Laboratory-Directed
Research and Development Program

FY2015 Annual Report

Thomas Jefferson National Accelerator Facility
Newport News, Virginia

(This page intentionally left blank)

APPROVALS

10/25/15

Hugh E. Montgomery Date
Director
Thomas Jefferson National Accelerator Facility

10/25/15

Lawrence S. Cardman Date
LDRD Program Manager
Thomas Jefferson National Accelerator Facility

Published By:
Thomas Jefferson National Accelerator Facility
12000 Jefferson Ave.
Newport News, VA 23606

Contents

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 second 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 FY2015 was only the second 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, with the completion of the three initial LDRD projects (started in FY2014) and two additional projects (started in FY2015) 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 FY2014, Jefferson Lab was authorized by DOE to establish a funding ceiling for the LDRD program of $0.80M, including General & Administrative (G&A) overhead. Scientists submitted 10 proposals (including three that were requests for continuation of ongoing projects), requesting about $3.2M in funding over a three year period (about $2.2M in FY2015). Five projects (including continuation of all three of the ongoing projects) were funded totaling $0.778M, with awards ranging from $62K to $207K.

Costs for the FY2015 program were $0.679 M, which equated to 0.394% of Jefferson Lab's FY2015 operating and capital equipment budget of $172.169 M.

Annual reports for the FY15 project activities follow.

1.0 Physics potential of polarized light ions with EIC@JLab

Principal Investigator: C. Weiss

Project Description

The 2-year (FY14/15) project aims to enable high-energy electron scattering experiments with polarized light ions (deuteron ^{2}H, ^{3}He) and **detection of spectator nucleons** at a future Electron-Ion Collider (EIC). Such experiments address key questions of nuclear physics: quark/gluon structure of the neutron, 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 with spectator nucleon tagging; (b) perform process simulations and demonstrate feasibility; (c) analyze simulated data and quantify physics impact. FY14 efforts focused on the development of basic simulation tools, estimates of reaction rates, and demonstration of feasibility. FY15 goals were the development of advanced theoretical models, control of systematic precision, documentation, and outreach to potential users. R&D was carried out in a collaborative effort by theorists and experimentalists, including JLab staff, consultants, and a 50% FTE postdoc.

Accomplishments

1) Developed advanced theoretical models for deep-inelastic scattering on ^{2}H with spectator nucleon tagging at EIC, describing nuclear structure, final-state interactions, coherent phenomena at small x (shadowing, diffraction), and polarization effects (vector/tensor polarization, spin-orbit interactions). Implementation in user codes complete for unpolarized scattering, well advanced for polarized. Journal publications in preparation. Codes and documentation publicly available at https://www.jlab.org/theory/tag/ .

2) Developed Monte-Carlo simulation tools (event generators, analysis scripts) for spectator tagging with EIC, incorporating EIC beam characteristics (momentum spread, crossing angle), suitable for parametric process simulations (rates, acceptance) and future detailed detector simulations (interface to GEMC). Codes and documentation publicly available at https://github.com/JeffersonLab/LightIonEIC.

3) Reached out to experimental, theoretical and broader nuclear physics community to raise awareness of EIC physics potential and encourage involvement in future EIC-related R&D. Several user groups are engaged in EIC-related studies using tools/methods developed in the LDRD project (Old Dominion U., Tel Aviv U., several more have expressed interest).

Project results were disseminated in >25 conference presentations (including several international conferences) and two proceedings articles. Journal publications are in preparation. 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), held just before FY2015 as part of the NSAC Long Range Planning process. A topical workshop was held at Old Dominion U., Mar 9-11, 2015, to make JLab users aware of the potential of spectator tagging at EIC. Project results were reviewed and recognized in DOE's Science and Technology Review at JLab, Jul 28-30, 2015.).

