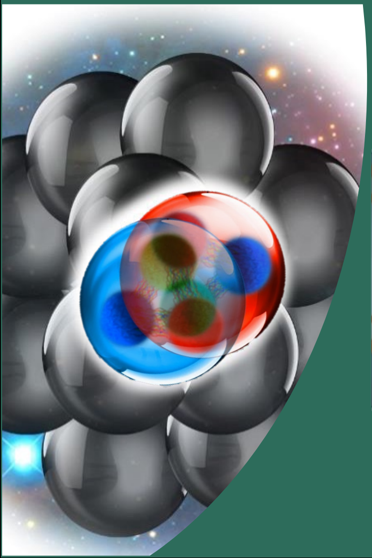
Probing QCD in Nuclei - From Jefferson Lab to the EIC

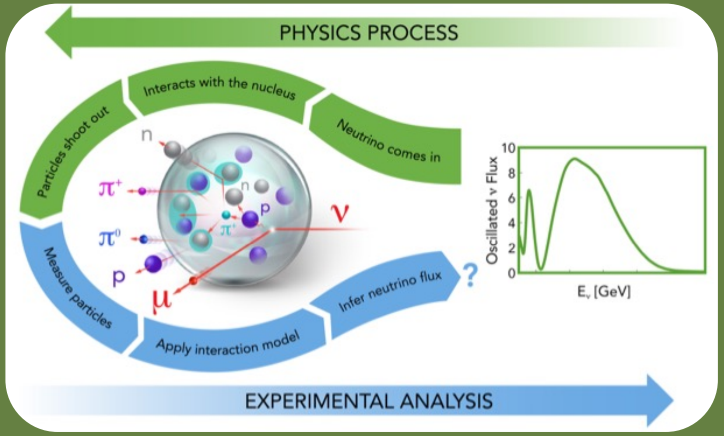
Or Hen
(MIT)

Symposium on QCD and Nuclei, October 10th, 2021.

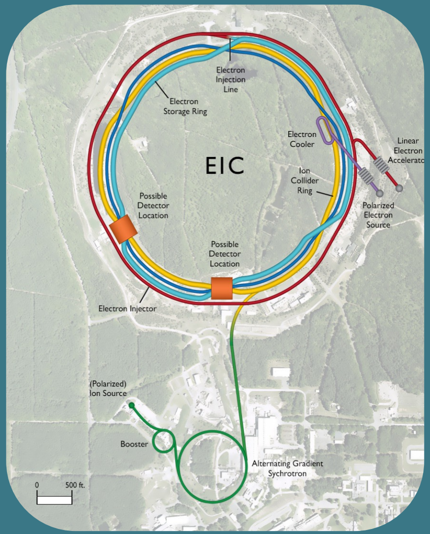
Correlations & Hadron structure @ JLab

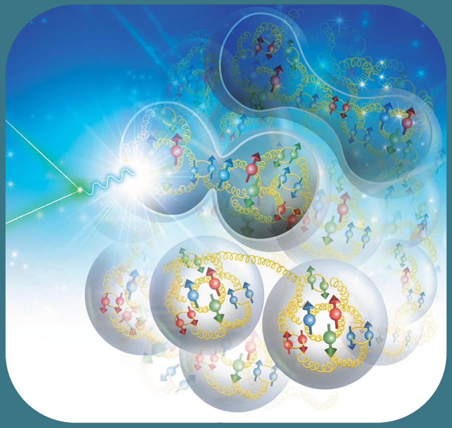


Neutrino-Nucleus Interactions @ FNAL & JLab

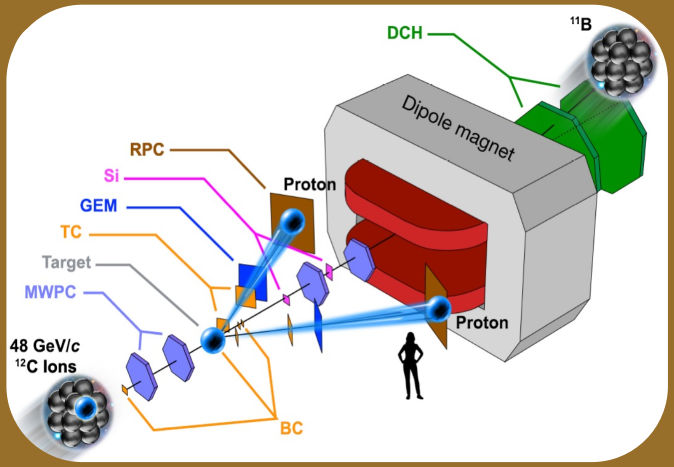


Electron-Ion Collider @ BNL

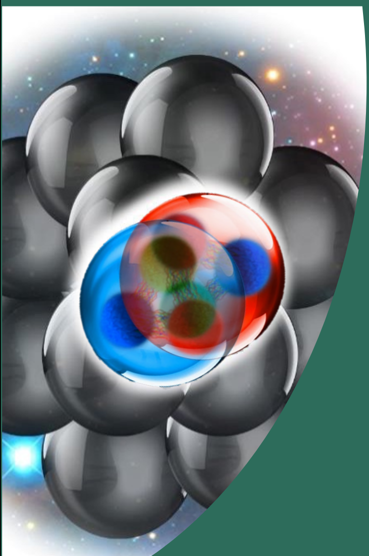




Hadronic Radioactive Matter @ GSI & JINR

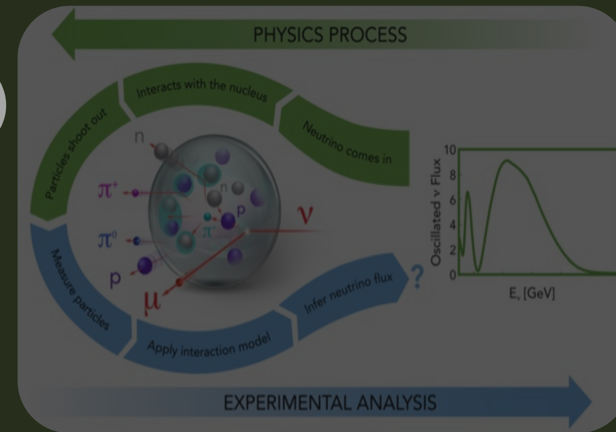


Correlations & Hadron structure @ JLab



Neutrino-Nucleus Interactions @ FNAL & JLab

Nature (2021)
PRD (2021)
PRL (2020)
EPJC (2019)



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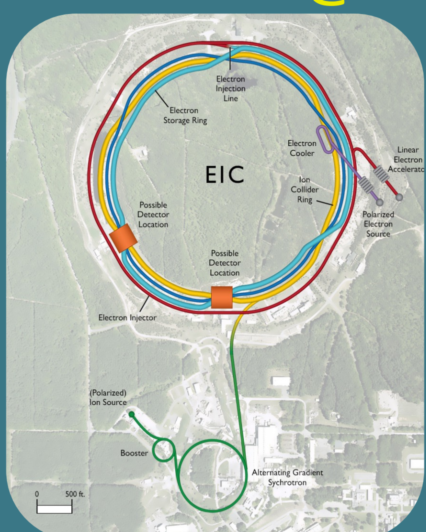
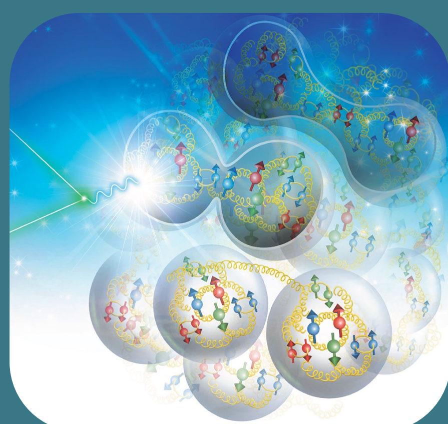
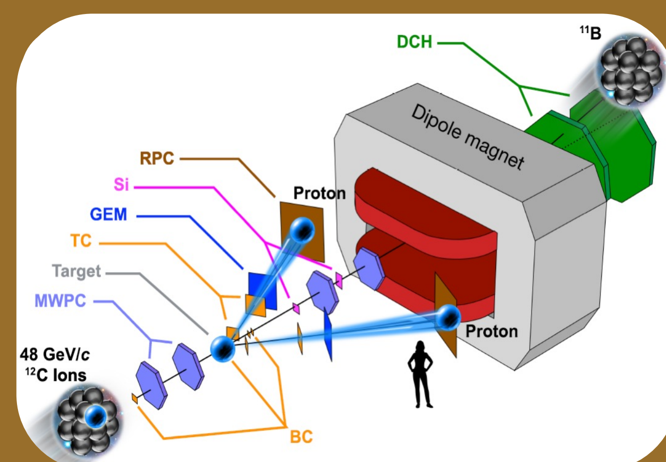
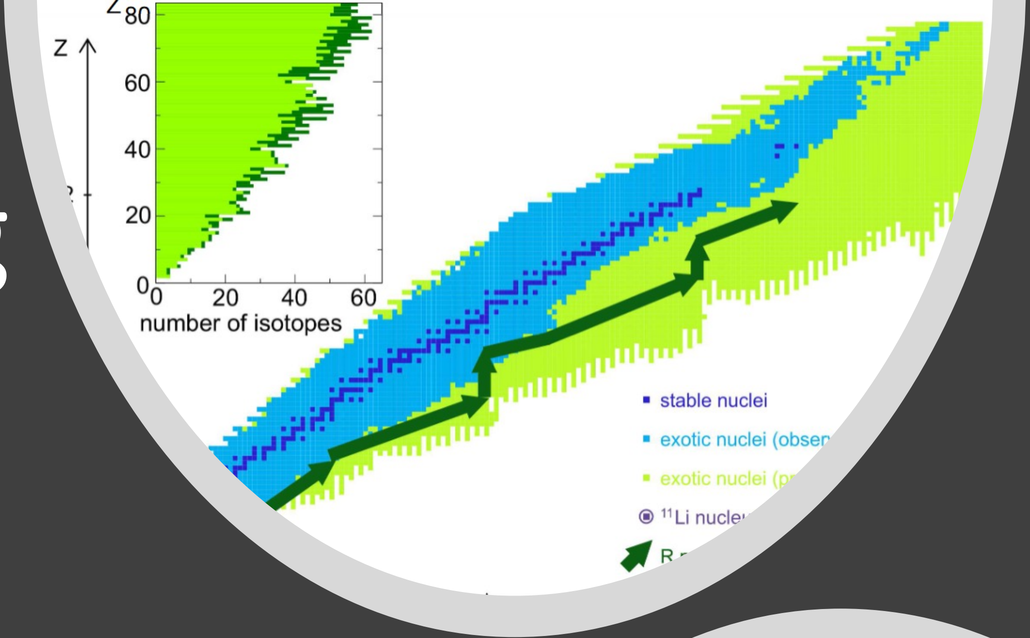




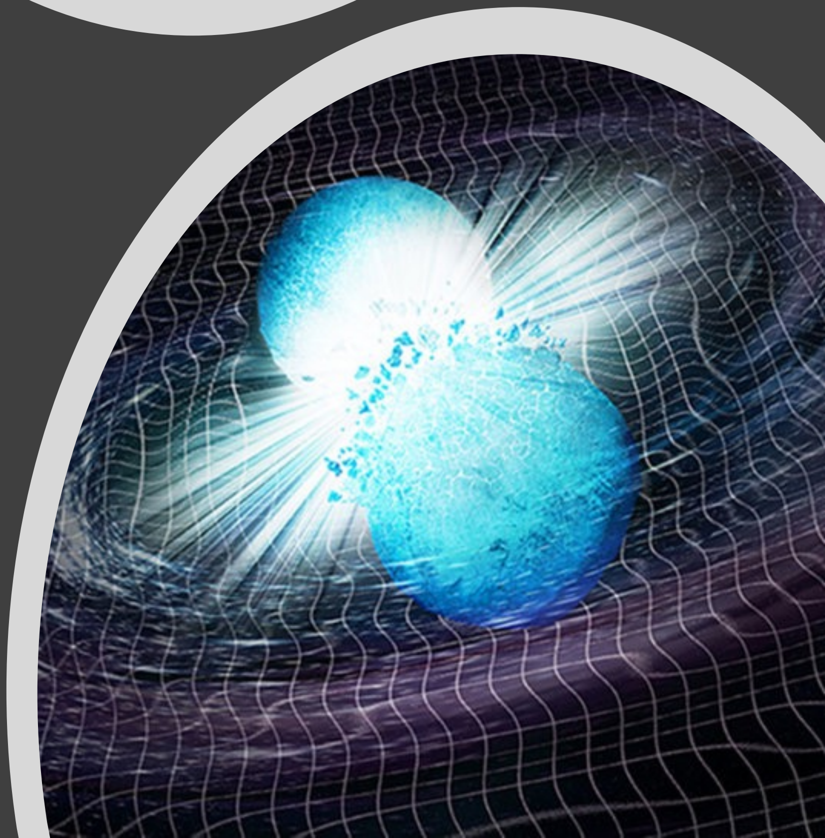
Hadronic Radioactive Matter @ GSI & JINR



Understanding nuclei

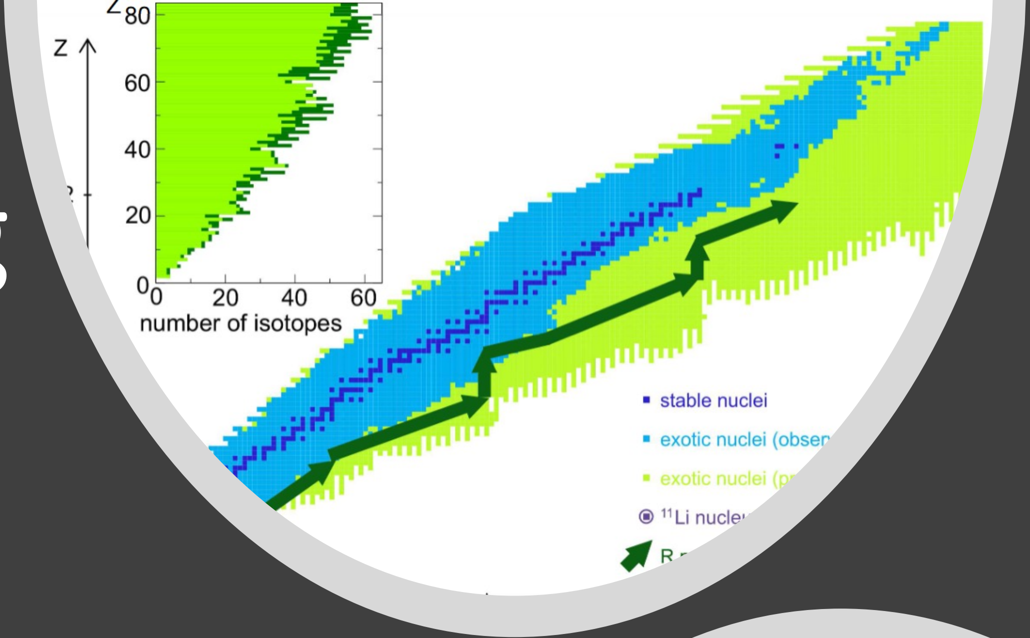


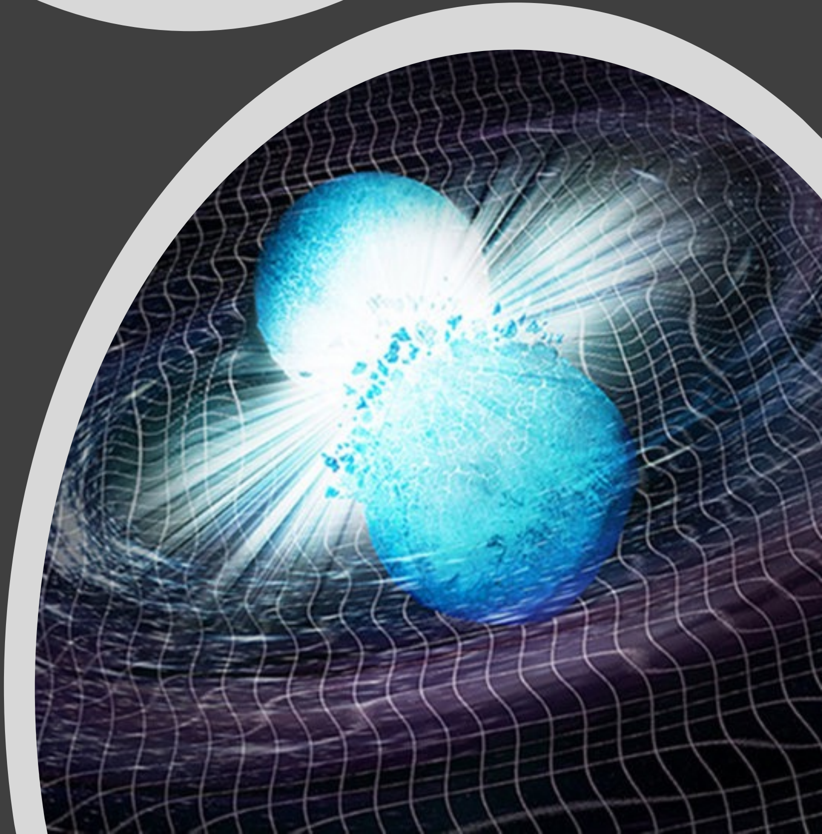
- Most of the visible mass in the universe.
  - ❖ Only ~9% of nucleon mass due to quark mass
  - ❖ Rest dynamically generated by quark-gluon interactions & trace anomaly



Understanding nuclei

- Most of the visible mass in the universe.
- Formation of the elements.
- Burning of stars and formation of galactic structures
- Lab for (new) interactions.





Understanding nuclei

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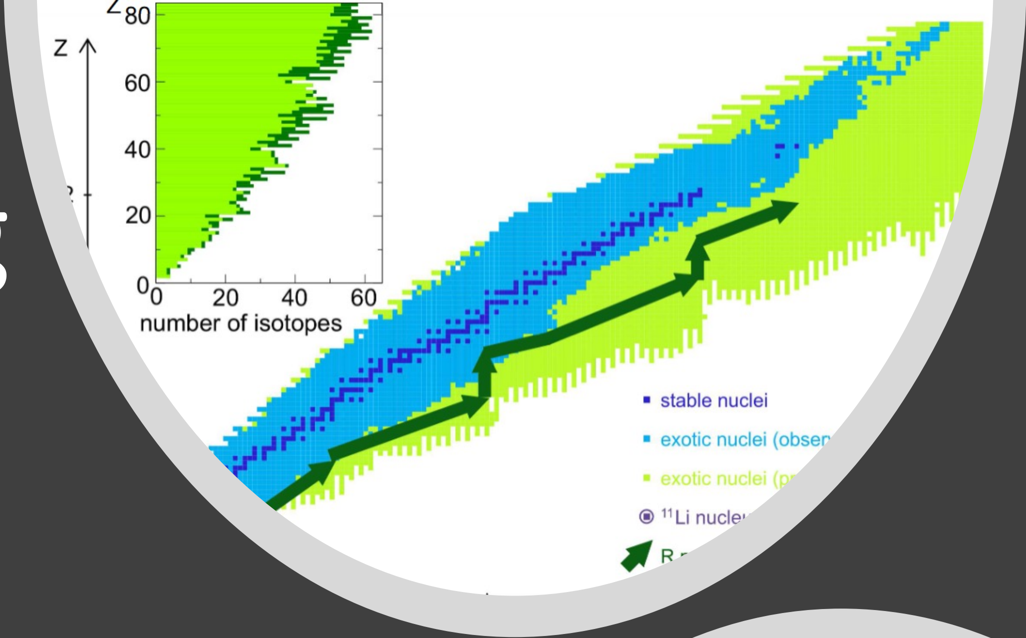
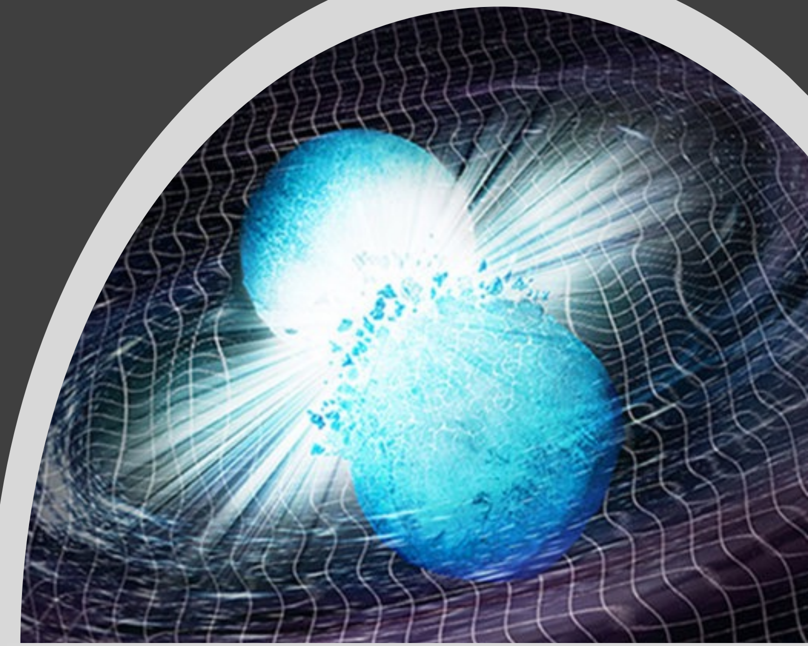
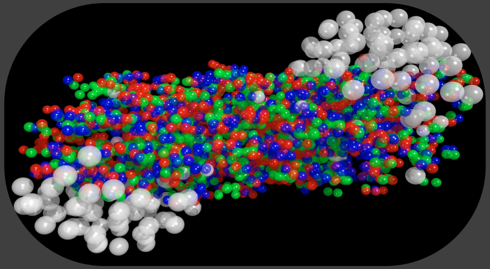




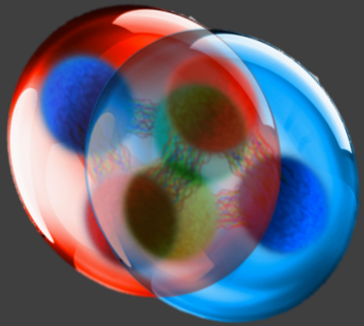
Cold Dense Nuclear Matter

QCD in Nuclei

Nuclei can produce high-density states where QCD is important and can be studied:



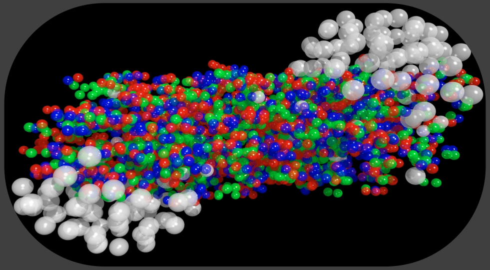
High-density high-T states
('man-made' HI collisions)



High-density low-T states
('naturally occurring' correlations)

QCD in Nuclei

Nuclei can produce high-density states where QCD is important and can be studied:



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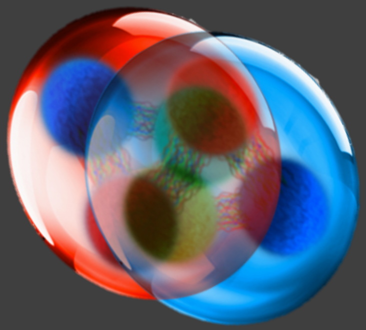
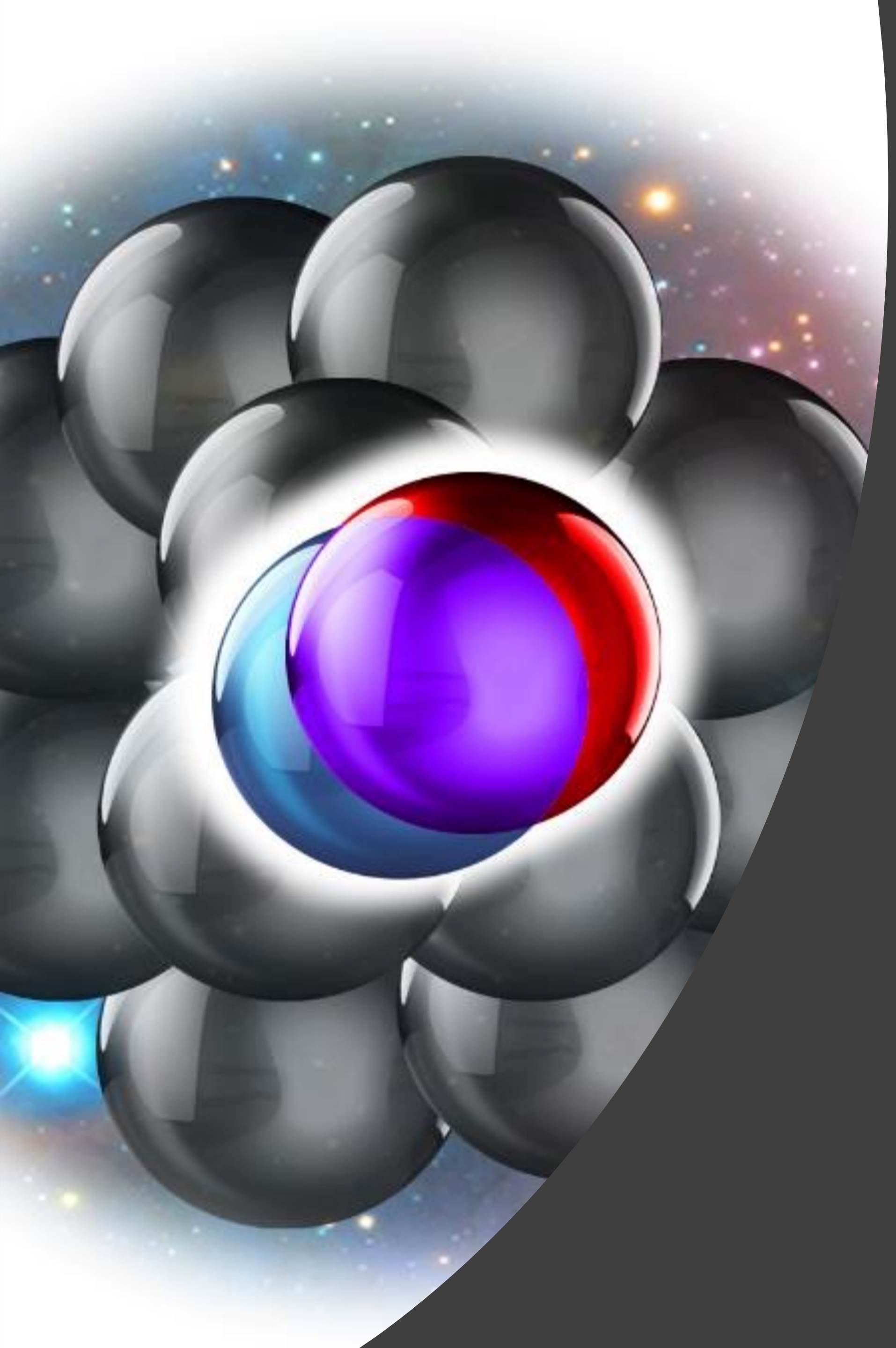
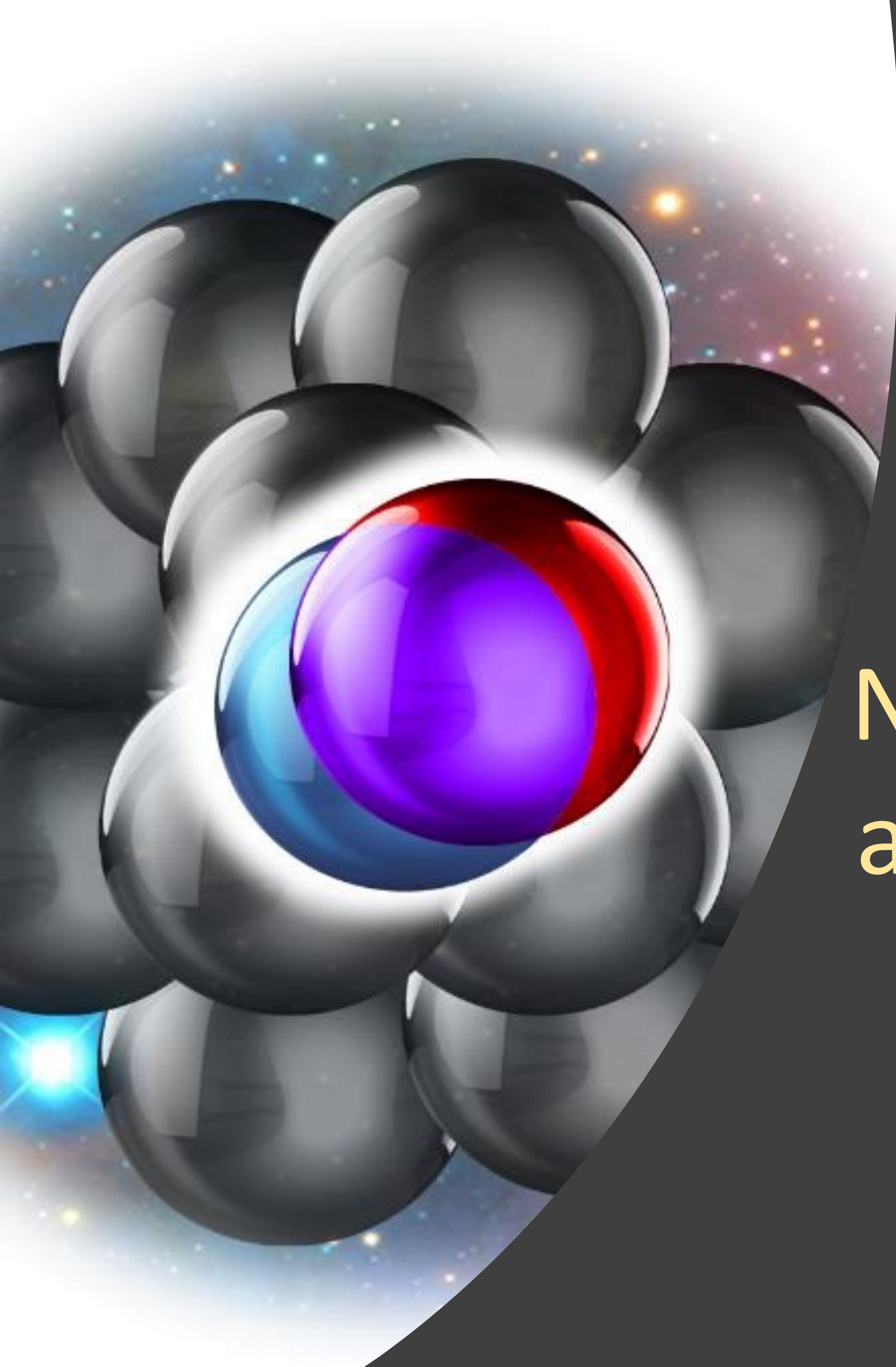


High-density low-T states ('naturally occurring' correlations)



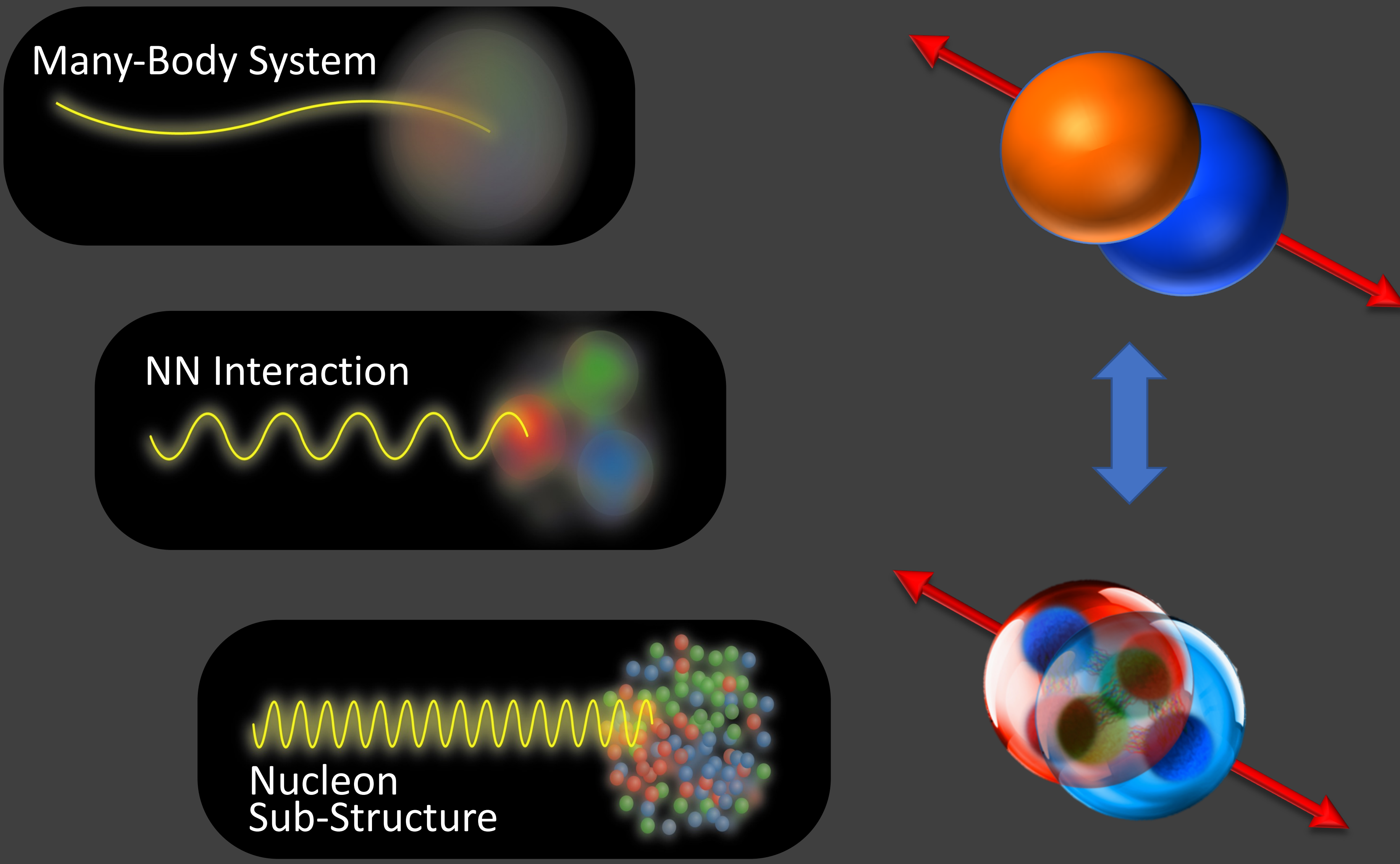
Short-Range Correlations (SRC)

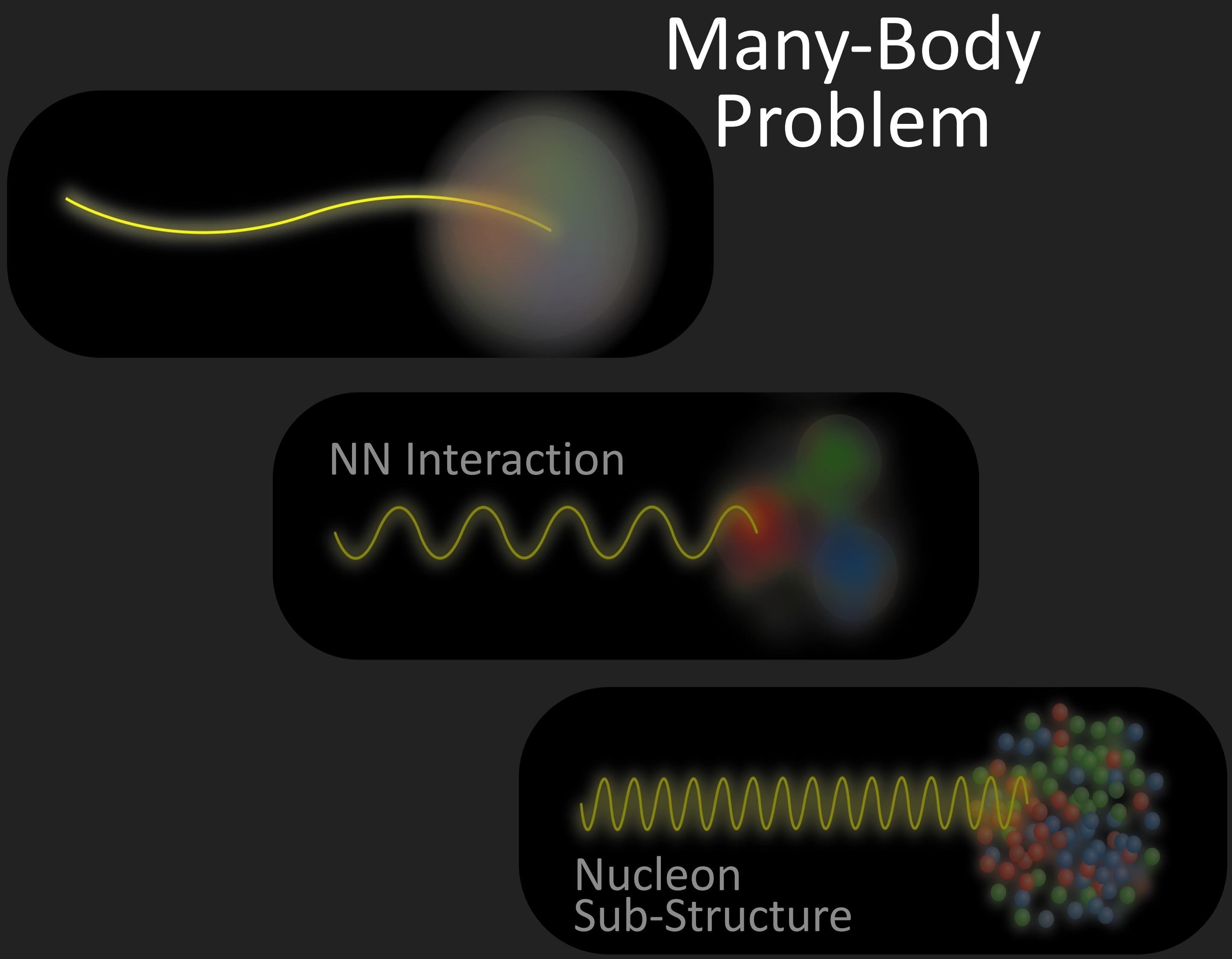


Short-Range Correlations (SRC)

