The Borexino Experiment Liquid Scintillator Purification and Containment System

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Abstract. Borexino is a large volume, real-time, liquid scintillator detector located at the Gran Sasso National Laboratory in Italy. The principal objective of the detector is to measure mono energetic (862 keV) ^{7}Be neutrinos from the sun present with a count rate of several tens of events per day. Measurement at this level requires an extremely low internal background due to natural radioactivity present in the detector components. In this paper the techniques used by Borexino to purify the scintillator and to build the nylon containment vessels are described. The unprecedented high radiopurity reached by Borexino permitted for the first time the real-time detection of ^{7}Be neutrinos from the sun[1].

1. The Borexino Design:

The design of Borexino is based on the principle of graded shielding by which the scintillator is shielded by a series of concentric shells of increasing radiopurity and the entire detector is located at 3500 m.w.e. underground. The scintillator (278 ton), composed of pseudocumene (PC) and 1.5 g/L of the fluor 2,5-diphenyloxazole (PPO), is contained in a thin (125 μm) nylon spherical shell (IV) with a radius of 4.25 m. Concentric with the IV is a second nylon sphere (OV) at a radius of 5.50m and a Stainless Steel Sphere (SSS) at 6.55 m. The medium between both vessels consists of 323+567 tons of PC+5g/L Dimethyl Phthalate (DMP) which quenches the light produced by radioactivity outside the IV. In addition, the OV acts as a radon barrier and the SSS supports the PMT's. Finally the SSS is itself embedded in 21,000 t of ultra-pure water (UPW) providing a shield against external radiation. Within the IV, a fiducial mass of 100 tons is defined by software selection of the events. The scintillator purification and containment systems play a central role in achieving the low backgrounds needed for the detection of the ^{7}Be solar neutrinos.

2. The Borexino Purification Process:

This unprecedented purity (4 decay/day/100 t scintillator) for a large-scale liquid scintillation detector was achieved with a purification system [2] that emphasized cleanliness and leak tightness. Pseudocumene (PC), the scintillator solvent, was delivered by tanker truck to the underground lab at Gran Sasso. It was loaded into storage tanks and purified at a rate of 800 L/h. The PC was fed to a 6 m tall, 0.75 m diameter 6-tray vacuum distillation column to remove low volatility radioactive impurities (e.g. U, Th, K). After distillation the PC was stripped of radioactive noble gas impurities (^{39}Ar and ^{85}Kr) with specialty nitrogen low in Argon and Krypton (LAKN). Gas stripping was done in a 8 m tall, 0.15 m diameter column filled with structured packing. Purified PC was mixed with either a pre-purified concentrated solution of the fluor (PPO) or quencher (DMP) to fill the scintillator and buffer volumes respectively. Five 860 L batches of concentrated fluor master solution (140 g-PPO/L-PC) were purified by a combination of water extraction, filtration, single stage vacuum distillation and nitrogen stripping. The scintillator and buffer regions were filled by periodically switching between volumes to maintain equal levels and hydrostatic head in all three volumes of the Borexino detector. The purification facility is entirely composed of stainless steel, which has been electropolished, and treated to be corrosion resistant. In addition, the equipment has been precision cleaned to a particulate level <30 (MIL-STD-1246C) and assembled in a class 100 clean room. All flanges are double sealed and are continuously purged with N_2. All fittings in the scintillator path have also been surrounded with special aluminum boxes and are continuously purged with N_2. After final assembly, each part of the entire system has been vacuum leak checked to the level of 10^{-8} mbar L/sec.

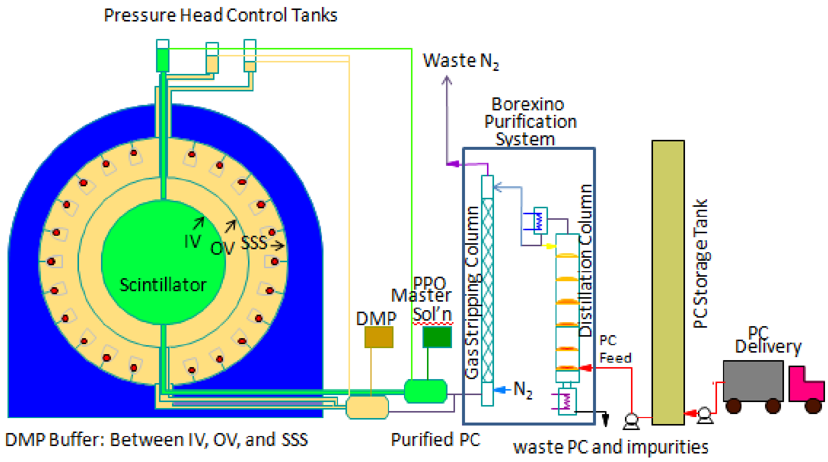

Figure 1: The Borexino Liquid Scintillator Purification System

3. The Liquid Scintillation Containment System (IV,OV):

The nylon chosen for scintillator containment [3] satisfied specific requirements such as chemical compatibility, mechanical strength, low radioactivity, optical transparency, clean fabrication, leak tightness, and low Rn permeability.

The assembly and installation of the nylon vessels was particularly complex, because of the kinds of materials used, and the methodology adopted to cut, assemble and bond the nylon. In addition, all operations were done in a class 100 clean room at Princeton University, in which by using a dedicated pressure-swing adsorption system the air was kept Rn-free. Each of the two nylon spheres is composed of more than 30 separate pieces, carefully stacked to prevent contamination, and bonded utilizing a precisely controlled resorcinol aerosol spray. Insertion of the completed IV within the outer OV was performed prior to OV sealing. A complicated set of winches, pulleys and scaffolding was used to raise the vessels into position within the SSS at Gran Sasso.

After installation, the vessels were purged with several volumes of LAKN N_2. Prior to the final filling with scintillator (completed in May 2007), the vessels were filled with ultra pure water for testing the purification facility and for shedding the nylon surface of nylon monomers and residual radioactive metal ions.

References

[1] Arpesella *et. al.*, accepted for publication Phys. Lett. B., arXiv:physics/0708.2251v2.
[2] J. Benziger *et. al.*, accepted for publication in Nucl. Instr. Meth. A., arXiv:physics/0702162.
[3] J. Benziger *et. al.*, Nucl. Instrum. Meth., A582, 509-534, 2007.