Publications

C. Weiss, *Electron-deuteron deep-inelastic scattering with spectator tagging at EIC*. Technical note; JLAB-THY-14-1997 (https://www.jlab.org/theory/tag/weiss/tag.pdf)

Workshops/Conferences

W. Cosyn, *Tagged spectator DIS off the deuteron as a tool to extract neutron structure*, Poster, 11th European Research Conference on Electromagnetic Interactions with Nucleons and Nuclei (EINN2015), Paphos, Cyprus, 1-5 November 2015 (http://www.cyprusconferences.org/einn2015/)

Ch. Hyde, *Forward Tracking with the JLab/MEIC detector concept*, 2015 Fall Meeting of the APS Division of Nuclear Physics, Santa Fe, NM, October 28–31 (http://meetings.aps.org/Meeting/DNP15/Session/KG.5) [User application of tools developed in LDRD project]

K. Park, *A study of neutron structure with (un)polarized deuterons and spectator tagging at EIC*, 2015 Fall Meeting of the APS Division of Nuclear Physics, Santa Fe, NM, October 28–31 (http://meetings.aps.org/Meeting/DNP15/Session/KG.1)

D. Higinbotham, *Opportunities with light ions at EIC*, 2015 Fall Meeting of the APS Division of Nuclear Physics, Santa Fe, NM, October 28–31 (http://meetings.aps.org/Meeting/DNP15/Session/JG.1)

C. Weiss, *Spectator tagging and short-range correlations with an Electron-Ion Collider*, EMMI Workshop "Cold dense nuclear matter: From short-range nuclear correlations to neutron stars", GSI Darmstadt, Germany, October 13-15, 2015 (https://indico.gsi.de/contributionDisplay.py?contribId=16&confId=3738)

K. Park, *Forward spectator tagging event generator*, EIC Software Meeting, Jefferson Lab, September 24-25 (https://www.jlab.org/conferences/eicsw/)

C.Weiss, *Simulating spectator tagging at EIC*, EIC Software Meeting, Jefferson Lab, September 24-25 (https://www.jlab.org/conferences/eicsw/)

K. Park, *A study of neutron structure with (un)polarized deuterons and forward spectator tagging at EIC*, 6th International Conference on Physics Opportunities at an Electron-Ion Collider (POETIC 6), Ecole Polytechnique, Palaiseau, France, September 7-11, 2015 (http://indico.cern.ch/event/379317/session/23/contribution/11)

C. Weiss, *DIS on light nuclei with spectator tagging: New applications at intermediate and small x*, 6th International Conference on Physics Opportunities at an Electron-Ion Collider (POETIC 6), Ecole Polytechnique, Palaiseau, France, September 7-11, 2015 (http://indico.cern.ch/event/379317/session/3/contribution/95)

C. Weiss, *MEIC polarized deuteron R&D*, DOE Science and Technology Review, JLab, July 28-30, 2015

C. Weiss, *Nuclear DIS with spectator tagging at EIC*, New Directions in Nuclear Deep Inelastic Scattering, ECT* Trento, June 8-12, 2015 (slides)

V. Guzey, *Nuclear Shadowing in Tagged DIS on Deuteron*, New Directions in Nuclear Deep Inelastic Scattering, ECT* Trento, June 8-12, 2015 (slides)

C. Weiss, *Nuclear DIS with spectator tagging at EIC*, QCD Evolution 2015, Jefferson Lab, May 26-30, 2015 (https://www.jlab.org/conferences/qcd-evolution2015/)

K. Park, *Neutron structure with (un)polarized deuterons and forward spectator tagging at the Electron-Ion Collider*, APS April Meeting, Baltimore, MD, April 12, 2015 (abstract)

C. Weiss, *Quark-Gluon Structure of Light Nuclei with Spectator Tagging at EIC*, APS April Meeting, Baltimore, MD, April 12, 2015 (abstract)

C. Weiss, High-Energy Nuclear Physics with Spectator Tagging. Workshop on High Energy Nuclear Physics with Spectator Tagging, Old Dominion University, March 9-11, 2015 (conference webpage)

K. Park, *Study of neutron structure with spectator tagging via eD → e'NX in MEIC*. Workshop on High Energy Nuclear Physics With Spectator Tagging, Old Dominion University, March 9-11, 2015 (conference webpage)

W. Cosyn, Final state interactions in inclusive and semi-inclusive DIS, 4th International Workshop on Nucleon Structure at Large Bjorken x (HiX2014), Laboratori Nazionali di Frascati, Italy, 16 Nov - 21 Nov 2014 *(conference webpage)*

P. Nadel-Turonski, *Physics at an Electron-Ion Collider*, 4th International Workshop on Nucleon Structure at Large Bjorken x (HiX2014), Laboratori Nazionali di Frascati, Italy, 16 Nov - 21 Nov 2014 (conference webpage)

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	Yes. Since EIC is recommended for future construction in the 2015 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?	Not Yet
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 two-year project addressed the first and second phases of exploratory development of a wireless, hand-held gamma 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 practical operation in a clinical setting. Goals in the first phase were to identify the individual and coupled technologies and establish the viability of each while showing that an overall system was feasible. Goals in the second stage were to pursue further development, acquire the essential components, design and construct interfaces, firmware and software so that a prototype could be constructed.

