Welcome and Overview

b_1/A_{zz} Tensor Collaboration

Jefferson Lab
2025-10-13

Karl J Slifer
University of New Hampshire

Jefferson Lab

E12-13-011: The b_1 *experiment*

41 Days in Jlab Hall C
A- Physics Rating

E12-15-005: A_{zz} *for x>1*

44 Days in Jlab Hall C
A- Physics Rating

Spokespersons

Chen, Day, Higinbotham, Kalantarians,
Keller, Long, Rondon, Santiesteban, Slifer

History

2010 : LOI-11-003 b1
2011 : PAC 37 cross section method. Withdrawn
2013 : PAC 40 PR12-13-001. A- C1 conditional approved
2014 : 1st Tensor Workshop at Jefferson Lab
2015 : PAC 43 PR12-15-005 Azz proposal. Conditional approved.

2022 : Full Approval after Conditional Review

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2023 : PAC 51 Jeopardy Review of b1/Azz

running conditions modified: P_{zz} from 30 ->26%, I from 115 to 85 nA

2023 : 2nd Tensor Workshop at ECT*
2024 : CLAS Approved Analysis of RG-C Deuteron Data
2025 : EPJA Topical Review
2025 : Tensor Collaboration Meeting

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2025 : Tensor Collaboration Meeting

2026? : ERR

3rd Tensor Workshop

Workforce

Grad Students

Jay Roberts (UVA)
Sujan Subedi (UVA)
Muhammad Farooq (UNH)
Michael McClellan (UNH)
Hector Chinchay (UNH)
Chhetra Lama (UNH)
Anchit Arora (UNH)
Zoe Wolters (UNH)
Devin Seay (UVA)
Aden Whitney (UNH)

Undergrads

Ian Cruz (UVA)
Eli Phippard (UNH)
Shane Clements (UVA)

Post-docs

Ishara Fernando
Jan Vanek
Forhad Hossain

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+Faculty

David Ruth
Carlos Yero

Jlab Staff

Jiwan Poudel
Jian-Ping Chen
Chris Keith
James Maxwell
+whole target group….
Dave Mack
Doug Higinbotham
Dave Gaskell
Hanjie Liu
Mark M. Dalton

Spokespeople

Jian-Ping Chen
Donal Day
Douglas Higinbotham
Narbe Kalantarians
Dustin Keller
Elena Long
Oscar Rondon
Nathaly Santiesteban
Karl Slifer

Observable: Tensor Asymmetry Azz

$$A_{zz} = \left[\frac{2}{f P_{zz}}\right]\left[\frac{\sigma(P_z, P_{zz}) + \sigma(-P_z, P_{zz})}{\sigma(P_z, 0) + \sigma(-P_z, 0)} - 1\right]$$

$$\sigma_1 = \sigma(+P_z, P_{zz})$$
$$\sigma_2 = \sigma(-P_z, P_{zz})$$
$$\sigma_3 = \sigma(+P_z, 0)$$
$$\sigma_4 = \sigma(-P_z, 0)$$

$$\text{sensitivity to slow drifts} \propto \frac{1}{\sqrt{N_{flips}}}$$

New Information

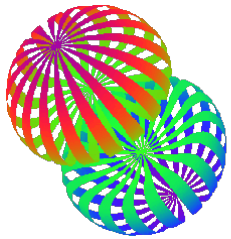
Since the original PAC review, we have increased the planned number of polarization state flips from about once per day to about once per hour

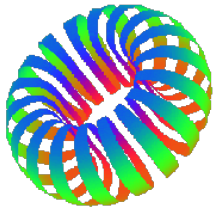
This reduces the sensitivity to slow drifts by about $1/\sqrt{24}$

And allows reduction in running requirements

P_{zz} = 26% (originally was 30%)
I = 85 nA (originally was 115nA)
Request for Polarized beam (originally assumed unpol)

Tensor polarization allows control of the nuclear spatial configuration





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Measuring A_{zz} over a broad range in x gives access to :

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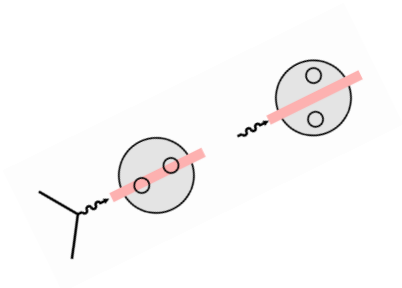

$$q^1_\uparrow(x) = q^{-1}_\downarrow(x)$$
$$q^1_\downarrow(x) = q^{-1}_\uparrow(x)$$
$$q^0_\uparrow(x) = q^0_\downarrow(x)$$

