Possible New Effort in ANL HEP R&D: Noble Liquid Detectors

Jonathan M Paley
ANL HEP Neutrino Group

HEP Division Retreat

December 15, 2010

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

Challenges of Future Neutrino, Proton Decay and Dark Matter Experiments

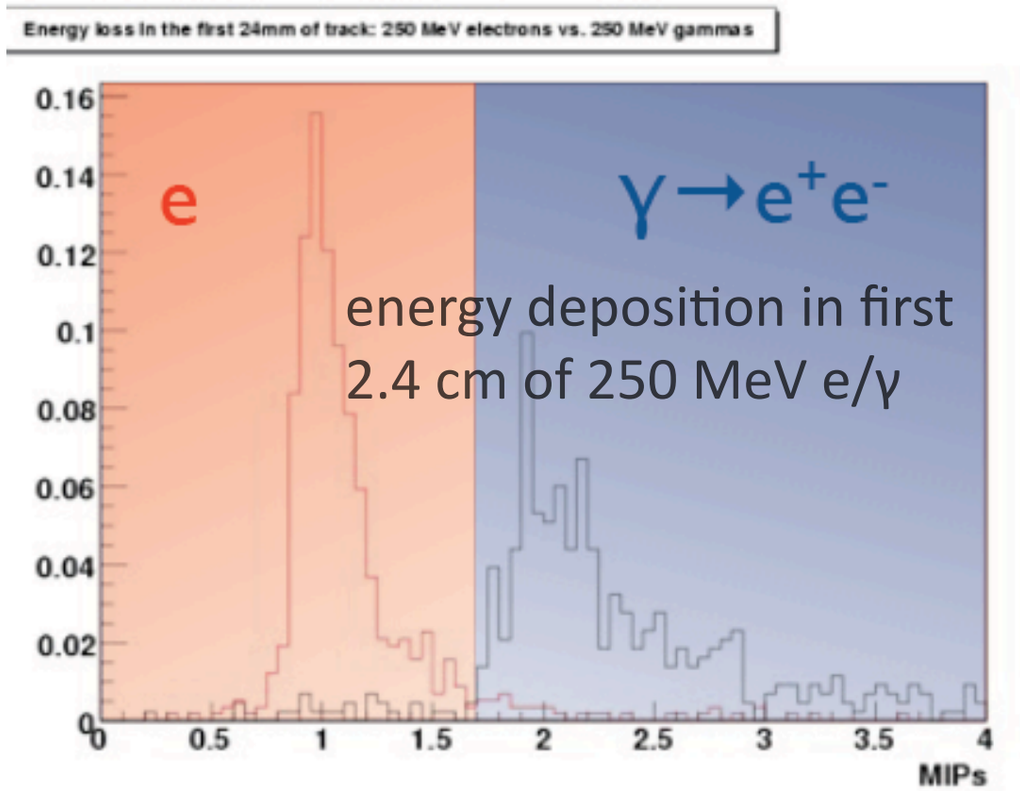
- Need **large** mass detectors
  - neutrino & proton decay experiments will require detectors at the kiloton scale
  - DM experiments will require detectors at the ton scale
- Excellent **background rejection**
  - separate π^0's from e's in neutrino experiments searching for θ_{13}
  - radioactive 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

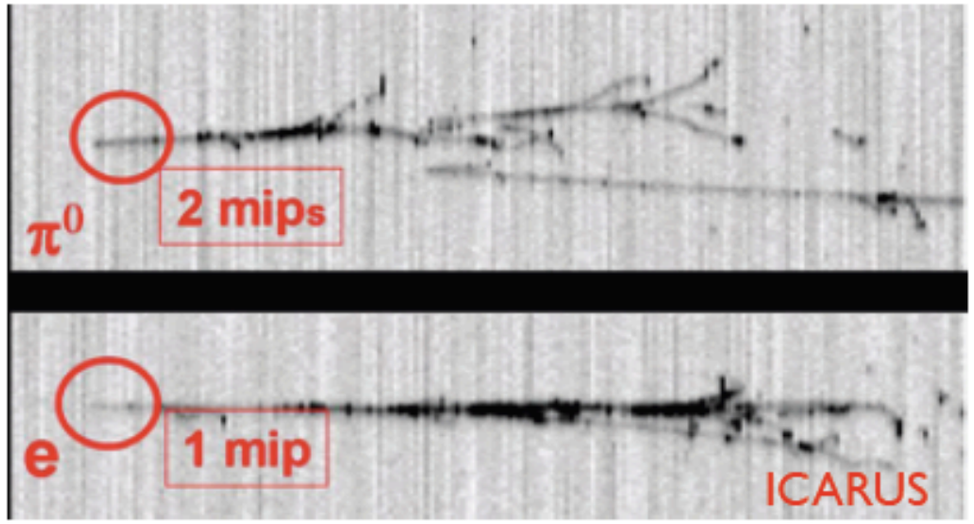
Liquid noble detectors meet these requirements.

