Tensor Polarized ND3 Target
For Measuring Spin-1 Structure Functions

Spin 2023

Durham, NC

2023-09-27

Karl Slifer

University of New Hampshire

This Talk

Tensor Structure Functions

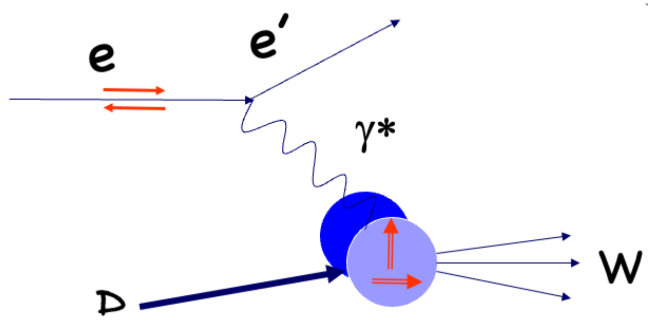
Tensor Asymmetry at high X_b

Experimental Update

Target Update

Planned Experiments

b_1 structure function



$$
\begin{aligned}
W_{\mu\nu} &= -F_1 g_{\mu\nu} + F_2 \frac{P_\mu P\nu}{\nu} \\
&\quad + 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) \\
&\quad - b_1 r_{\mu\nu} + \frac{1}{6} b_2 (s_{\mu\nu} + t_{\mu\nu} + u_{\mu\nu}) \\
&\quad + \frac{1}{2} b_3 (s_{\mu\nu} - u_{\mu\nu}) + \frac{1}{2} b_4 (s_{\mu\nu} - t_{\mu\nu})
\end{aligned}
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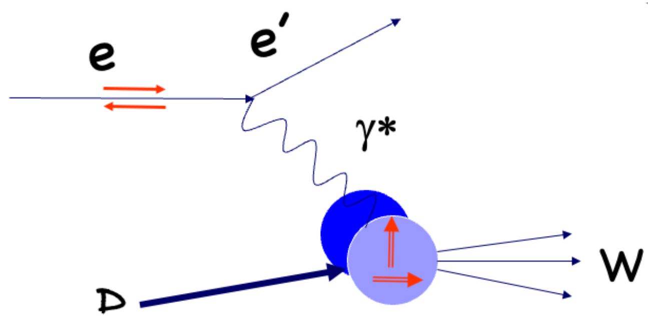
b_1 structure function



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Tensor Structure Functions

	Nucleon	Deuteron
F_1	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^{1/2} + q_{\downarrow\uparrow}^{-1/2}]$	$\frac{1}{3}\sum_q e_q^2[q_\uparrow^1 + q_\uparrow^{-1} + q_\uparrow^0]$
g_1	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^{1/2} - q_\downarrow^{-1/2}]$	$\frac{1}{2}\sum_q e_q^2[q_\uparrow^1 - q_\downarrow]$
b_1	$\cdots$	$\frac{1}{2}\sum_q e_q^2[q^0 - q^1]$

Leading Twist

Tensor Structure Functions

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b_1	$\cdots$	$\frac{1}{2}\sum_q e_q^2[q^0 - q^1]$

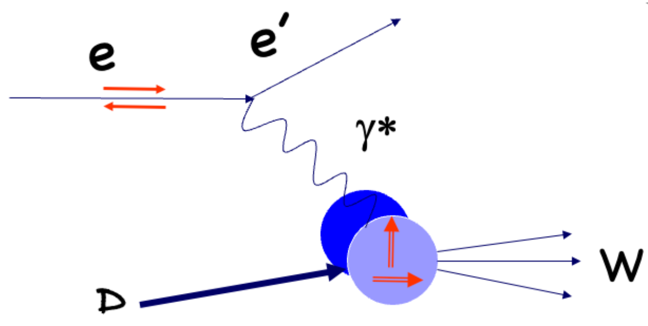
Leading Twist

b_2 : related to b_1 by A Callan-Gross relation

b_4 : higher twist, kinematically suppressed for a longitudinally polarized target.

b_3 : higher twist, like g_2

b_1 structure function



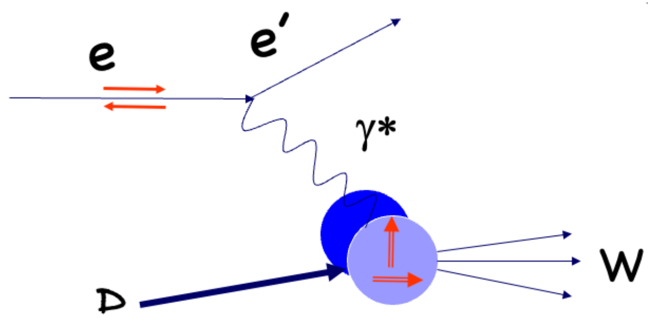
difference of spin averaged parton distributions
of a m=0 and m=1 nuclear target

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

Hoodbhoy, Jaffe & Manohar (1989)

Interpretation in Parton model

b_1 structure function



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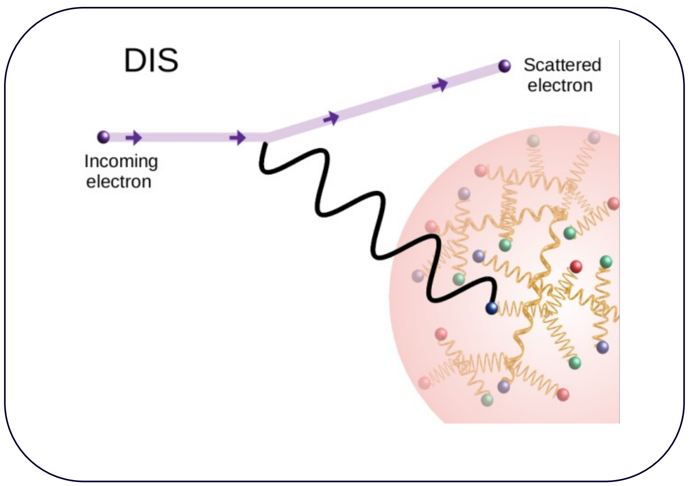
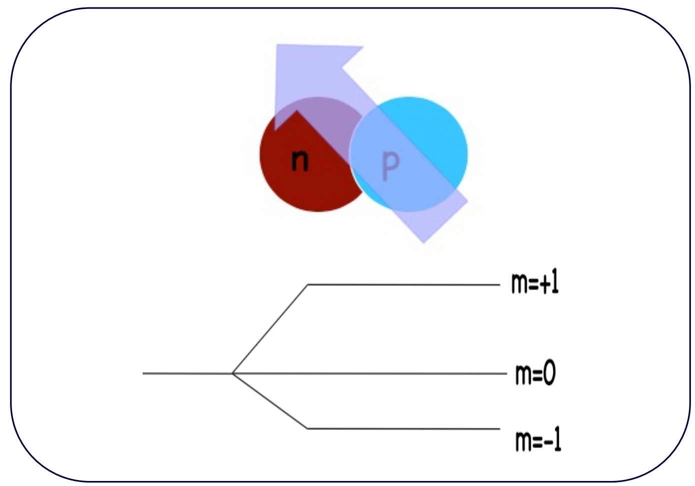


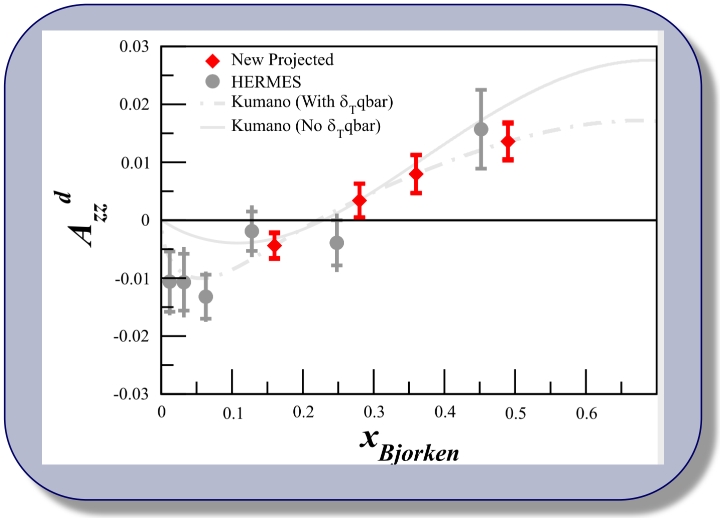
DIS (probing partons)



but depends on the Nuclear Spin State

E12-13-011: Deuteron DIS Structure Function b_1

KS, Chen, Long, Kalantarians, Keller, Rondon, Santiesteban, Solvignon



Measurement

$0.15 < x < 0.55$ $\quad 1.2 < Q^2 < 3.81$ GeV^2

P_{zz}= 26% with 85nA polarized beam.

36 PAC Days + 12 Days overhead

First tensor poltarg experiment at Jlab

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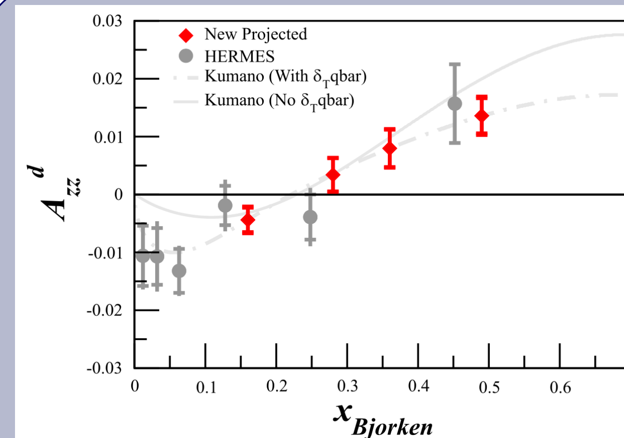

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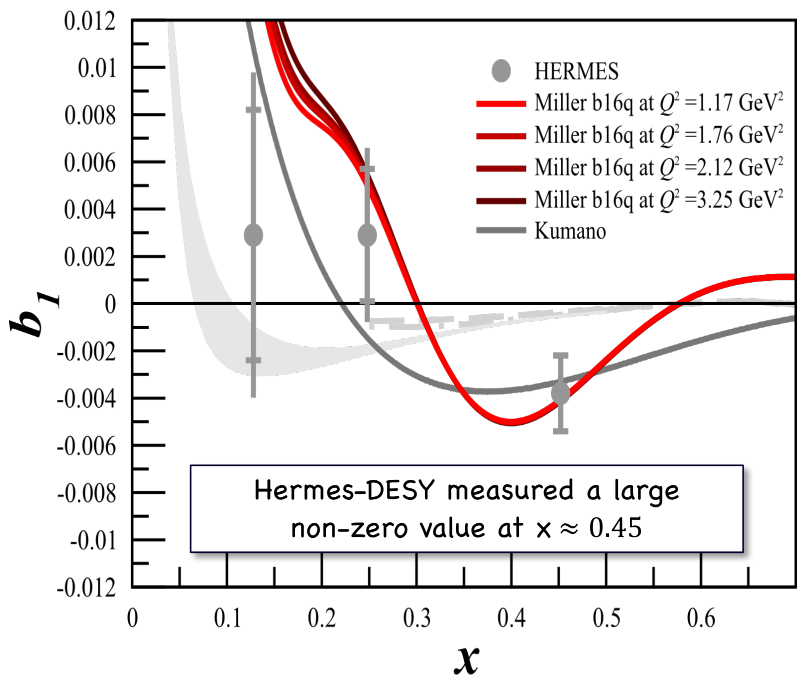
Technical

Fully approved after C_1 Conditional Review in 2022
Passed Jeopardy Review in 2023
New tensor polarized ND_3 target (UVa,UNH)
New JLab based polarizing magnet

Scientific Impact

Depends on partonic distribution & nuclear configuration
Uniquely sensitive to non-nucleonic components of
the Deut wave function: 6 quark & Hidden Color
Gluonic Contributions to Nuclear Structure
Crucial guidance for future Jlab, EIC, FNAL, NICA exps.

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.

Observable: Tensor Asymmetry Azz

$$A_{zz} = \frac{2}{fP_{zz}}\frac{\sigma_Q - \sigma_0}{\sigma_0}$$

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

At leading twist

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

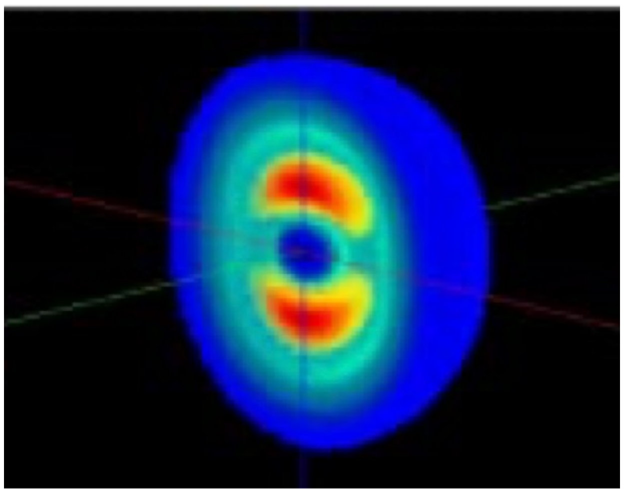
<u>New Information</u>

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

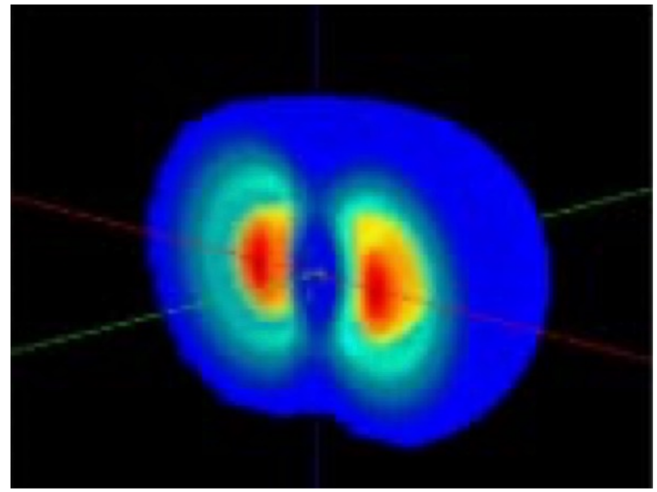
This reduces the sensitivity to slow drifts by about $1/\sqrt{24}$

