Tensor Experiments
b_1 and A_{zz}

Hall A/C Collaboration

Jefferson Lab

2022-06-17

Karl Slifer

University of New Hampshire

Tensor Program

Jefferson Lab

E12-13-011: "The b_1 experiment"

30 Days in Jlab Hall C
A- Physics Rating
Conditional Approval

Chen, Kalantarians, Long,
Rondon, Slifer, Solvignon

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

44 Days in Jlab Hall C
A- Physics Rating
Conditional Approval

Day, Higinbothan, Keller
Long, Slifer, Solvignon

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I. Fernando, D. Seay and J. Clement
University of Virginia

b_1 Structure Function

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

measured in DIS (so probing quarks), but depends solely on the deuteron spin state

Investigate nuclear effects at the level of partons!

q^0 : Probability to scatter from a quark (any flavor) carrying momentum fraction x while the *Deuteron* is in state m=0

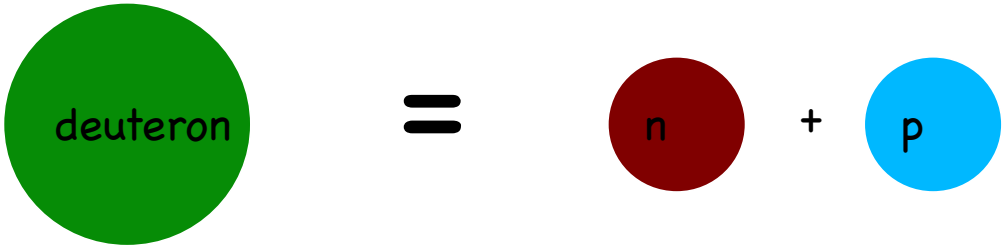
q^1 : Probability to scatter from a quark (any flavor) carrying momentum fraction x while the *Deuteron* is in state |m| = 1

b_1 Structure Function

Hoodbhoy, Jaffe and Manohar (1989)

b_1 vanishes in the absence of nuclear effects

i.e. if...



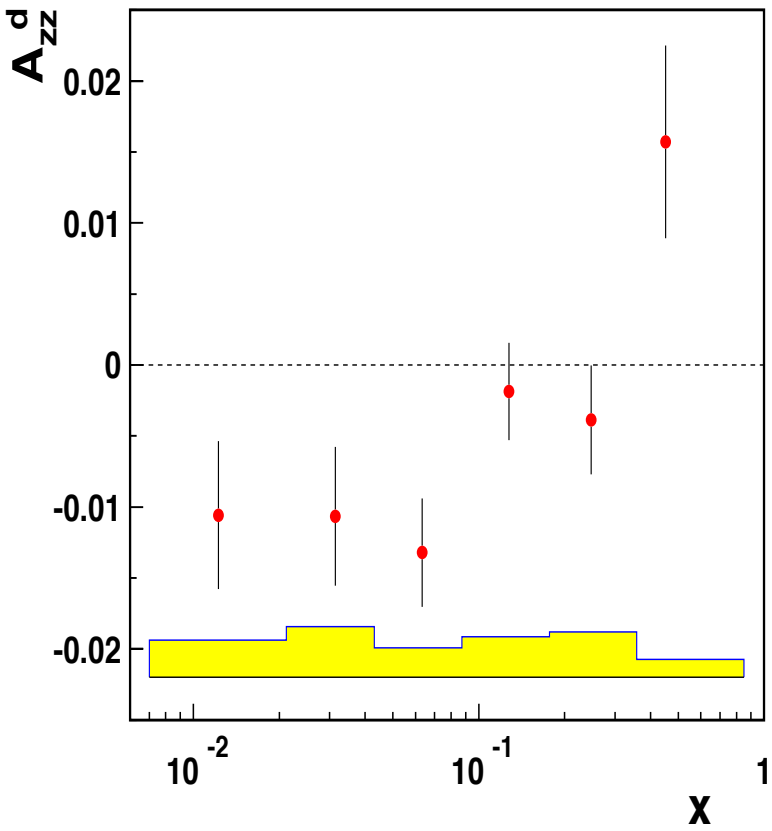
Proton Neutron in relative S-state

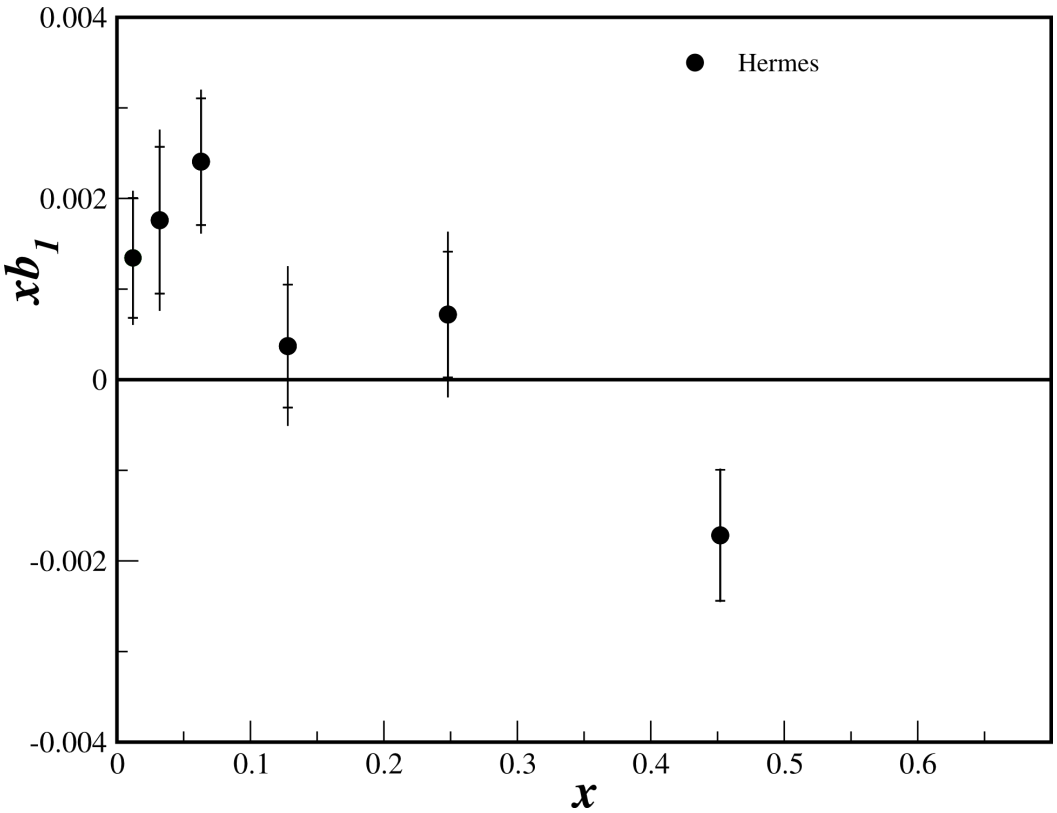
Even accounting for D-State admixture b_1 expected to be vanishingly small

