

MIT Contributions to CLAS12

Or Hen

Richard Milner

MIT-LNS Hadronic Physics Group



Background for this talk



- The MIT group has significant interest in contributing to the CLAS12 program.
- Attracted by the scientific program.
- Offer
 - excellent students and post-docs
 - technical and scientific expertise
- We are in fact already active with CLAS6 data mining and RG-B preparations, under limited membership for specific experiments.
- We are requesting to formally join CLAS, to increase our effort and investment in the CLAS12 program.



The Hadronic Physics Group



- **Faculty**

Prof. Or Hen
Prof. Richard Milner (Group Leader)
Prof. Robert Redwine
Prof. Michael Williams

- **Principal Research Scientists**

Dr. Shalev Gilad
Dr. Douglas Hasell

- **Research Scientists**

Dr. Jan Bernauer

- **Emeritus/a Faculty and Scientists**

Prof. Aron Bernstein
Prof. William Bertozzi
Dr. T. William Donnelly
Prof. Stanley Kowalski
Prof. June Matthews

- **Administrative Assistant**

Anna Maria Convertino

- **Research Associates (9)**

Dr. Adi Ashkenazi	Dr. Georgios Laskaris
Dr. Jean Bele	Dr. Matthew Musgrave
Dr. Daniel Craik	Dr. Maria Patsyuk
Dr. Cristiano Fanelli	Dr. Axel Schmidt
Dr. Ivica Friscic	

- **Graduate Students (14)**

Thomas Boettcher	Barak Schmookler
Charles Epstein	Efrain Segarra
John Hardin	Reynier Cruz Torres
Sangbaek Lee	Yimin Wang
Patrick Moran	Constantin Weisser
Navaphon Muangma	Yunjie Yang
Longwu Ou	
Afroditi Papadopoulou	

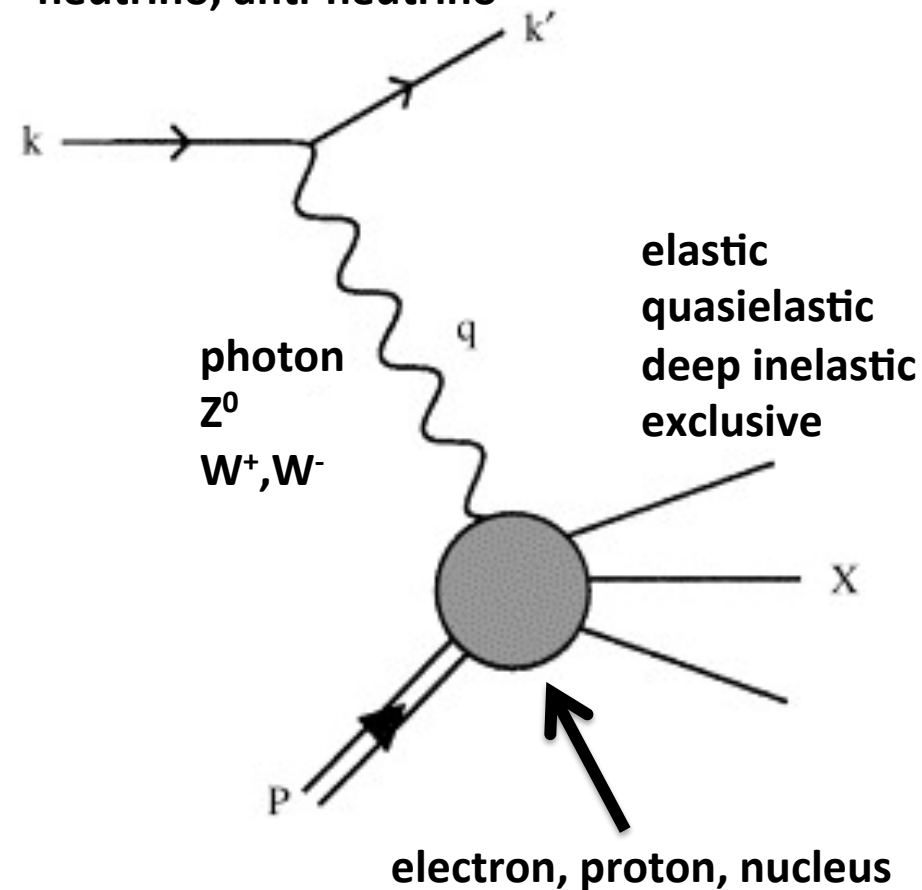
- + **Undergraduate Students**



Lepton-Hadron Scattering



electron, positron,
neutrino, anti-neutrino



polarized beams and targets

Modus operandi

- Use the electroweak theory to study hadrons
- Use hadrons to look for exotic or new physics
- Focus is at Jefferson Lab but willing to work at labs worldwide if science demands it
- Develop hardware
- Partner with theorists
- Collaborate
- Provide leadership role for young physicists



Scientific Overview



- **Nuclei and Bound Nucleon structure**

Short Range Structure; EMC effect

Hen

- **Nucleon Structure**

Proton radius

Bernauer

High Q^2 form-factor

Gilad

- **Search for Exotic Resonances in QCD**

GlueX

Williams

- **Reaction fundamentals**

OLYMPUS

Bernauer, Hasell, Milner, Redwine

Neutrino-nucleus interactions

Donnelly, Hen

Radiative Møller scattering

Milner

- **Search for New Physics**

Q_{weak} Kowalski

LHCb Williams

nEDM Redwine

DarkLight Bernauer, Hasell, Milner

- **Towards EIC**

Polarized source development

Milner, Redwine

Streaming readout

Bernauer, Hasell



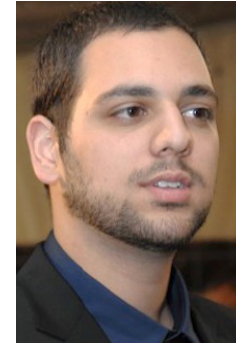
Our Physics Interests



3D Nucleon
Structure



SRC and the
EMC effect

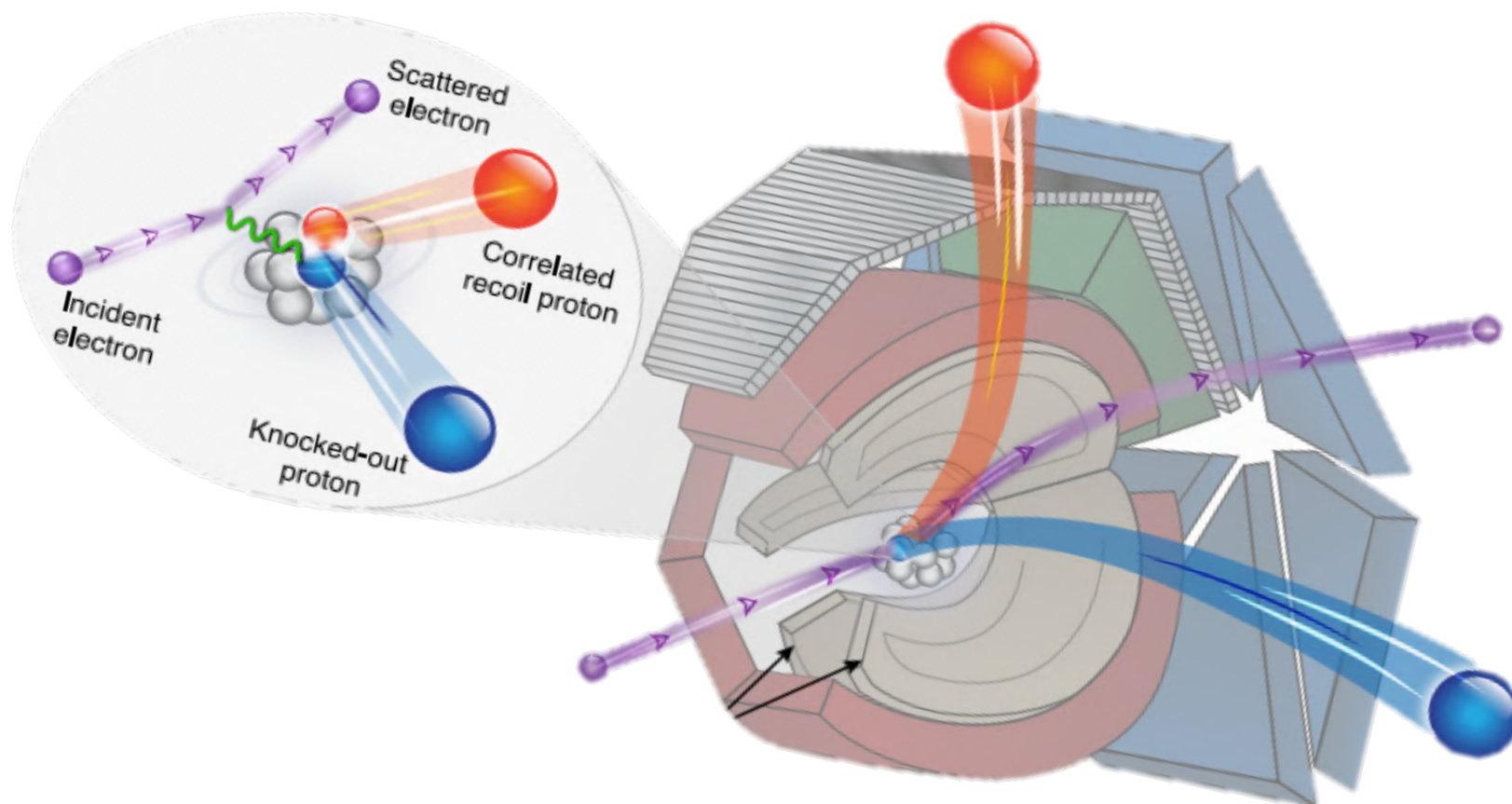


Hardware Contributions:

