Long Baseline Neutrino Experiment

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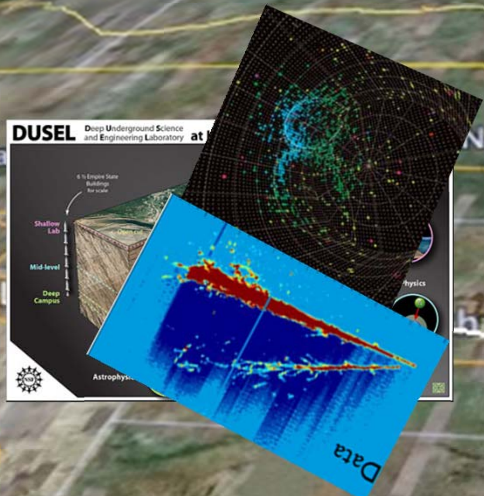
Fermilab Institutional Review
June 6-9, 2011

U.S. DEPARTMENT OF ENERGY

Fermilab

Long Baseline Neutrino Experiment



New Neutrino Beam at Fermilab…
…Directed towards a distant detector
Precision Near Detector on the Fermilab site
150-200 kton Water Cherenkov Detector
24-34 kton Liquid Argon TPC Far Detector
…And all the Conventional Facilities required to support the beam and detectors

Outline

- Physics Goals and Sensitivity
- Overview of Project Organization
- Progress in the past year
- Project Conceptual Design development
- Plans for the coming year
- Summary

The DOE and the NSF have agreed that DOE will be the "steward" of the LBNE Project, and that NSF will contribute financially to its construction as part of the DUSEL Project.

II. Physics Research Goals of LBNE

Following from the P5 recommendations, the DOE Mission Need Statement, discussions with the funding agencies (DOE Office of High Energy Physics and NSF Physics Division), Fermilab management, and the LBNE Science Collaboration, it is been determined that the priorities for the scientific research to be enabled by the LBNE Project are the following:

1. **The primary objectives** of the LBNE Project are the following experiments:

Understood to be in priority order.

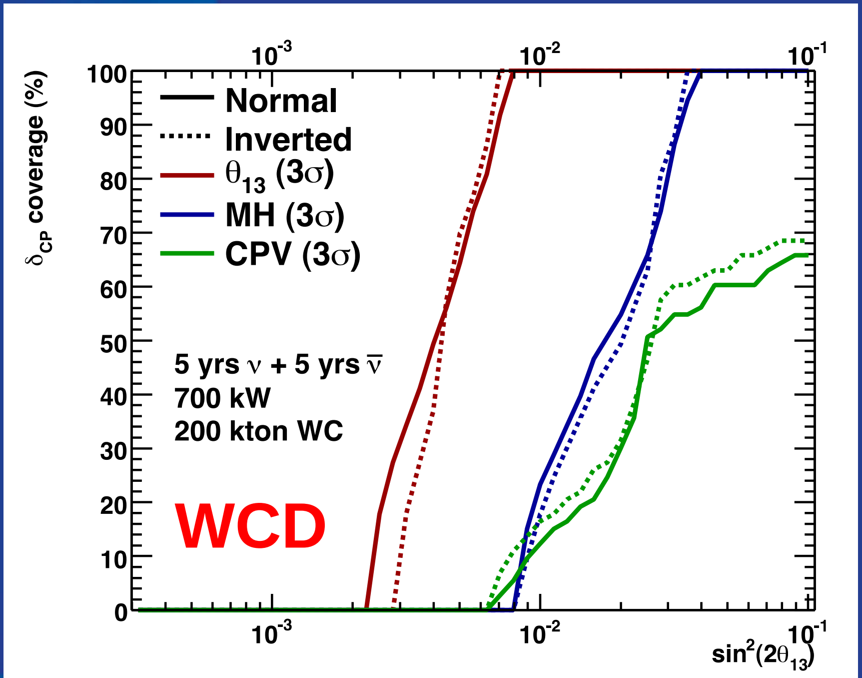
1.1 Search for, and precision measurements of, the parameters that govern $\nu_\mu \rightarrow \nu_e$ oscillations. This include measurement of the third mixing angle θ_{13}, for whose value only an upper bound is currently known, and if θ_{13} is large enough, measurement of the CP violating phase δ and determining of the mass ordering (sign of Δm^2_{32}).

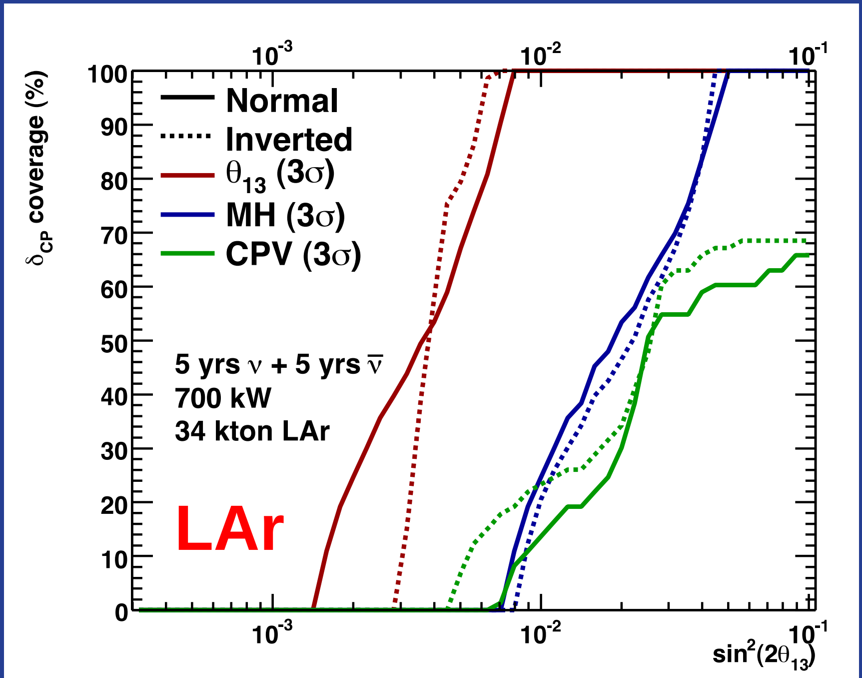
1.2 Precision measurements of θ_{23} and $|\Delta m^2_{32}|$ in the ν_μ disappearance channel.

1.3 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 $p \rightarrow K^+\nu$.

