DUNE Technical Note

Argonne SSP Characterization Testing for ProtoDUNE-SP

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I Introduction

This document describes the characterization procedure for the ProtoDUNE-SP photon readout board developed at Argonne –ANL-SSP. As described in the quality assurance and control document, the QA&QC at Argonne involves two steps:

1. Once an SSP is received it is tested by the group, engineering-level tests are performed under the "Post-assembly testing"

2. In the next stage "Charecterization testing" is done where a fully functional SSP module is tested under a mock physics data taking scenario

II SSP Characterization Testing Procedure

The characterization testing was carried out using a combination of LBNEWare (a windows based DAQ diagnostic tool) and Linux based DAQ (resembling the DAQ setup used by 35t experiment). Once the SSP board is received it is connected to the Linux based DAQ system. The testing of channels is done in the following sequence

1. Powered On SSP board
2. SSP board + 20 m cable
3. SSP board+20 m cable+coupler
4. SSP board+20 m cable+coupler+5 m cable
5. SP board+20 m cable+coupler+5 m cable+(unbiased SiPM hoverboard)
6. SSP board+20 m cable+coupler+5 m cable+(biased SiPM@24V hoverboard)
7. SSP board+20 m cable+coupler+5 m cable+(biased SiPM@25.5V hoverboard)
8. SSP board+20 m cable+coupler+5 m cable+(biased SiPM@26.5 V hoverboard)
9. SSP board+20 m cable+coupler+5 m cable+(biased SiPM@24 V hoverboard) (COLD)
10. SSP board+20 m cable+coupler+5 m cable+(biased SiPM@25.5V hoverboard) (COLD)
11. SSP board+20 m cable+coupler+5 m cable+(biased SiPM@26.5 V hoverboard) (COLD)

The above sequence is used to determine the intrinsic noise of the SSP and the noise introduced due to the cables etc.

Note 1: The coupler is used in lieu of the flange that separates the 20 m cable outside the detector from the 5 m cable that is inside the detector.

Note 2: The SiPM hover boards are connected tot he cable and immersed in LN2. In the actual ProtoDUNE experiment the SiPMs are embedded in an acrylic wavelength shifting paddle. However our setup should be a close approximation of the condition in the actual experiment, for testing purposes.

For the tests the SSP is ran under a timestamp mode (36 Hz) and waveforms collected. We look at both multiple waveforms and single waveforms for the RMS value to determine the noise in a particular setup. Figures 1,2 and 3 shows an example plot which is used to determine the RMS value

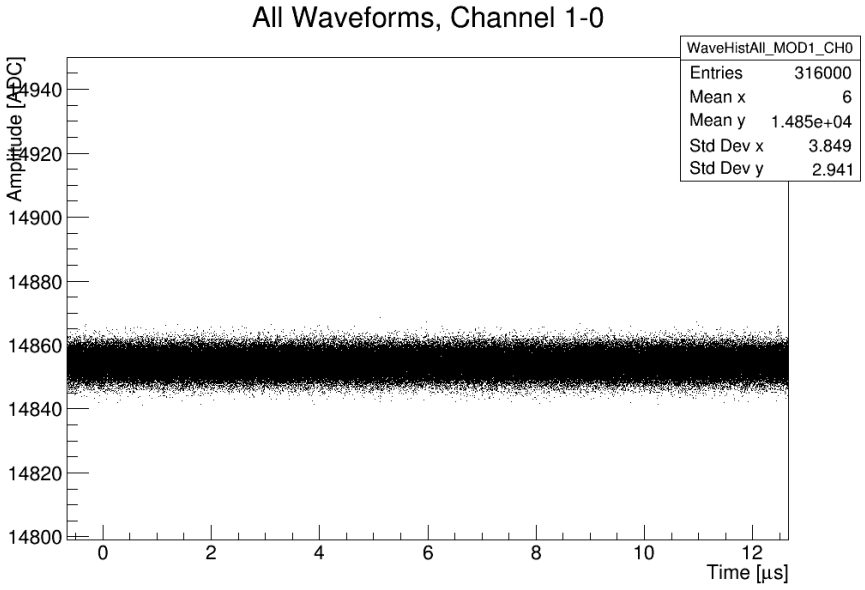

Figure 1: Example plots from SSP characterization testing. of channel 0 whenSSP was connected to 20m cable+coupler+5m cable. Left is looking at all waveforms collected during the test and right is looking at a single waveform. The standard deviation in Y is used as a measure of the noise in the system

