Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics B (Proc. Suppl.) 188 (2009) 127–129
NUCLEAR PHYSICS B PROCEEDINGS SUPPLEMENTS
www.elsevierphysics.com

Measurement of the solar ^{8}B neutrino flux down to 2.8 MeV with Borexino

D. Franco[a]*

On Behalf of the Borexino Collaboration:
G. Bellini J. Benziger S. Bonetti M. Buizza Avanzini B. Caccianiga L. Cadonati F. Calaprice C. Carraro A. Chavarria F. Dalnoki-Veress D. D'Angelo H. de Kerret A. Derbin A. Etenko K. Fomenko C. Galbiati S. Gazzana M. Giammarchi M. Goeger-Neff A. Goretti C. Grieb S. Hardy Aldo Ianni Andrea Ianni M. Joyce V. Kobychev G. Korga D. Kryn M. Laubenstein M. Leung T. Lewke E. Litvinovich B. Loer P. Lombardi L. Ludhova I. Machulin S. Manecki W. Maneschg G. Manuzio F. Masetti K. McCarty Q. Meindl E. Meroni L. Miramonti M. Misiaszek D. Montanari V. Muratova L. Oberauer M. Obolensky F. Ortica M. Pallavicini L. Papp L. Perasso S. Perasso A. Pocar R.S. Raghavan G. Ranucci A. Razeto P. Risso A. Romani D. Rountree A. Sabelnikov R. Saldanha C. Salvo S. Schönert H. Simgen M. Skorokhvatov O. Smirnov A. Sotnikov S. Sukhotin Y. Suvorov R. Tartaglia G. Testera D. Vignaud R.B. Vogelaar F. von Feilitzsch M. Wojcik M. Wurm O. Zaimidoroga S. Zavatarelli G. Zuzel

[a]Università degli Studi & INFN, 20133 Milano, Via Celoria 16, I-20133 Italy

We report the measurement of the ^{8}B solar neutrinos interaction rate with the Borexino detector. The extremly high radio-purity reached in the Borexino scintillator, combined with the efficient software rejection of cosmogenic background, allows to investigate the recoiled electron spectrum, induced by ^{8}B solar neutrinos, down to the unprecedented energy threshold of 2.8 MeV.

The rate of ^{8}B solar neutrino interaction as measured through their scattering on the target electrons is $0.26\pm0.04_{\rm stat}\pm0.02_{\rm syst}$ c/d/100 tons. This corresponds to an equivalent electron neutrino flux of $(2.65\pm0.44_{\rm stat}\pm0.18_{\rm syst})\times10^6$ cm^{-2}s^{-1}, as derived from the elastic scattering only, in good agreement with existing measurements and predictions.

Borexino [1,2] is a real-time experiment for low energy neutrino spectroscopy, operating since May 2007 at the underground Gran Sasso National Laboratories.

Solar neutrinos are detected by means of their elastic scattering off electrons in a liquid scintillator target: 278 tons of pseudocumene (PC,1,2,4-trimethylbenzene) doped with 1.5 g/l of PPO (2,5-diphenyloxazole, a fluorescent dye). The scintillator is housed in a thin (125 μm) nylon vessel and is shielded by a buffer of 1000 tons of pseudocumene. A second nylon vessel (11.5 m diameter) protects the active target from radon emanation from the periphery of the detector.

2212 photomultiplier tubes, mounted on a stainless steel sphere (SSS), detect the scintillation light. Finally, the SSS is installed inside a 3000 m^3 water tank which provides the necessary schielding against rock induced external backgrounds and is used as a Cerenkov detector to veto the residual muons that penetrate the Gran Sasso mountain.

Borexino obtained an excellent level of radiopurity in the innermost scintillator target: ^{238}U contamination is at $(1.6\pm0.1)\times10^{-17}$ g/g and the ^{232}Th contamination at $(6.8\pm1.5)\times10^{-18}$ g/g. The reduction of background from natural radioactivity to these unprecedented levels is a necessary pre-requisite for the observation of ^{8}B neutrinos with a low-energy threshold.

