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DESIGN OPTIMIZATION OF LIQUID SCINTILLATION COSMIC RAY VETO DETECTOR WITH BBQ SHIFTER

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Abstract

Certain design characteristics of a liquid scintillator detector for charged cosmic particles, have been studied. These include evaluation of scintillator emission spectra, absorption in various thicknesses of BBQ shifter bars and effective transmission in long lengths of BBQ acrylic. For our BBQ sample, 12.5 mm thick with semicircular shape, the shifted light was transmitted with 2.0 m absorption length.

Objective

A large volume liquid scintillation detector is to be used for neutrino oscillation experiments[1]. Detection of various cosmic events is imperative for background rejection to be accomplished during the data reduction[2]. It is planned to detect charged cosmic events by a veto counter that surrounds the central detector volume (4470 liter central volume with 2000 liter in the veto).

Our objective for the effort described here, was to obtain pertinent data leading to decisions for the choice of various component parameters affecting the detection efficiency of the veto detector. Such parameters included the scintillator solutes to best match the BBQ shifter[3] and the type of reflector. Associated studies were made of the absorption in various thicknesses of BBQ and transmission in long lengths of BBQ waveshifter bars.

Experimental Configuration

The veto counter features (Figs. 1 and 2) were chosen because of a desire to 1) provide three electrically independent signals due to cosmic events to be detected in the top, bottom, and sides of the detector, 2) minimize the total volume to be used by photomultiplier detection, thereby reducing cost of the drilled hole into which the detector was to be placed, and 3) to economize the cost for photomultiplier tubes.

Scintillator Emission Spectra

The large volume aspects of the detector led to a choice of p-xylene as the scintillator solvent from a desire for high light output, good transmission (preliminary measurements indicate 15 m absorption length for light produced by β particles), pulse shape discrimination capability and low cost.

Two solutes were evaluated: 1) p-terphenyl and POPOP (1,4-di-2-(5-phenyloxazolyl) benzene) because of economy and 2) butyl-PBD[4] (7 g/ℓ) because it is more readily soluble and has better spectral match to BBQ.

The emission spectrum from these scintillators was found to depend upon the method of excitation (soft X rays, ultraviolet light, and ^{60}Co gammas) and further studies were restricted to ^{60}Co gamma radiation since that more closely approximates cosmic muon excitation. Measured emission spectra are contained in Fig. 3.

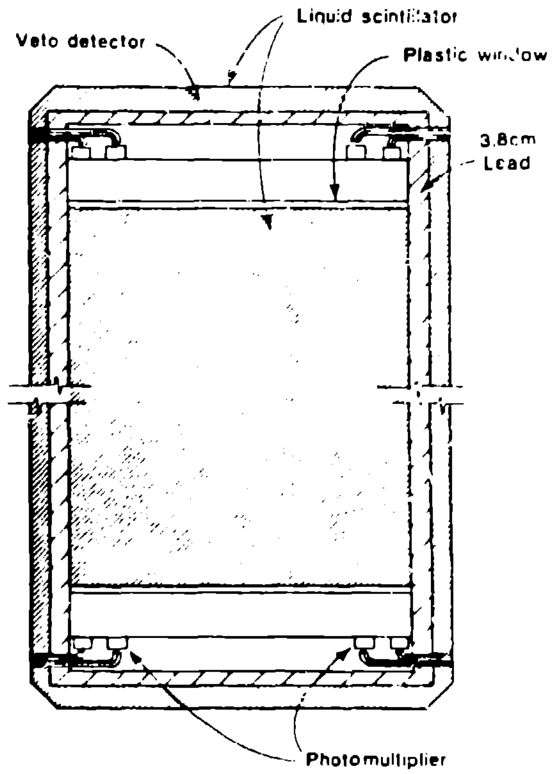

Fig. 1. Schematic of detector and veto regions. The outermost dimensions are 2.3 m dia. and 5.7 m high.

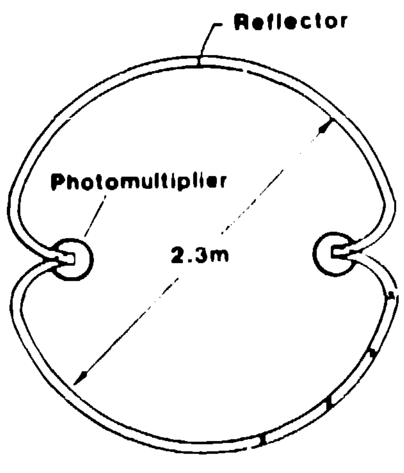

Fig. 2. Acrylic BBQ scintillator shape. Thickness is 12.5 mm. Positions of light source for current measurements are indicated by "X."

