Laboratory-Directed Research and Development Program

FY2014 Annual Report

Thomas Jefferson National Accelerator Facility
Newport News, Virginia

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APPROVALS

________________________________10/21/14
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Overview

The Department of Energy (DOE) and the Thomas Jefferson National Accelerator Facility (Jefferson Lab) encourage innovation, creativity, originality and quality to maintain the Laboratory's research activities and staff at the forefront of science and technology. To further advance the Laboratory's scientific research capabilities, the Laboratory allocates a portion of its funds for the Laboratory Directed Research and Development (LDRD) program. This is the first year of an LDRD program at Jefferson Lab, and it is already clear that the program will be a real asset to the laboratory. Areas eligible for LDRD support include:

- Advanced study of new hypotheses, new concepts and innovative approaches to scientific or technical problems;
- Experiments directed towards "proof-of-principle" or early determination of the utility of new scientific ideas, technical concepts or devices; and
- Conception and preliminary technical analysis of experimental facilities or devices.

Within these eligible research areas, the LDRD program is conducted with a scale of effort typically utilizing existing research facilities. The projects can be characterized as:

- Small-scale research and development activities or pilot projects;
- Bench-scale research projects;
- Computer modeling, conceptual design and feasibility studies.

With DOE guidance, the LDRD program enables Jefferson Lab scientists to make rapid and significant contributions to seeding new strategies for solving important national science and technology problems. In addition to building new core competencies that support the DOE missions, the LDRD project proposals may also conduct scientific research and development that support the missions of other federal agencies and/or non-federal sponsors.

The LDRD program supports the Jefferson Lab mission in several ways. First, because LDRD funds can be allocated within a relatively short time frame, Jefferson Lab researchers can respond quickly to forefront scientific problems and capitalize on new opportunities. Second, LDRD enables Jefferson Lab to attract and retain highly qualified scientists and to support their efforts to carry out world leading research. Finally, the LDRD program also supports new projects that involve graduate students and postdoctoral fellows, thus contributing to our education mission.

Since FY2014 was the first year of Jefferson Lab's LDRD program, it is too early to identify the long-term consequences on the laboratory of the supported research programs. However, it is already clear that the program is delivering results of great interest to our evolving plans for our future science, and that it has been received very positively by the staff as an important avenue for the recognition of excellent ideas and a source of funds for innovative research. As the program evolves, we will track carefully its impact on funding, student and post-doc support, inventions and patents, publications and conference presentations by laboratory staff.

Jefferson Lab has a formal process for allocating funds for the LDRD program. The process relies on individual scientific investigators and the scientific leadership of the laboratory to identify opportunities that will contribute to scientific and institutional goals. The process is also designed to maintain compliance with DOE Orders, in particular DOE Order 413.2B. From year-to-year, the distribution of funds among the scientific program areas changes. This flexibility optimizes Jefferson Lab's ability to respond to emerging opportunities.

Jefferson Lab LDRD policy and program decisions are the responsibility of the Laboratory Director. Under his instructions, the LDRD Program Manager initiates the program each year in February and schedules the supporting activities. The evaluation cycle runs through late September, when the successful proposals are announced, with funds available at the beginning of the fiscal year. We may hold some LDRD funds as unallocated to allow new ideas to be funded later in the year. The evaluation process begins with an optional letter of intent cycle, with the formal proposals due at the end of April. Proposals are reviewed by our Project Review Team (the ALDs supplemented by other experts) and, in cases where it is appropriate, supplemented by outside expert reviewers. Questions raised about individual proposals are given to the principle investigators for their response either in writing or as part of their presentation at a public review session held mid-July. Following that session, the Project Review Team rates and rank orders the proposals based on scientific merit and strategic value to the laboratory's future mission. The Team's recommendations are then sent to the Director, who makes the final decisions. The list is sent to the Jefferson Lab DOE Site Office for concurrence, typically in September, and then the winners are announced (nominally at the end of September). The Project Review Team also generates a written review of each individual proposal that is provided to each principle investigator following the announcement of the winners.