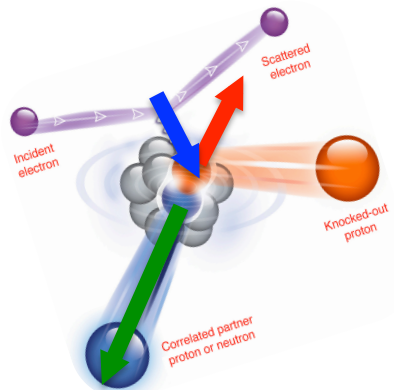
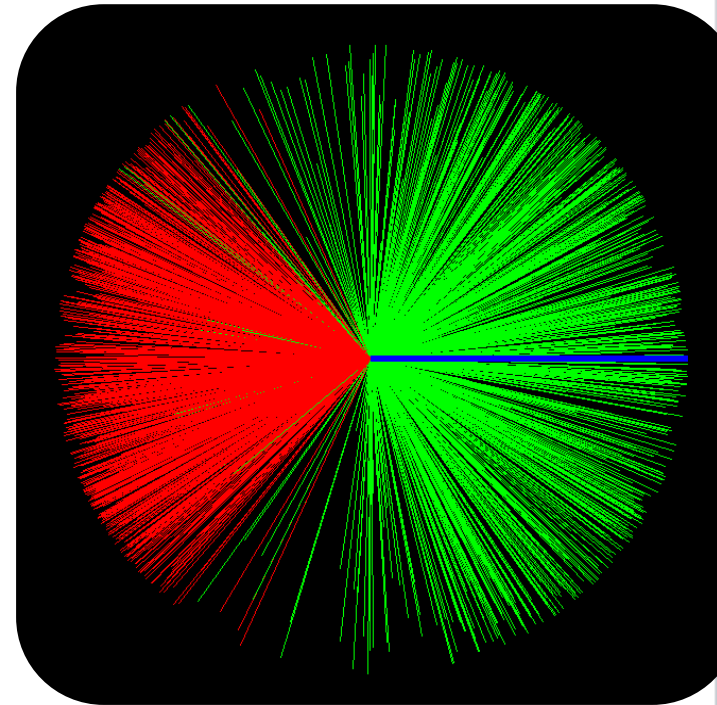
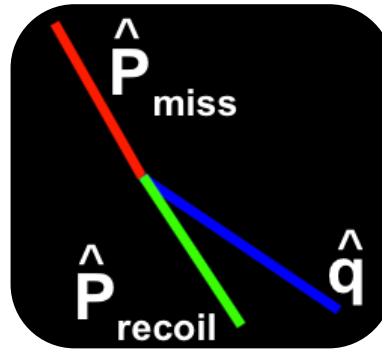
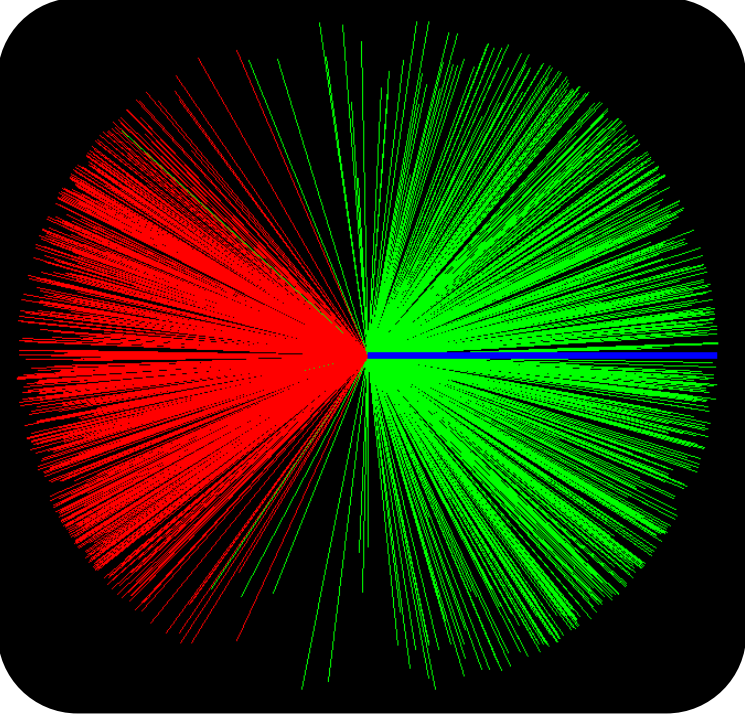
- Backward Angle Neutron Detector
- Streaming readout R&D



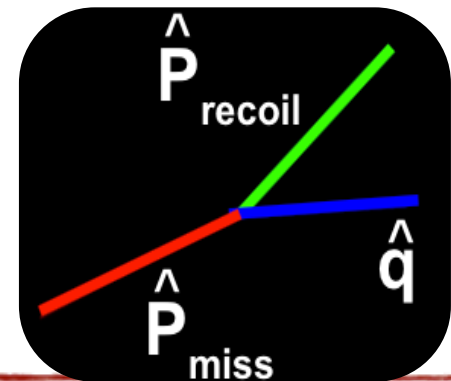
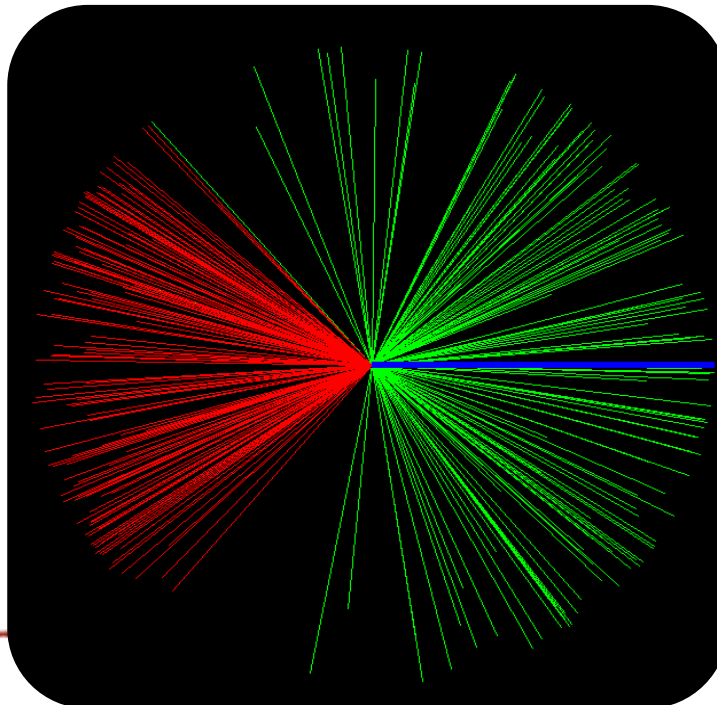
SRC @ CLAS



