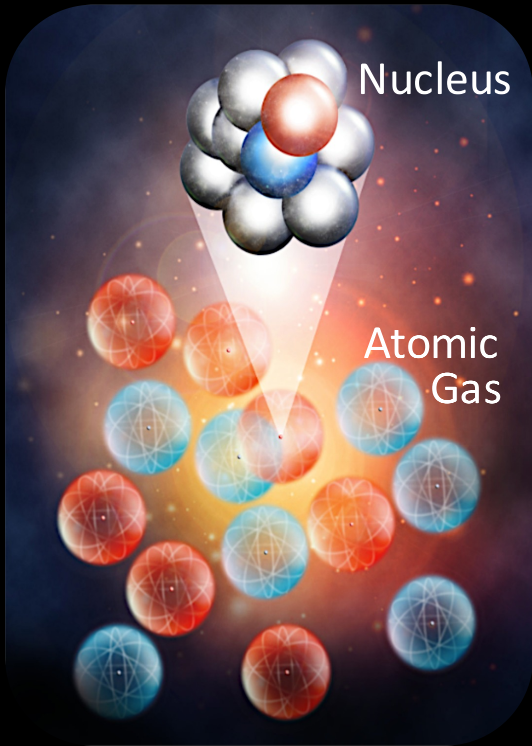
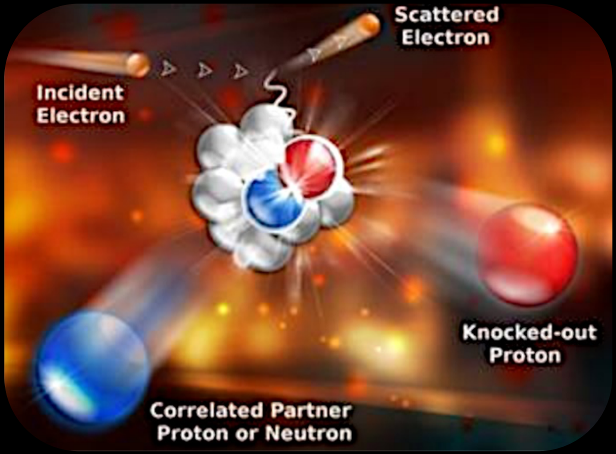
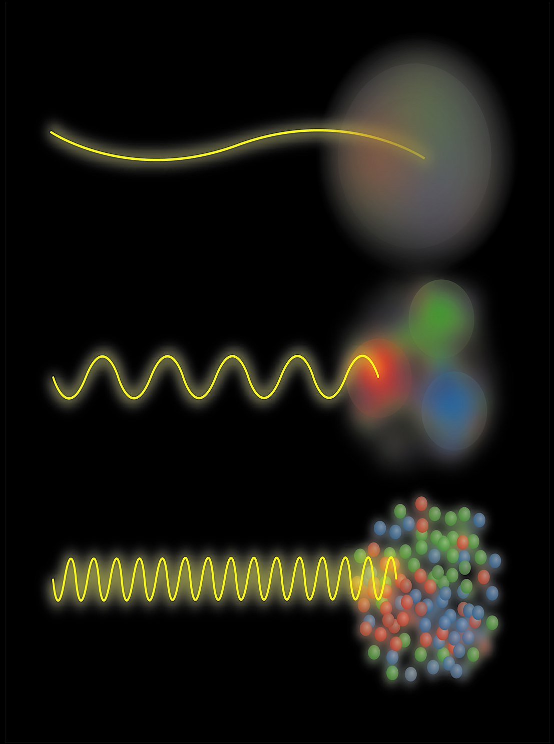
Acceptance Corrections for A(e,e’pp) Analysis



Or Hen

MIT

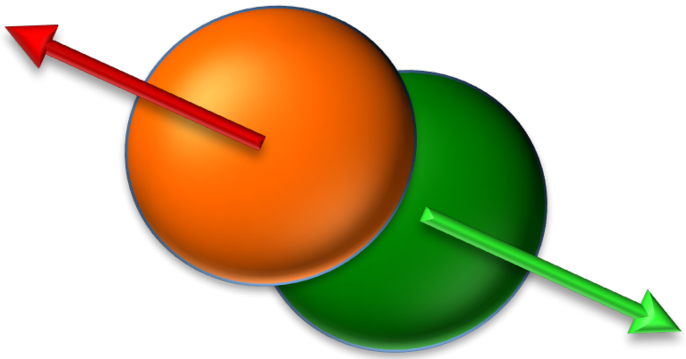


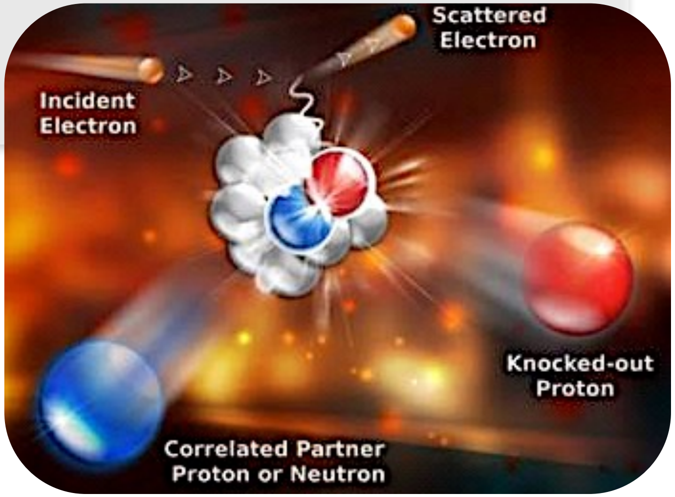


CLAS Collaboration meeting, JLab, February 25th, 2016.

What are Short-Range Correlation (SRC)

- Are close together (wave function overlap)
- Have *high relative momentum* and *low c.m. momentum* compared to the Fermi momentum (k_F)

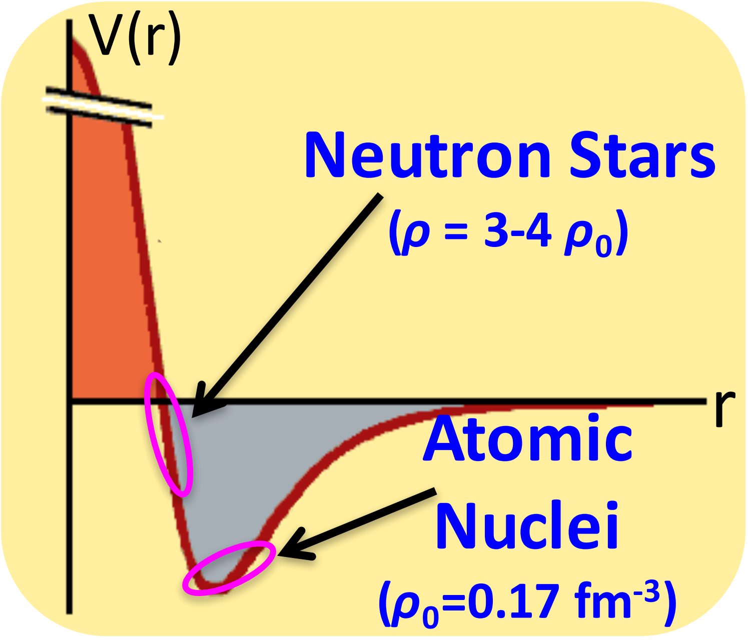




Why Study High-Momentum Nucleons?

Nuclear Physics

Better understanding of the *nucleon-nucleon interaction* and the nuclear momentum distribution



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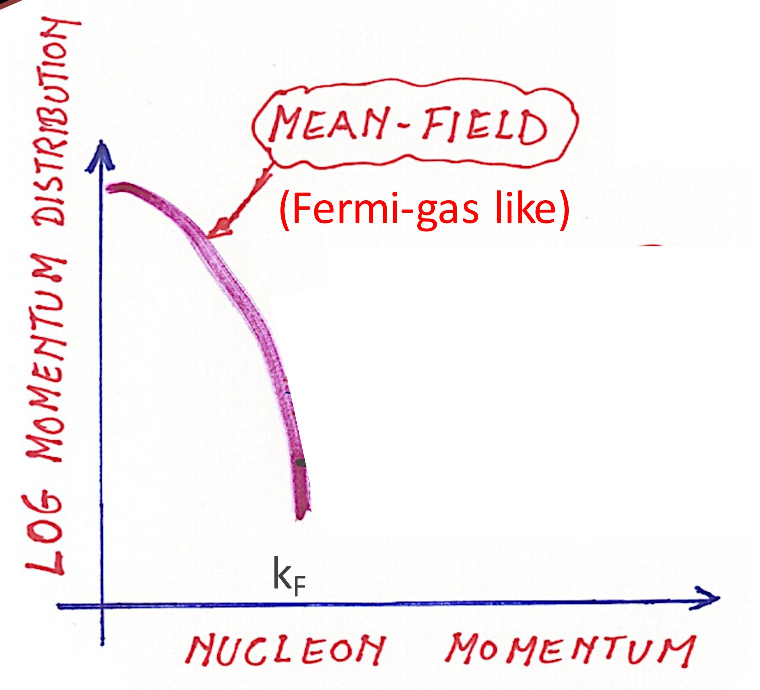

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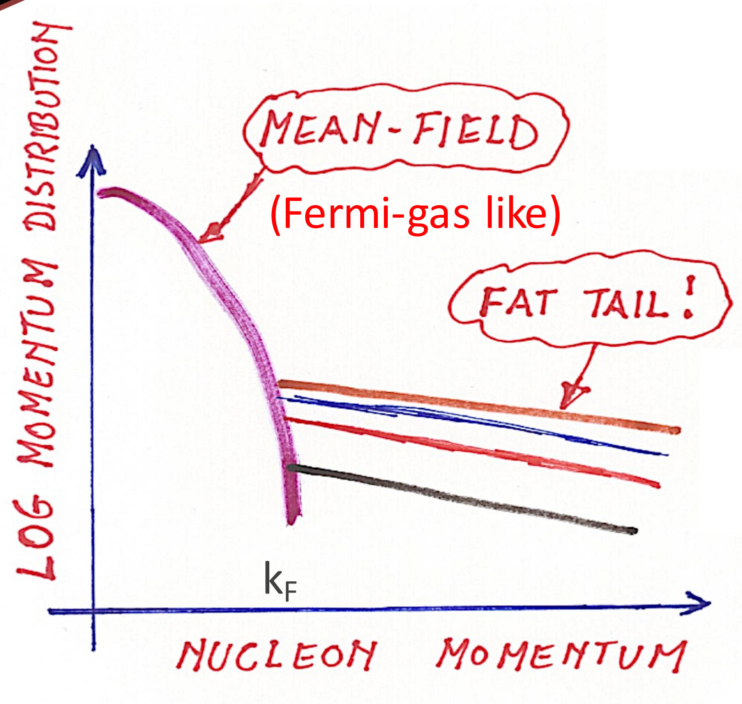
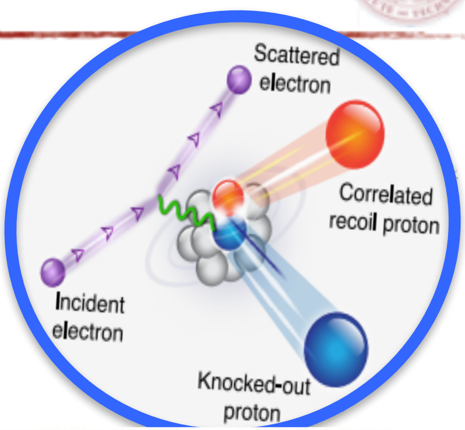


Why Study High-Momentum Nucleons?

