LBNE Collaboration Status

Bob Wilson
Colorado State University

Fermilab Program Advisory Committee
6/4/13

Artist: Winslow Homer, 1836-1910

http://prints.encore-editions.com/500/0/ship-building-gloucester-harbor-drawn-by-winslow-homer-w-h.jpg

Overview

- Science Motivation
- Collaboration Organization
- Strategy Towards World Class Long-Baseline Program
- Oscillation Parameters Sensitivities
- International Partners
- Updates
  - 35 t Prototype
  - Surface Operation
  - Beamline
- Conclusion

Scientific Motivation

- CP Violation in neutrino sector
  - Violation of a fundamental symmetry and viability of leptogenesis models
- Neutrino Mass Hierarchy
  - GUTs, String Theory, Dirac/Majorana nature and feasibility of $0\nu\beta\beta$ decay
- Testing the Three-Flavor Paradigm
  - Precision measurements of known fundamental mixing parameters
  - New physics -> non-standard interactions, sterile neutrinos… (beam+ atmos.ν's)
  - Precision neutrino interactions studies (near detector)
- Proton decay measurement
  - Grand Unification Theory
- Astrophysics
  - Supernova ν burst flux
- **These science goals led to DOE CD-0 approval in January 2010**
  - It took a decade of high-level review panel recommendations (P5, NAS etc.) and international consensus on the science to achieve this

LBNE Collaboration

Alabama
Argonne
Boston
Brookhaven
Cambridge
Catania
Columbia
Chicago
Colorado
Colorado State
Columbia
Dakota State
Davis
Drexel
Duke
Duluth
Fermilab
Hawaii
Indian Group
Indiana
Iowa State
Irvine
Kansas State
Kavli/IPMU-Tokyo
Lawrence Berkeley NL
Livermore NL
London UCL
Los Alamos NL
Louisiana State
Maryland
Michigan State
Minnesota
MIT

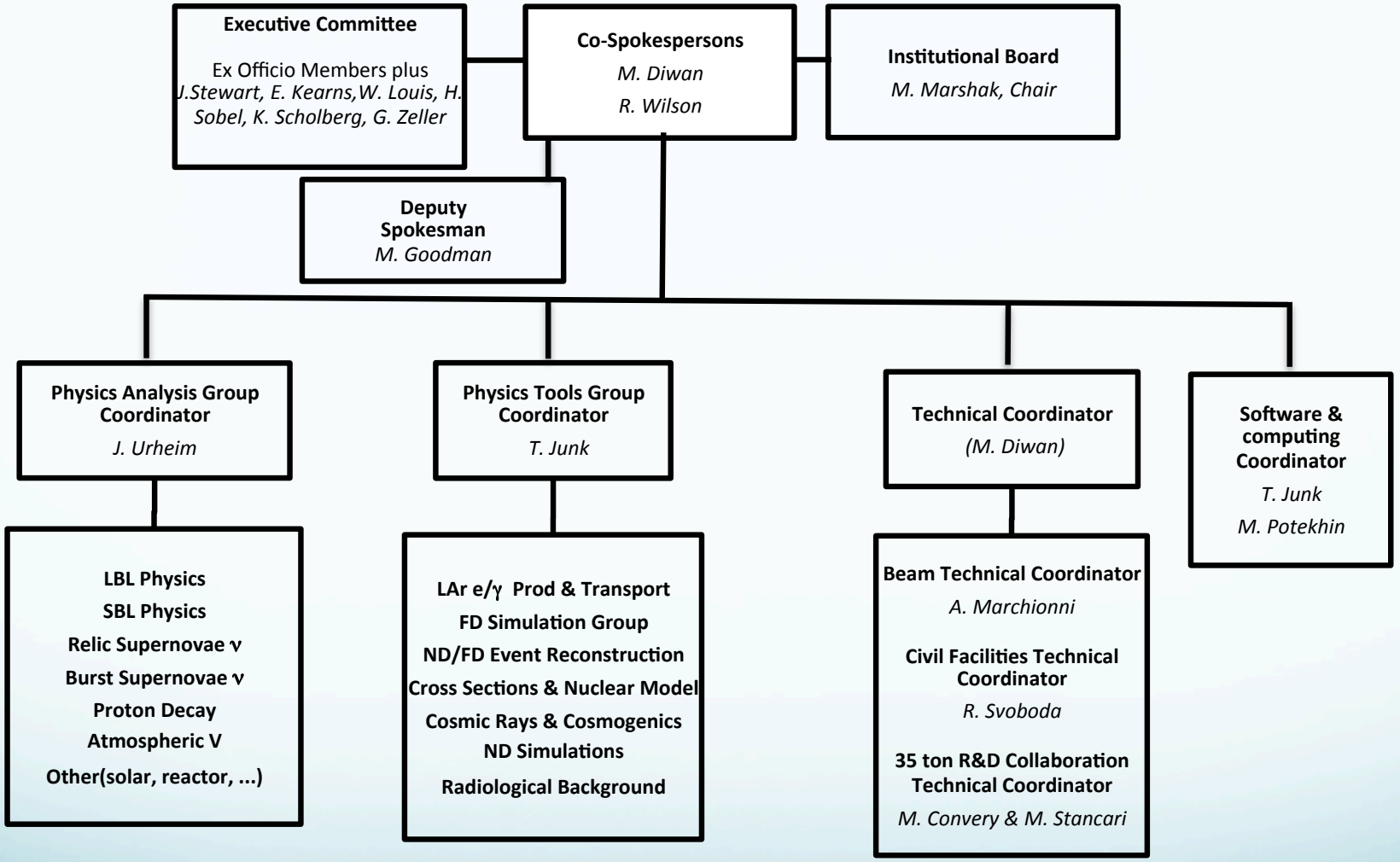
375 collaborators, 61 institutions, 5 countries
(April 2013)

Fermilab, March 2013

NGA
New Mexico
Northwestern
Notre Dame
Oxford
Pennsylvania
Pittsburgh
Princeton
Rensselaer
Rochester
Sanford Lab
Sheffield
SLAC
South Carolina
South Dakota
South Dakota State
SDSMT
Southern Methodist
Sussex
Syracuse
Tennessee
Texas, Arlington
Texas, Austin
Tufts
UCLA
Virginia Tech
Washington
William and Mary
Wisconsin
Yale

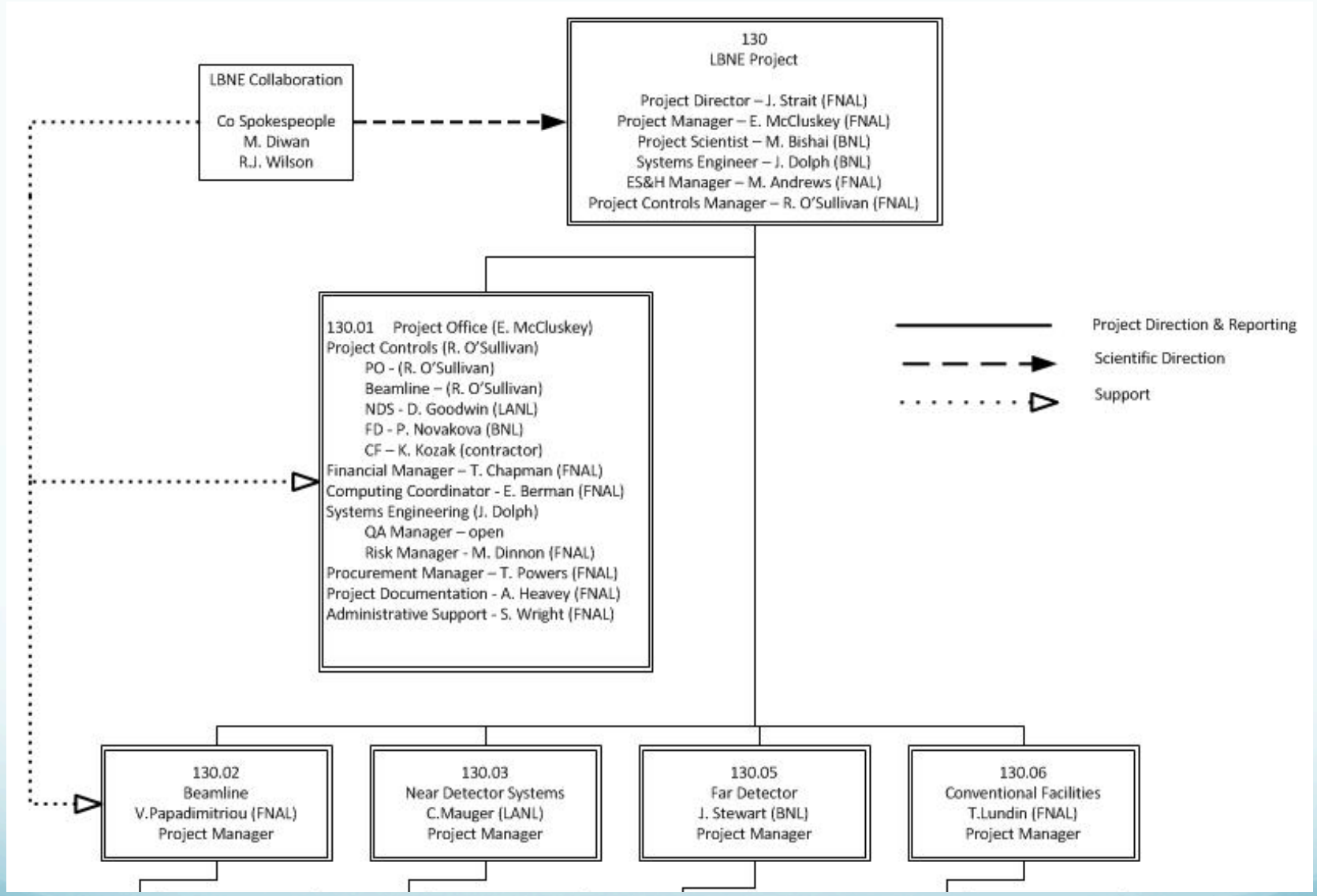
New since last PAC:
Texas-Arlington, Harish-Chandra Research Institute (India), William and Mary, SLAC

LBNE Collaboration Organization Chart (May 2013)



- International aspects being developed
  - We organized a symposium on international collaboration (Oct. 2012)
  - Consulting with ATLAS, CMS, SLAC (D. Leith), potential partners

LBNE Project Organization Chart



- ~ 70 people on the project team (down to L3/L4)

Collaboration Executive Committee

- EC composition revised December 2012
  - Reduce size and number of project management members
- Ex-officio members: the Co-spokespersons, the Deputy Spokesperson, the LBNE project director, the physics analysis working group convener, the physics tools working group convener, and the IB chair.
- Three members elected each year by the IB with one year terms.
- Three members appointed by the co-spokespersons for one year terms.
- Starting in January 2014, the composition of the executive committee should reflect the percentages of international participation.
- The co-spokespersons can also invite additional advisors to attend EC meetings as non-voting participants.
- A representative from the Young LBNE group is invited to meetings as an observer

LBNE is…

- A new neutrino beam at Fermilab
  - 700 kW, 60-120 GeV proton beam, 2.3 MW capable
- A near neutrino detector
- An optimal 1300 km baseline: Fermilab-SURF
- A 34 kt Liquid Argon TPC with 4550' overburden (SURF 4850L)

- An optimized cost/time effective path to the science
  - Large θ_{13} means δ_{CP} accessible

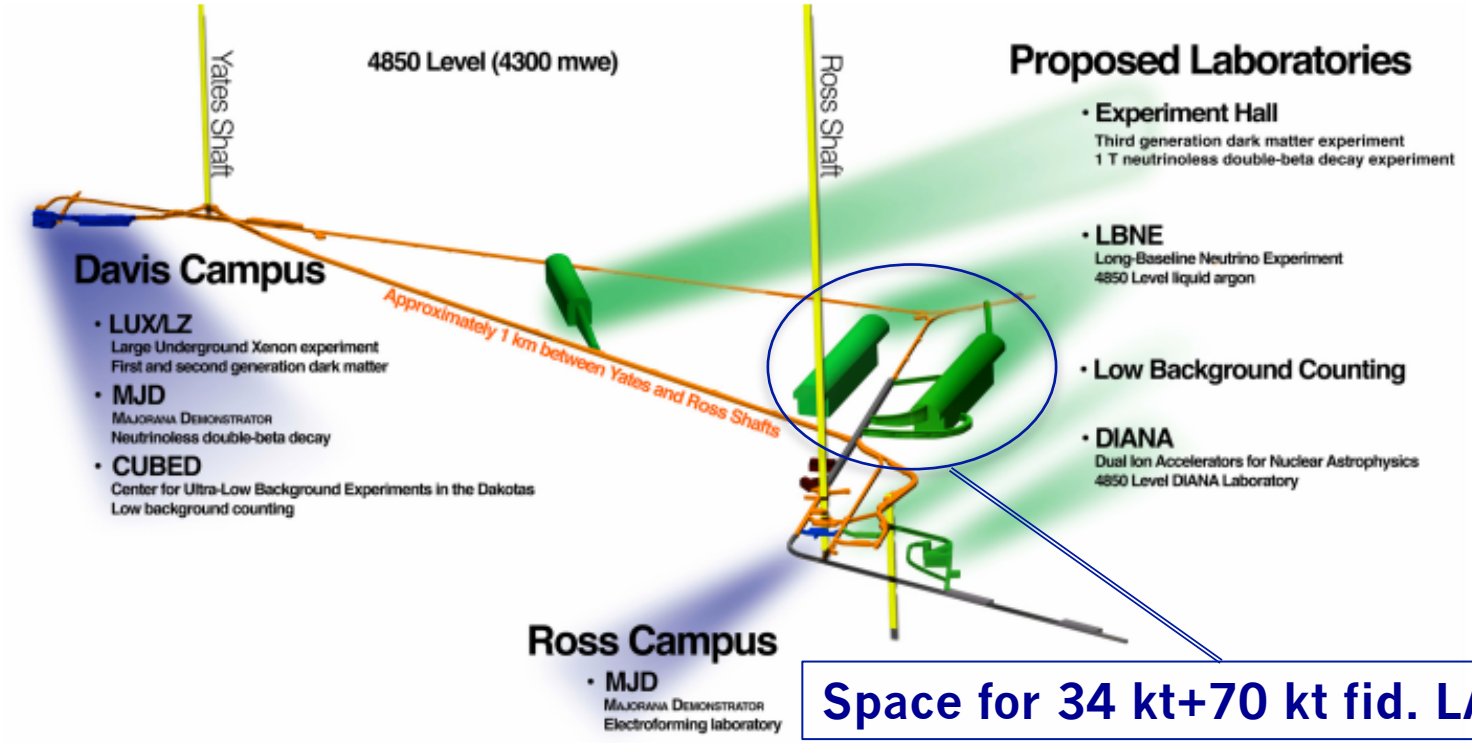
- This conceptual design…
  - Completed a successful CD-1 Director's Review (March 2012)
  - Updated cost estimate (July 2012):
    ~$1.5B (incl. contingency + escalation)

Sanford Underground Research Facility

Deep thoughts

Notes from the underground from Communications Director Bill Harlan — Tuesday, May 28, 2013

Sanford Lab: the long view



This graphic by Multimedia Specialist Matt Kapust illustrates what the 4,850-foot level could look like by the mid-2020s. Violet indicates current experiments. Green indicates proposed research. These experiments represent a future for the Sanford Lab that could extend to 2040 and beyond.

