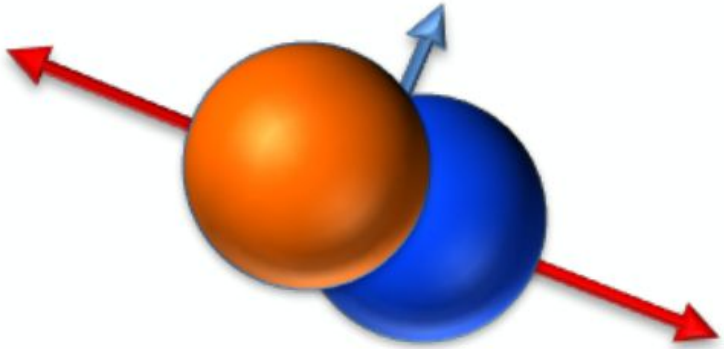
Precision Short Range Correlation studies in Nuclei

Justin Estee (MIT)

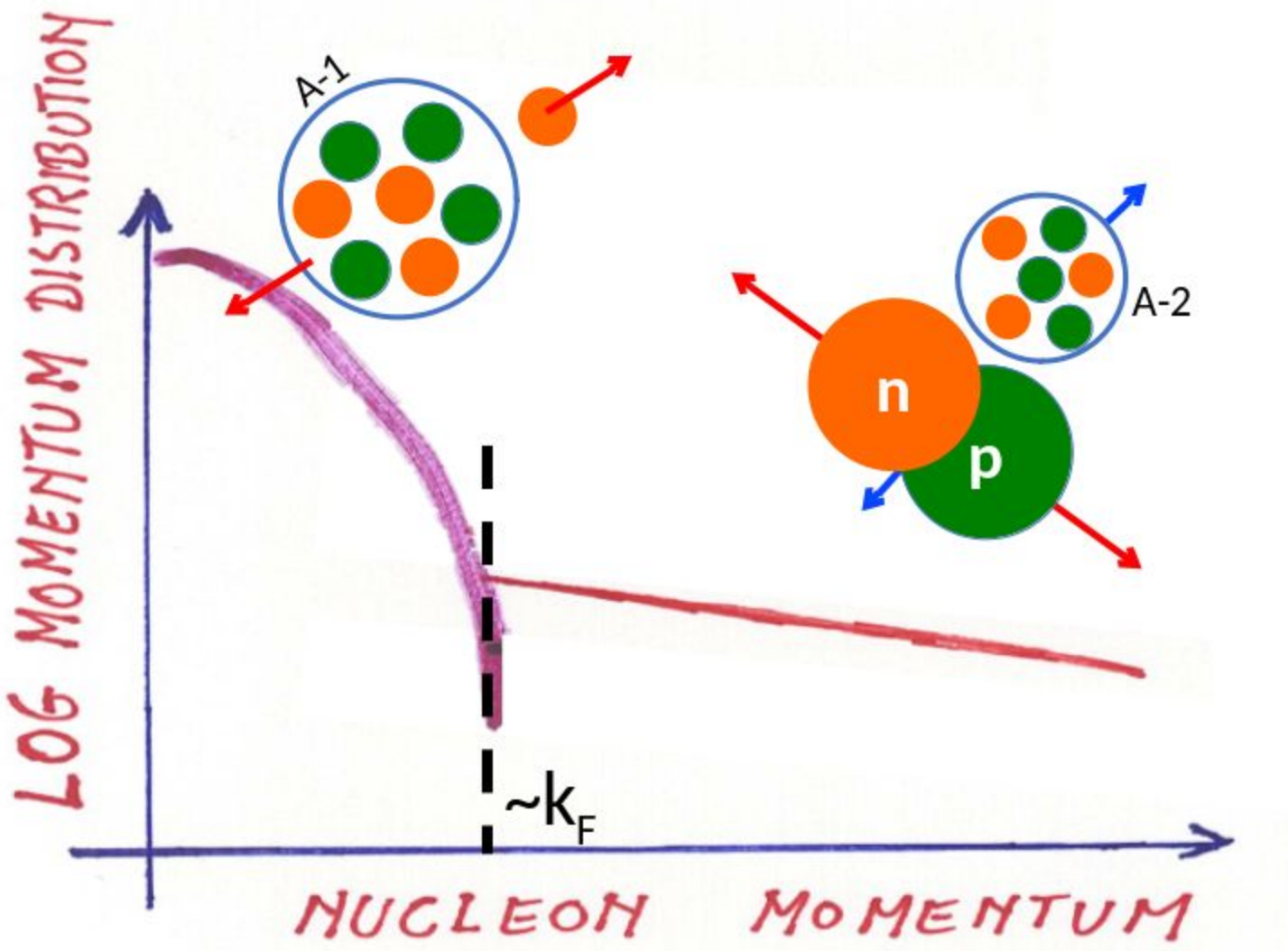
Short range, short lived,
highly correlated pairs

r-space

High relative momentum
Low center of mass momentum



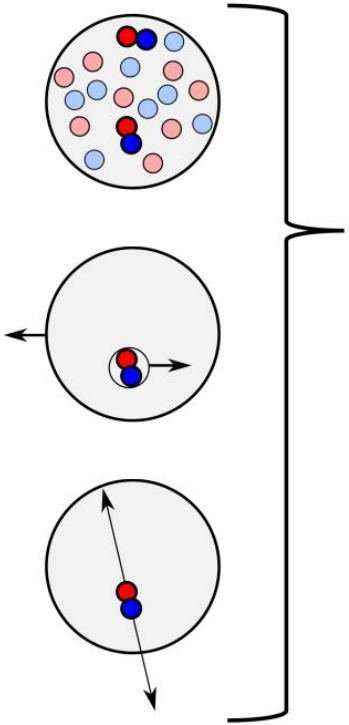
k-space


LOG MOMENTUM DISTRIBUTION
A-1
A-2
n
p
~k_F
NUCLEON MOMENTUM

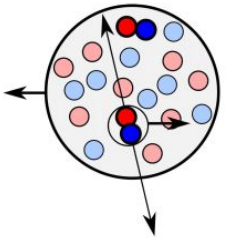
Pair Abundance

Center of Mass Motion

Pair Interaction



SRC Component of the Wave-Function

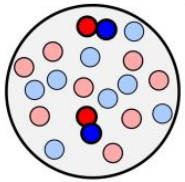


$$\sigma = \sigma_{eN}(q) \cdot C_A^{NN} \cdot |\phi(p_{rel})|^2 \cdot n(p_{CM})$$

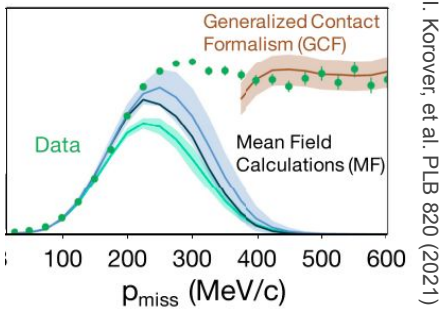
NN sum over (np,pp,nn)

