Exploring Short Range Correlations

Inclusive Scattering from Nuclei at x > 1 in the quasielastic and deeply inelastic regimes

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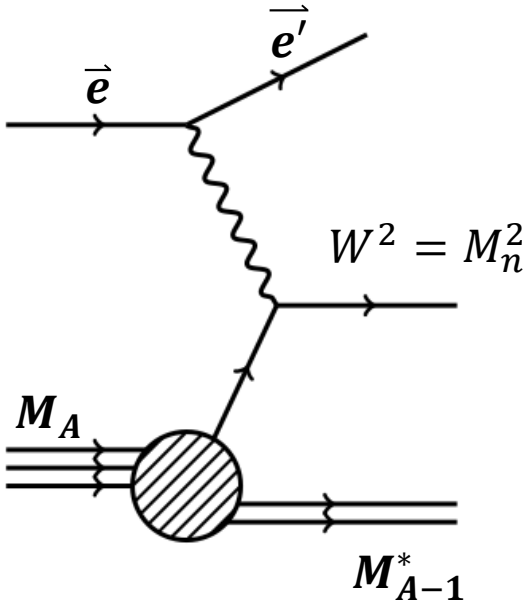
Overview

- Quasielastic and Deep Inelastic Scattering
- Bjorken x
- Parton distribution function
- High Momentum Nucleons
- Short Range Correlations
- Experiment
- References

Quasielastic vs Deep Inelastic

Quasielastic:
Scatter from **nucleons** in nucleus



Resolution: $\lambda = \frac{h}{\sqrt{Q^2}}$

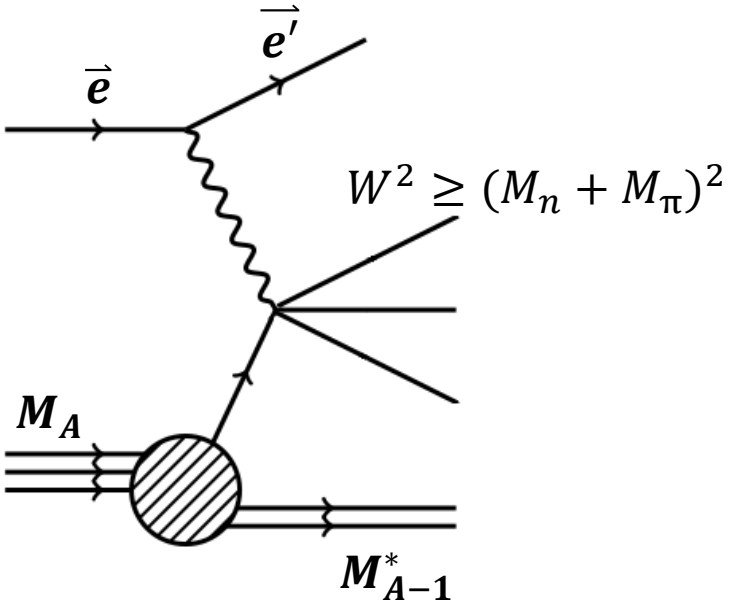
$$\nu = E - E'$$

$$Q^2 = -q^2 = \vec{q}^{\,2} - \nu^2$$

$$W^2 = 2M\nu + M^2 - Q^2$$

$$x = \frac{Q^2}{2M\nu}$$

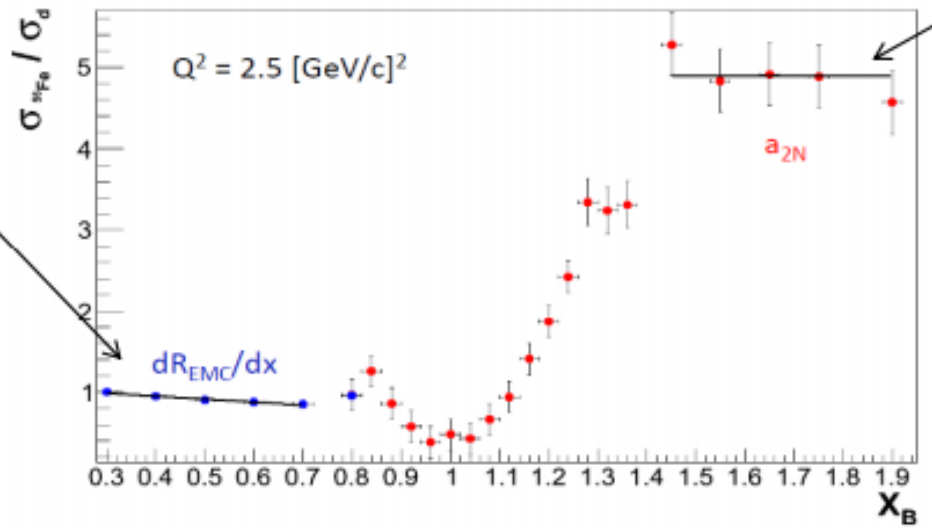
Deep Inelastic:
Scatter from **quarks** in nucleons



