LBNE

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Fermilab

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with help from:

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- what would a larger value of $\sin^2 2\theta_{13}$ mean for LBNE?

LBNE

- all slides and information shown use standard assumptions for LBNE*
  (unless otherwise stated)

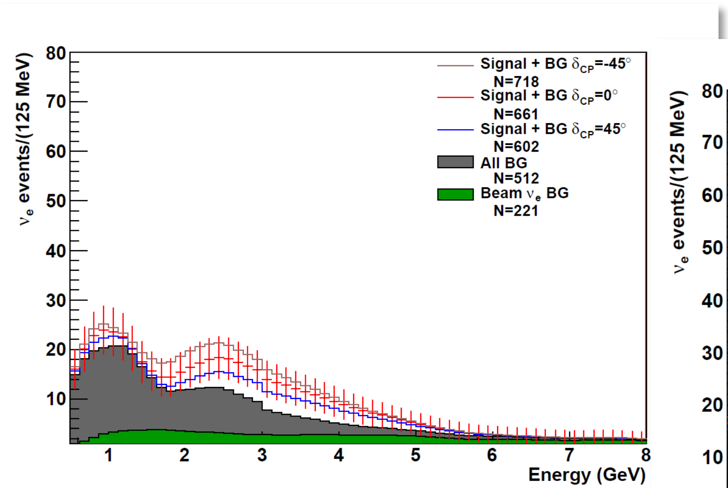
  - *200 kton WC detector (34 kton LAr detector is roughly equivalent)*
  - *1300 km baseline*
  - *700 kW on-axis broad band beam* ⟶ *resolve parameter degeneracies* (simultaneous θ_{13}, MH, $\not{CP}$)
  - *5+5 years $\nu + \overline{\nu}$ running*
  - *5% background uncertainties*
  - *3σ sensitivity projections*
  - *GLoBES*

* these results are subject to change and and do not necessarily reflect the official position of the LBNE collaboration

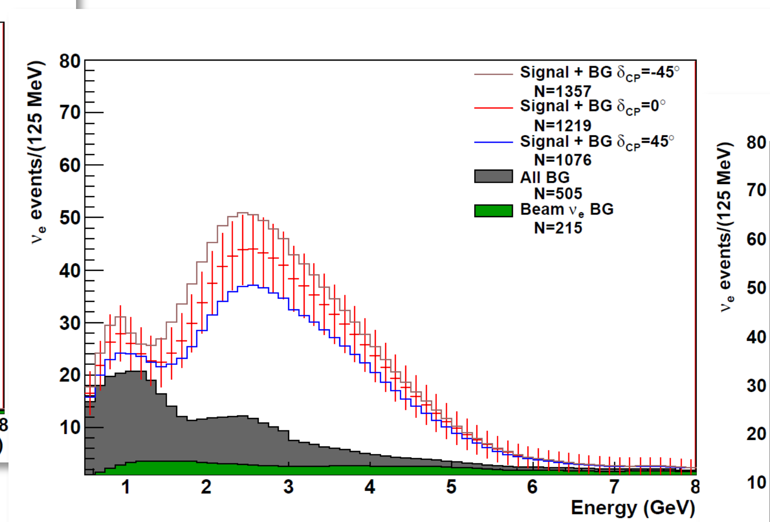
Larger θ_{13} Means Larger Signals

(M. Bass, B. Wilson)

