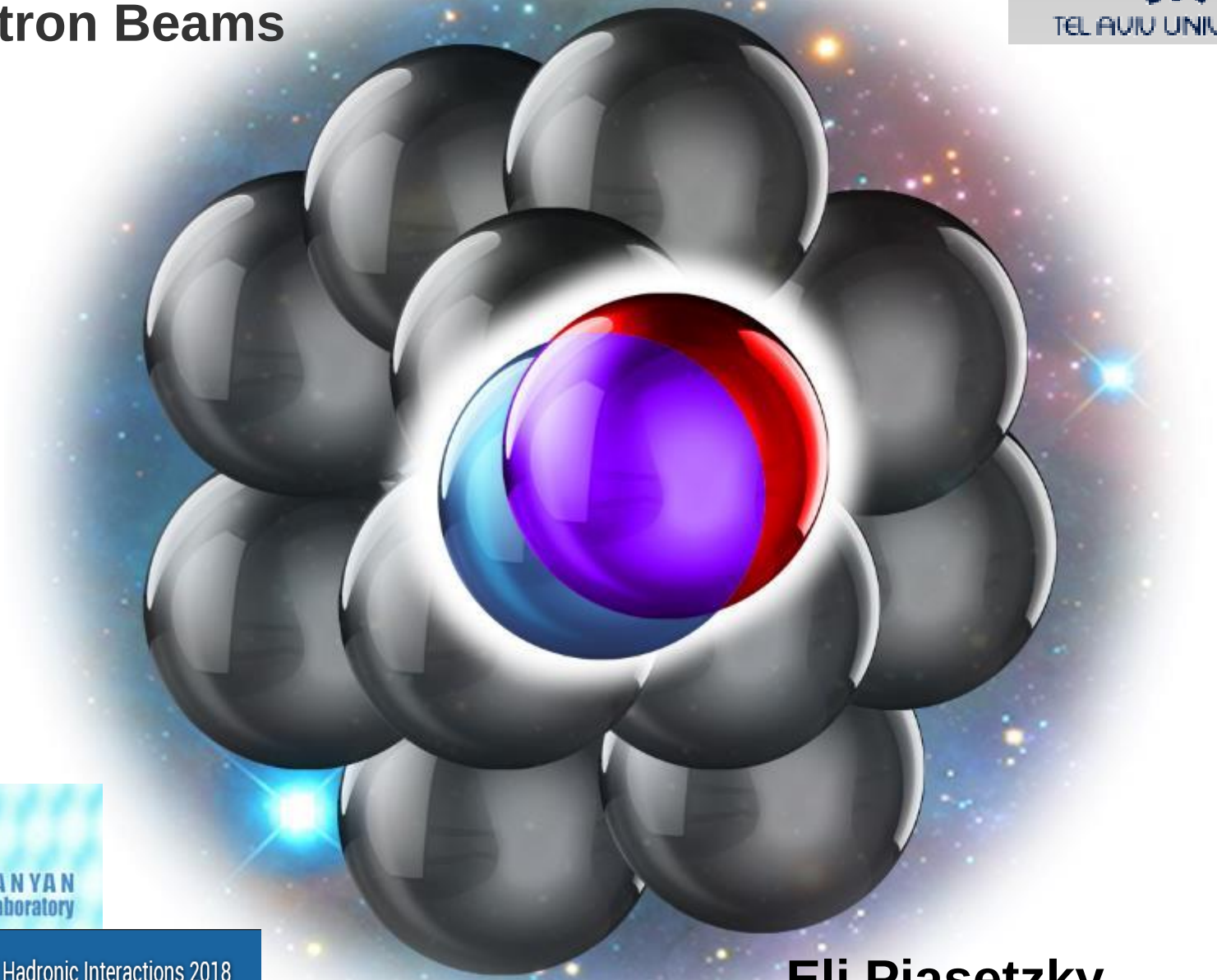
SRC studies with Proton and Electron Beams



A. ALIKHANYAN National Laboratory

Correlations in Partonic and Hadronic Interactions 2018

26 Sep 2018,
Yerevan Armenia

Eli Piasetzky

Tel Aviv University

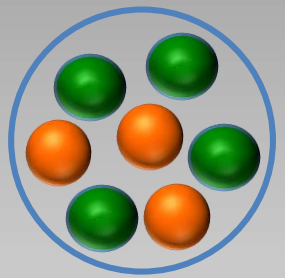
TEL AVIV UNIVERSITY

Correlations in Partonic and Hadronic Interactions 2018

TMDs S.Fs PDFs

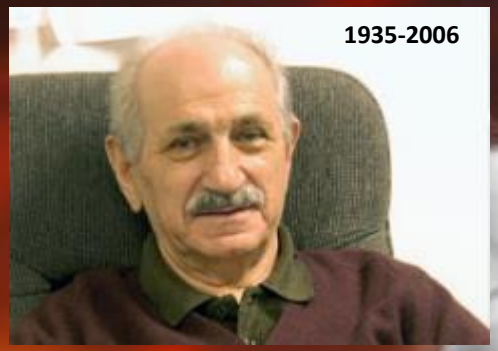
GPDs F.Fs

Is the partonic-structure of nucleons bound in nuclei the same as that of free nucleons?



Close nucleons

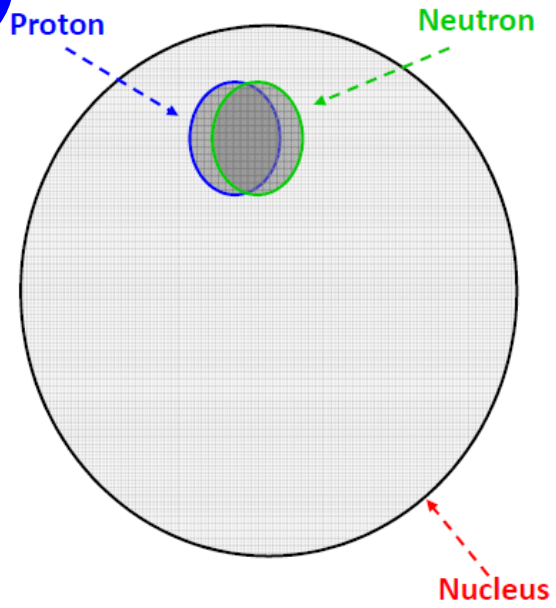
Kim Egiyan Memorial Interm



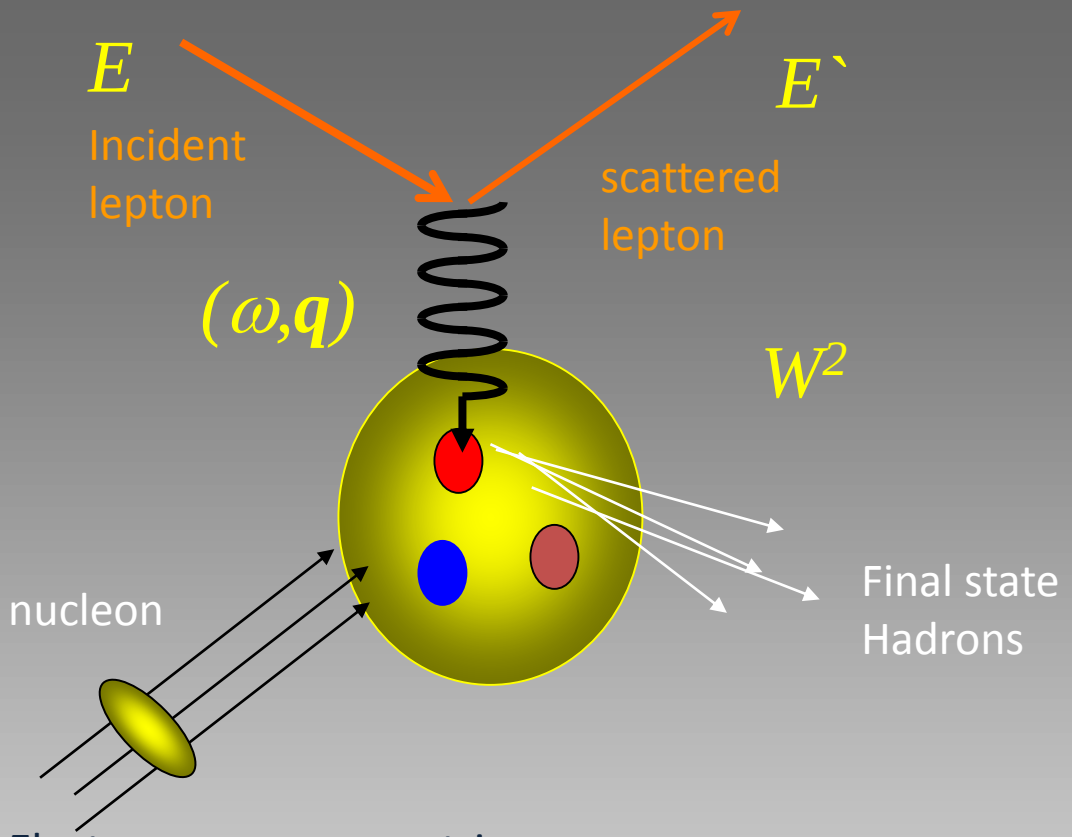
Anania Shirakatsi Medal

Are Nucleons Modified in SRC?

- Because nucleons in SRC are deeply bounded, they should be modified, e.g., in shape, in quark distributions.
- Electron scattering from the nucleons in SRC will probe these modifications. This contributes towards better understanding of nucleon structure.
- These studies are one of the main direction of electro-nuclear program at JLab.



Deep Inelastic Scattering (DIS)



$$Q^2 = -q_\mu q^\mu = q^2 - \omega^2$$

$$\omega = E' - E$$

$$x_B = \frac{Q^2}{2m\omega} \quad (= \frac{Q^2}{2(q \cdot p_T)})$$

$$0 \le x_B \le 1$$

SLAC, CERN, HERA, FNAL, JLAB

E, E' 5-500 GeV

Q^2 5-50 GeV^2

w^2 >4 GeV^2

$0 \le X_B \le 1$

X_B gives the fraction of nucleon momentum carried by the struck parton

Information about nucleon vertex is contained in $F_1(x,Q^2)$ and $F_2(x,Q^2)$, the unpolarized structure functions

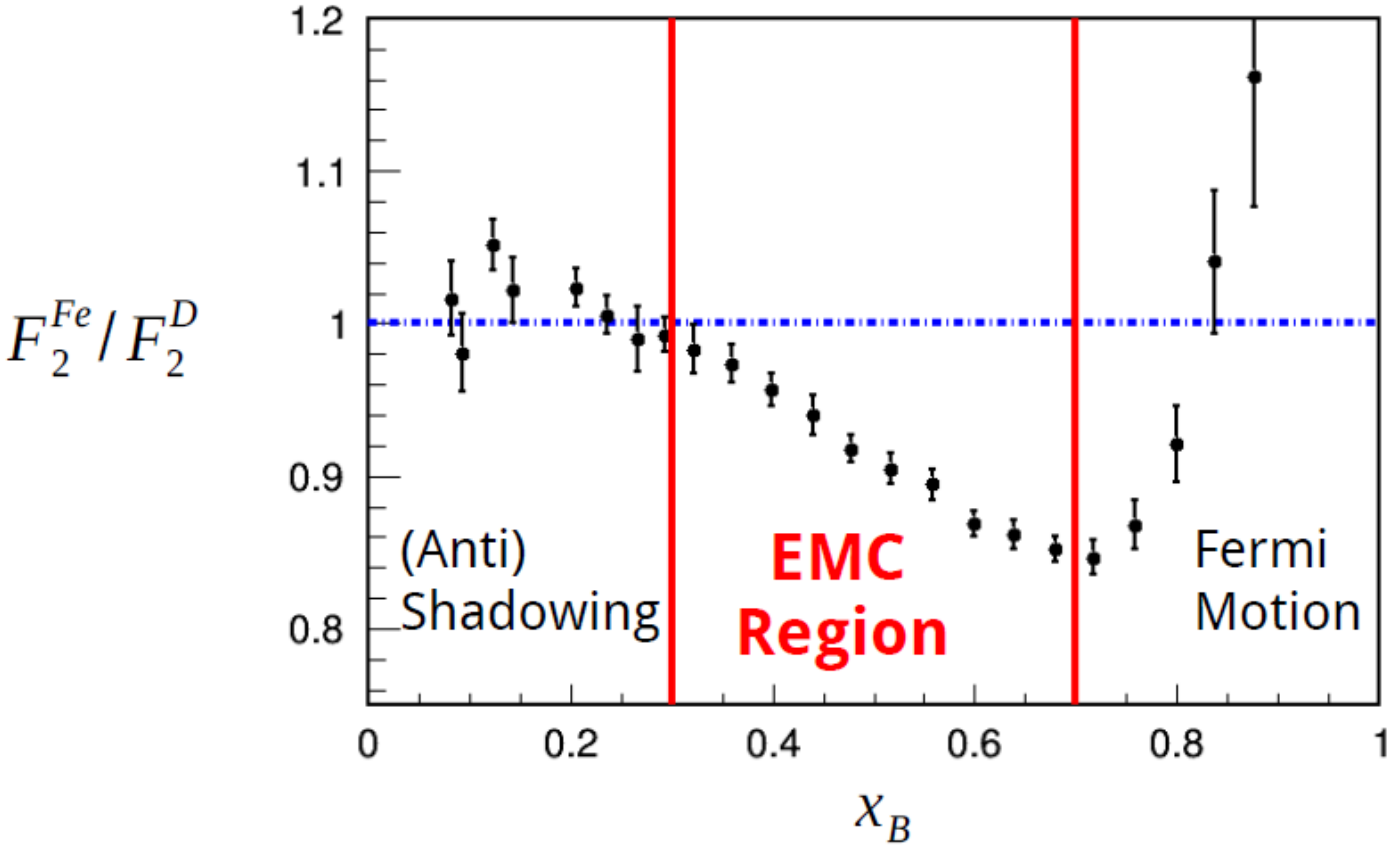
TMDs S.Fs PDFs

GPDs F.Fs

Is the partonic-structure of nucleons bound in nuclei the same as that of free nucleons?

