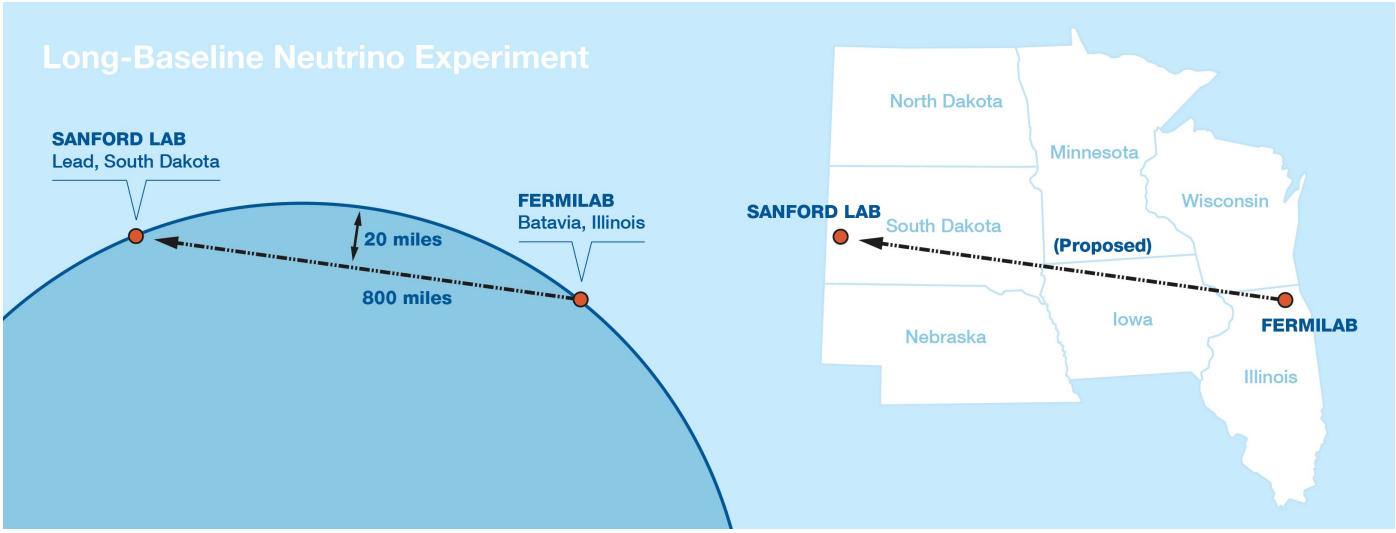
LONG-BASELINE NEUTRINOS AT FERMI NATIONAL ACCELERATOR LABORATORY

A new particle physics experiment, planned to take place at Fermilab and the Sanford Underground Research Facility, aims to transform our understanding of neutrinos and their role in the universe.



The Long-Baseline Neutrino Facility would send neutrinos from Fermilab in Illinois through the earth to Lead, South Dakota. (No tunnel is needed for this 1300 km trip.)

Mysterious Neutrinos

Neutrinos are the most abundant particles of matter in the universe, almost as numerous as photons. Trillions of neutrinos from the sun and other celestial objects pass through us every second, but they interact so rarely with other matter that they are very difficult to observe.

The latest developments in the science of neutrinos and the technology of particle accelerators and detectors make it possible to perform extraordinary new experiments in neutrino science.

A growing international collaboration of more than 530 scientists from 8 countries has proposed to build a world-leading neutrino experimental facility (LBNF) that would send an intense beam of neutrinos from Fermi National Accelerator Laboratory (Fermilab) located near Chicago in the USA to an advanced extremely sensitive detector at the Sanford Underground Research Facility (Sanford Lab) in Lead, South Dakota, a distance of 1300 km.

Neutrino Facts

Neutrinos are elementary particles that have no electric charge. They are emitted in radioactive decays of unstable nuclei.

A neutrino weighs at least a million times less than an electron, but the precise mass is still unknown.

