Nu 1 Working Group: Neutrino Oscillations and the Three-Flavor Paradigm

in a nutshell

Conveners: M. Bishai, K. Heeger, P. Huber

Snowmass on the Mississippi, August 2, 2012

Goal of this Talk

- Overview of figures used in Nu1 working group report on neutrino oscillations in the 3-flavor paradigm.
- You will hear the physics details in the following talks.
- Solicit feedback from community:
  - *Do these figures tell the complete story?*
  - *Is something missing?*
  - *Are they the right reference figures for the Snowmass report?*
- Your feedback and comments are critically important as we revised and finalize the writeup.

CP Values

the case for precision oscillation physics

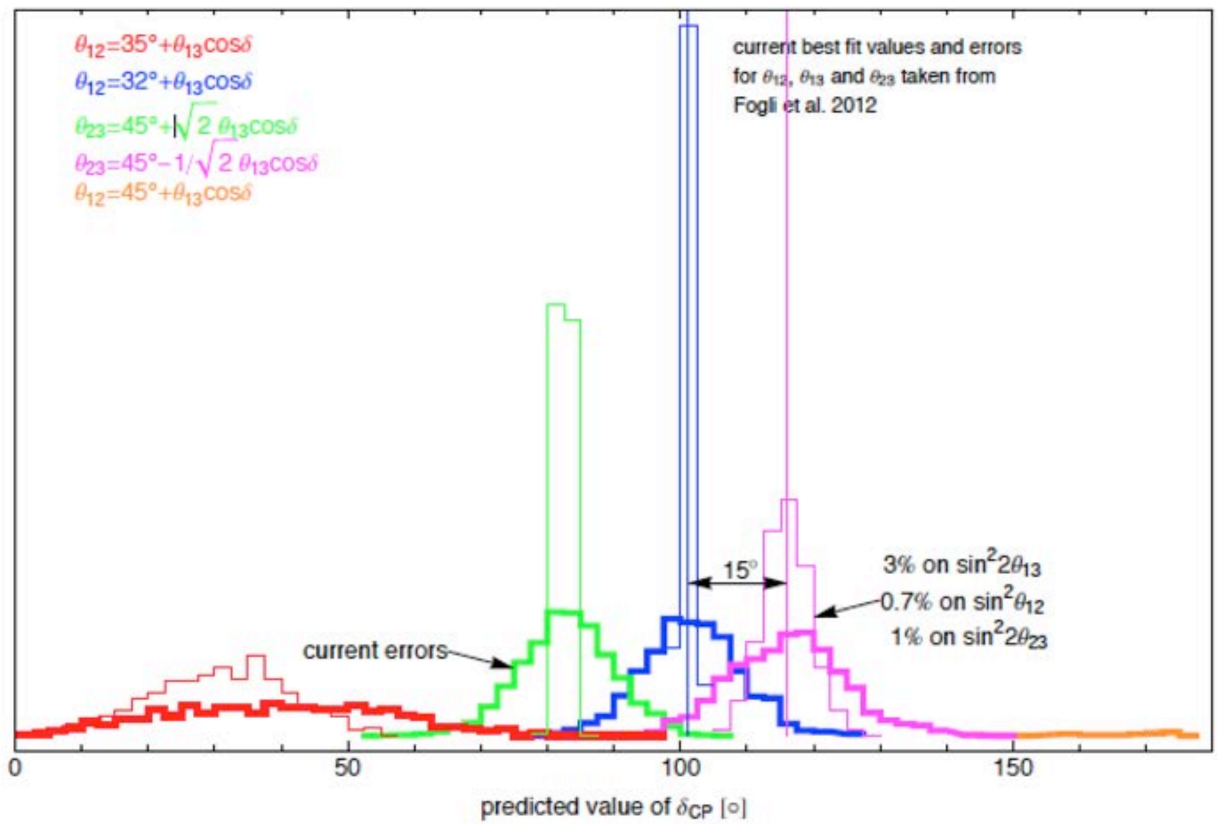

Figure 1-5. *Shown are the distributions of predicted values from δ from various sum-rule as denoted in the legend and explained in the text.*