What we know…

Pair Abundance

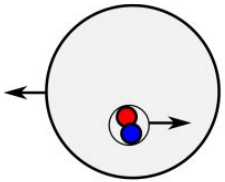


SRC dominate for p > 350 MeV/c

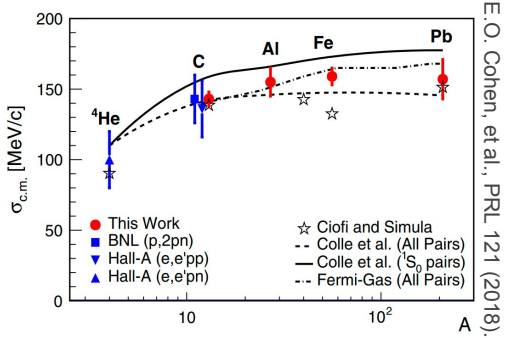


I. Korover, et al. PLB 820 (2021)

Center of Mass Motion

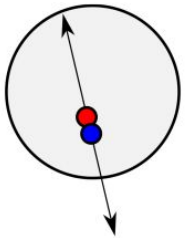


Measured P_{CM} motion

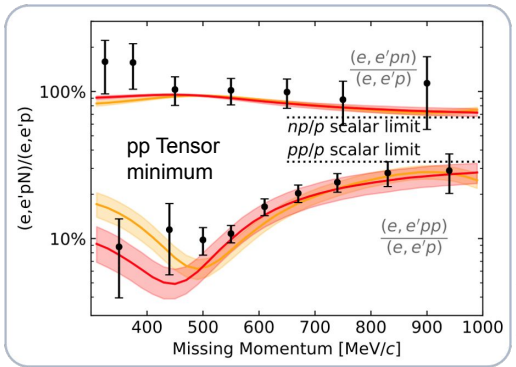


E.O. Cohen, et al., PRL 121 (2018).

Pair Interaction



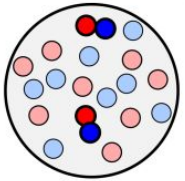
tensor to scalar transition
neutron-proton pairs dominate



Korover et al. PLB (2021)

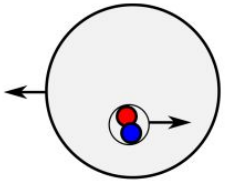
next generation questions…

Pair Abundance



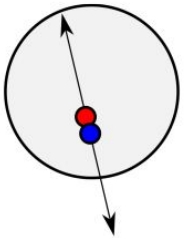
Where are pairs formed?
Which nucleons pair?
Do 3N SRC exist?