Staging the Experiment

- March 2012 DOE asked us to stage LBNE construction; an external review panel considered reconfiguration options including different far sites (including existing MINOS and NOvA sites)
  - We accepted the recommendation to proceed with emphasis on the most important aspects: 1300 km baseline, a site with infrastructure to support a massive underground detector (SURF) and a full capability beam
- December 2012: CD-1 approval for $867M first phase DOE funding
- The first phase goals for the Long-Baseline facility **go beyond** that described in CD-1, which was constrained by DOE budget
  - explanation to follow…

CD-1 Approval Document

lbne-doc-6681

Critical Decision 1
Approve Alternative Selection and Cost Range
of the
Long Baseline Neutrino Experiment (LBNE) Project
(Line Item Project 11-SC-40)
at the
Fermi National Accelerator Laboratory and
Sanford Underground Research Facility
Office of High Energy Physics
Office of Science

Purpose

The purpose of this paper is to document the review and approval by the DOE Office of Science Energy Systems Acquisition Advisory Board-equivalent for Critical Decision 1 (CD-1) "Approve Alternative Selection and Cost Range" for the Long Baseline Neutrino Experiment (LBNE) Project at the Fermi National Accelerator Laboratory (Fermilab) and Homestake Mine site in Lead, South Dakota.

Project Overview

The purpose of the LBNE Project is to design, construct and install an intense neutrino beam at Fermilab in Batavia, IL and a large neutrino detector located at the Homestake Mine site 1,300 kilometers away in Lead, SD. The neutrino beam is directed toward the detector, which is used to measure and study neutrino behavior over the long distance of travel, to yield fundamental knowledge about neutrino properties.

The High Energy Physics (HEP) program of the DOE Office of Science (SC) conducts basic research into the nature and interactions of the fundamental constituents of matter. As the only US Laboratory fully dedicated to particle physics, Fermilab is a major component of the US HEP Program. The LBNE experiment will use the accelerator facility at Fermilab to investigate neutrino oscillation, mass ordering and matter-antimatter asymmetry, which requires the combination of large detectors and more powerful beams capable of observing neutrino interactions where the beam and detector(s) are separated by 1000-1500 km.

The LBNE Project will provide U.S. researchers the opportunity to maintain and enhance a world-leading program in neutrino physics and support DOE HEP's strategic plan to mount a balanced and vital U.S. program in particle physics in the next decade. Without the research capabilities implemented in this project, crucial information fully characterizing the neutrino sector such as the degree of Charge-Parity (CP) violation and the ordering of the neutrino mass states, would not be obtained, compromising the ability to understand the matter-antimatter asymmetry and resulting dominance of matter in the universe.

To meet the scientific and technical objectives for the LBNE experiment, the following draft key performance parameters have been developed.

Critical Decision 1, Approve Alternative Selection and Cost Range
for the LBNE Project

Approval

Based on the information presente din this document and at the ESAAB review, I approve Critical Decision 1, Approve Alternative Selection and Cost Range for the Long Baseline Neutrino (LBNE) Project.

William Brinkman, Acquisition Executive
Director, Office of Science

12/10/12
Date

CD-1 Approval Document

lbne-doc-6681

Critical Decision 1
Approve Alternative Selection and Cost Range
of the

Critical Decision 1, Approve Alternative Selection and Cost Range
for the LBNE Project

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kilometers away in Lead, SD. The neutrino beam is directed toward the detector, which is used

Based on the above considerations, the alternative, *Construct a new low energy neutrino beamline with a 10 kton liquid LAr-TPC surface detector at Homestake site in South Dakota, at a 1,300 km baseline distance from Fermilab,* is the recommended alternative for LBNE. This preference is driven by the scientific advantages of a longer distance baseline between the neutrino source and detector afforded by siting the detector on the Homestake site. This alternative requires a new neutrino beamline to meet the necessary beam directional, energy and long-term operability requirements needed to initiate and sustain the LBNE program. This alternative provides the best alternative to realize a timely, cost-effective and scientifically capable LBNE, and provides a solid foundation for cost effectively extending scientific reach should additional funds become available.

CD-1 Approval Document

lbne-doc-6681

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William Brinkman, Acquisition Executive
Director, Office of Science

12/10/12
Date

Tailoring of the scope definition prior to CD-2 to enhance scientific capabilities may also be considered. The physics opportunities offered by the beam from Fermilab and the long baseline may attract the support of other agencies both domestic and international. Contributions from such other agencies offer alternative funding scenarios that could enhance the science capabilities of the Project. If additional domestic or international funding commitments are secured sufficiently prior to CD-2, the DOE LBNE Project baseline scope could be refined before CD-2 to include scope opportunities such as a Near Neutrino Detector complex at Fermilab or an underground location at SURF for the far detector.

To meet the scientific and technical objectives for the LBNE experiment, the following draft key performance parameters have been developed.

Staging the Experiment

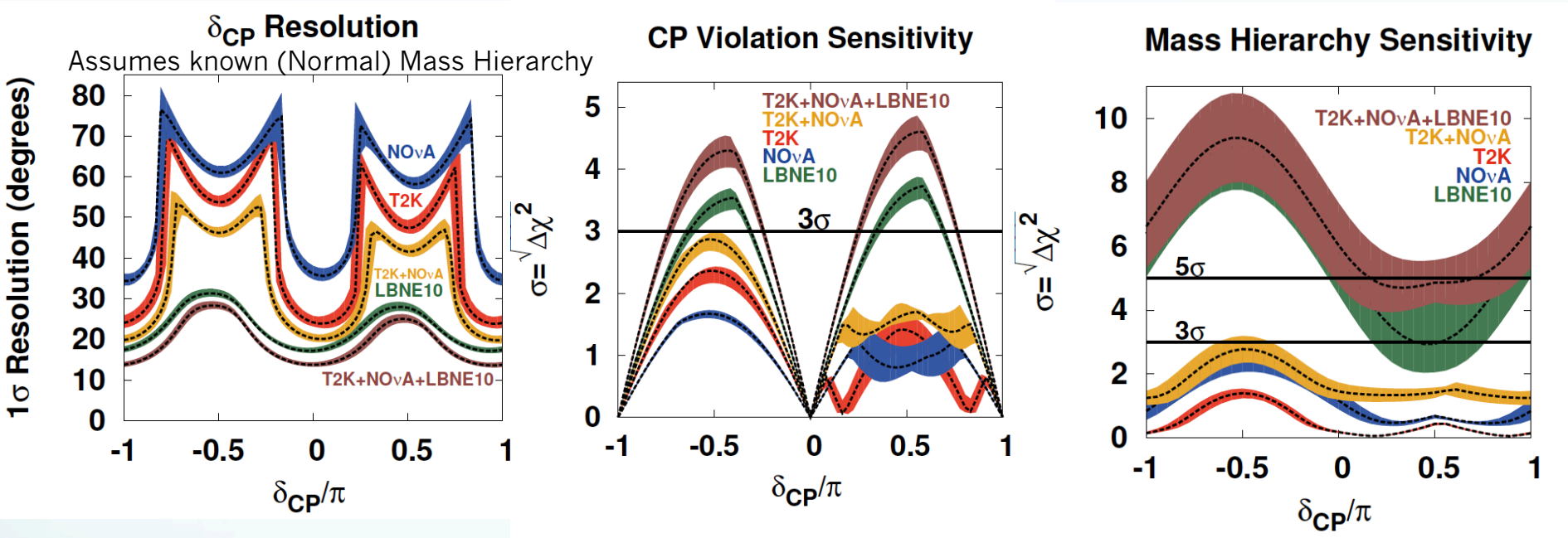
- CD-1 describes an extensive costing and schedule for a 10 kt LAr far detector (LBNE10s) on the surface that fits current DOE cost constraints
- But...
  - *CD-1 approval explicitly allows for scope change enabled by new partners with additional resources;*
  - *the design is* **not** *fixed.*
- **First phase goal:**
  Greater than 10 kt far detector *underground* and a *full capability near detector*
- Example: Recent decision to defer surface site geotech in favor of underground investigation

A *Strawman* Plan

DOE initial investment of $867M

Additional Investment (TPC)	Capability Added	Science Gained	Science Priority
+ $140M	Underground placement	ATM nus, p-decay, SNB nus	Very High
+ $130-190M	Near Detector	Enhanced LB physics, near detector physics	Very High
+ ~$350M	Add FD mass underground (10 kt -> 34 kt)	Precision CP and other 3-flavor paradigm measurements; p-decay	Very High

Just LBNE10 Would be a Major Advance



Bands: 1σ variations of θ_{13}, θ_{23}, Δm_{31}^2 (Fogli et al. arXiv:1205.5254v3)

T2K 750 kW x 5 yr (7.8×10^{21}pot) ν

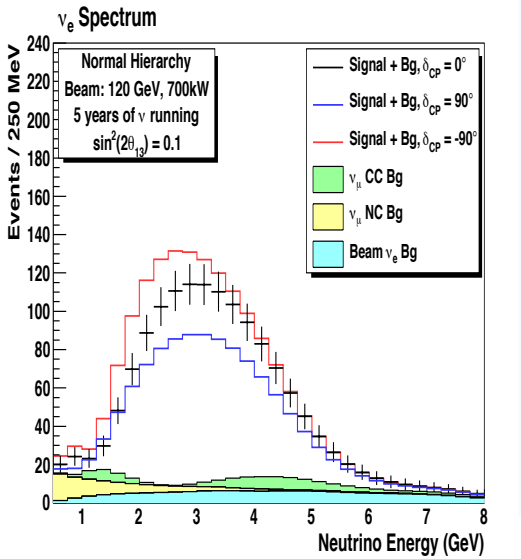
NOνA 700 kW x (3 yr ν + 3 yr $\bar{\nu}$) (3.8×10^{21}pot)

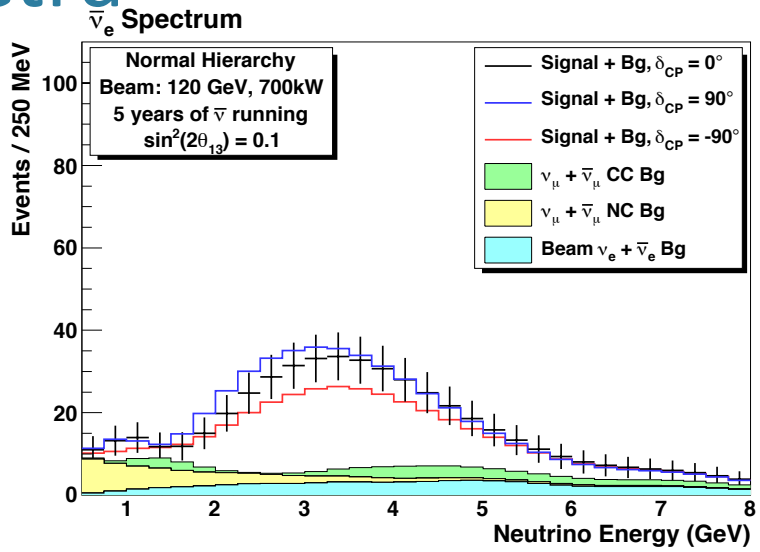
LBNE10 (80 GeV*) 700 kW x (5 yr ν + 5 yr $\bar{\nu}$)

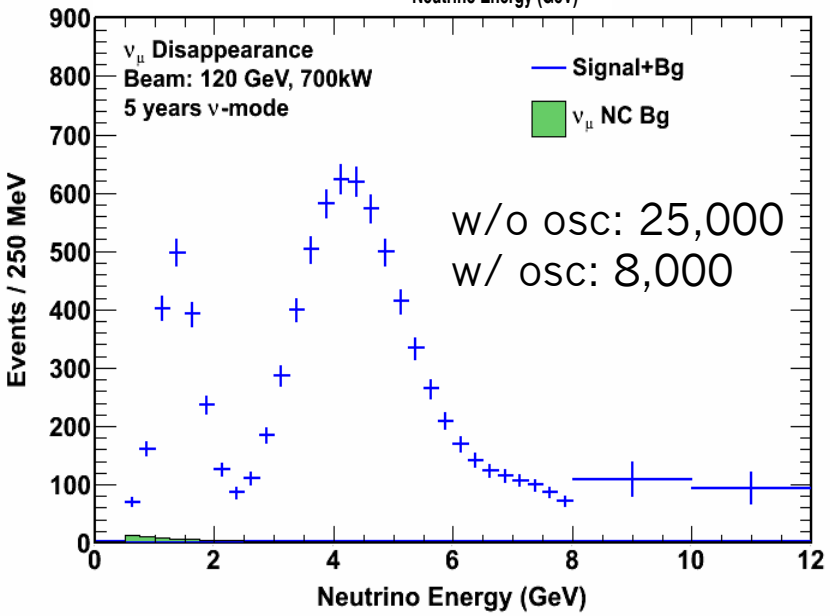
*Improved over CDR 2012 120 GeV MI proton beam

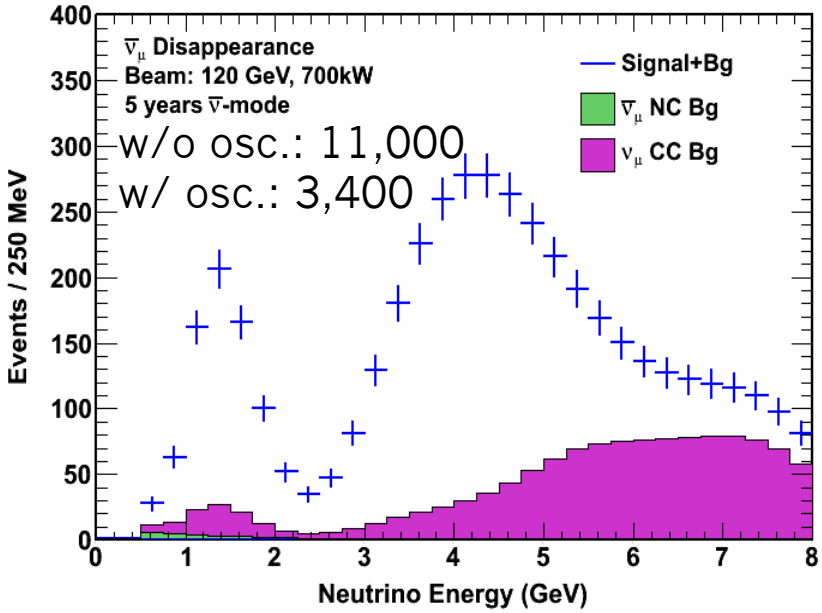
LBNE Spectra

34 kt fid.





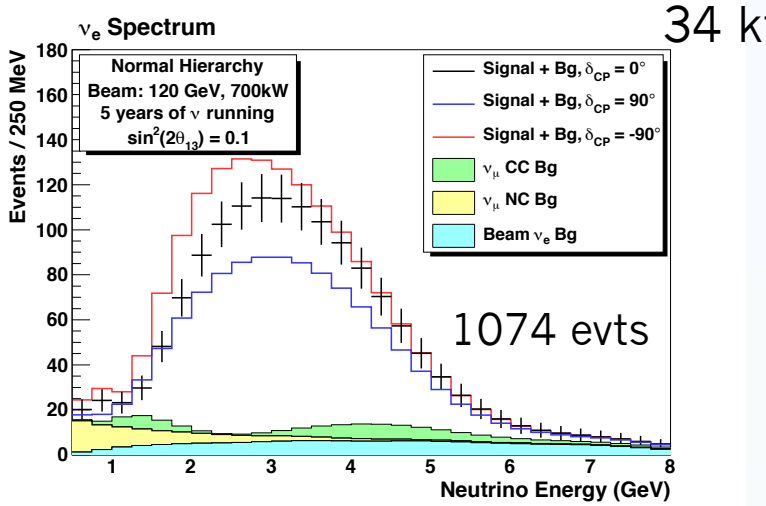


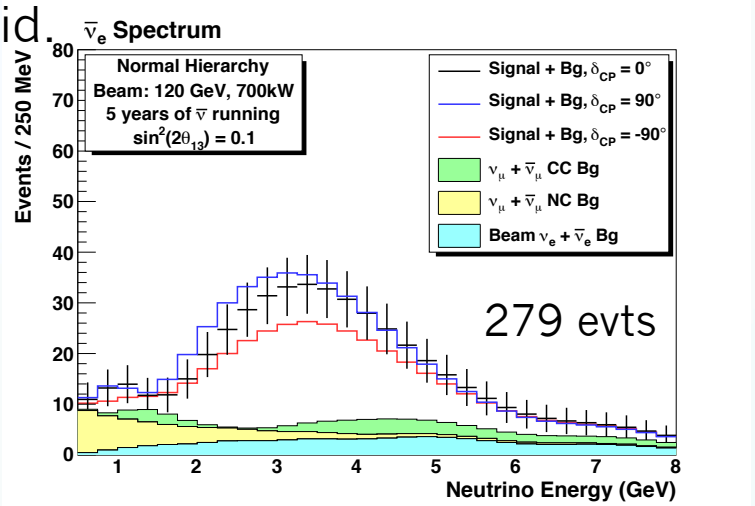


LBNE Spectra-Mass Hierarchy

34 kt fid.

