Snowmass2021 Letter of Interest: An R&D Collaboration for Scalable Pixelated Detector Systems

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Thematic Areas:
IF7: Electronics/ASICs
IF8: Noble Elements
IF9: Instrumentation Science: Cross Cutting and Systems Integration
NF10: Neutrino Detectors
UF03: Underground Detectors

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Introduction

Frontier experiments in neutrino and dark matter physics typically rely on large detectors, in the ton to many kiloton regimes. Achieving high-granularity readout in detectors at these scales requires new techniques in instrumentation design and production. Specific areas of development are large-area low-noise mixed-signal detector anode designs, system reliablity in the billion-channel regime, scalable and robust I/O architectures, and leveraging commercial methods for mass production. Recent advances in pixelated readout for large liquid argon time-projection chambers (LArTPCs) provide a concrete example of progress in this field [1, 2]. However, much development is still needed, and as the scale of that development necessarily increases, so do the required resources. Establishing a mechanism for coordinated R&D in this area that allows pooling of resources, similar to the CERN RD Collaboration model, would enable the required scale to meet the needs of future experiments.

Scalable Pixelated Detector Systems

Pixelated charge readout can provide unambiguous 3D imaging for large LArTPCs, but must meet stringent requirements on noise, power, and reliability in a cryogenic environment. The first-generation LArPix system provided a proof-of-concept for pixelated LArTPC readout [1], not only besting the targets for noise and heat but also providing 3D images of cosmic rays in an actual LArTPC detector. More recent work has focused on system scalability. A new design which embeds analog, digitial, as well as triggering functionality within a single large-area pixelated anode has resulted in improved cryogenic performance while substantially simplifying system assembly. A new low-power fault-tolerant data I/O architecture has been used to maintain detector functionality even with failure of multiple application specific integrated circuits (ASICs). Successful commercial production of these second-generation pixel anodes has demonstrated a viable strategy for instrumenting very large detectors. Future R&D activities will pursue finer detector granularity, improvements in embedded detector logic, increased system reliability, and advances in commercial mass production. Also of interest are adaptations of these techniques to meet other particle physics needs, such as higher-bandwith detector systems, adaptable readout logic, or large-area photodetection.

Detector R&D Collaboration

Continued development of scalable pixelated detector systems could benefit from a structured method for supporting detector R&D collaborations within the US DOE system. Such an approach can be seen in the CERN RD Collaborations, which have been essential for delivering the technologies used by the current generation of large high-energy physics experiments. These CERN-based collaborations have helped to ensure that the R&D program meets the experimental needs, and have provided a mechanism for the best ideas to come together into a final viable design with efficient use of available resources. They are also structured to aid cooperative technology development across multiple experiments. Some specific examples are RD42 for development of diamond detectors [3], RD50 for radiation hard semiconductors [4], RD51 for micro-pattern gas detectors [5], and RD53 for pixel readout integrated circuits for extreme rate and radiation [6]. These R&D collaborations have been successful at sharing expertise, providing common tools and processes, coordinating activities, and disseminating knowledge that underly the current generation of experiments. The DOE, through the national laboratories, could provide a similar shared infrastructure for supporting these R&D collaborations amongst a large number of university and laboratory partners. The scalable pixelated detector R&D proposed here could serve as a test case for this model within the US. Through this LOI we propose to launch an Expression of Interest process as part of Snowmass, where both individuals and research groups can come together and formulate the parameters of such an R&D collaboration and sign on to the idea (or not). Guidance and help from working group conveners would be greatly appreciated.

Bibliography

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