Run Group G

The EMC Effect in Spin Structure Functions

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(16 institutions, in 6 countries and on 5 continents,)

Will Brooks and Sebastian Kuhn, 25 September 2020

The EMC Effect in Spin Structure Functions

https://www.jlab.org/exp_prog/proposals/14/PR12-14-001.pdf

It has been known for more than 35 years that the basic structure functions of protons and neutrons are modified inside nuclei. This has been observed in many measurements over the decades, including recent experiments at JLab. However, ***no experiment has ever searched for this effect in the spin structure functions***.

Polarization can provide new insights into old problems.

Consider the impact of the polarization measurement of G_{Ep}/G_{Mp}: when compared to the historical unpolarized Rosenbluth method measurements, it revealed a surprisingly large two photon exchange effect.

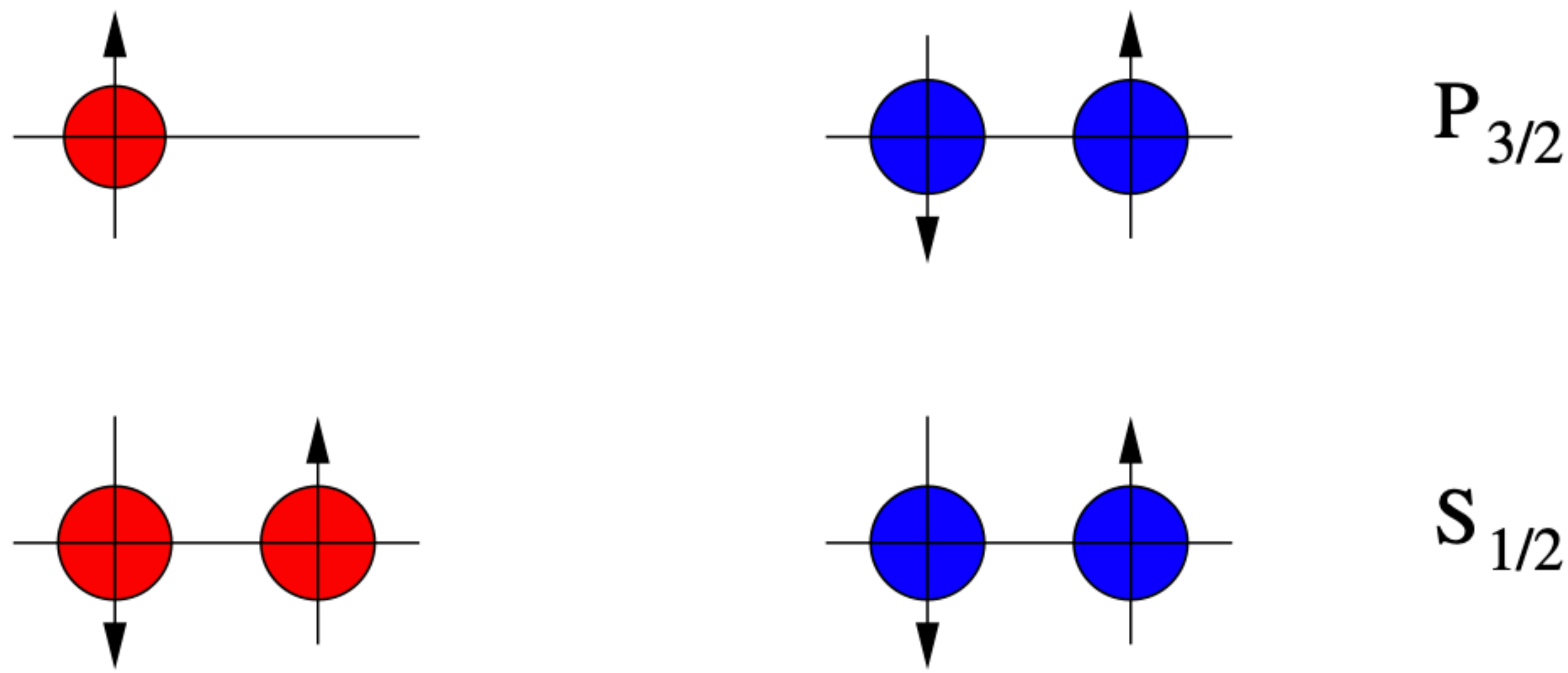
The strategy

We chose ^{7}Li because of its unique nuclear structure. In polarized ^{7}Li, **one proton** carries **nearly all of the polarization**. Thus it is a polarized proton embedded in a nuclear medium.

We chose two cells, in order to gain best control of systematic uncertainties by having polarized ^{7}Li and H simultaneously.

We take advantage of 99% of existing polarized target infrastructure for CLAS12, and the beam time can be scheduled to immediately follow Run Group C which uses that target, so only one major installation would be needed.

Shell model picture of ^{7}Li



86.6% of the ^{7}Li nuclear polarization is carried by the unpaired proton.

This result is confirmed by detailed Green Function Monte Carlo calculations.

New developments since 2014

In 2011 it was proposed that the EMC effect might be induced by short-range correlated nucleons (SRC; Weinstein, Piasetzky, et al.)

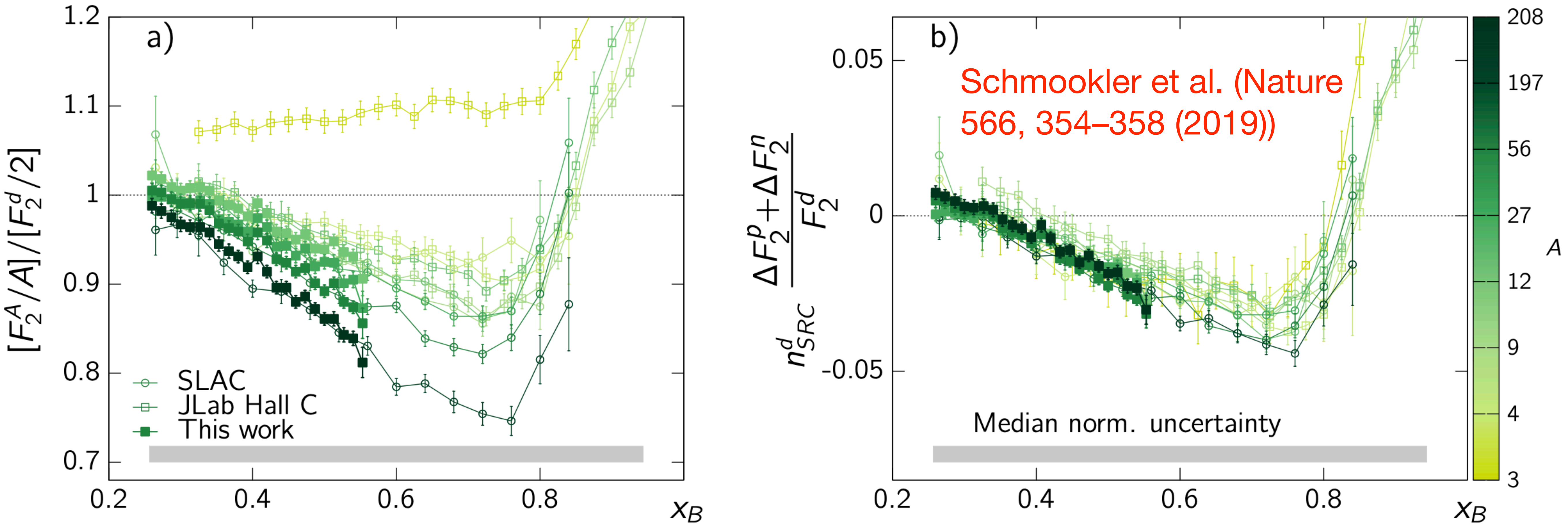
Since 2014 there have been both theoretical and experimental advances intensifying the debate over this assertion, underscoring the urgency of this experiment.

