# Nuclear Shell Structure governs Short-range Correlation pairing

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# (key) Open questions

2N SRC

- Scale dependence ($Q^2$)
  - All observables
- Probe independence ($e,p,\gamma$)
  - Confirm factorization
- Pairing mechanisms
- Precision of interpretation in terms of ground state properties (theory)
- Neutron rich systems

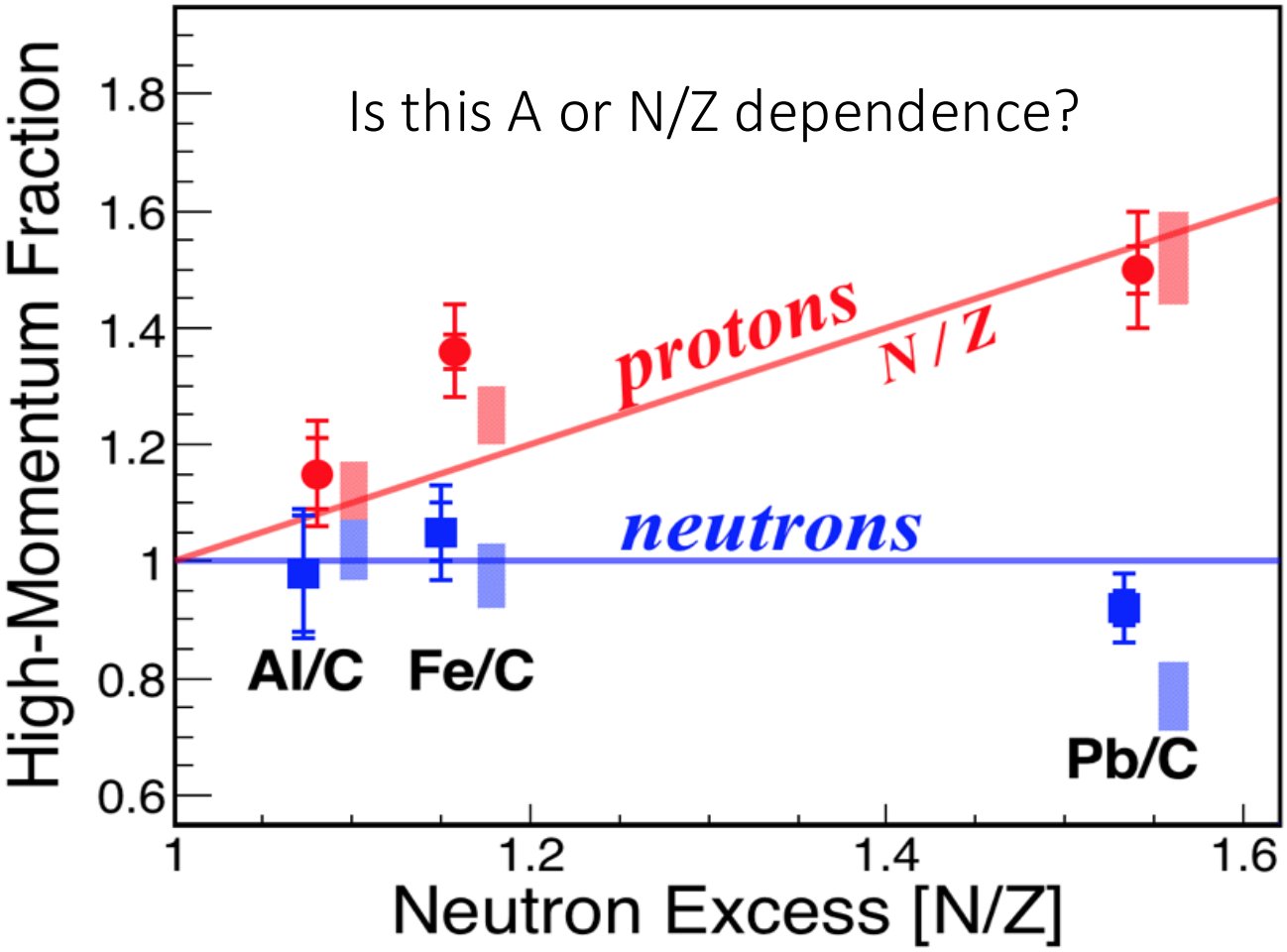
3N SRC

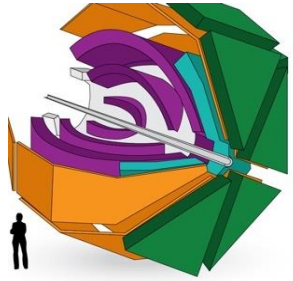
- (e,e') high $Q^2$ x>2
- 3N KO (e,e'ppN)

Theory guidance:

- Kinematics
- Ground state
- Factorization
- Phenomenology

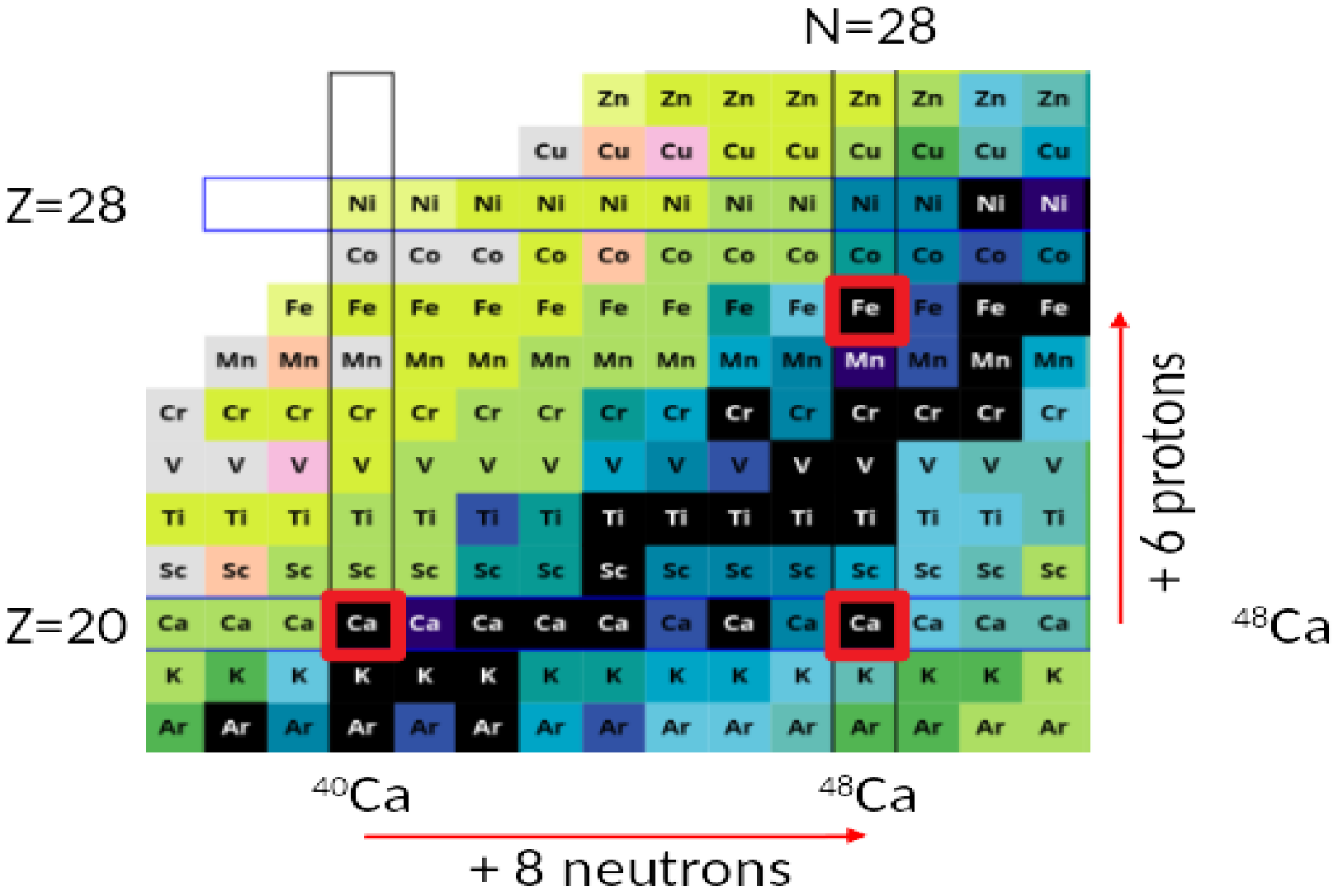
# What nucleons pair?