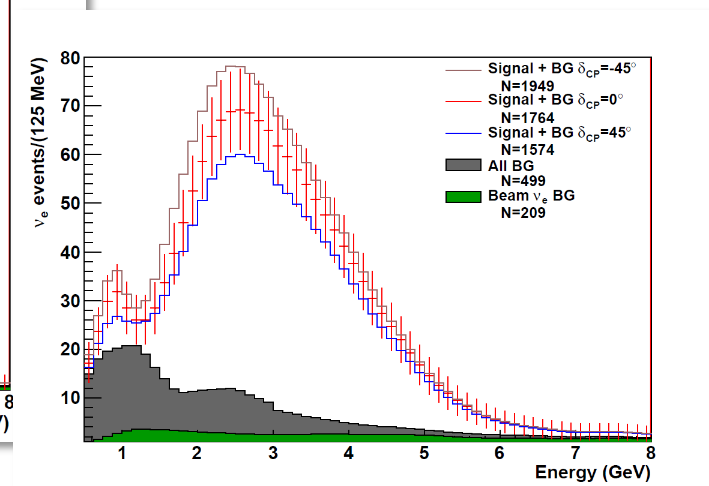
$\sin^2 2\theta_{13}=0.01$



$\sin^2 2\theta_{13}=0.06$



$\sin^2 2\theta_{13}=0.11$



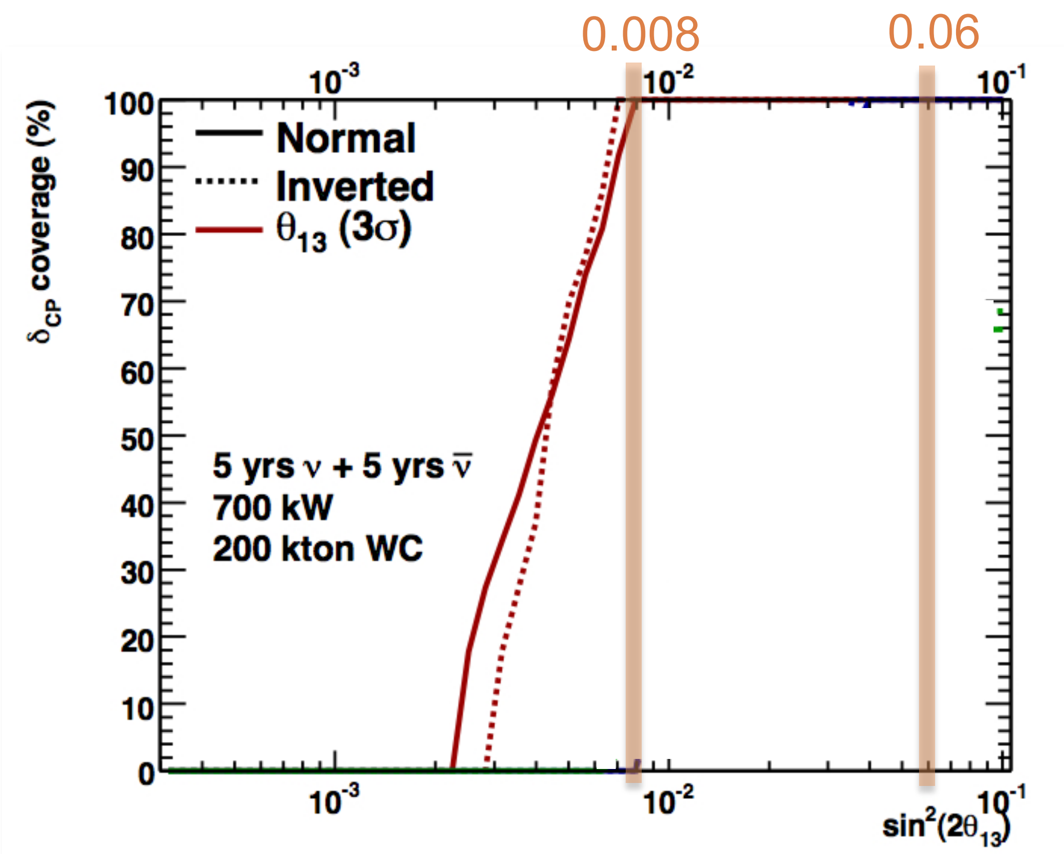
ν_e signal events for 200 kton WC, 5 yrs ν, 700 kW, 1300km, NH, $\delta=0$

(expect smaller rates for IH, smaller rates also for anti-ν running)

149	714	1,265

(almost x10 increase in # signal events in going from $\sin^2 2\theta_{13}=0.01$ to 0.1)

