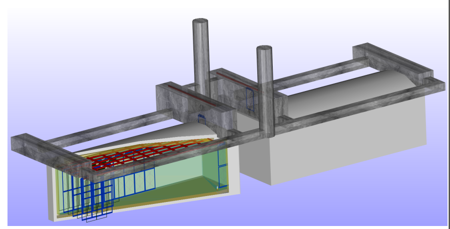
Status of LBNE project and collaboration

Milind Diwan

LBNE international symposium at NNN12

Oct. 3, 2012

BROOKHAVEN NATIONAL LABORATORY



Outline

- Description of the collaboration.
- Long-term goals and plans of the LBNE program
- Reality and Vision collide:
  The Reconfiguration of LBNE
- A phased approach to LBNE (and Project X)
- LBNE Project status and next steps
- Conclusions

LBNE Approach

- LBNE is planned to be a US based project with strong international participation.
- This plan allows us to have a clear path towards government and regulatory approvals.
- The upcoming CD1 review will be the next step in solidifying the US based plan.
- Between the CD1 and CD2 phase, the highest priority will be obtaining strong international participation.
- For CD1, we have to present a complete design for funding purposes, but much more intellectual input is possible and needed.

Long-Baseline Neutrino Experiment Collaboration

Alabama: S. Habib, I. Stancu

Argonne: M. D'Agostino, G. Drake. Z. Djurcic, M. Goodman, V. Guarino, S. Magill, J. Paley, H. Sahoo, R. Talaga, M. Wetstein

Boston: E. Hazen, E. Kearns, S. Linden

Brookhaven: M. Bishai, R. Brown, H. Chen, M. Diwan, J. Dolph, G. Geronimo, R. Gill, R. Hackenburg, R. Hahn, S. Hans, Z. Isvan, D. Jaffe, S.H. Kettell, F. Lanni, Y. Li, L. Littenberg, J. Ling, D. Makowiecki, W. Marciano, W. Morse, Z. Parsa, V. Radeka, S. Rescia, N. Samios,R. Sharma, N. Simos, J. Sondericker, J. Stewart, H. Themann, C. Thorn, B. Viren, E. Worcester, M. Yeh, B. Yu, C. Zhang

Caltech: R. McKeown, X. Qian

Cambridge: A. Blake, M. Thomson

Catania/INFN: V. Bellini, F. La Zia, F. Mammoliti, R. Potenza,

Chicago: E. Blucher, M. Strait

Colorado: S. Coleman, R. Johnson, S. Johnson, A. Marino, E. Zimmerman

Colorado State: M. Bass, B.E. Berger, J. Brack, N. Buchanan, D. Cherdack, J. Harton, W. Johnston, W. Toki, T. Wachala, D. Warner, R.J.Wilson

Columbia: R. Carr, L. Camillieri, C.Y. Chi, G. Karagiorgi, C. Mariani, M. Shaevitz, W. Sippach, W. Willis

Crookston: D. Demuth

Dakota State: B. Szcerbinska

Davis: M. Bergevin, R. Breedon, J. Felde, C. Maesano, M. Tripanthi, R. Svoboda, M. Szydagis

Drexel: C. Lane, S. Perasso

Duke: T. Akiri, J. Fowler, A. Himmel, Z. Li, K. Scholberg, C. Walter, R. Wendell

Duluth: R. Gran, A. Habig

Fermilab: D. Allspach, M. Andrews, B. Baller, E. Berman, R. Bernstein, V. Bocean, M. Campbell, A. Chen, S. Childress, A. Drozhdin, T. Dykhuis, C. Escobar, H. Greenlee, A. Hahn, S. Hays, A. Heavey, J. Howell, P. Huhr, J. Hylen, C. James, M. Johnson, J. Johnstone, H. Jostlein, T. Junk, B. Kayser, M. Kirby, G. Koizumi, T. Lackowski, P. Lucas, B. Lundberg, T. Lundin, P. Mantsch, A. Marchionni, E . McCluskey, S. Moed Sher, N. Mokhov, C. Moore, J. Morfin, B. Norris, V. Papadimitriou, R. Plunkett, C. Polly, S. Pordes, O. Prokofiev, J.L. Raaf, G. Rameika, B. Rebel, D. Reitzner, K. Riesselmann, R. Rucinski, R. Schmidt, D. Schmitz, P. Shanahan, M. Stancari, A. Stefanik, J. Strait, S. Striganov, K. Vaziri, G. Velev, T. Wyman, G. Zeller, R. Zwaska

Hawai'i: S. Dye, J. Kumar, J. Learned, J. Maricic, S. Matsuno, R. Meyhandan, R. Milincic, S. Pakvasa, M. Rosen, G. Varner

Houston: L. Whitehead

Indian Universities: V. Singh (BHU); B. Choudhary, S. Mandal (DU); B. Bhuyan [IIT(G)]; V. Bhatnagar, A. Kumar, S. Sahijpal(PU)

Indiana: W. Fox, M. Messier, S. Mufson, J. Musser, R. Tayloe, J. Urheim

Iowa State: I. Anghel, G.S. Davies, M. Sanchez, T. Xin

IPMU/Tokyo: M. Vagins

Irvine: G. Carminati, W. Kropp, M. Smy, H. Sobel

Kansas State: T. Bolton, G. Horton-Smith

LBL: B. Fujikawa, V.M. Gehman, R. Kadel, D. Taylor

Livermore: A. Bernstein, R. Bionta, S. Dazeley, S. Ouedraogo

London: A. Holin, J. Thomas

Los Alamos: M. Akashi-Ronquest, S. Elliott, A. Friedland, G. Garvey, E. Guardincerri, T. Haines, D. Lee, W. Louis, C. Mauger, G. Mills, Z. Pavlovic, J. Ramsey, G. Sinnis, W. Sondheim, R. Van de Water, H. White, K. Yarritu

Louisiana: J. Insler, T. Kutter, W. Metcalf, M. Tzanov

Maryland: E. Blaufuss, S. Eno, R. Hellauer, T. Straszheim, G. Sullivan

Michigan State: E. Arrieta-Diaz, C. Bromberg, D. Edmunds, J. Huston, B. Page

Minnesota: M. Marshak, W. Miller

MIT: W. Barletta, J. Conrad, B. Jones, T. Katori, R. Lanza, A. Prakash,

NGA: S. Malys, S. Usman

Notre Dame: J. Losecco

Oxford: G. Barr, J. de Jong, A. Weber

Pennsylvania: S. Grullon, J. Klein, K. Lande, T. Latorre, A. Mann, M. Newcomer, S. Seibert, R. vanBerg

Pittsburgh: D. Naples, V. Paolone

Princeton: K. McDonald

Rensselaer: D. Kaminski, J. Napolitano, S. Salon, P. Stoler

Rochester: L. Loiacono, K. McFarland, G. Perdue

Sheffield: V. Kudryavtsev, M. Richardson, M. Robinson, N. Spooner, L. Thompson

SDSMT: X. Bai, C. Christofferson, R. Corey, D. Tiedt

SMU.: T. Coan, T. Liu, J. Ye

South Carolina: H. Duyang, B. Mercurio, S. Mishra, R. Petti, C. Rosenfeld, X Tian

South Dakota: D. Barker, J. Goon, D. Mei, W. Wei, C. Zhang

South Dakota State: B. Bleakley, K. McTaggert

Syracuse: M. Artuso, S. Blusk, T. Skwarnicki, M. Soderberg, S. Stone

Tennessee: W. Bugg, T. Handler, A. Hatzikoutelis, Y. Kamyshkov

Texas: S. Kopp, K. Lang, R. Mehdiyev

Tufts: H. Gallagher, T. Kafka, W. Mann, J. Schnepps

UCLA: K. Arisaka, D. Cline, K. Lee, Y. Meng, A. Teymourian, H. Wang, L. Winslow

Virginia Tech.: E. Guarnaccia, J. Link

Washington: H. Berns, S. Enomoto, J. Kaspar, N. Tolich, H.K. Tseung

Wisconsin: B. Balantekin, F. Feyzi, K. Heeger, A. Karle, R. Maruyama, B. Paulos, D. Webber, C. Wendt

Yale: E. Church, B. Fleming, R. Guenette, K. Partyka, A. Szelc

~340 Members
62 Institutions
25 US States
5 Countries

1 October 2012 (340)

Institutions in LBNE (62)

Argonne
Alabama
Boston University
Brookhaven
Caltech
Cambridge
Catania
Columbia
Chicago
Colorado
Colorado State
Columbia
Crookston
Davis
Drexel
Duke
Duluth
Fermilab
Hawaii
Indian Universities[BHU, Delhi U., IIT(G), Panjab U.]
Indiana
Iowa State
IPMU-Tokyo
Irvine
Kansas State
Lawrence Berkeley National Lab
Livermore

London UCL
Los Alamos
Louisiana State
Maryland
Michigan State
Minnesota
MIT
NGA
New Mexico
Notre Dame
Oxford
Pennsylvania
Pittsburgh
Princeton
Rensselaer
Rochester
South Carolina
South Dakota State
SDSMT
Southern Methodist
Syracuse
Texas
Tufts
UCLA
Virginia Tech
Washington
Wisconsin
Yale

++++ need to update.