Mean-field based model calculations continue to consistently find modified spin structure functions.

Experiment-driven analyses found more evidence of the EMC⇔SRC hypothesis; however, disputed by some experts.

Important technical developments in target technology (see backup slides). All components in hand and tested.

New developments since 2014



Schmookler et al.: if assume EMC is caused entirely by *np*-SRC, can derive a universal function that describes EMC well for **all** nuclei. (Assumes F_2^{*p} and F_2^{*n} are universal.)

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

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

$$\Delta F_2^n \equiv F_2^{n*} - F_2^n$$

$$\Delta F_2^p \equiv F_2^{p*} - F_2^p$$

Reflections on the origin of the EMC effect

1809.06622

Anthony W. Thomas

Asserts that SRC will significantly depolarize the participants.

Do short-range correlations cause the nuclear EMC effect in the deuteron?

X. G. Wang,[1] A. W. Thomas,[1] and W. Melnitchouk[2]

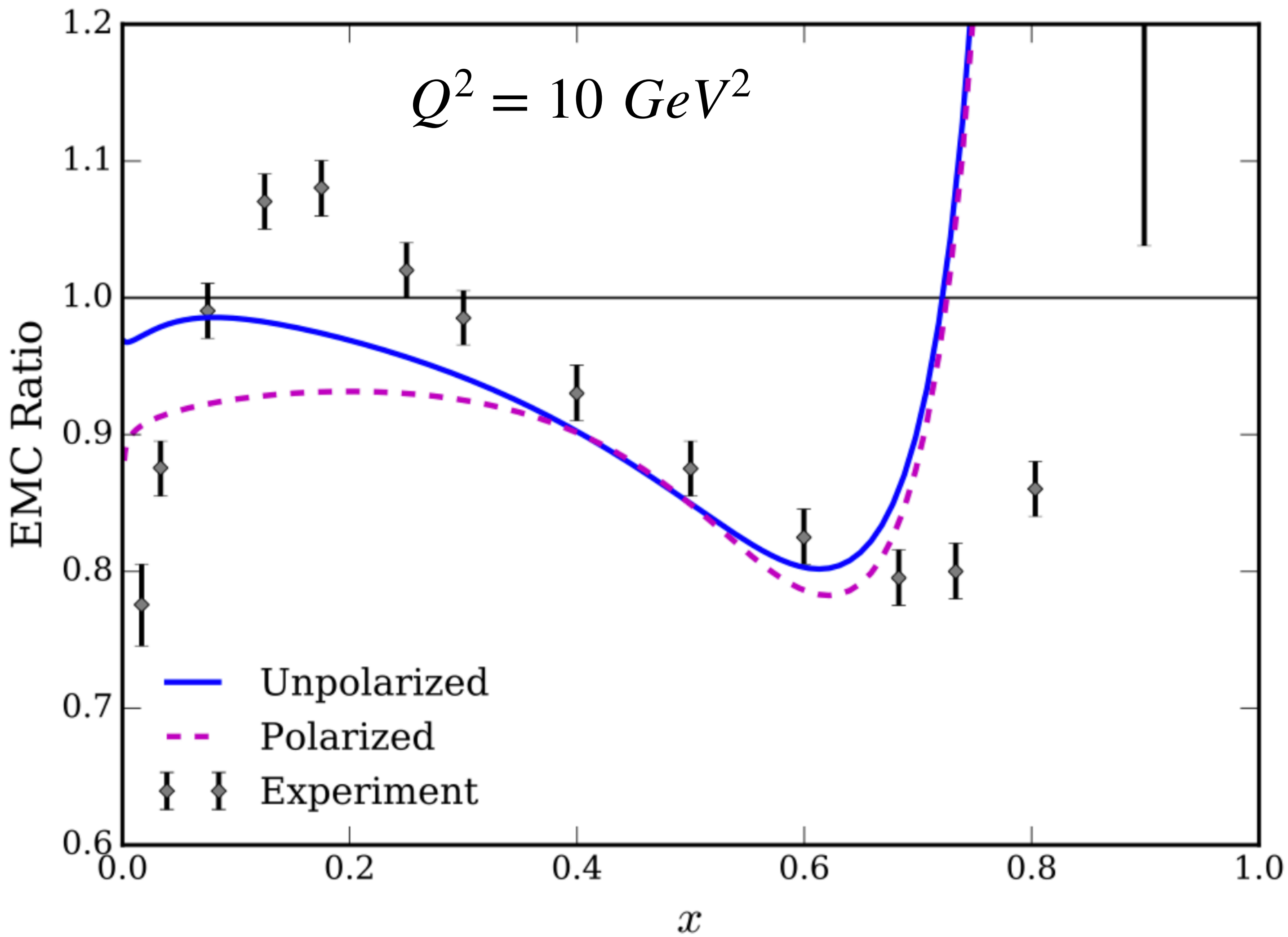
Test of three phenomenological models with nuclear binding, Fermi motion, and nucleon off-shell effects, can classify into low momentum and high momentum components. They found that high-momentum nucleons, such as those found in SRCs, were not the main source of the EMC effect in the models studied. 2004.03789