Fluctuations of Nucleon pairs that are close together in the nucleus

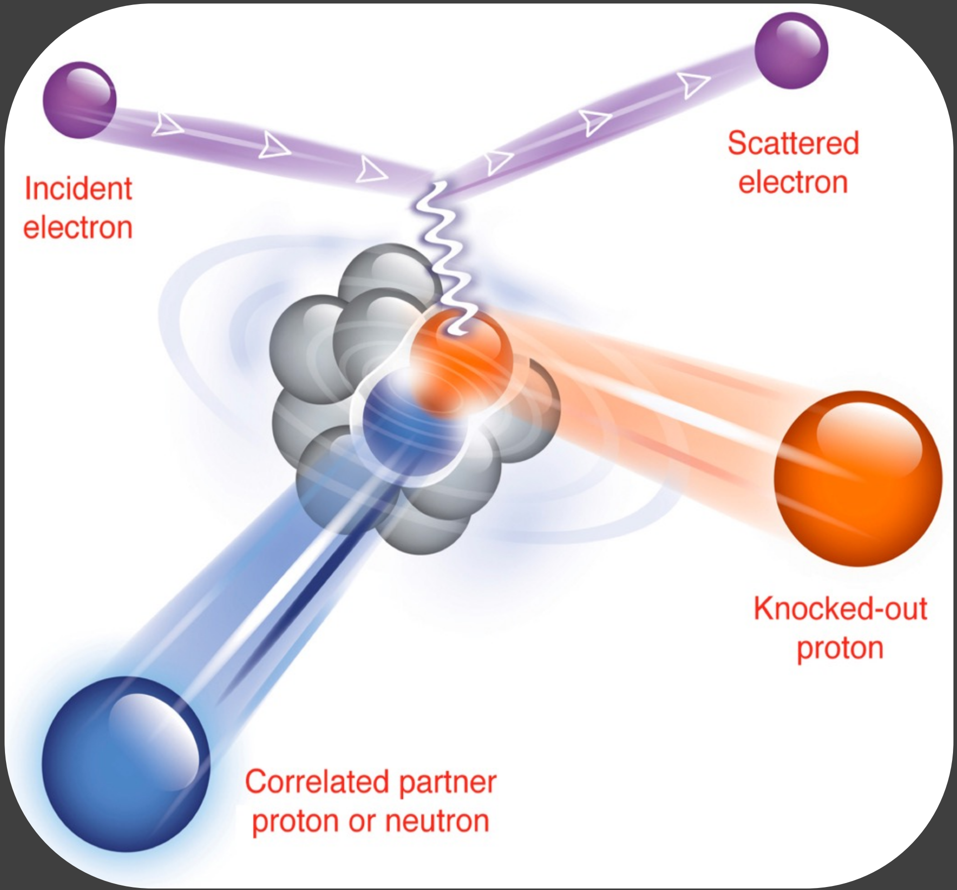
SRCs Across Scales




Many-Body
Problem
NN Interaction
Nucleon
Sub-Structure

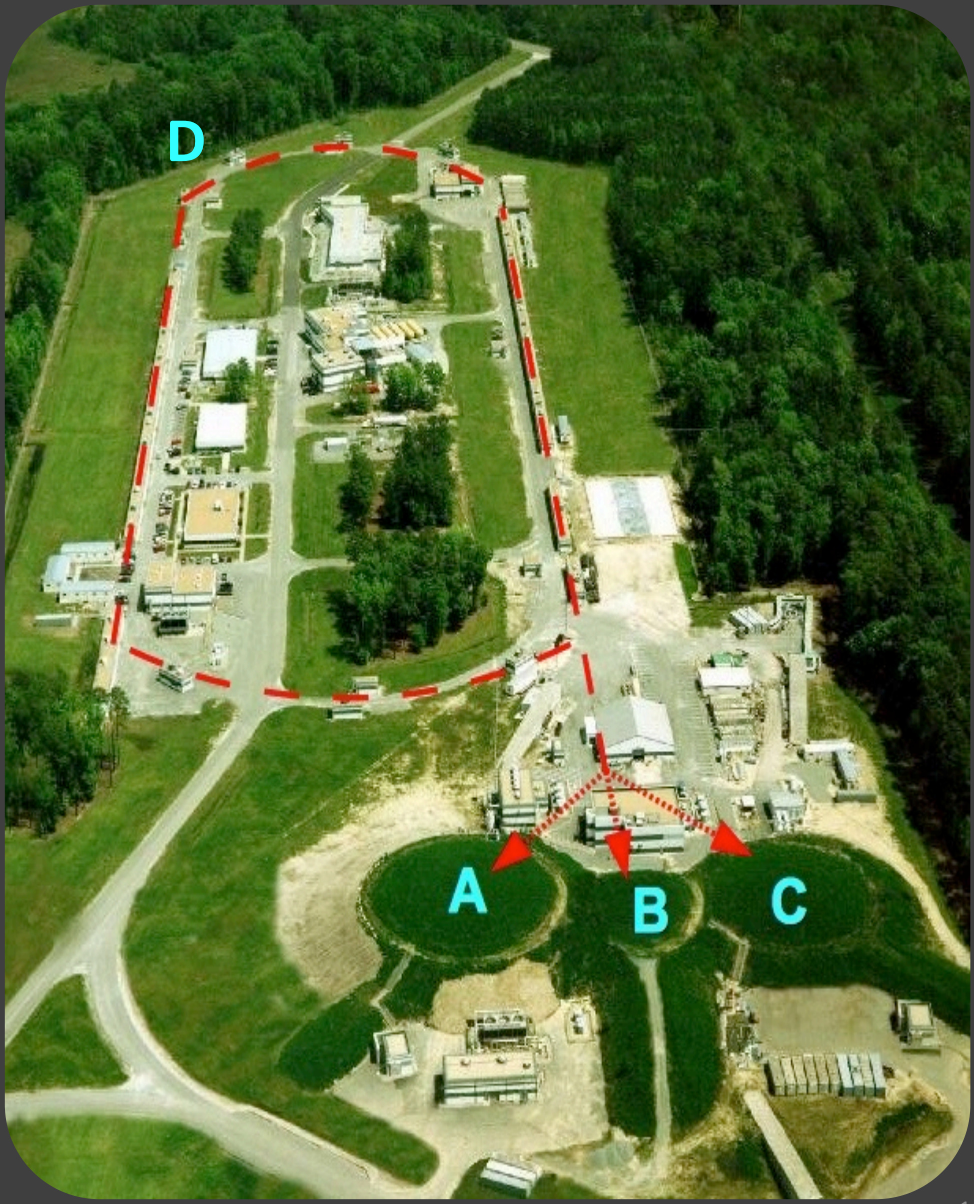
Looking for SRCs

Breakup the pair =>
Detect ***both*** nucleons =>
Reconstruct ‘initial’ state

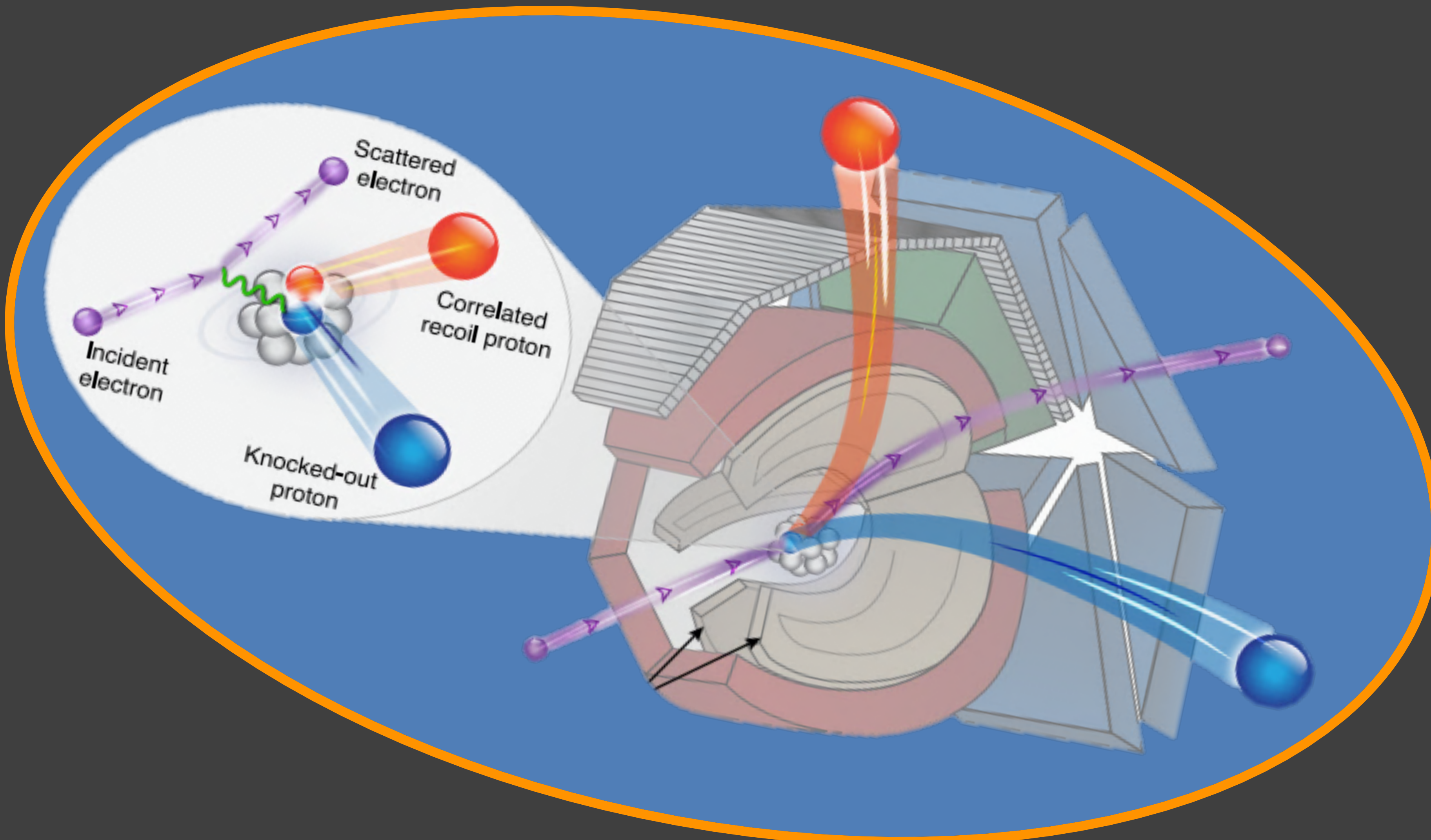


Jefferson-Lab

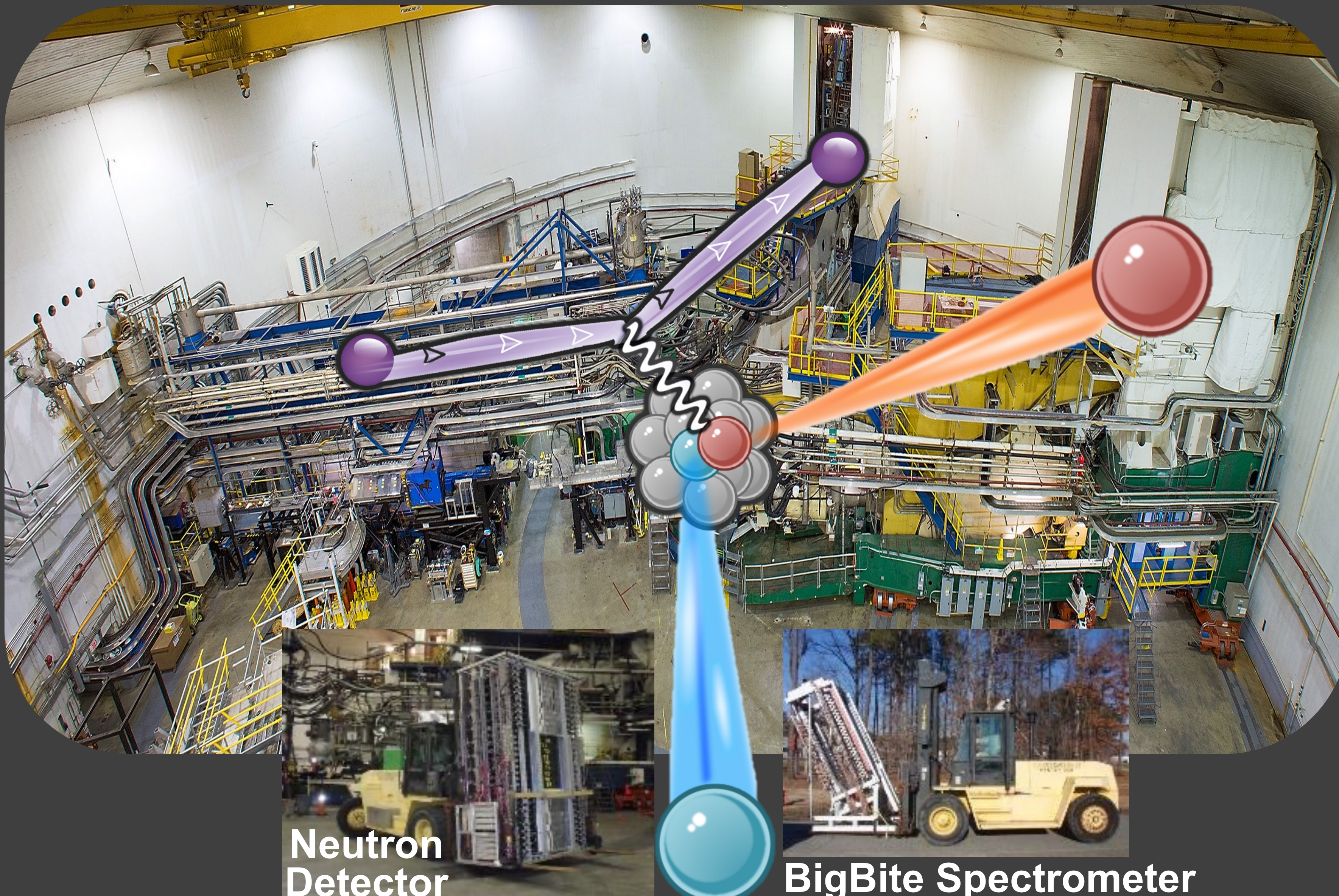
- Virginia, USA
- 1 – 11 GeV Electron beam
  [~80 uA; polarized]
- 4 experimental halls
- Approved physics program for coming decade; Leading to EIC

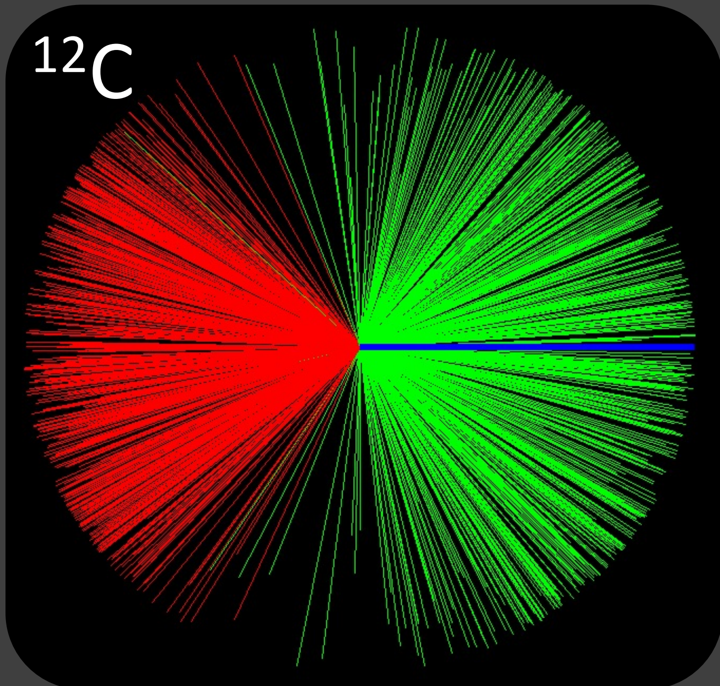


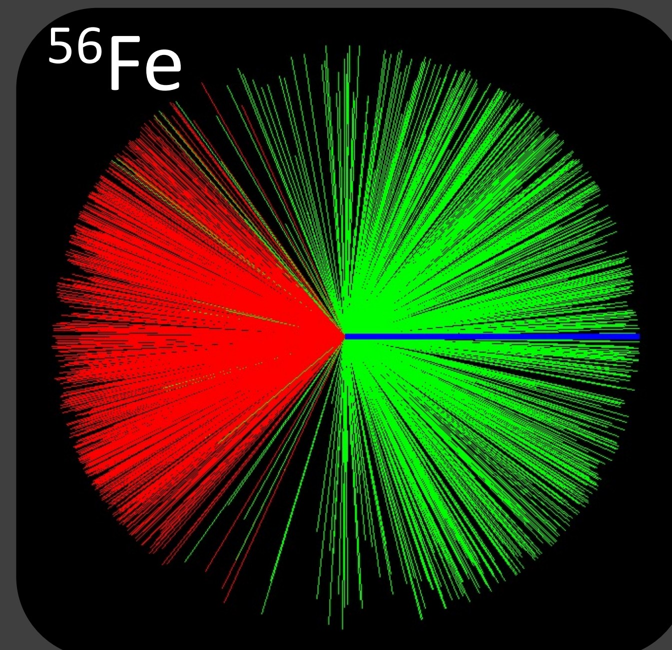
CEBAF Large Acceptance Spectrometer
[CLAS]

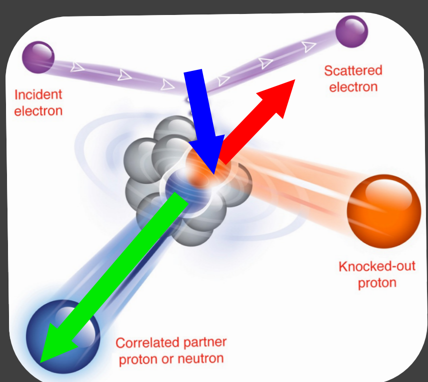


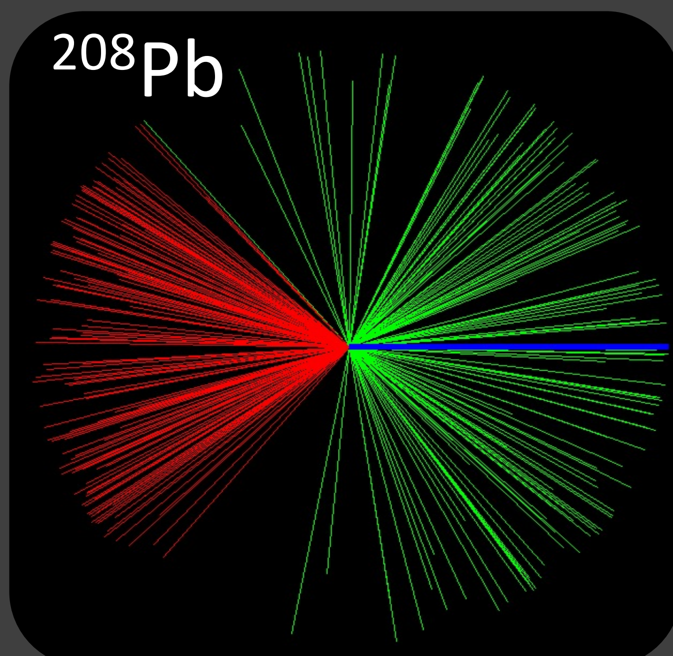
Hall-A: High-Resolution Spectrometers





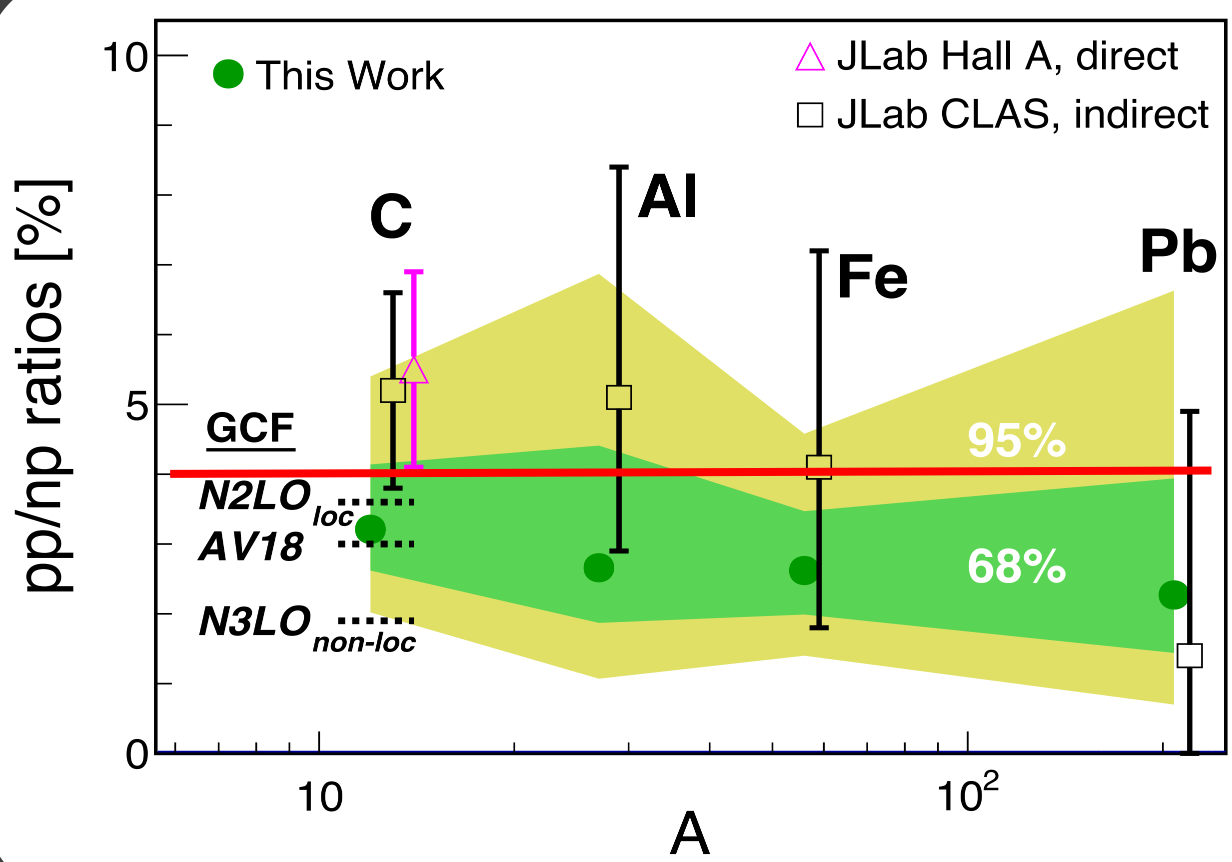






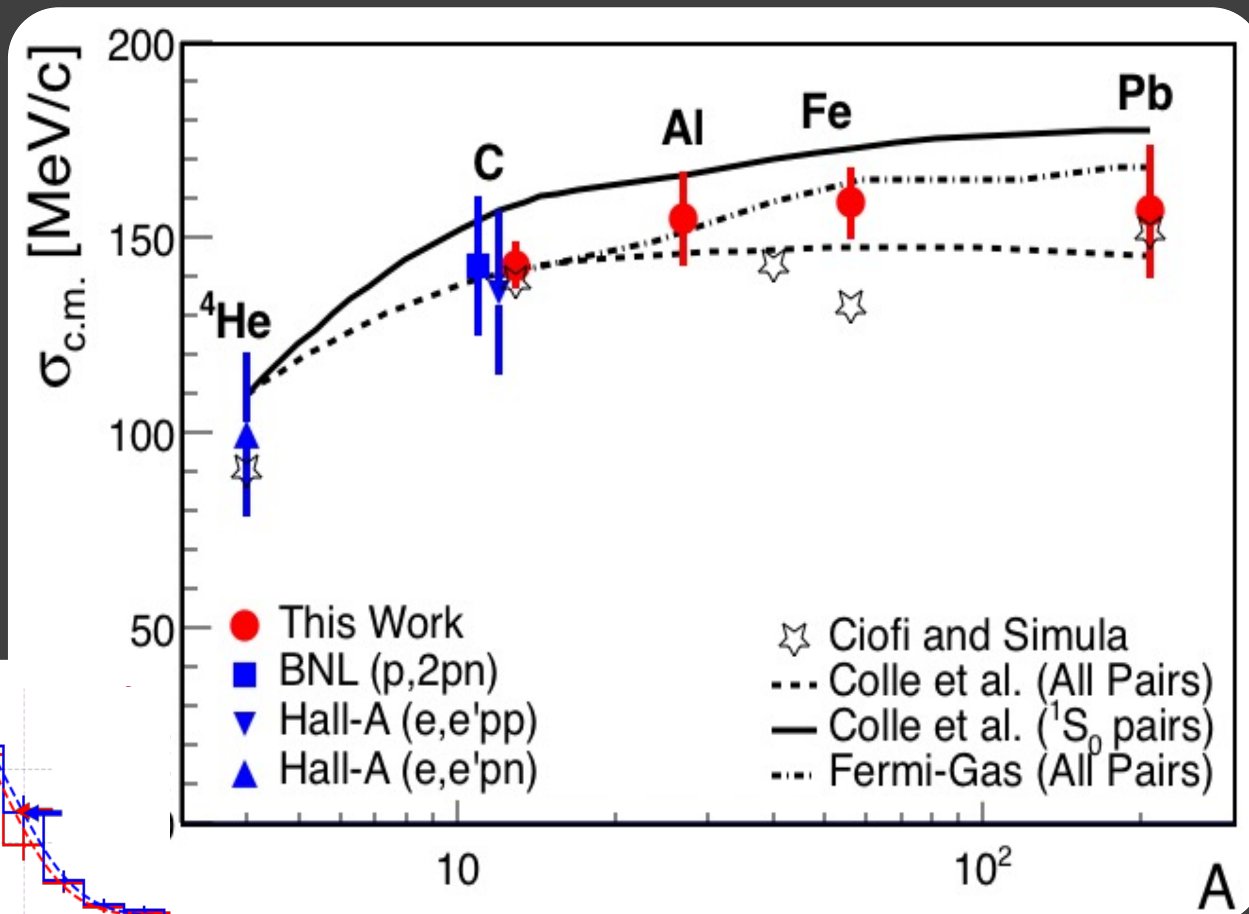
Back-to-back
= SRC pairs!

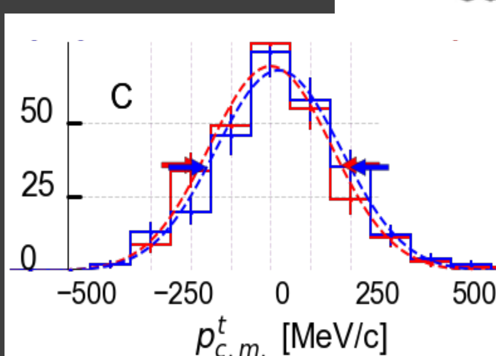
Neutron-proton pairs



Duer, PRL ‘19; Duer, Nature ’18; Cohen, PRL ‘18; Hen, Science ‘14; Korover, PRL ‘14; Subedi, Science ’08; Shneor, PRL ’07; Piasetzky, PRL ‘06; Tang, PRL ‘03; <u>Review:</u> Hen RMP ‘17;

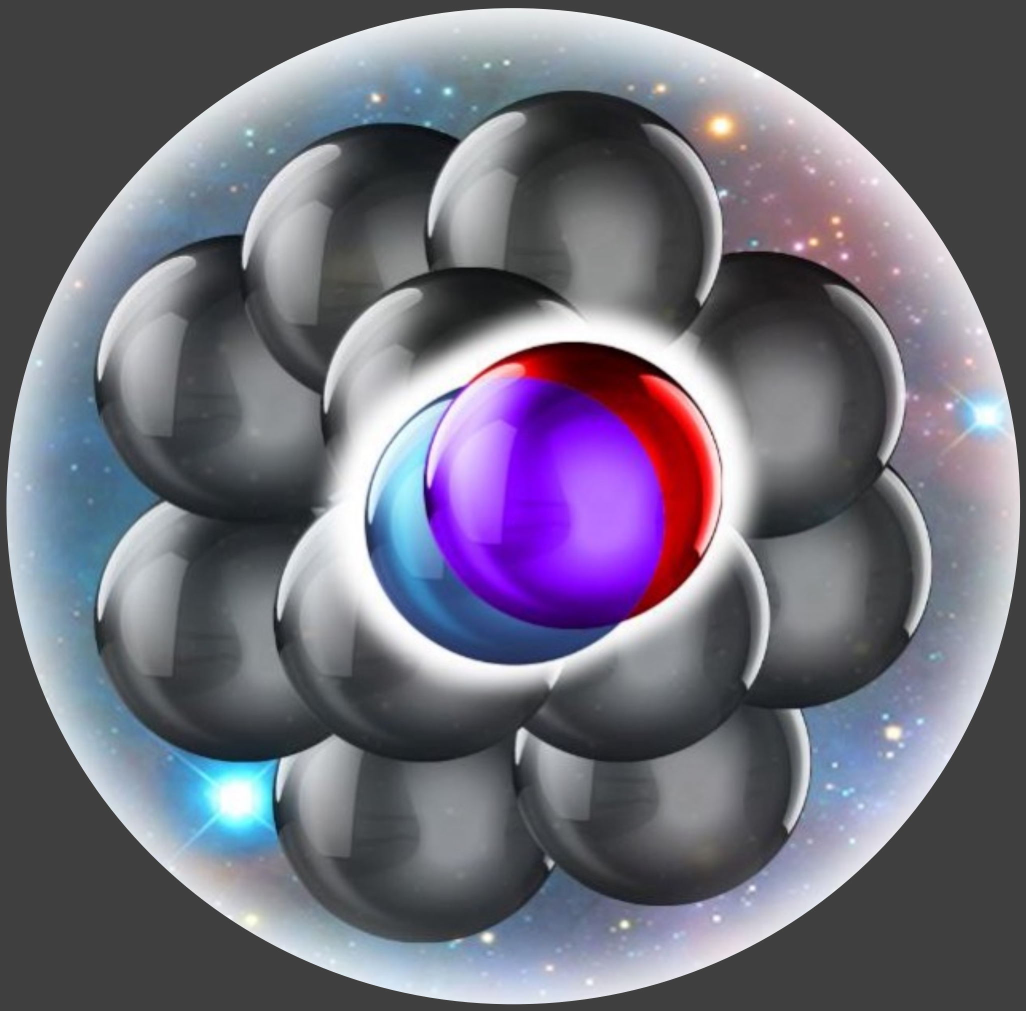
Weak coupling to A-2 system

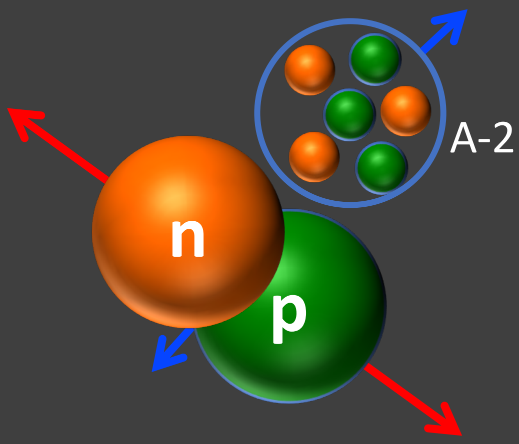




Duer, PRL '19; Duer, Nature '18; Cohen, PRL '18; Hen, Science '14; Korover, PRL '14; Subedi, Science '08; Shneor, PRL '07; Piasetzky, PRL '06; Tang, PRL '03; Review: Hen RMP '17;

Pairs ⇔ Scale Separation





R. Cruz-Torres et al., Nature Physics (2020)

R. Weiss et al., Phys. Lett. B 780 (2018)

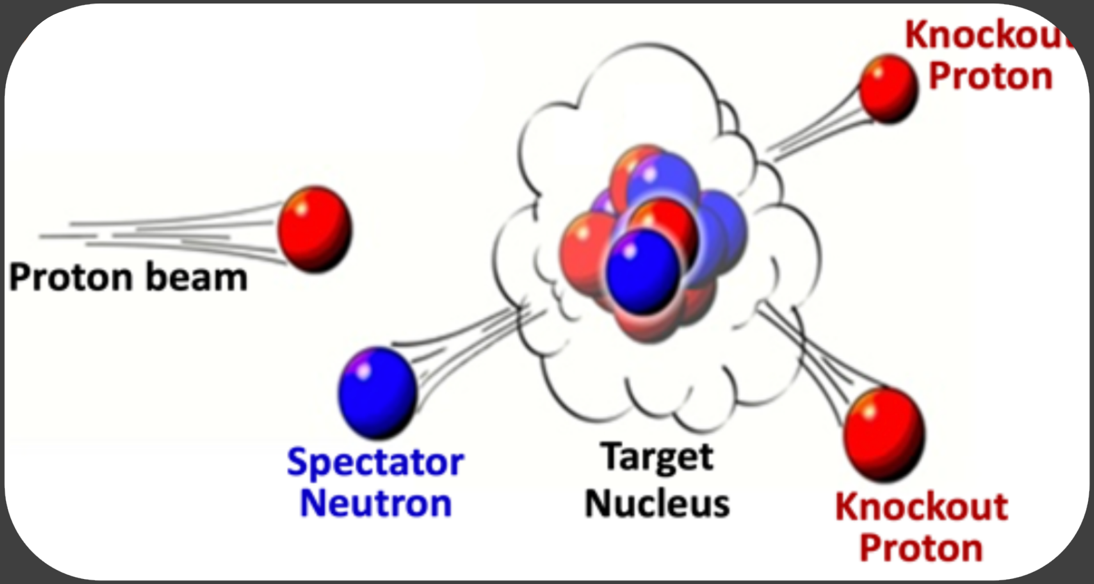
J.-W. Chen, W. Detmold, J. E. Lynn, A. Schwenk, PRL 119 (2017)

R. Weiss, B. Bazak, N. Barnea, Phys. Rev. C 92 (2015)

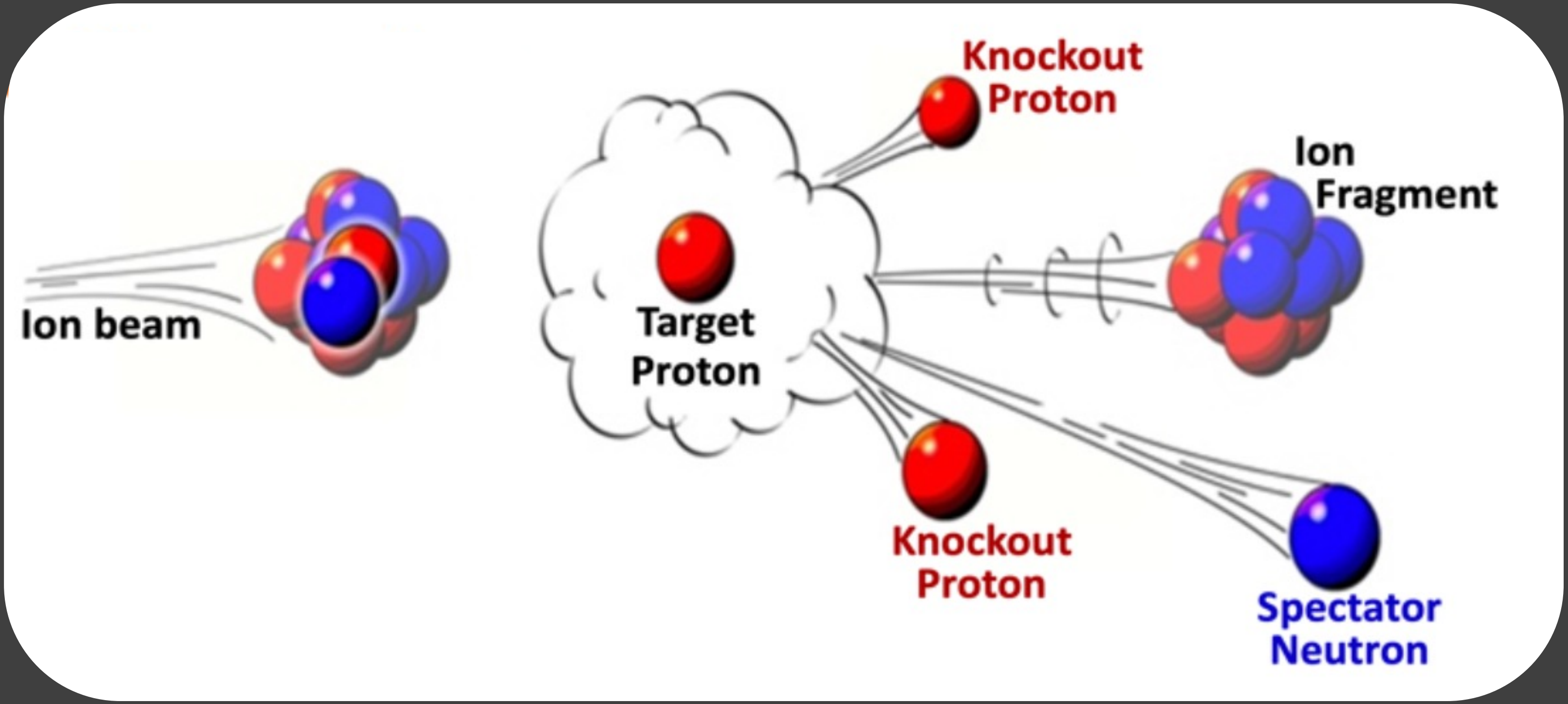
Pair factorization Implies no correlation between relative & c.m. motions

$$f(p_{rel}, p_{c.m.}, \theta_{rel,c.m.}) \approx C(p_{c.m.}) \times \varphi(p_{rel})$$

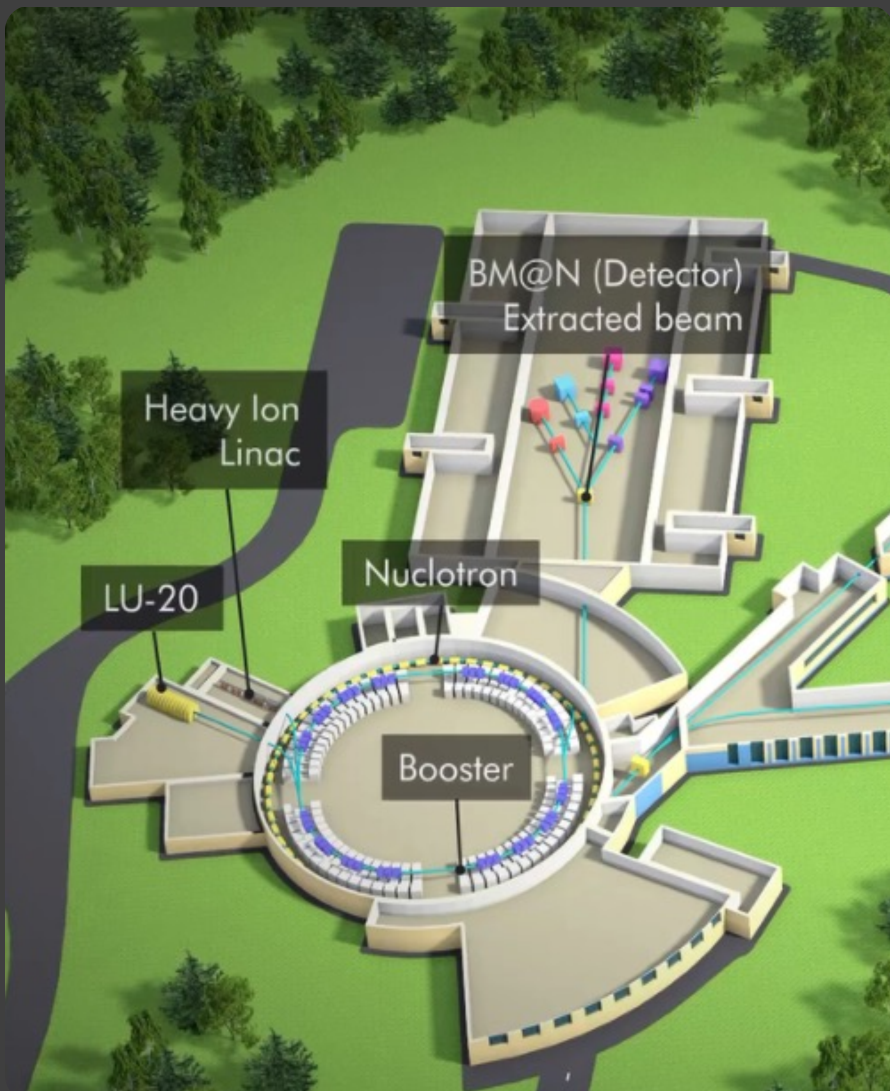
From Direct to Inverse Kinematics



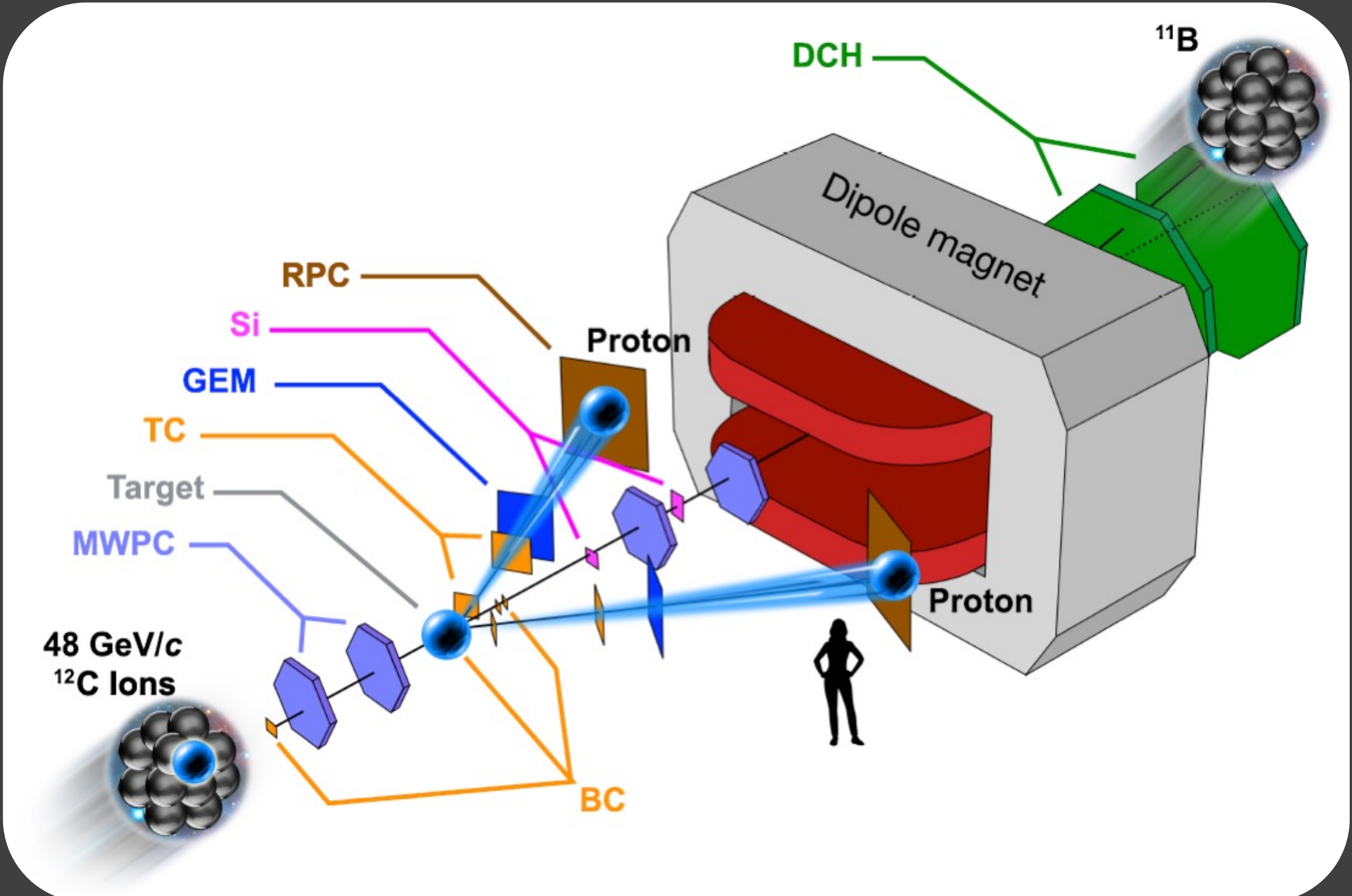
From Direct to Inverse Kinematics



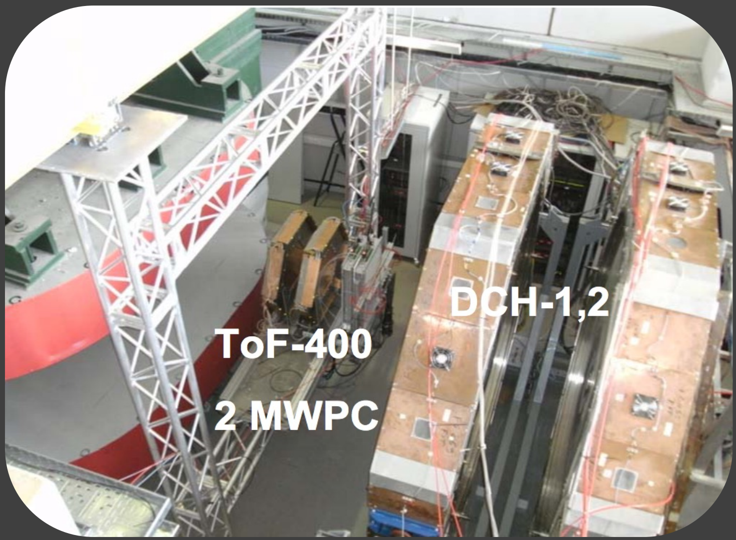
High-Energy Ion Beam @ JINR Nuclotron

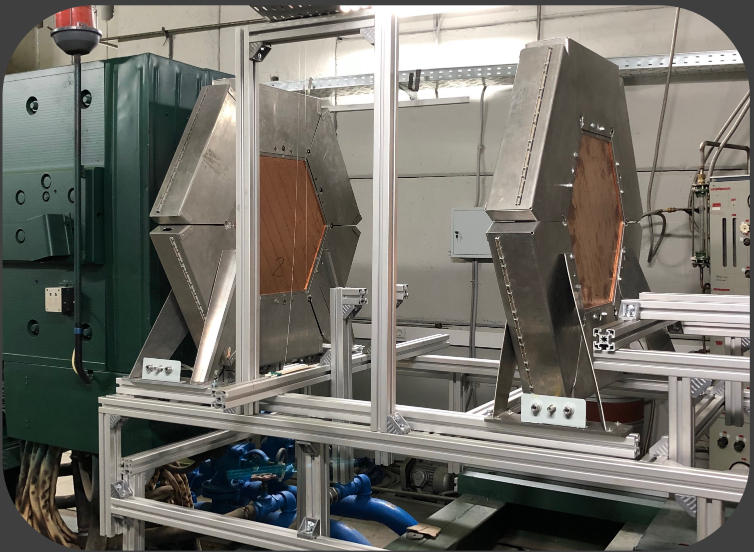


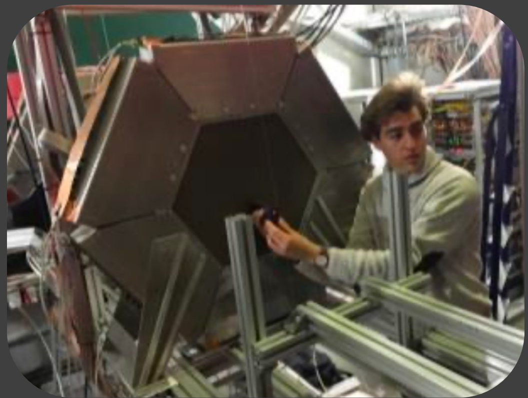
SRC @ BM@N



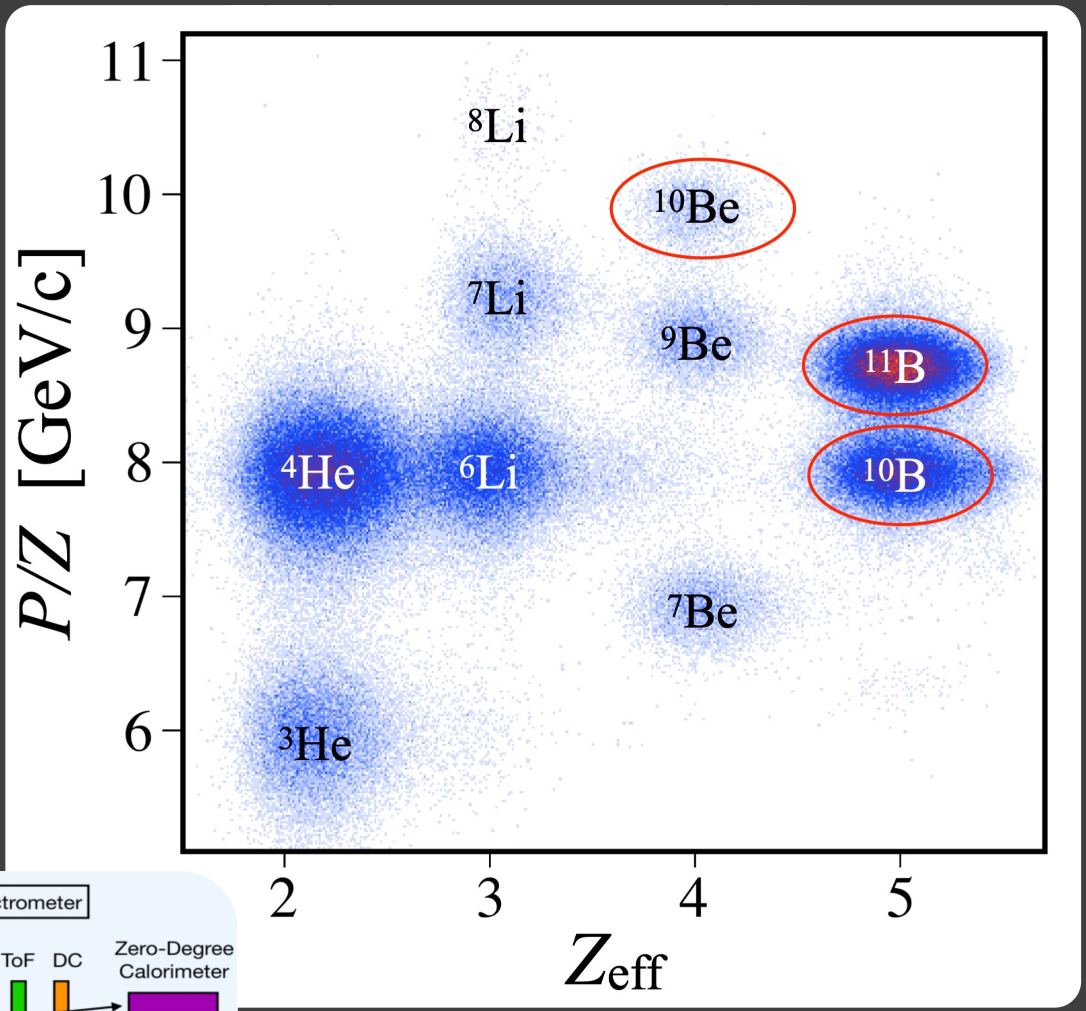
11B
DCH
Dipole magnet
RPC
Si
GEM
TC
Target
MWPC
Proton
Proton
48 GeV/c
12C Ions
BC

