Report:
LBNE Reconfiguration Steering Committee

The Steering Committee Report and Supporting Documents are available at
http://www.fnal.gov/directorate/lbne_reconfiguration/

Young-Kee Kim
Chair, the Steering Committee

HEPAP meeting
August 27, 2012

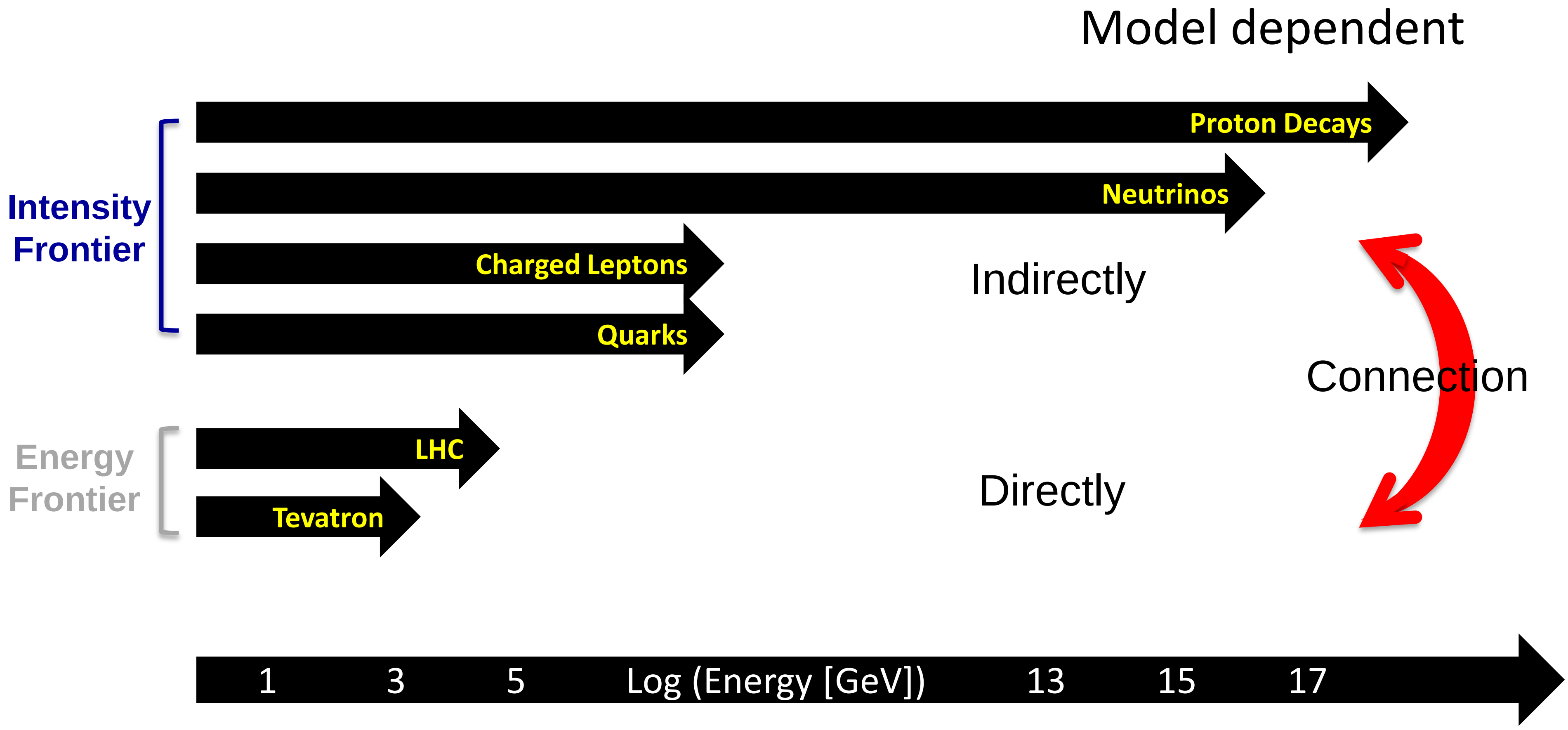
Outline

- LBNE
- Reconfiguring LBNE
  - Charge / membership
  - Process
  - Options considered
  - Viable options
  - Preferred option
  - Enhancing the physics scope of the preferred phase-1 option
- Conclusions

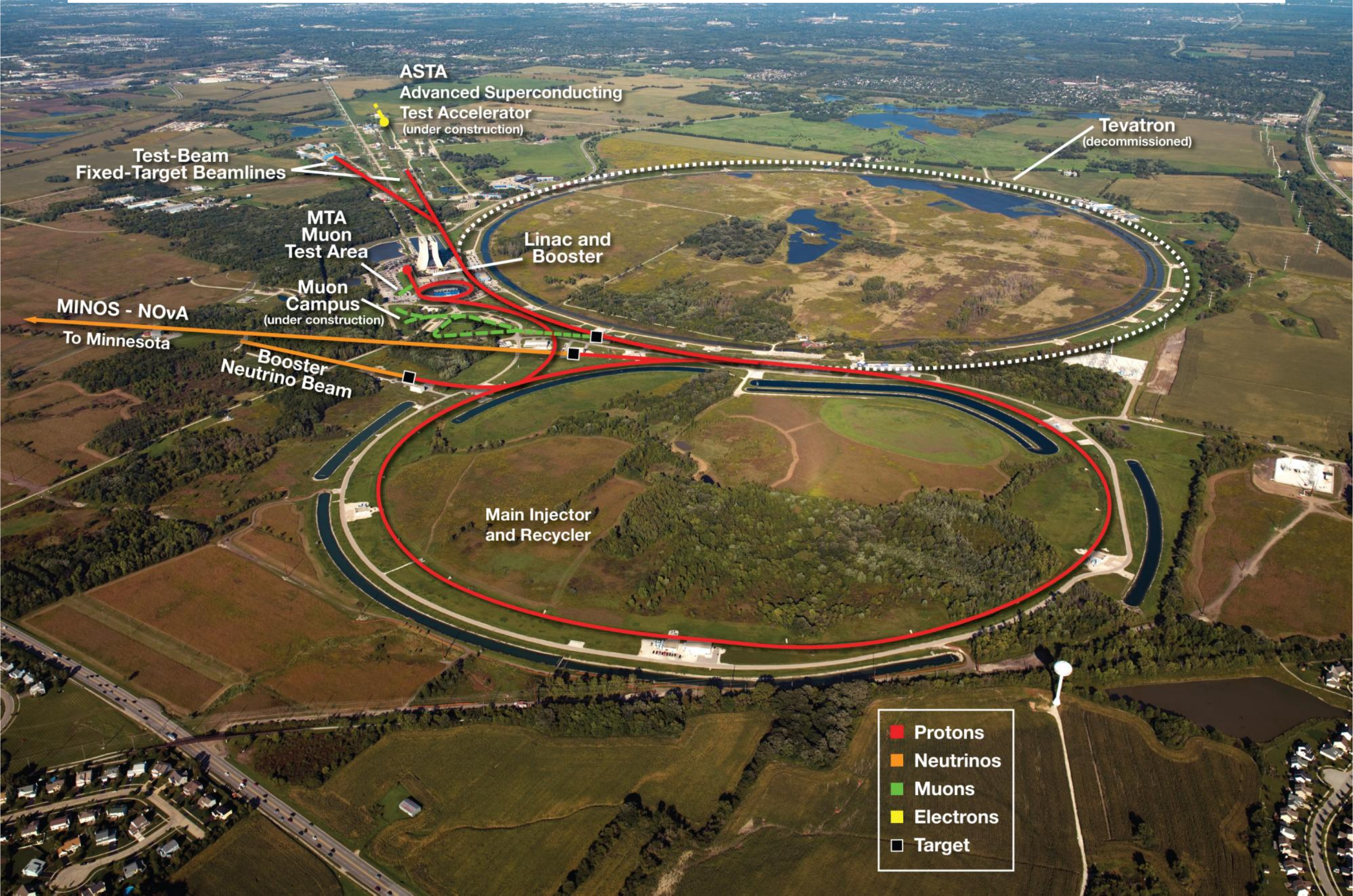
LBNE Physics Case

- The 2008 P5 report has as a central pillar of the future US HEP program a long-baseline neutrino program driven by a high-intensity beam from Fermilab because it would address a number of important physics questions.
  - Is there CP violation in the neutrino sector?
  - What is the ordering of the neutrino states?
  - Is the proton stable?
  - What physics & astrophysics can we learn from the neutrinos emitted in supernova explosions?
- P5 reaffirmed the 2008 plan in October 2010 (in conjunction with Tevatron extension consideration)
- Large value of θ_{13} (March 2012) → Physics risk was mitigated.
- Executing the P5 plan
  - Critical Decision-0 approval in Jan. 2010 (full LBNE); DOE CD-1 review is scheduled on Oct.30-Nov.1, 2012 (LBNE Phase 1)
  - Project / Collaboration accomplishments will be presented by Milind Diwan.

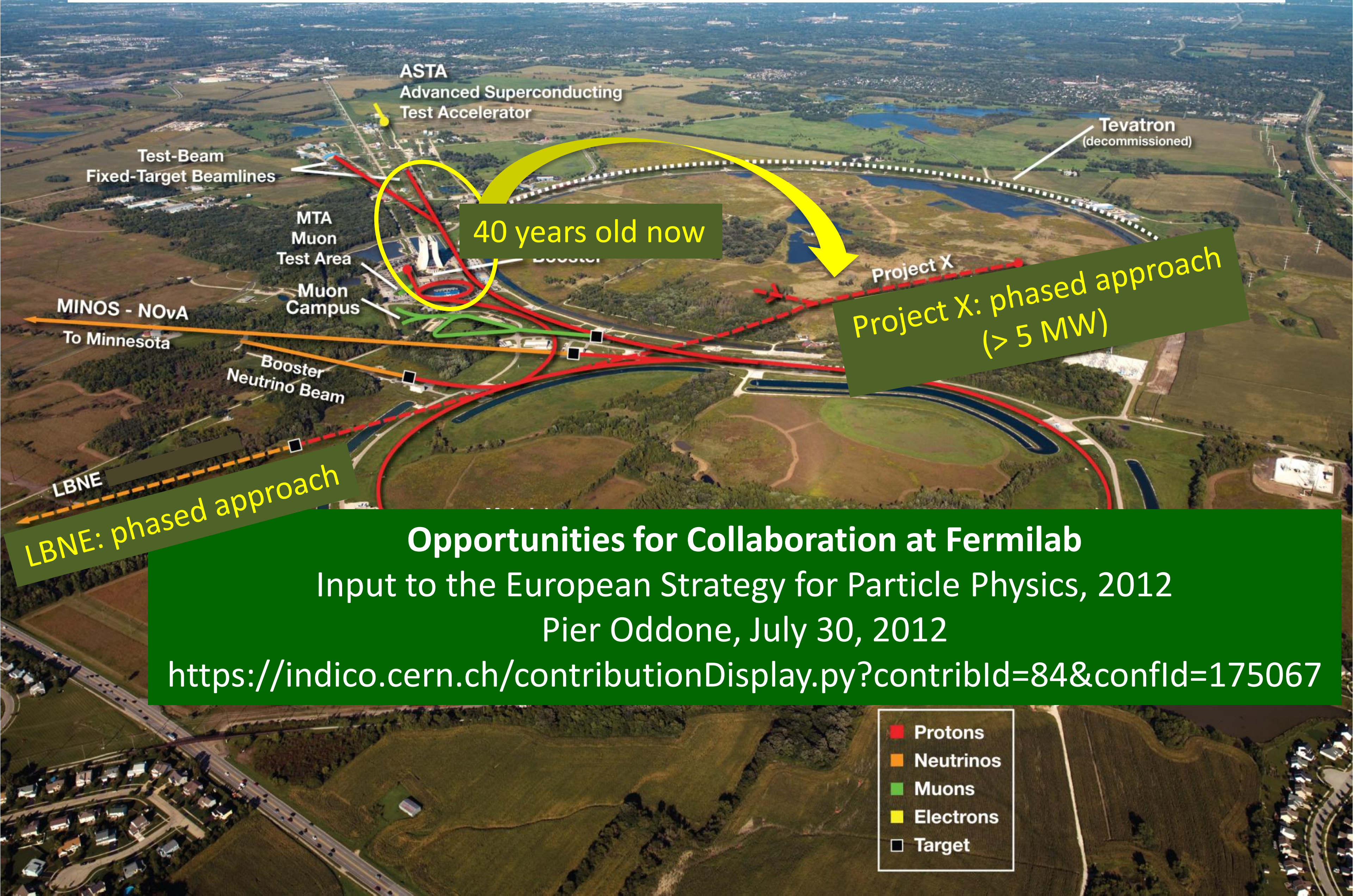
Vision of U.S. Intensity Frontier Programs
Experimental Reach



Fermilab Accelerator Complex: 2012



Fermilab Accelerator Complex: Vision



Opportunities for Collaboration at Fermilab

Input to the European Strategy for Particle Physics, 2012

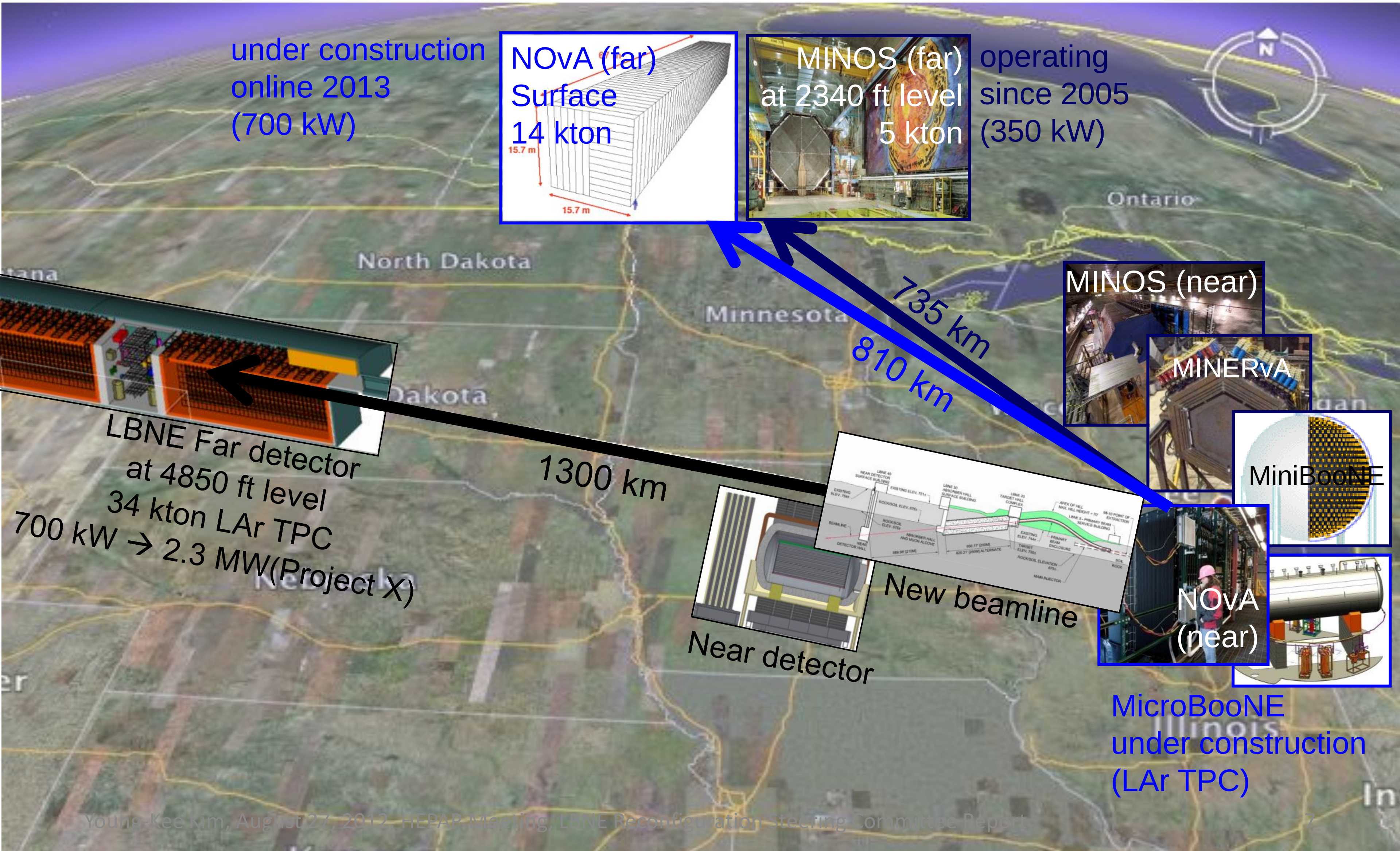
Pier Oddone, July 30, 2012

https://indico.cern.ch/contributionDisplay.py?contribId=84&confId=175067

Evolution of U.S. Long Baseline Neutrino Experiments

MINOS(2005-~2015) → NOvA(2013-~2022) → LBNE(~2022-~2040?)