$$F_2(x,Q^2)_{\text{Bound nucleon}} = F_2(x,Q^2)_{\text{Free nucleon}}$$

Deep Inelastic Scattering: **The EMC Effect**

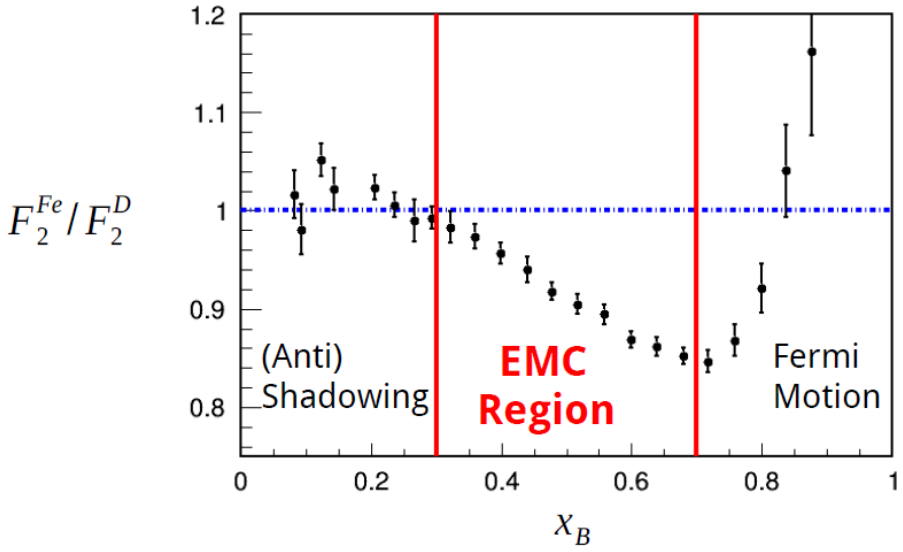


Bound nucleon DIS ≠ free DIS

$$F_2^A \neq Z \cdot F_2^p + N \cdot F_2^n$$

Aubert et al., PLB (1983); Ashman et al., PLB (1988); Arneodo et al., PLB (1988); Allasia et al., PLB (1990); Gomez et al., PRD (1994); Seely et al., PRL (2009); Schmookler et al., Submitted (2018)

35 years after discovery: still no consensus on underlaying cause

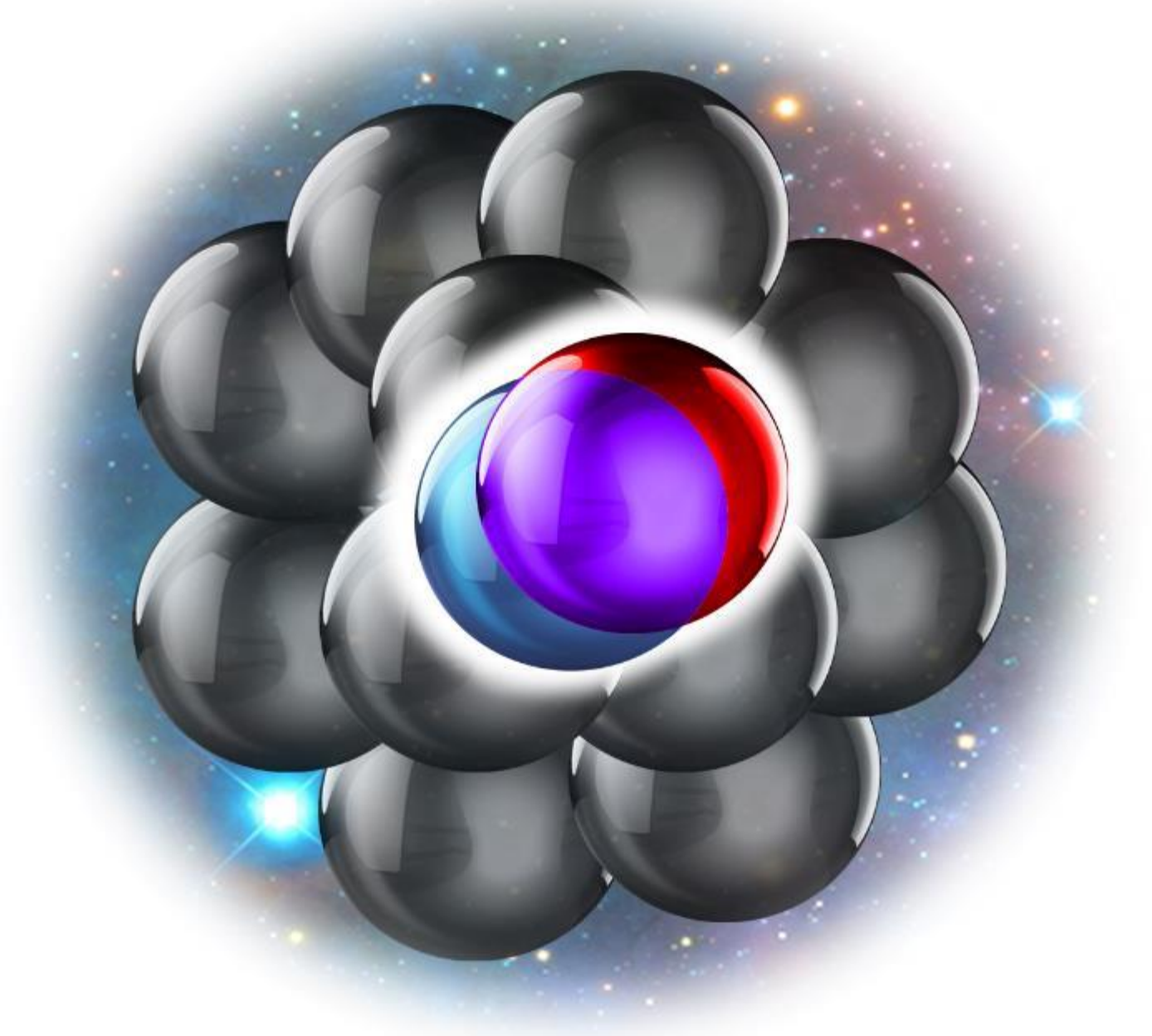


Bound nucleon DIS ≠ free DIS

$$F_2^A \neq Z \cdot F_2^p + N \cdot F_2^n$$

Close nucleons

Short-Range Correlations (SRC)



What are Short Range Correlations in nuclei ?

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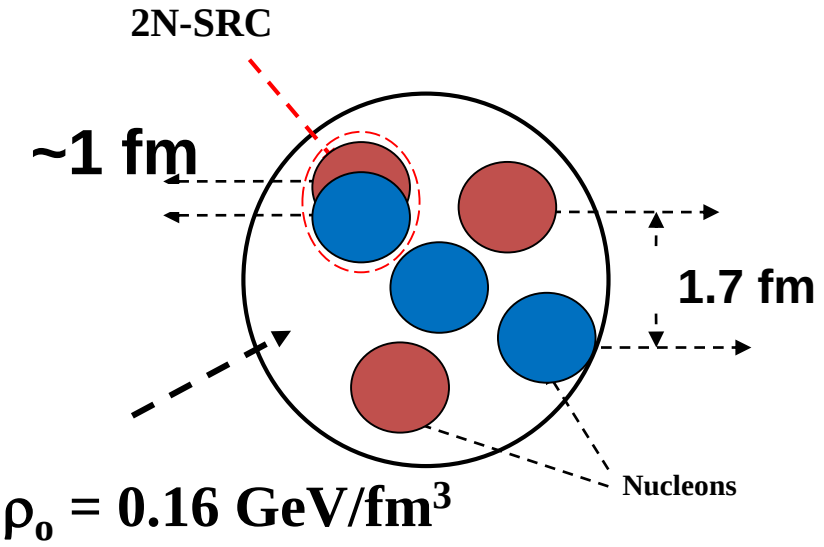
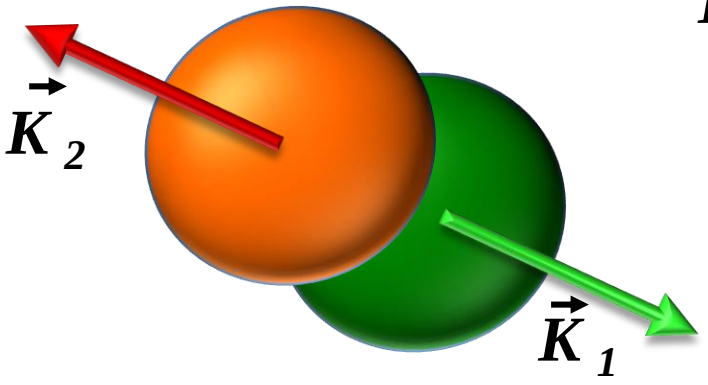
SRC ~R_N **LRC ~R_A**



$\rho_o = 0.16$ GeV/fm^3

In momentum space:



