Dual Phase Signal Detection System for Large-scale LAr TPCs

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Challenges of Future Neutrino, Proton Decay and Dark Matter Experiments

- Need **large** mass detectors
  - neutrino & proton decay experiments will require detectors at the kiloton scale
  - DM experiments will require detectors at the ton scale
- Excellent **background rejection**
  - separate π^0's from e's in neutrino experiments searching for θ_{13}
  - radioactive backgrounds in DM experiments
- Large range of energy thresholds highly desirable
  - E_{thresh} ~ GeV for p-decay + accelerator neutrino
  - E_{thresh} ~ MeV for solar neutrino
  - E_{thresh} ~ keV for DM
- Affordable

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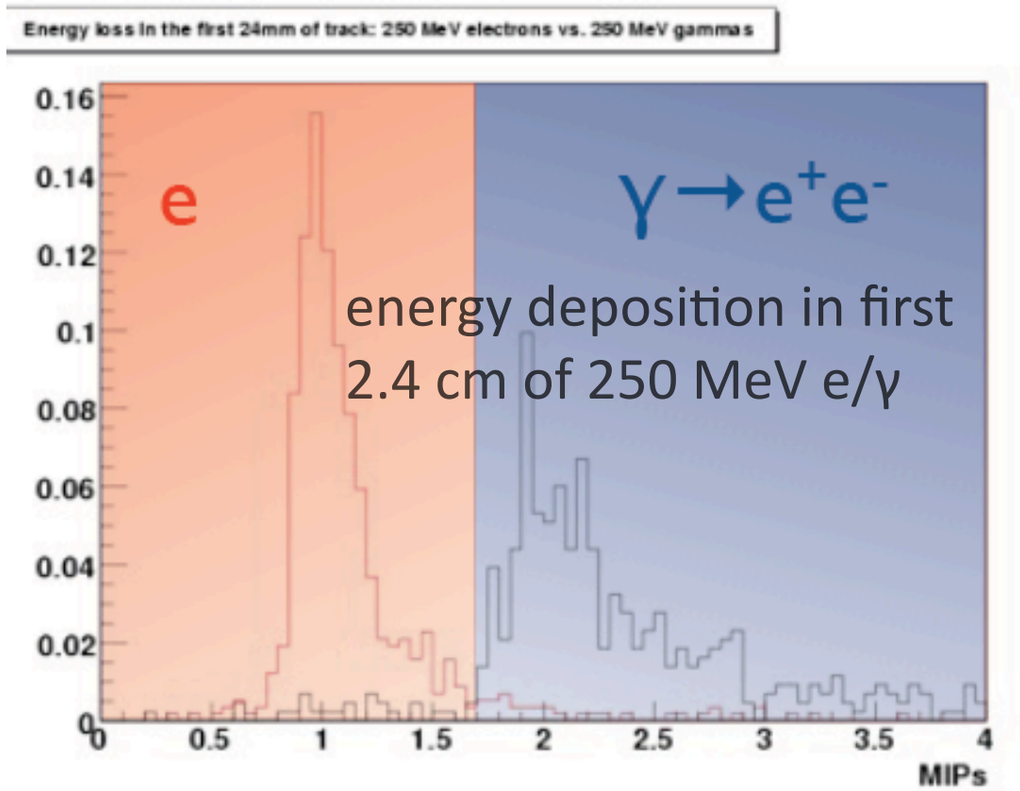
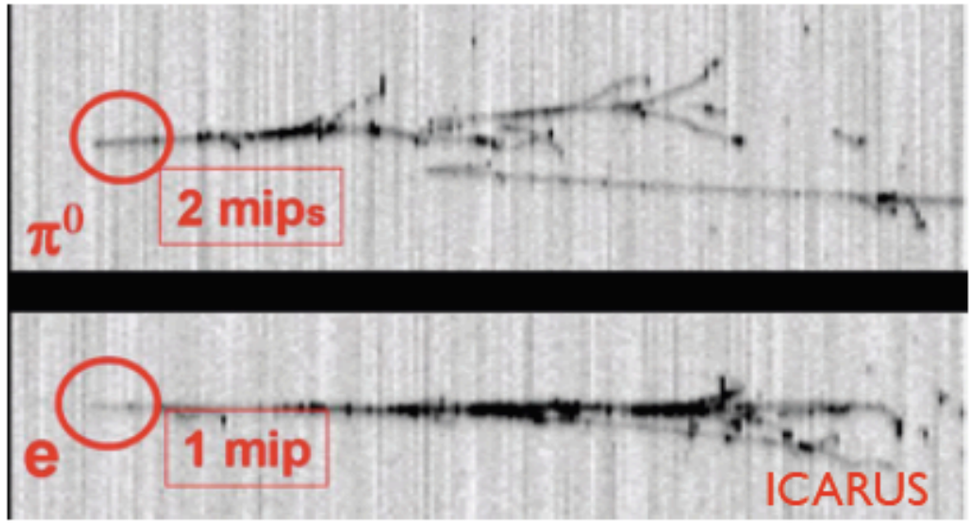
Liquid noble detectors meet these requirements.