Bjorken x

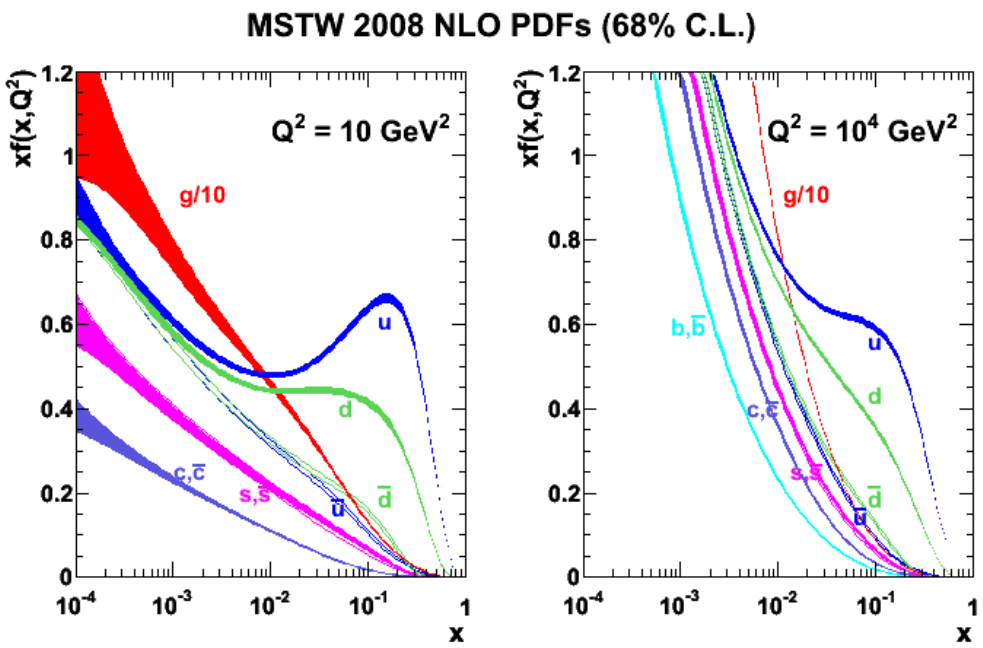
DIS probes partonic (quark) structure of hadrons

Inclusive scattering at x>1 probes partonic (nucleon) structure of nuclei.