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



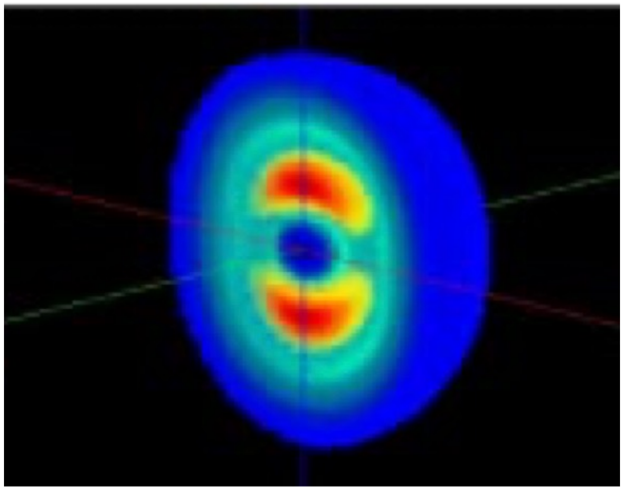
M = ± 1

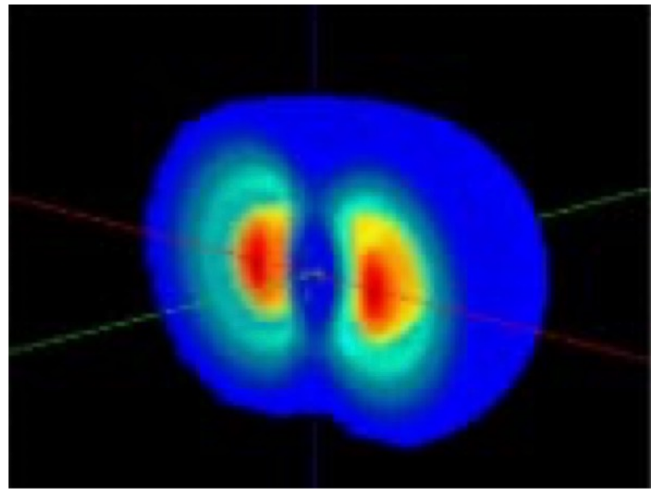


JLAB-THY-01-6

M = 0

Tensor polarization allows control of the nuclear spatial configuration

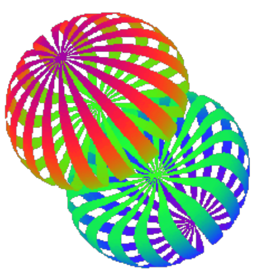


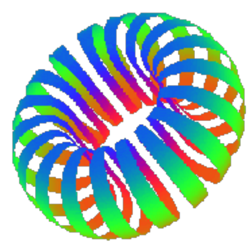


JLAB-THY-01-6

$M = \pm 1$

$M = 0$





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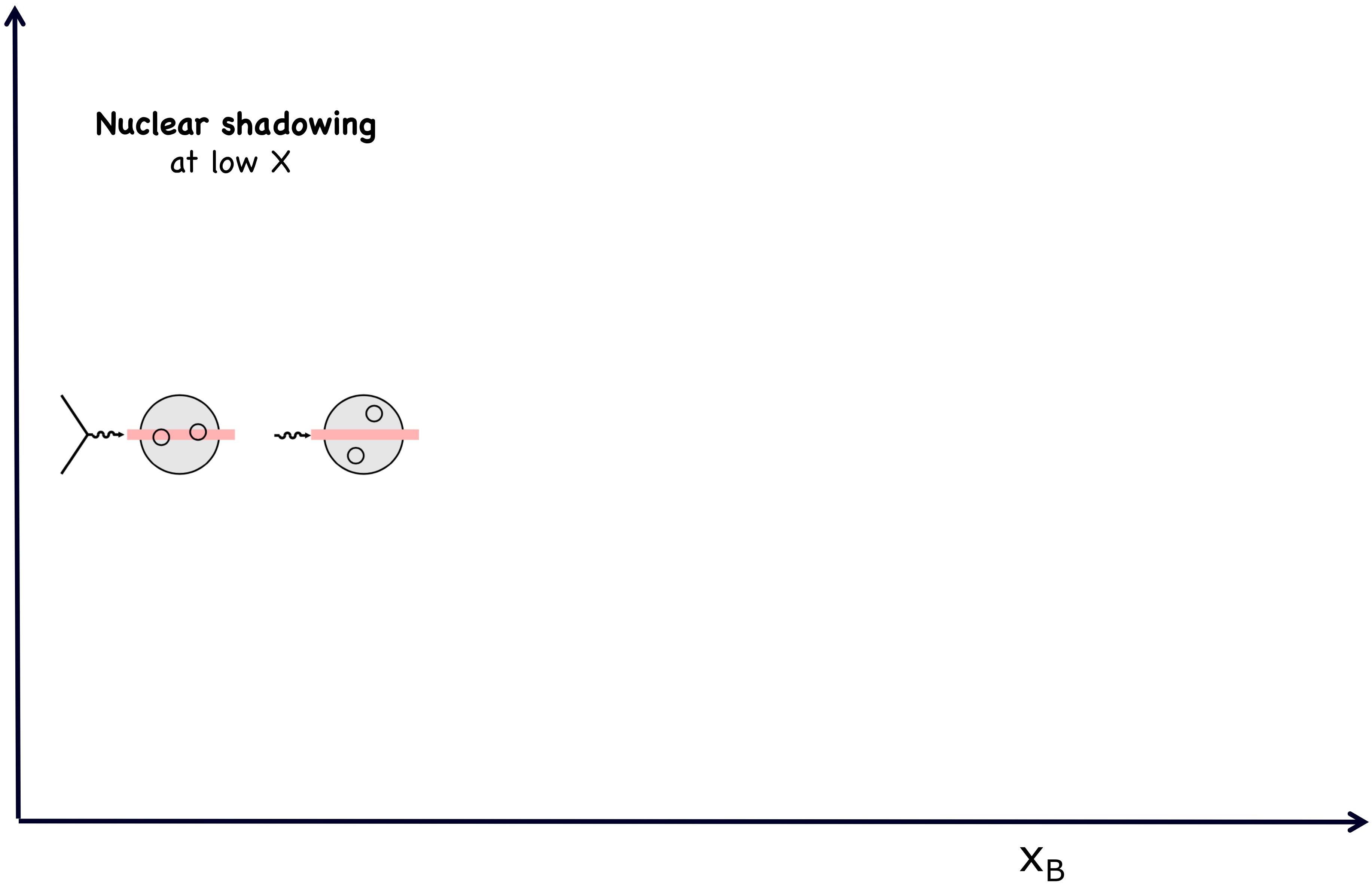
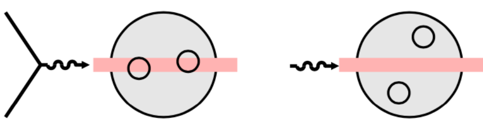
Measuring A_{zz} over a broad range in x gives access to :

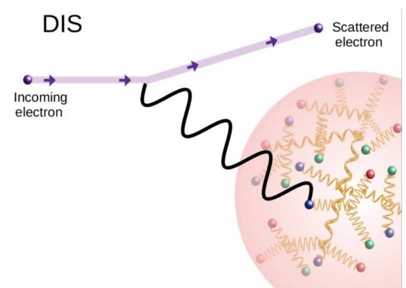


Measuring A_{zz} over a broad range in x gives access to :

Nuclear shadowing
at low X



Tensor structure functions
& momentum distributions in nucleus
Hidden color



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

x_B

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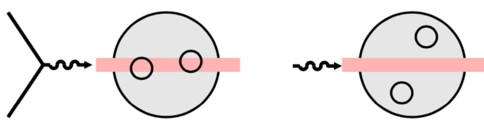

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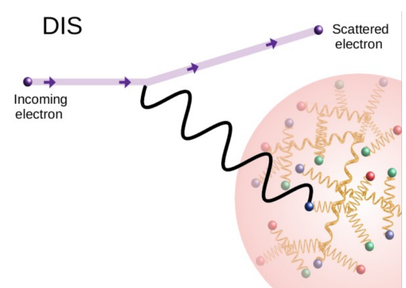
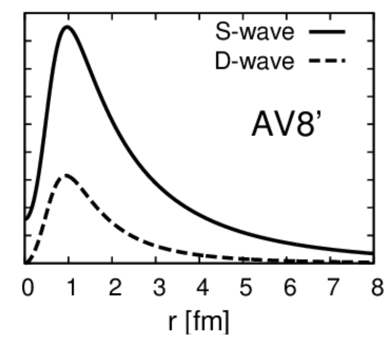


$$b_1(x) = \frac{q^0(x) - q^1(x)}{2}$$

S/D Wave components
SRCs at large x>1



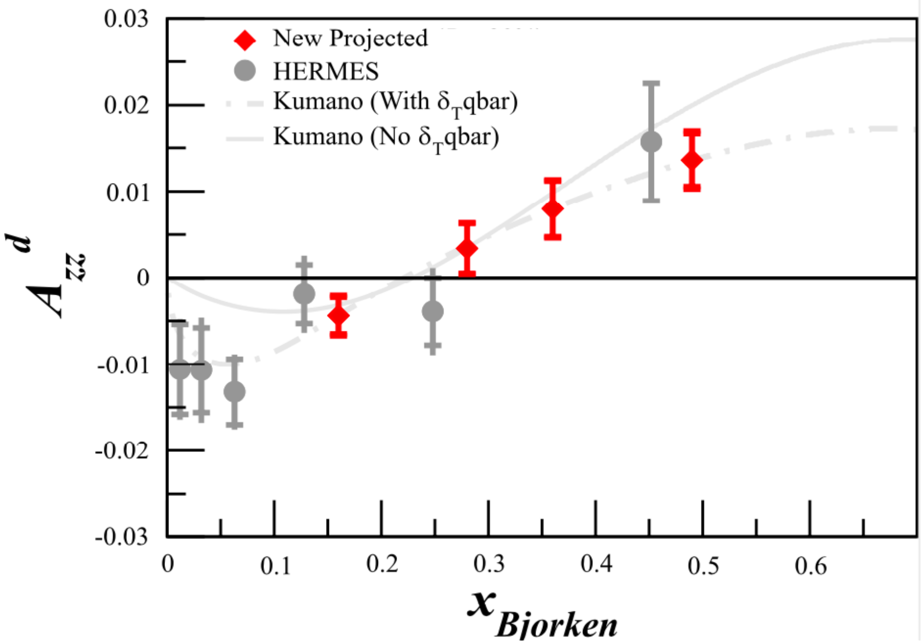
$D \to w(k)$

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

x_B

Projected Results

Measured Observable



<u>Projections based on</u>

P_{zz} = 26%

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36 PAC Days + 12 Days overhead

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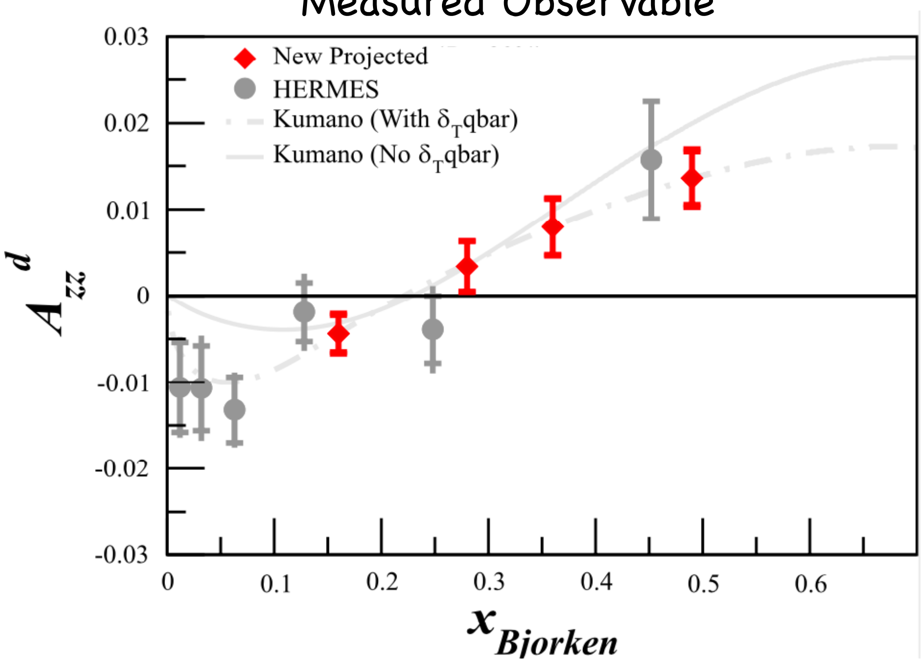

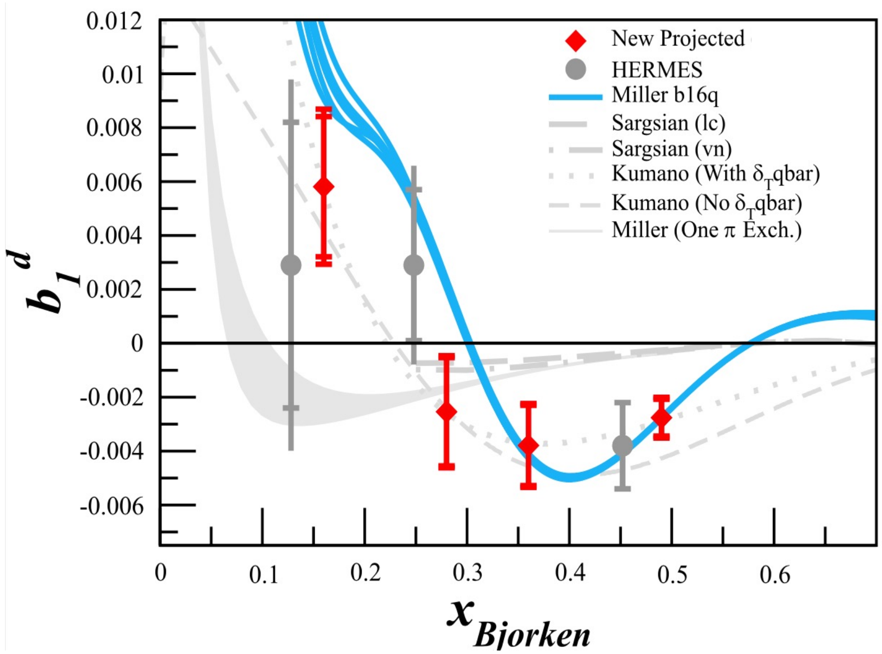

$$b_1 = -\frac{3}{2} F_1^d A_{zz}$$

<u>Projections based on</u>

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$$\int b_1(x)dx = 0$$

Close-Kumano Sum Rule

Gluon Contribution to Tensor Structure

$$\int b_1(x)dx = 0$$

$$\int x b_1(x)dx = 0$$

Efremov and Teryaev (1982, 1999)

Gluons (spin 1) contribute to both moments

Quarks satisfy the first moment, but

Gluons may have a non-zero first moment!