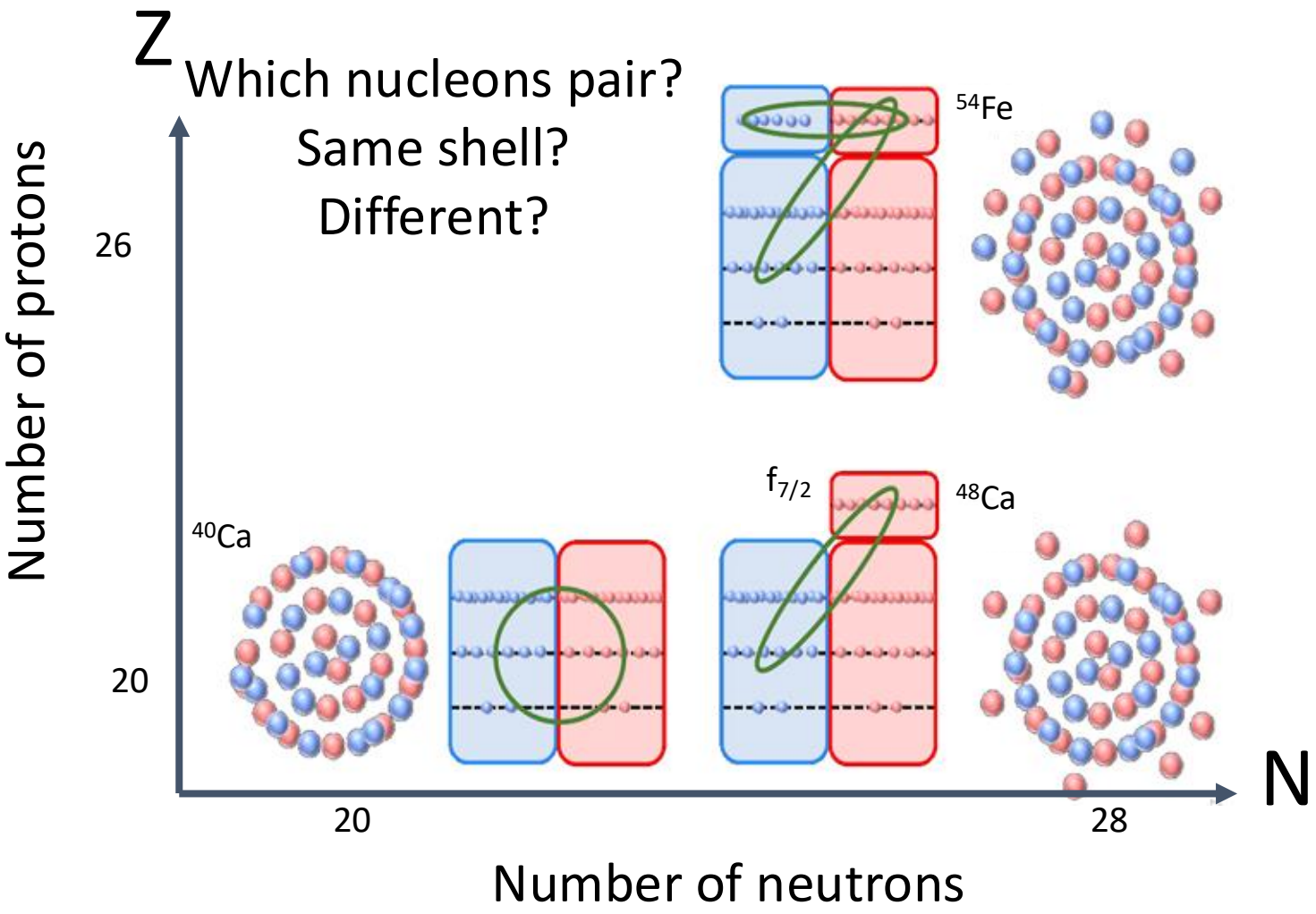



M. Duer et al. (CLAS collaboration), Nature 560, 617 (2018)

# SRC pairing mechanism



# The $^{40}$Ca, $^{48}$Ca, $^{54}$Fe system can teach us about pairing mechanisms.