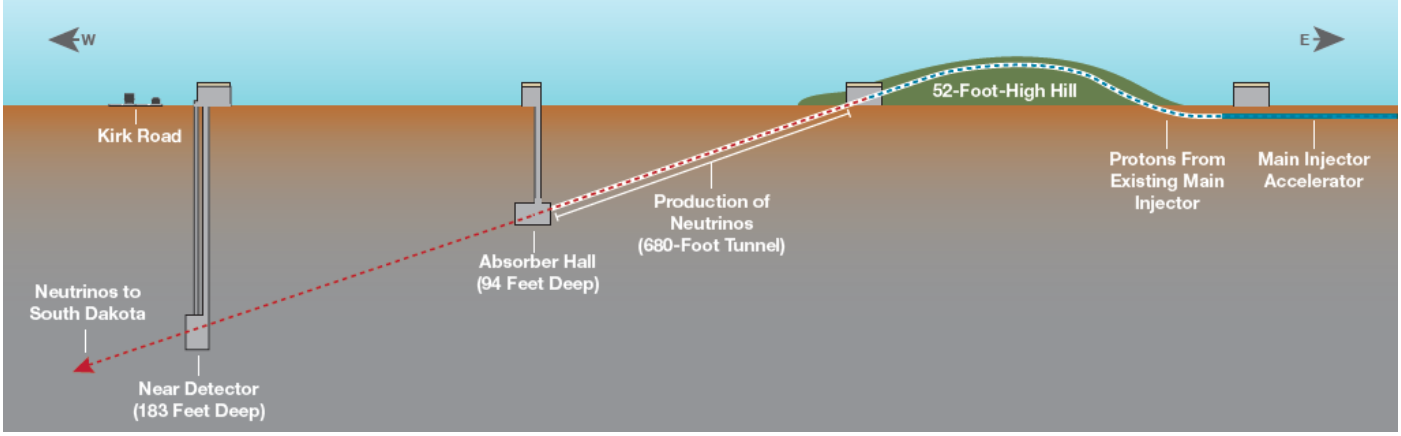
Neutrinos are produced in great quantities in the sun and supernova. Scientists can also make neutrino beams with particle accelerators.

Neutrinos pass harmlessly through matter, and only very rarely do they interact with other matter particles.

There are three known types of neutrinos: electron, muon, and tau type neutrinos.

Quantum mechanics allows transformation of the three neutrino types in flight. This process is called neutrino oscillation.

The distance of 1300 km between Fermilab and the Sanford Lab is ideal for measuring neutrino oscillations with the proposed Long-Baseline Neutrino Facility.



Fermilab plans to use the Main Injector accelerator to make neutrinos and send them through the earth to the LBNF neutrino detector in South Dakota. The project construction consists of several buildings, a 16 meter high hill, and a 200m long decay tunnel.

Scientific Goals

Neutrino mass and mixing, discovered through oscillation experiments, is the only definite evidence of new physics beyond the Standard Model of particle physics. The Long-Baseline Neutrino Facility will explore the physics of neutrino mass and mixing. The beam and detector facilities created will allow us to address the following topics of fundamental importance.

1) Probe deeper into neutrino physics so as to shed light on some of its crucial mixing angles, mass-ordering and most importantly matter and antimatter symmetry violation in the neutrino system. Learning about the violation of the CP symmetry in the neutrino system can shed light on the origin of the excess of matter over antimatter in the universe, which is essential to the origin of life and thus to our own existence. Furthermore, precise and comprehensive measurements of the neutrino parameters are essential for developing a deeper understanding of masses of matter particles and their origin.

2) Search sensitively for proton decay, whose discovery would have a profound significance for unification ideas and open up a new window for viewing physics at the grand unification scale (a trillion times higher in energy than that available at the LHC or any proposed new accelerator)

3) Study neutrinos from supernova explosions in our galaxy, essential to understand the complex dynamics of supernova core collapse and explosion and generation of all atomic elements.

Project Description

The long-baseline neutrino project has three important elements: a new, high-intensity neutrino source will be generated by a megawatt-class proton accelerator at Fermi National Accelerator Laboratory (Fermilab), and directed to the new large far detector at the Sanford Underground Research Facility in Lead, South Dakota. The near detector will be located about 500 m downstream of the neutrino production target to monitor the beam at the source.

- The neutrino beam-line is designed to deliver a wide-band, high-purity beam with a peak flux at 2.5 GeV, which optimizes the physics potential at the 1300 km baseline. The beam-line will operate initially at 1.2 MW and will be upgradable to 2.3 MW utilizing a proton beam with energy tunable from 60 to 120 GeV.
- The far neutrino detector is a liquid argon time-projection chamber (LArTPC) of 40,000 ton active mass and is modular, allowing flexibility in the choice of implementation.
- The far detector will be located 4,850 feet underground to eliminate cosmic ray muon backgrounds to search for proton decay and neutrinos from a core collapse supernova. The underground facility has been determined to have the capacity to host very large caverns for future upgrades.
- The high-precision near detector and its conventional facilities can be built as an independent project, separate from the far detector and beam-line.