Short-Range Correlations and the Nuclear EMC Effect in Deuterium and Helium-3

E.P. Segarra,[1] J.R. Pybus,[1] F. Hauenstein,[1,2] D.W. Higinbotham,[3] G.A. Miller,[4] E. Piasetzky,[5] A. Schmidt,[6] M. Strikman,[7] L.B. Weinstein,[2] and O. Hen[1,*]

June 2020 response in favor of EMC⇔SRC for A=2, 3 2006.10249

Other developments since 2014



1806.00481 (2018)

QMC model

S. Tronchin,

H. H. Matevosyan

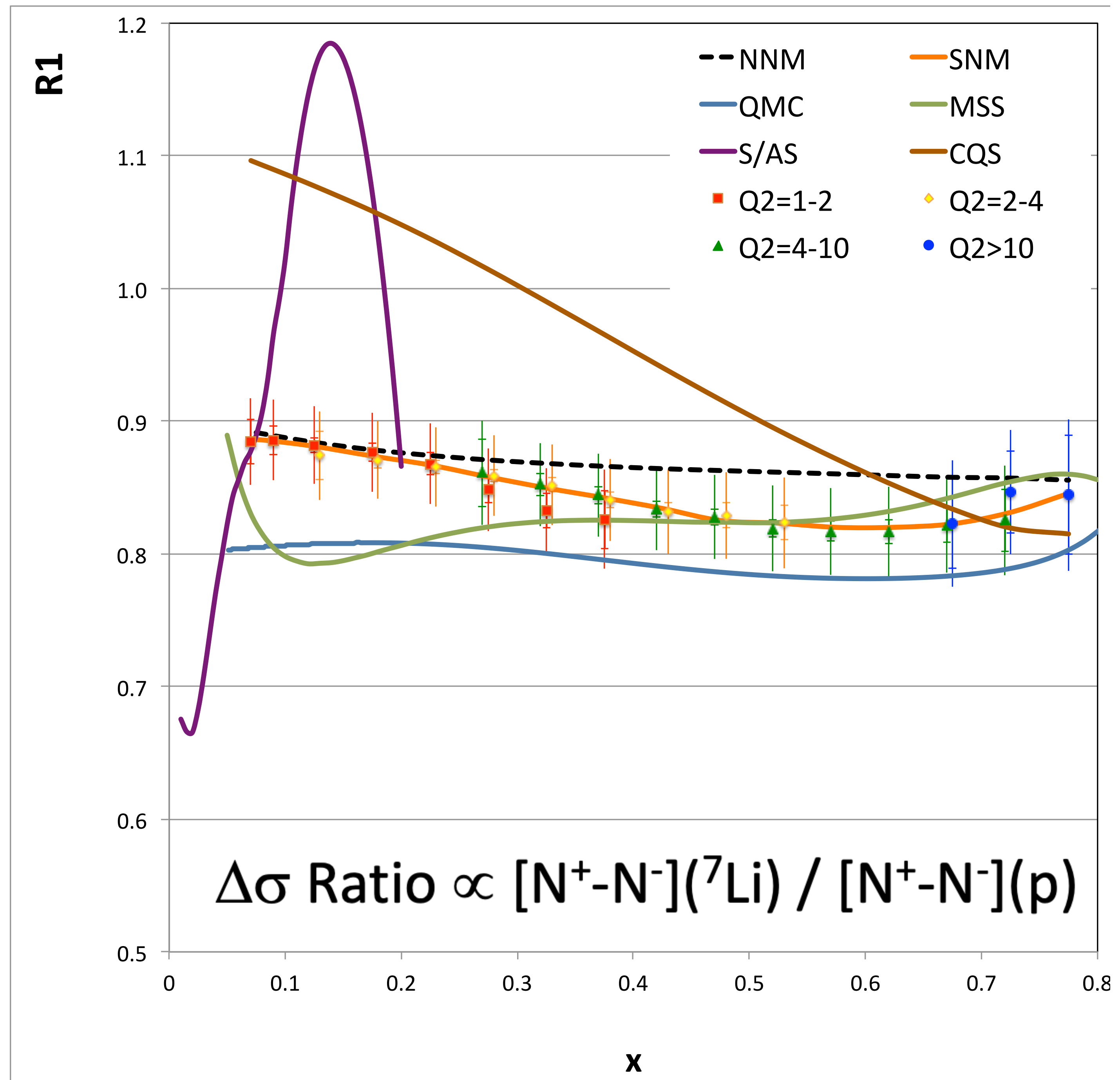
A. W. Thomas

"Short-Range Correlations and the EMC Effect in Effective Field Theory," J.-W. Chen, W. Detmold, J. E. Lynn, and A. Schwenk, Phys. Rev. Lett. 119, 262502 (2017). 1607.03065 - correlation between EMC slope and SRC comes naturally from a scale separation in EFT. Focus is on light nuclei.

Theory TAC Report comments

"Several new theoretical works published after the original approval in PAC 42 have only **increased** the **interest** and **importance** of this experiment."

"….the results of this run group proposal can be expected to provide **important clues** into an effect that has **puzzled** the nuclear physics community for **nearly 40 years**, and that are not available only considering unpolarized targets."



Conclusions

Many new developments since the experiment was approved in 2014. Clearly a vigorous community of scientists worldwide who are very interested in the related topics.

One of the main aims is to understand whether the EMC effect is a mean-field phenomenon or a short-range correlation phenomenon, or both. A polarization-based measurement will provide completely new information that will help to clarify this puzzle.

