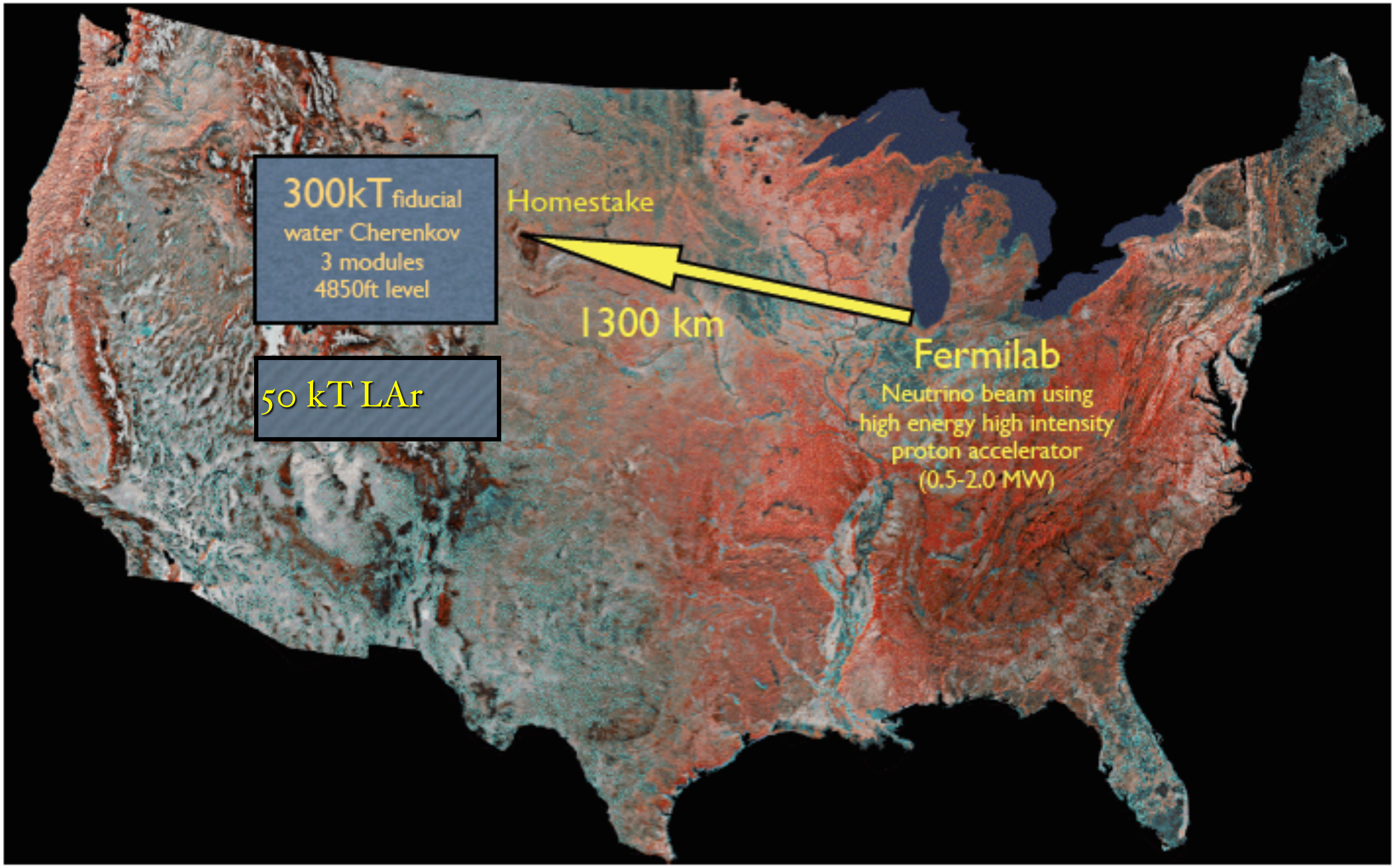
Status of LBNE

R.Svoboda, LAGUNA, 8 September 2010

Long-Baseline Neutrino Experiment



LBNE Physics

- *Measure the neutrino mass hierarchy.*
- *Explore the possibility for neutrino CP violation.*
- *Measure the neutrino mixing matrix more precisely.*
- *Extend the search for proton decay.*
- *Make a multi-flavor, high precision measurement of the neutrinos from a galactic SN.*
- *Measure the cosmological flux of neutrinos from ancient SN.*

LBNE Science Collaboration

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Pittsburgh: D. Naples, V. Paolone

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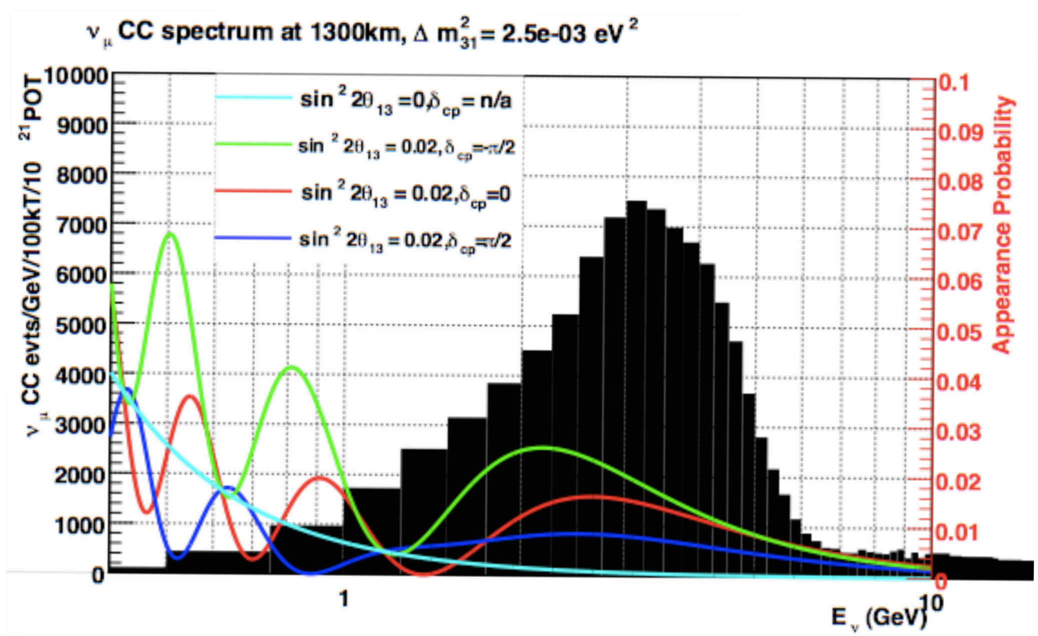
Wisconsin: B. Balantekin, F. Feyzi, K. Heeger, A. Karle, R. Maruyama, D. Webber, C. Wendt

Yale: B. Fleming, M. Soderberg, J. Spitz

- 54 inst. ~250 collaborators.
- Governance thru Inst. Board.
- Exec. Board for scientific and technical decisions.
- Next steps are international expansion.

Beam Design

- Broad band beam covering 0.5 to few GeV.
- Minimum flux above 5 GeV to lower backgrounds from feed down.
- Minimize electron neutrino background by design.
- Target, shielding, and materials need to handle 700 kW.
- Civil construction and some technical components to be rated for 2.3 MW.

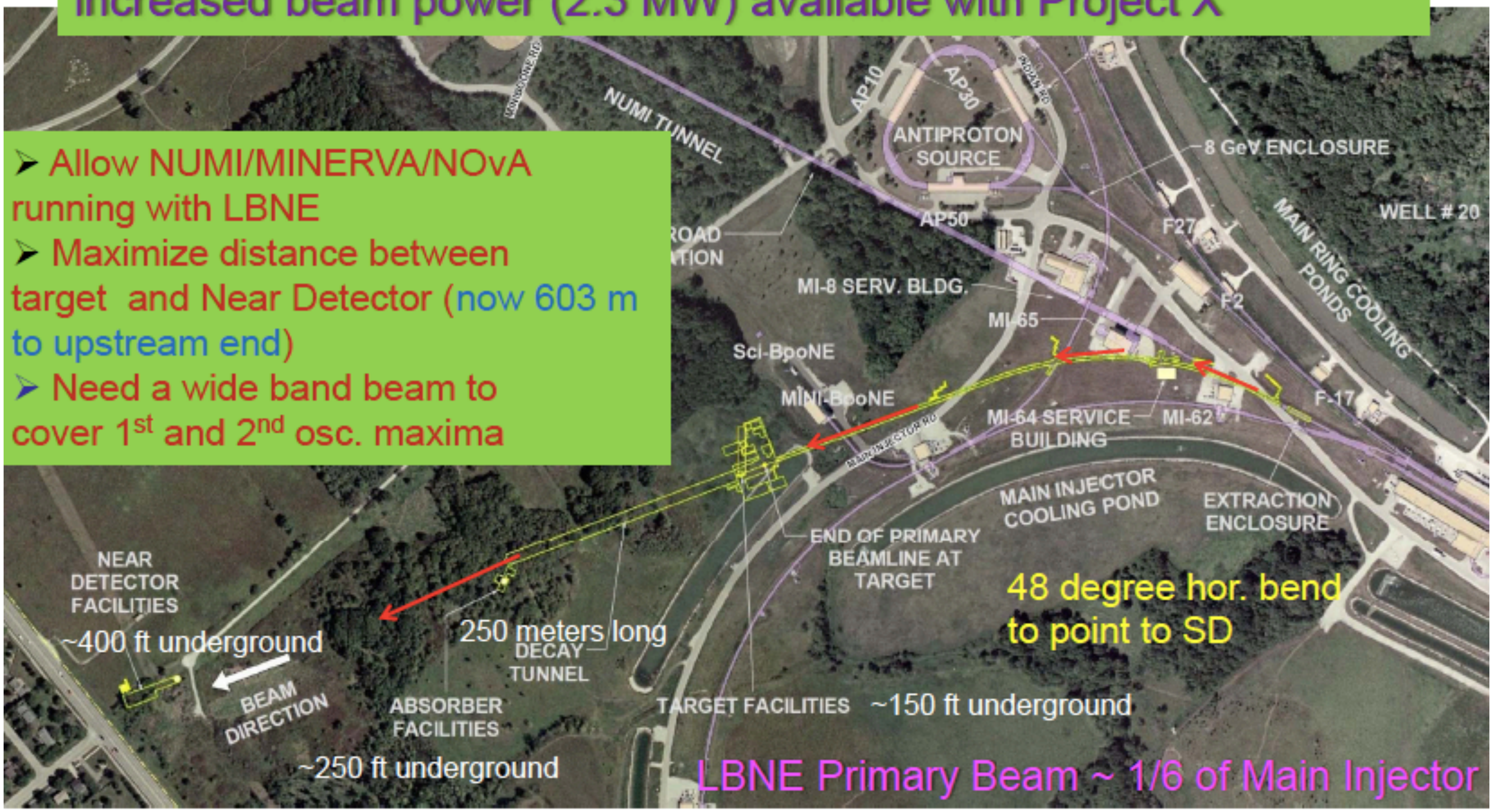


Bishai

The Neutrino Beam Facility at Fermilab

Start with a 700 kW beam, and then take profit of the significantly increased beam power (2.3 MW) available with Project X