3D Reconstruction

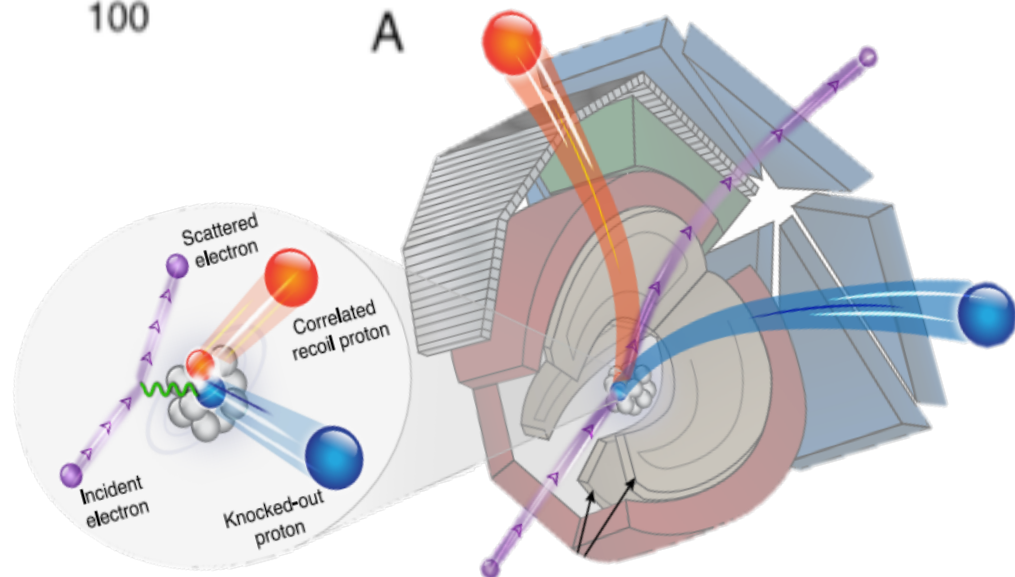
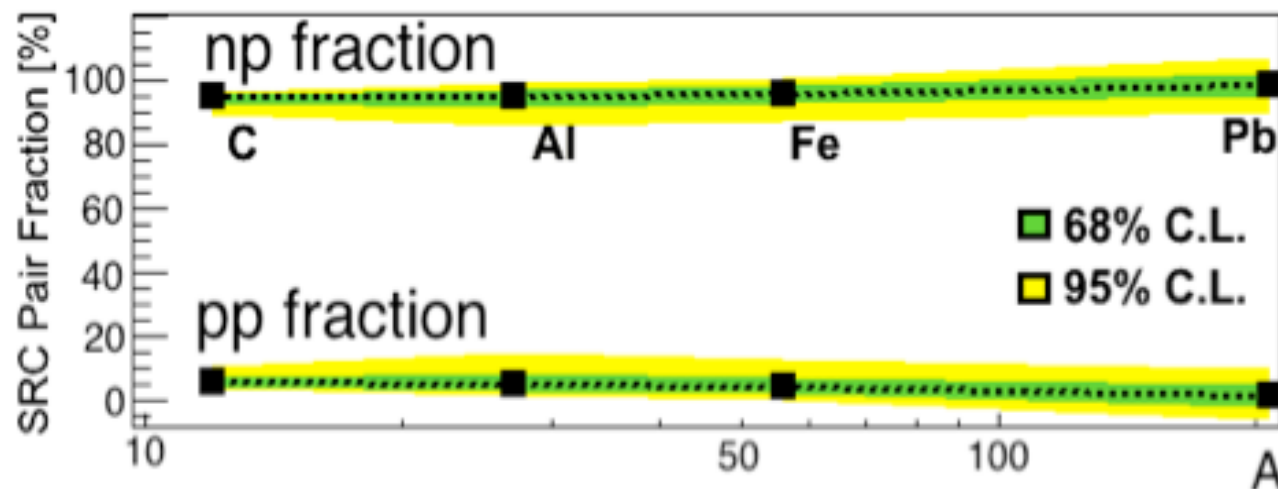


Back-to-back
= pairs!





np-SRC pair dominance in heavy nuclei



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

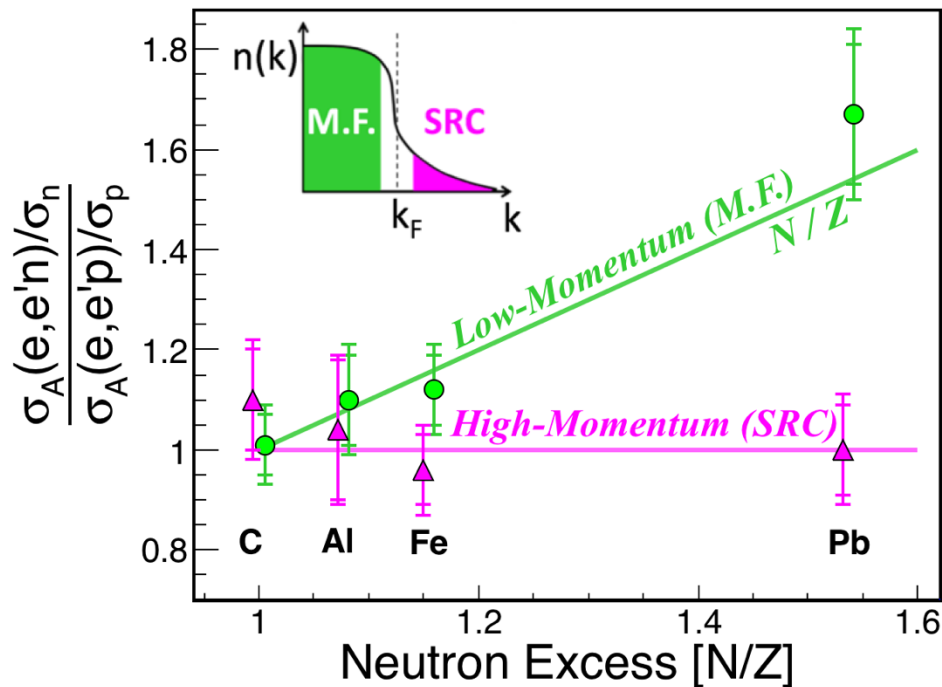
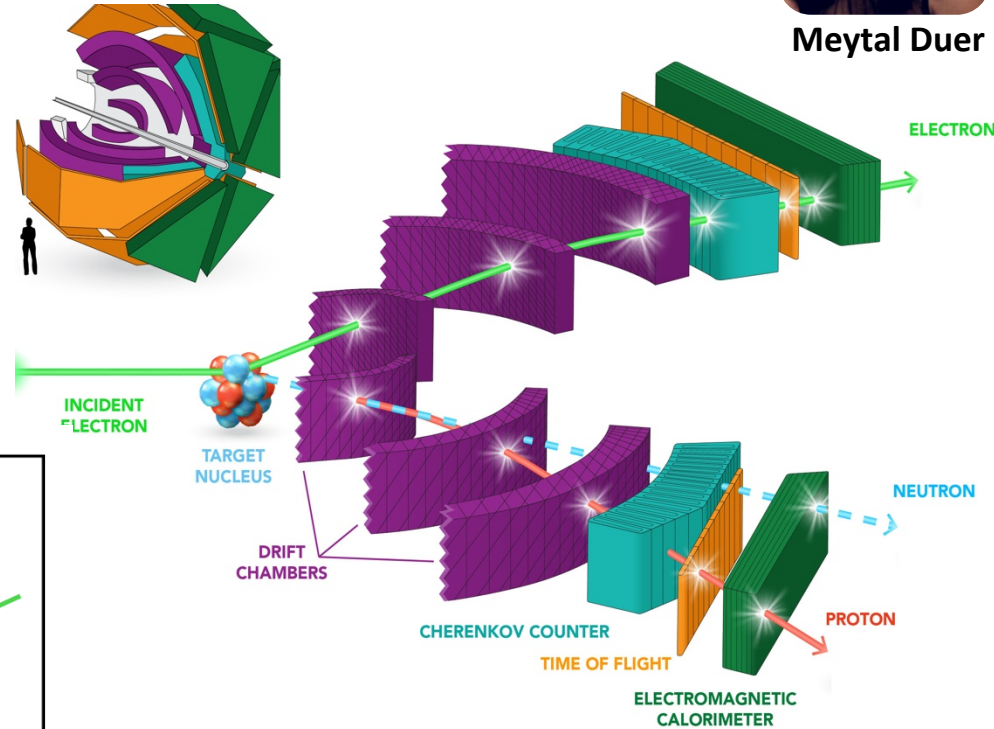


New CLAS Results (1)



Meytal Duer

Neutron correlation probability saturate in neutron-rich nuclei while proton probabilities grow



