The MicroBooNE Experiment

Liquid Argon Detector

Future Neutrino Experiment Project

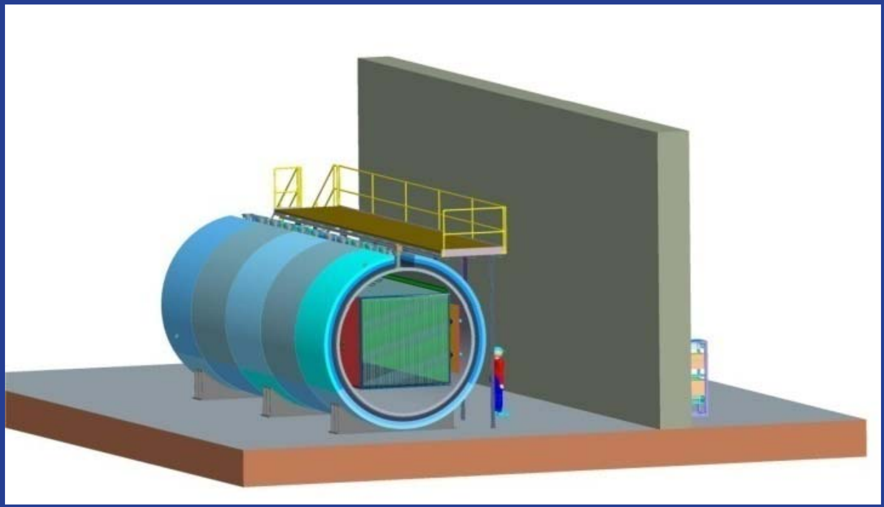
U.S. DEPARTMENT OF ENERGY

Fermilab

Introduction

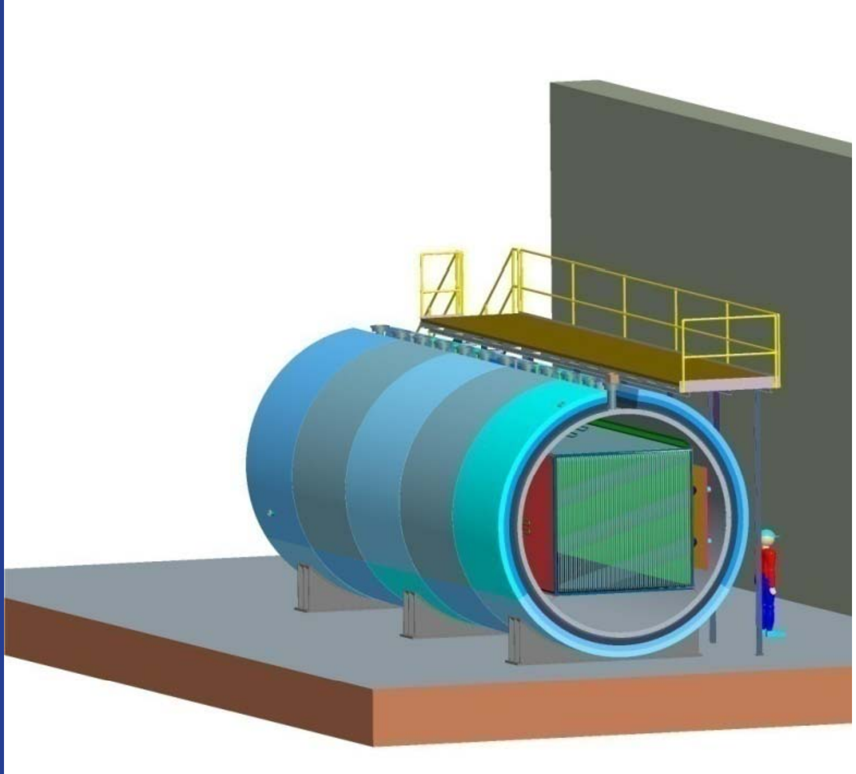
MicroBooNE is –

- A liquid argon Time Projection Chamber (LAr-TPC), placed next to the Mini-BooNE detector enclosure
- Combines physics and hardware R&D goals, using both to assess the technology for massive neutrino detectors



