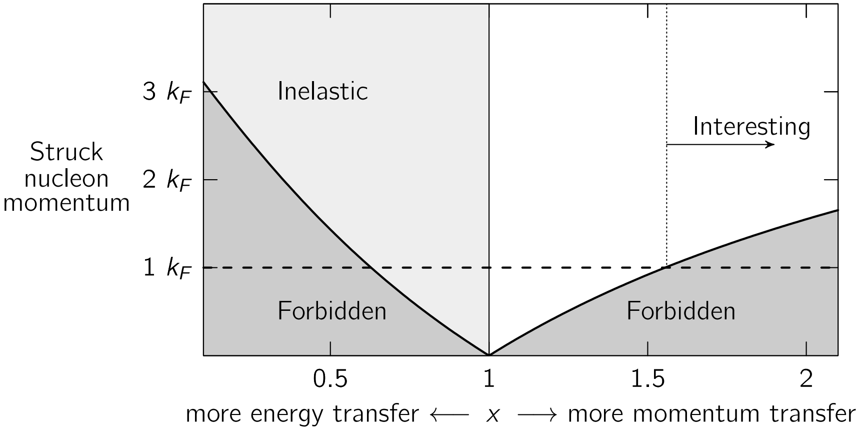


K.S. Egiyan et al. PRL 96, 082501(2006)

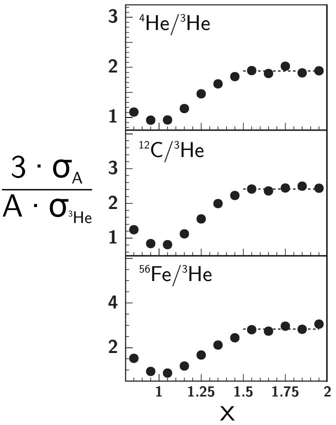


Fomin et al., PRL 108, 092502 (2012)

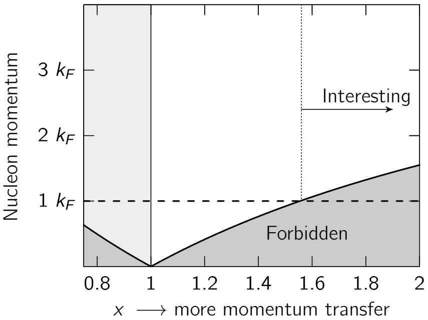
High-x kinematics restrict quasielastic scattering to high-momentum nucleons.



Scale factor a_2 is the per-nucleon density of SRC pairs.



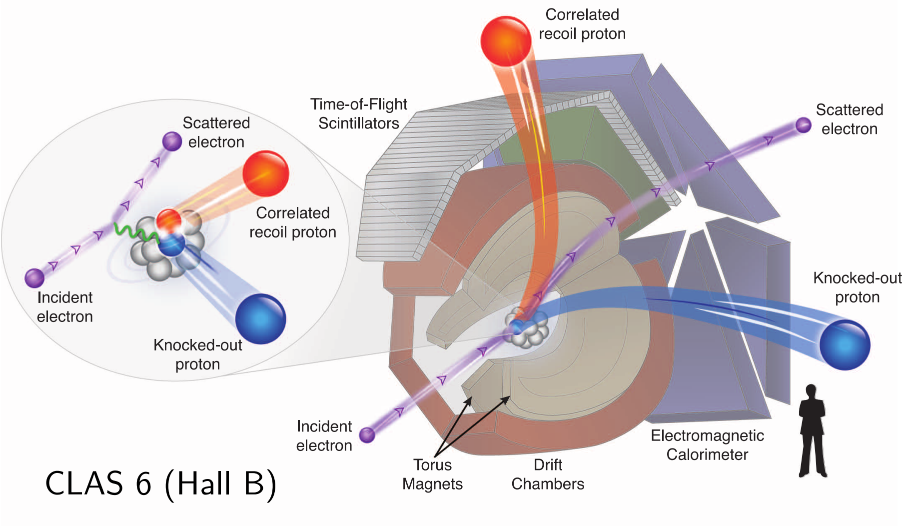
K.S. Egiyan et al. PRL 96, 082501(2006)



Scaling constant a_2:

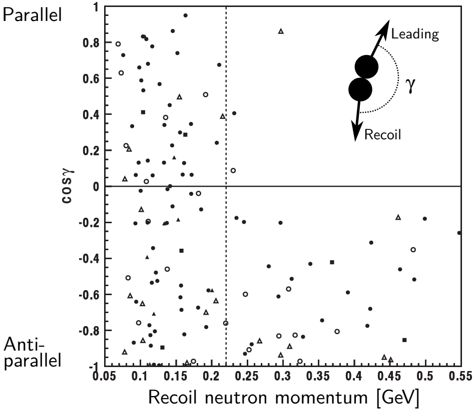
$$\sigma_A = \mathbf{a}_2 \times \frac{A}{2}\sigma_d$$

We have learned more about SRC pairs from coincidence experiments.