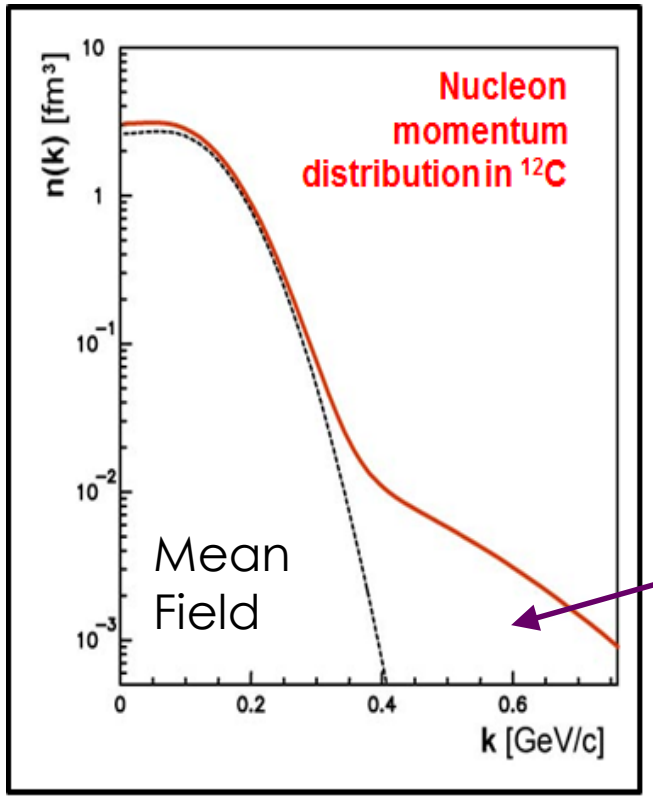
D. Higinbotham et al., arXiv: 1003.4497

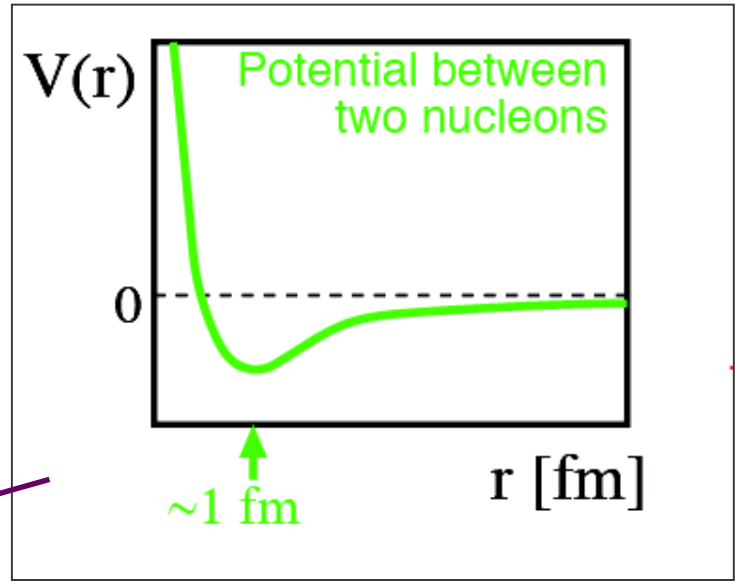
Parton Distribution Function

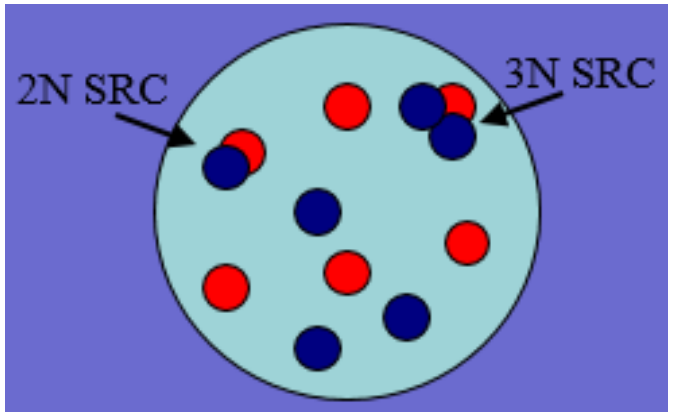


- Parton distribution function for the proton
  - x is longitudinal momentum fraction
- PDF gives probability of finding a particular parton having a particular momentum fraction of the nucleon
- $\lambda = \frac{h}{\sqrt{Q^2}}$ wavelength of virtual proton, which sets the scale for probe
  - Q^2 inc, λ dec to probe quarks

