SNO-STR-91-07

Backgrounds Estimates for the PMT Region SNO-STR-91-07

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The support frame and PMT properties have recently been characterized with enough detail to make it worthwhile to update the previous estimates of backgrounds in the PMT region [1]. In addition, the modelling of the geometry of the PMT has been improved, a model of the reflector has been introduced and the effect of additional PMT components has been considered.

Geometry

The "active" components of the support frame were taken to be 8.05 tonnes of stainless steel 3" dia., 1/8" thick tubing. The stainless steel was assumed to have 10 ppbU/Th, and to be 22.95 cm center to center away from 3000 phototube bulbs out of the total of 10000 PMTs. The hexagons used to hold the PMTs are assumed to be "clean" plastic so they contribute nothing to the background.

The PMTs themselves were assumed to have 0.75 kg of glass with 40 ppbU/Th and to have inside the bulb 0.25 kg of dynode metal (no radioactivity) and 0.029 kg of alumina ceramic with 1.29 ppmTh and 1.23 ppmU. The pinout assembly was modelled as a cylindrical cup 7.0 cm diameter by 6.0 cm long with its end touching the glass bulb and containing 0.090 kg of glass and 0.085 kg of metal. The radioactivity (25 μg of thorium and 25 μg of uranium) was placed in the base of the "cup" farthest away from the PMT bulb. The pinout metal was assumed to be "clean". The PMT bases were assumed to contain 6.2 grams of alumina capacitor per base with 5.8 ppmTh and 3.8 ppmU. No allowance has been made yet for metal connectors or for the presence of the potting compound.

The reflectors were modelled as a 20 cm dia. by 18 cm long cylinder extending forward from the center of the PMT. For the omega case each reflector contains 75 grams of aluminum which has 1 ppmU and 0.1 ppmTh in equilibrium (This gives 6.02 n/y/g). Five year old disequilibrium conditions were used to estimate the neutron spectrum. For glass reflectors 0.45 kg of 40 ppb glass was assumed.

Results and Discussion

A summary of the source strengths of the various components in the support frame region is given in Table 1. The column labelled "source" lists the component that generates the neutrons and direct (the (α,pγ)) γ rays. The column labelled "target" indicates the γ ray yield from the particular component that is irradiated by the neutrons from the corresponding source. Results are given as the number of γ rays per day released into 4π with energy greater than 5 MeV. Yields from both (n,γ) and (α,pγ) reactions are listed. In addition an estimate of the amount of thorium per PMT is included in order to indicate the relative importance to the PMT $\beta\gamma$ background. The (n,γ) yield is listed separately for each component in column 3 and the total (n,γ) yield for the particular source of neutrons is listed in column 4. The sum of the (n,γ) and (α,pγ) yields for a particular source are listed in column 6.

The dominant background in the present calculation is that from the (α,pγ) reaction in the aluminum of the omega reflector, which is at least a factor of 10 greater than that from any other component. The estimated total background using omega reflectors is approximately a factor of three greater than for glass reflectors. However it must be remembered that aluminum metal is normally in disequilibrium which can significantly affect both (α,n) and (α,pγ) yields. A depletion would result in a reduction of the yields - uranium by the depletion factor and thorium by a time-dependent factor of no more than about two or so. It is therefore likely that the present value of the omega background is an overestimate, possibly significantly so.

If glass reflectors are used, then the summed (n,γ) background from the geodesic provides the largest single background, being somewhat more than one third of the total background. The summed (n,γ) from all sources is about 45% of the total background.

If individual components of the background are compared in the case of glass reflectors, the total backgrounds from each of the components are within about a factor of 2 of each other, with the base providing the largest contribution and the geodesic providing the smallest one. The largest individual backgrounds are the (α,pγ) contribution from the base and the ceramic. The (n,γ) background is dominated by the irradiation of the stainless steel geodesic in all cases, with the base providing the largest contribution.

