DUNE-SP PDS Photosensor WG

R. Wilson (CSU), V. Zutshi (NIU)

Outline

- Principles and Specifications
- R&D Plan
- Status Report

Guiding Principles

- Photosensor choice limited to Silicon Photomultipliers
- Signal path separate from TPC readout
- Feed-through cable space limitations imply some level of ganging of the devices
- Consider only those devices that have the promise of ending up with vendor certified cryo packaging (could imply sole sourcing)
- SiPM packaging should allow for tileable arrays
- Since all photon detector options under consideration involve shifting the 128 nm light to various degrees; the optimal SiPM maybe different for different designs (need guidance/ requirements from photon collector group)

Requirements Specifications

- Close connection with other especially physics/simulations, photon collector and DAQ groups needed as these cannot be determined internally
- Size, total area, number of devices
- How low does the zero-suppression threshold need to be?
- Triggering on PD? Configuration? DAQ rates allowable?
- Is an “energy” measurement from the PD system useful? What dynamic range is really needed?
- Should timing be listed explicitly (current devices far exceed what we need)?

R&D Task: Understanding SiPM requirements in light of the physics goals

Risk: Mechanical failure of sensor under cryo conditions

Cryogenic Certification

- Needs to be a collaborative effort between the WG and Silicon Photomultiplier vendors
  - Ongoing and recent discussions with FBK & Hamamatsu
- Note this may prune the list of potential vendors
- Joint specification of testing protocol, sample sizes etc.
- Aims:
  - Vendor warranty
  - Process specification (part number specification not enough)
  - Cryo testing as part of the vendor's process control

R&D Task: Vendor contact and procurement of appropriate samples
Specification of testing regime for cryo certification
Testing & characterization of devices & packaging

Mechanical Integrity

- Need to understand differential CTE stresses for the SiPM-cold electronics board assembly (maybe useful to have a deeper understanding of the SensL failure)
  - Some educated guesses but need to pin this down
- Simulations may also point the way to safer designs and soldering schemes
- Configuration of sensor window (sealed, open,…). Could moisture build-up be an issue? Trapped air bubbles?
- Impact of LAr pressure on packaging

R&D Task: Mechanical engineering analyses for addressing these issues

Risk: Unsatisfactory Sensor Performance

Devices Characteristics

- Comparative evaluation of promising candidate SiPMs from multiple vendors (inherent characteristics + ganging) especially at cryogenic temperatures
- Comparative evaluation of promising SiPMs from multiple vendors in light of the photon collectors (form factor, spectral response, mating etc.)
- SiPMs with surface treatments (e.g. a WLS like TPB)
- Mean time between failures and failure mode analysis
- QA/QC plan

R&D Task: Vendor contact and procurement of appropriate samples
Specification of common testing regime
Testing & characterization of devices & their comparative eval.
MTBF specification and testing

Risk: Readout scheme performance and/or schedule

Electrical Integrity

- Electrical evaluation of the cold readout board and associated connector (close connection with electronics group)
  - Indications that current connectors are a weak point
- Note that noise rates on the current hover-boards tend to be higher than expected (could be unseen damage on the sensors but could also be…)
- Are we following best practices and using optimal materials (solder, insulation etc.) based on prior experience in noble liquid experiments?
- Long term aging of the assembly

R&D Task: Design, process and materials evaluation of current cold board
Design and prototyping of cold board based on lessons learned
Understanding long-term performance of assembly

Readout Scheme

- Understanding feed-through space constraints in light of the cable choice? Cost constraints may also play a role.
- Passive or active (realistic given TDR timescale ?) ganging
- Number of gangings (not just a sensor S/N issue)
- Series passive ganging as an option? (breakdown voltage becomes an important consideration)
- Robustness with respect to failure modes

R&D Task: understanding minimal ganging required due to space constraints
implementation of ganging options
testing and performance characterization of ganging options

Risk: Poorly understood requirements for operability

Calibration

- While the full extent of the calorimetric measurements needed is unclear; application and maintenance of an optimal threshold is key
- Single PE calibration and its monitoring
- Temperature will be very stable but there may be a spatial gradient (though most probably small from our point-of-view)
- LED system? Light distribution vs. pulse distribution?
- Timing calibration (cable lengths, clock distribution etc.)*

R&D Task: Specification and implementation of the response and timing calibration system

protoDUNE

- Important test-bed for not only collector options but also for SiPM performance and medium-term behavior
- Number of SiPM species (SensL, Hamamatsu in “cryo” and “non-cryo” packaging) along with passive ganging schemes

	Hamamatsu	SensL
series part #	S13360	DS-MicroC
Vbr range	48V to 58V	24.2V to 24.7V
Vop range	Vbr + 3V	Vbr +1V to +3V
Temp. dependence	54 mV/K	21.5mV/K
gain	1.7 x10^6	3x10^6
pixel size	50um	10um to 50um
sizes	2x2mm	1x1
	3x3mm	3x3
	6x6mm	6x6
wavelength	320 to 900nm	300 to 950nm
PDE peak wavelength	450nm	420nm
PDE @ peak	40%	24% to 41%
DCR @0.5PE	2 to 6 MHz	.3kHz to 1.2MHz
Crosstalk		7%
Afterpulsing		0.20%
Terminal capacitance	1300pF	3400pF
Lab experience	Good experiences from Mu2e and Arapuca	Crack at LN2/ change specs.

FBK/Darkside Collaboration

- Potential collaboration – early days!
- FBK (Fondazione Bruno Kessler) developed a SiPM in collaboration with Darkside for use in two-phase argon TPC for dark matter search
  - Several DUNE members are collaborators, including Ettore and Anna
- **14 m^2** of SiPM: 5210 50mm x 50mm tiles each with of 24 ganged 12.7 mm x 9.7mm SiPMs
- FBK design will be fabbed in a foundry under license
- Packaging in a custom facility by the collaboration; facility could be available on a timescale interesting to DUNE
- Have developed cold pre-amp/active-ganging electronics
- Discussions with FBK (Alberto Gola) and Darkside (presentation by Eugenio Scapparone, Cristiano Galbiati) – potential visit to LNGS+FBK in March

Status

- Institutional interests so far: Caltech, CSU, Iowa, LSU, NIU, Prague, UniCamp (apologies in advance if anyone has been left out inadvertently)
- Draft R&D proposal discussed with interested parties
- Initial contact with FBK, Hamamatsu, KETEK and SensL
- Strong interest from FBK/Darkside and Hamamatsu: need to communicate our initial requirements and specifications to them

Summary

- The protoDUNE experience has been useful to understand some of the potential pitfalls for the DUNE detector w.r.t. SiPMs
- In spite of the non-optimal experience with a generation of SensL devices there is ample room for optimism for SiPMs
- Strong interest from multiple vendors to work with us in developing and certifying specifications for cryogenic operation
- Need a robust R&D program on our side to meaningfully interact with them