Physics Research Goals of the LBNE Project

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Revision History

Revision	Date	Section No.	Revision Description
0.1	23 Sep 10	All	Initial draft for discussion.
0.2	29 Sep 10	II	Draft discussed with LBNE Executive Committee 13 Oct 2010
0.3	13 Oct 10	II.1	Promote supernova burst detection to a primary objective.
		II.2	Delete details under objective 2.1.
		II.3	Clarify the explanation of what this group of objectives is.
		II.4	Simplify and renumber the list of near detector objectives.
		II.5	Add an explanation of use of the additional objectives in project planning and reformat.
0.4	28 Oct 10	II.3	Specify that these are "Additional *secondary* objectives"
1.0	18 Nov 10	Title page	Update table of signatures to be obtained.
1.1	22 Dec 10	II.1	State that the primary objectives are listed in priority order.
1.2	21 Jan 11	I.	Remove references to DUSEL.
		II.	Remove references to NSF.
		II.5.1	Refer to the prioritization of the primary objectives.
1.9 DRAFT	30 Aug 12	All	General update to account for phased program. Remove "Key Assumptions" from the title.
1.91 DRAFT	20 Oct 12	III.	Re-order the paragraphs in section III to place the Purposes of the Near Detector System immediately after the Primary Objectives of LBNE.
2.0	20 Nov 12		Approved version (no changes from v1.91)

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I. Introduction

The Long Baseline Neutrino Experiment (LBNE) Project will enable the program envisioned by the Particle Physics Project Prioritization Panel (P5) in its 2008 report[1], which made the following recommendations:

> The panel recommends a world-class neutrino program as a core component of the US program, with the long-term vision of a large detector in the proposed DUSEL and a high-intensity neutrino source at Fermilab.
>
> The panel recommends an R&D program in the immediate future to design a multi-megawatt proton source at Fermilab and a neutrino beamline to DUSEL and recommends carrying out R&D on the technologies for a large multi-purpose neutrino and proton decay detector.

DUSEL refers to the proposed Deep Underground Science and Engineering Laboratory, which was to be sited in the former Homestake gold mine in Lead, SD. Homestake is now the site of the Sanford Underground Research Facility (SURF).

Following the P5 report, the United States Department of Energy (DOE) has issued a Mission Need Statement for a Long Baseline Neutrino Experiment (LBNE)[2], which states:

> The Office of High Energy Physics proposes construction of an experiment comprised of a large detector illuminated by a distant, intense neutrino source and a much smaller detector located close to the source.
> . . .
> The increased research capabilities afforded by a long baseline (distance between the detector and the neutrino source) neutrino experiment will enable a world-class program in neutrino physics that can measure fundamental physical parameters, explore physics beyond the Standard Model, and better elucidate the nature of matter and antimatter.
> . . .
> The large detector, if located underground, and thus shielded from cosmic backgrounds, could also be sensitive to proton decay, predicted by grand unified theories which are natural extensions of the Standard Model. … Furthermore, an underground detector could serve as an observatory for neutrinos generated by supernovae since the beginning of time and for neutrinos generated more recently by supernovae in our galactic neighborhood, yielding new information on the collapse mechanisms of stars.

This Mission Need Statement supported DOE Critical Decision (CD-0) for LBNE, which was approved in January 2010.

II. LBNE as a Phased Program

It is planned to implement LBNE as a phased program, with increasing scientific capabilities at each phase. The LBNE Project is defined to be the construction of the first phase, which will consist of the construction a new neutrino beamline at Fermilab, tertiary muon detectors to monitor the beam, and a 10 kt liquid argon TPC far detector located at SURF, placed at the surface under several meters of shielding. Subsequent phases, which are not part of the LBNE Project, could include the construction of a near neutrino detector on the Fermilab site and construction of a larger detector underground at SURF.

Prior to the realization that LBNE could be implemented only as a phased program, the LBNE Science Collaboration, working with LBNE Project Management, developed a prioritized set of research goals for the full implementation of LBNE, which was approved by the LBNE Project Manager, the LBNE Collaboration Co-Spokespeople, the Fermilab Director, and the LBNE Federal Project Director. This set of goals is presented in Version 1.0 of the present document[3].

