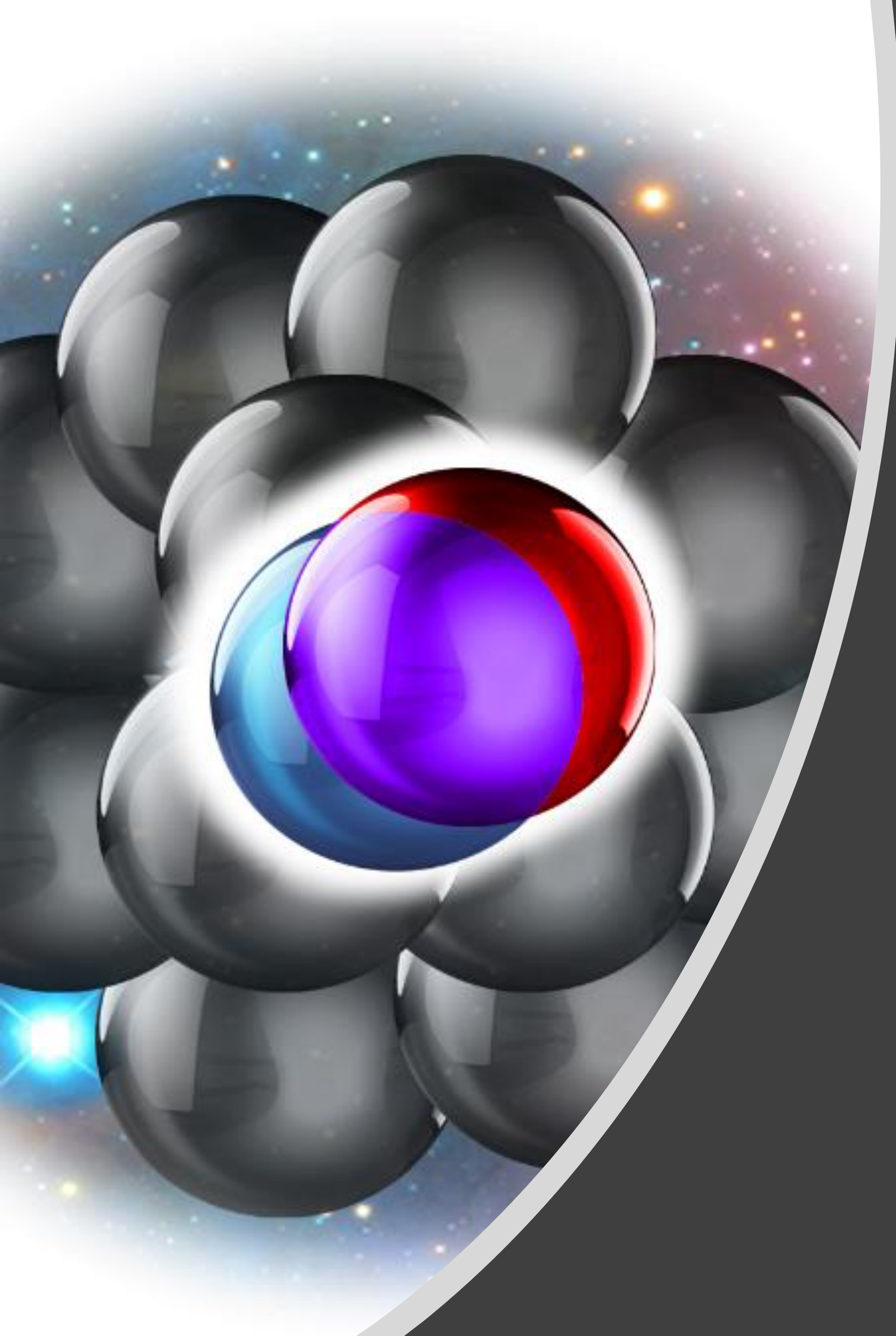
Short-Range Correlations and the Quarks Within

Or Hen (MIT)

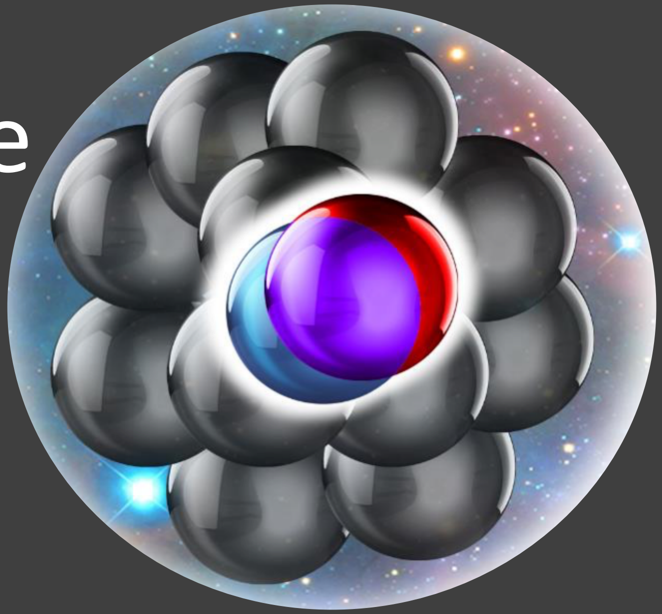
International Symposium on Clustering, January 24th 2020.

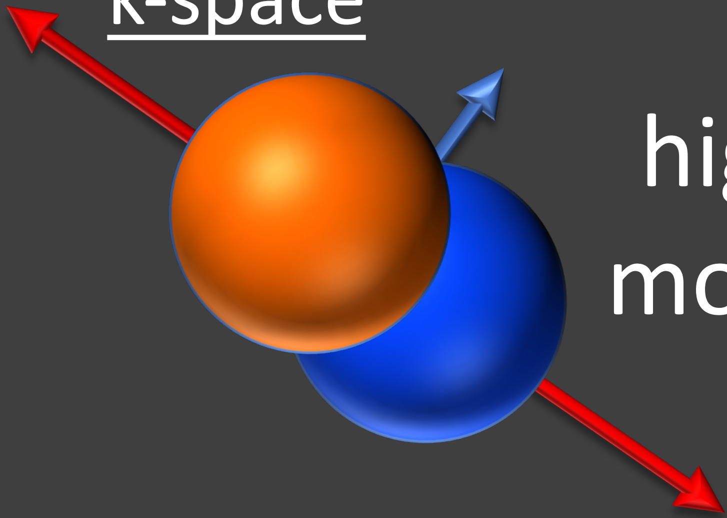


Short-Range Correlations (SRC)

r-space

Nucleon pairs that are close together in the nucleus

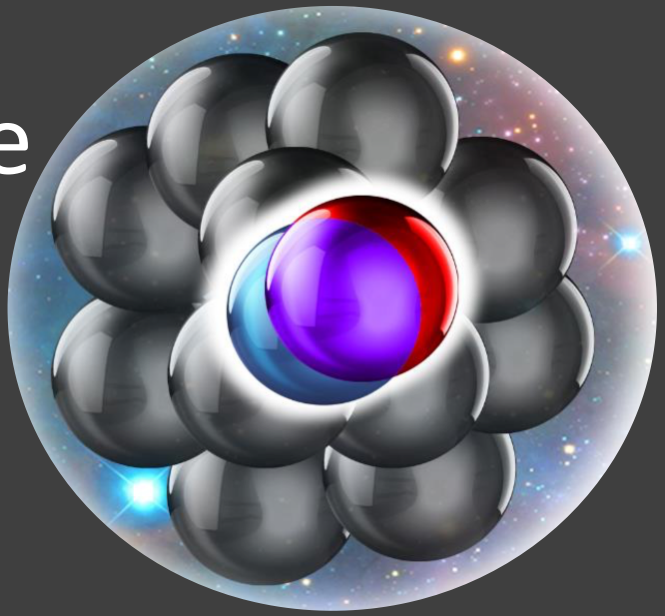




k-space

high ***relative*** and low ***c.m.*** momentum compared to k_F

r-space



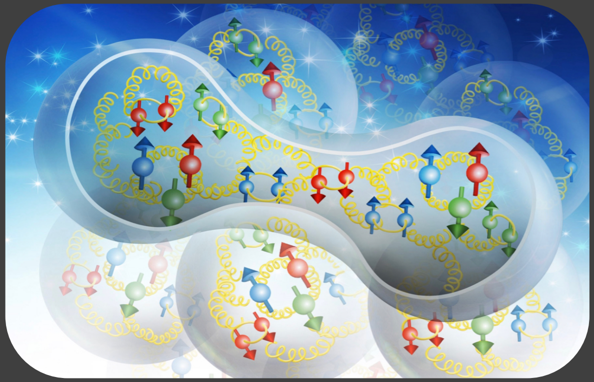
Nucleon pairs that are close together in the nucleus

Why SRC?

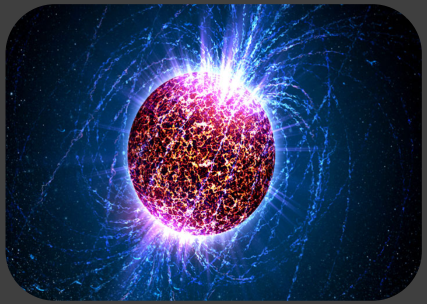
Why SRC?

Required for a high-resolution, first principle, description of nuclear systems & processes.

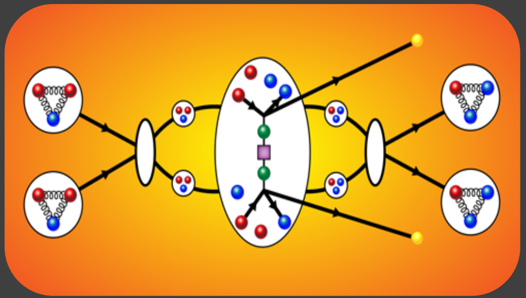
NN interaction from QCD & QCD in nuclei



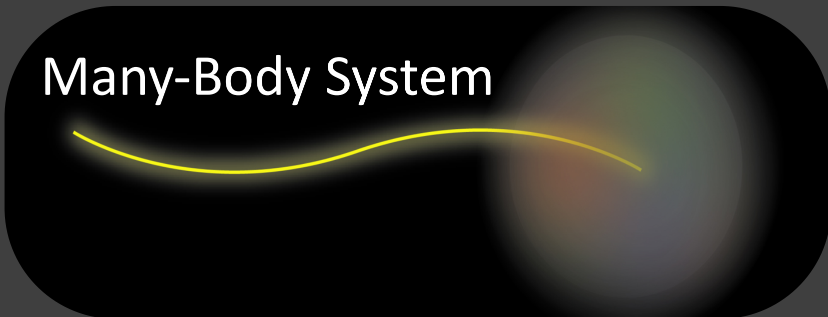
High-density systems

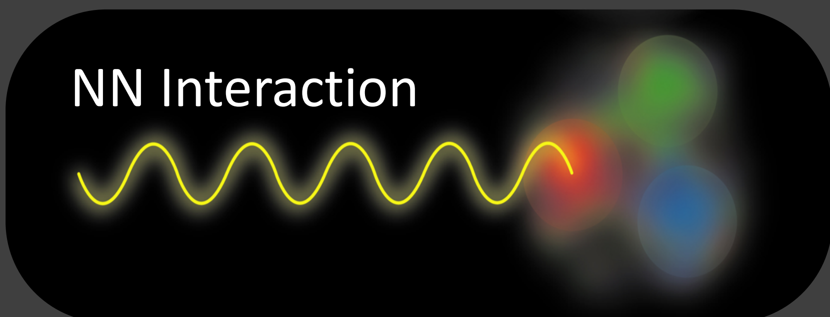


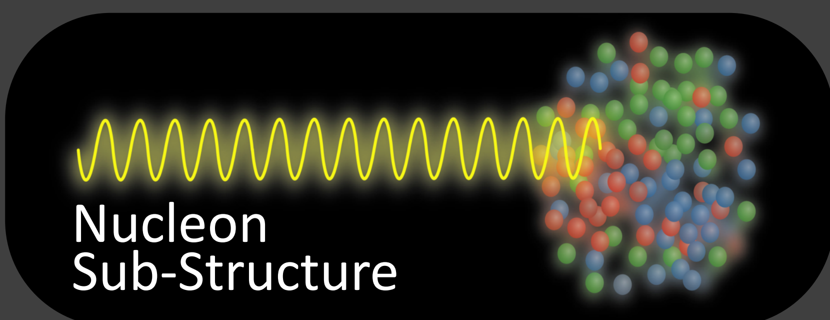
High-q processes
(e.g. $0\nu\beta\beta$ decay)

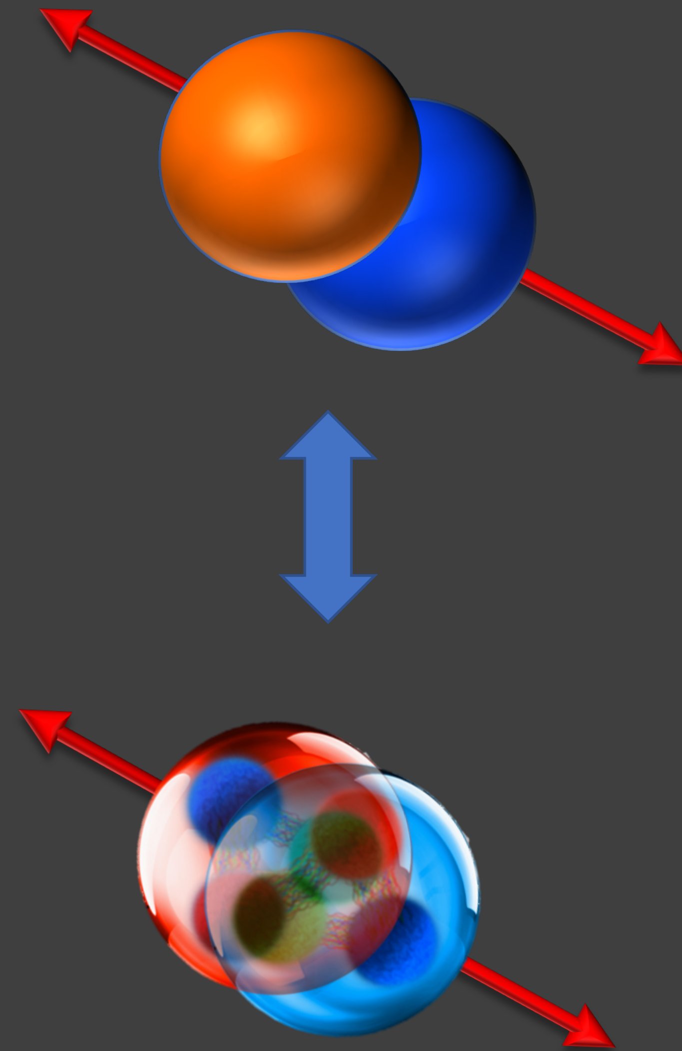


Today: SRCs Across Scales

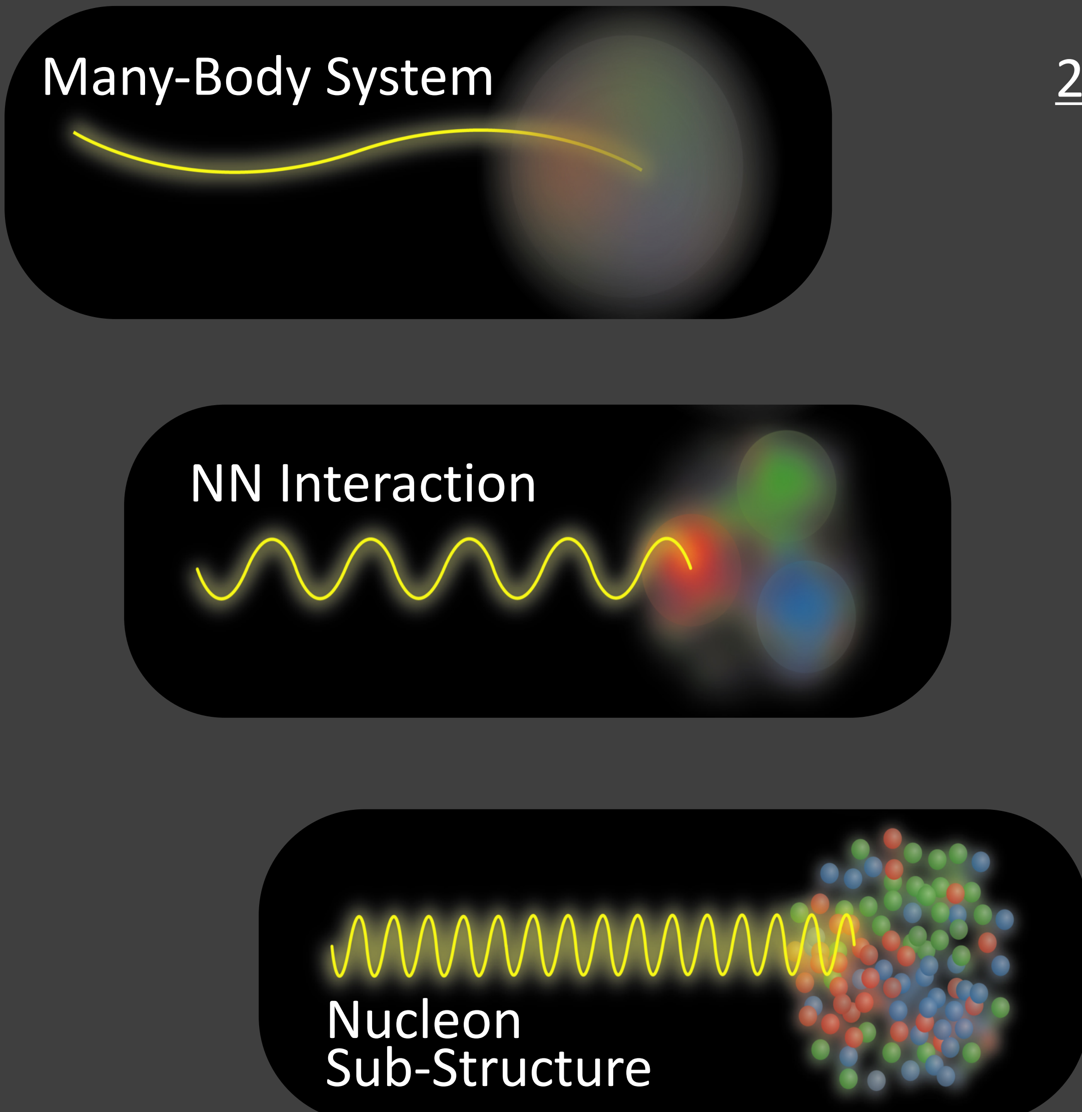








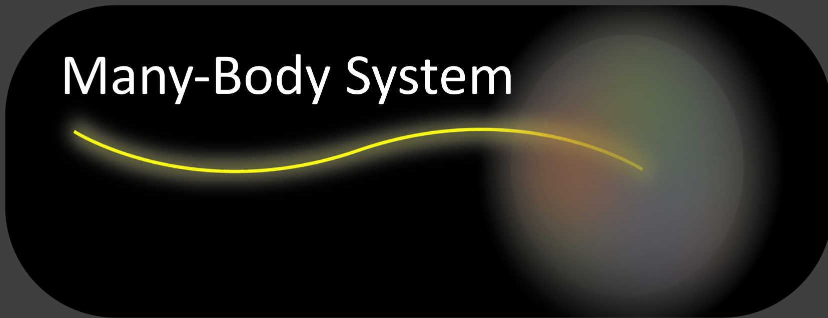
Today: SRCs Across Scales

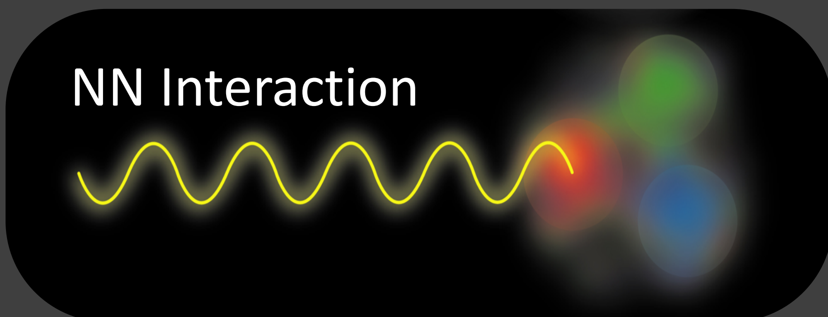


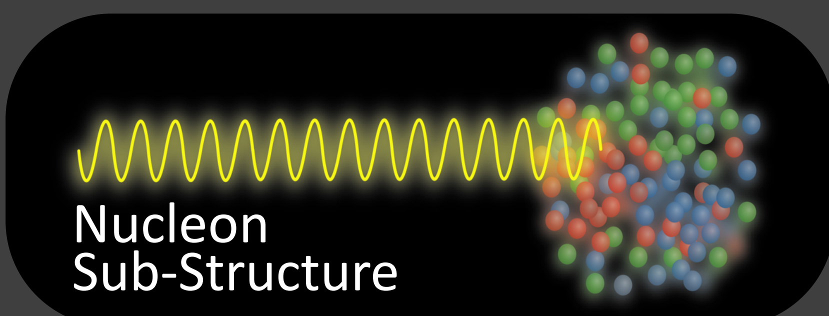
2018-20 SRC Publications:

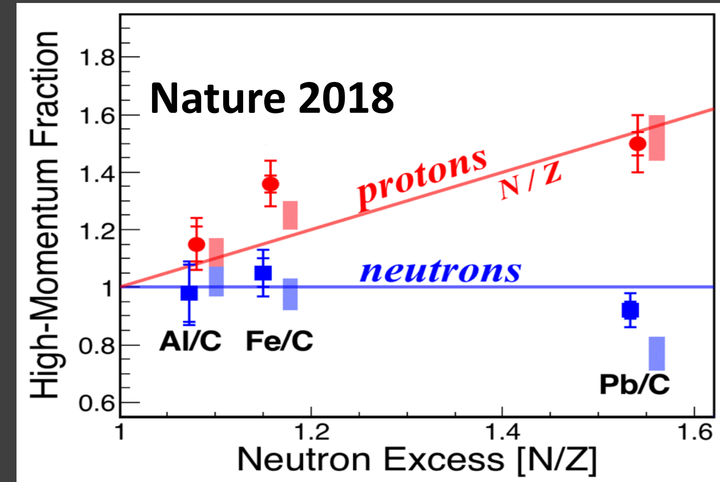
- Nature, In-Print (2020)
- Nature 566, 354 (2019)
- Nature 560, 617 (2018)
- PRL 122, 172502 (2019)
- PRL 121, 092501 (2018)
- Phys. Lett. B 800, 135110 (2019)
- Phys. Lett. B 797, 134890 (2019)
- Phys. Lett. B 797, 134792 (2019)
- Phys. Lett. B 791, 242 (2019)
- Phys. Lett. B 793, 360 (2019)
- Phys. Lett. B 785, 304 (2018)
- Phys. Lett. B 780, 211 (2018)
- Chin Phys. C 42, 064105 (2018)

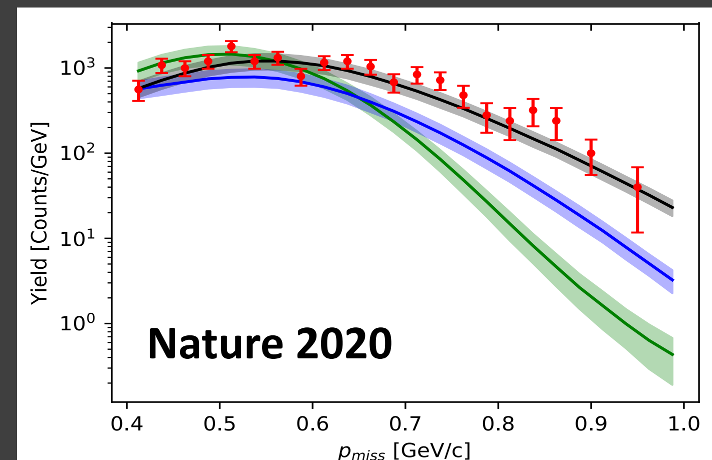
arXiv: 1908.02223; 1907.03658

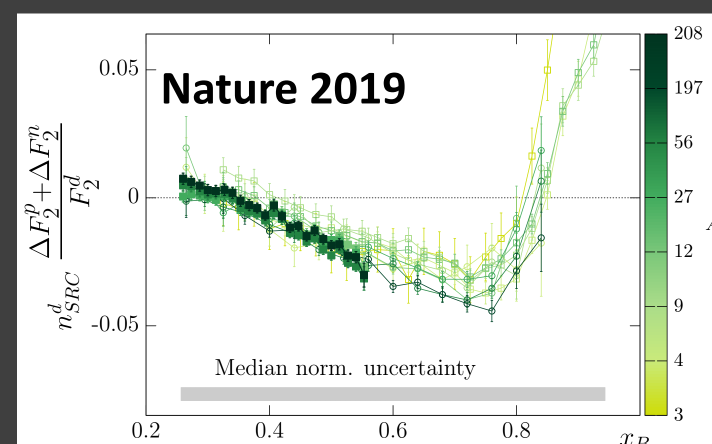

Many-Body System


NN Interaction

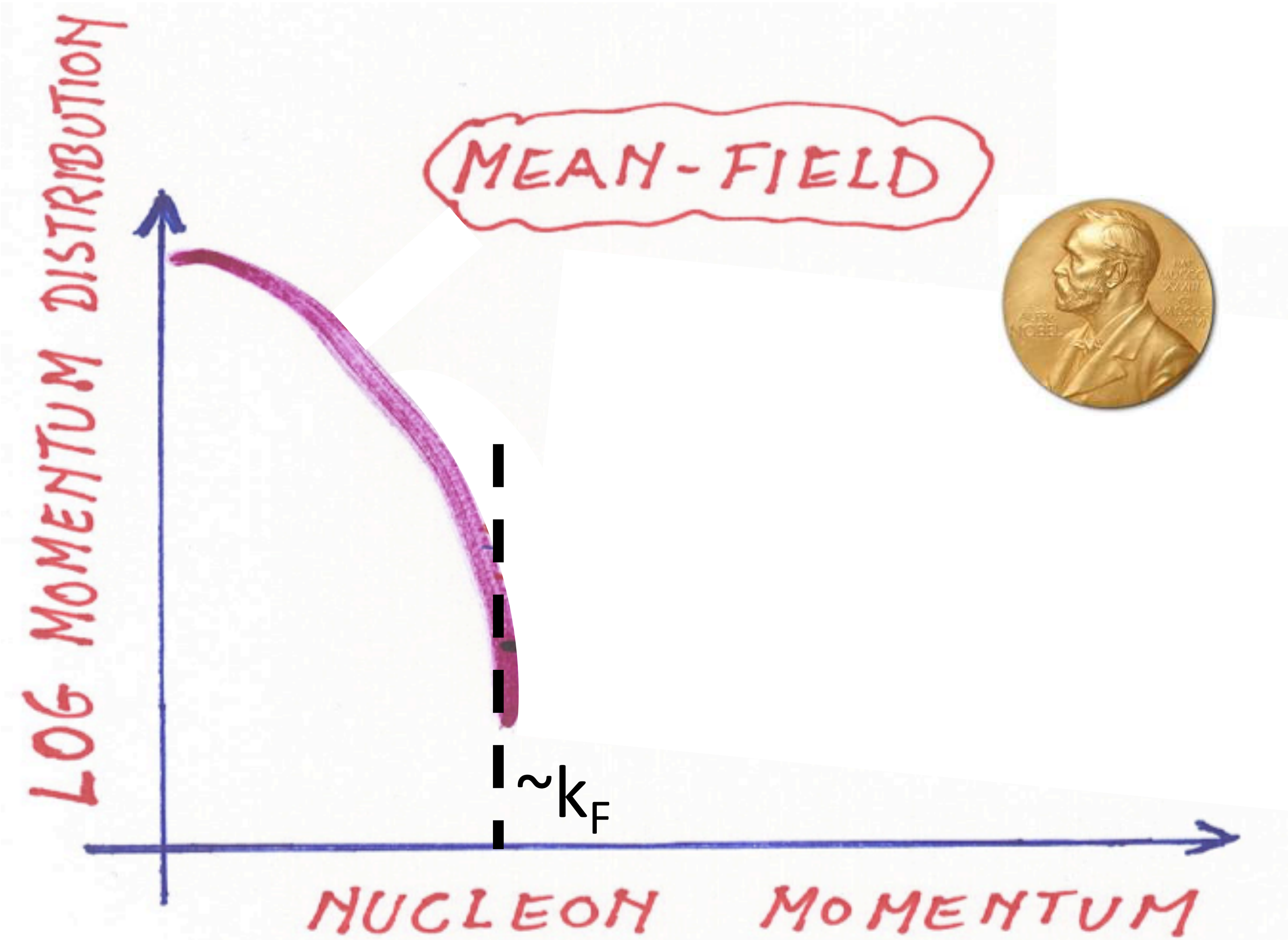

Nucleon
Sub-Structure

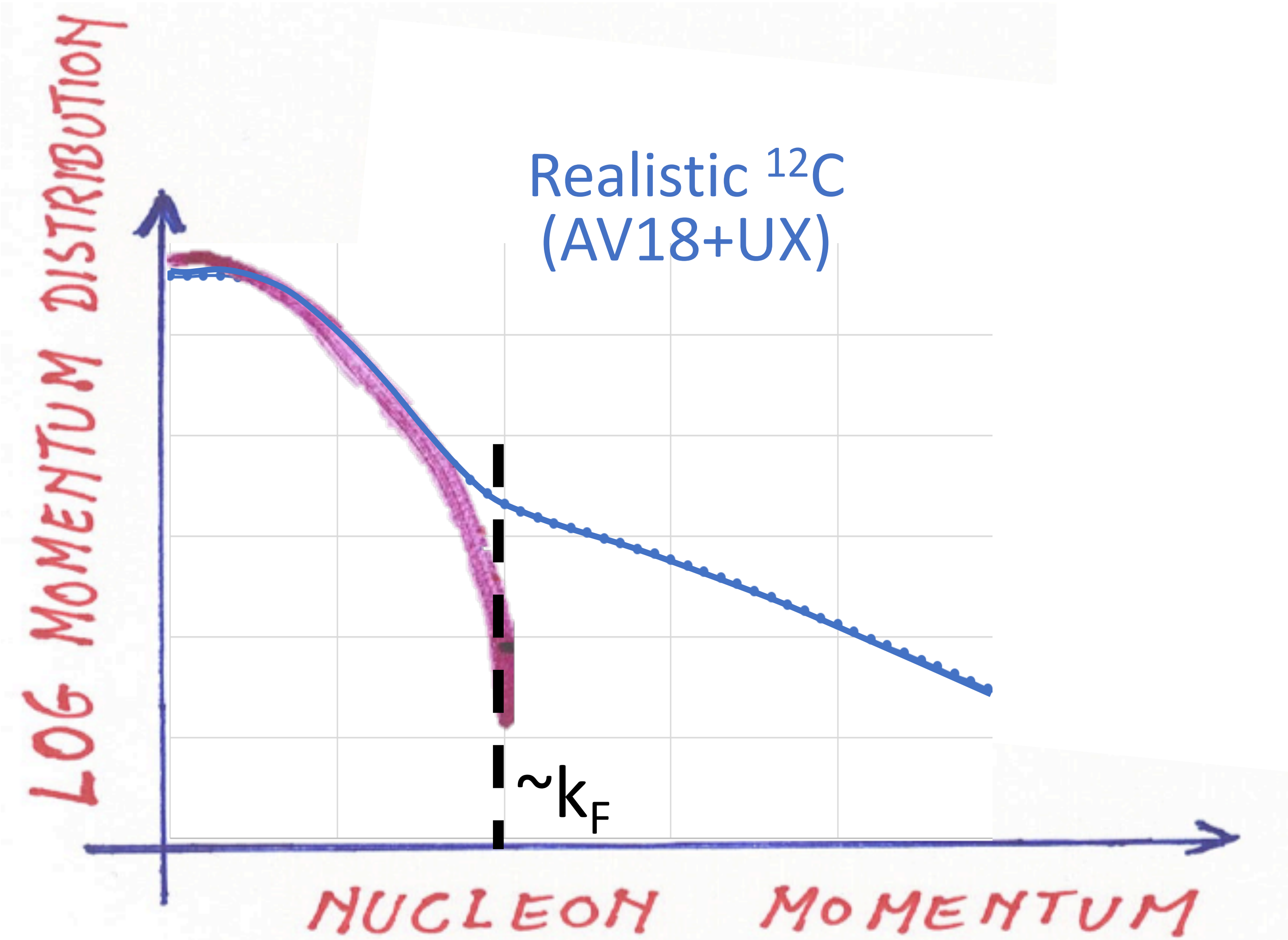

Nature 2018
High-Momentum Fraction
Neutron Excess [N/Z]
protons
N / Z
neutrons
Al/C
Fe/C
Pb/C
0.6
0.8
1
1.2
1.4
1.6
1.8
1
1.2
1.4
1.6


Nature 2020
Yield [Counts/GeV]
p_{miss} [GeV/c]
10^3
10^2
10^1
10^0
0.4
0.5
0.6
0.7
0.8
0.9
1.0

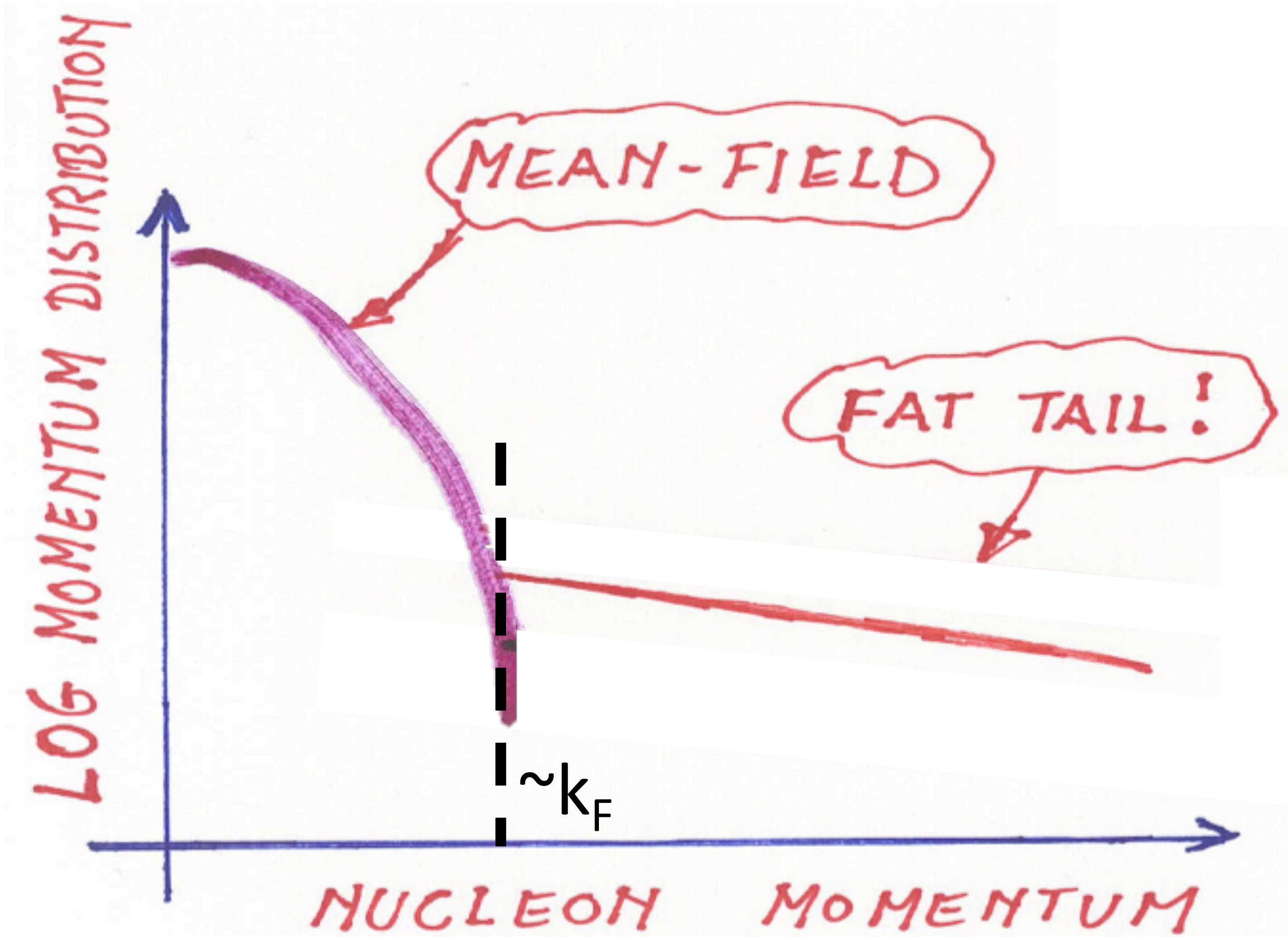

Nature 2019
$n^d_{SRC} \frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}$
x_B
Median norm. uncertainty
A
0.05
0
-0.05
0.2
0.4
0.6
0.8
208
197
56
27
12
9
4
3

Looking For Correlations

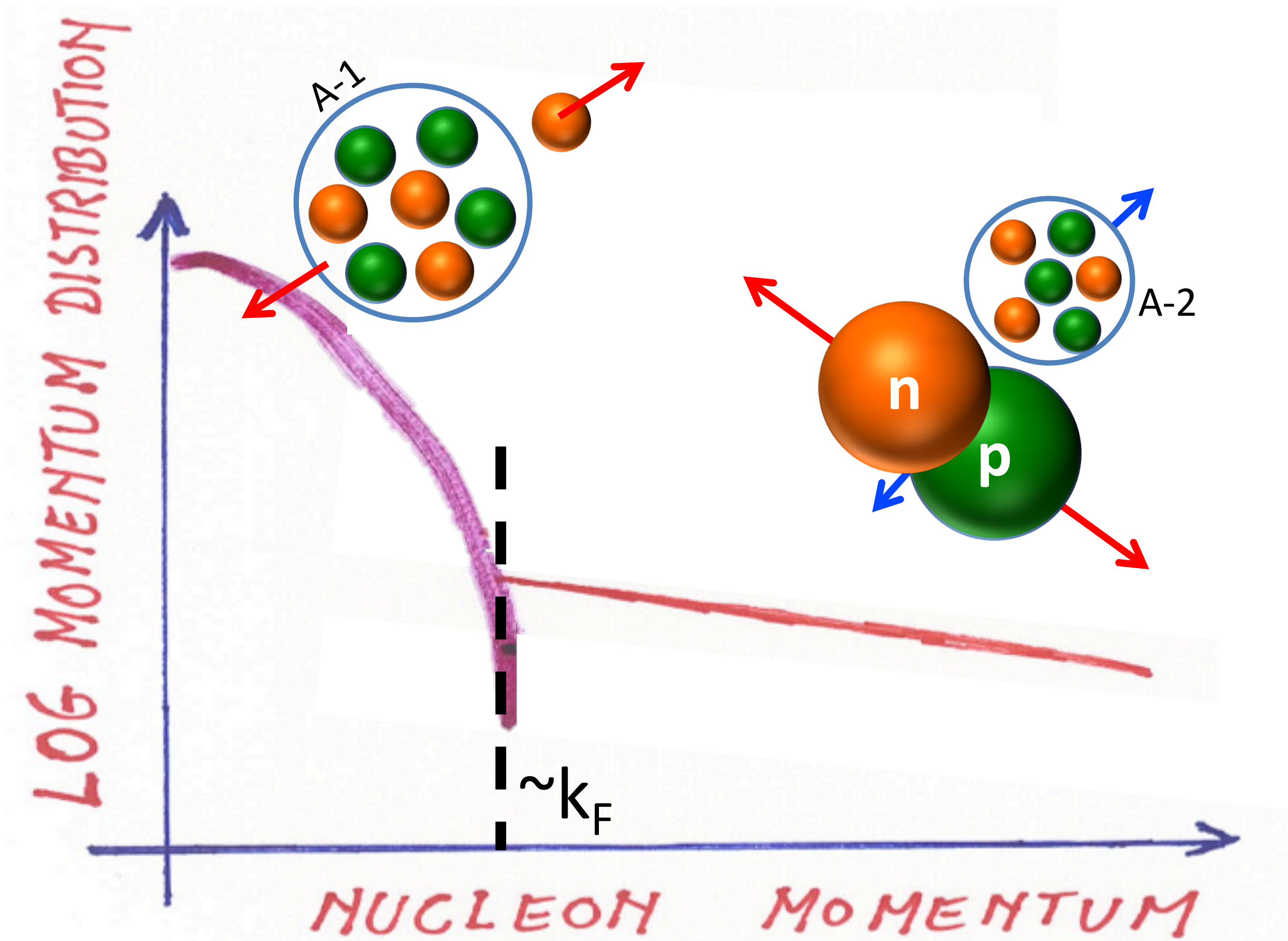




Wiringa, PRC (2014); Carlson, RMP (2015); …

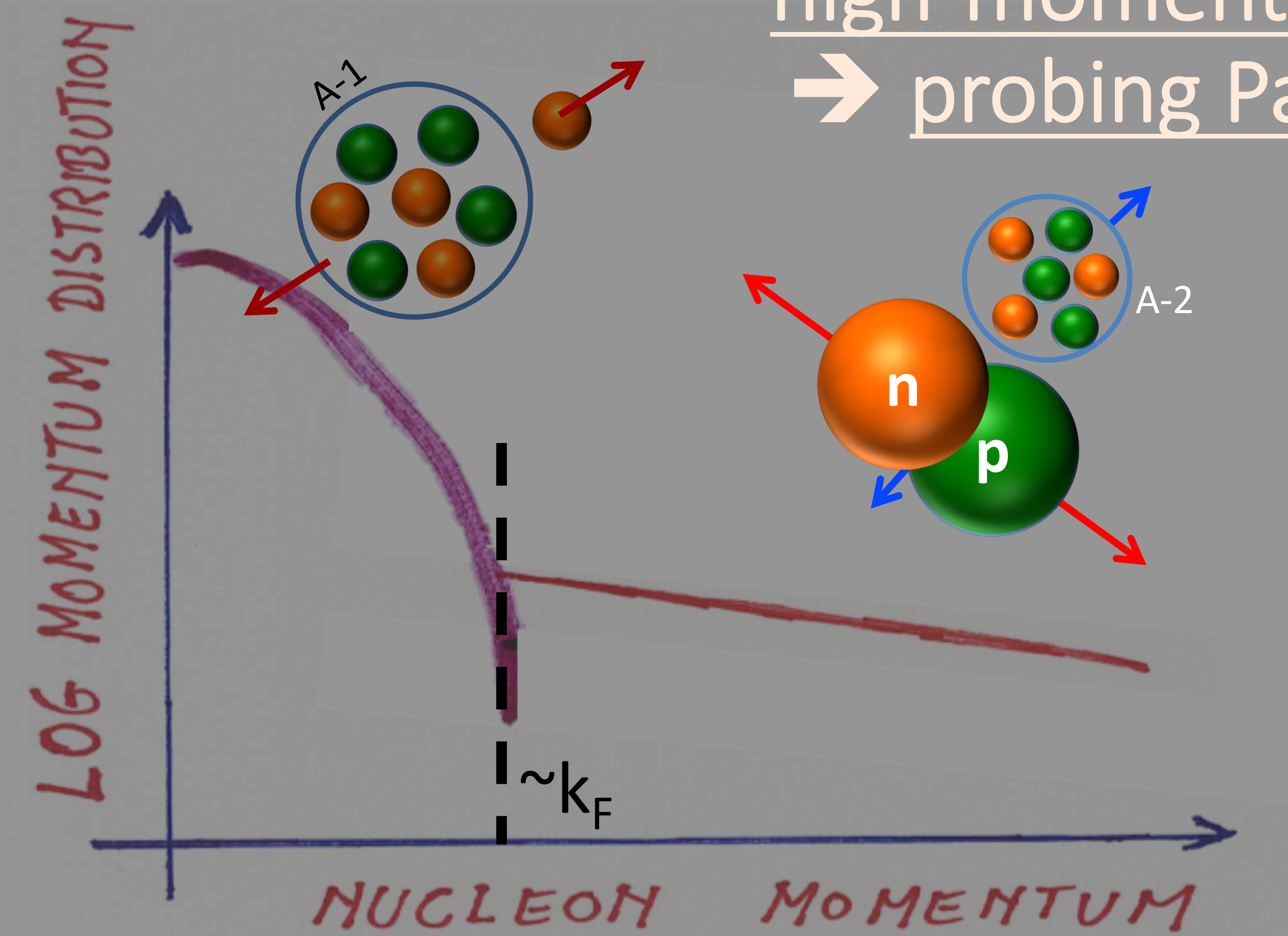


LOG MOMENTUM DISTRIBUTION
MEAN-FIELD
FAT TAIL!
~k_F
NUCLEON MOMENTUM

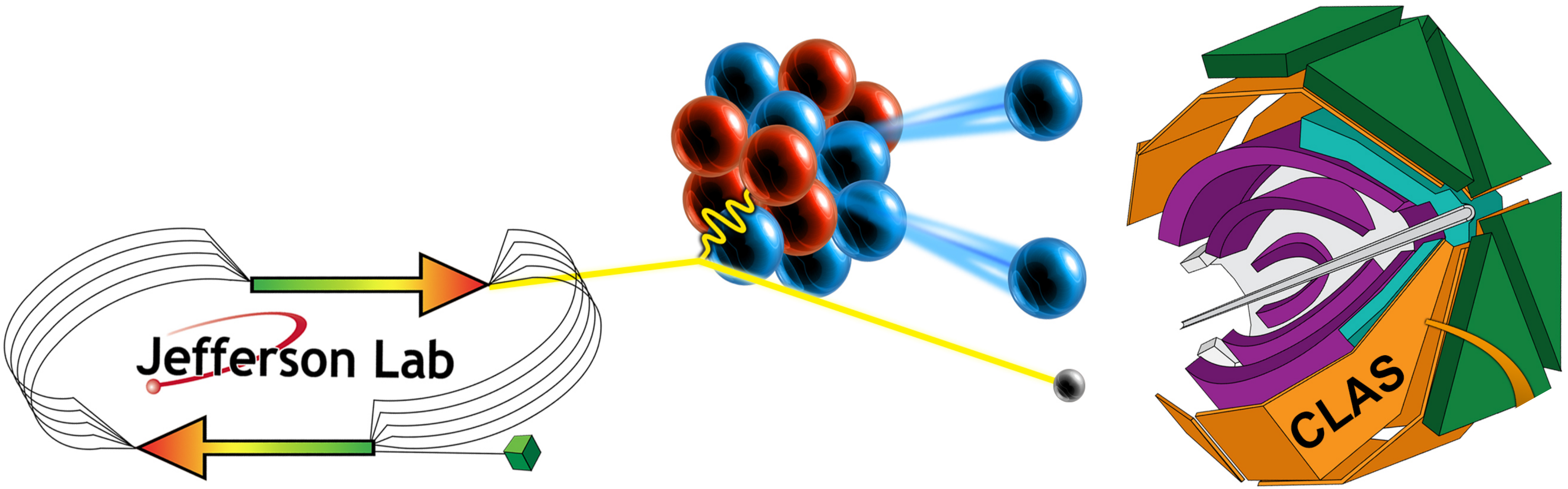


LOG MOMENTUM DISTRIBUTION
A-1
A-2
n
p
~k_F
NUCLEON MOMENTUM

high-momenta
→ probing Pairs



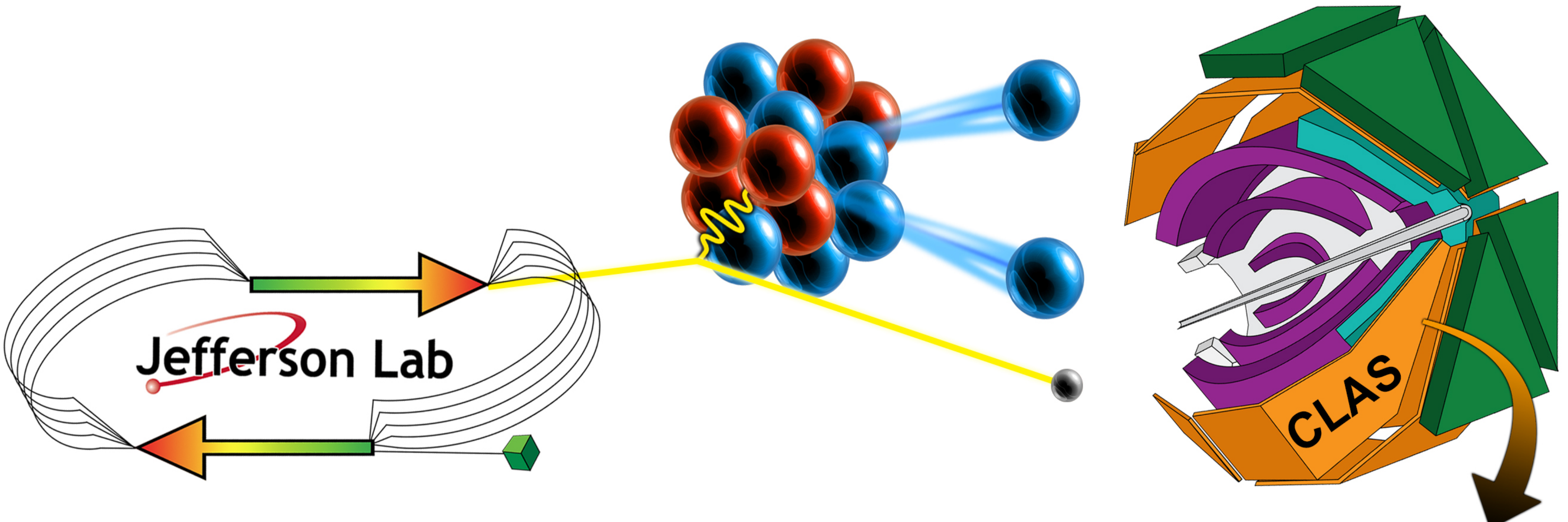
Breakup the pair =>
Detect ***both*** nucleons

