Neutron Captures in Borated Polyethylene: An Analysis of the Quenching Measurement Data from MicroCHANDLER at TUNL

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Introduction: This summer, the MicroCHANDLER particle detector was brought to the tandem accelerator at Triangle Universities Nuclear Laboratory to measure the detector's quenching factor using a beam of neutrons. Specifically, the goal was to obtain preliminary data to understand how MicroCHANDLER responds to protons that recoil off of fast neutrons. To prevent thermal neutrons from interfering with data acquisition while the beam was on, MicroCHANDLER was housed in a structure of borated polyethylene. Although this structure significantly attenuates thermal neutrons in the target room, neutron captures on hydrogen within the borated polyethylene often generate 2.2MeV gammas that can be seen in MicroCHANDLER. In fact, these neutron captures appear in the delta time plots with an exponential growth structure. Examining this growth structure reveals that setting the event window towards the beginning of the beam period will allow us to minimize the number of neutron capture gammas that register in the detector. Additionally, having identified this 2.2MeV gamma feature provides another calibration point for future runs. More data is required to be able to see a turnover in the rate of neutron captures as the majority of neutrons have already captured in the borated polyethylene. New data would also allow us to see the exponential decay in capture rates that should immediately follow turnover.

MicroCHANDLER

MicroCHANDLER is the smallest in a series of CHANDLER (Carbon Hydrogen Anti-Neutrino Detector with a Lithium Enhanced Raghavan optical lattice) detectors [1]. MicroCHANDLER utilizes an optical lattice of Eljen Technologies plastic scintillator cubes and neutron detection sheets. (Lattice developed by Raju Raghavan [2]). The combination of detection sheets and plastics was first used by the SoLid collaboration [3]. Photons from both the scintillators and detection sheets are registered by photomultiplier tubes fixed to the outside of the detector.

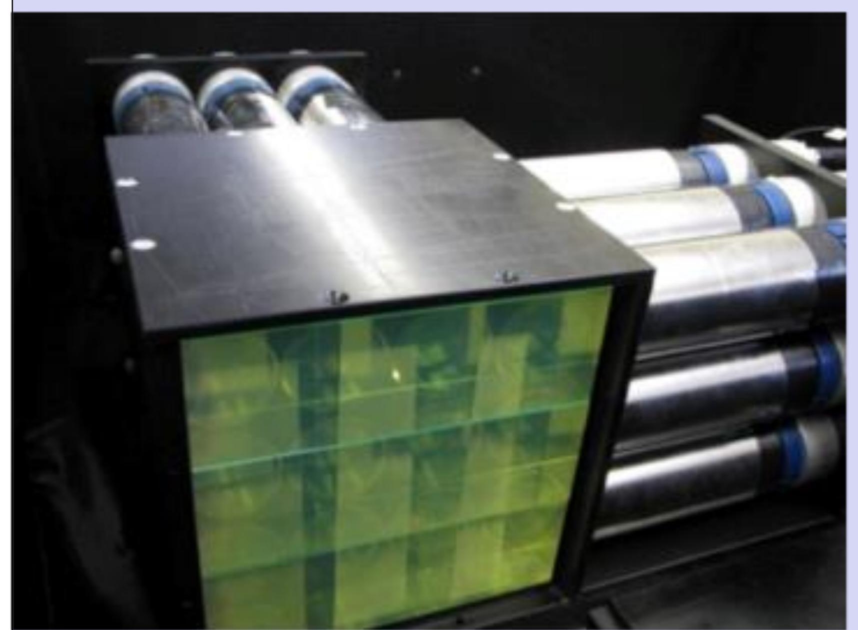

Figure 1a. (Above) MicroCHANDLER [4]
Figure 1b. (Left) Older version of MicroCHANDLER [5]
Figure 1c. (Right) MicroCHANDLER in borated polyethylene

MicroCHANDLER at TUNL

MicroCHANDLER was brought to the tandem particle accelerator at Triangle Universities Nuclear Laboratory (TUNL) to examine the detector's response to proton recoils off of fast neutrons. The neutron beam was generated by firing deuterons at a tritium target. This deuteron-tritium reaction produces a burst of neutrons and gamma rays. MicroCHANDLER was housed in a structure of borated polyethylene to attenuate thermal neutrons that bounce off of the walls of the target room while the beam is on. The boron 10 atoms in the borated polyethylene often undergo neutron capture due to their high cross-section for thermal neutrons. Hydrogen atoms within the shielding can also undergo neutron capture.