High Momentum Nucleons



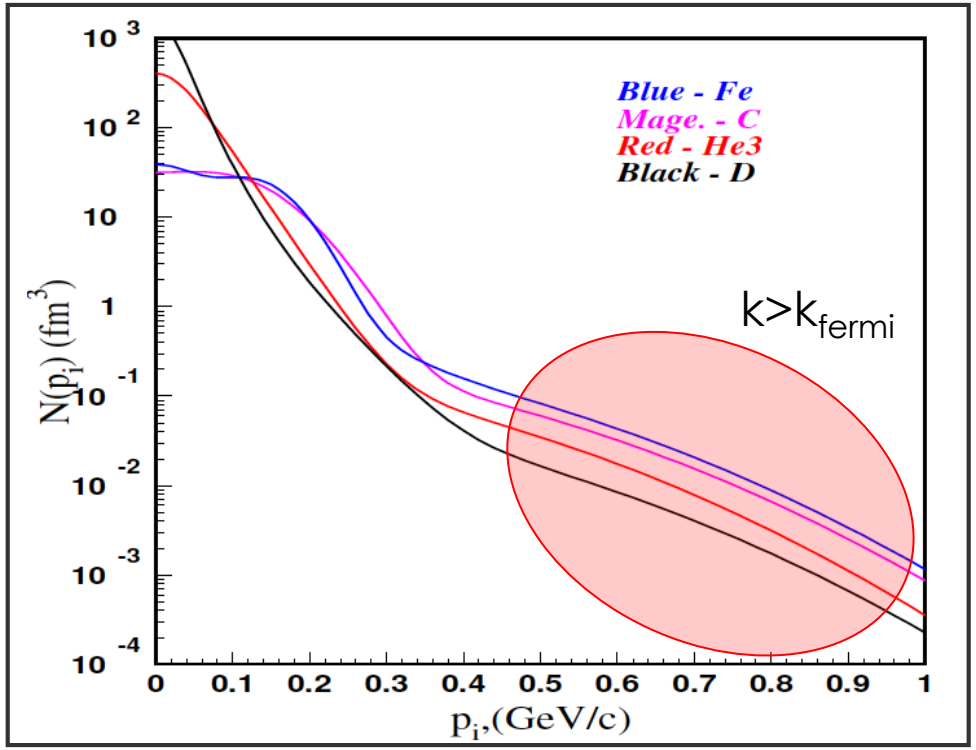




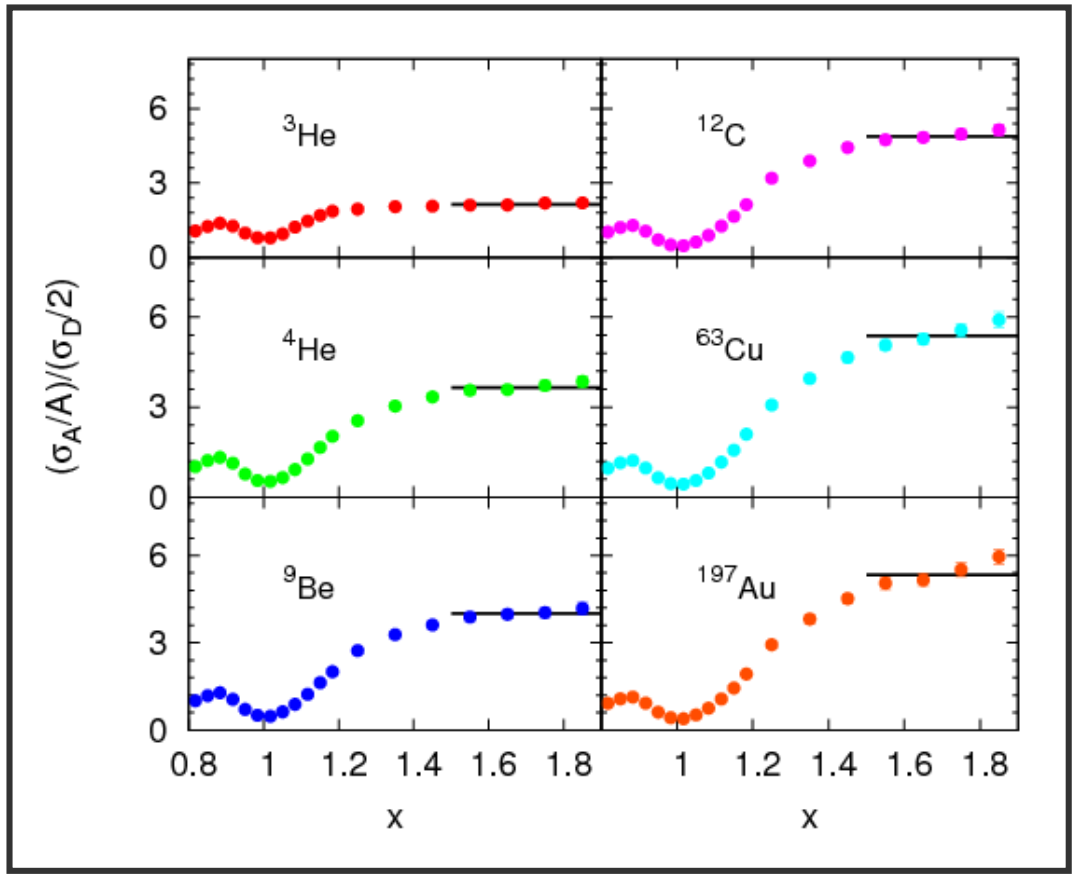
- Tail of momentum distribution a result of hard interactions between nucleons inside nucleus (Short Range Correlations)

High Momentum Nucleons

- High momentum nucleons have $k>k_{fermi}$
- Similar shape
- Calculable for nuclei up to 12C



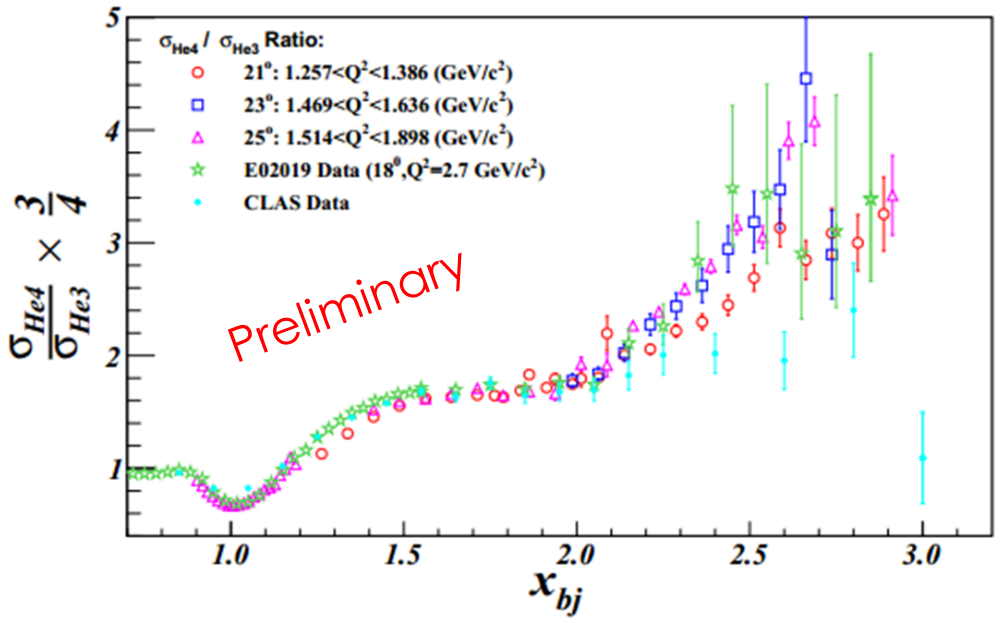
Short Range Correlations (SRCs)