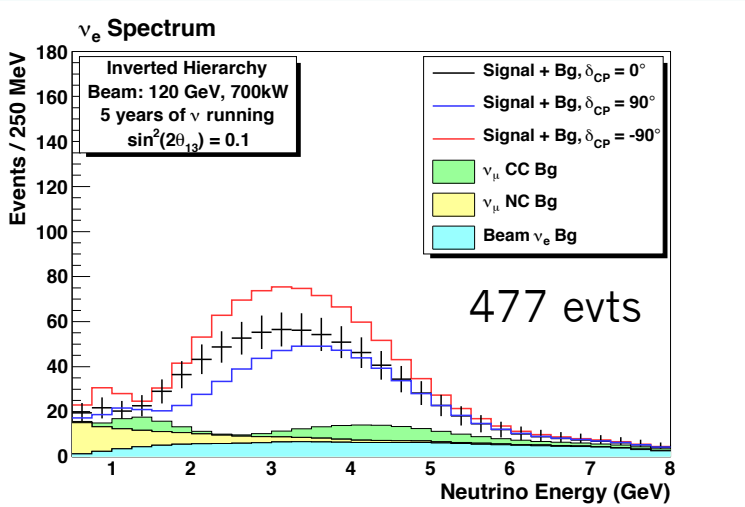
NORMAL

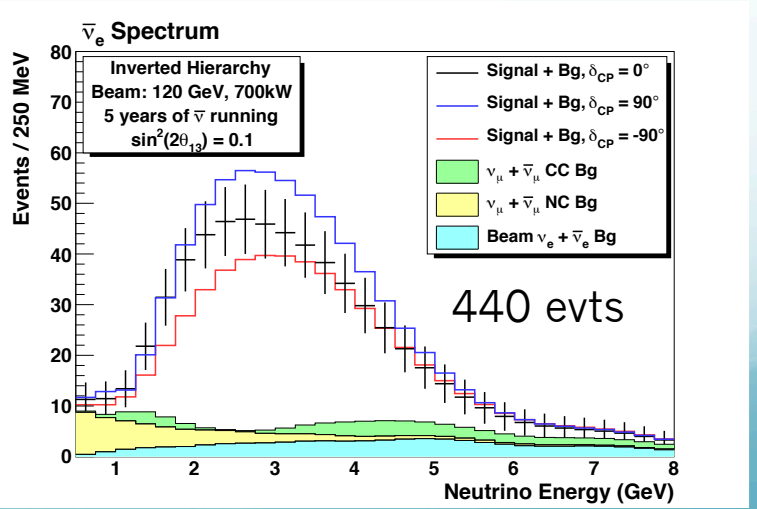




Difference due to mass ordering

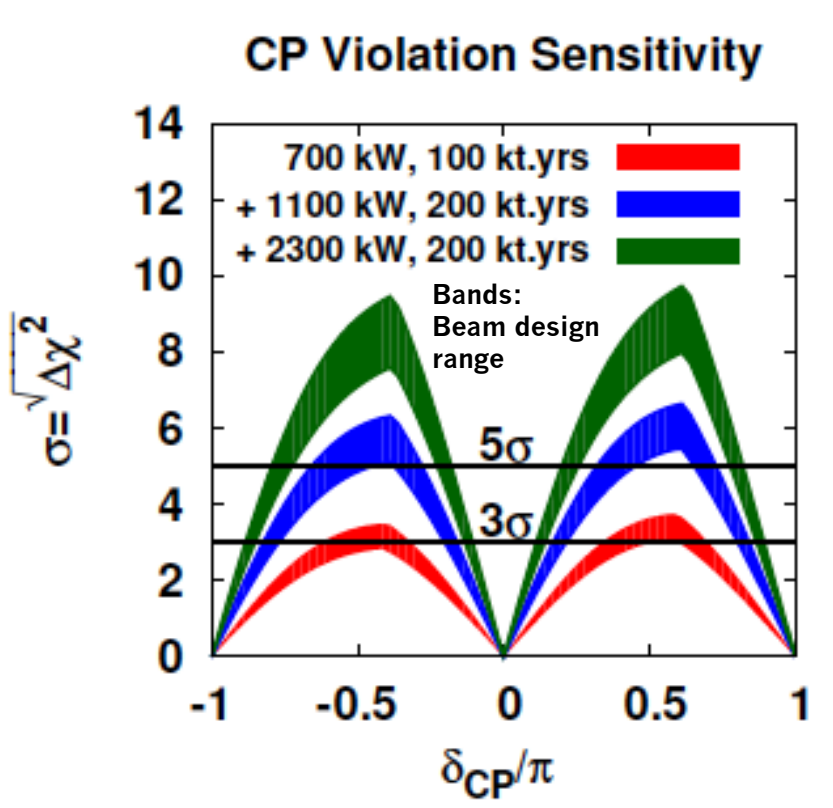
INVERTED

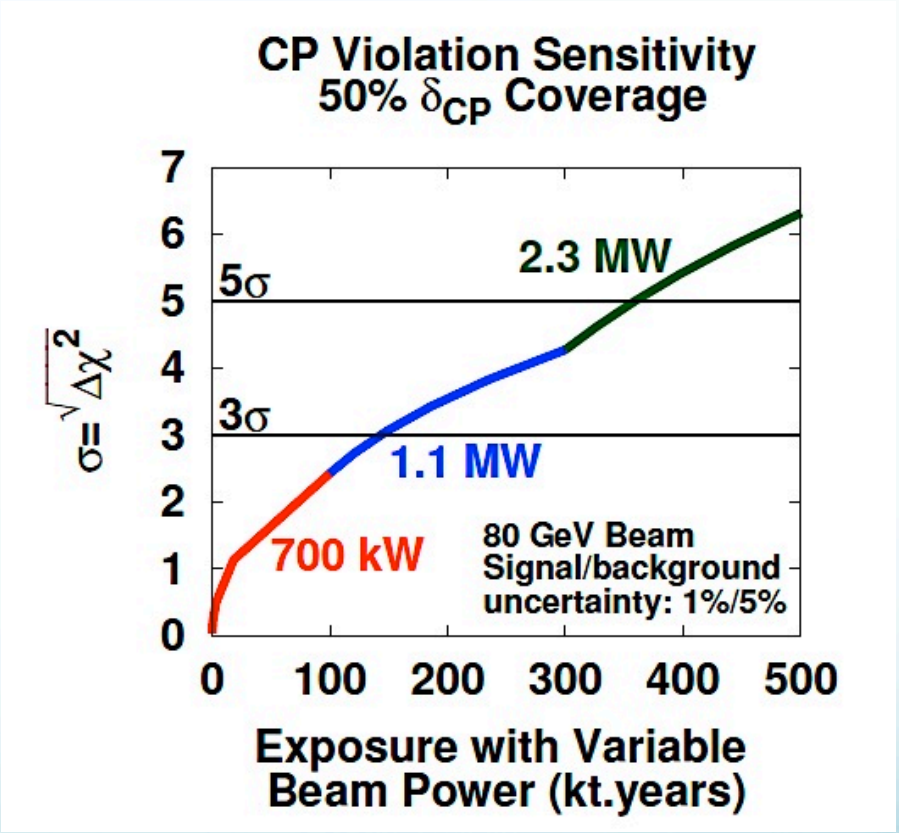




Spectra from PWG Report (2011)) - "2010 beam"

LBNE + Project X = Comprehensive Global Science Program

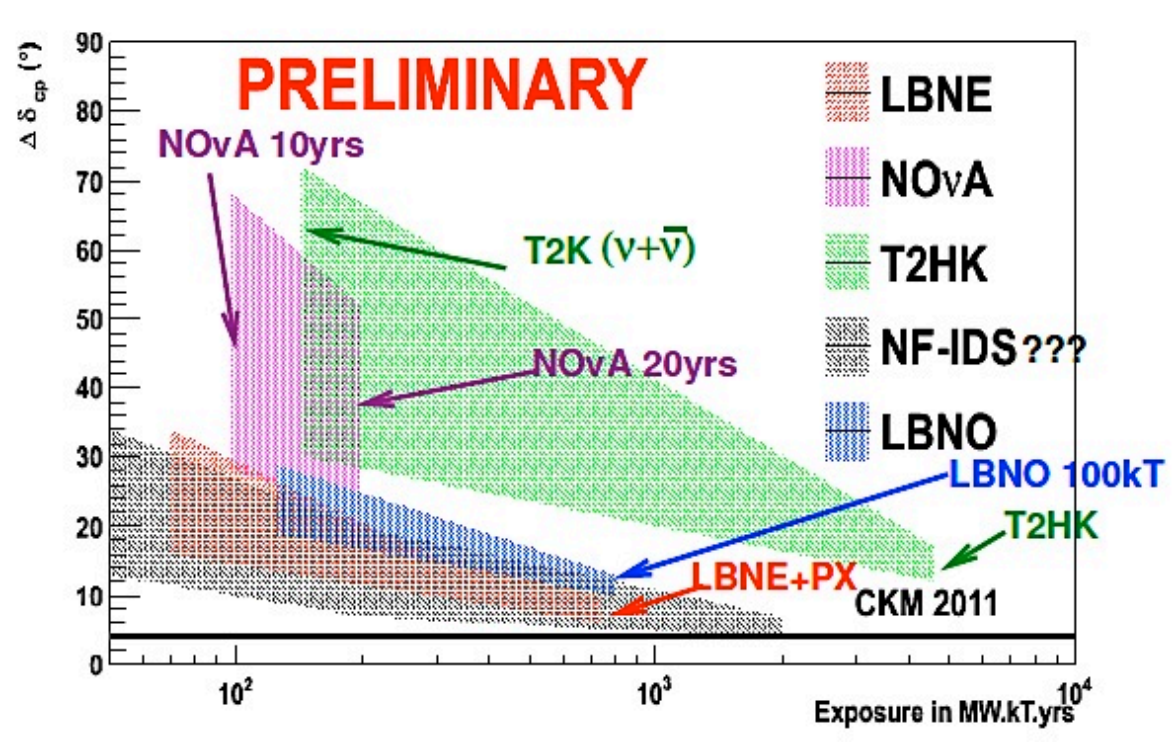




Optimized beam spectra (80 GeV MI protons)

Global Context

Bands: Range of δ_{CP} (best-worst case)



- LBNE+Project X will ultimately approach CKM level of precision

European Strategy Document

(Draft Jan., formalized 30 May, 2013)

High priority large-scale scientific activities

After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities have been identified as carrying the highest priority.

Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. *CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan.*

- This will establish a long-baseline neutrino experiment as a priority for CERN and directs serious discussions with LBNE
- This eases the way for individual European countries to engage in serious discussions with LBNE

θ_{13} large + CD-1+ the ESD draft were precipitating events for LBNE

Progress on International Partnerships

- UK
  - Five institutions already collaboration members; two beginning the process, three others have expressed intent
  - Presentations at UK "DPF" and held a well-attended LBNE-Info session
  - Met with STFC CEO, John Womersely
  - Internal discussions continuing within UK groups regarding participation in LBNE and related activities, and development of SOI (UK equivalent of CD-0)
- India
  - Five institutions already LBNE collaboration members
  - (Bi-)Weekly phone calls; joint LBNE-IIFC-νP in-person meeting at Fermilab 6-7 June to develop joint near- and longer-term work plans
  - Near Detector proposal to Department of Atomic Energy and Department of Science and Technology in India is pending

Progress on International Partnerships

- Italy
  - C. Rubbia/A. Guglielmi visit to Fermilab, Jan.; discussions in NeuTel 13 (Venice) with INFN and ICARUS groups; follow-up phone calls
  - In-person workshop in Padova 17-18 June to develop Italian role in LBNE and proposal to INFN
  - Seminars planned for several institutions on 19 June
  - Possible meeting at INFN headquarters, Rome, 19 June
- Brazil
  - Bi-weekly phone calls focused on developing list of potential collaboration topics
  - In March LBNE senior representatives visited Brazilian Synchrotron Light Laboratory, U. Goias, U. Campinas, U. ABC, CBPF, and Sao Paolo regional funding agency (FAPESP); we will attend Brazilian DPF in August and do an LBNE-Info session
- LAGUNA/LBNO
  - Occasional informal discussions continue (w/ A. Rubbia and D. Wark)
  - Possible initial collaboration on 6x6x6 m^3 prototype planned at CERN

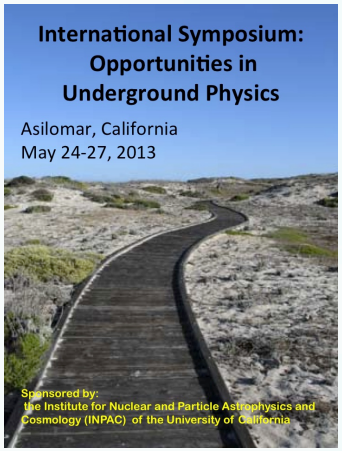
Progress on International and Other Partnerships

- Russia
  - Visit to Fermilab by Director of JINR, Dubna; reiterated interest in joining LBNE and NOvA; added to Fermilab-JINR MOU
- Japan
  - Fermilab-KEK LAr R&D cooperation
  - Informal discussions
- CERN
  - European Strategy formally adopted 30 May
  - Medium-term plan implementing the strategy to be presented to Council mid-June
  - Fermilab management discussion with CERN leadership regarding CERN role in coordinating possible European involvement in LBNE

Other Partnerships

- NSF
  - Twice-monthly meetings launched within the LBNE Collaboration aimed at developing a substantial proposal
- Illinois and South Dakota
  - Various options considered by Fermilab

ISOUPs



- International Symposium on Underground Physics
  - May 24-27, 2013
  - The “s” indicates a “Snowmass” meeting
- Forum to strengthen international support for large-scale underground detectors
- Strong theorist participation
- Senior lab representatives from Europe, Japan, US

Session 8: Panel Discussion (Moderator: R.Svoboda)