Non-Zero θ_{13}

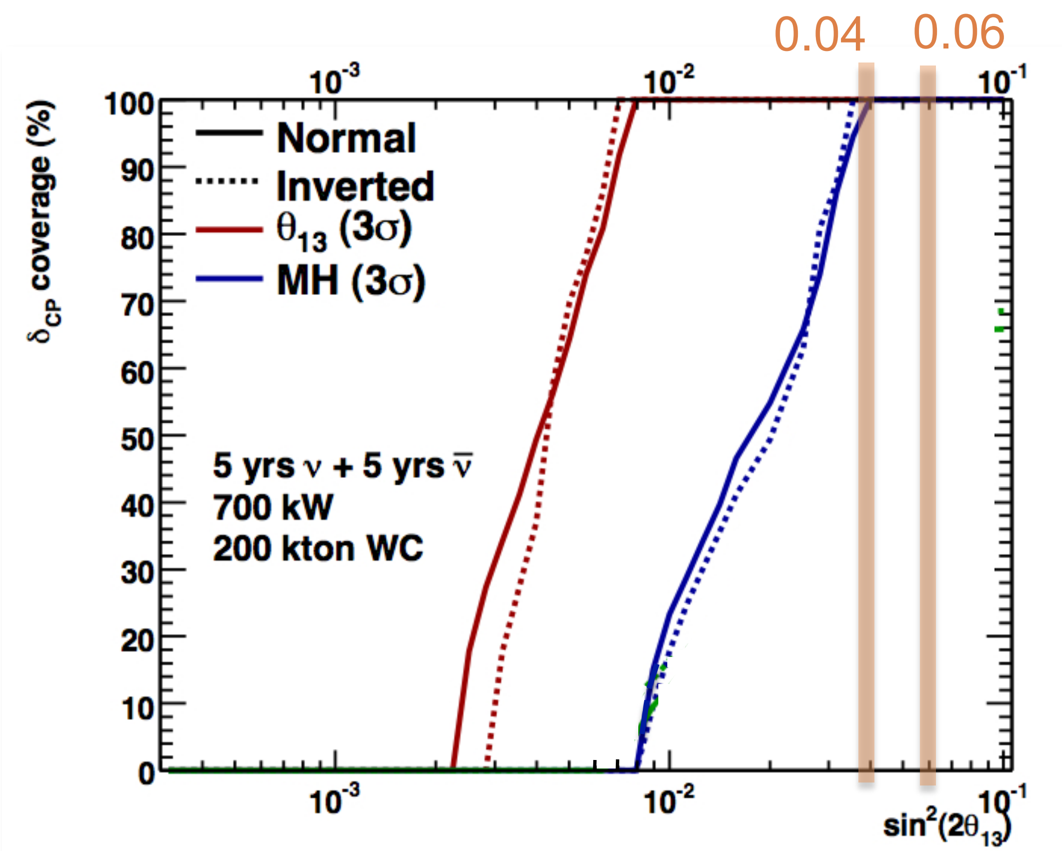


- ability to determine whether or not $\sin^2 2\theta_{13} \neq 0$ obviously improves with increasing θ_{13}

(LBNE can determine if θ_{13} is non-zero at 3σ for both mass hierarchies and 100% of δ_{CP} values if $\sin^2 2\theta_{13} \gtrsim 0.008$)

- but of course this is not the main goal of LBNE …

Mass Hierarchy



- LBNE's ability to resolve the mass hierarchy also improves with increasing θ_{13}

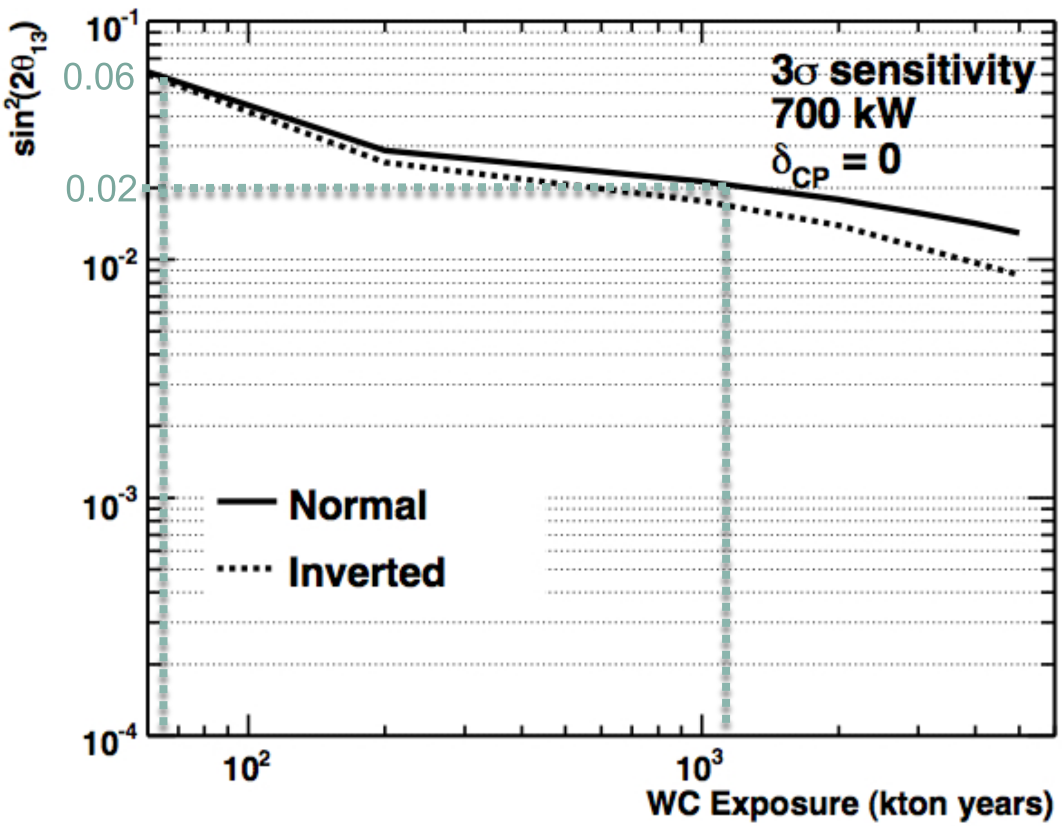
- if $\sin^2 2\theta_{13} \gtrsim 0.04$, LBNE can resolve MH at 3σ for 100% of δ_{CP} values

