MicroBooNE

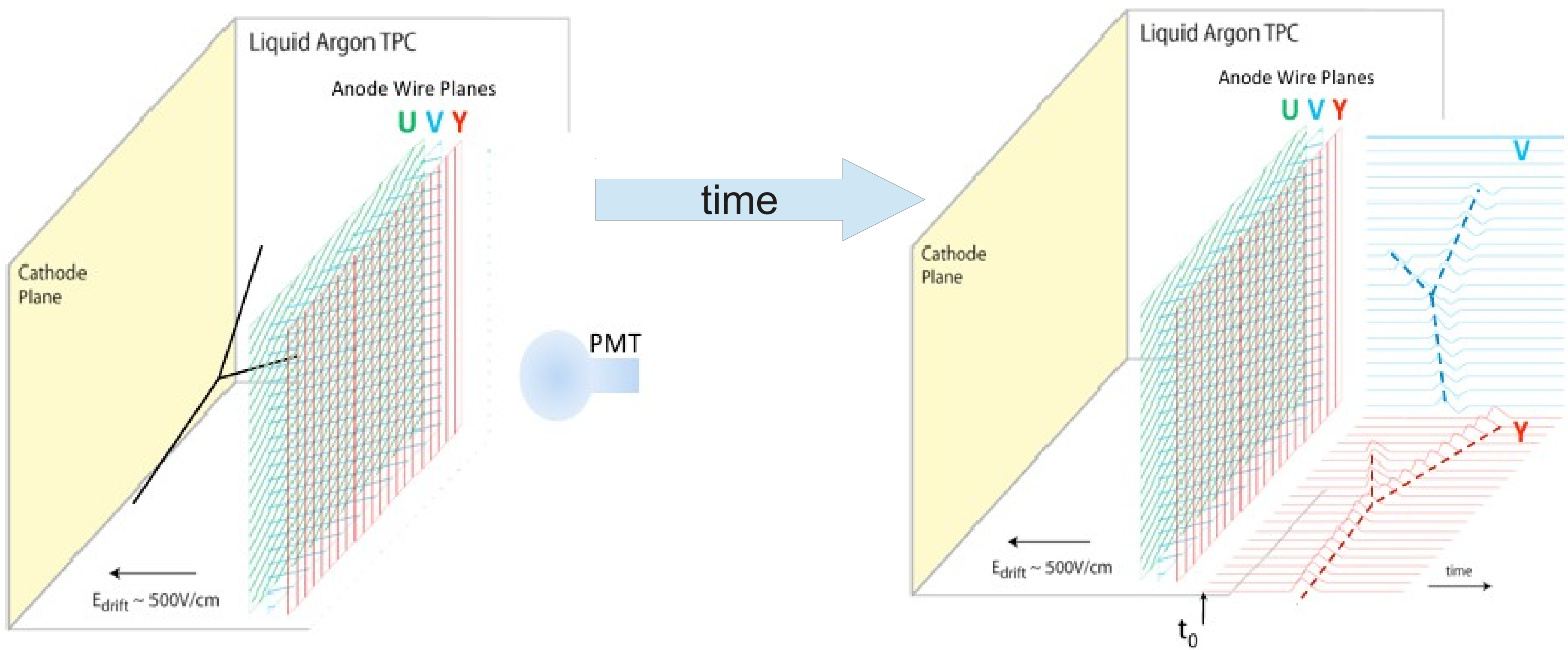
Andrzej Szelc
Yale University

Outline

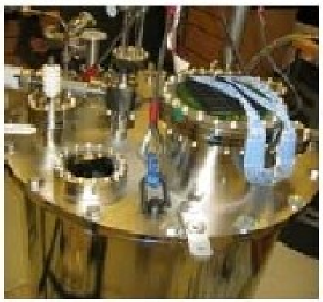
- The LArTPC.
- Physics with MicroBooNE.
- The MicroBooNE detector.

LArTPC Operation

- Charged particles in argon create electron-ion pairs and scintillation light.
- Electrons are drifted towards the anode wires.
- Multiple anode planes together with drift time allow 3D reconstruction.
- Collected charge allows calorimetric reconstruction.



US LAr R&D Program

Yale TPC


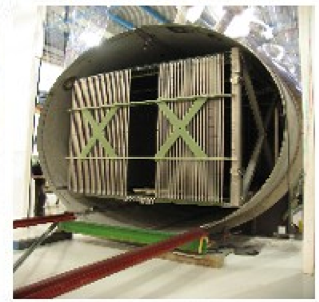
Location: Yale University
Active volume: 0.002 ton
operational: 2007

Bo

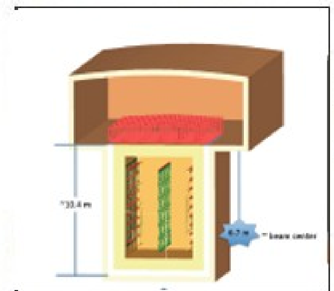

Location: Fermilab
Active volume: 0.02 ton
operational 2008

ArgoNeuT

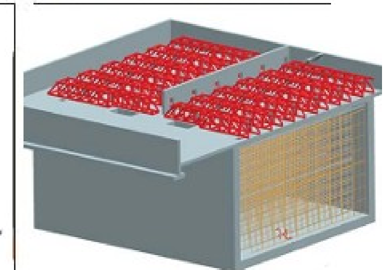

Location: Fermilab
Active volume: 0.3 ton
operational: 2008
First neutrinos: June 2009

MicroBooNE


Location Fermilab
Active volume: 0.1 kton
Operational: 2014

LAr1


Location: Fermilab
Active volume: 1 kton
Construction start: 2016?

LBNE


Location: Homestake
Active volume: 10/35 kton
Construction start 202?

Luke

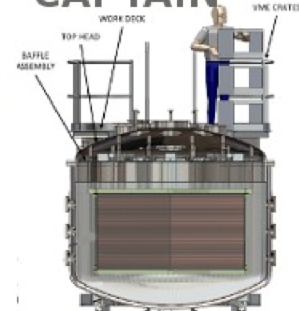

Location: Fermilab
Purpose: materials test st
Operational: since 2008

LAPD

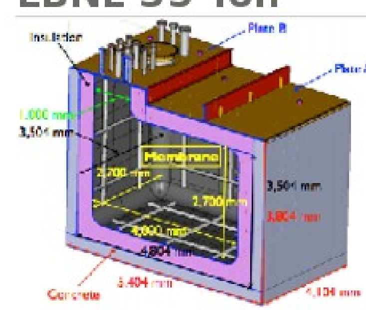

Location: Fermilab
Purpose: LAr purity demo
Operational: 2011

LArIAT


Location: Fermilab
Purpose: LArTPC calibration
Operational: 2014 (phase 1)

CAPTAIN


Location: LANL
Purpose: LArTPC calibration
Operational: 2014

LBNE 35 Ton


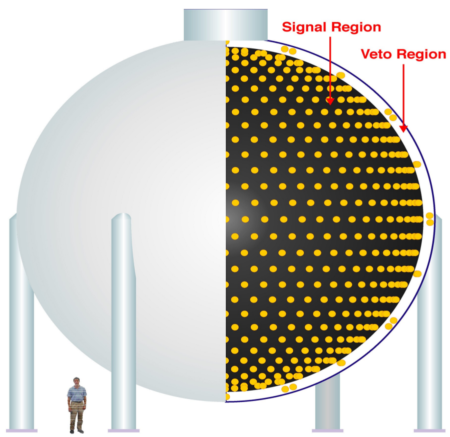
Location: Fermilab
Purpose: purity demo
Operational: 2013