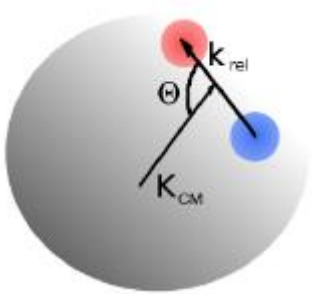
$\vec{K}_1 \cong \vec{K}_2$

$K_1 > K_F$,

$K_2 > K_F$

$K_{rel} > K_F$

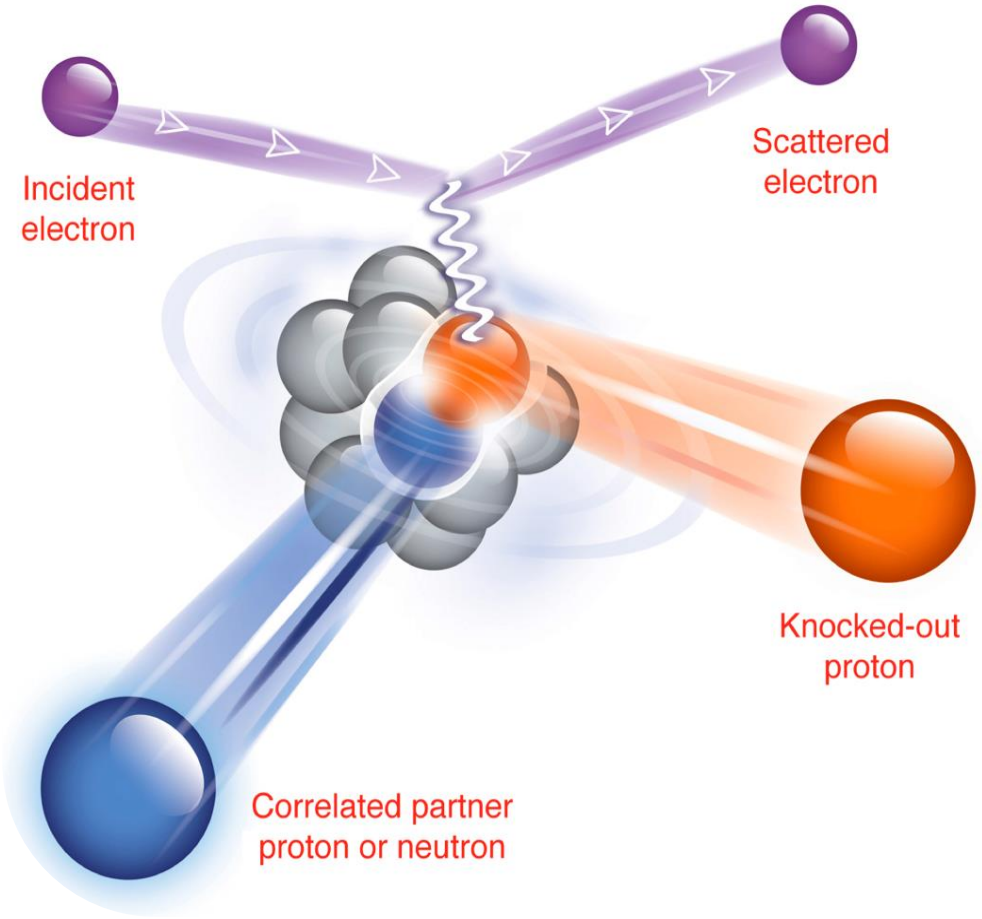
$K_{CM} < K_F$



$k_F \approx 250$ MeV/c

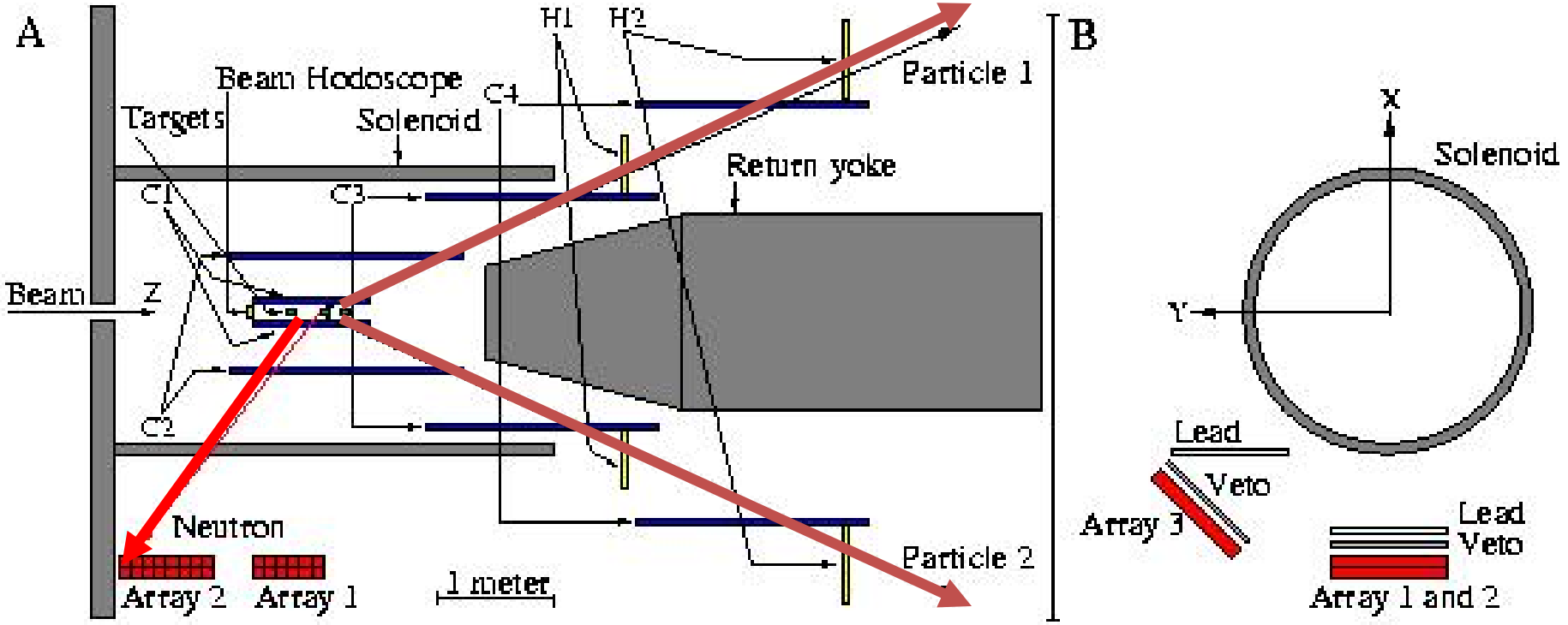
A pair with large relative momentum between the nucleons and small CM momentum.

Probing Correlations Using Hard Knockout Reactions



Same with high energy protons

The EVA spectrometer and the n-counters:



Array #2 was build by YERPHI

The first attempt do a triple coincidence measurement at Yerevan 1991

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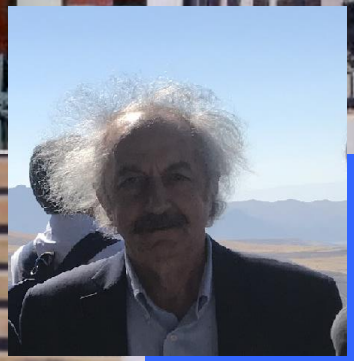
Detectors from Yerevan

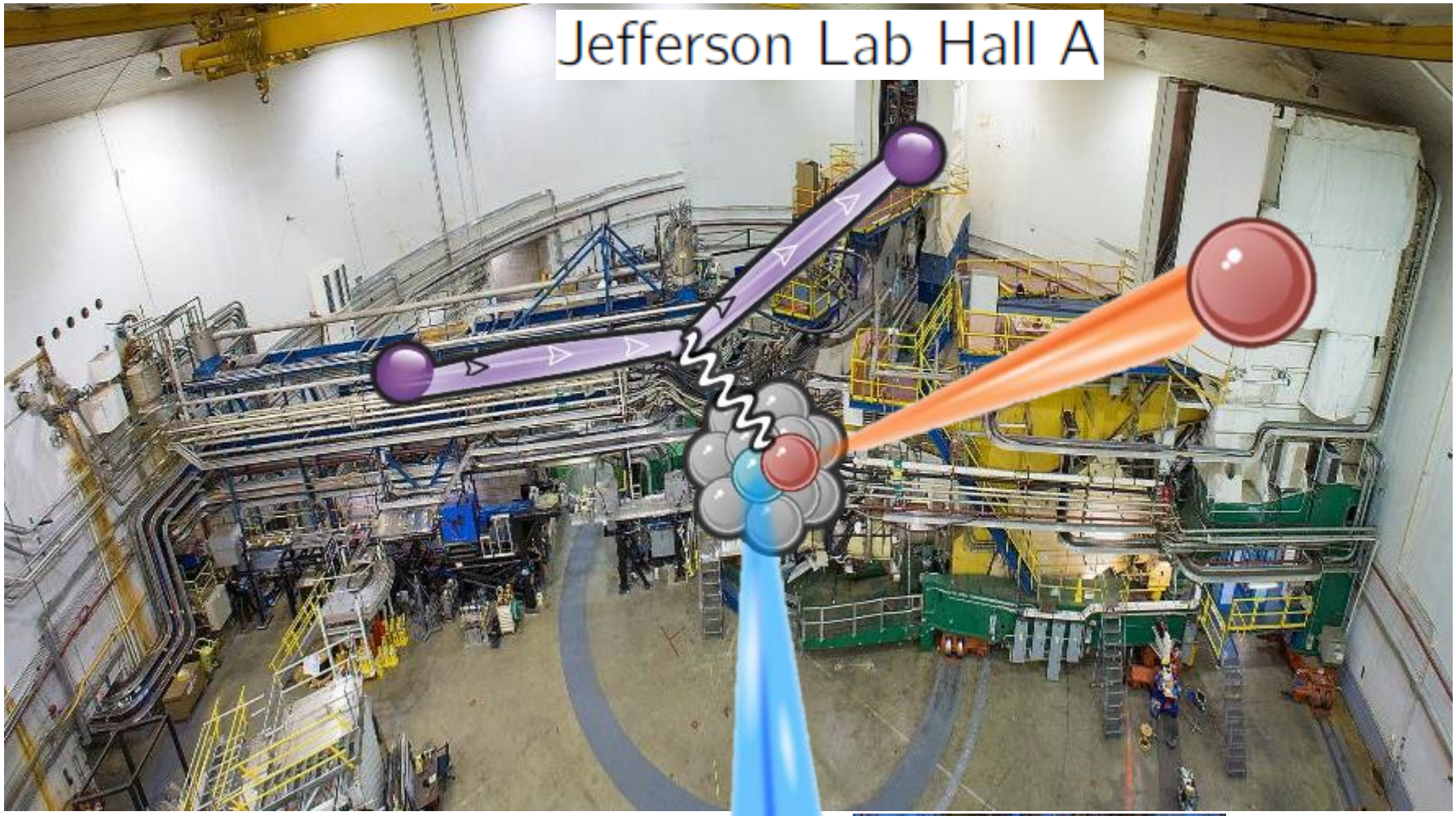
Fast electronics for Tel Aviv Univ.