Submitted to Nature.
Currently With referees

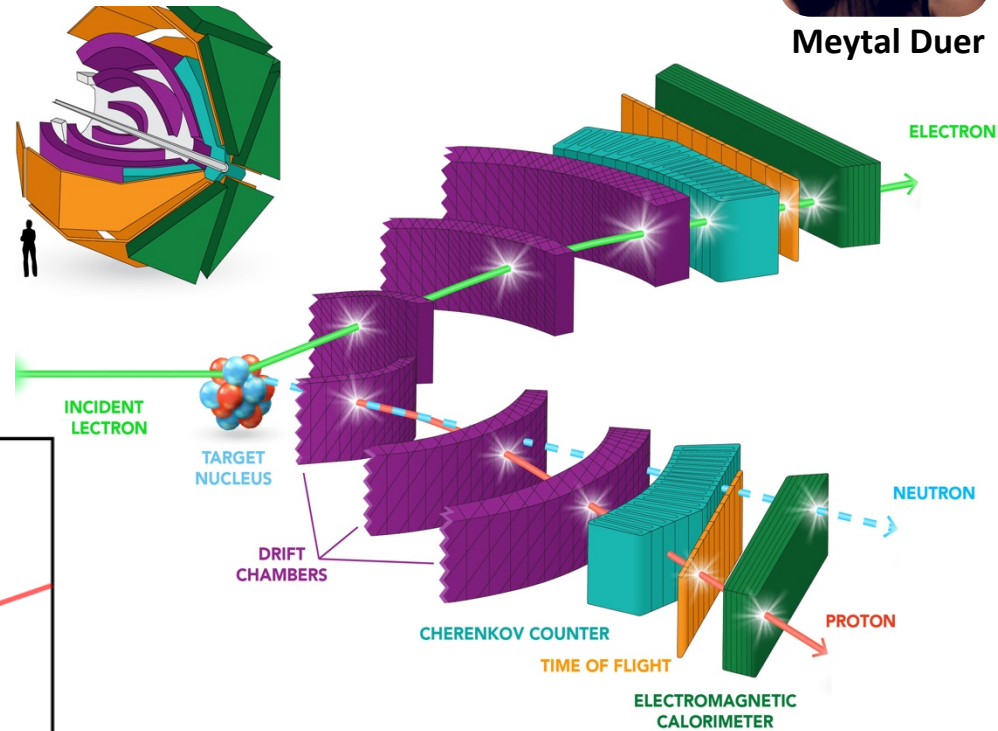
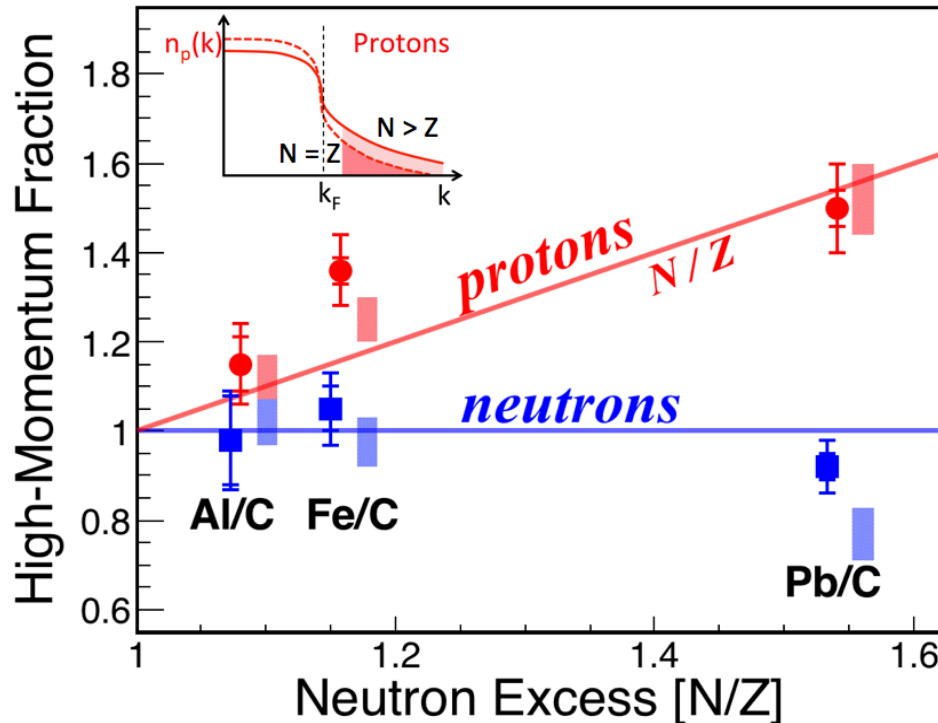


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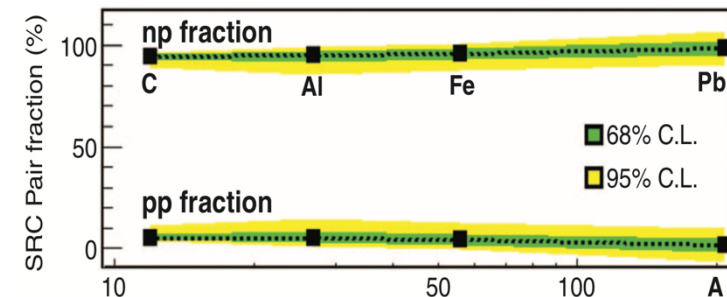
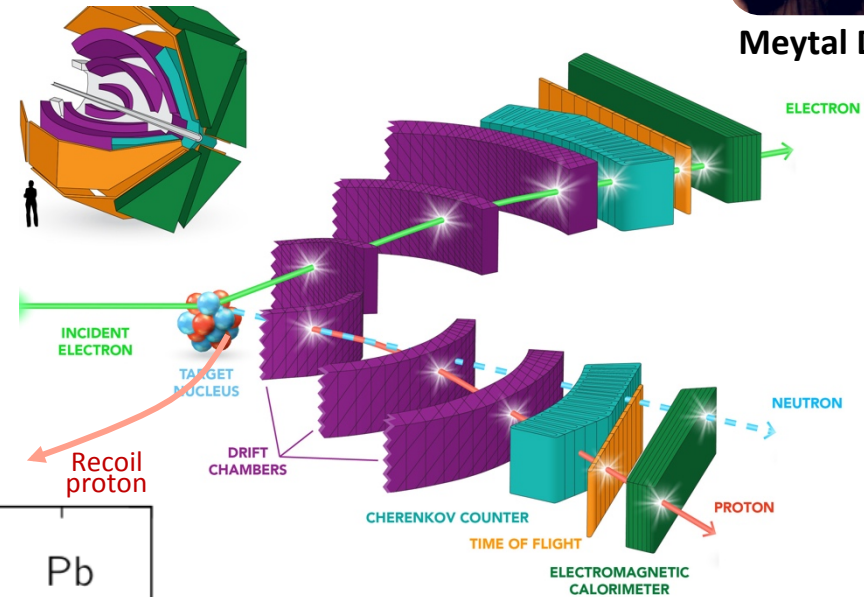
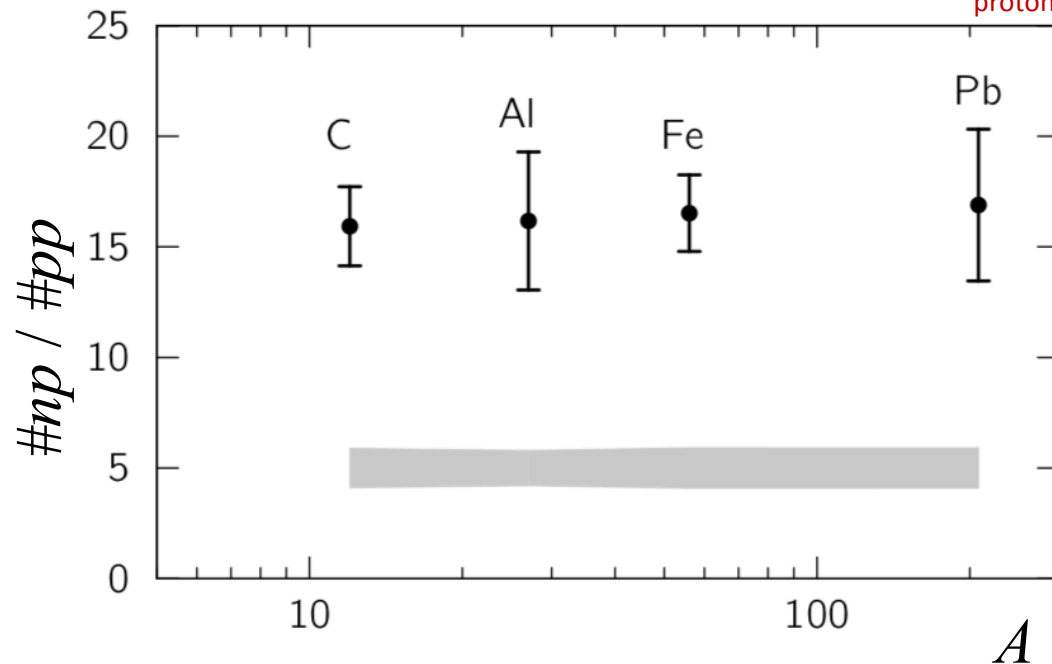
New CLAS Results (2)



