Status of MicroBooNE

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For the MicroBooNE Collaboration
IPA2013
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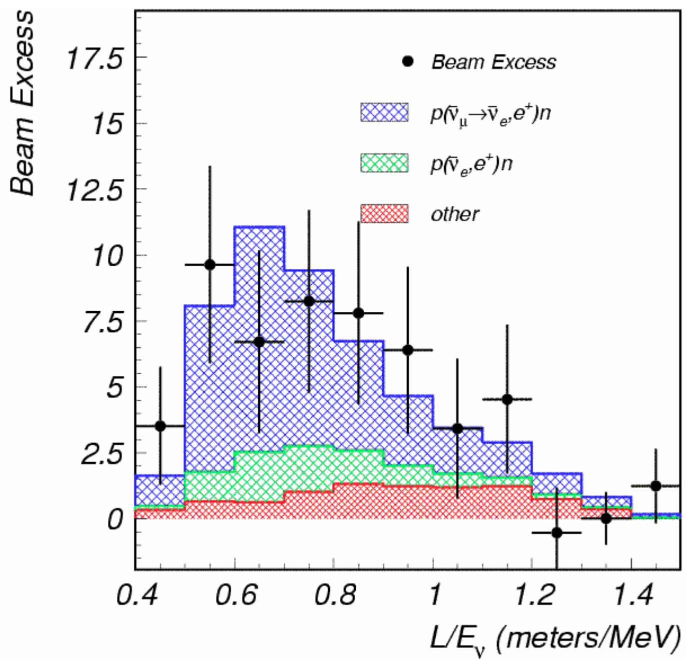
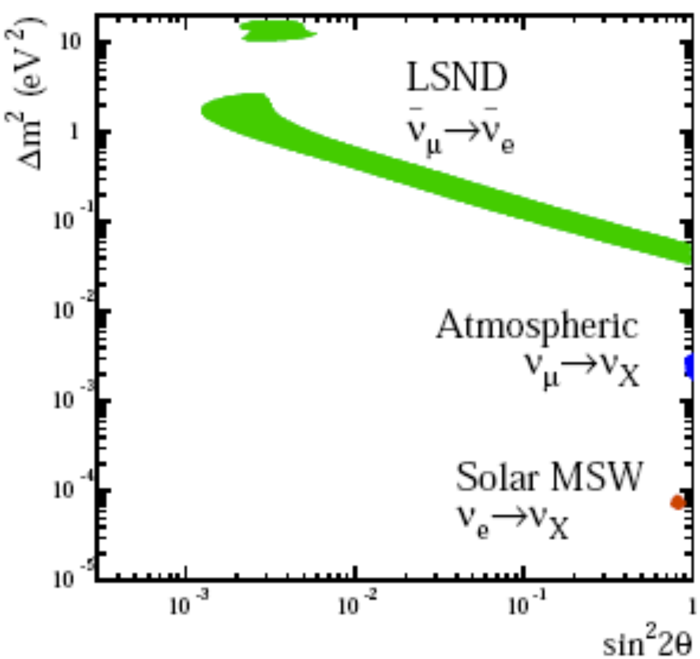
Motivation for MicroBooNE: MiniBooNE
Motivation for MiniBooNE: LSND

- LSND result: Observed an appearance signal consistant with oscillations at a Δm^2 not consistent with known mass splittings:

$$\Delta m^2_{solar} \sim 10^{-5} eV^2 \quad \Delta m^2_{atm} \sim 10^{-3} eV^2 \qquad P(\nu_\mu \to \nu_e) = \sin^2 2\theta \sin^2(1.27 \Delta m^2 \frac{L}{E})$$

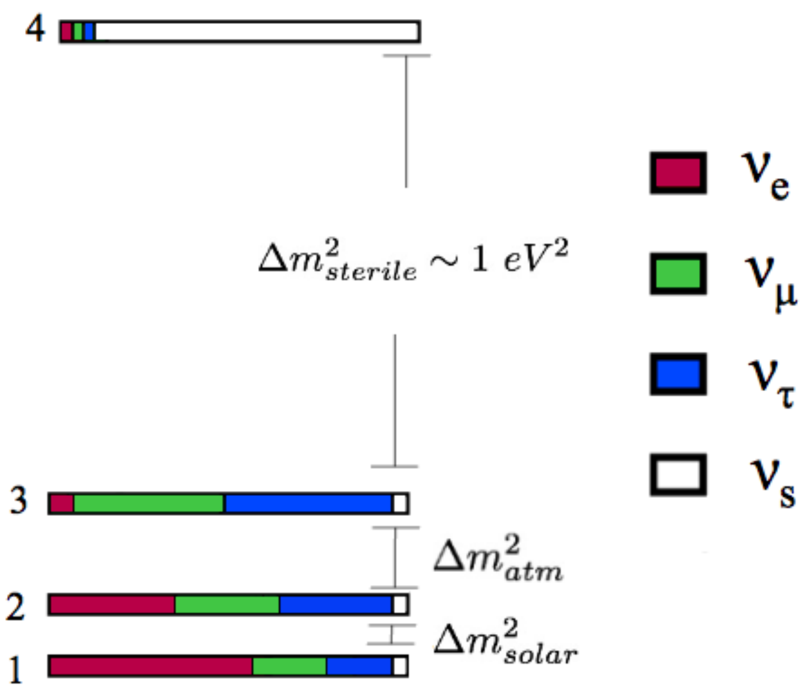
- A 3rd mass splitting would solve this problem: $\Delta m^2_{lsnd} \sim 1\ eV^2$





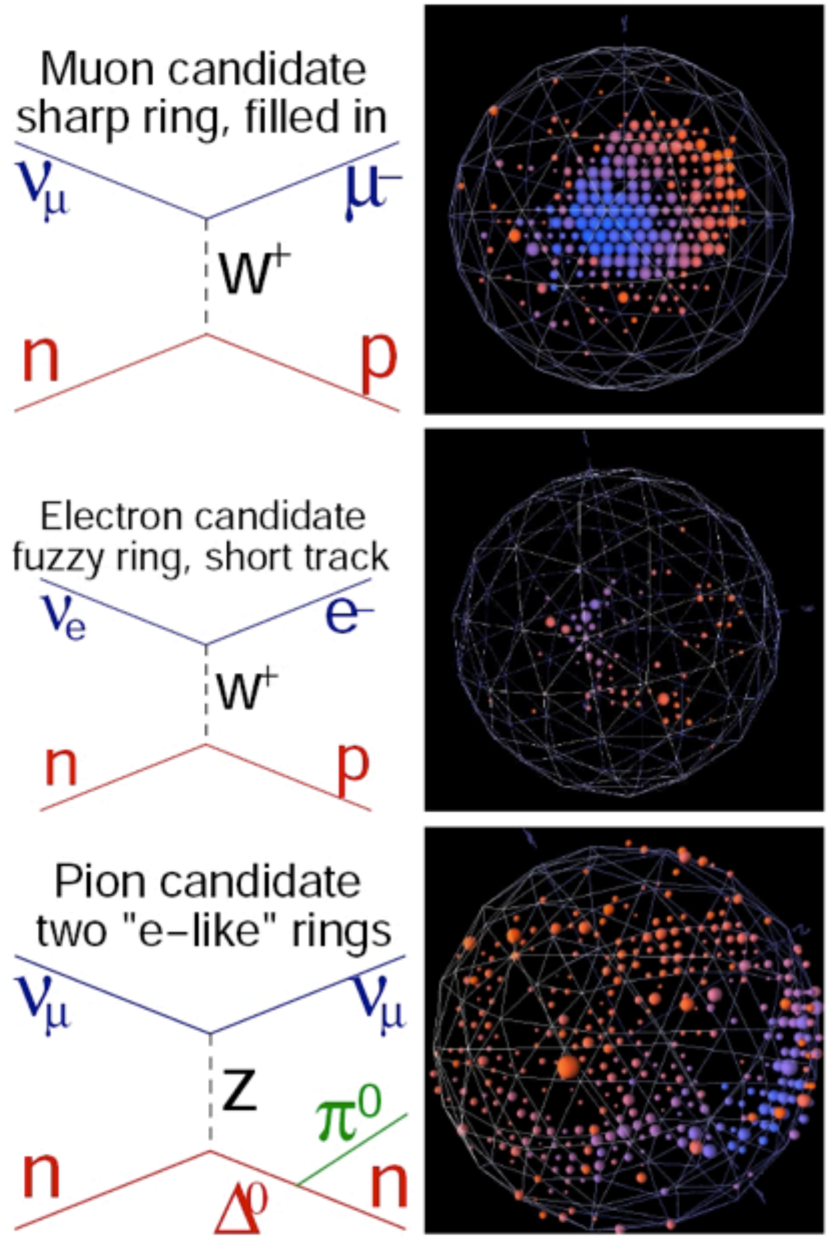
3+1 Sterile Neutrino Model

- Assume one more neutrino that doesn't interact through the weak force but can still oscillate with the other neutrinos
- $\Delta m^2_{sterile} \gg \Delta m^2_{atm}$ and Δm^2_{solar}, so these short baseline experiments can fit to a 2-neutrino model.



MiniBooNE

- Similar L/E to LSND to probe same Δm^2 region
- Looks for ν_e appearance in a ν_μ beam
- Cherenkov Detector
  - Detects Cherenkov rings created by charged particles
- Main sources of background:
  - intrinsic ν_e in the beam
  - mis ID $(\gamma \to e^+ e^-)$ from $\pi^0 \to \gamma\gamma, \Delta \to N\gamma$

