T2KK: Tokai to Kamioka and Korea

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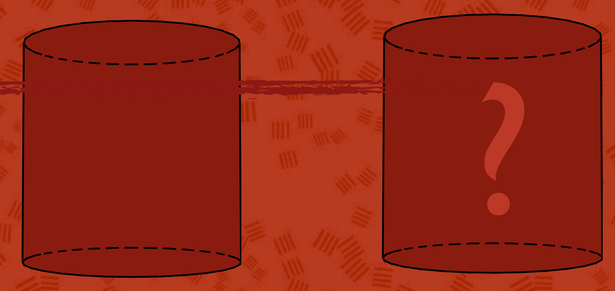


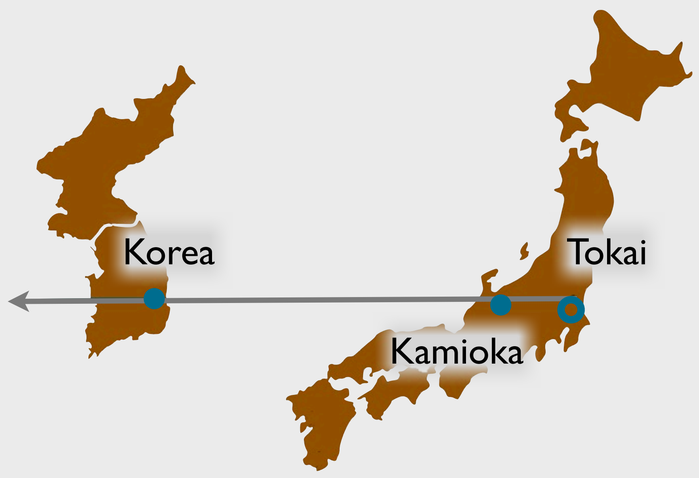
Introduction

Overview
The T2KK idea was first presented in 2005 [1]. It envisions placing a Mega-ton water Cherenkov detector in Korea in the line of the T2K beam, while the SuperKamiokande detector would be upgraded to a Mega-ton detector known as HyperKamiokande [2].
It was presented in 2010, that the best location for the Korean detector is at 1° degree off-axis so that the spectrum seen in Korea is a wide-band beam. [3]

Given the recent results of Daya Bay [4] and RENO [5] concerning the large value of θ_{13}, the discovery potential for the T2KK setup is even more interesting.

In the original paper [1] the assumed beam power was 4MW. We then were able to show that by placing the Korean detector at 1° degree off-axis, we are able to achieve a similar sensitivity with only 1.66 MW. But given the large value of θ_{13}, we are now presenting the potential of the T2KK setup for a beam of 750 kW which is the design luminosity of the T2K experiment and will very likely be available in 2017 already.

In this study I present the T2KK potential for determining the mass hierarchy and CP violation in the lepton sector for two possible beam power (750 kW and 1.66 MW) and I compare it to the T2HK potential for the same beams.

