Borexino and its Physics Program

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Borexino, a real-time detector for low energy neutrino spectroscopy is under construction in the underground laboratory LNGS at GranSasso, Italy. The experiment aims for the first direct measurement of the solar ^{7}Be-neutrino flux.

1. INTRODUCTION

The primary aim of Borexino experiment [1] is to measure the contribution of ^7Be neutrinos to the solar neutrino flux. The $^7Be\ \nu$ deficit is a main focus of the solar neutrino problem and Borexino will be able to detect these neutrinos by real time counting.

2. BOREXINO

Borexino, located in the underground Gran Sasso Laboratory, is an unsegmented liquid scintillator detector featuring 300 tons of well shielded ultrapure scintillator viewed by 2200 photomultipliers (fig. 1) The scintillator mixture is composed by pseudocumene (PC) as the solvent with PPO (1.5 g/ℓ) as a fluor, while the high-purity buffer liquid will be PC with DMP, a light quencher. The photomultipliers are supported by a steel sphere which also separates the inner part of the detector from the external shielding, provided by 2400 tons of pure water (water buffer).

The 200 photomultipliers in the outer water shield, serve as a veto for penetrating cosmic muons.

The background sources to consider in Borexino are the cosmic muons and induced activity, the material radioactivity and the intrinsic radiopurity of the scintillator. The detection of the ^{7}Be ν signal in the 100 tons of the Borexino Fiducial Volume requires a background of less than about 20 events/day in the same energy window.

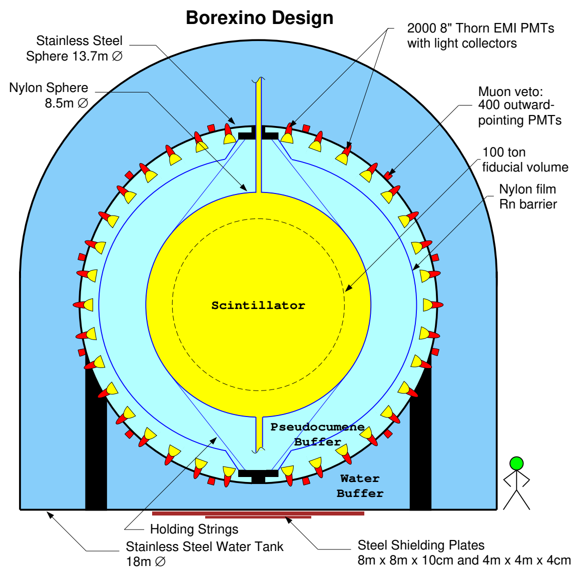

Figure 1. Schematics of the Borexino detector.

This event rate can be achieved if the radiopurity of the scintillator is of the order of 10^{-16} g/g of ^{238}U, ^{232}Th equivalent and no other significant backgrounds are present.

The Borexino design is based on the concept of a *graded shield* of progressively lower intrinsic radioactivity as one approaches the sensitive volume of the detector; this culminates in the use of 200 tons of the ultralow background scintillator to shield the 100 tons innermost Fiducial Volume.

*Borex Collaboration

3. THE SOLAR NEUTRINO SIGNAL IN BOREXINO

Solar neutrino detection in Borexino is based on $\nu - e^-$ scattering, using the technique of the liquid scintillation.

The $\nu - e$ scattering is driven by the charged and neutral weak current, wheras ν_μ and ν_τ scattering occurs only via the NC. The effective cross-section thus depends on ν flavor. In the $^7Be\ \nu$ signal window, the event rate due to the NC interaction alone is ~23% of the total rate.

Borexino observes the monoenergetic line at 0.862 MeV ($^7Be\ \nu$) which yields a unique "flat box" recoil profile with a spectral edge at 0.66 MeV. The recoil profile and its edge energy offer a signature for the $^7Be\ \nu$ signal. Since the photon emission in the scintillator is isotropic, the inherent directionality of the reaction is lost.

The basic data expected from Borexino are the magnitude of the $\nu - e$ scattering signal rate and a possible time dependence of this rate over day-night or seasonal periods. Also the spectral shape of the $^8B\ \nu - e$ scattering signal starting from 3 MeV will be measured.

With 100t of liquid scintillator target, the SSM and standard ν predict in the e^- recoil energy window of 250-800 KeV, a signal rate of 55/d, 80% of which is due to ^7Be neutrinos. Fig. 2 shows a simulated signal spectrum observable in Borexino and the background achievable with the class of radiopurity and tag efficiencies demonstrated in the CTF experiment (Counting Test Facility [2])

If the solar ν_e is fully converted into other active flavors the signal rate drops to ~11/d, arising only from the neutral current interaction. For full conversion into sterile neutrinos with a theoretically vanishing signal, a limit on the ^{7}Be-neutrino flux can be set depending on the background.

3.1. Neutrino Conversion Effects in Borexino

The physical scenarios for neutrino conversion are the MSW effect and vacuum oscillations. In the FV and in the e^- recoil energy window of 250-800 KeV, the MSW effects predicts in the SMA region for $^7Be\ \nu$ a nearly fully conversion, resulting in an expected rate of $\sim$ 12/d, in the LMA a reduction of the signal of $\sim$ 50% of the SSM value ($\sim$ 30/d), in the LOW region a rate of $\sim$ 29/d with a day-night effect. For vacuum oscillations the rate is seasonal dependent and in average is comparable to that of the LMA solution.

