The MicroBooNE TPC trigger and GPS timing studies

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for the MicroBooNE collaboration

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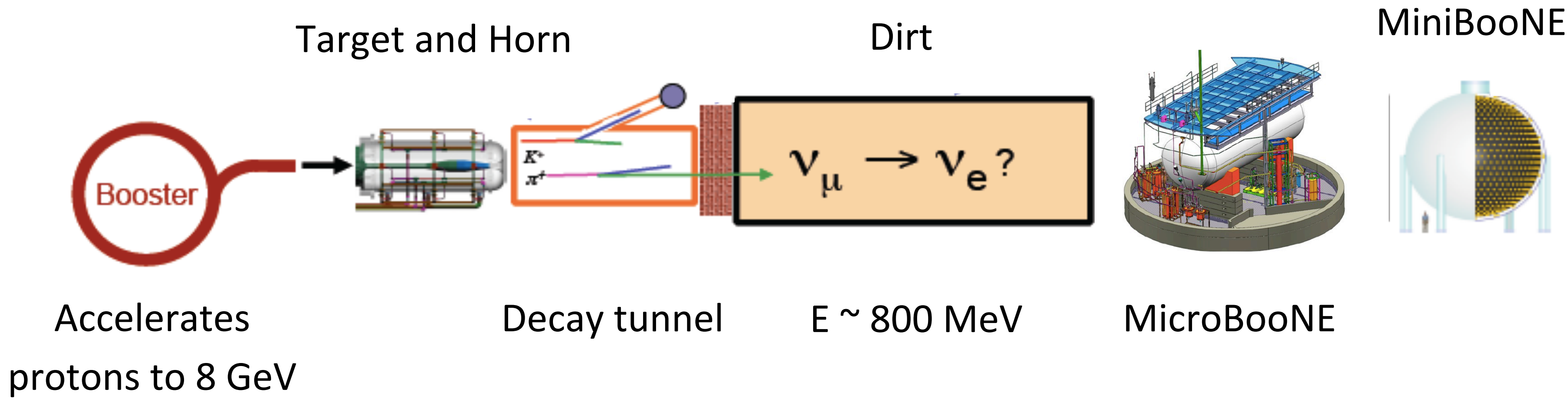
MicroBooNE

- MicroBooNE will be the largest Liquid Argon Time Projection Chamber (LAr TPC) operating in the United States (US).
- The primary objectives of this experiment are:
  - The investigation of the MiniBooNE low energy excess
  - Detailed measurements of neutrino interaction cross-sections and,
  - Study of the background related to proton decay searches in massive LAr detectors; such as LBNE, LBNO and Okinoshima.
- Of course all this effort is expected to further advance the LAr detector concept; a very promising technology well-suited for neutrino physics.
- Additional searches with the MicroBooNE detector include:
  - Burst neutrinos and,
  - Neutrinos from supernova explosions (SN).

Experimental layout

- MicroBooNE (just like MiniBooNE) will be installed along the Booster Neutrino Beam (BNB) in Fermi National Laboratory.



- Placed at a distance of ~470 m from the neutrinos' creation point in the Liquid Argon Test Facility (LArTF).
- It is expected to start data taking in 2014 and run for 2-3 years in the neutrino mode accumulating 6.6 10^{20} POT.

BNB and NuMI beamlines

- Besides BNB MicroBooNE will also receive Neutrinos from the Main Injector beamline (NuMI).

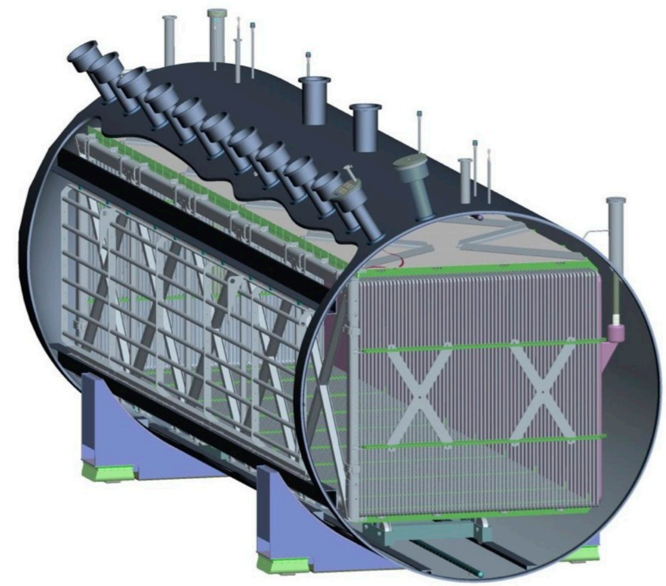
The MicroBooNE TPC

Characteristics :

