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# Magical properties of 2540 km baseline Superbeam Experiment

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Measurement of $P_{\mu e}$ in any long baseline experiment depends on all the three unknowns of neutrino physics $\theta_{13}$, $\delta_{CP}$ and the neutrino mass hierarchy. Hence, data from any one experiment is subject to $\theta_{13}$-hierarchy degeneracy as well as hierarchy-$\delta_{CP}$ degeneracy. New and innovative strategies are needed to overcome these degeneracies. Here we demonstrate the **magical** properties of the 2540 km baseline Superbeam experiment, whose flux peaks in the $3-4$ GeV range. We show that, such an experiment, in conjunction with reactor neutrino data, can determine the neutrino mass hierarchy *independent of* $\delta_{CP}$. And we need data only from the neutrino mode to achieve this.

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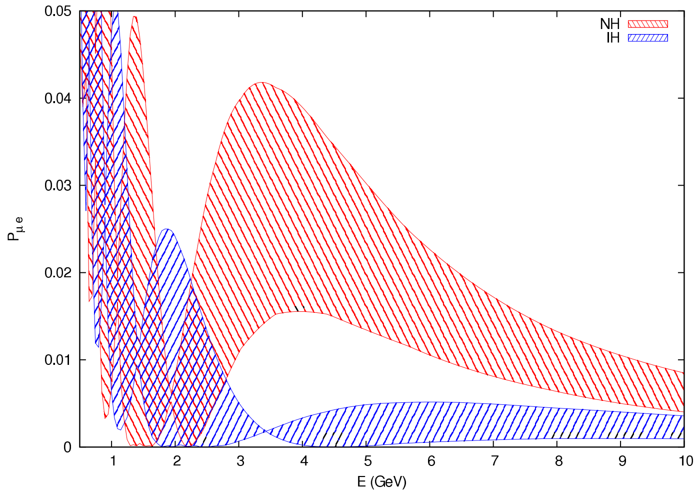


**Figure 1:** $P_{\mu e}$ as function of $E$ for $L = 2540$ Km and $\sin^2 2\theta_{13} = 0.02$. $P_{\mu e}$ is plotted for both NH and IH, each for the full range of values of $\delta_{CP}$.

As mentioned in the abstract, the $\nu_\mu \to \nu_e$ oscillation probability is sensitive to $\theta_{13}$, $\delta_{CP}$ and the hierarchy. A very useful, approximate expression for $P_{\mu e}$ is given by [1]

$$P_{\mu e} = C_0 \frac{\sin^2((1-\hat{A})\Delta)}{(1-\hat{A})^2} + \alpha\, C_1 \frac{\sin((1-\hat{A})\Delta)}{(1-\hat{A})} \frac{\sin(\hat{A}\Delta)}{\hat{A}} + \alpha^2 C_2 \frac{\sin^2(\hat{A}\Delta)}{\hat{A}^2}, \tag{1}$$

where $\Delta = (1.27\Delta_{31}L/E)$ and $\hat{A} = A/\Delta_{31}$. Only $C_1$ depends on $\delta_{CP}$. The term containing $C_1$ can be made to vanish by choosing either $\hat{A}\Delta = \pm\pi$ or $(1-\hat{A})\Delta = \pm\pi$. The first condition can be satisfied for both the hierarchies simultaneously and gives rises to the celebrated magic baseline $L = 7500$ km [2]. The second condition can be satisfied for only one hierarchy at a time. We choose to satisfy it for inverted hierarchy (IH). In addition, we require that, for normal hierarchy (NH), $(1-\hat{A})\Delta = \pi/2$. Solving the above two equations gives rise to the conditions $L = 2540$ km and $E = 3.3$ GeV [3]. For this baseline at this energy, we have $P_{\mu e}$ very small ($\approx 0.002$) for IH and measurably large for NH. This is illustrated in figure 1.

This proposal has two advantages over the magic baseline proposal. Since this baseline is one third of the magic baseline, the flux will be 9 times larger. Moreover, at magic baseline, $P_{\mu e}$ is independent of $\delta_{CP}$. Here, $P_{\mu e}$ loses $\delta_{CP}$ dependence only for IH but retains it for NH. For anti-neutrinos the situation is opposite. So we have the possibility of determining both hierarchy and $\delta_{CP}$ in a single experiment. The hierarchy discriminating ability of this proposal is discussed in [3].

## References

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