Center of
Mass Motion



Precision CM measurements

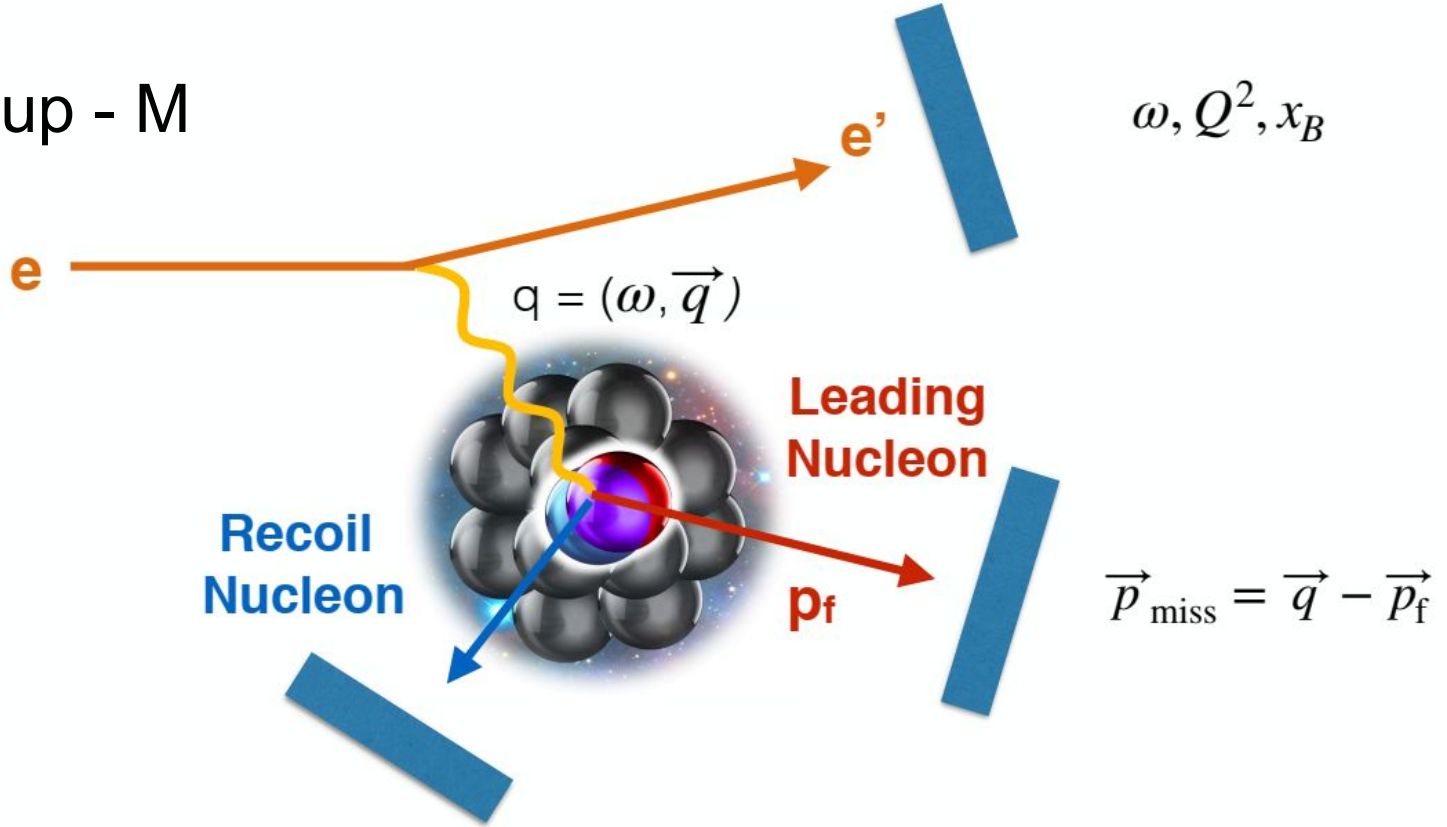
Pair Interaction



Precision NN interaction at short distances

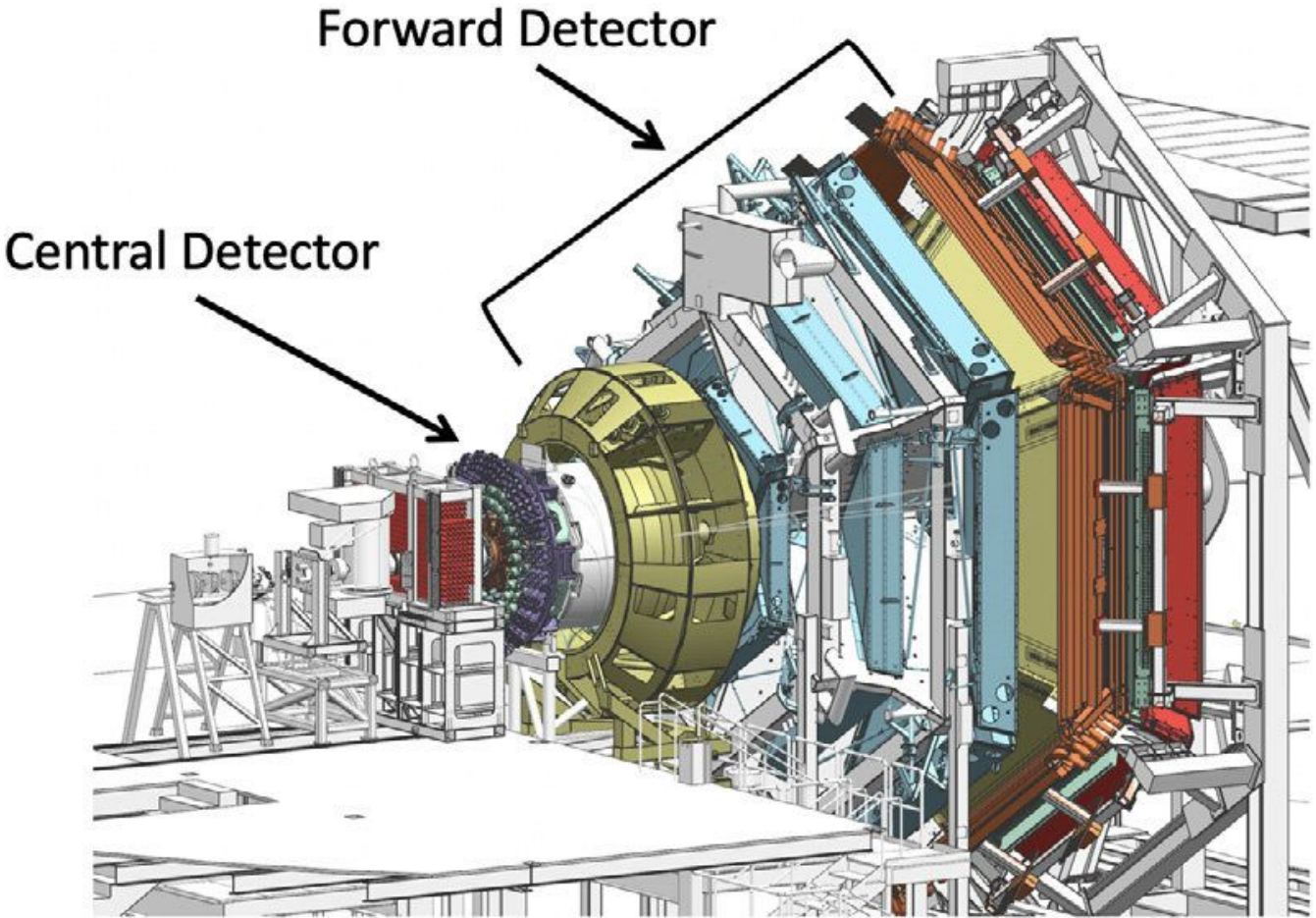
Scale (Q2) independence of SRC observables

Run Group - M



- (e,e') inclusive
- (e,e'N)
- (e,e'NN)

CLAS12 Detector (Hall B)
CEBAF Large Acceptance Spectrometer for operation at 12 GeV @ JLAB

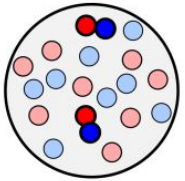


Run Group-M (RGM)

- Ran November 2021 - February 2022
- (H, D, ^{4}He, ^{40}Ar, ^{40}Ca, ^{48}Ca, ^{120}Sn)
- Fully calibrated, currently reconstructing data

next generation questions…

Pair Abundance



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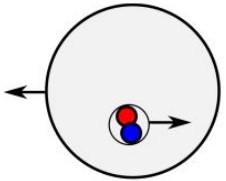
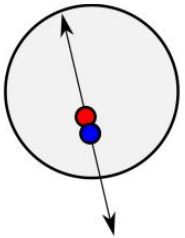


