

## **Final Report**

Gregory Snow / University of Nebraska

August 1, 2016

### **DOE award number, name, and address of the recipient**

DE-FG02-08ER46490

Board of Regents, University of Nebraska-Lincoln

Lincoln, NE 68588

### **Project Title and name of the Principal Investigator**

“The Luminosity Measurement for the DZERO Experiment at Fermilab”

Prof. Gregory R. Snow

### **Date of the report and period covered by the report with approved budget amount**

Date of report: August 1, 2016

Period covered: June 15, 2008 to June 14, 2011

Approved budget amount: \$425,352.00 from DOE, \$87,938.00 University of Nebraska cost share

### **Participating National Laboratory**

Fermi National Accelerator Laboratory, Batavia, Illinois. DZERO experiment spokesperson: Dr. Dmitri Denisov.

### **Brief description of the project goal and objective**

Primary project objective: The addition of University of Nebraska-Lincoln (UNL) human resources supported by this grant helped ensure that Fermilab’s DZERO experiment had a reliable luminosity measurement through the end of Run II data taking and an easily-accessible repository of luminosity information for all collaborators performing physics analyses through the publication of its final physics results.

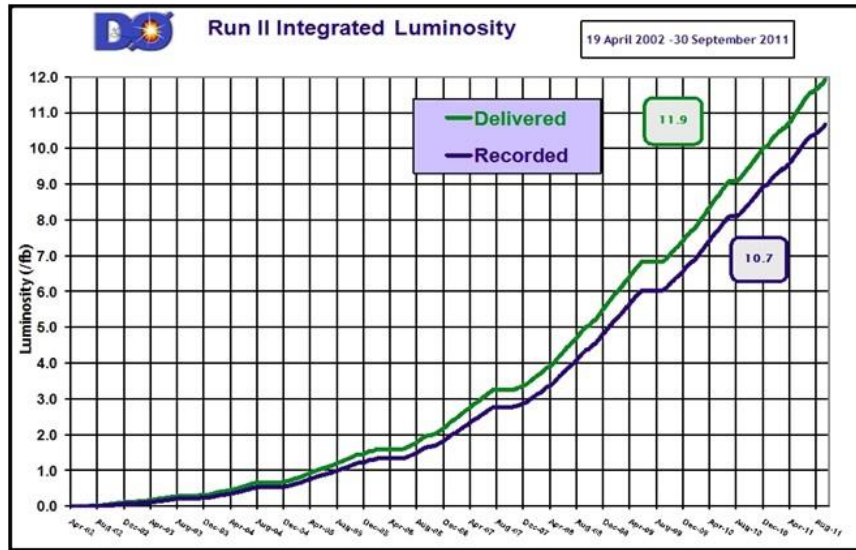
Secondary project objective: The collaboration between the UNL Instrument Shop and Fermilab’s Scintillation Detector Development Center enhanced the University of Nebraska’s future role as a particle detector R&D and production facility for future high energy physics experiments.

Overall project objective: This targeted project enhanced the University of Nebraska’s presence in both frontier high energy physics research in DZERO and particle detector development, and it thereby served the goals of the DOE Office of Science and the Experimental Program to Stimulate Competitive Research (EPSCoR) for the state of Nebraska.

### **Description of accomplishments**

The three-year funding of this award enabled the University of Nebraska group to continue to play a leading role in the measurement of the luminosity at the DZERO experiment at Fermilab. PI Gregory Snow served as co-convener of the Luminosity Working Group in the experiment during this period. He had responsibility for running the bi-weekly working group meetings and, overall, ensuring that the luminosity measurement was robust and stable. He reported directly to the Physics Convener and the Spokesperson of the experiment. Snow drew one month of summer salary from the grant each year but his involvement and commitment to the project were spread throughout the years.

Nebraska graduate student Kayle DeVaughan, in residence at Fermilab and supported full time by the grant, had primary responsibility for overseeing and verifying the accuracy of the daily, weekly, and monthly accumulated luminosity reports. These reports were used by the DZERO management to report the accumulated luminosity recorded by the experiment to the Fermilab Directorate and the Department of Energy – the integrated luminosity delivered to and recorded by the CDF and DZERO experiments were two of Fermilab's performance measures associated with the DOE contact managed by the Fermi Research Alliance which governs the laboratory. A plot of the accumulated luminosity delivered to and recorded by DZERO from the beginning of Tevatron Run II to the end of the experiment's data taking in September 2011 is shown below.