The 2.8 MeV energy threshold is imposed by

*davide.franco@mi.infn.it

0920-5632/$ – see front matter
doi:10.1016/j.nuclphysbps.2009.02.030

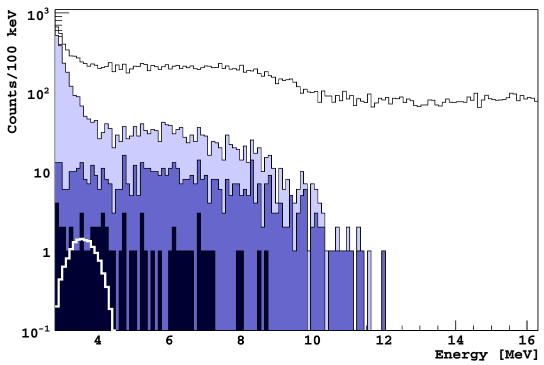

Figure 1. Energy spectra of candidate events after application of several cuts. The black line represents all events. The light blue- and blue-filled spectra are the samples after the muon cut and fiducial volume cut, respectively. The dark blue-filled spectrum is the final set of data after all cuts and before statistical subtraction of ^{208}Tl, whose expected contribution, taking into account also light quenching, is represented by the white line.

the 2.6 MeV γ's from the β-decay of ^{208}Tl due to radioactive contamination mainly in the photomultiplier tubes. Above 2.8 MeV, possible sources of background include the radioactive decays of residual ^{214}Bi (^{238}U chain, Q=3.272 MeV) and ^{208}Tl (^{232}Th chain, Q=5.001 MeV) in the liquid scintillator, decays of cosmogenic isotopes (mainly ^{12}B, ^{8}B and ^{8}Li), high energy gamma rays from neutron capture, and residual cosmic rays.

This paper is based on 245.9 live days of data-taking, between July 15, 2007 and June 21, 2008, with a target mass of 100 tons, defined by a fiducial volume cut of radius 3 m. The data selection relies on the following cuts:

- muon events identified by the outer detector are rejected;
- events following a muon, even crossing the water detector only, are rejected within a time window of 2 ms;
- external background is suppressed by rejecting events reconstructed outside a spherical fiducial volume of r<3 m;
- short-lived (τ < 2 s) cosmogenic isotopes, ^{12}B, ^{8}B and ^{8}Li, are removed with 99.7% efficiency, by vetoing the detector for 5 s after each muon crossing the scintillator (note that the cosmogenic cut introduces a dead time of 23.4%, reducing live-time to 187.9 d);
- among long-lived (τ > 2 s) cosmogenic isotopes, ^{11}Be contribution is neglected, given the extremely low cross-section of its production reaction [3] and ^{10}C candidates are tagged and rejected by the triple coincidence with the parent muon and neutron capture on proton [4];
- ^{214}Bi is rejected exploiting the ^{214}Bi - ^{214}Po delayed coincidence with 89% efficiency.

The effect of each step of the analysis sequence described above is shown in Fig. 1. The residual contamination due to the inefficiencies of the selection cuts is less than 0.01 c/d and hence negligible with respect to the expected ^{8}B signal (∼0.5 c/d in the entire energy spectrum). The final sample is still contaminated by the internal ^{208}Tl from ^{232}Th chain. The ^{208}Tl contribution is evaluated at 14±3 counts, by measuring the delayed coincidences of its branching competitor, ^{212}Bi-^{212}Po. We then subtract the ^{208}Tl contamination from the final sample and obtain a signal of 48±8 events above 2.8 MeV.

The final energy spectrum, after all cuts and statistical subtraction of ^{208}Tl, is shown in Fig. 2. Both the measured rate and spectrum are in agreement with the rate (0.26 ± 0.04 c/d/100 tons) and the spectrum predicted by the Standard Solar Model [5], based on the corona high-Z abundances reported by Grevesse and Sauval [6] BS07(GS98) model, including the MSW-LMA solution (Δm^2=7.69×10^{-5} eV^2, $\tan^2\theta$=0.45 [7]) .

The dominant sources of systematic error, already discussed in [8], come from the determination of the fiducial mass, and the uncertainty on the detector energy response function.