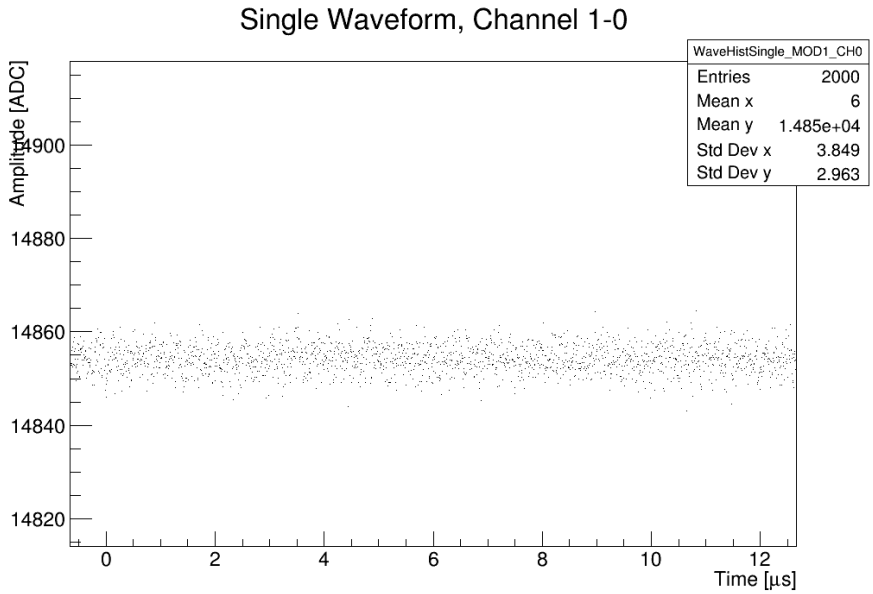

Figure 2: Example plots from SSP characterization testing. of channel 0 whenSSP was connected to 20m cable+coupler+5m cable. Above plot is looking at a single waveform. The standard deviation in Y is used as a measure of the noise in the system

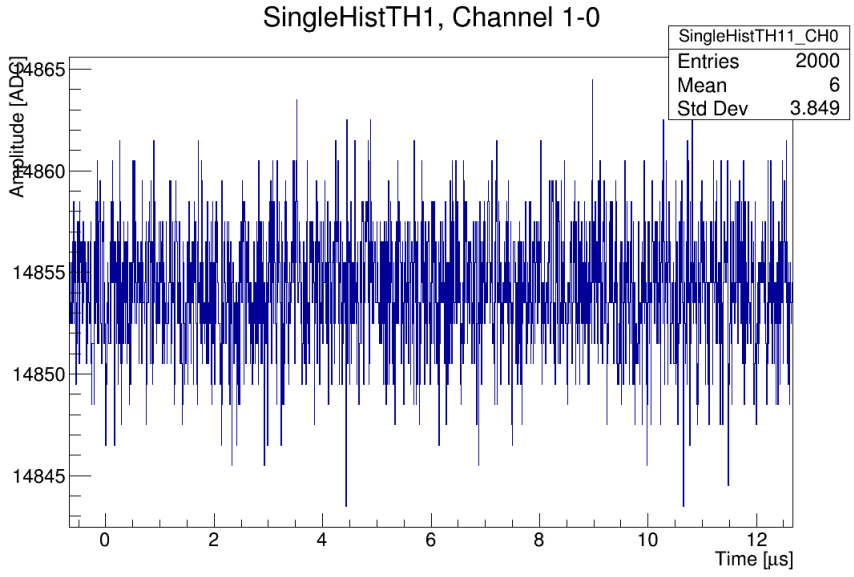

Figure 3: Example plots from SSP characterization testing. of channel 0 whenSSP was connected to 20m cable+coupler+5m cable.Above plot is a 1D plot showing the noise in the setup

III Results From SSP Characterization Testing

The test results of SSP board number 105 is summarized below. From similar studies in previous SSPs we determined that *RMS value of 3.5* in a fully connected (20 m cable+coupler+5 m cable+biased SiPM@24.0 V (COLD) is a benchmark value. Any value higher would mean that the channel be isolated and studied further.

