The Universal Physics of Short-Range Correlations

Lawrence Weinstein
(Old Dominion University)
Or Hen
(MIT)

Hen Lab
Laboratory for Nuclear Science @ MIT

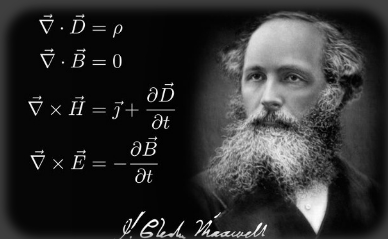
Electron-Ion Collider?

Apple

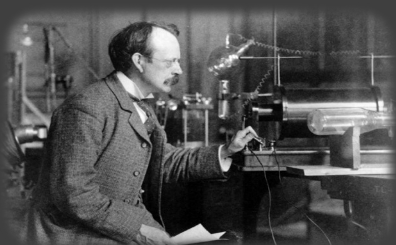

iPets
10:09
ACTIVITY
10:09
ACTIVITY

What *key* discoveries made it possible?

Mid-to-late 1800s:



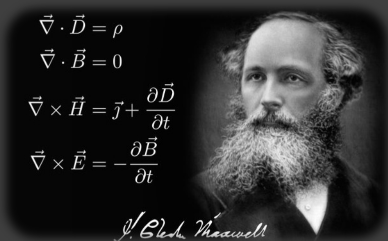
Maxwell formulates Electromagnetic Theory (1862)



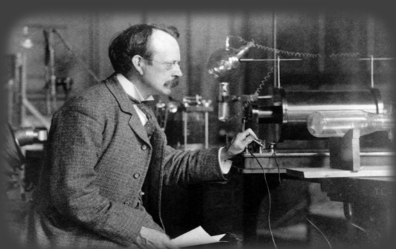
Thompson discovers the Electron (1897)

What *key* discoveries made it possible?

Mid-to-late 1800s:



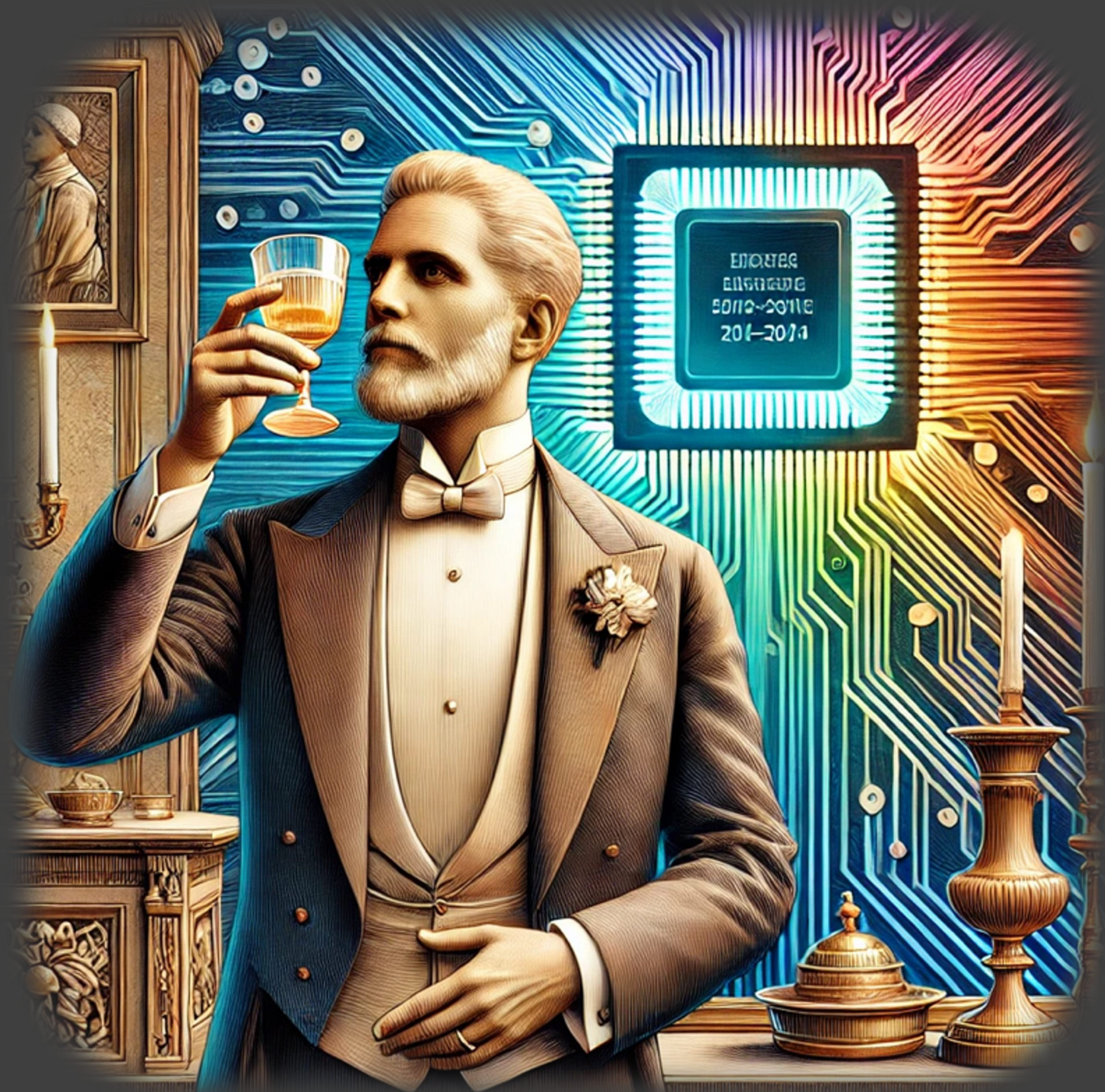
Maxwell formulates Electromagnetic Theory (1862)



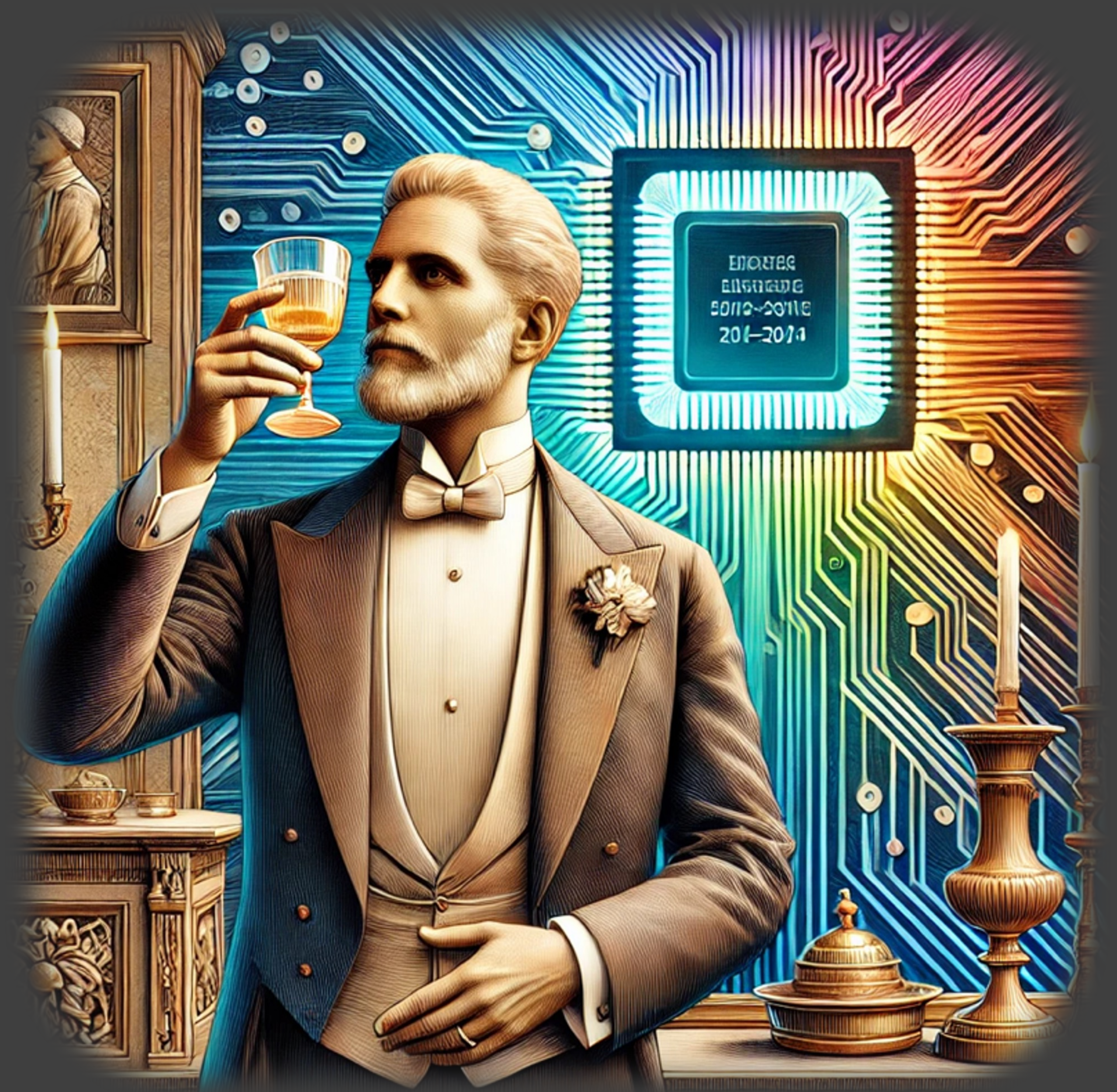
Thompson discovers the Electron (1897)

35 years of Electromagnetic development without knowing about electrons!

“To the Useless Electron” (1897)



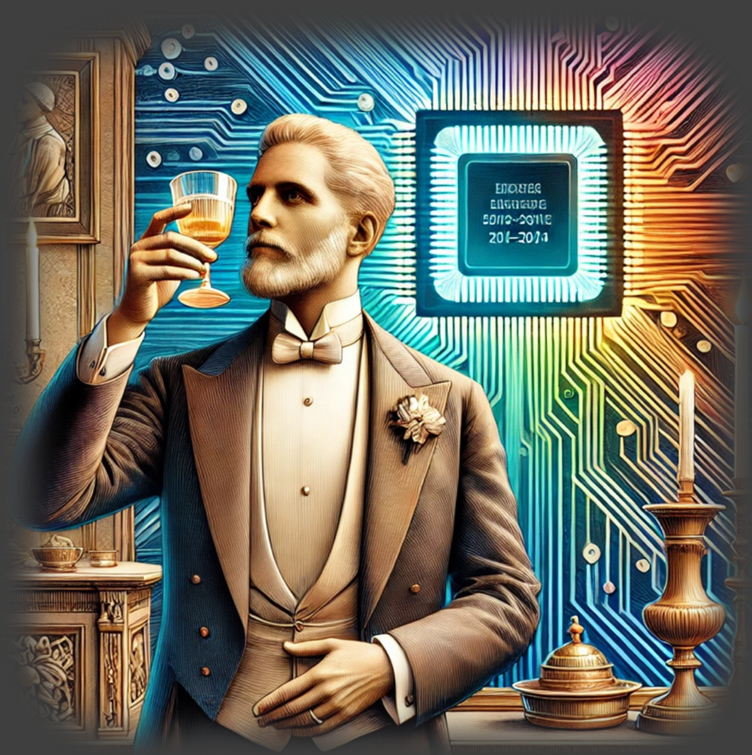
“To the Useless Electron” (1897)



1906

Why do we care?

Because deeper understanding
= A better world!



How?

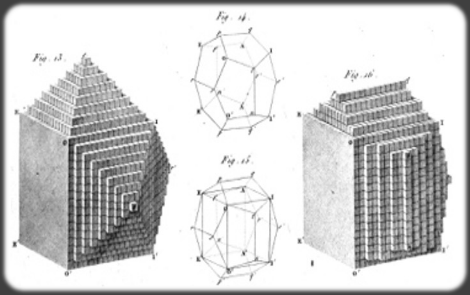
How?

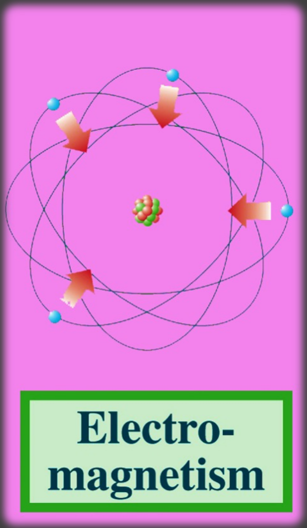
Just look…

How?

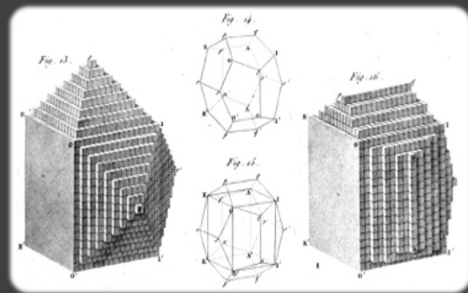
Just look… using the right lens

Solids Structure

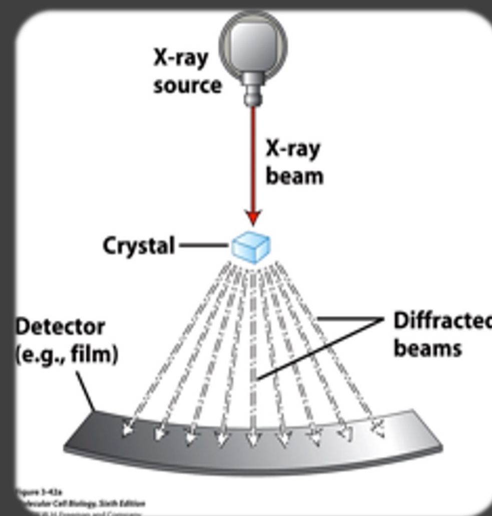


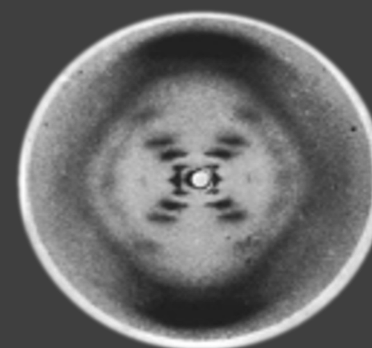


Solids Structure

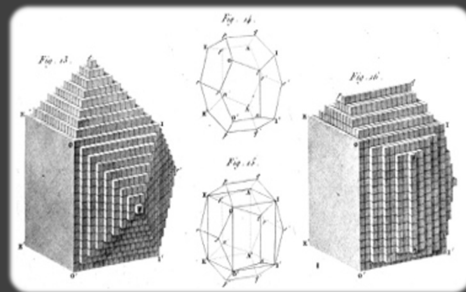


X-ray Diffraction

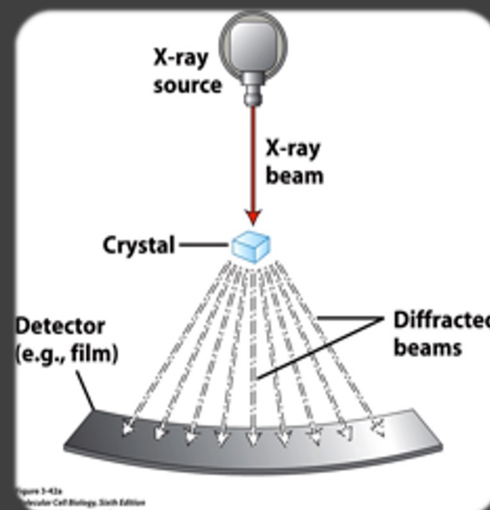


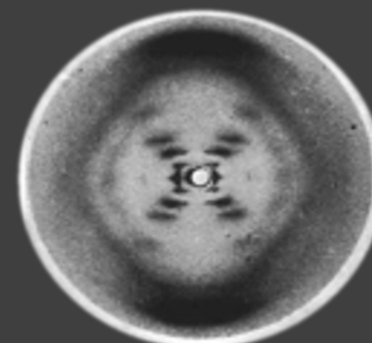


Solids Structure



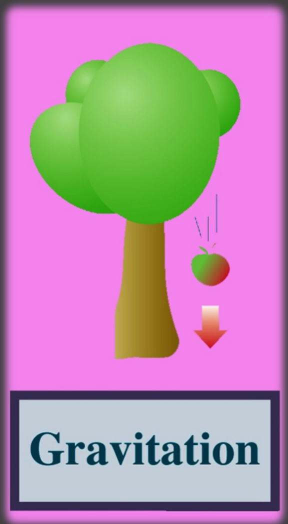
X-ray Diffraction





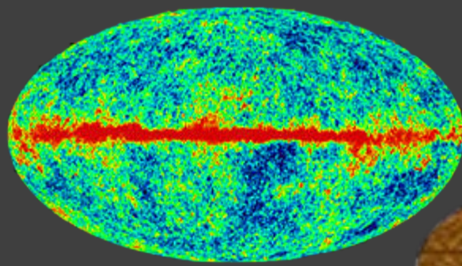
Solid state physics, Molecular biology

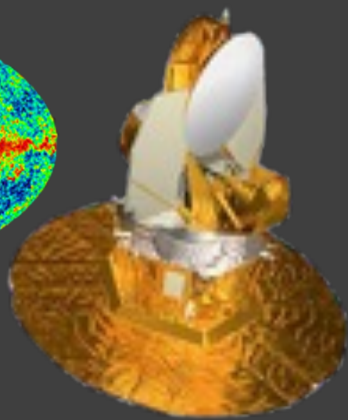
Universe



Universe

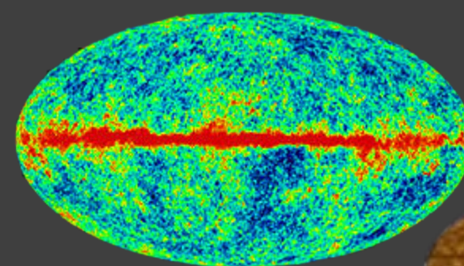
Large Scale Surveys

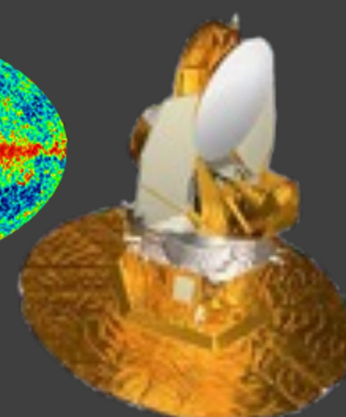


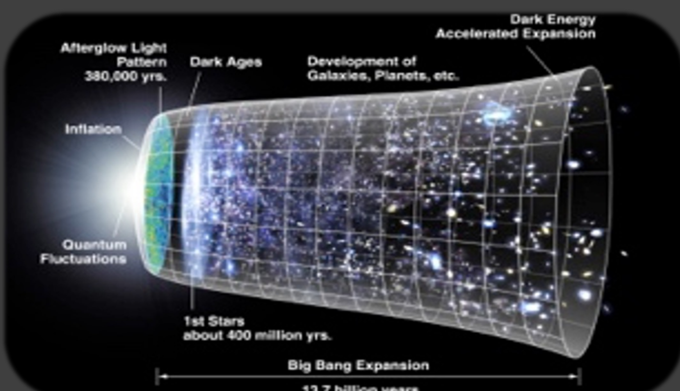


Universe

Large Scale Surveys

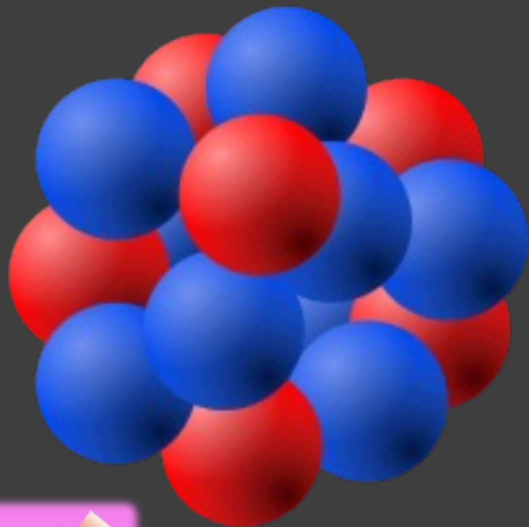


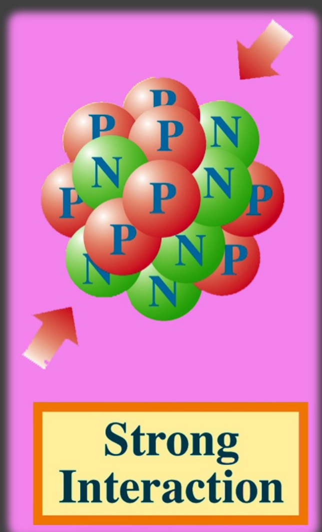




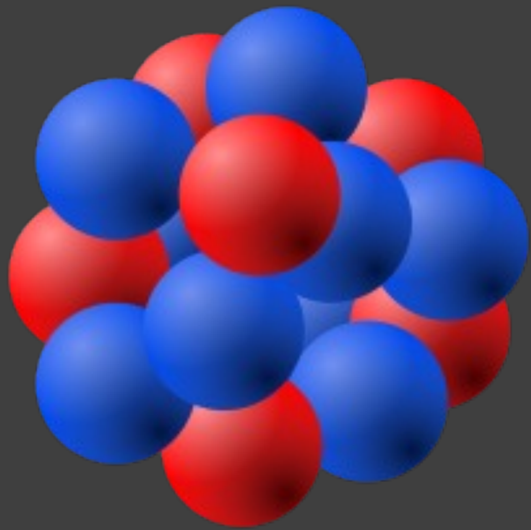
Precision Cosmology

Nucleon / Nucleus

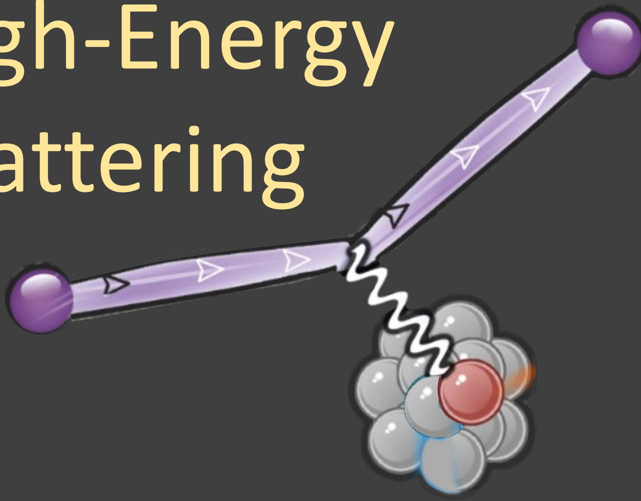




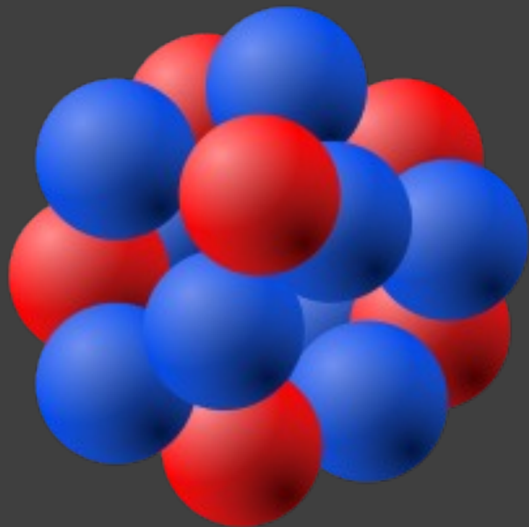
Nucleon / Nucleus



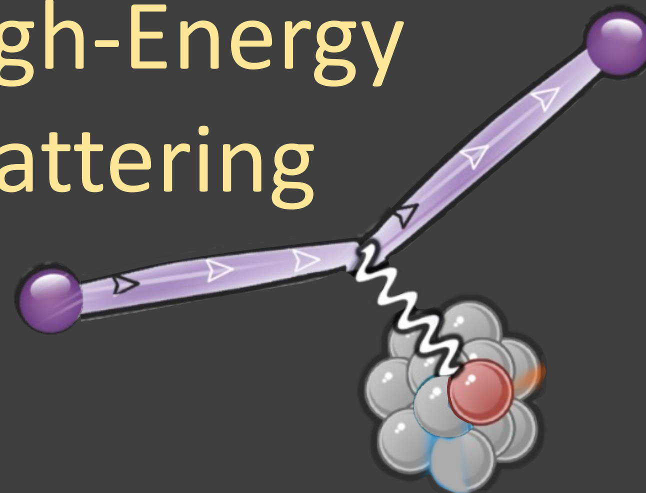
High-Energy Scattering

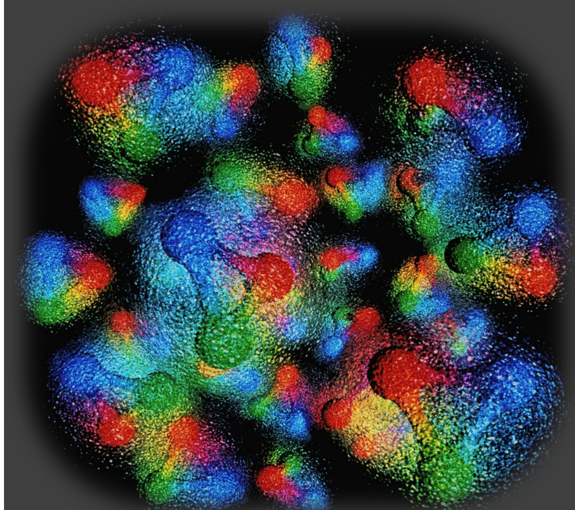


Nucleon / Nucleus



High-Energy Scattering



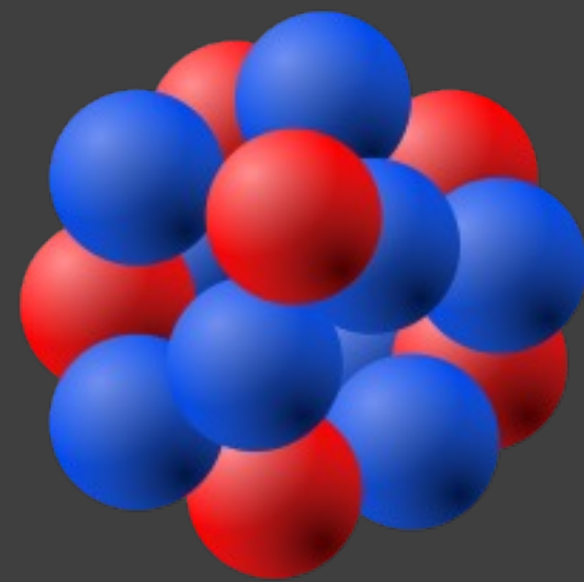


QCD &

Standard Model

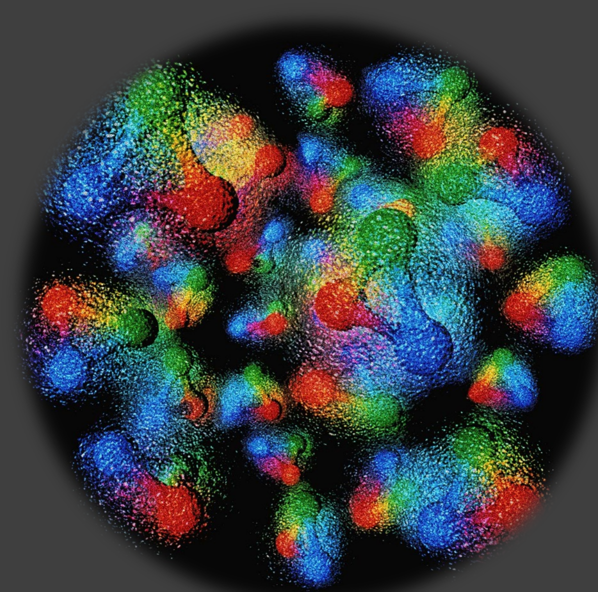
Physics of Nuclei

<u>Nuclei:</u> quarks and gluons, bound inside protons and neutrons



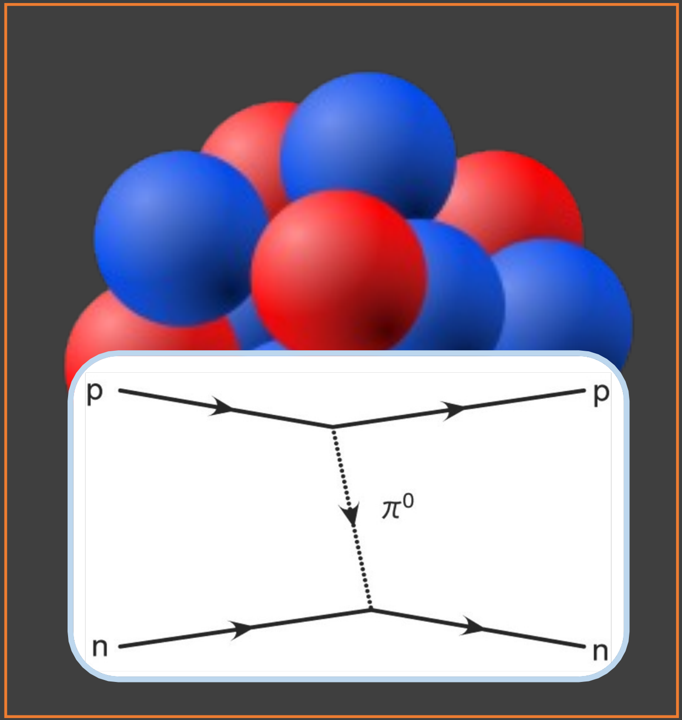
<u>Key Challenges:</u>

- Strongly Interacting Many-body system
  ➔ beyond shell structure
- Short-distance interactions, where distance scales ≤ nucleon radius



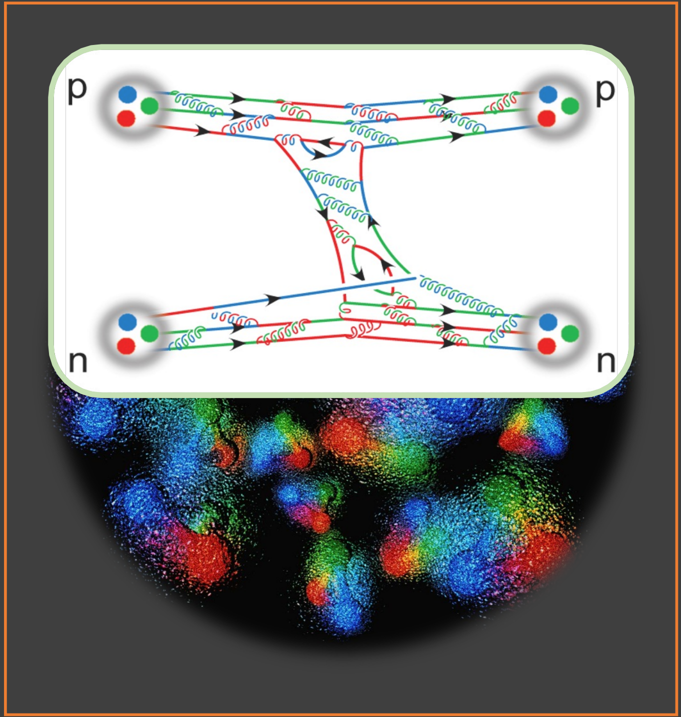
Physics of Nuclei

Nuclei: quarks and gluons, bound inside protons and neutrons

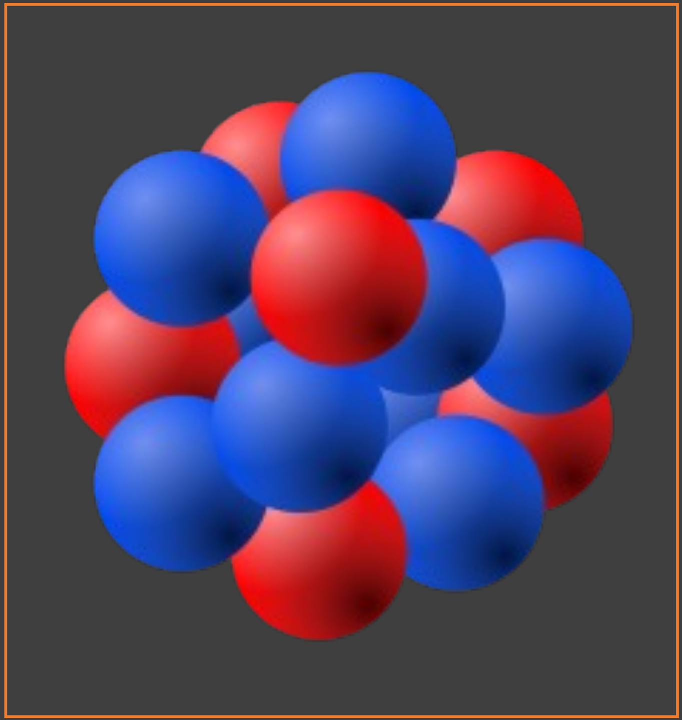


Key Challenges:

- Strongly Interacting Many-body system
  ➔ beyond shell structure
- Short-distance interactions, where distance scales ≤ nucleon radius



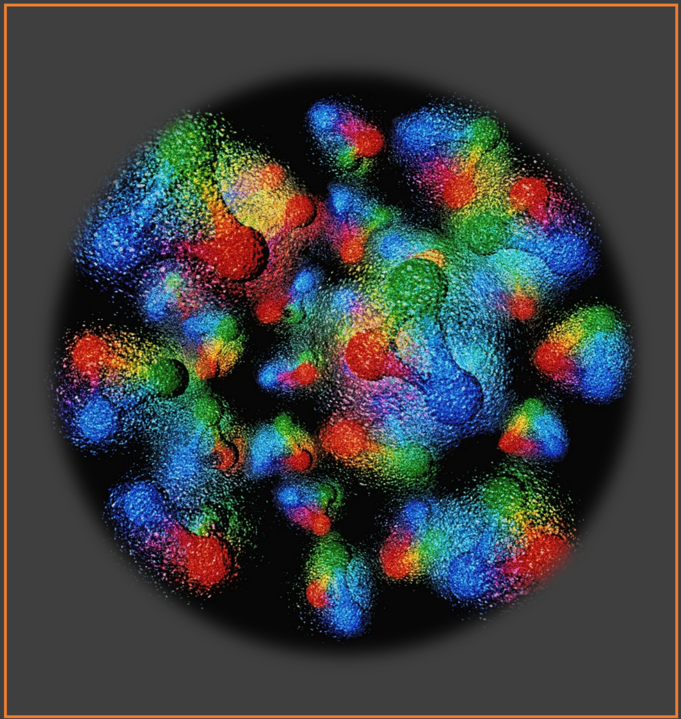
Physics of Nuclei



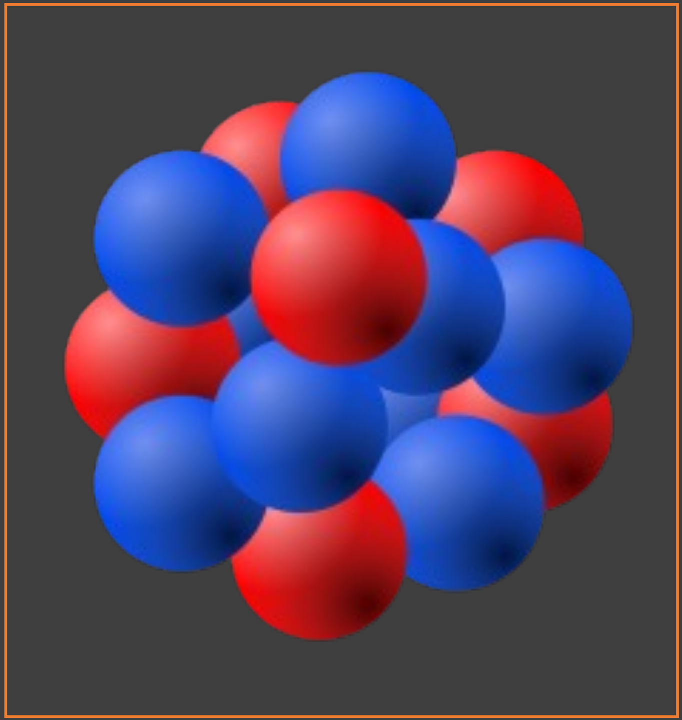
<u>Nuclei:</u> quarks and gluons, bound inside protons and neutrons

<u>Key Challenges:</u>

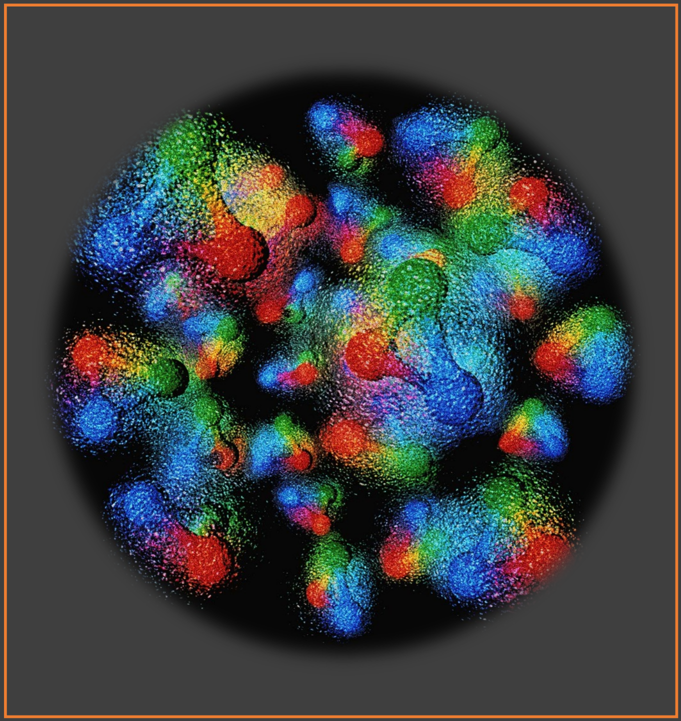
- Strongly Interacting Many-body system
  ➔ beyond shell structure
- Short-distance interactions, where distance scales ≤ nucleon radius



Physics of Nuclei



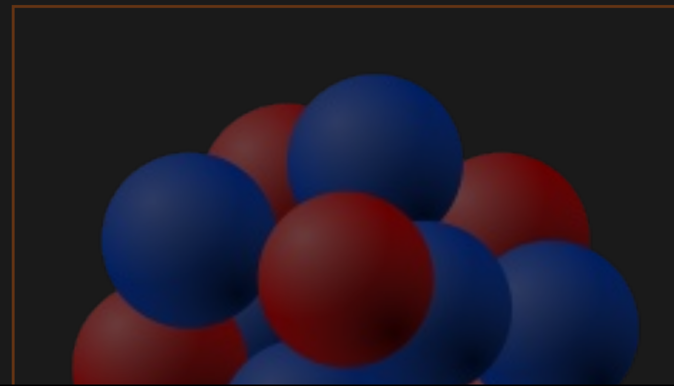
<u>Nuclei:</u> quarks and gluons, bound inside protons and neutrons



<u>Key Challenges:</u>

- Strongly Interacting Many-body system
  ➔ beyond shell structure
- Short-distance interactions, where distance scales ≤ nucleon radius

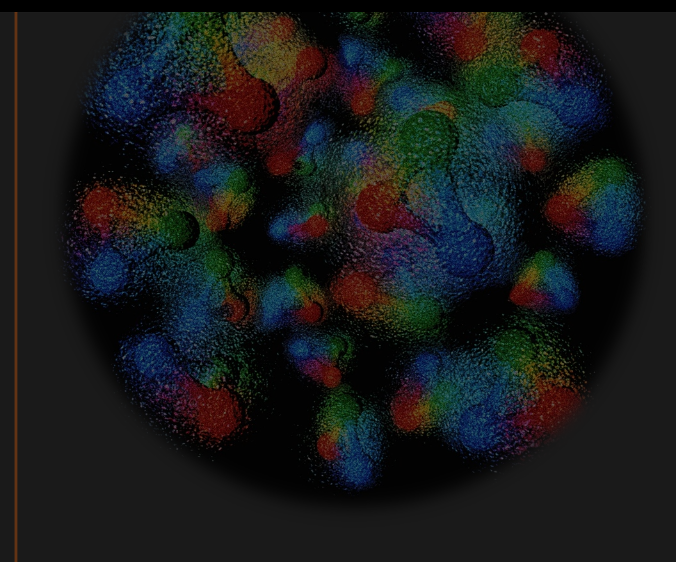
Physics of Nuclei



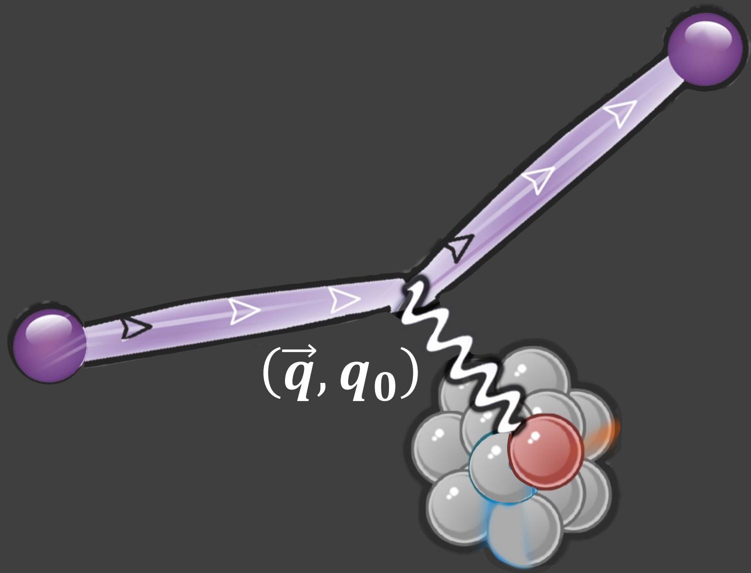
We study the short-ranged structure of nuclei and its impact on nucleon structure