Electron efficiencies 4% → 30% → > 80%



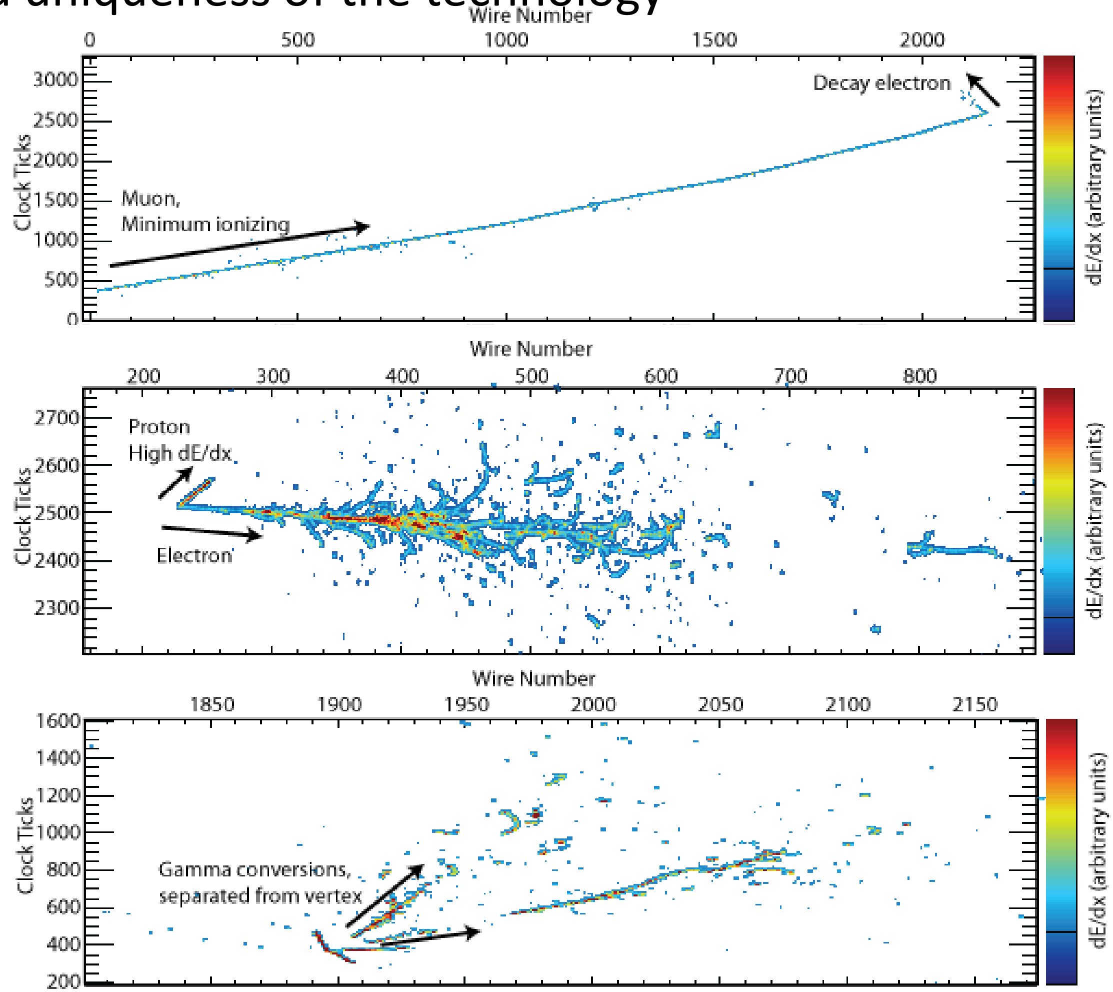
Detector Technology Choice Made (Jan. 2012)

Liquid Argon TPC based on its extremely high performance in particle identification and uniqueness of the technology

ν_μ CC event w/ μ decay

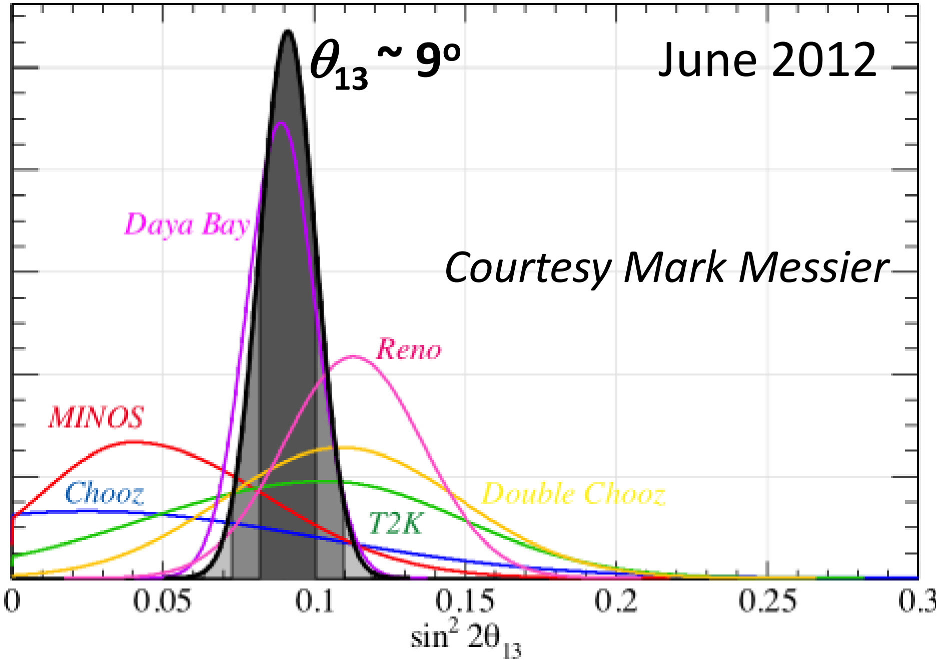
ν_e QE event

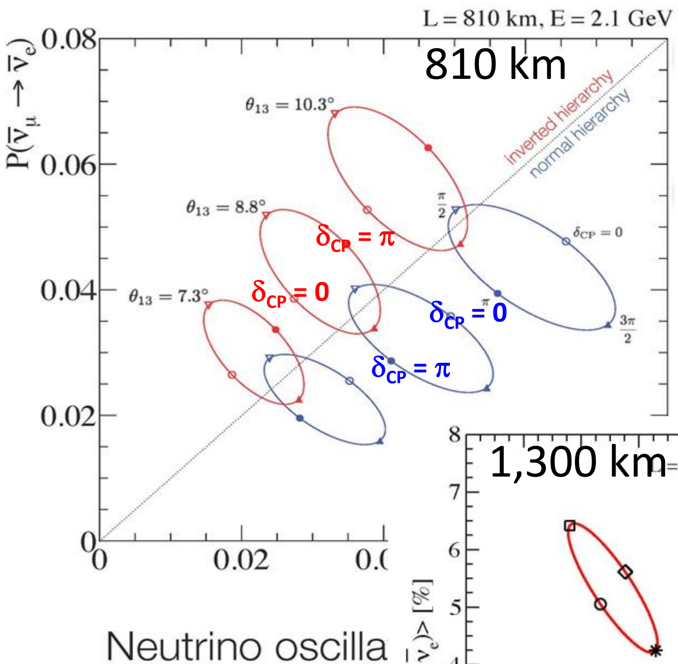
NC event w/ $\pi^0 \rightarrow \gamma\gamma$

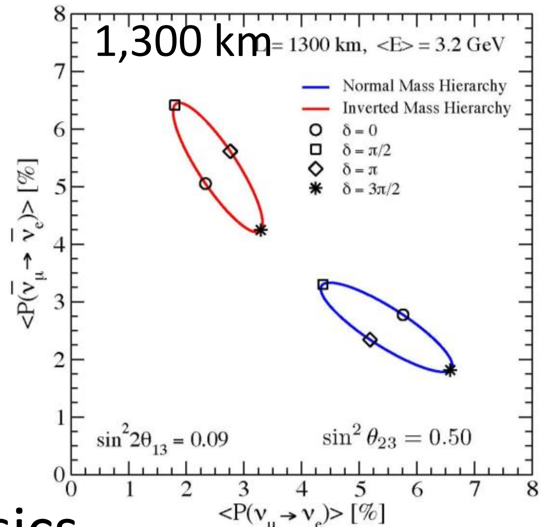


Exquisite 3D event information!

Large θ_{13} (March 8, 2012)







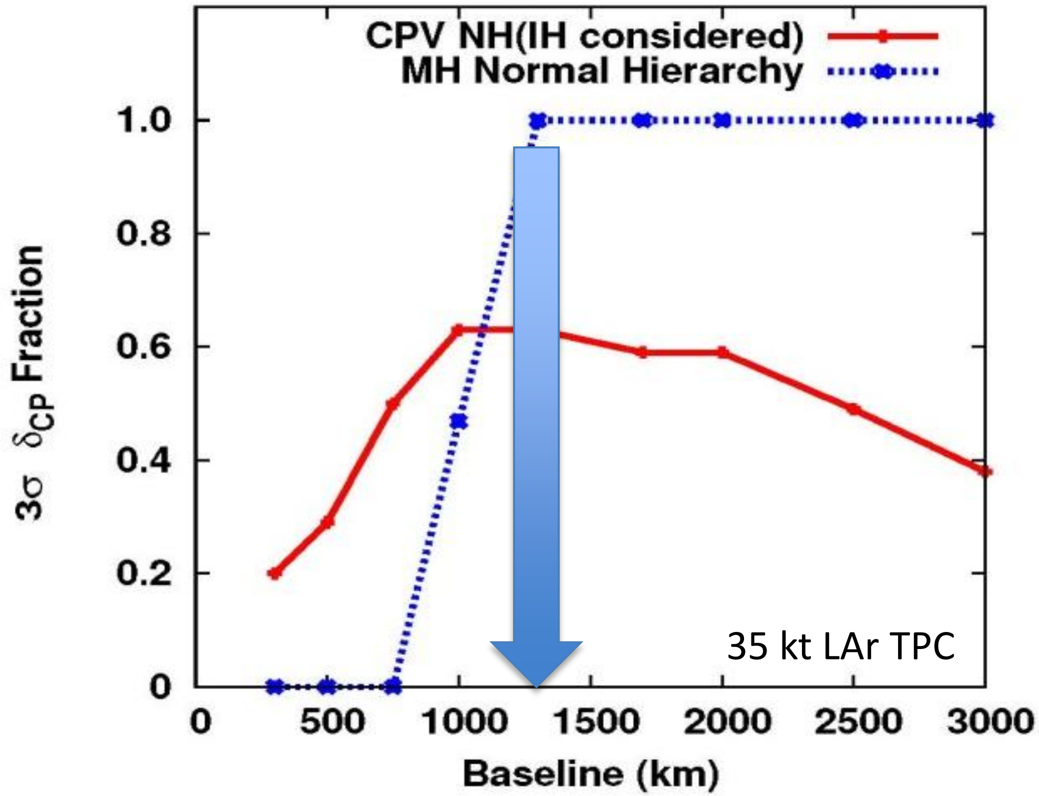
Richer long-baseline neutrino physics

Near term experiments have some sensitivity on the mass hierarchy.

What is the optimal baseline for the known value of $\theta_{13} \sim 9^{o}$?

Large θ_{13} (March 8, 2012)

Mass hierarchy and CP sensitivity vs. Baseline



~1,300 km is nearly optimal for a combined sensitivity of CP and mass hierarchy measurements.

Dr. Brinkman's Charge (March 19, 2012)

Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

March 19, 2012

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,

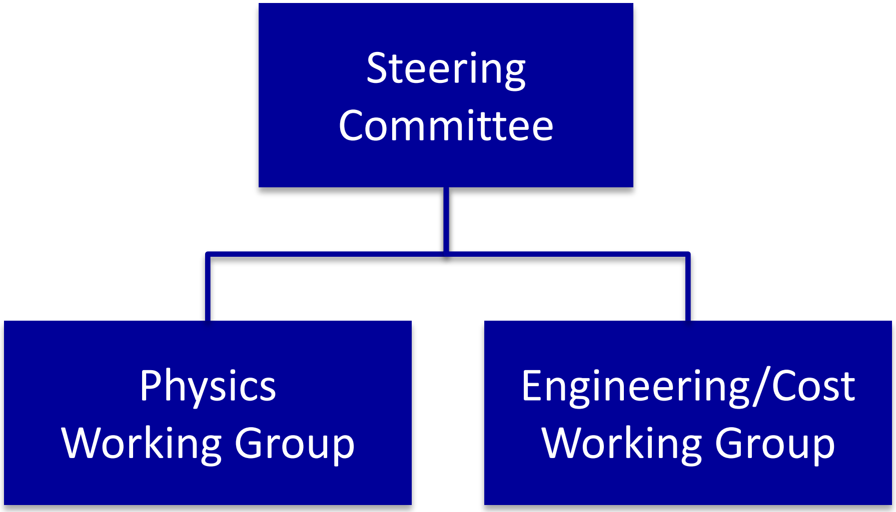
W. F. Brinkman
Director, Office of Science

DOE SC is planning investments in the next generation neutrino experiment, the LBNE.

