Development of a multi-neutron filter

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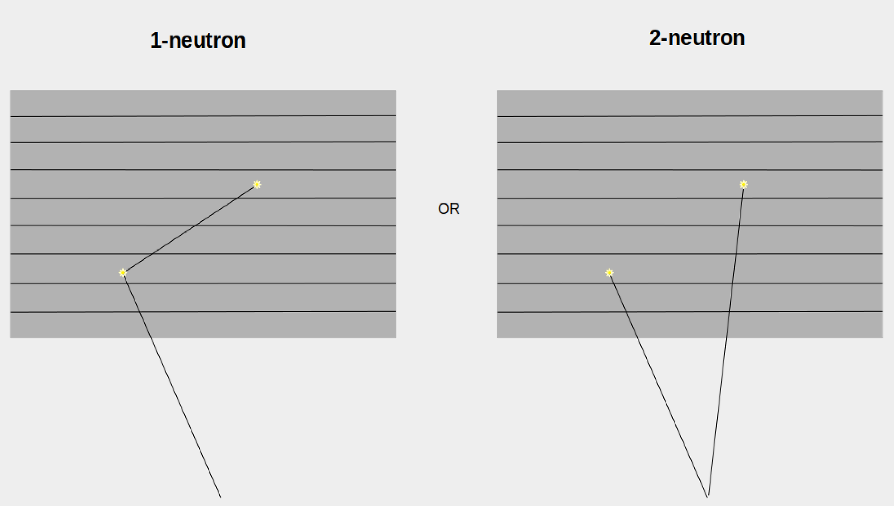
Detection of 1 vs Multi-Neutron Decays

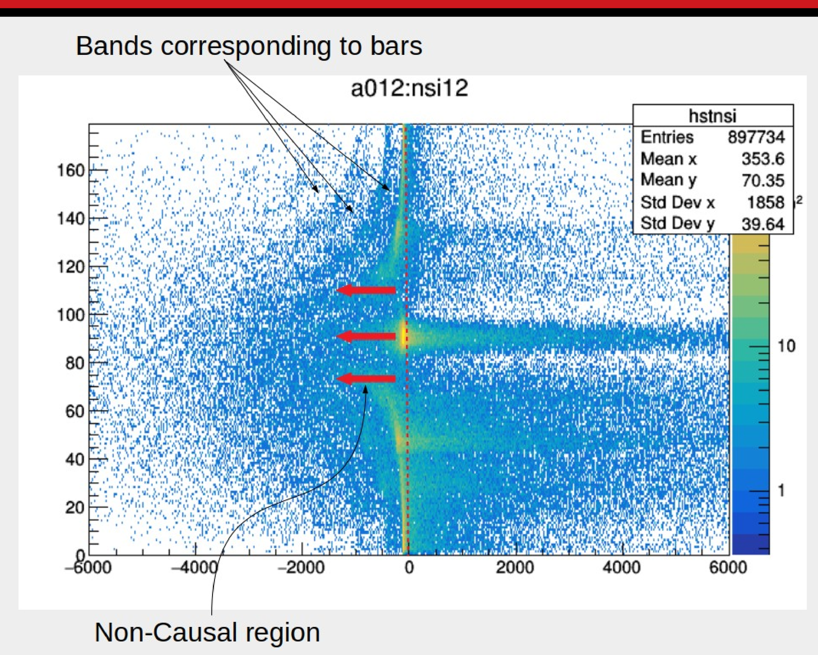
While the MoNA array is a very sophisticated neutron detection system, it does have some drawbacks. One being the difficulty of distinguishing between 1n and multi-n events. A neutron that hits the array, scatters, and strikes the Array somewhere else appears identical to a 2n event where 2 neutrons independently strike the detectors



1 neutron striking twice appears the same as 2 neutrons striking individually.

