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

Workshop on Correlations in partonic and hadronic interactions

Project Start Date (month/year) 9/2018

Project End Date (month/year) 9/2018

(●) New proposal ( ) Renewal

Total funds requested $2500

Total leveraged support / matching funds. Details of funds must be included in budget proposal. $7500

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

Principal Investigator (PI) Harut Avagyan

Institutional affiliation
Mailing address
Email / phone # Jefferson Lab, 12000 Jefferson Ave. Suite 5, Newport News, VA 23606
avakian@jlab.org / 1(757)269-7764

Co-PI (if more than 1, add pages with information) Misak Sargsian (FIU), Stepan Stepanyan (JLab)

Institutional affiliation
Mailing address
Email / phone # Florida International University Miami FL 33199, sargsian@fiu.edu / 305-348-3954
Jefferson Lab, 12000 Jefferson Ave. Suite 5, Newport News, VA 23606
stepanya@jlab.org / 1(757)269-7769

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) Rolf Ent, ent@jlab.org / 17572697373

( ) 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 Workshop on Correlations in partonic and hadronic interactions

Principal Investigator (PI) Harut Avagyan

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: Rolf Ent		
	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.)		
Registration fees	$1500	
Lodging for key speakers	$1000	
	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.

Requested funds will be used to support key speakers.
Leveraged support comes from JLab, University of Pavia, Argonne National Lab and University of Connecticut .
1) $2500 from JLab (Bob McKeown)
2) $2000 from Argonne (Kawtar Hafidi)
3) $1000 from UConn (Kyungseon Joo)
3) euro 2000 from Pavia University (Alessandro Bacchetta)

Correlations in partonic and hadronic interactions

H. Avakian (JLab), A. Bacchetta (Pavia U), A. Gasparian (NCAT U), K. Hafidi(ANL), K. Joo(UCONN), M. Sargsian (FIU), S. Stepanyan (JLab)

Executive Summary

Correlations in partonic and hadronic interactions, provide important information on underlying dynamics, manifesting itself in variety of observables widely recognized as key objectives of the JLab 12 GeV upgrade and a driving force behind construction of the Electron Ion Collider (EIC). The 12 GeV upgrade of JLab, provides a unique possibility to access detailed dynamics of strongly interacting matter, allowing studies of transverse partonic structure of the nucleons and nuclei, hadronization process, correlations of partons and hadrons, nuclear medium modification of partonic distributions, spectroscopy of exotic states and many other topics with unprecedented precision.

Most of the observables already approved for studies using upgraded JLab and considered as key for future EIC, deal with different aspects of non-perturbative dynamics of strong interactions. Due to complexity of strong interactions the relations between different subjects including partonic observables, short range correlations, medium modifications and so on are not well established or understood. We intend the proposed workshop to be an important opportunity to efficiently address the possible connections of different fields of nuclear physics, in particular the role of partonic correlations in studies of hadronic observables, such us short range correlations in the deep inelastic scattering from nuclear targets, dependence of medium modification of partonic distributions on short range nuclear structure.

With this proposal we are requesting support for a week-long workshop on Correlations in partonic and hadronic interactions, which will be held at Yerevan Physics Institute, Armenia from September 24-29 (or October 1-5) of 2018. We expect that the key researchers in the field will contribute to the development of a coherent program, involving different communities engaged in these studies, thereby increasing the international interest and support for the workshop.

The Science Motivation

The understanding of the structure of hadrons and nuclei, and in particular of spatial distributions of partons, encoded in Generalized Parton Distributions (GPDs), and transverse momentum dependent distributions, encoded in Transverse Momentum Distributions (TMDs), are key questions of the modern nuclear physics. The knowledge 3-D partonic structure of nucleons and nuclei is relevant for studies in proton colliders, even at the LHC energies. For example, the transverse-momentum spectrum of vector bosons produced in Drell-Yan-like processes at the LHC is influenced by the contribution of intrinsic partonic transverse momentum. The formalisms of TMDs and GPDs provide a framework for the three-dimensional imaging of the nucleon and nucleus experimentally. Flavor decomposition of 3D PDFs requires reliable and model independent technique for the extraction of transverse momentum dependent distribution and fragmentation functions from the experimental observables. Various assumptions involved in preliminary extraction of TMDs and GPDs from available data, have yet to allow credible estimates of systematic errors associated with those assumptions, preventing also useful projections for the statistics needed for extraction of relevant 3D PDFs. A similar situation exists for hadron-hadron collision experiments looking to extract TMDs from their anticipated data.

