Conceptual Design Report
The Neutrino Experiment

Ideas for the Intro sections

April 8, 2015

Contents

0.1 Introduction to LBNF and DUNE

fdune-each-vol

The global neutrino physics community is coming together to develop a leading-edge, dual-site experiment for neutrino science and proton decay studies, the Deep Underground Neutrino Experiment (DUNE), hosted at Fermilab in Batavia, IL. The facility required for this experiment, the Long-Baseline Neutrino Facility (LBNF), will be an internationally designed, coordinated and funded program, comprising the world's highest-intensity neutrino beam at Fermilab and the infrastructure necessary to support DUNE's massive, cryogenic far detectors installed deep underground at the Sanford Underground Research Facility (SURF), 800 miles (1,300 km) downstream, in Lead, SD. LBNF will also provide the facilities to house the experiment's near detectors on the Fermilab site. LBNF and DUNE will be tightly coordinated as DUNE collaborators design the detectors that will carry out its experimental program.

The LBNF scope includes

- an intense neutrino beam aimed at a far site
- construction of conventional facilities at both the near and far sites
- cryogenics infrastructure at the far site to support the DUNE liquid argon time-projection chamber (LArTPC) detector

The DUNE scope includes

- a fine-grained neutrino detector and beamline measurement system located a few hundred meters downstream of the neutrino source
- a massive LArTPC neutrino detector located deep underground at the far site
- (something about the physics program?)

With the facilities provided by the LBNF Project and the detectors provided by DUNE, the DUNE Science Collaboration proposes to mount a broad attack on the science of neutrinos with sensitivity to all known parameters in a single experiment. The focus of the program will be the explicit demonstration of leptonic CP violation, if it exists, by precisely measuring the asymmetric oscillations of muon-type neutrinos and antineutrinos into electron-type neutrinos and antineutrinos. Siting the far detector deep underground will provide opportunities for research in additional areas of physics, such as nucleon decay and neutrino astrophysics, in particular, studies of neutrino bursts from supernovae occurring in our galaxy.

0.1.1 About this Conceptual Design Report

The Long-Baseline Neutrino Facility (LBNF) Project team and the Deep Underground Neutrino Experiment (DUNE) co-spokespersons, Technical Coordinator and collaboration members have prepared this Conceptual Design Report (CDR) which describes a world-class facility and experiment to enable a compelling research program in neutrino physics.

The LBNF/DUNE Conceptual Design Report together with a set of annex documents is intended to describe, at a conceptual level, the scope and design of the experimental and conventional facilities that LBNF/DUNE plans to build to address its well-defined set of neutrino-physics measurement objectives. The CDR itself presents an overview of the overall design and points the reader to the annex documents for detailed information. At this Conceptual Design stage a *Reference Design* for LBNF/DUNE is presented, as well as alternative designs that are still under consideration for particular elements.

This CDR is organized into four stand-alone volumes.

titles haven't been picked yet

- Volume 1: Introduction and Executive Summary
- Volume 2: The Physics Program
- Volume 3: LBNF
- Volume 4: DUNE

0.1.2 DUNE and the International Neutrino-Physics Program

points to include in discussion:

- P5 2008
- mission need 2010
- LBNE CD-1
- LBNO and other int'l efforts
- P5 2014
- LOI

- LBNF/DUNE creation
- physics goals

Events Leading to LBNF/DUNE

In its 2008 report, the Particle Physics Project Prioritization Panel (P5) recommended a world-class neutrino-physics program as a core component of the U.S. particle physics program [?]. Included in the report is the long-term vision of a large detector at the formerly proposed Deep Underground Science and Engineering Laboratory (DUSEL) in Lead, S.D. (now SURF), and a high-intensity neutrino source at Fermilab.

On January 8, 2010, the Department of Energy (DOE) approved the Mission Need for a new long-baseline neutrino experiment that would enable this world-class program and firmly establish the U.S. as the leader in neutrino science. The LBNE Project is designed to meet this Mission Need.

(P5 info, iIEB, LOI, ELBNF, establishment of new structures)

Physics Objectives

Although the Standard Model of particle physics presents a remarkably accurate description of the elementary particles and their interactions, it is known that the current model is incomplete and that a more fundamental underlying theory must exist. Results from the last decade, revealing that the three known types of neutrinos have nonzero mass, mix with one another and oscillate between generations, point to physics beyond the Standard Model. Measuring the mass and other properties of neutrinos is fundamental to understanding the deeper, underlying theory and will profoundly shape our understanding of the evolution of the universe.