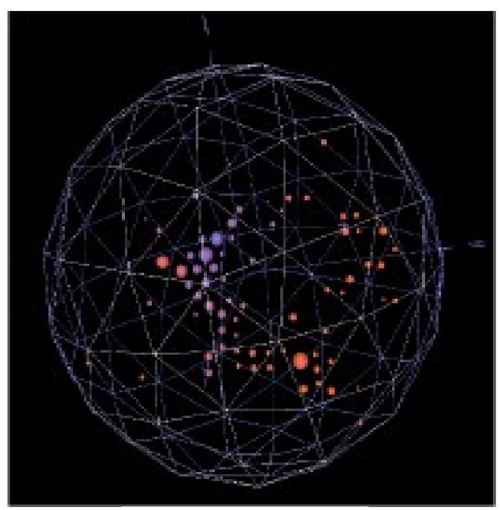
MicroBooNE Physics Goals

MiniBooNE

- MiniBooNE, a Cherenkov detector, ran on the Booster beam line.
- It observed an excess of ν_e-like signal in the ν_μ beam line.
- This result together with recent short baseline measurements of neutrinos from nuclear reactors and radioactive sources hint at possible oscillations into a sterile neutrino.
- It is not possible to determine whether the MiniBooNE signal is due to electrons or photons.

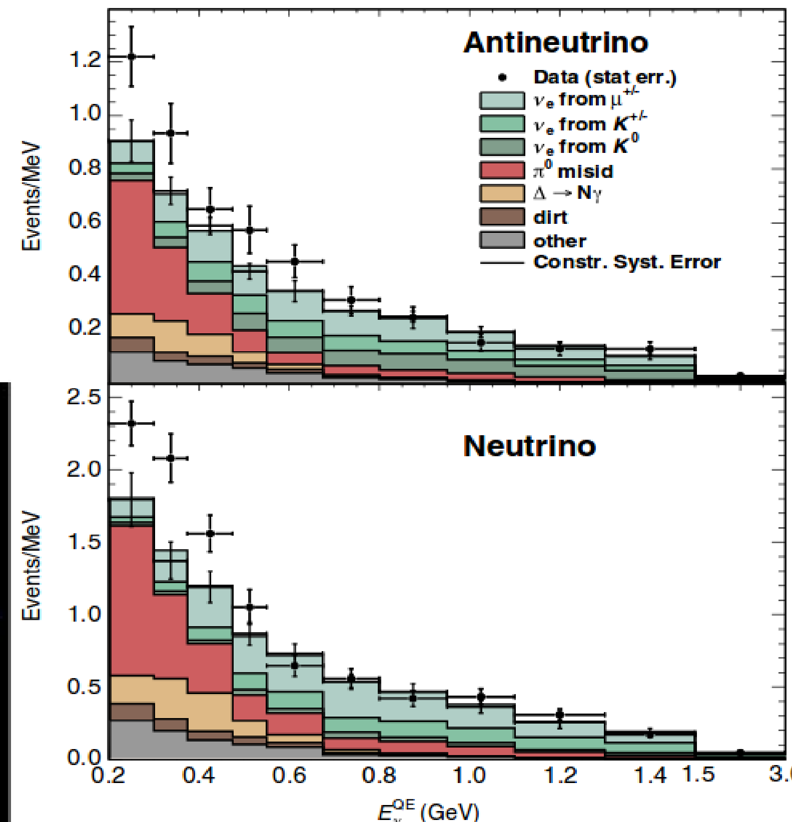
MiniBooNE Detector





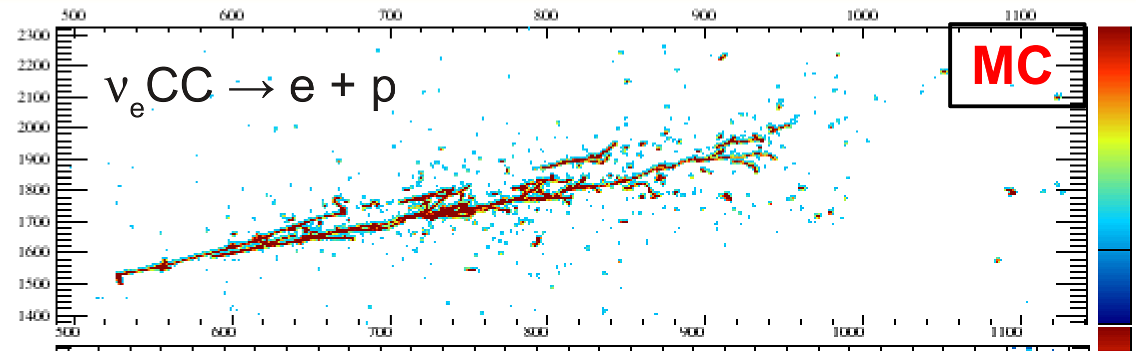
$$\nu_e n \to e^- p$$

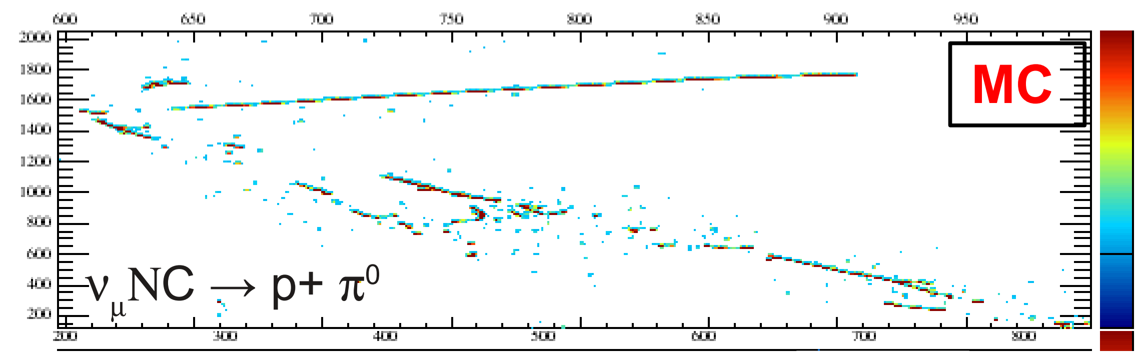
Phys. Rev. Lett. 110, 161801 (2013)

