



# MicroBooNE: a high resolution short base-line neutrino experiment

M. Weber, LHEP, Bern

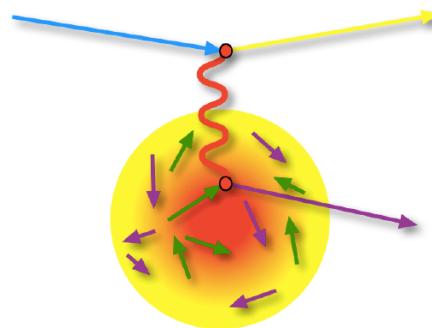
ICATPP, Villa Olmo, Como

The aim of MicroBooNE is to measure neutrino interaction cross sections in the Fermilab Booster Neutrino Beam, exploring the low energy excess observed by MiniBooNE and the possible existence of sterile neutrinos. MicroBooNE is based on a liquid argon time projection chamber with 60 ton fiducial volume. As will be shown, this detector offers high resolution tracking, calorimetry and excellent particle identification capabilities for neutrino interactions. We will show the design of the experiment and the status of the construction leading to a data taking start in early 2014. MicroBooNE will also serve as an R&D vehicle for larger liquid argon detectors planned for future experiments and employ new technologies like a UV-laser calibration system.

# Notable physics case for Short Base Line neutrino experiments



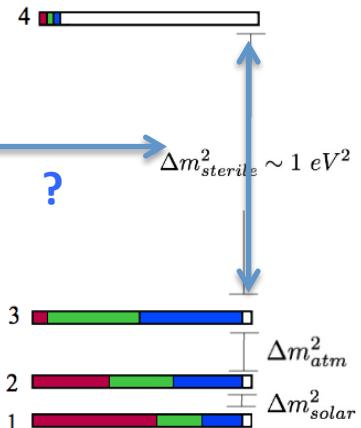
- We entered the era of precision measurements of neutrino oscillations -> precision detectors
- Liquid argon TPCs are perfectly suited for cross-section studies (particle ID) and SBL accelerator experiments
- Long standing issue with anomalies in  $\nu_\mu - \nu_e$  and anti- $\nu_\mu -$  anti- $\nu_e$  oscillations
  - assess the completeness of the 3-flavor mixing scenario vs additional sterile neutrinos (LSND and MiniBooNE signal/indications)
- Need for measurements of neutrino cross sections over a range of energies to develop nuclear interaction models



# LSND, MiniBooNE and MicroBooNE

## LSND

- excess of anti- $\nu_e$  in an anti- $\nu_\mu$  beam
  - High  $\Delta m^2 \sim 1 \text{ eV}^2$
  - Sterile neutrinos ?

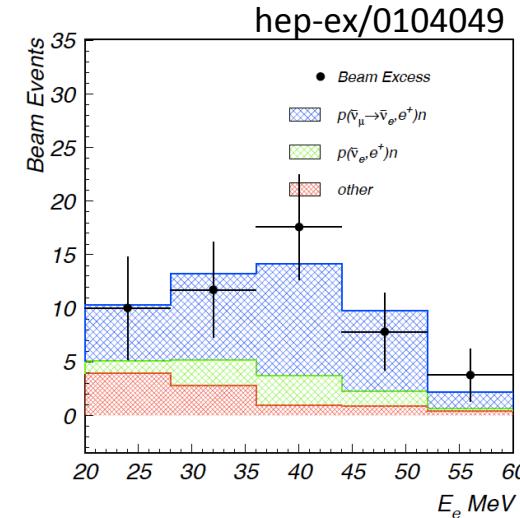


## MiniBooNE

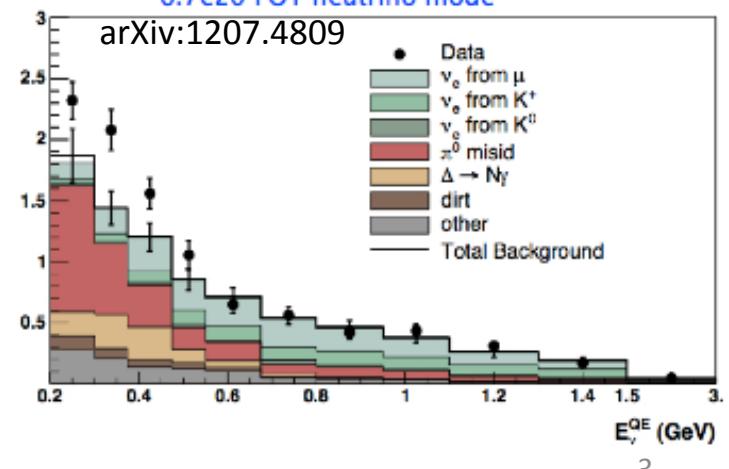
- excess of  $\nu_e$  in  $\nu_\mu$  beam at low energy

Gallium and reactor neutrino disappearance anomalies  
also pointing to sterile neutrinos ?

—> Need for experimental input:  
**MicroBooNE**

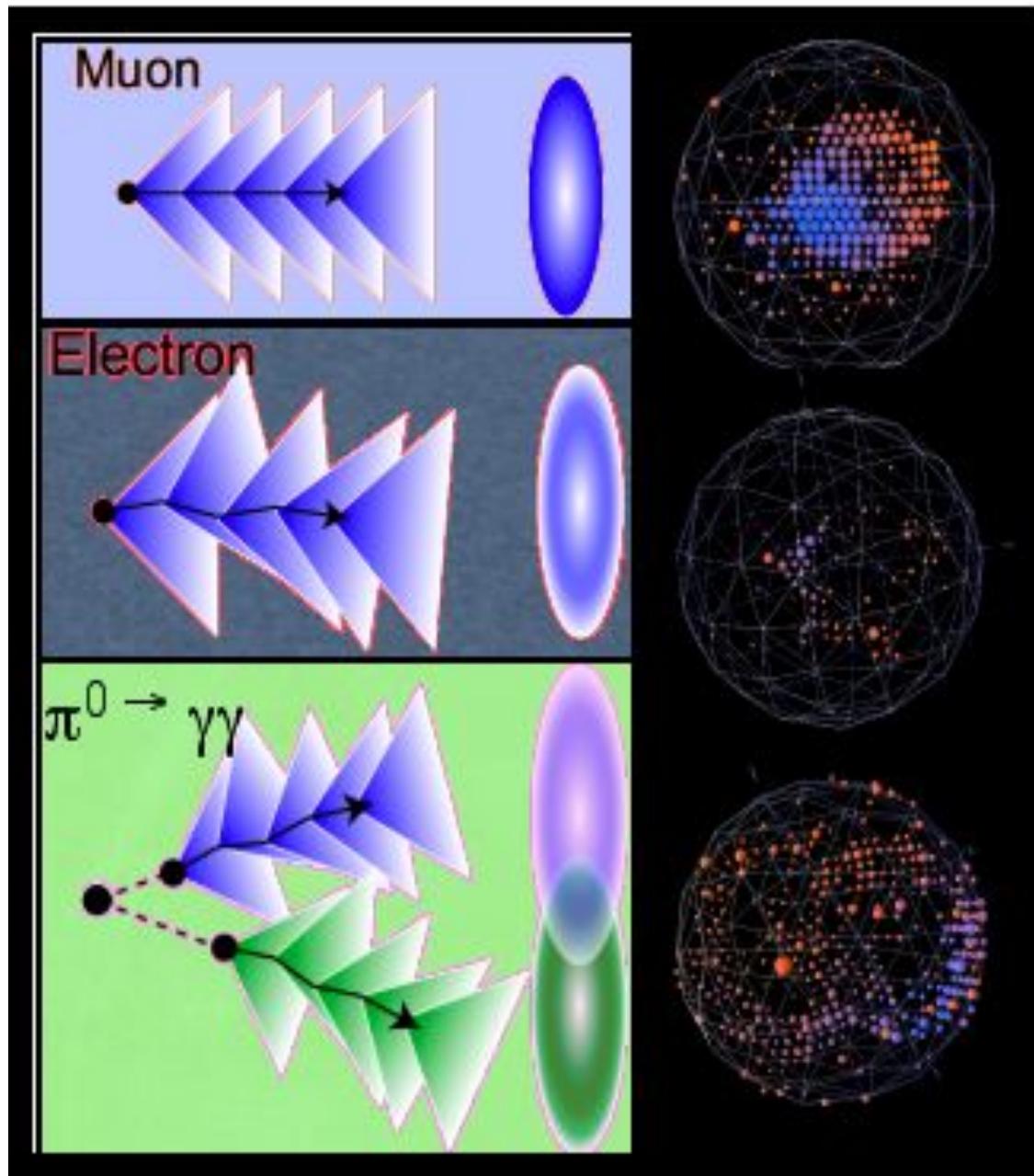
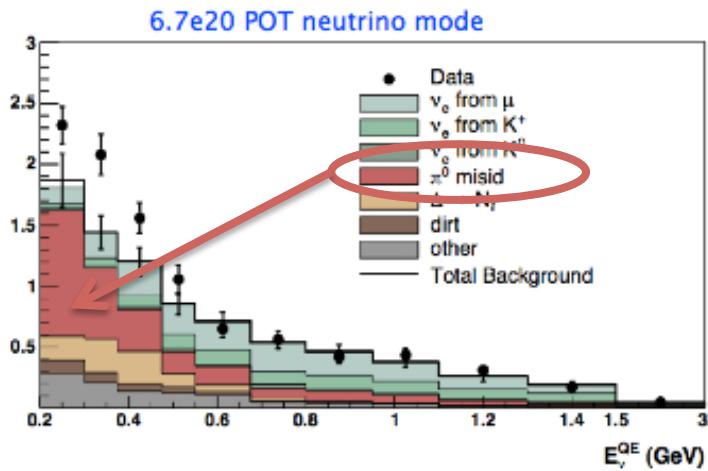


6.7e20 POT neutrino mode

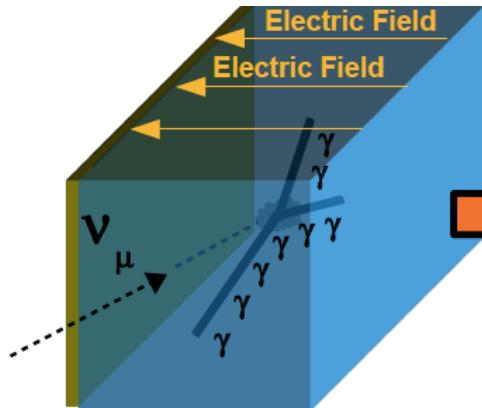


# The pictures a Cerenkov detector takes

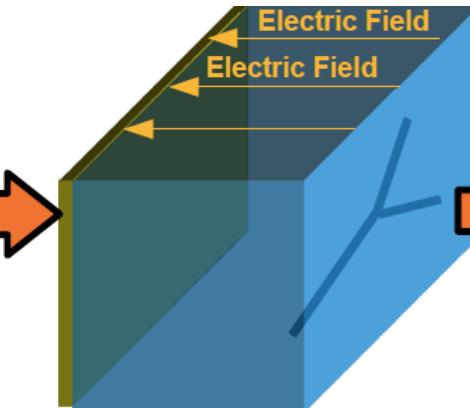
(Neutrino interactions in MiniBooNE)