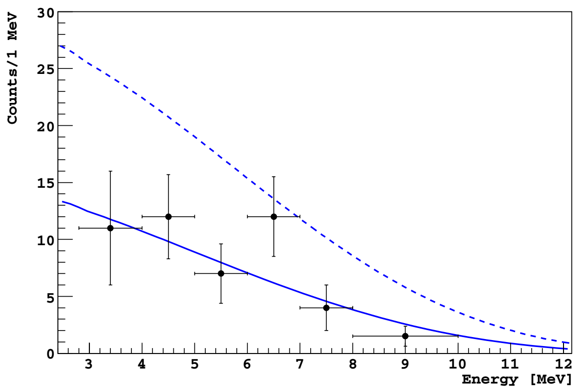

Figure 2. Energy spectrum of the events surviving all cuts and after statistical ^{208}Tl subtraction. The expected electron recoil spectrum due to oscillated (not oscillated) ^{8}B ν interaction, as determined from the BS07(GS98) solar model, is represented by the solid (dashed) line.

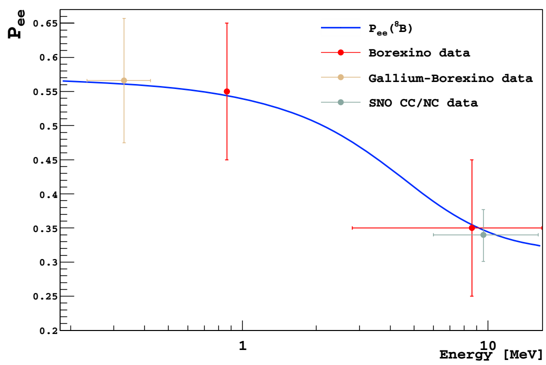

Figure 3. Electron neutrino survival probability (line) as function of the neutrino energy, evaluated for the ^{8}B neutrino source. Dots represent the Borexino results from ^{7}Be and ^{8}B measurements, the SNO results [10] from the charge and neutral current measurements in salt phase and results from the Gallium experiments compared with the Borexino ones [8].

The equivalent unoscillated ^{8}B neutrino flux, as derived from the rate above the 2.8 MeV threshold, is $(2.65 \pm 0.44_{\rm stat} \pm 0.18_{\rm syst}) \times 10^{6}$ cm^{-2}s^{-1}. From our data, neutrino oscillation is confirmed at 4.2σ, including the theoretical uncertainty (10%) on the ^{8}B flux.

The correspondent electron neutrino survival probability is P_{ee} = 0.35$\pm$ 0.10 [9] at the mean energy of 8.6 MeV. The survival probability of the 0.862 MeV ^{7}Be neutrinos was previously reported as 0.56$\pm$0.10 [8]. Eliminating the common sources of systematic errors, the ratio between the measured survival probabilities for ^{7}Be and ^{8}B neutrinos is 1.60$\pm$0.33, confirming at 93% C.L. the presence of a transition between the low energy vacuum-driven and the high-energy matter-enhanced solar neutrino oscillations, in agreement with the MSW-LMA theory prediction.

REFERENCES

1. G. Alimonti et al. (Borexino Collaboration), accepted by Nucl. Instr. Meth. A, arXiv:0806.2400 (2008).
2. C. Arpesella et al. (Borexino Collaboration), Phys. Lett. B **658**, 101 (2008).
3. T. Hagner et al., Astropart. Phys. **14**, 33 (2000).
4. C. Galbiati et al., Phys.Rev.C **71** 055805 (2005).
5. J.N. Bahcall, A.M. Serenelli, and S. Basu, Astrophys. J. Suppl. **165**, 400 (2006); C. Peña-Garay, talk at the conference Neutrino Telescopes 2007", March 6-9, 2007, Venice; A. Serenelli, private communication.
6. N. Grevesse and A.J. Sauval, Space Sci. Rev. **85**, 161 (1998).
7. G. L. Fogli, E. Lisi, A. Marrone, A. Palazzo and A. M. Rotunno, arXiv:0806.2649 (2008).
8. C. Arpesella et al. (Borexino Collaboration), Phys. Rev. Lett. **101** (2008) 091302.
9. G. Bellini et al. (Borexino Collaboration), arXiv:0808.2868 (2008).
10. B. Aharmim et al. (SNO Collaboration), Phys. Rev. C **72** (2005) 055502.