- Allow NUMI/MINERVA/NOvA running with LBNE
- Maximize distance between target and Near Detector (now 603 m to upstream end)
- Need a wide band beam to cover 1st and 2nd osc. maxima



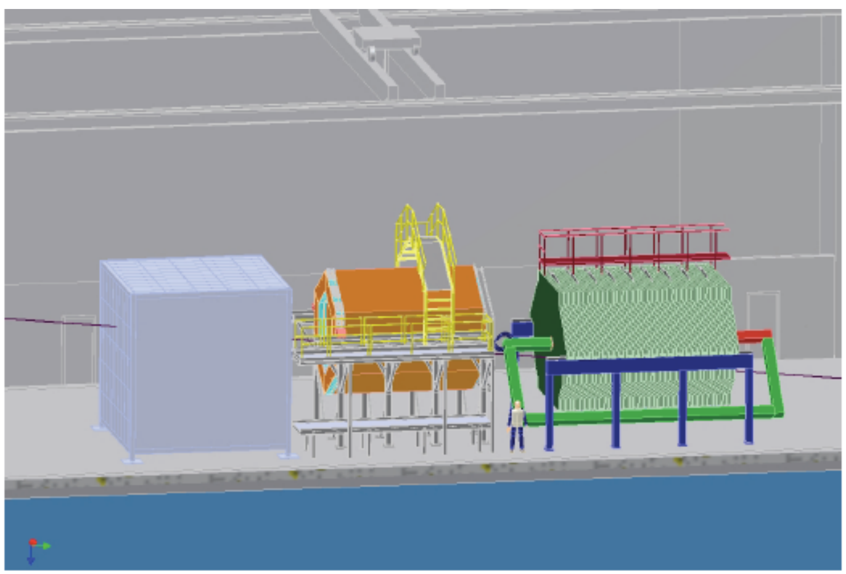
Primary beam energy (protons from the Main Injector) from 60 to 120 GeV

Design is becoming quite detailed and documented

Near detector

- Define the measurements required at the near site to meet the goals of the long-baseline neutrino oscillation analyses
- How well must we measure and predict the neutrino fluxes?
- How well must we predict signal and background rates and topologies?
  - what measurements must be made to accomplish these predictions?
  - charged current background and signal – extracting the neutrino flux at the far site
  - neutral current background

Christopher Mauger (LANL)

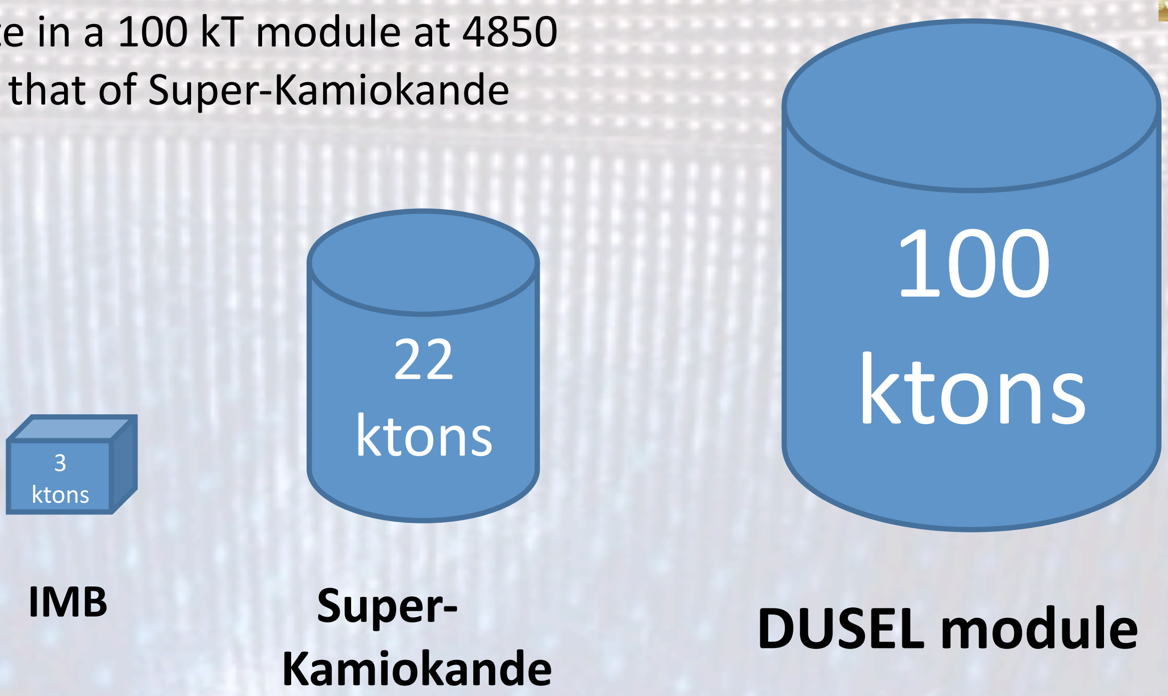


Currently many options being explored systematically.

A Large Water Cherenkov Detector Option for DUSEL

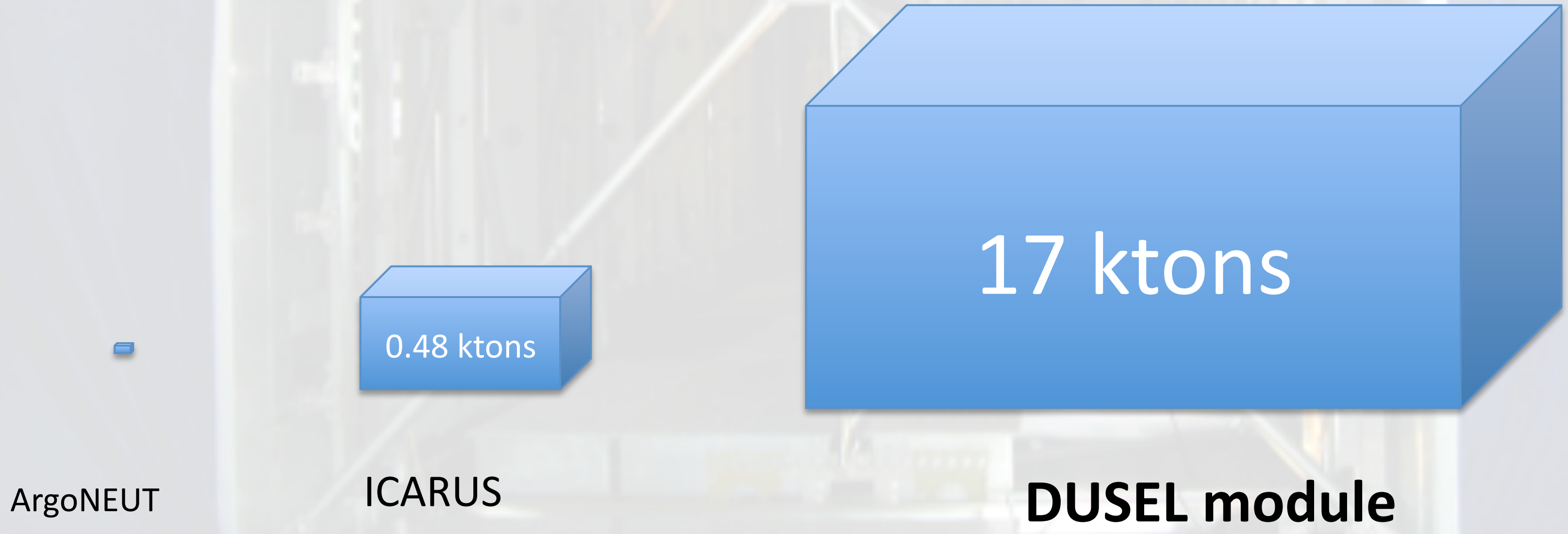
Note: the DUSEL detector would be realized in 1-3 modules

The muon rate in a 100 kT module at 4850 will be 1/30th that of Super-Kamiokande

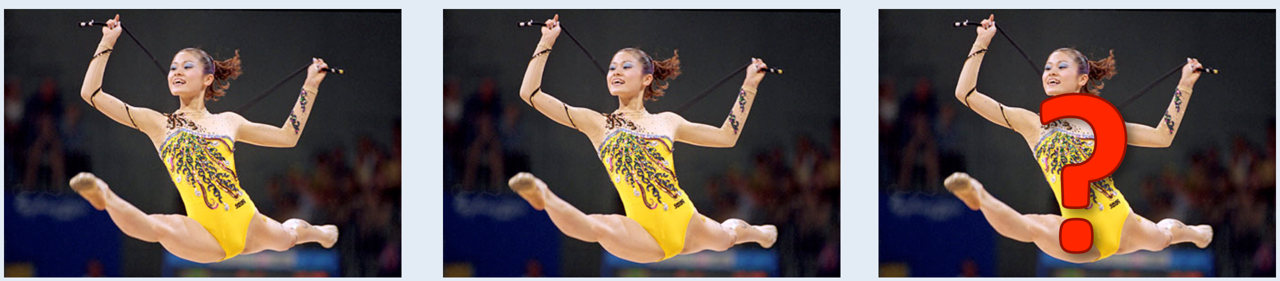


A Large Liquid Argon Detector for DUSEL

Note: The DUSEL detector would be realized in 1-3 modules.

