FD1 PDS FDR Review
DRAFT Calibration System Operation and Results in ProtoDUNE_SP Phase-I
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Summary

The PDS incorporates a pulsed UV-light system to calibrate and monitor PD response over time. The calibration system produces UV light flashes with a variable pulse amplitude, pulse width, repetition rate, and pulse duration. The goal of PDS UV-light calibration is to characterize and calibrate the PD gain, crosstalk, time resolution, channel-to-channel timing, and PDS stability over time. Examples of potential time instabilities and configuration changes to be monitored include dissolution of PTP coatings over time, or changes in SiMP bias to adjust the PD gain. The full prototype of the UV-light calibration and monitoring system was designed for the FD1-HD PDS and validated in ProtoDUNE-SP-I operation [1].

ProtoDUNE-SP-I Configuration

The system hardware for FD1-HD (and also in ProtoDUNE-SP-I) calibration and monitoring system consists of both warm (calibration module: electronics board with the light source and timing and DAQ interfaces, fibers to transport light from the module to the cryostat) and cold components (fibers to transport light from the warm side to dedicated diffuser located at the cathode plane), and the optical feedthrough that interfaces the warm and cold components. The system with these components has been successfully tested and operated in ProtoDUNE-SP-I (please see Figure 1)) and the high-quality data have been collected by PDS and used to calibrate PD gain, time-resolution, crosstalk, and the PDS stability over time [1].

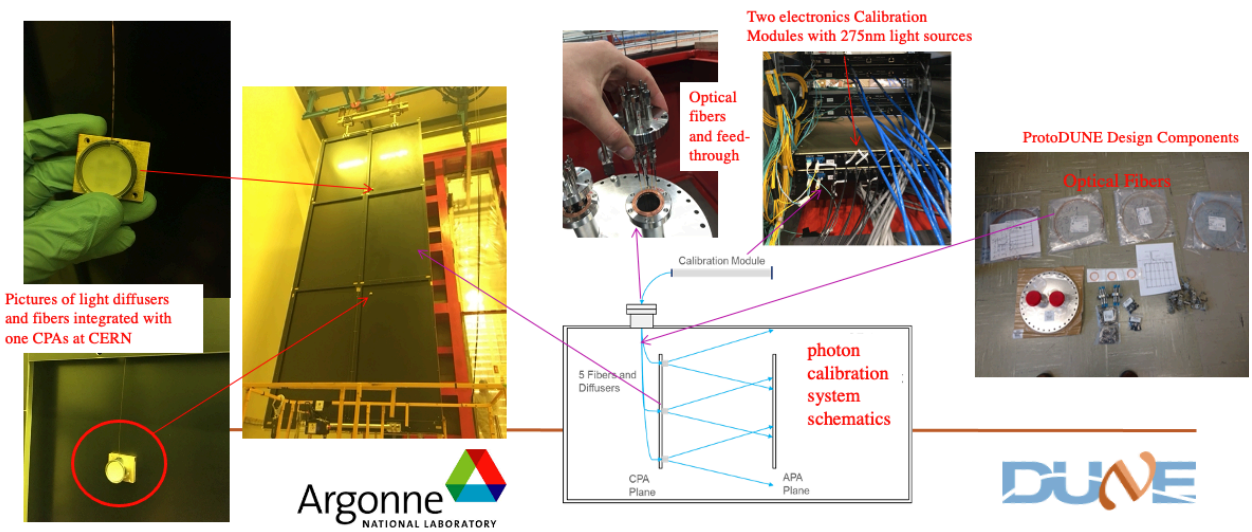

Figure 1: ProtoDUNE-SP-I calibration system components illustrated here in the single figure.

Operation

An example from the calibration system run log is presented in the following Figure 2. The columns represent the calibration run number, calibration module trigger type, description of what LEDs are flashed in each LArTPC, what DAQ configuration file was used in the run, how the photon readout electronics (SSPs) was triggered to see calibration pulses, what TPC APA photon detector component were collecting calibration data, wheterher or not the CRT was included in the run, if there was an additional trigger applied (the last two entrines are not relevant to calibratyion system operation). Other operation parameters describe calibration module controls on light pulse intensity (pulse height), how mabny light pulses will be emitted in the run (pulse sets), what is the time difference between two pulses if double pulse was emitted (pulse delay), pulse width of emitted pulses (pulse width), and special instructions/configurations.