Many-body system
➔ beyond shell structure

- Short-distance interactions, where distance scales ≤ nucleon radius

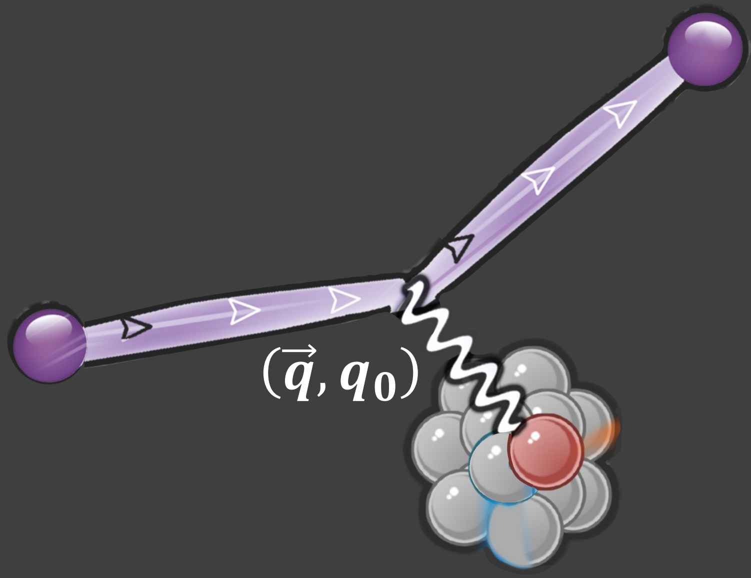


Electron Probes of Nuclei



Reaction Scale: $Q^2 = |\vec{q}|^2 - q_0^2$

Electron Probes of Nuclei

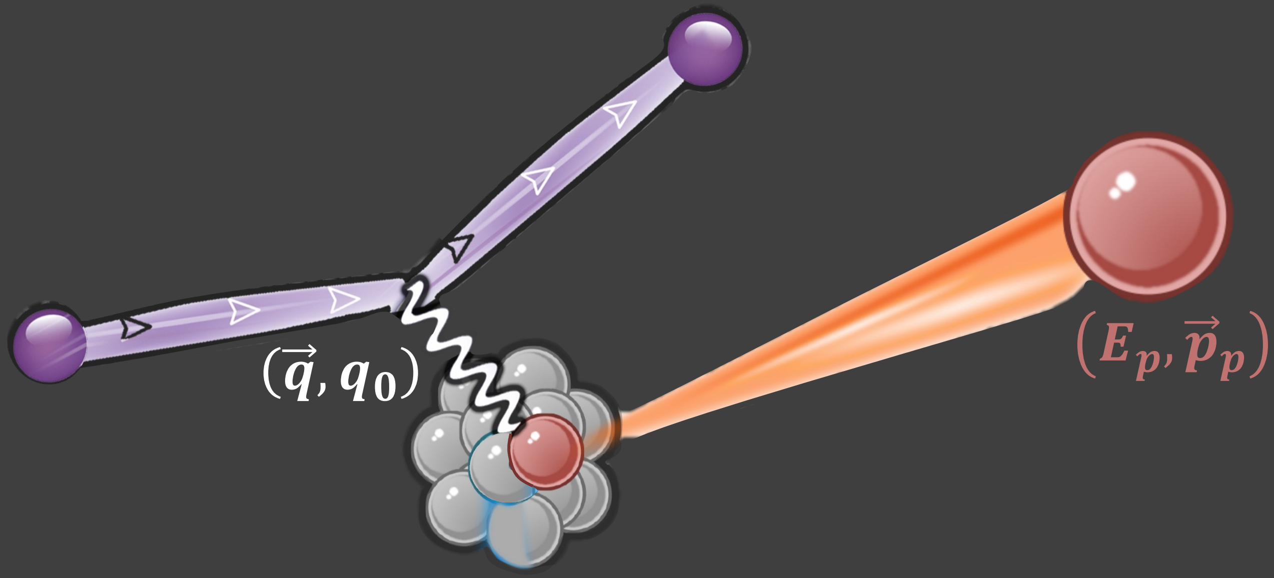


Reaction Scale: $Q^2 = |\vec{q}|^2 - q_0^2$

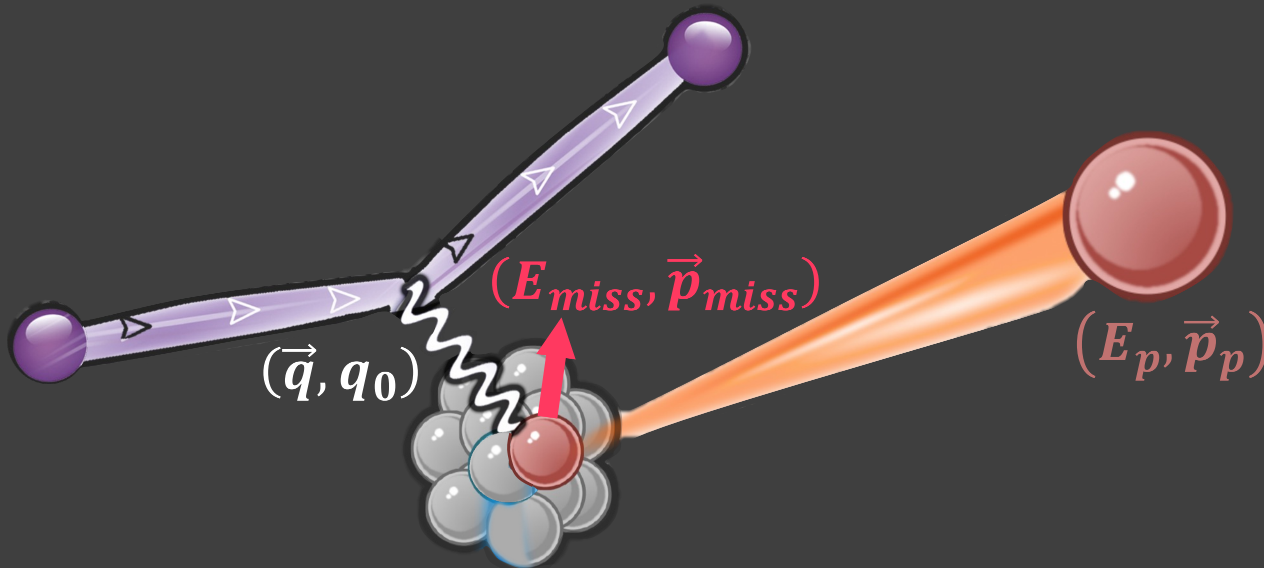
Reaction scale >> Nuclear energy scale

$$q_0, \vec{q} > 1 \text{ GeV} \gg |V_{NN}|, 2\, k_F$$

Electron Probes of Nuclei



Electron Probes of Nuclei

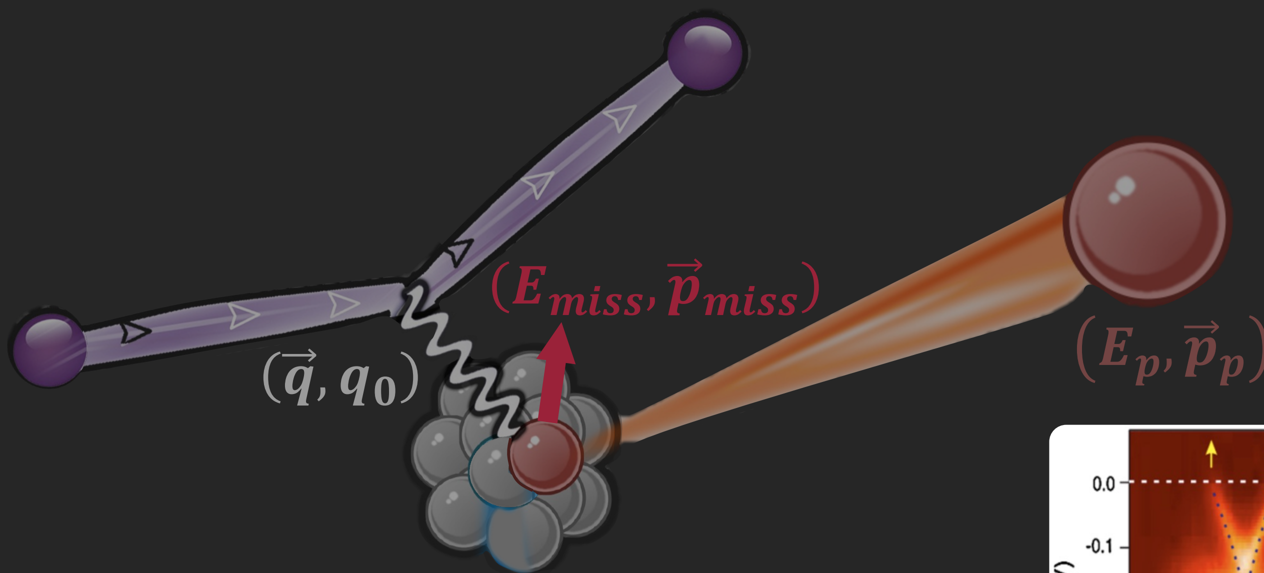


4-Momentum Conservation:

$$\vec{p}_{miss} = \vec{p}_p - \vec{q}$$

$$E_{miss} = E_p - q_0$$

Electrons Probs of Nuclei

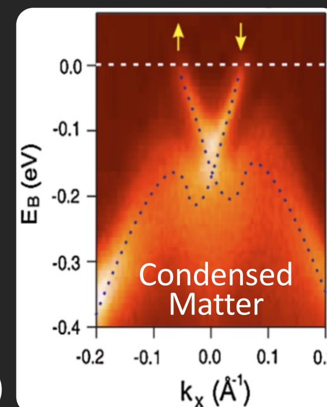


4-Momentum Conservation:

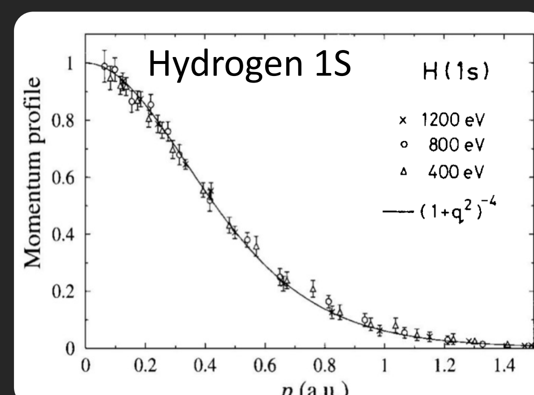
$$\vec{p}_{miss} = \vec{p}_p - \vec{q}$$

$$E_{miss} = E_p - q_0$$

(γ,e) ARPES: surface state bands (2009)

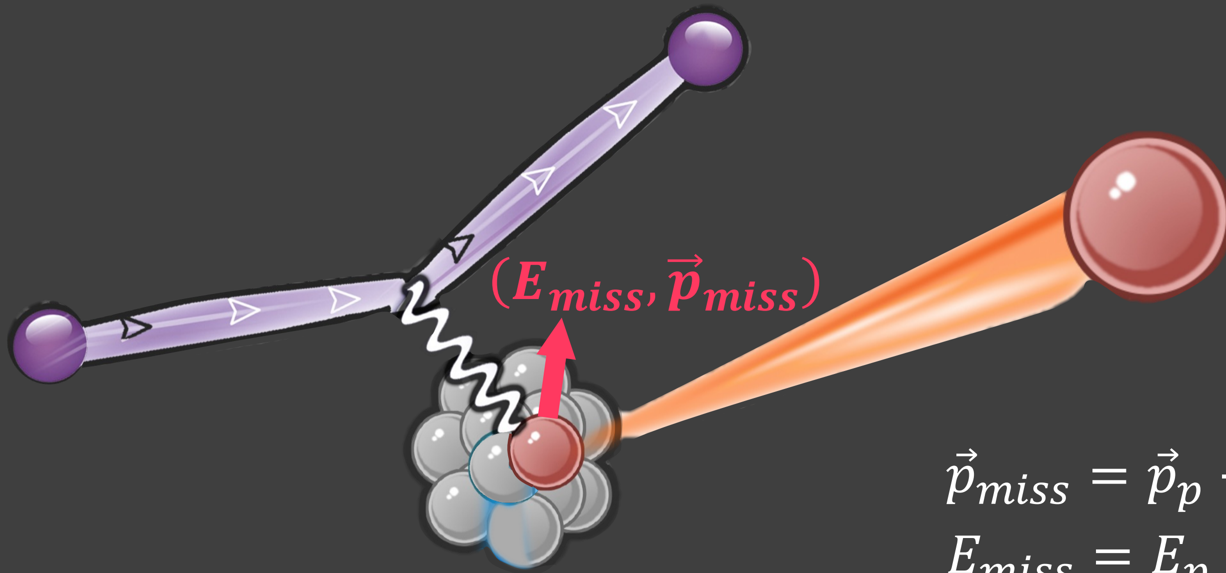


Similar to atomic / condensed matter spectral function extractions

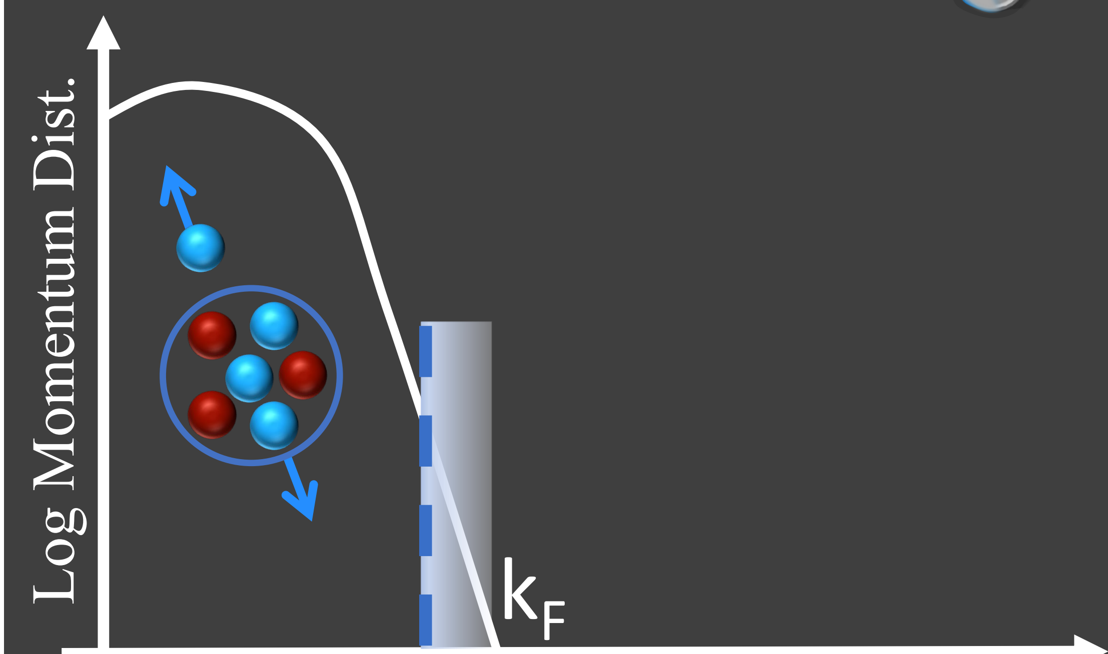


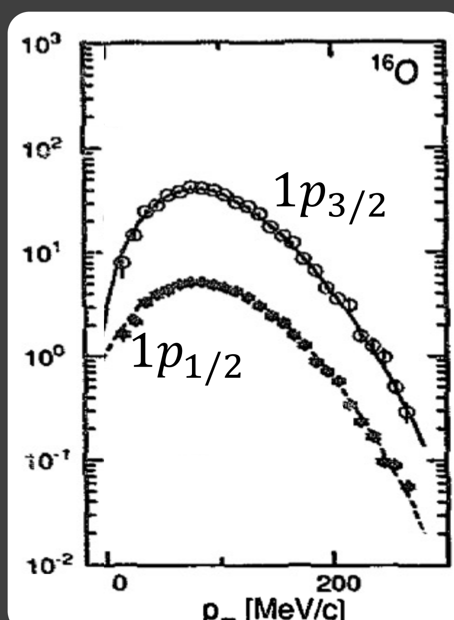
(e,2e) reduced cross-section (1981)

Electron Probes of Nuclei



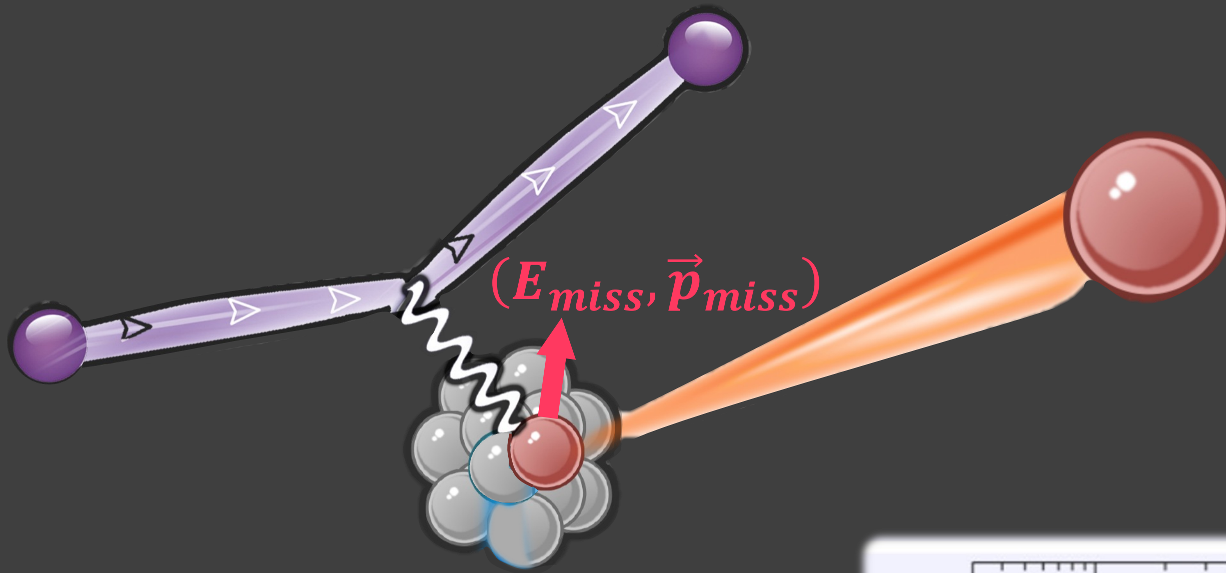
$$\vec{p}_{miss} = \vec{p}_p - \vec{q}$$
$$E_{miss} = E_p - q_0$$

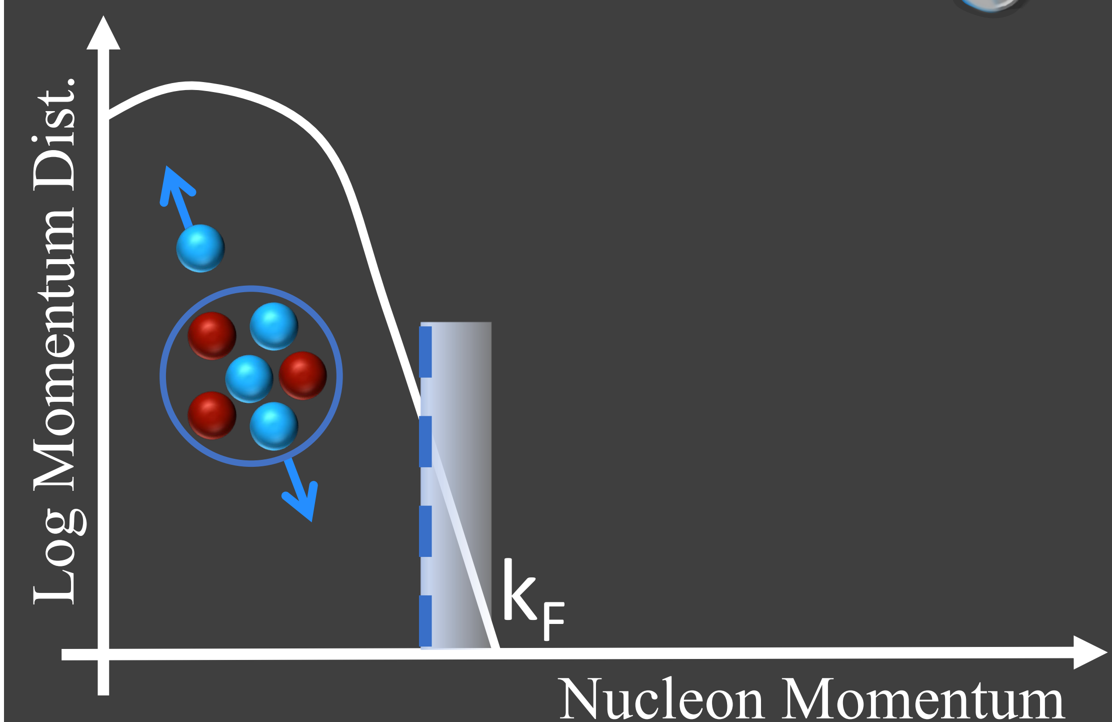


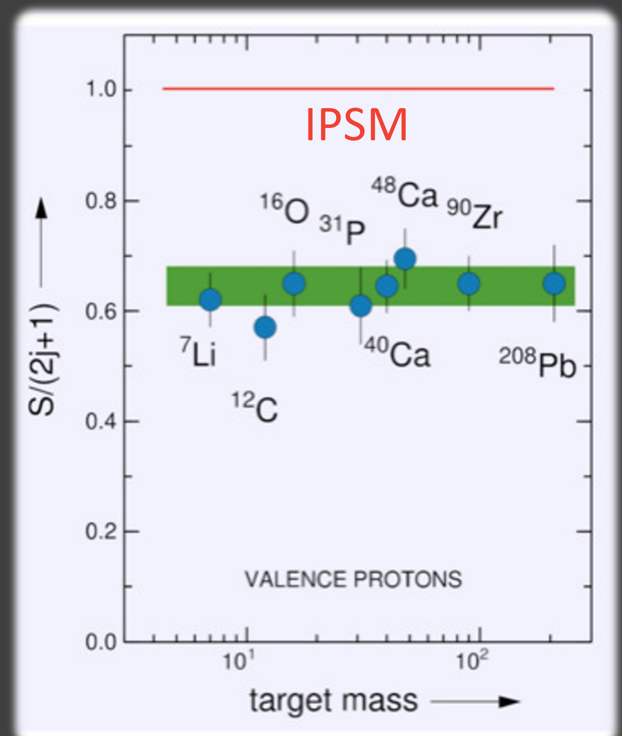


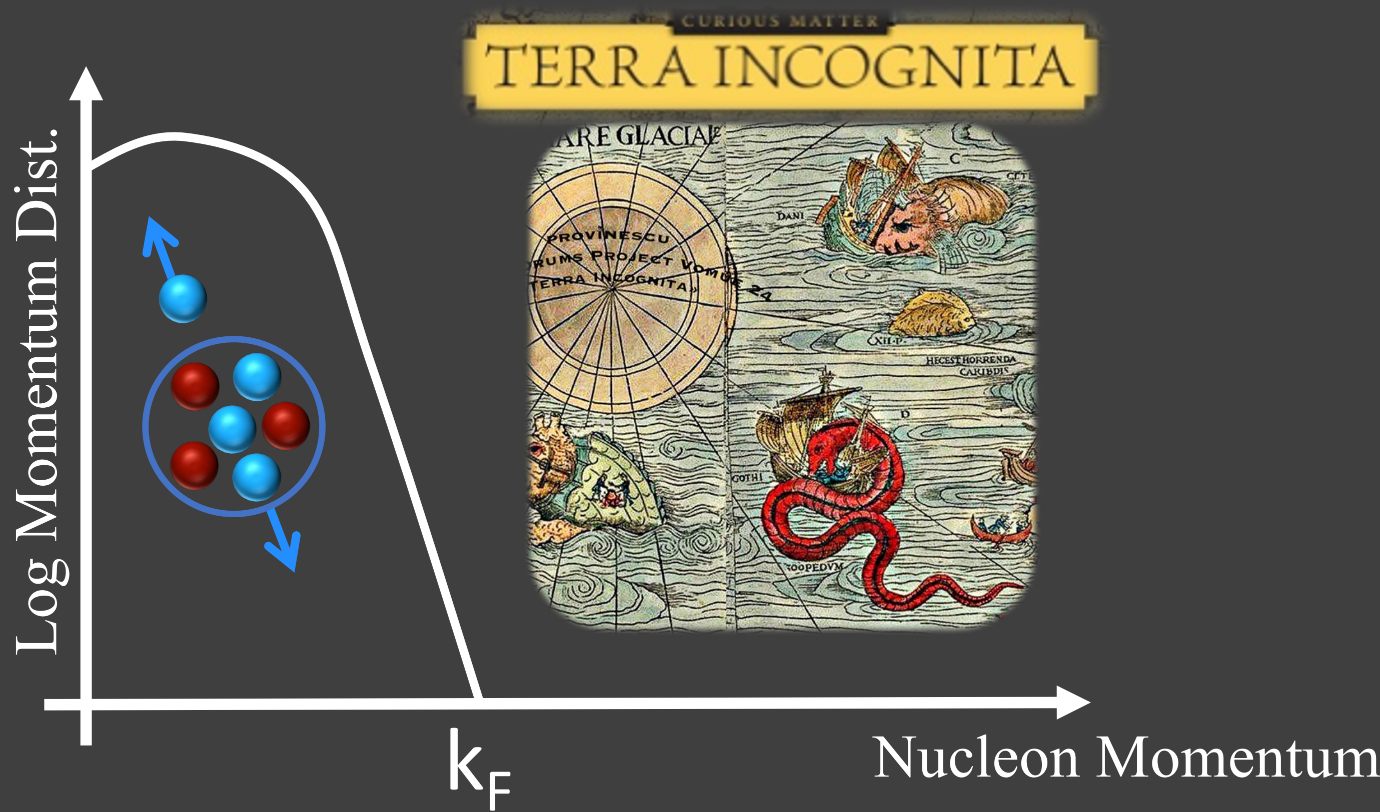
Lapikas Nuc. Phys. A '93

Electron Probes of Nuclei

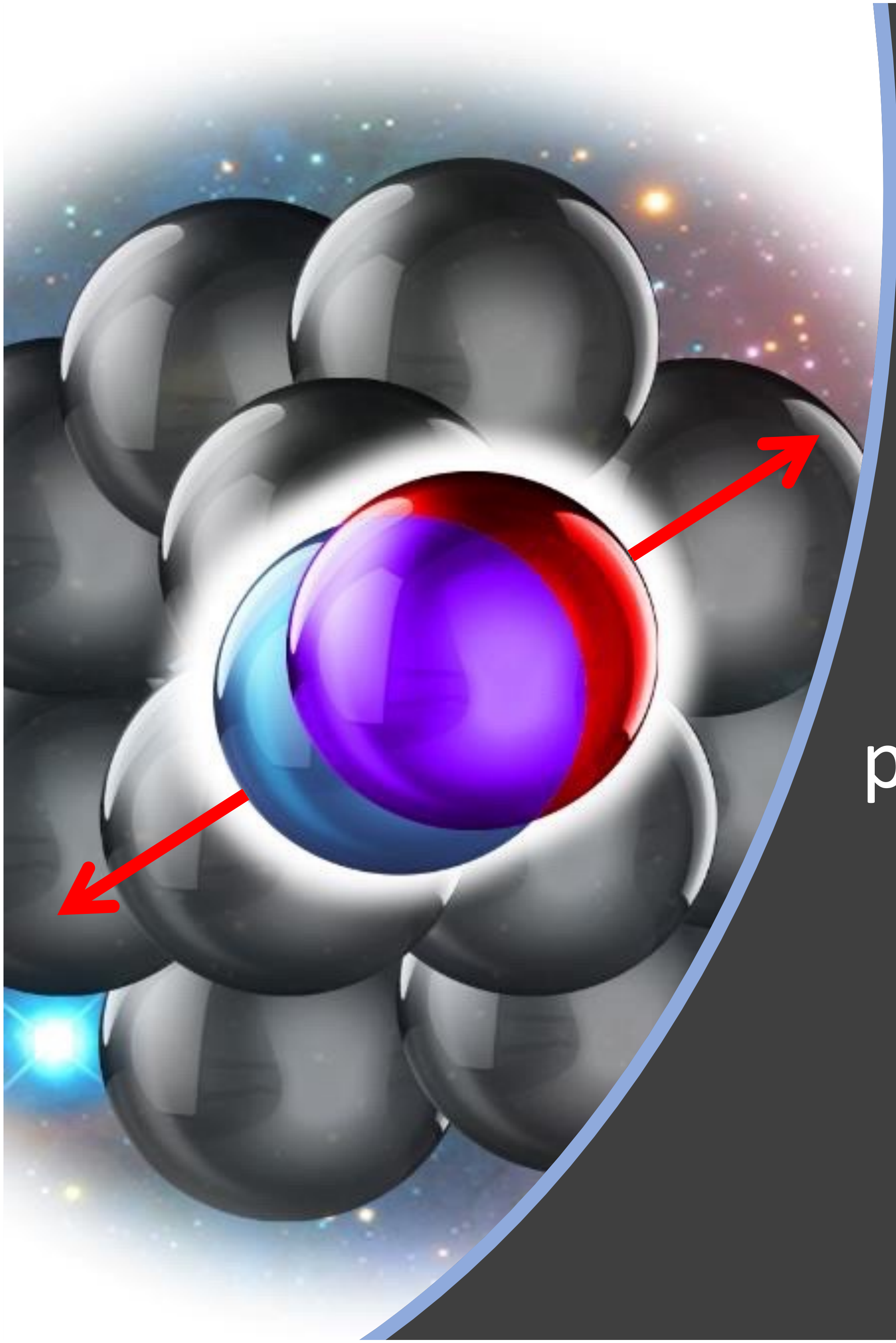








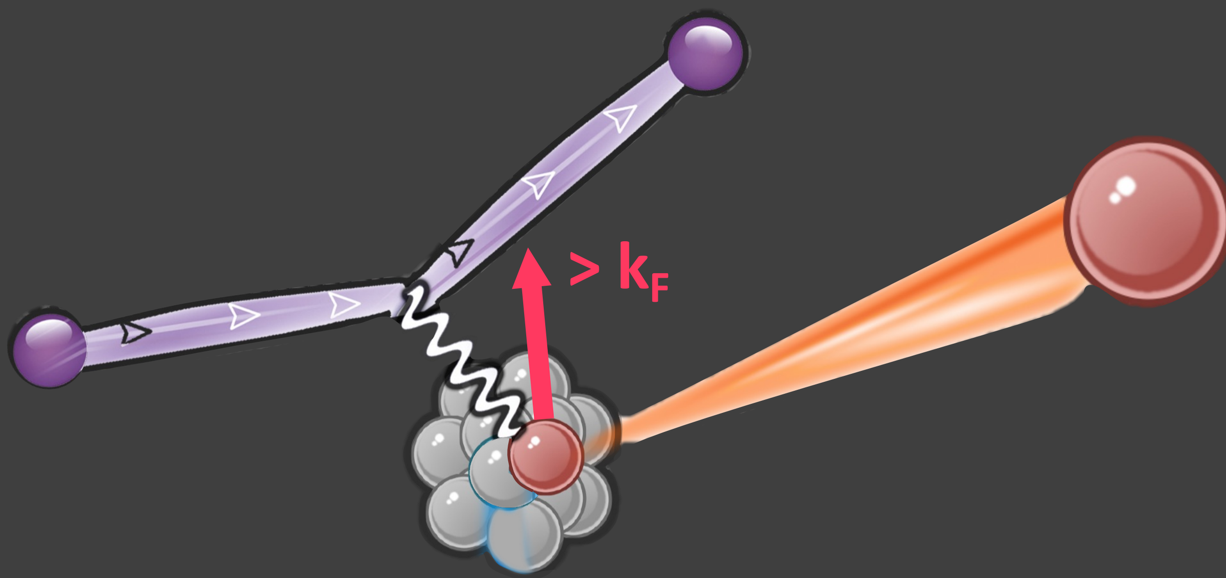
CURIOUS MATTER
TERRA INCOGNITA
Log Momentum Dist.
k_F
Nucleon Momentum

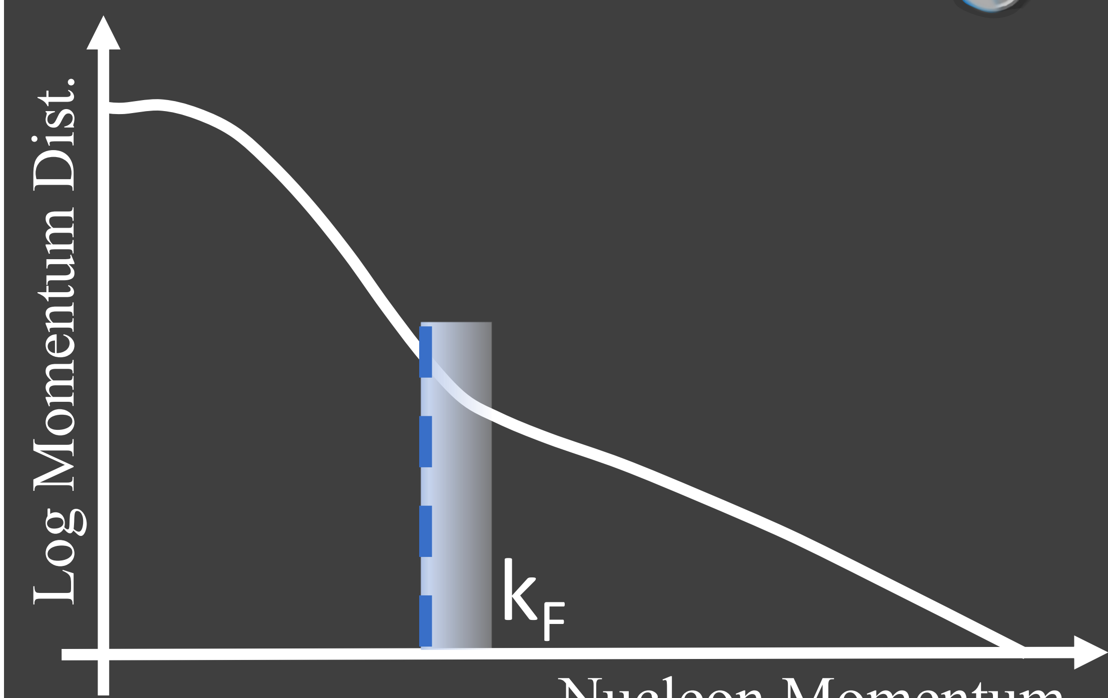


Short-Range Correlations (SRC)

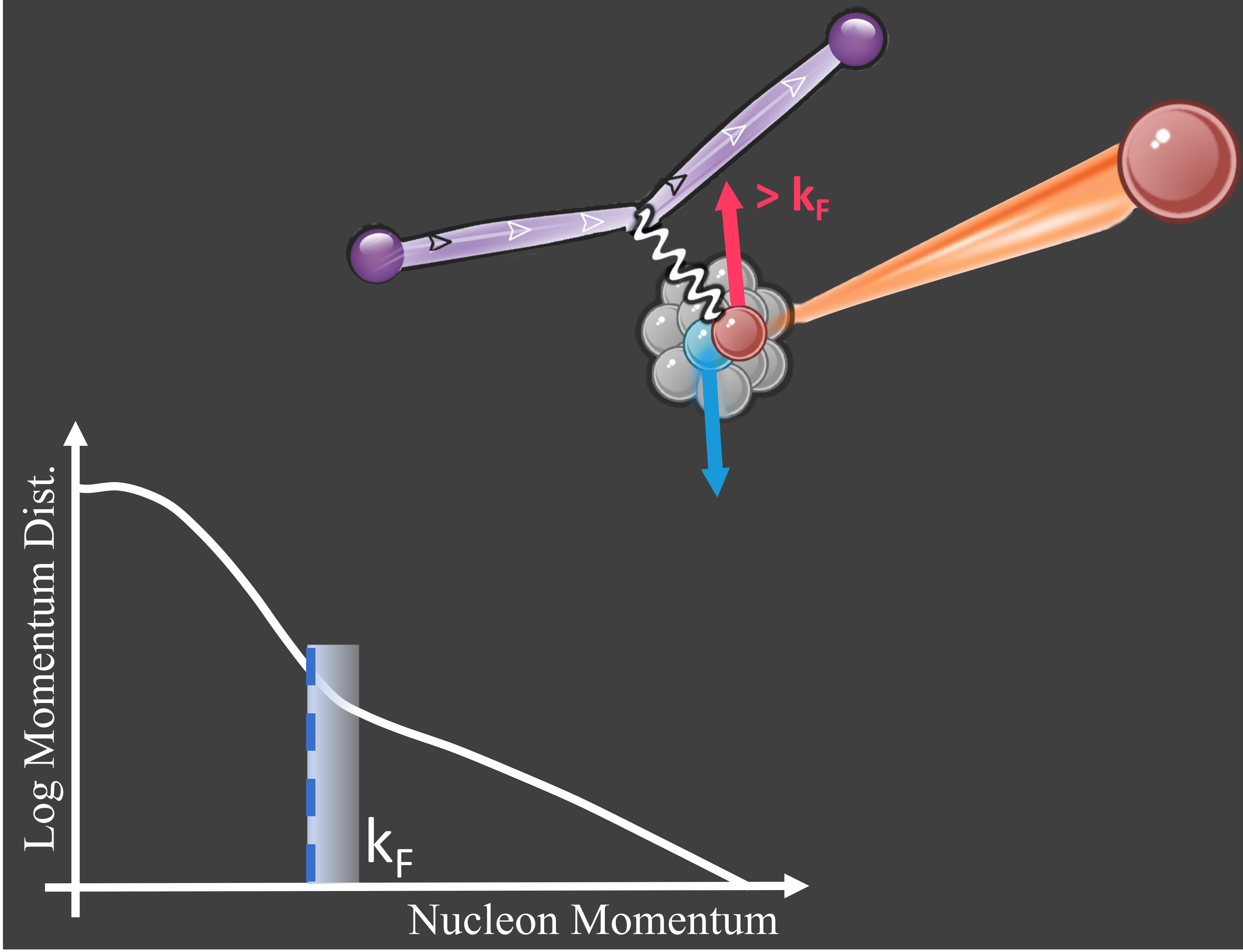
Fluctuations of close-proximity nucleon pairs

