Jefferson Science Associates, LLC
Managing and Operating the Thomas Jefferson National Accelerator Facility
for the U.S. Department of Energy

FY2018 JSA Initiatives Fund Proposal Summary Sheet

Proposal title

2nd International Workshop on Tensor Spin Observables

Project Start Date (month/year) 03/2018

Project End Date (month/year) 03/2018

○ New proposal ◉ Renewal

Total funds requested 2500

Total leveraged support / matching funds. Details of funds must be included in budget proposal. 5000

To be completed by JSA: Total funds awarded **$2,500**

Principal Investigator (PI) Karl Slifer

Institutional affiliation
Mailing address
Email / phone #

University of New Hampshire
9 Library Way
Durham NH 03861

Co-PI (if more than 1, add pages with information) Please see attachment

Institutional affiliation
Mailing address
Email / phone #

Check one category: If PI is a Lab employee, your identification of the appropriate Associate Director below represents the acknowledgement of that AD with your submittal of proposal. No signature required.

○ Lab employee: Identify Associate Director (email / phone)

◉ Lab user: Identify University affiliation (email / phone)
Joint appointee: identify University and Lab division association (email / phone)

○ Other: Identify Institutional affiliation (email / phone)

Proposal: Attach file with

(1) Executive summary and technical proposal

(2) Synopsis of scientific, educational, technical, and/or business merits, and alignment with and significance to Lab's current program

(3) Proposed evaluation plan to measure success. If this is a request for renewal of funds, assessment of prior year performance,

Your proposal may include letters of endorsement and other supporting information (maximum of 12 pages including this summary sheet and budget sheet)

Budget Proposal

Proposal Title 2nd International Workshop on Tensor Spin Observables

Principal Investigator (PI) Karl Slifer

Total funds requested 2500

To be completed by JSA: Total funds awarded $2,500

Item Description		Amount
Equipment. Lab users submitting proposals that include equipment to be used at the Lab must review with the appropriate Lab Associate Director. The provision of the name of the AD below represents the AD's acknowledgement. **No signature required.**		
Associate Director:		
	Subtotal Equipment	0
Travel Support. Provide break-out of estimates for registration fees, lodging and transportation, catering, and facility charges (room rentals, AV equipment; etc.)		
Lodging: $67/night for 3 nights for 5 speakers	1000	
Airfare: $300/person for 5 speakers	1500	
	Subtotal Travel	2500
Supplies		
	Subtotal Supplies	0
Consultants/Subcontracts		
	Subtotal Consultants/Subcontracts	0
Other Expenses. Examples include stipends and honoraria, prizes, awards.		
	Subtotal Other Expenses	0
	Total Budget Proposal	**2500**

Budget Justification: Include narrative to explain need for each line item in the budget, showing breakdown of calculations used to arrive at the amount in each line of the budget. Note that the JSA Initiatives Fund Program does not support salaries and salary-related expenses, or indirect expenses.

Leveraged Support/Matching Funds information. Identify the source, type and amount of dollar funds from each institution. Include **separately** estimated value of in-kind support. Your identification of the authorized representative who has committed institutional support for your proposal represents the acknowledgement of that individual. If support or funds are provided by the Lab, identify the associate director (or equivalent) as the authorized representative. Information may be included on separate page.

We request support for a two day workshop focused on tensor spin observables. The JSA contribution will be used to provide travel support for students and junior researchers who would otherwise not be able to participate. We anticipate the need to support the travel and lodging of 5 domestic junior researchers. The cost per night at the Jefferson Lab Residence facility is $67 and we assume a typical domestic flight cost of $300. Matching funds of $3500 have been committed by the University of New Hampshire and the University of Virginia. The University funds will be used to cover catering costs ($1000), proceedings ($1500) and travel support for one senior invited theorist ($1000).

$1,500 (JLab-Bob McKeown)

A Proposal to the JSA Initiatives Fund
August 11, 2017

2^{nd} International Tensor Spin Observables Workshop

Elena Long, Karl Slifer
University of New Hampshire

Donal Day, Dustin Keller
University of Virgina

Douglas Higinbothan, Jian-Ping Chen
Jefferson Lab

Executive Summary

Several experiments are planned at Jefferson Lab and other facilities which will utilize a solid tensor polarized target. This new program will help clarify how the properties of the nucleus arise from the underlying partons, and provide novel information about gluon contributions, quark angular momentum, and the polarization of the quark sea that is not accessible in spin-1/2 targets.

We request support for a two day workshop focused on tensor spin observables. The JSA contribution will be used to provide travel support for students and junior researchers who would otherwise not be able to participate. Matching funds have been commited by the participating institutions. This workshop follows a highly successful first meeting which was well attended, stimulated several successful new proposals and led to significant polarized target development.