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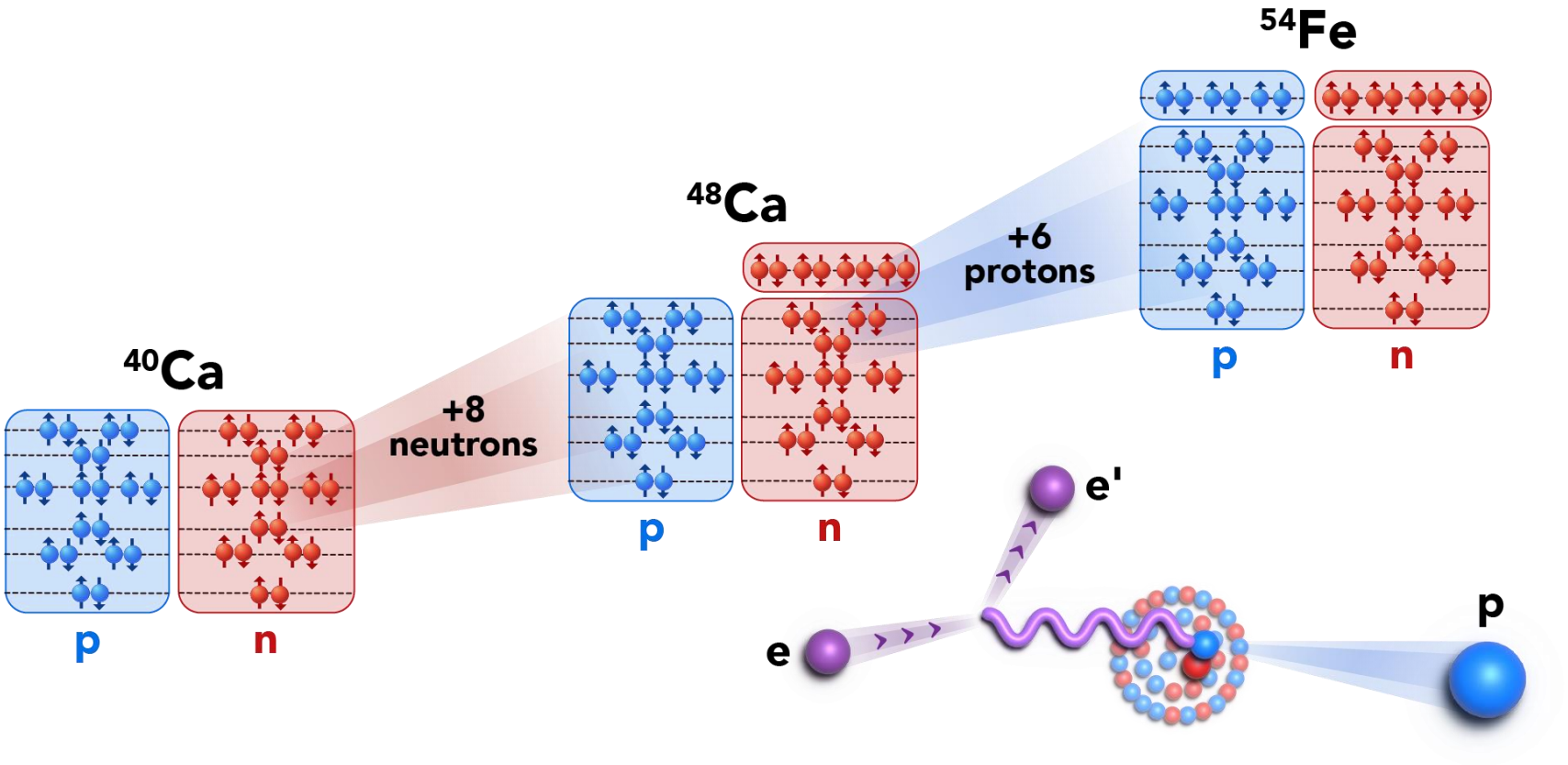
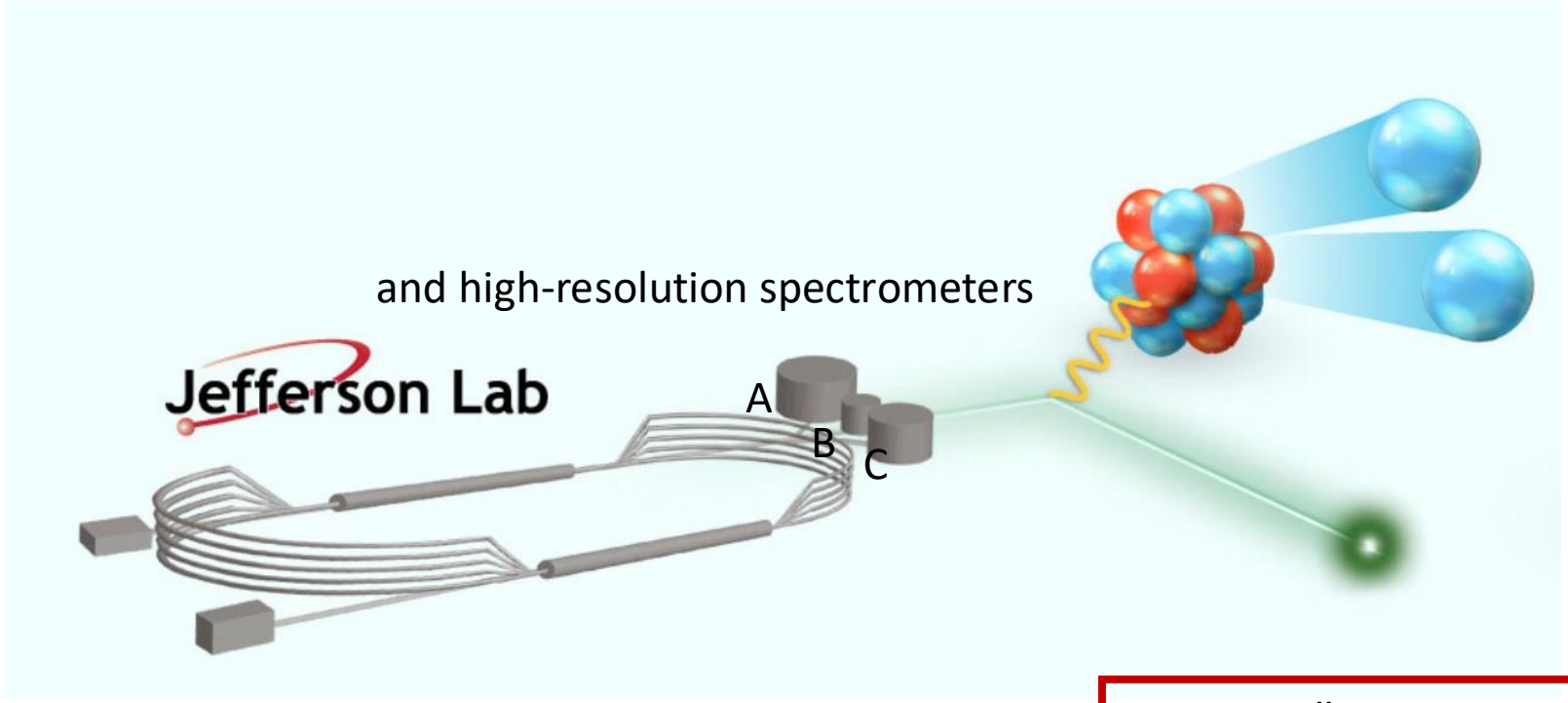
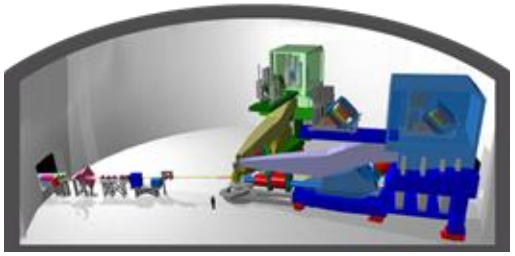


