Status of U.S. LBL Program

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LBNE: An Exciting Year…

- **December, 2011:** LBNE Science Collaboration recommends a 200 kton water Cherenkov Far Detector to the DOE Project Manager.
- **January, 2012:**The DOE Project Manager instead decides to pursue a 34 kTon liquid argon TPC Far Detector and 700 kW beam to Homestake for LBNE. He submits proposal U.S. Department of Energy Office of Science.
- **March, 2012:** The DOE Office of Science tasks the Fermilab Director to break LBNE into smaller parts that could be approved in "affordable" phases. DOE asks Fermilab to prepare phasing plans, which could include "alternate configurations."
- **June, 2012:** A panel convened by Fermilab to study the possible options identifies three phasing plans that fall within the guidelines of "affordable" for a first phase.

Group Members

Steering Committee	
Young-Kee Kim, FNAL (Chair)	LBNE LOG (Lab Oversight Group) member
James Symons, LBNL	LBNE LOG (Lab Oversight Group) member
Steve Vigdor, BNL	LBNE LOG (Lab Oversight Group) member
Bob Svoboda, UC Davis	LBNE co-spokesperson
Kevin Lesko, LBNL	SURF (Sanford Underground Research Facility) head
Gary Feldman, Harvard	NOvA co-spokesperson
Mel Shochet, U.Chicago	Physics working group chair, Former HEPAP chair
Mark Reichanadter, SLAC	Engineering/Cost working group chair DOE DUSEL review committee co-chair
Charlie Baltay, Yale	P5 chair
Jon Bagger, JHU	Former HEPAP deputy chair
Ann Nelson, UW, Seattle	HEPAP member

Steering Committee: Ex-officio members	
Andy Lankford, UC Irvine	HEPAP chair, DUSEL NRC study chair
Steve Ritz, UC Santa Cruz	PASAG (Particle Astrophysics Scientific Assessment Group) chair, Fermilab PAC member
Jay Marx, Caltech	DOE DUSEL review committee co-chair
Pierre Ramond, U. Florida	DPF chair
Harry Weerts, ANL	DOE Intensity Frontier Workshop co-chair
JoAnne Hewett, SLAC	DOE Intensity Frontier Workshop co-chair
Jim Strait, FNAL	LBNE Project Manager Engineering/Cost working group deputy chair
Pier Oddone, FNAL	Director, Fermilab
Susan Seestrom, LANL	LBNE LOG (Lab Oversight Group) member

Conclusion: Go to Homestake, even if more expensive

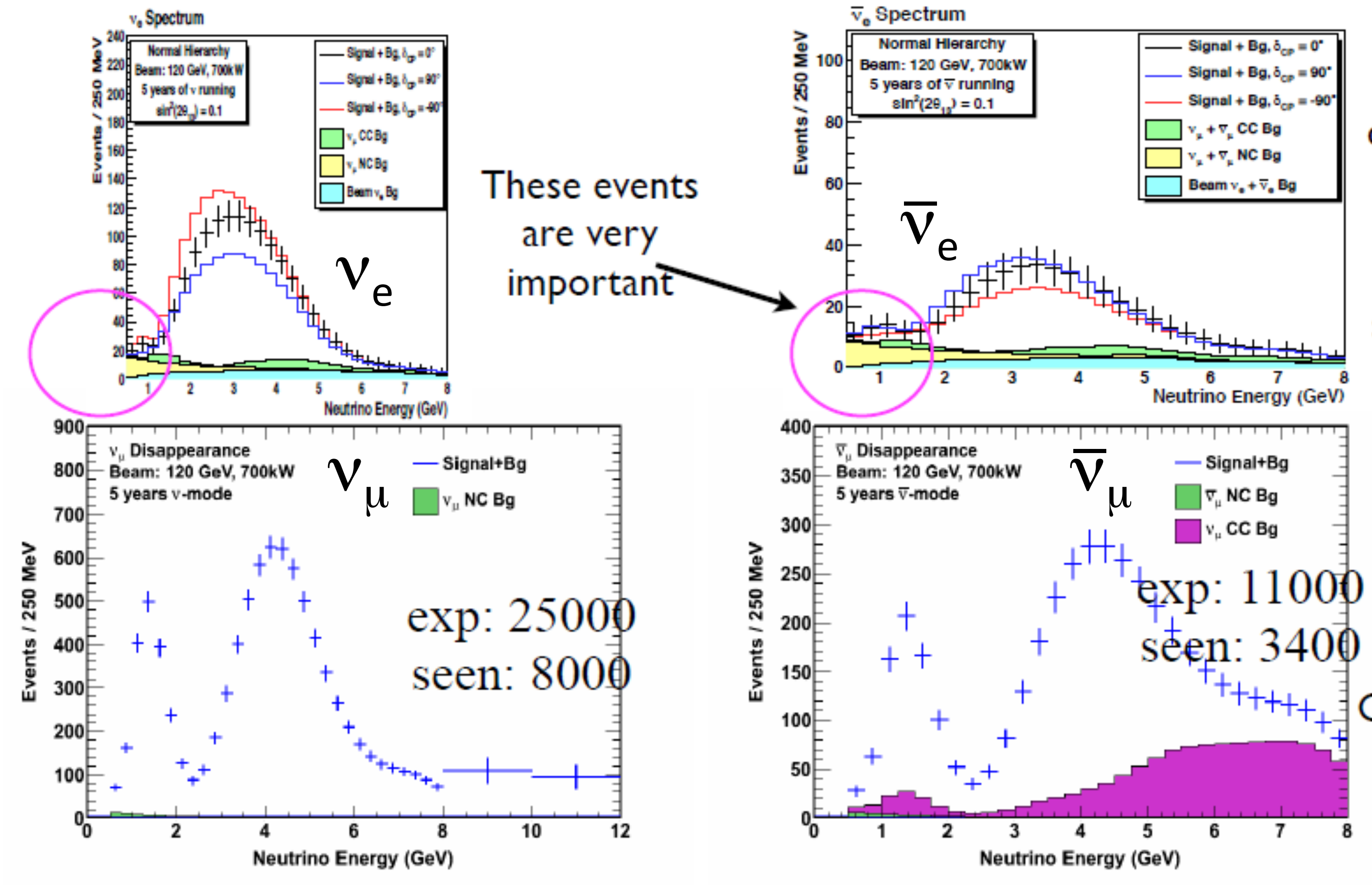
While each of these first-phase options is more sensitive than the others in some particular physics domain, the Steering Committee in its discussions strongly favored the option to build a new beamline to Homestake with an initial 10 kton LAr-TPC detector on the surface. The physics reach of this first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

From July 2012 Report of the Steering Committee to Fermilab Director

Bad part: Need 15% more funding to go underground that is not In current budget. Also, no funding for a near detector (similar to T2K situation at the start of that experiment)

Why Homestake?