Mass Hierarchy Sensitivity

with accelerator experiments

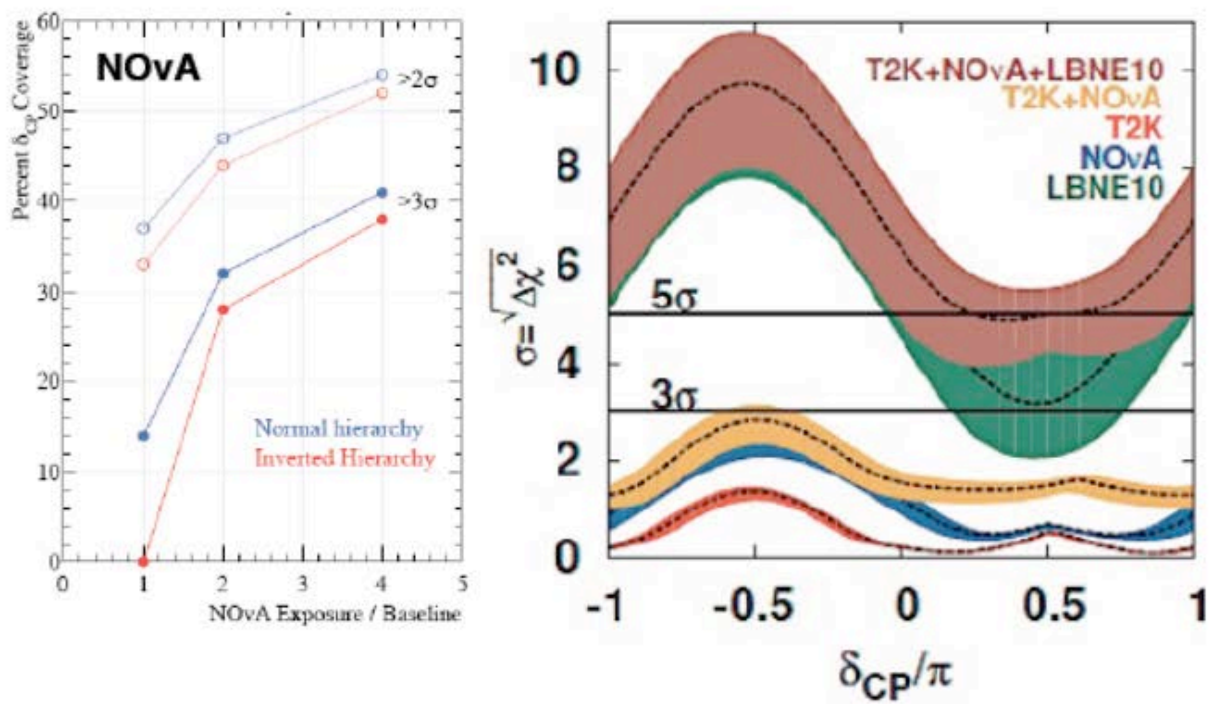

Figure 1-6. *Left: Percent of δ_{CP} values for which NOvA can resolve the neutrino mass hierarchy at 2 and 3 σ C.L. NOvA is in construction and has started data taking with a partial detector configuration. Right: Mass hierarchy sensitivity of LBNE10, NOvA, and T2K and combinations thereof. T2K is operational and taking data. NOvA is in the commissioning phase and will finish construction in 2014. LBNE10 is in preliminary design and R&D and preparing for Critical Decision 2. Figures from [73, 74].*