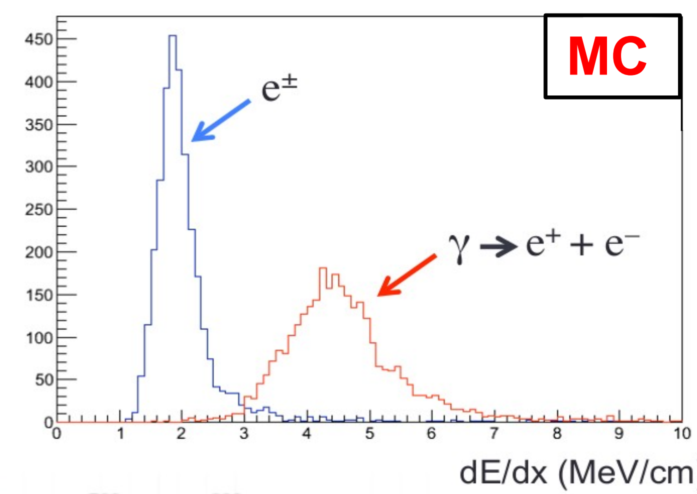


γ/e separation in LAr

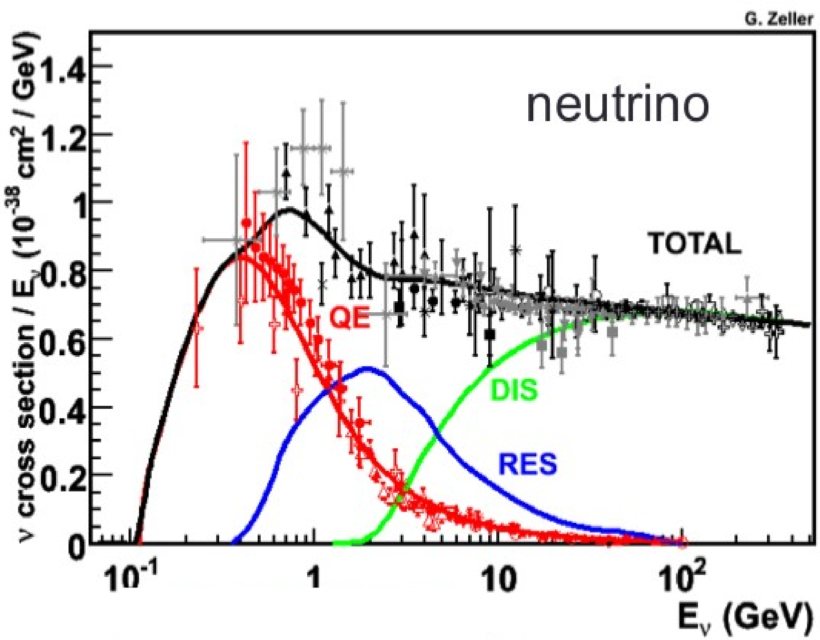
- The LArTPC provides a unique way to differentiate between electrons and photons based on the ionization at the start of the EM-shower.
- MicroBooNE is situated on the same beam line as MiniBooNE and will be able to determine whether the excess is a result of electrons or photons.
- Perfecting e/γ separation will be necessary for future long baseline ν_e appearance searches.

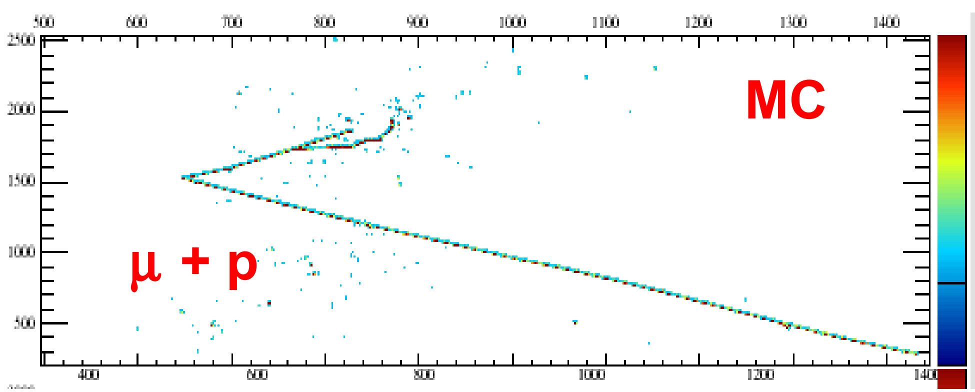






Cross-Section Physics





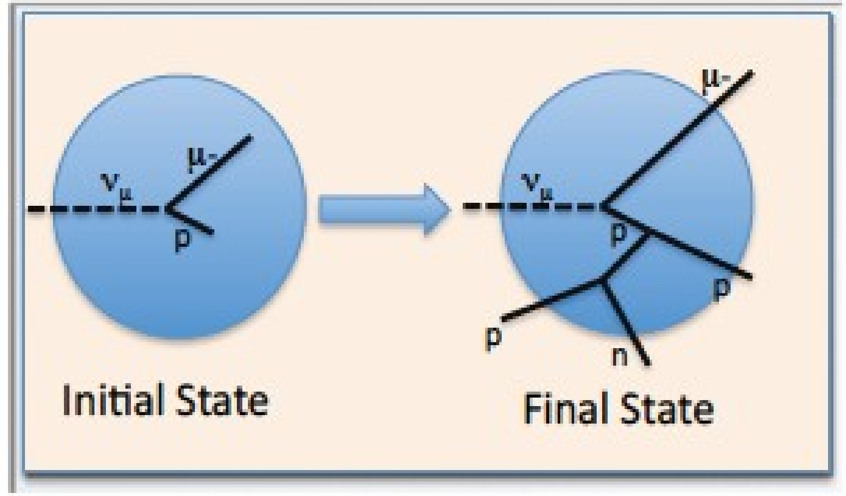
- The energy region accessible to MicroBooNE (~1GeV) is less explored than higher energies.

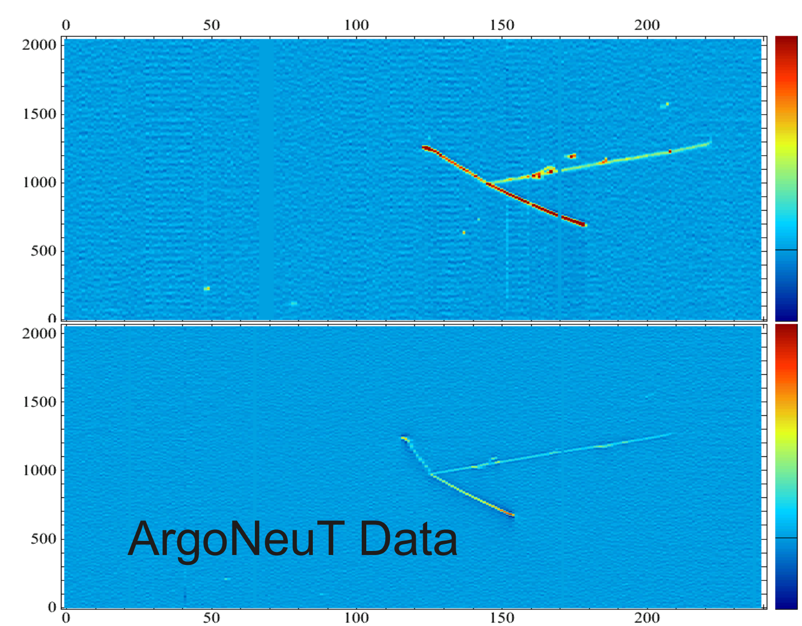
- No measurements for argon in this region.

- MicroBooNE will be able to explore a whole range of topologies to fill this gap.

Nuclear effects

- Argon is a large nucleus and nuclear effects will play a role in what we observe as final states
- ArgoNeuT has seen effects of FSI and hints of nucleon-nucleon correlations *(talk by J.Asaadi)*.
- MicroBooNE will have a smaller wire pitch (3mm vs 4mm - better precision) and more statistics.