1300 km expectation



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

Potential surprises:

Matter effect is not what is expected !

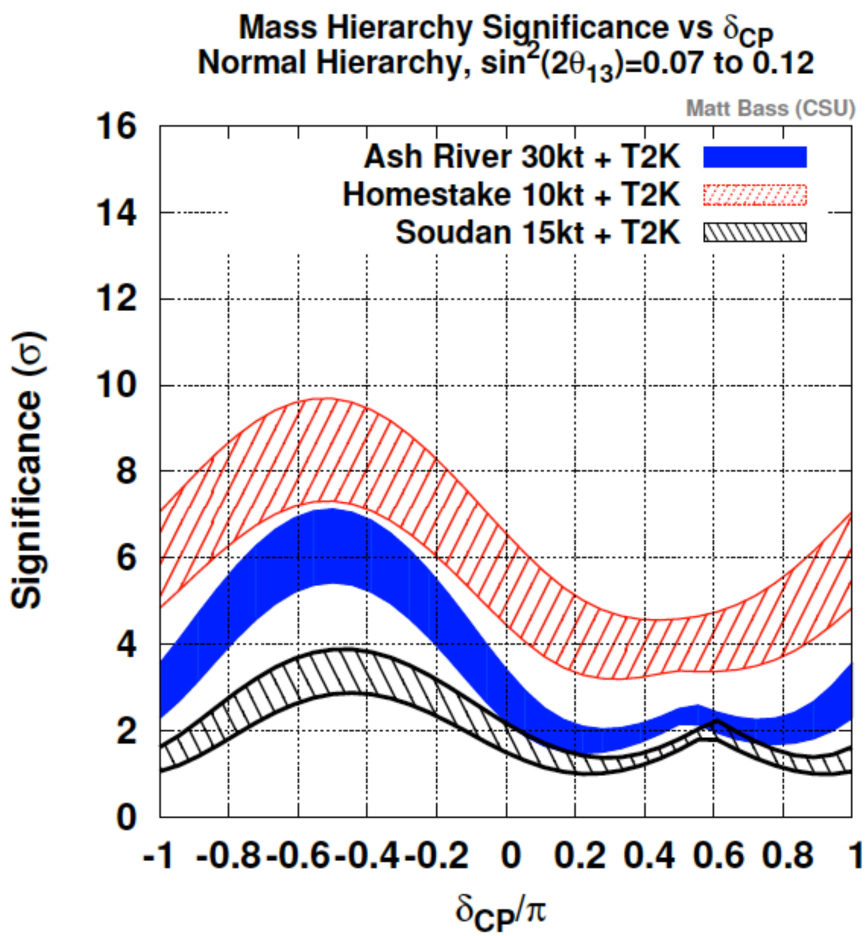
CPV does not have the proper energy 1/E dependence.

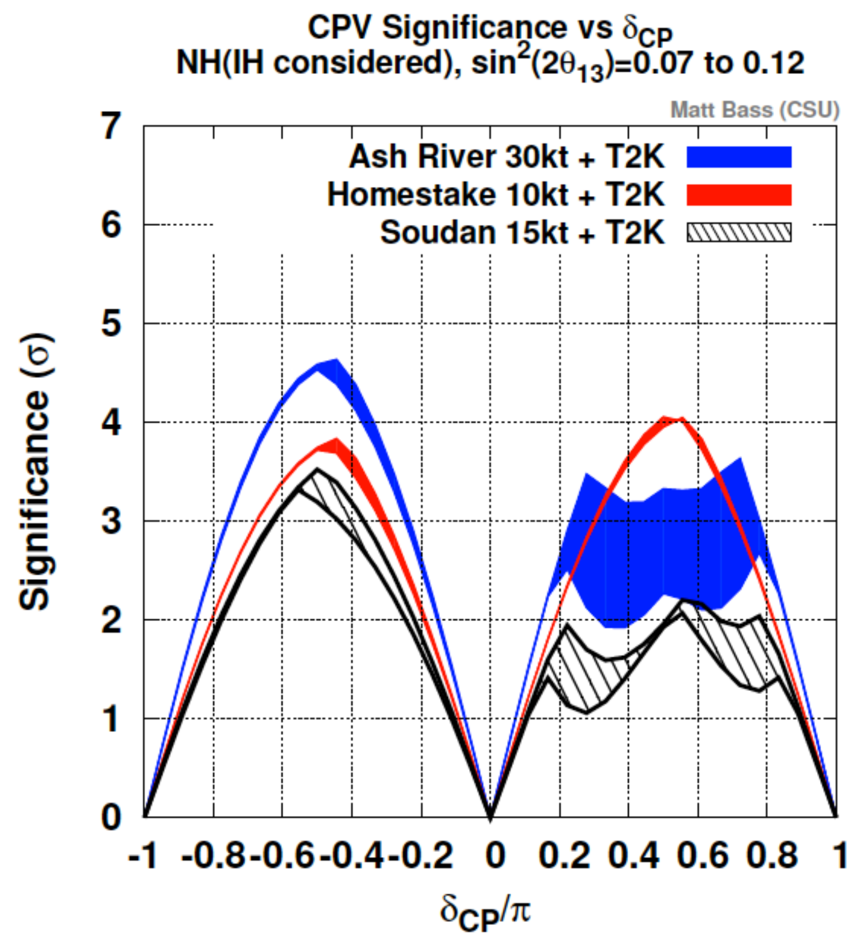
- With 1300 km the full structure of oscillations is visible in the energy spectrum. This spectral structure provides the unambiguous parameter sensitivity in a single experiment.

