Neutron Activation Analysis of Scintillators for the Solar Neutrino Experiment BOREXINO ◇

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For the feasibility of solar neutrino spectroscopy in liquid scintillators via elastic neutrino-electron scattering the contents of the quasistable nuclides ^{238}U,^{232}Th and ^{40}K is of crucial importance. The planned BOREXINO detector consists of a transparent nylon vessel containing 300t of liquid scintillator that is viewed by 2000 photomultipliers [1]. The location in the Hall C of the LNGS at Gran Sasso shields the experiment from the cosmic radiation. Ultrapure water surrounding the nylon vessel provides a shield against γ's being emitted by the outer detector components like photomultipliers and the environment. The most stringent limits of radio purity are set on the inner detector components. The limits calculated by Monte Carlo simulations are listed in table 1. The tolerable limit for the radio purity of ^{238}U,^{232}Th in the liquid scintillator is in the range of 10^{-16}g/g.

Material	*U (g/g)*	*Th (g/g)*	*K (g/g)*
Scintillator	10^{-16}	10^{-16}	10^{-14}
Water	10^{-13}	10^{-13}	10^{-10}
Nylon	10^{-12}	10^{-11}	10^{-8}

Table 1: Purity design goals for BOREXINO

For the selection of suitable detector components neutron activation analysis is applied to analyse the liquid scintillators Pseudocumene and phenyl-o-Xylylethene. A tool for the survey of the contamination was developed and the detection sensitivity was improved to $5 \cdot 10^{-16}$g/g for U and 10^{-15}g/g for Th. This sensitivity allows to monitor the Uranium and Thorium content in the region required for BOREXINO. For testing purification efficiencies and quality of the liquid scintillators the analysis of liquid scintillators proved to be an indispensable tool as NAA is capable to detect the interesting impurities.

The increase in sensitivity was achieved by the extension of the irradiation time up to 100 hours at a thermal flux of $5 \cdot 10^{12} cm^{-2} s^{-1}$ and the use of a 150% high purity Germanium detector with a considerable high detection efficiency above 80keV and a LOAX high purity Germanium detector. For the irradiations of the liquid samples we made use of a unique facility at the research reactor (FRM I) in Munich, which allows to irradiate liquid samples up to a volume of 250ml. The activated products of Potassium, Uranium and Thorium were removed besides other ions from the irradiated liquid samples by acidic extraction with 5% HNO_3. This procedure had to be applied because of the heavy radiation induced disintegration of the scintillator which is connected to the loss of scintillating properties. However scintillation properties are needed for the detection of the β decays in the sample providing additional information leading to a significant reduction of the background. For the measurement of the actinides they were separated from the aqueous solution by liquid extraction with organophosphates and mixed into a scintillator cocktail. By this means a reduction of the background caused by other activated impurities was achieved and delayed coincidence techniques could be applied for the detection of Uranium.

The use of delayed $\beta - e^- - \gamma$ coincidences improves the signal to noise ratio by a factor of 10^4 compared to common γ spectroscopy by the suppression of the internal background of the sample. Because there is no special signature for the detection of Thorium, except the correlated beta, the content of Thorium was determined by $\beta - \gamma$ coincidences reducing the external background of the γ -spectrometer. Due to the high detection efficiency of the 150% Germanium detector the detection limit of Potassium was improved up to 10^{-13} g/g for the investigated scintillators. For the detection of the activated ^{42}K emitting a single 1524.6keV γ any coincidences were used because the sample's internal background is dominating. The application of an anticompton spectrometer could therefore suppress the compton background as well as the interfering decay of ^{24}Na. The nylon samples can be analysed without any decomposition leading to a sensitivity sufficient for BOREXINO in the detector configuration currently in existence.

Material	*U (g/g)*	*Th (g/g)*	*K (g/g)*
Scintillator	$\leq 2 \cdot 10^{-15}$	$\leq 5 \cdot 10^{-15}$	$\leq 10^{-11}$
Water	$1 \cdot 10^{-14}$	not measured	$3 \cdot 10^{-10}$
Nylon	$2 \cdot 10^{-12}$	$5 \cdot 10^{-12}$	$1 \cdot 10^{-8}$

Table 2: Determined concentration of inpurities

At the moment the irradiation facilities at the FRMI are extended for the analysis of nylon and wavelength shifters while the lead shieldings of the Germanium detectors are being optimized. In order to reduce the radon originated background the inner of the γ-spectrometers will be flushed with nitrogen to replace the air.

References

[1] BOREXINO Collaboration, "Borexino Project, the Counting Test Facility, its results and the BOREXINO design", internal report to the INFN, July 1995

[2] T. Goldbrunner et al., Neutron Activation Analysis of Detector Components for the Solar Neutrino Experiment BOREXINO, proceedings of MTAA-9, 1995 September 24-30, Seoul, Korea, to be published in Journal of Radioanalytical and Nuclear Chemistry

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