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

Data from HERMES

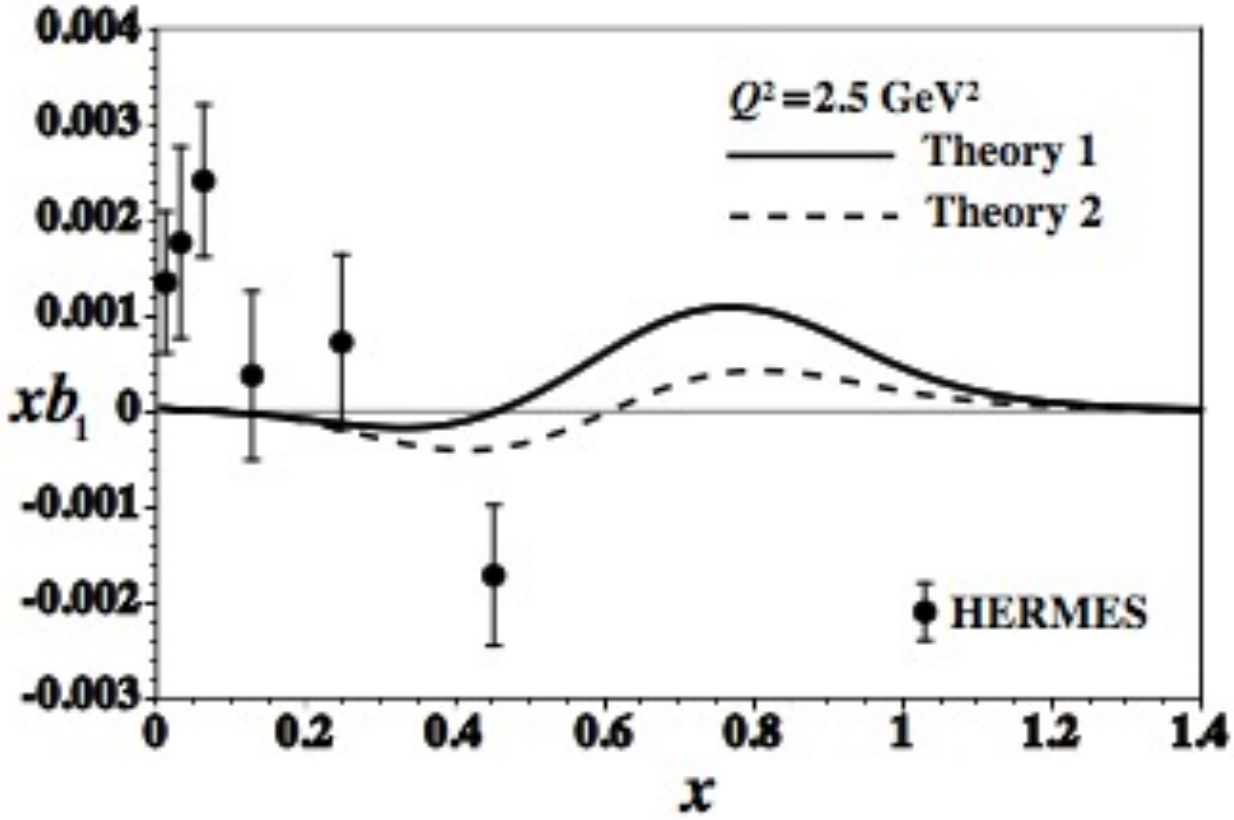




$$b_1 = -\frac{3}{2} F_1 A_{zz}$$

C. Reidl PRL **95,** 242001 (2005)

b_1 in standard convolution description



W. Cosyn, Y. Dong, S. Kumano, M. Sargsian

PRD95 (2017) 074036

Standard model of Nuclear Physics can not explain the large x results

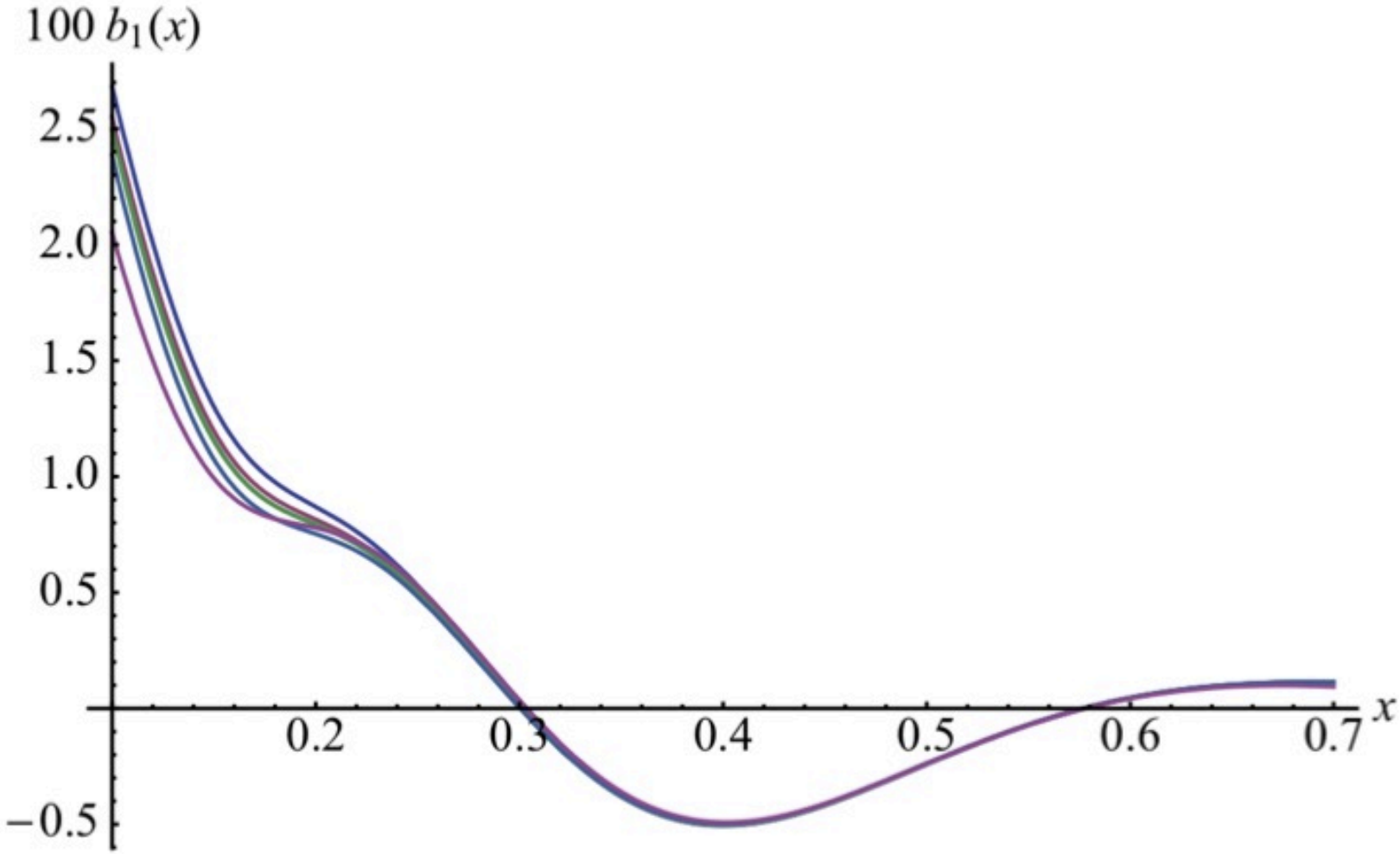
[need a] "new mechanism to explain large differences between current data and our theoretical results"

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

6-quark, Hidden Color

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

"Pionic and Hidden-Color, Six-Quark Contributions to the Deuteron **b**1 Structure Function"