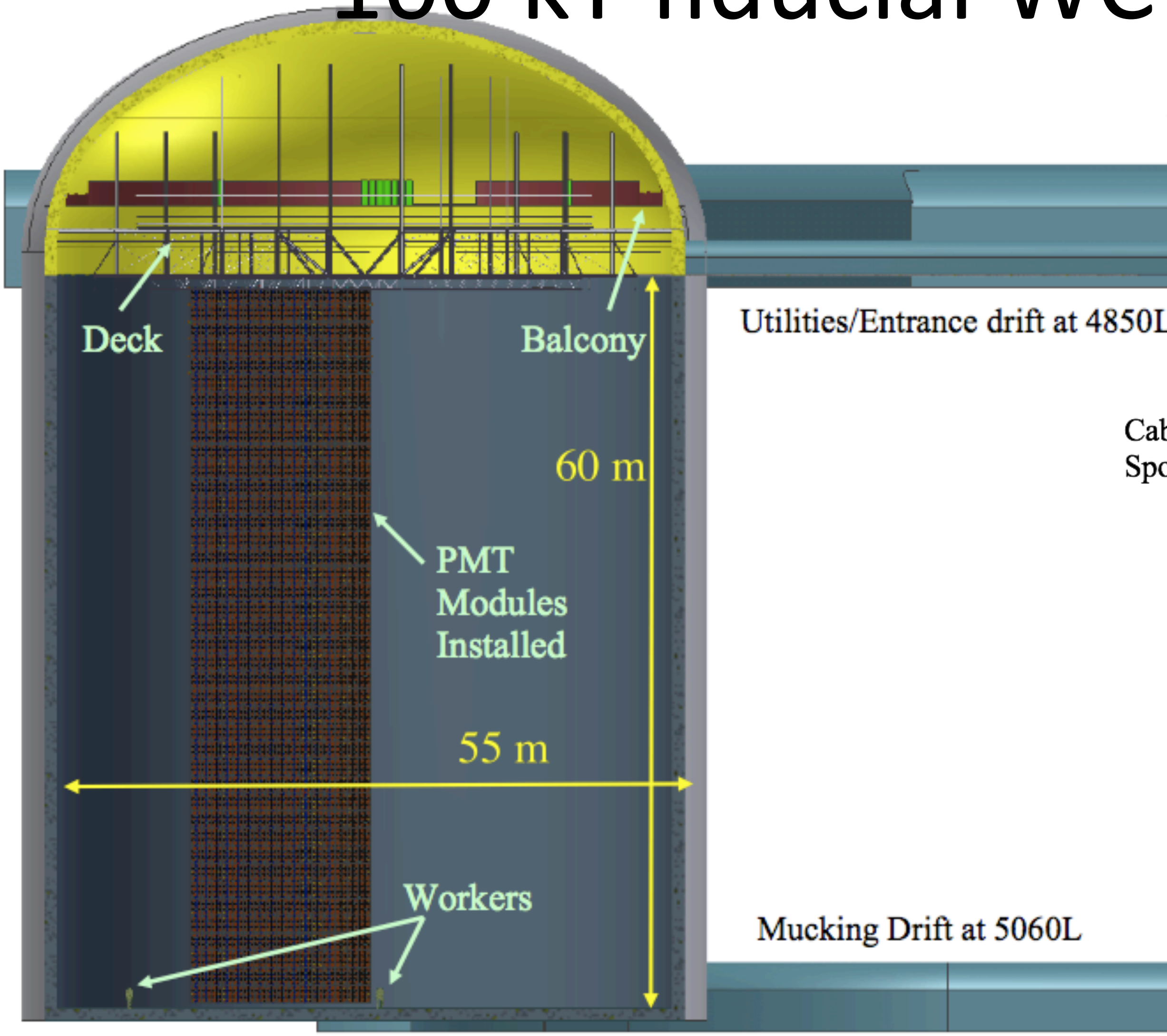


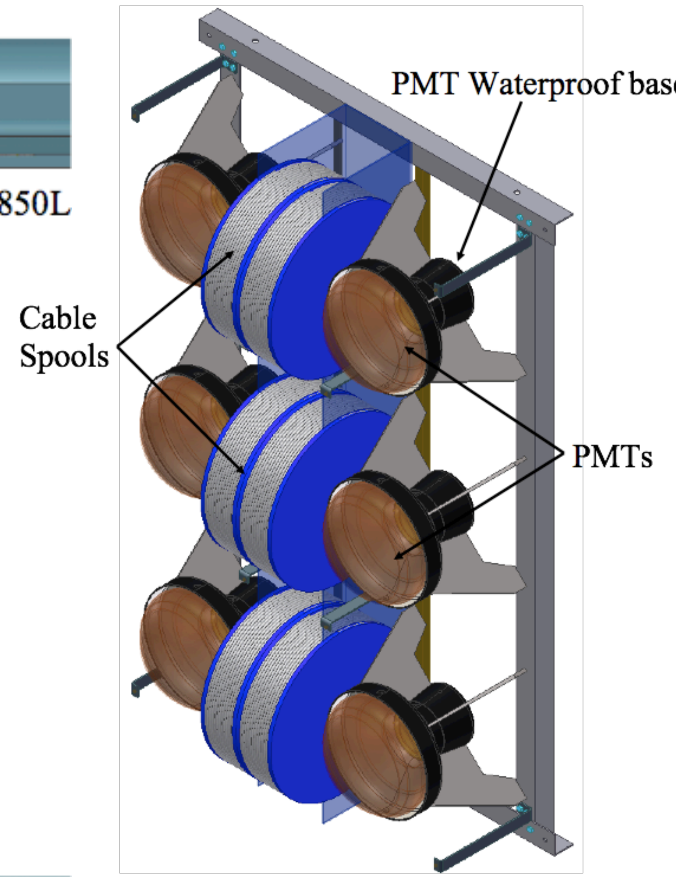
LBNE SC would like three modules: DOE and NSF have said “only money for two”



Studies for both two or three modules – called “Water Cherenkov Equivalent” (WCE) have been done. Both WC and LA will be developed to a conceptual design stage.

100 kT fiducial WC detector





Rather detailed simulation exists due to simulation group led by C.Walter and I.Stancu. Experience from SNO, Super-Kamiokande, IMB, and miniBooNE.

Gadolinium Option

- Sensitivity to neutron capture via 8 MeV gamma cascade improves physics reach in many areas.
- Could be implemented after construction completed, no schedule risk.
- Technical challenges:

  - material compatibility. Chose materials that do not contaminate the water.

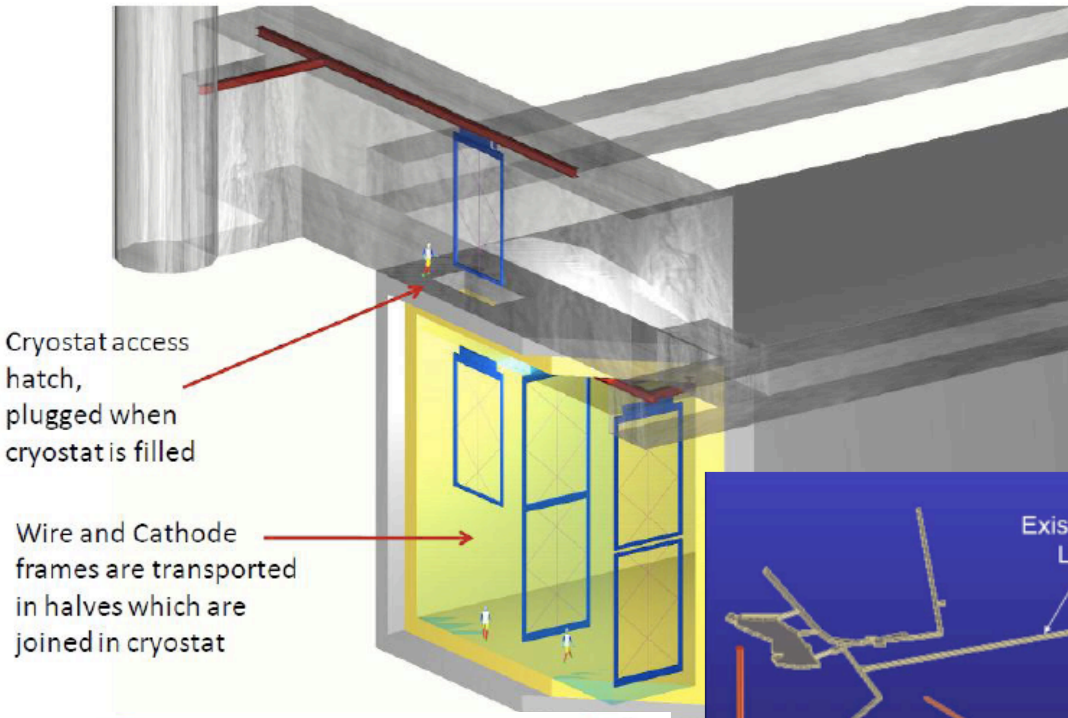
  - water treatment . Remove impurities but leave gadolinium in solution.

  - requirements for additional light collection could be expensive

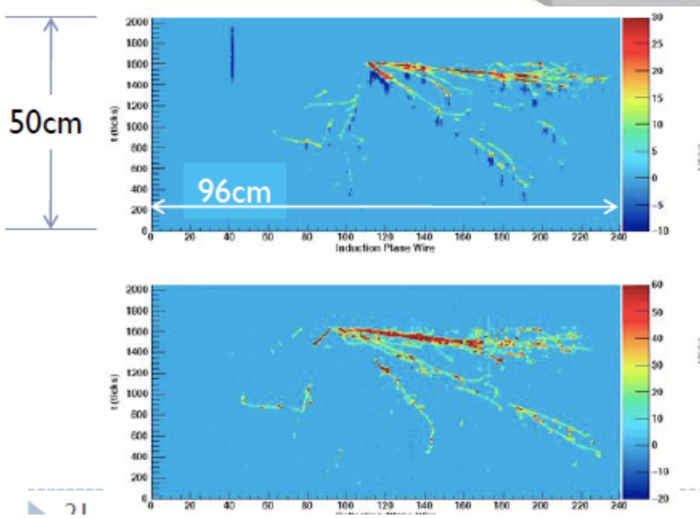
17 kT LA detector

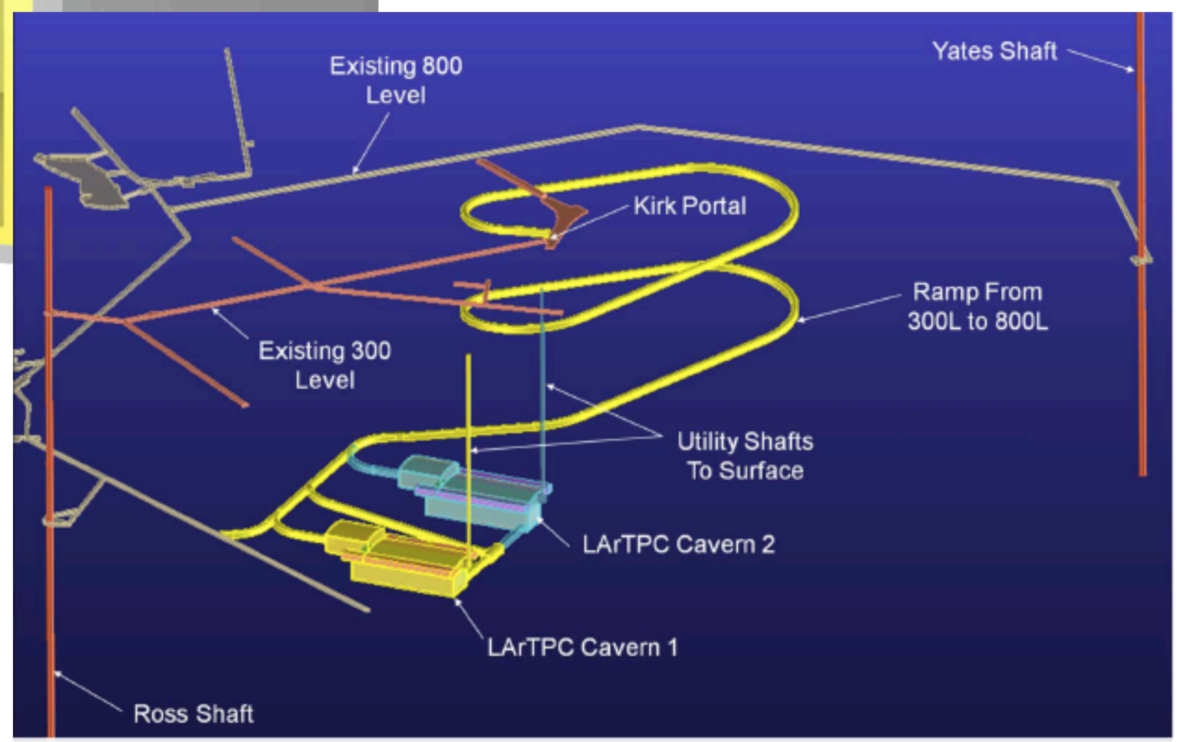
- Agreed on a preferred design
  - Reference Design3a – membrane cryostat with cold electronics
  - Located on the 800 level
  - Cosmic ray veto
  - Agreed on 3mm wire spacing
  - Agreed on three wire planes + 1 un-instrumented grid plane
  - Details given in Reference Design talk