Mass Hierarchy Studies

with reactor neutrinos

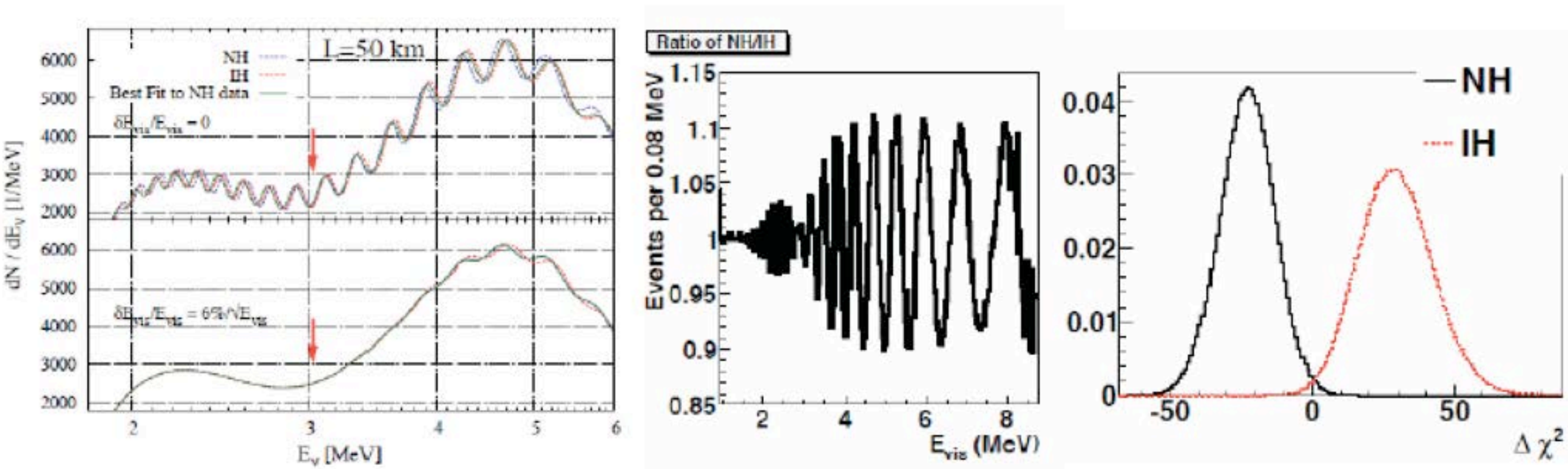

Figure 1-7. *Left: Energy distribution of reactor antineutrinos with baseline length of 50 km. The solid line shows the best fit of IH assumption to the NH data. The red arrow points out the energy at which the difference due to the mass hierarchy vanishes. The lower panel shows the effect of 6% energy resolution. Figure from [75]. Middle: Ratio of reactor antineutrino spectra for NH and IH case for the ideal energy spectrum without fluctuation and fixed Δm^2_{31} . Statistical fluctuations, the unknown true value of Δm^2_{31}, as well as experimental effects such as energy scale uncertainty will degrade the observable effect. Right: The $\Delta\chi^2$ spectrum from Monte Carlo simulation. The probability of the mass hierarchy being NH is calculated as $P_{NH}/(P_{NH}+P_{IH})$ and found to be 98.9% for 100kT-year exposure. Figures from [76].*

