Beta-Gamma Backgrounds from ^{212}Bi, ^{228}Ac and ^{234}Pa in the Heavy Water and Acrylic
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The isotopes in the ^{232}Th and ^{238}U decay chains which are of the most concern in the SNO detector are ^{208}Tl and ^{214}Bi respectively. Both of these elements produce important γ-rays with energies above 2.223 MeV, and in addition the total decay energies are above 3 MeV. Monte Carlo simulations using the EGS4 code, with the decay schemes of these isotopes as input, have previously been performed. Showers were initiated in the D_2O, the acrylic, the H_2O within 2.5 m of the acrylic vessel, and the PMT glass, and the numbers of events which were reconstructed as having taken place in the D_2O were plotted versus energy.

The other isotopes which produce high-energy beta-gamma coincidences are ^{212}Bi and ^{228}Ac in the ^{232}Th chain and ^{234}Pa in the ^{238}U chain. Simulations based on the decay schemes for these elements have now been run with the showers initiated in the heavy water and the acrylic. The decay schemes used were simplified versions of the true decay schemes, considering only important γ-rays with energies above 1 MeV, and sometimes combining two or three γ-rays with nearly identical energies and starting levels.

The activity of each of the new isotopes is given in Table 1.

Table 1: Activity levels of ^{212}Bi, ^{228}Ac and ^{234}Pa in the SNO detector

	D_2O	Acrylic
^{232}Th conc. (g/g)	11×10^{-15}	1.9×10^{-12}
^{238}U conc. (g/g)	11×10^{-15}	3.6×10^{-12}
^{212}Bi β-γs/year	904596	4687454
^{228}Ac β-γs/year	1413444	7324212
^{234}Pa β-γs/year	4315465	42370022

As some of the elements undergo many decays per year, and computer time considerations made running more than 5,000,000 showers per simulation impractical, fewer than a year's worth of showers were started in some cases. The fractions of one year's decays that were run are shown in Table 2.

Table 2: Fractions of one year's decays simulated

Element	D_2O	Acrylic
^{212}Bi	1.0000	1.0000
^{228}Ac	3.5375	0.5000
^{234}Pa	1.0000	0.1000

The resulting plots are shown in Figures 1 through 4. Figure 1 is a plot which includes only ^{208}Tl and ^{214}Bi in the D_2O and acrylic curves. Figure 2 shows the sums of all five elements in the curves. Figure 3 shows the complete acrylic curve and separate plots of ^{212}Bi, ^{228}Ac and ^{234}Pa in the D_2O. In Figure 4, the D_2O curve includes all elements, while the three new elements are plotted separately for the acrylic.

In both the D_2O and the acrylic, the ^{234}Pa makes a significant contribution to the total background at 1.5 MeV, increasing the acrylic ^{208}Tl + ^{214}Bi total by about 40% and increasing the corresponding D_2O figure by about 30%. The other two isotopes are not as important. At 2.5 MeV and higher energies, none of the three new isotopes adds much to the totals. Because of the large ^{234}Pa contribution at 1.5 MeV, the acrylic background now dominates that from the D_2O at all energies.

Conclusion:

The addition of the backgrounds from ^{212}Bi, ^{228}Ac and ^{234}Pa to those from ^{208}Tl and ^{214}Bi does not cause a significant change in the totals for energies above 1.5 MeV. At 1.5 MeV, however, there are enough ^{234}Pa β-γ events reconstructed inside the D_2O to noticeably increase both the D_2O and the acrylic totals. The acrylic background dominates that from the D_2O at all relevant energies.

Unfortunately, time constraints did not allow simulations of ^{212}Bi, ^{228}Ac or ^{234}Pa decays to be run with the light water or the PMT glass as the starting regions. However, judging by the results from the D_2O and the acrylic, there would probably not be much effect on the background at energies above 1.5 MeV.