Expt	ν_μ CC Unosc.	ν_μ CC Osc.	ν_μ NC	ν_e beam CC	$\nu_\mu \to \nu_e$ CC	$\nu_\mu \to \nu_\tau$ CC	$\bar{\nu}_\mu$ CC Unosc.	$\bar{\nu}_\mu$ CC Osc.	$\bar{\nu}_\mu$ NC	$\bar{\nu}_e$ beam CC	$\bar{\nu}_\mu \to \bar{\nu}_e$ CC	$\bar{\nu}_\mu \to \bar{\nu}_\tau$ CC
Ash River 810km	18K	7.3K	3.6K	330	710	38	7.1K	2.5K	1.8K	110	210	
Soudan 735km	73K	49K	15K	820	1500	166	27K	18K	13K	285	495	54
Hmstk 1300km	29K	11K	5.0K	280	1300	130	11K	3.8K	3.0K	86	273	46

- Event rate at three potential site/detector combinations per 100 kt-10^{21} POT at 700 kW (Normal Hierarchy, $\delta_{CP} = 0$). **Homestake shows best performance per kton of far detector.**
- For absolute event rates per year ($2\text{x}10^7$ seconds) for 10 ktons at Homestake, divide by 13.3. For Ash River (30 ktons), divide by 4.4; and for Soudan (15 ktons) divide by 8.8.

Sensitivity assuming T2K continued running to 2021*





Preliminary: LBNE Physics Working Group

* using luminosity profile from JPARC management


Planned LBNE site
as seen from SURF
entrance area

Is it possible to run near the surface?

- Liquid argon detector are slow devices. A planned 2.3 meter drift gives a 1.4 ms drift time. Space charge effects can also be significant.
- Looking for $\nu_\mu \rightarrow \nu_e$ conversion is a rare process, only 30-100 events/year for a 10 kton detector at Homestake. For a 2-3 meter depth, 70 muons are expected per spill drift time. With a 1.33 second repetition time and 2×10^7 seconds/year operating time, about 10^9 muons are expected per year.
- need 10^8 reduction. LBNE SC working group established to address this with simulations.

Muon-induced background for beam neutrinos at the surface

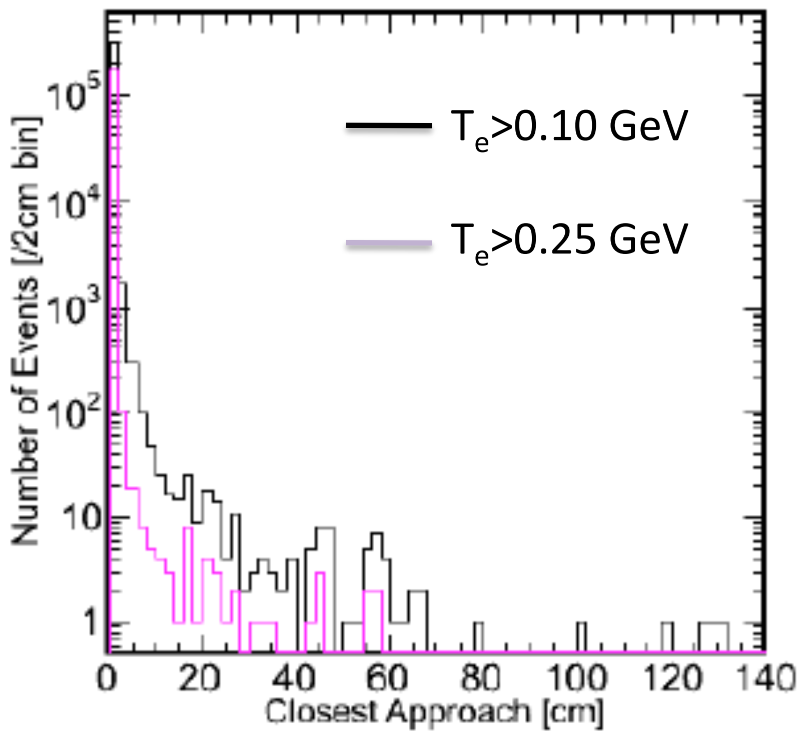
D. Barker[1], E. Church[2], M. Diwan[3], M. Goodman[4], J. De Jong[5], V. A. Kudryavtsev[6], D.-M. Mei[1], M. Richardson[6], M. Robinson[6], K. Scholberg[7], R. Svoboda[8], C. Zhang[1]

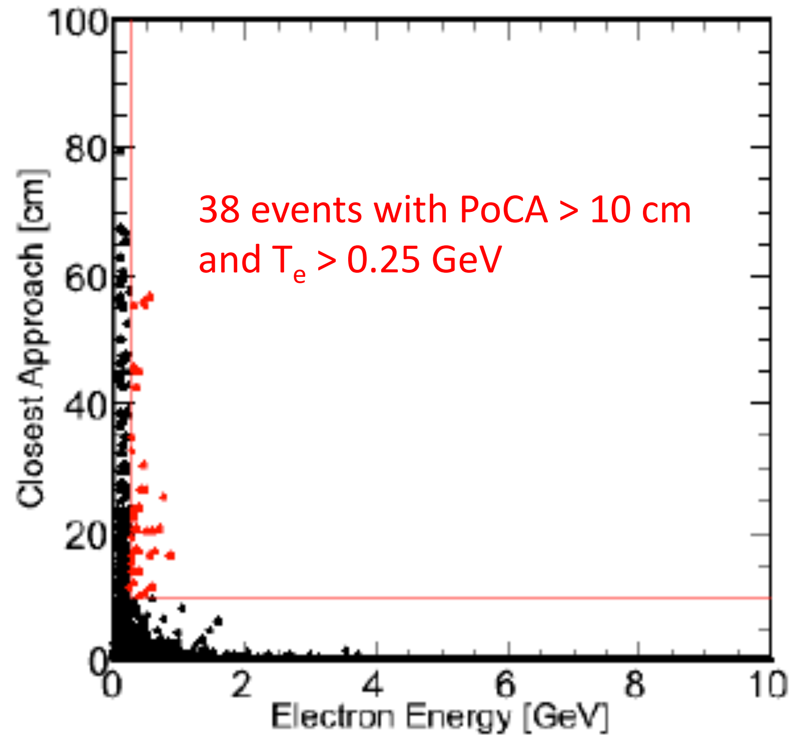
July 2012 Report from LBNE Cosmic Ray and Cosmogenics Group