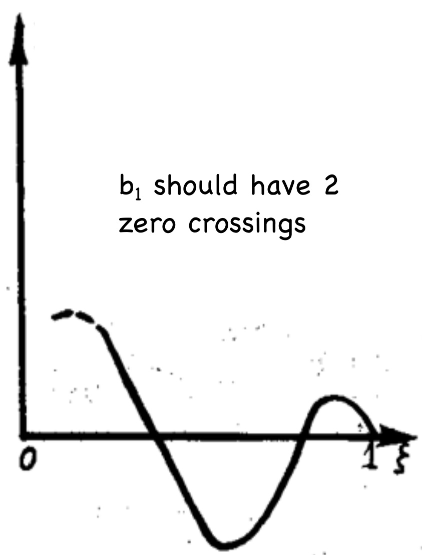

Рис. 1

Efremov, Teryaev, JINR PreprintR2-81-857(1981), Yad. Phys. 36, 950 (1982)
A.V. Efremov, O. V. Teryaev JINR-E2-94-95 (1999)
Jaffe, Manohar Phys.Lett. B223 (1989) 218

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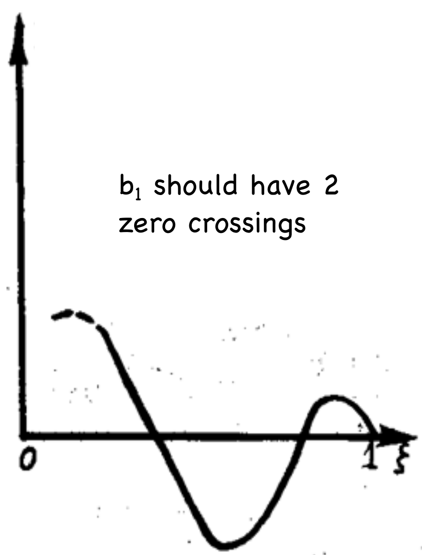

Рис. 1

Efremov and Teryaev (1982, 1999)

Gluons (spin 1) contribute to both moments

Quarks satisfy the first moment, but

Gluons may have a non-zero first moment!

2nd moment more likely to be satisfied experimentally since the collective glue is suppressed compared to the sea

Study of b_1 allows to discriminate between deuteron components with different spins (quarks vs gluons)

Efremov, Teryaev, JINR PreprintR2-81-857(1981), Yad. Phys. 36, 950 (1982)
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There is an active theoretical discourse about these questions, with several new results appearing in the last years, and the experiment is supported by a coherent community, closely connected to the physics of the EMC effect and other topics in nuclear physics. ***The experiment is therefore very well motivated.***

Once this pioneering experiment has been performed, a measurement of the x dependence of b_1 at fixed Q^2, and/or the Q^2 dependence at fixed x (even if over a more limited kinematic range than the one here) should be considered as a next step.

JLAB Theory Report 2023

I remain strongly supportive of these tensor measurements. ***The measurement of the b1 structure function remains as a very powerful, possibly unique, probe of exotic (non nucleon-nucleon) components of the deuteron wave function.*** *Theoretical calculations, performed after my paper, have again found that nucleon-nucleon components alone cannot reproduce the previously measured data points.*

G. Miller 2023

From the late 2020's to the beginning of 2030's, the b1 and tensor-polarized parton distribution functions will be investigated at other accelerator facilities, such as Fermilab, NICA, LHCspin, EIC, and EicC by using polarized deuteron targets and polarized deuteron beams. The JLab b1 experiment should play the leading role in these experimental projects, and ***we believe that the JLab experiment will create a new unique field in hadron physics.***

S. Kumano 2023

This structure function is zero in scattering from a free static pn pair and thus uniquely sensitive to nuclear effects.

There are plans to measure tensor polarized observables in hadronic collisions (at Fermilab and at future facilities at LHC and NICA) and in DIS at the EIC

The scientific case remains strong

These pioneering efforts may provide a foundation for new experiments at Jefferson Lab and elsewhere

JLAB PAC51 Report July 2023

*"**the UVa and UNH groups** have made **substantial strides beyond previous work**, particularly in the analysis of the deuteron lineshape following RF manipulation."*

2022 Jlab Conditional Review → Full Approval

Brief Sample of Recent Theoretical Developments

QCD hidden-color hexadiquark in the core of nuclei

Jennifer Rittenhouse West[a,b,c,*], Stanley J. Brodsky[c], Guy F. de Téramond[d], Alfred S. Goldhaber[e], Iván Schmidt[f]

A New Structure in the Deuteron

Misak M. Sargsian and Frank Vera
Florida International University, Miami, Florida 33199, USA
(Dated: August 22, 2022)

PHYSICAL REVIEW D 95, 074036 (201

Tensor-polarized structure function b_1 in the sta description of the deuteron

W. Cosyn,[1] Yu-Bing Dong,[2,3] S. Kumano,[4,5] and

Deep-inelastic electron-deuteron scattering with spectator nucleon tagging at the electron-ion collider. Extracting free nucleon structure

Alexander Jentsch,[1] Zhoudunming Tu,[1,2] and Christian Weiss[3]

On the physics potential to study the gluon deuteron at NICA SPD

A. Arbuzov et al.

Progress in Particle and Nuclear Physics **119** 103858 (2021)

PHYSICAL REVIEW C 95, 044001 (2017)

Factorization breaking of A_d^T for polarized deuteron targets in a relativistic framework

Sabine Jeschonnek[1] and J. W. Van Orden[2,3]

Twist-2 relation and sum rule for tensor-polarized parton distribution functions of spin-1 hadrons

S. Kumano and Qin-Tao Song

J. High Energ. Phys. **2021** 141 (2021)

Transverse Angular Momentum Sum Rule

O. Alkassasbeh, M. Engelhardt, S. Liuti and A. Rajan (2022)

eron polarizations in the proton-deuteron Drell-Yan process for ng the gluon transversity

ano and Qin-Tao Song

PHYSICAL REVIEW D 106, 114013 (2022)

Spatial densities of momentum and forces in spin-one hadrons

Adam Freese[1,*] and Wim Cosyn[2,3,†]

[1]Department of Physics, University of Washington, Seattle, Washington 98195, USA
[2]Department of Physics, Florida International University, Miami, Florida 33199, USA
[3]Department of Physics and Astronomy, Ghent University, B9000 Gent, Belgium

Transversity generalized parton distributions for the

W. Cosyn and B. Pire

Equation-of-motion and Lorentz-invariance relations for tensor-polarized parton distribution functions of spin-1 hadrons

S. Kumano[a,b], Qin-Tao Song[c,d,*]

Exposing novel quark and gluon effects in nuclei

I C Cloët, R Dupré, S Riordan, W Armstrong, J Arrington, W Cosyn, N Fomin, A Freese, S Fucini, D Gaskell, C E Keppel, G A Miller, E Pace, S Platchkov, P E Reimer, S Scopetta, A W Thomas, and P Zurita

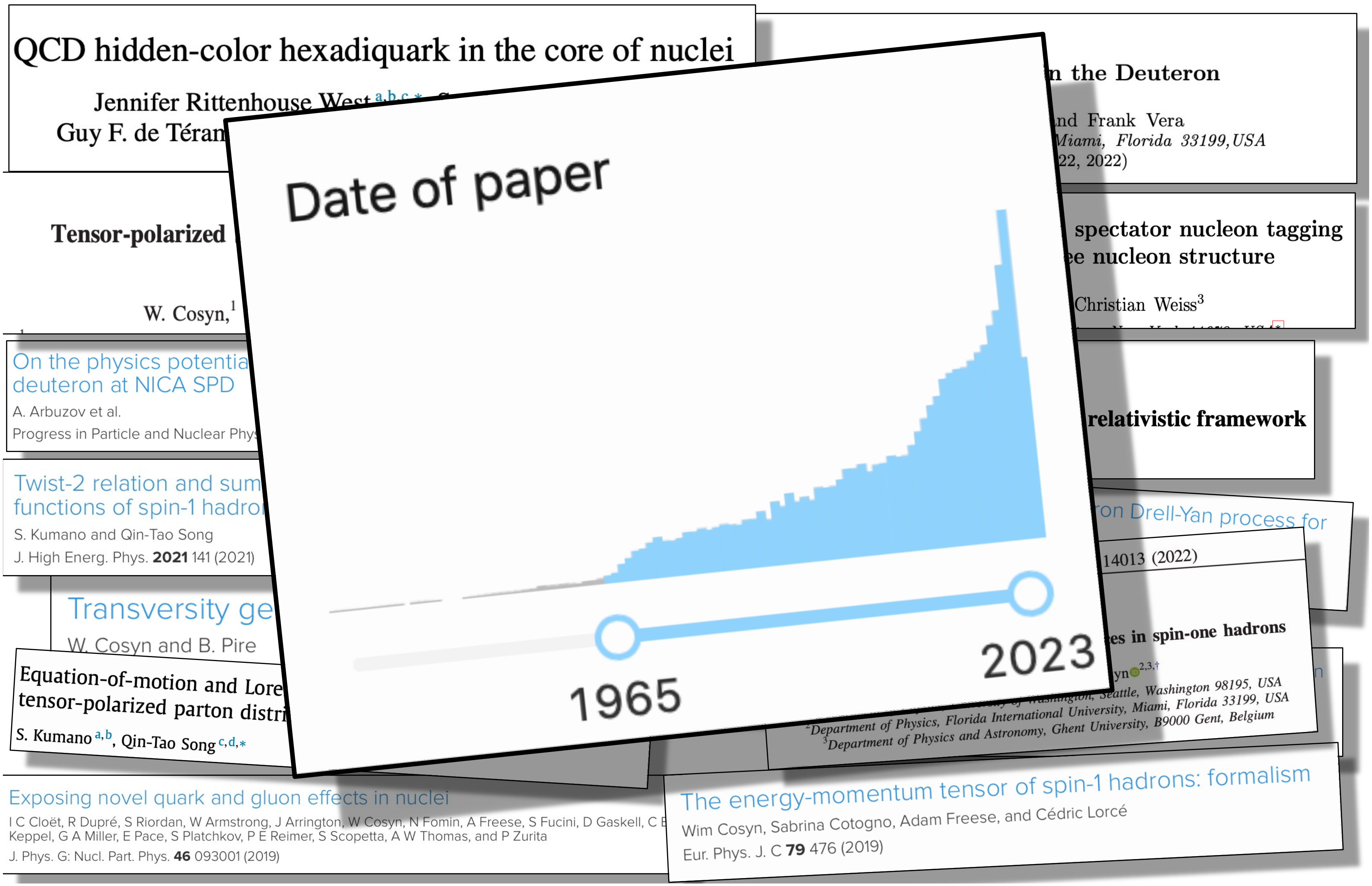
J. Phys. G: Nucl. Part. Phys. **46** 093001 (2019)

The energy-momentum tensor of spin-1 hadrons: formalism

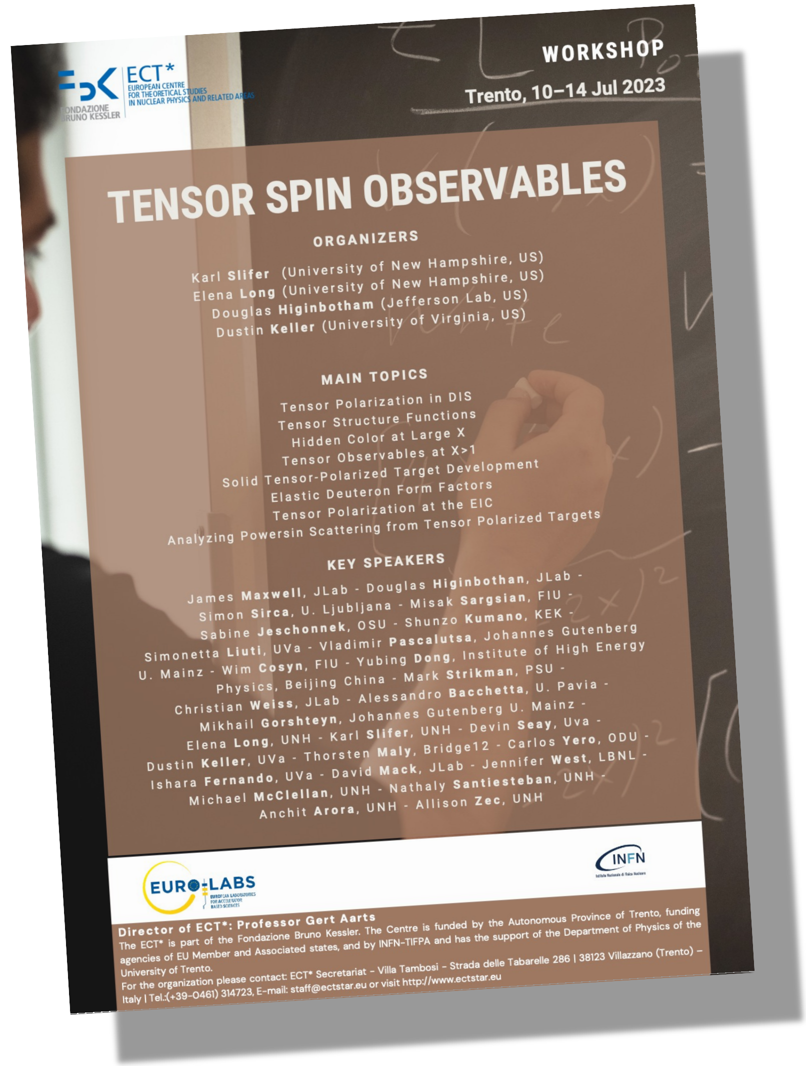
Wim Cosyn, Sabrina Cotogno, Adam Freese, and Cédric Lorcé

Eur. Phys. J. C **79** 476 (2019)

Brief Sample of Recent Theoretical Developments



Collaboration Status



<u>Collaboration</u>

- 50 active members of b_1/Azz collaboration
- 14 Institutions
- 10 PhD students from 3 different universities
- 2 Active Post-Docs.
- 2 more committed to the experimental run
- In-line with previous poltarg efforts

<u>Activities</u>

- Active Group meets bi-weekly
- Preparing for ERR
- Tensor Workshop at ECT*
- Active Polarized target development
  - UVa target group
  - UNH target group
  - Jlab target group

<u>2022 Conditional Review → Full Approval</u>

<u>*2023 Jeopardy Review* → Scientific motivation remains strong</u>


TENSOR
SPIN OBSERVABLES
WORKSHOP
JULY 10–14, 2023
ECT*, TRENTO, ITALY
TOPICS:
• Tensor Polarization in DIS
• Tensor Structure Functions
• Hidden Color at Large x
• Tensor Observables in x>1
• Solid Tensor-Polarized Target Development
• Elastic Deuteron Form Factors
• Tensor Polarization at EIC
• Analyzing Powers in Scattering From Tensor-Polarized Targets
FIU FLORIDA INTERNATIONAL UNIVERSITY
Jefferson Lab
ORGANIZING COMMITTEE:
Douglas Higinbotham (JLab)
Dustin Keller (UVA)
Elena Long (UNH)
Karl Slifer (UNH)
INDICO.ECTSTAR.EU/EVENT/173

