Discrimination of Muon Neutrino from Electron Neutrino in the Virtual Super-Kamiokande Detector

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Abstract

We have constructed a Virtual Super-Kamiokande in the computer. We have generated muon events and electron events for discrimination between muon and electron. We have derived own estimators for the discimination. We have compared our results with those by Super-Kamiokande(SK, hereafter). We have concluded that the estimator by SK has some ambiguities essentially and that the clear discrimination between electron and muon by the SK seems to be doubtful.

1. Introduction

The strong assertion that Super-Kamiokande (SK, hereafter) has found neutrino oscillation between ν_μ and ν_τ is essentially based on the complete discrimination between electron and muon by KEK proton synchrotron[1].

However, in our opinion, the discrimination procedure of the muon from the electron adopted by SK should be carefully examined for the following reasons: 1. It absolutely lacks the sense of fluctuations in the physical processes which produce the Cherenkov light. 2. The physical processes producing Cherenkov light are approximated by point-like models, while the real ones have some dimensions, at least longitudinal ones. For example, shower length amounts to about 4 m for 1 GeV electron. The point-like approximation used by the SK seems to be an inadequate oversimplification. 3. The SK utilize exactly the same fluctuation estimate for both muon and electron in discrimination criterion, which is expressed in average quantities. This distorts the difference in angular structure of the Cherenkov light between muon and electron. As a matter of fact, the physical fluctuations of the real phenomena(e-shower, my-track) should appear in the criterion.

For these reasons, we constructed a new discrimination procedure which is based the Monte Carlo simulation, taking into account fluctuation effect in-

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Table 1.

Angles	radius				(m)
(degree)	10.00	12.59	16.90	20.00	25.00
05	1.5809	1.2197	0.8445	0.6772	0.5007
10	1.5644	1.2142	0.8445	0.6777	0.5015
20	1.4988	1.1903	0.8445	0.6829	0.5096
30	1.4136	1.1472	0.8445	0.6947	0.5268
40	1.8275	1.2890	0.8445	0.6702	0.4977
42	2.2527	1.4400	0.8445	0.6319	0.4360
50	2.1585	1.4171	0.8445	0.6332	0.4354
60	2.1090	1.4013	0.8445	0.6375	0.4420
70	2.1006	1.3970	0.8445	0.6377	0.4426
80	2.1050	1.3979	0.8445	0.6365	0.4415
90	2.1073	1.4019	0.8445	0.6375	0.4418

evitably arisen in physical processes which produce the Cherenkov light. We simulate every physical event in a virtual SK laboratory in our computer adequate assumptions with the use of GEANT3-21. For the sake of simplicity, in present paper, we limited our discussion to the Cherenkov light only, not mentioning the photoelectrons which are produced by the Cherenkov light.

2. Discussion and Conclusion

First, we simulate the physical processes for the Cherenkov light asexactly as possible using GEAT 3-21., and develop new mean angular strucuture functions for the Cherenkov light for pattern recognition of the Cherenkov light due to both muon and electron. Second, we derive the relative fluctuation functions for the Cherenkov light distribution which are critical for the constructing an estimator for particle identification. Our approach includes: Approach 1.Definition of the mean total longitudinal size of muon-track/e-shower as the length including 99.5% of mean total number of Cherenkov photon emitted; Approach 2. Division of this length into a number of equal segments (the number of which depends on the particle type and energy and the required accuracy of image presentation.; Approach 3. Definition of the mean angular distribution and its relative fluctuation for each segment I, which means that we finally have approximations for the mean angular distributions and their relative fluctuations as functions of radiation angle, and water layer thickness, t.

They introduce the point like approximation to estimate amount of direct Cherenkov light in the electron like event. We calculate them in an exact way without any approximation. Table 1 shows the ratio of the amount of the

Cherenkov light from electron showers under point-like approximation to corresponding ones under no approximation. The primary energy of electron is 1GeV and sampling number for calculation is 10000.

