Tensor Polarized DIS Experiments

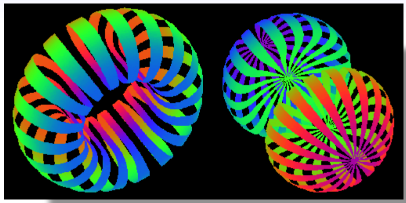
Polarized Light Ion Physics
with EIC

Gent, Belgium
2018-02-08

Karl Slifer
University of New Hampshire

This Talk

Brief Review of Tensor Polarization

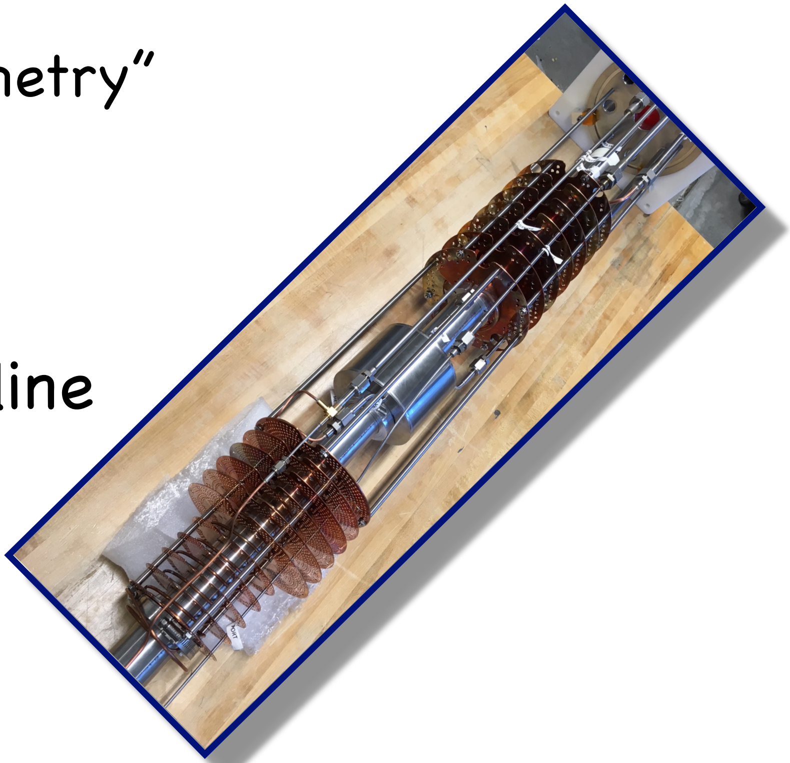


Solid Tensor PolTarg Experiments

E12-13-011: "The b_1 *experiment*"
E12-15-005: "A_{zz} *for* $x>1$"
LOI-12-16-006: "Nuclear Gluometry"

Latest Target Developments

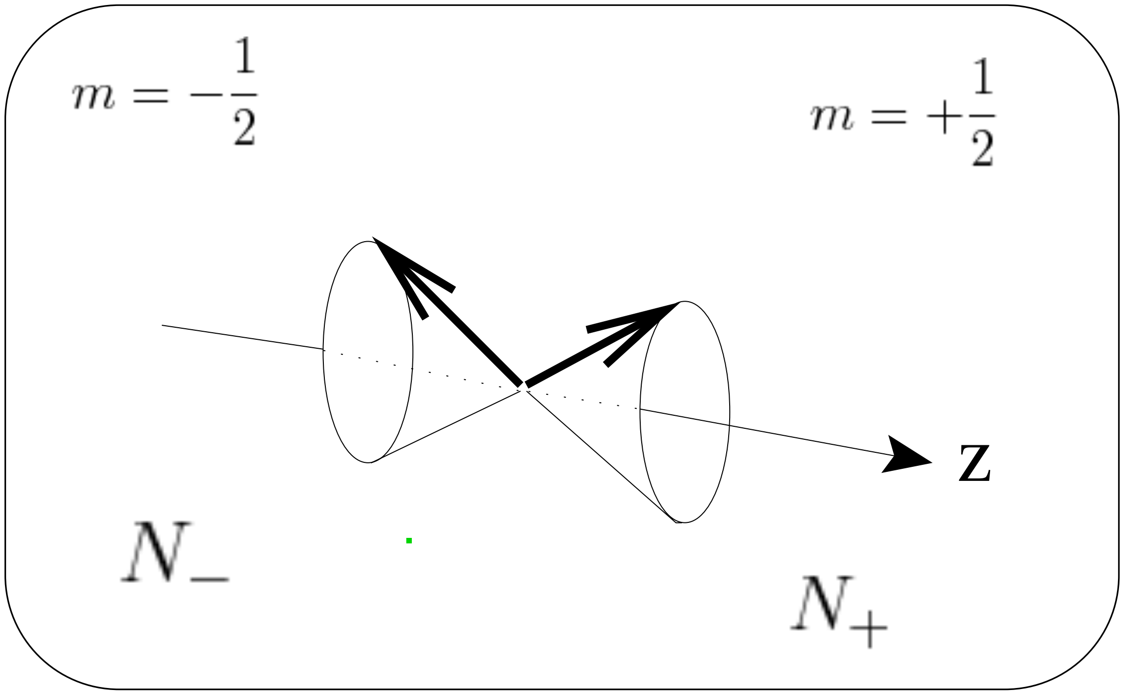
$P_{zz} \approx 40\%$ @ UVa
New Lab at UNH coming online



Future

Spin-1/2

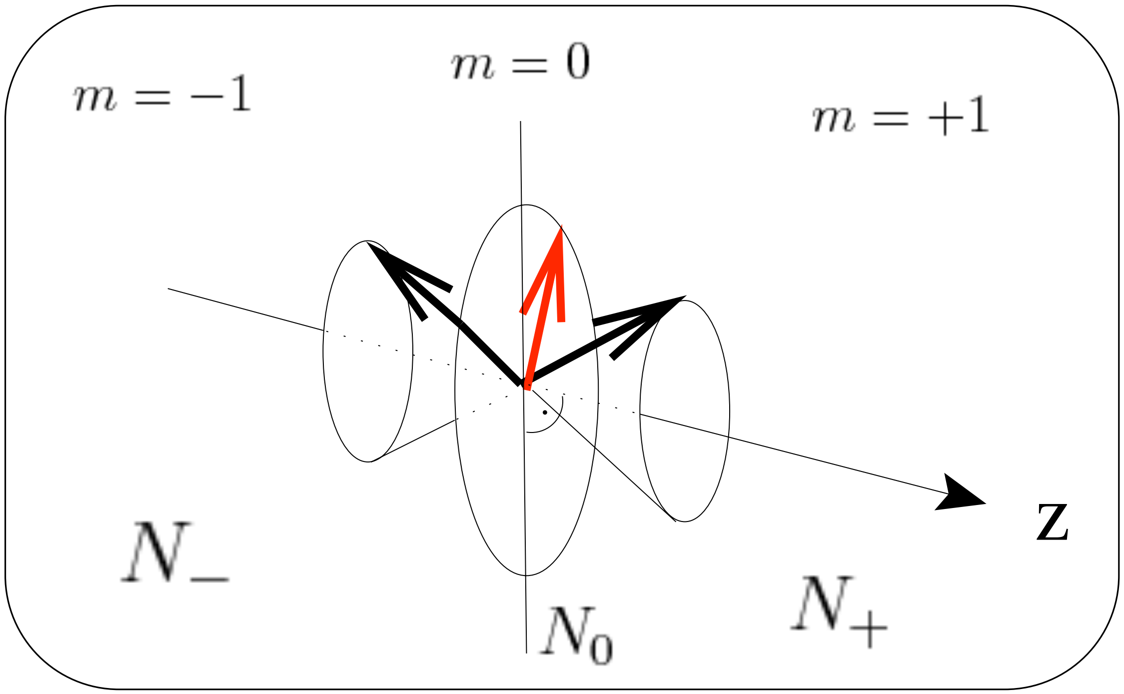
Spin-1/2 system in B-field leads to 2 sublevels due to Zeeman interaction



$$P_z = \frac{N_+ - N_-}{N_+ + N_-}$$

$\boxed{-1 < P_z < +1}$

Spin-1

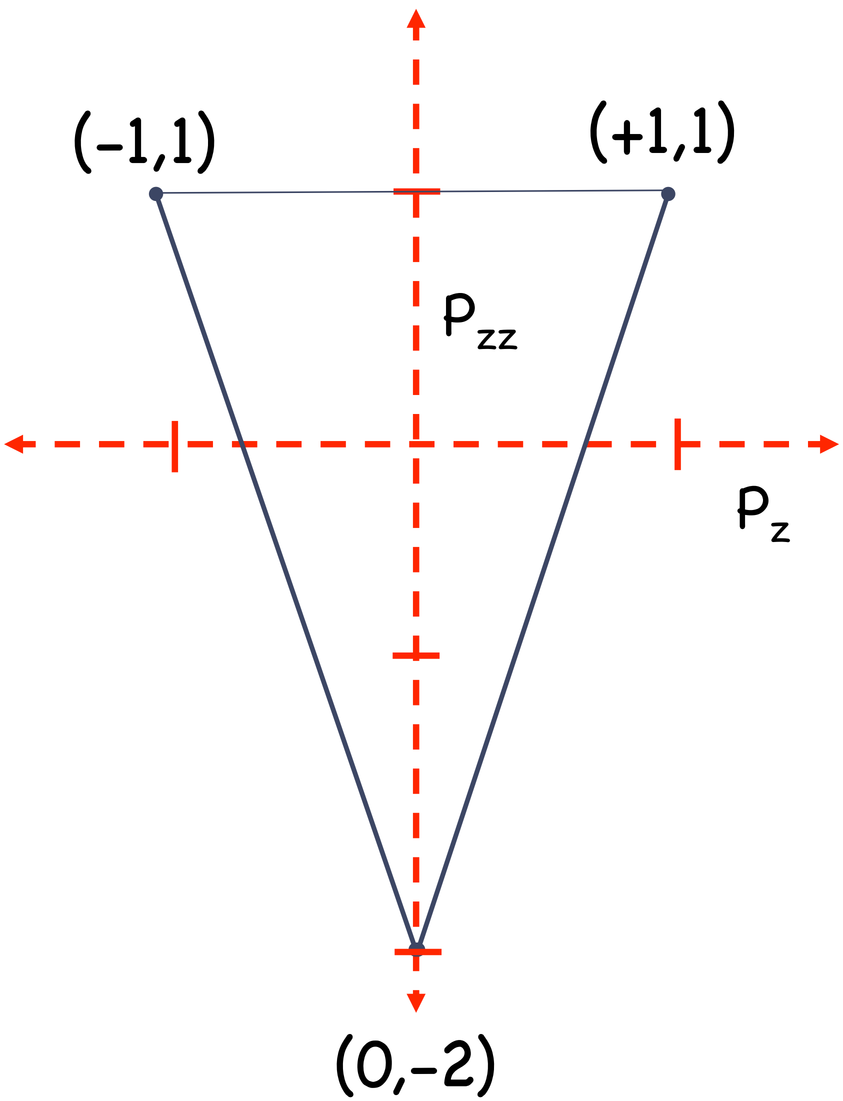


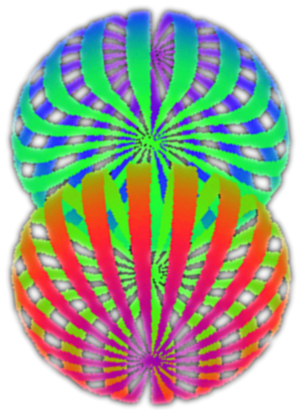
$$P_z = \frac{N_+ - N_-}{N_+ + N_-}$$

$\boxed{-1 < P_z < +1}$

$$P_{zz} = \frac{(N_+ - N_0) - (N_0 - N_-)}{N_+ + N_0 + N_-} = \frac{(N_+ + N_-) - 2N_0}{N_+ + N_0 + N_-}$$

$\boxed{-2 < P_{zz} < +1}$

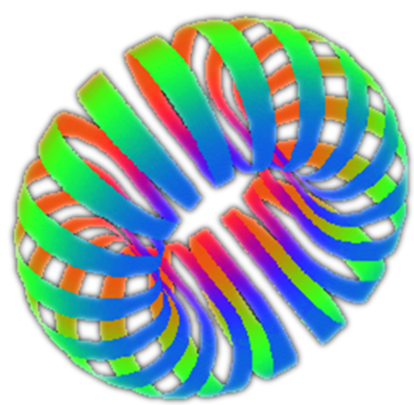




$$P_{zz} = +1$$

Pure Vector Polarization

m=0 level depopulated



$$P_{zz} = -2$$

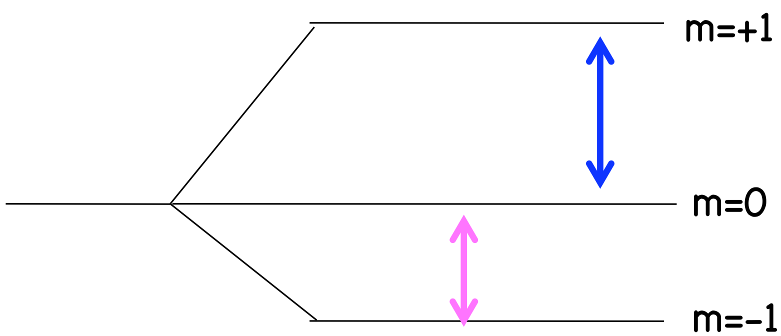
Pure Tensor Polarization

All spins in the m=0 level

Splitting

red : 0 <--> -1

blue : 0 <--> +1

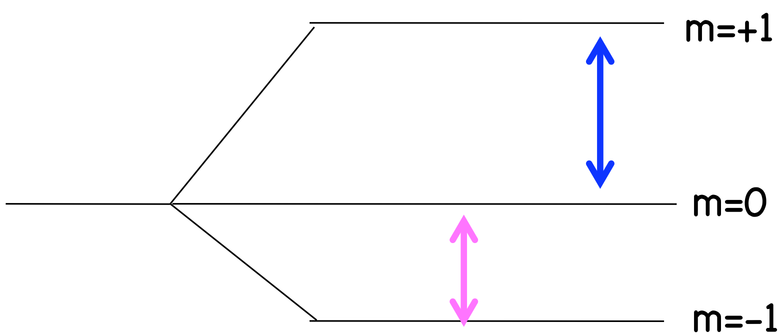


Energy Levels shifted asymmetrically
due to quadrupole interaction

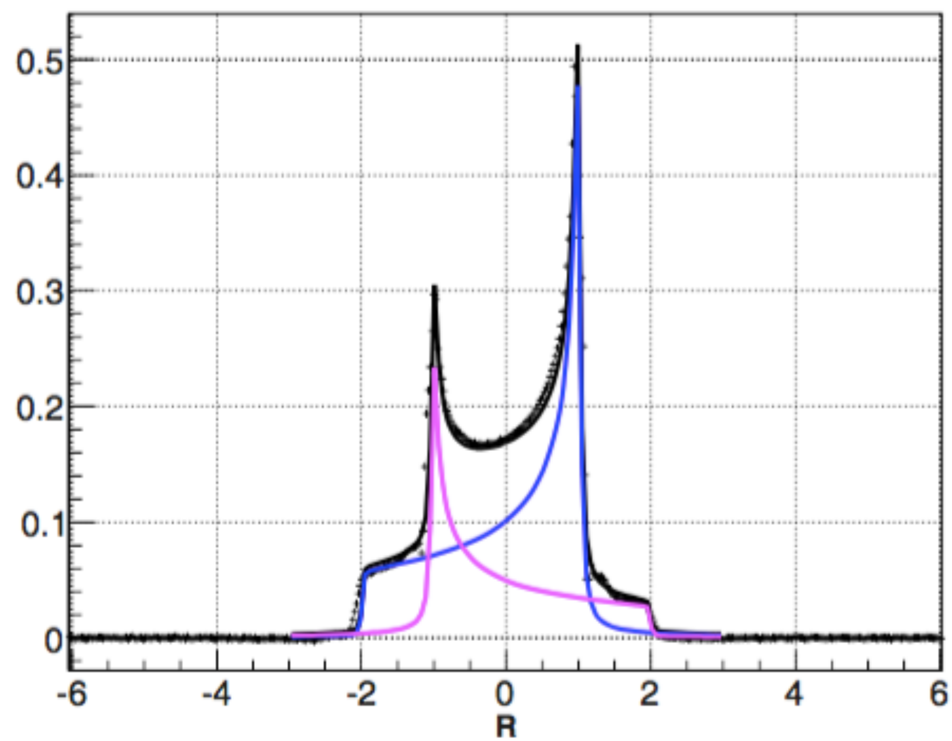
Splitting

red : 0 <--> -1

blue : 0 <--> +1



Energy Levels shifted asymmetrically
due to quadrupole interaction



At Equilibrium

$$P_z = \frac{4 + \tanh \frac{\mu B}{2kT}}{3 + \tanh^2 \frac{\mu B}{2kT}}$$

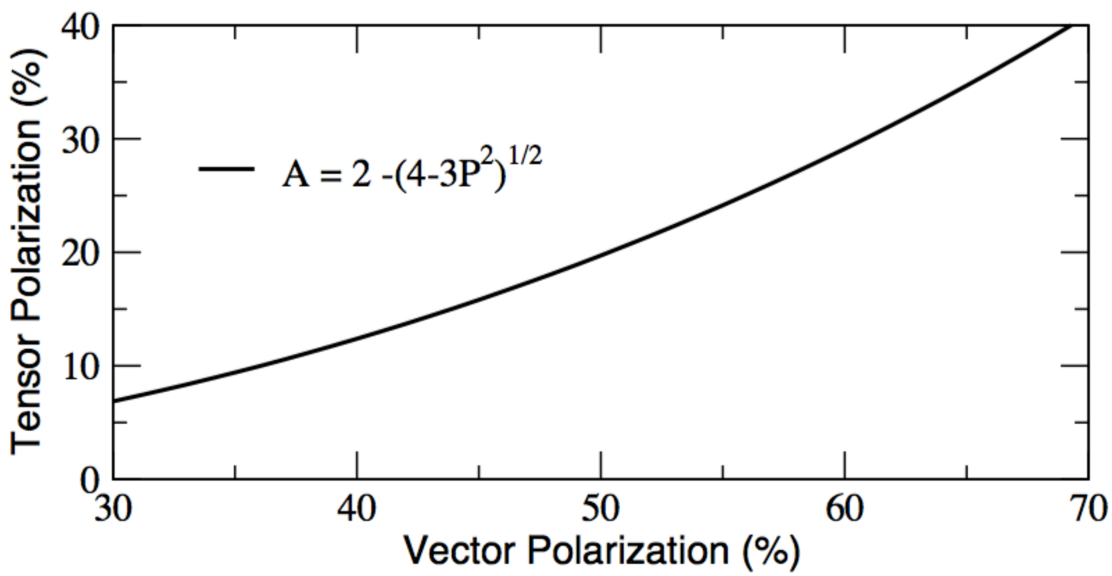
$$P_{zz} = \frac{4 + \tanh^2 \frac{\mu B}{2kT}}{3 + \tanh^2 \frac{\mu B}{2kT}}$$