Particle Physics

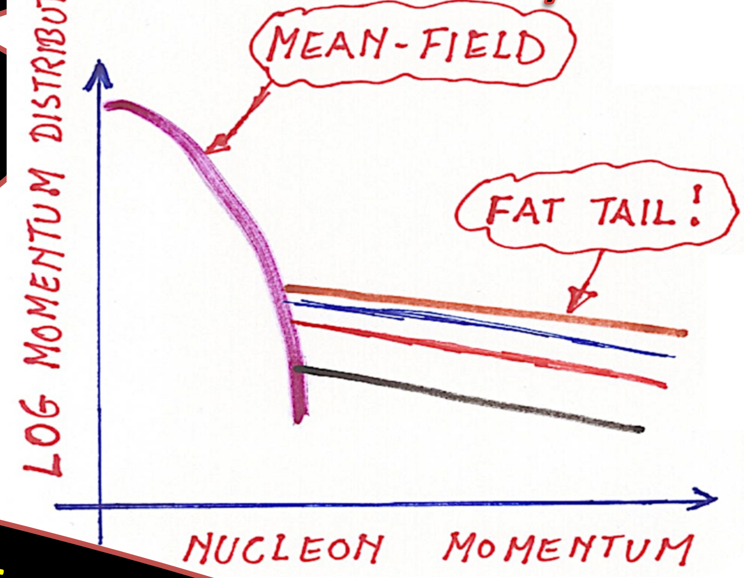
The EMC Effect.
Neutrino-Nucleus Scattering.
The NuTeV Anomaly.



Astrophysics

Neutron Stars.
Nuclear Symmetry Energy.

Nuclear Physics



Quantum / Atomic Physics

Energy Sharing in Imbalanced Fermi Systems.
Contact Interaction in Universal Fermi Systems.

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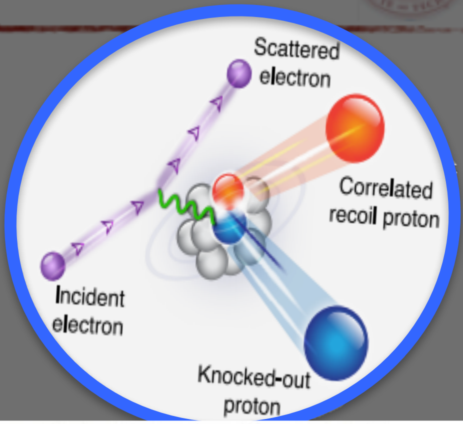

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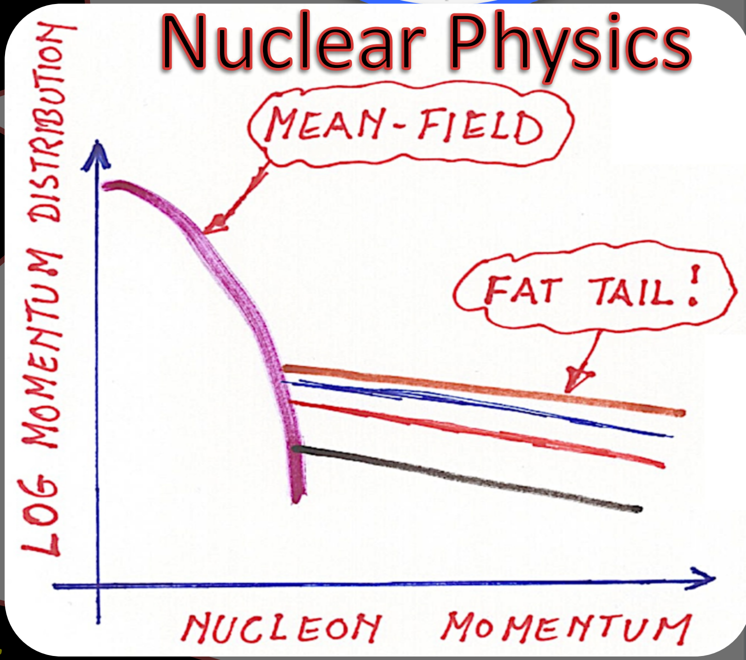
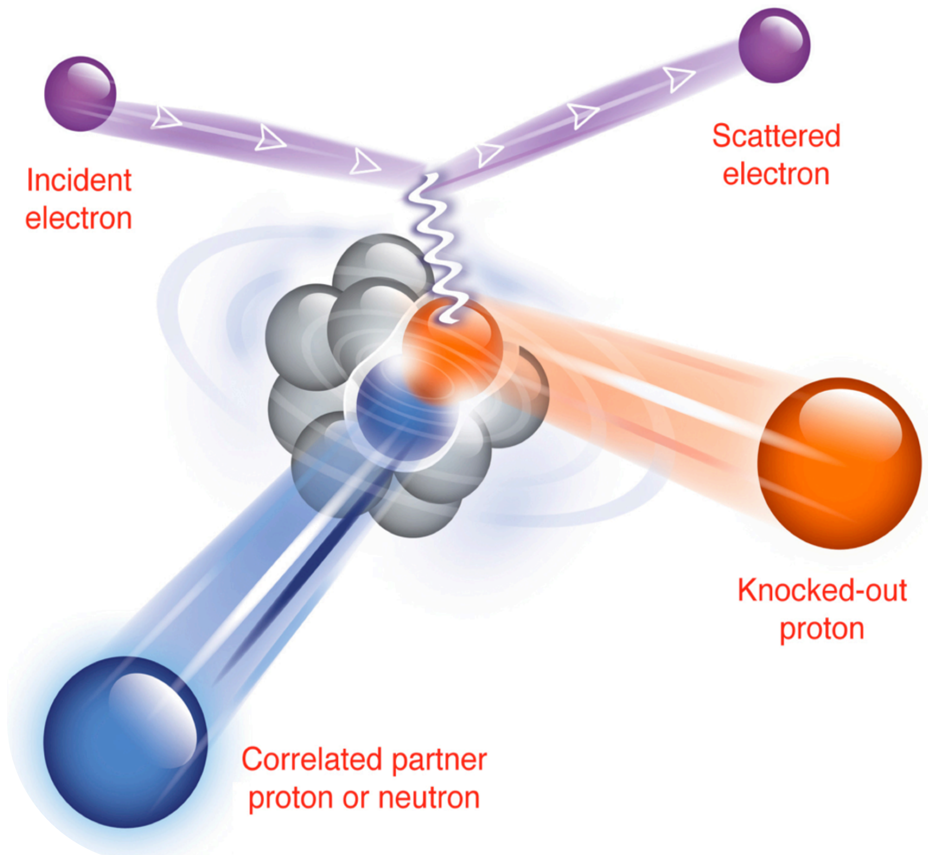


Quantum / Atomic Physics

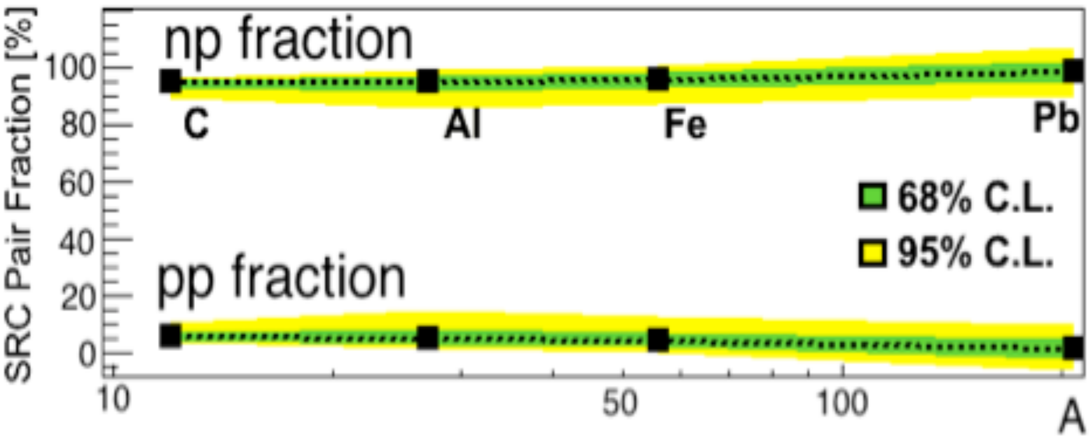
Energy Sharing in Imbalanced Fermi Systems.
Contact Interaction in Universal Fermi Systems.

Exclusive 2N-SRC Studies

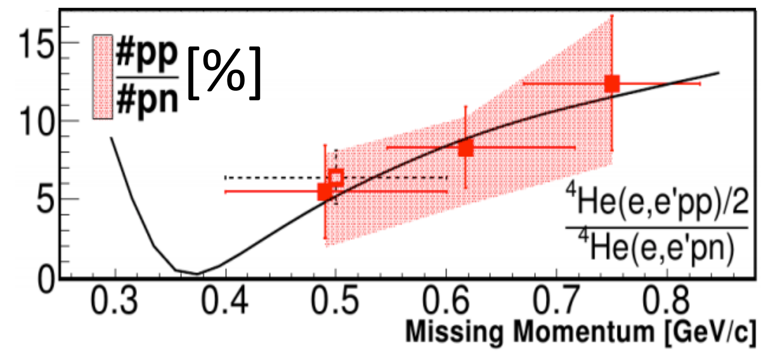
Breakup the pair =>
Detect both nucleons =>
Reconstruct 'initial' state



