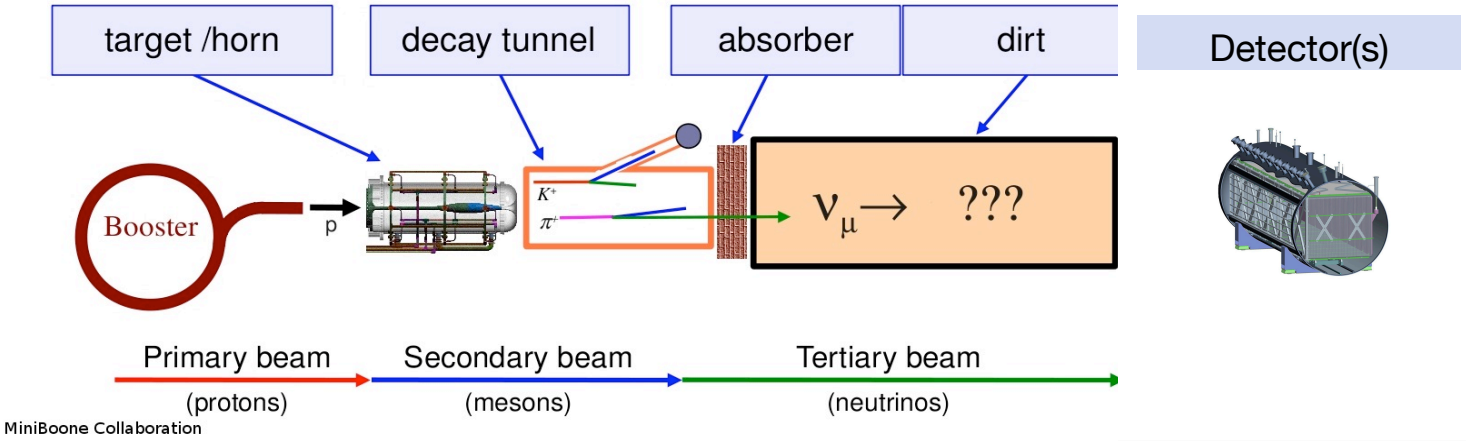
Short-baseline neutrino physics at Fermilab

Liquid Argon TPCs on the Booster Neutrino Beamline to explore new physics

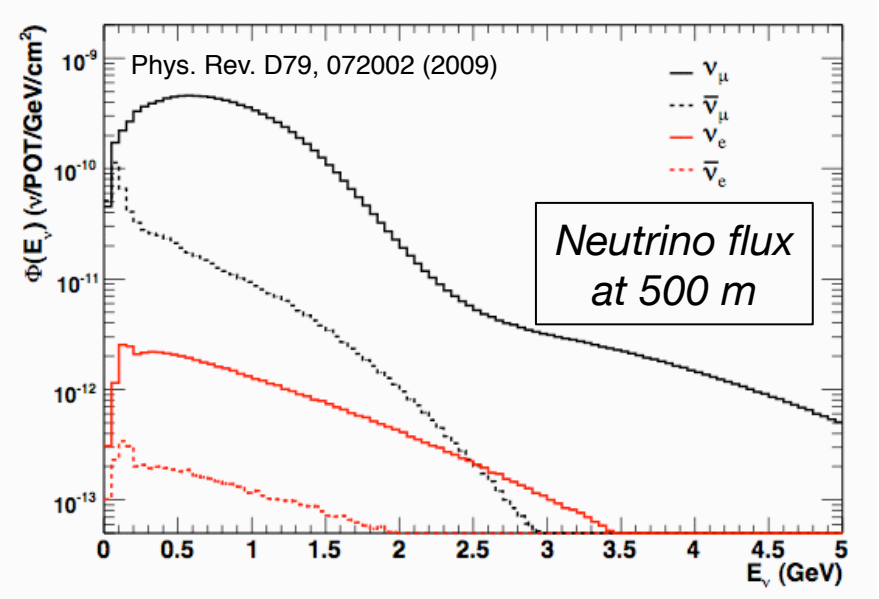
Wesley Ketchum

Los Alamos National Laboratory

THE BOOSTER NEUTRINO BEAMLINE (BNB)



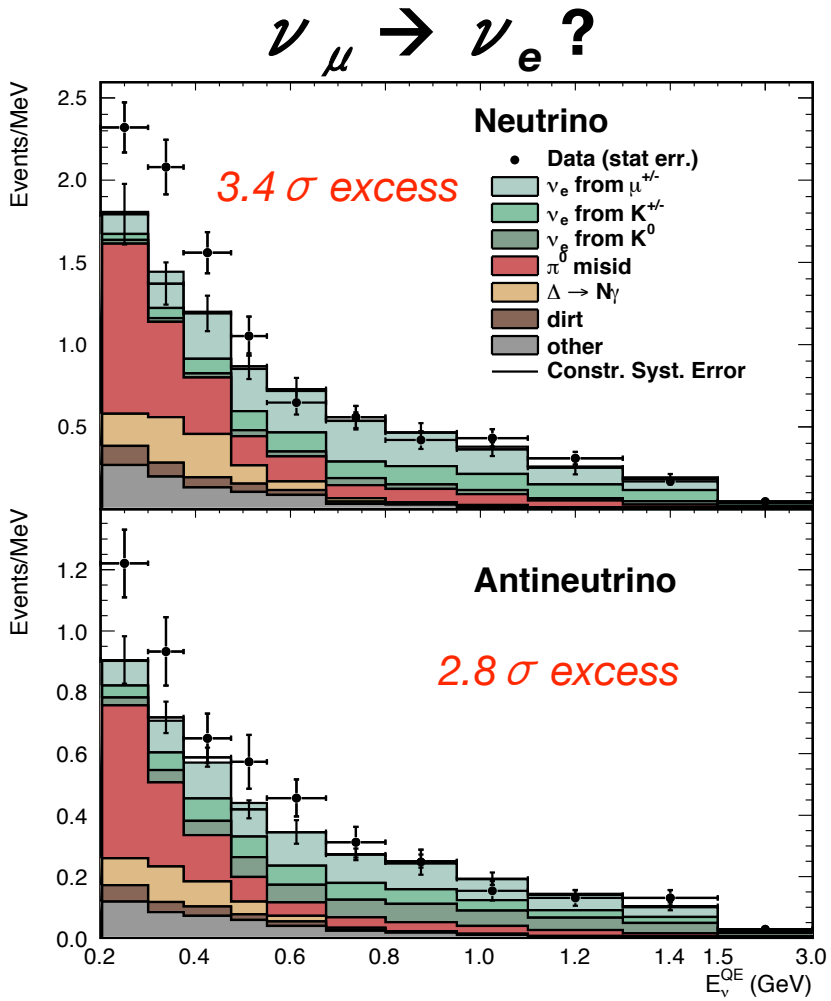
- 8 GeV protons hit Be target
- Magnetic horn focuses (defocuses) neutrino (antineutrino) parents
  - Muon neutrino energy peaks ~700 MeV
- Previous experiments on BNB: MiniBooNE & SciBooNE