# SRC studies with electron scattering at JLab

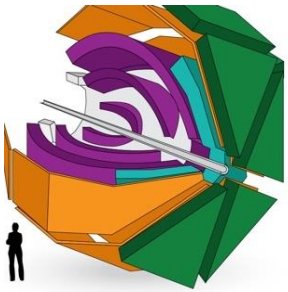
Electron beam to probe nuclear targets



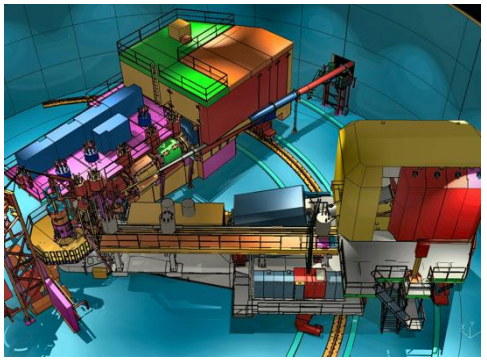

Hall A: HRS



Hall B: CLAS, CLAS12

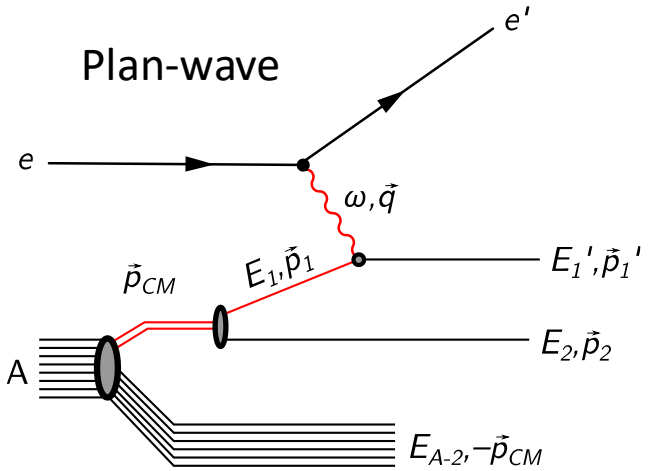


Hall C: HMS, SHMS

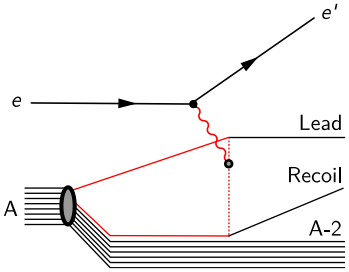


# The detection of hadrons is complicated by final-state interactions.

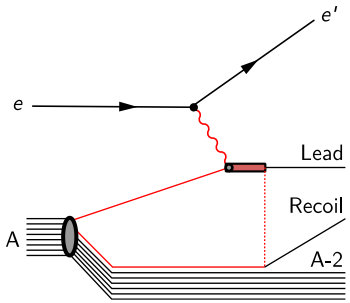
Plan-wave




Meson-Exchange Currents




Isobar Configurations

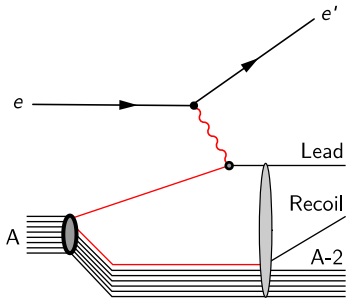



***Very specific kinematics!***

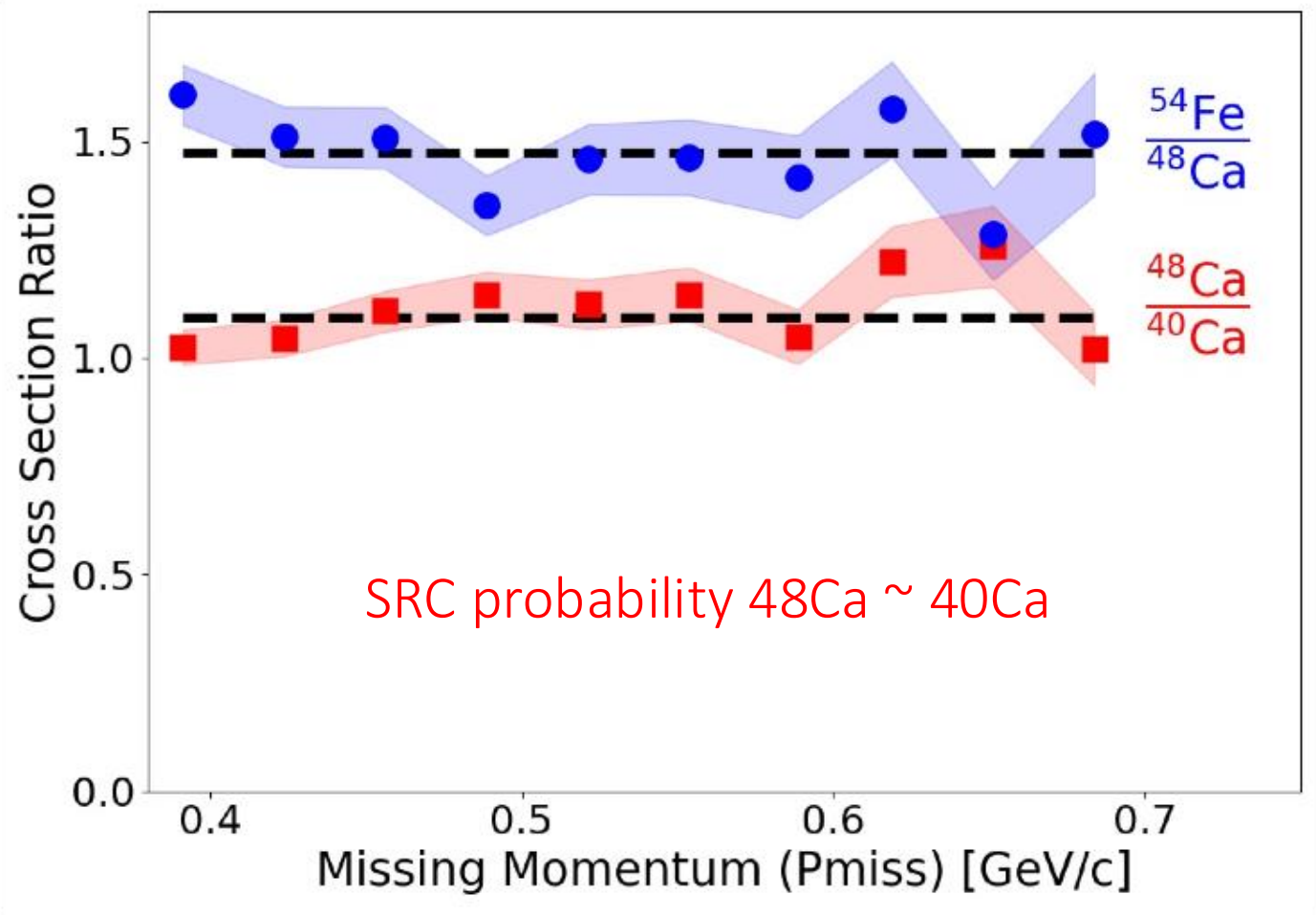
to suppress final state interactions

- $x_B > 1.2$
- Large $Q^2 > 1.8$
- $\theta_{rq} < 40^o$
- $700 > \vec{\boldsymbol{p}}_{miss} > 375$ MeV/c