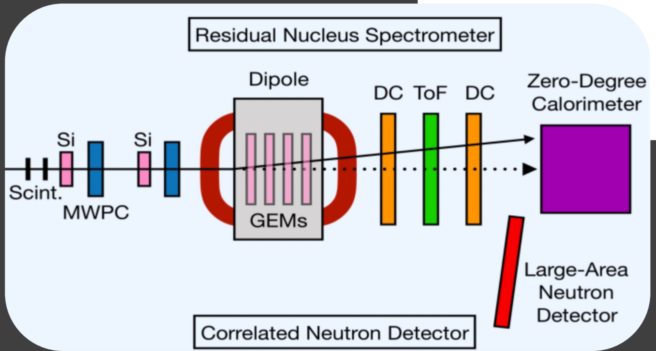

DCH-1,2
ToF-400
2 MWPC





Fragment PID



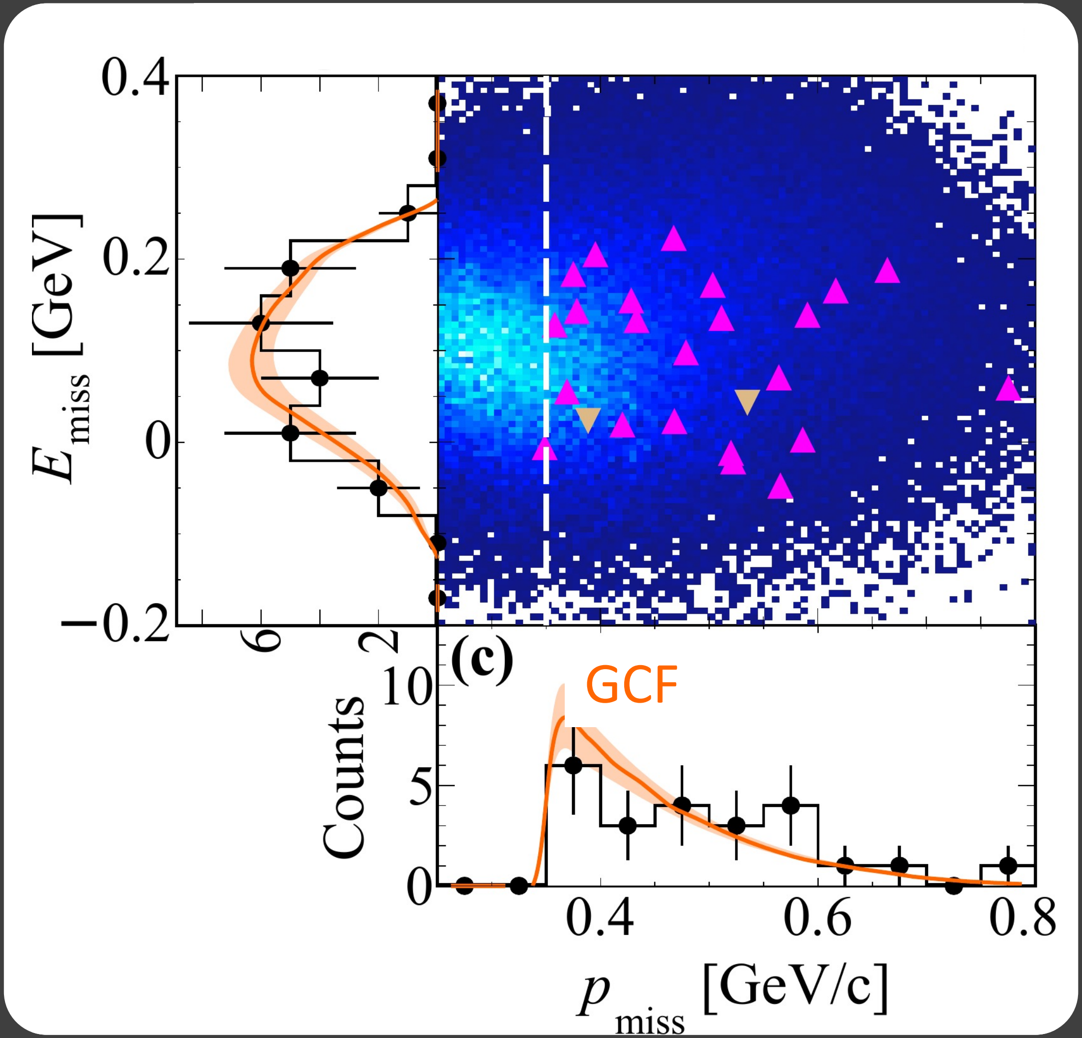


SRC + A-2: First Observation

23 ^{10}B events

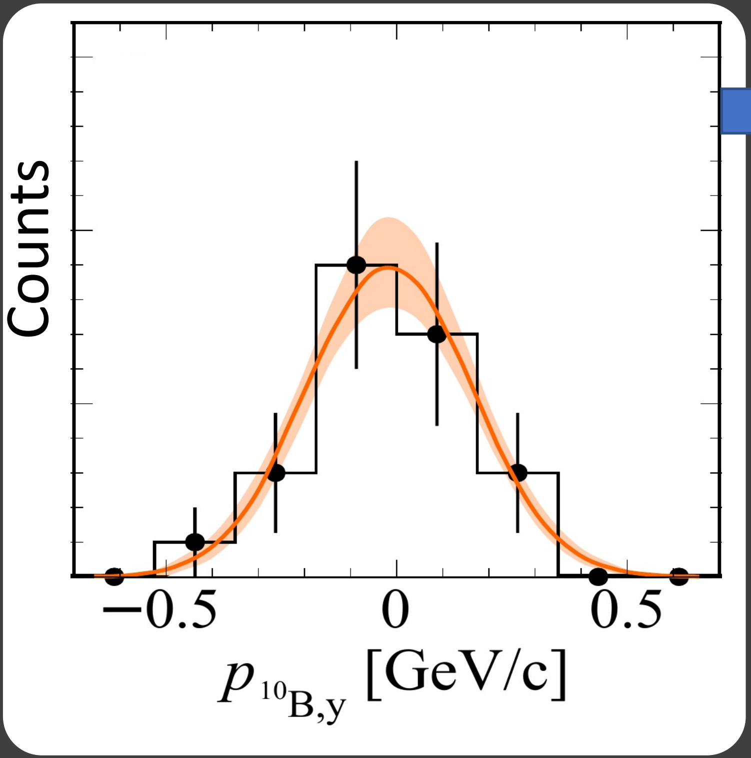
2 ^{10}Be events

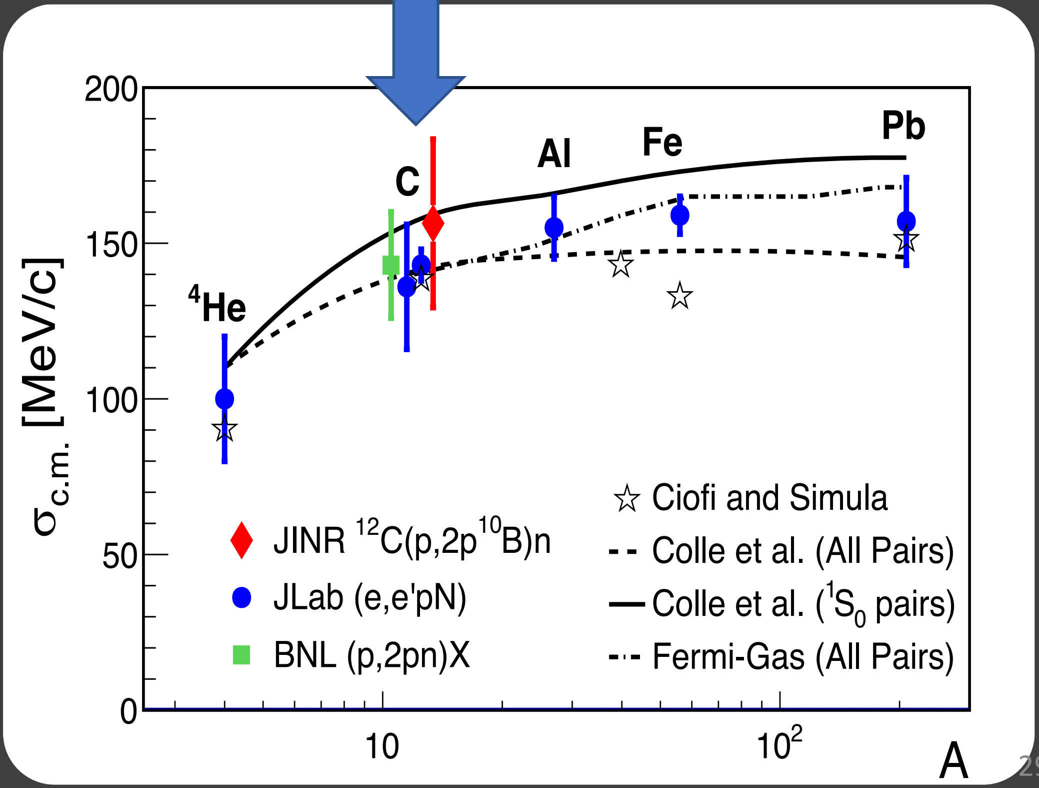
→ *np* pair dominance



Patsyuk and Kahlbow et al.,
Nature Physics 17, 693 (2021)

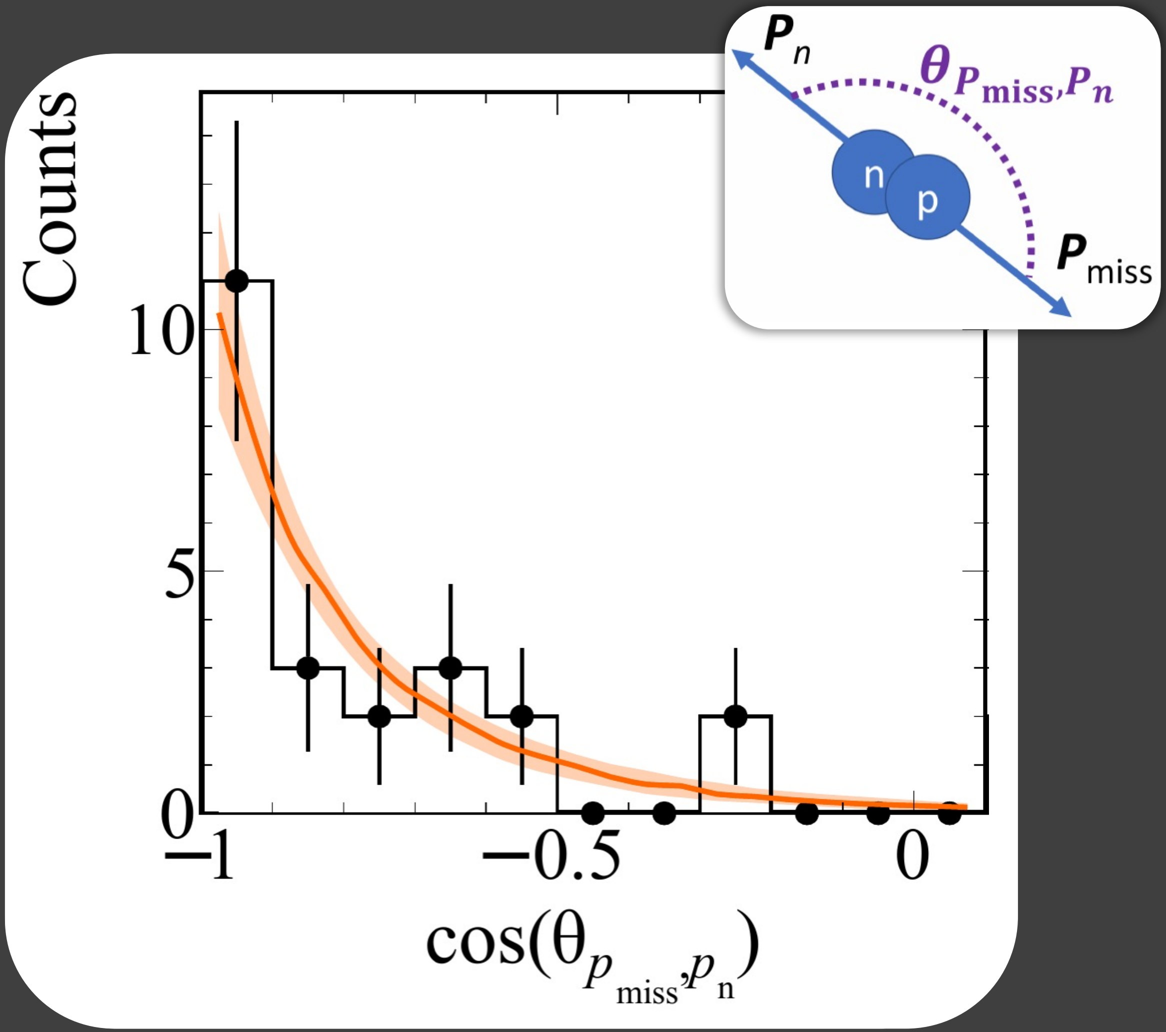
Pair Motion
(Agree \w JLab data)





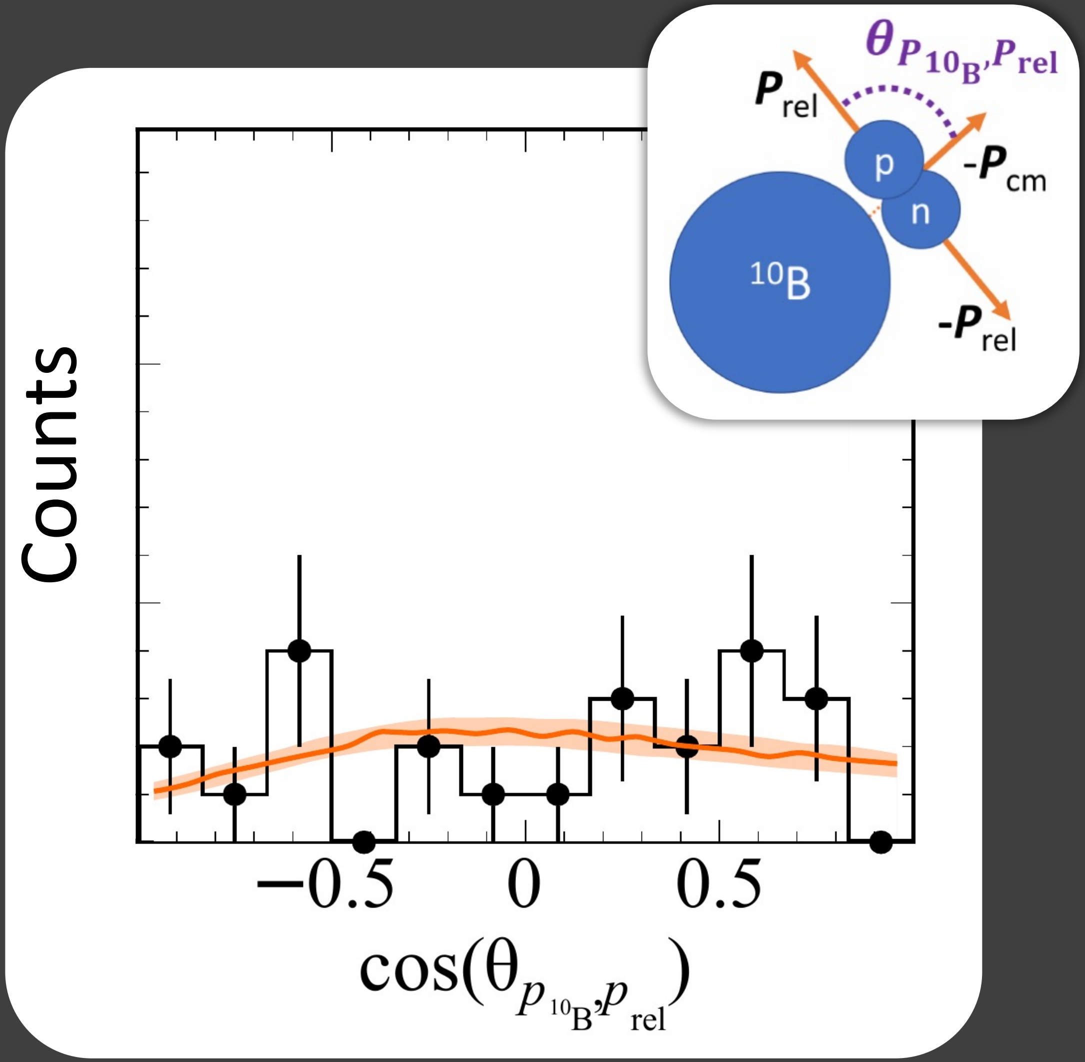

Patsyuk and Kahlbow et al.,
Nature Physics 17, 693 (2021)

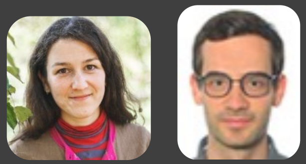
Back-to-Back Pair Signature



Patsyuk and Kahlbow et al.,
Nature Physics 17, 693 (2021)

Factorization of SRC distributions



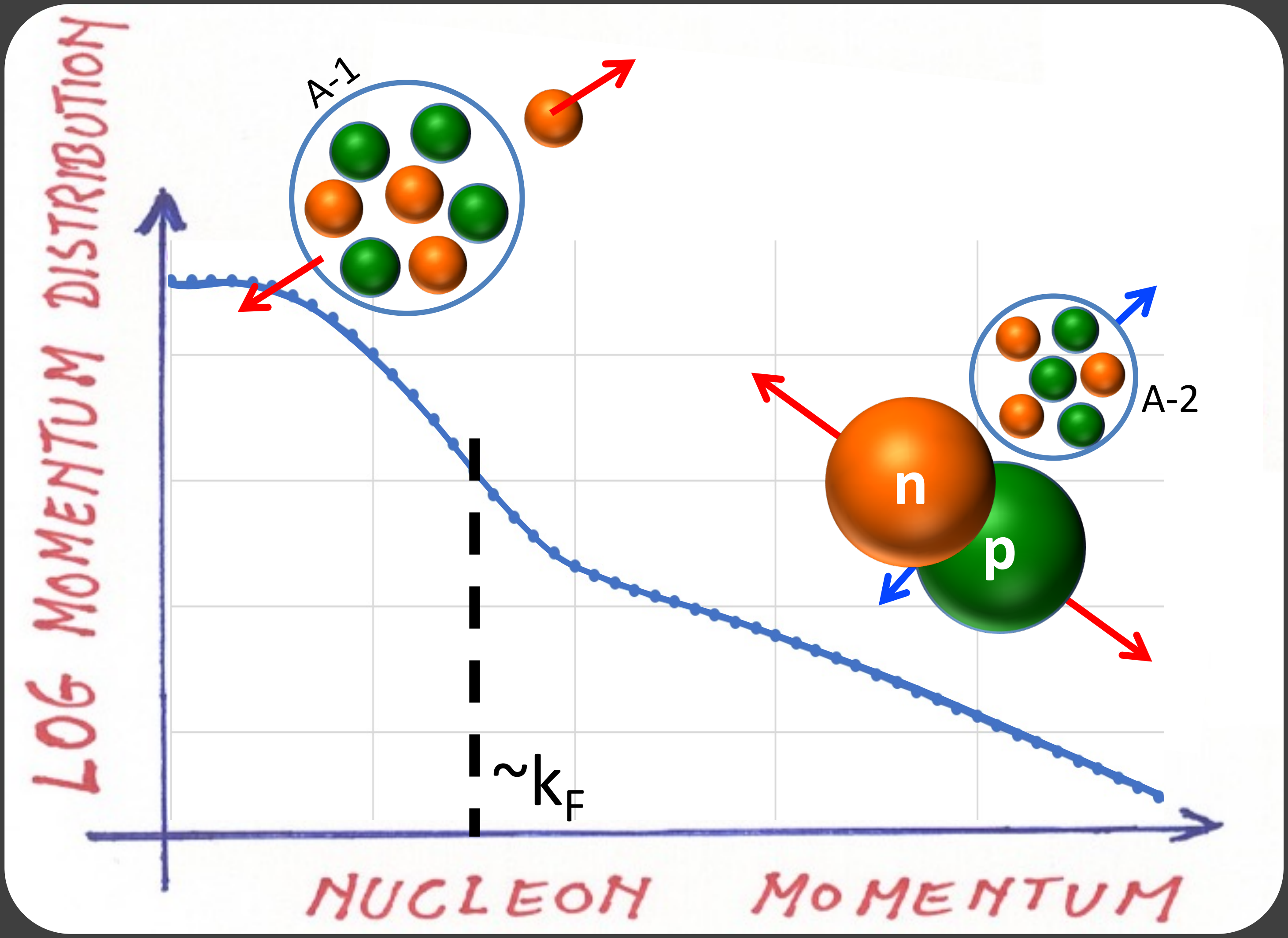


Patsyuk and Kahlbow et al., Nature Physics 17, 693 (2021)

✓ Experimentally observed factorization!

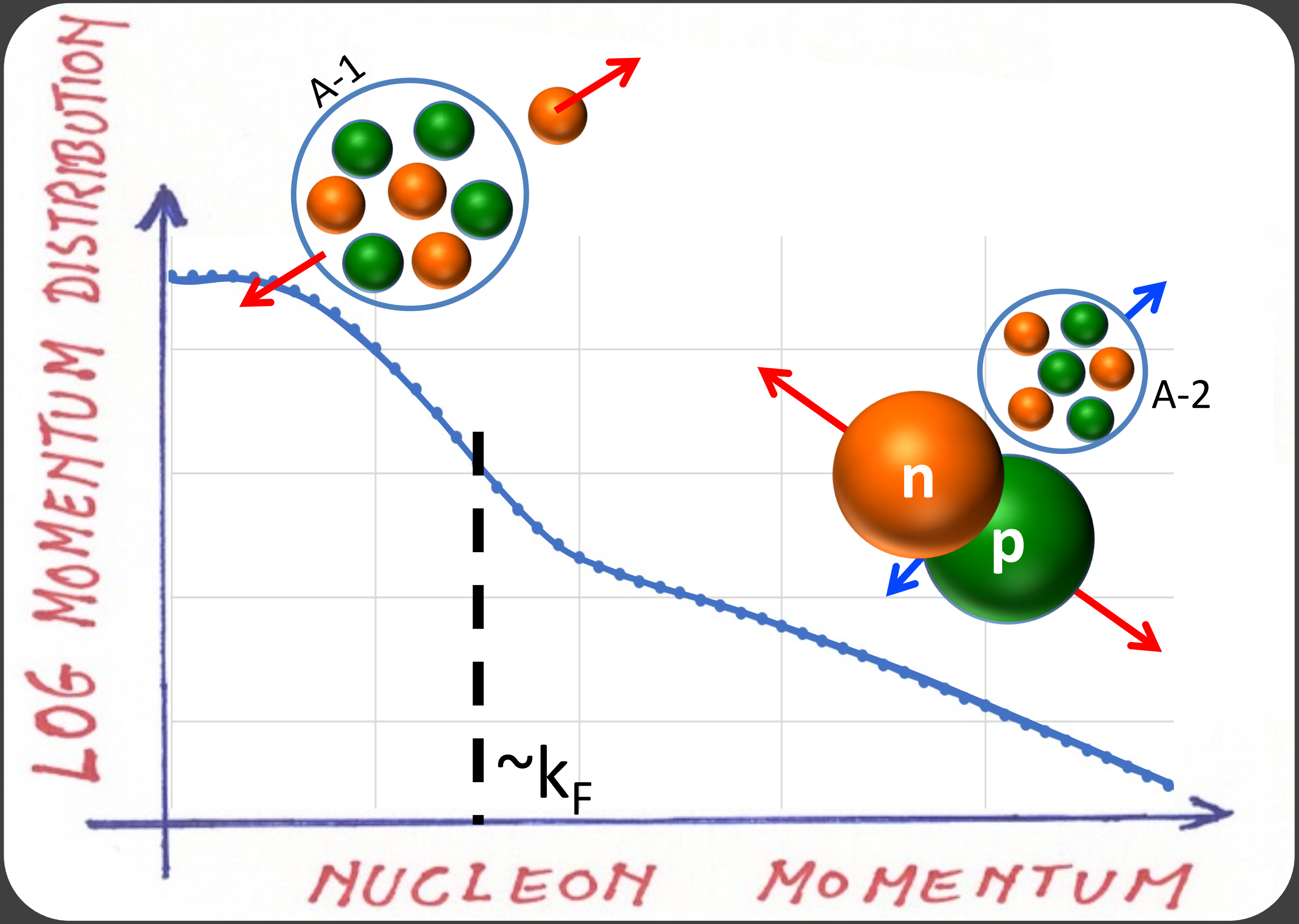
$$f\left(p_{rel}, p_{c.m.}, \theta_{rel,c.m.}\right) \approx C\left(p_{c.m.}\right) \times \varphi\left(p_{rel}\right)$$

M. Patsyuk et al., Nature Physics 17, 693 (2021)



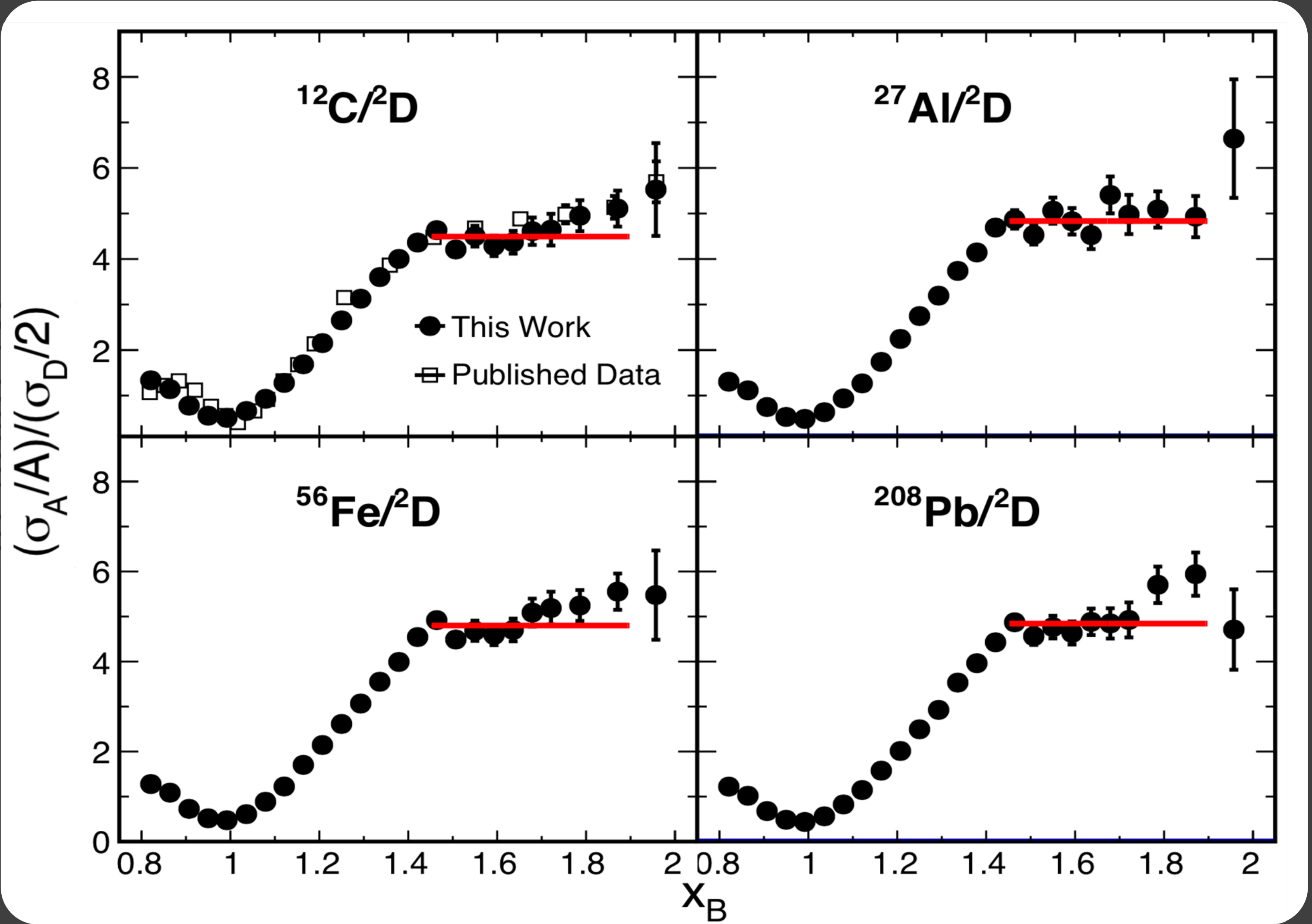
Wiringa, PRC (2014); Carlson, RMP (2015); …

➔ When SRC dominate, nuclei resemble deuterium



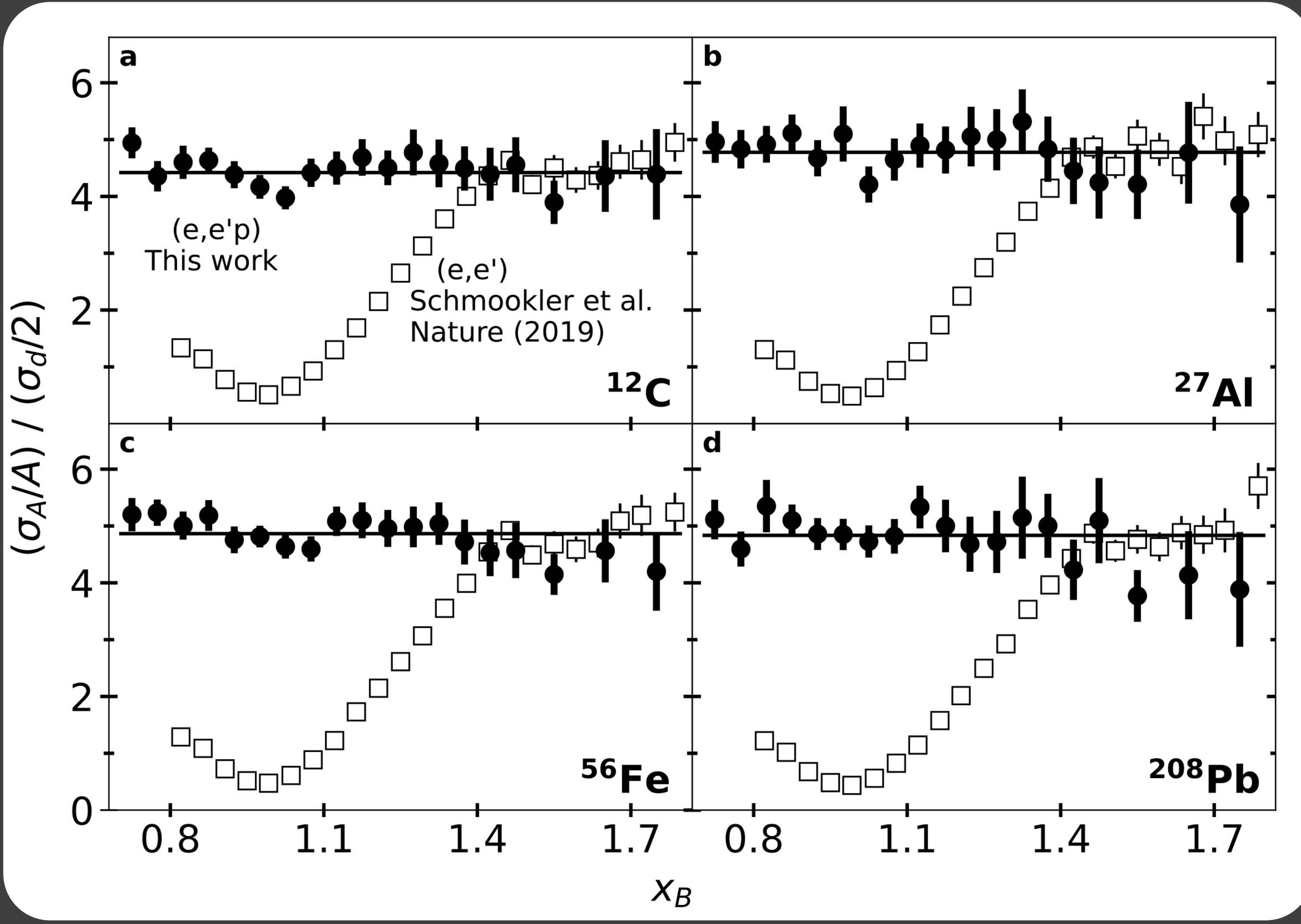
Wiringa, PRC (2014); Carlson, RMP (2015); …

Universality in high-momenta Scattering



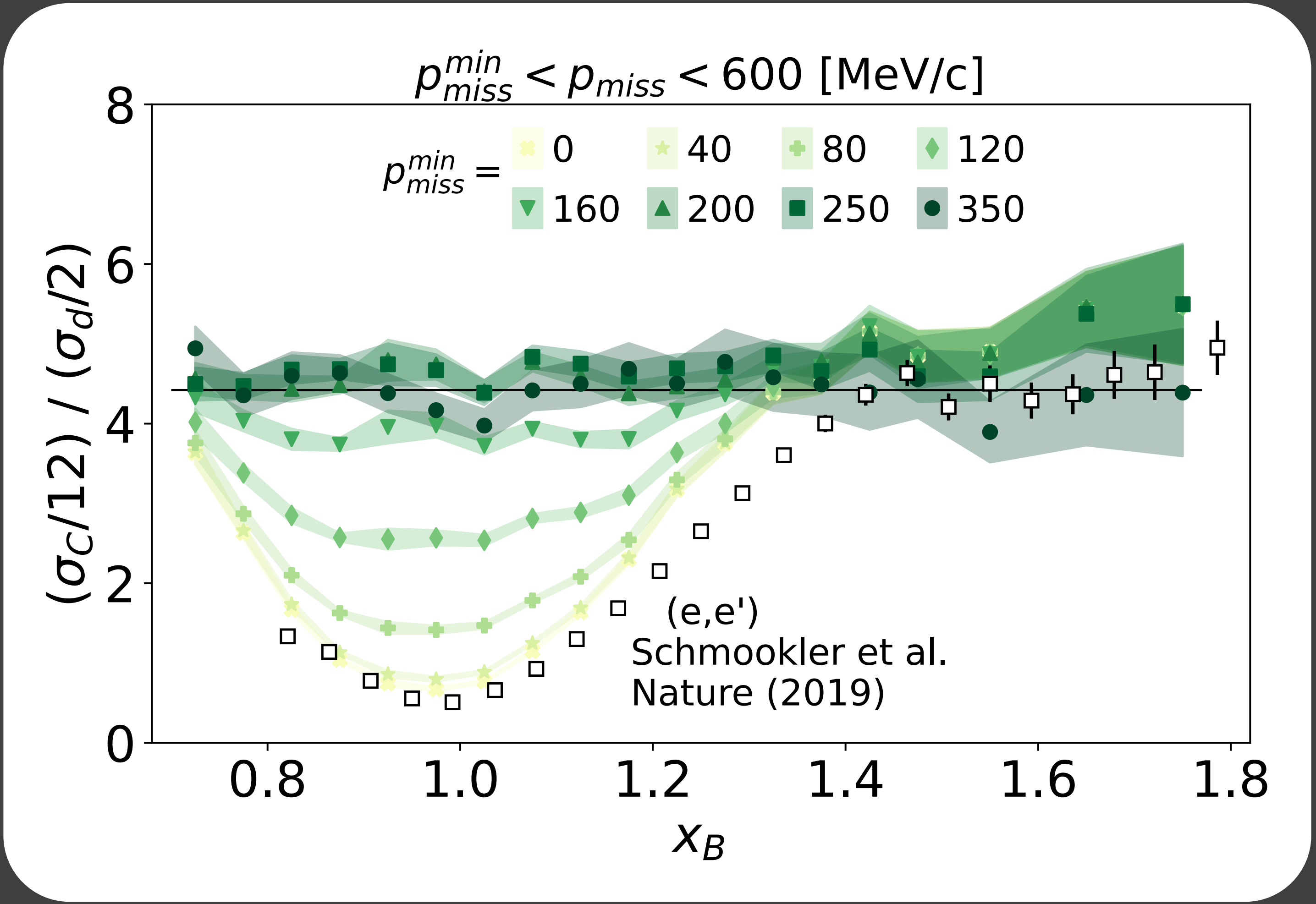
Schmookler et al., Nature (2019)

Universality in high-momenta Scattering



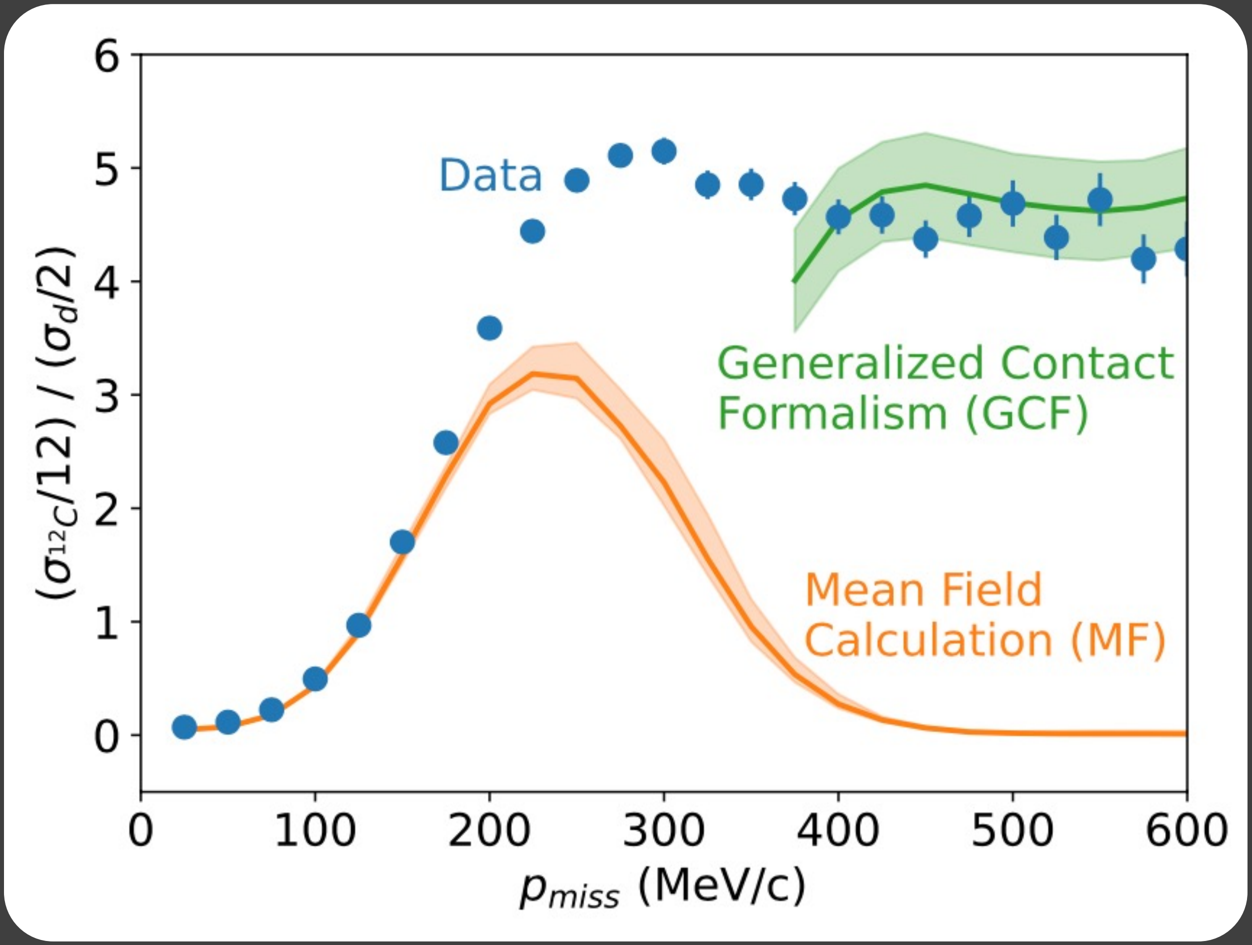
I. Korover et al., Submitted (2021)

Scaling onsets around k_F



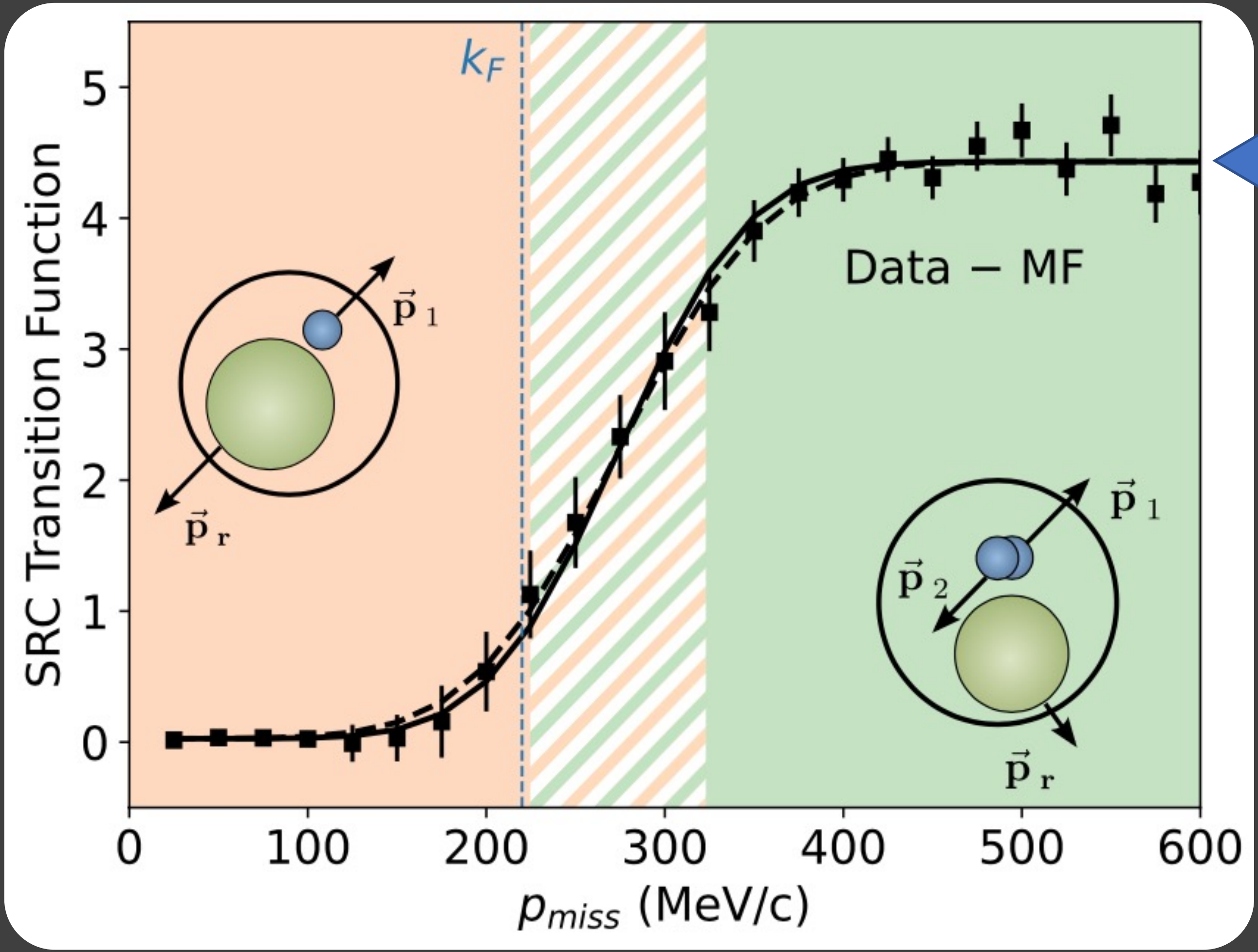
I. Korover et al., Submitted (2021)

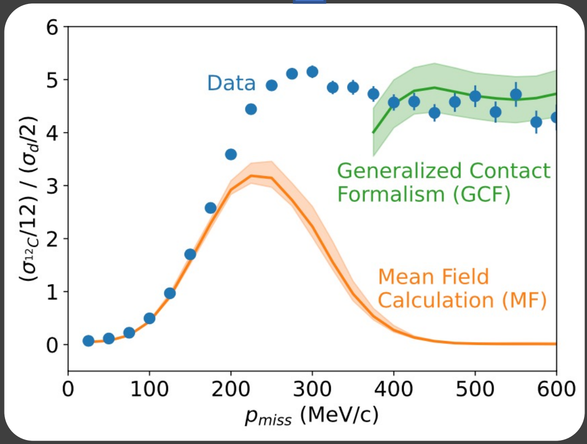
Quantifying SRC Dominance



I. Korover et al., Submitted (2021)

SRC Transition Function

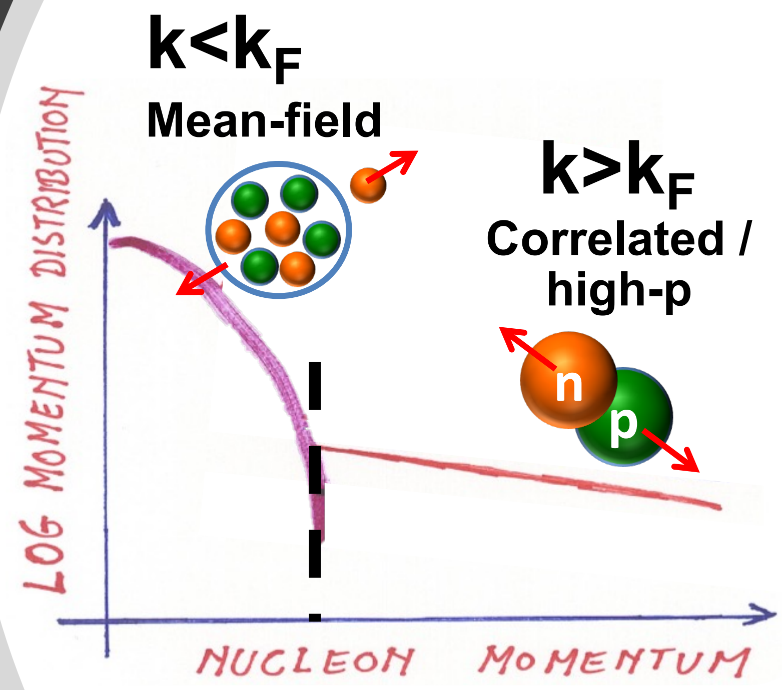




I. Korover et al., Submitted (2021)

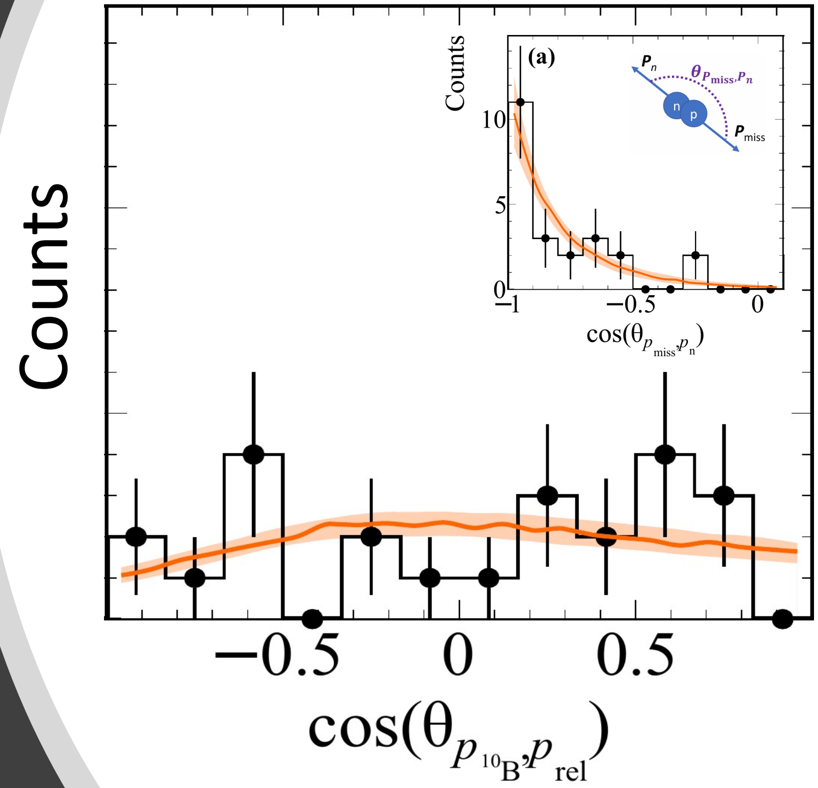
Interim Summary

- Nuclear momentum distribution has two distinct regions.