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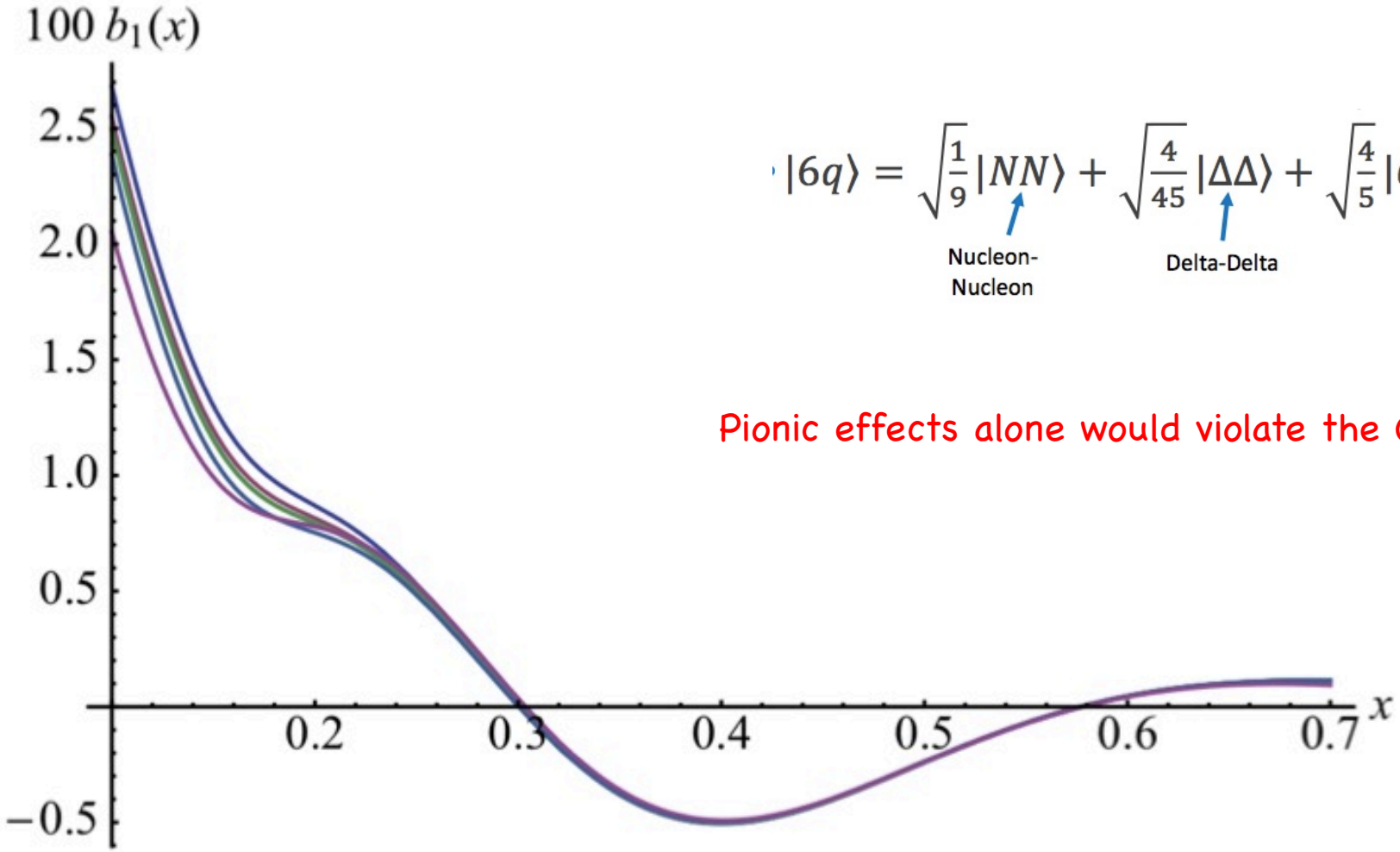
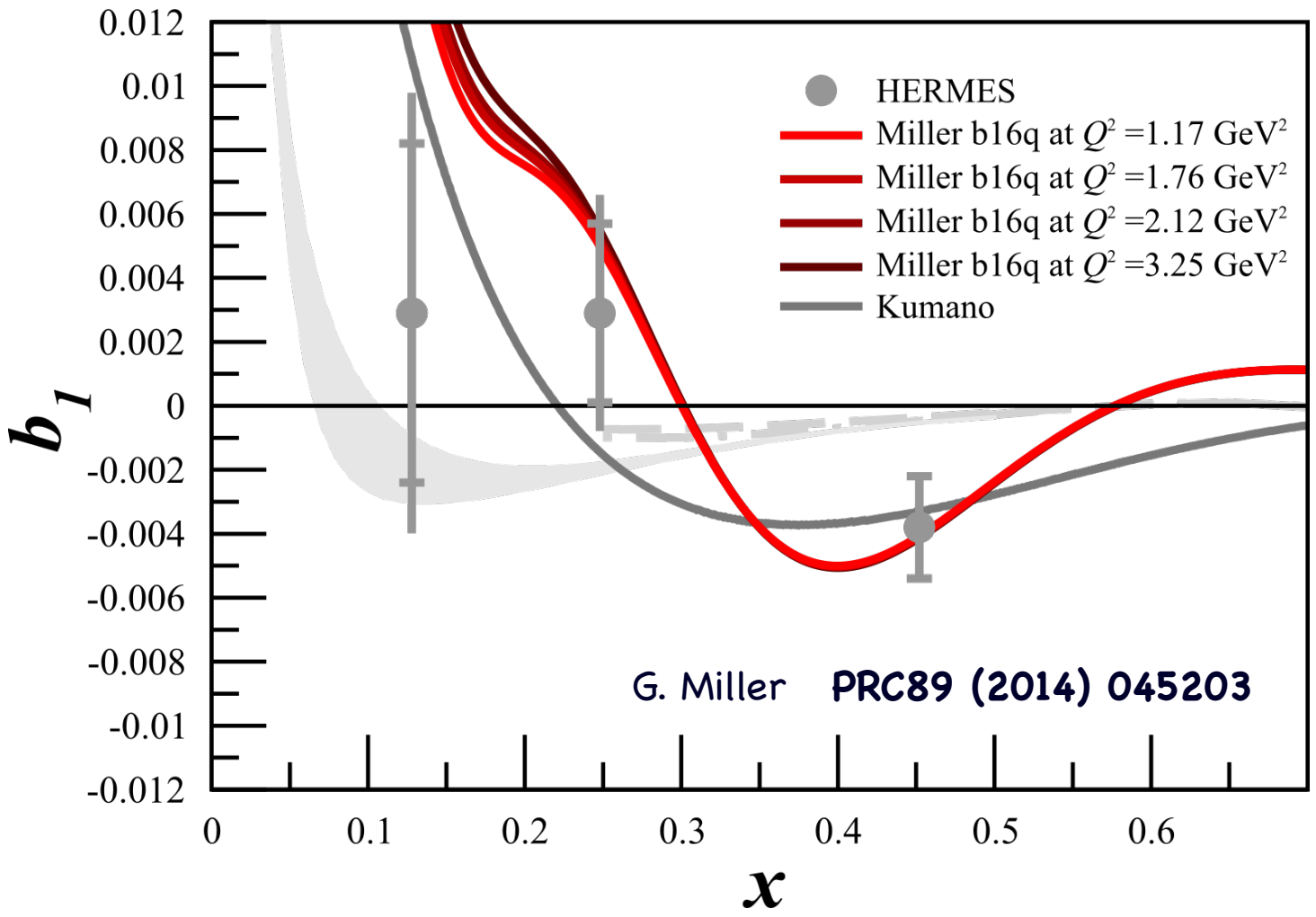


$$|6q\rangle = \sqrt{\frac{1}{9}}|NN\rangle + \sqrt{\frac{4}{45}}|\Delta\Delta\rangle + \sqrt{\frac{4}{5}}|CC\rangle$$

Nucleon-Nucleon | Delta-Delta | Hidden Color

Pionic effects alone would violate the Ck sum rule

Unique Signal of Hidden Color



no conventional nuclear mechanism can reproduce the Hermes data,

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

Gluon Contribution to Tensor Structure

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

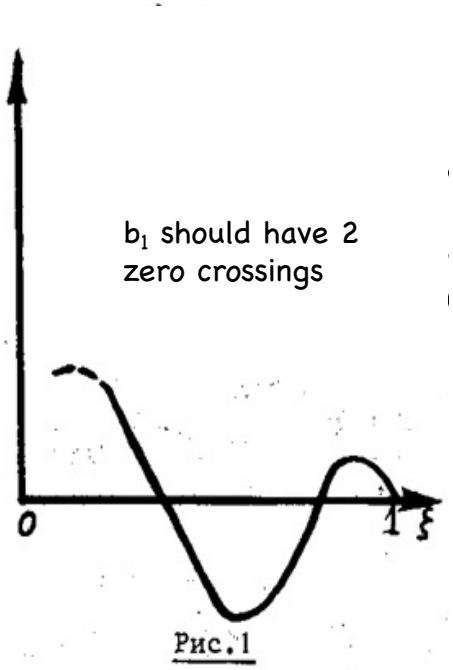
$$\int x b_1(x)dx = 0$$

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!



