Abstract

The preponderance of matter over antimatter in the early Universe, the dynamics of the supernova bursts that produced the heavy elements necessary for life and whether protons eventually decay — these mysteries at the forefront of particle physics and astrophysics are key to understanding the early evolution of our Universe, its current state and its eventual fate. The Long-Baseline Neutrino Experiment (LBNE) represents an extensively developed plan for a world-class experiment dedicated to addressing these questions.

Experiments carried out over the past half century have revealed that neutrinos are found in three states, or *flavors*, and can transform from one flavor into another. These results indicate that each neutrino flavor state is a mixture of three different nonzero mass states, and to date offer the most compelling evidence for physics beyond the Standard Model. In a single experiment, LBNE will enable a broad exploration of the three-flavor model of neutrino physics with unprecedented detail. Chief among its potential discoveries is that of matter-antimatter asymmetries (through the mechanism of charge-parity violation) in neutrino flavor mixing — a step toward unraveling the mystery of matter generation in the early Universe. Independently, determination of the unknown neutrino mass ordering and precise measurement of neutrino mixing parameters by LBNE may reveal new fundamental symmetries of Nature.

Grand Unified Theories, which attempt to describe the unification of the known forces, predict rates for proton decay that cover a range directly accessible with the next generation of large underground detectors such as LBNE's. The experiment's sensitivity to key proton decay channels will offer unique opportunities for the ground-breaking discovery of this phenomenon.

Neutrinos emitted in the first few seconds of a core-collapse supernova carry with them the potential for great insight into the evolution of the Universe. LBNE's capability to collect and analyze this high-statistics neutrino signal from a supernova within our galaxy would provide a rare opportunity to peer inside a newly-formed neutron star and potentially witness the birth of a black hole.

To achieve its goals, LBNE is conceived around three central components: (1) a new, high-intensity neutrino source generated from a megawatt-class proton accelerator at Fermi National Accelerator Laboratory, (2) a fine-grained near neutrino detector installed just downstream of the source, and (3) a massive liquid argon time-projection chamber deployed as a far detector deep underground at the Sanford Underground Research Facility. This facility, located at the site of the former Homestake Mine in Lead, South Dakota, is $\sim$1,300 km from the neutrino source at Fermilab — a distance (baseline) that delivers optimal sensitivity to neutrino charge-parity symmetry violation and mass ordering effects. This ambitious yet cost-effective design incorporates scalability and flexibility and can accommodate a variety of upgrades and contributions.

With its exceptional combination of experimental configuration, technical capabilities, and potential for transformative discoveries, LBNE promises to be a vital facility for the field of particle physics worldwide, providing physicists from institutions around the globe with opportunities to collaborate in a twenty to thirty year program of exciting science.