In light of the current budget climate, Dr. Brinkman asked Fermilab to find a path forward to reach the goals of the LBNE in a phased approach or with alternative options. His letter notes that 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.

Steering Committee and WGs formed (April 3, 2012)

- Pier Oddone, Director of Fermilab, formed a Steering Committee and two working groups (Physics and Engineering/Cost Working Groups), to address this request.



- The Steering Committee to provide guidance to the working groups, to identify viable options and to write the report to the DOE.

- The Physics WG to analyze the physics reach of various options on a common basis, and the Engineering/Cost WG to provide cost estimates and to analyze the feasibility of the proposed approaches with the same methodology.

The Steering Committee

Steering Committee

Membership	Institution
Jon Bagger	JHU
Charlie Baltay	Yale
Gary Feldman	Harvard
Young-Kee Kim , Chair	Fermilab
Kevin Lesko	LBNL
Ann Nelson	UW Seattle
Mark Reichanadter	SLAC
Mel Shochet	Chicago
Bob Svoboda	UC Davis
James Symons	LBNL
Steve Vigdor	BNL

Ex-officio group

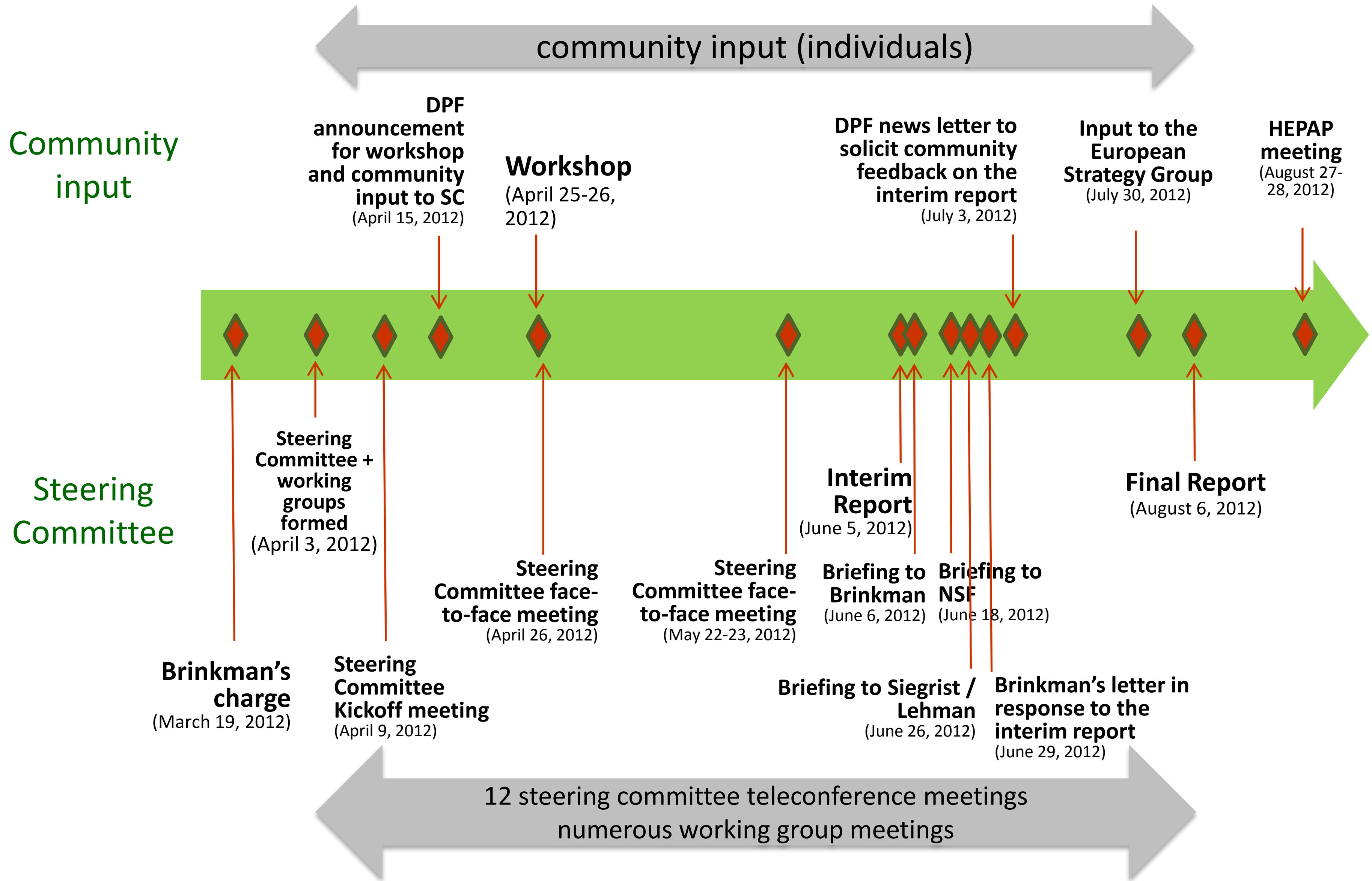
Membership	Institution (comments)
Andy Lankford	UC Irvine (HEPAP chair, DUSEL NRC study chair)
Steve Ritz	UC Santa Cruz (PASAG chair)
Jay Marx	Caltech (DUSEL review committee co-chair)
Pierre Ramond	U. Florida (DPF chair)
Harry Weerts	ANL (Intensity Frontier Workshop co-chair)
JoAnne Hewett	SLAC (Intensity Frontier Workshop co-chair)
Jim Strait	FNAL (LBNE Project Director, Engineering/Cost WG deputy chair)
Pier Oddone	FNAL (Director, Fermilab)
Susan Seestrom	LANL (LBNE Lab Oversight Group member)

Working Groups

Physics Working Group	Engineering / Cost Working Group
• Jeff Appel, FNAL (Scientific secretary) • Matthew Bass, Colorado State Univ. • Mary Bishai, BNL • Steve Brice, FNAL • Ed Blucher, U. Chicago • Daniel Cherdack, Colorado State Univ. • Milind Diwan, BNL • Bonnie Fleming, Yale • Gil Gilchriese, LBNL • Zeynep Isvan, BNL • Byron Lundberg, FNAL • Bill Marciano, BNL • Mark Messier, Indiana U. • Stephen Parke, FNAL • Mark Reichanadter, SLAC • Gina Rameika, FNAL • Kate Scholberg, Duke U. • Mel Shochet, U. Chicago (Chair) • Jenny Thomas, UCL • Bob Wilson, Colorado State Univ. • Elizabeth Worcester, BNL • Charlie Young, SLAC • Sam Zeller, FNAL	• Jeff Appel, FNAL (Scientific secretary) • Bruce Baller, FNAL • Jeff Dolph, BNL • Mike Headley, SURF • Tracy Lundin, FNAL • Marvin Marshak, U. Minnesota • Christopher Mauger, LANL • Elaine McCluskey, FNAL • Bob O'Sullivan, FNAL • Vaia Papadimitriou, FNAL • Mark Reichanadter, SLAC (Chair) • Joel Sefcovic, FNAL • Jeff Sims, ANL • Jim Stewart, BNL • Jim Strait, FNAL (Deputy Chair)

Strong young scientists' involvement

Process


community input (individuals)
Community input
DPF announcement for workshop and community input to SC (April 15, 2012)
Workshop (April 25-26, 2012)
DPF news letter to solicit community feedback on the interim report (July 3, 2012)
Input to the European Strategy Group (July 30, 2012)
HEPAP meeting (August 27-28, 2012)
Steering Committee
Steering Committee + working groups formed (April 3, 2012)
Interim Report (June 5, 2012)
Final Report (August 6, 2012)
Steering Committee face-to-face meeting (April 26, 2012)
Steering Committee face-to-face meeting (May 22-23, 2012)
Briefing to Brinkman (June 6, 2012)
Briefing to NSF (June 18, 2012)
Brinkman's charge (March 19, 2012)
Steering Committee Kickoff meeting (April 9, 2012)
Briefing to Siegrist / Lehman (June 26, 2012)
Brinkman's letter in response to the interim report (June 29, 2012)
12 steering committee teleconference meetings
numerous working group meetings

Workshop (April 25-26, 2012)

More than 200 participants
~5 hours devoted to community voice

Open Process

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

All documentation on this web site

LBNE Reconfiguration Fermilab | U.S. DEPARTMENT OF ENERGY

Fermilab: Home | Help | Press Room | Phone Book | Fermilab at Work

LBNE Reconfiguration
- Organization
- Steering Committee
- Physics Working Group
- Engineering/Cost Working Group
- March 19, 2012 Charge letter from Brinkman to Oddone
- Workshop (April 25-26, 2012)
- Community Voice
- Interim Report (June 5, 2012)
- June 29, 2012 letter from Brinkman in response to the Interim Report
- Input to the European Strategy Group

LBNE Reconfiguration Report
- Steering Committee Report (PDF) — August 6, 2012
- Supporting Documents

Relevant Reports
- Marx/Reichanadter Report (May 2011)
- DUSEL Science NRC

Office of Science Director Bill Brinkman has charged Fermilab with finding a path forward to reach the scientific goals of the Long-Baseline Neutrino Experiment in a phased approach. A Steering Group has been formed by Fermilab to study phased approaches and alternative experimental configurations.

LBNE Reconfiguration Report
- Steering Committee Report (PDF) — August 6, 2012
- Supporting Documents
  - Physics Working Group Report (PDF)
  - Engineering / Cost Working Group Report (PDF)
  - Muon-induced background for beam neutrinos at the surface (PDF)
  - Can the NuMI beam-line be further optimized for a lower-neutrino-energy spectrum? (PDF)
  - The Science and Strategy for a Long-Baseline Neutrino Experiment Near Detector (PDF)
  - Physics Opportunities with Stage 1 of Project X (PDF)

Charge from William Brinkman's letter to Pier Oddone:

The charge is contained in the letter of Bill Brinkman to Pier Oddone that states in part:

"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."

Timeline

The timeline is determined by the need to provide detailed information on our plans to Congress for its

Issues for LBNE Phase 1

- A guideline of LBNE Phase 1 budget:
  - about \$700M ~ \$800M (including escalation and contingency)
  - about half of the full LBNE cost (more about cost later)

- Main issues for Phase 1:
  - What physics to be compromised in order to make it affordable
  - What long-term physics limitations are imposed by the different Phase-1 options

- The fundamental practical choice:
  - Do we use the existing NuMI beamline to Soudan / Ash River or do we develop a new beamline to Homestake?

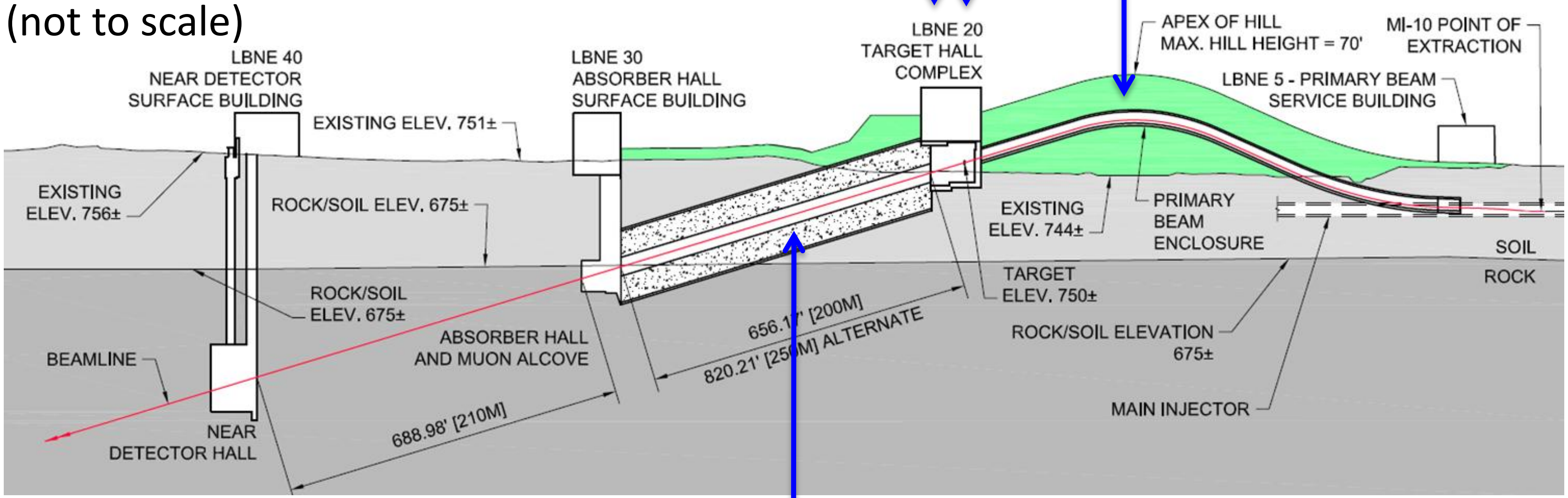
A beamline is a significant investment.

Target hall with remote handling in high-radiation environment

Beam extraction and transport from the Main Injector to target

Focusing horns for secondary particles

Beamline to Homestake (not to scale)



Large underground decay pipe (4m x 200m for Homestake ; 2m x 675m for NuMI)

Homestake beamline: much better aquifer protection than the NuMI beamline

Issues for LBNE Phase 1

- Using the existing NuMI beamline
  - saves the cost of a new beamline and allows funding a more ambitious detector in Phase 1
  - but may limit the future physics reach for neutrino physics.
  - also beamline maitanability issues and safety concerns
- Developing a new beamline to Homestake
  - requires the investment of substantial resources that reduces the mass of the Phase 1 detector
  - but preserves the ability to develop the full physics potential in the long term.

Options considered

- Homestake options (1,300 km baseline)
  a) New beamline + a smaller detector → long baseline neutrino physics
  b) No beamline + a large detector → non-accelerator based physics

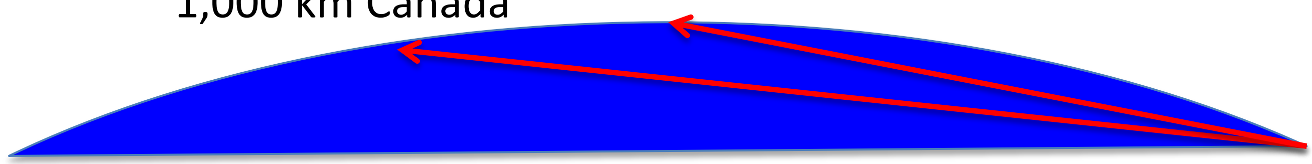
  Conclusion: accelerator-based neutrino physics has higher priority, and we chose (a) over (b).