International Partnerships

The new strategic plan for U.S. particle physics projects (P5 2014 plan) focused on the global nature of particle physics facilities. The report recognizes that the Long-Baseline Neutrino Facility represents an important opportunity for an international project in the U.S. It recommends that a new collaboration be created that invites the entire international community to participate in the R&D, design, and construction of this project. The current international collaboration (LBNE) members are expected to continue to play a major role.

The new collaboration is being formed in a series of steps starting with an interim board composed of the main stakeholders from the U.S., Europe, Asia, and the Americas. The process of collaboration formation is expected to continue into 2015 as the new collaboration prepares a proposal.

The international partners will jointly coordinate, organize, and make decisions on the funding and management of the beam and the detectors for LBNF. The successful model of CERN-Large Hadron Collider (LHC) experiments will be used to create working groups and governance to build the LBN detectors and to define scientific priorities. The international distributed computing paradigm will be used for storing and processing LBN data.

Additional international partnerships are expected on the advanced accelerator upgrades needed at Fermilab to upgrade the Main Injector to 1.2 MW of beam power; and ultimately reaching 2.3 MW.

Budget and Schedule

The project engineering team has made preliminary estimates of the technical schedule for the project. According to this schedule, the full technical design of the project will be ready by 2018, immediately followed by the start of construction of the underground spaces for the detector. The detectors and the beam could be ready for operation by 2024. Using this schedule and with proper assumptions for inflation and contingencies, the cost for the full project is $1.5B. The US DOE has provided first level approval to this project with a current commitment of approximately $0.9B. Commitments from other international partners are being negotiated, the project is expected to move forward in phases with each phase being dictated by the scientific priorities and interests of the global collaboration.

More Information:

Long-baseline Neutrinos Science Opportunities: http://arxiv.org/abs/1307.7335

Scientific Collaboration Contacts

Milind V. Diwan, phone: 1-631-344-3327, email: diwan at bnl.gov

Robert J. Wilson, phone: 1-970-491-5033 email: bob.wilson at colostate.edu

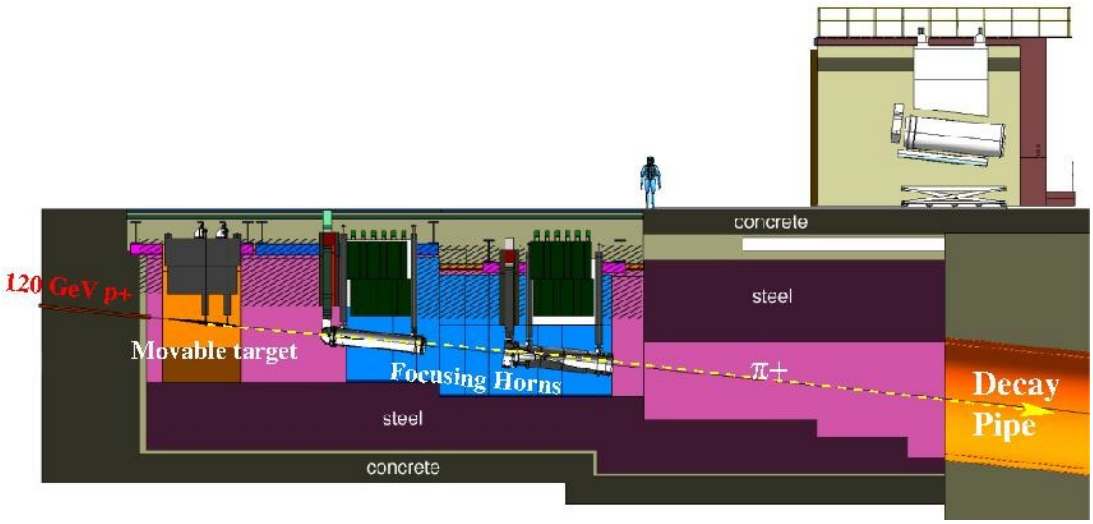
Review Reports and Links

Plan for U.S. Particle Physics in the Global Context, Report of the U.S. Particle Physics Prioritization Panel. http://www.usparticlephysics.org/p5/