Mass Hierarchy Studies

with atmospheric neutrinos under water/ice

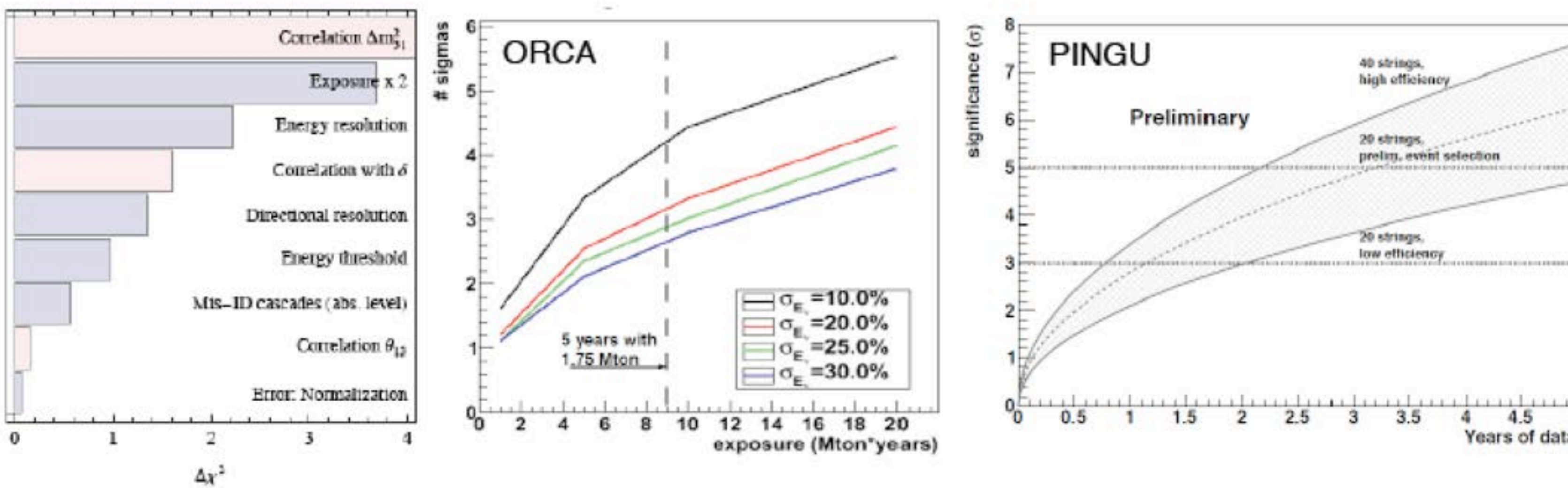

Figure 1-8. *Left: Impact of experimental and systematic uncertainties on the determination of the mass hierarchy with atmospheric neutrino experiment such as PINGU and ORCA. The impact is given in form of $\Delta\chi^2$ for normal hierarchy and $\delta = 0$ on the default systematics described in [78]. The blue bars indicate experimental systematics. The exposure, energy scale, and directional resolution are most important for the experiment under consideration. Figure from [78]. Right: Sensitivity of the ORCA and PINGU proposals to mass hierarchy. Experimental sensitivities are preliminary. Figures from [79, 77].*

Mass Hierarchy Studies

with atmospheric neutrinos in LAr

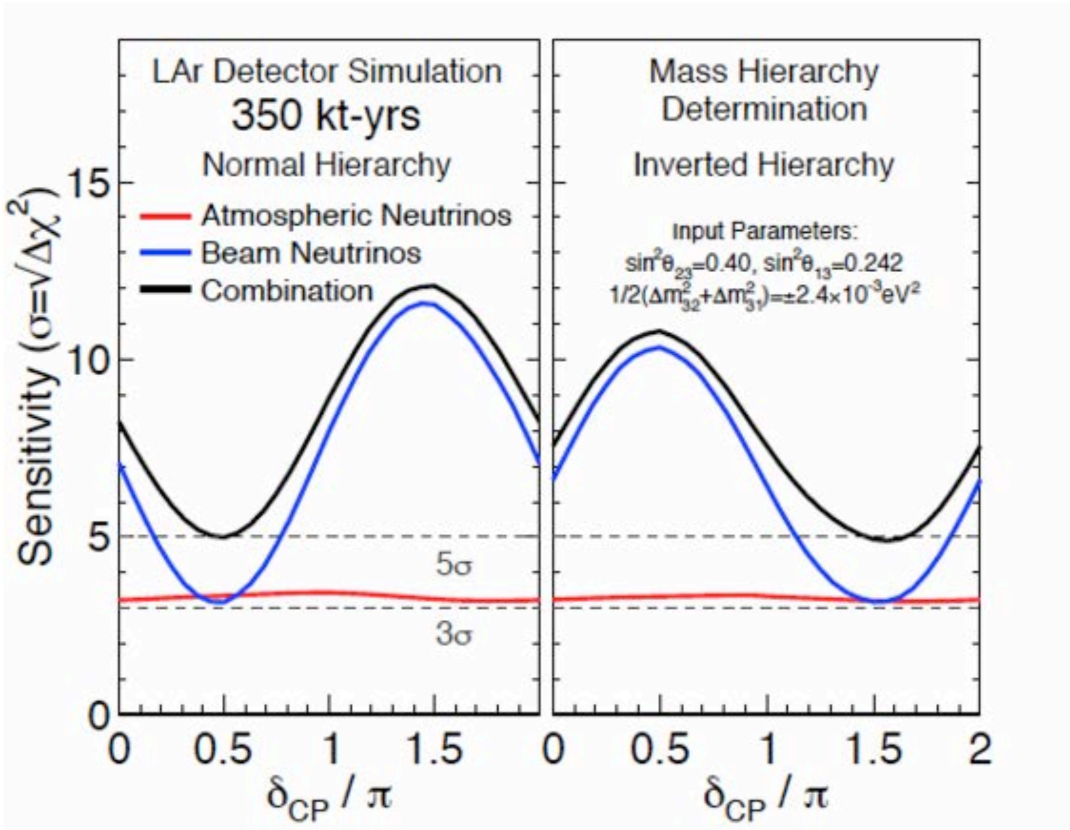

Figure 1-9. *Mass hierarchy determination possible with atmospheric neutrinos in a 35 kton-year exposure of an underground liquid argon TPC in LBNE shown as a function of possible δ_{CP} values for both normal (left) and inverted (right) hierarchies. Atmospheric neutrino information can be combined with beam information in the same detector to improve overall sensitivity. Plot courtesy of A. Blake.*