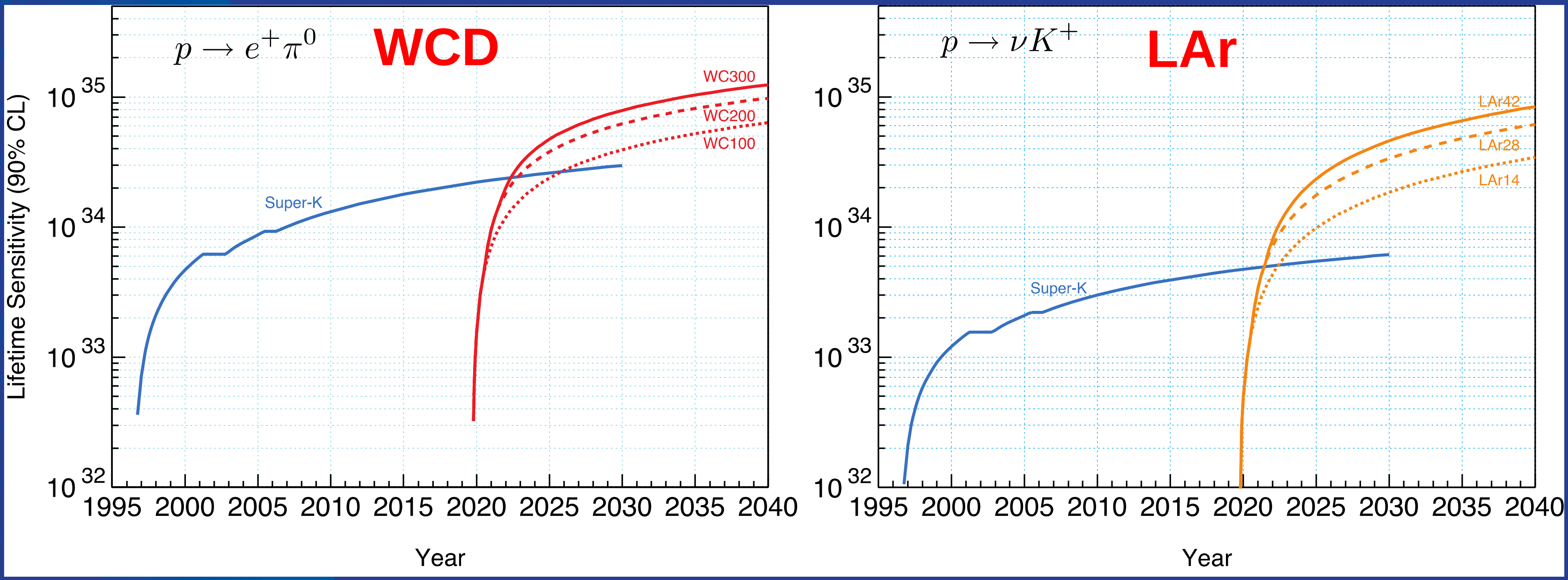
1.4) Detection and measurement of the neutrino flux from a core collapse supernova within our galaxy, should one occur during the lifetime of LBNE.

Performance of LBNE: Long-Baseline $\nu_\mu \rightarrow \nu_e$ Oscillations





Performance of LBNE:
Proton Decay



Long-Baseline Neutrino Experiment Collaboration

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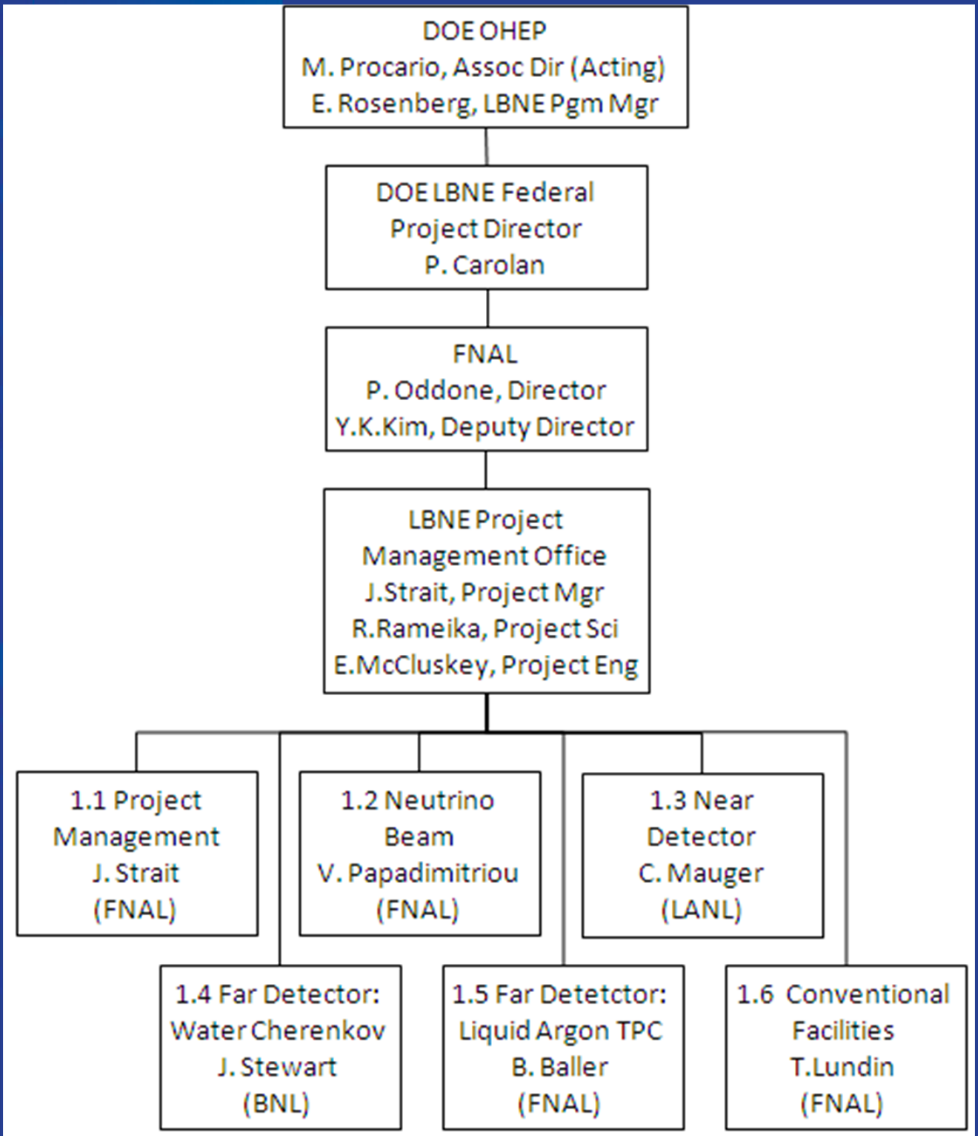
306 individuals
58 institutions
25 US States
5 countries

LBNE Project Organization



- Fermilab is the Lead Lab
- BNL is responsible for the Water Cherenkov Detector
- LANL is responsible for the Near Detector

- The Project and Collaboration are well integrated:
  - Project leadership are Collaboration members.
  - Collaboration is heavily involved in Project planning.
  - Project leadership are members of the Collaboration Exec Committee.
  - Spokespeople are members of the Project Management Board.