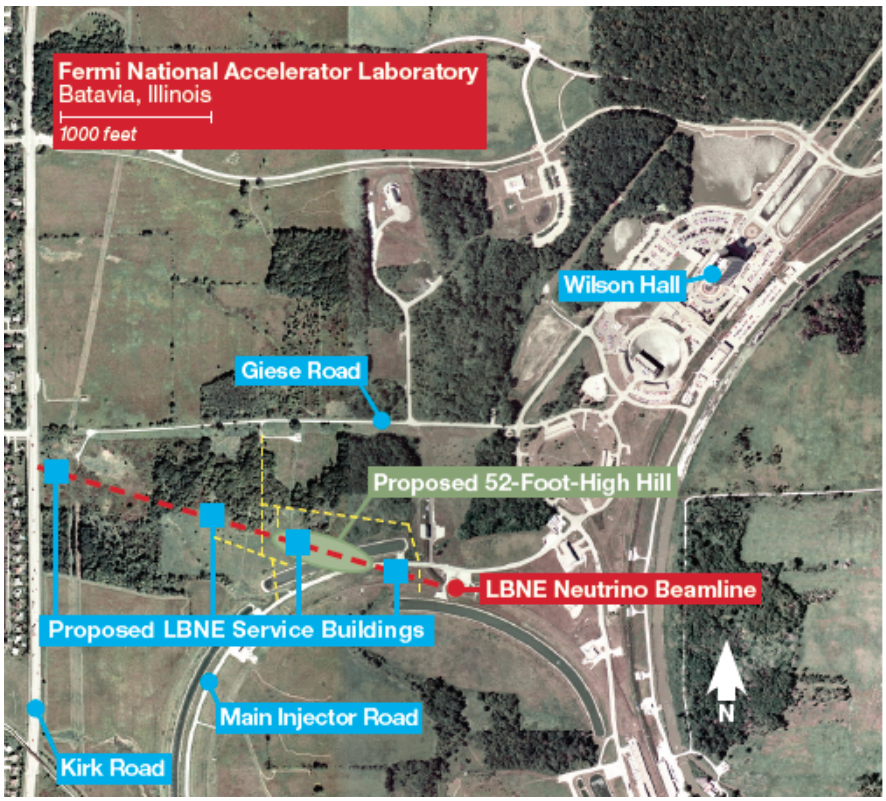
lbne.fnal.gov

http://bigstory.ap.org/article/physics-panel-feds-beam-us-some-neutrinos

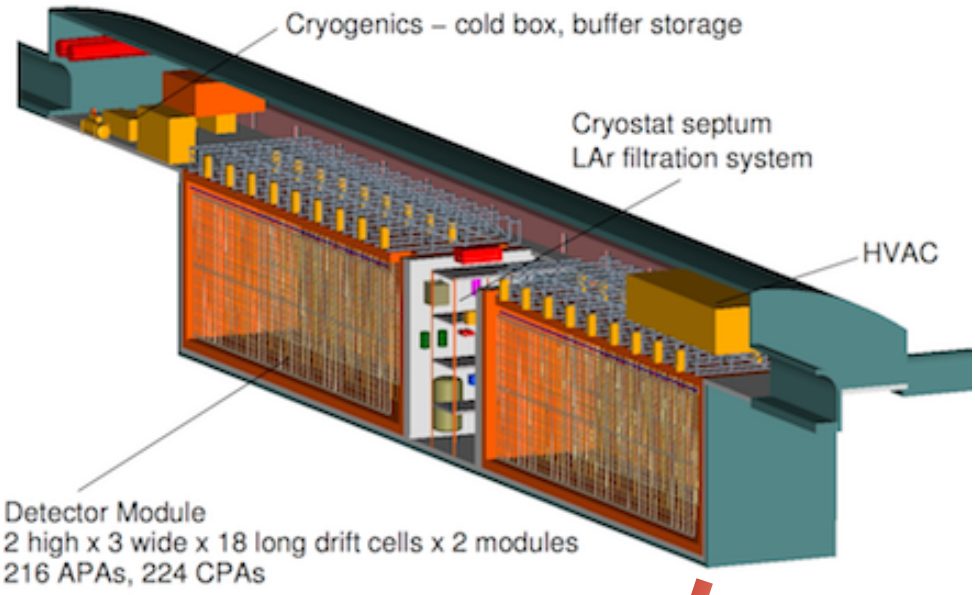
http://arstechnica.com/science/2014/04/forget-the-higgs-neutrinos-may-be-the-key-to-breaking-the-standard-model/