BUT

No electrici ele

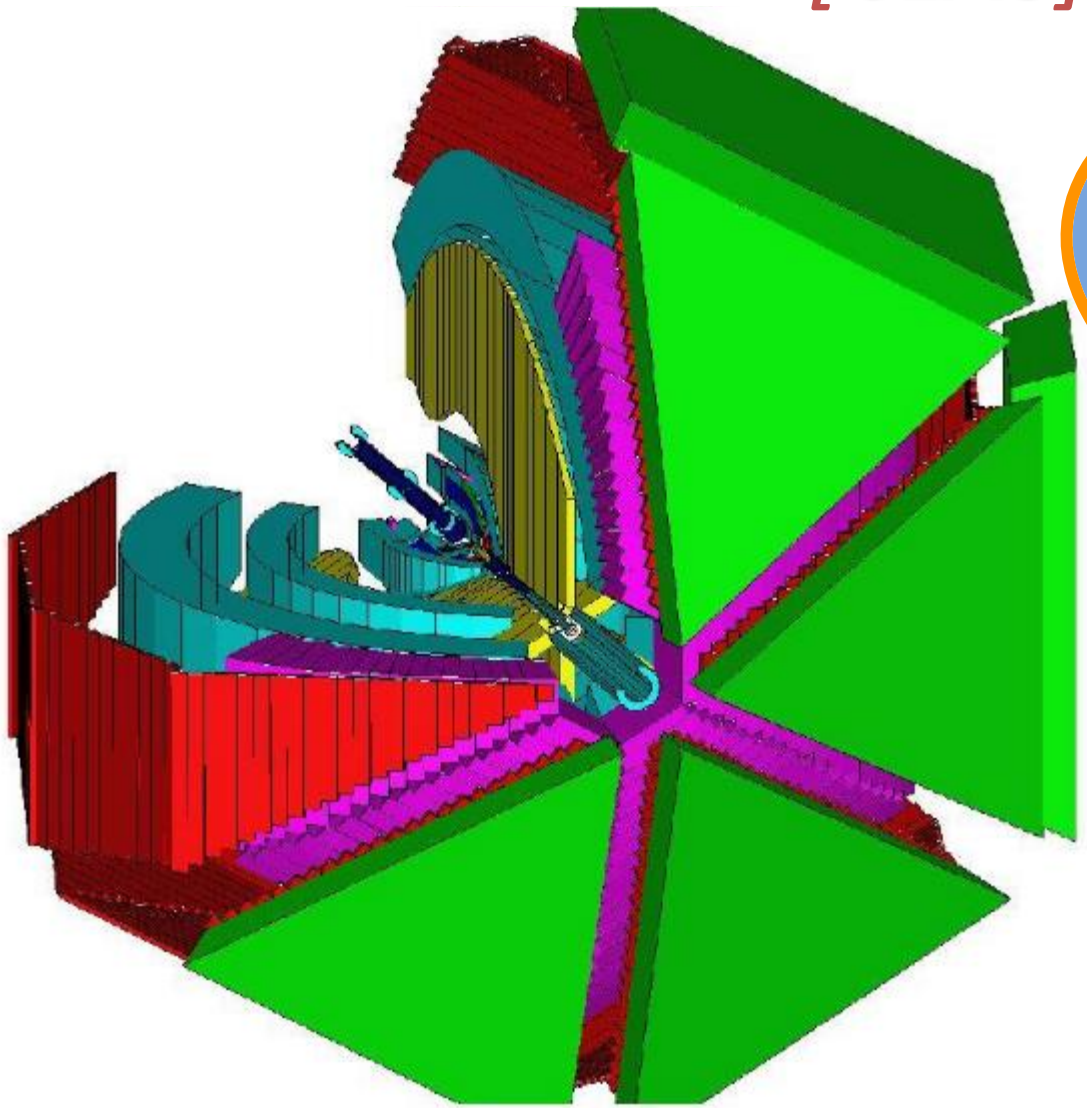


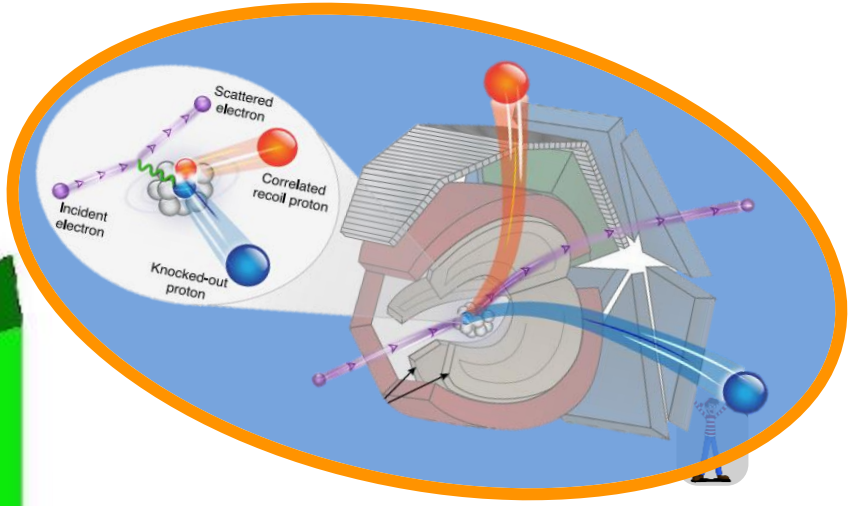
Thanks Asryan Geghan for the pictures

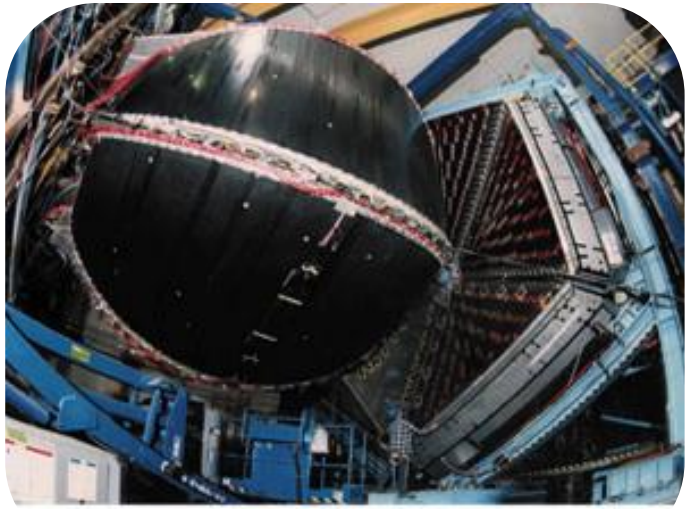


BigBite Spectrometer

CEBAF Large Acceptance Spectrometer *[CLAS]*





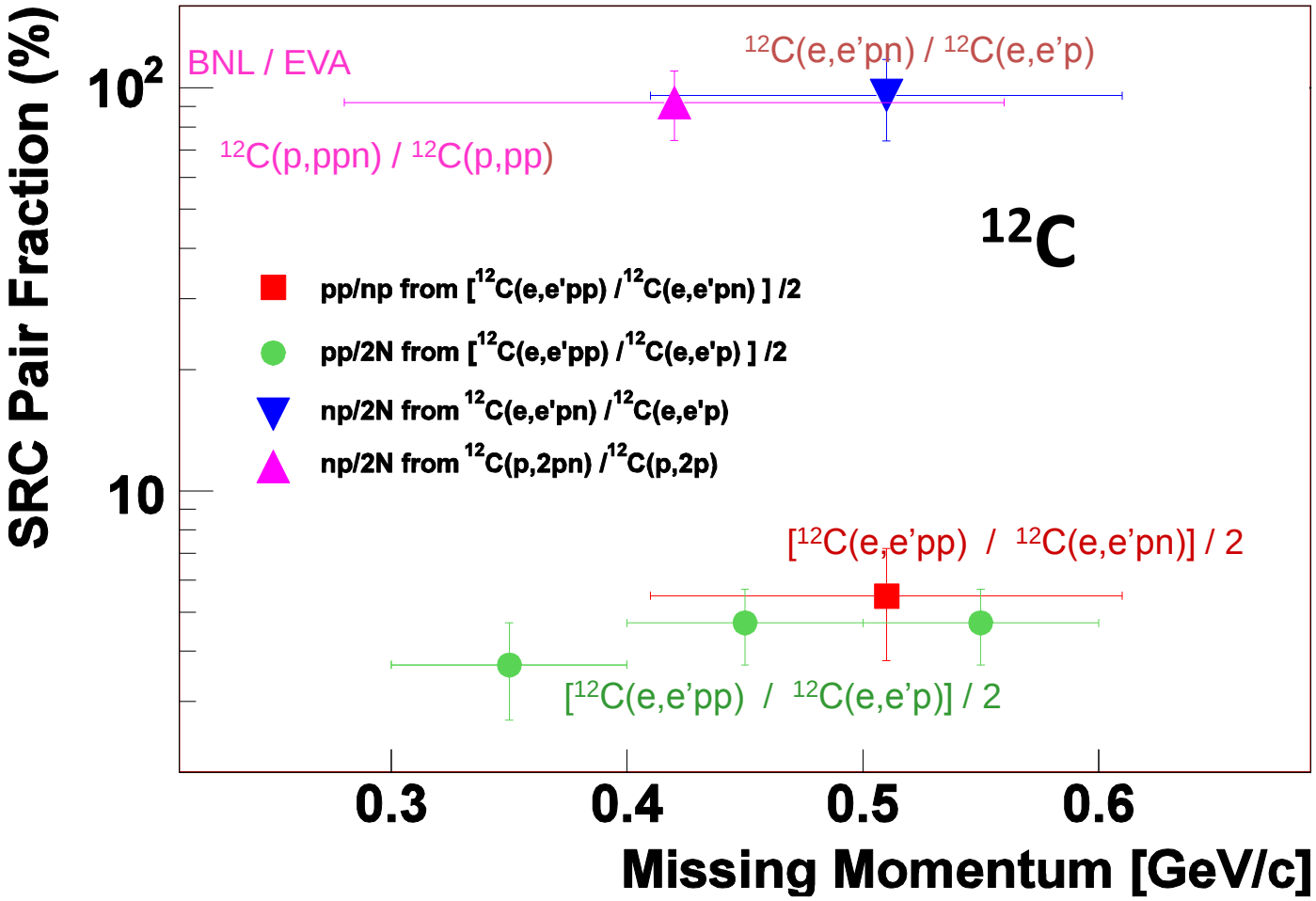


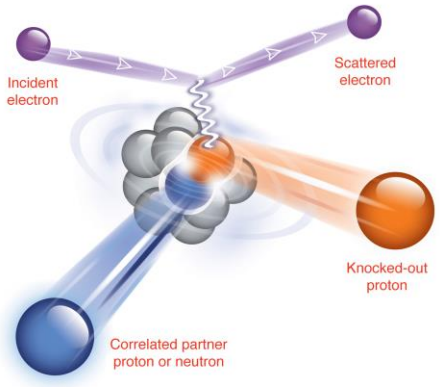
Hall B Large Acceptance Spectrometer

Open (e,e') trigger, Large-Acceptance, Low luminosity (~10^{34} cm^{-2} sec^{-1})

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

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

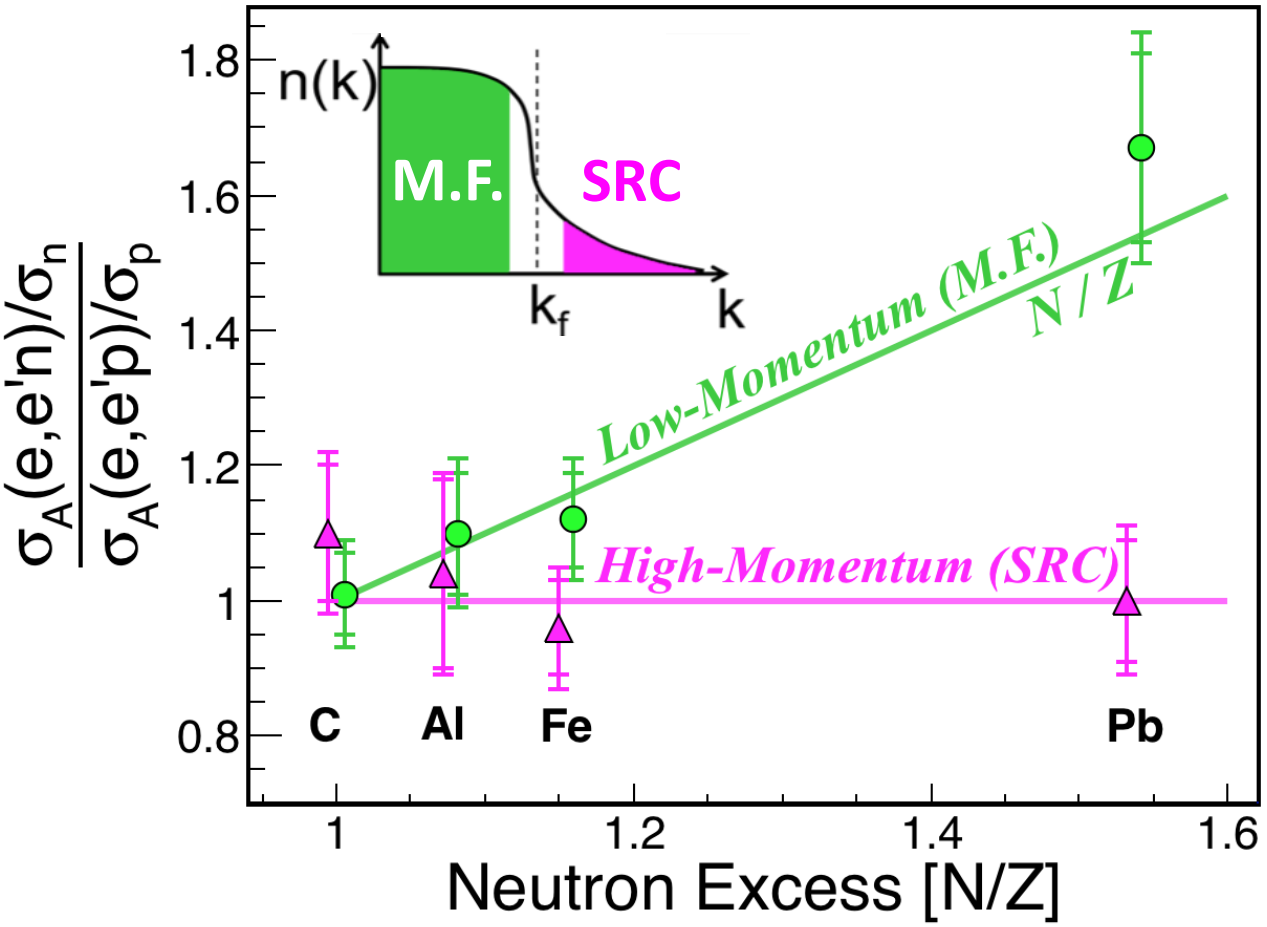




The high momentum tail in nuclei is dominated by SRC pairs

Most of the SRC pairs (90%) are np only 5% pp and 5% nn

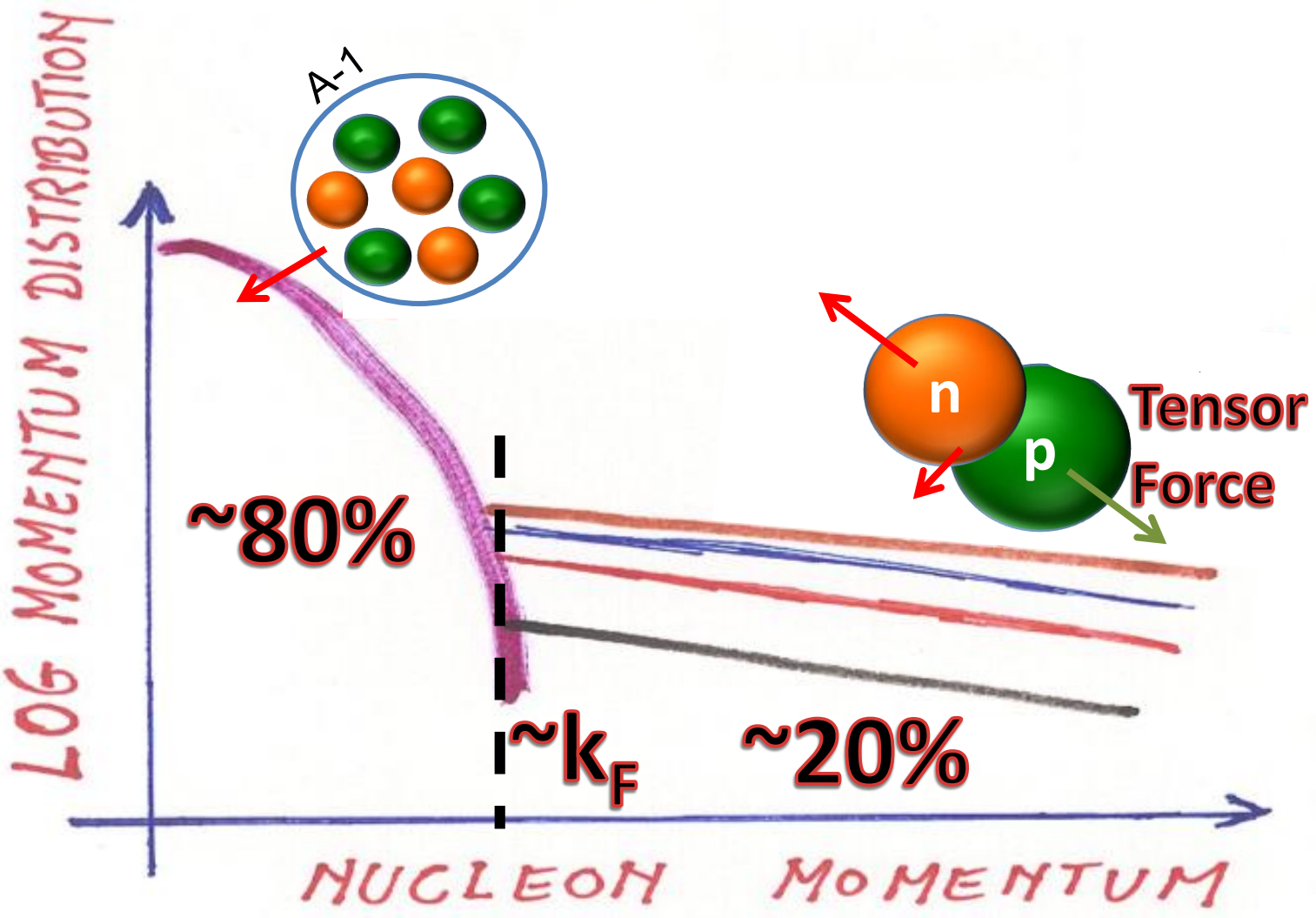
Proton vs. Neutron Knockout $A(e,e'p)$ $A(e,e'n)$