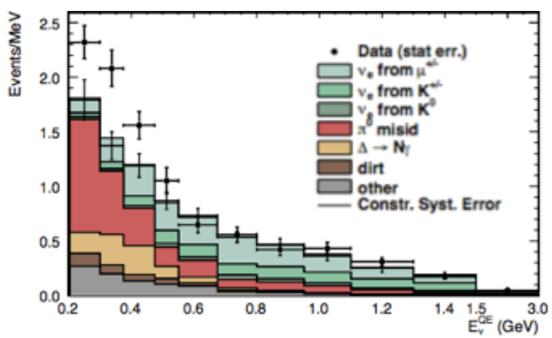


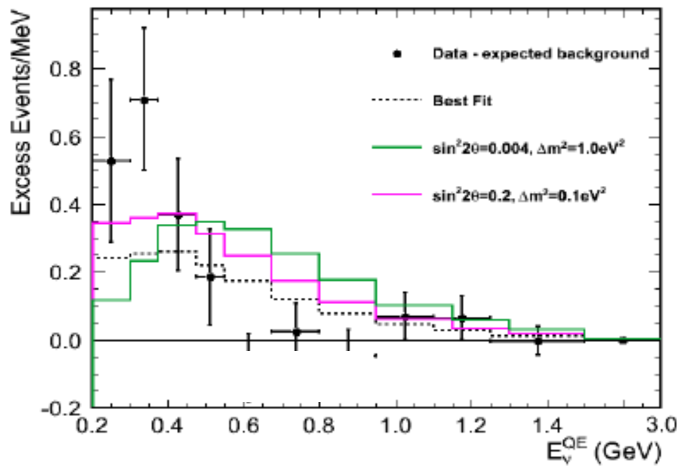
MiniBooNE Results

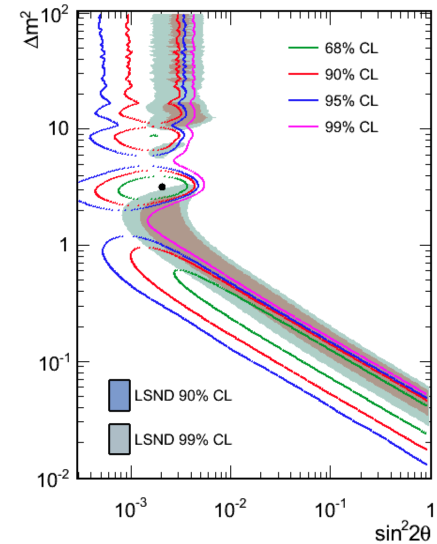
arXiv:1303.2588

Allowed regions: overlap with LSND

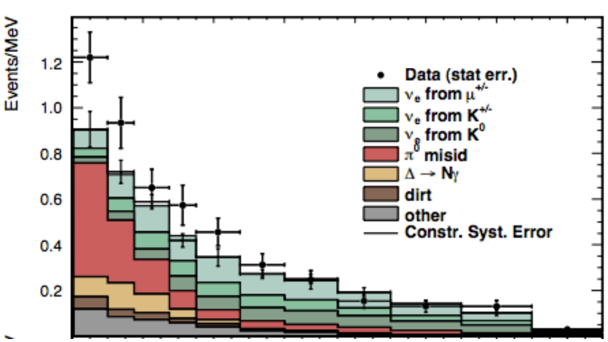
$\nu_\mu \rightarrow \nu_e$ search

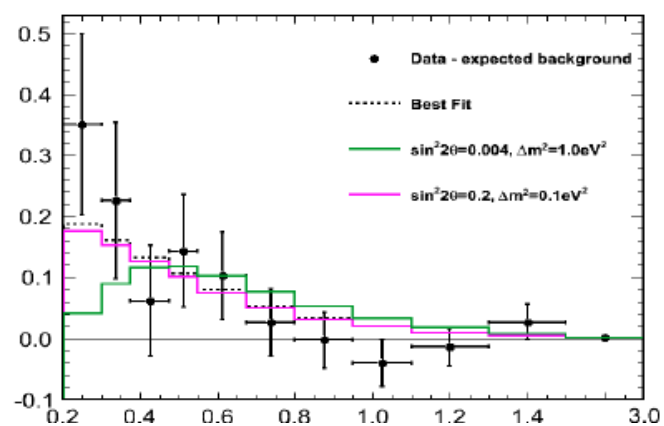


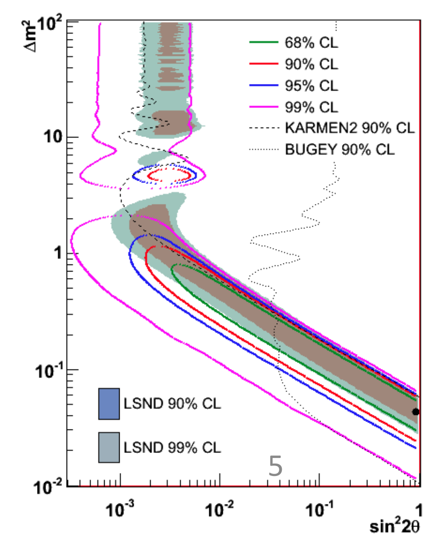




$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ search

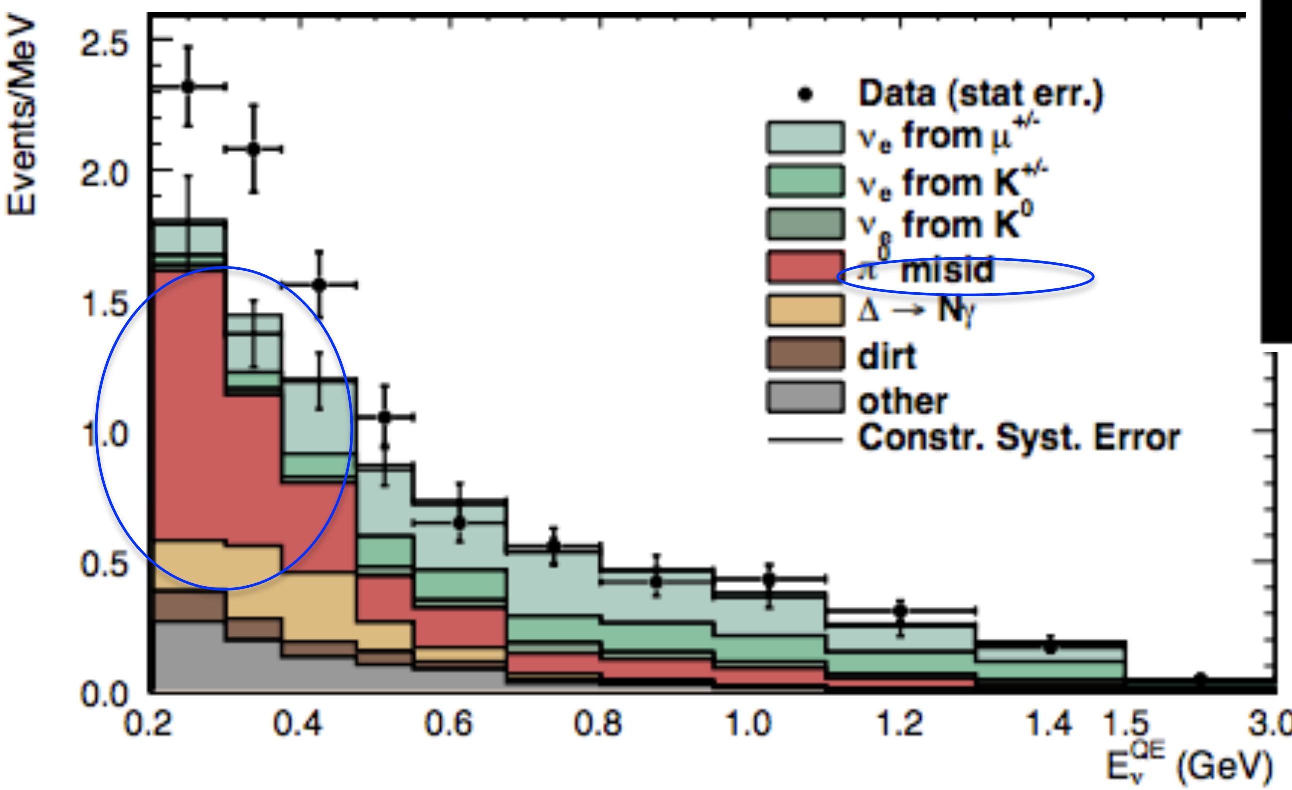


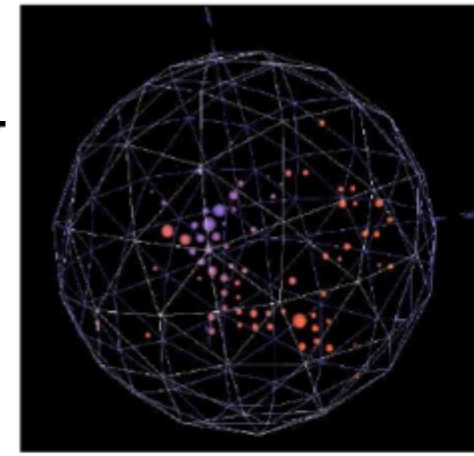




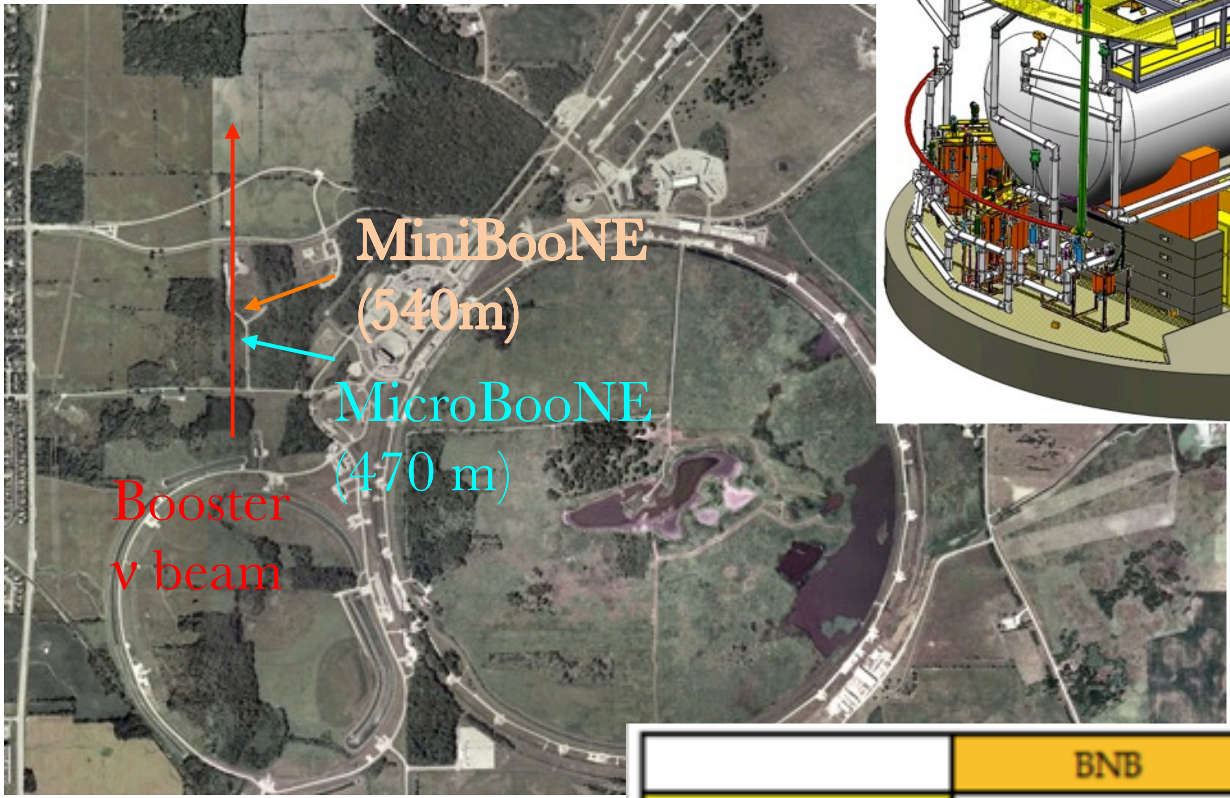
Main source of background

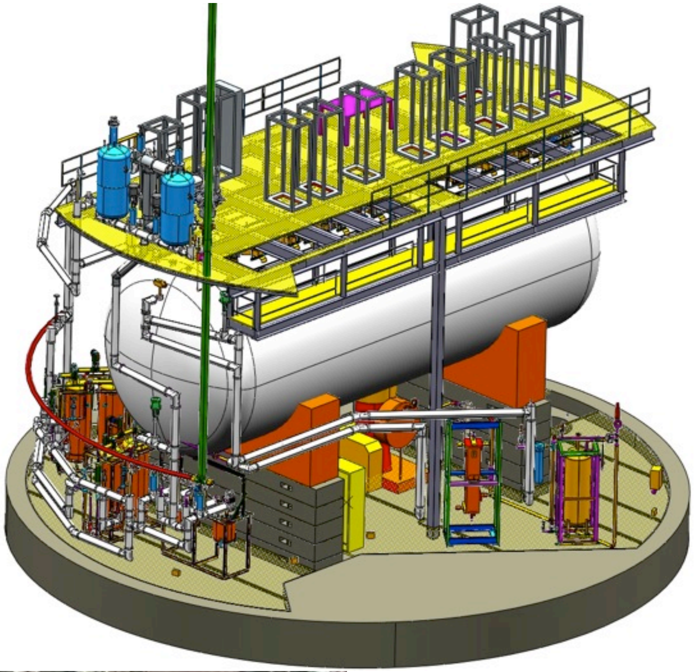
A single γ looks like an e!