62 institutions, ~340 collaborators

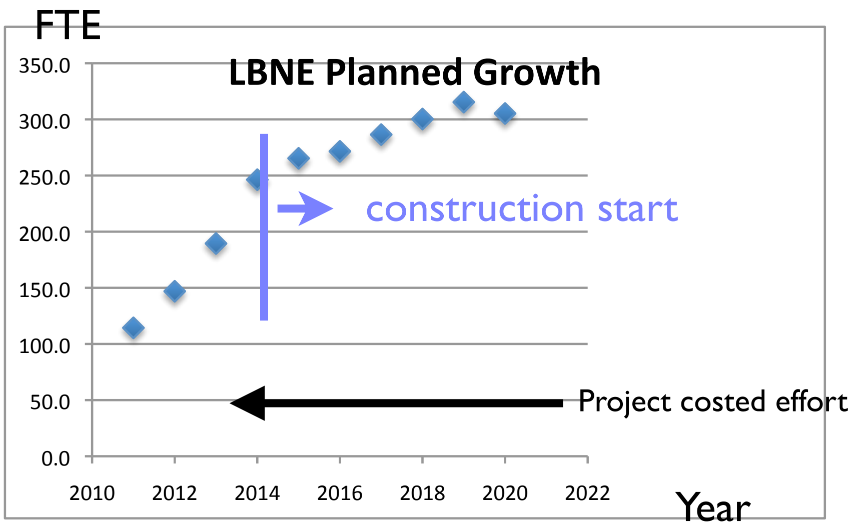
University: ~220
Laboratory: 115

Tenure Track or recently tenured: ~23

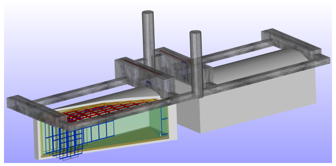
Postdocs + students: ~20

Collaboration Growth

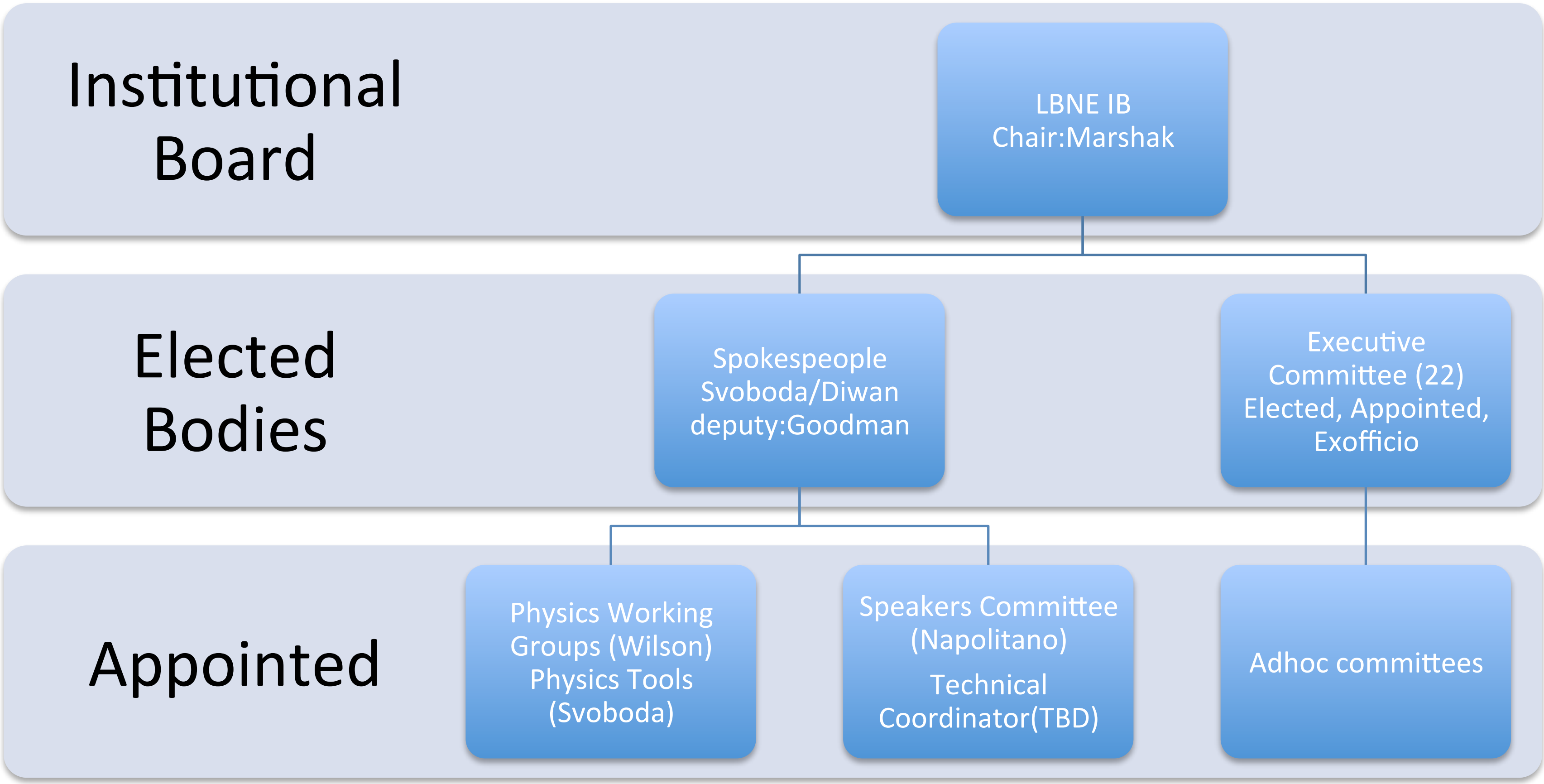
- Numbers still have large errors. With a lot of guesswork.
- Used current number of physics/ technical working groups as a guide. (there are ~15 WG)
- Includes costed project personnel ~ 30-50 FTE
- If one takes average FTE/head count ~ 0.5, collaboration needs to be ~500-600 strong.
- A large collaboration needs a diverse scientific agenda.



Future growth needs be international.



