BOREXINO

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Physics Goals and Neutrino Detection with Borexino

The aim of the solar neutrino experiment Borexino is to measure in real time the solar neutrino flux with low energy threshold at high statistics, and energy resolving via pure leptonic neutrino electron scattering $\nu + e \rightarrow \nu + e$.

Motivation for Borexino comes from the long standing solar neutrino puzzle. Data analysis of the existing experiments leads to the assumption of severe suppression of the solar ^7Be-branch, which probably cannot be explained by modifications of the standard astrophysical model of the sun. The monoenergetic ^7Be-neutrinos give rise to a compton like recoil spectrum in Borexino. Its edge will be at 660 keV, significantly higher than the aimed energy threshold of ca. 250 keV. Thus ^7Be-neutrino detection is very efficient in Borexino.

Assuming validity of the standard model a counting rate for ^7Be-neutrinos, which would consist in this case purely as ν_e, of roughly 55/day in Borexino is expected.

In scenarios of total neutrino flavour conversion (i.e. for neutrino mass differences $\Delta m^2 \approx 10^{-6} \rightarrow 10^{-5}\ eV^2$) a reduced flux of approximately 12/day would be measured due to the lower cross section of $\nu_{\mu,\tau}$ scattering, which occurs only via neutral current interaction.

In case of vacuum oscillations (i.e. for neutrino mass differences $\Delta m^2 \approx 10^{-10}\ eV^2$) Borexino would see a distinct time dependent periodical neutrino signal due to the seasonal eccentricity of the earths orbit around the sun.

For neutrino mass differences in the range of $\Delta m^2 \approx 10^{-7}\ eV^2$ and for large mixing Borexino should see a 'day/night' effect due to electron neutrino recovery during the path through the earth.

Borexino also can serve for additional projects in neutrino physics. Search for a magnetic moment can be performed by means of terrestial neutrino sources by investigating the electron recoil shape at low momentum transfer. Via the inverse beta-decay $\bar{\nu_e} + p \rightarrow e^+ + n$ Borexino can look for signals from geophysical neutrinos as well as for neutrinos emitted by european nuclear power plants. The latter would serve as a long baseline neutrino oscillation experiment probing the so-called large mixing angle solution for the solar neutrino problem.

The Detector and Background Considerations

The detector is shielded successively from outer radioactivity by means of an onion-like structure. Here the adjacent inner layer serves as shielding and has to provide an increased purity in terms of internal radioactivity.

Borexino is placed in hall C of the underground laboratory at Gran Sasso, Italy. An overburden of ca. 3500m.w.e. suppresses the cosmic muon flux to roughly 1 $/m^2$. The outer part of the detector consists of a steel tank with 18m in height and diameter. Inside this 'external' tank a stainless stell sphere will support 2200 phototubes on the inside and 200 tubes at the outside. Most of the tubes inside the sphere will be equipped with light guides in order to increase the geometrical coverage and hence the energy resolution. Between external tank and sphere high purity water will serve as shielding against external gamma rays and as active Cherenkov counter agianst cosmic muons. The steel sphere will be filled with a tranparent, high purity buffer liquid which itself holds a nylon sphere, filled with organic scintillator. The active scintillator mass will be around 300t. By means of time of flight measurements event position can be reconstructed and a fiducial volume for solar neutrino interaction defined. Latter should be about 100t, establishing a counting rate of 55 neutrinos per day according to the standard solar model. The outer part of the scintillator sphere serves as active shielding.

The demands on purity in terms of radioactivity in Borexino, especially for the scintillator itself, are very severe. In order to be able to extract a clear signal from background events also in case of total flavour conversion, an intrinsic concentration in Uranium and Thorium of ca. 10^{-16} should not be exceeded significantly. The amount of $^{14}C/^{12}C$ must not be higher than $\approx 10^{-18}$. In order to test scintillating materials a large Counting Test Facility (CTF) has been built up in hall C of the underground laboratory at Gran Sasso, which resembles to a small prototyp (ca. 5t of scintillator) of Borexino. From beginning of 1995 until summer 1997 several tests about the feasibilty of Borexino including procedures to maintain the purity of the scintillator has been performed, which showed very encouraging results: $^{14}C/^{12}C = 1.85 \cdot 10^{-18}$, $^{238}U = (3.5 \pm 1.3) \cdot 10^{-16}\ g/g$, $^{232}Th = (4.4 \pm 1.5) \cdot 10^{-16}\ g/g$. A complete discussion of the CTF results including experimental techniques for further background suppression is given in [1] and [2]. Details about the experimental setup of the CTF can be found in [3].

Highly developed neutron activation analysis of scintillation samples performed in Munich is now sensitive in the same regime. For uranium an upper limit of $^{238}U < 2 \cdot 10^{-16}\ g/g$ (90% CL) has been obtained. In addition concentration values or limits have been measured by this method for a various amount of isotopes, including man-made nuclei. For details, see [4].

Background studies for Borexino include also the interaction of cosmic muons. The direct detector response on muons has been determined by a coincidence measurement between the CTF and a muon telescope on top of it. The time distribution of such events can be used to discriminate between muon events and neutrino candidates at a level of 98%. However, to reach the sensitivity needed to reach the goals in Borexino, the leak rate for muons must not exceed a level of $\approx 10^{-4}$. Our design of the muon veto system therefore is threefold: The outer region between external tank and steel sphere acts as Cherenkov counter, a special configuration of the tubes inside the sphere will act as an additional muon identification system, and finally the offline study of event topology like the time structure will help to suppress this kind of background sufficiently.

Cosmogenic generation of radioactive nuclei has been sudied this fall at the 180 GeV muon beam at SPS in CERN. Most dangerous source of events will come from ^{11}C-production in the scintillator and surrounding buffer liquid. However, the energy spectrum of these events is between 1 MeV and 2 MeV since the decay mode is positron decay at 1 MeV endpoint energy. Thus the detection of ^{7}Be-neutrinos is not affected, however that of pep-neutrinos.

Prospects

Borexino is an international collaboration of about 60 scientists. Approved funding already comes from INFN, Italy and Germany (BMBF and DFG). A substantial part should also be covered by NSF, USA in the next future. Work on the external tank of Borexino is almost completed. We expect to finish with the inner steel sphere in 1999. Simultaneously the CTF will be upgraded. Finally it will serve as test facility for Borexino scintillator procurement in batch mode. Given full funding also for our american collaborators first data taking may be expected end of the year 2000.

References

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