Probing SRCs

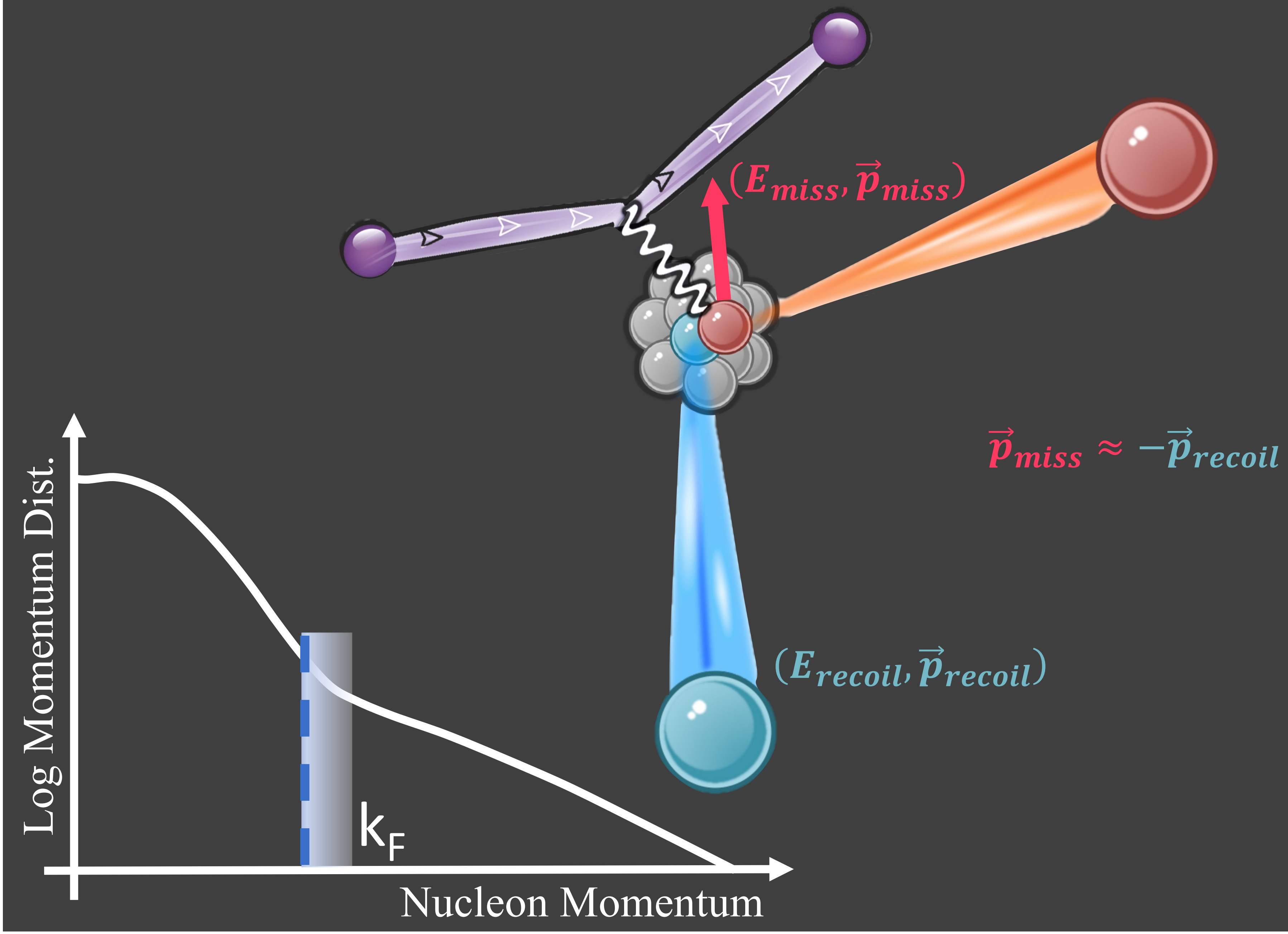




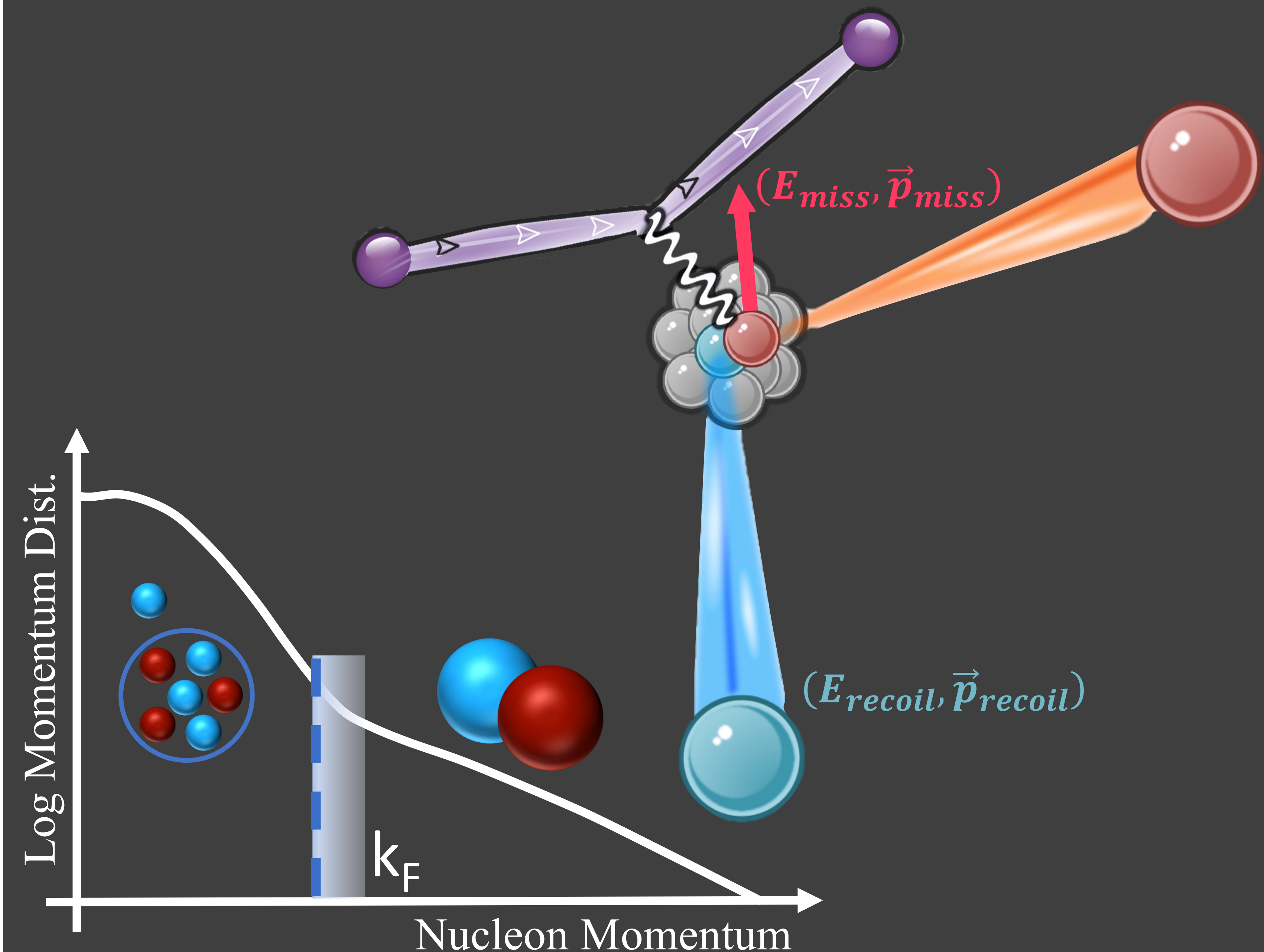
Probing SRCs



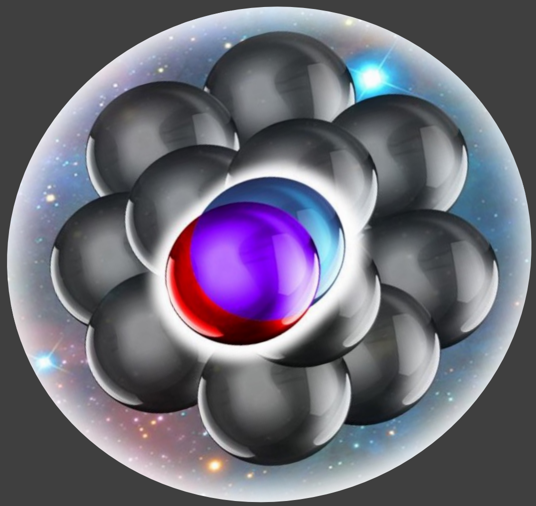
Probing SRCs



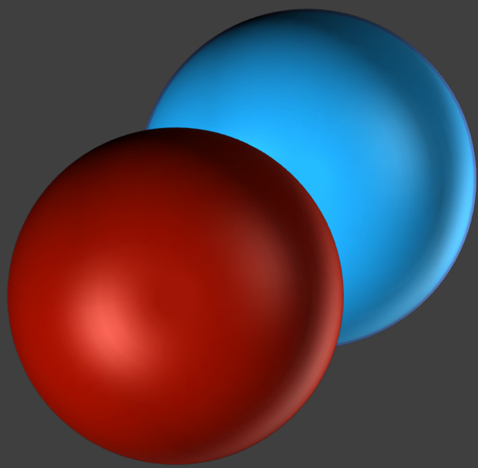
Probing SRCs



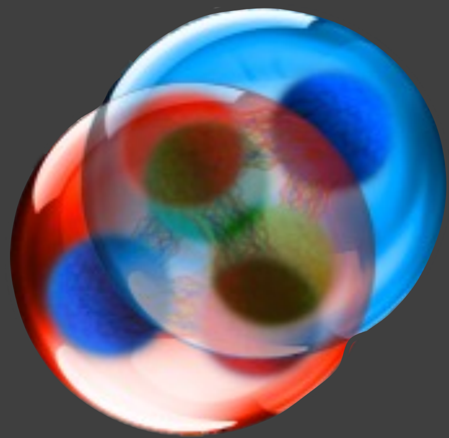
Nuclear many-body challenge

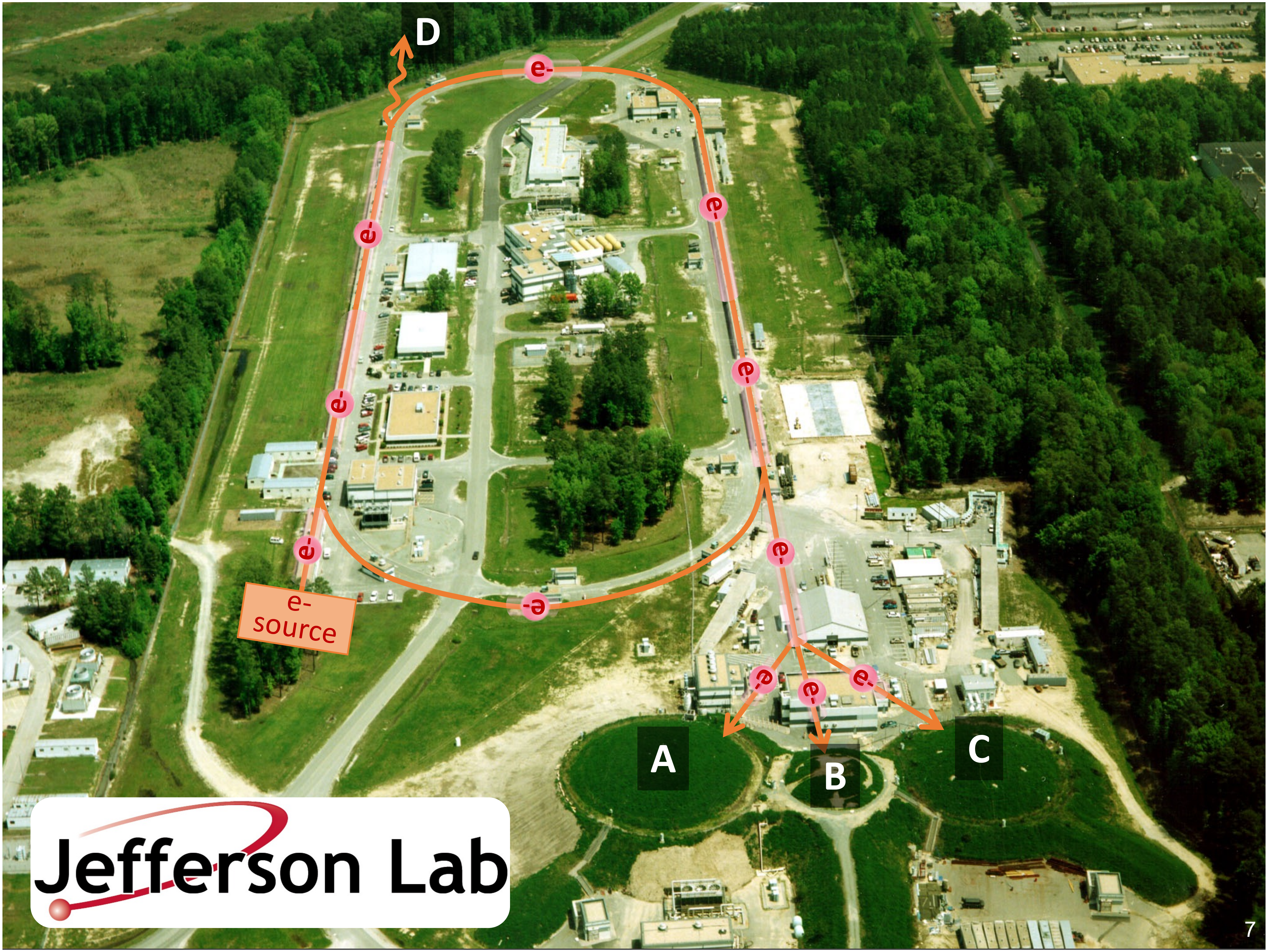


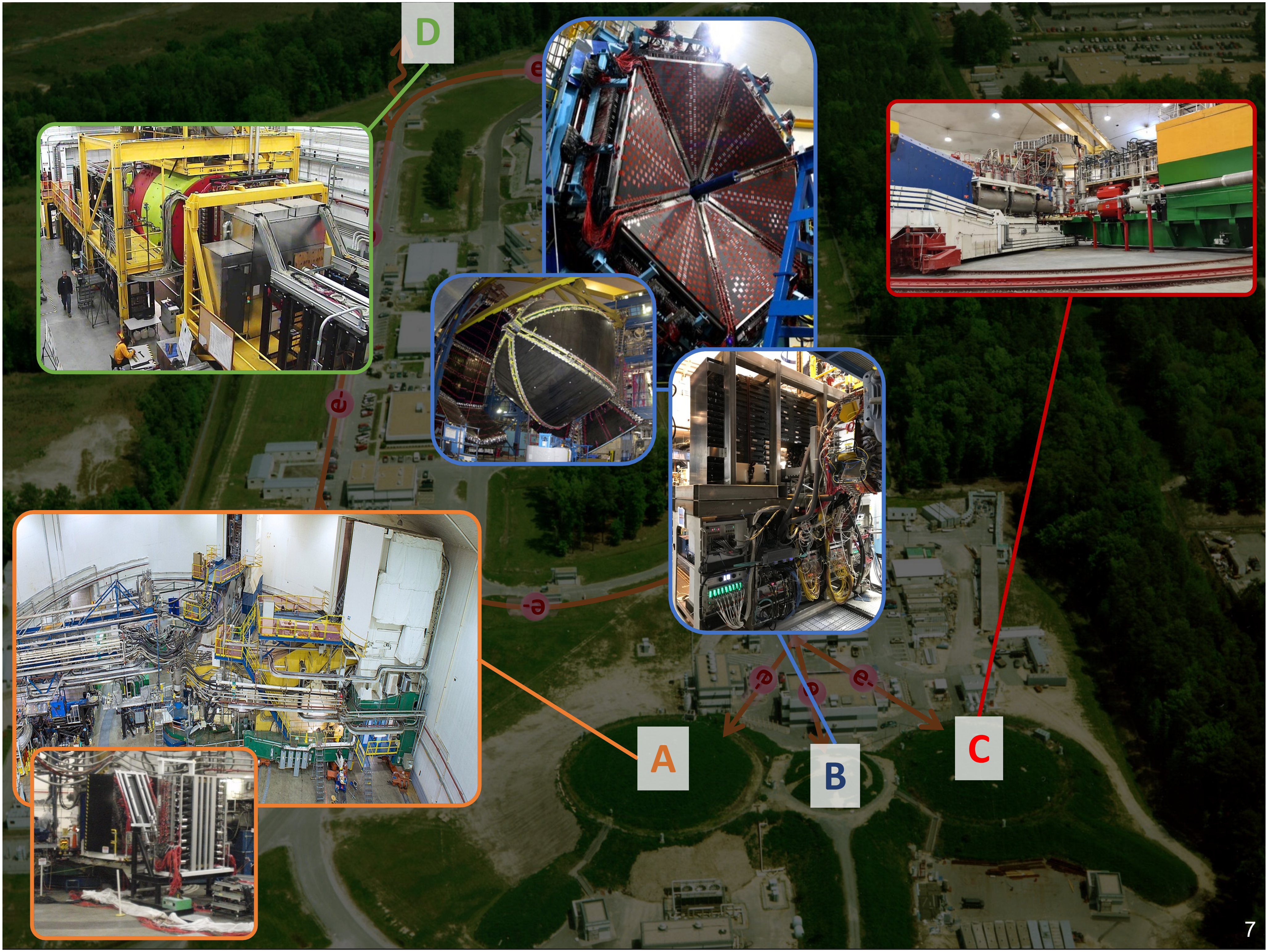
Nucleon-nucleon interaction



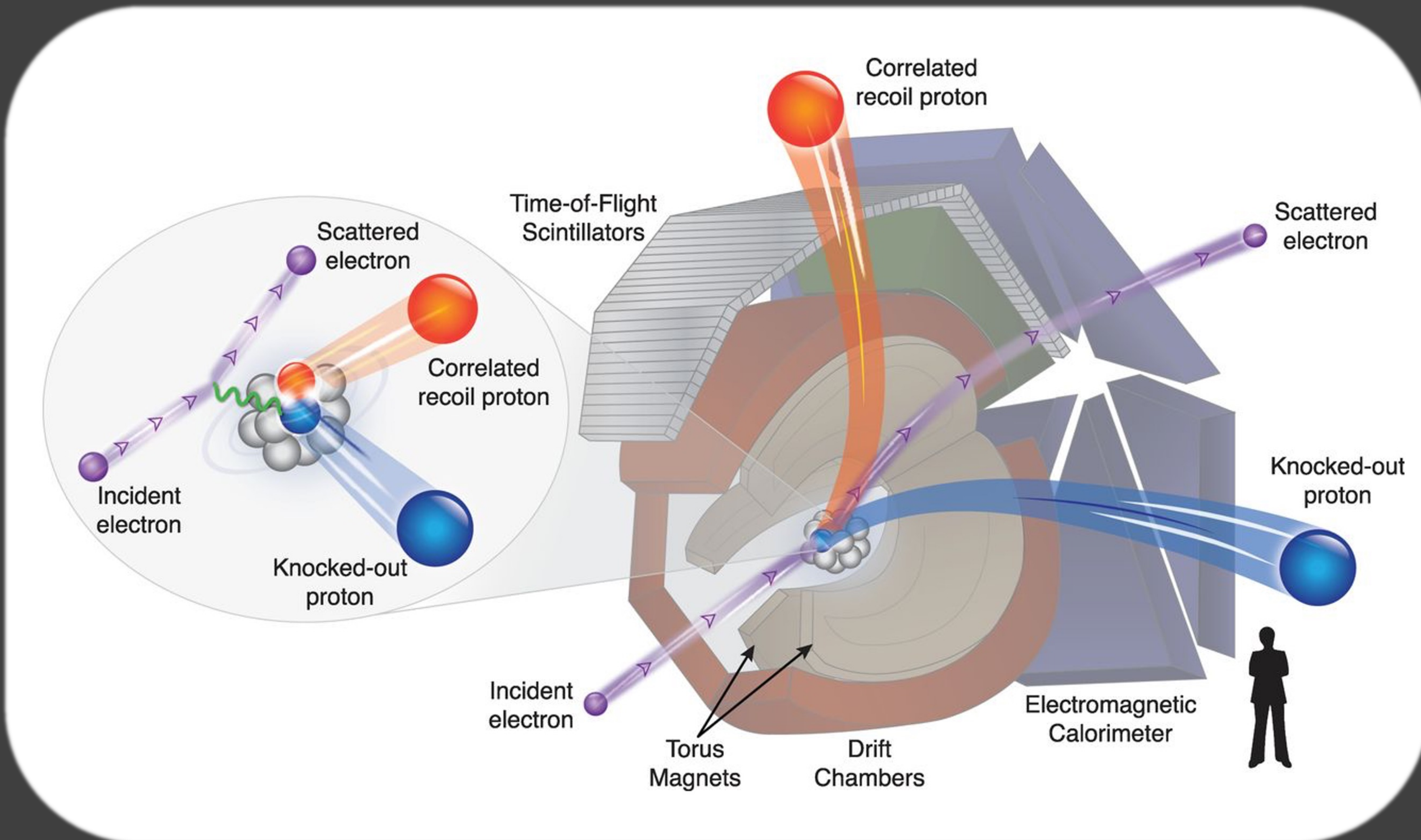
Quark-gluon structure of nuclei

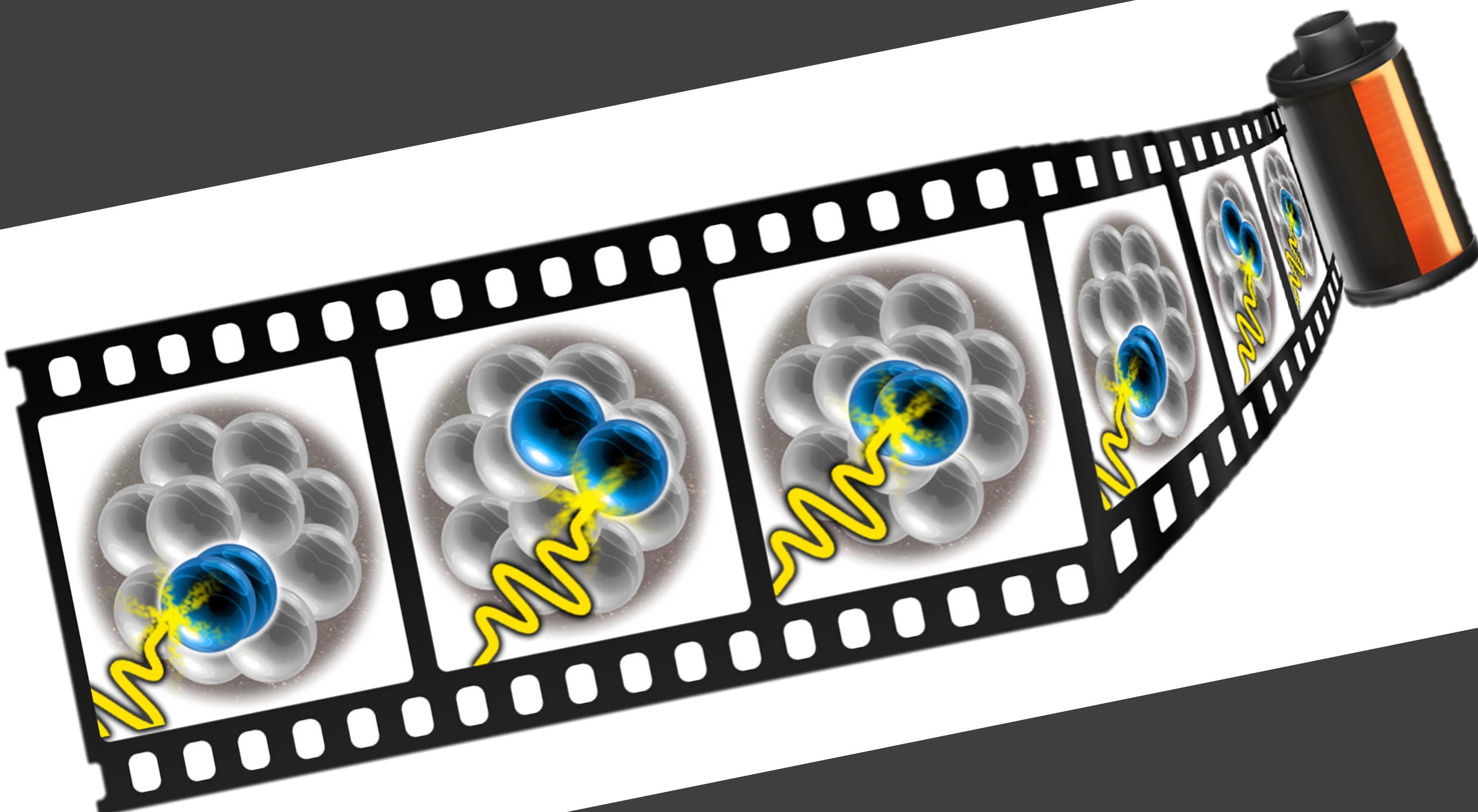


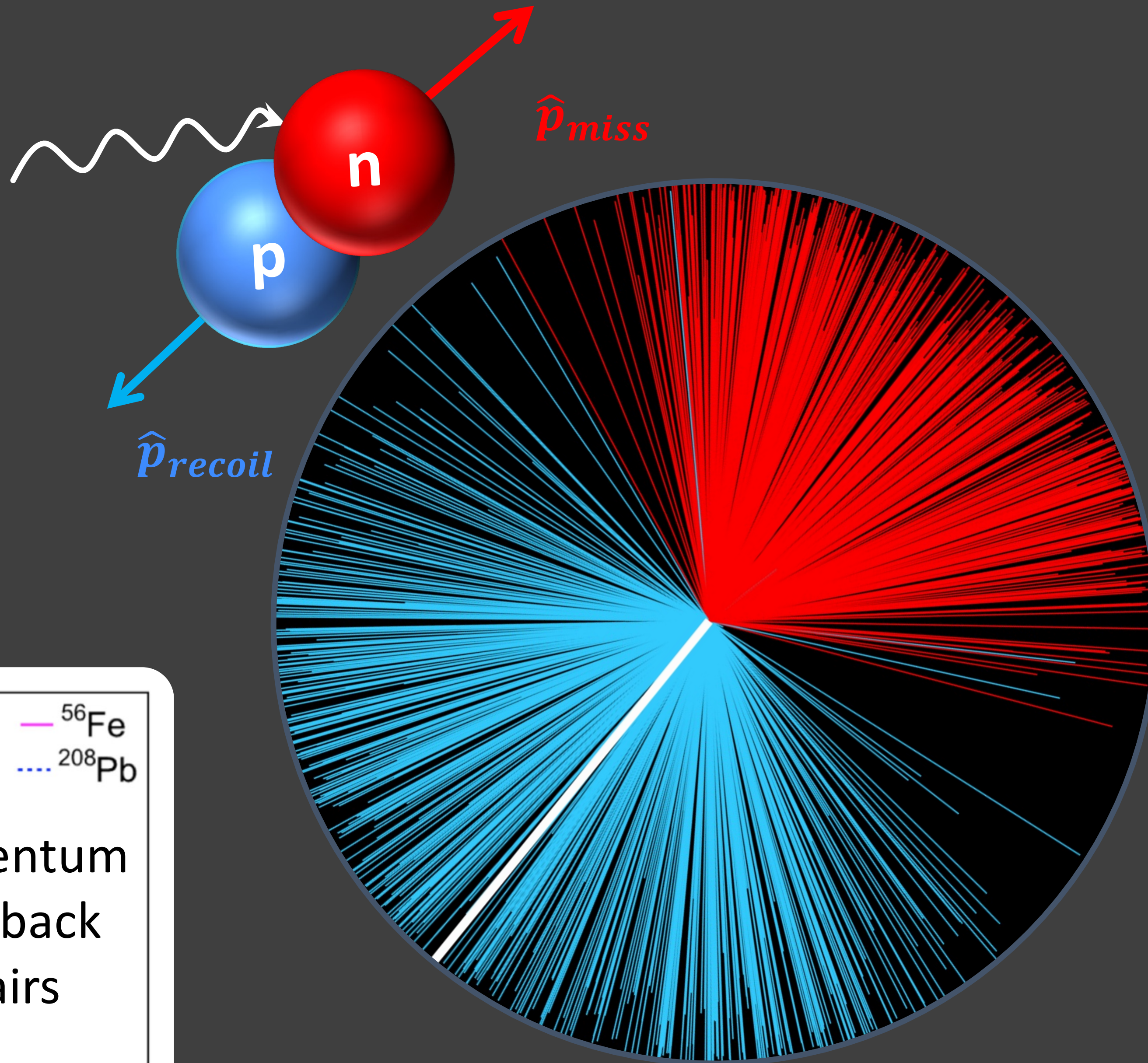

D
e-
e- source
A
B
C
Jefferson Lab

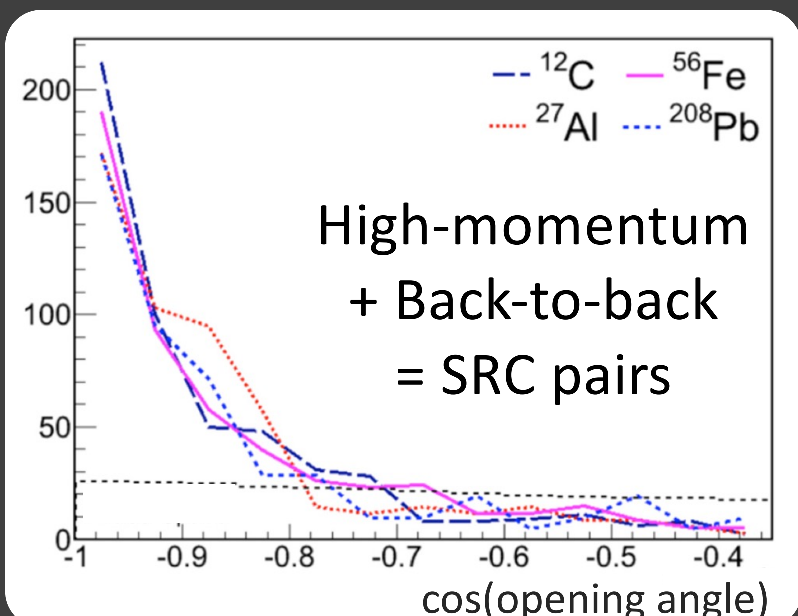

D
A
B
C

Jefferson Lab CLAS (Hall B)





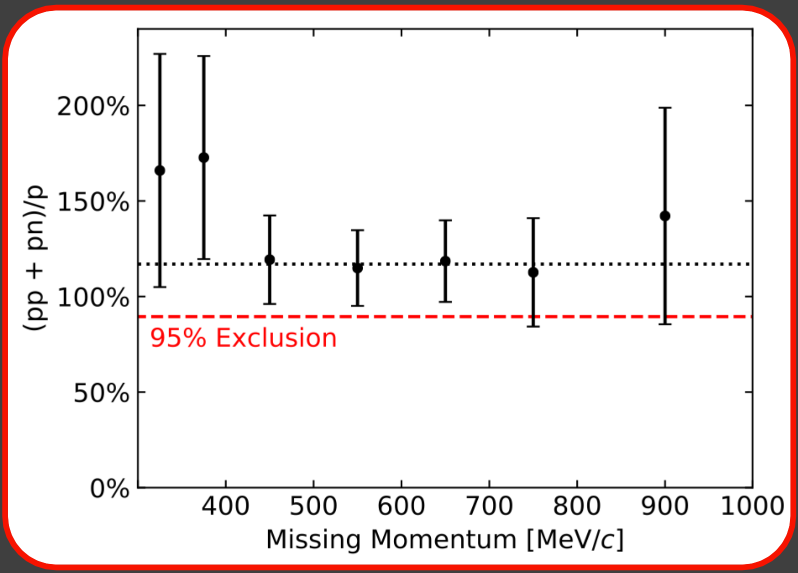




Hen et al., Science 2014

Short-Range Correlations (SRC)

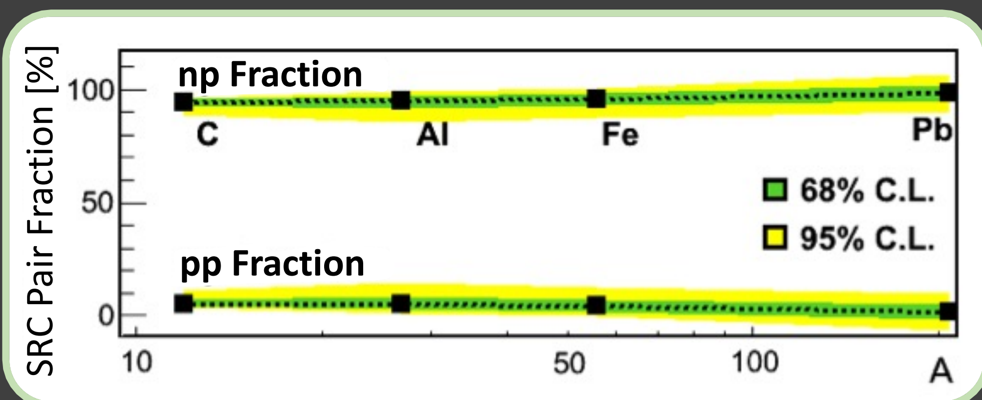
- Produce high-momentum states(>k_F)
- Predominantly neutron-proton pairs
- Universal Deuteron-like Scaling
- Scale separated from residual system



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

Short-Range Correlations (SRC)

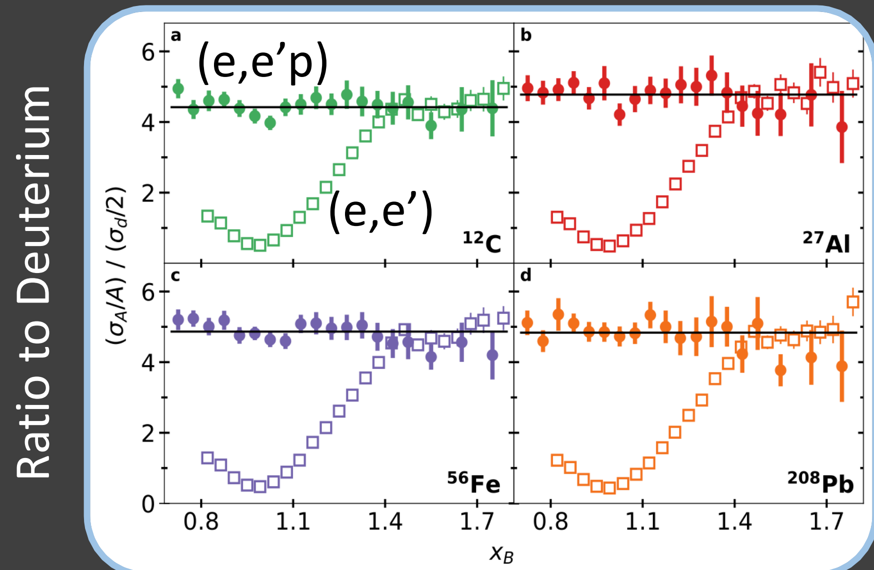
- Produce high-momentum states(>k_F)
- Predominantly neutron-proton pairs
- Universal Deuteron-like Scaling
- Scale separated from residual system

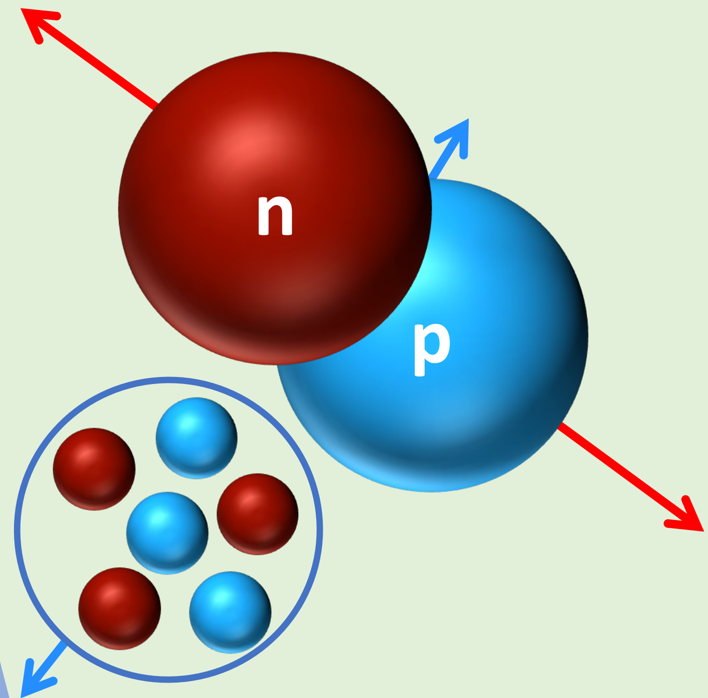


Korover PLB ‘21; Duer PRL ‘19; Duer Nature ’18; Hen Science ‘14; Korover PRL ‘14; Subedi Science ’08; Shneor PRL ’07; Piasetzky PRL ‘06; Tang PRL ‘03; Review: Hen RMP ‘17

Short-Range Correlations (SRC)

- Produce high-momentum states(>k_F)
- Predominantly neutron-proton pairs
- Universal Deuteron-like Scaling
- Scale separated from residual system



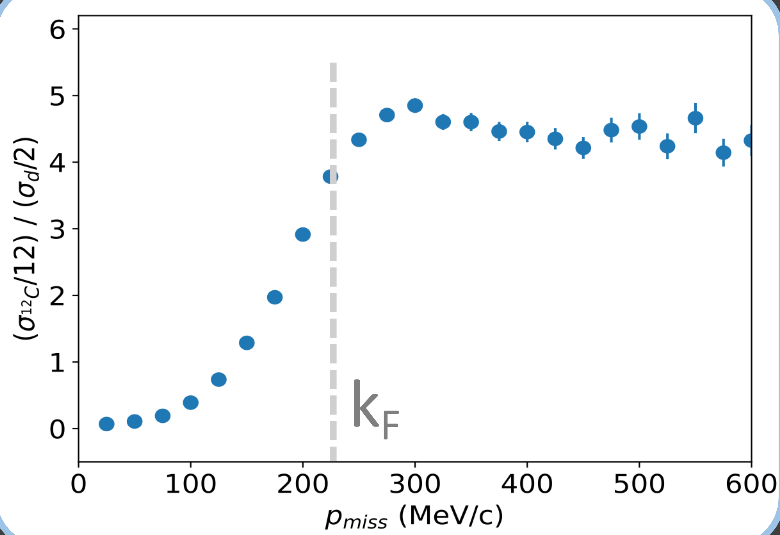


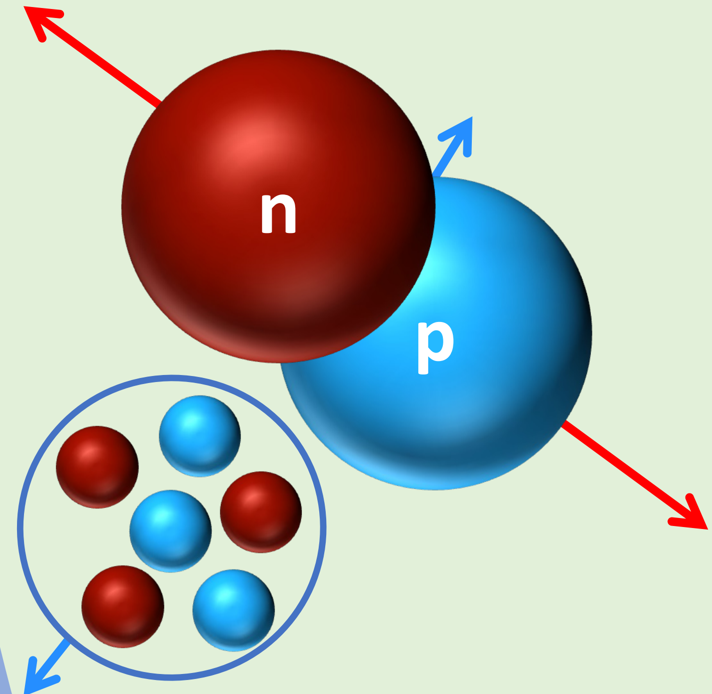
Korover and Denniston et al., PRC Lett. (2023)

Short-Range Correlations (SRC)

- Produce high-momentum states(>k_F)
- Predominantly neutron-proton pairs
- Universal Deuteron-like Scaling
- Scale separated from residual system