09:50-11:30 Panel Discussion and Q&A

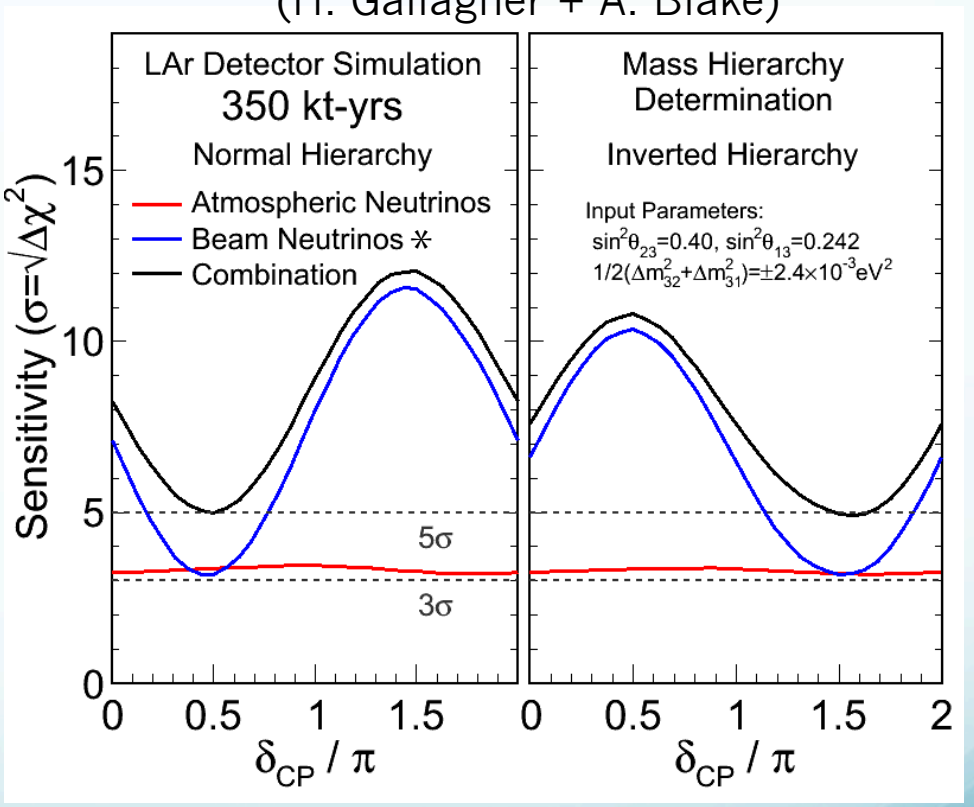
J.Hewett (SLAC)	A.Masiero (INFN)
M.Nessi (CERN)	P.Oddone (FNAL)
Y.Okada (KEK)	J.Pati (SLAC)
N.Roe (LBNL)	H.Sobel (UC Irvine)

- Will produce a document for Snowmass

ISOUPs - Atmospheric Neutrinos

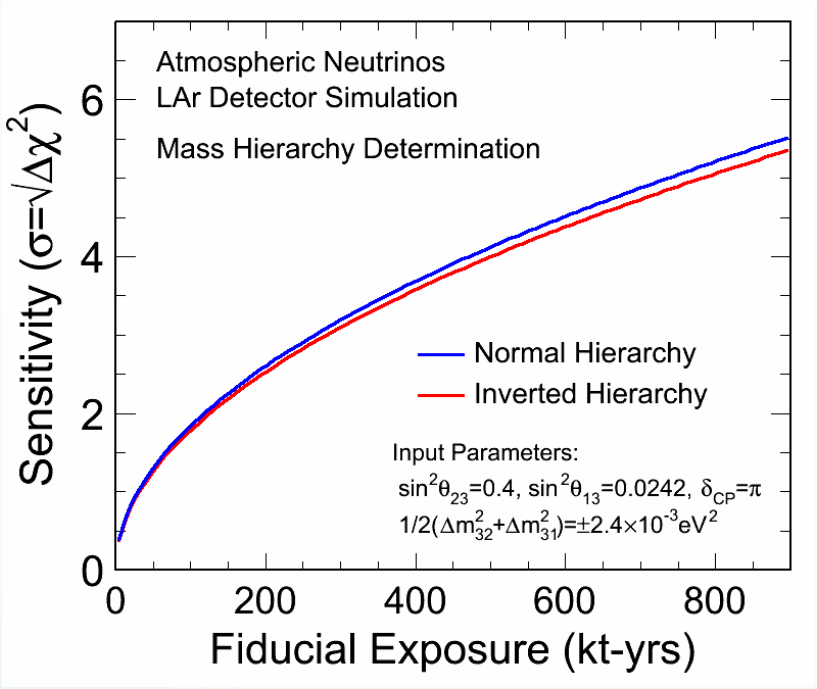
- Large range of energy and baseline
- In δ_{CP} range least favorable to the beam, atmospheric neutrinos have MH sensitivity comparable to the beam
- Atmospheric neutrinos help eliminate degeneracies in beam-only analyses
- MH from atmospheric neutrinos alone is >3σ for both hierarchies and all values of δ_{CP} in 350 kt-yrs
- Combined sensitivity is >5σ for both hierarchies and all values of δ_{CP} in 350 kt-yrs.
- θ_{23} octant sensitivity
- Searches for new physics

PRELIMINARY
(H. Gallagher + A. Blake)



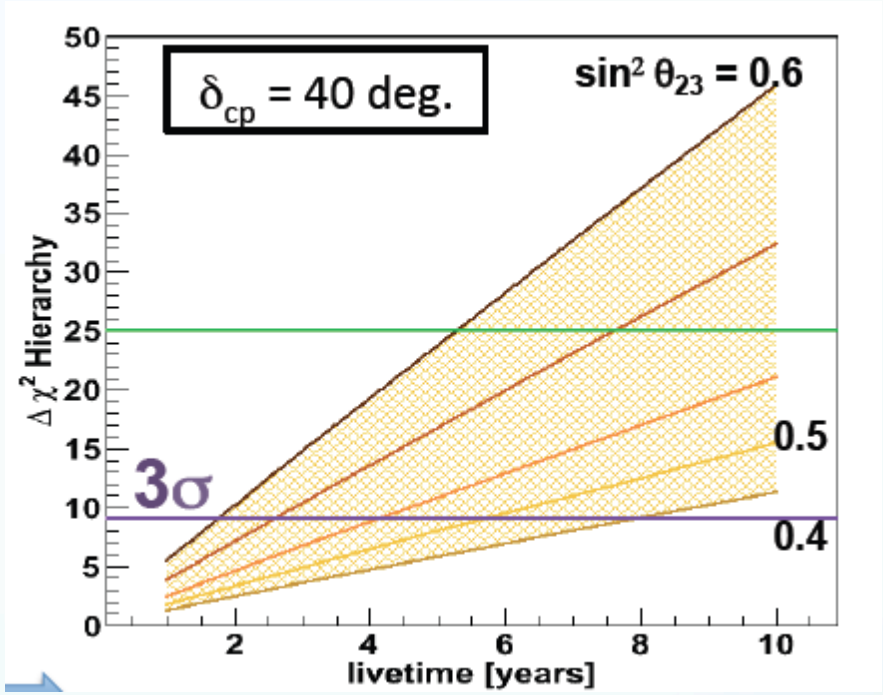
- * Conceptual Design Report beam
- ~4000 e-like, 6000 μ-like fully-contained events
- Proton and decay-electron tagging for Atm. nus calculation

ISOUPs - Atmospheric Neutrinos



LBNE MH Sensitivity

(H. Gallagher + A. Blake)

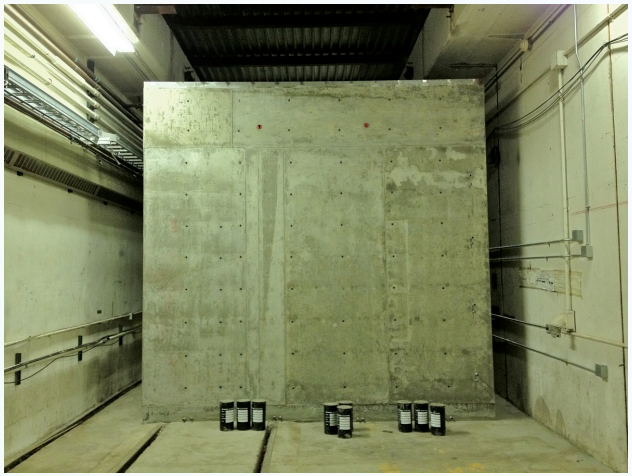


HyperK MH Sensitivity

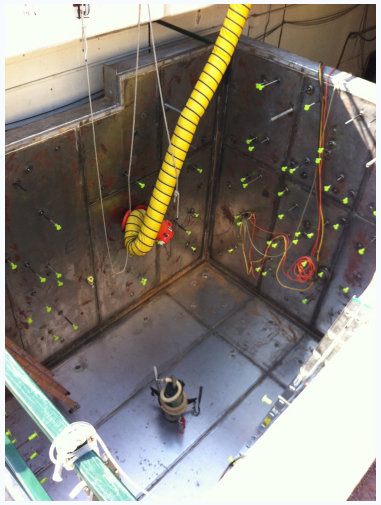
(C. Walter)

- **HyperK and LBNE have comparable sensitivity to the MH with atmospheric neutrinos!**
- LBNE's higher resolution of event energy and direction makes up for smaller mass.

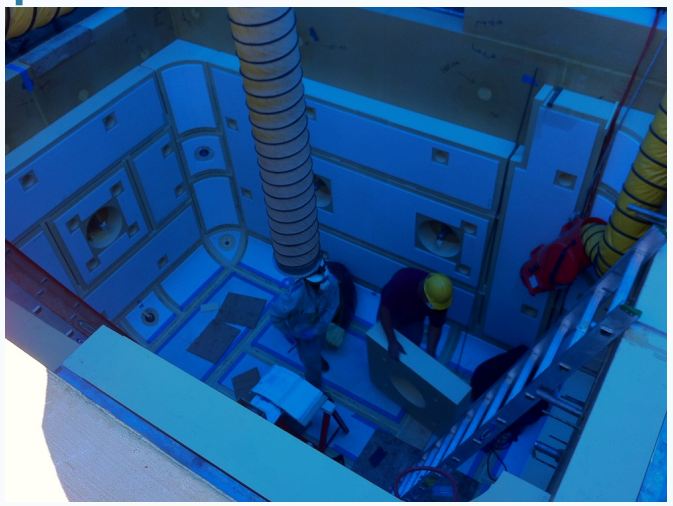
35t Prototype



Concrete vault in PC4 trench



Leak testing steel
vapor barrier inside vault



Installing insulating foam (working under a blue tarp in mid summer!)

Installation of Plate B top with Ports

Hut in place (no more tarp!)

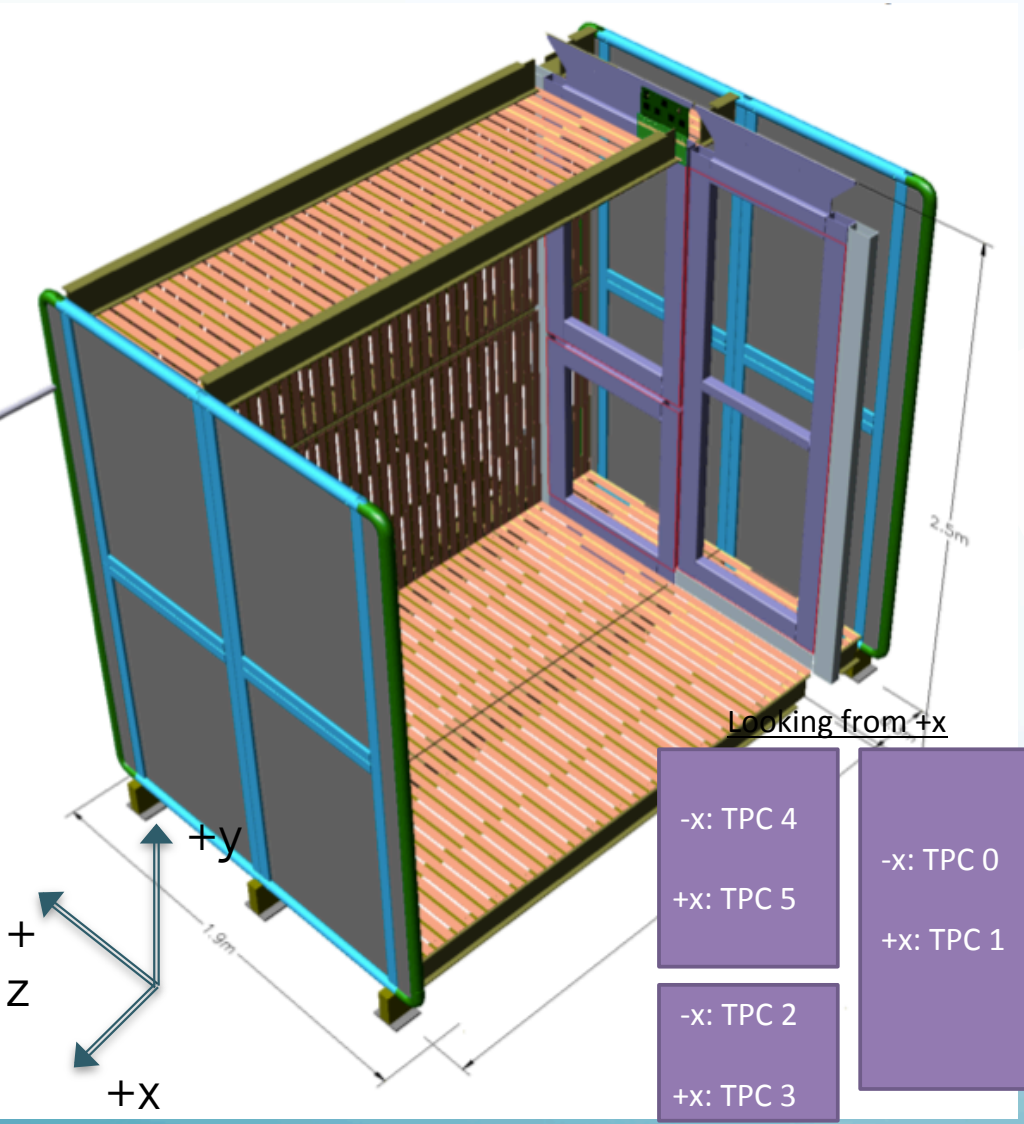
Getting LBNE 35-ton cryostat ready for cool-down

David Montanari stands by the LBNE 35-ton cryostat. *Photo: Anne Heavey*

35t Prototype Schedule

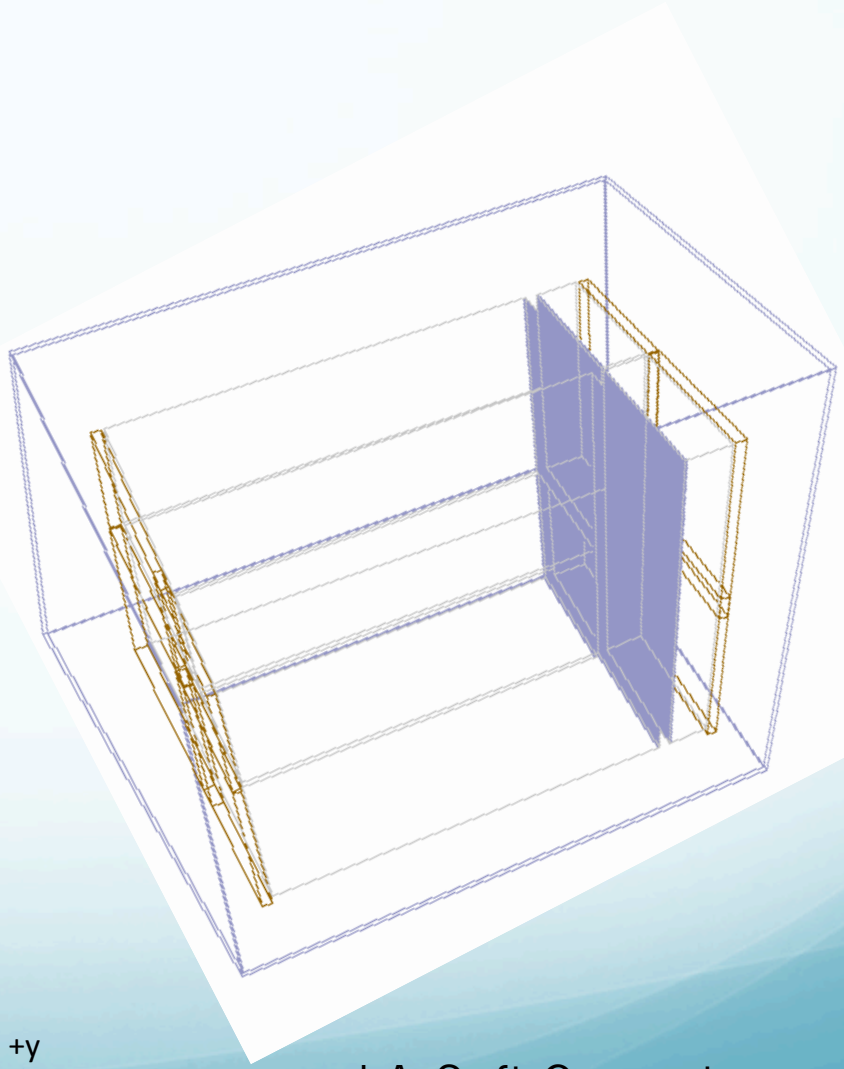
- Phase 1-- Demonstrate Membrane Cryostat can achieve LBNE Purity requirements
  - Continuing hookups to LAPD Purification facility
  - Expect cool-down and purity run (~2 months) at end of this summer
- Phase 2-- Install and operate reduced-scale LBNE TPC with Photon Detectors
  - Install in summer of 2014
  - Run in Fall 2014
  - Use prototype versions of the LBNE Far Detector systems
    - e.g. DAQ proposed by SLAC recently selected

