Pixels for Noble Element TPC's

PRD-1 (Enhance and combine existing modalities to increase signal-to-noise and reconstruction fidelity)

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Relevant LOI's:
"Multi-modal pixels for noble element time projection chambers" (contact: Elena Gramellini <elenag@FNAL.GOV>)
"Q-Pix: kiloton-scale pixelated liquid noble TPCs" (contact: Jonathan Asaadi <jonathan.asaadi@uta.edu>)
"An R&D collaboration for scalable pixelated detector systems" (contact: Dan Dwyer <dadwyer@lbl.gov>)

Instrumentation requirements to achieve physics goals

Frontier experiments in neutrino and dark matter physics 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.

- Developments in large area low-noise mixed-signal detector anode designs
- System reliability in the billion-channel regime,
- Scalable and robust I/O architectures,
- Leveraging commercial methods for mass production.

Two examples of such pixels architectures exist (LArPix [1] and Q-Pix [2])

- Physics gains from such high-granularity readouts are being explored [3]
- Low noise / low threshold readouts may serve as an enabling technology to realize a “multimodal” pixel capable of detecting both light and charge
  - Requires research into UV photoconductors to realize this aim

Significant instrumentation challenges

- **Stringent requirements on noise, power, and reliability in a cryogenic environment**
  - Specifics are defined by their application, but the general themes of < 10W/m^2 average power with ~mm scale pixels, ~500 e- ENC, sub-% failure tolerance
- **Scalability**
  - Ton scale channel counts ~10 million pixels
  - Kiloton scale channel counts ~200 million pixels
- **Charge and Light**
  - Integration of conventional light readout with opaque (and heavily occupied) pixel anode
  - New technologies utilizing novel photoconductors to integrate Q+L signals
- **Pushing the detection threshold limit**
  - Want to be ready for discovery while maintaining the fidelity of high energy depositions
  - Challenge for “dynamic range” and data rates
- **Finding and sharing common solutions**
  - Advocating for a common R&D platform similar to the CERN RD Collaborations

Relevant physics areas

LArPix and Q-Pix are solutions targeting the DUNE experiment (near and far detector respectively).

- Neutrino Oscillation Experiments
- Rare decays (proton decay, n-bar)
- Supernova & Solar Neutrinos

The ability to readout at high density, high fidelity, and low threshold (~0.3 fC) can broaden the application of pixels to more noble element TPC applications

- Beyond Standard Model Searches
- Rare event searches (dark matter, neutrinoless double beta decay)

The ability to combine Q+L signal into a single multi-modal sensor could be a transformative step for noble element TPC's

Relevant cross-connections

- IF02: Photon Detectors
- IF07: Electronics/ASICs
- IF09: Instrumentation Science: Cross Cutting and Systems Integration
- NF01: Neutrino Oscillations
- NF03: BSM
- NF10: Neutrino Detectors