- To probe SRC must be in the high-momentum region ($x_b > 1$)
  - For a free nucleon $x_b \leq 1$, but momentum is shared between nucleons giving a max of ≈A
- $\sigma(x, Q^2) = \sum_{i=1}^{A} A \frac{1}{j} a_j(A)\, \sigma_j(x, Q^2)$
  - $a_j(A)$ const. ∝ prob. of nucleon being in j-nucleon correlation
  - $\sigma_j(x, Q^2)$ cross section of scattering from j-nucleon correlation

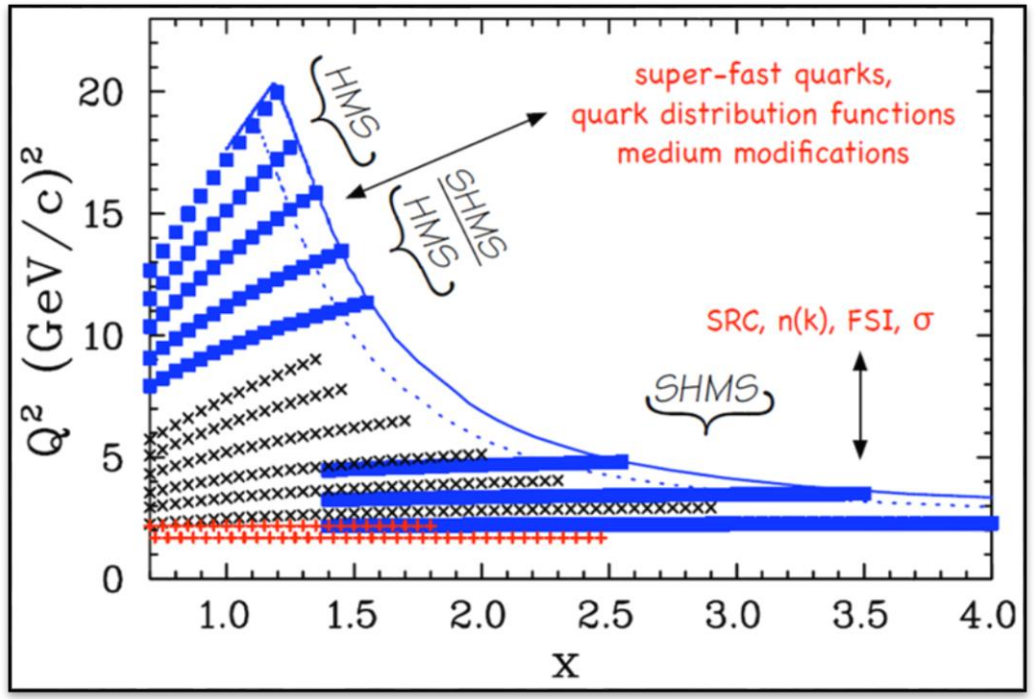
$<Q^2>=2.7\ \mathrm{GeV}^2$

Short Range Correlations (SRCs)



- $\frac{\sigma_A(x,Q^2)}{\sigma_D(x,Q^2)}\frac{2}{A} = a_2(A)$
  - 2N correlations, 1.4 < x < 2
- $\frac{\sigma_A(x,Q^2)}{\sigma_{A=3}(x,Q^2)}\frac{3}{A} = a_3(A)$
  - 3N correlations, 2.4 < x <3