With the facilities provided by the LBNF Project and the detectors provided by DUNE, the DUNE Science Collaboration proposes to mount a broad attack on the science of neutrinos with sensitivity to all known parameters in a single experiment. The focus of the program will be the explicit demonstration of leptonic CP violation, if it exists, by precisely measuring the asymmetric oscillations of muon-type neutrinos and antineutrinos into electron-type neutrinos and antineutrinos.

The experiment will result in precise measurements of key three-flavor neutrino-oscillation parameters over a very long baseline and a wide range of neutrino energies, in particular, the CP-violating phase in the three-flavor framework and the mass ordering of neutrinos. The unique features of the experiment – the long baseline, the broad-band beam, and the high resolution of the detector – will enable the search for new physics that manifests itself as deviations from the expected three-flavor neutrino- oscillation model. The scientific goals and capabilities of DUNE are outlined in Volume 1 of this CDR and the

do we mention the LBNE science doc here?

2010 Interim Report of the Long-Baseline Neutrino Experiment Collaboration Physics Working Groups [**?**].

Siting the Far Detector deep underground will provide opportunities for research in additional areas of physics, such as nucleon decay and neutrino astrophysics, in particular, studies of neutrino bursts from supernovae occurring in our galaxy.

0.1.3 LBNF/DUNE Organization, Coordination and Management Structures

The effort to design, build and operate the envisioned experiment is divided between the entities that manage the facility (LBNF) and the experiment (DUNE). These entities are responsible for interacting with the funding agencies in the various countries to construct the experimental and conventional facilities.

The successful model used by CERN for managing the construction and exploitation of the LHC and its experiments will be used as a starting point for the joint management of the LBNF and DUNE projects. Fermilab, as the host laboratory, will take on the responsibility for the oversight of both the LBNF and DUNE projects. Mechanisms to ensure input from and coordination among all of the international funding agencies supporting collaboration, modeled on the CERN Resource Review Board, will be adopted. A similar structure, an International Joint Advisory Committee, chaired by the DOE Office of High Energy Physics, will be employed to coordinate among funding agencies supporting the LBNF and DUNE construction and operation.

Close and continuous coordination between DUNE and LBNF is required to ensure the success of the combined enterprise. An Experiment-Facility Interface Group oversees and ensures the required coordination during the design phase, and will continue to do so during the construction and operational phases of the facility and the experiment.

0.1.4 Principal Parameters of the LBNF/DUNE Experimental Facilities

The principal parameters of the major Project elements are given in Table 1.

Table 1: LBNE Principal Parameters

Project Element Parameter	Value
Near- to Far-Site Baseline	1,300 km
Primary Proton Beam Power	708 kW, upgradable to 2.3 MW
Protons on Target per Year	6.5×10^{20}
Primary Beam Energy	60 – 120 GeV (tunable)
Neutrino Beam Type	Horn-focused with decay volume
Neutrino Beam Energy Range	0.5 – 5 GeV
Neutrino Beam Decay Pipe Diameter × Length	4 m × 203.7 m
Far Detector Type	LArTPC
Far Detector Active (Fiducial) Mass	total active? (40) kt (metric kilotons)
Far Detector Depth	4,850 ft (1,475 m)

0.1.5 Supporting Documents

A host of information related to the CDR is available in a set of supporting documents. Detailed information on risk analysis and mitigation, value engineering, ES&H, costing, project management and other topics not directly in the design scope can be found in these documents, listed in Table 2. Each document is numbered and stored in a document database, accessible via a username/password combination provided by LBNF/DUNE management. Project documents stored in this database are made available to internal and external review committees through Web sites developed to support individual reviews.

Table 2: LBNF/DUNE CD-1 "Refresh" Documents

Title	**Doc Number(s)**
Acquisition Plan	5329
Alternatives Analysis	4382
Case Study Report; Liquid Argon TPC Detector	3600
Configuration Management Plan	5452
DOE Acquisition Strategy	5442
Integrated Environment, Safety and Health Management Plan	4514

LAr-FD Preliminary ODH Analysis	2478
Global Science Objectives, Science Requirements and Traceback Reports	4772
Preliminary Hazard Analysis Report	4513
Preliminary Project Execution Plan	5443
Preliminary Security Vulnerability Assessment Report	4826
Project Management Plan	2453
Project Organization Chart	5449
Quality Assurance Plan	2449
Report on the Depth Requirements for a Massive Detector at Homestake	0034
Requirements, Beamline	4835
Requirements (Parameter Tables), Far Detector	3747 (3383)
Requirements, Far Site Conventional Facilities	4408
Requirements, Near Detectors	5579
Requirements, Near Site Conventional Facilities	5437
Risk Management Plan	5749
Value Engineering Report	3082
Work Breakdown Structure (WBS)	4219

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