- ~1.6 ms drift time (~2.5 m drift length)
- 8256 total channels
- Three planes of wires at 3 mm pitch
  - One collection plane at 0° from vertical
  - Two inductions planes at ±60°
- Optical system of 30 cryogenic PMTs

Current status (under construction):

- Field cage already built
- Wire planes constructed
- Cryostat delivered
- The LArTF building will be soon ready



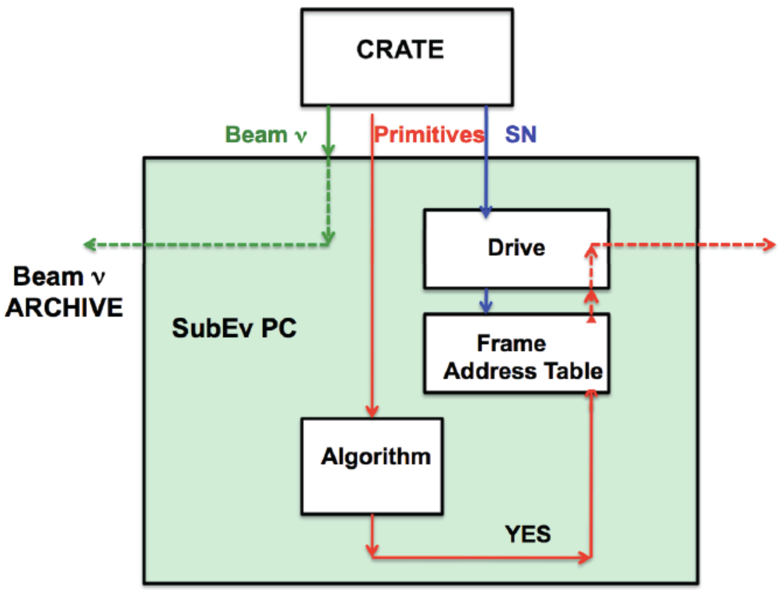
10.4 m × 2.3 m × 2.5 m
uniform field of 500 V/cm
170 tons of purified LAr
(active volume 83 m^3)

Triggering options

- Neutrinos from the BNB have a well-known timing structure
  - The signal gate is a priori known.
- Besides this, MicroBooNE can also trigger leaning on the timing information obtained from the optical system.
  - Contrast to the electron drift times (~ms) light is propagated almost simultaneously (~ns).
- Additionally we are exploring the possibility to “trigger” events according to their signature in the TPC.
- This will be an offline “trigger” termed as *the TPC trigger* (and will occupy the first part of this talk …).
- This is an important ingredient for :
  - Cosmic ray studies
  - Studies of background sources relevant for proton decay

Continuous data stream

- Two distinct data streams envisaged in MicroBooNE.
  - Beam events and the SN continuous data flow