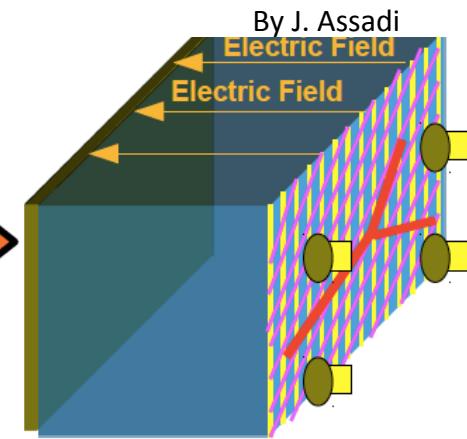
# Liquid Argon Time Projection Chamber



Neutrino interaction in LAr produces ionization and scintillation light



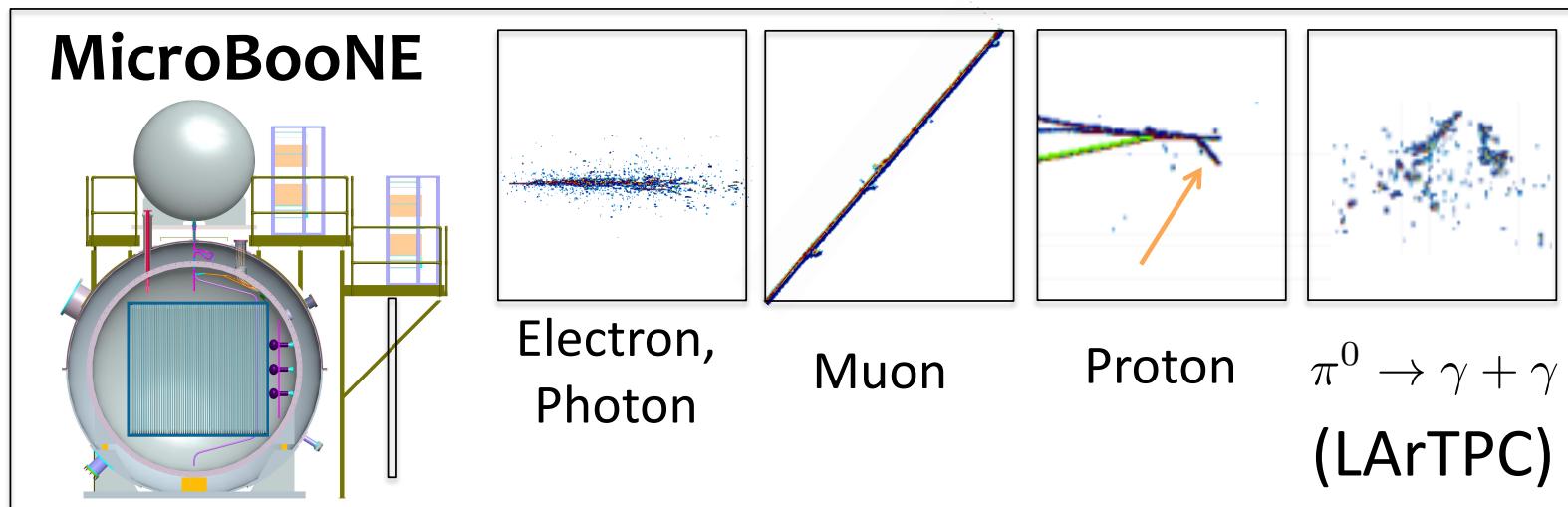
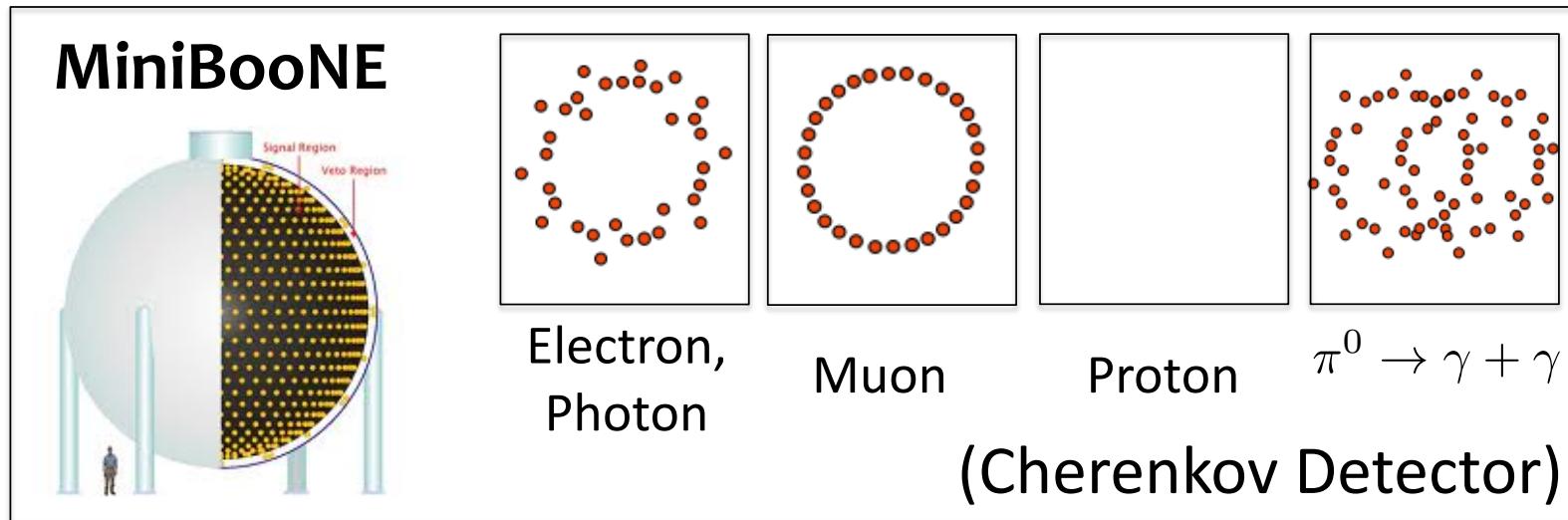
Drift the ionization charge in a uniform electric field



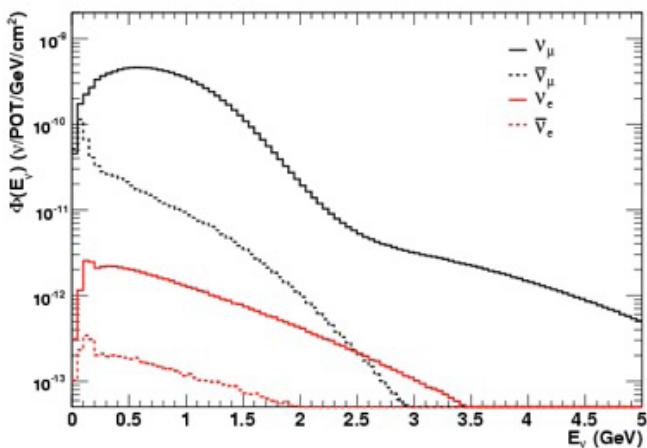
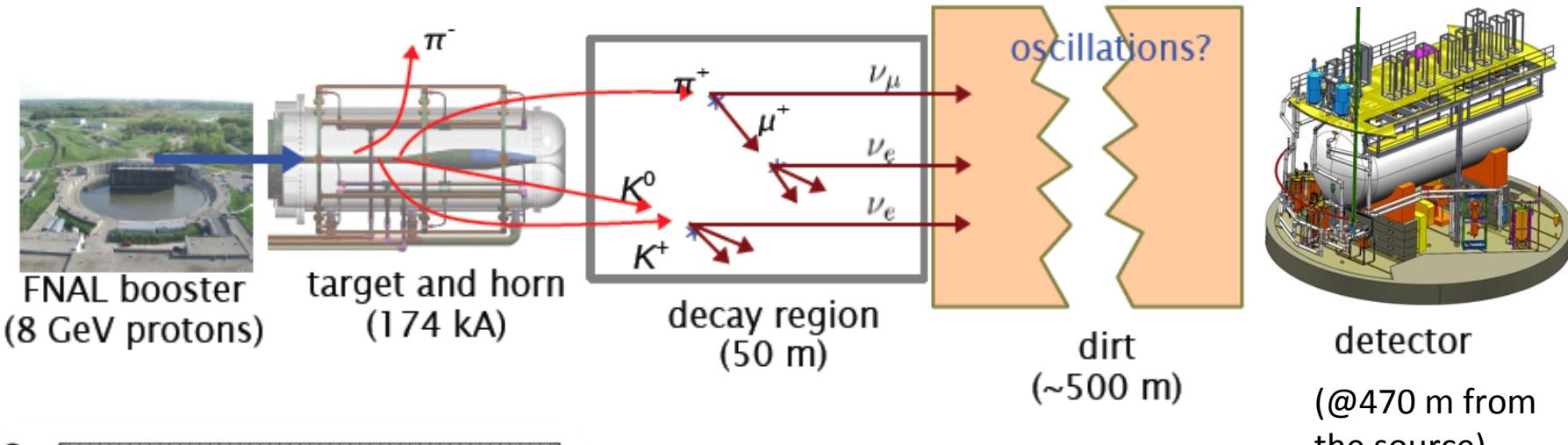
Read out charge and light produced using precision wires and PMT's

## Liquid argon:

- dense ( $1.4 \text{ g/cm}^3$ )
- abundant (1% of the atmosphere)
- ionization yield of 55,000 e/cm for a MIP
- high electron mobility ( $545 \text{ (cm/s)/(V/cm)}$  at 87 K)
- scintillates and is transparent to the light produced
- liquid at 87K



# MicroBooNE: a “classical” SBL oscillation experiment



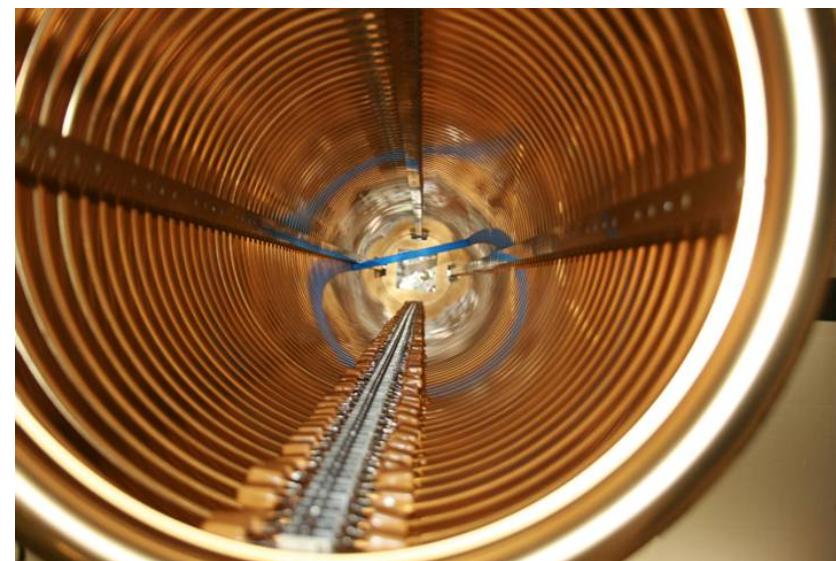
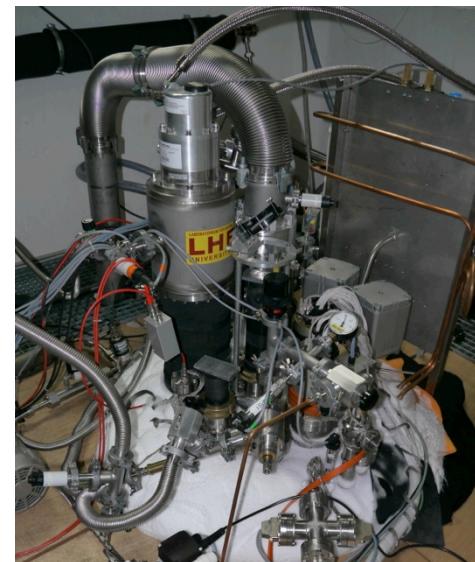
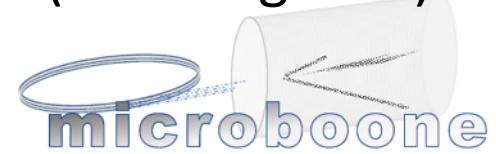
Planned start of data taking in 2014:  
in 3 years expect  $6.6 \times 10^{20}$  pot ( $\nu$ )  
and  $\sim 140$  k events (BNB)