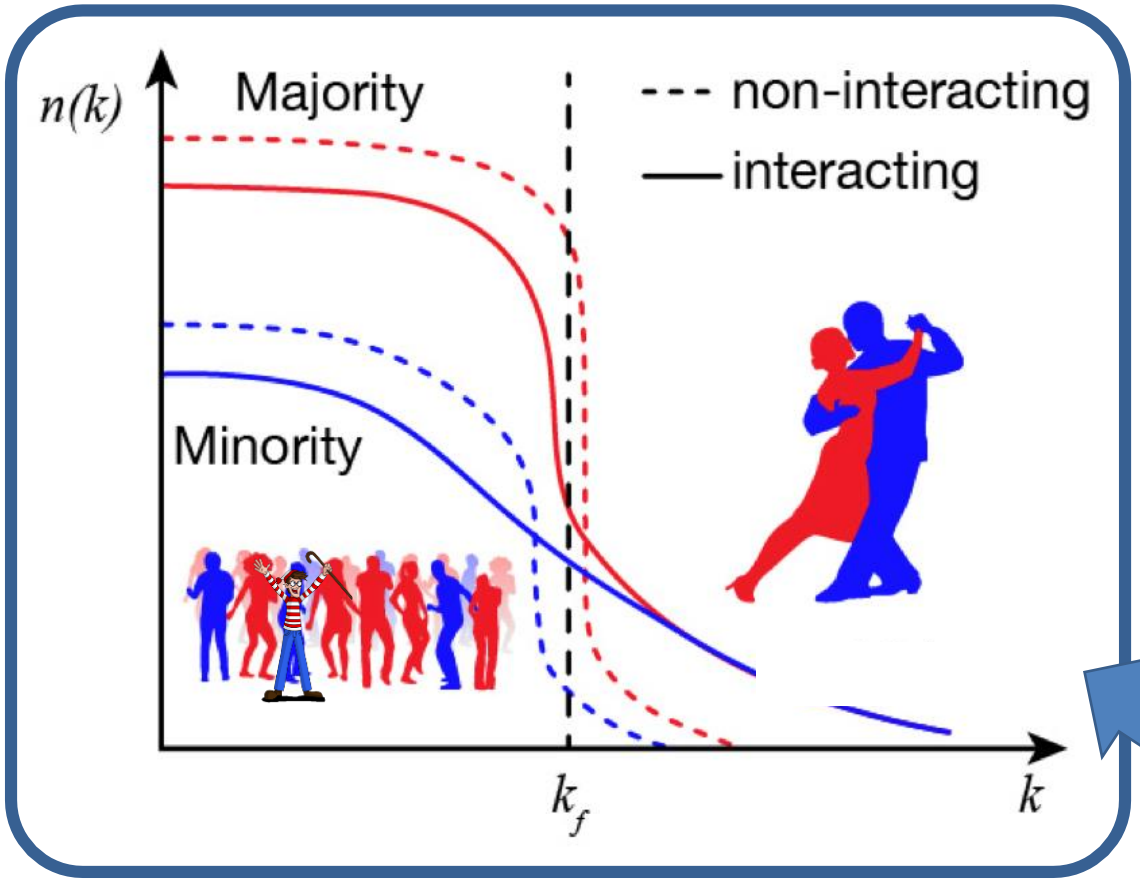
➔ **Same # of high-momentum protons and neutrons**

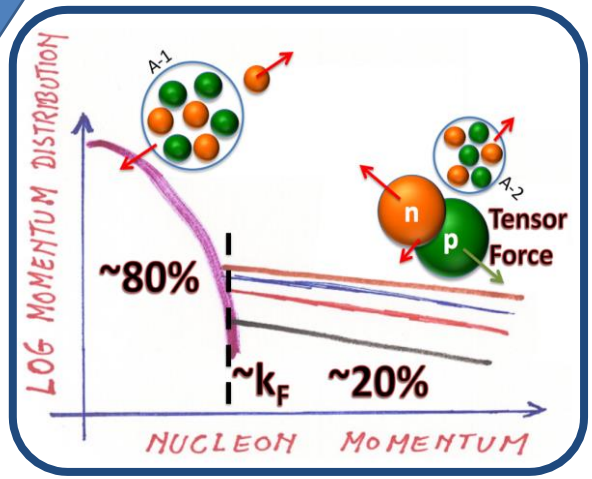
M. Duer et al. (CLAS Collaboration), Nature, 560 (2018) 617-621

np – dominance



np- dominance and Asymmetric Nuclei





For nuclei with N>Z:

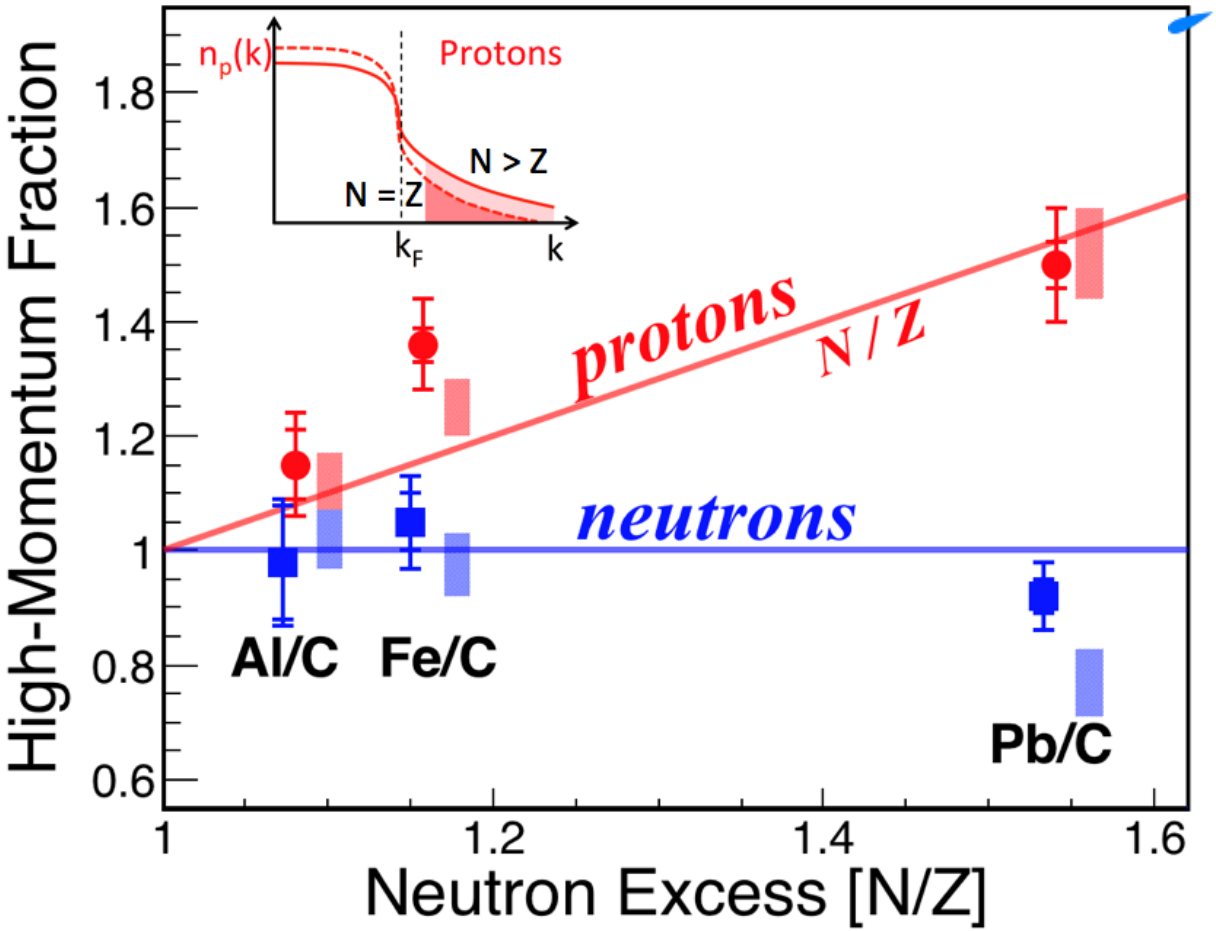
Protons have a greater probability than neutrons to be above the Fermi sea.

What do the outer shell neutrons do ?

Do they produce SRC pairs with the inner shells protons ?

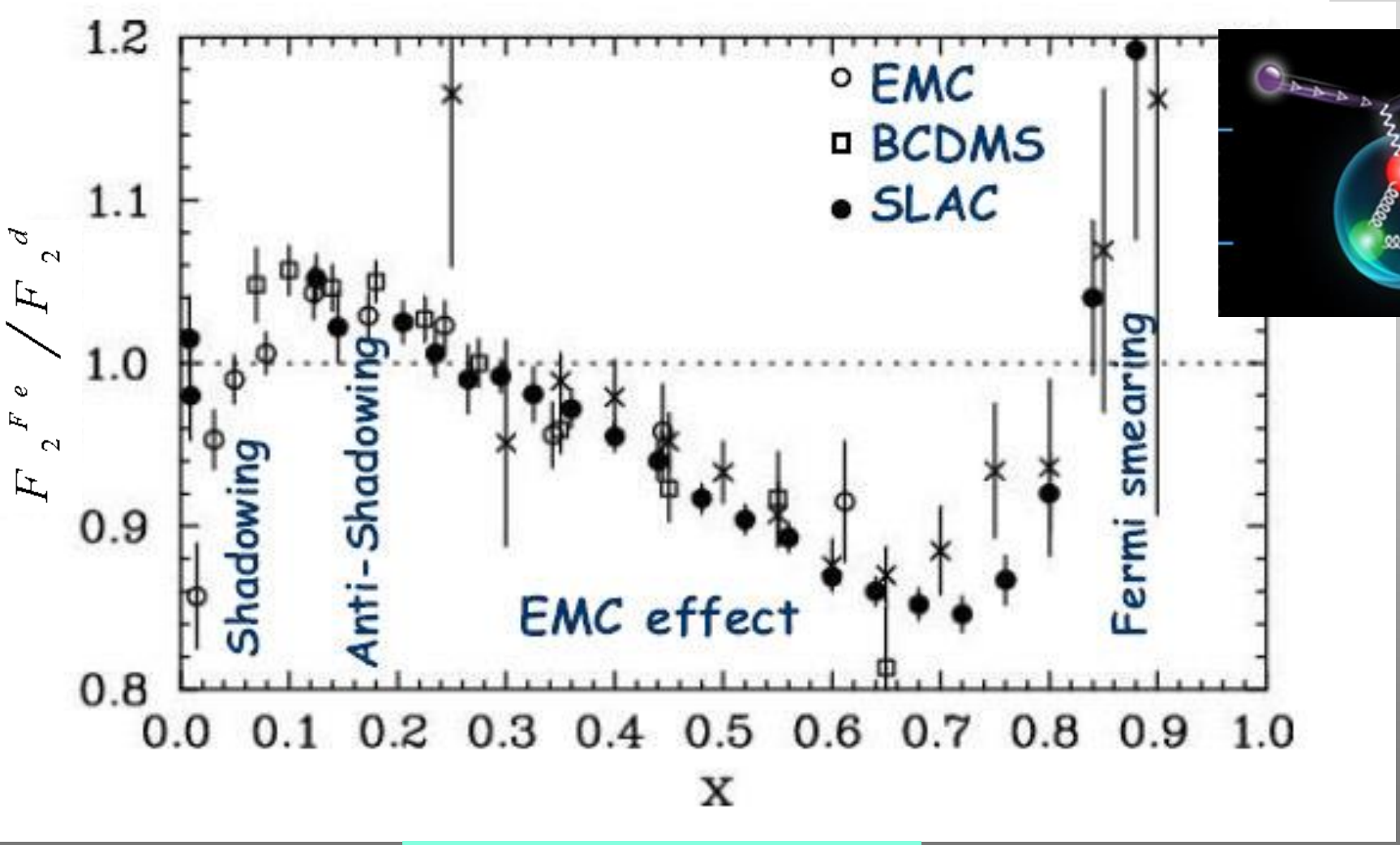
M. Duer et al. (CLAS Collaboration), Nature, 560 (2018) 617-621