Cryostat end cut open to show frame assembly

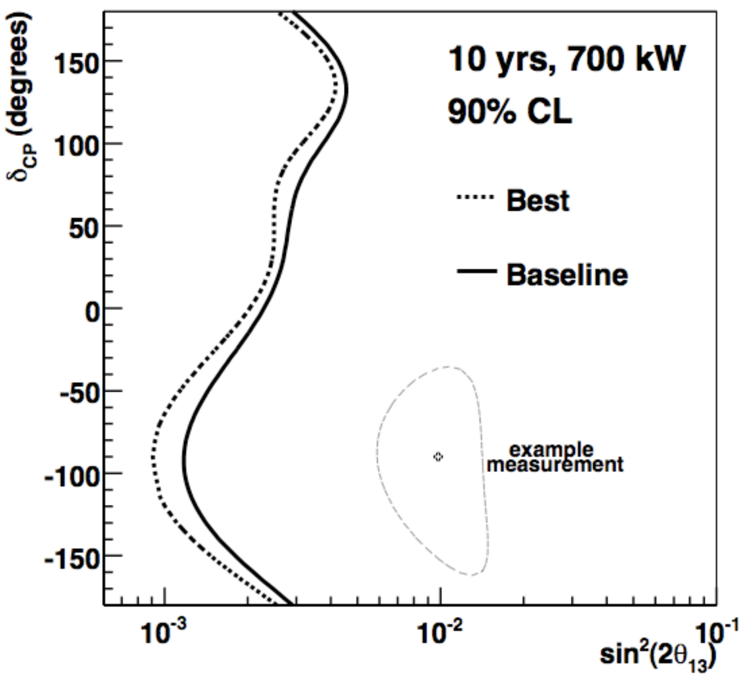


800 ft depth with an active veto shield. Simulation and performance based on Argoneut

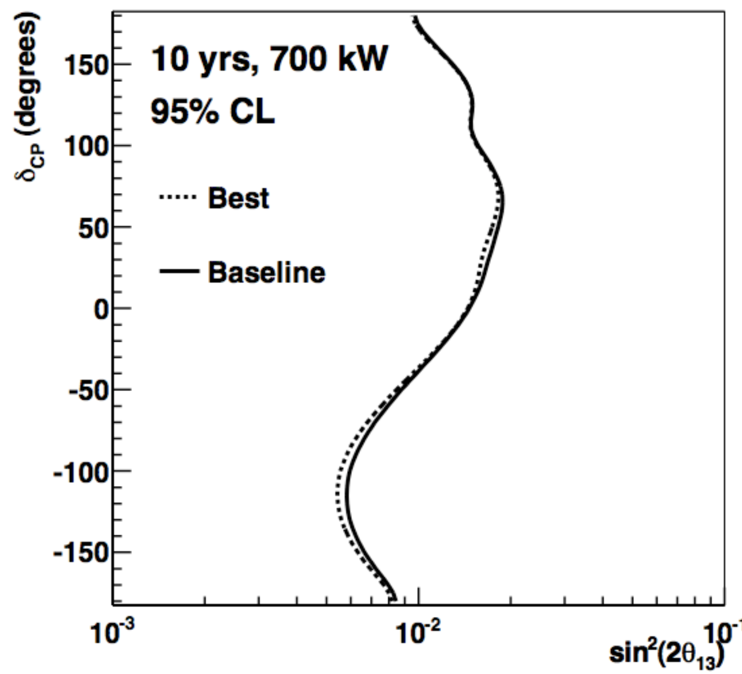




Sensitivity for 200 ktons WCE (only weakly dependent on far detector technology)

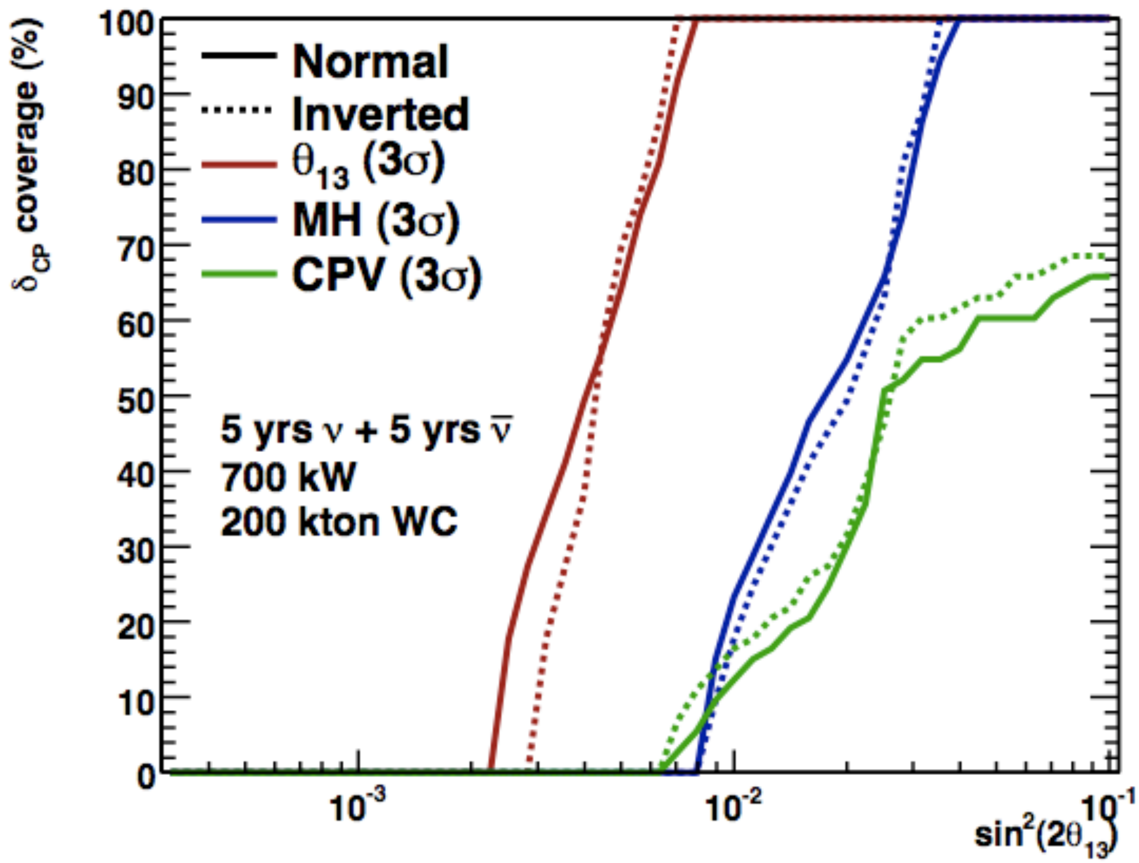


Limits on θ_{13} correlated with δ_{CP}. Normal hierarchy. “Best” = statistical only.

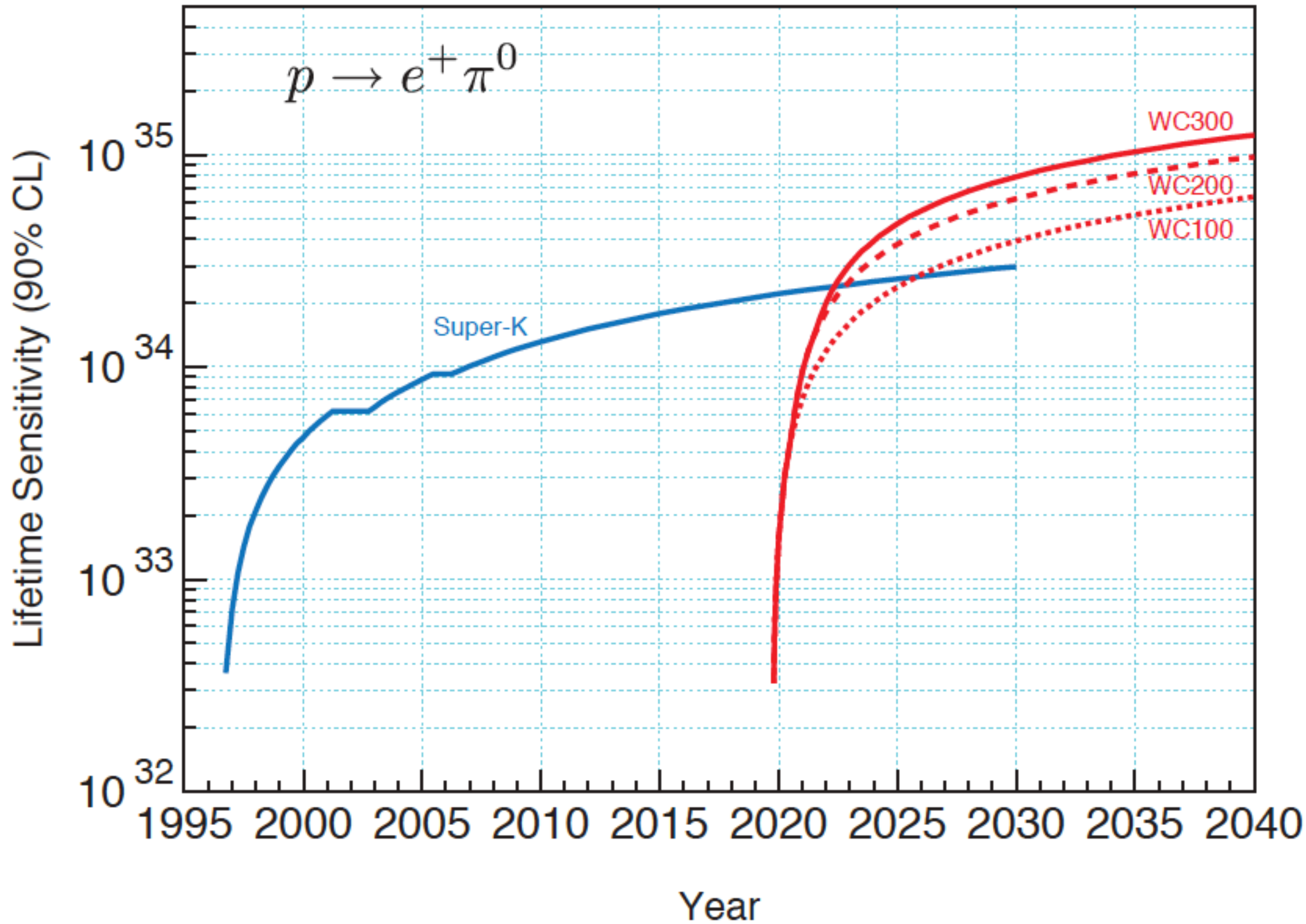


Determination of mass hierarchy correlated with δ_{CP}. Normal hierarchy. “Best” = statistical only.