CLAS 6 (Hall B)

All high-momentum nucleons have a correlated partner.

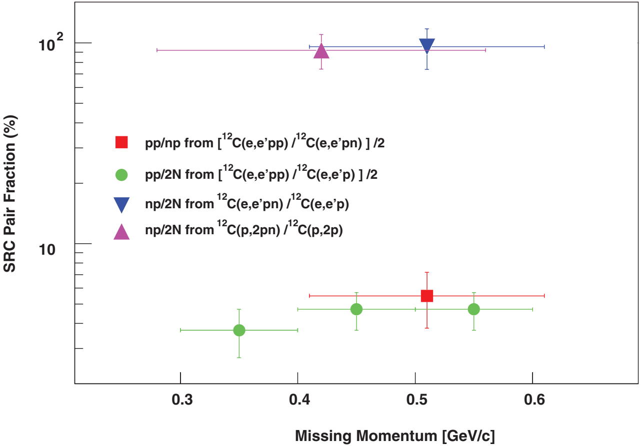


p scattering from Carbon:

- Always a correlated partner
- Anti-parallel momenta

J.L.S. Aclander et al., Phys. Lett. B 453, 211 (1999)
A. Tang et al., Phys. Rev. Lett. 90, 042301 (2003)
E. Piasetzky et al., PRL 97 162504 (2006)

Between 300–600 MeV, *np* pairs predominate.

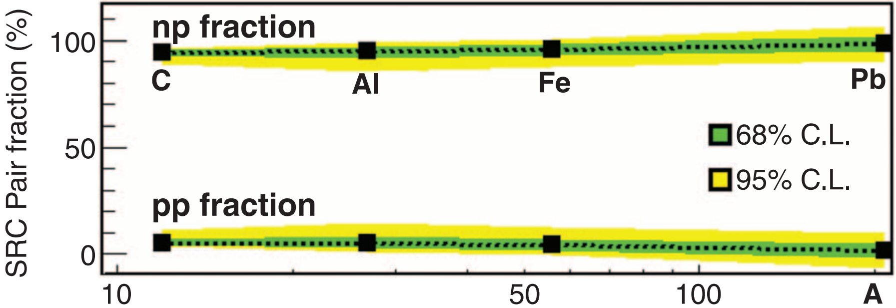


E. Piasetzky et al., PRL 97 162504 (2006)

R. Shneor et al., Phys. Rev. Lett. 99, 072501 (2007)

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

This has been verified over many nuclei.

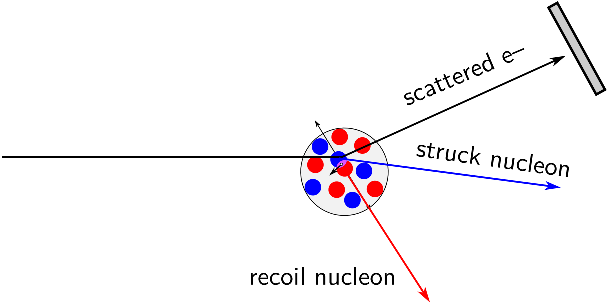


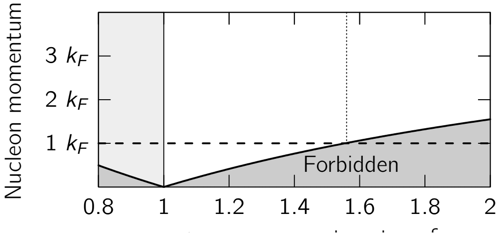
O. Hen et al, Science 346, 614 (2014)

In my talk today:

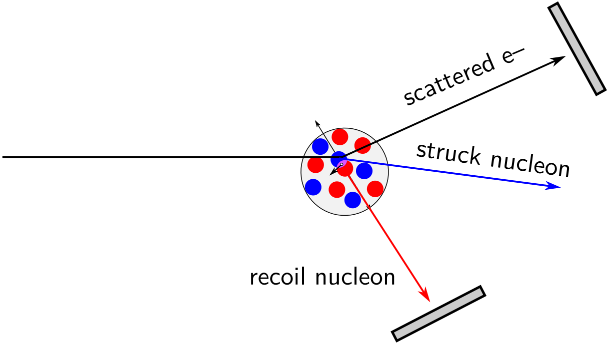
1. Important past results
2. **Recent developments**
3. Future plans

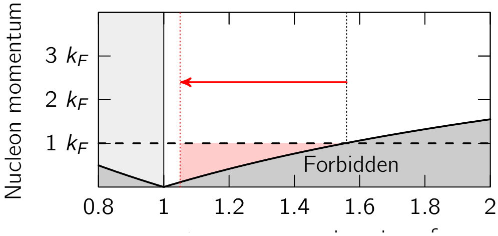
Recoil tagging may extend a_2 scaling to lower x.



