PDS Photosensor TDR Sections

Bob Wilson

Photosensor Working Group Meeting

November 20, 2018

Eric J. – September 2018 collaboration meeting

- SP-PD 30% Design Review: November 12-13 @ FNAL
- DAQ 30% Design Review: December 3-4 @ CERN (TBC)
- LBNC Meeting: December 7-9 @ CERN
- LBNF/DUNE-US DOE IPR: January 8-10 @ FNAL
- Collaboration Meeting: January 28-31, February 1 @ CERN

- RRB Meeting: March 14-15 @ FNAL
- LBNC Meeting: April 1-3 @ FNAL
- LBNC Meeting: July 31, August 1-2 @ FNAL
- RRB Meeting: September 19-20 @ FNAL
- LBNF/DUNE-US DOE CD-2/CD-3B Review: October @ FNAL

Plenty of time, right …

Stefan S-R – September 2018 collaboration meeting

Technical Design Report

Main Editors: Tim Bolton and Sam Zeller

- **September**: Consortium/working group editors appointed
- **October**: Outlines due including outline of protoDUNE strategy
- **November:** First drafts due including first pass at requirements table. Editors' initial review complete by November 15
- **December**: Second drafts due. Must include initial cost, risk, schedule, and interface tables, plus any iteration of protoDUNE strategy and requirements.
- **January**: Review of second drafts.
- **February**: Outcome of independent reviews of second drafts back to consortia/working groups
- **March**: Final drafts due
- **April**: Review of final documents complete
- **April 15**: Submit final document to LBNC

Decided to have staggered chapter drafts

LBNC will be involved in review as early as possible, planning for staged review

Tim B. – email 10/29/18

Consortium	1st draft	2nd draft	LBNC
SP-HV	November 2, 2018	December 7, 2018	December 21, 2018
SP-APA	November 2, 2018	December 7, 2018	December 21, 2018
SP-DAQ	November 2, 2018	December 7, 2018	December 21, 2018
SP-PDS	November 30, 2018	January 11, 2019	January 25, 2019
SP-CISC	November 30, 2018	January 11, 2019	January 25, 2019
TC	November 30, 2018	January 11, 2019	January 25, 2019
PHYSICS	November 30, 2018	January 11, 2019	January 25, 2019

TDR Photosensor Sections

- Overview

1.1.2.2 Silicon Photosensors

In each photon collector concept, the final stage of converting a visible wavelength photon into an electrical signal is performed by a SiPM. The device must operate reliably for many years at LAr temperatures. Experience with a promising early candidate that failed in later batches, due to an unadvertised change in the fabrication process, emphasizes the importance of a multi-source approach with active engagement of potential vendors to develop a device expressly for cryogenic operation. Currently, there are ongoing investigations of MPPCs (multi-pixel photon counters) produced by Hamamatsu[4] (Japan) including a model specifically designed for cryogenic operation, and a device developed for operation in LAr by FBK[5] (Italy) in collaboration with the DarkSide experiment.

- Change text to reflect MPPC as baseline with FBK option being vigorously pursued

TDR Photosensor Sections

- Photon Detector System Design

1.3.2 Silicon Photosensors

Content update: Zutshi

Update text to identify two candidates MPPC and FBK.

The SP module PDS uses a multi-step approach to scintillation light detection with final stage of conversion into electrical charge performed by silicon photomultipliers (SiPM). Robust photon detection efficiency, low operating voltages, small size and ruggedness make their use attractive in the SP design where the photon detectors must be accommodated inside the APA frames. As implemented in ProtoDUNE-SP, there are twelve $6\times6\,\mathrm{mm}^2$ SiPMs per bar and 6 to 12 per ARAPUCA box. With this configuration, a 10 kt SP module with 150 anode plane assemblies, each with 10 PD modules, would contain 18,000-36,000 (single or double-ended readout) SiPMs for the light guide designs and 10-20 times more for the higher granularity ARAPUCA design. This corresponds to approximately 1-13 m^2 of active SiPM surface area.

The following summarizes the most salient guiding principles and requirements for this SiPM-based photodetection system.

- The full suite of SiPM requirements (number of devices, spectral sensitivity, dynamic range, triggering, zero-suppression threshold etc.) is determined by the physics goals and the photon collection implementation. As discussed in Section 1.1.1, the requirements for SNB neutrinos are not yet fully established however, R&D carried out to date indicates that devices from several vendors have the performance characteristics close to that needed for the PDS (see Table 1.4). Nearly one thousand of several types of these devices are used in the ProtoDUNE-SP PD[12], which will provide an excellent test bed for evaluating and monitoring SiPM performance in a realistic environment over a period of months.

- IDR had about 2 pages + ~1 page table
- Need to change the tense and tone to TDR level
- Maybe add more justification but not add more pages

TDR Photosensor Sections

- 1.3.2 Baseline and options sensor characteristics

Table 1.4: Candidate Photosensors Characteristics.

	Hamamatsu	sensL	KETEK	Advansid
Series part #	S13360	DS-MicroC	PM33	NUV-SiPMs
Vbr range	48 V to 58 V	24.2 V to 24.7 V	27.5 V	24 V to 28 V
Vop range	Vbr + 3 V	Vbr +1 V to +3 V	Vbr+2V to +5 V	Vbr +2 V to +6 V
Temp. dependence	54 mV/K	21.5 mV/K	22 mV/K	26 mV/K
Gain	1.7×10^6	3×10^6	1.74×10^6	3.6×10^6
Pixel size	50 μm	10 μm to 50 μm	15 μm to 25 μm	40 μm

- No point to details on devices we are not considering. Can mention them in the text, including cautionary tale of sensL.
- Add FBK DarkSide device details?
- Proceed or replace with a specifications table?
- Include ganging studies in this section, or in Electronics?

TDR Photosensor Sections

- 1.4 Production and Assembly

1.4.9 Photosensor Modules

Content: Zut-shi/Can

Depending on the photon collector technology selected, the SiPM analog signal will be ganged in groups of 6-48 in close proximity to the sensors inside the LAr volume; both *passive* and *active* ganging schemes are under consideration. Passive ganging (sensors in parallel) implemented with traces on the SiPM mounting board (module) and has been implemented for ProtoDUNE-SP. The SiPMs are mounted using a pick-and-place machine and standard surface mount device soldering procedures. The ganged analog signals are then brought out via long cables (approximately 25 m) for digitization outside the cryostat. ProtoDUNE-SP will provide essential operational experience with a passive ganging board and signal transport provided by Teflon ethernet CAT6 cables. It is already apparent that R&D is needed to optimize the connectors used to couple the cable to the board; it is a priority to understand the mechanical stresses involved in the SiPM-PCB-Connector system (with different CTEs) as it is cooled (or cycled) to cryogenic temperatures.

A basic level of active ganging locates summing circuitry on the board carrying the photosensors or on a separate PCB also mounted on the PD module. A more complex scheme is being considered that would include cold amplifiers and ADCs. This solution would provide more flexibility in the level of photosensor ganging and also obviate the need for carrying analog signals of long cables. Production of the board would follow standards practices but the complexity introduces concerns with reliability and long-term stability issues related to cold electronics. Basic active ganging prototypes are under study with high priority but the design is not yet at a mature stage.

- Describe in the context of X-ARAPUCA
- Has a paragraph on ganging – update to current status/efforts

TDR Photosensor Sections

- Despite Thanksgiving… updates needed by this weekend!
  - Even that leaves just < one week for iterations and top level edits before first draft deadline - 30 November
- Not such a big challenge for the photosensors group compared to others