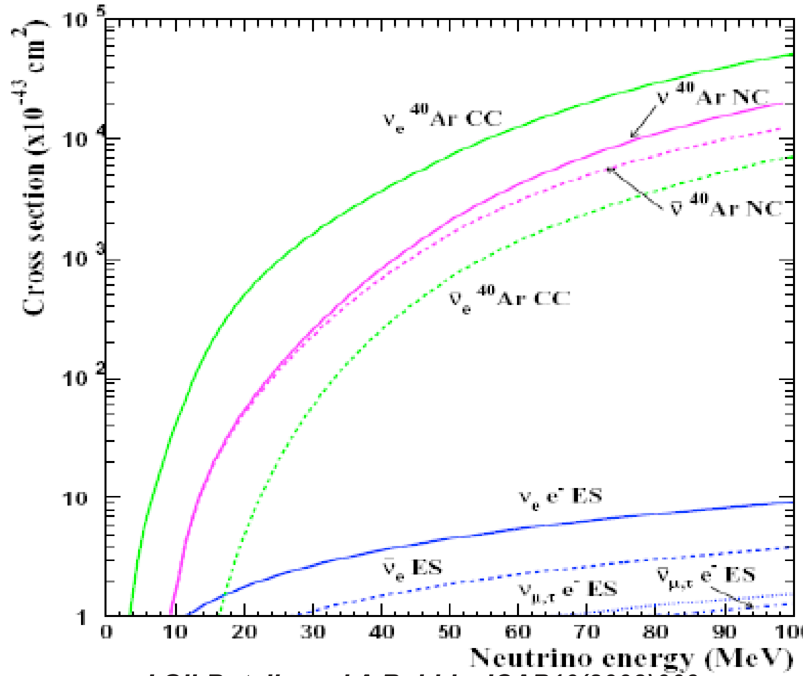
SuperNova neutrinos

- CC ν_e Absorption (on Ar) is the dominating process, $\nu_e + Ar \rightarrow K^* + e^-$

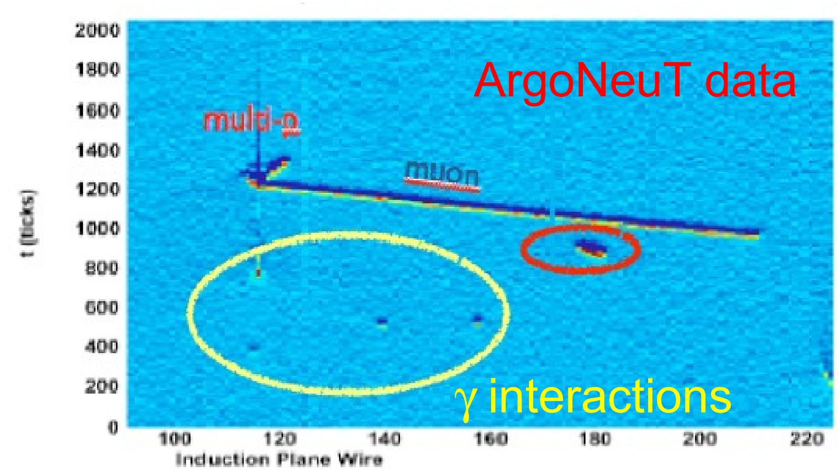
  @ E_ν=20MeV σ_{abs} = $6\times10^{-41}cm^2$

- Complementary to WC detectors (mainly sensitive to anti-ν_e)
- LAr can detect the interaction of the de-excitation gammas from the excited K states
- MicroBooNE cannot trigger on SN, due to surface location and will rely on a trigger from SNEWS.

- Expect ~10-20 from SN in galactic center (in a time period of ~20s).



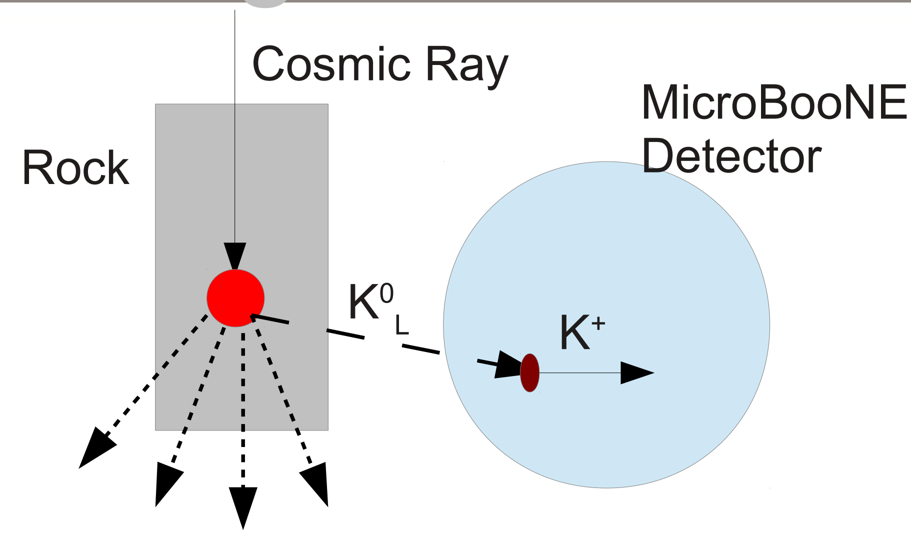
I Gil-Botella and A Rubbia JCAP10(2003)009

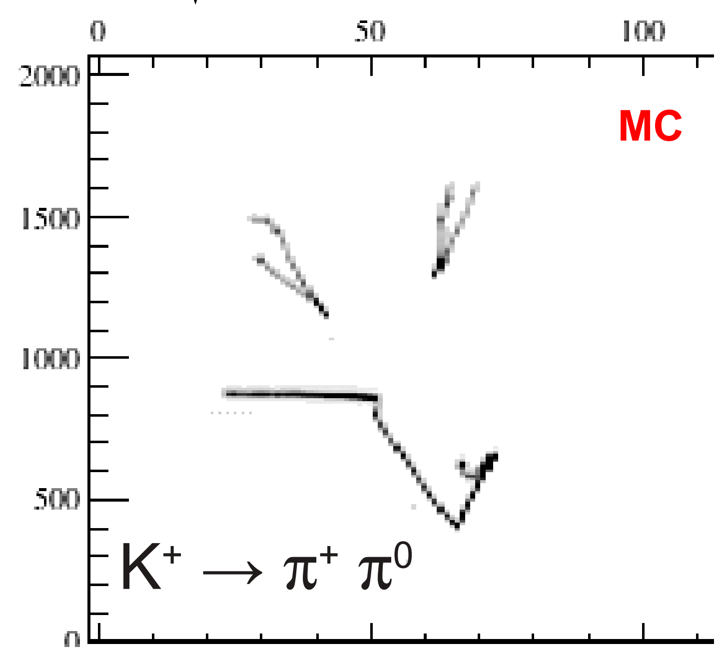


Proton Decay Backgrounds

•Future large liquid argon detectors can be competitive in proton decay studies by virtue of being able to reconstruct topologies difficult for Cherenkov detectors.

•MicroBooNE will be able to refine reconstruction techniques for the relevant topologies and study their backgrounds.





What would you like to operate a TPC?