One Hard Drive (HD) per section of the TPC

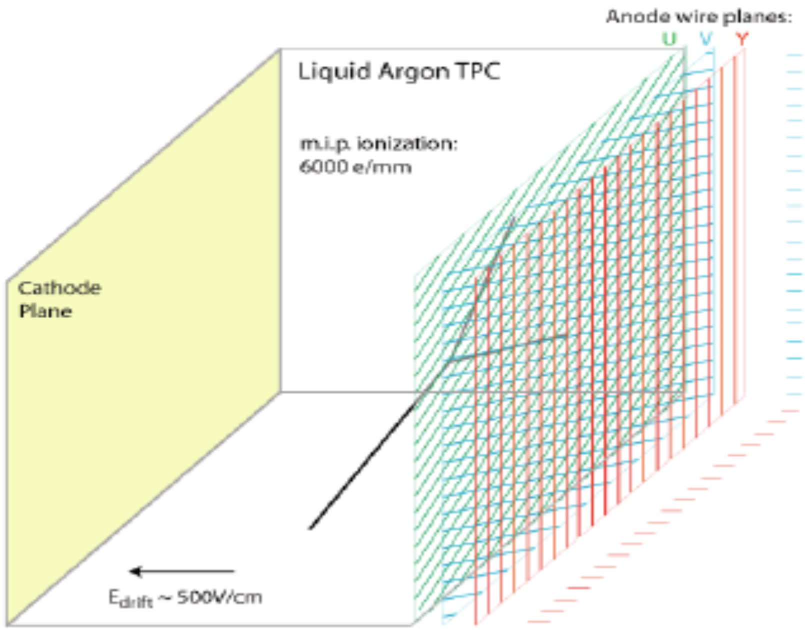
<u>SN stream:</u>

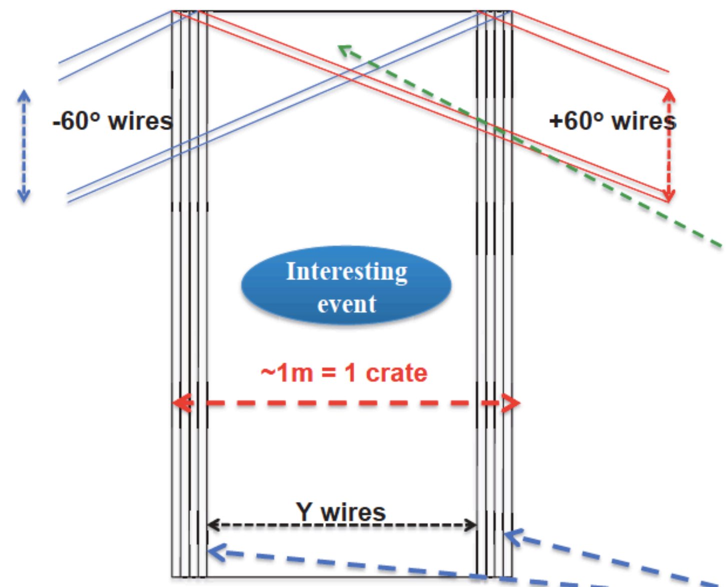
- Saved continuously in a disk.
  - Large amount of data
- Stored in a circular buffer and retained there for an hour.
- Develop fast algorithms to select the interesting events

