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

FY2017 JSA Initiatives Fund Proposal Summary Sheet

Proposal title Workshop on 3D Nucleon Tomography and Extraction Methodology

(●) New proposal ( ) Renewal **Total funds requested** 4,500 **Total leveraged support / Matching funds * See Note below.** 4,000

To be completed by JSA: **Total funds awarded** **$4,500**

Note: Identify in your budget proposal the source, type and amount of support from each institution.

Principal Investigator (PI) Latifa Elouadrhiri

Institutional affiliation
Mailing address
Email / phone # Jefferson Laboratory Suite #1, 12000 Jefferson Avenue, Newport News,VA 23606

Co-PI (if more than 1 add pages with information) Amber Boehnlein and David Richards

Institutional affiliation
Mailing address
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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	If Lab employee, Associate director (email / phone)	ent@jlab.org/269-7373
( ) Lab user	If Lab user, University affiliation. Joint appointees, identify Lab division association.	
( ) Other	If Other, Institutional affiliation	

Executive summary including the projected begin/end dates. **Project Start Date** (mm/yy) 02/2017 **Project End date** (mm/yy) 06/2017
Add additional pages if necessary.

The goal is to bring experimentalists, theorists and computer scientists together to develop a methodology for 3D nucleon tomography extraction that can be applied to extant and future worldwide experimental data, incorporating state-of-the-art theoretical calculations and parameterizations and capitalizing on the latest developments in computation and data handling. 3D nucleon tomography is one of the flagship experimental programs of the 12GeV upgrade of JLab, of COMPASS at CERN, and a vital driver for a proposed Electron-Ion Collider, which has been identified in the 2015 NSAC Long-Range Plan as the highest priority for new facility construction following the completion of FRIB. This proposal requests funding for a workshop aimed at fostering an international collaboration that places JLab in a world-leading position in the analysis and interpretation of 3D structure of the nucleon. Further details can be found in the attached document.

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Proposal title Workshop on 3D Nucleon Tomography and Extraction Methodology

Principal Investigator (PI) Latifa Elouadrhiri

Synopsis of scientific, educational, technical, and/or business merits, and alignment with and significance to Lab's current program. Add additional pages if necessary.

This work is aligned with the Jefferson Lab Priorities in the analysis of the current 6GeV data, the preparation of the analysis of the 12 GeV data, and the development of the science program at a future EIC. The goal of this workshop is the analysis of combined worldwide experimental data and controlled theoretical interpretation of the data.

Proposed evaluation plan to measure success. If this is a request for renewal of funds, assessment of prior year performance. Add additioinal pages if necessary.

We will have dedicated working groups with specific charges, as outlined in the attached agenda. A summary of the outcomes of the workshop will be presented at the completion of the workshop, and a whitepaper produced within four months of the workshop underlying the path forward for this effort. A longer-term goal is the establishment of an effective international collaboration aimed at 3D nucleon tomography.

Your proposal may include letters of endorsement and other supporting information. A maximum of 10 additional pages may be appended to this proposal form.

Budget Proposal

Proposal Title Workshop on 3D Nucleon Tomography and Extraction Methodology

Principal Investigator (PI) Latifa Elouadrhiri

Total funds requested 4,500 **To be completed by JSA: Total funds awarded** $4,500

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.)		
Coffee Breaks, Networking Reception and Working Dinner	1125	
Travel Support for key international participants	3375	
	Subtotal Travel	4,500
Supplies		
	Subtotal Supplies	0
Consultants/Subcontracts		
	Subtotal Consultants/Subcontracts	0
Other Expenses. Examples include stipends and honoraria, prizes, awards. The JSA Initiatives Fund Program does not support salaries and salary-related expenses, or indirect expenses. Describe other expenses below.		
	Subtotal Other Expenses	0
	Total Budget Proposal	**0**

Budget Justification and Leveraged Support/Matching Funds information. Identify the source, type and amount of support from each institution. For in-kind support, provide estimate of value. 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. Add additional pages if necessary.

We have requested 3K from JLab through the Bob McKeown (Deputy Director for Science), and we plan to request 1K from participating institutions.

Workshop on 3D Nucleon Tomography and Extraction Methodology

Introduction

From the earliest observations of Bjorken scaling in Deep Inelastic Scattering, a one-dimensional longitudinal description of the nucleon encapsulated in the unpolarized and polarized *Parton Distribution Functions* (PDFs) has been a quest in the nuclear and high-energy-physics communities, providing the essential input to explorations of the Standard Model and its extensions at the LHC. In contrast, the transverse distribution of charge and currents was probed in elastic scattering, encapsulated in the electric and magnetic form factors. However, a three-dimensional description, correlating both the longitudinal and transverse structures, remained elusive. This changed dramatically with the discovery of *Generalized Parton Distributions* (GPDs), proposed by D. Müller (1993) and by A. Radyushkin and X. Ji (1996). This revolutionary concept enabled the inner workings of the nucleon to be revealed, in the same way that *Computer Tomography* in medicine has revealed the innermost features of the body. More recently, a complementary yet related three-dimensional imaging, encapsulated in *Transverse-Momentum-Dependent Distributions* (TMD) has provided yet further insight into the nucleon.

