The Effects of Tritium in NCDs

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Introduction

The spec for tritium levels in an NCD is set to 2.7 nCi/l. This contamination level corresponds to a rate of 1000 Hz in a 200 cm NCD and to 5000 Hz in a 10 m string. These two values will be used to calculate the affects of tritium pileup in a 4 μs integration window.

To simplify the calculations, it will be assumed that tritium pulses are of zero width and that pileup simply results in a summation of their energy. This represents a worst case scenario as pulses of finite width will deposit some of their energy outside of the integration window. On the other hand, pulses preceding the trigger time will deposit some additional energy in the integration window. However, such pulses will also raise the baseline prior to the trigger, thus offsetting their contribution to the integrated energy.

Figure 1 shows the beta spectrum for tritium decay. The mean energy is 5.7 keV and the endpoint is 18.6 keV. Also shown is the spectrum for the pileup of two tritium pulses.

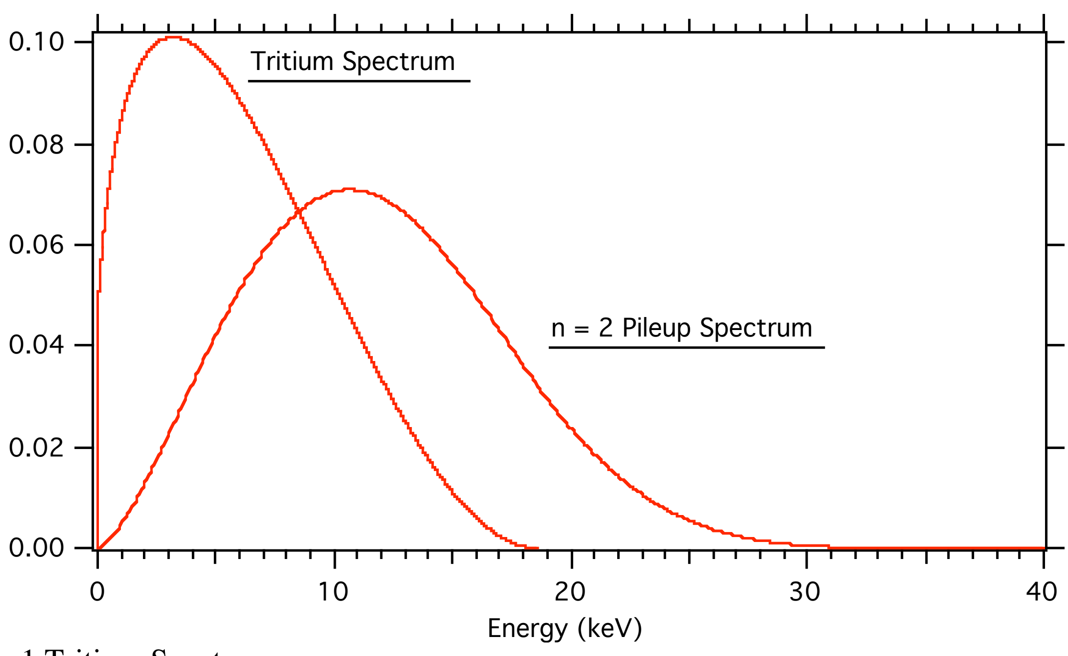

Fig. 1 Tritium Spectra

Dead Time

With the NCDs installed, the electronics will be set with a digitizer trigger level of 100 keV and an ADC trigger level of 20-30 keV. Both of these are above the endpoint of tritium and so will not record the intrinsic tritium rate. At 5000 Hz intrinsic rate, we expect a pileup rate of approximately 3.8 Hz above 20 keV. This will not create any significant dead time.

Events in the Neutron Window

If enough pulse can pileup in a 4 μs window, it will be possible to trigger the digitizer and possibly simulate a neutron. The following table shows the number of events expected per year for a pileup of 1 – 5 tritium pulses in 4 μs.

Number of tritium pulses in pileup event	**n = 1**	**n = 2**	**n = 3**	**n = 4**	**n = 5**
Mean Energy	5.7 keV	11.4 keV	17.1 keV	22.7 keV	28.4 keV
Endpoint	18.6 keV	37.2 keV	55.8 keV	74.4 keV	93 keV
Events/year (intrinsic tritium rate = 1000Hz)	$8.6x10^{7}$	$1.7x10^{5}$	229	0.23	$1.8x10^{-4}$
Events/year (intrinsic tritium rate = 5000 Hz)	$4.2x10^{8}$	$4.2x10^{6}$	$2.8x10^{4}$	141	0.56

Fig. 2 Events per year for pileup

We expect a pileup of 5 pulses to occur less than once a year. The maximum energy that 5 tritium pulses can produce is 93 keV, below the digitizer trigger level of 100 keV. Thus we see that tritium will not lead to a significant rate in the neutron window.