<u>Requirements:</u>

- Robust performance
- Minimize CPU time

The TPC trigger



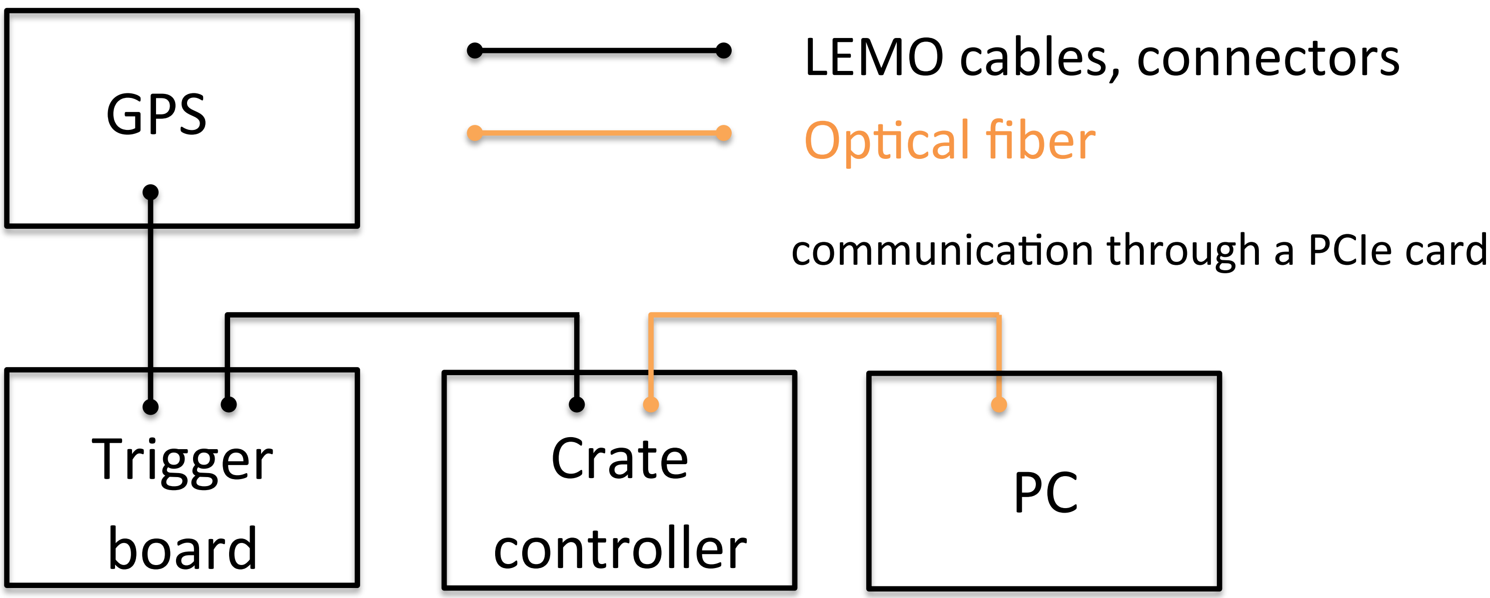


CR entering from sides: veto on energy deposition in L or R wires

- U, V and Y wires overlap in a region of 30-60 cm at the top of each crate.
- Requiring a time coincidence between groups of U, V and Y wires will signal a particle that comes through the top of the TPC.
- Additionally hits in the Y plane only betray vertical going particles (cosmic muons)
- In general, exploit the geometry of the TPC to characterize topologies.

GPS timing

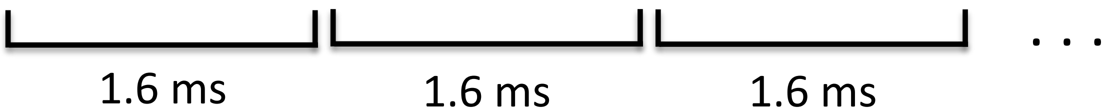
- For the global timing information we use, naturally, a commercial GPS card (Symmetricom PCIe).



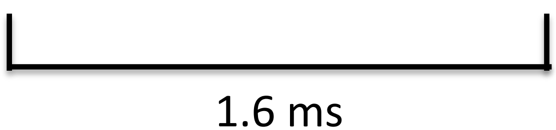
- Its software has been modified for our linux machines (Yale).
- A customized firmware developed to cast the Trigger Board (TB) time-stamp (Nevis Labs).

Trigger board time-stamp

I. Consecutive frames of 1.6 ms :



II. Every frame consists of 2 MHz samples :



1.6 ms × 2 MHz = 3200 samples, 0.5 μs

III. Samples digitized by 16 MHz clock :

Each sample is split in eight divisions; ultimate graining 62.5 ns

Combine the two functionalities

(Current work at Virginia Tech.)

- The GPS card will “interrupt” normal data taking with a one pulse per second (PPS).
- Consequently the TB will issue its three-fold counter stamp to this external signal.
- Then a combined software will intervene and relate the time of this event to the TB timestamp.
  - Future triggers will also be assigned with the proper timing.
- This will allow:
  - Precise global timing for all data
  - Correlate events with possible SN explosions

Ending themes

- MicroBooNE will be a very beautiful and a multi-purpose detector
- … and presumably will deliver some equally wide and rich physics results !
- The TPC trigger will be an integral part of the detector and the read-out, allowing to study non-beam events; a rather challenging task.
- When completed, this work could influence and further inspire future and existing LAr TPC detectors.
- MicroBooNE is expected to start data taking in 2014.
- Until then stay tuned !

Delivery of the cryostat, March 2013

Thank you !