35t TPC Prototypes



Looking from +x

-x: TPC 4 +x: TPC 5	-x: TPC 0 +x: TPC 1
-x: TPC 2 +x: TPC 3	

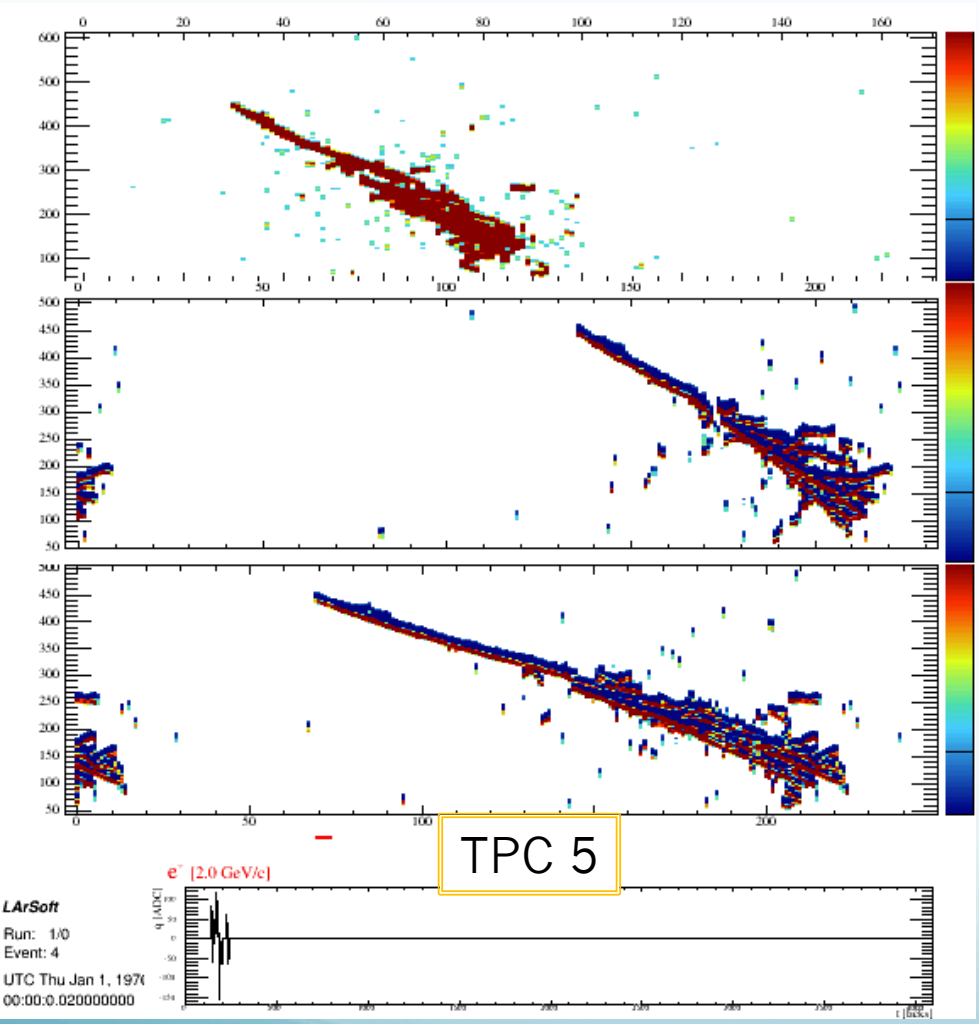


LArSoft Geometry

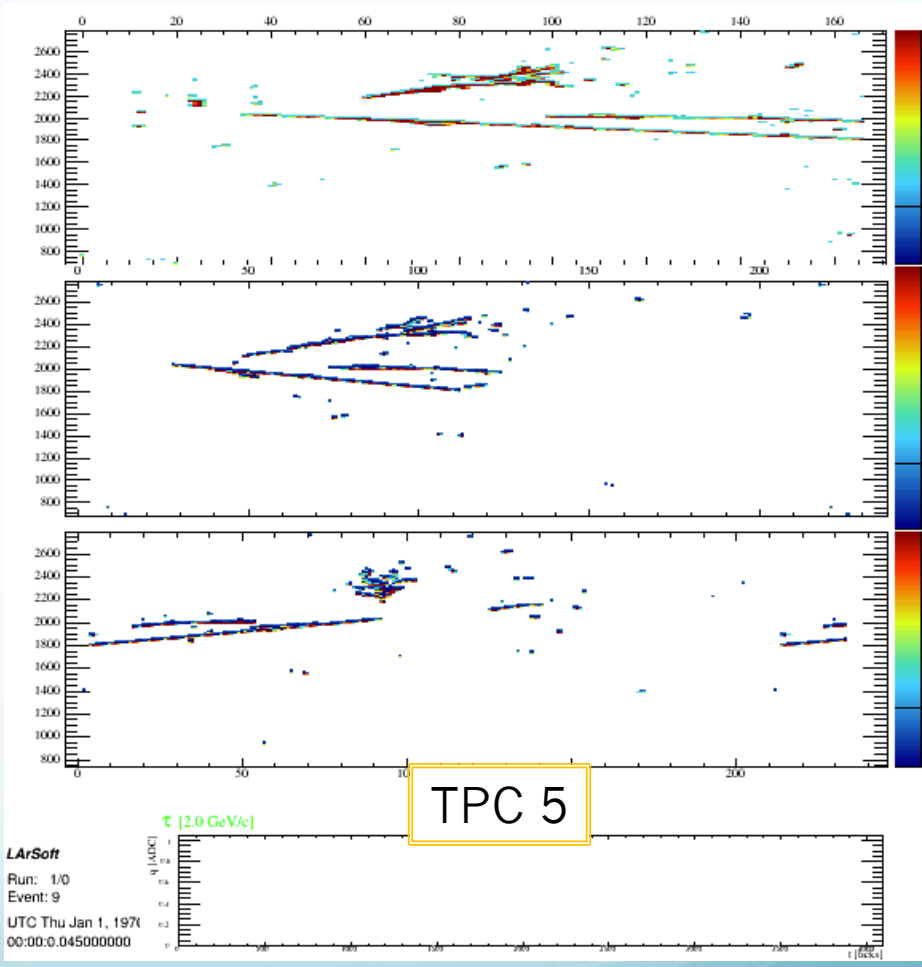
+y
+z

35t Simulation

2 GeV Electron



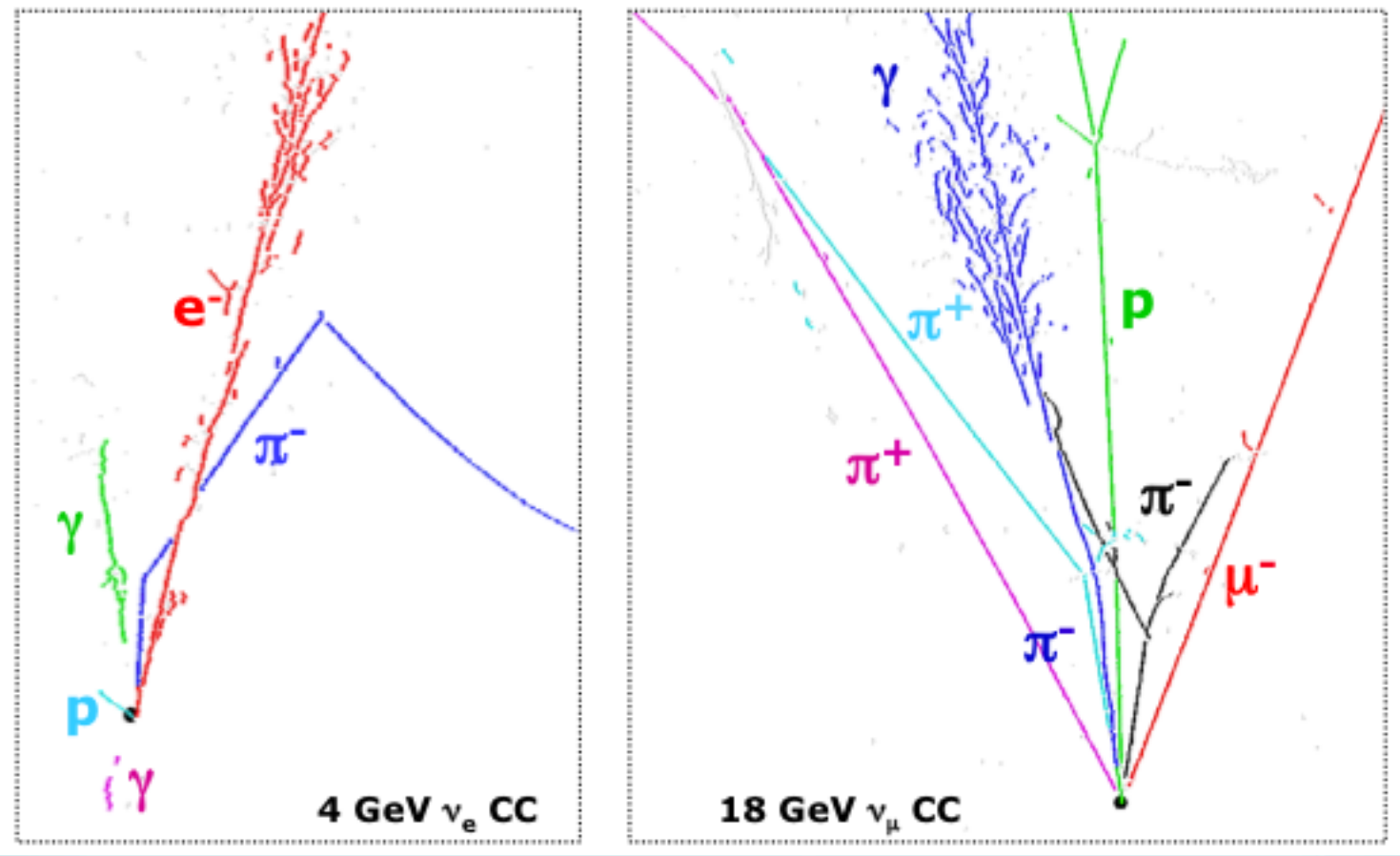
2 GeV Tau



- Produced with LArSoft package – now managed by Fermilab Scientific Computing Division

LAr Reconstruction

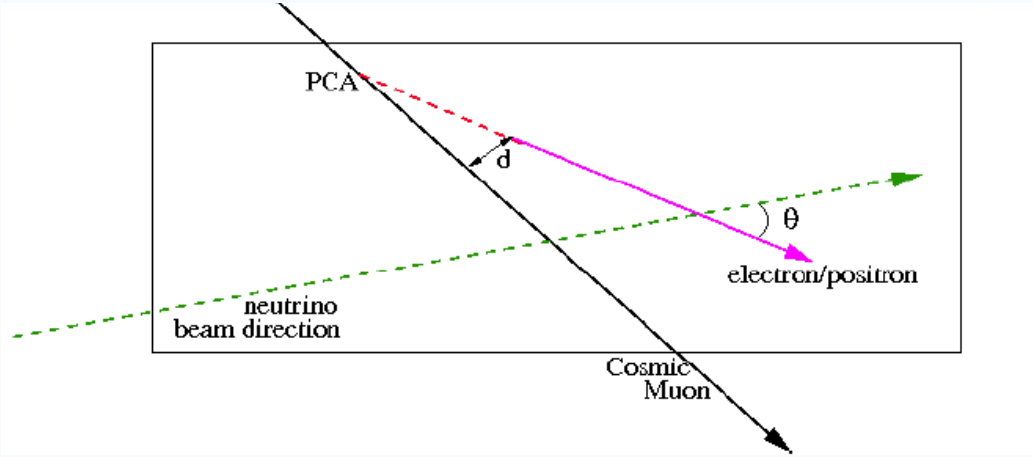
2-d



- Incorporating PANDORA (Cambridge) into LBNE framework
  - Currently LBNE events in MicroBooNE geometry
- Colors are the reconstructed particle, labels are truth

10 kt Surface Operation

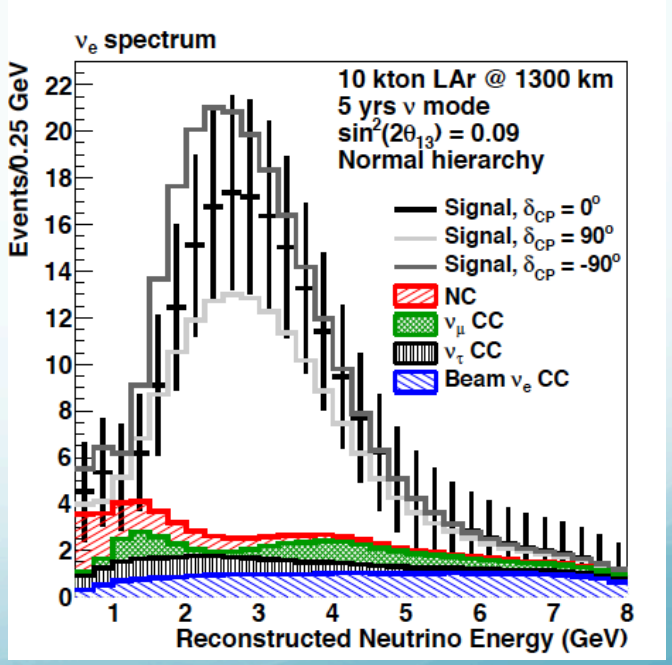
- Nu_e appearance cosmogenic backgrounds



- Cuts and assumptions
  - Look at EM shower in fid. vol. only
  - 0.25 GeV < E_{dep} < 5 GeV,
  - PoCA/distance from walls > 30 cm
  - energy dependent angle cut with respect to the beam,
  - energy dependent e/gamma discrimination,
  - 10 microseconds time window (efficient photon detector)

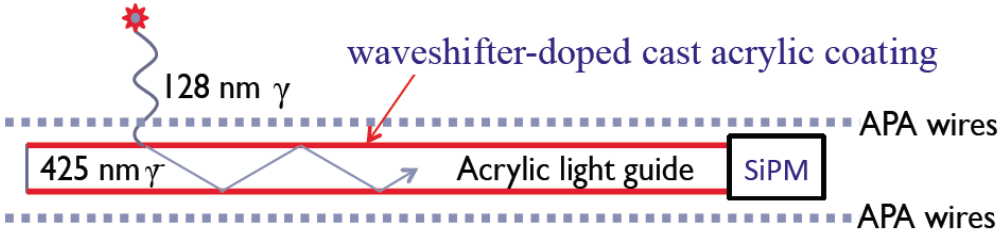
10 kt Surface Operation

- Backgrounds resulting from
  - muons passing through the detector: ~14 evts per year
  - muons missing the detector: ~0.05-0.20 evts per year.
  - neutrons from the surface: ~0.6 evts per year
  - Total 10-15 events per year; < 2 evts, E_{dep}>0.5 GeV; < 0.04 evt, E_{dep}> 1 GeV
  - Uncertainty: a factor of four (e/gamma discrimination, efficiency of the photon detector, gammas from the surface, statistics)