Precision COM measurements

Pair Interaction



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Precision NN interaction

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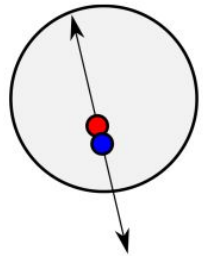
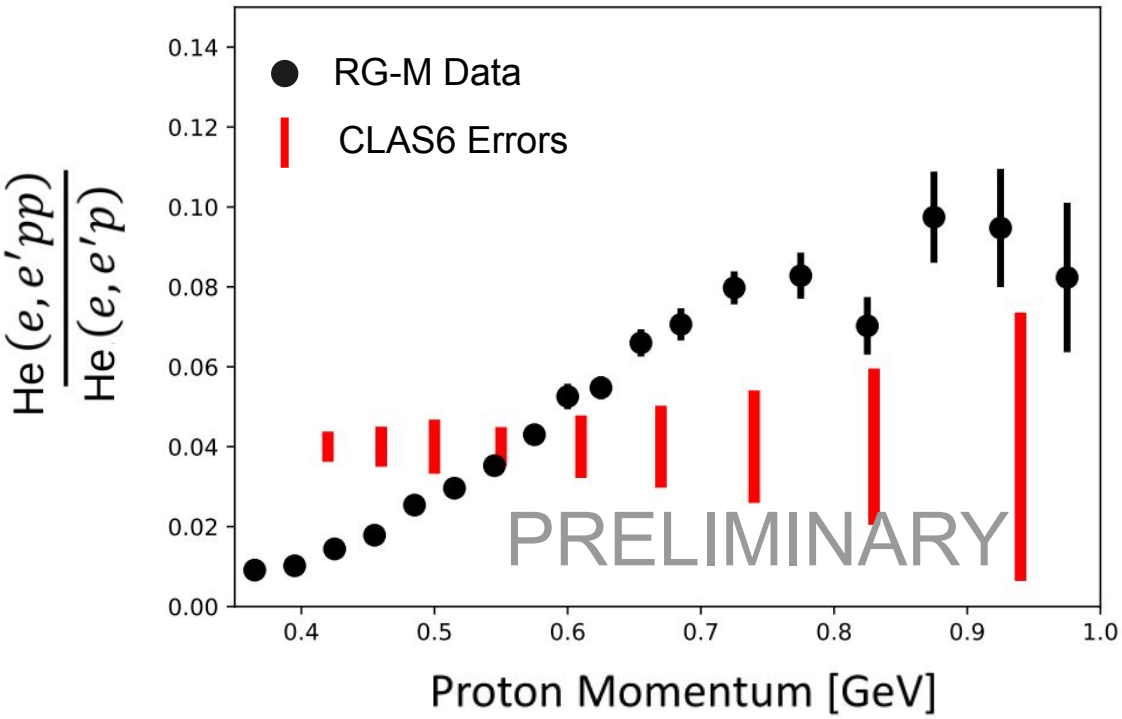
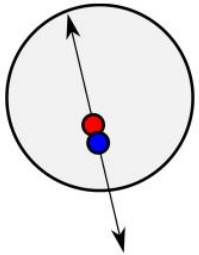
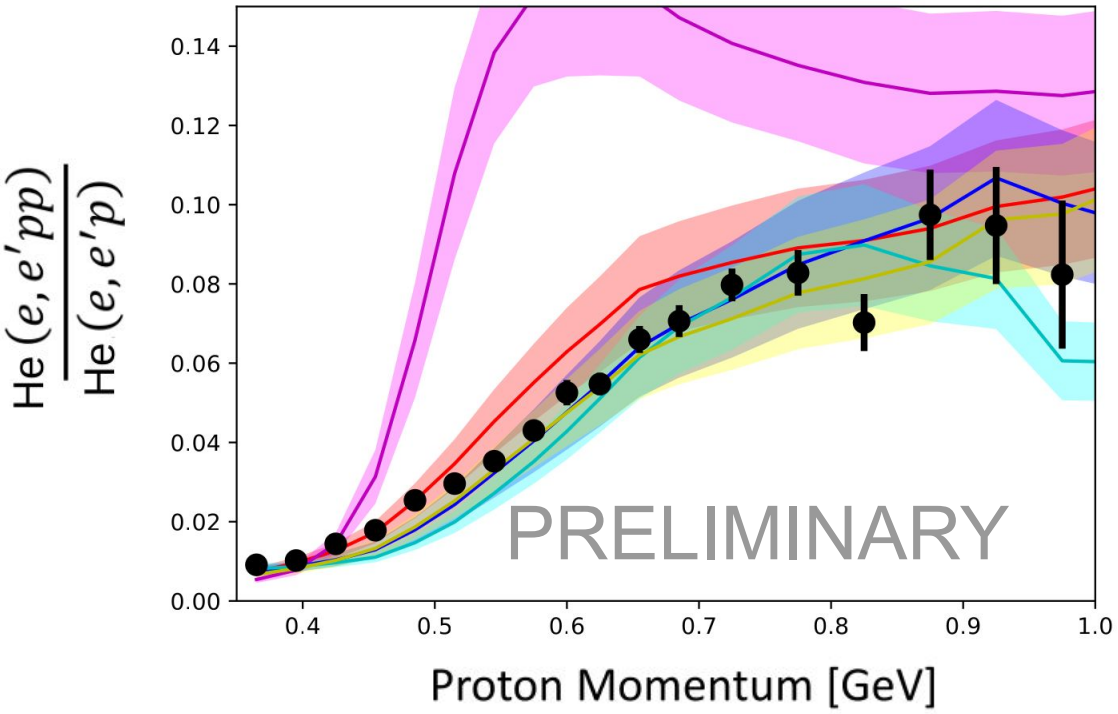




Precision NN interaction

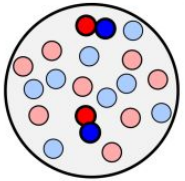
Pair Interaction





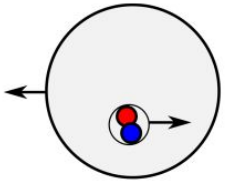
next generation questions…

Pair Abundance



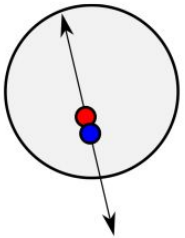
Where are pairs formed?
Which nucleons pair?
Do 3N SRC exist?

Center of
Mass Motion



Precision COM measurements

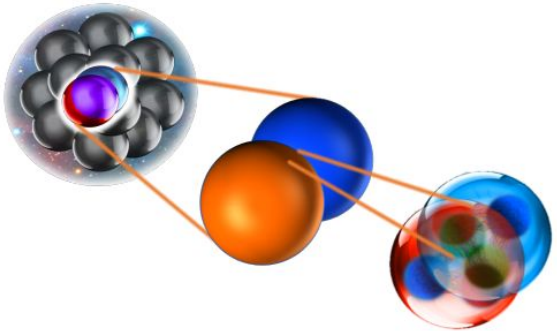
Pair Interaction



Precision NN interaction at short distances

Scale (Q2) independence of SRC observables

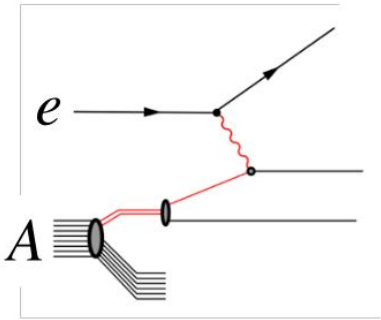
Scale

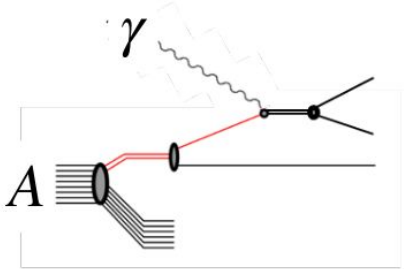


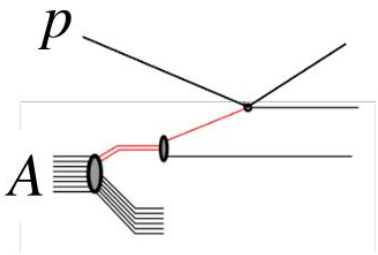
Change the resolution **scale** of the reaction by looking at dependence on momentum transfer Q^2, $|t|$

Probe

Compare different reactions using different **probes**: Electron-scattering, Proton-scattering, Photoproduction

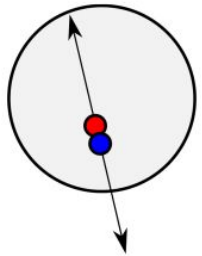


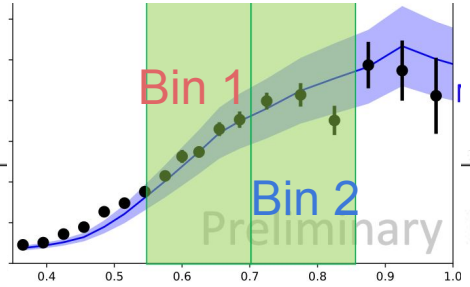




See Jackson Pybus's talk after this

Scale independence of Pair Interaction





Bin 1

$0.55GeV < p_{miss} < 0.7GeV$

N2LO 1.0fm

Preliminary

Bin 2

$0.7GeV < p_{miss} < 0.85GeV$

N2LO 1.0fm

Preliminary

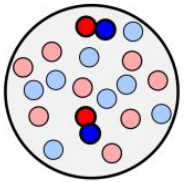
$\frac{\mathrm{He}\,(e,e'pp)}{\mathrm{He}\,(e,e'p)}$

Q^2

Q^2

next generation questions…

Pair Abundance



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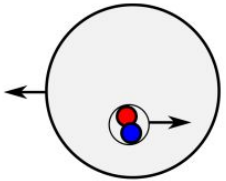