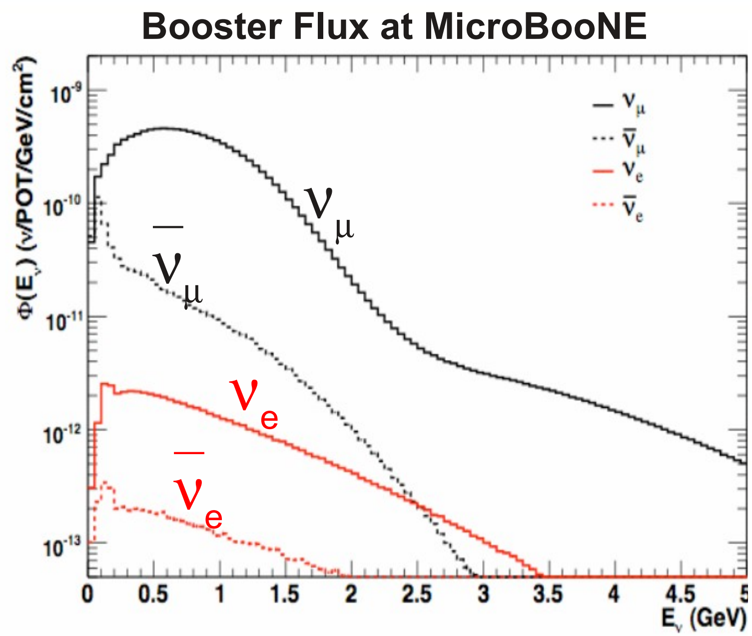
- A source of neutrinos.
- Time Projection Chamber.
- High Voltage to drift electrons.
- Argon, cooled and pure.
- Photomultipliers.
- Readout electronics + DAQ.
- UV Laser.
- A cryostat to hold it all in.
- A building to put the cryostat.

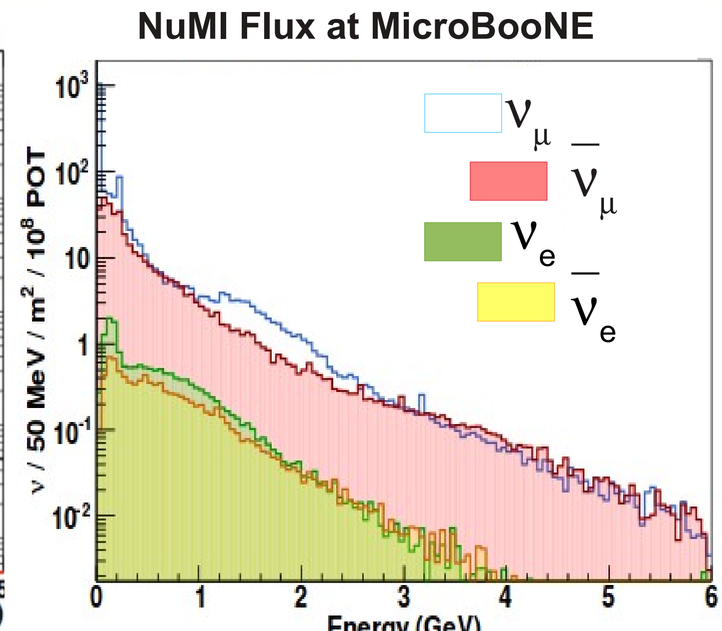
Booster Neutrino Beam + NuMI Neutrino Beam

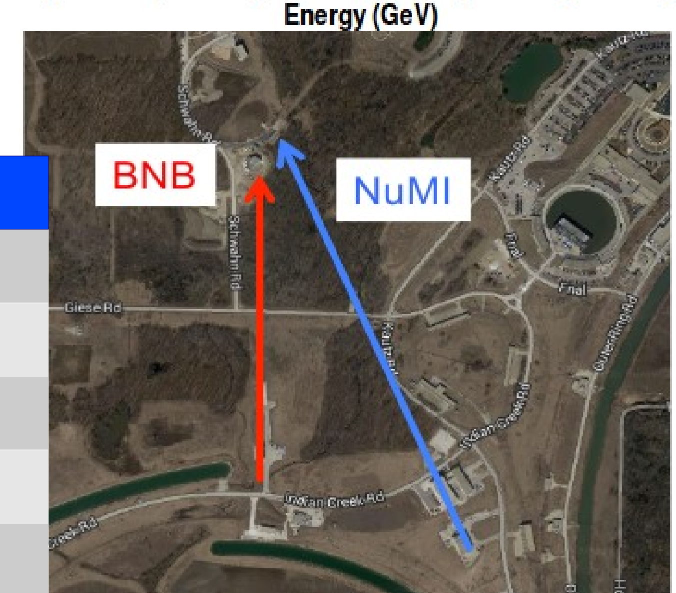
- MicroBooNE is positioned on the Booster Beam line, just in front of the MiniBooNE detector.

- It will also see neutrino from the higher energy off-axis NuMI beam.

- This allows for a diverse and rich physics program.



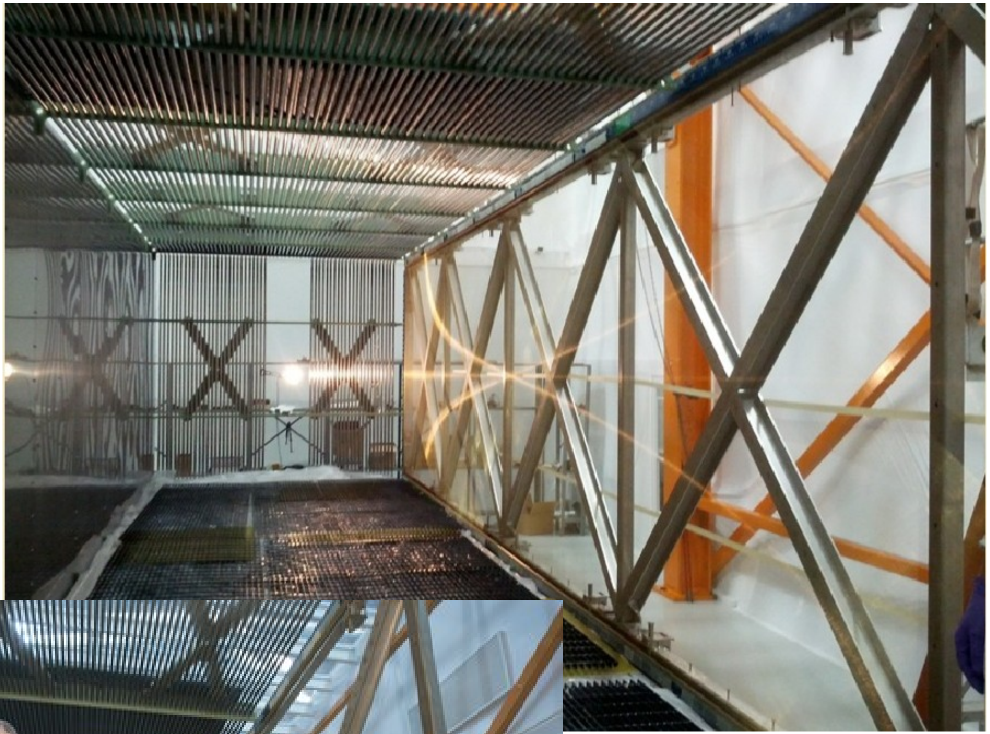




	BNB	NuMI
POT (3 years)	6×10^{20}	8×10^{20}
Nm CCQE	66,000	25,000
NC p0	8,000	3,000
Ne CCQE	400	1,000
Total	143,000	60,000