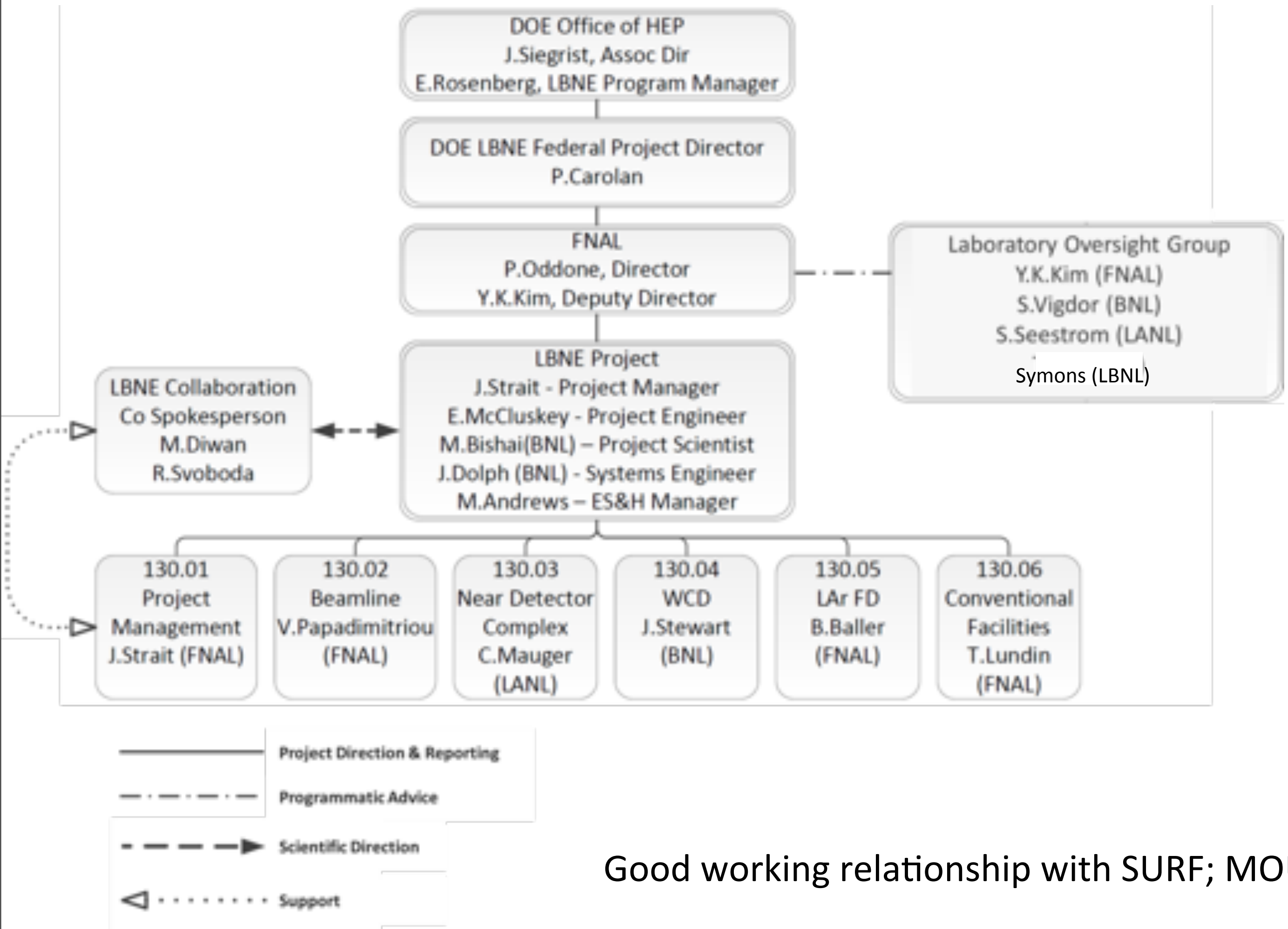
Collaboration structures



Large efforts with large and diverse funding need a corporate structure. IB is ruled by a governance document that sets the charge for each office and terms of appointment or election. There have been 3 elections so far.

The collaboration structure will evolve to meet the demands of internationalization.

Project Organization



- Fermilab is the Lead Lab
- The BNL/FNAL/LANL project leadership are well integrated.
- Substantial University participation to be strengthened further.
- Exploring further strengthening of the Project Office.
- The Project and Collaboration are well integrated.

Good working relationship with SURF; MOU expected soon

This structure will evolve for international agreements/MOUS.

Important Events

- December 2010, NSB turned off NSF consideration for DUSEL.
- 2011 Review from the NRC/BPA committee reaffirmed the science for LBNE and DUSEL.
- July 2011 Marx/Reichanadter committee reviewed the costs and technologies. Costs for LBNE roughly known since summer of 2011. Clear that could not afford both a water and LAr detectors (the collaboration preference).
- Fall of 2011, extensive internal reviews for detector technology choice.
- In December 2011, the LBNE Exec Board/Fermilab/DOE had extensive negotiations over the far detector technology. Both technologies were considered excellent choices for the science. The collaboration board preferred the water detector because of the cost/schedule certainties.
- Final decision was for a 34 kTon LAr detector based on the better performance for higher energies (due to L/E and 1300 km) and uniqueness of the technology: complementarity for proton decay and supernova physics to existing water detectors.
- Deemed ready for CD1 review in March when the Daya Bay result was announced.
- DOE asked that LBNE be structured in phases leading to the reconfiguration panel.

Collaboration Effort

- Level and quality of effort has been very high for LBNE. The physics working group has produced numerous reports. The reconfiguration panel relied on the collaboration for physics input.
- Active collaboration with > 6000 documents in the document database so far.
- The collaboration has grown since Dec. 2010 by about 5 institutions.
- The collaboration remains committed and strong and will seek expansion of the science program.

Physics Research Goals of LBNE

The primary science objectives of the LBNE Project are:

1. A search for, and precision measurements of, the parameters that govern $\nu_\mu \rightarrow \nu_e$ oscillations. This includes measurement of the third mixing angle θ_{13}, for whose value only an upper bound is currently known, and if θ_{13} is large enough, measurement of 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. $p \rightarrow e + \pi^0$ 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.

Though outside of the primary objectives, the far detector placed at the proposed depth could enable studies of atmospheric ν physics, and with additional upgrades, studies of day/night ^{8}B solar ν physics and relic supernova neutrinos.

These goals are in priority order. They have been accepted by management and funding agencies

LBNE – Neutrino Oscillation Goals

LBNE plans a comprehensive program to measure neutrino oscillations, to:

- Measure full oscillation patterns in multiple channels, precisely constraining mixing angles and mass differences.
- Search for CP violation both by measuring the parameter δ_{CP} and by observing differences in ν and $\bar{\nu}$ oscillations.
- Cleanly separate matter effects from CP-violating effects.

- The full scope of LBNE calls for a 1300 km baseline, 700 kW wide band beam, a near detector, and a 34 kTon LAr detector at 4850 ft depth.

Vision Encounters Reality

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

March 19, 2012

Received on March 26

Dr. Pier Oddone
Director
Fermilab
Wilson and Kirks Road
Batavia, IL 60510-5011

Dear Pier,

Thank you for your recent presentation on the status and plans for the Long Baseline Neutrino Experiment (LBNE). The project team and the scientific collaboration have done an excellent job responding to our requests to assess the technology choices and refine the cost estimates for LBNE. We believe that the conceptual design is well advanced and the remaining technical issues are understood.

The scientific community and the National Academy of Sciences repeatedly have examined and endorsed the case for underground science. We concur with this conclusion, and this has been the motivator for us to determine a path forward as quickly as possible following the decision of the National Science Board to terminate development of the Homestake Mine as a site for underground science.

We have considered both the science opportunities and the cost and schedule estimates for LBNE that you have presented to us. We have done so in the context of planning for the overall Office of Science program as well as current budget projections.

Based on our considerations, we cannot support the LBNE project as it is currently configured. This decision is not a negative judgment about the importance of the science, but rather it is a recognition that the peak cost of the project cannot be accommodated in the current budget climate or that projected for the next decade.

In order to advance this activity on a sustainable path, I would like Fermilab to lead the development of an affordable and phased approach that will enable important science results at each phase. Alternative configurations to LBNE should also be considered. Options that allow us to independently develop the Homestake Mine as a future facility for dark matter experiments should be included in your considerations.

A report outlining options and alternatives is needed as soon as practical to provide input to our strategic plan for the Intensity Frontier program. OHEP will provide additional details on realistic cost and schedule profiles and on the due date for the report.

Thank you,

W. F. Brinkman
Director, Office of Science

Reconfiguring LBNE

http://www.fnal.gov/directorate/lbne_reconfiguration/index.shtml

LBNE Reconfiguration

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LBNE Reconfiguration

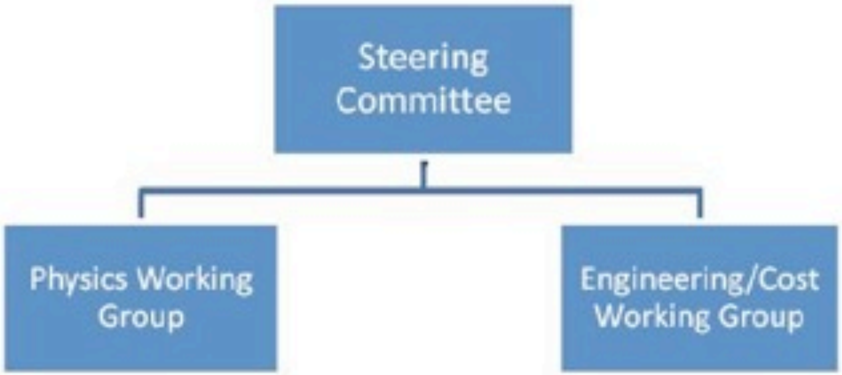
- Organization
- Steering Committee
- Physics Working Group
- Engineering/Cost Working Group
- March 19 Charge letter from Brinkman to Oddone
- Community Voice
- Marx/Reichanadter Report

Workshop April 25-26

- Agenda
- Registration
- Registrants List
- Travel and Lodging

Organization

We are forming the following groups to deliver on the charge:

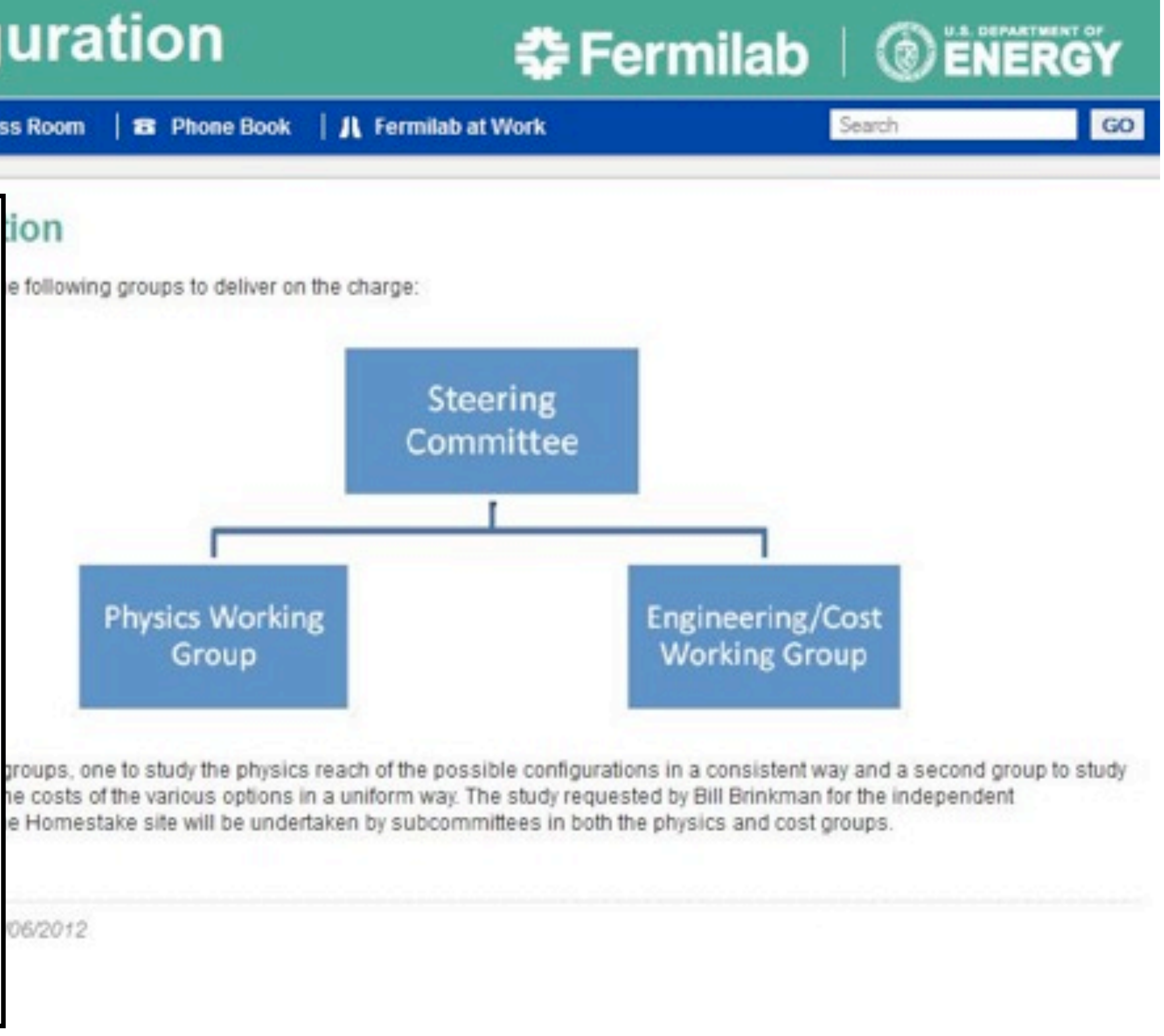


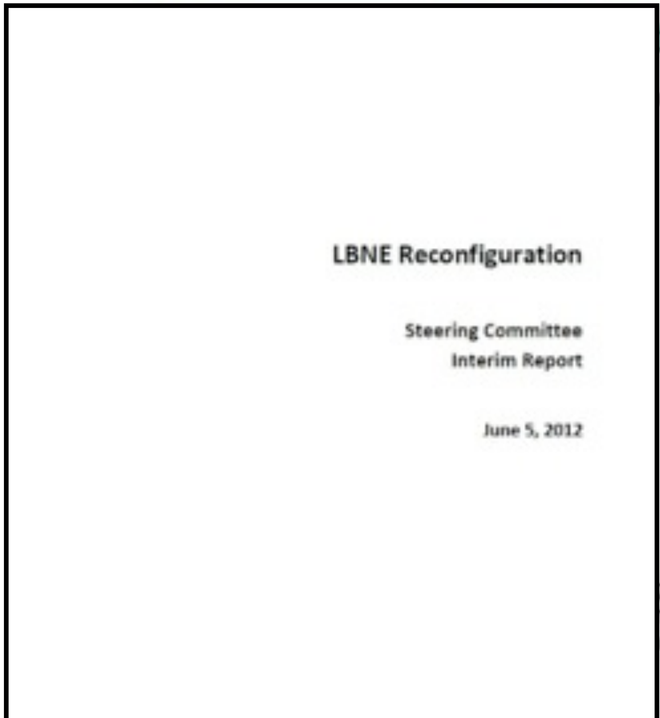
We will have two groups, one to study the physics reach of the possible configurations in a consistent way and a second group to study and understand the costs of the various options in a uniform way. The study requested by Bill Brinkman for the independent development of the Homestake site will be undertaken by subcommittees in both the physics and cost groups.

Last modified: 04/06/2012

Reconfiguring LBNE

http://www.fnal.gov/directorate/lbne_reconfiguration/index.shtml





https://indico.fnal.gov/conferenceDisplay.py?confId=5622

Reconfiguration Interim Report

Interim Conclusions

To achieve all of the fundamental science goals listed above, a reconfigured LBNE would need a very long baseline (>1,000 km from accelerator to detector) and a large detector deep underground. However, it is not possible to meet both of these requirements in a first phase of the experiment within the budget guideline of approximately $700M – $800M, including contingency and escalation. The committee assessed various options that meet some of the requirements, and identified three viable options for the first phase of a long-baseline experiment that have the potential to accomplish important science at realizable cost. These options are (not priority ordered):

- Using the existing NuMI beamline in the low energy configuration with a **30 kton** liquid argon time projection chamber (LAr-TPC) **surface detector** 14 mrad off-axis at Ash River in Minnesota, **810 km** from Fermilab.
- Using the existing NuMI beamline in the low energy configuration with a **15 kton** LAr-TPC **underground (at the 2,340 ft level) detector** on-axis at the Soudan Lab in Minnesota, **735 km** from Fermilab.
- Constructing a new low energy LBNE beamline with a **10 kton** LAr-TPC **surface detector** on-axis at Homestake in South Dakota, **1,300 km** from Fermilab.

The committee looked at possibilities of projects with significantly lower costs and concluded that the science reach for such projects becomes marginal.

Steering Committee Conclusions

While each of these first-phase options is more sensitive than the others in some particular physics domain, the Steering Committee in its discussions strongly favored the option to build a new beamline to Homestake with an initial 10 kton LAr-TPC detector on the surface. The physics reach of this first phase is very strong; more over this option is seen by the Steering Committee as a start of a long-term world-leading program that would achieve the full goals of LBNE in time and allow probing the Standard Model most incisively beyond its current state. Ultimately this option would exploit the full power provided by Project X. At the present level of cost estimation, it appears that this preferred option may be ~10% more expensive than the other two options, but cost evaluations and value engineering exercises are continuing.

But there are risks:

In the next few months the LBNE collaboration and external experts will be studying the operation of LAr-TPCs on the surface to verify that the cosmic ray backgrounds are manageable. The operation on the surface may require shorter drift times than required for underground operations and the localization of the event in the TPC coincident with the ten microsecond-long beam from Fermilab. The Phase 1 experiment will use the existing detectors (MINOS near detector, MINERvA, and NOvA near detector) as near detectors for the two NuMI options, and use muon detectors to monitor the beam for the Homestake option. The Physics working group is currently studying the impact of near detectors on the physics reach.

First studies suggest that the risks are manageable, but work continues

DOE Responds

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

June 29, 2012

Dear Pier,

I would like to thank you and your management team for your recent presentation on the revised plans for the Long Baseline Neutrino Experiment (LBNE). The steering group and project team have done an excellent job responding to our request to reconfigure the project in ways that lead to an affordable and phased approach that will enable important science results at each phase. The report of the LBNE steering group outlining the options and alternatives considered provides clear and thoughtful input to our strategic plan for the Intensity Frontier program.