Results I: Isospin Structure

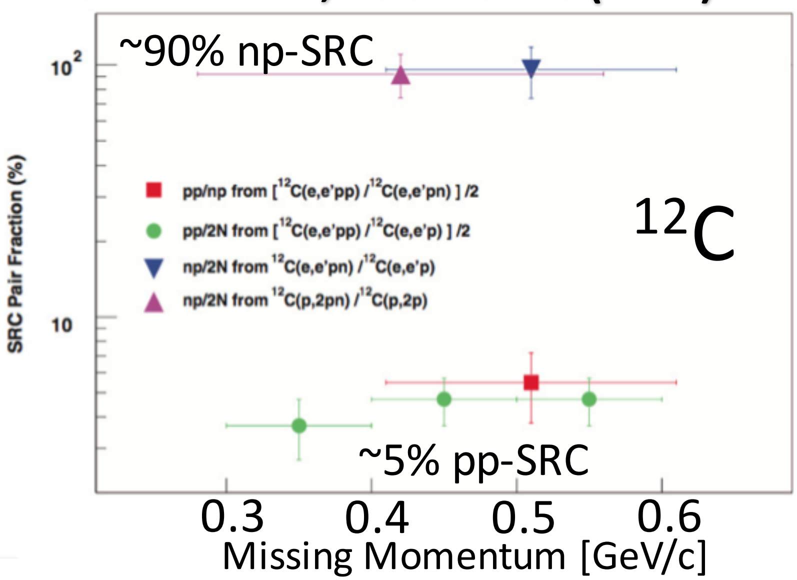


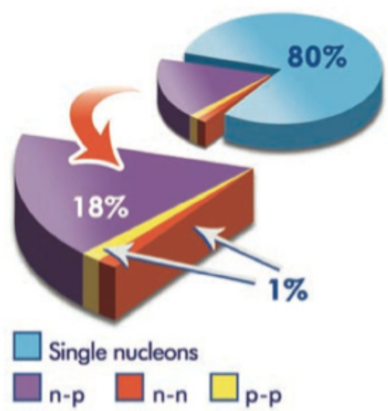
O. Hen et al., Science 364 (2014) 614

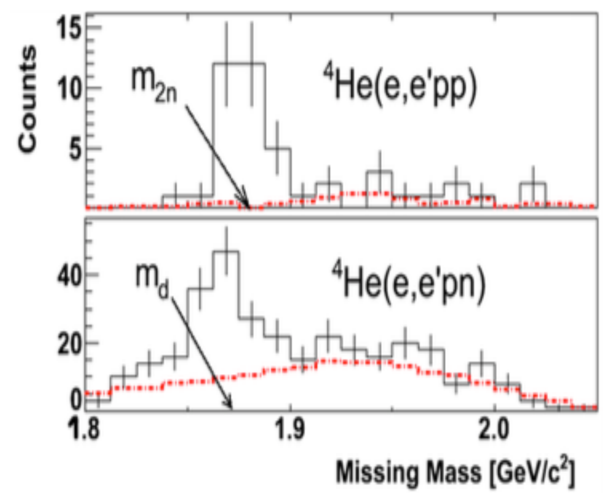


R. Subedi et al., Science 320 (2008) 1476

I. Korover et al., PRL 113 (2014) 022501







A. Tang et al., PRL (2003); E. Piasetzky et al., PRL (2006); R. Shneor et al., PRL (2007)

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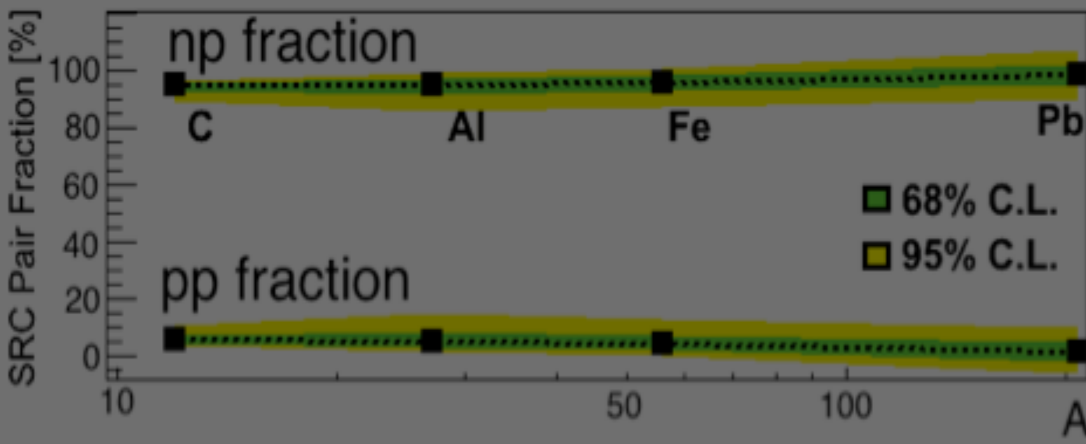
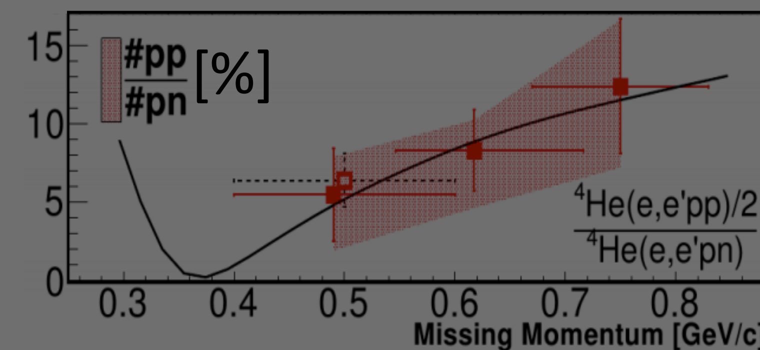


O. Hen et al., Science 364 (2014) 614



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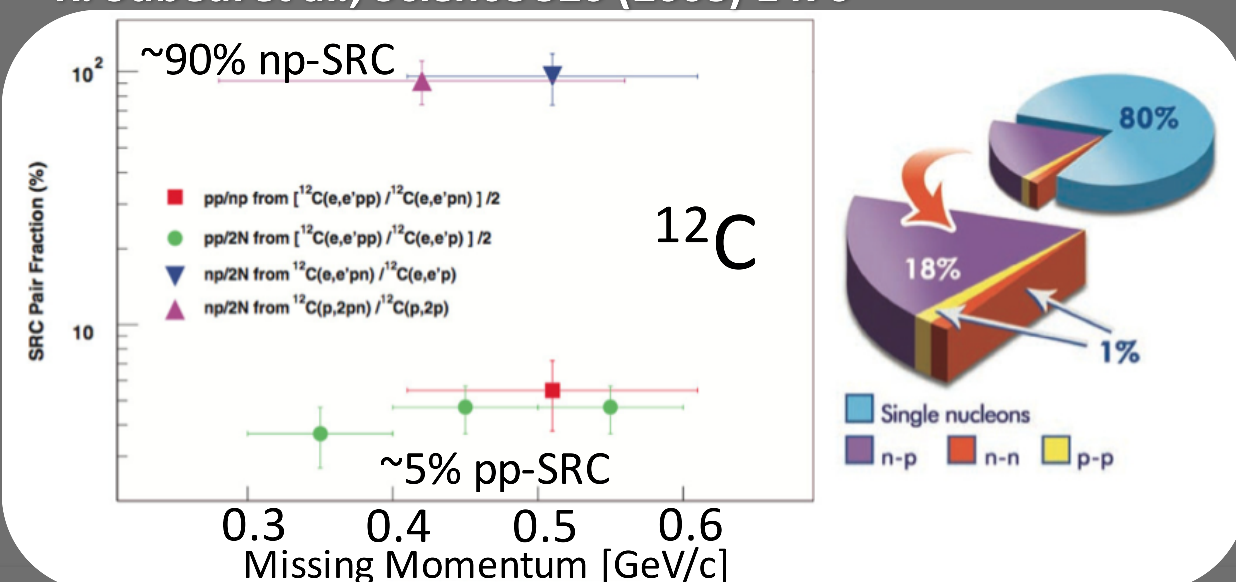

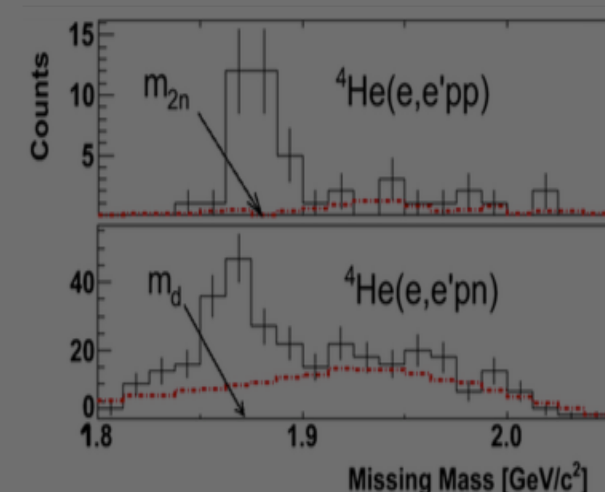

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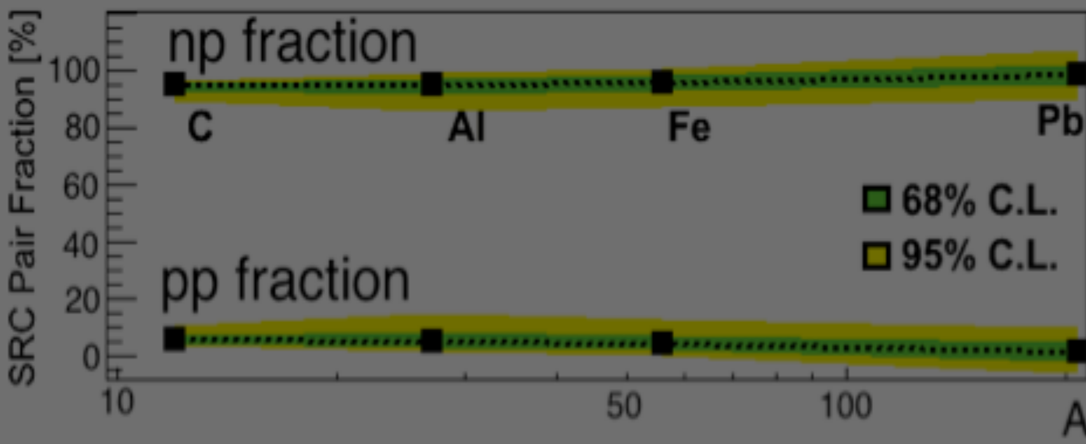
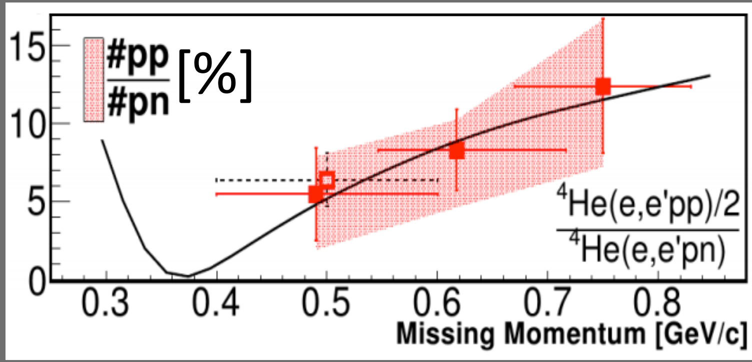


O. Hen et al., Science 364 (2014) 614



I. Korover et al., PRL 113 (2014) 022501

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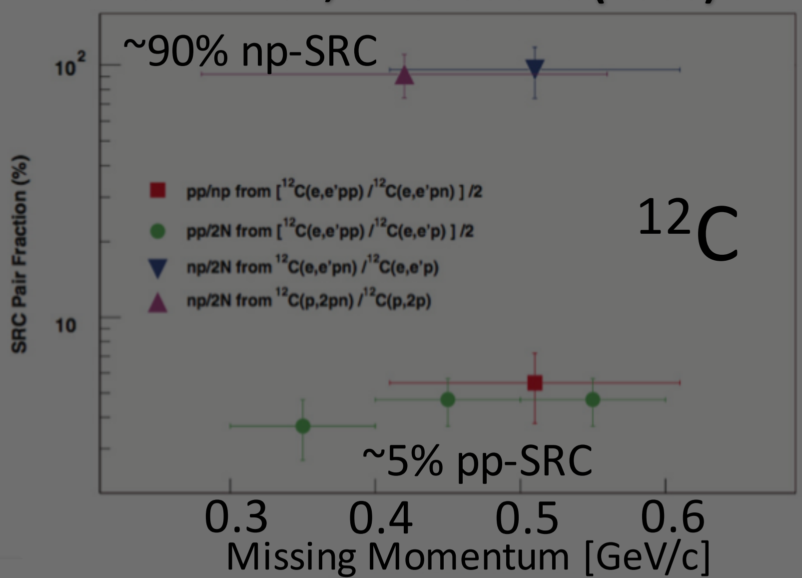

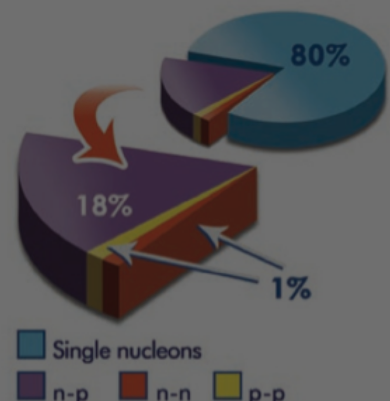

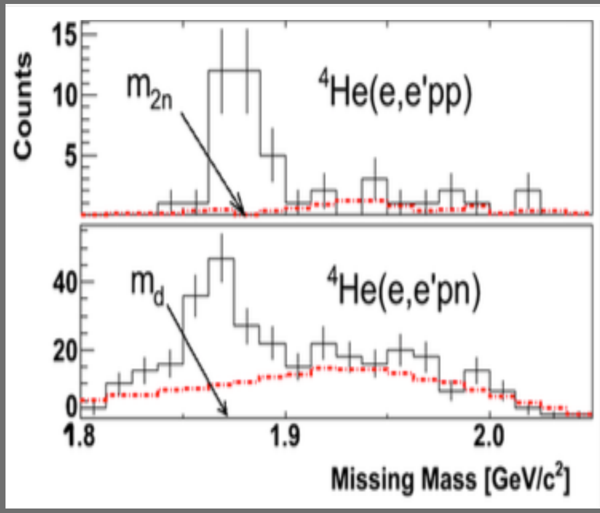

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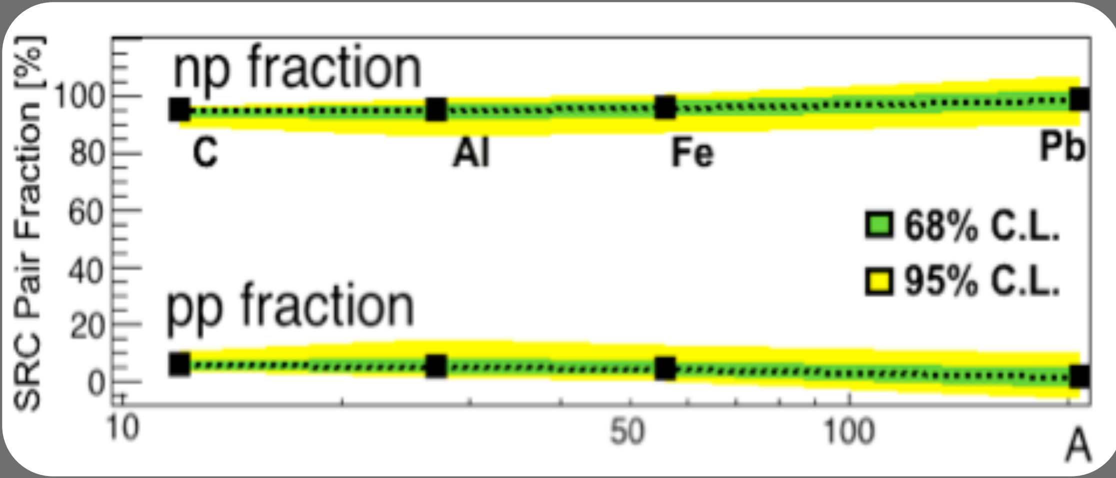
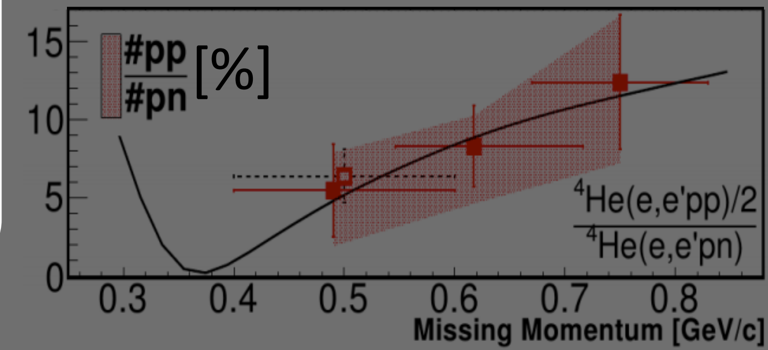