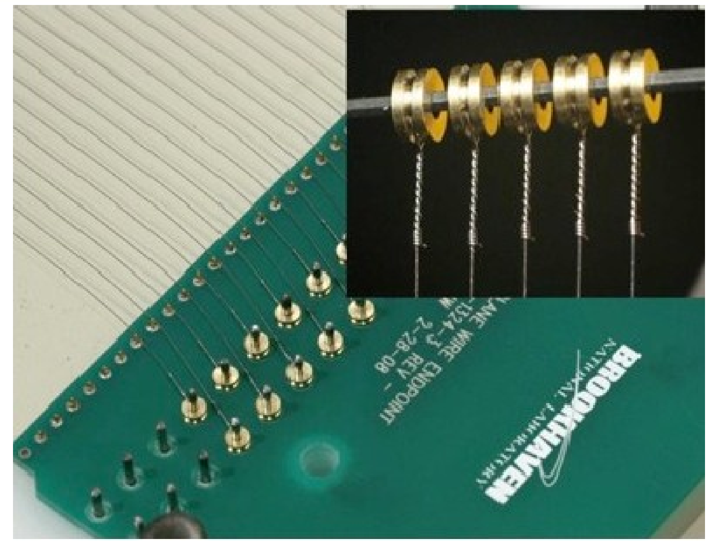
TPC+wires

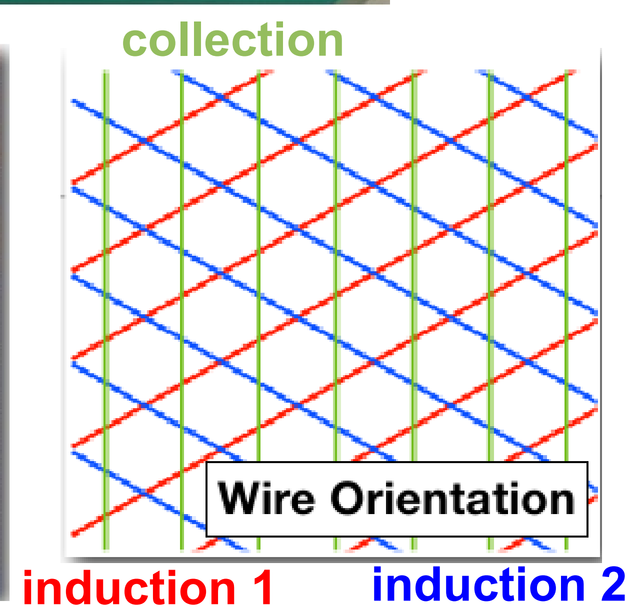
- 87 tons (active mass).
- 256 cm drift.
- 233 cm chamber height.
- 1036 cm length.
- Holds more than 250 ArgoNeuT TPCs.
- 8256 wires (3mm pitch) in 3 planes:
  - 3456 Collection channels.
  - 4800 Induction channels.
- All wires mounted and ready!



TPC+wires

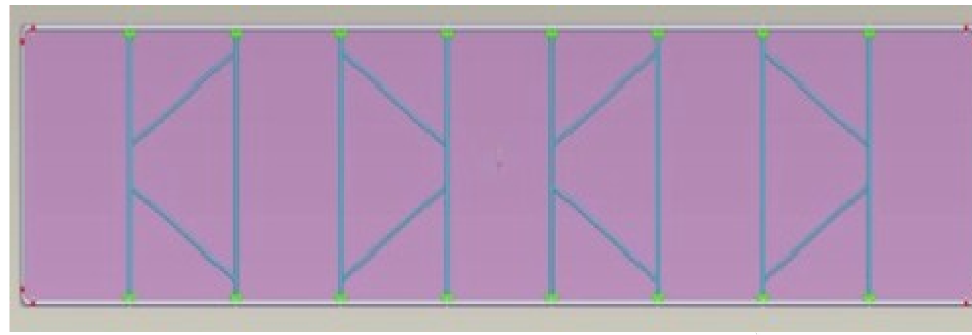
- Wires mounted on wire carrier boards.
- Three orientations give redundancy in reconstruction and break degeneracies.
- Wire tension is being tested.
- The TPC will the be rolled into the cryostat using special rails.

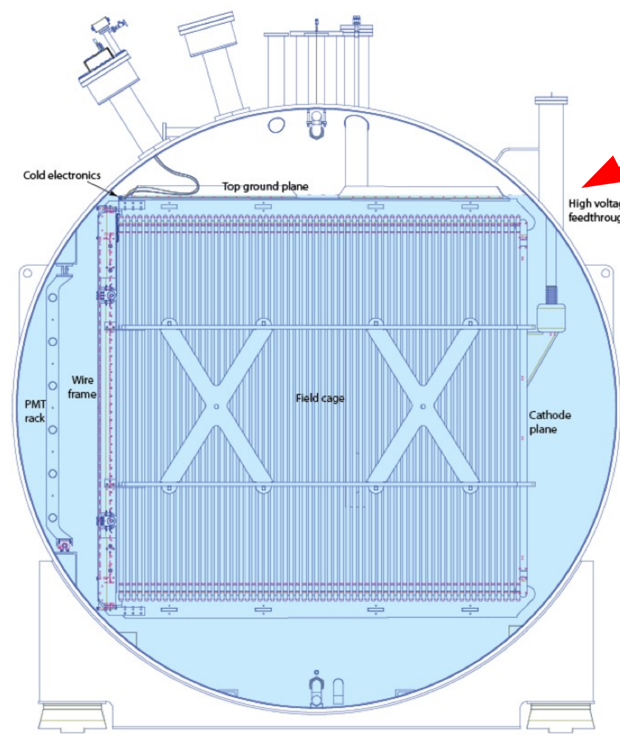


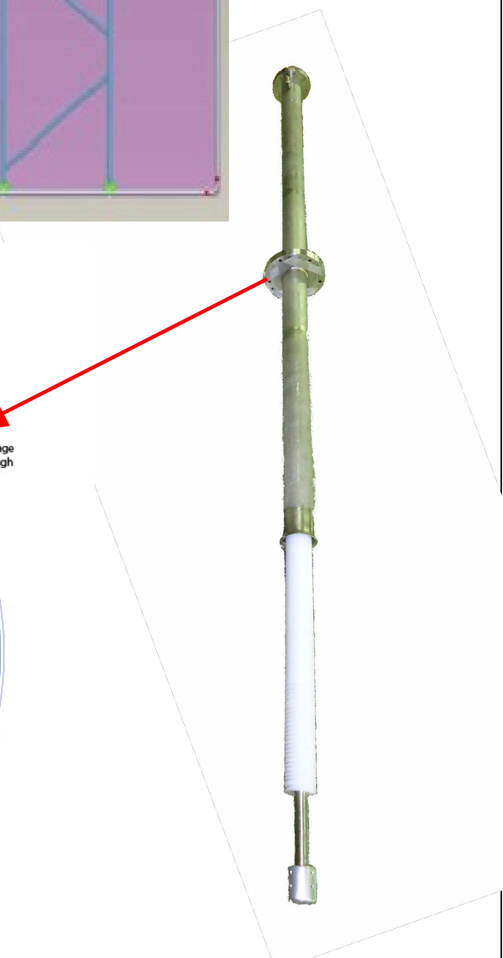


High Voltage

- The cathode plane is made of nine stainless steel sheets.
- The HV feed through is modeled after an ICARUS design.
- Need to generate field to sustain 2.56 meter drift.
- Require -128 kV at the cathode for 0.5kV/cm field.