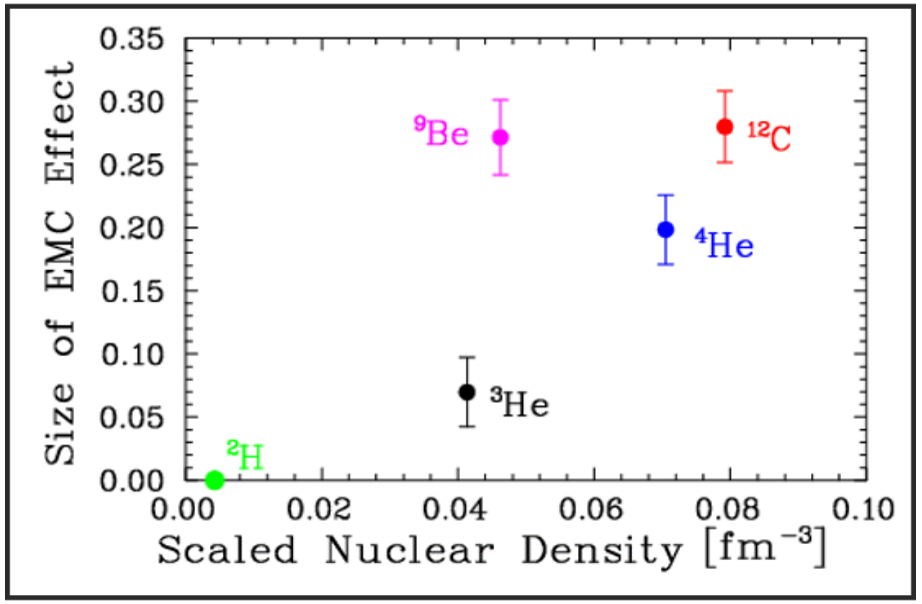
Experiment



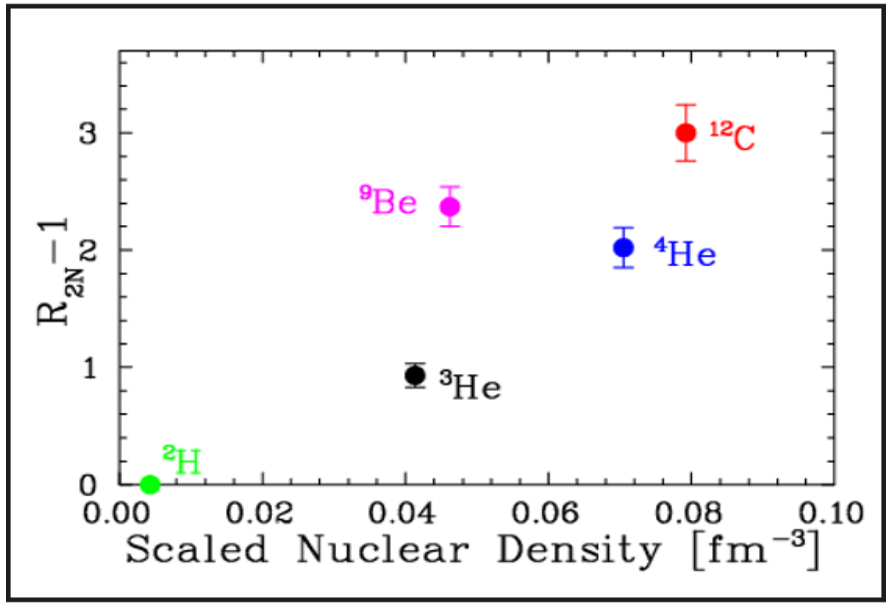
- Jlab 12 GeV's upgrade has allowed to explore a greater range of Q^2 and x_B
- My experiment: E12-06-105
  - Inclusive Scattering from Nuclei at x>1 in the Quasielastic and Deep Inelastic regimes
  - Data to be taken on 11B, 10B in 2016 during Hall C commissioning