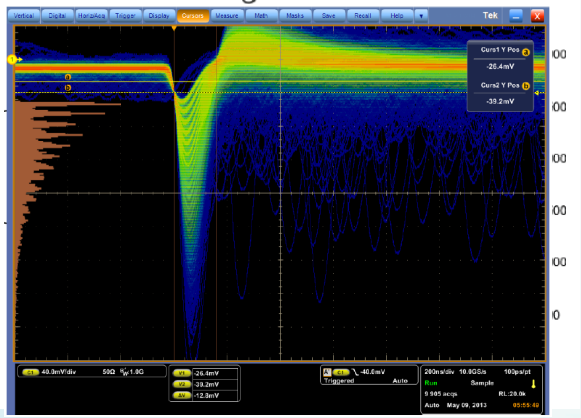
- Small compared to beam backgrounds except below 1 GeV, where 10 kt FD has few signal events
  - Significance increases for larger detector and high intensity beam

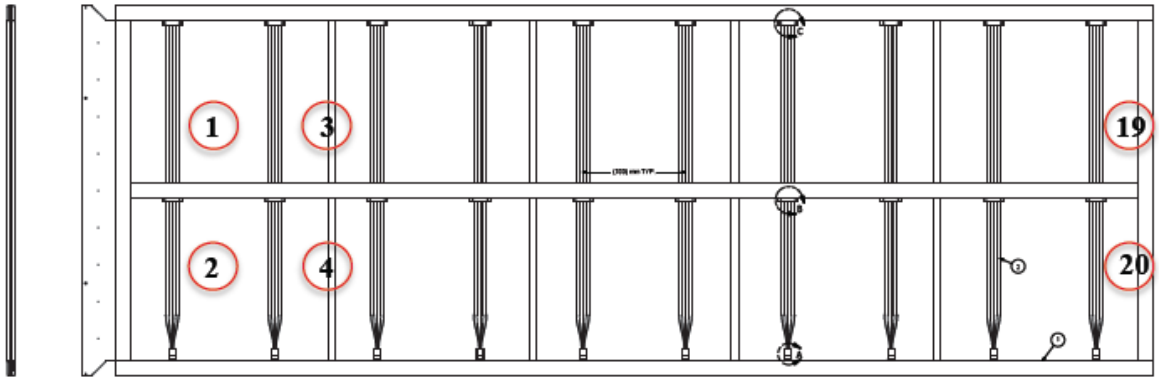
Photon Detector System



- **Primarily university groups (incl. L3 manager)**

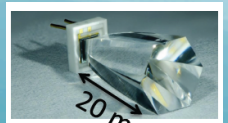
- Successfully exercised PD chain
  - Acrylic waveguide with Bis-MSB
  - SensL SiPM (3) *
  - Nevis shaper/amplifier
  - CAEN 12-bit digitizer

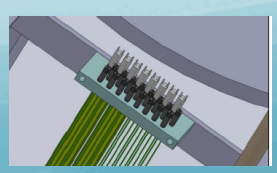




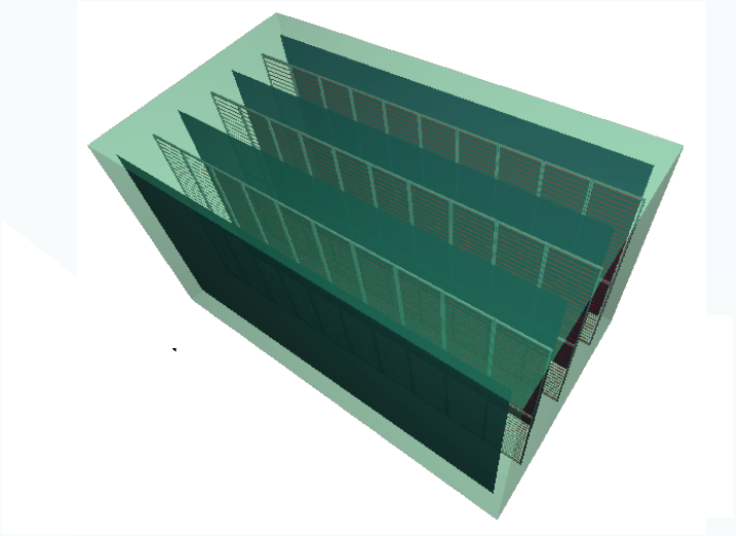
*Other SiPM candidates to be investigated

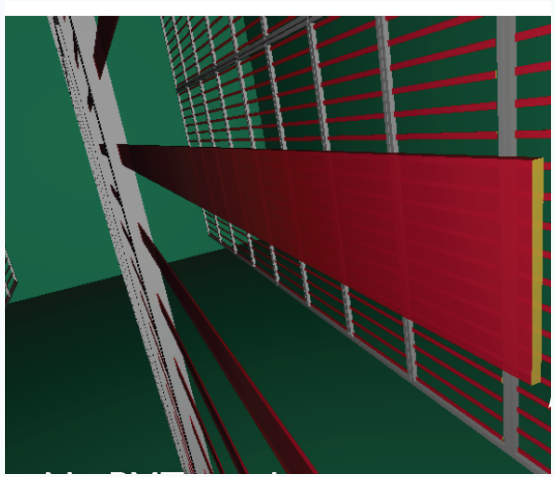
- New facility to test full length paddles online this summer
- R&D on other approaches
  - Cathode plane photon detector; fiber in wider acrylic panels; WLS-fiber based system





Photon Detector Sim/Recon





- Optical Simulation and Reconstruction
  - Building on tools in LArSoft developed for MicroBooNE – full photon stepping and look up tables (doesn't scale well to LBNE though)
  - Photon simulation with Chroma (Penn) – full wavelength –dependent optical simulation of TPB, acrylic and PMTS (based on MiniCLEAN)
- Detector geometry implemented
  - Realistic digitized signals produced including noise
- Not yet able to do full analysis

LBNE R&D Needs Committee

- Goals for the LBNE RDNEC group:
  - Identify and communicate the R&D needs of LBNE to ongoing or proposed R&D efforts outside the LBNE collaboration.
  - Obtain updates from the R&D efforts and ascertain if the R&D needs of LBNE are being met.
- Membership:
  - Collaboration senior management (incl. tech, s/w & analysis)
  - Project director, FD manager and beam tech. coord.
  - FNAL PPD head (or designate)
  - Representative from current R&D groups e.g. LAPD, LArIAT, CAPTAIN
  - MicroBooNE rep.
- Currently chaired by M. Diwan

Snowmass (CSS13)

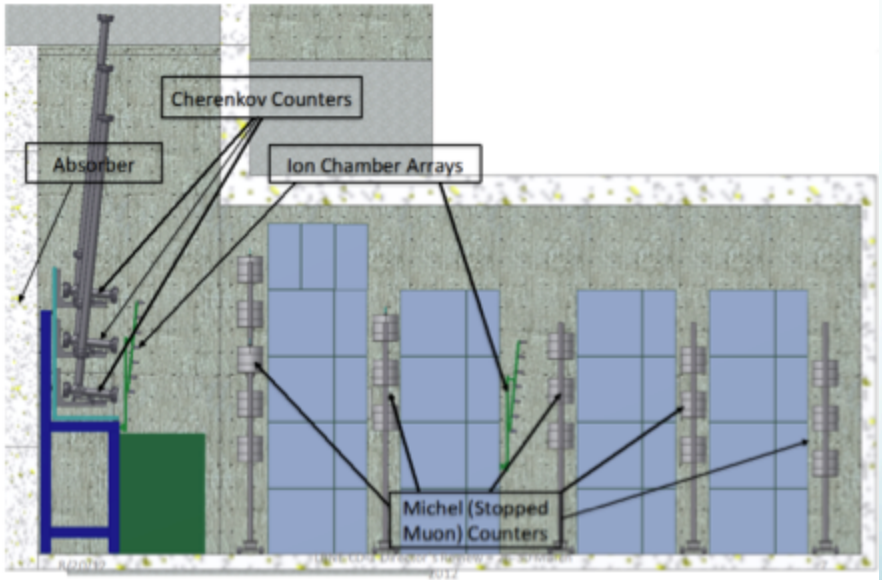
- Senior LBNE members are Snowmass (sub-)group conveners
- LBNE has submitted three one-page whitepapers so far
- Contributing sections to the Project X whitepaper
- Participation in Neutrino and Intensity Frontier workshops
- Organized Snowmass Workshop on underground science (ISOUPs)
- Plan to submit two more whitepapers
  - Short "Executive Summary" of LBNE
  - Longer update of previous Physics Working Group Report
- Plan to participate in Minneapolis meeting
  - Number uncertain due to DOE restrictions on Lab funds
  - Some university people affected – about to be told they cannot use lab service account funds

Near Detector System

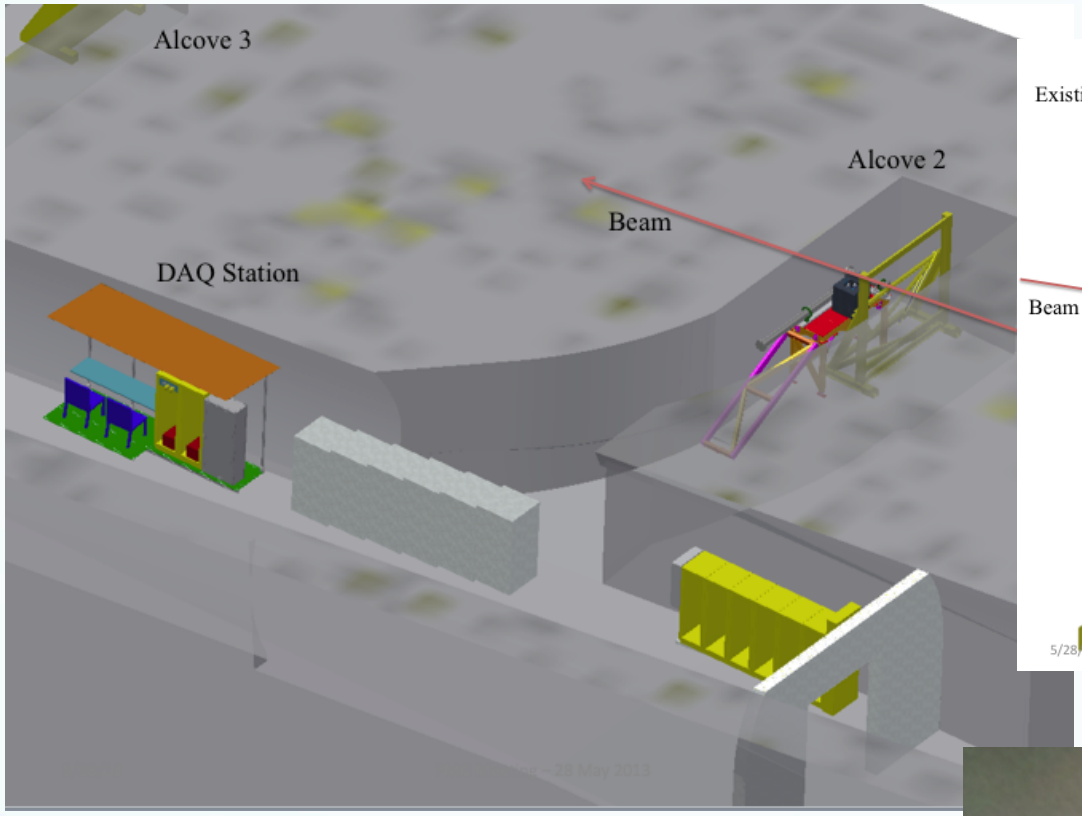
- No Near Neutrino Detector in CD-1 – but is being developed with US+India collaborators; a proposal to DAE for a highly-capable NND is pending
- CD-1 includes a substantial tertiary beam monitor system

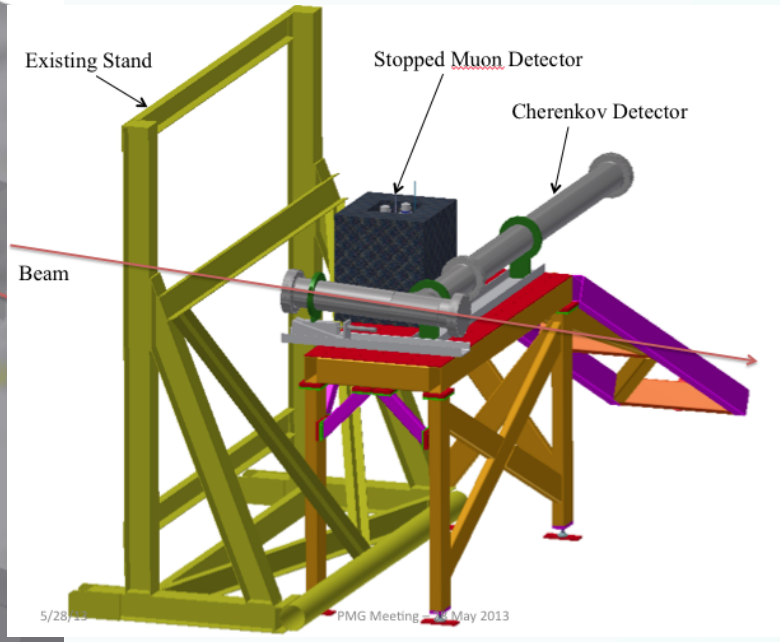
Measurements of muons post-absorber – primary NDS activity is prototyping these systems

Ionization Chambers:
spill-by-spill beam profile
Cherenkov Detectors:
measure all muons above a variable threshold
constrains muon spectrum (correlated with E_ν)
Michel Decay Detectors:
measure muons that stop at a given depth in material
constrains muon spectrum
may give absolute flux constraint



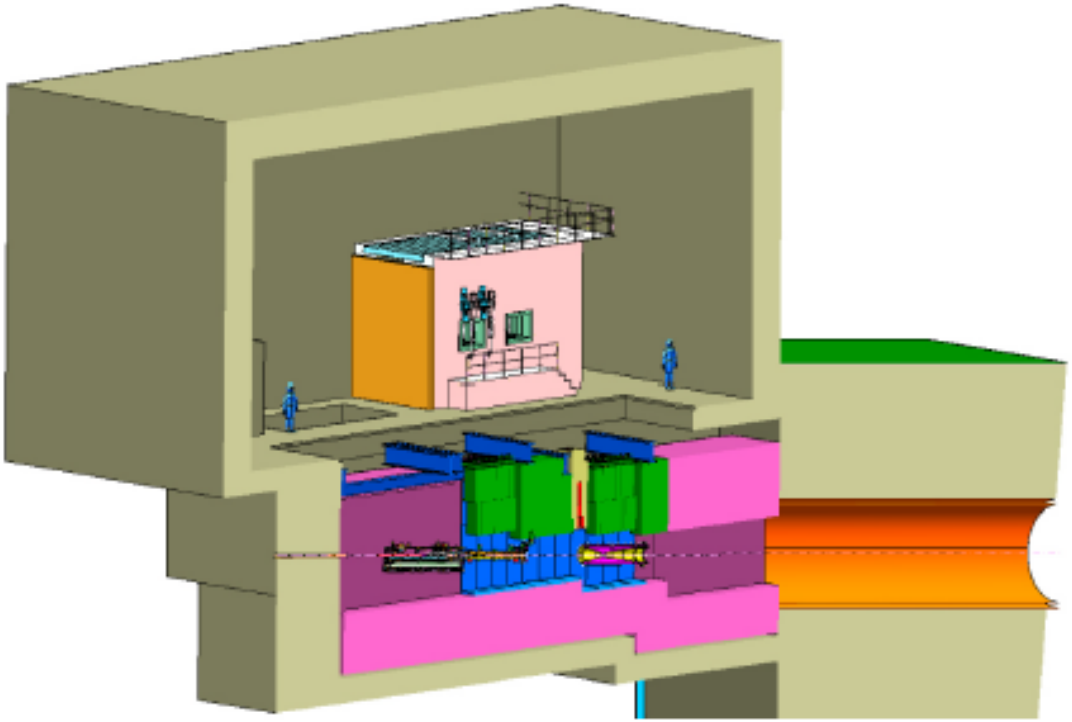
Includes planning measurements of hadron production in external beamlines on materials from which the target and horns are composed