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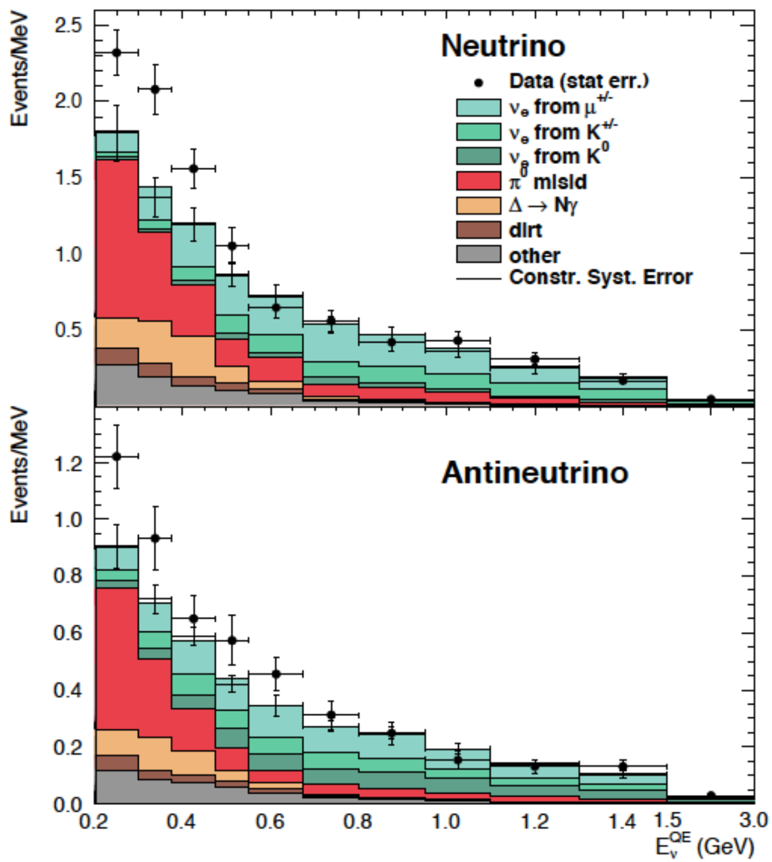
Extra details and information

BACKUP SLIDES

MiniBooNE low-energy excess

arxiv.org/1207.4809



Tension below 475 MeV

Limitations of the 2ν model ?

Misidentified backgrounds ?

200 MeV < E_ν < 1250 MeV

Neutrino mode:

- Data: 952 events
- Background: 790.0 ± 28.1 ± 38.7
- Excess: 162.0 ± 47.8 (3.4 σ)

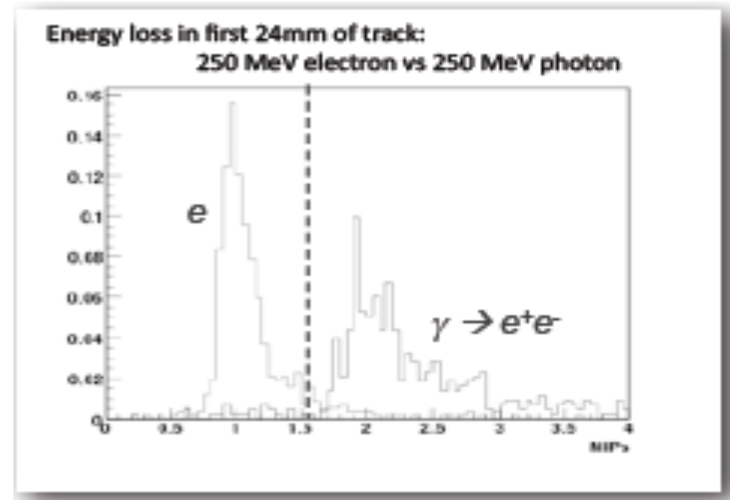
Antineutrino mode:

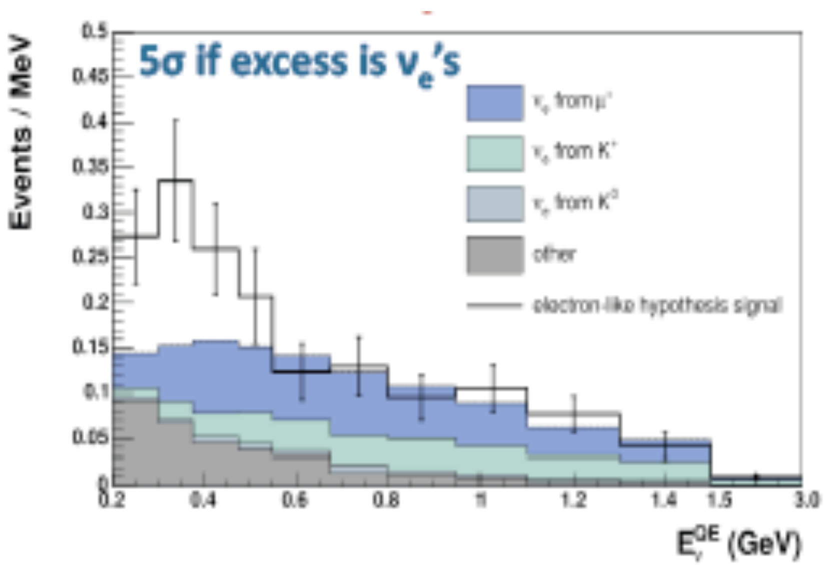
- Data: 478 events
- Background: 399.6 ± 20.0 ± 20.3
- Excess: 78.4 ± 28.5 (2.8 σ)