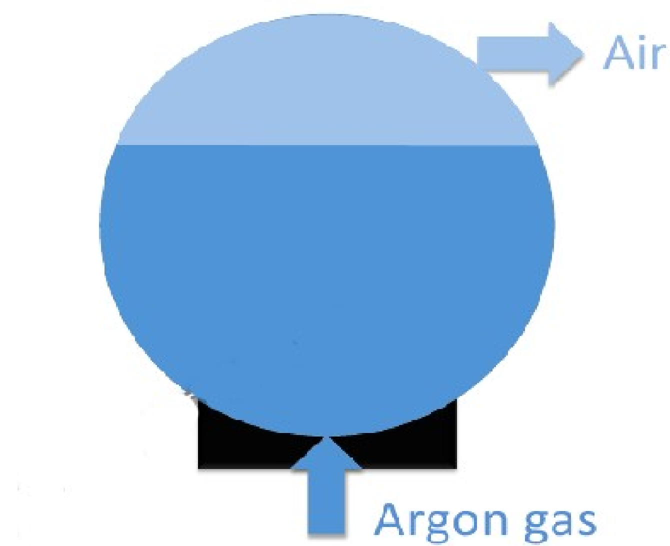


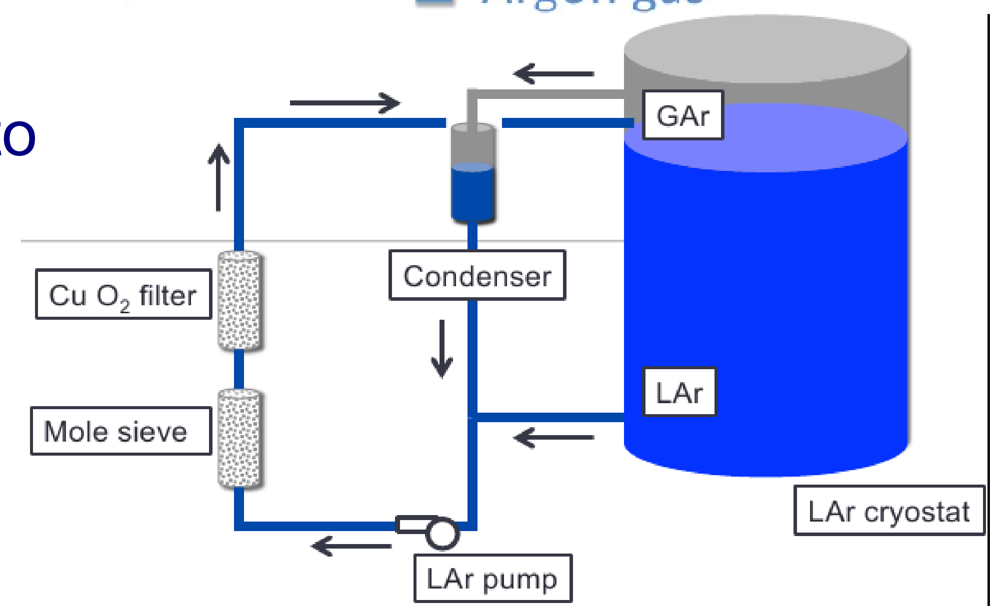




Argon cooling and purification

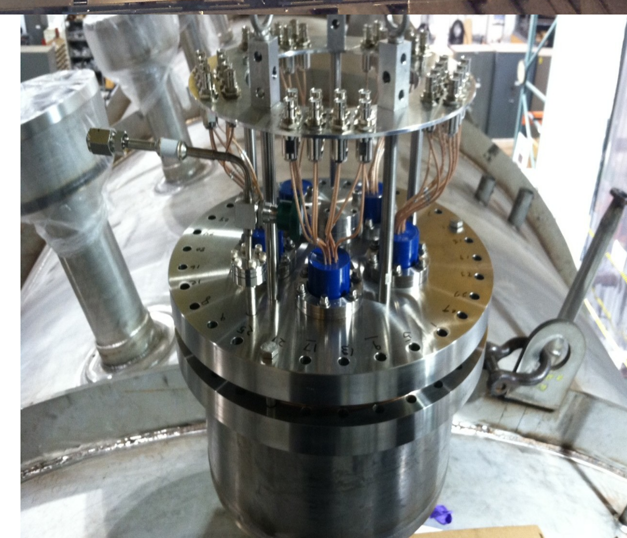
- Argon needs to be pure – impurities attach the drifting charge and weaken the signal.
- Constant recirculation through CuO_2 and molecular sieve to remove impurities.
- Will use argon gas piston to remove air from cryostat (although we are capable of evacuation). The technique has already been shown to work in LAPD.
- The cryogenic system is being deployed in the detector hall and getting ready for a test run.





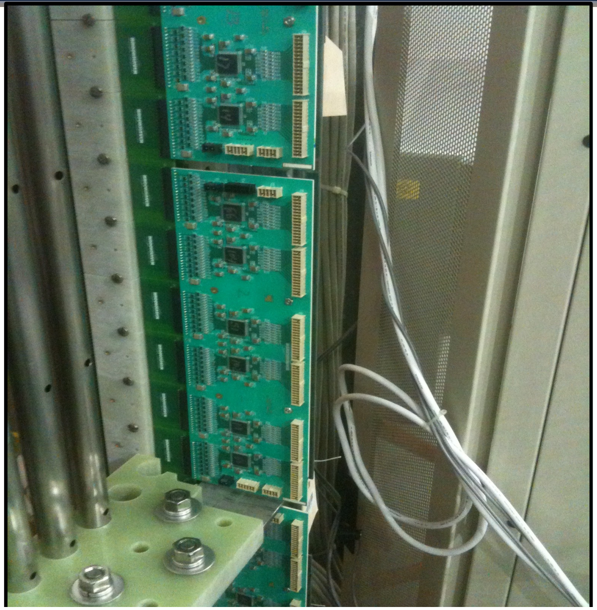
Photomultipliers

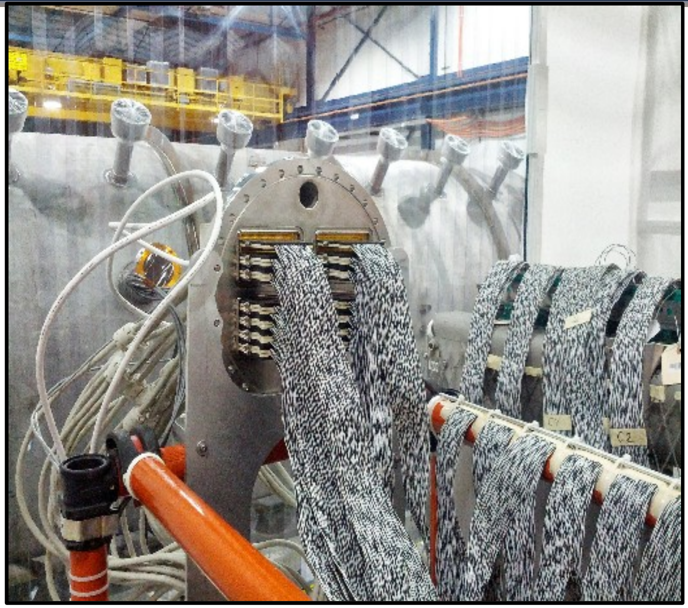
- Liquid argon produces scintillation light (40k photons/MeV).
- It is in the VUV range, so need a wavelength shifter to see it in PMTs.
- Will use acrylic plates coated with TPB.
- PMTs already installed in the cryostat!