1 Scientific Merits

The first Tensor Spin Observables Workshop* was held at Jefferson Lab in 2014. The program covered theoretical motivations for tensor spin observable measurements and also polarized target technology. Several new experiment proposals grew from that meeting, and the workshop discussions provided strong motivation for the subsequent improvements that have been made in polarized target technology. Since that time, there has been significant new developments both in the theoretical treatment of tensor observables and in the technical aspects of producing tensor polarized targets. The time is ripe for another workshop focused on the physics possible with a solid tensor polarized target. We discuss now the science driving the Tensor Spin Observables program.

In the spin-1 system, the inclusive structure functions F_1, F_2, g_1, and g_2 are supplemented by four additional tensor structure functions: b_1, b_2, b_3, and b_4. Jefferson Lab E12-13-011

*https://www.jlab.org/conferences/tensor2014

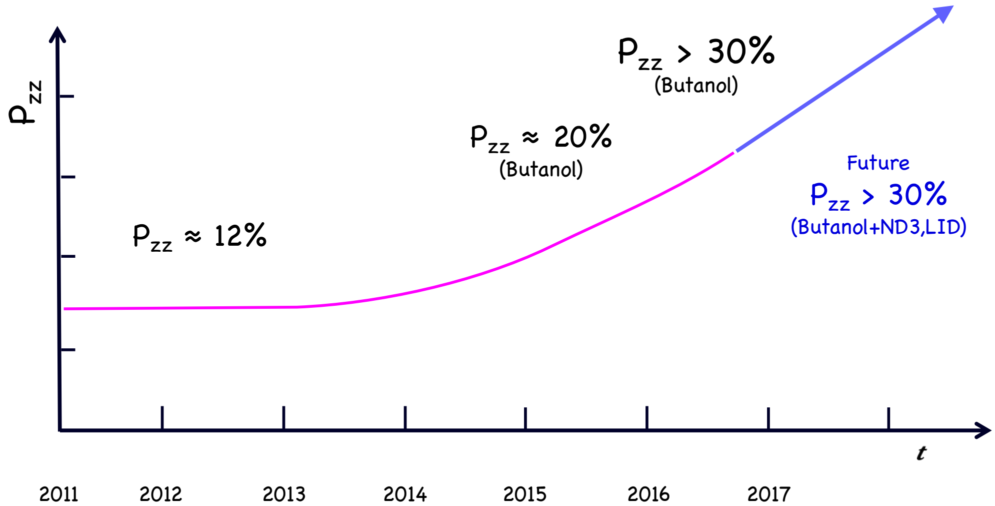

Figure 1: Approximate maximum tensor polarization per year.

is an experiment to measure the leading twist deuteron tensor structure function b_1. The experiment has been conditionally approved, contingent on target performance, with A$^-$ physics rating to run with 30 days of 11 GeV incident beam on a tensor polarized solid target.

The b_1 observable describes quark distributions within a spin polarized deuteron, providing unique insight into how nuclear properties arise from partonic degrees of freedom. All conventional nuclear models predict a small or vanishing value of b_1 at moderate x. However, the first measurement of b_1 at Hermes revealed a cross-over to a large negative value in the region $0.2 < x < 0.5$, albeit with relatively large experimental uncertainty. Recently, Miller [1] showed that exotic effects from hidden color 6-quark configurations could be at work. Critically, Miller showed that 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.

Teryaev [2] also noted that measuring b_1 probes the gluon contribution to tensor structure with discrimination between deuteron components of different spin. b_1 also probes the coupling of quarks to gravity via an equivalence principle. And Kumano [3] pointed out that b_1 can be used to probe orbital angular momentum. He then extracted the tensor polarized quark and anti-quark distributions from a fit to the Hermes data and found that a non-negligible tensor polarization of the sea is necessary to reproduce the data.

Another tensor polarized target experiment, E12-15-005, will measure the tensor asymmetry A_{zz} in the quasi-elastic and elastic regions using the same equipment as the b_1 experiment. Tensor polarization enhances the D-state in the deuteron wavefunction and is sensitive to short-range QCD effects. Knowing the properties of the deuteron's nucleon-nucleon potential is essential for understanding short-range correlations as they are expected to be largely dependent on the tensor force. In the quasi-elastic region, A_{zz} provides a unique tool to experimentally constrain the ratio of the S- and D-state wavefunctions at large momentum, which has been an ongoing theoretical issue for decades.

Excellent progress has been made in developing the solid tensor polarized targets necessary for this program, and a wide range of exciting experiments awaits. For example, the recent Nuclear Gluonometry experiment (J. Maxwell, R. Milner) *Letter of Intent* outlines an experiment to look for novel gluonic components in the nuclei that are not present in nucleons.