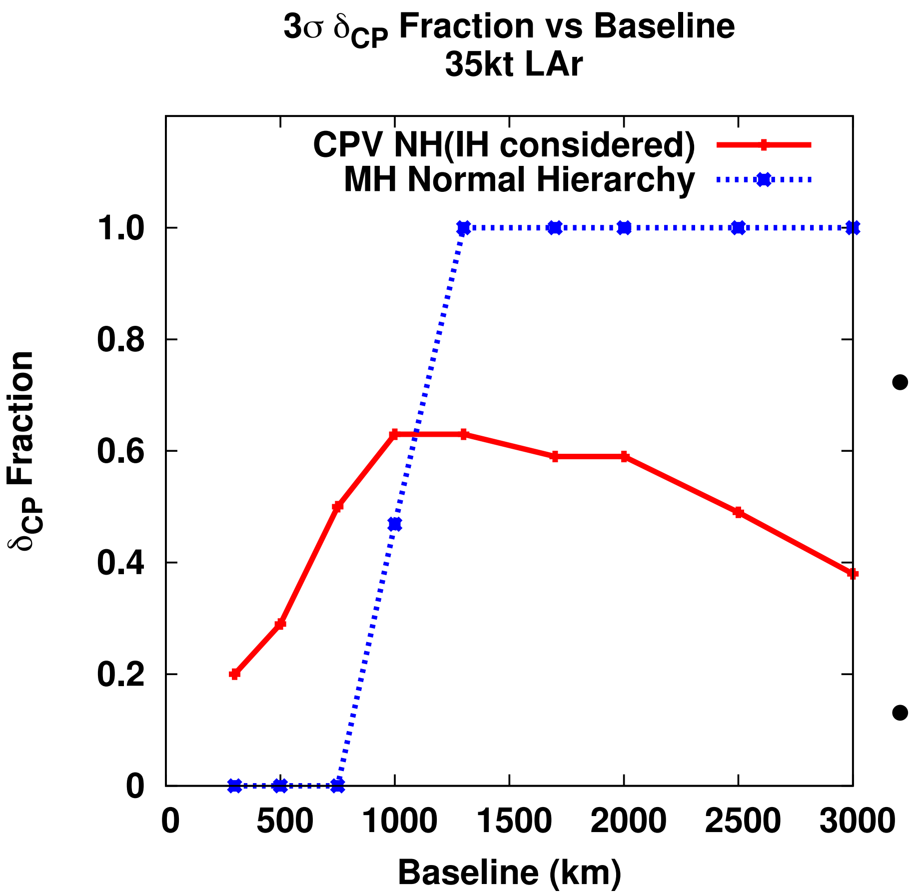
We would like you to proceed with planning a Critical Decision 1 review later this year based on the reconfigured LBNE options you presented. Please work with Jim Siegrist and Dan Lehman on the timing of this review.

I am hopeful that we can put the LBNE project on a sustainable path and thereby secure a leadership position for Fermilab in the Intensity Frontier. We look forward to working with you to achieve this goal.

Sincerely yours,

W.F. Brinkman

Reasons for the preference

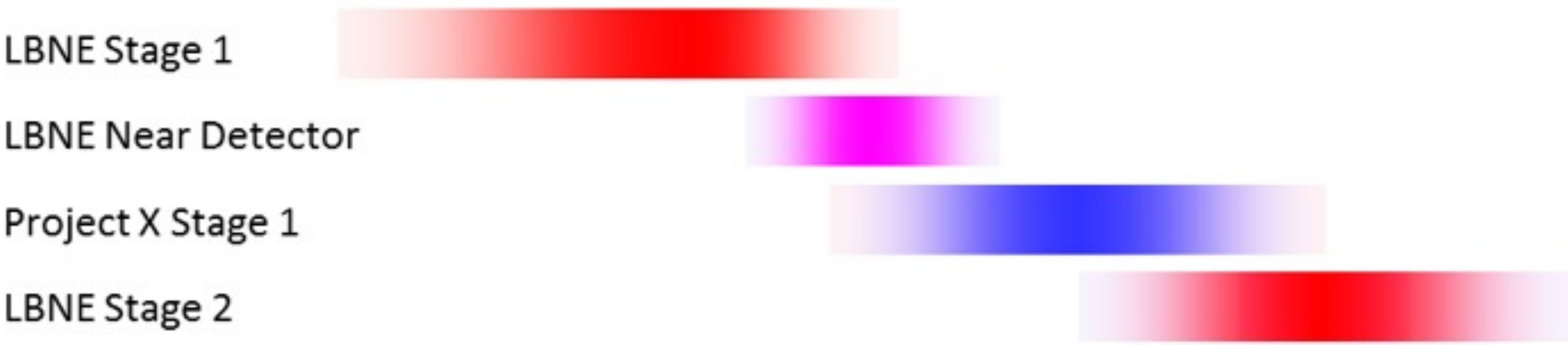


- The long baseline neutrino physics is the highest priority because it is viewed to have a guaranteed positive scientific outcome.
- The choice preserves the comprehensive nature of LBNE since we have the technological ability to execute it.
- The choice also preserves the deep option by choosing the site.

Projects must have truly unique features or parameters that define them. These features serve the scientific program in the long run.

Phased LBNE Program: Possible Example

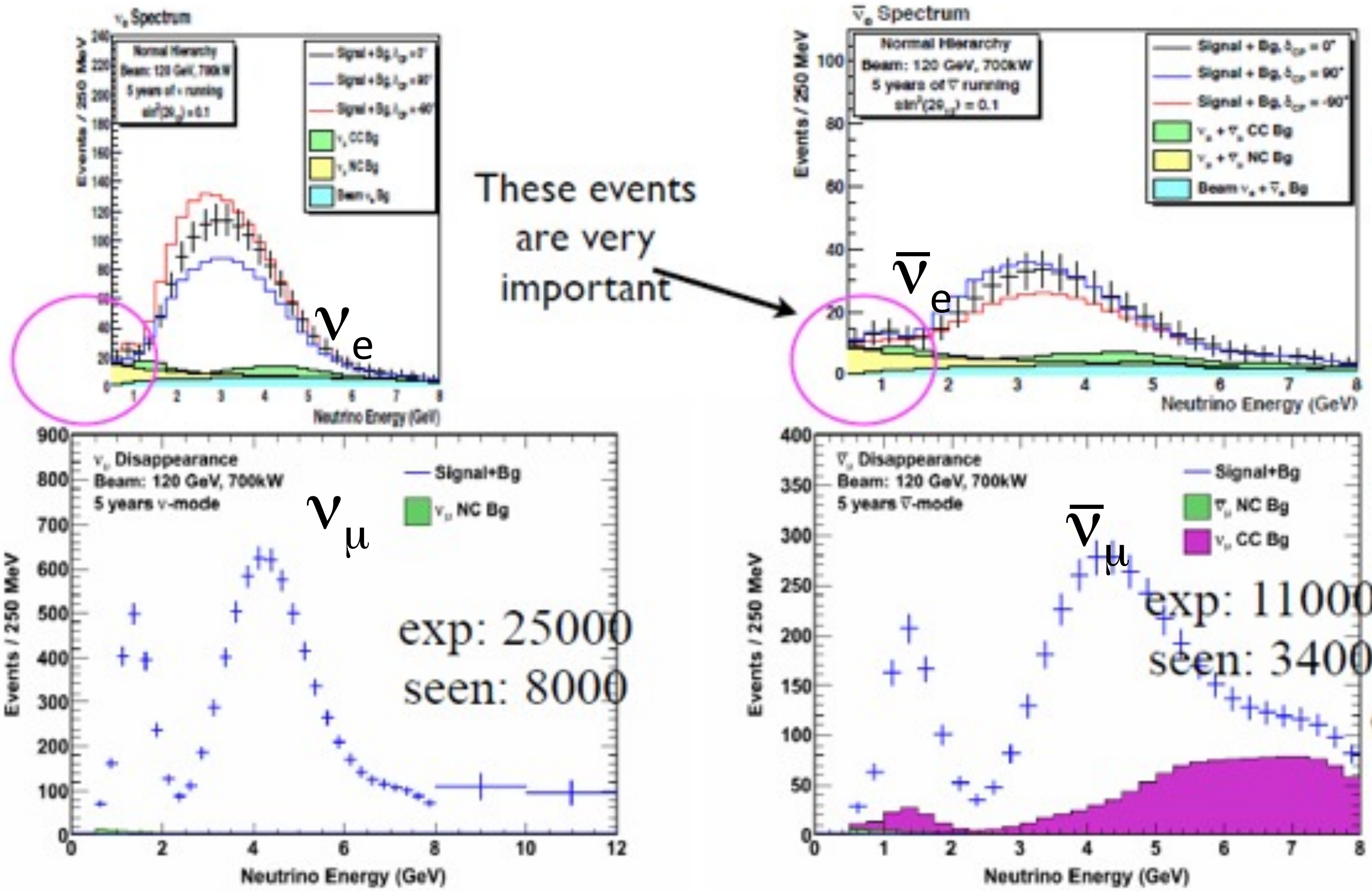
1) 10 kt LAr detector on surface at Homestake + LBNE beamline (700 kW)
2) Near Neutrino Detector at Fermilab
3) Project X stage 1 → 1.1 MW LBNE beam
4) Additional 20-30 kt detector deep underground (4300 mwe)



Additional national or international collaborators could help accelerate the implementation of the full LBNE program.