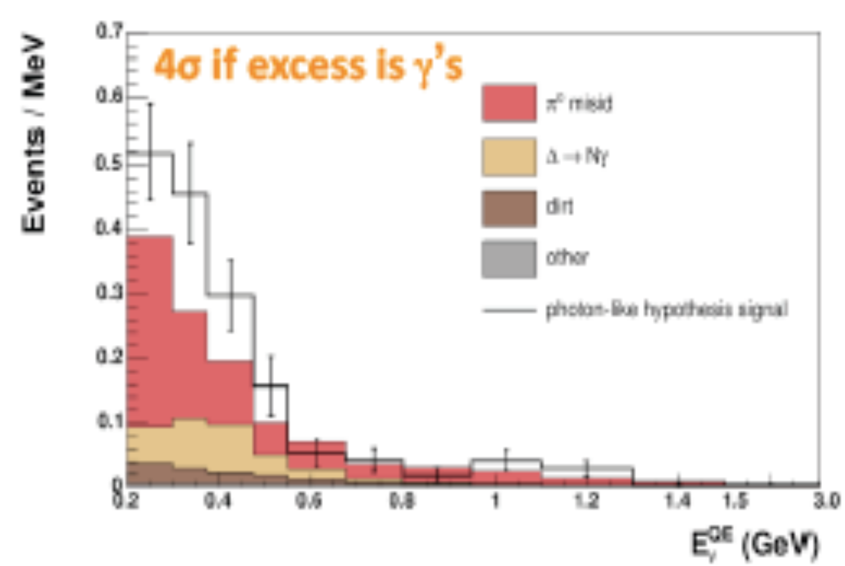
Combined:

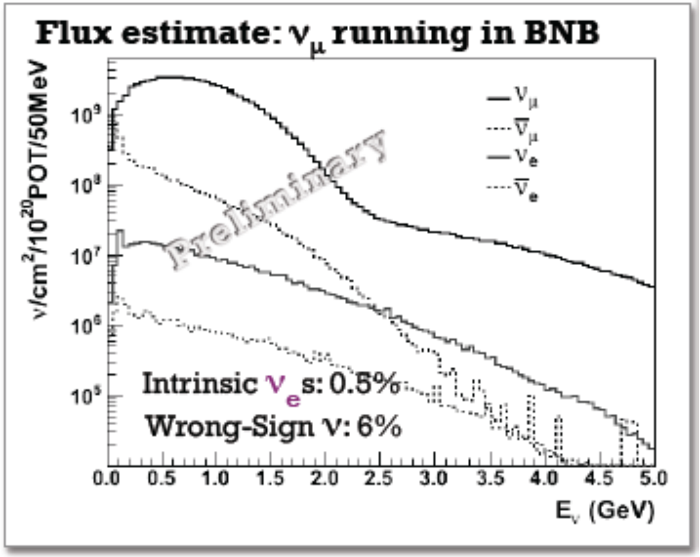
- Excess: 240.3 ± 34.5 ± 53.6
- 3.8 σ statistical significance