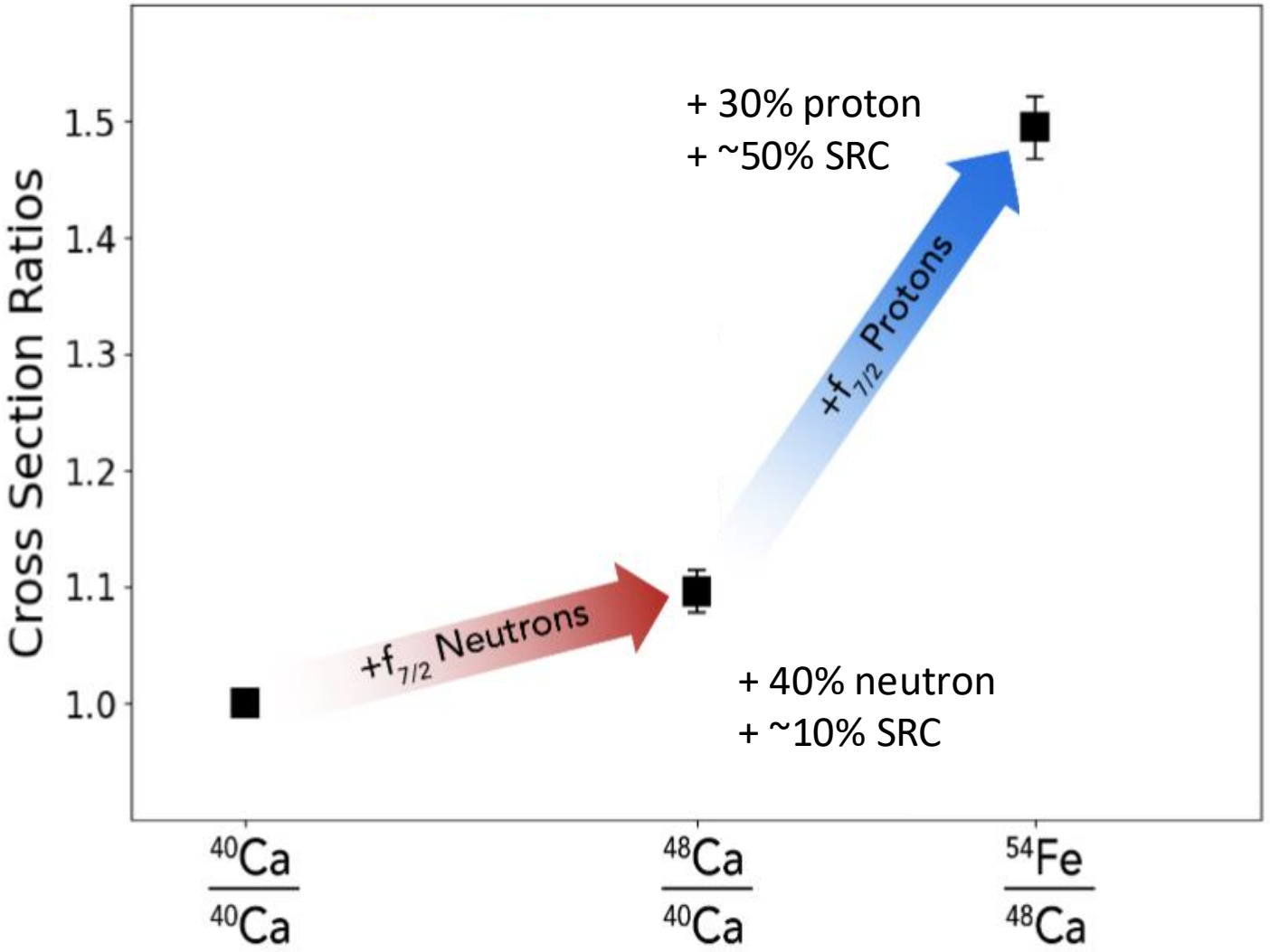
Final-State Rescattering



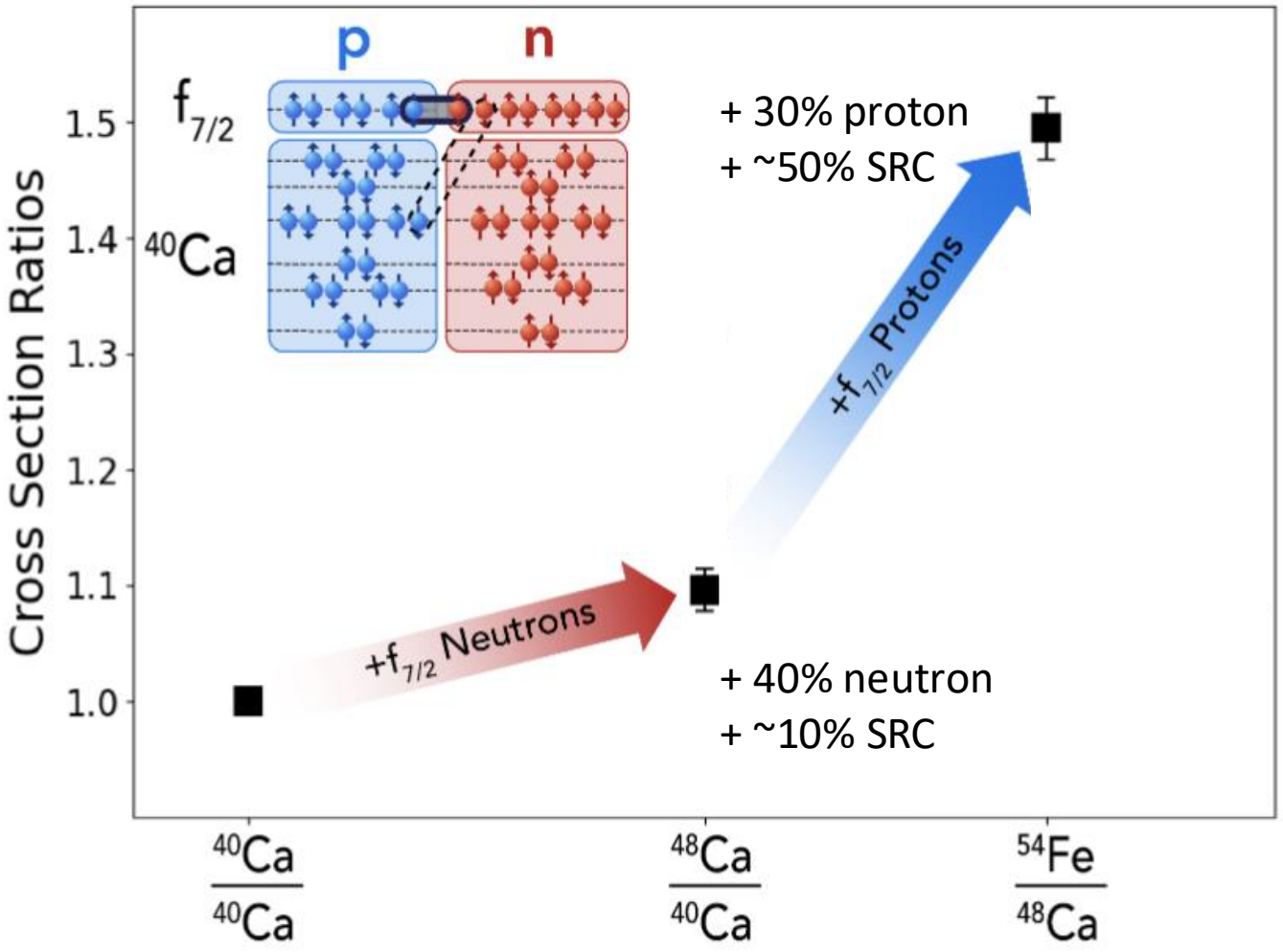
# Isolate SRC signal.