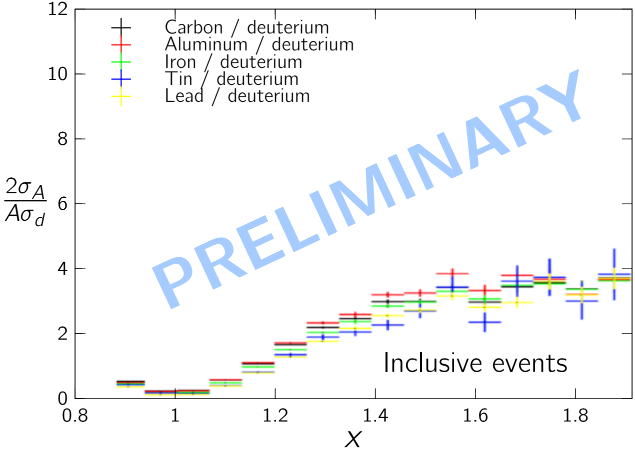


Recoil tagging may extend a_2 scaling to lower x.



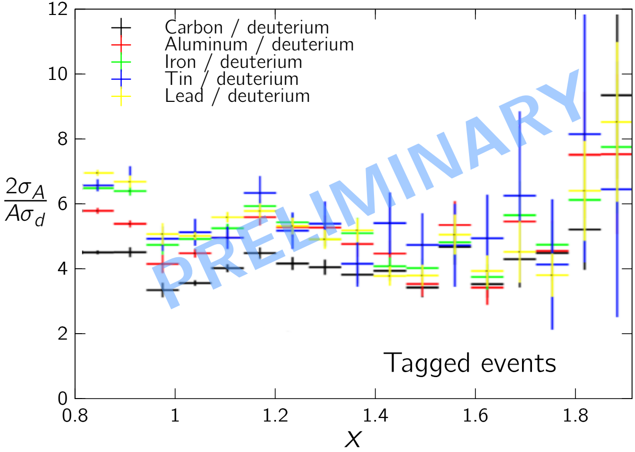


Analyis of CLAS data suggests an extended scaling region.



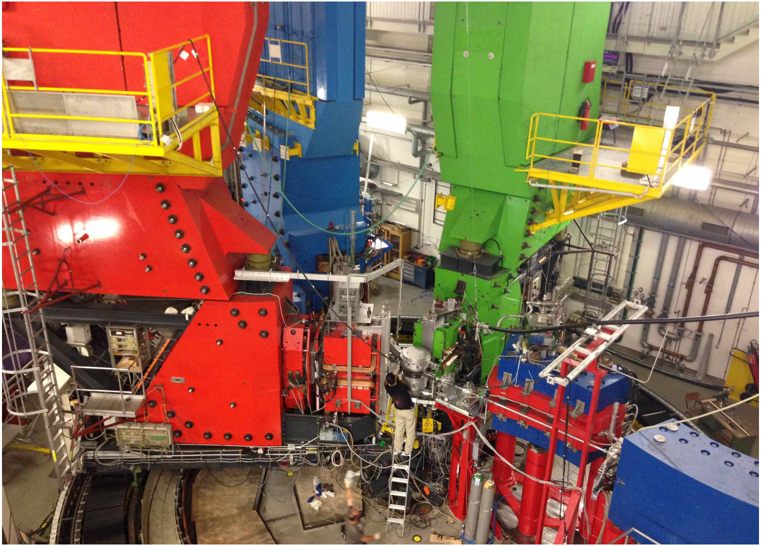
B. Schmookler et al., in preparation

Analyis of CLAS data suggests an extended scaling region.

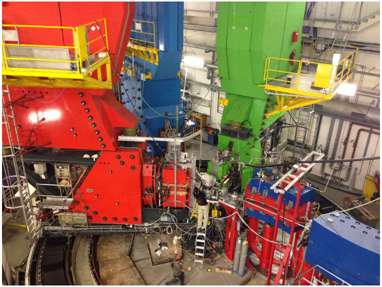


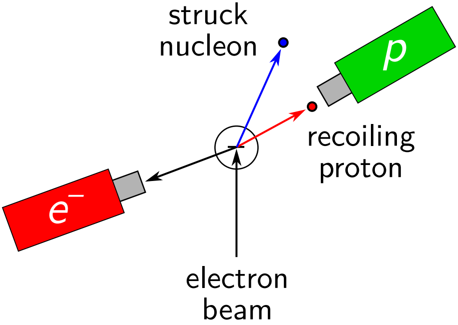
B. Schmookler et al., in preparation

We recently performed a recoil-tagging experiment at Mainz using the A1 spectrometers.



