Correlating Neutron Multiplicity Meter and Low Background Counting Facility Veto Shield Muon Data

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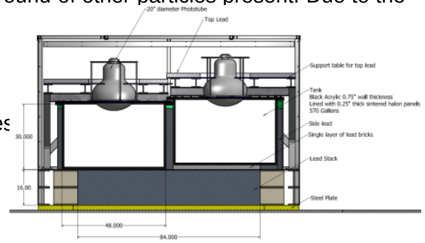
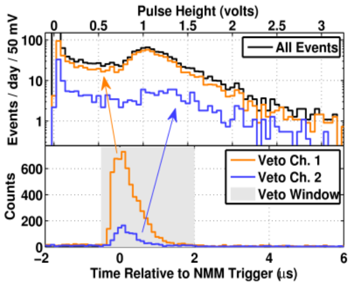
Goals

To correct the apparent timing shifts in the LBCF veto shield data, and correlate muon data between the NMM and the LBCF veto shield.

Background

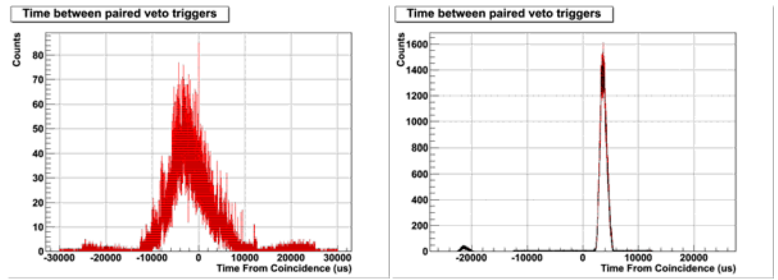
The Soudan mine houses some notable rare-event searches including CDMS, MINOS, and various other projects including the LBCF veto shield (see apparatus section for more information). These experiments are looking for either very specific or weakly-interacting particles, so it is desirable to have a low background of other particles present. Due to the half mile of rock above the cavern, only muons make it down to the cavern. Sometimes the muons also interact with the rock in the cavern wall and produce neutrons. It is important to understand the properties of these muons and neutrons so that the background of these sensitive experiments can be properly accounted for. One experiment that studies these background particles is the Neutron Multiplicity Meter (shown above [1]), which is designed to detect neutrons but is also sensitive to muons. When correlated with the LBCF veto shield which surrounds the NMM, a muon rate for within the cavern can be determined. Based on previous data taken by the NMM, the total numbers of muons events is expected to be about 1300 per day (shown below [2]). When the actual number of muons detected was determined, it was found that the number did not significantly deviate from the expected random noise of the system. Itwas determined that an error in front end electronics of the shield is causing a shift in the time stamps of LBCF data. The timing shifts were found to be varying, and distinct for each different parts of the veto shield. This caused larger than expected resolution in timing and made it seem as though the data is not correlated.



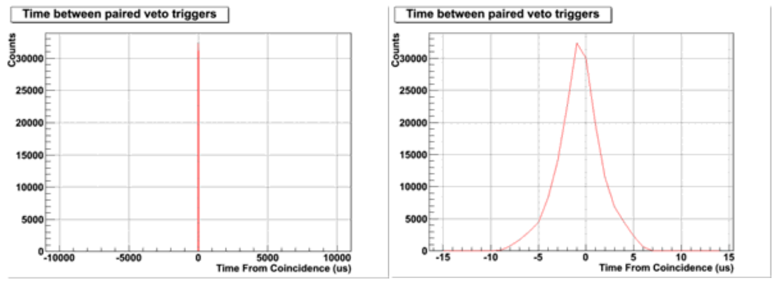


Above: Plot of events seen per day on NMM. First three bins are ignored in calculations due to noise. Ch. 1 and Ch. 2 indicate the shield panels above and below the NMM, respectively.

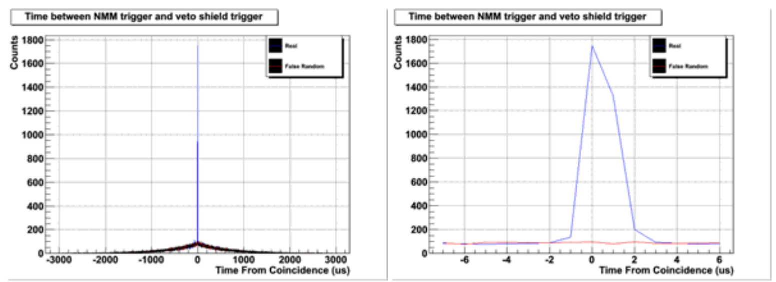
Findings & Results



Examples of bad timing that were found. A shift of about 3ms and a resolution of approximately 10ms can be seen on the left between the NE and SE station. A shift of approximately 4ms and a resolution of approximately 2ms can be seen on the right between the NE and NW stations.



Good timing found before fix between SE and SW stations. The result is a sharp peak with no shift and a resolution of about 4us, which is the expected result.



The shifts were fixed, and NMM events were correlated with veto shield events. Approximately ~3500 counts were found in three days, which is comparable to the estimate of ~3900 counts. Note the deviation from the randomly generated noise (shown in red).

References

1. Hennings-Yeomans, R and Akerib, D.S. “A neutron multiplicity meter for deep underground muon-induced high-energy neutron measurements” November, 2006.
2. Bunker, Raymond. “NMM veto correlations” https://zzz.physics.umn.edu/lowrad/_detail/nmm/timing/nmm_veto_correlations_v1.png?id=nmm%3Alrtproceedings

Apparatus & Technique

The LBCF veto shield is comprised of panels of proportional tubing that completely cover the inner walls of the Soudan cavern. The system is broken up into ten different muxes that read the signal coming from the veto tubes and send the resulting data to four computer stations (labeled NE, NW. SE, and SW).

To determine the timing shifts, a unique signal pattern is manually sent to one tube on each mux using a pulser signal that is split off (shown above). The signal is read into the tubes via a pre-amp attached to each tube (shown left). The signal is sent when the high voltage is off, ensuring that no background is seen. Working under the assumption that the NMM has the correct timing, the unique signal pattern is compared to the NMM data, and the timing shifts can be read off.

Further Work

Though the current set-up is functional, it is a long, physical task to start each data run. Further work would include making the start-up and shift-finding procedure automated. It would also include continuing work to map the position of each tube and then analyzing the muon flux as well as the angular distribution within the cavern.

Acknowledgements

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