Brief history since S&T review last year

- Director's review in July 2010 => on track towards CD-1, but not as fast as hoped.
- Project Manager's CDR, cost and schedule reviews fall 2010 => designs sound, but overall cost was too high.
- Value Engineering launched in November. More than 80 proposals have been considered, which have substantially reduced cost without compromising the primary physics goals. This process continues.

Brief history since S&T review last year

- December 2010 – NSF withdrew support from DUSEL, dramatically changing the boundary conditions.
- LBNE has
  - Developed designs and plans for the case in which LBNE is the only occupant of the Homestake site.
  - Submitted a set of documents to the Office of Science Independent Review of Options for Underground Science describing LBNE with a water, liquid argon, or mixed technology far detector complex, assuming no larger Laboratory at Homestake.
  - Made initial, exploratory contact with potential alternate sites for the far detectors.

Current Status and Plans

- LBNE is working towards DOE's CD-1, and therefore is in the Project Definition phase.
- We are currently exploring a range of designs for all parts of the Project, to find the most cost-effective way to implement the experiment.
- In what follows, we present a range of configurations for the LBNE beam, near detector and far detector that correspond to a range in cost, risk and capability for the LBNE experiment as a whole.

Neutrino Beamline

Main Beamline Parameters

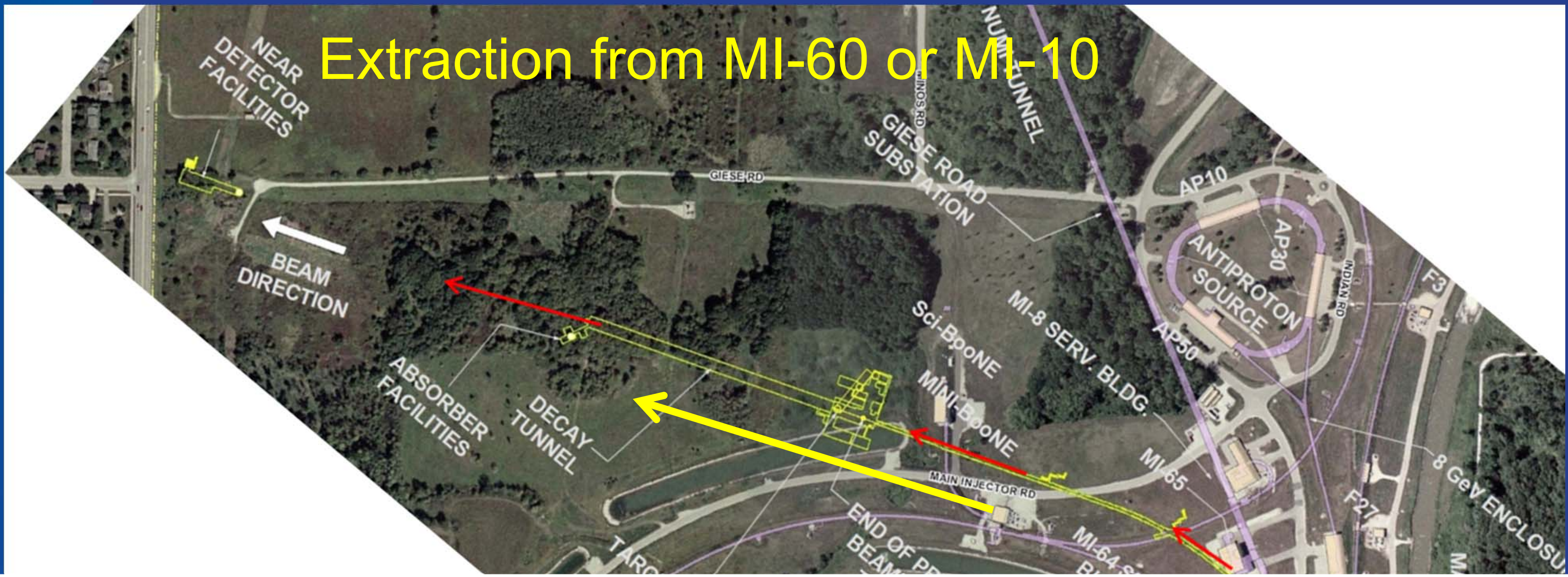
- Horn-focused neutrino beam, optimized to cover the first and second oscillation maxima => $E_\nu < 10$ GeV.
- Driven by Main Injector: $60 \leq E_{beam} \leq 120$ GeV.
- Design for initial operation with $E_{beam} = 700$ kW; facility designed to enable upgrade to 2.3 MW.
- Decay pipe: 4 m (diameter) x 200~250 m long.

Main alternatives under consideration:

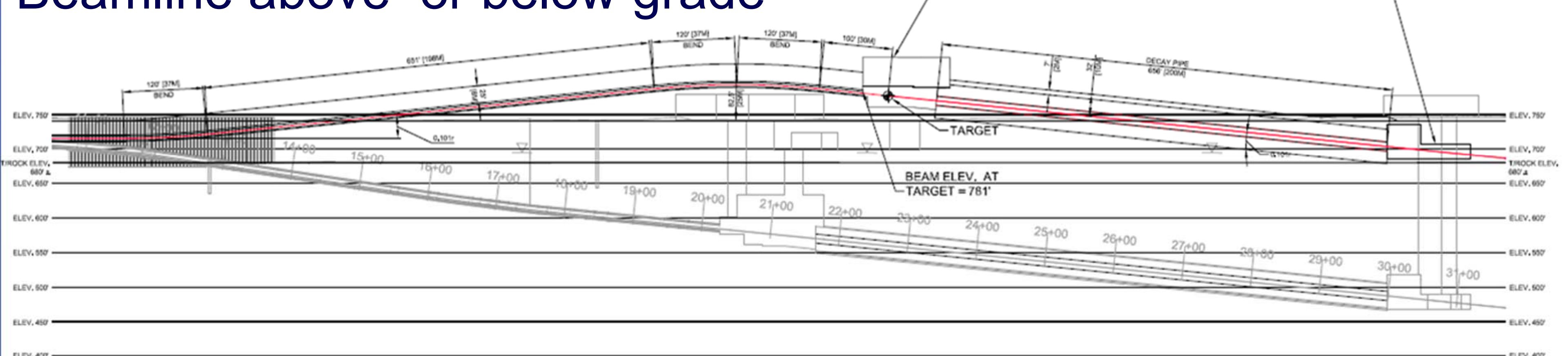
- Proton beam extracted from MI-10 or MI-60.
- Varying depth of the beamline components relative to the rock-soil interface.