- Investigated using kinematic cuts on electron events, and an estimated 98% γ/e separation.
- Tracking electromagnetic showers back to the "Point of Closest Approach" (PoCA) was the most effective strategy. In 16 days of simulated operations, only 38 electron events survived cuts that have essentially 100% efficiency for real events (PCA>10 cm and E>0.25 GeV) .

Main Background Processes

GrandParent	Parent	Process	Number
μ	γ	$\mu \to \gamma \to e^+e^-$	282270
γ	e^+/e^-	electron scattering	26236
π^0	γ	$\pi \to \gamma\gamma \to e^+e^-$	3142
η	γ	η decay	62
η	π^0	η decay	1
$\eta\prime$	γ	$\eta\prime$ decay	19
γ	π^0	photonuclear resonance	20
γ	γ		4
γ	π^-	photonuclear resonance	1
π^-	π^0	pion decay	1
Σ^0	γ	Σ^0 decay	1
ρ^0	π^-	ρ^0 decay	1





Selection	Remaining Electrons	Events/year
Kinetic Energy >0.1 GeV	312208	7.03×10^6
PoCA>10 cm	207	4662
Electron Energy>0.25 GeV	38	856

- No electrons from K^0 were seen in this run.
- A detailed study of neutrals coming into the detector from the outside showed that a 30 cm vertex cut reduces this background significantly below that from through-going muons.
- Higher statistics are being generated to further validate these results

Conclusion: This extrapolates to 12 events/year assuming 98% e/γ separation. Tagging with vertex activity, photon trigger, and possibly kinematic cuts w.r.t. beam will reduce this further. Can also measure very precisely using beam off data.

- **July 2012:** The Panel recommends that the DOE build a new beam to Homestake, with detector on the surface (to fit within the funding guidelines). The Office of Science concurs, **and asks Fermilab to advance the schedule of conceptual design approval (CD-1) to this year (instead of 2013).**
- **August 2012:** Fermilab now seeking International Partners to make up the 15% of the project cost necessary to move the Far Detector underground, and also to build a Near Detector. Target date to do this is 2015 (when initial construction could start, and final design must be approved). First International workshop to be held day before NNN (October 3).

Sanford Underground Research Facility (SURF)

- Official opening May, 2012 with LUX experiment moving underground and Majorana demonstrator beginning full installation. Lab will continue development (e.g. shaft work and lab outfitting using private and state funds)
- DIANA accelerator seeking approval to start construction. This is likely to be the next underground experiment.
- By approving LUX and Majorana, DOE committed to run for at least another six years.

Conclusions

- LBNE will proceed with first phase plan: new 700 kW beam (upgradable to 2.3 MW), 10 kton liquid argon detector on surface to meet funding guidelines.
- Fermilab will seek International participation at the level of 15% to move underground to 4200 mwe. First International workshop planned for Oct 3 (day before NNN) at Fermilab.
- SURF is now officially open, with a definite commitment from DOE. Shaft improvements and other work underway to accommodate new experiments.