2 Workshop Goals

The workshop goals are to communicate recent theoretical and experimental advances that have been made since the first meeting, stimulate progress in the theoretical treatment of polarized spin-1 systems, to foster the development of new proposals, and to stimulate further advances in target development.

The discussions from the past Tensor Workshop lead to the development and successful proposal to measure the quasi-elastic tensor asymmetry A_{zz}, the elastic tensor asymmetry T_{20}, as well as a letter of intent to measure the tensor observable Δ. Each of these has stimulated new treatments of tensor degrees of freedom, with the A_{zz} measurement itself generating nearly 49 unique theory calculations. The opportunities shown by the currently approved experiments have generated interest in new types of tensor observables, including testing new sum rules and a new helicity term through tensor DVCS, utilizing tensor TMDs to directly measure a T-off function, and opening 60 new structure functions through tensor Drell-Yan processes.

We would like to continue building on this progress to encourage the interest of theorists and to raise awareness in the community of this exciting new avenue of research.

2.1 Encouraging New Proposals

The approval of C12-13-011 and C12-15-005 opened the possibility of pursuing several interesting new experiments at JLab. The polarized target installation also requires significant overhead, so it has traditionally been beneficial to schedule multiple experiments sequentially. With this in mind, we discuss a few of promising potential measurements that could be performed at JLab with a tensor polarized target. It is our goal to better focus the physics motivation of these potential experiments and stimulate discussion of even more novel applications of tensor polarization, so that one or more new proposals can be submitted to the next PAC.

Tensor Transverse Momentum Distributions

D$(e,e'p)$ A_{zz} in the Low Q^2 Region

JLab's PAC13 approved experiment E97-102, which would have measured A_{zz} in the D$(e,e'p)$ channel in order to extract the cross-sections with the deuteron in the $m=\pm 1$ and $m=0$ spin states. The collaboration intended for this measurement to be taken over the range 0.051 (GeV/c^2) $< Q^2 <$ 0.185 (GeV/c^2) and 0.2 GeV/c $< p_{miss} <$ 0.4 GeV/c, which is dominated by the D-state wave function of the deuteron ground state. This experiment never ran, but received an A- physics rating with the PAC determining,

> "The structure of the ground state wave function in nuclei at small interparticle distance is still an unsolved problem. The deuteron is a suitable target to start this investigation because its structure can be calculated with high precision using realistic NN potentials. The PAC strongly encourages effort to optimize kinematics to match standard energies."

The Tensor Asymmetry A_{UT} and the Orbital Angular Momentum Sum Rule

The spin-1 angular momentum sum rule, as discussed in Ref. [4], provides a test of whether the orbital angular momentum of the deuteron can be derived directly from quark contributions of individual protons and neutrons, or whether there are other contributions, such as from gluons. By examining the energy momentum tensor for the deuteron, the authors showed that it was possible to define an additional sum rule (see Eq. 12 in Ref. [4]) where it was demonstrated that the second moment of this quantity is non vanishing, being related to one of the gravitomagnetic deuteron form factors.

To study this sum rule, the authors suggest a measurement of the tensor-polarized deuteron's transverse spin asymmetry, A_{UT}, which is derived in terms of GPDs [5, 6]. It is also important to notice that b_1 singles out the role of the D-wave component in distinguishing coherent nuclear effects through tensor polarized correlations from the independent nucleon's partonic spin structure. A similar role of the D-wave component was also found in the recently proposed spin sum rule where it plays a non-trivial role producing a most striking effect through the spin flip GPD, E.

Higher Twist Structure Functions, b_2, b_3, and b_4

The leading-twist structure function b_1 has been previously measured at HERMES and has been approved to be measured at Jefferson Lab. However, it is only one of four additional structure functions present in the spin-1 hadronic tensor, $W_{\mu\nu}$. The b_2 structure function is expected to be related to b_1 through a Callan-Gross-type relation, $2xb_1 = b_2$. The b_3 and b_4 do not contribute at leading twist, and all three have not been directly explored experimentally.

2.2 Target Development

As outlined in Fig. 1, the maximum possible tensor polarization has grown significantly in recent years. The experimental program at JLab and other facilities that emerged from the 2014 workshop played a large role in driving this progress and we would like to ensure that this trend continues. The majority of this progress is with deuterated butanol, and it is desirable to continue this progress in other materials such as ND_3 and LiD.

Informal discussion has begun within the community on the characteristics desirable in the next generation polarized target for 12 GeV. While the most economical approach would be to simply procure a replacement magnet for the existing target, the approved b_1 experiment might benefit from a new, specialized solenoid coil with multiple, in-line target samples. This approach has been utilized for many years by the EMC, SMC, and COMPASS collaborations. Unfortunately, a solenoidal design limits the potential for large angle scattering, and precludes the multiple field orientations that are possible with a more generalized design. It is important that we have a thorough, open discussion of the optimal configuration before investing resources and manpower into either option.