At Equilibrium

$$P_z = \frac{4 + \tanh \frac{\mu B}{2kT}}{3 + \tanh^2 \frac{\mu B}{2kT}} \qquad P_{zz} = \frac{4 + \tanh^2 \frac{\mu B}{2kT}}{3 + \tanh^2 \frac{\mu B}{2kT}}$$

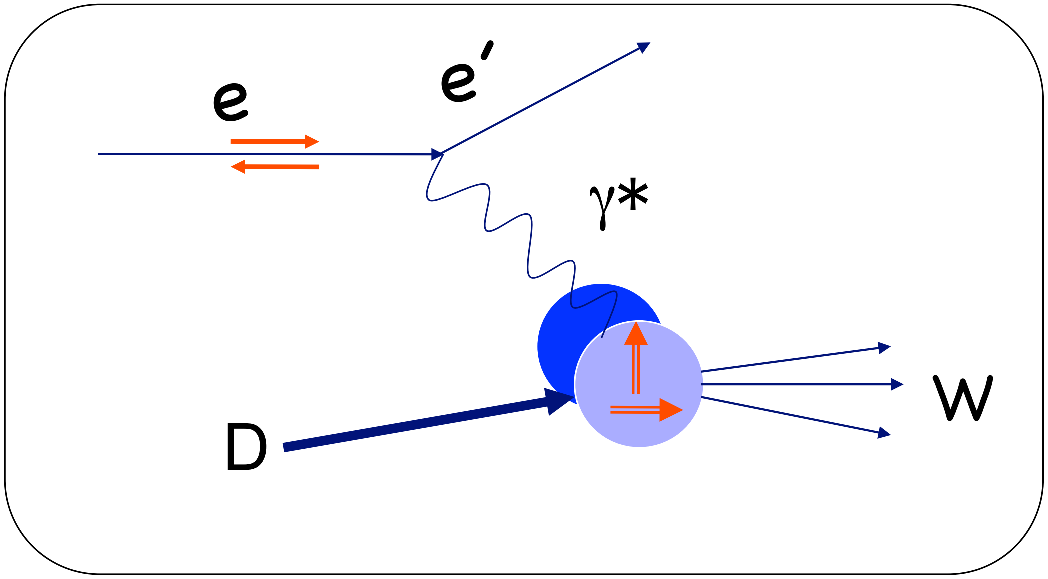
$$P_{zz} = 2 - \sqrt{4 - 3P_z^2}$$

(Only when in Thermal Equilibrium with the Solid Lattice)



does not hold when actively enhancing P_{zz}

Inclusive Scattering



Construct the most general
Tensor W consistent with
Lorentz and gauge invariance

Frankfurt & Strikman (1983)

Hoodbhoy, Jaffe, Manohar (1989)

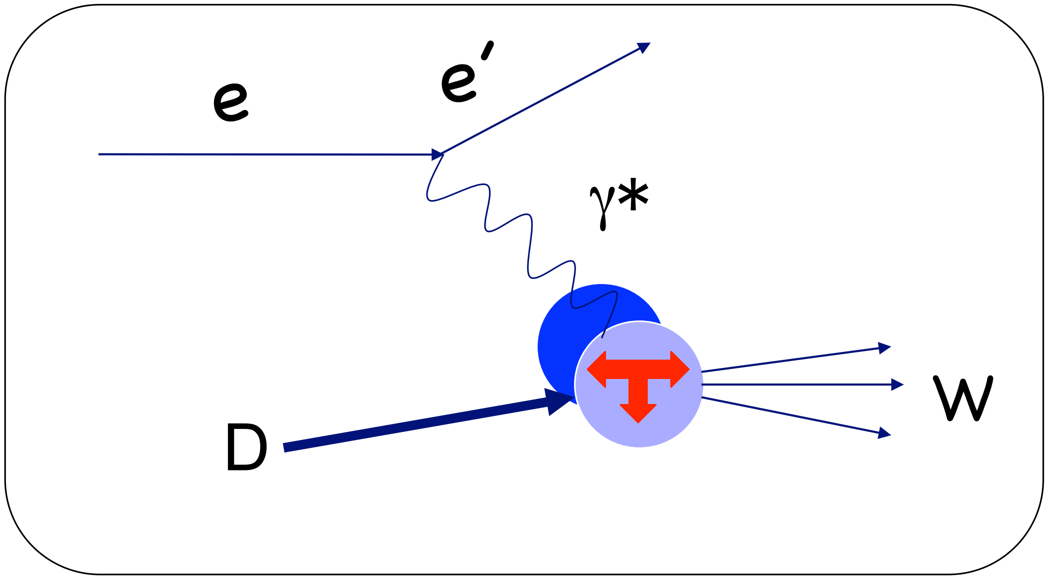
$$W_{\mu\nu} = -F_1 g_{\mu\nu} + F_2 \frac{P_\mu P\nu}{\nu}$$

Unpolarized Scattering

$$+i\frac{g_1}{\nu}\epsilon_{\mu\nu\lambda\sigma}q^\lambda s^\sigma + i\frac{g_2}{\nu^2}\epsilon_{\mu\nu\lambda\sigma}q^\lambda(p\cdot qs^\sigma - s\cdot qp^\sigma)$$

Vector Polarization

Tensor Structure Functions



Construct the most general Tensor W consistent with Lorentz and gauge invariance

Frankfurt & Strikman (1983)

Hoodbhoy, Jaffe, Manohar (1989)

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

Caution : There is an alternate similar formulation by Edelmann, Piller, Weise

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

	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

b_2 : related to b_1 by A Callan-Gross relation

b_4 : Also Leading Twist, but kinematically suppressed for a longitudinally polarized target.

b_3 : higher twist, like g_2

Parton Distributions

$q^m_{\uparrow\downarrow}$ Probability to scatter from a quark with spin up/down carrying momentum fraction x while the *Deuteron* is in state m

Parton Distributions

$q^m_{\uparrow\downarrow}$ Probability to scatter from a quark with spin up/down carrying momentum fraction x while the *Deuteron* is in state m

$$q_1(x) = q^1_\uparrow(x) + q^1_\downarrow(x)$$

$$q^0(x) = q^0_\uparrow(x) + q^0_\downarrow(x)$$

spin averaged parton distributions

Parton Distributions

$q^m_{\uparrow\downarrow}$ Probability to scatter from a quark with spin up/down carrying momentum fraction x while the *Deuteron* is in state m

$$
\begin{aligned}
q_1(x) &= q^1_\uparrow(x) + q^1_\downarrow(x) \\
q^0(x) &= q^0_\uparrow(x) + q^0_\downarrow(x)
\end{aligned}
$$

spin averaged parton distributions

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

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

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

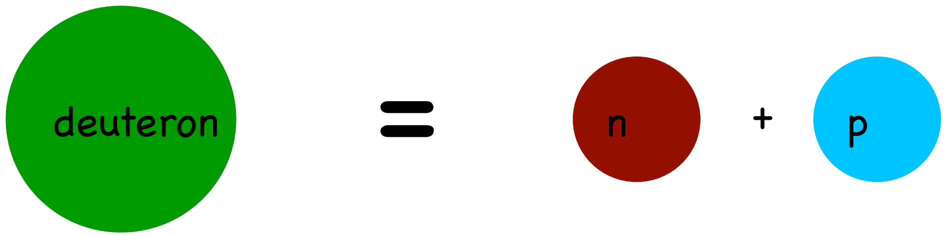
q^1 : Probability to scatter from a quark (any flavor) carrying momentum fraction x while the *Deuteron* is in state |m| = 1

b_1 Structure Function

Hoodbhoy, Jaffe and Manohar (1989)

b_1 vanishes in the absence of nuclear effects

i.e. if...



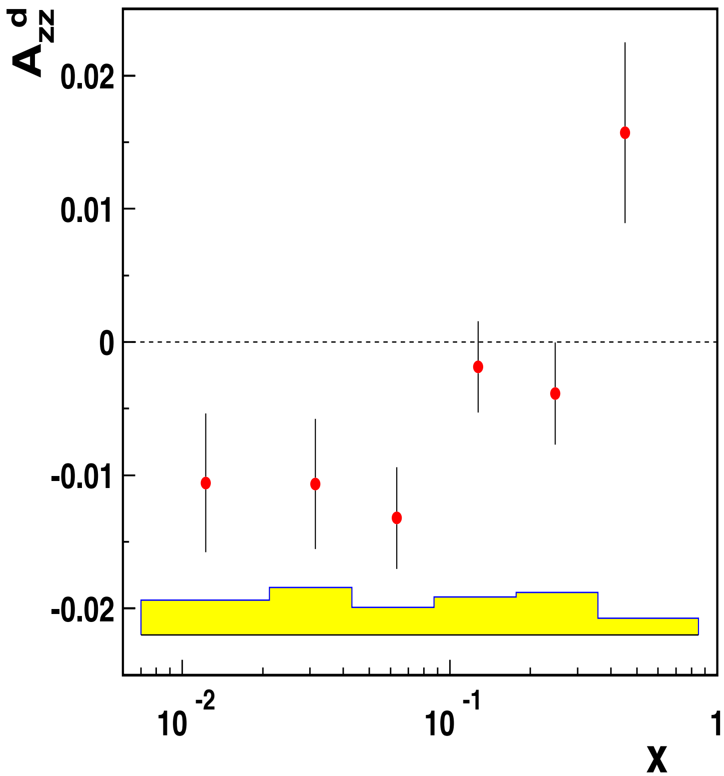
Proton Neutron in relative S-state

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

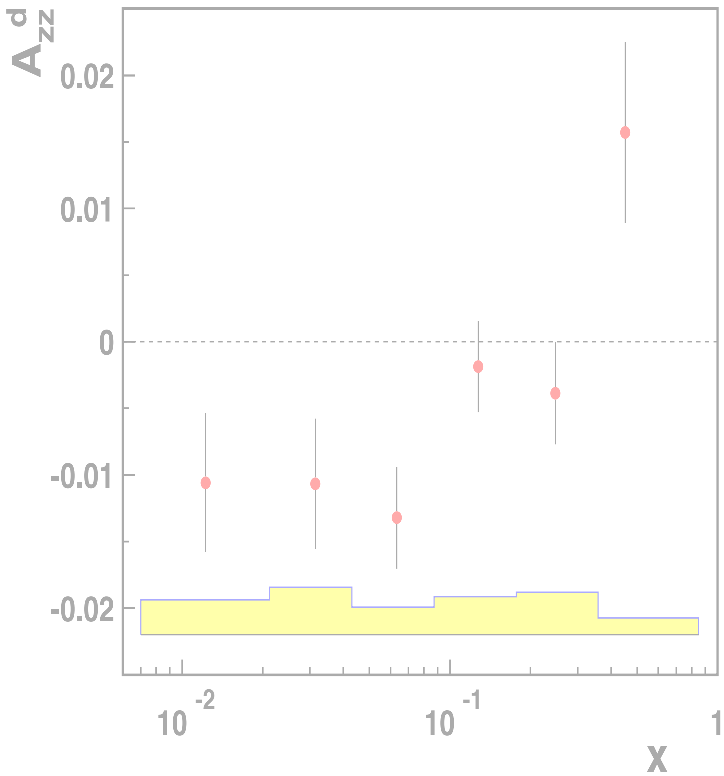
Umnikov, PLB 391, 177 (1997) : $b_1 \approx O(10^{-3})$
Relativistic convolution with Bethe-Salpeter formalism