backup slides

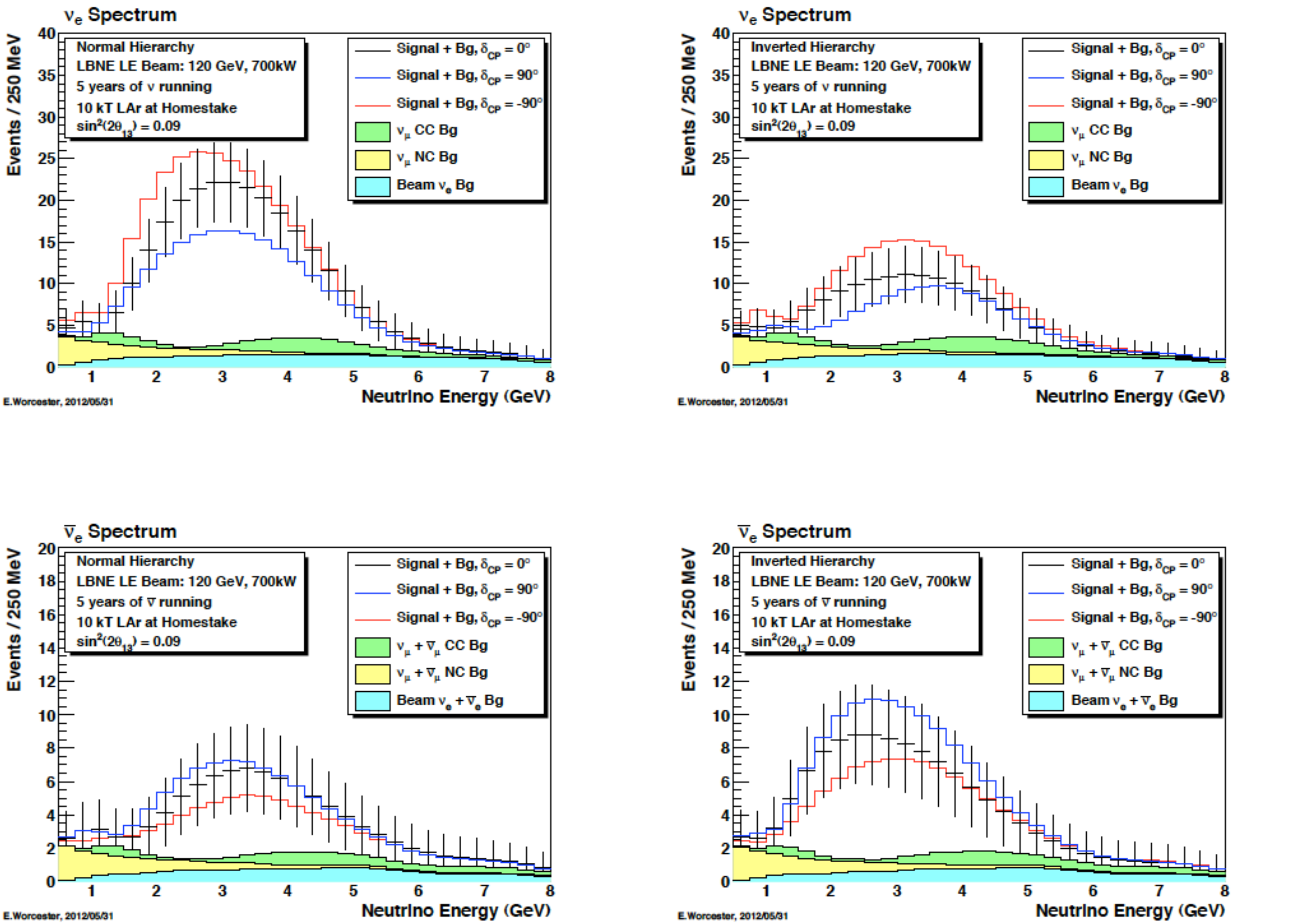
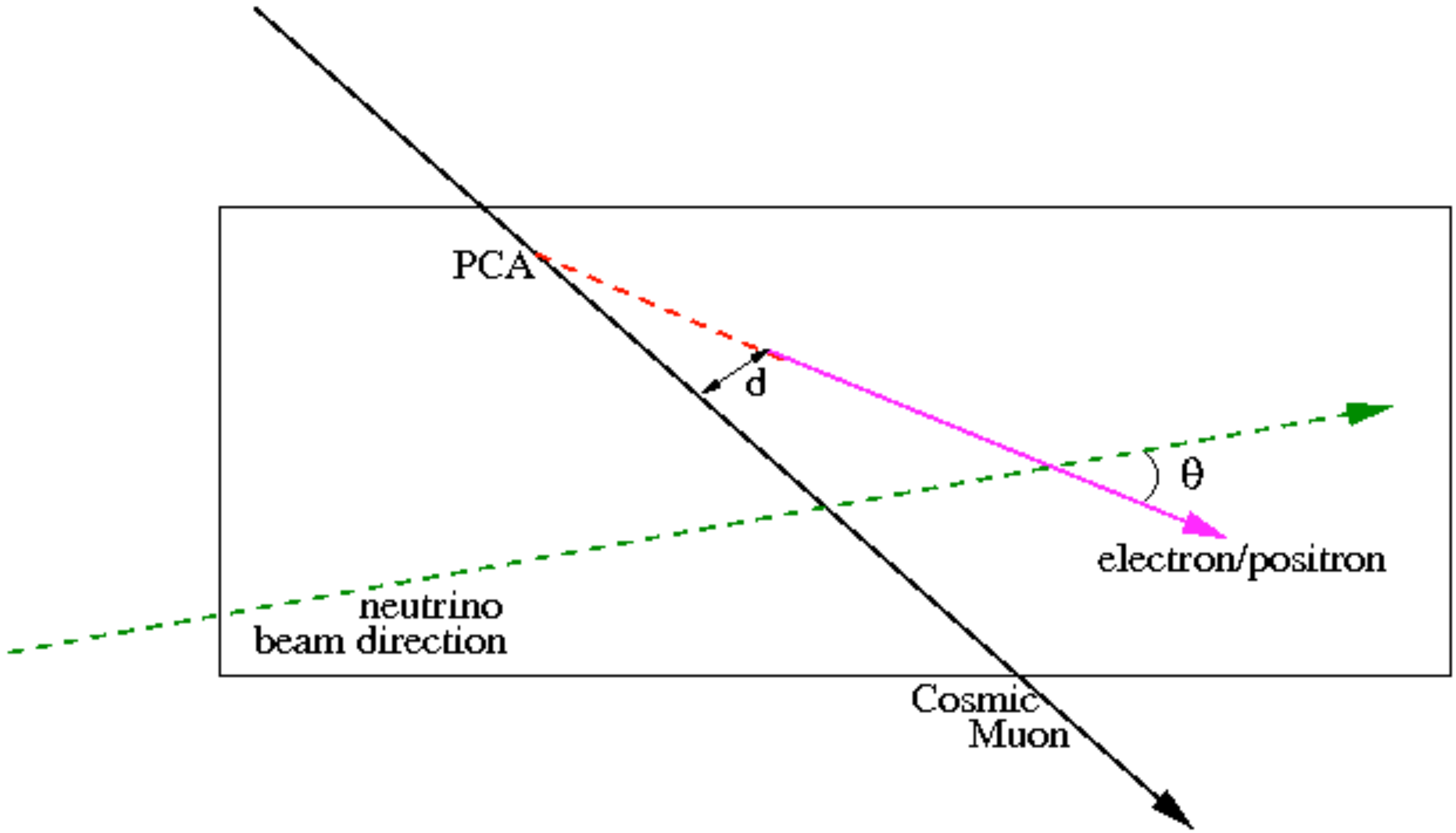
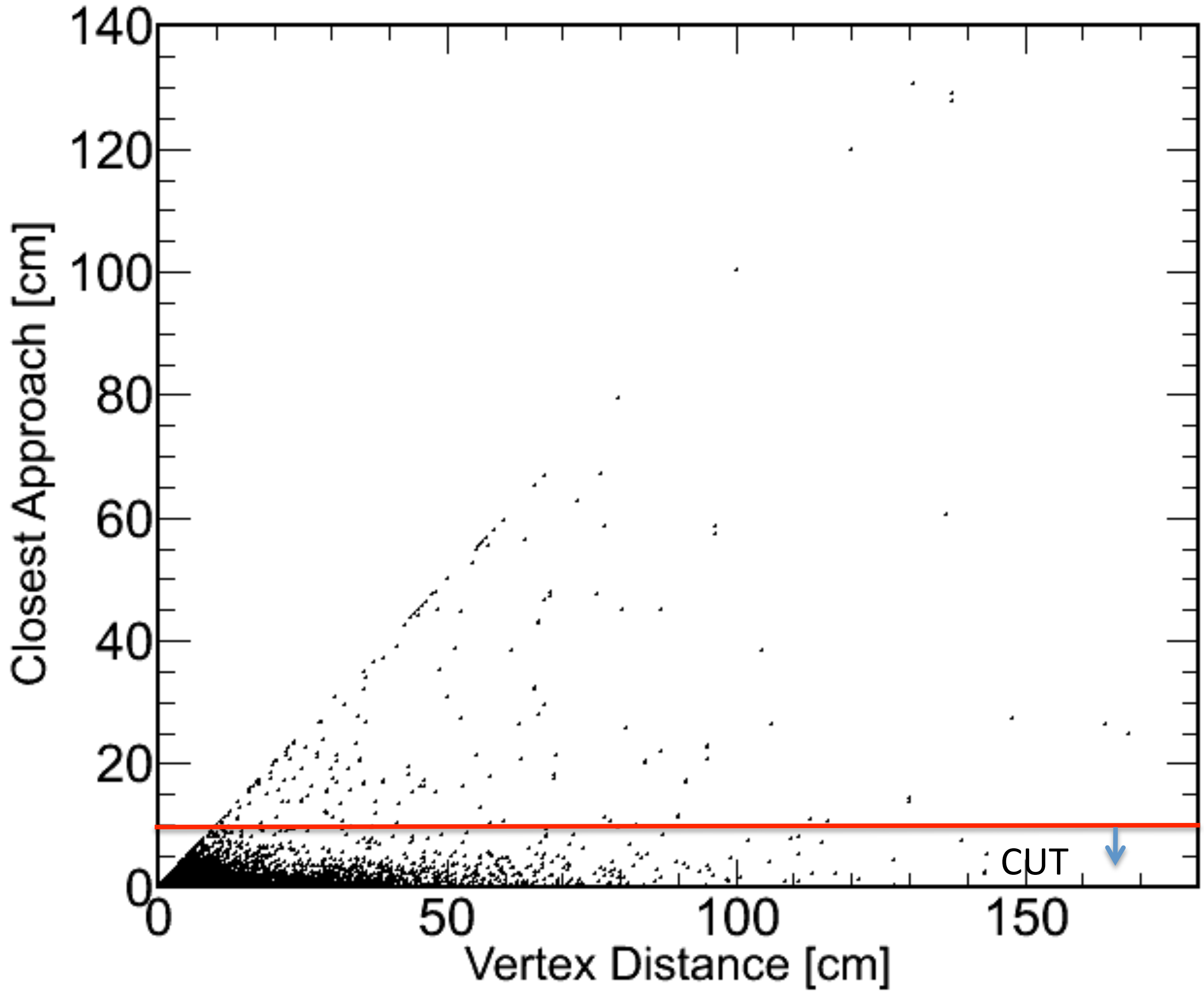