1300 km expectation

With full scope LBNE



For each bin, conversion fraction of electrons can be calculated. Matter effect can be substracted to obtain explicit CP signal.

Potential surprises:

Matter effect is not what is expected !

CPV does not have the proper energy 1/E dependence.

- With 1300 km the full structure of oscillations is visible in the energy spectrum. This spectral structure provides the unambiguous parameter sensitivity in a single experiment.

The LBNE Project

The LBNE Project is to deliver the first phase of this program:

- A new neutrino beam at Fermilab:
  - Aimed at Homestake
  - Spectrum optimized for this distance
  - Upgradeable to ≥ 2.3 MW proton beam power
- A 10 kt LAr TPC detector on the surface at Homestake
  - In a pit just below the natural grade
  - Shielded against hadronic and EM component of CR showers

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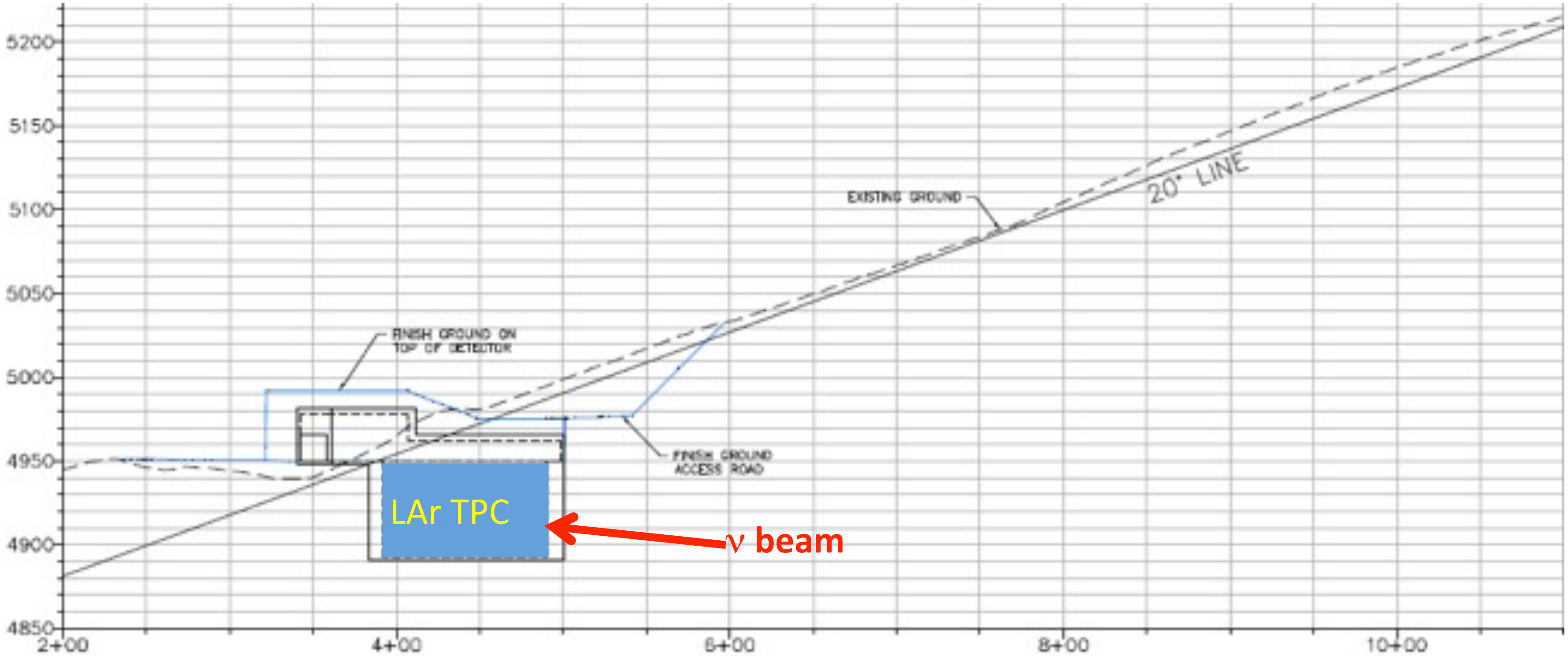

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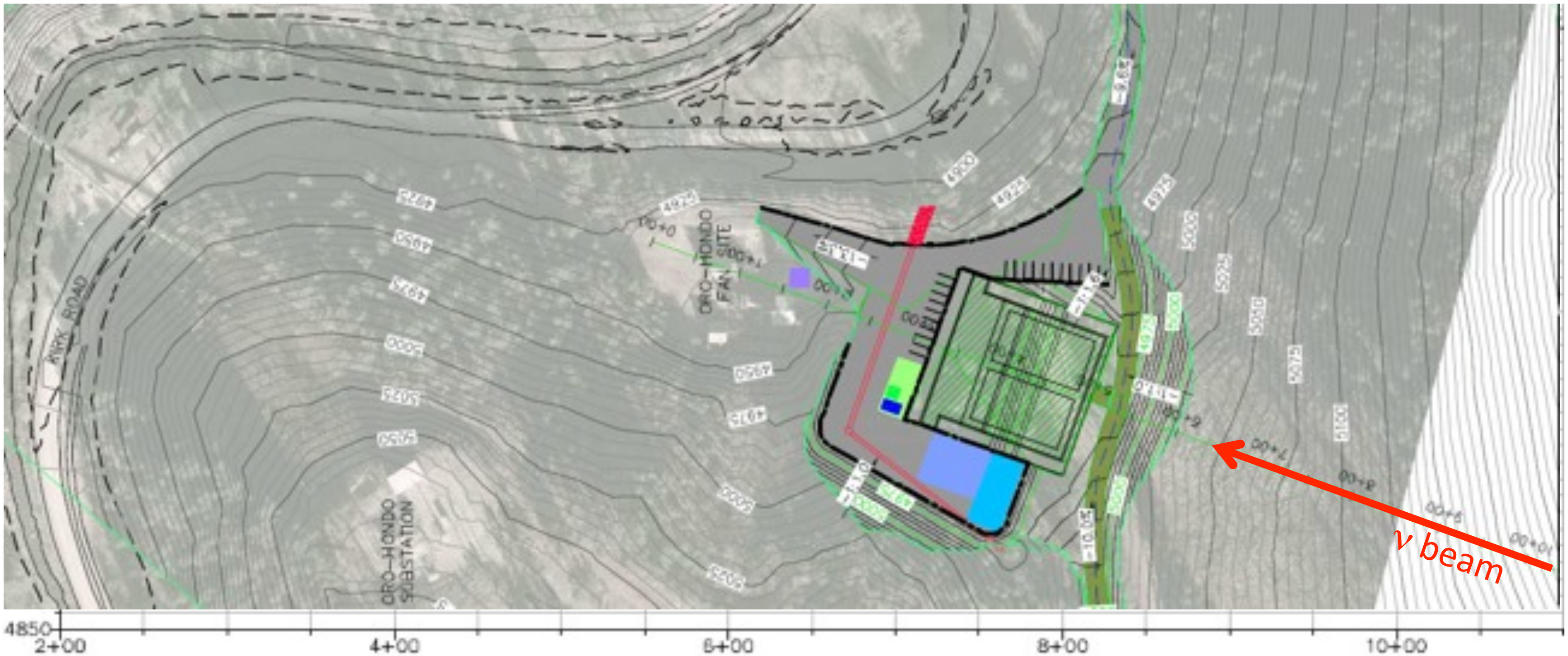

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The LBNE Project

The LBNE Project is to deliver the first phase of this program:

- A new neutrino beam at Fermilab:
  - Aimed at Homestake
  - Spectrum optimized for this distance
  - Upgradeable to $\geq$ 2.3 MW proton beam power
- A 10 kt LAr TPC detector on the surface at Homestake
  - In a pit just below the natural grade
  - Shielded against hadronic and EM component of CR showers
- Tertiary muon detector to monitor the neutrino beam
  - ionization chambers
  - variable pressure gas Cherenkov detectors
  - stopped muon detectors