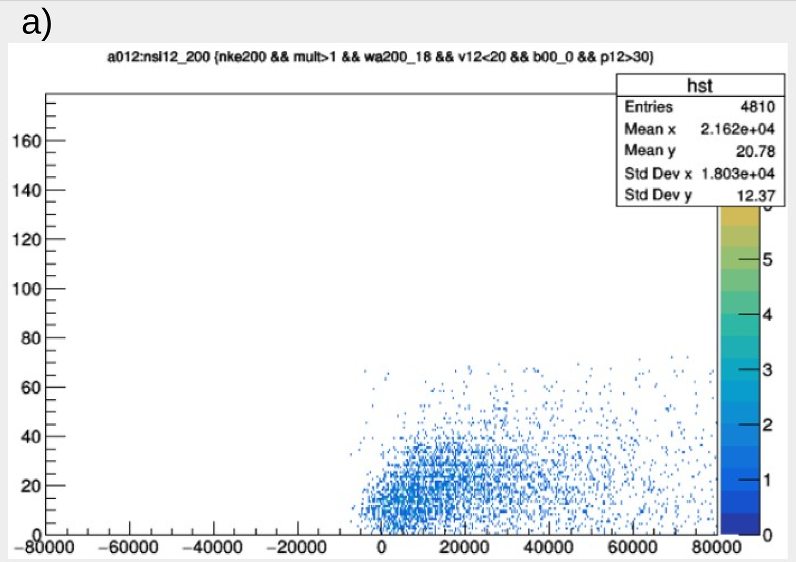
Neutron Space Time Interval (nsi)

Analogous to the space time interval, the neutron space time interval describes the causality of two events. Events that lie to the left of the origin are considered to be non-causal while events to the right have the potential of being causal.



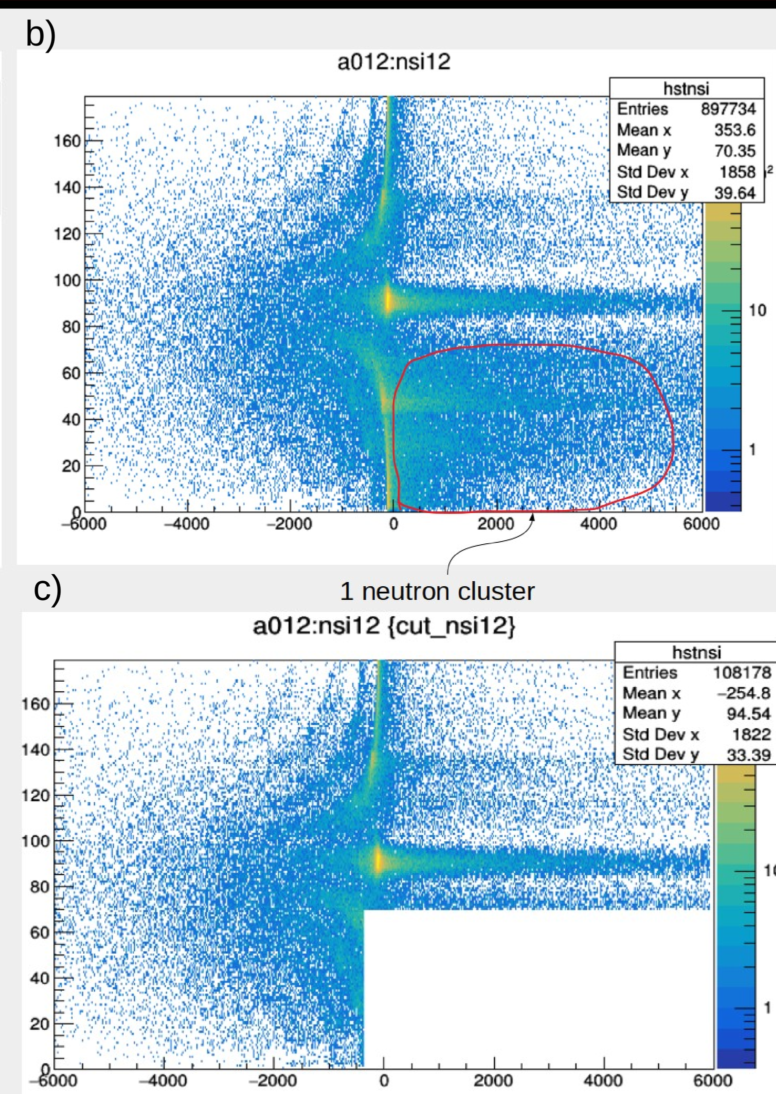
Causal Gate

a)



When plotting a 1n data set, we notice a cluster at the bottom of the nsi plot in the causal region. By placing a gate around this cluster, we can essentially cut out events where one neutron scattered several times. This nsi check can be performed on any two hits on the array to determine whether they are causal or not.