Accomplishments

The larger objectives were largely met during the project's two phases. In the first phase a set of suitable technologies were identified and a concept design developed. 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 were the power supply elements, including energy storage, voltage regulation and battery charging technology. The second phase pursued the integration and interfacing design between these elements, procurement and mechanical design.

The dataflow conceptual design was refined 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 readout requiring four channels of A/D conversion. An FPGA was selected to manage the high speed clocking of data from the A/D converter. Firmware for the FPGA was developed and test benched. The selected RF module was interfaced and software developed to test the link throughput. Details of the packet structure, buffering and time tagging were finalized.

Several plastic models were prototyped on a 3-D printer during the second phase to experiment with design concepts for a hand held package. Provisions for interchangeable collimators, shielding options, and dual-material construction were explored. The scintillator design was finalized and procured. The SiPM arrays were acquired. The geometry of these SiPM arrays is a significantly thinner design than previous surface mounted devices. A flexible PCB was designed and procured which provides a very low profile connection between the SiPM array and the first stage amplifiers. This rigid-flex design solved several challenges: minimization of shield volume and mass, low profile interconnection and location of the RF antenna and charging loops outside of the shielding.

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 testing of the RF and software components.

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 cool the ion beam in the collider ring an electron beam current of up to 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 it is proposed 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 Dr. A. 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. The required kicker frequency is higher than anything that has been tried before. A practical test will be accomplished using a stripline kicker on loan to us from SLAC.

Accomplishments

A detailed MATLAB simulation was created to simulate the addition of sub harmonics and to evaluate their relative frequencies and amplitudes as well as other properties (jitter, phase). ELEGANT beam dynamics simulations were developed which show the effects of such a summed waveform on an electron bunch, circulating many times within a simplified electron cooler. Results were promising, with <0.4% horizontal emittance growth for a 5 kV kick and <4% for 50 kV. A novel pre-distortion scheme was explored which would address emittance growth in certain kicking waveform solutions (for instance, when optimizing the "flat top" of the kick). CST time domain simulations were performed to model the stripline kicker and kicking scheme. It was estimated that tens of kW of RF power may be needed with the current design of cavity.

A bench experiment was performed which showed the summation of a set of harmonics, through a broadband amplifier. This demonstrated that the theory is sound and validated the MATLAB model. It was noted that the summed waveform is very sensitive to any phase disturbance throughout the system. A Goubau line (primarily used in beam position monitor calibrations) was set up to measure coupling between the line and the cavity electrodes. The line was driven in various modes with the summed waveform and measured on one of the cavity electrodes. The experiment validated our theory and demonstrated that waveform generation, summation and amplification through the stripline cavity look extremely promising for a potential fast kicker for future applications.

Publications

N/A

Workshops

N/A

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	No
Source of support for follow-on funding?	N/A
Has follow-on funding been obtained?	No
Amount of follow-on funding ($K)?	N/A
Number of Post Docs supported by LDRD project?	0.2
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

4.0 Study of Experimental Demonstration of Cooling By A Bunched Electron Beam

Principal Investigator: Yuhong Zhang

Project Description

A critical R&D for MEIC is an experimental demonstration of cooling of ions by a bunched electron beam. This LDRD project focuses on feasibility of this proof-of-principle experiment, which is scheduled for April, 2016 at one of two DC electron coolers at Institute of Modern Physics (IMP) in China. Collaboration with a team of IMP researchers was established during execution of this LDRD project.

Accomplishments

The key idea of this experiment utilizing a DC cooler is to modulate the high voltage of the thermionic gun of this cooler such that the beam coming from it is bunched.