Figure 1: ^{208}Tl and ^{214}Bi $\beta-\gamma$ in D_2O and Acrylic

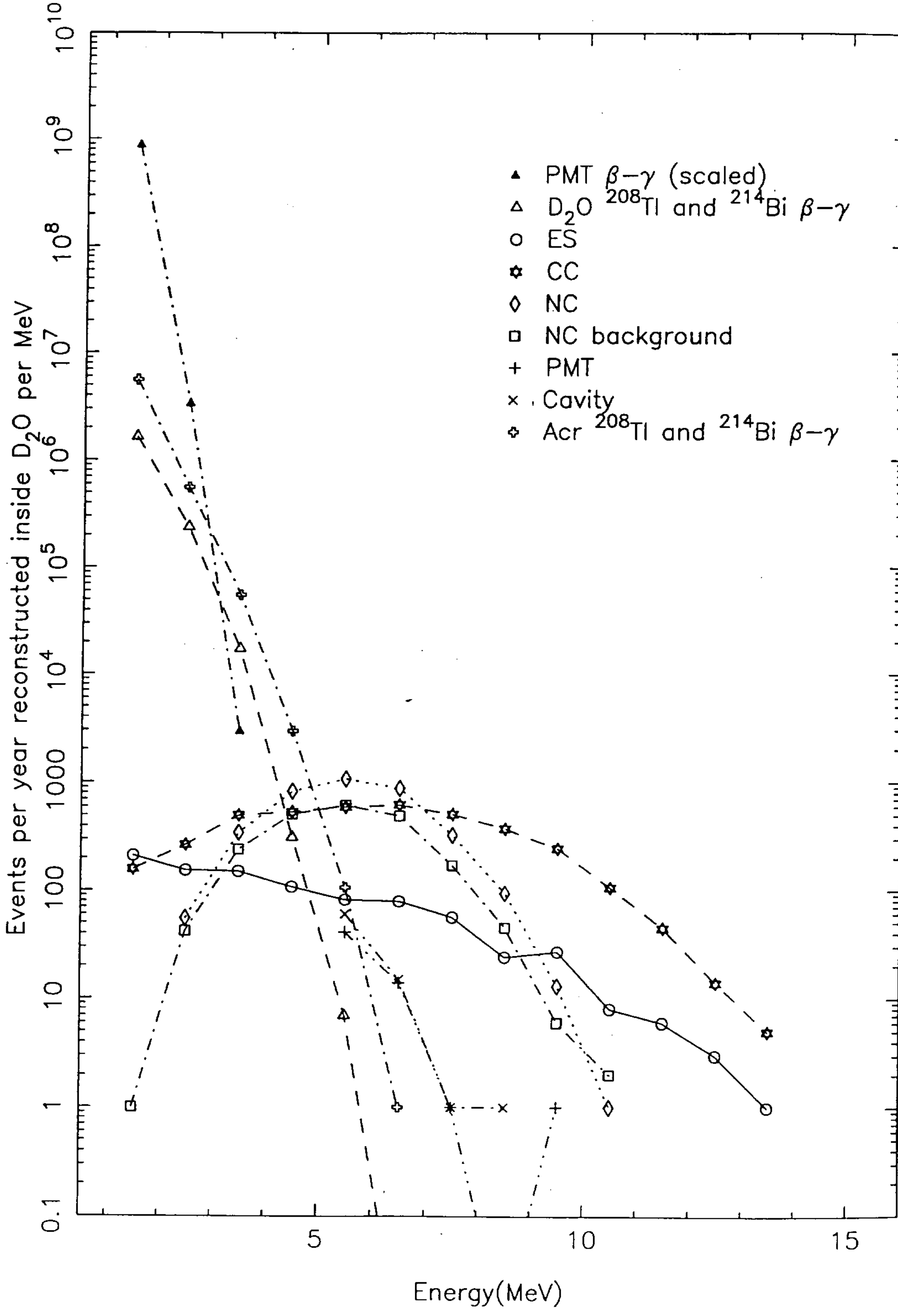