Neutron Captures on Hydrogen

After calibrating the ADC (MicroCHANDLER's energy response) scale using a sodium 22 source, we found that 230 ADC is equivalent to about 1060keV. Therefore, the peak in Figure 2 indicates an energy value of 2074 ± 140 keV. This energy range strongly suggests that the peak corresponds to the 2.2 MeV gamma produced by neutron captures on hydrogen within the borated polyethylene. These gammas can deposit a maximum energy of 1940keV.

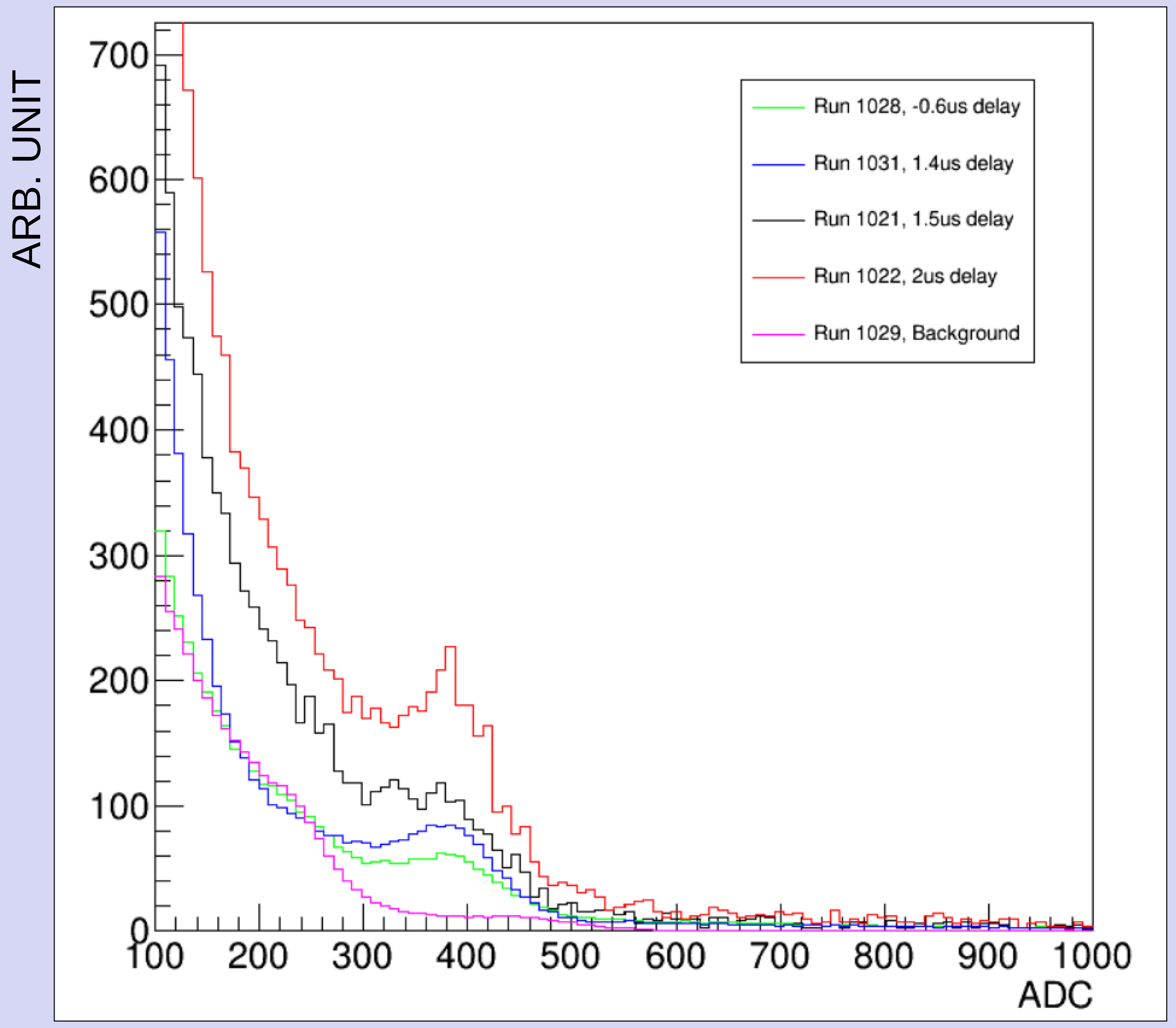

Figure 2. ADC plots for "beam-on" data acquisition runs

Neutron Capture Turn-On

There is also a turn-on feature in the time structure of our data. Using the beam pulse monitor of the accelerator as a time reference, a delta time plot was generated for the runs taken at TUNL (see Figure 3). This plot indicates a beam-correlated exponential growth in neutron capture gammas soon after a given neutron burst. Note that the gray peak is an artifact of the beam (gammas from the deuteron-tritium reaction) and is omitted from the fit.

