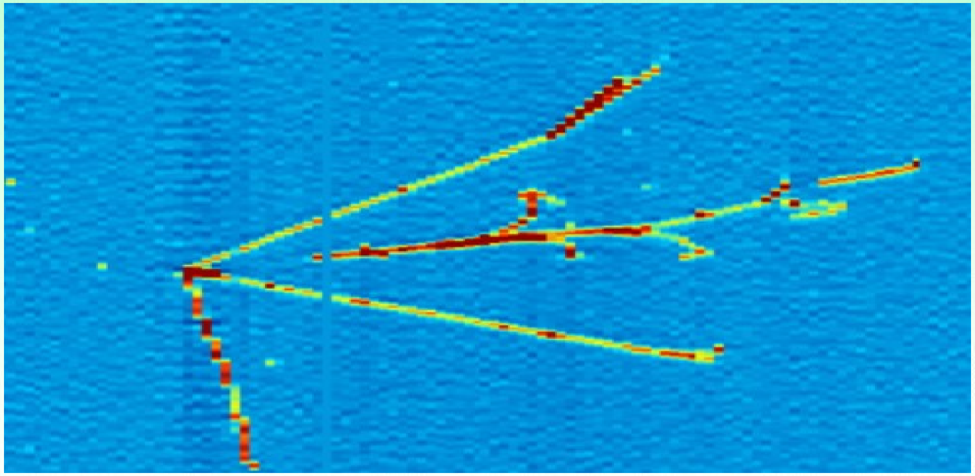
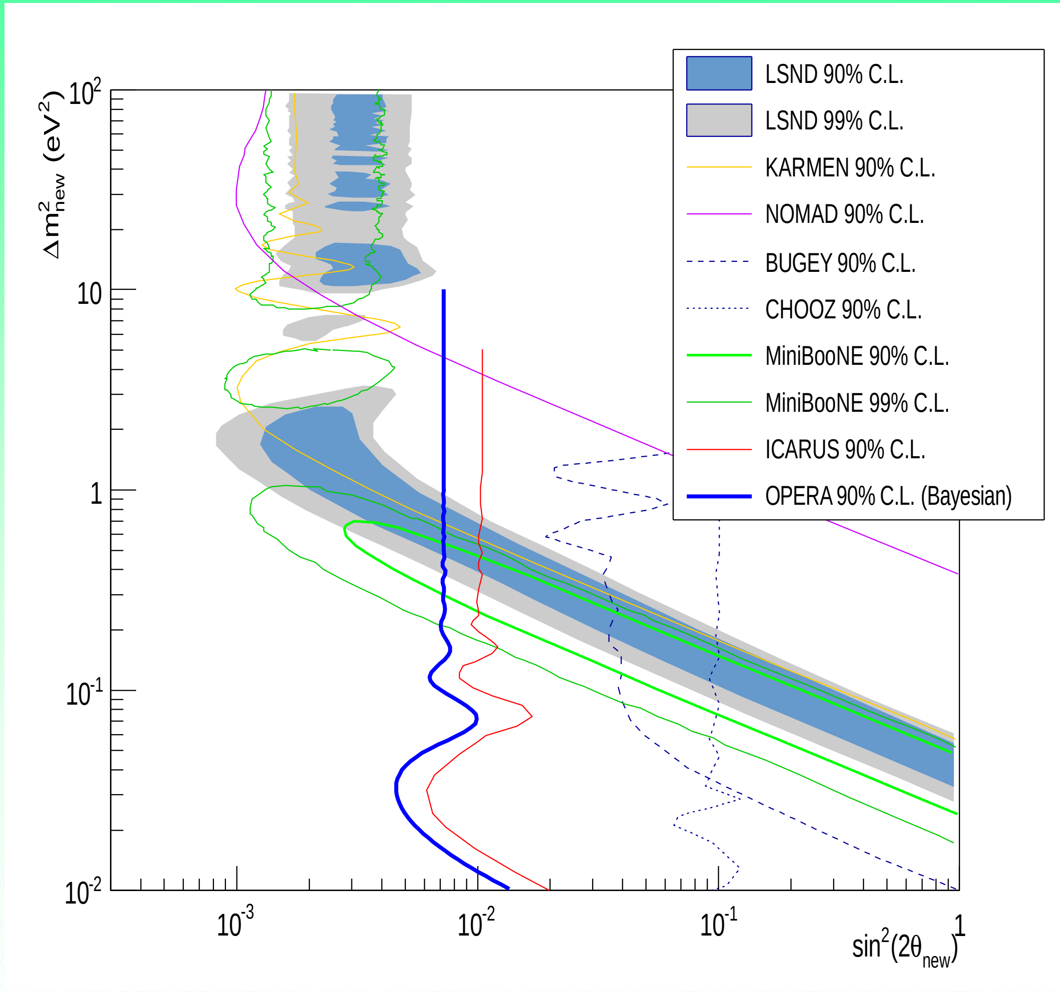
MicroBooNE : testing neutrino anomalies

Igor Kreslo
on behalf of MicroBooNE collaboration
and AEC, LHEP, Uni-Bern



Liquid Scintillator Neutrino Detector (LSND) anomaly and MiniBooNE observation



Los Alamos 1997:
LSND observed excess of $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ with significance of 3.8 σ

- Can be interpreted as neutrino oscillations, but with large Δm^2
"Sterile" neutrinos ??

Fermilab 2009: MiniBooNE (Mini-Booster Neutrino Experiment)

- Excess of $\nu_\mu \rightarrow \nu_e$ and $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$

Not compatible with 3 mass model.
Heavy "sterile" neutrino?

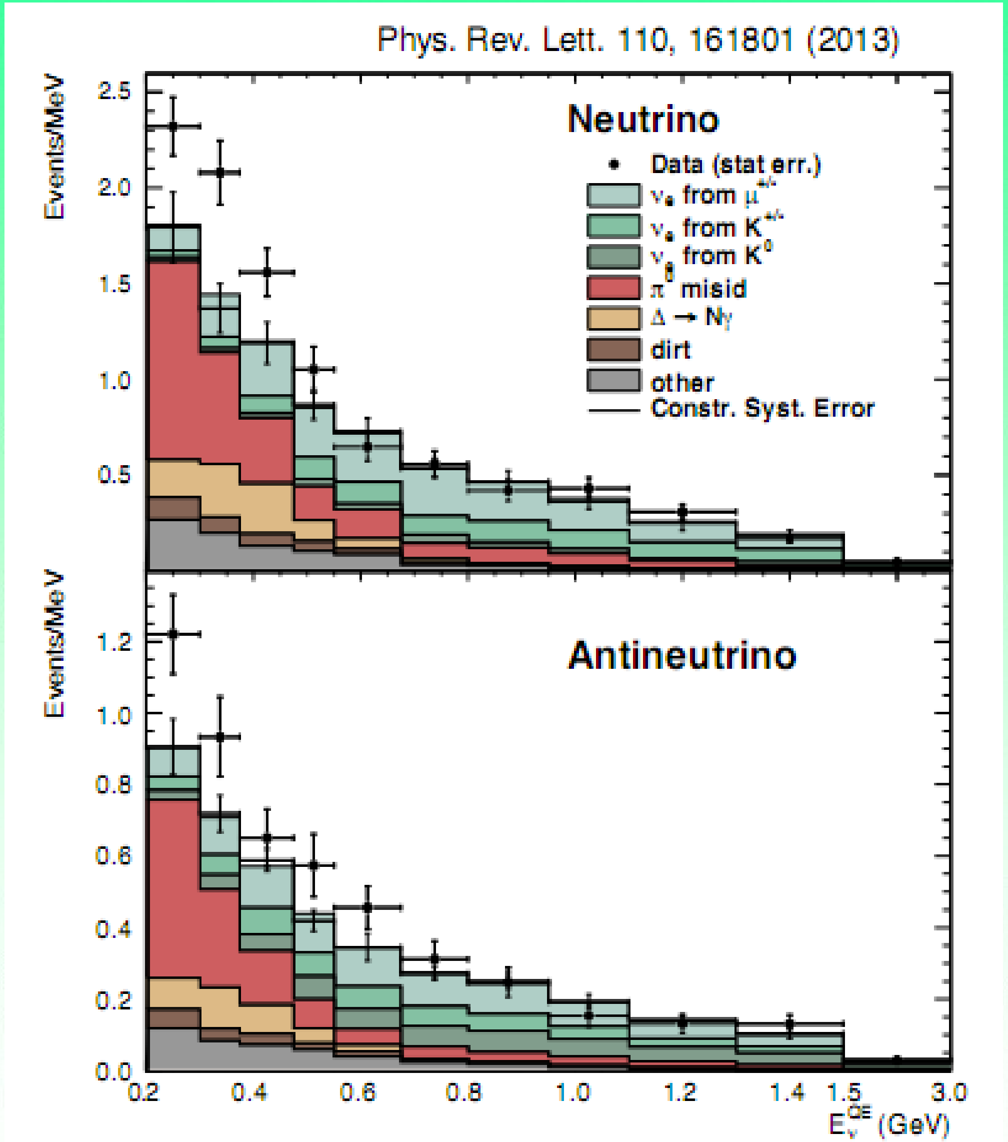
What MiniBooNE actually saw?

Excess of electromagnetic activity in the low energy region

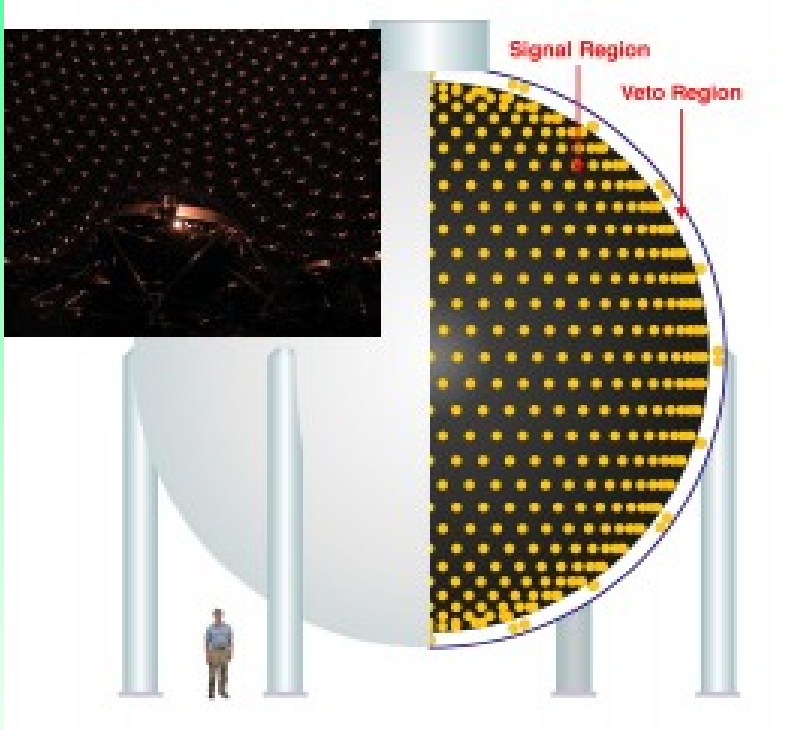
Strongest BG constituents:
$\pi^0 \rightarrow \gamma\gamma$
$\Delta \rightarrow N\gamma$

