Background Events on the Kamiokande Observation of Solar Neutrino Flux

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Abstract

The main background events seem to be caused by the low enegy atmospheric neutrinos. However, the events number can not interpleted by the expected numbers from the relevant cross sections $\nu_e + e^- \rightarrow \nu_e + e^-$ and $\overline{\nu}_e + p \rightarrow n + e^-$.
We show the number of background to be consistent with contribution of neutrons generated in nuclear showers initiated by muons underground, following to Ryazhskaya's estimation.

Key words: PACS number(s): solar neutrinos, neutron flux underground, atmospheric neutrino flux.

1 Introduction

The Kamiokande detector consists of an inner main detector and an outer anti-counter, located at 2,700 mwe underground. The fiducial mass for the ^{8}B neutrino measurement is 680 ton. The group has detected electrons recoiled on the scattering of 8^B solar neutrinos which form a $cos\ \theta_{sun}$ distrbution including background. The solar neutrino events may concentrate near the direction of the sun. Accordingly we can evaluate the number of background events by counting directly number of events in the region of $cos\ \theta_{sun}$ distrbution $\leq$. From the figure of measured $cos\ \theta_{sun}$ distrbutions in Hirata et al [1], thus, the observed number of background can be counted as $3,015 \pm 72$ in the 590 live-detector days. From the most recent report in 1966 live-detector days of Suzuki [2], the observed number of background can be counted as $8,311 \pm 100$. These errors attribute to the effect of scattered measured data. Using the trigger efficiency curve against total electron energy of Hirate et al, we can estimate 82.4% efficiency for $E_e \geq 7$ MeV and 86.5% for $E_e \geq 7.5$ MeV. If the trigger efficiency is necessary to apply even the background events, the corrected numbers are $3,486 \pm 83$ in Hirata et al and $10,086 \pm 120$ in Suzuki.

2 Origin of background events

With the seemingly thinking, the main background events seem to be caused by the low energy atmospheric neutrinos; $\nu_e + e^- \rightarrow \nu_e + e^-$ and $\overline{\nu}_e + p \rightarrow n + e^-$. The relevant cross sections are [3];

$$\sigma(\nu_e - e^-) = 0.94 \times 10^{-43} cm^2 (E_\nu / 10MeV),$$
$$\sigma(\overline{\nu}_e - p) = 0.89 \times 10^{-41} cm^2 (E_e / 10MeV)^2.$$

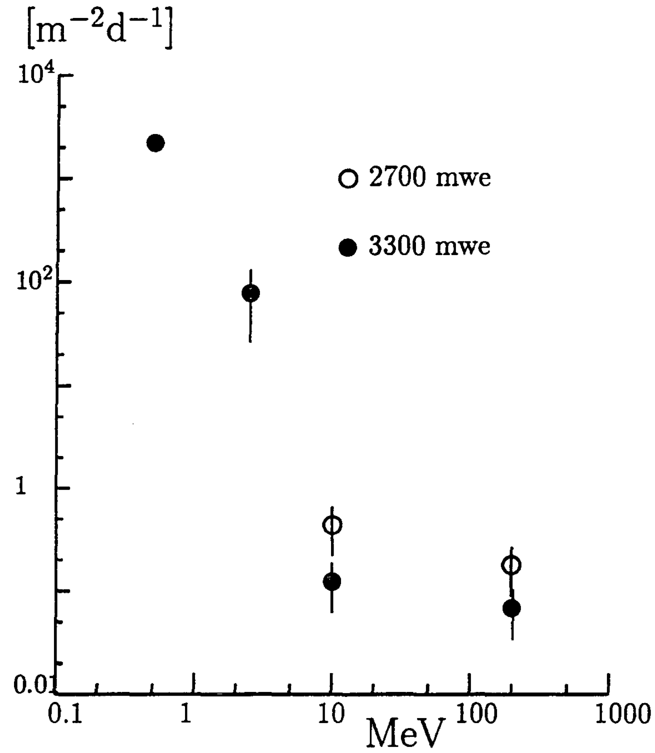

Figure 1: Neutron flux at underground depths of 2700 mwe and 3300 mwe.