- Long baseline (1,000 km – 2,300 km) accelerator-based neutrino physics options that require a new beamline
  a) Homestake
  b) Other sites (less developed than Homestake)

  Conclusion: (b) is not cheaper than the Homestake option, thus no gain, but loss (there has been significant investments by South Dakota, funding agencies, LBNE project). We chose (a) over (b).

Options considered (cont.)

- 1,000 km baseline using the existing NuMI beamline



  – At 1,000 km, the beam is 21 mrad off axis and the neutrino flux is too low for CP. This option became not viable.

Options selected for further studies

Beam			Far Detector (LAr TPC)			
Energy	Baseline	Off-axis angle	Location	Depth (ft)	Mass (kt) (physics)	Mass (kt) (cost)
NuMI LE (wide band)	735 km	0	Soudan	0	5, 10, 15, 34	5, 17, 34
NuMI LE (wide band)	735 km	0	Soudan	2340	5, 10, 15, 34	5, 17. 34
NuMI ME (narrowest band)	810 km	14 mrad	Ash River	0	5, 10, 15, 34	5, 17. 34
NuMI LE (narrow band)	810 km	14 mrad	Ash River	0	5, 10, 15, 34	5, 17. 34
LBNE LE (wide band)	1300 km	0	Homestake	0	5, 10, 15, 34	5, 17. 34
LBNE LE (wide band)	1300 km	0	Homestake	4850	5, 10, 15, 34	5, 17. 34

NuMI LE (ME) = the low-energy (medium-energy) tunes of the existing NuMI beamline
LBNE LE = the low-energy tune of a new proposed beamline aimed at Homestake
The costs of other detector masses estimated by interpolation.

- LBNE Phase 1 running (ν and $\bar{\nu}$): 120 GeV proton beam, 700 kW (or 6 x 10^{20} protons on target / year) for 10 years
- NOvA running (ν and $\bar{\nu}$): 6 years for the Homestake site and 16 years for the Minnesota sites
- T2K running (neutrinos only): 5 x 10^{21} protons on target in total

Physics Sensitivity Studies

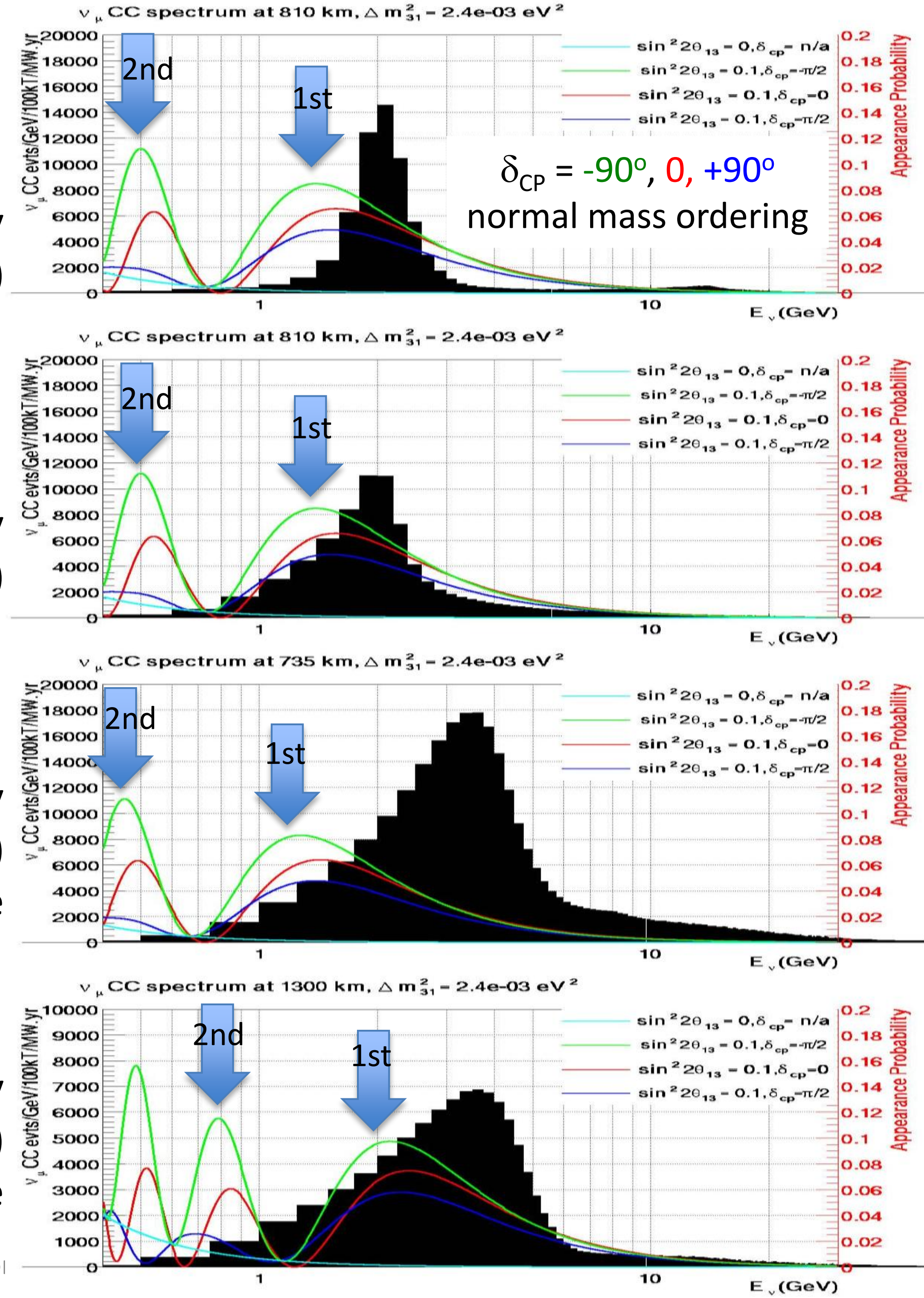
Unoscillated ν_μ charged-current spectra with ν_e appearance probability curves.

Ash River Medium Energy (810 km)

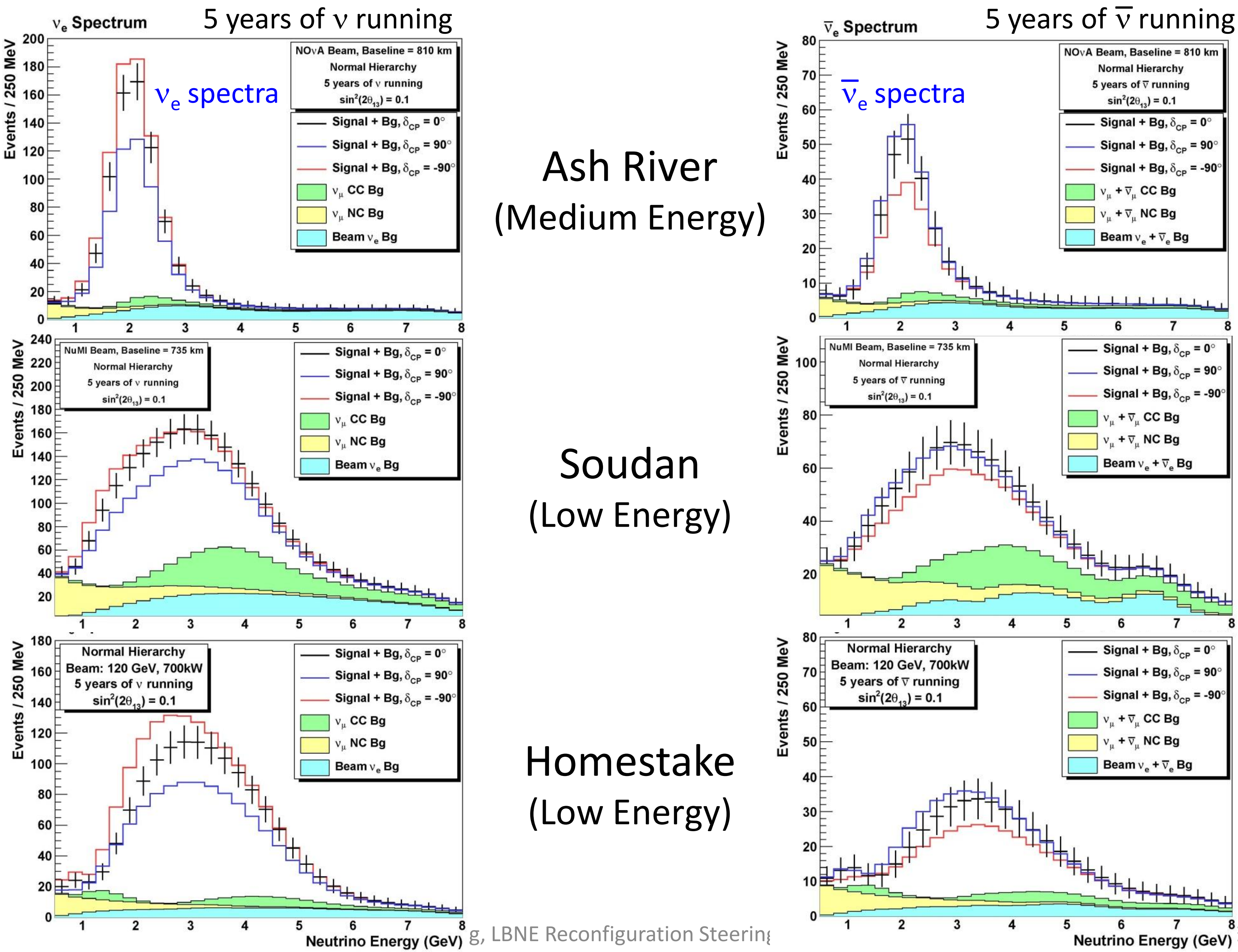
Ash River Low Energy (810 km)

Soudan Low Energy (735 km) underground=surface

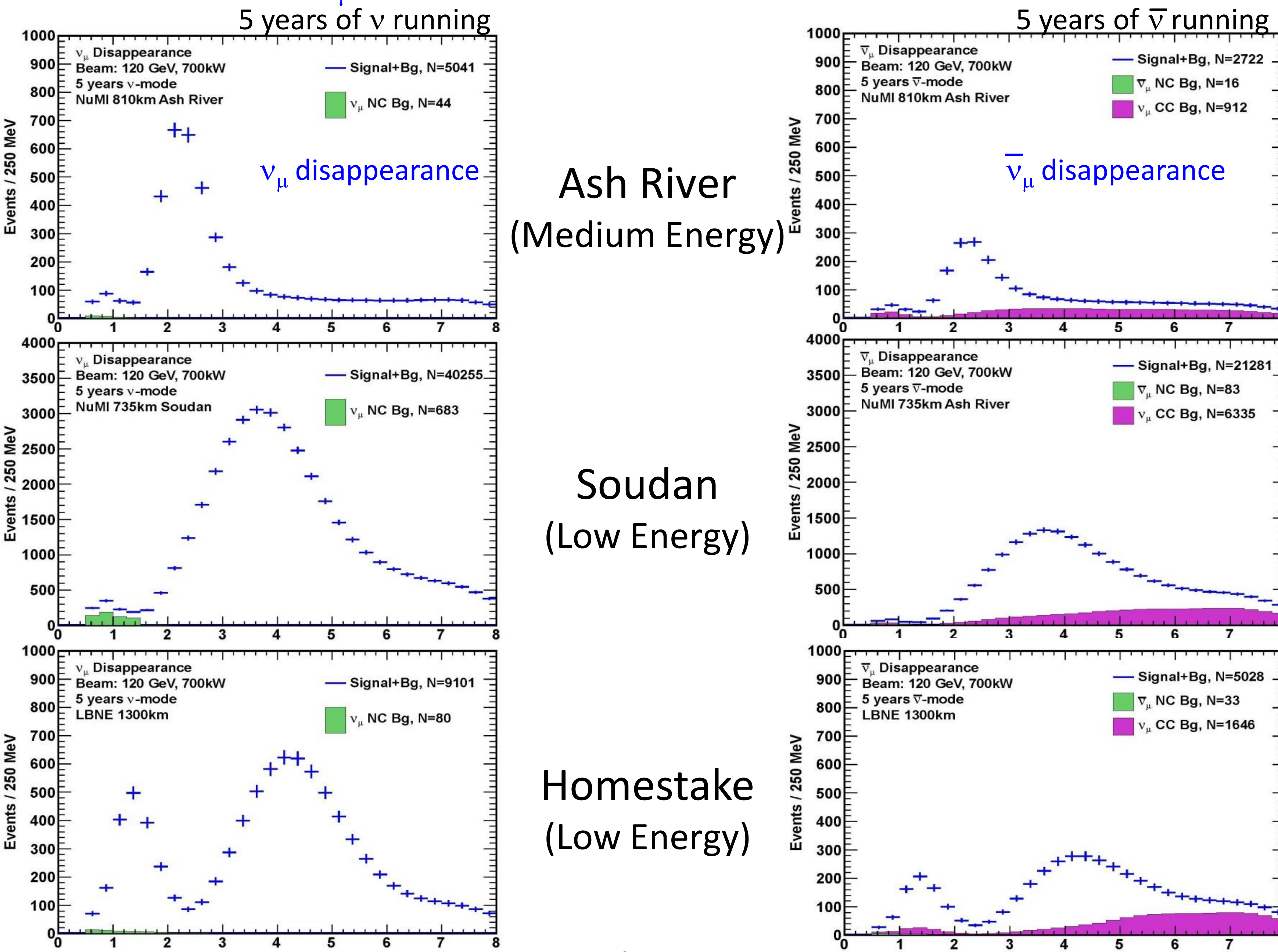
Homestake Low Energy (1,300 km) underground=surface



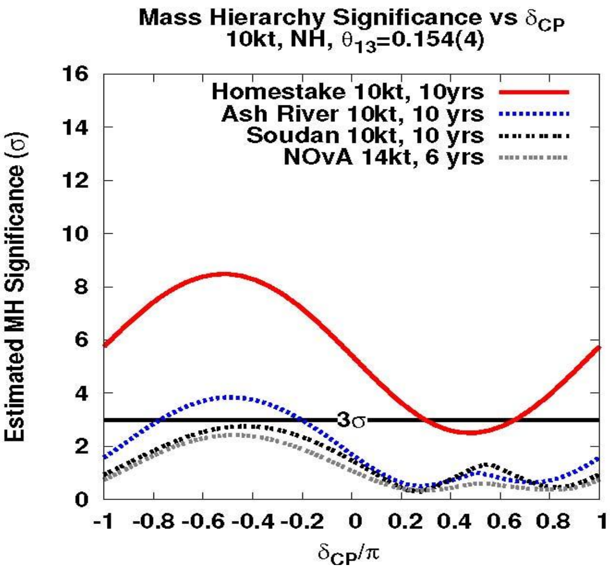
Expected ν_e appearance spectra (34 kt LAr detector)