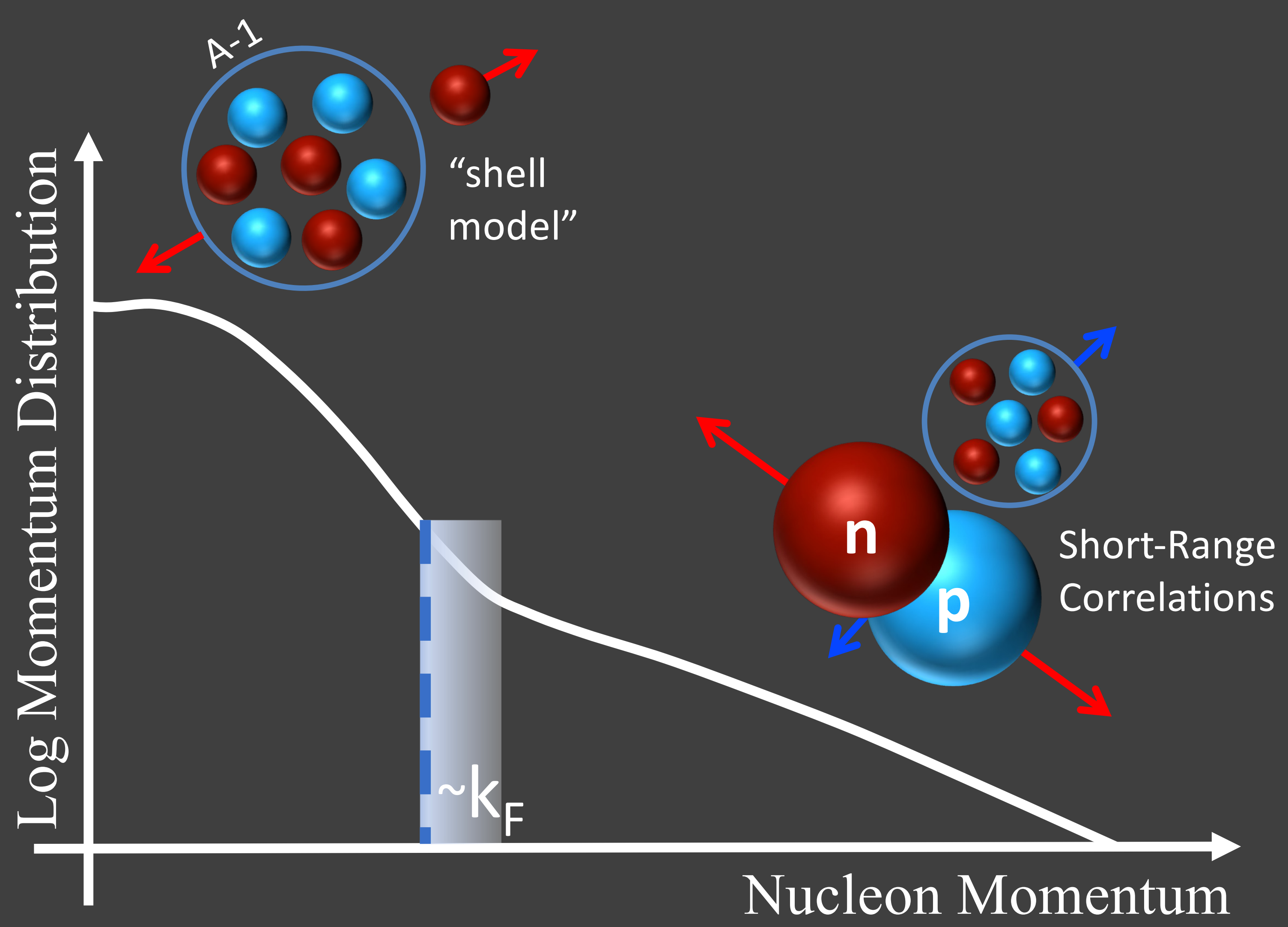
Ratio to Deuterium

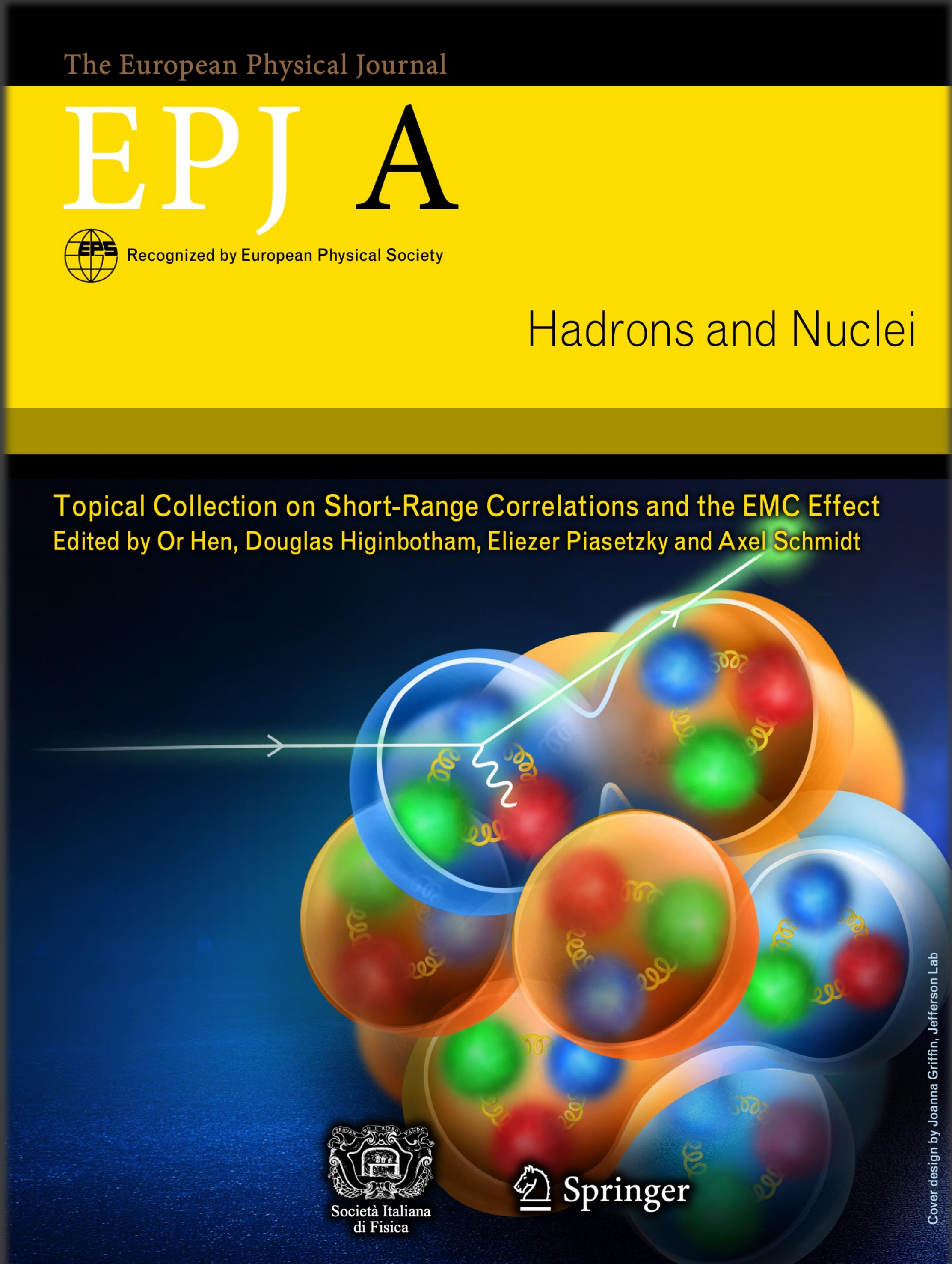




Korover and Denniston et al., PRC Lett. (2023)

The Two-Phased Nucleus





Isospin Structure:

Phys. Rev. Lett. 122, 172502 (2019)
Nature 560, 617 (2018)
Science 346, 614 (2014)
Phys. Rev. Lett. 113, 022501 (2014)

C.M. Motion:

Phys. Rev. Lett. 121, 092501 (2018)

Hard-Reaction Dynamics:

Nature Physics 17, 693 (2021)
Phys. Lett. B 797, 134792 (2019)
Phys. Lett. B 722, 63 (2013)

Nuclei / Nuclear Matter Properties:

Phys. Lett. B 800, 135110 (2020)
Phys. Lett. B 793, 360 (2019)
Phys. Lett. B 785, 304 (2018)
Phys. Rev. C 91, 025803 (2015)

Effective Theory:

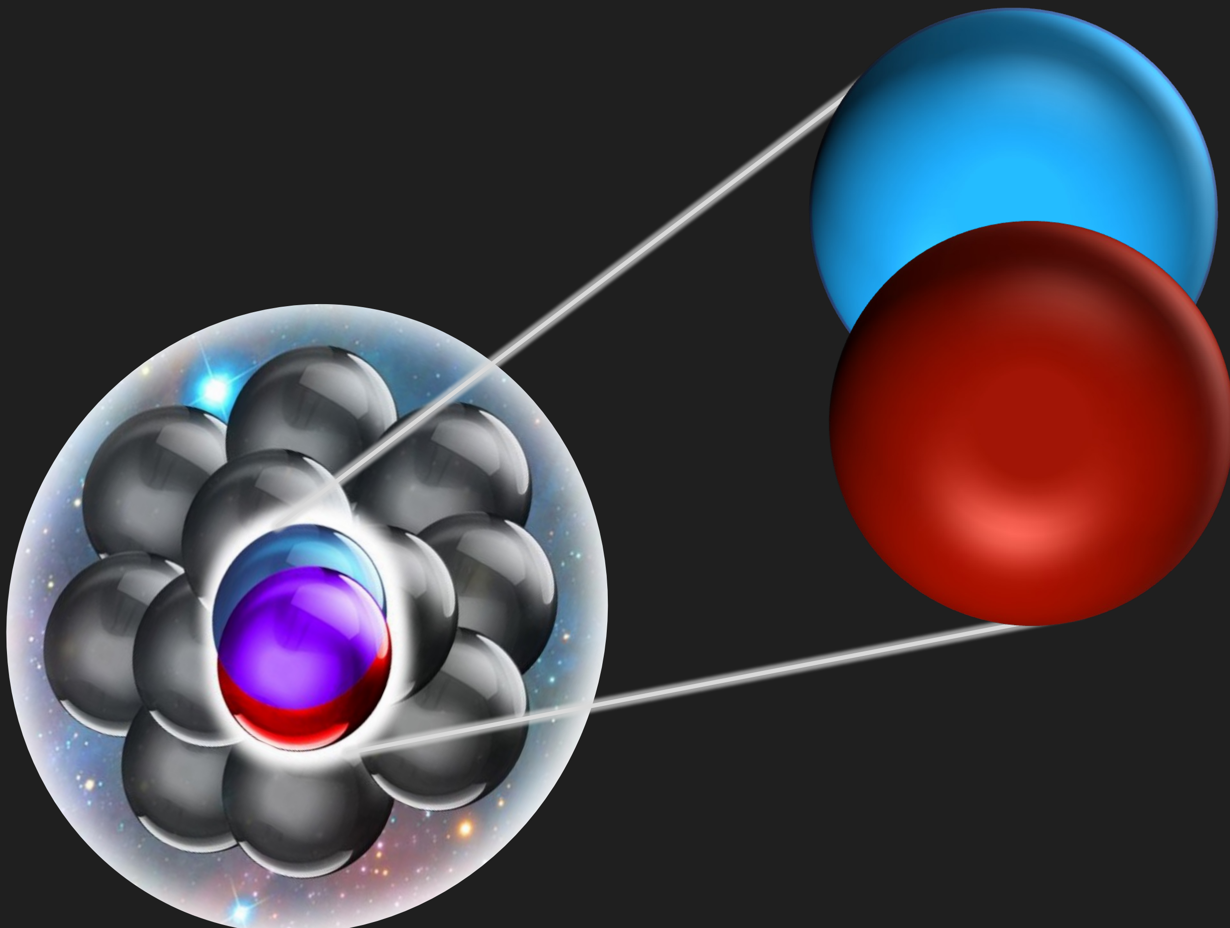
Nature Physics 17, 306 (2021)
Phys. Lett. B 805, 135429 (2020)
Phys. Lett. B 791, 242 (2019)

Quantum Numbers, Mass, Asymmetry Dependence:

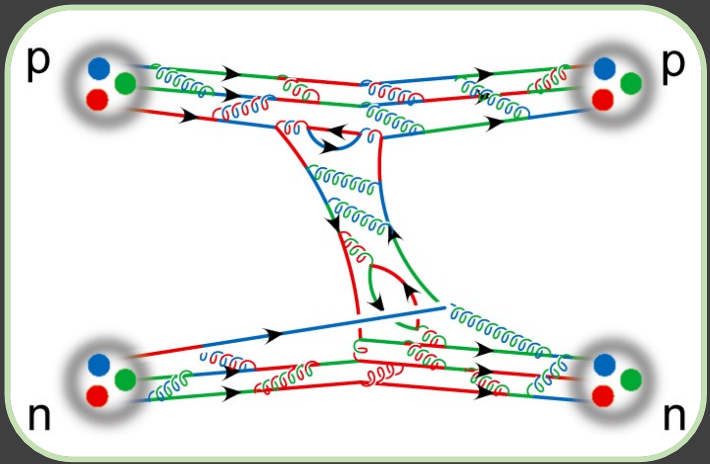
Phys. Rev. C 103, L031301 (2023)
Phys. Lett. B 780, 211 (2018)
PRC 92, 024604 (2015)
PRC 92, 045205 (2015)

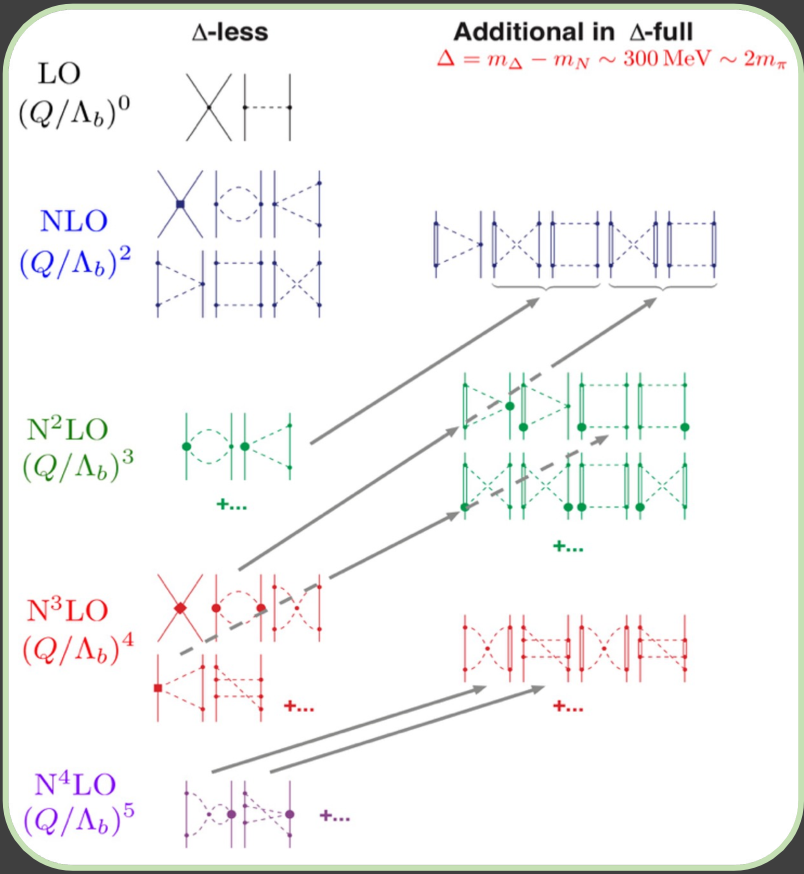
➔ The Nucleus as a lab for high-density matter states!

Probing the NN interaction at short distances



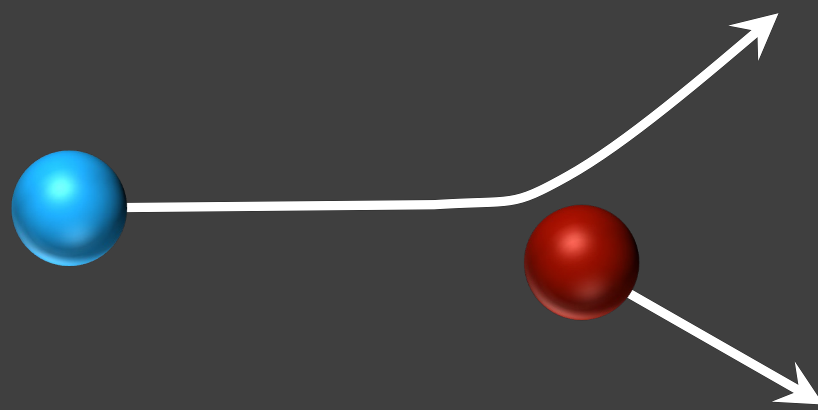
Effective Nucleon-Nucleon Interactions

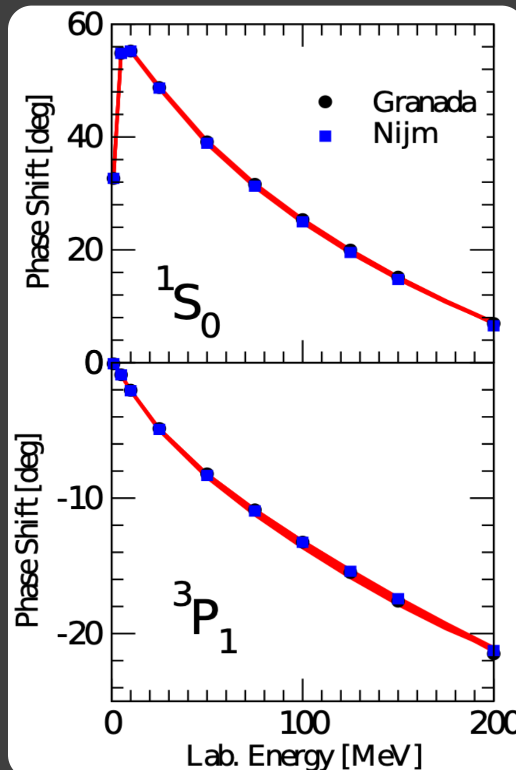




Models Need Experimental Constraints

- Model parameters constrained by data*
- Direct constraints below 400 MeV/c (π threshold)
- Higher momenta (shorter distance) not directly constrained / tested

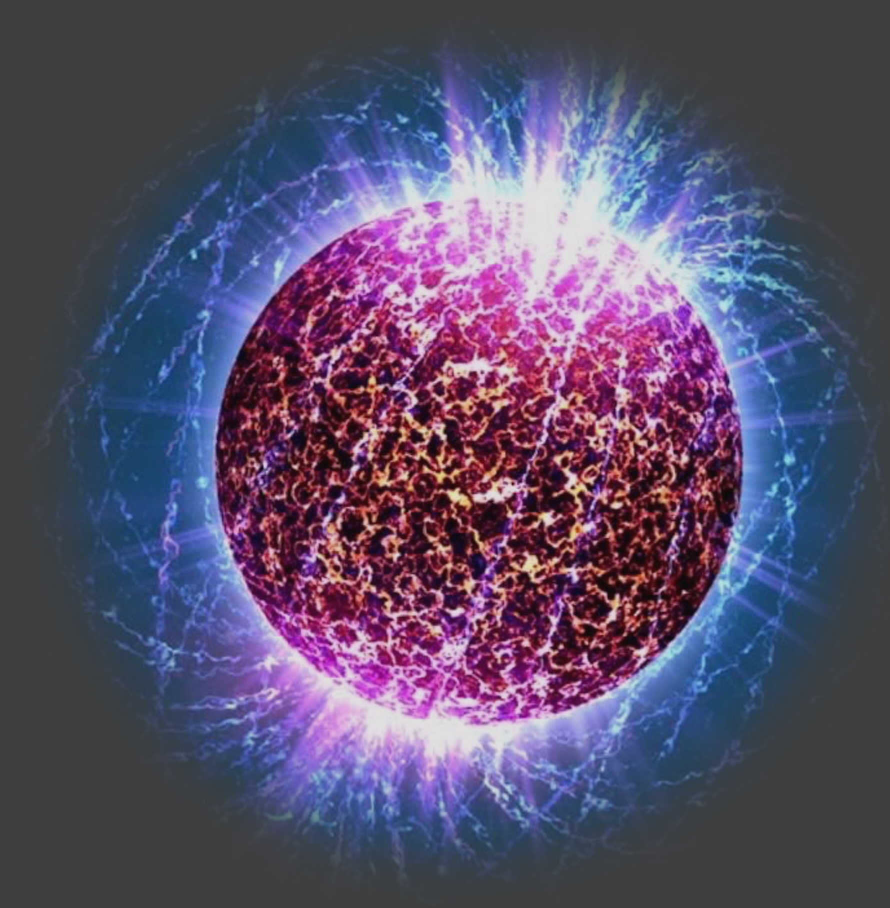




*Recently also lattice QCD

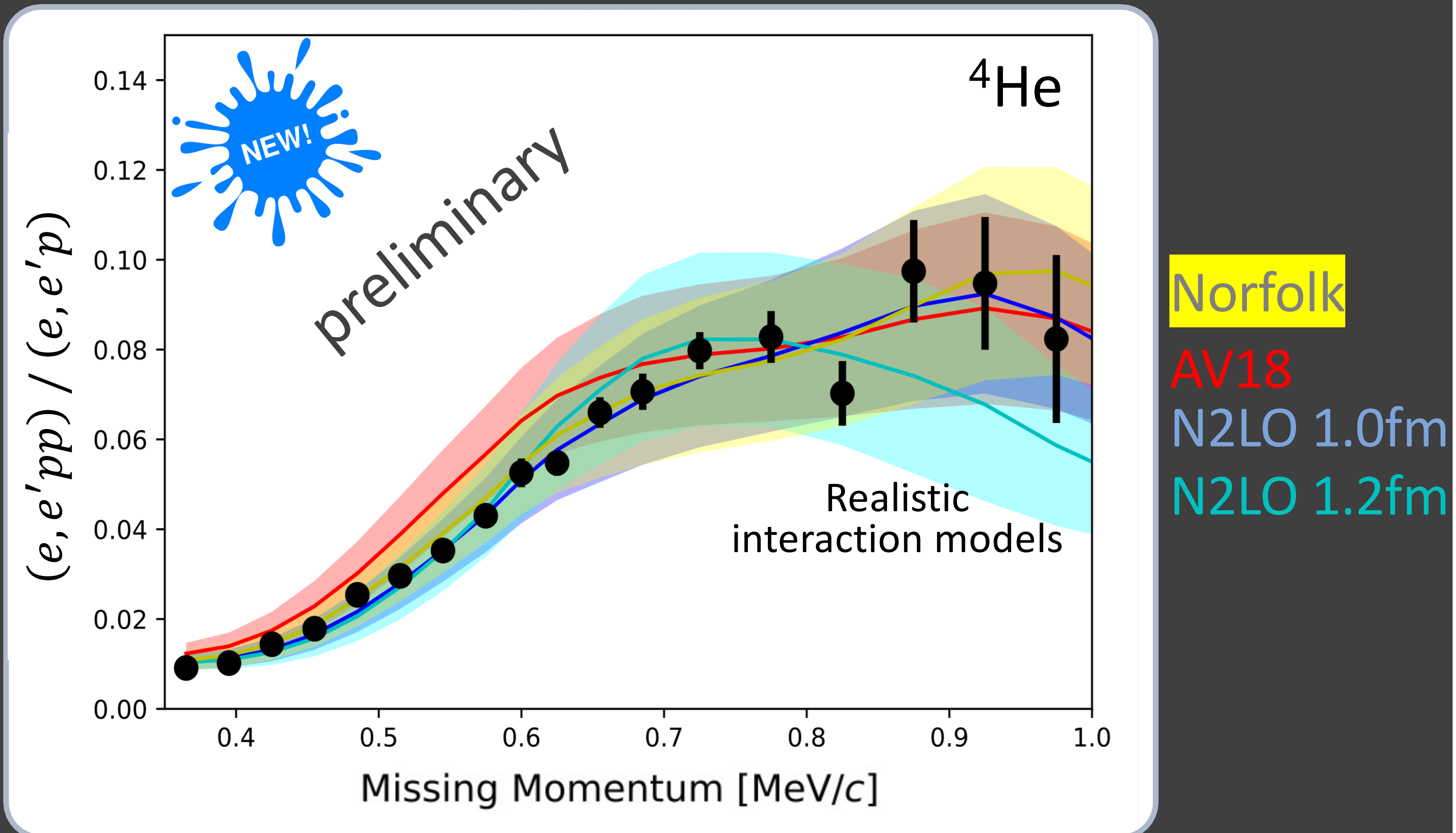
Models Need Experimental Constraints

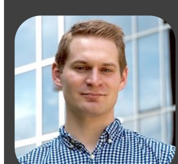
- Model parameters constrained by data*
- Direct constraints below 400 MeV/c (π threshold)
- Higher momenta (shorter distance) **not directly constrained / tested**

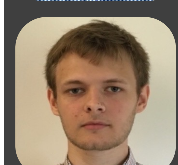


*Recently also lattice QCD

Probing the Repulsive Core

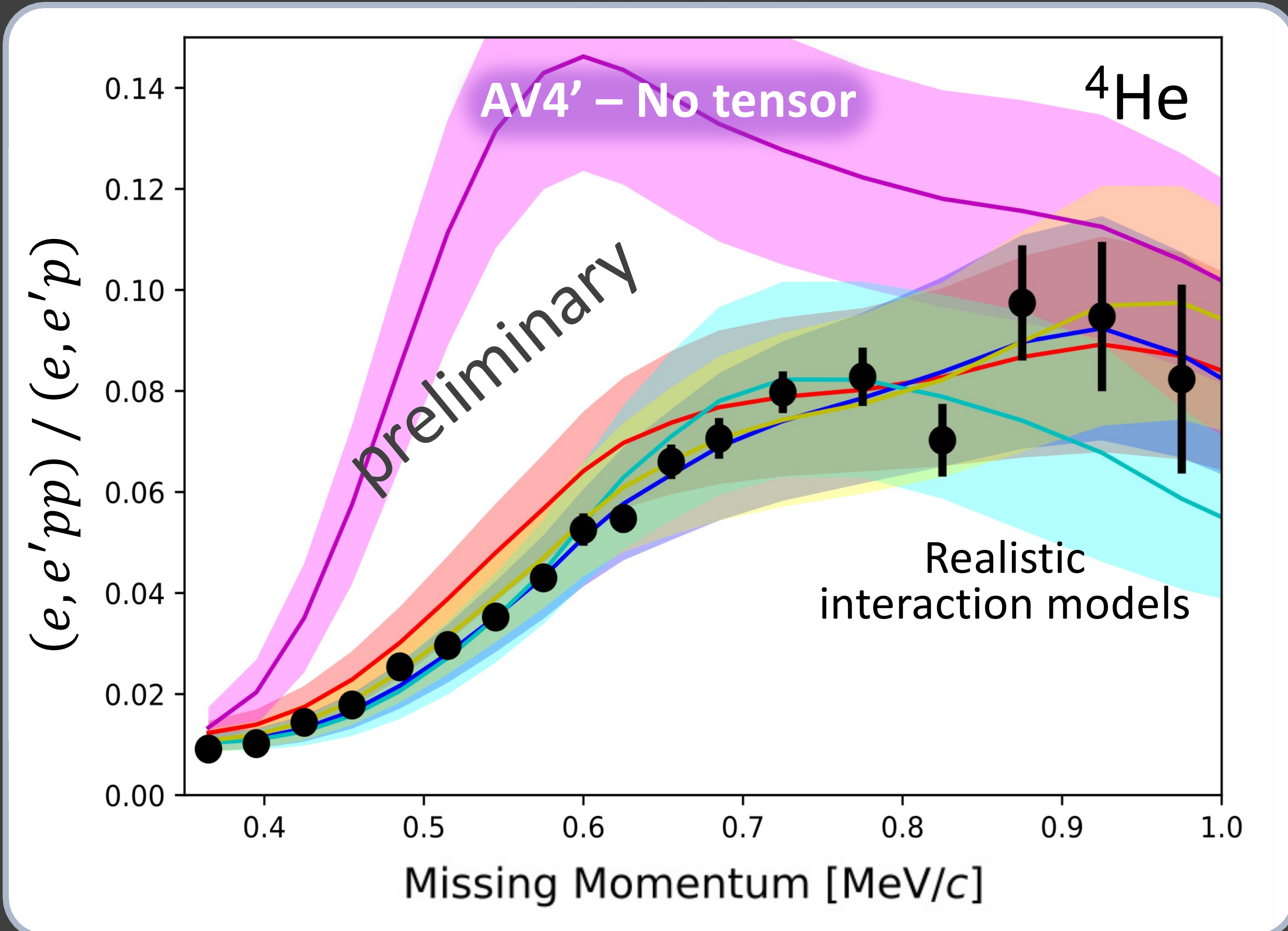




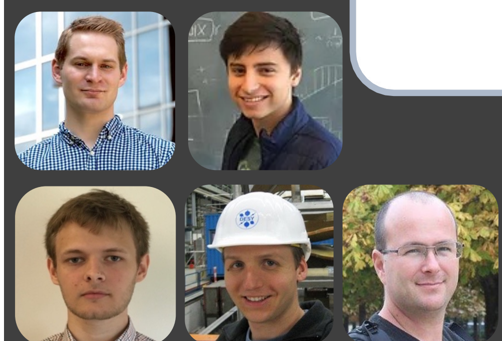


Schmidt and Pybus et al., Nature (2020)
Pybus et al., PLB (2020);
Korover and Pybus et al., PLB (2021)
New high-stat data (2025)

Tensor-to-Scalar Transition!



Norfolk
AV18
N2LO 1.0fm
N2LO 1.2fm



Schmidt and Pybus et al., Nature (2020)
Pybus et al., PLB (2020);
Korover and Pybus et al., PLB (2021)
New high-stat data (2025)

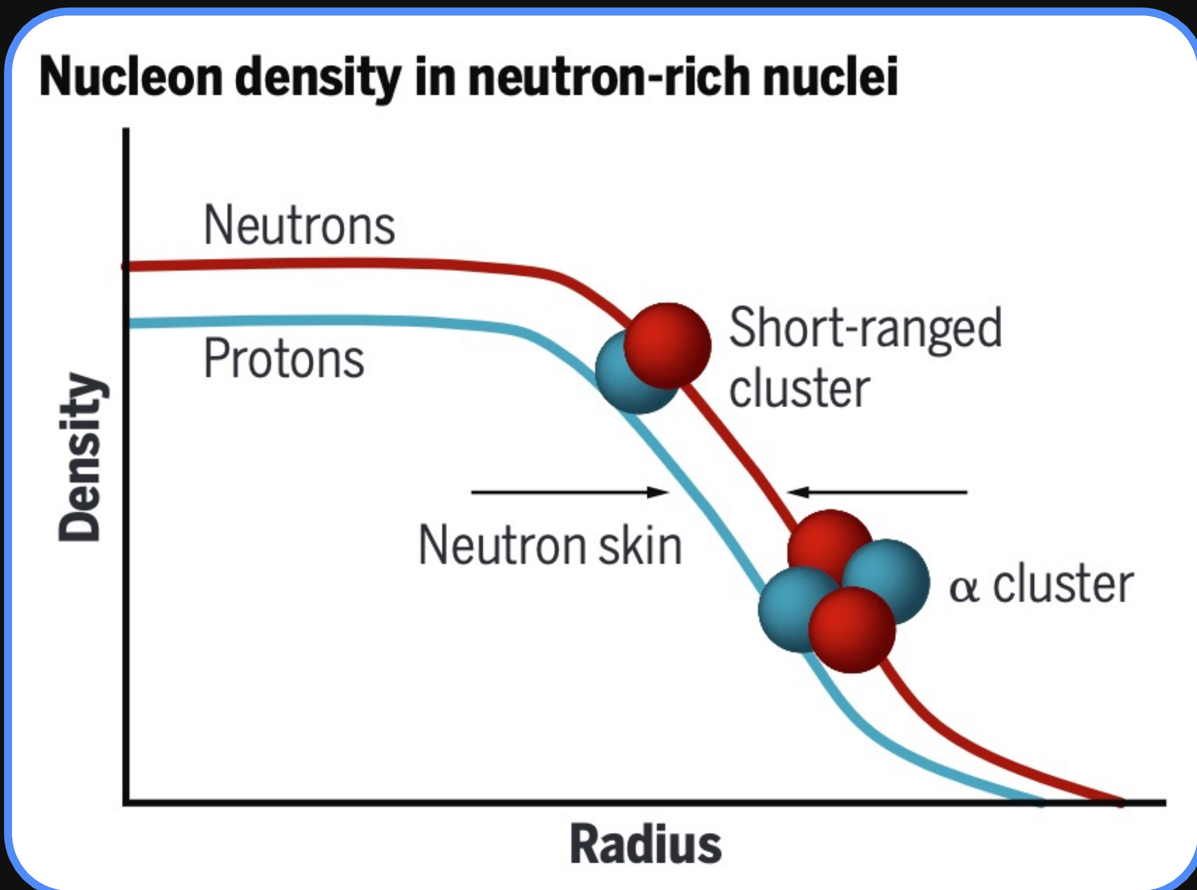
INSIGHTS | PERSPECTIVES

Science AAAS

NUCLEAR PHYSICS

From nuclear clusters to neutron stars

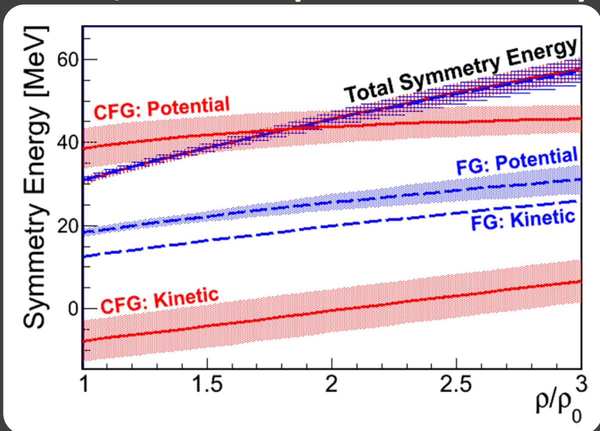
Hen, Science 371, 232 (2021)

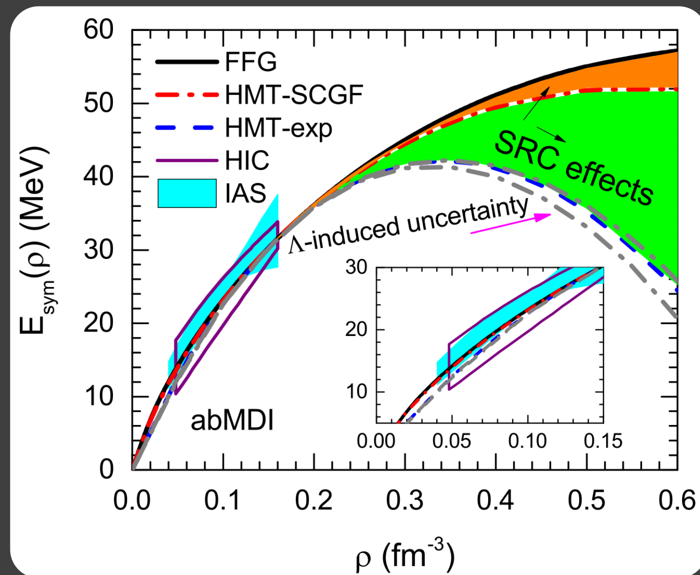


Duer Nature (2018)

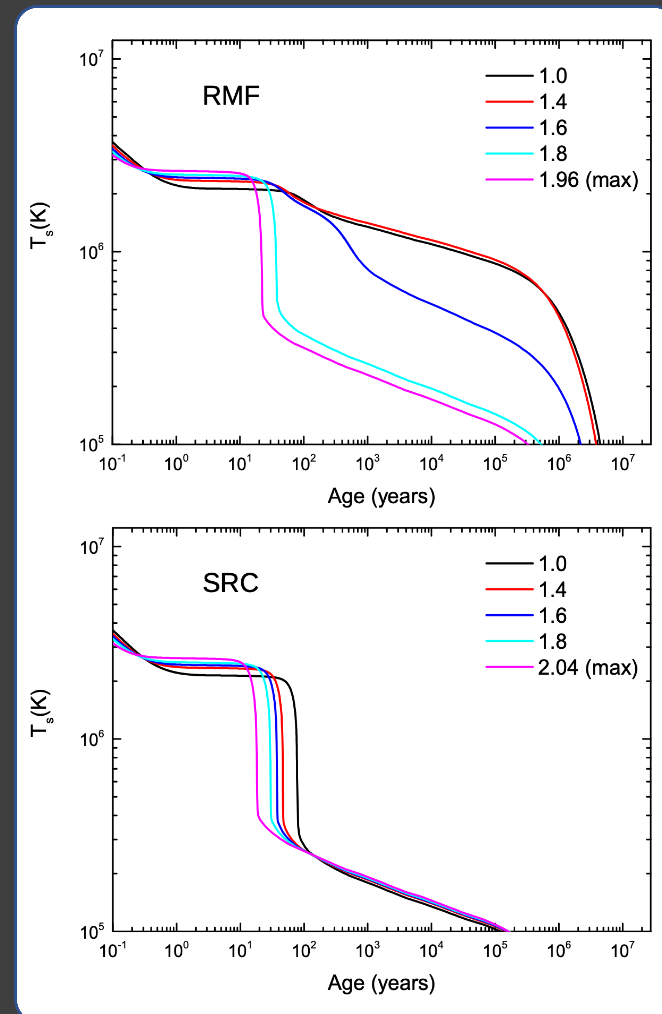
Affects neutron star calculations

Hen+, PRC ’15 (>100 citations)

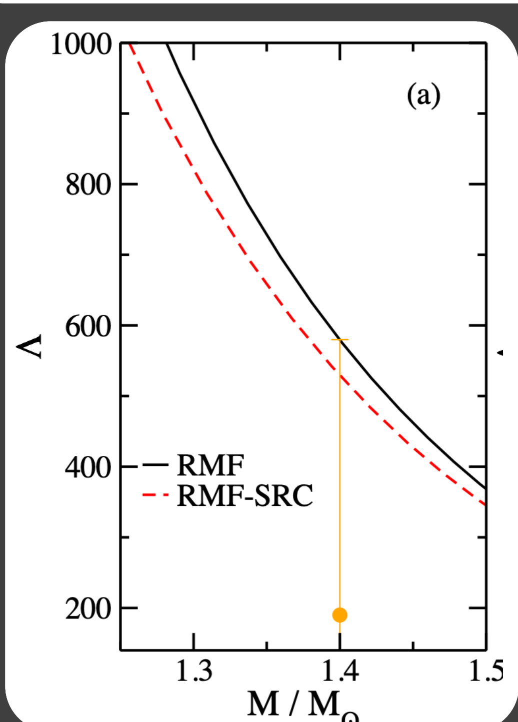




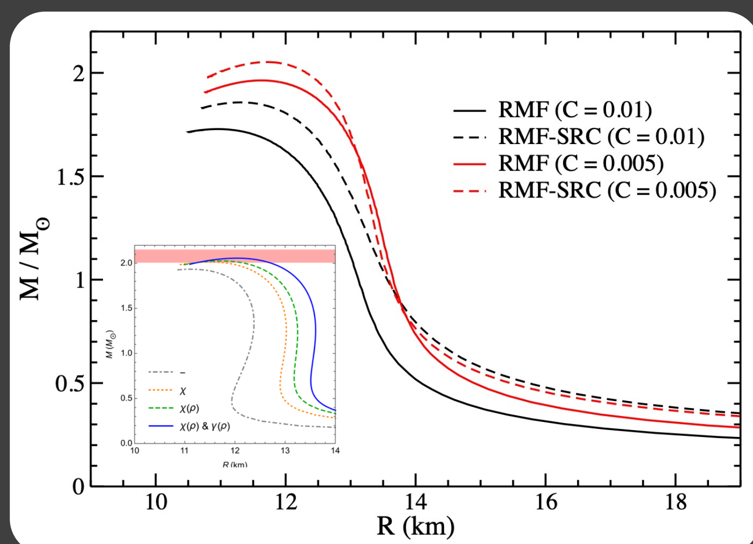
Prog. Part. Nucl. Phys. 99, 29 (2018)
Eur. Phys. J. A 55, 117 (2015)



arXiv 2004.10309



PRC 101, 065202 (2020)
NPA 990, 118 (2019)




HOLD YOUR HORSES

SRC data interpretation relies on a factorization framework for “high-resolution” reactions

Q: Are the extracted “ground states” universal?

SRC data interpretation relays on a factorization framework for “high-resolution” reactions

Q: Are the extracted “ground states” universal?