The factors which would most effectively reduce the background in the PMT region assuming glass reflectors are a reduction in the geodesic steel mass and reduction in the base activity. The geodesic mass seems unlikely to be reduced further, but it appears to be possible to reduce the activity in the base. This source is dominated by the activity in the capacitors. However it should be remembered that no estimate of the effect of the potting compound or the cables and connectors has been included. On the other hand the estimated activity of the capacitors was a conservative value. Also, the estimate for the effect of the pinout glass likely is somewhat low because the calculation uses a complete sphere of glass for the PMT bulb. This has the effect of artificially placing a boron-loaded plug between the (hot) pinout and the metallic electron multiplier assembly in the PMT.

It is also possible to compare the effect of the PMT region background with that from other sources. This is shown in Fig. 2 for the case of omega reflectors. The detected background spectra for a 6 m fiducial radius are shown. Also shown for comparison are the various signal spectra. The elastic scattering and charged-current rates are for 1/3 SSM and the neutral current rate is for a full SSM. The neutral current background is for the White Book activities in the H_2O, D_2O and acrylic vessel, but for a 30 tonne vessel mass. The vessel support ropes have not been included. The contribution from the PMT region (marked "PMT") is slightly smaller than the contribution from the external cavity. If glass reflectors were used the PMT region background would be about a factor of 3 smaller than the cavity background level. (These comments are subject to the provisos about disequilibrium discussed earlier.)

The PMT region background level shown in Fig. 2 is conservative in that *all* the contributions from the PMT region have been estimated as if they were located at 8.5 m, the front face of the reflectors. This is a reasonable estimate for the omega case since the main contribution comes from the reflector itself. In the case of a glass reflector the mislocation of the other components would be more significant, especially the base. However, the most important trajectories for γ rays reaching the vessel for most of the components considered are those through the PMT, which is mostly vacuum. It therefore seems likely that including the detailed geometry for these components would add little more than the water between the front face of the reflector and the front face of the PMT. This amounts to about 7 cm, corresponding to roughly a 20% increase in attenuation. The contribution from the support frame itself would likely be attenuated by an amount closer to the full geometric distance, so that an additional attenuation of approximately a factor of two could be applied to the frame activity.