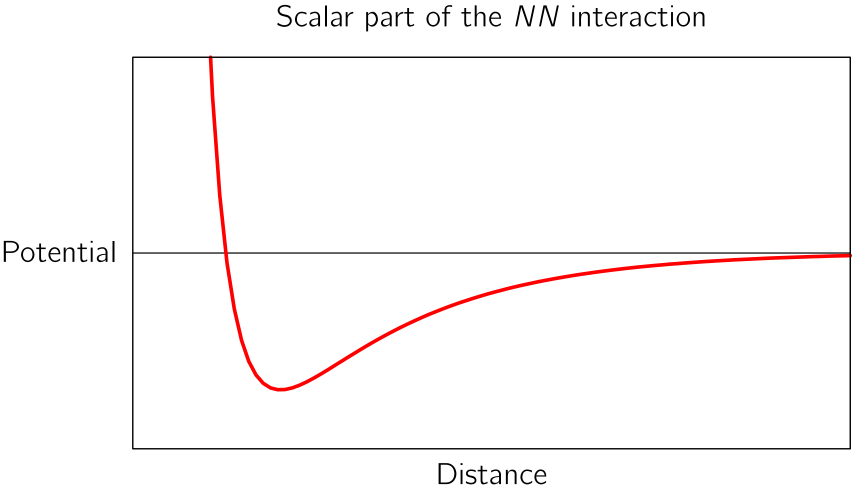
We recently performed a recoil-tagging experiment at Mainz using the A1 spectrometers.



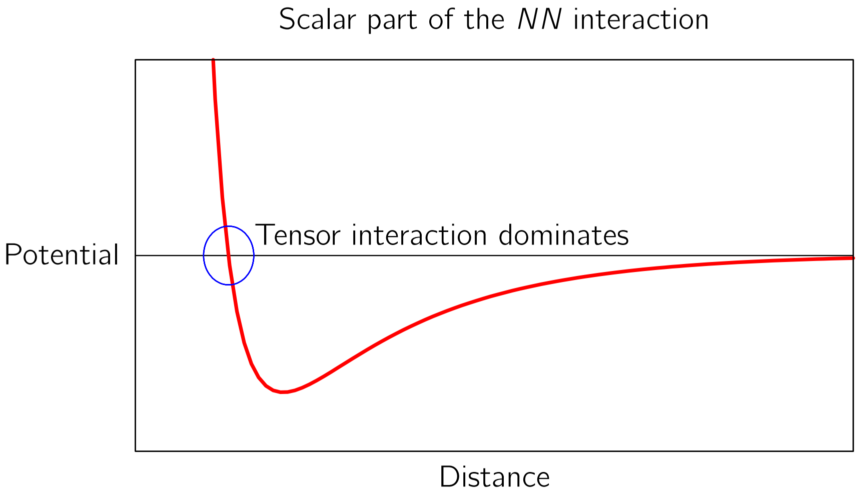


A. Ashkenazi et al., analysis underway!

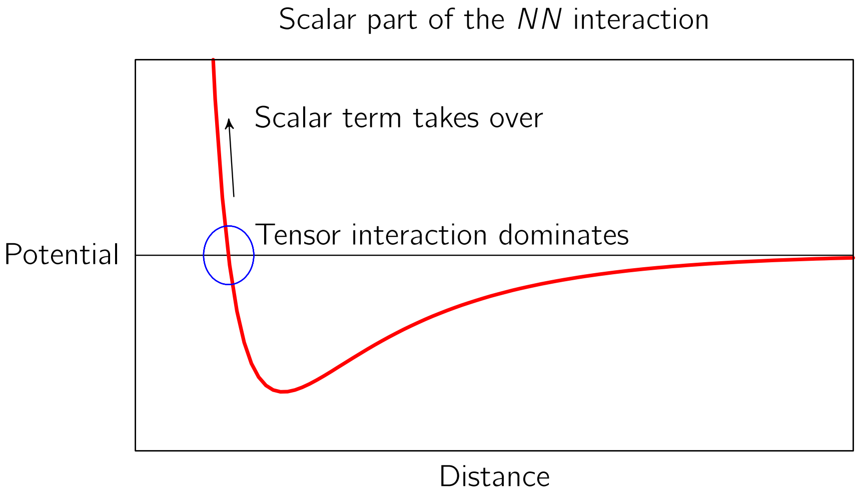
np dominance comes from tensor interaction.



np dominance comes from tensor interaction.

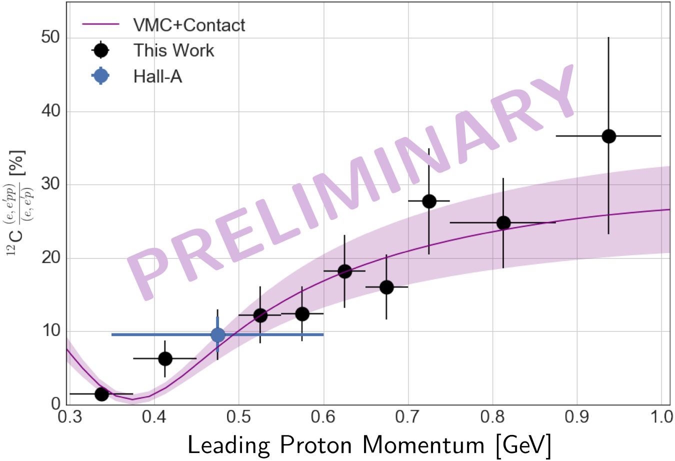


np dominance comes from tensor interaction.