PUZZLES FROM MINIBOONE

- MiniBooNE: mineral oil Cerenkov detector located ~500 m from target
- Anomaly in searches for electron neutrino (and antineutrino) appearance
  - Problem: irreducible photon backgrounds at low reconstructed energies

Where is this low-energy excess coming from?



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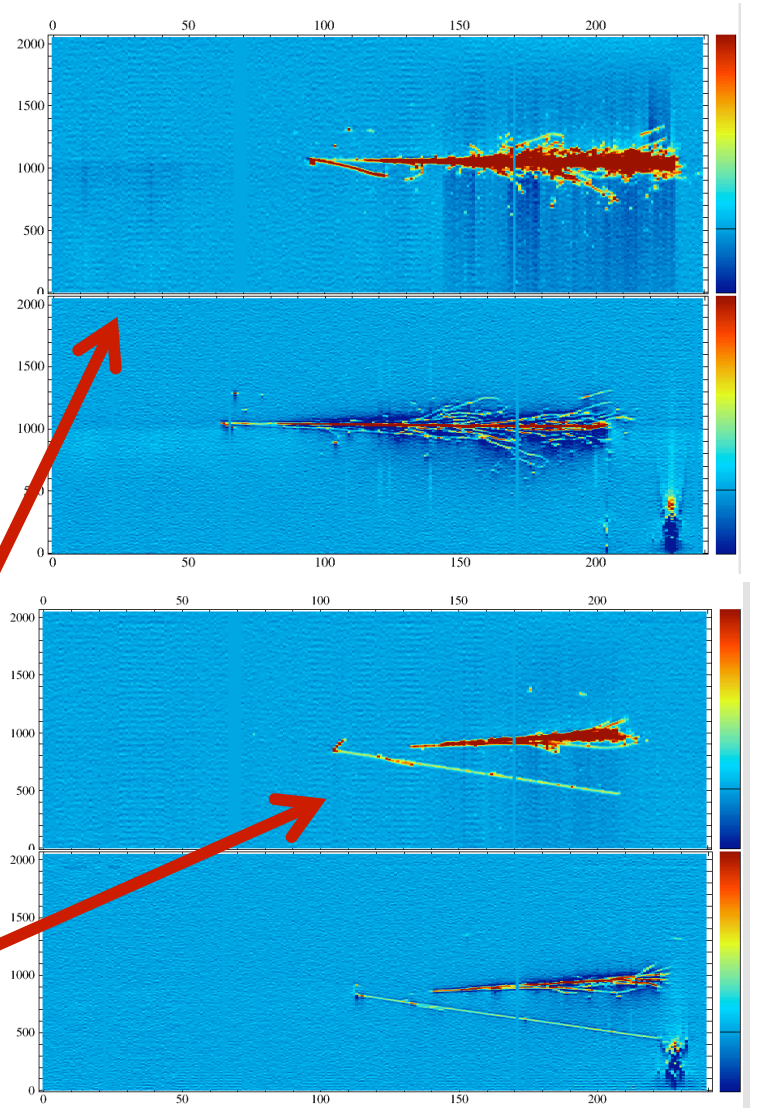
LIQUID ARGON TPCS (LARTPCS)

Offers high-definition look at the interaction vertex

- Discriminate photons from electrons: topology
  - Electron showers not displaced from vertex
  - Photons may be displaced
- Additional activity → clues to the interaction