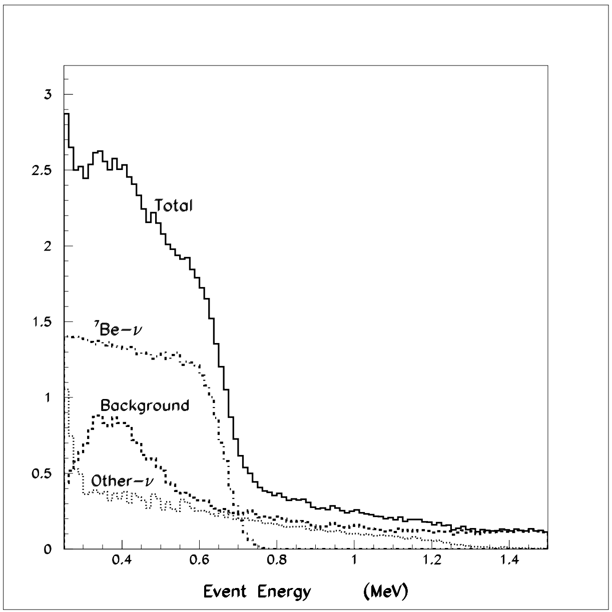

Figure 2. Monte Carlo simulation of ν signal and background. Plotted are the $^7Be - \nu$ signal (dotted-dashed), the signal from all other neutrino sources together (dotted), the background (dashed), and the sum spectrum (solid line).

3.1.1. Temporal variation of the ^{7}Be ν signal

The vacuum oscillation effect depends on the variation of the Earth-Sun distance in the Earth's eccentric orbit, thus the time variation is seasonal. This scenario is valid for maximal mixing and very small mass parameter. Fig. 3 shows the daily signal over one year of measurement for two values of Δm^2 compatible with present data.

Even without flavor conversion, time variations of the signal of the order of $\Delta(1/R^2) = 7\%$ could be a signature of the Borexino signal, especially

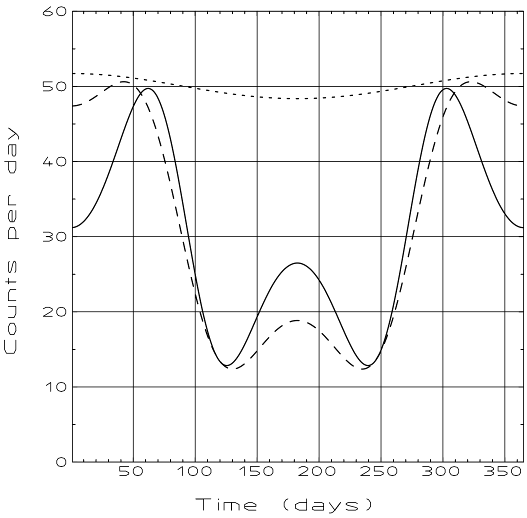

Figure 3. Variation of the daily counting rate in Borexino for vacuum oscillations due to Earth's eccentricity: $\Delta m^2 = 4.2 \cdot 10^{-10}\, eV^2$ (solid line) and $\Delta m^2 = 3.2 \cdot 10^{-10}\, eV^2$. The dashed upper curve shows the simple $1/R^2$ effect ($\sim$7%).

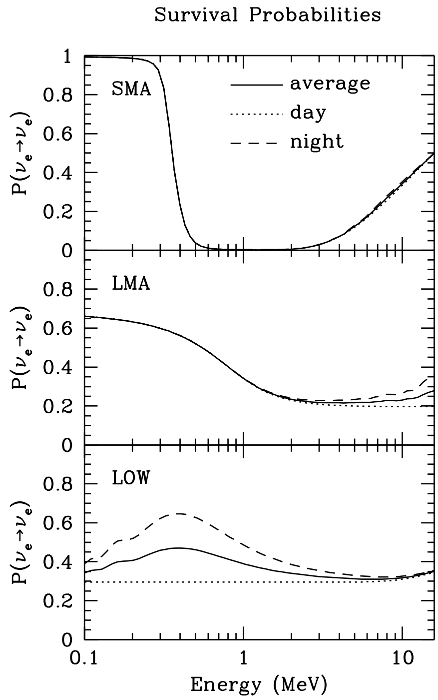

Figure 4. The survival probability of a solar nu_e upon its arrival on the Earth. Shown are yearly average survival probabilities: total (solid line); day-time(dotted); night-time(dashed)

for moderately depleted signals.

The passage through the Earth occurs nightly, thus, MSW regeneration of the electron-flavor in the Earth matter enhances the signal during the night and produce a day-night variation of the signal. Earth regeneration effects are particularly enhanced in the LOW region (Fig. 4) and at the ^7Be ν energy.

4. CALIBRATION AND MONITORING

Observation of time variations of the signal, depends on the magnitude and stability of the background in the signal window. An accurate calibration of the detection system is of paramount importance for the precision and stability of the spectroscopy. The calibration and monitoring program covers the energy and time response of the detector using built-in systems, active tags of trace impurities in the scintillator as well as external sources inserted periodically into the tank and possible insertions of radioactive sources into the active volume.

5. CONCLUSION

The solar neutrino experiment Borexino will be the first real-time detector to explore the sub-MeV energy region. The major installations have been already completed in the Hall C of LNGS.

REFERENCES

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2. G.Alimonti et al., Astroparticle Phys.8 (1998) 141, Phys. Lett. B422 (1998) 349.