O. Hen et al., Science 364 (2014) 614



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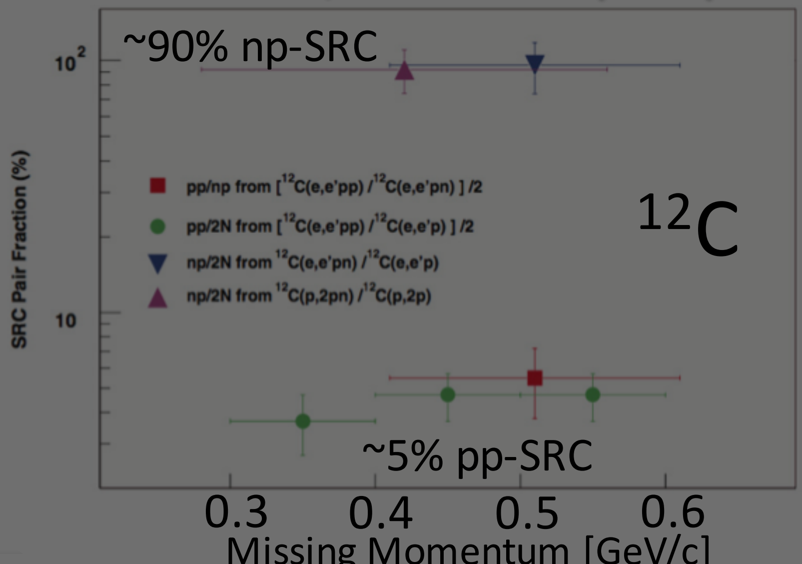

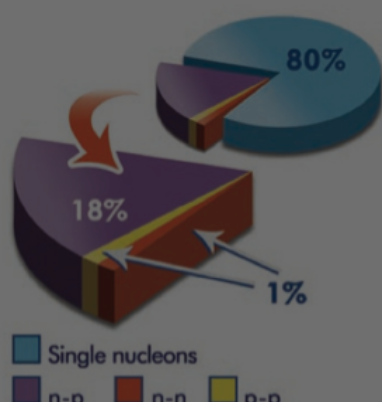

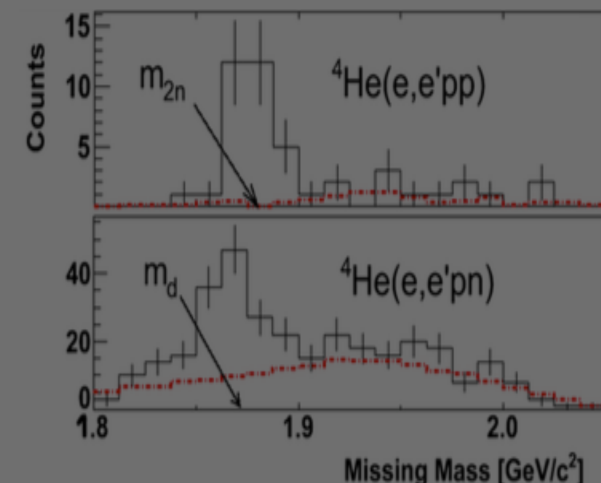

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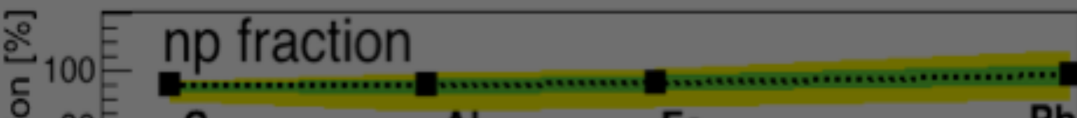
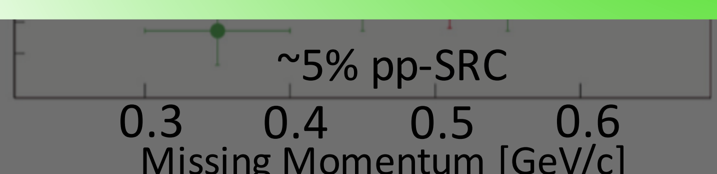


O. Hen et al., Science 364 (2014) 614

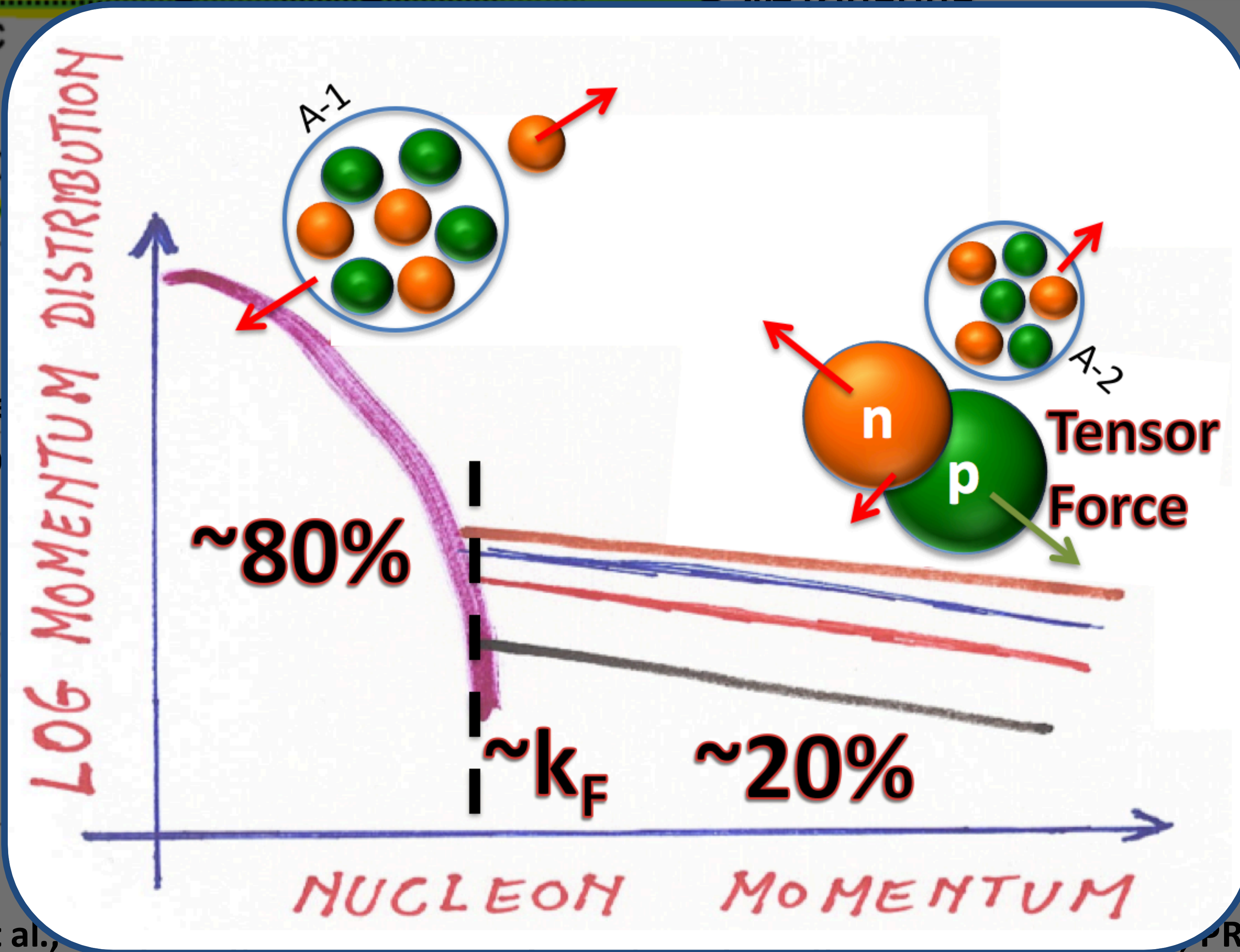
<u>Bottom Line:</u>

- np-SRC dominance observed in A = 4 – 208 nuclei.
- Strong indication for Tensor force dominance at short distance



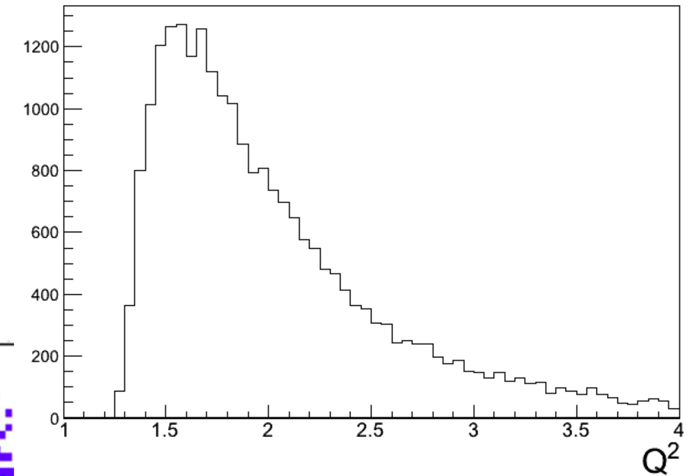
A. Tang et al., PRL (2003); E. Piasetzky et al., PRL (2006); R. Shneor et al., PRL (2007)

Universal structure of nuclear momentum distributions



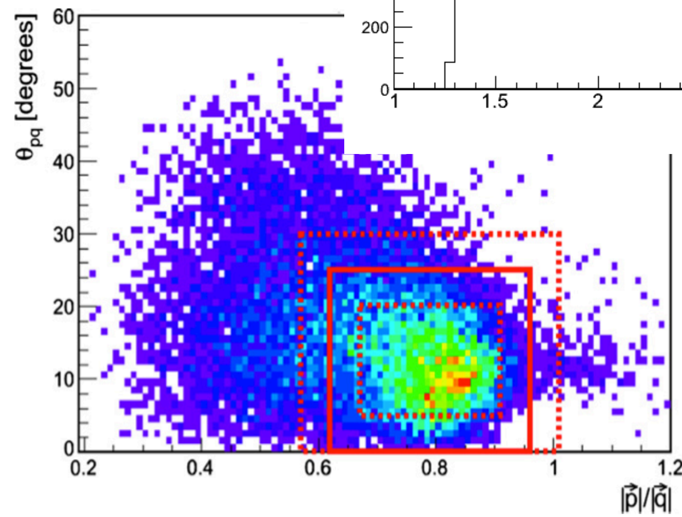
Mining CLAS Data for SRCs

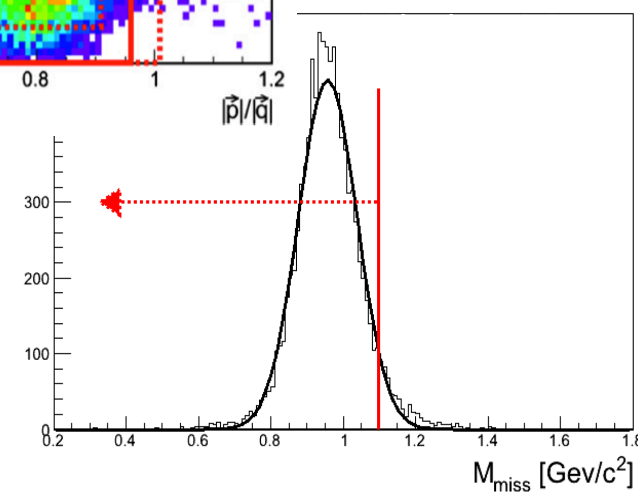
Reanalyzed existing CLAS data via a data-mining initiative