Nuclear shadowing
at low X

Tensor structure functions &
momentum distributions in nucleus
Possible 6 quark states, Hidden color

X_B

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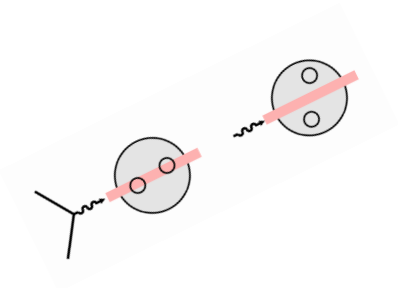

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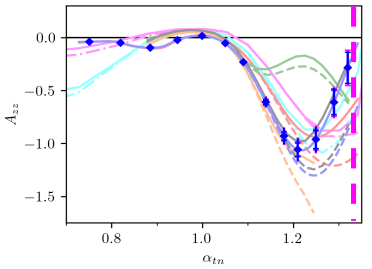

$$A_{zz} \overset{D \to w(k)}{\propto} \frac{\frac{1}{2}w^2(k) + u(k)w(k)\sqrt{2}}{u^2(k) + w^2(k)}$$

Nuclear shadowing
at low X

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Possible 6 quark states, Hidden color

S/D Wave components
SRCs at large x

X_B

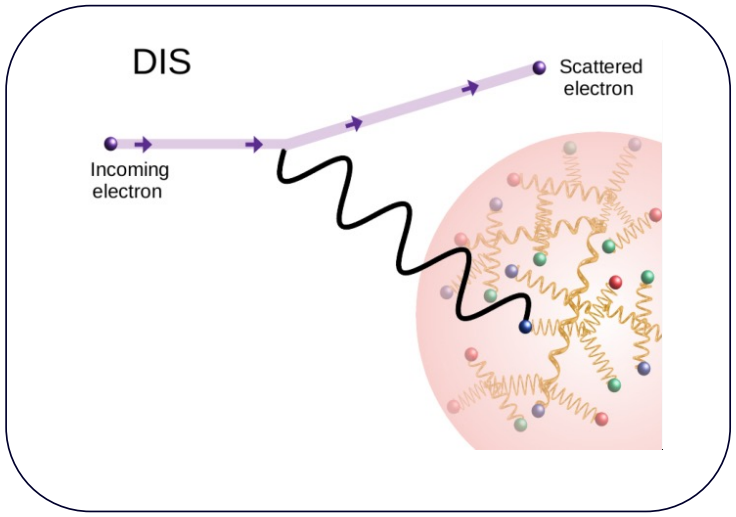
b_1 structure function

$$
\begin{aligned}
W_{\mu\nu} &= -F_1 g_{\mu\nu} + F_2 \frac{P_\mu P\nu}{\nu} \\
&+ i\frac{g_1}{\nu}\epsilon_{\mu\nu\lambda\sigma}q^\lambda s^\sigma + i\frac{g_2}{\nu^2}\epsilon_{\mu\nu\lambda\sigma}q^\lambda(p\cdot q s^\sigma - s\cdot q p^\sigma) \\
&- b_1 r_{\mu\nu} + \frac{1}{6}b_2(s_{\mu\nu}+t_{\mu\nu}+u_{\mu\nu}) \\
&+ \frac{1}{2}b_3(s_{\mu\nu}-u_{\mu\nu}) + \frac{1}{2}b_4(s_{\mu\nu}-t_{\mu\nu})
\end{aligned}
$$

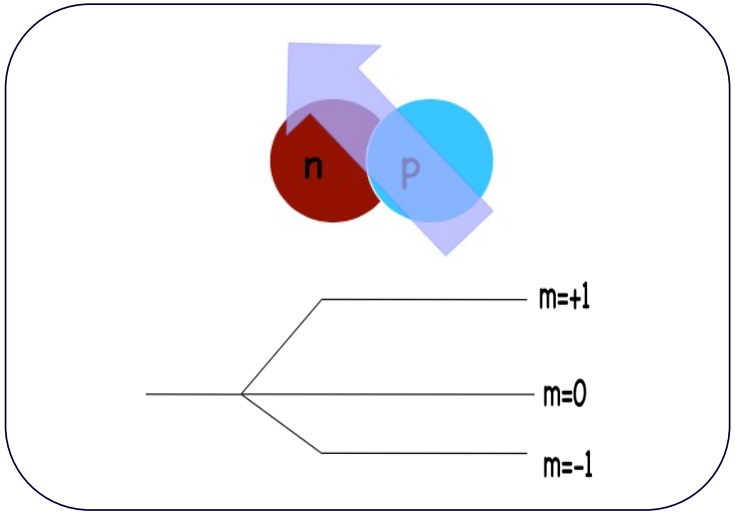
difference of spin averaged parton distributions
of a m=0 and m=1 nuclear target