Sensitivity summary

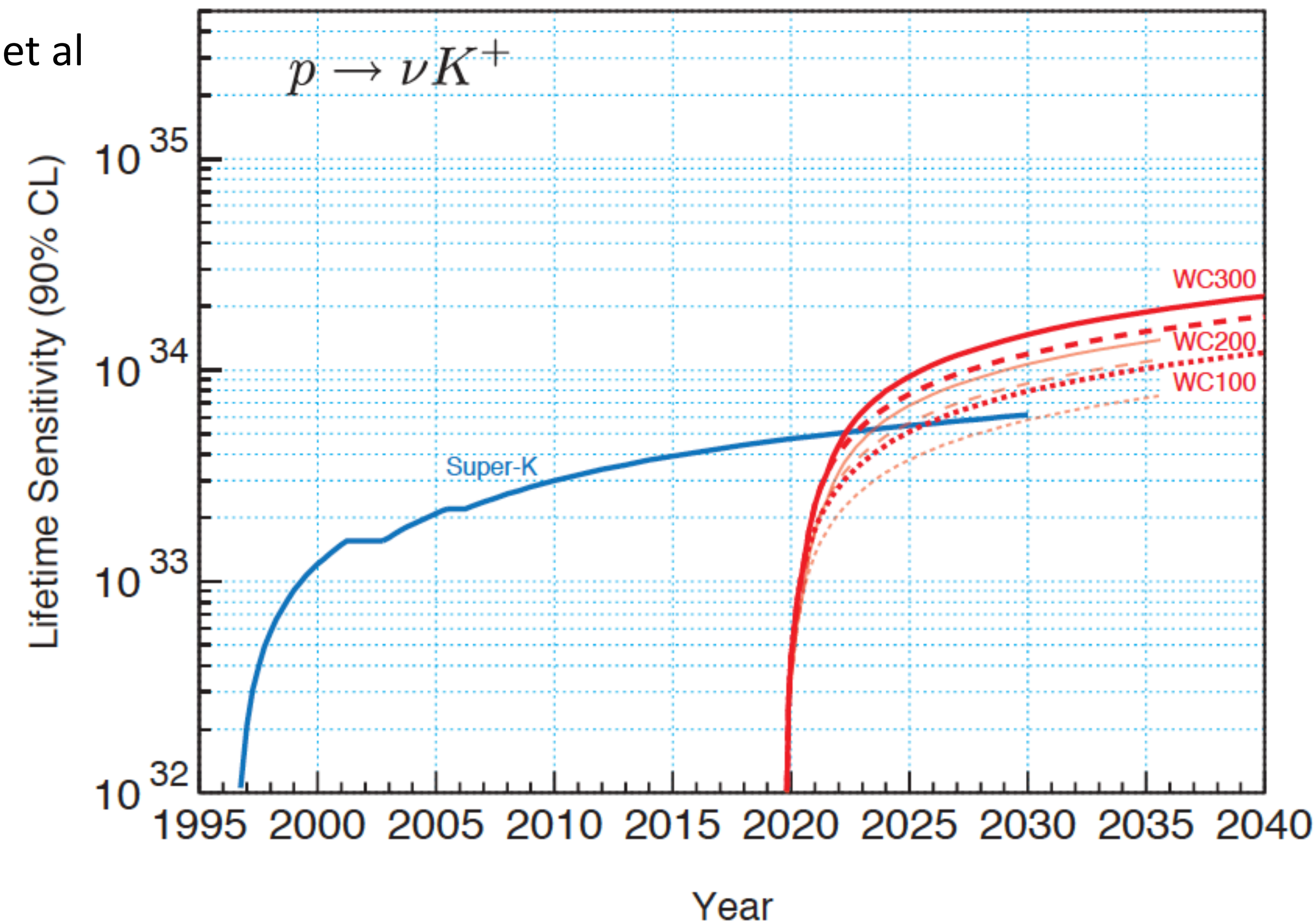


E.Kearns, et al



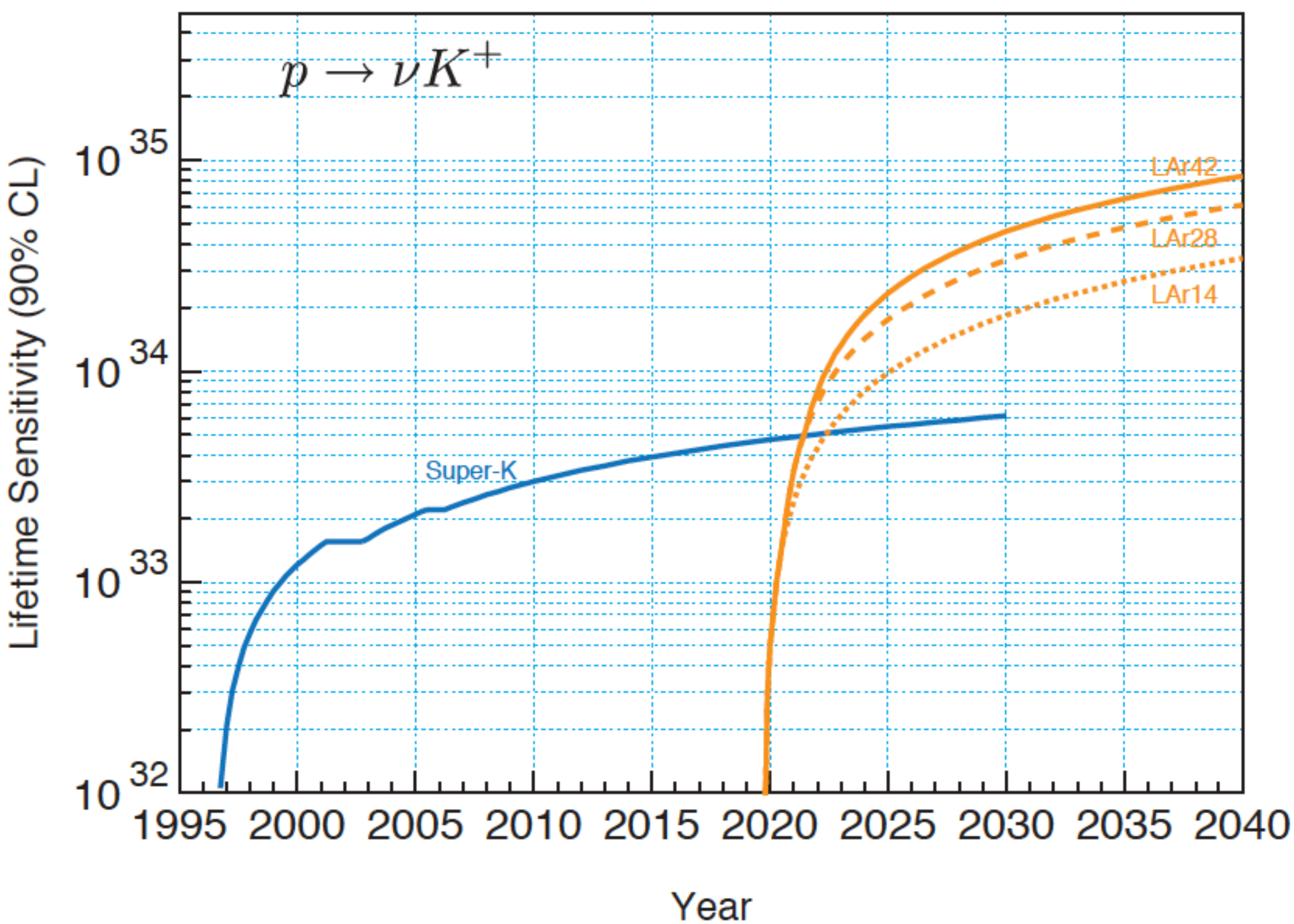
After 20 years, if no improvements are made to SK analysis LBNE would have 14 background events in 300 ktons. Can we do better? E.g. gadolinium tagging or More precise background measurements? Note: SK currently has no candidates In this mode.

E.Kearns, et al



For this mode, if we just used SK analysis – we would have ~40 events background After 20 years? Note: SK currently has no candidates in this mode. Can we do better with gadolinium tagging and improved photomultipliers and electronics?

E.Kearns, et al



While a liquid argon detector is too small to make significant improvement in the $e^{+}\pi^{0}$ mode, there is the possibility to have a factor of ten improvement in νK^{+} if the detector is large enough.

There are issues with backgrounds at shallow depths. Studies by Bueno, et al (arXiv:hep-ph/0701101) indicate that a muon veto could solve these issues. We are investigating this.

