Artificial neutrino source experiment in Borexino

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On behalf of the Borexino collaboration

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Abstract. An experiment with an artificial neutrino source in Borexino is presented. The neutrino source can be located outside the detector or eventually, at the end of the solar neutrino phase, could be deployed inside. The physics case for the source experiment includes the search for short-baseline neutrino oscillations, neutrino-electron scattering at sub-MeV range, neutrino magnetic moment. Preliminary predictions of the sensitivity are reported for the sterile neutrino search.

1. Introduction

Observations based on solar, atmospheric, reactor and accelerator neutrinos can be explained assuming neutrino oscillations and a three mass eigenstates mixing [1]. In particular, it turns out that $\sin^2\theta_{12} = 0.861^{+0.026}_{-0.022}$, $\Delta m^2_{12} = (7.59 \pm 0.21) \times 10^{-5}$ eV^2, $\sin^2\theta_{23} > 0.92$ and $|\Delta m^2_{32}| = (2.43 \pm 0.13) \times 10^{-3}$ eV^2 [1]. However, in this picture the so-called LSND anomaly on short-baseline [2] is not included. This anomaly can be explained by means of $\bar{\nu}_\mu \to \bar{\nu}_e$ oscillations with $\Delta m^2 \sim 1$ eV^2. Recently, the MiniBooNE experiment, designed with the same L/E as for LSND, in the neutrino mode has shown the same anomaly [3]. New reactor antineutrino spectra applied to old reactor neutrino experiments with a baseline of less than 100 m have shown an anomaly which again could be described with neutrino oscillations and a mass-squared difference of the order of 1 eV^2 [4]. Moreover, the deficit of the electron neutrinos measured in the radioactive source experiment of the GALLEX and SAGE detectors could also be described in terms of short-baseline oscillations [5]. In the last year these results have revived

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the interest in a possible sterile neutrino which could show up in short-baseline experiments. A brief summary of the sterile neutrino phenomenology can be found in [6].

In this framework we would like to consider a neutrino source experiment in Borexino. The basic idea is to locate an intense (anti)neutrino source by a detector to search for short-baseline oscillations. A number of studies and possibilities have already been reported in the literature [7], [8]. In Tab. 1 we summarize the main features of the possible artificial neutrino sources proposed for sterile neutrino searches.

Table 1. Possible isotopes for artificial neutrino source experiments.

Isotope	Decay mode	Mean life [days]	Energy [MeV]	kg/MCi	W/kCi
^{51}Cr	e-capture (E_γ=0.32 MeV, BR=10%)	40 (BR=81%)	0.746	0.011	0.19
^{37}Ar	e-capture	50.5 (BR=90.2%)	0.811	0.01	0.02
^{90}Sr-^{90}Y	fission product β^-	15160 (BR=100%)	<2.28	7.25	6.6
^{144}Ce-^{144}Pr	fission product β^-	411 (BR=97.9%)	<2.99	0.314	7.6

We point out that a $\sim$ 1.8 MCi (66 PBq) ^{51}Cr source has been used by GALLEX [9] and $\sim$ 0.5 MCi (18.5 PBq) ^{51}Cr source has been used by SAGE [10]. Moreover, a $\sim$ 0.4 MCi (14.8 PBq) ^{37}Ar source has been used by SAGE [11]. The production of such intense sources is a difficult task as it is described in details in the literature. The use of a 1.85 PBq ^{144}Ce-^{144}Pr source is discussed in [7] to be employed for sterile neutrino search coupled with detectors such as Borexino, KamLAND and SNO+. The same source is proposed in [8] to be used at Daya Bay reactor experiment.

2. The neutrino source in Borexino

The idea to make use of an artificial neutrino source in Borexino is not new. In 1991 the Borexino proposal reports about a ^{90}Sr-^{90}Y source to search for the neutrino magnetic moment [12]. Later, the possibility to employ the ^{51}Cr source made for GALLEX was discussed to be used for the neutrino magnetic moment with the Borexino detector [13], [14]. In [15] both the ^{90}Sr-^{90}Y and ^{51}Cr were considered to search for neutrino-electron weak coupling at 1 MeV scale and for sterile neutrinos in addition to the neutrino magnetic moment. In the construction of the Borexino detector a tunnel underneath the water tank has been built to allow the deployment of a neutrino source. In this configuration the source will sit 8.25 m away from the center of the detector. The main idea was, eventually, to make use of the ^{51}Cr which produces monoenergetic neutrinos at the same energy as the ^{7}Be solar neutrinos measured by Borexino. This source could be employed for a number of physics goals: energy scale calibration for the solar neutrino measurement, neutrino magnetic moment, neutrino-electron scattering at 1 MeV scale, short-baseline (10 m) neutrino oscillation search. In Fig. 1 we show three possible locations for the source in Borexino. We have named these locations as: A, outside in the tunnel at 8.25 m away from the center; B, inside the Water Tank, at most 4.5 m away from the center; C, at the center of the detector.