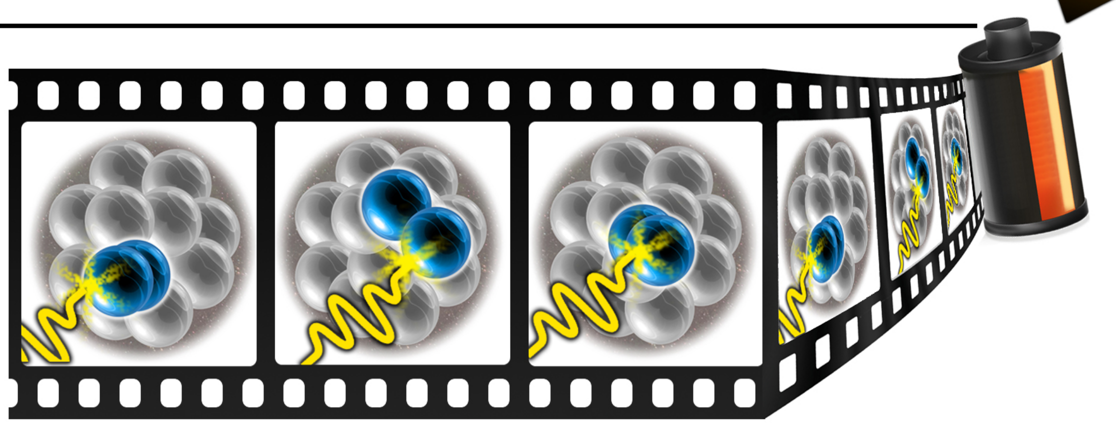


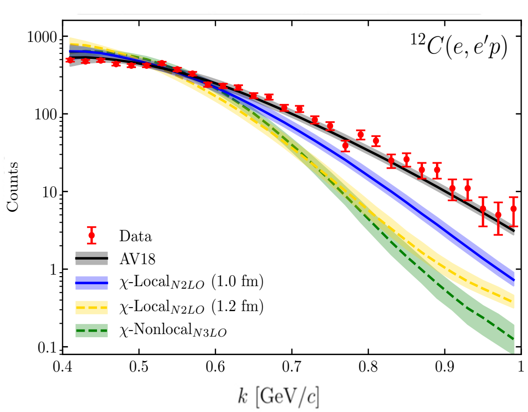
Breakup the pair =>

Detect ***both*** nucleons =>

Reconstruct 'initial' state

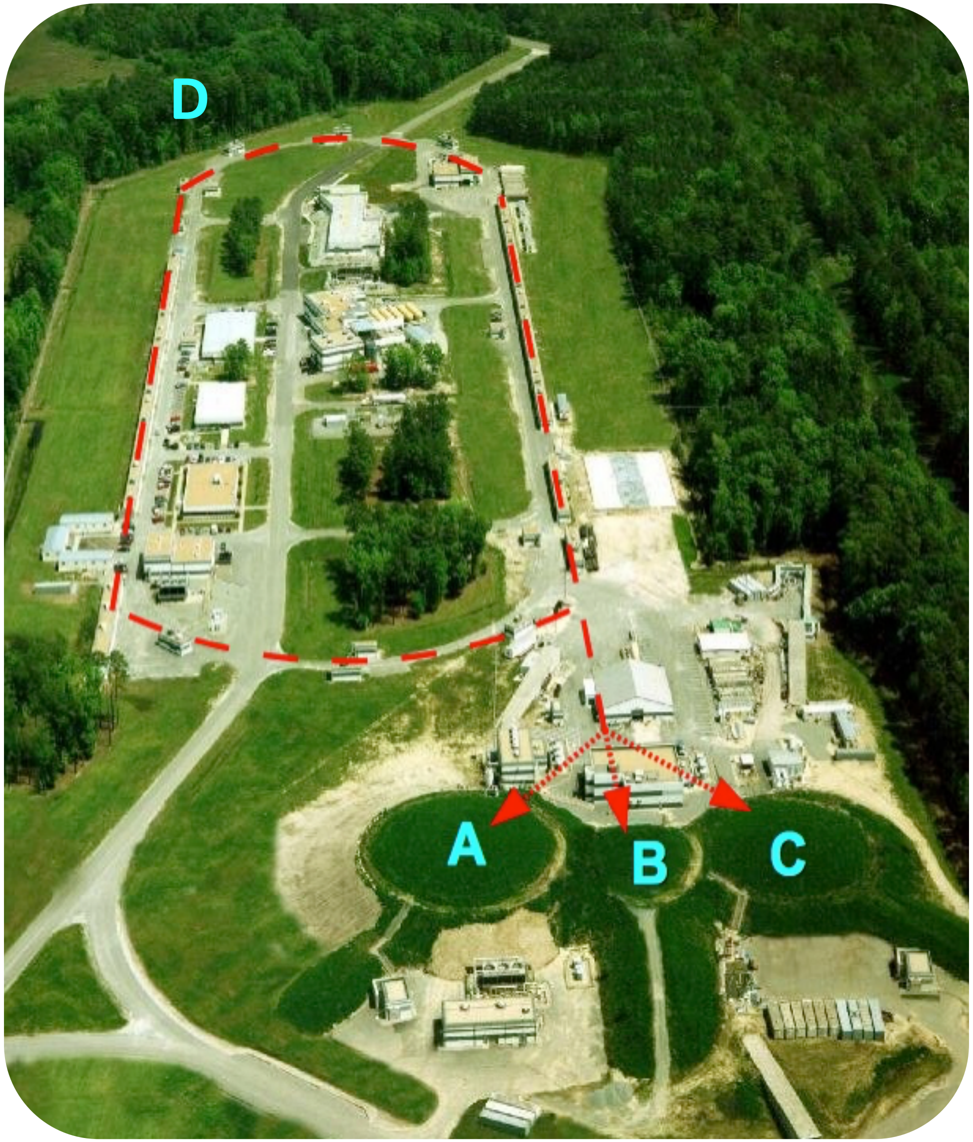




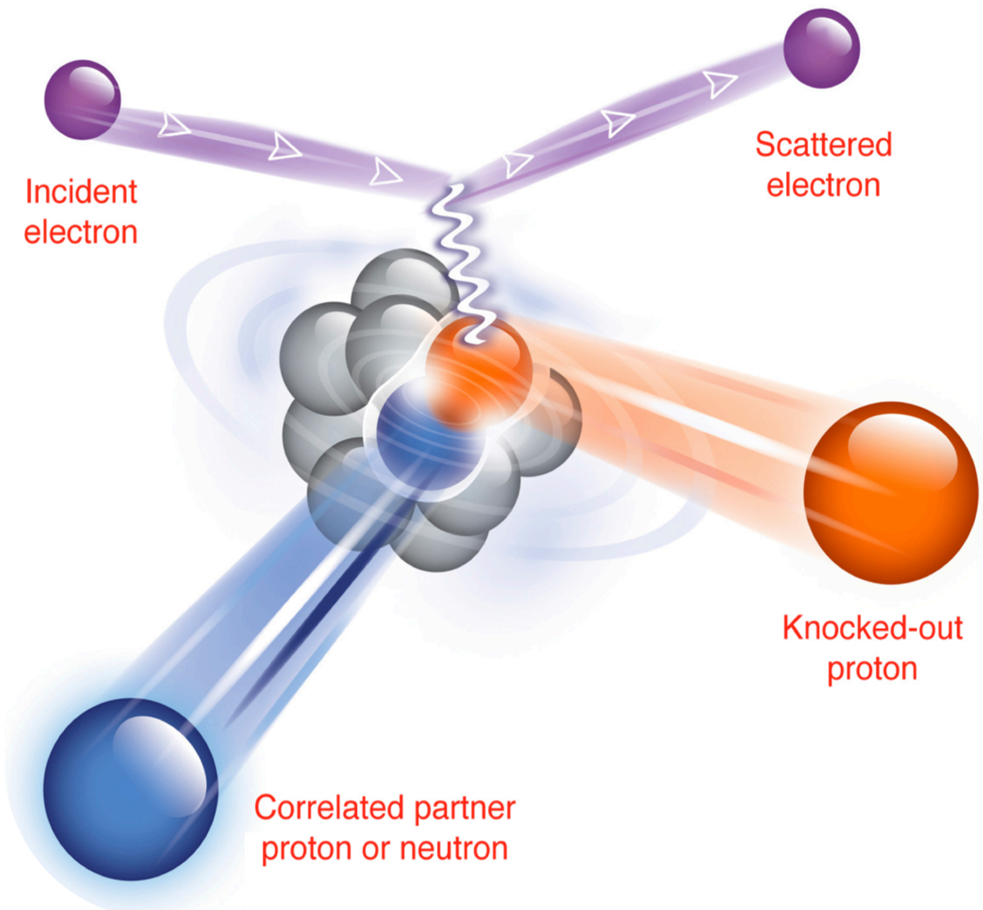


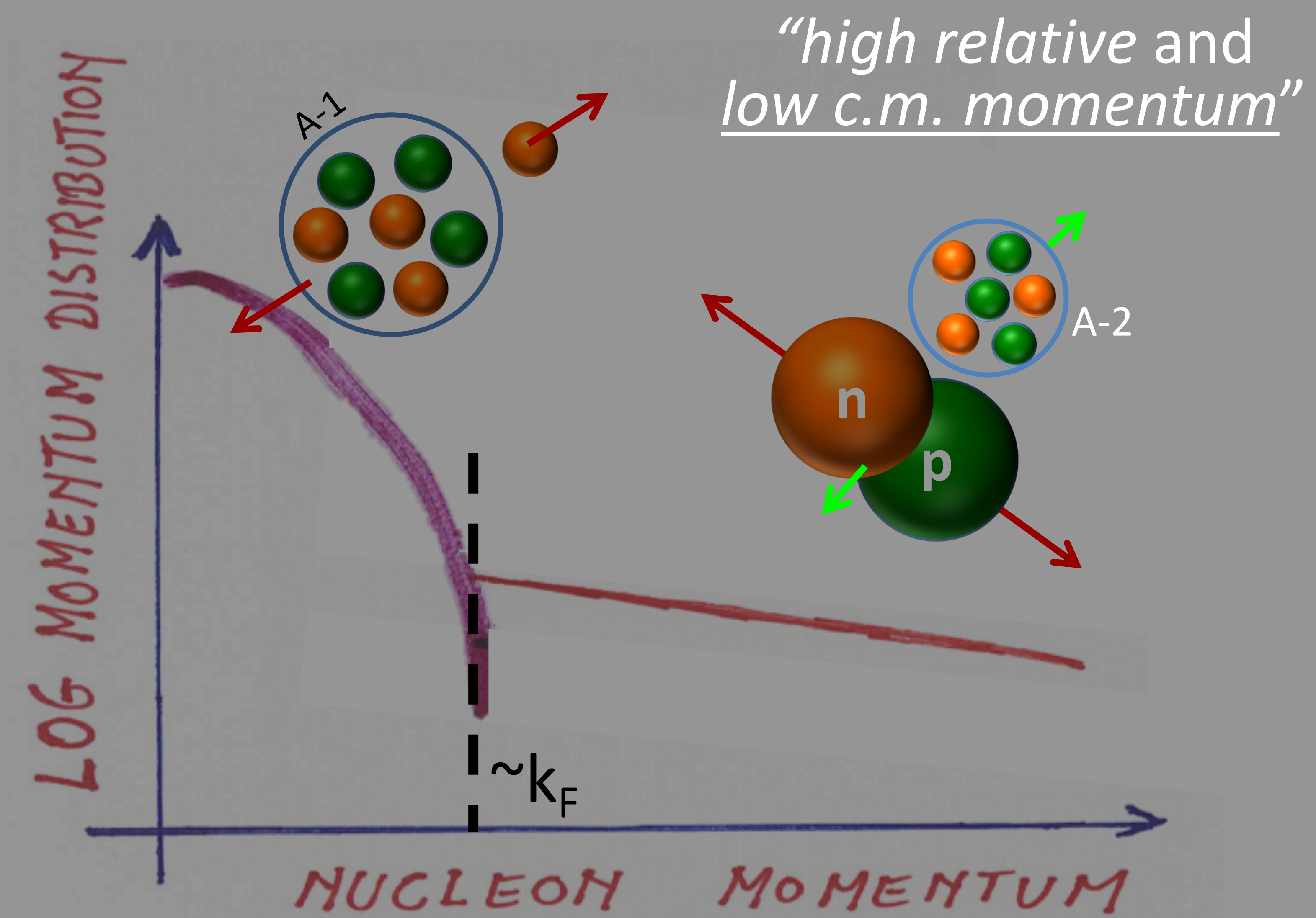
Jefferson-Lab National Accelerator Facility

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



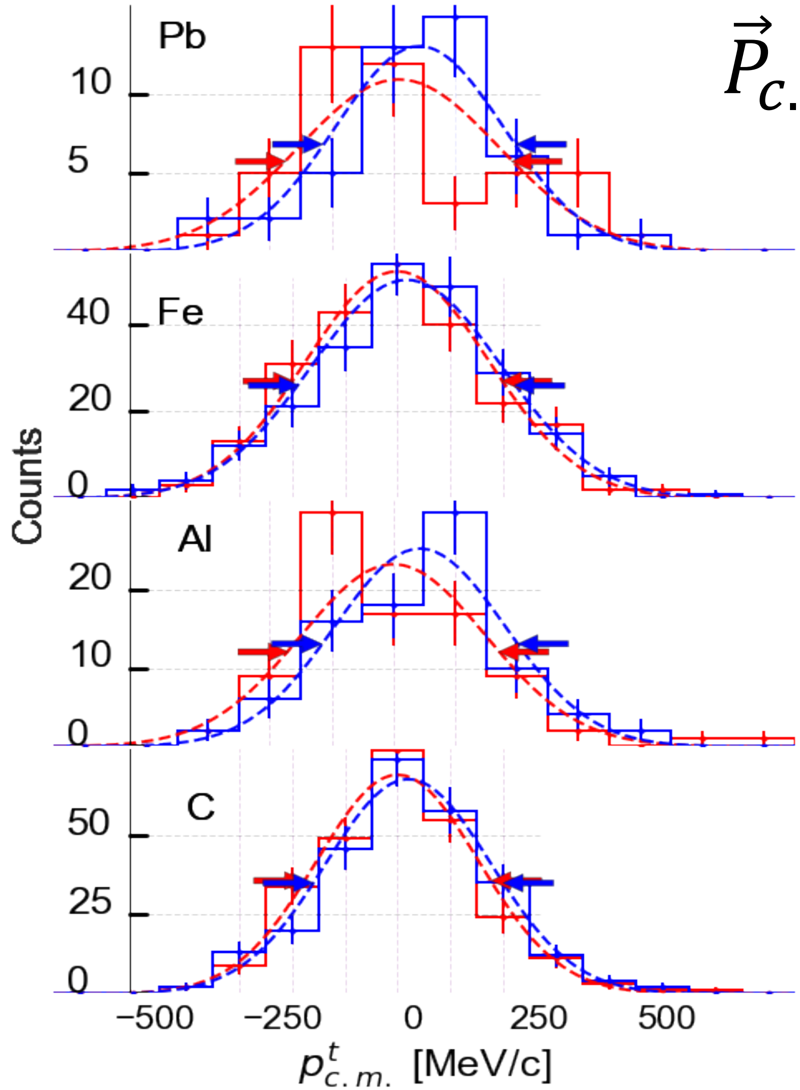
Breakup the pair =>
Detect ***both*** nucleons =>
Reconstruct 'initial' state





"*high relative* and
low c.m. momentum"
A-1
A-2
n
p
~k_F
LOG MOMENTUM DISTRIBUTION
NUCLEON MOMENTUM

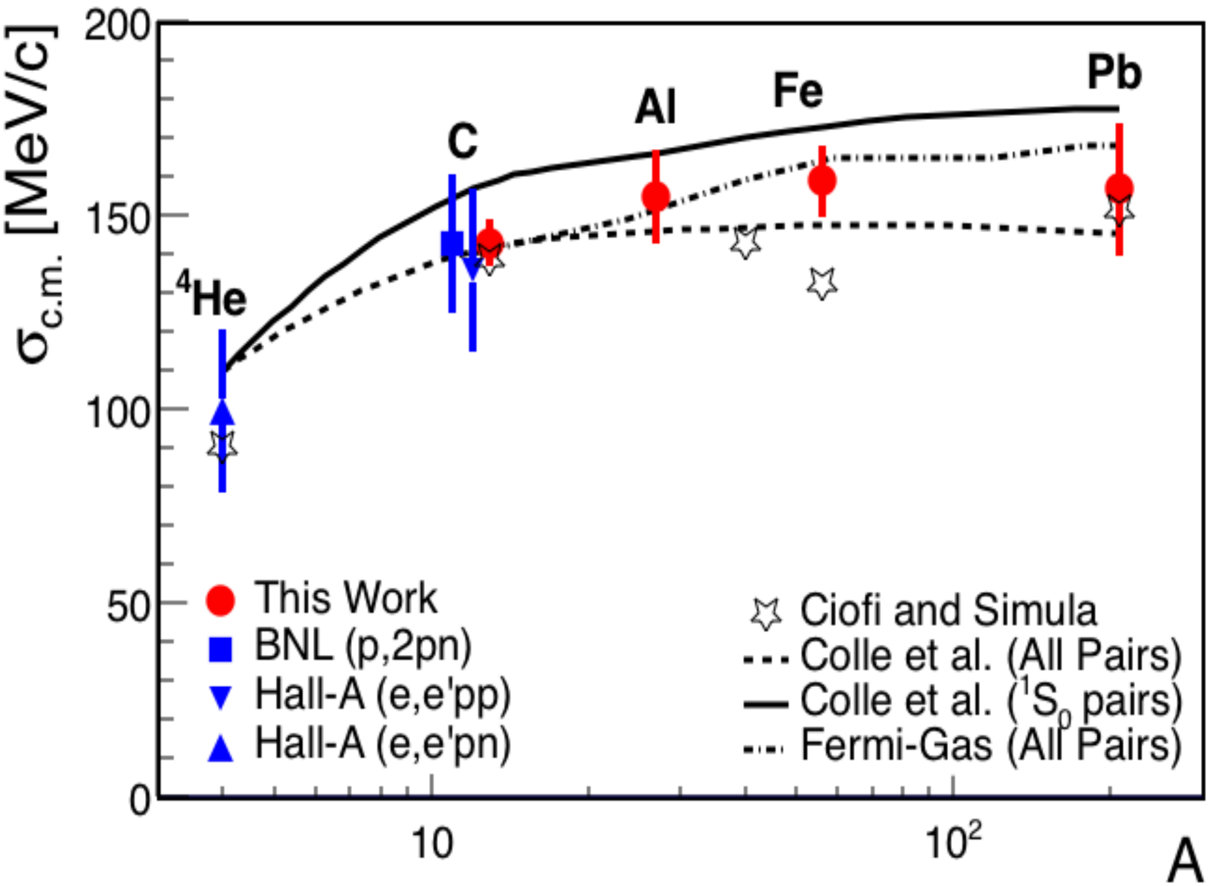
Low Pair C.M. Motion

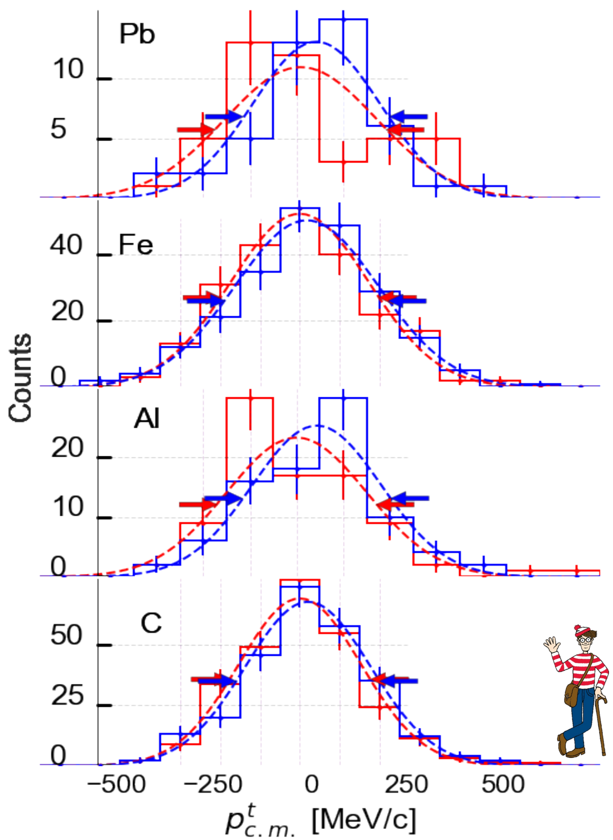


$$\vec{P}_{c.m.} = \vec{P}_{N1} + \vec{P}_{N2}$$

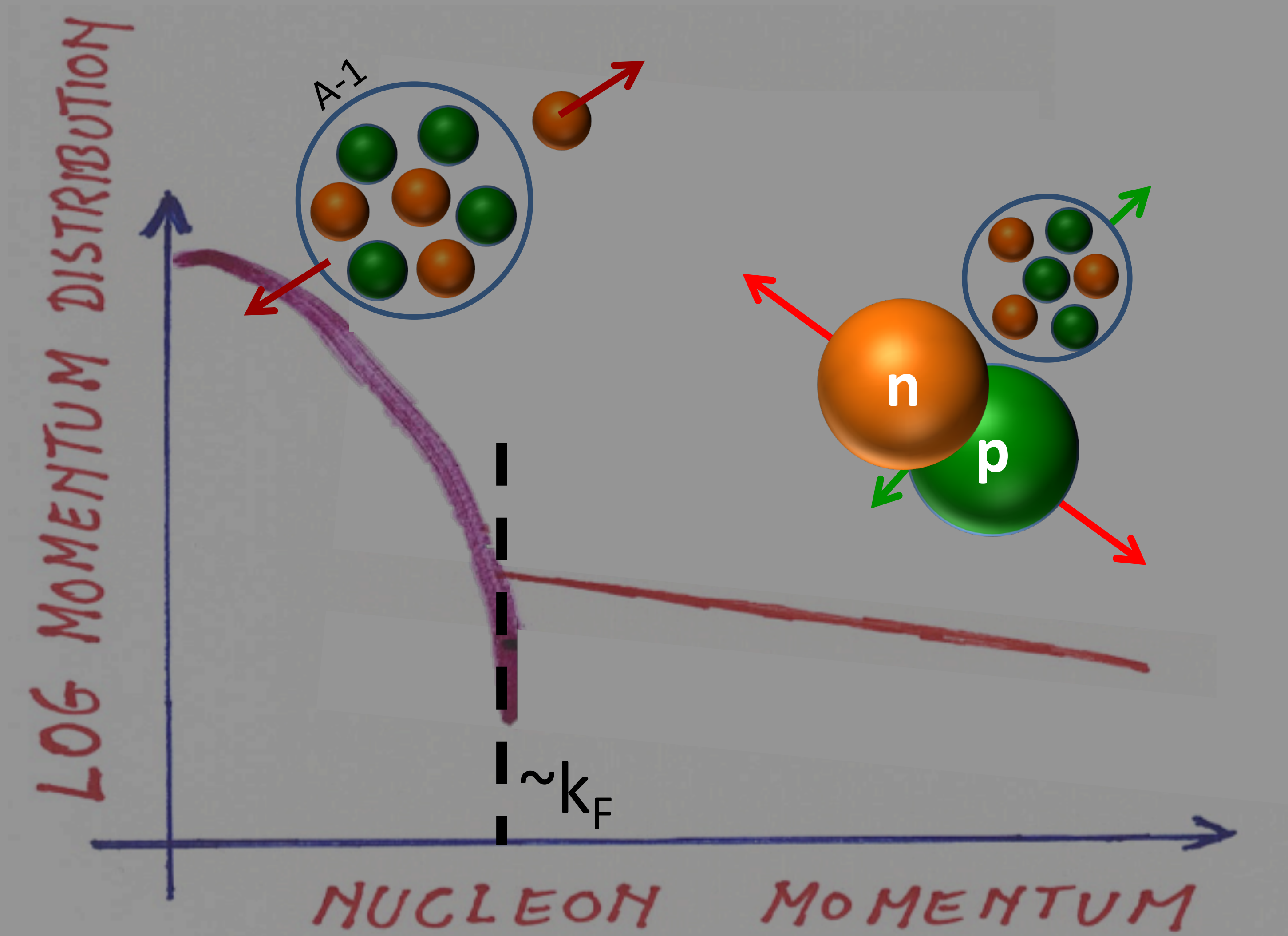
Cohen, PRL (2018).

Consistent \w combining two mean-field nucleons

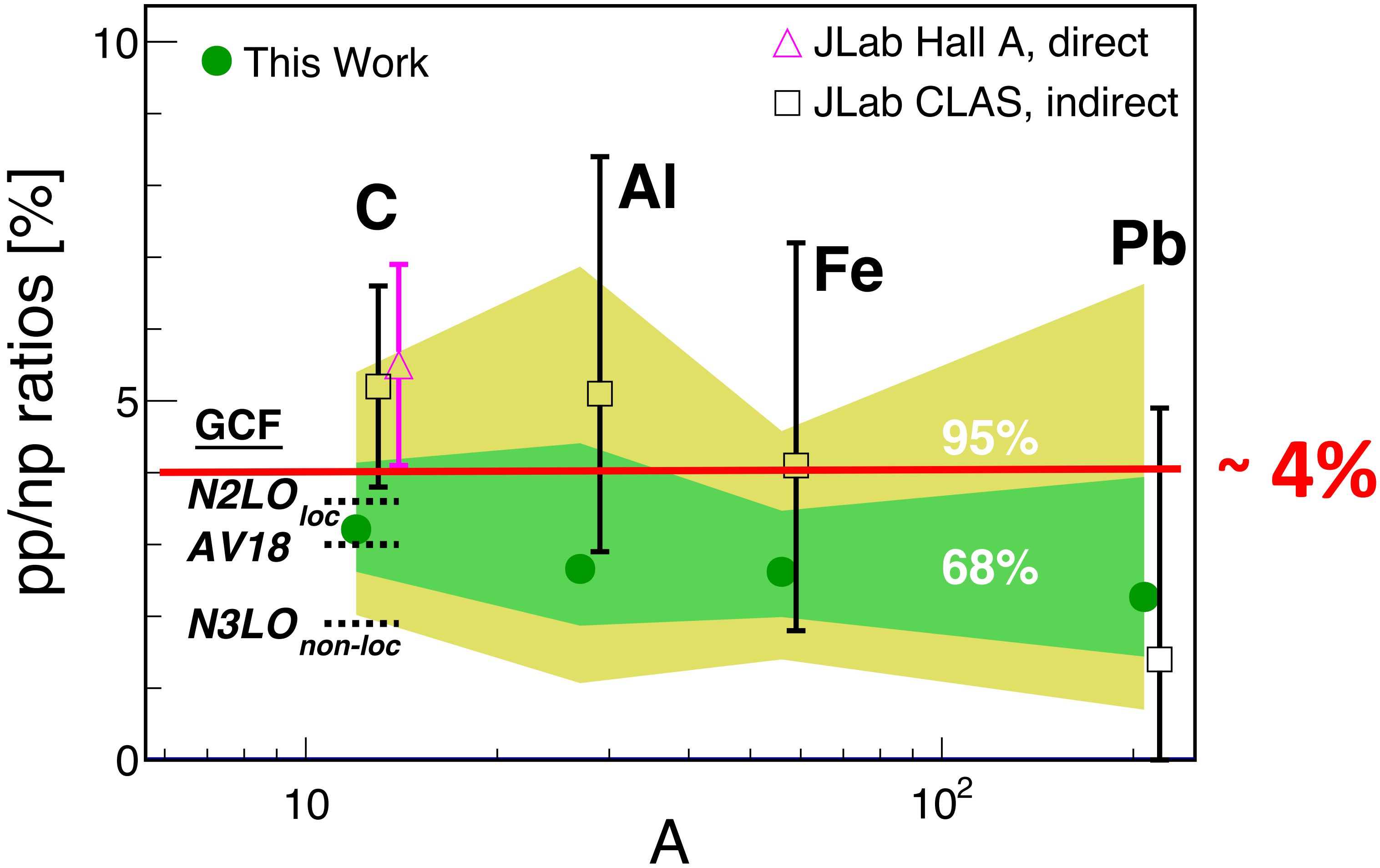




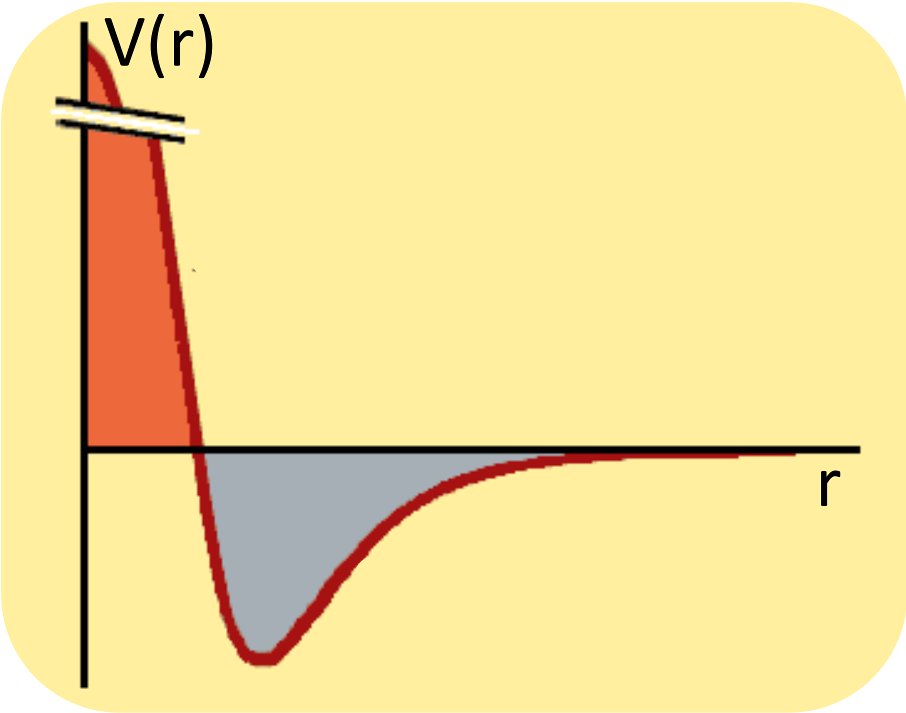
Cohen, PRL (2018),
Korover, PRL (2014),
Shneor, PRL (2007),
Tang, PRL (2003).

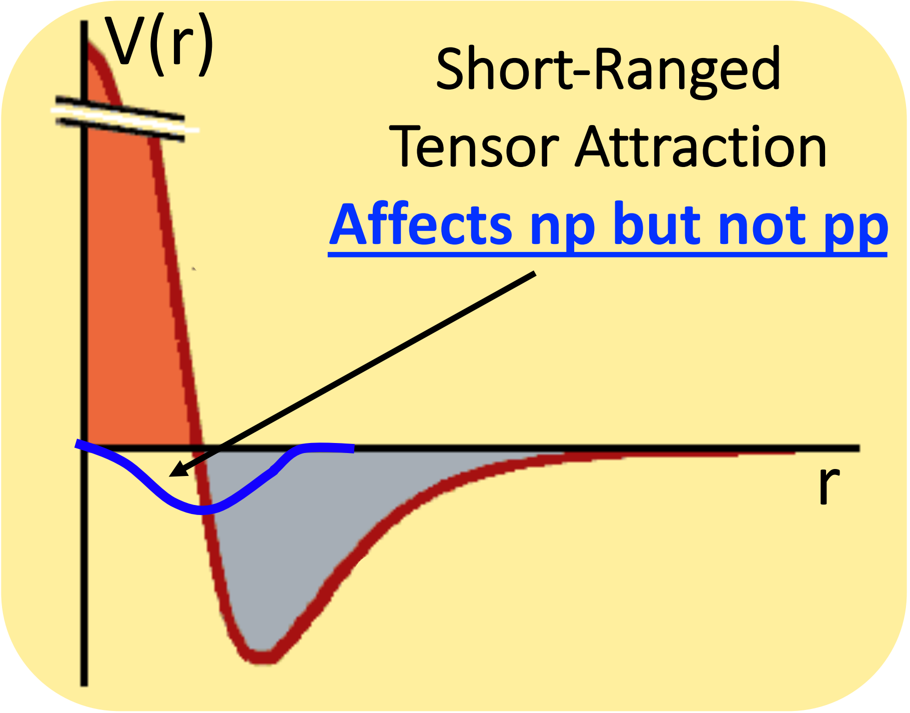

LOG MOMENTUM DISTRIBUTION
A-1
n
p
~k_F
NUCLEON MOMENTUM

np pairs predominate



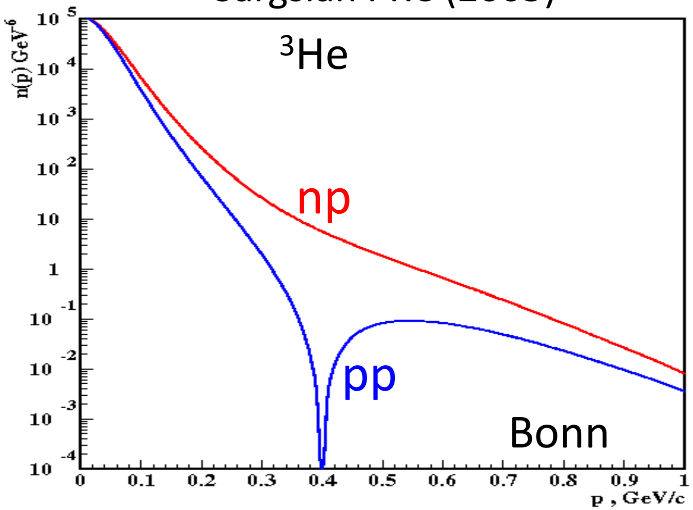
Duer, PRL (2019); Duer, Nature (2018); Hen, Science (2014); Korover, PRL (2014); Subedi, Science (2008); Shneor, PRL (2007); Piasetzky, PRL (2006); Tang, PRL (2003); <u>Review:</u> Hen RMP (2017);


V(r)
r

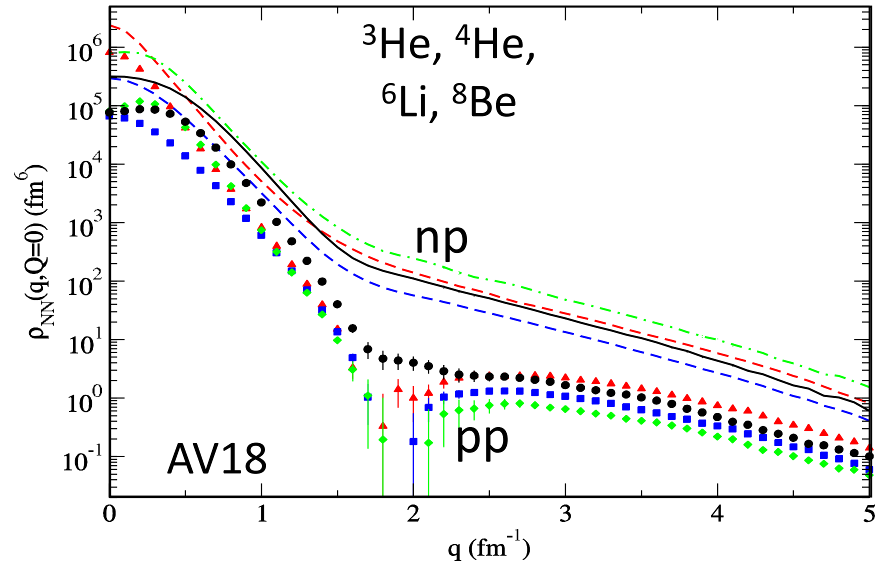

V(r)
Short-Ranged
Tensor Attraction
Affects np but not pp
r

Also seen in ab-initio pair distributions

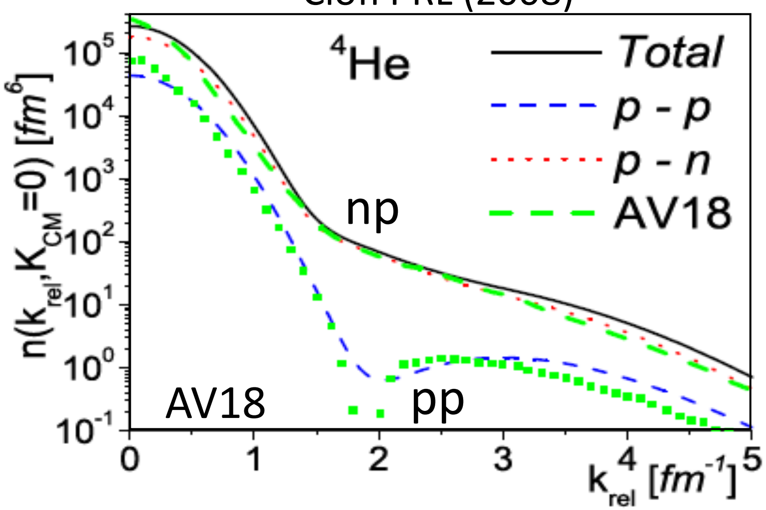
Sargsian PRC (2005)



Schiavilla PRL (2007)



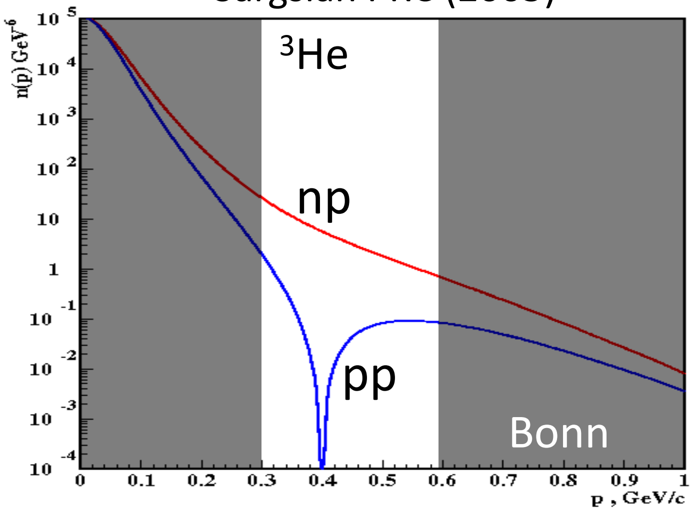
Ciofi PRL (2008)