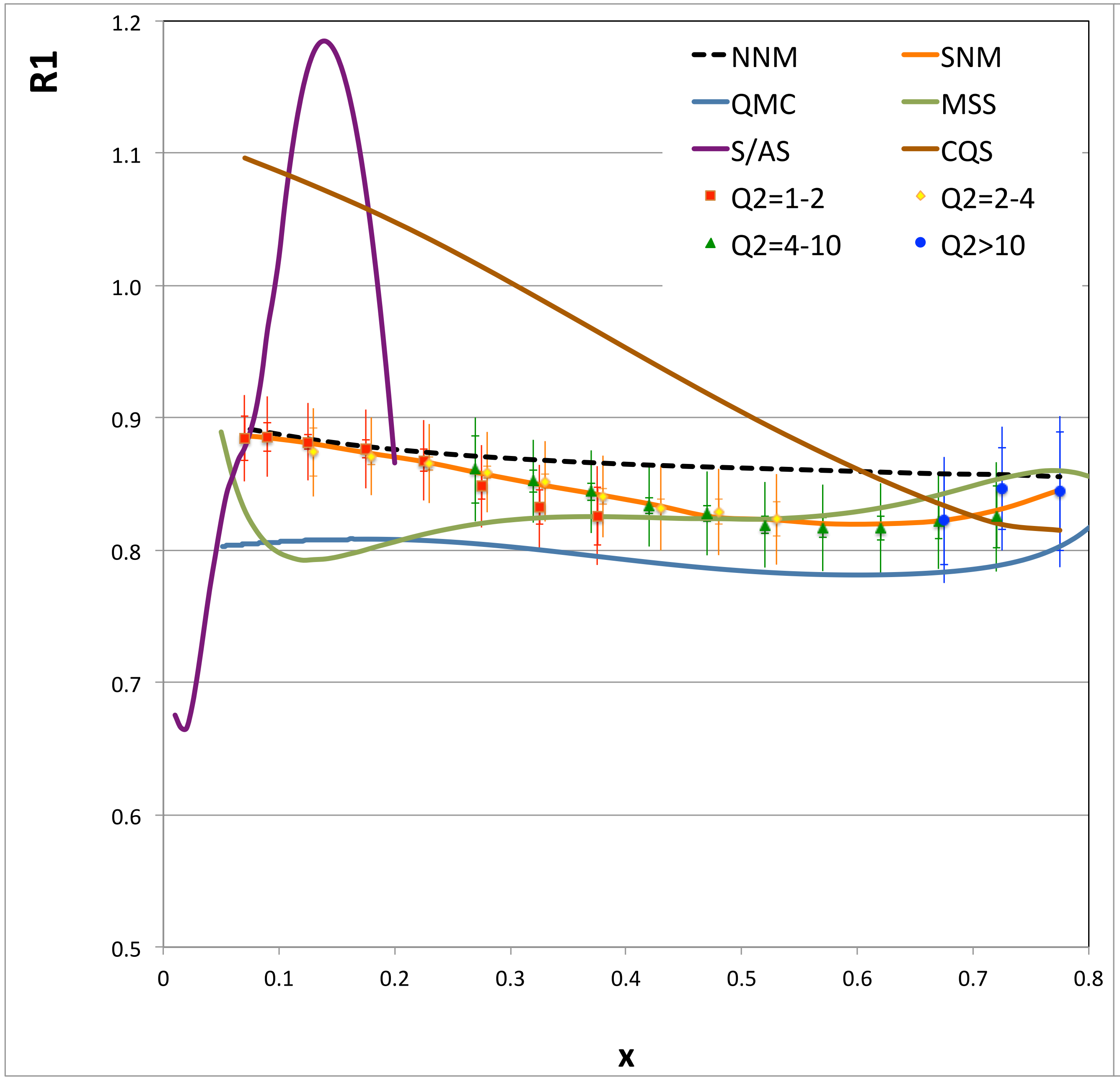
In the foreseeable future, JLab is the only lab in the world where this experiment can be done.

We request that you review our scientific rating in the light of the developments since the 2014 PAC.

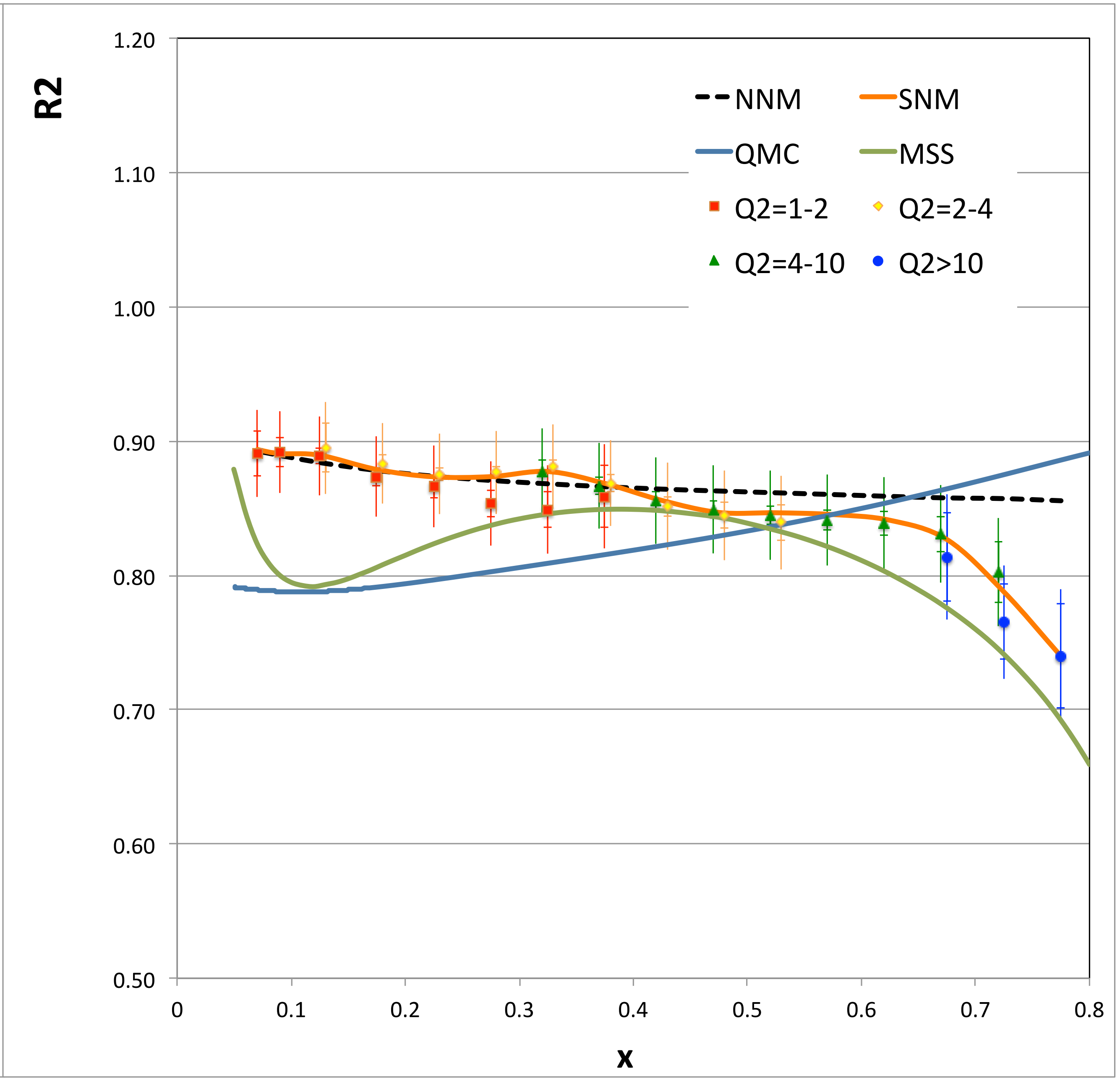
Backup Slides

RG-G Expected Results

$\Delta\sigma$ Ratio $\propto [N^+ - N^-](^7Li) / [N^+ - N^-](p)$



$A_{||}$ Ratio $\propto A_{||}(^7Li) / A_{||}(p)$



NNM = Shell model prediction (p 87% pol.) SNM = Standard Nuclear Model (convolution w/out change in medium; equiv. to SRC model) QMC = Mean Field (Quark-Meson Coupling) MSS (rescaling/modified sea scheme) S/AS = Shadowing/Antishadowing (Guzey/Strikman) CQS = Chiral Quark Soliton (Smith/Miller)