Supernova Burst

- **Huge signal for a galactic supernova. Potential to select between generic SN models**
- **Spectral evolution is sensitive to mass hierarchy and mixing – work ongoing to investigate this.**

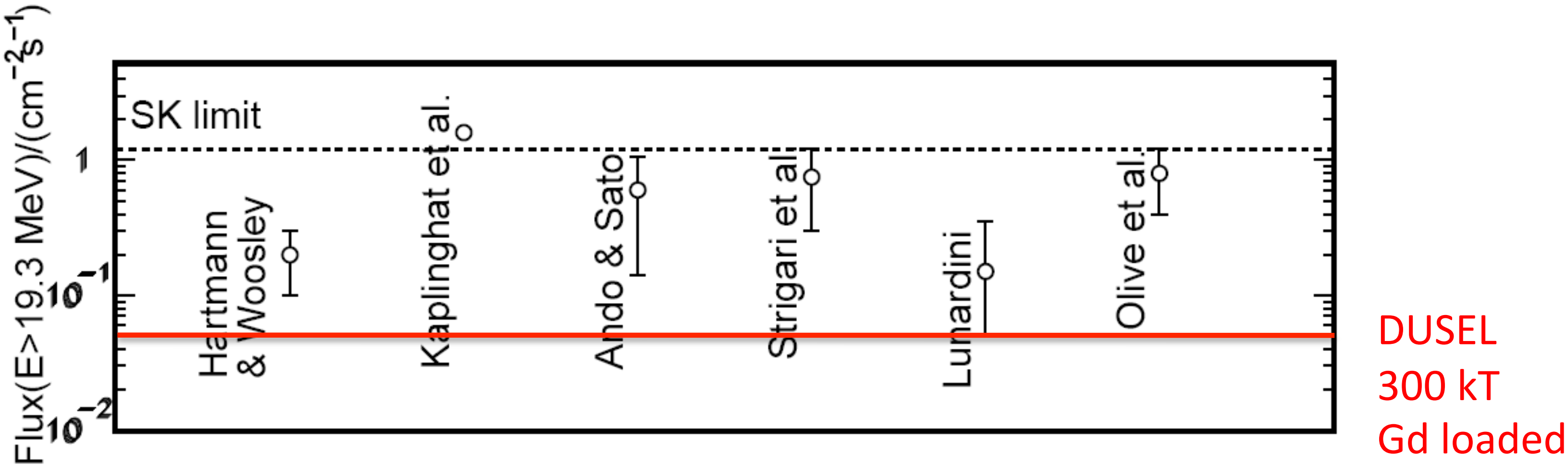
Channel	Events, "Livermore" model	Events, "Kneller" model
$\bar{\nu}_e + p \rightarrow e^+ + n$	27116	16210
$\nu_x + e^- \rightarrow \nu_x + e^-$	868	534
$\nu_e +^{16} \mathrm{O} \rightarrow e^- +^{16} \mathrm{F}$	88	378
$\bar{\nu}_e +^{16} \mathrm{O} \rightarrow e^+ +^{16} \mathrm{N}$	700	490
$\nu_x +^{16} \mathrm{O} \rightarrow \nu_x +^{16} \mathrm{O}^*$	513	124
Total	29284	17738

TABLE XIV. Event rates for different models in 100 kt of water, for the 30% coverage reference configuration.

Channel	Events, "Livermore" model	Events, "Kneller" model
$\nu_e +^{40} \mathrm{Ar} \rightarrow e^- +^{40} \mathrm{K}^*$	1154	1424
$\bar{\nu}_e +^{40} \mathrm{Ar} \rightarrow e^+ +^{40} \mathrm{Cl}^*$	97	67
$\nu_x + e^- \rightarrow \nu_x + e^-$	148	89
Total	1397	1580

TABLE XV. Event rates for different models in 17 kt of LAr.

Diffuse SN flux: Added depth at DUSEL and large detector mass would makes detection possible



(for a complete description, see arXiv 0907.4183)

DUSEL muon rate an order of magnitude smaller than Kamioka, so expect 15.5 MeV threshold instead of 19.3 MeV.

This enhances signal by 40% in addition to just detector mass scaling.

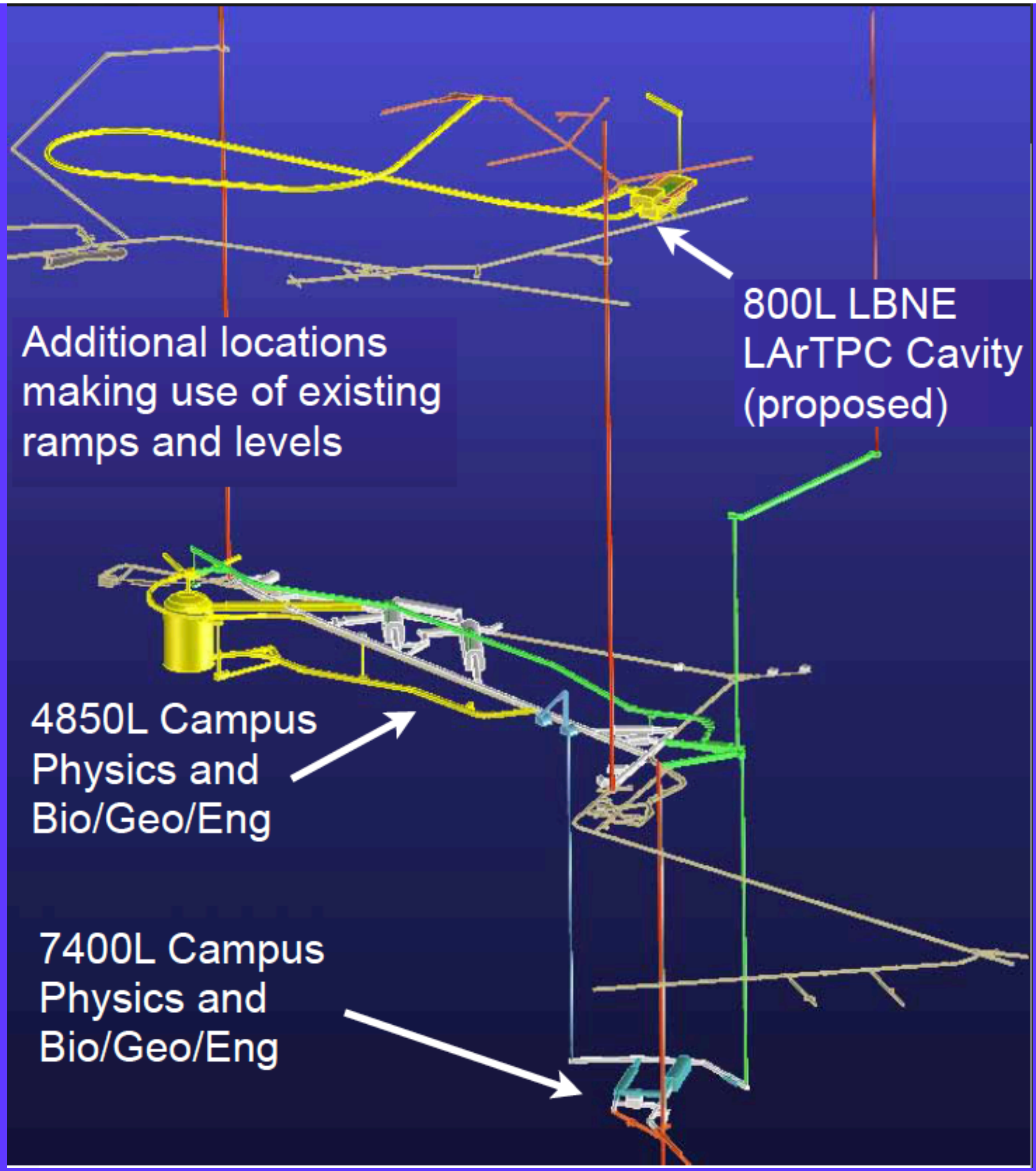
Gadolinium loading *plus* extra depth would increase sensitivity by ~factor of two. Thus improvement of factor of more than twenty is possible.

Status of DUSEL

Preliminary Design Report (PDR) “Roll Out” At FNAL last week

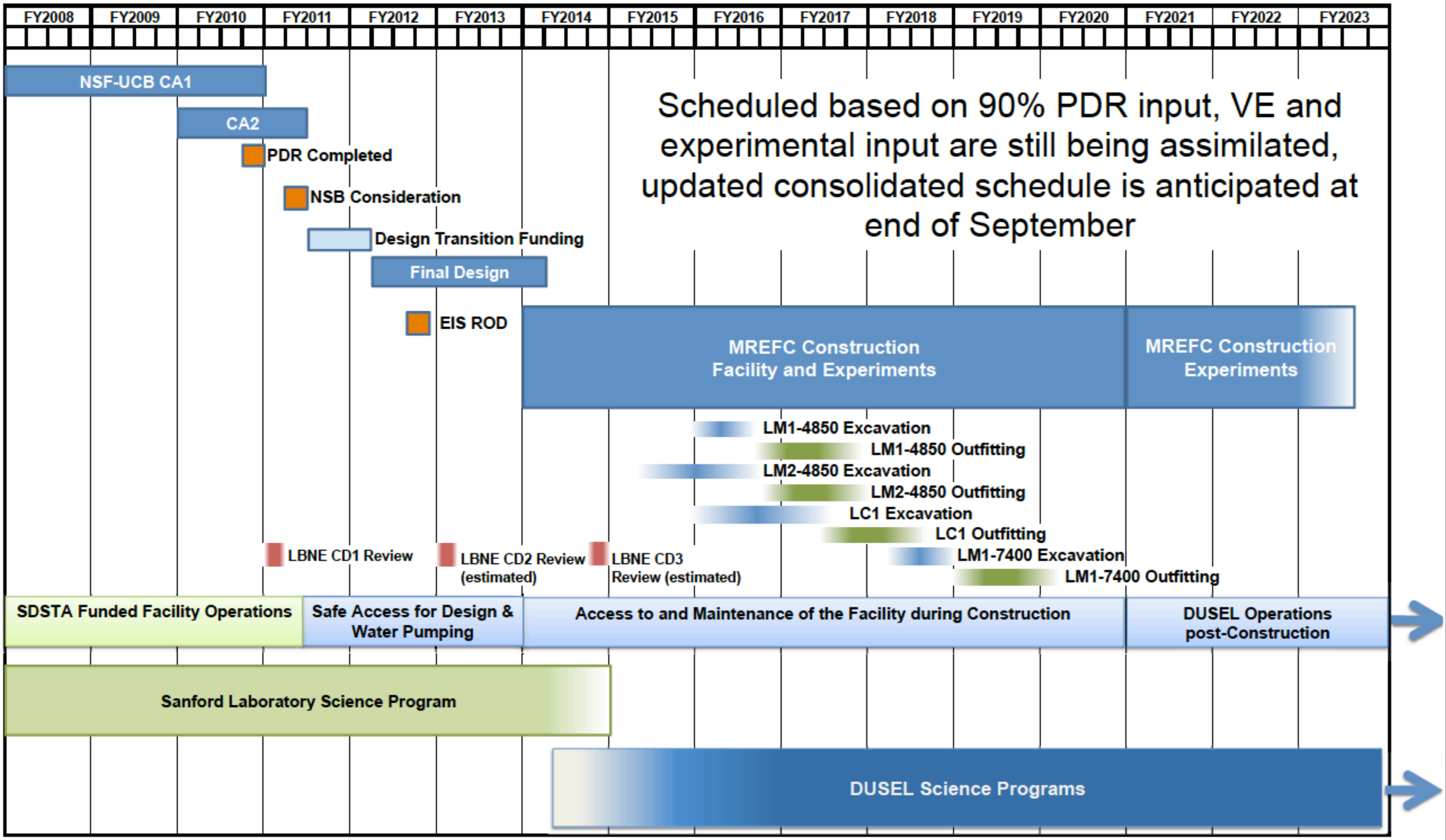
PDR to be reviewed by National Research Council (NRC) and report to the NSF National Science Board (NSB) In spring, 2011

NSB recommendation to NSF expected in late Summer, 2011.