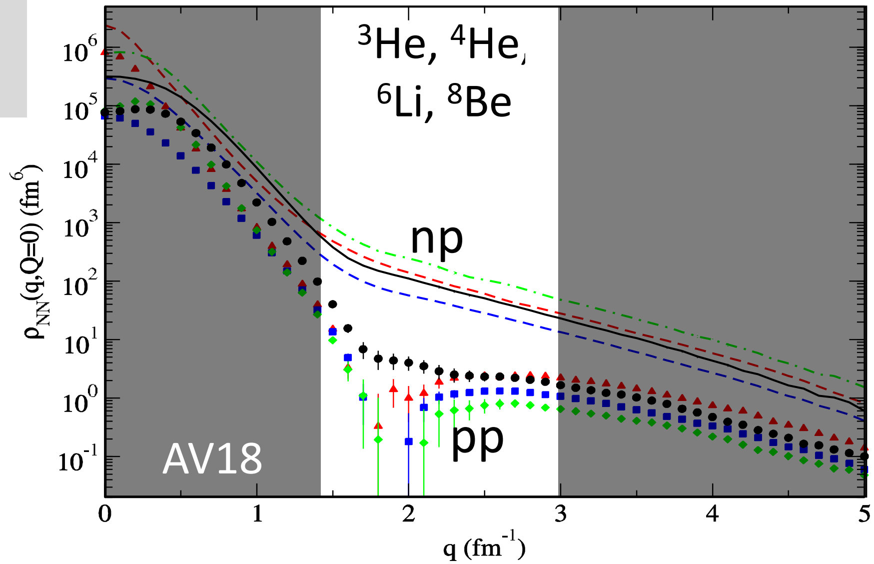
Also seen in ab-initio pair distributions

300 – 600 MeV/c Window

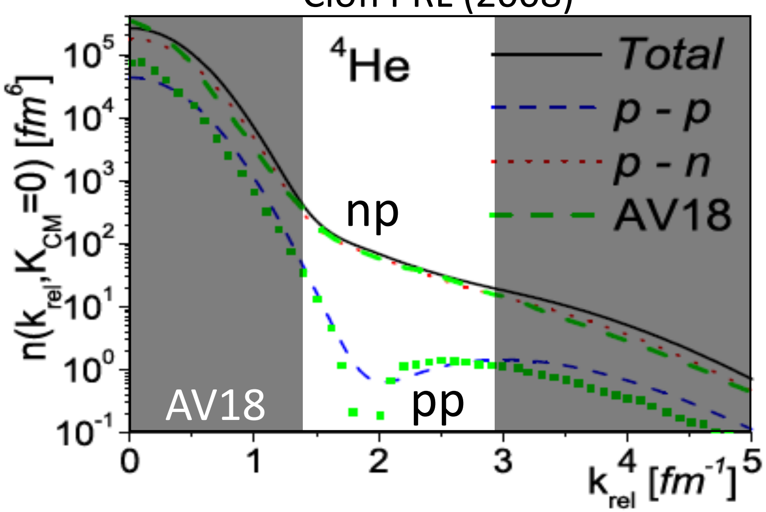
Sargsian PRC (2005)

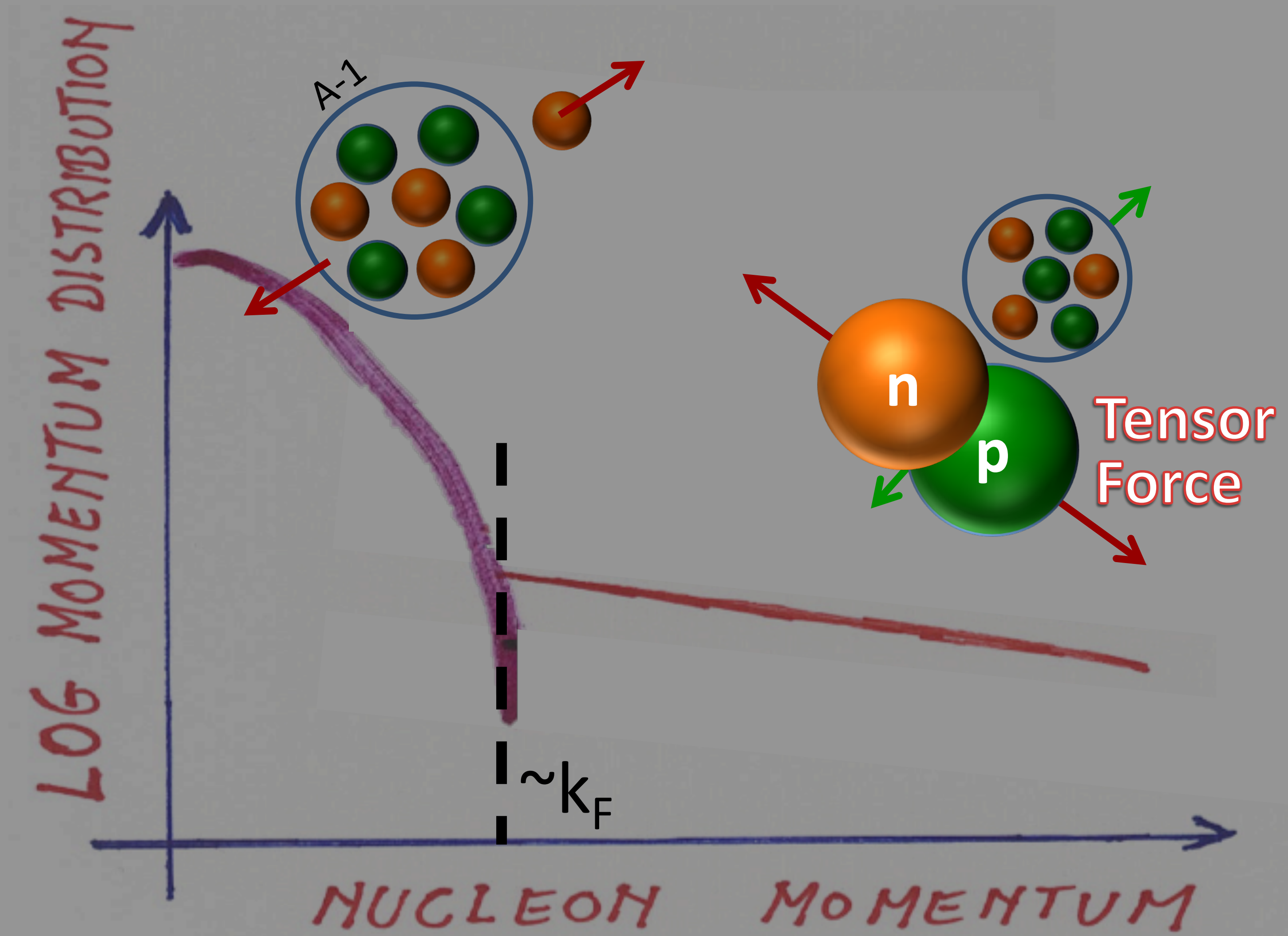


Schiavilla PRL (2007)



Ciofi PRL (2008)





LOG MOMENTUM DISTRIBUTION
A-1
n
p
Tensor Force
~k_F
NUCLEON MOMENTUM

Going neutron rich:

What do excess neutrons do?

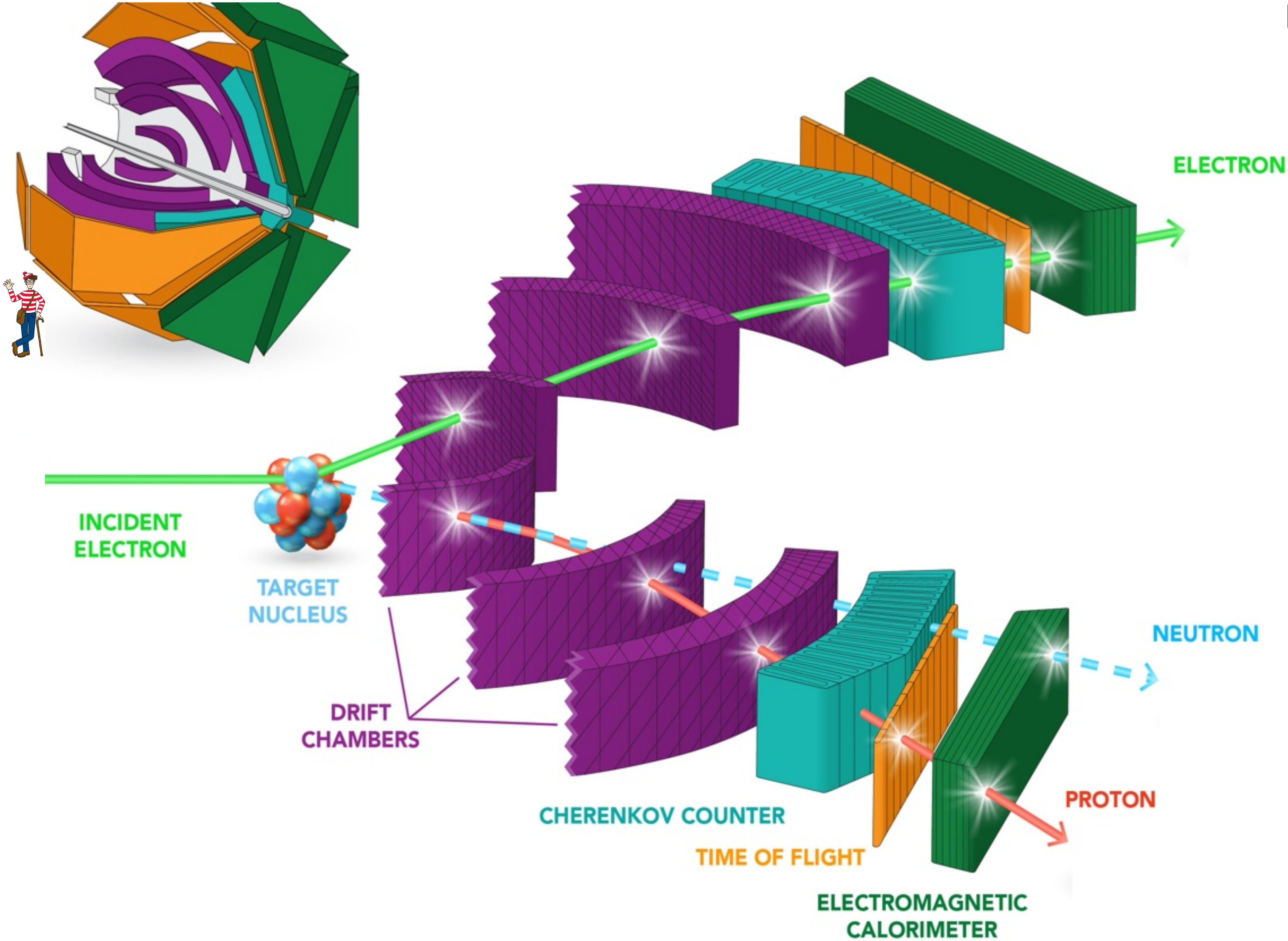
don’t correlate?

correlate with each other?

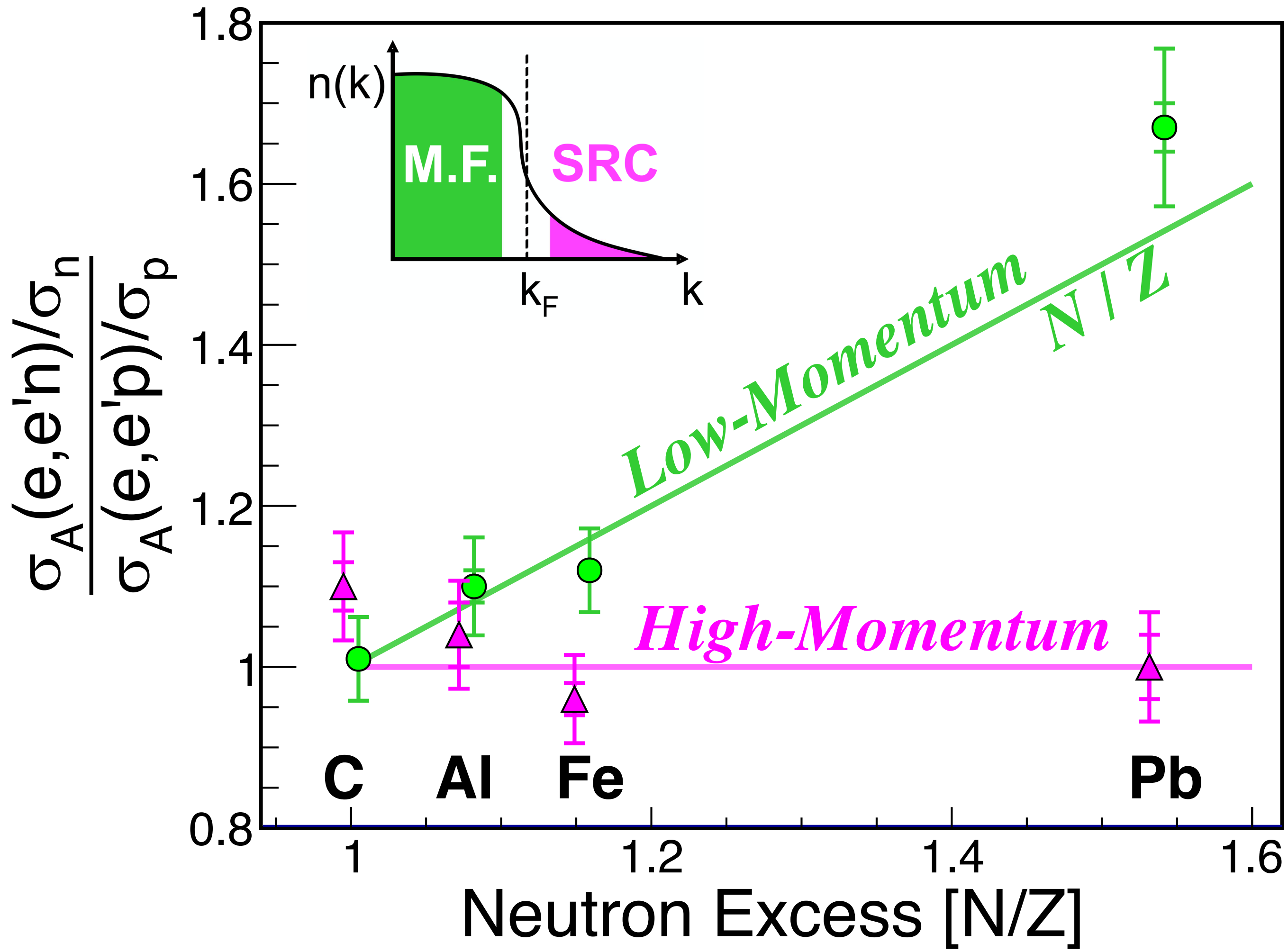
correlate with core protons?

Proton vs. Neutron Knockout

M. Duer



Same # of high-momentum p & n



Going neutron rich:

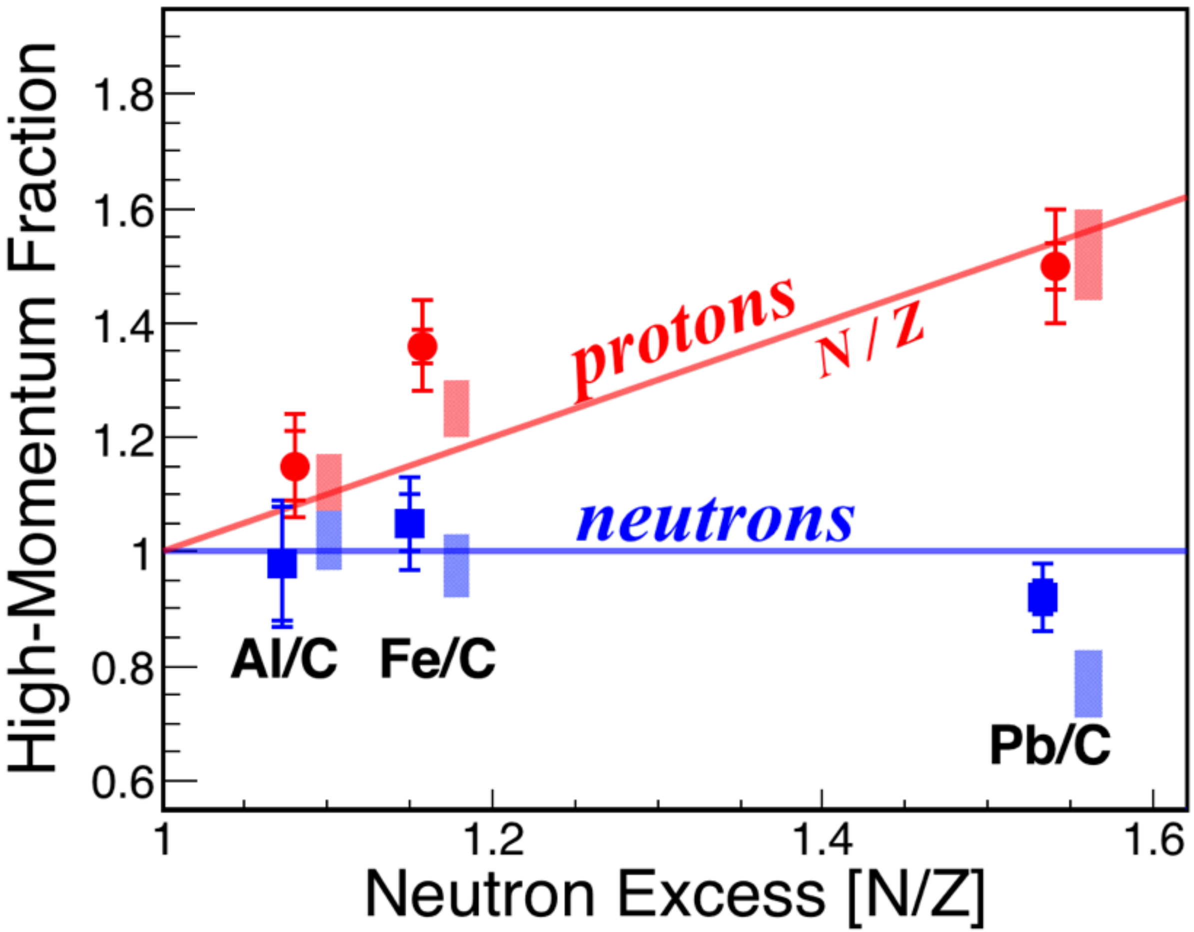
What do excess neutrons do?

don't
correlate?

~~correlate with
each other?~~

correlate with
core protons?

Correlation Probability:
Neutrons saturate Protons grow



Duer Nature (2018)

Going neutron rich:

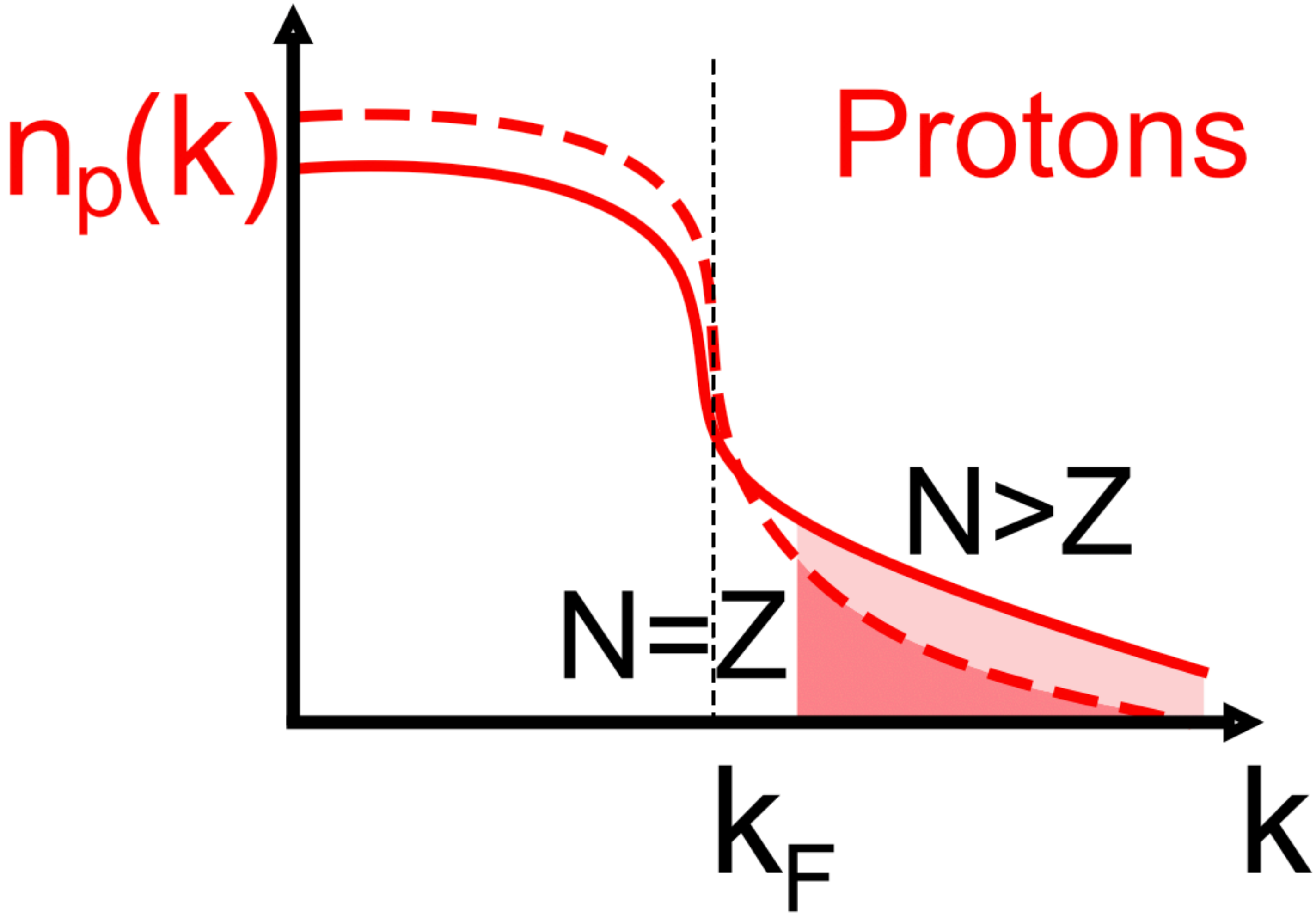
What do excess neutrons do?

~~don't correlate?~~

~~correlate with each other?~~

✓ correlate with core protons?

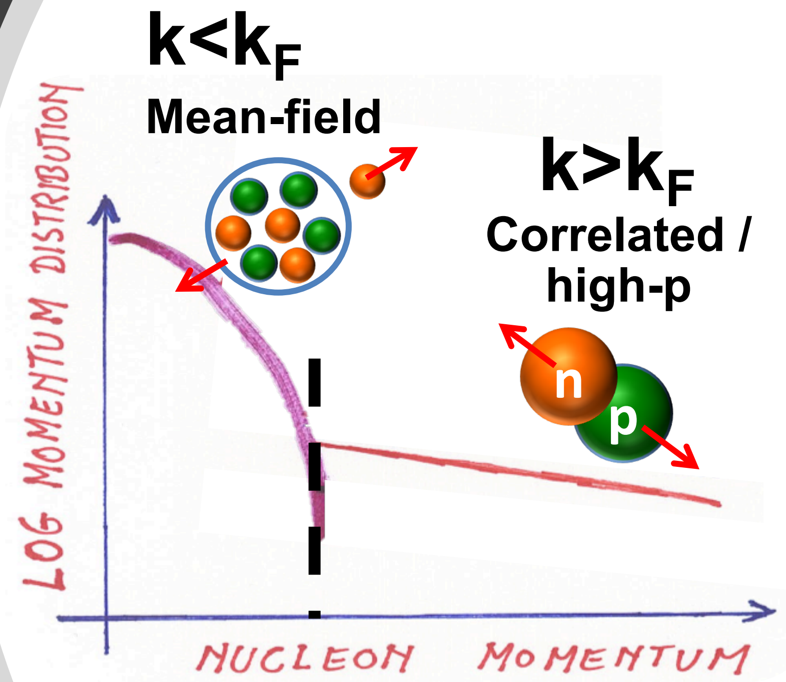
Protons 'Speed-Up' In Neutron-Rich Nuclei



Duer Nature (2018)

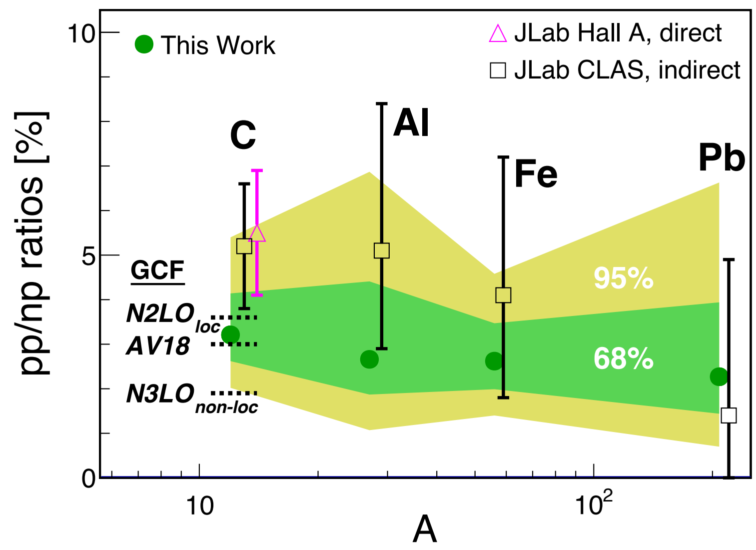
Interim Summary

- Nuclear momentum distribution has two distinct regions.



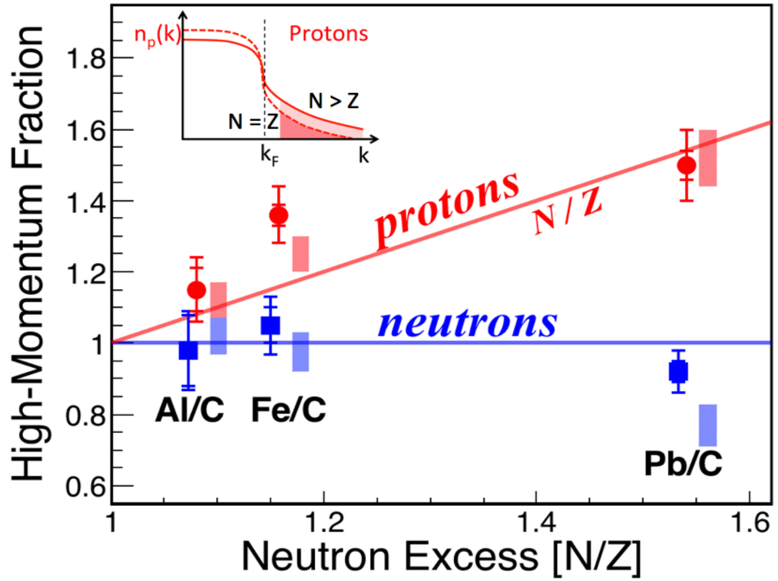
Interim Summary

- Nuclear momentum distribution has two distinct regions.
- #SRC-protons = #SRC-neutrons, independent of neutron excess.



Interim Summary

- Nuclear momentum distribution has two distinct regions.
- #SRC-protons = #SRC-neutrons, independent of neutron excess.
- The fraction of correlated
  protons / neutrons
  grow / saturate
  with neutron excess.



Interim Summary

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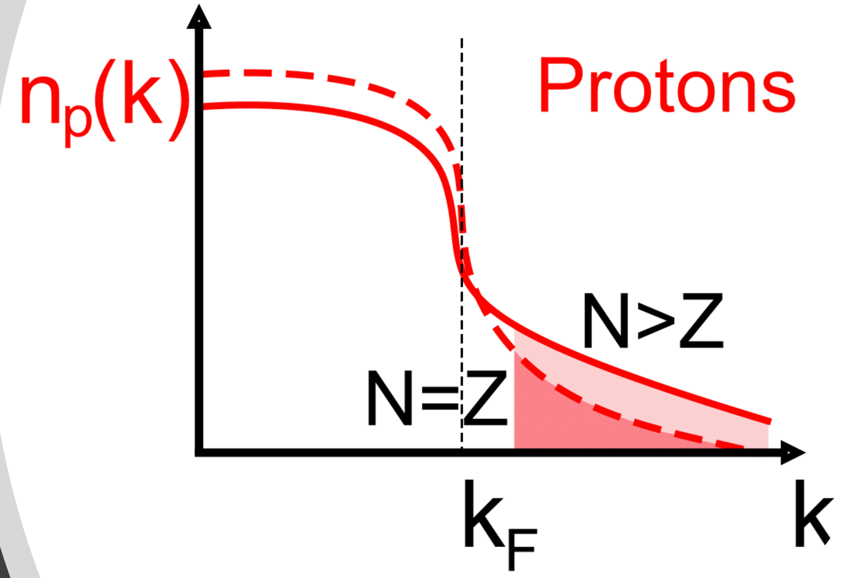
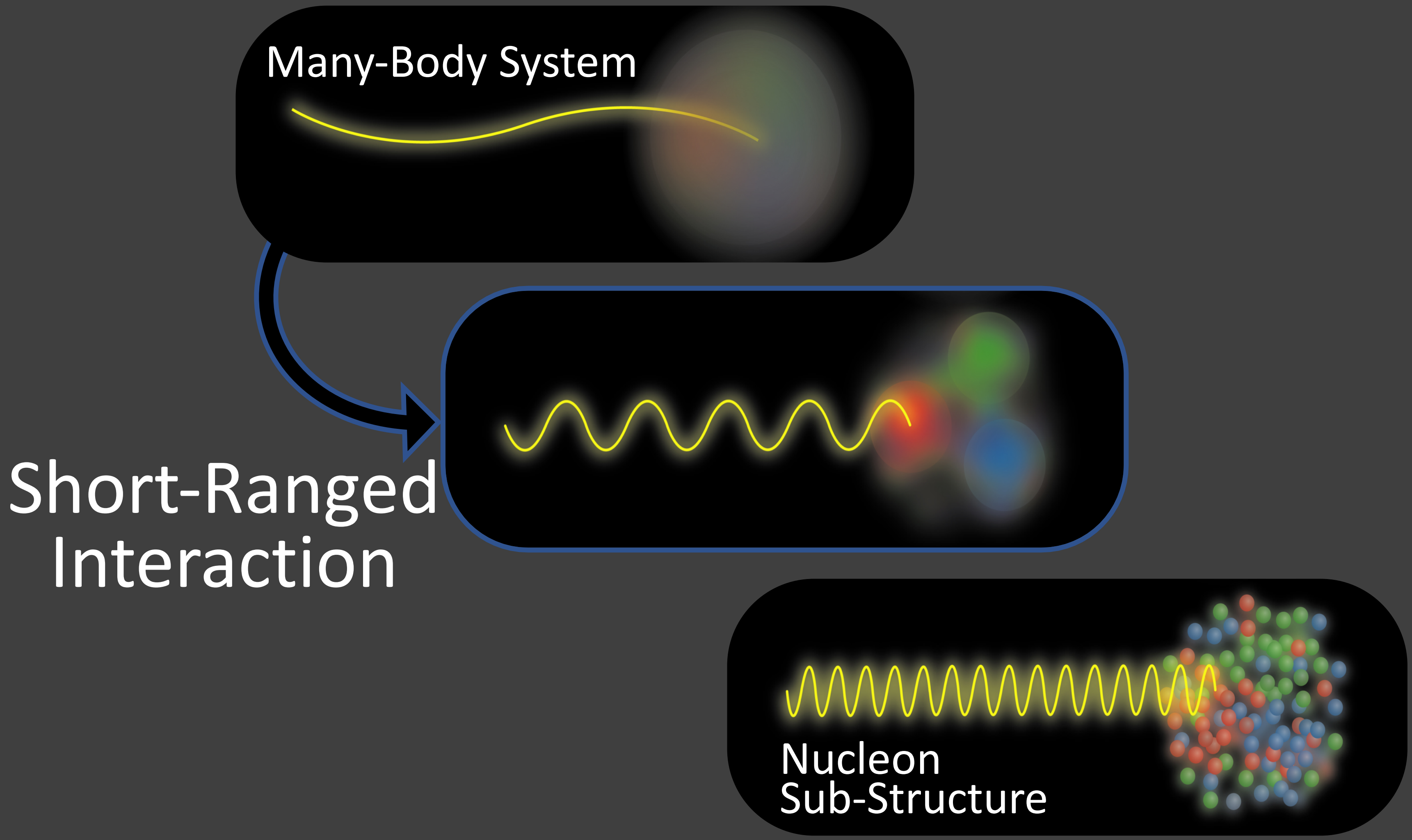



Many-Body System
Short-Ranged Interaction
Nucleon Sub-Structure

Probing the NN Interaction

- Measure one- and two-nucleon knockout cross-sections.
- Compare with calculations using different NN interactions.
- See which one works best

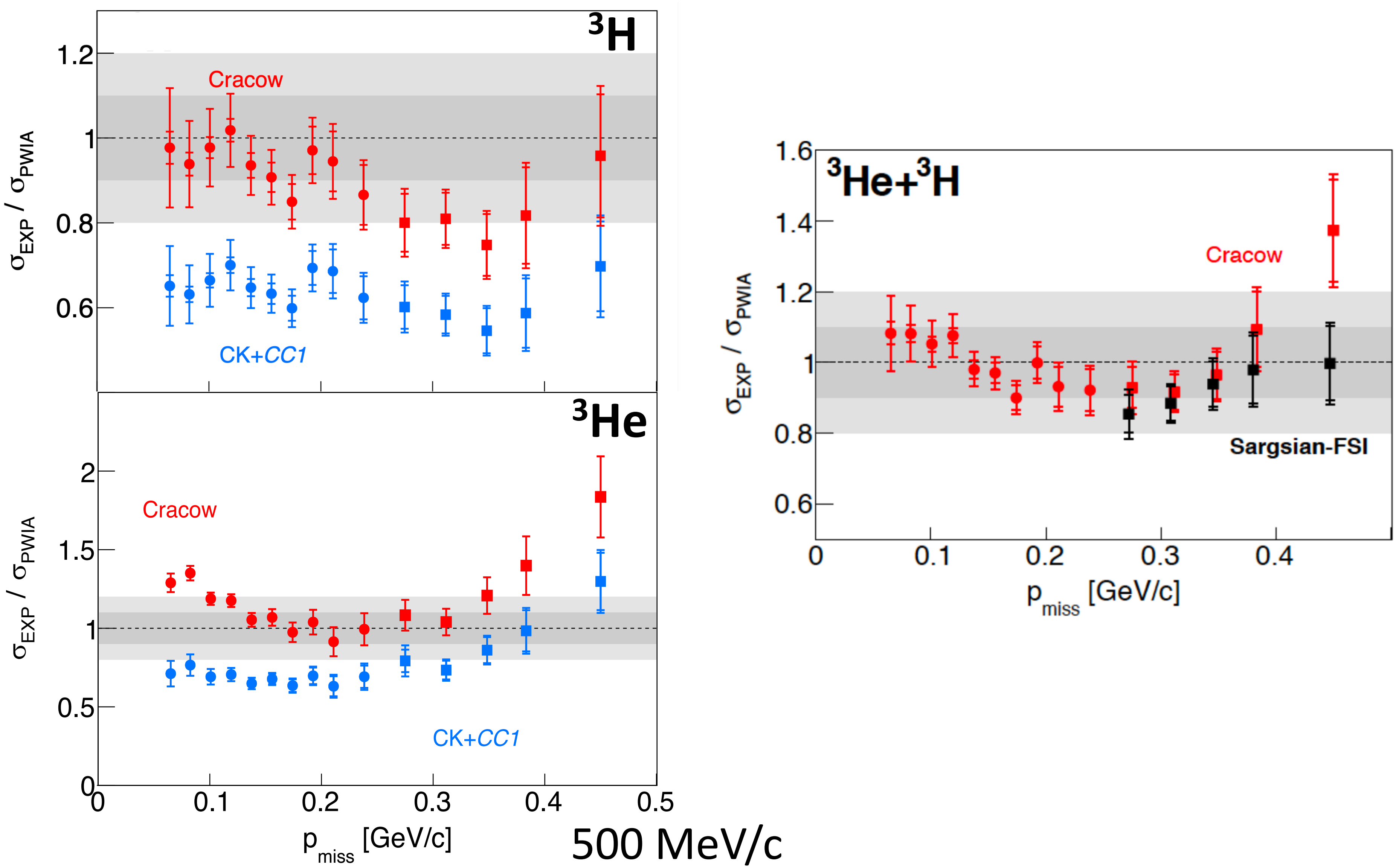
Probing the NN Interaction

What's needed?

- Data

- Ab-initio cross-section calculations

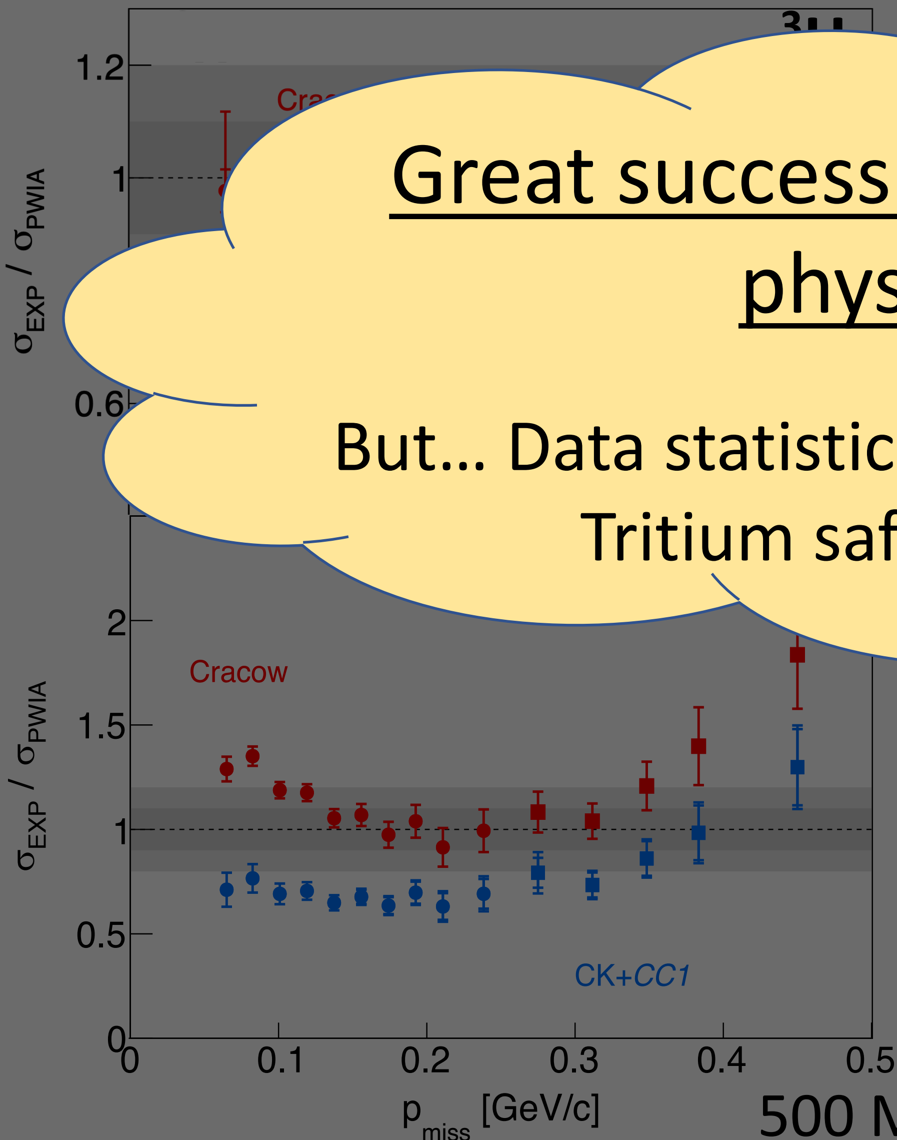
First high-Q^2 A=3 Studies

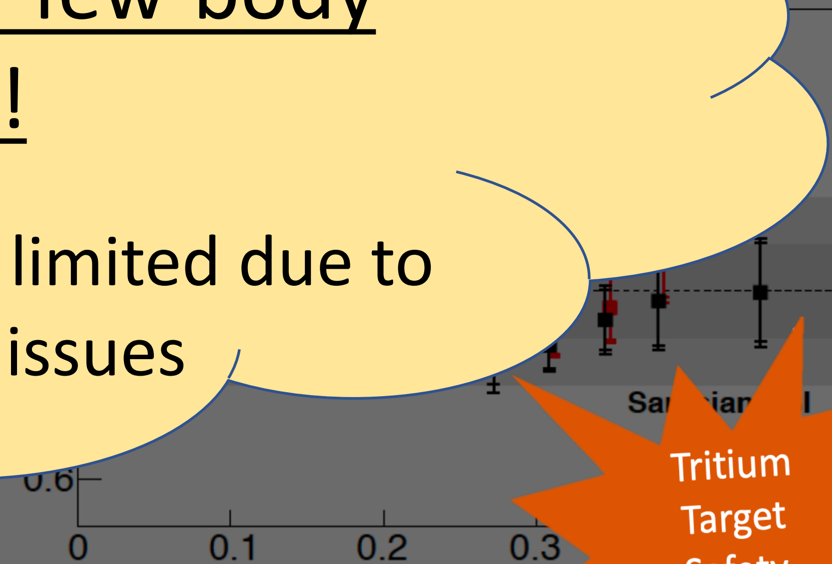


500 MeV/c

Cruz Torres and Nguyen et al., arXiv 2001.07230 (2020)

First high-Q^2 A=3 Studies





<u>Great success for few-body physics!</u>

But… Data statistically limited due to Tritium safety issues

Tritium Target Safety

500 MeV/c

Cruz Torres and Nguyen et al., arXiv 2001.07230 (2020)

What About Heavier Nuclei?

<u>What's needed?</u>

✓ Data (\w high stat)

- ~~Ab-initio cross-section calculations~~

What About Heavier Nuclei?

What's needed?

✓ Data

- ~~Ab-initio cross-section calculations~~

✓ Factorization \w spectral functions from NN interaction

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

What About Heavier Nuclei?