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
run number	DCM triggering?	flashing LED	configuration file	triggers	APAs included	CRT included?	fake trigger rate (	HV (V)	pulse height	pulse sets	pulse delay	pulse width	special instructions	
5903	Yes	All rack side	PD_bias_scan_co	Externals only	All	Yes	25	0	0x00040806	0x0001FFFF	0x3E8	0x20		
5906	Yes	All rack side	PD_bias_scan_co	Externals only	All	Yes	25	180	0x00040806	0x0001FFFF	0x3E8	0x20		
5907	Yes	All rack side	PD_bias_scan_c	Externals only	All	Yes	25	180	0x00040806	0x0001FFFF	0x3E8	0x20		
5889	Yes	All rack side	PD_bias_scan_co	Externals only	All	No?	25	0	0x00040806	0x0001FFFF	0x32	0x20		
5890	Yes	All rack side	PD_bias_scan_c	Externals only	All	No?	25	0	0x00040806	0x0001FFFF	0x3E8	0x20	PreTrigLength: 37500 # in ticks, and PostTr	
5891	Yes	All rack side	PD_Test_00006	Externals only	All	No?	25	0	0x00040806	0x0001FFFF	0x3E8	0x20	trigger_input_delay: 0x00000010	
5892	Yes	All rack side	PD_bias_scan_co	Externals only	All	No?	25	0	0x00040806	0x0001FFFF	0x3E8	0x20	First started run, then sent DCM pulses	
5893	Yes	All rack side	PD_Test_00007	externals only	All	No?	25	0	0x00040806	0x0001FFFF	0x3E8	0x20	ALL_p_window: 0x10	
5894	Yes	All rack side	PD_bias_scan_c	Externals only	All	No?	25	0	0x000407ff	0x0001FFFF	0x3E8	0x20		
5895	Yes	All rack side	PD_bias_scan_c	Externals only	All	No?	25	0	0x00040806	0x0001FFFF	0x3E8	0x40		
5896	Yes	All rack side	PD_bias_scan_c	Externals only	All	No?	25	0	0x00040800	0x0001FFFF	0x3E8	0x20		
5897	Yes	All rack side	PD_bias_scan_co	Externals only	All	No?	25	0	0x00040801	0x0001FFFF	0x3E8	0x20		
5898	Yes	All rack side	PD_bias_scan_c	Externals only	All	No?	25	0	0x00040802	0x0001FFFF	0x3E8	0x20		
5899	Yes	All rack side	PD_bias_scan_co	Externals only	All	No?	25	0	0x00040803	0x0001FFFF	0x3E8	0x20		
5900	Yes	All rack side	PD_bias_scan_c	Externals only	All	No?	25	0	0x00040804	0x0001FFFF	0x3E8	0x20		
5901	Yes	All rack side	PD_bias_scan_co	Externals only	All	No?	25	0	0x00040805	0x0001FFFF	0x3E8	0x20		
5880	Yes	All rack side	PD_bias_scan_co	Externals only	All	No?	25		0x00040805	0x0001FFFF	0x3E8	0x20	triggering the DCM1	
5887	Yes	All DAQ side	PD_bias_scan_co	Externals only	All	No?	25		0x00040FFF	0x0001FFFF	0x3E8	0x20	triggering the DCM2	
5888	Yes	All rack side	PD_bias_scan_co	Externals only	All	No?	25		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5877	Yes	All rack side	PD_bias_scan_co	internals+externa	1,2,3,4,5	No?	25		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5747	No	UL	PD_bias_scan_config_00007			No?	75		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5748	No	LL	PD_bias_scan_config_00008			No?	75		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5750	No	LR	PD_bias_scan_config_00008			No?	75		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5494	No	different LEDs	PD_bias_scan_config_00004		1,2,3,5,6	No?	75		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5500	No	UL	PD_bias_scan_config_00004		1,2,3,5,6	No?	75		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5501	No	LL	PD_bias_scan_config_00004		1,2,3,5,6	No?	75		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5503	No	LR	PD_bias_scan_config_00004		1,2,3,5,6	No?	75		0x00040FFF	0x0001FFFF	0x3E8	0x20		
5061	No	UR Rack side				No?	25		0x00040FFF	0xffff	0x3E8	0x20		
5062	No	LL Rack side				No?	25		0x00040FFF	0xffff	0x3E8	0x20		
5074	No	LR Rack side				No?	25		0x00040FFF	0xffff	0x3E8	0x20		
5065	No	Center Rack side				No?	25		0x00040FFF	0xffff	0x3E8	0x20		

Figure 2: Calibration system runs and configuration parameters: example from the photon detector system operations log in ProtoDUNE-SP-I.