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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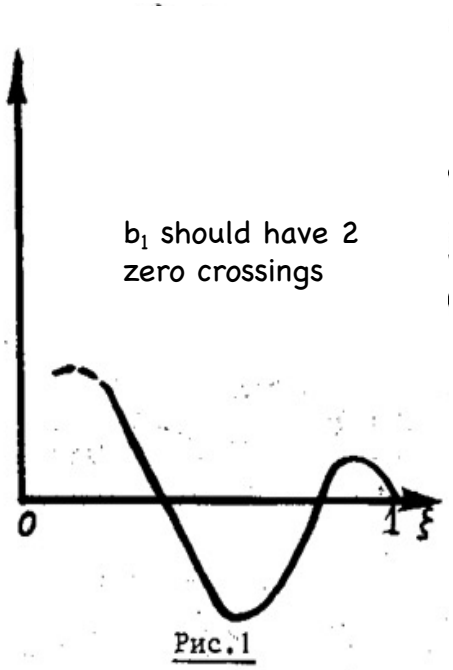

Рис.1

2nd moment more likely to be satisfied experimentally since the collective glue is suppessed 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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Experimental Method

$$A_{zz} = \frac{2}{f P_{zz}} \frac{\sigma_\uparrow - \sigma_0}{\sigma_0}$$

$$= \frac{2}{f P_{zz}} \left(\frac{N_\uparrow}{N_0} - 1 \right)$$

Observable is the Normalized XS Difference

B-Field, density, temp, etc. held same in both states

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

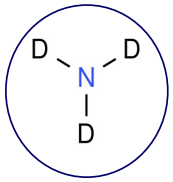
$\sigma_\uparrow$: Tensor Polarized cross-section