# LAr TPCs challenges

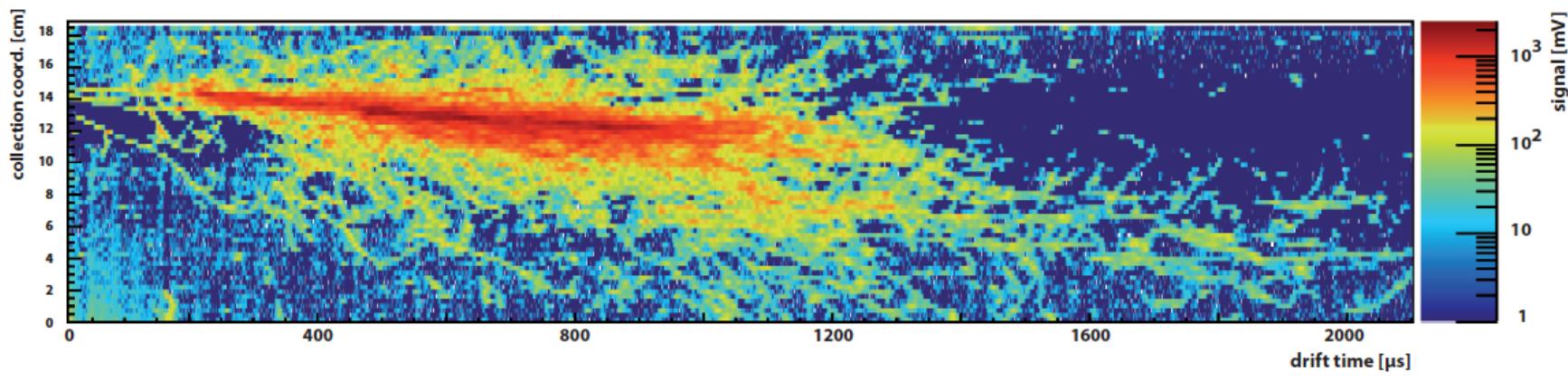
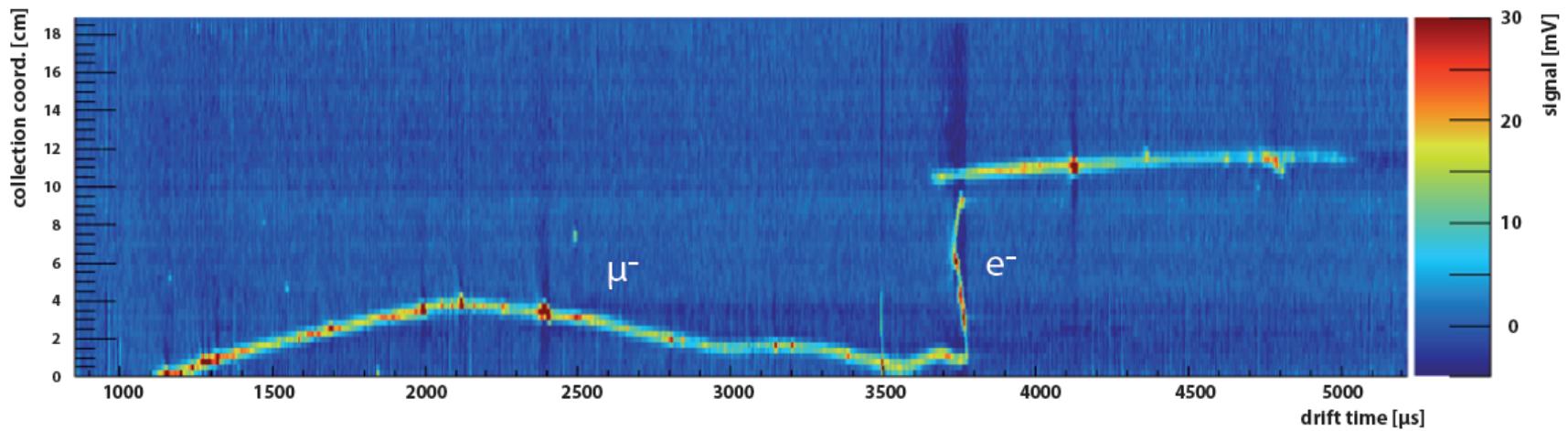


- Realization of XXL observatories: long drift distance is an issue
- Sensitive charge readout with good S/N
- Charge recombination, charge lifetime(drift), diffusion
- High voltage (how to supply and limitations)
- Insulation, evacuation, mechanics,...
- Calibration
- Event reconstruction:  
exploit the rich information from the raw data

# The Bern ARGONTUBE (5 m long drift)



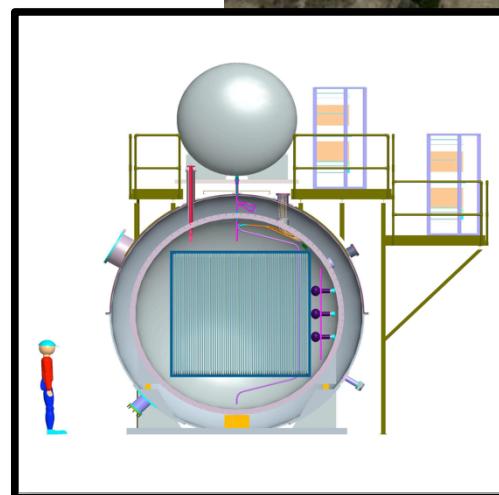
# Example events from ARGONTUBE



# MicroBooNE @ FNAL

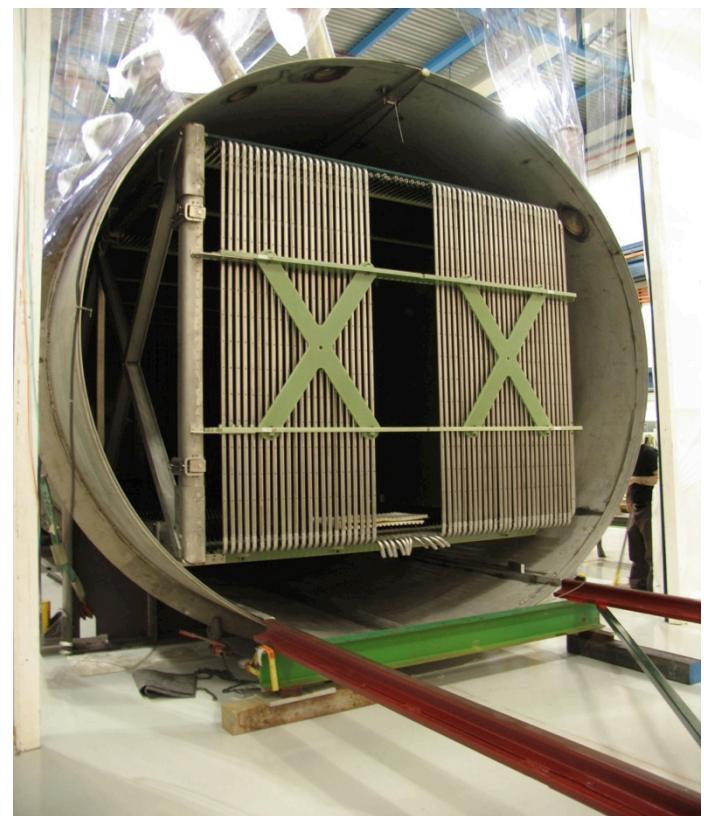
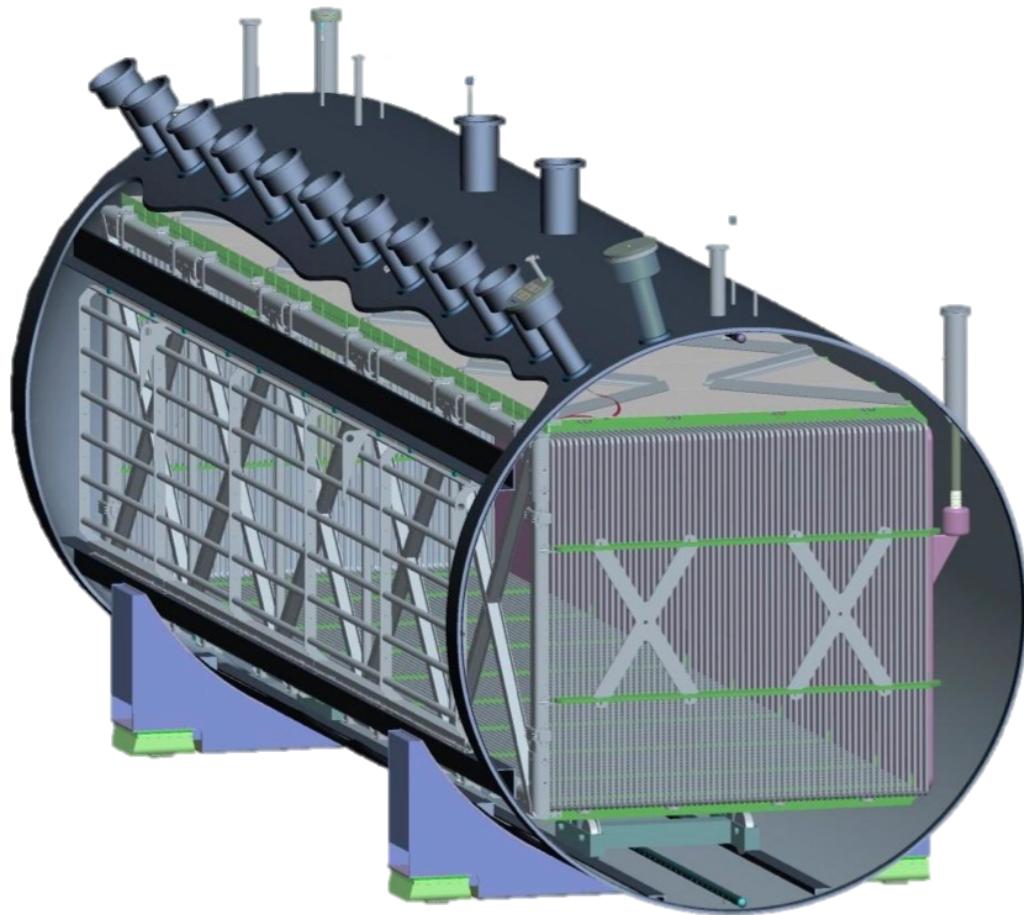


- 170 tons LAr ( $\sim 60$ t fiducial)
- Foam insulated cryo-volume
- $2.5 \times 2.3 \times 10.4 \text{ m}^3$  TPC
- 2.5m charge drift
- U,V,Y wire planes
- Signal pre-amplification in liquid (cold)
- PMT system (32 x 8'')
- Laser calibration system