Neutrino Beam Alternate Designs

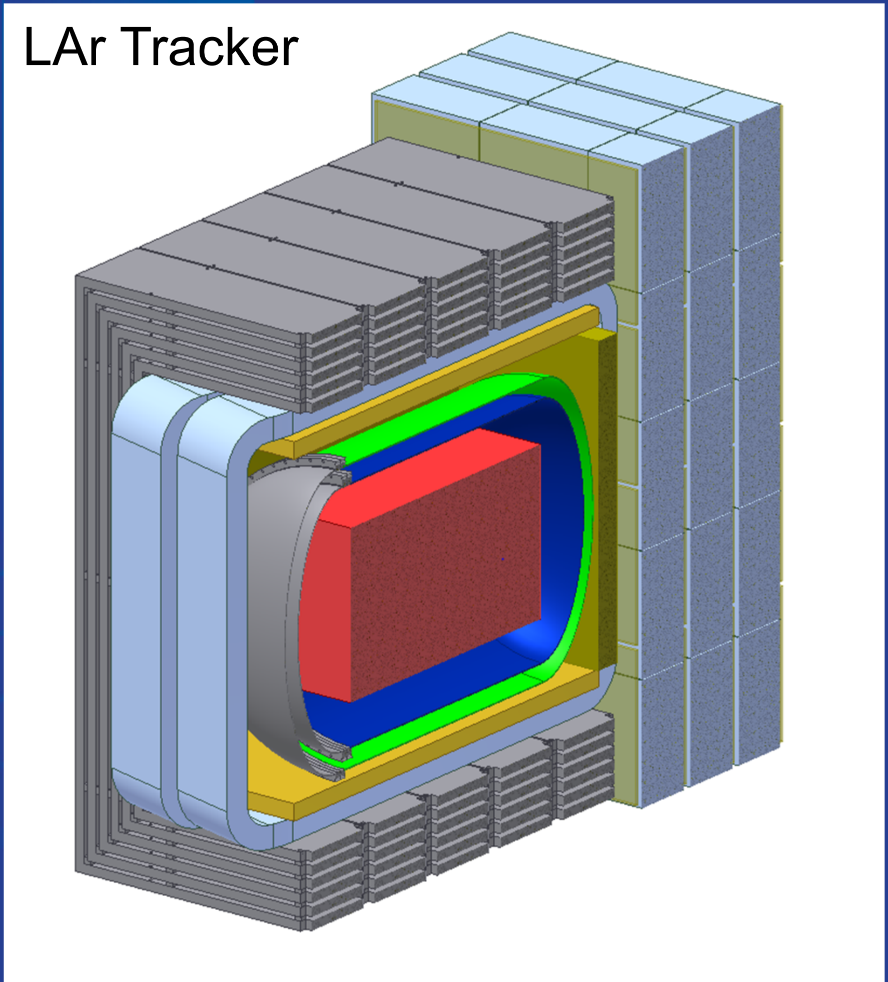
Extraction from MI-60 or MI-10

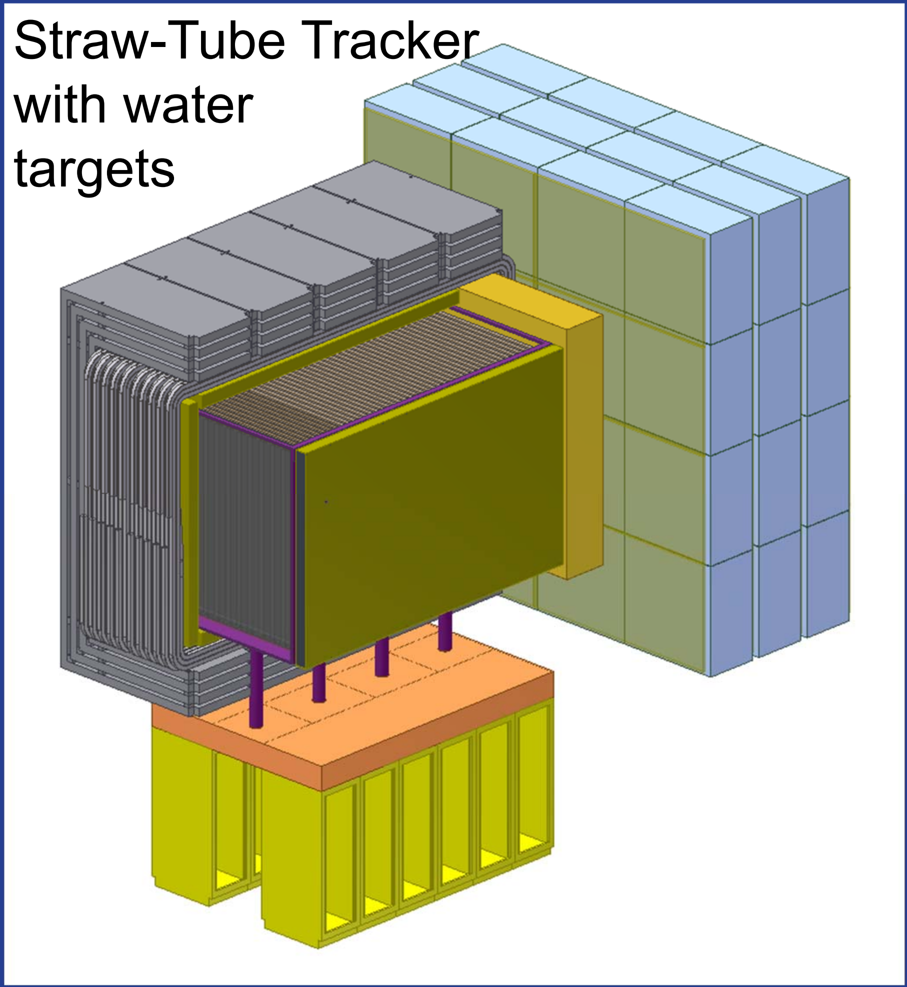


Beamline above or below grade

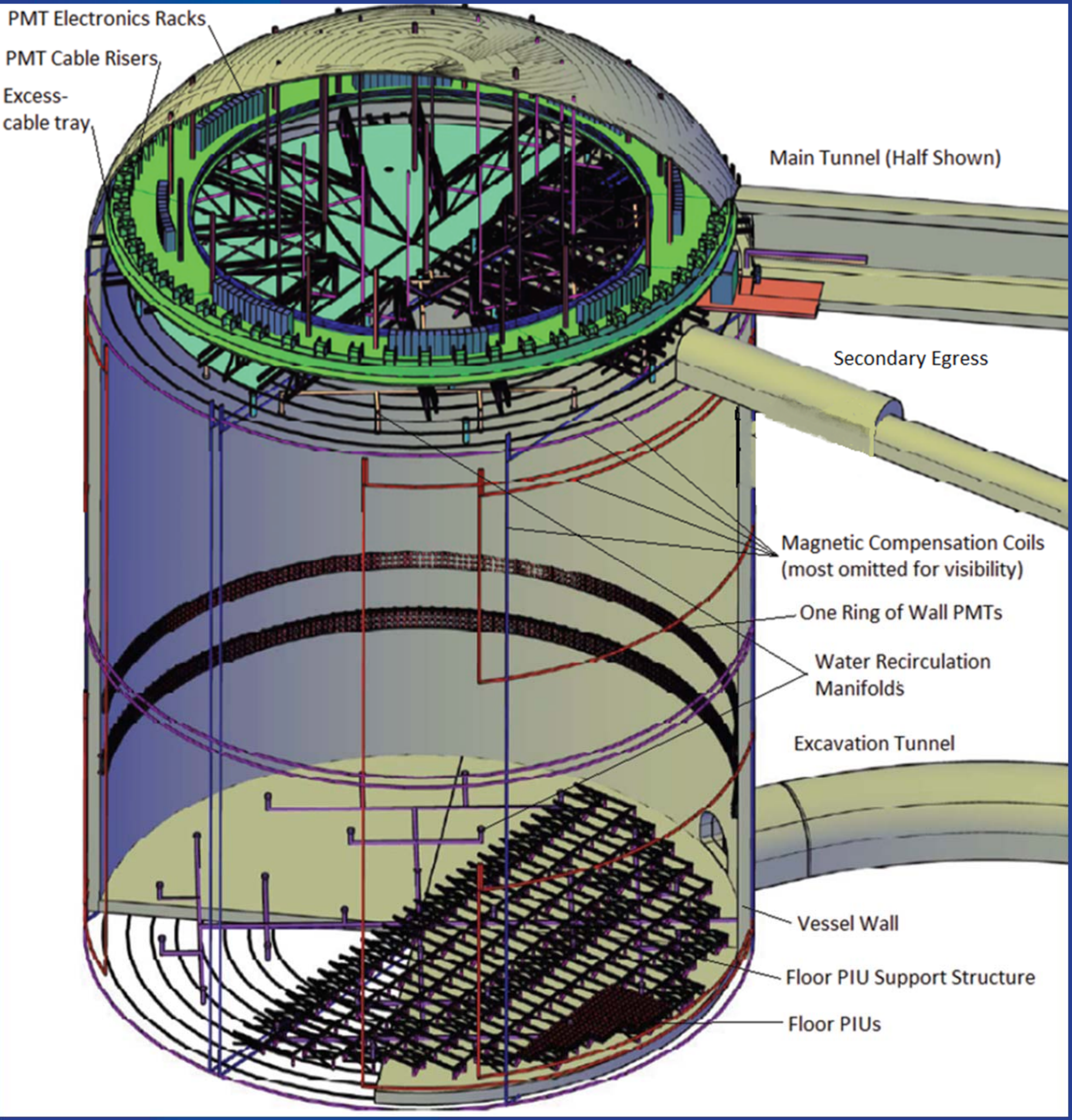


Near Neutrino Detector Options



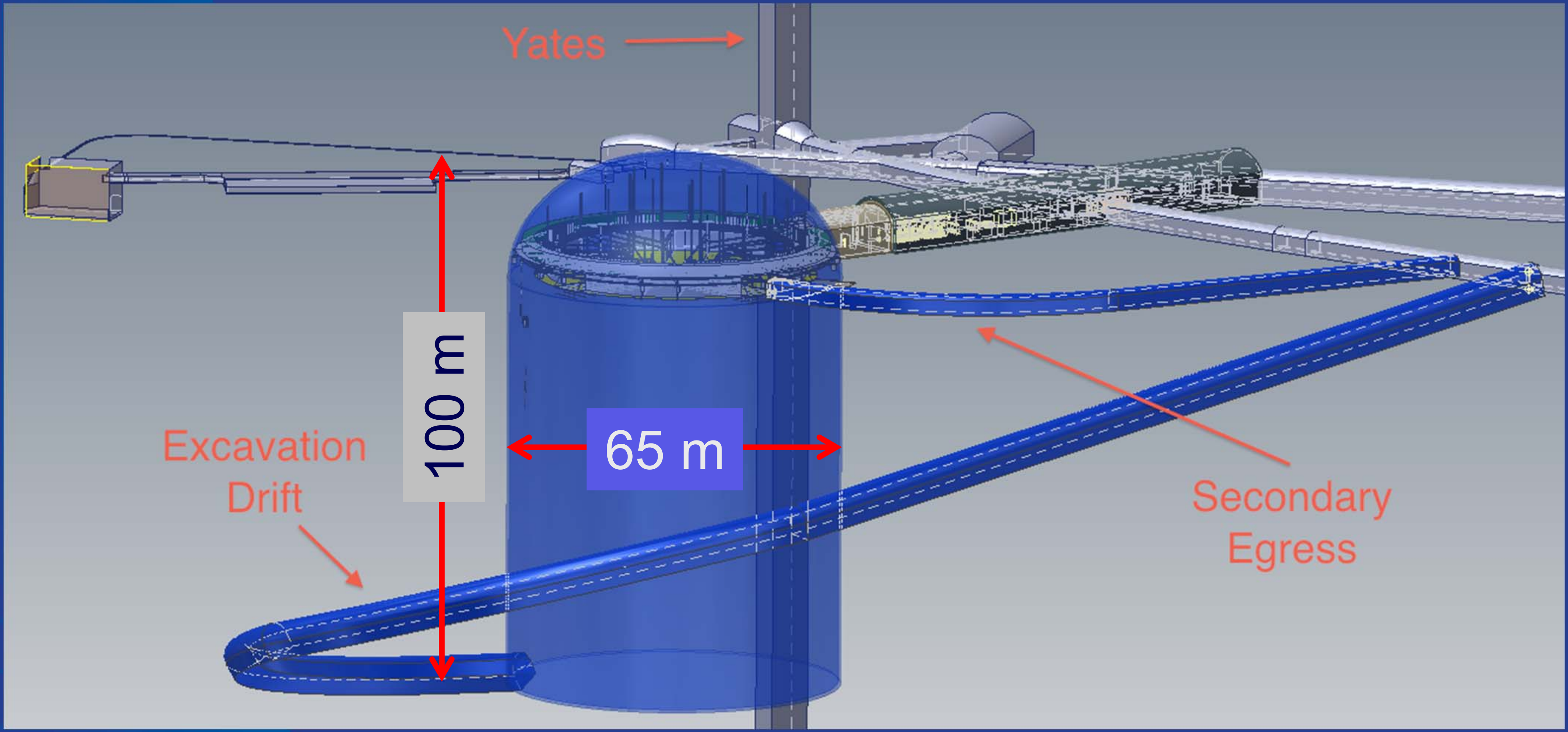