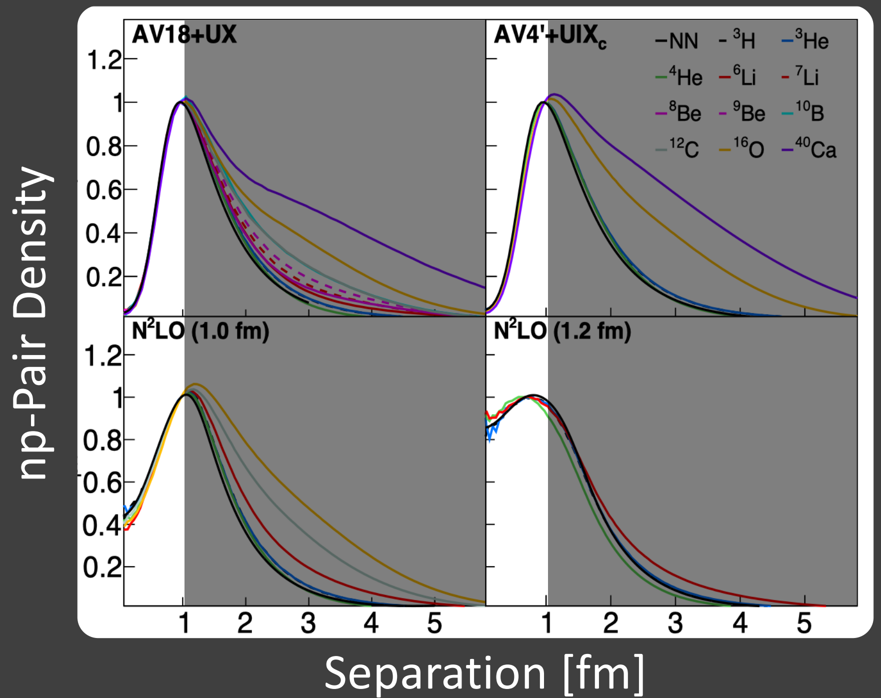
Similar to extracting quark distributions from deep inelastic scattering data

Interlude: Scale Separation and Factorization

$$\rho_A^{NN,\alpha}(r) \underset{r<1\text{ fm}}{\cong} C_A^{NN,\alpha} \times |\psi_{NN}^{\alpha}(r)|^2$$

Total Dist. = Constant x Two-body

(Low-Energy) (High-Energy)

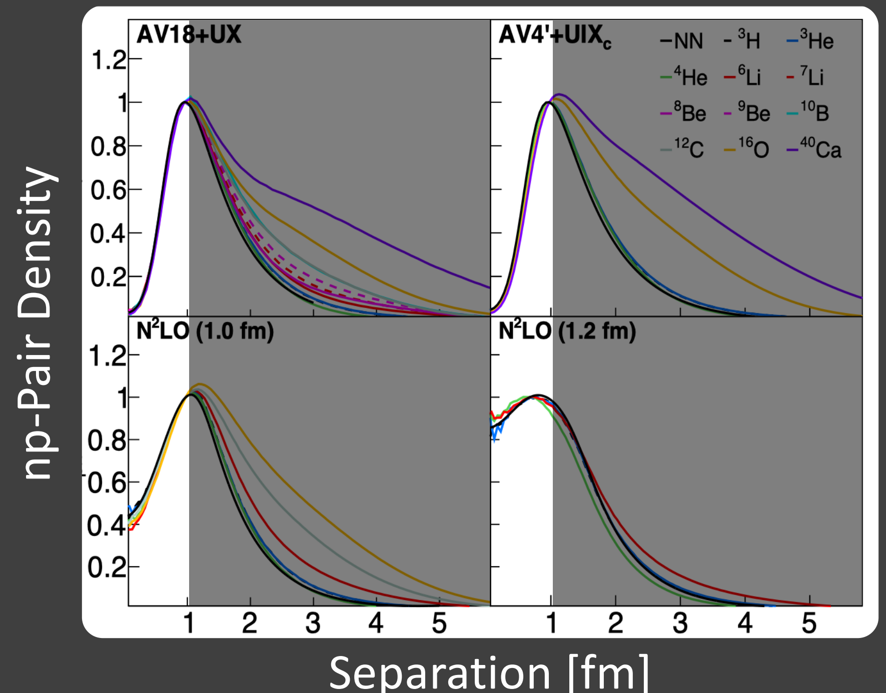


Cruz-Torres et al., Nature Physics (2021)
Weiss et al., Phys. Lett. B 780 (2018)
Weiss, Bazak, Barnea, Phys. Rev. C 92 (2015)
Tropiano et al., Phys. Rev. C 104, 034311 (2021)
Lynn et al., JPG 47, 045109 (2020)
Chen, Detmold, Lynn, Schwenk, PRL 119 (2017)
Ryckebusch et al., Phys. Lett. B 792, 21 (2019)
…

Interlude: Scale Separation and Factorization

$$\rho_A^{NN,\alpha}(r) \underset{r<1\text{ fm}}{\cong} C_A^{NN,\alpha} \times |\psi_{NN}^{\alpha}(r)|^2$$

Total Dist. = Constant (Nucleus specific) x Two-body (Universal)



Cruz-Torres et al., Nature Physics (2021)
Weiss et al., Phys. Lett. B 780 (2018)
Weiss, Bazak, Barnea, Phys. Rev. C 92 (2015)
Tropiano et al., Phys. Rev. C 104, 034311 (2021)
Lynn et al., JPG 47, 045109 (2020)
Chen, Detmold, Lynn, Schwenk, PRL 119 (2017)
Ryckebusch et al., Phys. Lett. B 792, 21 (2019)
Ciofi and Simula, Phys. Rev. C 53, 1689 (1996)
…

Interlude: Scale Separation and Factorization

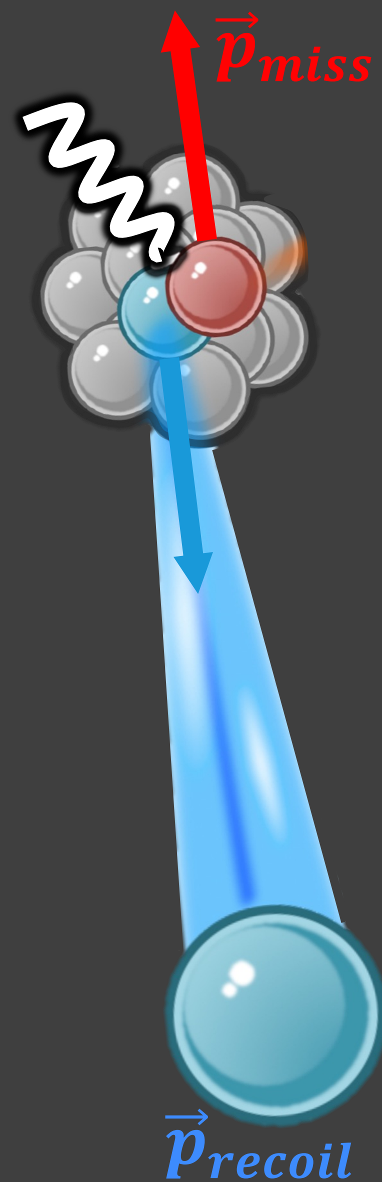
$$\rho_A^{NN,\alpha}(r) \underset{r<1\,\mathrm{fm}}{\cong} C_A^{NN,\alpha} \times |\psi_{NN}^{\alpha}(r)|^2$$

Factorized ground-state ➔
Factorized reaction model

$$\sigma^A \cong \mathrm{K} \times \sigma^N \times \sum_{NN,\alpha} C_A^{NN,\alpha}\, |\psi_{NN}^{\alpha}|^2$$

Single-nucleon coupling

Pair distribution



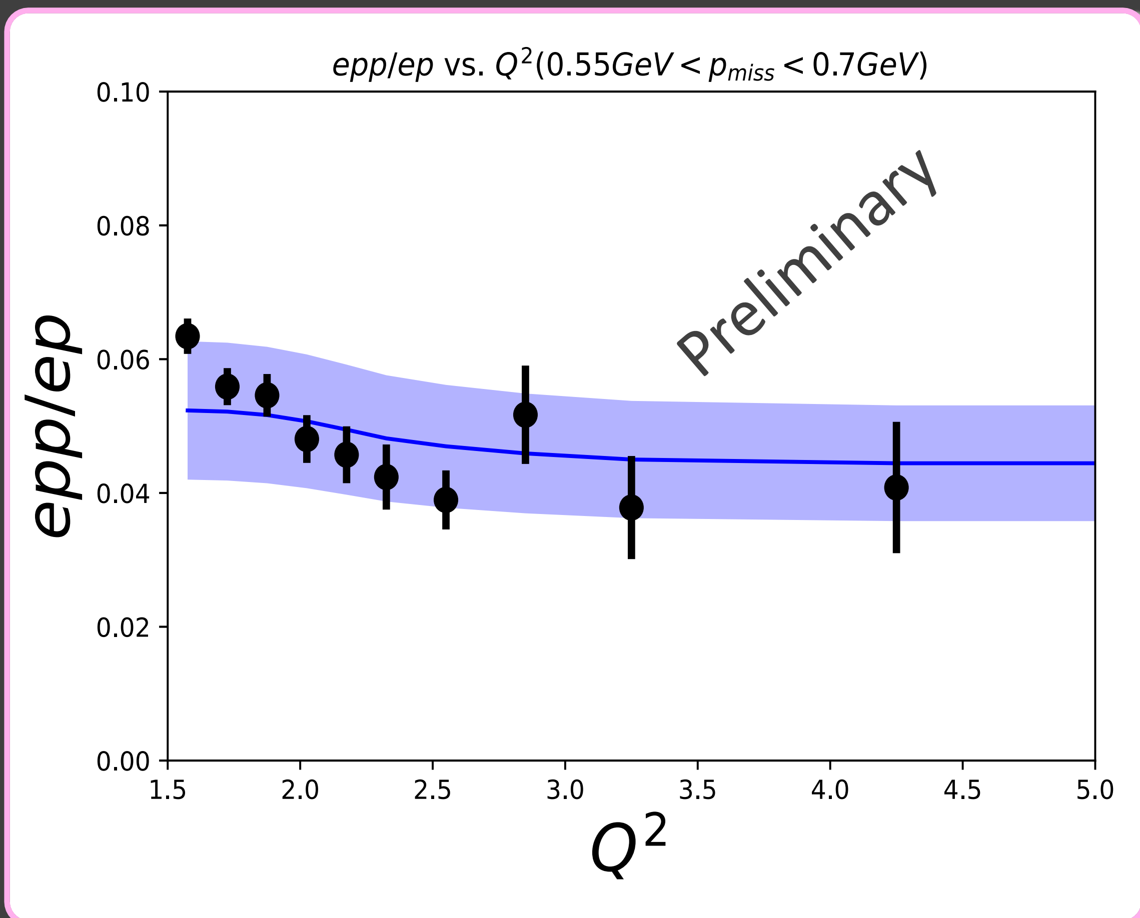
Double Factorization

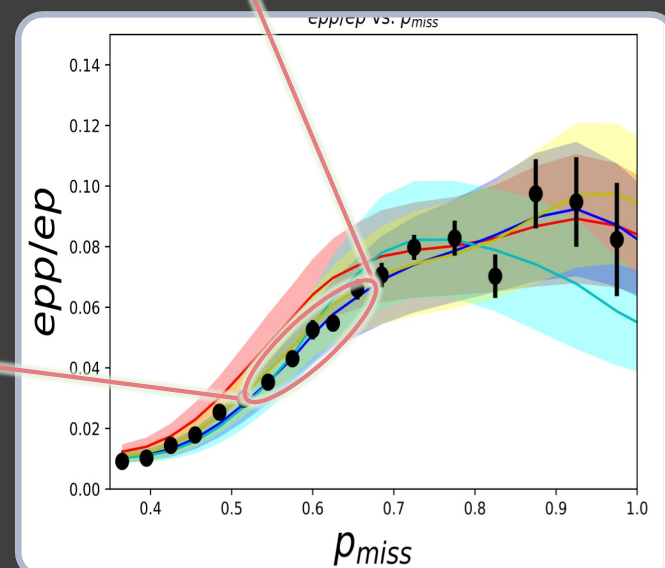
$$\sigma^A \cong K \times \sigma^N \times \sum_{NN,\alpha} C_A^{NN,\alpha} \, |\psi_{NN}^{\alpha}|^2$$

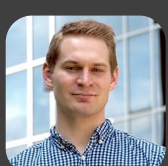
Single-nucleon coupling

Pair distribution

✓ Scale Independence





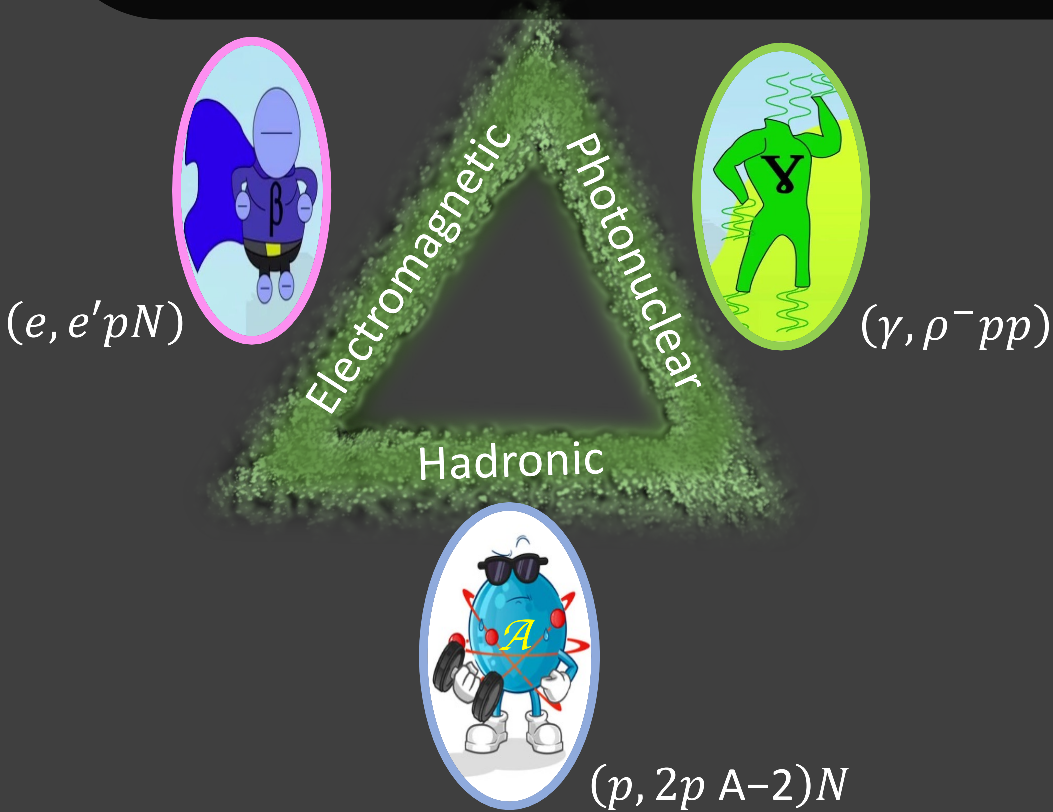


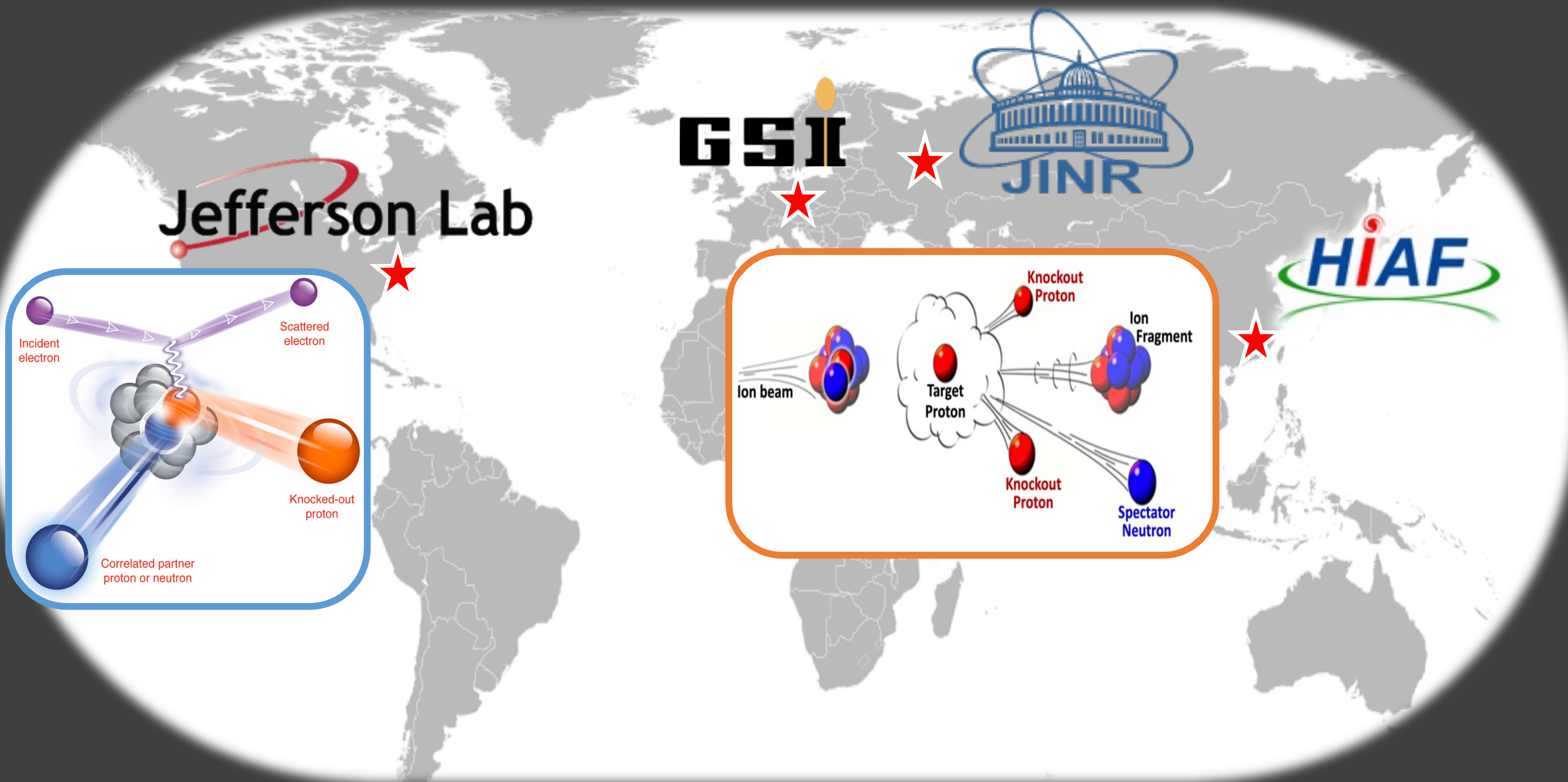
Probe Independence?

$$\sigma^{A} \cong \mathrm{K} \times \sigma^{N} \times \sum_{NN,\alpha} C_{A}^{NN,\alpha} \, |\psi_{NN}^{\alpha}|^{2}$$

Single-nucleon coupling

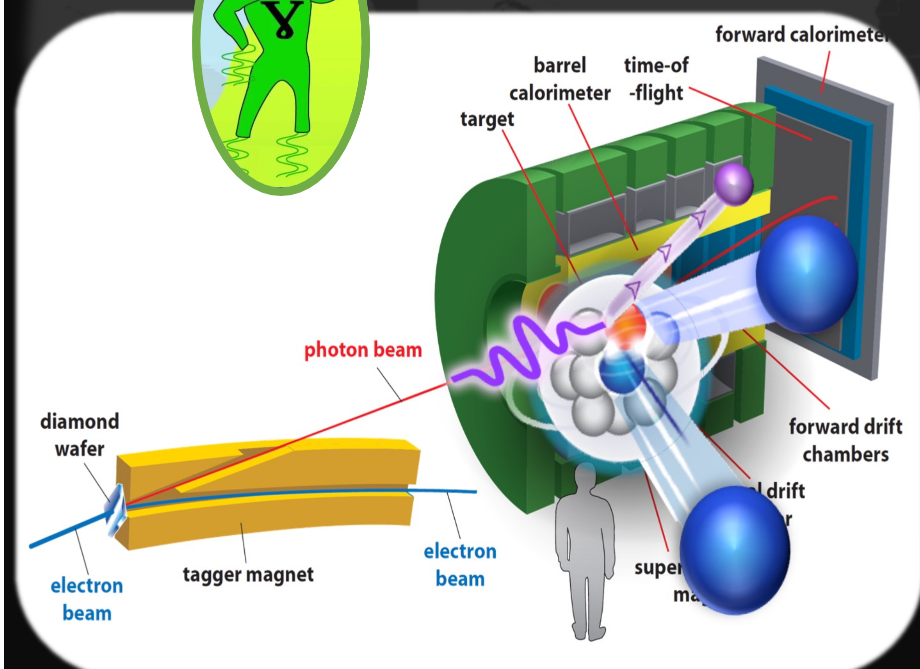
Pair distribution



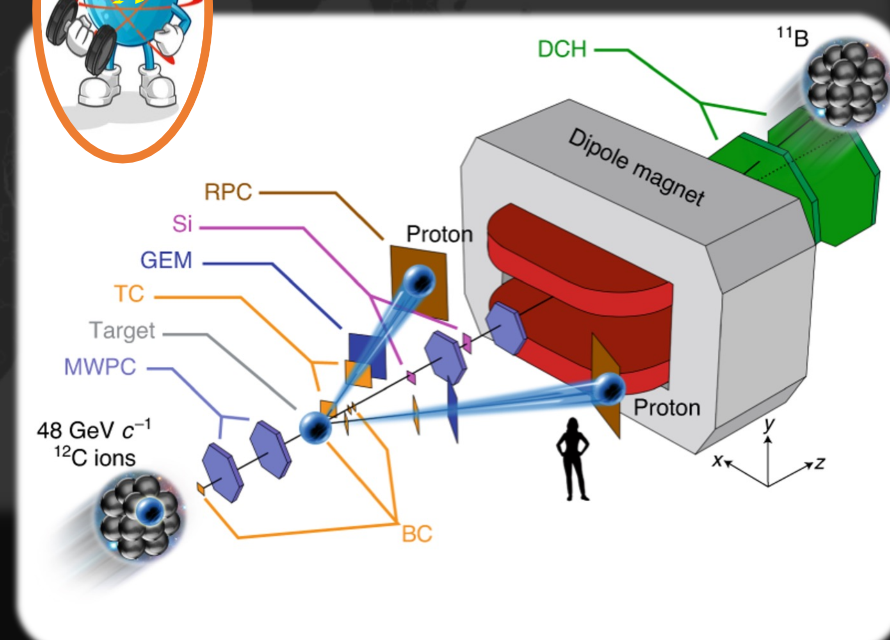


GSI
JINR
Jefferson Lab
HIAF
Incident electron
Scattered electron
Knocked-out proton
Correlated partner proton or neutron
Knockout Proton
Ion Fragment
Ion beam
Target Proton
Knockout Proton
Spectator Neutron

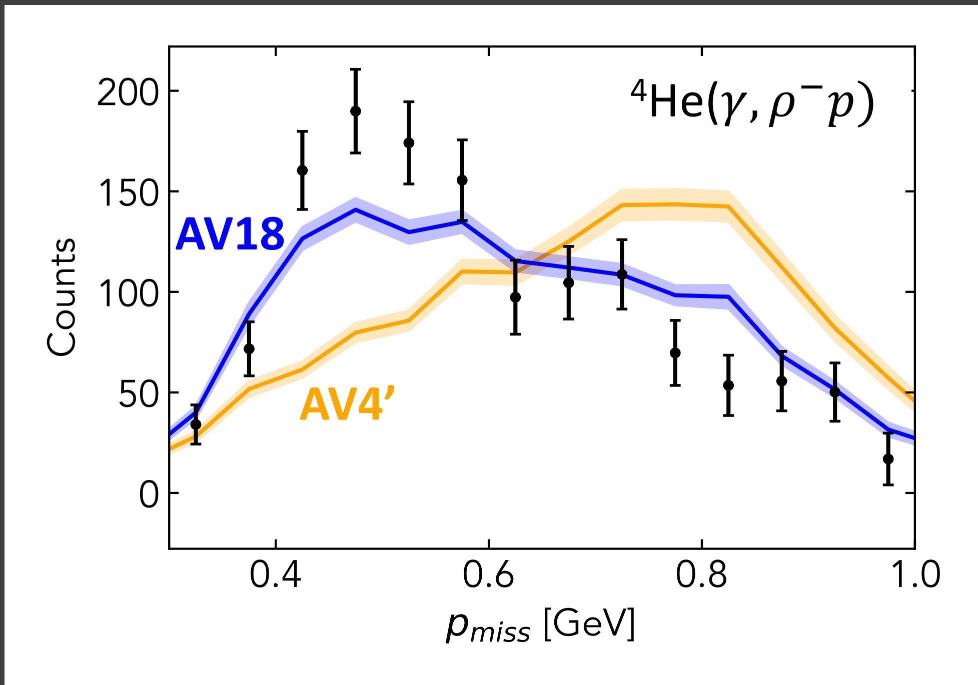
$(\gamma, \rho^{-} pp)$



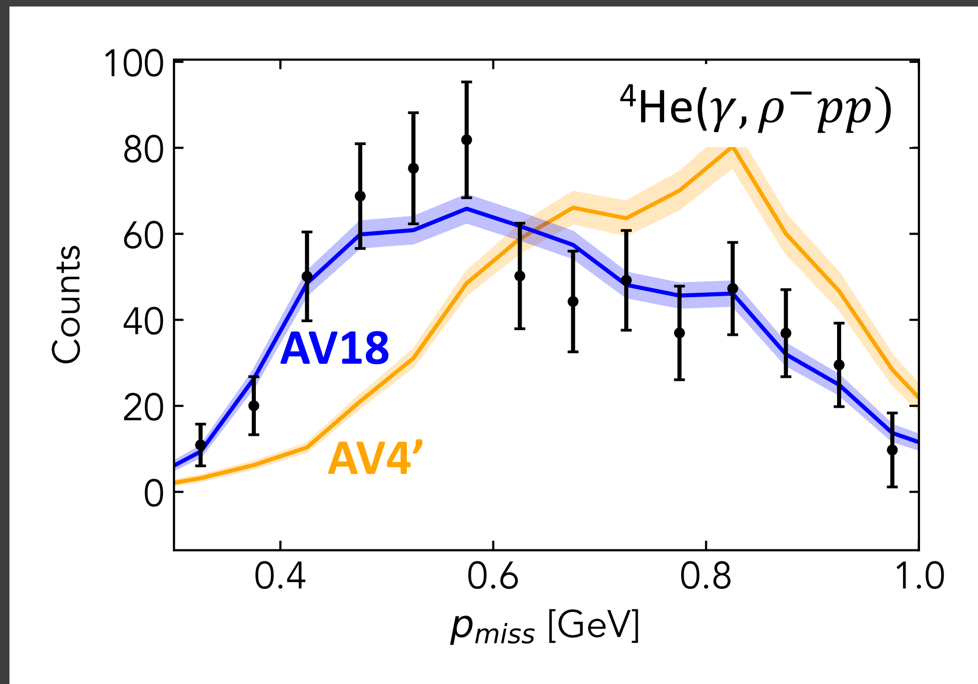
$(p, 2p\ \mathrm{A{-}2})N$



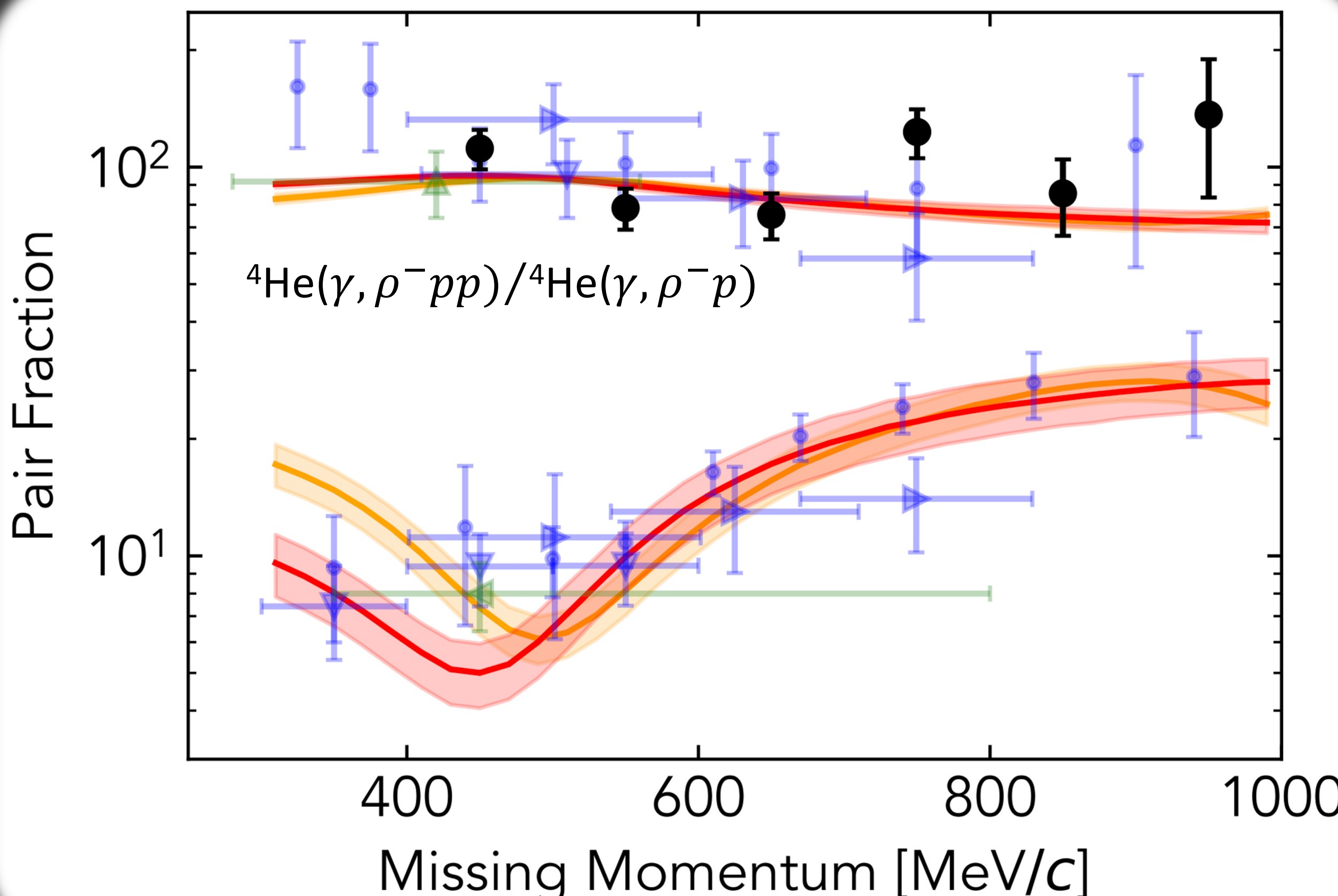
Photoproduction factorizes too!



^{4}He($\gamma, \rho^- pp$)

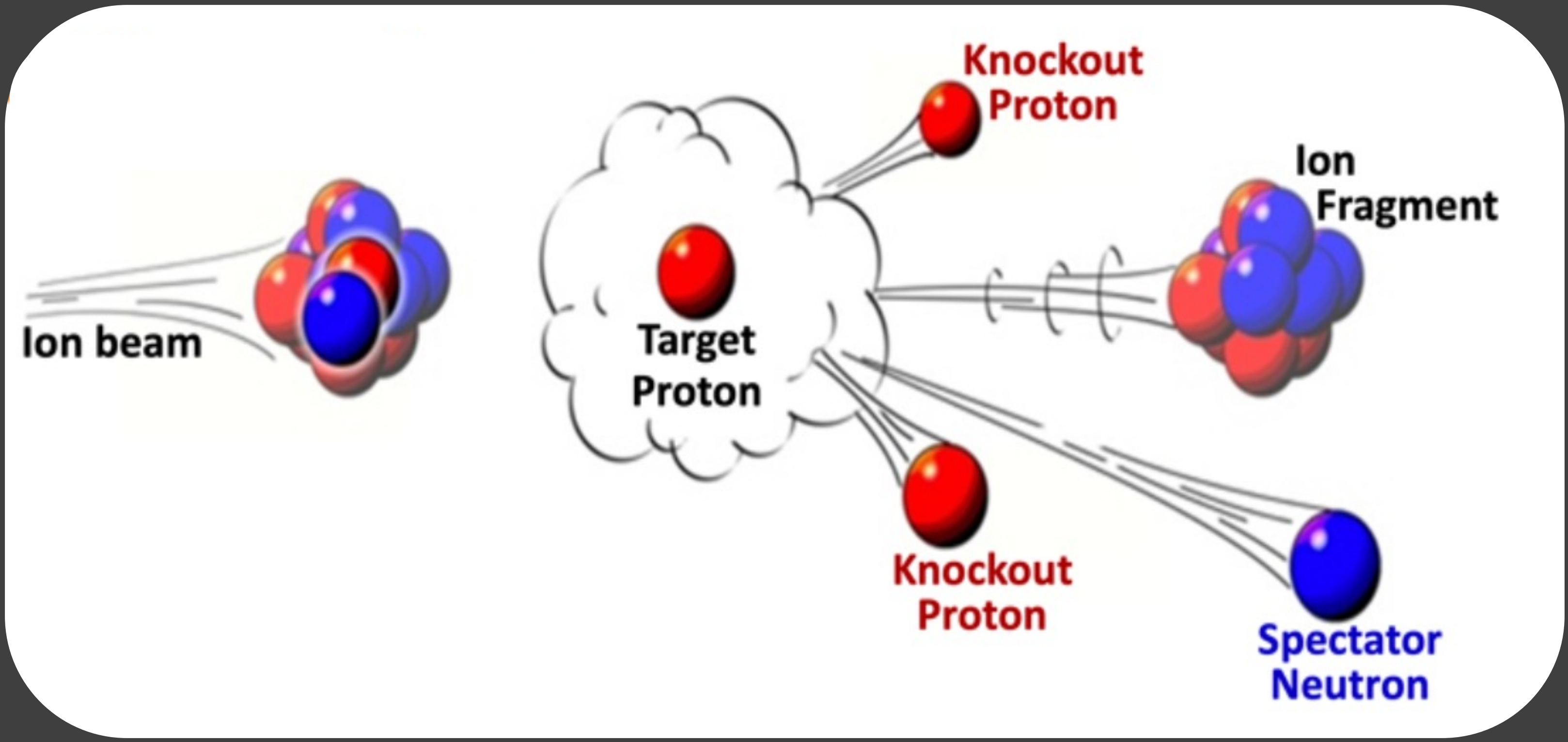


np-SRC Dominate in Photoproduction too!



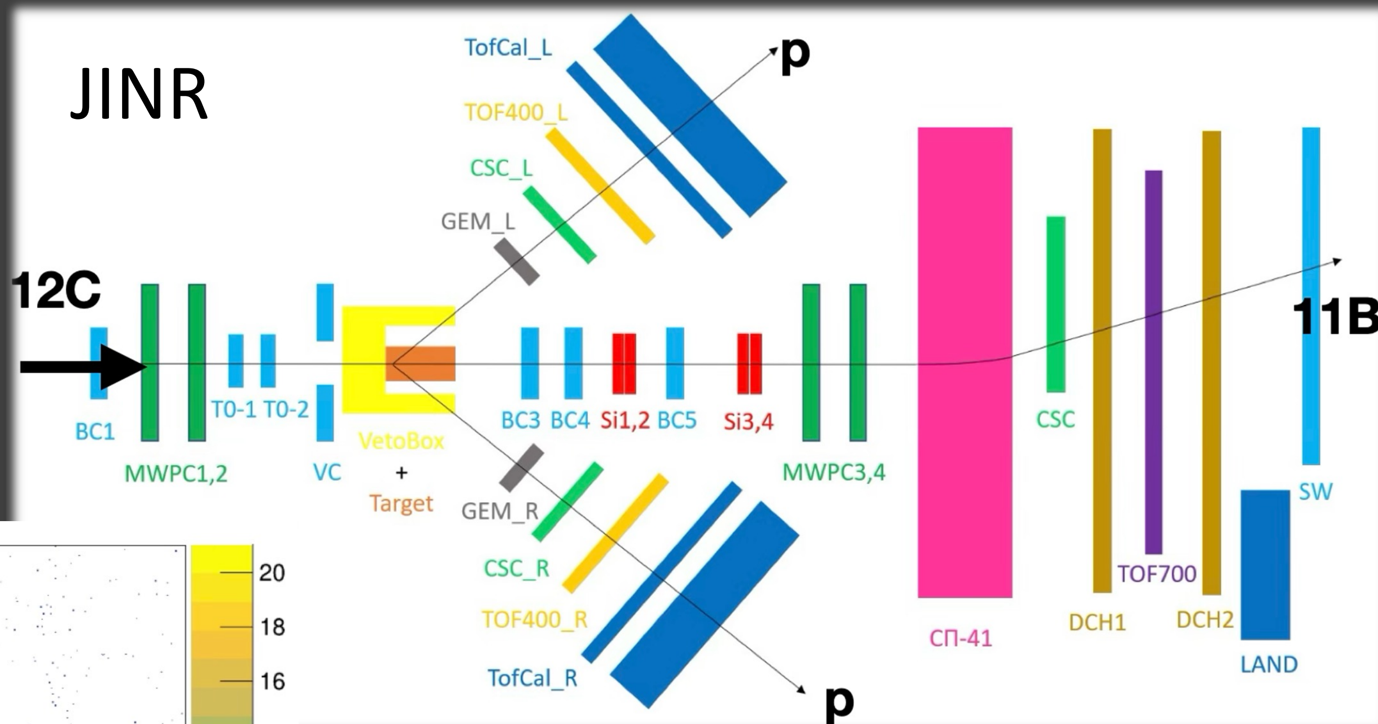
Inverse Kinematics Measurement

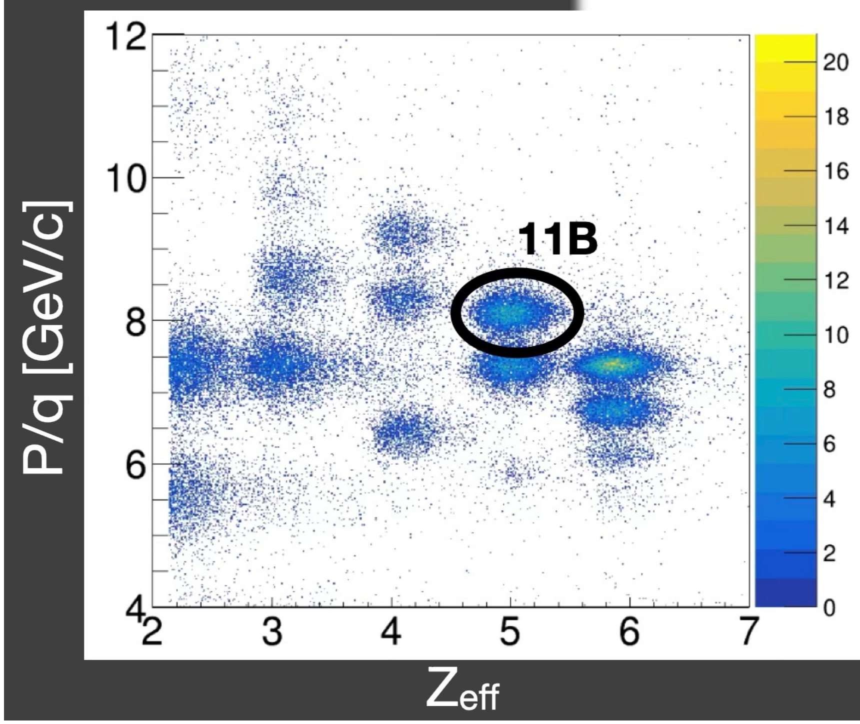
$$A + p \rightarrow (\mathrm{A}-2) + p + p + N$$



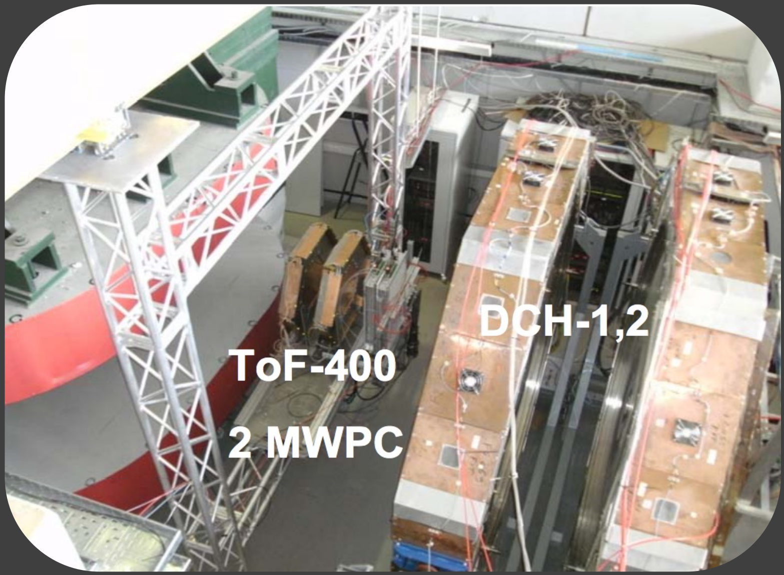
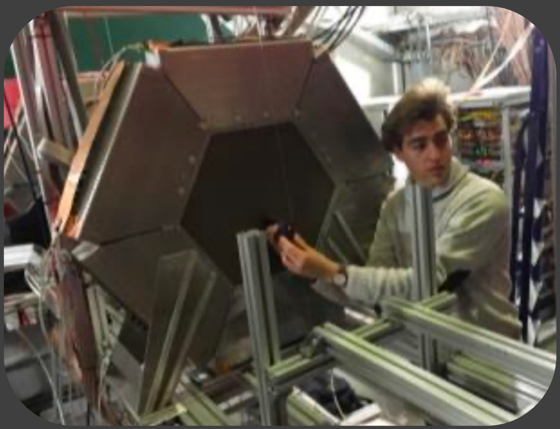
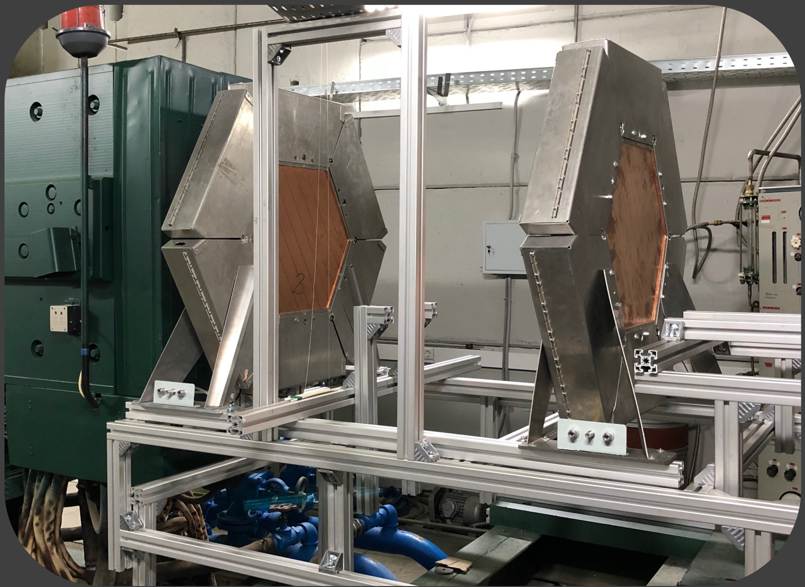
$$\mathrm{C} + p \rightarrow {}^{10}\mathrm{B} + p + p + (n)$$
$$\mathrm{C} + p \rightarrow {}^{10}\mathrm{Be} + p + p + (p)$$

C(p,2p) in inverse kinematics

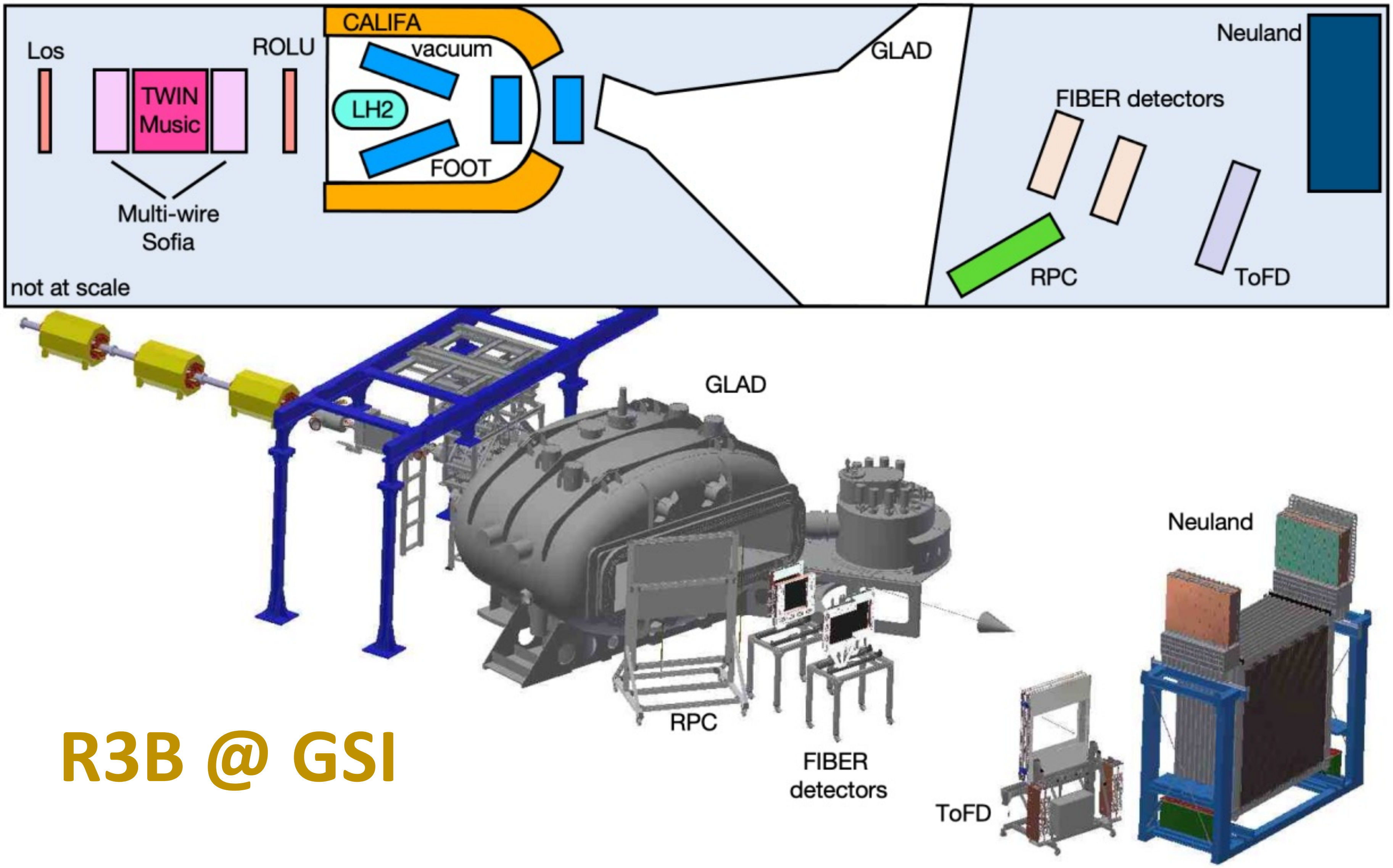




large momentum transfer (~ 90° c.m.)