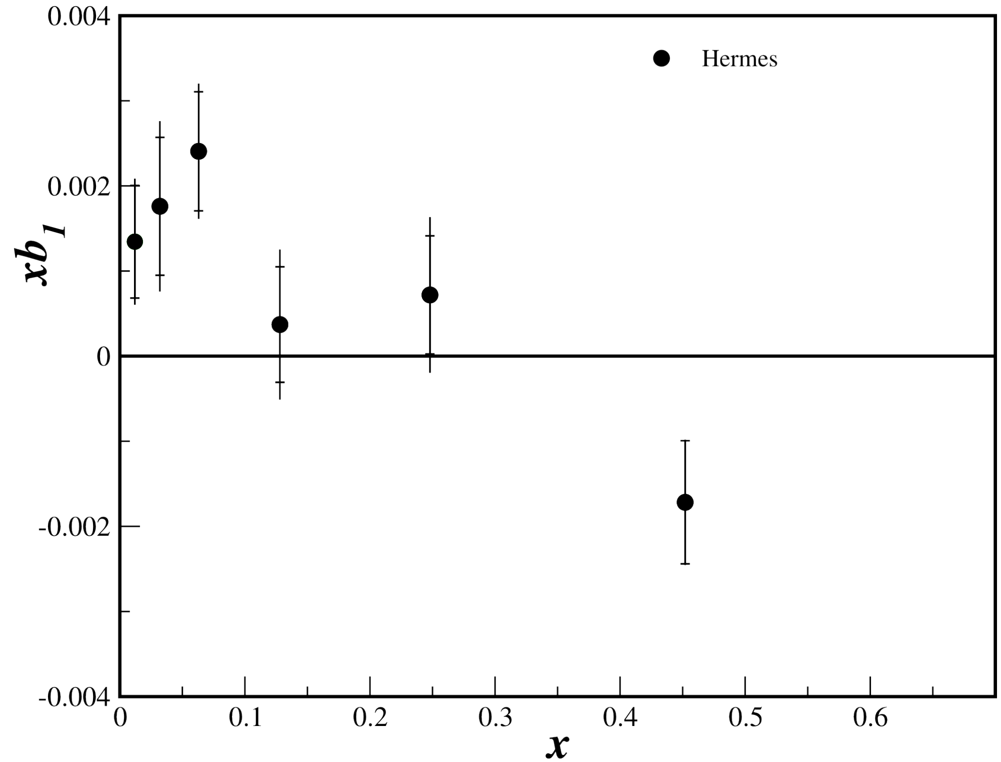
Data from HERMES



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

Data from HERMES

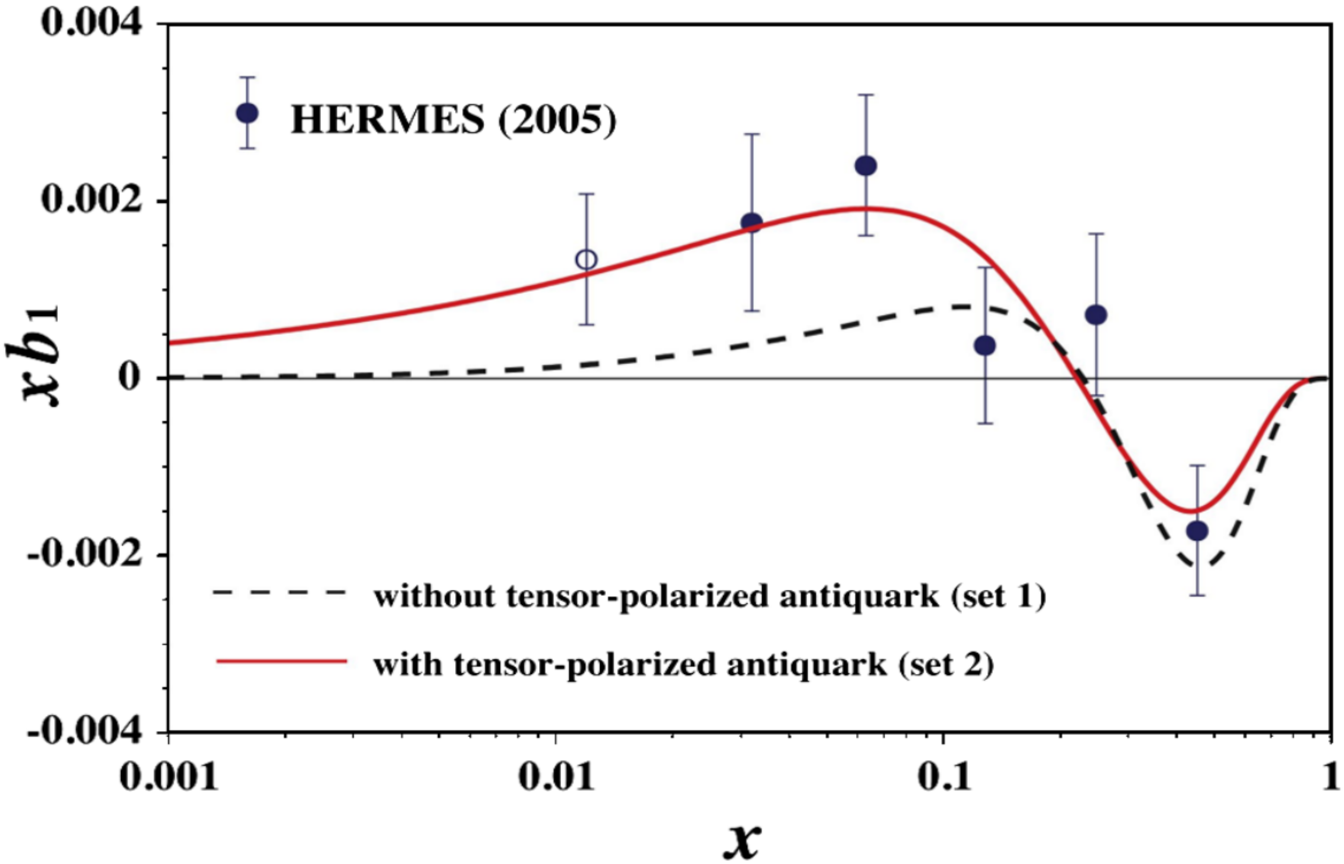




$$b_1 = -\frac{3}{2} F_1 A_{zz}$$

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

Tensor polarization of the sea



S Kumano,
PRD **82** 017501 (2010)

Fit improves when tensor polarization of the antiquark distributions is included

Close-Kumano Sum Rule

$$\int b_1(x)dx = \frac{1}{9}\Theta Q_s$$

$$\boxed{\int b_1(x)dx = 0}$$

if the sea quark tensor polarization vanishes

Close-Kumano Sum Rule

$$\int b_1(x)dx = \frac{1}{9}\Theta Q_s$$

$$\boxed{\int b_1(x)dx = 0}$$

if the sea quark tensor polarization vanishes

<u>Hermes result</u>

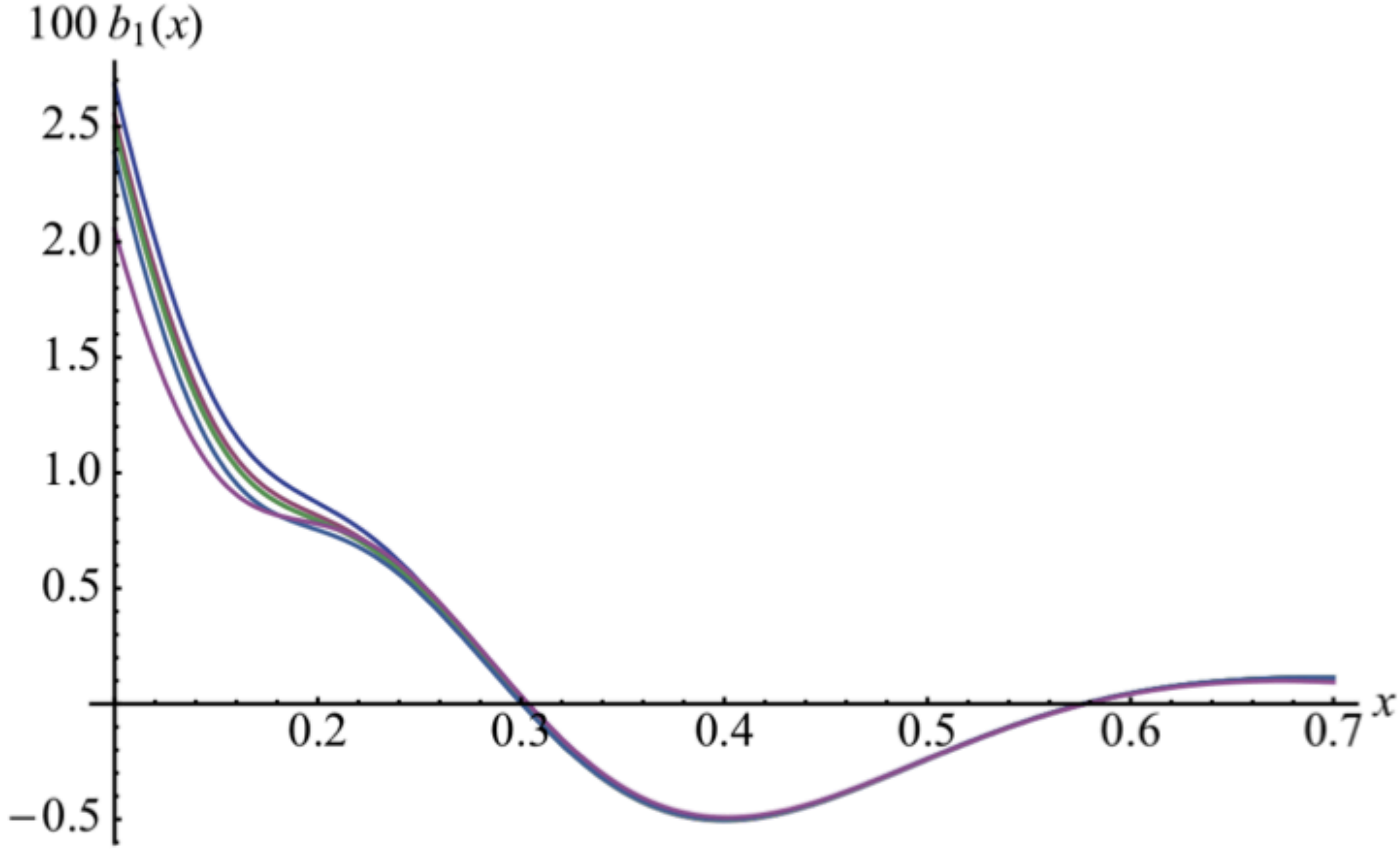
$$\int_{0.0002}^{0.85} b_1(x)dx = 0.0105 \pm 0.0034 \pm 0.0035$$

2.2 σ difference from zero

6-quark, Hidden Color

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

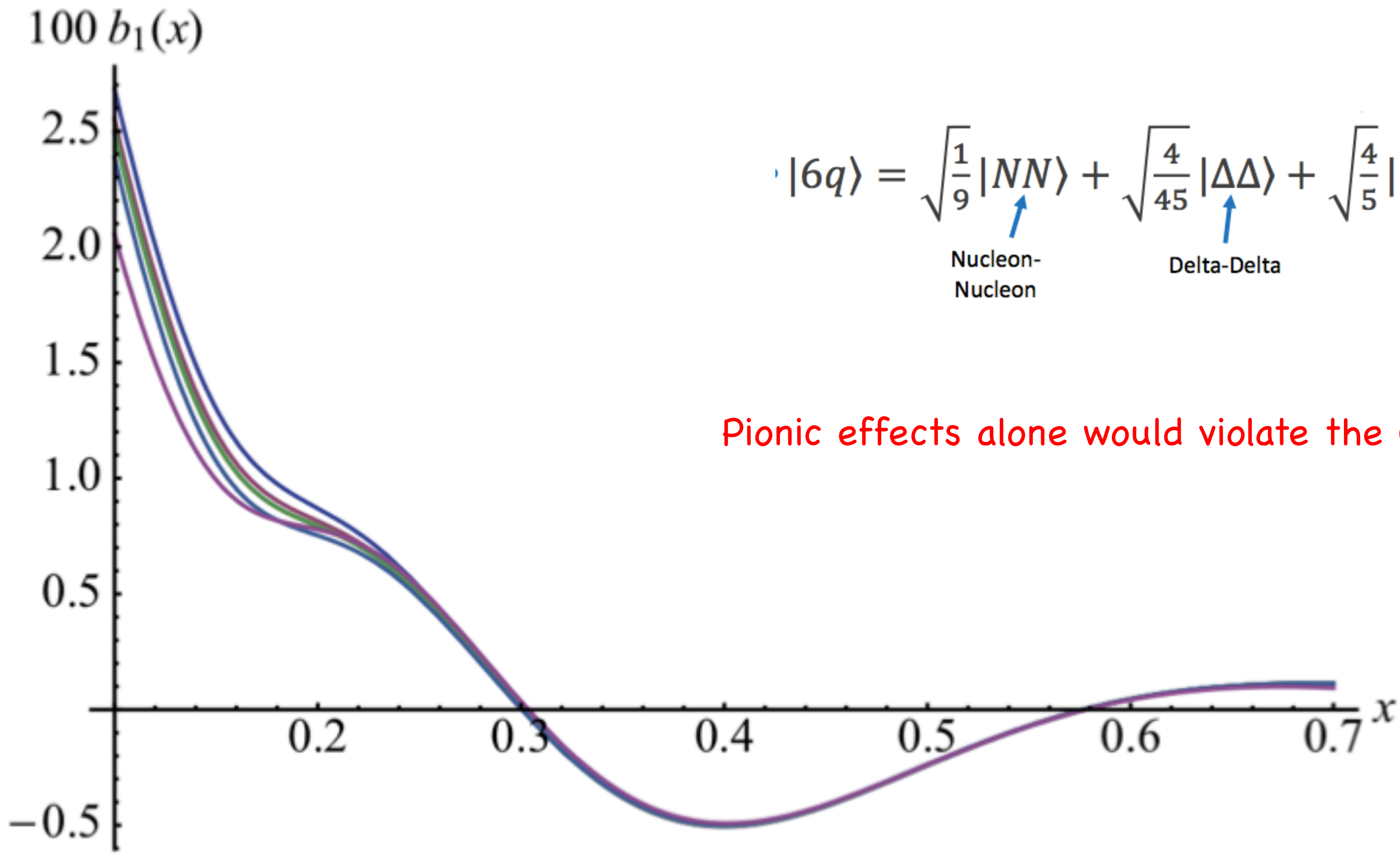
"Pionic and Hidden-Color, Six-Quark Contributions to the Deuteron **b1** Structure Function"



6-quark, Hidden Color

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

"Pionic and Hidden-Color, Six-Quark Contributions to the Deuteron **b1** Structure Function"



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

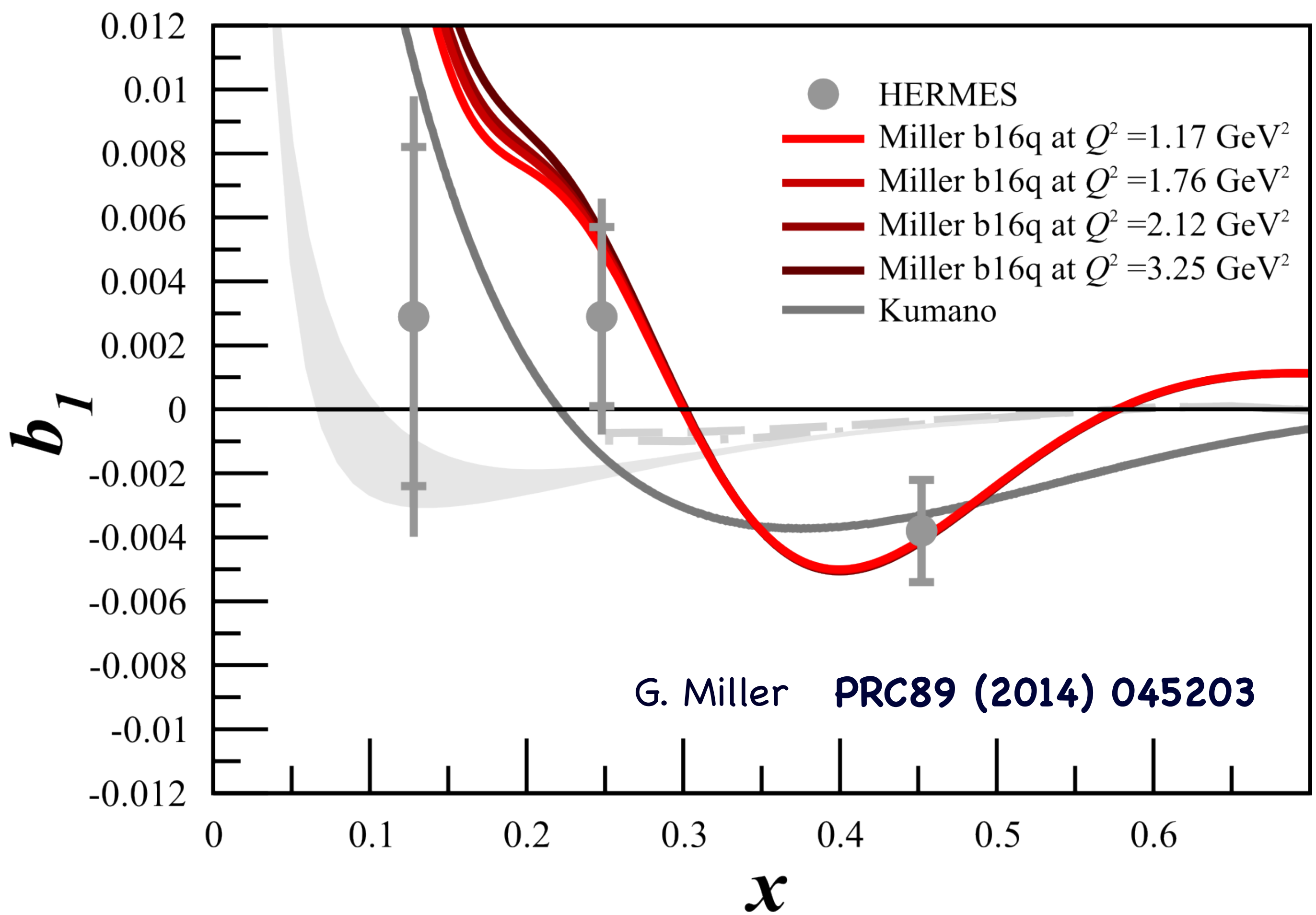
Nucleon-Nucleon

Delta-Delta

Hidden Color

Pionic effects alone would violate the Ck sum rule

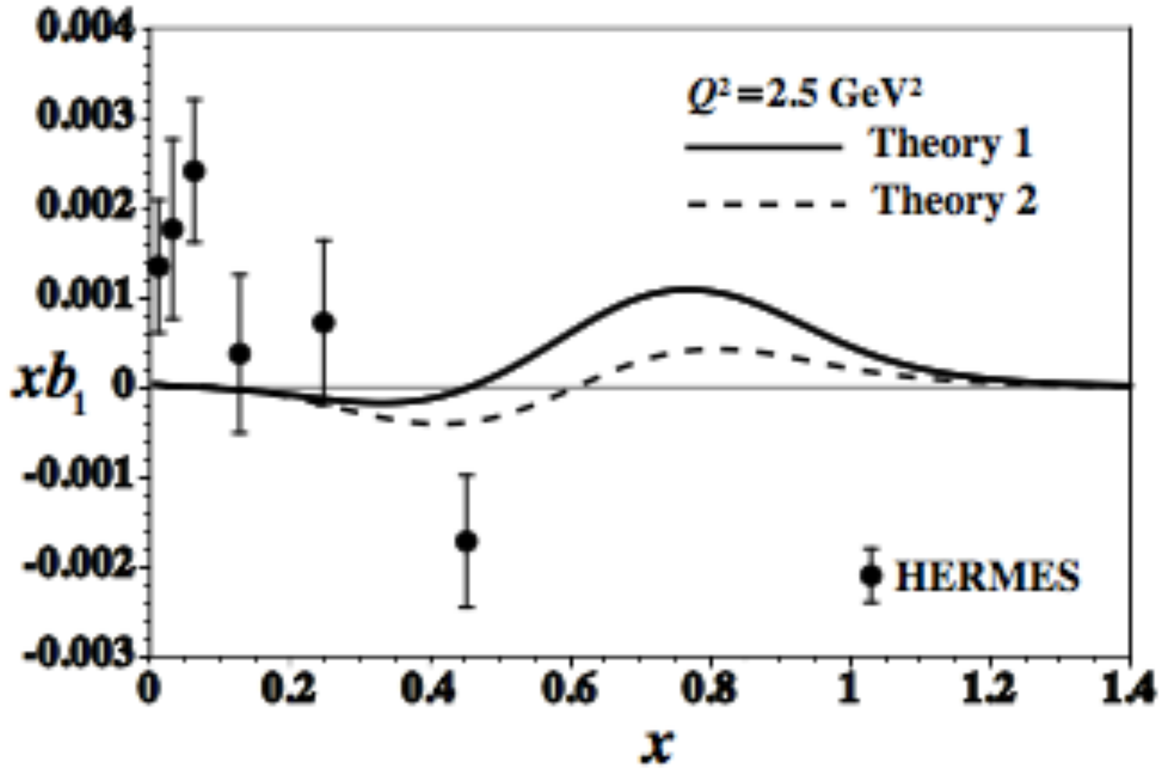
Unique Signal of Hidden Color



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.

b_1 in standard convolution description



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

[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"

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!