5 GeV electrons on ^{12}C, ^{27}Al, ^{56}Fe, and ^{208}Pb:

1. Cut (e,e'p) kinematics to simulate previous measurements*.
2. Look for a correlated recoil proton.

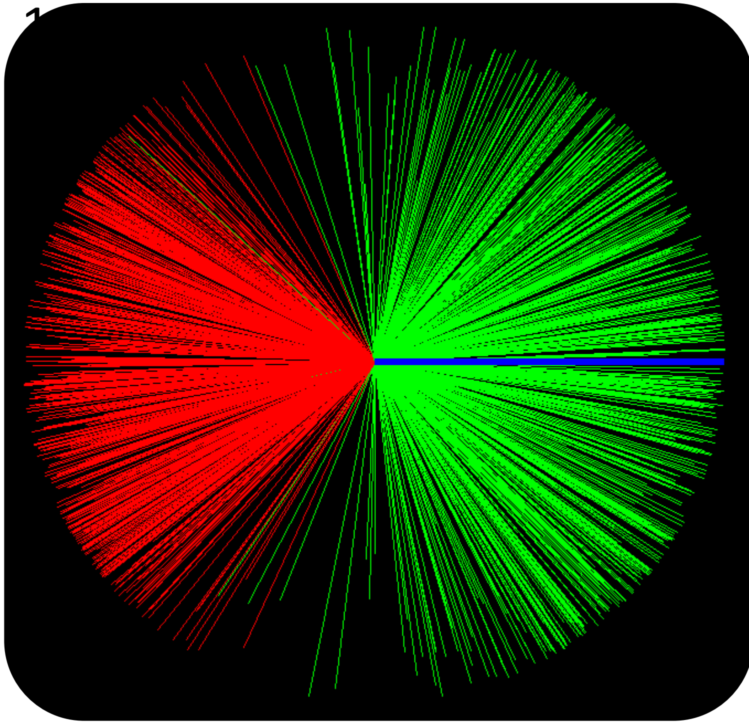


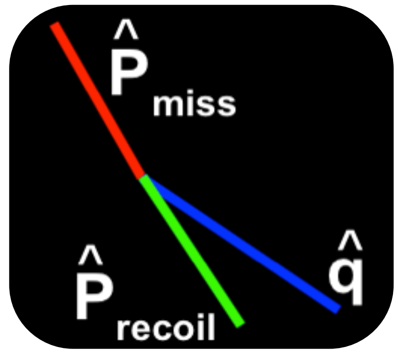


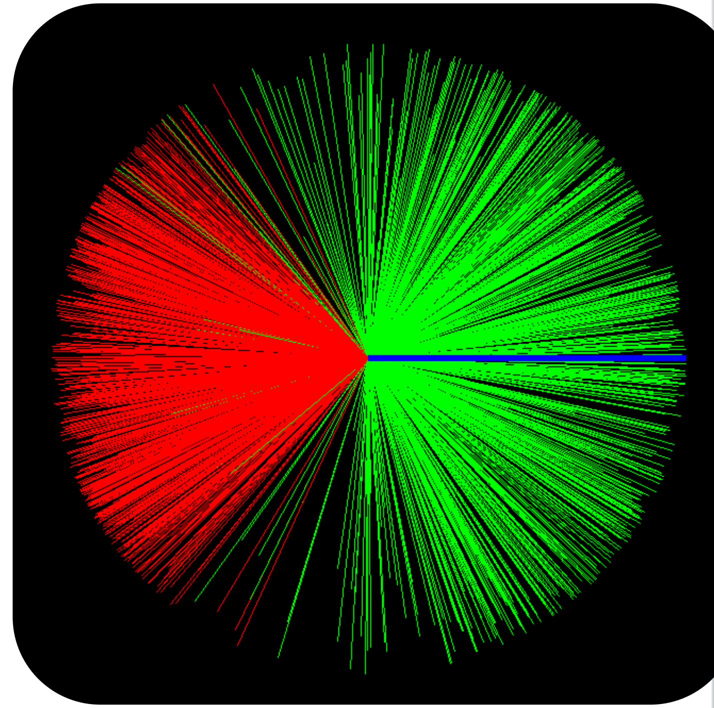
O. Hen et al. (CLAS Collaboration), Phys. Lett. B **772**, 63 (2013)

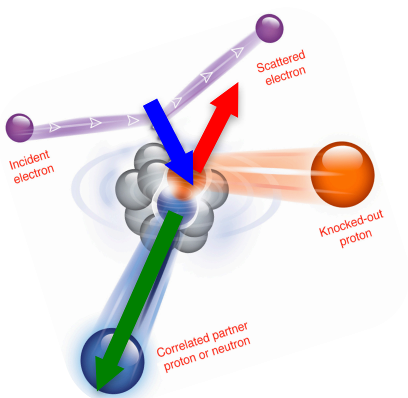
*Quasielstic knockout of high-initial-momentum protons

3D Reconstruction

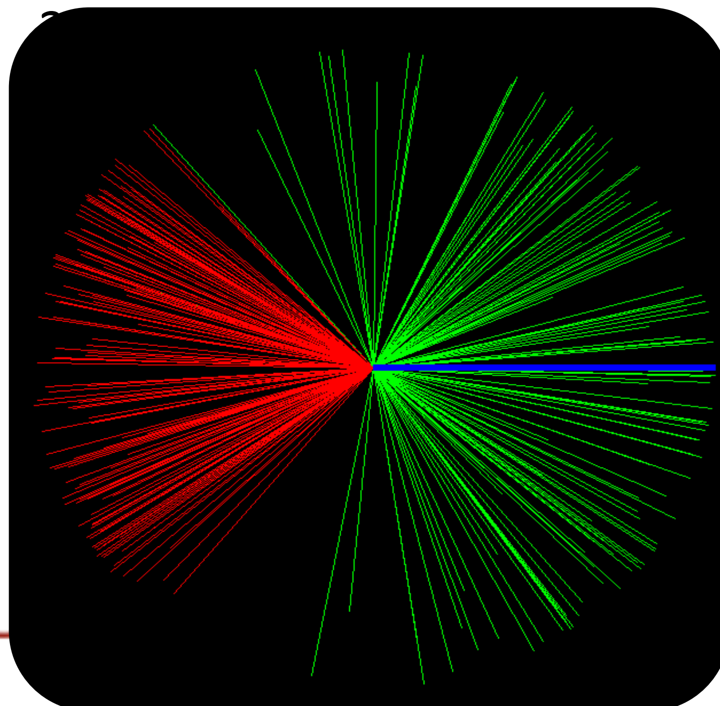


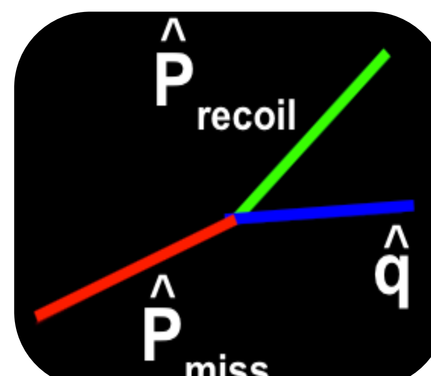




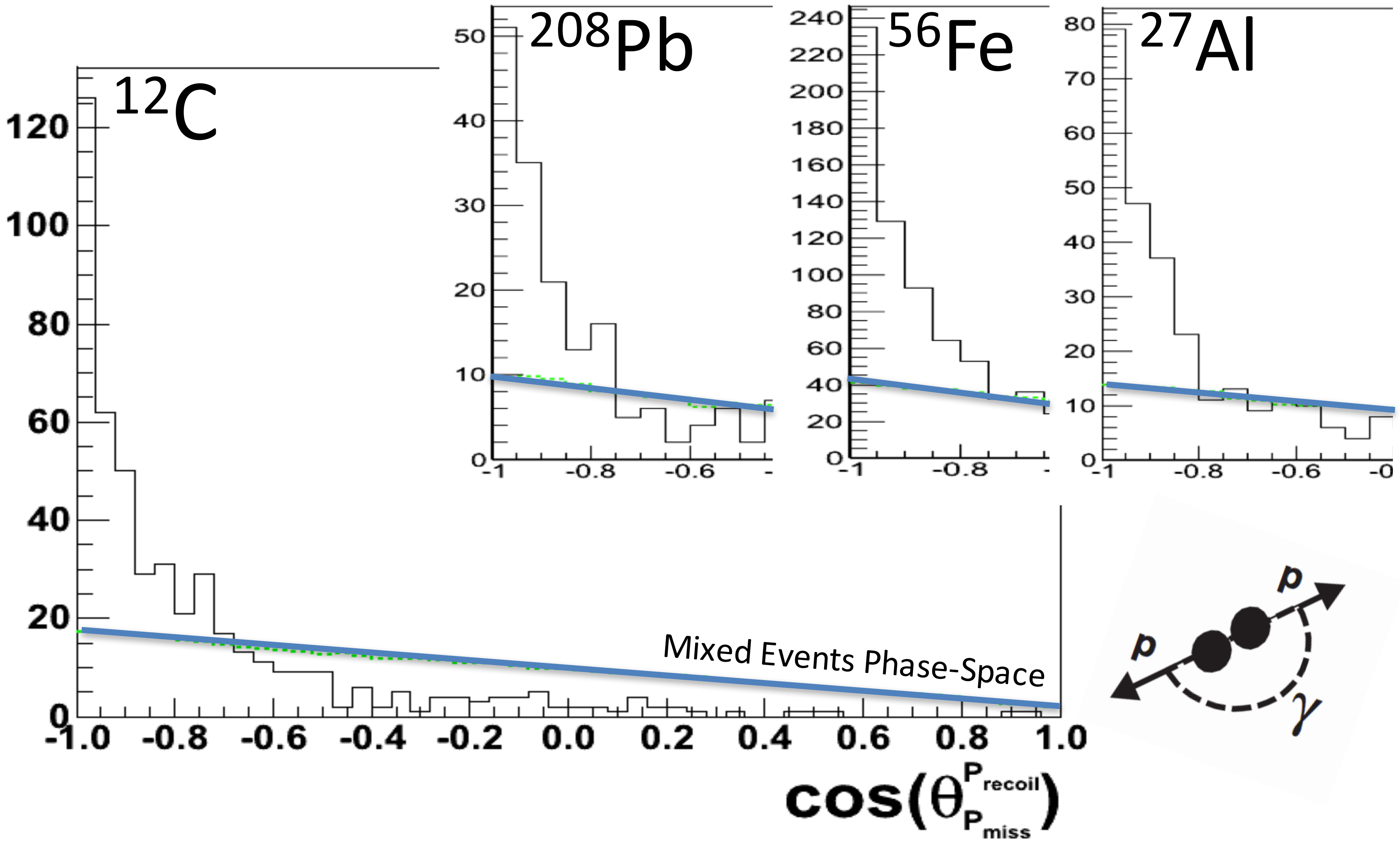


Back-to-back =
SRC pairs!