Data from ArgoNeuT

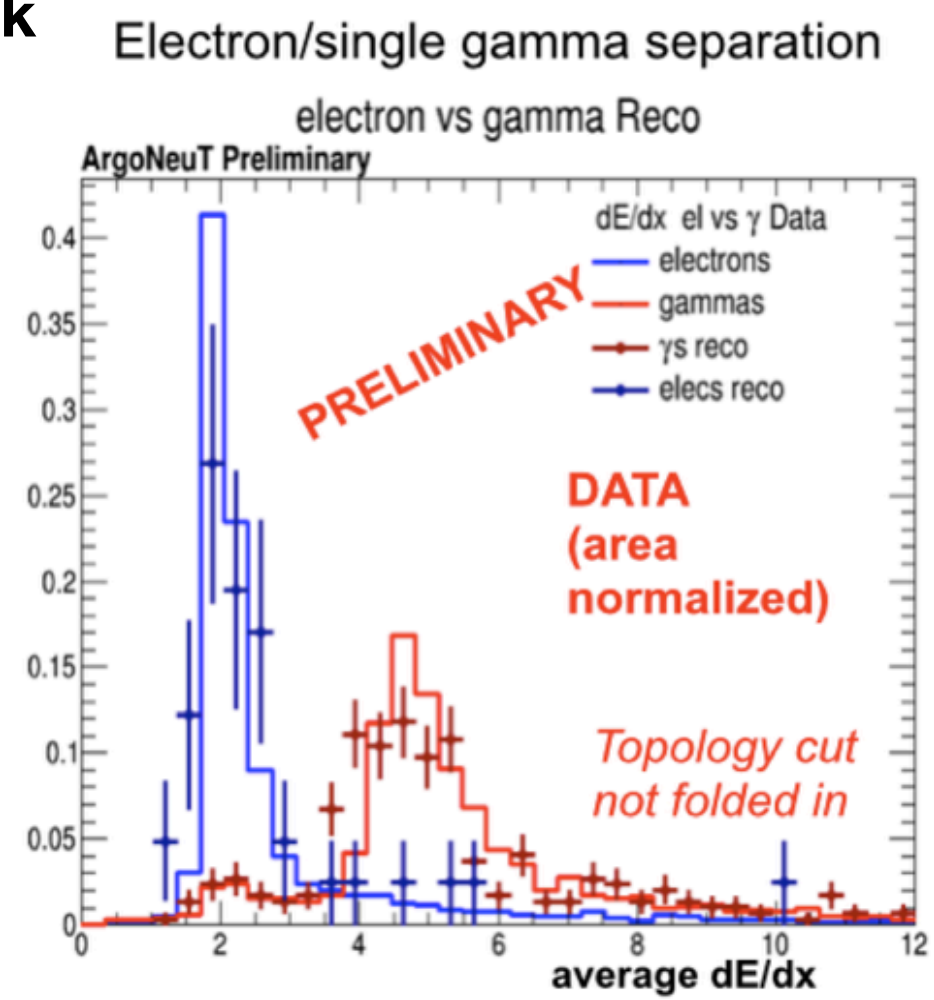
- *Electron-like shower event*
- *Single photon-like shower event*



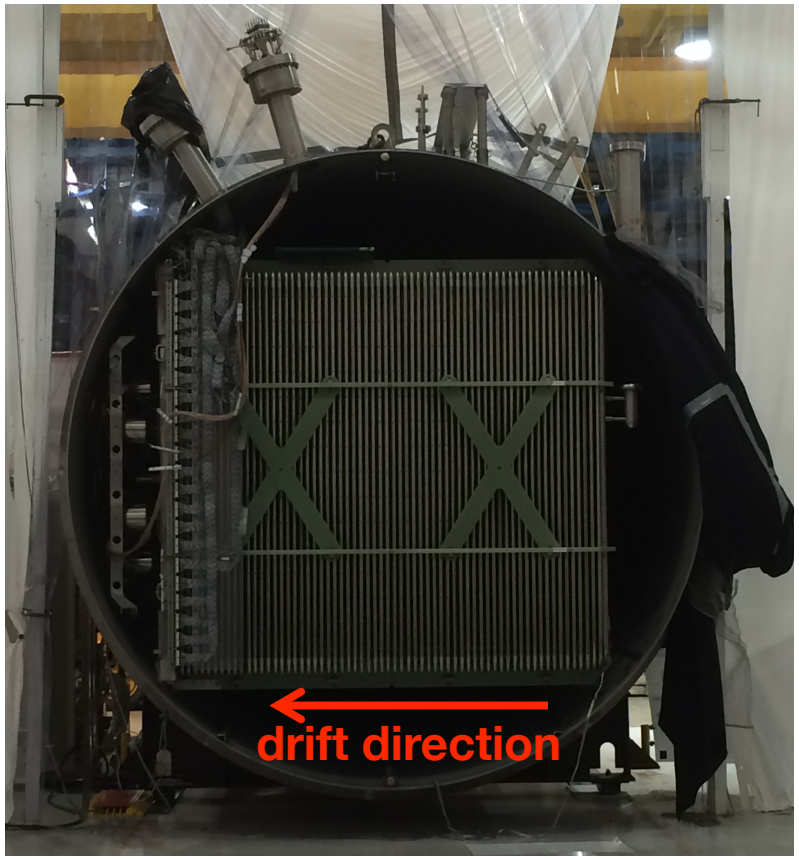
LIQUID ARGON TPCS (LARTPCS)

Offers high-definition look at the interaction vertex

- Discriminate photons from electrons: dE/dx
  - Electron-initiated showers have lower ionization in first few centimeters
  - Photons which pair-produce have higher initial ionization