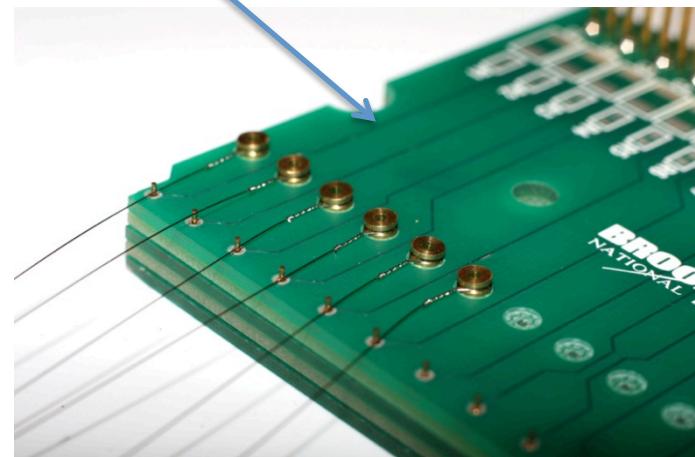
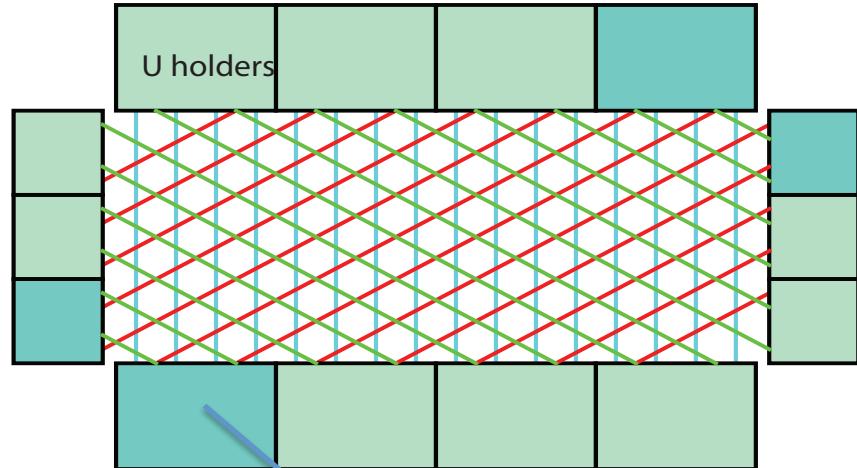
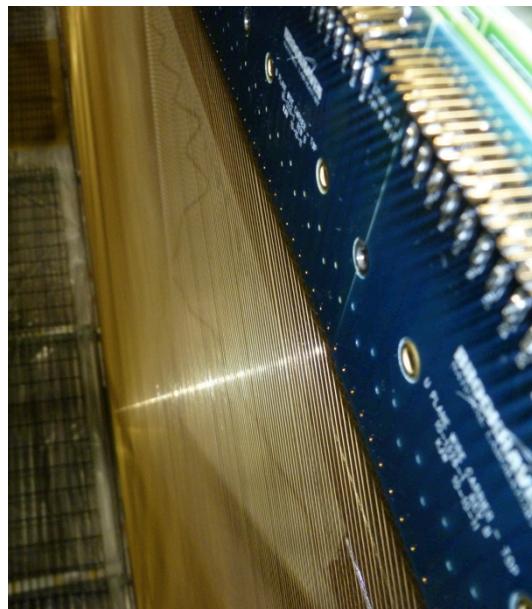




# Anode Wire Planes



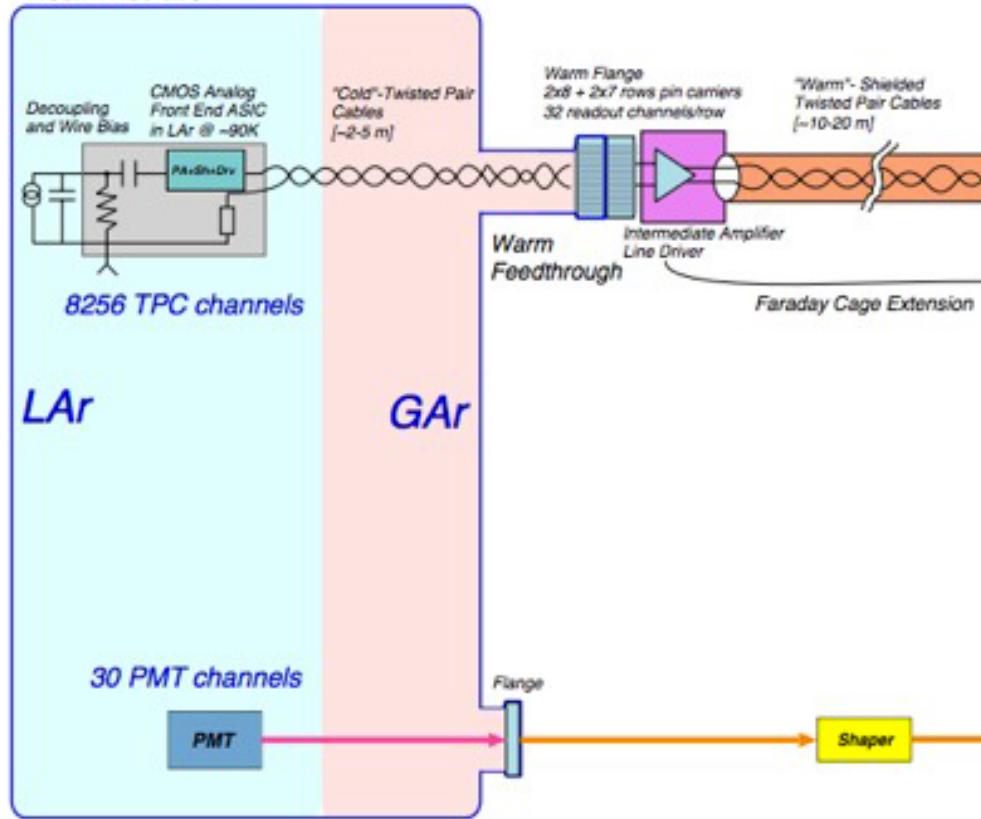
- 3 wire planes (U,V,Y)
  - Y (3456 wires): vertical
  - U (2400 wires):  $+60^\circ$
  - V (2400 wires):  $-60^\circ$
- 3 mm wire pitch



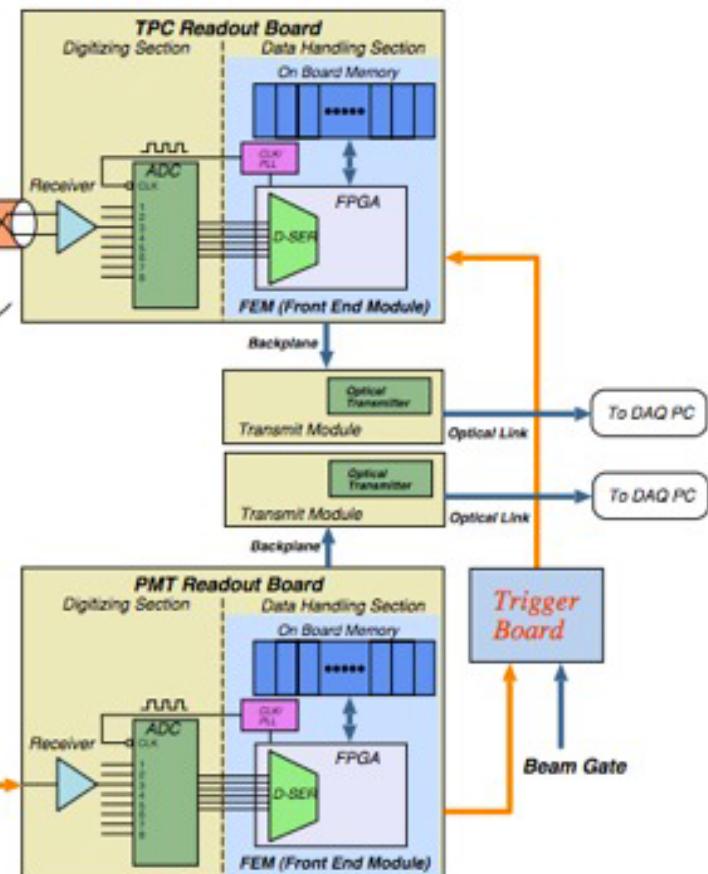
# Data Acquisition



*Single Vessel Cryostat with 8-10% Ullage  
Foam Insulation*



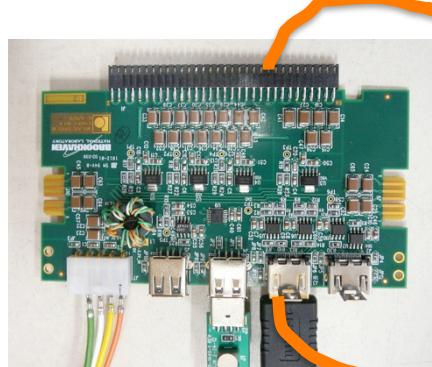
*DAQ in Detector Hall*



# TPC Front End Electronics

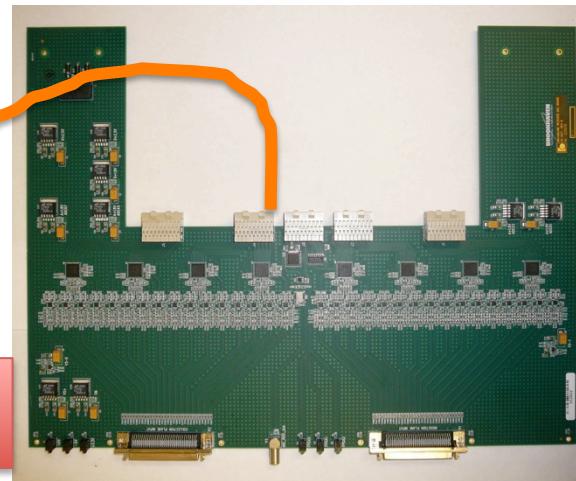


- Pre-Amp CMOS ASIC in liquid at 87K
  - reduce capacitive noise and pickup and lower thermal noise
- V. Radeka et al, *J. Phys.: Conf. Ser.* **308** 012021
- Warm interface electronics
  - Intermediate amplifiers, service board