Factorization, operator definitions and gauge invariance of parton densities are important ingredients of the 3D PDF extraction framework. During the past several years enormous efforts have been devoted on understanding how various spin-azimuthal asymmetries observed in semi-inclusive and exclusive measurements can be described in terms of QCD factorization using TMDs and GPDs.

A crucial prerequisite for a global analysis is the development of a Monte Carlo event generators including transverse degrees of freedom in a systematic way that is applicable in a wide range of energies. Several

programs have been developed covering different aspects of TMD and GPD analysis and using different sets of models for TMDs and GPDs.

Various assumptions used in different extraction frameworks require strict procedures for validation of the extracted 3D PDFs. Development of calculational tools, which would allow for easy comparison of results, also using libraries of PDFs like TMDlib in the extraction and validation stage, will be important to understand systematics due to different models and parametrizations.

It is essential to identify outstanding issues in calculations of radiative corrections and their integration into data analysis procedures. Examples include treatment of bremsstrahlung beyond peaking approximation, resummation of multiphoton emission, two-photon exchange effects for TMD and GPD measurements, and Coulomb corrections for SIDIS on heavy nuclei.

Due to lack of the analysis framework the current physics program of the EIC doesn't cover observables involving hadrons produced in the target fragmentation region, which can shed light on the non-perturbative structure of the nucleon. Extending the studies of the nucleon structure beyond the traditional current fragmentation, when a hadron in the target fragmentation region is observed in association with another hadron in the current fragmentation region will provide a new window to study the nucleon complex structure.

In spite of being now available for a decade and in spite of numerous dedicated theoretical and phenomenological studies, the underlying mechanisms for observables at 1/Q level remain not understood and the issue of factorization is not clarified. Twist-3 azimuthal asymmetries were the first experimentally established single spin phenomena in SIDIS, and are among the largest and clearest asymmetries. The detailed understanding of these data belongs to the most important and challenging goals.

It is relevant to investigate to what extent 3D proton structure may be important not only for factorization of hard processes but also for the understanding of soft particle production and, in particular, of the multi-parton interactions which are found to be needed at low to moderate transverse momenta for Monte Carlo simulations to describe experimental data on underlying events, particle multiplicities and spectra. Double parton interactions including parton's transverse momentum dependence are starting to be investigated, as is the role of parton's transverse momentum in the interpretation of energy flow measurements, charged particle multiplicities, and underlying events at the LHC Run II. The associated initial-state / final-state color correlations at small q_T could be studied to examine factorization-breaking contributions in the region of very small transverse momenta.

Another aspect of current research involves QCD studies in the nuclear medium. Many aspects of research envisioned for 12 GeV JLab program has direct relevance for LHC physics. Such as the detailed extraction of nuclear PDFs including $x > 1$ region, understanding of the dynamics of the nuclear medium modification of QCD observables as well using tagged processes to study the space time evolution of quarks to observed hadrons. Recent advanced in nuclear short-range correlation studies at JLab opened new venues of QCD studies that my be influenced from the short-range structure of the nuclei. These are the dominance of the proton-neutron short range correlations that can result in the flavor dependence of medium modification of partonic distributions. The understanding such phenomena may be crucial for analysis of the neutrino-nuclei DIS processes aimed at extraction of the standard model parameters. The emerging subject of Nuclear QCD research is studies of medium modification of GPDs and TMDs that can exhibit strong sensitivity to the nuclear structure at short distances. Finally, another important part of the program will be studies of hadronization processes in tagged nuclear SIDIS. The experimental advanced made in recent years in detecting slow hadrons in nuclear fragmentation region created new opportunities of probing DIS processes at different stages of hadronization at varying kinematics of tagged hadrons.