Introduction

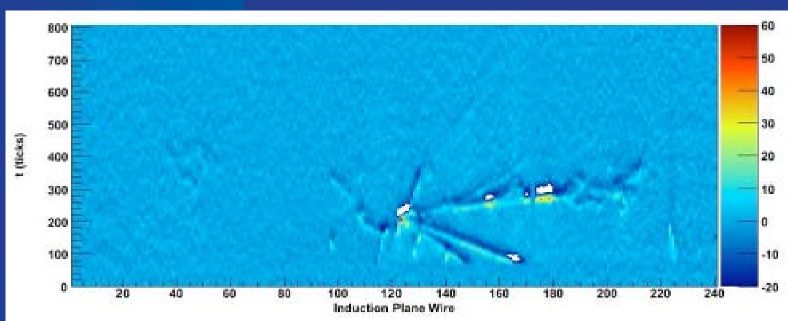
- Detector Overview
  - Single-walled insulated cylindrical vessel ~12m long, ~3.5m diameter
  - Holds ~170 tons of liquid argon
  - ~70 ton fiducial volume, inside the TPC
  - 2.6m drift (500 V/cm E-field gives a 1.6 ms drift time
  - 3 readout planes (+30-degrees, vertical)
  - ~10,000 channels
  - pre-amplifiers, sitting in cold argon gas, above TPC; digitizing electronics located outside the vessel
  - ~40 PMTs for trigger
  - Cryogenic system for purification and recirculation



Why LAr-TPC

- An attractive detector technology for neutrino physics
  - Fine-grained spatial resolution, energy deposition information

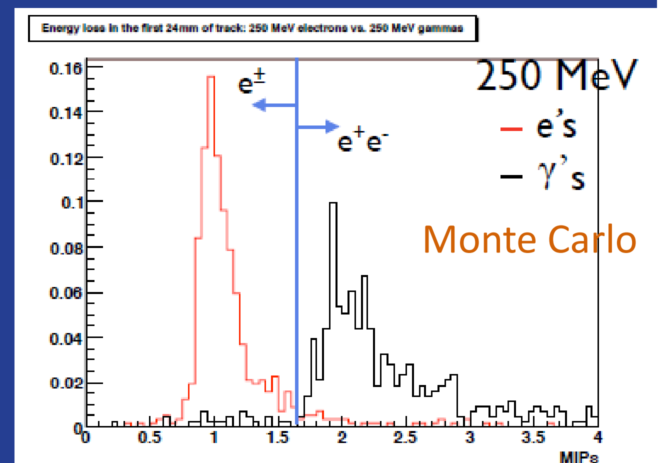
LAr-TPC detectors produce amazing bubble-chamber like visualization of events



ArgoNeuT neutrino event, June 2009

One can have particle ID capability, from dE/dx along a track

In particular, e-γ separation



dE/dx for electrons and gammas in first 2.4 cm of track

- Detectors for neutrino appearance experiments need good e-γ separation, to identify CC ν_e signal events from NC background events

LAr-TPC Development Program

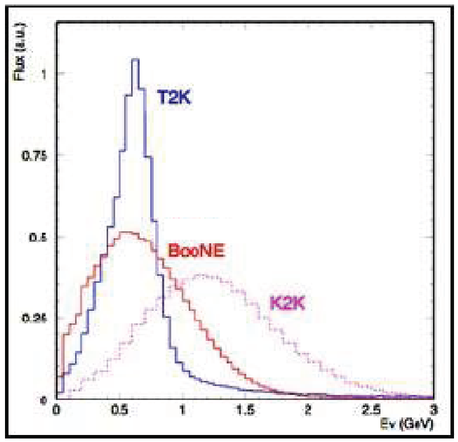
- In principle, these detectors are scalable to large sizes
  - Future neutrino experiments will require massive detectors
- US efforts with the technology have been expanding in recent years
  - At FNAL – Cryogenic Test Stands at PAB, ArgoNeuT