- Digitizing electronics
  - Receiver and ADC board

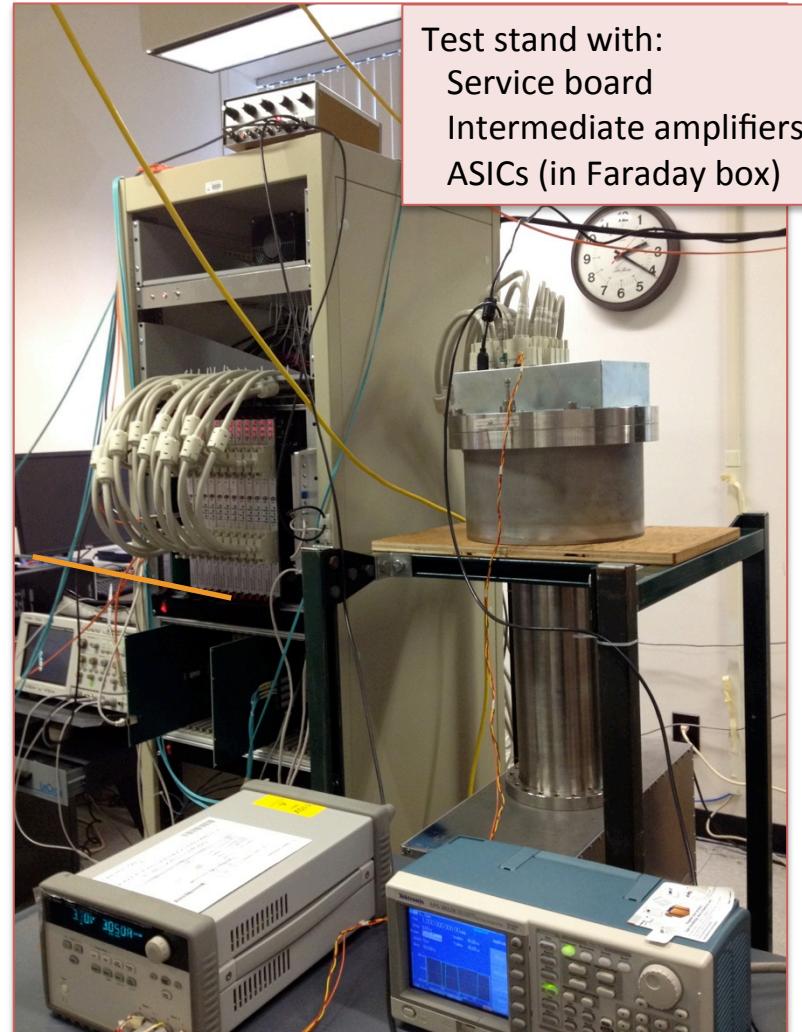
Receiver/ADC  
board



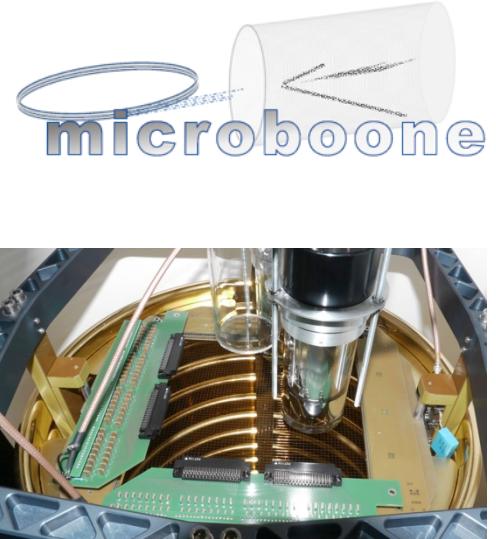
# Readout



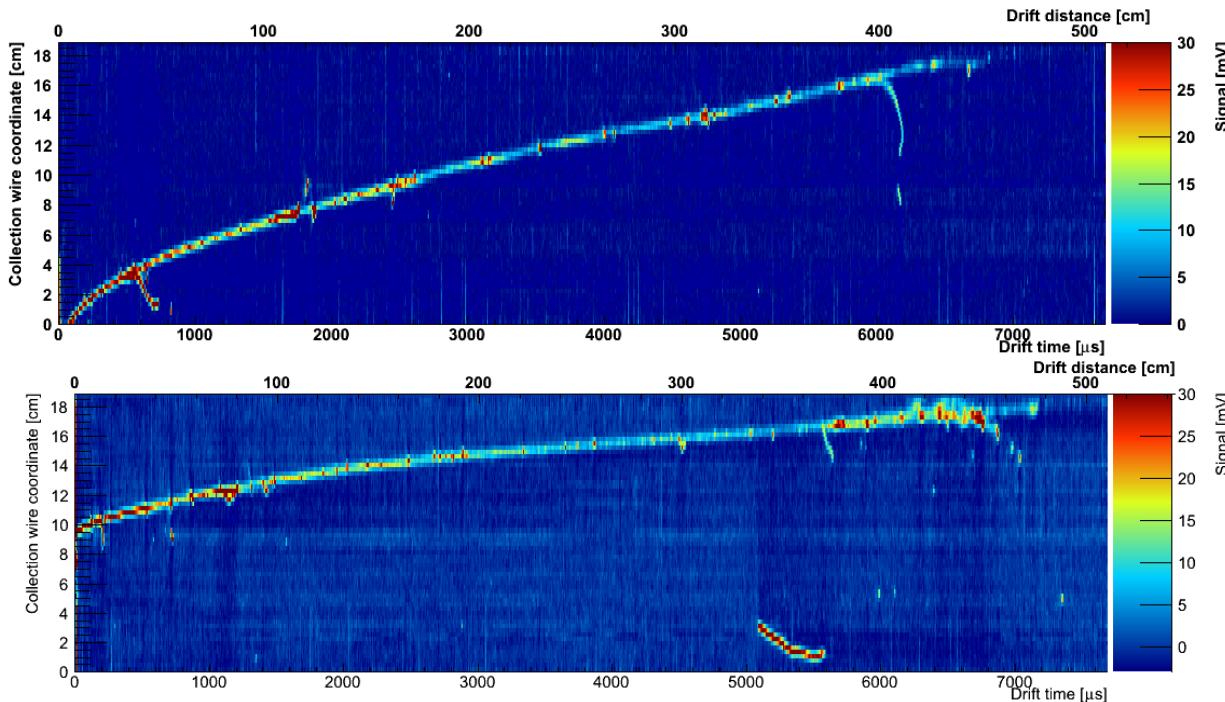
- Readout with Receiver/ADC boards and Front End Modules tested in a test stand
- Chain also used to perform a test of each channel after mounting of the TPC with readout boards



# MicroBooNE cold pre-amplification tested in ARGONTUBE



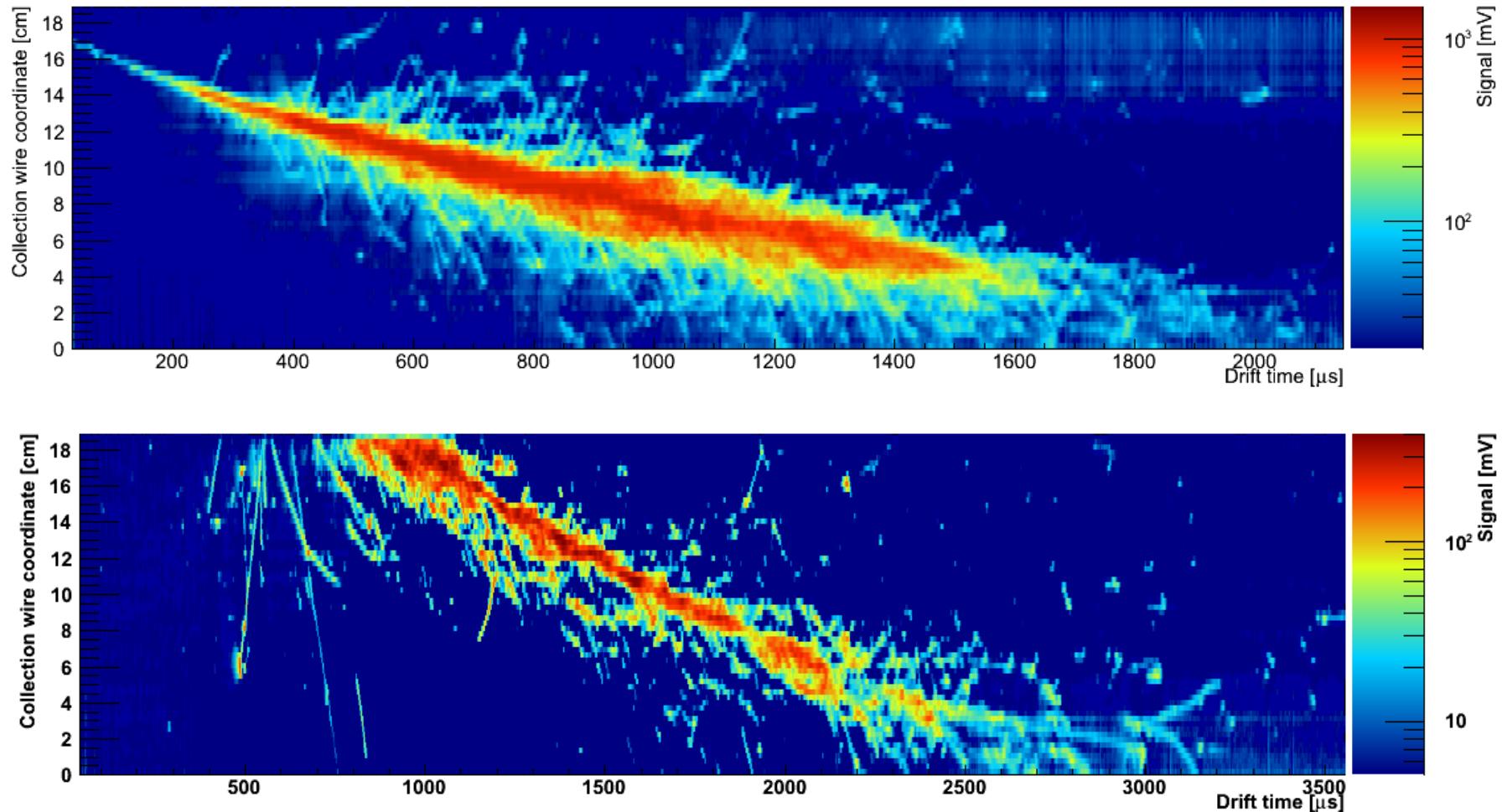
5m maximal drift distance, twice of MicroBooNE



Same ASIC as used  
for MicroBooNE

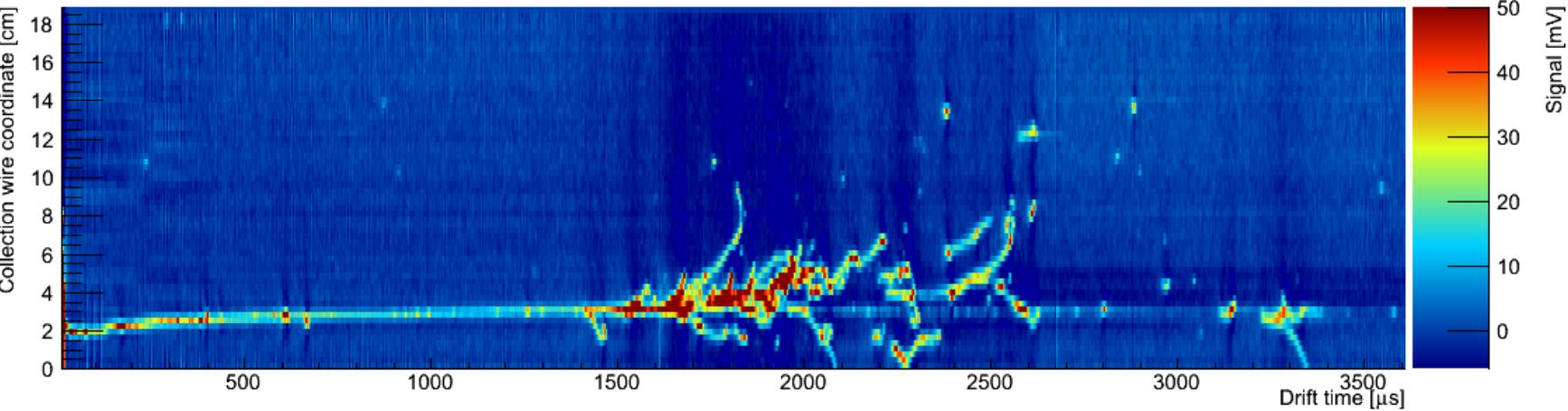
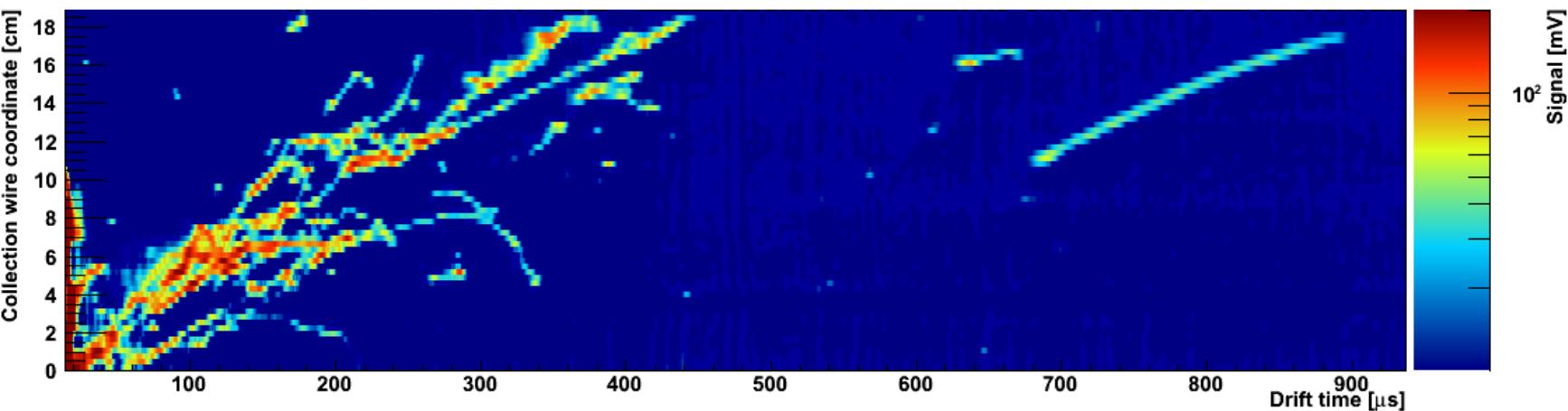
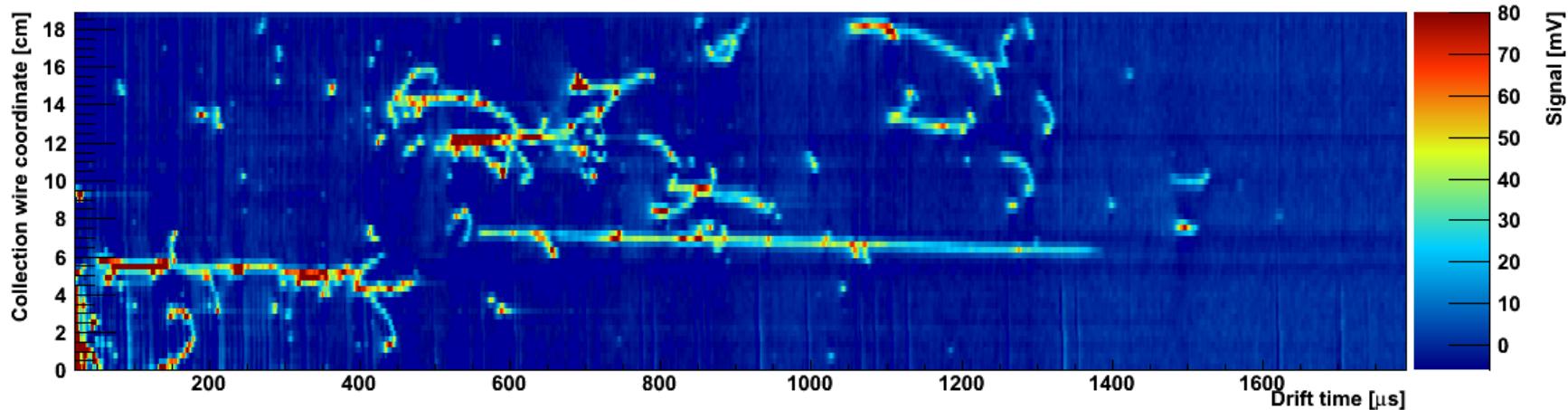
Directly on the wire  
planes, close to  
signal source