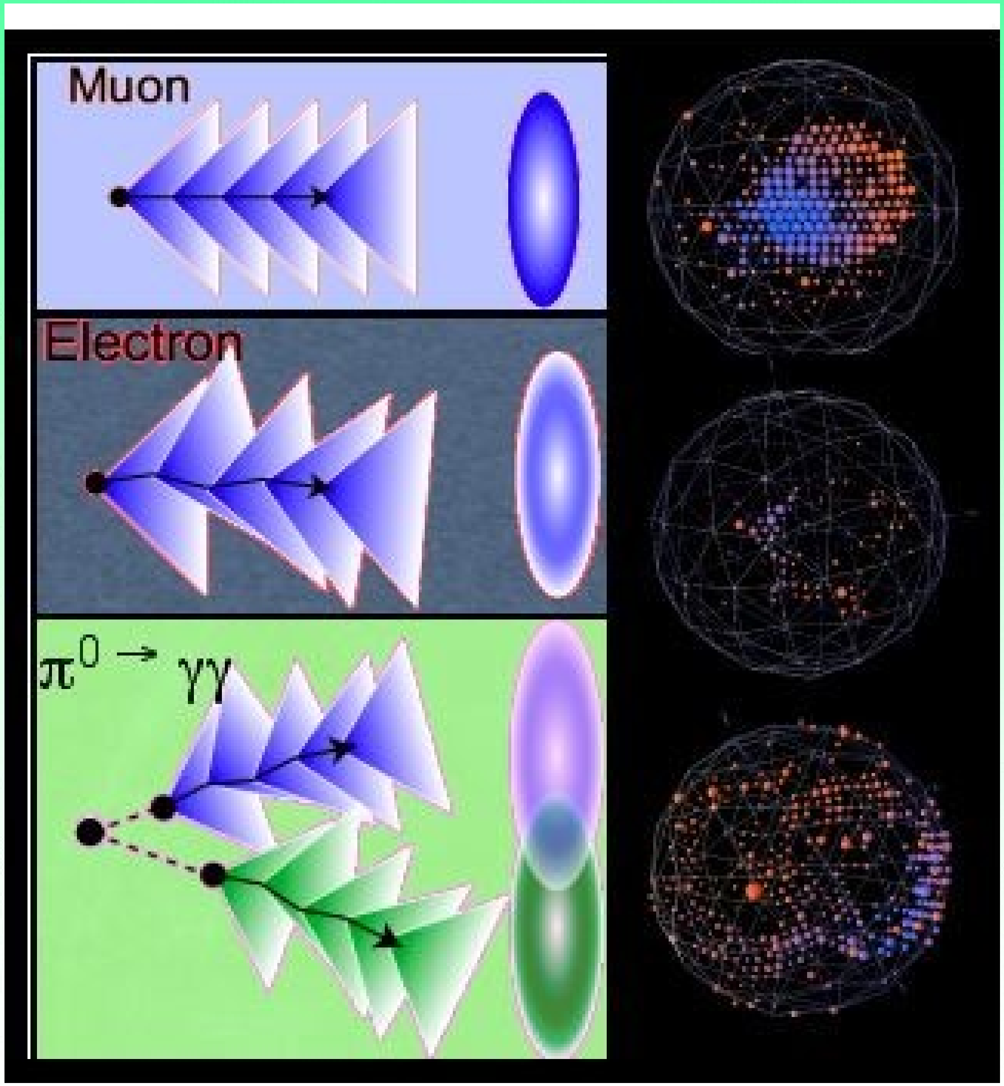
What is the excess due to?
Is it photons or electrons?

Hard to distinguish with Cerenkov detector...



Events in MiniBooNE

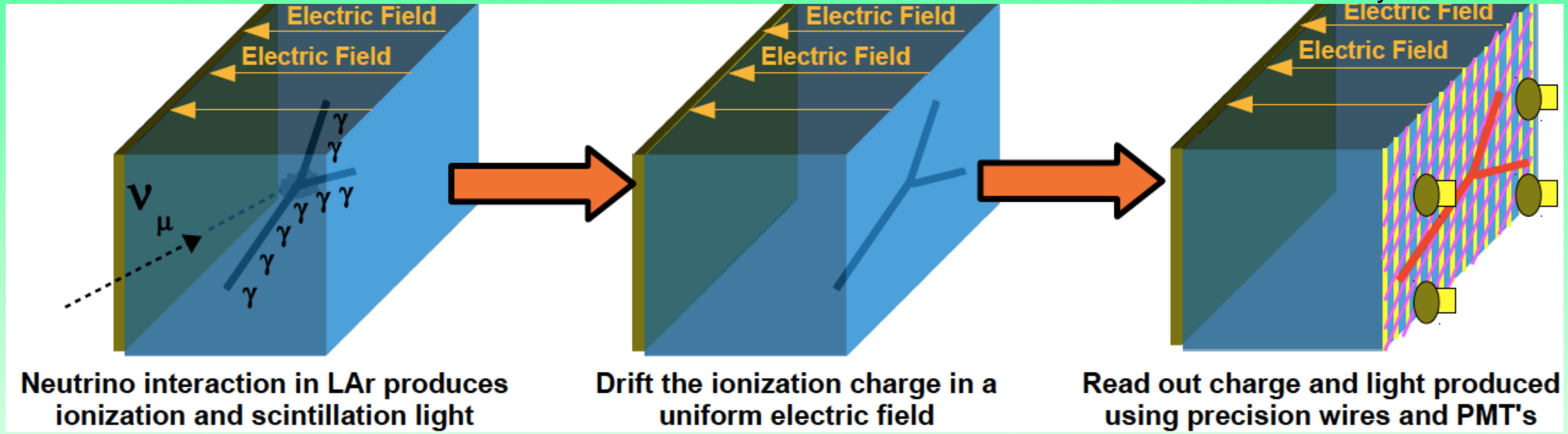




Need for high-granularity &
High-resolution tracking
detector !

Time projection chamber with liquified Argon

By J. Assadi

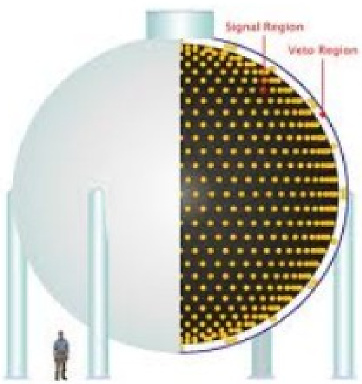


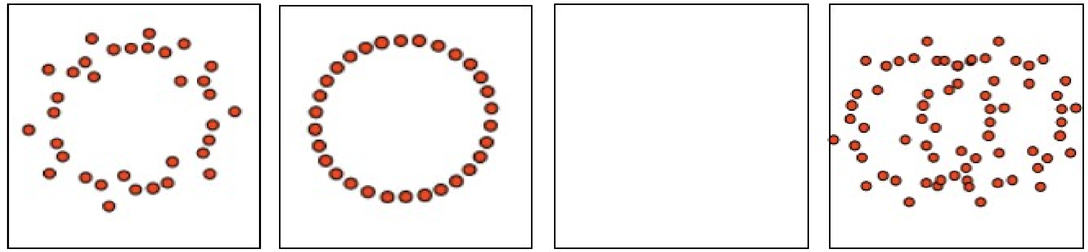
Liquid argon:

→ dense (1.4 g/cm3)
→ abundant (1% of the atmosphere)
→ ionization yield of 55,000 e/cm for a MIP
→ high electron mobility (545 (cm/s)/(V/cm) at 87 K)
→ scintillates and is transparent to the light produced
→ liquid at 87K

LAr TPC vs Cerenkov

MiniBooNE

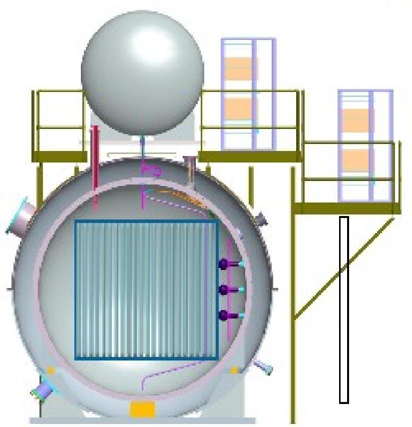


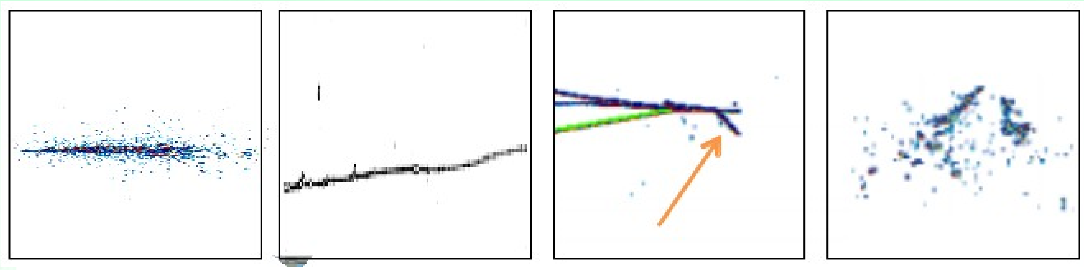


Electron (photon) | Muon | Proton | $\pi^0 \rightarrow \gamma\gamma$

Cerenkov detector

MicroBooNE





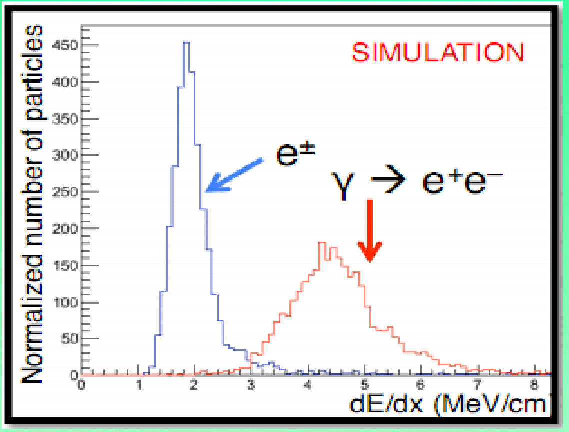
Electron (photon) | Muon | Proton | $\pi^0 \rightarrow \gamma\gamma$