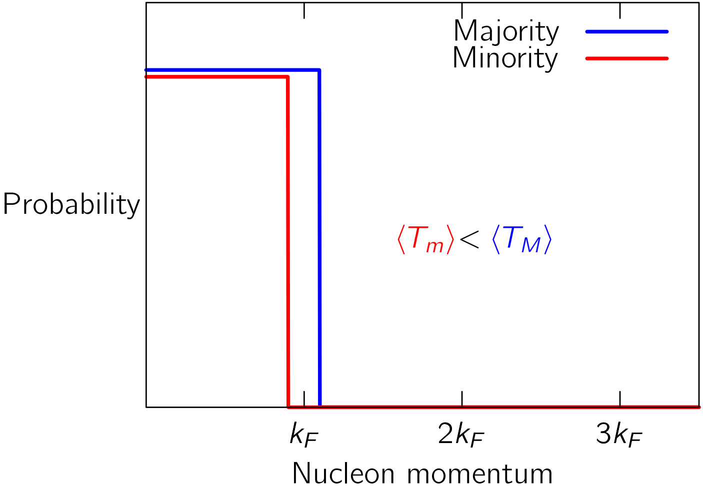
We expect that the *pp* fraction should rise with nucleon momentum.

The fraction of *pp* pairs increases with *k*.

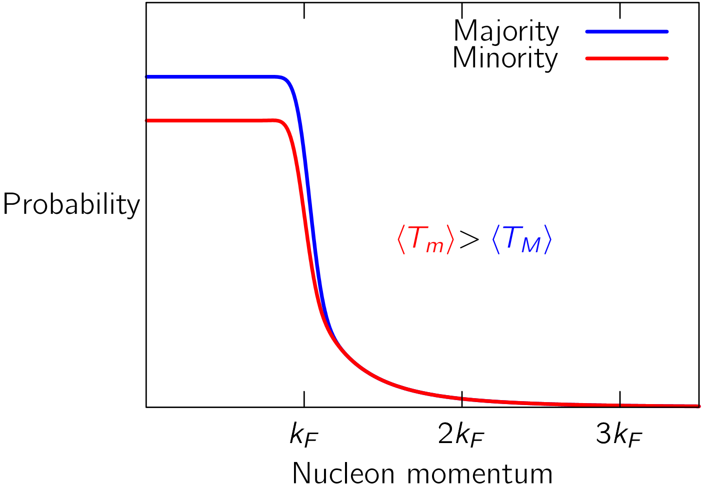


E. Cohen, O. Hen et al., in preparation

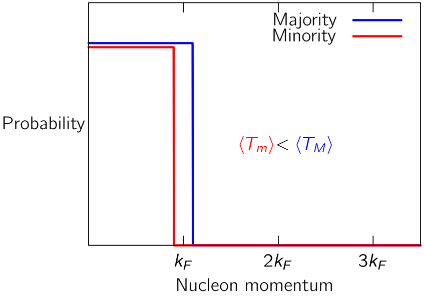
Which species has more kinetic energy in an asymmetric nucleus?

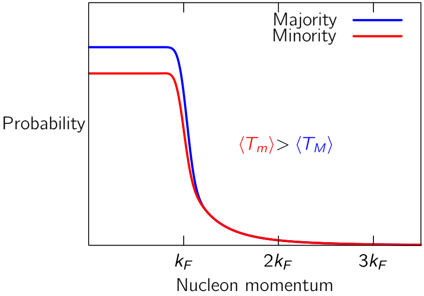


Which species has more kinetic energy in an asymmetric nucleus?



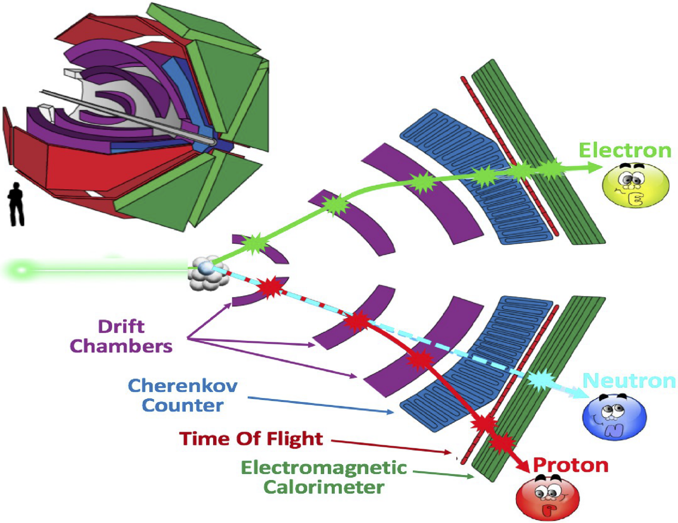
There are two competing forces.



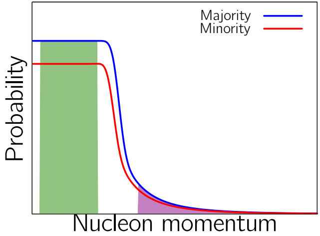


Which is stronger?