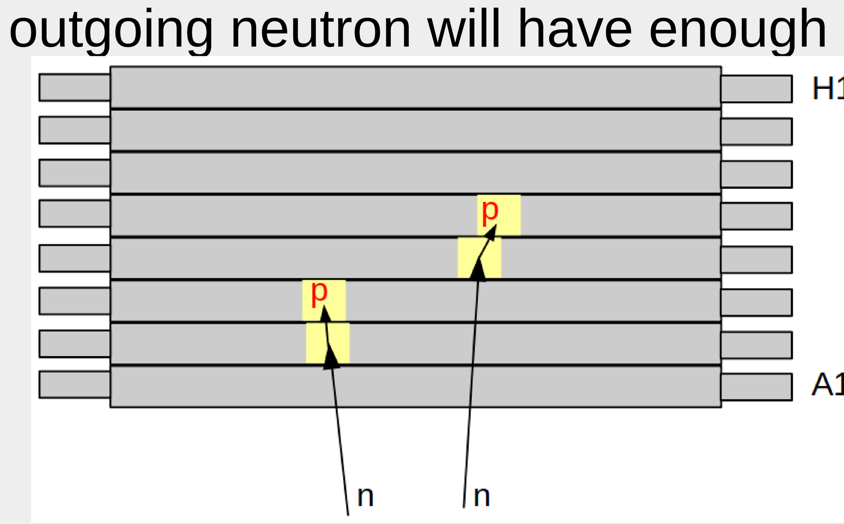
b)



a) nsi plot of 1n data. b) 2n data with the 1n region highlighted. c) 2n data with the 1n region cut out to remove 1n background

Proton Cross-Talk

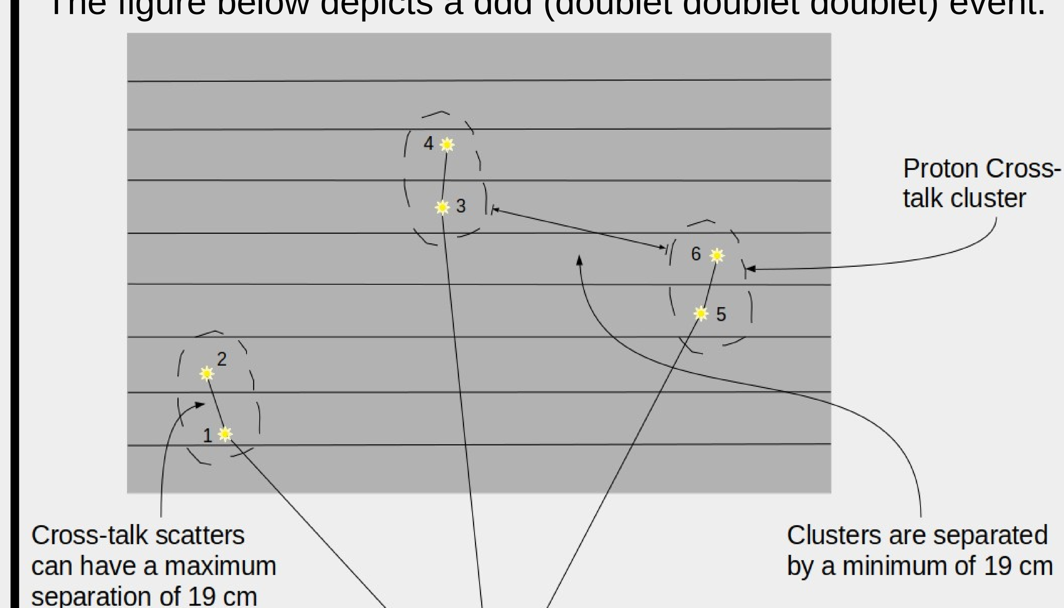
Proton Cross-talk is the phenomenon where high energy protons take part in a charge exchange scatter with H and C nuclei. Thins reaction causes a proton to travel to another part of the detector and create light. This results in light being produced in adjacent detector bars. After such a collision, it is highly unlikely that the outgoing neutron will have enough energy to produce any other Light, let alone another cross-talk scatter. With this in mind, we can know that two proton cross-talk scatters occurring in our detectors resulted from two separate neutrons. Ergo, we can use cross-talk as a filter on multi-n events



Two individual high energy protons are each taking part in charge exchange forming proton cross-talk.