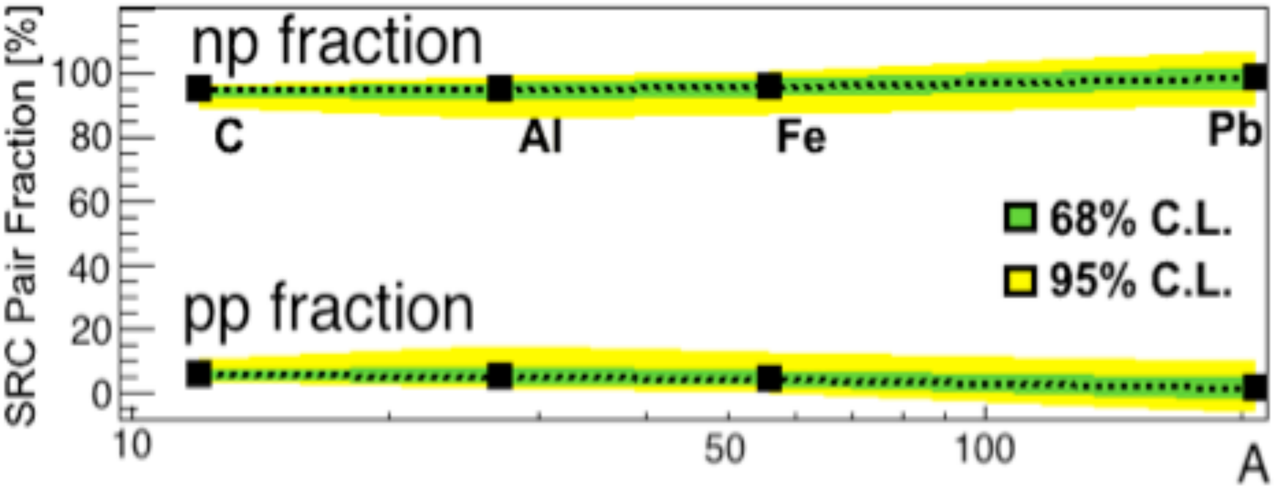




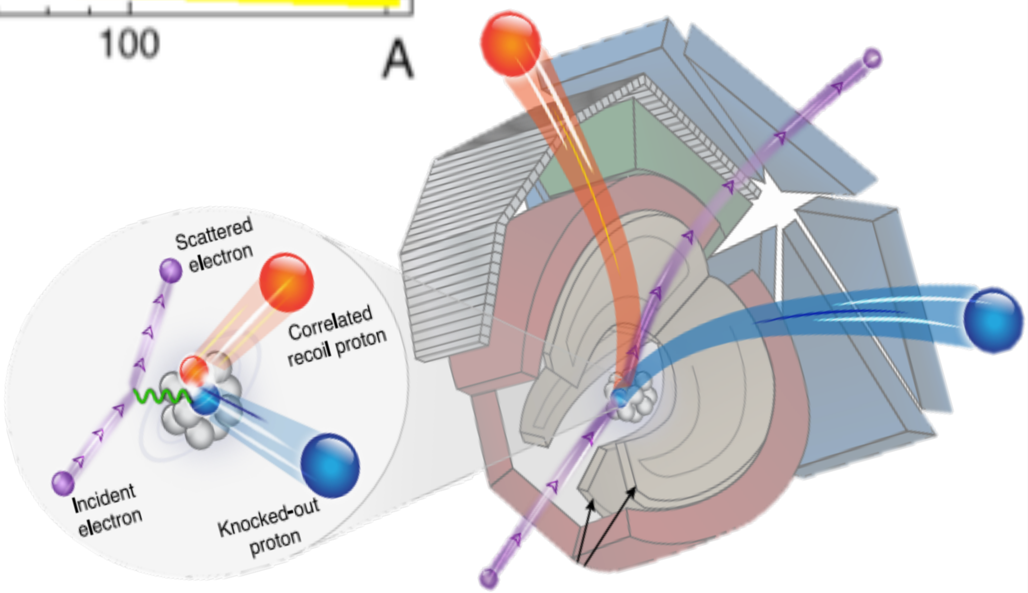
Opening Angle



np-pairs dominance in *heavy* nuclei



Extracted from
A(e,e’pp)/^{12}C(e,e’pp) and
A(e,e’pp)/^{12}C(e,e’pp)
Cross-section ratios



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

What Else? (e,e'pp)/(e,e'p)

- Previously published A(e,e'p)/^{12}C(e,e'p) and A(e,e'pp)/^{12}C(e,e'pp) cross-section ratios

- Still need to extract A(e,e'pp)/A(e,e'p) ratios, as a function of $|P_{miss}|$.
  - Relates to the fraction of pp-SRC pairs out of all high-momentum protons.
  - Expected to grow with $|P_{miss}|$, as we move from tensor dominated to the scalar (??) repulsive core.

A(e,e'pp)/A(e,e'p) Extraction

The leading proton kinematics [i.e. A(e,e'p) part] is identical for the two reactions.

⇒The ratio extraction only required correcting for the recoil proton acceptance.

How to correct for the acceptance?

1. Use a theory motivated event generator to extract the recoil proton distribution in A(e,e'pp) events.
2. Run it thorough the CLAS M.C.
3. See how many events are accepted

Data Based Event Generator

Standard Procedure:

1. Start with the measured A(e,e'p) events.
2. For each event raffle 100 c.m. momentum vectors ($P_{c.m.}$) that are Gaussians in each direction with a constant width ($\sigma_{c.m.}$).
3. Define a recoil proton momentum using:

   $$P_{recoil} = P_{c.m.} - P_{miss}$$

4. Run the generates A(e,e'pp) events through the detector simulation.
5. Repeat 1-4 using different $\sigma_{c.m.}$ until best agreement with the measured c.m. distribution is observed

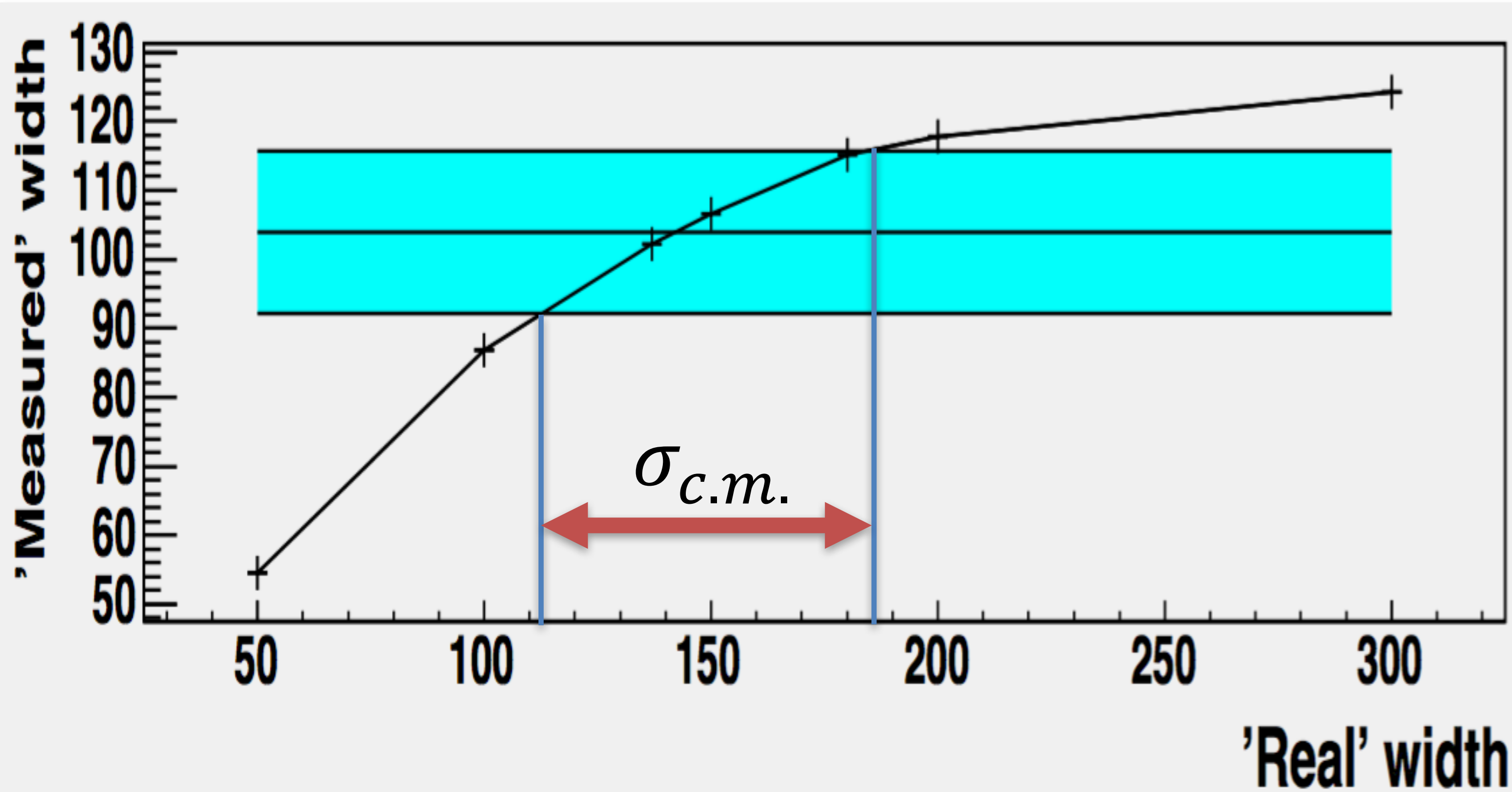
R. Shneor et al., PRL (2007) ; R. Subedi et al., Science (2008) ; I. Korover et al., PRL (2014)

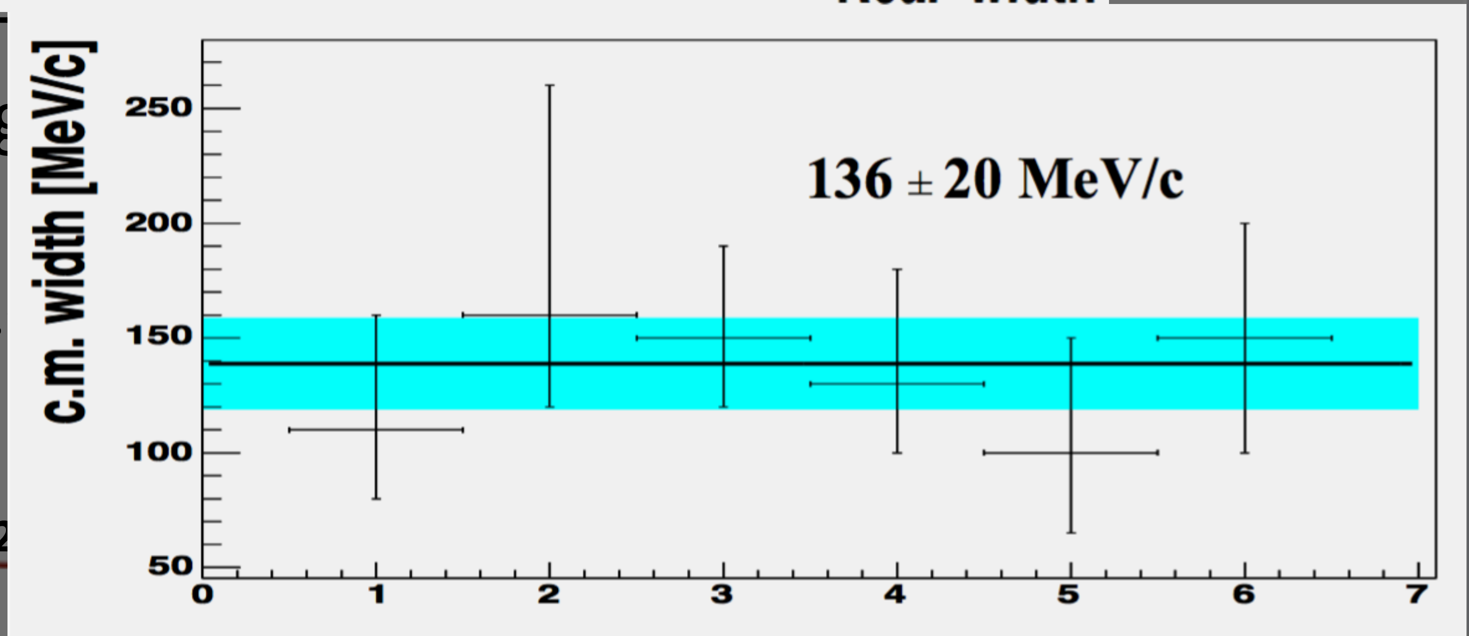
…or

…vectors
…with a

p_{recoil} …

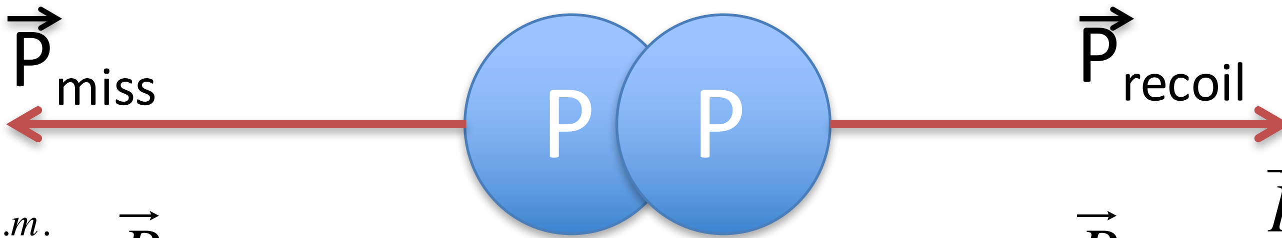
4. Run the … detector …
5. Repeat 1… with the …





