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Low Energy ^{8}B Solar Neutrinos with the Wideband Intelligent Trigger at Super-Kamiokande

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Low Energy ^8B Solar Neutrinos with the Wideband Intelligent Trigger at Super-Kamiokande

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Abstract. The water Cherenkov experiment Super-Kamiokande (SK) has accumulated a sample of $\sim$ 90k solar neutrino data in the past two decades. Currently, the detector measures recoil electrons from solar ^8B neutrino-electron scattering above a kinetic energy of $\sim$ 3.5 MeV, limited by the capacity of the software trigger, although electrons as low as 2.5 MeV can be reconstructed. The next frontier for the low energy program at Super-K is the current operation of the Wideband Intelligent Trigger (WIT) to push the trigger threshold to the event reconstruction limit of 2.5 MeV. This opens up the possibility to explore the lower energy edge of the Mikheyev-Smirnov-Wolfenstein (MSW) effect in the sun. In this work we will present the prelimiary analysis of the accumlated WIT data taken so far as well as future prospects.

1. Introduction

The Super-Kamiokande experiment [1] has recorded an unprecedented amount of solar neutrinos for the past 20 years [2]. The SK experiment detects solar neutrinos by the way of elastic scattering of neutrinos on electrons in the 50 kton pure water target (with a nominal fudicial volume of 22.5 ktons). The detector utilizes the 11,129 photo-multiplier tubes (PMTs) designed to detect cerenkov light with about 6 detected photo-electrons per MeV. The PMTs are read out by front-electronics named the QBEEs (QTC-based electronics with Ethernet). The QBEEs were newly implemented in phase IV of the detector (September 2008) enabling the integration of the recorded charge and the recording of the time of every PMT signal. The output is then fed into a software-based trigger system where it searches for coincidences within 200 ns to trigger on an *event*.

The lowest energy threshold of such coincidence trigger is chosen to be 34 hits (referred to as Super Low Energy, SLE) with a trigger rate of 3.0-3.4 kHz. However, improvements in the temperature control of the water recirculation system resulted in less Radon background in the center and threshold of 31 hits. While the improved electronics were functional since the inception of phase IV of the experiment, a rudimentary sum of all software-recorded hits is performed in an analogous fashion to previous phases (I, II and III); instead of the utilization of the newer capabilities of the QBEE electronics. Hence, the construction and operation of the WIT system where online reconstruction of digitized time and charge is performed following by vertex reconstruction since fall of 2015 as shown in section 2.

With an energy threshold $\sim$ 2.5 MeV the SK detector is well suited for detecting distortions in the energy specturm resulting from the Mikheyev-Smirnov-Wolfenstein (MSW) effect [3] in the sun for ^8B solar neutrinos as shown in Figures 1 and 2.

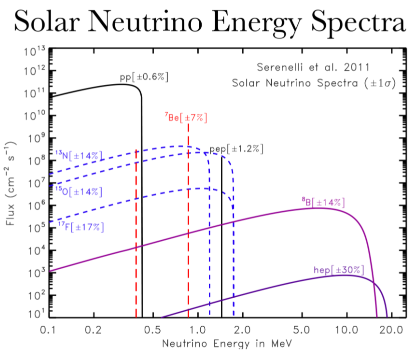

Figure 1. The energy region for the B^8 solar neutrino spectra.

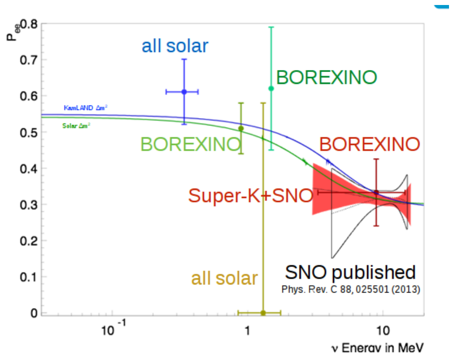

Figure 2. Electron survival probability showing the MSW effect and the expected sensitivity of different solar neutrino experiments to such effect.

2. The WIT Trigger System

The WIT system is designed to extend the SLE trigger lower by an extra 1 MeV. It consists of a cluster of high performance online computers designed to reconstruct and preform vertex reconstruction of recorded hits in real time. The processed data is then saved on tape for later off-line processing.