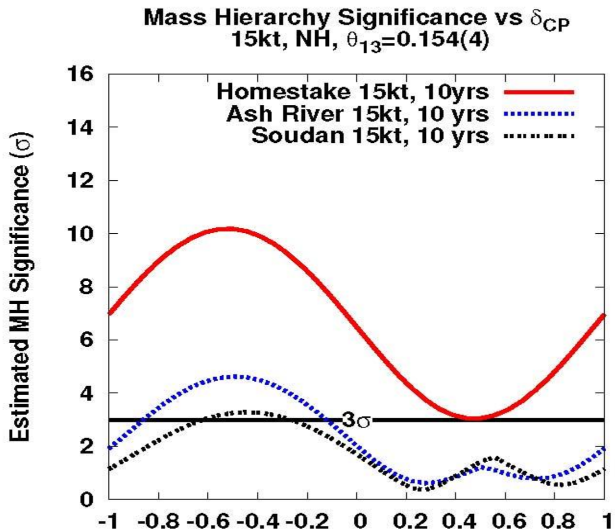


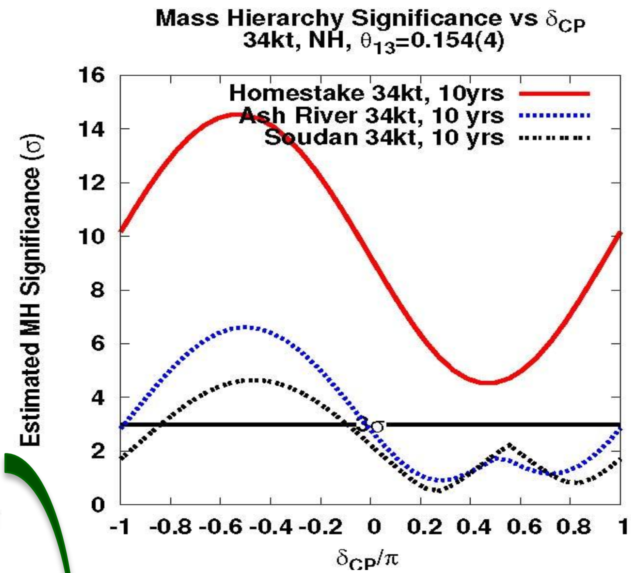
Expected ν_μ disappearance spectra (34 kt LAr detector)

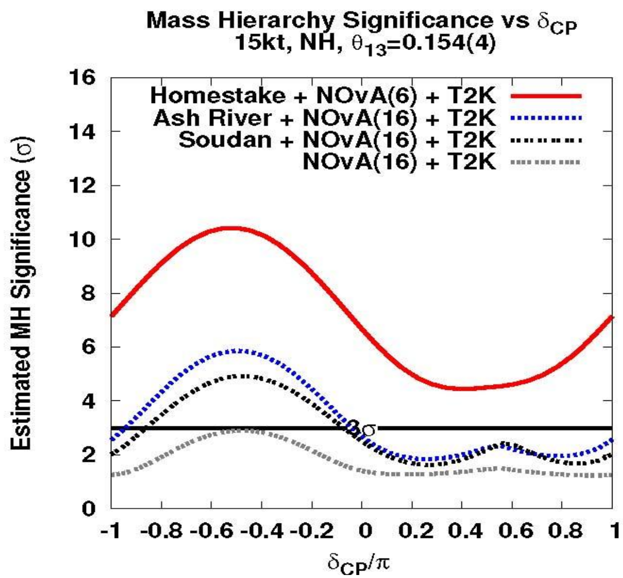


Mass Hierarchy Reach



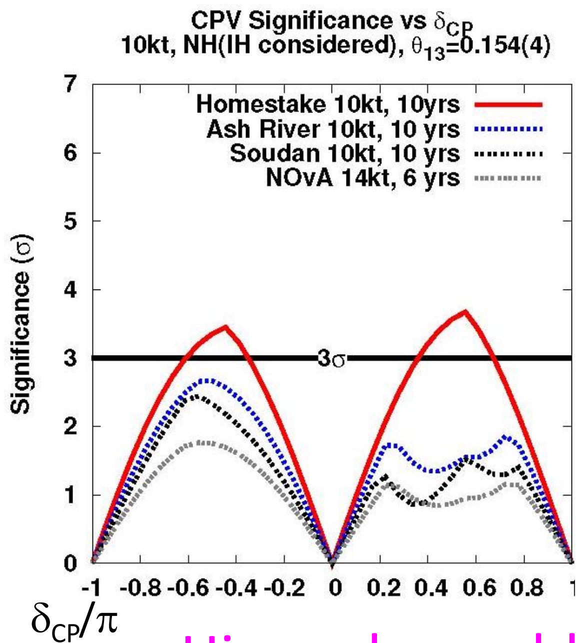


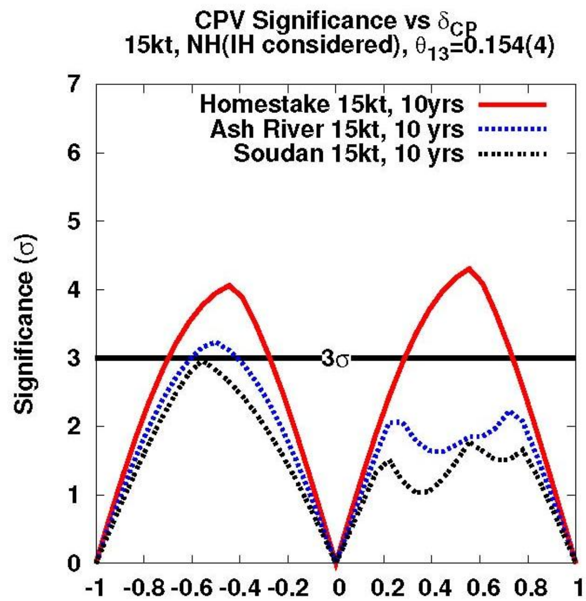


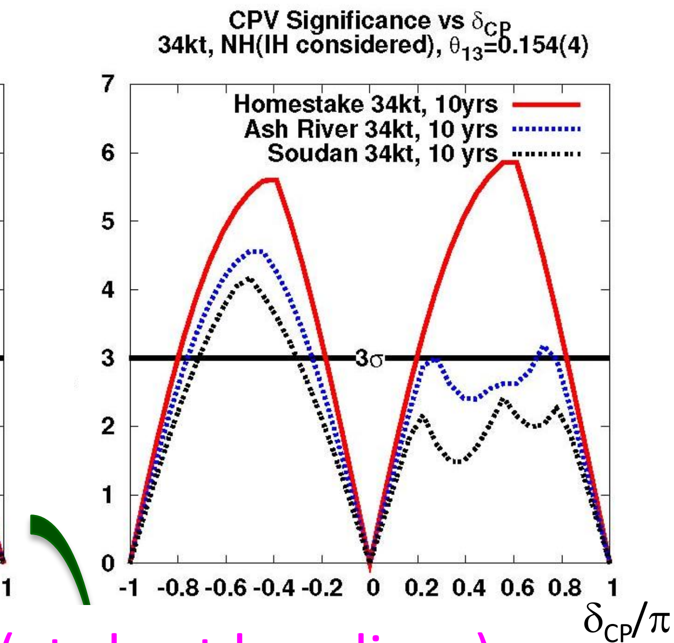


Adding NOvA & T2K

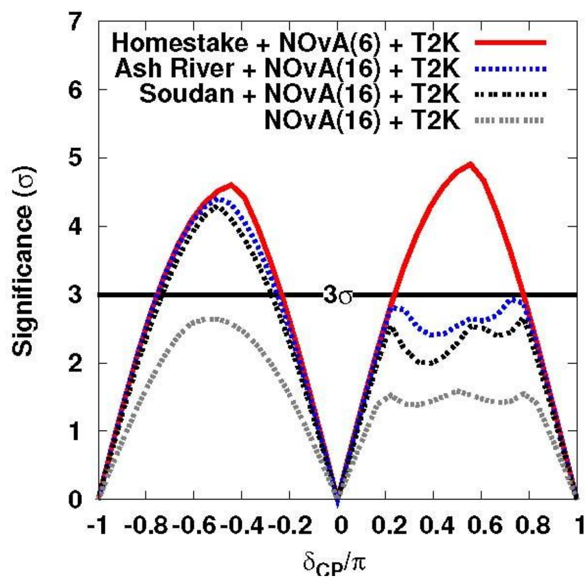
CP Violation Reach







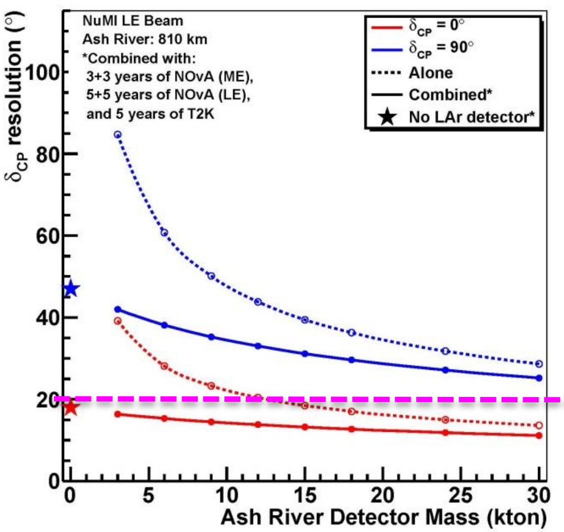
Hierarchy problem → δ_{CP}>0 problem (at short baselines)



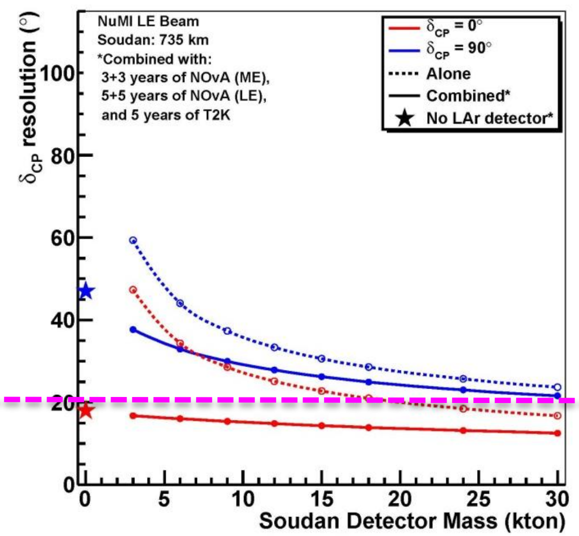
Adding NOvA & T2K

δ_{CP} Measurements (resolution)