The expected ratio of events, $R = \phi(\nu_e)n_e\sigma(\nu_e - e^-)/\phi(\overline{\nu}_e)n_p\sigma(\overline{\nu}_e - p)$, is in the range of $R \simeq 0.06 - 0.12(10MeV/E_\nu)$ where ϕ is the integrated flux of ν_e's (or $\overline{\nu}_e'$s), n_e is the number density of electrons, and n_p is the number density of free protons. Some calculations [4] have estimated the atmospheric neutrino spectrum, although the intesities less than 1 Gev are ambigious. The flux intesities of the most recent calculation obtained by Honda and Kasahara [4] is middle between the intesity values of Gaiser et al and of Bugaev et al [4]. So, using their predicted fluxes from 7.5 MeV to 15 MeV of ^{8}B neutrinos and the above cross sections, we estimated the expected number of 5×10^{-4} events from the scattering process and 8×10^{-3} events from the capture process by the Kamiokande detector in 590 live-detector days and 2×10^{-3} events from the scattering process and 4×10^{-2} events from the capture process in 1996 live-detector days. Even if contributions of the neutrinos in some higher energy region are taken into consideration, the observed background number cannot be interpreted by the intesity of atmospheric neutrinos. The flux value of Gaiser et al is only about 2 times larger. Further, we must consider there are no sources of neutrinos except the atmospheric neutrinos and the solar neutrinos. Accordingly the 4π solid angle anticounter surrounding the main detector does not protect completely any other events to trigger the main detector. What process contributes to the backgrounds? Some studies [5], [6], [7] have already shown that contribution of cascade neutrons, generated in nuclear showers initiated by muons, pro-

Table 1: Fast neutron flux in various energy region of underground measurements and estimations.

Enegy region	*Neutron flux*		Reference
(MeV)	3300 mwe	2700 mwe	
$0.5 < E < 10$	2212 ± 233 (m^{-2}d^{-1})		[5]
> 2.5	78 ± 52 (m^{-2}d^{-1})		[6]
> 10	$45 \pm (50\%)$ (m^{-2}y^{-1})	$160 \pm (50\%)$ (m^{-2}y^{-1})	[7]
> 200	$25 \pm (50\%)$ (m^{-2}y^{-1})	$65 \pm (50\%)$ (m^{-2}y^{-1})	[7]

duce strong background due to their interactions with the underground detector nuclei. Their neutron flux values at 2700 mwe (Kamioka) and 3300 mwe (Gran Sasso) are given in Table 3. The values with larger than 10 MeV are evaluated from their measurement at the depth of 570 mwe [8]. The values shown in Fig. 4, obtained by different investigators for different energy region, do not seem to contradict among them.

Following Ryazhskaya's calculation [7], the background events (the threshold energy > 7.5 MeV) caused by β decay of the nuclei ^{16}N appearing in reaction $^{16}O(n,p)^{16}N$ to be observed by the Kamiokande detector are estimated to be 2,430 $\sim$ 3,240 in the 590 live-detector days and 8,210 $\sim$ 10,950 in the 1996 live-detector days. These values are consistent with the respective numbers of background events with $3,015 \pm 72$ (the corrected $3,486 \pm 83$) in Hirata et al and $8,311 \pm 100$ (the corrected $10,086 \pm 120$) in Suzuki. Also the discussion with the energy spectrum of the observed events in Hirata et al [1] has shown that energy spectral shapes of the solar events and the background events are the same with a power index of about -0.5. The neutron energy spectrum up tp 150 MeV has been observed with $E_n^{-(0.5\sim0.6)}dE_n$ [8], whereas the electron energy spectrum produced from the atmospheric neutrinos for the energy region of several MeV to 20 MeV has almost flat index of the power form. The agreement of the index value of background with that of neutron spectrum may emphasize the main contribution of neutrons produced by muons to the background events. This gives another important problem for measurements by the water Cherenkov detector. According to this contribution, the neutron background can give rise significant effects to the deficit measurement and to the up-down going difference of the atmospheric electron-neutrino flux which gives an evidence of neutrino oscillations. As seen from this discussion, also, the ^{8}B neutrinos and the neutron background events within the direction of the sun are impossible to be distinguished with each other. This shows that the Kamiokande experiment is not a real time experiment at the exact sense and still insufficient with the 4π solid-angle anti counter system. Accordingly researching for short time variation of ^{8}B neutrinos are difficult. Although the previous Kamiokande report [1], [9] indicated the existence of variation between the day-time and night-time fluxes of the solar neutrinos, the difference disappears in the Kamiokande latest report [2]. Also the experimental plan to reseach for neutrino oscillations using the accelerator neutrino beam by the Super Kamiokande detector should be carefully designed for removing the neutron effect.

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