

Annual Report for Period:09/2010 - 08/2011

Submitted on: 10/01/2011

Principal Investigator: Bunn, Emory F.

Award ID: 0922748

Organization: University of Richmond

Submitted By:

Bunn, Emory - Principal Investigator

Title:

MRI: Acquisition of a Computing Cluster for Astrophysics and Nuclear Physics Research at the University of Richmond

Project Participants

Senior Personnel

Name: Bunn, Emory

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Gilfoyle, Gerard

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Name: Musalo, Chistopher

Worked for more than 160 Hours: Yes

Contribution to Project:

During the summers of 2010 and 2011 (full-time), as well as during the academic year (part-time), Chris Musalo installed, tested, and benchmarked software to be used in the nuclear physics research program. He has begun using this software to perform simulations of Jefferson Lab accelerator data.

Name: Carbonneau, Joshua

Worked for more than 160 Hours: Yes

Contribution to Project:

During the summers of 2010 and 2011, Josh Carbonneau installed, tested, and benchmarked software to be used in the nuclear physics and astrophysics research programs.

Name: Lee, Robert

Worked for more than 160 Hours: Yes

Contribution to Project:

During the summer of 2011 (full-time) and the spring 2011 semester (part-time), undergraduate Robert Lee worked on the creation of simulations of cosmic microwave background map-making. He was supported in part by another NSF award.

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Thomas Jefferson National Laboratory

Co-PI Gilfoyle's research involves analysis and simulation of experiments performed at Jefferson Laboratory. His collaborators at the Laboratory are involved in the analysis and will make use of the cluster.

University of Wisconsin-Madison

PI Bunn collaborates with Peter Timbie's group at the University of Wisconsin, Greg Tucker's group at Brown University, and Ben Wandelt's group at the Institut d'Astrophysique (Paris) on the simulation of future CMB observations. The simulations being performed by this collaboration are a large part of the astrophysics portion of the research program supported by this MRI award.

Brown University

PI Bunn collaborates with Peter Timbie's group at the University of Wisconsin, Greg Tucker's group at Brown University, and Ben Wandelt's group at the Institut d'Astrophysique (Paris) on the simulation of future CMB observations. The simulations being performed by this collaboration are a large part of the astrophysics portion of the research program supported by this MRI award.

Institut d'Astrophysique (Paris)

PI Bunn collaborates with Peter Timbie's group at the University of Wisconsin, Greg Tucker's group at Brown University, and Ben Wandelt's group at the Institut d'Astrophysique (Paris) on the simulation of future CMB observations. The simulations being performed by this collaboration are a large part of the astrophysics portion of the research program supported by this MRI award.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:

Three undergraduates (Joshua Carbonneau, Christopher Musalo, and Robert Lee) have worked on all aspects of the work supported by this award (installation and testing of the cluster as well as science activities), supported by other funds. These students gained invaluable experience in high-performance scientific computing.

Outreach Activities:

Journal Publications

P.M. Sutter, B.D. Wandelt, S. Malu, "Bayesian power spectrum analysis of interferometric data", *Astrophysical Journal*, p. , vol. , (2011). Submitted,

Books or Other One-time Publications

G.P. Gilfoyle, "Measuring the Fifth Structure Function in $2\text{H}(e, e'p)n$ ", (2011). Collaboration meeting presentation, Published
Collection: CLAS Collaboration Meeting
Bibliography: CLAS Collaboration Meeting

G.P.Gilfoyle, M.Ungaro, J. Carbonneau, M. Moog, and C. Musalo, "Simulated CLAS12 Neutron Detection Efficiency in the Forward Time-of-Flight System", (2011). Jefferson Lab Collaboration Note, Published
Collection: CLAS Note
Bibliography: CLAS-NOTE-2011-15, September 29, 2011.

C. Musalo, J.Carbonneau, and G.P.Gilfoyle, "Simulation of the CLAS12 dual hydrogen-deuterium target", (2011). Conference presentation, Published
Collection: Abstract of presentation at APS Division of Nuclear Physics meeting
Bibliography: Bull. Am. Phys. Soc., Fall DNP Meeting, EA.00102 (2011).

Web/Internet Site**Other Specific Products****Contributions**

Contributions within Discipline:

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

In part as a result of the acquisition of the computing cluster supported by this grant, an alumna of the University has given the department funding to develop a separate high-performance computing lab for use in teaching. Acquisition of equipment for this additional lab is underway. The University of Richmond is committed to closely integrating research and teaching, and the new educational computer lab will be of great help in our effort to tie our computational research together with our educational efforts.