  (and at 5σ if $\sin^2 2\theta_{13} \gtrsim 0.06$)

- will provide definitive measurement of mass hierarchy; important for $\not{C}P$

Mass Hierarchy

(L. Whitehead)



(note: kink at ~200 kt-yrs is a sampling artifact)

- in terms of time …

  a larger $\sin^2 2\theta_{13}$ will allow a more rapid determination of the mass ordering

- LBNE can resolve MH at 3σ in ~4 months of running if $\sin^2 2\theta_{13}=0.06$

  (200 kton WC, 700 kW, $\delta_{CP}=0$, NH)

  compared to ~6 years if $\sin^2 2\theta_{13}$ is 0.02

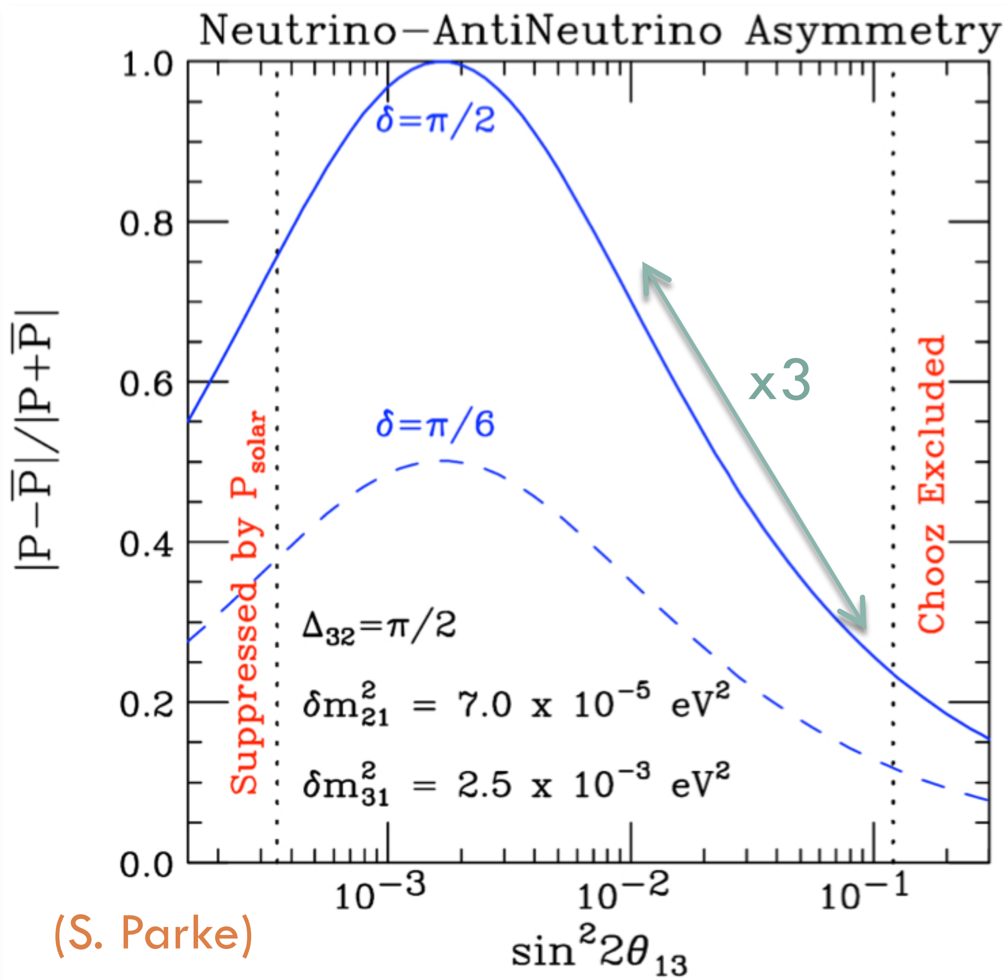
CP Violation

- main goal of LBNE is to unambiguously measure CP violation

- the θ_{13} and MH measurements will benefit significantly from a larger $\sin^2 2\theta_{13}$, but the measurement of $\not{CP}$ and δ_{CP} is largely unaffected by the value of $\sin^2 2\theta_{13}$

