Scintillator purification, detector performance and first results from Borexino

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Abstract. The Borexino experiment has begun data taking in May 2007 after a long R&D work and preparation. The liquid scintillator purity exceeds even optimistic expectations, and the first detection of 7Be solar neutrinos has been possible after less than two months of data taking. This note shows briefly which are the main issues that were addressed in order to obtain such an extreme radiopurity, the detector performance and a few details concerning this first result.

1. Introduction
The Borexino experiment [1], now operating at the Laboratori Nazionali del Gran Sasso, has been designed and built mainly with the purpose of detecting low energy solar neutrinos, in particular those emitted by the electron capture decay of 7Be in the Sun. Solar neutrinos are detected by means of their elastic scattering off electrons in a liquid scintillator target made of pseudocumene (PC, 1,2,4-trimethylbenzene) and doped with PPO (2,5-diphenyloxazole, a fluorescent dye) at a concentration of 1.5 g/l. The scintillator is contained in a 300 m3 thin (125 μm) nylon vessel (R=4.25 m). This inner nylon vessel is kept almost buoyant free at the center of a large Stainless Steel Sphere (R=6.85 m) which acts at the same time as a container of the remaining buffer liquid (~1000 m3 of PC with a small addition DMP to quench the unwanted scintillation light coming from pure PC) and as mechanical support of 2212 EMI PMTs that collect the scintillator light produced in the scintillator. Another outer nylon vessel (R=5.5 m) act as a barrier against Rn emanated from the SSS and the PMTs and against other possible contaminations. Finally, the SSS is installed.
inside a 3000 m$^3$ Water Tank which provides the necessary shielding against rock induced external backgrounds and is used as a Cerenkov detector to tag the residual muons that penetrate the Gran Sasso mountain. A schematic view of the Borexino detector is shown in Fig. 1

The detection of solar neutrinos by means of scintillation allows good energy resolution, very low energy threshold (about 50 KeV), good spatial reconstruction, and good discrimination between $\alpha$ and $\beta$ nuclear decays. However, the direction of the incoming neutrino cannot be measured and each neutrino induced event is intrinsically indistinguishable from any $\beta$ or even $\gamma$ decay within the scintillator. This fact makes the experiment feasible only if extreme radiopurity requirements are met for both the scintillator and the materials of which the detector is built.

### 2. Scintillator purification and detector filling

In the last 15 years the Borexino collaboration has developed innovative techniques for the measurement of ultra low radioactive backgrounds in materials and for the purification of the scintillator [1]. A set of purification plants have been designed and built, and their effectiveness was tested by means of the Counting Test Facility [2] at Gran Sasso. These plants include, among others, a water plant, an ultrapure nitrogen plant, a PC distillator, and another distillator designed for the purification of PPO dissolved in concentrated solution in PC.

The water plant can produce water at a rate of 1.8 m$^3$/h with $^{238}$U and $^{232}$Th content below $10^{-14}$ g/g, $^{222}$Rn content around 1 mBq/m$^3$ and typical resistivity around 18.2-18.3 M$\Omega$ at 20 °C.

Particular attention was devoted to the development of low Argon Krypton nitrogen that was used to purify the scintillator from all air borne contaminations. The content of both $^{39}$Ar and $^{85}$Kr in this nitrogen is such that the expected background in the 100 t fiducial volume should be below 1 c/d.

The whole amount of PC (~1300 m$^3$), both in the scintillator and in the buffer, was distilled by means of a 6 stages distillator at 60 mbar pressure and ~90 °C temperature. The PC was then sparged with nitrogen gas to remove air borne impurities ($^{222}$Rn, $^{39}$Ar and $^{85}$Kr) and humidified to preserve the mechanical properties of the nylon vessel. Being the PPO solid, the purification of PPO was done preparing a concentrated solution PPO in PC (120 g/l) and then purifying this solution first with several cycles of water extraction and then by means of a single stage distillator.

The filling of the detector was done as following: first, the nylon vessel and the SSS have been filled with ultrapure water. This water filling allowed a final rinsing of the detector and of the nylon
vessels. Then, the water was replaced with PC-PPO solution in the inner nylon vessel and with PC-DMP solution in the buffers. At the same time, the water taken out of the SSS was passed through a charcoal filter and used to fill the Water Tank. The filling proceeded smoothly from August 1st, 2006 until May, 2007 when data taking began.

Figure 2 – Left: the effect of different cuts in the Borexino spectrum; the black curve is the raw spectrum; the brown one is after muon cut, the purple one is after fiducial volume cut and the red one is the final after Rn cut. For comparison, on the right the expected rate due to $^7$Be neutrinos and irreducible background is shown.

3. First detection of $^7$Be solar neutrinos
The purity of the Borexino scintillator is good enough to allow the clear detection of $^7$Be solar neutrinos using a couple of months of data. Fig. 2 shows a comparison between the expected signal rate in 100 t of fiducial volume and the corresponding spectrum seen on data. The compton shoulder expected from mono-energetic neutrinos scattering on electrons is evident (red curve).

The analysis does not require many cuts. The red curve in Fig. 2 (left) is obtained just by removing muon induced events by exploiting the capabilities of both the outer Cerenkov detector and the inner detector pulse shape, by removing $^{222}$Rn events and its daughters and by removing the external background by means of a fiducial volume cut. The spectrum in Fig. 2 left is not converted into energy. The conversion is approximately linear below 1 MeV with a yield of about 500 pe/MeV.

The very good $\alpha/\beta$ separation and the very good light yield allow to fit the spectrum both with and without the statistical subtraction of the $^{210}$Po peak which is evident in the spectrum. The two approaches yield consistent results. Details of this result are published in [3] and [4].

4. Conclusions
The Borexino experiment has successfully completed the construction of the detector and the data taking has begun. The scintillator is very pure and the first detection of $^7$Be solar neutrinos has been possible after a few months of data taking. Precision measurement will require better understanding of the detector, more statistics and a calibration campaign. This paper is dedicated to the memory of Cristina Arpesella, Martin Deutsch, Burkhard Freudiger, Andrei Martemianov and Sandro Vitale.

References
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