Correlation Probability:
Neutrons saturate Protons grow



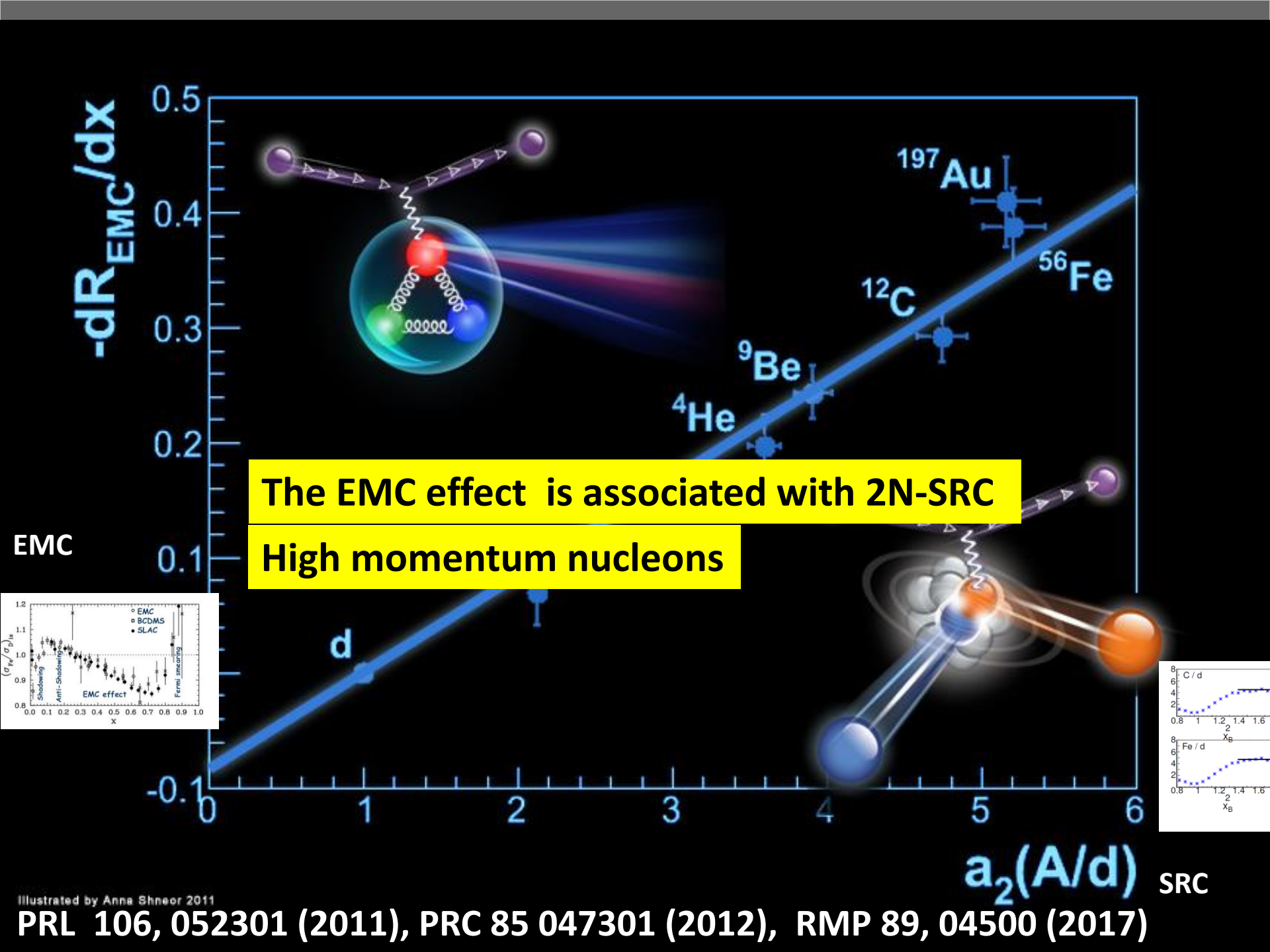
M. Duer et al. (CLAS Collaboration), Nature, 560 (2018) 617-621

The European Muon Collaboration (EMC) effect



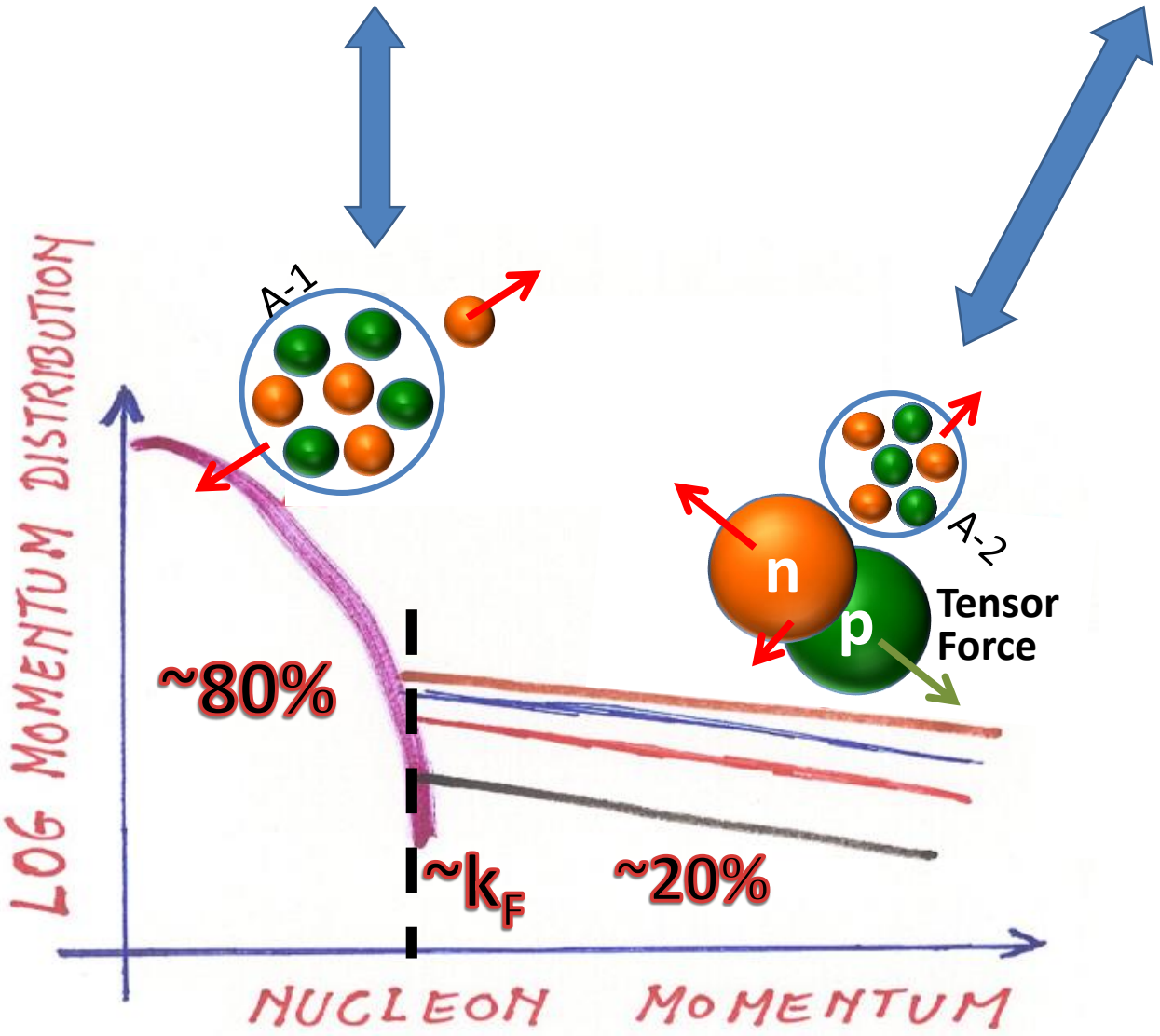
$$F_2^A \neq Z \cdot F_2^p + N \cdot F_2^n$$

After 30 years no consensus on cause of EMC effect



PRL 106, 052301 (2011), PRC 85 047301 (2012), RMP 89, 04500 (2017)

Bound S.F. = Free S.F. + Modified S.F.



Prediction 1:

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EMC effect is isospin dependent

A larger fraction of the Proton than neutron will be modify in nuclei.

Prediction 2:

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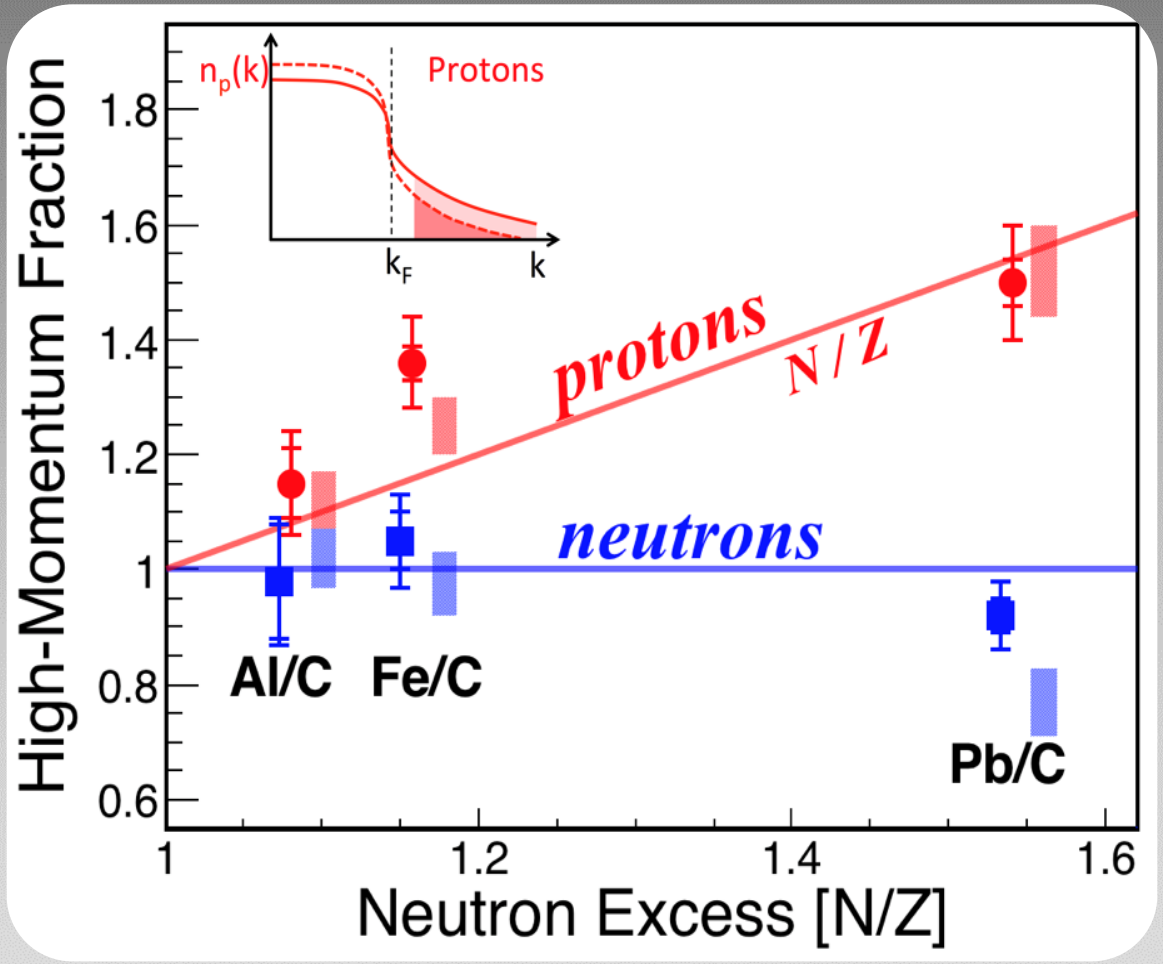
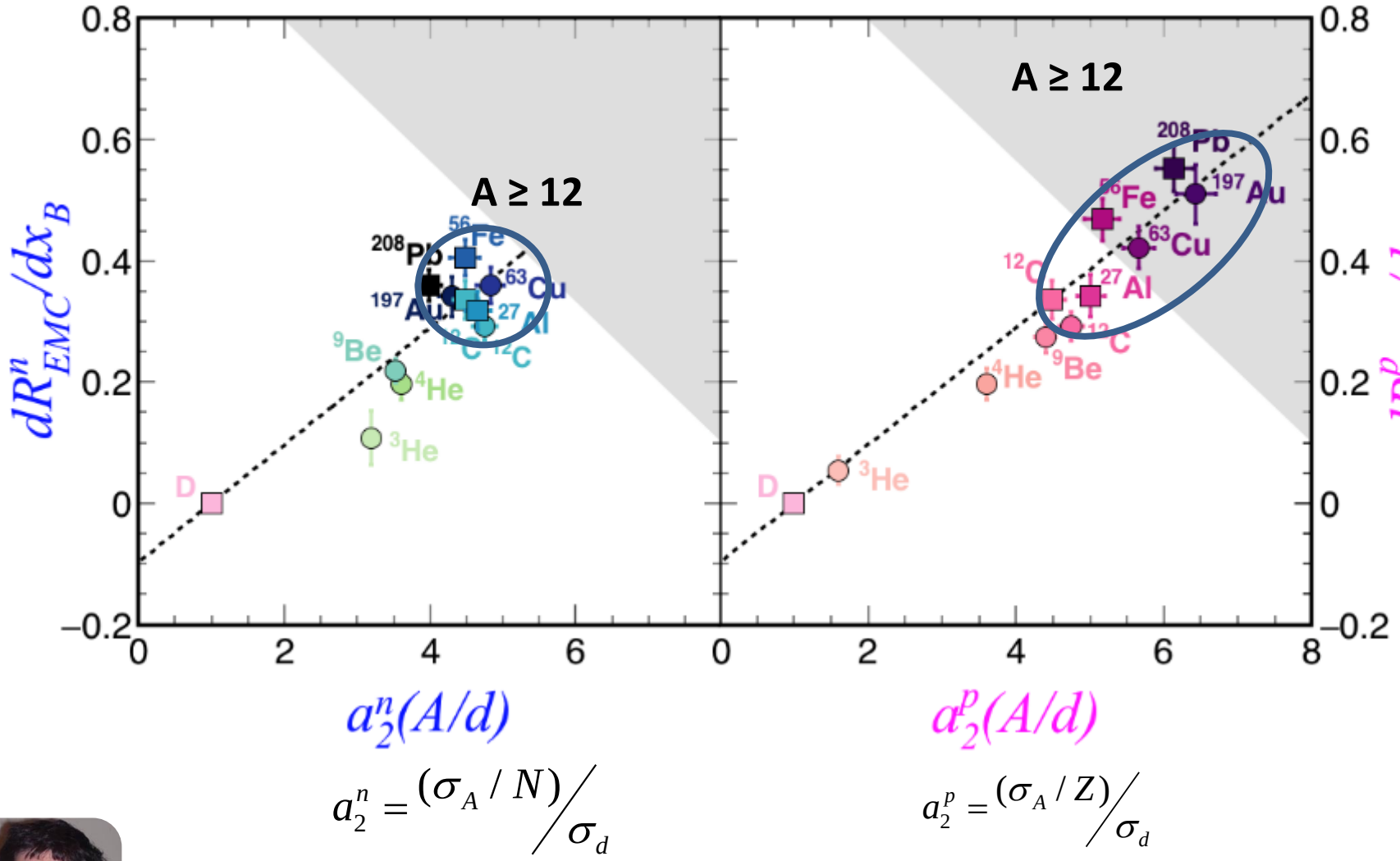
EMC effect should saturate for neutrons and grow for protons