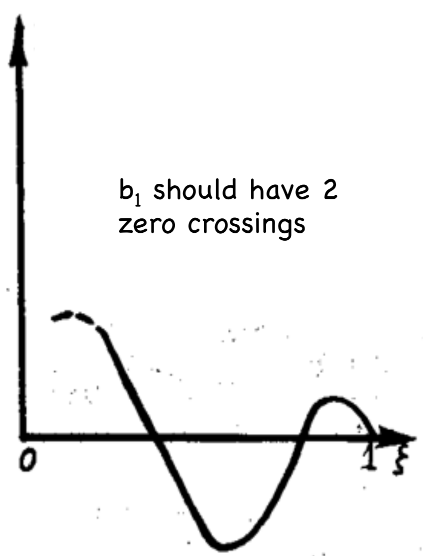


Рис.1

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

Gluon Contribution to Tensor Structure

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

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

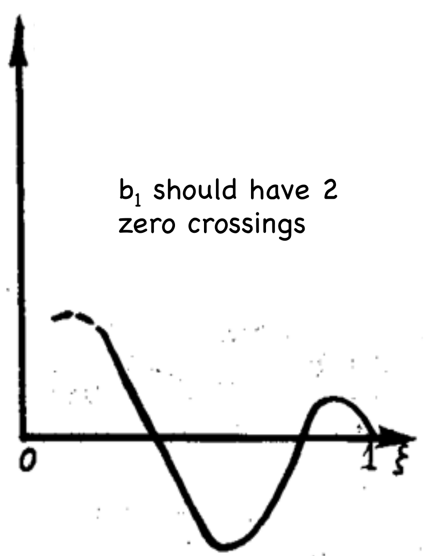


Рис.1

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

Tensor Program

E12-13-011: "The b_1 experiment"

30 Days in Jlab Hall C
A- Physics Rating
Conditional Approval (Target Performance)

Contact : K. Slifer

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

44 Days in Jlab Hall C
A- Physics Rating
Conditional Approval (Target Performance)

Contact : E. Long

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.

Conditions:
The experiment is conditionally approved with the condition that a tensor polarization of at least 30% be achieved and reliably demonstrated under experimental conditions.

The Deuteron Polarized Tensor Structure Function b_1

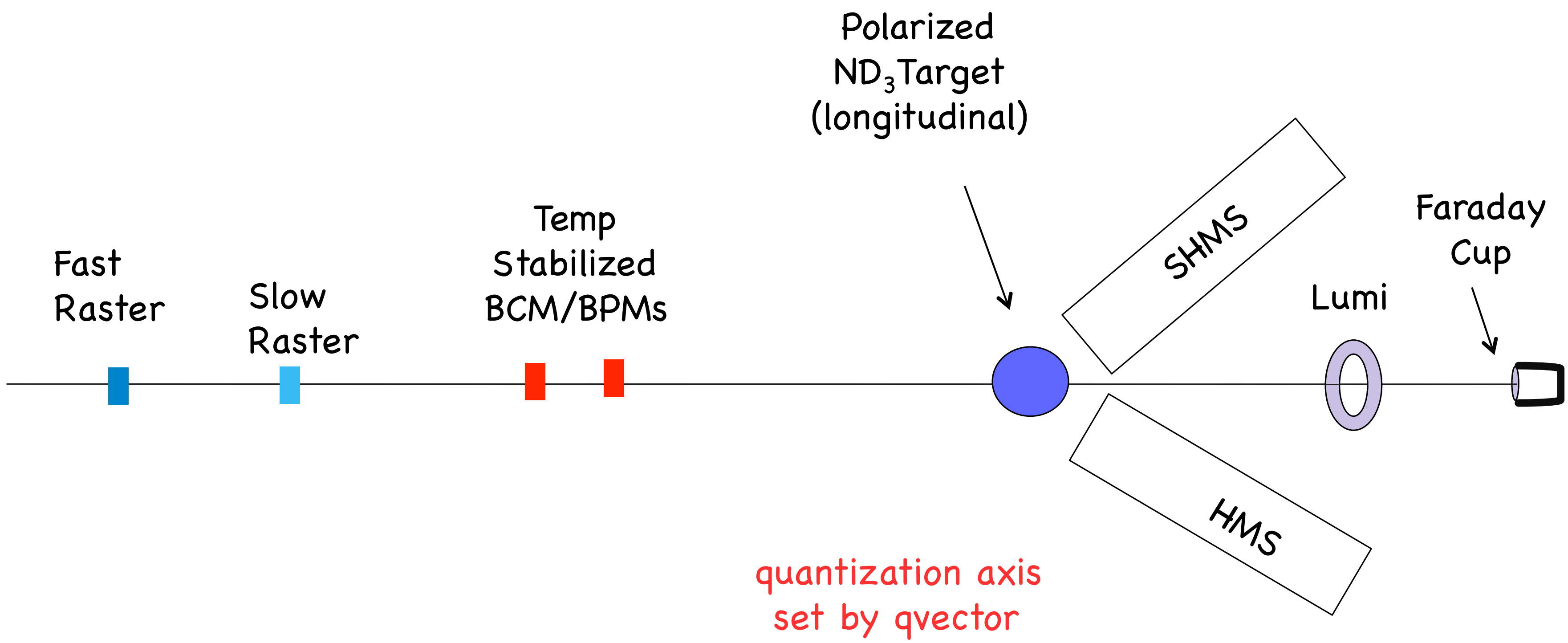
JLAB E12-14-011

A^{-} rating by PAC40
(C1: conditional on target performance)

Spokespersons

Slifer, Solvignon, Long, Chen, Rondon, Kalantarians

JLAB HALL C



Unpolarized Beam
UVa/JLab Polarized Target

Magnetic Field Held Along qvector

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

Experimental Method

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

$$= \frac{2}{fP_{zz}} \left(\frac{N_{\dagger}}{N_0} - 1 \right)$$

Observable is the Normalized XS Difference

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

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

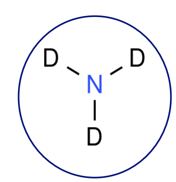
$\sigma_{\dagger}$: Tensor Polarized cross-section

σ_0 : Unpolarized cross-section

P_{zz} : Tensor Polarizzation

dilution factor

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



Impact on the observable

$$\boxed{\delta A_{zz} = \pm \frac{2}{f P_{zz}\sqrt{N_{cycles}}}\delta\xi}$$

Dedicated team to systematics/false asyms

similar manpower requirement to g2p exp. where we had several teams completely separate from the polarized target effort.

$\delta\xi$

Charge Determination

< 2 x 10^{-4}, mitigated by thermal isolation of BCMs and addition of 1 kW Faraday cup

Luminosity

< 1 x 10^{-4}, monitored by Hall C lumi

Target dilution and length   step like changes observable in polarimetry

< 1 x 10^{-4}

Beam Position Drift effect on Acceptance

< 1 x 10^{-4} (we can control the beam to 0.1 mm, raster over 2cm diameter)

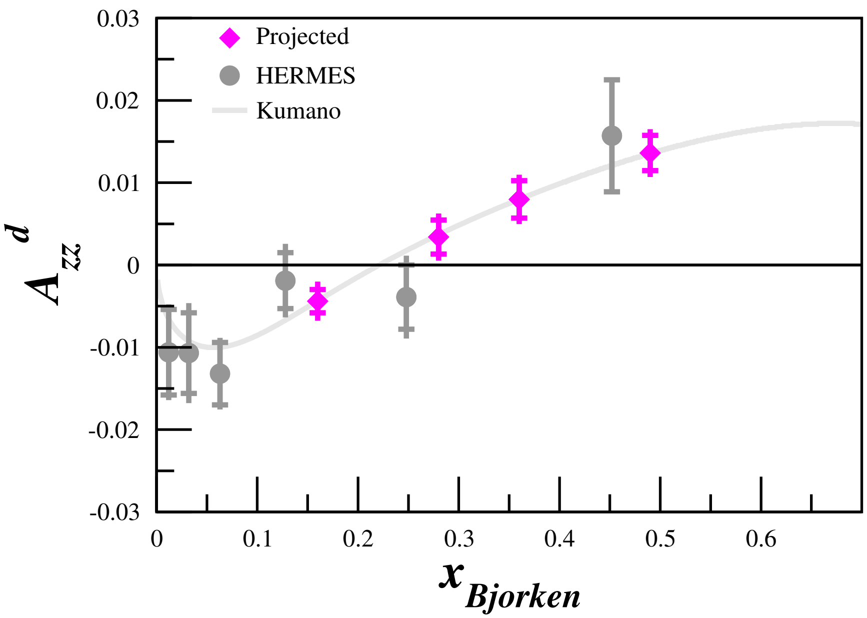
Effect of using polarized beam

< 2.2 x 10^{-5}, using parity feedback

Want to improve the statistics?   *Increase P_{zz}*

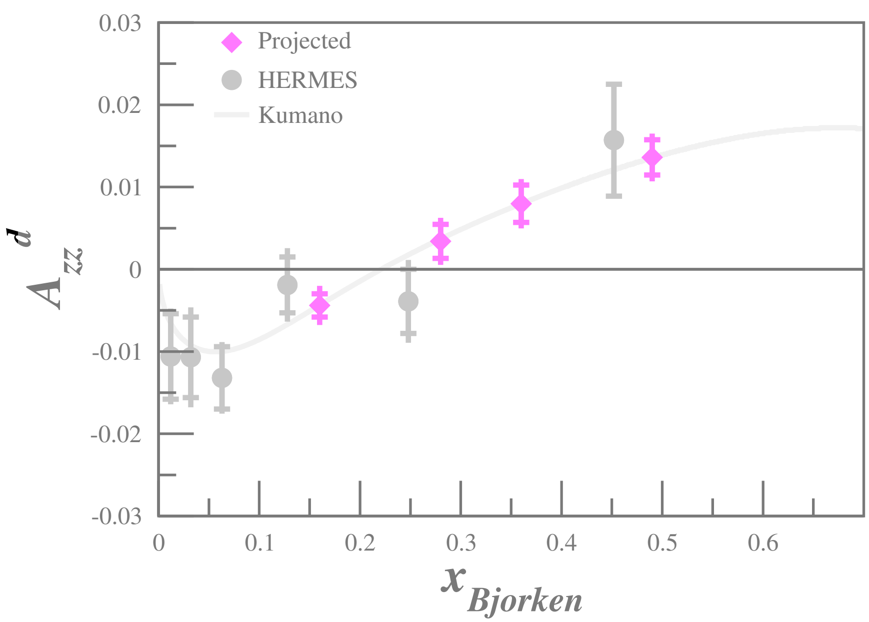
Want to improve the systematics?   *Increase P_{zz}*

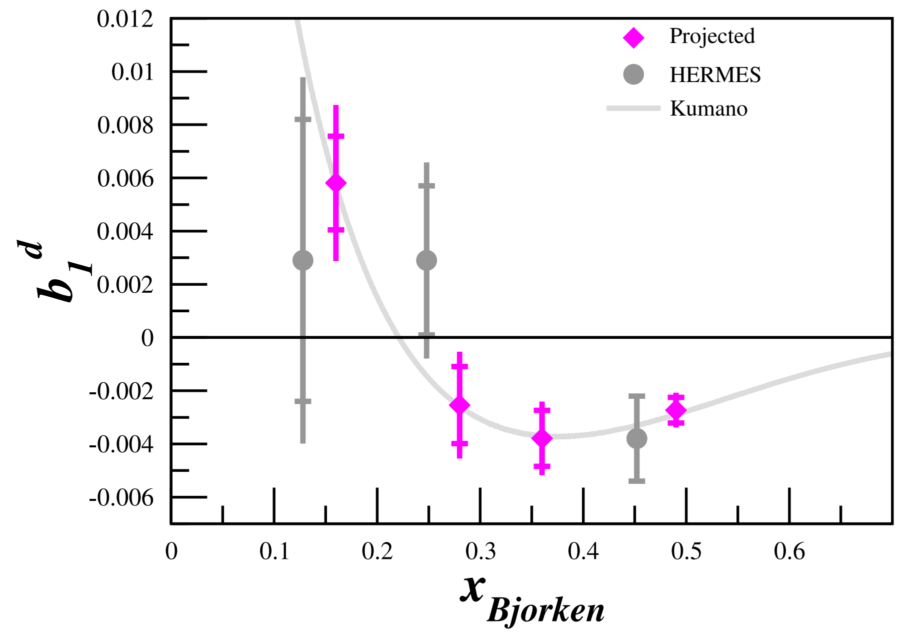
Projected Results for P_{zz} = 35%



30 Days in Jlab Hall C

Projected Results for P_{zz} = 35%





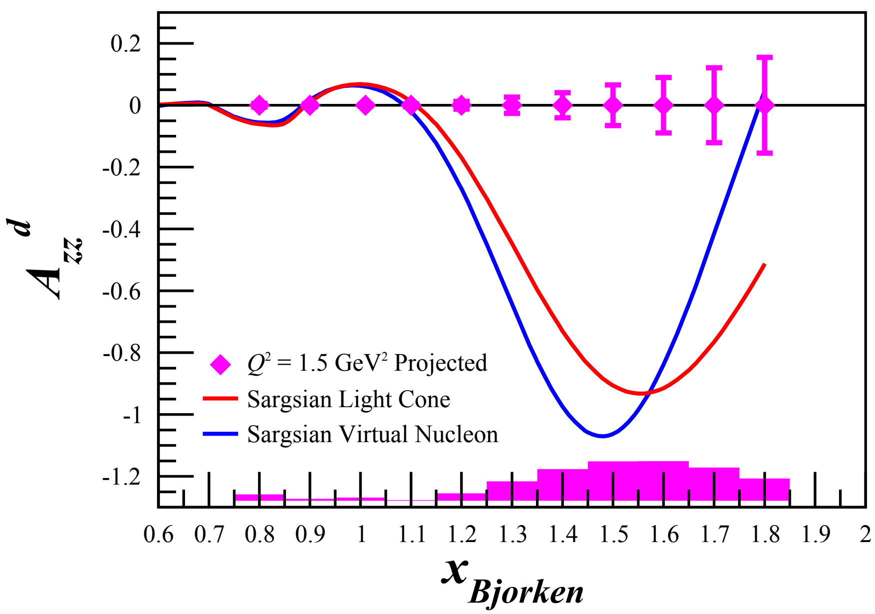
30 Days in Jlab Hall C

verification of zero crossing
essential for satisfaction of CK Sum

E12-15-005

A_{zz} in the x>1 Region

Ellie Long, Slifer, Solvignon,
Day, Higinbothan, Keller

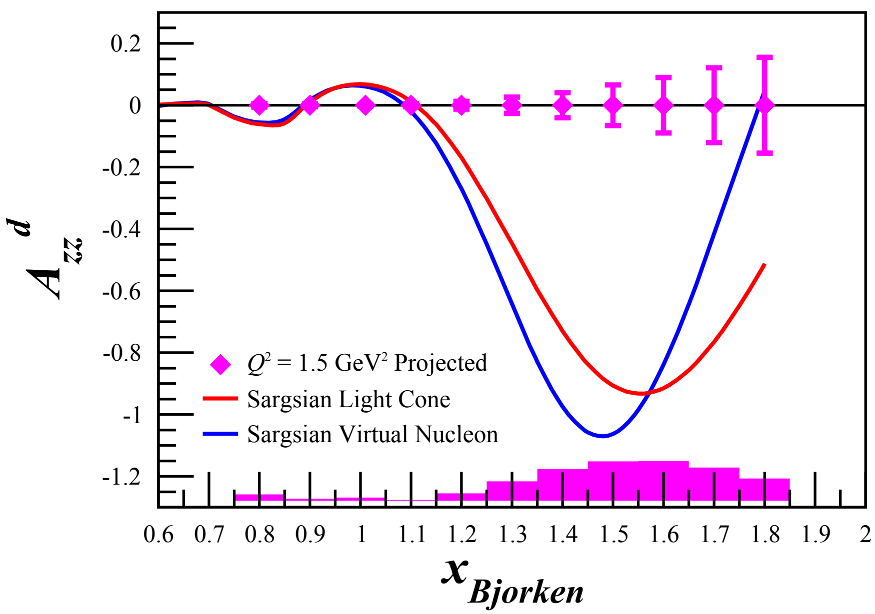


Very Large Tensor Asymmetries predicted

E12-15-005

A_{zz} in the x>1 Region

Ellie Long, Slifer, Solvignon,
Day, Higinbothan, Keller



Very Large Tensor Asymmetries predicted

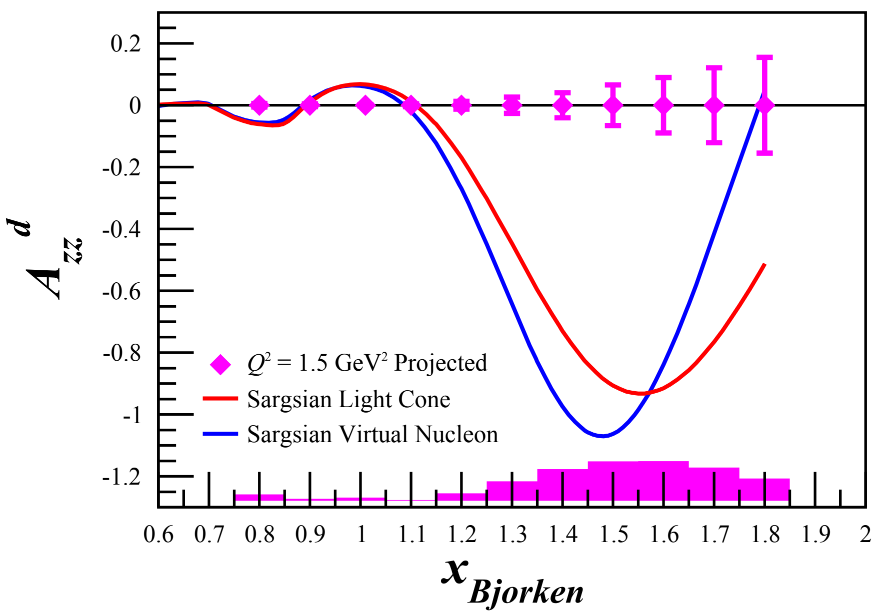
Sensitive to the S/D-wave ratio in the deuteron wave function