MicroBooNE





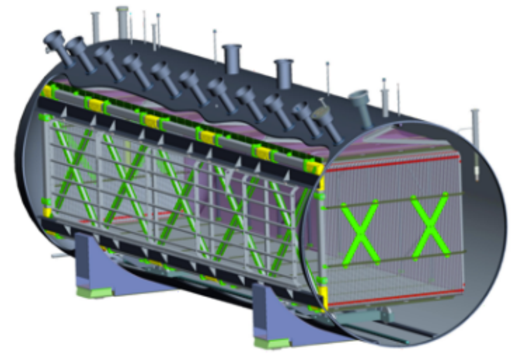
- Same location and beamline as MiniBooNE
- New detector technology

	BNB	NuMI
Total Events	145k	60k
ν_μ CCQE	68k	25k
NC π^0	8k	3k
ν_e CCQE	0.4k	1.2k
POT	6×10^{20}	8×10^{20}

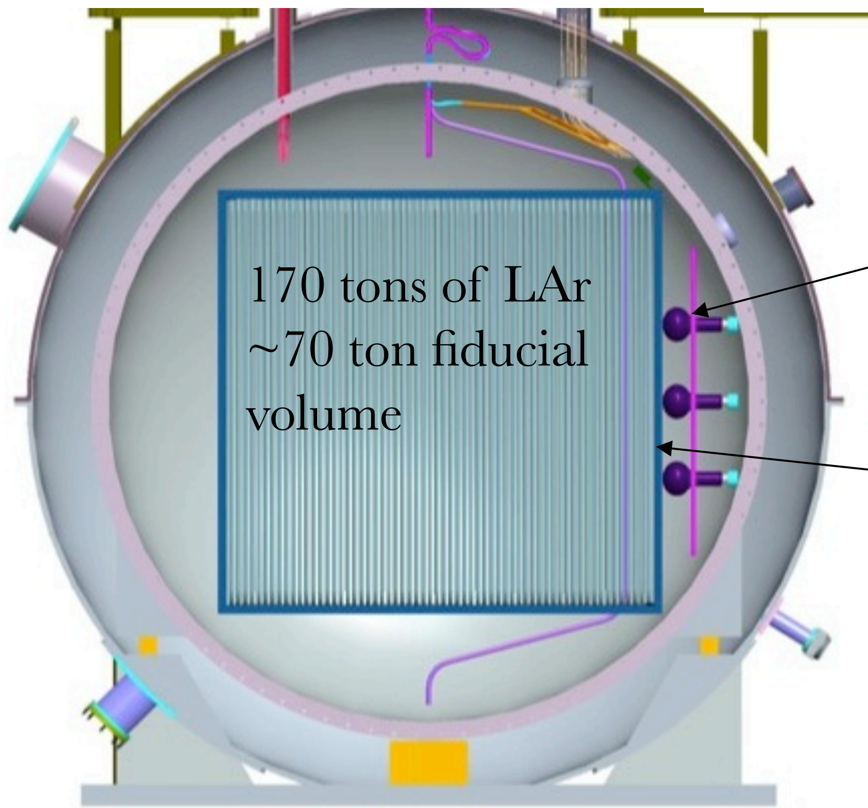
Projected Event Rates for MicroBooNE in 2-3 years.

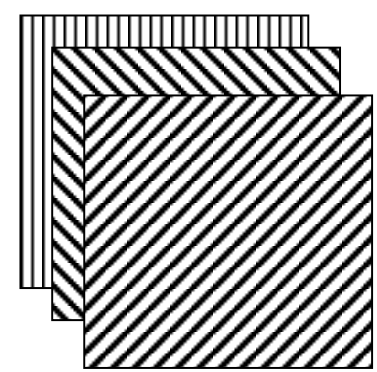
MicroBooNE Detector

- MicroBooNE is a Liquid Argon Time Projection Chamber (LArTPC)
- 2 detection components:
  - Charge-detection (TPC)
  - Light collection (PMTs)



Dimensions:
10 m x 2.3 m x 2.5 m





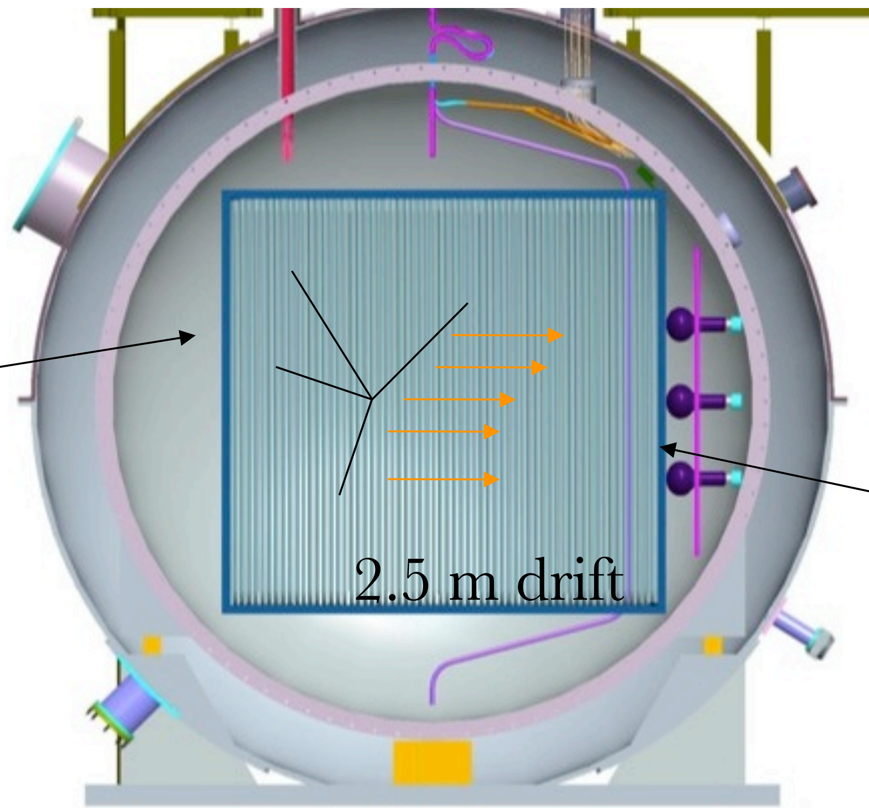
MicroBooNE Detector

Charged particles produced in neutrino interactions ionize the argon

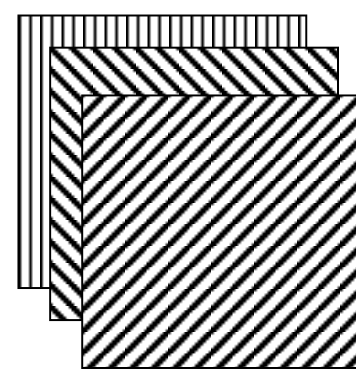
Ionization electrons drift slowly toward the wire chambers