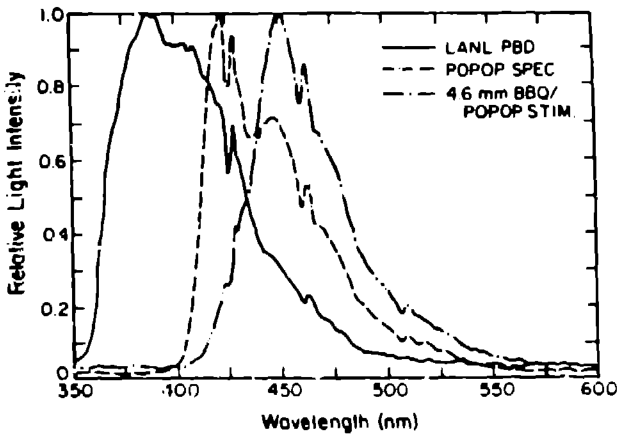

Fig. 3. Normalized emission spectra of two liquid scintillators, produced by ^{60}Co gamma radiation, in comparison with stimulated emission from BBQ acrylic.

<u>Absorption in BBQ</u>

Light was created in liquid scintillator (p-xylene with 5 g/ℓ p-terphenyl and 0.4 g/ℓ POPOP) by ^{60}Co gamma radiation. Such light was directed normal to the BBQ (90 mg/ℓ BBQ[5] in acrylic) surface illustrated in Fig. 2. Transmission and spectra of light were measured with the Tracor Northern TN-1710 Multi-Channel Analyzer. This system utilizes the TN-1150 Holographic Rating Monocrometer and the TN-1223-21512 element intensified reticon array. A 100 micron slit was used for these measurements. Therefore, the resolution of the spectra measurements are ±3 nm. The transmission for various wavelengths is indicated in Fig. 4. At wavelengths shorter than about 440 nm, the absorption is strong with attenuation length of several mm.

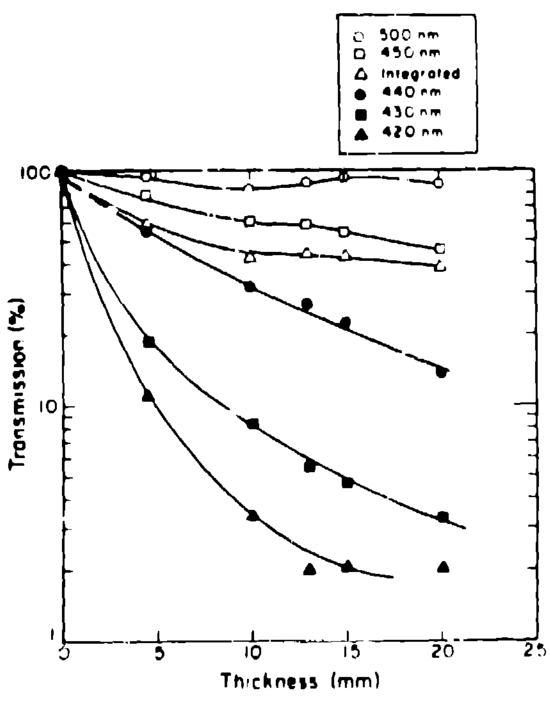

Fig. 4. Optical transmission at various wavelengths for differing thicknesses of BBQ in acrylic.

The scintillator light just described was also directed normal to the BBQ of various thicknesses, while we observed the corresponding current from a photodiode (S20 response) at the end of the shifter bar, a distance of 10 cm from the location of the scintillator light source passing through the BBQ. Figure 5 indicates this dependence for scintillators with POPOP and with butyl-PBD.

Inconsistencies in the data of Fig. 5 make a detailed conclusion difficult, possibly due to differences in the scintillator efficiencies (our samples were not of the same batch). These data suggest nearly linear dependence of light output on BBQ thickness up to ~15 mm, for the POPOP case. Output for the case of butlyl-PBD appears to be linear up to ~5 mm. This seems consistent with the data presented in Fig. 4. That is, butyl-PBD spectrum is mostly comprised of light below 420 nm where the absorption length is less than ~2 mm, as indicated in Fig. 4. The POPOP/terphenyl spectrum, however, contains significant fraction of light near 440 nm where the absorption length is near 8 mm.