The LBNE Project

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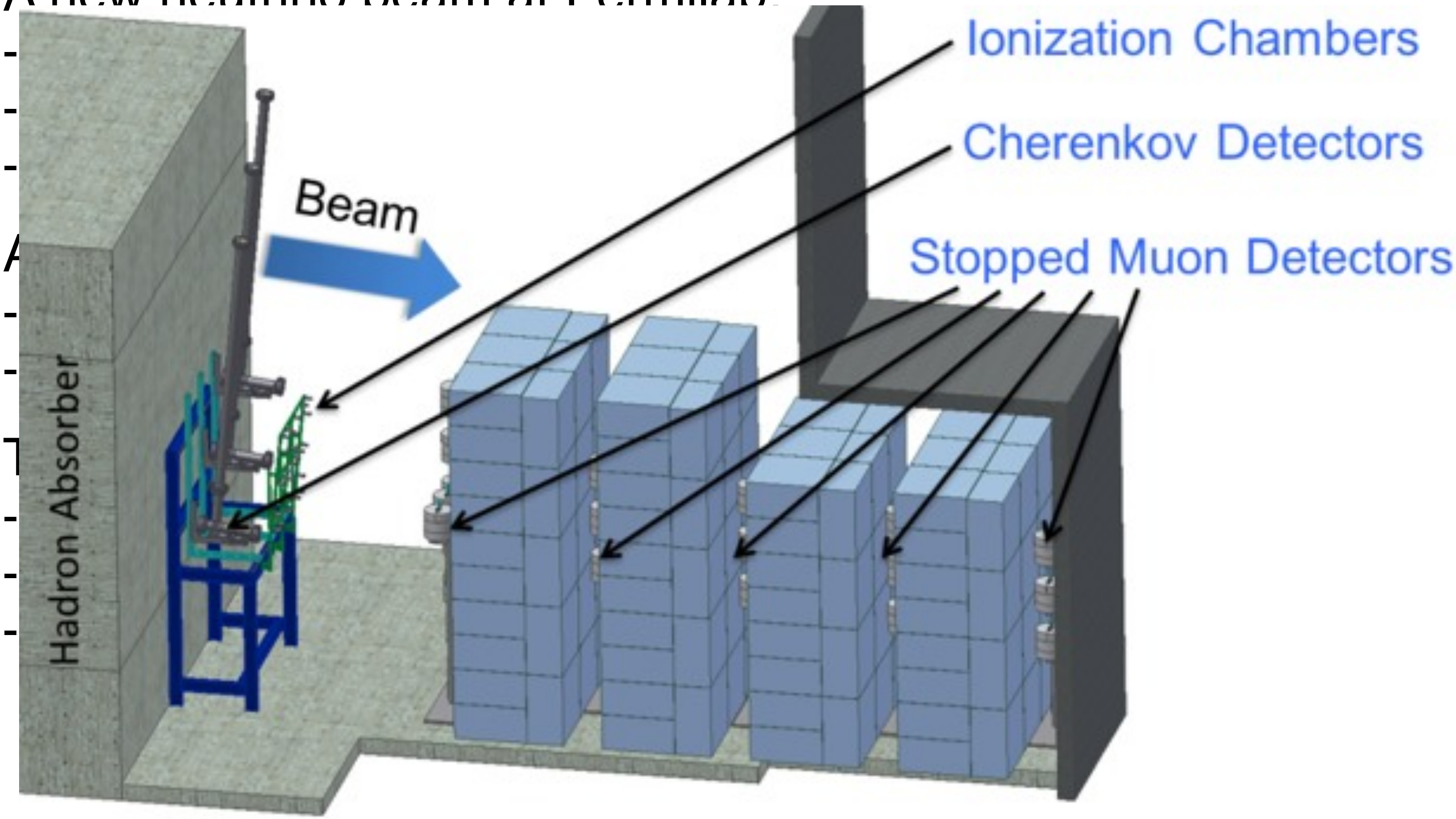
- A new neutrino beam at Fermilab:



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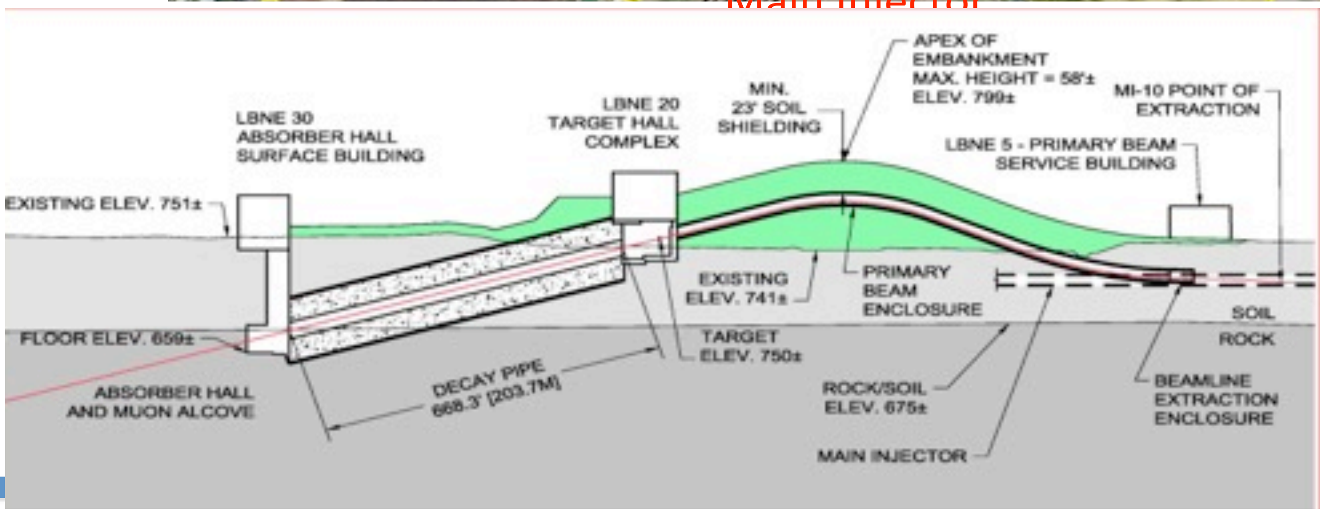
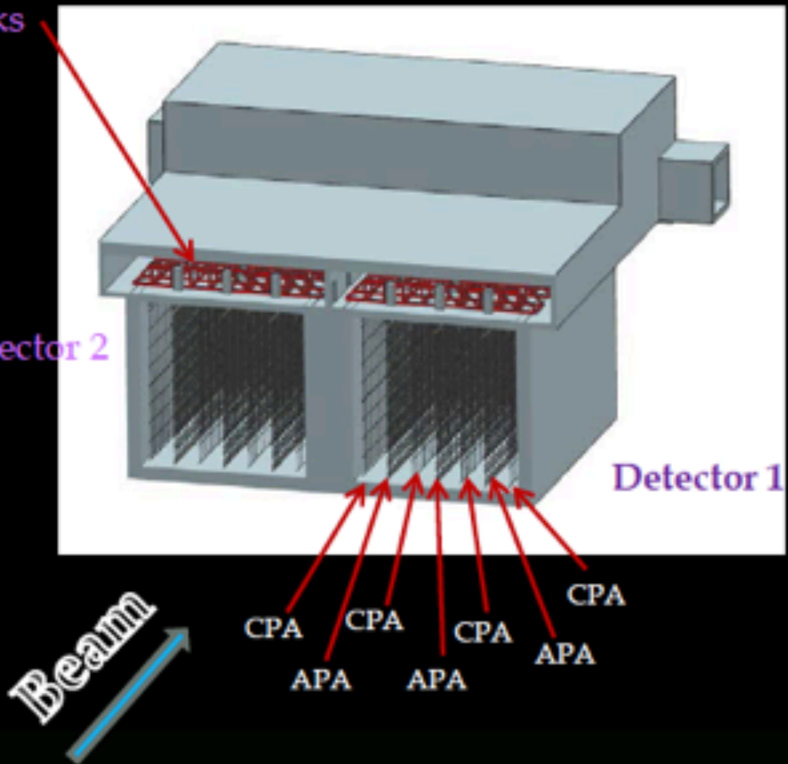
  - Stopped muon detectors

LBNE Beamline Reference Design: MI-10 Extraction, Shallow Beam

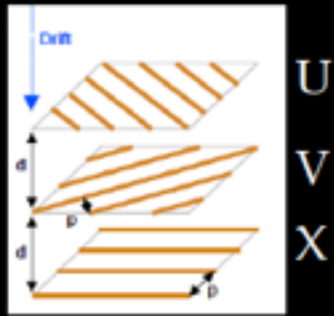


Wednesday, October 3, 12

TPC Design



- 2.3 m drift length
- 5 mm wire spacing
- 3 stereo views



Each 5 kton cryostat has:

- 60 APAs, 80 CPAs,
- 1100 m^2 field cage
- 6.72 kton active mass
- 5 kton fiducial mass
- 25m(L)x14m(W)x14m(H)

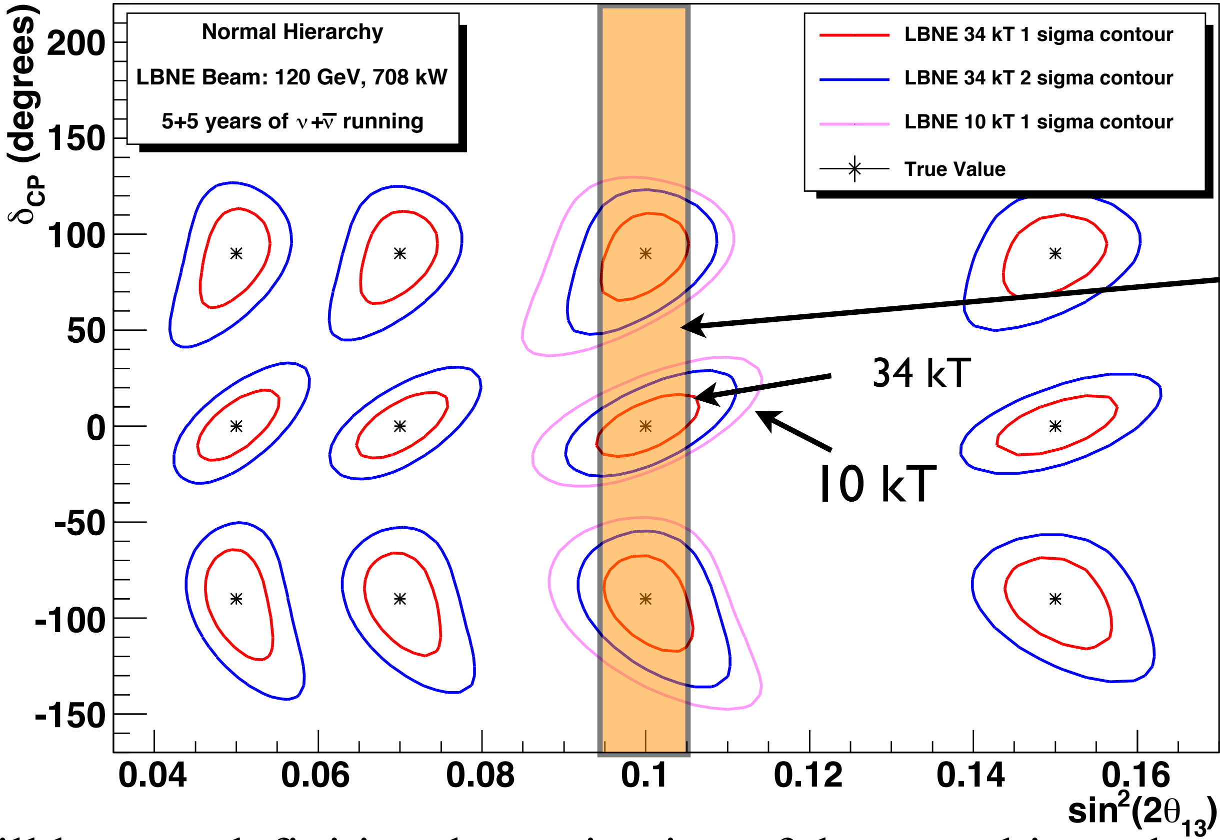
Each APA has:

- 2560 readout channels
- 3680 wires

The entire TPC structure is supported by 7 mounting rails (Under the cryostat ceiling)

LBNE Parameter measurement

Phase I ν_e(anti-ν_e) ~50 (~20) events per year with >50% modulation



Expected final 1 sigma error from reactors (centered on 0.1)

- LBNE will have a definitive determination of the mass hierarchy.
- LBNE will have a measurement of the phase and θ_{13} with no ambiguities.
- The phase measurement will range from ±20 to ±30 deg for Phase I when combined with reactor data.
- Parameter measurement will continue to improve with statistics.

Phased Program

The preferred configuration would be the first step in a phased program.

In the 1st phase, LBNE would determine the sign(Δm^2_{32}) and measure δ_{CP}, as well as measuring other oscillation parameters: θ_{13}, θ_{23}, and $|\Delta m^2_{32}|$.

Subsequent phases would include:

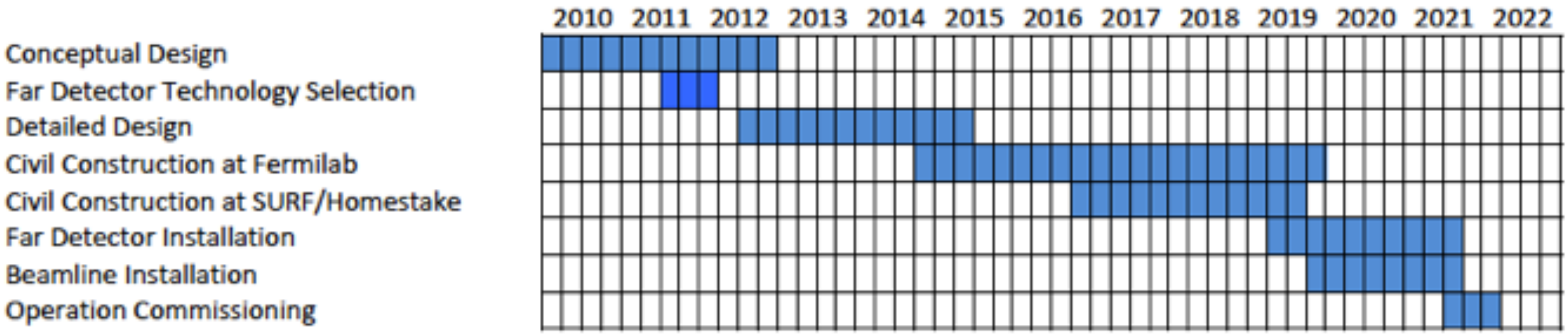
- Build a highly capable near neutrino detector,
  - reduce systematic errors on the oscillation measurements
  - enable a broad program of non-oscillation neutrino physics.
- Increase the detector mass or increase the beam power (Project X)
  - add statistical precision to all of the neutrino measurements.
- Add a large detector at the 4850 foot (4300 mwe) level at Homestake
  - enable proton decay, supernova neutrino, and other non-beam physics
  - further improve the precision of the main oscillation measurements
  - enable use of more difficult channels for a fully comprehensive program of oscillation measurements

The actual order and scope of the next phases would, of course, depend on physics, resources, and the interests of current and new collaborators.

The LBNE Project – Next Steps

- The next step in the DOE project approval process is "CD-1," which approves the conceptual design and overall cost scale and schedule of the Project.
- We have been encouraged by DOE to achieve this milestone by the end of December 2012.
- A prerequisite is to pass two major reviews:
  - Fermilab Director's Review 25-27 September
    - Validates the design Accomplished
  - DOE ("Lehman") Review 30 October – 1 November
    - Validates the project plan
- CD-1 will allow us to move forward to complete the design and to prepare for construction.

LBNE Phase 1 Schedule



- This is a review driven schedule. Current funding profile is expected to cause 11 month delay.
- The period up to far detector construction start offers good opportunity to seek major non-DOE and international partners.
- Deep placement of far detector as well as a near detector expansion can be accommodated in the current plan by CD2.

Costs after Reconfiguration

Scope	Cost (TPC)
LBNE 34 kTon@4850L and near detector	$1.440B
LBNE Phase I, 10 kTon surface	$0.789B
+Place Underground	$0.924B
+ Near Detector	$1.054B

Our plans for expansion of science program

- Locating the detector underground will cost $135M or 15% of the LBNE Phase I total and enable the physics of proton decay and supernova neutrinos.
- Similarly, a full capability near detector needs about $130M including civil construction.
- Collaboration is considering various non-DOE proposals/ avenues to enable underground placement of the detector for substantial broadening of the program.
- There were conversations with European physicists at the ESPG on Sep. 10-12, 2012. There are technical collaborations with UK/RAL already.
- High level agreements with some countries have begun.

Conclusion

- The goal of finding the phenomena of CP violation in the neutrino sector is extraordinary and has been strongly endorsed.
- US based accelerator/detector capability and the geographical situation could not be better matched to the science of neutrino oscillations.
- The LBNE collaboration and project are well organized and ready to construct and operate LBNE.
- The steering panel report is a culmination of a very long process of design/costing/planning by a broad section of the community. It puts us on a track to a massive detector for CP violation and proton decay.
- The collaboration (with FNAL and DOE) is committed to work towards strong international investment and expansion of the science program.