TPC with liquid Argon

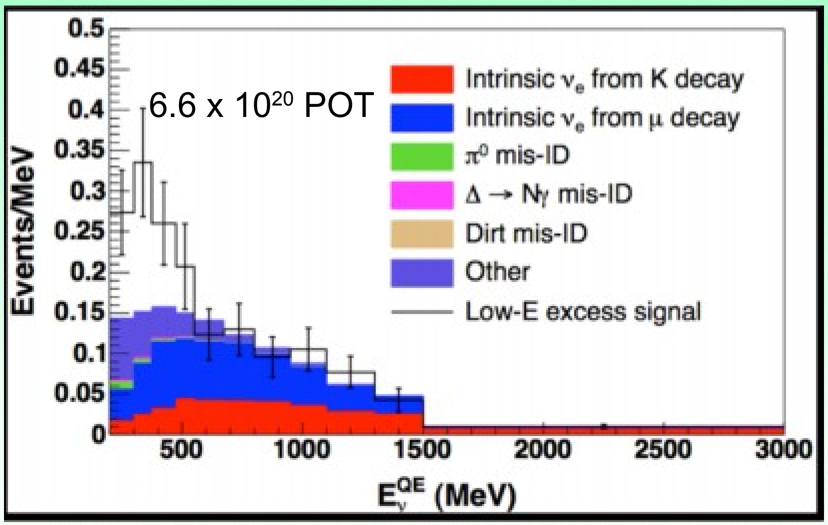
What MicroBooNE will see?

dE/dx at the first 3 cm of the shower separates electrons from photons

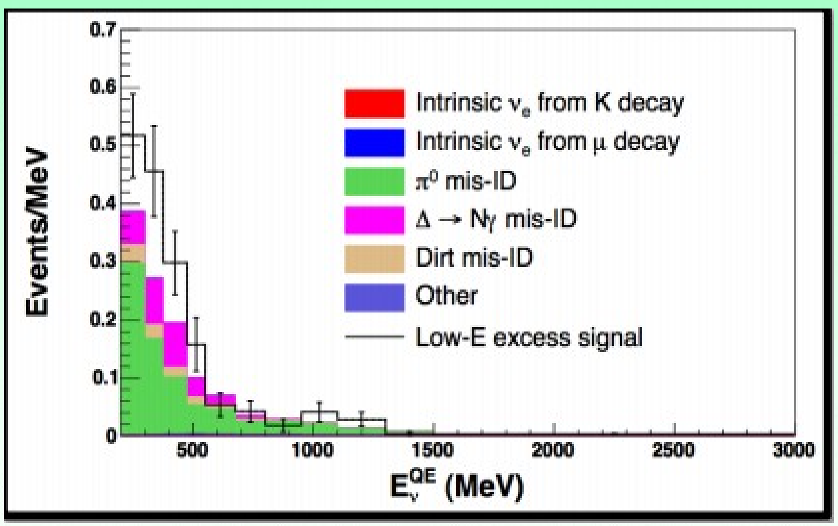
High coordinate resolution helps to distinguish particles from primary/secondary interactions



Electron-selection cut :



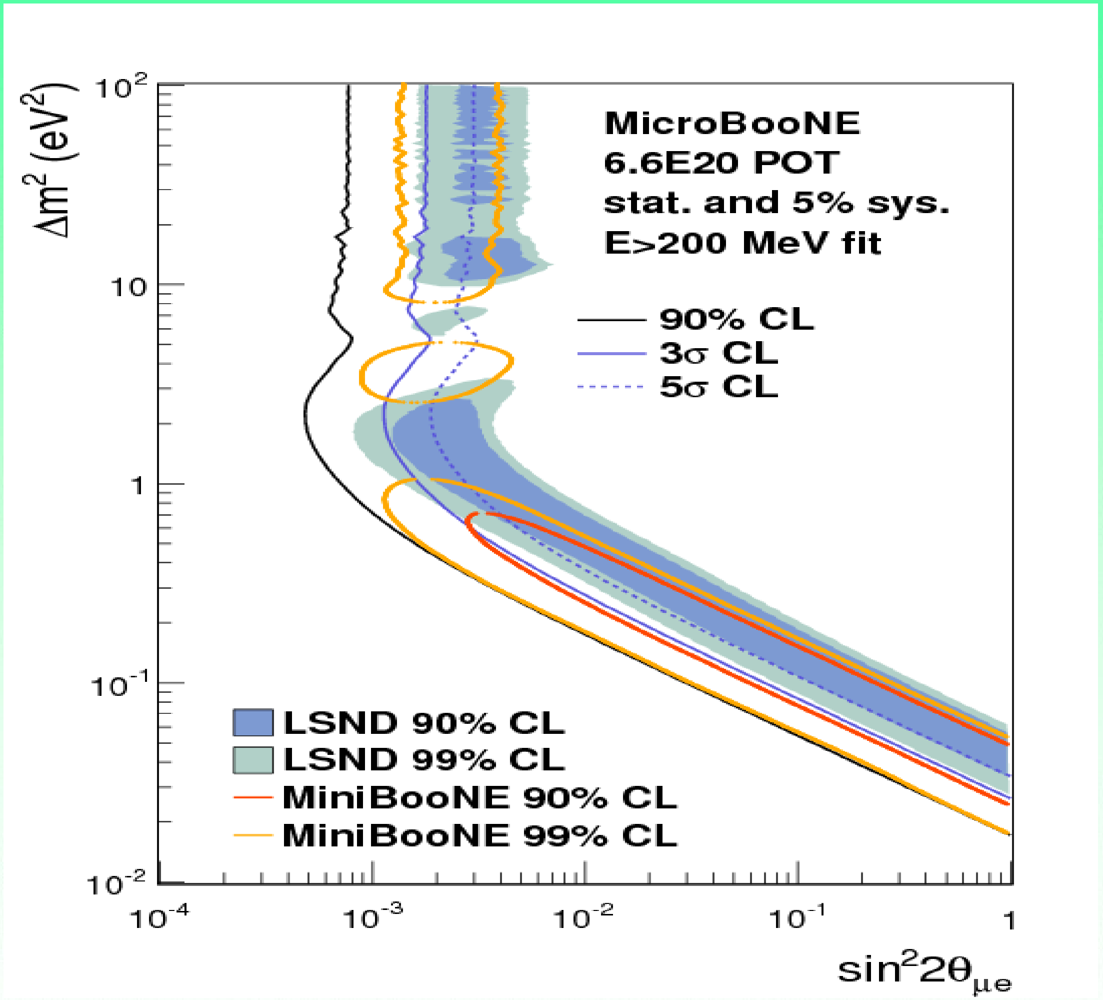
Photon-selection cut :



$$\nu_\mu \longrightarrow \nu_s \longrightarrow \nu_e \quad ?$$

Wrong model for γ and/or π^0 ?
New type of neutrino interaction with photon in final state ?

MicroBooNE sensitivity to heavy 4th neutrino

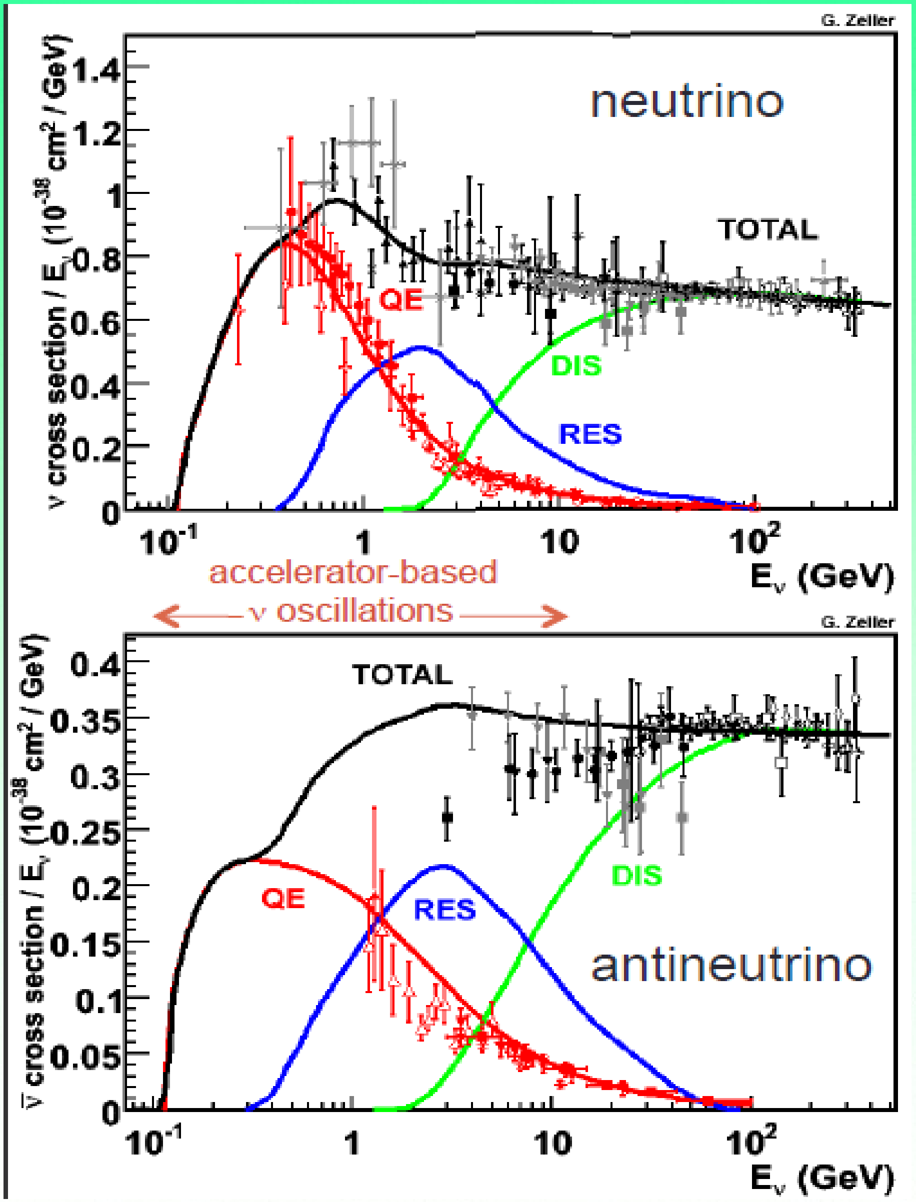


MicroBooNE and neutrino crossection

- Contribution to nuclear interaction model(s)
- Cross sections in ~1 GeV region not well known
- On Argon , not known at all!
- Measurements needed for future detectors

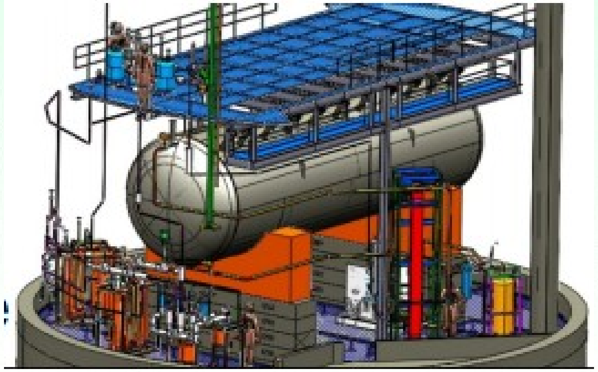
Why MicroBooNE LAR TPC?