High Voltage, 125 kV

Drift field: 500 V/cm

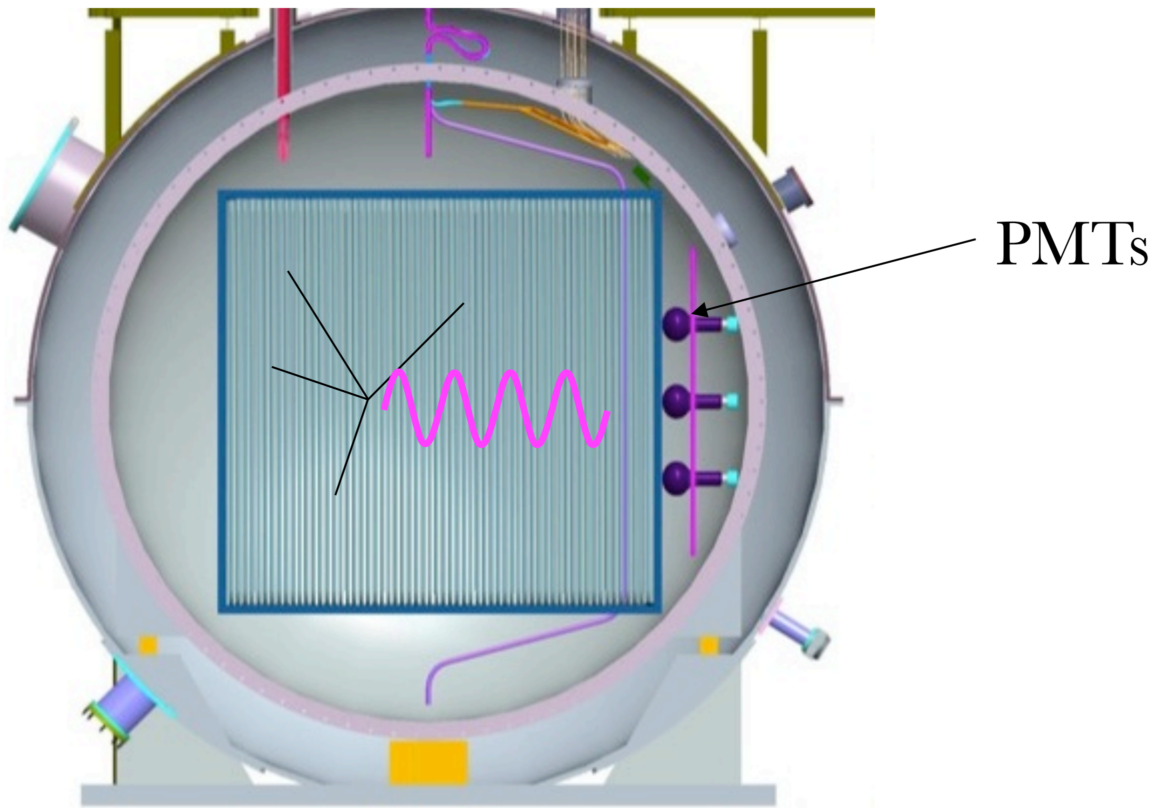


Wire planes

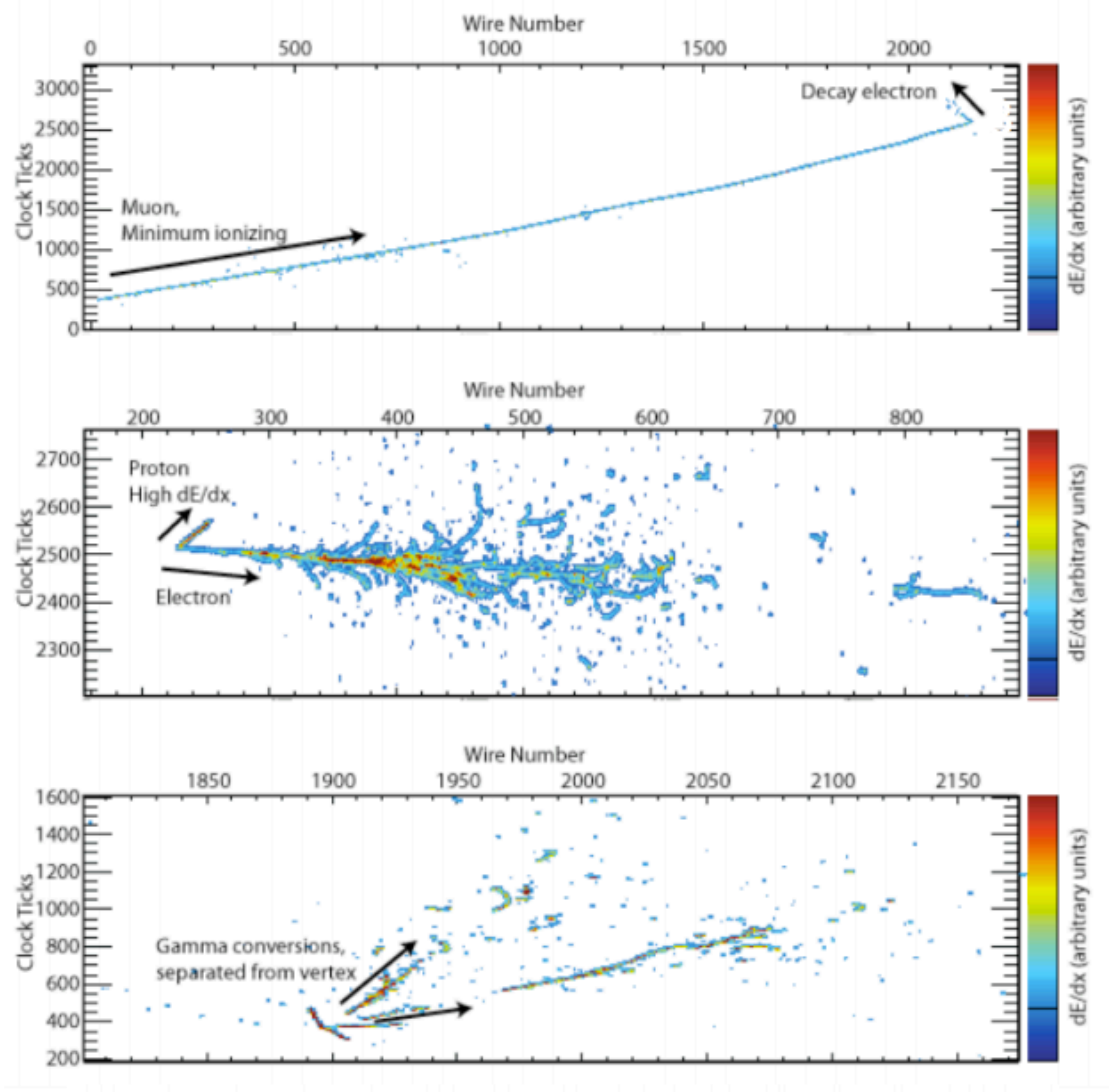


MicroBooNE Detector

Scintillation light from the event is observed by PMTs behind the wire planes

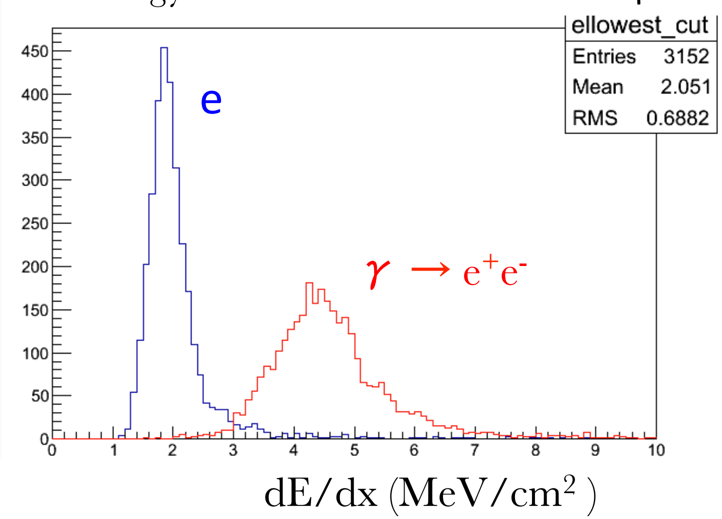


Event displays and e-γ separation



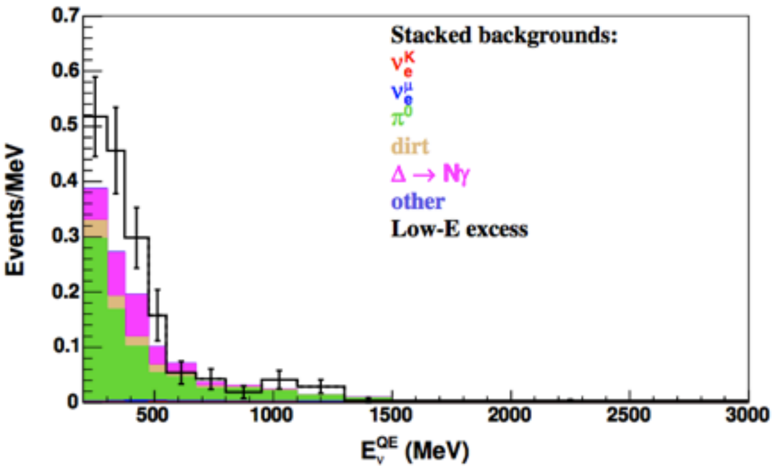
Uses dE/dx and event topology to distinguish e's from gammas

Energy loss for 0.5 –4.5 GeV e's and γ's



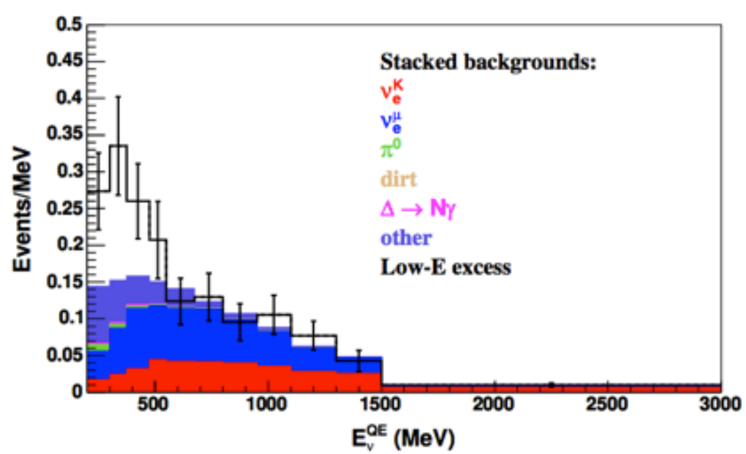
e-γ separation

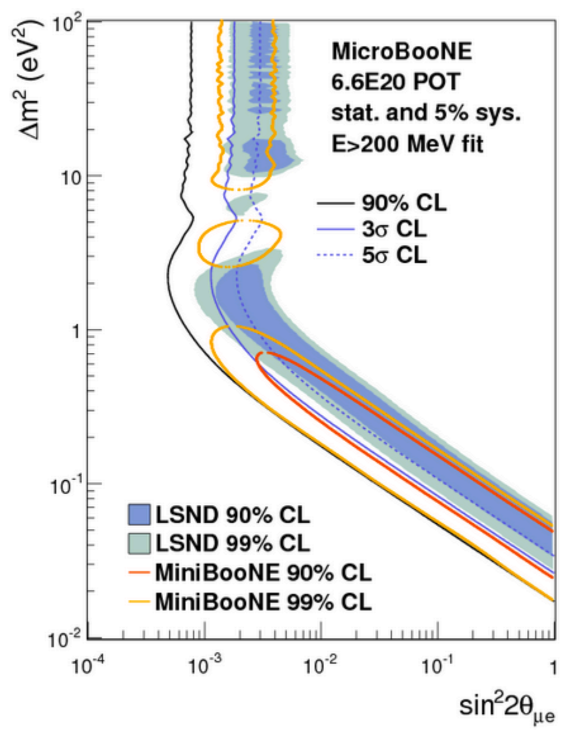
If γ-like signal in μBooNE over γ backgrounds
(Analyzed using cuts favoring γ's and rejecting e's)



If some or all of the MiniBooNE low energy excess is due to γ's, MicroBooNE will be able to tell!

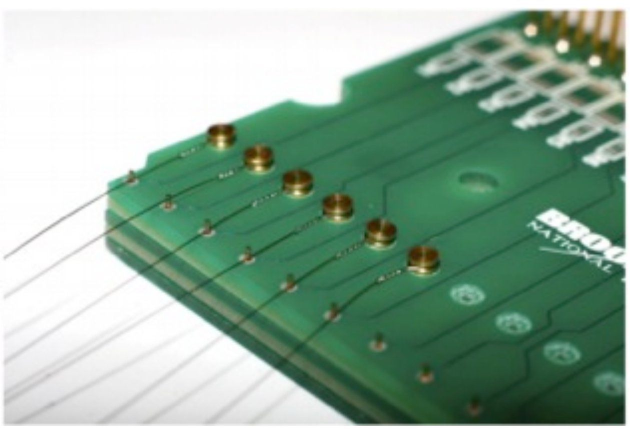
If e-like signal in μBooNE over e backgrounds
(Analyzed using cuts favoring e's and rejecting γ's)



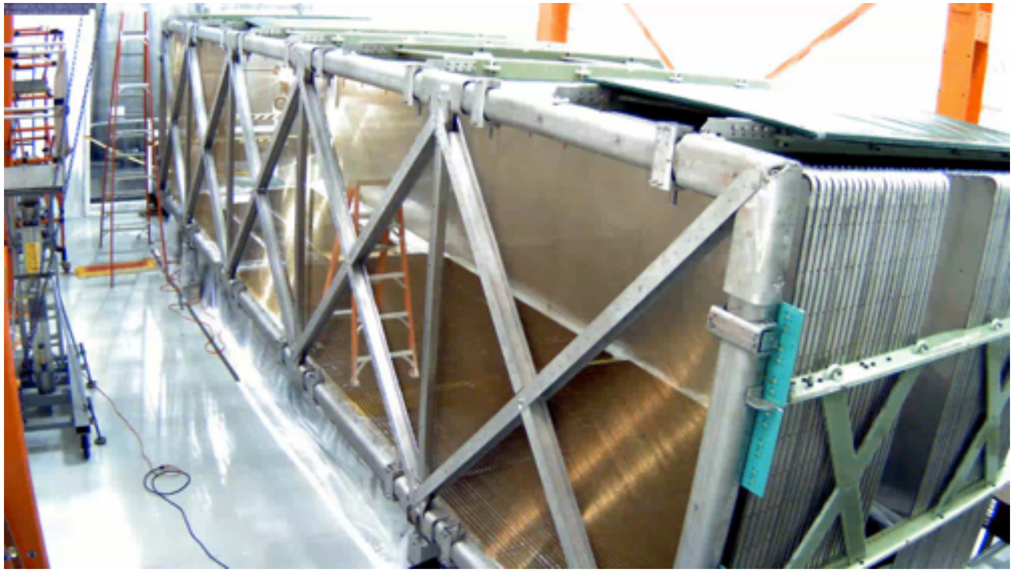


Wire planes

- 3 mm spacing
- Stainless steel coated with copper and gold
- Y: vertical plane (2.5 meter long wires), U,V planes: +/- 60 degrees from vertical (5 meters long)



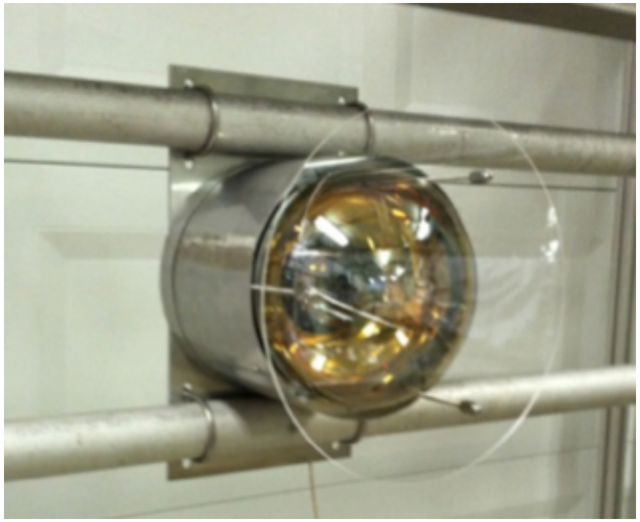
Wire planes are already installed!