# Which nucleons pair?

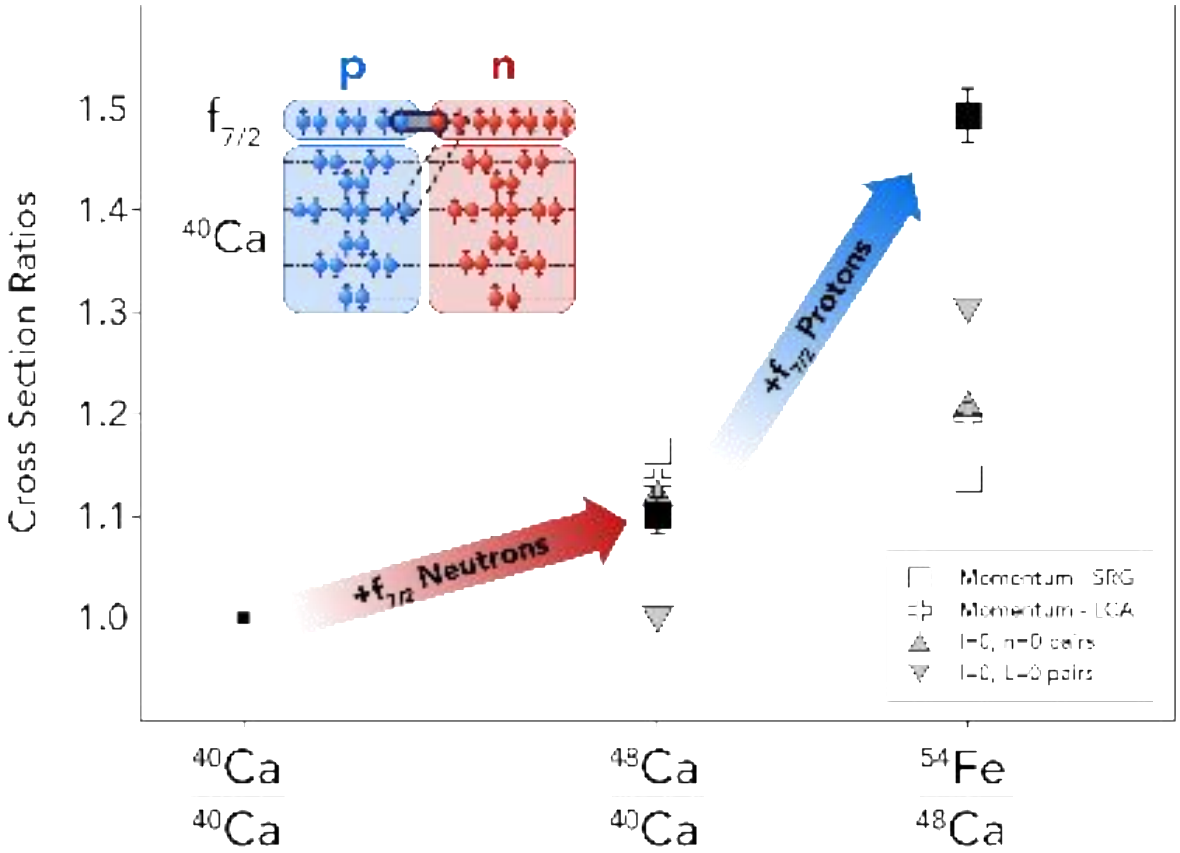


# SRC pairing within the same shell



# SRC pairing within the same shell

Weak cross shell pairing, Strong pairing within the same shell




Quantum number of protons, neutrons impact the SRC pairing mechanism

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# Nuclear shell structure governs short-range nucleon pairing

D. Nguyen, C. Yero, H. Szumila-Vance, F. Hauenstein, N. Swan, L. B. Weinstein ✉, J. Kahlbow, G. A. Miller, A. Schmidt, E. Piasetzky, O. Hen, C. Ayerbe Gayoso, E. Cohen, P. Datta, A. Denniston, B. R. Devkota, M. Diefenthaler, C. Fogler, B. R. Gamage, D. Higinbotham, I. Korover, C. Morean, M. Nycz, M. Satnik, ... E. W. Wertz + Show authors

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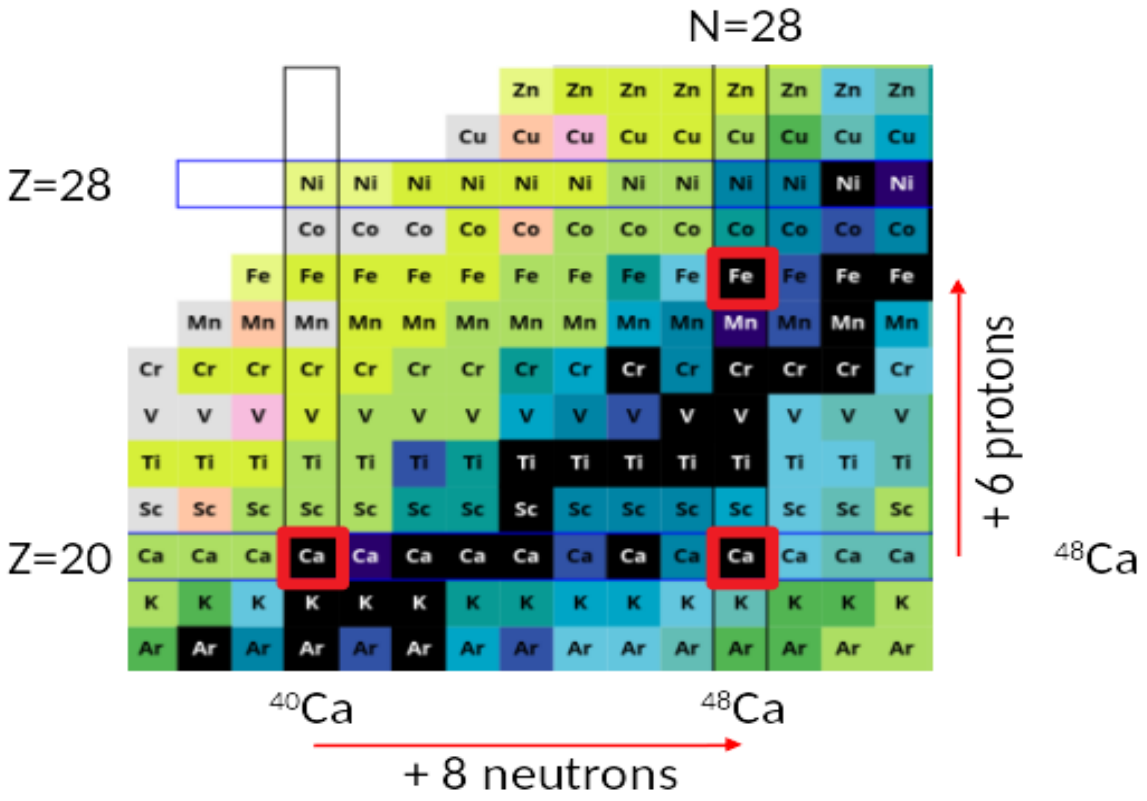
# SRC Pairing Mechanism: cont..