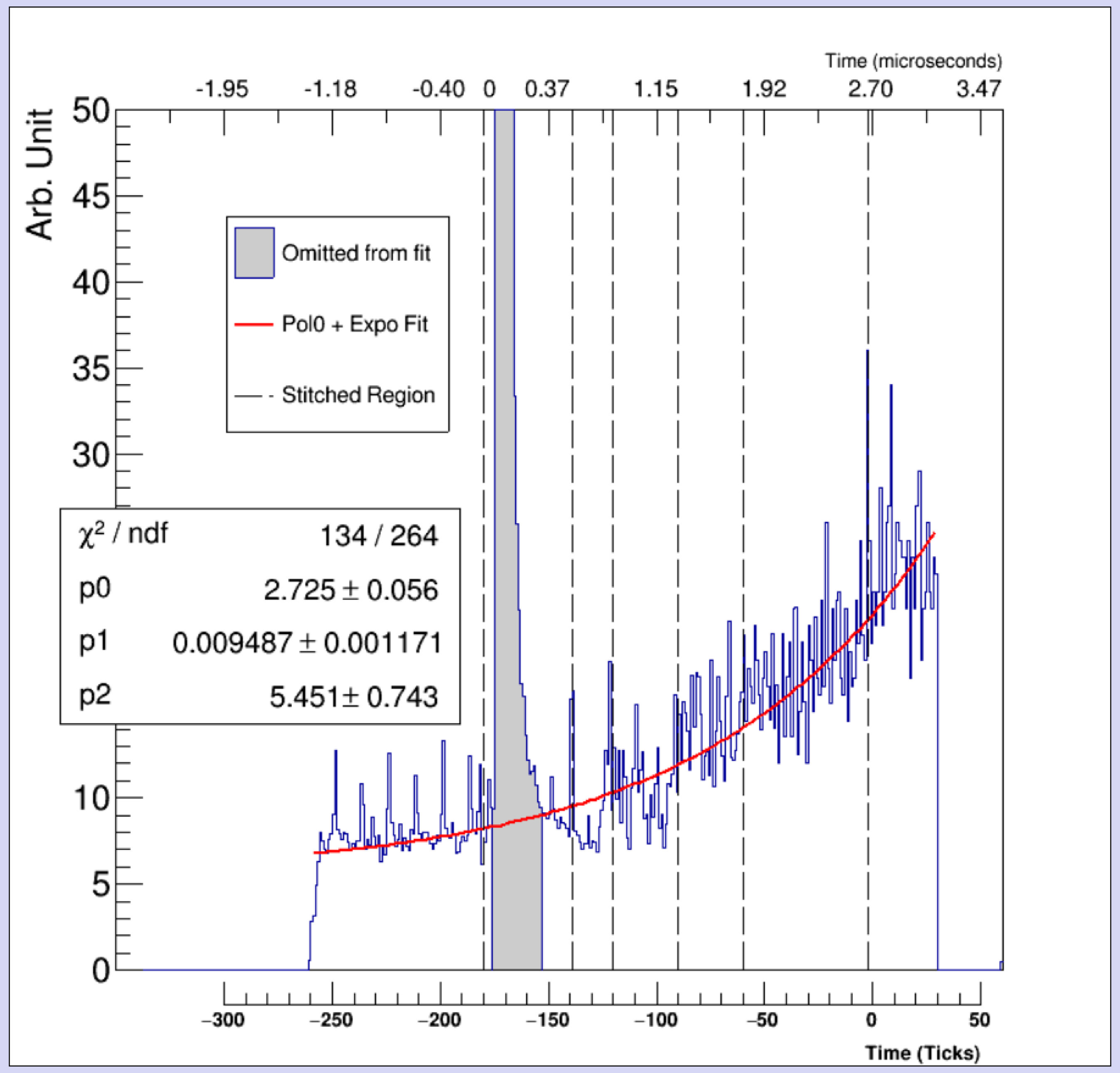

Figure 3. A combined delta time plot for multiple "beam-on" runs

Conclusion

From this study, we now have a better understanding of the duration of neutron captures on hydrogen in borated polyethylene. Since this interaction results in a 2.2 MeV gamma, we also have another calibration point for MicroCHANDLER's energy response. More data is required to span a longer range of time in the delta time plot.

Acknowledgments

The work performed by Jacob Steenis this summer was primarily funded by the National Science Foundation's Research Experiences for Undergraduates program.

References

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4. Image Credit to Connor Awe
5. Image Credit to CHANDLER Collaboration