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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 ^{7}Be solar neutrino flux. The efficient software rejection of cosmogenic background also allows to investigate the recoiled electron spectrum induced by ^{8}B solar neutrinos down to 3 MeV, the lowest energy threshold ever reached in real time detection. This is the first observation of solar ^{8}B 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 ^{7}Be and ^{8}B 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. – ^{7}Be and ^{8}B neutrino flux measurements

Thanks to its extreme radiopurity, Borexino measured for the first time in real time the ^{7}Be 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 ^{238}U and ^{232}Th 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.

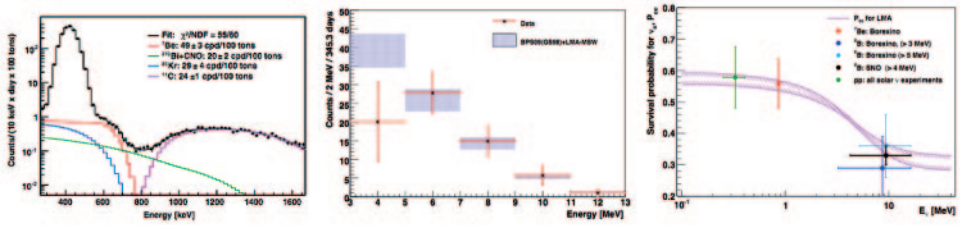

Fig. 1. – (Colour on-line) Left: obtained energy spectrum after background removal for the ^{7}Be neutrino analysis. Results of fitting procedure are also shown. Middle: comparison of the final spectrum after data selection and background subtraction (red dots) to Monte Carlo simulations (blue) of oscillated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

The ^{7}Be 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 $(49 \pm 3_{\text{stat}} \pm 4_{\text{sys}})$ 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 ^{8}B solar ν, down to 3 MeV, the lowest energy threshold ever reached in real time.

Energy spectrum of ^{8}B 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 $(0.217 \pm 0.038_{\text{stat}} \pm 0.008_{\text{sys}})$ 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 (^{7}Be ν) and matter-enhanced regions (^{8}B 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 ± 0.10) and 8.9 MeV (0.29 ± 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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