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The Analysis of *Upward Through Going Muon Events* and *Upward Stopping Muon Events* by the Computer Simulation

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Abstract: Compared with the analysis of *Fully Contained Events* and *Partially Contained Events* occurring inside the detector in Super-Kamiokande for the investigation of the neutrino oscillation, the analysis of *the Upward Stopping Muon Events* and *Upward Through Going Muon Events* occurring outside the detector is much easier, although the quality of the experimental data is inferior to the former. We analyze neutrino events occurring outside the detector by the computer numerical experiment. As the result of it, we find that our "experimental" data are neither agree with the null oscillation nor agree with oscillation.

Introduction

Super-Kamiokande collaboration -abbreviated as SK simply, hereafter,– have obtained $\sin^2 2\theta > 0.92$ and $1.5\times10^{-3}eV^2 < \Delta m^2 < 3.4\times10^{-3}eV^2$ at 90 % confidential level for neutrino oscillation parameters through the analysis of the topologically different four types of the events, namely, *Fully Contained Events* and *Partially Contained Events* which occur inside the detector, and *Upward Through Going Muon Events* and *Stopping Muon Events* which occur outside the detector, without paying attention so seriously to the difference on the level of uncertainty in experimental accuracies originating from the topologically different events[1].
In previous paper[2], we explain our idea on the computer numerical experiment. Therefore, we immediately touch the core on the dispute issue around the existence on the neutrino oscillation.

The energy spectra for incident neutrino

We utilize the same energy spectrum incident neutrino as SK adopt[3]. In Figure 1, we show the interaction energy spectrum of the incident neutrinos without oscillation which are obtained from the Honda spectrum[3] through several procedures[4]. In Figure 2, we give the corresponding spectrum under SK parameters on neutrino oscillation. It is clear from the figure that the oscillatory nature appear strongly in the energy region from 1 GeV to several ten GeV where *Fully Contained Events* and *Partially Contained Events* participate in and there are almost no oscillatory in the energy region from several hundreds GeV to 10000 GeV, where neutrino events occurring outside detector, such as, *Upward Through Going Muon Events* and *Stopping Muon Events*, participate in. Therefore, it is rather very difficult to find the evidence for neutrino oscillation in this energy region, even if exist, if we assume the neutrino oscillation parameters obtained by SK in the examination. However, SK claim to find neutrino oscillation in this energy region (See, [1]).

Zenith Angle Distribution for Upward Through Going Muon Events and Stopping Muon Events

Our computer numerical experiment starts from the sampling of energy from the interaction energy spectrum without and with neutrino oscillation where SK parameters are adopted. The sampled muon neutrino is pursued in the stochastic way by

