Status of the Borexino Experiment

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1. Introduction

Main goal of Borexino is the first real time measurement of solar neutrinos below 1 MeV, especially the monoenergetic ^{7}Be neutrinos with an energy of 862 keV. With the measurement of the ^{7}Be neutrino flux with an accuracy of ± 10 % and including the solar luminosity constraint and the already known oscillation parameters, the primary pp neutrino flux can be determined with an accuracy better than 1 %. As the theoretical error of the standard solar model is also of the order of 1 %, the solar model can be tested with unprecedented precision. Besides the ^{7}Be neutrinos, also pep and CNO neutrinos will be registered and constrain the contribution of the CNO cycle to the solar energy production.

The Borexino detector is located in the Gran Sasso underground laboratory in Italy at a shielding depth of 3600 mwe. The solar neutrinos will be detected via neutrino electron scattering in liquid scintillator. 300 t of liquid scintillator are contained in a spherical nylon vessel of 8.5 m diameter. Only the inner 100 t will be used for neutrino detection, the outer 200 t provide shielding against external background. The scintillator is additionally shielded by 1300 t of transparent liquid contained in a 13.7 m diameter stainless steel sphere. 2200 photo multipliers mounted on the inside of the sphere detect the scintillation photons. The whole setup is immersed in ∼ 2000 t of water contained in a steel dome of about 18 m diameter and 18 m height. The water serves as shielding against external radiation, but also as Cerenkov detector to recognize cosmic ray muons crossing the water tank. 208 additional PMTs are mounted in the external water tank to register the Cerenkov light created by the muons in the water.

The detector construction has been finished in 2004, but the filling is delayed due to civil work on the infrastructure of the laboratory.

With LMA neutrino oscillations, about 35 ^{7}Be neutrino events per day are expected in Borexino, and about 1 pep and CNO neutrino events per day. The main challenge in Borexino is the discrimination of the neutrino signal against background induced by radioactivity and cosmic rays. Solar neutrinos are detected via the energy deposit of the scattered electron in the scintillator. As the ^{7}Be neutrinos are monoenergetic (862 keV), the spectrum of the scattered electrons is Compton like, with the edge being at 660 keV. Signals from beta or gamma decays in this energy region are indistinguishable from neutrino events. Therefore the radiopurity of the scintillator itself as well as the shielding against external radiation are crucial for the experiment. The lower detection threshold of 0.25 MeV has to be set due to the activity of ^{14}C in the organic scintillator. For the detection of pep and CNO neutrinos the radiopurity requirements are even higher due to their lower flux. Once sufficiently clean conditions are met, muon induced radioactivity (mainly ^{11}C) is the dominant background in this energy region.

2. Detection of ^{11}C in the CTF

^{11}C is produced in the liquid scintillator by spallation of cosmic ray muons (or their secondaries) on ^{12}C. In 95 % a free neutron is produced in the final state

$$\mu +^{12}\mathrm{C} \rightarrow \mu +^{11}\mathrm{C} + \mathrm{n}.$$

^{11}C decays β^{+} with a mean life of 29.4 min and an endpoint energy of 0.96 MeV. The total energy released in the scintillator by the decay and the subsequent positron annihilation lies between 1 and 2 MeV.

Neutrons are captured in the scintillator by hydrogen with a mean life of 250 μs emitting a characteristic γ of 2.2 MeV. A threefold coincidence (μ signal, n capture, ^{11}C decay) can therefore in principle be used to tag ^{11}C event by event, though the long mean life of ^{11}C makes this feasible only for very low background conditions.

In order to identify and suppress the ^{11}C background in Borexino, each 2.2 MeV γ shortly after a muon signal will be localized in space and time, and a set of potential ^{11}C candidates will be identified within a certain time window t and a radius r from the neutron capture event. These will be discarded in order to improve the signal/background ratio for the pep neutrino detection. The successful detection of pep (and CNO) neutrinos in Borexino will depend on the efficiency of the ^{11}C detection with the minimum loss of detector mass and time.

In order to test the potential of the threefold coincidence technique, the method has been applied to data from the Borexino Couting Test Facility CTF. The CTF is the Borexino prototype detector also situated in the Gran Sasso underground laboratory. It was designed in order to study the radiopurity of the liquid scintillator, and features 4 tons of liquid scintillator, watched by 100 photomultipliers and shielded by 100 tons of ultrapure water. The analyzed data correspond to a detector livetime of 611 days (June 2002 - February 2005). 227 candidate events have been selected by the threefold coincidence method. A fit with the free parameters A (number of ^{11}C nuclides) and τ (mean life of ^{11}C), assuming a constant background, finds $A = 54 \pm 12$ and $\tau = 27 \pm 10$ min, in agreement with the ^{11}C life time. Taking into account the cut efficiencies (dereived from Monte Carlo simulations), this corresponds to a ^{11}C production rate of

$$R(^{11}C) = 0.134 \pm 0.024(\mathrm{stat}) \pm 0.014(\mathrm{sys})/(\mathrm{day} \cdot \mathrm{ton}).$$

For details of the analysis see [1]. This result is in agreement with the value extrapolated from a measurement performed at the NA54 CERN facility in a muon target experiment $R(^{11}C) = 0.146 \pm 0.015/(\mathrm{day} \cdot \mathrm{ton})$ [2], and makes us confident to improve the signal/background ratio for the pep and CNO neutrino detection in Borexino from about 0.1 to 1.

References

[1] Borexino collaboration, M. Balata *et al.*, (2006)
[2] T. Hagner *et al.* Astropart. Phys. **14** (2000) 33