The experimental exploration of GPDs through Deeply Virtual Compton Scattering was pioneered in 2001 at Jefferson Lab in the CEBAF Large Acceptance Spectrometer (CLAS) and later in Hall A and CLAS, and at DESY in HERMES. Since then, three-dimensional tomography has become a cornerstone of the 12GeV upgrade of Jefferson Lab, focusing on the imaging of the valence quarks; a future EIC will advance this tomography still further, by imaging the gluon and sea-quark contributions to the structure of the nucleon. Further insight has been gained through calculations of the moments of GPDs and of TMDs through lattice gauge calculations, and through QCD-inspired pictures of the nucleon.

Fully capitalizing on both the experimental and theoretical efforts demands that a structured connection between theory, experiment and phenomenology be developed. Both theory and experiment present challenges in data-processing requirements. The volume is increasing rapidly, and the movement of data across systems has become the gating factor. We therefore need to develop methods to process data close to where it resides, through

moving the software closer to the data. We need a framework that encompasses component-based application design ("Lego blocks"), thereby making it straightforward for researchers to implement their approaches, software-component mobility, and data-stream processing.

The aim of the workshop is to detail the requirements for an analysis framework, to examine the theoretical and experimental components that it need be incorporated, and to study approaches to the computational challenges that these requirements will entail. We expect the outcome of the workshop to be, in the first instance, a white paper and beyond that the establishment of collaborative effort aimed at tackling the challenges, and ensuring that the resultant framework can be applied across the emerging nuclear experimental and theoretical programs, including at a future EIC.

This workshop, and the follow-on activities that it will engender, affords an important opportunity for Jefferson Lab to establish a leadership role in the extraction, analysis and interpretation of worldwide 3D nucleon imaging data through experiment, theory, and computation.

Goals of the Workshop

The workshop and resulting white paper will address three specific topics:

- *The Analysis Methodology:* We will survey and discuss the data and analysis requirements of current and upcoming experiments, including not just those at JLab, but at CERN, BNL, GSI and at a future EIC. In particular, we will aim to develop a strategy to enable future experimental results, computational and theoretical models to incorporated, and to enable both theoretical and experimental uncertainties to propagate faithfully to the extraction of 3D distributions.

- *Theory and Phenomenology Requirements:* We will review the current status of GPD phenomenological formalism and lattice QCD calculations, and the resulting requirements for the interface of the theory/phenomenological components within the analysis framework.

- *Experimental Extraction and Validation Framework:* We will discuss how to implement the experimental analysis components for both hard exclusive photon and meson production, and for semi-inclusive DIS relevant to the extraction of GPDs and TMDs respectively. Notably, we will aim to identify the steps needed for multi-dimensional Monte

Carlo simulation components that incorporate GPD and TMD phenomenological models, and state-of-the-art QED radiative correction calculations. Finally, we will discuss how to incorporate all these elements into the extraction and validation framework.

We anticipate a two and one-half day workshop, with sessions dedicated to the issues above. The emphasis will be on the construction of a white paper and establishment of a collaborative effort, rather than a "physics conference". To that end, we will allow ample time for discussion, and the assignment of two working groups to address the theoretical and experimental demands, respectively. We expect around thirty invited participants, drawn from the experimental, theoretical and computing communities, with around one third from within the laboratory.

Anticipated Invitees

Experimental Nuclear Physics

Harut Avakian, Marcus Diefenthaler,Nicole D'hose, Carlos Camacho, Tanya Horn, Charles Hyde, David Ireland, Zein-Eddine Meziani, Julie Roche, Rik Yoshida

Theoretical Nuclear Physics

Alessandro Bacchetta, Marcus Diehl, Robert Edwards, Xiangdong Ji, Huey-Wen Lin, Simmonetta Liuti, Wally Melnitchouk, Herve Moutarde, Maxim Polyakov, Jianwei Qiu, Anatoly Radyushkin, Peter Schweitzer, Sergey Syritsyn, Christian Weiss

Computation and Data

Wes Bethel, Lori Daichin, Kirstin Kleese van Dam, Vardan Gyurjyan, Graham Heyes, Pete Petravick

Proposed Agenda

Day 1

	Welcome	0845 - 0900
	Objectives and Planning	0900 - 0930
	Overview of Worldwide Experimental 3D Imaging Program	0930 - 1030 (45 + 15)
	Coffee	1100 - 1130
	Theoretical Challenges and Opportunities	1100 - 1145 (30 + 15)
	Lattice QCD	1145 - 1230 (30 + 15)
	Lunch	1230 - 1400
Working Group I Theory Requirements and interface	*Working Group II* Experimental Requirements and interface	1400 - 1600
	Coffee	1600 - 1630
	Summary and Discussion	1630 - 1800
	Networking Reception	1830

Day 2

	Data Extraction and Computation	
	Parton Distribution Functions	0900 - 0945 (30 + 15)
	Generalized Parton Distributions	0945 - 1030 (30 + 15)
	Coffee	1030 - 1100
	Transverse Momentum Distribution	1100 - 1145 (30 + 15)
	Error propagation:theory and expt.	1145 - 1230 (30 + 15)
	Lunch	1230 - 1400
	Computational Methodologies	
	CLARA: an exemplar framework	1400 - 1500 (45 + 15)
	Data visualization	1500 - 1545 (30 + 15)
	Coffee	1545 - 1615
Working Group I	*Working Group II*	1615 - 1800
	Working Dinner	1830

Day 3

Working Group I	*Working Group II*	0900 - 1000
	Coffee	1000 - 1030
	Working-group Summaries	1030 - 1130
	Discussion and Future Timetable	1130 - 1230