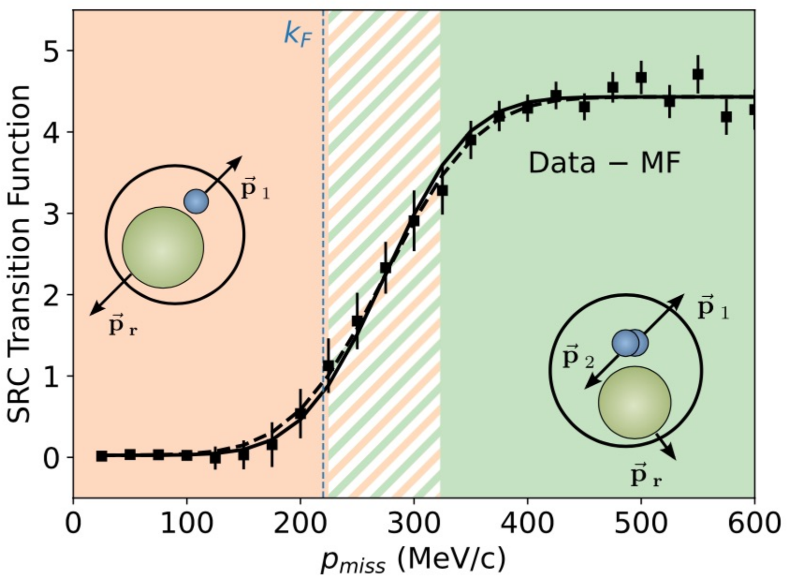
Interim Summary

- Nuclear momentum distribution has two distinct regions.
- Correlated region is scale separated from the many-body system.



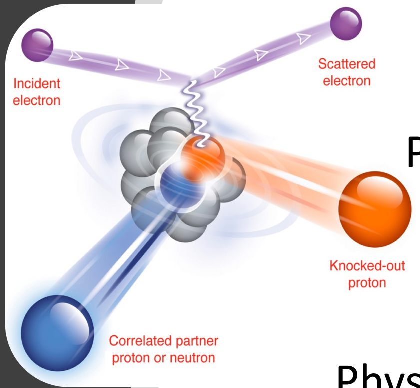
Interim Summary

- Nuclear momentum distribution has two distinct regions.
- Correlated region is scale separated from the many-body system.
- Onset right above the Fermi skin.



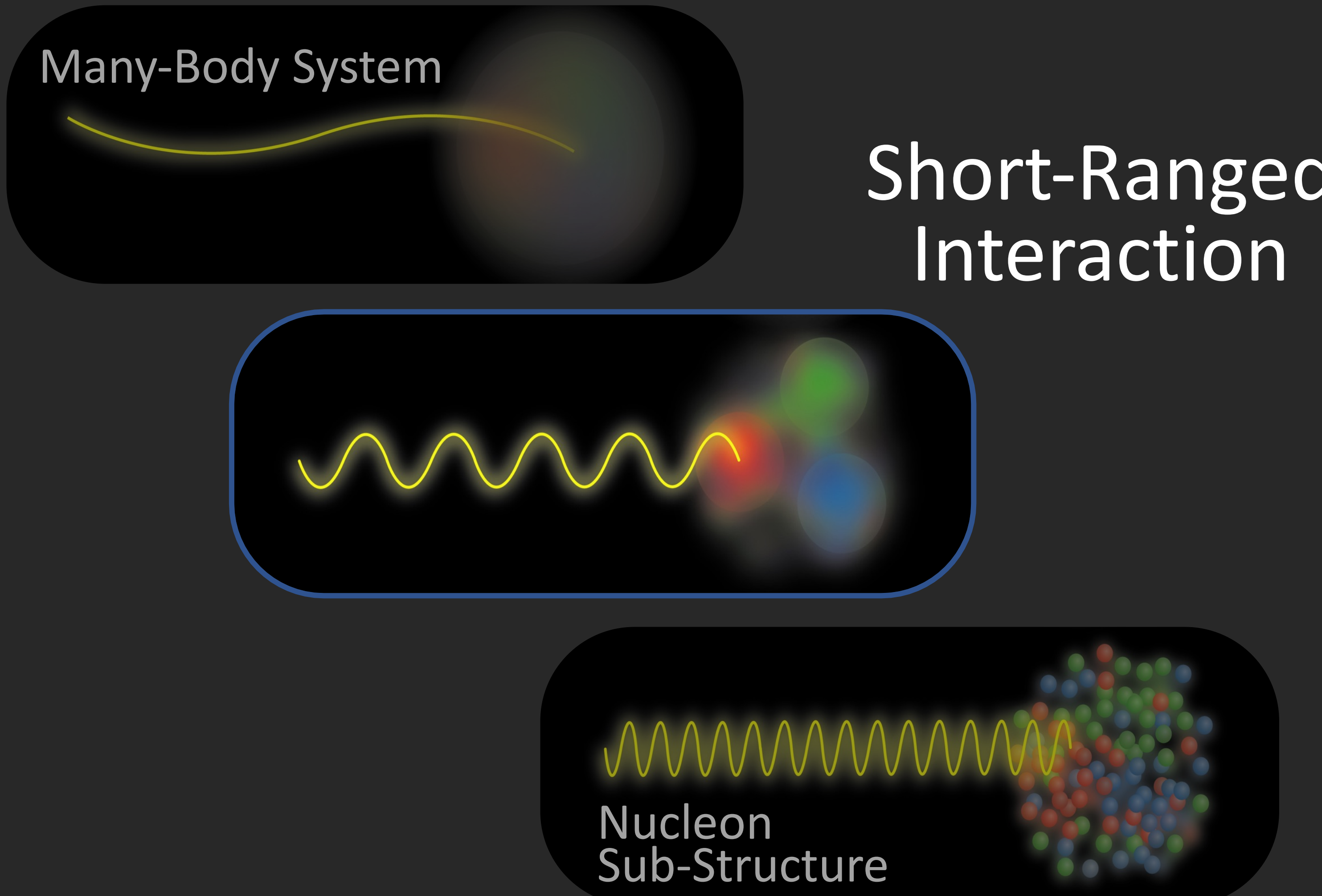
Interim Summary

- Nuclear momentum distribution has two distinct regions.
- Correlated region is scale separated from the many-body system.
- Onset right above the Fermi skin.
- Quantify SRC properties.
  (quantum numbers; isospin structure; c.m. motion; mass & asymmetry dependence; ...)

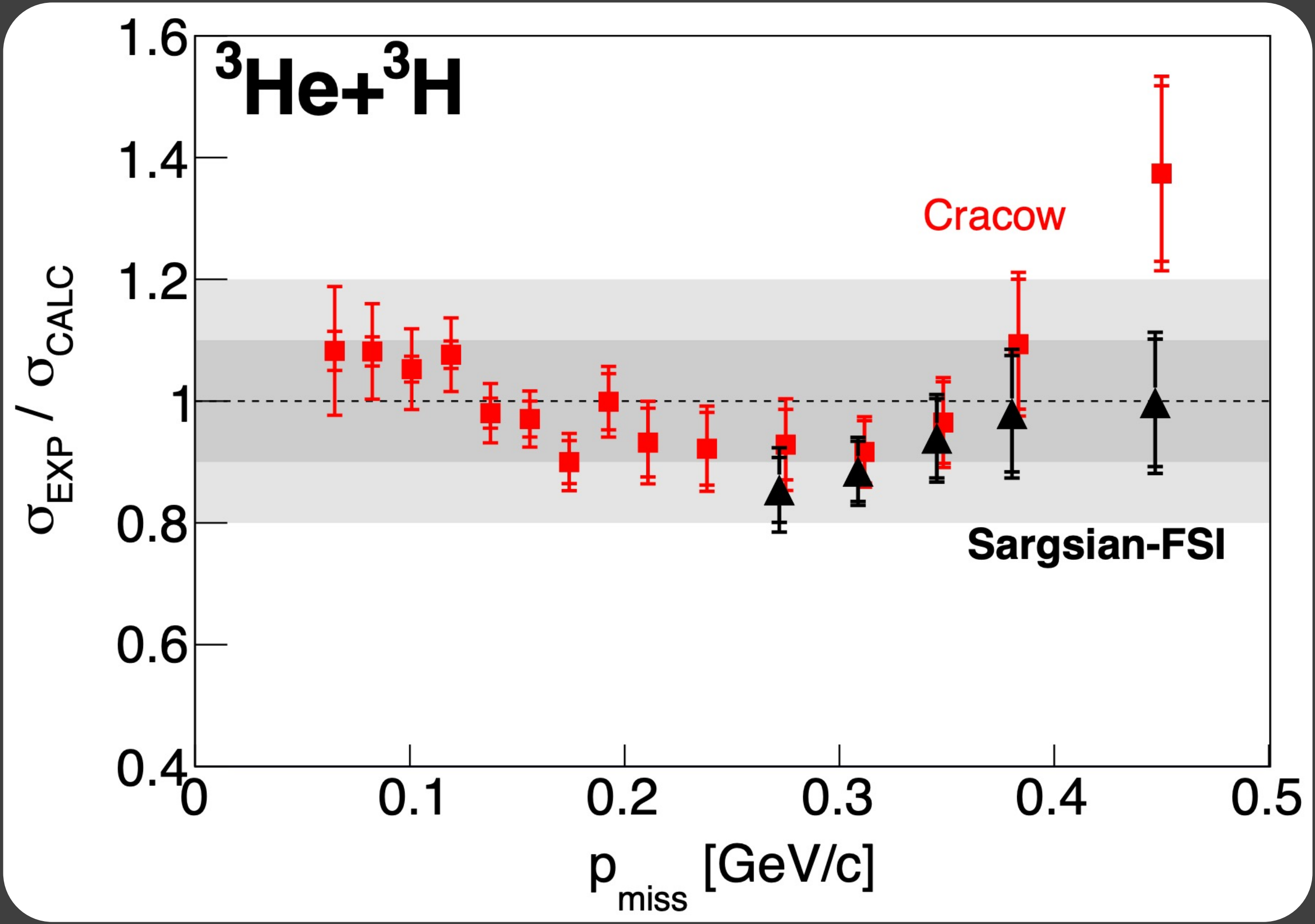


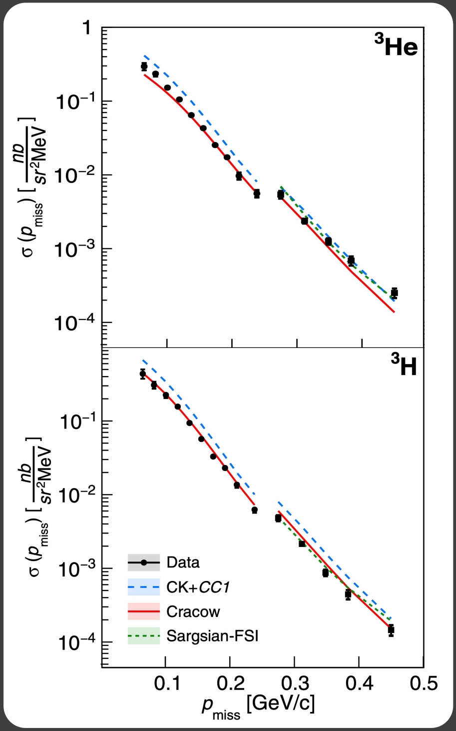
Nature 560, 617 (2018)
Science 346, 614 (2014)
Nature Physics 17, 693 (2021)
Nature Physics 17, 306 (2021)
PRL 122, 172502 (2019)
PRL 121, 092501 (2018)
PRL 113, 022501 (2014)
PRC 103, L031301 (2021)
PRC 92, 045205 (2015)
PRC 92, 024604 (2015)
PRC 91, 025803 (2015)
Phys. Lett. B 805, 135429 (2020)
Phys. Lett. B 800, 135110 (2020)
Phys. Lett. B 797, 134792 (2019)
Phys. Lett. B 791, 242 (2019)
Phys. Lett. B 793, 360 (2019)
Phys. Lett. B 785, 304 (2018)
Phys. Lett. B 780, 211 (2018)

“SRC Lab”


Many-Body System
Short-Ranged Interaction
Nucleon
Sub-Structure

A=3 (e,e'p): testing few-body physics





Cruz Torres and Nguyen et al., PRL (2020)

Modeling heavier nuclei?

- High-Q^2: Factorization \w spectral functions from NN interaction:

$$\frac{d^4\sigma}{d\Omega_{k'}\, d\epsilon'_k d\Omega_{p'_1}\, d\epsilon'_1} = p'_1 \epsilon'_1 \sigma_{eN} S^N(\boldsymbol{p}_1, \epsilon_1)$$

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- In SRCs regime:

$$\begin{aligned} S^p(p,\varepsilon) \;=\; & C_A^{pn,\,s=1} \cdot S_{pn}^{s=1}(p,\varepsilon) + \\ & C_A^{pn,\,s=0} \cdot S_{pn}^{s=0}(p,\varepsilon) + \\ & 2C_A^{pp,\,s=0} \cdot S_{pp}^{s=0}(p,\varepsilon) \end{aligned}$$

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- In SRCs regime:

$$S^p(p,\varepsilon) = C_A^{pn,\,s=1} \cdot S_{pn}^{s=1}(p,\varepsilon) + C_A^{pn,\,s=0} \cdot S_{pn}^{s=0}(p,\varepsilon) + 2C_A^{pp,\,s=0} \cdot S_{pp}^{s=0}(p,\varepsilon)$$

- Pair convolution:

$$s_{NN}^{\alpha} = \int \frac{dp_2}{(2\pi)^3}\, \delta[f(p_2)]\, \underbrace{|\varphi_{NN}^{\alpha}(p_1 - p_2)/2|^2}_{\text{Relative}}\, \underbrace{n_{NN}^{\alpha}(p_1 + p_2)}_{\text{c.m.}}$$

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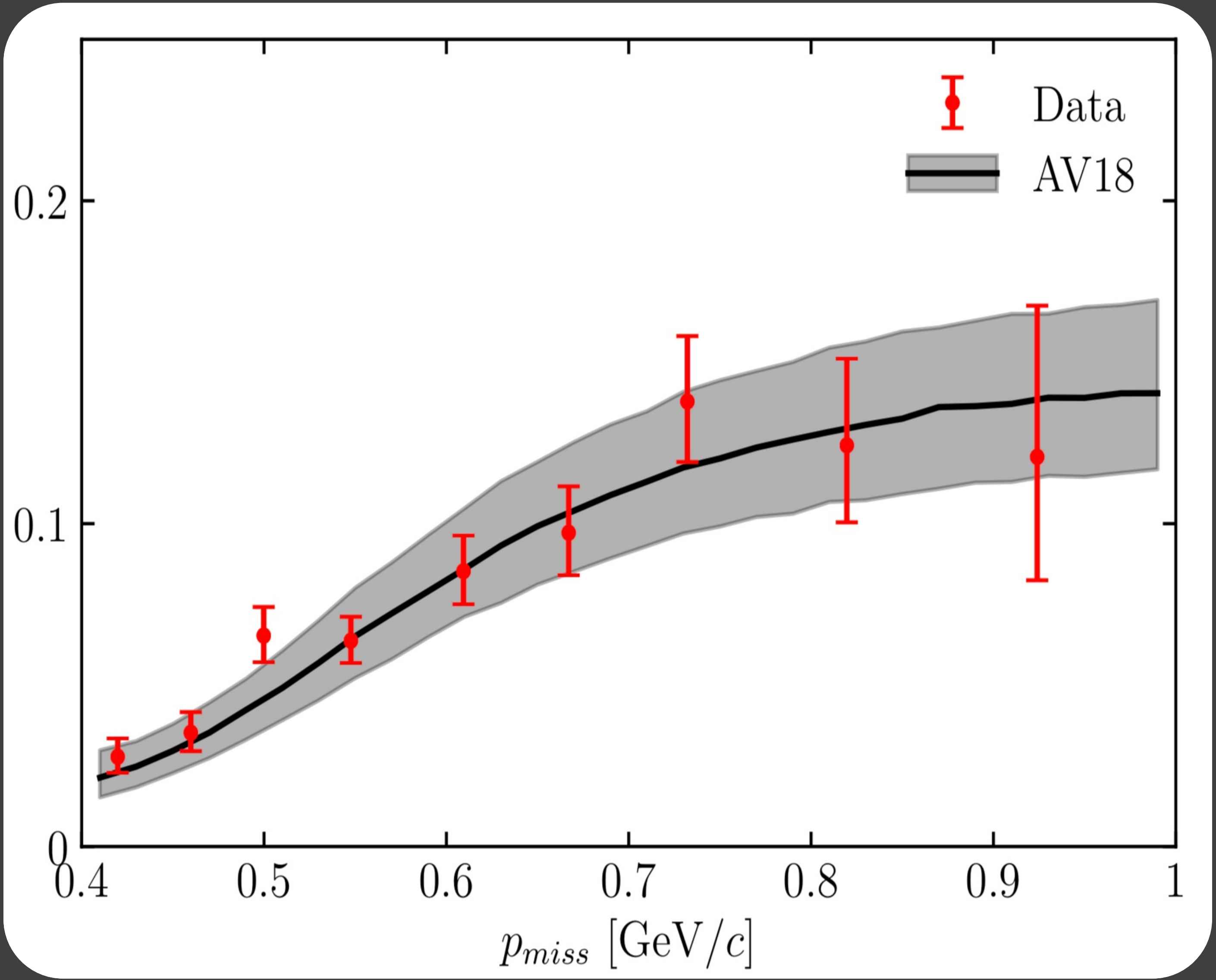
Reaching the Repulsive Core

$$\frac{^{12}C(e,e'pp)}{^{12}C(e,e'p)}$$



Schmidt et al., Nature (2020)

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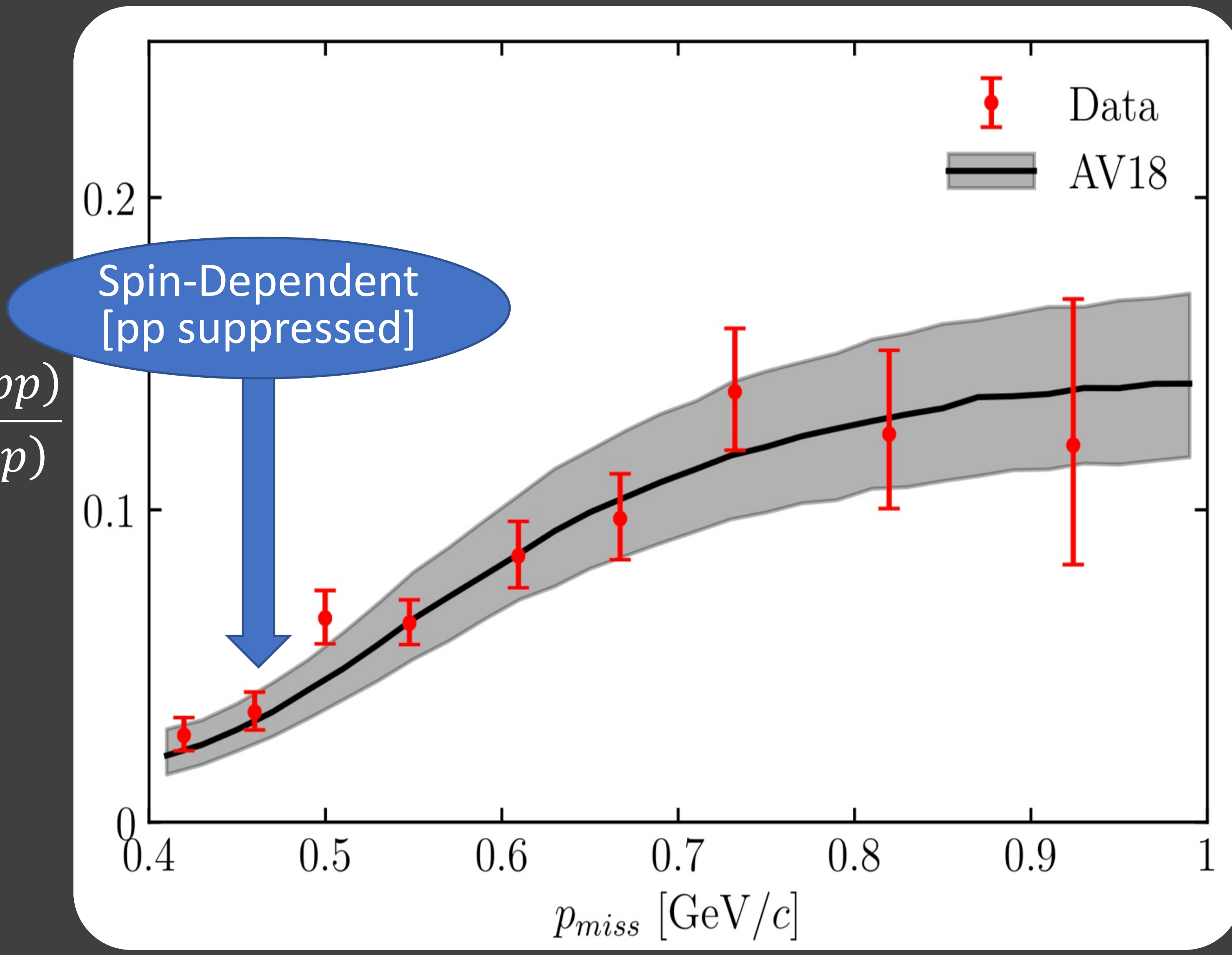

Schmidt et al., Nature (2020)

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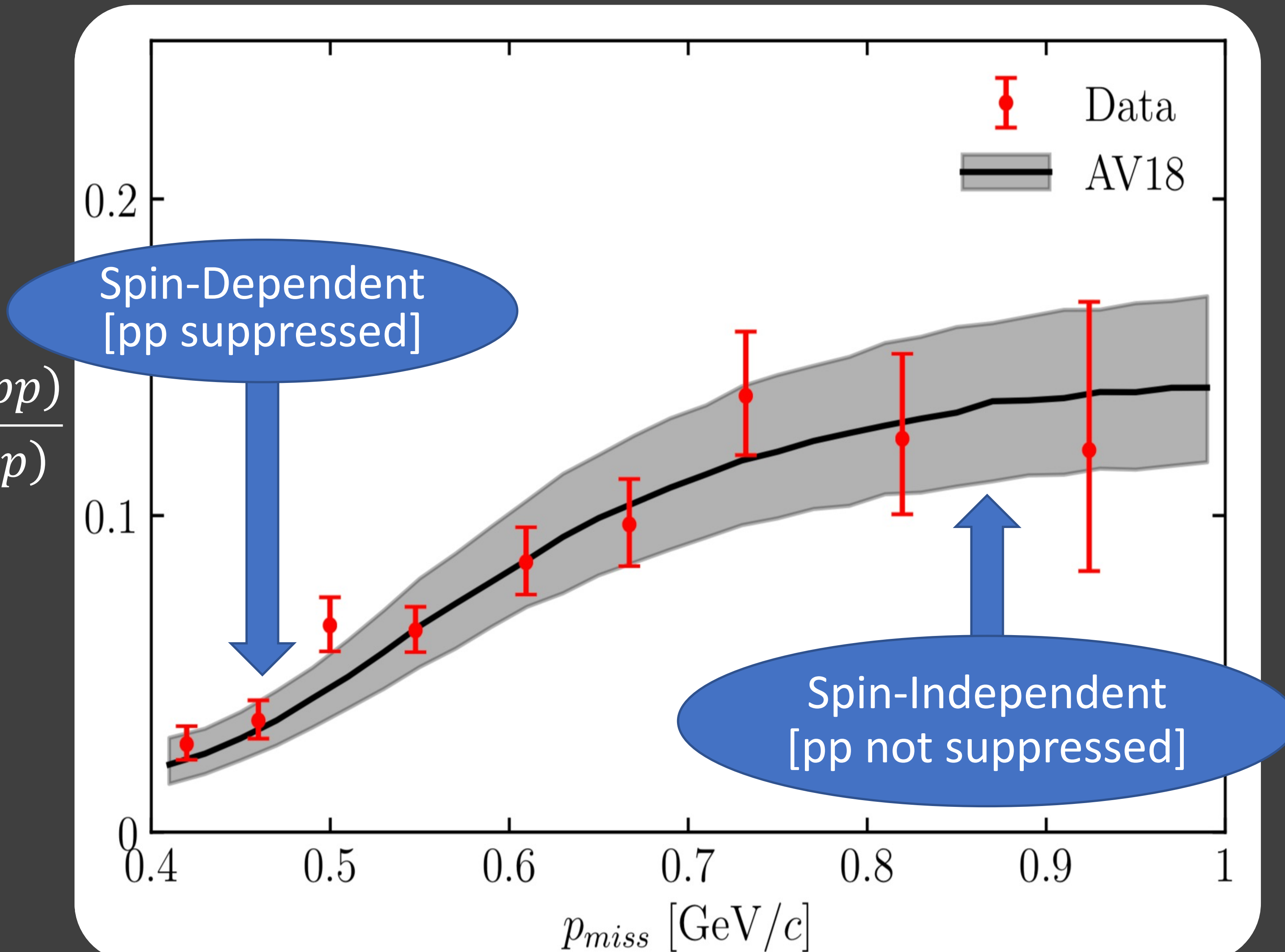
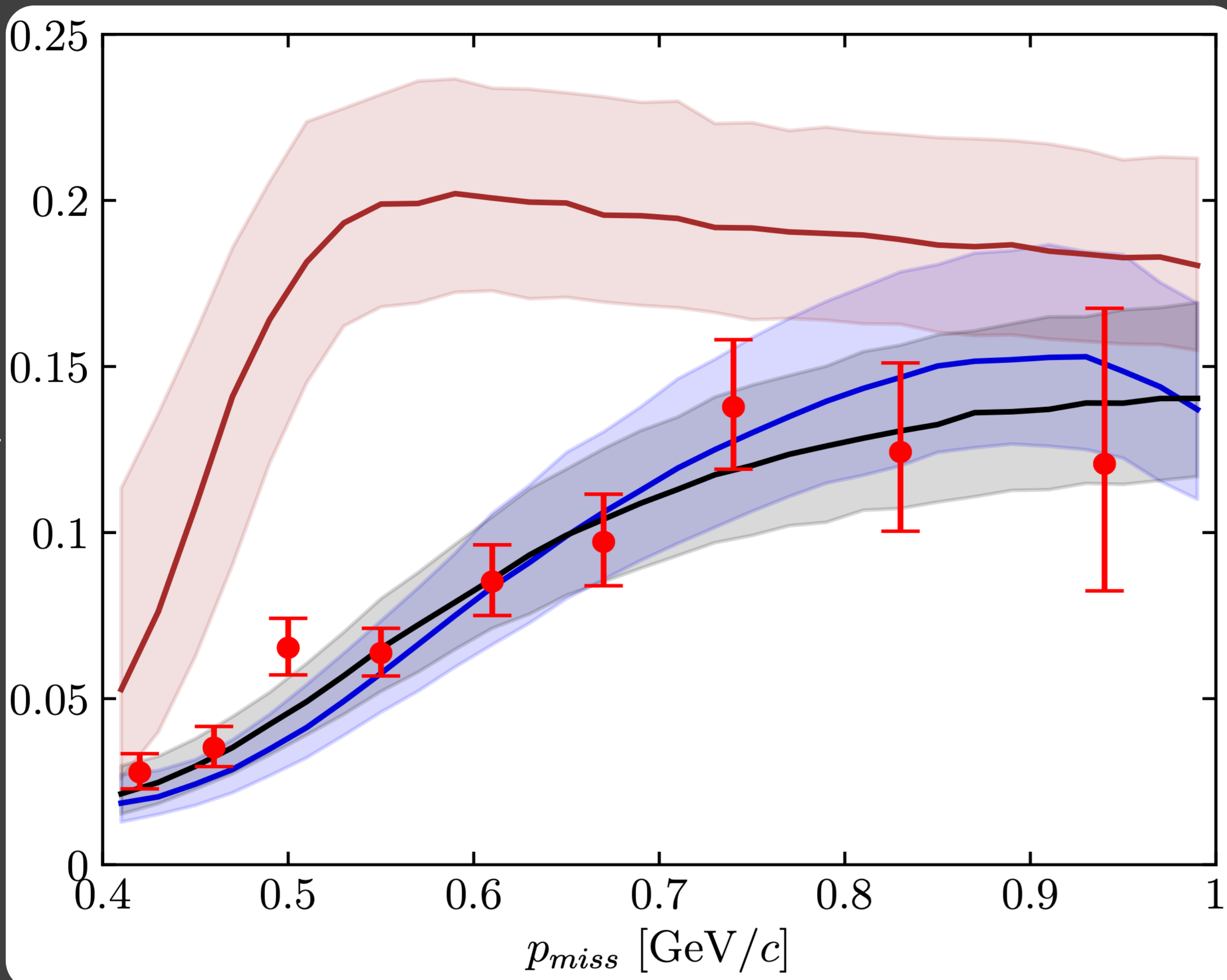


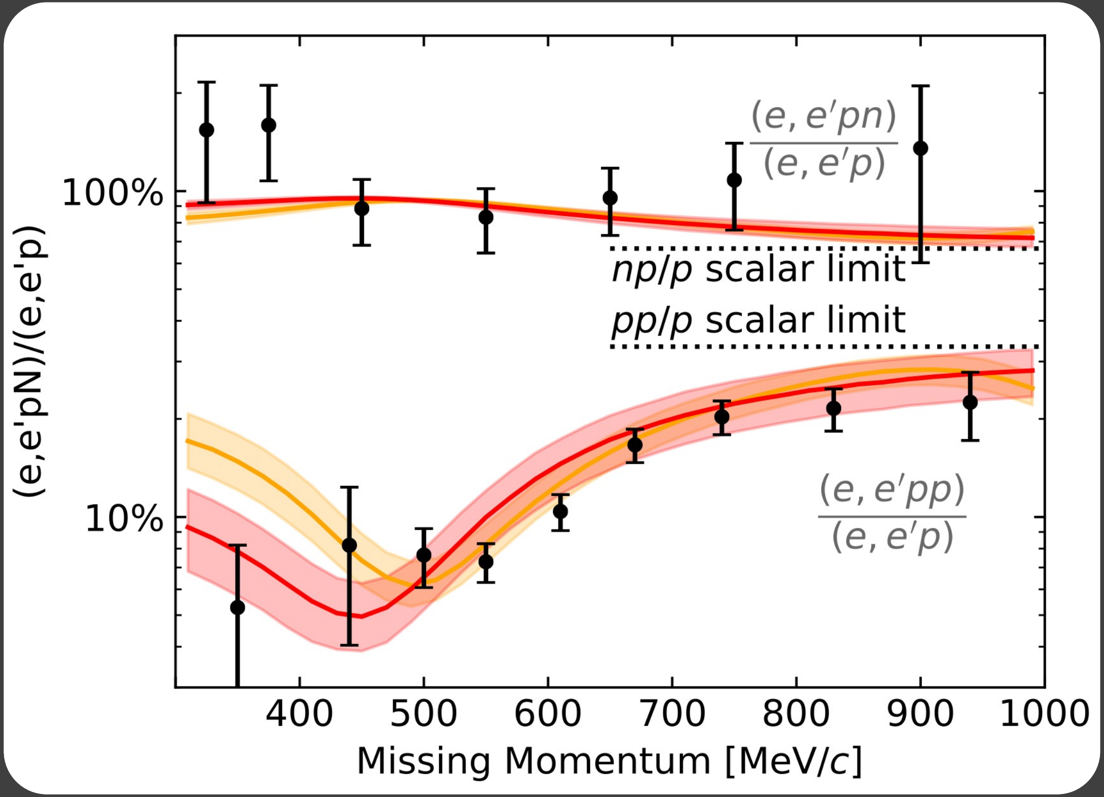
Schmidt et al., Nature (2020)

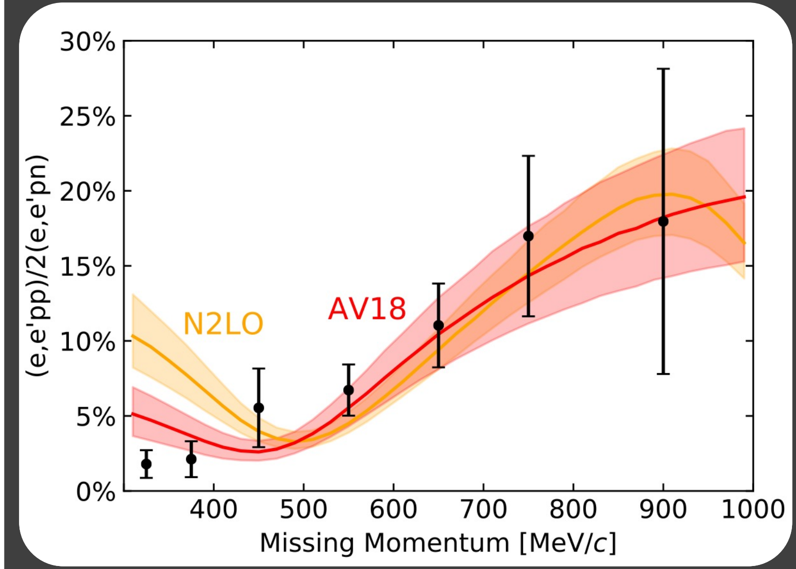
Reaching the Repulsive Core



Schmidt et al., Nature (2020)

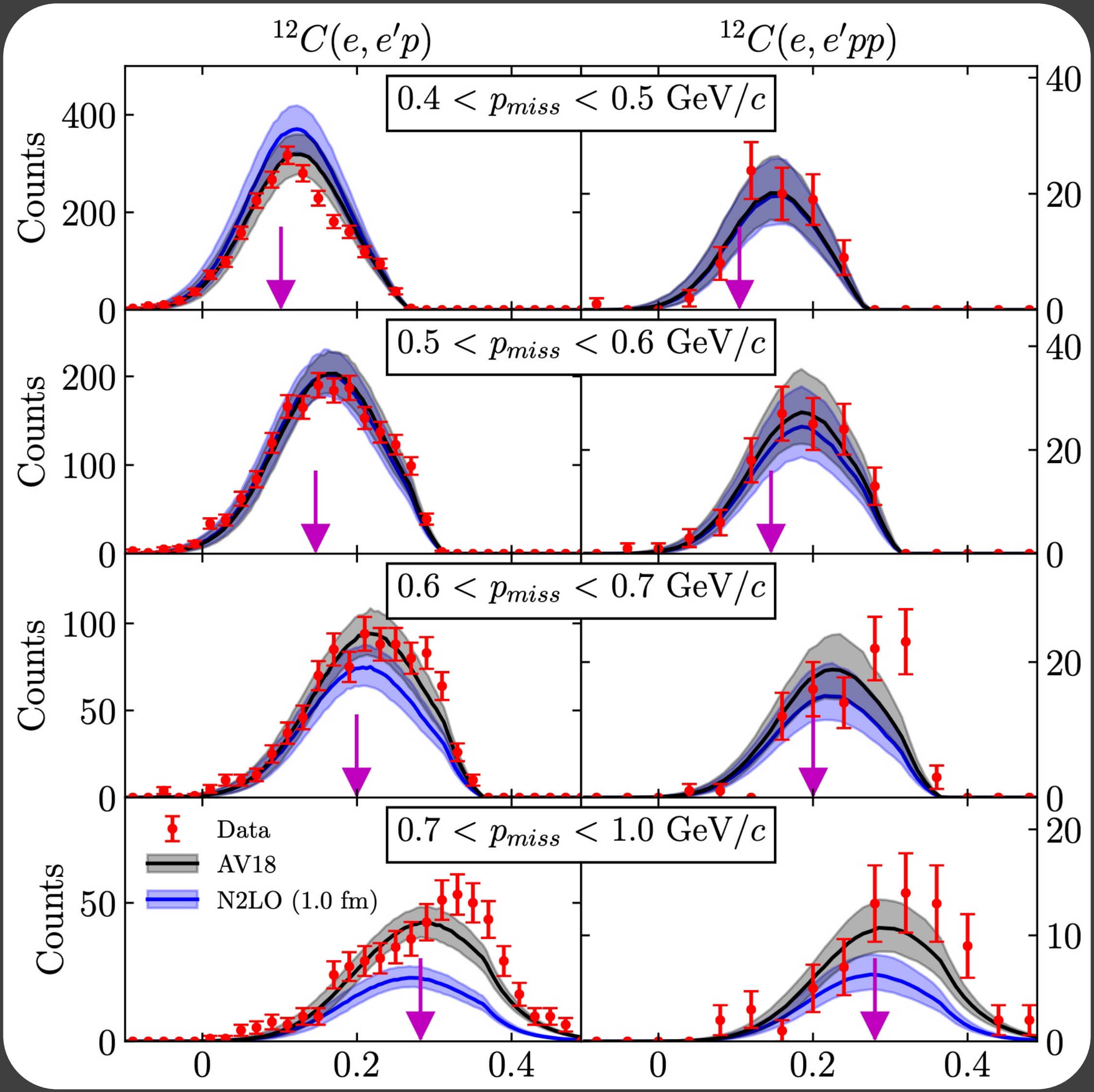
pn also consistent!