Experiment

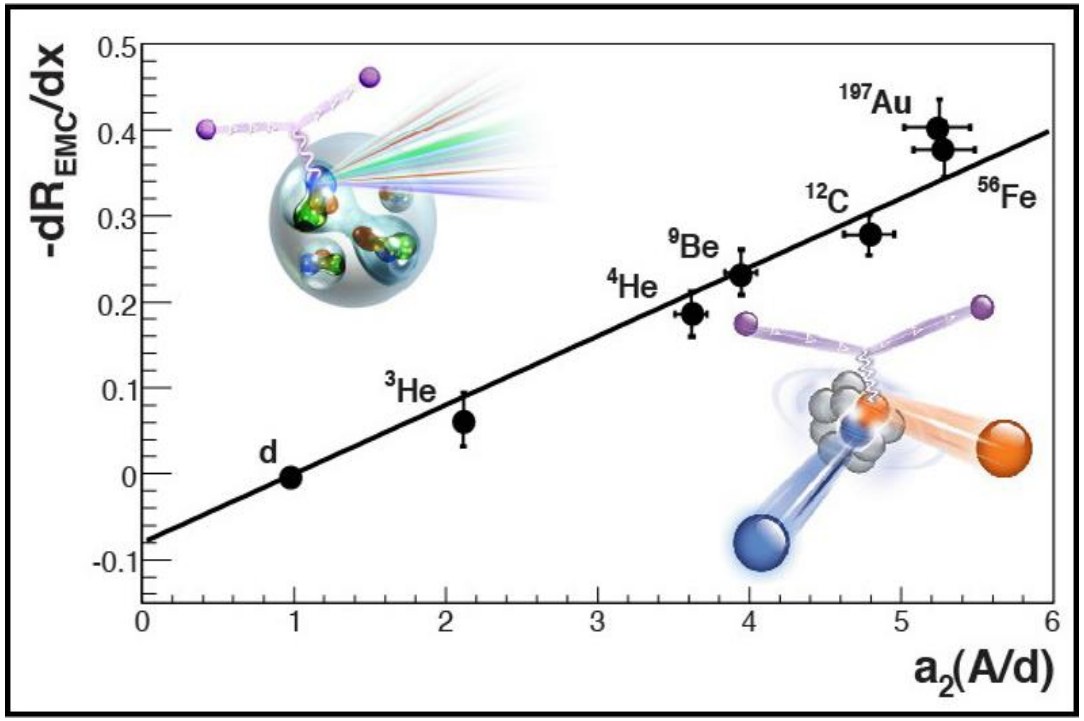
EMC Effect



SRCs

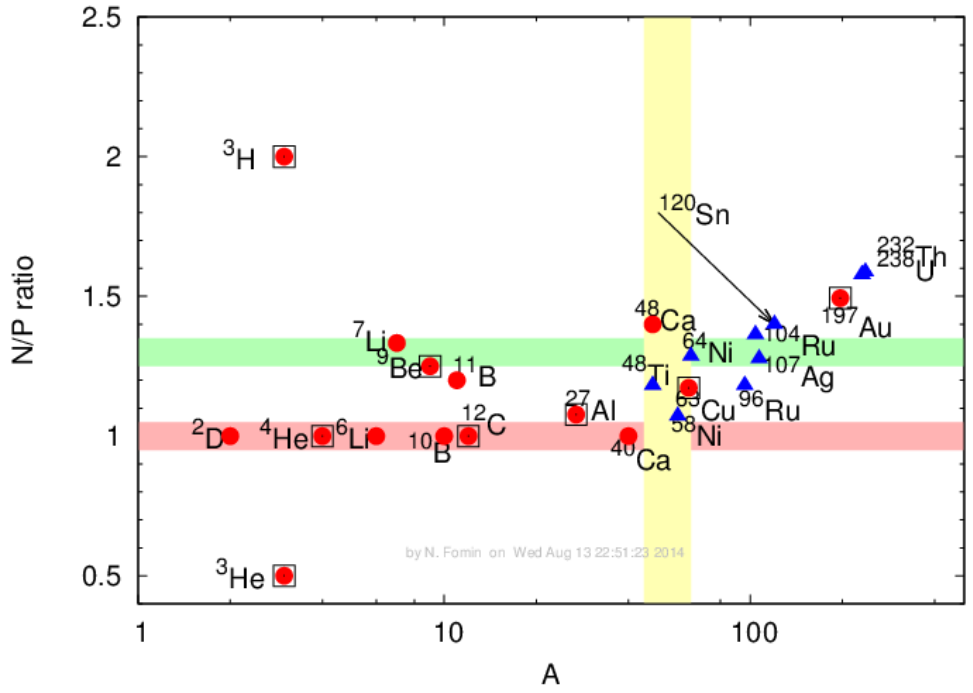


Experiment

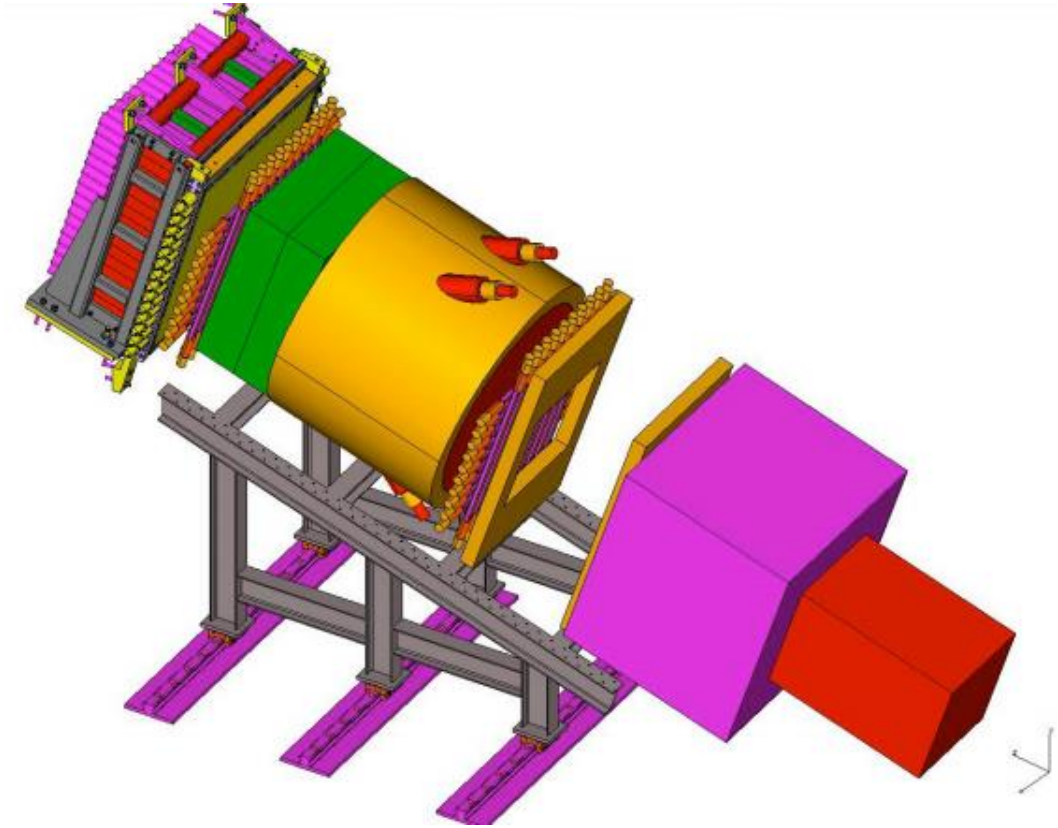

-dR_EMC/dx
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
1
2
3
4
5
6
a_2(A/d)
d
3He
4He
9Be
12C
197Au
56Fe