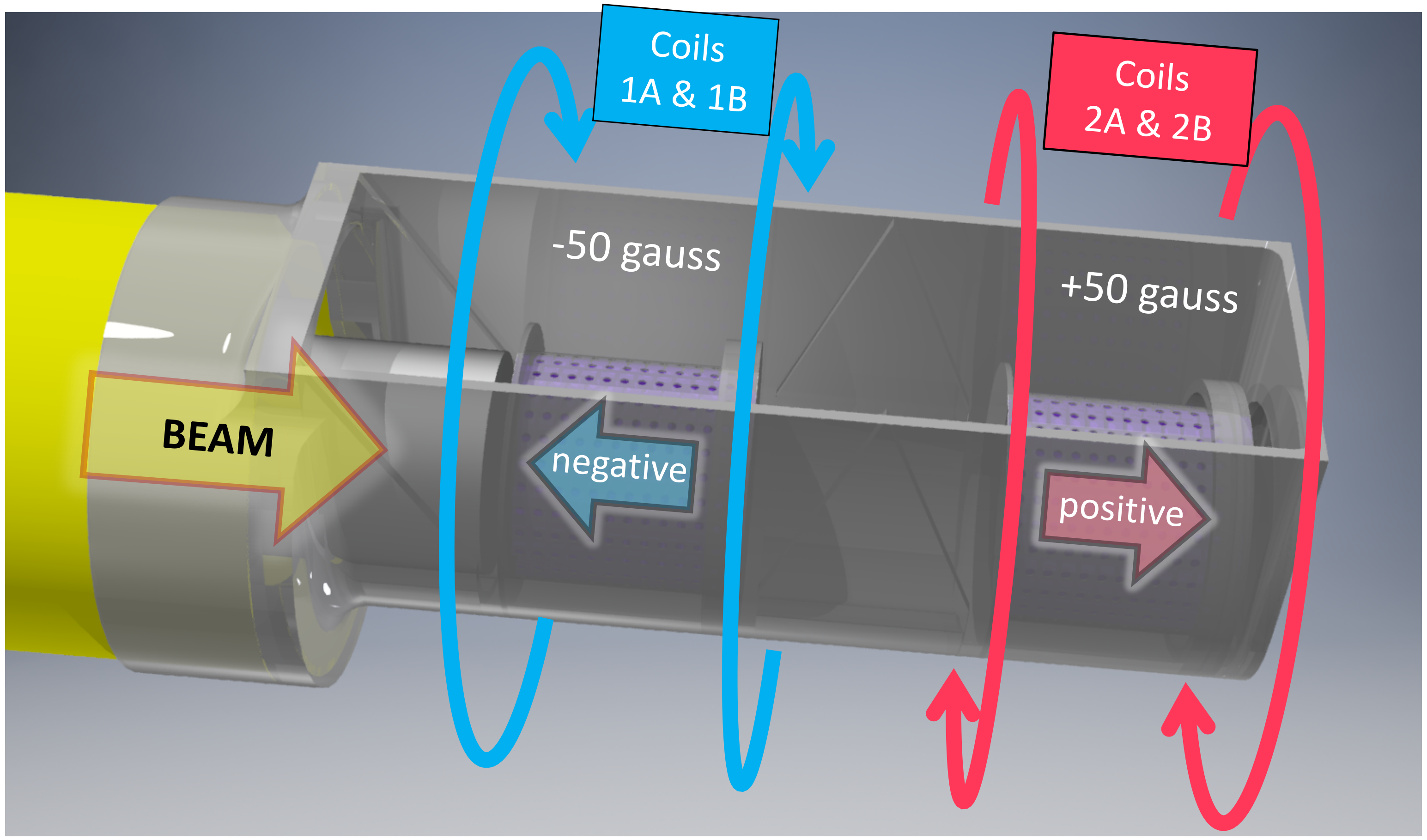
Double-cell Polarization

Can we polarize two samples at once, in opposite directions?
Small coils inside target cryostat shift the 5 T polarizing field:

- Upstream sample -50 gauss
- Downstream sample +50 gauss

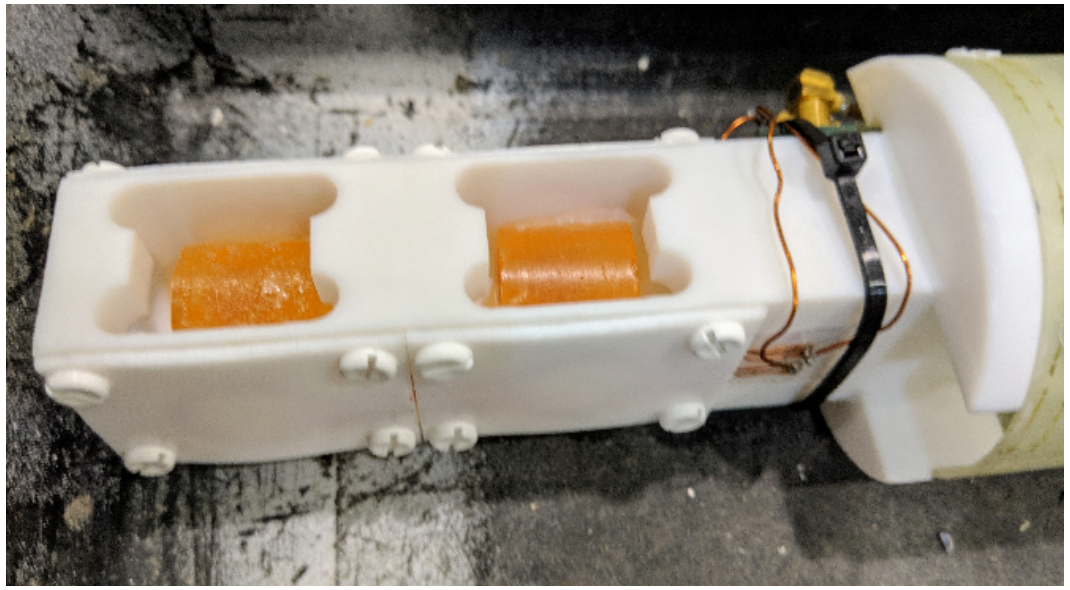
Microwave frequency halfway between the normal (+) and (-) polarization frequencies:

- high field sample will polarize (+)
- low field sample will polarize (-)

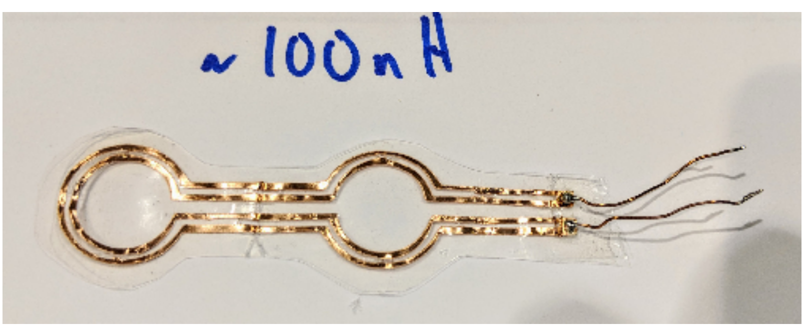


Double-cell Polarization

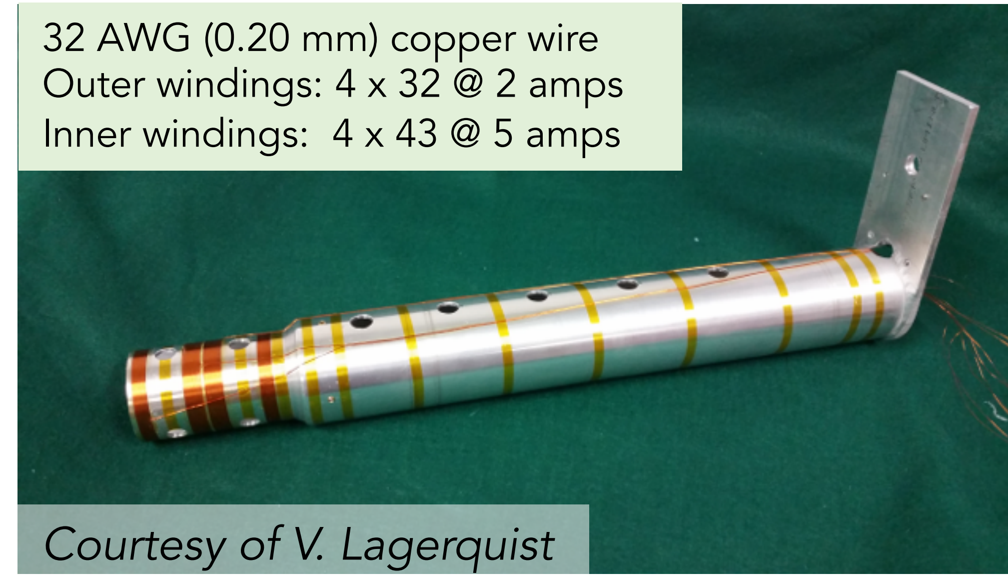
Proof-of-principle tests performed at 77 K and 5 T using TEMPO-doped polymer