Korover et al. Phys. Lett. B (2021)

Spectral function Sensitivity



Momentum

400 – 500 MeV/c

500 – 600 MeV/c

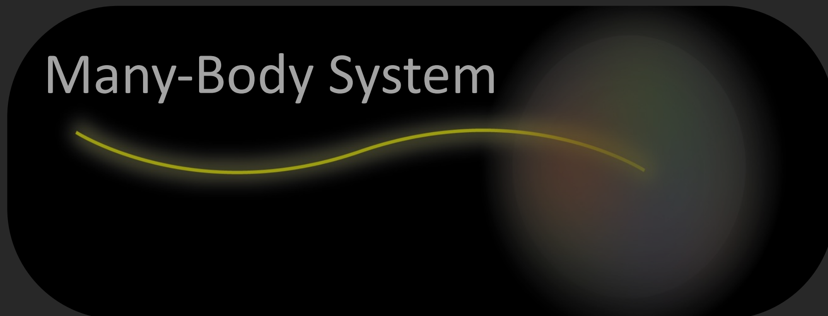
600 – 700 MeV/c

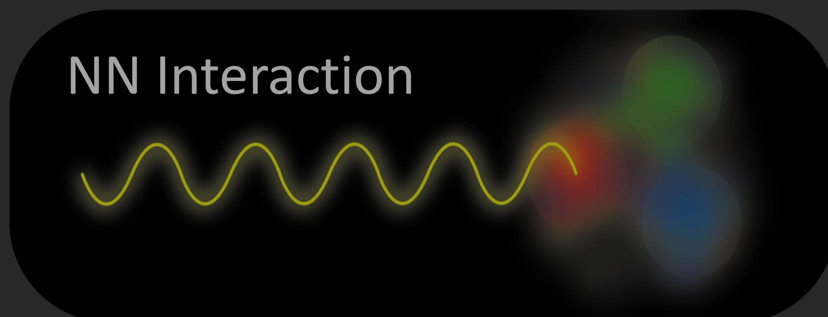
700 – 1000 MeV/c

Energy

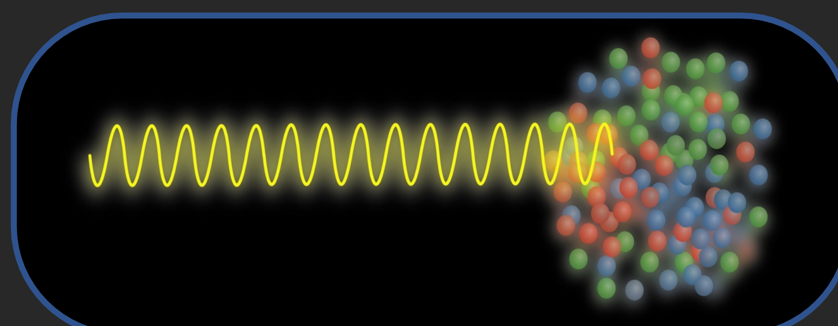
Schmidt et al., Nature (2020)

“SRC Lab”

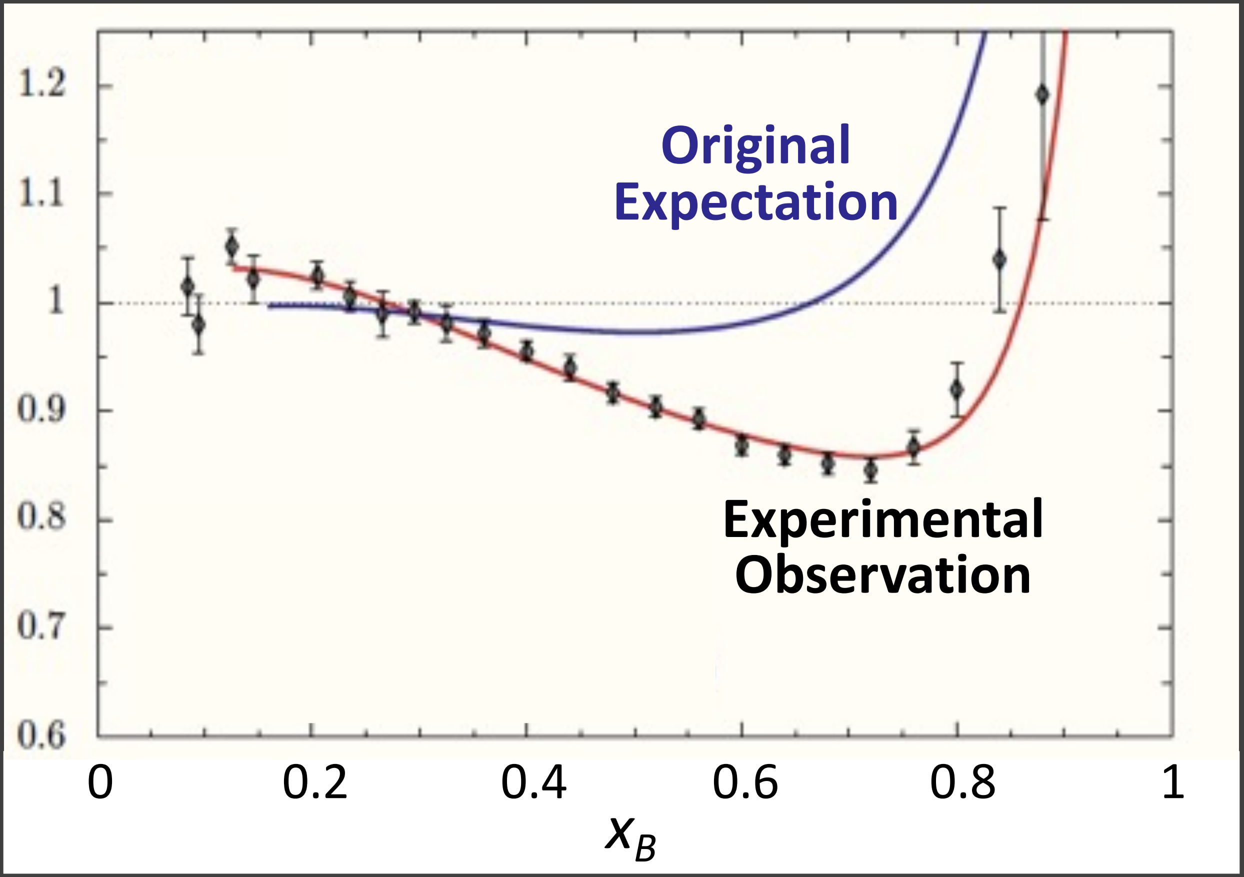




Quarks in the Nucleus



EMC Effect:



Iron / Deuterium Structure Function

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., Nature (**2019**)

EMC Effect:

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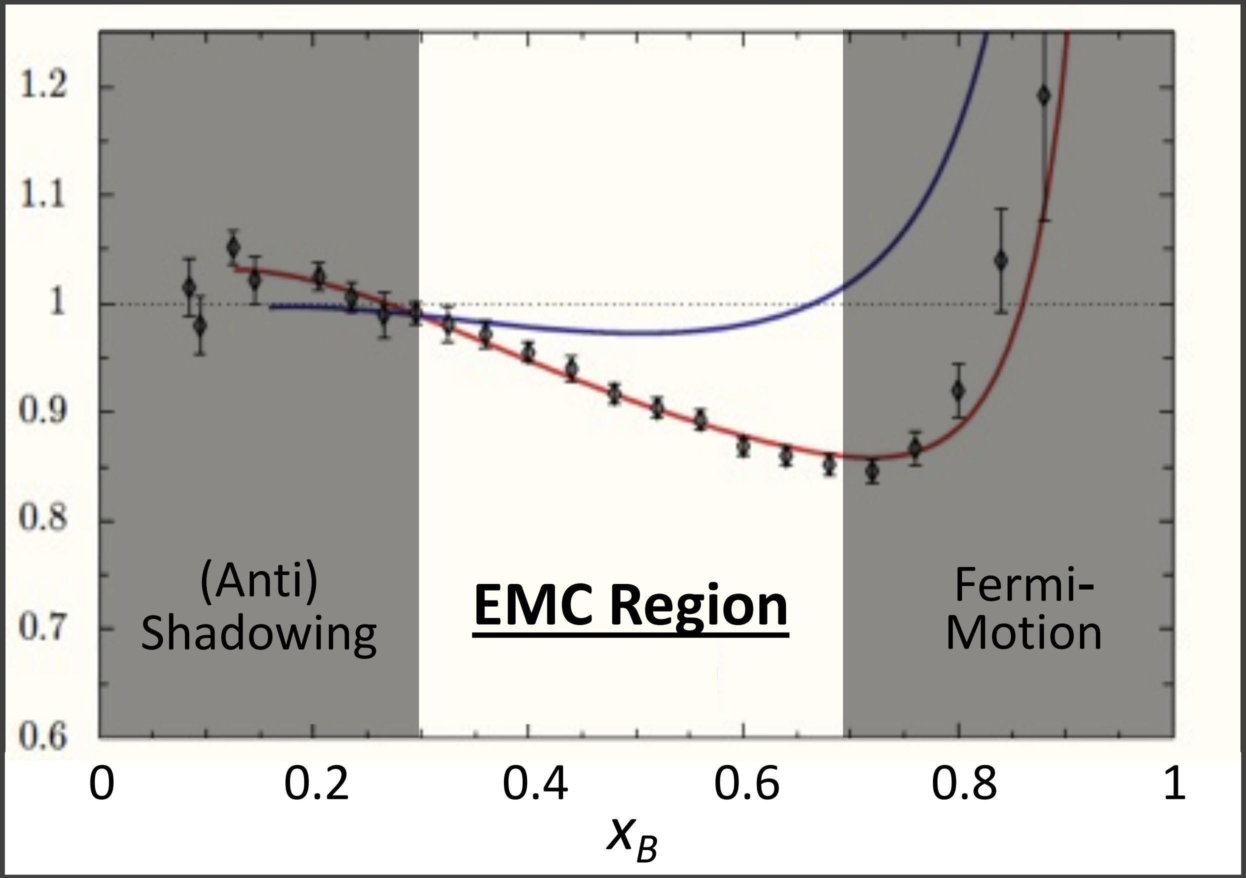

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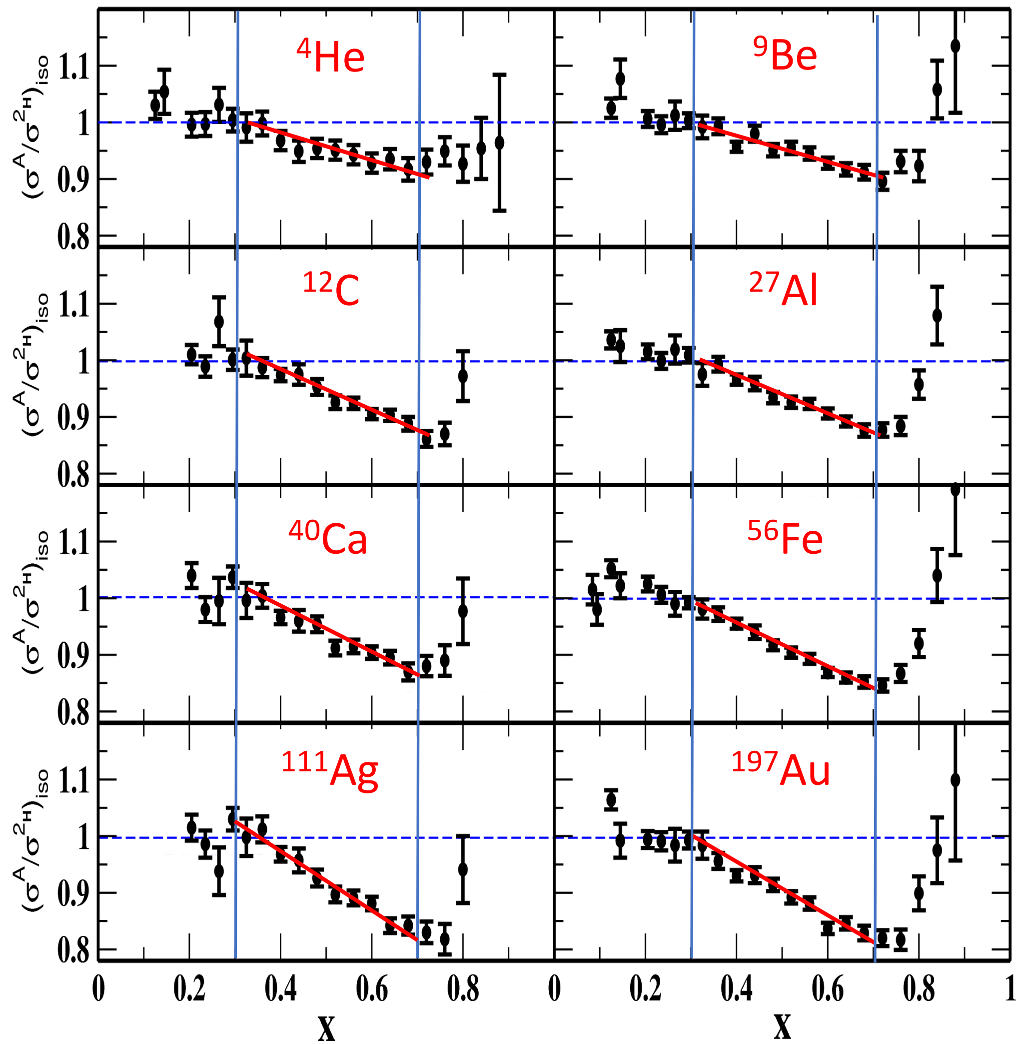
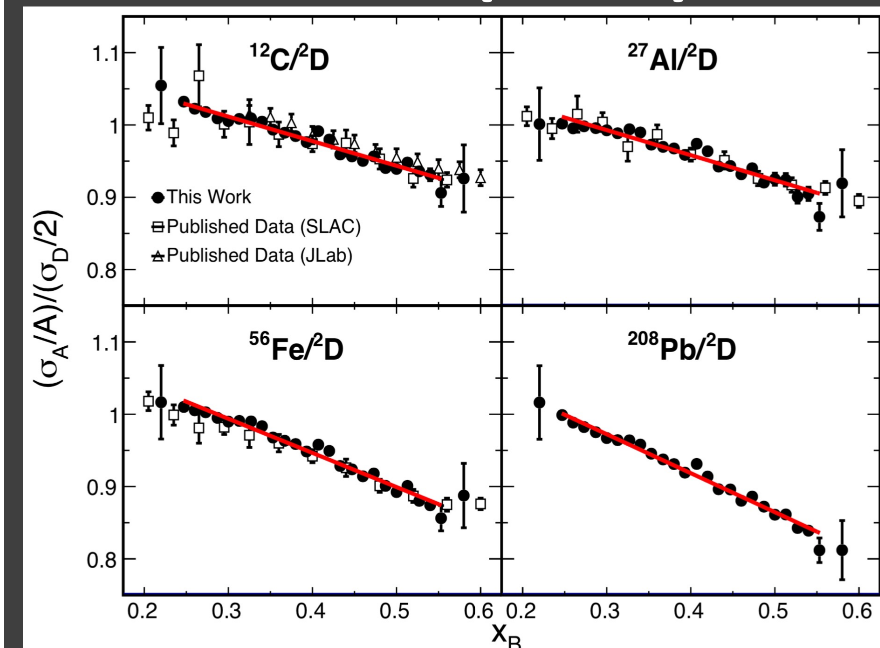
‘Global’ EMC Data



Gomez PRD (1994)

SLAC (1994)

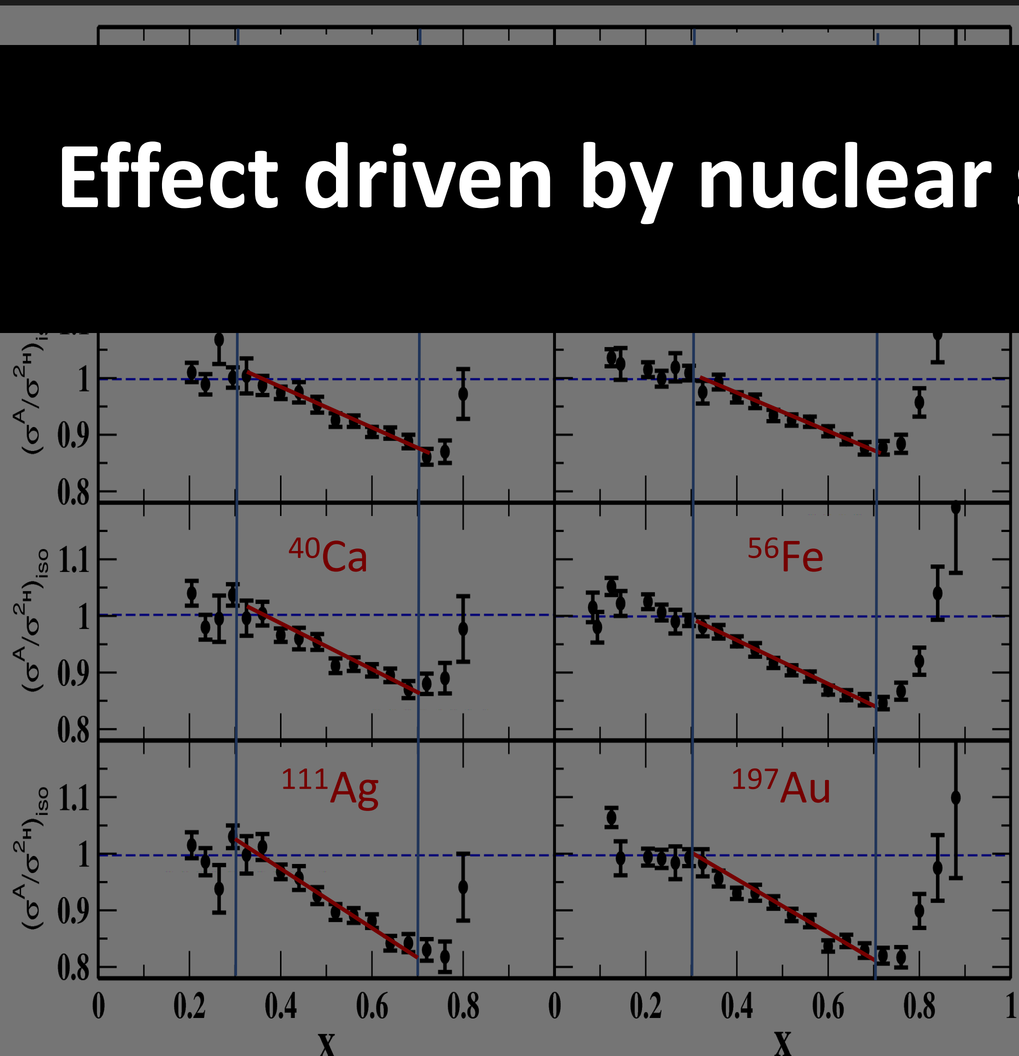
JLab (2019)



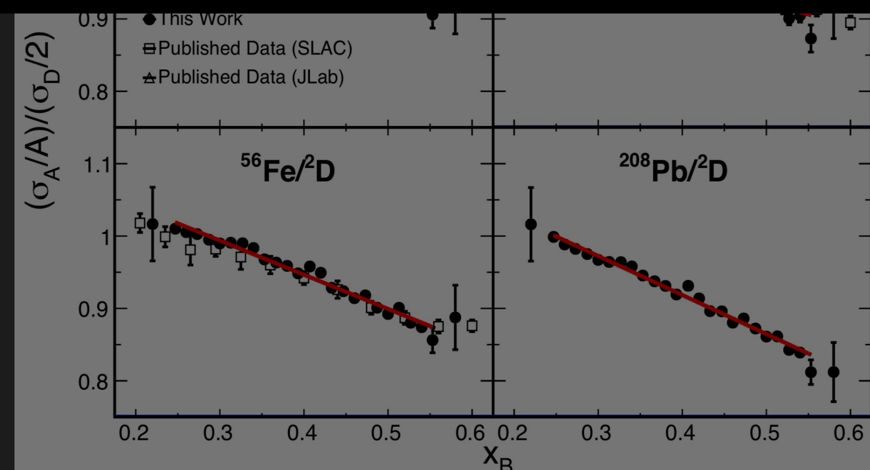
Schmookler, Nature (2019)

‘Global’ EMC Data

Effect driven by nuclear structure & dynamics



Gomez PRD (1994)



Schmookler, Nature (2019)

SLAC (1994)

38 years, >1000 papers, 3 Ideas

1. Proper treatment of ‘known’ nuclear effects
   - Nuclear Binding and Fermi motion, Pions, Coulomb Field.
   - **No modification of bound nucleon structure.**

2. Bound Nucleons are ‘larger’ than free nucleons.
   - Larger confinement volume => slower quarks.
   - Static, mean-field effect.

3. Short-Range Correlations
   - Beyond the mean-field.
   - **Dynamical.**

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Science (1993) AAAS

PERSPECTIVES

Where Are the Nuclear Pions?

George F. Bertsch, Leonid Frankfurt, Mark Strikman

Unexpected results in a number of experiments in high-energy and medium-energy nuclear physics are chipping away one of the cornerstones of nuclear physics, namely the pi meson (or pion) as a dominant carrier of the nuclear force. In the 1930s, H. Yukawa suggested that nuclear forces would have particles associated with them, and the discovery of the pions in 1947 was a beautiful confirmation of his prediction. Since then, many more mesons have been found and our understanding of the nuclear force has been refined and modified to include contributions from all the meson exchanges that could occur. Nevertheless, the pion has special importance because it is the lightest of the mesons. According to the Yukawa theory, the smaller the mass of the particle, the larger the distance over which the force acts. The

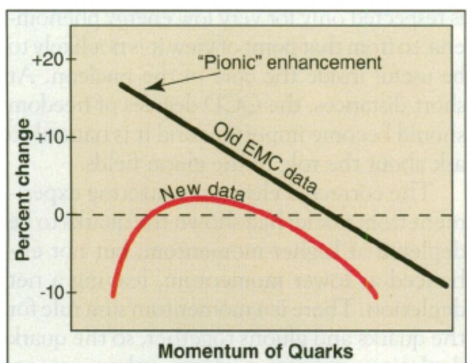

Fig. 1. The relative number of quarks in a heavy nucleus compared to those in an equal mass of deuterium. The upper curve shows the trend of the old muon scattering data, which found an enhancement of 15 to 20%. In the newer data, the enhancement has almost completely disappeared.

energies, the muons scatter from the quarks in the target. More quarks were found than could be accounted for by the number of nucleons in the nucleus. The interpretation (3) was that the extra quarks came from the pion field. As expected from the nuclear physics, the pion field would be enhanced by the interactions of the nucleons, giving in effect more virtual pions in a nucleus than for the same number of isolated nucleons. This experiment also showed the quarks to be depleted at higher momentum. According to the explanation by pions, this effect would be a consequence of the observed enhancement at lower momentum.

The nuclear pions should also affect the scattering of nucleons from a nuclear target (4). The most sensitive method for probing the pion field with nuclear scattering is to use polarized beams and to measure the polarization transfer. The pions' interaction depends on the nucleon spin orientation with respect to the momentum transfer direction, giving a characteristic signature to the spin transfer cross section. An experiment (5) measuring the spin behavior of scattered protons in 1986 produced the surprising result that the scattering was independent of

38 years, >1000 papers, 3 Ideas

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    - ~~Nuclear Binding and Fermi motion, Pions, Coulomb Field.~~
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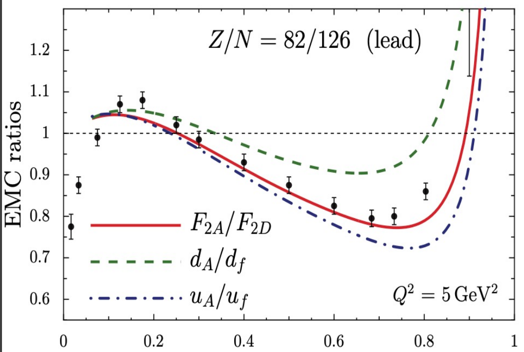

3. Short-Range Correlations
    - Beyond the mean-field.
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O. Hen et al., Rev. Mod. Phys. 89, 045002 (2017)

38 years, >1000 papers, 3 Ideas

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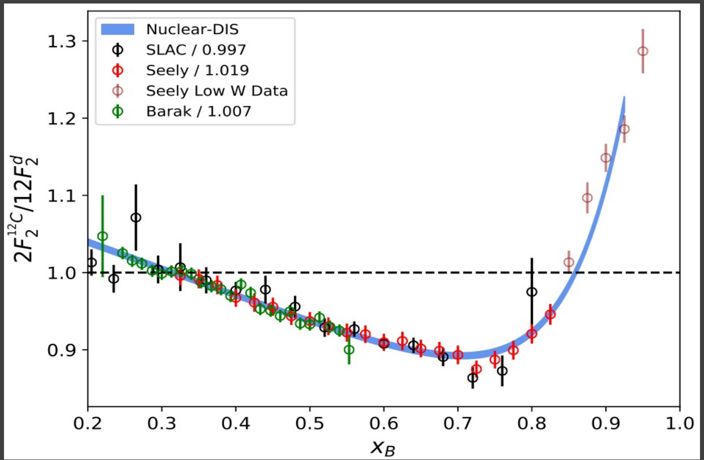
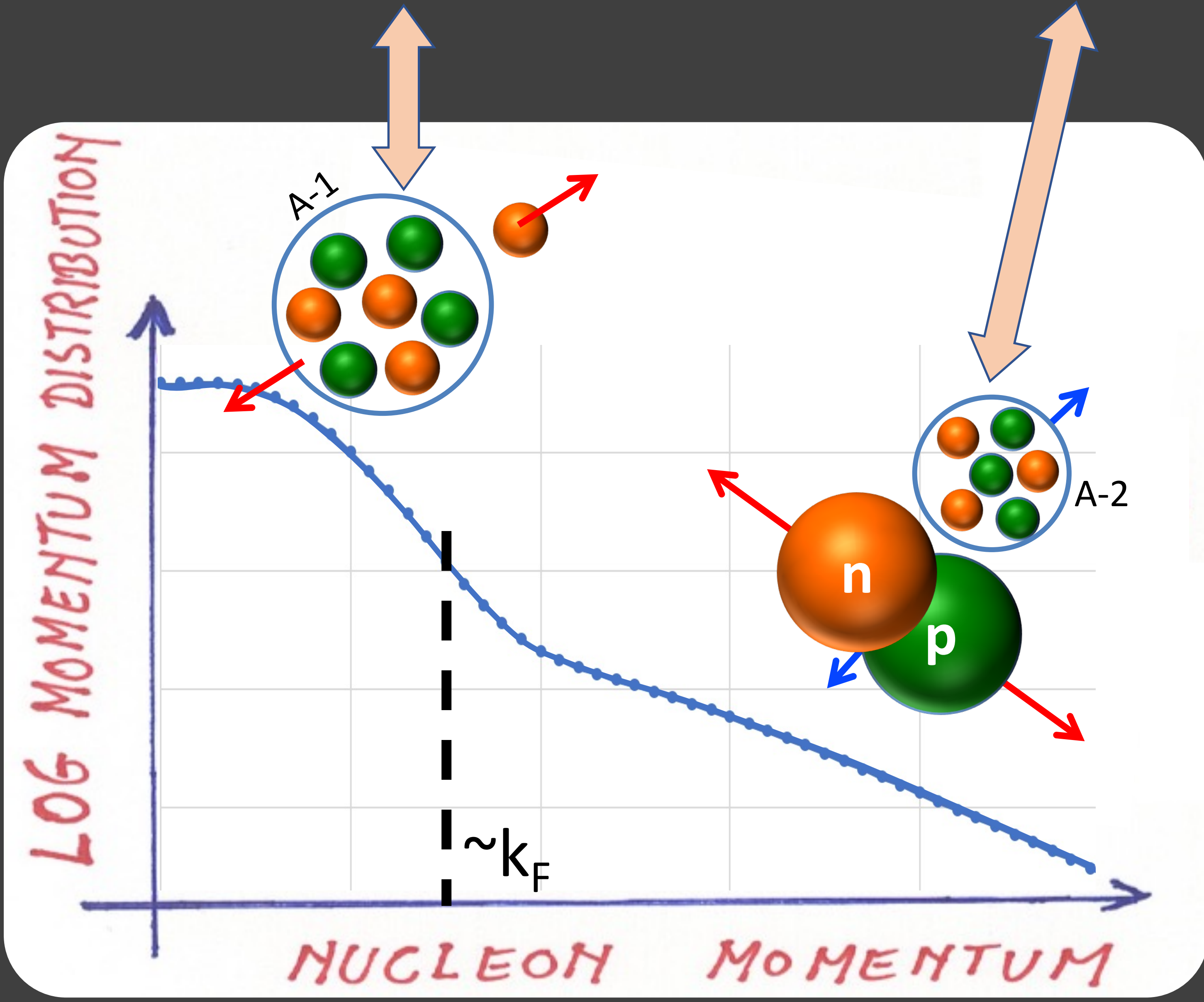
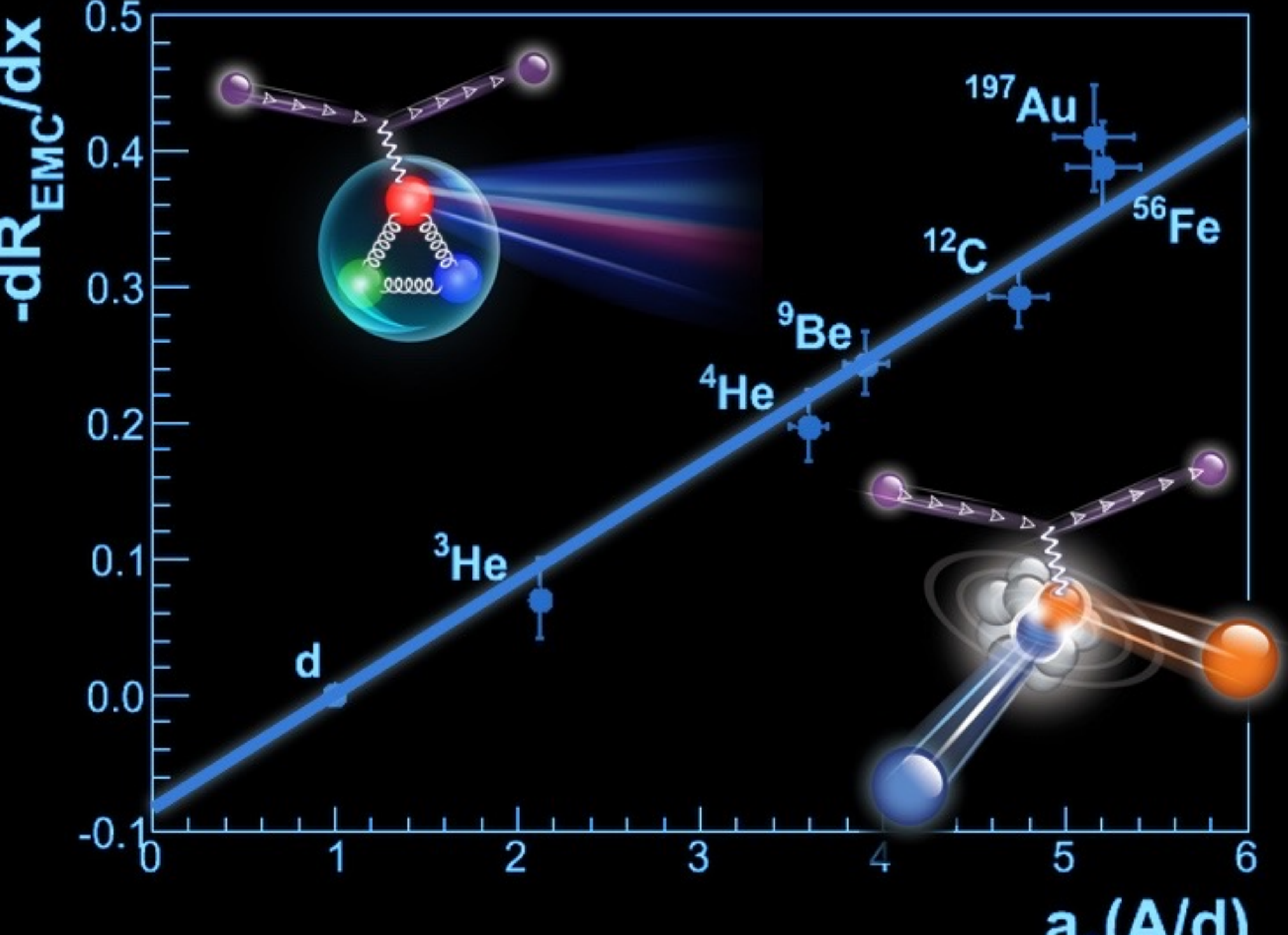


O. Hen et al., Rev. Mod. Phys. 89, 045002 (2017)

Bound = 'quasi Free' + Modified SRCs



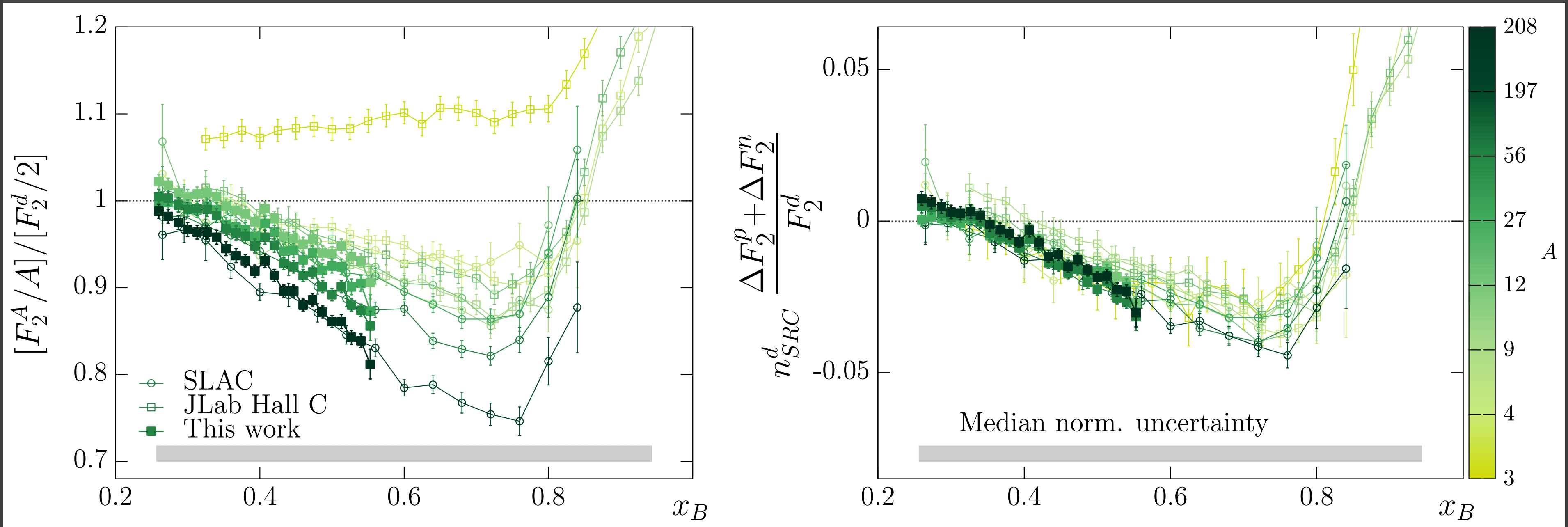
EMC – SRC Correlation



Nature (2019); RMP (2017); IJMPE (2013); PRC (2012); PRL (2011);

All Nucleons

SRC Pairs



Schmookler et al., Nature (2019)

All Nucleons

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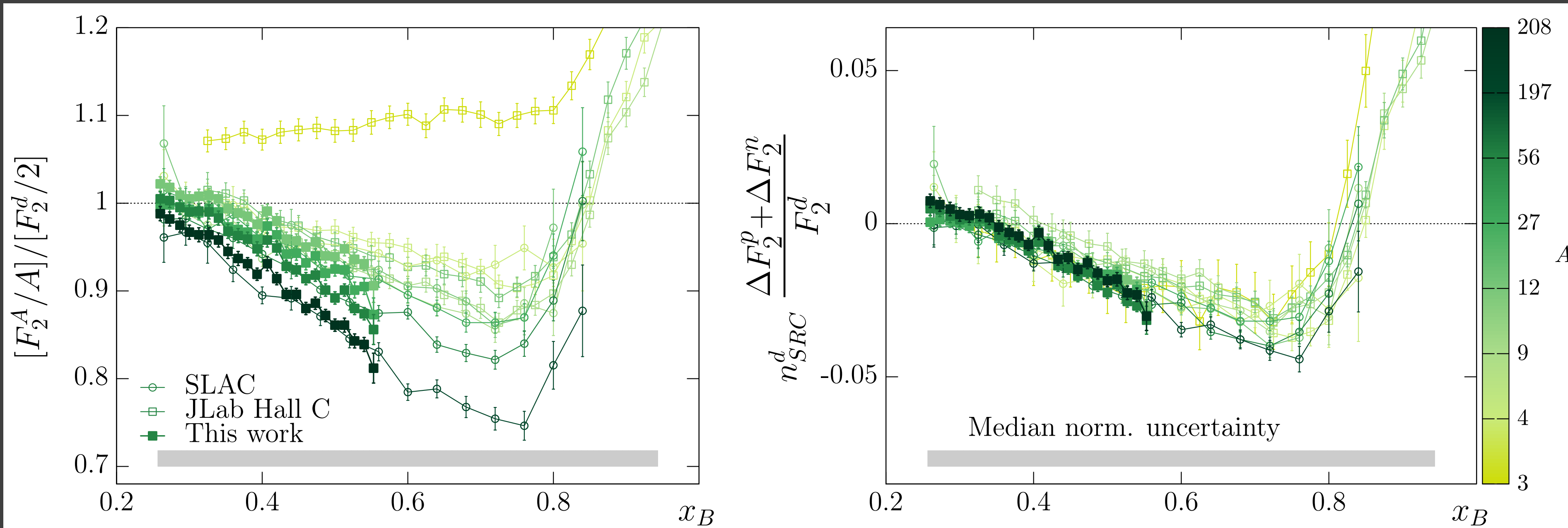
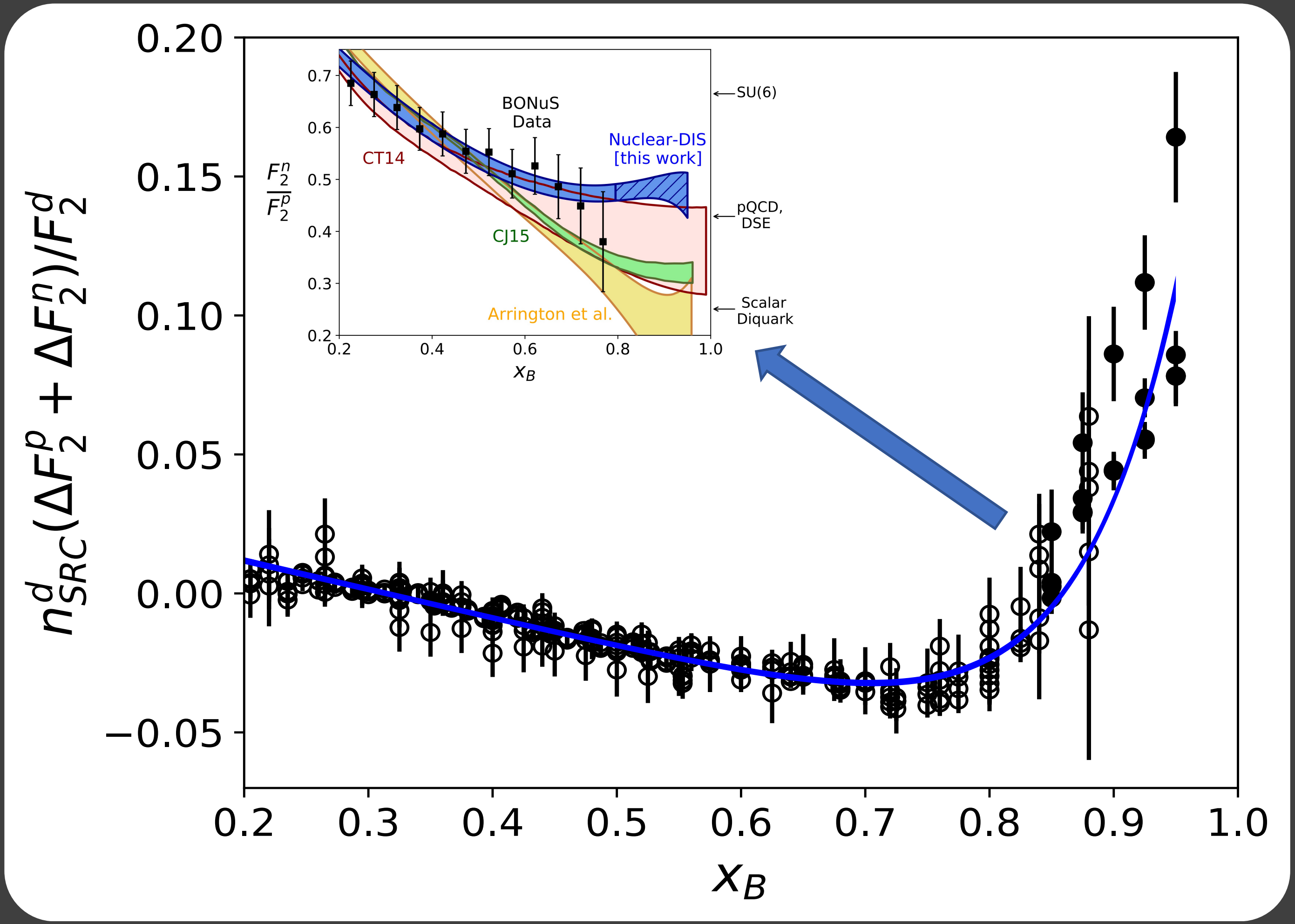


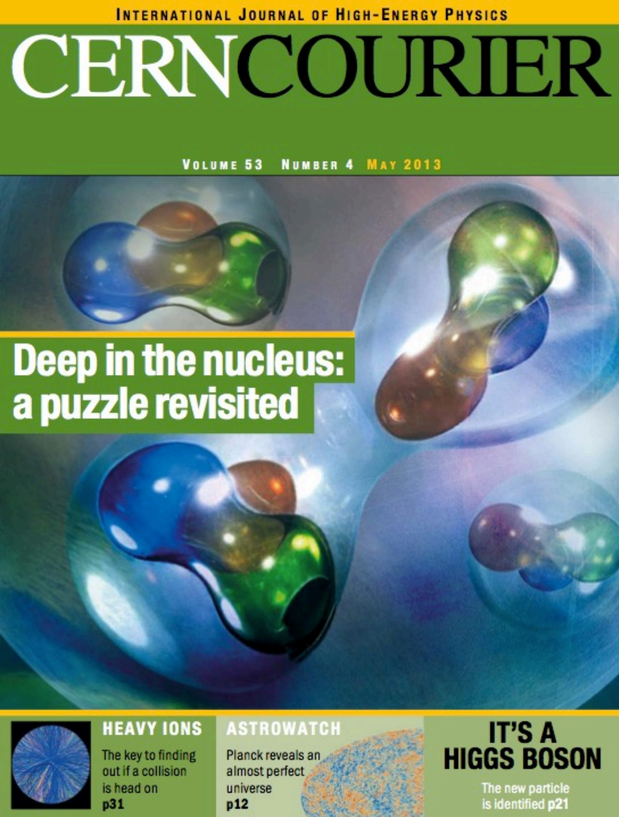
SRC Universality!