References

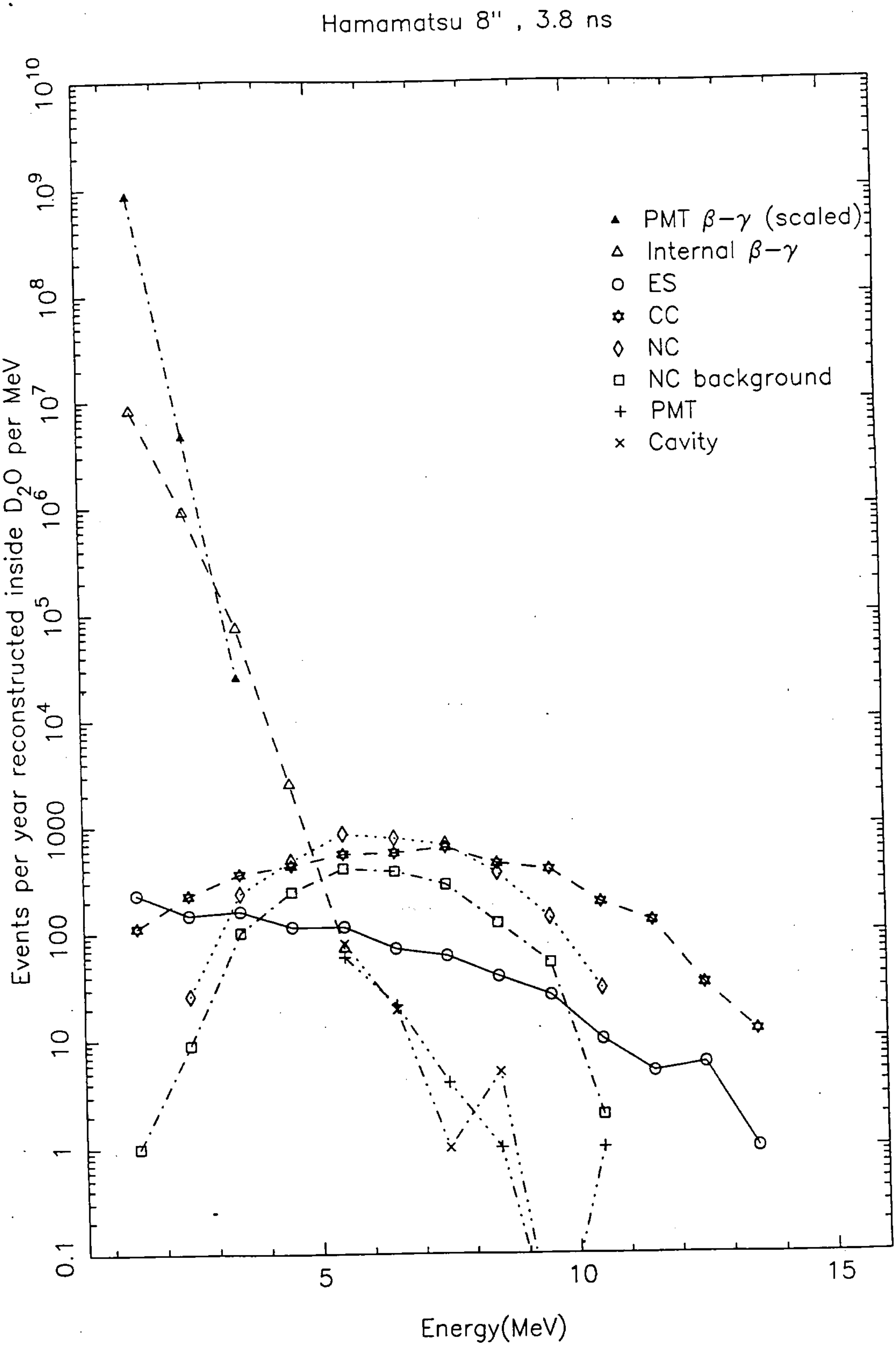
[1] P. Skensved, H. Lee, R. K. Heaton and B. C. Robertson, **The Effect of Aluminum on Backgrounds in the Phototube Region**, SNO-STR-89-83.

Table 1.

Frame Background Summary

Source	"Target"	* Reaction (HEgammas per day 4pi) *				
		* (n,gamma)		(alphapgamma)	sum *	betagamma
geodesic	PMT	-				
	geod	14.0	14	-	14	
	refl	-				
PMT(glass)	PMT	4.2		15		30 ug
	geod	20.6	26		41	
	refl	1.1				
(pinout)	PMT	5.5		13		25 ug
	geod	26.6	33		46	
	refl	0.5				
(ceramic)	PMT	1.5		44		22 ug
	geod	7.9	10		54	
	ref	0.4				
(base)	PMT	6.5		61		35 ug
	geod	31.4	39		100	
	refl	0.6				
Reflector (omega)	PMT	18.6				
	geod	19.2	47	603	650	8 ug
	refl	8.8				
(glass)	PMT	1.2				
	geod	3.6	5	9	14	18 ug
	refl	0.2				
				Total	903 (omega)	
					267 (glass)	

Units for (n,gamma) and (alpha,pgamma) are gammas (>5 MeV) per day into 4pi. Units for betagamma are micrograms of thorium, since this determines the high


Hamamatsu 8" , 3.8 ns
PMT $\beta-\gamma$ (scaled)
Internal $\beta-\gamma$
ES
CC
NC
NC background
PMT
Cavity
Events per year reconstructed inside D_2O per MeV
10^{10}
10^9
10^8
10^7
10^6
10^5
10^4
1000
100
10
1
0.1
5
10
15
Energy(MeV)