- to first order, this is due to two competing effects…
  → size of asymmetry you are trying to measure
  → size of event sample

$\nu/\bar{\nu}$ Asymmetry in Vacuum



(S. Parke)

(ignoring matter effects & backgrounds for now)

- the asymmetry

$$\frac{P(\nu_\mu \rightarrow \nu_e) - P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)}{P(\nu_\mu \rightarrow \nu_e) + P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)}$$

is proportional to $\sim 1/\sin\theta_{13}$

- **the asymmetry gets smaller as θ_{13} increases**

~75% for $\sin^2 2\theta_{13}=0.01$
~25% for $\sin^2 2\theta_{13}=0.10$ } $\delta_{CP}=\pi/2$

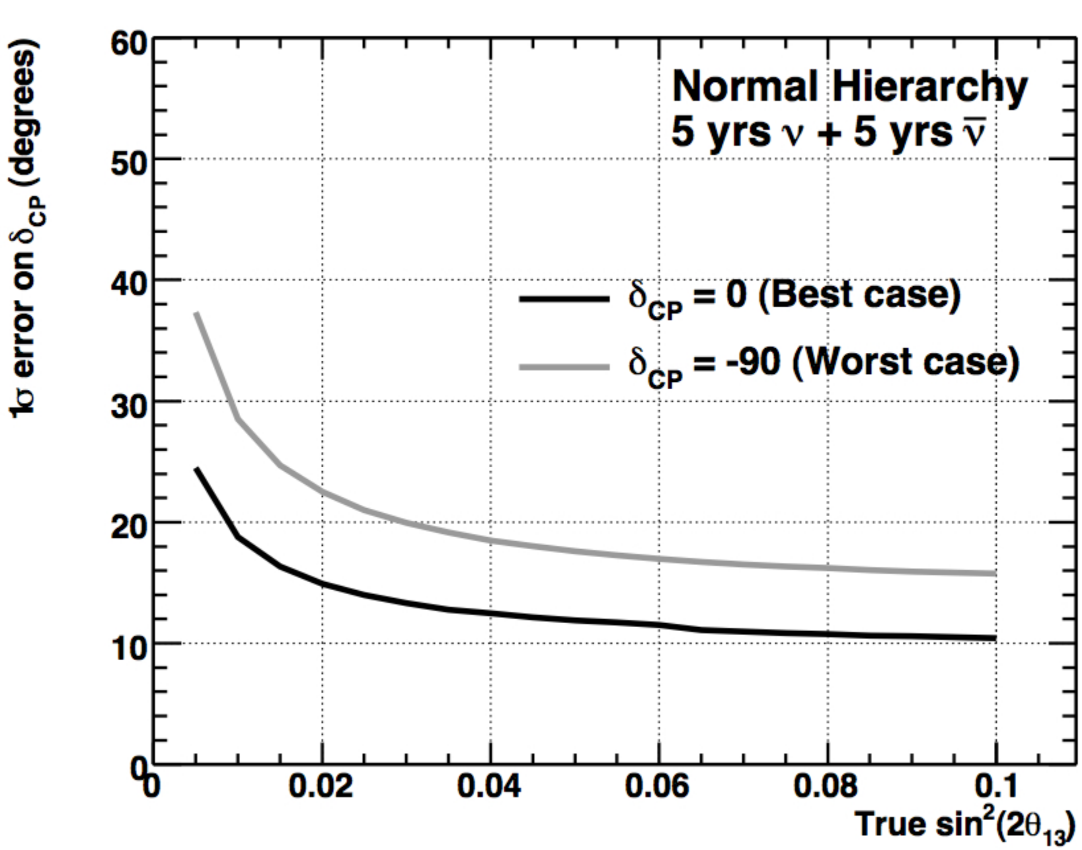
factor ~3 reduction in CP asymmetry (independent of baseline)