Selected Results

Gain Calibration: Figure 3 shows the photon-detector system waveforms collected by the SSP digitizer in a calibration system run displayed in persistence trace mode shows recorded single and multi-photon signals. Each time tick (tt) represents 6.67 ns (Left). Also shown is the sample waveforms of single photon signal from the calibration system runs: 3-S-SiPM channel (center) and 12-H-MPPC channel (right), corresponding to three and twelve sensors passively ganged in parallel, respectively.

Figure 4 shoes the charge distribution for typical 12-H-MPPC channel (VB = 48V) (left) and 3-S-SiPM channel (VB = 26 V) (right) under low amplitude pulsed LED illumination.

Figure 5 shows the gain as a function of applied bias voltage for 12-H-MPPC channels (left), and for 3-S-SiPM channels (right). Linearity of individual channel response is shown by the linear fit (red line) across the points at different bias voltage setting.

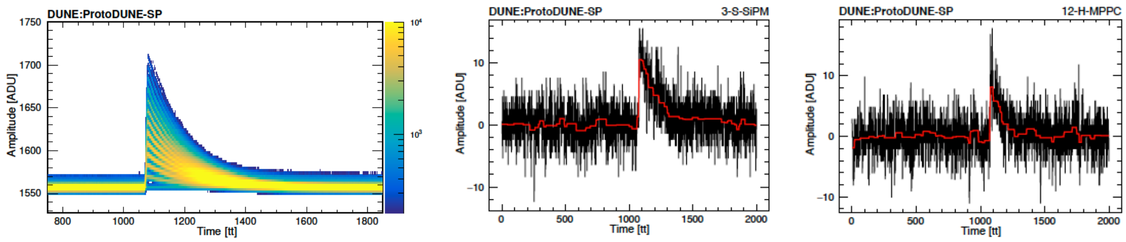

Figure 3: Single- and multi-PE data collected with the UV light calibration system in ProtoDUNE-SP-I.

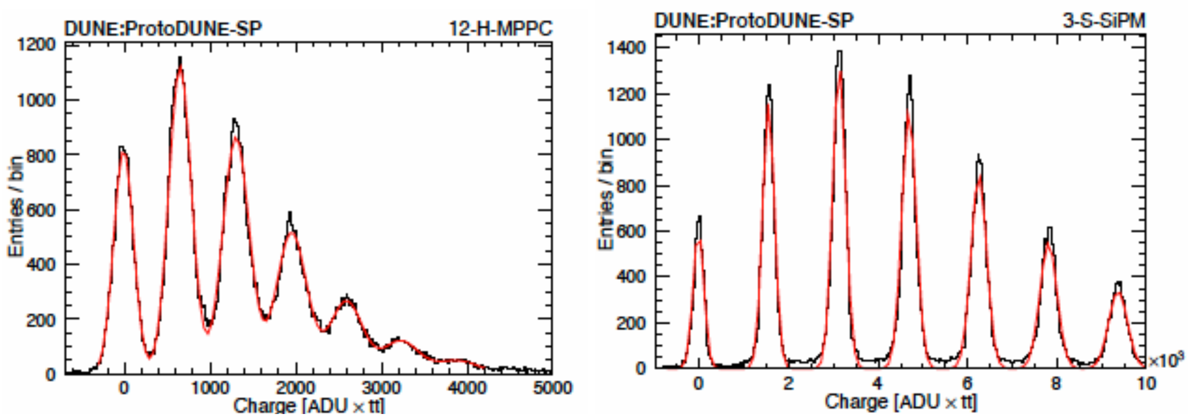

Figure 4: SiPM array charge distributions.