Precision COM measurements

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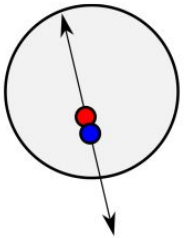
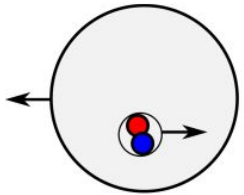


Precision NN interaction at short distances

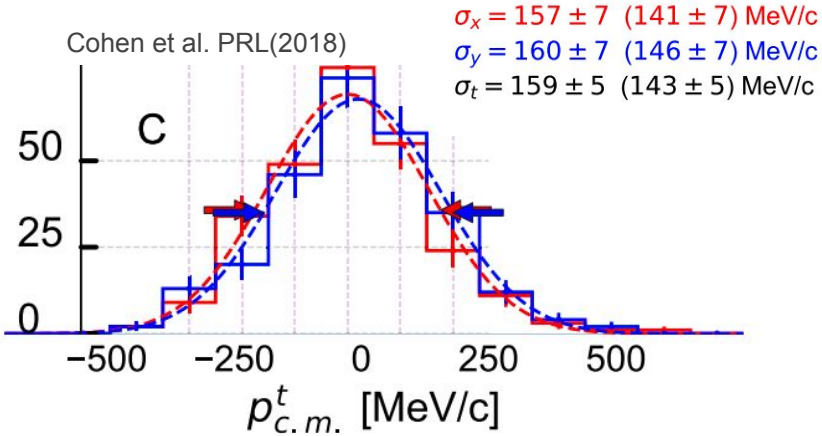
Scale (Q2) independence of SRC observables

Precision C.M. motion

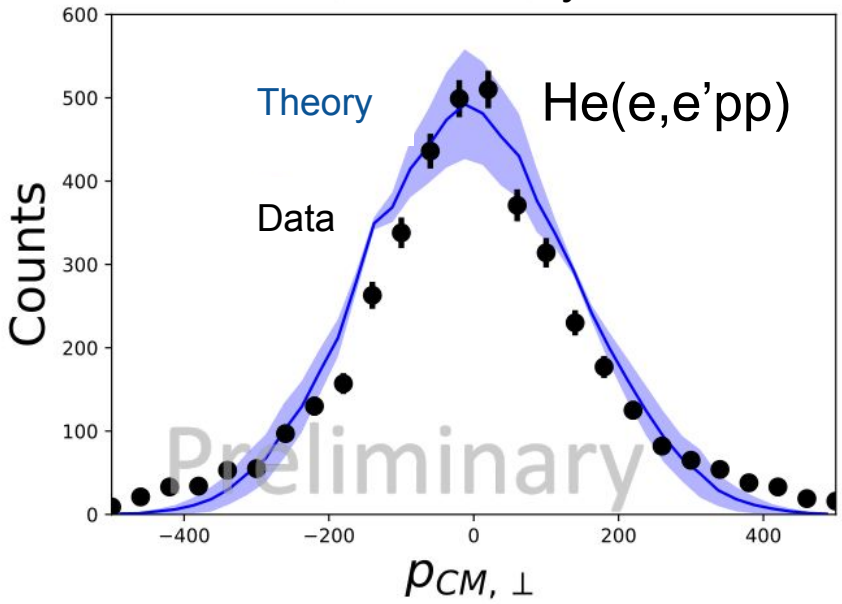
Center of Mass Motion



CLAS6 Data



RG-M Preliminary Data



Scale independence

Center of
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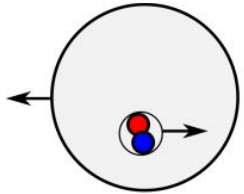
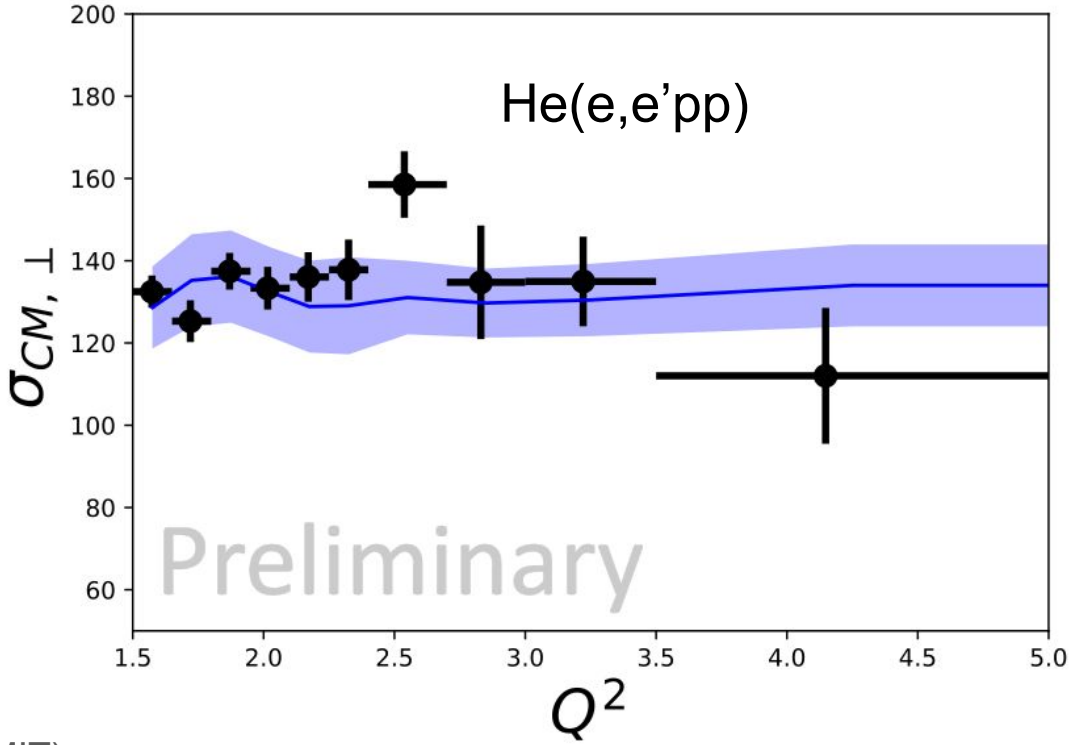
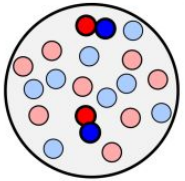




next generation questions…

Pair Abundance



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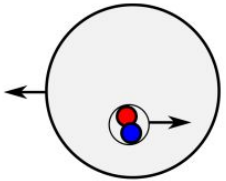