Liquid Noble TPCs

- Large, homogeneous detectors may be built at reasonable cost
- Channel count scales as cross-sectional area, not volume
- Relatively inexpensive, easily obtained (especially Ar, which is ~$1/L)
- Excellent spatial resolution. eg, LAr TPCs have been shown to have ~0.05 cm resolution.
- Scintillation light produces as well as ionization
  - transparent to the scint. light, can be used for triggering
  - ~40k γ/MeV
- Low energy threshold; $\langle dE/dx \rangle_{MIP}$ ~ 2.1 MeV/cm (LAr), ~3.8 MeV/cm (LXe)
- mip ionization: ~6000 e/mm
- Easily purified, radioactive isotopes can be reduced to extremely low levels.
- Nearly optimized for SUSY-favored $p \rightarrow K^+ \nu$ mode
- Large atomic number (A(Xe) = 131) increases WIMP scattering rates
- There are very active R&D programs in Europe and more recently in the US, with data already collected and analyzed
  - Xenon10/100 DM experiment
  - Argoneut

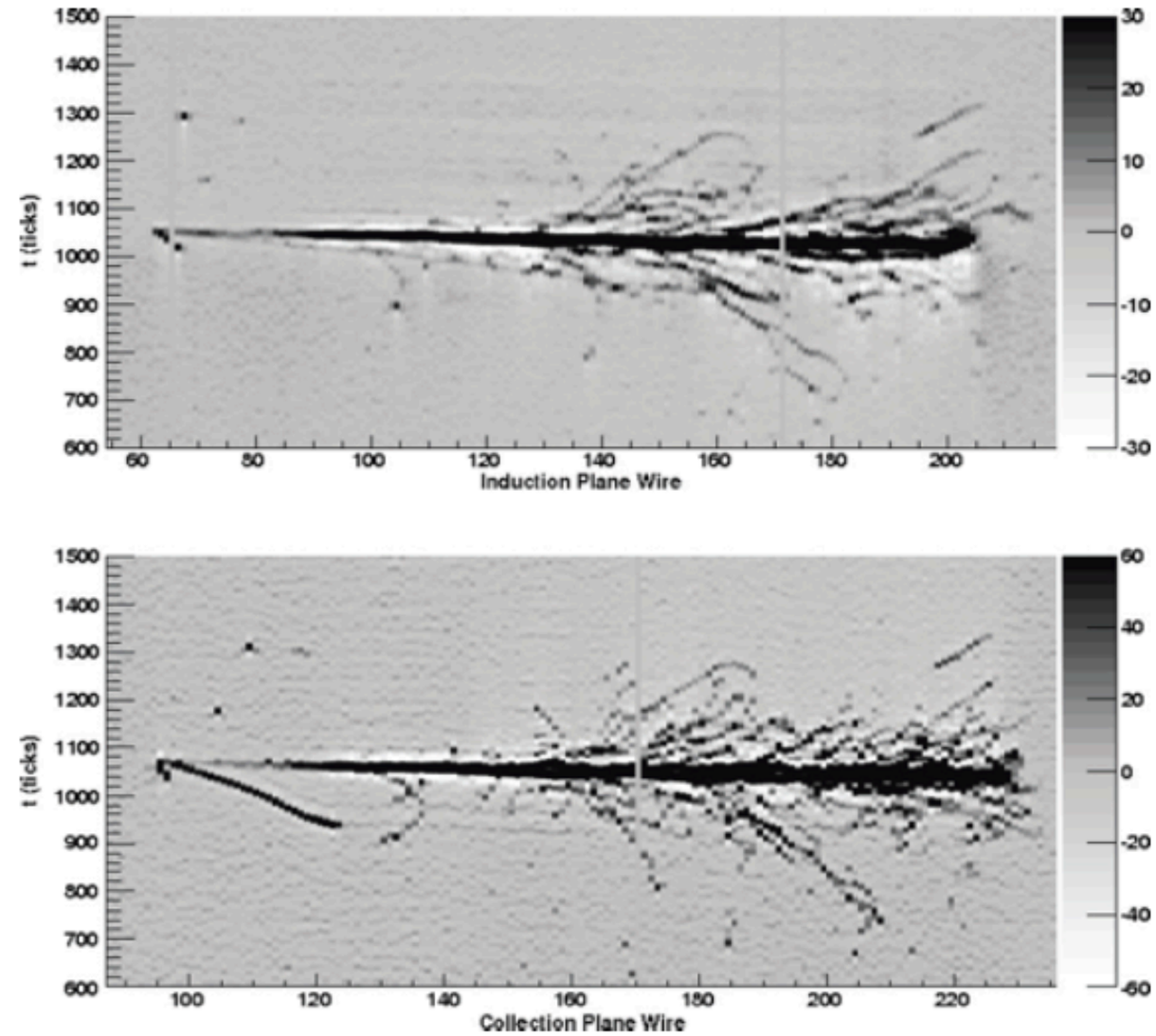
Neutrinos: Advantages of the LAr TPC





from Brian Rebel, NuFact 2010

Candidate ν_e event in ArgoNeuT



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Why Should We Get Involved

- This detector technology is exciting and novel
- It is my belief that this is the future of neutrino physics, regardless of what happens to/in LBNE
- P5 report to HEPAP: “The panel recommends support for a vigorous R&D program on liquid argon detectors and water Cerenkov detectors in any funding scenario considered by the panel. The panel recommends designing the detector in a fashion that allows an evolving capability to measure neutrino oscillations and to search for proton decays and supernovae neutrinos.”
- Stronger connection between Neutrino & Astrophysics groups