$$b_1(x) = \frac{q^0(x) - q^1(x)}{2}$$

Hoodbhoy, Jaffe & Manohar (1989)
Interpretation in Parton model

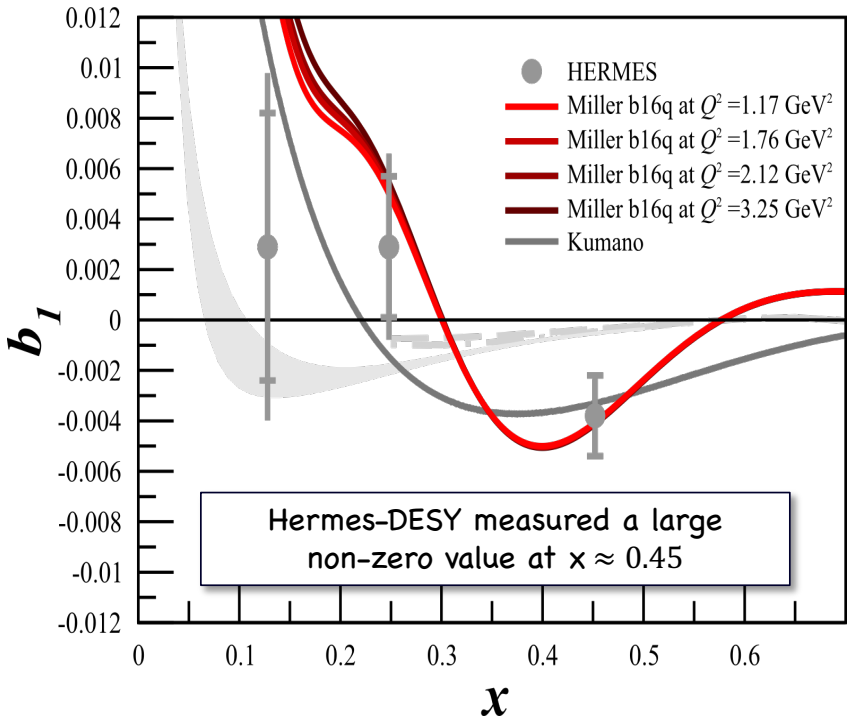


DIS (probing partons)



but depends on the Nuclear Spin State

Conventional Nuclear Physics can not reproduce HERMES Data



Khan & Hoodbhoy, PRC 44 ,1219 (1991) : $b_1 \approx O(10^{-4})$
Relativistic convolution model with binding

Umnikov, PLB 391, 177 (1997) : $b_1 \approx O(10^{-3})$
Relativistic convolution with Bethe-Salpeter formalism

W. Cosyn, Y. Dong, S. Kumano, M. Sargsian PRD95 (2017) 074036
Standard Convolution description

"new mechanism [is needed] to explain large differences between current data and our theoretical results"

"room for more advanced or exotic mechanisms playing an important role"

