# Laboratory Directed Research and Development

**Proposal Title:** Data Acquisition Improvement for the LBNE Experiment

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| **Proposal Term**   | From: 10/2012  
Through: 09/2013 |

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Abstract

We propose to investigate the possibility of greatly enhancing the Data Acquisition (DAQ) capabilities of the Long Baseline Neutrino Experiment (LBNE) over that previously proposed. This will be accomplished by incorporating the SLAC-developed DAQ toolkit, including the RCE module, into the LBNE DAQ system.

Summary of Proposal

Description of Project

The Long Baseline Neutrino Experiment (LBNE) is a project that, as proposed, uses an intense neutrino beam, produced at Fermilab and detected 1300 km away in the Homestake mine, to measure neutrino properties such as $\delta_{\text{CP}}$ and the neutrino mass hierarchy. LBNE’s baseline design for the Homestake far detector is a 34 kT active volume Liquid Argon Time Projection Chamber (LAr TPC). The large size of this detector is needed for sufficient beam neutrino statistics, but may also give sensitivity to “non-beam” physics such as supernova-produced neutrinos and nucleon decay. Since LBNE is expected to be the flagship accelerator experiment operating in the US in the next decade, it could form an important part of the future SLAC HEP program. Successful SLAC participation in LBNE could be greatly facilitated by a small, but significant, amount of R&D that is the topic of this proposal.

Changes to the baseline far detector design, and indeed to the entire LBNE project, are currently being considered. This is in response to a recent directive from the DOE Office of Science to find alternative designs and a more “phased” approach. Changes such as using a surface site, rather than the Homestake mine, and building smaller LAr TPC modules are being considered. However, it remains likely that the far detector technology will be LAr TPC. Accordingly, support has been expressed from DOE for continuing the ongoing R&D effort towards developing large-scale LAr TPCs. The studies supported by this LDRD proposal go beyond the current R&D effort, but are likely to remain relevant for almost any final configuration of LAr TPC.

The global LAr TPC R&D effort is studying a large number of issues including LAr purity, cryogenic electronics and TPC design. One important issue that matches well with a SLAC core capability is that of back-end DAQ read out. The
large size and channel count of the proposed TPCs produces a large data rate, especially in comparison to previous neutrino experiments. The current baseline LBNE DAQ system appears to have sufficient bandwidth for an underground detector with no extraneous noise sources. However, if a surface site is chosen, or if there are other unanticipated noise sources, insufficient DAQ bandwidth may lead to loss of data, or the application of higher than desirable readout thresholds. Application of more modern DAQ techniques could mitigate this problem.

We propose to investigate the use of RCEs (Reconfigurable Cluster Elements) in the DAQ system for the LBNE LAr TPC. RCEs are SLAC-designed modules that offer significantly higher readout speeds than are available with the current baseline system. This would enable increased flexibility in the DAQ system and possibly enhance the sensitivity to low-energy events such as those coming from supernova neutrinos. The work to be done in the proposal will demonstrate that the RCE system is capable of handling the large data rate of the LBNE TPC and that the system can be interfaced with its front-end electronics.

**Expected Results**

We expect to demonstrate that the RCEs can handle the expected LBNE data rate and can readout the front-end electronics. This is the first step to demonstrating that the RCEs present a suitable solution for the LBNE DAQ system with performance far superior to the currently proposed system.

**Proposal Narrative**

**Purpose/Goals**

We propose an R&D program aimed at improving the LBNE DAQ system. Successful completion of this program will improve the flexibility of this system, giving it greatly improved immunity to noise and possibly improving the sensitivity of LBNE to supernova and other lower energy neutrinos. It will also serve to establish SLAC as an important part of the LBNE collaboration. This would likely lead to significant roles in the building and operation of the full-scale LBNE detector.

**Approach/Methods**

This proposal seeks to improve upon the current LBNE DAQ baseline design. This system relies on a stage of data sparsification performed at the front-end readout of the TPC, inside the cryostat. This sparsification lowers the data rate
from 60Gbps-per-anode plane (there are a total of 210 anode planes in the 34kT TPC) to ~15Mbps. The output from the front-end is then sent to a set of Data Concentrator Modules (DCMs), with 64 inputs at 24Mbps, which concatenates the data into individual events and sends them to a commercial ethernet switch and then to an online CPU farm for further analysis.