New Jlab Magnet

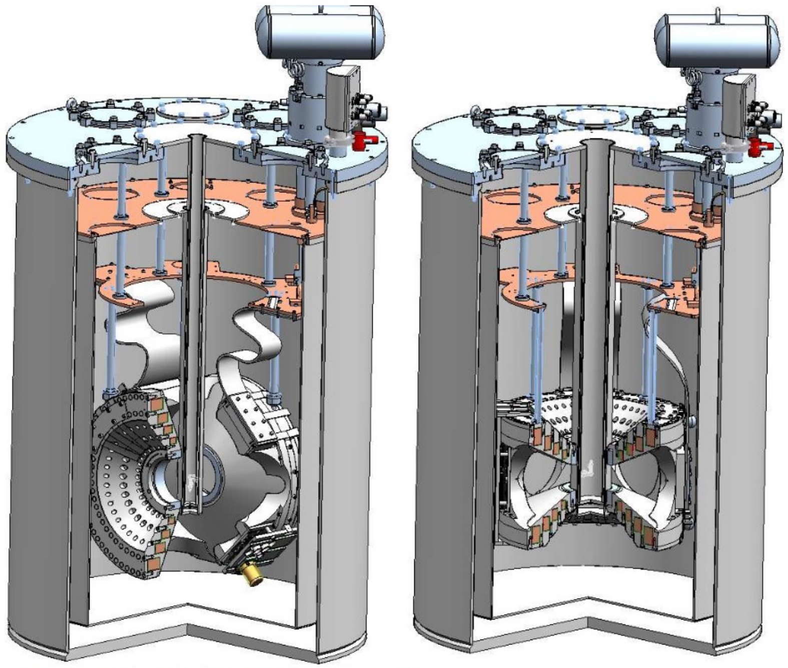


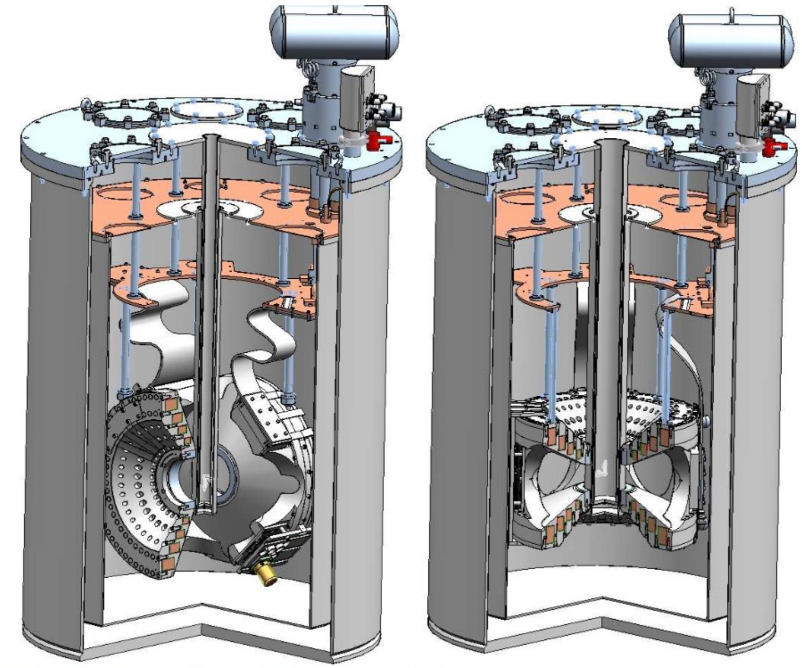
Figure 7: Cut-away of the 2 orientations for the magnet.

The new magnet will provide acceptances:
±35° for longitudinal polarization (30% smaller)
±25° for transverse polarization (67% larger)

Coils cooled by a 4K cryo pulse tube

See C. Keith / J. Maxwell

New Jlab Magnet & NMR System



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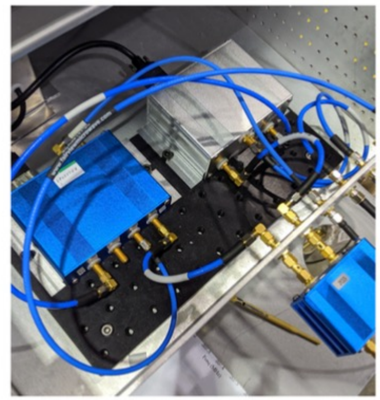

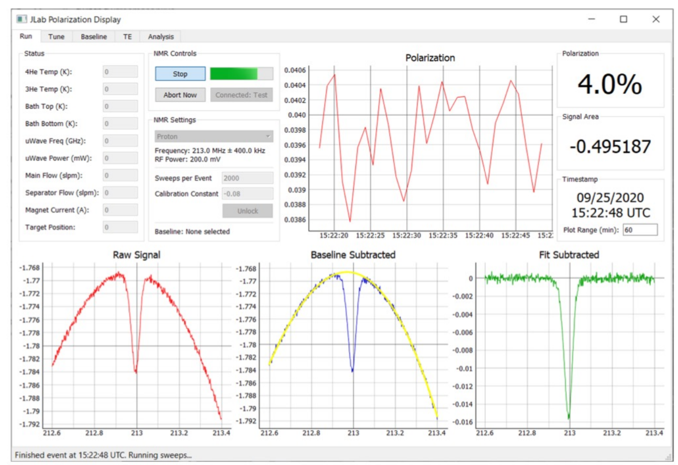

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Courtesy J. Maxwell

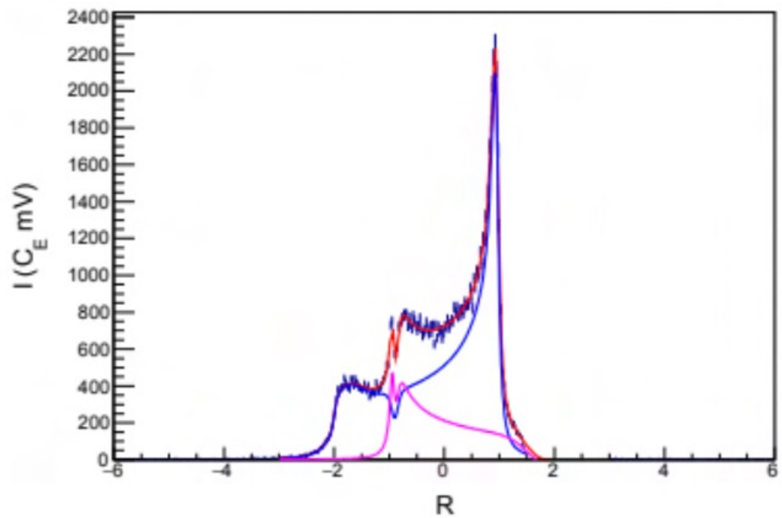
Tensor Enhancement

In 2014, tensor polarization P_{zz} of 10-20% was typical

$$\boxed{P_{ZZ} = 2 - \sqrt{4 - 3P_Z^2}}$$

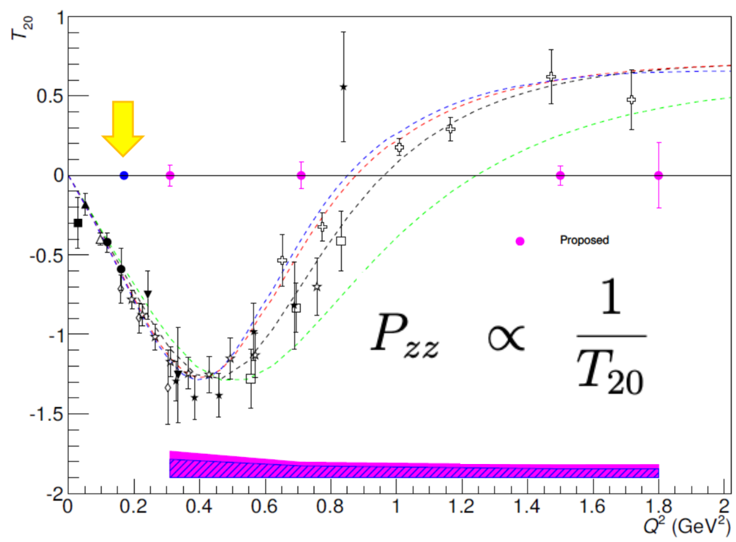
Now SS-RF techniques can be used to reliably achieve tensor polarizations of about 30%

Polarization Uncertainty



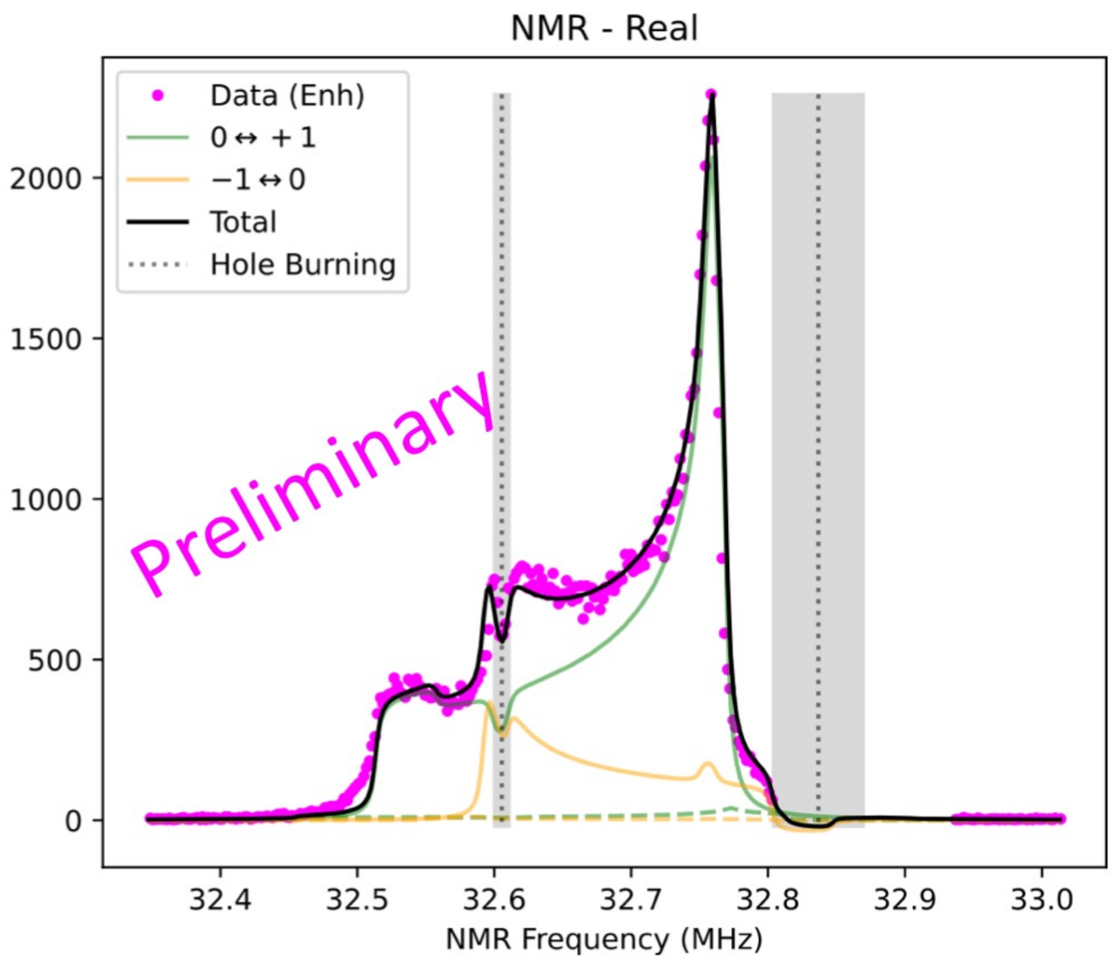
P_{zz} can be extracted from NMR Lineshape
with about 8-9% relative error

Courtesy D. Keller UVA



P_{zz} can be extracted from T_{20}
with about 8.6% relative error

Line Shape Analysis



Linefit courtesy Michael McClellan (UNH)

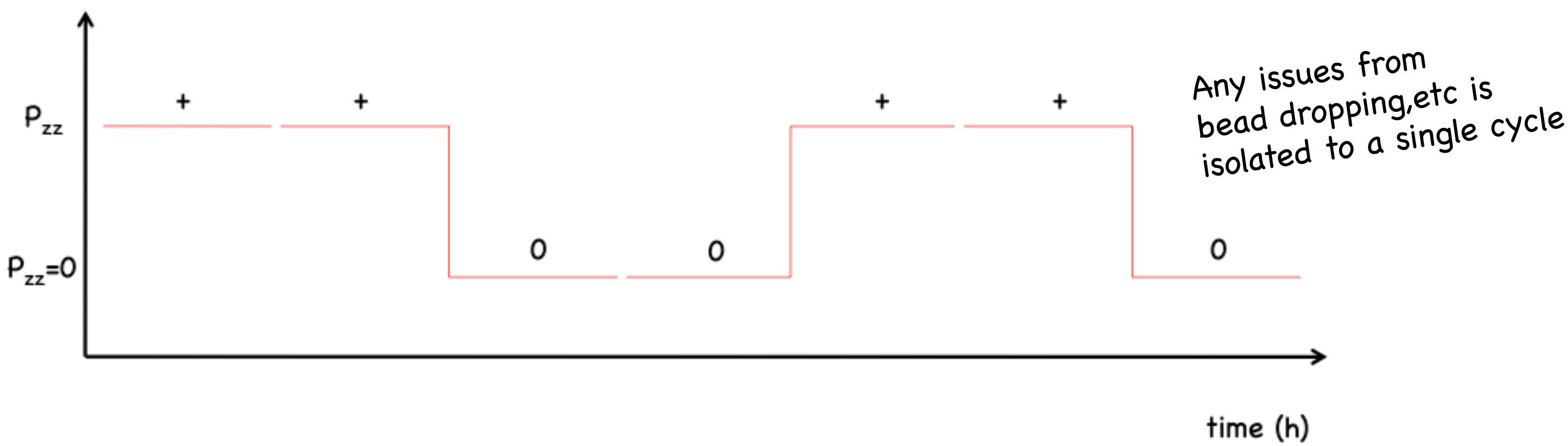
Switching Tensor Spin State

$$\boxed{A_{zz} = \frac{2}{fP_{zz}} \frac{\sigma_Q - \sigma_0}{\sigma_0}}$$

In the proposals we planned to transition between tensor enhanced state to unpolarized every 12 hours via DNP