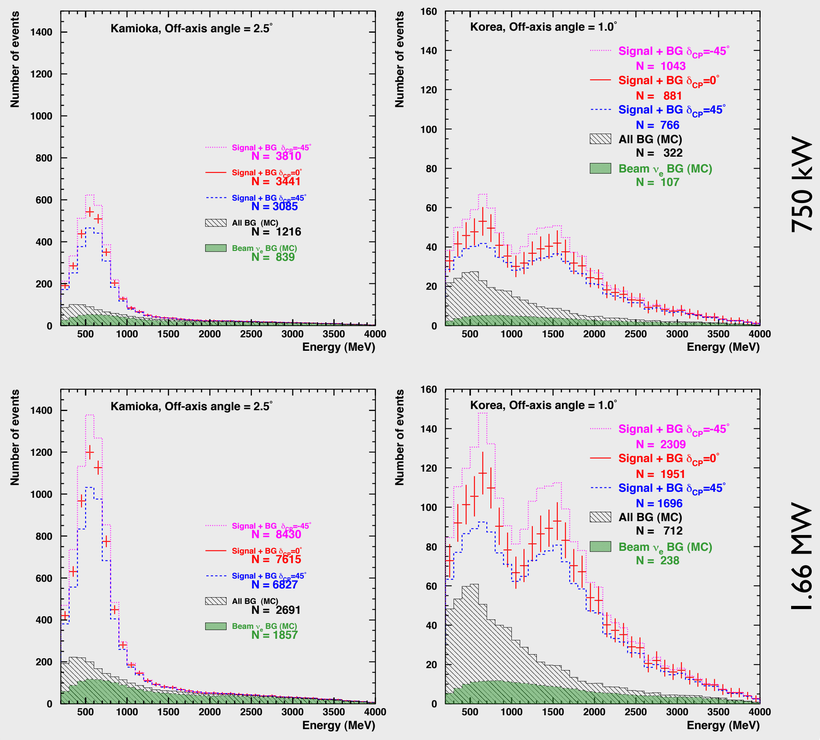


Specs

	T2HK	T2KK
Volume	0.56 Mton (FV)	2* 0.27 Mton (FV)
Baseline	295 km	295 km + 1050 km
Off-axis angle	2.5°	2.5° + 1°
Beam power	750 kW or 1.66 MW	750 kW or 1.66 MW
Proton energy	40 GeV	40 GeV
Time	10^7 * 5 (sec) ν + 10^7 * 5 (sec) anti-ν	10^7 * 5 (sec) ν + 10^7 * 5 (sec) anti-ν
POT equivalent	1.17 x 10^{21} POT or 2.59 x 10^{21} POT	1.17 x 10^{21} POT or 2.59 x 10^{21} POT

Event spectra

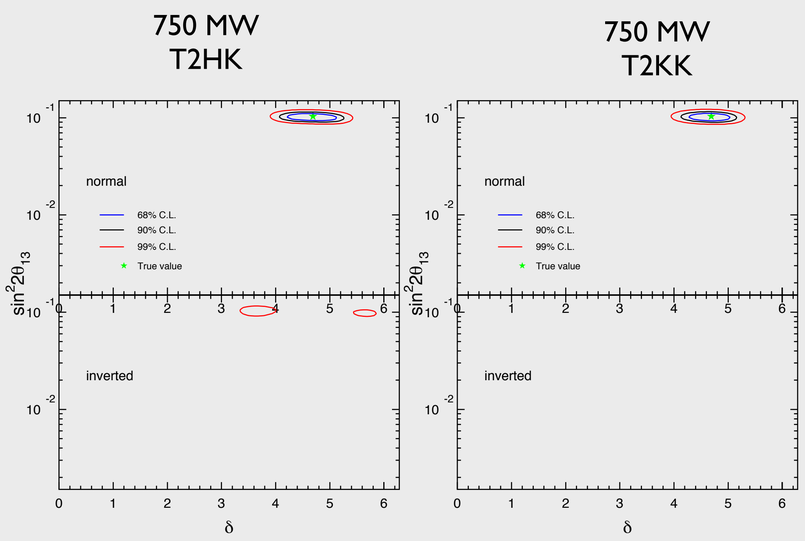
Two beam powers
I envisioned two possible beam powers for this study. In the first case (top plots) I used 750kW which is the design power of the T2K experiment. In the second (bottom plots) I used 1.66MW which was the power chosen in previous T2KK studies [3]. Note that for the sake of comparison I limited myself to one module of T2HK so all the plots are for a 0.27 MTon (FV) detector and sin² 2θ_{13}=0.1.



Degeneracies

Using the extra information given by the long baseline to Korea and the wider beam seen by the Korean detector, it is possible to determine both the mass hierarchy and the CP phase. It is a much harder task for one detector alone at a short baseline on a narrow-band beam because of the degeneracies.