Note: aspect ratio compressed ~10x horizontally



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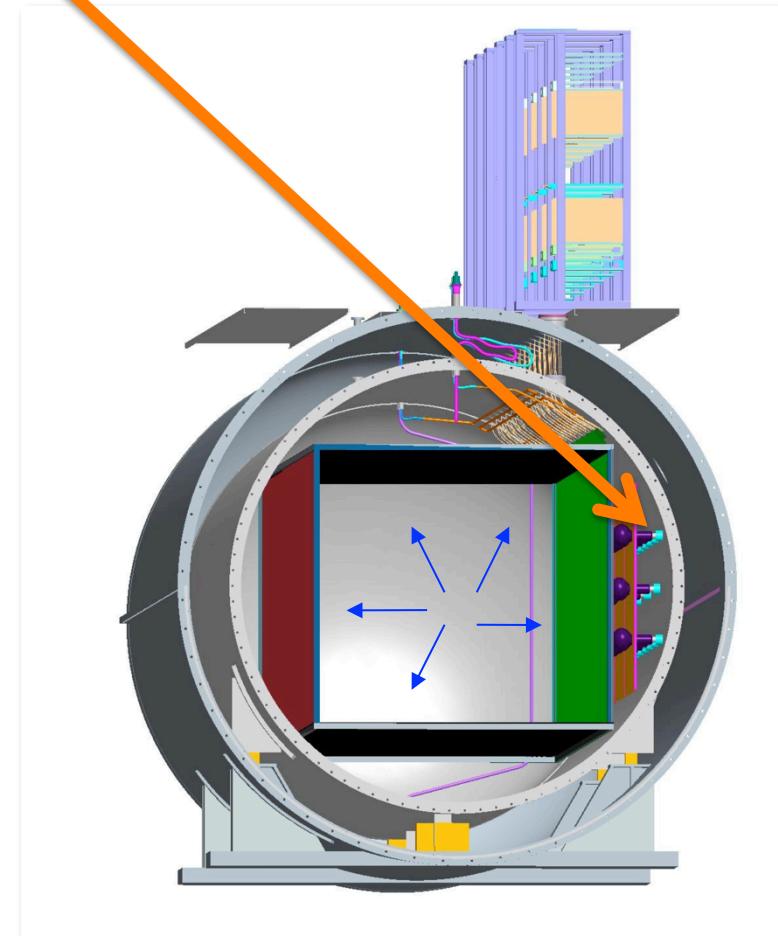
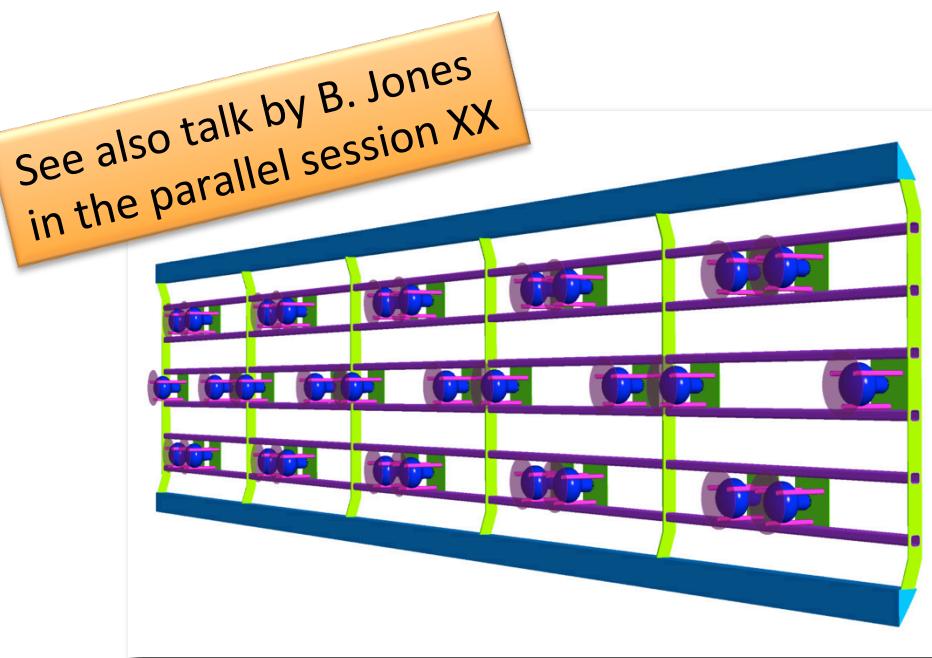


# Optical System (PMTs)



Used primarily for triggering, based on the strong prompt component of scintillation light in argon

Optical information can also contribute to reconstruction

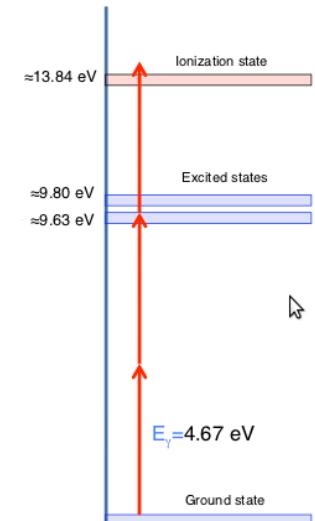




# Laser calibration system



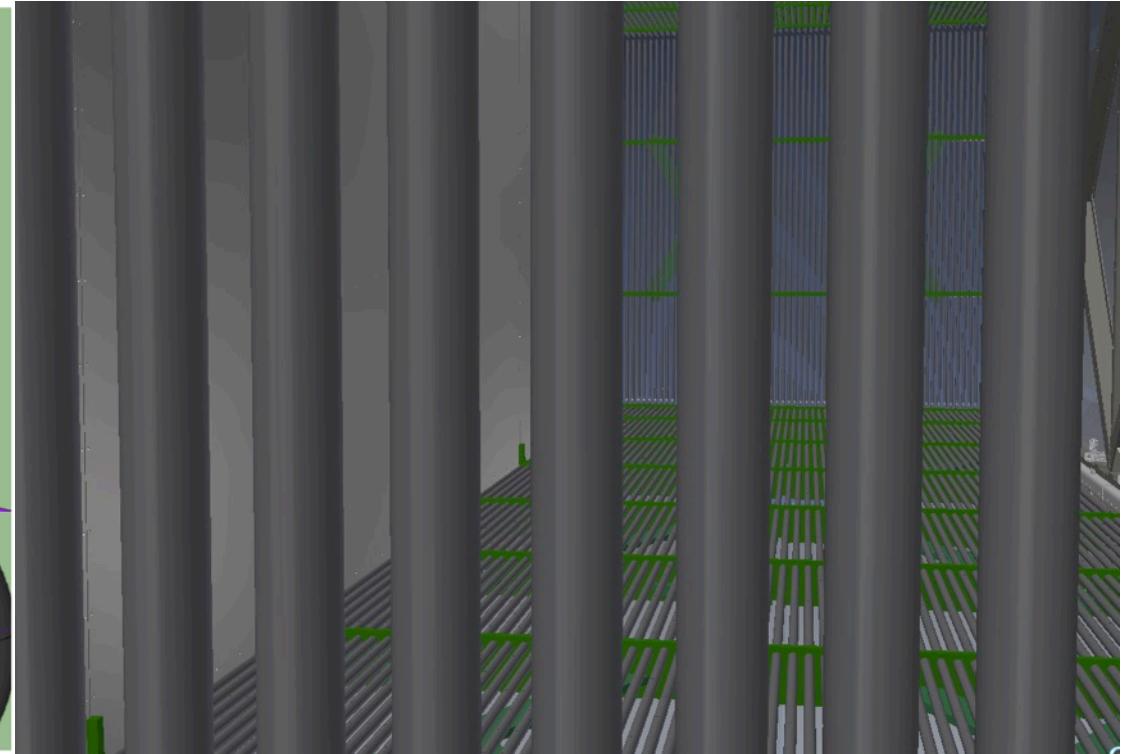
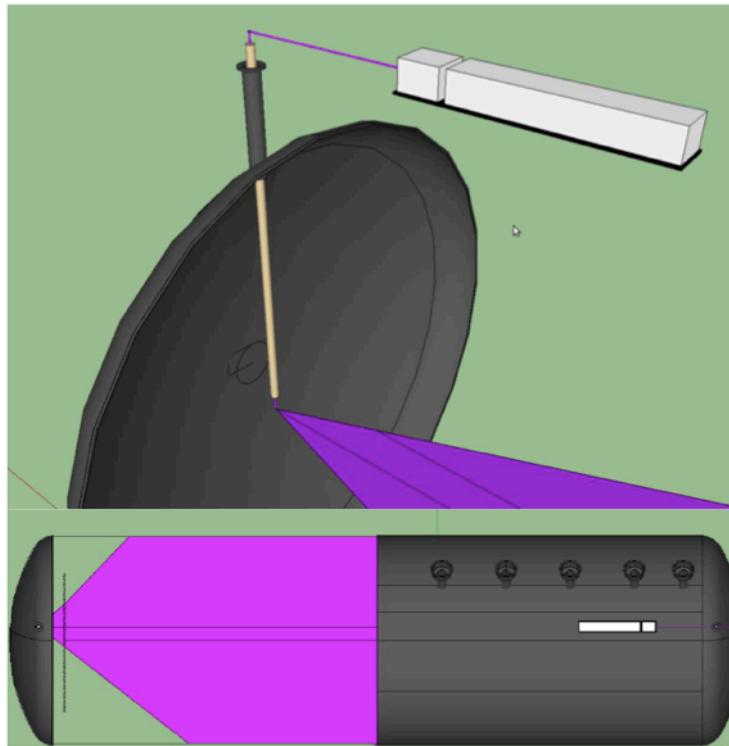
- Calibrate the electric field (non-uniformities)
- Induce reproducible ionization tracks
- Measure charge diffusion, charge lifetime