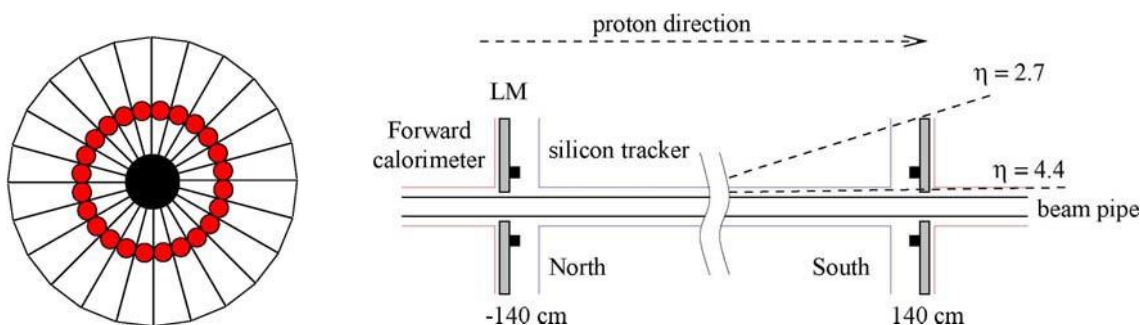
*Plot of the accumulated proton-antiproton luminosity delivered to and recorded by the DZERO experiment during Run II. The flat intervals during the summers of 2009 and 2010 represent accelerator shutdown periods when the Luminosity Monitor's scintillators were replaced due to radiation damage.*

On November 1, 2008, the Nebraska group hired postdoctoral researcher Ioannis Katsanos, a recent PhD recipient from Columbia University who completed his dissertation research on DZERO. Ioannis was based at Fermilab and supported full-time by the grant. Ioannis's primary responsibility concerned the database that contains the luminosity information for DZERO collaborators to access when performing physics analysis. The Working Group made the database the sole repository for luminosity information during the period of this grant, replacing the ASCII text files the experiment had been using for several years. Many checks comparing the luminosity derived from the database and the ASCII text files needed to be performed before the group was certain that the time was right for the transition.

For both DeVaughan and Katsanos, tasks associated with the luminosity measurement represented their sole service responsibilities on the experiment, and they devoted approximately 50% of their time to these tasks. In addition to what is mentioned above, they participated in each bi-weekly Working Group meeting, and they carried pagers 24/7 to be on call for luminosity problems noticed by collaborators staffing data-taking shifts in

the DZERO control room. Each performed physics analyses as well -- DeVaughan working on jet physics in the Quantum Chromodynamics analysis group, and Katsanos working on a search for a possible “Z- prime” excited partner of the Z intermediate vector boson.

During the spring 2009, using grant funds, PI Gregory Snow purchased acrylic scintillator material from the company Satin-Gobain Crystals which was used to replace the existing Luminosity Monitor (LM) scintillators during the summer 2009 accelerator shutdown. Two types of scintillator were purchased – a batch of cut and polished wedges that were ready to be used in the replacement and a large piece of rough-cut scintillator material to be prepared for use by the Instrument Shop in Nebraska’s Department of Physics and Astronomy. The LM scintillators needed to be replaced every 1-2 years due to the radiation damage they accumulated when in place inside the DZERO detector. The LM scintillators were also replaced a final time during the summer of 2010. The LM system is shown in the figure below.



*The Luminosity Monitor (LM) detectors of the DZERO experiment at Fermilab.*

Each replacement of the LM scintillators during the Tevatron accelerator shutdowns was a big job that involved dismantling the current LM detectors from the DZERO endcap calorimeters, removing the photomultiplier tubes from the current scintillator wedges, preparing the new scintillator wedges for gluing the photomultiplier tubes, wrapping the scintillator wedges in reflective aluminum, testing the completed new detectors, and reinstalling the new detectors on the endcap calorimeters.

During the period of grant funding, the Luminosity Working Group also worked on the determination of an updated calibration constant that converts measured hit rates in the LM detectors to absolute luminosity for Run IIb which spanned the period from June 2006 to September 2011. This resulted in the NIM article which is cited in the section below.