Challenge: Triggering on Non-beam Related Events

- TPCs rely on drift time to determine one of the coordinates
- Drift time corrections are typically needed for <dE/dx> measurement (particle ID)
- Drift velocity in LAr TPCs is slow (~1.6 mm/μs), so one can use beam triggers for beam-related events
- For non-beam-related events, without a scintillation light-based trigger, one must continuously read-out the detector. One also loses drift time information. Both of these represent challenges to both detector operation and analysis.
- For large TPCs, traditional light detection implies instrumenting the detector with many photodetectors, which can increase the cost significantly.
- PMTs require glass, and for low background experiments, glass introduces a fair amount of radioactive background.
- Currently, the photon-detection system is in danger of being removed from the LBNE LAr TPC due to its estimated cost.

Idea: Dual-phase Detection System Using LEMs

- Large Electron Multipliers (LEMs): essentially like a GEM, but much larger.
- Other LEM advantages for Liquid Noble TPCs:
  - structurally more sound than planes of wires.
  - 2D position information available, instead of relying on formation of wire crossings.
- Possible disadvantages:
  - Much higher channel count.
  - Height of detector limited to max. electron drift distance.
- Options for dual-phase detection system:
  - collect light using something like TPB on face of LEM
  - LAPPD-type detector in LAr?
  - something completely new

Argonne Lab Multi-Division Effort

- HEP Mechanical: mechanical structure, design of modular TPC
- HEP Electronics: readout, cold electronics
- Chemistry: wavelength-shifter, light guide
- APS: cryogenics