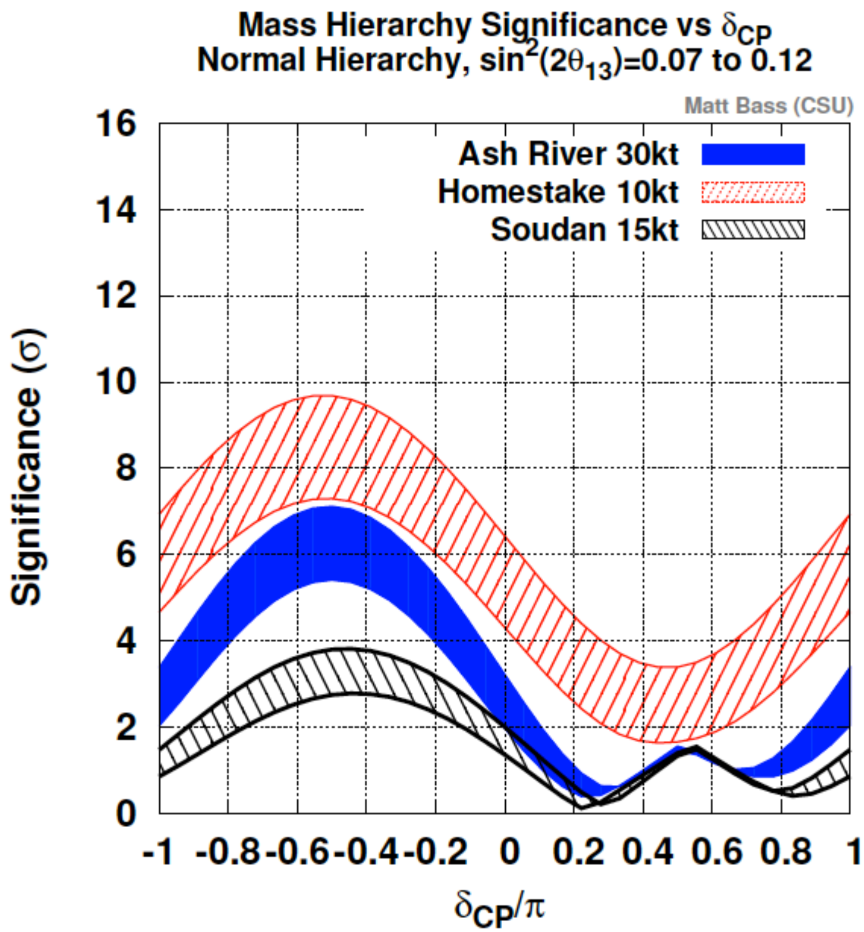
Figure 1: Spectra for a 10 kT LAr detector at Homestake