Contributions Beyond Science and Engineering:

Conference Proceedings**Special Requirements**

Special reporting requirements: None

Change in Objectives or Scope: None

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Activities and Findings: Any Outreach Activities

Any Web/Internet Site

Any Product

Contributions: To Any within Discipline

Contributions: To Any Other Disciplines

Contributions: To Any Human Resource Development

Contributions: To Any Beyond Science and Engineering

Any Conference

Activities

In the last year the Richmond Research Cluster has been heavily used by the nuclear and astrophysics groups. The development of the cluster is largely complete and the work has been focussed on the science.

Nuclear Physics

In nuclear physics, the cluster has been used for three main projects. (1) The analysis of the nuclear reaction ${}^2\text{H}(e, e'p)n$ measured in Hall B at Jefferson Lab is nearing completion. The goal is to extract the seldom-measured fifth structure function. The structure functions encode the information about the structure of the neutron and proton bound into deuterium. The data are described well by a relativistic calculation of the response functions by Jeschonnek and Van Orden. The data set is large (about 1 GByte) and the analysis is computationally intensive. The use of the cluster dramatically reduces the time needed for an analysis run. The results were presented at the March, 2011 CLAS Collaboration meeting [1].

We have developed a simulation of the CLAS12 detector in collaboration with our colleagues at Jefferson Lab. The CLAS12 detector is a large particle detector being built to take advantage of the new physics opportunities of the 12 GeV Upgrade at Jefferson Lab. We are performing simulations in preparation for an experiment (E12-07-104) that is approved to run in the first five years after the Upgrade entitled ‘Measurement of the Neutron Magnetic Form Factor at High Q^2 Using the Ratio Method on Deuterium’. Gilfoyle is the spokesperson and contact person for the experiment. Neutrons will be measured in E12-07-104 with the time-of-flight (TOF) system in CLAS12 and, using the cluster, we have completed a study of the neutron detection efficiency in the TOF system. The study found the simulation closely agrees with previous measurements of the efficiency of the TOFs [2]. We also completed a study of the simulated response of the electromagnetic calorimeter in CLAS12 to neutrons. The calorimeter provides a second, independent measurement of the neutrons and Gilfoyle was responsible for implementing it in the simulation. The cluster was used to test the performance which was found to be consistent with previous studies of the calorimeter [3, 4].

The Richmond cluster has been used as a development platform for the CLAS12 software framework. The package, entitled CLARA, is an environment where data processing algorithms filter continuously flowing data. In CLARA's domain of loosely coupled services, data is not stored, but rather flows from one service to another, evolving constantly along the way. The environment can take full advantage of modern, multi-core, multi-threaded processors in a distributed environment. The code is under nearly constant development by researchers at JLab and at Richmond [5, 6].

Astrophysics

The astrophysics research program focuses on simulation of cosmic microwave background (CMB) data sets.

Bunn is a leading member of a collaboration (funded via another NSF award) that is building a suite of simulation software to assess the viability of interferometric methods in CMB polarimetry. The state of the art in simulating “traditional” imaging telescopes is far more advanced than interferometric simulations. In order to insure that we use the optimal strategy to pursue the goals of CMB polarimetry, we must close that gap.

This project is making rapid progress, due in large part to the hiring of postdoctoral researcher Le Zhang (based at the University of Wisconsin) as well as graduate student Ata Karakci at Brown. Many pieces of the simulation pipeline, including the creation of visibility data sets with realistic systematic errors, are in place.

Ben Wandelt’s group at the Institut d’Astrophysique in Paris, particularly postdoc Paul Sutter, have used the cluster funded under this grant for a preliminary analysis of CMB interferometric data via the Gibbs sampling technique. A paper describing this work has recently been submitted for publication [7]

Bunn and undergraduate Robert Lee are working on a separate project involving the simulation of CMB map-making (i.e., deriving sky maps from time-ordered data) in the context of some novel and unusual telescope designs. This work is in an early stage. Lee has successfully written much of the simulation code.