MicroBooNE

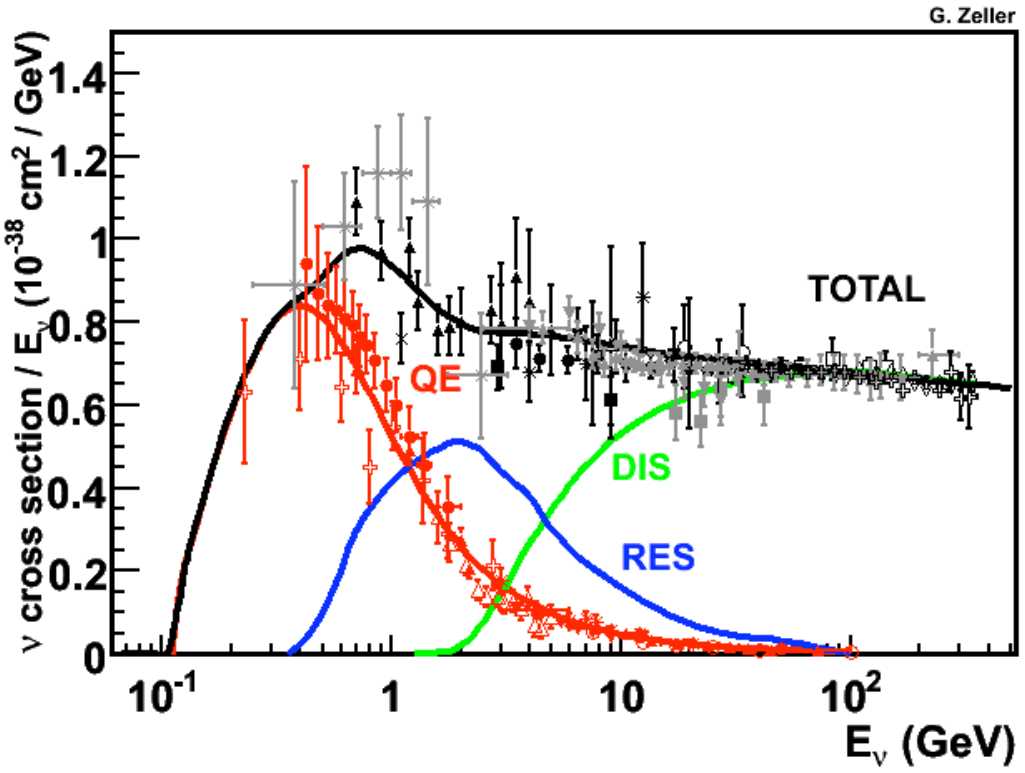


New LArTPC neutrino detector located 470 m from BNB target

- Long drift (2.6 m)
  - High cathode voltage and purity
- Fill without evacuating
  - Ar purge before fill
- Electronics inside LAr
  - Low noise → better signal sensitivity
- Operating on surface
  - Cosmic rays in drift window

NEUTRINO INTERACTION CROSS SECTIONS

- ~GeV region very interesting
- Argon data needed as foundation for future LArTPC detectors
- MicroBooNE will conduct rigorous program to measure cross sections on argon

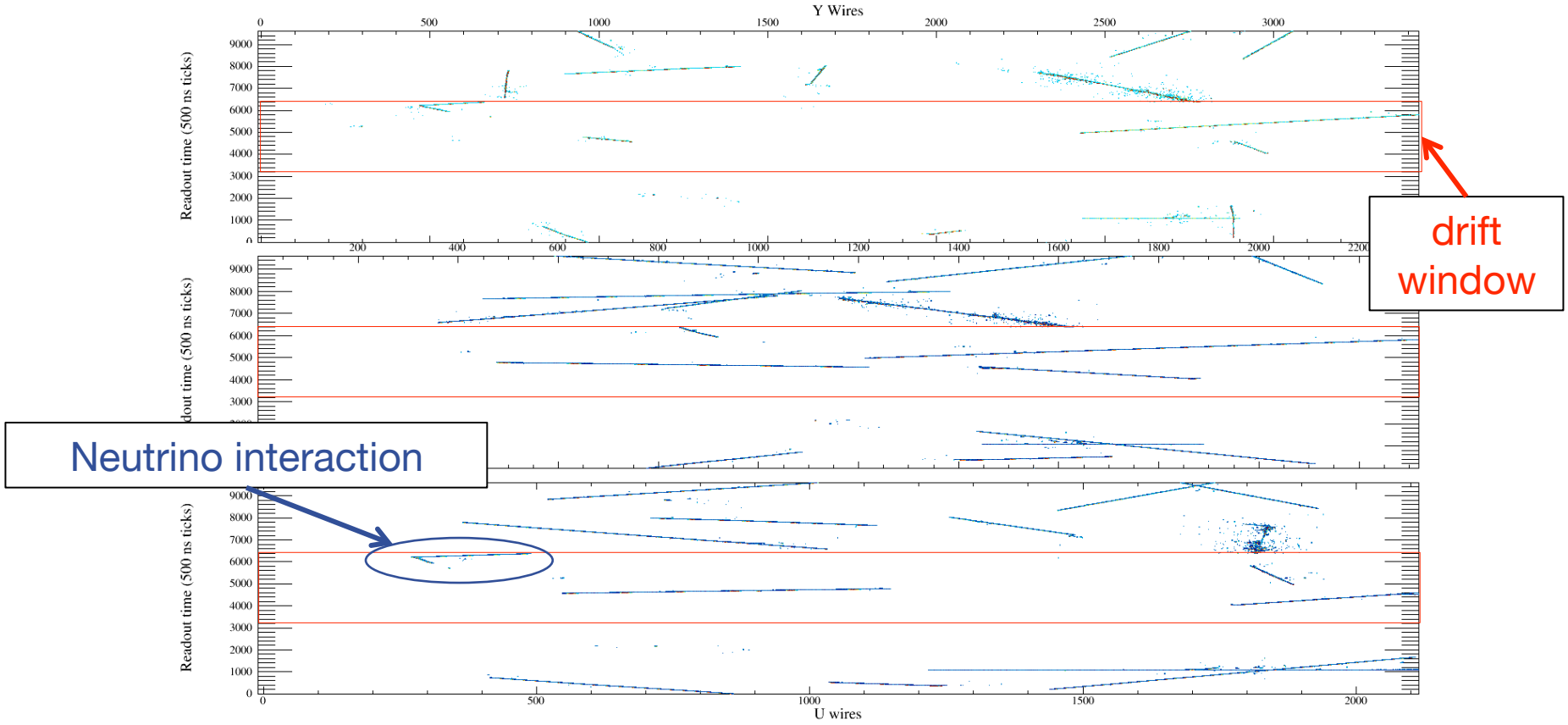


MicroBooNE: Detector Status

- TPC inside cryostat, and cryostat welded shut
- *Just moved to location on BNB in Liquid Argon Test Facility!*
- Expect: commissioning this fall, first neutrino interactions this winter