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

E12-15-005

A_{zz} in the x>1 Region

Ellie Long, Slifer, Solvignon,
Day, Higinbothan, Keller



Very Large Tensor Asymmetries predicted

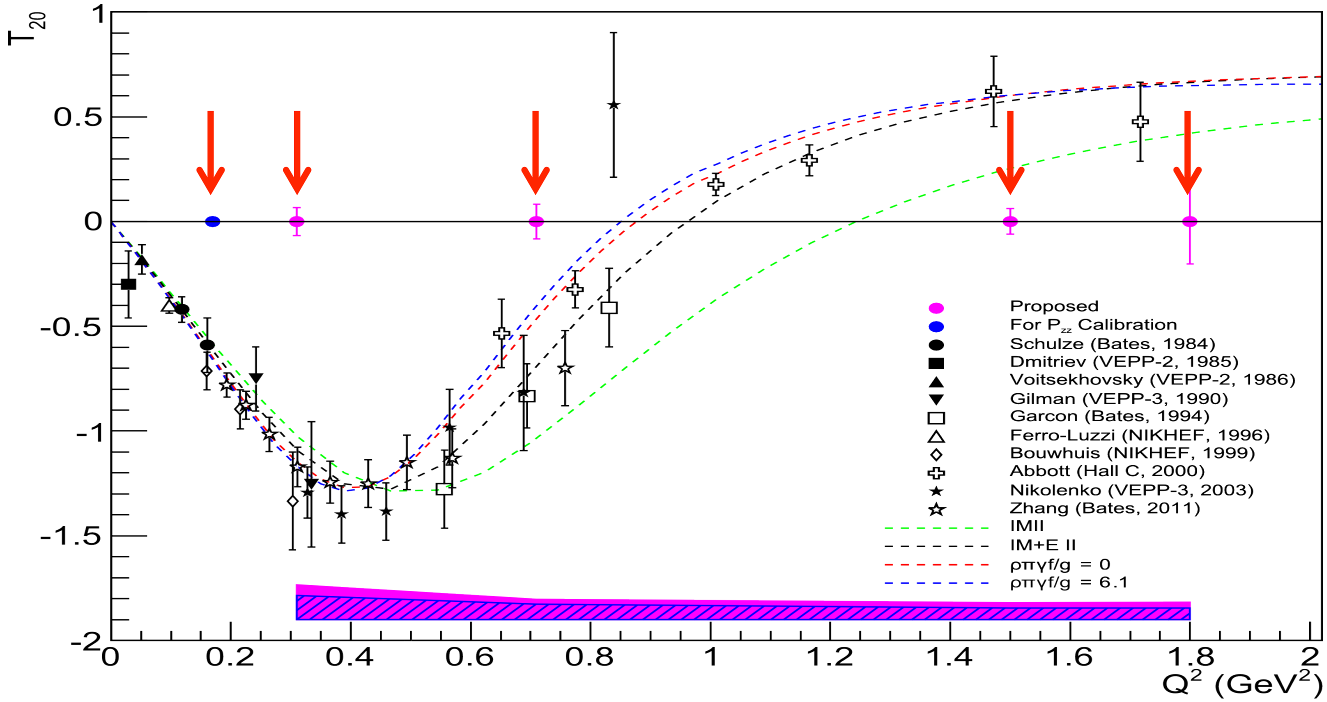
Sensitive to the S/D-wave ratio in the deuteron wave function

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

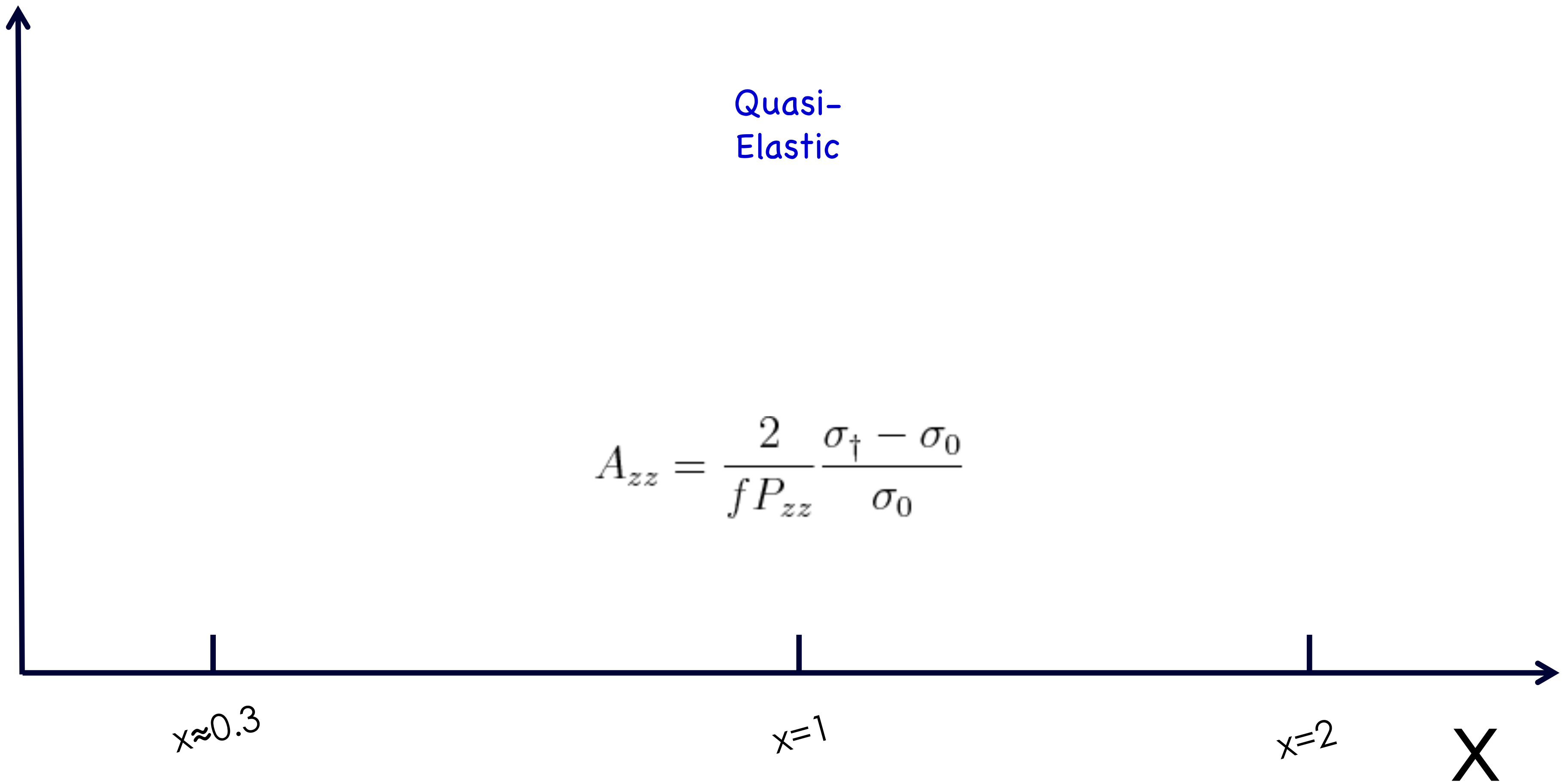
A_{zz} EXPERIMENT



We simultaneously measure nuclear elastic

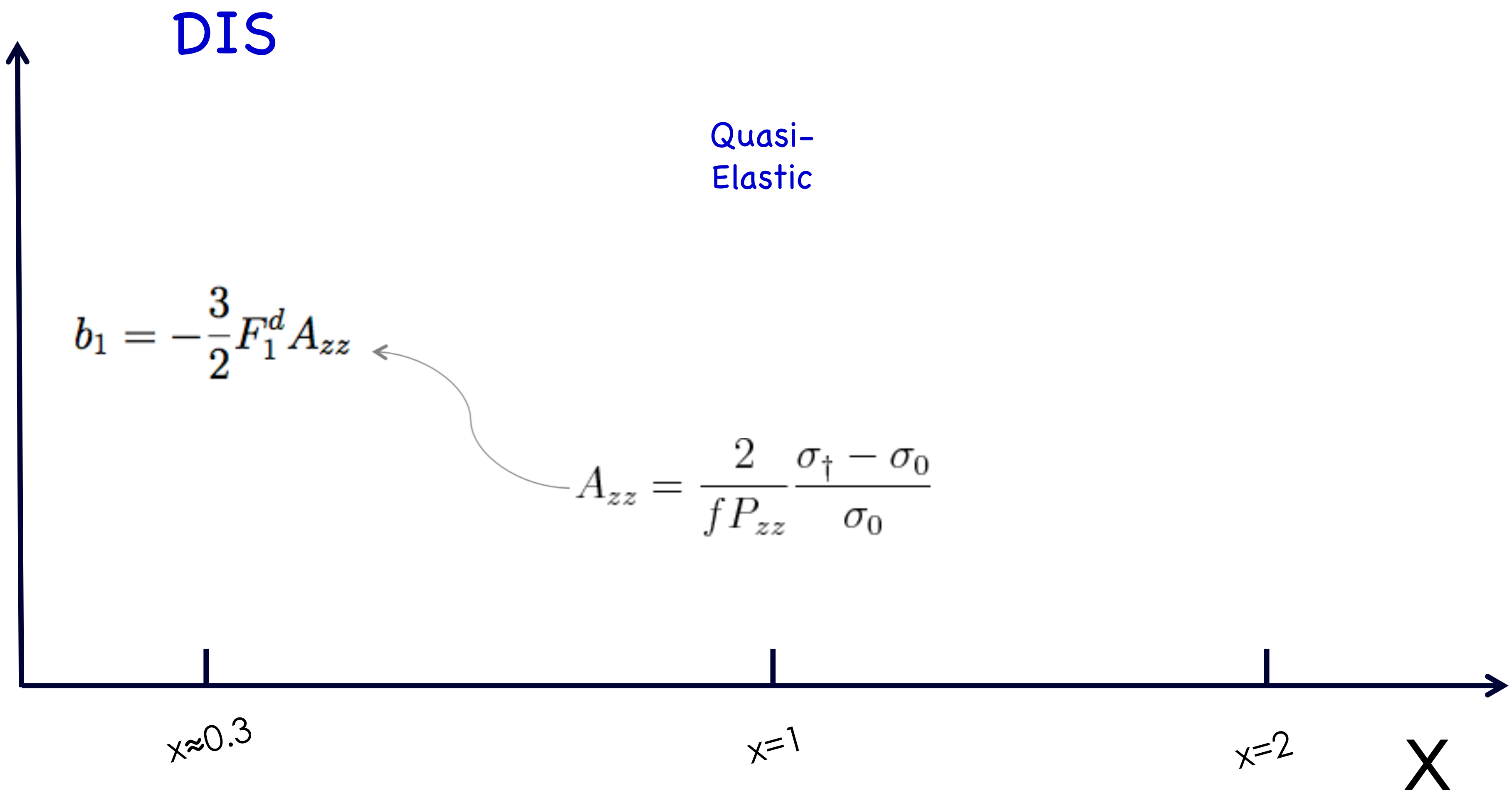
-> T_{20} over huge Q^2 range
-> measure T_{20} at largest Q^2 yet
-> will use to cross-check Pzz

Tensor Spin Observables



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

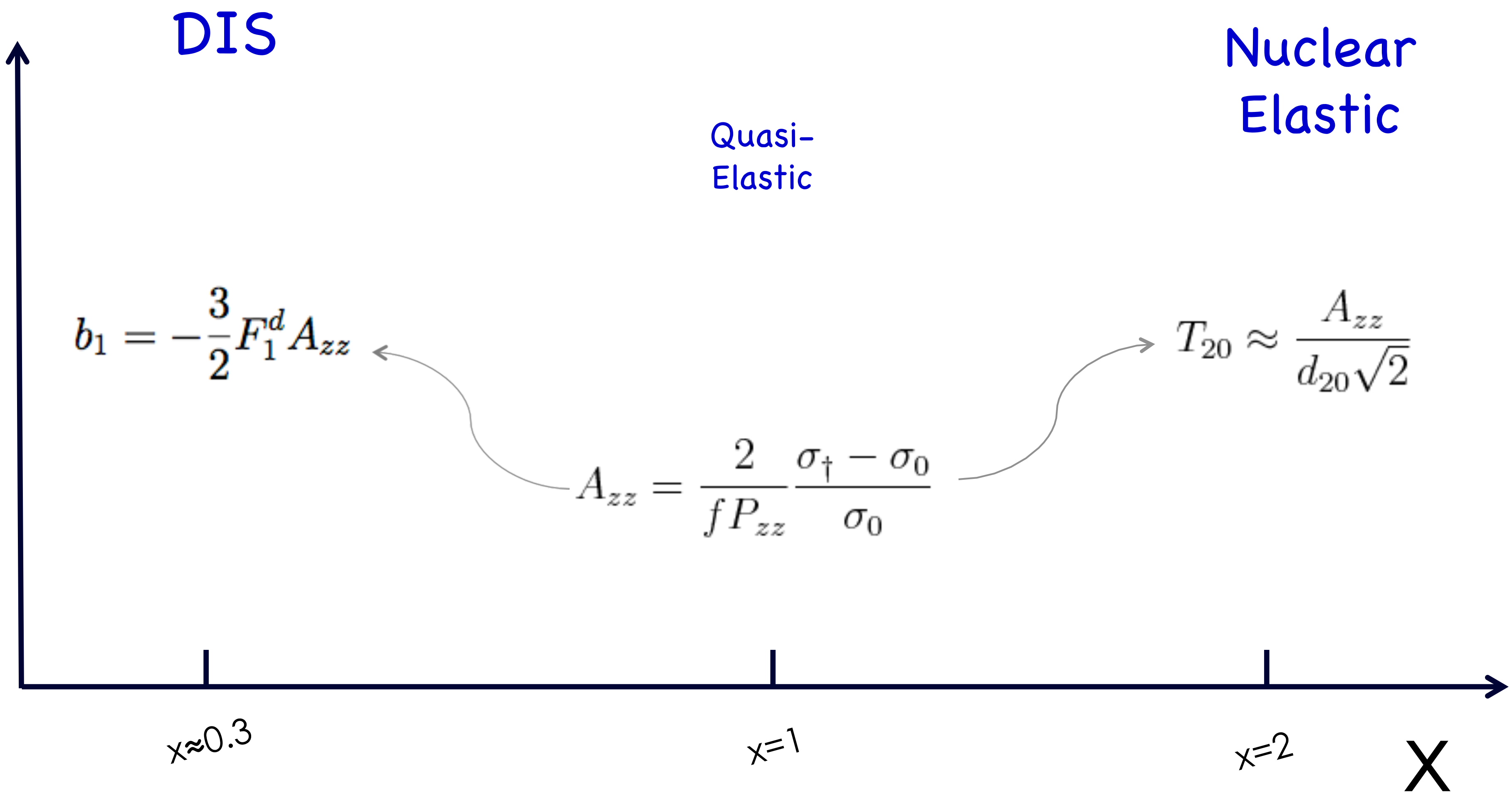
Tensor Spin Observables



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

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

Tensor Spin Observables

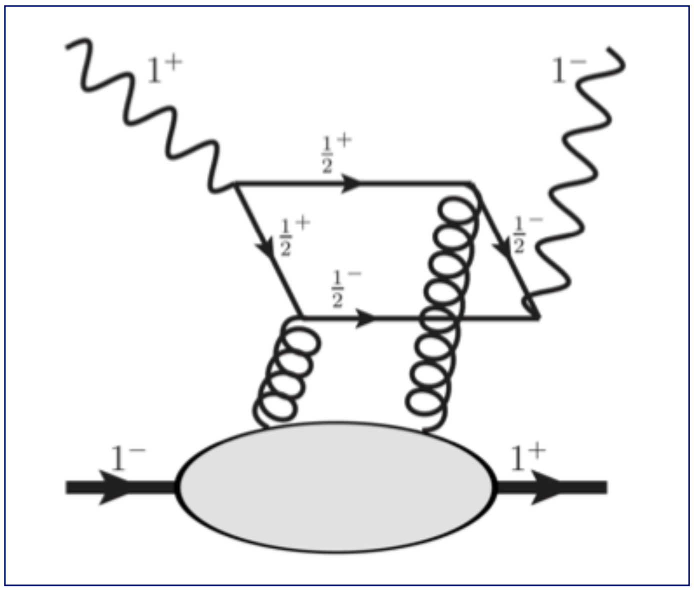


LOI-12-16-006

See R. Milner @ Spin2016
"State and Future of Spin Physics"