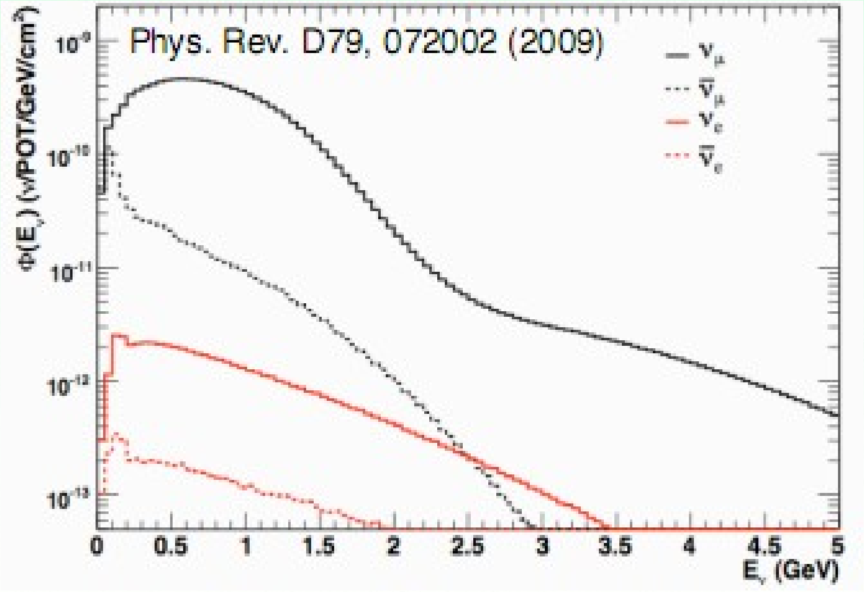
- Great coordinate and momentum resolution
- LAR TPC reconstructs proton tracks down to ~20 MeV



MicroBooNE at FNAL BNB

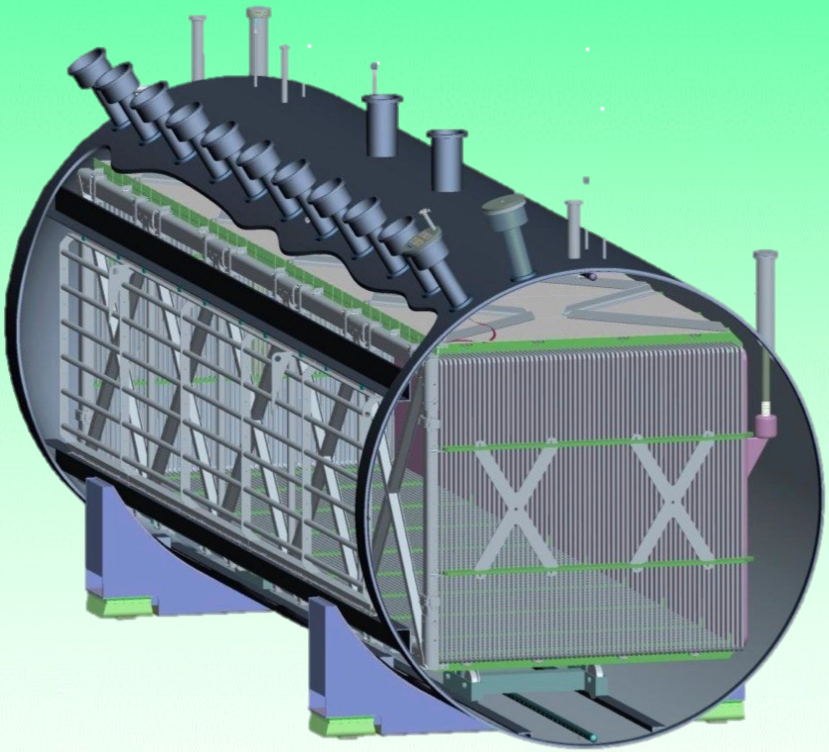
- FNAL Booster 8 GeV protons
- 174 kA horn
- 50 m long decay pipe
- Baseline 470 m



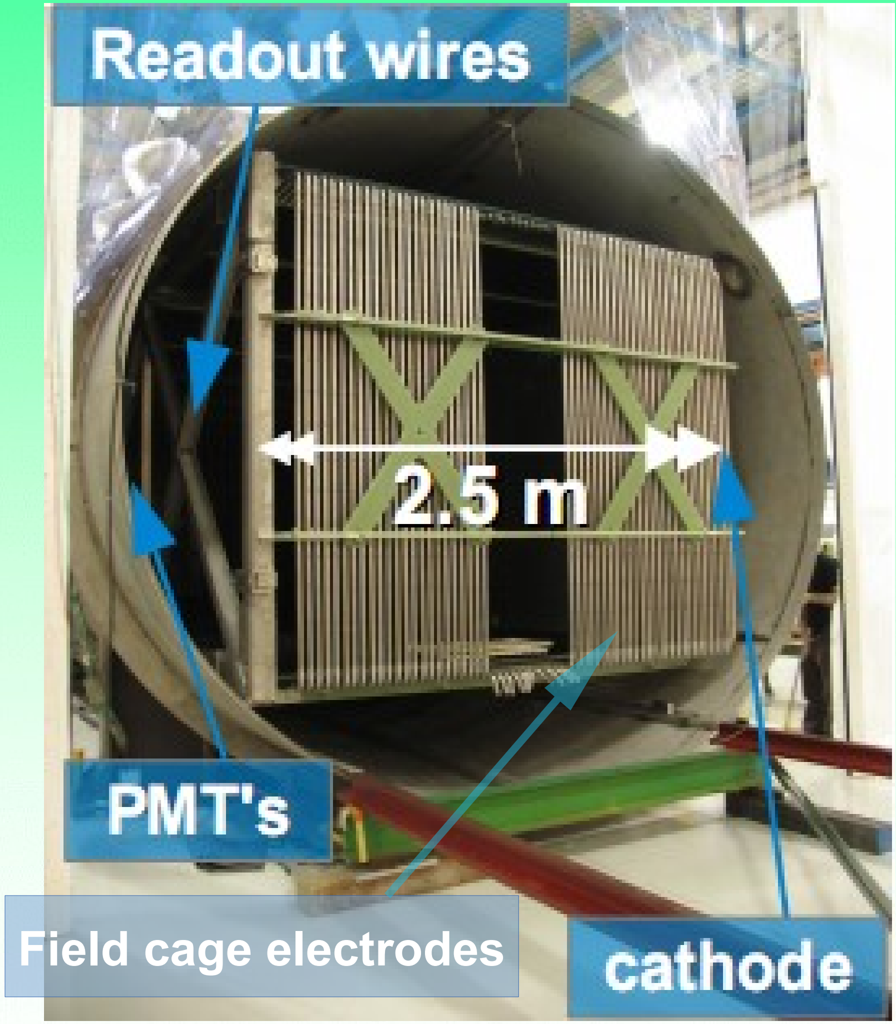


MicroBooNE at FNAL

- 170 tons LAr (~60t fiducial)
- Foam insulated cryo-volume
- 2.5 x 2.3 x 10.4 m^3 TPC
- 2.5m charge drift
- U,V,Y wire planes
- Signal pre-amplification in liquid (cold)
- PMT system (32 x 8’’)
- Laser calibration system