β–γ Coincidences

It is hoped that one will be able to look for coincidences between beta events in the NCDs and gamma events recorded by the PMT array. Of interest is the Bi-Tl window, between approximately 25 and 35 Nhit. Accidental coincidences can occur when a tritium pileup event occurs in an NCD during the 4 μs following an Nhit trigger. Figure 3 shows the number of accidental coincidences expected in a year for 1000 and 5000 Hz of tritium (in one string). The thresholds are the ADC thresholds for the NCDs.

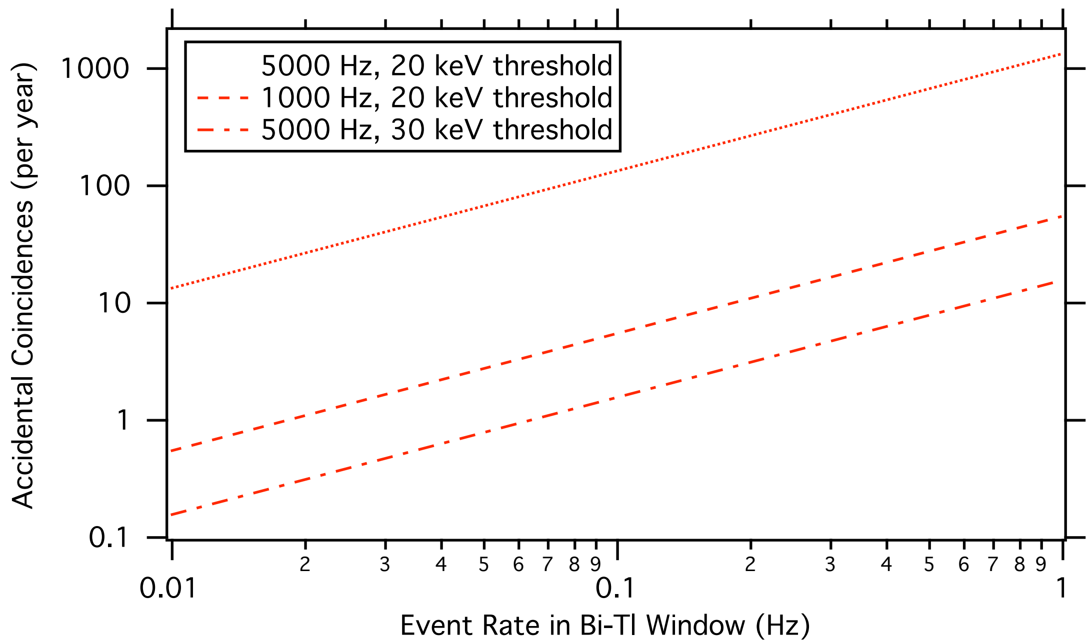

Fig. 3 Accidental coincidences between PMTs and NCDs in one string.

With an event rate of 0.1 Hz in the Bi-Tl window and 5000 Hz of intrinsic tritium events, one gets an accidental coincidence rate of 0.06 events per year using a 30 keV ADC threshold. If the entire NCD array had the same tritium level (2.7 nCi/l) one would get 5.8 coincidence events per year. At 1000 Hz, the accidental coincidence rate is insignificant. If the Bi-Tl rate is higher, one must scale these numbers by the appropriate factor. So, at 1 Hz in the Bi-Tl window, we get approximately 58 coincidence events per year.

These numbers should be compared to the $\beta-\gamma$ coincidence signal. This rate has not been calculated but must be at least 1000 events/year (for the entire array) if it is to be competitive with alpha counting techniques in the NCDs.

If one instead uses a 20 keV threshold, the accidental coincidences would be 474 events for the entire array (assuming every counter has 2.7 nCi/l of tritium and 0.1 Hz in the Bi-Tl window). One sees that high tritium levels may require us to set an ADC analysis threshold of 30 keV.

^{210}Po Events

A final concern is that tritium events may overlap a ^{210}Po event in an NCD, possibly simulating a neutron event. It is estimated that the tail of the ^{210}Po peak should put approximately 1% of its events below 1 MeV. At an average Po rate of 50 events/m^2/day in the array, one then expects a total of around 22,000 Po events to fall below 1 MeV per year. Of these events, only 380 (14% SSM) are expected to overlap with a tritium event. This assumes that every string exhibits 2.7 nCi/l of tritium.

Of these events, we are only concerned about those where the tritium pulse occurs after the trigger, thus extending the risetime. A typical Po alpha which deposits less than 1 MeV in the gas will have a t_{50} of 0.2 - 0.3 μs, whereas to make it into the neutron window it must have a t_{50} of 0.5 - 0.7 μs. To affect the risetime in such a way, the tritium pulse would need to account for a large fraction of the measured energy. However, comparing the energies involved tells us that the tritium beta will typically contribute 0 – 6% of the total energy. A detailed Monte Carlo should show very little or no contamination of the neutron window.

Conclusions

All calculations and discussion have been ultra conservative and show that we can tolerate a tritium level of 2.7 nci/l. This may require a small increase in the threshold for β–γ coincidence analysis.