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APEX: Scale up photon detectors for large detector area coverage

Tuesday, 7 November 2023 13:30 (20 minutes)

In this talk, we propose a detector concept called APEX (Aluminum Profiles with Embedded X-arapucas) for large LArTPC detectors by instrumenting large-area X-arapuca photon detectors on the entire LArTPC field cage. The photon detectors will cover four sides of a typical cuboid LArTPC volume like the DUNE VD module excluding the two anode planes, with a covered area of up to 2500m^2. The PoF (power over fiber) and SoF (signal over finer) technologies developed and successfully demonstrated in DUNE VD make such a design possible and promising. Despite this, the scaling up of the X-arapuca detectors to thousands of square meters as well as integrating with the LArTPC field cage structure poses many challenges to mechanics and electronics.

One particular challenge is understanding how the instrumented PD modules interplay with the LArTPC E field. To address this, we perform a material charge-up test in a tabletop TPC system at the surface environment to understand the evolution of the LArTPC E field. Further tests in an underground environment are also planned to understand the charge-up behavior due to the limited available charges. The PoF and SoF require multiple optical fibers to supply detector power and read out signals. The routing of hundreds-of-kilometers-long fibers inside and outside aluminum field cage profiles without affecting the E field requires new profile and field cage designs. The large area detector also puts higher requirements on detector production speed. While the production of large wavelength shifting plates is possible, the current production of dichroic filters based on glass substrates is slow. Each unit filter takes hours to coat and the produced unit sizes are small. Large-area dichroic coating with physical vapor deposition and atomic layer deposition technologies are both aggressively pursued to address the issue. Large-scale production of the pTerphenyl coating for first wavelength shifting of the LAr scintillation light with an industrialized light source is actively investigated.

The scaling up of the photon detectors also drastically increases the number of readout channels. This brings challenges to the power consumption of cold electronics and signal readout bandwidth. In response to these challenges, we proposed a new design of PoF that can supply the high SiPM bias for many PD modules sitting on equipotential FC profiles. This solution will mitigate both power consumption challenges and noise problems. A wavelength-division multiplexing solution in combination with a novel ring resonator modulation technology that offers hundreds of GB/s readout ability is proposed to address the bandwidth problem. The signal amplification and digitization with in-house designed ASICs are also proposed to reduce the cost and power consumption.

At the end of the talk, I will also go through prototype plans and relevant physics studies. The APEX detector concept will be extremely useful for the next generation long baseline neutrino experiment DUNE which requires 40 kilotons of LAr fiducial mass to achieve its main physics goal specified in the 2014 P5 report. To complete the fiducial mass, the DUNE phase 2 program requires two more far detector modules. The APEX concept proposed in this talk increases detector coverage area fraction up to 75% and will enable DUNE with improved event reconstruction, energy resolution, background rejection, and expansion of its physics reach to the MeV energy region. More importantly, our proposal can be combined with most of the proposed phase 2 VD LArTPC technologies.

Early Career

Yes

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