<u>What's needed?</u>

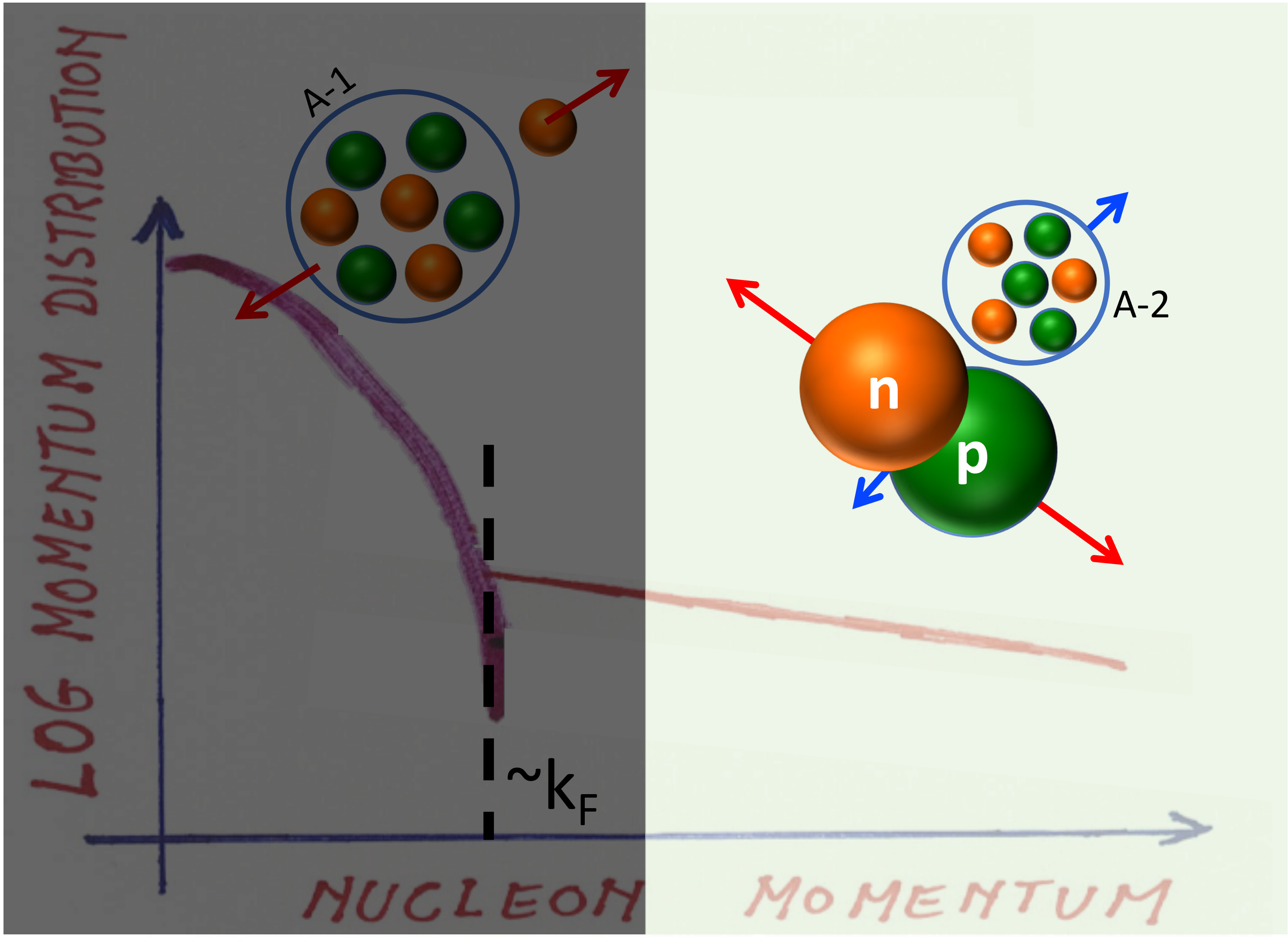
✓ Data

- ~~Ab-initio cross-section calculations~~

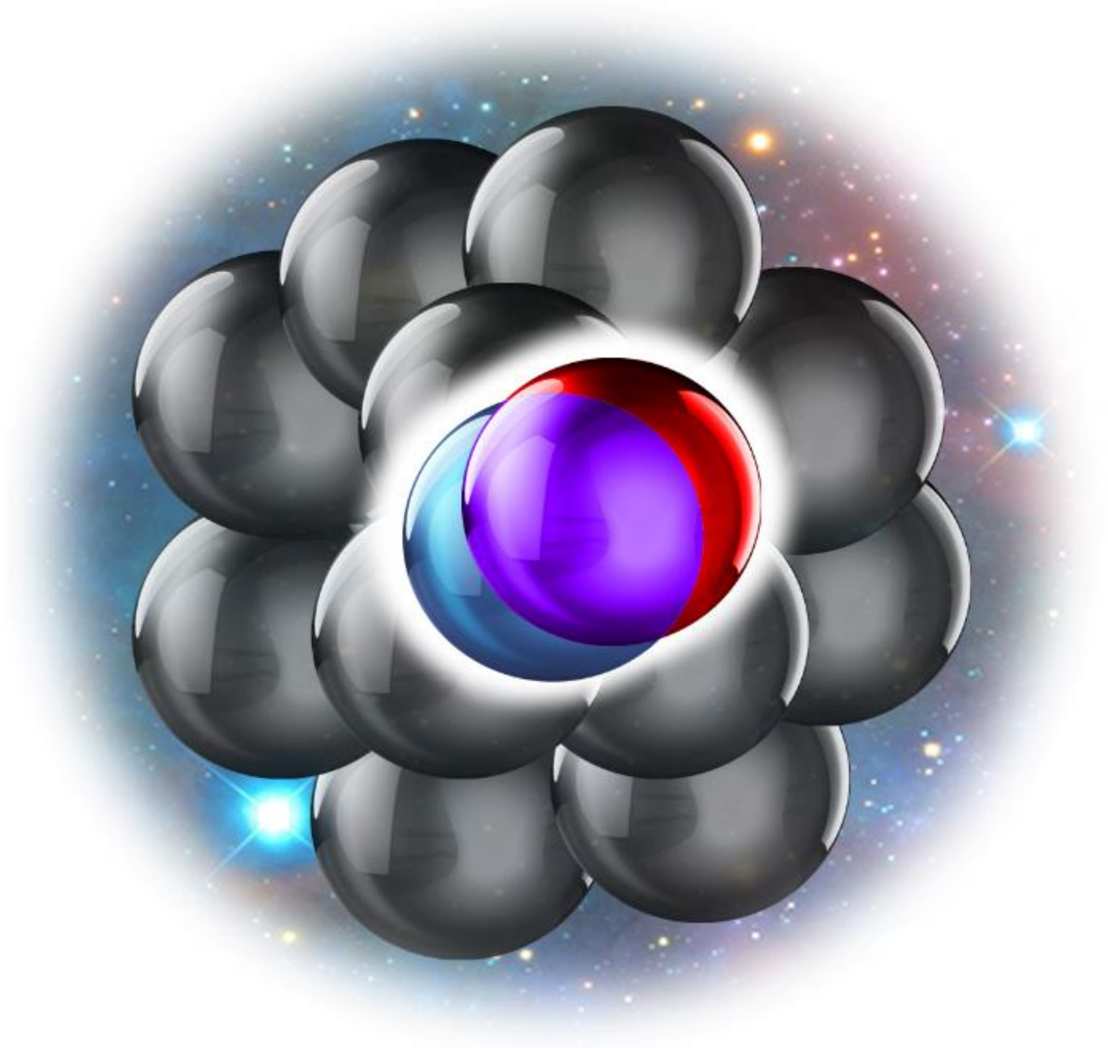
✓ Factorization \w spectral functions from NN interaction

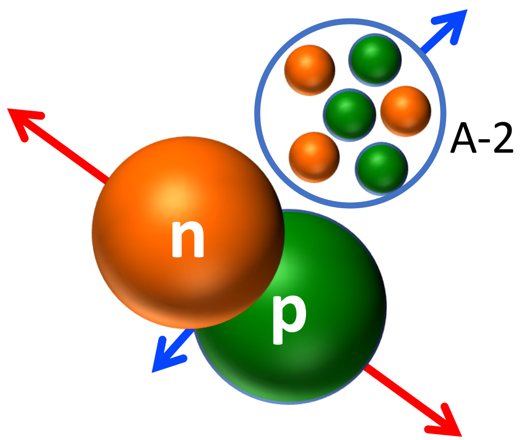
$$\frac{d^4\sigma}{d\Omega_{k'}\, d\epsilon'_k\, d\Omega_{p'_1}\, d\epsilon'_1} = p'_1 \epsilon'_1 \sigma_{eN} S^N(\boldsymbol{p}_1, \epsilon_1)$$

High-Momenta => Pairs Spectral Functions



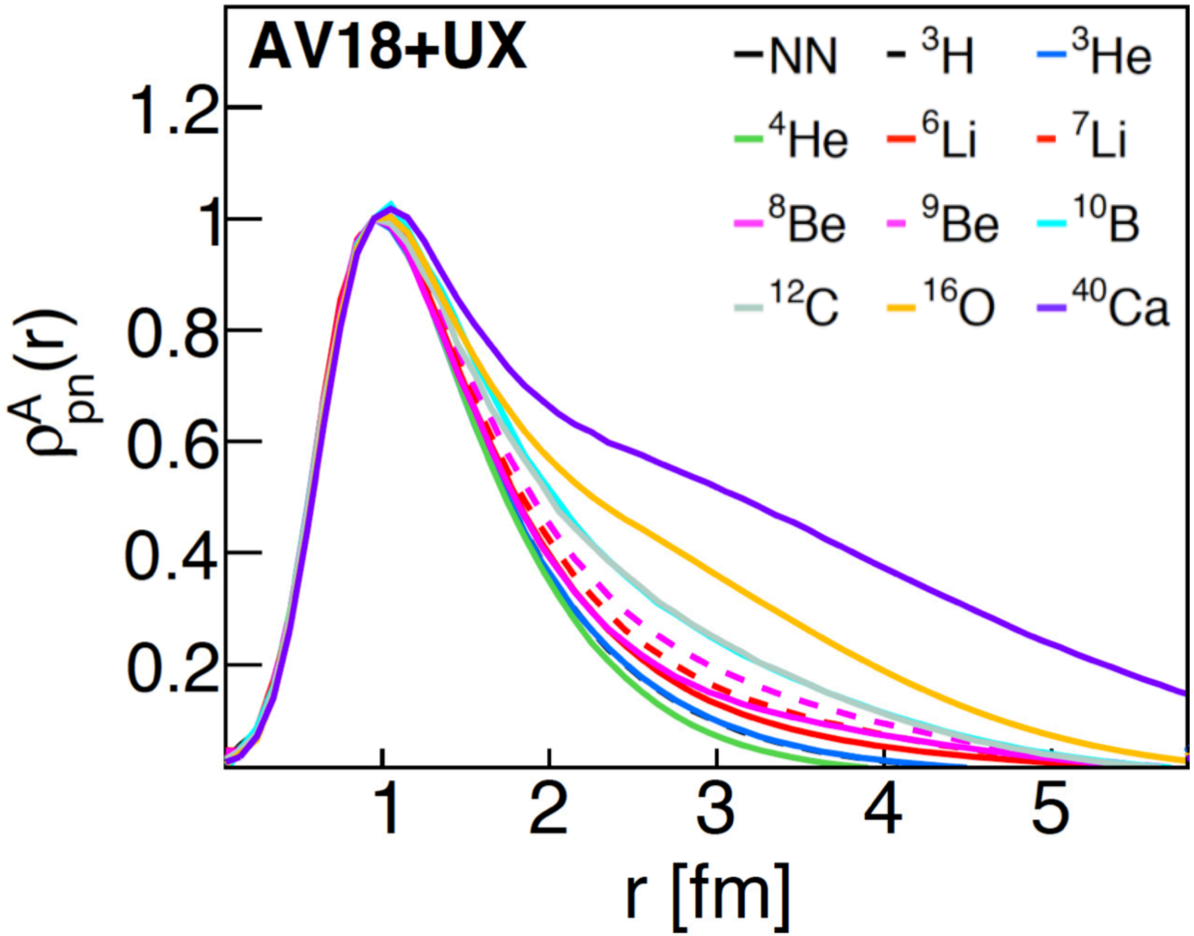
Pairs ⇔ Scale Separation





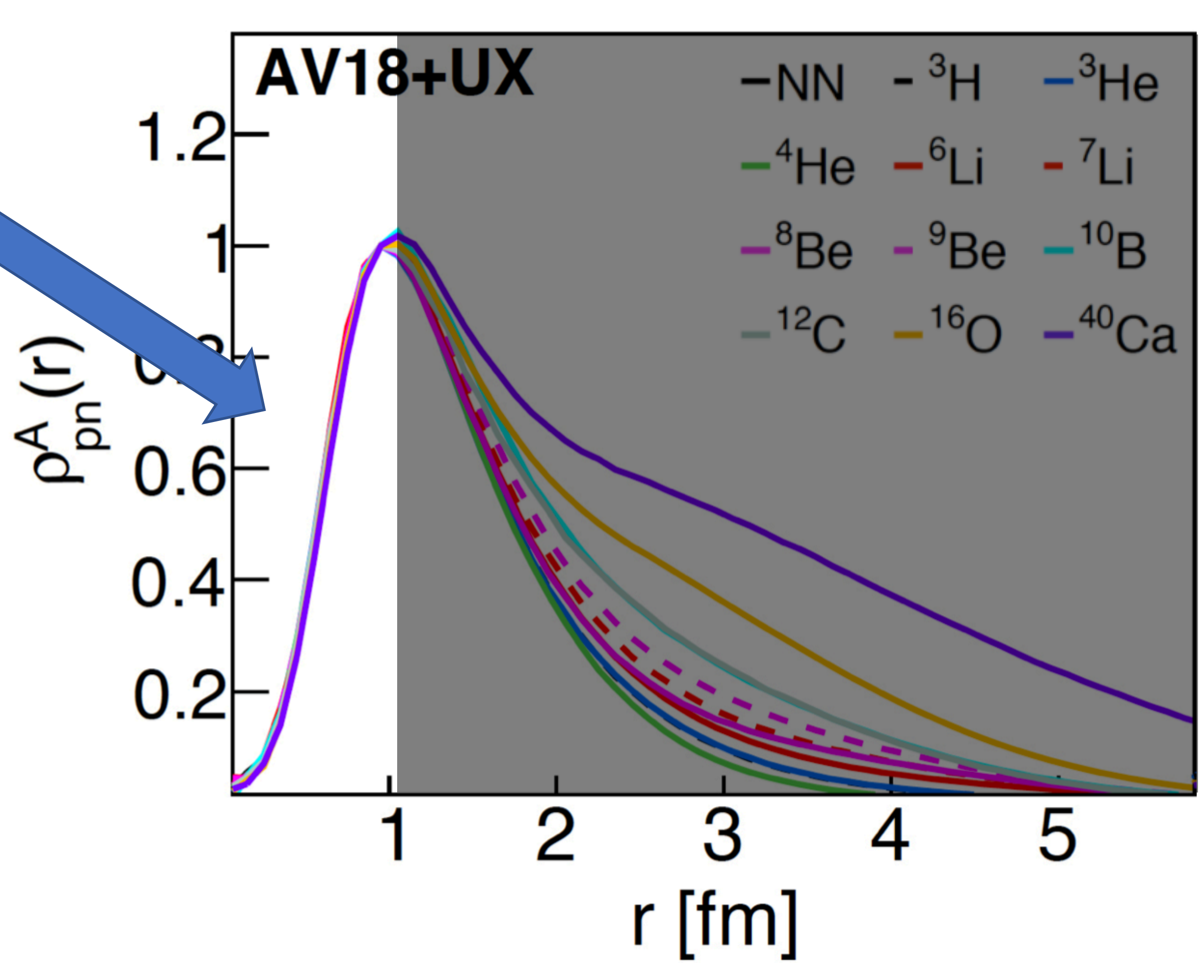
SRCs from Quantum Monte-Carlo (QMC):

Pair Distance Distributions



Cruz Torres and Lonardoni et al., arXiv: 1907.03658 (2019)

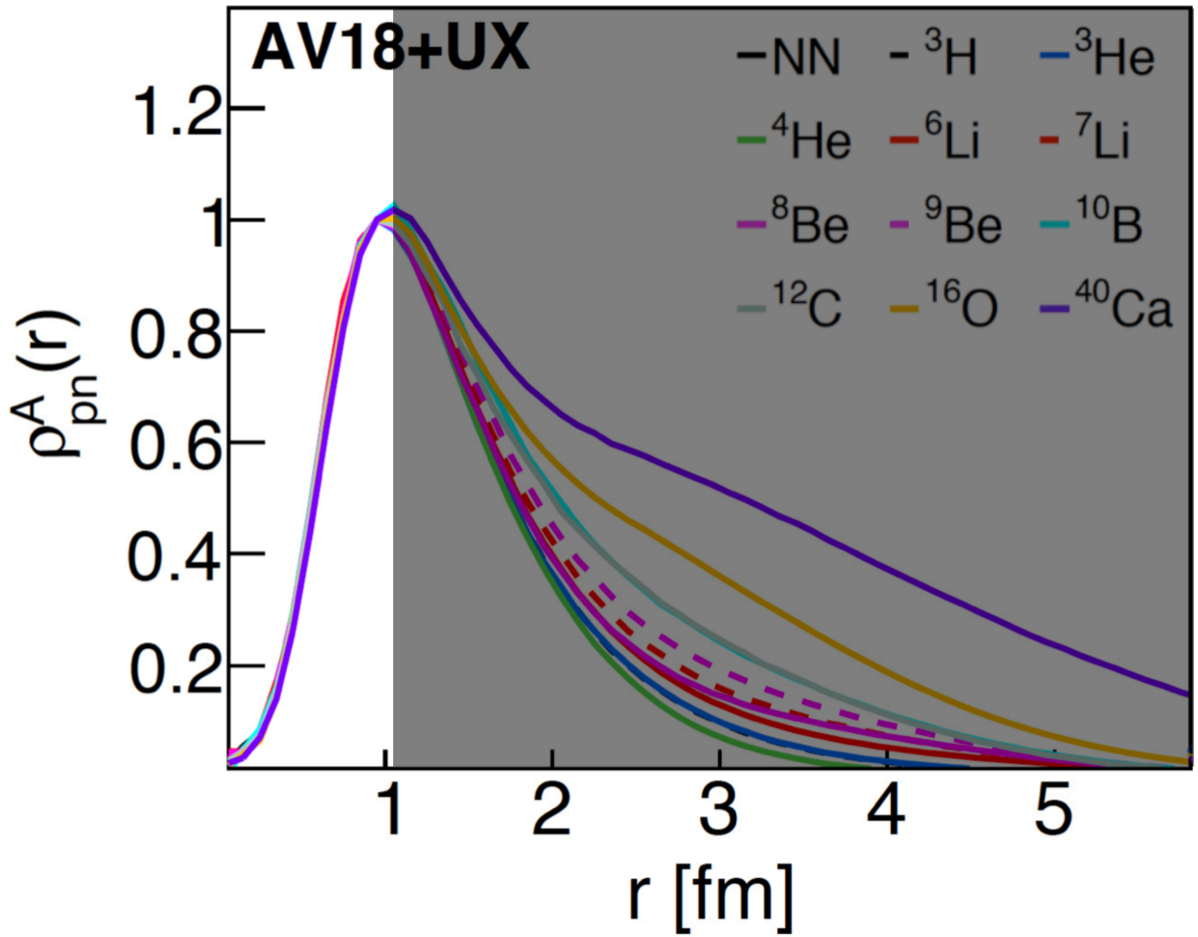
Many Body = Constant x Two-Body



Cruz Torres and Lonardoni et al., arXiv: 1907.03658 (2019)

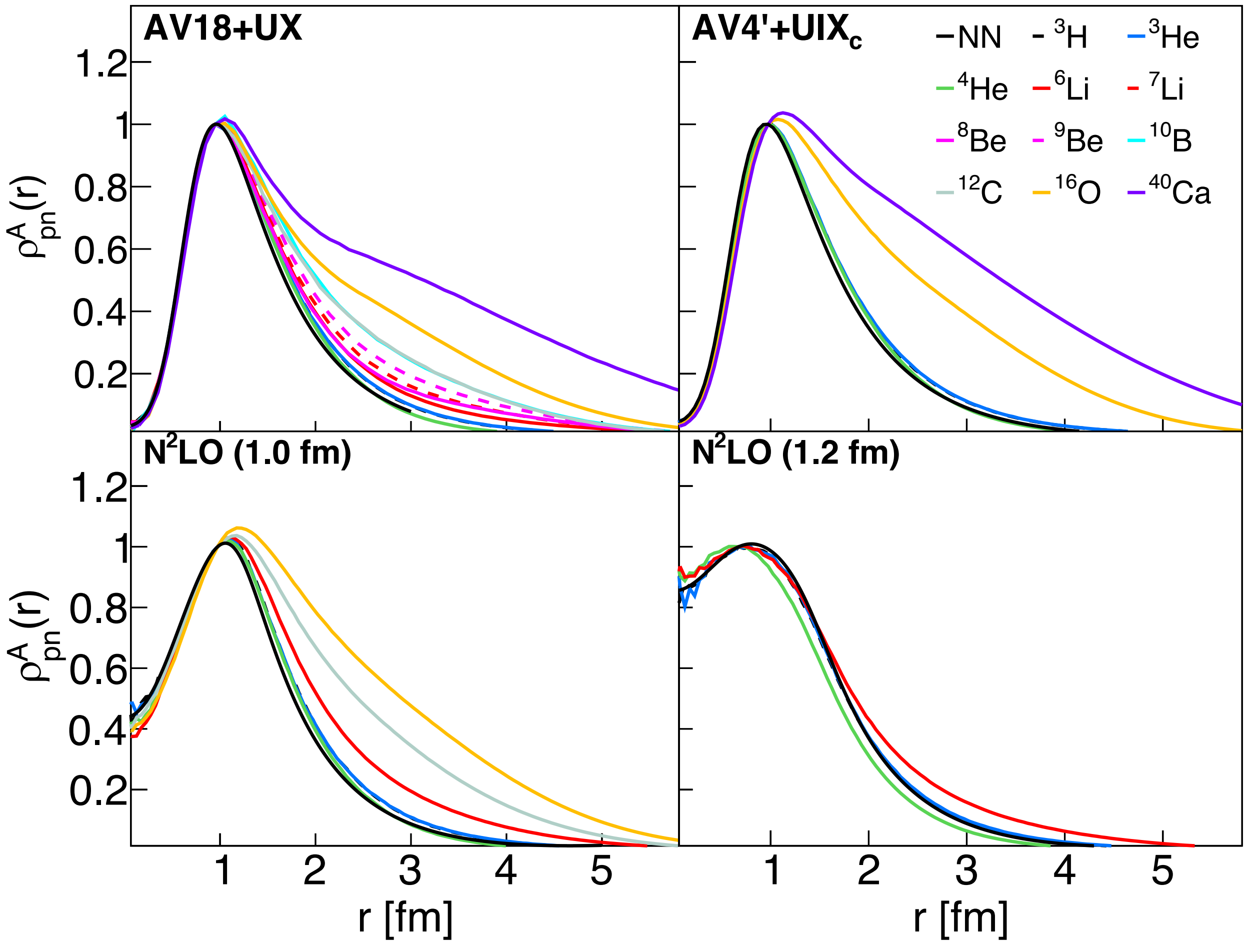
$$\rho_A^{NN,\alpha}(r) = C_A^{NN,\alpha} \times |\varphi_{NN}^{\alpha}(r)|^2$$

Many Body = Constant x Two-Body



Cruz Torres and Lonardoni et al., arXiv: 1907.03658 (2019)

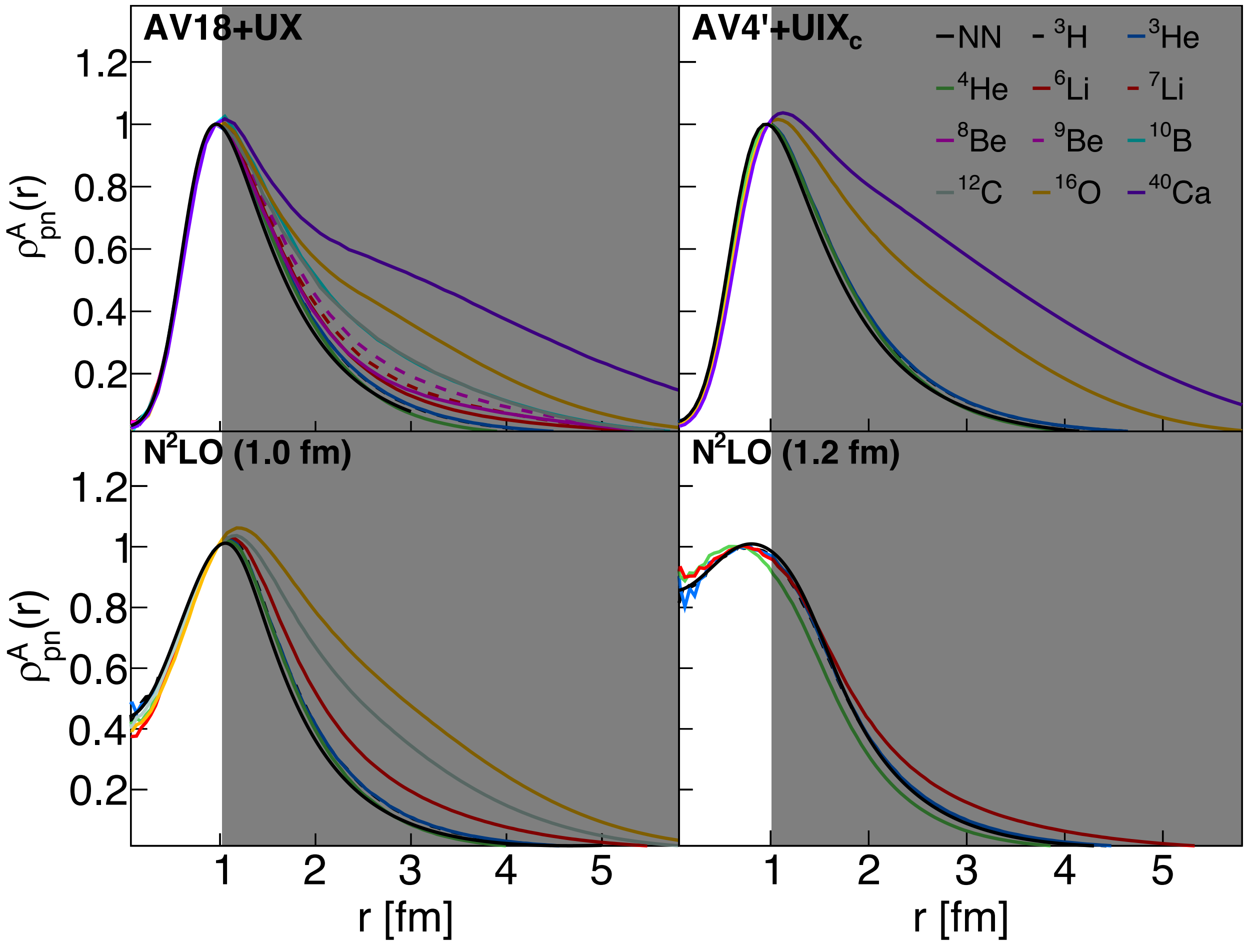
Factorization is Scheme Independent



Cruz Torres and Lonardoni et al., arXiv: 1907.03658 (2019)

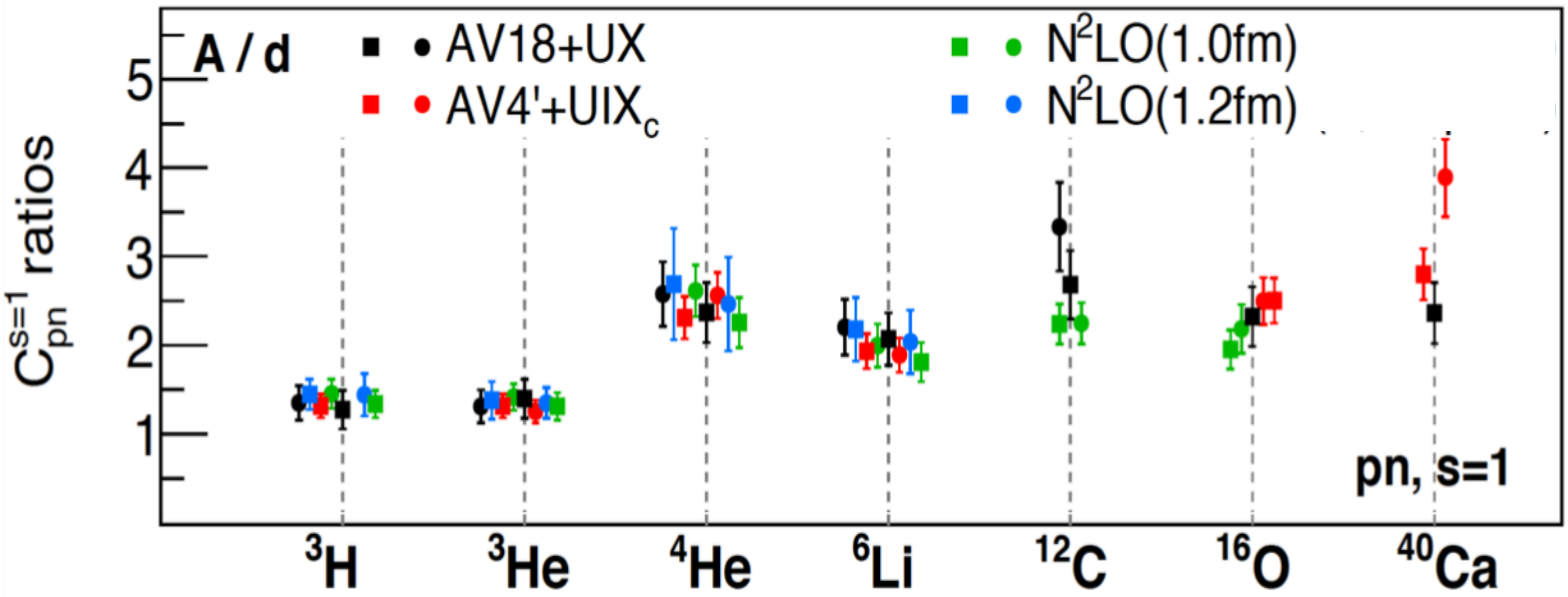
Factorization is Scheme Independent

$$\rho_A^{NN,\alpha}(r) = C_A^{NN,\alpha} \times |\varphi_{NN}^{\alpha}(r)|^2$$



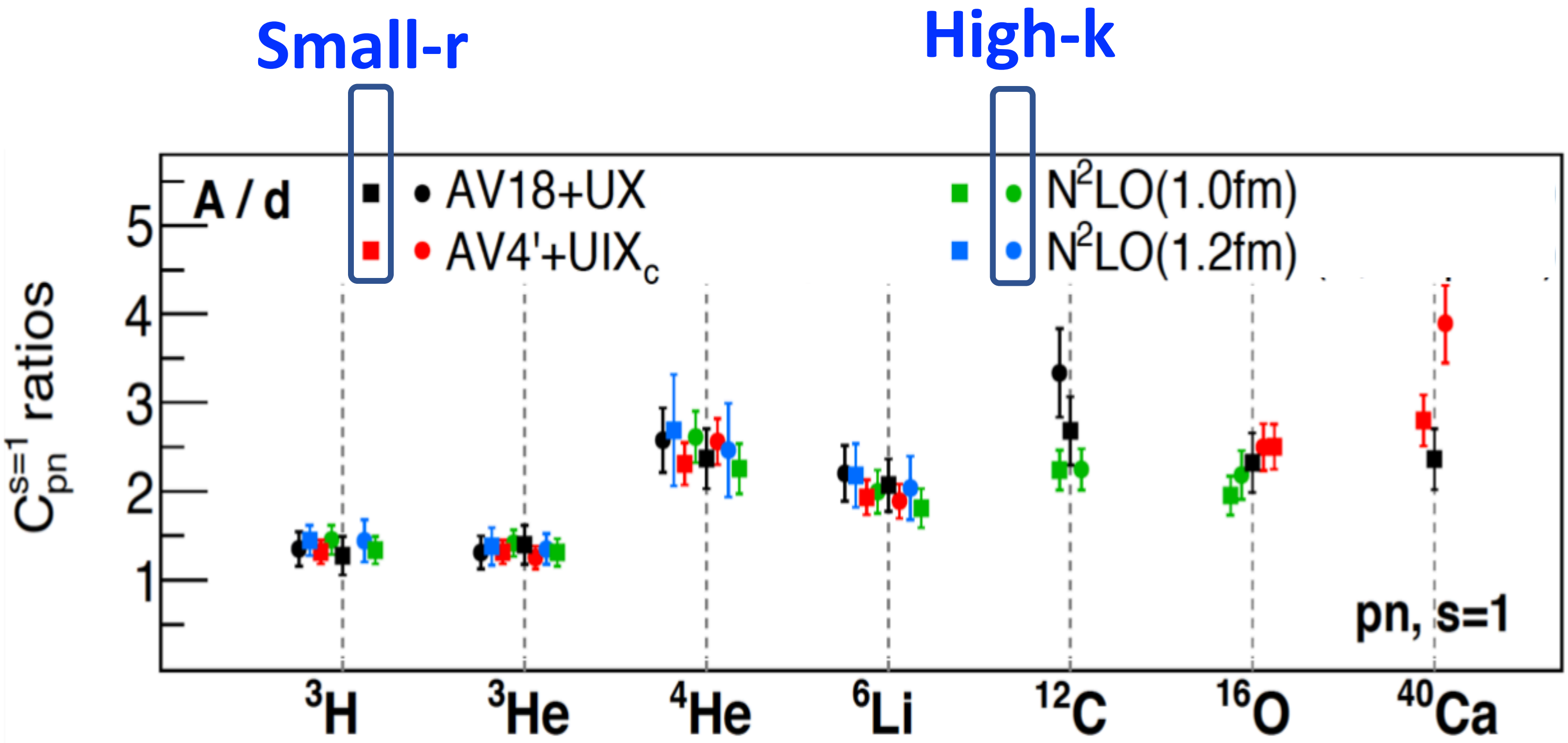
Cruz Torres and Lonardoni et al., arXiv: 1907.03658 (2019)

Scale & Scheme Independence
Momentum–Position Equivalence



Cruz Torres and Lonardoni et al., arXiv: 1907.03658 (2019)

Scale & Scheme Independence
Momentum–Position Equivalence



Cruz Torres and Lonardoni et al., arXiv: 1907.03658 (2019)

Scale Separation

$$\rho_A^{NN,\alpha}(r) = C_A^{NN,\alpha} \times |\varphi_{NN}^{\alpha}(r)|^2$$

Total Dist. = Constant x Two-body

(Low-Energy) (High-Energy)

Generalized Contact Formalism (GCF):

Pairs Spectral Functions

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

Weiss, Phys. Lett. B (2018); Cruz Torres, Phys. Lett B (2018); Weiss Phys. Lett B (2019).
+ many works by Claudio Ciofi; Jan Ryckebusch; Frankfurt Strikman; …

Generalized Contact Formalism (GCF):

Pairs Spectral Functions

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

Low-Energy x High-Energy

Weiss, Phys. Lett. B (2018); Cruz Torres, Phys. Lett B (2018); Weiss Phys. Lett B (2019).
+ many works by Claudio Ciofi; Jan Ryckebusch; Frankfurt Strikman; …

Generalized Contact Formalism (GCF):

Pairs Spectral Functions

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Each pair is convoluted with c.m. motion:

$$s_{ab}^{\alpha} = \frac{1}{4\pi}\int \frac{dp_2}{(2\pi)^3}\,\delta[f(p_2)]\;|\varphi_{ab}^{\alpha}(p_1-p_2)/2|^2\,n_{ab}^{\alpha}(p_1+p_2)$$

Weiss, Phys. Lett. B (2018); Cruz Torres, Phys. Lett B (2018); Weiss Phys. Lett B (2019).

Generalized Contact Formalism (GCF):

Pairs Spectral Functions

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

Each pair is convoluted with c.m. motion:

$$
s_{ab}^{\alpha} = \frac{1}{4\pi}\int \frac{dp_2}{(2\pi)^3}\,\delta[f(p_2)]\,\underbrace{|\varphi_{ab}^{\alpha}(p_1-p_2)/2|^2}_{\text{Relative}}\,\underbrace{n_{ab}^{\alpha}(p_1+p_2)}_{\text{c.m.}}
$$

Weiss, Phys. Lett. B (2018); Cruz Torres, Phys. Lett B (2018); Weiss Phys. Lett B (2019).

Generalized Contact Formalism (GCF):

Pairs Spectral Functions

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

Each pair is convoluted with c.m. motion:

$$s_{ab}^{\alpha} = \frac{1}{4\pi} \int \frac{dp_2}{(2\pi)^3}\, \delta[f(p_2)]\, \underbrace{|\varphi_{ab}^{\alpha}(p_1 - p_2)/2|^2}_{\text{AV18 / N2LO / ...}}\, \underbrace{n_{ab}^{\alpha}(p_1 + p_2)}_{\text{Gaussian}}$$

Weiss, Phys. Lett. B (2018); Cruz Torres, Phys. Lett B (2018); Weiss Phys. Lett B (2019).

Probing the NN Interaction

<u>What's needed?</u>

✓ Data

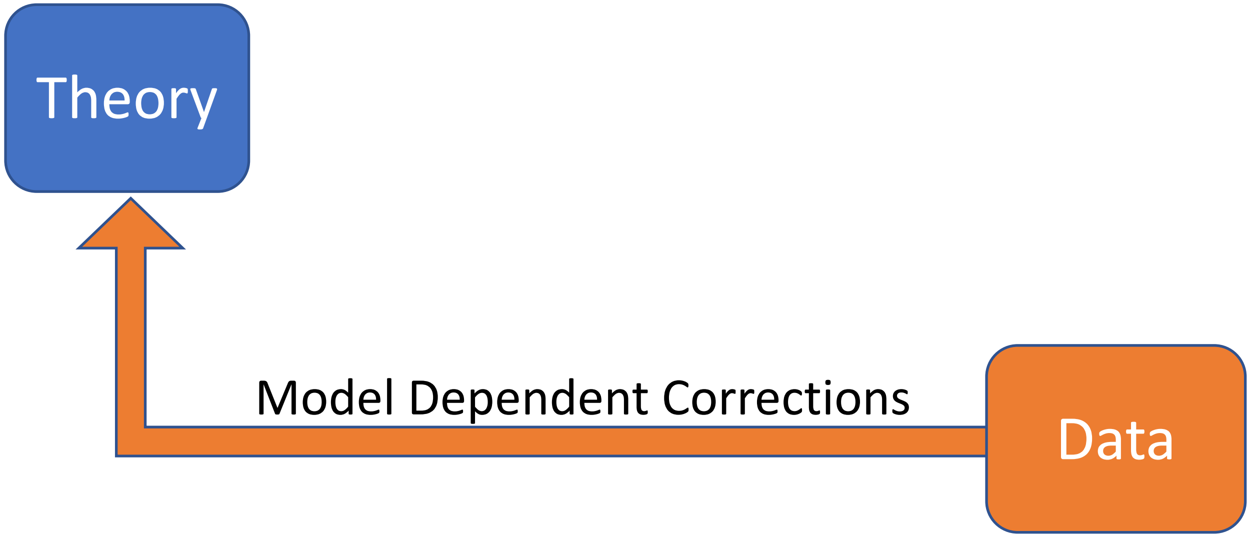
- ~~Ab-initio cross-section calculations~~

✓ Factorization \w spectral functions from NN interaction

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

Theory-Data Comparisons

Experiments usually correct data for detector acceptance and reaction mechanism effect before comparing with theory.



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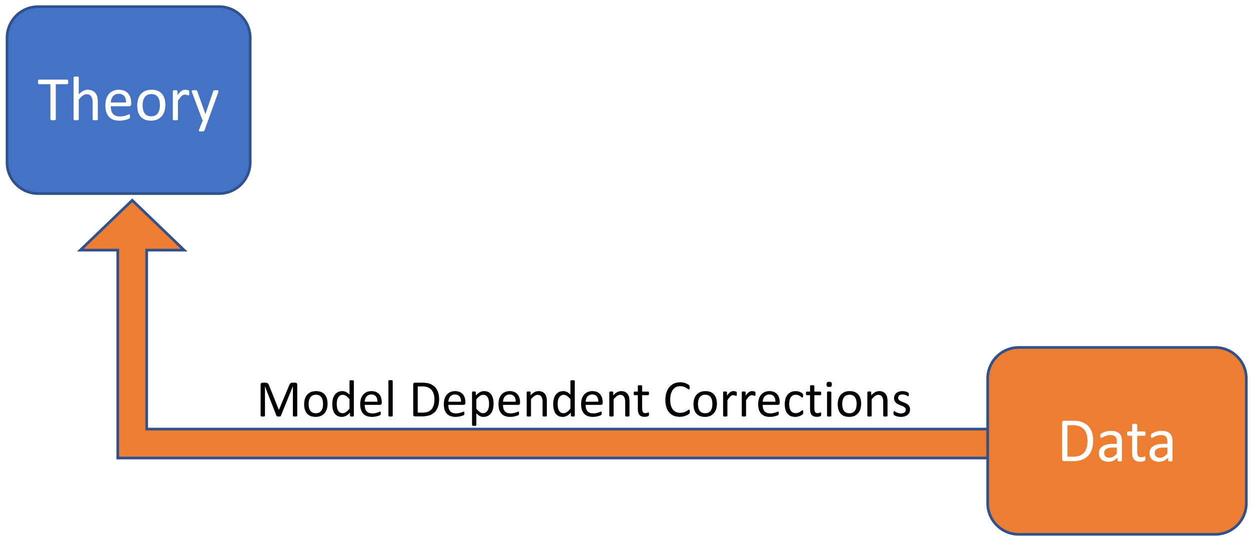

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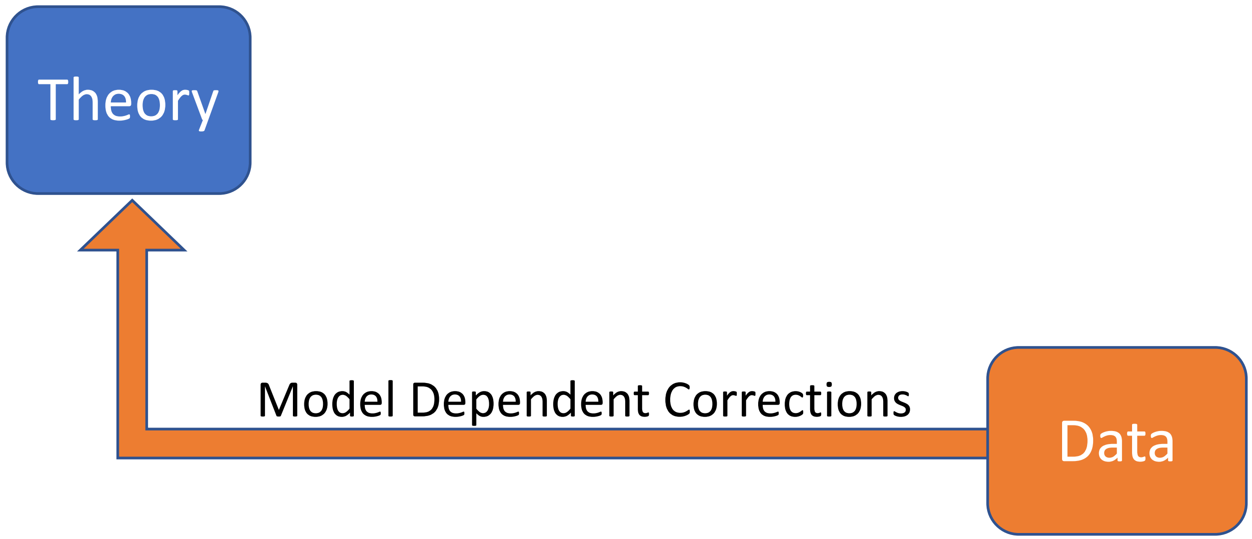
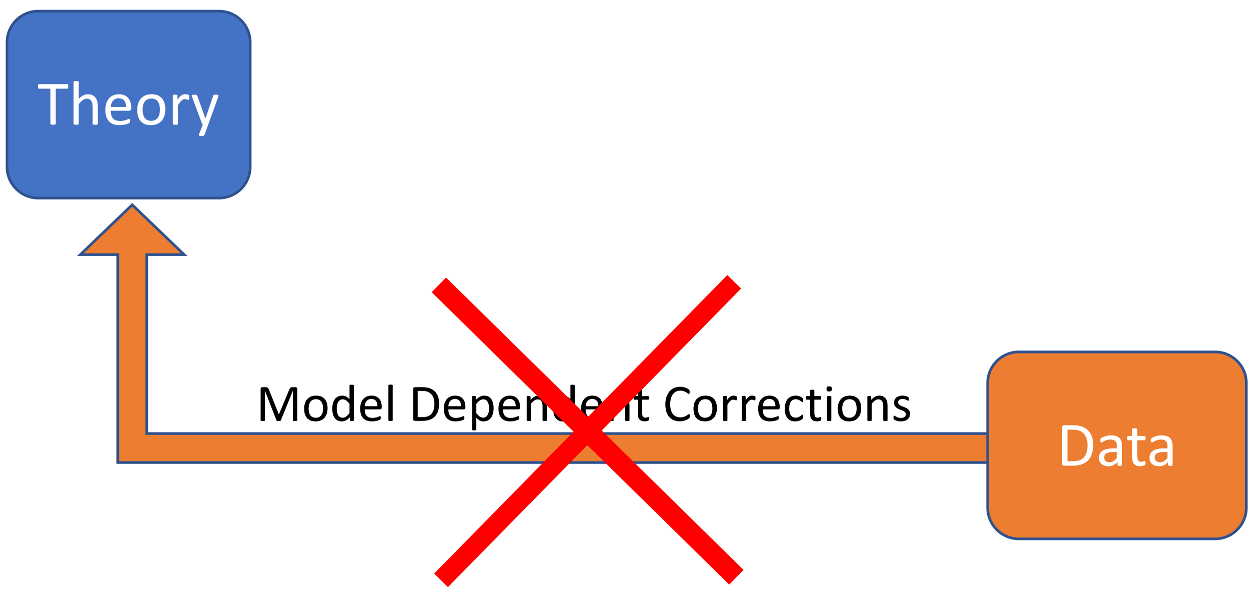


Theory-Data Comparisons

Experiments usually correct data for detector acceptance and reaction mechanism effect before comparing with theory.