Courtesy of J. Maxwell



- Two samples
- One NMR coil

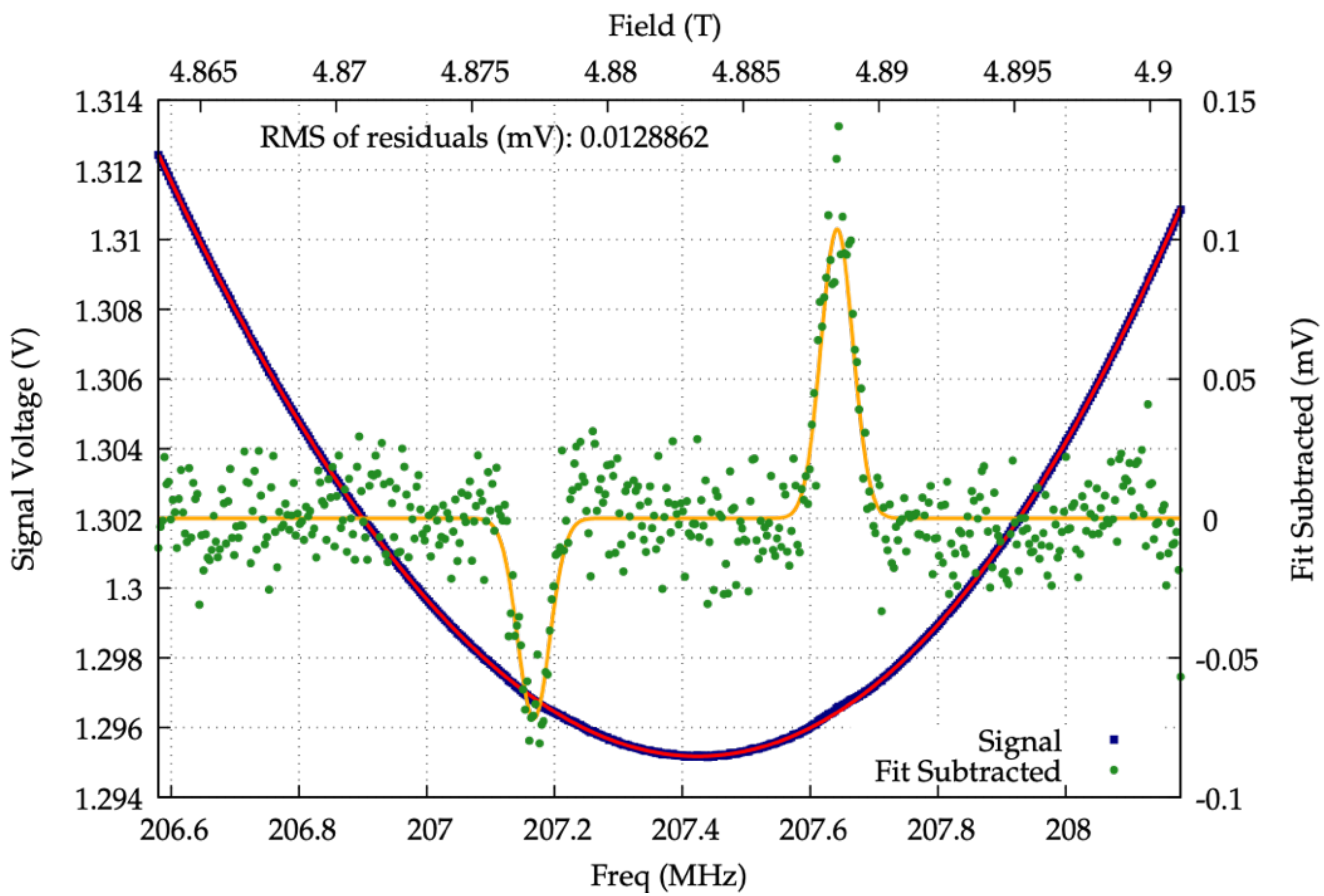


5 T solenoid used for FROST

Double-cell Polarization

Proof-of-principle tests performed at 77 K and 5 T using TEMPO-doped polymer

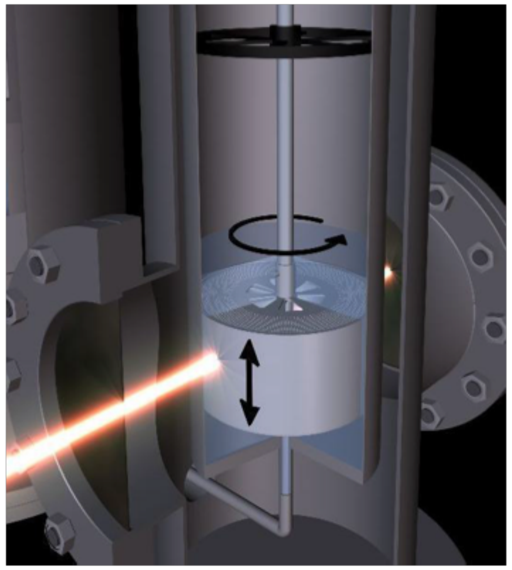
Success!

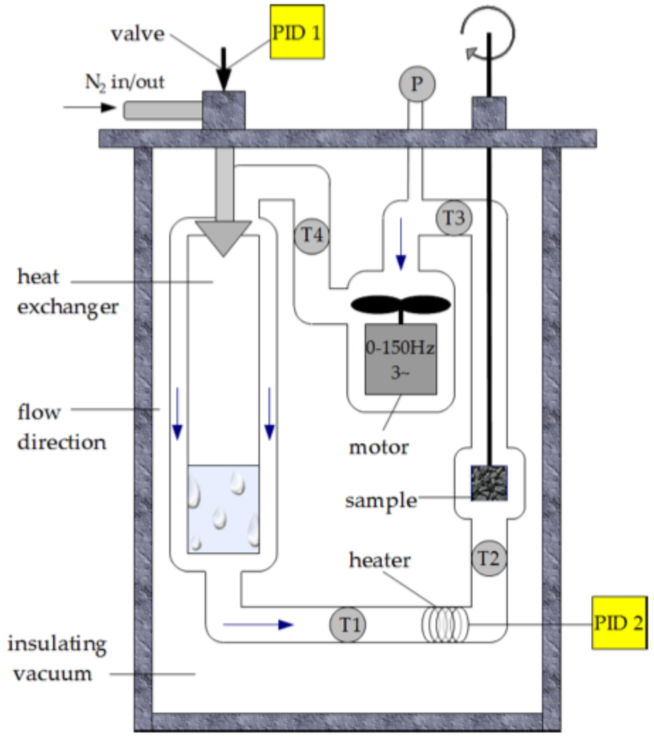


DNP of Lithium Hydride

Under 1K/5T conditions, 7Li has been polarized to about 80% and 6Li to 30%.

Optimal polarization requires pre-irradiating the samples in a narrow temperature band around 185 K.





This can be performed at the UITF, using a custom-built, variable-temperature irradiation cryostat.

Photos and drawings: Scott Reeve, U. Bonn.