R. Shneor et al., PRL (2…

CLAS issue – complex c.m. model



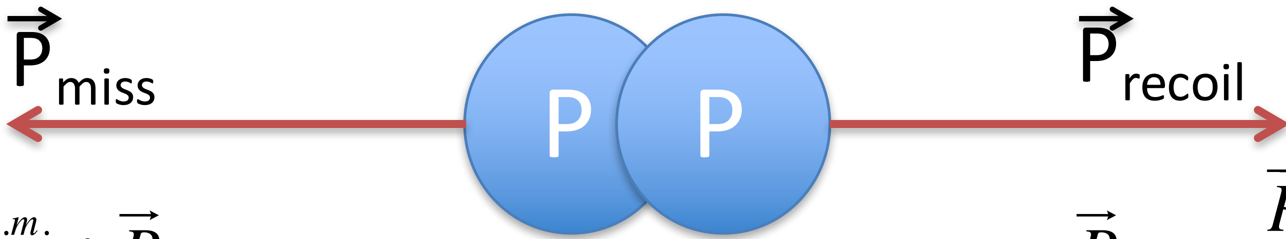
$$\vec{P}_{miss} = \frac{\vec{P}_{c.m.}}{2} + \vec{P}_{relative}$$

$$\vec{P}_{miss} = \frac{\vec{P}_{c.m.}}{2} - \vec{P}_{relative}$$

$$|P_{miss}| \neq |P_{recoil}|$$

[Due to c.m. motion of the pair]

CLAS issue – complex c.m. model



$$\vec{P}_{miss} = \frac{\vec{P}_{c.m.}}{2} + \vec{P}_{relative}$$

$$\vec{P}_{miss} = \frac{\vec{P}_{c.m.}}{2} - \vec{P}_{relative}$$

$$|P_{miss}| \neq |P_{recoil}|$$

[Due to c.m. motion of the pair]

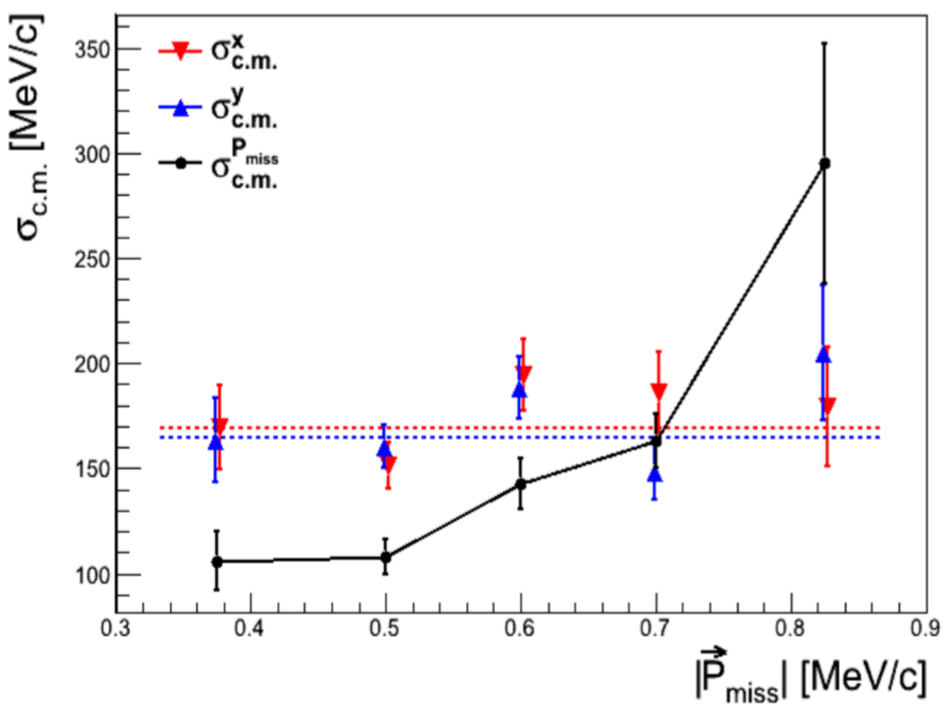
Focus on $\vec{P}_{miss}$:

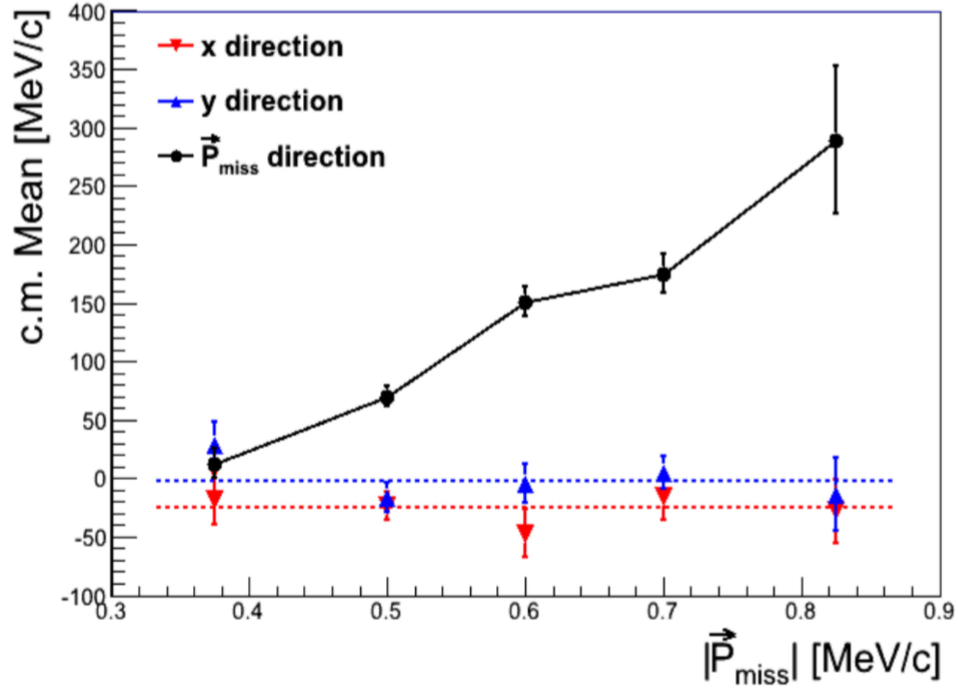
Case I:

Case II:

$$\vec{P}_{miss} = \frac{\vec{P}_{c.m.}}{2} + \vec{P}_{relative}$$

CLAS issue – complex c.m. model





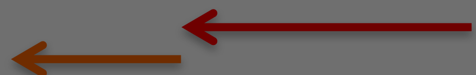
CLAS issue – complex c.m. model

<u>Bottom Line:</u>

1. Need to do a 3D fit that requires substantial resources.
2. Simple χ^2 (/log-likelihood) test is not appropriate for 3D – need to employ a ‘smarter’ statistical test.

and a $P_{c.m.}$ that points in its direction (i.e. case II)

Case II:



Way out

1. Implement at fast M.C.
   – Apply fiducial cuts to the recoil proton (previously done for π^+).
   – Extract from GSIM the proton detection efficiency in the fiducial region.
   – Use maps to determine if a simulated event in within the fiducial and if so weight it by the detection efficiency.
2. Preform an ‘Energy-Test’ to compare the simulated and measured c.m. distributions in 3D, including their $|P_{miss}|$ dependence.

Energy test

- Calculate the self-energy and interaction energy of a sample of data-events (D) and monte-carlo events (MC).

$$\Phi_D = \frac{1}{n_D^2} \sum_{i=2}^{n_D} \sum_{j=1}^{i-1} \psi(|\mathbf{x}_i^D - \mathbf{x}_j^D|)$$

$$\Phi_{MC} = \frac{1}{n_{MC}^2} \sum_{i=2}^{n_{MC}} \sum_{j=1}^{i-1} \psi(|\mathbf{x}_i^{MC} - \mathbf{x}_j^{MC}|)$$

- Minimize the interaction energy to determine the most appropriate fit value.

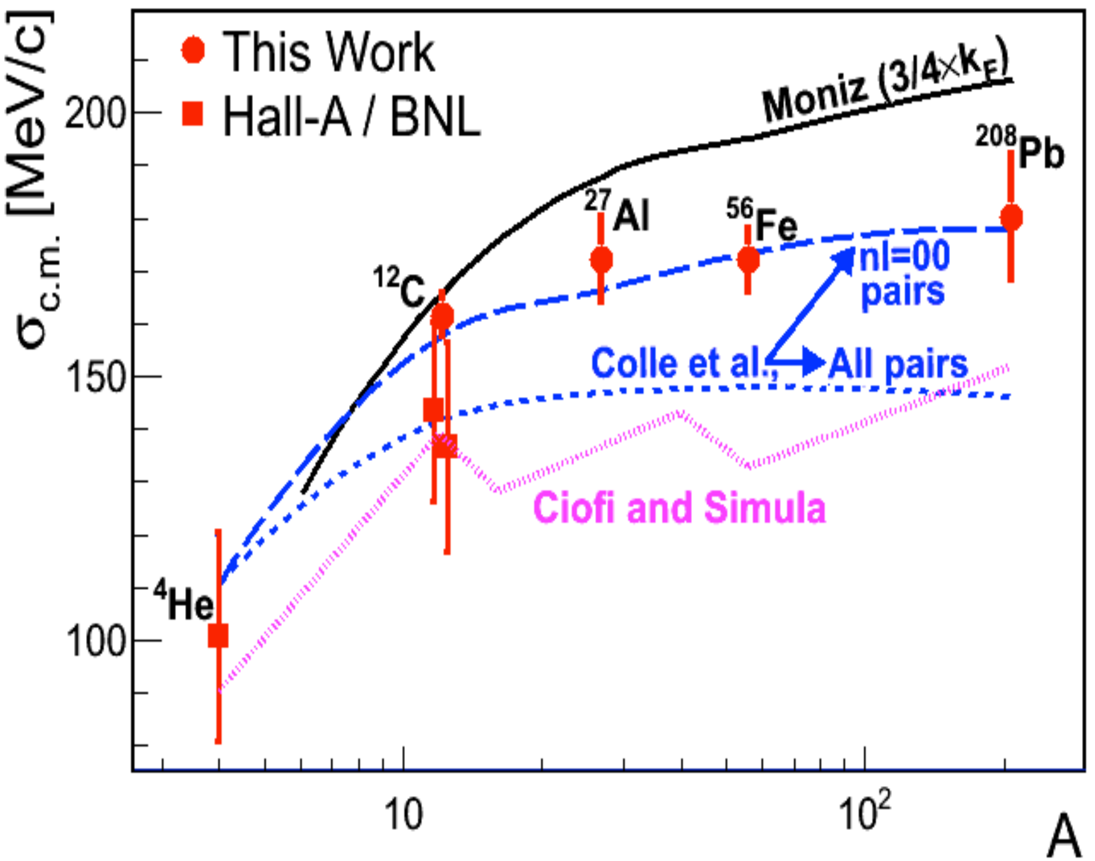
$$\Phi_{DMC} = -\frac{1}{n_D n_{MC}} \sum_{i=1}^{n_D} \sum_{j=1}^{n_{MC}} \psi(|\mathbf{x}_i^D - \mathbf{x}_j^{MC}|)$$