James Maxwell (contact)

"Nuclear Gluonometry"



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

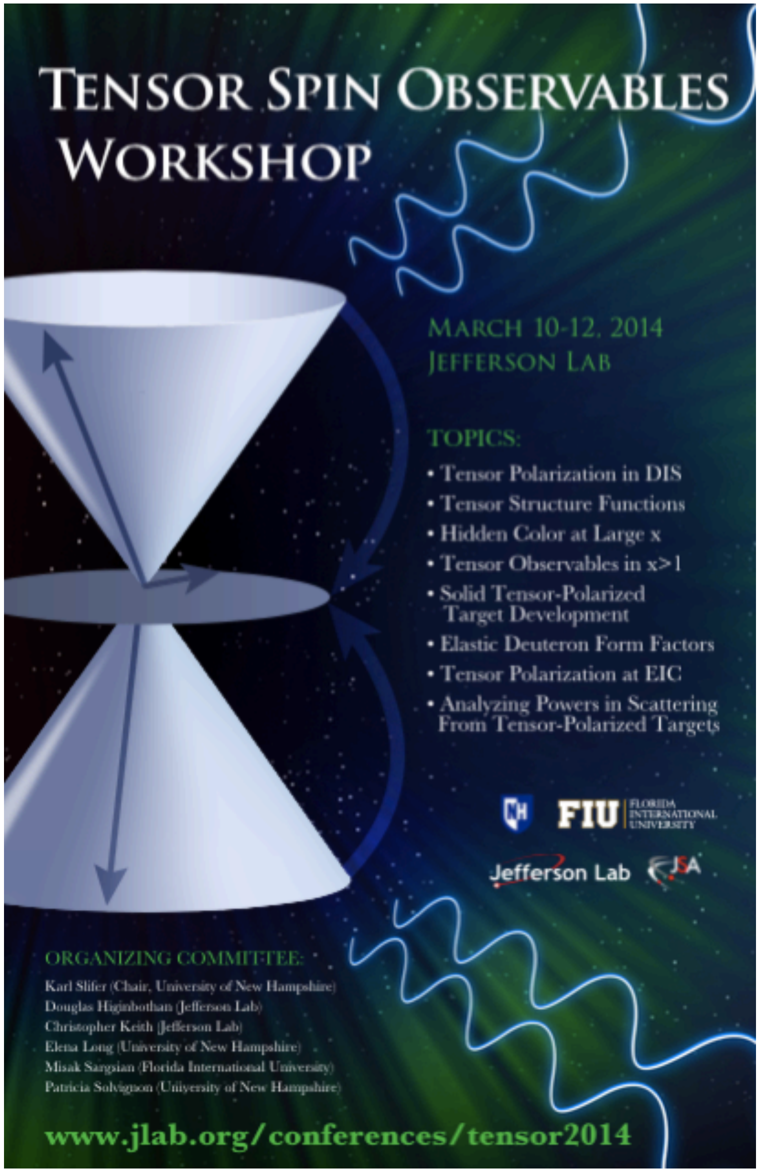
Non-zero value would be a clear signature of exotic gluon states in the nucleus

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

Tensor workshop 2018

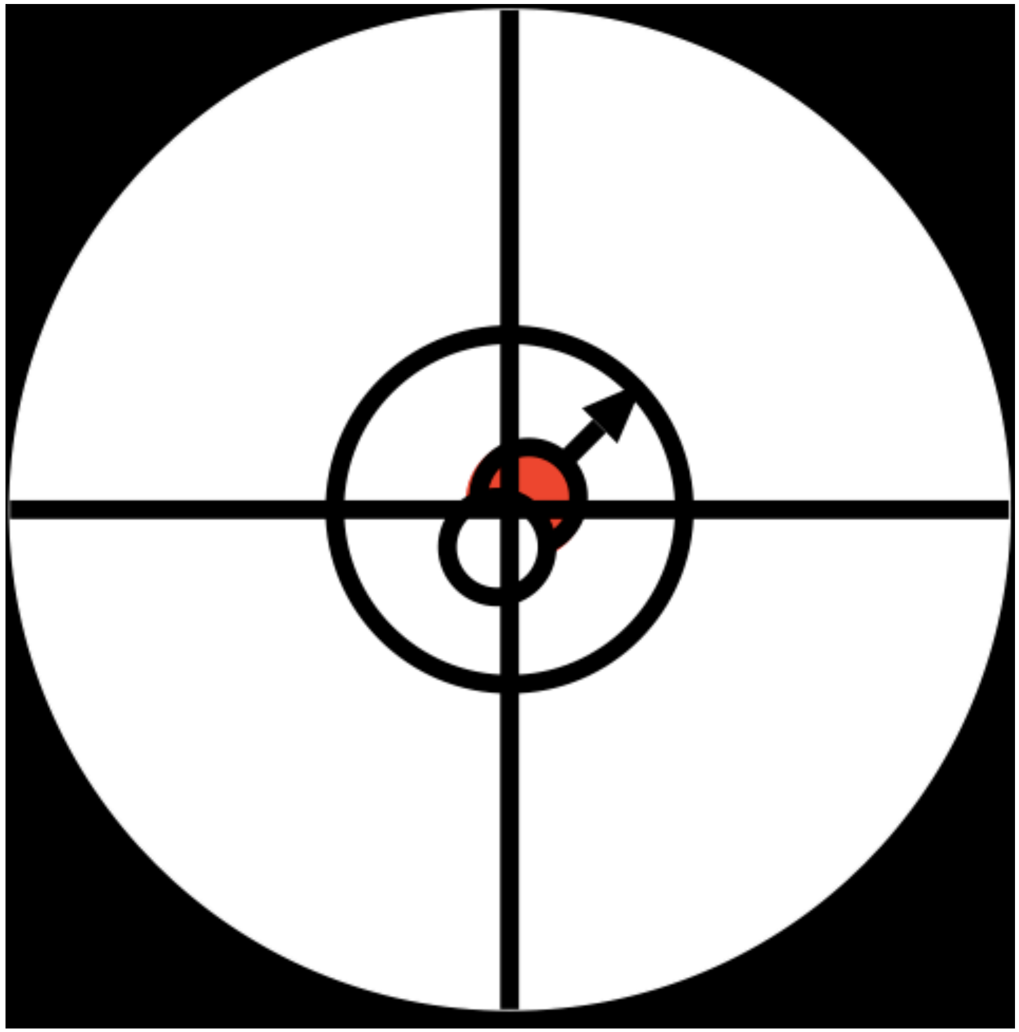


Workshop on Tensor Spin Observables

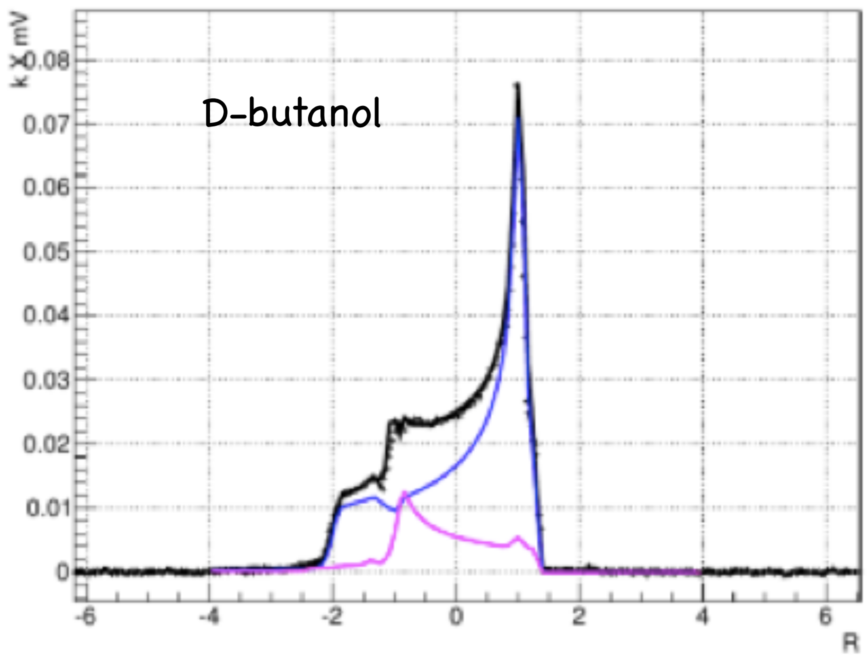
→ There should be a session on EIC!

→ Any volunteers? ☺

Technical Developments



Tensor Polarized Target



MC overlap with d-but. NMR experimental points (Pn=51→45,Qn:20→31%)

Significant progress

Enhancing P_{zz} via semi-selective saturation

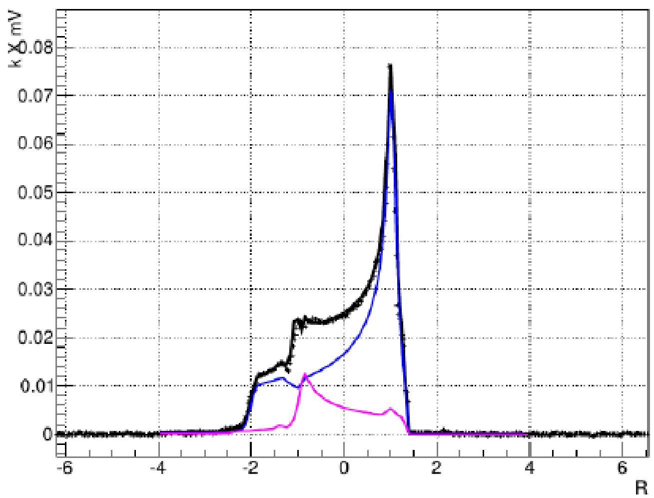
& understanding the NMR lineshape

D Keller, Eur.Phys.J.A.,**53** no.7, 155 (2017)
D Keller, PoS, PSTP2015:014 (2016)
D Keller, J.Phys.Conf.Ser., **543**(1):012015 (2014)
D Keller, Int.J.Mod.Phys.Conf.Ser., **40**(1):1660105 (2016)

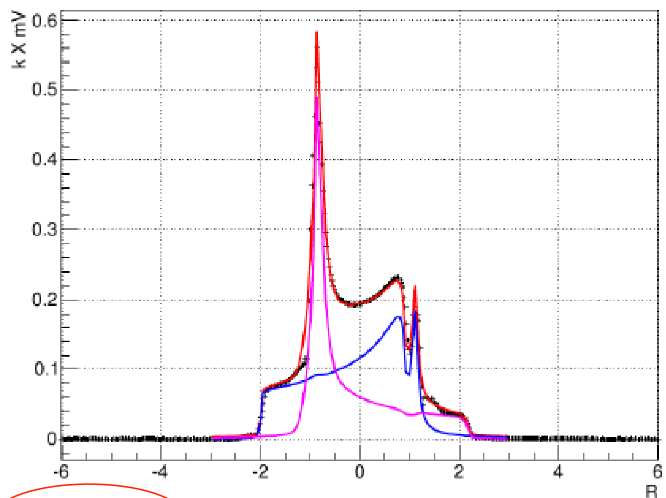
T_{20} measurement at Higs to verify NMR analysis

Dustin Keller
Hall A/C Collab

Selective Semi-saturation
(or just hole burning)



MC overlap with d-but. NMR experimental points (Pn=51→45,Qn:20→31%)



MC with fit and d-but. NMR experimental points (Pn=48→46,Qn:18→6%)

$$R = \frac{\omega - \omega_d}{3\omega_q}$$

DK Eur.Phys.J. A53 (2017) no.7, 155 arXiv:1707.07065

Dustin Keller
Hall A/C Collab

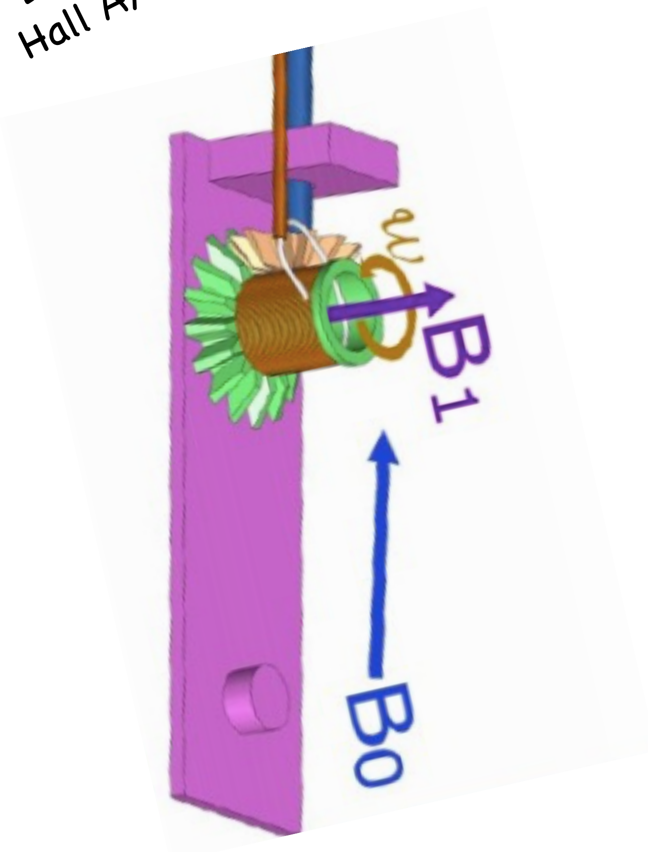
Achieved so far

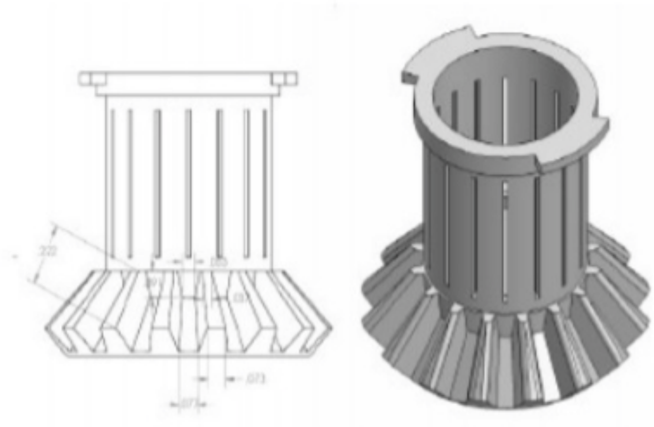
- Before recent research (1984): ~20%
- Recent studies SSS (2014-2015): ~30%
- AFP with SSS (2016): ~34%
- Rotation SSS so far: ~38% (neg Q possible)

Still more to come, we can probably do much better than this by improving B/T should expect Q>>40%