The scintillator light was directed normal to the BBQ surface illustrated in Fig. 2, at various points along the length of the BBQ shifter bar. The relative currents from a detector at the end of the BBQ are contained in Fig. 6.

An absorption length of 2.0 m (1/e value) is indicated from these measurements for the BBQ stimulated emission spectrum, a value which contains the effects of bulk absorption as well as attenuation due to geometry and surface imperfections. Variation of the detector response from S20 to S11 did not alter the absorption length observed.

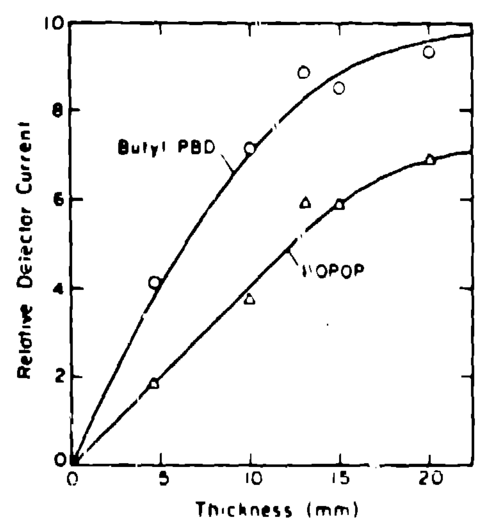

Fig. 5. Relative light collected at end of BBQ acrylic of various thicknesses, for two different incident light spectra from liquid scintillators. In both cases, the ^{60}Co gamma irradiation was held constant.

<u>Comparison of POPOP with butyl-PBD</u>

For the same geometrical conditions, butyl-PBD gave more light output for the detector at the end of the BBQ than POPOP by a factor of 1.37. This result, however, was obtained with a glass window between the liquid scintillator and the BBQ. Our detector configuration entails a window of 5 mm acrylic with

0.'3 mm clear Teflon, materials that attenuate the lower wavelength butyl-PBD light and give less light collection at the end of the BBQ shifter by a factor of 2 in comparison to POPOP. This loss factor could have been eliminated largely by use of UV transmitting acrylic window and use of a material such as aluminum foil on the inner surfaces of the liquid container. Such a foil material, having a higher reflectivity below 400 nm than most white surfaces, allows multiply reflected light to reach the BBQ that otherwise would be lost to the liquid container surfaces.

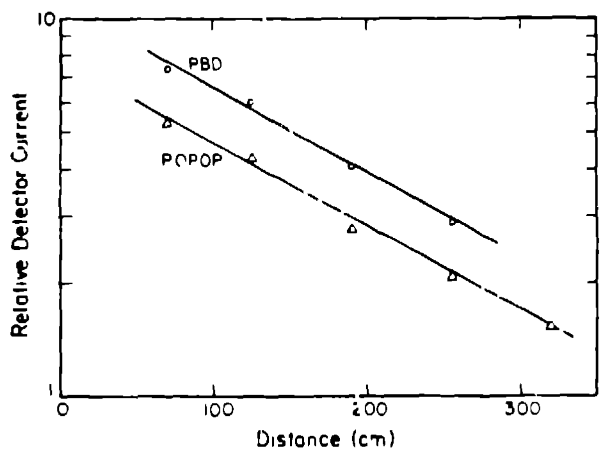

Fig. 6. Observed dependence of detector current on BBQ acrylic distance, when stimulated by differing spectra from liquid scintillators. The thickness of BBQ was 12.5 mm in a semicircular shape. The positions of the liquid scintillator light on the BBQ is illustrated in Fig. 2.

Reflector Materials

We searched for a good economical reflector which was chemically compatible with our liquid scintillators, primarily containing xylene. We found that Epoxy Patch 560[6] met these criteria. It can be thinned with methanol to permit painting on a large surface and its reflectivity can also be enhanced by adding MgO, BaS, or TiO_2. Commercially available vinyl paint appears unacceptable since a residue forms after a few days. NE-561[5] and ND707[4] appear acceptable from the standpoint of chemical stability and physical appearance. Evaluation of reflectivity is in progress.

Reflective materials placed adjacent to the BBQ plastic were found to be helpful in retaining a greater fraction of the incident light energy. Crumpled aluminum foil, aluminized Mylar, or white Styrofoam all increased light collected at the end of the BBQ ring (Fig. 2) by about 10%. However, an optical grease coupling between BBQ and the photo-multiplier reduc[illegible] he light collected by 5% in comparison to [illegible]pling.

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