LArTPC RECONSTRUCTION EFFORT

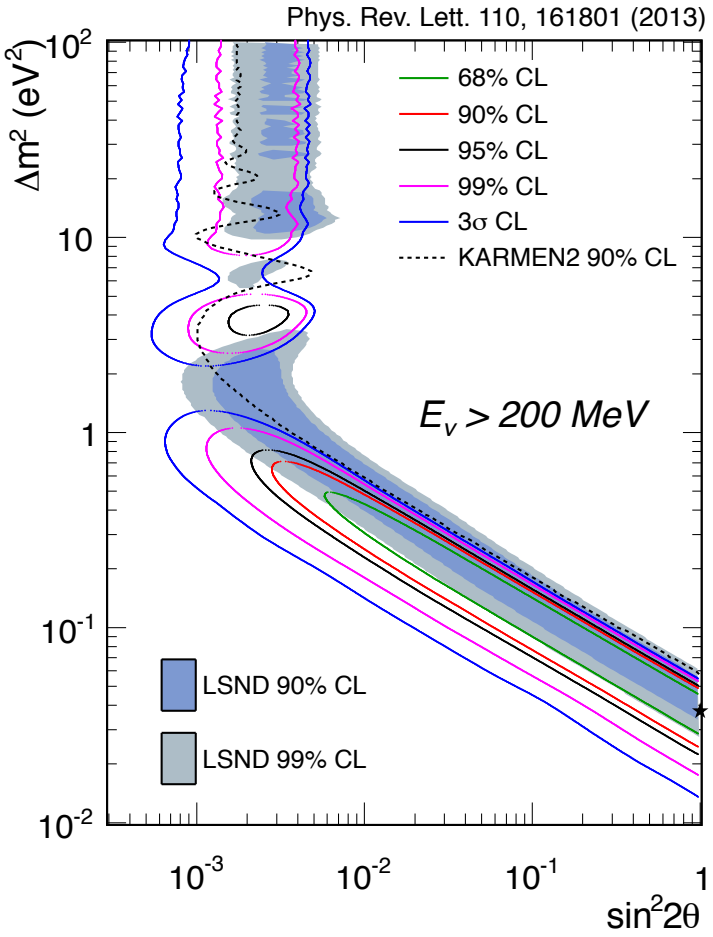
- LArSoft: a LArTPC simulation, reconstruction, and analysis package
- End goal: a fully-automated reconstruction chain



MicroBooNE and sterile neutrinos

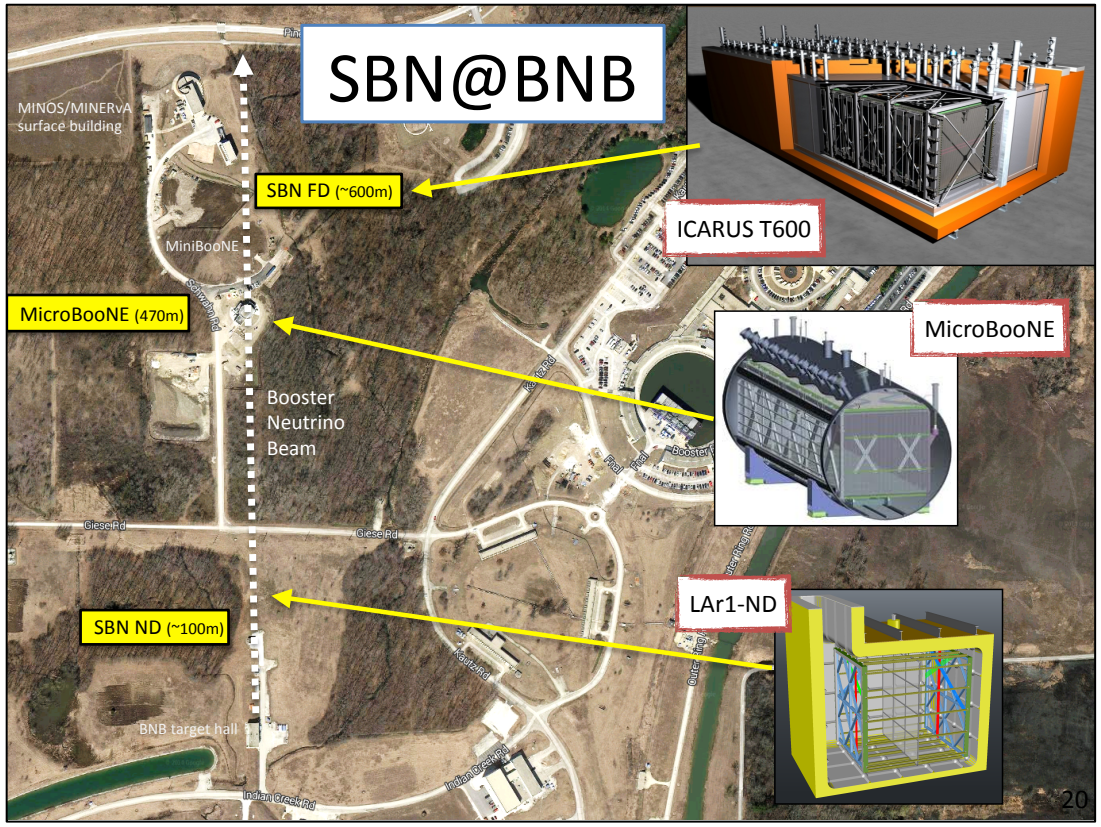
- MicroBooNE will tell use what kinds of events make up MiniBooNE low-energy excess
- Low-energy excess can be interpreted as part of broader evidence for sterile neutrinos