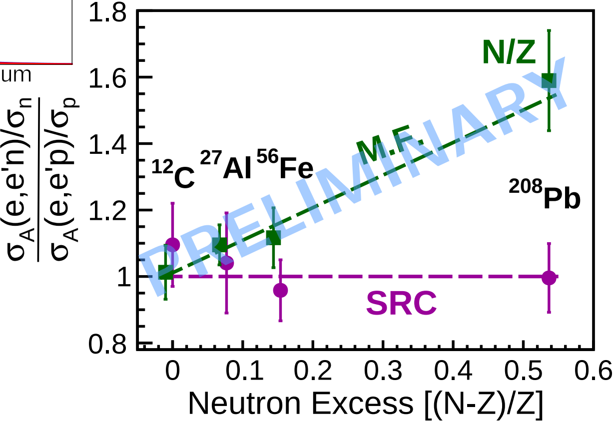
Analysis of $(e, e'p)$ and $(e, e'n)$ in CLAS



Data reconfirm *np* dominance.



Analysis by Meytal Duer

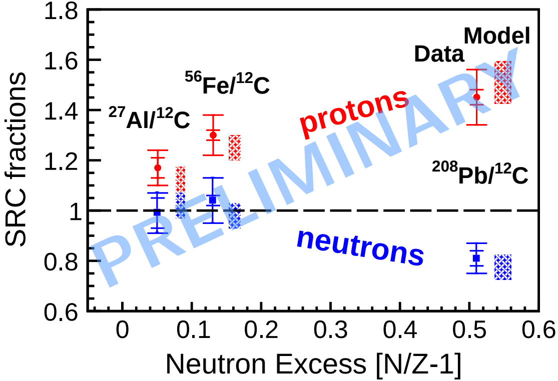


As neutron number increases, the fraction of high-momentum neutrons decreases.

$$\text{SRC Fraction} \equiv \frac{\sigma^{A}_{\text{SRC}}(e,e'N)}{\sigma^{A}_{\text{MF}}(e,e'N)} \Big/ \frac{\sigma^{C}_{\text{SRC}}(e,e'N)}{\sigma^{C}_{\text{MF}}(e,e'N)}$$

As neutron number increases, the fraction of high-momentum neutrons decreases.

$$\text{SRC Fraction} \equiv \frac{\sigma^{A}_{\text{SRC}}(e,e'N)}{\sigma^{A}_{\text{MF}}(e,e'N)} \Big/ \frac{\sigma^{C}_{\text{SRC}}(e,e'N)}{\sigma^{C}_{\text{MF}}(e,e'N)}$$



M. Duer et al., in preparation

In my talk today:

1. Important past results
2. Recent developments
3. **Future plans**

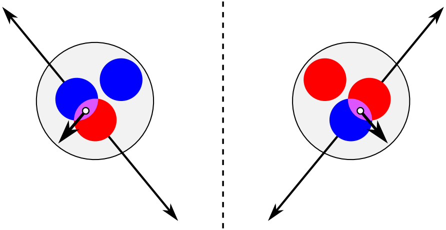
Some remaining questions:

- How do short-range pairs evolve with A and $(N - Z)$?
- What role do SRCs play in the EMC effect?
- What happens to the remnant nucleus after hard knockout?
- Are there three-N correlations?

Two upcoming $(e, e'p)$ experiments will look at asymmetric nuclei.

SRCs in ^{3}H, ^{3}He

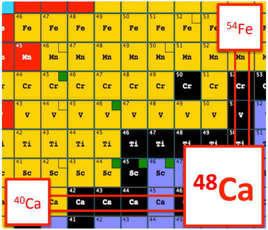
E12-14-001 (Hall A)



- Hall A tritium target
- Exploit isospin symmetry
- ^{3}H and ^{3}He are extremely asymmetric!

The CaFe Experiment

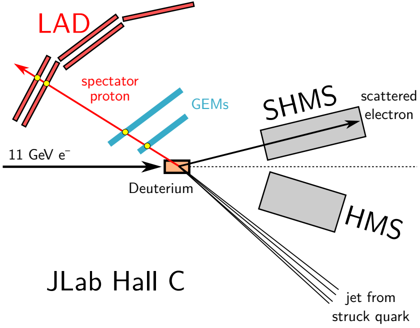
E12-17-005 (Hall C)



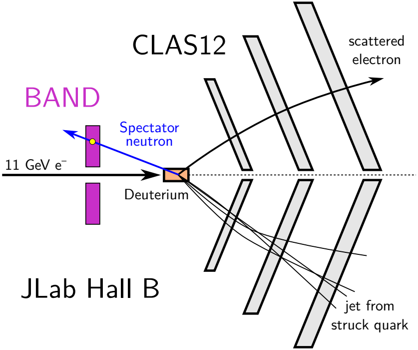
- Disentangle asymmetry and mass number dependence
- $^{40}\text{Ca} \rightarrow {}^{48}\text{Ca} \rightarrow {}^{54}\text{Fe}$
- Pairing from different orbitals

Two upcoming experiments will test the EMC-SRC connection.