e/γ discrimination







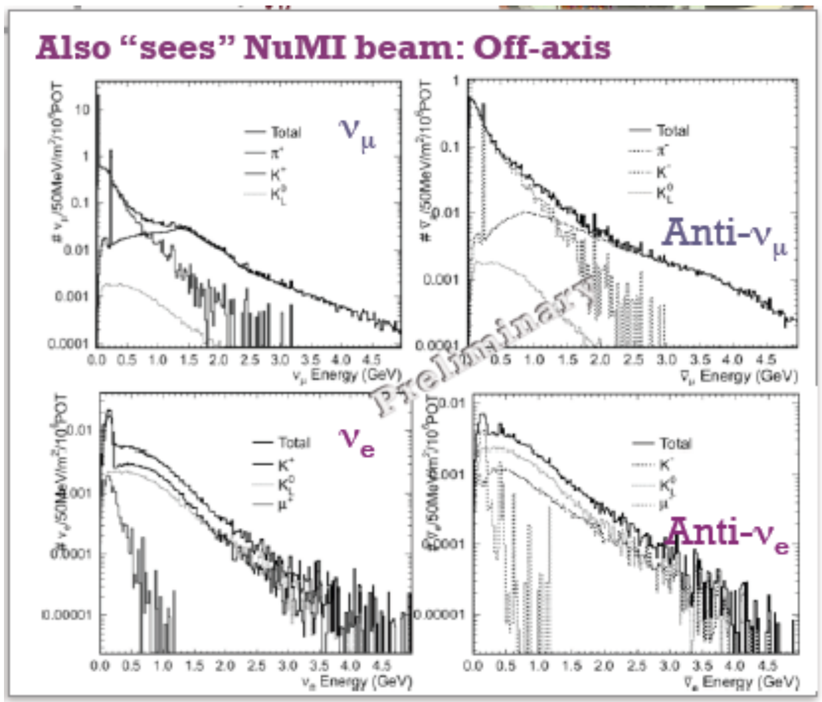


Expected event rate for BNB 6.6 x 10^{20} POT
60 ton fiducial volume

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

Nuance-generated events on LAr, MicroBooNE Collaboration

Preliminary



Expected rates from upgraded NuMI beam (700kW, 6E20POT/yr) 1 yr, 60 ton fiducial volume

Higher energy beam + increased ν_e content

Preliminary

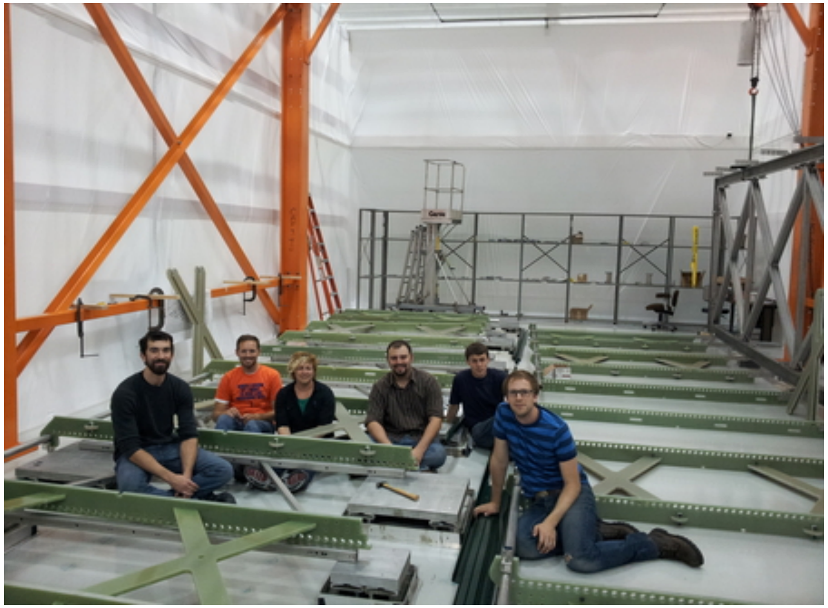
40k ν_μ CC
8k anti-ν_μ CC
2k ν_e CC
400 anti-ν_e CC

