Characterizing the Performance of Novel Charge Readout Structures in High-Pressure Gaseous TPCs

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RDC6, RDC4, RDC1

Our Institutions

new collaborators welcome!

INDIANA UNIVERSITY

Fermilab

University of Colorado Boulder

UNIVERSITY AT ALBANY
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UNIVERSITY OF MINNESOTA DULUTH
Driven to Discover

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Overview & Motivation

- Benchmark achievable energy threshold and spatial resolution for <MeV-scale signals in high pressure gas argon TPCs using optimized/novel charge readout structures in a low energy neutron beam
- Impact:
  - Approach full reconstruction of all secondaries in neutrino interactions
    - Improve neutrino interaction physics modeling for future neutrino oscillation experiments
  - Extend BSM sensitivities:
    - Constrain standard interaction backgrounds for BSM searches (Neutral Heavy Leptons)
  - CEvNS searches
- Modern charge readout systems like GEMs not extensively used in high-pressure gas TPC prototypes

Why High Pressure

Advantages:

- Target material = density of the detecting medium
  - Addresses scalability challenges for future experiments that require a higher interaction rate without increasing detector size
  - A TPC similar in size to the one used in the ALICE experiment can collect approximately one million muon neutrino interactions in argon in a 1.2 MW beam when pressurized to 10 atm
- dE/dx for the final state particles

Novelty & Challenges:

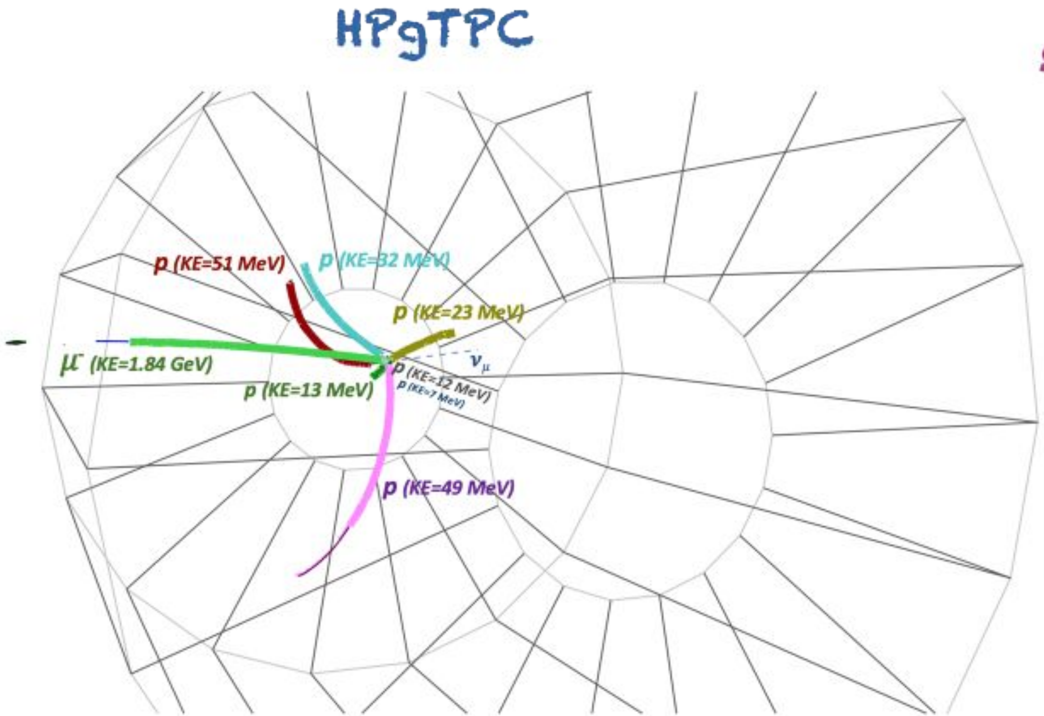
- Higher pressure affects position resolution due to shorter ranges of nuclear recoil:
  - Requires higher spatial resolution to accurately reconstruct shorter-ranged recoils
- Operating charge amplification readout systems at high pressure:
  - Affects mean free path to secondary ionizations
  - Reduces multiplication gain of the readout system