LDRD accounting procedures and financial management are consistent with the Laboratory's accounting principles and stipulations under the contract between Jefferson Science Associates and the Department of Energy, with accounting maintained through the Laboratory's Chief Financial Officer and Budget Office.

In FY2013, Jefferson Lab was authorized by DOE to establish a funding ceiling for the LDRD program of $0.75M, including General & Administrative (G&A) overhead. Scientists submitted 18 proposals, requesting about $5.4M in funding over a three year period (about $2.5M in FY2014). Three projects were funded totaling $0.372M, with awards ranging from $62K to $164K.

Costs for the FY2014 program were $0.218M, which equated to 0.150% of Jefferson Lab's FY2014 operating and capital equipment budget of $144.95M

Annual reports for the FY14 project activities follow.

1.0 Physics potential of polarized light ions with EIC@JLab

Principal Investigator: C. Weiss (JLab Theory)

Project Description

The project aims to enable high-energy electron scattering experiments with polarized light ions (deuteron ^2H, ^3He) and **detection of spectator nucleons** at a future Electron-Ion Collider (EIC). Such experiments address key questions of nuclear physics: neutron spin structure, nuclear modification of quark/gluon densities, and coherent nuclear phenomena in Quantum Chromodynamics (QCD). The method uses the unique capabilities of the JLab MEIC design: polarized deuteron beams, and efficient detection of forward-moving protons/neutrons. R&D objectives are: (a) develop simulation tools for high-energy scattering on light nuclei with spectator nucleon tagging (theoretical models, event generators); (b) perform process simulations with the MEIC beam/detector design and demonstrate feasibility of spectator tagging; (c) analyze simulated data and quantify physics impact. The project is carried out as a collaborative effort of theorists and experimentalists, including JLab staff (theory/exp), consultants (theory), and a 50% FTE postdoc (exp).

Accomplishments

1) Developed and implemented theoretical models for deep-inelastic scattering on polarized deuteron ^2H with spectator proton tagging at EIC, including effects of nuclear binding, polarization, final-state interactions, and coherent QCD phenomena. Formulated basic model for unpolarized ^3He. Documents and computer codes publicly available at https://www.jlab.org/theory/tag/

2) Developed and implemented event generators for deep-inelastic scattering on polarized light ions with spectator tagging, using two independent formulations and incorporating MEIC beam characteristics (momentum spread, crossing angle), as well as tools for fast Monte-Carlo simulation of specific final states. Linked event generators with GEMC-based detector simulations to enable future studies of particle tracking and detector response. Codes and documentation available on web page.

3) Demonstrated feasibility of precise neutron structure measurements in electron-deuteron scattering with spectator proton tagging at MEIC (reaction rates, detector resolution, event reconstruction), especially neutron spin structure with polarized deuterons.

4) Enabled EIC physics studies by user groups, using the tools and methods developed in the LDRD project: Ch. Hyde (ODU), S. Kuhn (ODU), E. Piasetzky et al. (Tel Aviv). Several other groups have expressed interest in using the resources and conducting follow-up studies.

Project results were disseminated in several conference presentations and two proceedings articles. The first journal publication is in preparation. The broader impact on EIC development was summarized in presentations at the 2014 DNP Town Meetings on Nuclear Structure and Nuclear Astrophysics (Texas A&M U., Aug 21-23) and QCD (Temple U., Sep 13-15, 2014).