<u>This often leads to 'model dependent data'</u> 😬

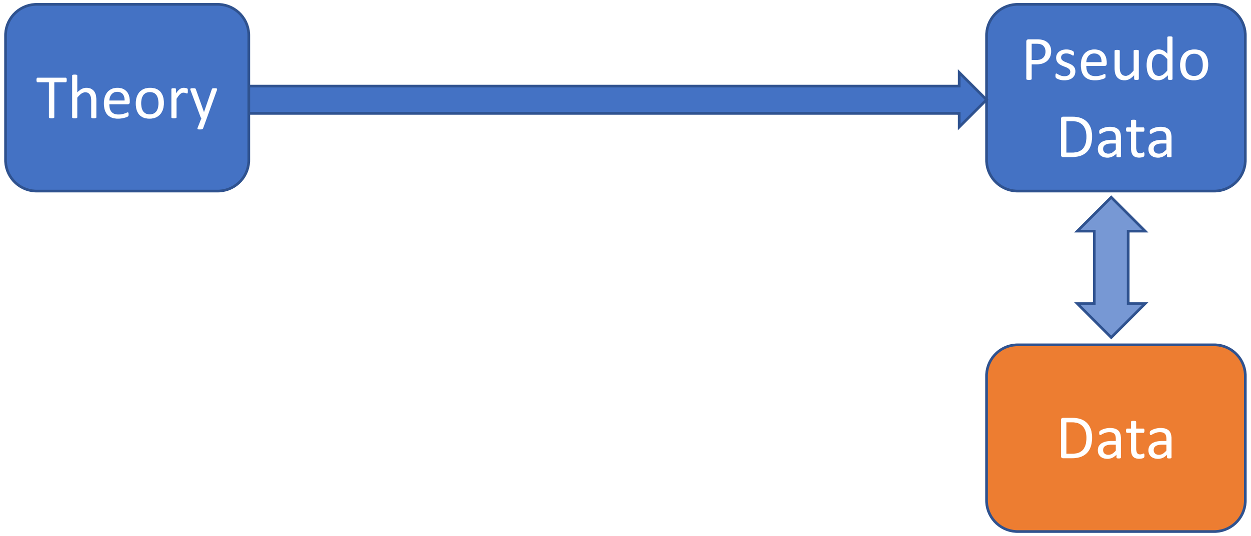


Theory-Data Comparisons

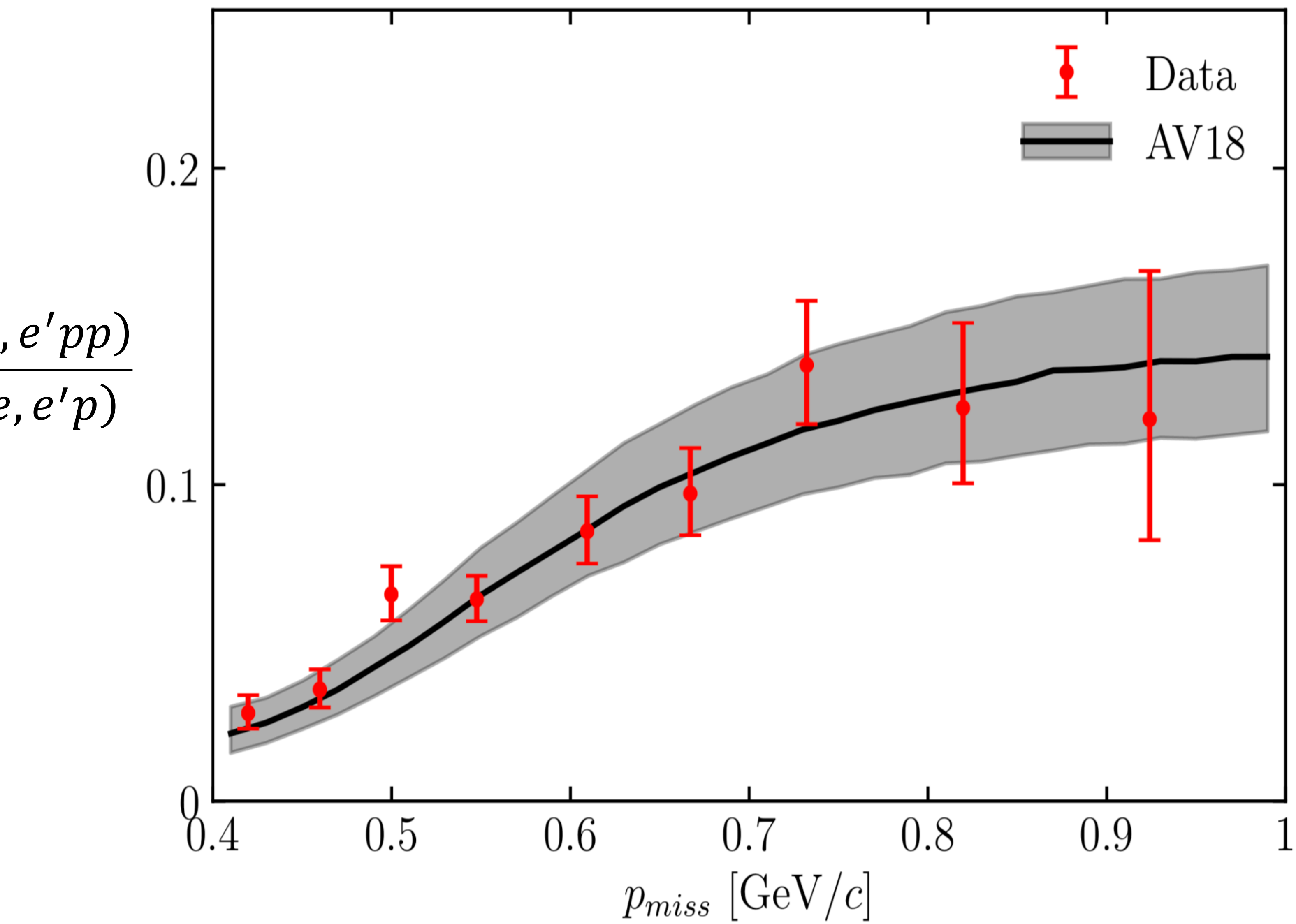
Experiments usually correct data for detector acceptance and reaction mechanism effect before comparing with theory.

Instead, we bring theory to data!

[theory based simulation forms 'pseudo-data' that is overlaid on exp-data]

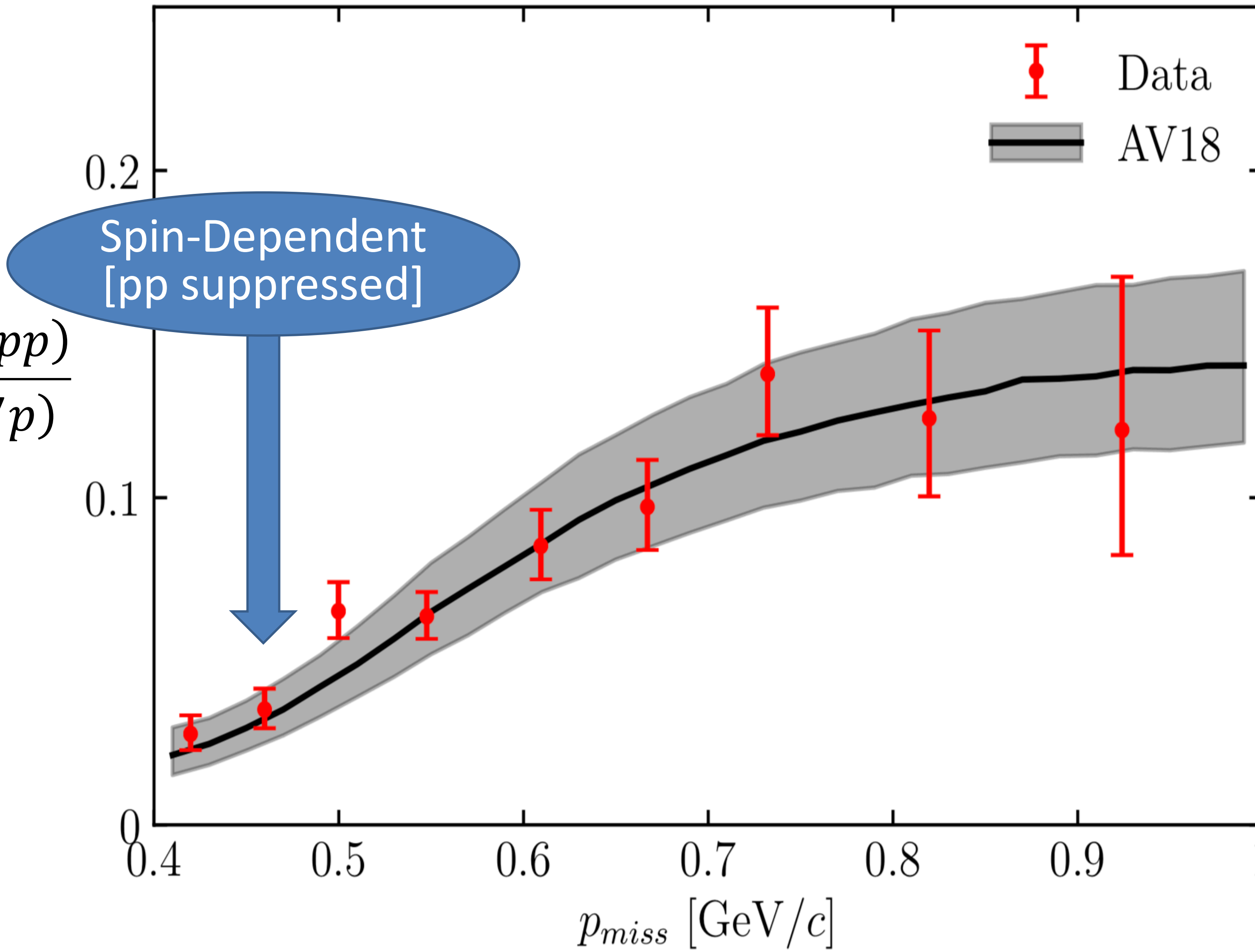


Reaching the Repulsive Core



Schmidt et al., Nature (2020)

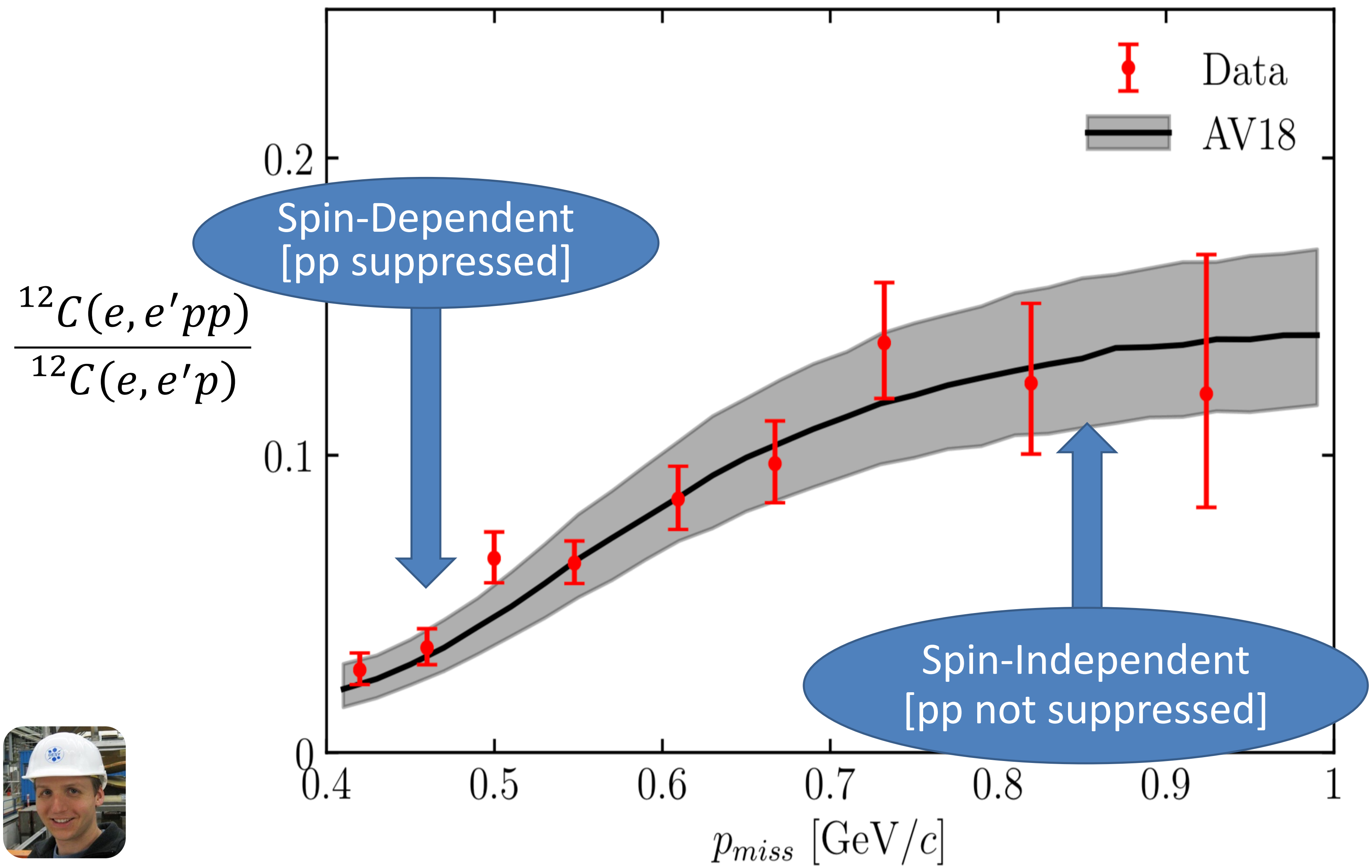
Reaching the Repulsive Core



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

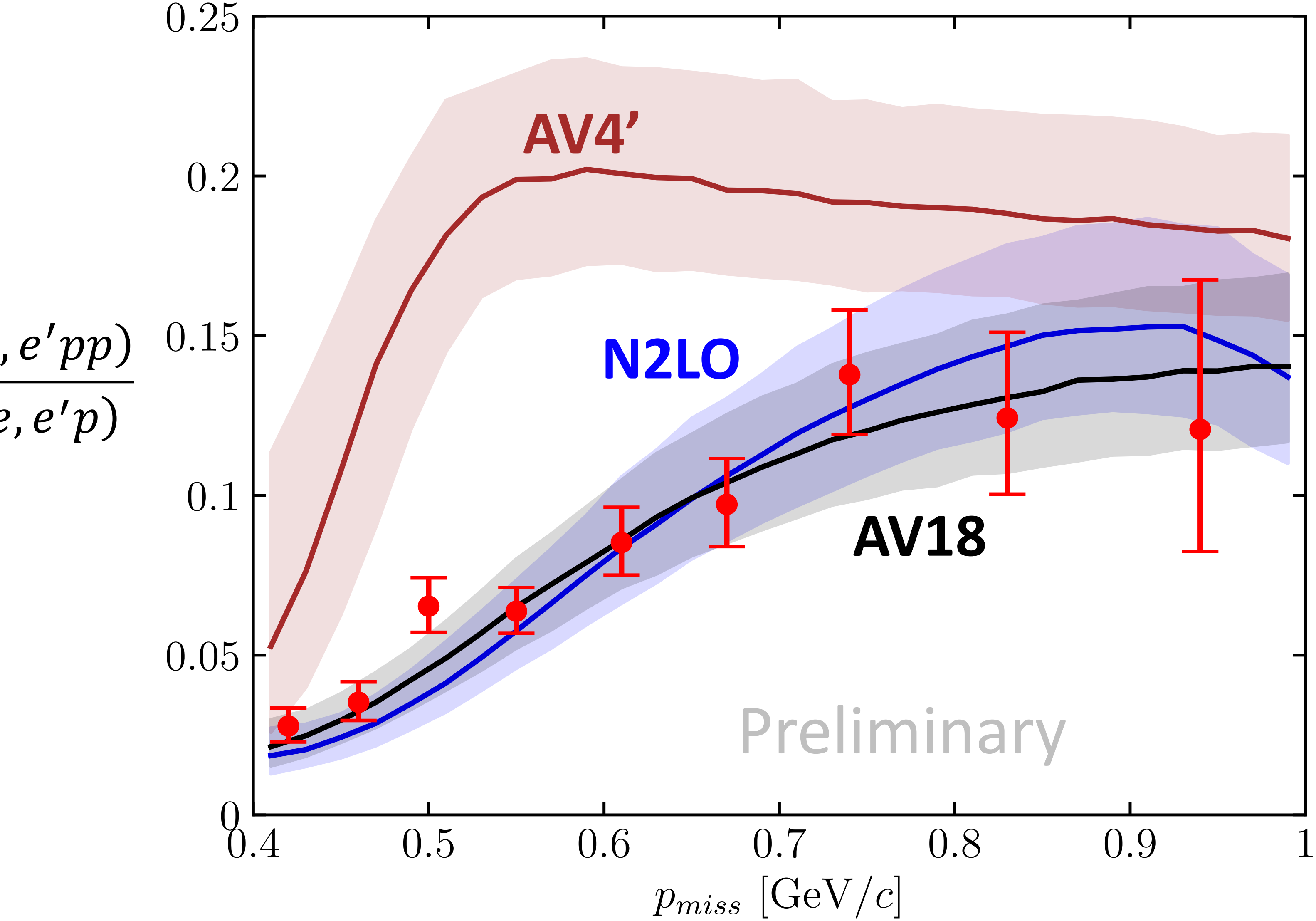
Schmidt et al., Nature (2020)

Reaching the Repulsive Core



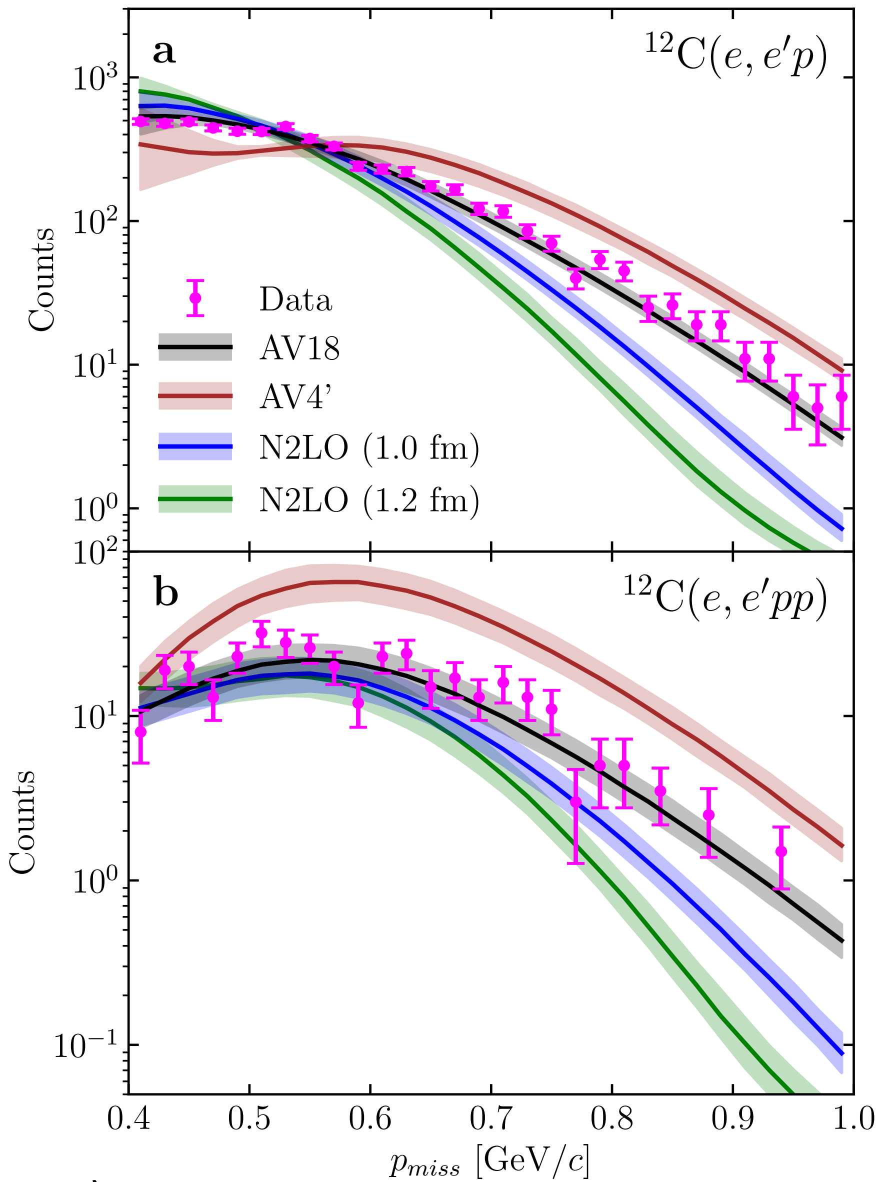
Schmidt et al., Nature (2020)

Reaching the Repulsive Core



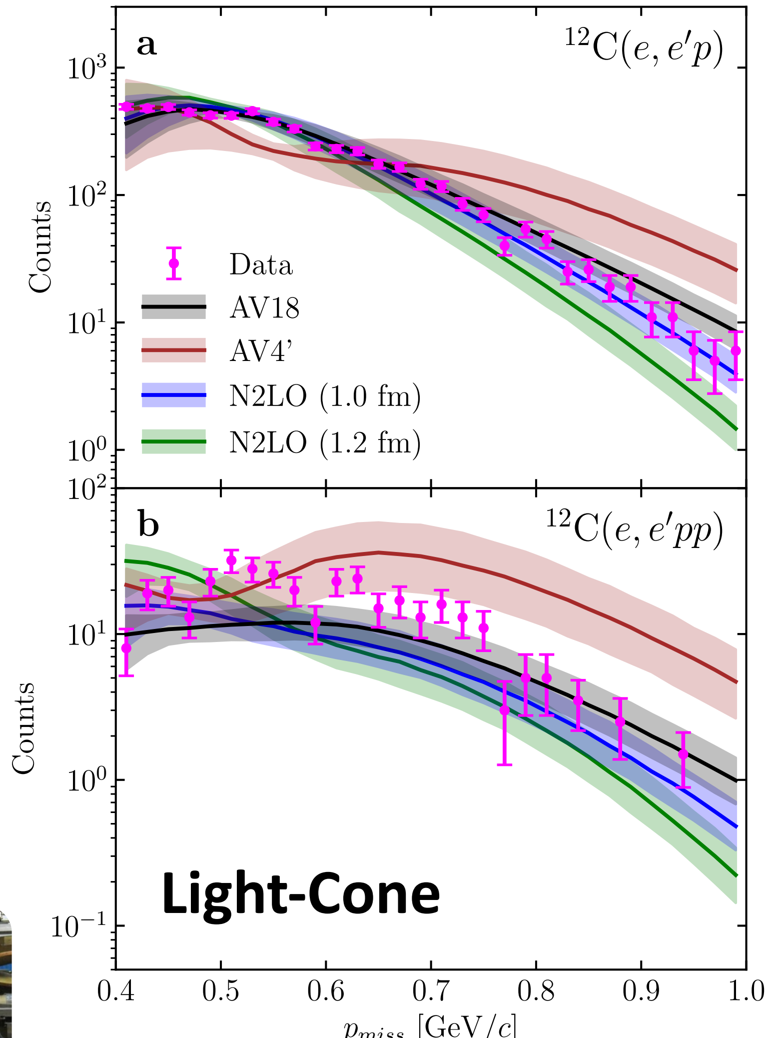
Schmidt et al., Nature (2020)

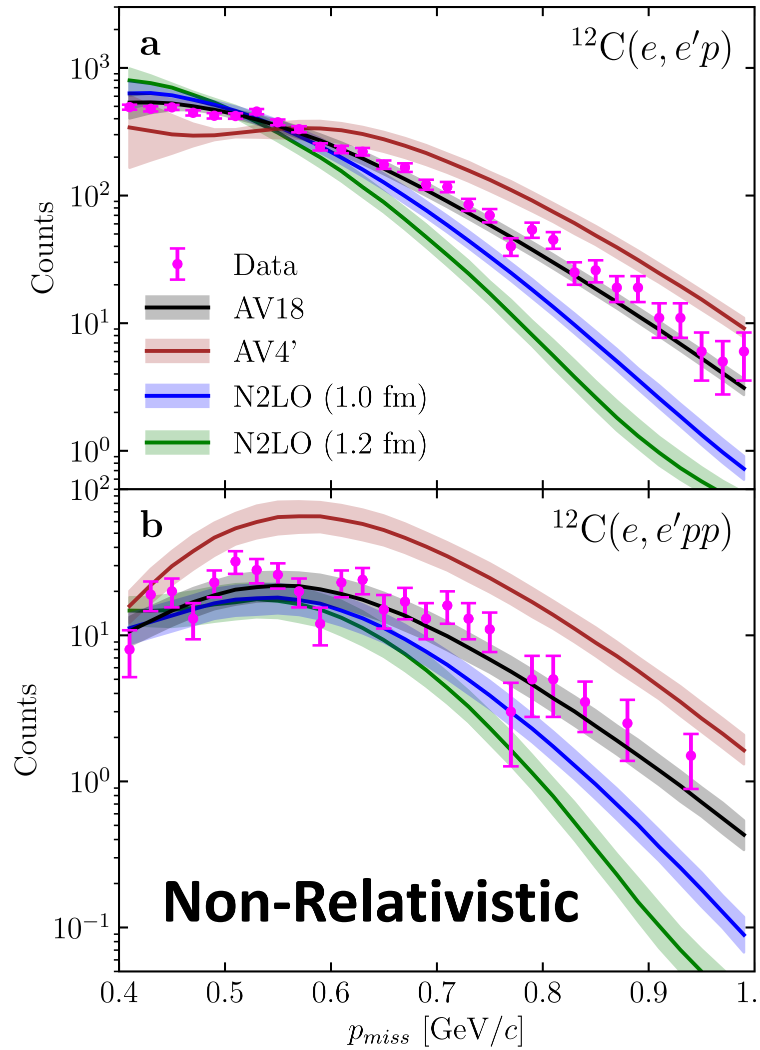
Nucleon Distributions Sensitivity



Schmidt et al., Nature (2020)

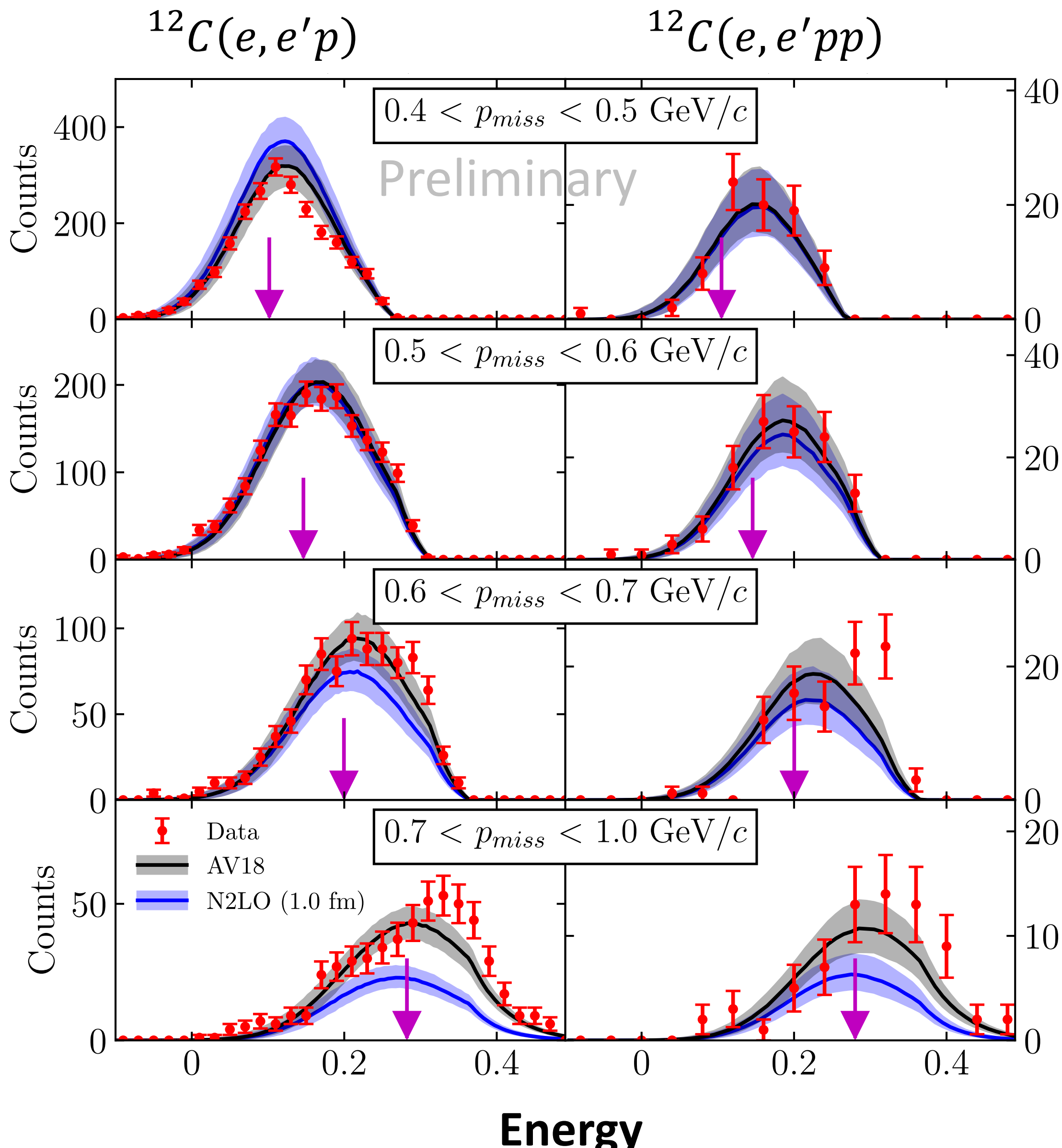
Relativistic Effects:
Light-Cone Formalism (Frankfurt & Strikman)





Schmidt et al., Nature (2020)

Spectral function Sensitivity



Momentum

400 – 500 MeV/c

500 – 600 MeV/c

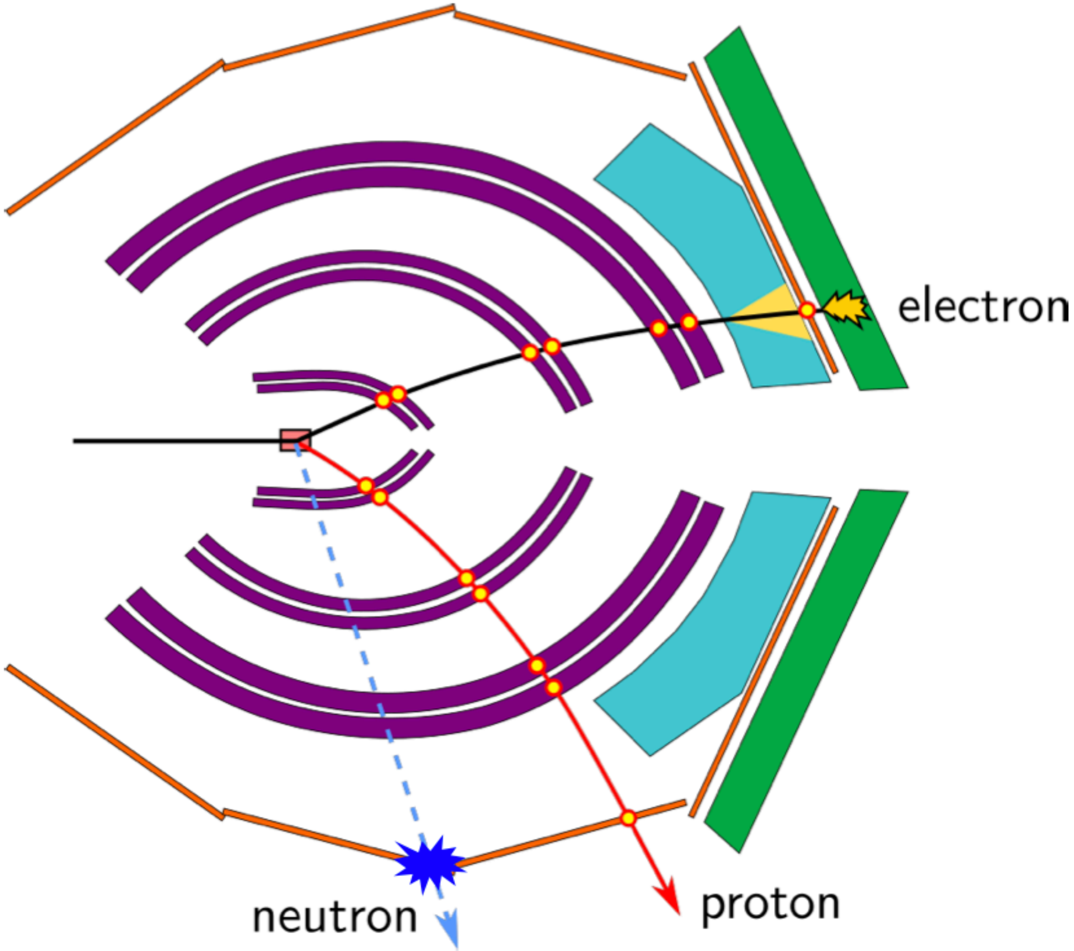
600 – 700 MeV/c

700 – 1000 MeV/c

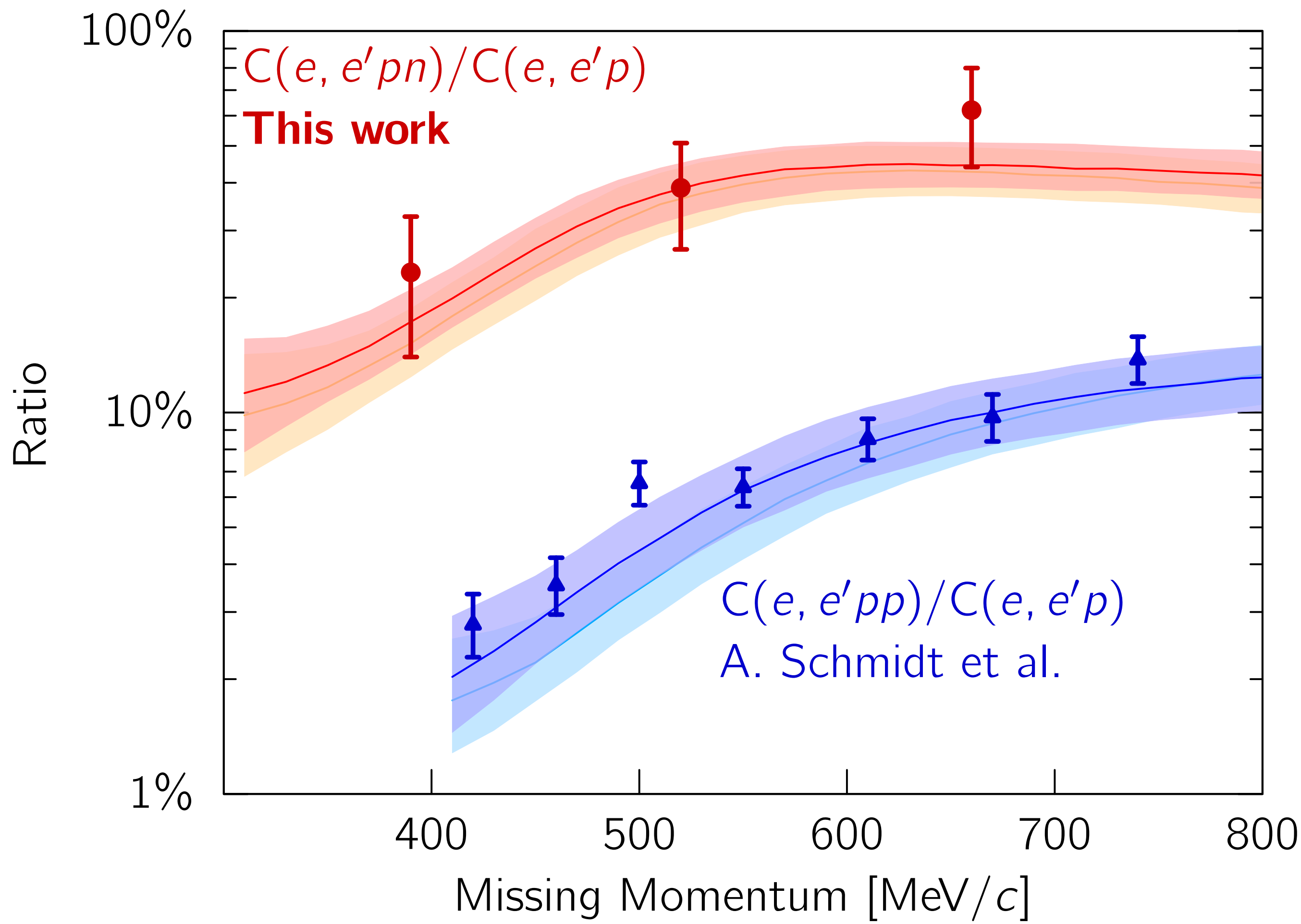
Schmidt et al., Nature (2020)

pn data completes the picture!

Korover et al. (2020)



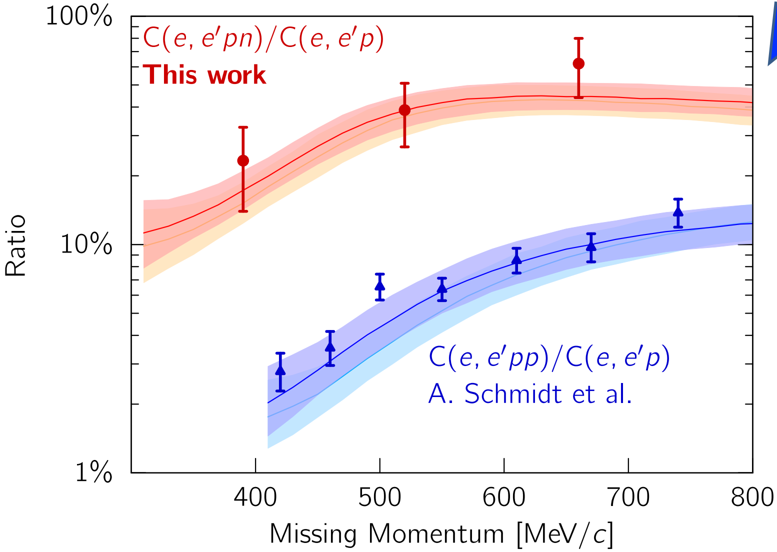
pn consistent with theory!



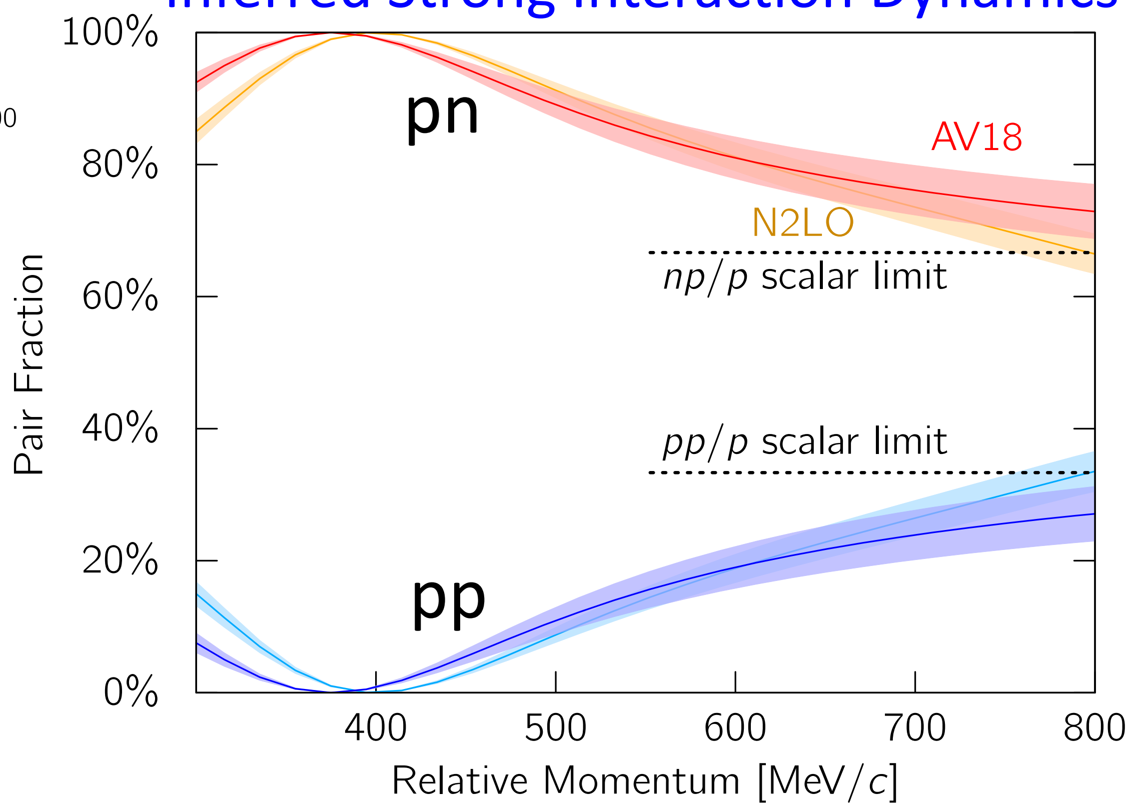
Korover et al. (2020)

Observation of scalar core

Measured cross-sections



Inferred Strong Interaction Dynamics

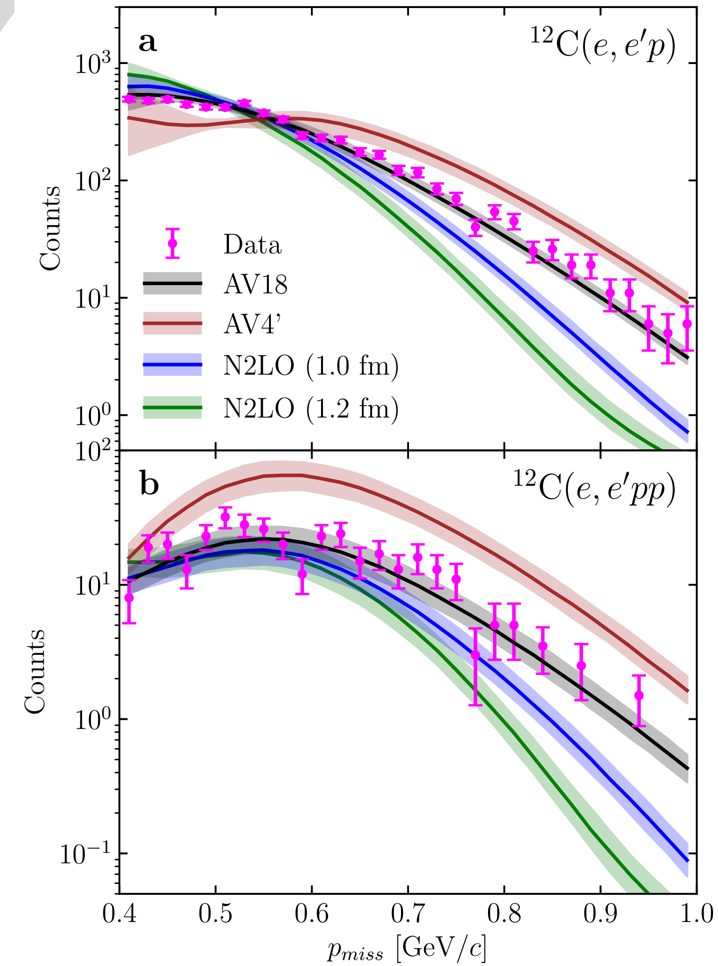


Korover et al. (2020)

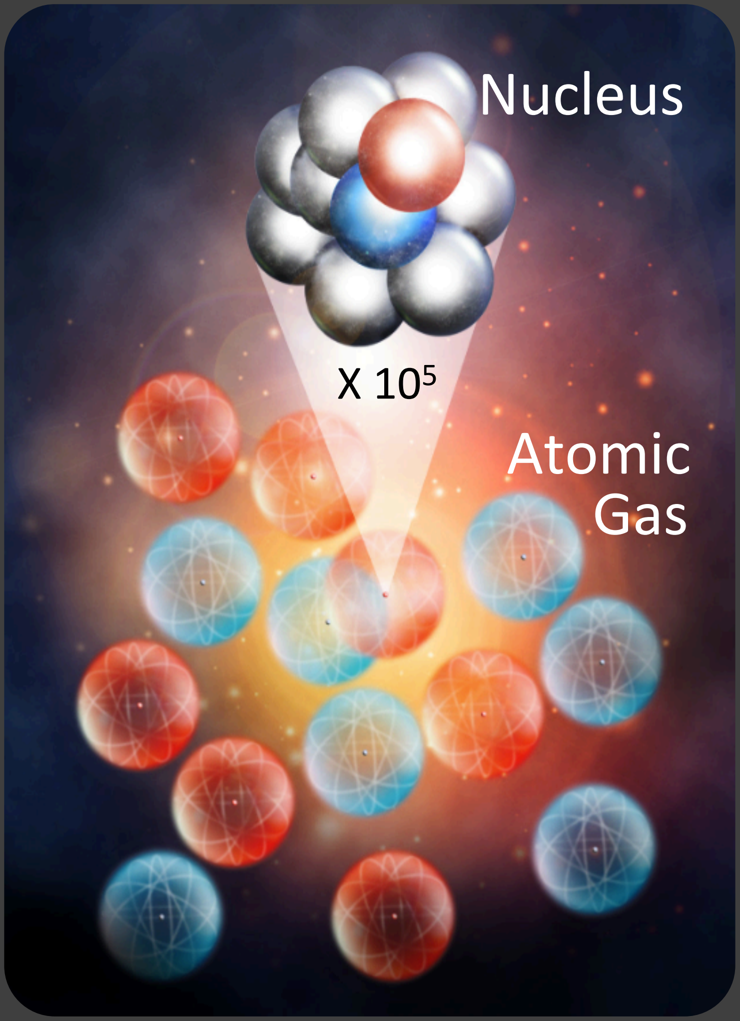
Interim Summary

- Nuclear momentum distribution has two distinct regions.
- #SRC-protons = #SRC-neutrons, independent of neutron excess.
- The fraction of correlated protons / neutrons grow / saturate with neutron excess.