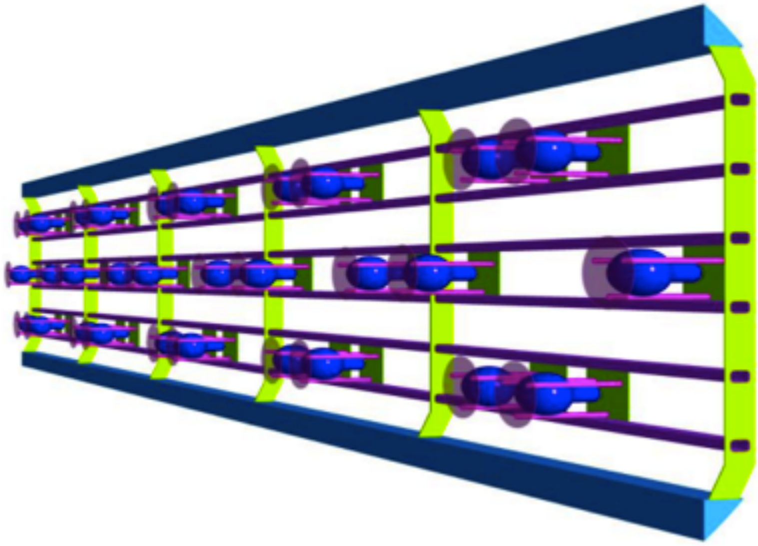


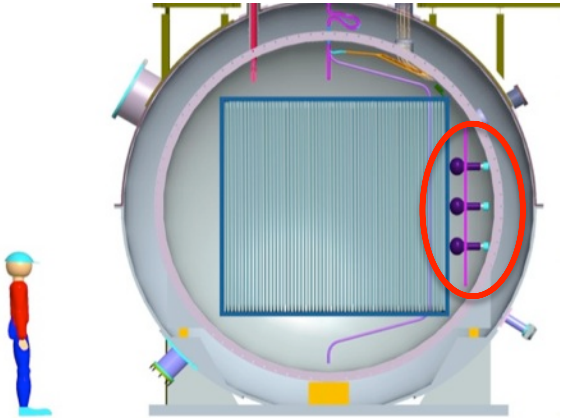
MicroBooNE light collection system

arXiv:1304.0821

- 30 PMTs behind wavelength shifting plates on the side of the cryostat.
- Primarily used for triggering, background rejection, and correcting for charge losses and diffusion as a function of drift distance

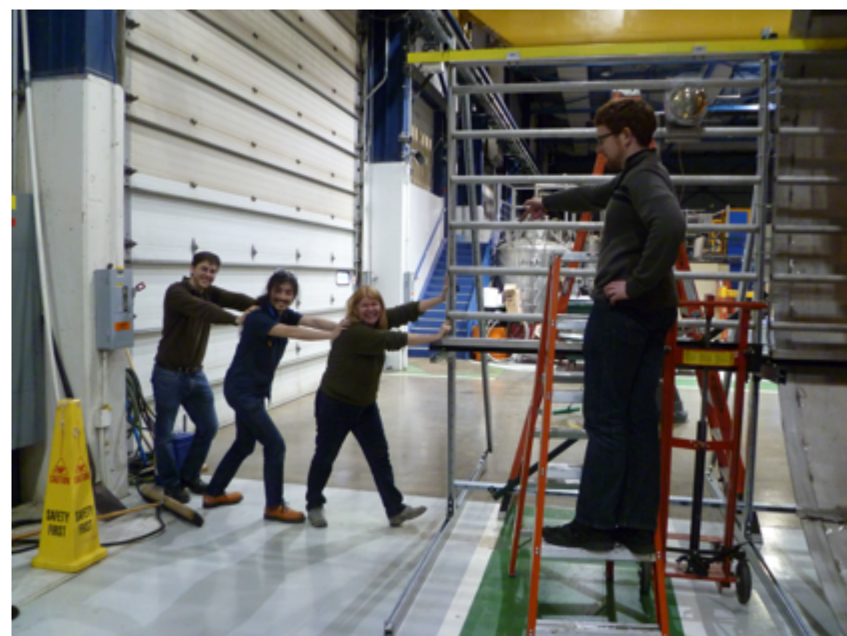






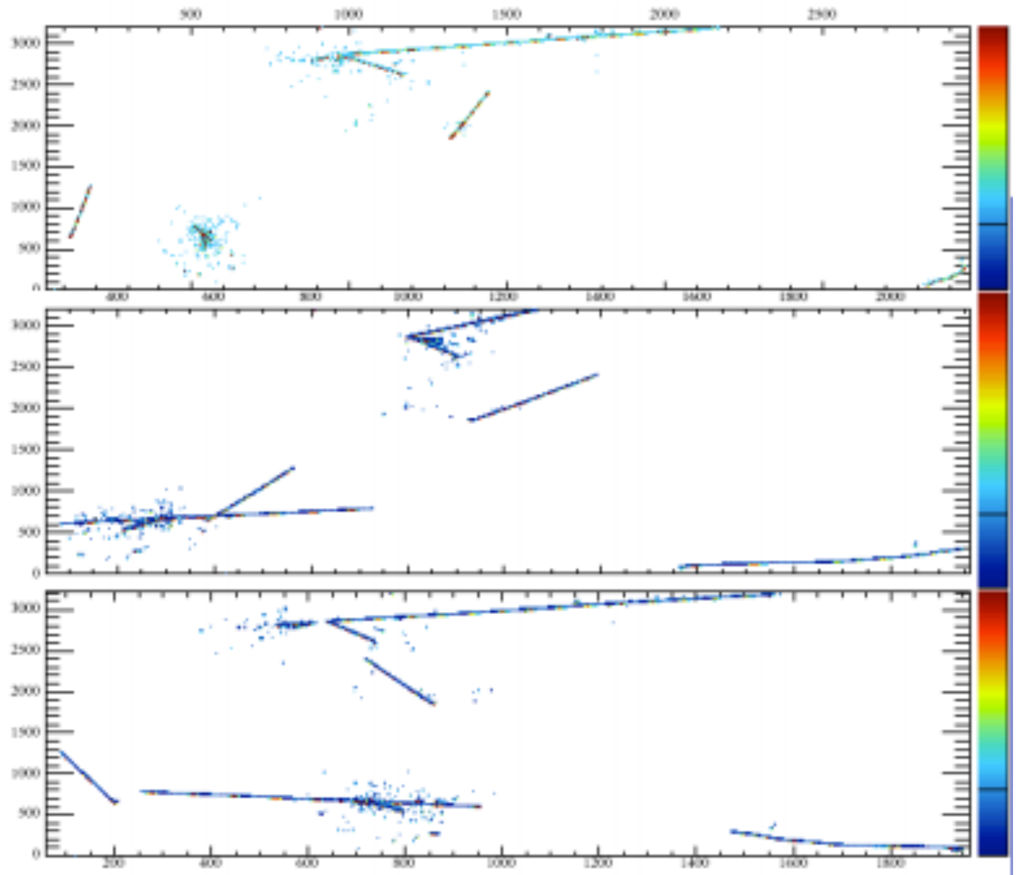
PMT Dry run

- Make sure we can push in 5 PMT racks with TPC in place (harder than expected, but we managed!)
- Purpose of dry run:
  - Check for mechanical interference
  - Demonstrate cabling scheme



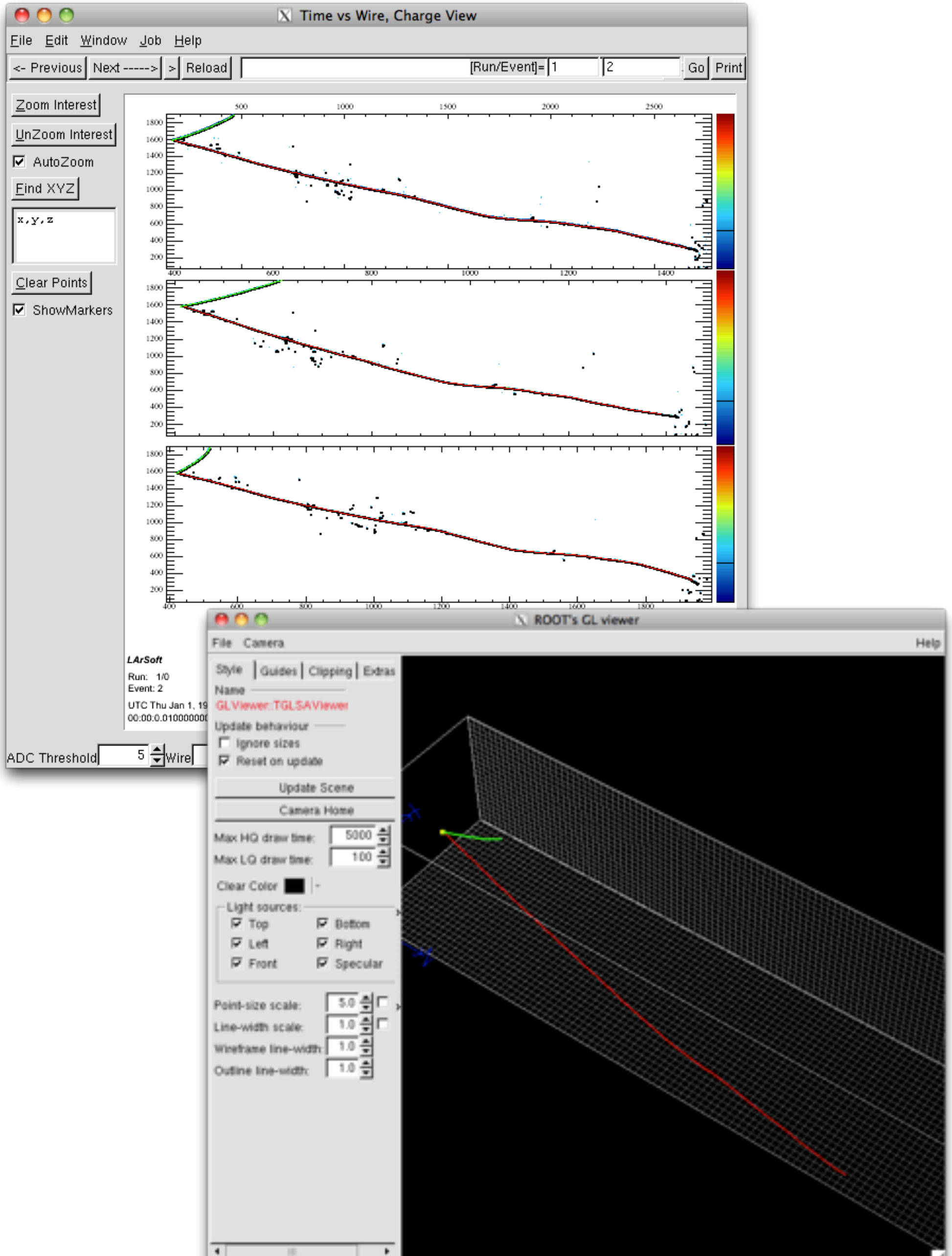
MicroBooNE Software: LArSoft

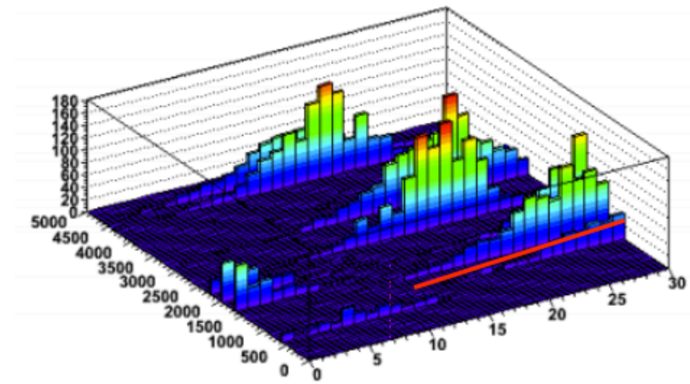
- Simulation, analysis and reconstruction in MicroBooNE are performed in the LArSoft framework
- LArSoft supports all US LArTPC efforts : MicroBooNE will both build on the work of ArgoNeuT and contribute to software for LBNE.
- LArSoft simulations interface with specialized neutrino and cosmic ray event generators and implement a full Geant4 particle simulation
- Electron drift and photon propagation are treated and realistic digitized detector signals are simulated
- Liquid argon TPC reconstruction effort is ongoing, and great progress is being made