Doublets & Singlets

The figure below depicts a ddd (doublet doublet doublet) event.



When a proton cross-talk event occurs, we call it a doublet (d). Likewise, when a single neutron hits the array, we call it a singlet (s). With this nomenclature, we can express 2n events consisting of two proton cross-talks as a dd (doublet doublet) event, and a 3n event consisting of two cross-talks and a singlet as dds.

Filter Combination

By combining both nsi and cross-talk filters, we can create a filter that removes the majority of 1-n events, while also preserving a large portion of multi-n events. Locating doublets and singlets allows us to pin point events, while the nsi filter allows us to determine whether these events are causally connected or not.

Permutations

3n Permutations

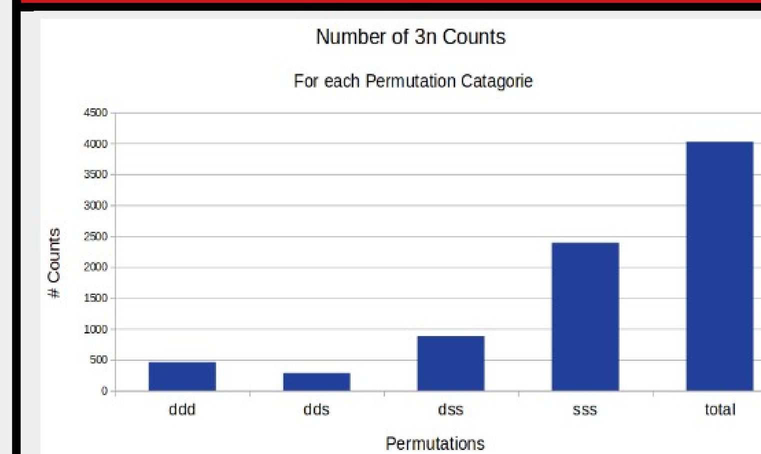
ddd: (12) (34) (56), (12) (35) (46), (12) (36) (45), (13) (24) (56), (13) (25) (46), (13) (26) (45), (14) (23) (56), (14), (25), (36), (14) (26) (35), (15) (23) (46), (15) (24) (36), (15) (26) (34), (16) (23) (45), (16) (24) (35), (16) (25) (34)	15
dds: (1) (23) (45), (1) (24) (35), (1) (25) (34), (2) (13) (45), (2), (14) (35), (2) (15) (34), (3) (12) (45), (3) (14) (25), (3) (15) (24), (4) (12) (35), (4) (13) (25), (4) (15) (23), (5) (12) (34), (5) (13) (24), (5) (14) (23)	15
dss: (1) (2) (34), (1) (3) (24), (1) (4) (23), (2) (3) (14), (2) (4) (13), (3) (4) (12),	6
sss: (1) (2) (3)	1
Total Permutations:	37

2n Permutations

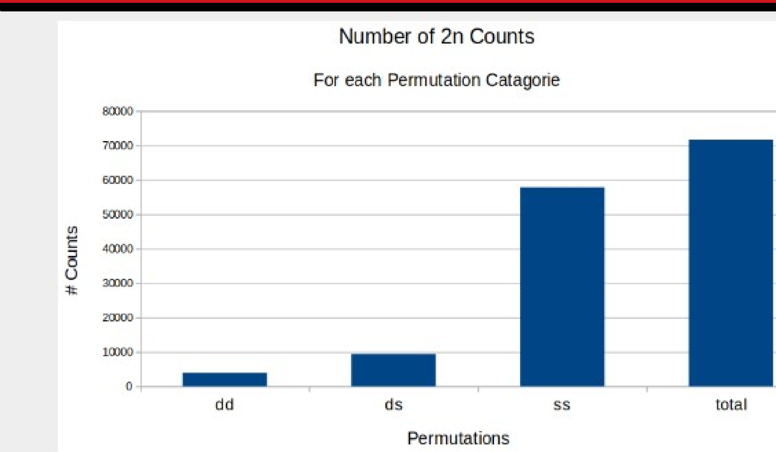
dd: (12) (34), (13) (24), (14) (23)	3
ds: (1) (23), (2) (13), (3) (12)	3
ss: (1) (2)	1
Total Permutations:	7