Precision COM measurements

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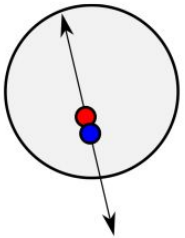
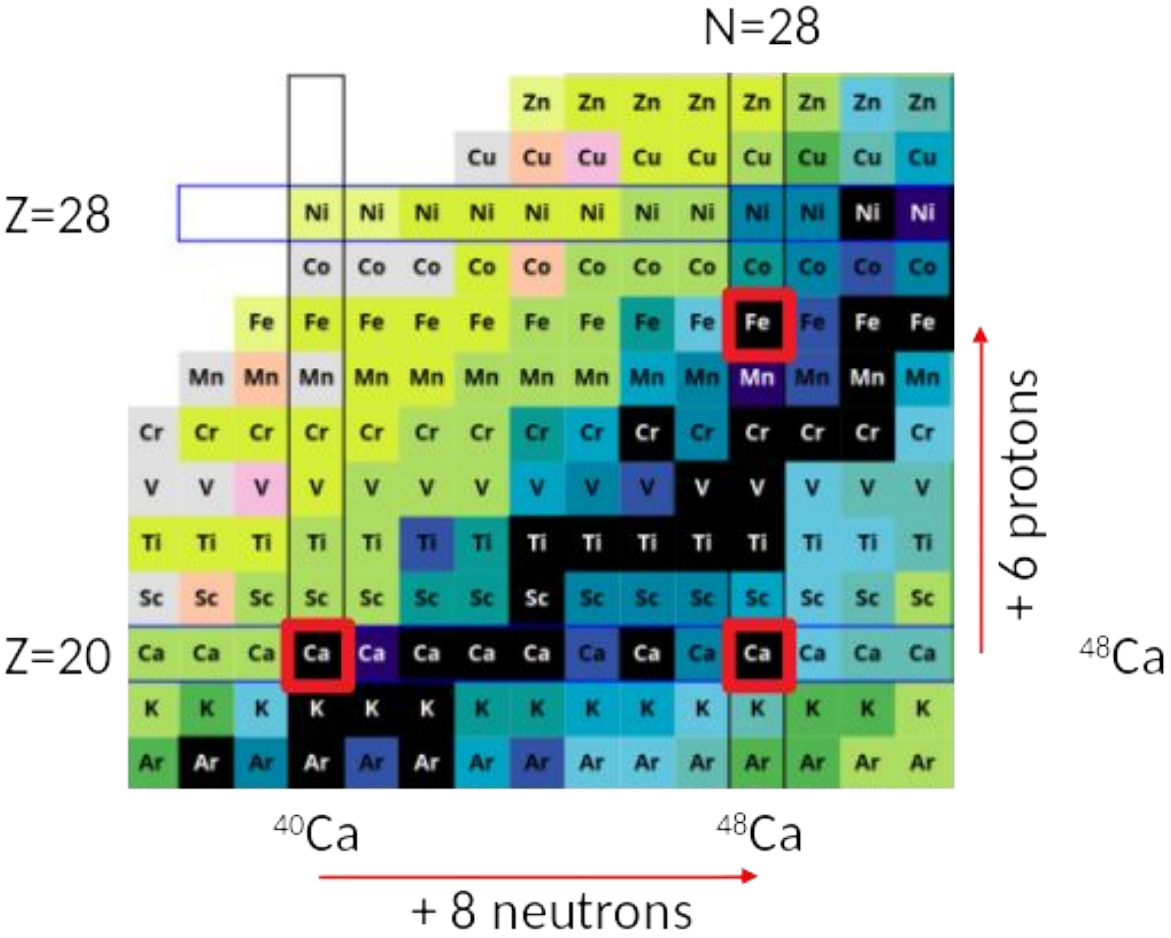
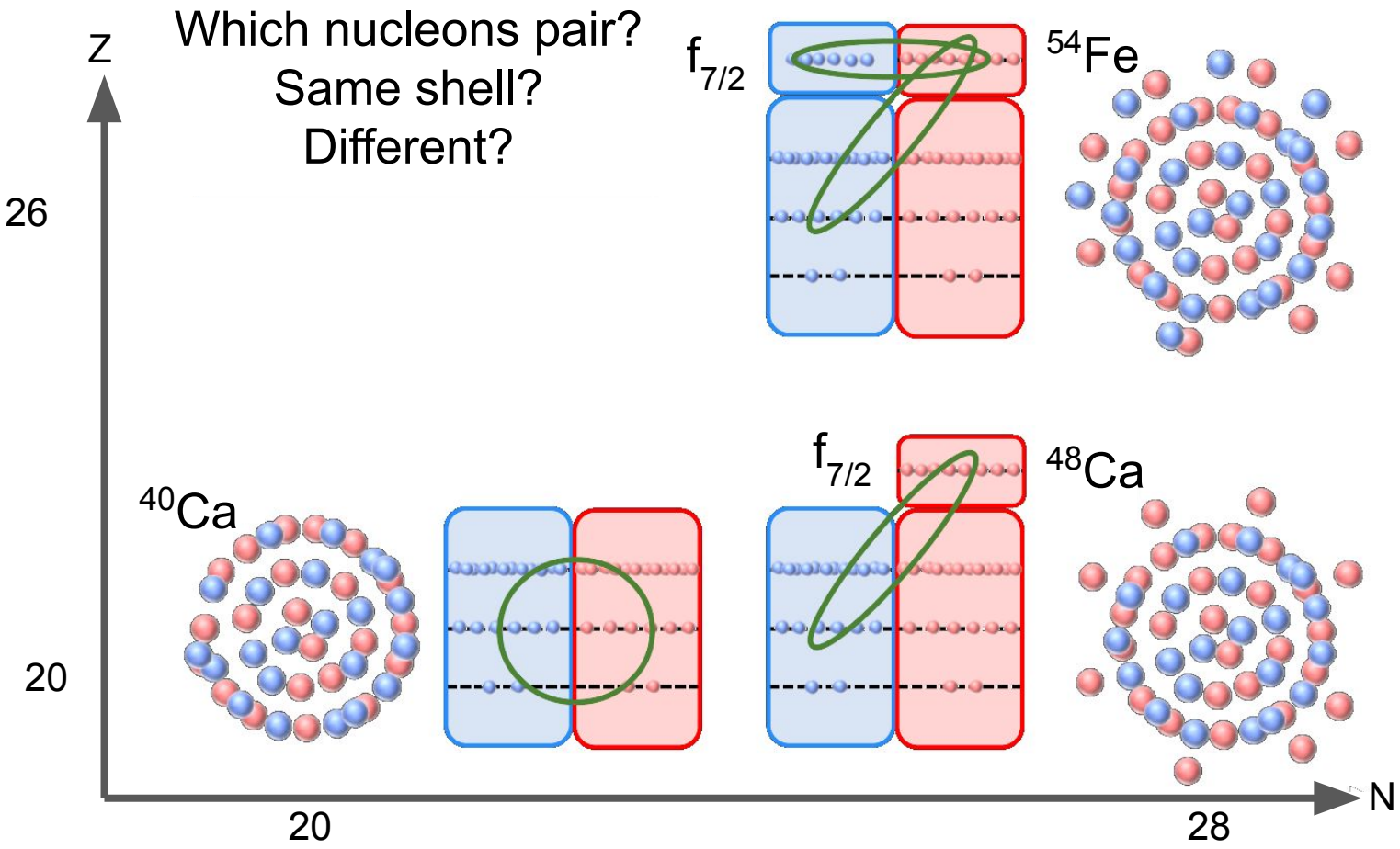