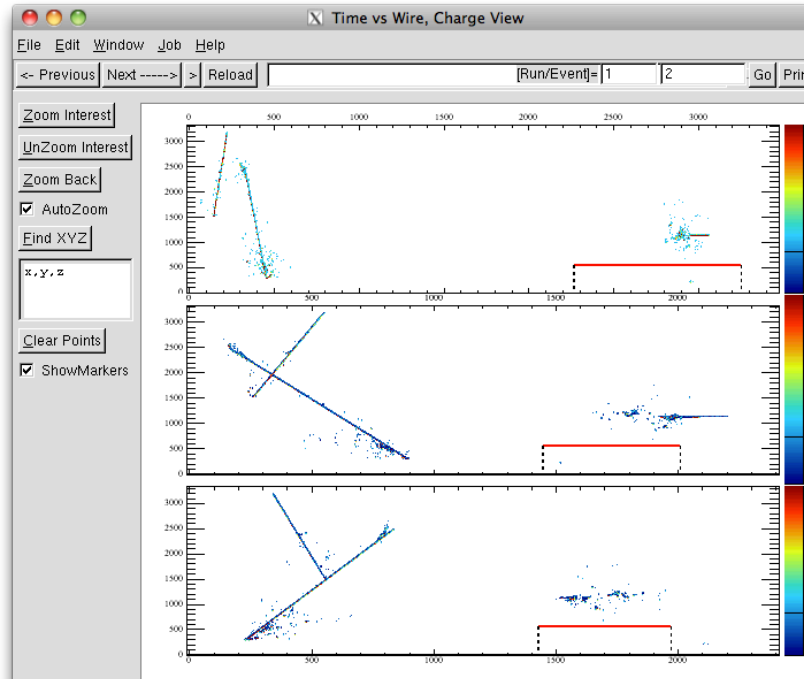


A simulated neutrino event with expected cosmic ray background overlaid

Slide from Ben Jones







PMT system timing information used to highlight beam event

A 3D reconstructed CCQE event in LArSoft

From Ben Jones

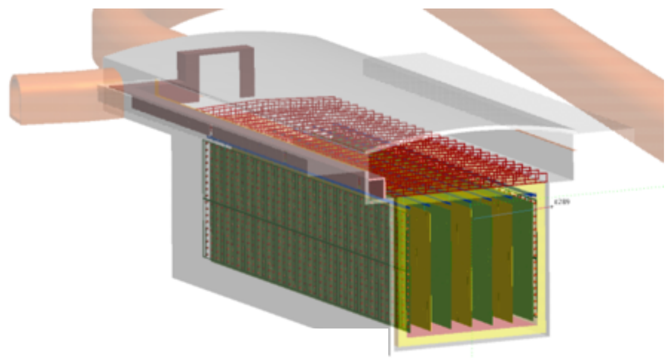
More Physics Goals

- Low energy cross section measurements
  - Coherent vs. resonant pion production, K production, ν_e cross sections
- Burst supernova detection capability
  - Data buffer, trigger from SNEWS
  - Would have gotten about 29 events for SN1987a
- Prepare for future proton decay searches ($p^+ \rightarrow K^+ \nu$) possible with larger LArTPCs.
  - Prepare PID, triggers, study backgrounds
- Sensitive to ΔS (fraction of proton spin carried by strange quark)
  - Information on final states for modeling events in LAr, input for spin-dependent WIMP searches,

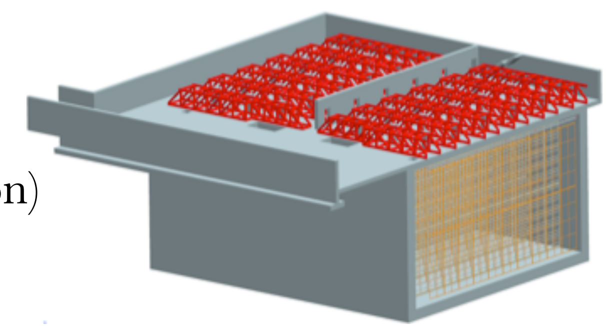
MicroBooNE is also important R&D for the development of future LArTPCs

- Demonstrate scalability of technology
- Cold electronics
- Purity
- Analysis tools

Example future LAr detectors:



- LAr1: 1 kton:
  2 detector sterile neutrino search



- LBNE: 10 kton (or 35 kton)
  CP violation

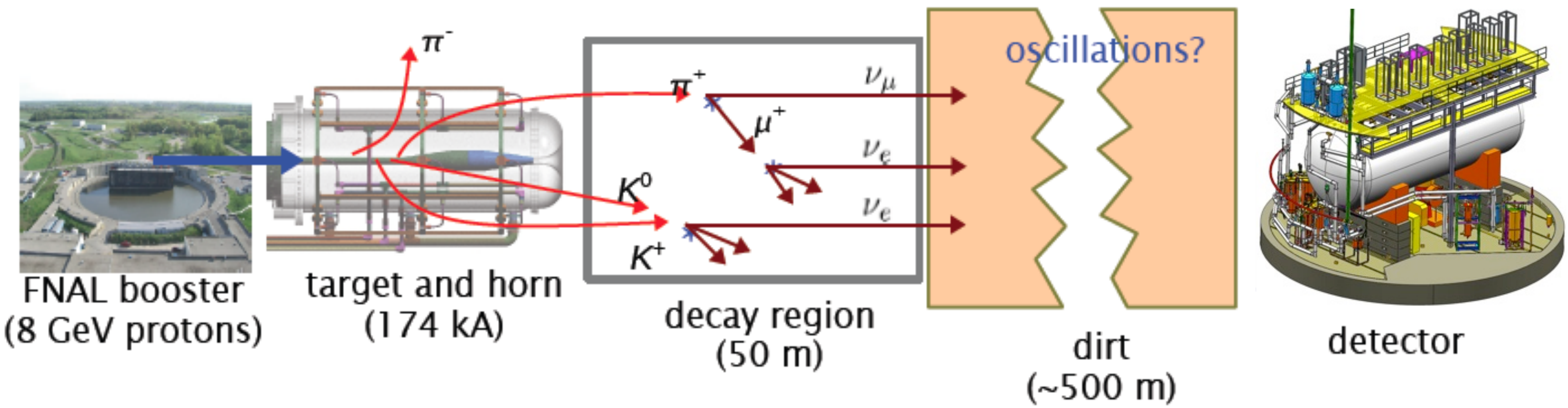
Conclusion

- MicroBooNE will address the MiniBooNE low energy excess, measure low energy neutrino interactions in argon, and represents an important step for LArTPC technology
- We are on schedule and will begin taking data in 2014!

Backup

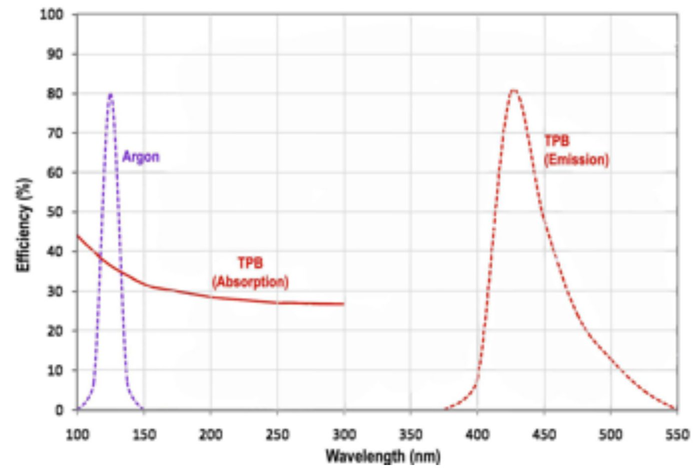
MiniBooNE & MicroBooNE Beam

- Similar L/E to LSND (since MiniBooNE designed to explore LSND anomaly)
  - Can run in neutrino or antineutrino mode by choosing positive or negative mesons with a focusing horn



Wavelength shifting for light detection

Light produced at 128 nm (invisible to PMTs)



- We use a wavelength shifting material called Tetraphenyl Butadiene (TPB) to coat plates which will go in front of the PMTs
- We use a mixture of 50% TPB and 50% polystyrene (PS) for our plate coating
- We find that mixing the TPB in PS makes the plates more durable and is much more cost effective

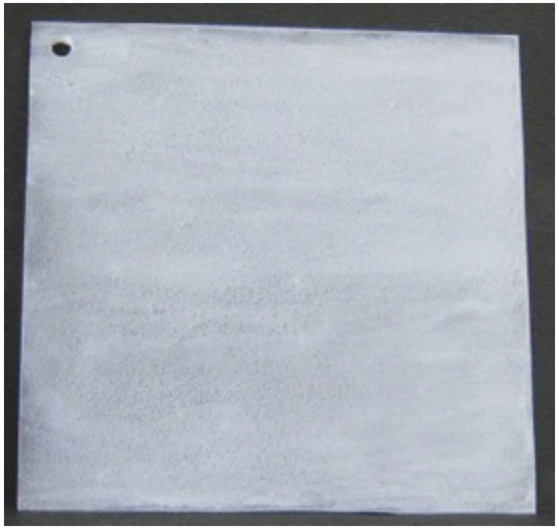
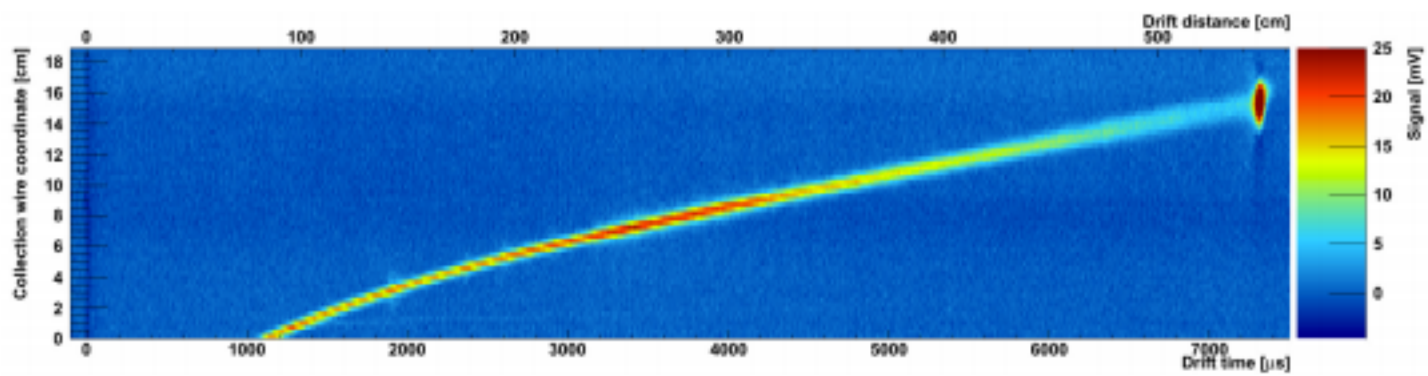


