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Vacuum-matter transition of solar neutrino oscillations with the Borexino experiment

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Summary. — Thanks to the excellent levels of achieved radiopurity and to the accurate data analysis techniques, Borexino has performed the first real time measurement of the ⁷Be solar neutrino flux. The efficient software rejection of cosmogenic background also allows to investigate the recoiled electron spectrum induced by ⁸B solar neutrinos down to 3 MeV, the lowest energy threshold ever reached in real time detection. This is the first observation of solar ⁸B neutrinos in a liquid scintillator detector. For the first time, the same apparatus can measure the two different oscillation regions (vacuum-driven and matter-enhanced) predicted by the MSW-LMA model. Borexino also quotes the ratio between the survival probabilities, corresponding to 1.93 ± 0.75 , validating the presence of the transition region predicted by the MSW-LMA solution.

PACS 95.55.Vj – Neutrino, muon, pion, and other elementary particle detectors; cosmic ray detectors.

PACS 29.40.Mc – Scintillation detectors.

1. – Introduction

We present the measurement of ⁷Be and ⁸B solar neutrinos fluxes in the data-taking period between May 2007 and August 2009 with the Borexino experiment and the corresponding confirmation about the presence of a transition for the electron neutrino (ν_e) survival probability (P_{ee}) in the MSW-LMA scenario (see [1-3] for details).

2. - ⁷Be and ⁸B neutrino flux measurements

Thanks to its extreme radiopurity, Borexino measured for the first time in real time the ⁷Be energy spectrum in the energy region [0.2, 2] MeV. The background sources in this energy window are: cosmic muons, γ 's from capture of cosmogenic neutrons, contaminations from internal ²³⁸U and ²³²Th chains and external background. Each type of background is rejected through a specifical removal technique. In left panel of fig. 1 the measured spectrum in 192 days is shown.

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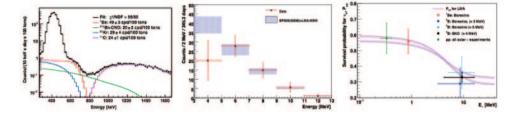


Fig. 1. – (Colour on-line) Left: obtained energy spectrum after background removal for the ⁷Be neutrino analysis. Results of fitting procedure are also shown. Middle: comparison of the final spectrum after data selection and background subtraction (red dots) to Monte Carlo simulations (blue) of oscillated ⁸B ν interactions, with amplitude from the Standard Solar Model BPS09 (GS98) [4], and from the MSW-LMA model. Right: ⁷Be and ⁸B electron neutrino survival probability as measured by Borexino compared to previous measurements and MSW-LMA predictions.

The ⁷Be signal rate in Borexino is obtained fitting the energy spectrum by a superimposition of the spectra due to solar neutrinos and to the not taggable backgrounds; it corresponds to $(49 \pm 3_{\text{stat}} \pm 4_{\text{sys}}) \text{ c/d/100}$ t. The equivalent ν_e survival probability is 0.56 ± 0.10 and the non-oscillation hypothesis is rejected at 4σ CL. Therefore Borexino provides the first direct P_{ee} measurement in the vacuum regime (see [2] for details).

Thanks to the efficient software rejection of cosmogenic background, important above 1 MeV, Borexino also measured the energy spectrum induced by ⁸B solar ν , down to 3 MeV, the lowest energy threshold ever reached in real time.

Energy spectrum of ⁸B ν candidates is shown in the middle panel of fig. 1. The number of selected events is (75 ± 13) in 345.3 days of lifetime and the corresponding rate is $(0.217 \pm 0.038_{\text{stat}} \pm 0.008_{\text{sys}}) \text{ c/d/100t [3]}$. The equivalent ν_e survival probability, assuming the Standard Solar Model [4], is (0.29 ± 0.10) at the effective energy of 8.9 MeV. The non-oscillation model is excluded at 4.2σ CL (see [3] for details).

3. – The survival probability in the vacuum-matter oscillation transition

Borexino is the first experiment able to simultaneously measure solar ν fluxes both in vacuum-dominated (⁷Be ν) and matter-enhanced regions (⁸B ν). The obtained results for P_{ee} are shown in the right panel of fig. 1 and compared with the prediction of MSW-LMA theory [2]. The agreement is fair. Remembering the obtained values for the survival probability at 0.862 MeV (0.56 \pm 0.10) and 8.9 MeV (0.29 \pm 0.10) and removing the systematic error associated with the determination of the fiducial volume (affecting both the analysis), we obtain a ratio between the two probabilities of 1.93 ± 0.75 ; it differs from unity by 1.9σ [3]. For the first time using data from a single detector, it is possible to point out the presence of a transition region between the two oscillation regimes, in agreement with the prediction of the MSW-LMA solution for solar neutrinos.

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