MicroBooNE can be part of broader short-baseline neutrino program to more definitely address sterile neutrino question



PLANNING FOR A COMPREHENSIVE SHORT-BASELINE PROGRAM AT FNAL

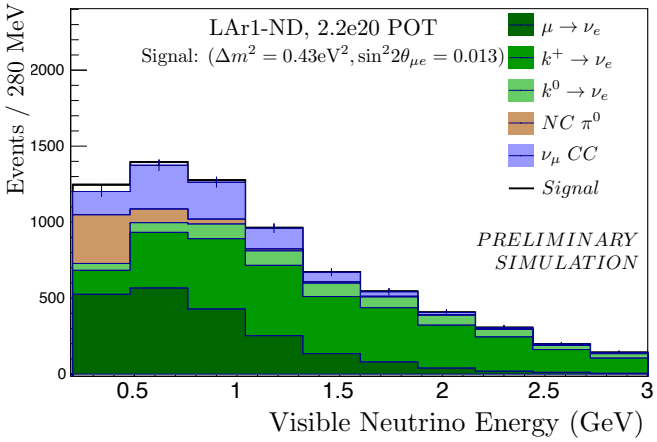
- A (new) near LArTPC (~50 t fid.) located at ~100 m from target
- MicroBooNE (~80 t fid.) at 470 m
- ICARUS T600 (476 t fid.) at ~600 m



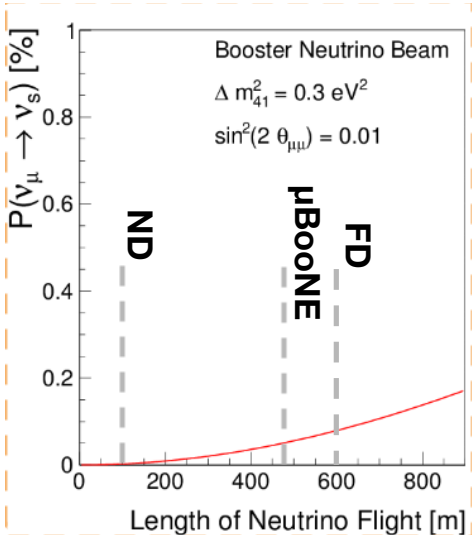
Same detection technology + same beamline → reduced systematic uncertainties