Deep inelastic scattering on deuterium, tagging a recoiling nucleon:

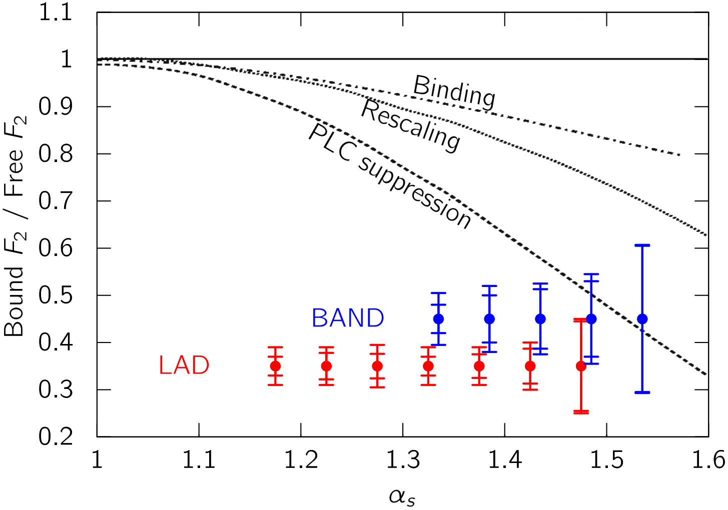


E12-11-003A

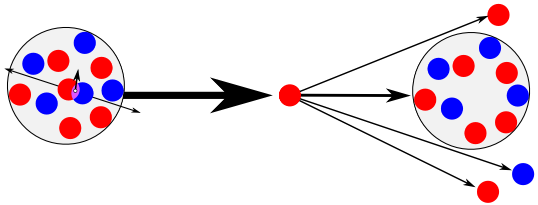


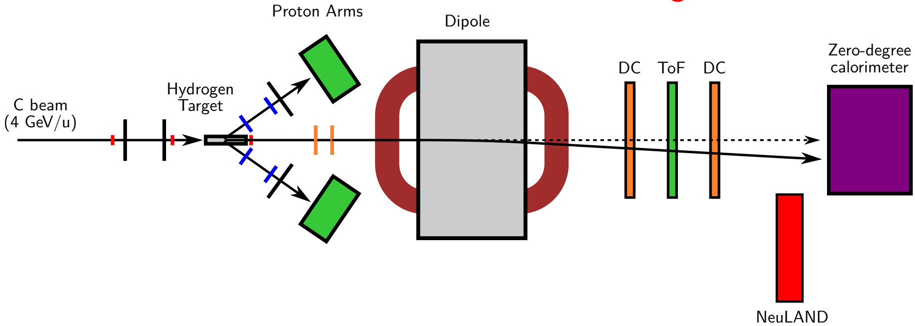
E12-11-107

BAND and LAD will tell us about nucleon modification and virtuality.

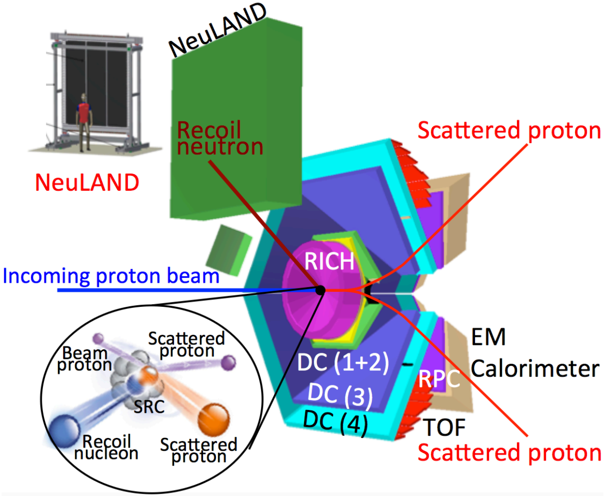


Inverse kinematics at Dubna: detecting the nuclear remnant.

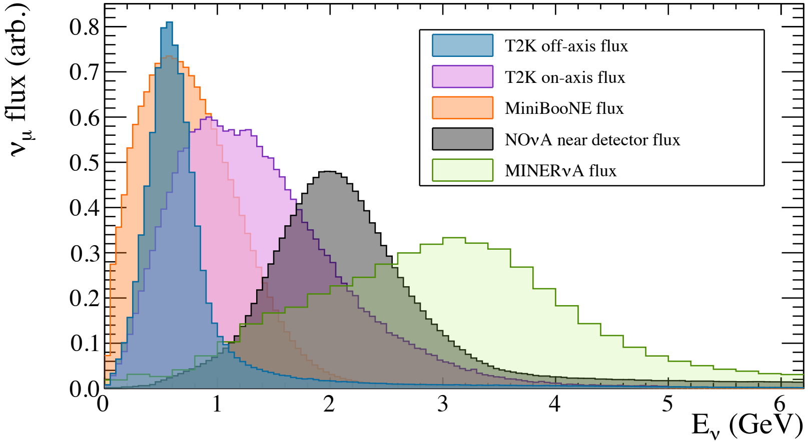




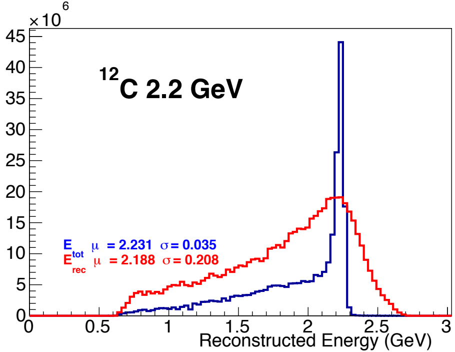
We are proposing to look at SRCs with HADES at GSI.