The fast online vertex reconstruction proceeds by recording coincidences (above the expected dark noise rate) of the PMT hits in a 5 ns time window based on the likelihood of the arrival times of the hits, with the arrival time being corrected for time taken by the emitted cerenkov light to reach that specific PMT.

Finally, reconstructed events that are sufficiently away from the detector walls (i.e. not being a radioactive ambient backgrounds) are selected as the good events.

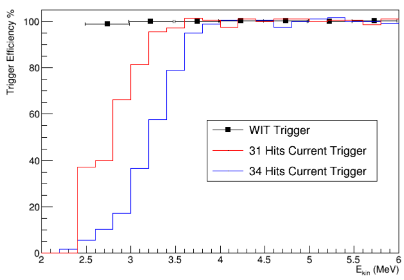

Figure 3. The Wideband Intelligent Trigger (WIT) efficiencies compared to SLE 34 and 31 hit efficiencies.

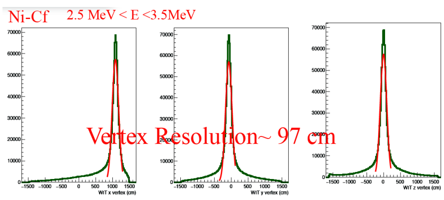

Figure 4. Reconstructed vertex resolution estimated using the Ni-Cf calibration source.

2.1. Calibrations with WIT

The WIT efficiencies were evaluated using Ni-Cf calibration sources used as a 9.0 MeV gamma source by the capture of thermalized neutrons on Nickel. The resulting efficiencies are estimated to be $\sim$ 100% for the 3.0 MeV energy threshold as in Figure 3, the resolution of the vertex reconstruction is also shown in Figure 4.

2.2. WIT Monitoring and offline results

The continuous operation of the WIT system is achieved by monitoring tools implemented in the online system as part of the shift duties. The reconstructed vertex coordinates are monitored for WIT triggered and non-triggered events as shown in Figure 5. In Figure 6, the offline reconstructed vertices are shown. The vertice are selected with the following cuts:

- A tight fiducial volume cut chosen specifically for low energy bins.
- Removal of inward-going events by using the effective distance from the vertex to the PMT surface.
- A K-S test of the azimuthal symmetry and timing goodness of the vertex.

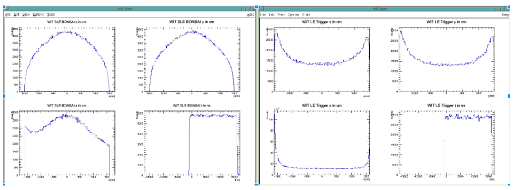

Figure 5. (Left) Online reconstructed vertex coordinates for WIT events. (Right) The same but for non-WIT triggered events.

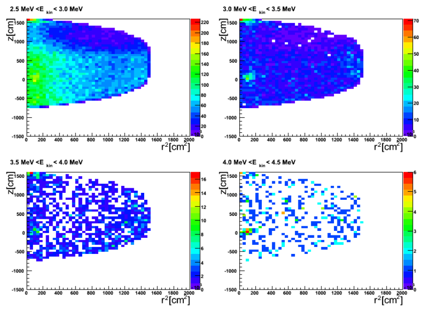

Figure 6. Distribution of reconstructed vertices (after quality cuts) for energy bins; 2.5 - 3.0 MeV, 3.0 - 3.5 MeV, 3.5 - 4.0 MeV and 4.0 - 4.5 MeV.

3. Summary and Future

The neutrino experiment Super-Kamiokande with the largest ever neutrino target has collected the largest sample of solar neutrino data, the next frontier in solar neutrino physics program is the newly commissioned WIT system. It extends the reach of the low energy solar neutrino program all the way down to 2.5 MeV electron kinetic energy. Such lowering of the energy threshold will allow the probe of the MSW effect predicted for the transition between vacumm and matter in the sun. Also, with the future refurbishment of the detector with Gadolinium-doped water, a lower threshold will allow Super-Kamiokande to observe the predicted Diffuse Supernova Neutrino Background (DSNB) with a higher efficiency, acquiring higher statistics for reactor neutrinos and the possibility of detection of the Si-burning stage of core collapse supernovae .

The WIT system has been continuously collecting data since the fall of last year with its efficiency evaluated using calibration sources, Ni-Cf. Currently, the WIT system is in the process of collecting more statistics that is sufficient for the observation of a solar signal and evaluating techniques for reduction of the backgrounds that might be dominate at the lowest energy bins.

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