DCH-1,2
ToF-400
2 MWPC



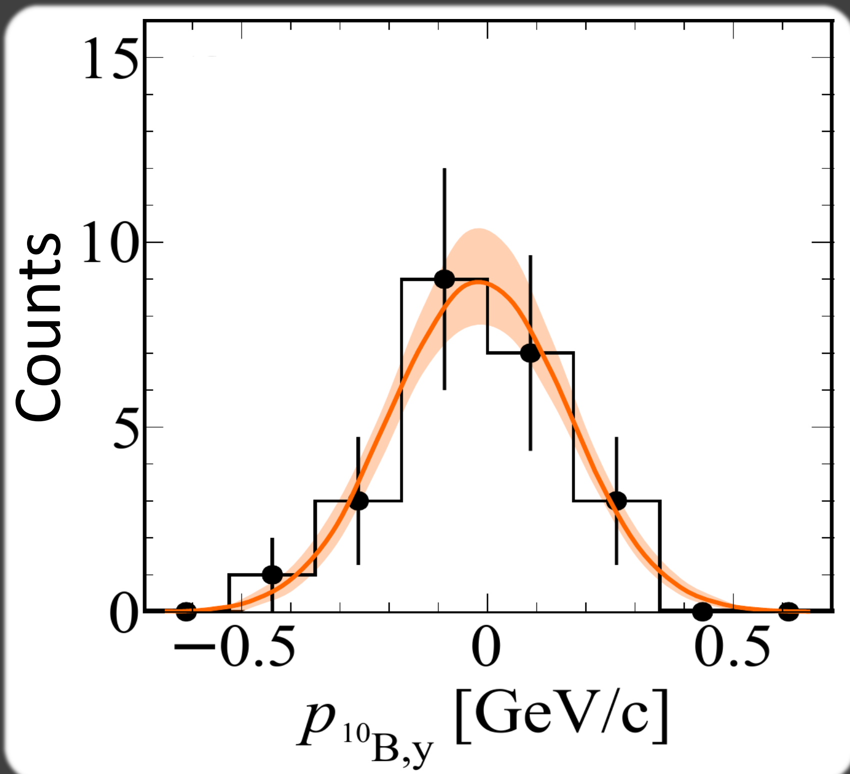
^{12}C & ^{16}C Beams!

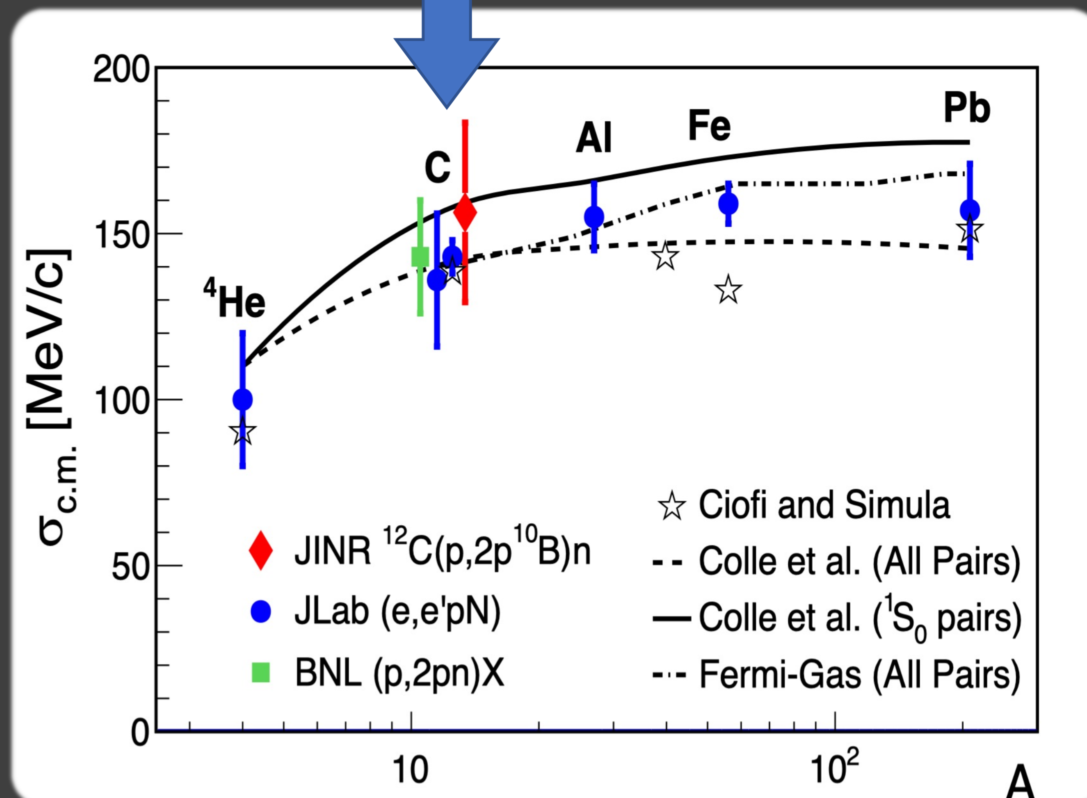


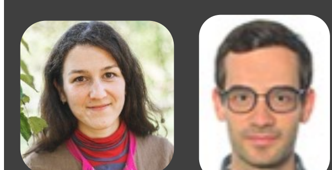
R3B @ GSI

SRC: Pair Motion from measured 10B

(Agree \w JLab data)



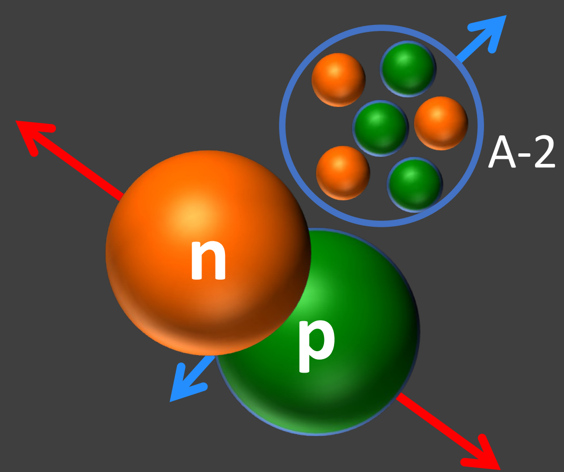




Patsyuk and Kahlbow et al.,
Nature Physics 17, 693 (2021)

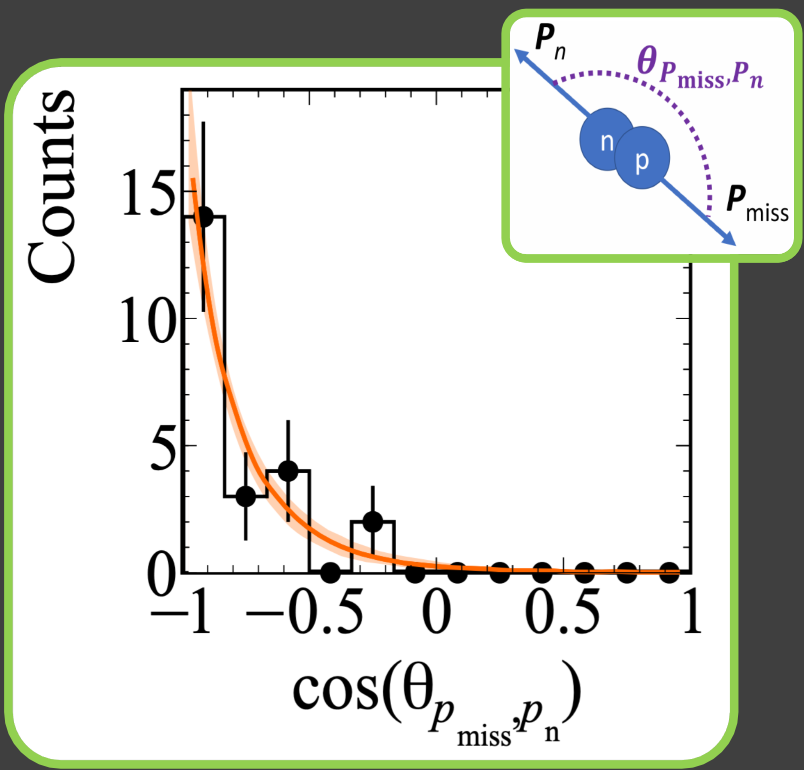
SRC Experimental Signature: no correlation between relative & c.m. motions

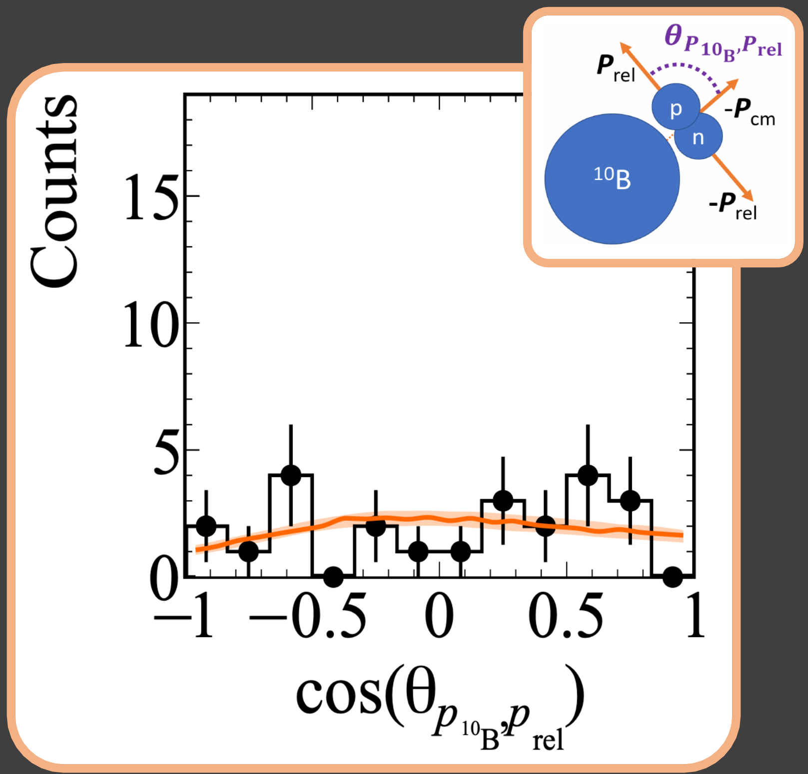
$$f\left(p_{rel}, p_{c.m.}, \theta_{rel,c.m.}\right) \approx C(p_{c.m.}) \times \varphi(p_{rel})$$



SRC Experimental Signature: no correlation between relative & c.m. motions

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

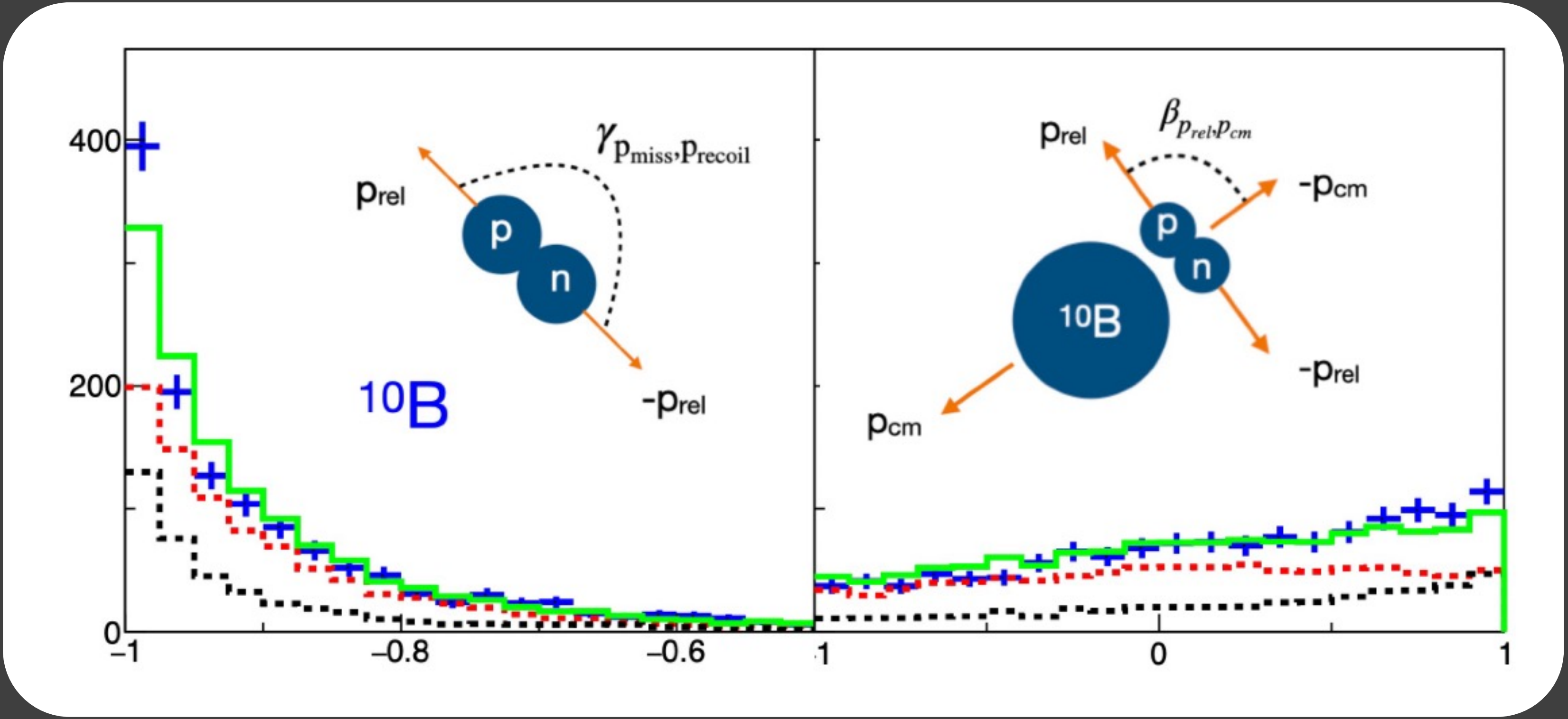




Patsyuk and Kahlbow et al., Nature Physics (2021)

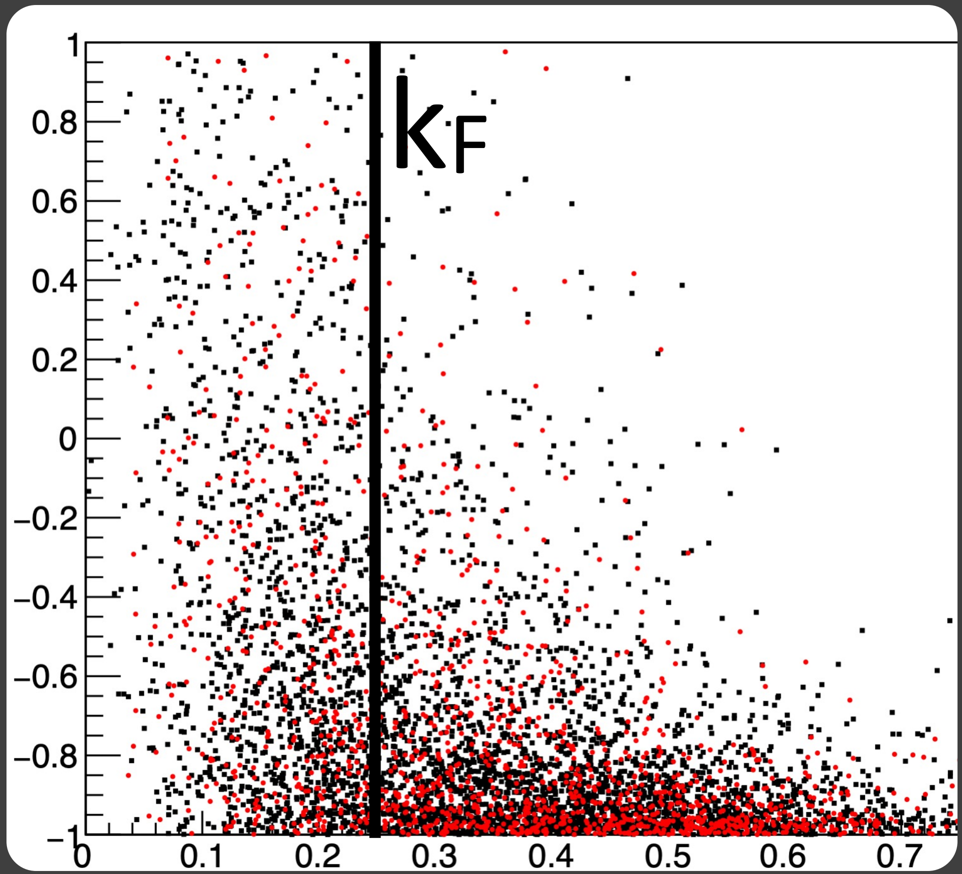
SRC Experimental Signature: no correlation between relative & c.m. motions

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



$\cos\alpha_{p_{miss},p_{rec}}$ $\cos\beta_{p_{CM},p_{rel}}$

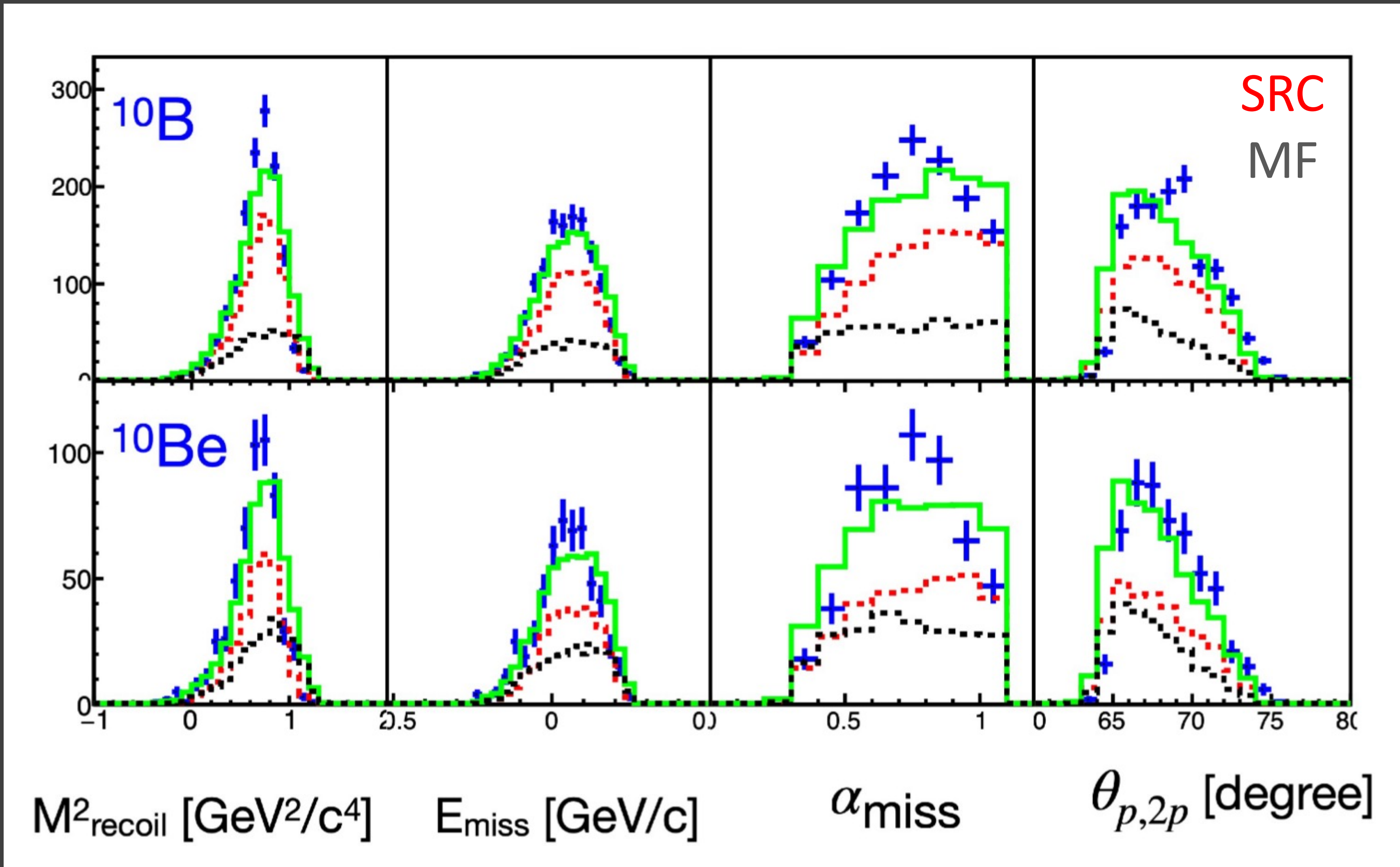
MF-to-SRC Transition



$\cos\alpha_{p_m, p_{rec}}$

P_m [GeV/c]

Good Data-Theory Agreement



Deuteron Quantum States

$^{16}C \rightarrow$ np-SRC + ^{14}B

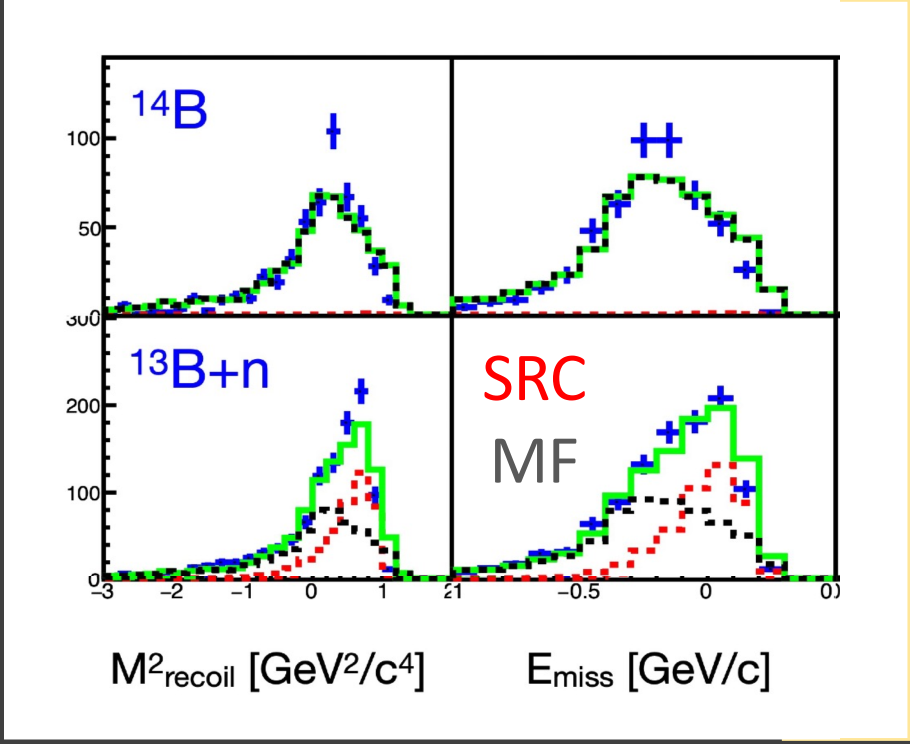
^{16}C - pn $\rightarrow$ ^{14}B

$J^{\pi}=0^{+}$ $J^{\pi}=1^{+}$ $J^{\pi}=1^{+}$

E [MeV]	J^{pi}
0.0	2^{-}
0.74	1^{-}

^{14}B bound states

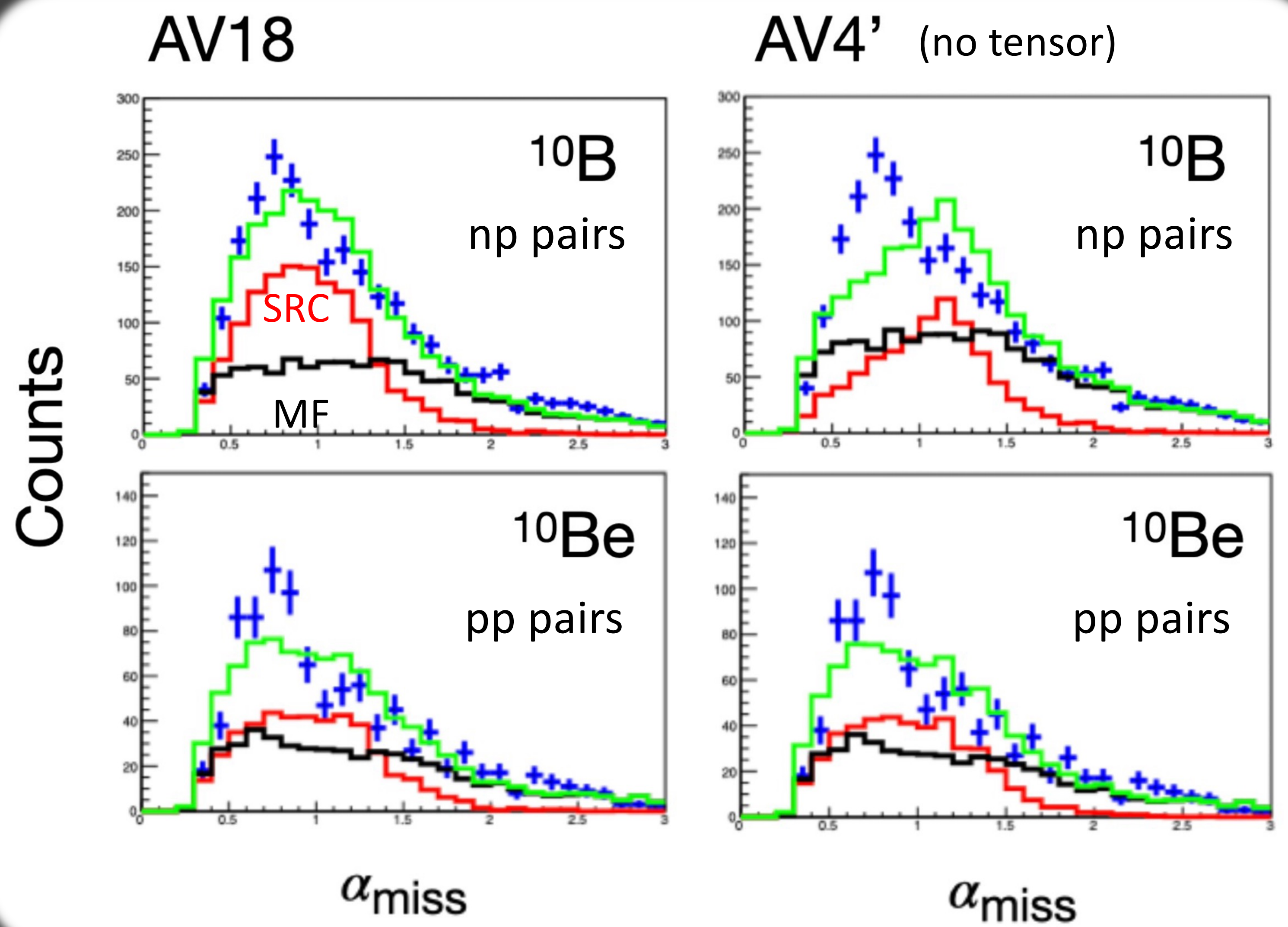
Quantum Number Selectivity



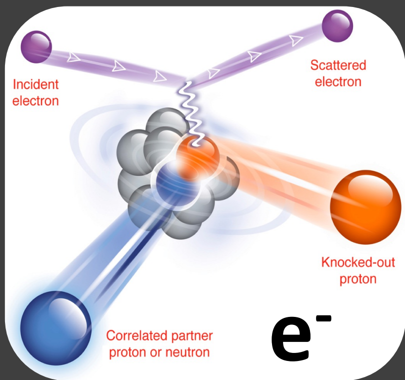
^{14}B: Mean-field only because
^{16}C → np + ^{14}B
is blocked

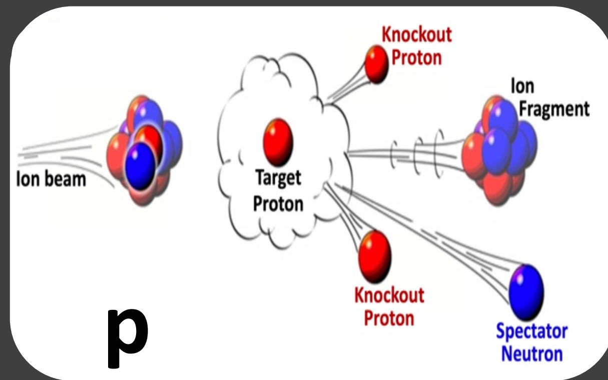
^{14}B* → ^{13}B+n:
SRC contribute

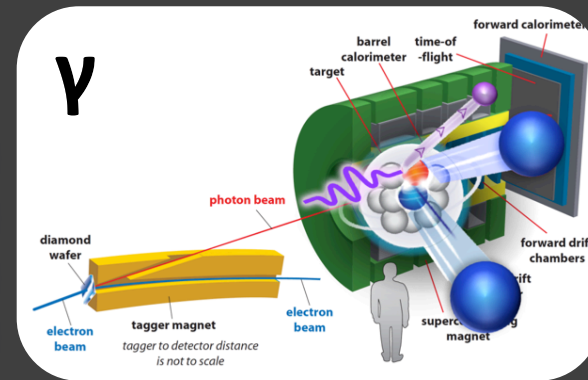
NN Interaction Sensitivity!



Results show universality!



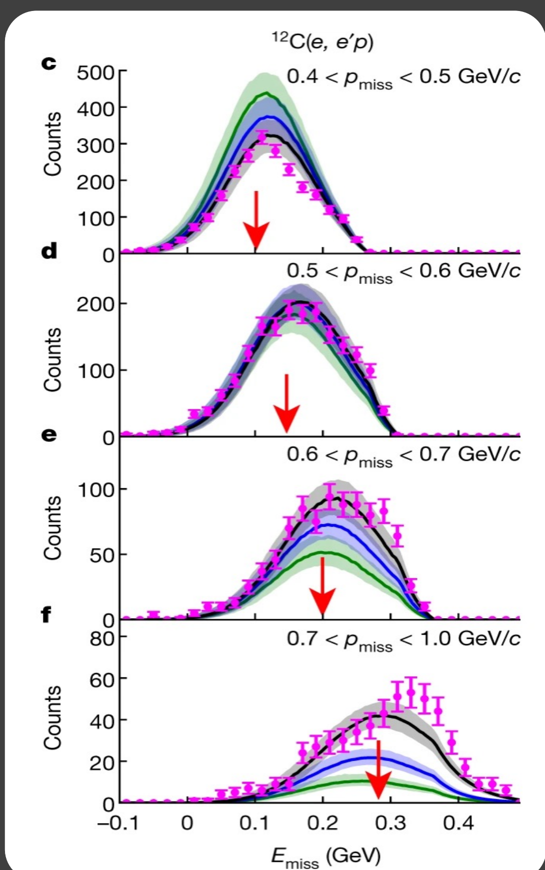


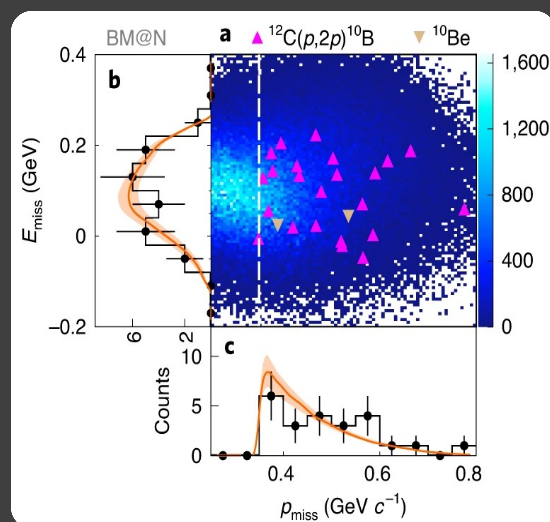


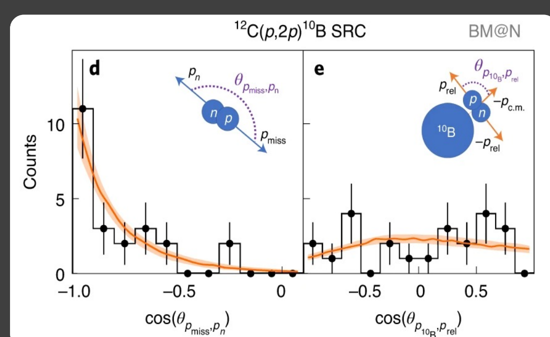
Nature '20

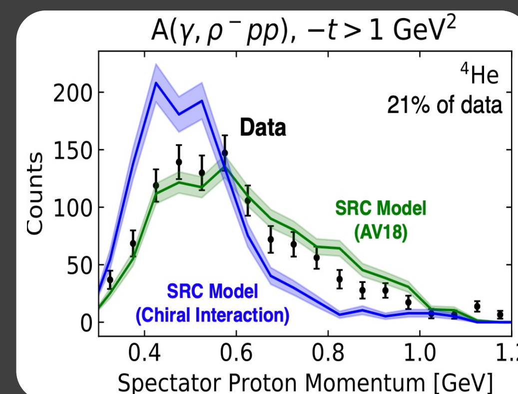
Nature Physics '21

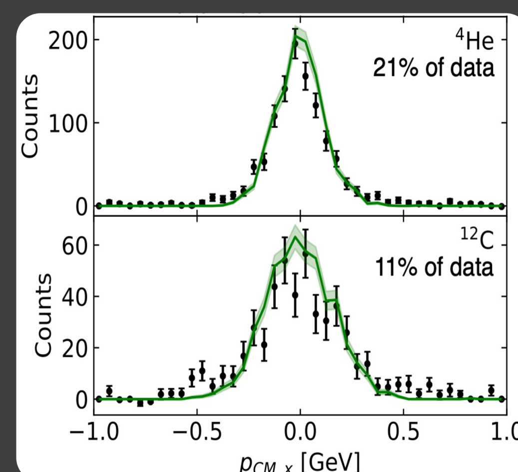
Brand new data!





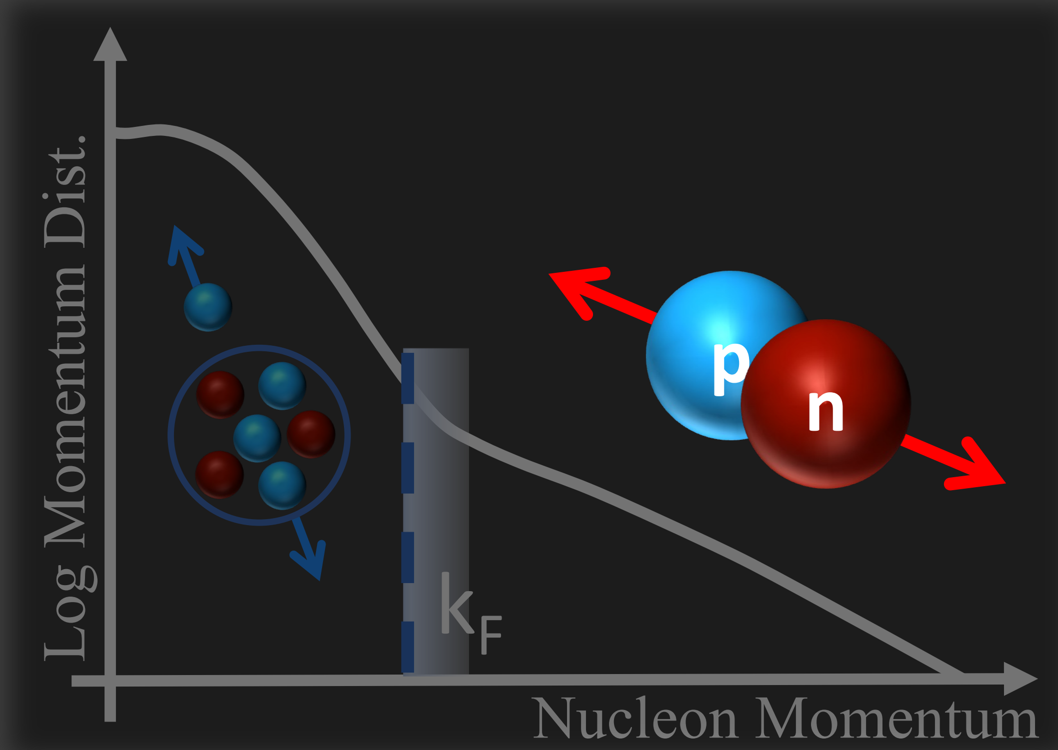




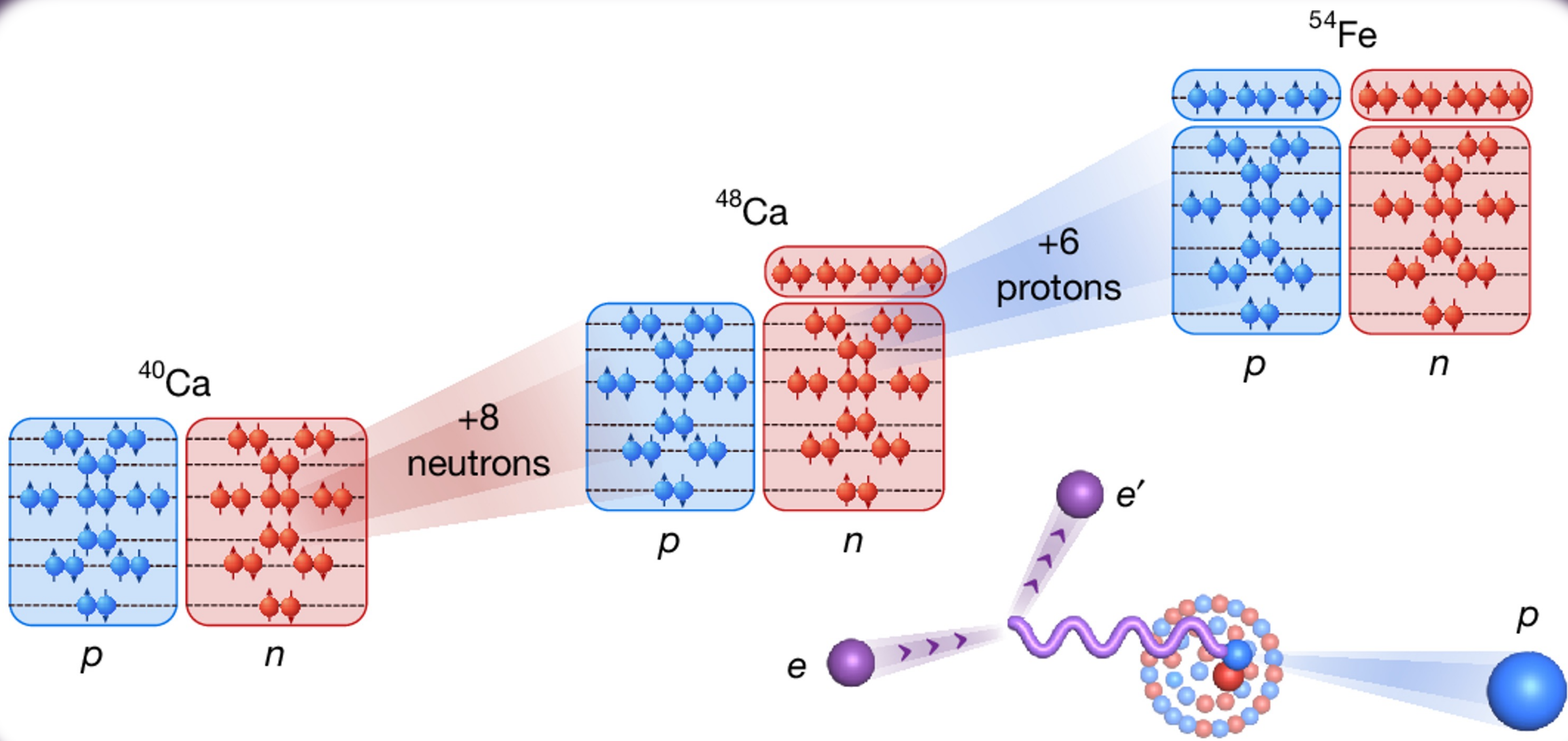


Short-Range Correlations Use the Nucleus as a lab for high-density matter states!

