Reduction of Spallation Background by Identifying 2α events.

Janet Conrad, December 13, 2004

This memo explores a new way to cut the spallation background beyond what was presented in the $\sin^2\theta_W$ paper. The method involves identifying and cutting events due to the presence of 2 α's. In three of the isotopes of concern, the α's are associated directly with the decay. In one case, the α's are a product of a daughter decay in the chain, but can be used to open a software veto to remove the grandparent isotope. The result is that the spallation rates will be cut by a factor of $\sim$2.

The expectation for spallation rates from the $\sin^2\theta_W$ is presented in Table 1 (see the end of this memo). The final rate is events/day/detector. At the end of this memo this table is adjusted for the cut by identifying 2α's (Table 2). It should be noted that the geometry – detector size, depth, 3-region design, used in developing this table no longer reflects our plans. But for the point of this memo, which is the fractional reduction from the new cuts, scaling from the table is convenient and the update of absolute spallation rates will be done later.

1 Decays Which Are Identifiable Due to Two Accompanying α's

Some spallation isotopes do not produce an end-nucleus. Instead, the end-nucleus disintegrates into two α's. The α's quench, which according to Borexino, leads to characteristically long scintillation times [1].

The CTF pulse shape analysis[2] to identify α's used the fraction of photocurrent collected from 32 to 500 ns compared to the total. They used ^{214}Po which produces a 2.2 MeV α and ^{214}Bi which produces and α of 5.6 MeV, 0.02% of the time, and a β of up to 3.3 MeV, 99.98% of the time. They report 97% efficiency for removing α's while maintaining all but 2.5% of β's from a ^{214}Bi source. This analysis is particularly relevant since the β from Bi extends into the energy window of the $\sin^2\theta_w$ analysis. Thus it argues that the high efficiencies found by CTF should be possible in this analysis.

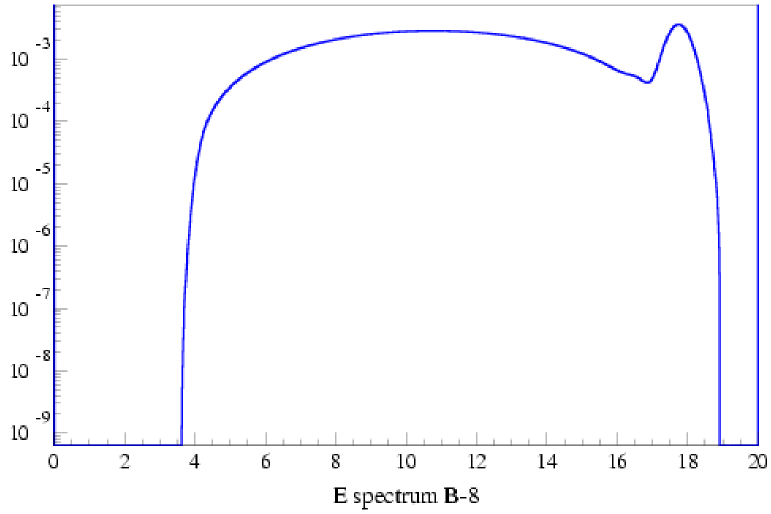

Figure 1: Energy deposited by ^{8}B decays

In the decays discussed below, 2 α's are produced. As a result, the separation should be much better than for the Borexino studies which had only 1 α. Therefore, we assume that these spallation events can be reduced to a negligible level.

2 Decays Directly Identified By the 2 α's

2.1 ^{8}B

This decay is:

$$^8\mathrm{B} \to \beta^+ + \beta^- + 2\alpha$$

The spectrum is shown in Figure 1. The offset comes from the presence of the α's. The α's had 16 MeV of energy, but they quenched, thus the offset is much smaller.