σ_0 : Unpolarized cross-section

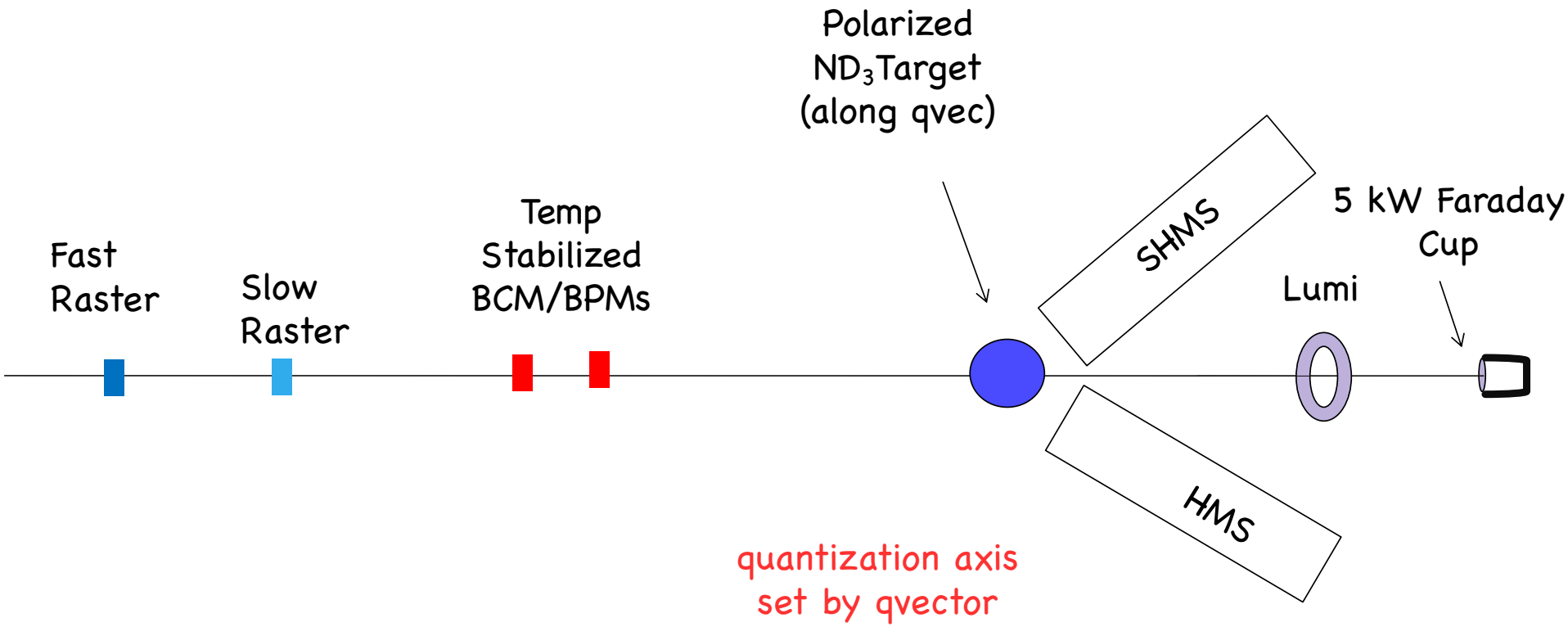
P_{zz} : Tensor Polarizzation

dilution factor

$$f \approx \frac{6}{20}$$



Jlab Hall C

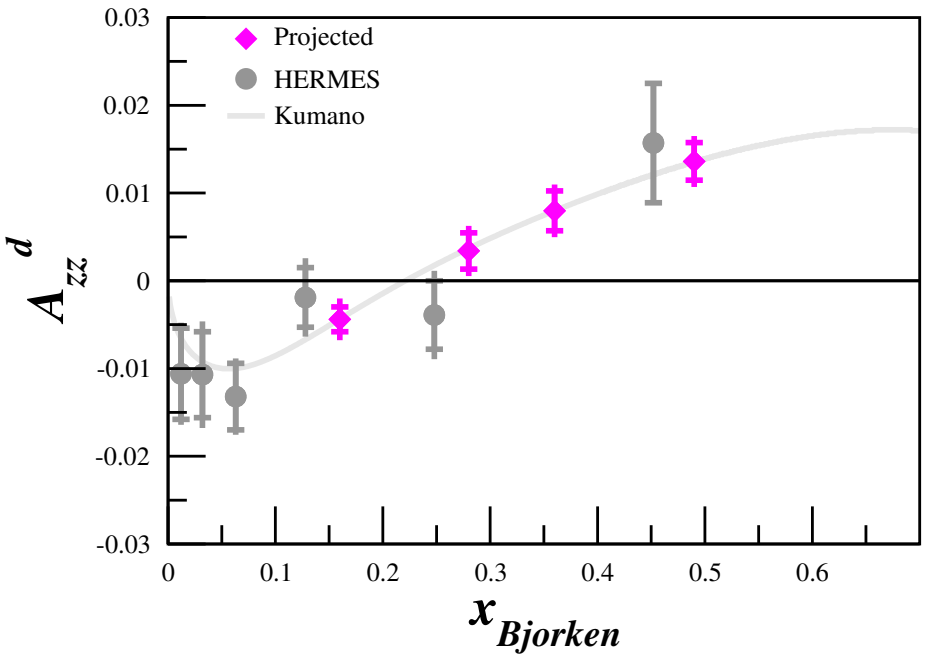


Unpolarized Beam
UVa/JLab Polarized Target

Magnetic Field Held Along qvector

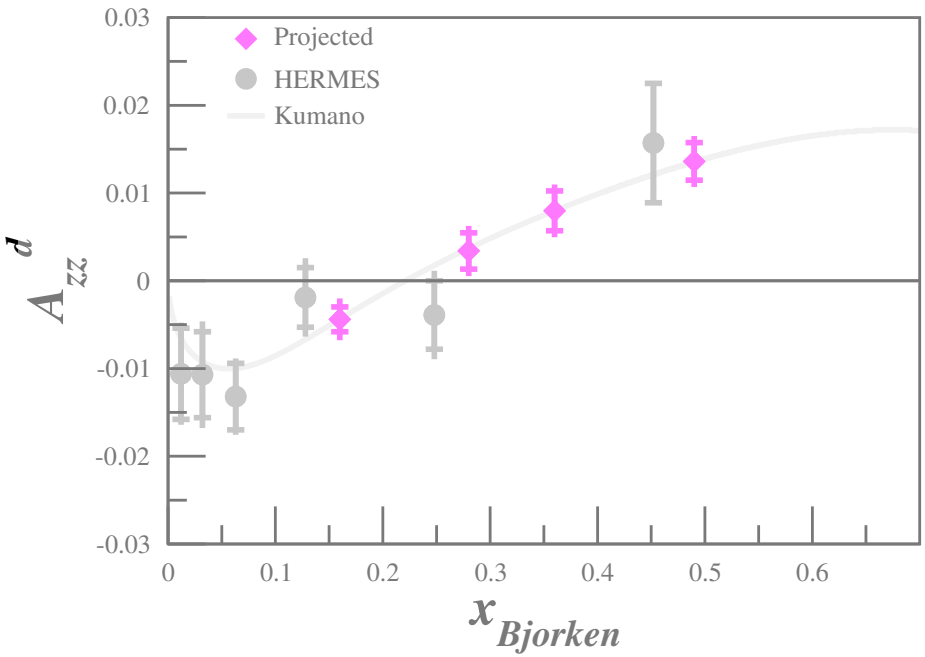
$\mathcal{L}=10^{35}$

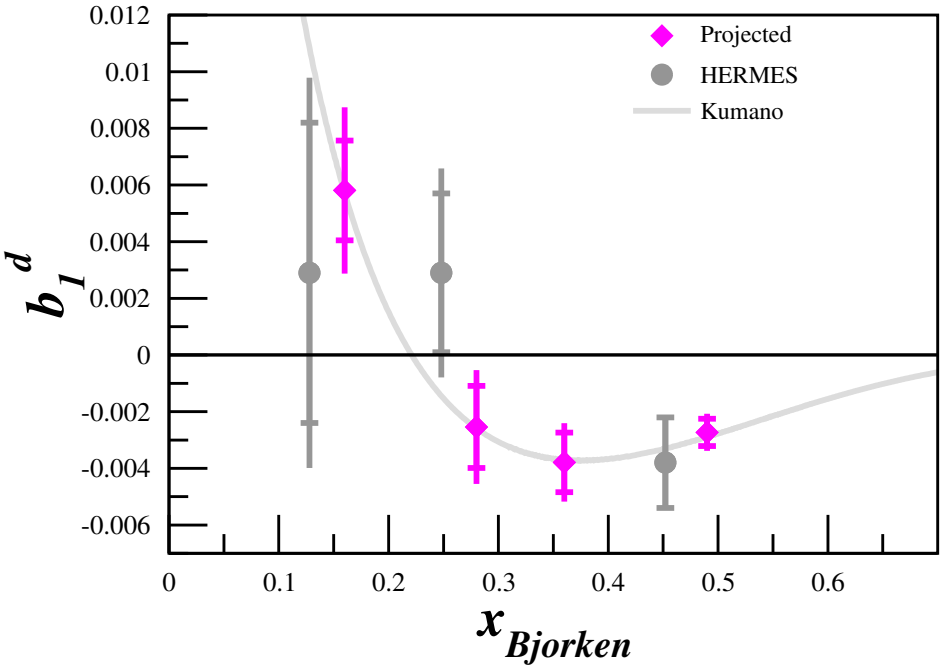
Projected Results for P_{zz} = 35%



30 Days in Jlab Hall C

Projected Results for P_{zz} = 35%





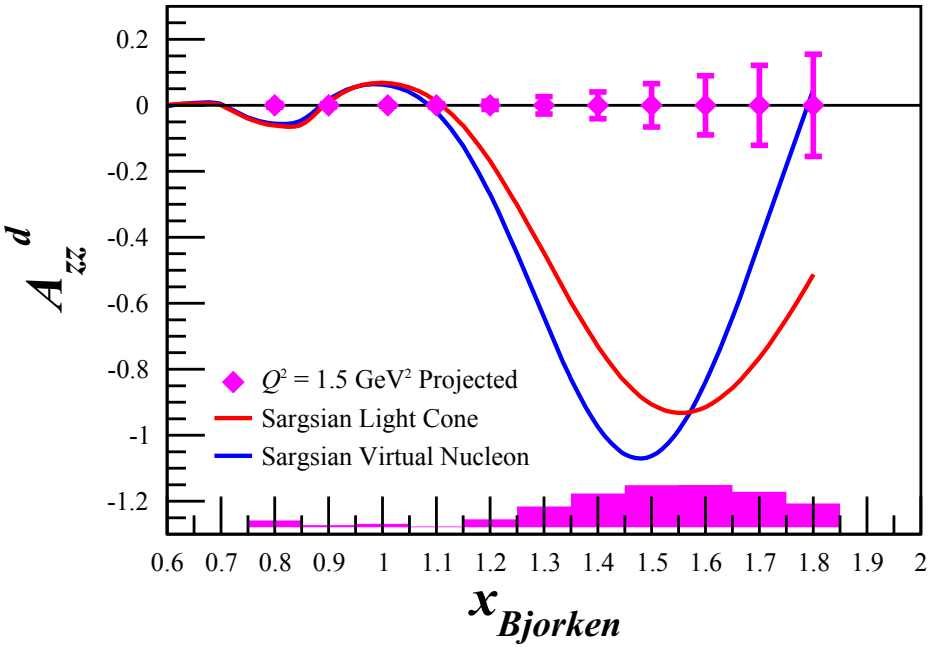
30 Days in Jlab Hall C

verification of zero crossing
essential for satisfaction of CK Sum