Figure 2: Total $\beta-\gamma$ in D_2O and Acrylic

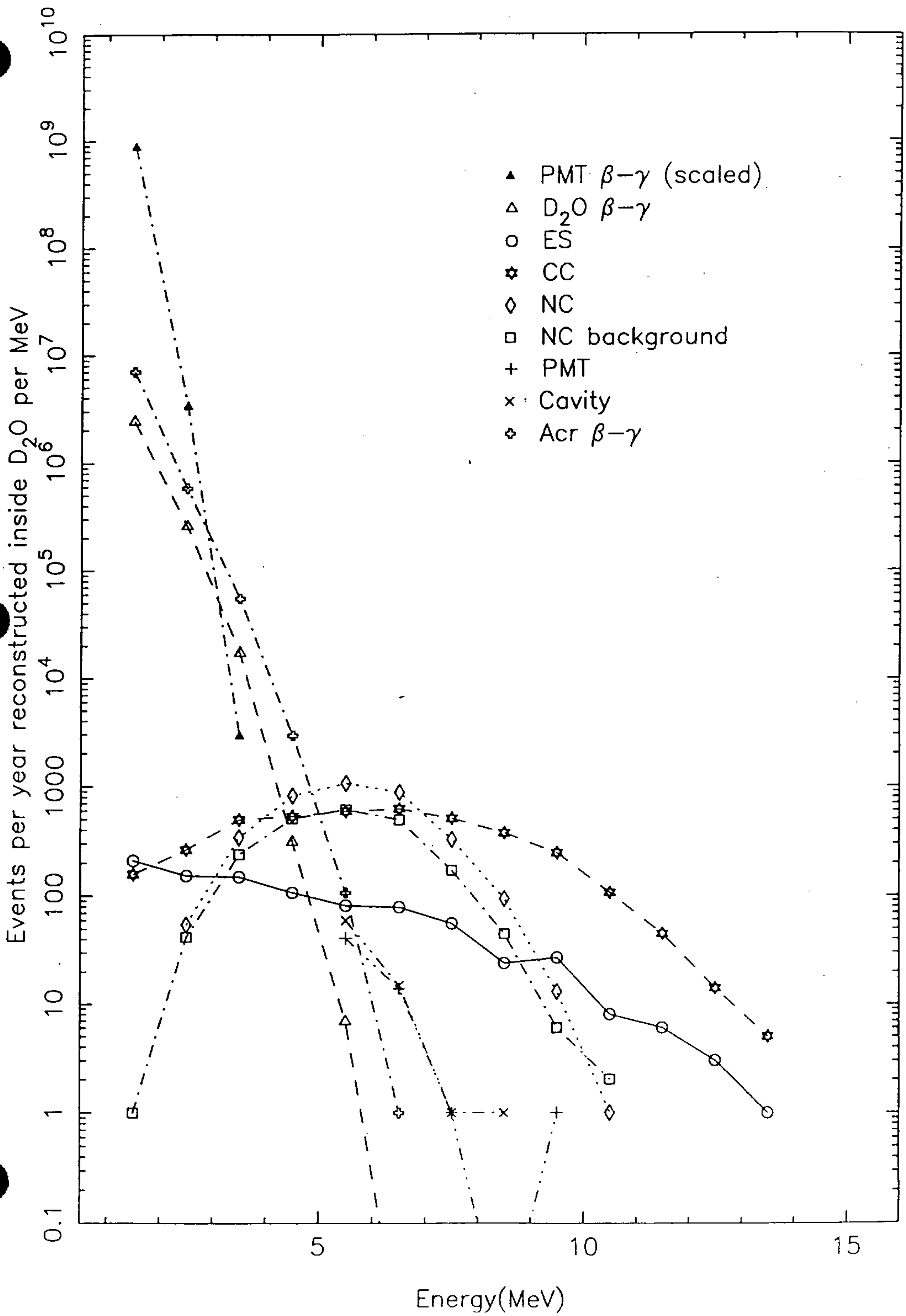

Figure 3: Contributions from Individual