SS-RF allows transition from tensor enhanced to unpolarized several times per hour reducing our sensitivity to slow drifts

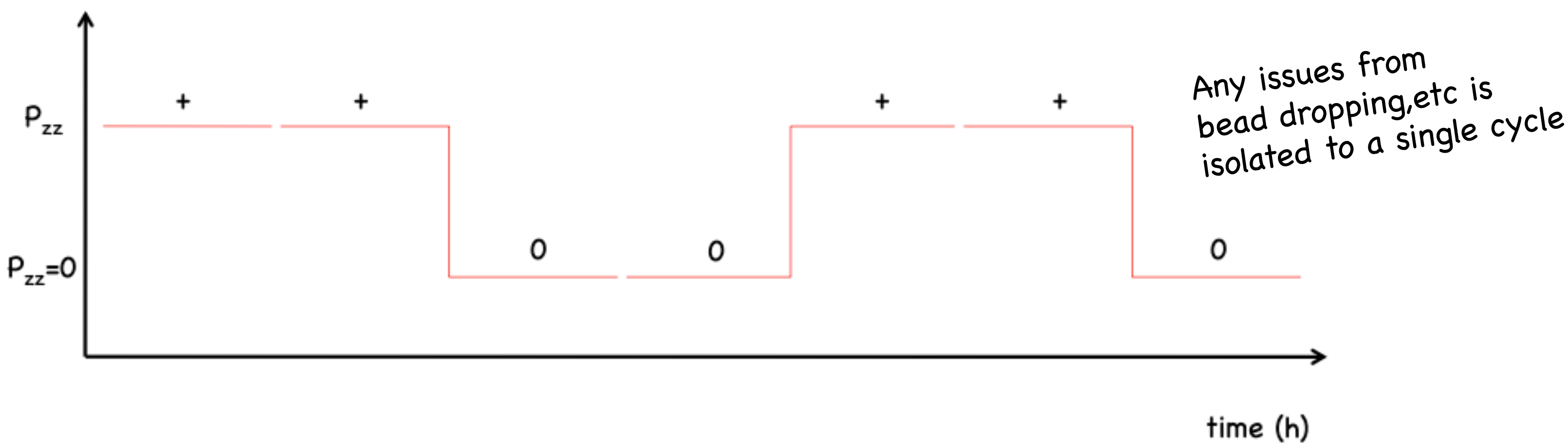
Switching Tensor Spin State



Proposal Assumption: Switching from unpolarized state to tensor state requires a DNP spin up.
So we would do this only once per day

We now know we can do this switch very rapidly via RF by filling/emptying the m=0 state
So we now plan to do this a few times per hour
Switching from Tensor enhanced to unpolarized requires a few seconds
Switching from unpolarized back to Tensor enhanced requires a few minutes.

Switching Tensor Spin State



Proposal Assumption: Switching from unpolarized state to tensor state requires a DNP spin up. So we would do this only once per day

We can now match the PAC conditions even for significantly lower current and P_{zz}

eg.: I=85 nA, P_{zz}=0.26 gives smaller total uncertainty than PAC approved conditions

Switching from unpolarized back to Tensor enhanced requires a few minutes.

This significantly reduces our sensitivity due to slow instrumental drifts

$$\text{Systematic} \propto \frac{1}{\sqrt{N}}$$

polarization state pairs

JLab Schedule

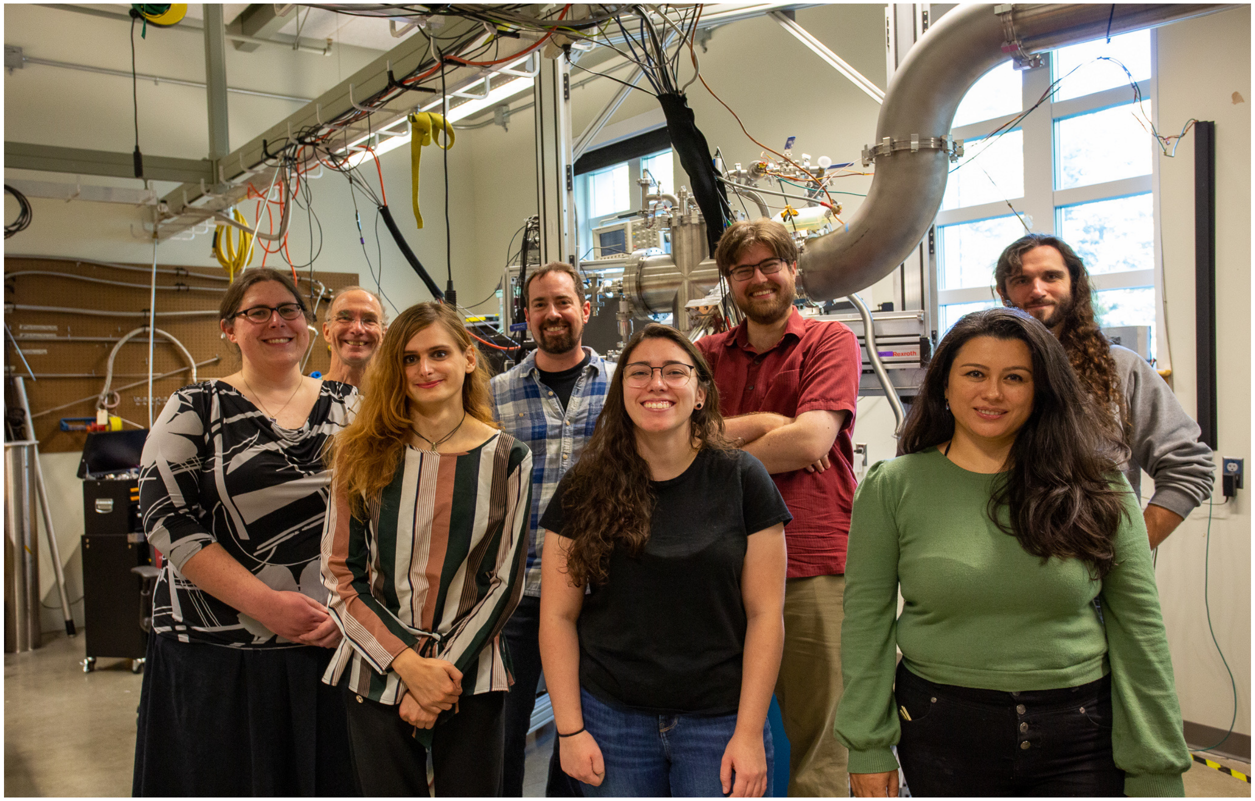
August 2022 : Conditional Status Removed, Full Approval

July 2023 : Passed Jeopardy Review of b_1/A_{zz}

2024-2025 : Experimental Readiness Review

>2026 : Run in Hall C

UNH Polarized Target Lab



3 faculty
-Slifer, Long, Santiesteban

2 post-doc
4 grad students:

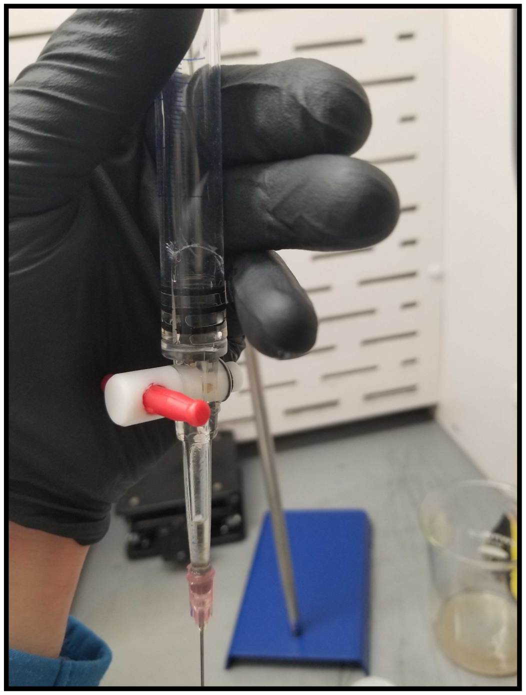
lots of undergrads

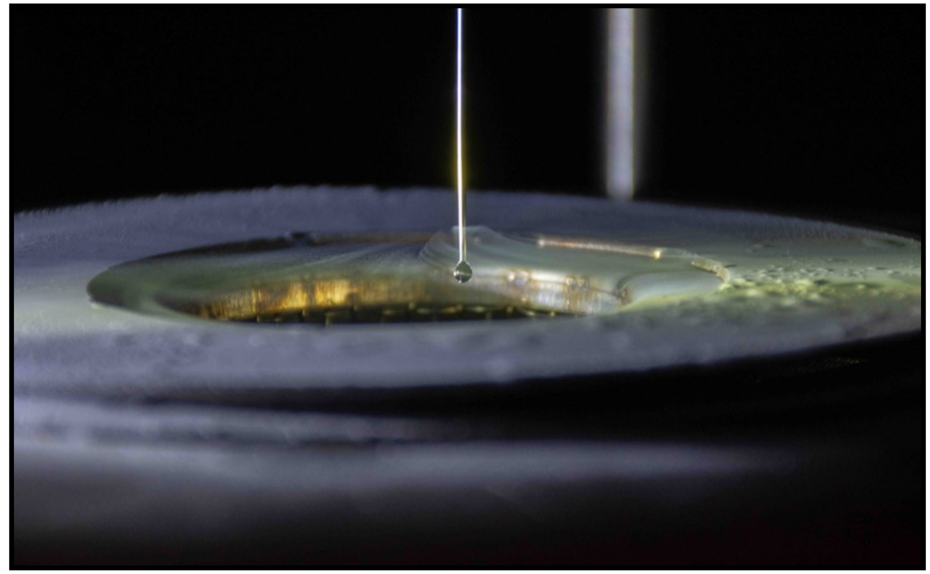
Projects

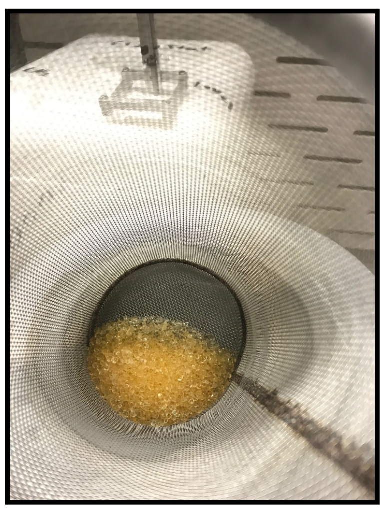
- Polarized Target Material Production & Labview controls
- Tensor Polarization R&D

See Talk of A. Zec

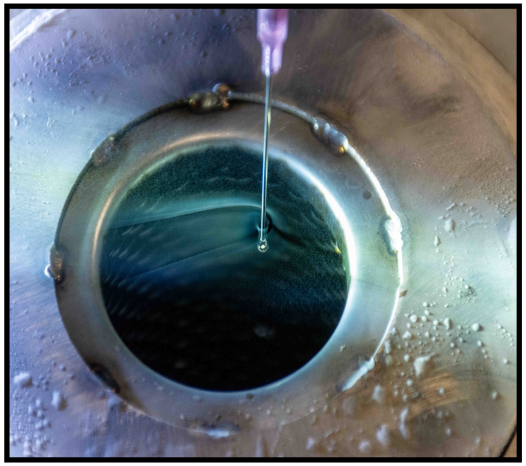
Target Material Production at UNH







Target Material Production at UNH

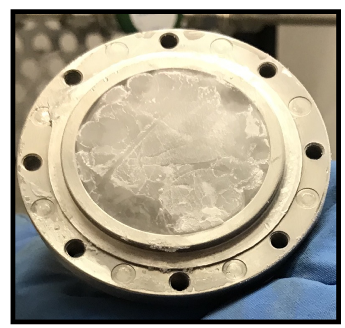


Butanol and other alcohols solidification

grade 5.5 NH_3 & ND_3

Chemical Doping

Rapid vs SlowCooling of NH_3



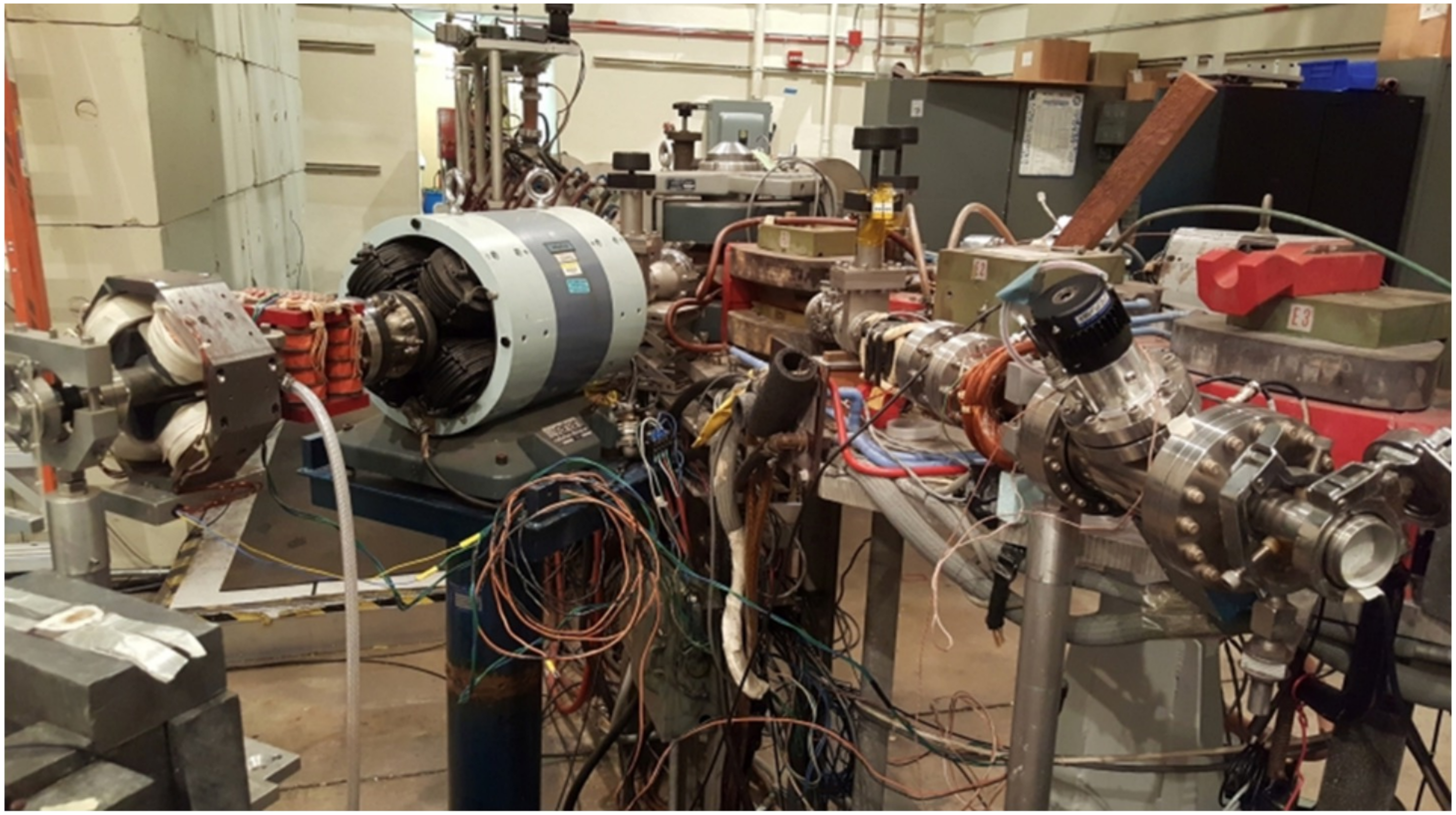
Target Material Production at UNH

-Dedicated **fume hood** for Handling Ammonia and other caustic/toxic materials

-**Vacuum GloveBox** allows for over/under-pressuring

-Primarily chemical doping of ammonia and alcohols for now.
But potential to do much more.