Water Cherenkov Detector



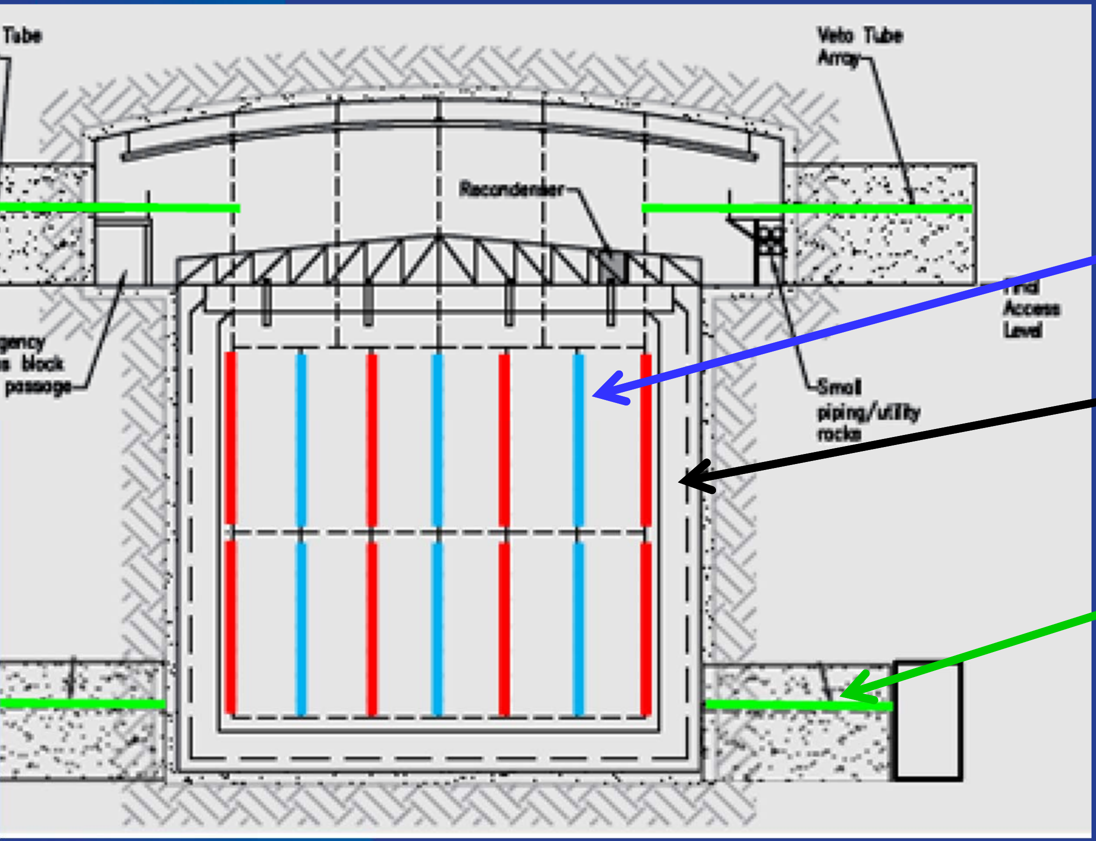
- Large Cavern at 4850 ft depth
- Water Vessel
- Ultra-pure water system
- PMT + light collectors to give photon detection efficiency equivalent to SuperK II
- 2 sizes under consideration: 200 kt or 150 kt fiducial mass (7-9 x SuperK)