The MicroBooNE experiment offers a step along the LAr-TPC development path, with the opportunity to perform physics measurements in a neutrino beam

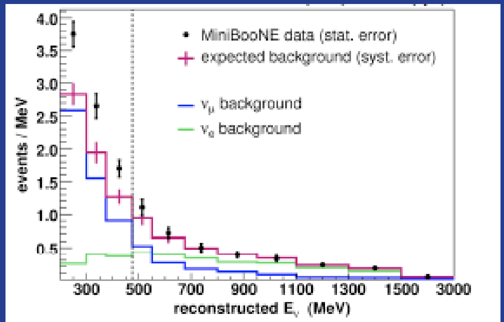
(see P. Shanahan's plenary talk)

Physics Goals

- Physics results will be primarily in neutrino interaction cross-sections
  - The BNB neutrino spectrum is exactly the neutrino energy in the 2nd oscillation maximum expected in the proposed LBNE beamline
  - It is also the spectrum observed in the T2K beam – why SciBooNE was here
  - Cross section results will inform NOvA, T2K, and LBNE



- In measuring cross sections, we will record and identify the events which fall into the MiniBooNE low energy excess



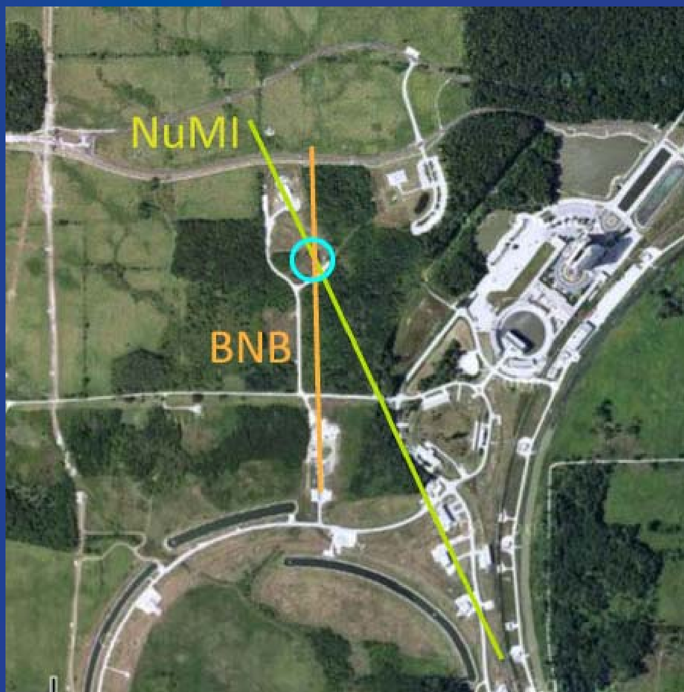
MicroBooNE will have 9σ significance for electrons, 3.4σ for photons

- Software development, in simulation and reconstruction, is a focus of the collaboration. No LAr-TPC has yet had a fully automated event reconstruction
- Operating with physics goals in a neutrino beam provides an excellent assessment of the detector technology strengths and weaknesses

R&D Goals

- MicroBooNE can make contributions to the technical planning for LAr-TPC detectors proposed for future long-baseline neutrino experiments
  - Attain sufficient argon purity without prior evacuation to pull out impurities, via cold gas purge before filling
  - Attain low-noise electronics operation
  - Long drift length, which tests purity and reconstruction schemes
  - PMT operation in cryogens, for neutrino event triggering ability
  - Data handling – what does it take to be “always on” and sensitive to super-nova and proton decay?
  - Construction methods – assembly in a can
  - Software development is being done with future detectors in mind

