Upgrading MINERνA for Future Runs: Challenges for DAQ and Light Yield

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1 Looking Forward

It is easy to assume that detectors that are around and working now will be around and working forever. This is not a good assumption. Upgrades are required if the MINERνA Experiment is to survive and function as a long-term program beyond its planned physics run during the NOνA Era.

2 MINERνA Readout

The fundamental technologies of MINERνA are: plastic scintillator, wavelength-shifting fiber, and multi-anode PMTs. Readout is conducted using custom Front End Boards (FEBs), custom VME boards, and off-the-shelf rack-mount PCs via a commercial CAEN optical to PCI interface. The FEBs interface with the VME electronics via LVDS using Cat6 ethernet cables.

2.1 Readout Issues

Readout is slow at $\sim$1 MB/s, but this rate is by design and exceeds the original specification of 100 kB/s on a duty-factor of one 10-μs beam spill every 2.2 seconds. Given the actual event sizes, our rate allows for one physics trigger and one calibration trigger per spill. The bottleneck on readout is due to design choices that create an effectively serial readout. A new interface card will allow parallelization and boost readout rates by a factor of five to ten. This increase should cost approximately $100,000, including design and labor, and is needed for the NOνA era when the Main Injector cycle will change from one spill every 2.2 seconds to one every 1.33 seconds or we will jeopardize data.

*https://neutrino.otterbein.edu/Glaucus/public/list_people.cgi

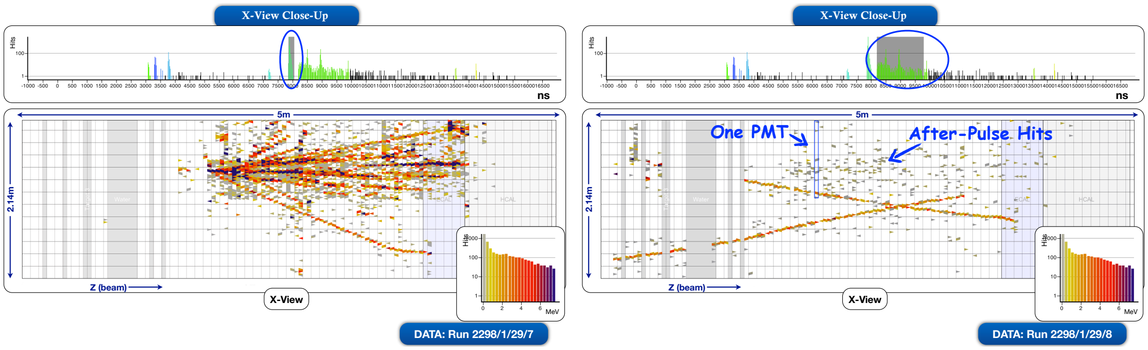

Figure 1: After-pulsing typically occurs after large hits and may generate a sufficient number of "ringing" hits to saturate the readout buffers completely.

The FEBs read 7(+1) hit buffers (the last one is "un-timed" and does not carry hit timing information). Our PMTs after-pulse due to residual gas in the tubes - this wastes hit buffers and introduces avoidable dead-time. See Figure **??** for an illustration.

Additionally, higher intensity or higher energy beam will use more buffers. MINERνA has operated comfortably in the NuMI "Low Energy" mode at 35×10^{12} protons per pulse, but higher intensities and energies may cause problems.

Finally, light yield is a problem. Currently MINERνA operates at approximately 5 p.e./MeV. This somewhat low number is due to the great deal of optical fiber involved in readout leading to high attenuation, but it is within design specifications. However, further drops at a few percent per year (due to scintillator aging) lead to about a 35% loss over a decade which is sufficient to impact timing and tracking resolution.

2.2 Readout Fixes

SiPMs would solve the after-pulsing problem. Those devices are noisy, but the spurious hits are not correlated with pulse height and so are much simpler to calibrate. Would they also solve the hit buffer saturation problem? In other words, are 7(+1) hit buffers sufficient in higher energy configurations with no after-pulsing? We need a study. And a few million dollars for the SiPM upgrade.

SiPMs would also help increase light yield. By removing a large amount of optical fiber from the system, we would gain a $\sim$30% light yield gain.