Other Nebraska group members also participated in DZERO’s luminosity measurement. Faculty members Daniel Claes, Kenneth Bloom, and Aaron Dominguez helped supervise DeVaughan and Katsanos through the weekly Nebraska group meetings we held with videoconference connections to Fermilab and through the frequent trips they took to the laboratory. These faculty members often attended the bi-weekly meetings of the Luminosity Working Group either in person or via videoconference connections.

### **List of papers in which DOE support is acknowledged**

A list of DZERO publications (published, accepted, and submitted), too long to list individually here, can be found at the web site:

Each paper acknowledges the support of the Department of Energy. At the time of writing this final report, a total of 355 Run II papers were published, 1 was accepted, and 3 were submitted, mainly to the journals *Physical Review Letters*, *Physical Review D*, and *Physics Letters B*. These papers cover the experiment's noteworthy results in the areas of Quantum Chromodynamics, B-meson physics, top quark physics, electroweak physics, searches for new phenomena (like supersymmetry and extra dimensions), and searches for the Higgs boson. Publications based on Run IIa data which quote the integrated luminosity used in the analysis includes a reference to a Fermilab Technical Memo whose primary author was PI G. Snow, "The DZERO Experiment's Integrated Luminosity for Tevatron Run IIa", T. Andeen, *et al.*, FERMILAB-TM-2365 (2007). Publications based on the Run IIb data set include a reference to the NIM article "The D0 Run IIb luminosity measurement", B.C.K. Casey, *et al.*, NIM A **698** (2013) 208-223.

#### **List of people working on the project**

- Dr. Ioannis Katsanos, postdoctoral research associate, fully supported by this grant.
- Kayle DeVaughan, graduate student, fully supported by this grant.
- Prof. Gregory Snow, PI of this grant, partially supported by this grant. G. Snow drew one month of summer salary from the grant each year, although his effort on the project was spread throughout the year. One month of summer salary represents 1/9 of Snow's academic year salary provided by the University of Nebraska.
- Prof. Kenneth Bloom, no support from this grant.
- Prof. Daniel Claes, no support from this grant.
- Prof. Aaron Dominguez, no support from this grant.

#### **List of other support**

- Other grants on which PI Gregory Snow served as PI or co-PI:
  - U.S. Department of Education, P200A060311, "Graduate Assistantships in Areas of National Need", PI G. Snow, \$380,016; August 14, 2006 – August 13, 2009. This grant provided support for graduate students in all physics subfields in Nebraska's Department of Physics and Astronomy. There is no overlap of this grant with the DOE/EPSCoR grant.
  - National Science Foundation, EPP-0653592, "Experimental High Energy Physics", Co-PIs D. Claes and G. Snow, \$570,000; July 1, 2007 – June 30, 2010. This is a base funding grant for the Nebraska high energy physics group which supports its efforts in CERN's CMS experiment, Fermilab's DZERO experiment, and the Pierre Auger Cosmic Ray Observatory in Argentina. There is no overlap of this grant with the DOE/EPSCoR grant. All activities associated with the luminosity measurement at the DZERO experiment were supported by the DOE/EPSCoR grant.
  - University of Nebraska-Omaha NASA Space Grant Office, "Enhancement of Online Physics Courses, General Physics I & II, with NASA Education Materials", PI G. Snow, \$1980; January 1, 2009 – December 31, 2009.

There is no overlap of this grant with the DOE/EPSCoR grant.

- University of Nebraska-Omaha NASA Space Grant Office, “Design and Construction of a Prototype LIDAR Enhancement Detector for the Pierre Auger Cosmic Ray Observatory”, PI G. Snow, \$7354; January 1, 2009 – December 31, 2009. There is no overlap of this grant with the DOE/EPSCoR grant.

#### **Cost status**

- Approved budget for the full budget period: \$425,342 (DOE share).
- Actual costs incurred for the full budget period: \$425,342 (DOE share). Actual costs incurred included full salary support for DeV Vaughan and Katsanos, one month summer salary support for PI G. Snow each year, materials and supplies, travel to Fermilab and to DOE/EPSCoR meetings, plus university indirect costs on the budget’s modified total direct costs.
- Cost Sharing/University Matching: \$87,938 for the full budget period. As listed in the budget explanation of the proposal for this grant, the cost share contributions came from Nebraska state dollars that supported the partial academic-year research salaries of Profs. Bloom, Claes, and Dominguez, as well as travel support for DZERO spokesperson Dmitri Denisov to visit the high energy physics group at the university to discuss progress on the luminosity project.