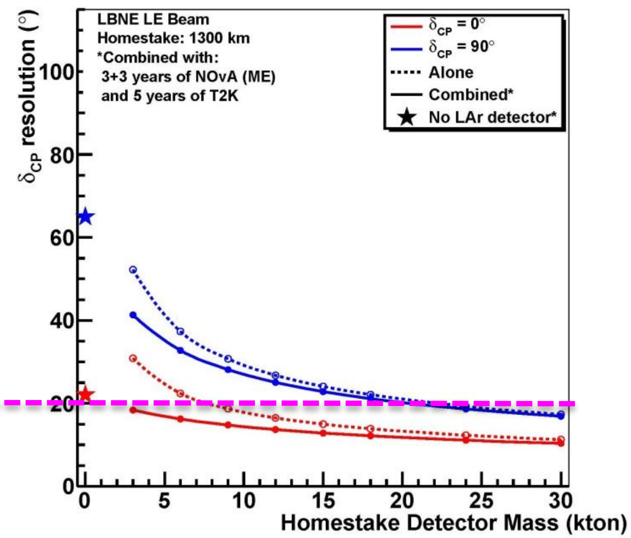
Ash River



Soudan Mine



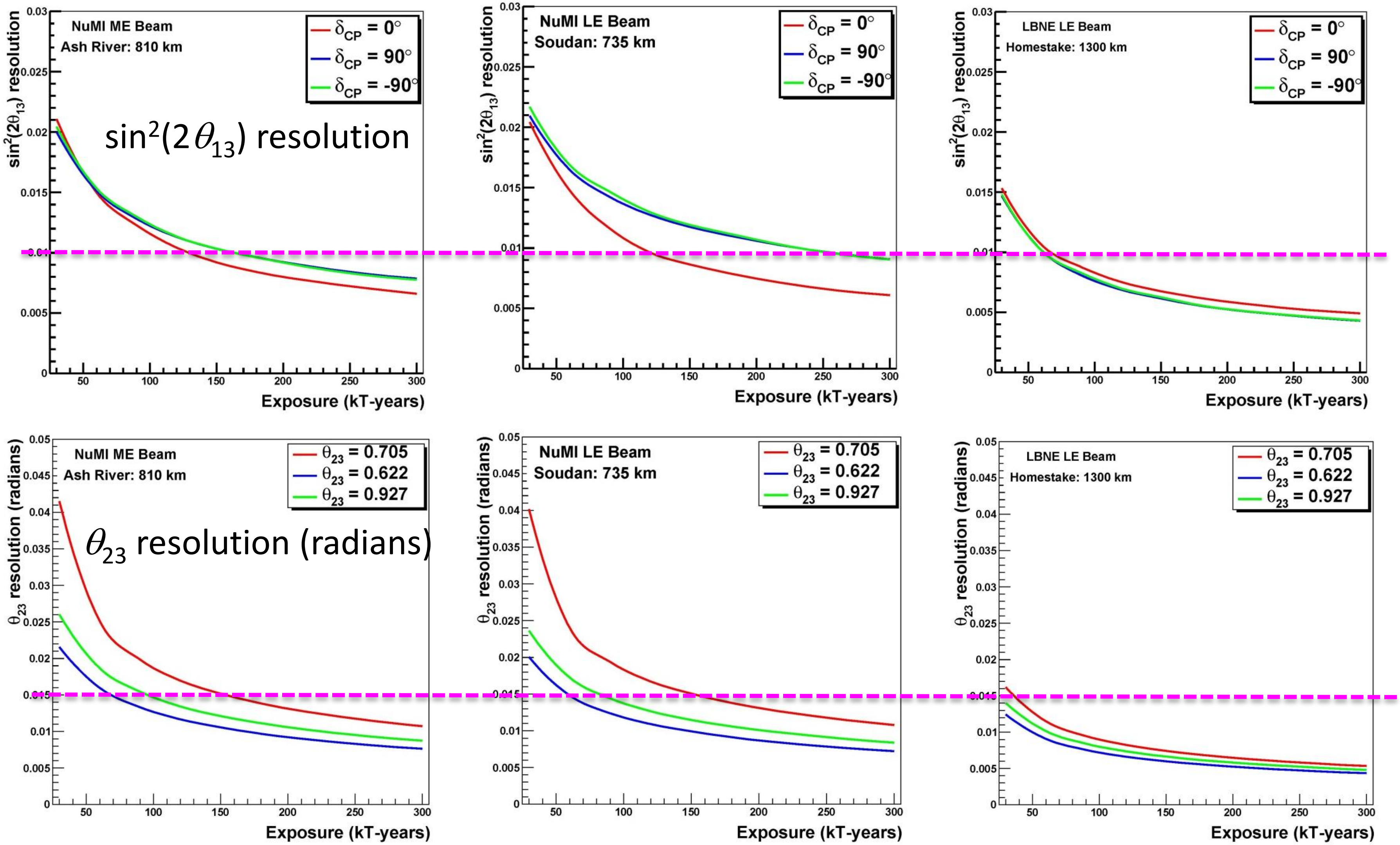
Homestake



δ_{CP} = 0, +90°

Other mixing parameters

Ash River | **Soudan Mine** | **Homestake**

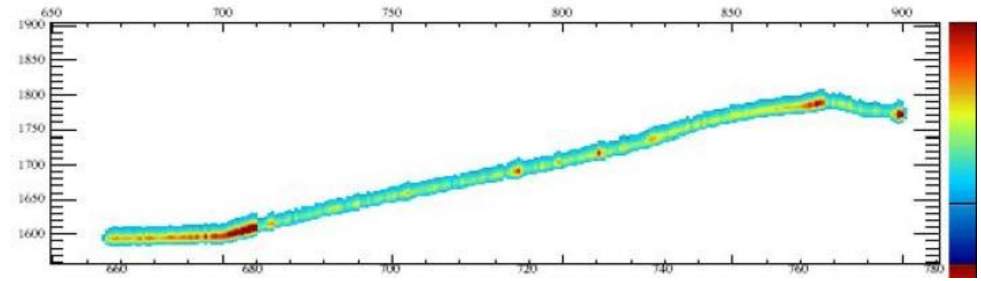


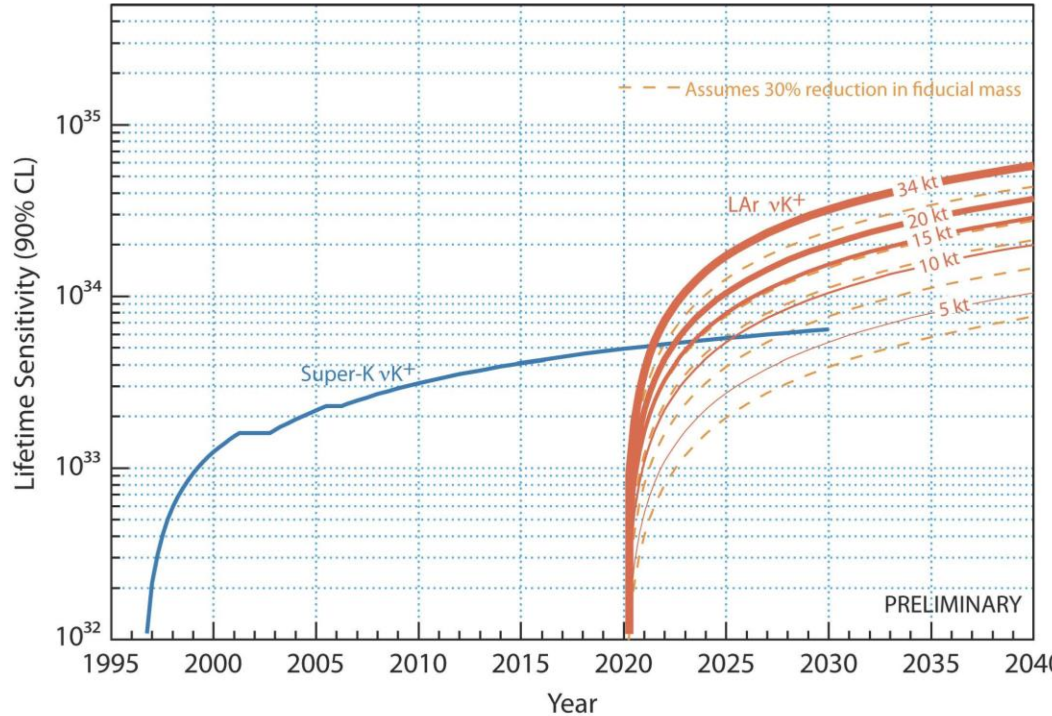
Searching for new physics

- Using a wideband beam and long baseline to look for a breakdown of the 3 generation mixing model.
  - neutral current non-standard matter effects
  - long-range interactions between neutrinos and background sources
  - active-sterile neutrino mixing from the neutral current event rate

Non-accelerator physics

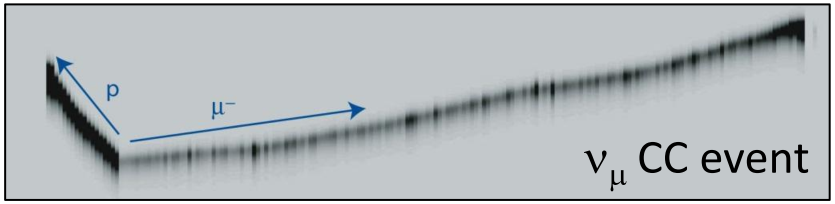
- Proton Decay ($p \rightarrow K\nu$)
  - distinctive in LAr ($K \rightarrow \mu \rightarrow e$)
  - Favored mode for SUSY-inspired GUTs
  - Must be underground and at least 10 kt to be competitive.
  - Studies of proton decay are complementary to those being performed with existing water Cerenkov detectors.

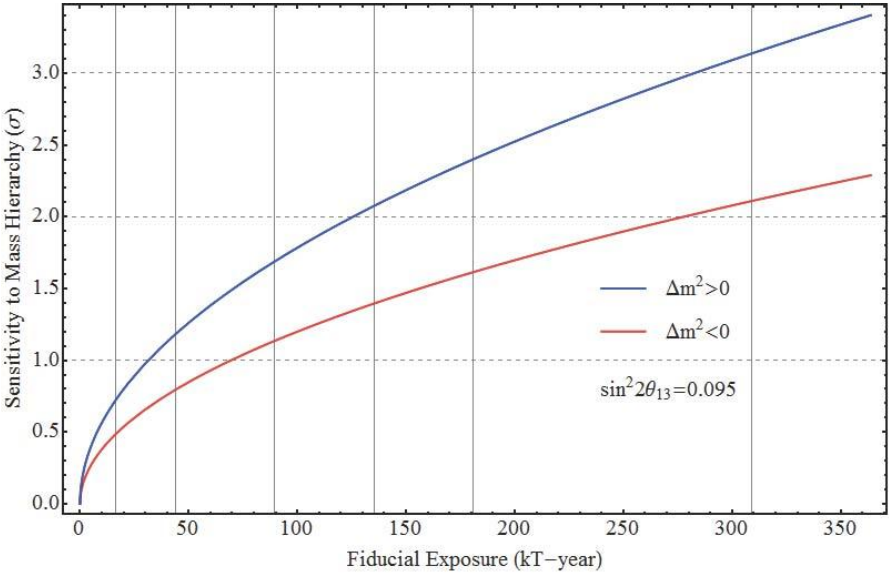




Non-accelerator physics (cont.)

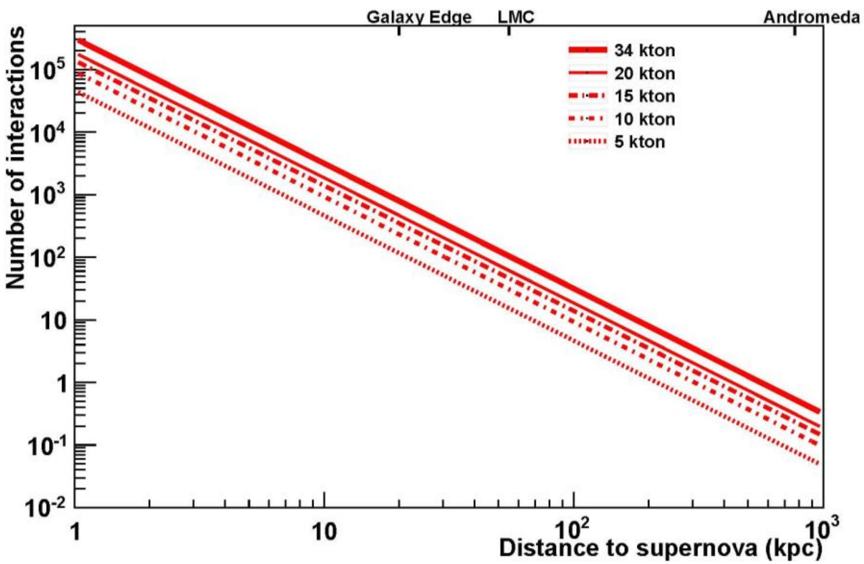
- Atmospheric neutrinos
  - Similar to accelerator-ν events
  - underground necessary (background)
  - mass hierarchy sensitivity





Non-accelerator physics (cont.)

- Supernova Core Collapse Neutrinos
  - Needs to be underground
  - A time-correlated burst over a well measured background rate.
  - LAr TPCs are sensitive to neutrinos whereas WC detectors are sensitive to antineutrinos
  - Core collapses are expected to occur a few times per century at a most-likely distance of about 10-15 kpc.



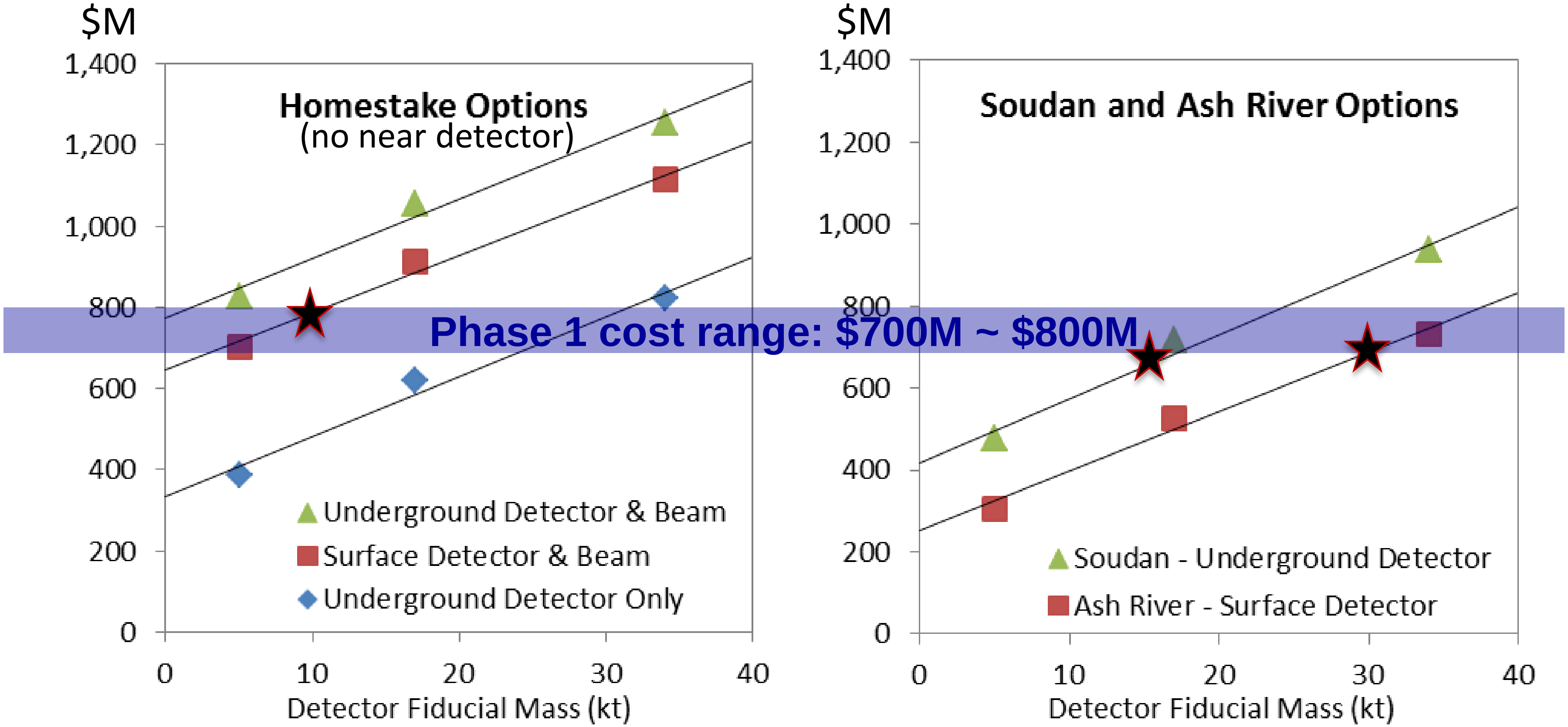
Physics Sensitivities: Summary

- The neutrino hierarchy and the CP phase angle are accessible with the options being considered.
- A longer baseline allows complete separation between matter and CP effects.
- A longer baseline and a wide-band beam allow observation of multiple oscillation peaks and the valleys between them in the long term. This provides broader sensitivity to neutrino oscillation physics beyond that described by the standard 3×3 matrix.
- The search for proton decay and the study of atmospheric and supernova-burst neutrinos require the detector to be underground.
  - Homestake at 4850 ft depth: excellent opportunities
  - Soudan lab at 2340 ft depth: modest compromise in physics reach

Engineering/cost studies

- LBNE has developed a CD-1-level conceptual design and cost estimate for the full project, which has been reviewed and found to be sound.
- The reconfiguration cost estimates are based to the greatest extent possible on that cost estimate.
- Value Engineering during the reconfiguration process lowered the cost estimate for the full LBNE to $\lesssim$\$1.5B.
  - This was done by simplifying designs to a minimal configuration while maintaining the same scientific capability
- Comparison between the Homestake cost estimates and operational methods and actual experience at Soudan and Ash River was very helpful in this process.