+ Allow probing NN interaction up to 1 GeV/c.



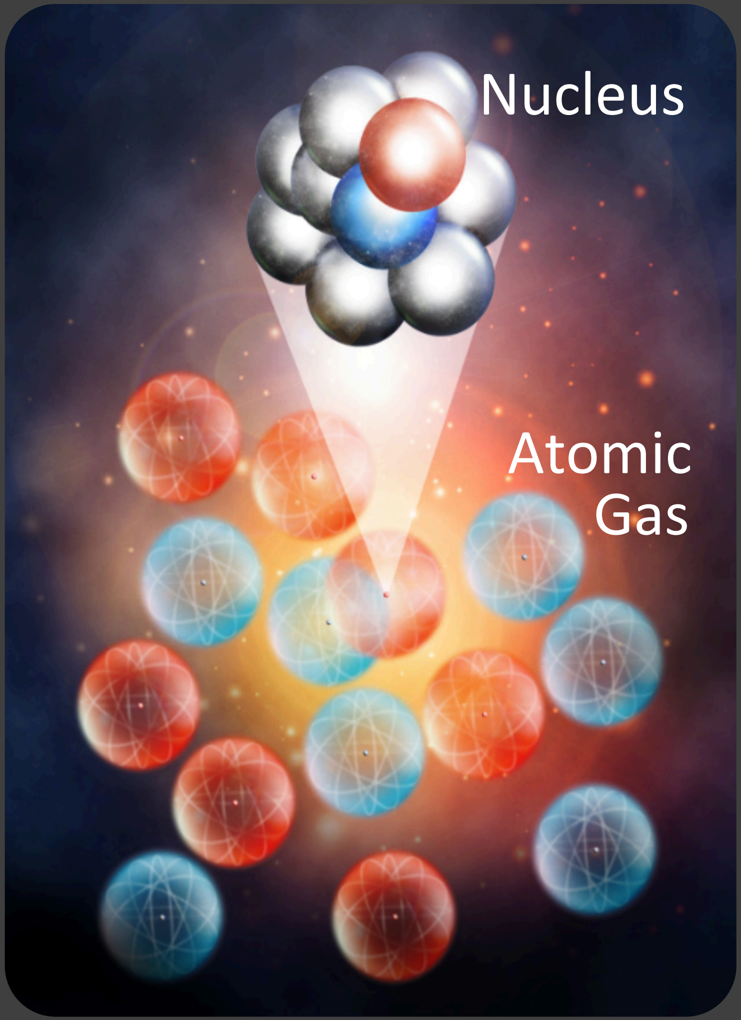
Generalization of the Atomic Contact Formalism



Generalization of the Atomic Contact Formalism

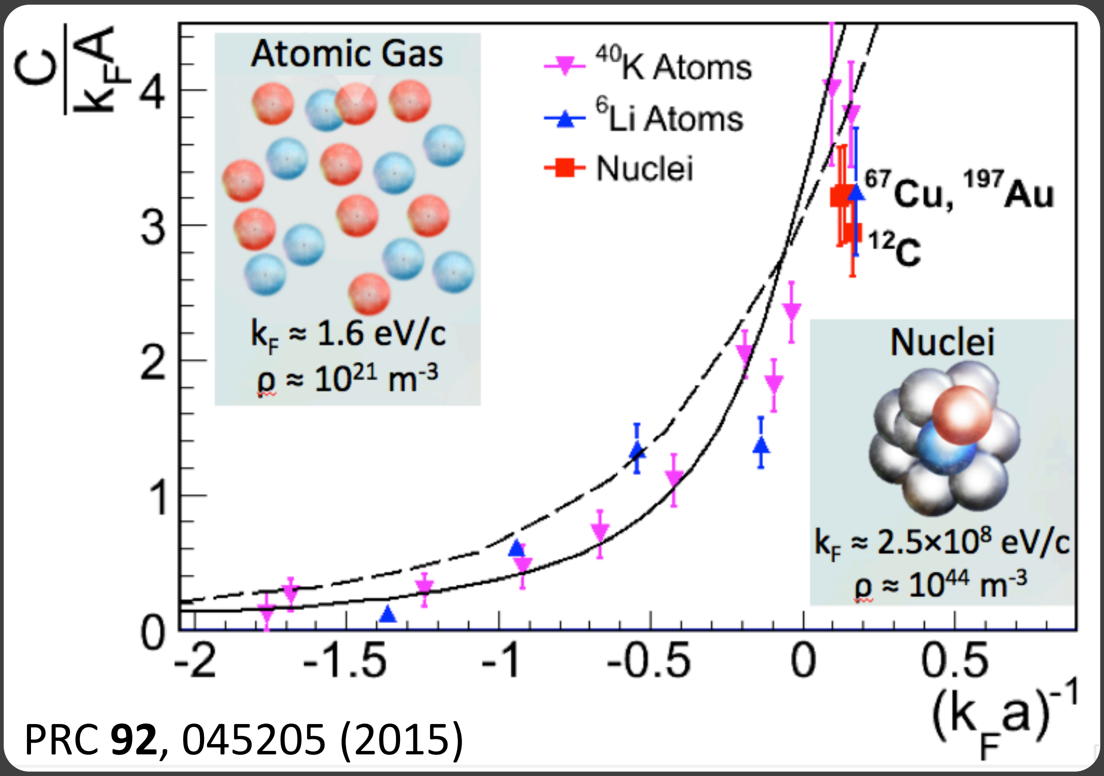
While two body interactions can differ….

… Many tools can be shared



Generalization of the Atomic Contact Formalism

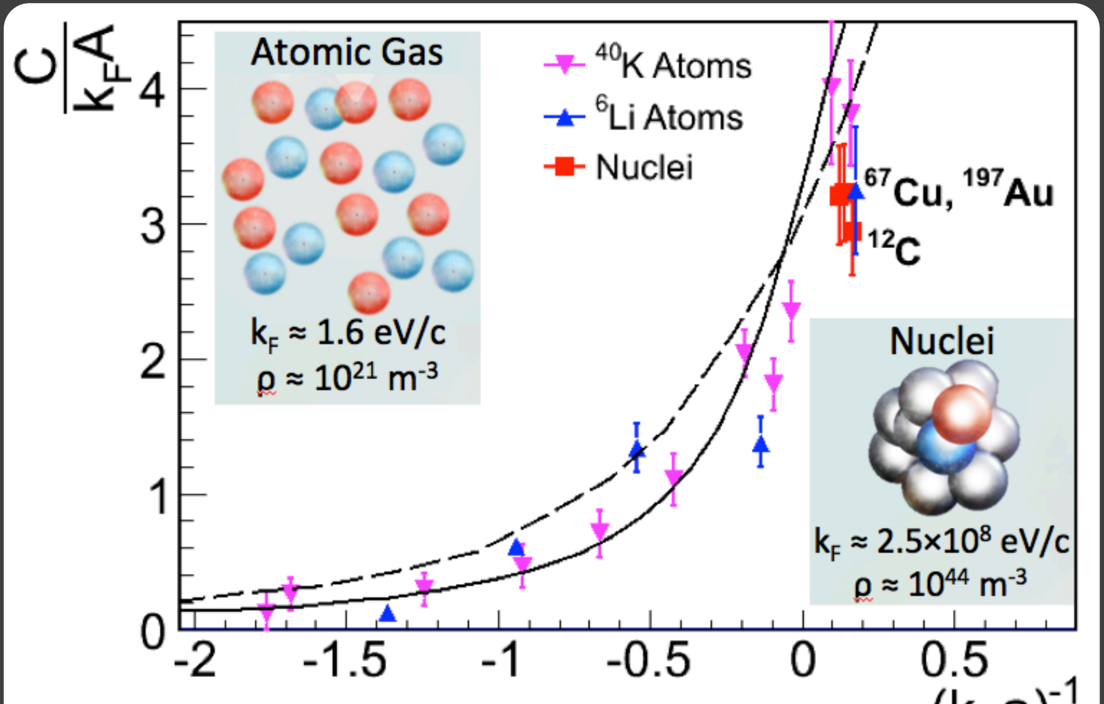
Correlation probability



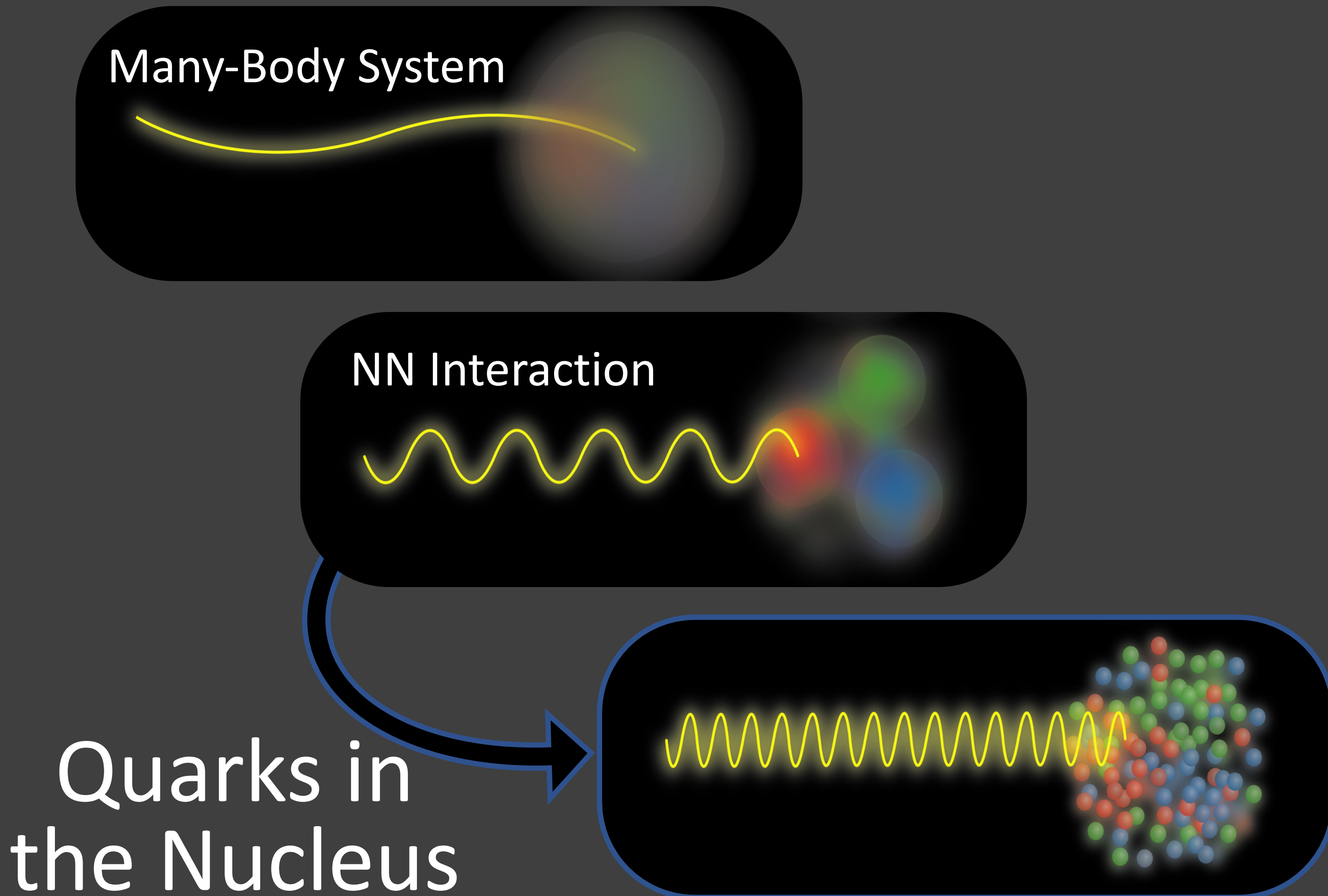
Dimensionless Interaction Strength

No accident…

Contacts are low-energy objects, governed by mean-field dynamics => <u>consistency \w atomic results not surprising</u>!

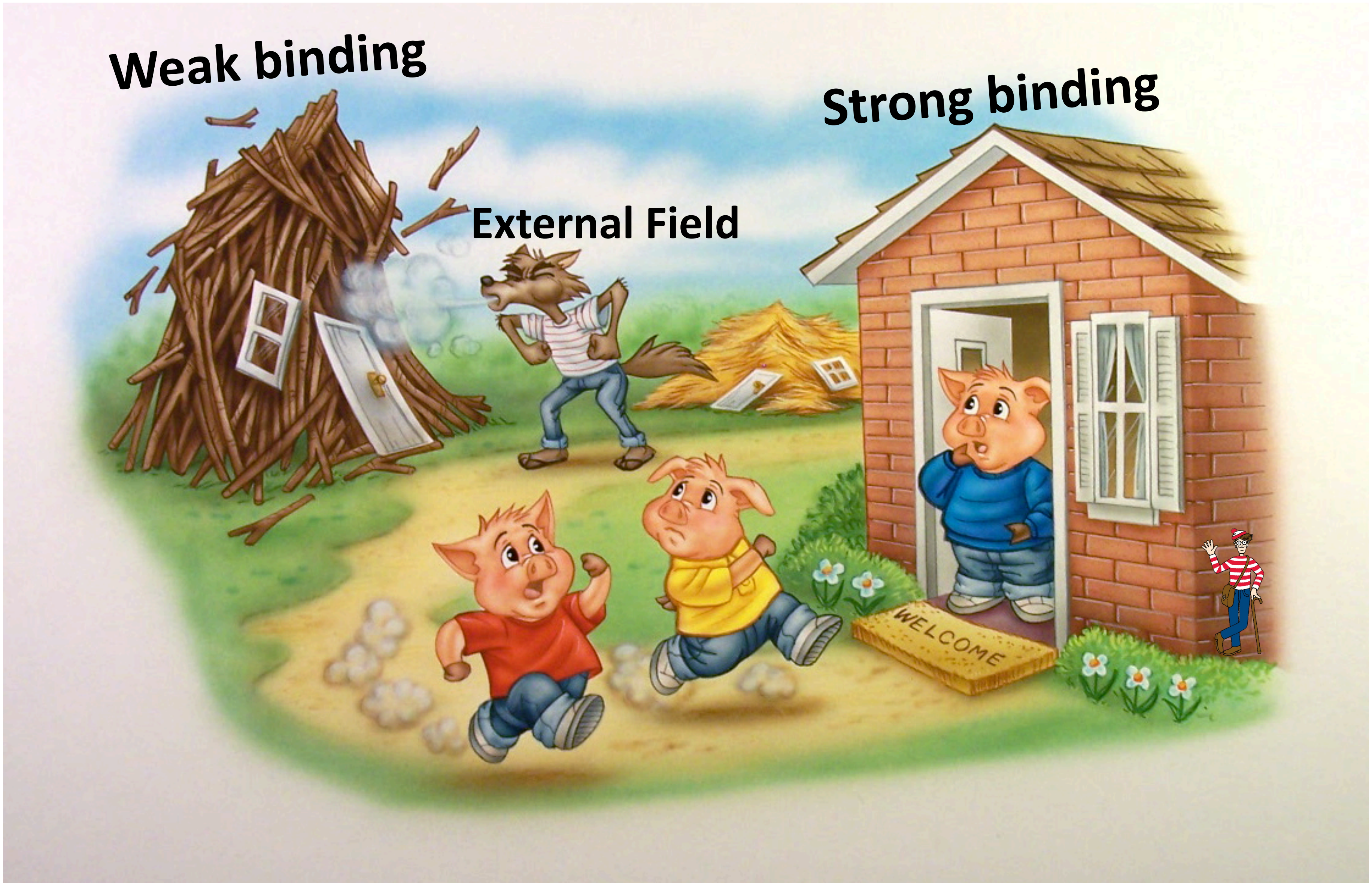


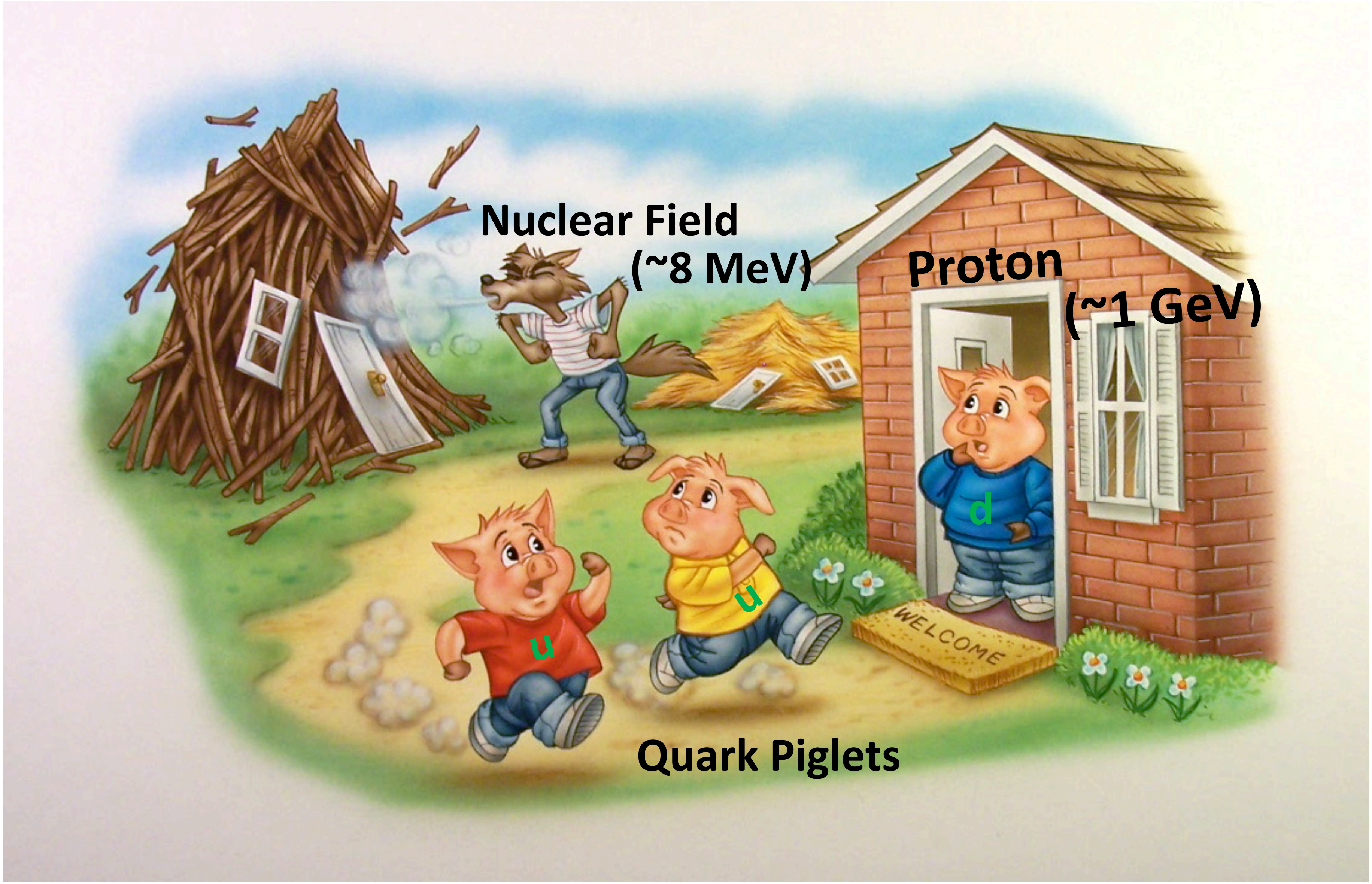
PRC **92**, 045205 (2015)


Many-Body System
NN Interaction
Quarks in
the Nucleus


WELCOME

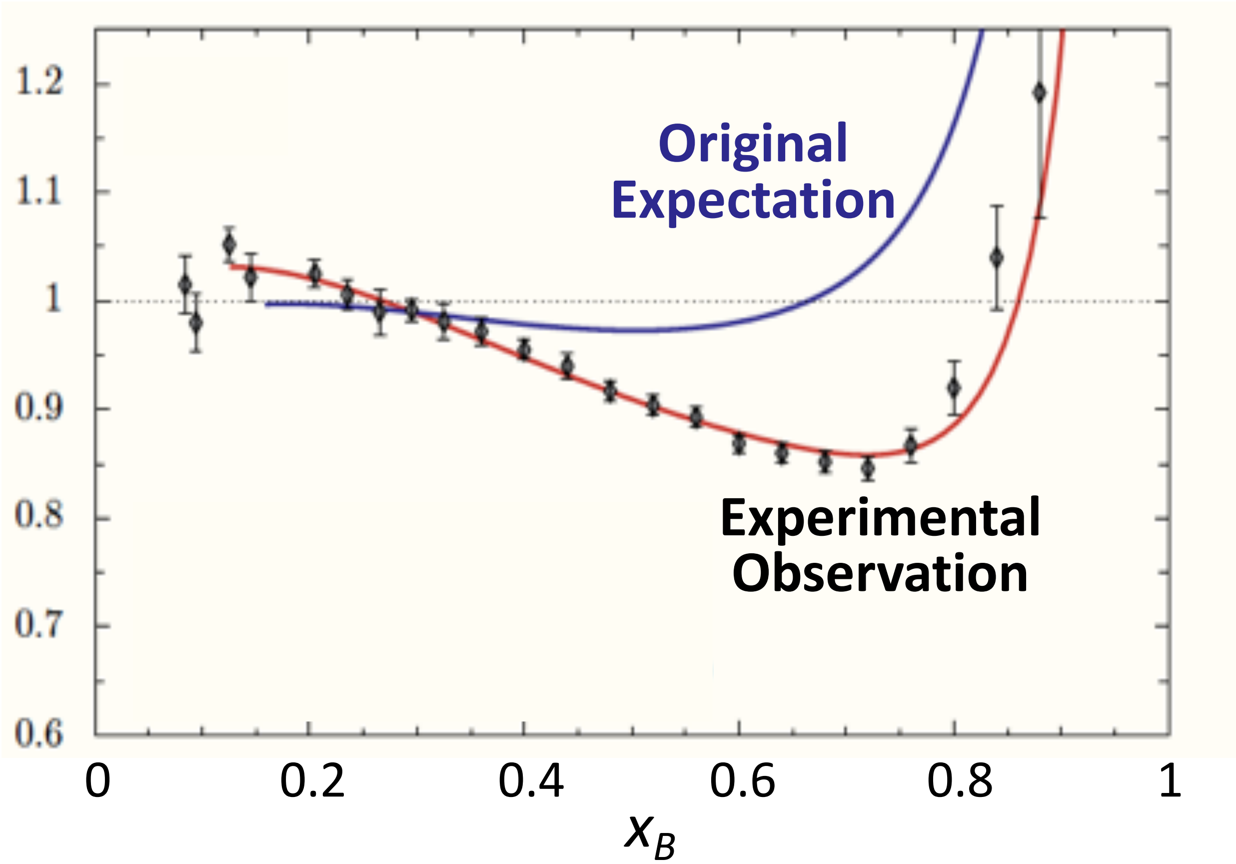
A Tale of *Scale Separation & Confinement*


Weak binding
External Field
Strong binding
WELCOME


Nuclear Field
(~8 MeV)
Proton
(~1 GeV)
d
u
u
WELCOME
Quark Piglets

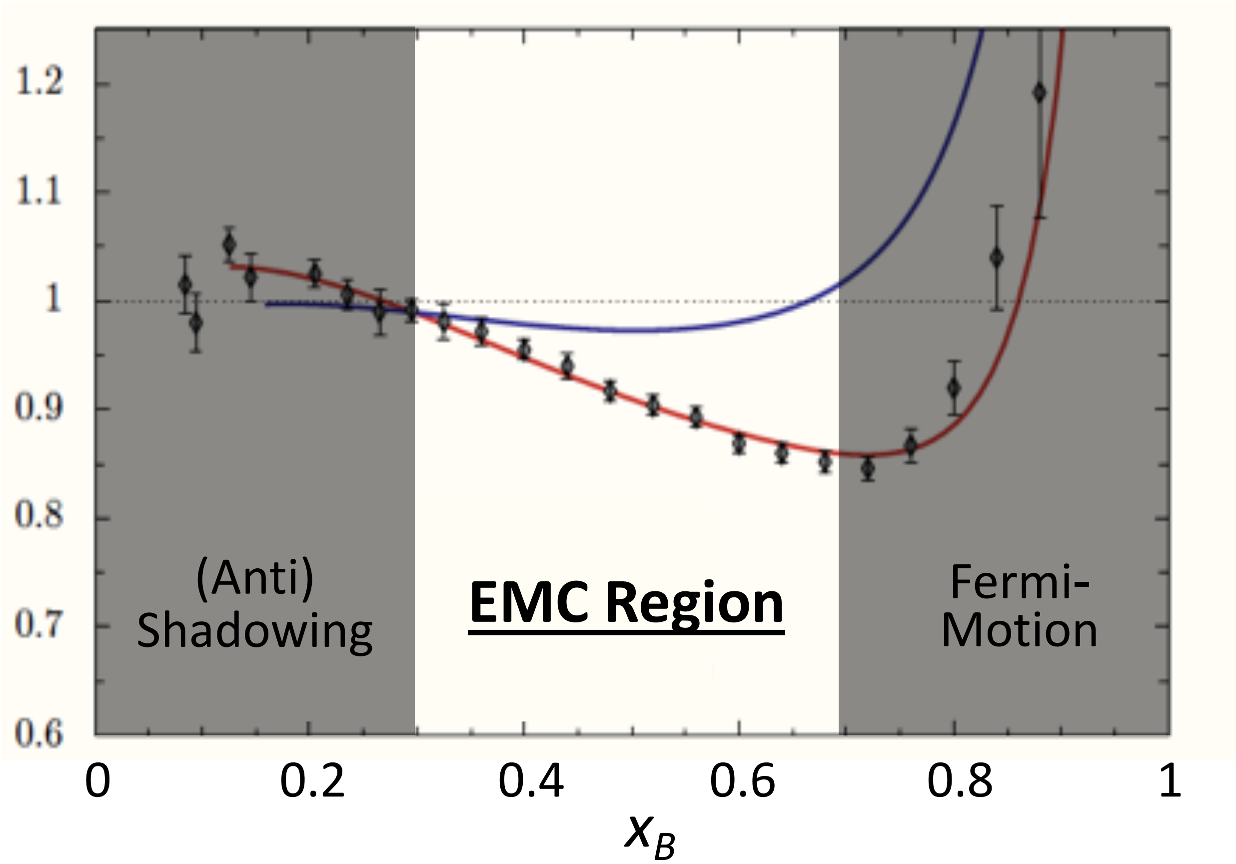
EMC Effect:

Iron / Deuterium Structure Function



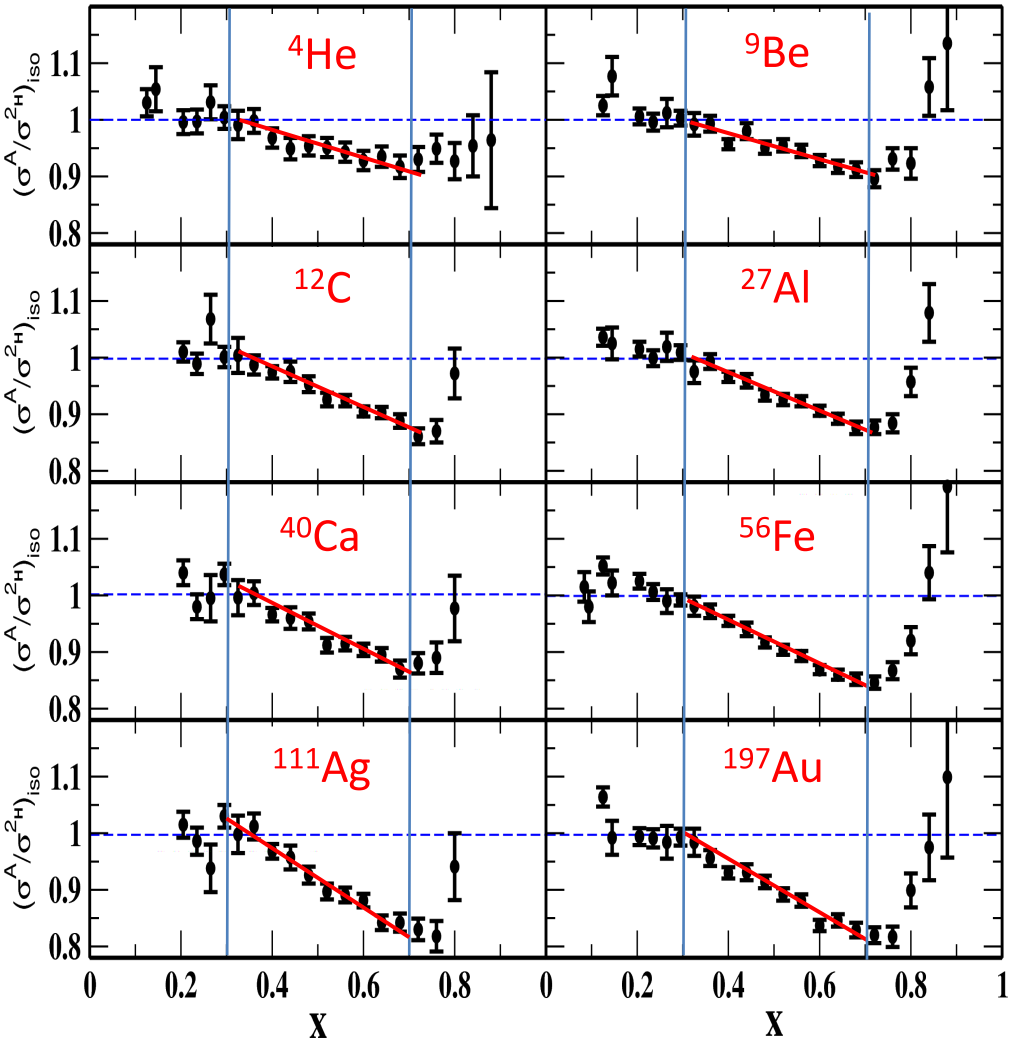
Aubert et al., PLB (**<u>1983</u>**); Ashman et al., PLB (1988); Arneodo et al., PLB (1988); Allasia et al., PLB (1990); Gomez et al., PRD (1994); Seely et al., PRL (2009); Schmookler et al., Nature (**<u>2019</u>**)

EMC Effect:



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)

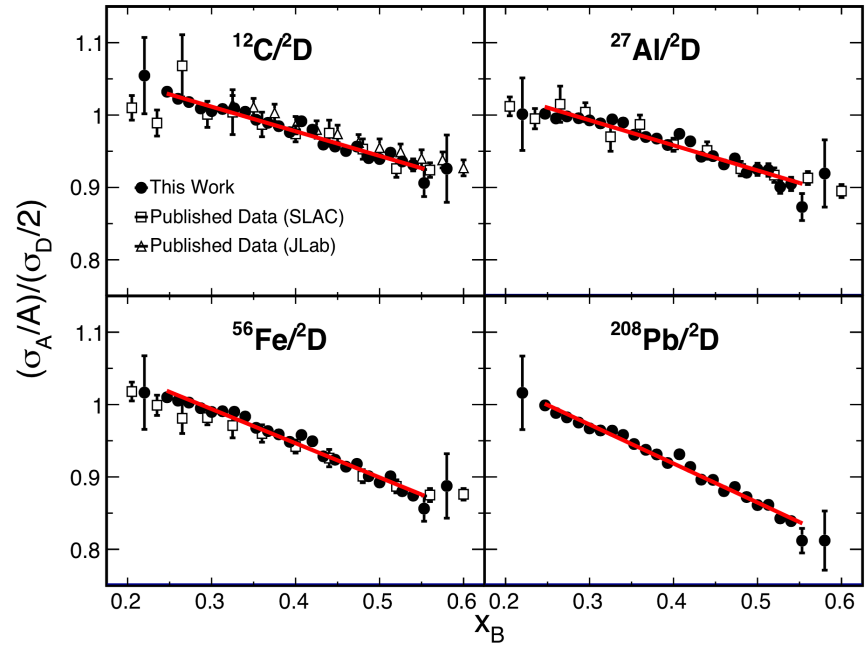
'Global' EMC Data



Gomez PRD (1994)

SLAC (1994)

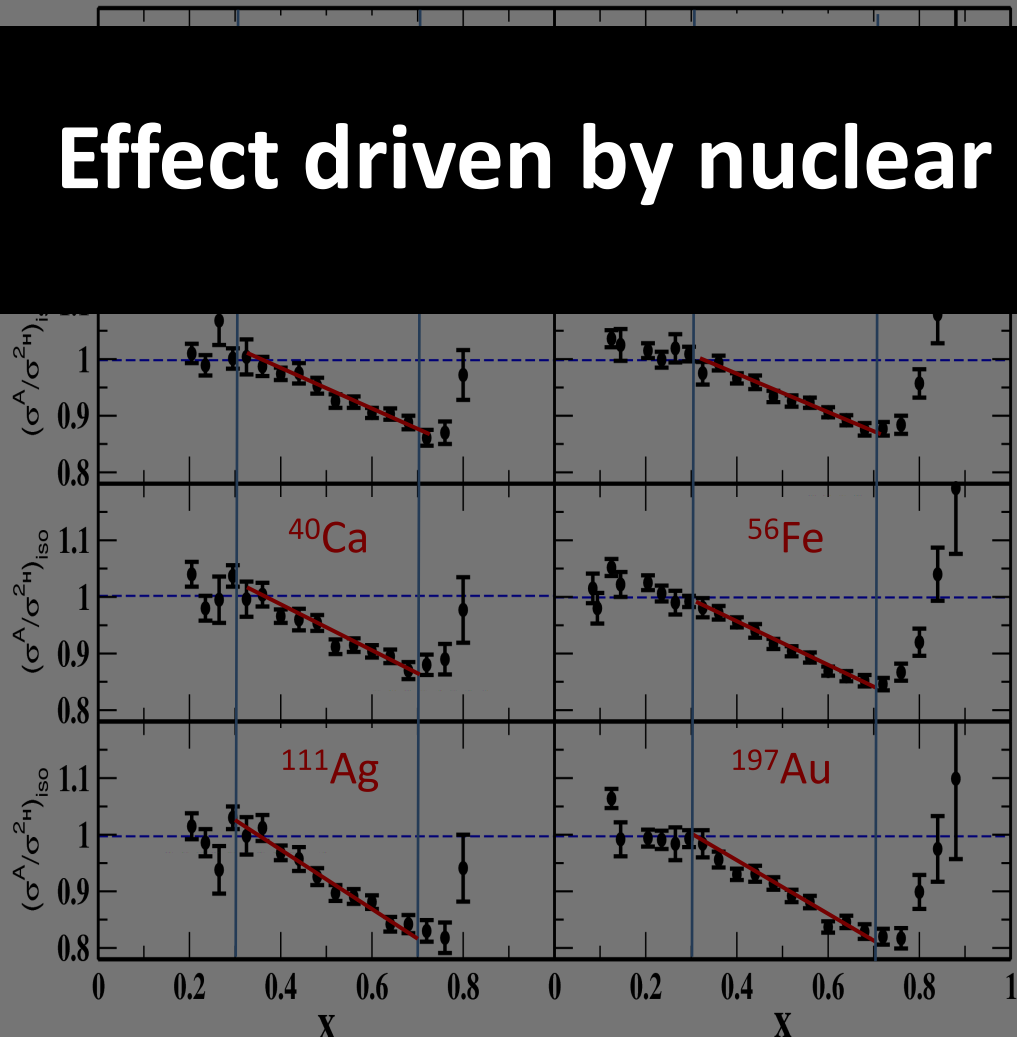
JLab (2019)



Schmookler,
Nature (2019)

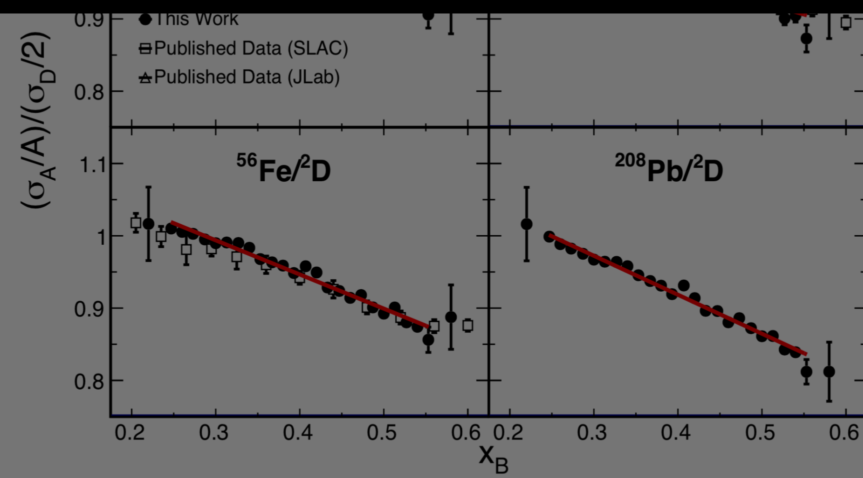
‘Global’ EMC Data

Effect driven by nuclear structure & dynamics



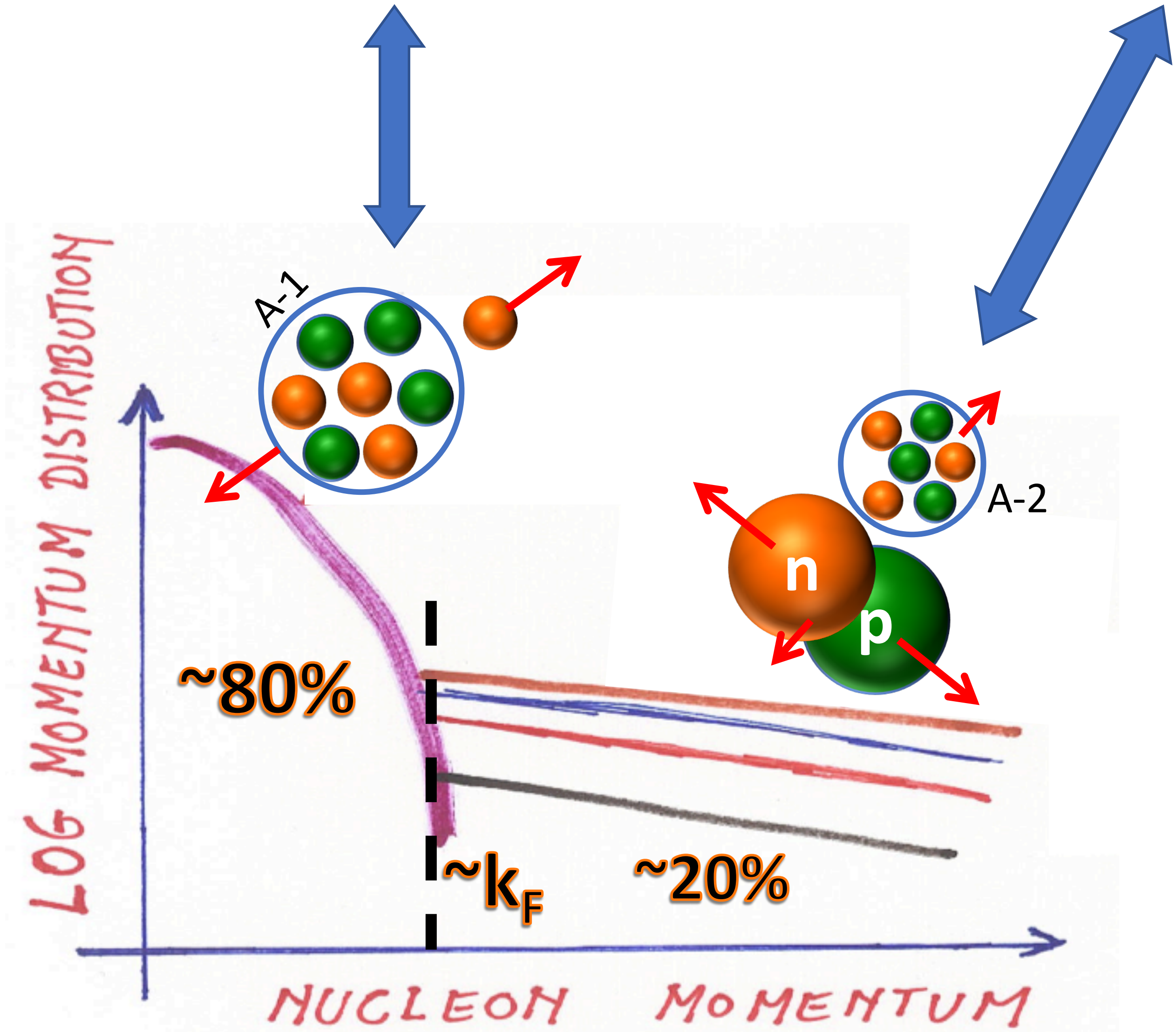
Gomez PRD (1994)