Meytal Duer

Direct observation of np-SRC dominance in Heavy nuclei

1st step towards discovery of 3N-SRC



Submitting for analysis review



New CLAS Results (3)

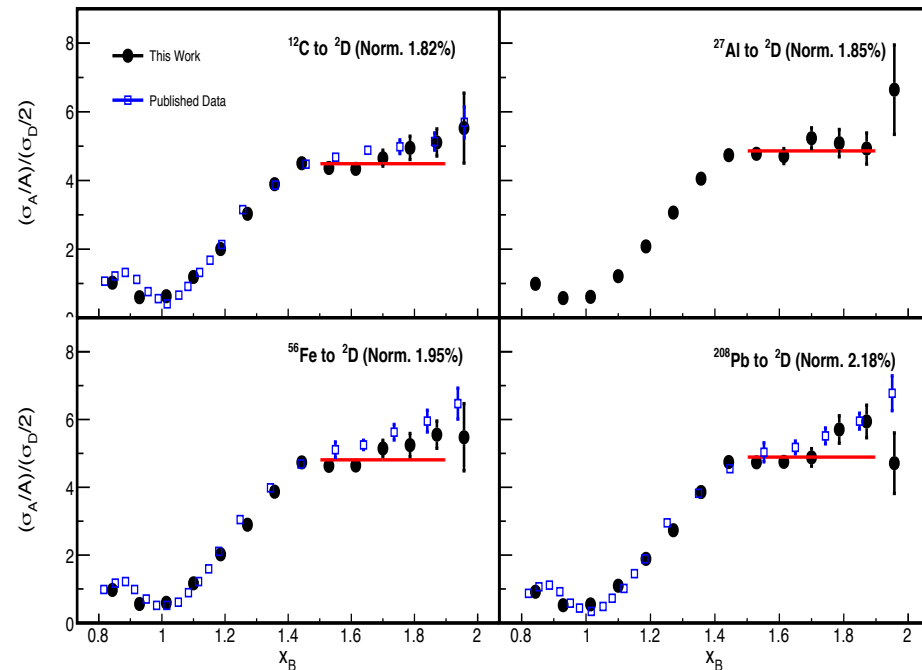


Barak
Schmookler

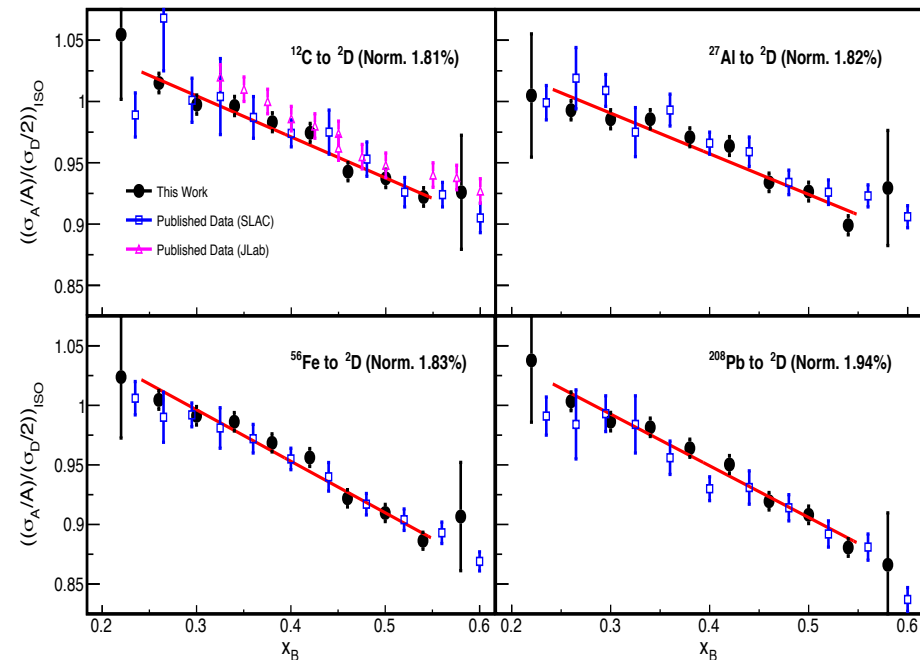
EMC Effect due to np-SRC
pairs. Saturates for neutrons
but grows for protons!

Submitted to Science.

SRC Scaling



EMC Ratios



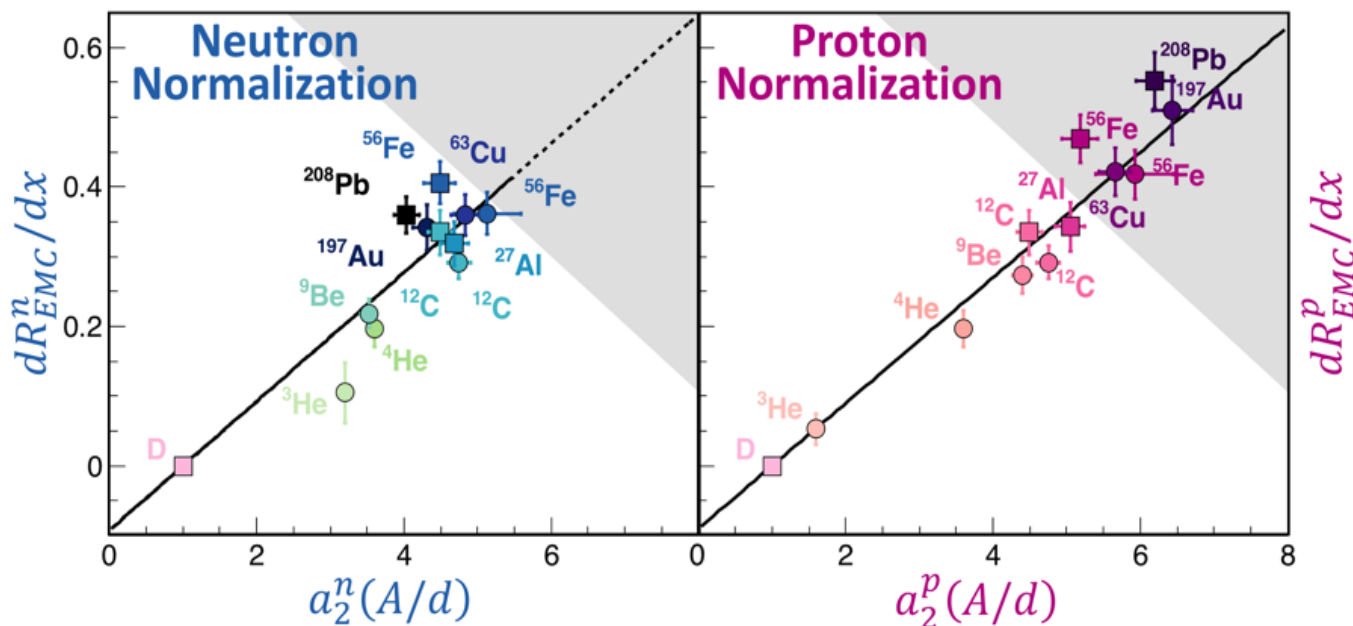
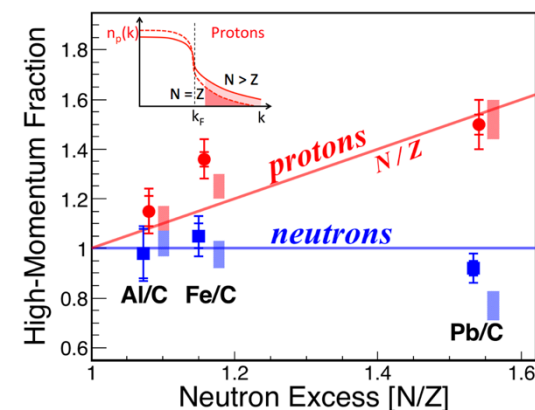


New CLAS Results (3)



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EMC Effect due to np-SRC pairs. **Saturates for neutrons** but grows for protons!