Cosyn *et. al* **PRD95 (2017) 074036**

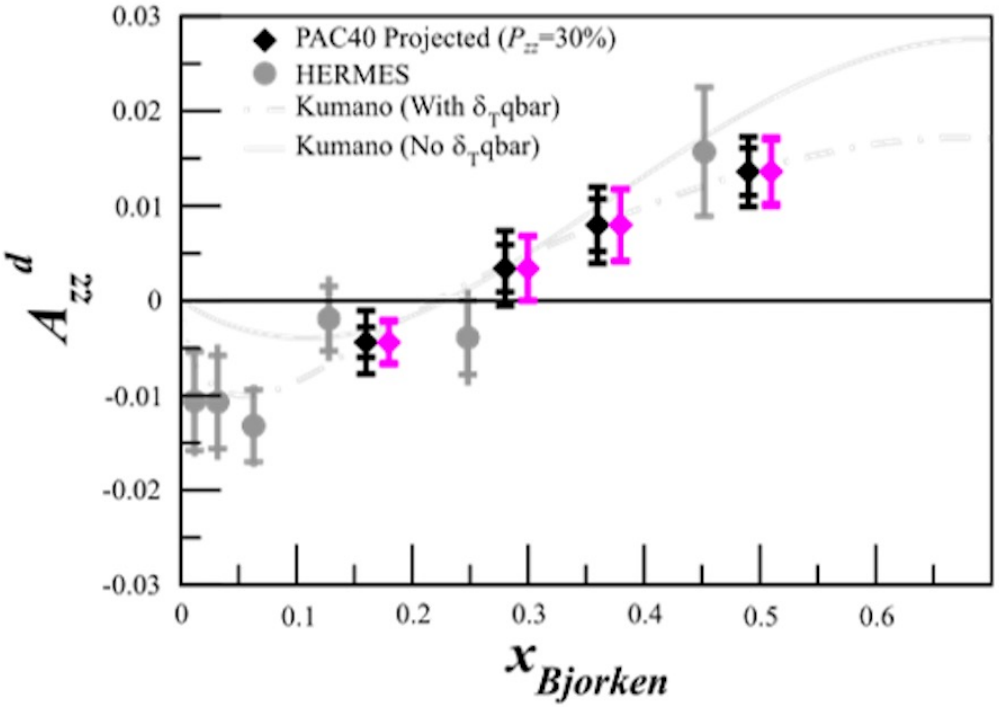
G. Miller PRC89 (2014) 045203
Pionic and Hidden-Color, Six-Quark Contributions to the Deuteron b1 Structure Function

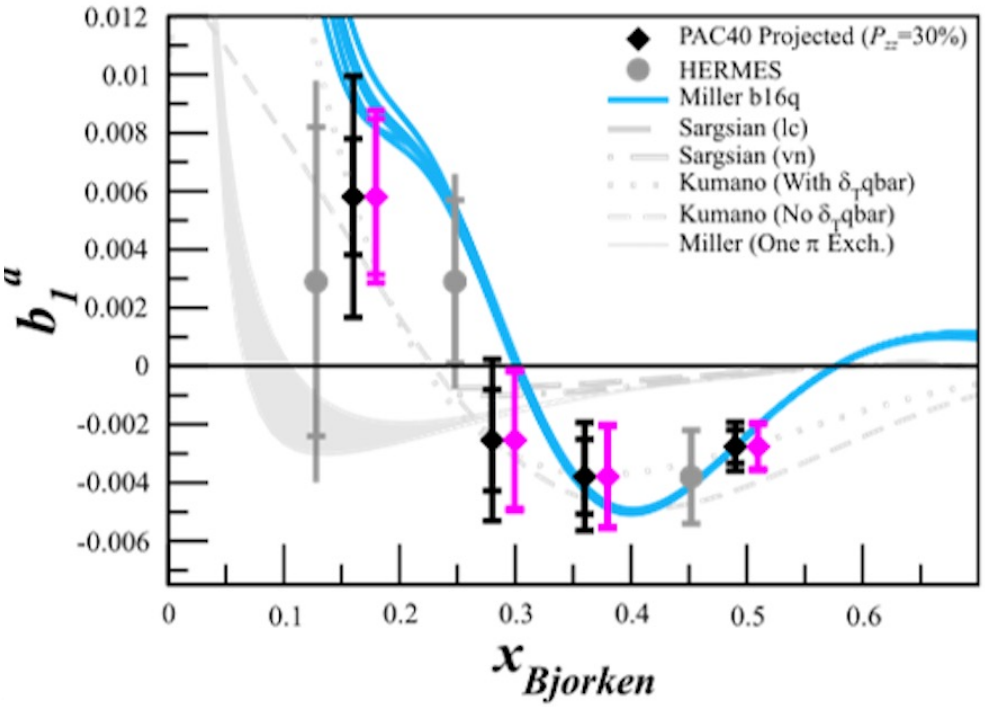
6-quark probability needed to (P_{6Q} = 0.0015) is small enough that it does not violate conventional nuclear physics.