- **signal rate increases w/ θ_{13}**

factor ~10 increase from 0.01 to 0.1 so x3 improvement in stat sig of signal

Measurement of CP Phase

(L. Whitehead)



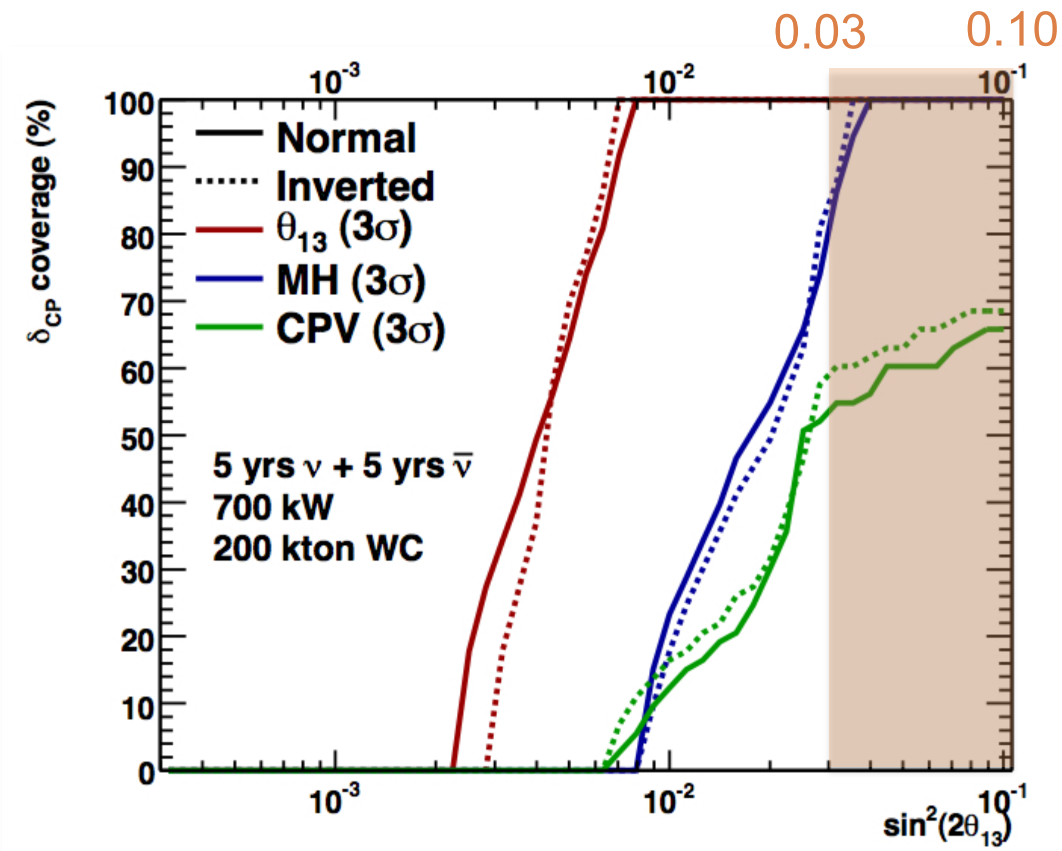
(calculation includes backgrounds, background uncertainties, and matter effects)

- as a result, the error on the CP asymmetry and thus how well can measure δ_{CP} is essentially independent of the value of θ_{13}

- can provide an excellent measurement of δ_{CP} over a very broad range of θ_{13}

(10-20^0 for $\sin^2 2\theta_{13}$~0.03-0.10; gets a little worse for smaller θ_{13})