Detector Location

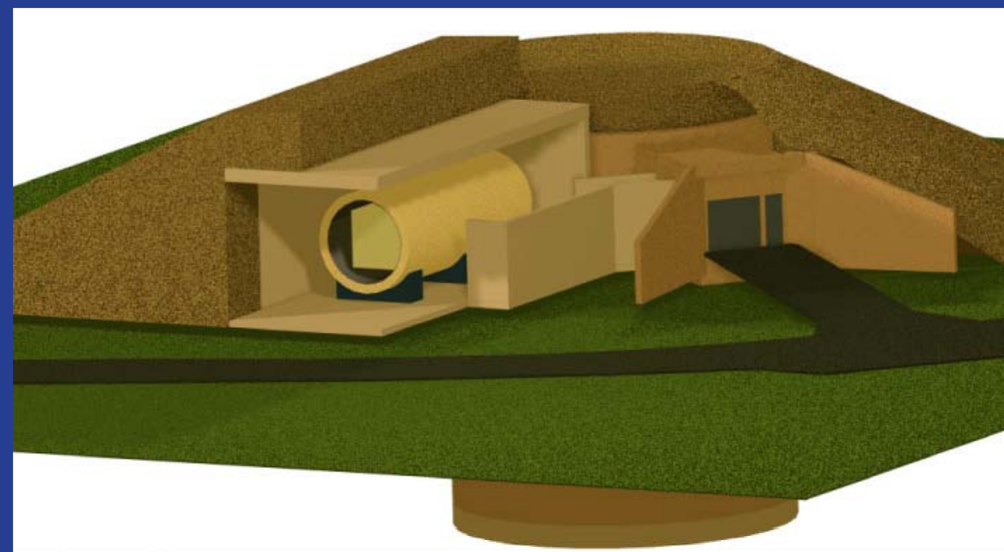


	BNB	NuMI
Total Events	100k	60k
ν_μ CCQE	39k	21k
NC π^0	8k	7k
ν_e CCQE	250	1.7k
POT/year	$2\text{-}3\times10^{20}$	4×10^{20}

- ~2 years running

Neutrino beams are not laser-pointer-focused

The detector will see off-axis NuMI neutrinos



On the surface, next to MiniBooNE enclosure

- An addition to that enclosure – connected by a hallway
- On the Booster Neutrino Beam axis (plan view, not elevation)
  - No changes to the BNB

Status

- Approved by the Lab in July 2008
- Collaboration growth, approximately doubled, to present ~60 scientists & postdocs from 11 Institutions
- Design, construction, installation managed as a Lab/DOE Project
  - Project Manager appointed by FNAL Oct 2008
  - WBS, Level 2 sub-systems laid out
    - Cryostat & Cryogenics – FNAL, BNL
    - TPC & Phototubes – Yale, MIT, BNL, FNAL, Princeton
    - On-Detector Electronics – BNL, FNAL
    - Digitizing Electronics – Columbia, BNL, FNAL
    - DAQ & Monitoring – Princeton, FNAL
    - Building – FNAL
    - Installation – FNAL, BNL

Status

- DOE Project Timeline
  - Mission Need – CD-0 – document currently circulating within DOE
    - Project provided information and materials winter/spring 2009
  - Starting the Project Review preparations
    - Document preparation – Conceptual Design Report, many other project docs
    - Internal Design Reviews – by sub-system, invite experts from outside the collaboration to review and comment
  - Hope to schedule a Director's CD-1 Readiness Review, and a following DOE CD-1 Review, by the end of calendar 2009
  - CD-4 in 2013
- Work hard to keep the total Project cost under $20M
  - Cost estimate process in progress, based on conceptual design
  - Expect about $1.5M in NSF contributions
  - Have budget guidance from the Lab, no official funding profile
  - DOE can provide MIE funds starting FY-11

Current Work

- R&D in FY09 and FY10, toward final designs
    - MOU/SOW with collaborating institutions in progress now