- Detector active volume: 63 m dia. x 77 (58) m high for 200 (150) kt.

Water Cherenkov Detector Cavern



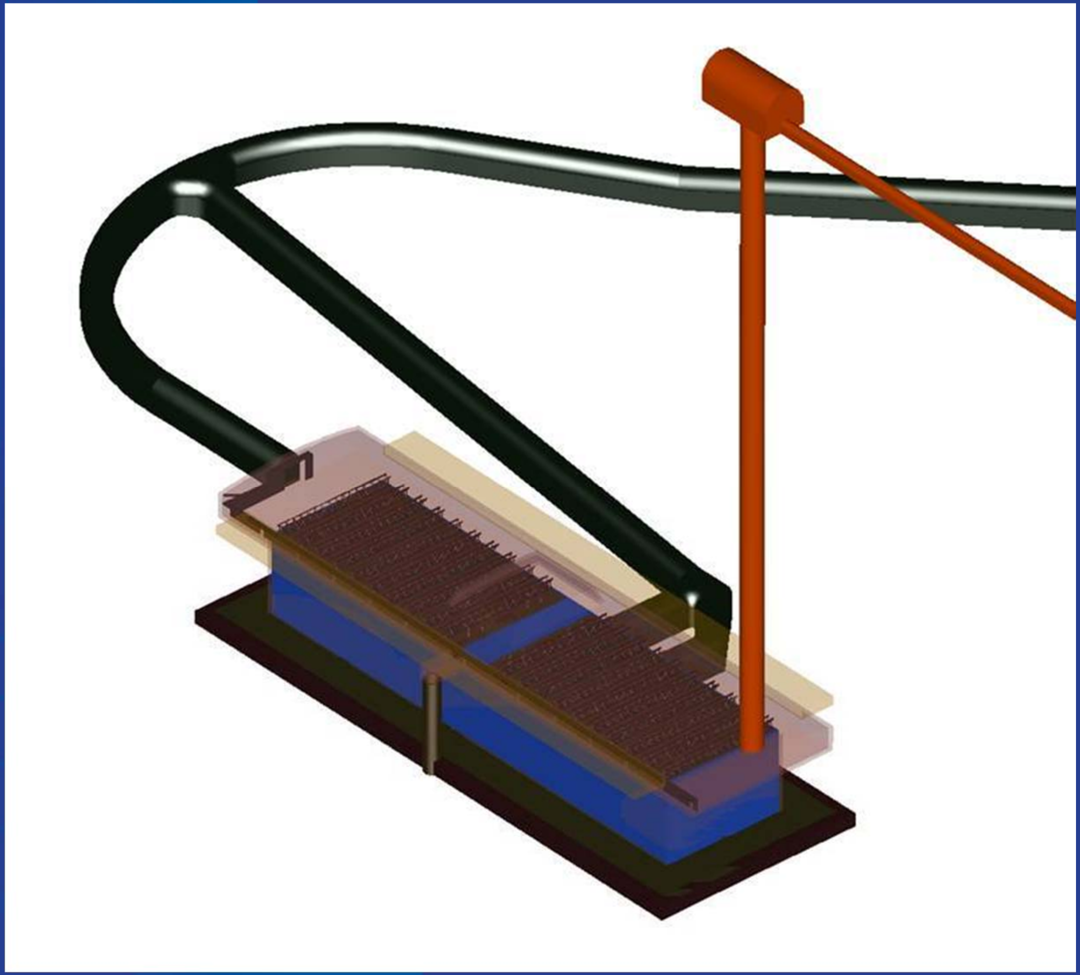
- DUSEL's Large Cavity Advisory Board endorses the constructability of the 200 kt water detector cavern.
- Excavation design still evolving for simplicity and cost savings.