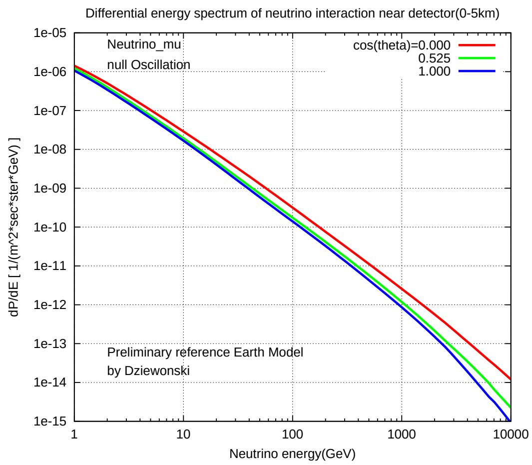

Figure 1: The interaction energy spectrum without neutrino oscillation

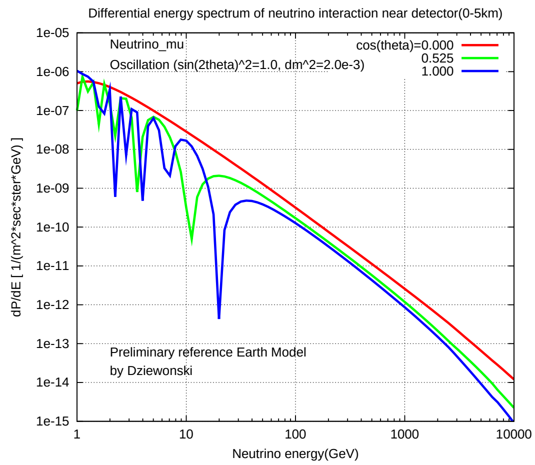

Figure 2: The interaction energy spectrum with neutrino oscillation

exact Monte Carlo Method where the effects from direct electron pair production, bremsstrahlung and nuclear interaction are correctly taken into account. In Figure 3, we compare the experimental data by SK with corresponding our computer numerical results for both with neutrino oscillation and without neutrino oscillation in the case of Upward Through Going Muon Events for the same 1645.9 live days. From the figure, we could not conclude that the experimental data agree with null oscillation or with oscillation. Namely, we could say that 1645.9 live days does not give enough statistics for drawing definite conclusion on the neutrino oscillation under SK neutrino oscillation parameters even if they really exist, because the statistical fluctuation from the average values are not small. If we compare our results with oscillation to our results without oscillation in the figure, we could find the event number with oscillation is larger than that without oscillation in the three bins $(0.0 \sim -0.1)$,$(-0.1 \sim -0.2)$ and $(-0.9 \sim -1.0)$. Such phenomena comes from the statistical fluctuation. In Figure 4, we give corresponding results for 164590 days, one hundred times of the SK real live days. Now, we understand from the figure that our results with oscillation is always smaller than that without oscillation which result in larger statistics. Also, comparing Figure 3 with Figure 4, we understand that the difference between that with oscillation and that without oscillation decrease, as the event number increase by one hundred times. In Figure 4, we add, on purpose, the SK experimental data for 1645.9 live days, together with our data for 164590 live days. From the comparison between SK results for 1645.9 live days and our result for 164590 live days, we could not conclude directly that SK experimental data rather agree with our results with oscillation, because statistics of both results is quite different from each other and we are not allowed to compare them directly neglecting the difference in their statistics. Comparing the smoothness of the histogram in Figure 3 with these in Figure 4, we could conclude that the average values of the zenith angle distributions attain at sufficiently at the "true" ones. In other words, SK live days does not give enough statistics to draw clear cut conclusion under SK neutrino oscillation parameters. It is natural to think that *Upward Stopping Muon Events* are much influenced by fluctuation, because the effect of stopping in the detector by chance. In Figure 5, we compare the SK experimental data with our data with oscillation and without oscillation for *Upward Stopping Muon Events* for 1645.9 live days. From the figure, also, we could not conclude that SK experimental data agree with either our data with oscillation or that without oscillation. In the figure, it should be noticed that the number of the neutrino events with oscillation is larger than that without oscillation due to fluctuation effect for $\cos\theta = -0.05(0.0 \sim -0.1)$. In Figure 6, we give our results with oscillation and without oscillation

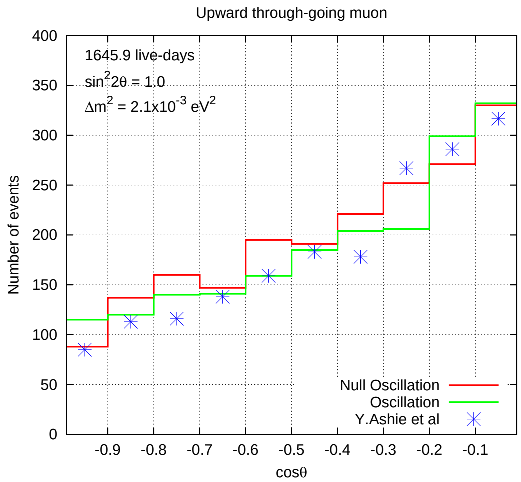

Figure 3: Zenith angle distribution for the Upward Through Going Muon Events for 1645.9 live days

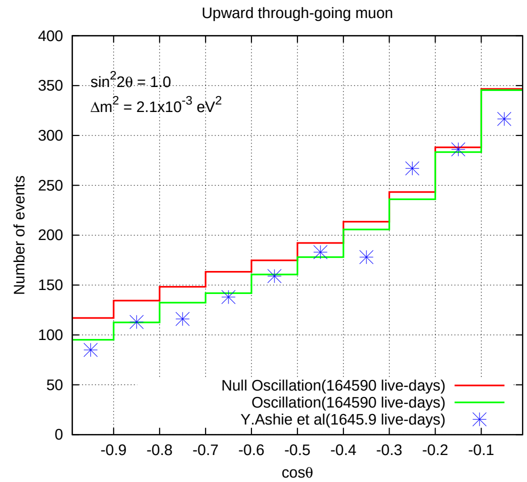

Figure 4: Our zenith angle distribution for the Upward Through Going Muon Events for 164590 live days

for 164590 live days together with SK experimental data which should not be allowed to be compared with our data due to big difference in statistics. Compared Figure 6 with Figure 5, we understand that the difference between quantity with oscillation and that without oscillation in Figure 6 decrease compared with that in Figure 5 and both histograms become smooth compared with those in Figure 5, which is evidence that "average value" at ideal average value. Here, we compare SK Monte Carlo with our Monte Carlo for the case without oscillation. For the moment, assuming that the SK Monte Carlo results for 100 live years attain at true average value as our results for 450 live years does, we compare SK results for 100 live years for *Upward Through Going Muon Events* and our results for 450 live years for the same events which is shown in Figure 7. In Figure 8, we give the same relation for *Stopping Muon Events.* It is understood from the figures that (1) SK Monte Carlo results lacks in smoothness which is expected from large sampled results and (2) SK results are smaller than our result for *Upward Through Going Muon Events* while SK results are larger our results for *Stopping Muon events*.