Liquid Argon

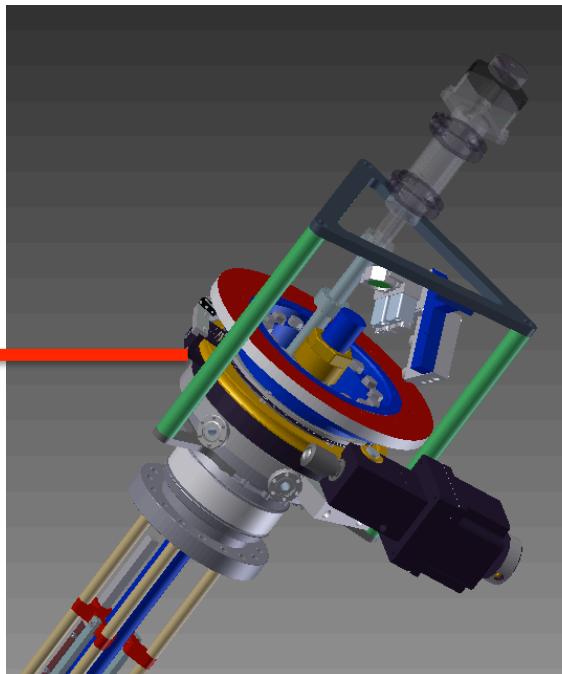
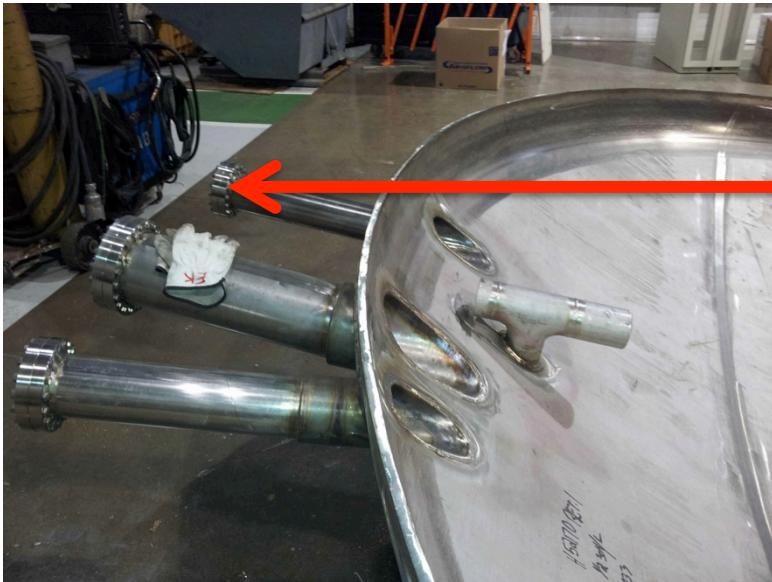
- Nd:YAG laser with 1064 nm output
- Wavelength of 266 nm produced by two second-harmonics generators



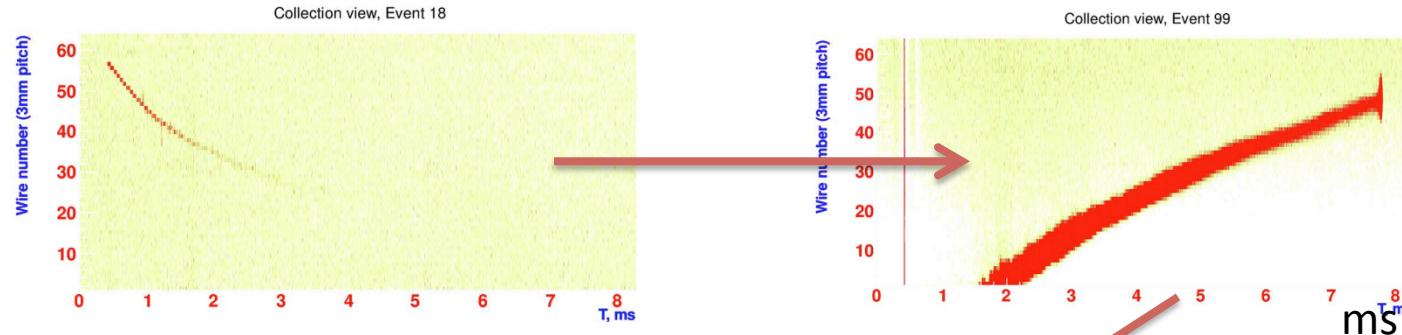
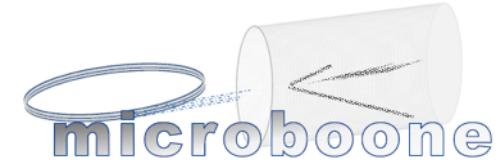


Two independent laser lines on either side of the cryostat

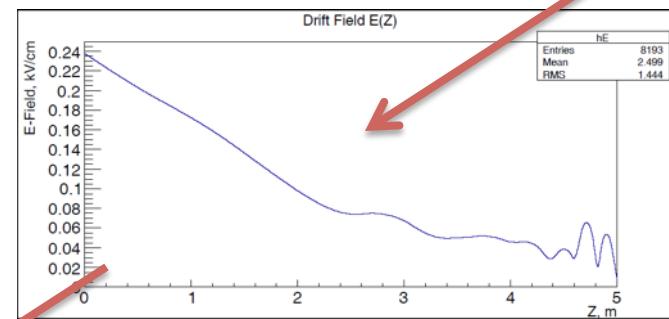
# Remote controlled steered laser beam (mirrors)



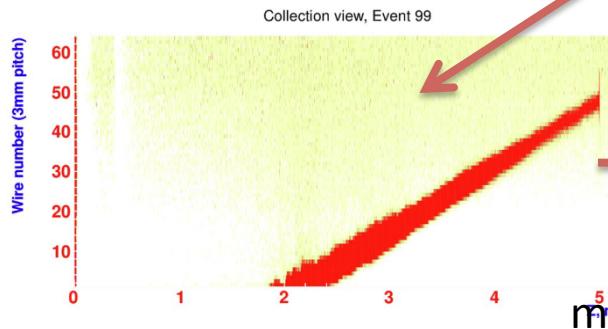
# Track calibration with laser (actual measurement ARGONTUBE)



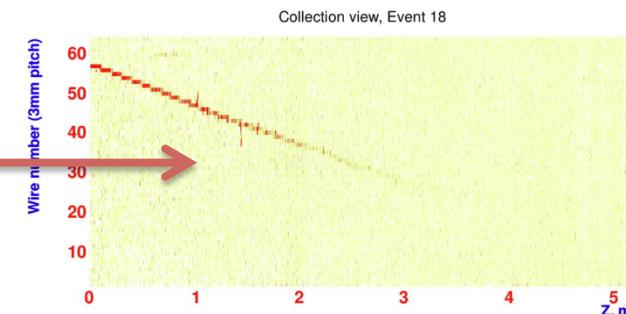
Distorted muon track, due  
to a hardware failure in the  
electric field generation



Field map



Corrected laser tracks



Corrected muon track

# Full scale test of the MicroBooNE laser system



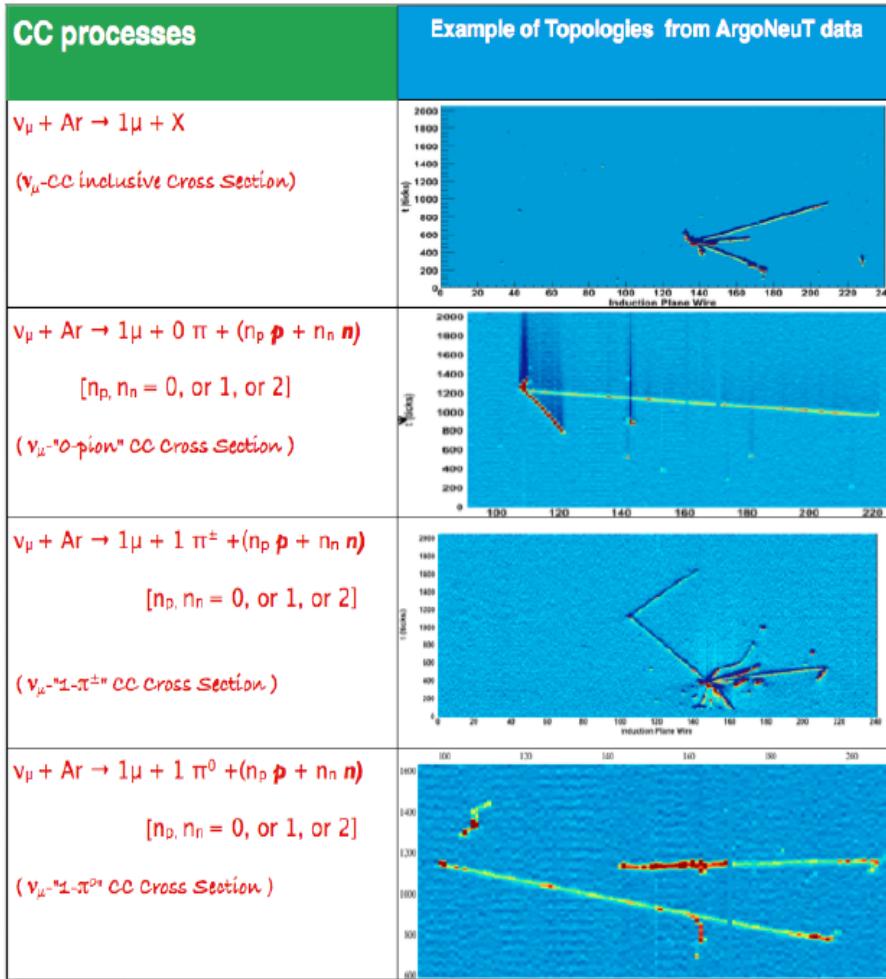
ArgoNeuT



- ArgoNeuT: 175 l of liquid Argon
- Placed in the NuMI neutrino beam at Fermilab
- 4 mm wire pitch
- Electric field of 500 V/cm
  
- Large samples of low-energy neutrino interactions (0.1-10 GeV) collected and analyzed



# Reconstruction of ArgoNeuT events



## Journal publications:

JINST 7 (2012) P10020

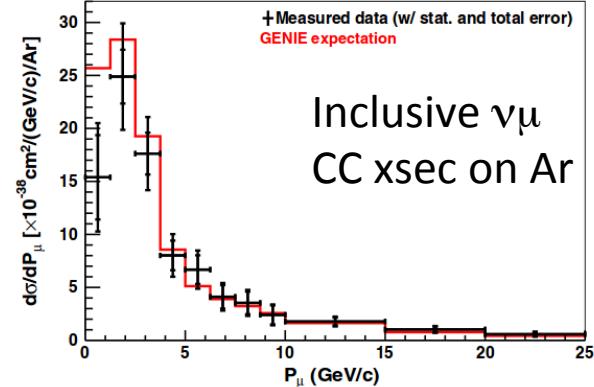
Analysis of a large sample of neutrino-induced muons