These are the possible event permutations for 2n and 3n data. Notice how increasing multiplicity by 1 greatly increases the permutations

Results

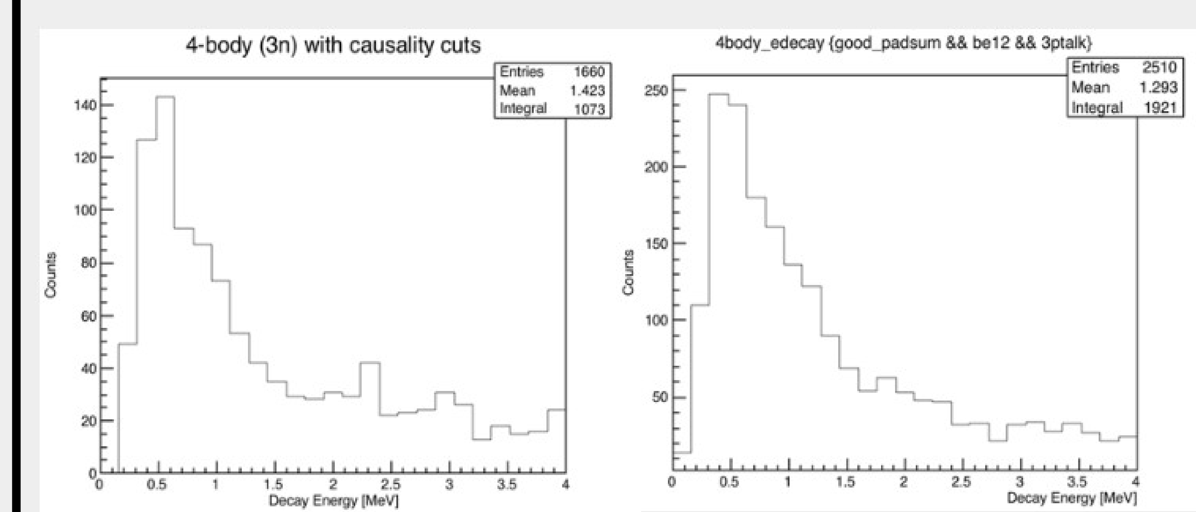


Contributions of each permutation to the total number of counts for 3n data.



Contributions of each permutation to the total number of counts for 2n data.

After applying the filter to Jesse Snyder's multi-neutron data, We were able to understand the probabilities of each permutation. The charts above show that sss and ss events for 3n and 2n data, respectively, contribute the most statistics to the multi-n data. Interestingly enough, ddd events were discovered to be more numerous than dds events for the 3 neutron scatters.



Increase in counts from former causal gates to new multi-n filter

The former gates used for multi-n data sets used a highly restrictive causal separation to filter out single neutron events. The figure to the left shows 3n Decay energy data filtered using this causal gate. The figure to the left, however, was created using the new multi-n filter. The statistics increases when we use the new filter by a factor of almost 2.

Shortcomings/Development on Improved Algorithm

Despite the success we have had with this process, there are still shortcomings as well as improvements to be made. The issue with the current working filter is that it does not highlight which hit number to focus on when creating plots with the filtered data. If we wish to make a plot, we need to know which hit in the array corresponds to neutrons and which are background. Since several of the array strikes are actually protons, it is difficult to isolate the neutrons to get any useful information. A new code is currently in development that will identify the hit number for each neutron in an event and re-assign it a new hit value so that all neutrons are properly ordered.

Acknowledgments

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