Engineering/cost studies



Fixed costs

- All options: Project management (~10% of the project)
- Homestake with beam: new beamline
- Soudan underground detector: two new shafts + beamline upgrade
- Ash River or Soudan surface detector: surface infrastructure + beamline upgrade

The Steering Committee Conclusions for LBNE Phase 1

Viable Options

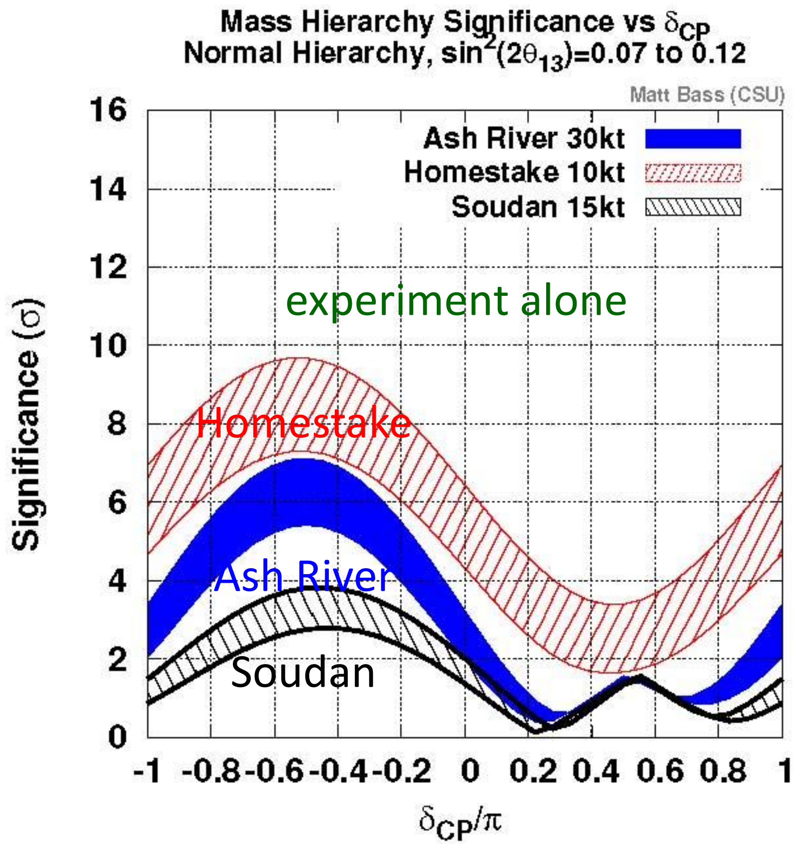
Preferred Option

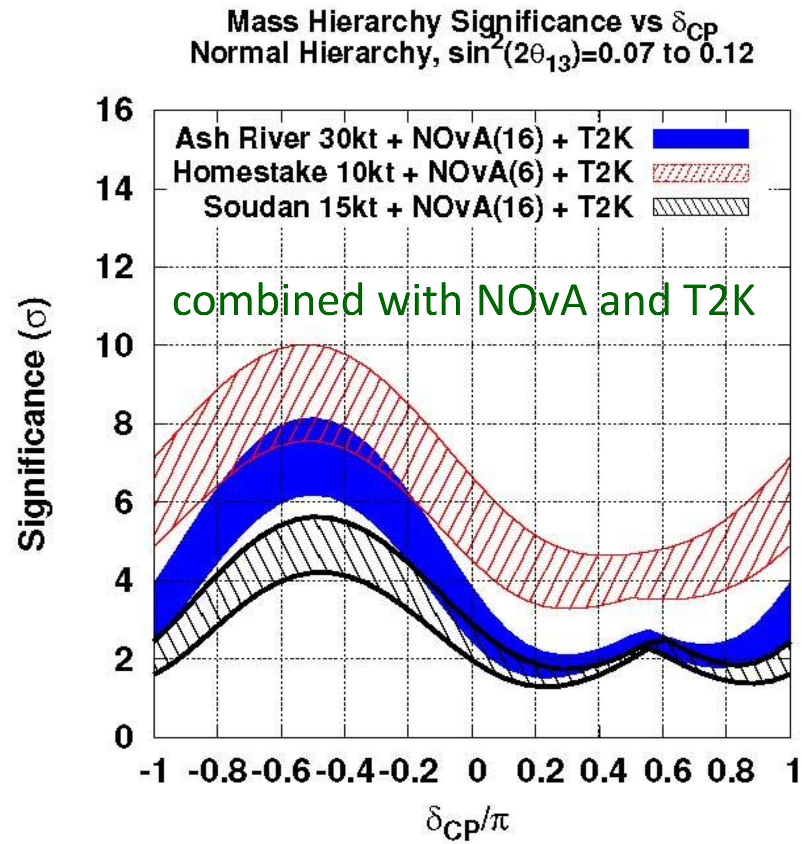
Strategy to enhance the physics scope of the preferred option

Three options

- Three options are (not priority ordered):
  - Using the existing NuMI beamline in the low energy configuration with a 30 kt LAr-TPC surface detector 14 mrad off-axis at Ash River, 810 km from Fermilab. ($684M)
  - Using the existing NuMI beamline in the low energy configuration with a 15 kt LAr-TPC underground (at the 2,340 ft level) detector on-axis at the Soudan Lab, 735 km from Fermilab. ($675M)
  - Constructing a new low energy LBNE beamline with a 10 kt LAr-TPC surface detector on-axis at Homestake, 1,300 km from Fermilab. ($789M)
- The committee looked at possibilities of projects with significantly lower costs and concluded that the science reach for such projects becomes marginal.

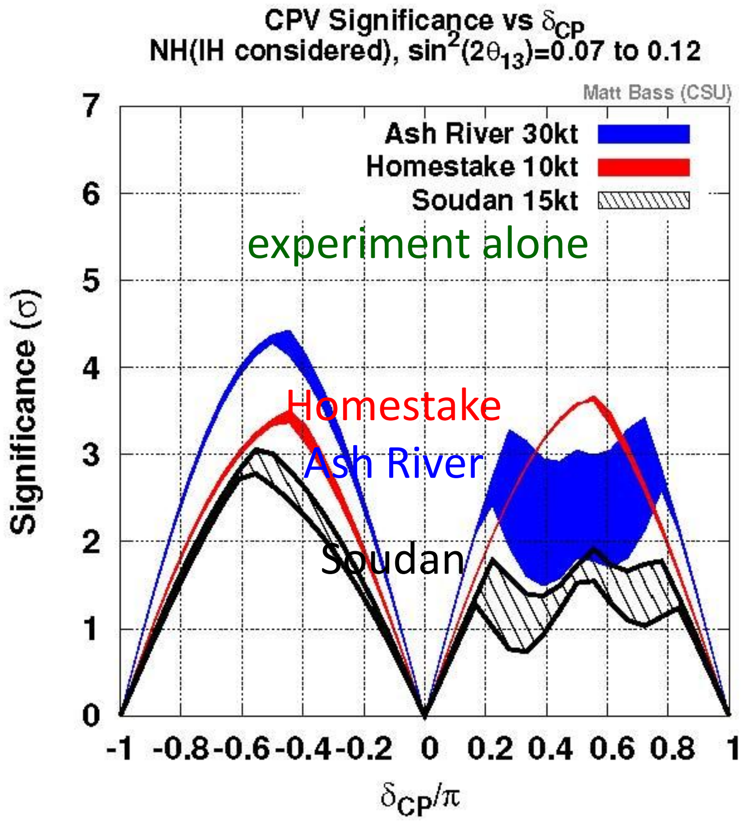
Mass hierarchy reach for the three options

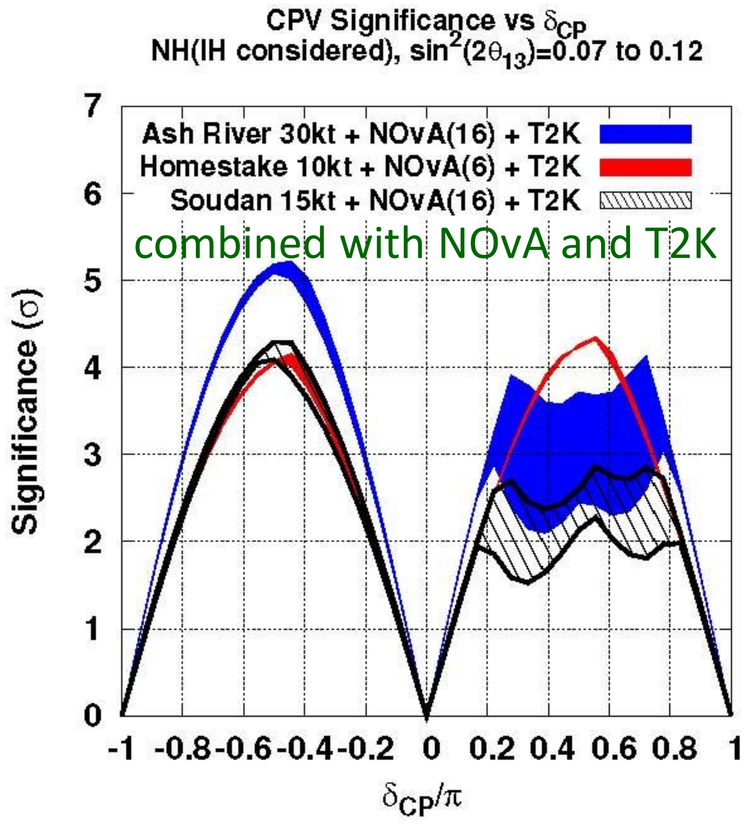




widths – impact of $\sin^2(2\theta_{13})$ range (0.07 ~ 0.12) on Mass Hierarchy

CP reach for the three options



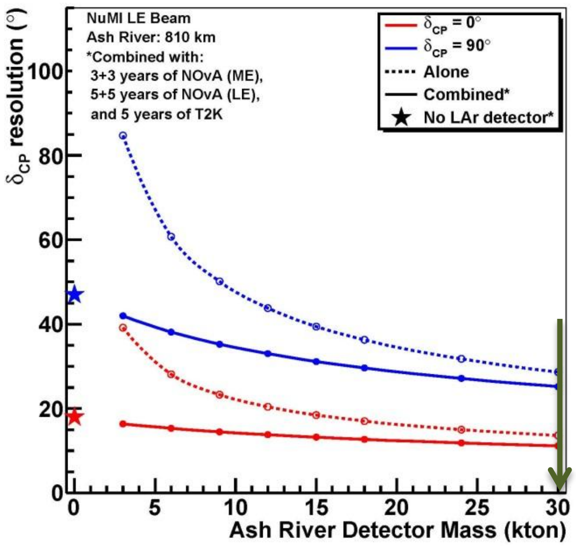


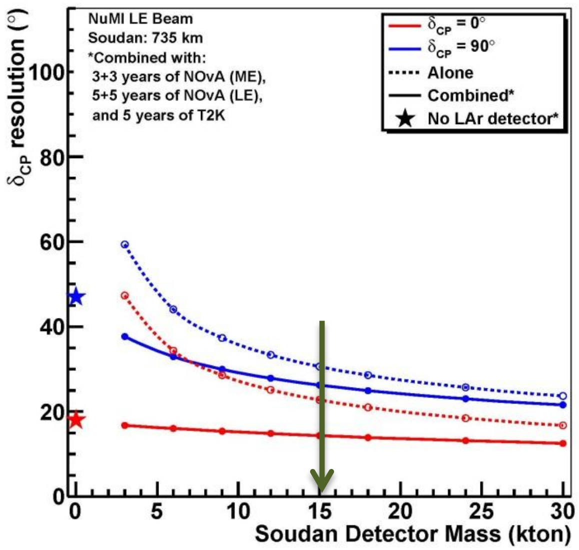
widths – impact of $\sin^2(2\theta_{13})$ range (0.07 ~ 0.12) on CP reach

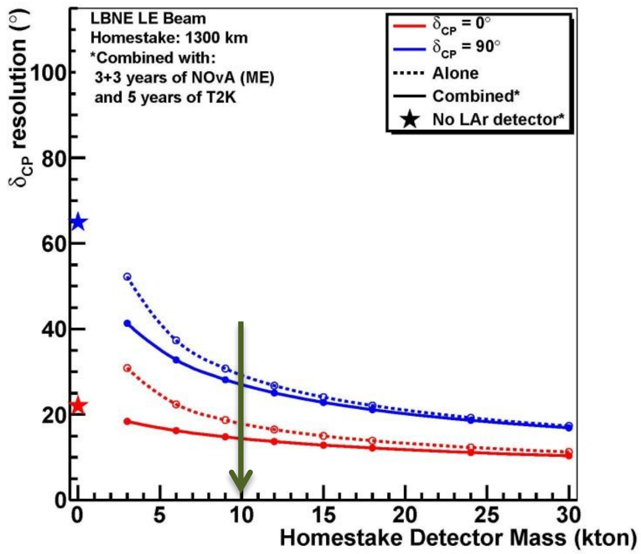
δ_{CP} measurements for the three options

Ash River **Soudan Mine** **Homestake**

δ_{CP} = 0, +90°







Summary: 30 kt at Ash River (810 km, surface)

Pros	• Best Phase 1 CP-violation sensitivity in combination with NOvA and T2K results for the current value of θ_{13}. The sensitivity would be enhanced if the mass ordering were known from other experiments. • Excellent (3σ) mass ordering reach in nearly half of the δ_{CP} range.

Cons	• Narrow-band beam does not allow measurement of oscillatory signature.
	• Shorter baseline risks fundamental ambiguities in interpreting results.
	• Sensitivity decreases if θ_{13} is smaller than the current experimental value.
	• Cosmic ray backgrounds: impact and mitigation need to be determined.
	• Only accelerator-based physics.
	• Limited Phase 2 path:
	    ○ Beam limited to 1.1 MW (Project X Stage 1).
	    ○ Phase 2 could be a 15-20 kt underground (2,340 ft) detector at Soudan.

Summary: 15 kt at Soudan (735 km, 2340 ft)

Pros	• Broadest Phase 1 physics program: ○ Accelerator-based physics including good (2σ) mass ordering and good CP-violation reach in half of the δ_{CP} range. CP-violation reach would be enhanced if the mass ordering were known from other experiments. ○ Non-accelerator physics including proton decay, atmospheric neutrinos, and supernovae neutrinos. • Cosmic ray background risks mitigated by underground location.
Cons	• Mismatch between beam spectrum and shorter baseline does not allow full measurement of oscillatory signature. • Shorter baseline risks fundamental ambiguities in interpreting results. This risk is greater than for the Ash River option. • Sensitivity decreases if θ_{13} is smaller than the current experimental value. • Limited Phase 2 path: ○ Beam limited to 1.1 MW (Project X Stage 1). ○ Phase 2 could be a 30 kt surface detector at Ash River or an additional 25-30 kt underground (2,340 ft) detector at Soudan.

Summary: 10 kt at Homestake (1300km, surface)

Pros	• Excellent (3σ) mass ordering reach in the full δ_{CP} range. • Good CP violation reach: not dependent on *a priori* knowledge of the mass ordering. • Longer baseline and broad-band beam allow explicit reconstruction of oscillations in the energy spectrum: self-consistent standard neutrino measurements; best sensitivity to Standard Model tests and non-standard neutrino physics. • Clear Phase 2 path: a 20 – 25 kt underground (4850 ft) detector at the Homestake mine. This covers the full capability of the original LBNE physics program. • Takes full advantage of Project X beam power increases.
Cons	• Cosmic ray backgrounds: impact and mitigation need to be determined. • Only accelerator-based physics. Proton decay, supernova neutrino and atmospheric neutrino research are delayed to Phase 2. • ~15% more expensive than the other two options: cost evaluations and value engineering exercises in progress.

