Findings:

1. The peak-to-peak noise in the digitized waveforms recorded from three ganged SiPMs in small scale tests is approximately 10 ADC counts. This noise level is low enough so that single PE signals can easily be resolved from noise.
2. The peak-to-peak noise in “good” digitized waveforms recorded in the 35-ton test with TPC electronics off is 20-30 ADC counts.
3. The peak-to-peak noise in digitized waveforms recorded in the 35-ton tests with TPC electronics on and reading out is approximately 250 ADC counts.
4. All small scale tests of DUNE photon detectors in liquid argon performed to date have used Gore twinax cables. Plans for ProtoDUNE-SP call for the use of CAT-6 cables.

Comments:

1. Small scale tests demonstrate that the SSP digitizer system has low enough intrinsic noise to distinguish single PE signals from three SENSL MicroFC-60035-SMT SiPMs ganged together. However, even with the TPC electronics turned off, the noise observed in the 35-ton test was at least 2 times higher than this level. One third of the SiPM channels had anomalous noise significantly higher than this. When the TPC was on and reading out, the noise in the SiPM waveforms was approximately 25 times the level present in small scale tests. ProtoDUNE-SP will operate approximately 3 times more SiPM readout channels than the 35-ton test. There is a significant risk that excessive noise will severely compromise the test of photon detectors in ProtoDUNE-SP.
2. Most tests of prototype photon detectors done to date have used Gore cables with high quality braided shields. The plan is to use commercial Cat 6 cables in ProtoDUNE-SP. We suggest testing the new cables for noise immunity soon to validate the soundness of this plan.

Recommendations:

1. Add to the risk register the risk that the ProtoDUNE-SP photodetector system will not provide information of sufficient quality to inform the DUNE design because excess noise degrades the quality of waveform digitization. Pursue mitigation of this risk with an aggressive attempt to understand the sources of noise in the 35-ton test (as is being done for the APA readout).
2. As part of the effort to avoid excess noise in the SiPM readout, we recommend tests of the readout of (even a partial) APA assembly including both TPC electronics and photon detectors. Either or both of the FNAL and BNL test systems could be modified to include SiPM readout.
3. The 35-ton test has shown that noise pickup is a concern for the photon system. It is likely that this pickup can be minimized by minimizing the length of cable outside the cryostat. We recommend that the SSPs be mounted on top of the cryostat as proposed and as close to the feed through ports as possible. The use of 48 volt DC for the power will also minimize the possibility of noise pickup from external sources.

Responses to the Charge Questions:

Q1. There is a serious risk that excessive noise in the SiPM readout will prevent the ProtoDUNE-SP test from providing a validation of the DUNE photon detector requirements or information that would lead to refinements to those requirements.

Q2. The significant risk of excess noise associated with the photon detection system has not been captured in the risk registry.

Q3. The commissioning plan does not include sufficient time to mitigate excessive noise if noise similar to that found in the 35-ton test is present in protoDUNE-SP.

Q5. The photon detector feed through port is not yet designed. This is a critical part of the photon detector electronics.

Q6. Same comment as for 5

Q9. There appears to be no plan to test the photon detector system in conjunction with the new APA systems in either the FNAL or BNL test stands. In light of the results of the 35-ton test, this appears to be a serious oversight.