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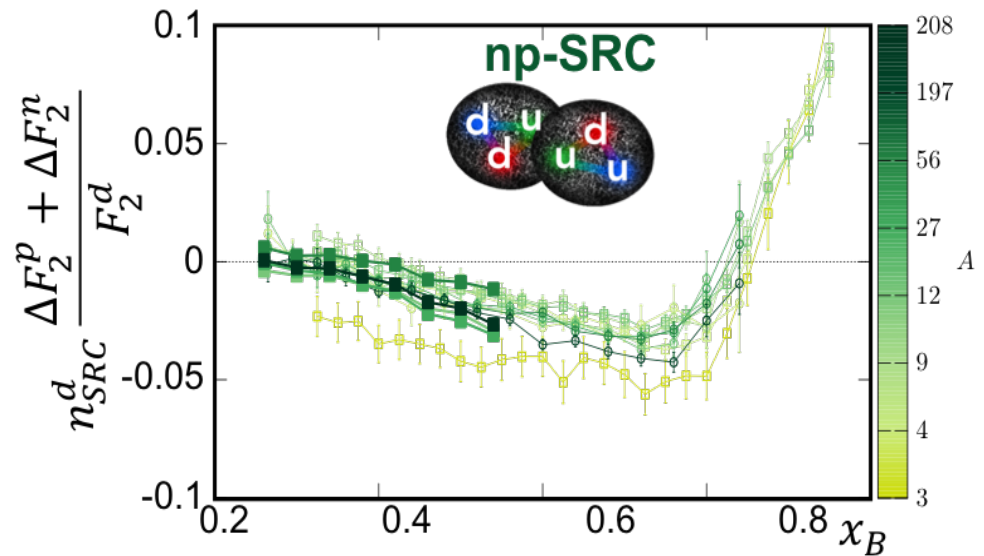
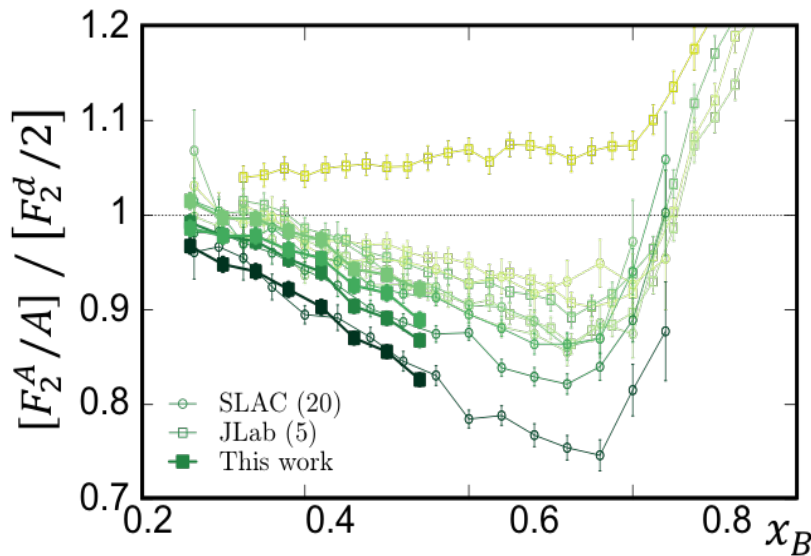


New CLAS Results (3)



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Schmookler

EMC Effect **due to np-SRC**
pairs. Saturates for neutrons
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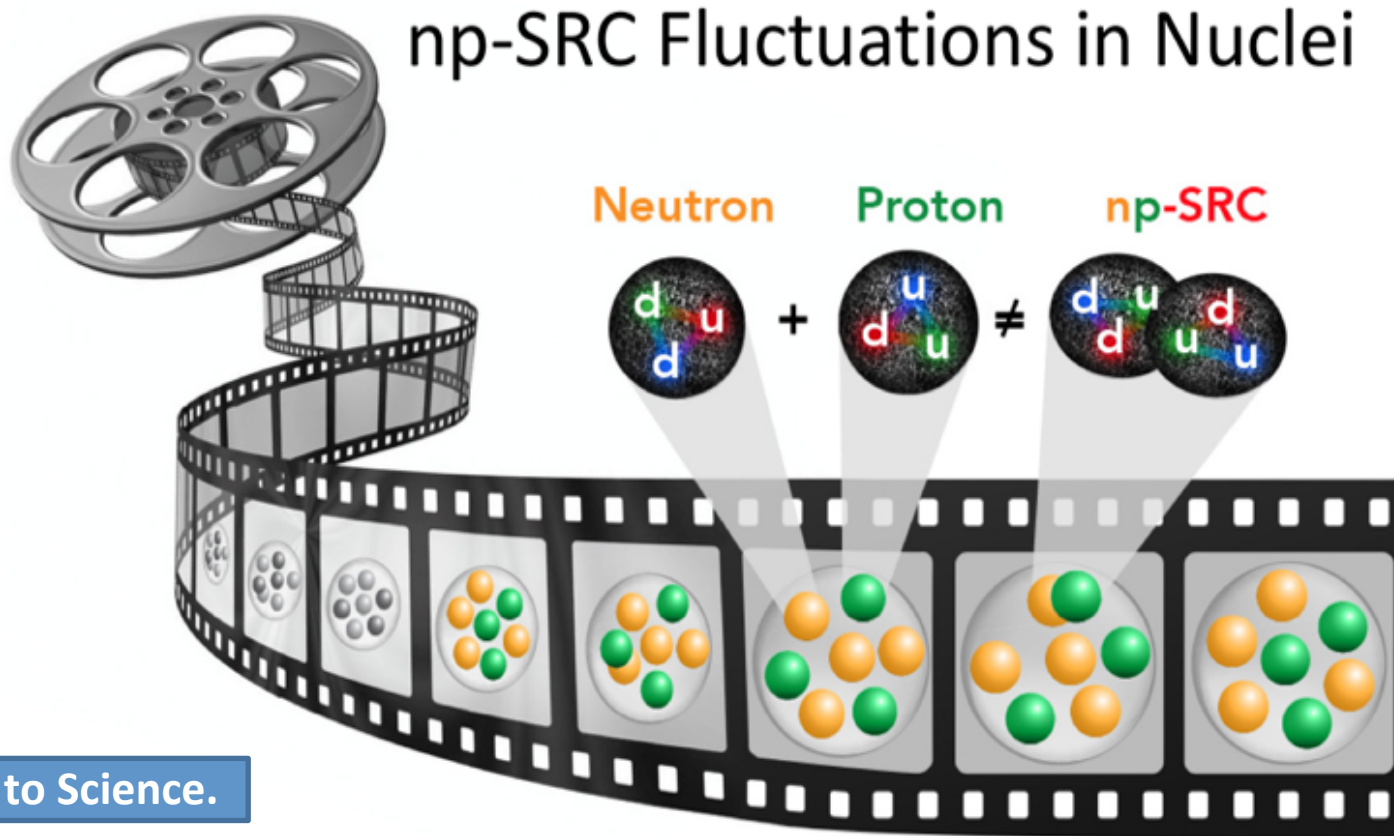


New JLab Results (3)



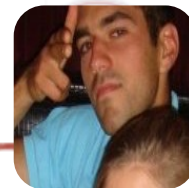
Barak
Schmookler

EMC Effect due to np-SRC pairs.
Saturates for neutrons but grows for protons!