- Cryostat/Cryogenics development (FNAL, BNL)
    - Investigating vessel support options (saddles, slings) and their impact on the Building
    - Investigating insulation materials and methods
    - Ongoing vessel design details, and physical layout of plumbing
- TPC development (Yale, BNL)
    - Risk analysis of wire breakage, using data from test stands, both existing and to-be-developed
    - Develop a prototype semi-automated wire-winding machine
    - Investigate methods to measure wire tension during installation
    - Study the mechanical reliability of pressed-in field cage resistors

Current Work, continued

- R&D in FY09 and FY10, toward final designs
  - Photodetector development (MIT, FNAL)
    - Prototype a base for the phototubes
    - Set up phototube preparation and testing assembly line at PAB
    - Prototype tube support frame, used to store tubes after testing
  - Electronics development (BNL, Columbia, FNAL, MSU)
    - Produce a small quantity of the boards described in the CDR
    - Develop test stations for the readout chain (vertical slice)
    - Develop FPGA code
    - Investigate data compression algorithms (ArgoNeuT data)
    - Investigate options to the CDR design
  - Installation planning
    - Continuing discussions on how the detector is installed, and how the installation procedure affects the design

Summary

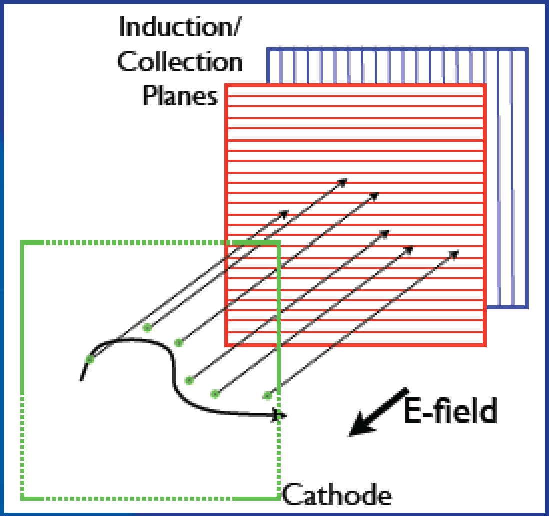
MicroBooNE combines detector R&D with physics

- Pursues R&D questions relevant to massive LArTPC detectors
- In progress
  - Becoming organized as a Project
  - Entering the R&D preliminary design phase
  - Getting ready for Project reviews

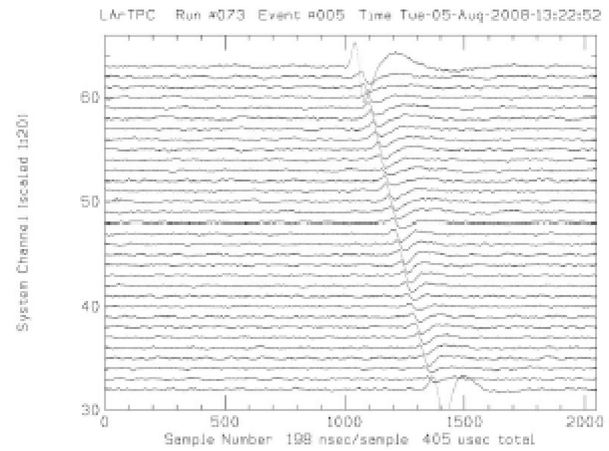
Backup Slides

How a LAr-TPC Works

- Interactions inside the TPC produce ionization particles that drift along electric field lines to readout planes.
- Scintillation light is also present, can be collected by PMT and triggered on.
- Knowledge of the drift speed, the T-zero of events, and the physical location of the wires, can be used to reconstruct the interaction.
- Argon is an excellent medium for this technique due to it’s inert properties.
- Argon must be very clean (parts-per-trillion) to allow drift over a few meters without large attenuation.

