Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics B 908 (2016) 178–198
NUCLEAR PHYSICS B
www.elsevier.com/locate/nuclphysb

The impact of Borexino on the solar and neutrino physics

Gianpaolo Bellini

Istituto Nazionale di Fisica Nucleare, via Celoria 16, 20133 Milano, Italy

Received 30 January 2016; received in revised form 6 April 2016; accepted 6 April 2016

Available online 25 April 2016

Editor: Tommy Ohlsson

Abstract

The Borexino detector is characterized by a very low background level due to an unprecedented radio-purity, which allows to study the entire spectrum of solar neutrinos from very low energies (∼150 keV). The solar neutrino rates from pp, ^{7}Be, pep, ^{8}B (with a threshold down to 3 MeV) and a stringent limit of the CNO cycle rate have been already measured. In addition evidences of a null day/night asymmetry and of the solar neutrino flux seasonal variation have been reached.

The contribution provided until now by Borexino in understanding the neutrino oscillation phenomenon concerns the first evidence of the oscillation in vacuum and the determination of the ν_e survival probability in vacuum: these results validate the paradigmatic MSW model in the vacuum regime.

The Borexino results are also in good agreement with the Standard Solar Model predictions, but the metallicity puzzle is still unsolved. In addition the pp flux measured by Borexino shows a good agreement with the Solar luminosity.

Evidence of geo-neutrinos has been also obtained at the level of 5.9σ C.L.

Borexino is still taking data in order to: upgrade the precision of the solar neutrino rates already measured, increase the sensitivity to the neutrino flux from the CNO cycle and hopefully measure it (very challenging), and test the existence of very short base-line neutrino oscillations.

E-mail address: gianpaolo.bellini@mi.infn.it.

http://dx.doi.org/10.1016/j.nuclphysb.2016.04.011

1. Introduction

Borexino, installed at the Gran Sasso laboratory (Hall C), is continuously taking data since May 2007, with the exception of the period: May 2010–October 2011, when a further radio-purification of the scintillator has been carried out to suppress or reduce the residual contaminants, which survived the initial purification (during the detector filling). The data collected from May 2007 to May 2010 (the so called phase 1) have been already analyzed, reaching several results which are breakthroughs in the neutrino and in the Sun physics. The data taken until now during the phase 2 (which started in October 2011), and partially analyzed, have been provided already important results, but other challenging efforts are in progress.

The key constraints for the Borexino detector were dictated by the experiment goal to study the solar neutrinos with a threshold at 150–200 keV, a study never carried out before in real time by other experiments. In order to achieve this goal, the required radio-purity level of the detecting material (liquid scintillator) has to be 9–10 orders of magnitude lower than the natural ambient radioactivity. With the techniques developed during a long and intense period of R&D effort, Borexino reached and exceeded this goal, achieving unprecedented levels of radio-purity which allowed for the first time to measure in real time the neutrino rates produced by the pp, ^{7}Be, pep solar reactions and to reach a stringent upper limit for the CNO cycle.

2. The detector

Borexino is a scintillator detector, which employs a mixture of Pseudocumene (PC; 1,2,4 trimethylbenzene) and a fluorescent dye PPO (2,5 diphenyloxazole) at a concentration of 1.5 g/l. Borexino is designed following the basic requirement to keep the radioactivity at a very low level, and is based on the principle of graded shielding; it consists of concentric shells of increasing radio-purity, with the highest one at the center where the liquid scintillator core is placed. In Fig. 1 the detector design and layout are shown. Starting from outside, a water tank (WT) contains a stainless steel sphere (SSS) surrounded by 2100 m^3 of highly purified water. The SSS supports 2212 Photomultipliers (PMTs), coupled to optical concentrations (30% of optical coverage), and contains a nylon vessel (IV), 300 m^3 of volume, surrounded by 1050 m^3 of pseudocumene (buffer liquid), an aromatic chosen also as a diluent of the two component liquid scintillator inserted into the IV. The light emitted by the scintillator is detected by 2212 PMTs (Inner Detector – ID). The nylon wall of the IV is 125 μm thick and, as a consequence, the buoyancy on it has to be very small: so the density of the external shielding liquid is only slightly different from the one of the internal scintillator. A second nylon balloon functions as a barrier against the ^{222}Rn emitted mostly by the PMTs. In the buffer of Pseudocumene, 5 g/l of a quencher (DMP) is added to withdraw the scintillating power of the Pseudocumene alone.

Finally between the SSS and the WT, 208 PMTs assure the cosmic muon identification by exploiting the Cherenkov light produced in the highly purified water of the Water Tank (Outer Detector – OD).

The choice of the liquid scintillation technique was dictated by the high light-yield of the scintillator (50 times more than in the Cherenkov technique), and thus a good energy resolution. However, to the contrary of water Cherenkov detectors, the information on the incident neutrino direction is lost.

For more details see Refs. [1,2].

To cope with the goal of a very low radioactive background, many tools have been used during the installation. The crude oil for the Pseudocumene preparation has been procured from old