Schmookler et al., Nature (2019)

Universal Modification



Schmookler et al., Nature (2019)
E.P. Segarra et al., PRL (2020)



052301 (2011) PHYSICAL REVIEW LETTERS wee 4 FEBR

Short Range Correlations and the EMC Effect

L. B. Weinstein,[1,*] E. Piasetzky,[2] D. W. Higinbotham,[3] J. Gomez,[3] O. Hen,[2] and R. Shneor[2]

PHYSICAL REVIEW LETTERS **124,** 092002 (2020)

Neutron Valence Structure from Nuclear Deep Inelastic Scattering

E. P. Segarra,[1] A. Schmidt,[1,2] T. Kutz,[1,2] D. W. Higinbotham,[3] E. Piasetzky,[4] M. Strikman,[5] L. B. Weinstein,[6] and O. Hen[1,*]

PHYSICAL REVIEW C **85,** 047301 (2012)

strengthen the connection between short range correlations and the EMC

O. Hen,[1] E. Piasetzky,[1] and L. B. Weinstein[2]

NUCLEAR PHYSICS A

PHYSICAL REVIEW D **84,** 117501 (2011)

Constraints on the large-x d/u ratio from electron-nucleus scattering at $x > 1$

O. Hen,[1] A. Accardi,[2,3] W. Melnitchouk,[3] and E. Piasetzky[1]

Short range correlations and the EMC effect

etzky[a], L.B. Weinstein[b], D.W. Higinbotham[c], J. Gomez[c], O. Hen[a]

International Journal of Modern Physics E
Vol. 22, No. 7 (2013) 1330017 (30 pages)

THE EMC EFFECT AND HIG NUCLEONS IN NU

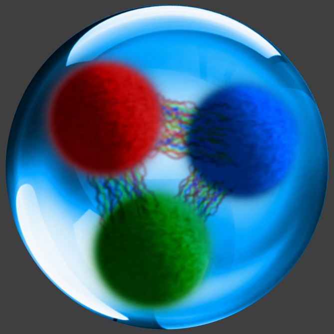
O. Hen, D.W. Higinbotham, G.A. Miller, Piasetzky

REVIEWS OF MODERN PHYSICS, VOLUME 89, OCTOBER–DECEMBER

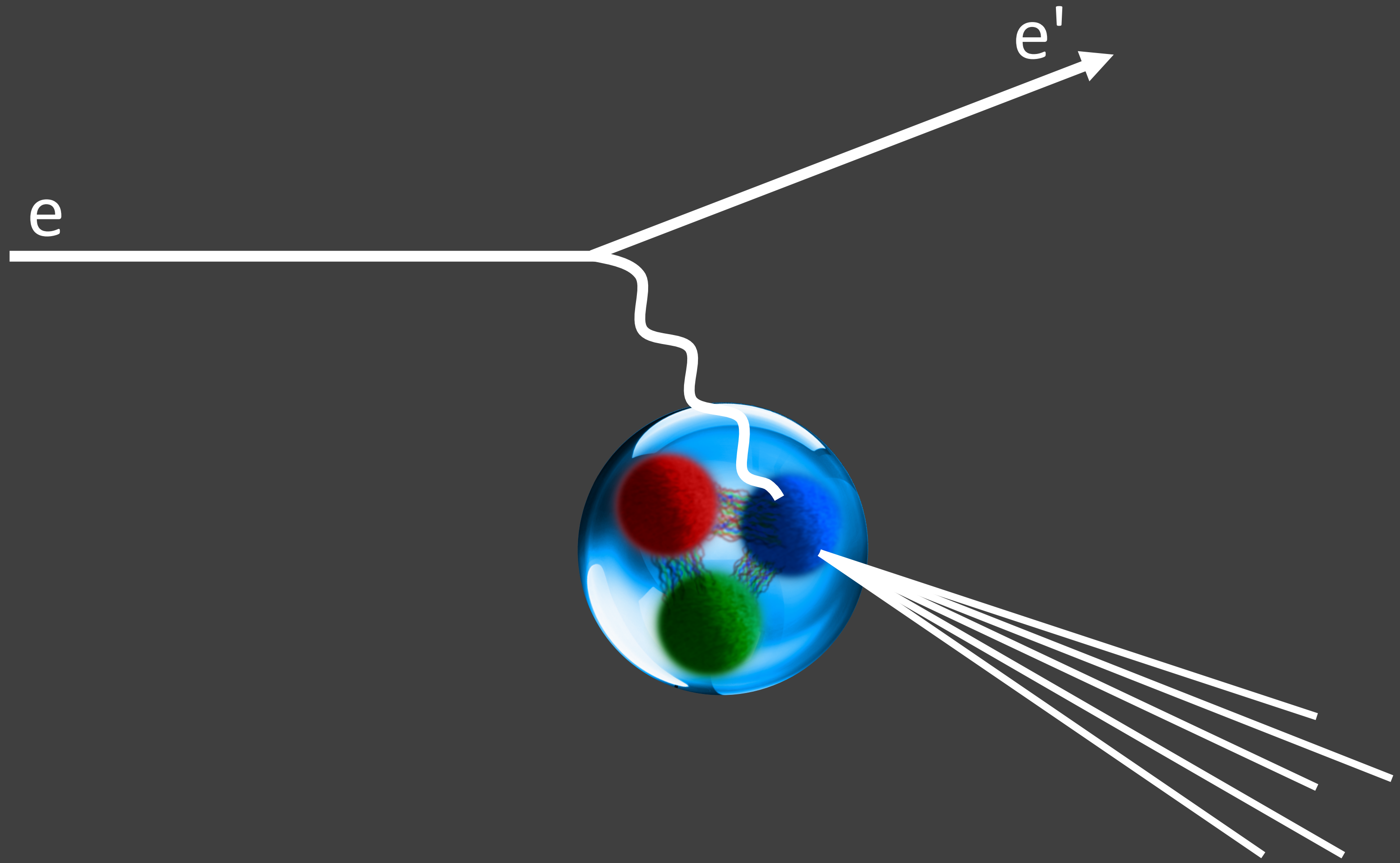
Nucleon-nucleon correlations, short-lived excitations, and the quarks within

Or Hen Gerald A. Miller Eli Piasetzky Lawrence B. Weinstein

SRC quark-gluon structure



SRC quark-gluon structure



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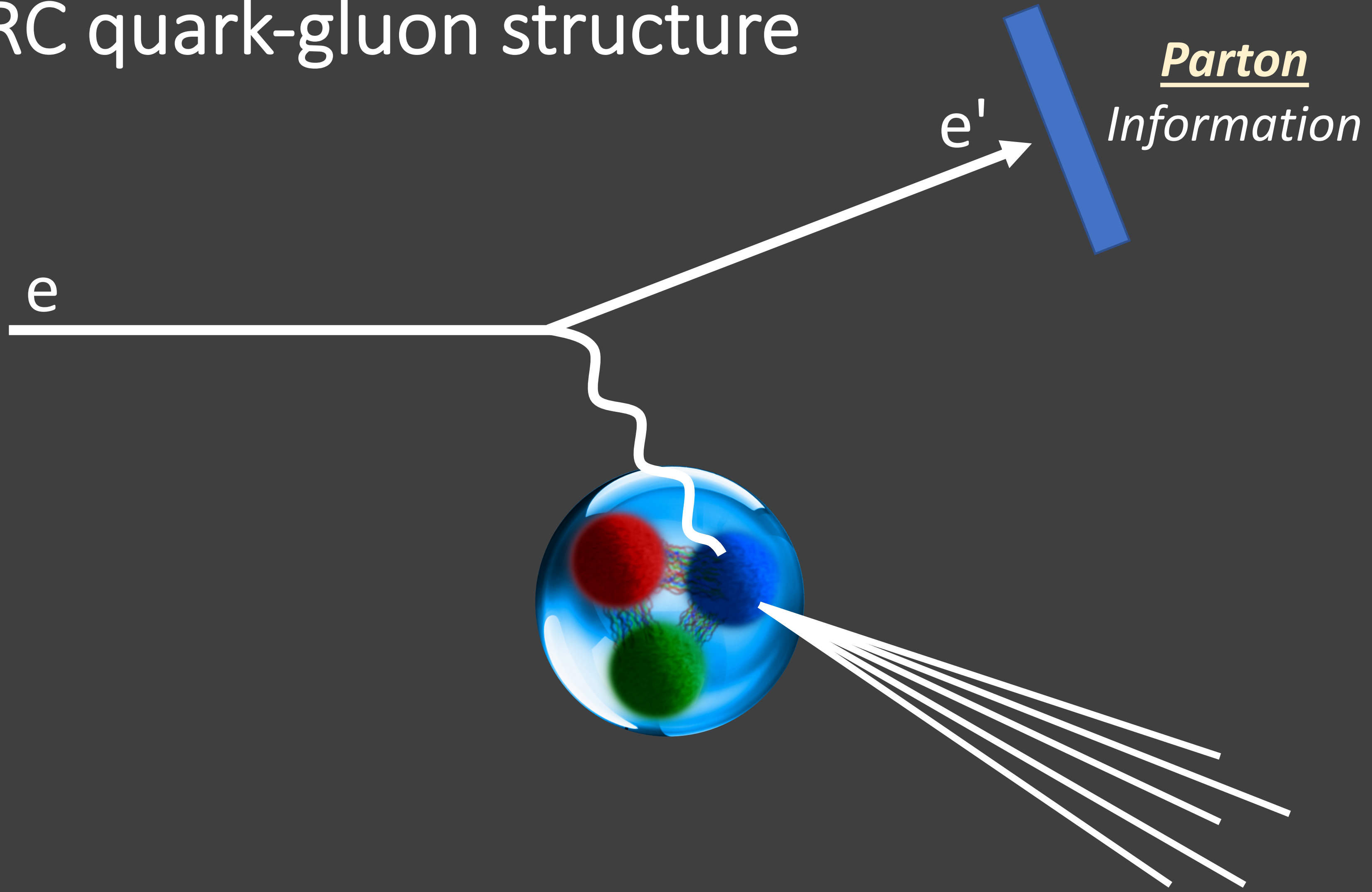

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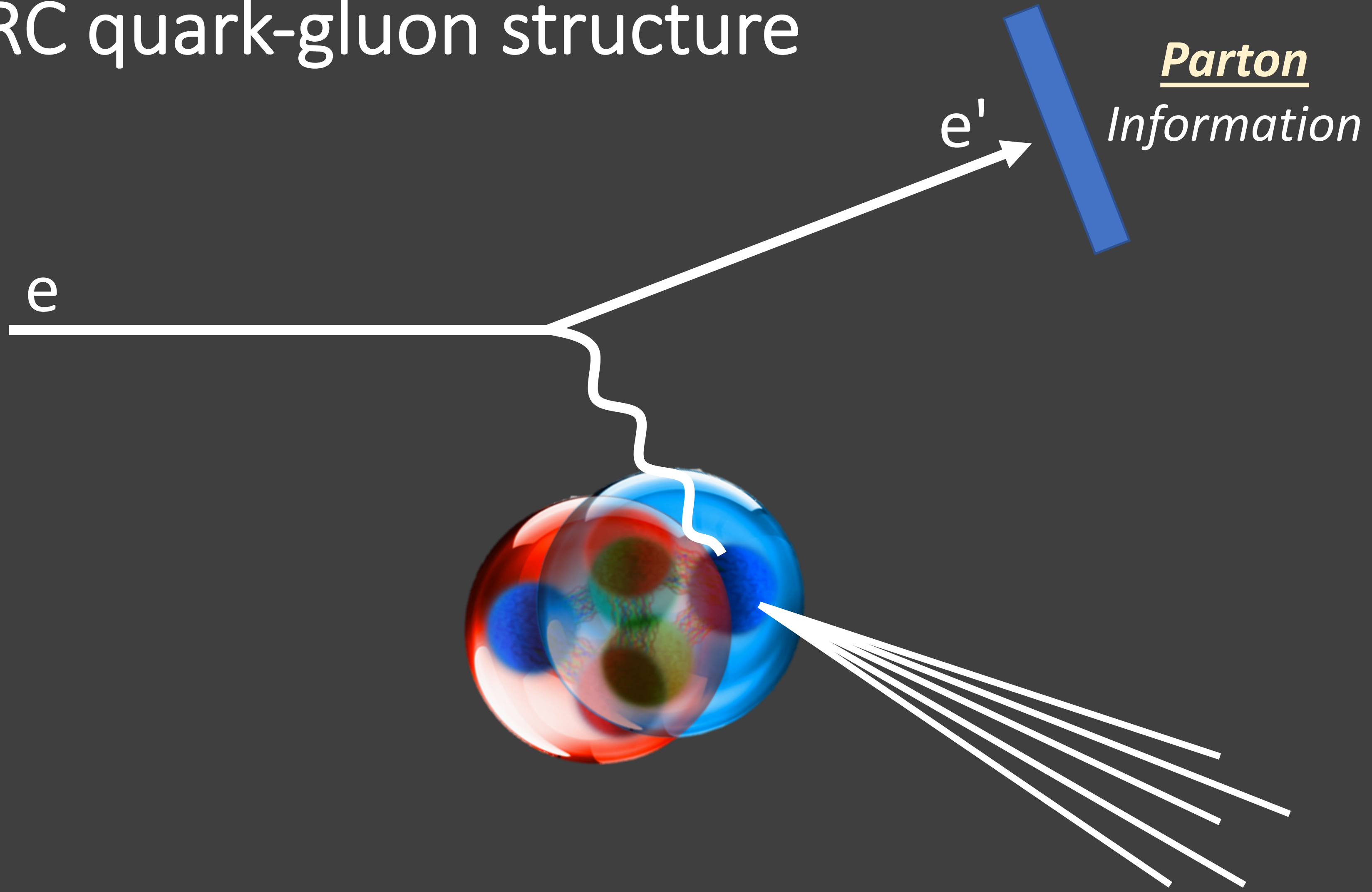

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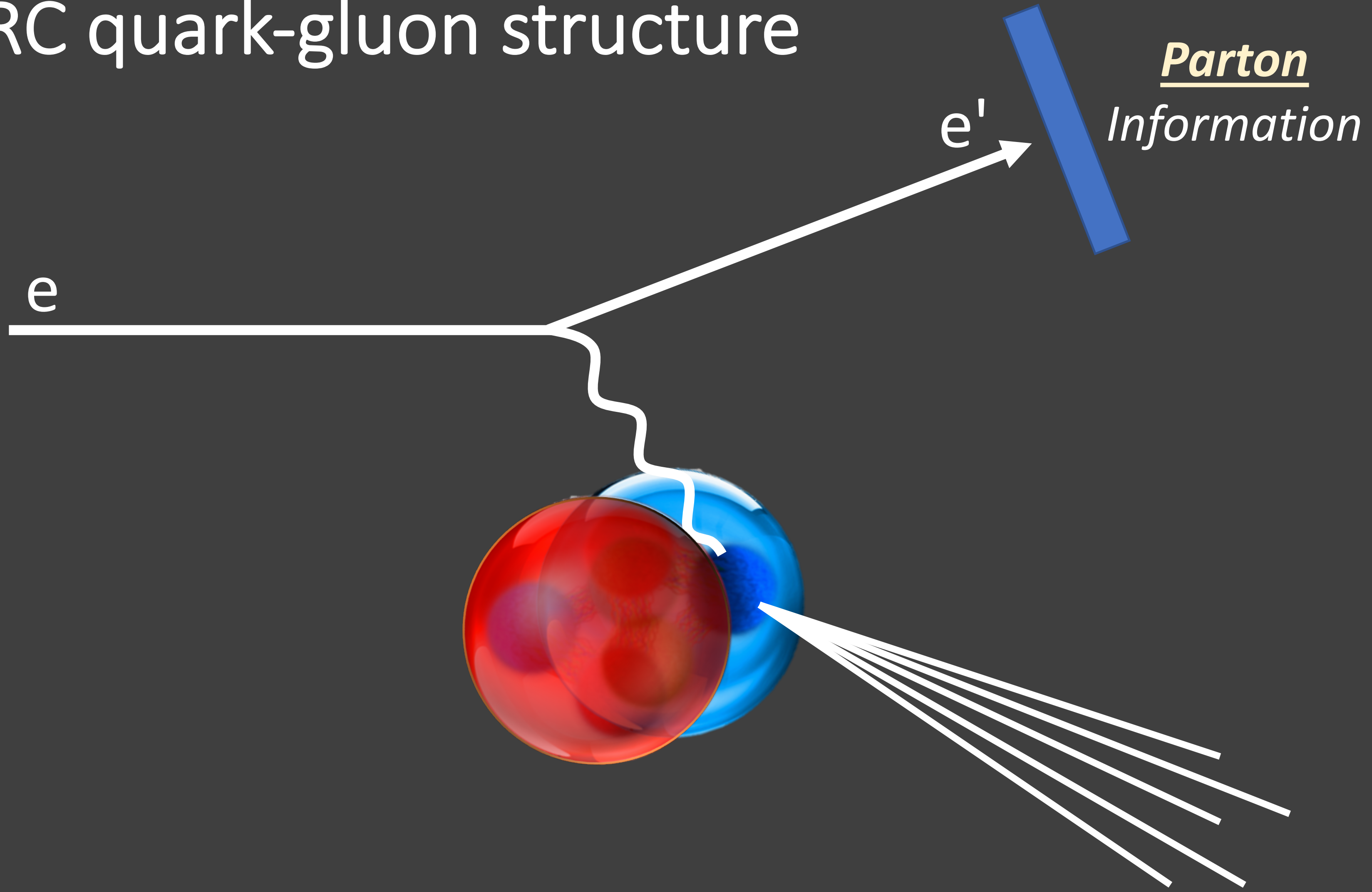

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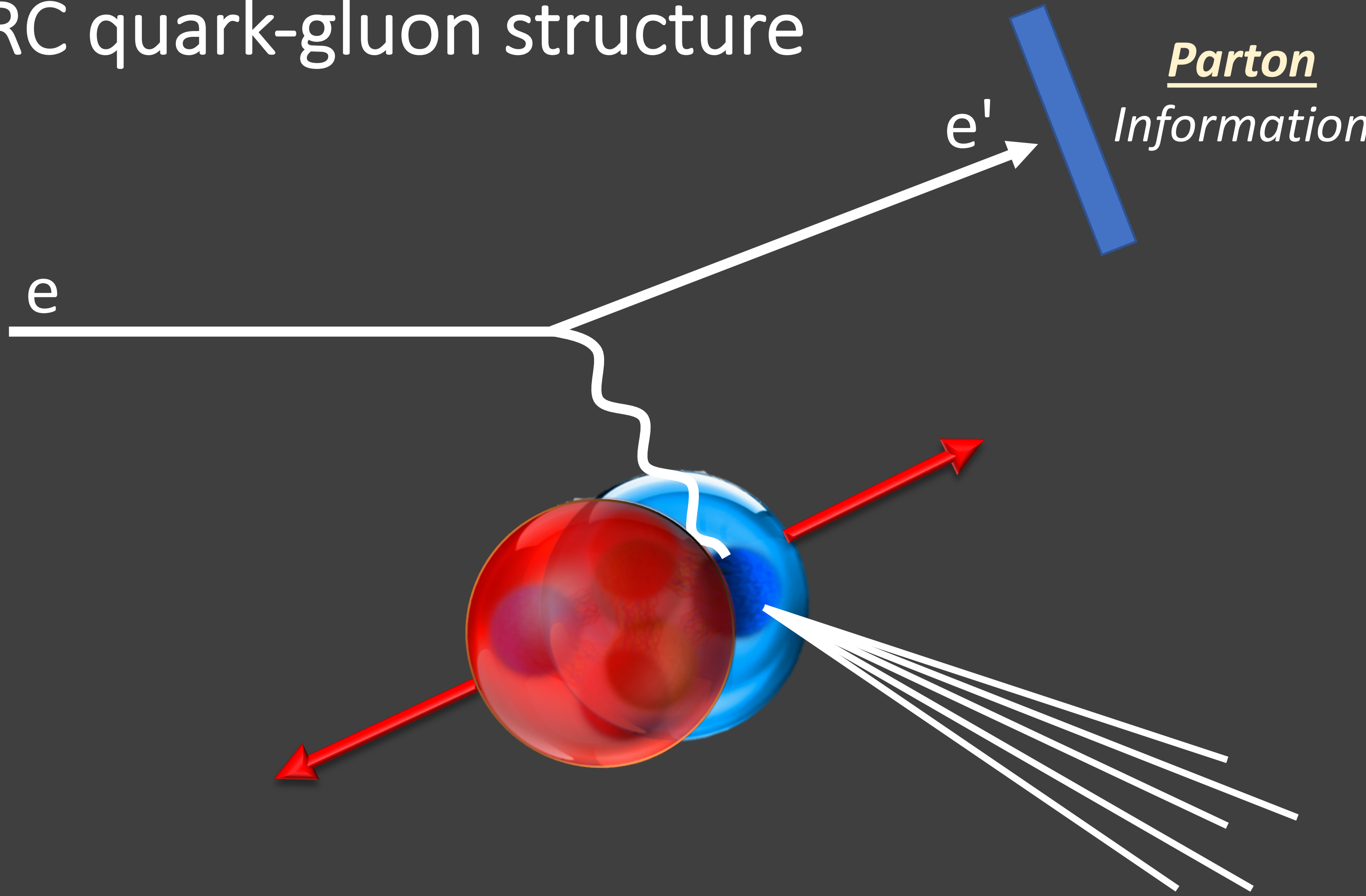

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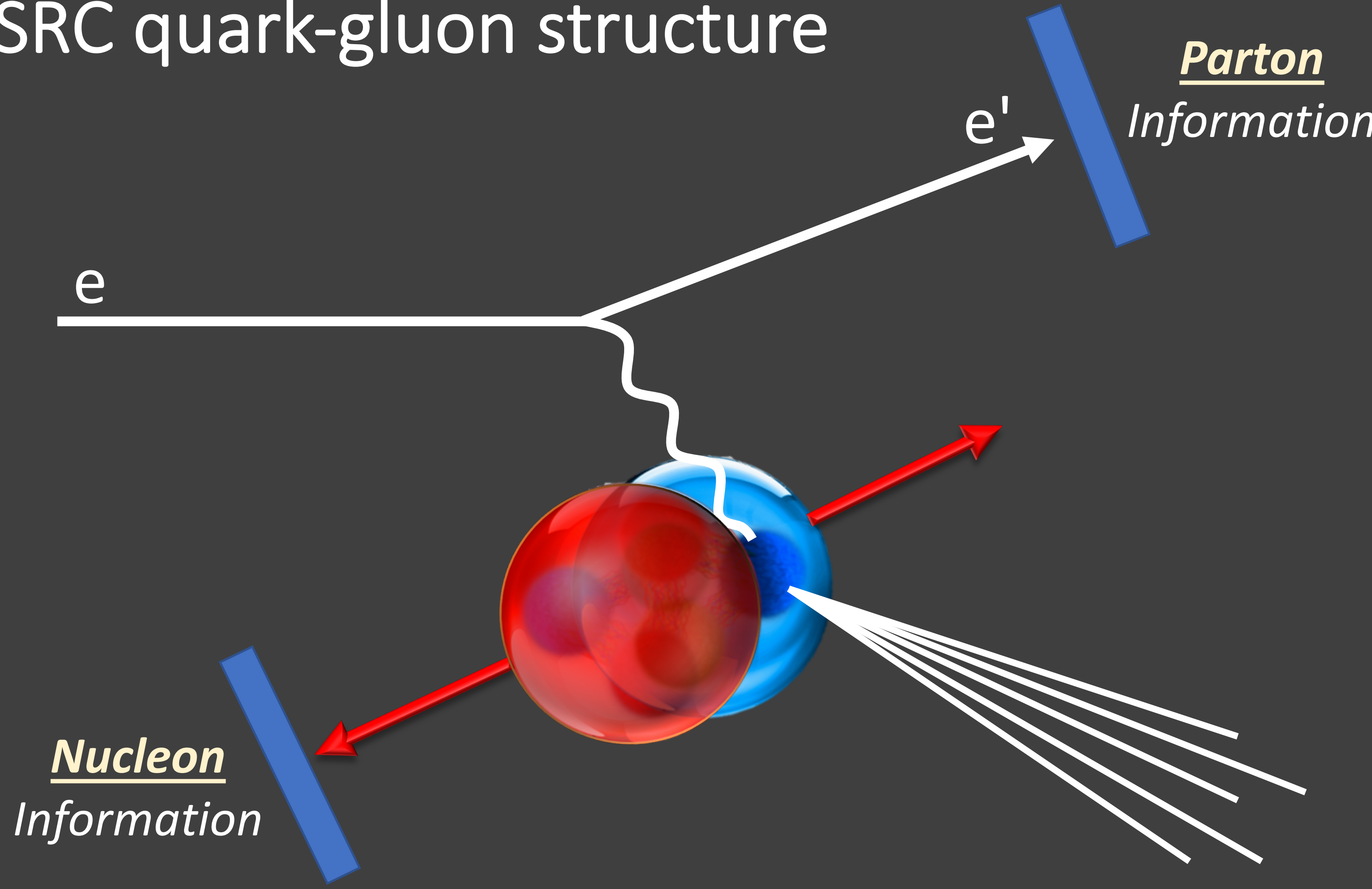

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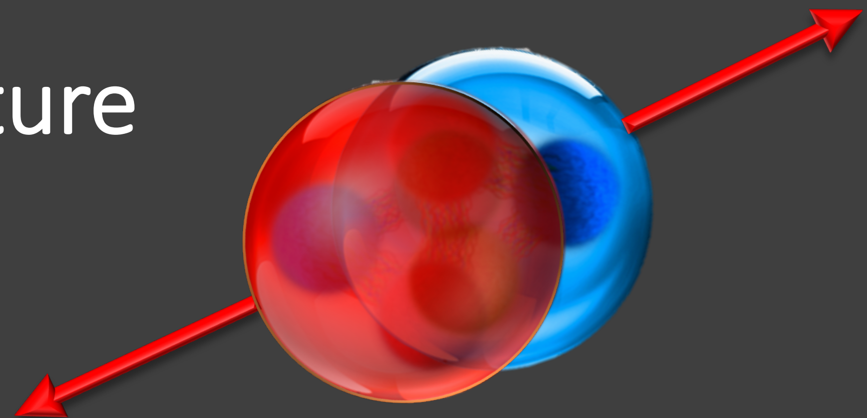
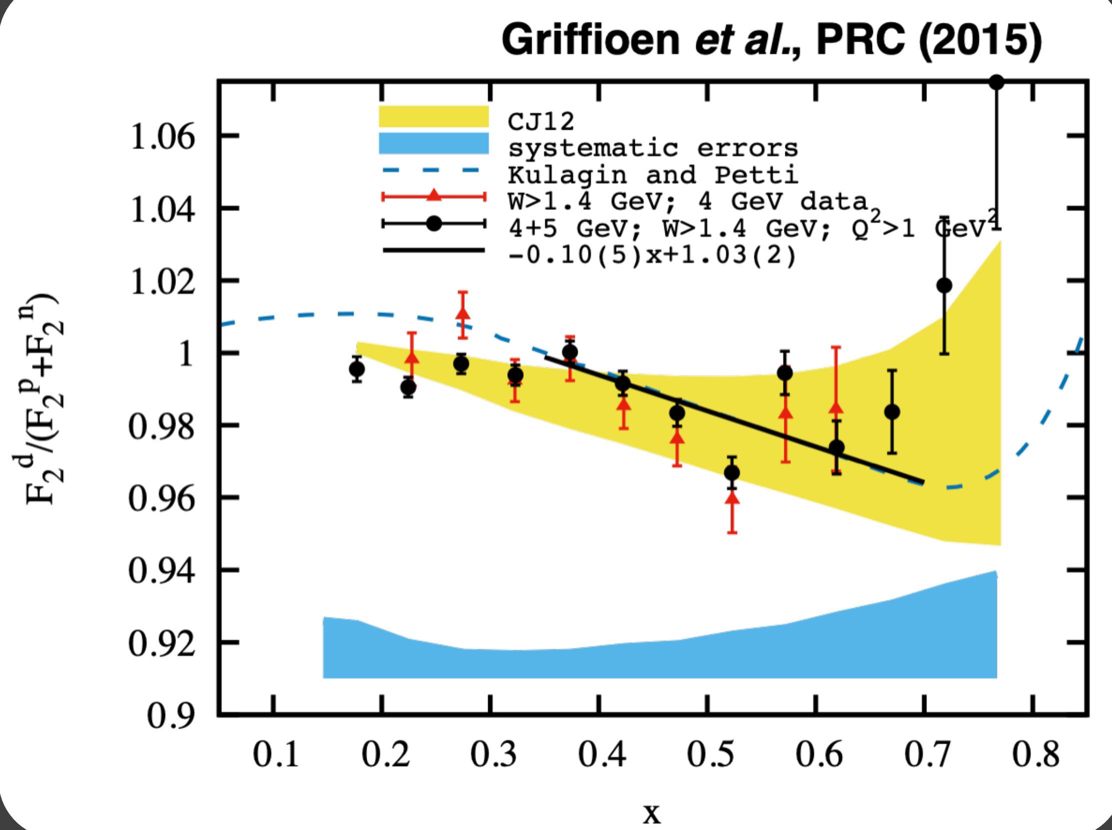
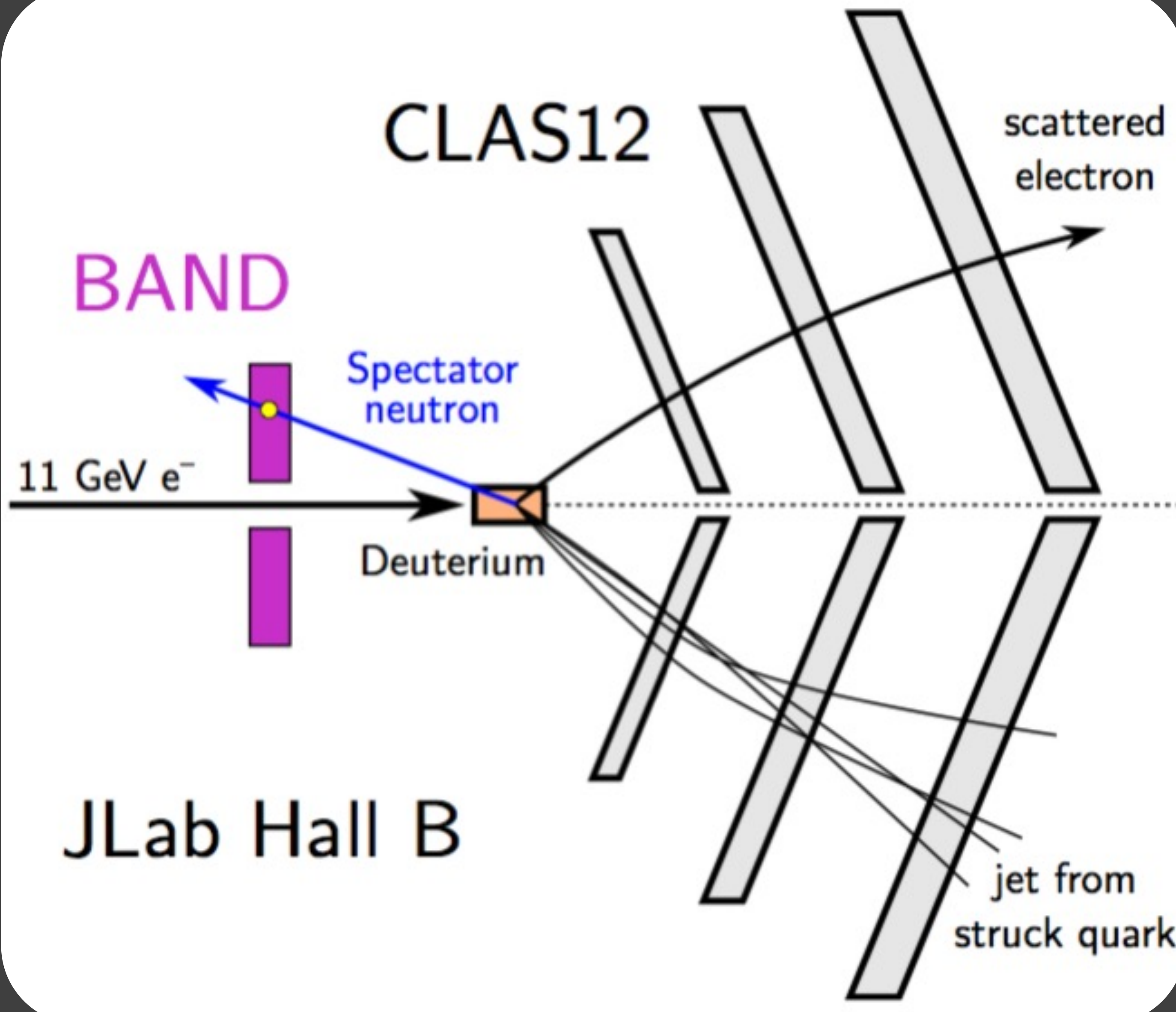


Deuteron:

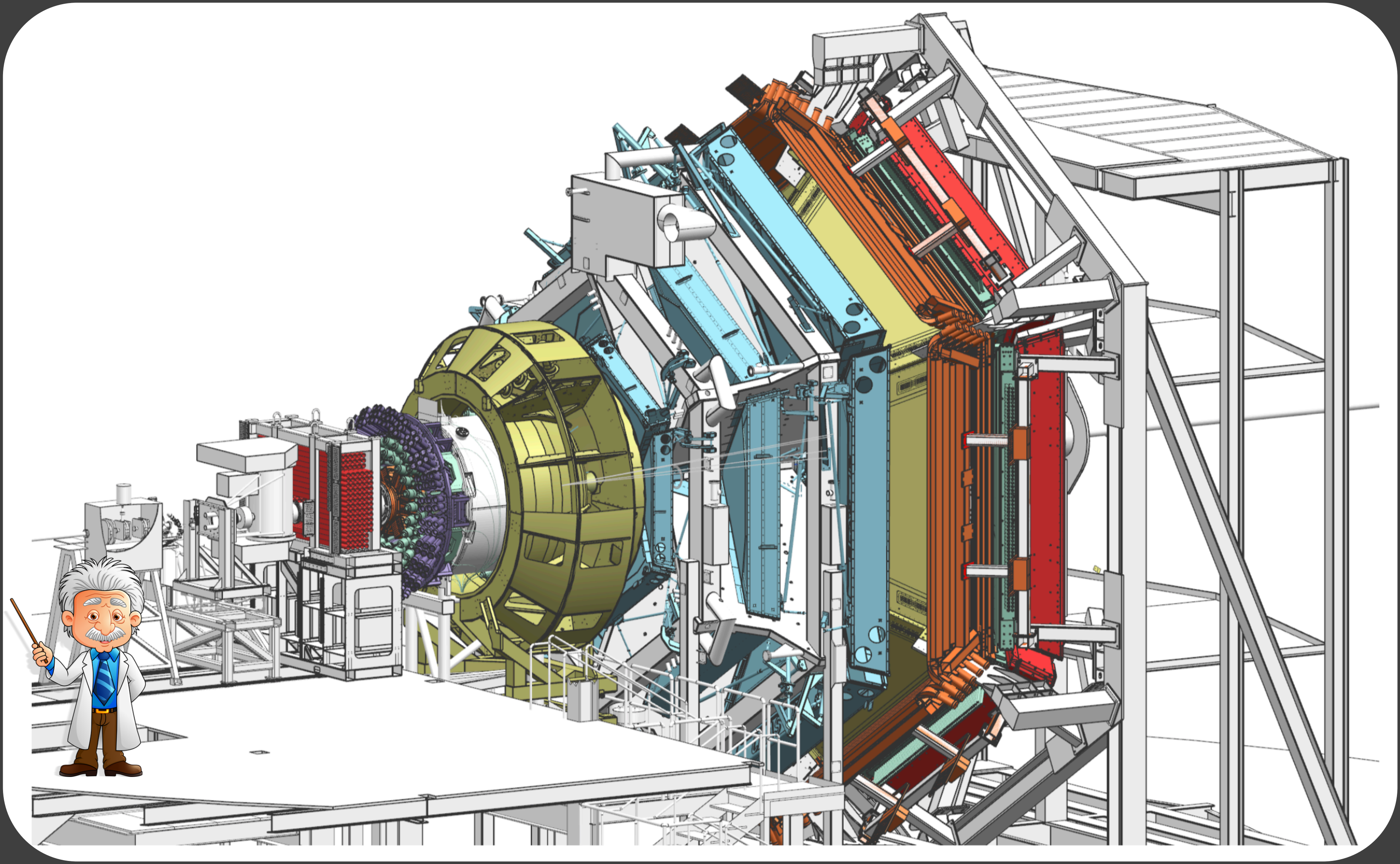
- Small EMC Effect
- Small SRC fraction

→ Still expect large modification for SRC nucleons




CLAS12
scattered
electron
BAND
Spectator
neutron
11 GeV e⁻
Deuterium
JLab Hall B
jet from
struck quark