CP Violation



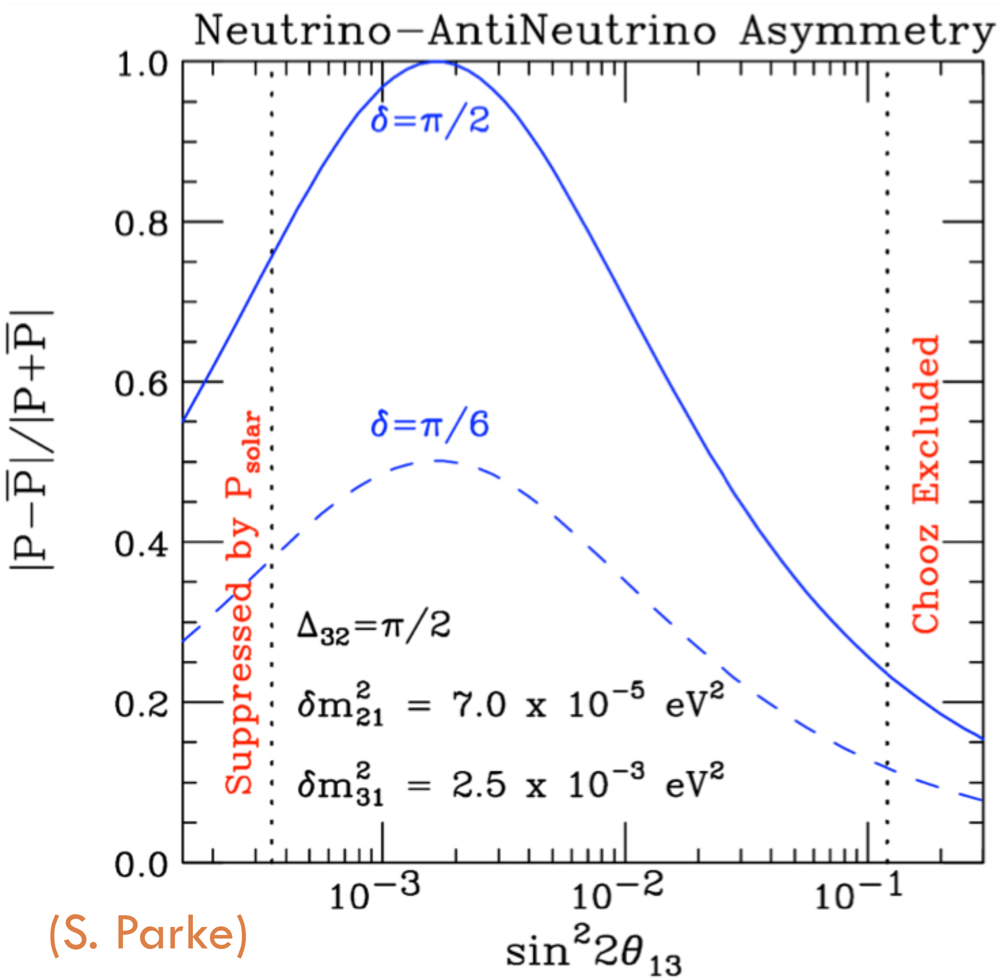
(green curve shows range of values over which CP violation can be established at 3σ)

- LBNE's sensitivity to ~~CP~~ is also largely independent of θ_{13} for $\sin^2 2\theta_{13}$~0.03-0.10
- can measure ~~CP~~ at 3σ for 50-70% of δ_{CP} values (NH, IH) over a broad range of θ_{13}

Conclusions

- a positive indication of θ_{13} makes LBNE scientifically very important
- for larger values of $\sin^2 2\theta_{13}$:
  - LBNE can determine the mass hierarchy much more quickly
  - ability to measure CP violation and CP phase is largely unaffected by the value of $\sin^2 2\theta_{13}$ (true for $\sin^2 2\theta_{13} \gtrsim 0.03$)
- to perform a definitive measurement of CP violation, one must maintain a large exposure (detector mass, beam delivery) no matter what the value of θ_{13} … this is what ultimately drives the scale of the experiment
  - additional effects (matter effects, backgrounds, and uncertainties) only increase the need for more statistics

Also …



(S. Parke)

- also important to note that if θ_{13} is large, the asymmetry you're trying to measure is small, so:
  - need to know underlying $\nu/\bar{\nu}$ flux & σ more precisely
  - bkg content &uncertainties start to become more important