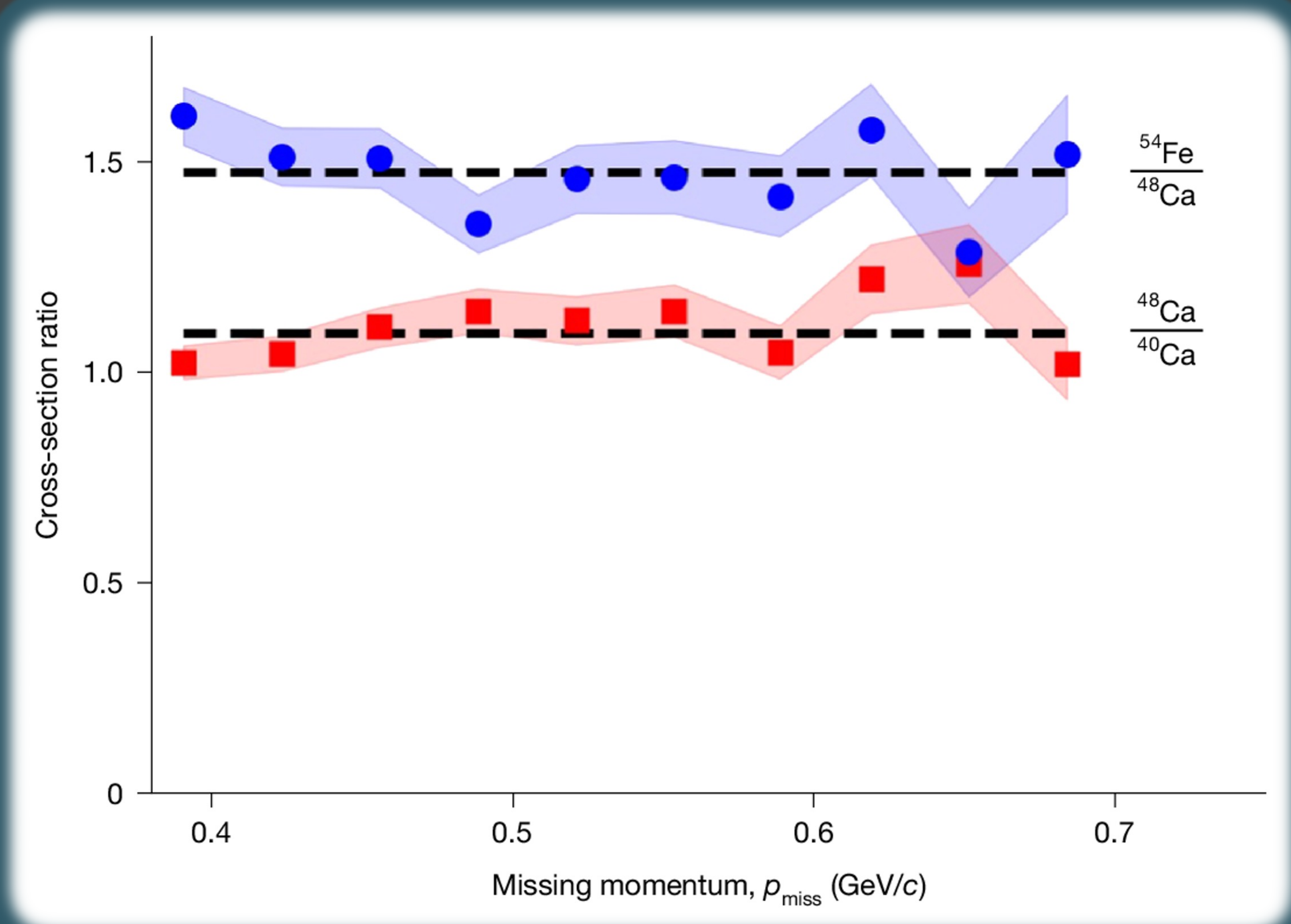
- → Discovery of a universal (factorized) correlated phase
- → First probe of the NN interaction core
- → Asymmetry effects impact neutron stars



Understand Pair Formation: CaFe

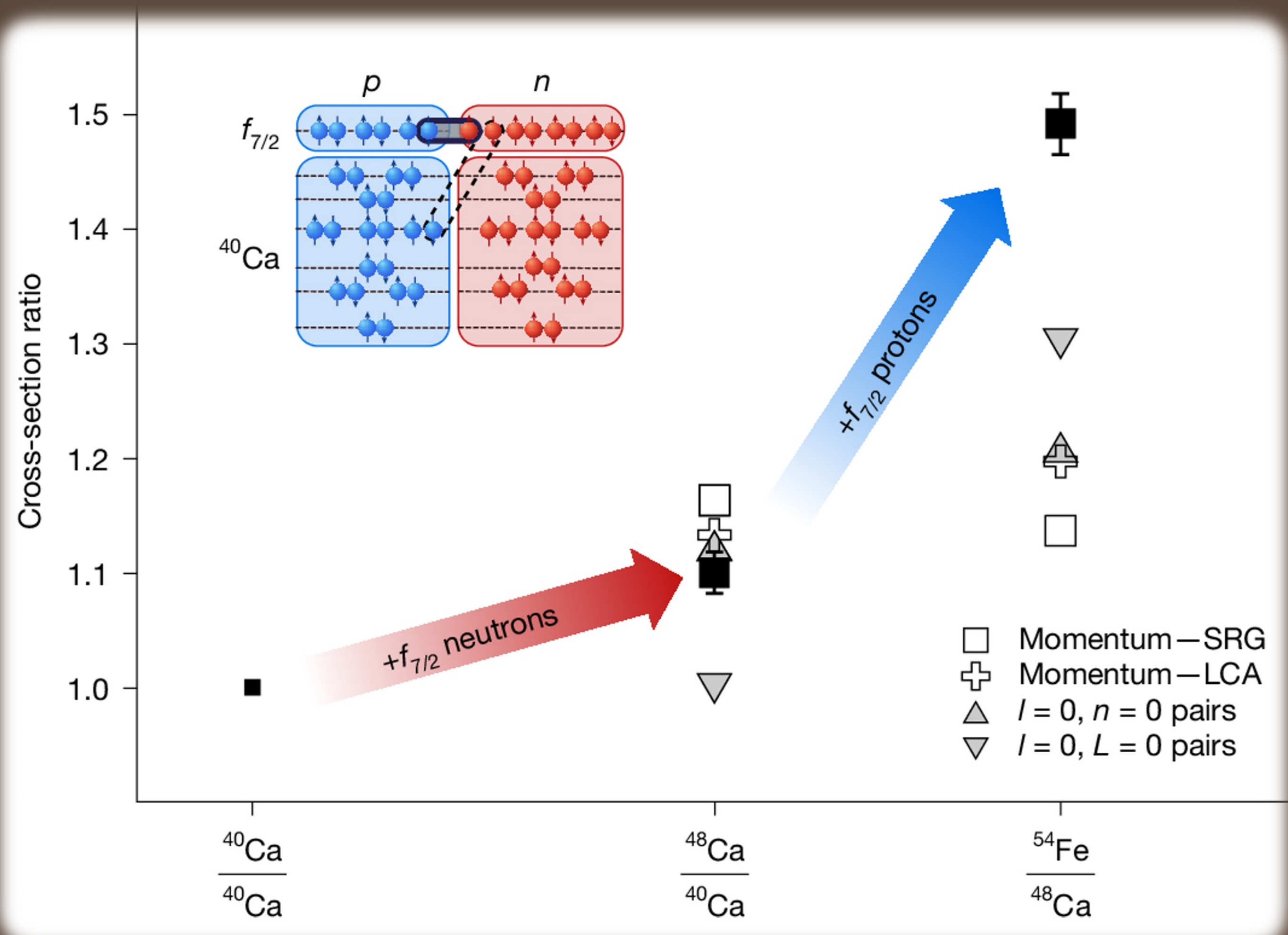


High-Momentum Scaling



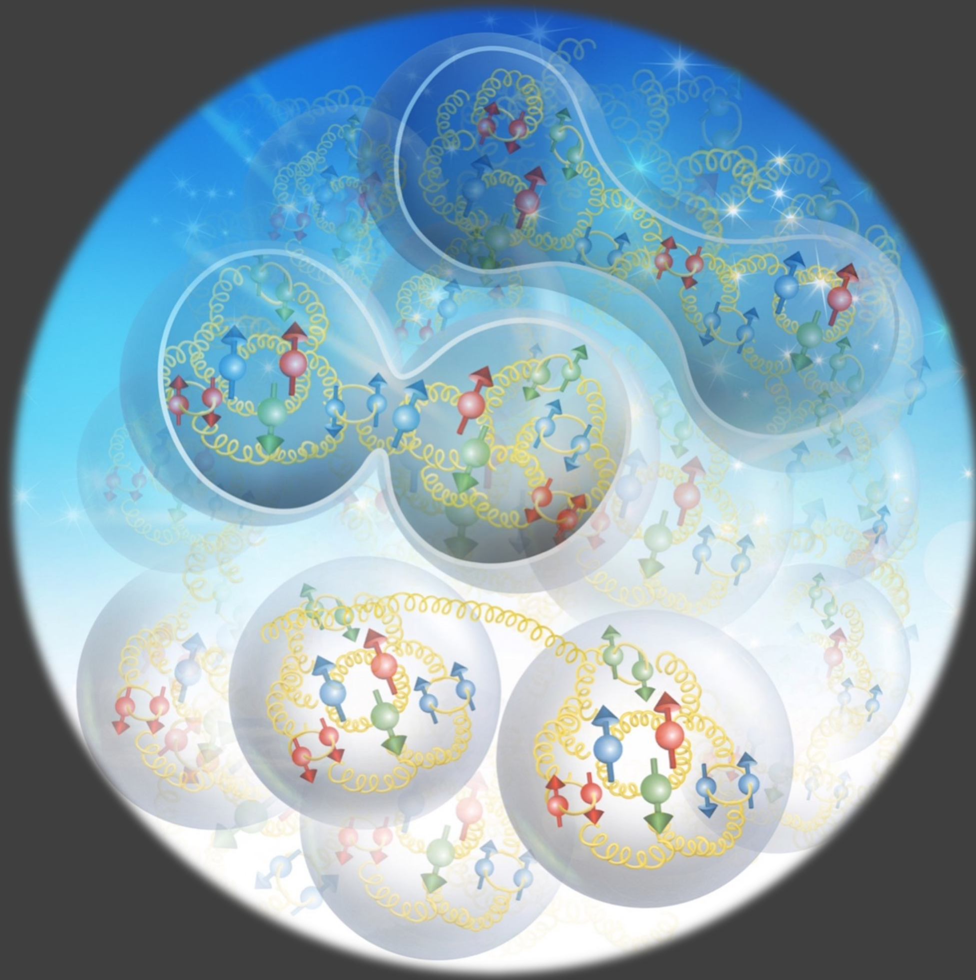
Nguyen et al., Nature (2026)

Same-Shell Pairing → New Quantum Selection Rules!

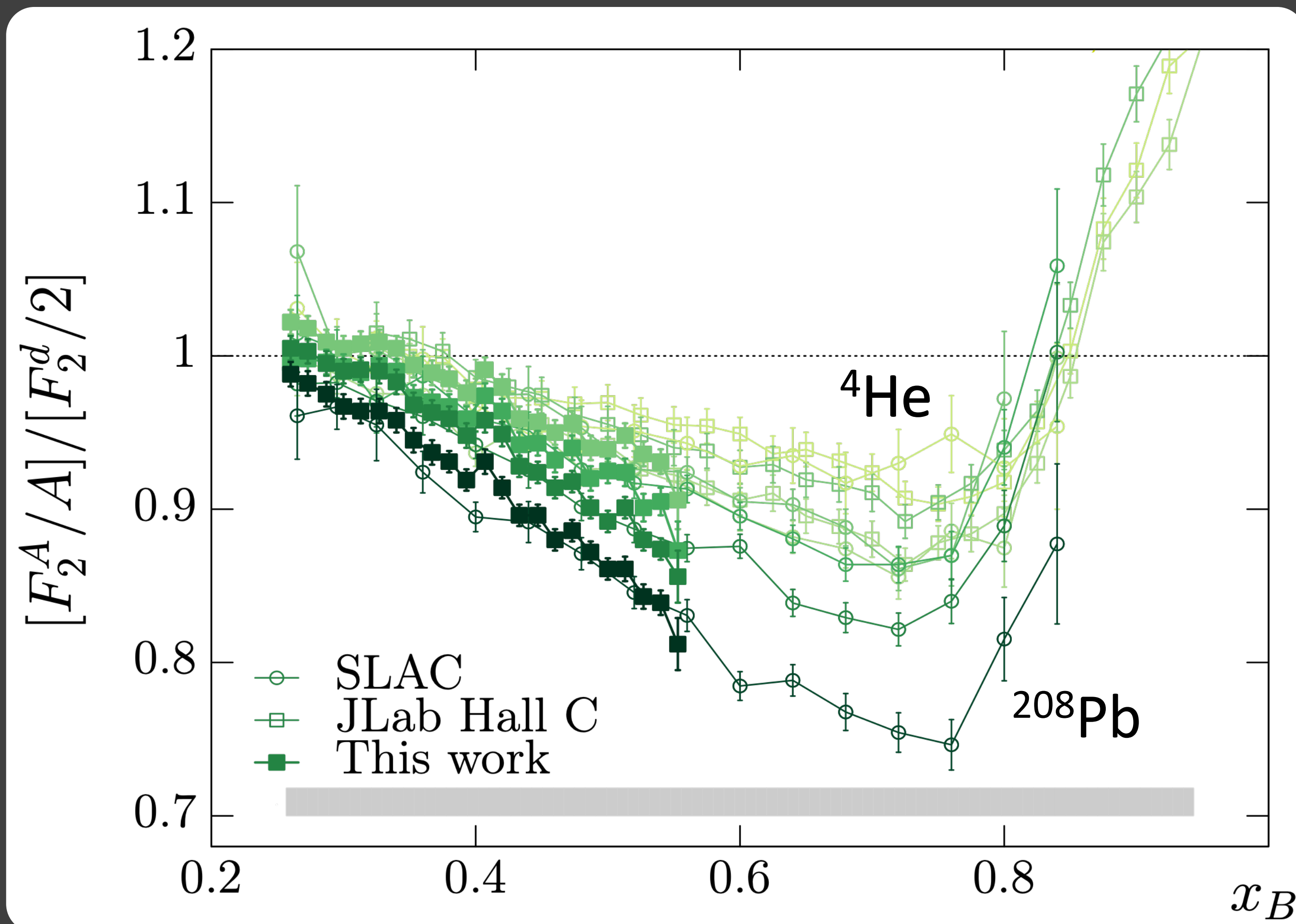


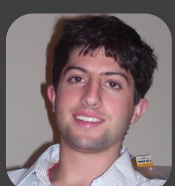
Nguyen et al., Nature (2026)

The Proton in the Nucleus



Quark Momentum Suppression in Nuclei (EMC Effect)



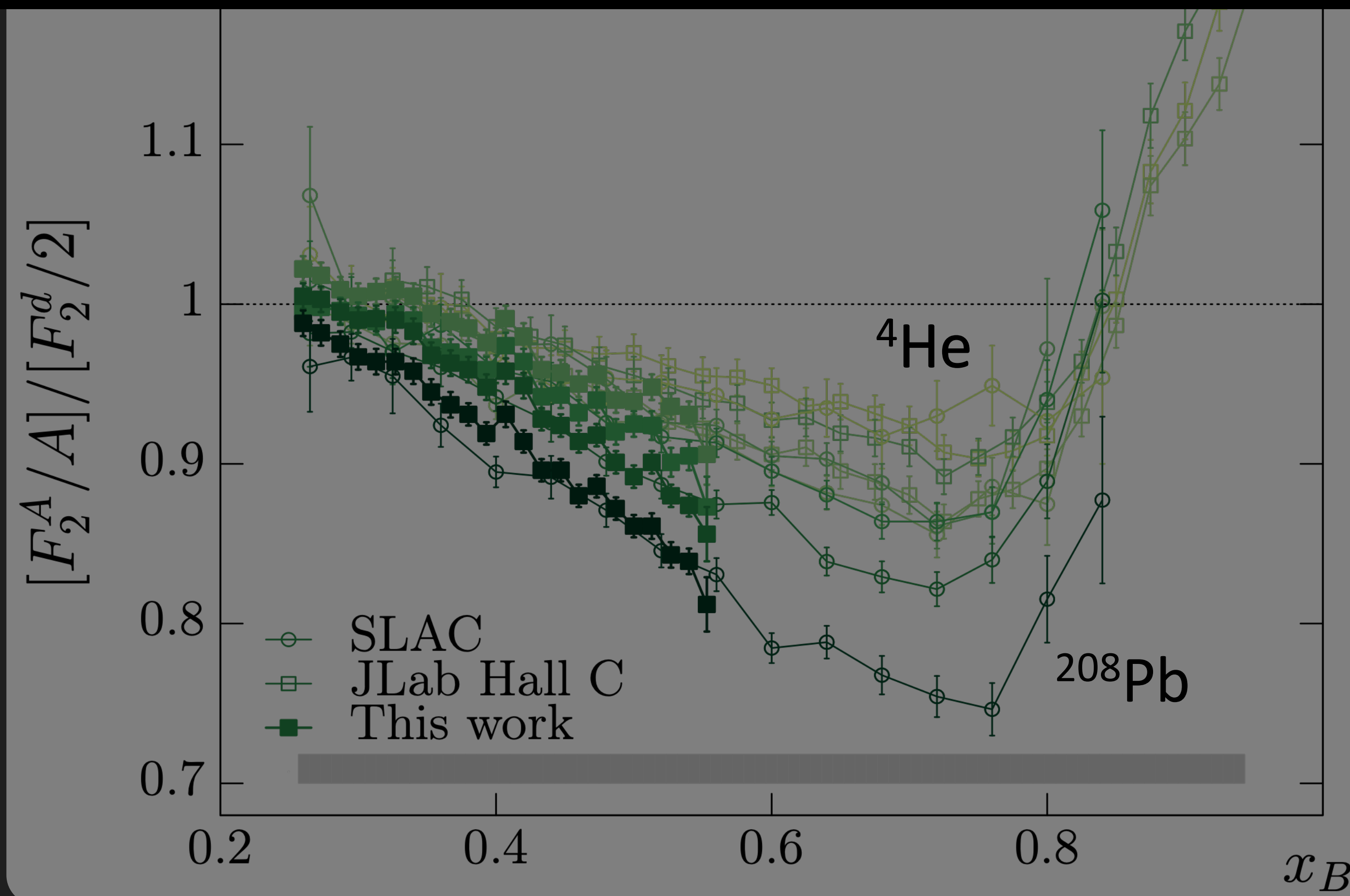


x_B = quark momentum fraction

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**)

Quark Momentum Suppression

43 years, > 1000 publications, no consensus.



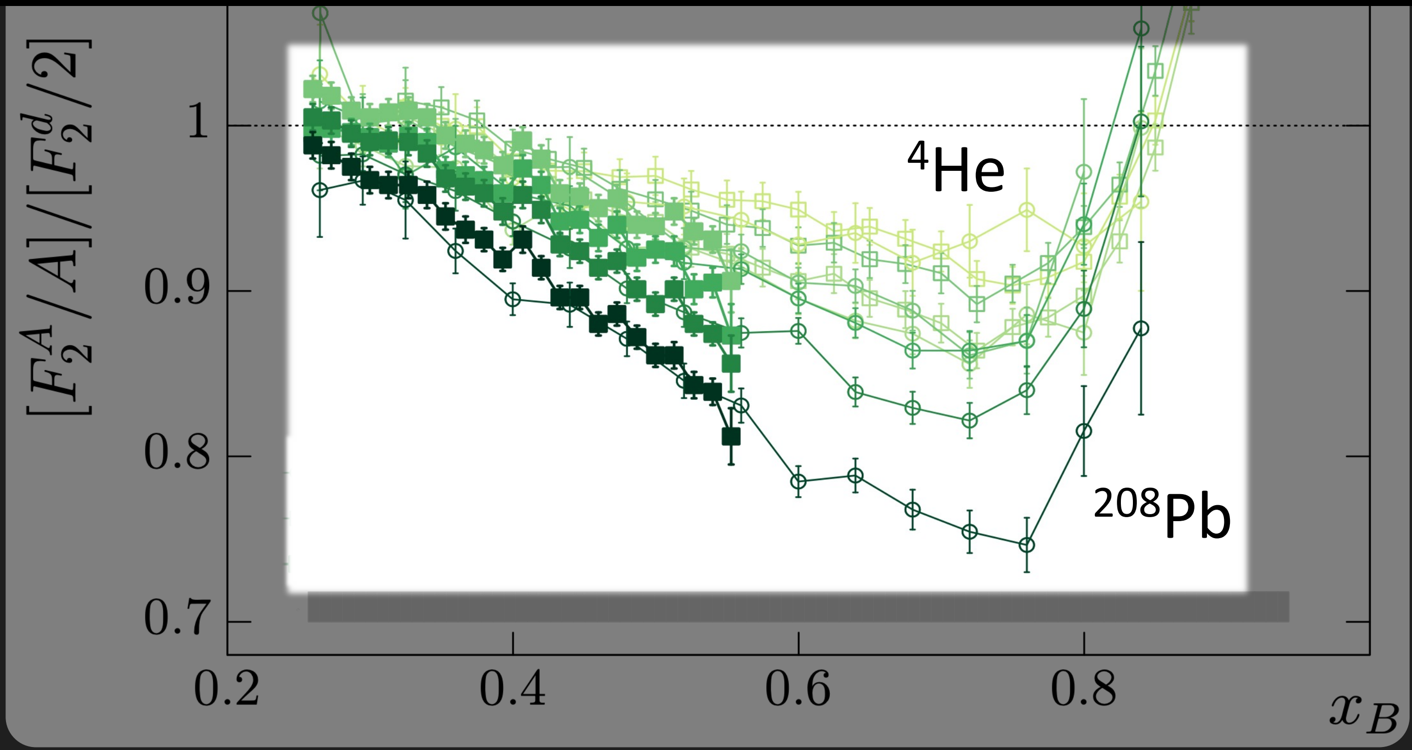
x_B = quark momentum fraction

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**)

Quark Momentum Suppression

43 years, > 1000 publications, no consensus.

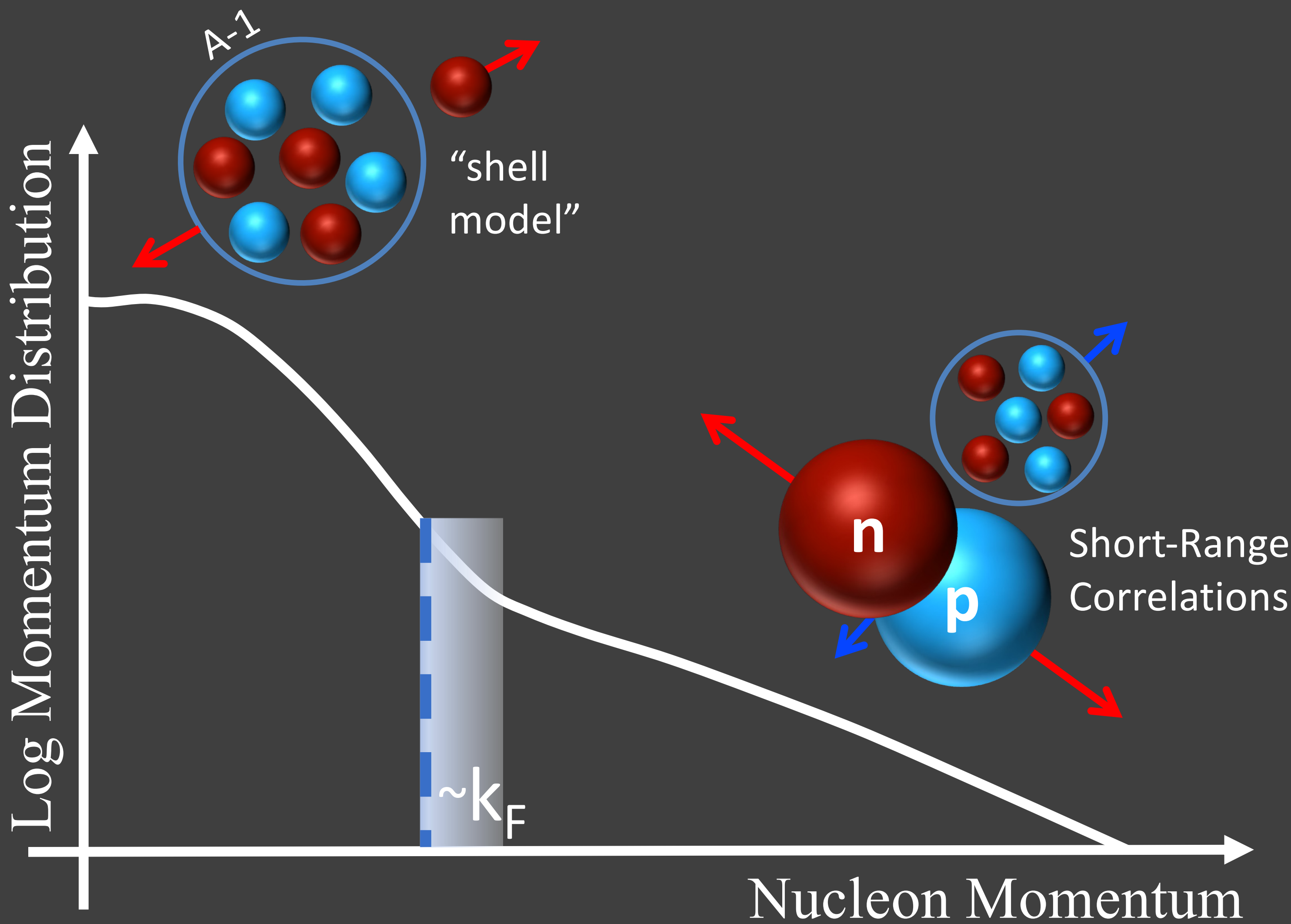
But, effect clearly driven by nuclear dynamics

x_B = quark momentum fraction

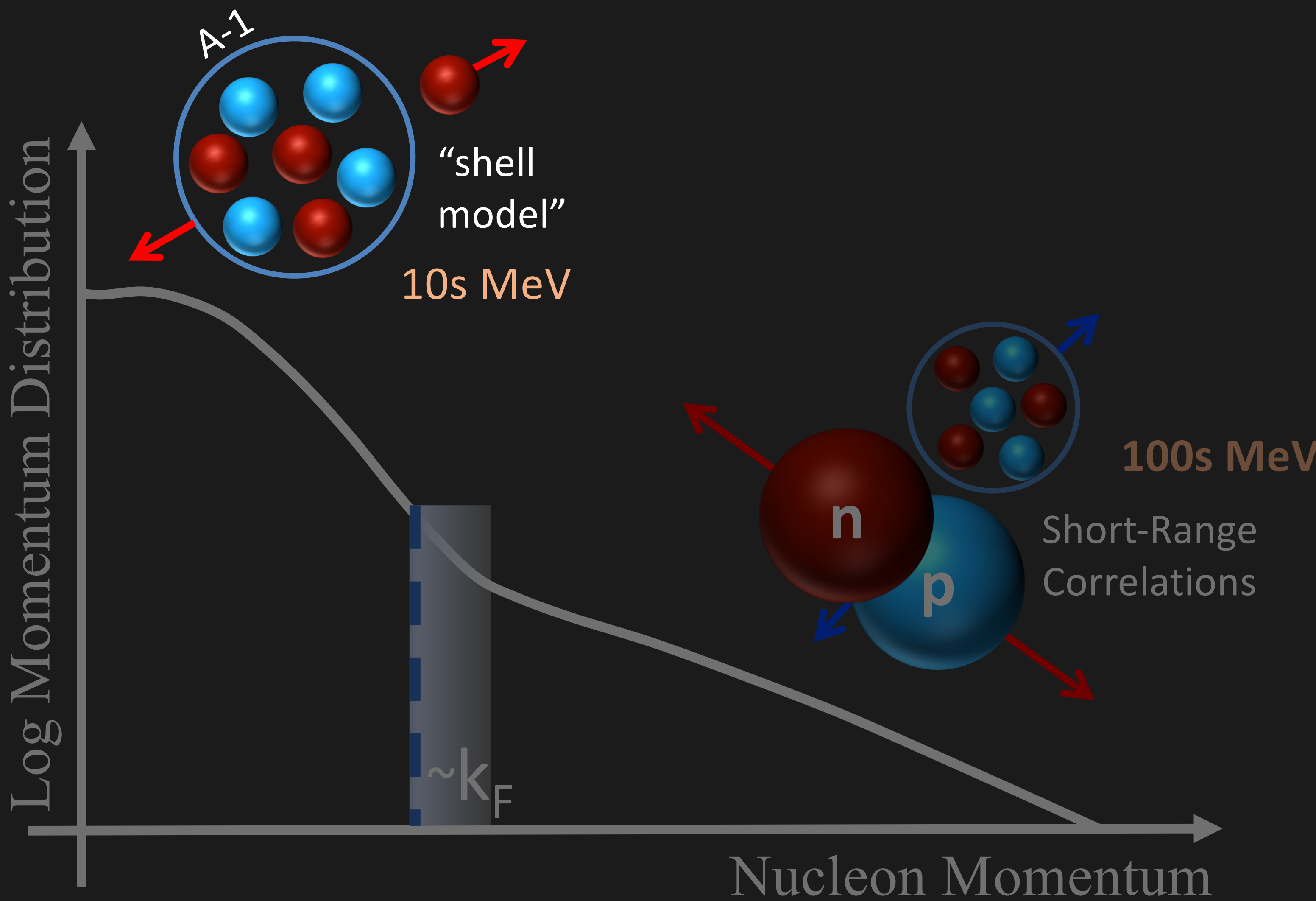
Aubert et al., PLB (**1983**); Ashman et al., PLB (1988); Arneodo et al., PLB (1988); Allasia et al., PLB (1990); Gomez et al., PRD (1994); Seely et al., PRL (2009); Schmookler et al., Nature (**2019**)

The Two-Phased Nucleus



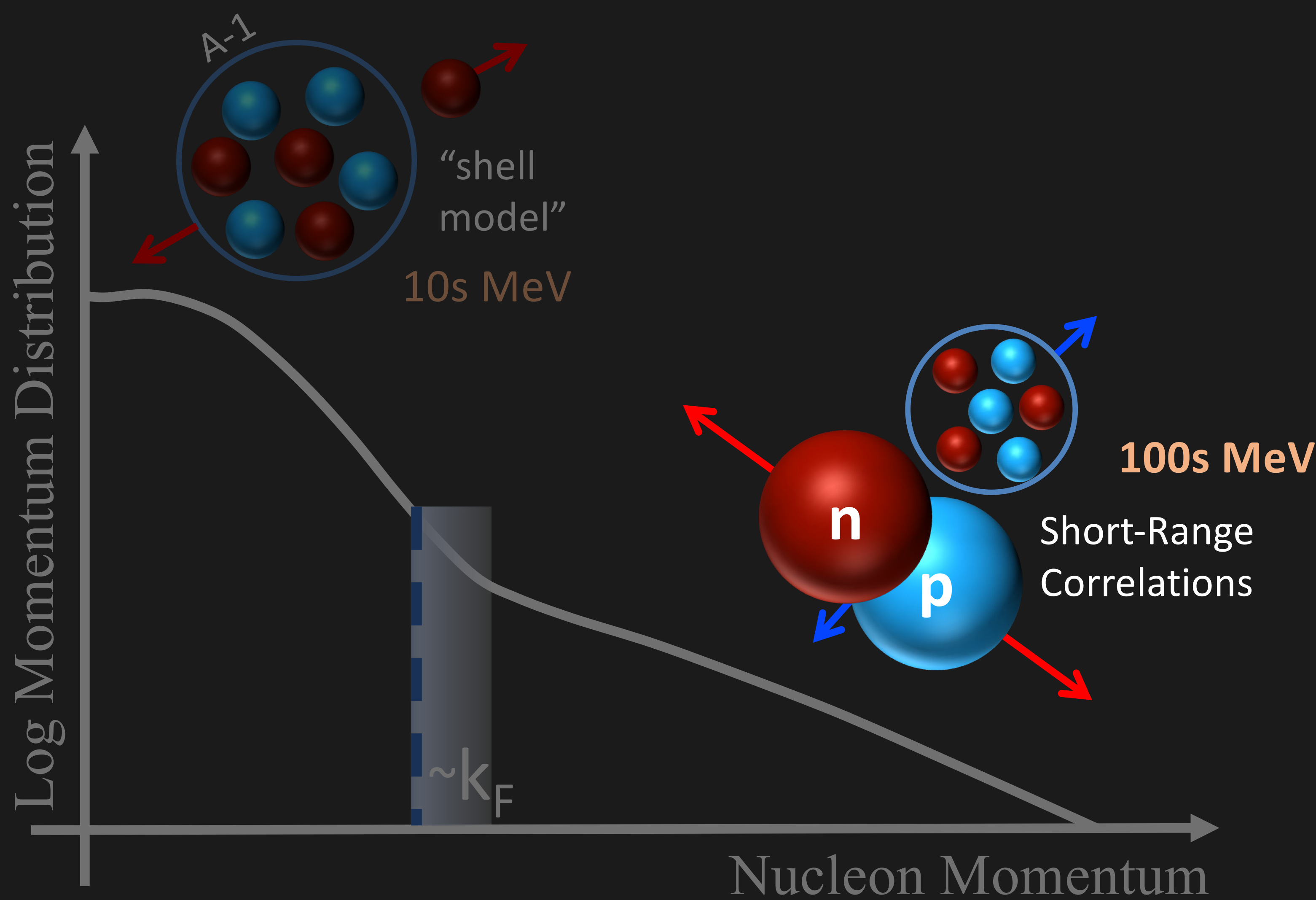
Korover PLB '21; Duer PRL '19; Duer Nature '18; Hen Science '14; Korover PRL '14; Subedi Science '08; Shneor PRL '07; Piasetzky PRL '06; Tang PRL '03; <u>Review:</u> Hen RMP '17

The Two-Phased Nucleus



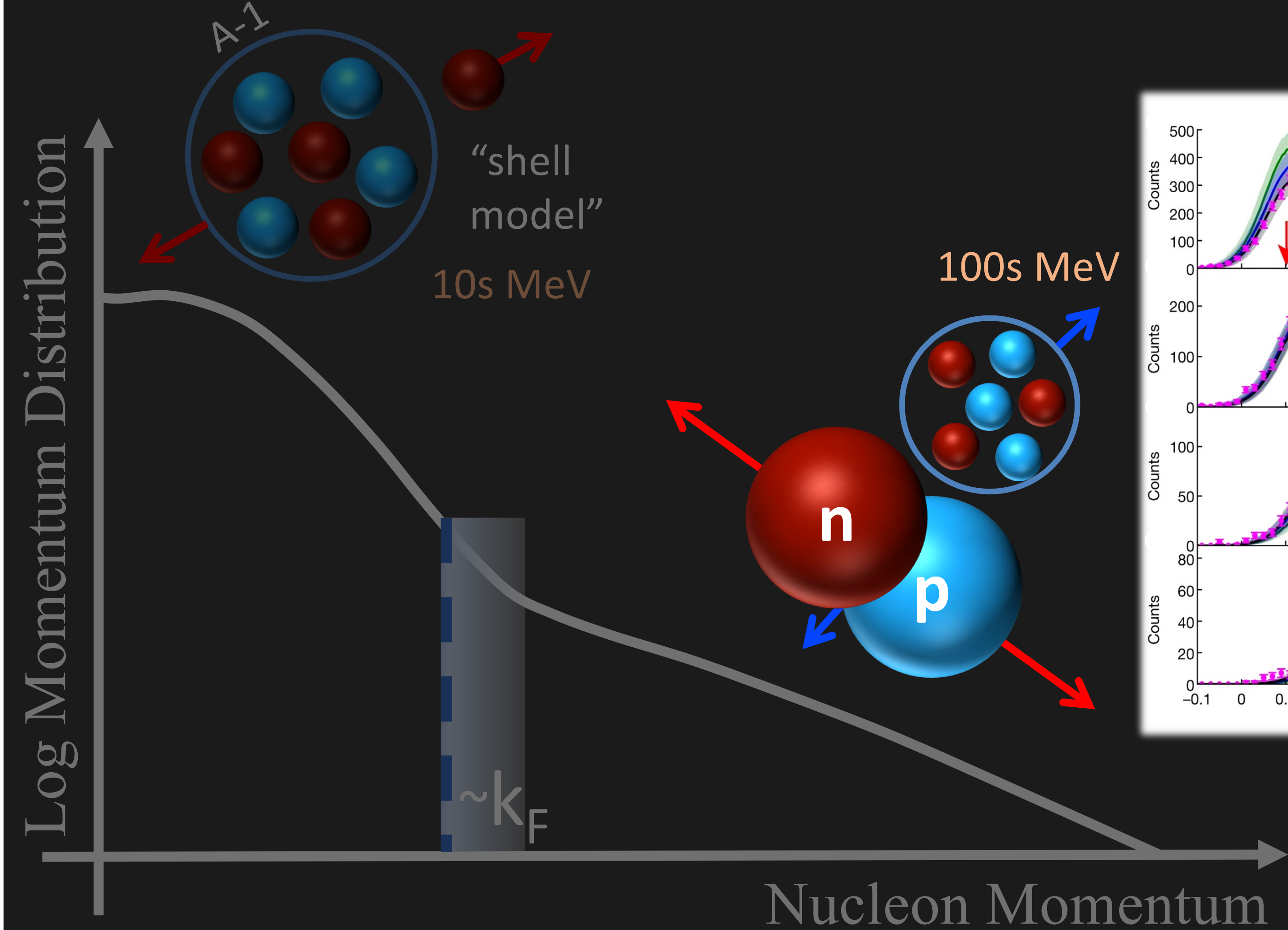
Korover PLB '21; Duer PRL '19; Duer Nature '18; Hen Science '14; Korover PRL '14;
Subedi Science '08; Shneor PRL '07; Piasetzky PRL '06; Tang PRL '03; Review: Hen RMP '17

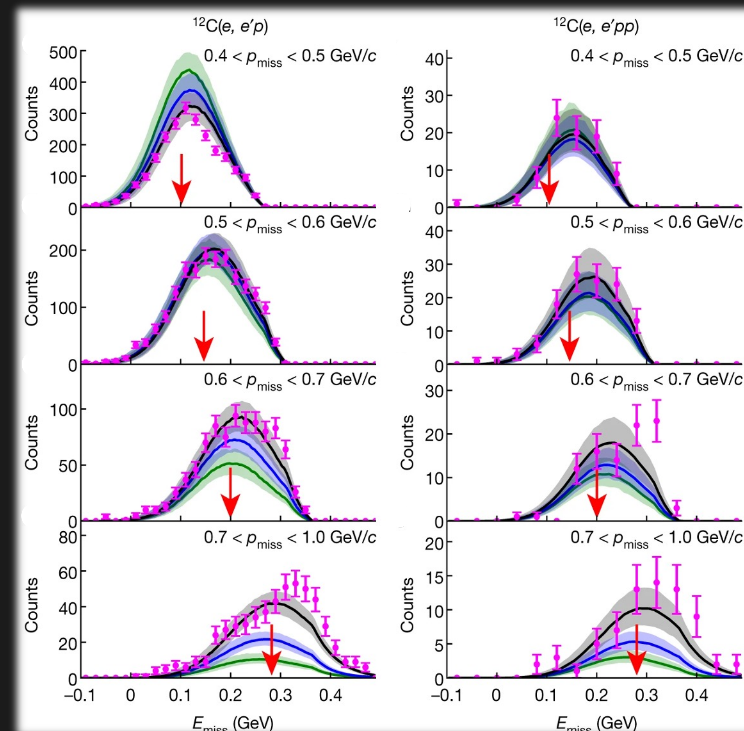
The Two-Phased Nucleus



Korover PLB '21; Duer PRL '19; Duer Nature '18; Hen Science '14; Korover PRL '14;
Subedi Science '08; Shneor PRL '07; Piasetzky PRL '06; Tang PRL '03; Review: Hen RMP '17