JINST 8 (2013) P08005

Study of electron-ion recombination

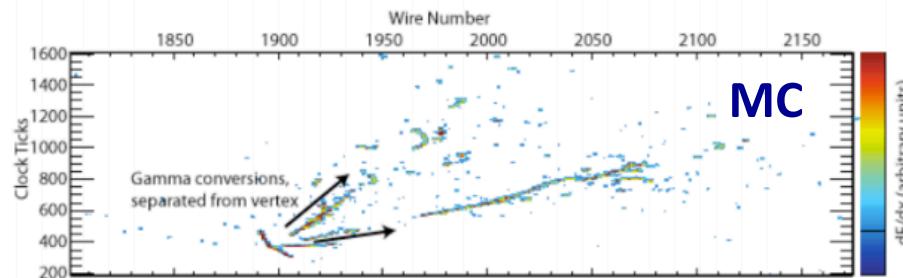
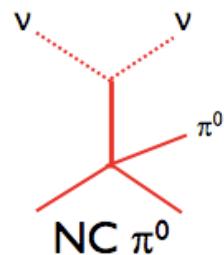
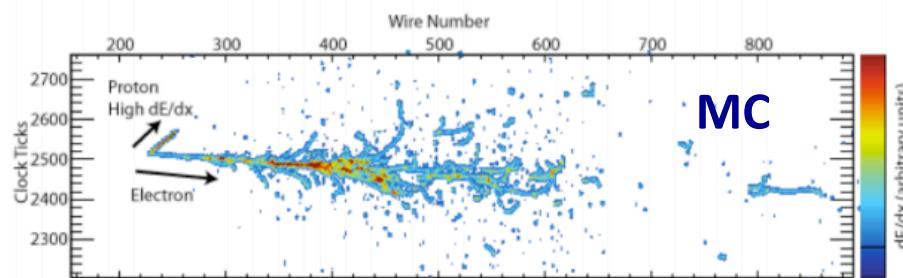
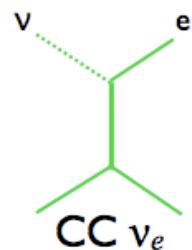
Phys. Rev. Lett. 108 (2012) 161802

First neutrino cross-section measurement on Argon

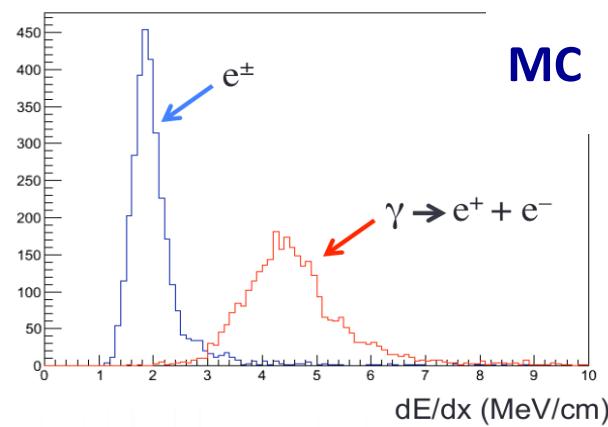


→ More to come

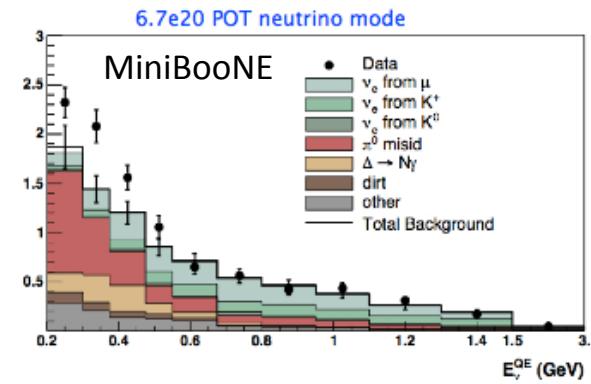
# $e/\gamma$ separation performance ( $dE/dx + \text{topology}$ )



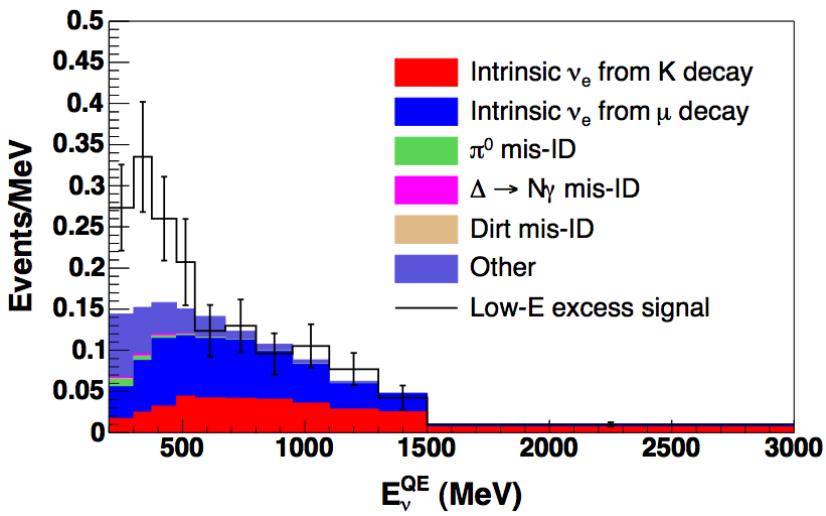
Can distinguish single photons from electrons in MicroBooNE by  $dE/dx$



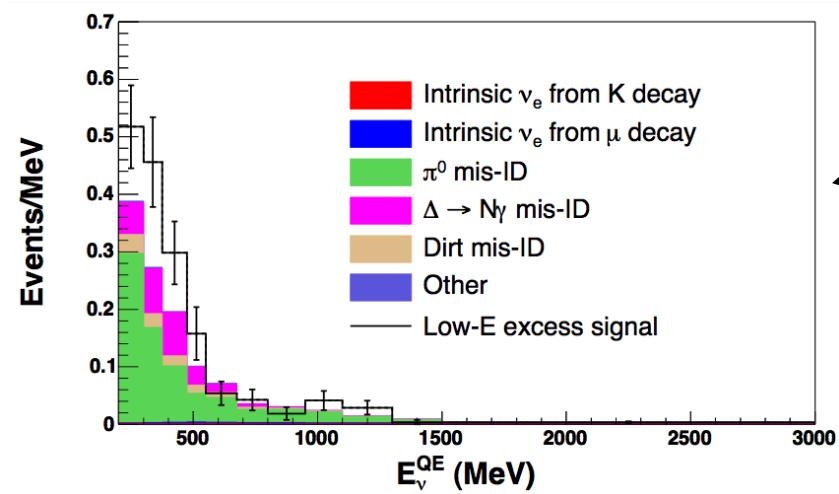
In ~1% of the events one photon is not seen (similar to  $e^-$ )



# MicroBooNE oscillation projections



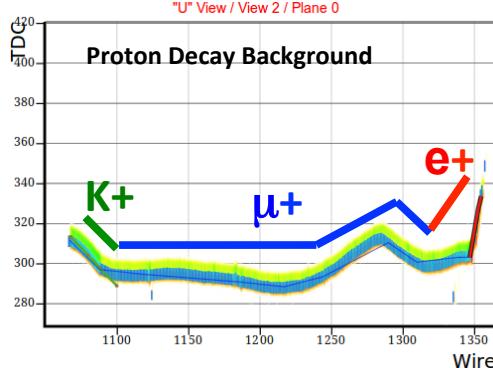
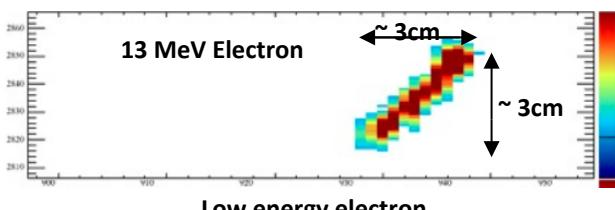
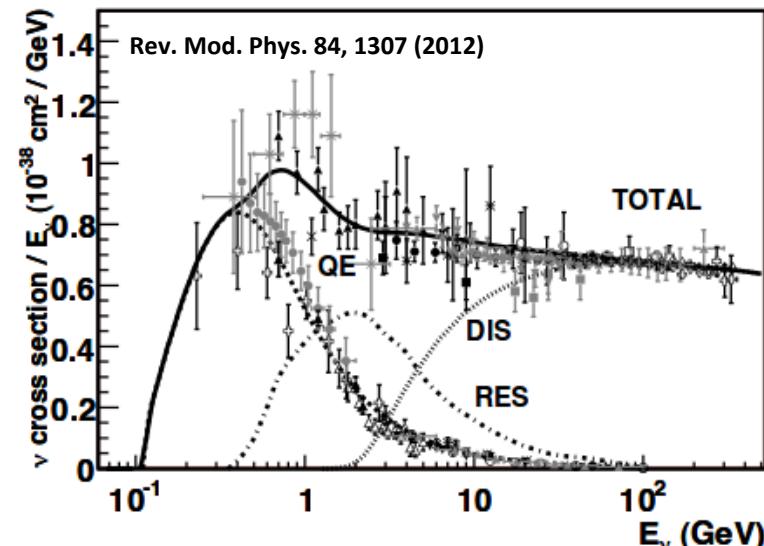
Confirm that the MiniBooNE  
signal is coming from an actual  
electron signal ( $>5\sigma$ )



Confirm a photon source  
( $>4\sigma$ )

(projections for  $6.6 \times 10^{20}$  POT)

# More physics goals



## Cross-section physics

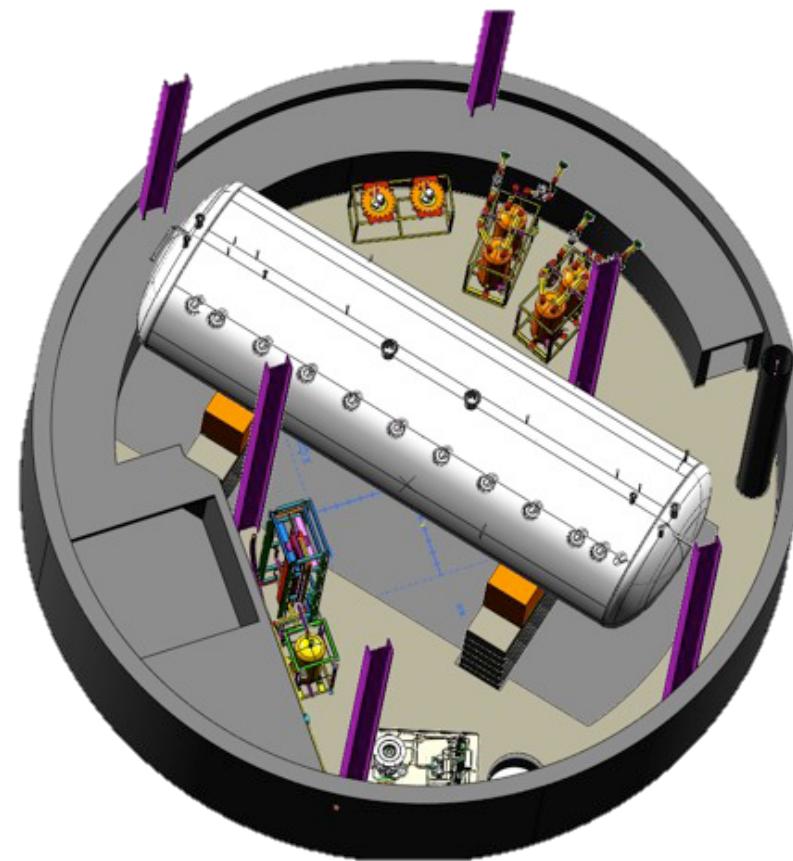
- Nuclear models
- Understanding low energy cross-sections crucial to oscillation experiment (present and future)
- MicroBooNE will see the NuMI and BNB beam, covering great energy range

## Supernova

- Low energy electron reconstruction

## Proton decay

- Study Kaon decays as background to “golden” channel  $p \rightarrow K^+ \nu_\mu$





# Summary



- Precision era in neutrino physics
- Liquid Argon TPCs provide necessary granularity and size
- MicroBooNE will:
  - explore the MiniBooNE low energy excess
  - perform neutrino cross section measurements
  - provide more interesting hints for neutrino models ?
  - serve as a step towards XXXL detectors
- TPC is built, optical system installed, readout ready.
- Installed in final experimental building this year, data taking starts 2014