Conclusion

It is impossible for us to draw positive evidence on the neutrino oscillation from the analysis for *Upward Through Going Muon Events* and *Stopping Muon Events*, if one assume neutrino oscillation parameters obtained by SK.

References

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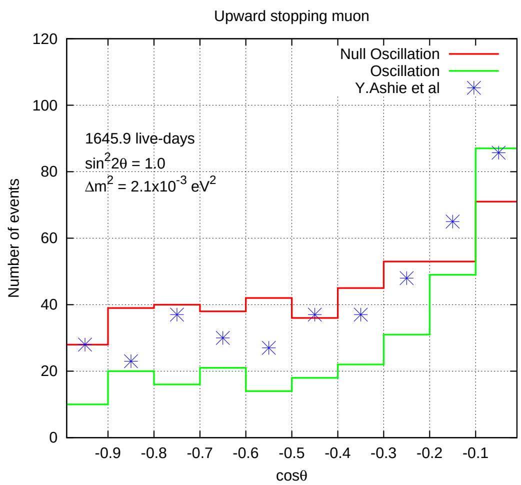

Figure 5: Zenith angle distribution for *Upward Stopping Muon events* for 1645.9 live days

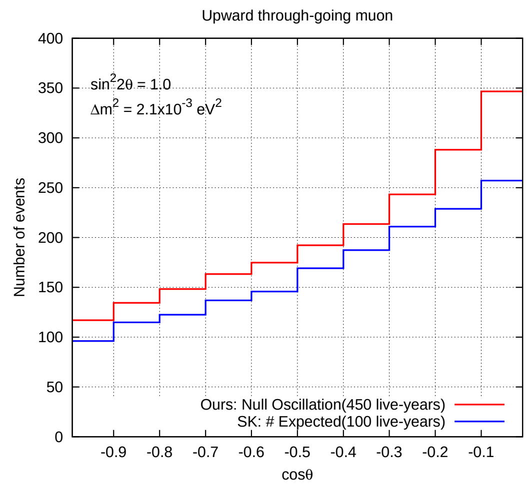

Figure 7: Comparison between SK Monte Carlo results for 100 live years and our results for 450 live years for *Upward Through Going Muon Events* in the case of null oscillation

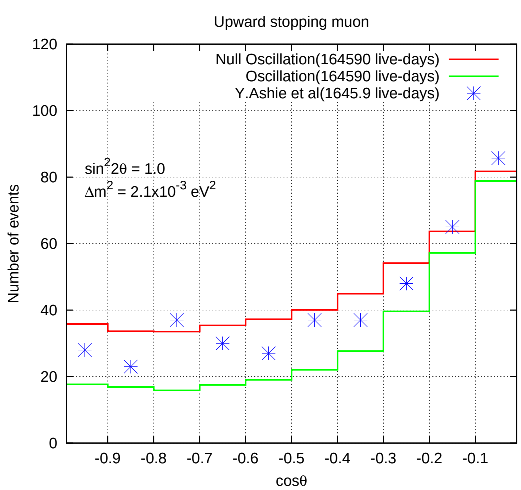

Figure 6: Our zenith angle distribution for *Upward Stopping Muon events* for 164590 live days

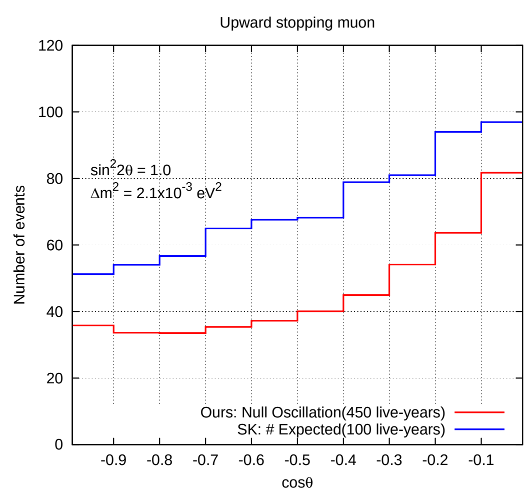

Figure 8: Comparison between SK Monte Carlo results for 100 live years and our results for 450 live years for *Stopping Muon events* in the case of null oscillation