M. Duer et al. (CLAS Collaboration), Nature, 560 (2018) 617-621

Neutrons Saturate, Protons Grow

DIS slop/N



DIS slop/Z

$$a_2^n = (\sigma_A / N) / \sigma_d$$

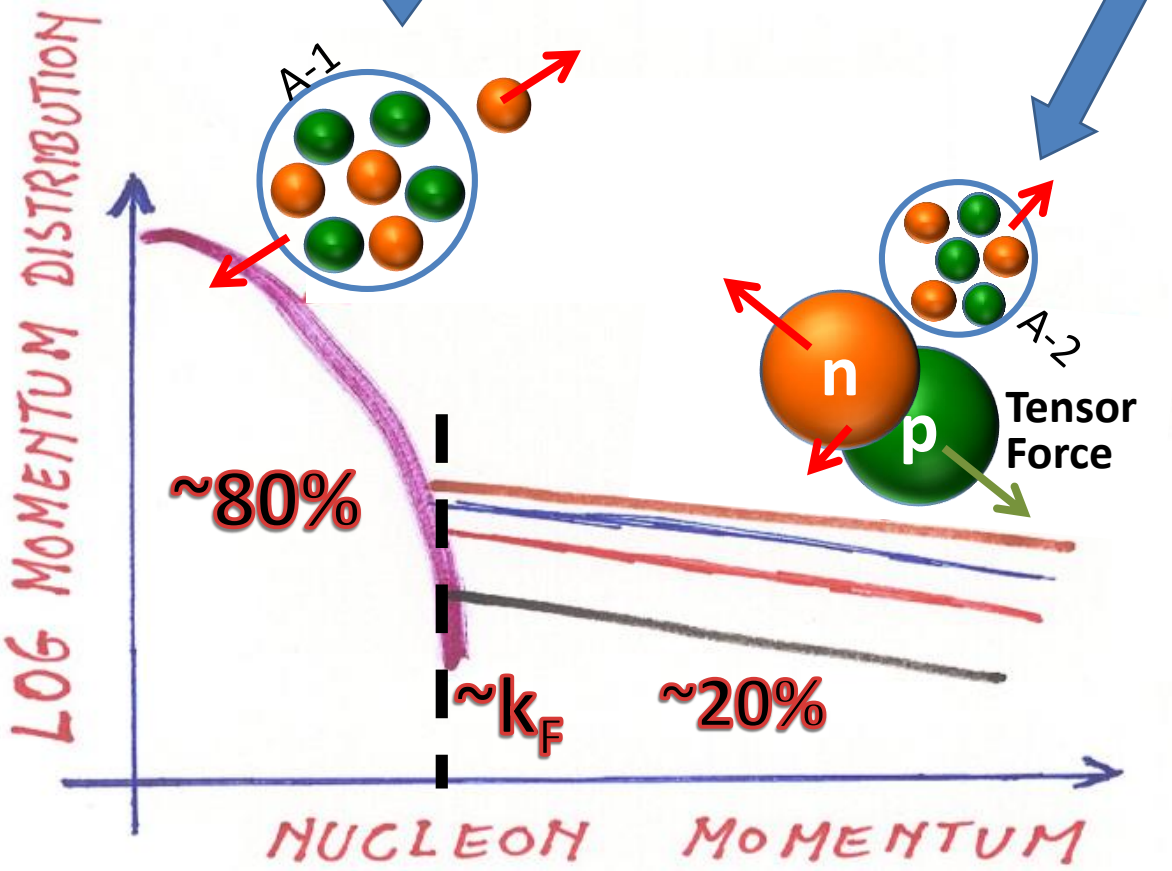
$$a_2^p = (\sigma_A / Z) / \sigma_d$$

Schmookler, Duer, and Schmidt et al., submitted (2018)

Bound = 'quasi Free' + Modified SRCs

$$F_2^A = ZF_2^p + NF_2^n + n_{SRC}^A\left(\Delta F_2^p + \Delta F_2^n\right)$$

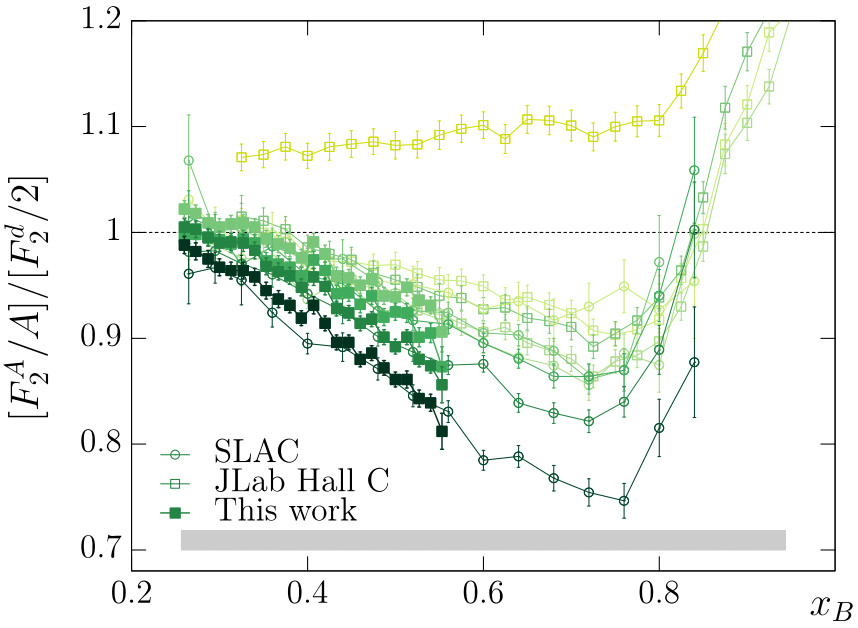
$$\Delta F_2^N = F_2^{N*} - F_2^N$$

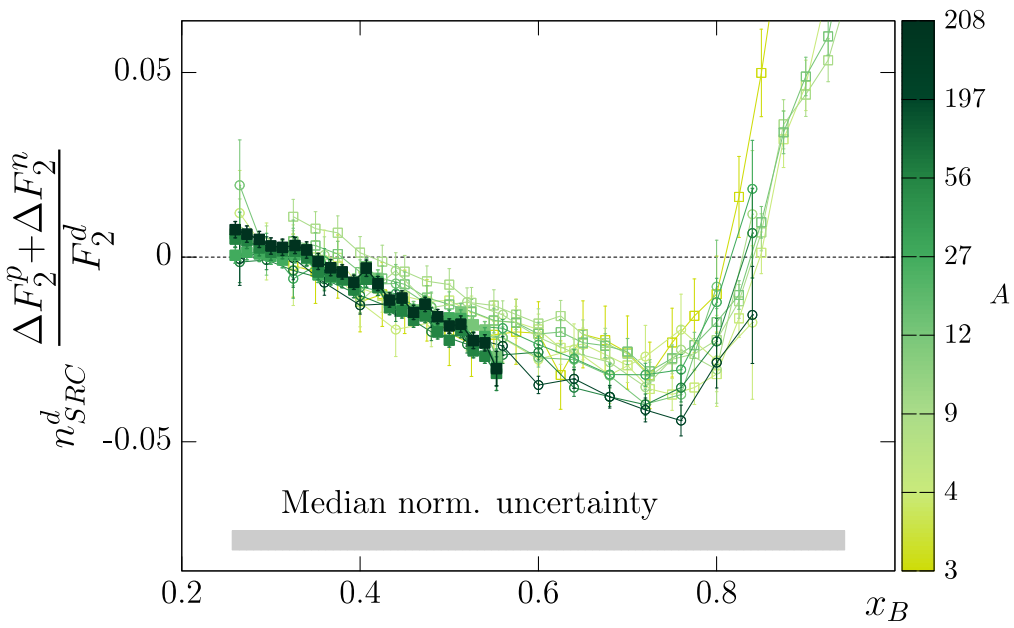


$$\frac{F_2^A}{F_2^d} = \left(n_{SRC}^A - N n_{SRC}^d\right) \frac{\Delta F_2^p + \Delta F_2^n}{F_2^d} + (Z-N)\frac{F_2^p}{F_2^d} + N$$

