1 Question 1

It seems that the ^{9}Li Background is one of the most difficult ones. KamLAND experience suggests that the probability of ^{9}Li formation (as well as high multiplicity neutron production) is much larger for the relatively rare "showering muons." Thus, if one can separate the two classes of muon events, one can (as in KamLAND) veto the showering ones much longer, thus reducing the ^{9}Li background substantially. Can this be done in your detector?

1.1 Synopsis

A simulation of muon showering and energy loss in the detector in combination with the study of ^{9}Li production as a function of preceding muon energy deposition in KamLAND, demonstrates that by rejecting events within a half second of a muon that deposits more than 1.5 GeV in the detector we can reject 72% of all ^{9}Li events. This combination of cuts would result in a loss of about a 7% of active running, which is by far the largest source of dead time for the experiment, but certainly tolerable. The resulting ^{9}Li background after these cuts would be about 0.7 events/detector/day. In three years of running each detector would have a sample nearly 2000 tagged ^{9}Li correlated decays that could be used to fit the neutrino candidate energy distribution and determine the ^{9}Li background to high precision.

1.2 Details

In this analysis we estimate the ^{9}Li background rate and dead time in the Braidwood detector that are the result from the application of a simple set of ^{9}Li tagging criteria. The analysis is based on

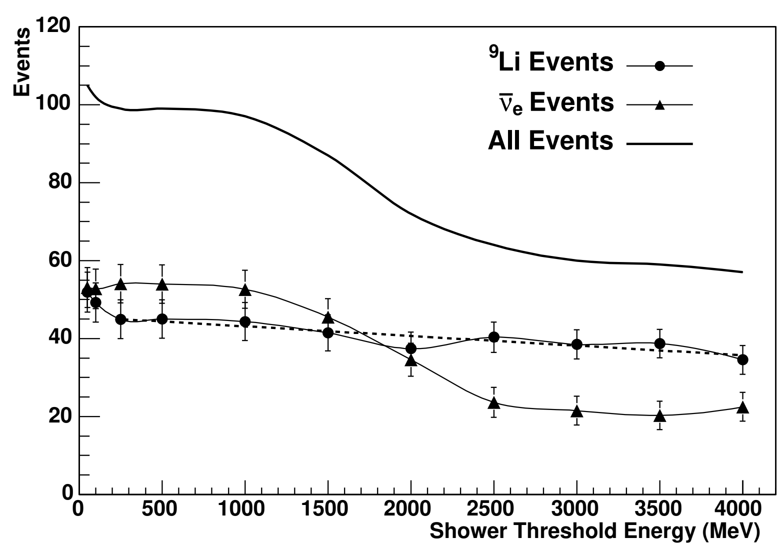

Figure 1: This plot shows the number of surviving ^{9}Li background events as a function of minimum energy deposition of the preceding muon in KamLAND. Selecting muon showers with greater than 3.7 GeV (corresponding to the ionization loss of a 1 TeV muon traversing the entire 1300 cm diameter of the scintillating balloon) capture 85% of all ^{9}Li events.

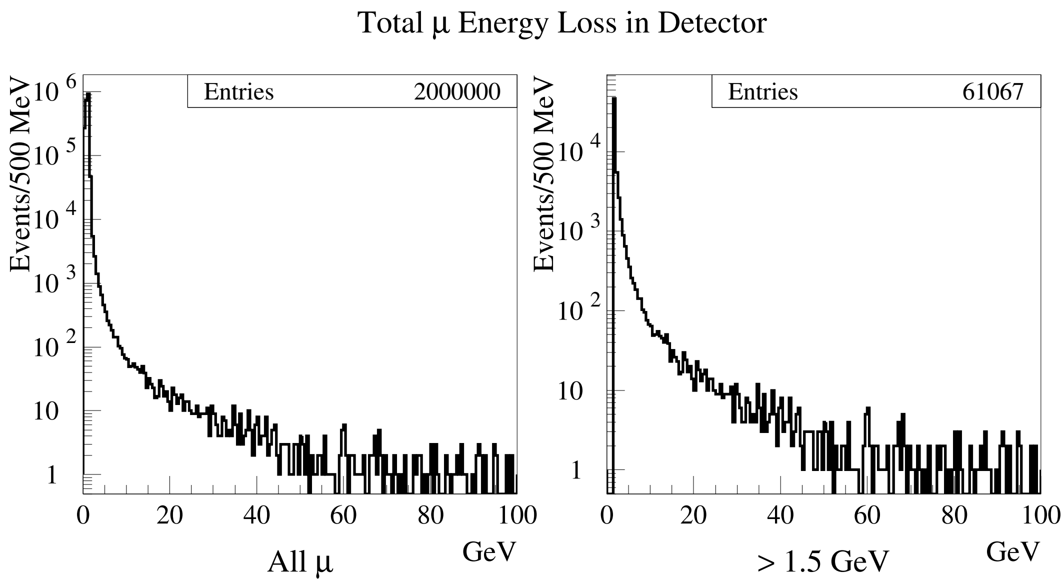

Figure 2: These figures show the results of a simulation of energy deposition (both ionization and hadronic shower) with 2,000,000 muons in a Braidwood detector. Only about 3% of muons deposit more that 1.5 GeV (ionization loss for a 1 TeV muon in 520 cm) in the detector.

the experiences of KamLAND presented in the thesis of Kevin McKinny (University of Alabama, 2003) and a simulation of muon energy loss in Braidwood based on (Groom *et al.*, Atomic Data and Nuclear Data Tables, 78, 183, 2003). This analysis is intended to represent the minimum that could be achieved. After experience with the real detector, a more complex analysis would likely be developed that should result in better rejection, less dead time, or both.

Figure 1 shows the number of ^{9}Li background events that survive a cut on the energy of the preceding muon as a function of the cut value in KamLAND. The data show that the majority of ^{9}Li production can be identified by looking at events that closely follow a muon that deposits more energy in the detector than one expects from ionization losses alone. A 1 TeV muon that covers the full 1300 cm diameter of the KamLAND scintillator will deposit 3.7 GeV of energy from ionization. To produce spallation isotopes like ^{9}Li, requires a hadronic interaction which typically would result in deposition of significant additional energy. This hypothesis is supported by the KamLAND data. Reading from Figure 1, muons which deposit greater that 3.7 GeV energy in the KamLAND detector are responsible for 85% of all ^{9}Li production. The corresponding ionization loss of a 1 TeV muon traversing the 520 cm diameter of a Braidwood detector is 1.5 GeV. The half-life of ^{9}Li is 178 ms, so in a window 0.5 s one expects 85% of all to decay. Therefore, a half second search window following energy muon that deposits more that 1.5 GeV in the detector will result in the capture of 72% of all ^{9}Li decays.

Our calculation of the ^{9}Li production at a depth off 450 mwe (see answer to questions 2 and 4) estimates that 0.078 ^{9}Li isotopes are produced per ton per day. The branching fraction to the βn correlated decay is 50% and each Braidwood detector has a scintillating target of 65 tons. So we expect 2.5 possible background events per day of which 0.7 are untagged.

To estimate the dead time associated with this set of cuts we start with the muon rate in the detector which is 4.5 Hz. Figure 2 shows the results of a simulation of muon energy loss and hadronic showering in a Braidwood detector. It indicates that only 3% of all muons will deposit more that 1.5 GeV or 0.14 Hz. Combined with a a half second veto this results in an effective dead time from the ^{9}Li tag of only 7%.