The goals for the full LBNE program have not changed as a result of the development of a phased implementation of the program. However, not all of the goals of the full program can be achieved in the first phase. This document presents the full set of research goals, and specifies (in normal font) which goals will be addressed by the LBNE *Project*, and which ones (*in italics*) can only be addressed by subsequent phases of the *program.*

III. Physics Research Goals of LBNE

Following from the P5 recommendations, the DOE Mission Need Statement, discussions with the DOE Office of High Energy Physics, Fermilab management, and the LBNE Science Collaboration, it is been determined that the priorities for the scientific research program of LBNE are the following:

A. The primary objectives of LBNE, in priority order, are the following experiments:

1. Precision measurements of the parameters that govern $\nu_\mu \rightarrow \nu_e$ oscillations. This includes measurement of the third mixing angle θ_{13}, the CP violating phase δ and determining of the mass ordering (sign of Δm^2_{32}).

2. Precision measurements of θ_{23} and $|\Delta m^2_{32}|$ in the ν_μ disappearance channel.

3. *Search for proton decay, yielding a significant improvement in current limits on the partial lifetime of the proton (τ/BR) in one or more important candidate decay modes, e.g. $p \rightarrow e^+ \pi^\circ$ or $p \rightarrow K^+ \nu$.*

4. *Detection and measurement of the neutrino flux from a core collapse supernova within our galaxy, should one occur during the lifetime of LBNE.*

Of these, the first two can be addressed by the LBNE Project. *The second two require a deep underground location for the far detector, and can only be addressed in a subsequent phase of LBNE.*

B. Purposes of the Near Detector System

1 **The primary objective of the Near Detector System** is to make measurements necessary to achieve the primary physics research objectives listed above.

2. ***Secondary objectives of the Near Detector System*** *are studies of neutrino interactions, which may be enabled by the facility that is designed to achieve the primary objectives or by future upgrades to the facility and detectors. These include:*

- *Studies of the Weak Interaction.*
- *Studies of nuclear and nucleon structure.*
- *Searches for New Physics.*

All secondary objectives require the construction of a near neutrino detector, which is not part of the LBNE Project, and therefore these objectives can be addressed only in a subsequent phase of LBNE.

C. Secondary objectives, which may be enabled by the facility that is designed to achieve the primary objectives include:

1. Other accelerator-based neutrino oscillation measurements.

2. Measurements of neutrino oscillation phenomena using atmospheric neutrinos.

3. Measurement of other astrophysical phenomena using medium energy neutrinos.

Objective 2.1 can be addressed by the LBNE Project. *Objectives 2.2 and 2.3 require a deep underground location for the far detector, and can only be addressed in a subsequent phase of LBNE.*

D. Additional secondary objectives, the achievement of which may require future upgrades to the facility that is designed to achieve the primary objectives, include:

1. Detection and measurement of the diffuse supernova neutrino flux.

2. Measurements of neutrino oscillation phenomena and of solar physics using solar neutrinos.

3. Measurements of astrophysical and geophysical neutrinos of low energy.

All of the additional secondary objectives require a deep underground location for the far detector, and can only be addressed in a subsequent phase of LBNE.

E. These priorities will be considered in planning the configuration of the facilities constructed by the LBNE Project.

1. Configurations will be chosen which maximize the effectiveness of the facility to achieve those primary objectives which can be addressed by the LBNE Project.

2. The ability to achieve secondary objectives will be considered in cases in which a modest investment will enable or enhance one or more of them, thereby broadening the LBNE physics program, without significantly compromising the ability to achieve the primary objectives.

3. Achieving the additional secondary objectives, as well as those primary and secondary objectives which cannot be addressed by the LBNE Project, is expected to require substantial investment beyond that required to achieve the primary objectives. These will be considered if a modest initial investment can leave open the option of future upgrade(s) that would enable one or more of them, and only if it does not significantly compromise the ability to achieve the primary objectives.

IV. References

[1] US Particle Physics: Scientific Opportunities, A Strategic Plan for the Next Ten Years, Report of the Particle Physics Project Prioritization Panel, 29 May 2008, http://www.er.doe.gov/hep/files/pdfs/P5_Report 06022008.pdf

[2] Mission Need Statement for a Long Baseline Neutrino Experiment (LBNE) Major System, September 2009,LBNE-doc-6259.

[3] Key Assumptions: Physics Research Goals of the LBNE Project, LBNE-doc-3056-v4, 18 November 2010, http://lbne2-docdb.fnal.gov/0030/003056/004/KeyAssumptions-PhysicsGoals_V1.0.pdf.