Neutrino Appearance

in accelerator-based experiments

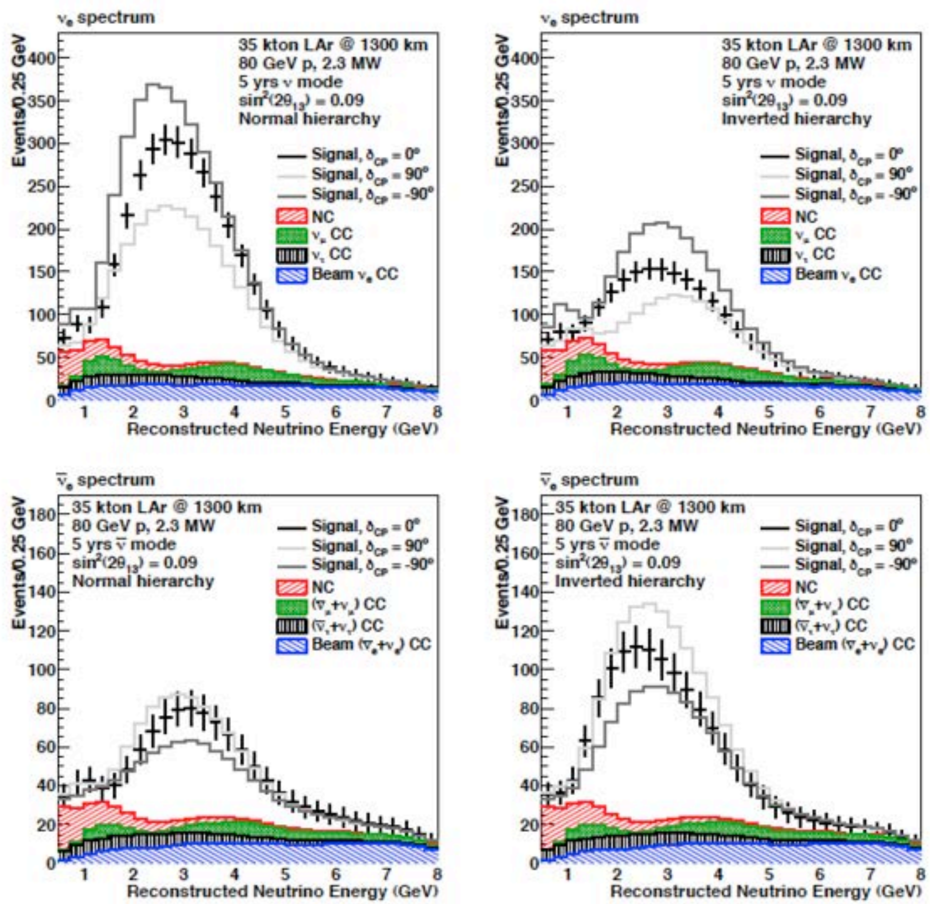

Figure 1-10. *The expected appearance of ν_e (top) and $\bar{\nu}_e$ (bottom) signals for the possible mass orderings (left: normal hierarchy, right: inverted hierarchy) and varying values of CP δ for the example of LBNE/Project X.*