For full update see:
http://www.dusel.org/workshops/fallworkshop10/index.htm#agenda

Project Milestone Schedule through Construction



Physics Working Group: LBNE Internal Report
Released Sept 3, 2010

DRAFT - Fall 2010 Report from the LBNE Physics Working Group - DRAFT

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[†] *Topical Group Convener* [*] *Physics Working Group Coordinator/Editor*

(Dated: August 30, 2010)

This report has been prepared by the LBNE Science Collaboration Physics Working Group coordinator and Topical Groups conveners at the request of the collaboration co-spokesmen and the Executive Committee. It is the first of an anticipated series of internal documents intended to assist the collaboration and the LBNE Project with establishing the best possible science case.

This report will eventually be public after after the collaboration has approved.

LBNE Physics Working Groups

- long baseline neutrinos
- proton decay
- supernovae
- atmospheric neutrinos
- high energy neutrinos (astrophysics, dark matter, etc.)
- solar neutrinos
- short baseline neutrino physics (cross sections, new phenomenon)
- low energy neutrino physics

We want a broad program.
Neutrinos have a history of confounding our expectations (especially at Homestake!)

Looking Ahead: How will LBNE decide what we want to build?

- What is the Science? (PWG Report)
- What are the Issues? Science? Risk? Cost? Schedule?
- What is the Process? Time scale? Who is involved?
- SC EC Geneva (U.S.A.) meeting

Lake Geneva, Wisconsin

- The LBNE Executive Committee will meet next week for a two day closed session
- We will deal with these last two issues
- We will look at narrowing down the possible options
- We will present our first set of recommendations at the LBNE collaboration meeting on September 13
- We are establishing the requirements for a final configuration choice and strategy

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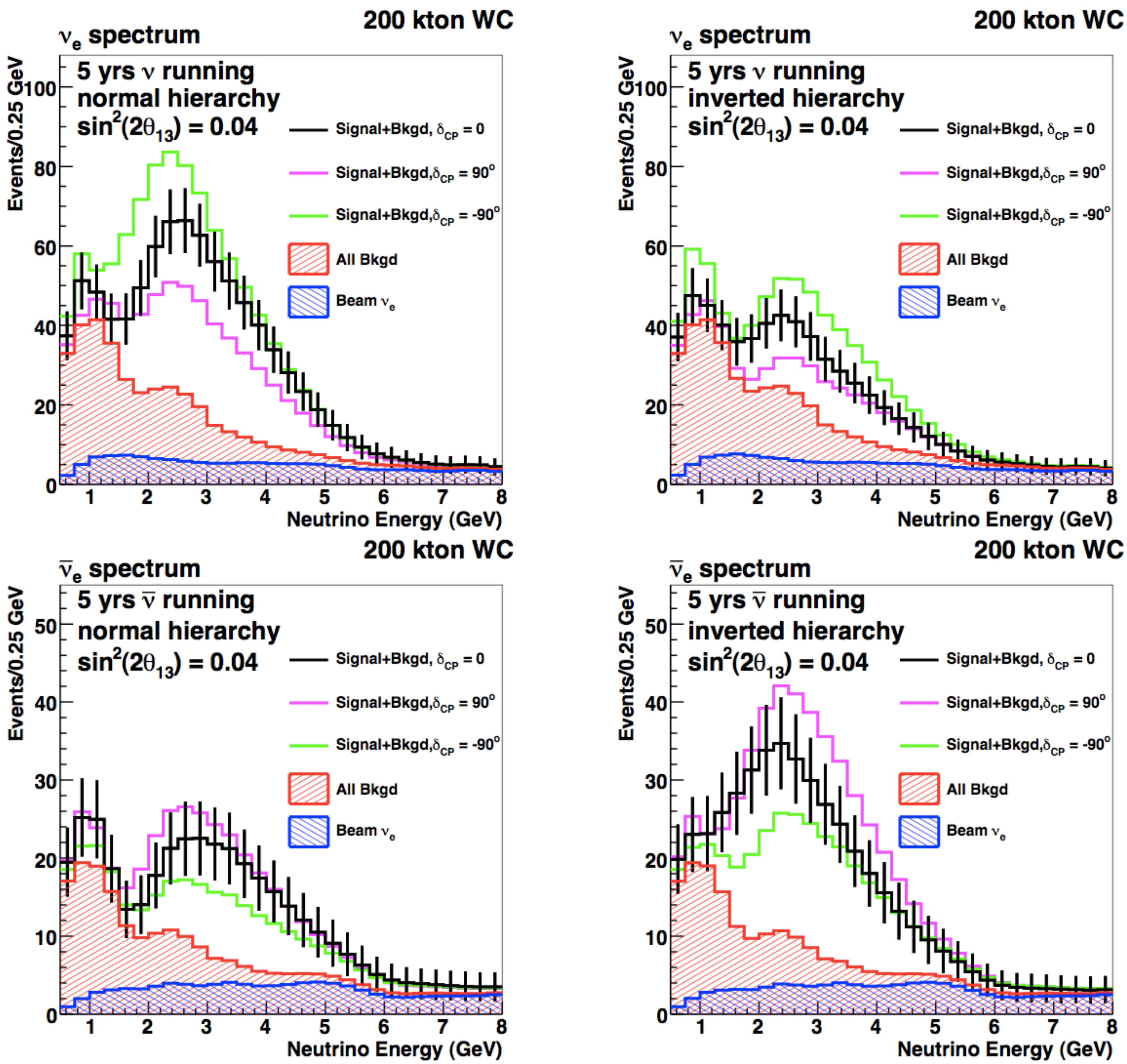
G.Rameika
G.Sullivan
R.Svoboda
M.Diwan
M.Goodman
J.Strait
Gina Rameika
V.Papadimitriou
C.Mauger
J.Stewart
B.Baller

backup

normal inverted

nu

anti-nu

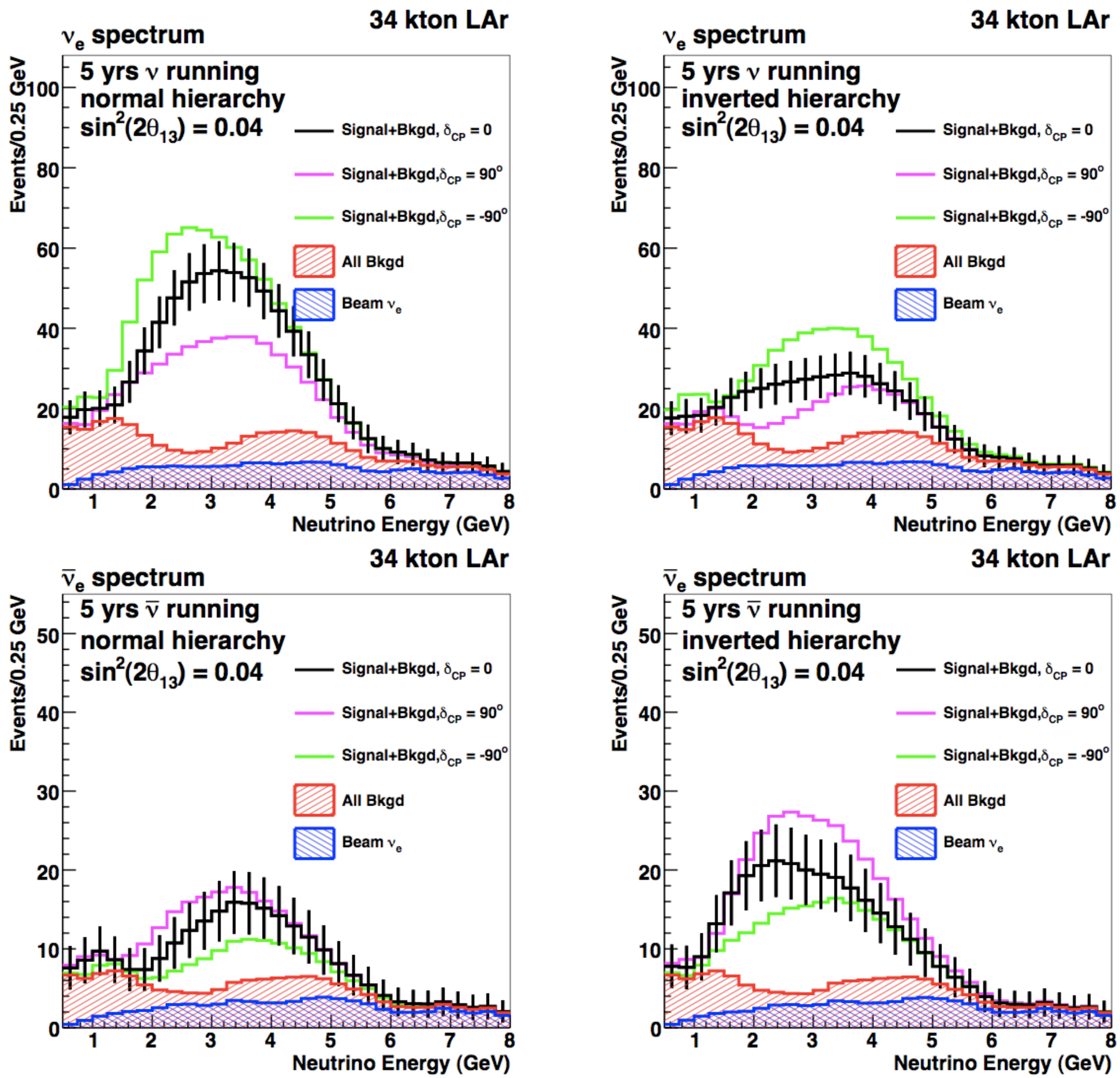


Lisa Whitehead

normal inverted

nu

anti-nu



Lisa Whitehead

The Issues

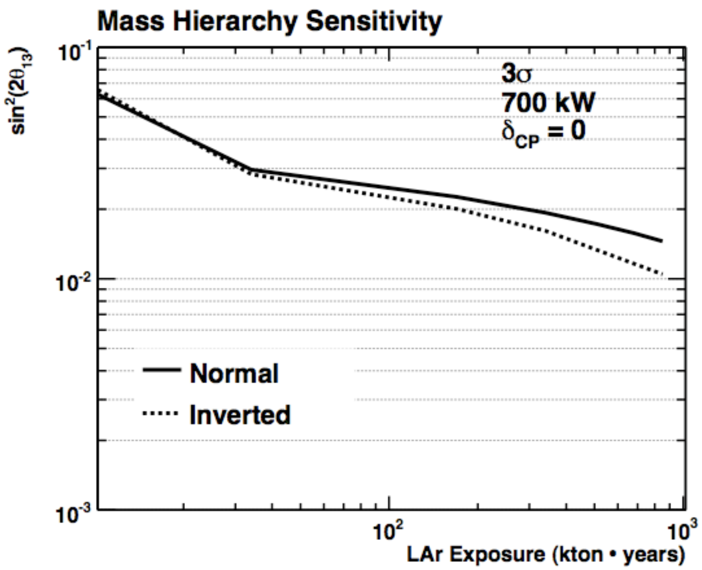
- pions can scatter in the nucleus via charge exchange, ruining momentum balance. Thus detector efficiency is ultimately determined mostly by the free proton ratio and nuclear size.
- Conservation of strangeness does us a favor for postive kaons.