Plate sample with a 50% TPB-PS coating

UV laser calibration system

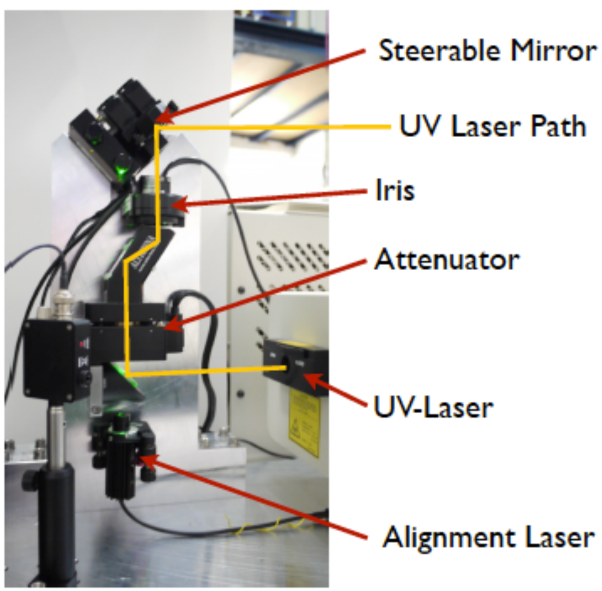
- Uses a well known ionization path to calibrate the E-field in the detector
- Path is introduced by precise steerable UV laser

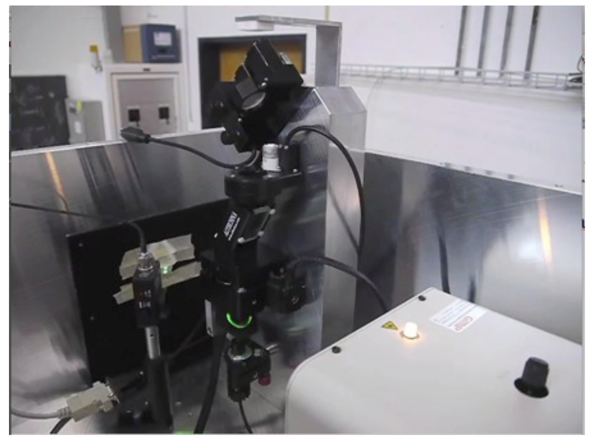


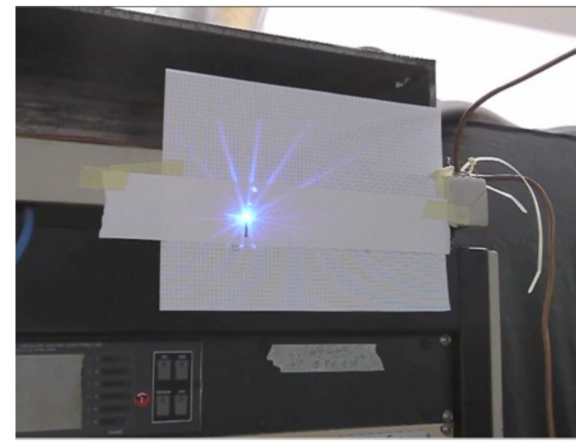
arXiv:1304.6961

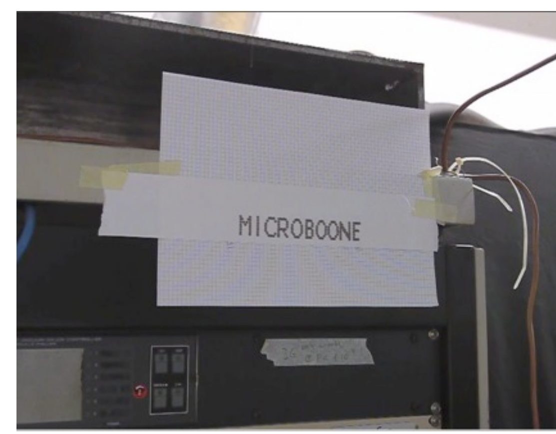
UV laser calibration system

www.youtube.com/watch?v=3HRkpn_Ogj8









More MicroBooNE Physics:

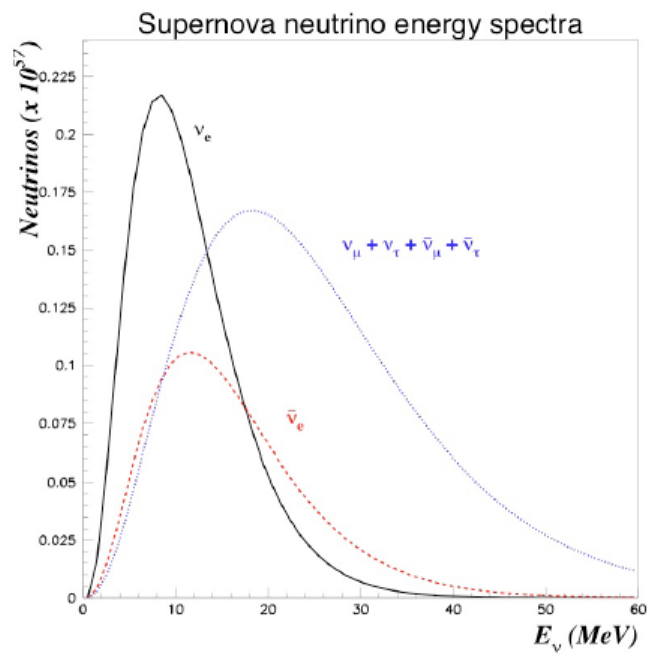
Low energy cross section measurements

Expected event rates for 6.6×10^{20} POT

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

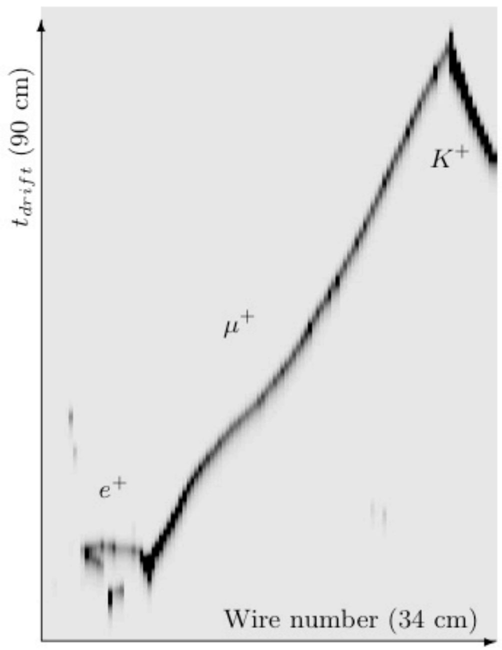
More MicroBooNE Physics

- Burst supernova detection capabilities
  - Would have gotten about 29 events for SN1987a
- Trigger from SNEWS



More MicroBooNE physics

- Prepare for future proton decay searches ($p^+ \rightarrow K^+\nu$)
  - Invisible to Cherenkov detectors
  - We're not big enough to actually search for this yet but can develop PID, triggers, and understand background



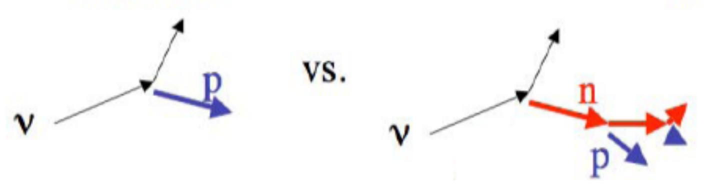
Simulated Proton decay event in LAr

More MicroBooNE Physics

- Sensitive to ΔS (fraction of proton spin carried by strange quark)

$$R_{NC/CC} = \frac{\sigma(\nu p \rightarrow \nu p)}{\sigma(\nu n \rightarrow \mu^- p)}$$

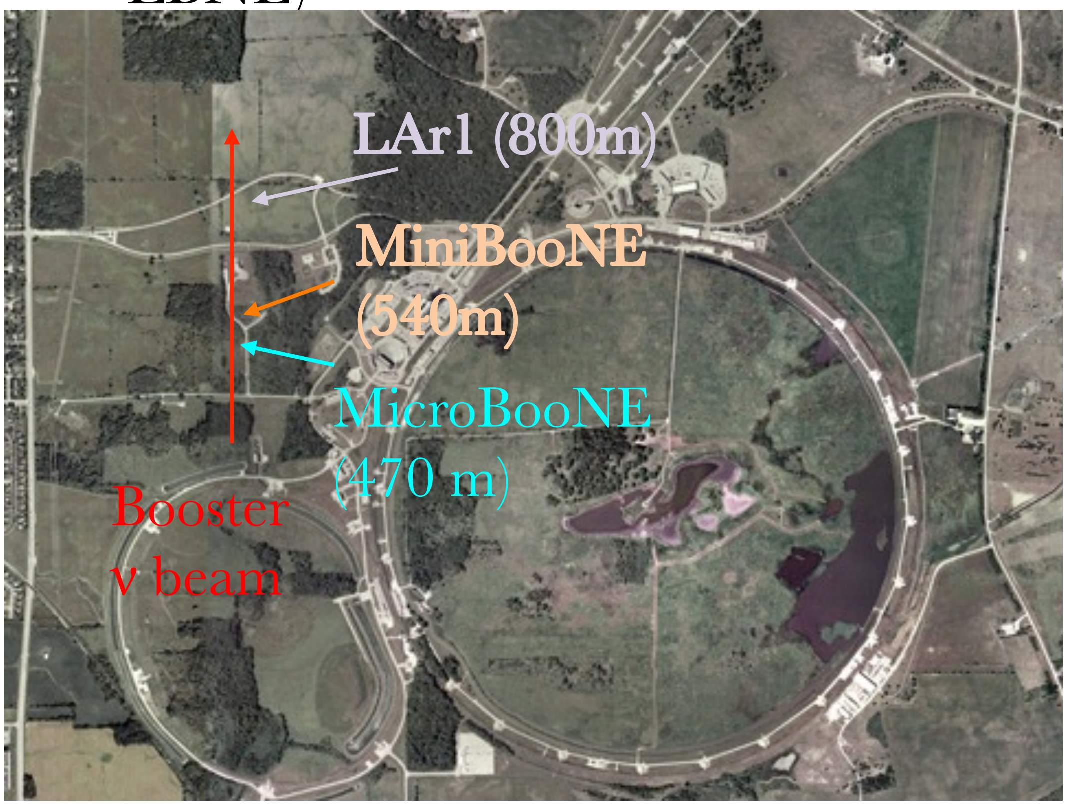
  - May help us to better understand proton spin
  - Input for spin-dependent WIMP searches
  - Information on final states for modeling events in LAr
  - This is impossible for most detectors because it is hard to tell protons from neutrons