We have completed preparatory work in four areas. The first area is participating in a study leading to construction of a high voltage platform with a RF modulator. It could produce a negative electric field near the cathode thereby suppressing emission of electrons. Changing the potential therefore switches on/off the beam with repetition rate determined by the RF module

Based on this work and other studies, a parameter set for the experiment has been developed. The selected ion species is $^{12}C^{6+}$, and it has a low energy (7 to 30 MeV/u) thus the cooling effect should be strong even with a modest electron beam current. This ion beam can be either coasting or bunched by an existing RF system of 0.7 MHz. If the bunch repetition rate is locked to an integer times the revolution frequency, there should be a weak bunching effect on the ion beam in the longitudinal direction. Observation of it is another goal of this experiment

In the third area, we have performed simulations to predict the cooling rates by a bunched electron beam using a code developed by this LDRD. The new code is based on an improved model for bunched beam cooling of a coasting beam. The coasting ion beam is sampled only in the section co-moving with the cooling electron bunch. The cooling effect is averaged in a coasting ion beam by ion diffusive motion. The electron profile could be also taken into account using this model. The new code has been benchmarked with BETACOOL for several typical cooling scenarios and they agree well. Simulations demonstrated the equilibrium of beam emittance can be reached within 50 seconds. In the first order, the cooling rate is proportional to the average electron beam current.

In the fourth area, we have completed an assessment of the beam diagnostic requirement for the experiment, conducted a survey of existing diagnostic capability of the IMP cooler and developed an improvement plan. Presently, the ring has a limited capability in diagnostics of both stored ion beams and cooling electron beam. We have explored feasibility to make modification of two existing BPMs for current measurement. The preliminary finding is positive. This work will be continued under the support from other funding sources.

Publications

Haipeng Wang, JLab technote JLab-TN-15-039

Workshops/Conferences

L. Mao, A. Hutton, J. Li, X. Ma, V. Parkhomchuk, V. Reva, M. Tang, H. Wang, H. Zhang, T. Zhang and H. Zhao, "*Progress in Experimental Demonstration of Cooling of Ions by a Bunched Electron Beam*", Poster at COOL'15 Workshop, Newport News, Virginia, USA, Sept. 28 to Oct. 2, 2015.

L. Mao, "*Progress of Bunched Beam Electron Cooling Demo*", Invited presentation at MEIC Collaboration Meeting fall 2015, Newport News, Virginia, USA, Oct. 5 to 7, 2015

H. Wang, "*Beam Diagnostic Requirements for Bunched Beam Cooling Demo*", Invited presentation at MEIC Collaboration Meeting fall 2015, Newport News, Virginia, USA, Oct. 5 to 7, 2015

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	Yes
Source of support for follow-on funding?	DOE/NP
Has follow-on funding been obtained?	Not yet
Amount of follow-on funding ($K)?	130
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

* To cover expenses for participation in an experiment in China that we anticipate will result from this work

5.0 Experimental studies of optics schemes at CEBAF for suppression of coherent synchrotron radiation (CSR)

Principal Investigator: Yves Roblin

Project Description

Electron cooling is fundamentally important to the MEIC proposal for reaching its high luminosity goal. We proposed a test of an emittance compensation scheme that is critical to the design of an optimal solution for MEIC high energy cooling. The opportunity to directly test this concept with beam provided the incentive for this LDRD whose goal is to carry out all the preliminary studies necessary for the planning of such an experiment at CEBAF by reconfiguring the recirculator lattice appropriately.

Accomplishments

The first part of the plan consisted in narrowing down which beam parameters were required for measuring the CSR suppression. We determined that one has to use at least 40 pC of bunch charge while keeping the transverse emittance below one mm.mrad normalized

Next, the existing CEBAF injector setup was investigated to see if one could produce these conditions. We concluded that one needed to design a shorter injector. This was done using the FEL injector design as a starting point. The components are available at Jefferson Lab and can be reused for this experiment.

The next phase of the project consisted in studying the transport of this beam through the CEBAF north linac and into the east arc. An optimal longitudinal match was found which preserved the beam characteristics during acceleration. Two lattices were produced specifically for the east arc in CEBAF. By design, one lattice suppresses the CSR microbunching while the other enhances it.

A start to end simulation from the injector to the end of the CEBAF recirculation arc validated the design. Diagnostics were examined, more specifically, the use of transverse phase space tomography to characterize this emittance growth, which we determined, can be used. Finally, the radiological conditions were examined. This led to the design of an insertable beam dump with appropriate shielding which can be installed at the end of this ARC.