3 Workshop Organization

We anticipate the need for two full days of invited talks, which will be roughly split into three topics: Theory, Target Development, and New Proposals as outlined in Table 1, which is a draft of the scientific program, and lists the core speakers that we anticipate will likely participate in this workshop.

The participating institutions have agreed to contribute $3500 to cover the costs of workshop catering, travel for invited speakers and workshop proceedings. We request $2500 from the JSA Initiatives Fund in order to provide travel and lodging support for several junior researchers to participate.

4 Proposed Evaluation Plan to Measure Success

As discussed above, our goals are to communicate recent theoretical and experimental advances, to stimulate further progress in the theoretical treatment of polarized spin-1 systems, to foster the development of new proposals, and to discuss the optimal polarized target configuration for the tensor spin program. The anticipated products of this workshop will be new JLab proposals to measure tensor observables, a proceedings, and further polarized target development.

Immediately after the workshop we will produce a list of participants to indicate the level of community interest in this topic. Within 6 months we will publish the proceedings. Over the next 3 years we can anticipate the submission of new proposals and further improvements in polarized target technology.

5 Summary

We request support for a two day workshop focused on tensor spin observables to be held at Jefferson Lab. The workshop goals are to communicate recent theoretical and experimental advances that have been made since the first Tensor Workshop, stimulate further progress in the theoretical treatment of polarized spin-1 systems, continue fostering the development of new proposals, and to reach a consensus on the optimal polarized target configuration for the tensor spin program.

References

[1] G. A. Miller, Phys. Rev. **C89**, 045203 (2014).

Experiment Updates Session

Speaker	**Institution**	**Topic**
Dustin Keller	UVA	*Current Target Status from the UVA Lab*
Elena Long	UNH	A_{zz} & T_{20}
Richard Milner	MIT	Δ *and Exotic Gluonic States*
Karl Slifer	UNH	b_1 *and Updates from the UNH Lab*
Panel Discussion	All	*Removing Conditions & Scheduling Experiments*

Theory Session

Speaker	**Institution**	**Topic**
Gerald Miller	U. Washington	*Accessing Hidden Color with b1*
Misak Sargsian	F.I.U.	A_{zz} *in Q.E. Scattering and* $x > 1$
Mark Strikman	F.I.U.	A_{zz} *in the light cone approximation*
Simonetta Liuti	U. Virginia	*Spin-1 Angular Momentum Sum Rule*
Shunzo Kumano	KEK	*Tensor Polarized Distribution Functions*
Marc Vanderhaeghen	U. Mainz	*Tensor Structure Functions*
Chueng-Ryong Ji	N.C.S.U.	*Hidden Color*
C. Weiss	Jefferson Lab	*Polarized Deuterons with the EIC*
Wally Van Orden	O.D.U.	*Tensor Spin Observables Calculations*
Panel Discussion	All	*New Directions in Tensor Spin Physics*

Target Development Session

Speaker	**Institution**	**Topic**
Chris Keith	Jefferson Lab	*The Jefferson Lab Polarized Target*
Don Crabb	U. Virginia	*Survey of Deuterated Materials*
Dustin Keller	U. Virginia	*Progress in Enhancing Tensor Polarization*
James Maxwell	Jefferson Lab	*The JLab Polarized Test Stand*
Panel Discussion	All	*The Ideal 12 GeV Polarized Target*

New Proposals Session

Speaker	**Institution**	**Topic**
David Kleinjan	Fermilab	*Polarized Drell Yan*
James Maxwell	Jefferson Lab	The Δ structure function
Dustin Keller	U. Virginia	T20 at Higs
Elena Long	UNH	TMDs at Jefferson Lab
Panel Discussion	All	*Prioritizing New Physics Proposals*

Table 1: Planned Workshop Speakers

[2] Efremov, Teryaev, JINR PreprintR2-81-857(1981), Yad. Phys. 36, 950 (1982) A.V. Efremov, O. V. Teryaev JINR-E2-94-95 (1999).

[3] S. Kumano, Phys. Rev. **D82**, 017501 (2010).

[4] S. K. Taneja, K. Kathuria, S. Liuti, and G. R. Goldstein, Phys.Rev. **D86**, 036008 (2012).

[5] E. R. Berger, F. Cano, M. Diehl, and B. Pire, Phys.Rev.Lett. **87**, 142302 (2001).

[6] E. R. Berger, M. Diehl, and B. Pire, Eur.Phys.J. **C23**, 675 (2002).