SLAC (1994)



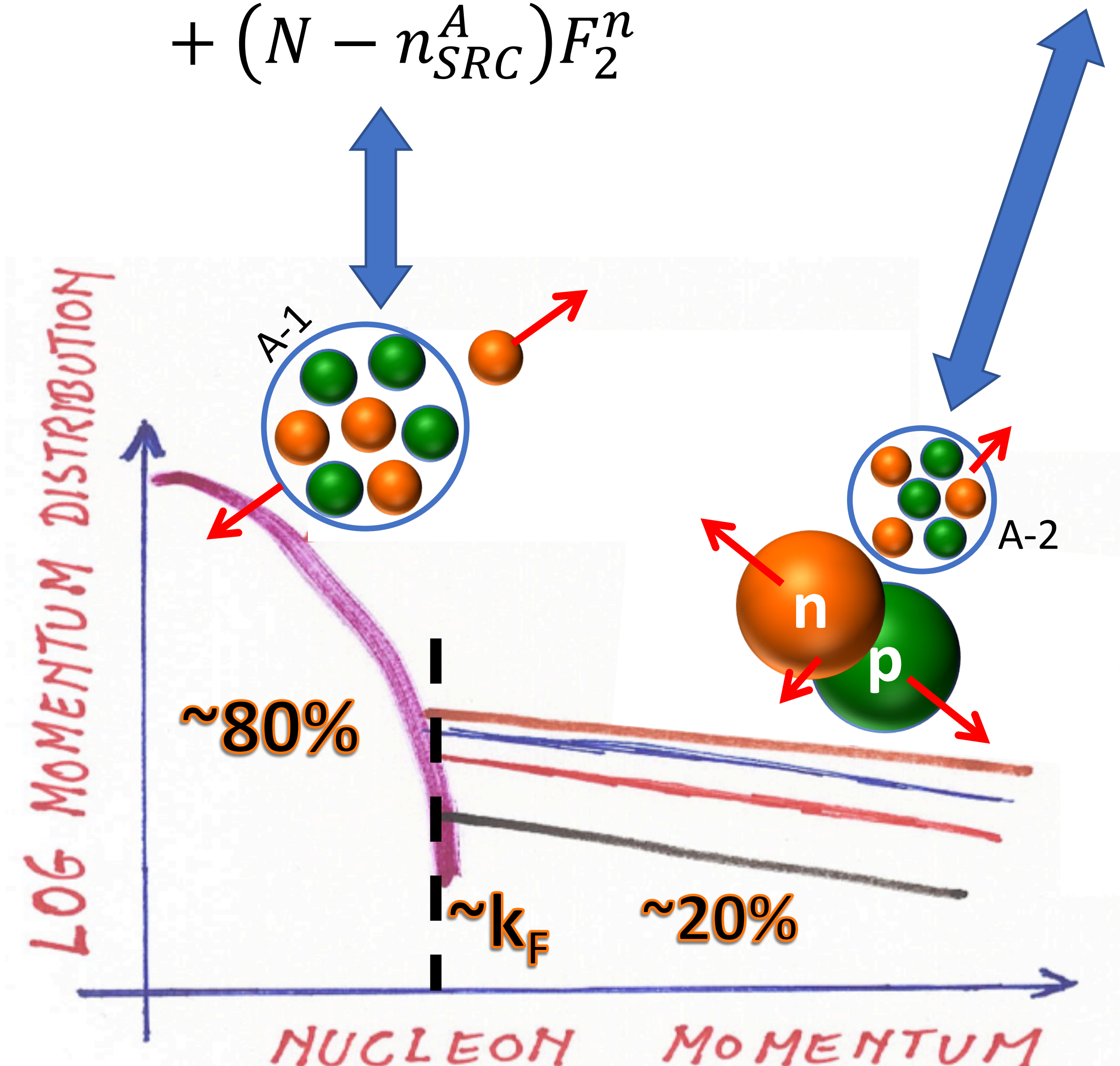
Schmookler, Nature (2019)

Bound = ‘quasi Free’ + Modified SRCs



Bound = 'quasi Free' + Modified SRCs

$$F_2^A = (Z - n_{SRC}^A)F_2^p + (N - n_{SRC}^A)F_2^n + n_{SRC}^A(F_2^{p*} + F_2^{n*})$$



Schmookler, Nature (2019)

Bound = 'quasi Free' + Modified SRCs

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

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

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

Schmookler, Nature (2019)

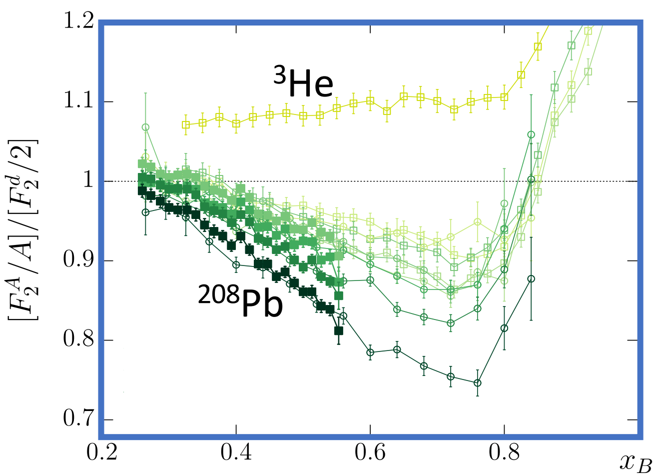
Bound = 'quasi Free' + Modified SRCs

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

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

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

✓ **EMC**



Schmookler, Nature (2019)

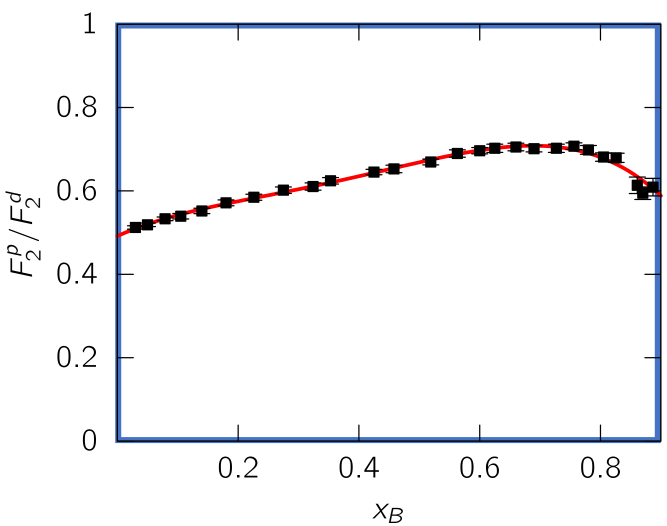
Bound = 'quasi Free' + Modified SRCs

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

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

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

✓ **EMC** ✓ **DIS**



Schmookler, Nature (2019)

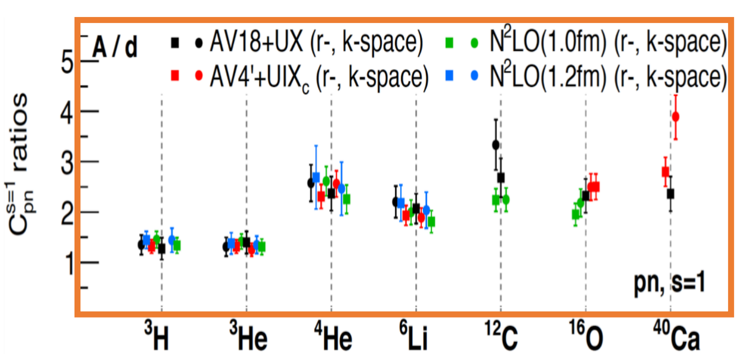
Bound = 'quasi Free' + Modified SRCs

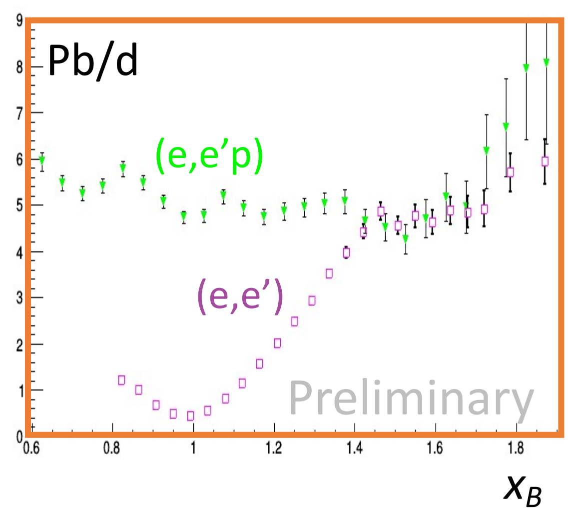
$$F_2^A = ZF_2^p + NF_2^n + n_{SRC}^A\left(\Delta F_2^p + \Delta F_2^n\right)$$

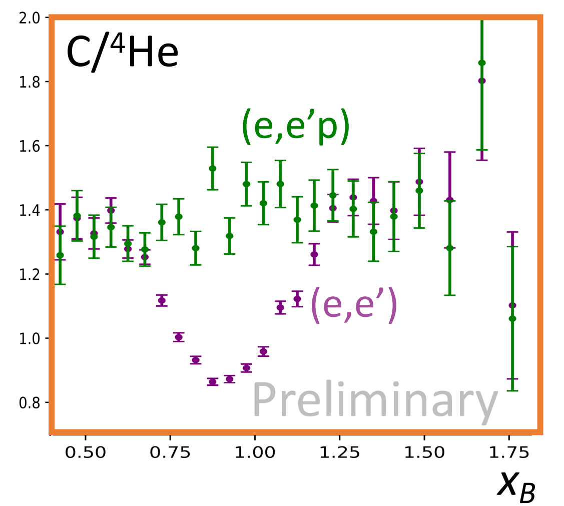
$$F_2^d = F_2^p + F_2^n + n_{SRC}^d\left(\Delta F_2^p + \Delta F_2^n\right)$$

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

✓ EMC ✓ DIS ✓ QE / Ab-Initio







Schmookler, Nature (2019)

Bound = 'quasi Free' + Modified SRCs

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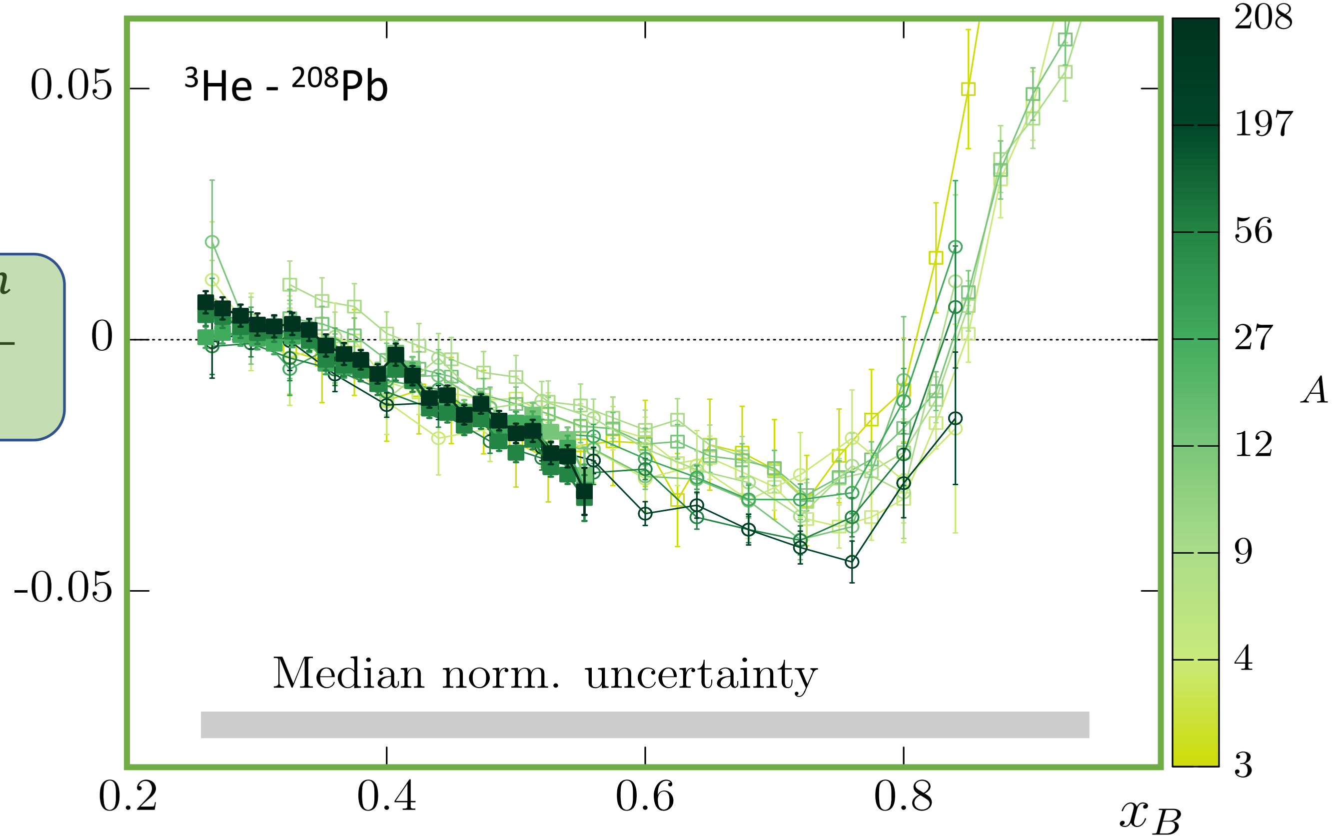
✓ EMC ✓ DIS ✓ QE / Ab-Initio <u>Universal?</u>

Schmookler, Nature (2019)

SRC Universality!

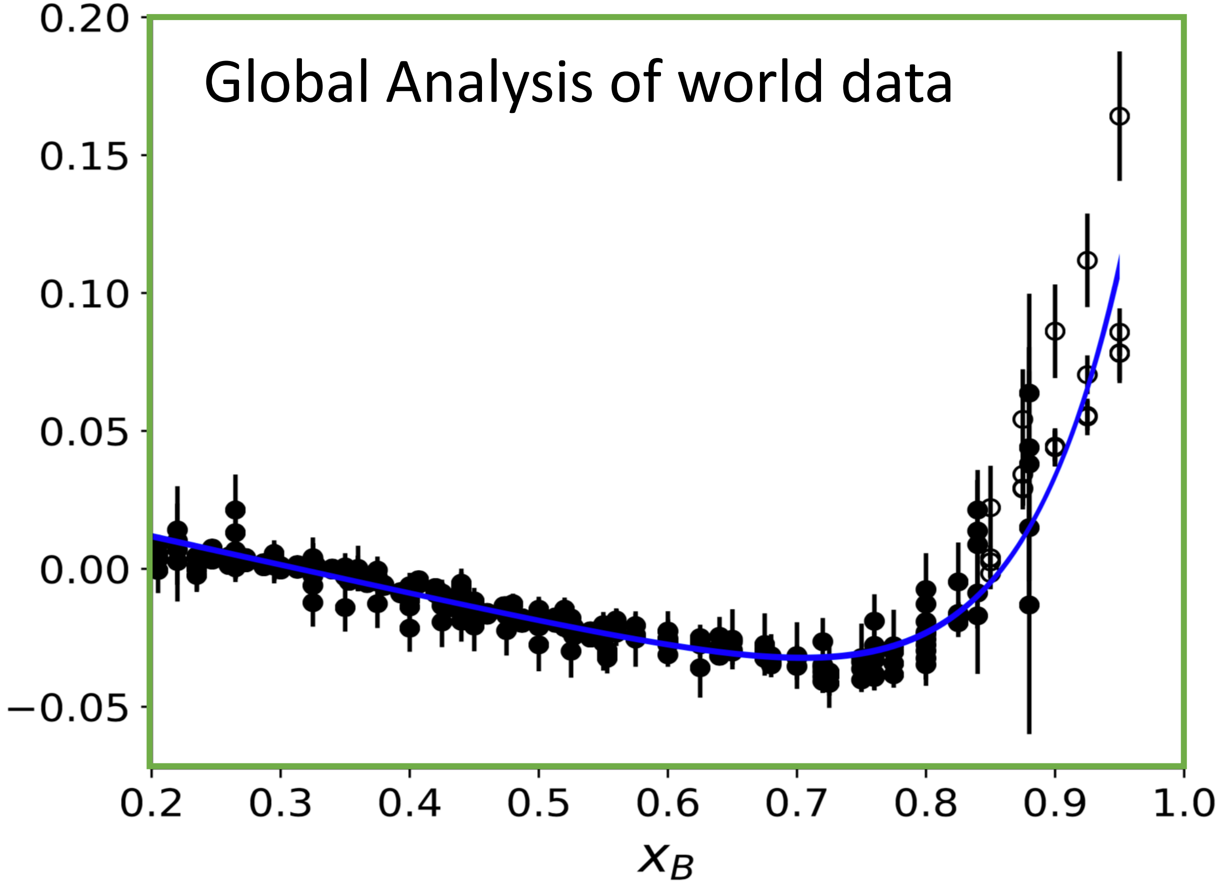
$$n_{SRC}^{d}\,\frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}$$



Schmookler, Nature (2019)

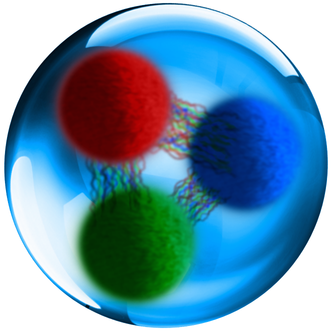
SRC Universality!

$$n_{SRC}^{d} \frac{\Delta F_2^p + \Delta F_2^n}{F_2^d}$$

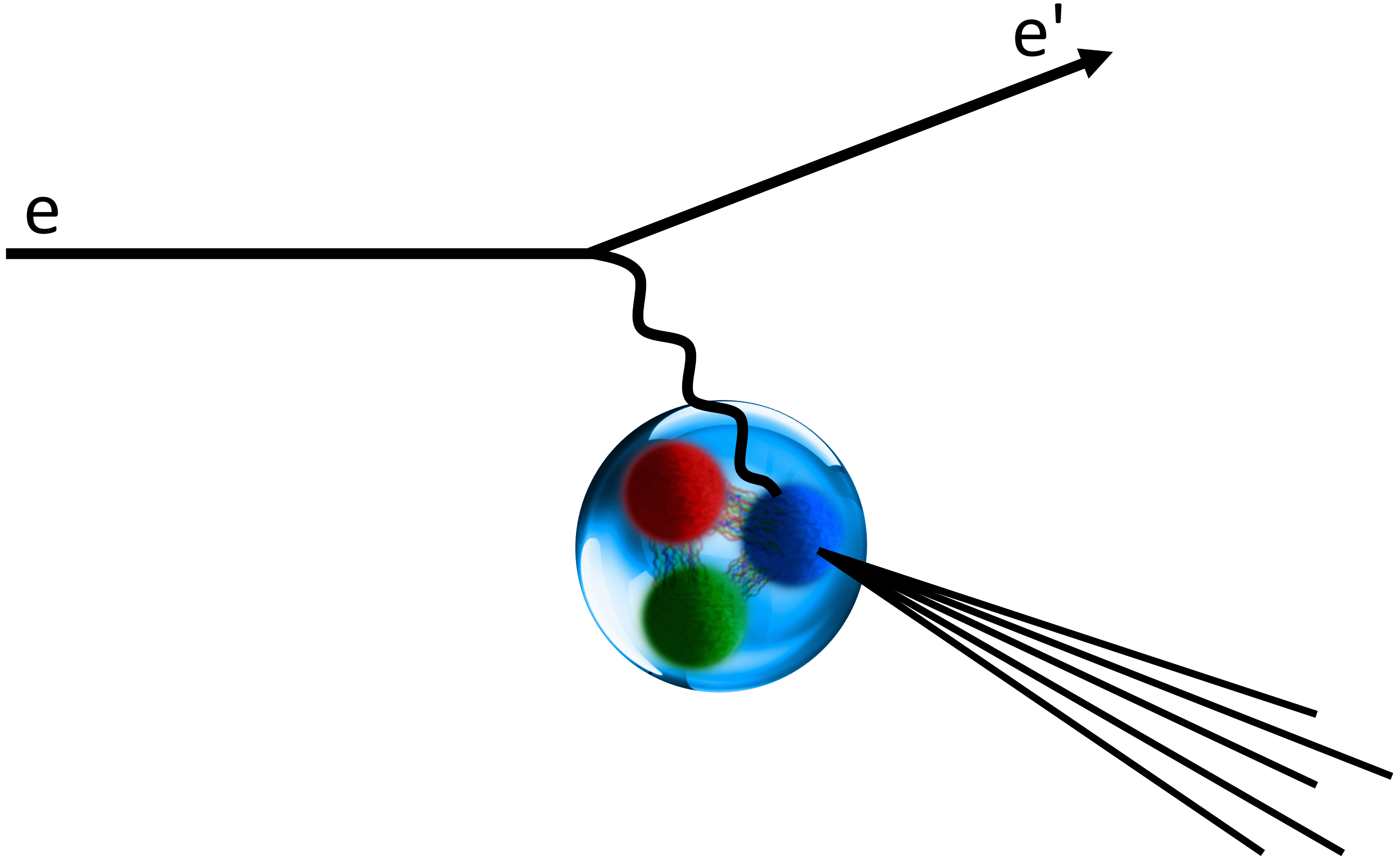


E.P. Segarra et al., arXiv: 1908.02223 (2019)