E12-15-005

A_{zz} in the x>1 Region

Long, Slifer, Solvignon,
Day, Higinbothan, Keller

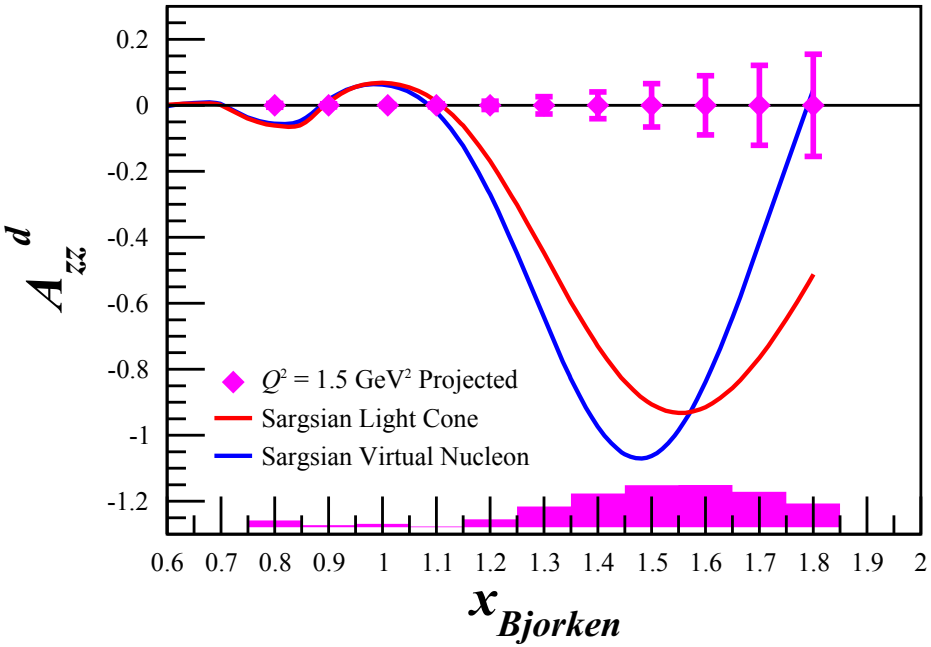


Very Large Tensor Asymmetries predicted

E12-15-005

A_{zz} in the x>1 Region

Long, Slifer, Solvignon,
Day, Higinbothan, Keller



Very Large Tensor Asymmetries predicted

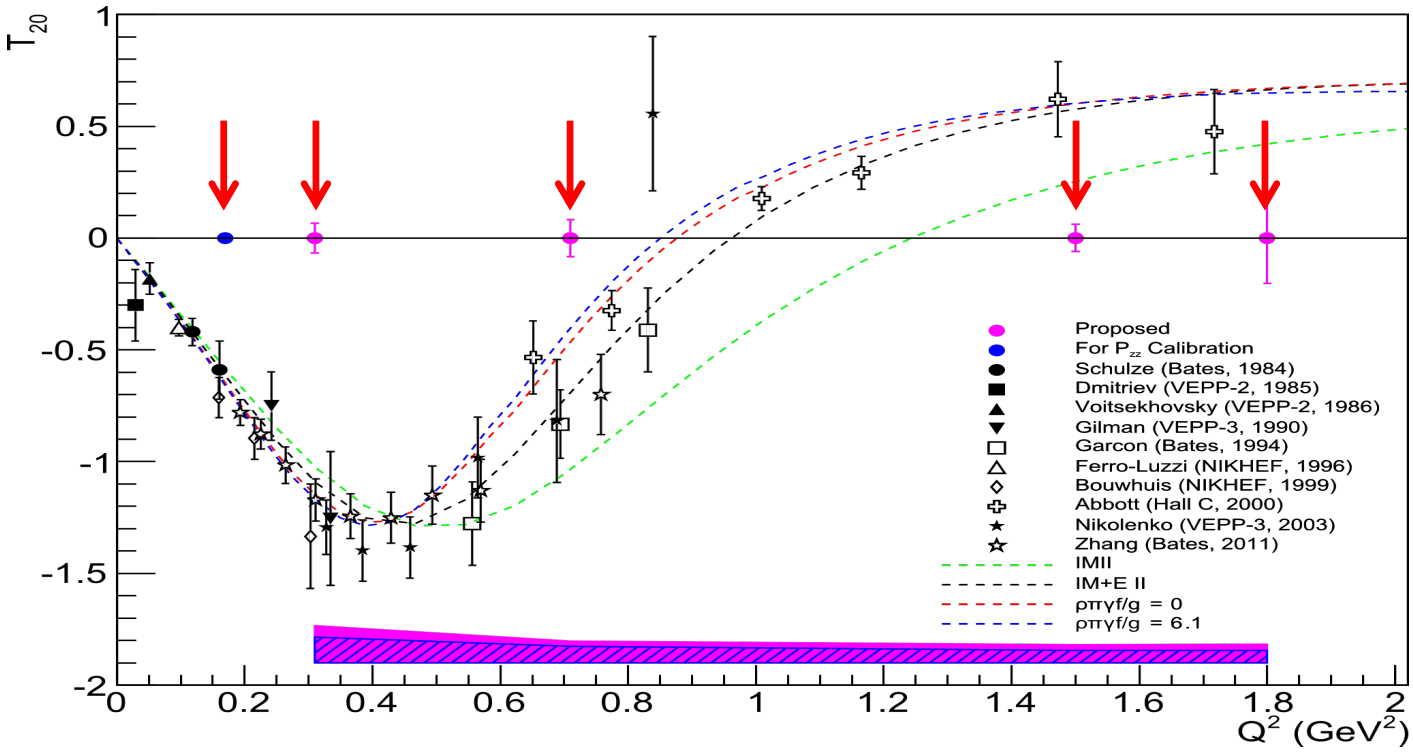
Sensitive to the S/D-wave ratio in the deuteron wave function

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."

PAC44 Theory Report

A_{zz} experiment



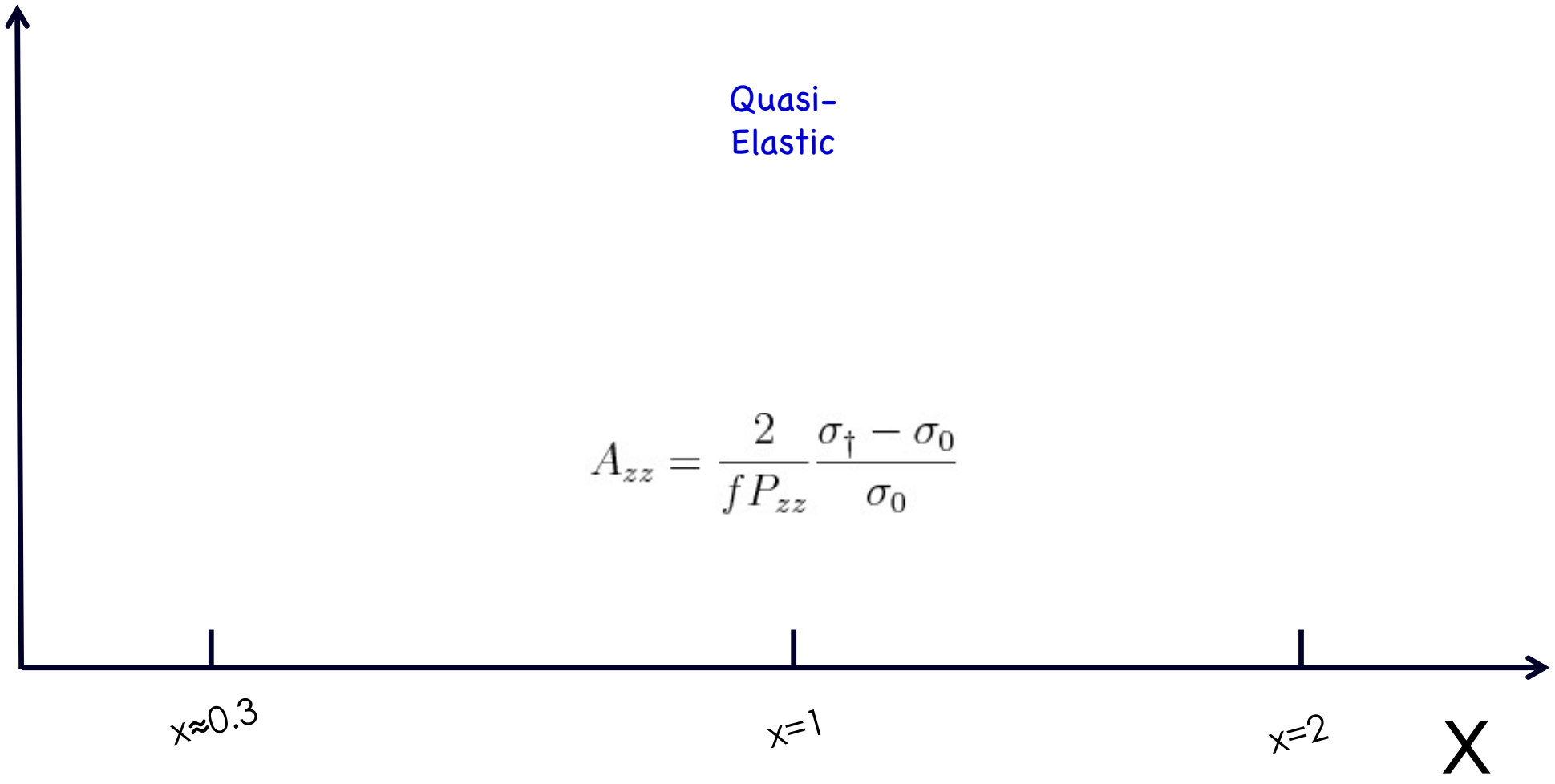
We simultaneously measure nuclear elastic