Publications

- W. Cosyn, V. Guzey, D.W. Higinbotham, C. Hyde, S. Kuhn, P. Nadel-Turonski, K. Park, M. Sargsian, M. Strikman, C. Weiss, *Neutron spin structure with polarized deuterons and spectator proton tagging at EIC*, Proceedings of Tensor Polarized Solid Target Workshop, JLab, March 10-12, 2014; JLAB-THY-14-1955; arXiv:1409.5768 (INSPIRE)
- V. Guzey, D. Higinbotham, Ch. Hyde, P. Nadel-Turonski, K. Park, M. Sargsian, M. Strikman, C. Weiss, *Polarized light ions and spectator nucleon tagging at EIC,* Proceedings of DIS 2014, XXII. International Workshop on Deep-Inelastic Scattering and Related Subjects, University of Warsaw, Poland, April 28 - May 2, 2014; JLAB-THY-14-1913; arXiv:1407.3236 (INSPIRE)

Workshops/Conferences

- C. Weiss, *Next-Generation Nuclear DIS with EIC: Polarized Light Ions and Spectator Nucleon Tagging*, QCD Town Meeting, Temple University, Philadelphia, September 13-15, 2014 (.pdf)
- Ch. Hyde, *Neutron spin structure via spectator tagging at EIC,* QCD Town Meeting, Temple University, Philadelphia, September 13-15, 2014 [User application of tools developed in LDRD project]
- C. Weiss, *Nuclear structure with an Electron-Ion Collider,* DNP Town Meeting on Nuclear Structure and Nuclear Astrophysics, Texas A&M University, August 21-23, 2014 (.pdf)
- K. Park, *Study of Neutron Structure via Far-Forward Tagging of eD → e'NX in EIC,* 2014 EIC Users Group Meeting, Stony Brook University, 24-27 June, 2014 (.pdf)
- C. Weiss, *Neutron structure with spectator tagging at MEIC*, 2014 JLab Users Group Meeting, JLab, 2-4 June, 2014 (.pdf)
- C. Weiss, *Light-front methods in next-generation nuclear physics at EIC,* Light Cone 2014: Theory and Experiments for Hadrons on the Light Front, NC State University, Raleigh, NC, 28 May 2014 (.pdf)
- V. Guzey, P. Nadel-Turonski, C. Weiss, *Physics opportunities with tagged deep inelastic scattering on polarized light nuclei at EIC,* XXII International Workshop on DIS and Related Subjects, Warsaw, Poland, May 1, 2014 (.pdf)
- K. Park et al., *Neutron structure via forward tagging of the eD -> e'NX reaction at the Electron-Ion Collider,* APS April Meeting, Savannah, GA, April 5-8, 2014 (.pdf)
- C. Weiss, *Next-Generation Nuclear Physics with Forward Proton/Neutron Detection at MEIC,* Accelerator Science and Technology for the Electron-Ion Collider (EIC14), JLab, March 17-21, 2014, JLAB-THY-14-1860 (.pdf)
- C. Weiss, *Polarized Deuterium Physics with EIC*, Tensor Polarized Solid Target Workshop, JLab, March 10-12, 2014, JLAB-THY-14-1859 (.pdf)

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	Yes. If the EIC is recommended for future construction in the next NSAC Long-Range Plan, we expect regular funding for R&D of physics applications of light ions and spectator tagging
Source of support for follow-on funding?	JLab/DOE
Has follow-on funding been obtained?	No
Amount of follow-on funding ($K)?	N/A
Number of Post Docs supported by LDRD project?	Two partially supported: 50% FTE experimental postdoc; theory postdoc as consultant
Number of students supported by LDRD project?	None.
Number of scientific staff/technical staff hired with LDRD funding?	None hired. Labor of 50% FTE postdoc was purchased from Old Dominion U.
Number of copyrights filed (beyond publications)?	None
Number of invention disclosures filed?	None
Number of patent applications filed?	None

2.0 Wireless, Hand-Held Data Acquisition System for Imaging Detector

Principal Investigator: Jack McKisson

Project Description

This project addressed the first phase exploratory development of a wireless, hand-held gamma Single-Photon Emission Computed Tomography (SPECT) camera. The objectives were to identify candidate off-the-shelf technologies for data conversion, data management, power supplies and data communication that could demonstrate a workable approach to the challenges of practical operation in a clinical setting. The goals in the first phase were to reach bench testing and demonstration stages for the individual and coupled technologies and establish the viability of each while showing that an overall system was feasible without resorting to highly customized design.