2.2 ^{9}C

This decay is:

$$^9\mathrm{C} \to \beta^+ + \beta^- + 2\alpha +^1 \mathrm{H}$$

As with ^{8}B, the α's in these events will allow them to be discriminated from the ES background. For reference, the spectrum is shown in Figure 2

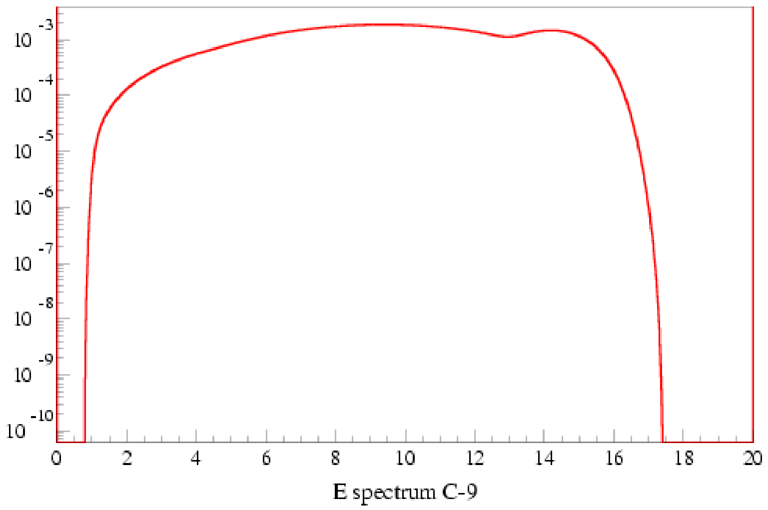

Figure 2: Energy deposited by ^{9}C decays

and the energy offset from the α's is visible. The total energy of the two α's is 11 MeV, but has quenched.

2.3 ^{8}Li

This decay is:

$$^8\text{Li} \rightarrow \beta^- + 2\alpha.$$

As with ^{8}B, the α's in these events will allow them to be discriminated from the ES background. For reference, the spectrum is shown in Figure 3 and the energy offset from the α's (which totaled 16 MeV, but has quenched) is visible.

3 Removal of ^{8}He By a Two α Veto

The decay is:

$$^8\text{He} \rightarrow ^8\text{Li} \rightarrow \beta^- + 2\alpha$$

The spectrum for ^{8}He is shown in Figure 4. The offset is due to a 980 keV photon.

The use of the decay chain to veto this type of event is promising, The lifetime of the first decay to ^{8}Li is 119 ms and the lifetime of the ^{8}Li is 838