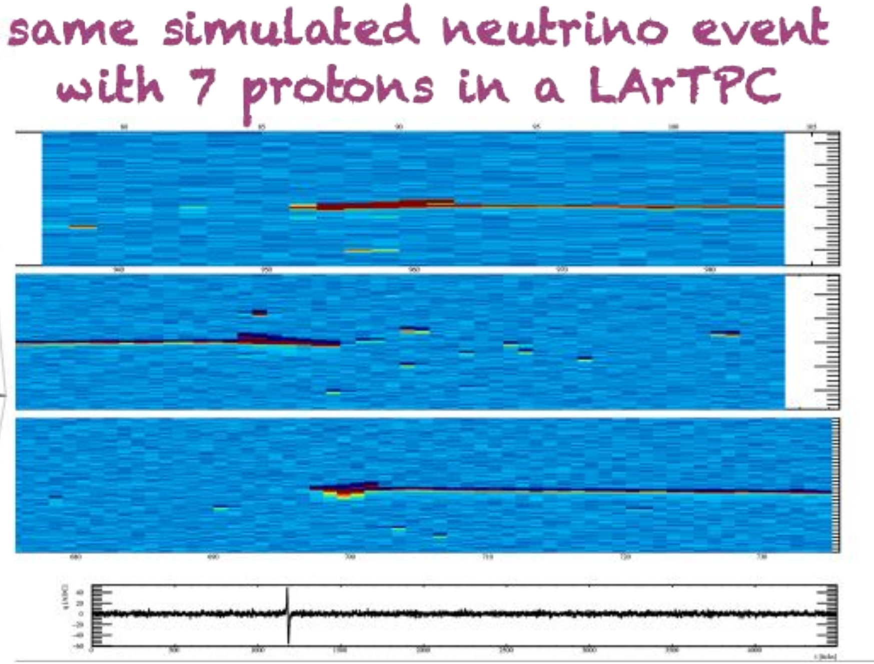
High-level Milestones & Preliminary Timeline

- Test charge readout systems (GEMs/THGEMs, Micromegas) up to 10 atm in existing small-scale test stand using a calibration source – year 1:
  - Evaluate gas gain and diffusion
  - Determine necessary design optimizations
  - Simulation framework for charge readout system performance and tracking in the beam prototype starts in this year
- Apply the lessons learned to develop and test a charge readout system with high gain and spatial resolution, then scale it up to the size of a prototype – year 2-3
- Construct the prototype with the optimized charge readout system for a neutron beam test (pressure vessel and beam run costs covered by a start-up) – year 4–5:
  - Validate its performance at Indiana University's Low Energy Neutron Source facility
  - Expected proton track energies from neutrons ~100s of keV to few MeV

Thanks for the opportunity to share our idea; questions and feedback are very welcome!

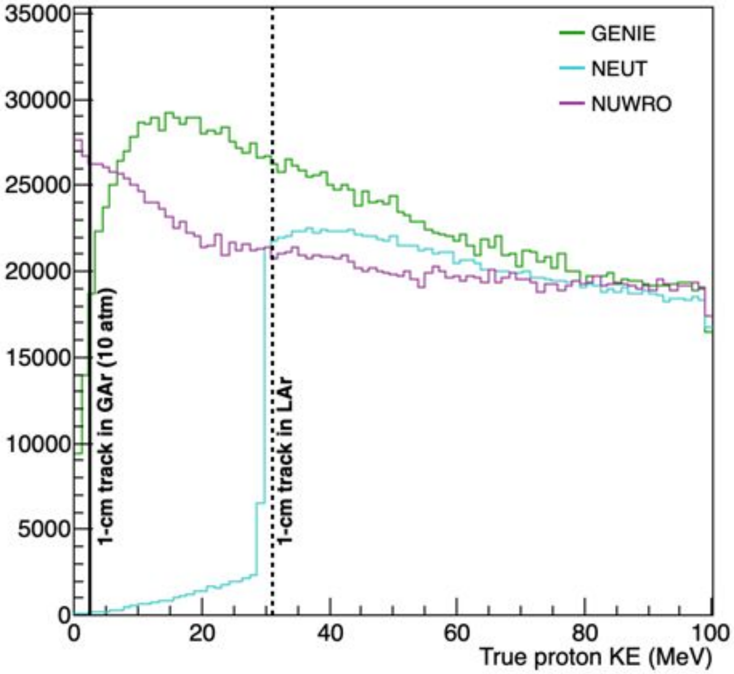
Same neutrino event in a High Pressure gas TPC vs LArTPC with full reconstruction





Importance of Tracking of Low Energy Protons for Neutrino Oscillation Experiments

- The HPgTPC allows a future neutrino oscillation experiment like DUNE to be more sensitive to low energy hadrons where neutrino interaction models are at odds, helping to resolve these disagreements



Existing Small-scale Test Stand