Solar Neutrino Results from the Sudbury Neutrino Observatory

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Abstract

The Sudbury Neutrino Observatory (SNO) is an imaging water Cherenkov detector. It has detected solar neutrinos from the decay of ^{8}B via the charged current (CC) and neutral current (NC) reactions on deuterium and by the elastic scattering (ES) of electrons. While the CC reaction is exclusively sensitive to ν_e, the NC reaction is equally sensitive to all types of active neutrinos. In its first phase of running with pure D_2O the non-ν_e component of the NC flux was found to be greater than zero at the 5.3 σ level, providing strong evidence for ν_e flavor transformation. A global solar neutrino analysis in terms of matter-enhanced oscillations favors the Large Mixing Angle (LMA) solution to the solar neutrino problem. In the second phase NaCl has been added to the D_2O in order to increase the NC sensitivity. Data acquisition of the salt phase is nearly complete and first results on the NC measurement of this phase are expected to be presented at this conference. The third operational phase of SNO foresees the deployment of neutral current detectors (NCD) inside the D_2O volume and hence allows an independent measurement of the NC.

1. Introduction

The Sudbury Neutrino Observatory (SNO) detects ^{8}B solar neutrinos through the reactions:

$$\begin{array}{lll} \nu_e + \mathrm{d} & \rightarrow & \mathrm{p} + \mathrm{p} + \mathrm{e}^- \qquad \text{(CC)}, \\ \nu_x + \mathrm{d} & \rightarrow & \mathrm{p} + \mathrm{n} + \nu_x \qquad \text{(NC)}, \\ \nu_x + \mathrm{e}^- & \rightarrow & \nu_x + e^- \qquad \text{(ES)}. \end{array}$$

The charged current reaction (CC) is sensitive exclusively to electron-type neutrinos, while the neutral current reaction (NC) is equally sensitive to all active neutrino flavors ($x = e, \mu, \tau$). The elastic scattering reaction (ES) is sensitive to all flavors as well, but with reduced sensitivity to ν_μ and ν_τ. Sensitivity to these three reactions allows SNO to determine the electron and non-electron active neutrino components of the solar flux [3]. The CC and ES reaction results [1] as well

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as the NC results [2] have recently been presented. This note exhibits the analysis of the NC flux for the salt phase of SNO.

SNO [4] is a water Cherenkov detector located at a depth of 6010 m of water equivalent in the INCO, Ltd. Creighton mine near Sudbury, Ontario, Canada.

The detector uses ultra-pure heavy water contained in a transparent acrylic spherical shell 12 m in diameter to detect solar neutrinos. Cherenkov photons generated in the heavy water are detected by 9456 photomultiplier tubes (PMTs) mounted on a stainless steel geodesic sphere 17.8 m in diameter. The geodesic sphere is immersed in ultra-pure light water to provide shielding from radioactivity in both the PMT array and the cavity rock.

2. Data and Analysis

The data for the current salt phase analysis were recorded between July, 2001 and March, 2002. This represents a large fraction of the time for which NaCl was present in the D_2O volume. The principle analysis procedure is similar to that described in [2] but it contains important modifications related to the change in detector response which is a consequence of differences in detector configuration. PMT times and hit patterns were used to reconstruct event vertices and directions and to assign to each event a most probable kinetic energy, $T_{\rm eff}$. The total flux of active ^{8}B solar neutrinos with energies greater than 2.2 MeV (the NC reaction threshold) is measured with the NC signal (Cherenkov photons resulting from γ rays from neutron capture on chlorine and deuterium.) Neutron capture on chlorine can produce multiple gamma-rays resulting in different event topologies compared to events which originate from neutron capture on deuterium. A modified event isotropy calibration is applied to account for this effect. The analysis threshold is $T_{\rm eff} \geq 5$ MeV. Above this energy threshold, there are contributions from CC events in the D_2O, ES events in the D_2O and H_2O, capture of neutrons (both from the NC reaction and backgrounds), and low energy Cherenkov background events.

In order to reduce external backgrounds and systematic uncertainties associated with optics and event reconstruction near the acrylic vessel the fiducial volume was limited to within 550 cm from the detector center. The neutron response and systematic uncertainty was calibrated with a ^{252}Cf source. The salt increases the neutron detection efficiency by more than a factor of three compared to the pure D_2O phase. This is caused by the large neutron capture cross section on ^{35}Cl and the larger gamma-ray energy .

At the time of the deadline for these proceedings, updates on detector calibration and systematics, backgrounds for the salt phase and details of the analysis techniques are still being reviewed by the SNO collaboration. Results are expected to be available by the time of the conference.

3. Summary

The ability of the SNO detector to measure solar neutrinos is described. The presence of NaCl inside the sensitive detector volume significantly enhances the ability to measure the NC flux. NC flux results of the salt phase of SNO are expected to be available by the time of the conference.

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