While the proposed scheme should work, it does not have much head room if the background rates (or noise from the TPC) are higher than expected. It also lacks scalability or flexibility. For instance, it may be desirable to do much less sparsification at the front end in order to observe spallation products, which could be a background for supernova and proton decay events. If a surface site is chosen for the far detector, the noise rates would likely be too high for DCMs to handle. Another consideration is that the DCMs were originally designed for the NoVA experiment and are based on technology that is already 10 years old.

We believe that by using the RCEs and the ATCA architecture, we can build a highly scalable and flexible DAQ system that would allow us to pull as much data out of the cryostat as needed and at a price that is comparable to the current baseline design. For an underground site, this is highly desirable improvement. For a surface site, it may be essential.

Due to the uncertainty of the LBNE development program, we have decided to propose a single year of work to get the RCE project started. Once the LBNE situation is clearer, we expect to submit a follow-on proposal for FY14-FY15 that will complete the viability demonstration.

In this first year, we plan three development steps:

1. Design and build a Data Simulator Board. This board will produce and transmit artificial digitized data at the rate and format expected from LBNE. This data will be fed into RCE to demonstrate that it can handle the data rates as needed. The LBNE DAQ coordinator has confirmed that no such board exists and would be a useful addition to the R&D effort. This board will also be made available to LBNE collaboration members developing competing DAQ systems.

2. Write prototype “feature extraction” software, which runs in the hardware of the RCE.

3. Obtain and operate a prototype FEB from Brookhaven and demonstrate that it can be read out with an RCE.

Subsequent years’ work will demonstrate the use of RCE technology on an existing LAr TPC prototype and implement RCE readout for the large 1kT
prototype, to be built at Fermilab. However, these activities are not covered under this proposal.

If the research proposed in this LDRD and subsequent years is successful, the RCE approach may be chosen as the baseline design for the LAr TPC DAQ.

**Specific Location of Work**

This work will be done in the existing labs of the PPA Electronics Group.

**Anticipated Outcomes/Results**

We expect to demonstrate that the RCEs can handle the expected LBNE data rate and can read out the front-end electronics. This is the first step to demonstrating that the RCEs present a suitable solution for the LBNE DAQ system with performance far superior to the currently proposed system.

This demonstration could have a significant impact on SLAC’s involvement in LBNE, as it would establish our capability to contribute an important detector component. In the case of a surface site being chosen, this contribution would be especially important since the currently proposed system would likely not be able to handle the higher rates. An improved DAQ system would then become a necessity. Since there is no other planned DAQ R&D, demonstrating that the RCE’s can fill this need in FY13 would likely make them the preferred solution. This could lead to a significant role in the final LBNE construction.
VITA (Lead Scientist)

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DEGREES
Ph.D. Physics, Princeton University, 1996.
B.S. Physics, University of California, Berkeley, 1987.

EXPERIENCE
2003-Present: Staff Physicist, SLAC National Accelerator Laboratory
1996-2003: Research Associate, SLAC National Accelerator Laboratory
1990-1996: Graduate Student, Princeton University

HONORS
1992-93: Porter Ogden Jacobus Fellowship, Princeton University. "For the graduate student who has evinced the highest scholarly excellence in graduate work during the year".
1989-92: National Science Foundation Graduate Fellowship.

SELECTED PUBLICATIONS
More than 200 publications in peer-reviewed journals reporting the work of large collaborations
B. Aubert et al., "Branching Fraction Measurements of B^+\rightarrow\phi\gamma, B^0\rightarrow\phi^0\gamma and B^0\rightarrow\omega\gamma", Physical Review Letters 98,151802 (2007).
Budget Explanation

The included spreadsheet contains the details for the proposed project. Labor for physicists’ time totals 0.5 FTE and will be mostly software work. Labor for Engineering and Software support totals 0.5 FTE. The M&S is for items such as the Data Simulation Board and other needed electronics. It totals $27,000.
SLAC NATIONAL ACCELERATOR LABORATORY

Approvals

Use this section to add signatures. Signatures are required.

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