A Dependent — **Universal!** — **A Dependent**

$$\Delta F_2^N = F_2^{N*} - F_2^N$$

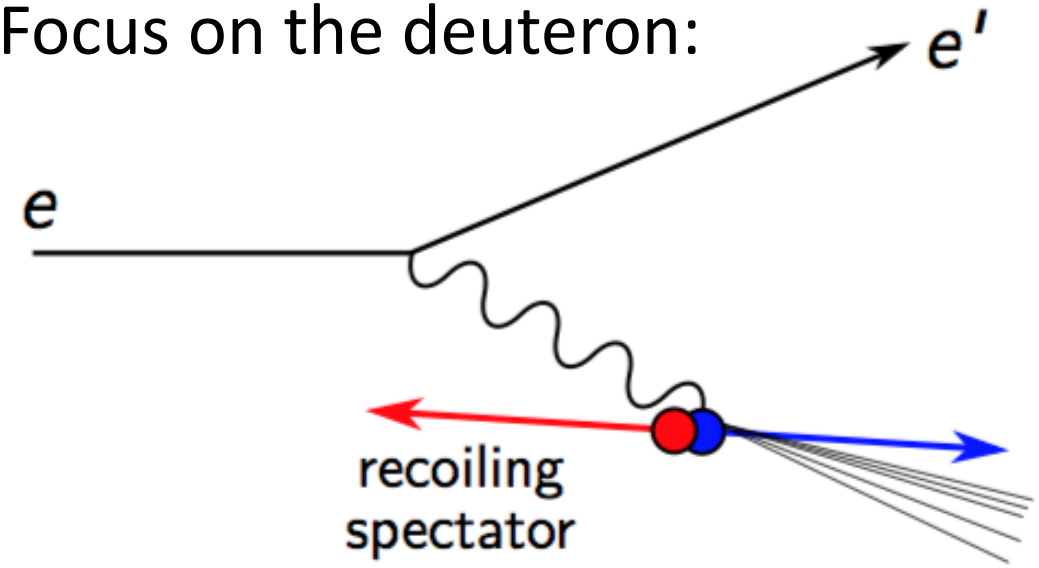




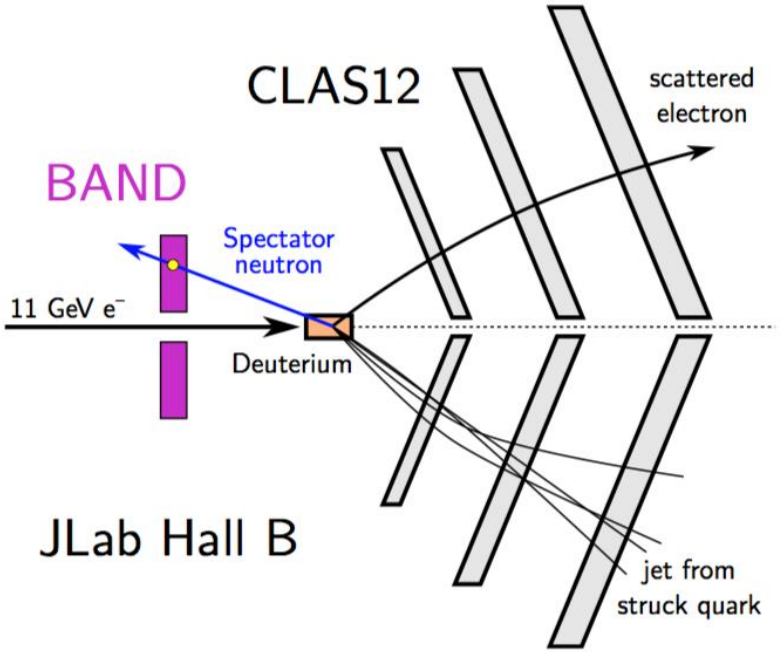
Schmookler, Duer, and Schmidt et al., submitted (2018)

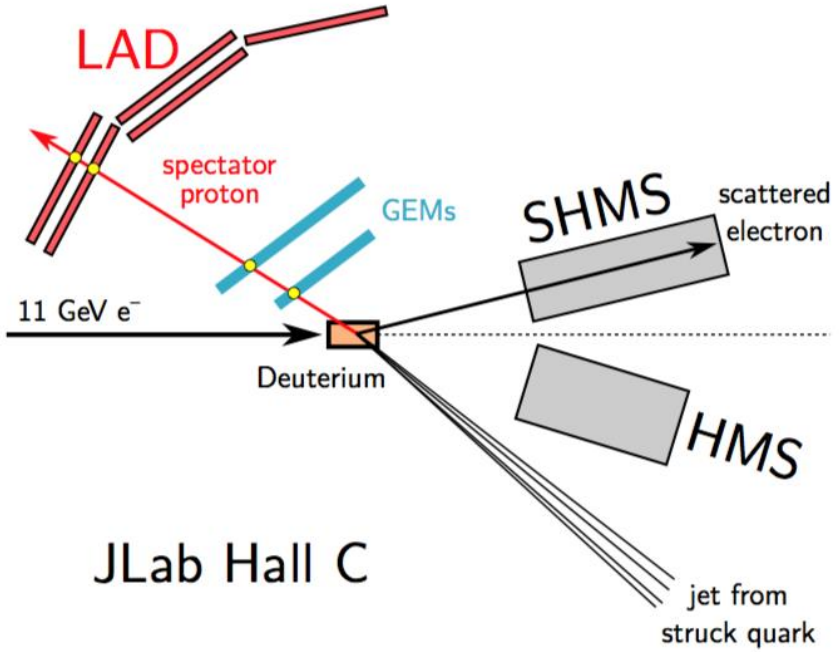
Internal Structure of Bound Nucleons

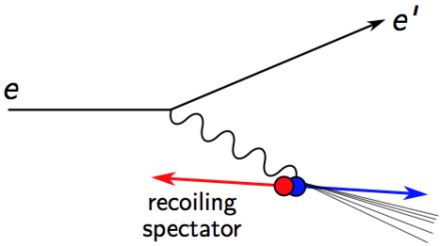
Focus on the deuteron:

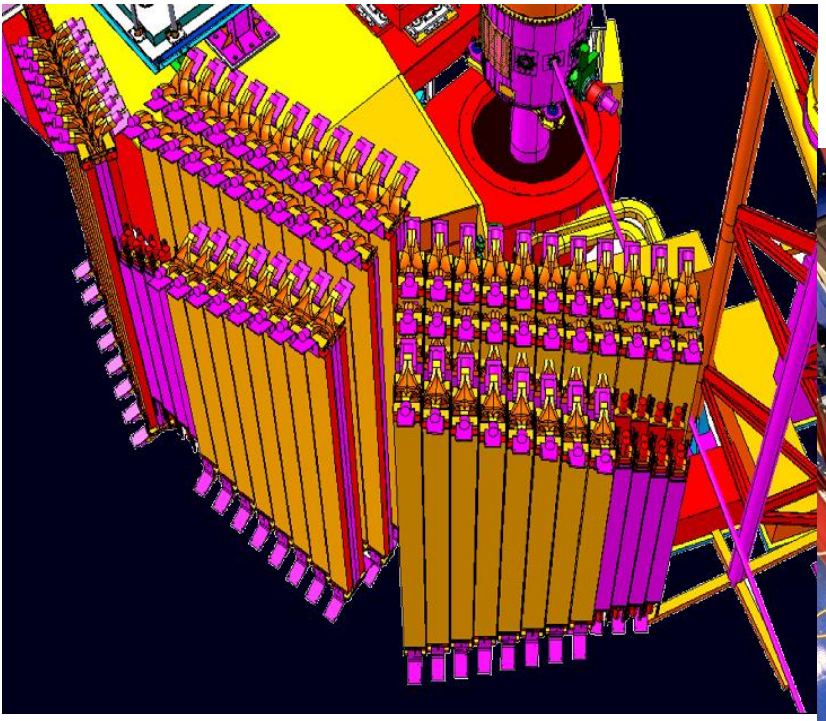


Internal Structure of Bound Nucleons

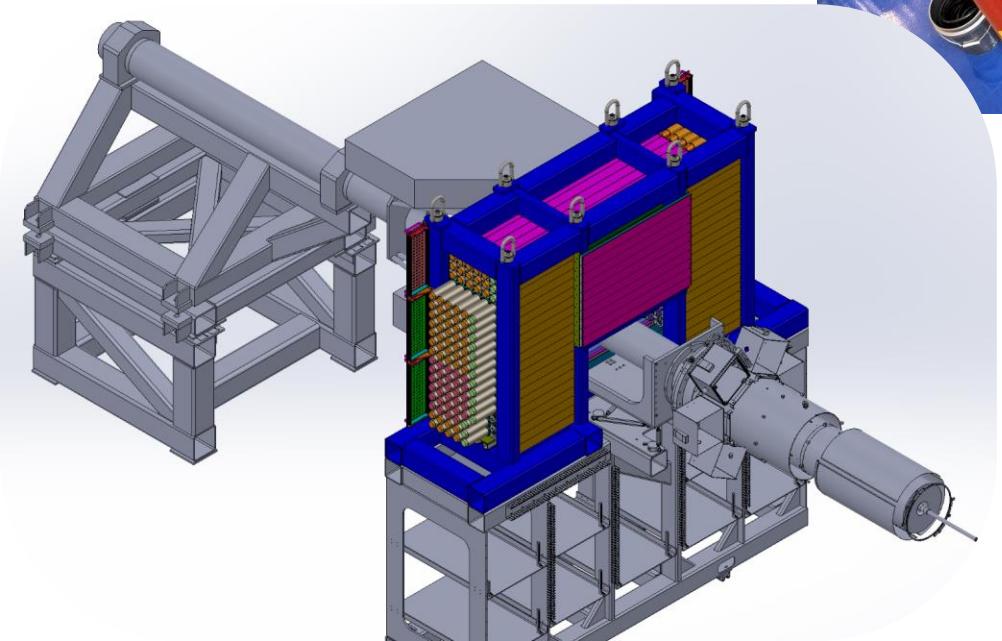








Large Acceptance Detector (LAD@Hall-C)



Backward Angle Neutron Detector (BAND@Hall-B)

MIT-BATES / TAU / ODU / UTSM

Summary

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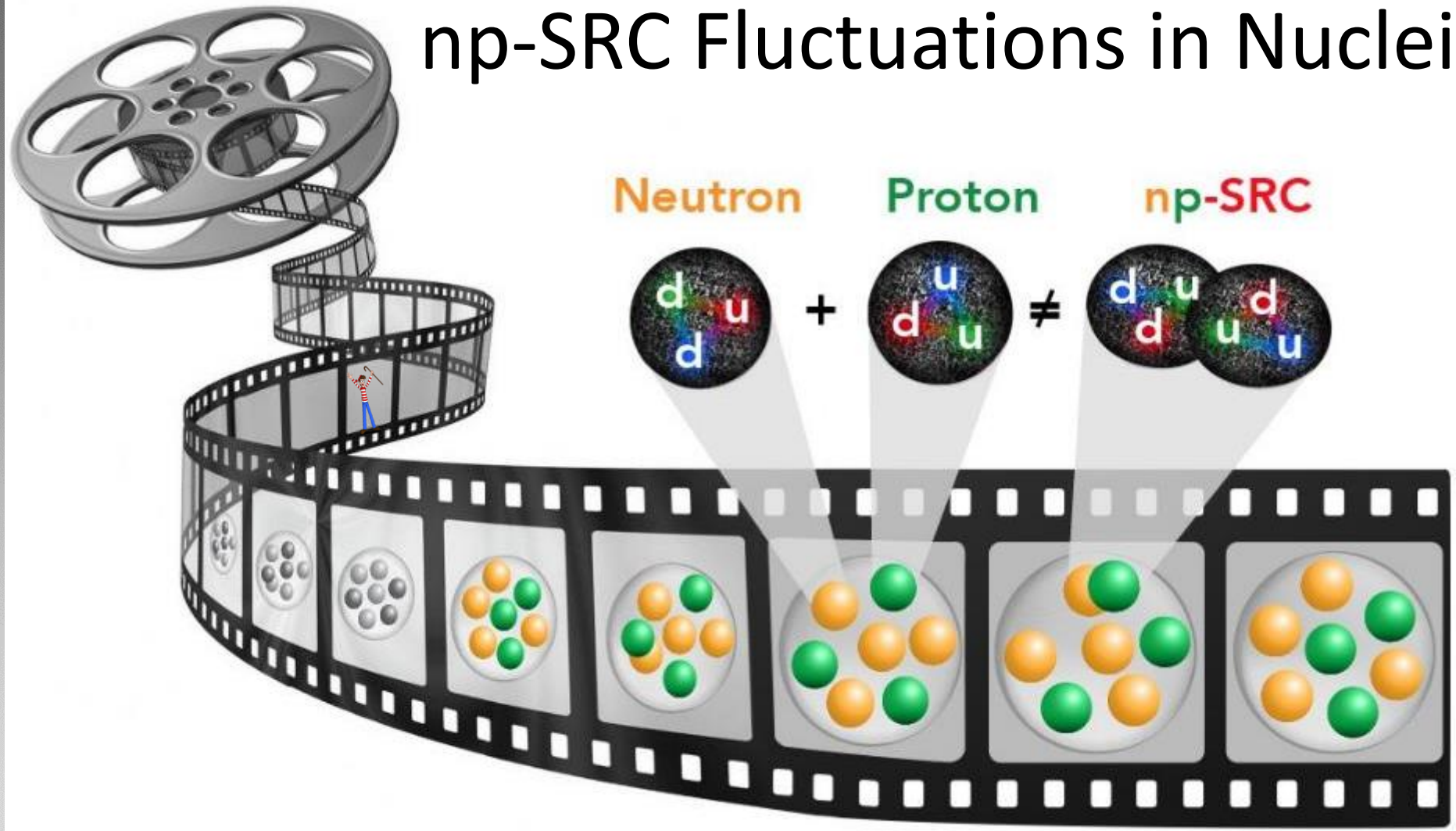
np-SRC Fluctuations in Nuclei



Acknowledgment

I thank the organizers and my many good friends in Armenia

Sep 2018
Yerevan, Armenia

Acknowledgment

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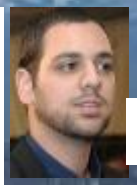
Collaborators

Massachusetts Institute of Technology

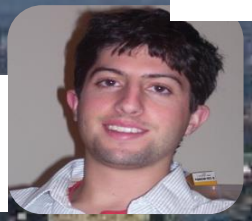


Or Hen

NEW!

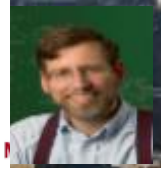
Meytal Duer

Massachusetts Institute of Technology



Barak Schmookler

OLD DOMINION UNIVERSITY



Larry Weinstein

Data-Mining collaboration

CLAS collaboration

Jefferson Lab