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)
- 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

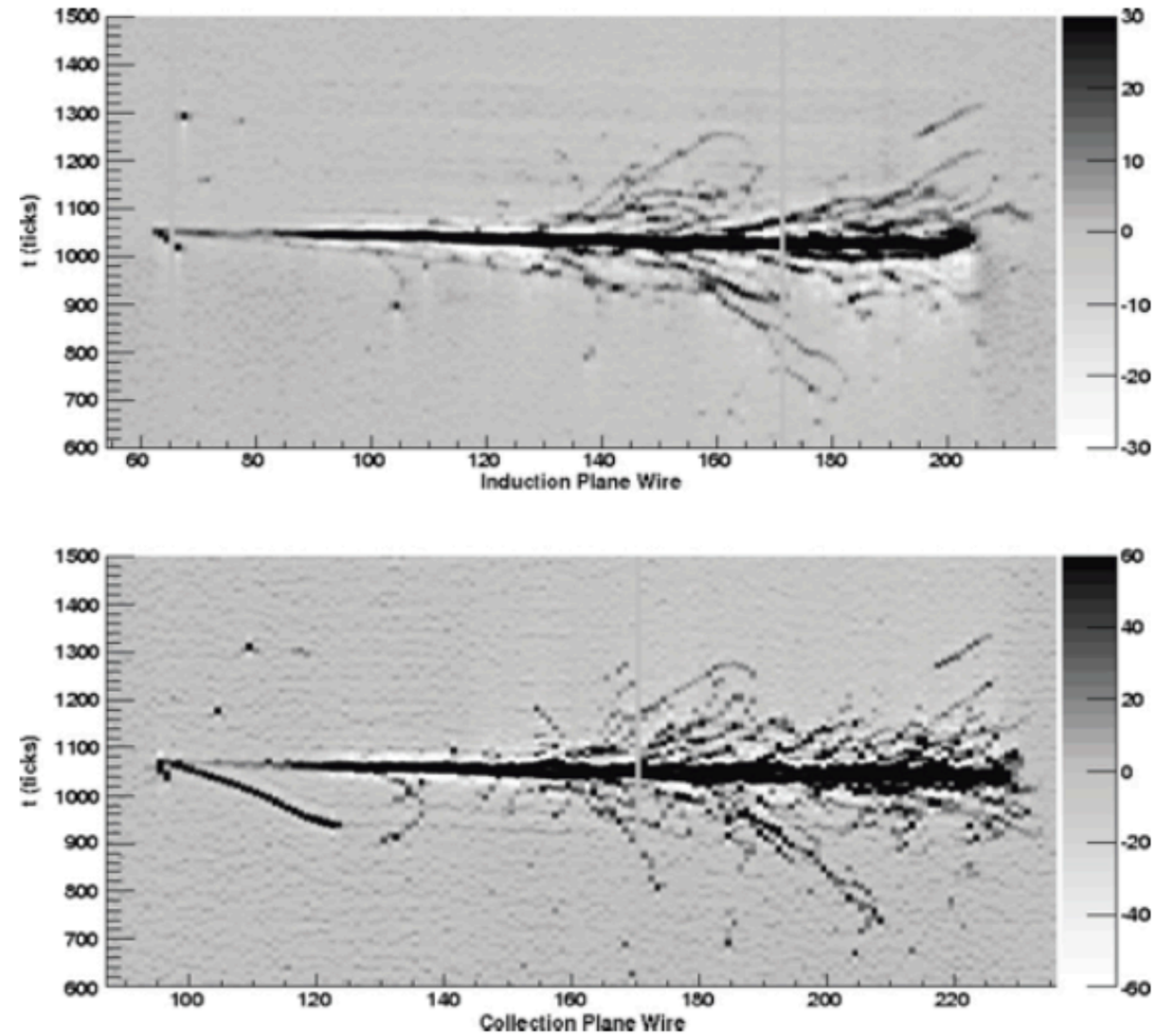
Neutrinos: Advantages of the LAr TPC





from Brian Rebel, NuFact 2010

Candidate ν_e event in ArgoNeuT



from Brian Rebel, NuFact 2010

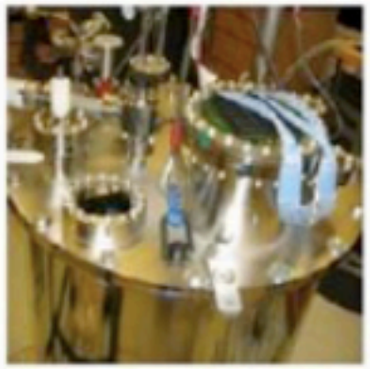
Status of LAr TPC R&D Program in the US

Liquid-Argon Time Projection Chambers

Status of R&D Program in the US

The first TPCs in the United States:

Yale TPC



Location: Yale University
Active volume: 0.00002 kton
Year of first tracks: 2007

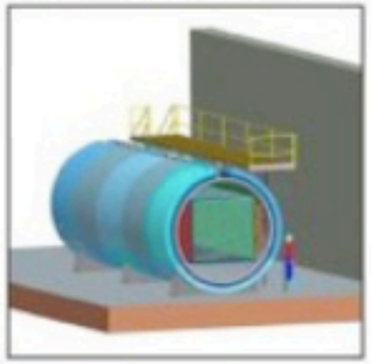
Bo

Location: Fermilab
Active volume: 0.00002 kton
Year of first tracks: 2008

ArgoNeuT

Location: Fermilab
Active volume: 0.0003 kton
Year of first tracks: 2008
First neutrinos: June 2009

MicroBooNE



Location: Fermilab
Active volume: 0.1 kton
Start of construction: 2010

Pure R&D ⟷ Physics Results

Test stands to improve liquid-argon technology:

Luke

Location: Fermilab
Purpose: materials test station
Operational: since 2008

LAPD

Location: Fermilab
Purpose: LAr purity demo
Operational: 2010

+ Several more as part of LBNE project

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

Where Can We Get Involved?

- **Mechanical design of LBNE prototype and final detectors**
- Cryo engineering?
- Electronics:
  - **DAQ**
  - Cold electronics
  - **Wireless**?
- **Large Area Photo Detectors**
- Test-beam calibration effort at FNAL
- Other suggestions or ideas?