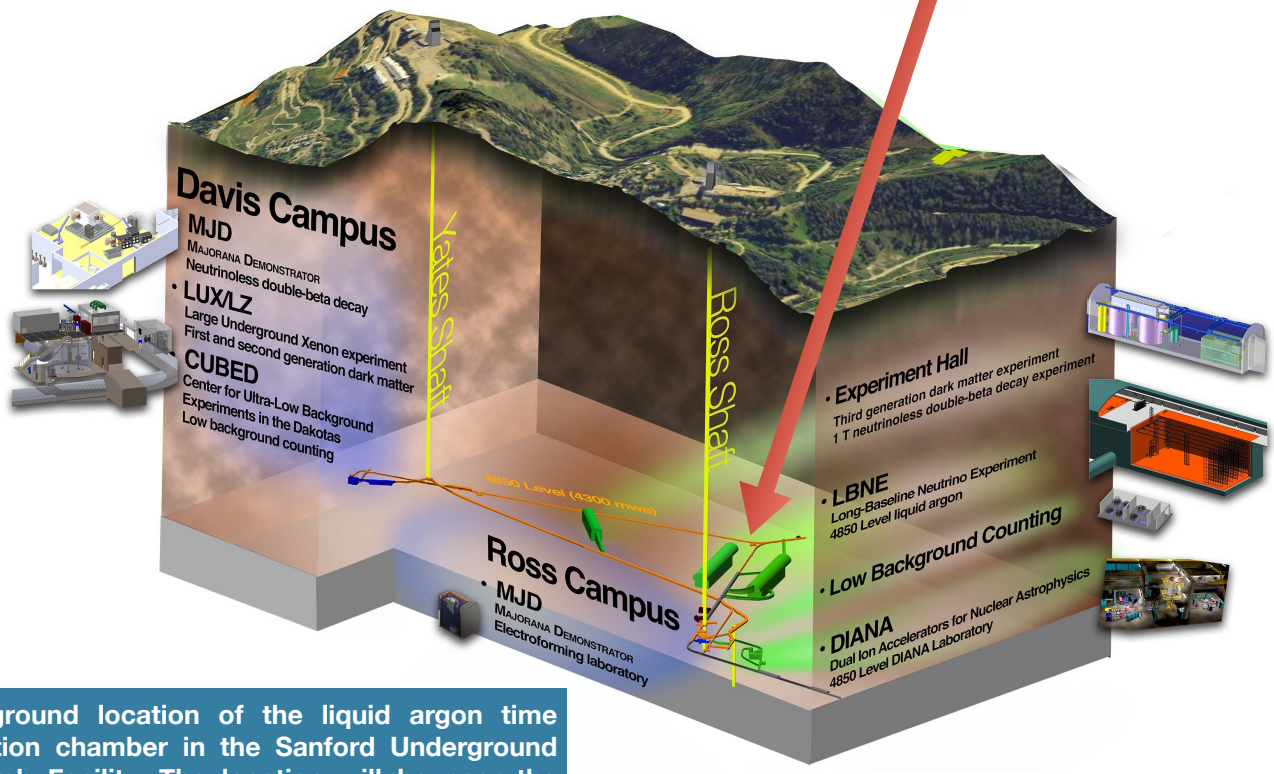
Target and beam components for LBNF. The Main Injector accelerator provides 120 GeV protons aimed a graphite target. The emerging charged pions and kaons are focused in the forward direction by powerful magnetic lenses called horns.



The neutrino beam line at Fermilab would be located on the western part of the site. The beam would be extracted from the Main Injector which accelerates protons to 120 GeV. The beam comes in pulse widths of 10 microsecond approximately every second. It is extracted in a single turn from the Main Injector and transported initially up a hill before tilting downwards onto a graphite target as shown in the figure above. The Main Injector accelerator gets its proton bunches from a source comprised of a linear accelerator and a circular booster. These devices must be upgraded to provide increased intensity. The target station and other devices in the beam must also be designed for this high beam power.



Detector schematic for a single phase liquid argon time projection chamber. 2 detector modules each of length = 51 m, width = 23 m, height = 18 m (APA and CPA are anode and cathode plane assemblies, respectively)



Underground location of the liquid argon time projection chamber in the Sanford Underground Research Facility. The location will be near the Ross shaft in newly excavated cavern(s).