The second year continuation project will pursue construction of a prototype using the elements identified in the first phase with polytungsten housing and sodium iodide scintillator.

Accomplishments

The overall objectives were largely met during the project term. A set of suitable technologies were identified and a concept design was developed that leverages the technological features into a design that meets criteria sufficient for clinical application of a hand held gamma imager (>30 min lifetime, 500 event s^{-1} cm^{-2}). The most critical elements to be identified were in the data path: the A/D converter, data management and the RF data link. Less critical, but dependent on the power requirements of the critical elements were the power supply elements, including energy storage, voltage regulation and battery charging technology. Each of those elements presented performance characteristics that were traded off against their power consumption and volume. The dataflow conceptual design was developed as understanding of the design/performance tradeoffs accumulated. As a SPECT camera in a clinical setting, the data rate for the hand held imager are likely to be in the 100 to 500 event s^{-1} cm^{-2} which allows the use of an Anger encoded resistive readout requiring only four channels of A/D conversion to locate the event centroid. A simultaneous sampling quad A/D converter was identified that offered very low power with high speed and sufficient resolution.

A Programmable System on a Chip (PSoC) integrated circuit was chosen as the data management and control element. Software was developed to test the rate capability of the PSoC system and to interface with and control the RF component. Programmable logic firmware codes which perform the integration and event discrimination were developed and then tested successfully on the PSoC system.

A self-contained RF module was selected to provide the wireless communication based on speed of its digital interface and its support of multiple TCP/IP socket capability. In our tests, two simultaneous independent secure socket wireless connections were established between the PSoC device and a desktop PC: one at 8 Mbit/s for data and the other at 10 Kbit/s for control.
A lithium-ion battery was identified that would demonstrate sufficient (>30 minute) run time given the initial estimates of power consumption. Updated lifetime estimates extended the lifetime to as much as 1.3 hours. A wireless battery charging system was identified and tested that would make the recycle/recharge time for the hand held device less than 2 hours in worst case and possibly much shorter depending on depth of discharge.

During the summer months one of the Science Undergraduate Laboratory Internship students assigned to our group was able to participate in the development of the interface between the PSoC development system and the RF module, writing and testing code for both PSoC and for the desktop PC server and setting up RF communication experiments.

Publications

None

Workshops

None

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	Yes
Source of support for follow-on funding?	Private Commercial
Has follow-on funding been obtained?	No
Amount of follow-on funding ($K)?	N/A
Number of Post Docs supported by LDRD project?	0
Number of students supported by LDRD project?	0
Number of scientific staff/technical staff hired with LDRD funding?	0
Number of copyrights filed (beyond publications)?	0
Number of invention disclosures filed?	0
Number of patent applications filed?	0

3.0 Fast RF Kicker for the MEIC Electron Cooler

Principal Investigator: Andrew Kimber

Project Description

The current plan for JLab's future beyond the 12 GeV upgrade is the design and construction of the Medium energy Electron Ion Collider (MEIC). In order to properly cool the ion beam in the collider ring of the MEIC an electron beam current of 1.5 A is required. Since this cooler will be operating constantly the amount of charge that the electron gun would need to extract is two orders of magnitude higher than the current state of the art photo-cathode gun. Due to the large current at the energies we require, energy recovery must be performed. Therefore, the cooler has taken the form of an energy recovery linac with an attached circulator ring. In order to reduce the amount of charge required we have decided to re-use the electrons 10-100 times in the circulator ring. The circulator ring requires a set of fast kickers for injection and extraction. There are several possible kicking schemes, the one we wish to test was conceptualized by Andrew Hutton, and would operate as a continuous wave, similar to a Radio Frequency (RF) separator. By superimposing a series of RF waves with different frequencies in the kickers, a full ring could have every 11th bunch replaced. The required kicker frequency is higher than anything that has been tried before, however if it is successful it could find uses outside of the MEIC project. One possible application is the International Linear Collider where the damping ring requires kickers with a similar repetition rate. This test will be accomplished using a stripline kicker on loan to us from SLAC, and a purpose built power source.