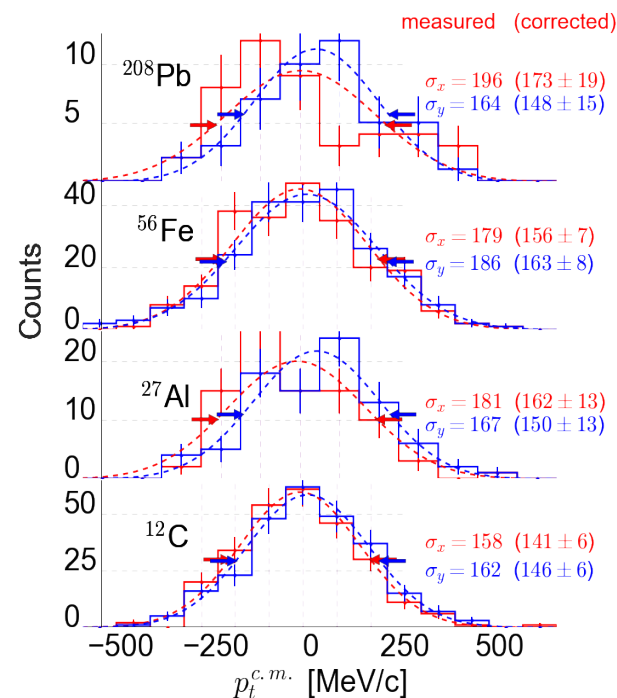
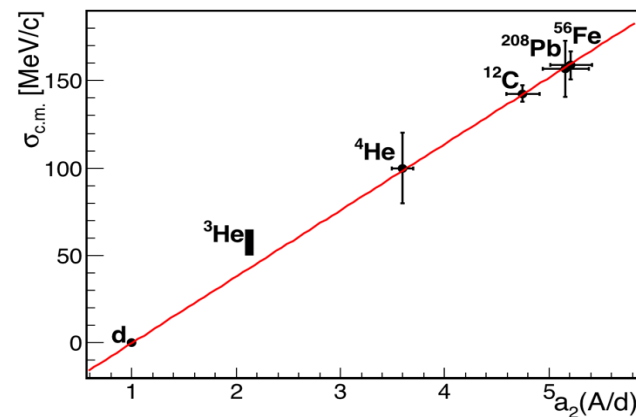
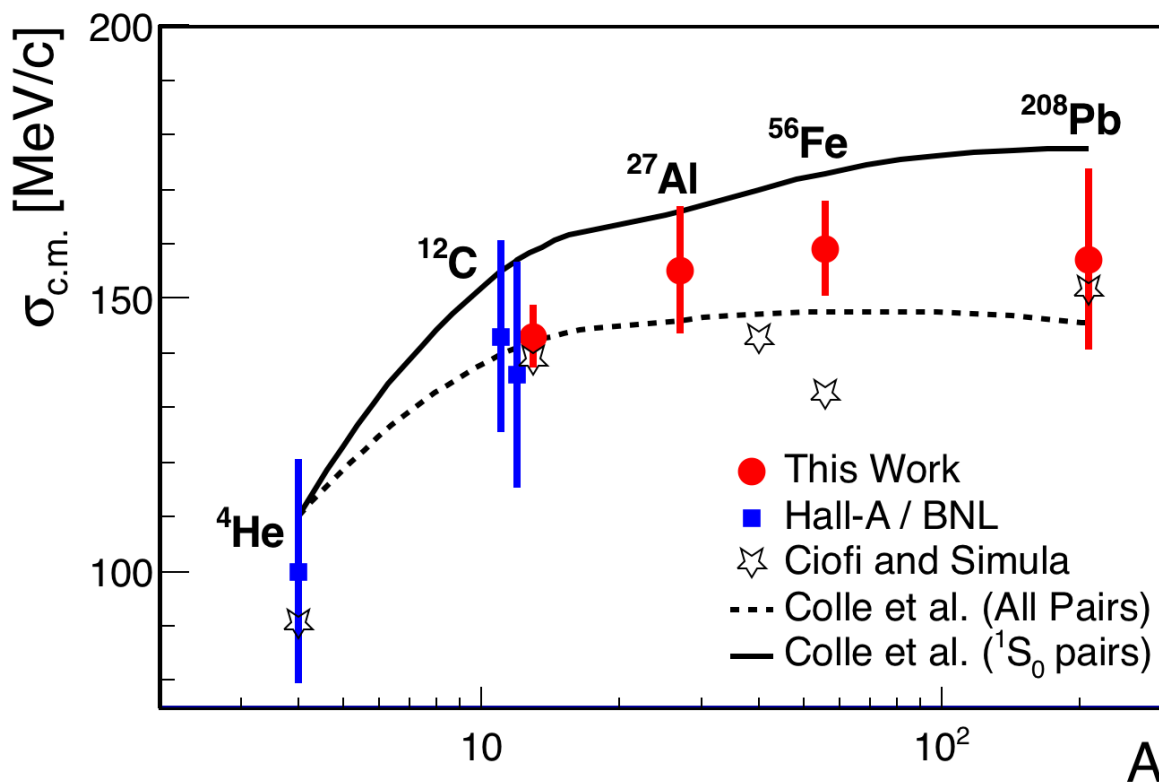


New JLab Results (4)



Erez Cohen

New universal characteristics
of SRC pairs in heavy nuclei



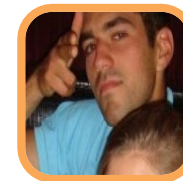
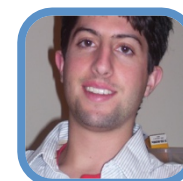
Under Ad-Hoc Review



Ongoing Data-Mining Analyses

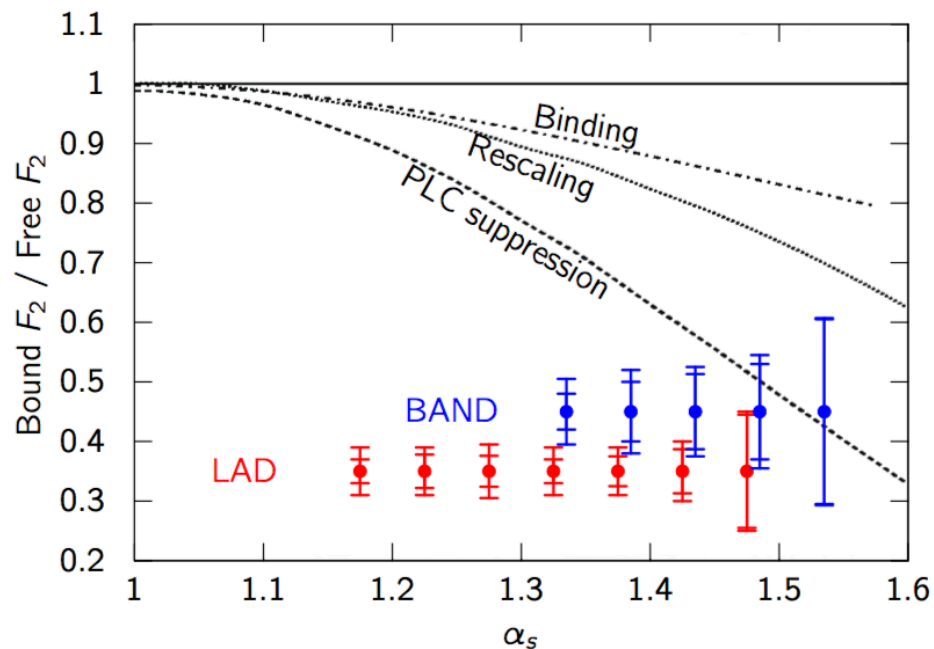
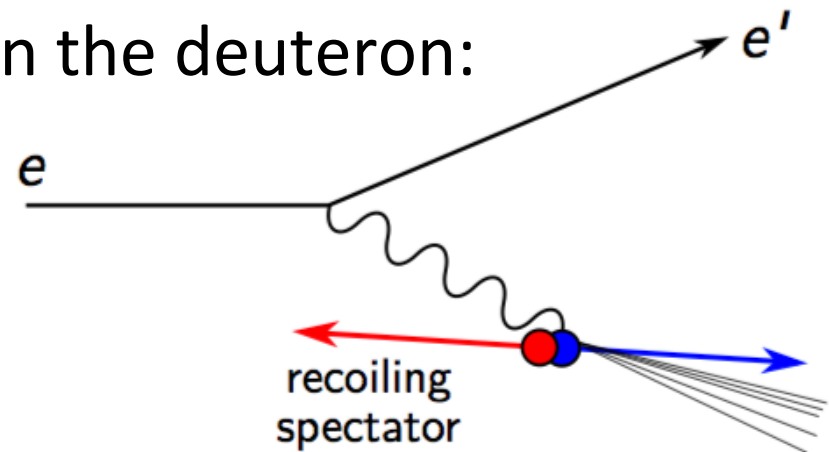


- 3N-SRC searches in exclusive channels via $A(e,e'ppp)$; $A(e,e'npp)$ and $A(e,e'ppn)$
- SRC dynamics in few-body systems via ${}^3,4\text{He}(e,e'N)$
- Tagged EMC and SRC measurements via $A(e,e'p_{\text{recoil}})$
- Constraining the repulsive core of the NN interaction via $A(e,e'pp)/A(e,e'p)$ and ${}^4\text{He}(e,e'pp)/{}^4\text{He}(e,e'pn)$
- Electrons 4 Neutrinos