References

- [1] ‘Measuring the Fifth Structure Function in $^2\text{H}(e, e'p)n$ ’, G.P.Gilfoyle, CLAS Collaboration Meeting, March 10, 2011.
- [2] ‘Simulated CLAS12 Neutron Detection Efficiency in the Forward Time-of-Flight System’, G.P.Gilfoyle, M.Ungaro, J. Carbonneau, M. Moog, and C. Musalo, CLAS-NOTE-2011-15, September 29, 2011.
- [3] ‘Simulation of the Electromagnetic Calorimeter in CLAS12’, G.P.Gilfoyle, M.Ungaro, J. Carbonneau, M. Moog, and C. Musalo, CLAS-NOTE in preparation.
- [4] C. Musalo, J.Carbonneau, and G.P.Gilfoyle, ‘Simulation of the CLAS12 dual hydrogen-deuterium target’, Bull. Am. Phys. Soc., Fall DNP Meeting, EA.00102 (2011).
- [5] “CLARA: A Contemporary Approach to Physics Data Processing”, V Gyurjyan¹, D Abbott, J Gilfoyle, D Heddle, G Heyes, S Paul, C Timmer, D Weygand, E Wolin, CLHEP, 18-23 October 2010, Academia Sinica, Taipei, Taiwan.
- [6] J.Carbonneau, Mark Moog, Vardan Gyurjyan, Sebouh Paul and G.P.Gilfoyle, ‘Development of A Clara Service for Neutron Reconstruction’, Bull. Am. Phys. Soc., Fall DNP Meeting, EA.00024 (2011).
- [7] P.M. Sutter, B.D. Wandelt and S. Malu, “Bayesian power spectrum analysis of interferometric data,” arxiv:1109.4640 (2011).

Findings

The cluster has been used for several projects in nuclear physics and astrophysics, as described under “Activities.” Key results of those projects are summarized here.

Nuclear Physics

- We are nearing completion in the analysis of the nuclear reaction ${}^2\text{H}(e, e'p)n$ measured in Hall B at Jefferson Lab. The data are described well by a relativistic calculation of the response functions by Jeschonnek and Van Orden. The results were presented at the March, 2011 CLAS Collaboration meeting [1].
- We have completed a study of the neutron detection efficiency in the time of flight (TOF) system, finding that the simulation closely agrees with previous measurements of the efficiency of the TOFs [2].
- We completed a study of the simulated response of the electromagnetic calorimeter in CLAS12 to neutrons. The calorimeter provides a second, independent measurement of the neutrons and Gilfoyle was responsible for implementing it in the simulation. The cluster was used to test the performance which was found to be consistent with previous studies of the calorimeter [3, 4].
- The Richmond cluster continues to be used as a development platform for the CLAS12 software framework [5, 6].

Astrophysics

- Rapid progress is being made in the development of a CMB interferometric pipeline. We expect the first scientific results from this effort soon.
- A paper has been submitted [7] presenting a Bayesian power spectrum and signal map inference engine for interferometric CMB data sets.
- We have implemented a set of tools for simulating the map-making process for a set of novel possible CMB instrument designs. Preliminary scientific results for this project are expected soon.

References

- [1] ‘Measuring the Fifth Structure Function in ${}^2\text{H}(e, e'p)n'$ ’, G.P.Gilfoyle, CLAS Collaboration Meeting, March 10, 2011.
- [2] ‘Simulated CLAS12 Neutron Detection Efficiency in the Forward Time-of-Flight System’, G.P.Gilfoyle, M.Ungaro, J. Carbonneau, M. Moog, and C. Musalo, CLAS-NOTE-2011-15, September 29, 2011.
- [3] ‘Simulation of the Electromagnetic Calorimeter in CLAS12’, G.P.Gilfoyle, M.Ungaro, J. Carbonneau, M. Moog, and C. Musalo, CLAS-NOTE in preparation.
- [4] C. Musalo, J.Carbonneau, and G.P.Gilfoyle, ‘Simulation of the CLAS12 dual hydrogen-deuterium target’, Bull. Am. Phys. Soc., Fall DNP Meeting, EA.00102 (2011).
- [5] “CLARA: A Contemporary Approach to Physics Data Processing”, V Gyurjyan¹, D Abbott, J Gilfoyle, D Heddle, G Heyes, S Paul, C Timmer, D Weygand, E Wolin, CLHEP, 18-23 October 2010, Academia Sinica, Taipei, Taiwan.
- [6] J.Carbonneau, Mark Moog, Vardan Gyurjyan, Sebouh Paul and G.P.Gilfoyle, ‘Development of A Clara Service for Neutron Reconstruction’, Bull. Am. Phys. Soc., Fall DNP Meeting, EA.00024 (2011).
- [7] P.M. Sutter, B.D. Wandelt and S. Malu, “Bayesian power spectrum analysis of interferometric data,” arxiv:1109.4640 (2011).