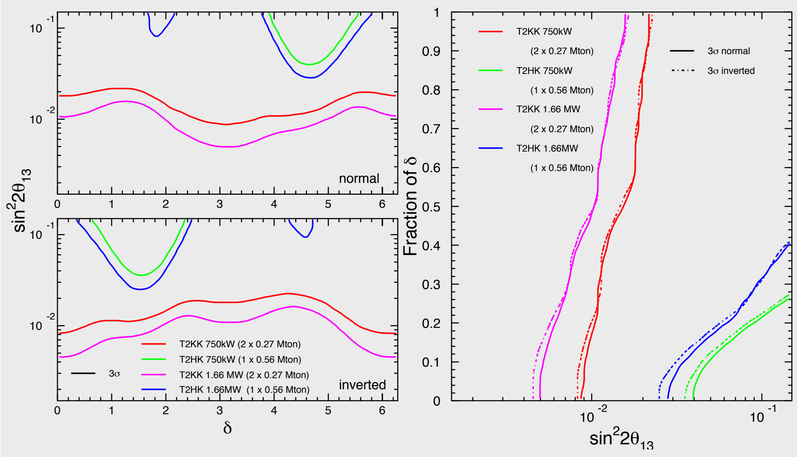
On the left plot, I show the contour at 68% C.L, 90 % and 99% for T2HK with a 750 kW beam, assuming sin² 2θ_{13} = 0.1, a CP phase of 270 degree and normal hierarchy. On the right, it is the same measurement for T2KK. As we can see the T2KK setup is able to remove all the degeneracies (ie there is no contour left except around the chosen true values) while for the T2HK setup, there are still degeneracies about the mass hierarchy and the value of the CP phase.



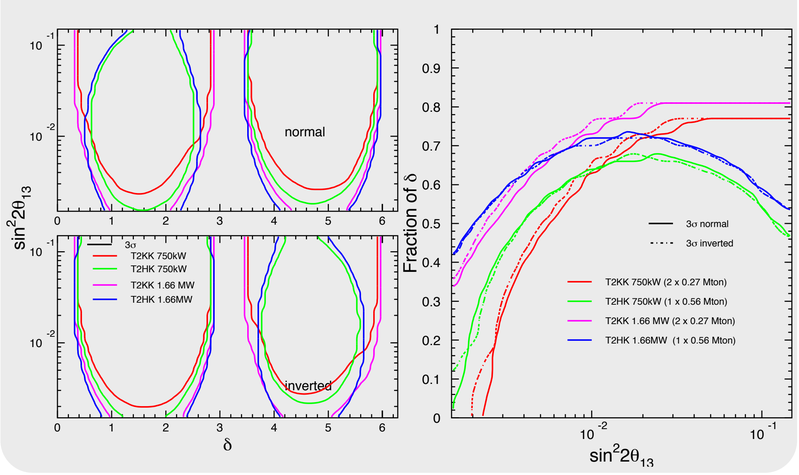
Sensitivity

Comparing setups and beam powers
Even if we now know that θ_{13} is large, it is still interesting to compare the sensitivity reach of each setups and for the two beam power proposed.

This first set of plots tells us that for sin² 2θ_{13}=0.1, the T2KK setup can easily solve the mass hierarchy for any values of the CP phase and this still true with a 750 kW beam.



For CP violation, even though T2HK is better for small values of θ_{13}, at the current measured value, T2KK gives an 80% coverage while T2HK only provides 50% coverage for finding CP violation.



Conclusions

Given the large value of θ_{13}, the T2KK setup with a 750 kW beam is able to solve the mass hierarchy for any values of the CP phase and tells us if there is CP violation in the lepton sector for 80% of the values of the CP phase.

It is important to notice that T2HK alone cannot achieve this as the longer baseline to Korea is needed to solve the mass hierarchy and therefore solve the degeneracies of the parameter space.

References

1. "*Resolving Neutrino Mass Hierarchy and CP Degeneracy by Two Identical Detectors with Different Baselines*" arXiv:hep-ph/0504026v2
2. "*The Hyper-Kamiokande experiment (LOI)*" arXiv:1109.3262v1 [hep-ex]
3. "*Further study of neutrino oscillation with two detectors in Kamioka and Korea*" arXiv:1001.5165v1 [hep-ph]
4. "*Observation of electron-antineutrino disappearance at Daya Bay*" arXiv: 1203.1669v2 [hep-ex]
5. "*Observation of Reactor Electron Antineutrino Disappearance in the RENO Experiment*" arXiv:1204.0626v2 [hep-ex]