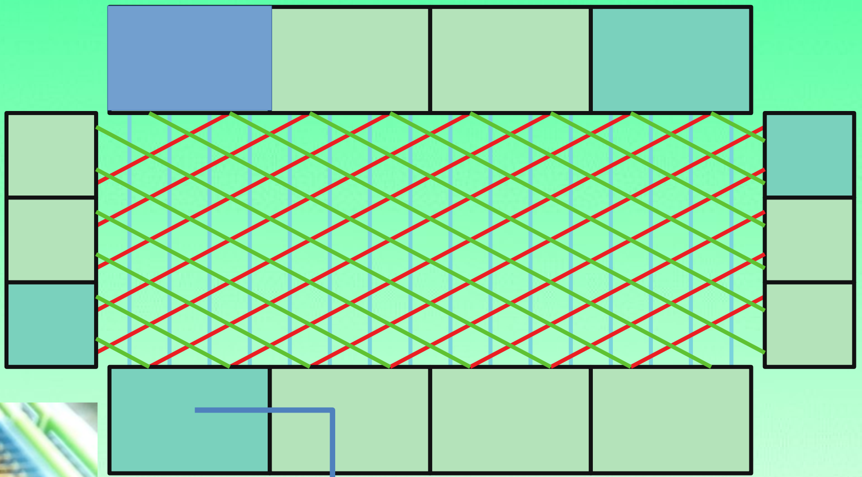
MicroBooNE at FNAL

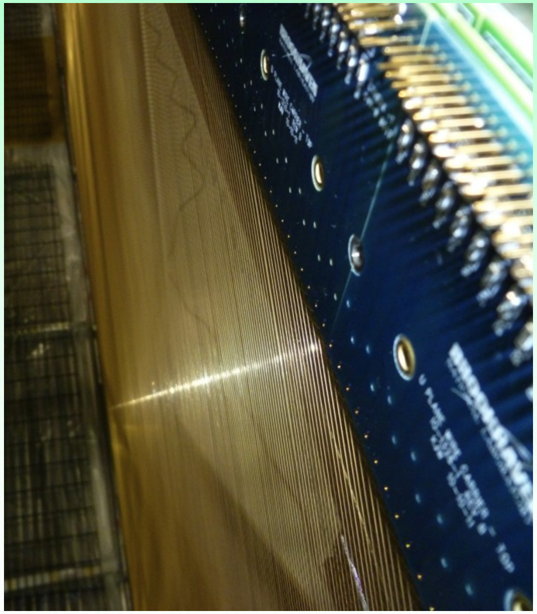


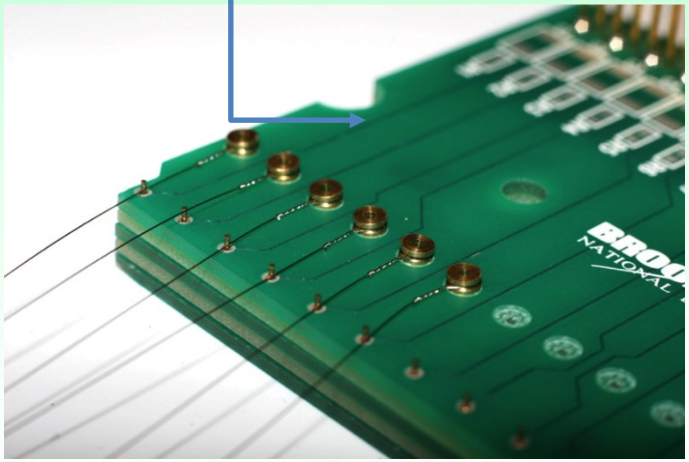
MicroBooNE at FNAL

Anode wire planes

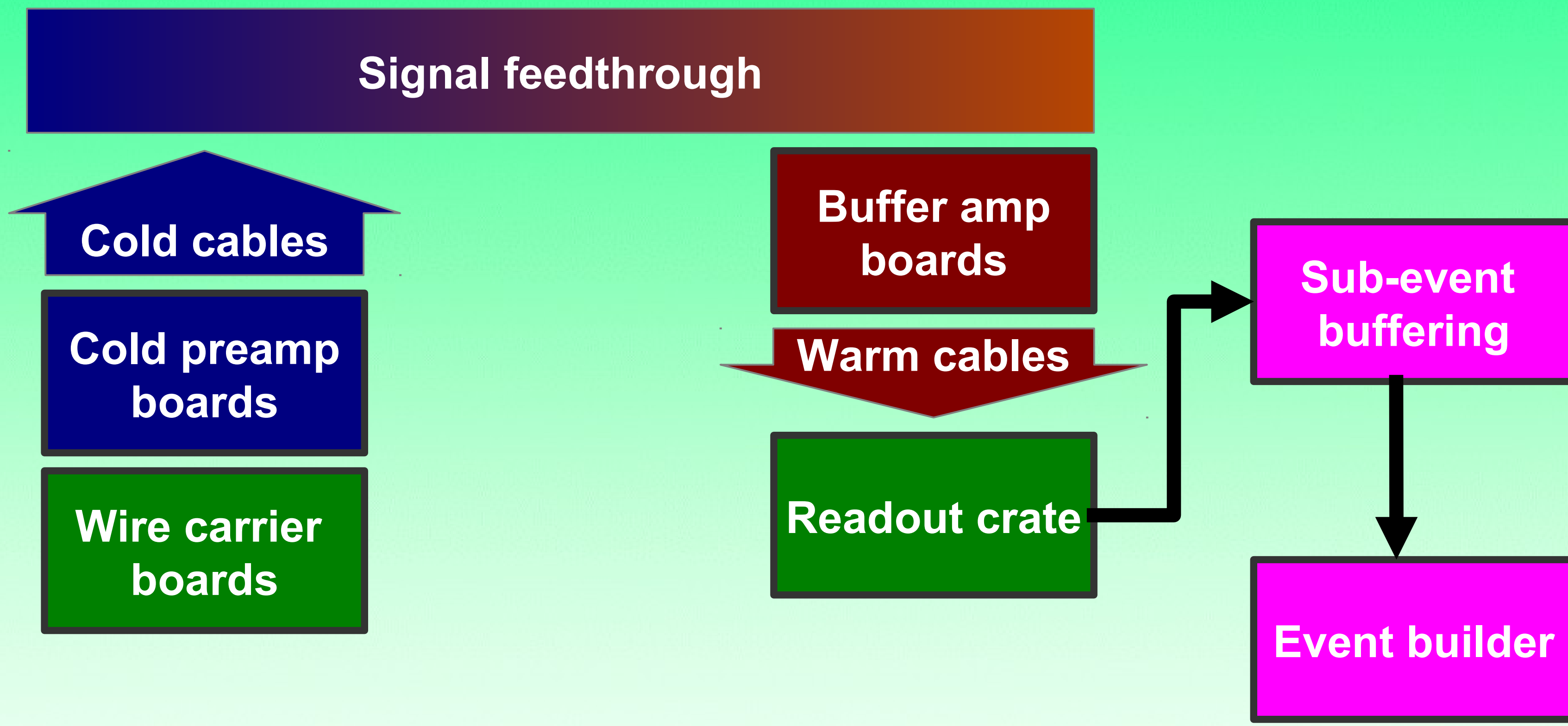
- 3 wire planes (U,V,Y)
  - Y (3456 wires): vertical, collection
  - U (2400 wires):+60°, ind.
  - V (2400 wires): -60°, ind.
- 3 mm wire pitch







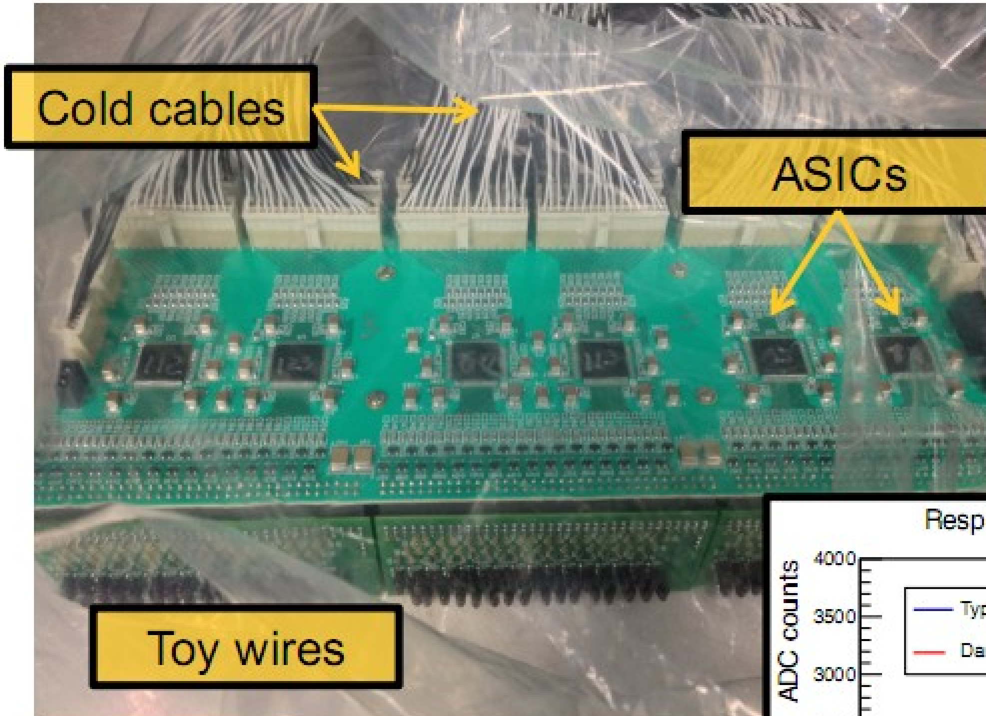
Charge Data Acquisition System

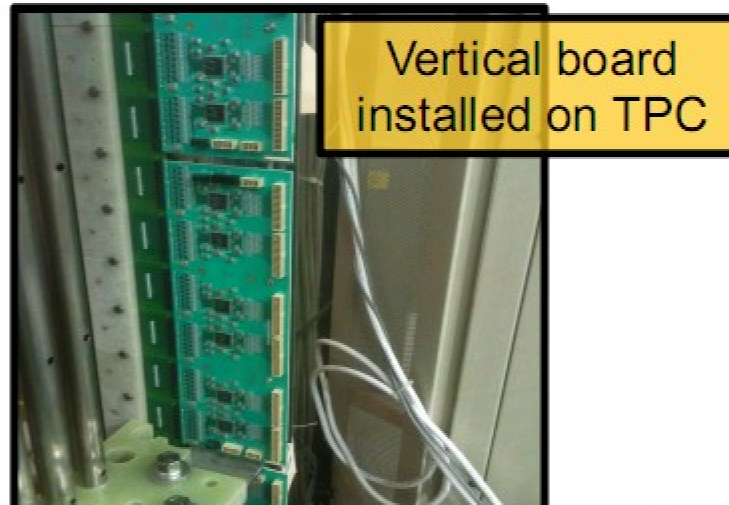


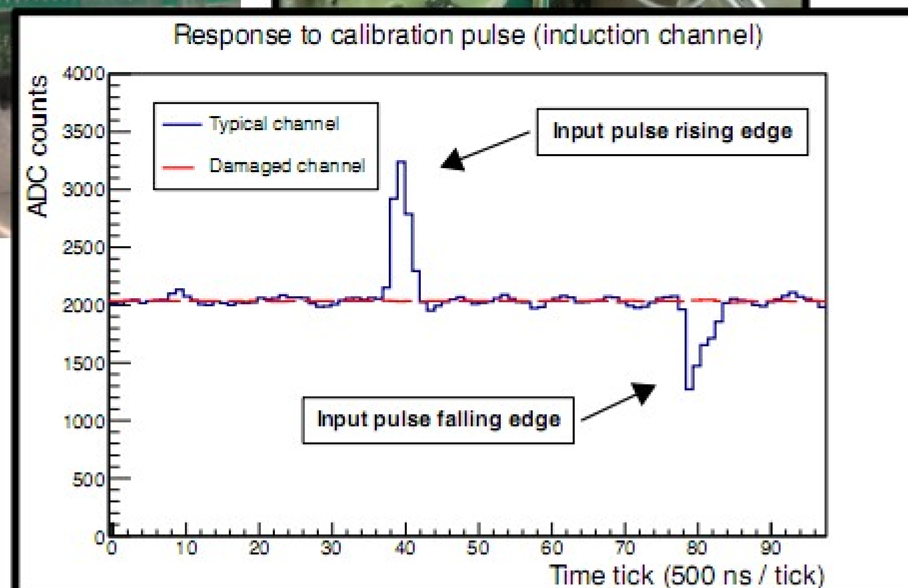
- Beam trigger
- Continuous 1h ring buffer, (Nevis)
- Calibration

Cryogenic charge amplifiers

BNL Electronics Group (Veljko Radeka et al.)





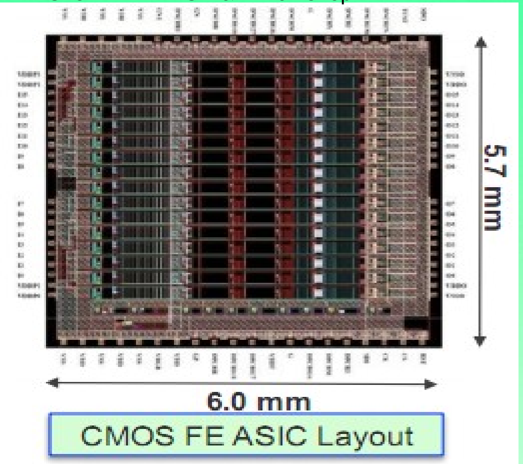


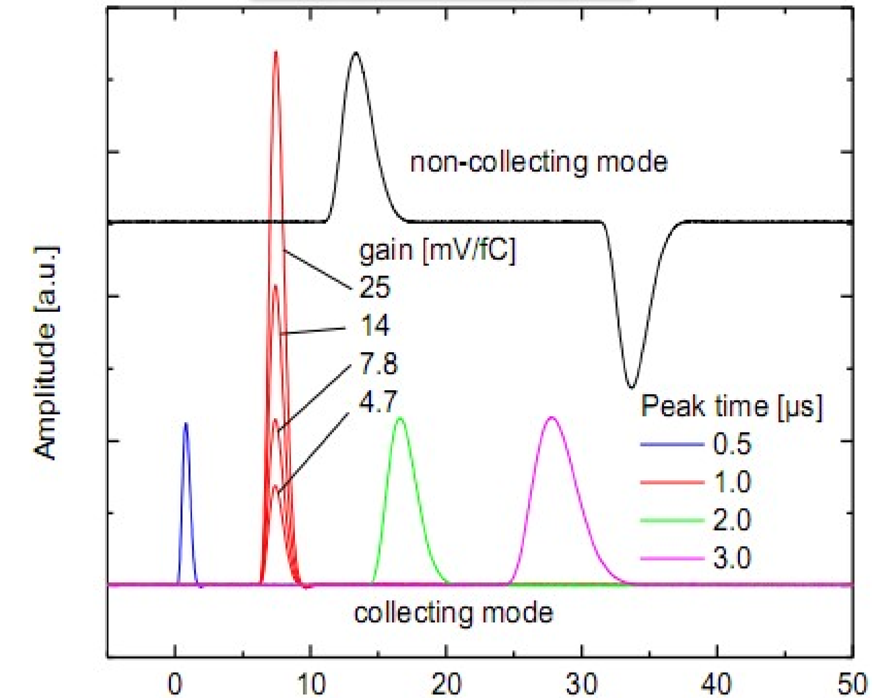
All motherboards currently mounted on TPC and successfully tested!