The proton charge radius studies are uniquely connecting three basic domains in modern physics: nuclear, particle and atomic physics. The precise knowledge of this quantity is central to advance our understanding about how QCD works in the non-perturbative region. It is also a crucial input to high precision tests of QED based on hydrogen Lamb shift measurements. The discrepancy between determination of proton charge radius using electron scattering and hydrogen Lamb shift measurements and measurements using muonic hydrogen Lamb shift, is known as the "proton radius puzzle". It led to intense theoretical efforts aiming at explaining this disagreement and triggered a worldwide development of new experimental programs.

The following list represents several current key questions of nuclear structure to be addressed by proposed workshop.

1) Transverse Structure of nucleon and QCD issues associated with 3D structure

- **Factorization issues in hadron production.**
- **Study of the QCD evolution properties of 3D PDFs.**
- **Unintegrated and Generalized Transverse Momentum Distributions.**
- **Evolution of TMDs and fits to physical cross sections**.
- **MC generators for global analysis of 3D PDFs.**
- **Phenomenology of 3D parton distribution and fragmentation functions.**
- **Gluonic form factors**
- **Validation of extraction frameworks**
- **Extraction of PDFs from di-hadron production.**
- **Radiative corrections to hard scattering in exclusive and semi-inclusive processes.**

2) Partonic Structure beyond Densities

- **Medium modifications of distribution functions.**
- **Medium modifications of fragmentation functions.**
- **Target fragmentation and conditional probabilities**
- **Higher twist asymmetries in SIDIS.**
- **New insights on 3D PDFs from non-perturbative models.**

3) Essential observables, which will direct the future experimental effort.

The global analysis of 3D PDFs require coordination of efforts from different experiments world wide including SIDIS, pp, πp, $\bar{p}p$, pN, NN, and e^+e^- facilities.

- **Electroproduction with fixed target facilities and EIC.**
- **Drell-Yan lepton pair production and Drell-Yan plus jets.**
- **Higgs boson production and Higgs boson plus jets**.
- **Heavy flavor production**.
- **Soft particle production and multi-parton interactions**.
- **"Proton radius puzzle" from electron-proton and muon-proton scattering experiments**

4) QCD in the Nuclear Environment

- **PDF medium modifications and short-range nucleon correlations**
- **Flavor dependence of medium modification effects**
- **Nuclear partonic distributions including x>1 region**
- **Tagged SIDIS processes off nuclear targets**
- **Hadronization processes in Nuclear SIDIS**

- **Hard nuclear QCD processes and Color transparency**

Workshop Outcomes

- **One of the goals of the workshop will be the development of a clear and specific plan for the extraction of 3D PDFs in nucleons and nuclei. We also contemplate the exchange of ideas between different physics communities leading to addition of new collaborators and the coordination of efforts on studies of the partonic structure of the matter worldwide, thereby supporting the JLab12 physics program as well as the development of a strong physics case for EIC.**

STANFORD UNIVERSITY

SLAC NATIONAL ACCELERATOR LABORATORY

SLAC, Mail Stop 81
2575 Sand Hill Road
Menlo Park, CA 94025
(650) 926-2644
sjbth@slac.stanford.edu

August 11, 2017

Jefferson Science Associates, LLC
c/o Southeastern Universities Research Association, Inc.
1201 New York Avenue
Suite 430
Washington, DC 2000

To: Jefferson Science Associates

I writing this letter is strong support of the proposal by Dr. Harut Avakian and his colleagues to organize a Workshop "Correlations in partonic and hadronic interactions" in Yerevan, Armenia in the fall of 2018.

The excellent proposal submitted to the JSA outlines many topics at the forefront of hadron and nuclear physics.