Accomplishments

A detailed MATLAB simulation has been created to simulate the addition of sub harmonics and to evaluate their relative frequencies and amplitudes. This information will be used extensively throughout the project. Several interesting characteristics have already been investigated. A set of parameters for experimentation has been generated. Future efforts will be used to add functionality to the model including the effects of phase stability/jitter.

Beam dynamics simulations have also been developed which show the effects of such a summed waveform on an electron bunch, circulating many times within a simplified electron cooler. Initial results are encouraging but more work is needed to simulate the effect of the waveform on non-kicked bunches, as well as electron-ion interaction.

A bench experiment was performed which showed the summation of a set of harmonics, through a broadband amplifier. This demonstrates that the theory is sound and validates the MATLAB model. It was noted that the summed waveform is very sensitive to any phase disturbance throughout the system. Efforts will be needed in this area to ensure overall waveform stability in the final design.

A secondary bench experiment has been prepared which utilizes the kicker cavity and JLab's Goubau line (Figure 1). In this experiment, it is hoped to simulate the effect of the created waveform on an 'electron beam', represented by the Goubau line. Results and further studies are pending.

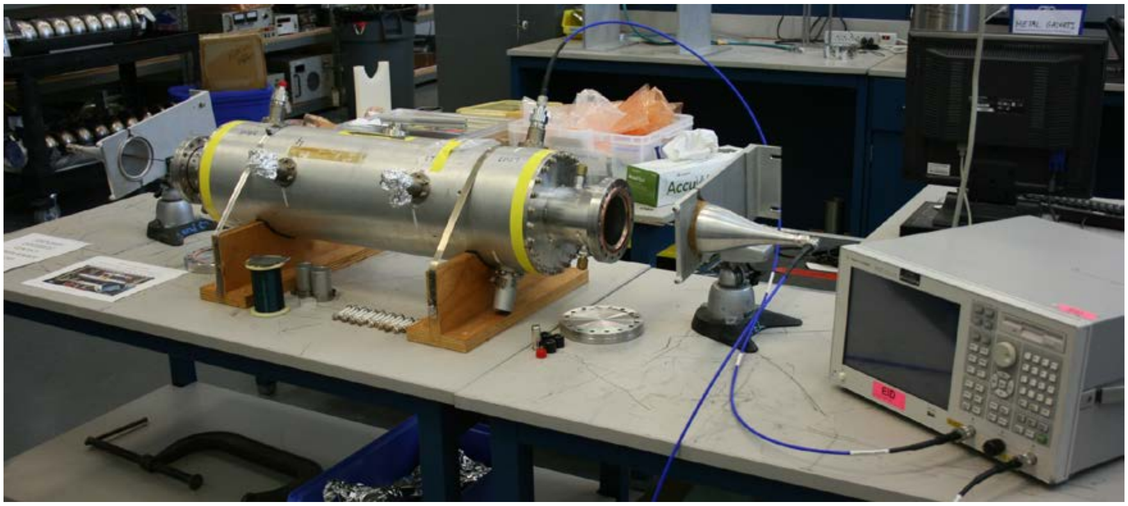

Figure 1: Initial experimental setup for a Goubau line test

Publications

N/A

Workshops

N/A

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	Yes
Source of support for follow-on funding?	TBD
Has follow-on funding been obtained?	No
Amount of follow-on funding ($K)?	TBD
Number of Post Docs supported by LDRD project?	0
Number of students supported by LDRD project?	0
Number of scientific staff/technical staff hired with LDRD funding?	0
Number of copyrights filed (beyond publications)?	0
Number of invention disclosures filed?	0
Number of patent applications filed?	0