**ANL Technical and Scientific Contributions with Photon-Detection System (PDS)**

**Opportunity:** The ANL research program is focused on improving physics sensitivities using energy scale calibration and energy reconstruction that combines collected TPC charge with measured PDS light. An important aspect in understanding the detector response is inclusion of timing and calorimetry information from the PDS. With the DUNE TDR requirements for increased PDS light yield, there is now opportunity to explore if the PDS can also be used to directly measure energy calorimetrically for all classes of events, working as a cross-check to the energy measured by the TPC or improving the resolution when both measurements are used together. In order to achieve this goal, Argonne will lead the calibration of PDS gain and its timing. Measurement and monitoring of the time-resolution, the light collection efficiency and linearity are also required.

**Argonne Contributions:** Within the DUNE PDS Consortium, Zelimir Djurcic (ANL Scientist) is co-convener of the DUNE PDS Electronics and Calibration Working Group (WG) with a charge to optimize PDS readout for DUNE and to enable international collaborators from Latin America to fabricate ~6,000 readout channels for DUNE FD. The group has written TDR chapters on PDS Readout, Calibration, including inputs from ProtoDUNE-SP. ANL PDS focus on DUNE will be on the design and delivery of ~150 PDS Calibration and Monitoring channels for DUNE 10-kt FD, including the optical, mechanical, and electronics components. ANL currently leads the PDS data analysis effort to fully characterize ProtoDUNE-SP PDS and our goal is to transition this expertise and results into the DUNE Far Detector. Zelimir Djurcic is co-convener of DUNE’s ProtoDUNE Analysis and Operations WG. Aleena Rafique (ANL Postdoc) operated the PDS at CERN in the beam data-taking phase; she now leads the analysis of Michel electrons from stopping muons at ProtoDUNE-SP. The progress and results from the activities above have been presented at DUNE meetings, reviews (such as recent PDS 30% review), and at conferences/workshops.

**Deliverables:** ANL will deliver the photon-detector calibration and monitoring system, consisting of electronics and optomechanical components, to operate over 20+ years.For our proposed effort on the PDS Calibration/Monitoring system, we will follow the technical steps as listed in PDS WBS: 1) Calibration/monitoring pre-production reviews. 2) Verification of the design through ProtoDUNE data collection and analysis. 3) Final design and engineering of monitoring system. 4) Final selection and verification of LED flasher monitoring system. 5) Monitoring system materials verification. 6) Final pre-production prototype fabrication and testing. 7) Final engineering design and prototype verification of PD fiber feed-through. 8) Procurement and testing of PD monitoring/calibration system 9) Procurement and fabrication of PD monitoring system 10) Fiber cable feedthrough Fabrication/Procurement. 11) QA/QC tests of monitoring /calibration system (optical fibers, diffusers, LED drivers) for 1 10kt detector. 12) Calibration/monitoring equipment QA/QC test station. 13) Cryostat flange test station. 14) Completion of QA plan and equipment. 15) Monitoring/system production and delivery.

**Impact:** ANL will enable US and latin American colleagues in the design, fabrication, and delivery of the PDS. The ANL PDS calibration/monitoring strategy has synergy with our proposed Laser Calibration System. The combined studies of charge- and light-based energy reconstruction will improve the measurement of the CP violating phase. Our current involvement and deployment of the system in ProtoDUNE-SP is a key for our success in designing a system and performing relevant analyses. Therefore, the ANL group has proposed a well-rounded DUNE calibration program tied to energy reconstruction that motivates all three DUNE science drivers.

**Estimated effort**: We estimate that throughout the DUNE FD commissioning (2020-2025) we will require 0.60 FTE of physicist leading the PDS efforts together with 0.75 FTE postdoc, and 0.5 FTE engineer. We assume that this work is to be performed in collaboration with university groups who will assist in testing, QA/QC, integration, installation, and analysis efforts.