Rotating Target cell

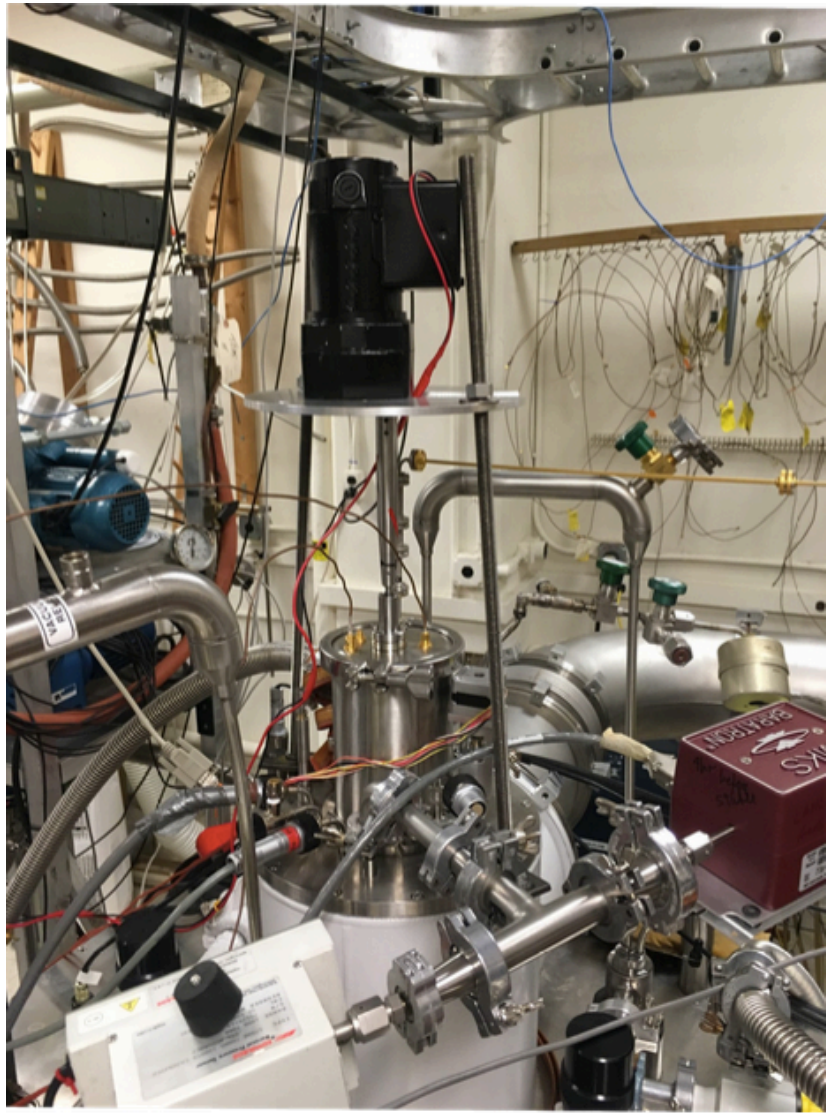
Dustin Keller
Hall A/C Collab





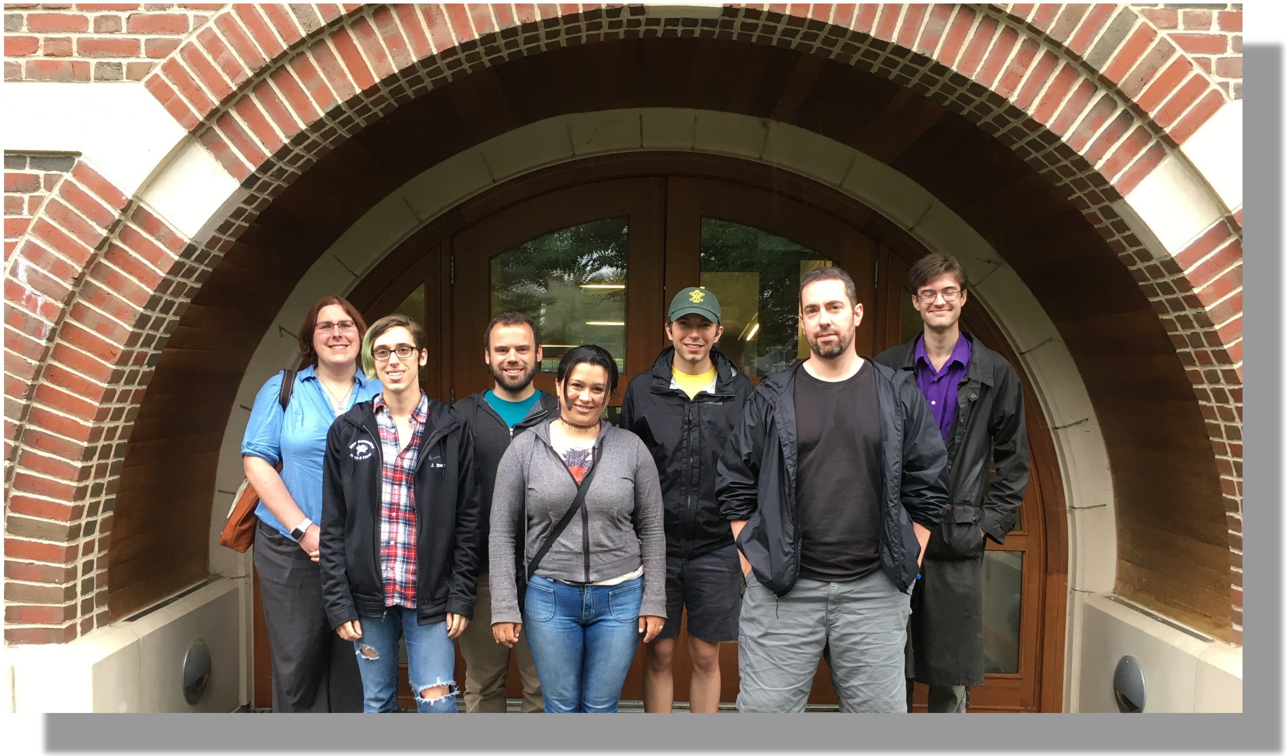
Rotating Target cell

Dustin Keller
Hall A/C Collab



Motor Driven Circular Motion

UNH Polarized Target Lab



2 faculty
-K.Slifer & Ellie Long

1 post-doc to hire

2 grad students:
--David R : significant time
--Nathalie S. : partial time

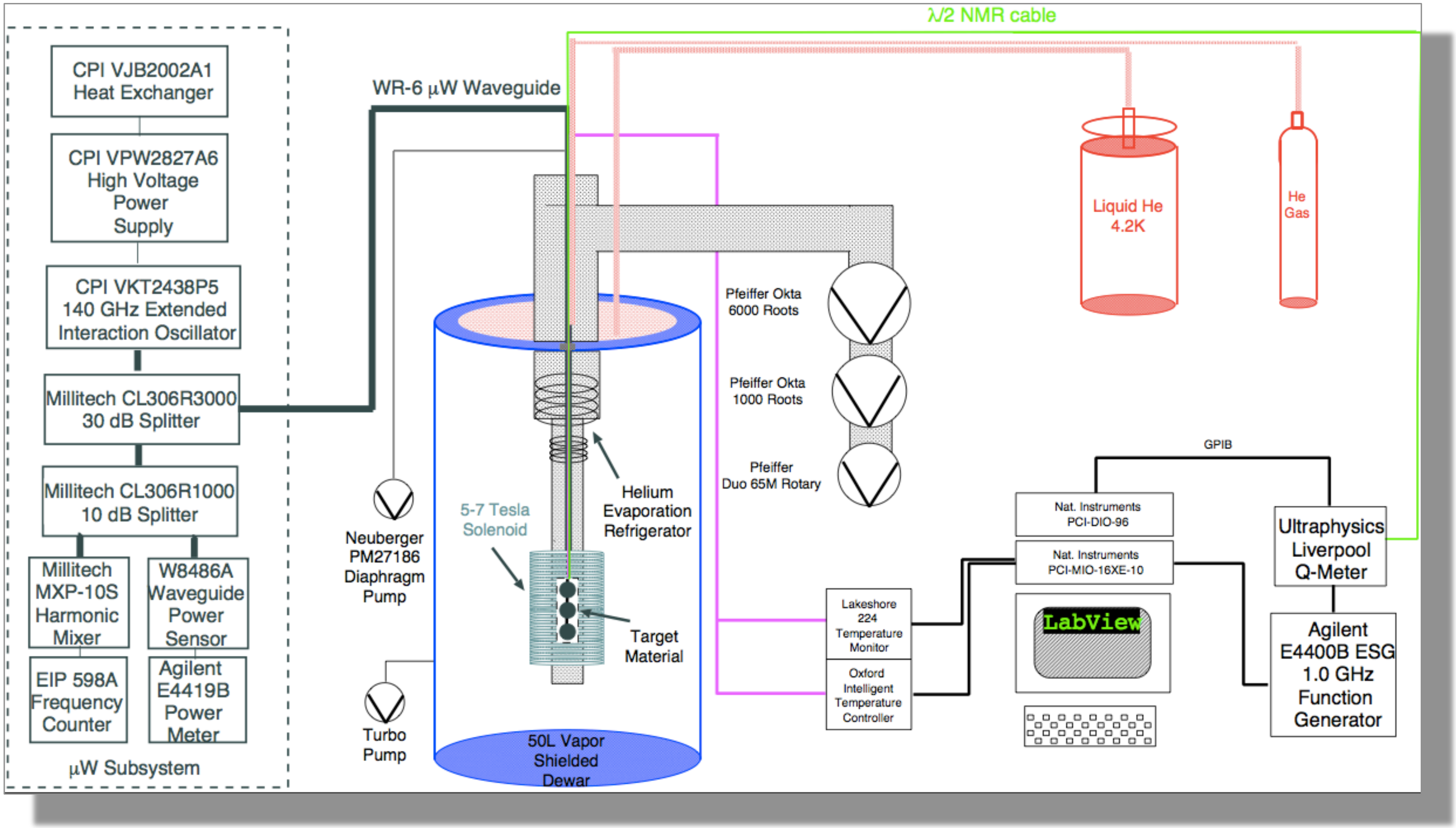
lots of undergrads

Projects

- Polarized Target Material Production & Labview controls for E1039
- Tensor Polarization R&D

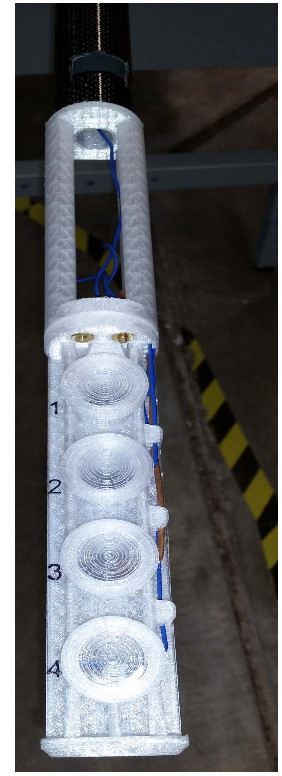
+2 part-time technicians at UNH

UNH Polarized Target Lab



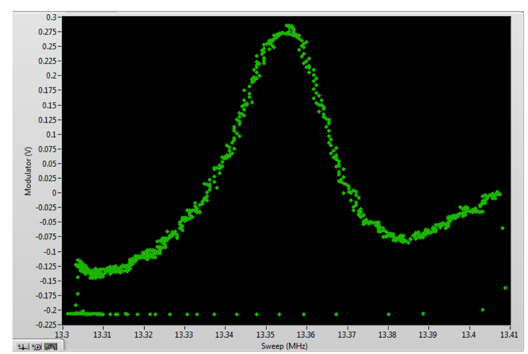
Very complicated / difficult system!

UNH Polarized Target Lab

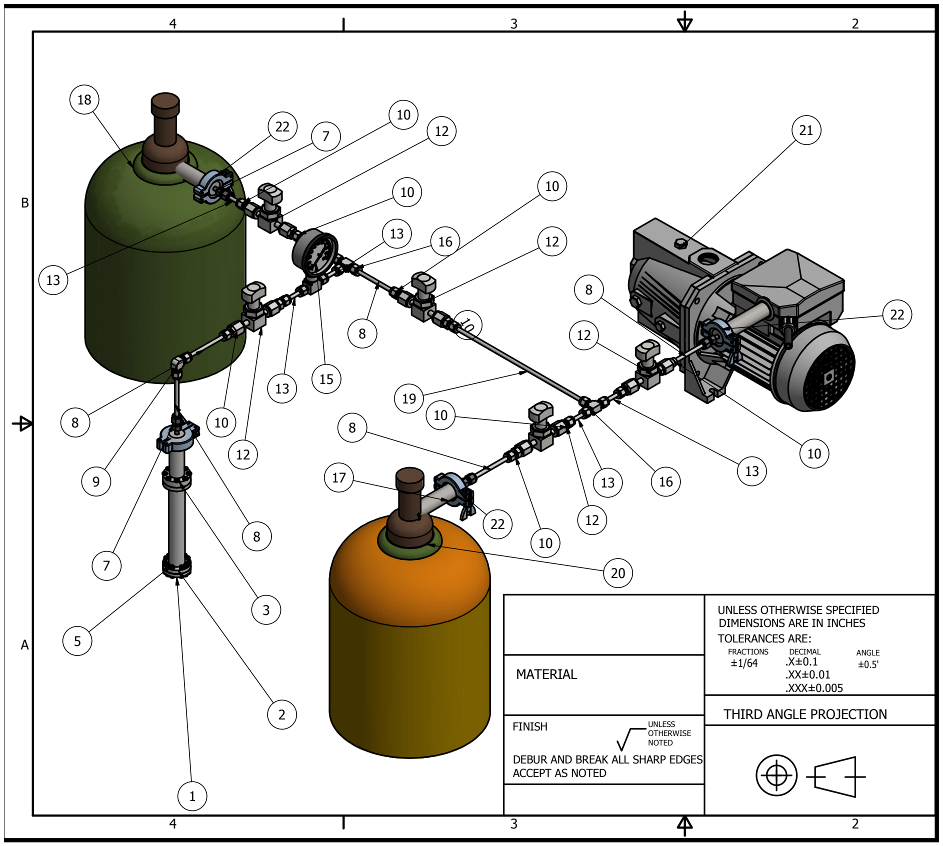


Reached 1K/7T
Have Working NMR system
Developed high vacuum expertise
Just Completed Construction of new fridge
Still assembling the microwave subsystem

New Faculty hire (Elena Long)
University made a significant investment in infrastructure



Target Material Production at UNH



Status

-Gas line completed in Dec 2017

-glycerin contamination from a vacuum gauge delayed 2 weeks. Now 10^{-7} Torr.

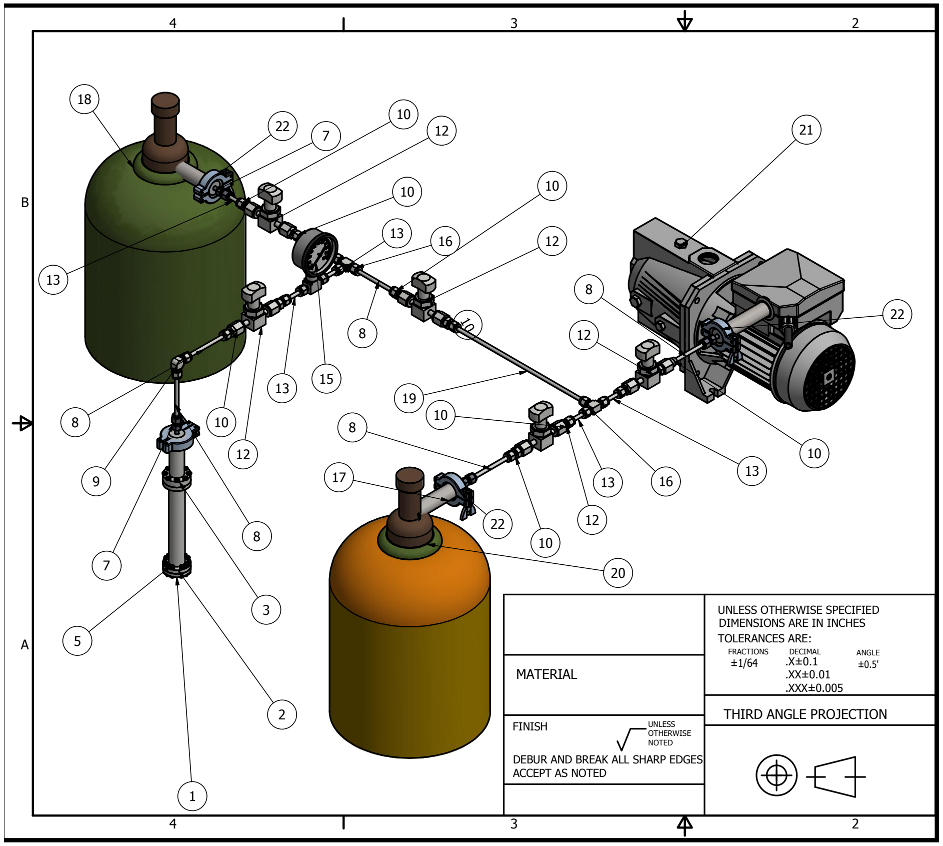
-Safety requested we run all lines thru the hood service ports or otherwise keep inside hood.

-First test (CO_2) in December was successful.

-First milestone met : grade 5.5 NH_3 production in January.

-Goal: 200 grams for E1039

Target Material Production at UNH



Status

-Gas line completed in Dec 2017

-glycerin contamination from a vacuum gauge delayed 2 weeks. Now 10^{-7} Torr.