Precision NN interaction at short distances

Scale (Q2) independence of SRC observables

SRC in Asymmetric Nuclei CaFe Exp. (Hall C)

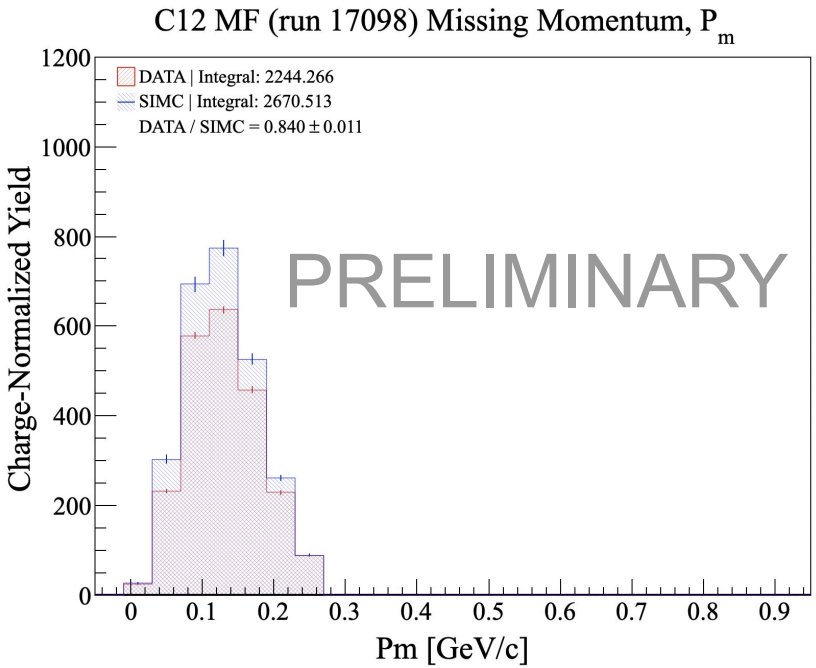


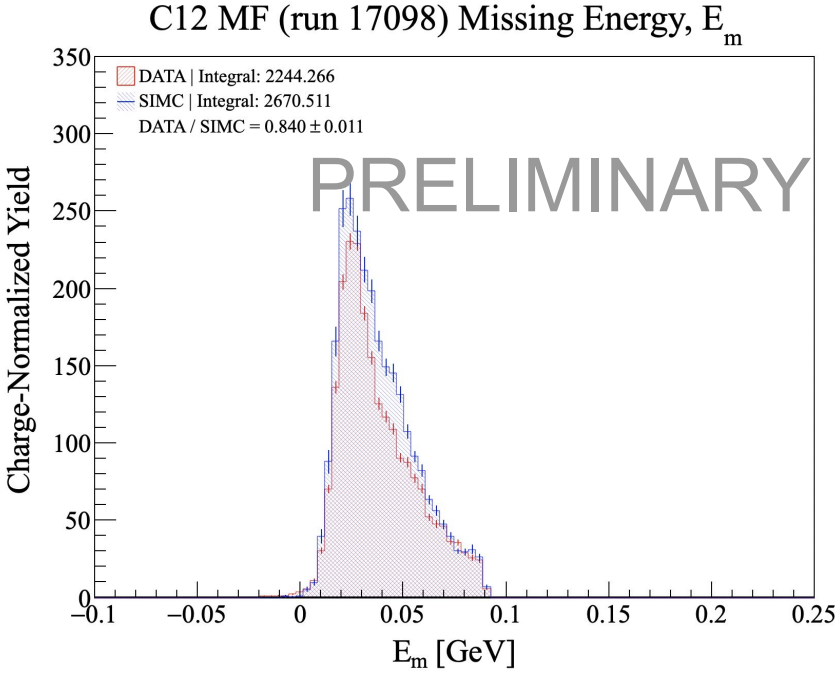

Which nucleons pair?
Same shell?
Different?
Z
26
20
20
28
N
$f_{7/2}$
^{54}Fe
^{40}Ca
$f_{7/2}$
^{48}Ca

CaFe and RG-M

- CaFe
  - 11 GeV: ^{9}Be, ^{10}B, ^{11}B, ^{12}C, ^{40}Ca, ^{48}Ca, ^{54}Fe
  - Small aperture spectrometers
  - Separate Mean field and SRC kinematic settings
  - (e,e’p) only
- RG-M
  - 6 GeV : C, ^{40}Ca, ^{48}Ca, ^{120}Sn
  - CLAS12
  - (e,e’p), (e,e’pN)

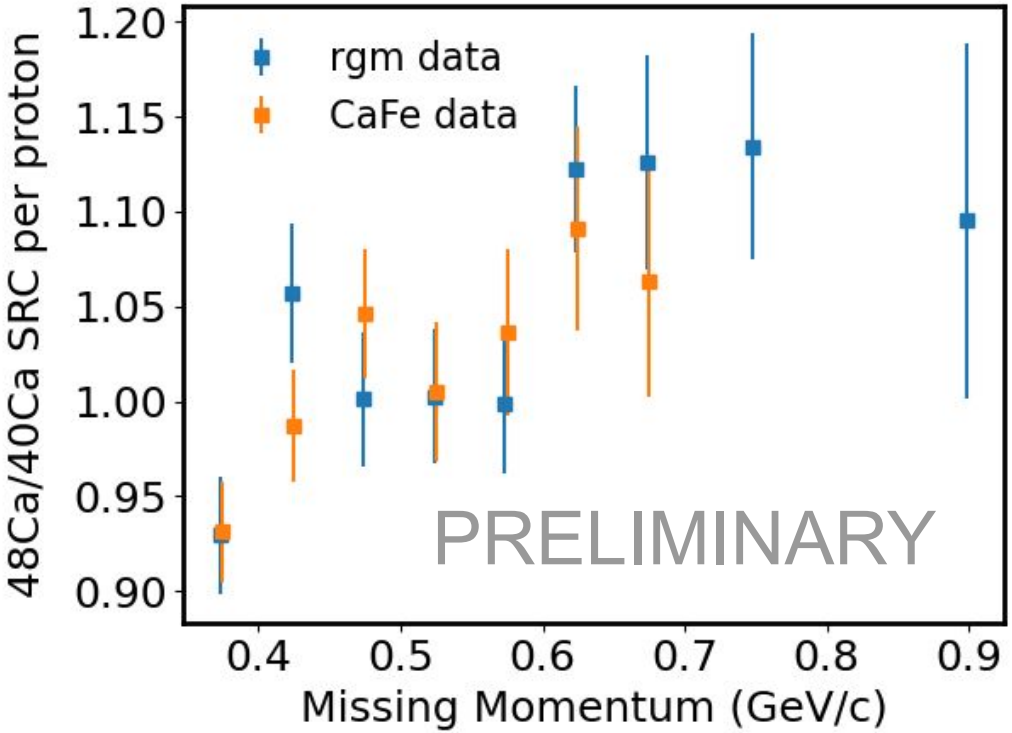
Data / MC comparison





Good agreement with mean field nucleons between data and simulation (SIMC)