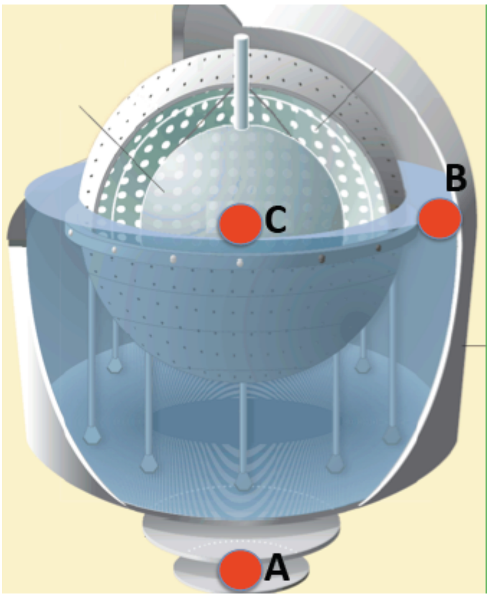

Figure 1. Possible locations for a neutrino source in Borexino. See text for details.

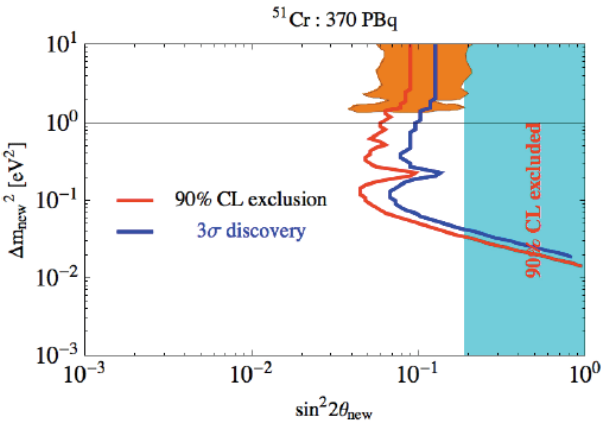

Figure 2. Sensitivity predicted for a 370 PBq ^{51}Cr source located outside the Borexino detector. See text for details.

Location A is existing and does not ask for any change in the detector configuration. For location B the Water Tank must be drained and some work is needed to deploy the source. For location C significant changes are required. This latter option can be pursued at the end of the solar and geo-neutrino measurement. In Fig. 2 we show the result of a two-neutrino oscillation experiment done with a 370 PBq ^{51}Cr source located outside the detector. In the same figure we report the 90% allowed region from a combined analysis of the reactor and gallium anomalies. We also report the 90% excluded region for the mixing angle θ_{14} (in our case named θ_{new}) due to the present solar sector phenomenology. For this study we have assumed as backgrounds the solar neutrino signal above 250 keV, the ^{210}Bi between 250 and 800 keV at 10 cpd/100tons. These assumptions suppose that the ^{85}Kr contamination has been removed by nitrogen stripping and that the existing contamination of ^{210}Po and ^{210}Bi has been reduced. This is actually the

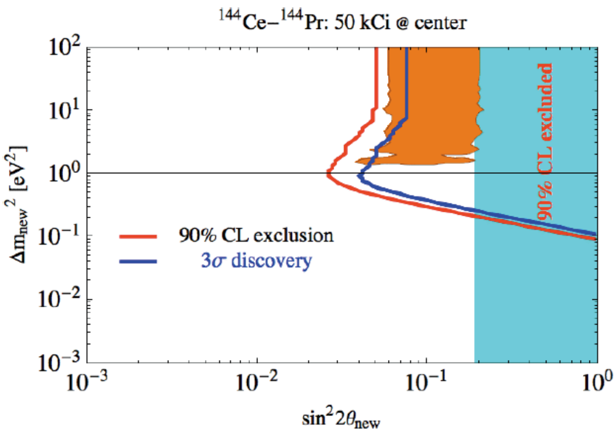

Figure 3. Sensitivity predicted for a 1.85 PBq ^{144}Ce-^{144}Pr source located at the center of the Borexino detector. See text for details.

case for ^{85}Kr and is within reach for ^{210}Po and ^{210}Bi in a time scale of 1-2 years. In Fig. 3 we report the result of a study with the source at the center for ^{144}Ce-^{144}Pr. In this case we have used a FV between 2m and 5.5m from the center. Therefore, about 29.5 tons of liquid scintillator work to shield the radioactivity coming from the copper and tungsten which make the source housing, which consists of an inner tungsten shielding and an outer copper one to reduce the emission of the 320 keV gamma-ray (see Tab. 1). The feasibility of a ^{144}Ce-^{144}Pr source is discussed in [7]. The feasibility of an intense (> 185 PBq) is being considered by means of a high thermal neutron flux ($\sim 2-5\times10^{14}$ cm^{-2}s^{-1}) reactor and enriched ^{50}Cr.

3. Conclusions

A possible neutrino source experiment in Borexino has been discussed. The feasibility to make intense neutrino or antineutrino sources is under consideration. An external source experiment with ^{51}Cr could be performed in a time scale of a few years. A location for the source at 8.25 m away from the center of Borexino already exists. A more sensitive experiment with the source at the center is considered. This experiment asks for major changes in the detector apparatus and will be done on the basis of the research program and international framework.

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