The Two-Phased Nucleus

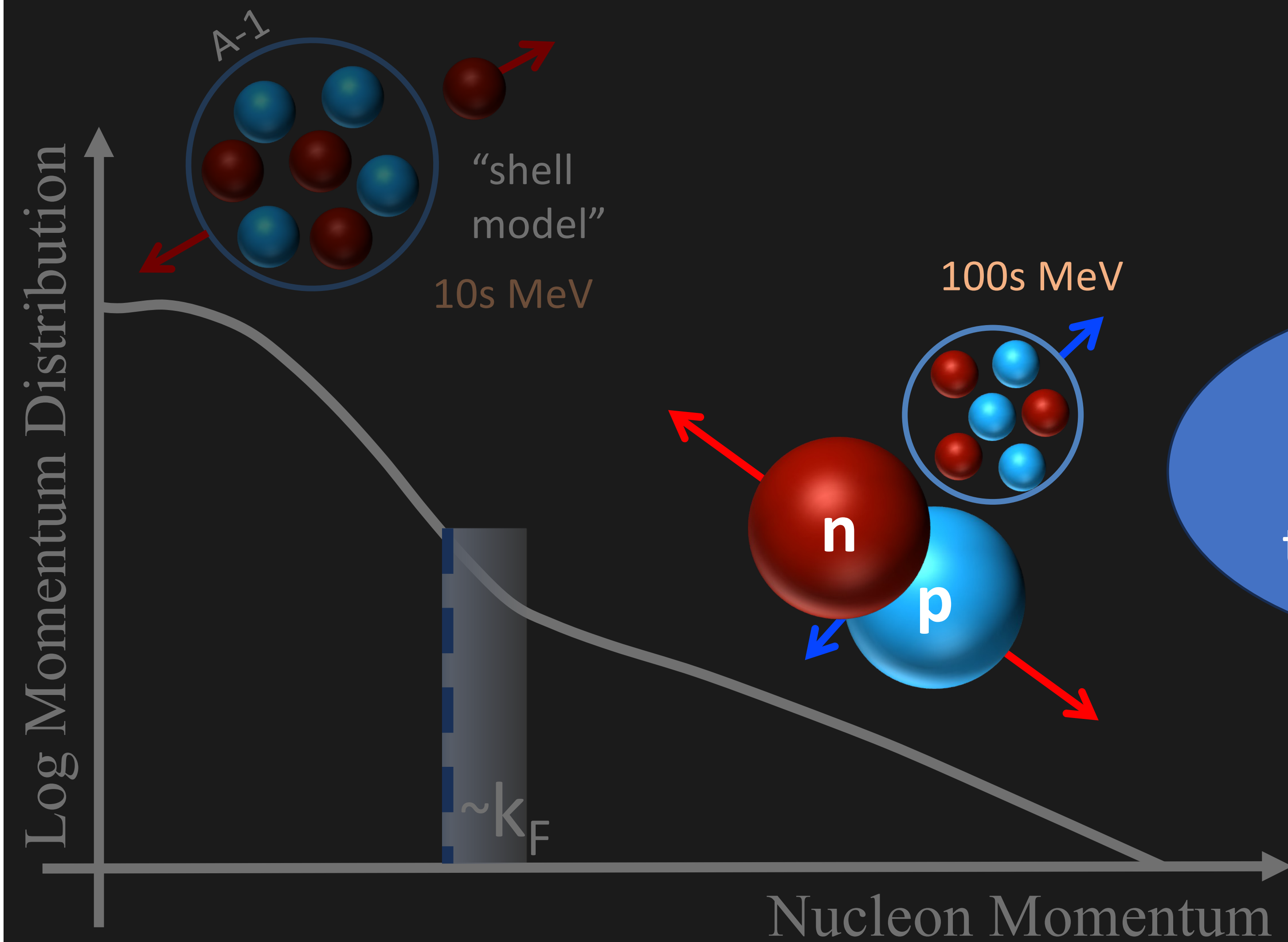




Nature 578, 540 (2020)

Korover PLB '21; Duer PRL '19; Duer Nature '18; Hen Science '14; Korover PRL '14;
Subedi Science '08; Shneor PRL '07; Piasetzky PRL '06; Tang PRL '03; Review: Hen RMP '17

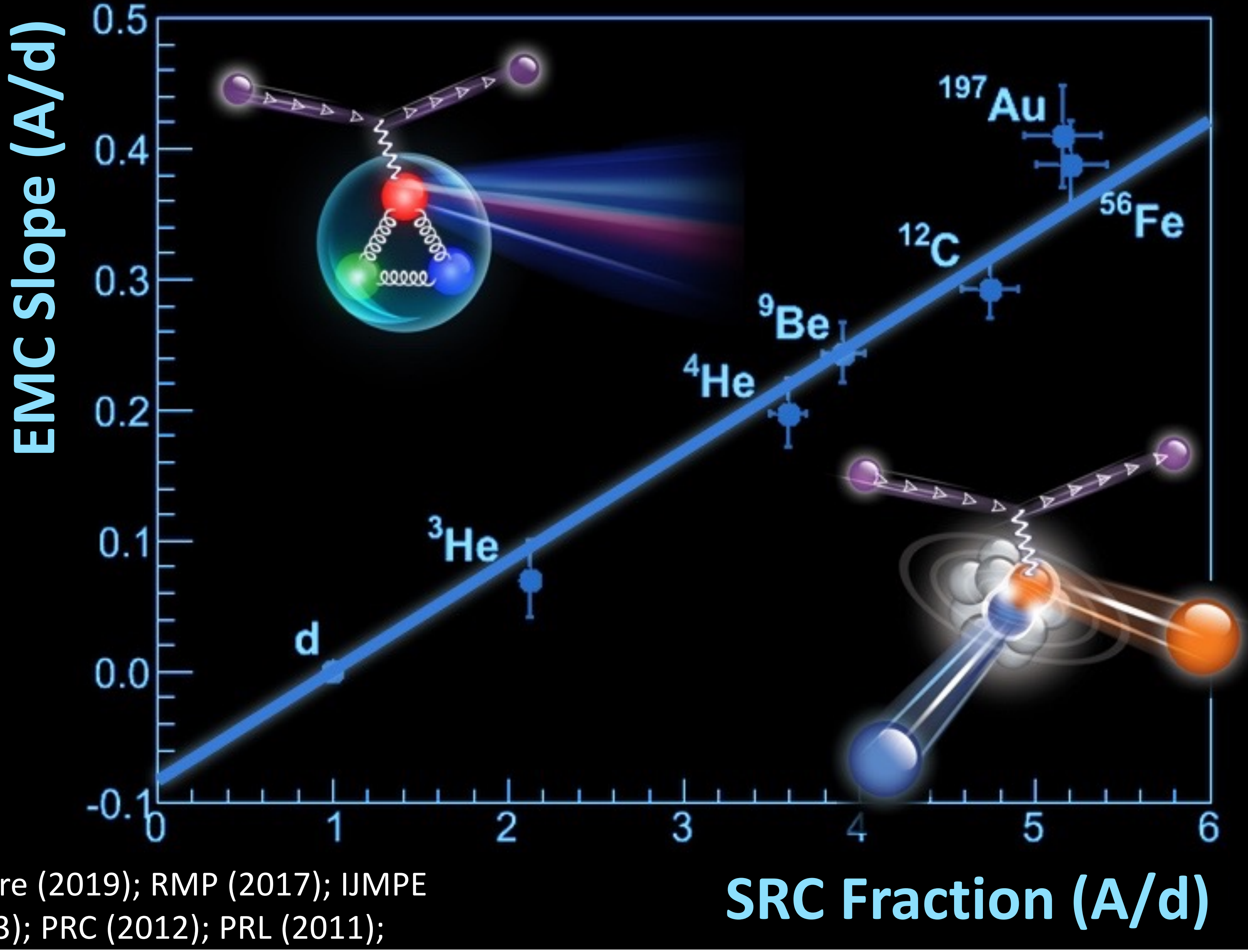
The Two-Phased Nucleus



Can SRCs be a main driver for the EMC effect?

Korover PLB '21; Duer PRL '19; Duer Nature '18; Hen Science '14; Korover PRL '14;
Subedi Science '08; Shneor PRL '07; Piasetzky PRL '06; Tang PRL '03; Review: Hen RMP '17

EMC – SRC Correlation



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

052301 (2011) PHYSICAL REVIEW LETTERS we 4 FEB

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]

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

Constraints on the large-*x* *d*/*u* ratio from electron-nucle

O. Hen,[1] A. Accardi,[2,3] W. Melnitch

PHYSICAL REVIEW RESEARCH **3,** 023240 (2021)

Short-range correlations and the nuclear EMC effect in deuterium and helium

a,[1] J. R. Pybus,[1] F. Hauenstein,[1,2] D. W. Higinbotham,[3] G. A. Miller,[4] E. Piasetzky,[5] A M. Strikman,[7] L. B. Weinstein,[2] and O. Hen[1,*]

Short range correlations and the EMC effect

NUCLEAR PHYSICS A

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

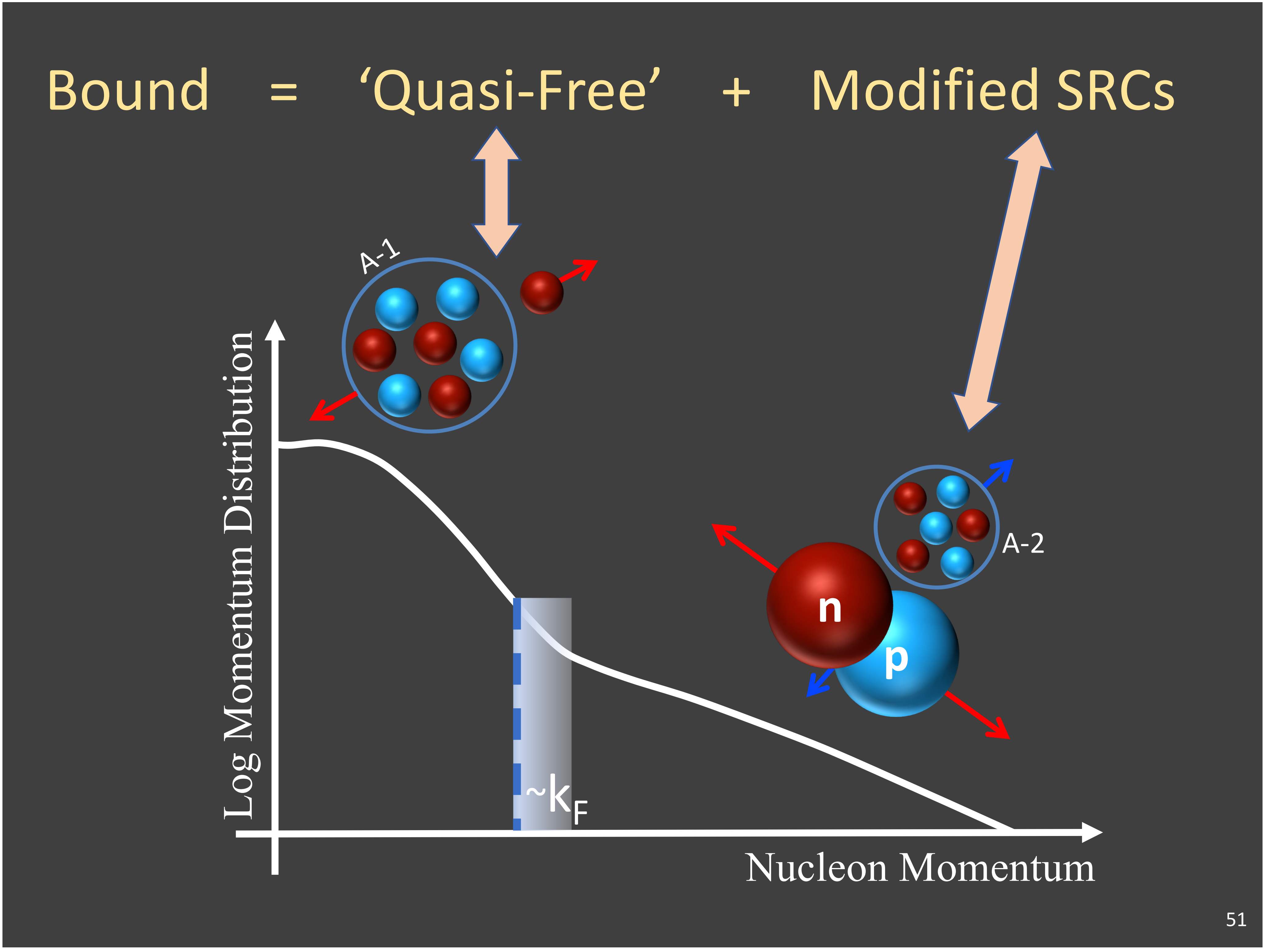
International Journal of Modern Physics E
Vol. 22, No. 7 (2013) 1330017 (30 pages)

THE EMC EFFECT AND HIGH MOM NUCLEONS IN NUCLEI

REVIEWS OF MODERN PHYSICS, VOLUME 89, OCTOBER–DECEMB

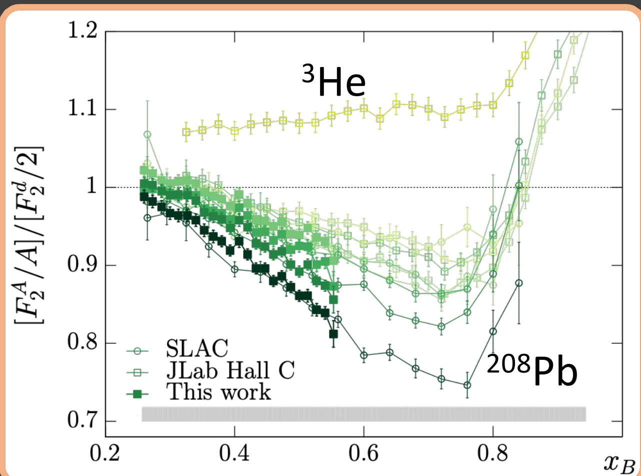
Nucleon-nucleon correlations, short-lived excitations, and the quarks within

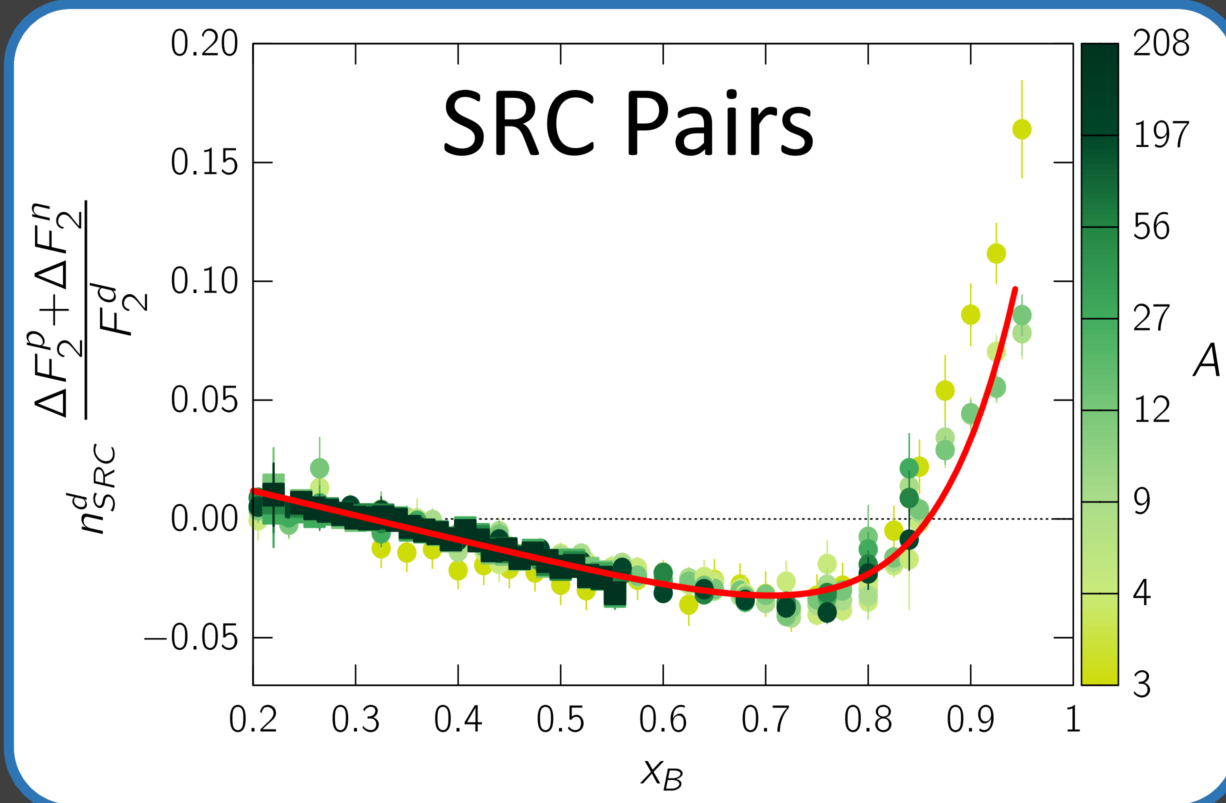
Or Hen Gerald A. Miller Eli Piasetzky Lawrence B. Weinstein


Bound = 'Quasi-Free' + Modified SRCs
A-1
A-2
n
p
Log Momentum Distribution
~k_F
Nucleon Momentum

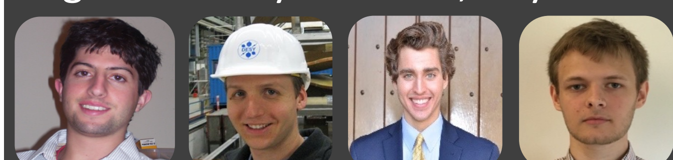
SRC Universality!

All Nucleons

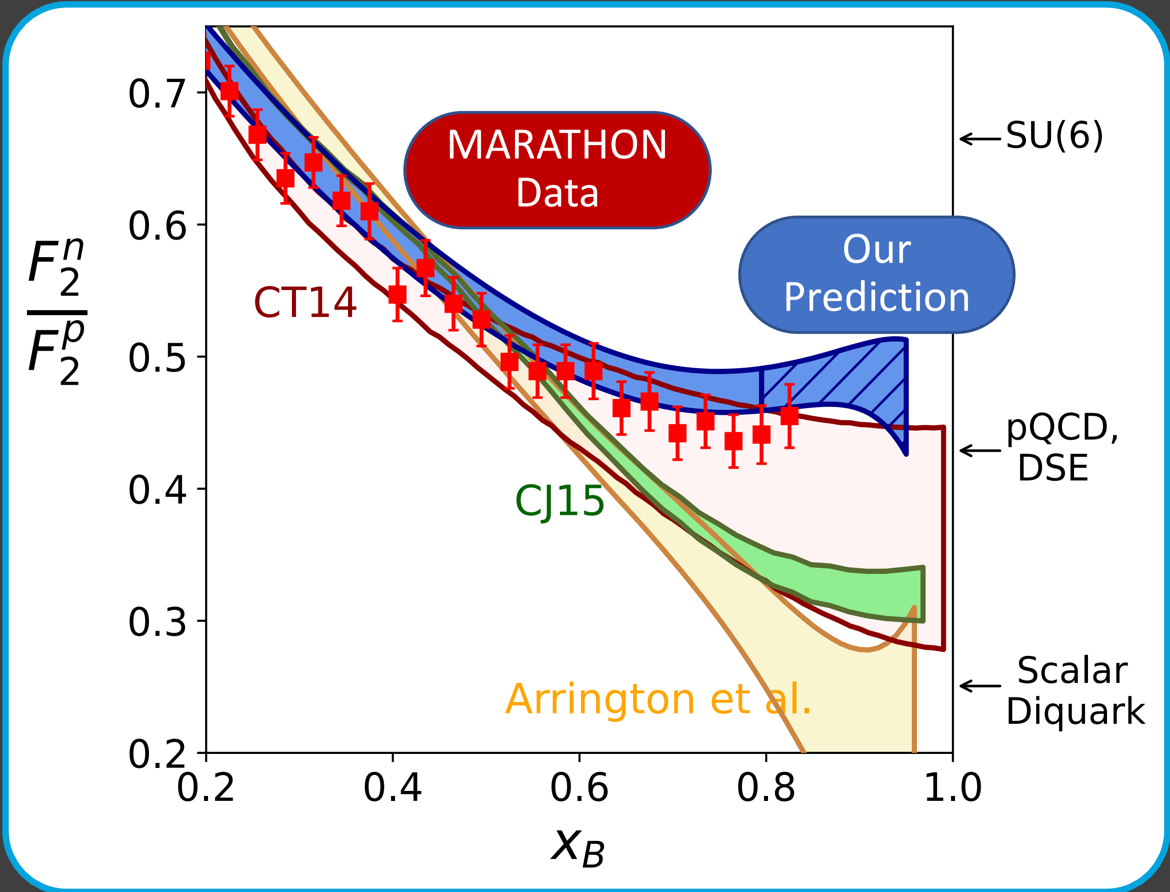




Schmookler et al., Nature (2019);
Segarra et al., Phys. Rev. Lett. (2020);
Segarra and Pybus et al., Phys. Rev. Research (2021)

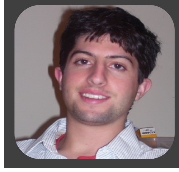


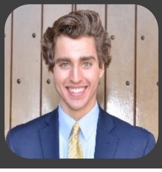
Verified Predictions!



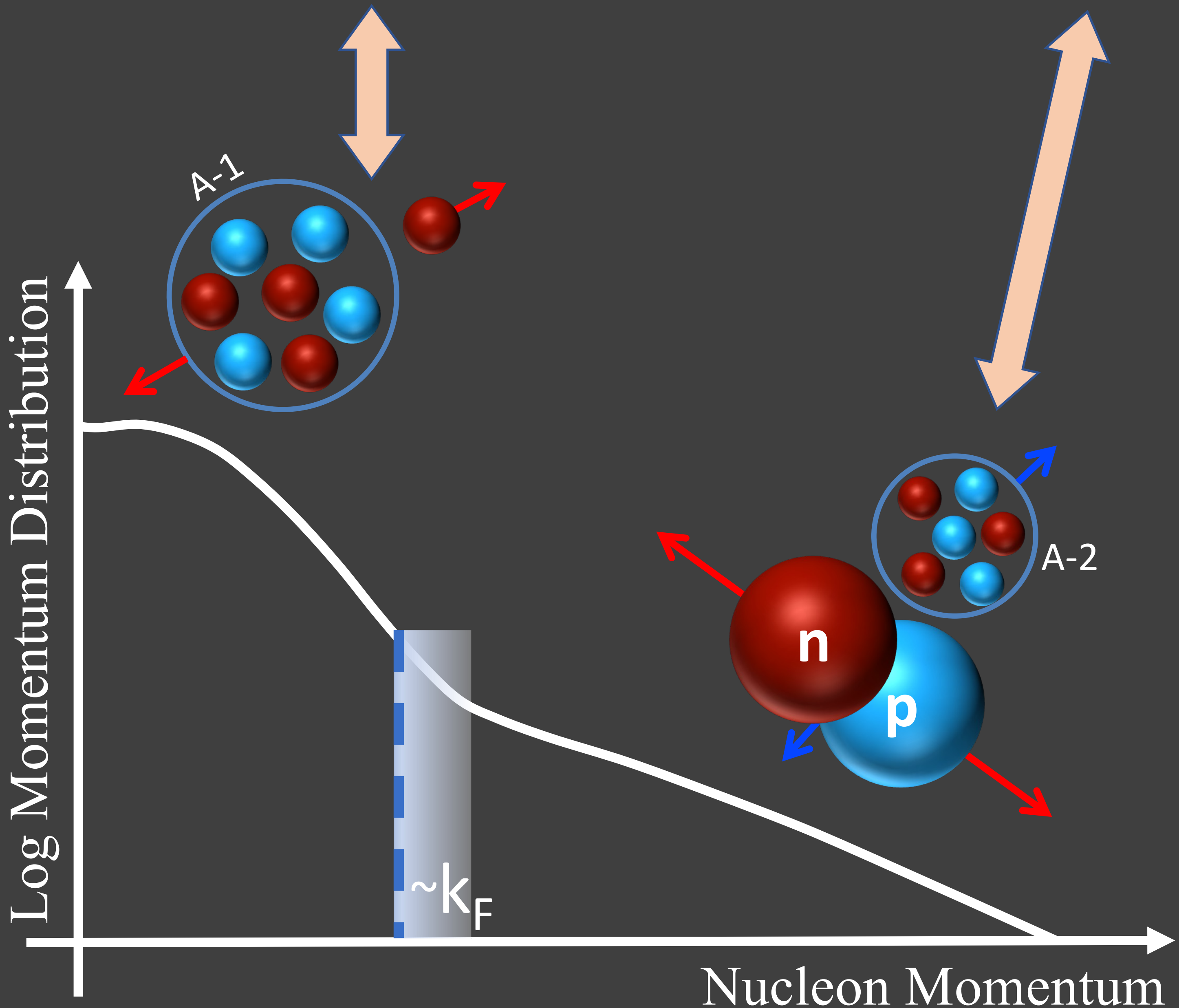
MARATHON Data: Abrams et al., Phys. Rev. Lett. (2022)

Our Prediction: Segarra et al., Phys. Rev. Lett. (2020)






Bound = 'Quasi-Free' + Modified SRCs



Nuclear Quark-Gluon Distributions From Global Analysis

$$q_i^A(x,Q) = \left(1 - \%_{SRC}^A\right) \times f_i^{free}(x,Q)$$

$$+$$

$$\%_{SRC}^A \times f_i^{SRC}(x,Q)$$

Utilizing PRD 103, 114015 (2021)

Nuclear Quark-Gluon Distributions From Global Analysis

$$q_i^A(x,Q) = \left(1 - \%_{SRC}^A\right) \times f_i^{free}(x,Q)$$

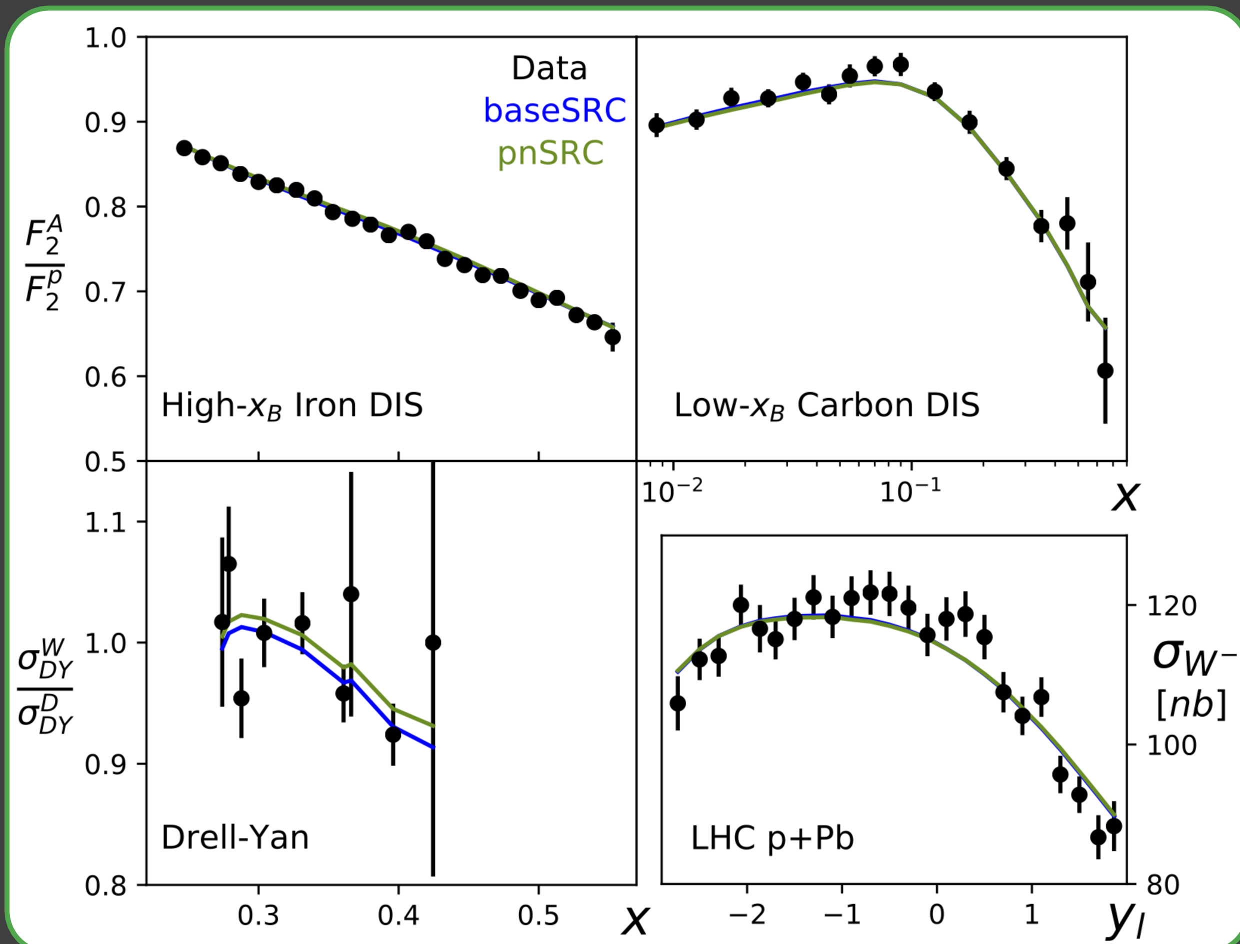
$$+$$

$$\%_{SRC}^A \times f_i^{SRC}(x,Q)$$

Fit parameters

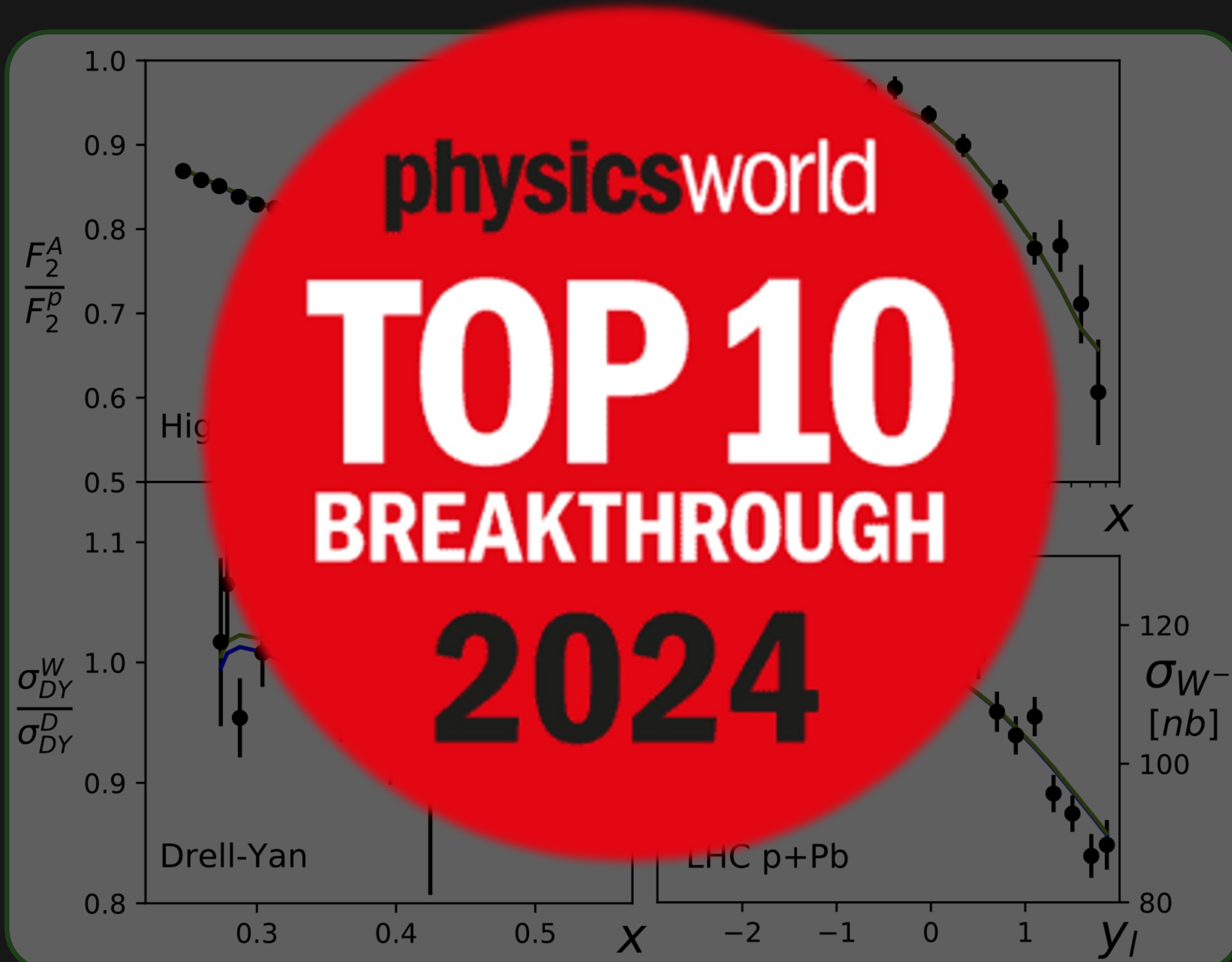
Utilizing PRD 103, 114015 (2021)

Nuclear Quark-Gluon Distributions From Global Analysis



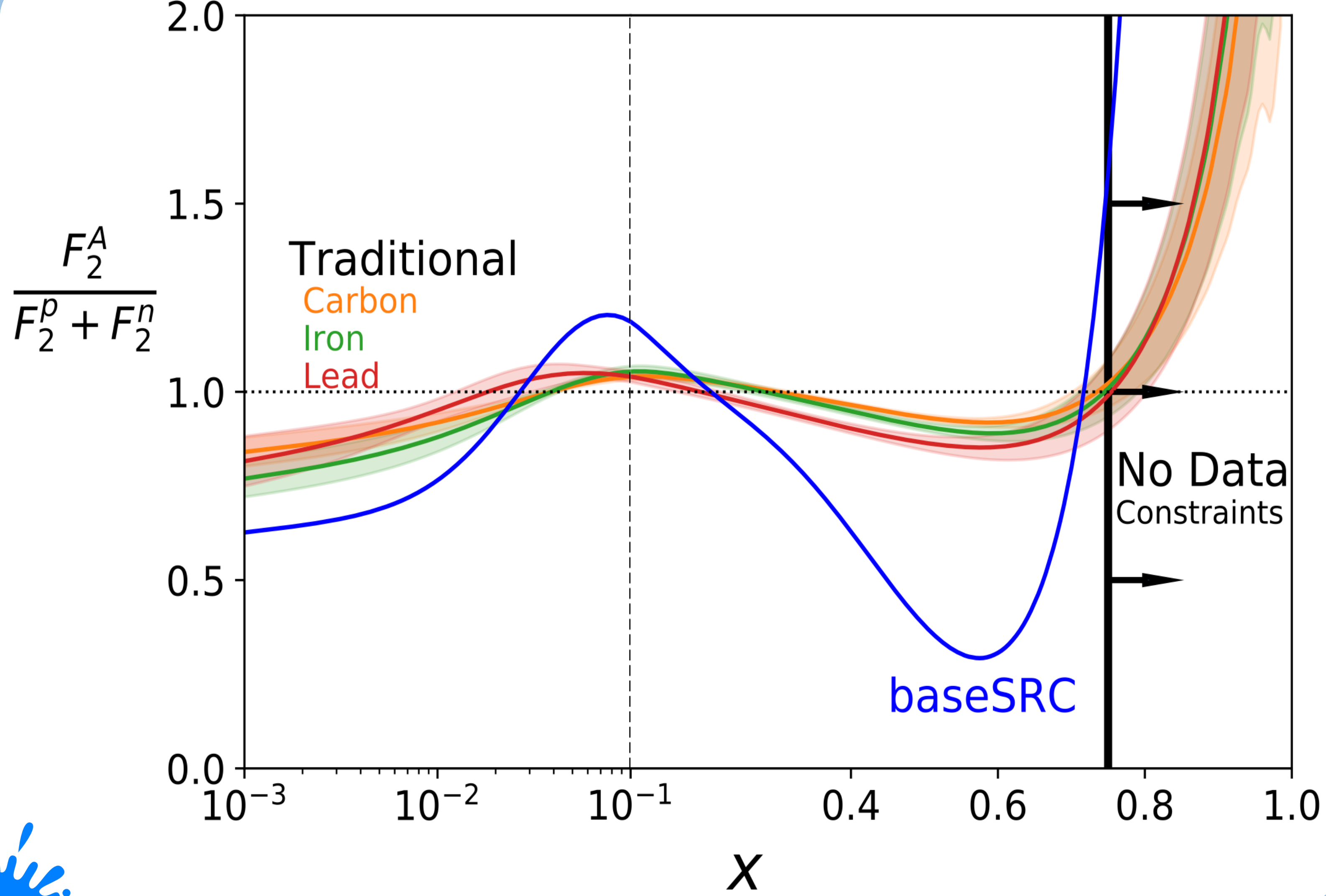
Utilizing PRD 103, 114015 (2021)

Nuclear Quark-Gluon Distributions From Global Analysis

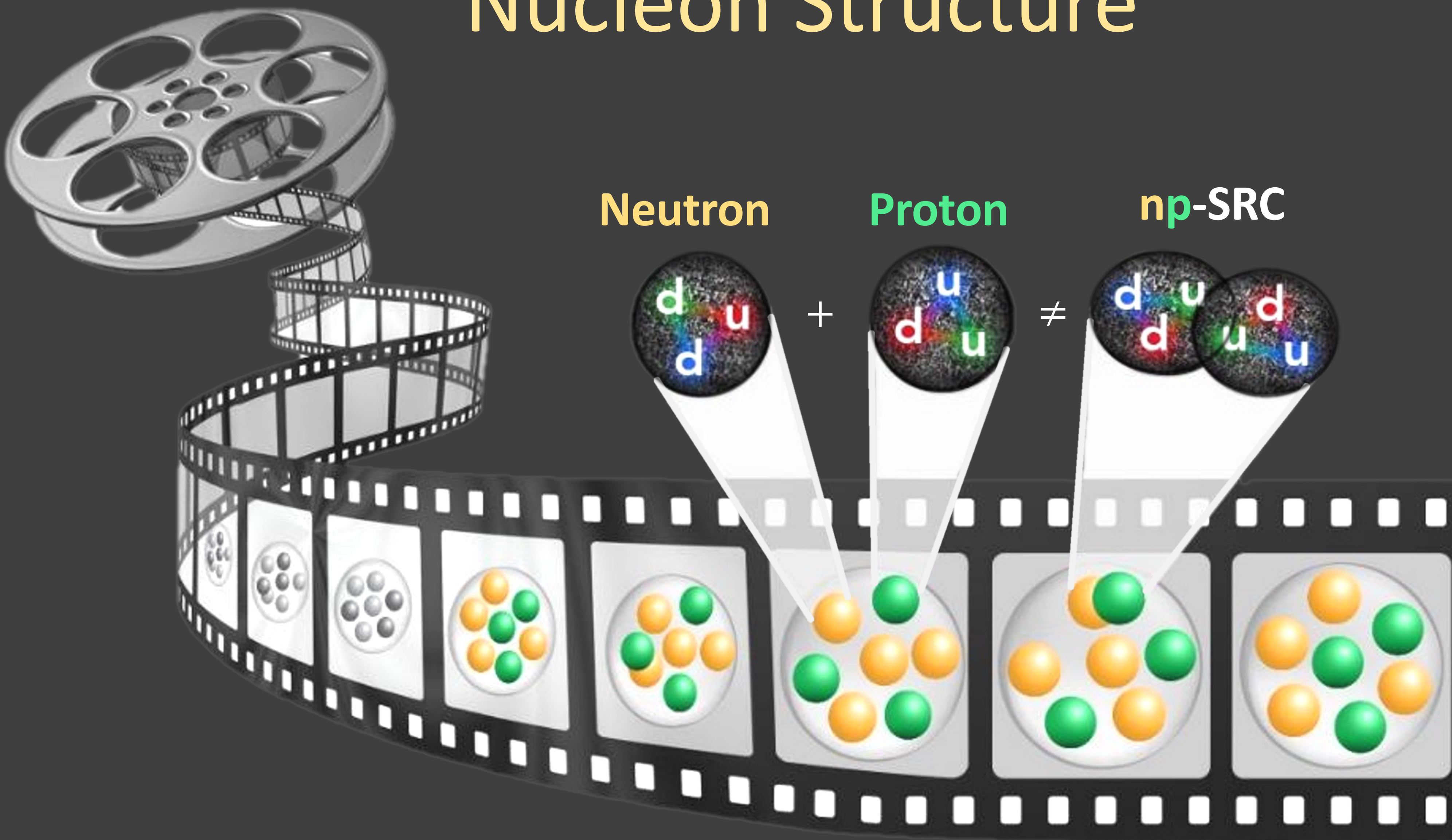


Utilizing PRD 103, 114015 (2021)

+ Predict Large SRC Modification



Nuclear Interactions Impact Nucleon Structure



Thank You!

Exciting
times ahead!