RG-M and CaFe Agreement



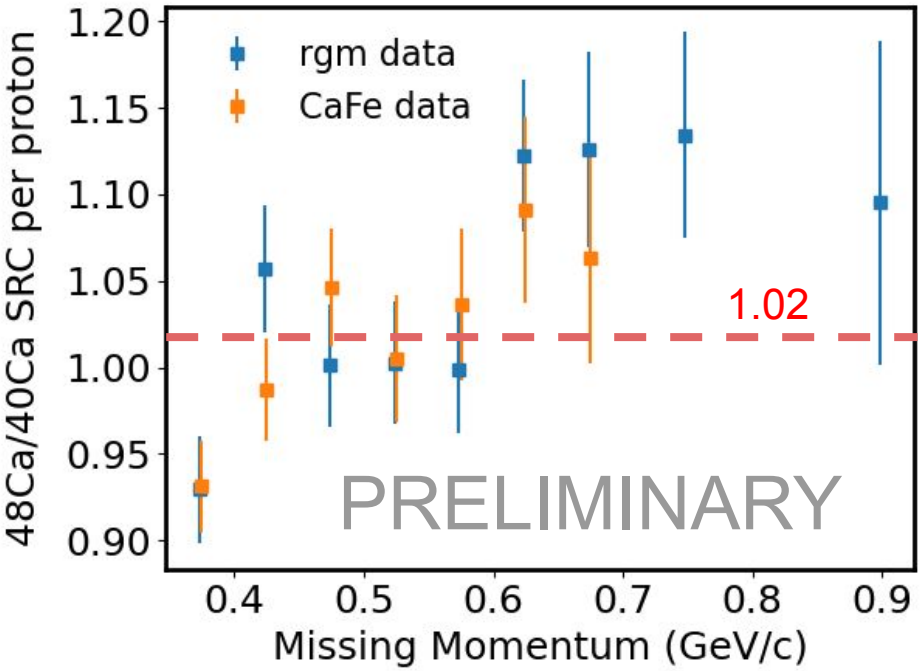
PRELIMINARY No systematic errors.	Integrated Ratios $^{48}Ca/^{40}Ca$ SRC per proton
RG-M (Hall B)	1.03 (2)
CaFe (Hall C)	1.02 (1)

RGM very preliminary
Confirms CaFe results
<10% of RG-M data set

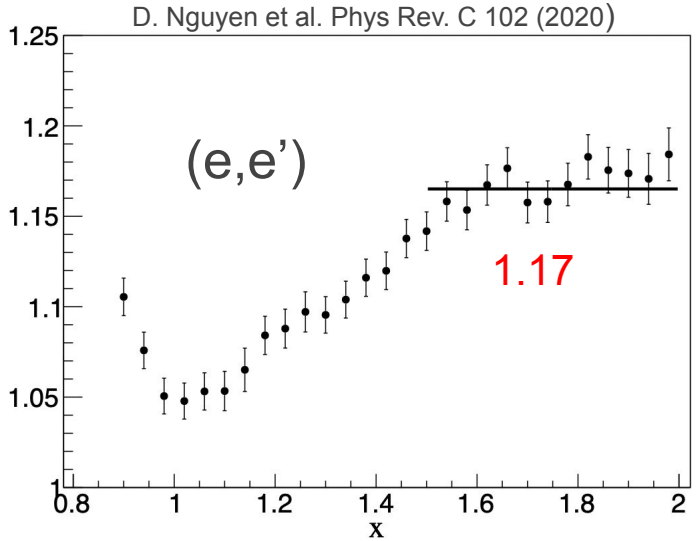
CaFe:
Carlos Yero (ODU)
Dien Nguyen (JLAB)

RG-M
Julian Kahlbow (MIT)
Ron Wagner (Tel Aviv U.)

(e,e’) and (e,e’p) disagreement?



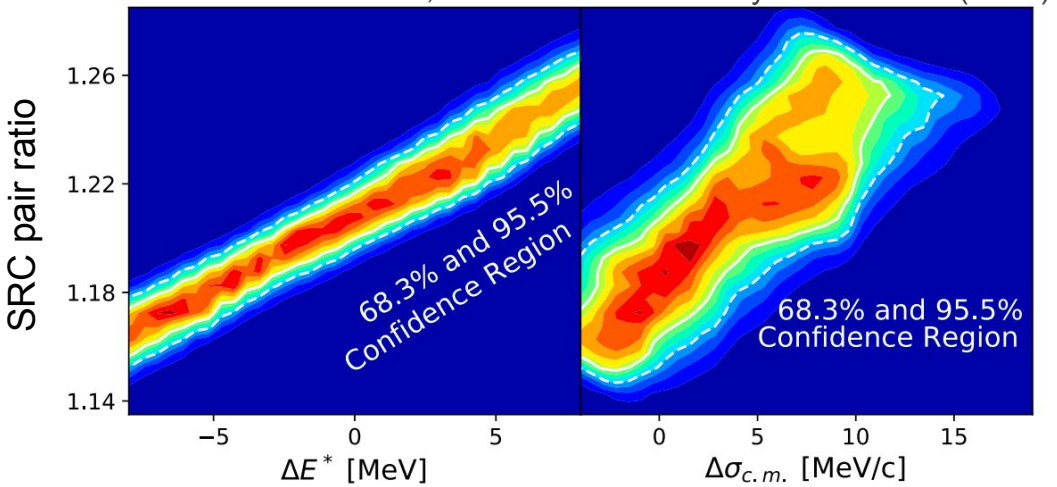
$$\frac{\sigma(^{48}\mathrm{Ca})}{\sigma(^{40}\mathrm{Ca})}$$



Contradiction????

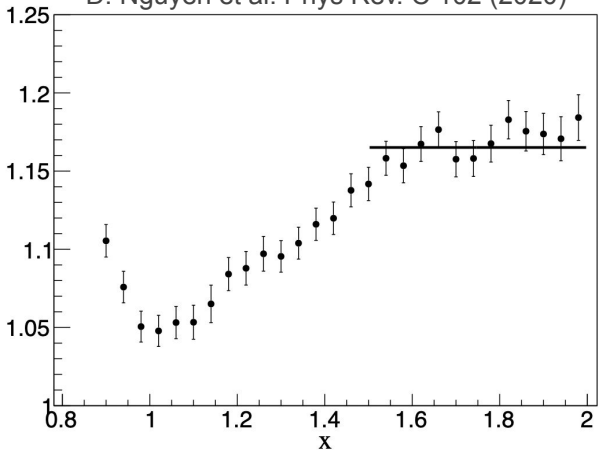
(e,e’) cross section ratio is NOT the SRC pair ratio!

R. Weiss, A. Denniston et al. Phys Rev. C 103 (2021)



$$\frac{\sigma(^{48}\mathrm{Ca})}{\sigma(^{40}\mathrm{Ca})}$$

D. Nguyen et al. Phys Rev. C 102 (2020)



Varying model parameters changes SRC pair ratio by 10%

(e,e’) measures (np, pp, nn) pairs

Conclusions

- Lots of exciting new physics to do
- Lots of data to analyze and work to be done
- Stay tuned for more exciting results

Thank you!