Material Irradiations



UVa led Irradiations (D. Keller) the 2nd week of October at MIRF
- -UNH students will be assisting

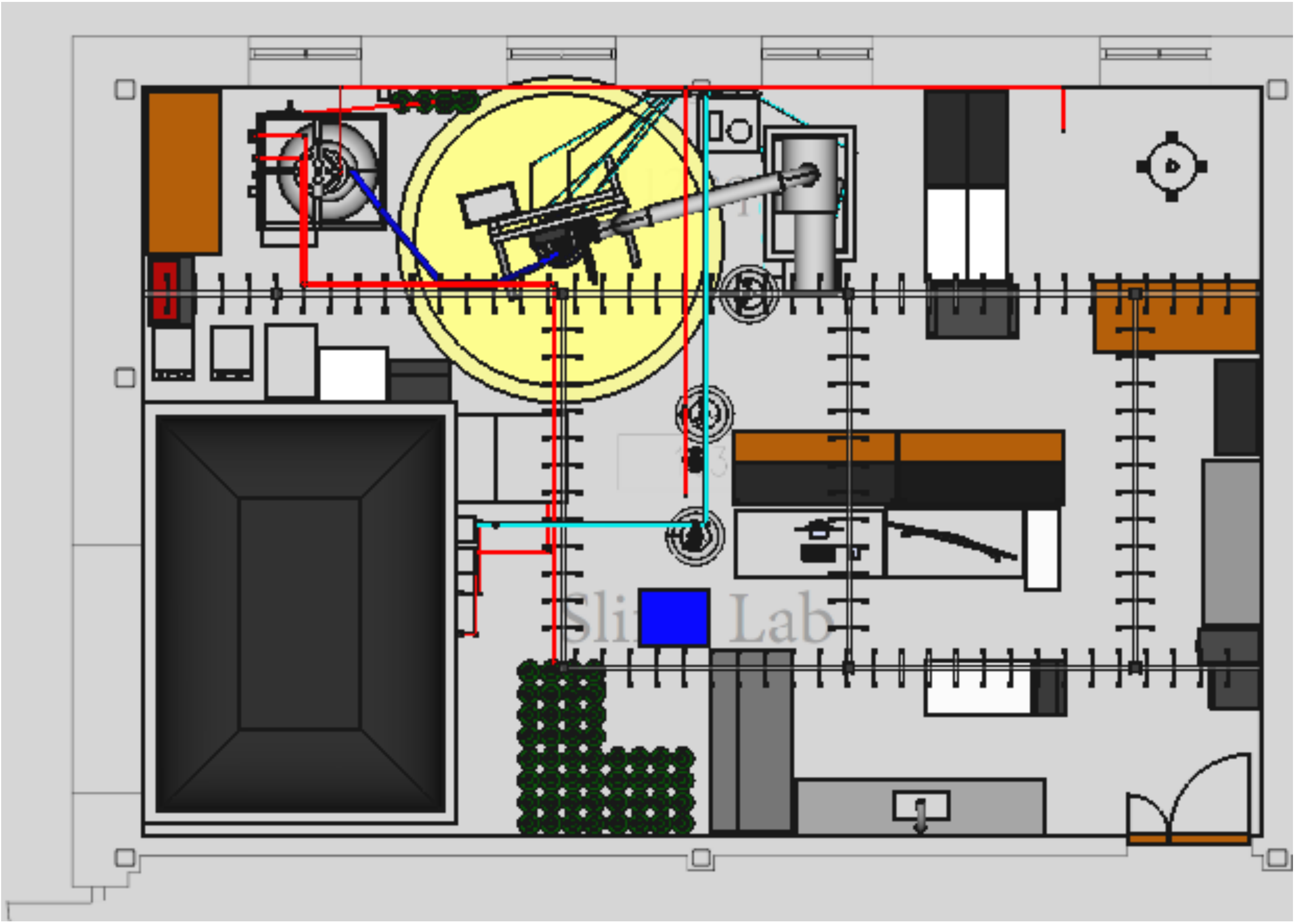
We still very much need to find a solution for irradiations at JLAB
- -JLab effort led by C. Keith

New Helium Recapture System

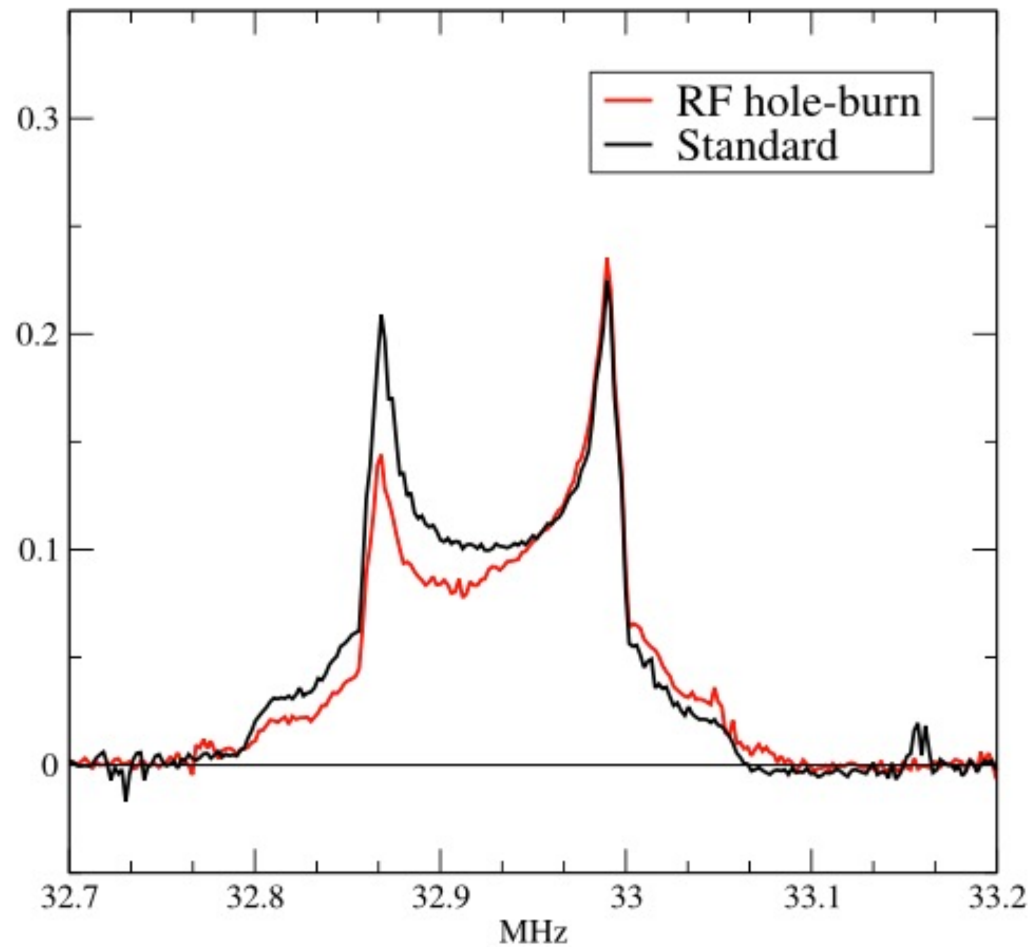
Quantum Technologies

Delivery: Next Week!!!

New Helium Recapture System

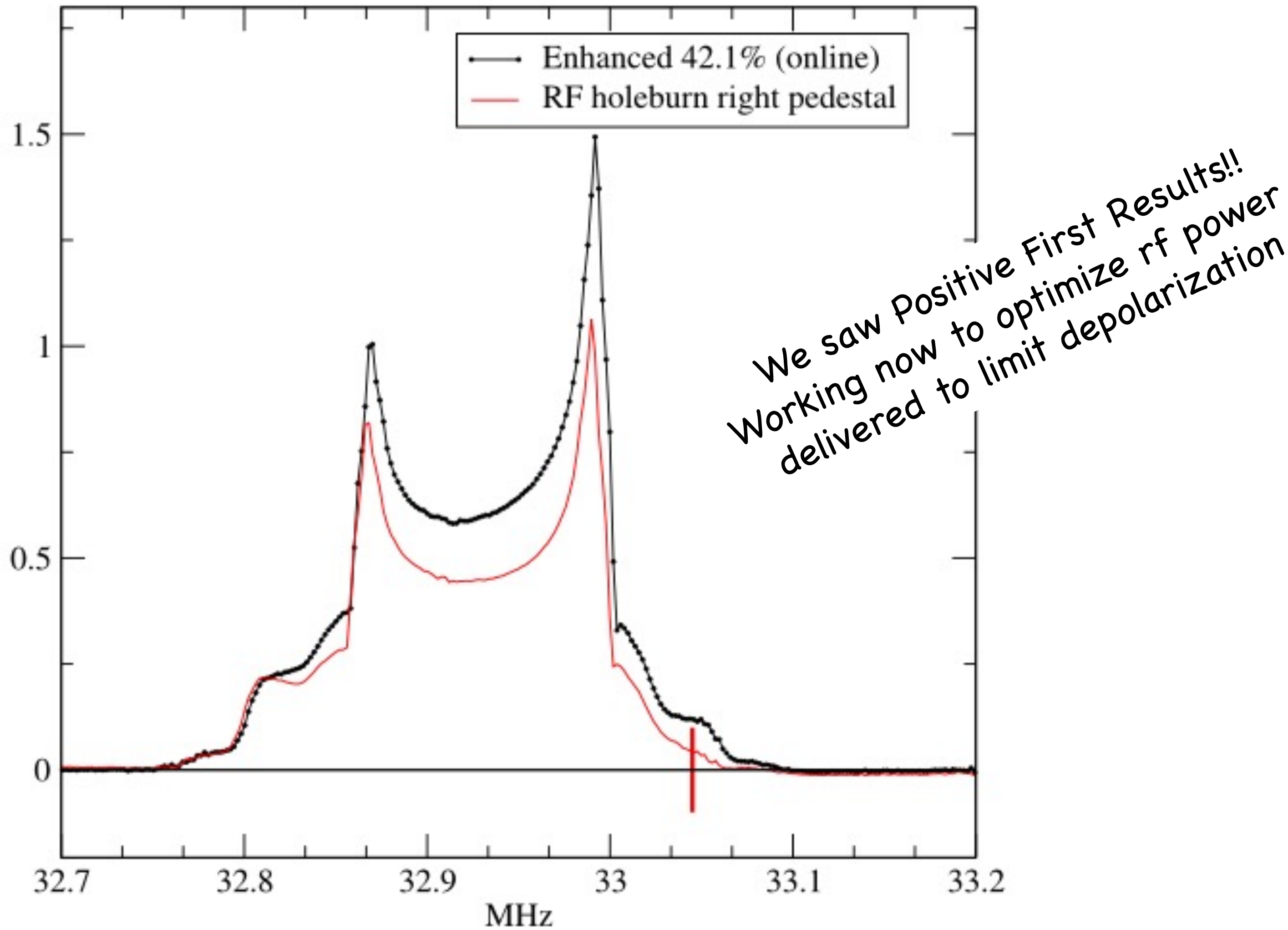


Deuteron Tensor Enhancement at UNH



Tensor Enhancement by factor of 5.7 after rf-hole burning the left peak
1,2-Propanediol-d8, chemically doped with OX063, with 5T/1K

Deuteron Tensor Enhancement at UNH



Tensor Enhancement to $P_{zz} \cong 16(\pm 5)\%$

after rf-hole burning the left peak and right shoulder.