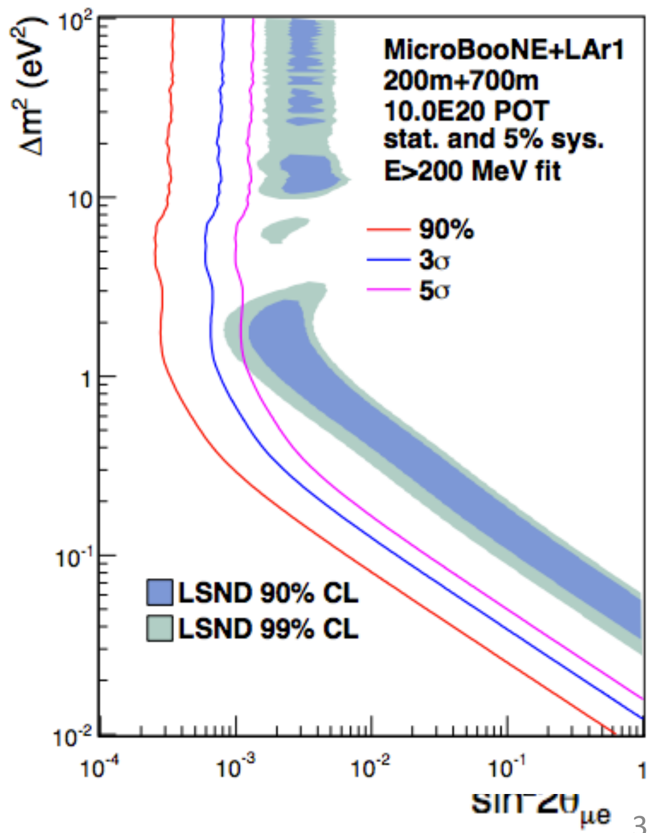


MicroBooNE may be able to. It can measure the energy of the outgoing proton and may be able to see the disconnected neutron-proton vertex

LAr1

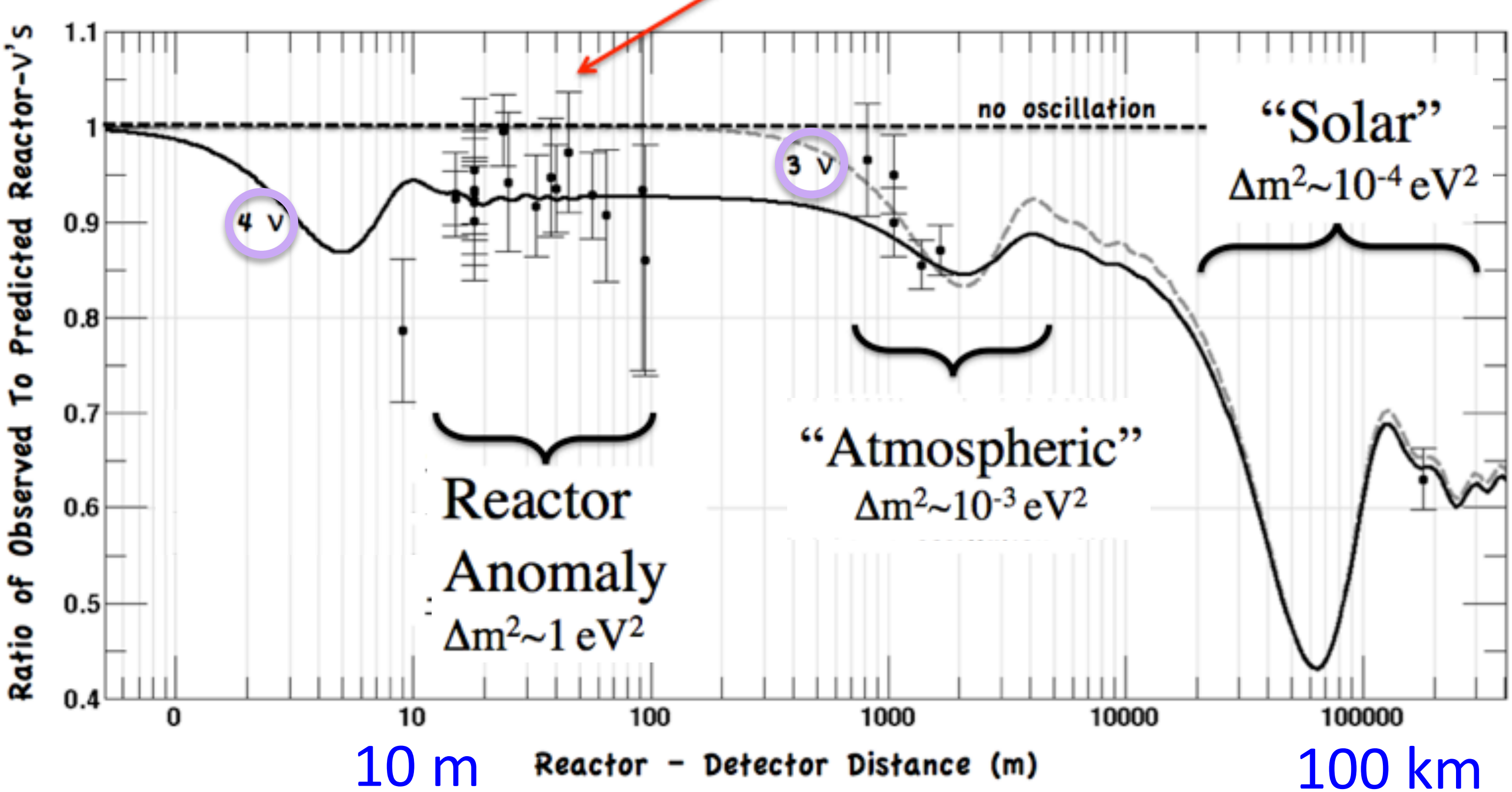
- Far detector to MicroBooNE (MicroBooNE would move forward to 200m)
- Step in the U.S. Liquid Argon TPC program (leading up to LBNE)





Reactor Anomaly

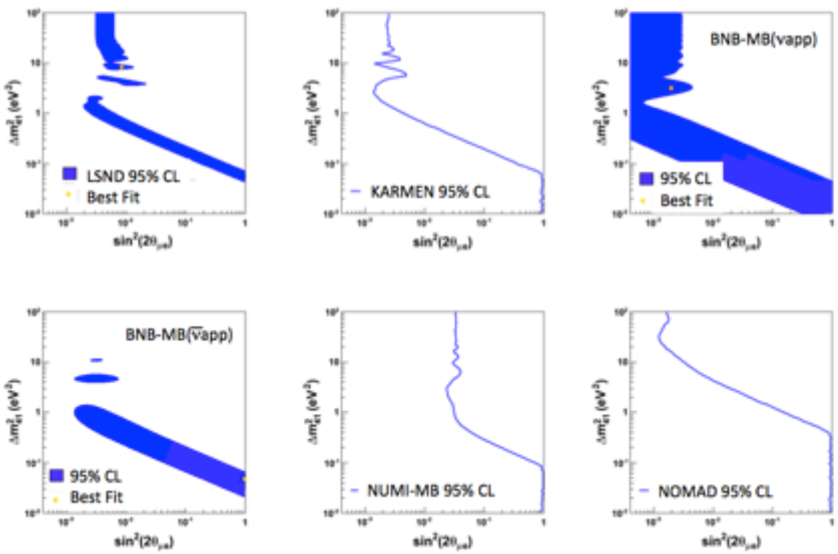
- Observed/predicted averaged event ratio: R=0.927±0.023 (3.0 σ)



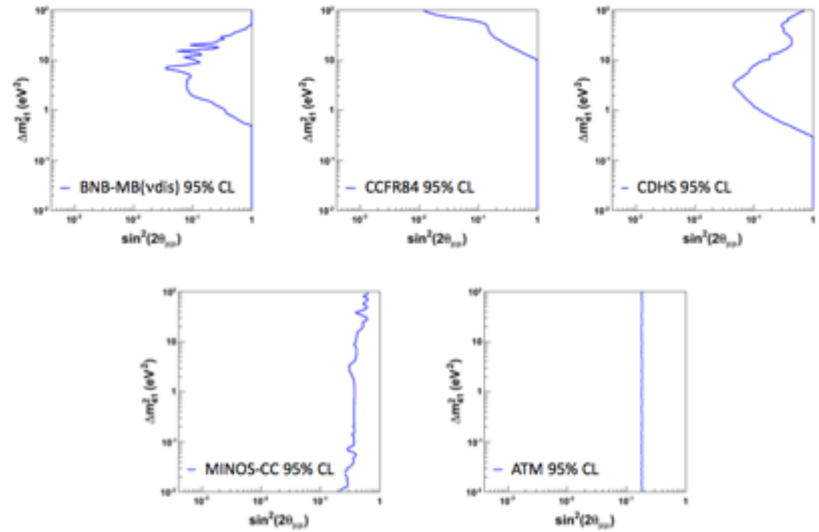
The addition of one or more sterile neutrinos could resolve this issue

Global Fits to 3+N sterile neutrino models

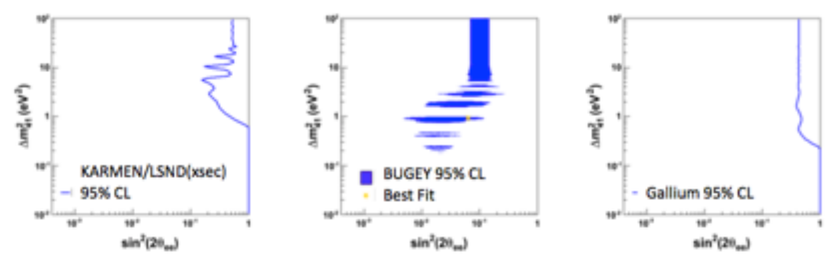
ν_e and $\bar{\nu}_e$ Appearance:



ν_μ and $\bar{\nu}_\mu$ Disappearance:



ν_e and $\bar{\nu}_e$ Disappearance:



Global Fits

	χ^2_{min} (dof)	P_{best}
3+1		
All	233.9 (237)	55%
App	87.8 (87)	46%
Dis	128.2 (147)	87%
ν	123.5 (120)	39%
$\overline{\nu}$	94.8 (114)	90%
3+2		
All	221.5 (233)	69%
App	75.0 (85)	77%
Dis	122.6 (144)	90%
ν	116.8 (116)	77%
$\overline{\nu}$	90.8 (110)	90%
3+3		
All	218.2 (228)	67%
App	70.8 (81)	78%
Dis	120.3 (141)	90%
ν	116.7 (111)	34%
$\overline{\nu}$	90.6 (105)	84%

	χ^2_{PG} (dof)	PG (%)
App vs. Dis	17.8 (2)	0.013%
ν vs. $\overline{\nu}$	15.6 (3)	0.14%
App vs. Dis	23.9 (4)	0.0082%
ν vs. $\overline{\nu}$	13.9 (7)	5.3%
App vs. Dis	27.1 (6)	0.014%
ν vs. $\overline{\nu}$	10.9 (12)	53%

Sterile neutrino Global best fit parameters (solid lines) don't favor MB excess either! (arxiv:1207.4765)