b_1 Projected Results

Measured Observable

$$b_1 = -\frac{3}{2} F_1^d A_{zz}$$



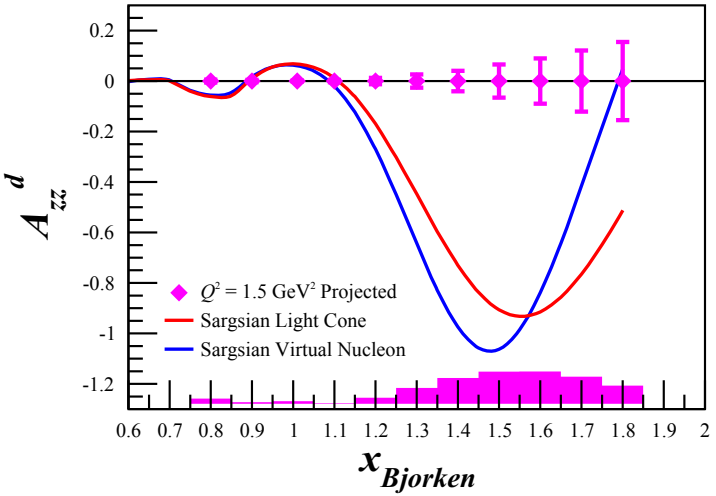


Projections based on

- PAC40 Projected (P_{zz}=30%, I=115nA)
- New Projected (P_{zz}=26%, I=85nA) With frequent spin flips

E12-15-005: A_{ZZ} Experiment

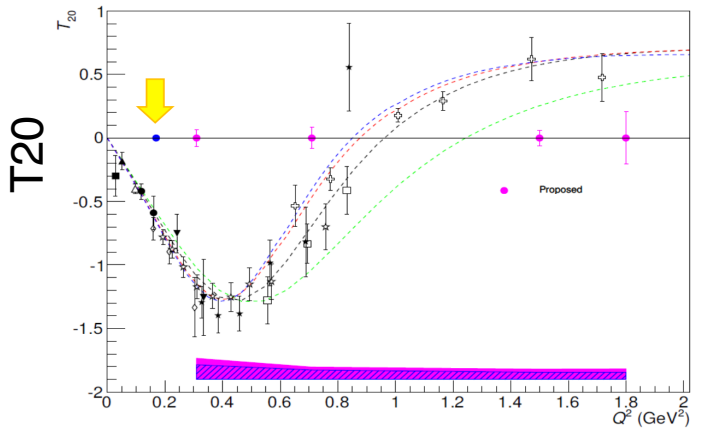
A_{zz} in the x>1 Region



Very Large Tensor Asymmetries predicted

Sensitive to the S/D-wave ratio in the deuteron wave function

4σ discrim between hard/soft wave functions
6σ discrim between relativistic models



"further explores the nature of short-range pn correlations, the discovery of which was one of the most important results of the 6 GeV nuclear program."

PAC44 Theory Report

CLAS APPROVED ANALYSIS OF RGC DATA

[Submitted on 27 Feb 2025 (v1), last revised 11 Jun 2025 (this version, v3)]

Spin 1 Transverse Momentum Dependent Tensor Structure Functions in CLAS12

Jiwan Poudel, Alessandro Bacchetta, Jian-Ping Chen, Dustin Keller, Ishara Fernando, Elena Long, David Ruth, Nathaly Santiesteban, Karl Slifer

We propose to analyze CLAS12 RG-C data to study the tensor transverse-momentum-dependent parton distribution functions (TMDs) on deuteron data. The deuteron is the lightest nucleus with spin-1, in essence a weakly bound system of two spin-1/2 nucleons. However, one of the most intriguing characteristics of the deuteron is that the tensor polarized structure provides direct access to the quark and gluon distribution of light nuclear system, which cannot be naively constructed from the proton and neutron. We will study the tensor polarized structure functions with the Semi-inclusive Deep Inelastic Scattering (SIDIS) eD \arrow eP_{h}X and Inclusive processes in the available data on deuterated ammonia (ND3) target. We will perform the first ever SIDIS analysis extraction of the tensor structure functions, which can be interpreted in term of completely unexplored tensor polarized TMDs. Our analysis will focus on the extraction of the tensor structure functions b1 from inclusive process, and F_{U(LL),T} and F^{cos 2\phi_{h}}_{U(LL)} from SIDIS. These last two structure functions carry information related to two tensor-polarized TMDs, f_{1LL} and h^{\perp}_{1LL}. These initial exploratory measurements of tensor-polarized structure functions will enable the first extraction of spin-1 TMDs and motivate more precise future measurements.