Liquid Argon TPC



- Two detectors, end-to-end in a common cavern at the 800 level.
- Alternating Cathode and Anode Plane Assemblies.
- Foam-insulated cryostat inside concrete vessel (membrane cryostat)
- Veto system to tag cosmic rays passing through the adjacent rock.
- Photon detectors provide t=0 for non-beam physics.
- Two sizes under consideration: 33 kt or 24 kt total (2 detector) fiducial mass

LAr Detector Size



- Active volume of each detector:
  22.5 m
  14 m high
  33-55 m long
  (depending on fiducial mass)
- Two detectors end-to-end in common cavern

LAr Prototyping Program

LBNE LAr development builds on world-wide R&D program

LBNE-specific prototyping program includes:

- 3 x 3 m^2 membrane cryostat wall panel – testing in progress
- 3 x 3 x 3 m^3 membrane cryostat prototype
  - Understand cryostat technology
  - Verify purity in this cryostat
  - Preliminary design complete; operational in 2012
- kton-scale full engineering prototype
  - Full engineering prototype of complete detector system
  - Leverage DZero infrastructure to minimize construction cost and time, and operating cost.
  - Early planning stage; schedule depends on funding, but could be operational in 2014.
- Installation mockup
  - Concept exists; premature to devote significant resources.

Cost Estimate Summary – WCD
(FY2011 M$, including contingency)

		150 kton Low		200 kton Medium		200 kton High	
		Cost	Cont %	Cost	Cont %	Cost	Cont %
	LBNE TPC + Operations	**1238.5**		**1305.7**		**1608.7**	
1.0	**LBNE TPC**	**1127.3**	**33%**	**1194.5**	**33%**	**1476.3**	**33%**
1.1	Project Management	35.3	15%	35.3	15%	47.8	19%
1.2	Neutrino Beamline	149.7	35%	149.7	35%	163.4	34%
1.3	Near Detector Complex	40.6	33%	40.6	33%	62.8	36%
1.4	WCD Far Detector	224.5	26%	262.7	26%	290.9	26%
1.6.1	CF – Management	6.4	20%	6.4	20%	13.7	20%
1.6.2	CF – Neutrino Beamline	180.8	36%	180.8	36%	281.3	36%
1.6.3	CF – Near Detector	66.1	36%	66.1	36%	71.4	36%
1.6.4	CF – WCD Far Detector	423.9	35%	452.9	35%	545.1	37%
	LBNE-specific costs	264.5	37%	293.3	37%	287.9	37%
	Common facilities costs	159.4	32%	159.6	32%	257.2	36%
2.0	**Operations (WCD)**	**111.2**		**111.2**		**132.4**	
	CD-4 =	*2021*		*2021*		*2023*	

Cost Estimate Summary – LAr
(FY2011 M$, including contingency)

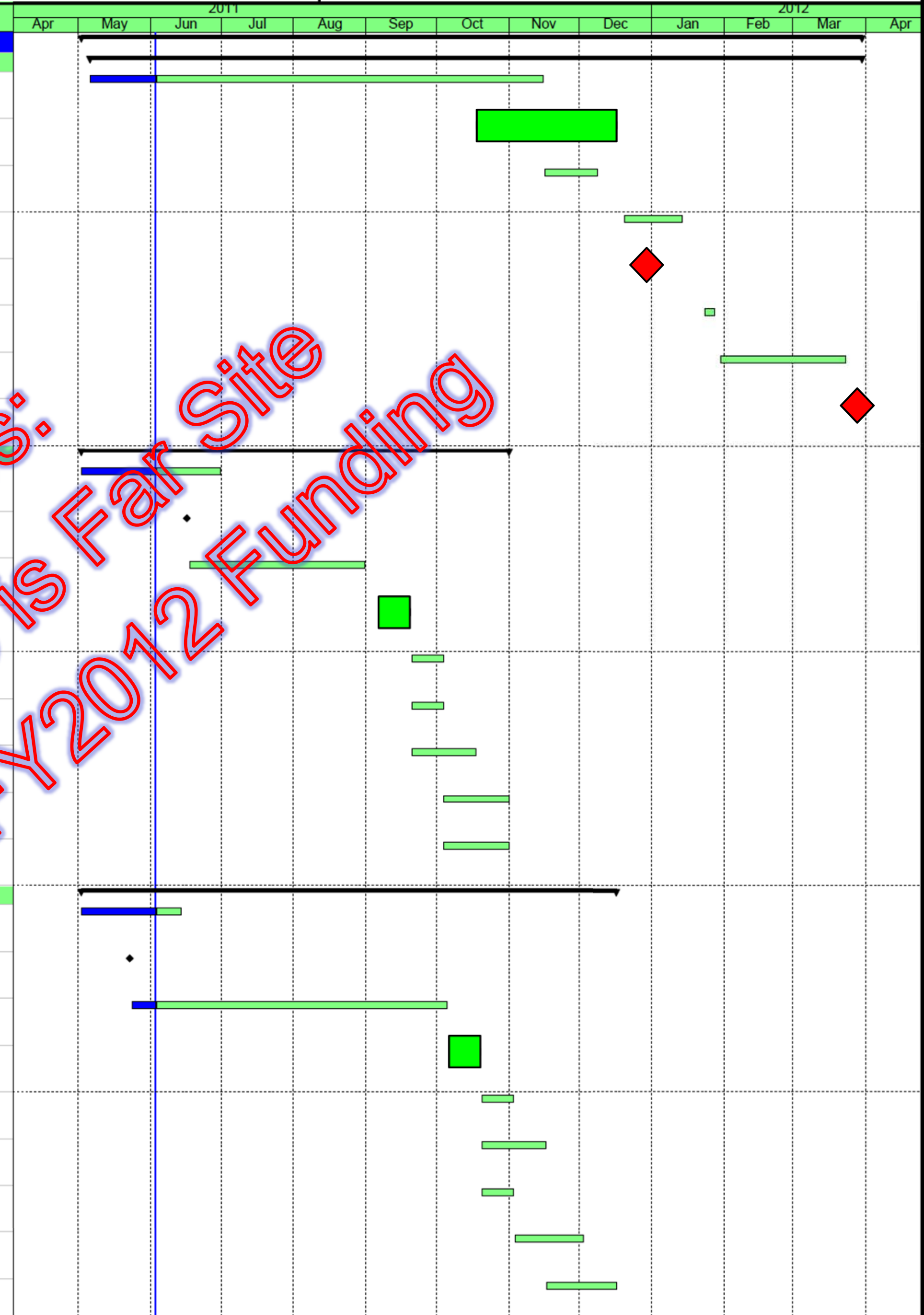
		24 kton		34 kton		34 kton	
		Low		Medium		High	
		Cost	contin-gency %	Cost	contin-gency %	Cost	contin-gency %
	LBNE TPC + Operations	**1065.9**		**1145.1**		**1440.6**	
1.	**LBNE TPC**	**977.5**	**35%**	**1056.7**	**35%**	**1335.4**	**36%**
1.1	Project Management	35.3	15%	35.3	15%	47.8	19%
1.2	Neutrino Beamline	149.7	35%	149.7	35%	163.4	34%
1.3	Near Detector Complex	37.3	31%	37.3	31%	60.5	39%
1.5	LAr TPC Far Detector	311.6	38%	370.1	38%	474.5	38%
	LAr Detector	291.1		349.6		454.0	
	LAr Prototypes	20.6		20.6		20.6	
1.6.1	CF - Management	6.4	20%	6.4	20%	13.7	20%
1.6.2	CF - Neutrino Beamline	180.8	36%	180.8	36%	281.3	36%
1.6.3	CF - Near Detector Complex	66.1	36%	*66.1*	*36%*	*71.4*	*36%*
1.6.5	CF - LAr TPC Far Detector	190.3	36%	211.0	36%	222.9	36%
	LBNE-specific costs	152.4	36%	173.2	36%	185.1	36%
	Common facilities costs	37.8	33%	37.8	33%	37.8	33%
2.	**Operations**	**88.4**		**88.4**		**105.2**	
	CD-4 =	*2021*		*2021*		*2023*	