Experiment

- Strategically chosen targets in order to probe possible correlation between EMC and SRC



Experiment: SHMS



- Nobel Gas Cherenkov
- Wire Chamber
- Hodoscope
- Heavy Gas Cherenkov
- Calorimeter

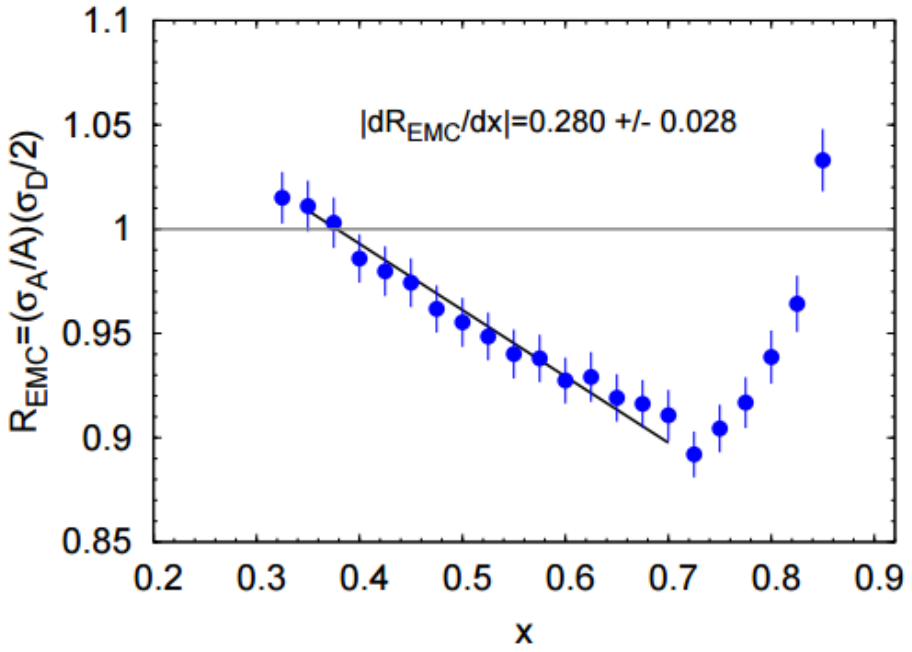
References

- Short-Distance Structure of Nuclei. DW Higinbotham, E. Piasetzky, SA Wood. August 2009. June 2015. https://iopscience.iop.org/1742-6596/299/1/012010/pdf/1742-6596_299_1_012010.pdf
- C. Ciofi degli Atti and S. Simula, Phys. Rev. C 53 (1996).
- Single-Nucleon Momentum Distributions. ANL. September 2014. June 2015. http://www.phy.anl.gov/theory/research/momenta/
- Research prespectives at Jefferson lab: 12 Gev and beyond. Kees de Jager. February 2004.
- https://userweb.jlab.org/~johna/proposal/proposal/node4.html

Extra: More on Scattering

Energy transfer	Type of scattering	Electron
Low	Elastic	Interacts with entire nucleus (x ~ A)
Medium	Quasielastic	Knocks out nucleon (x =1)
High	Inelastic	Nucleon excited into higher energy state (x < 1)
Very High	Deep Inelastic	Interacts with a single quark (x < 1)

Extra: EMC Effect



- Slope of EMC effect differs depending on A
  - Fit slope of ratios $0.3 \leq x_B \leq 0.7$
  - Same overall shape of for all A
  - Depth at minimum depends on nuclear mass- Is EMC due to average density?
- EMC is measure of medium modification of quark distributions

Extra: Experiment

Parameter	SHMS Specification	HMS Performance
Central momentum range	2.5 - 11 GeV/c	0.4 - 7.3 GeV/c
Scattering angle range	5.5° - 25°	10.5° - 90°
Momentum acceptance	-15 to +25%	±10%
Momentum resolution	<0.2%	0.1%
Angular acceptance	2 msr (SSA tune) 4 msr (LSA tune)	6.7 msr
Angular resolution (hor)	2-4 mrad	0.8 mrad
Angular resolution (ver)	1-1 mrad	1 mrad
Target length acc. (90°)	50 cm	10 cm
Vertex resolution	0.2-0.6 cm	0.3 cm
Maximum DAQ rate	10 kHz	2 kHz
e/h Discrimination	10^3 at 98%	10^3 at 98%
π/K Discrimination	100 at 95%	100 at 95%