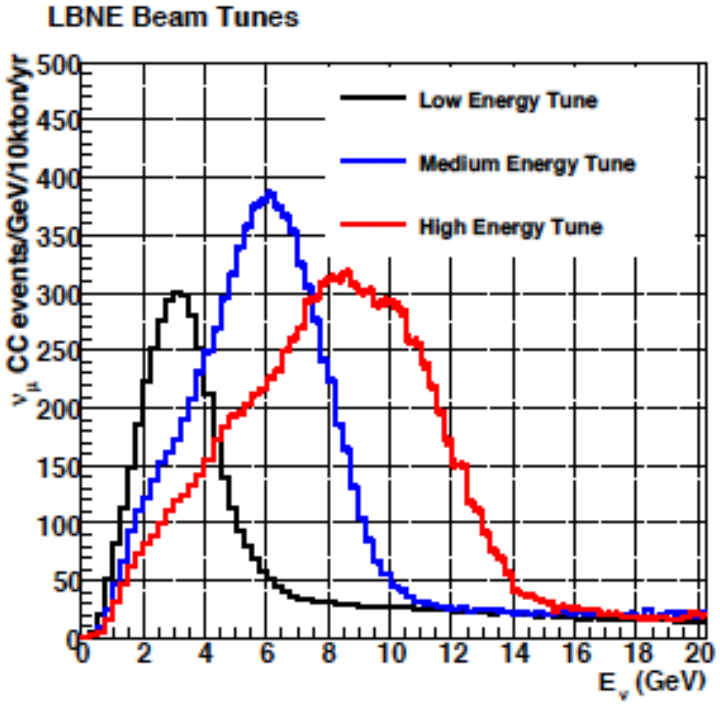




Near Detector System Stopped Muon/Cherenkov Detector Prototypes

Using NuMI focusing = tunable beam energies





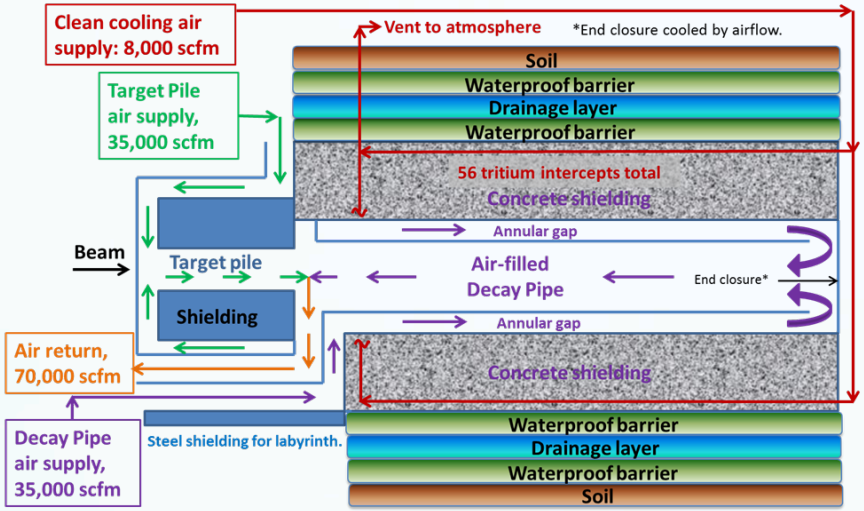
The LBNE ν beam improvements under consideration:

Impact on $\nu_\mu \longrightarrow \nu_e$ appearance rates at the far site:

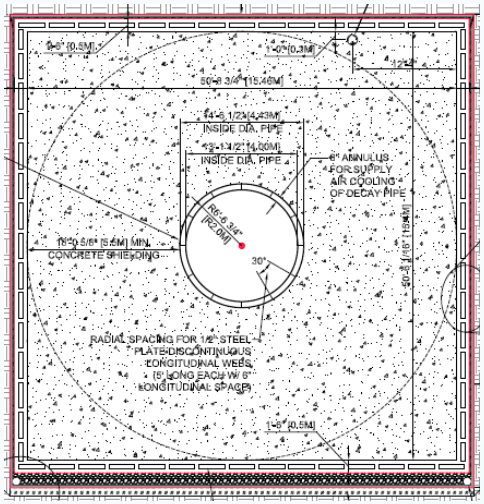
Changes	0.5-2GeV	2-5GeV
Decay pipe air $\longrightarrow$ He	1.07	1.11
DP length 200m$\longrightarrow$ 250m	1.04	1.12
Horn current 200kA $\longrightarrow$ 230kA	1.00	1.12
E_p 120 $\longrightarrow$ 80GeV,700kW	1.14	1.05
Tgt NuMI $\longrightarrow$ Be	1.00	1.03
DP diameter =4m $\longrightarrow$ 6m	1.06	1.02
Total	1.3	1.5

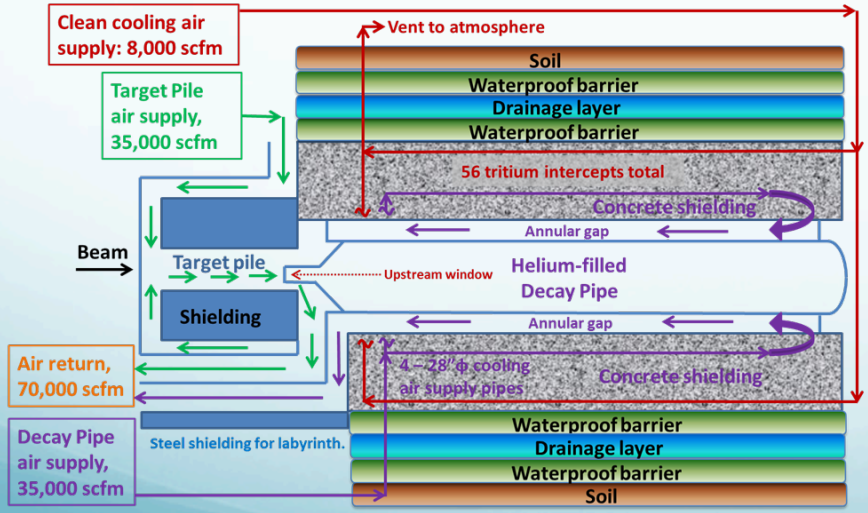
Costs for the options have been developed

Decay Pipe Cooling Task Force

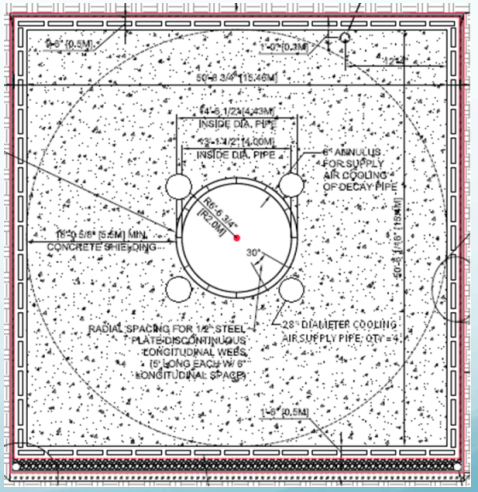


Air-filled/
Air-cooled





He-filled/
Air-cooled



Cost vs. Technical Issues vs. Physics Impact

Other Project Activity

- Work progressing on full-scale steel TPC Anode Frame
  - Solder tension setup/tests underway
- Selected SLAC-designed RCE (Reconfigurable Cluster Elements) for DAQ backend
  - High-bandwidth important for surface operation
  - Supported by LDRD grant
- NEPA Public Information Meeting at Fermilab, May 2013 (part of Environmental Assessment Development)
- Geotechnical site investigation for beamline at Fermilab concluded in late May

Conclusion

- CD-1 approval for $867M phase 1 funding
  - 10 kt surface far detector, no near detector, 700 kW beam
  - Approval to seek partners to enable expanded scope facility
- Phase 1 Goal: At least 10 kt at SURF 4850L underground, highly capable near detector, 700 kW beam capable of 2.3 MW
- Good progress on engaging potential partners
- Good progress in most important project lines
- Primary concerns about funding profile

Backup

Long-Baseline Neutrino Experiment Collaboration

Alabama: S.Habib, I.Stancu
Argonne: Z.Djurcic, G.Drake., M.Goodman, V.Guarino, S.Magill, J.Paley, H.Sahoo, L.Suter, R.Talaga
Arlington: A.Bashyal, A.Brandt, K.De, A.Farbin, C.Jackson, S.Park, B.Watson, A.White, J.Yu
Boston: E.Hazen, E.Kearns, S.Linden
Brookhaven: M.Bishai, R.Brown, H.Chen, K.Chen, M.Diwan, J.Dolph, G.Geronimo, R.Gill, R.Hackenburg, R.Hahn, S.Hans, Z.Isvan, D.Jaffe, S.H.Kettell, F.Lanni, S.Li, Y.Li, L.Littenberg, J.Ling, G.Mahler, 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
Cambridge: A.Blake, J.Marshall, M.Thomson
Catania/INFN: V.Bellini, F.La Zia, F.Mammoliti, R.Potenza
Chicago: E.Blucher, D.Schmitz, M.Strait, M.Wetstein
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, M.Shaevitz, W.Sippach, W.Willis
Dakota State: B.Szczerbinska
Davis: M.Bergevin, H.Berns, R.Breedon, J.Felde, C.Grant, C.Maesano, M.Tripanthi, R.Svoboda, M.Szydagis
Drexel: C.Lane, M.Thiesse
Duke: T.Akiri, J.Fowler, A.Himmel, Z.Li, K.Scholberg, C.Walter
Duluth: R.Gran, A.Habig
Fermilab: M.Andrews, B.Baller, R.Bernstein, E.Berman, V.Bocean, A.Chen, S.Childress, A.Drozhdin, C.Escobar, H.Greenlee, A.Hahn, R.Hatcher, 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, B.Lundberg, T.Lundin, P.Mantsch, A.Marchionni, E .McCluskey, N.Mokhov, C.Moore, D.Montanari, J.Morfin, B.Norris, V.Papadimitriou, R.Plunkett, C.Polly, S.Pordes, O.Prokofiev, J.L.Raaf, R.Rajendran, G.Rameika, B.Rebel, D.Reitzner, K.Riesselmann, R.Rucinski, R.Schmidt, P.Shanahan, T.Shaw, M.Stancari, A.Stefanik, J.Strait, S.Striganov, S.Tariq, 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.Bhatnagar, B.Bhuyan [IIT(G)], B.Choudhary, R.Gandhi (HRI), A.Kumar, S.Mandal (DU); S.Sahijpal(PU), V.Singh (BHU)
Indiana: M.Baird, B.Baptista, W.Fox, M.Messier, S.Mufson, J.Musser, E.Niner, R.Tayloe, J.Urheim, D.Whittington
Iowa State: I.Anghel, G.S.Davies, M.C.Sanchez, T.Xin
Irvine: G.Carminati, W.Kropp, M.Smy, H.Sobel
Kansas State: T.Bolton, G.Horton-Smith, D.McKee
Kavli IPMU/Tokyo: M.Vagins, R.Wendell
LBL: B.Fujikawa, V.M.Gehman, R.Kadel, D.Taylor
Livermore: A.Bernstein, S.Dazeley
London: A.Holin, A.Perch, J.Thomas
Los Alamos: L.Bartoszek, J.Boissevain, S.Elliott, A.Friedland, G.Garvey, E.Guardincerri, T.Haines, D.Lee, W.Louis, C.Mauger, G.Mills, Z.Pavlovic, J.Ramsey, M.Ronquest, G.Sinnis, W.Sondheim, R.Van de Water, H.White, K.Yarritu
Louisiana: R.Imlay, J.Insler, T.Kutter, W.Metcalf, M.Tzanov
Maryland: E.Blaufuss, S.Eno, R.Hellauer, G.Sullivan
Michigan State: E.Arrieta-Diaz, C.Bromberg, D.Edmunds, J.Huston, B.Page
Minnesota: D.Demuth M.Marshak, W.Miller
MIT: W.Barletta, J.Conrad, B.Jones, T.Katori, R.Lanza, A.Prakash
NGA: S.Malys, S.Usman
Northwestern: A.de Gouvea, L.Fields, H.Schellman
Notre Dame: J.Losecco
Oxford: G.Barr, J.de Jong, A.Weber
Pennsylvania: S.Grullon , P.Keener, J.Klein, K.Lande, T.Latorre, A.Mann, M.Newcomer, S.Seibert, R.vanBerg
Pittsburgh: D.Naples, V.Paolone
Princeton: K.McDonald
Rensselaer: J.Napolitano
Rochester: L.Loiacono, K.McFarland, G.Perdue
Sanfordlab: M.Headley, J.Heise, D.Taylor, J.Willhite
Sheffield: V.Kudryavtsev, J.Perkin, M.Richardson, M.Robinson, N.Spooner, L.Thompson
SLAC: M.Convery, M.Graham, D.Muller
SDSMT: X.Bai, C.Christofferson, R.Corey, D.Tiedt
SMU: T.Coan, T.Liu, J.Ye
South Carolina: H.Duyang, J.Libo, 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
Sussex: L.Falk, J.Hartnell, S.Peeters, A.Waldron,
Syracuse: M.Artuso, J.Asaadi, S.Blusk, T.Skwarnicki, M.Soderberg, S.Stone
Tennessee: W.Bugg, T.Handler, A.Hatzikoutelis
Texas: S.Kopp, K.Lang, R.Mehdiyev
Tufts: J.Coelho, H.Gallagher, W.Mann, N.Mayer, J.Schneps
UCLA: D.Cline, K.Lee, Y.Meng, A.Teymourian, H.Wang, L.Winslow
Virginia Tech: E.Guarnaccia, J.Link, C.Mariani
Washington: S.Enomoto, J.Kaspar, N.Tolich
William and Mary: R.McKeown, X.Qian, W.Wang
Wisconsin: B.Balantekin, F.Feyzi, L.Greenler, K.Heeger, B.Paulos, D.Wahl
Yale: C.Adams, F.Cavanna, E.Church, B.Fleming, R.Guenette, O.Palamara, K.Partyka, A.Szelc