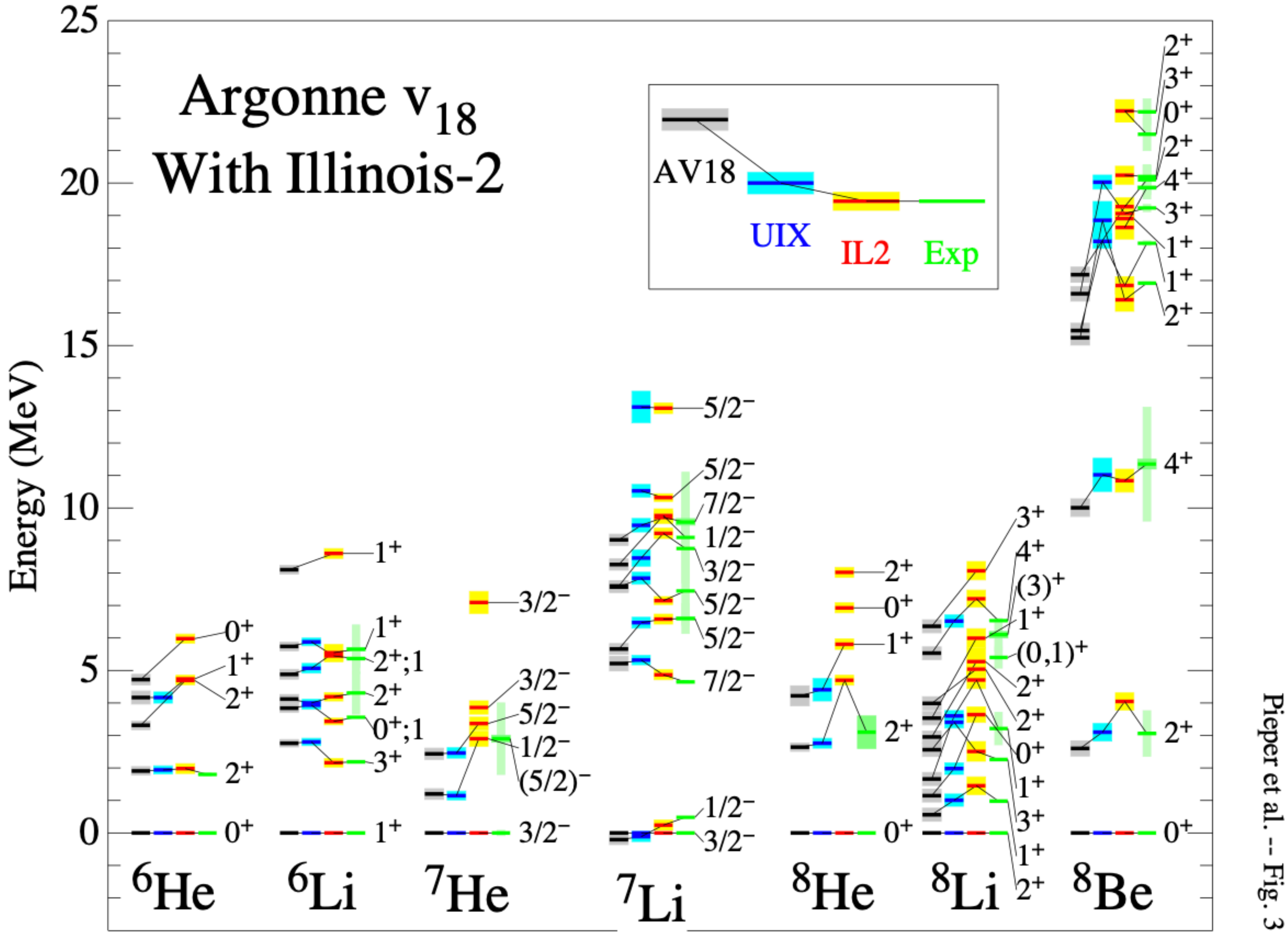


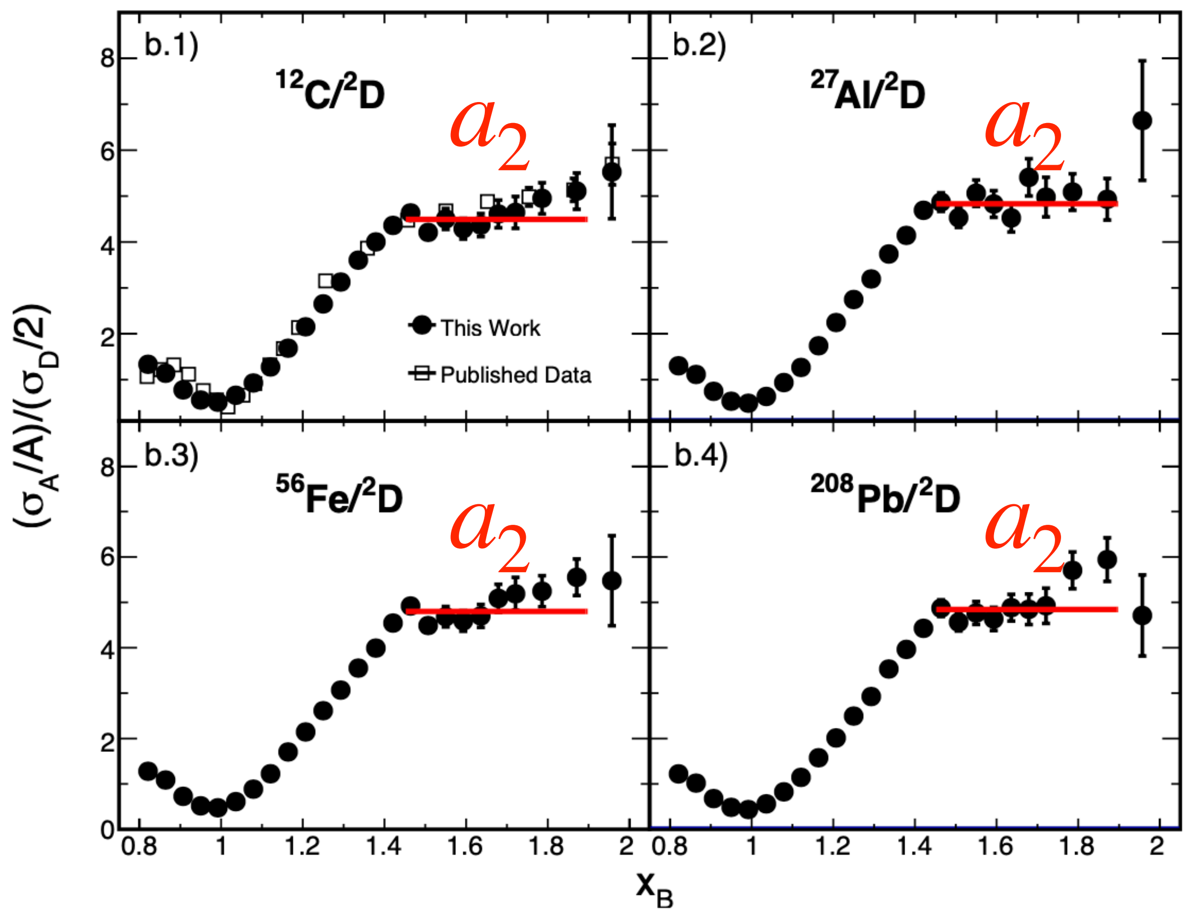
FIG. 3. Green's Function Monte Carlo (GFMC) calculations for ground states and excited states in the $A = 6 - 8$ region from [42]. This figure illustrates the precision achieved in modern few-body nuclear structure calculations. Typical deviation from experimental values (where available) are of order 100 keV or less.

$$R_{pol} = \frac{g_{1A}^{z}}{g_{1p}}$$

Since there are no model-independent measurements of F_2^n, we apply Eq. 1 to the deuteron, rewriting F_2^n as $F_2^d - F_2^p - n_{SRC}^d(\Delta F_2^p + \Delta F_2^n)$. We then rearrange Eq. 1 to get:

$$\frac{n_{SRC}^d(\Delta F_2^p + \Delta F_2^n)}{F_2^d} = \frac{\frac{F_2^A}{F_2^d} - (Z-N)\frac{F_2^p}{F_2^d} - N}{(A/2)a_2 - N}, \qquad \text{Eq. 2}$$

where F_2^p/F_2^d was previously measured [28] and a_2 is the measured per-nucleon cross-section ratio shown by the red lines in Fig. 1b. Here we assume a_2 approximately equals the per-nucleon SRC-pair density ratio of nucleus A and deuterium: $(n_{SRC}^A/A)/(n_{SRC}^d/2)$



- O. Hen, G. A. Miller, E. Piasetzky, and L. B. Weinstein, Rev. Mod. Phys. 89, 045002 (2017).
- S. Malace, D. Gaskell, D. W. Higinbotham, and I. Cloet, Int. J. Mod. Phys. E23, 1430013 (2014), 1405.1270.