Table 1 shows the RMS values for each channel as the steps in sectionII are carried out. Note: the peaks seen in some channels in a biased state is due to photons captured due to the biased state of SiPMs. Figure 4 shows the trend in the noise variation as the various cable+detector elements are added tot he SSP board. Table 2 and Figure 5 show the same for the case of single waveforms in SSP 105

channel	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11
0	2.411	2.916	2.919	2.941	2.896	2.867	2.881	2.886	3.431	2.871	2.868
1	2.474	2.942	2.954	2.944	2.937	2.891	2.911	2.917	3.45	2.902	2.902
2	2.467	3.068	3.073	3.067	2.952	2.901	2.924	2.922	3.438	2.912	2.908
3	2.451	2.91	2.924	2.92	2.884	2.874	2.889	2.885	3.508	2.872	2.861
4	2.426	2.892	2.902	2.921	2.872	2.848	2.856	2.862	3.374	2.851	2.851
5	2.469	2.954	2.964	2.962	2.939	2.907	2.924	2.925	3.517	2.909	2.905
6	2.451	2.994	3.00	2.998	2.883	2.853	2.859	2.849	3.355	2.845	2.844
7	2.445	2.903	2.907	2.91	2.874	2.854	2.858	2.865	3.48	2.858	2.855
8	2.431	2.897	2.896	2.917	2.869	2.849	2.855	2.859	2.841	2.851	2.845
9	2.413	2.89	2.897	2.893	2.879	2.857	2.853	2.859	2.846	2.843	2.844
10	2.431	3.027	3.015	3.016	2.906	2.882	2.883	2.881	2.876	2.876	2.874
11	2.437	2.884	2.898	2.888	2.87	2.851	2.853	2.855	2.836	2.842	2.842

Table 1: Multiple waveforms RMS values for all channels in SSP 105 as function of steps in II

IV Further Characterization Testing of SSP 104

Connecting SSP 104 to LBNEWare, waveforms were studied to look for examples of individual phot electrons (PE) as seen by the SiPM hoverboard and recorded by the

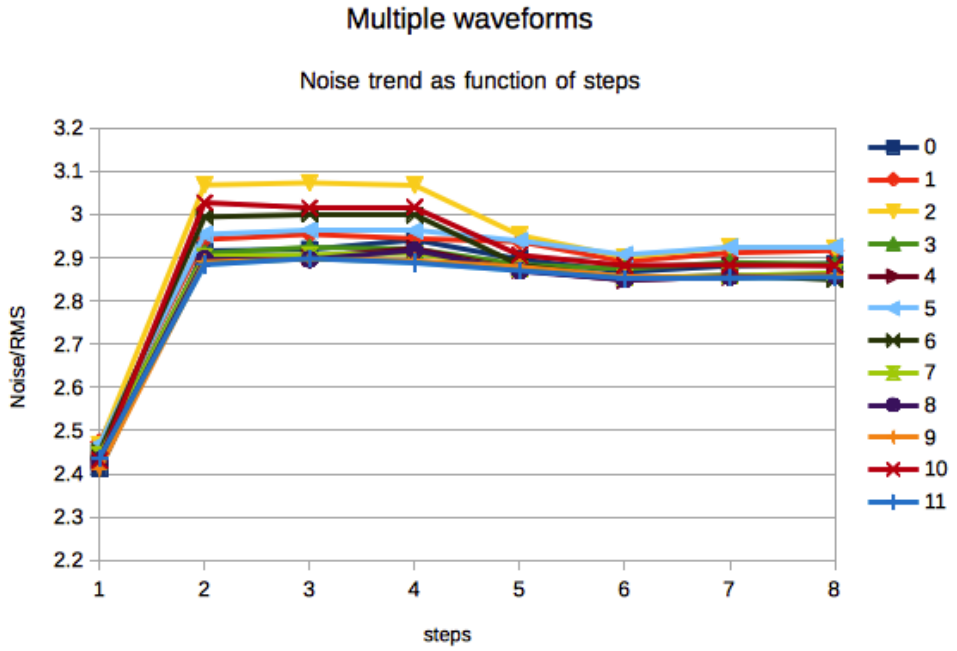

Figure 4: Trend in noise characteristics of SSP 105 as the steps outlined in section 2 are carried out. Steps beyond 8 are not plotted due to the fact that photons were captured by the biased SiPMs

channel	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8	Step 9	Step 10	Step 11
0	2.486	2.98	2.958	2.963	2.921	2.925	2.861	2.85	2.9	2.842	2.851
1	2.453	2.924	3.03	2.919	2.94	2.824	2.915	2.856	3.011	2.868	2.897
3	2.424	2.917	2.895	2.8	2.846	2.863	2.893	2.809	3.185	2.885	2.857
4	2.382	2.982	2.861	2.816	2.952	2.852	2.875	2.853	2.924	2.853	2.807
5	2.461	2.973	3.018	2.983	2.974	2.853	2.947	2.827	3.068	2.935	2.977
6	2.427	3.027	3.001	2.926	2.962	2.873	2.85	2.833	2.882	2.877	2.745
7	2.443	3.02	2.891	2.879	2.973	2.864	2.85	2.947	2.987	2.876	2.833
8	2.315	2.914	2.906	2.87	2.815	2.835	2.83	2.885	2.813	2.751	2.825
9	2.432	2.875	2.86	2.862	2.837	2.807	2.822	2.837	2.842	2.874	2.899
10	2.421	3.024	2.995	2.999	2.901	2.859	2.877	2.874	2.932	2.912	2.875
11	2.426	2.867	2.848	2.9	2.861	2.691	2.798	2.851	2.741	2.778	2.832