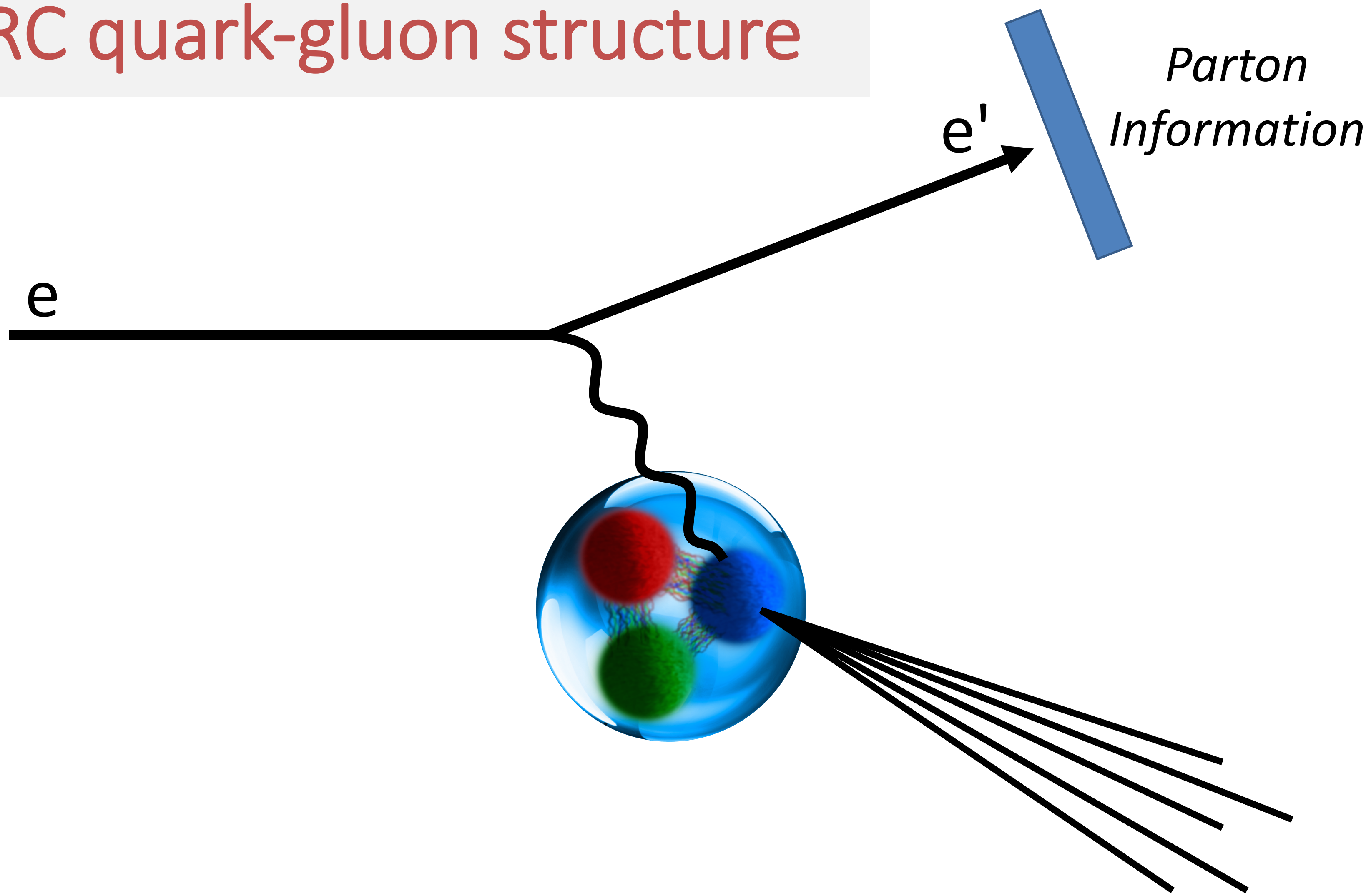
SRC quark-gluon structure



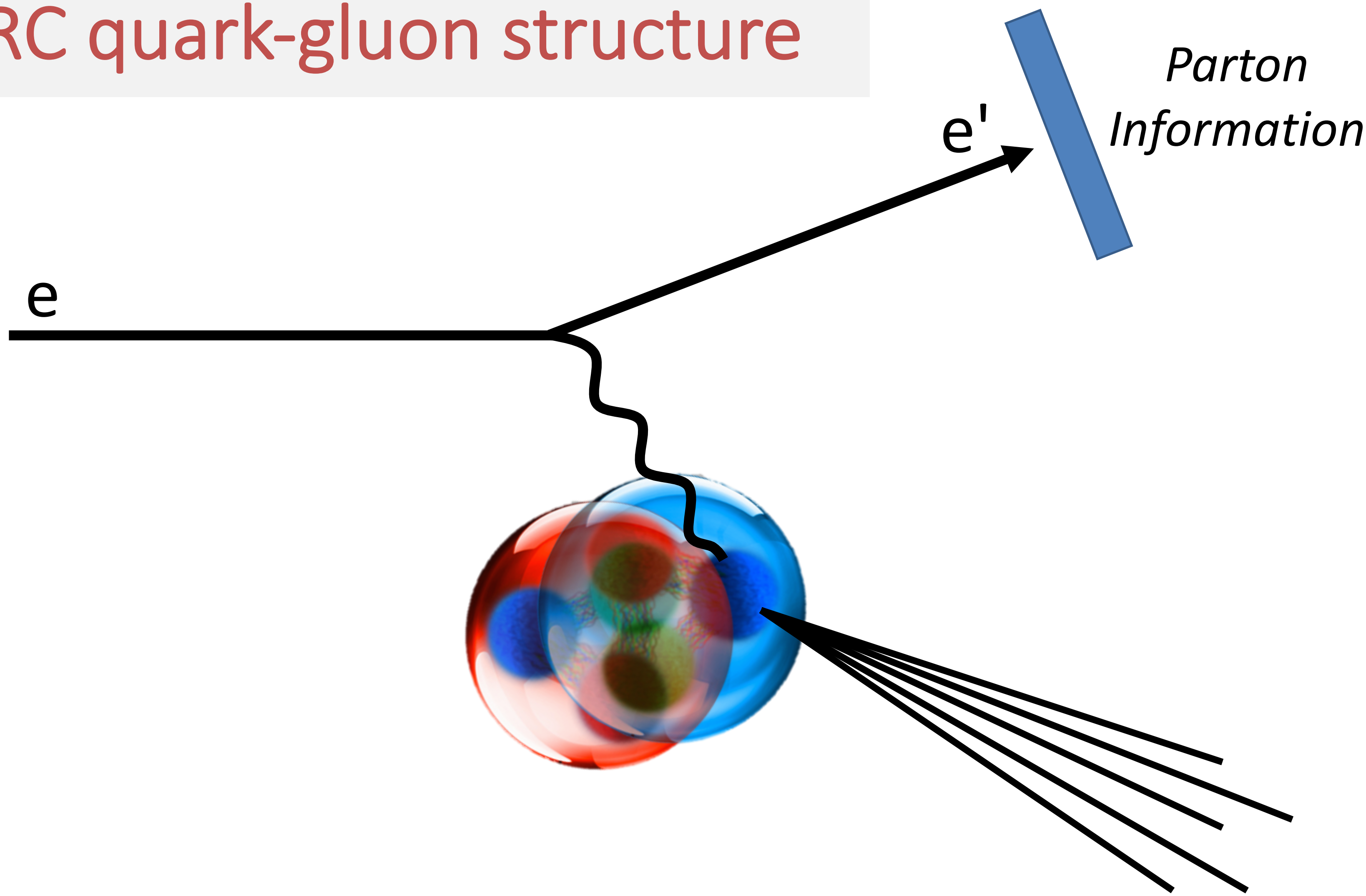
SRC quark-gluon structure



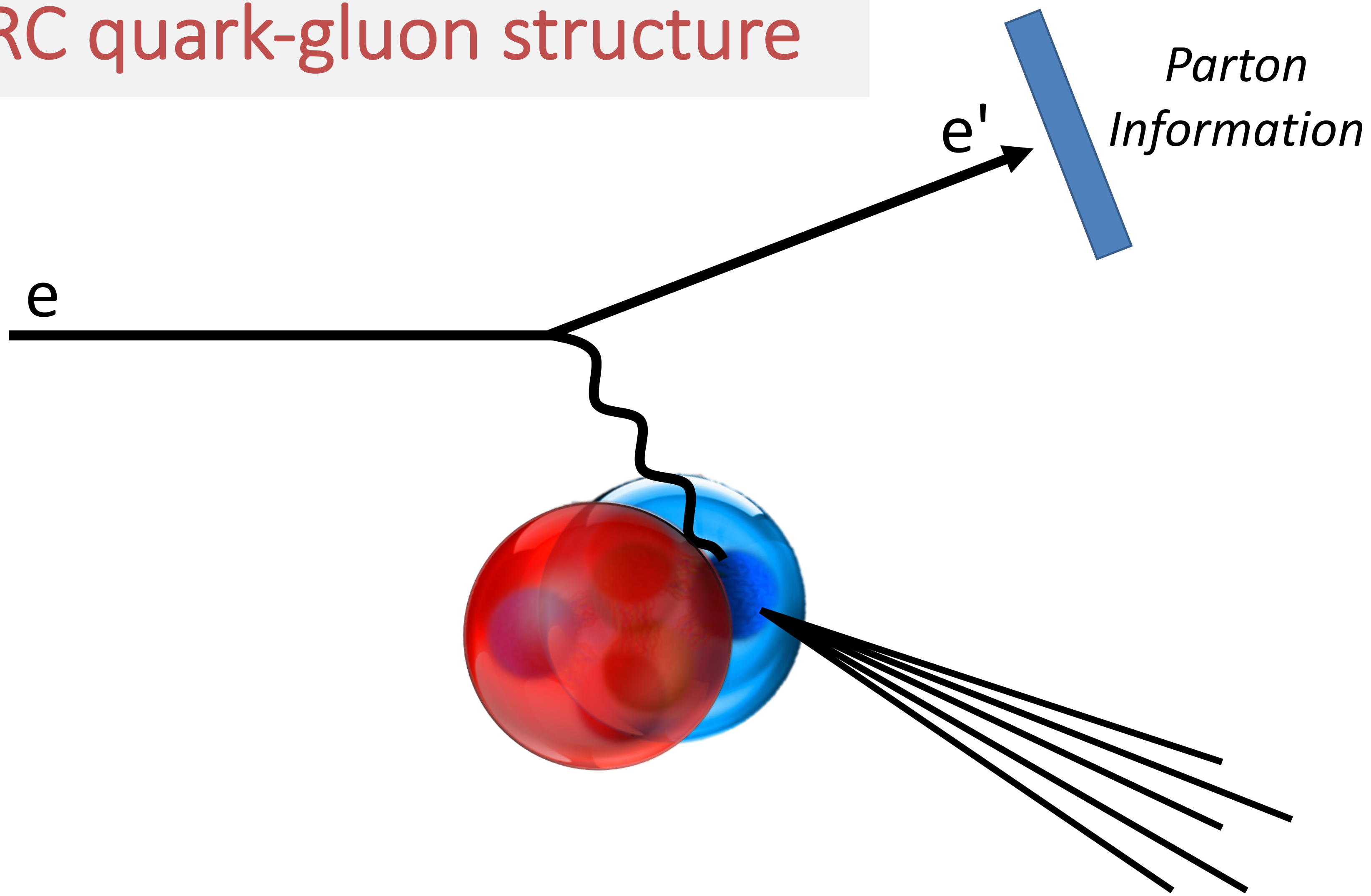
SRC quark-gluon structure



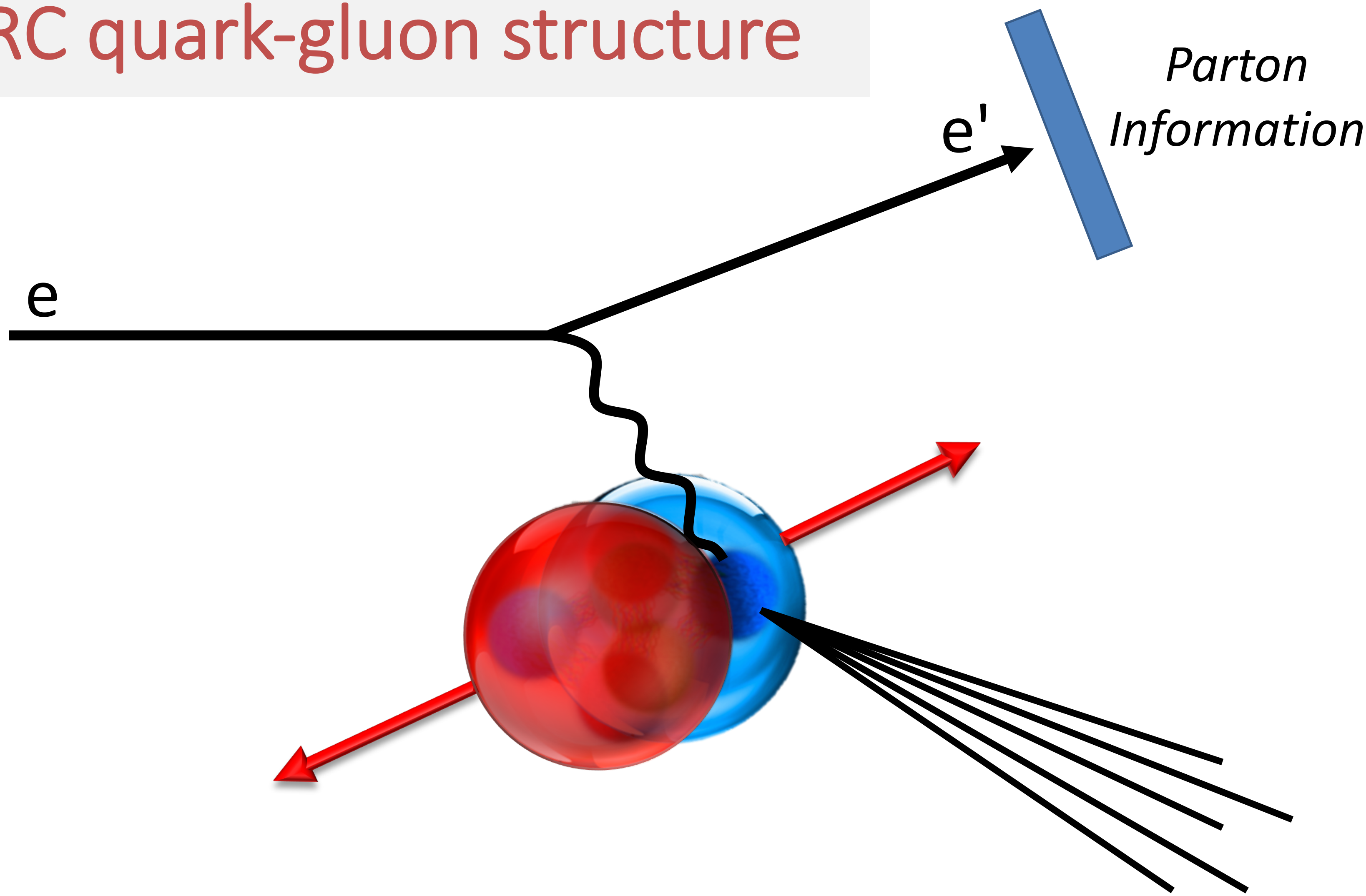
SRC quark-gluon structure



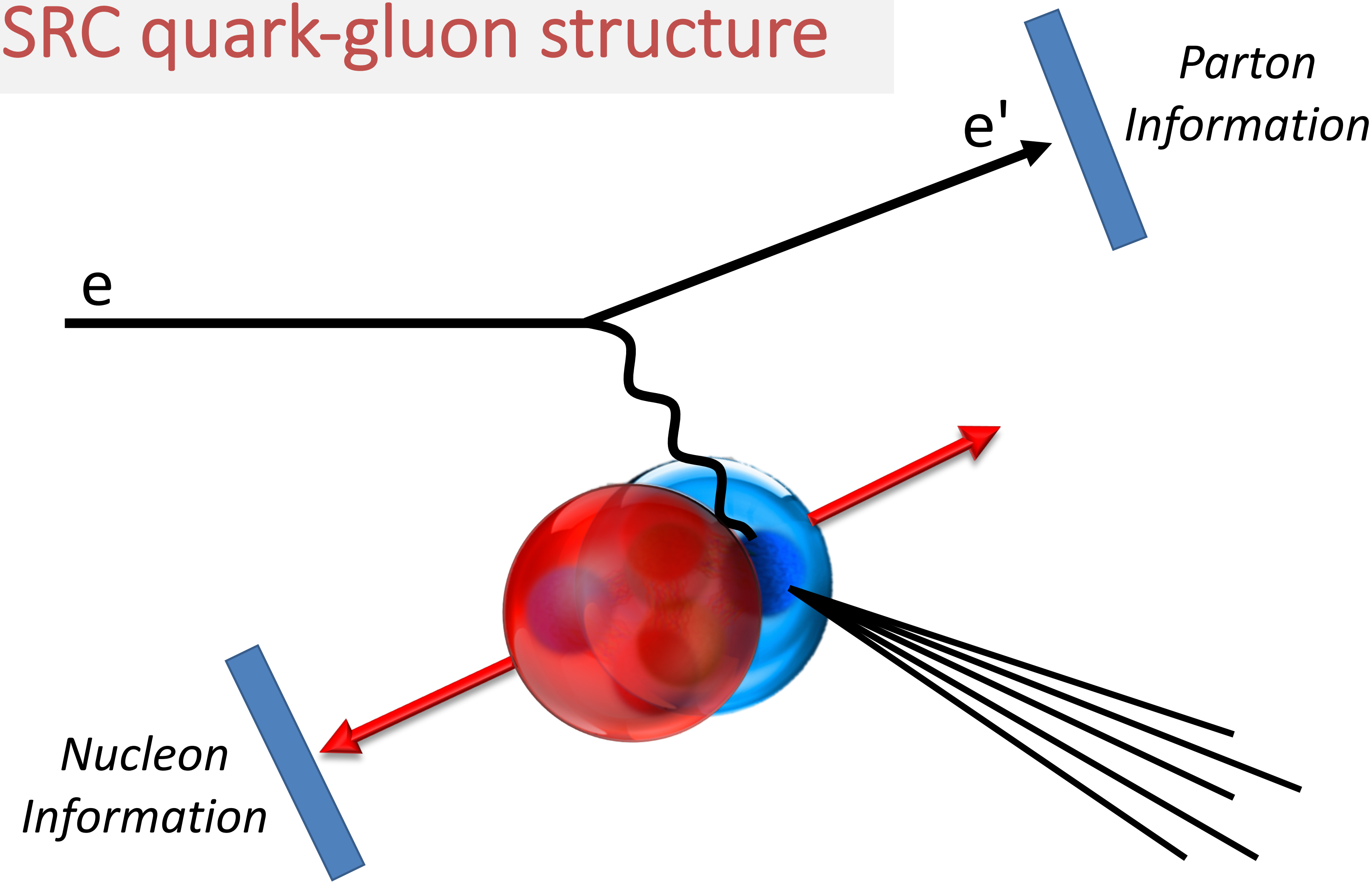
SRC quark-gluon structure



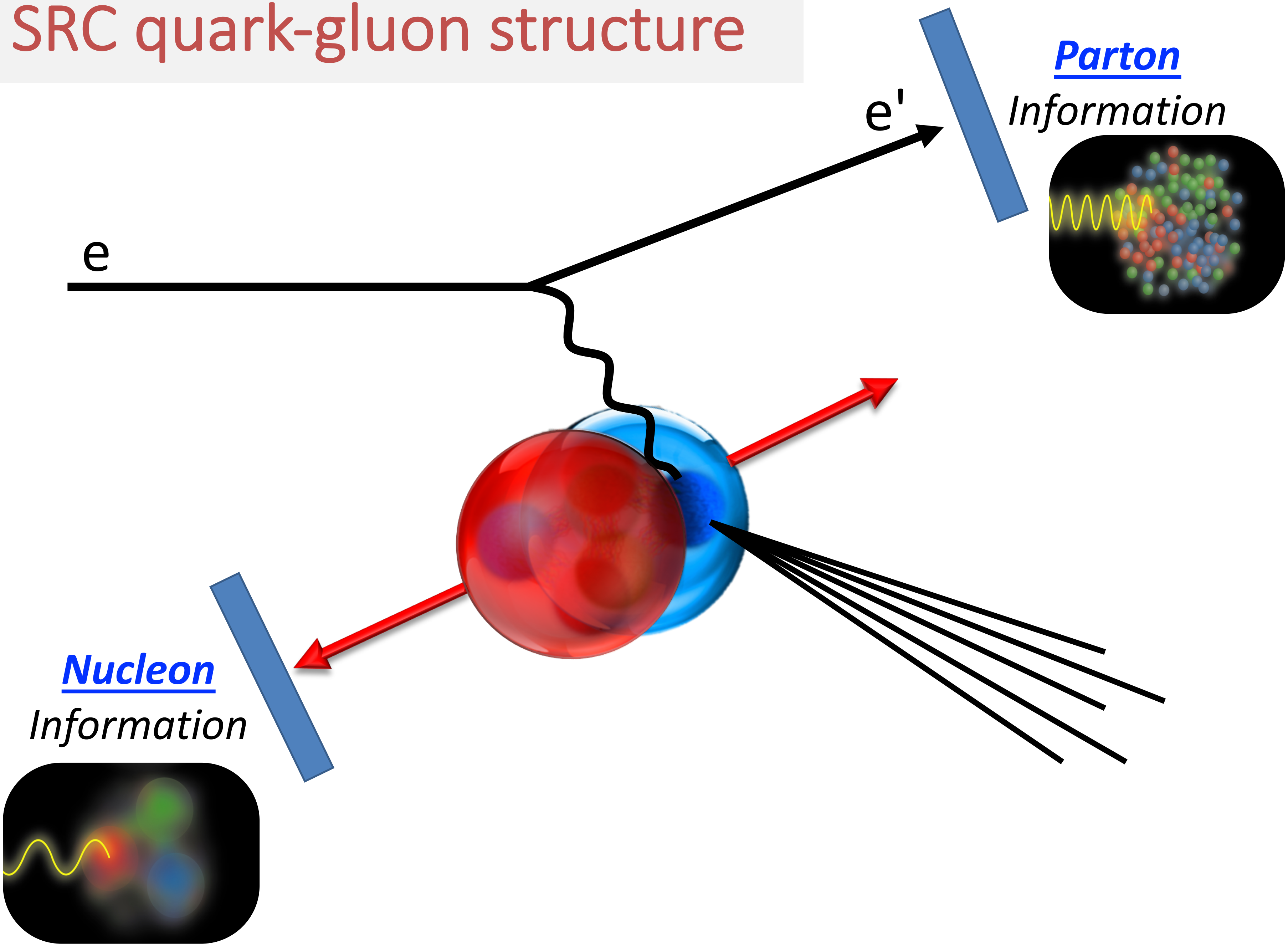
SRC quark-gluon structure



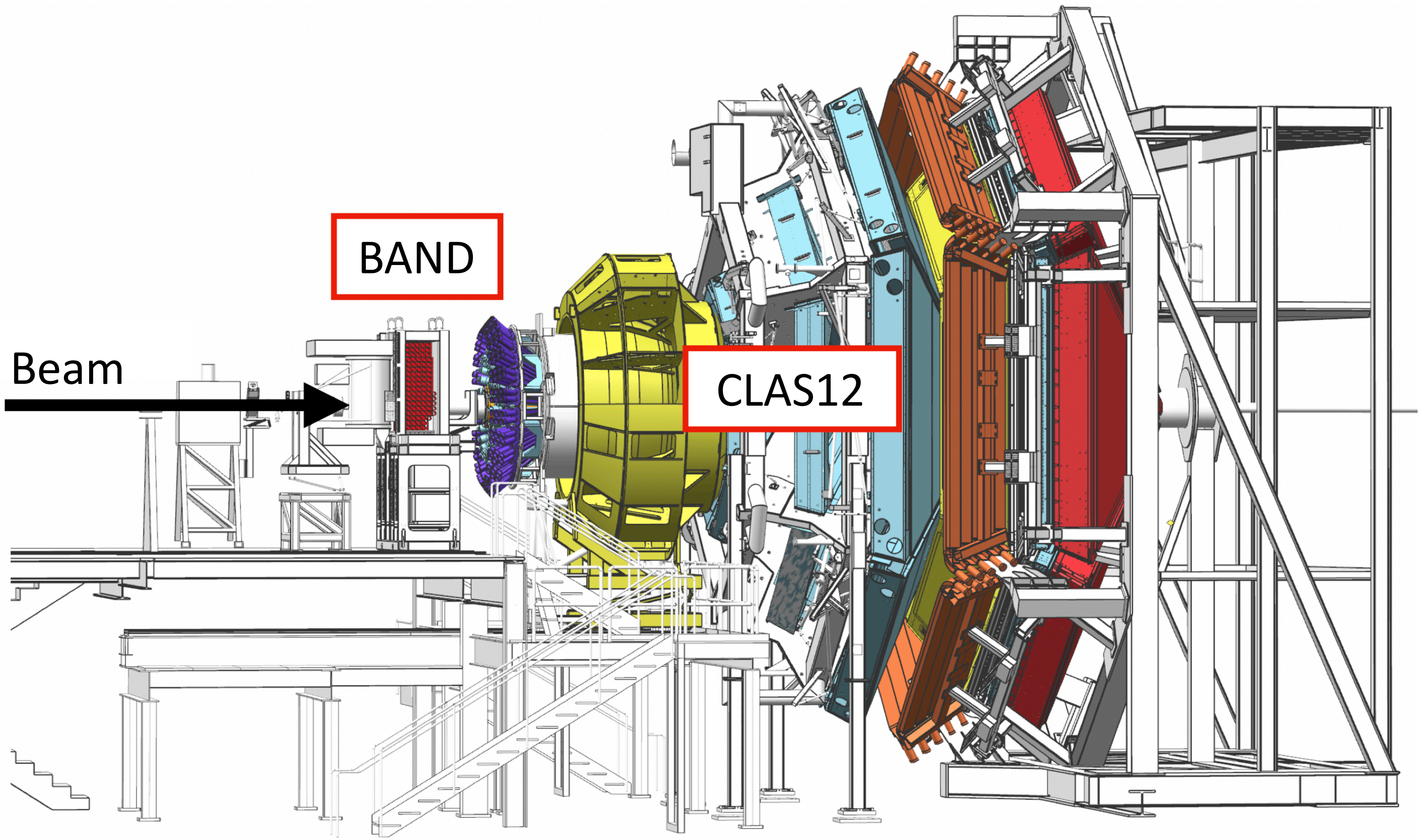
SRC quark-gluon structure



SRC quark-gluon structure

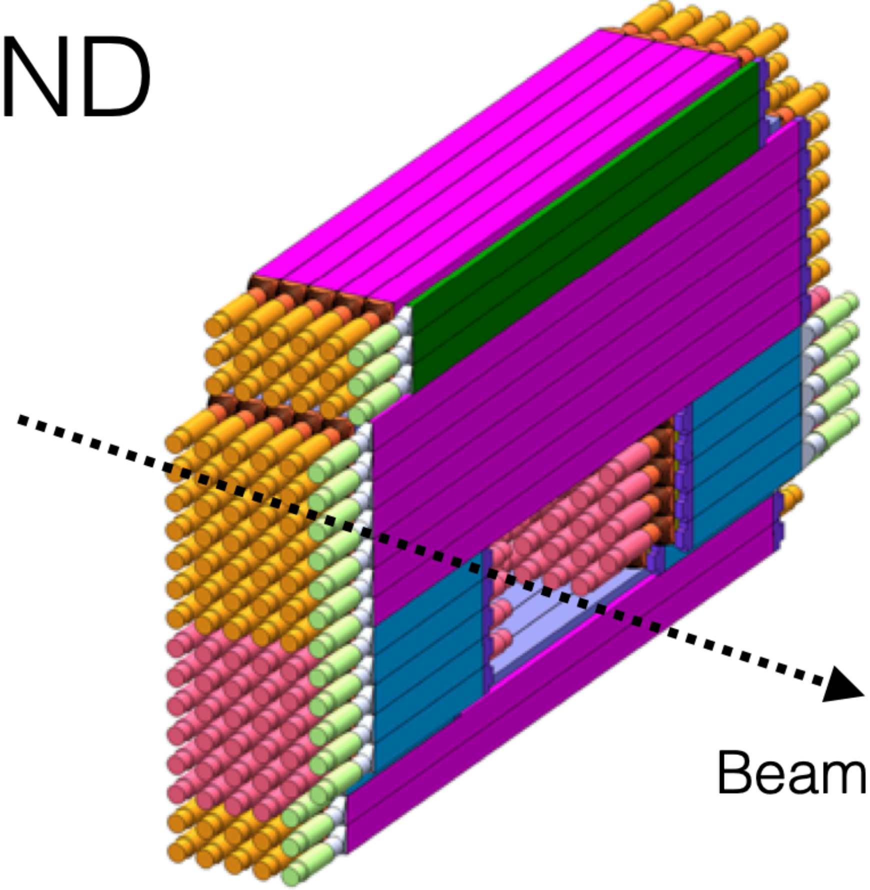


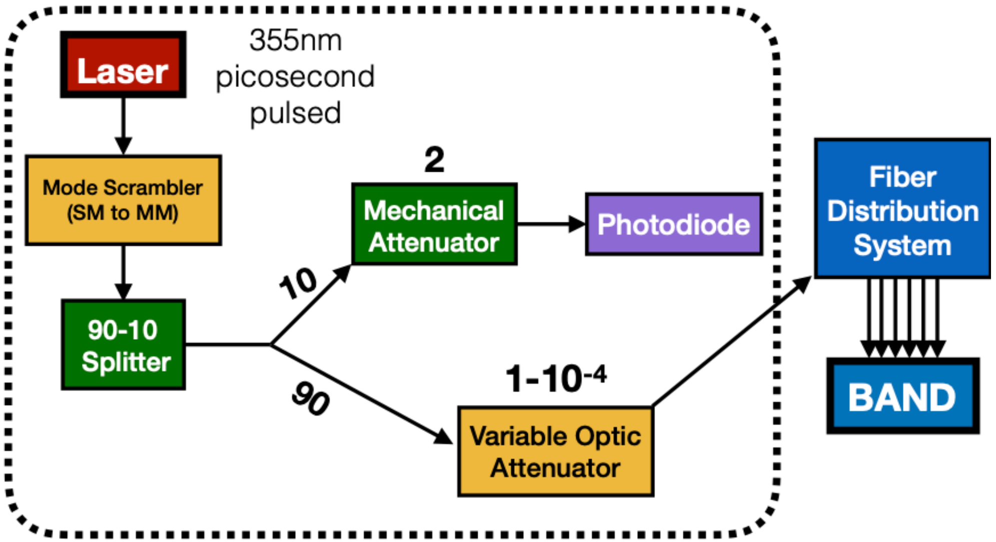
CLAS12 + BAND



BAND

- 140 scintillator bars
- 5 layers thick (36cm total) with veto layer (2cm thick)
- ToF resolutions < 250 ps
- 3 meters upstream of target, coverage in θ ~ 155-176°
- Design neutron efficiency ~35% and momentum resolution ~1.5%
- Laser system for calibrations





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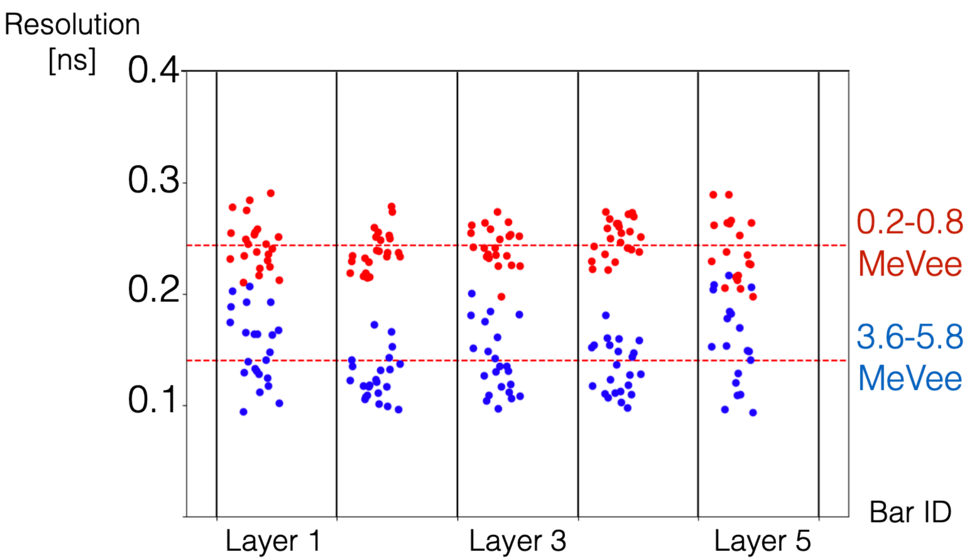
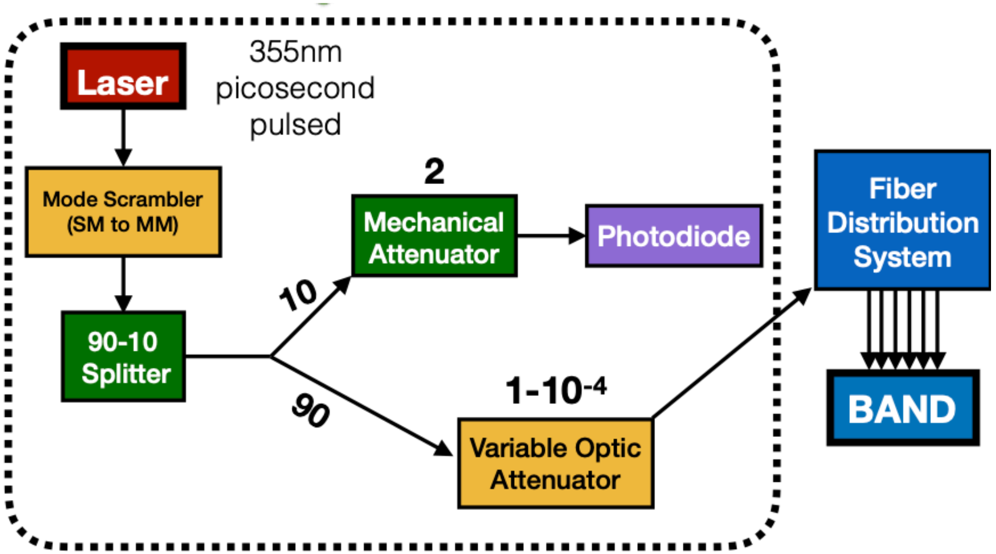
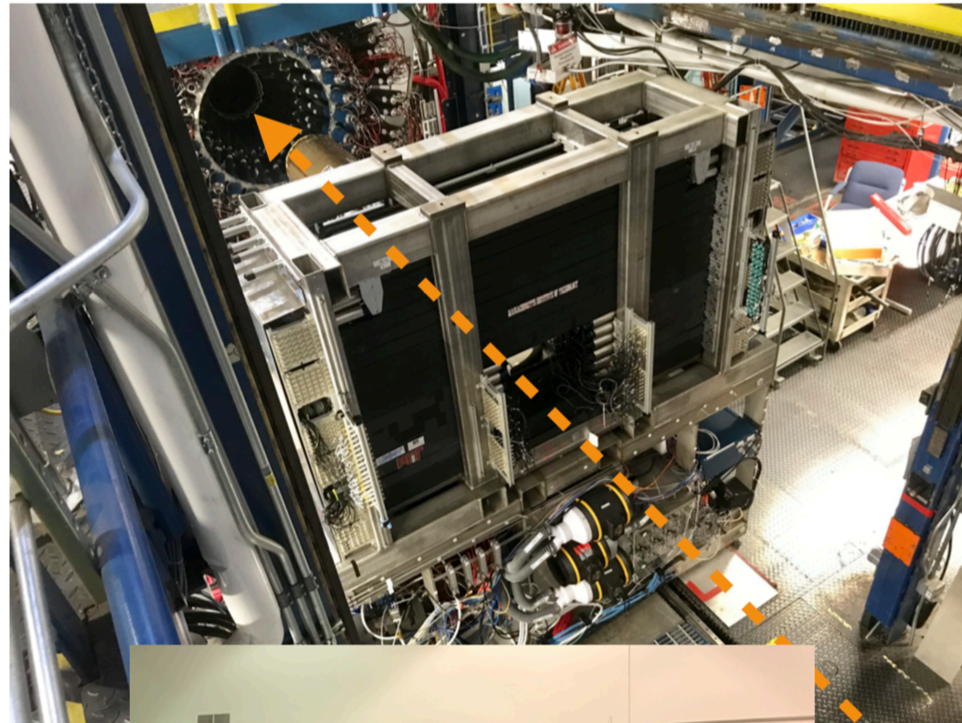
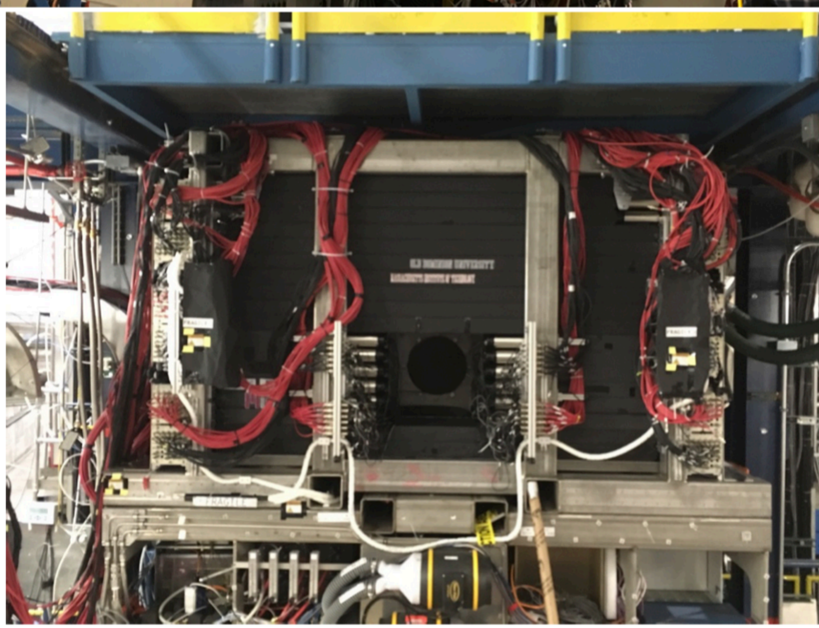


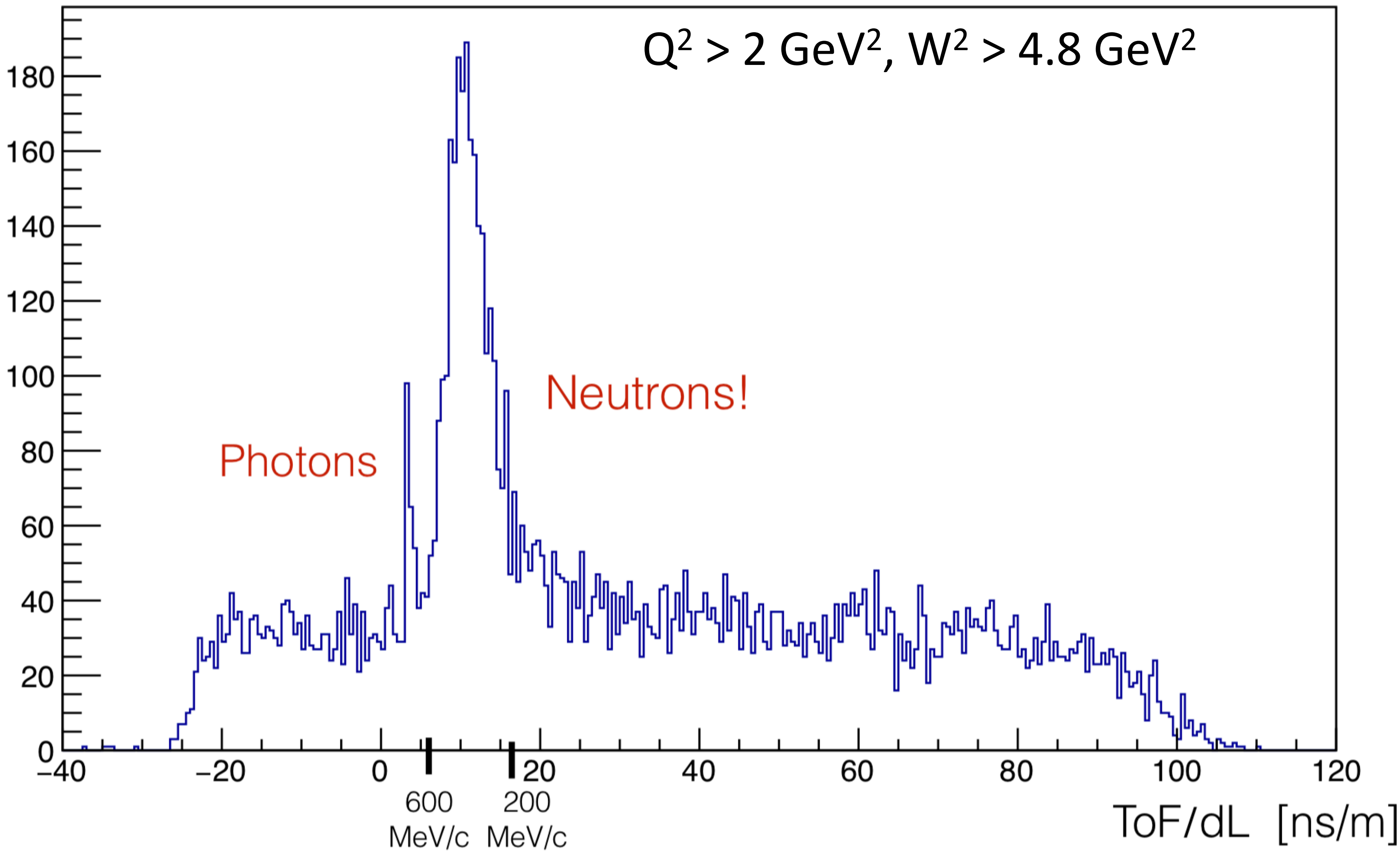


BAND @ JLab Hall B

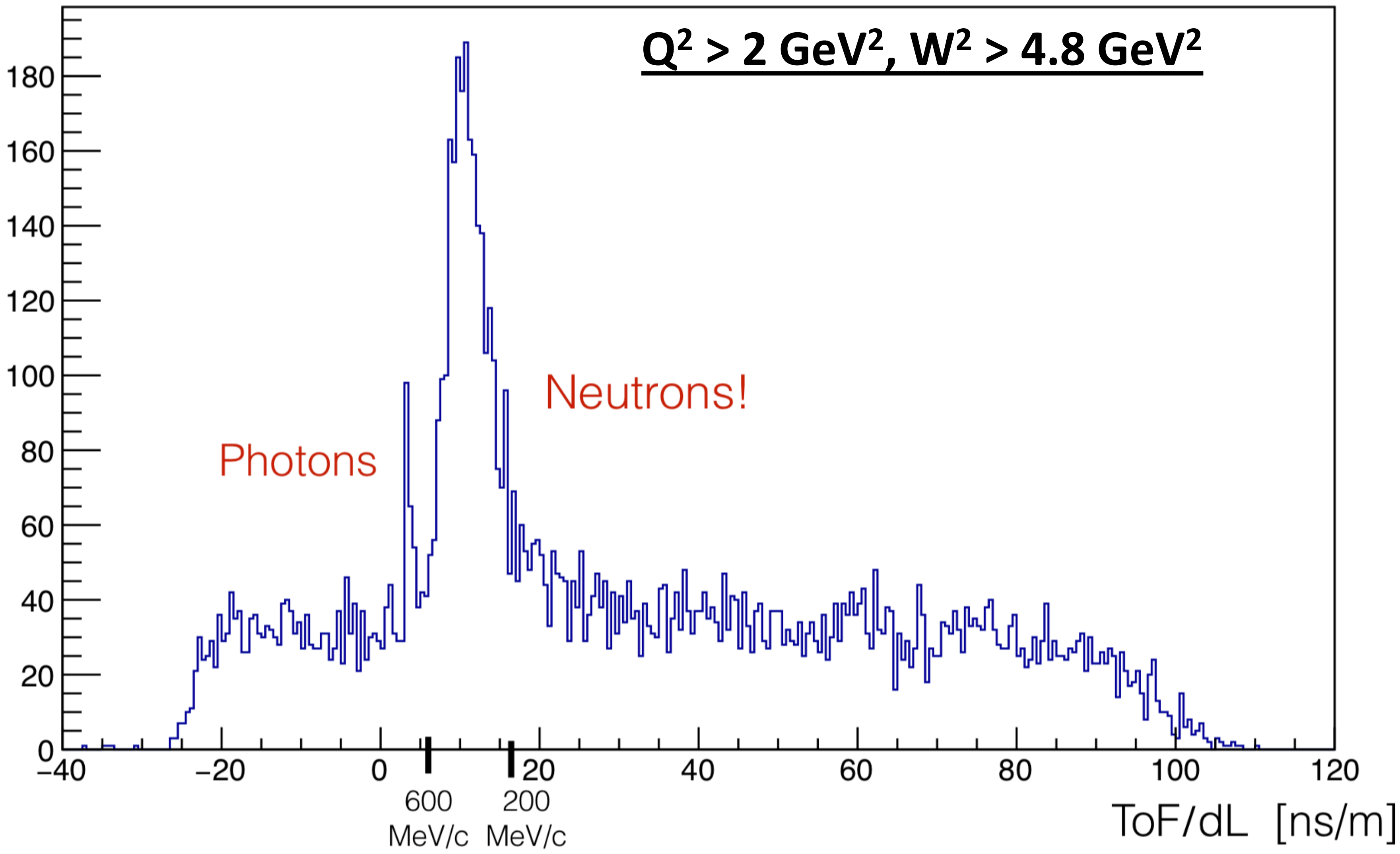


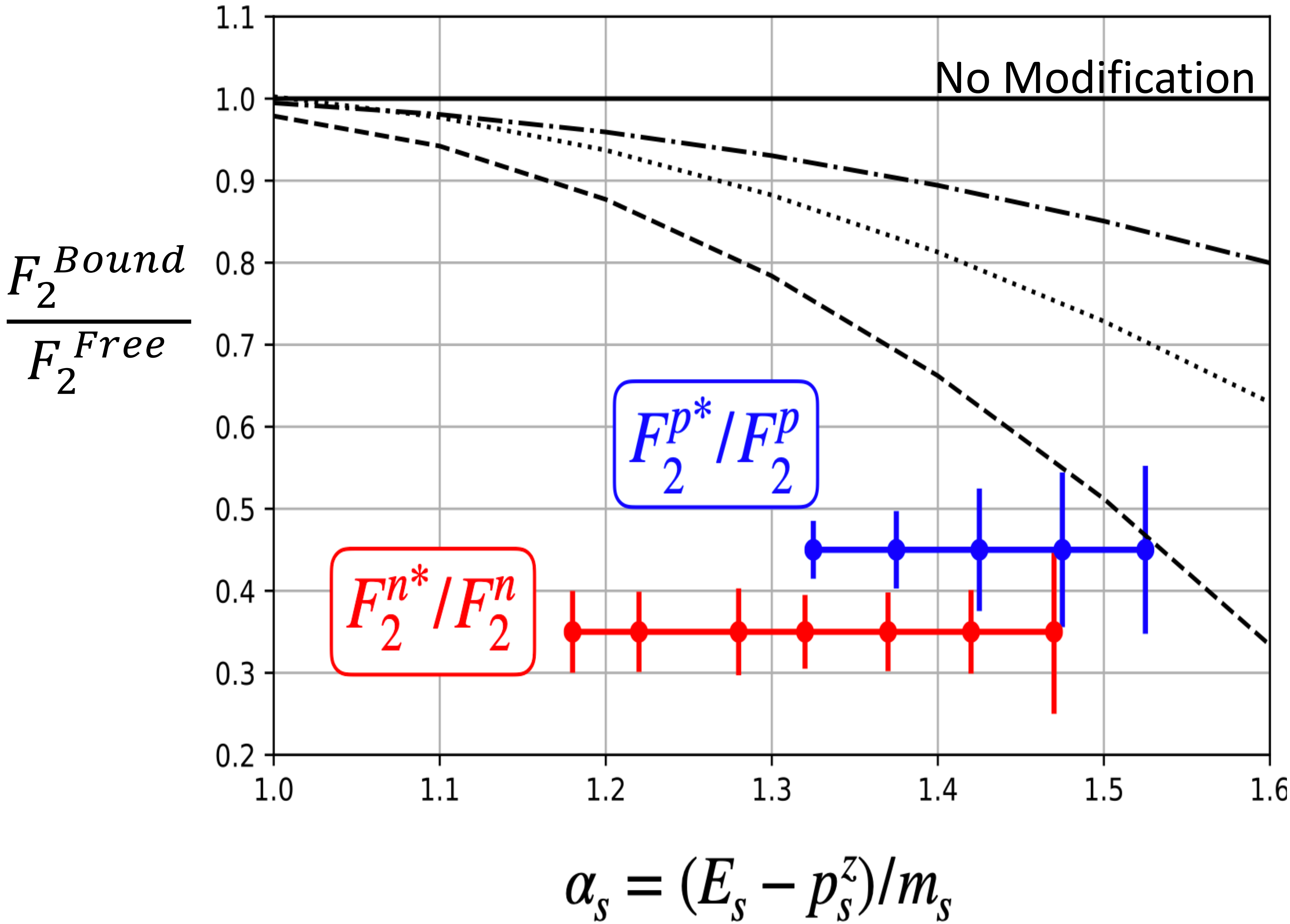


CLAS12+BAND: DIS \w Tagged Neutrons!!



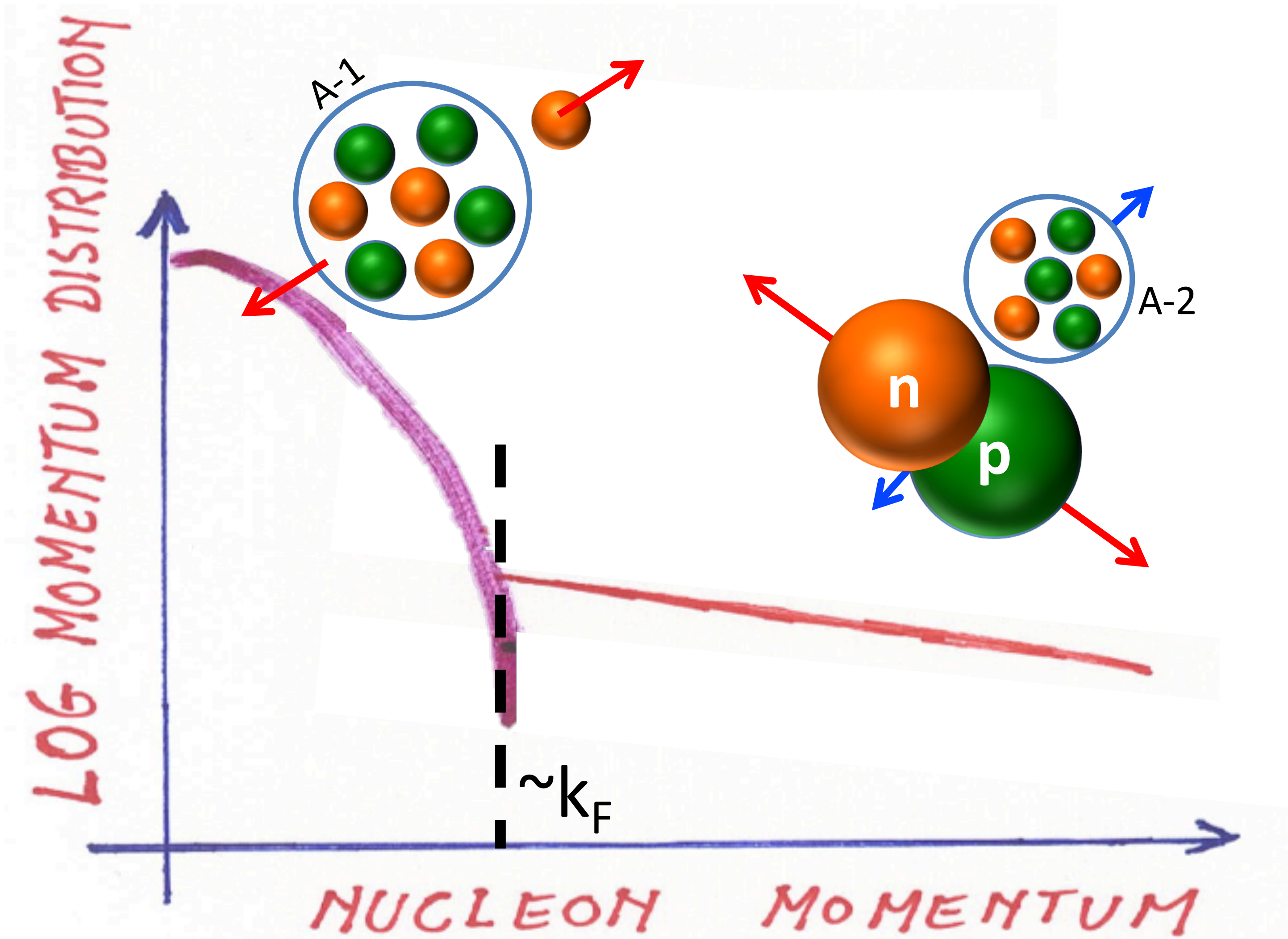
CLAS12+BAND: DIS \w Tagged Neutrons!!



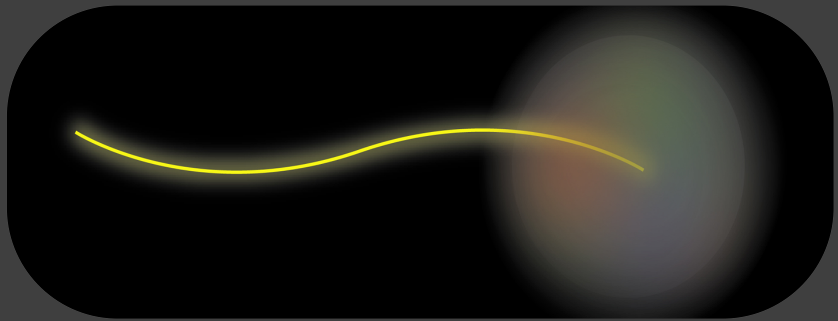


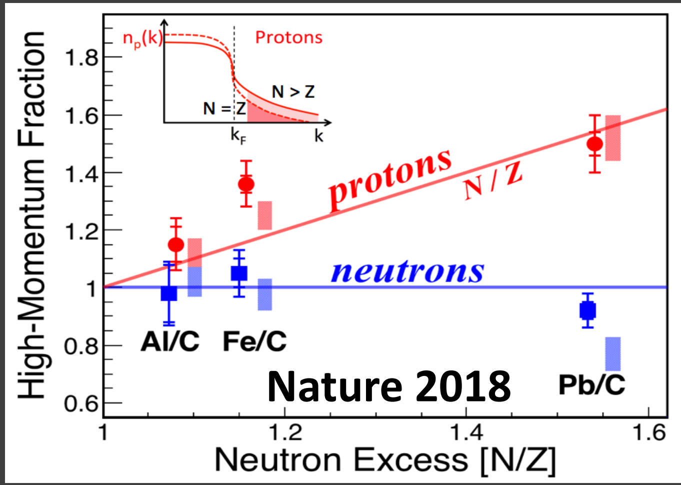
No Modification
F_2^{Bound} / F_2^{Free}
F_2^{p*}/F_2^{p}
F_2^{n*}/F_2^{n}
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1.0
1.1
1.2
1.3
1.4
1.5
1.6
$\alpha_s = (E_s - p_s^z)/m_s$

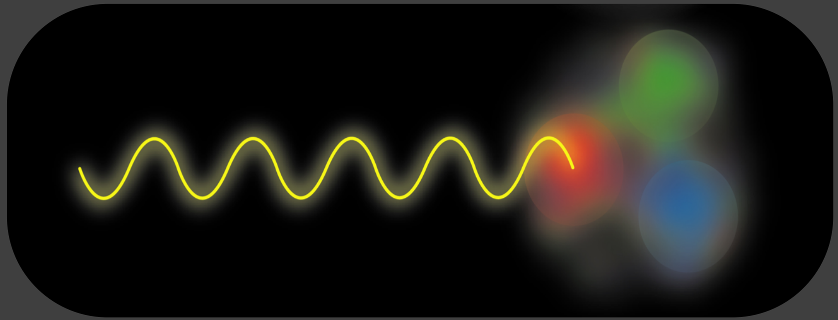
(1) Atomic nuclei have 2 'phases'

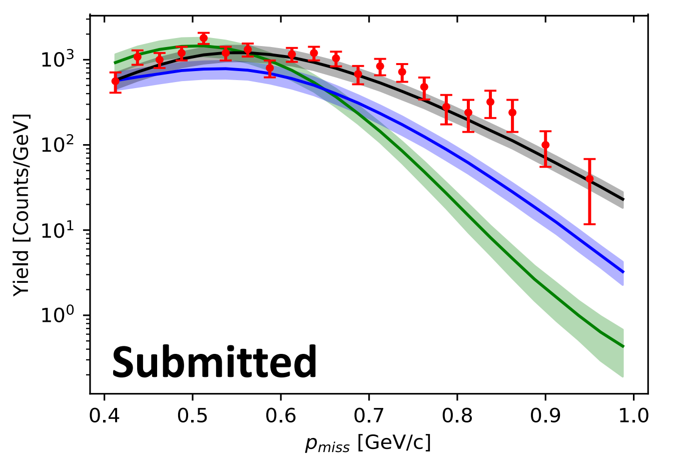


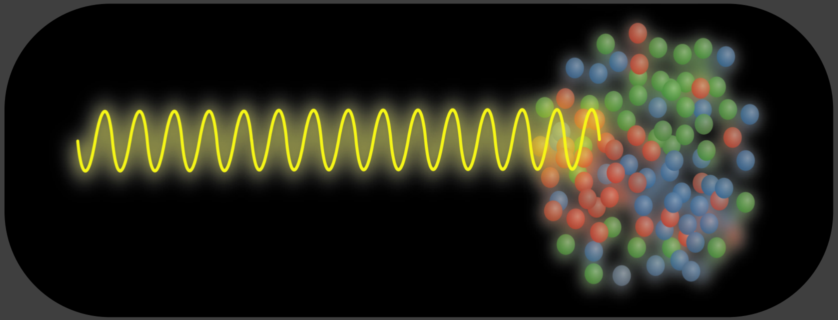
(2) Correlated phase significant across scales

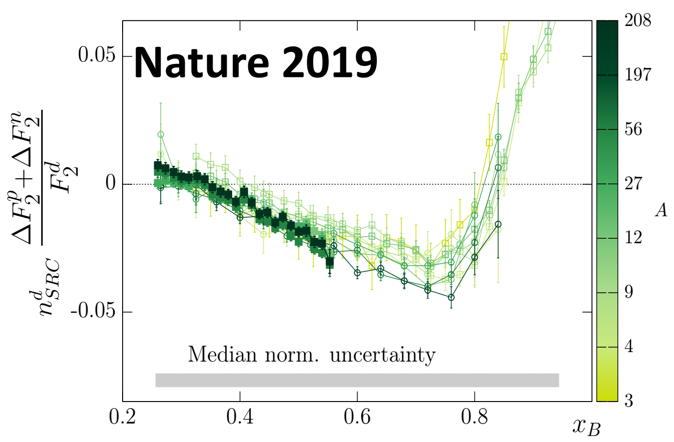






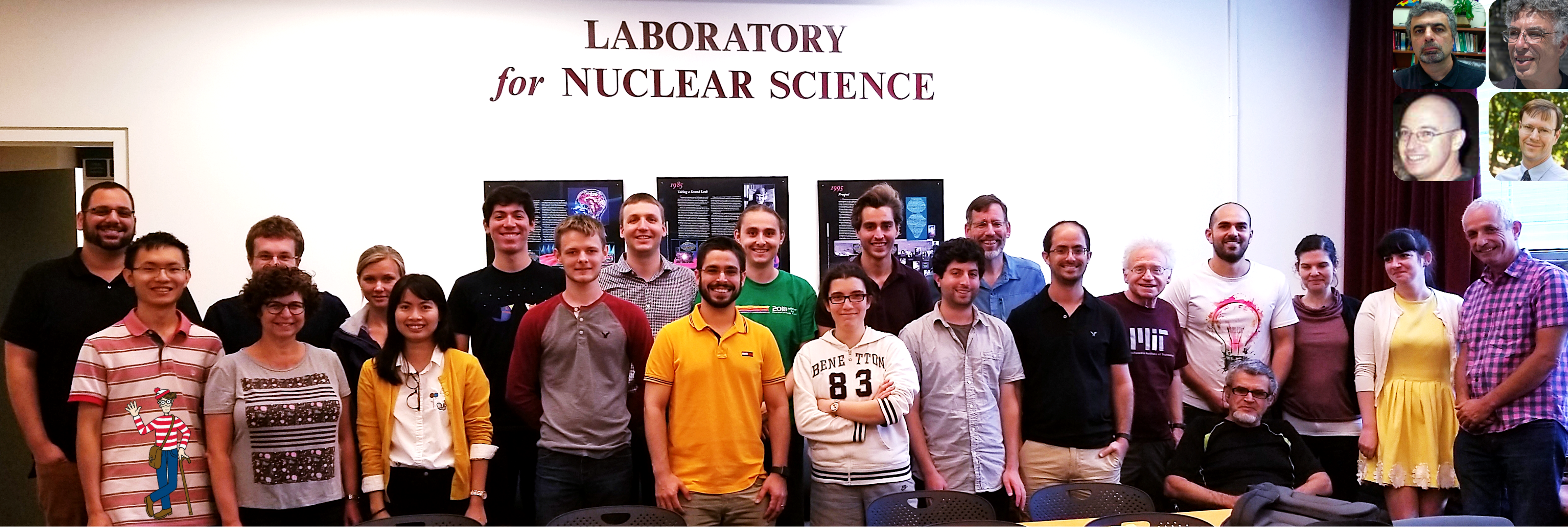






‘Our’ SRC World

+ Many Theory Collaborators: UW, PSU, HUJI, LANL, ANL, Gent, FIU, Perugia, Pisa, …



Dr. Adi Ashkenazy

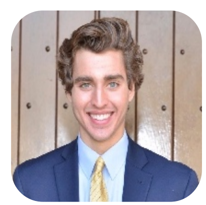
Dr. Dien Nguyen

Dr. Holly Vanse

Dr. Tyler Kutz

Dr. Florian Hauenstein

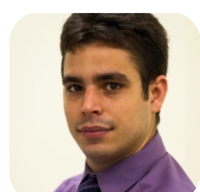
Dr. Julian Kahlbow



Efrain Segarra

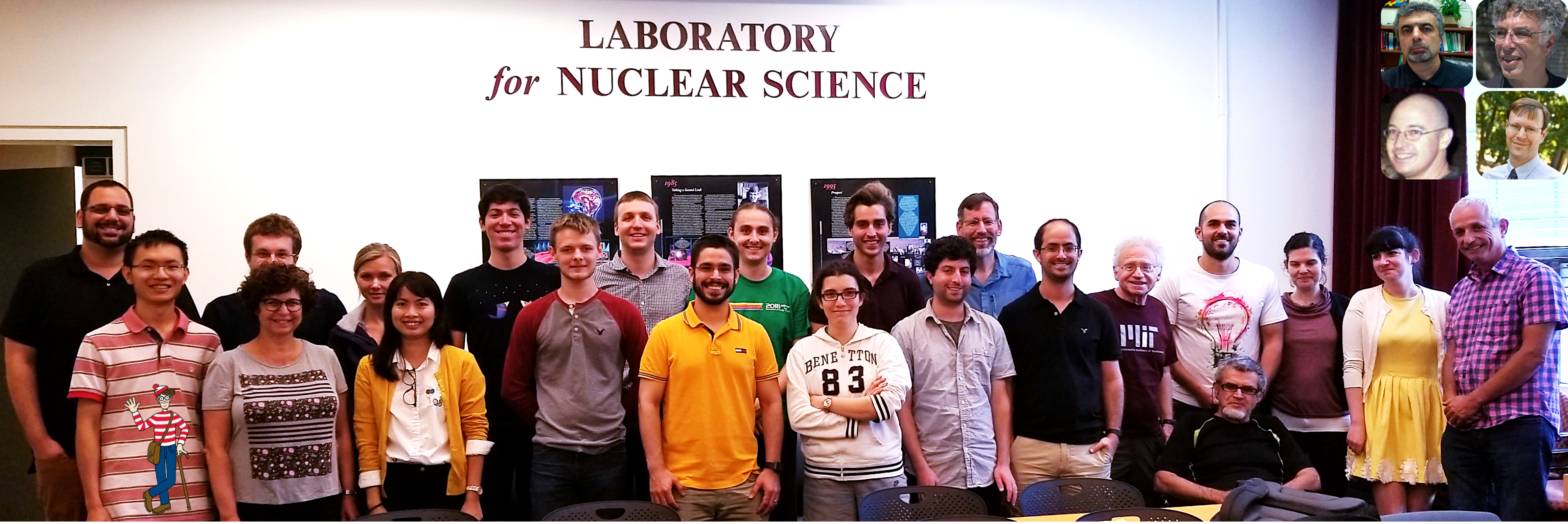
Jackson Pybus

Afroditi Papadopoulou



Reynier Cruz-Torres

Andrew Denniston



<u>2018-20 SRC Publications:</u>

- Nature, In-Print (2020)
- Nature 566, 354 (2019)
- Nature 560, 617 (2018)
- Phys. Rev. Lett. 122, 172502 (2019)
- Phys. Rev. Lett. 121, 092501 (2018)
- Phys. Lett. B 800, 135110 (2019)
- 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)

arXiv: 1908.02223; 1907.03658.