Bootstrap to get the uncertainty

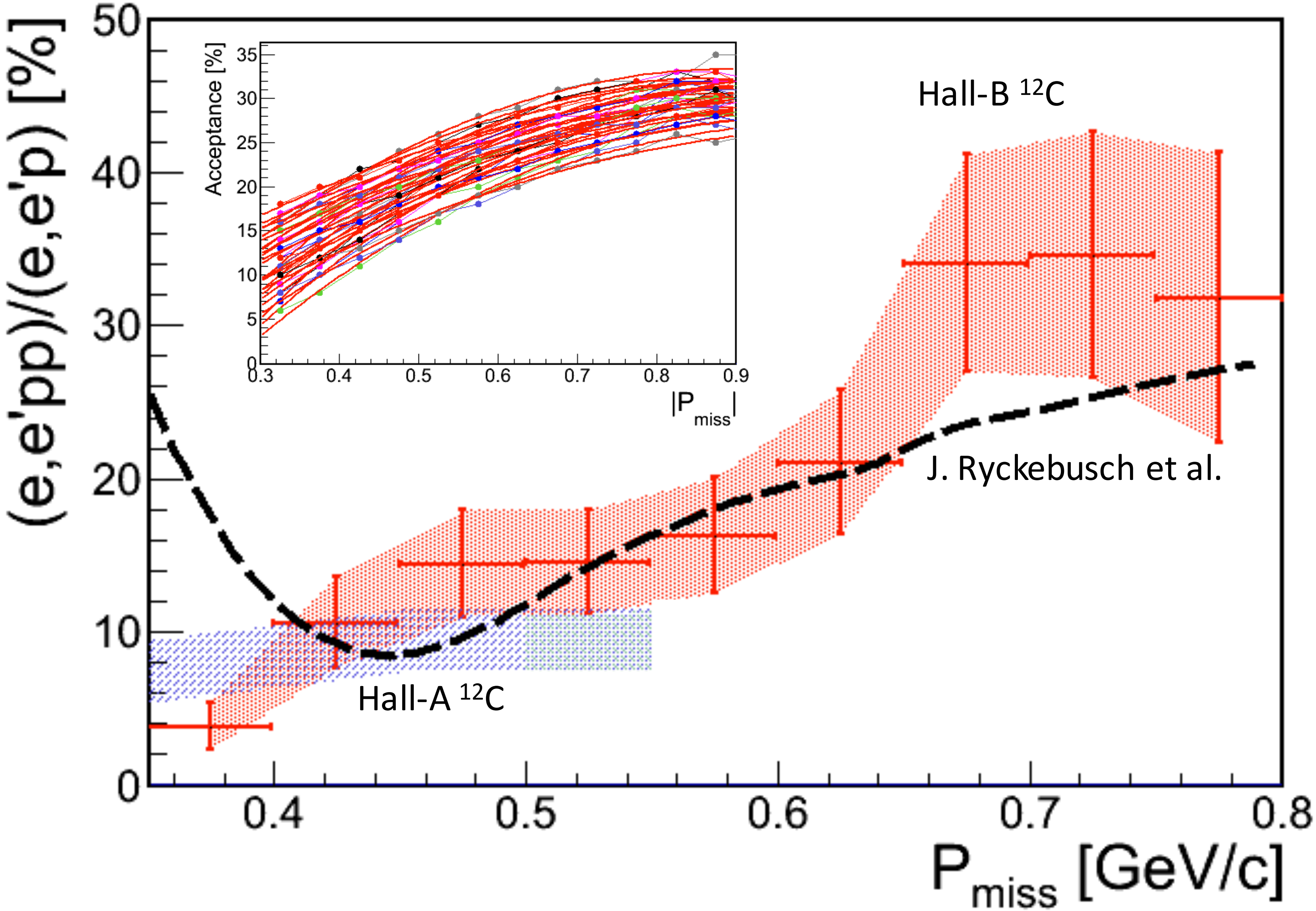
Preliminary Results

"… high relative momentum and *<u>low c.m. momentum</u>* compared to the Fermi momentum (k_F)"

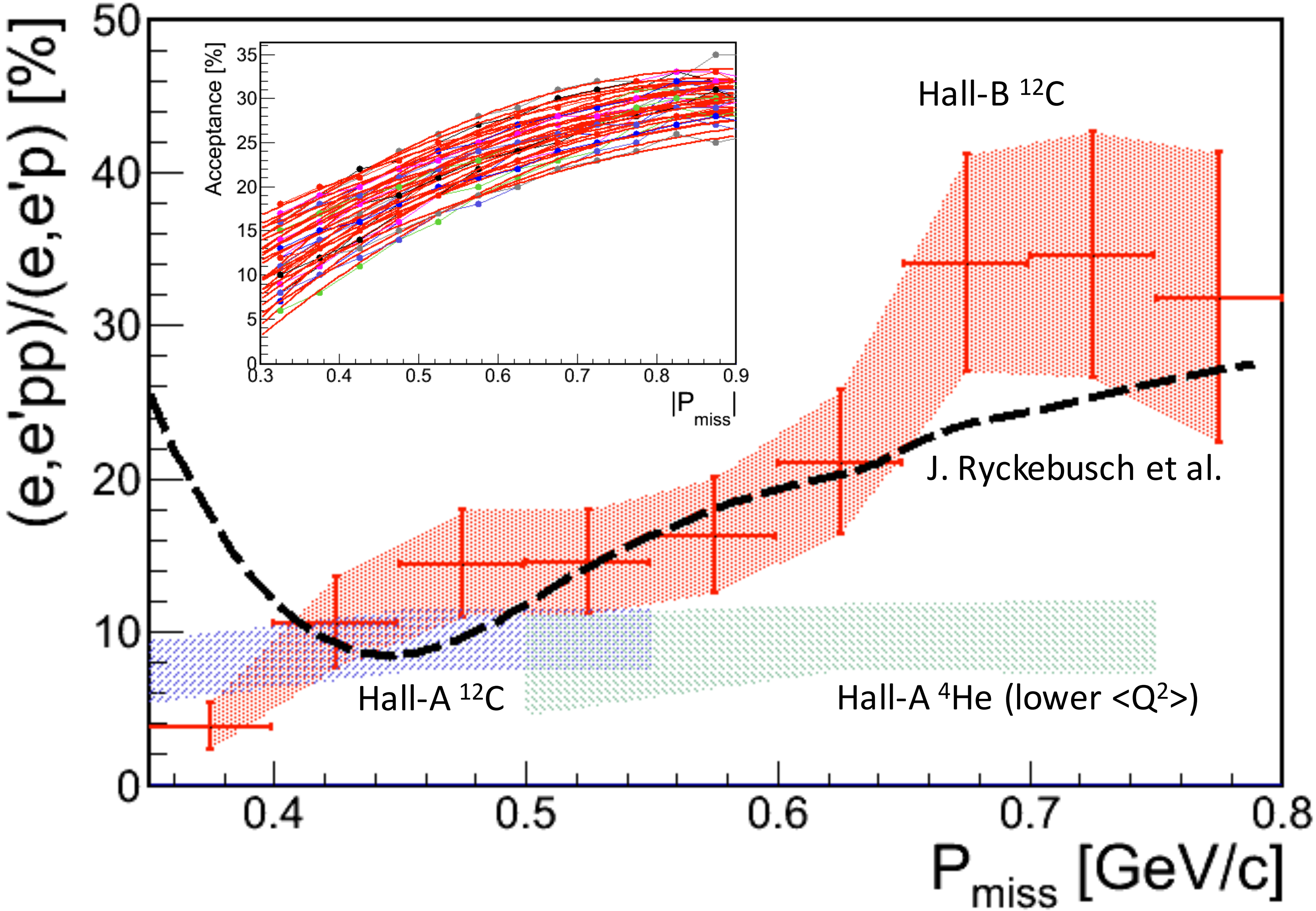
- Reconstructed total (c.m) pair momentum insensitive to FSI in the pair.
- Observed to be Gaussian in each direction.
- Small width, consistent with calculations.



Preliminary Results



Preliminary Results



The group

- MIT:

Barak Schmookler

Navaphon (Tai) Muangma

Reynier Torres

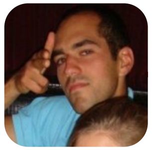
  – Or Hen
  – Shalev Gilad

- ODU:

Mariana Khachatryan

  – Larry Weinstein

- Tel-Aviv:



Erez Cohen

Meytal Duer

Igor Korover

  – Eli Piasetzky

- Many theory friends ☺

Looking for two new postdocs !

The group

- MIT:

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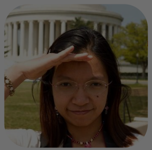

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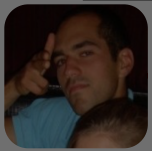

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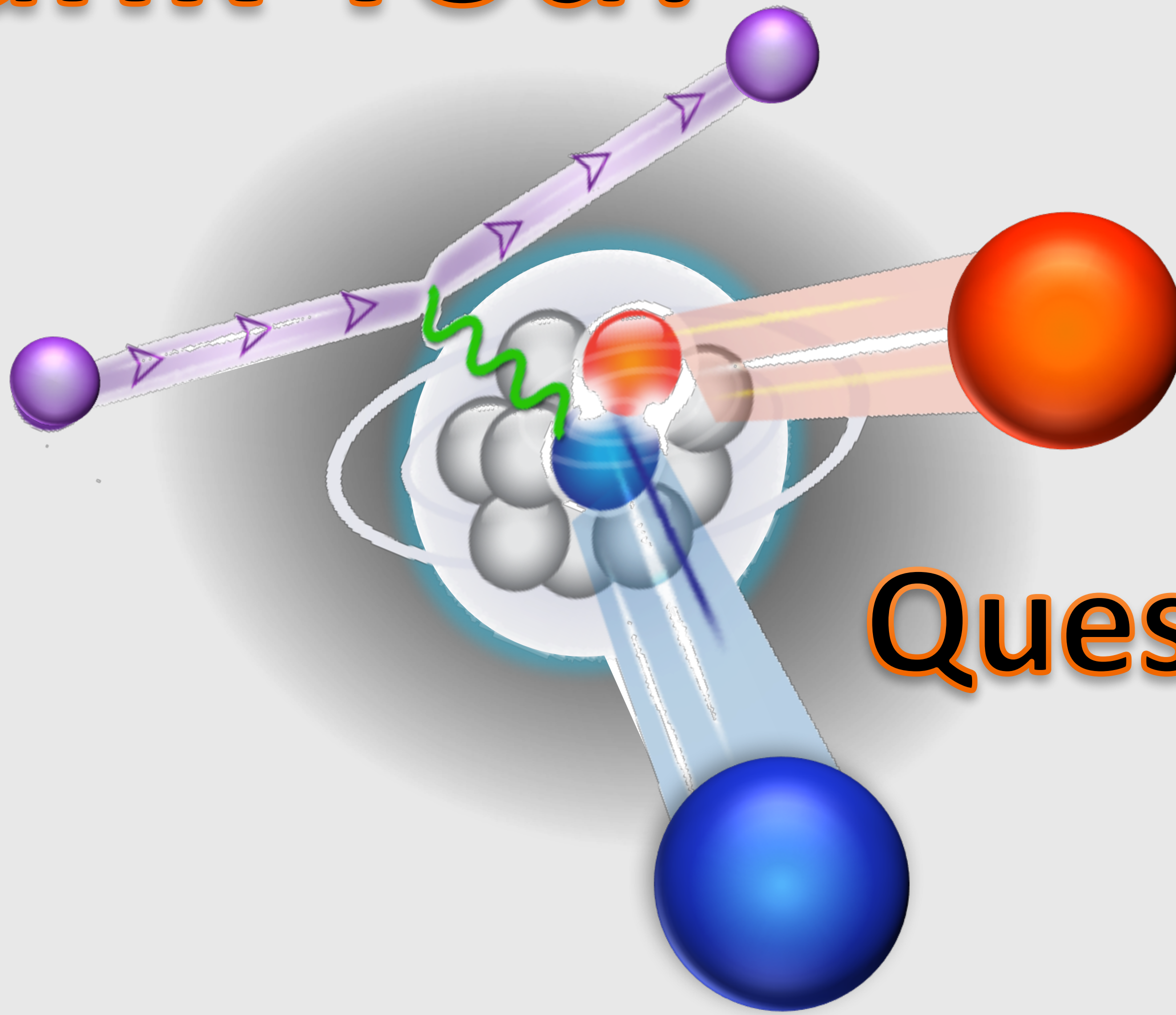
Thank You!



Questions?