The Design Study for the Hyper Baikal Detector(HBD) in lake Baikal for Extremely High Energy Neutrino Astrophysics - Strategy and the present purpose

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Abstract

Neutrino events are classified into [Fully Contained Events], [Partially Contained Events], [Stopping Events] and [Upward Through Going Events] related to the detector. We have forcused on [Fully Contained Events] and discussed accuracies for energy determination, the vertexpoint and direction for electron neutrino events of 1 TeV.

1. Introduction

Our final goal is to carry a design study for extremely high energy neutrino astronomy above 10^{21} eV, the observed highest energy by the extensive air shower

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apparatus, beyond the scale of 1km^3 detector in lake Baikal[1]. For realization of such fantastic project, we must solve following two technically difficult problems, one in the hardware and other in the software. If we stick to detect extremely high energy neutrino optically, we are absolutely requested to develop new photon detector instead of the PMT, possibly, the photon detector based on the semi-conductor technique. As for the software problem, we must develop facilities for software programs by which we could carry out design study for the fantastic project elaborately. The most important problems to be solved for the experimental neutrino astrophysics are to estimate accuracies for energy determination of the neutrino event and its interaction point and its direction. From the topology of the physical neutrino events relating to the detector, they are classified as [Fully Contained Events], [Partially Contained Events] , [Stopping Events] and [Passing Through Events] . The first two are events which are produced inside the detector and the last two are events which are produced outside the detector. [Fully Contained Events] are the least of ambiguous compared with other three different categories for more possible clear interpretation of the events concerned.

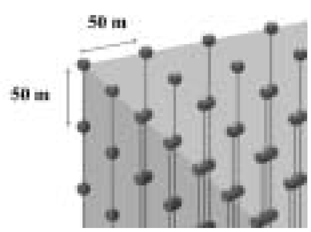

Fig.1-1

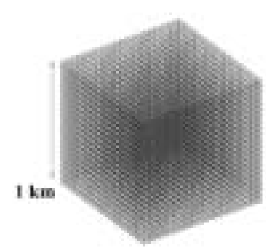

Fig.1-2

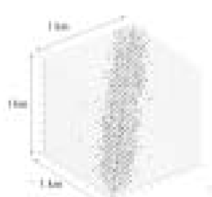

Fig.2

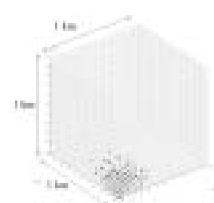

Fig.3

2. Results

Our tentative apparatus is given in Figure 1. We simulate Cherenkov light due to muon of primary energy 500 GeV exactly by using the GEANT 3-21. The result is shown in Figure 2. The muon runs along the direction of the diagonal of the 1 kim^3 detector. As easily imagined from the figure , muon events with bigger than 500 GeV could not be [Fully Contained Events], even if we construct 1 km^3 detector. Namely, we could not expect precise experiment on the muon at energies higher 500 GeV (possibly 300 GeV). In Figure 3, we show spatial development of the Cherenkov light due to primary electron of 10 TeV (electron shower). Although the electron shower are affected by the LPM effect as the energy of primary electron increase so that the electron showers concerned are extended compared with the BH showers, we could measure the electron showers with primary energy less than 10^{20} eV as [Fully Contained Events]. In our present paper, we are interested exclusively in [Fully Contained Events] in the detector and limit our interest in the electron events, not muon event. Electron (Electron shower) events with 1 TeV are randomly simulate within 120 m^3 whose center is the same as 1km^3 detector and measure the detected energy. If the electron shower maxima of the electron events locate accidentally near the photon detector, the electron events concerned produce larger Cherenkov light than what are far from photon detectors, which produce fluctuation in the detected Cherenkov light. These electron events are exactly [Fully contained Event] so that the emitted Cherenkov light of these electron events are same, because of law of energy conservation. However, their detected Cherenkov light has wider fluctuation.

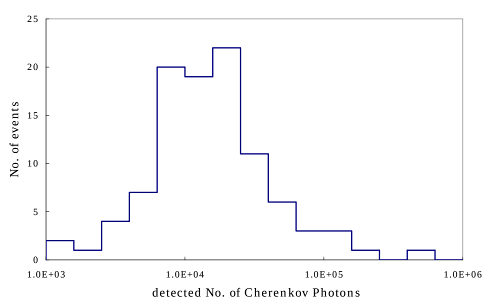

Fig.4

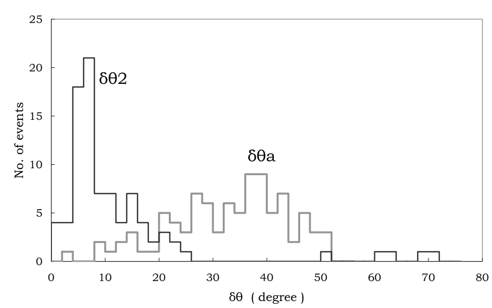

Fig.5

In Figure 4, we give the distribution of the detected Cherenkov light due to electron events. The sampling number is 100. The average of the detected Cherenkov light 2.8×10^4 and its standard deviation is 5.63×10^4. Roughly speaking, uncertainty of the energy estimation to 1 Tev eV is 200%. In Figure 5, we give uncertainties in the direction of the electron neutrino interaction. The $\delta\theta$a are obtained as follows: the three photon detectors (typically, PMT) are selected in which the first three fastest times for the Cherenkov light are recorded and the average location of these photon detectors concerned is approximated as the starting point of the electron event. Next, the three photon detector are also selected in which the last three latest times for the Cherenkov light are recorded. The average location of these photon detectors is approximated as the end point of the electron point. The line which connects the starting point with the end point is regarded as the direction for advance of the electron event. From the difference between the direction thus obtained and the real direction of the electron event, we obtain uncertainty in angles. The $\delta\theta 2$ are obtained from the pattern recognition procedure , taking into account the detailed structure of the Cherenkov cone. The average uncertainty in the direction of the electron events is 12.4 degree and the standard deviation is 13.4 degree in $\delta\theta 2$ procedure, while the uncertainty in the direction of the electron events is 33.0 degree and the standard deviation is 10.7 degree in the $\delta\theta$a procedure. It is concluded from figure 5 that we need the concept of pattern recognition for the Cherenkov cone produced by the electron shower to seek more reliable direction. In Figure 6, we give the uncertainty in the vertex position of electron events. The δr2 procedure is essentially same as the $\delta\theta 2$. In the δra procedure, we utilize the first fastest time information only. The average uncertainty in the vertex points is 23.4 meter and the standard deviation is 11.7 meter in the δr2 procedure, while the average uncertainty in the vertex points is 30.8 meter and the standard deviation is 8.4 meter in the δra procedure. It is also concluded from the figure that we could give more precise uncertainty in the vertex point , taking into the pattern recognition for the Cherenkov cone.

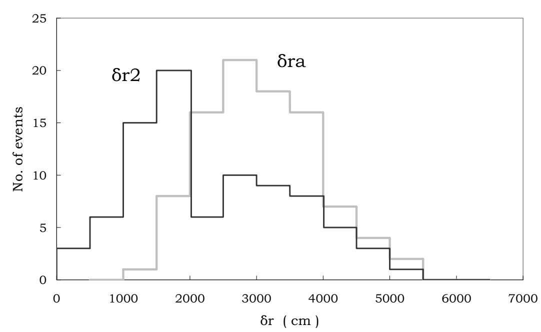

Fig.6

3. References

1. Anokhina A. et al. 2002, 18th ELRS, HE44p