-> T_{20} over huge Q^2 range

-> measure T_{20} at largest Q^2 yet

-> will use to cross-check Pzz

Tensor Spin Observables



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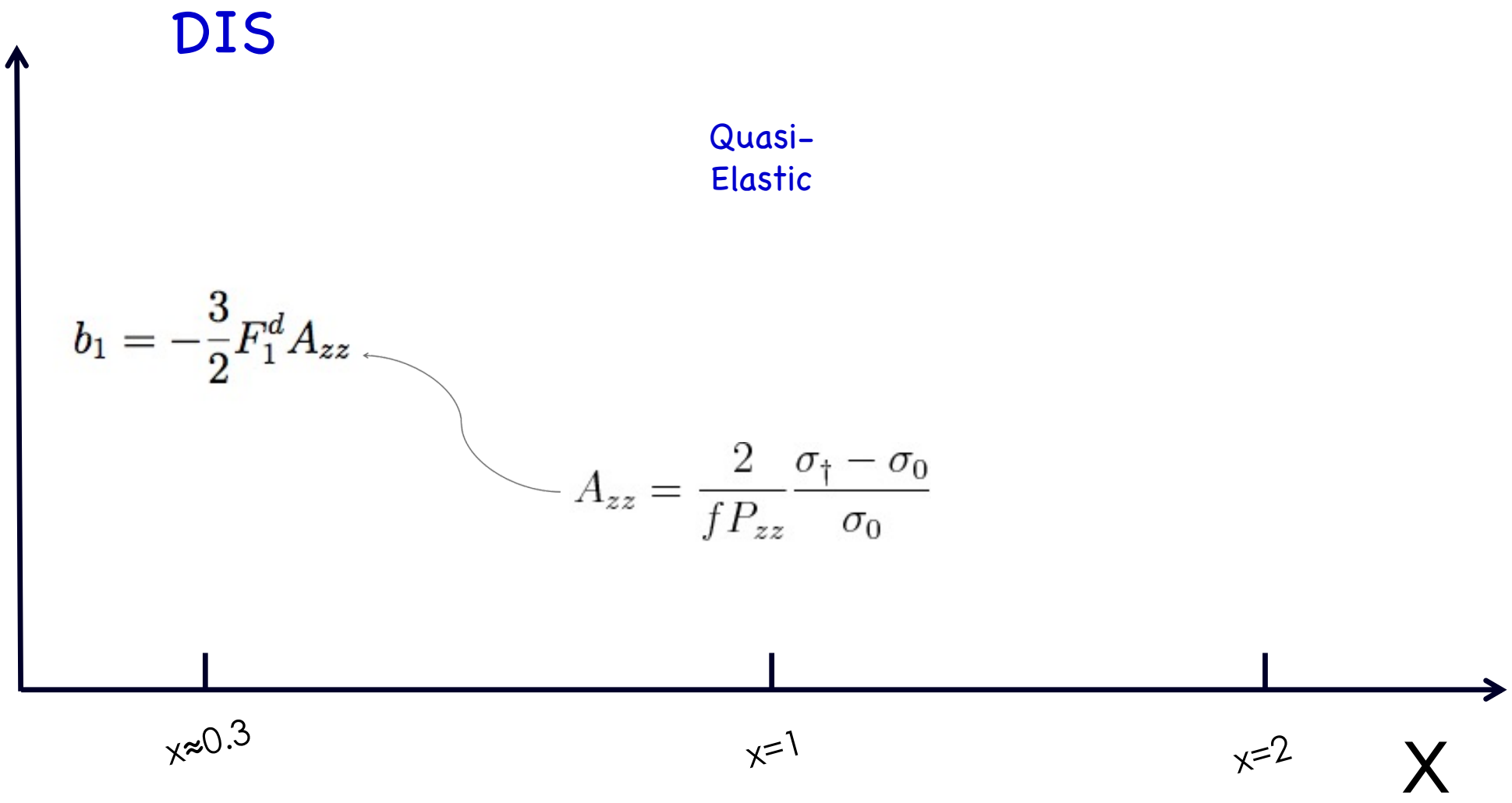

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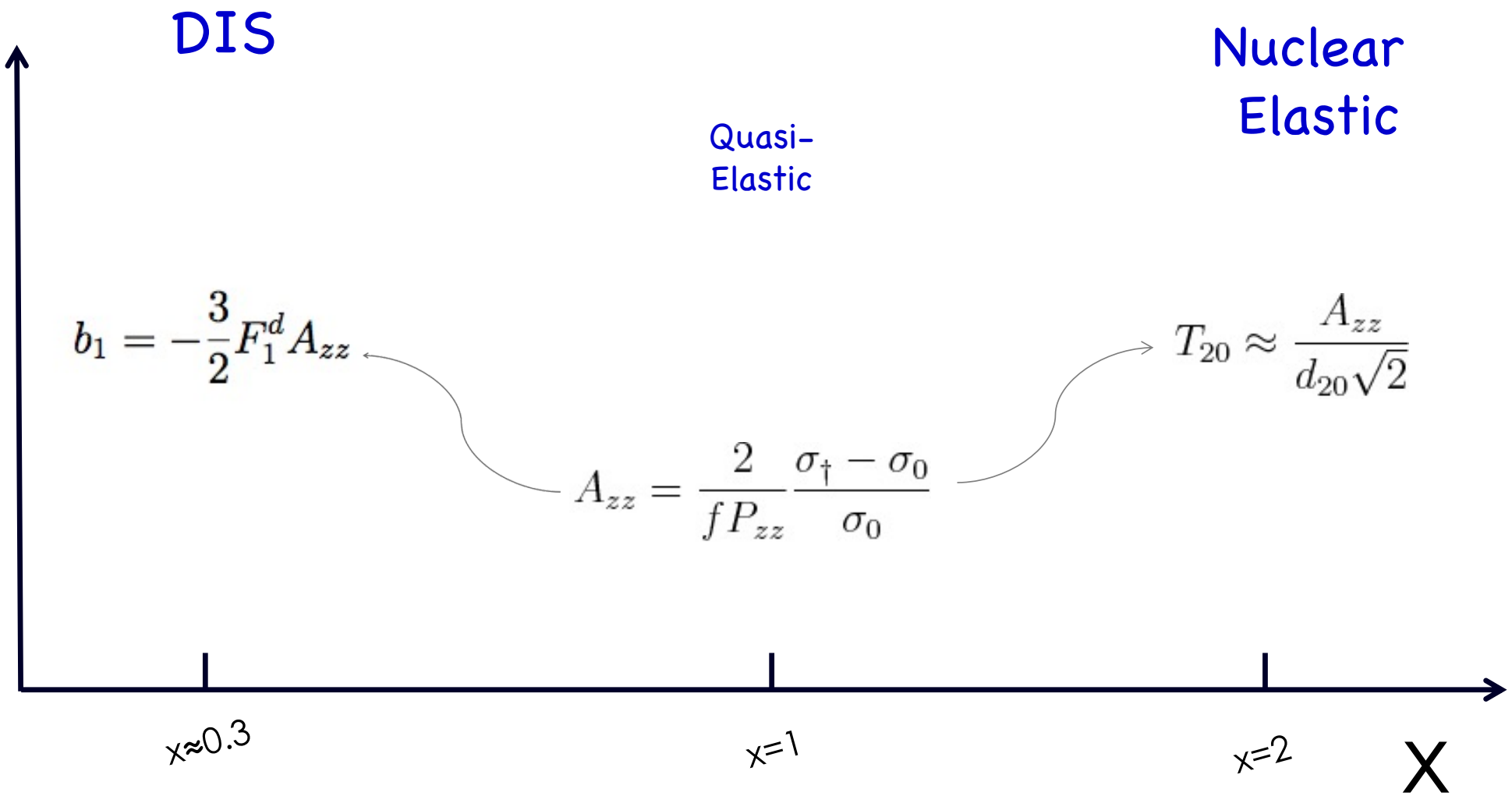


