Optimization of the thickness of the water wall

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1. Water purification level
   The Borexino water purification system provides water with ^{232}Th/^{238}U/^{nat}K in a level of ~3 $\times 10^{-14}$ g/g and 10^{-14} g/g [1]. What we require the radiopurity of water is about 10^{-13} g/g. At this level, the gamma rays produced in the water will not contribute significantly to the total gamma-ray flux in the shielded room.
2. Gamma-ray flux from the experimental hall
   We measured the gamma-ray flux at the levels of the 800 ft, 2000 ft, and 4550 ft. Using the knowledge of the rock chemical composition and the radioactivity level counted by Al Smith at LBL, we are able to predict the gamma-ray flux at the 4850-ft level. The flux is about 1.76 cm^{-2} s^{-1} [2].
3. Gamma-ray flux from the supporting materials
   We investigated the supporting materials for the water shield.
   Case 1: stainless steel. GERDA experiment counted the radioactivity from several samples of stainless steel [3]. The conclusion is that the radioactivity level in stainless steel is about 1 mBq/kg for both ^{232}Th and ^{238}U but 19 mBq/kg for ^{60}Co [3]. The counted stainless steel samples from Borexino [1] show a similar level of radioactivity. Using this measured radioactivity and the dimensions of the water room with a thickness of 1/8 inches of stainless steel, we estimate that the gamma-ray fluxes induced by the radioactivity in the stainless is about 10^{-5} cm^{-2} s^{-1} originating from the ^{232}Th and ^{238}U and ~10^{-4} cm^{-2} s^{-1} from ^{60}Co.
   Case 2: acrylic. SNO [4] and EXO [5] have counted the radioactivity in the acrylic samples. The measured levels are 14 × 10^{-12} g/g and 24 × 10^{-12} g/g for ^{232}Th and ^{238}U. The natural potassium is less than 2.4 × 10^{-9} g/g. The gamma-ray flux is estimated to be ~10^{-5} cm^{-2} s^{-1}.
4. Optimization of the thickness of the water shield
   The simulation of the reduction factor as a function of water thickness for both gamma-rays and neutrons are shown in figure 1.

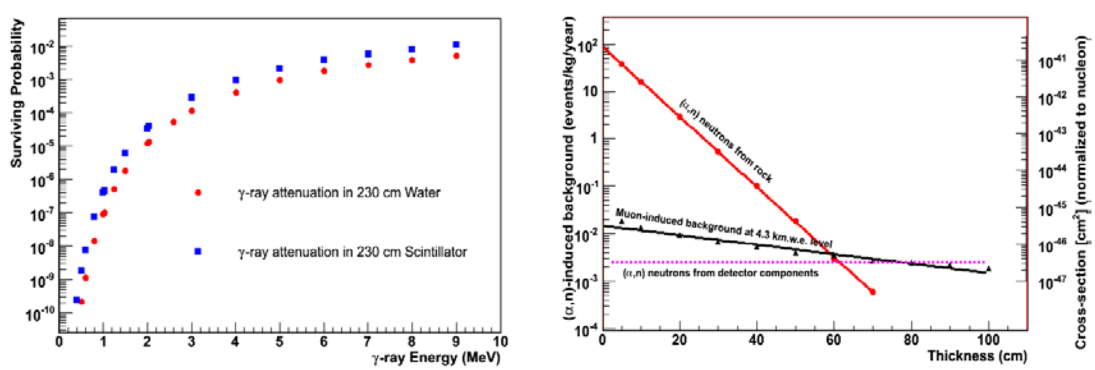

Figure 1. Left: Gamma-ray survival probability as a function of energy in water and scintillator. Right: Neutrons reduction factor as a function of thickness in water.

As can be seen in figure 1, after 230 cm of water, the gamma-rays and neutrons from the rock are reduced to a level (10^{-5}) at which the gamma-ray flux and neutron flux are dominated by the radioactivity from the supporting materials, assuming stainless steel and acrylic structures. Additional active shielding or pure copper will be needed for individual screeners, depending on their required sensitivity. Therefore the optimized thickness of water shield would be 230 cm.

References:

[1] Measurements of extremely low radioactivity levels in Borexino, the Borexino Collaboration.

[2] Early Results on Radioactivity Background Characterization for Sanford Laboratory and DUSEL Experiments, D.-M. Mei, C. Zhang, K. Thomas, F. Gray, arXiv: 0912.0211.

[3] Measurements of extremely low radioactivity levels in stainless steel for GERDA, W. Maneschg et al., NIM A 593 (2008) 448 – 453.

[4] Measurements of Th & U in Acrylic for SNO, E. D. Earle and E. Bonvin.

[5] Systematic study of trace radioactive impurity in candidate construction materials for EXO-200, D. S. Leonard et al., arXiv: 0709.4524v2.