Elements in D_2O

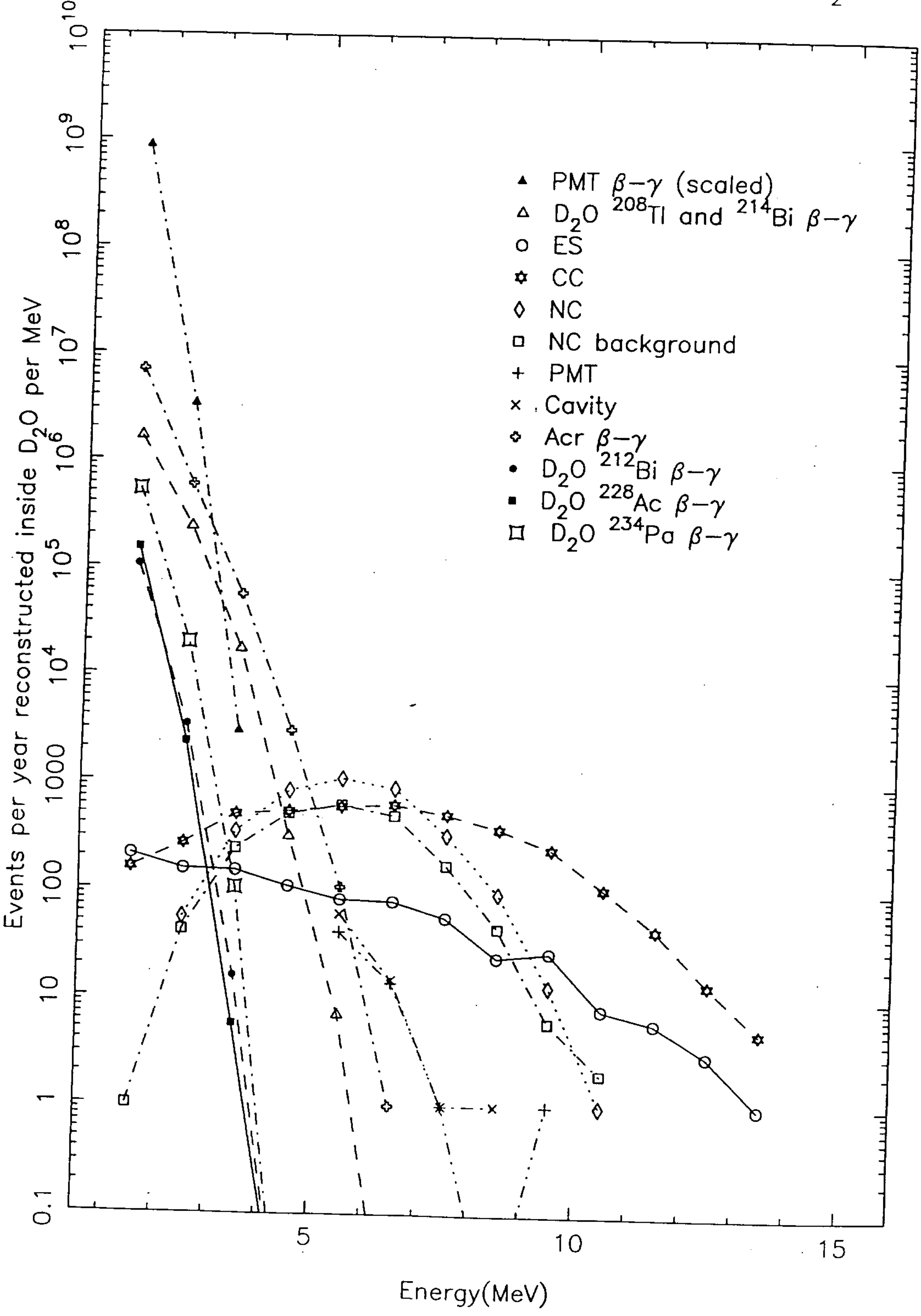

Figure 4: Contributions from Individual Elements in Acrylic