SBN: ELECTRON NEUTRINO APPEARANCE

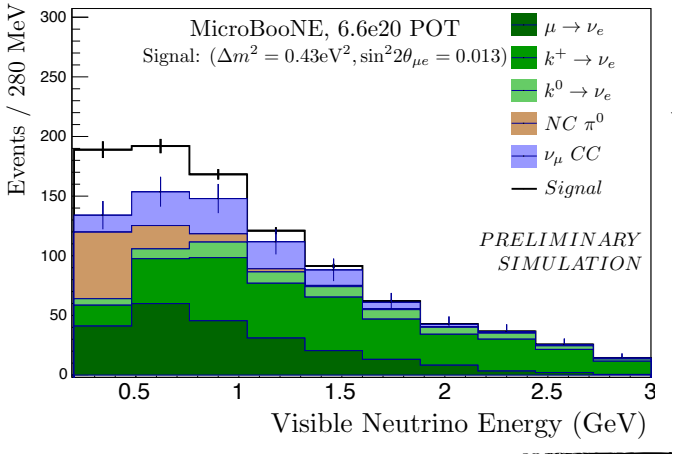
ND @ 100 m



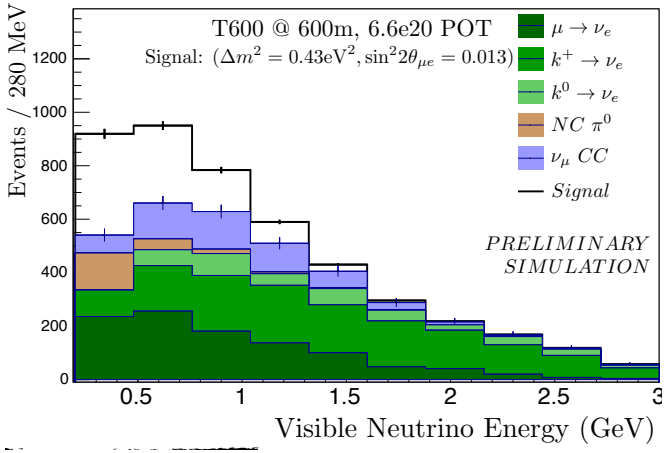
$\nu_\mu \rightarrow \nu_e$



MicroBooNE @ 470 m

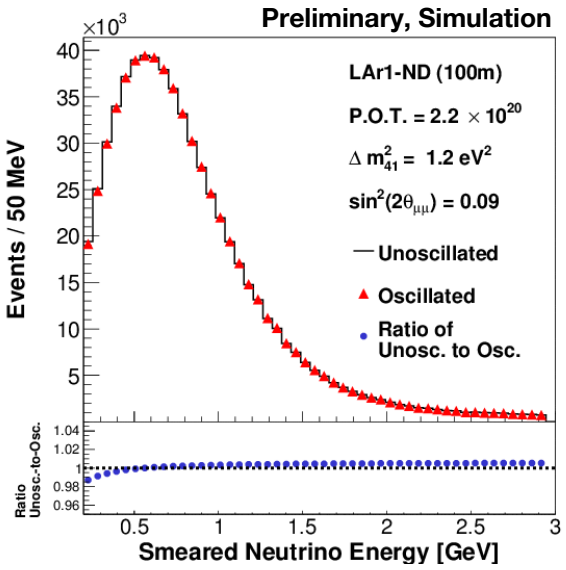


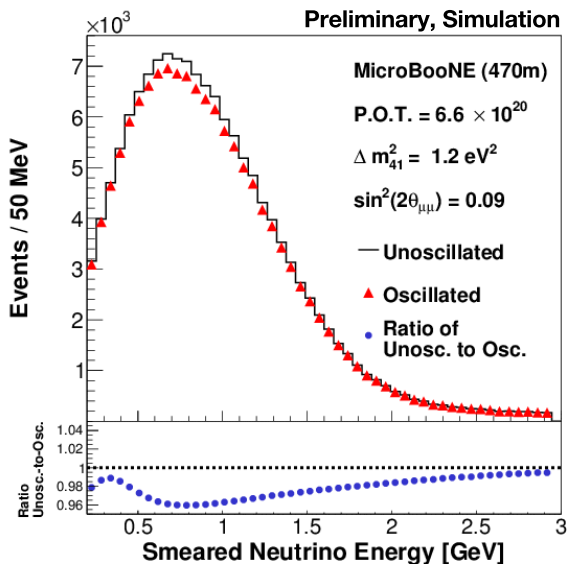
ICARUS T600 @ 600 m

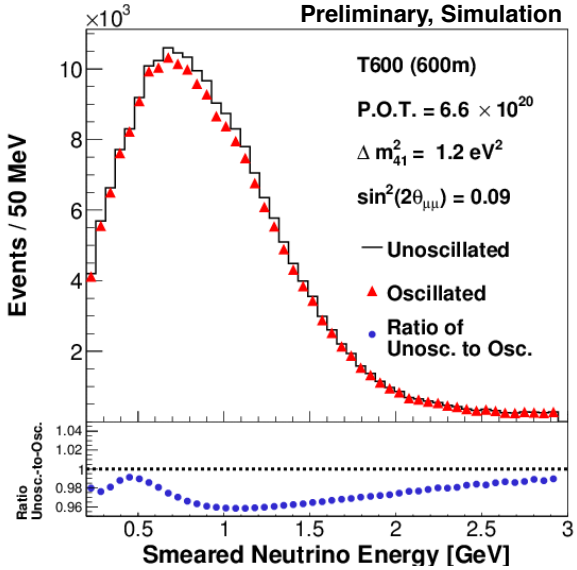


SBN: MUON NEUTRINO DISAPPEARANCE

- With BNB, can also do muon neutrino disappearance search
- *If* excess in electron search due to oscillations, should see deficits in muon neutrino flux at far detectors



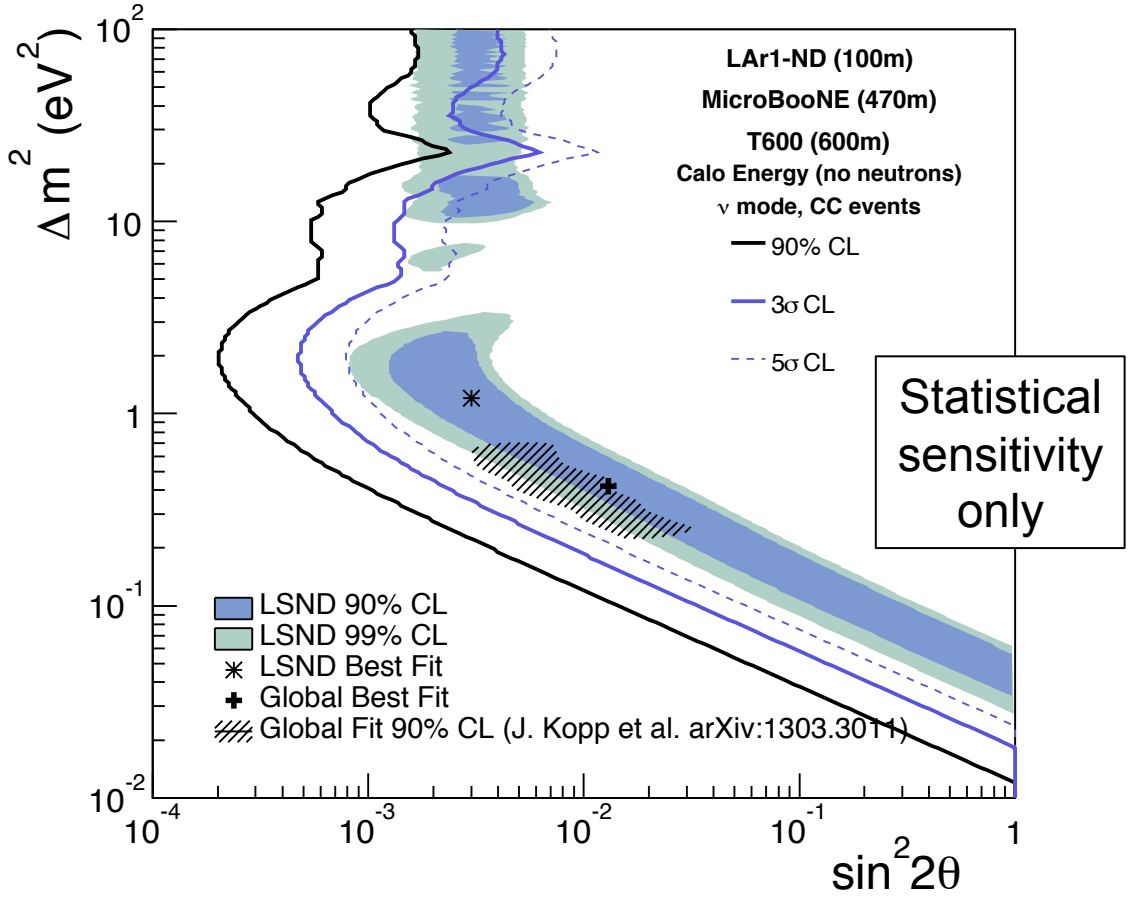




PROJECTED SENSITIVITY FOR COMPREHENSIVE PLAN

- Covers significant parts of sterile neutrino parameter space
  - Almost entirely covers LSND allowed regions at 5 σ