I am particularly interested in the topics of this workshop because the remarkable and exciting new developments using AdS/QCD and light-front holography which not only determine the light-front wavefunctions that underly hadron dynamics, but also the mechanism which confines color and underlies hadron spectroscopy. In addition, by using superconformal algebra, one obtains an elegant unified Regge spectroscopy of meson, baryon, and tetraquarks, including supersymmetric relations between the masses of mesons and baryons of the same parity. One also predicts observables such as hadron structure functions, transverse momentum distributions, and the distribution amplitudes defined from the hadronic light-front wavefunctions. The mass scale underlying confinement and hadron masses can be connected to the mass parameter in the QCD running coupling by matching the nonperturbative dynamics to the perturbative QCD regime. The result is an effective coupling defined at all momenta and the determination of a momentum scale which sets the interface between perturbative and nonperturbative hadron dynamics.

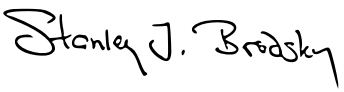
The Yerevan workshop can also address novel physics topics and critical ques-

tions such as (1) Is the antishadowing of nuclear structure functions non-universal? (2) Are shadowing and antishadowing phenomena compatible with sum rules for nuclear parton distribution functions? (3) The role of intrinsic heavy quarks in producing hadron states containing charm quarks at threshold, including the production of exotic hadronic states such as pentaquarks, tetraquarks and even octoquarks; and (4) The effect of QCD "hidden color " degrees of freedom in nuclear wavefunctions,

More details on these topics can be found in my papers "Advances in Light-Front QCD: Supersymmetric Properties of Hadron Physics from Light-Front Holography and Superconformal Algebra," published in Few Body Syst. **58**, no. 3, 133 (2017) [arXiv:1611.07194 [hep-ph]] and "Novel QCD Phenomena at JLab," published in PoS QCDEV **2015**, 003 (2015) [arXiv:1511.04142 [hep-ph]].

I attended a QCD meeting on "Transversity" in Yerevan in June, 2009 that was organized by Dr. Harut Avakian. It was truly an outstanding, memorable meeting. I am very happy to add my strong support to the new meeting in Yerevan in 2018.

Sincerely yours,



Stanley J. Brodsky
Professor
Theoretical Physics

Institute for Structure & Nuclear Astrophysics
University of Notre Dame, Notre Dame, IN (USA)

August 12, 2017

Jefferson Science Associates, LLC
c/o Southeastern Universities Research Association, Inc.
1201 New York Avenue
Suite 430
Washington, DC 2000To Whom It May Concern:

To: Jefferson Science Associates

It is with enormous enthusiasm that I write this letter of support in behalf of the proposal by Dr. Harut Avakian (and his colleagues) to organize a workshop in Yerevan Armenia on "Correlations in partonic and hadronic interactions". The Jefferson National Laboratory is home to many scientists from the former Yerevan Physics Institute and the present day Alikhanyan National Laboratory of Armenia. While ANL in recent years is expanding to the studies of structure in nuclei with the new cyclotron facilities, studies of the structure of hadrons at JLAB and CERN are still a high priority. This workshop would provide a tremendous venue to join the physics across the spectrum of hadrons to nuclei. That is the component that I find very exciting and I am very enthusiastic about seeing its realization.

I was a part of developing the last Nuclear Science Advisory Committee's Long Range plan for nuclear physics in 2015 where the JLAB upgrade was seen as the highest priority for nuclear Physics. Also, amongst key areas was the strengthening of university laboratories in the USA. The Nuclear Science Laboratory at Notre Dame has an MOU with ANL and has been an active proponent of developing the nuclear part of this workshop's program.

I attended the workshop organized by the same group in Yerevan in 2009 and it was a tremendous success. The proposal for 2018 will have a somewhat broader scope and greater implications to the development of studies in nuclei.

I strongly urge you to support the proposal presented for 2018!

Sincerely,

Frank M. Freimann Professor of Physics
University of Notre Dame
aapraham@nd.edu
Tel: 574 631-8120