MicroBooNE and Liquid Argon Time Projection Chambers (TPCs)

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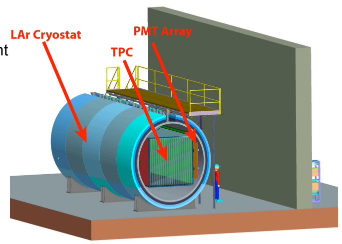
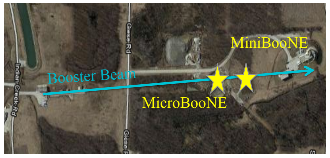
Abstract: The MicroBooNE experiment is a 170-ton Liquid Argon Time Projection Chamber (LArTPC) that will begin running on-axis in the Booster Neutrino Beamline at Fermilab in 2013. LArTPC detectors combine fine-grained tracking with calorimetry, allowing for excellent imaging and particle identification ability. The primary physics goal of MicroBooNE is to explore the low energy excess of events seen by MiniBooNE, and it is the next step in the U.S. R&D program to make LArTPC's a viable option for future large neutrino detectors.

The MicroBooNE detector

- Detector volume: 170 tons of liquid Argon, with 86 ton active volume.
- 30 PMTs: triggering and event timing information.
- To sit on surface, on-axis of Booster beam, and off-axis of NuMI beam.
- TPC parameters:
  - 3mm wire spacing.
  - ~2.5m drift (500V/cm).
  - 3 readout planes.
  - 8256 channels (cold preamps).

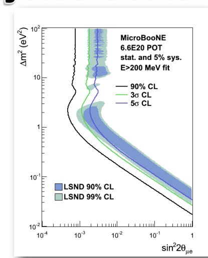




- MicroBooNE located 470m downstream of neutrino production.
- Data corresponding to a total of 6.6 x 10^{20} protons on target (POT).

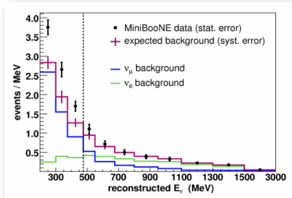
MicroBooNE Physics Goals

production mode	# events
CC QE ($\nu_\mu n \to \mu^- p$)	60,161
NC elastic ($\nu_\mu N \to \nu_\mu N$)	19,409
CC resonant π^+ ($\nu_\mu N \to \mu^- N \pi^+$)	25,149
CC resonant π^0 ($\nu_\mu n \to \mu^- p \pi^0$)	6,994
NC resonant π^0 ($\nu_\mu N \to \nu_\mu N \pi^0$)	7,388
NC resonant $\pi^\pm$ ($\nu_\mu N \to \nu_\mu N' \pi^\pm$)	4,796
CC DIS ($\nu_\mu N \to \mu^- X$, $W > 2$ GeV)	1,229
NC DIS ($\nu_\mu N \to \nu_\mu X$, $W > 2$ GeV)	456
NC coherent π^0 ($\nu_\mu A \to \nu_\mu A \pi^0$)	1,694
CC coherent π^+ ($\nu_\mu A \to \mu^- A \pi^+$)	2,626
NC kaon ($\nu_\mu N \to \nu_\mu K X$)	39
CC kaon ($\nu_\mu N \to \mu^- K X$)	117
other ν_μ	3,678
total ν_μ CC	98,849
total ν_μ NC+CC	133,580
ν_e QE	326
ν_e CC	657



- **Address the MiniBooNE low energy excess.**
  - Aside: sterile neutrinos?
- Utilize e-/gamma differentiation with topological and dE/dx information.
- Low energy cross-section measurements (NC π^0, $\Delta \to N\gamma$, Kaon production, photonuclear, …)
  - Multi-nucleon cross section effects.
- Study proton-decay sensitivity with sample of Kaons (backgrounds).
- Develop automated reconstruction.

Motivations: MiniBooNE and the Low-Energy Excess

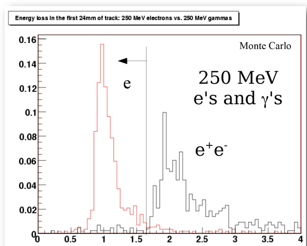


- MiniBooNE antineutrino mode results see excess of events above background consistent with LSND signal.
- Neutrino mode results see very small excess above 475 MeV.

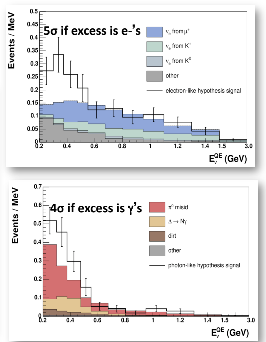
• But, MiniBooNE results show a significant unexpected event excess below 475 MeV… Misestimated background, or new physics?

MicroBooNE: Is Low-Energy Excess ν_e or γ Interactions?

- MiniBooNE results possibly interpreted as electron-like or photon-like.
- e-/γ separation capability removes ν_μ induced single-γ backgrounds.
- ν_e detection efficiency is ~2x better than MiniBooNE.
- Sensitivity at low energies (tens of MeV in MicroBooNE versus 200MeV in MiniBooNE).



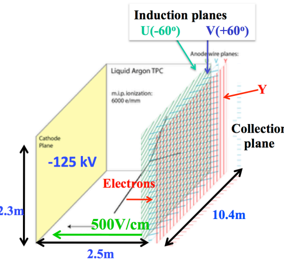
Simulated electron and gamma separation for neutrino energies close to the MiniBooNE anomalous region. ~94% separation efficiency is obtained.



Excess predictions obtained by scaling the MiniBooNE reconstructed spectra given the difference in POT, efficiency, and fiducial volume, and splitting them into e- and gamma events, assuming 6% mis-ID rate

Time Projection Chambers

- Interactions inside TPC produce charged particles that ionize the argon. Ionization electrons drift along electric field to 3 wire planes.
- Location of wires within a plane give 2 coordinates.
- Knowledge of drift speed, and t_0 give the 3rd coordinate and allow to reconstruct interaction.
- Scintillation light collected by PMTs.



Liquid Argon TPCs

Advantages

- High resolution (~3mm)
- LAr ionization and scintillation light used for detection (transparency to own scintillation)
- LArTPC scalable to larger sizes.
  - Long drift distances (meters).
  - Very good dielectric properties allow high-voltages in detector.
  - Argon is cheap.
- 80% signal efficiency, ~94% single-photon background rejection.
- Topological cuts possible.

Challenges

- Purity level desired (ppt) is demanding.
  - Necessary for long drift distances.
  - Detector materials impact on purity must be understood.
- Safety issues (ODH hazards) when operating underground.
- Wire signals are small, electronics noise must be controlled
- MicroBooNE will address these challenges.