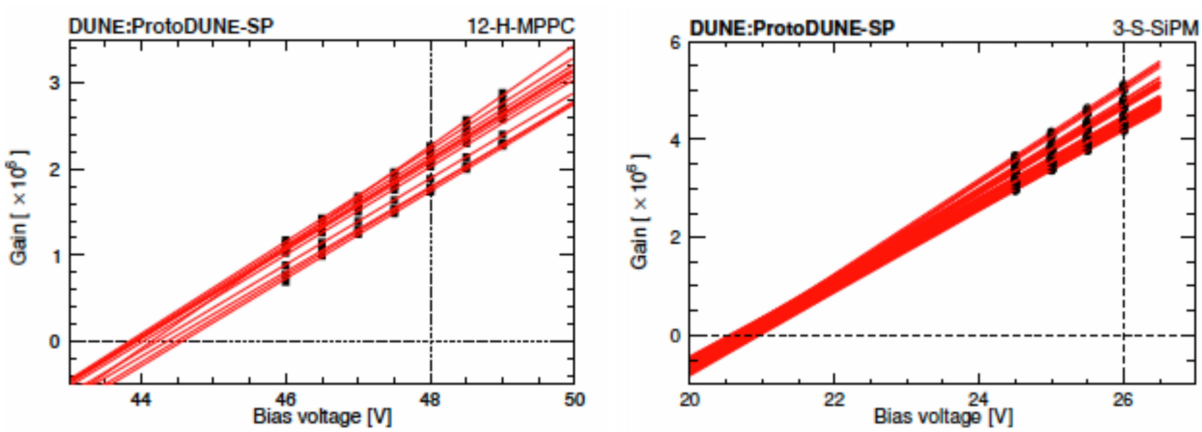

Figure 5: Gain as a function of applied bias voltage.

PDS/SiPM Characterization: Figure 6 shows the Signal-to-Noise Ratio (SNR) for the 3-S-SiPM channels (left), for the 3-H-MPPC channels (center), and for the 12-H-MPPC channels (right). Figure 7 shows the Afterpulse and crosstalk contribution to the photosensor signal expressed by the average number of avalanches generated per detected photon for the 3-S-SiPM channels (left), for the 3-HMPPC channels (center), and for the 12-H-MPPC channels (right).

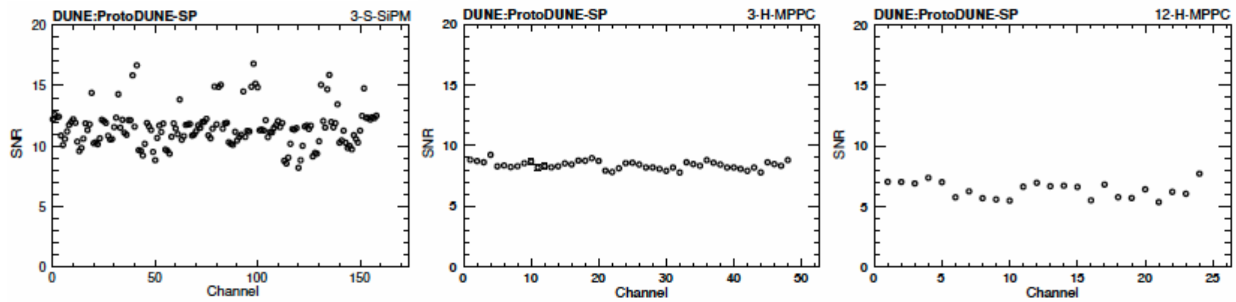

Figure 6: Signal-to-Noise Ratio studies.

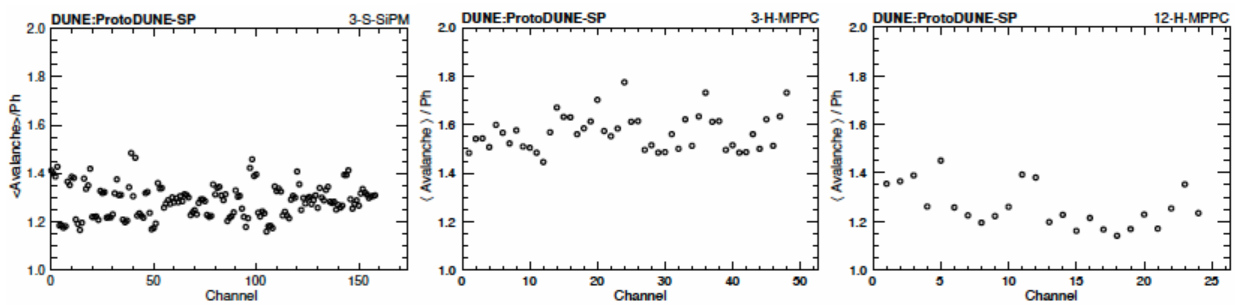

Figure 7: Afterpulse and crosstalk studies.