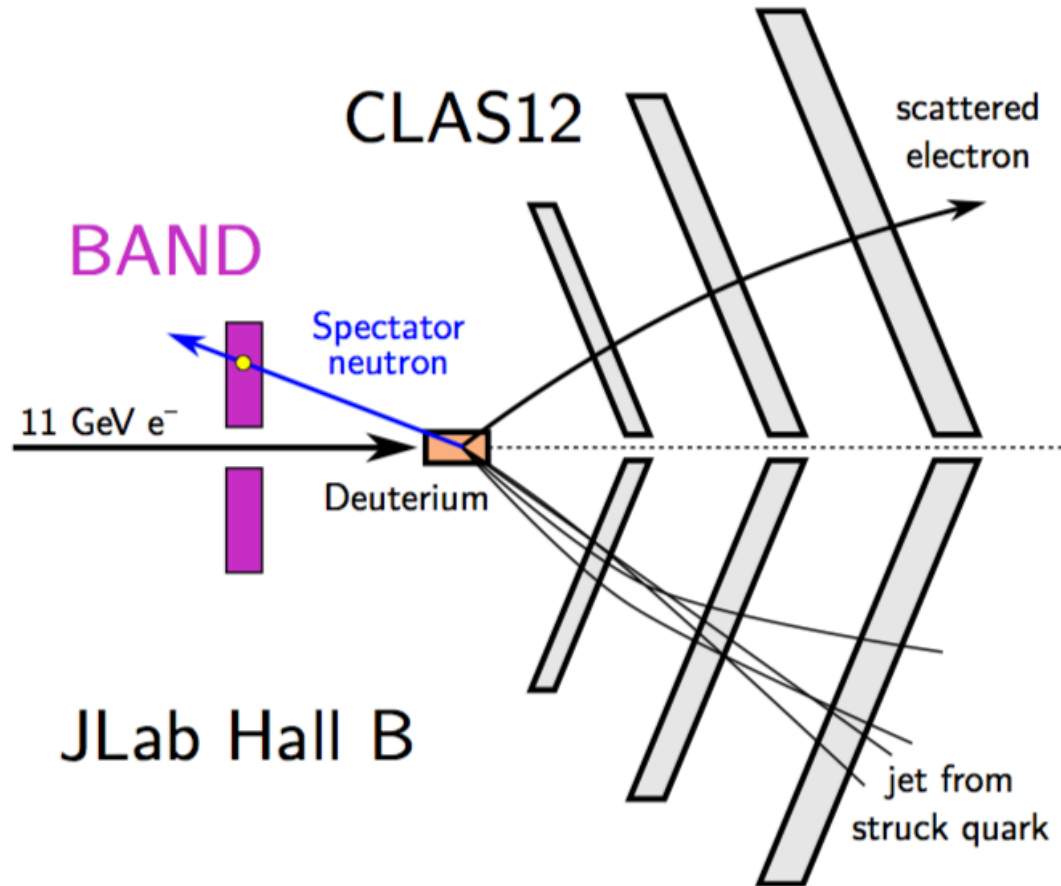


12 GeV: Internal Structure of Bound Nucleons (BAND)

Focus on the deuteron:



12 GeV: Internal Structure of Bound Nucleons (BAND)



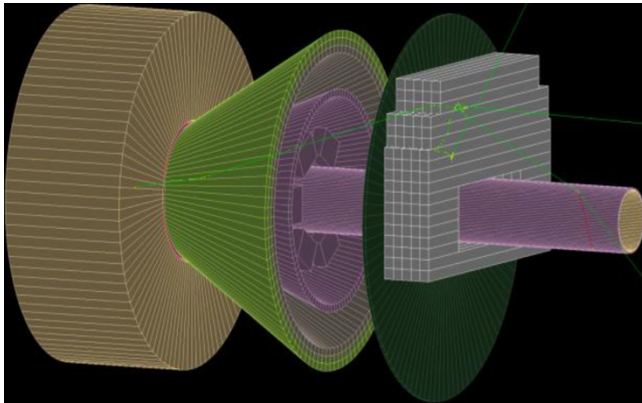
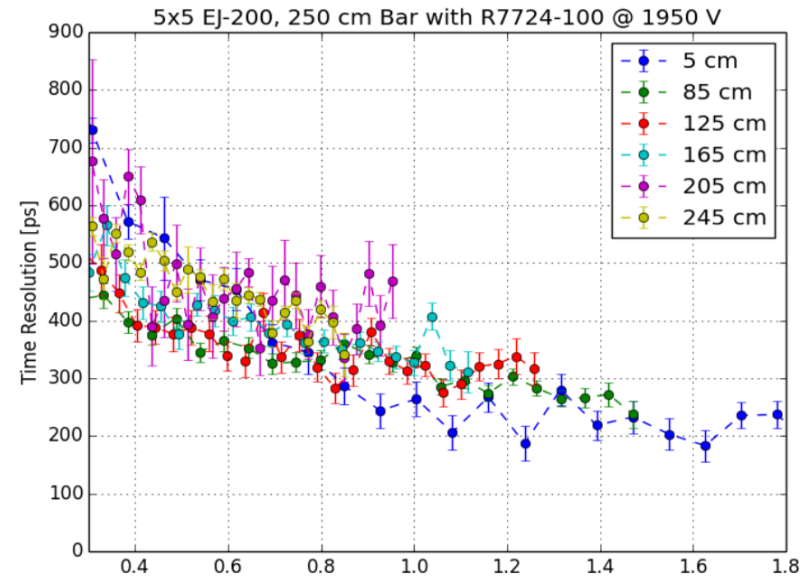


BAND Detector



- R&D Completed (NIM being drafted)
- Mechanical design by UTSM
- Scintillators / PMTs / electronics purchased
- Assembly and tests @ MIT-BATES and ODU

Move to JLab in the summer.



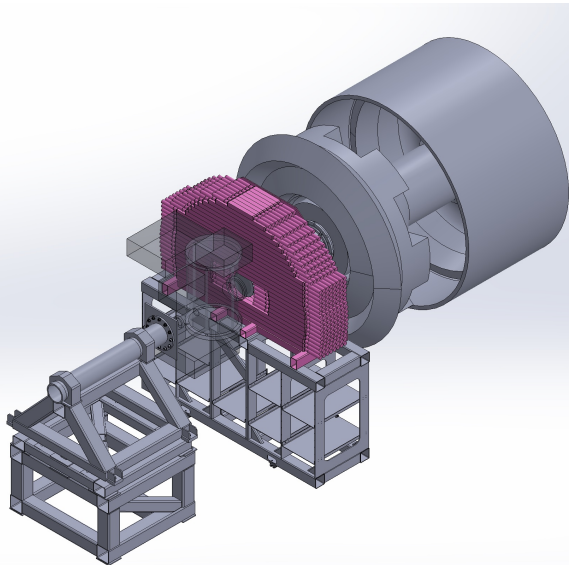
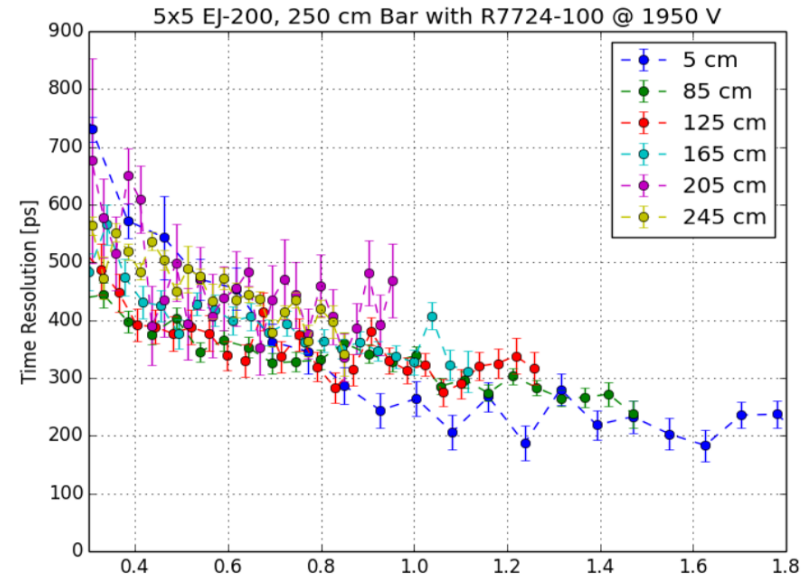


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Streaming Readout



- Our interest originated with the DarkLight experiment
- Stream all data to disk with no external physics trigger
- Most recent EIC Streaming Readout Workshop at MIT (Bernauer and Hasell) on January 29-30, 2018
- Seeking to identify existing detector systems that could be used to develop as prototypes.
- Jefferson Lab a leader in the EIC effort.



Summary



- Propose to enhance present significant participation to full collaboration membership by MIT-HPG (Hen and Milner).
- Propose ramp up of participation by students and post-docs in FY19-21.
- Interested to identify further hardware contributions that we can make.
- Already in summer 2018 can engage members of our group.