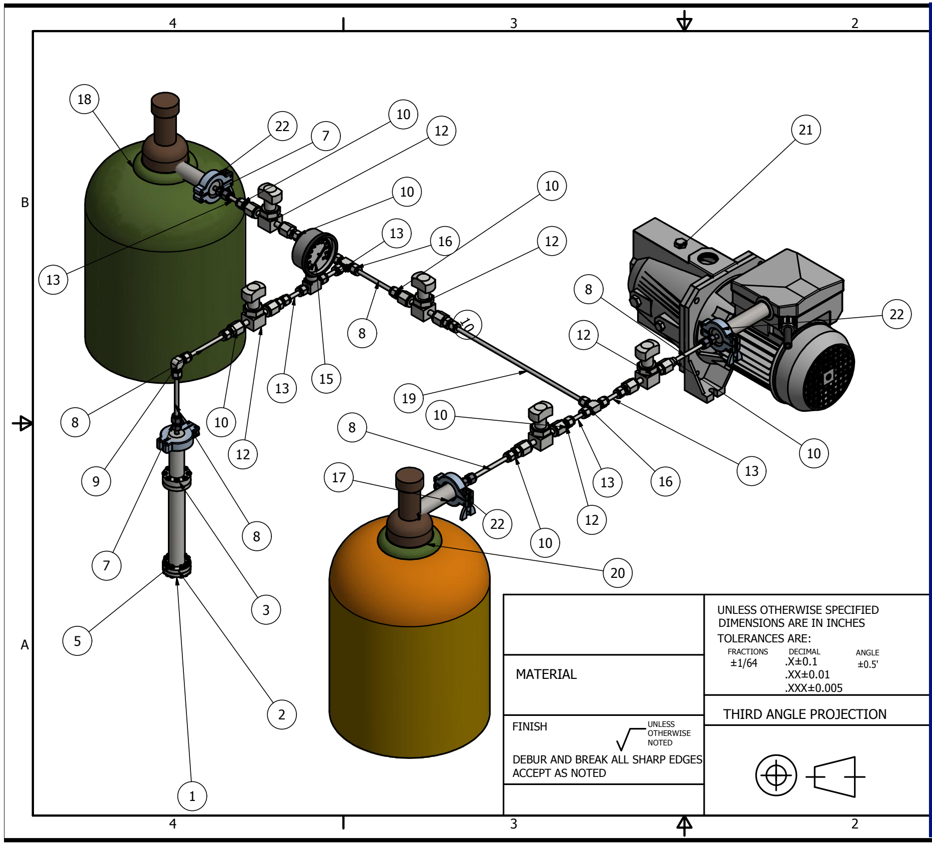
-Safety requested we run all lines thru the hood service ports or otherwise keep inside hood.

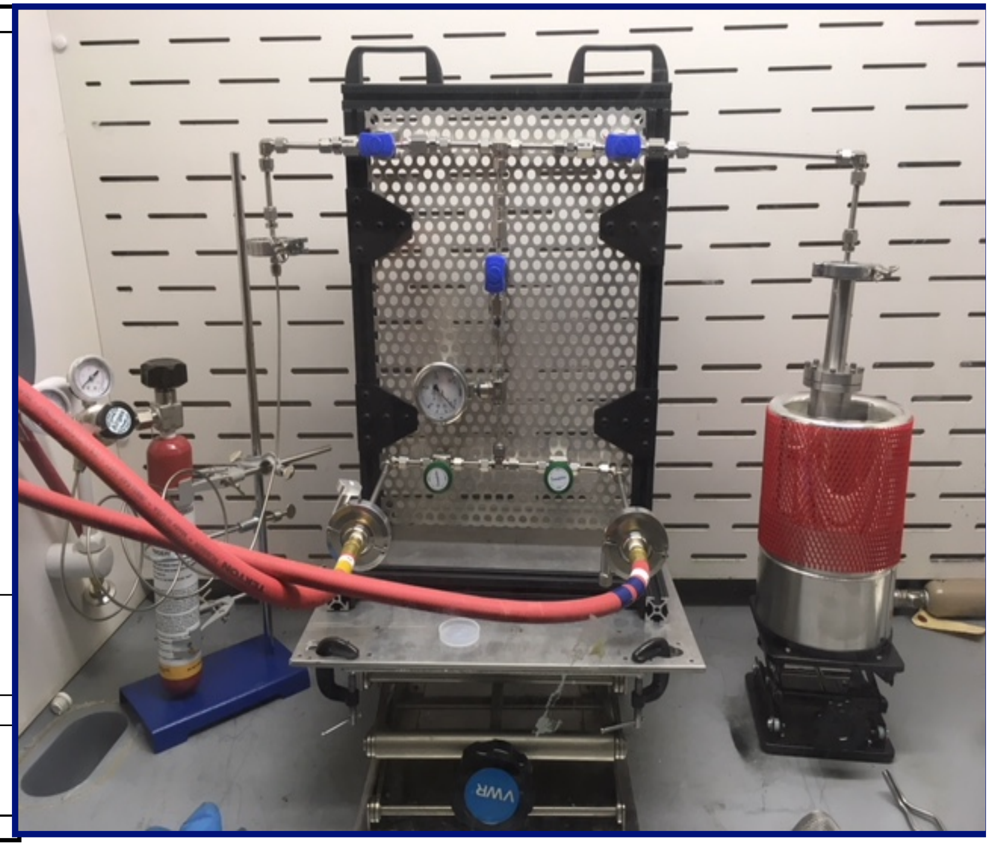
-First test (CO_2) in December was successful.

-First milestone met : grade 5.5 NH_3 production in January.

-Goal: 200 grams for E1039

Target Material Production at UNH





<u>Status</u>

-Gas line completed in Dec 2017

-glycerin contamination from a vacuum gauge delayed 2 weeks. Now 10^{-7} Torr.

-Safety requested we run all lines thru the hood service ports or otherwise keep inside hood.

-First test (CO_2) in December was successful.

-First milestone met : grade 5.5 NH_3 production in January.

-Goal: 200 grams for E1039

Target Material Production at UNH

Status

-Gas line completed in Dec 2017

-glycerin contamination from a vacuum gauge delayed 2 weeks. Now 10^{-7} Torr.

-Safety requested we run all lines thru the hood service ports or otherwise keep inside hood.

-First test (CO_2) in December was successful.

-First milestone met : grade 5.5 NH_3 production in January.

-Goal: 200 grams for E1039

UNH He Evaporation Refrigerator

(assemb "upside down")

UNH Machinist
Phil DeMaine

All Machining Complete

- ✓ Heat Exchanger
- ✓ Separator Pot
- ✓ Radiation Baffles
- ✓ Needle valves
- ✓ Vacuum Shells

December

1) Pre-Assembly at UNH (pictured) -complete

2) Leak testing new vacuum shells at UNH complete. 10^{-7} Torre

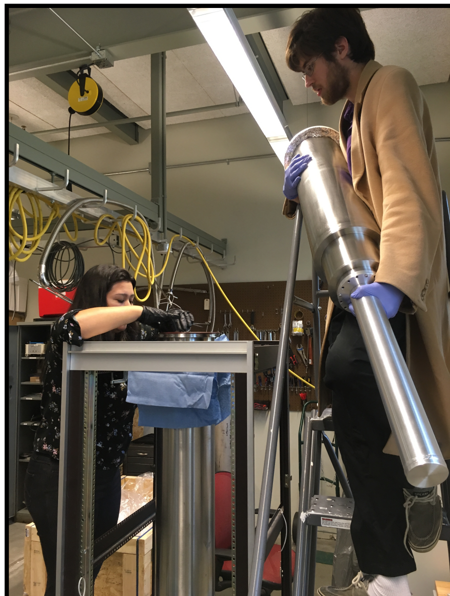
3) Final brazing/welding of needlevalves fittings @ Jlab completed in January

Successful LN2 Cooldown in January

Goals: test indium seals, vacuum
all good

UNH He Evaporation Refrigerator

Complete Fridge



Vacuum shells

All Machining Complete

- ✓ Heat Exchanger
- ✓ Separator Pot
- ✓ Radiation Baffles
- ✓ Needle valves
- ✓ Vacuum Shells

December

1) Pre-Assembly at UNH (pictured)
   -complete

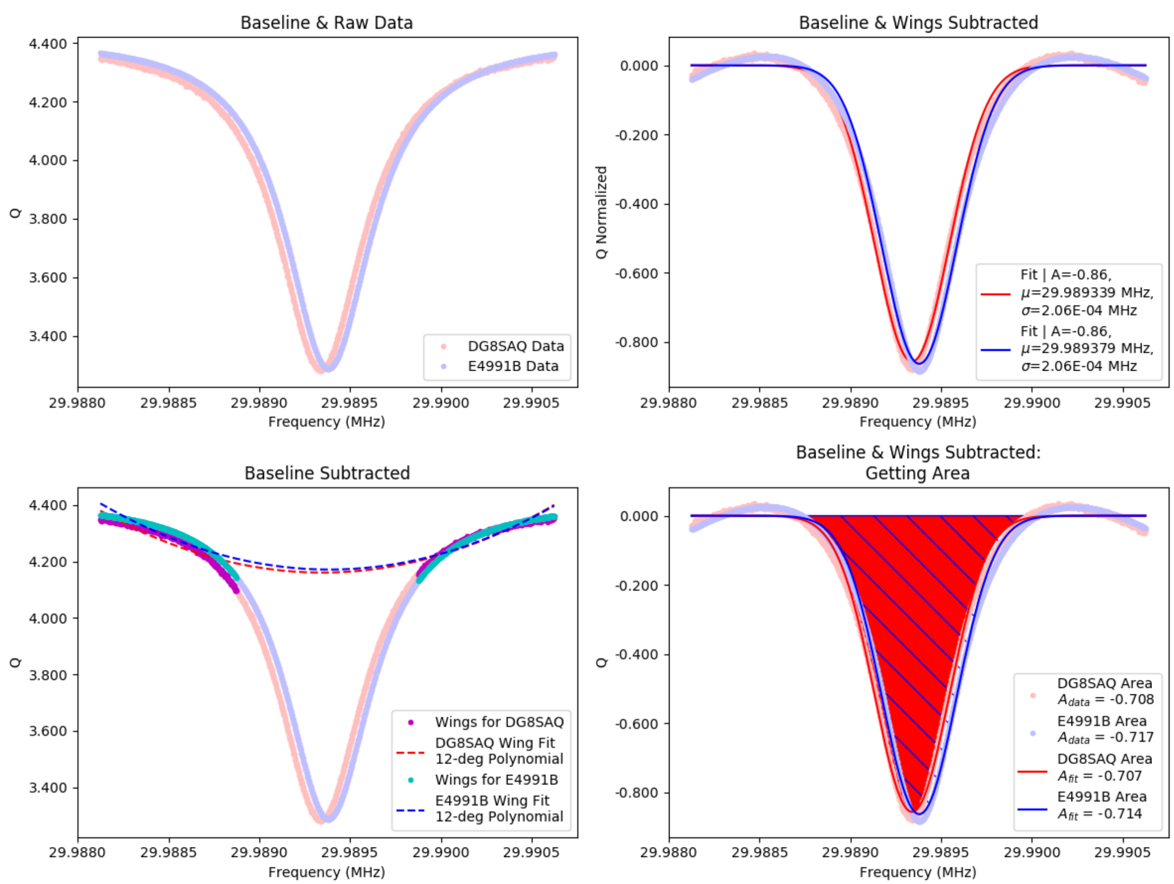
2) Leak testing new vacuum shells at UNH
   1-2 weeks : complete. 10-7 Torre

3) Final brazing/welding of swagelok
   fittings @ Jlab in January : complete

LHe Cooldown in Feb

Goals: 1 K in new fridge
Cross calibrate new NMR with QMeter

NMR Tests at UNH



Oscillator signal

Ellie Long

Cross tested an SDR network analyzer against impedence analyzer for 30 MHz oscillator

Results look promising

- Can easily find resonance with 10 MHz (!) sweep
- Will cross check against Qmeter next cooldown.

Also cross testing
- LNAL VME system
- New Pulse NMR
- EPR

Further Improvements to P_{zz}

Larger Magnetic Field

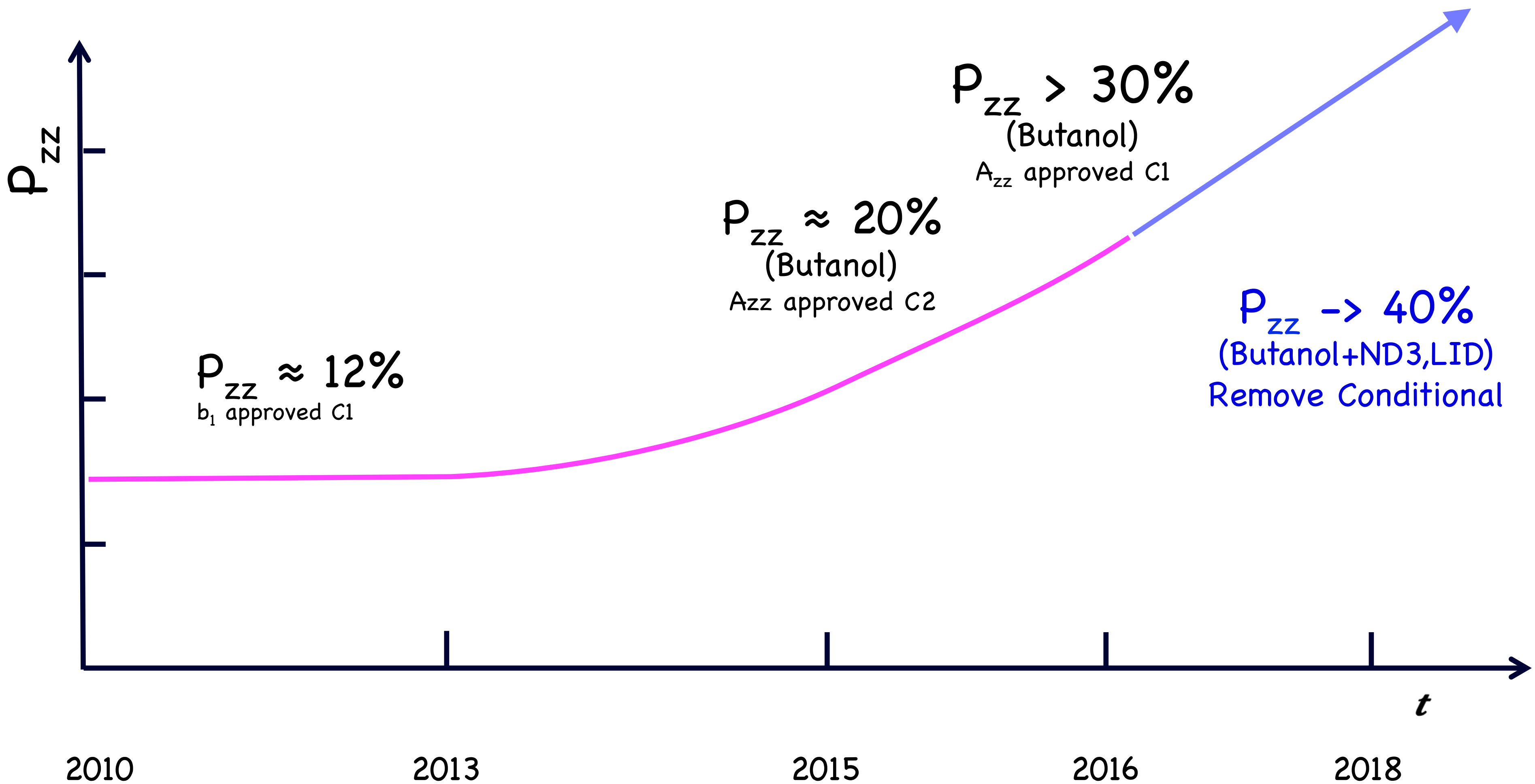
Lower Temperature with Optimized Cooling

Directly pumping individual ESR lines simultaneously

Manipulation of polarization with AFP

Different Materials

Tensor Polarization progress



UNH Target Summary

1) LabView Controls and material production for E1039

2) Fridge parts all Machined. Assembly/leak testing complete. Cooldown in Feb.

3) Ammonia Line: Dry run with CO_2 in Dec. 1^{st} Ammonia production in January.

4) NMR : New method using SDR kit. We will cross calibrate against Q-Meter/VME in Feb.

5) microwave subsystem delivery expected in Feb/March. Probably take us a few mos to commission

Summary

Tensor Program

E12-13-001: b_1 of the Deuteron (systematics suppressed by $1/P_{zz}$)

E12-14-002: A_{zz} for x>1 (HUGE asymmetries expected)

LOI12-14-001: Tensor Structure Function Δ

Other ideas : SIDIS, DVCS, Tensor polarized Drell Yan, ...

Significant progress

High tensor polarizations demonstrated with SSS and rotation: P_{zz} -> 40%
Dramatic improvement in statistic and systematic uncertainties.

No reason this represents a limit. Much higher polarizations may be possible.

UNH target lab soon fully functional.

Future

Tensor Workshop
Tensor spin observables with EIC

ND3 vs D-Butanol

- Needs warm (87 K) and cold (1-4 K) to get maximum polarization
- There is a need for the cold produced centers which are not known or understood
- It doesn't stay optimized after cold irradiation
- Never been produced outside of experiments so not clear what temperature, dose or beam energy is needed, or how best to anneal for optimization
- So far only one data point :

  ($1X10^{15}$ e^-/cm^2 ,14MeV, 4K)~18%

d-but is use under the assumption that the lineshape behaves the same as ND3 and the max polarization from irradiation is about the same