Time resolution: Figure 8 shows the photon-detector timing measurements with LED calibration system. Double pulse light signal using the photon detector calibration system (left) and the resolution in the time difference measurement between correlated light signals (right) is presented.

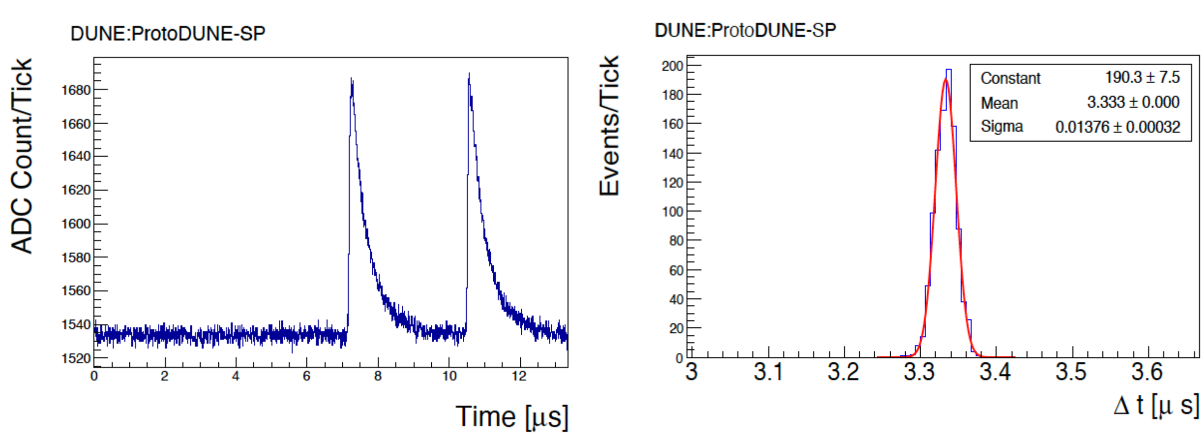

Figure 8: Photon-detector time resolution studies.

Stability Monitoring: Figure 9 shows the gain stability (charge signal per avalanche) for typical 12-H-MPPC channel (left) and 3-S-SiPM channel (right), from calibration runs performed over 100 days of operation. The shaded band corresponds to a 5% gain interval. Gain variations over time are contained well within the band. Statistical error bars are small, not visible inside the symbol.

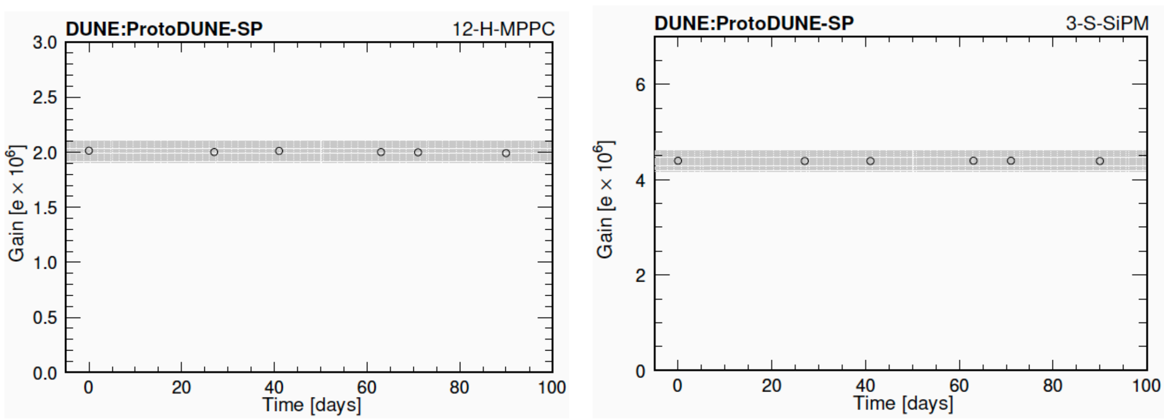

Figure 9: Stability of the photo-sensor response over time.

References

[1] First results on ProtoDUNE-SP, arXiv:2007.06722 (JINST).