Can a LAr detector successfully operate on the surface?

- Issues:
  - long drift time of electrons in the TPC ~ 1.4 ms
  - beam spill duration ~ 10 μs (1.33 second beam spill repetition)

- The LBNE collaboration has conducted initial studies.

- A combination of simple cuts together with the low (~2%) expected probability of e-γ misidentification can reduce background to a level below the expected ν_e appearance signal. Positioning the detector behind a hill (a location exists) together with optional photon detection system and veto would largely improve background rejection.

- Studies are ongoing to increase statistics and to identify and remove rarer processes.

- The shorter drift distance for surface options is chosen to mitigate the effects of space charge build-up due to cosmic rays.

The need for a near detector during Phase 1

- Phase 1
  - Soudan / Ash River: the existing near detectors + MINERvA.
  - Homestake: muon detectors to monitor the beam – adequate for Phase 1
    - The statistical uncertainties dominate, at least for the mass hierarchy and CP phase measurements.
    - Background determination will be better due to the LAr detector.
    - The LBNE beam will be very similar to NuMI, so the measurements there will be transferable.
    - Measurement of the neutrino and antineutrino cross sections on Argon will have been measured with MicroBooNE.
- A complete LBNE near detector system will be required in a later stage to achieve the full precision of the experiment.

Preferred option: Homestake

- While each phase-1 option is more sensitive than the others in some particular physics domain, the Steering Committee strongly favored the Homestake option (a new beamline and a 10 kt LAr-TPC detector on the surface).

- The physics reach of this first phase is very strong; it would determine the mass hierarchy with no ambiguities and measure the CP-violating phase δ_{CP} with $20^o \sim 30^o$ resolution and measure other oscillation parameters: θ_{13}, θ_{23}, and $|\Delta m^2_{32}|$.

- Moreover 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.

Preferred option: Enhancing the physics scope

- Placing a 10 kt detector underground in the first phase would
  - allow for a rich physics program including proton decay, and supernova and atmospheric neutrinos
  - Support a broader community
  - increase the cost by ~$135M

- Additional national or international collaborators have the opportunity to increase the scope of the first phase (place the detector 4850 ft underground and provide a full near detector) and accelerate the implementation of subsequent phases.

Conclusions

- On Mar. 19, 2012, we received a letter from Brinkman that stated that LBNE as currently conceived could not be funded within the expected budget envelope for Office of Science and charged us to present a phased approach or alternatives, with physics productivity at every stage.
- We have answered the charge through the work of the Steering Committee, the Physics and the Engineering/Cost Working Groups, and with input from the physics community.
- The committee identified 3 viable options for the first phase of LBNE:
  - Using the existing NuMI beamline in the low-energy configuration with a 30 kt LAr-TPC surface detector 14 mrad off-axis at Ash River, 810 km from Fermilab.
  - Using the existing NuMI beamline in the low-energy configuration with a 15 kt LAr-TPC detector underground (at the 2,340-ft level) on-axis at the Soudan Lab, 735 km from Fermilab.
  - Constructing a new low-energy LBNE beamline with a 10 kt LAr-TPC surface detector on-axis at Homestake in South Dakota, 1,300 km from Fermilab.

Preferred option

Conclusions

- Preferred Homestake option: a new beamline and an initial 10-kt LAr-TPC detector on the surface.
  - The physics reach is very strong; moreover 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 over time and allow for the most incisive studies of neutrinos.
  - Clear Phase 2 path: a 20 – 25 kt underground (4850 ft) detector at the Homestake mine. This covers the full capability of the original LBNE physics program.
  - Takes full advantage of Project X beam power increases.
- The Committee produced an interim report and presented it to Dr. Brinkman on June 6. On June 29, Dr. Brinkman wrote a letter to Pier Oddone, asking the laboratory to proceed with planning a Critical Decision 1 review later this year based on the reconfigured LBNE options. The CD-1 review is scheduled on October 30 – November 1, 2012 (baseline: Homestake option).

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.

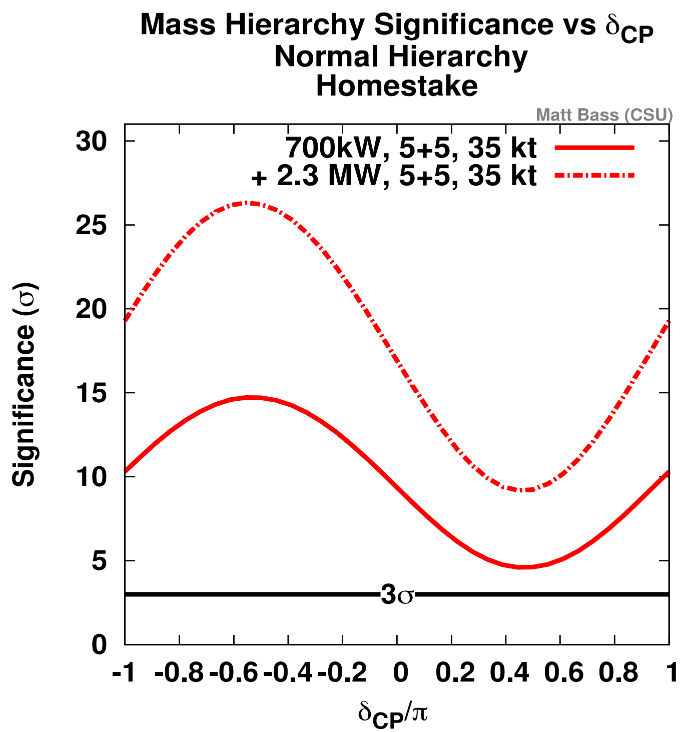
Sincerely yours,

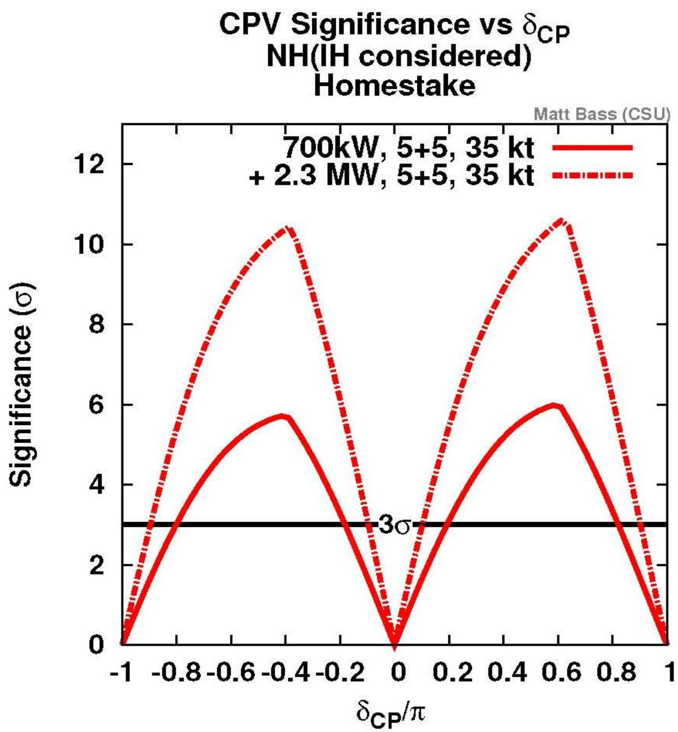
W.F. Brinkman

Conclusions

- Additional national or international collaborators have the opportunity to increase the scope of the first phase of LBNE (e.g. place the detector underground) and accelerate the implementation of subsequent phases
- Ongoing discussions with NSF
- LBNE and Project X collaboration between Indian institutions and Fermilab
  - On July 17, 2011; the U.S. DOE and India's Department of Atomic Energy (DAE) signed an Implementing Agreement on Discovery Science that provides the framework for India's participation in the next generation particle accelerator facility at Fermilab.
    - http://www.state.gov/r/pa/prs/ps/2011/07/168740.htm
  - U.S. has "In Principle" agreed to share technology with Indian DAE for the Indian program: Project Annex I and II (DOE→DAE)
  - DAE has "In Principle" recommended to make significant "In-Kind" contributions to Project X and LBNE construction.
  - Awaiting Indian Government Approval and Signing of the DOE-DAE Project Annex (I & II) before CY 2012.

This is a start of a long-term world-leading program





<u>and much more</u>

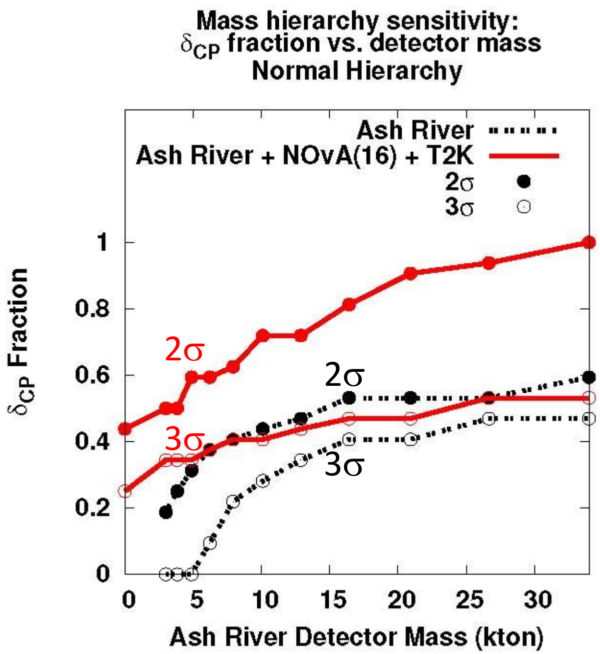
other neutrino oscillation parameters
new physics in the neutrino sector
proton decay (various modes)
atmospheric neutrinos
neutrinos from supernova explosions

…….

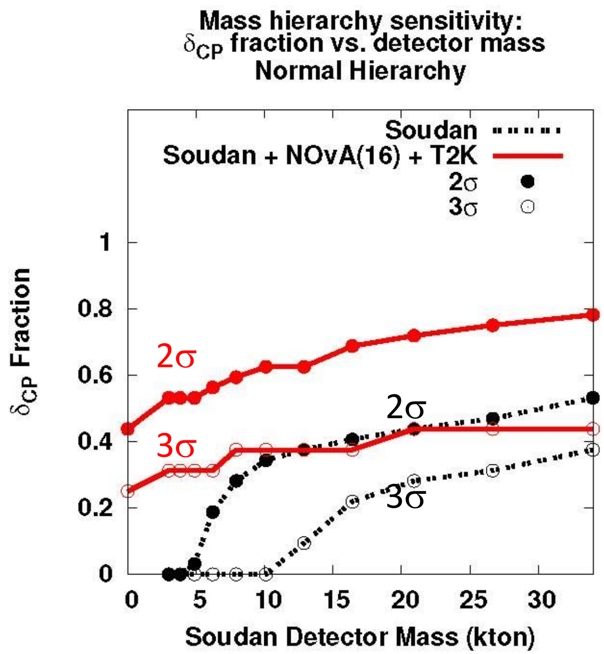
Backup slides

Fraction of δ_{CP} values for 2, 3σ mass hierarchy sensitivity

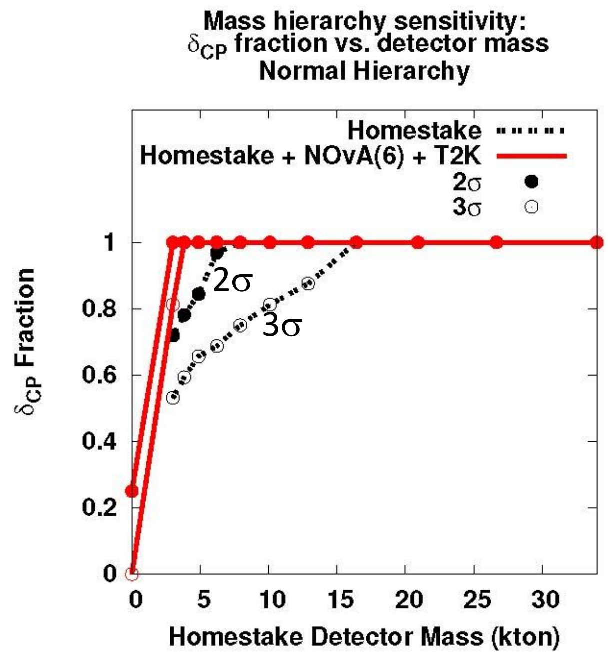
Ash River



Soudan Mine



Homestake



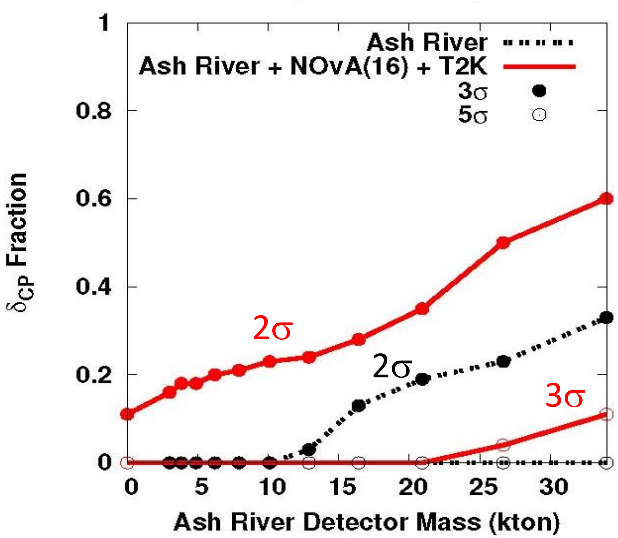
Red: combined with NOvA + T2K

Black: experiment alone without NOvA + T2K

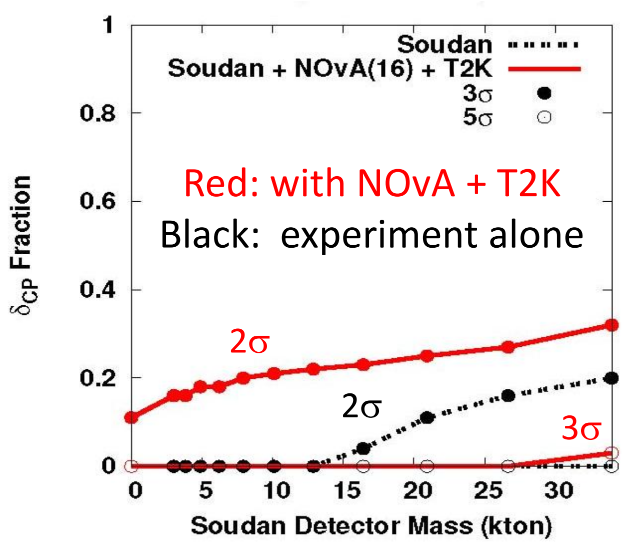
CP Violation Reach

Fraction of δ_{CP} values for 3, 5σ δ_{CP} sensitivity

Ash River



Soudan Mine



Homestake