Cryogenic charge amplifiers

BNL Electronics Group (Veljko Radeka et al.)

H. Chen - LAr TPC R&D Workshop





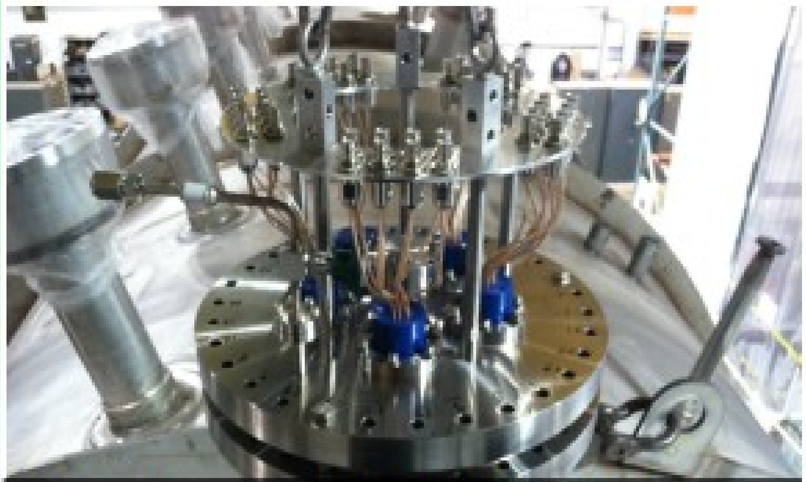
CMOS Analog Front End ASIC

- 16 channels per chip
- Charge amplifier, 5-order filter
- Adjustable gain: 4.7, 7.8, 14, 25 mV/fC
- Adjustable filter time constant (peaking time): 0.5, 1, 2, 3 μs
- ENC ~ 500e @ Cdet=150 pF
- Selectable collection/induction mode
- Selectable dc/ac (100 μs) coupling
- Rail-to-rail analog signal processing
- Band-gap referenced biasing
- Temperature sensor (~ 3mV/°C)
- 136 registers with digital interface
- **5.5 mW/channel**

Designed for long cryo-lifetime

Scintillation readout system

- 32 X 8" PMTs mounted on wire side
- WLS coated screens (128 nm to 420 nm)
- Provide t_0 for TPC events
- Help to sort out cosmic pile-up



PMT flange and cables installed on the MicroBooNE cryostat

All 32 PMTs installed inside the cryostat (covered with dark bags for protection)

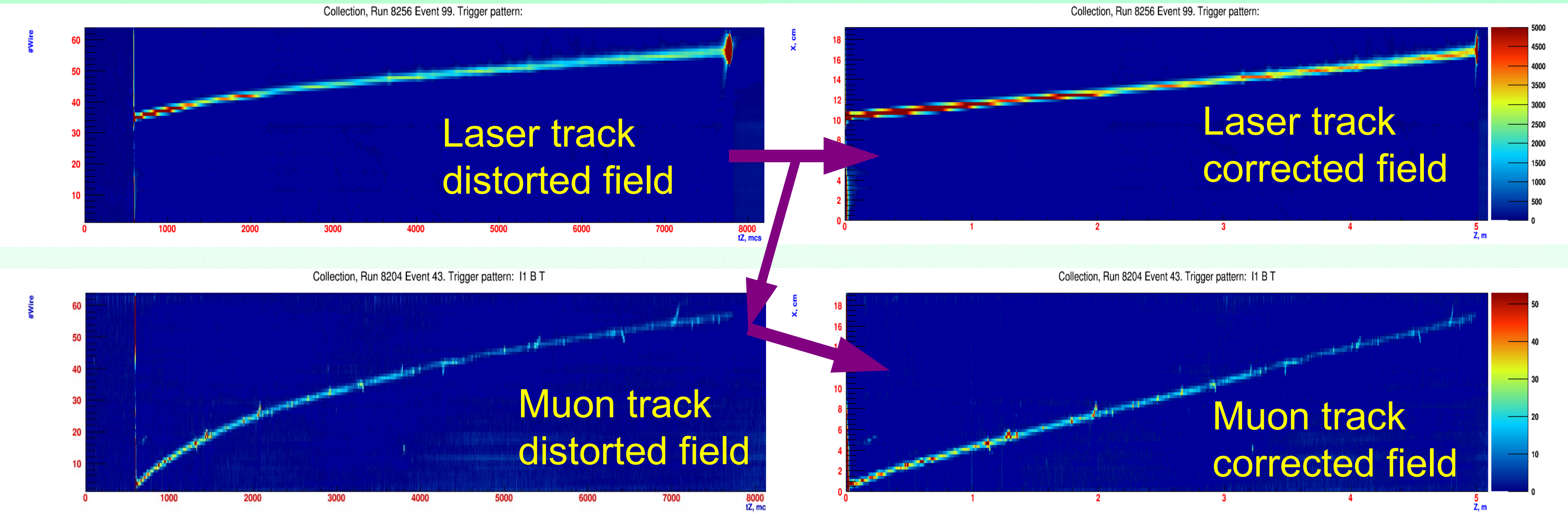
Laser system for drift field calibration

Ion space charge from cosmic muon flux → drift field is not uniform

Cosmic muons are here for free, but...

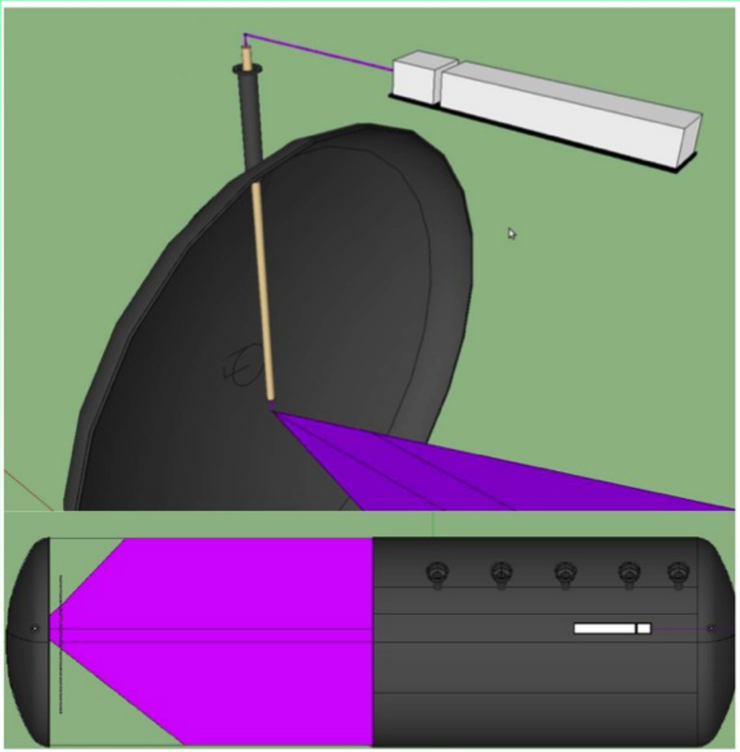
- Delta-electrons
- Coulomb multiple scattering
- Charge recombination
- Low statistics

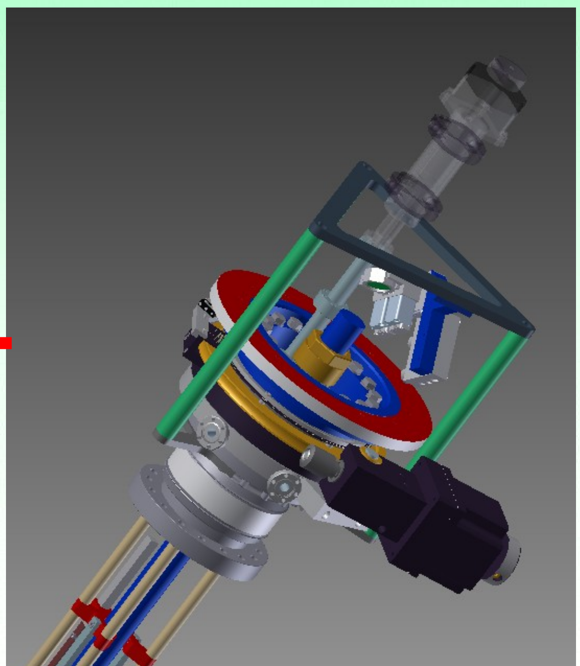
Solution: Laser-produced ionization track !



Laser system for drift field calibration

- 266 nm laser beam
- Ionization by three-photon absorption
- Steered mirror to cover TPC volume





Beam positioning accuracy:
1 mm at 10 m

MicroBooNE at FNAL

- Construction is on schedule
- Field cage is mounted
- Scintillation R/O is complete
- Wire planes are in place
- DAQ is in testing phase
- Beginning of taking data in 2014 !

Meanwile: extensive tests ...

- USA (FNAL, Nevis, BNL, and many others)
- Europe (ARGONTUBE detector in Bern)

ARGONTUBE at LHEP, Bern

Chamber characteristics

- Drift distance: 5 m
- Readout surface: 20 × 20 cm^2
- Active volume: 200 l
- Active mass: 280 kg
- Inner volume: 1.1 m^3
- Outer volume 1.2 m^3
- Number of readout channels: 2 × 64