CLAS12 + BAND



Massachusetts Institute of Technology

UNIVERSIDAD TECNICA FEDERICO SANTA MARIA

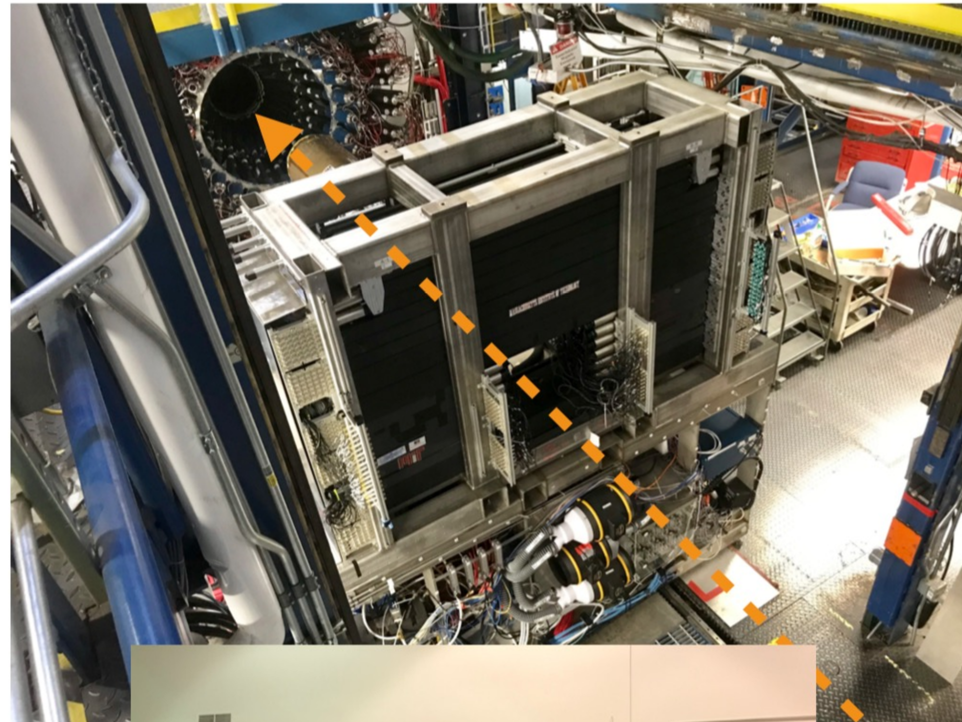
OLD DOMINION UNIVERSITY

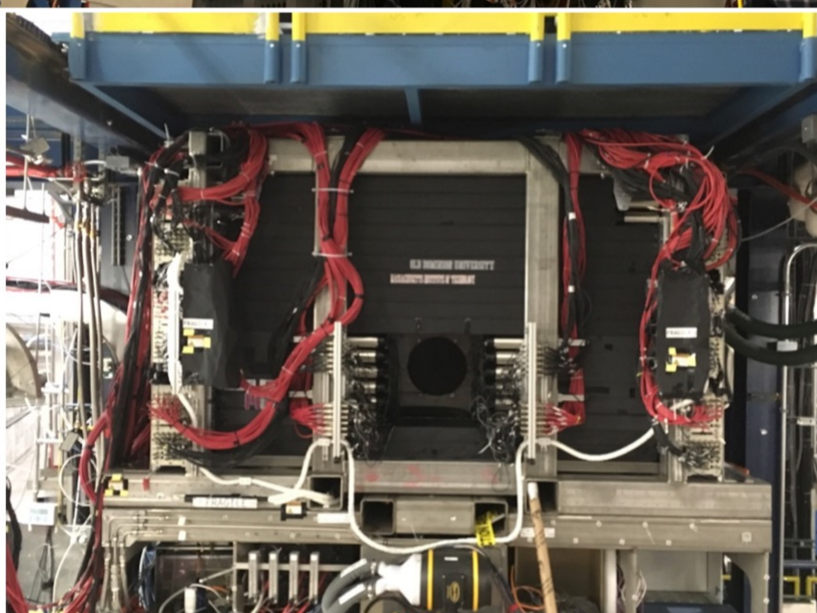
TEL AVIV UNIVERSITY

FLORIDA STATE UNIVERSITY 1851


Harvard-Yale
Drive Challenge 2007
American Red Cross
GREEN SPOT
1-14B

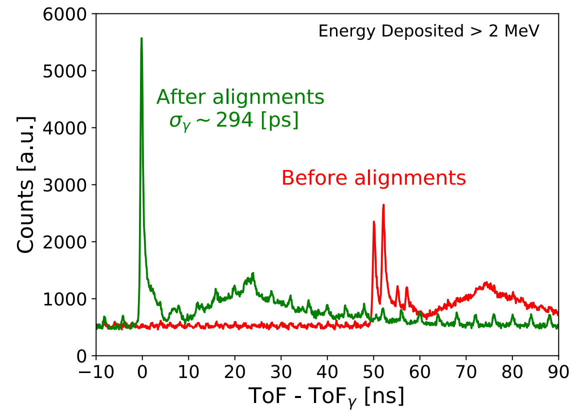
BAND @ JLab Hall B



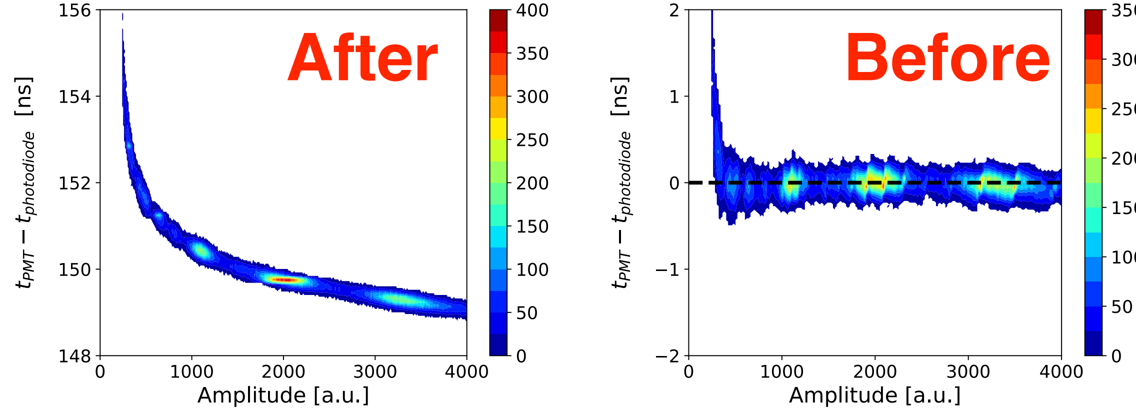


BAND calibrations

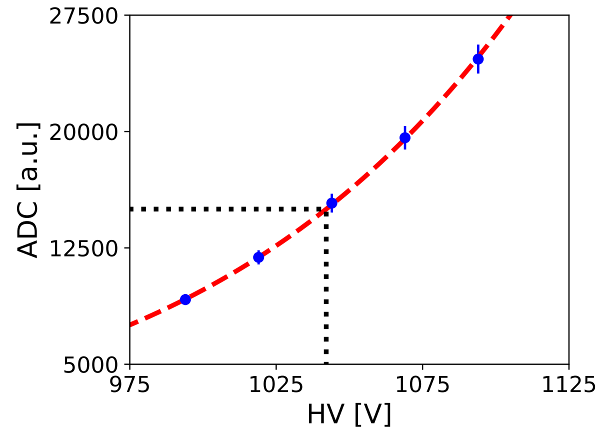
- ✓ Gamma peak alignment



- ✓ Left-right offsets
- ✓ Timewalk correction

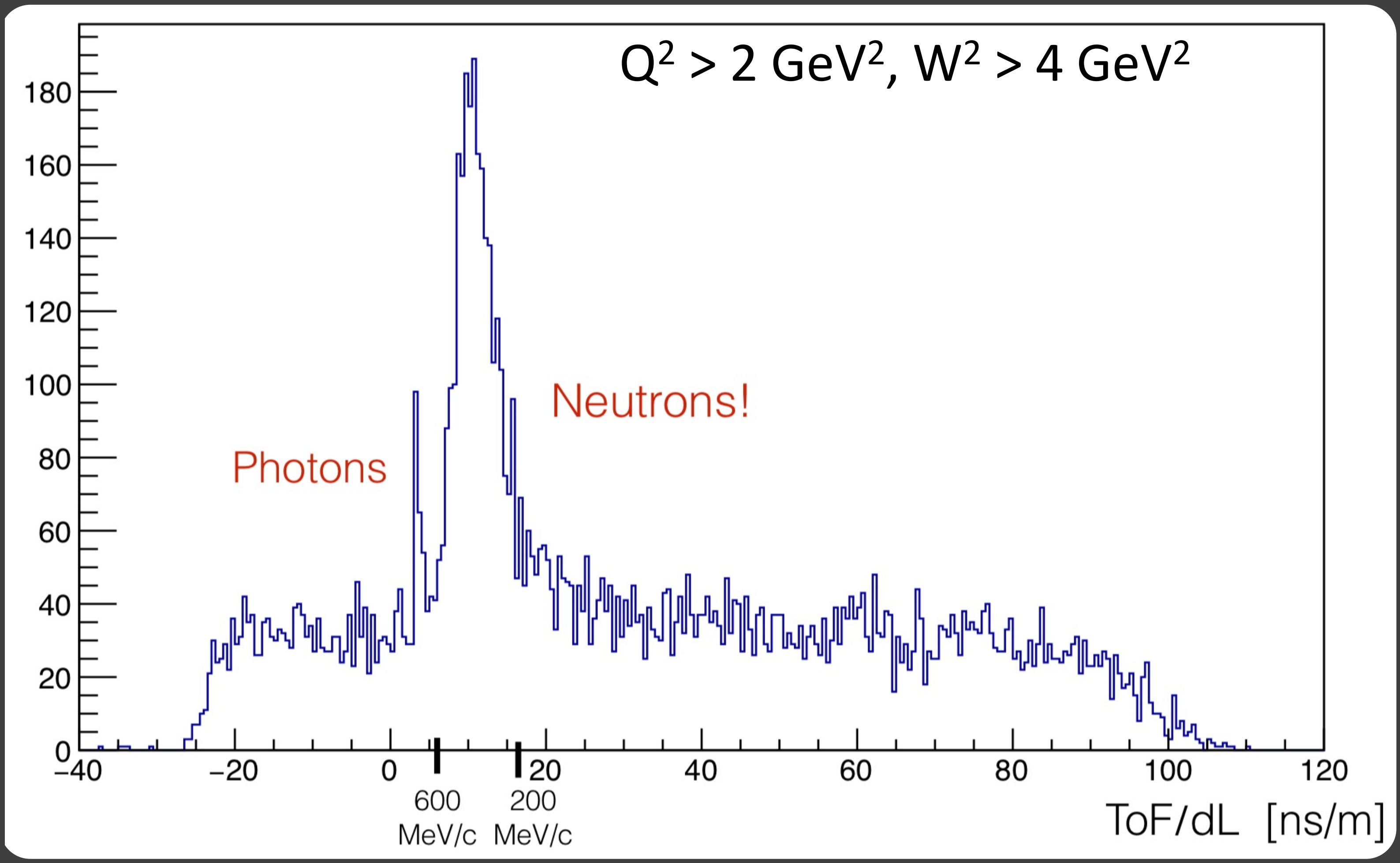


- ✓ Absolute energy from cosmic rays
- ✓ HV gain matching

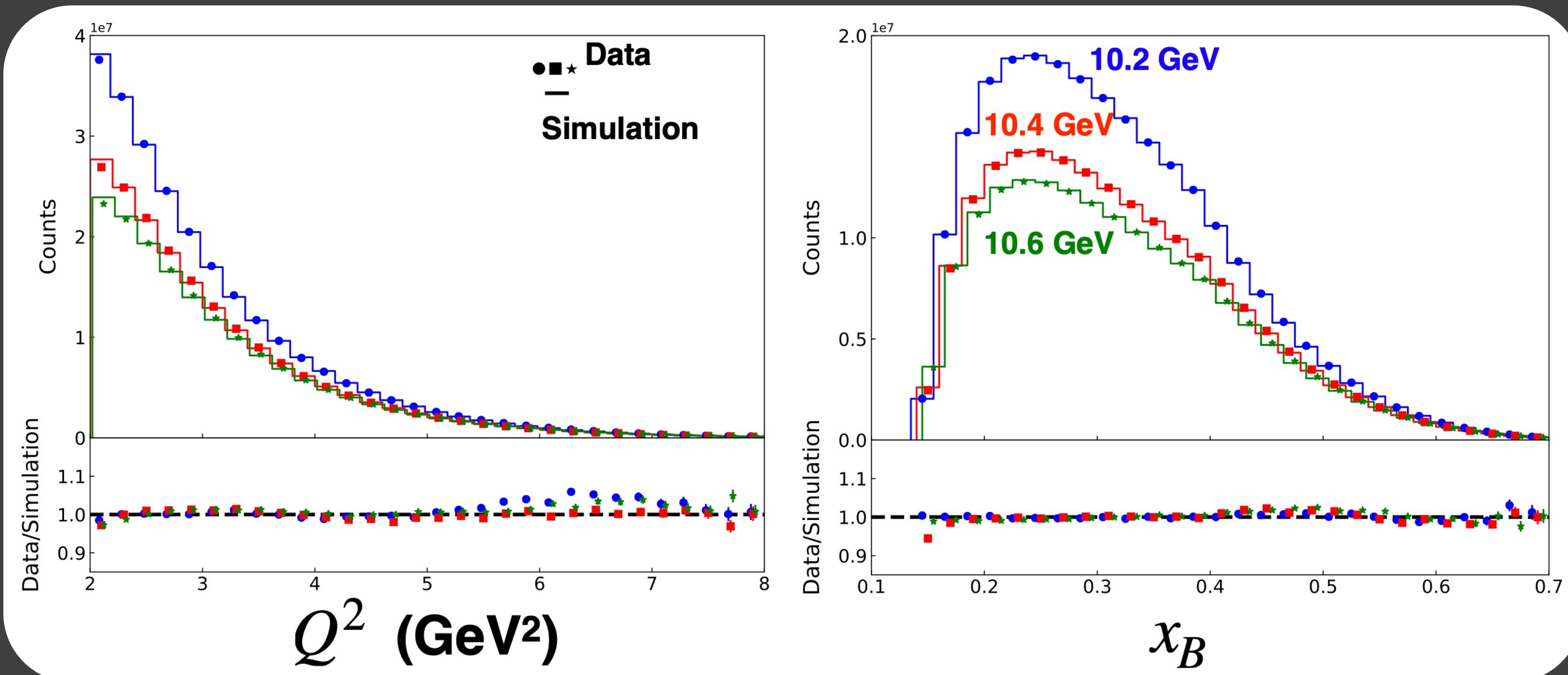


X

CLAS12+BAND: DIS \w Tagged Neutrons



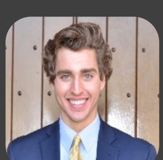
Inclusive DIS d(e,e’)X



$Q^2 > 2$ GeV^2

$W^2 > 4$ GeV^2

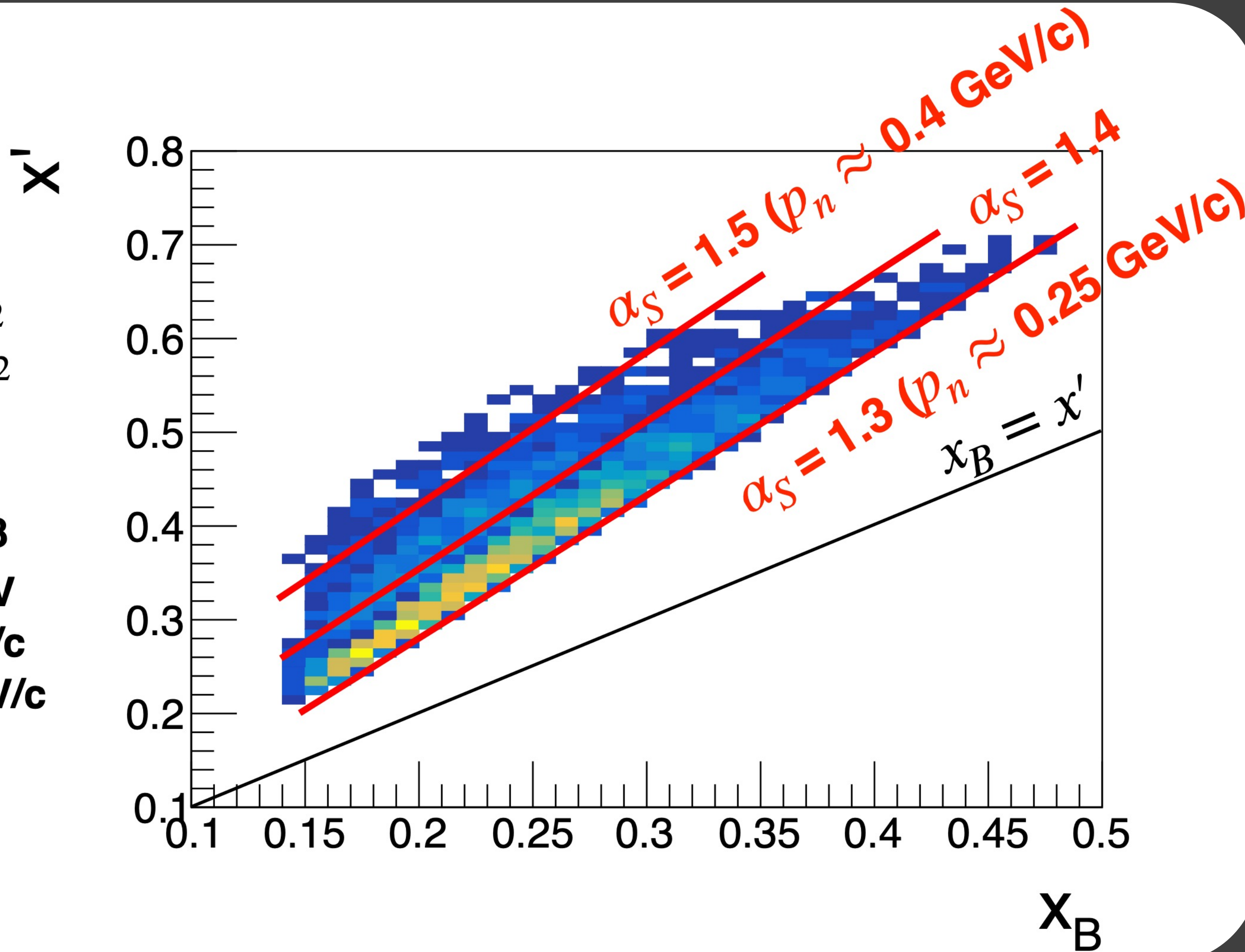
$y < 0.7$



Tagged DIS d(e,e'n)X

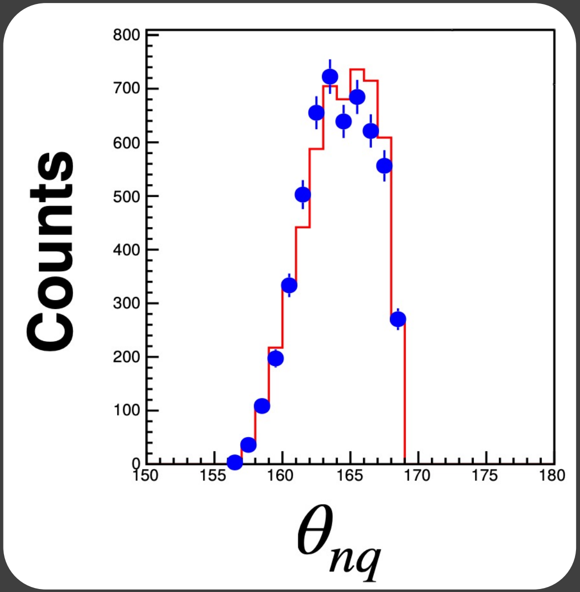
$Q^2 >$ **2 GeV**^{2}
$W^2 >$ **4 GeV**^{2}
$y <$ **0.7**

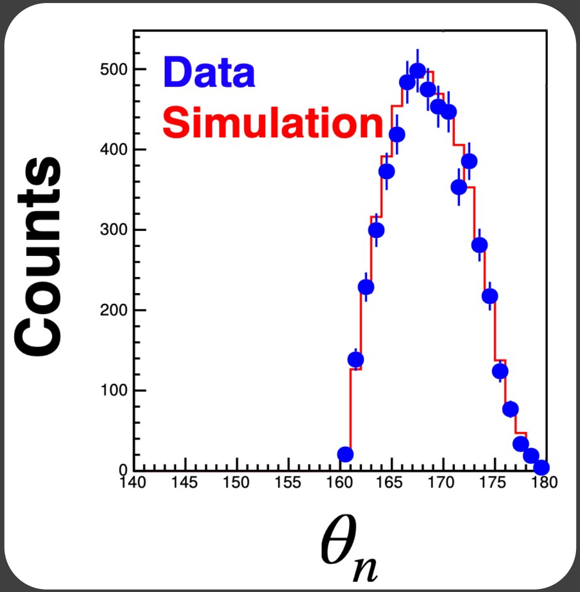
cos θ_{nq} **< -0.8**
$W' >$ **1.8 GeV**
p_T **< 0.1 GeV/c**
p_n **> 0.25 GeV/c**

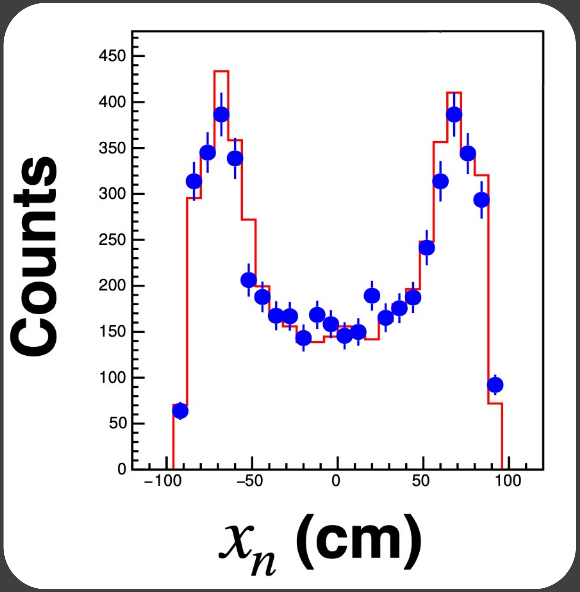


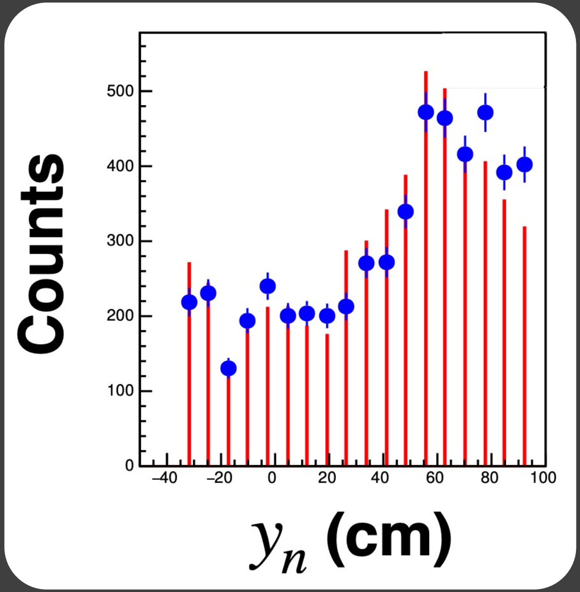


Tagged DIS d(e,e’n)X

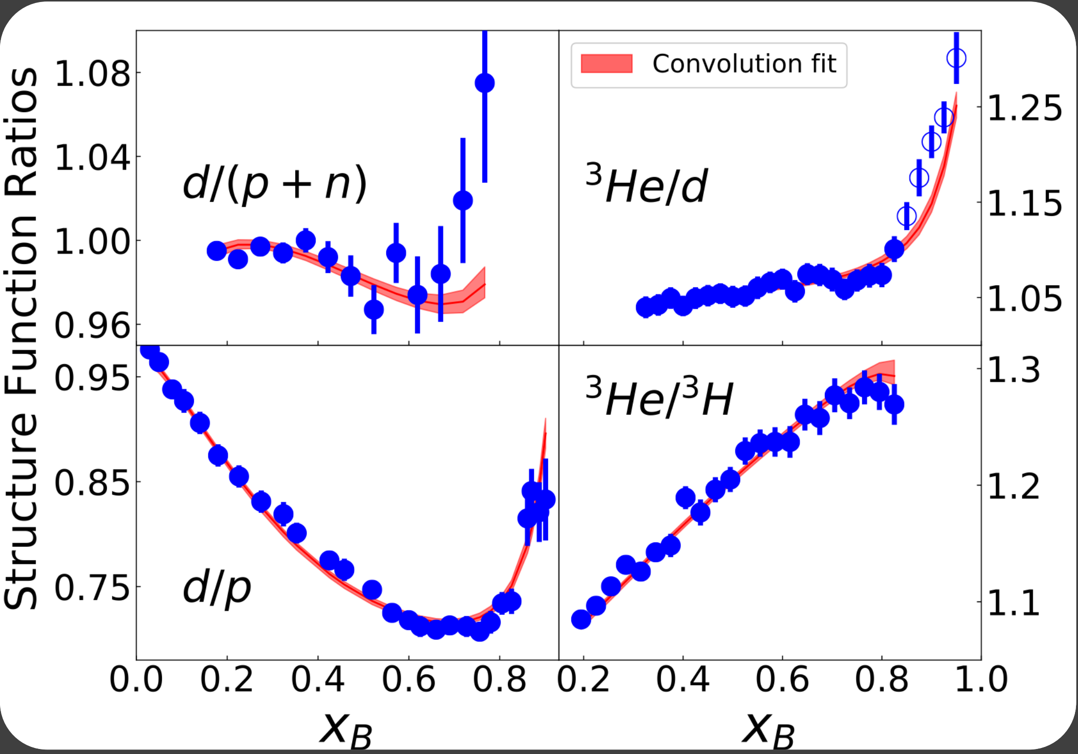


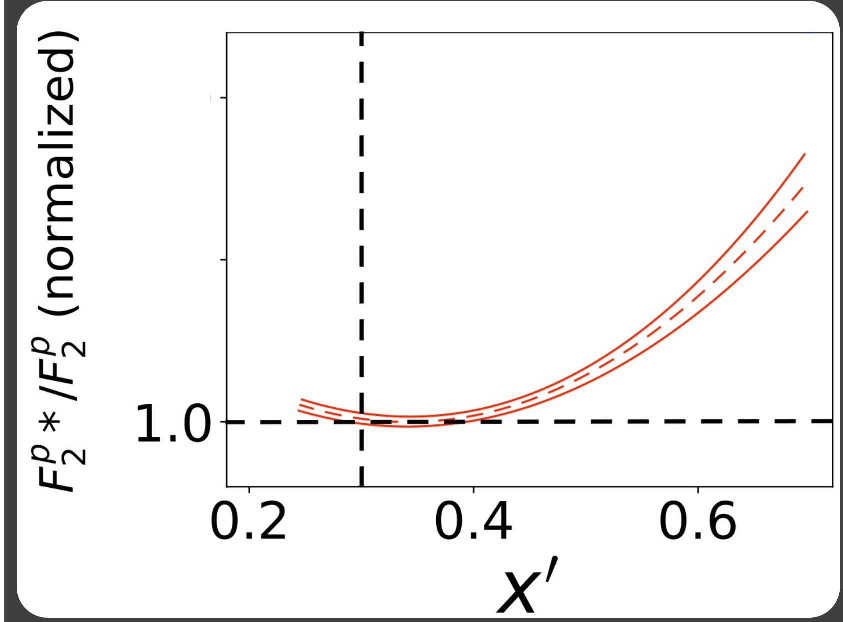




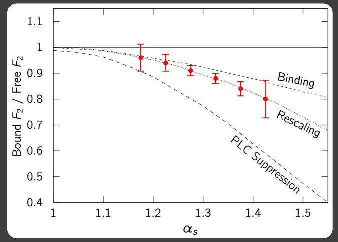


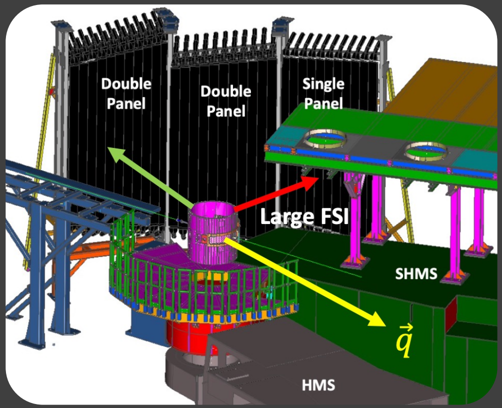
Initial prospect for explaining EMC (few-body systems)

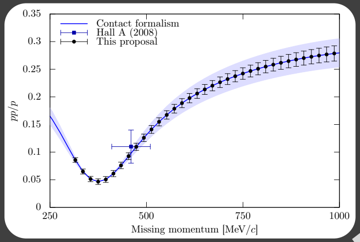




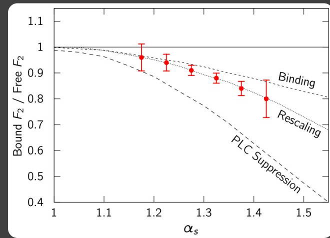
Phys. Rev. Research 3, 023240 (2021)

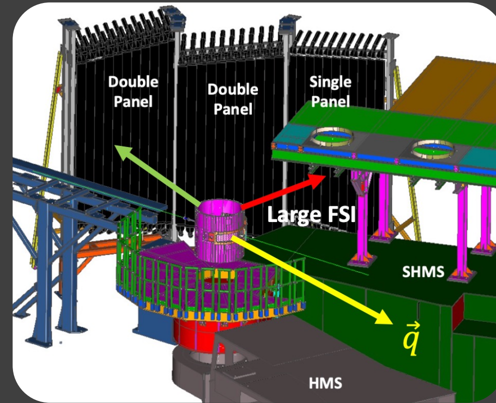

Bound F2 / Free F2
Binding
Rescaling
PLC Suppression
αs

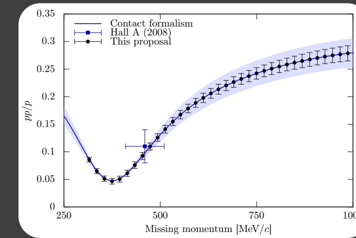

Double Panel
Double Panel
Single Panel
Large FSI
SHMS
HMS
q


Contact formalism
Hall A (2008)
This proposal
Missing momentum [MeV/c]

JLab12

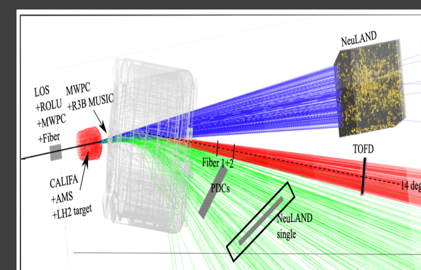


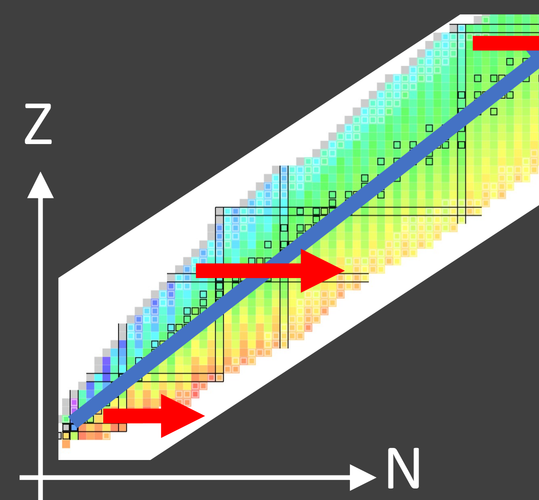


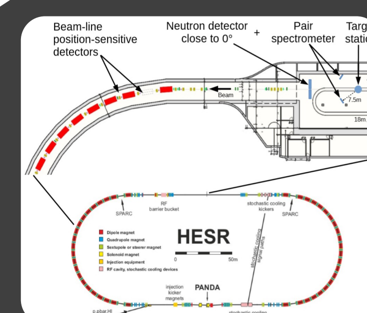


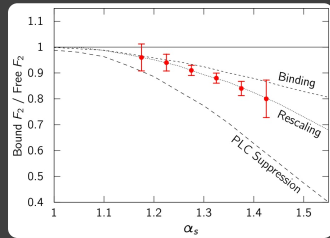
JLab12

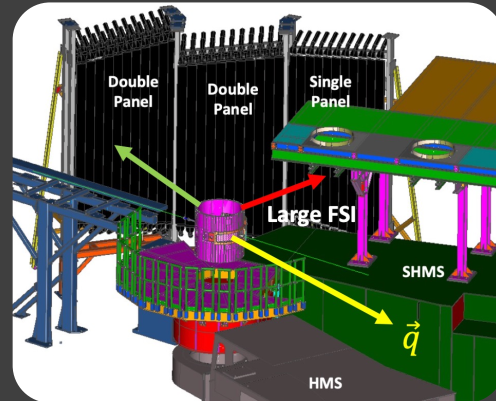
Radioactive-Ion Beams

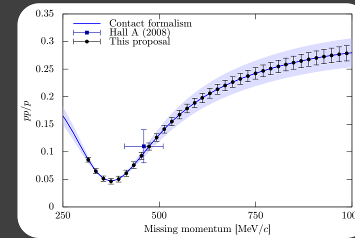








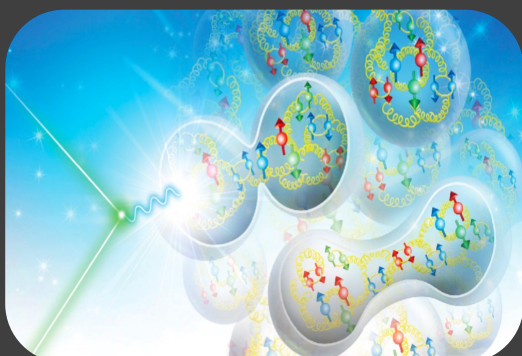


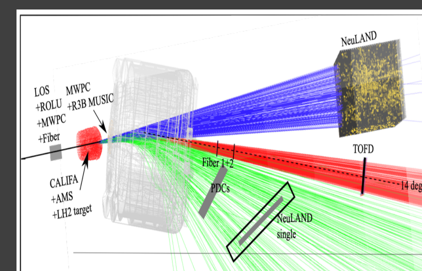


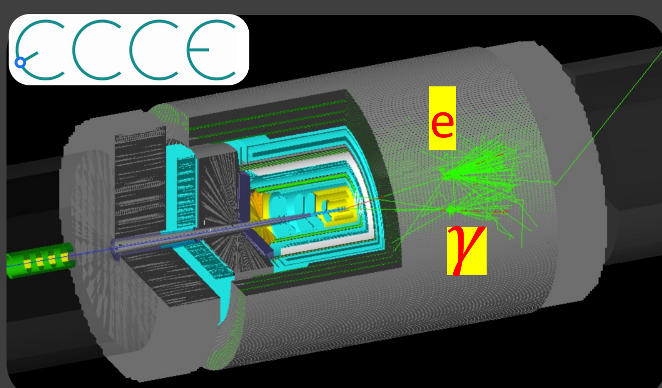
Electron-Ion Collider

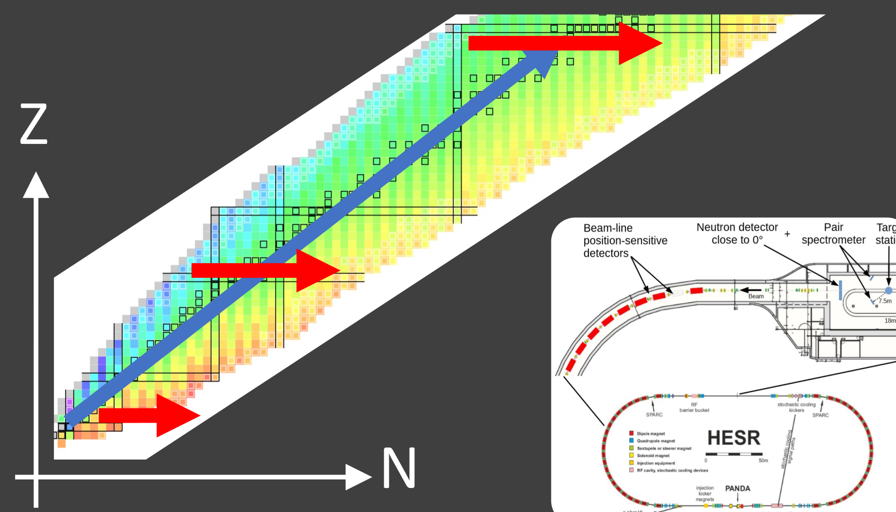
JLab12

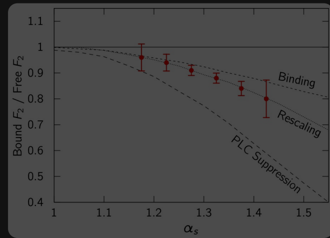
Radioactive-Ion Beams

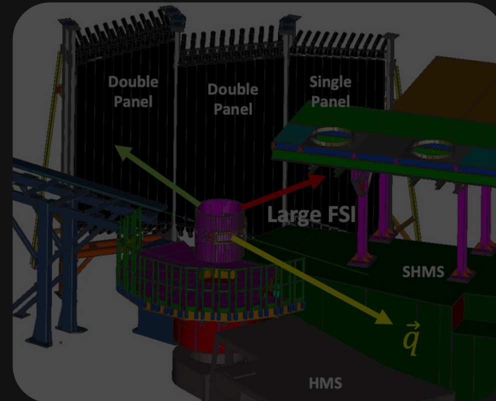


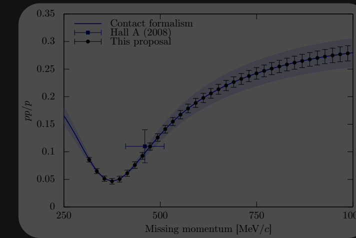








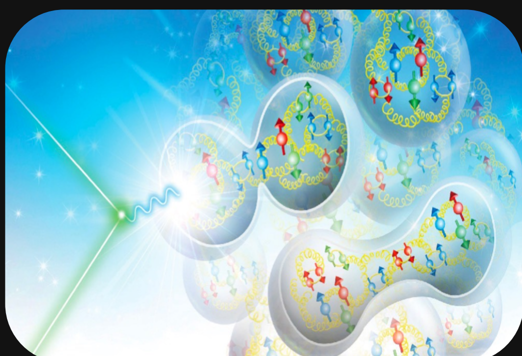


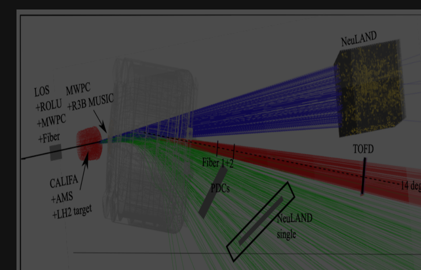


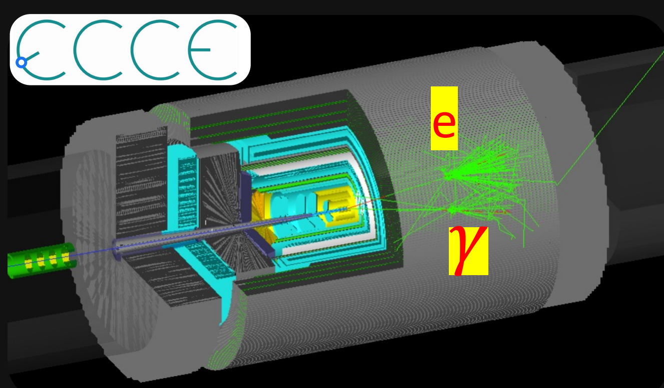
Electron-Ion Collider

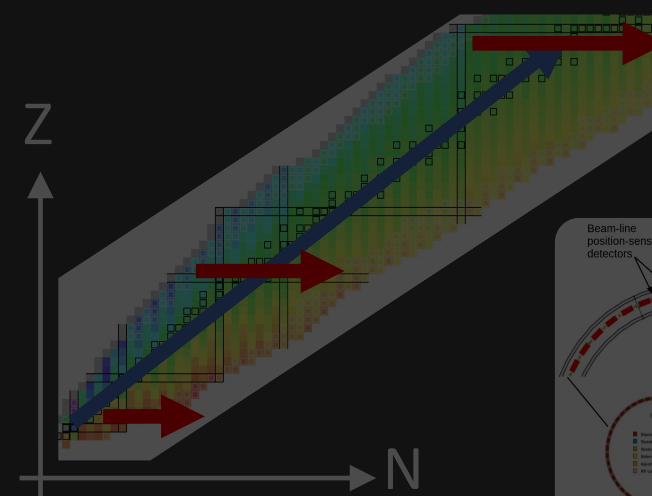
JLab12

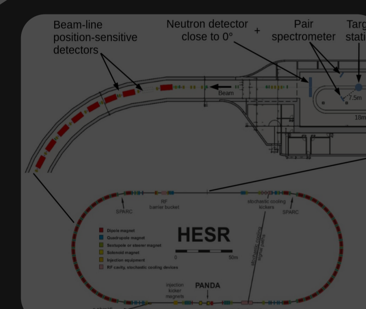
Radioactive-Ion Beams





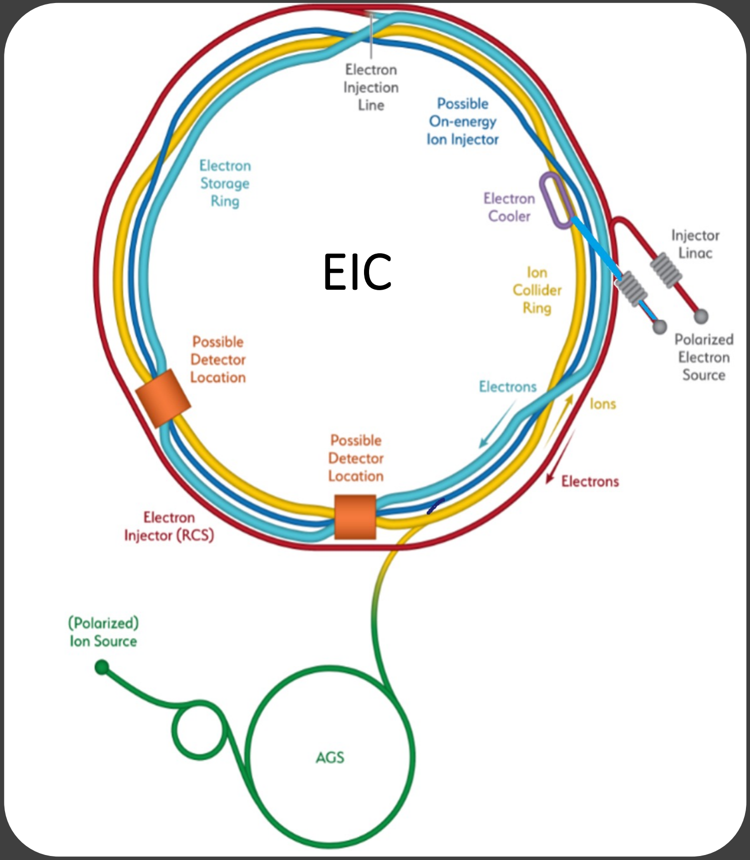






Electron-Ion Collider

- Brookhaven National Lab (\w JLab partnership)
- ~ $2 billion (passed CD-1)
- Explore structure of matter via QCD:
  - Origin of Hadron Mass & Spin
  - Confinement
  - Nucleon / Nuclear Femtography
  - Dense Gluon States
  - BSM

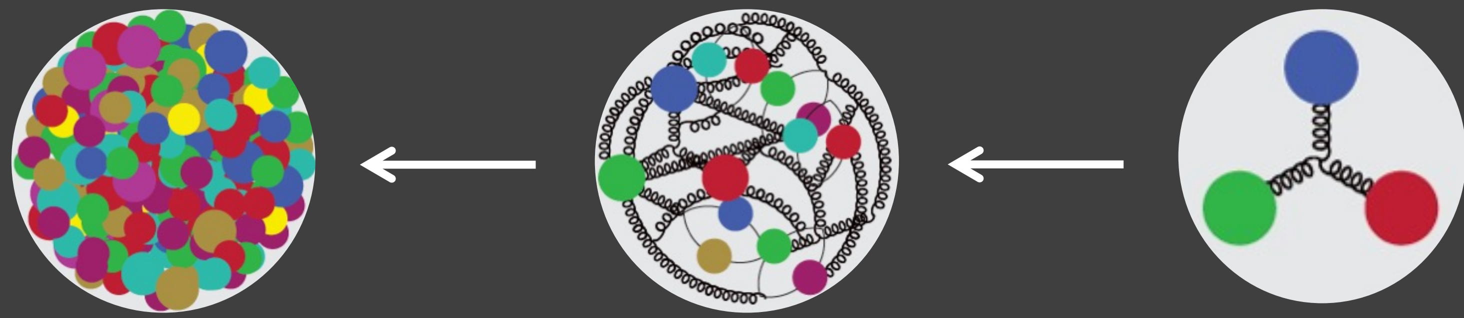


- Start Operations in 2030(ish)
- Detector proposal review

  Dec. ‘21 – March ‘22.
- Advanced design starts mid ‘22.
- Opportunity to get involved \w detectors design & construction

Imaging physical systems is key for gaining new understanding

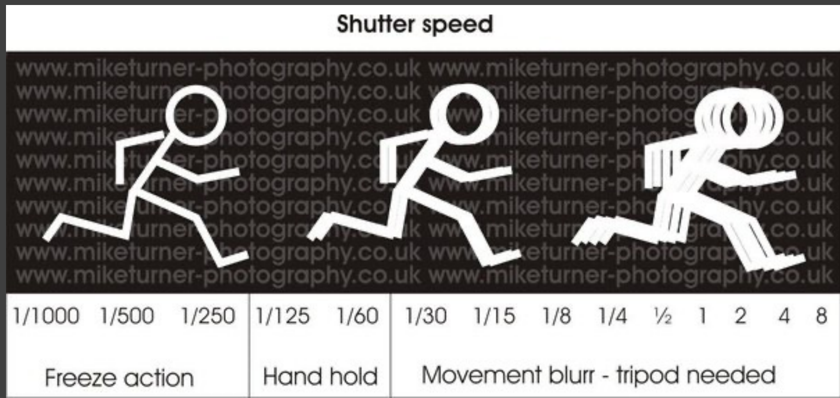
Snapshots where 0 < x < 1 is the shutter exposure time



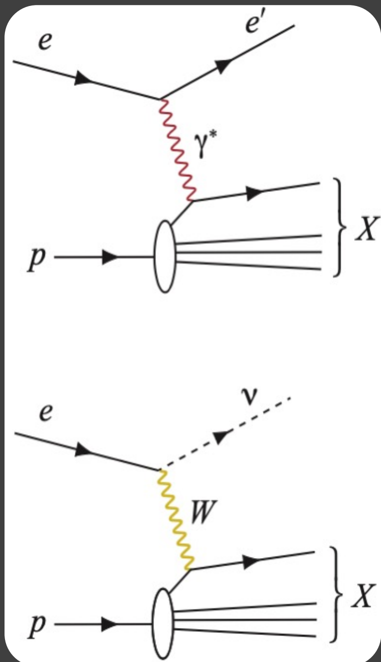
$x \approx 10^{-4}$
Probe non-linear dynamics
short exposure time

$x \approx 10^{-2}$
Probe rad. dominated
medium exposure time

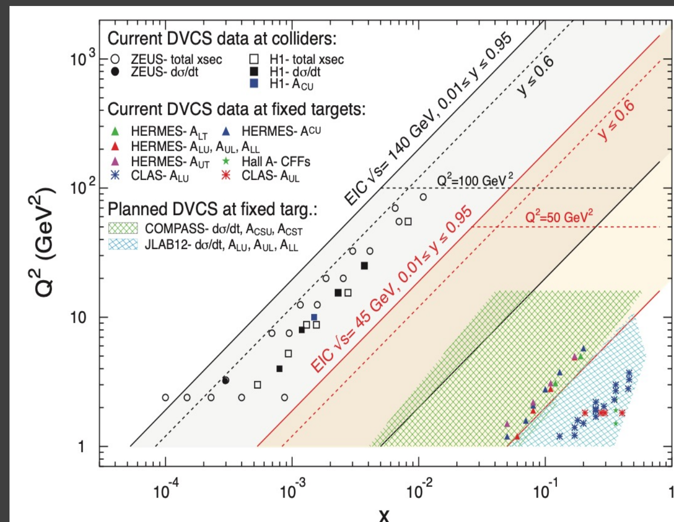
$x \approx 0.3$
Probe valence quarks
long exposure time



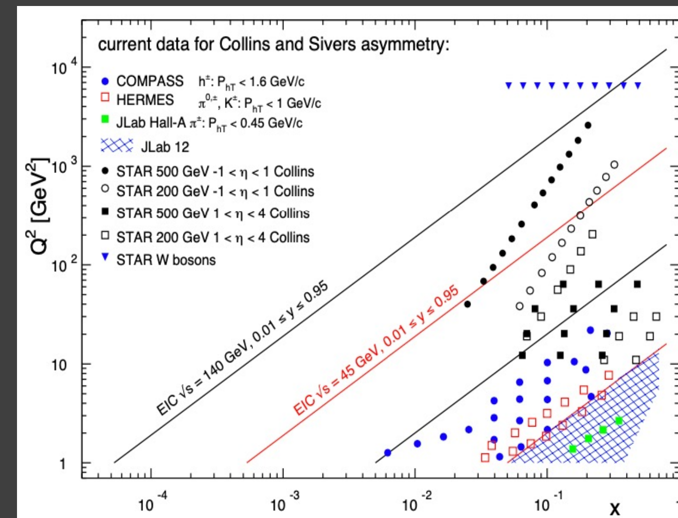
EIC is a versatile Machine



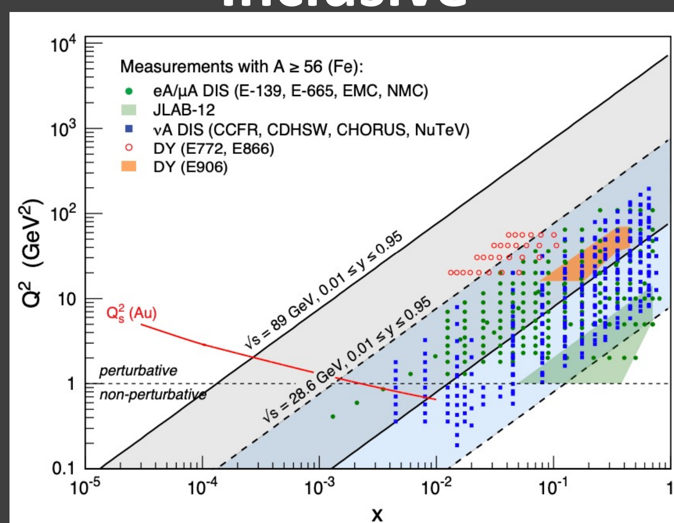
Exclusive



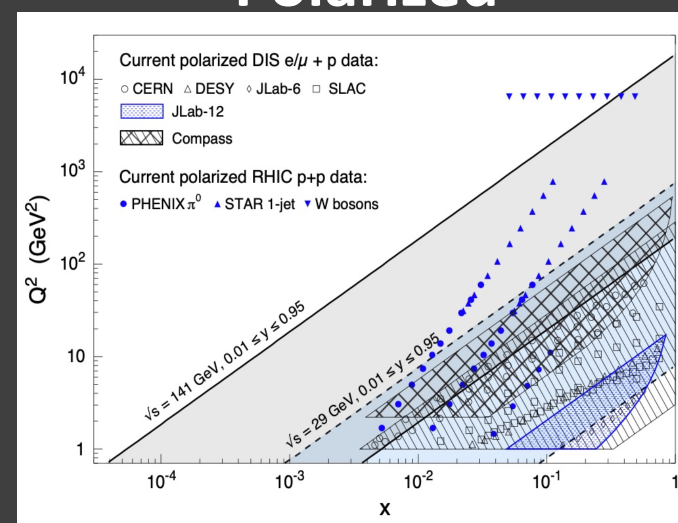
SIDIS

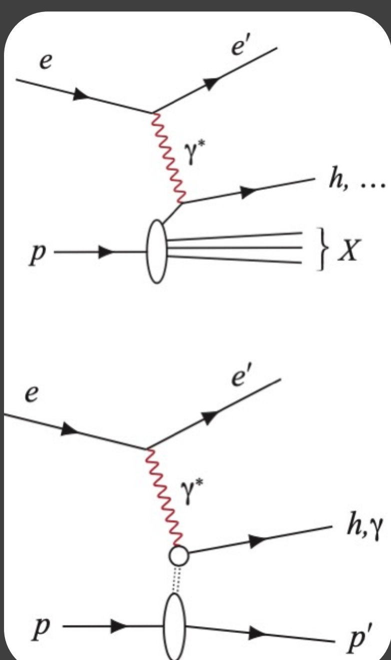


Inclusive

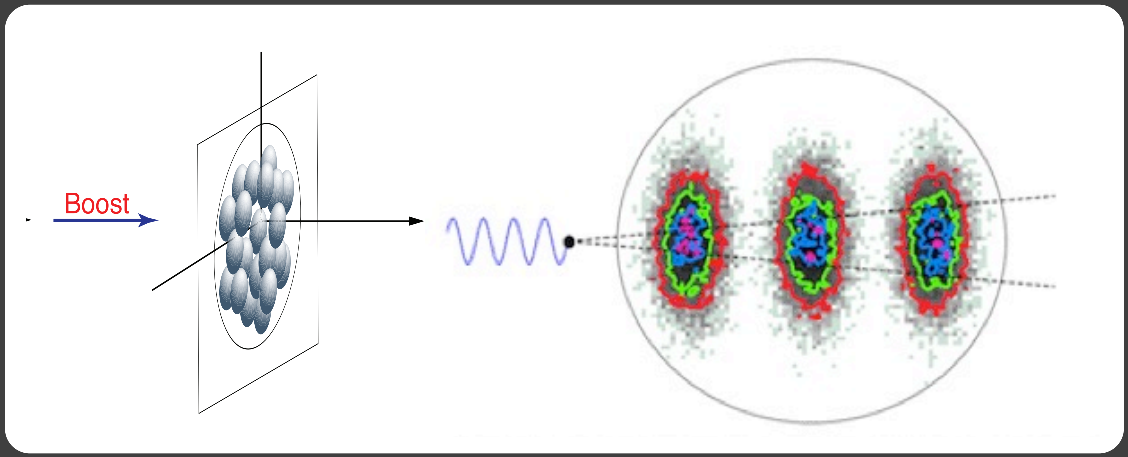


Polarized

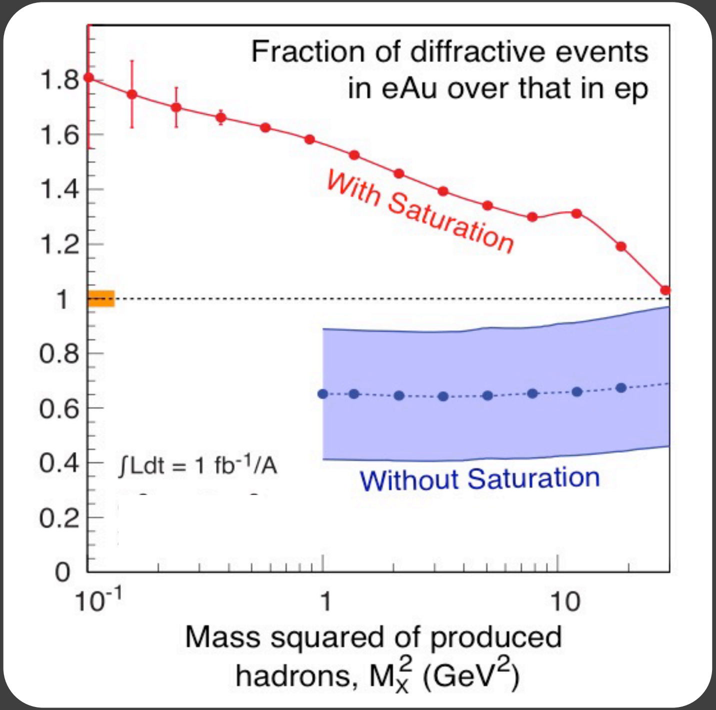


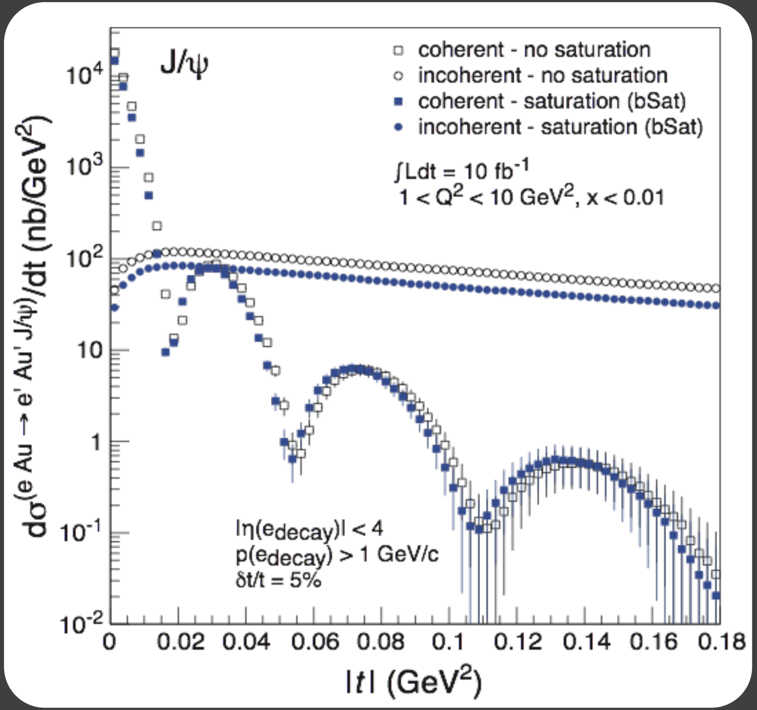


Imaging Gluons & looking for Saturation

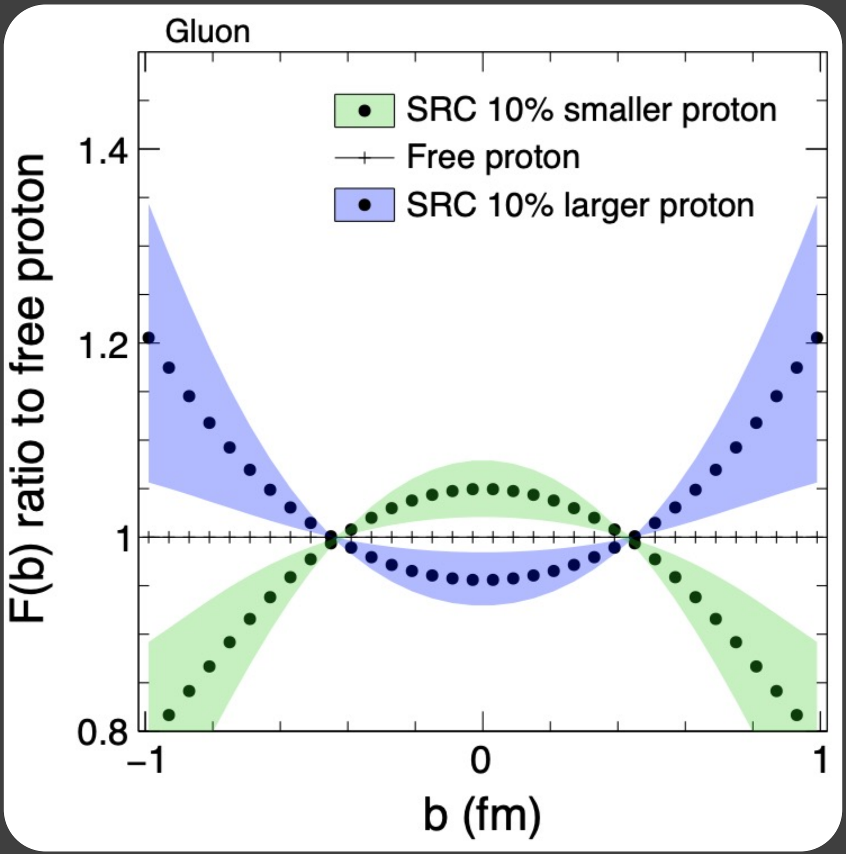


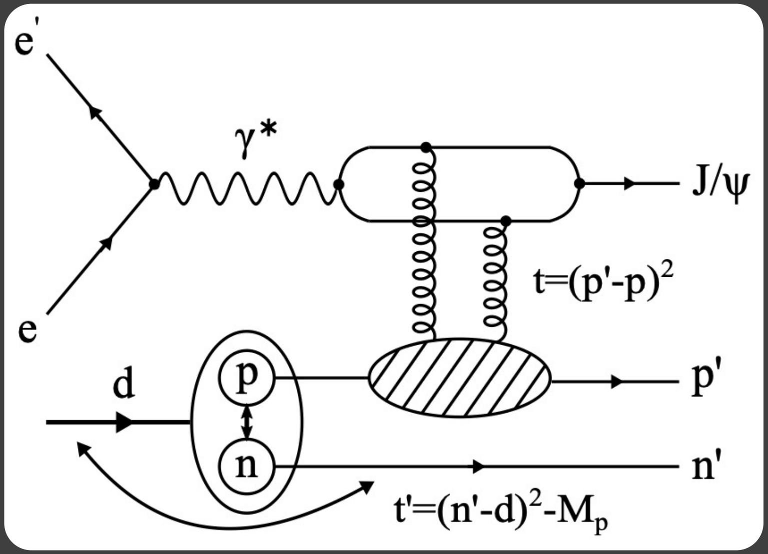
Delocalized partons @ high-x?