Table 2: Single waveforms RMS values for all channels in SSP 105 as function of steps in II

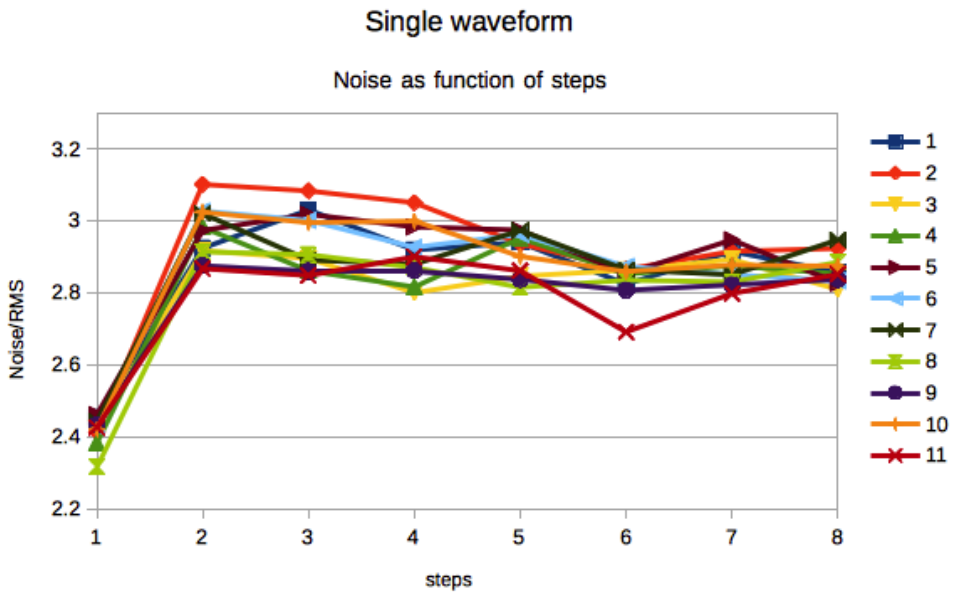

Figure 5: Trend in noise characteristics of SSP 105, looking at single waveforms. Steps beyond 8 are not plotted due to to the fact that photons were captured by the biased SiPMs