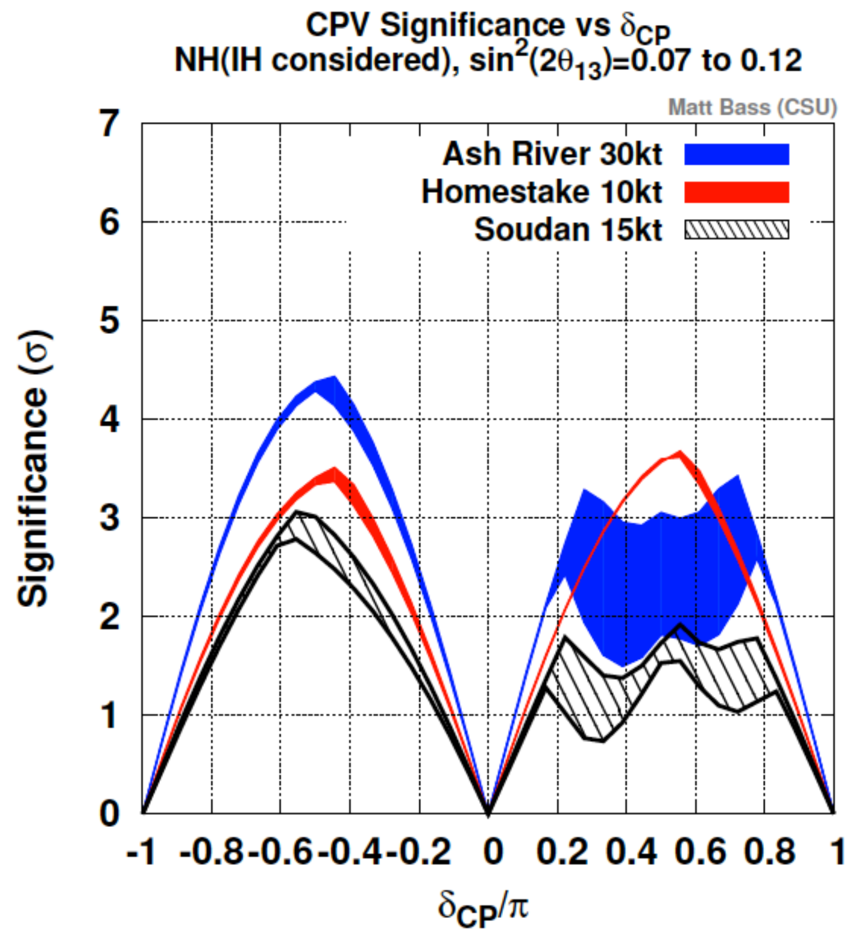

PCA
d
θ
electron/positron
neutrino
beam direction
Cosmic
Muon



PCA is much more effective than distance to vertex in rejecting muon-associated events