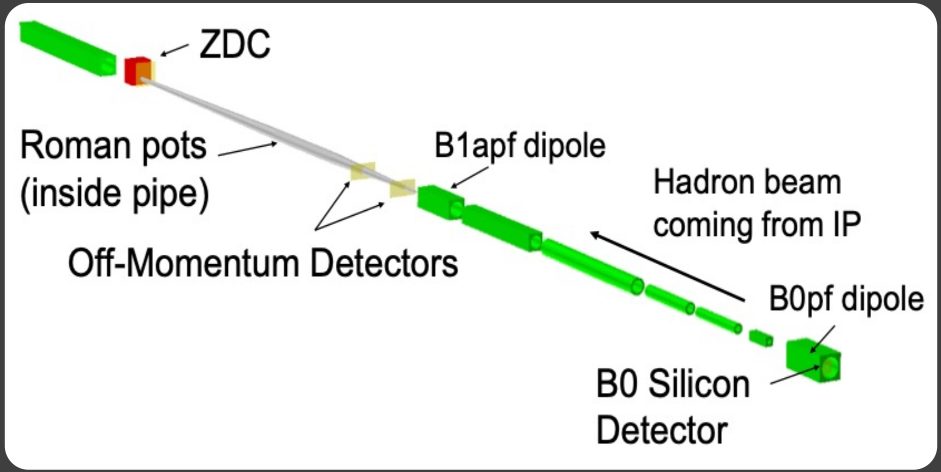




Understanding Gluons & NN Interaction

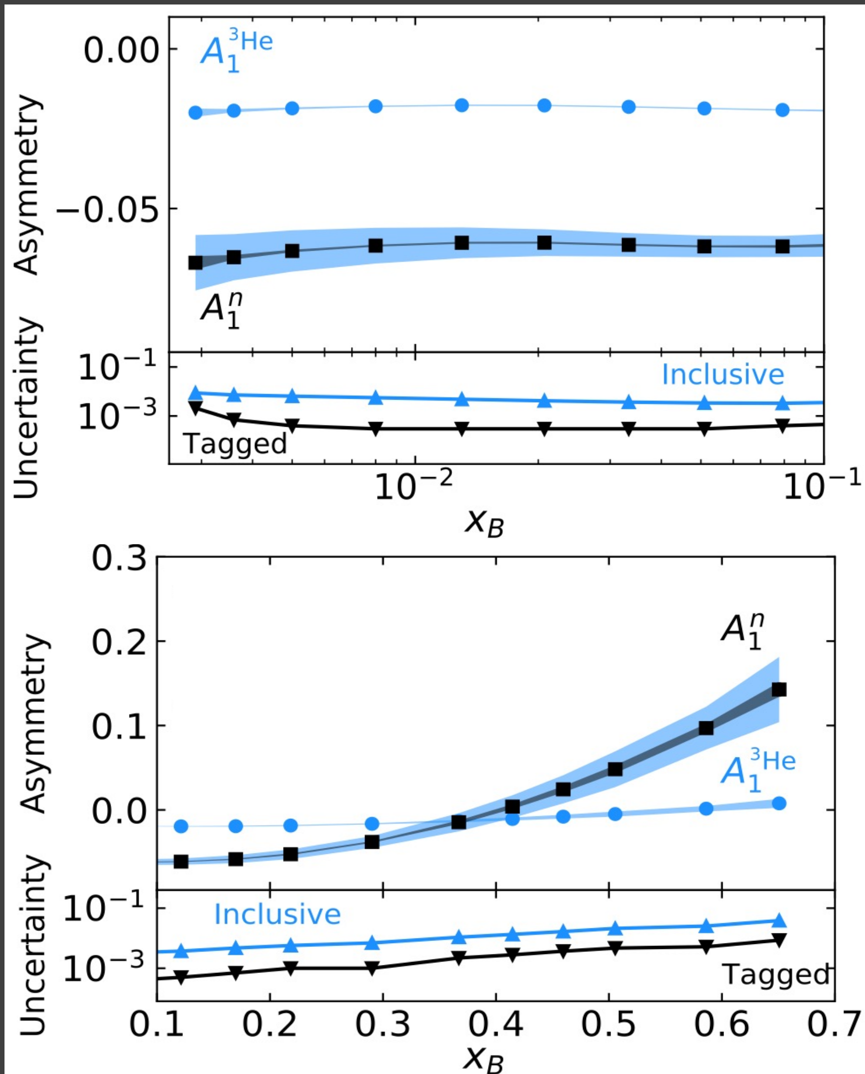


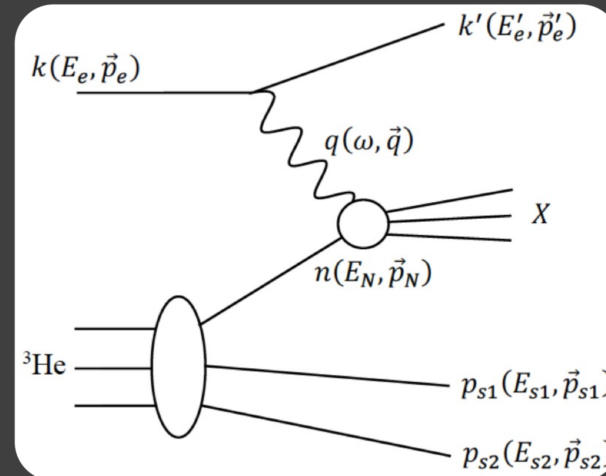




Tu and Jentsch et a., Phys. Lett. B 811, 135877 (2020)

Neutron Spin from Double Tagging





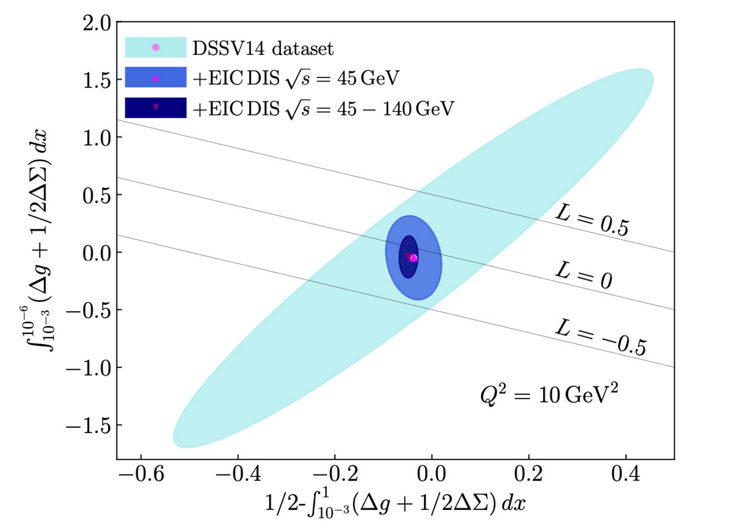
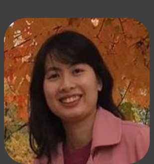
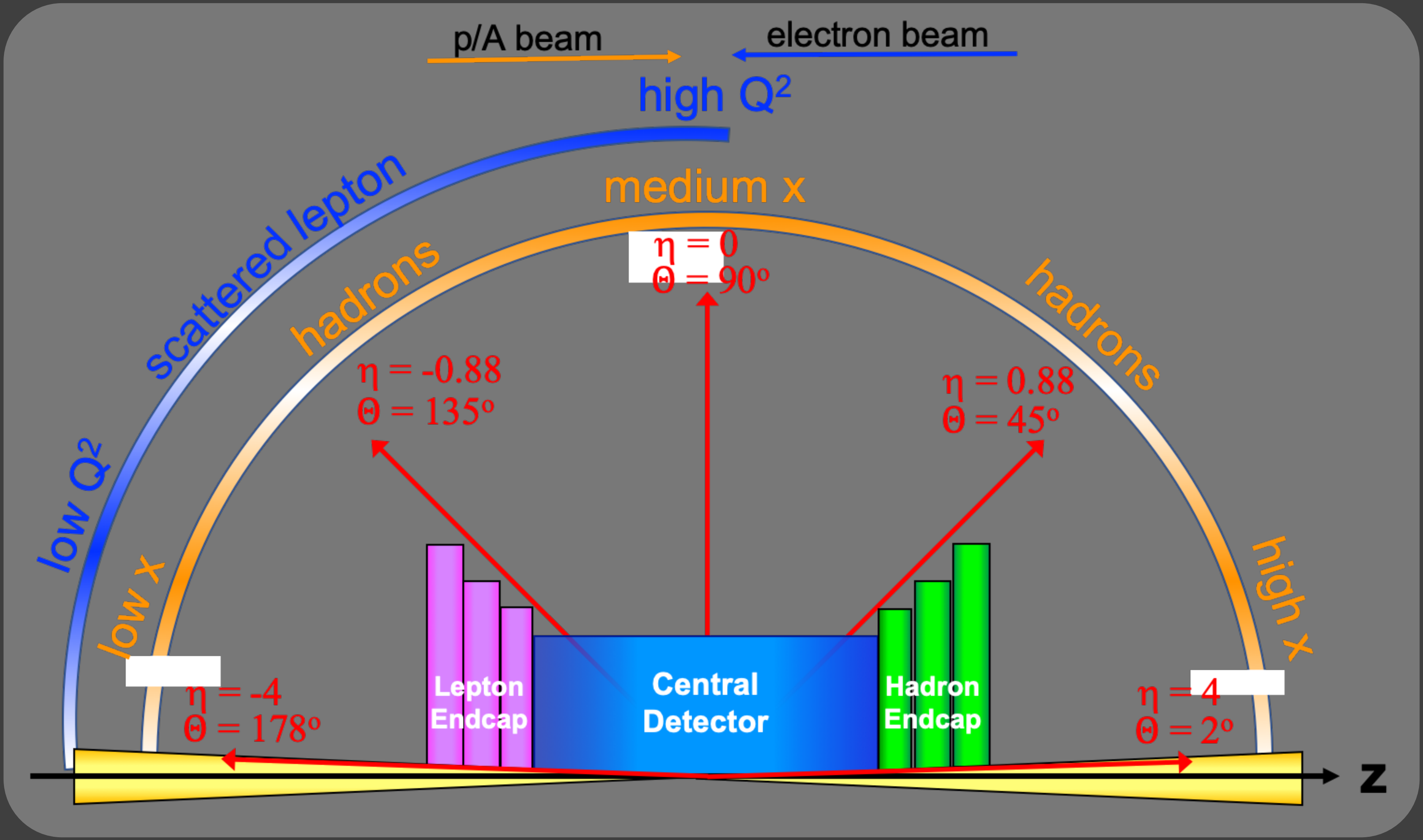


Figure 7.17: Room left for potential orbital angular momentum contributions to the proton spin at $Q^2 = 10\,\text{GeV}^2$, according to present data and future EIC measurements.

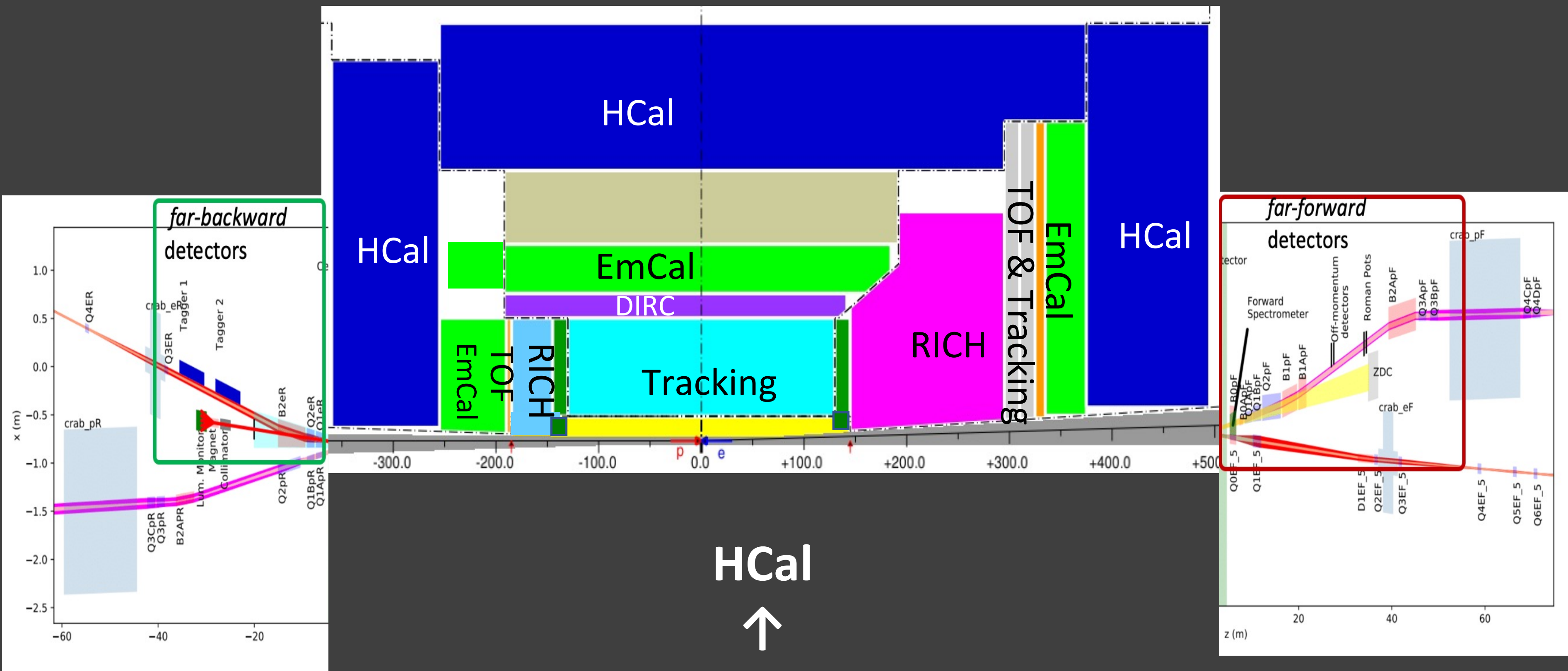


Friscic and Nguyena et al.,
Phys. Lett. B, In-Print (2021)

EIC Detector Layout



EIC Detector Layout



HCal

↑

EM-Cal

↑

Cherenkov & TOF PID

↑

Tracking

ECCE

EIC Comprehensive Chromodynamics Experiment

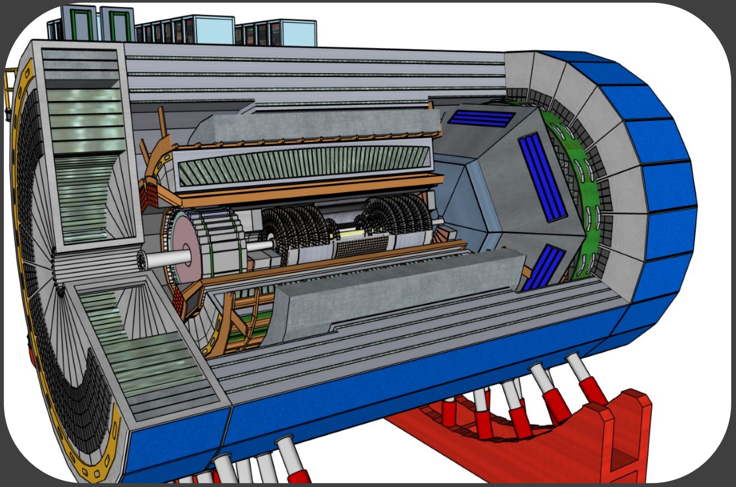
ATHENA

A Totally Hermetic Electron-Nucleus Apparatus

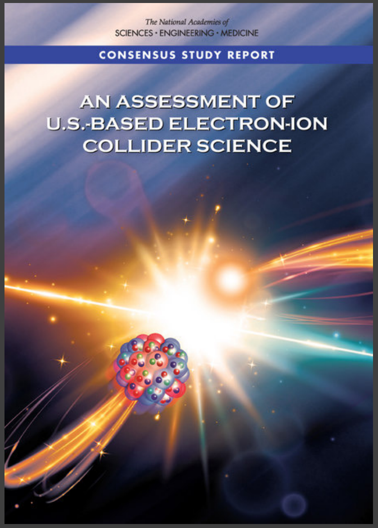
EIC Comprehensive Chromodynamics Experiment

Scientist from 80 institutions

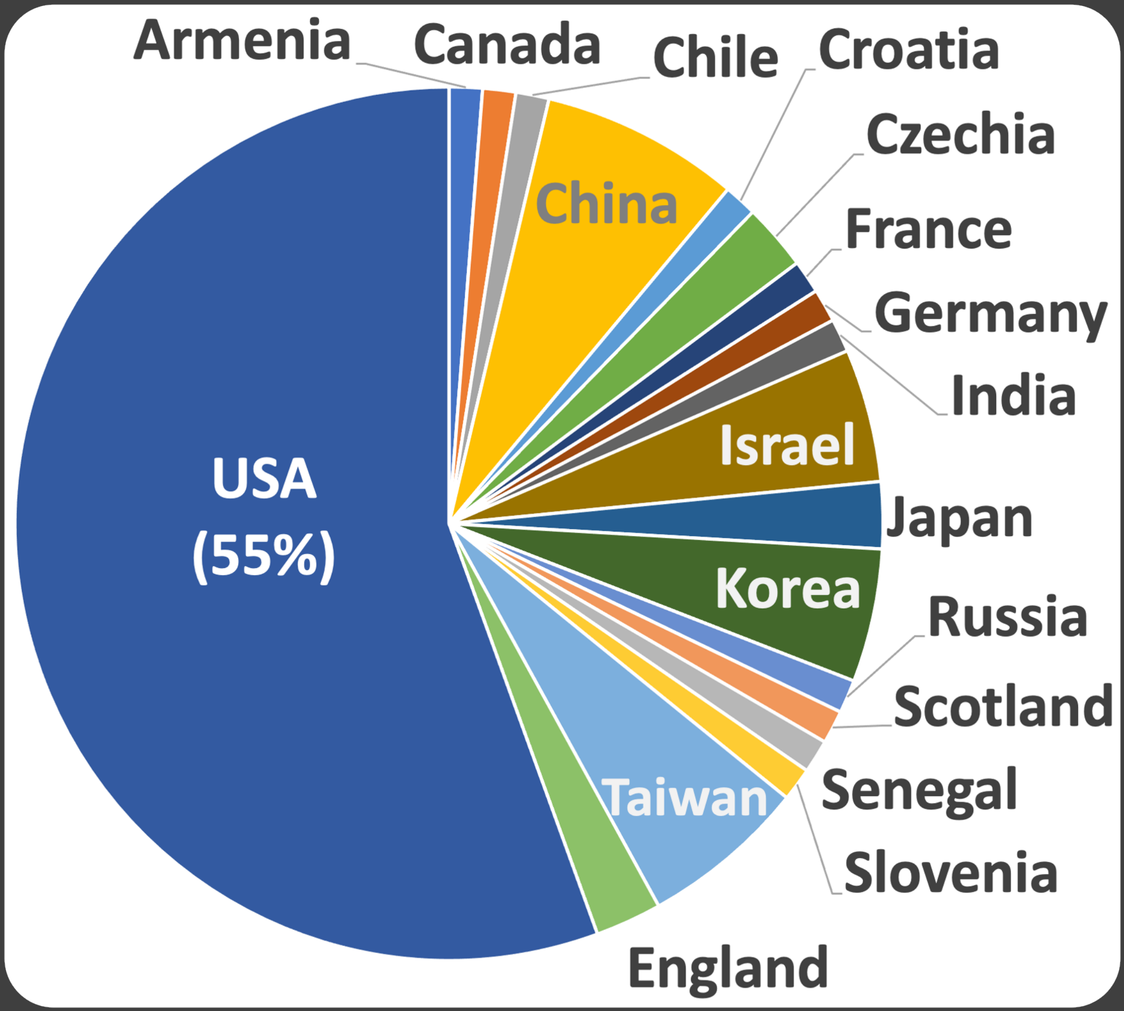
Designing (& building!) a detector



To deliver on EIC science mission



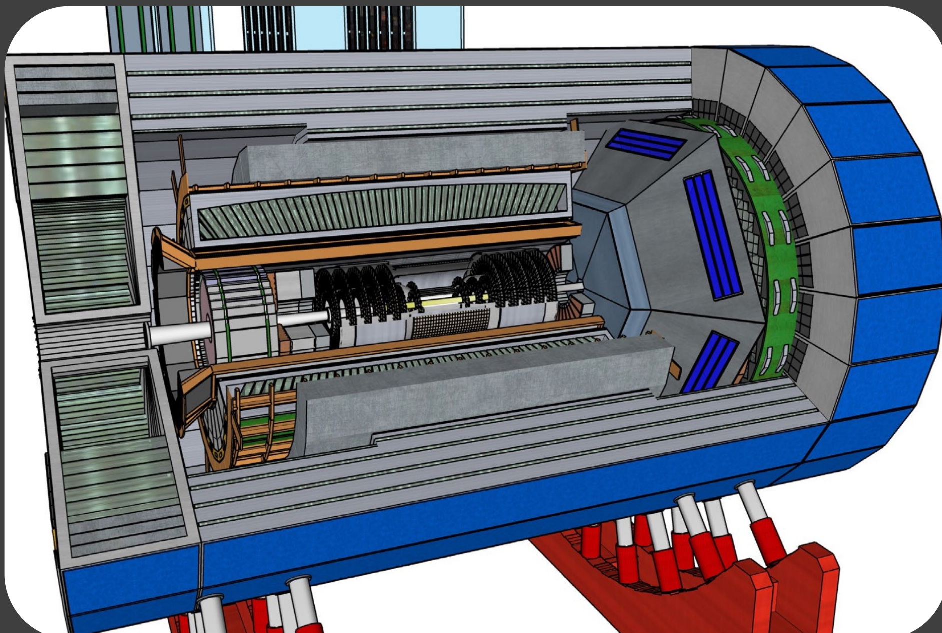
EIC Comprehensive Chromodynamics Experiment

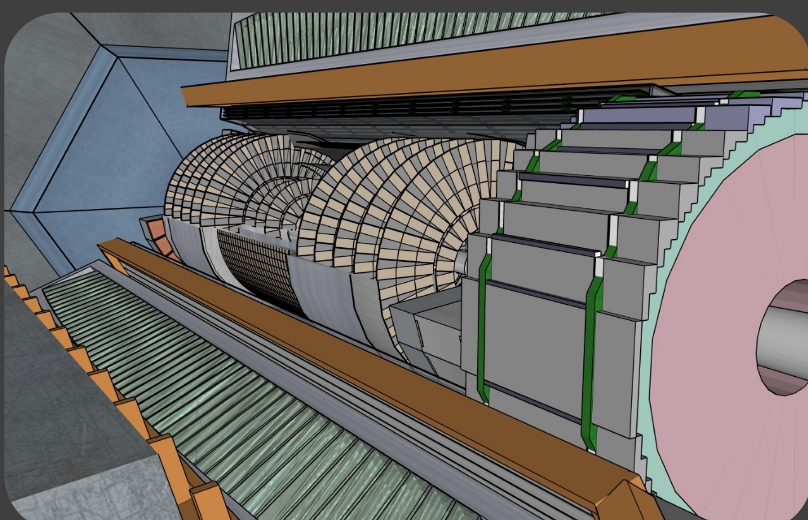


Background / Experience:

50% 'RHIC'
40% 'JLab'
10% Both

ECCE Detector Layout





ELECTRON ENDCAP

Tracking: Large area μRWELL
Electron Detection:

- Inner: PbWO4 crystals (reuse some)
- Outer: SciGlass (backup PbGl)

h-PID: mRICH & AC-LGAD
HCAL: Fe/Sc (STAR re-use)

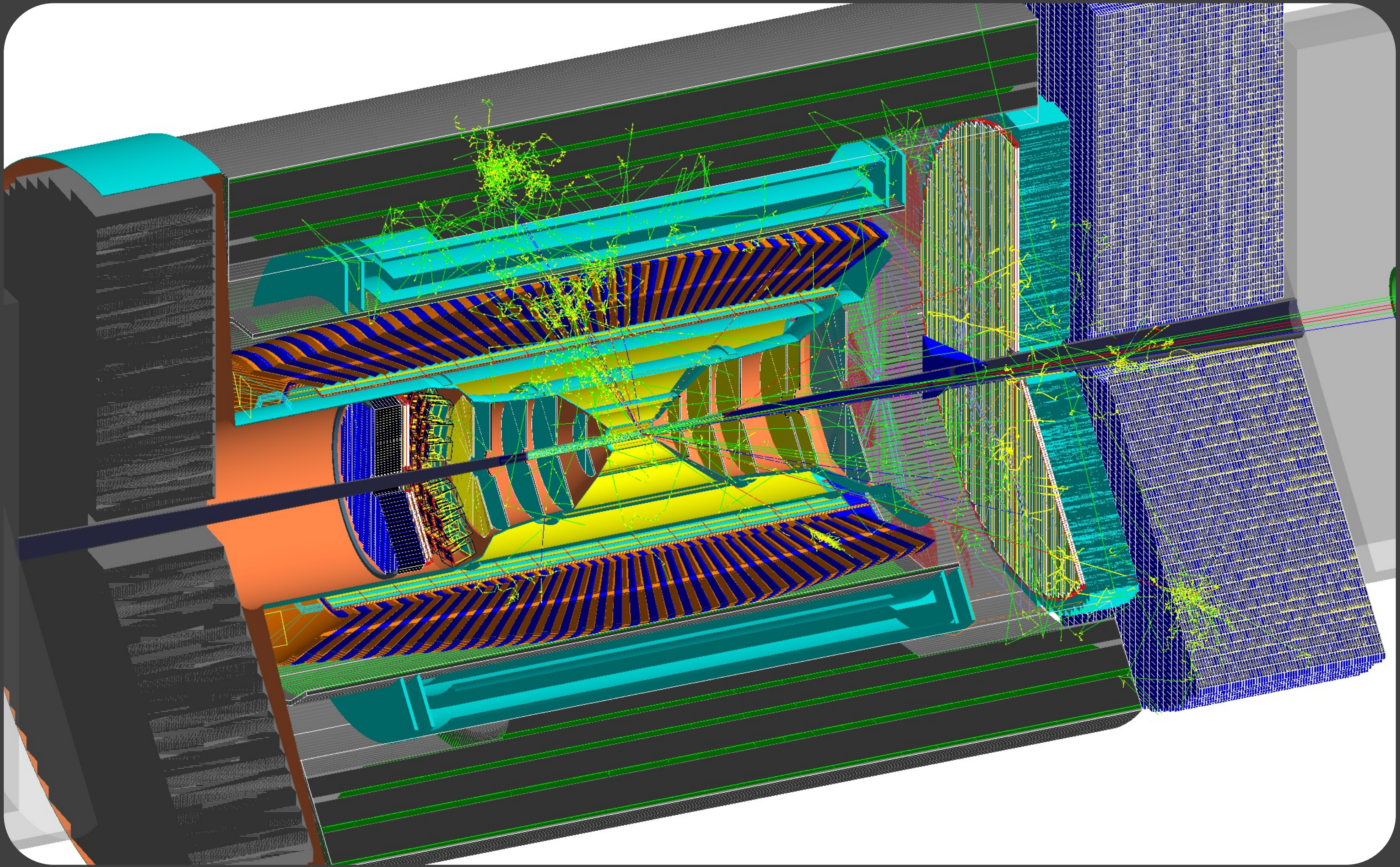
CENTRAL BARREL

Tracking: MAPS Si for vertexing and endcaps
(design to be optimized)
Electron PID: SciGlass (alt: PbGl or W(Pb)/Sc shashlik)
(plus instrumented frame)
h-PID: hpDIRC & AC-LGAD
HCAL: Fe/Sc (sPHENIX re-use)

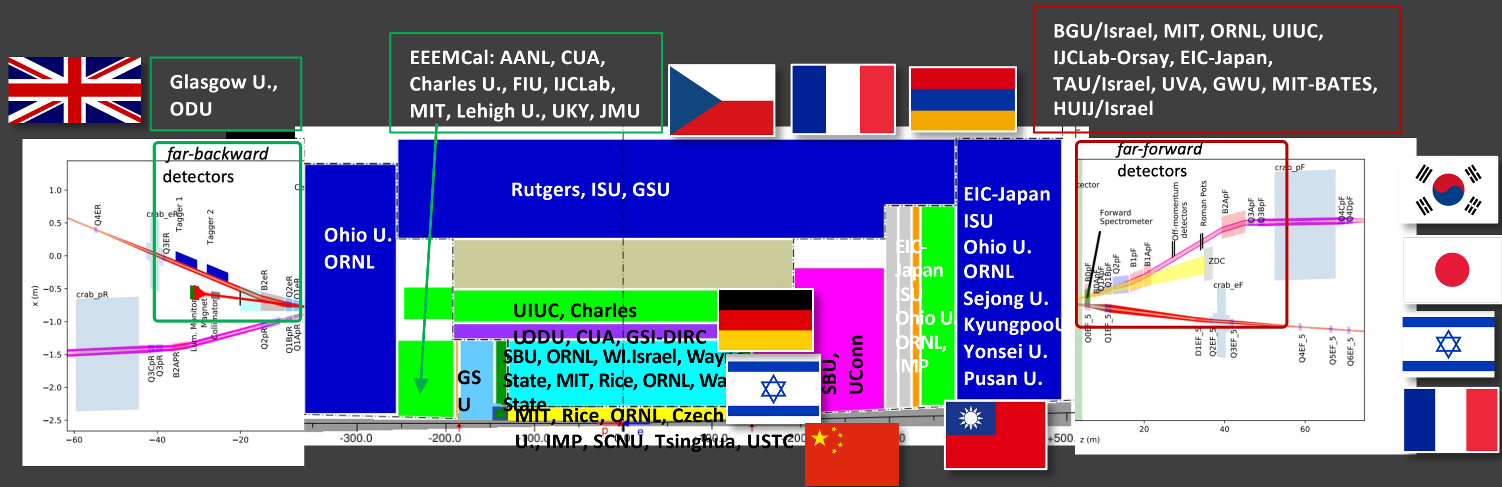
HADRON ENDCAP

Tracking: Large area μRWELL
PID: dual-RICH & AC-LGAD
Calorimetry: (option A)
standard Pb/ScFi shashlik (PHENIX re-use)
long. sep. HCAL
(other options under study)

ECCE Detector Layout



Significant International Interest



Polarized Beam and polarimetry: MIT, UNH, SBU

Electronics: Columbia, ORNL

DAQ/Trigger: ISU, CU Boulder, OU, ORNL, SBU, UConn, LLNL

Artificial Intelligence: MIT, CNU, Brunel U.

CENTRAL

Tracking:

- Silicon: China, Czech Republic, Japan

Calorimetry

- PWO and SciGlass: Czech Republic, Armenia, France
- Forward Calo/Dual Readout: China, Japan, South Korea

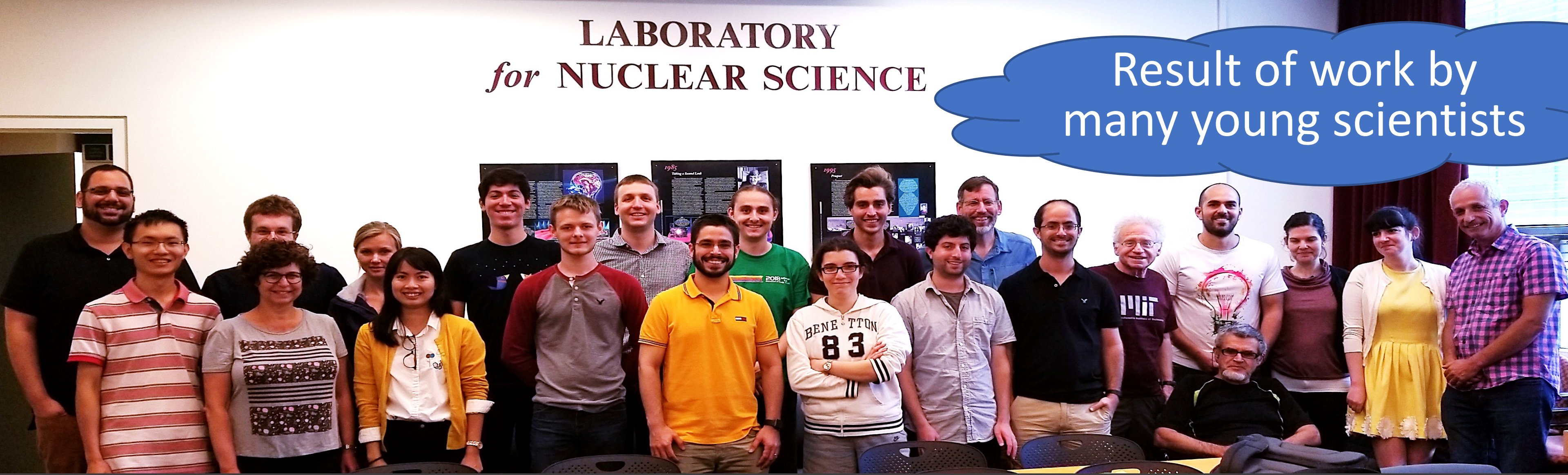
Particle ID

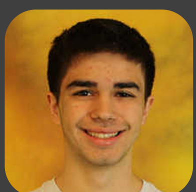
- DIRC: GSI/Germany

FAR FORWARD – FAR BACKWARD

- Roman pots: France
- Off momentum: Israel
- ZDC: Japan
- Luminosity monitors: Israel
- Low Q2 tagger: UK

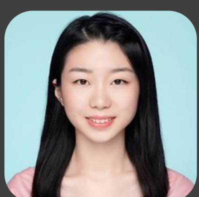
Starting ECCE construction 😁




Alex Kiral*


Andrew Denniston


Natalie Wright


Hang Qi


Jason Phelan


Efrain Segarra


Elena Magdalena


Jackson Pybus


Afroditi Papadopoulou


Dr. Florian Hauenstein


Dr. Julian Kahlbow


Dr. Igor Korover

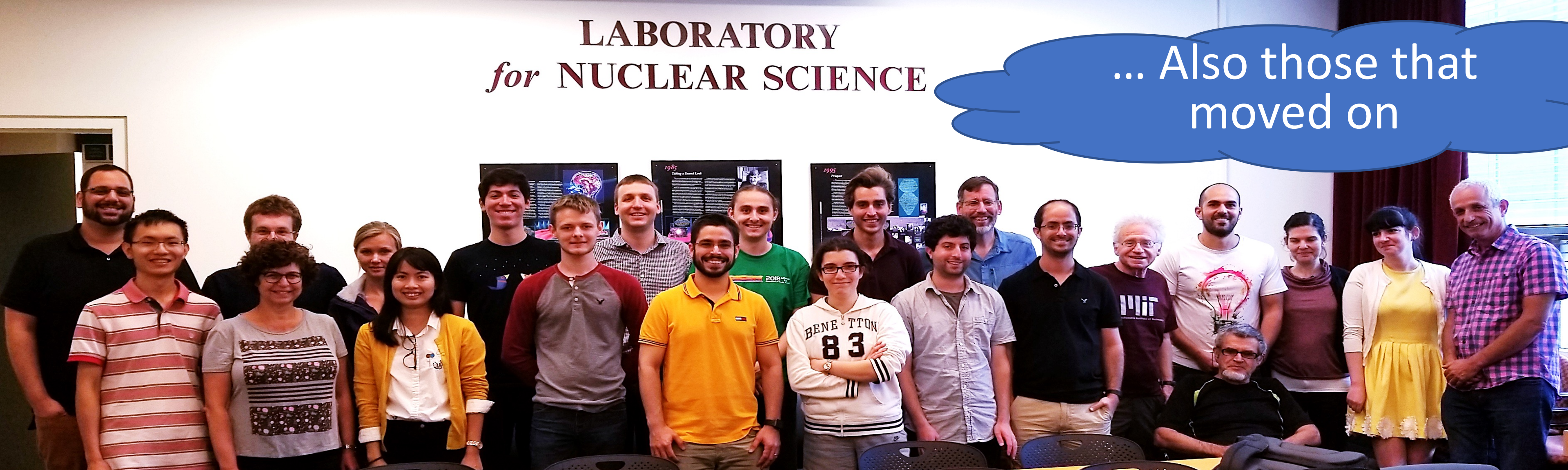

Dr. Josh Barrow


Dr. Justin Estee


Dr. Tyler Kutz


Dr. Nathaly Santiesteban

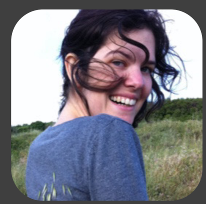
*Postback



… Also those that moved on

Postdocs

Faculty, GWU



Faculty, TAU

Staff Scientist, JINR

Staff Scientist, JLab

Consultant

Isgur Fellow, JLab

Staff Scientist (starting soon)

Graduate Students

Postdoc, Berkley

Postdoc, Stony Brook

AI Scientist

2018-21 Publications:

- Nature, In-Print (2021)
- Nature 578, 540 (2020)
- Nature 566, 354 (2019)
- Nature 560, 617 (2018)
- Nature Physics 17, 693 (2021)
- Nature Physics 17, 306 (2021)
- PRL 125, 201803 (2020)
- PRL 124, 212501 (2020)
- PRL 124, 092002 (2020)
- PRL 122, 172502 (2019)
- PRL 121, 092501 (2018)
- PRC 103, L031301 (2021)
- PRD 103, 114015 (2021)
- PRD 103, 113003 (2021)
- Phys Rev Research 3, 023240 (2021)
- Phys. Lett. B, In-Print (2021)
- Phys. Lett. B 820, 136523 (2021)
- Phys. Lett. B 811, 135877 (2020)
- Phys. Lett. B 805, 135429 (2020)
- Phys. Lett. B 800, 135110 (2020)
- Phys. Lett. B 797, 134890 (2019)
- Phys. Lett. B 797, 134792 (2019)
- Phys. Lett. B 791, 242 (2019)
- Phys. Lett. B 793, 360 (2019)
- Phys. Lett. B 785, 304 (2018)
- Phys. Lett. B 780, 211 (2018)
- EPJC 79, 673 (2019)
- NIM-A 1018, 165825 (2021)
- NIM-A 973, 164177 (2020)
- NIM-A 978, 164356 (2020)

arXiv: 2109.09509; 2104.07130
2104.05090; 2109.14524

Understanding Nuclei from QCD