Subjects: **High Energy Physics - Phenomenology (hep-ph)**; High Energy Physics - Experiment (hep-ex)
Cite as: arXiv:2502.20044 **[hep-ph]**
(or arXiv:2502.20044v3 **[hep-ph]** for this version)
https://doi.org/10.48550/arXiv.2502.20044

Phd Students analyzing RGC deuteron data in preparation for b1/Azz

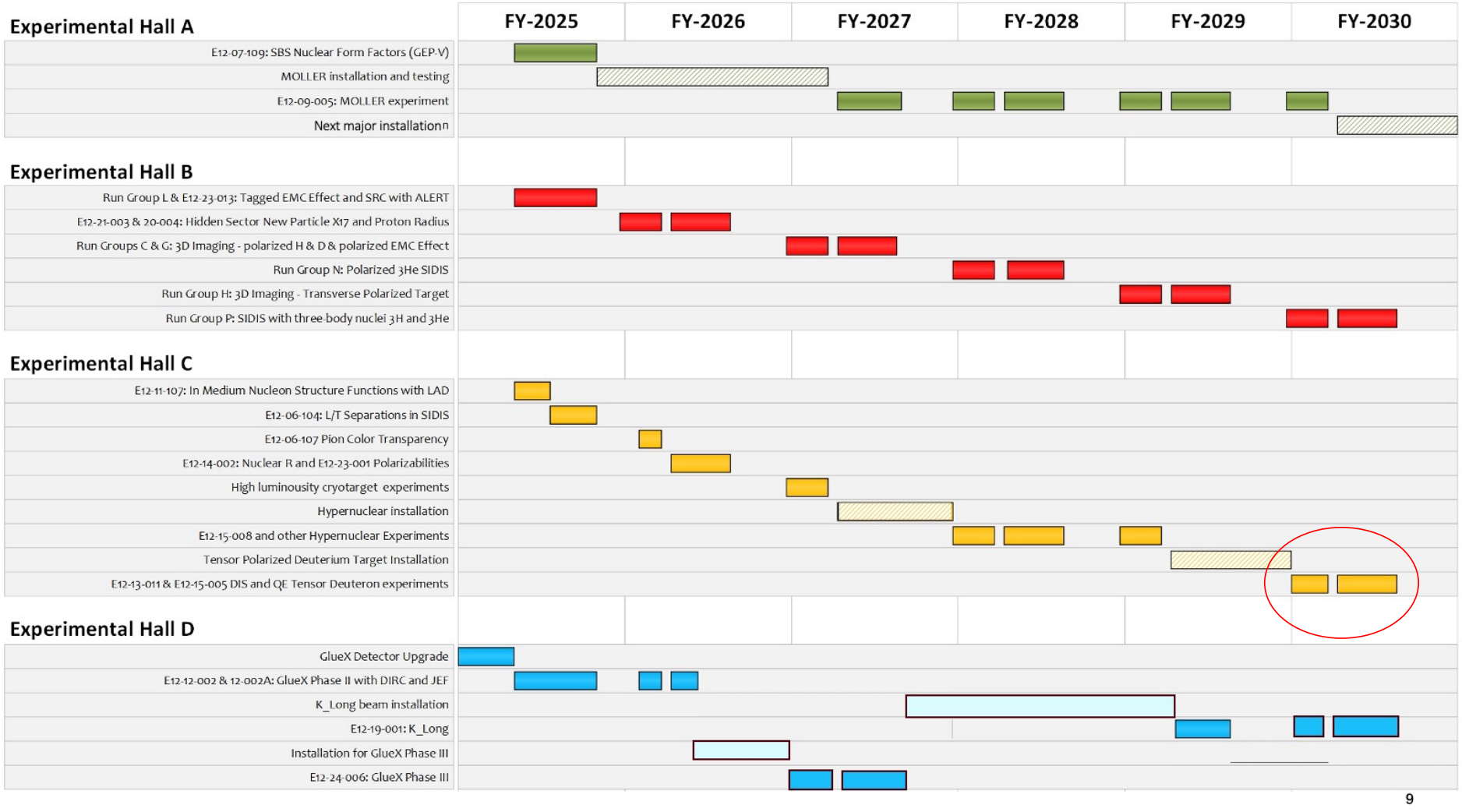
Chhetra Lama : Inclusive Quasi-elastic Tensor Asymmetry

M. Farooq : Inclusive DIS Tensor Asymmetry

Hector Chinchay : Semi-Inclusive DIS Tensor Asymmetry

Coordinated by Nathaly S.

Accelerator Schedule



D. Higinbotham
Nuclear Physics Experimental Schedule
July 21, 2025. PAC 53

Goals of this meeting

1) Assess progress made since 2023 (Jeopardy)

2) Set a specific goal date for the ERR

3) Advocate for the earliest possible Running

Group Photo at 1st coffee break

Social Event

7:00 PM Monday

Tradition Brewing Company

700 Thimble Shoals Blvd
Newport News, VA 23606