CP Violation Sensitivity

in accelerator-based experiments

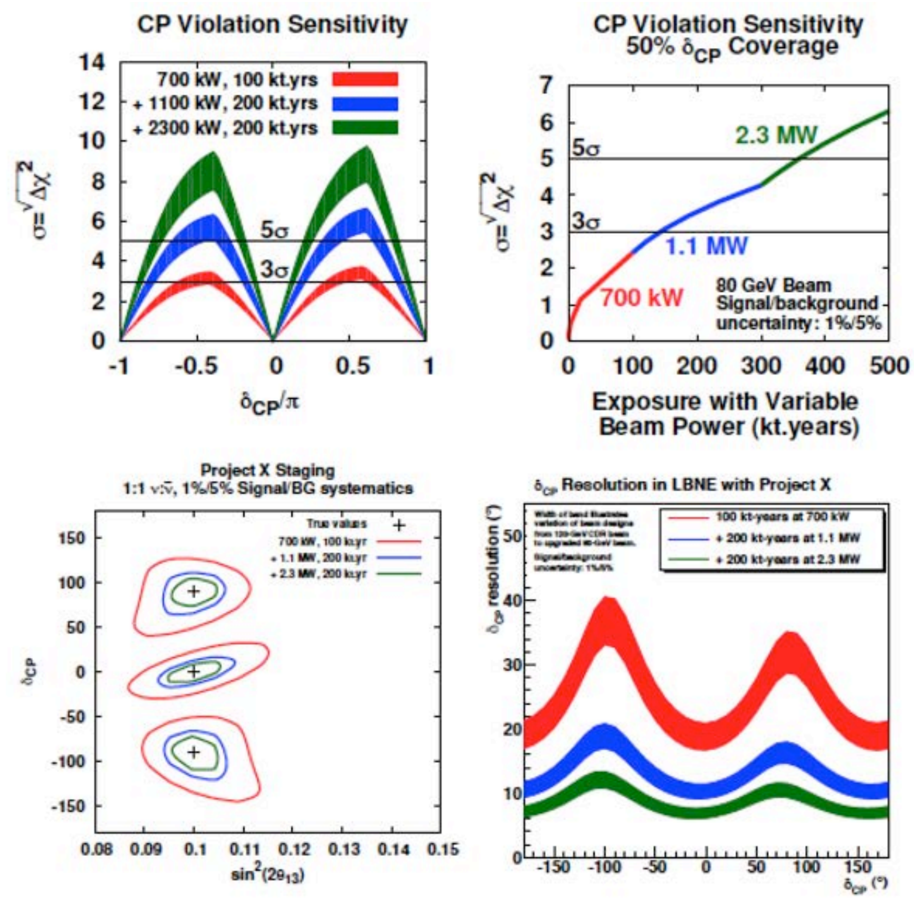

Figure 1-11. *CP violation sensitivity as a function of δ_{CP} (top left) and exposure for 50% coverage of the full δ_{CP} range (top right). Also shown are the projected precision on the measurement of δ_{CP} for various true points in the δ_{CP}-$\sin^2 2\theta_{13}$ plane (bottom left) and as a function of δ_{CP} (bottom right). All plots show the increasing precision possible in a staged long-baseline neutrino program in LBNE starting from nominal 700kW running (red), through 1.1 MW using Project X Stage 1 (blue), to 2.3 MW with Project X Stage 2 (green).*

CP Violation Sensitivity

from beams + atmospheric neutrinos

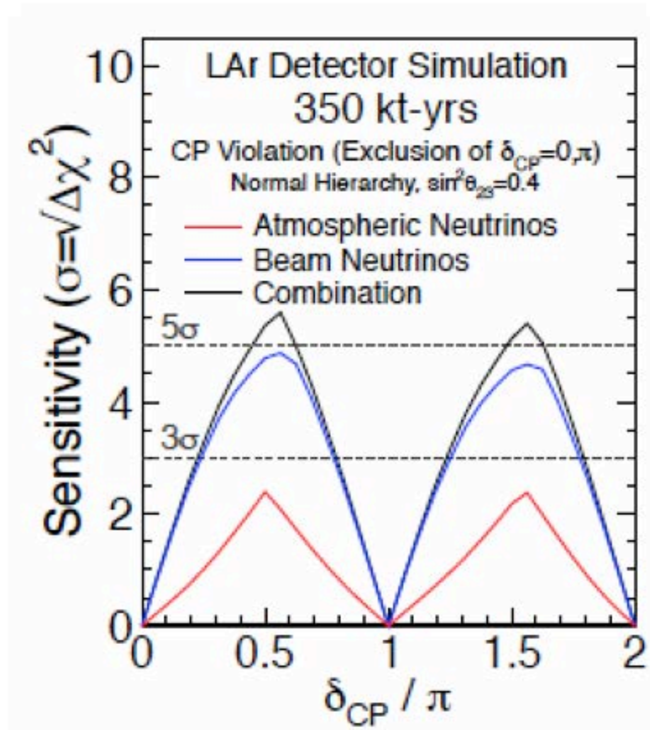

Figure 1-14. *Sensitivity to CP violation as a function of δ_{CP} for a liquid argon detector showing the results of combining information from both beam (blue) and atmospheric (red) neutrinos. Plot courtesy of A. Blake.*