Setup features and highlights

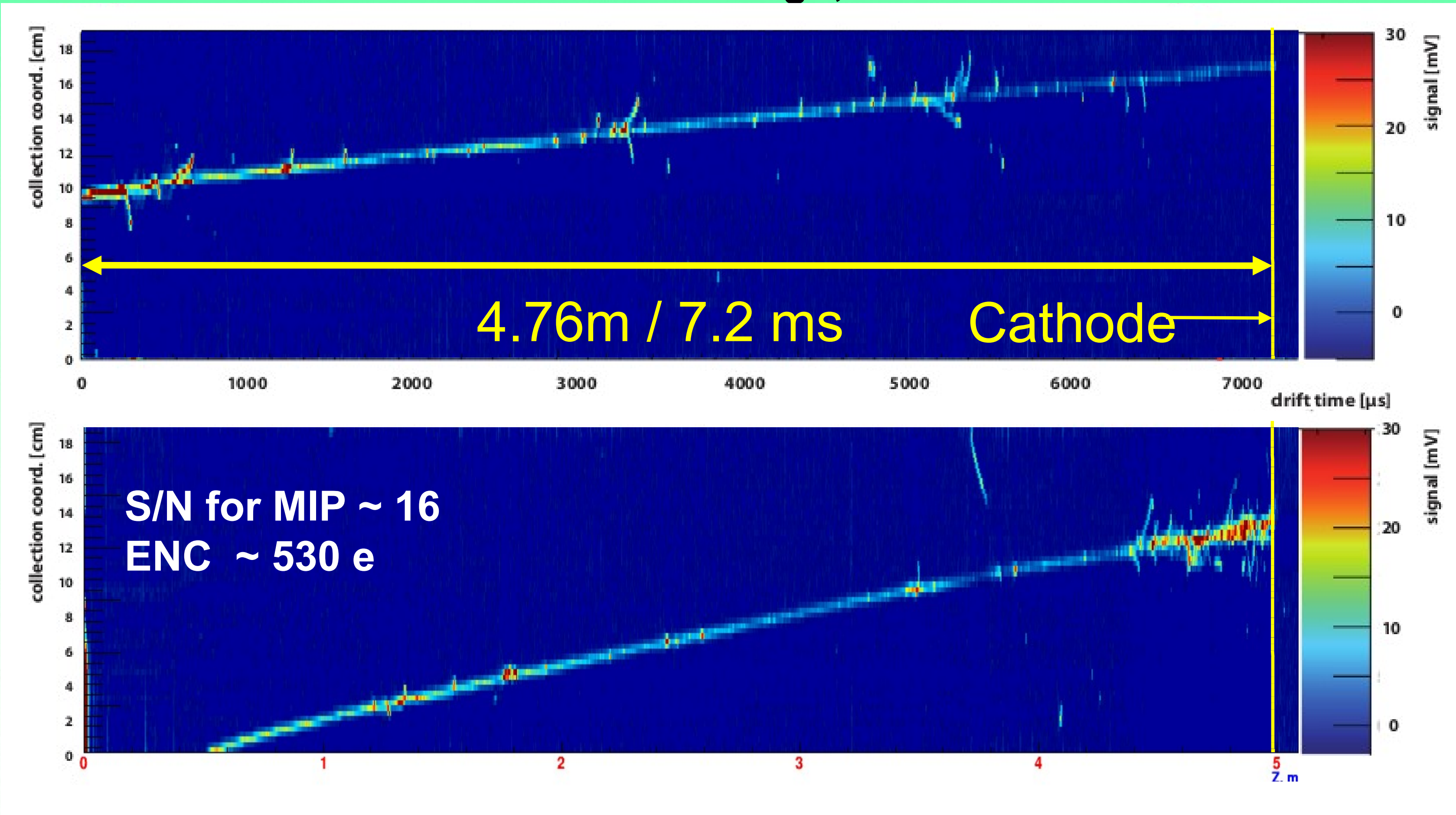
- Double bath cryostat
- Large aspect ratio of 25
- Few hundred kV required
- Greinacher circuit for HV generation
- Liquid purification system
- Two PMTs are installed above the wire planes
- External triggering system with scintillator planes is installed

	uBooNE Design values	ARGONTUBE Stable conditions
Drift distance [cm]	250	476
Cathode voltage [kV]	- 125	- 100
Drift field [V/cm]	500	~200
Maximum drift time [ms]	1.6	7.2
Electron life time [ms]	> 3	2.5 — 3.0

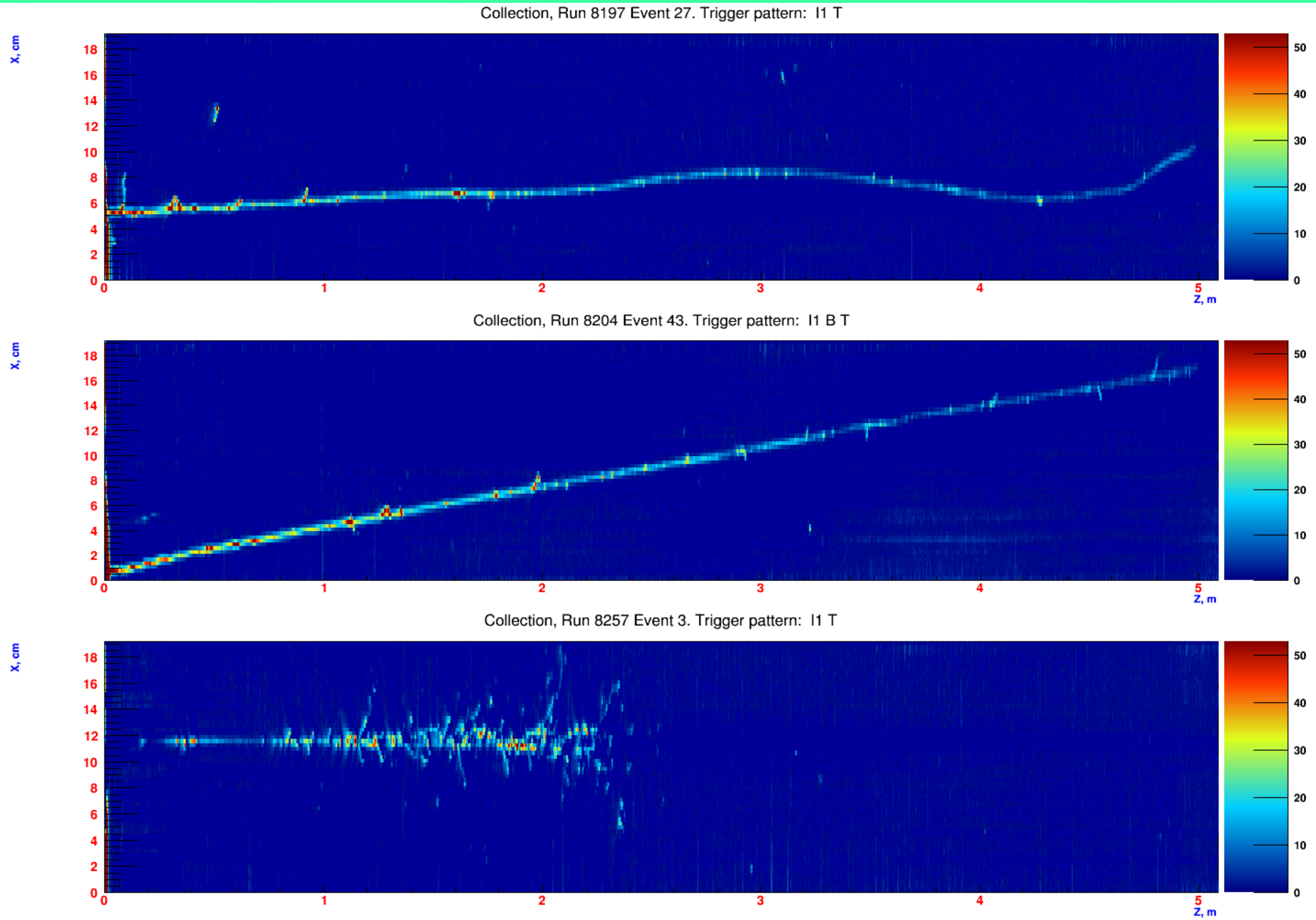
Testing MicroBooNE cold preamps with ARGONTUBE

~ 5 m long electrons drift in LAR: first time!

twice MicroBooNE drift lentgh, < ½ E-field

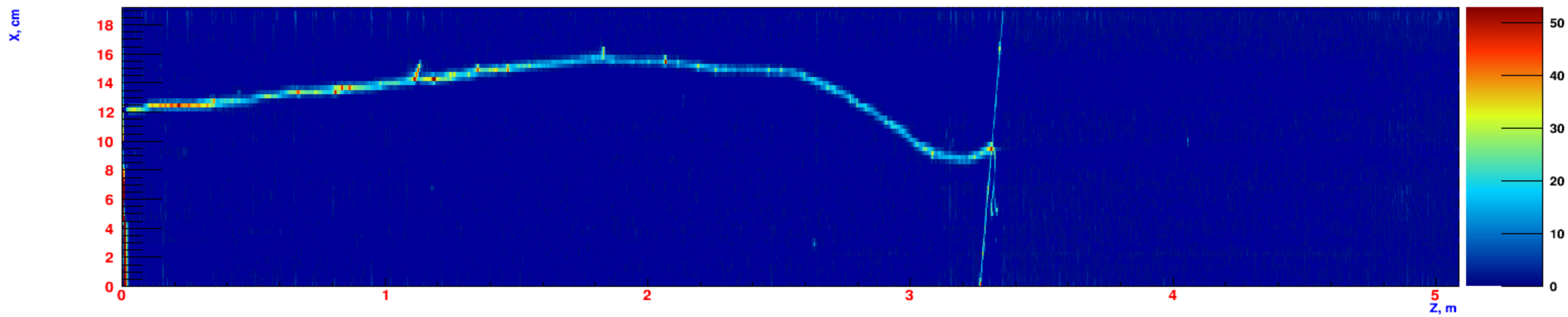


Testing MicroBooNE cold preamps with ARGONTUBE

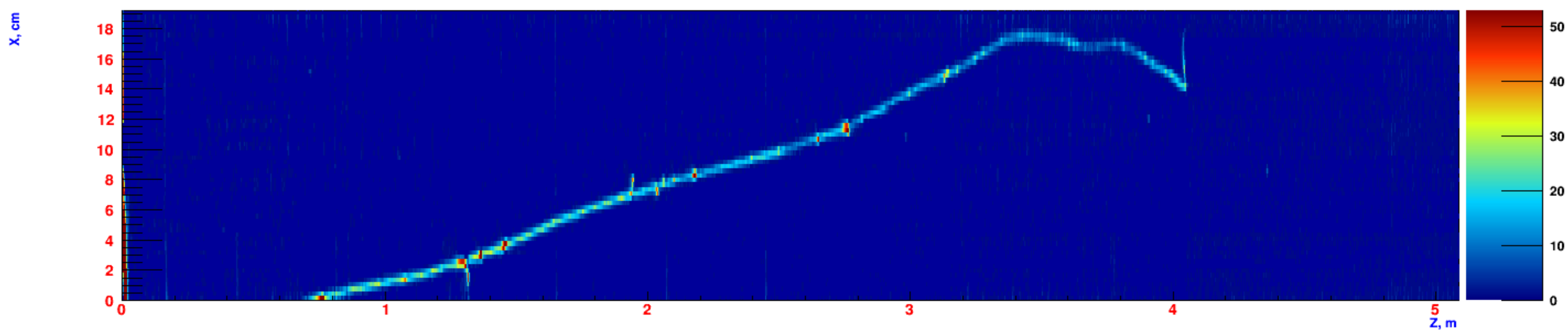


Testing MicroBooNE cold preamps with ARGONTUBE

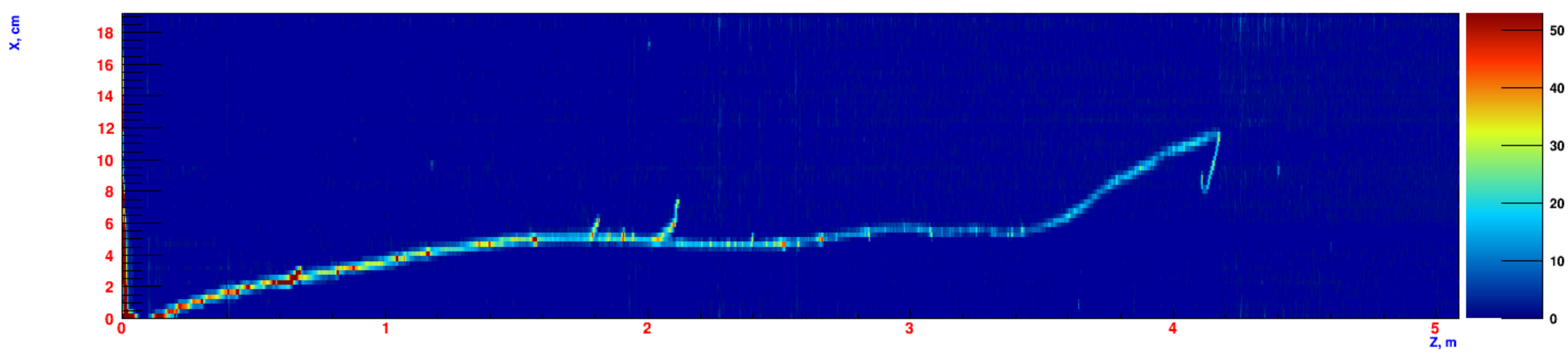
Collection, Run 8203 Event 33. Trigger pattern: I1 T