Will benefit tremendously from multiple detectors with same target and technology



ADDITIONAL PHYSICS WITH SBN PROGRAM

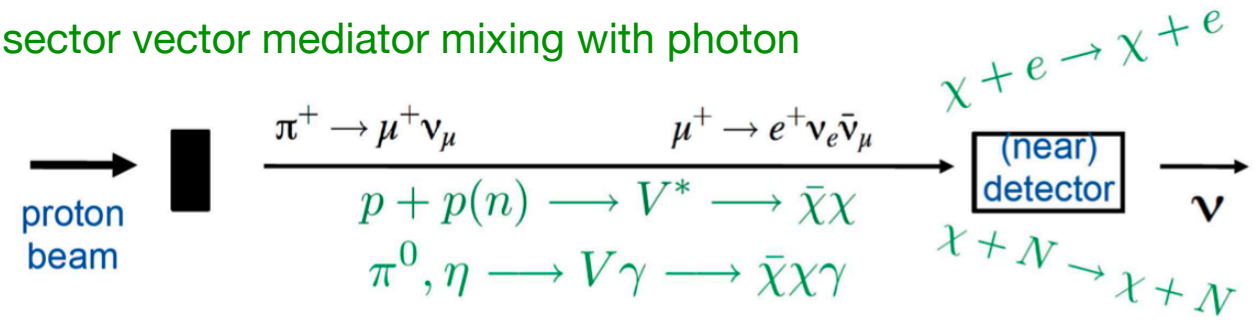
Neutrino cross section measurements

- Detector close to target → much higher neutrino flux
- >15x neutrino interaction rate than MicroBooNE despite smaller size

Searches for sub-GeV dark matter

- Direct detection of WIMPs limited by galactic halo velocity
- To search lower: produce WIMPs in a beam dump

V – dark sector vector mediator mixing with photon



χ – WIMP dark matter

SUMMARY

Fermilab's BNB provides excellent source of neutrinos for short-baseline neutrino physics

LArTPCs are a powerful detection technology perfect for conducting this physics

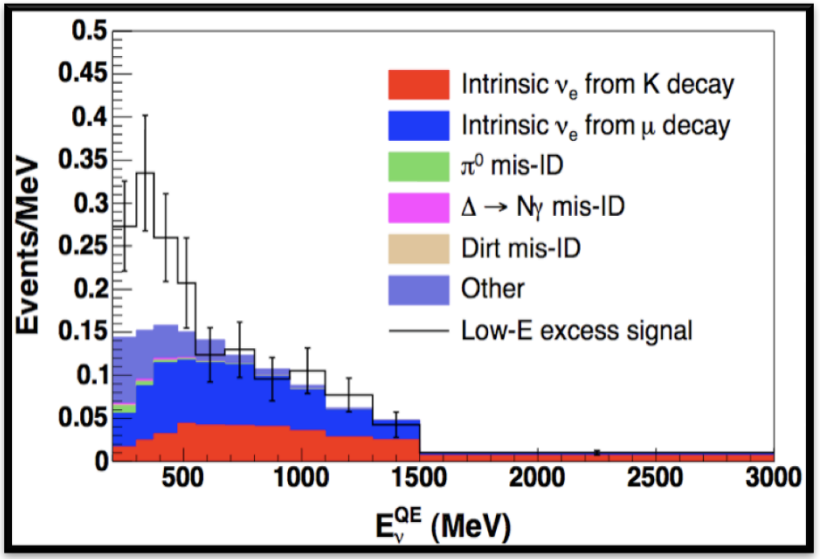
- MicroBooNE will begin taking data soon!
  - Resolve source of MiniBooNE low-energy excess
  - Perform crucial cross section measurements of neutrino interactions on argon
- SBN program can test full parameter space of best hints at sterile neutrinos
  - Potential for discovery of beyond-SM physics!

BACKUP SLIDES

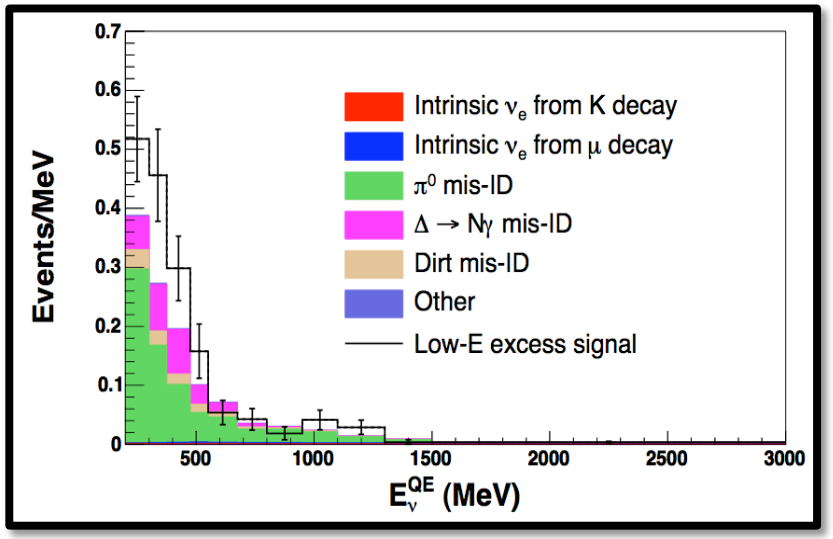
MicroBooNE Physics Goals

Resolve source of MiniBooNE low-energy anomaly

If the excess were electron-like:



If the excess were photon-like:



Projections assuming 6.6 x 10^{20} POT