Comparison of Phase 1 Sensitivities to Mass Hierarchy and CP Violation





Preliminary: LBNE Physics Working Group

5 years neutrino + 5 years antineutrino

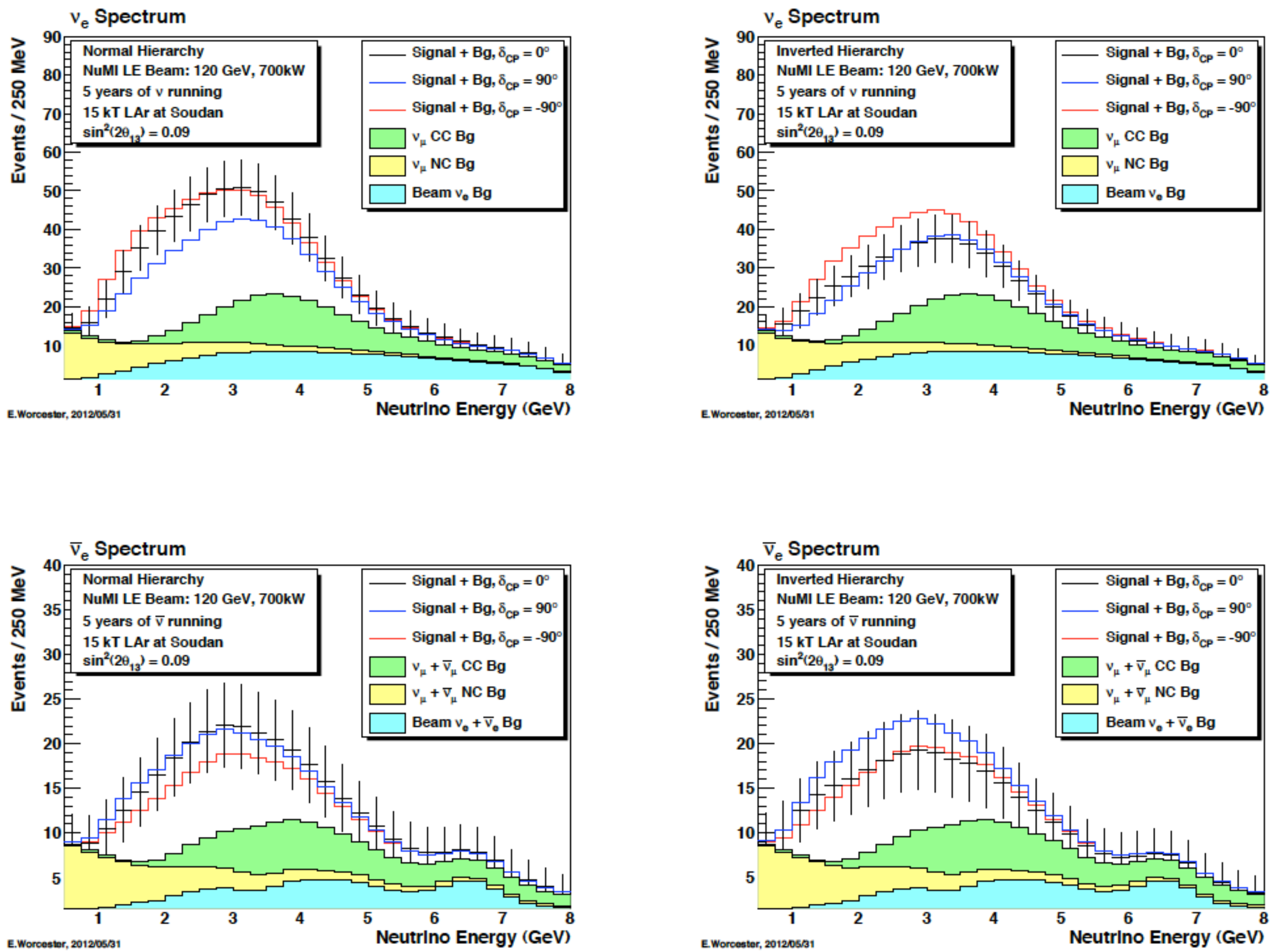


Figure 2: Spectra for a 15 kT LAr detector at Soudan

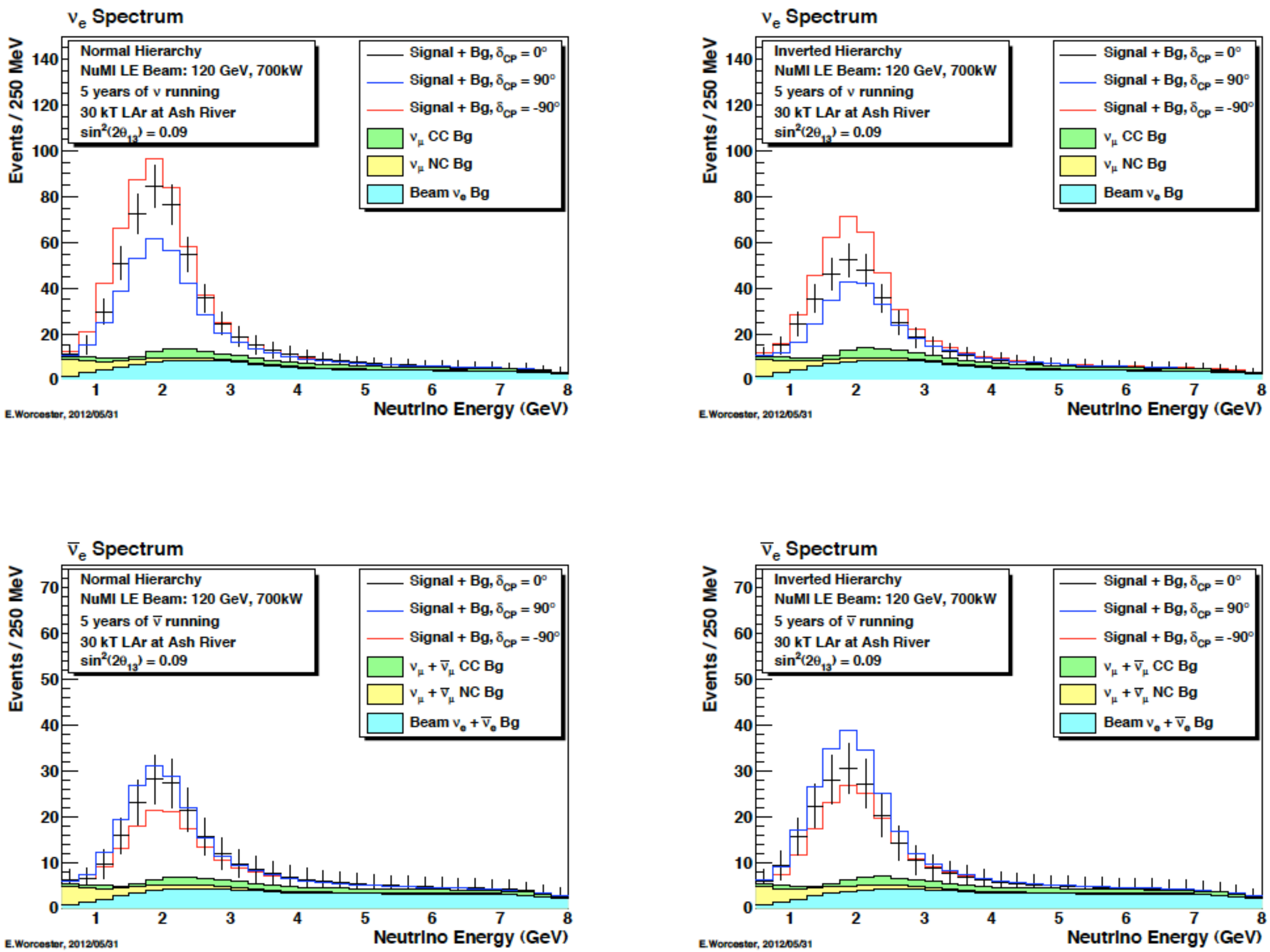


Figure 3: Spectra for a 30 kT LAr detector at Ash River

Homestake

Pros	• Excellent 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 sufficient standard neutrino measurements, and best sensitivity to Standard Model tests and non-standard neutrino physics. • Clear LBNE Phase 2 path – a 25 kton underground (4850 ft) detector at the Homestake mine. This will cover the full capability of the LBNE physics program. • This option will take full advantage of Project X beam power increases.
Cons	• Cosmic ray backgrounds: impact and mitigation to be determined. • Only accelerator-based physics. Proton decay, supernova neutrino and atmospheric neutrino research is delayed to Phase 2. • ~10% more expensive than the other two NuMI options: cost evaluations and value engineering exercises in progress.