We give the mean angular structure function for 0.5 GeV electron contributed from the first segment in Figure 1, and the corresponding one for 0.5 GeV muon in Figure 2, respectively. Note that the shapes of the functions are different in both electron and muon, reflecting from the difference of collectively Cherenkov light generation, while SK assumes the same shape functions in both electron and muon. We give relative fluctuation angular structure function for 0.5 Gev electron in Figure 3 and the corresponding one for 0.5 GeV muon in Figure 4. Note that big difference in the relative fluctuation between electron and muon. SK never consider such kind of fluctuation in their discrimination procedure.

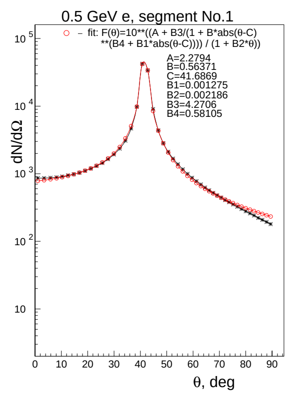

Fig.1

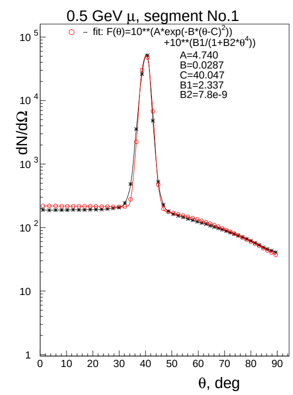

Fig.2

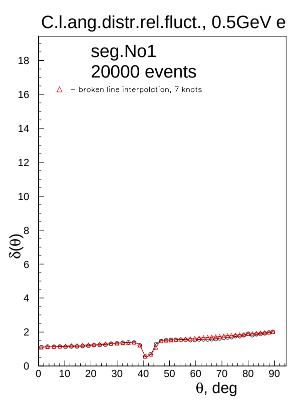

Fig.3

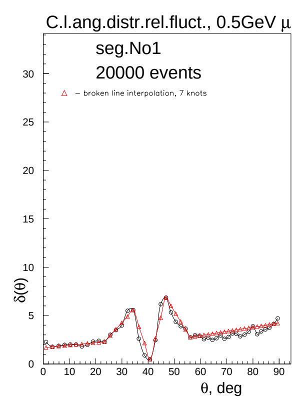

Fig.4

In Figure 5, we show clear separation between electron like events and muon like events in our approach. Figure 5 the qel-qmu distribution for simulated events for 300 MeV electrons and 500 MeV muons in the SK detector. The notation “300*0.3 GeV e” denotes the result for 300 MeV electrons from 300

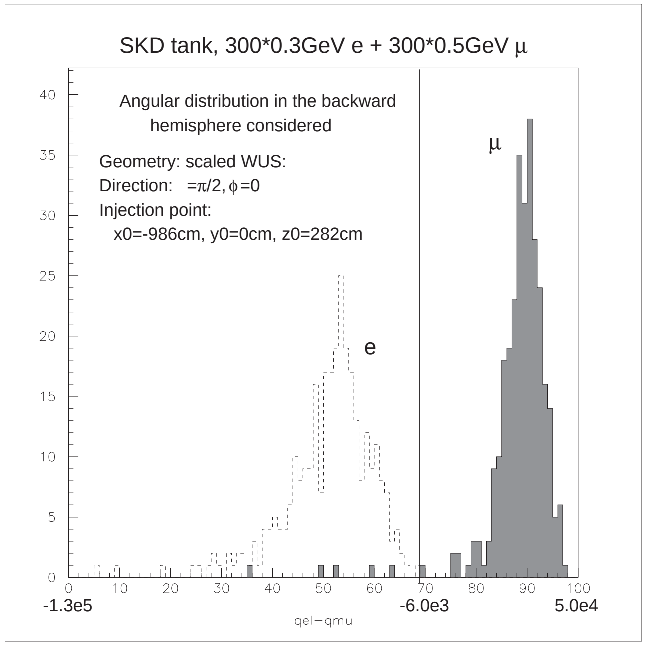

Fig.5

simulations. Note that the beautiful separation give lower limit. The real one is not so clear, because we never consider factors which surely invite ambiguities into real results, photoelectrons and scattered Cherenkov light.

3. References

1. Kasuga S. et al. 1996, Phys. Lett B, 374, 238