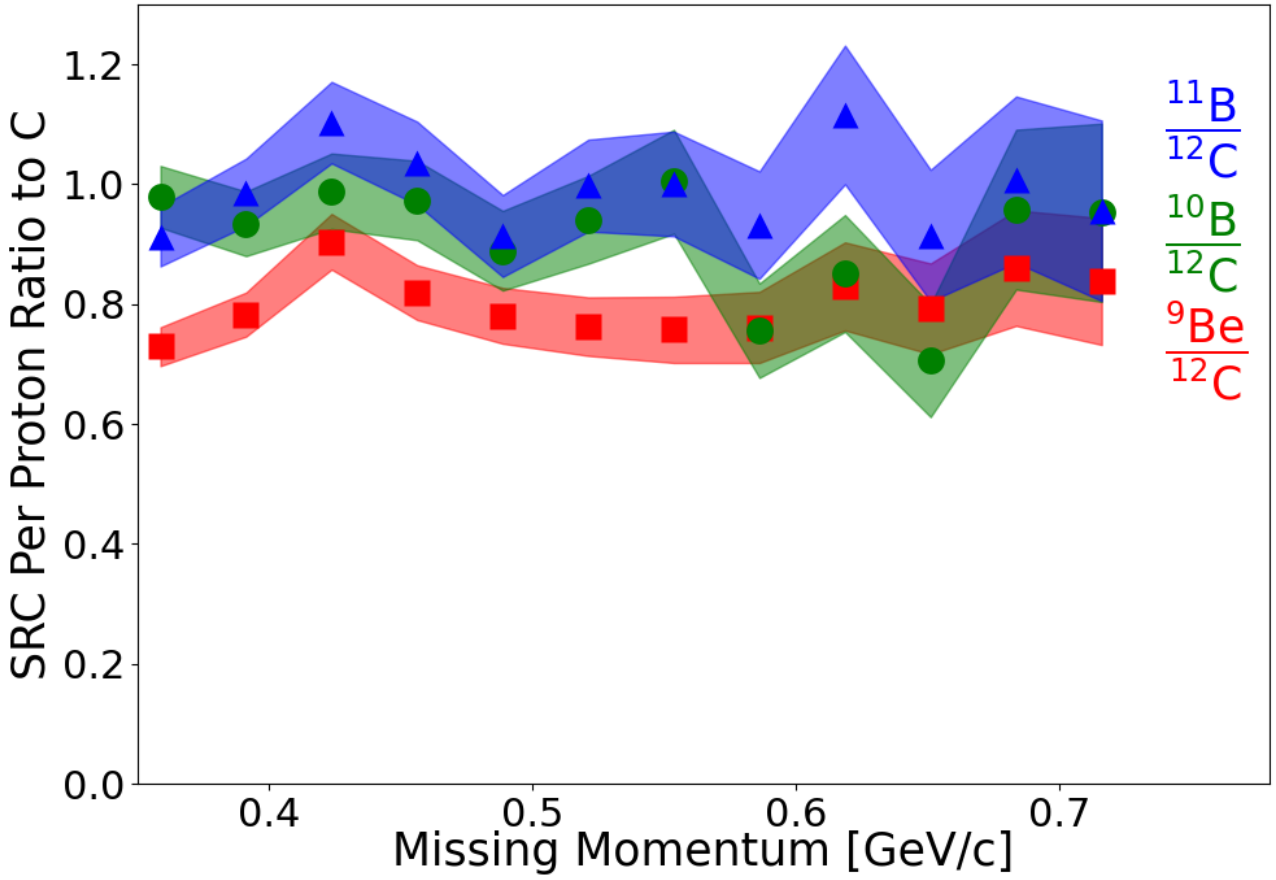



**More data**

- $^{9}$Be
- $^{10}$B
- $^{11}$B
- $^{12}$C
- $^{197}$Au

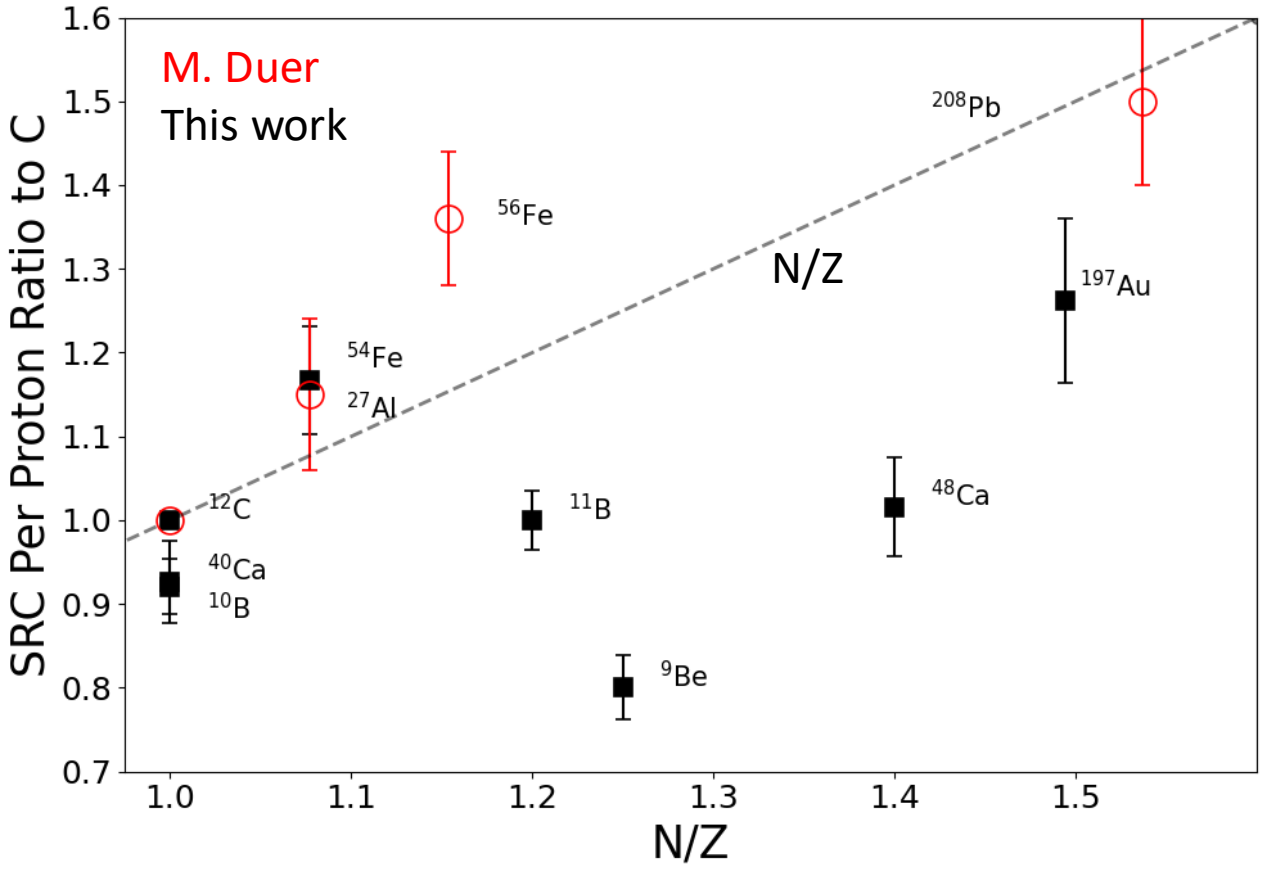
# SRC ratio of light nuclei to C12

$$(\sigma_A/Z) \,/\, (\sigma_C/6)$$

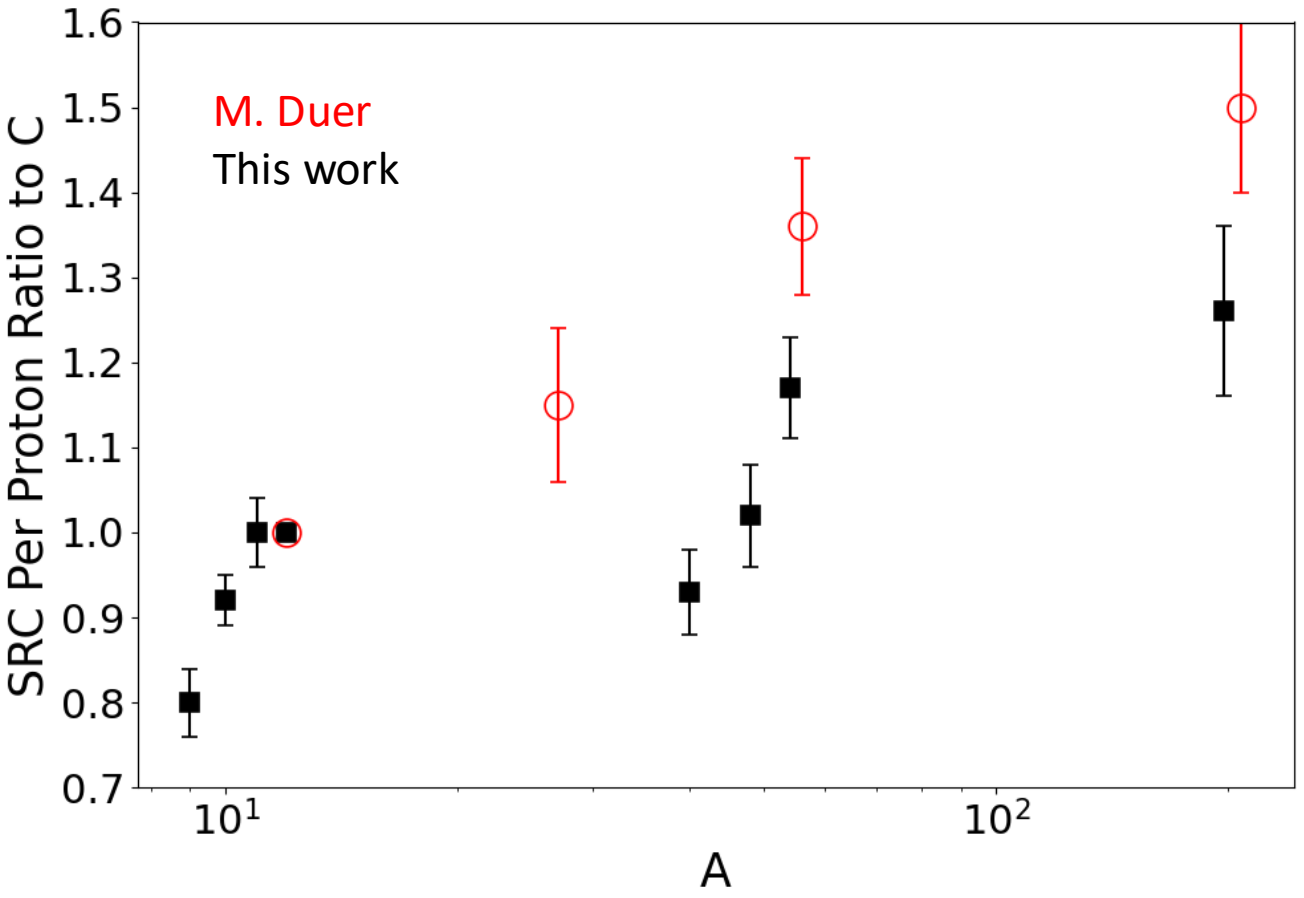


# N/Z dependence?

$$(\sigma_A/Z) \,/\, (\sigma_C/6)$$

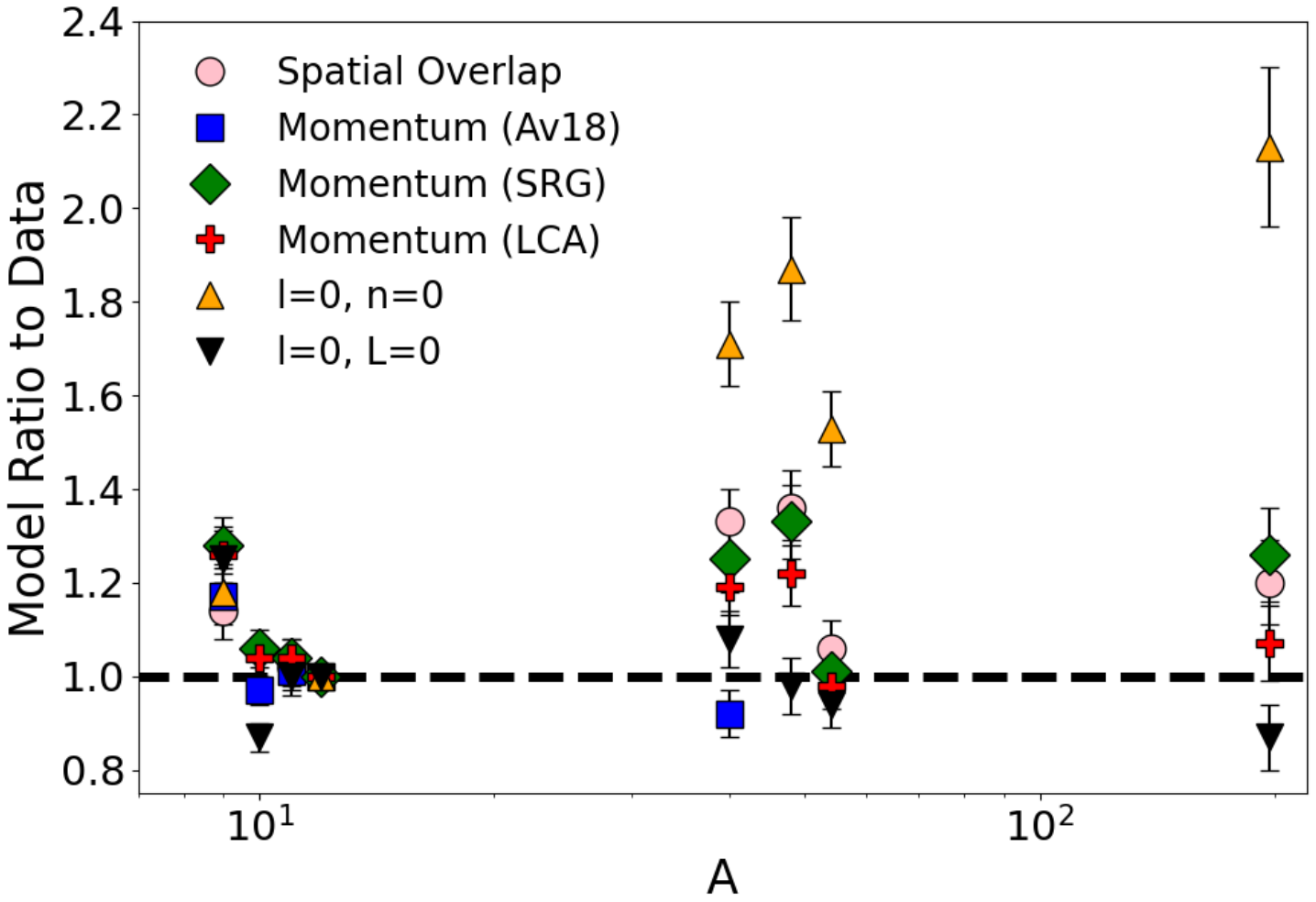


# A dependence?




- Increasing gradually with A
- Long-range nuclear shell structure is more important

# Comparison with available Theory models



# Summary

- Ca40 -> Ca48 -> Fe54: show Weak cross shell pairing, Strong pairing within the same shell

Quantum number of proton and neutron impact the SRC pairing

- All targets: Show  no N/Z dependence, some A dependence

Indicate the long-range nuclear structure has large impact than nuclear mass in SRC pairing

# Thank you


- **CaFe Team**: Carlos Yero (CAU), Holly Szumila-Vance (ODU), Noah Swan (ODU), Julian Kahlbow (LBL)
- **CaFe spokesperson**: D. Higinbotham (Jlab), F. Hauenstein (Jlab), Or Hen (MIT), Larry Weinstein (ODU)
- Hall C collaboration, Thomas Jefferson lab
- All shift workers, staffs and everyone who supported the CaFe experiment