PAC Conditions

Scientific Rating: A-
Recommendation: Conditional Approval (C1)

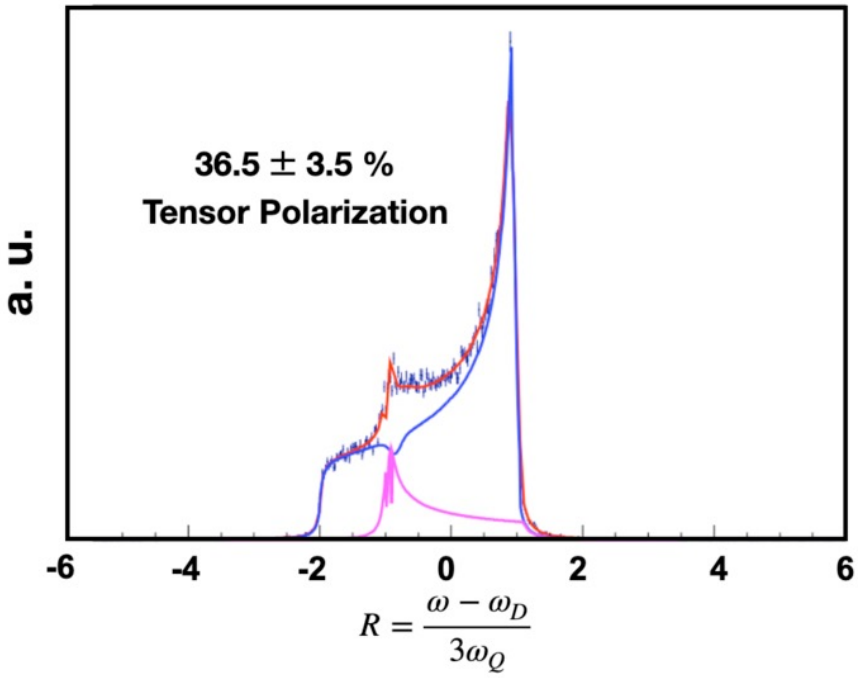
- E12-13-011 (*The Deuteron Tensor Structure Function b1*)
- E12-15-005 (*Tensor Asymmetry in Quasielastic Region*)

Issues:
In order to obtain conclusive data with sufficient precision it is crucial to achieve a tensor polarization significantly higher than the value of 20% assumed in the proposal. While methods such as RF- "hole burning" are known to increase the tensor polarization above the thermal equilibrium value, these techniques including the polarization measurement have to be developed further to allow for a reliable operation under experimental conditions.

The b1 and Azz experiments were C1 conditionally approved by PACs 41&44, respectively, with the requirement that:

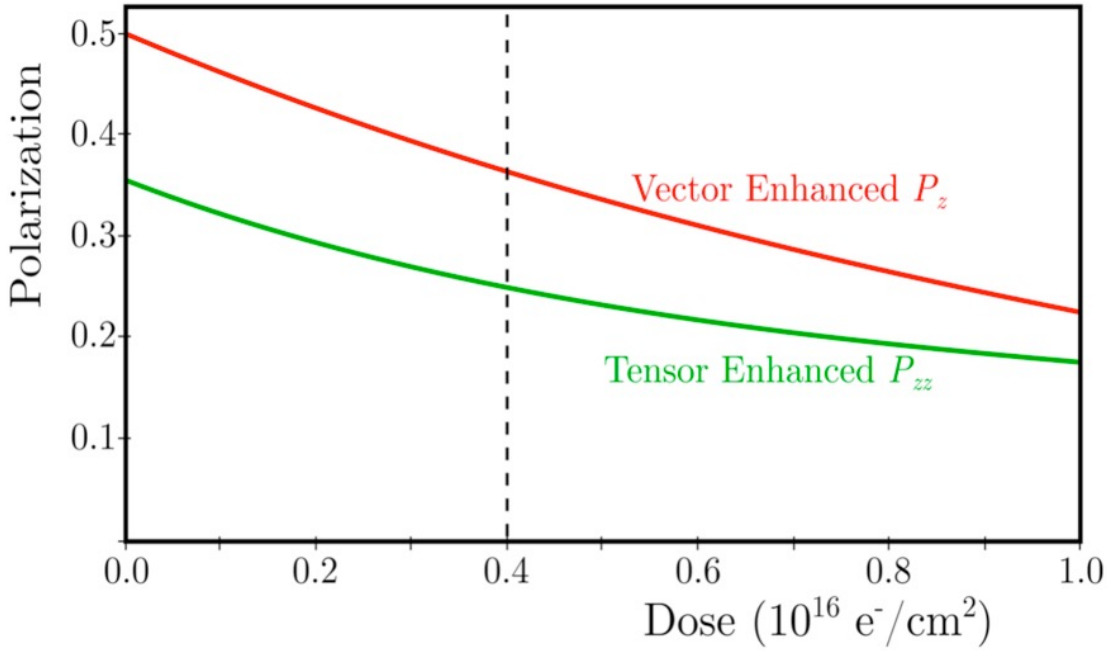
"*a tensor polarization of at least (close to) 30% be achieved and reliably demonstrated under experimental conditions.*"

Technical Developments



[1] D. Keller, et al., NIM A **981**, 164504 (2020)
[2] D. Keller, Eur. Phys. J. A **53**, 155 (2017)

NMR Spectra after ss-RF and target rotation
Resulting in a tensor polarization of 36.5+-3.5(absolute)%



Model of Vector and tensor polarizations with respect to the dose in beam
The vertical line indicates when annealing will be performed.

See also Elena Long's talk

Summary

Tensor spin observables will be measured
over a wide range of x

Working group making good progress

special thanks to Nathaly Santiesteban, Allison Zec,
Michael Mclellan and Emad Mustafa at UNH
and Ishara Fernando, Devin Seay and Joseph Clement at UVa

Preparing for Jlab review of Conditional Status

Weekly meetings Tuesdays at 9:30
new collaborators welcome!