CP Violation Sensitivity

with Daedalus

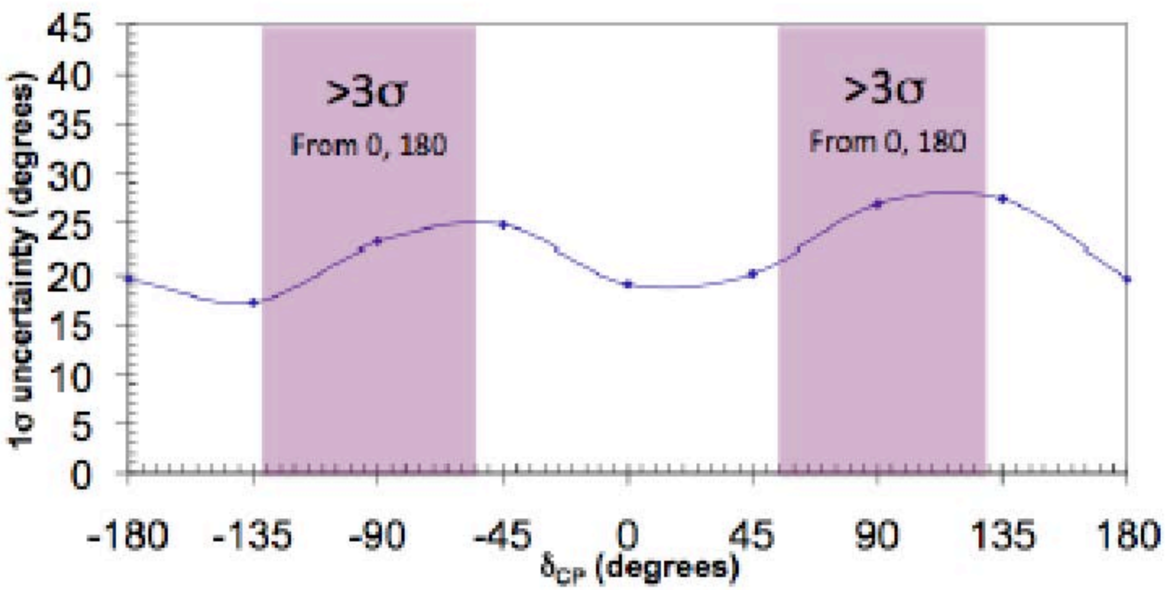

Figure 1-15. *Sensitivity of a CP search for DAEδALUS combined with LENA [80].*

CP Violation Sensitivity

with HyperK

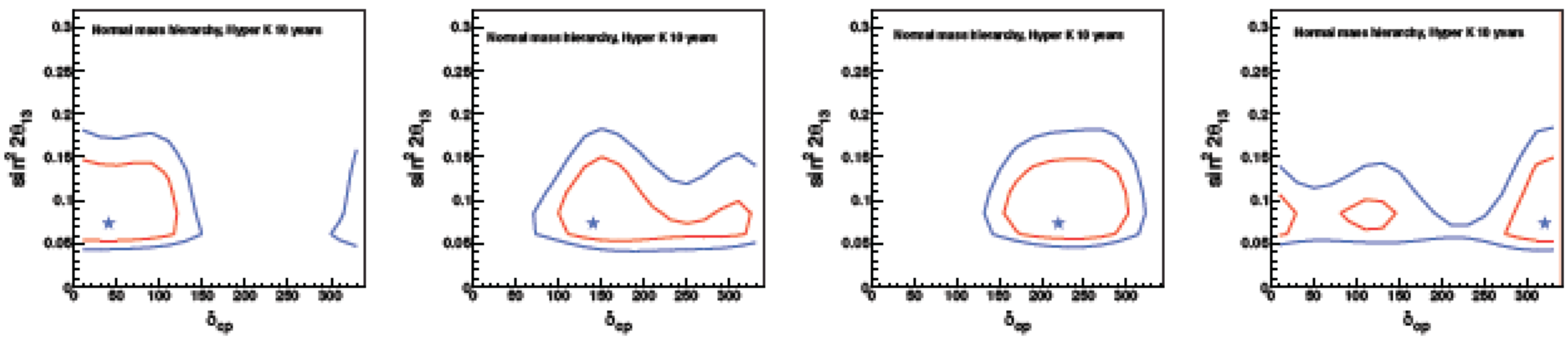

Figure 1-13. *Expected sensitivities for δ and $\sin^2 2\theta_{13}$ at 90% CL (red) and 99% CL (blue) with a livetime of 10 Hyper-K years. Stars in the contours represent the true parameters. Normal mass hierarchy is assumed. Figure from [81].*

CP Violation Precision

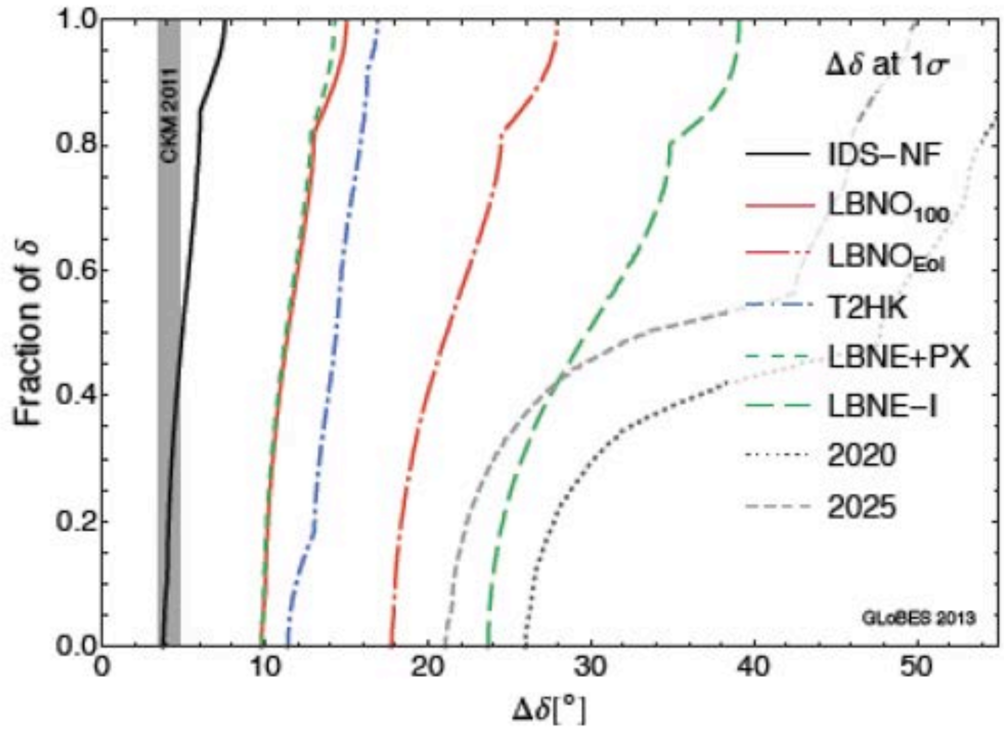

Figure 1-12. *Projected precision for a CP measurement. Shown is the fraction of all possible true values of δ_{CP} as a function of the 1σ error in the measurement of δ_{CP}. A CP fraction of 1 implies that this precision will be reached for all possible CP phases, wheras a CP fraction of 0 means that there is only one value of δ_{CP} for which the measurement will have that precision. The various lines are for a variety of possible experiments as labeled in the legend and explained in the text. The vertical gray shaded area, labeled "CKM 2011", indicates the current errors on the CP phase in the CKM matrix. This calculation includes near detectors and assumes consistent flux and cross section uncertainties across different setups. Plot courtesy of P. Coloma.*

We welcome your feedback!

mbishai@bnl.gov
karsten.heeger@yale.edu
pahuber@vt.edu

or

if-neutrino-conveners@fnal.gov