1,2-Propanediol-d8, chemically doped with OX063, with 5T/1K

Future

Spin-1 deuteron experiments from the middle of 2020's

JLab

A Letter of Intent to Jefferson Lab PAC 44, June 6, 2016

Search for Exotic Gluonic States in the Nucleus

M. Jones, C. Keith, J. Maxwell*, D. Meekins

Thomas Jefferson National Accelerator Facility, Newport News, VA 23606

W. Detmold, R. Jaffe, R. Milner, P. Shanahan

Laboratory for Nuclear Science, MIT, Cambridge, MA 02139

D. Crabb, D. Day, D. Keller, O. A. Rondon

University of Virginia, Charlottesville, VA 22904

J. Pierce

Oak Ridge National Laboratory, Oak Ridge, TN 37831

Proposal (approved),
Experiment: middle of 2020's

Fermilab

The Transverse Structure of the Deuteron with Drell-Yan

D. Keller[1]

[1] *University of Virginia, Charlottesville, VA 22904*

Proposal,
Fermilab-PAC: 2022
Experiment: 2020's

NICA

Progress in Particle and Nuclear Physics

Review

On the physics potential to study the gluon content of proton and deuteron at NICA SPD

Prog. Nucl. Part. Phys.
119 (2021) 103858,
Experiment: middle of 2020's

LHCspin

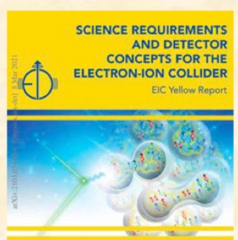
CERN-ESPP-Note-2018-111

The LHCSpin Project

arXiv:1901.08002,
Experiment: ~2028

see Appendix V
for some history

2030's EIC/EicC



R. Abdul Khalek *et al*.
arXiv:2103.05419.

D. P. Anderle *et al*.,
Front. Phys. 16 (2021) 64701.

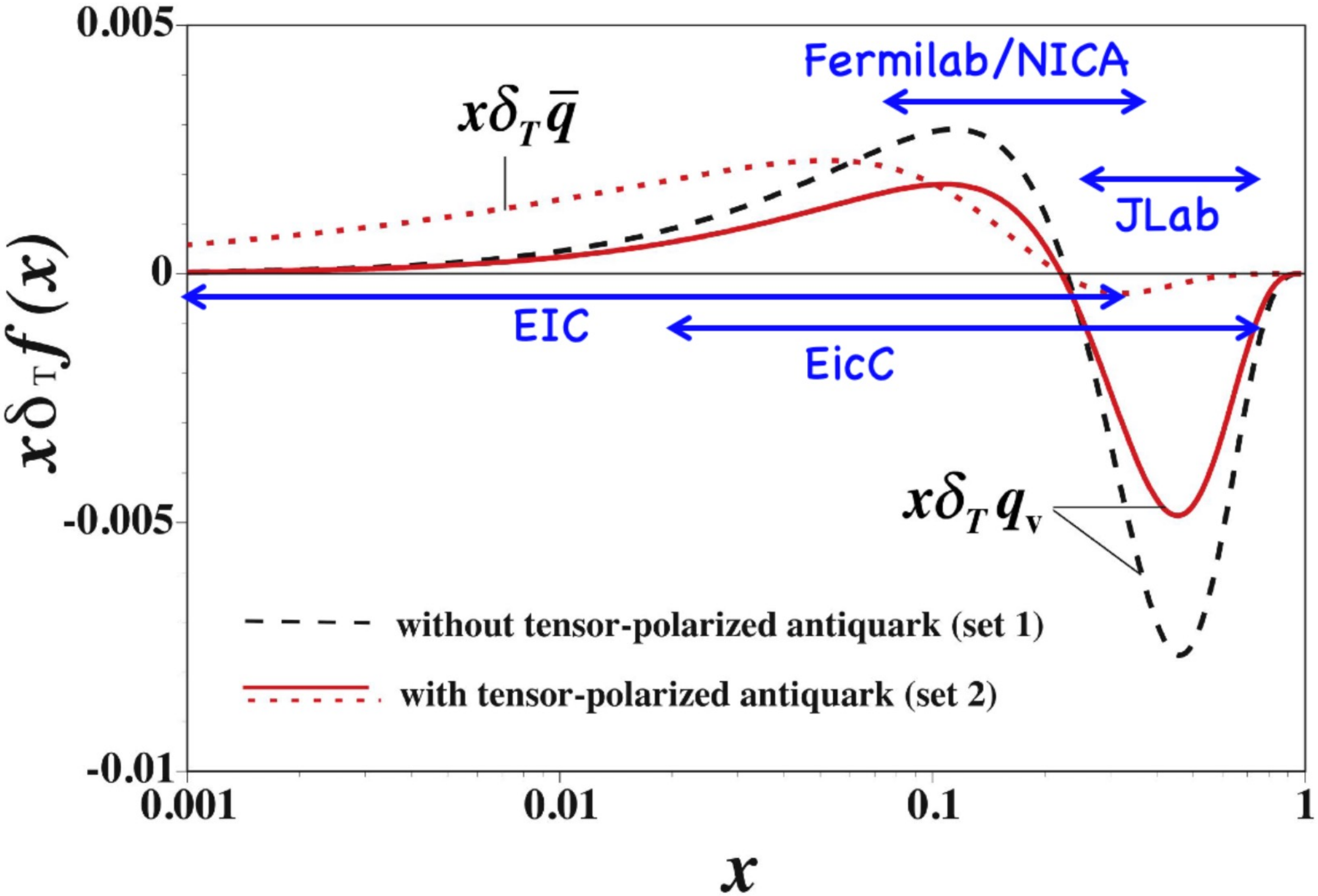
Frontiers of Physics

REVIEW ARTICLE

Electron-ion collider in China

See talk of Kumano

Future

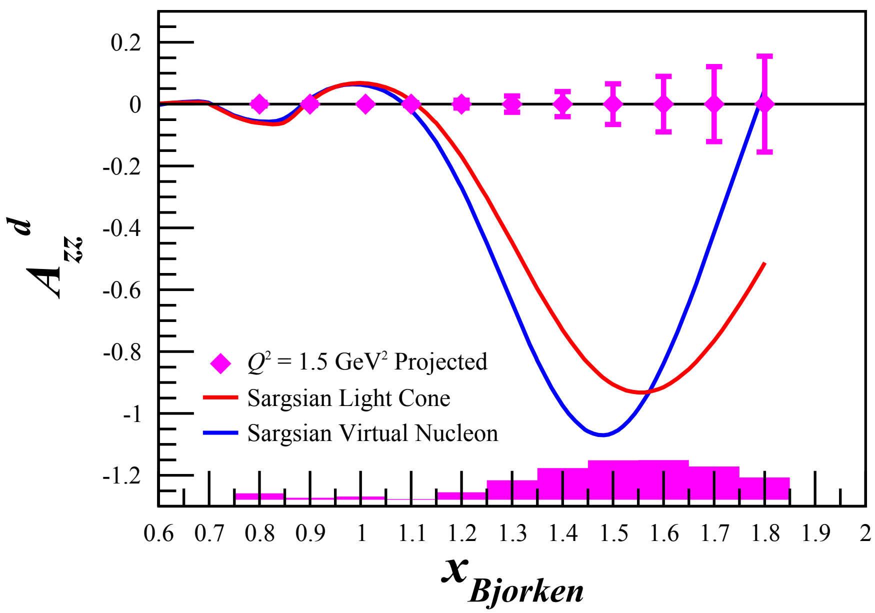


Tensor Experiments planned at Jlab, Fermilab, NICA, EIC, EICC, LHC spin

E12-15-005

A_{zz} in the x>1 Region

Long, Slifer, Solvignon,
Day, Higinbothan, Keller



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

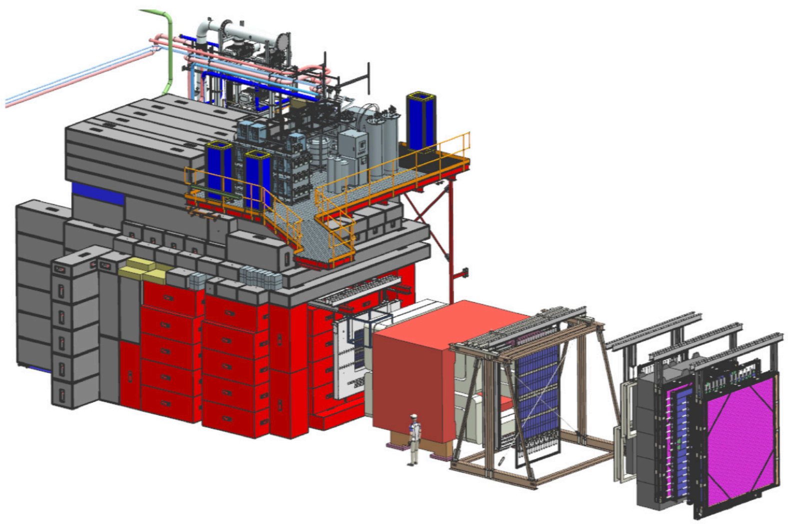
"further explores the nature of short-range pn correlations, the discovery of which was one of the most important results of the 6 GeV nuclear program."

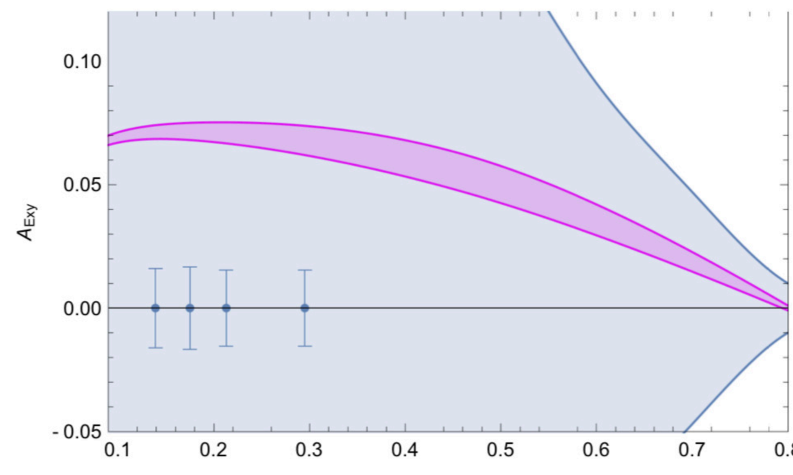
See E. Long's talk

Deuteron Transversity TMDs

D. Keller et al (SpinQuest collab)

Exotic glue contributions to the nucleus not associated with individual nucleons





Linear polarized gluon asymmetry

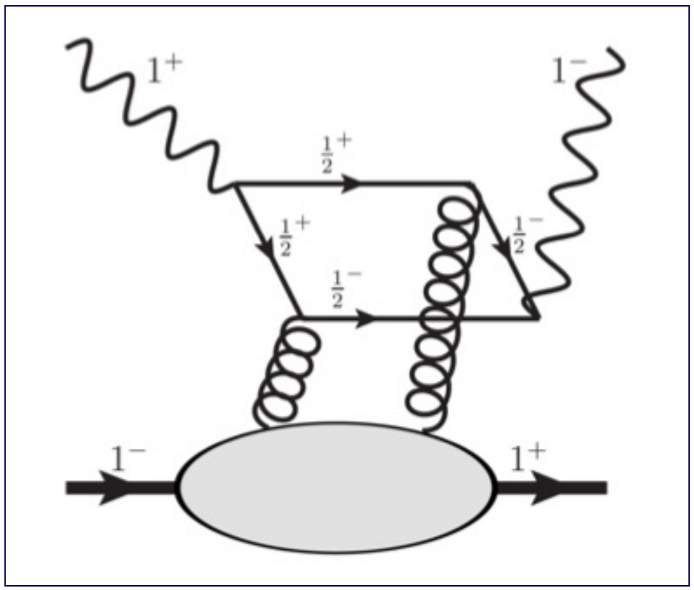
120 GeV proton Beam
Tensor ND3 target
SpinQuest Target and NM4 detector

Courtesy D. Keller, Fernando

Jlab LOI-12-16-006

James Maxwell (contact), R. Milner, …

"Nuclear Gluonometry"



Look for novel gluonic components in nuclei that are not present in nucleons

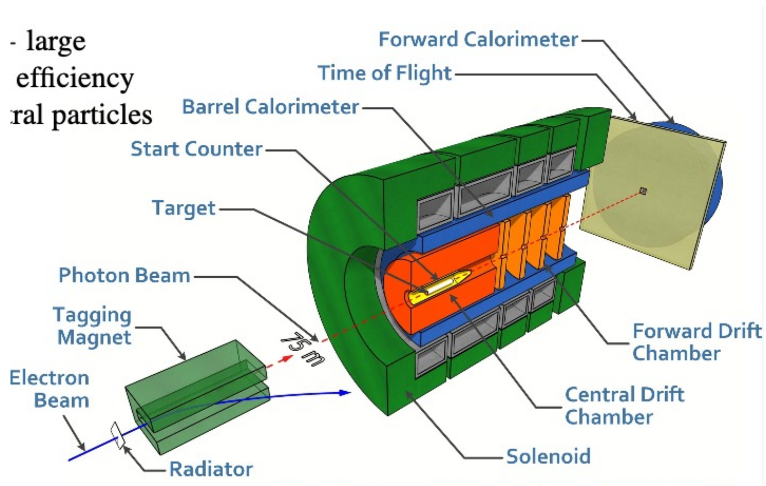
Non-zero value would be a clear signature of exotic gluon states in the nucleus

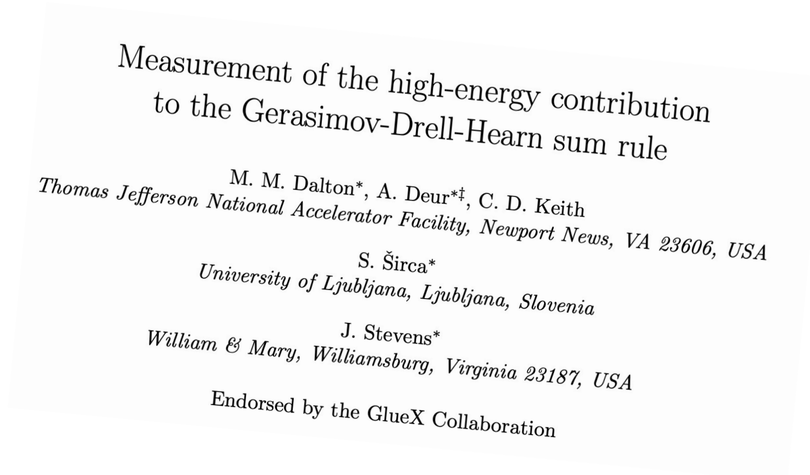
Deep inelastic scattering experiment:
- Unpolarized electrons
- Polarized $^{14}NH_3$ Target
- Target spin aligned transverse to beam

$\Delta(x,Q^2)$ double helicity flip structure function

Encouraged for full submission by PAC44

DNP Target in Hall D





Measurement of the high-energy contribution to the Gerasimov-Drell-Hearn sum rule

M. M. Dalton*, A. Deur*‡, C. D. Keith
Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, USA

S. Širca*
University of Ljubljana, Ljubljana, Slovenia

J. Stevens*
William & Mary, Williamsburg, Virginia 23187, USA

Endorsed by the GlueX Collaboration

arXiV: 2008.11059

Real photons provide great opportunity
for the next generation of Tensor Polarized target experiments

See Talks of M. Dalton

https://indico.ectstar.eu/event/173/

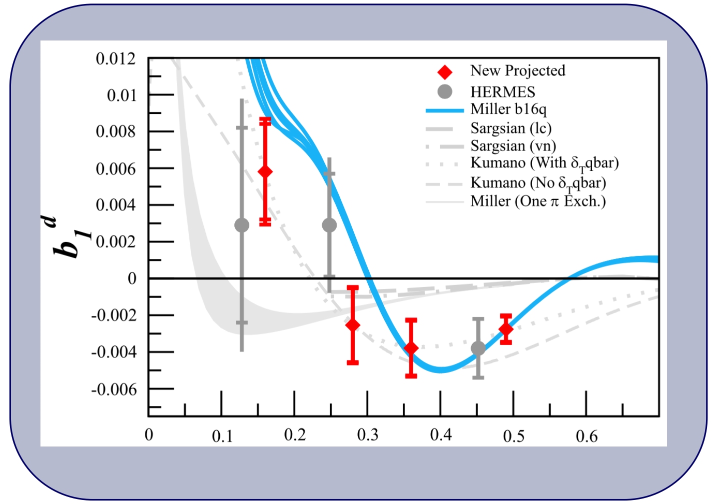
Expected/Planned Future Experiments

1. Vector and tensor polarized Deuterons at the EIC, and this community's engagement is essential to advocate for and plan for the necessary EIC facility upgrade.
2. 2 LOIs for tensor polarized target in SoLiD (**Slifer, Long**)
3. LOI to measure higher twist Delta structure function (**Maxwell, Milner....)**
4. Exclusive measurements (planned as a followup) to allow tagged selection of highly tensor polarized states (and large asymmetries). (**Carlos Yeros, Nataly Santiesteban, Mark Jones**)
5. Measurements of the higher twist tensor structure functions which are as yet unexplored (b3, b4)
6. Measurements of tensor polarized Drell Yan transversity at FermiLab (**Dustin Keller, Ishara Fernandez**)
7. Nica Spin
8. The b1 effort and collaboration will set a critical foundation for 2^{nd} generation JLab experiments that are in various stages of planning:
    1. Exclusive tensor polarized d(e,e')p,
    2. f_{1LL} in SIDIS,
    3. Tensor polarized DVCS,
    4. SIDIS Transversity, photon tensor polarization observables.

