PDS

10. ***What is the process to decide the PDS layout: cathode, field cage and the alternative location on the membrane? What simulations and test results will drive it?***

We have a reference design (4pi option) and we are in the process of understanding the funding model.

Test results from on-going VD PD R&D are needed to validate 4pi-PDS: the 4pi-PDS solution operates PD on HV surface, with electrically floating photo-sensors and r/o electronics, ie with Power (IN) and Signal (OUT) transmitted via non-conductive cables (eg optical fibre). **None of the commercially available technologies for transmission on fibre is rated to operate in Cold (at LAr Temperature).** Goals of the on-going VD PDS R&D in 2021 are:

- Demonstration of COTS Power over Fibre (PoF) technology in cold (LAr T) for supplying Power via optical fibre for SiPM and for r/o Cold Electronics.

- Demonstration of COTS Digital *OR* Analog Optical Transceivers in cold (LAr T) for high throughput Signal transmission rates.

- Determination of overall Power budget in LAr required by PoF+Opt. Transceivers + r/o CE within limit established by cryogenic plant.

Test Results from these R&D items should be sufficient to drive into decisions on PDS configurations. If all successful, 4pi-PDS could be baselined.

Simulations have been performed (separately and independently) **for 4pi-PDS and for PDS-on-membrane** (and cross checked). Simulations showed that PDS-on-membrane alone has a reduced trigger efficiency (~64% for 10 MeV events) and diminished energy and position reconstruction capabilities with respect to 4pi-PDS (>99% trigger efficiency for 10 MeV events).

The same simulations show that a careful optimization of threshold and majority requirements can allow for a good definition of the T0, with efficiency above 70% for energy depositions as low as 5 MeV, while keeping a background rejection (for 39Ar activity) at the level of 0.1%. Further investigations are underway.

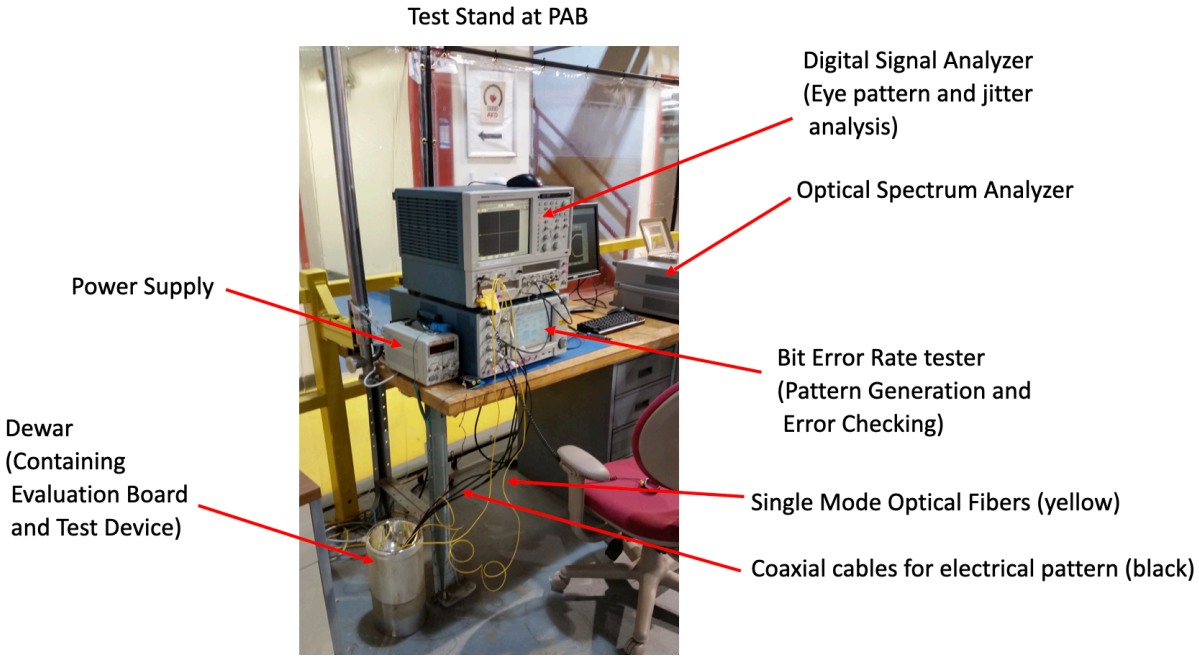
[Additional Information on Current status of **VD PD R&D**:

- R&D was carried out in 2020 at FNAL and CERN, before and during VD proposal writing, demonstrated that commercial **PoF technology** - with minor custom adjustments - **works well in cold** (actually it showed an increase in efficiency compared to specs at room T). In particular PoF was certified for bias Voltage supply to SiPM(tunable voltage > 60V, very low current), and validated on short-term stability (SiPM board powered at CERN, 50 lt test set-up).

- R&D in 2021 at FNAL is currently certifying **PoF for CE power supply.** CE power supply requires lower Voltage (= and < 5 V) but higher current. Tests in cold of higher PoF

receivers with larger heat sink have been completed successfully on two modules, showing higher opto-to-electrical efficiency. Power stability at low Voltage (1 V for FPGAs) is required, and stability tests are planned/on-going.

- On-going (very aggressive) R&Dâ€™s primary goal is to identify solutions for PD Signal transmission via optical fibre:
  - *Option 1* - **Digital** Optical Transceiver: 12 different types of OptoLinks (used in LHC Exp. ATLAS/CMS - *Versatile Link and Versatile Link Plus projects, led by CERN*) have been selected, procured and fully benchmarked Room T. Test stand moved to PAB (cryogenic facility at FNAL) for cold tests [starting March 4 *-today* - after clearance to operate with cryogens].
  - *Option 2* - **Analog** Optical Transceiver: COTS optoelectronic devices for the transmission of analog signals via fiber are being developed by *DarkSide Collaboration* - a collaborative synergic efforts started between DUNE VD Eu-Grps (in France and Italy) and DS on Analog opto-links development.]



[Additional Information: summary/reminder on photon detector system mandates:

1. Provide very robust and efficient trigger capability in the Low-En range.
   Present studies onÂ LAr-TPC self-triggering indicate that the charge readout can in principle run in self triggering mode, also allowing uniform detections down to 5-10 MeV scale.Â Combination of PDS and LArTPC might contribute to reduce fake triggers and data streaming bandwidth (This is in a region where natural radioactivity will dominate).

2. The prompt signals of the PD are essential in the determination of the T=0 of each event, allowing positioning of events along the drift axis. This is important for the definition of the fiducial volume and for correcting charge deposition attenuation due to finite electron lifetime. The good S/N of X-Arapucas for single photon detection plays here a fundamental role.

3. Extend the physics reach toward low energy scale, acting as an independent detector and opening new physics channels.]

11. How will the PDS system be demonstrated in the coldbox and NP02? What changes to the field cage design would be needed for the membrane solution? (Filippo)

A 3x3.3 m2 cathode module with two xARAPUCA tiles equipped with prototype versions of the r/o CE will be implemented as part of the short drift VD TPC for test in the ColdBox at CERN. Power for SiPM and CE will be supplied by the cold PoF system developed at FNAL and already utilized at CERN 50 lt test stand. Data will be transmitted through OptoLinks (either digital or analog, assuming successful validation from bench tests in cold).

All this represents a full scale prototype for the PDS on the cathode, and serves as a demonstrator for operating PDS in LAr on HV.

In case the solution for PD signal readout from HV surfaces is not available at that moment, we will place the X-Arapuca outside the active volume on the membrane cryostat walls at ground.

PD modules (xARAPUCA+CE) for the FC are very similar to the PD modules for the cathode. At present, no FC xARAPUCA modules are envisaged for tests in ColdBox in 2021. However, an installation plan of PD modules on FC, power distribution and signal transmission will be developed in full details, including prototypes for dedicated lab tests.