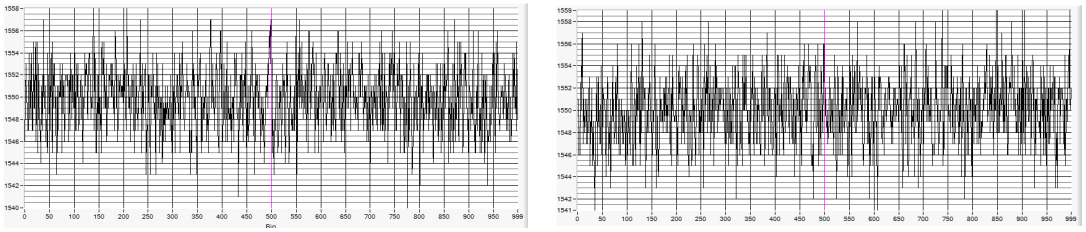

Figure 6: Examples of noise pulses in SSP 104

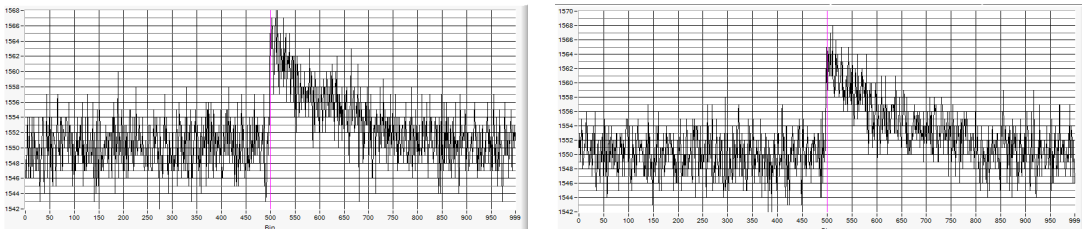

Figure 7: Examples of 1 PE pulses in SSP 104

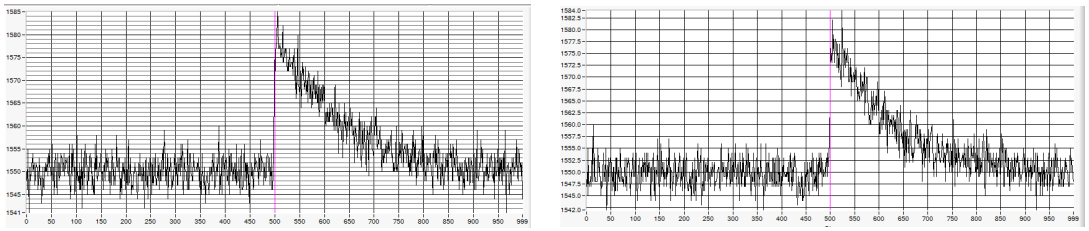

Figure 8: Examples of 2 PE pulses in SSP 104

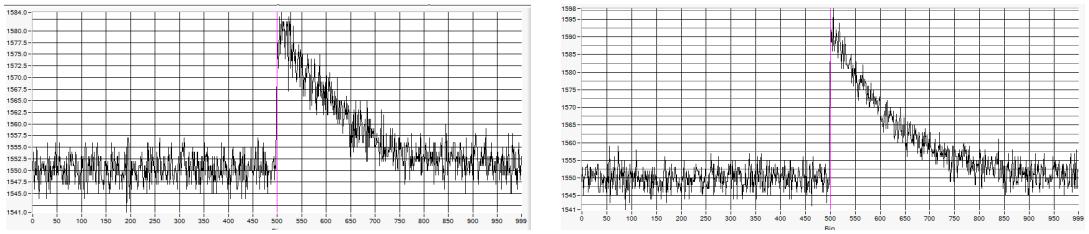

Figure 9: Examples of 3 PE pulses in SSP 104

SSP. For this study the SiPM hoverboard was cooled to LN2 temperature and connected to the SSP via the 20 m cable + coupler + 5 m cable. The bias was 26.5 V. In the following figures we see examples of noise pulse (Fig.6) , 1 PE (Fig.7), 2 PE (Fig.8) and 3 PE (Fig.9) waveforms. Finally in we see the integrated energy spectrum (Fig.10) which clearly shows the 1PE and 2 PE peaks following the nose peak centered around 0.

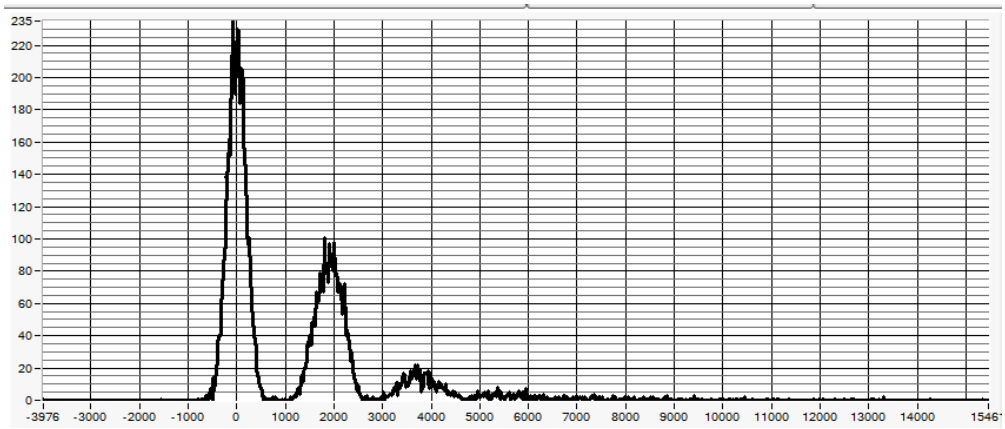

Figure 10: Integrated energy plot for 10000 events collected in SSP 104. The first peak centered around zero is the noise peak. The subsequent peaks are 1 PE and 2 PE peaks.

V Conclusions

From the charecterisation study in II we estimate that a noise level of about 3.5 in step 6 (SSP board+20 m cable+coupler+5 m cable+(biased SiPM@24V hoverboard)) is acceptable, anything above should be further investigated.

In section IV, from a study of single and multiple PE waveform studies we see that for a SiPM biased at 26.5 V ,single PE peaks are seen 12 counts above noise level. The 2 PE waveforms show about 25 counts above noise and 3 PE waveforms show about 35 counts above noise.

References

[1] DUNE docdb 3126 v1