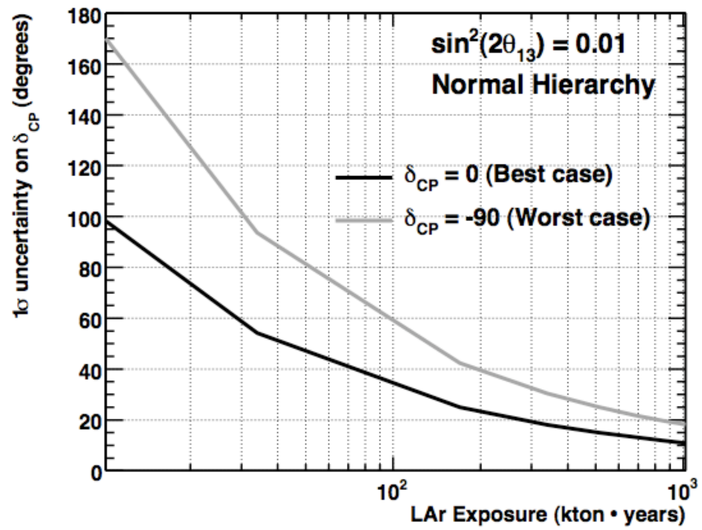
Reaction	Q-value
$K^- + n \rightarrow \pi^0 + \Sigma^-$	101 MeV
K- + p -> $\pi^0 + \Sigma^0$	104 MeV
$K^- + n \rightarrow \pi^- + \Lambda$	178 MeV
K- + p -> $\pi^0 + \Lambda$	181 MeV
$K^+ + n \rightarrow K^0 + p$	-2.6 MeV
$K^+ + p \rightarrow K^0 + \Delta^{++}$	-298 MeV

K^+ inelastic scattering in nucleus
Is limited to K^+n mode, with small
phase space/. Not true for K^-

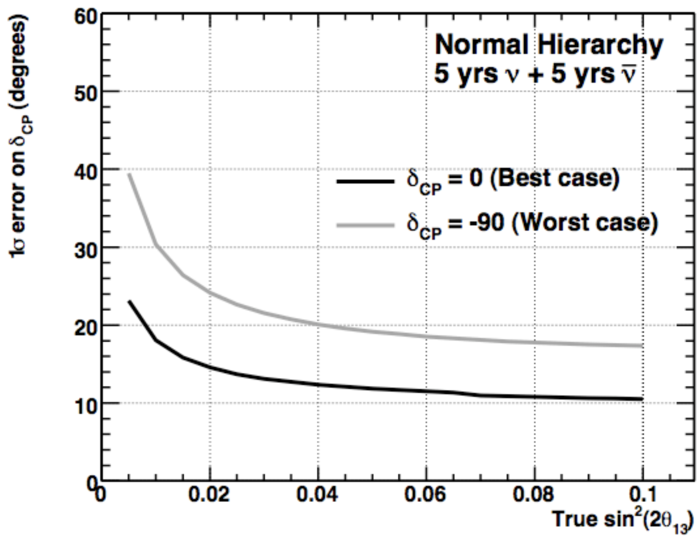
Production of K^+ by atmospheric neutrinos is small and reasonably well-understood. K^0, n, and Λ production by CR muons is the big issue. These can enter the detector, then make real K^+ - chipping away at the useable fiducial volume. What is the production, and what is the trade-off Between muon veto, depth, and fiducial volume?

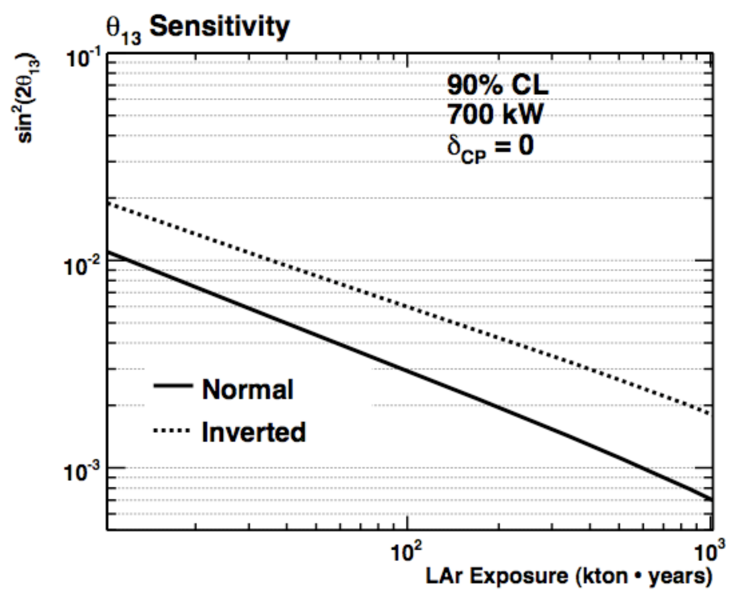
Measurement capability





34 kton LAr



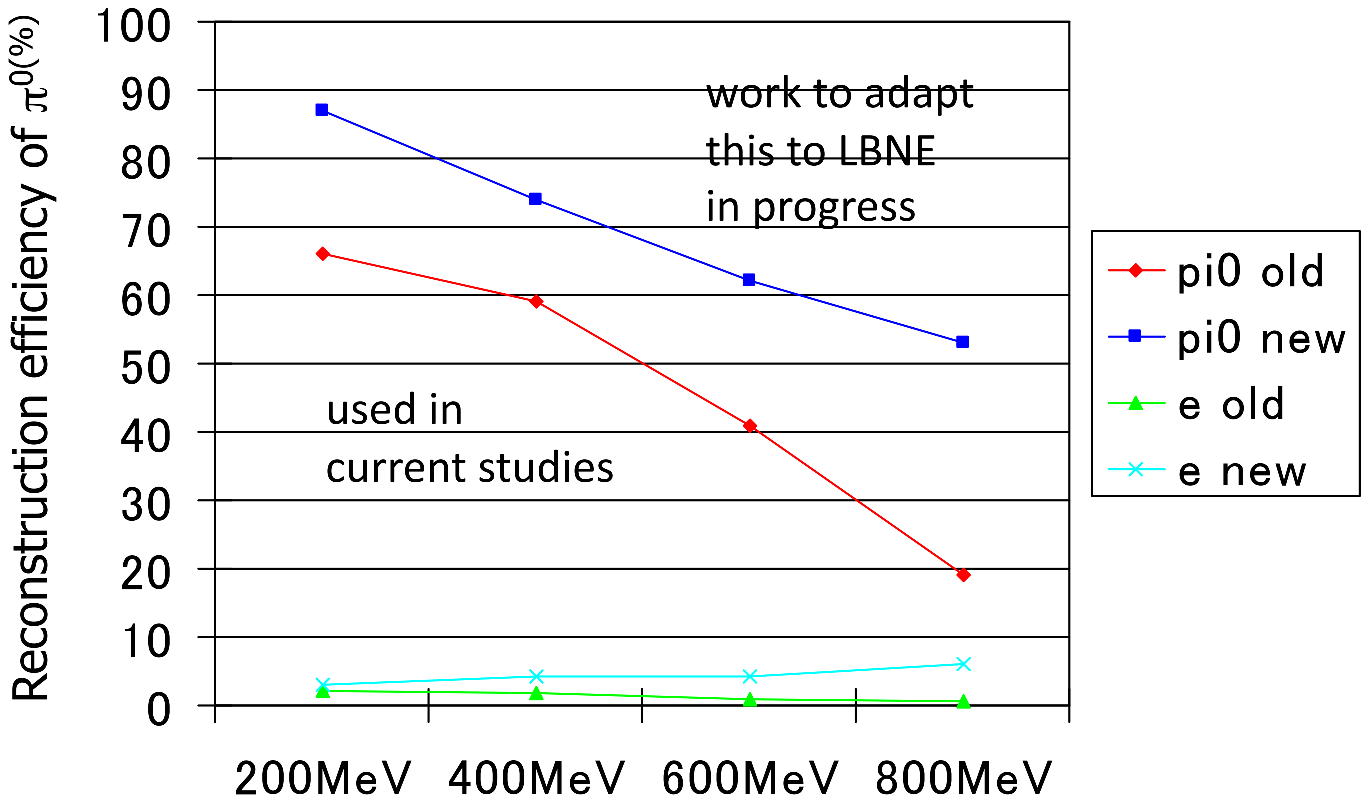


Liquid Argon versus Water Cherenkov

- Two major backgrounds for CPV/mass hierarchy measurement: intrinsic ν_e in beam and misidentification of NC π^o.
- A liquid argon detector should be much better with π^o identification. Downside: technology not as well-developed, cost and schedule risks not well known.
- A water Cherenkov detector can be made much larger for more signal. Downside: poorer resolution on π^o background.

Improved π^0/e separation in SK

- 2−R e-like tag (old ring-finder)
- π^0 fitter (improved ring-finder)



From M.Smy

LBNE Science Collaboration : Depth Document

Physics	Water	Argon
Long-Baseline Accelerator	1000	0-1000
$p \to K^+ \nu$	>3000	>3000
Day/Night ^{8}B Solar ν	~4300	~4300
Supernova Burst	3500	3500
Relic supernova	4300	>2500
Atmospheric ν	2400	2400

Required depth in meters of water equivalent (MWE) for Water Cherenkov and liquid argon detectors

arXiv:0907.4183

Completed Critical Geotechnical Investigations

- 4850 Level Mapping - Completed
- Geological Model - Developed
- Coring and Logging - Completed
  - holes 1, 2, 3: Sanford Lab
  - holes 3, M, N: LC 1
  - holes B, C: LC 2, LC3
  - holes D, J: 4850 Lab Modules
  - 4363.1 feet of core
  - enough geotech for Preliminary design - Large Cavity Advisory Board
- *In situ* testing - Completed
- Laboratory testing - Completed

Good news: Little Water, Good to Very Good Rock Quality