Collection, Run 8203 Event 135. Trigger pattern: I1 I2 T

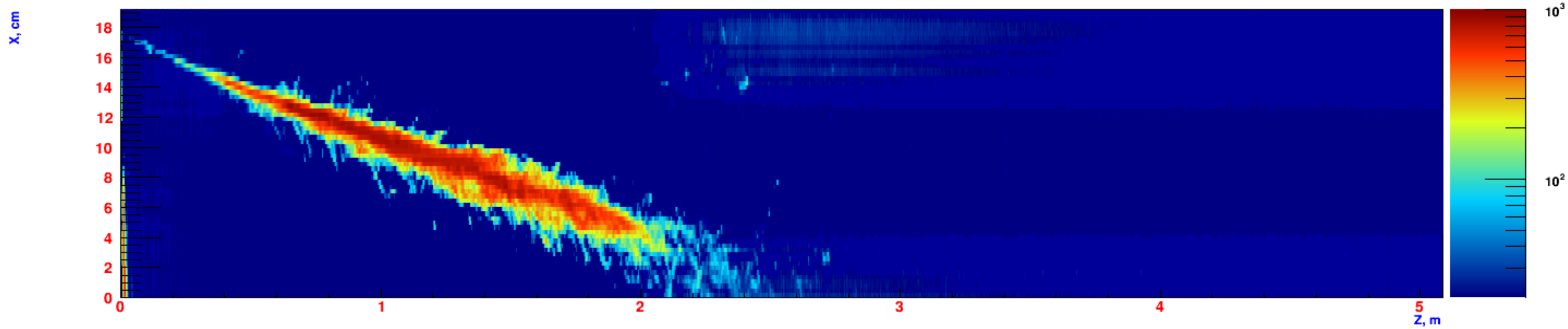


Collection, Run 8200 Event 142. Trigger pattern: I1 I2 T

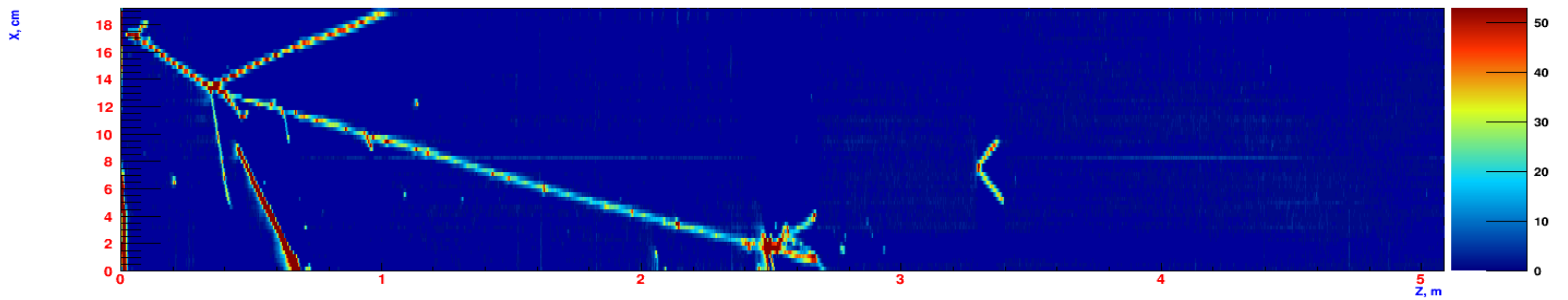


Testing MicroBooNE cold preamps with ARGONTUBE

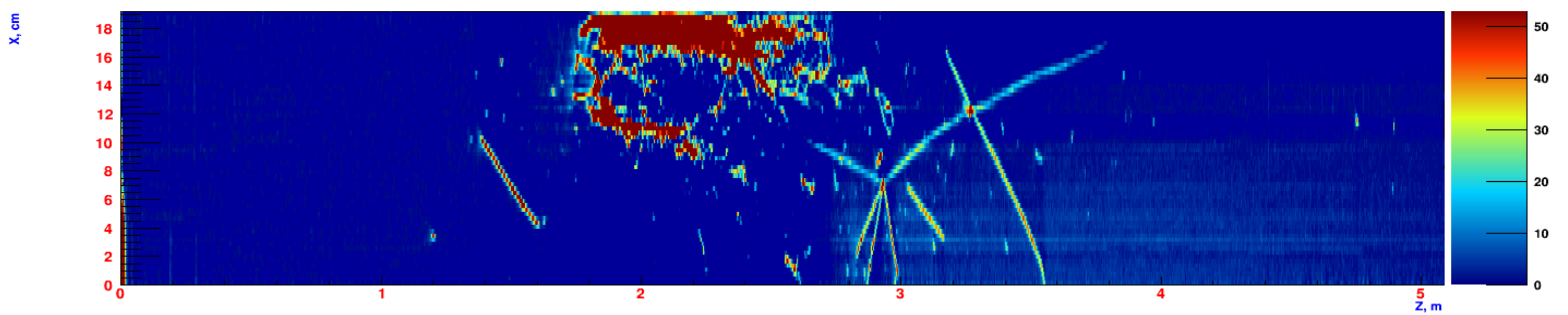
Collection, Run 8135 Event 74. Trigger pattern: I1 I2 S



Collection, Run 8200 Event 145. Trigger pattern: I1 I2 S



Collection, Run 8202 Event 45. Trigger pattern: I1 I2 B S



Summary

Precision era in neutrino physics

Liquid Argon TPCs provide necessary granularity and mass

MicroBooNE will:

explore the MiniBooNE low energy excess (Sterile neutrinos?)
provide more information on nuclear models
perform neutrino cross section measurements
serve as a natural step towards XXXL detectors

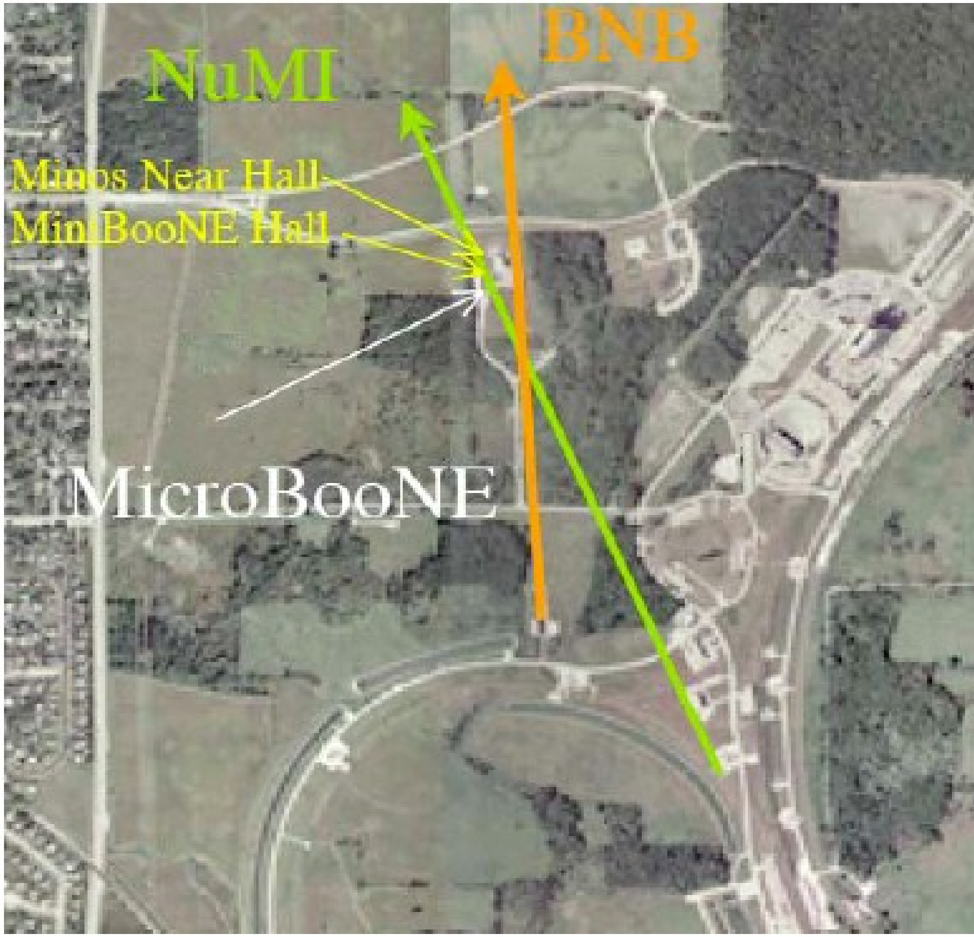
TPC is built, optical system installed, readout ready.
Installed in the final experimental building this year.
Cryogenic system is being built.

Data taking starts **2014.**

Backup slides

Expected event rates for 6.6 x 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



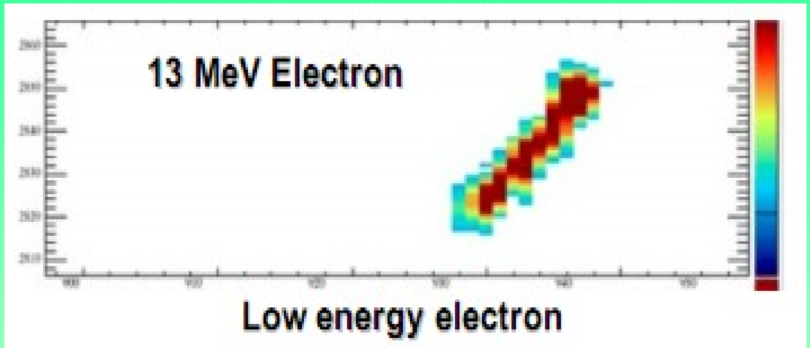
	BNB	NuMI
Total Events	145k	60k
ν_μ CCQE	68k	25k
NC π^0	8k	3k
ν_e CCQE	0.4k	1.2k
POT	6x10^{20}	8x10^{20}

Projected Event Rates for MicroBooNE in 2-3 years.

Additional physics of MicroBooNE

Supernova neutrino

– Low energy electron reconstruction



Proton decay backgrounds

– Study Kaon decays as background to “golden” channel p → K^+ ν