Far Detector Decision Process

- The current plan is to decide between WCD and LAr prior to CD-1 Review
- Decision process is being developed jointly by the Project, the Collaboration, and Fermilab management.
- Main elements:
  1) Establish and validate the facts:
     - External review of science cases
     - External review of conceptual designs
     - External reviews of the cost estimates
  2) Collaboration Executive Committee, potentially augmented by additional members, provides formal advice to the Project Manager
  3) Concurrence of Fermilab Director, Laboratory Oversight Group, DOE/OHEP required

LBNE Program Plan to CD-1 Lehman Review | Data Date: 03-Jun-11 | Print Date: 08-Jun-11 10:

Activity ID	Activity Name	Remaining Duration	Start	Finish
LBNE Program Plan to CD-1 Lehman Review		**207**	**02-May-11 A**	**30-Mar-12**
Project Management		**207**	**06-May-11 A**	**30-Mar-12**
A1450	Develop Project Mgmt Documation for CD-1	116	06-May-11 A	15-Nov-11
A1030	**Independent Cost Review**	42	18-Oct-11*	16-Dec-11
A1250	PM Documentation Review (Pre-FNAL review)	15	16-Nov-11*	08-Dec-11
A1230	PM Cost Estimate & Sch Review	15	20-Dec-11*	13-Jan-12
A1060	**Far Detector Decision**	0		29-Dec-11*
A1170	FNAL Director's Review	5	23-Jan-12*	27-Jan-12
A1260	Address Recommendations from Directors Review/ Prepare for DOE CD-1 Review	40	30-Jan-12*	23-Mar-12
A1240	**DOE CD-1 Review**	5	26-Mar-12*	30-Mar-12
Near Site (FERMI)		**105**	**02-May-11 A**	**31-Oct-11**
A1880	Finalize Initial VE Efforts	20	02-May-11 A	30-Jun-11
A1850	New Reference & Alt. Design Determinations	0	16-Jun-11*	
A1890	Assemble Conceptual Design Report (Drawings & Specs)	53	17-Jun-11*	31-Aug-11
A1210	**CDR Reviews (Beam, Near Det)**	10	06-Sep-11*	19-Sep-11
A1400	Conceptual Design Review Findings/ Report	10	20-Sep-11	03-Oct-11
A1910	Risk Assessment	10	20-Sep-11	03-Oct-11
A1830	Create Conceptual Design BOEs/ Cost Estimates	20	20-Sep-11	17-Oct-11
A1870	Incorporate Comments from Conceptual Design Review - Finalize Conceptual Design/ Reports/Etc	20	04-Oct-11	31-Oct-11
A1840	Update Resource Load Schedule (with Updated Cost Est)	20	04-Oct-11	31-Oct-11
Far Site (DUSEL)		**137**	**02-May-11 A**	**16-Dec-11**
A1660	Finalize Initial VE Efforts	7	02-May-11 A	13-Jun-11
A1860	New Reference & Alt. Design Determinations	0	23-May-11 A	
A1670	Assemble Conceptual Design Report (Drawings and Specs)	97	24-May-11 A	05-Oct-11
A1640	**CDR Reviews (Far Detectors)**	10	06-Oct-11*	19-Oct-11
A1680	Conceptual Design Review Findings/ Report	10	20-Oct-11	02-Nov-11
A1610	Create Conceptual Design BOEs/ Cost Estimates	20	20-Oct-11	16-Nov-11
A2010	Risk Assessment	10	20-Oct-11	02-Nov-11
A1650	Incorporate Comments from Conceptual Design Review - Finalize Conceptual Design/ Reports/Etc	20	03-Nov-11	02-Dec-11
A1730	Update Resource Load Schedule (with Updated Cost Est)	20	17-Nov-11	16-Dec-11



Assumes:
Homestake is Far Site
Adequate FY2012 Funding

Summary

- LBNE is an important next step in neutrino physics.
  - It will be the only experiment capable of fully untangling the physics governed by θ_{13}, for $\sin^2 2\theta_{13} \gtrsim 0.01$.
  - It will have world-leading reach for measuring θ_{13} down $\sin^2 2\theta_{13}$ on the of order 10^{-3}, when coupled to Project X.
- It will enable a broad physics program including:
  - other precision neutrino oscillation measurements
  - search for proton decay,
  - measurements of neutrinos form a core-collapse supernova in the galaxy,
  - studies utilizing atmospheric neutrinos,
  - with potential upgrades, measurement of the flux of “relic” supernova neutrinos and measurements with solar neutrinos.

Summary

- LBNE is exploring a range of configurations to implement this crucial experiment, with corresponding ranges of cost.
- All are capable of achieving the primary scientific goals in a period of 10-14 years of running:
  - long-baseline $\nu_\mu \rightarrow \nu_e$ oscillation measurements
  - proton decay searches
  - neutrino astrophysics
- Assuming a positive decision regarding Homestake, we plan to be ready for CD-1 in FY2012.