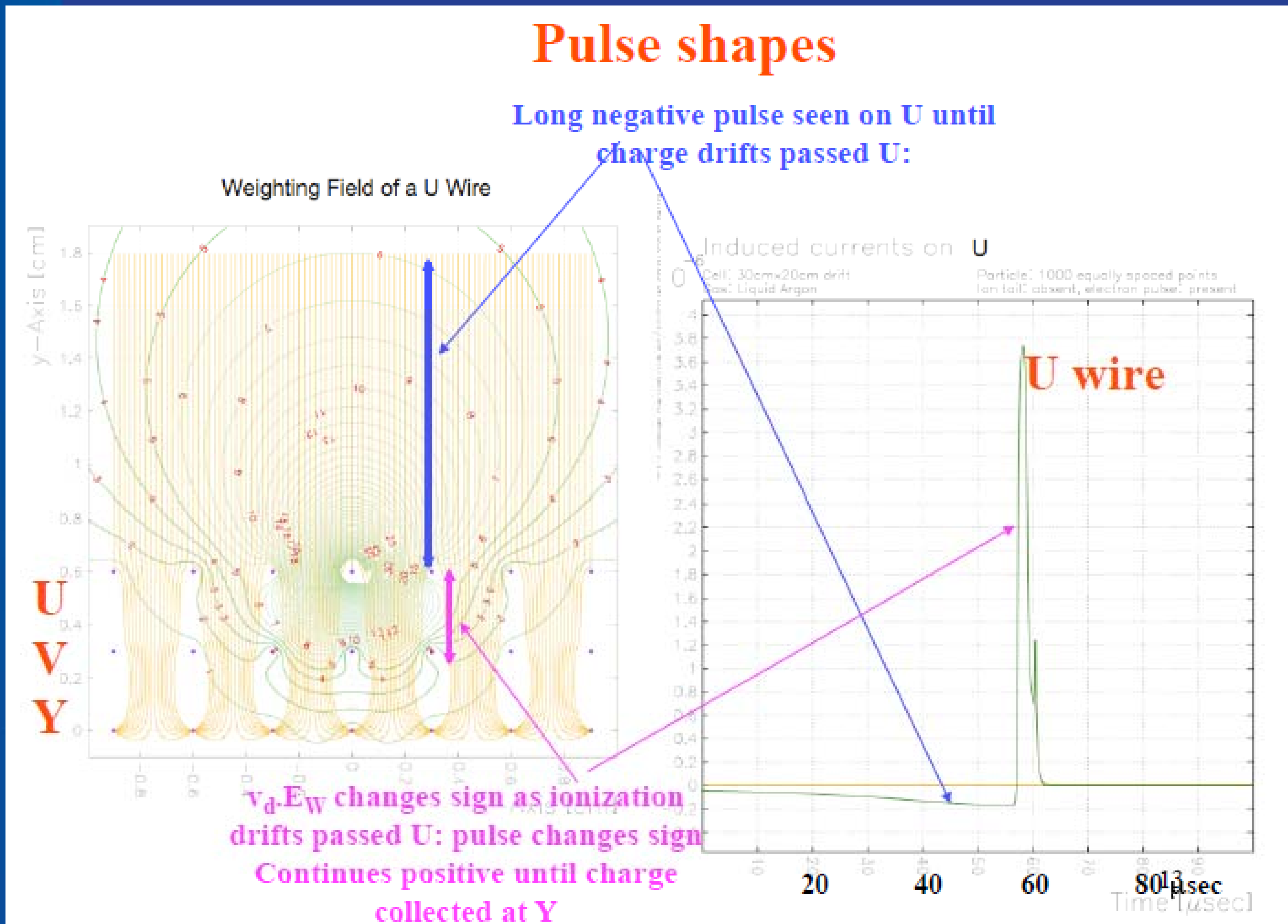


Train of pulses, with time offsets due to different drift lengths.



Event taken with “Bo” detector at PAB.

Pulse shapes seen by wires - 1



Pulse shapes seen by wires - 2