375 Members
61 Institutions
25 US States
5 Countries

40 more members, 5 new institutions since last year

25 March 2013 (375)

Collaboration Executive Committee

Revised: December 2012

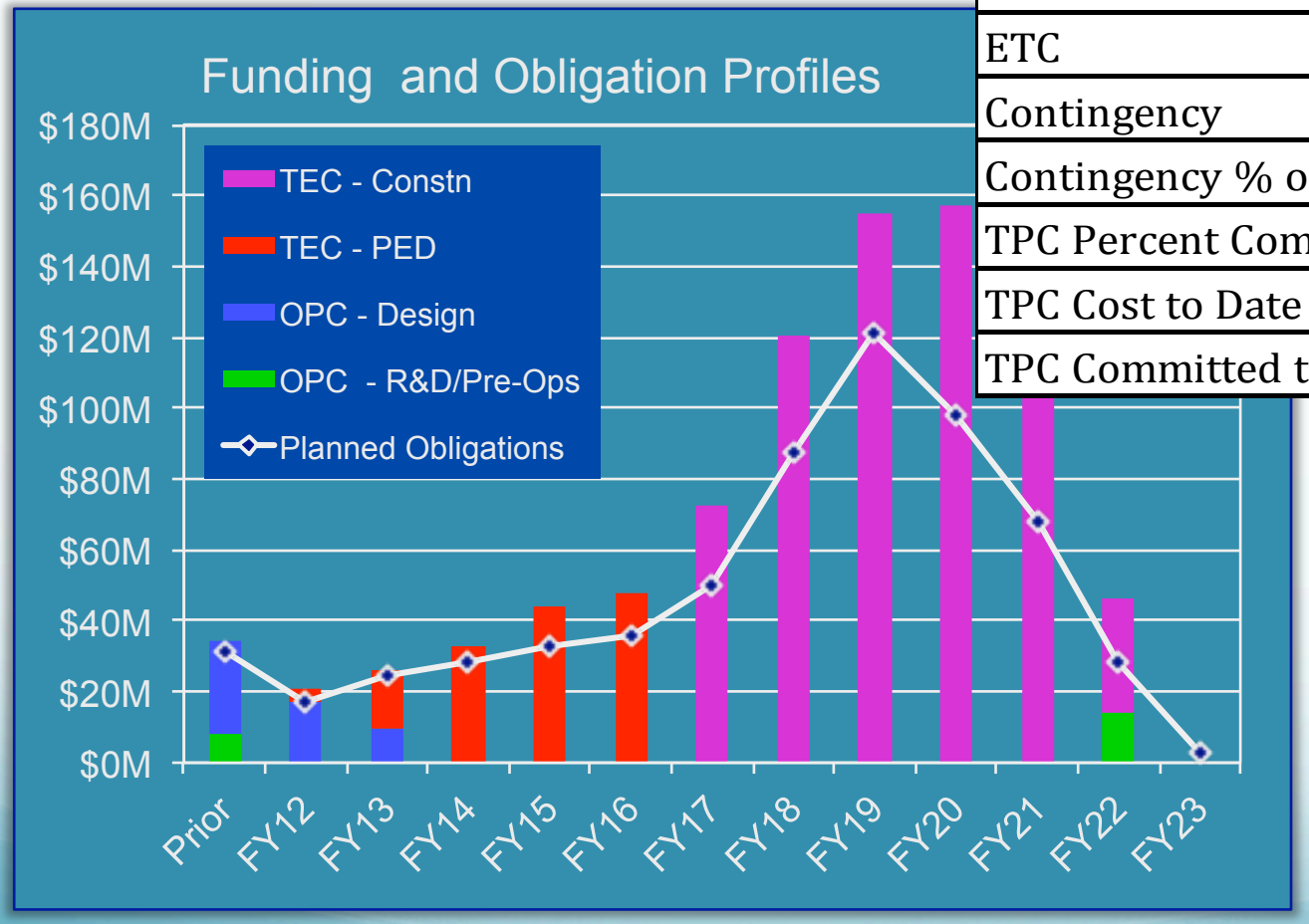
Ex-officio members from the collaboration
Marvin Marshak (IB Chairperson)
Robert Wilson (co-spokesperson), Milind Diwan (co-spokesperson)
Maury Goodman (deputy spokesperson)
Jon Urheim (Physics WG Convener),
Tom Junk (Physics Tools WG Convener)

[*Ex-officio members from the project*] Jim Strait (Project Director)

[*Elected/Appointed 1 Jan 2012 – 31 Dec 2013*]
Jim Stewart (BNL), Ed Kearns (Boston), Bill Louis (LANL), Hank Sobel (Irvine), Kate Scholberg (Duke), Sam Zeller (FNAL)

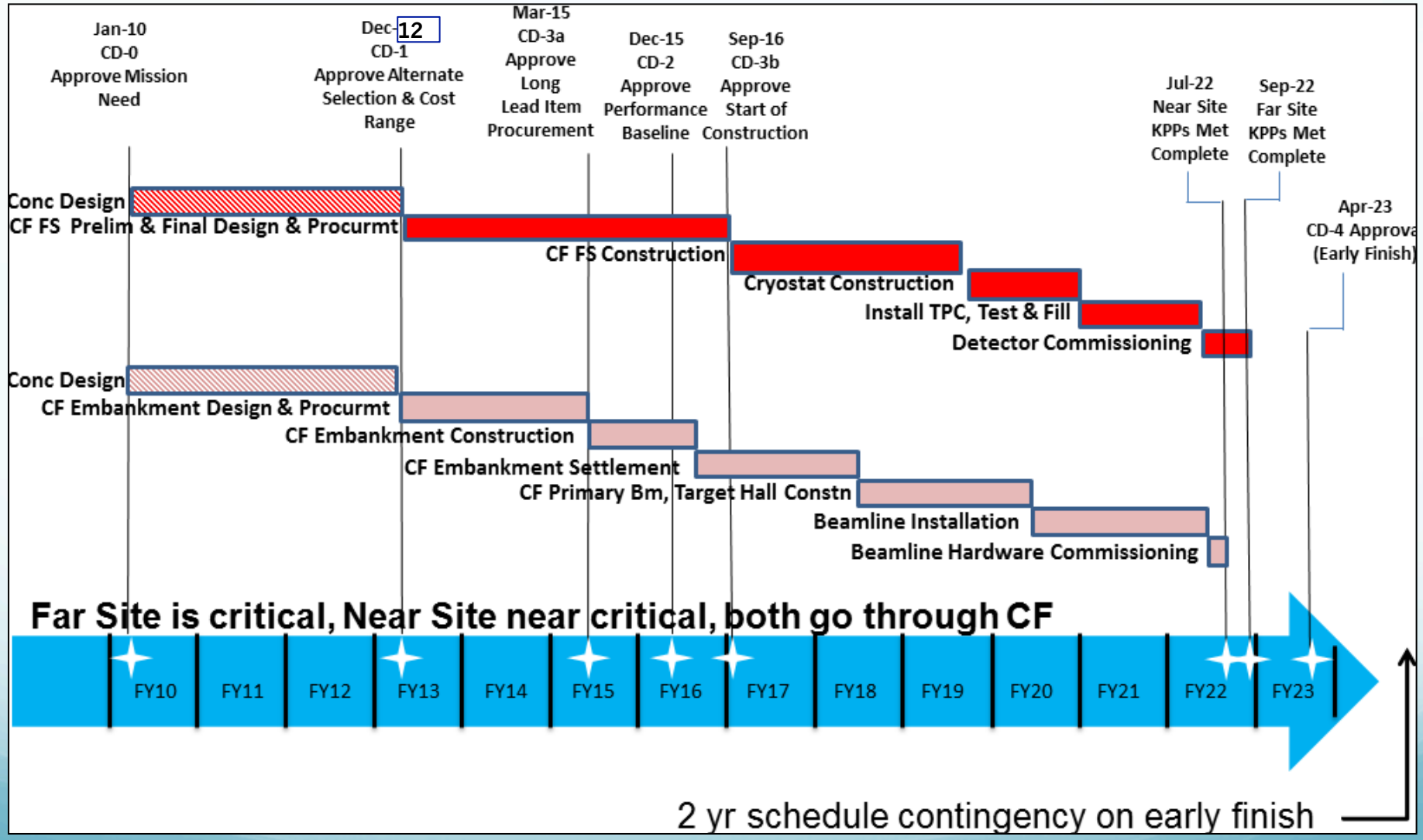
[*Young LBNE Observer*] Andrej Szelc (Yale)

CD-1 LBNE (Phase 1) Project Cost

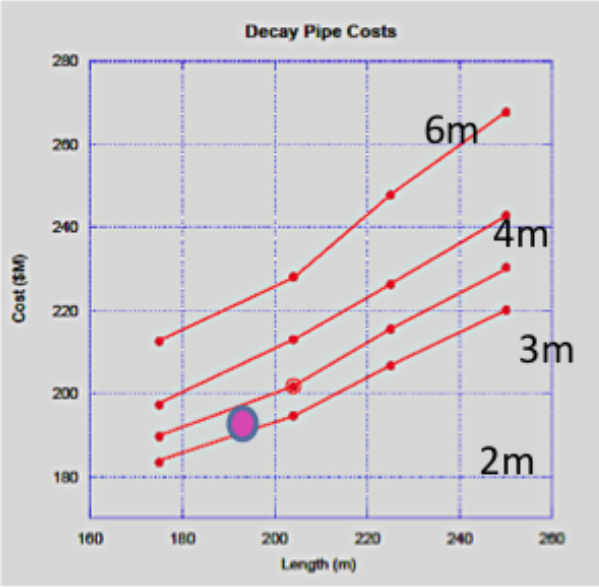


	Plan	Actual
TPC	$867M	
TEC	$792M	
ETC	$578M	
Contingency	$241M	
Contingency % of ETC	42%	
TPC Percent Complete	9%	9%
TPC Cost to Date	$55M	$54M
TPC Committed to Date	$59M	$56M

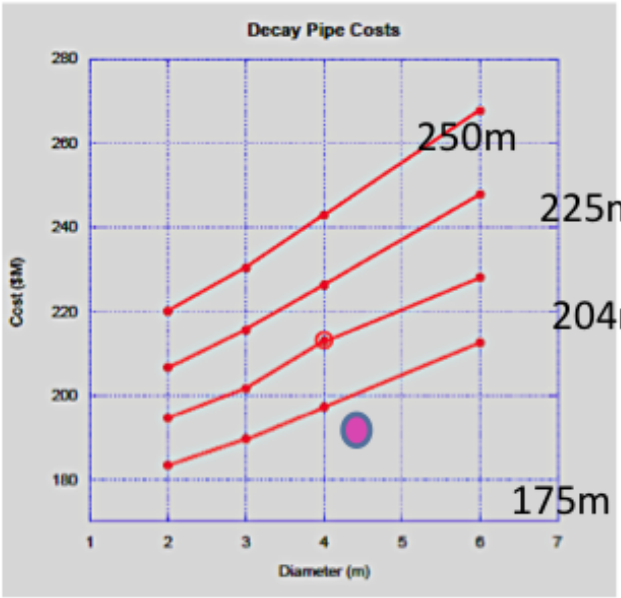
CD-1 LBNE (Phase 1) Project Schedule



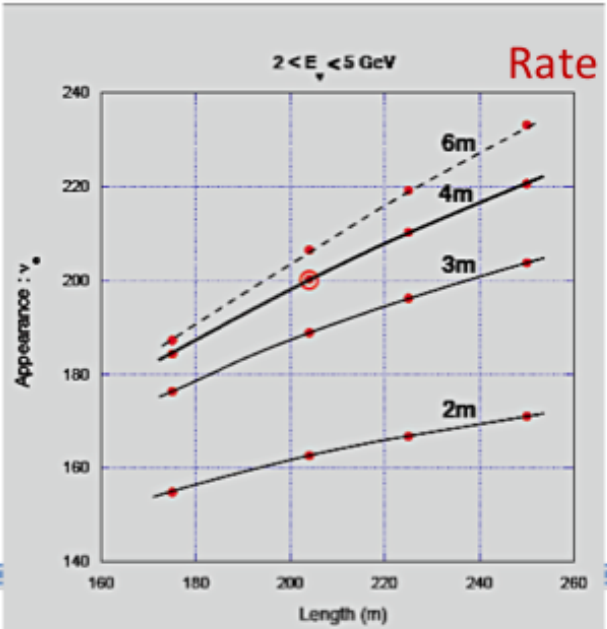
Re-optimization of decay pipe geometry
Costs and rates as a function of decay pipe size



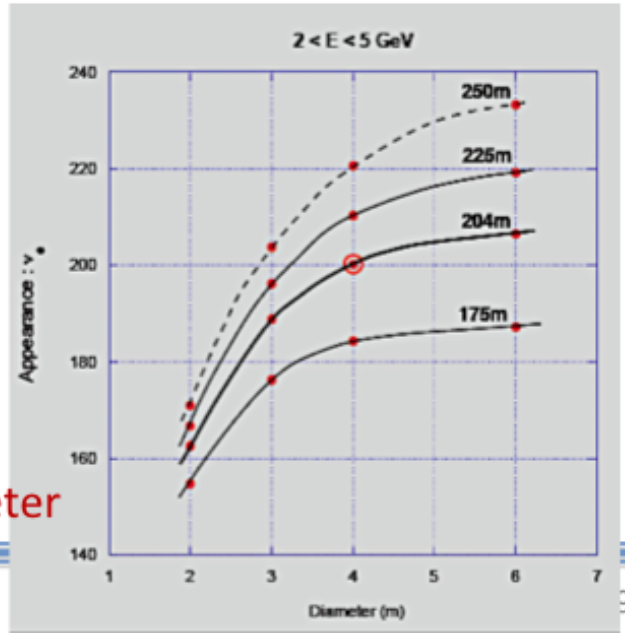
Costs included:
Conventional Facilities for Decay Pipe & Absorber ;
Absorber



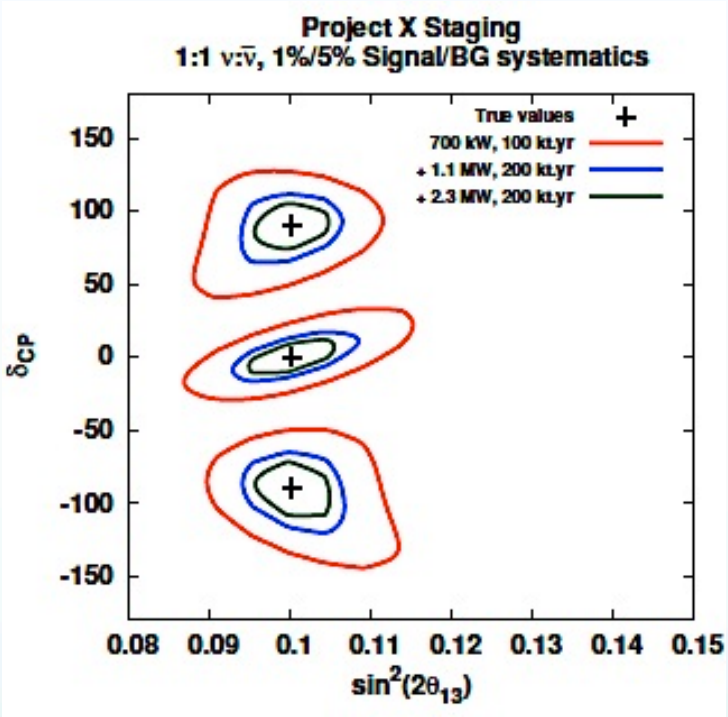
Rate vs length



Rate vs diameter



LBNE + Project X



Atmospheric Nu Systematics

	Atmospheric	Beam (Assume ND)
Normalisations	Overall (15%)	μ-like (1%) e-like (1%)
NC Backgrounds	(No ND decomposition for atmos ν) e-like (10%)	μ-like (10%) e-like (5%)
Spectrum Ratios	up/down (2%) ν_e/ν_μ (2%) anti-ν_μ/ν_μ & anti-ν_e/ν_e (5%) } Flux ratios cancel strongly, so these are estimated detector uncertainties	
Spectrum Shape	Apply separate functions for ν_μ, ν_e, anti-ν_μ, anti-ν_e	$f(E<E_0)=1+\alpha(E-E_0)/E_0$ $f(E>E_0)=1+\alpha\log(E/E_0)$ where $\sigma_\alpha=5\%$
Energy Scales (Correlated)	Muons (stopping 1%, exiting 5%) Electrons (1%) Hadronic system (5%)	

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