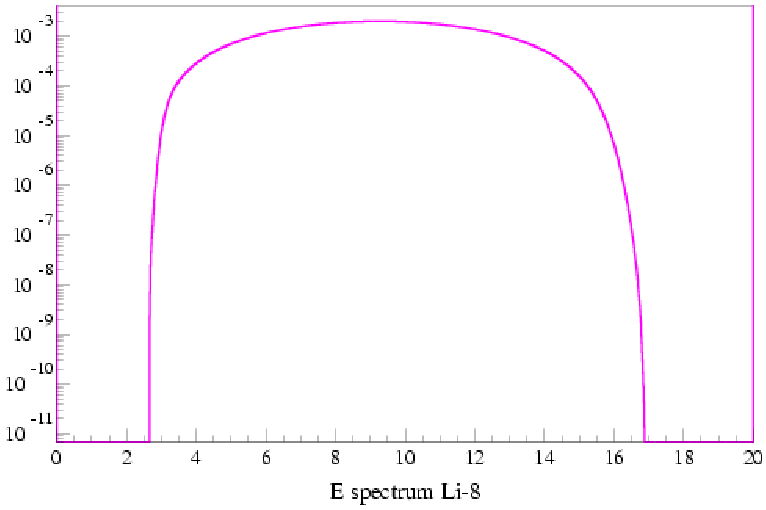

Figure 3: Energy deposited by ^{8}Li decays

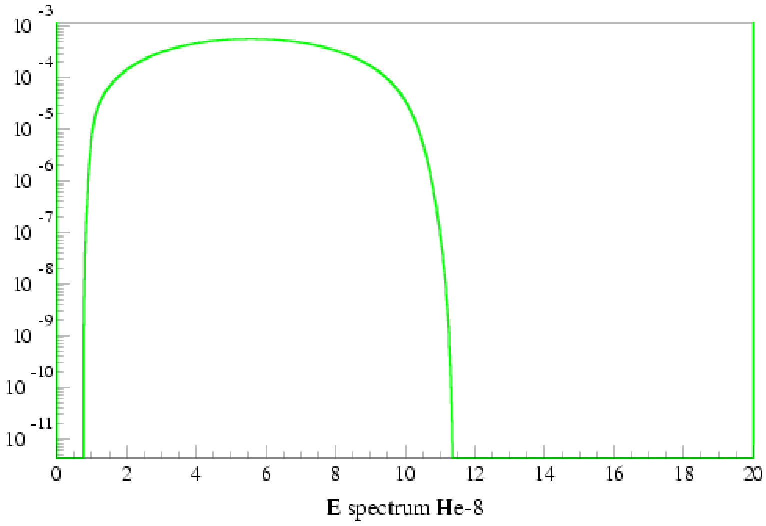

Figure 4: Energy deposited by ^{8}He decays

ms. The ^{8}Li decay is identifiable by the 2 α's which are produced. Thus the whole sequence will have a characteristic time of ~ 1 s. This indicates the value of a new software veto in which, for events with 2α's, any prior event occurring within the 3 s period are removed. The deadtime for this will need to be studied, but it can be expected to be small since the spallation rates are fractions of an event per day. Therefore, I propose that we plan on this veto. In this case the ^{8}He events are reduced to a negligible level.

4 Summary

Table 2 summarizes this memo. Eliminating events with 2 α's reduces the spallation background by 54% and the error by 55%.

References

[1] G. Alimonti *et al.* [Borexino Collaboration], "Science and technology of Borexino: A real time detector for low energy solar neutrinos," Astropart. Phys. **16**, 205 (2002) [arXiv:hep-ex/0012030].

[2] G. Alimonti *et al.*, "A large-scale low-background liquid scintillation detector: The counting test facility at Gran Sasso," Nucl. Instrum. Meth. A **406**, 411 (1998).

Isotope	E_{vis} Cut (MeV)	decay-correlated n	muon-neutron veto	Final rate
^{9}Li	0.18±0.03 (19%)	0.09±0.02 (50%)	N/A	0.09±0.02
^{8}He	0.29±0.08 (30%)	0.24±0.07 (84%)	N/A	0.24±0.07
^{8}Li	0.47±0.19 (13%)	N/A	0.15±0.06 (32%)	0.15± 0.06
^{6}He	0.29±0.05 (2%)	N/A	N/A	0.29±0.05
^{9}C	0.53±0.17 (12%)	N/A	0.02±0.01 (3%)	0.02±0.01
^{8}B	0.65±0.16 (10%)	N/A	0.02±0.01(3%)	0.02±0.01

Table 1: From $\sin^2\theta_W$ paper: Isotopes decays/detector/day after each cut, applied sequentially. Value in parenthesis is the percent of the original rate retained after the cut.

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Isotope	Rate from paper	New Rate	Reason/comment
^{9}Li	0.09±0.02	0.09±0.02	Pure β (events with n already removed)
^{8}He	0.24±0.07	$\sim$0	Cut by the proposed 2 α software veto
^{8}Li	0.15±0.06	$\sim$0	Cut by 2 α identification
^{6}He	0.29±0.05	0.29±0.05	Pure β, can be cut entirely if $T_{min} = 3.5$
^{9}C	0.02±0.01	$\sim$0	Cut by 2 α identification
^{8}B	0.02±0.01	$\sim$0	Cut by 2 α identification
Total	0.81±0.11	0.38±0.05	

Table 2: New estimate of the spallation background. Total is reduced by 54% and error is reduced by 55%.

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