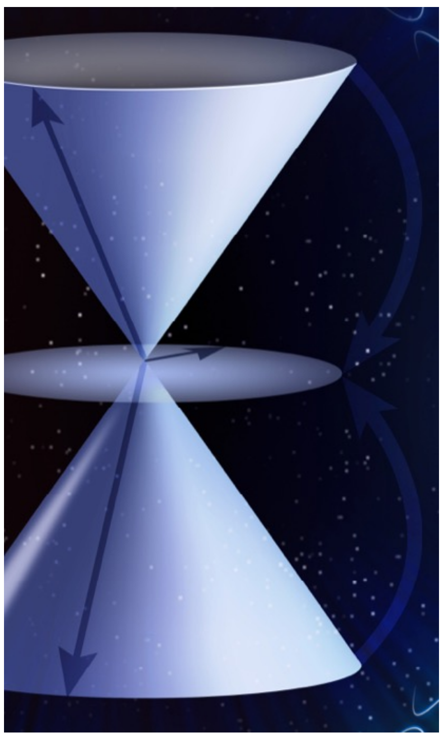
All of these efforts will look to this pioneering experimental run to learn what is possible and what is challenging.

Summary

Measurement of b1



$0.15 < x < 0.55$ $Q^2 = 3.81$ GeV^2
P_{zz}= 26% with 85nA polarized beam.
36 PAC Days + 12 Days overhead
First tensor poltarg experiment at Jlab



Developments

Fully approved after C_1 Conditional Review in 2022
Engaged community
ECT* Tensor Spin Workshop

Scientific Impact

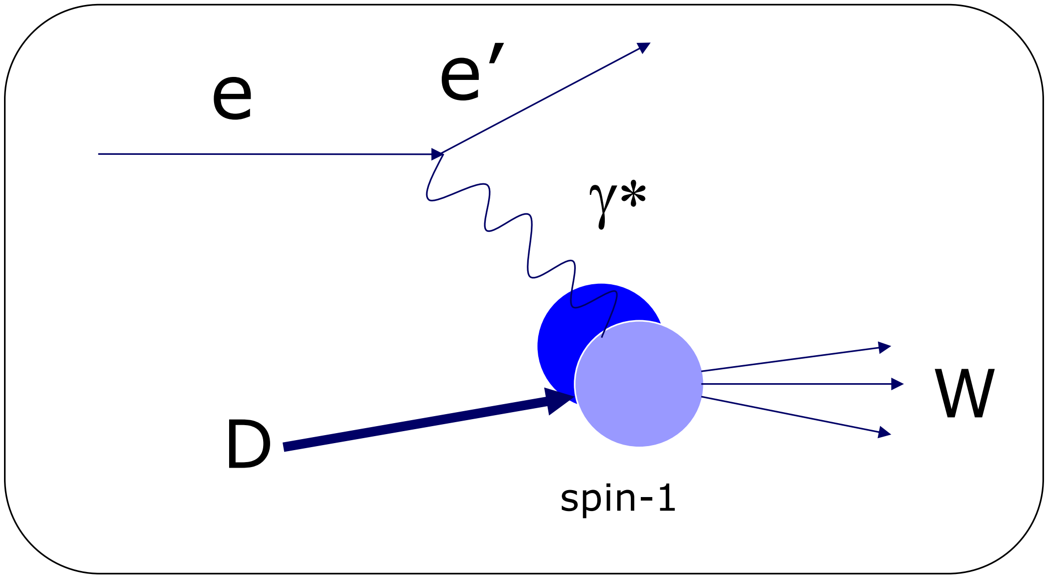
"powerful, possibly unique, probe of exotic Components of the deuteron wave function"

"will create a new unique field in hadron physics."

Critical first data for many many experiments to follow (see backups)

Backups

Tensor Structure Functions

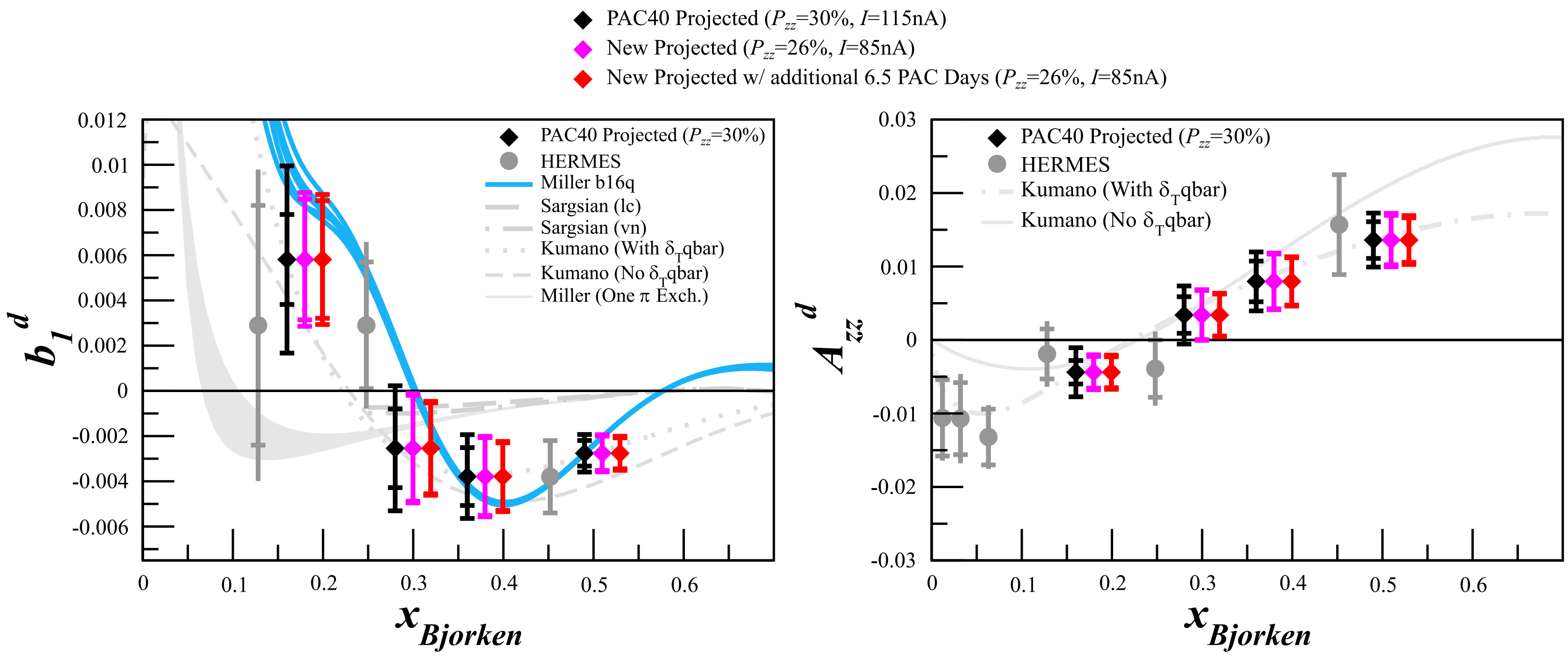


Most general Tensor consistent with Lorentz & gauge invariance

Hoodbhoy, Jaffe, Manohar (1989)
Frankfurt & Strikman (1983)
Efremov and Teryaev (1982, 1999)

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

Projected Results for Q = 26%



Backups

	$\overline{x}$	$\overline{Q^2}$ (GeV^2)	$\overline{W}$ (GeV)	P_0 (GeV)	θ (deg.)	Rates (kHz)	time (days)
SHMS	0.15	1.21	2.78	6.70	7.35	1.66	6
SHMS	0.30	2.00	2.36	7.45	8.96	0.79	14.65
SHMS	0.452	2.58	2.00	7.96	9.85	0.38	15
HMS	0.55	3.81	2.00	7.31	12.50	0.11	35.65

Overhead	PAC Time
Vector Polarization/Depolarization	7 days, 6 hours
Target T.E. Measurements	22.5 hours
Packing Fraction/Dilution Runs	22.5 hours
BCM Calibration Runs	18 hours
Optics Runs	16 hours
Target Anneals	15 hours
Tensor Pol. Spin Flips	9.5 hours
Target Cup Changes	5 hours
Target Material Changes	4 hours
LINAC Changes	4 hours
Momentum/Angle Changes	3 hours
	11.7 days

Parton Model Interpretation

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

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

where:

$$\begin{aligned} q^0(x) &= q^0_\uparrow(x) + q^0_\downarrow(x) = 2q^0_\uparrow \\ q^1(x) &= q^1_\uparrow(x) + q^1_\downarrow(x) \end{aligned}$$

Mirror symmetry along z-axis reveals

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

Summary of Conditional Review

1. *What technique(s) will be used to produce "a tensor polarization of 30% under standard experimental conditions".*

2. *How will the tensor polarization be measured and with what uncertainty? What crosschecks or auxiliary measurements can be made to validate the results? Will this uncertainty be sufficient to achieve meaningful physics results?*

3. *What assumptions are made regarding the vector polarization of the target? How is the tensor polarization expected to respond as the vector polarization decays in beam?*

4. *What is the current experimental situation? What is the maximum tensor polarization that has been achieved under the anticipated polarizing conditions of 5 T and 1 K?*

The collaboration presented our response to this charge and in consequence, the C1 conditional status was removed and full approval granted by Jefferson Lab in August 2022 to both E12-13-011 and E12-15-005

the UVa and UNH groups have made substantial strides beyond previous work, particularly in the analysis of the deuteron lineshape following RF manipulation.

Gluon Contribution to Tensor Structure

$$\int b_1(x)dx = 0$$

$$\int x b_1(x)dx = 0$$

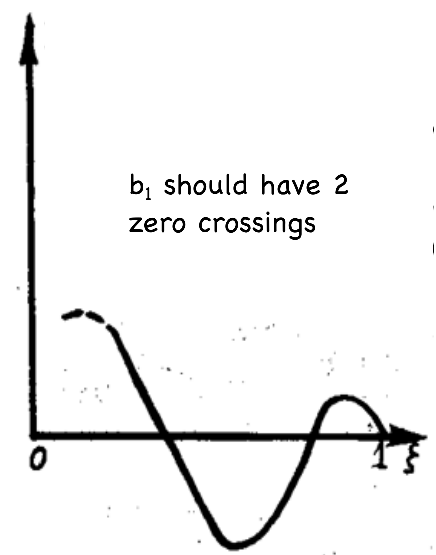


Рис.1

Efremov and Teryaev (1982, 1999)

Gluons (spin 1) contribute to both moments

Quarks satisfy the first moment, but

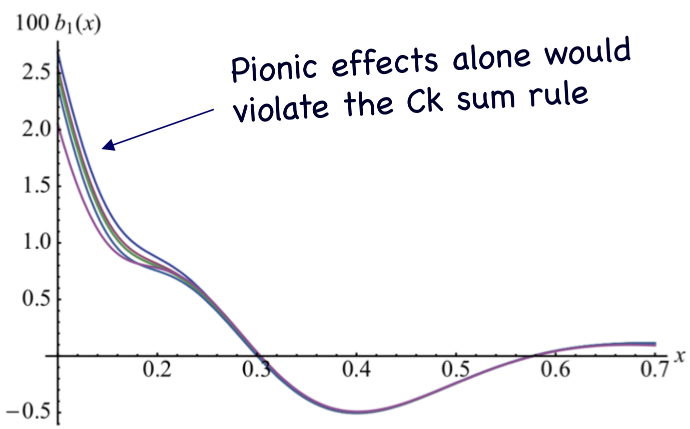
Gluons may have a non-zero first moment!

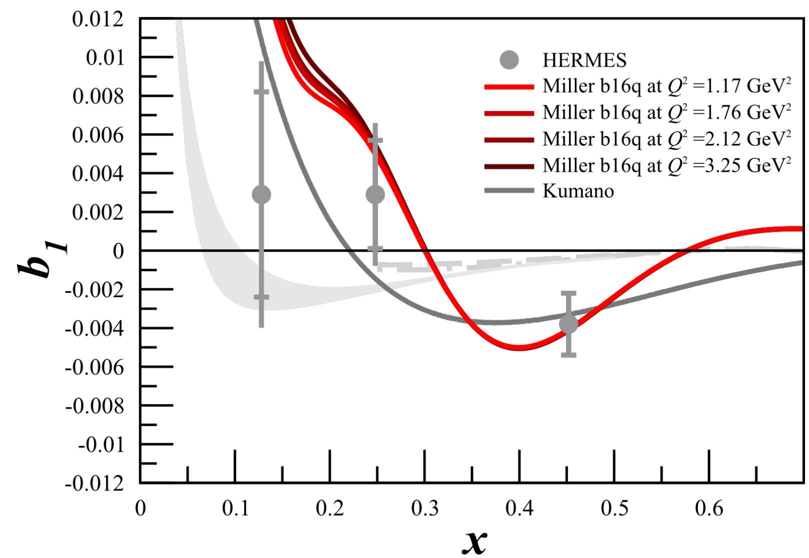
2nd moment more likely to be satisfied experimentally since the collective glue is suppressed compared to the sea

Study of b_1 allows to discriminate between deuteron components with different spins (quarks vs gluons)

Efremov, Teryaev, JINR PreprintR2-81-857(1981), Yad. Phys. 36, 950 (1982)
A.V. Efremov, O. V. Teryaev JINR-E2-94-95 (1999)
Jaffe, Manohar Phys.Lett. B223 (1989) 218

Unique Signal of Hidden Color





no conventional nuclear mechanism can reproduce the Hermes data,

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

G. Miller **PRC89 (2014) 045203**