Neutrino oscillation experiments must reconstruct E_ν event by event.



We are proposing to benchmark νA MC codes using electron scattering.

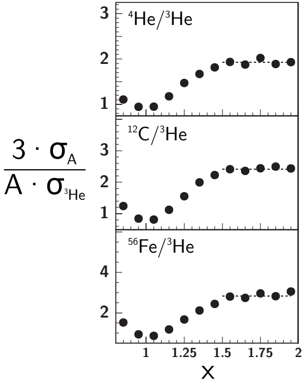


Work by M. Khatrachyan, E. Cohen, A. Papadopoulou, et al.

- CLAS12 proposal PR12-17-006
- H, He, C, O, Ar, Pb targets
- Benchmark:
  - Event rates
  - Energy recon.
- Conditionally approved, PAC45

In my talk today:

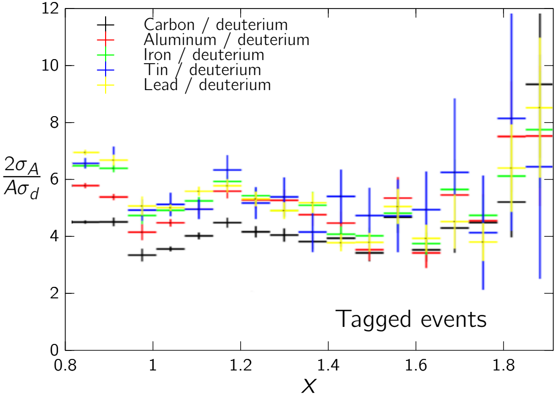
1. Important past results



K.S. Egiyan et al. PRL 96, 082501(2006)

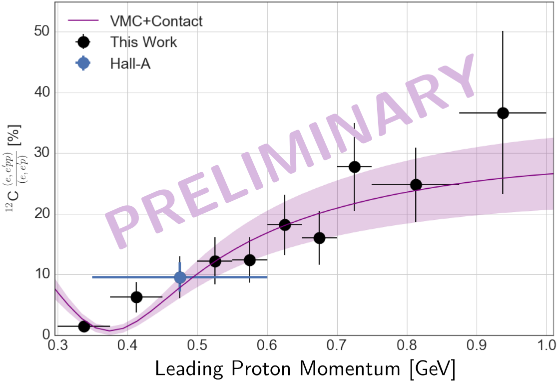
In my talk today:

1. Important past results
2. Recent developments



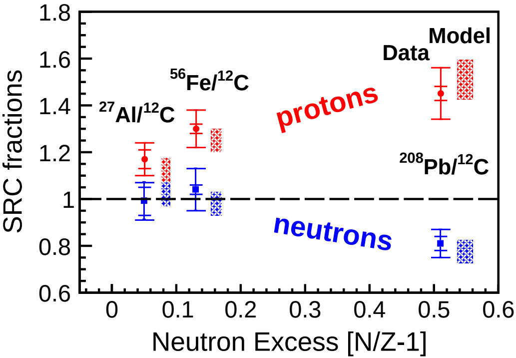
In my talk today:

1. Important past results
2. Recent developments



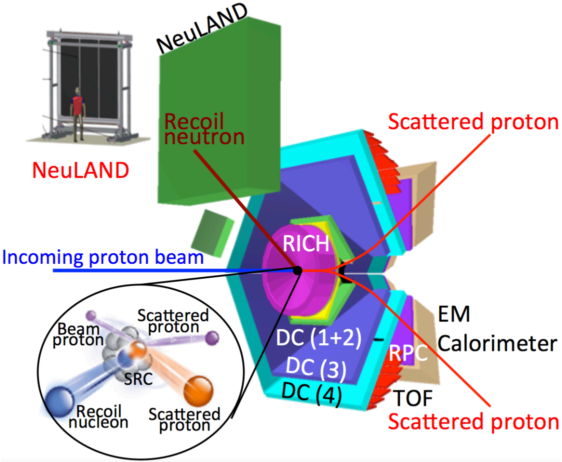
In my talk today:

1. Important past results
2. Recent developments



In my talk today:

1. Important past results
2. Recent developments
3. Future plans



Conclusions

- SRCs are 20% of the nuclear wave-function but they have far-reaching impacts.
- Our experimental program is diverse
  - Many facilities, probes, techniques
- Results are on the way!