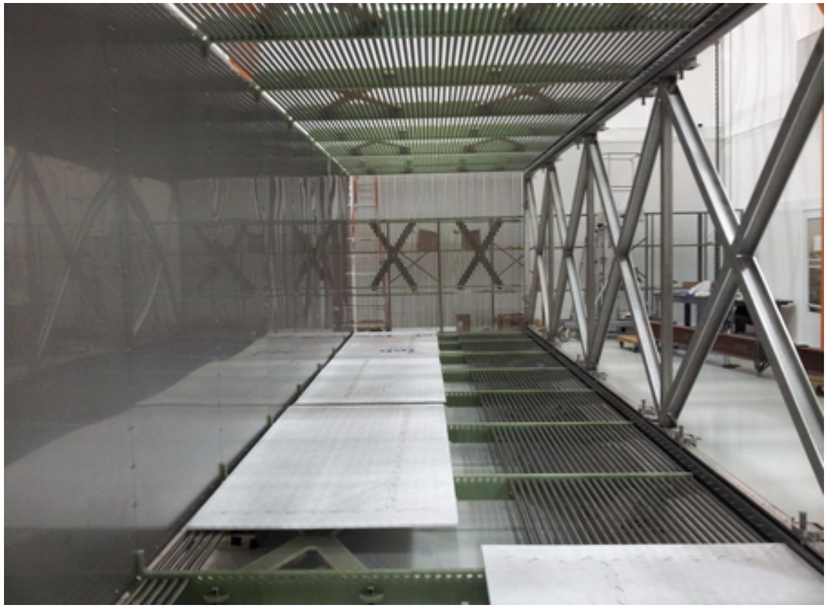
few 100's of Λ^os

MicroBooNE Collaboration

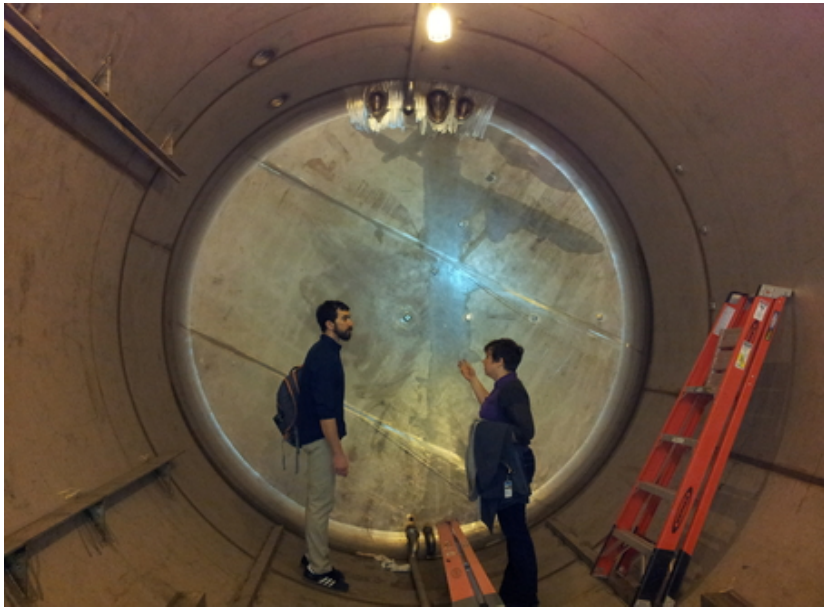
LArTF chronicles

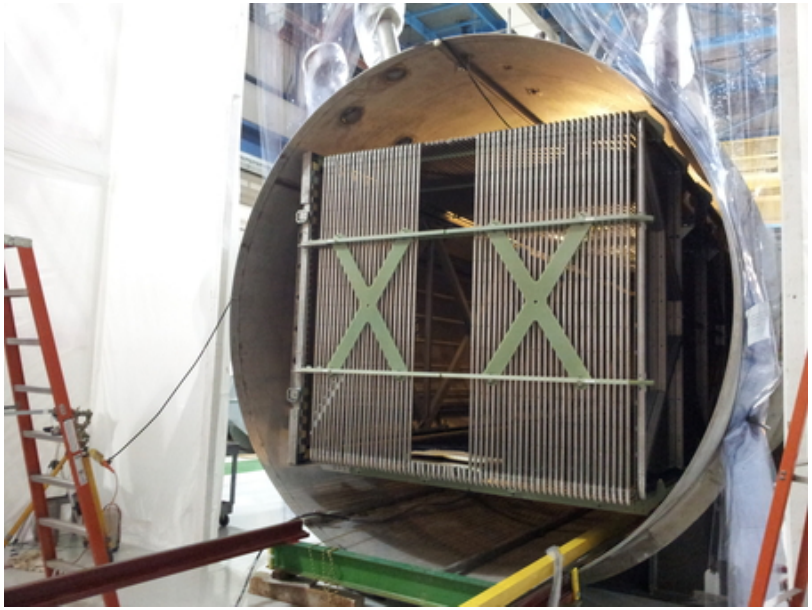
TPC cage construction





Arrival of the cryostat





GPS at DAB

GPS antenna placed at the roof of
D-zero assembly building

Symmetricom Bc637PCIe

cost ~ 3k $
~ 10^2 ns accuracy