In conclusion, we have achieved the goals of this LDRD, which were to carry out all the preliminary studies for a potential experiment at CEBAF. A proposal for the program advisory committee at Jefferson Lab is in preparation.

Publications

Y. R. Roblin, *et al.*, *Experimental studies of optics schemes at CEBAF for suppression of coherent synchrotron radiation.* May 2016; JLAB proposal to PAC44, in preparation.

Workshops/Conferences

Y.R. Roblin, *Experimental studies of optics schemes at CEBAF for suppression of coherent synchrotron radiation induced emittance growth*, MEIC collaboration meeting, Newport News, March 30-31, 2015.

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	No
Source of support for follow-on funding?	No
Has follow-on funding been obtained?	No
Amount of follow-on funding ($K)?	n/a
Number of Post Docs supported by LDRD project?	None
Number of students supported by LDRD project?	None
Number of scientific staff/technical staff hired with LDRD funding?	None
Number of copyrights filed (beyond publications)?	None
Number of invention disclosures filed?	None
Number of patent applications filed?	none

6.0 Enhancing Simulation Capability for Electron Cooling in MEIC Project

Principal Investigator: He Zhang

Project Description

We proposed to develop a computational platform for modeling and simulation of electron cooling, which addresses (*i*) the bunched electron cooling of coasting ion beam, focusing on the evolution of the macroscopic beam parameters such as emittances and momentum spread, and (*ii*) single pass electron cooling process, focusing on the interaction between individual particles from microscopic view. The new platform will be adaptive to modern high performance hardware.

Accomplishments

A new program was developed to simulate the evolution of the macroscopic beam parameters under the intrabeam scattering (IBS) effect and/or electron cooling. The program can calculate the expansion rate and simulate the expansion dynamic process for all the four cases: DC electron beam with coasting ion beam, DC electron beam with bunched ion beam, bunched electron beam with coasting ion beam, and bunched electron beam with coasting ion beam. A serial version of the program has been finished and benchmarked with BETACOOL for typical scenarios in MEIC electron cooling design. The results of the two programs agree very well with each other. By avoiding redundant computation, the new program has achieved much better efficiency than BETACOOL. For a typical cooling process simulation, which calculates the evolution of the emittances and momentum spread in 10s to 100s seconds, the new program is ten times faster than BETACOOL. The new program also brings more flexibility to better fulfill the requirements of MEIC on electron cooling simulations. Now with moderate effort, we can integrate new models that BETACOOL does not provide, for example a bunched electron beam with correlation between momentum and longitudinal position, into simulations. We have actively implemented the new program in MEIC electron cooler design. A multiple thread version of the program will be finished in the second year.

For single pass electron cooling simulation, one needs to correctly treat the following three problems: modeling the electron beam and the ion beam, tracking the particles, and calculating the binary collisions in near region. For particle tracking, it is essential to calculate the field between the huge amount of charged particles accurately and efficiently. We have developed a new algorithm, using traceless totally symmetric Cartesian tensors with the fast multipole method, which allows to calculate the Coulomb field between millions of charged particles in a short time. For example, the Coulomb field between one million electrons can be calculated within 44 second in a laptop with Intel i7-3630QM processor keeping the relative error less than 1×10^{-3}. We will parallelize the new algorithm on the CPU-GPU hybrid platform and develop the particle tracking program for electron cooling simulations in the second year.

Publications

none

Workshops/Conferences

H. Huang, *Fast Multipole Method for Coulomb Interaction Based on Traceless Totally Symmetric Tensor*, American Physical Society April Meeting, Baltimore, Maryland, April 11-14, 2015.

H. Zhang, *Traceless Totally Symmetric Tensor Based Fast Multipole Method for Space Charge Field Calculation*, FEIS-2: Femtosecond Electron Imaging and Spectroscopy, Lansing, Michigan, May 6-11, 2015.

H. Zhang, *Electron Cooling Simulation Program Development for MEIC*, COOL Workshop 2015, Newport News, Virginia, September 28 - October 2, 2015.

Questionnaire

Question	Answer
Will follow-on funding (post-LDRD project) be applied for?	NA
Source of support for follow-on funding?	NA
Has follow-on funding been obtained?	NA
Amount of follow-on funding ($K)?	NA
Number of Post Docs supported by LDRD project?	0.625
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