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Front-End Electronics and DAQ for Large Scintillator Arrays

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Thematic areas:
- (IF2) Photon Detectors
- (IF4) Trigger and DAQ
- (IF7) Electronics/ASICs

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Scintillator strips have been used in experiments for decades. They are mechanically robust and require no consumables. Their behavior is well understood with typical spatial resolution of *mm* to *cm* and time resolution of *nsec*.

Recent improvements in the manufacture of scintillators and developments in photosensors have led to much higher manufacturing capacity and greatly reduced detector cost. Bars of arbitrary length are produced in a continuous extrusion process with the cross section shape determined by a die[1]. Co-extruding a cover layer eliminates the often labor-intensive step of wrapping each scintillator bar. While light attenuation length in scintillator is 10's *cm*, green light emitted by wavelength shifting fibers (WLS) has an attenuation length of *meters*. This allows the use of long bars to cover large detector areas[2]. Silicon photomultiplier (SiPM) is a now mature industrial technology with many vendors. Compared with traditional photomultipliers (PMT), SiPM operates at much lower voltage, typically 10's of V, it is mechanically more robust, it is far more immune to magnetic fields than PMT, its small size makes it easier to integrate into a detector system, and the channel cost is also lower than that of PMT.

This approach has been adopted in a number of recent experiments such as Belle-2 KLM upgrade[3] and Mu2e[4], and is being considered for several proposals where large area coverage

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1 A. Pla-Dalmau et al, Fermilab-Conf-03-318-E.
2 A. Artikov et al, NIM A890 (2018) 84-95.
3 T. Aushev et al, arXiv:1406.3267v3.
4 Mu2e Technical Design Report, arXiv:1501.05241.

is required. For example, MATHUSLA[5] is a proposal for a large-scale surface detector at the Large Hadron Collider (LHC) at CERN to search for hypothetical long-lived particles produced by proton collisions at the LHC. It calls for $\tilde{}10^5\ m^2$ of detector area with $\tilde{}10^6$ channels. Muon detectors in future lepton colliders such as the ILC, FCC-ee and CEPC, are other natural applications of this approach, with detector area in each case of $O\left(10^4\right)\ m^2$.

To realize the full potential of this approach, it is critical to develop a system of front-end electronics and DAQ with matching technical capabilities as well as low unit cost. These parameters include:

- Single photo-electron sensitivity.
- Coincidence of signals from two ends of a scintillator bar. Without it, data would be dominated by SiPM dark count rate (DCR). Typical DCR of $O(10)\ KHz$ per SiPM implies up to over GHz of non-physics noise hits to read out, store and analyze.
- Good timing resolution. A resolution of *nsec* is often adequate to correlate hits in different scintillator bars. Achieving a resolution of $\tilde{}100\, psec$ will allow the use of time difference to determine the longitudinal position along the length of a scintillator bar at the 1-*cm* level, comparable to width segmentation, thus giving the experiment greater flexibility in its design.

While these parameters are readily achieved in isolation, R&D is crucial to understand the tradeoffs and to have a cost-effective system design with the requisite science performance.

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[5] H. Lubatti, arXiv:1901.04040.