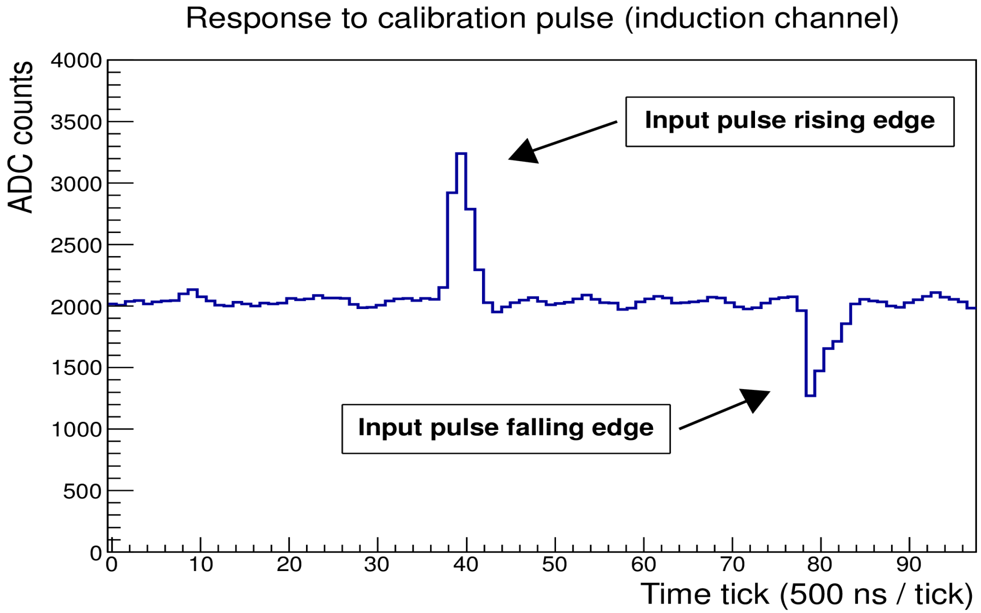
Cold Electronics

- Cold electronics are the same as those to be used in LBNE.
- Lower noise, and allows driving the signal longer distances (important for future large detectors).



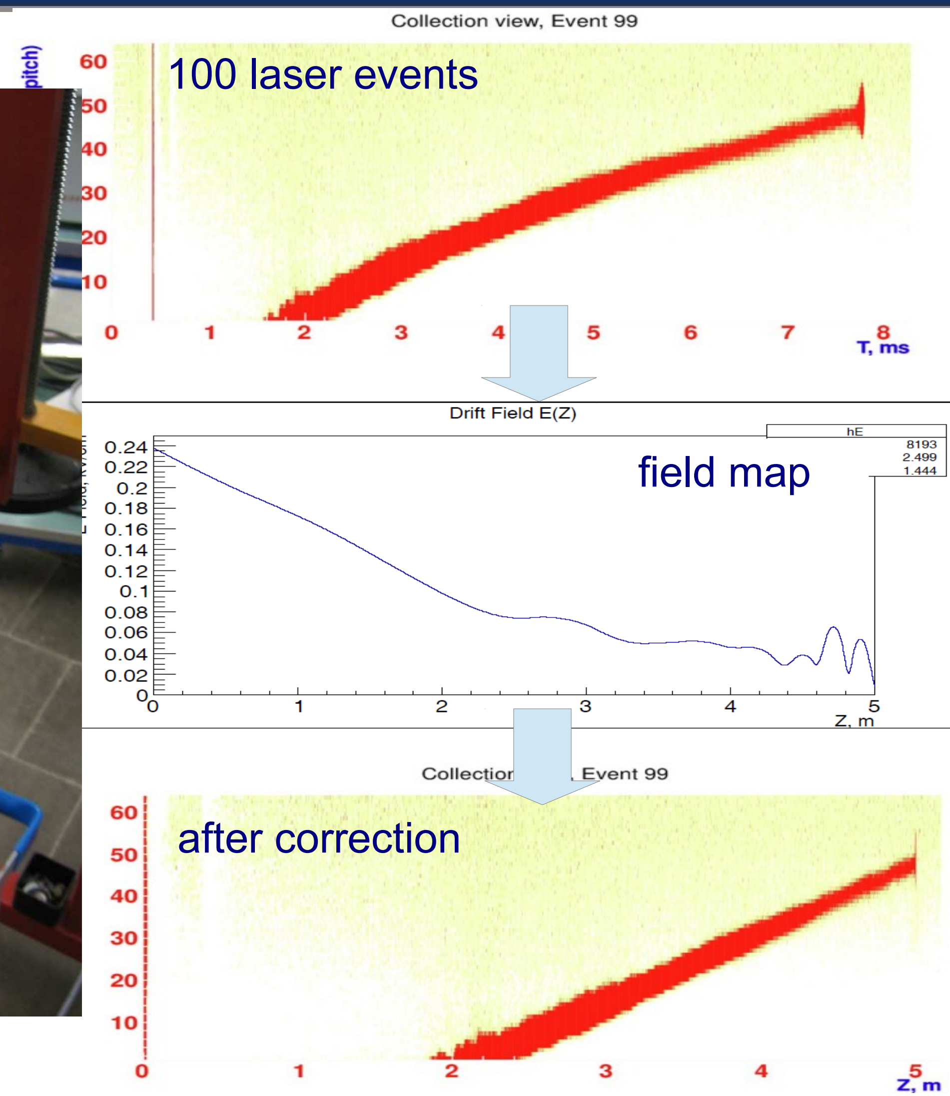


- Motherboards installed on the wire carrier boards.
- All channels tested, one feed-through at a time.



UV Laser

- UV Laser being installed to use for calibration.
- Allows mapping potential field distortions with a “track” guaranteed to be straight - muons can undergo multiple scattering.
- Laser goes in via optical feedthrough.
- Internal mirror allows remote change of angle.



The Cryostat

- The Cryostat is already at Fermilab.
- TPC insertion has been tested.
- Once the TPC is in, the endcap will be welded on and the cryostat transported to the detector building.
- The cryostat will be insulated with foam.

Liquid Argon Test Facility (LArTF)

- The building is ready.
- The preparations to host the detector are in full swing.

- DAQ racks already in place.
- The cryostat with TPC inside will be lowered by crane.

Conclusions

- The construction of the MicroBooNE detector is nearing completion.

- After the final touches it will be transported to the detector hall.

- We're looking forward to taking physics data in 2014.

- Stay tuned!

Muito Obrigado!

MicroBooNE Collaboration

Brookhaven Lab
Mary Bishai
Hucheng Chen
Kai Chen
Susan Duffin
Jason Farell
Francesco Lanni
Yichen Li
David Lissauer
George Mahler
Joseph Mead
Veljko Radeka
Sergio Rescia
Andres Ruga
Jack Sondericker
Craig Thorn
Bo Yu

University of Chicago
Will Foreman
Johnny Ho
David Schmitz

University of Cincinnati
Ryan Grosso
Jason St. John
Randy Johnson
Bryce Littlejohn

Columbia University
Nancy Bishop
Leslie Camilleri
David Caratelli
Cheng-Yi Chi
Jennet Dickinson
Georgia Karagiorgi
David Kaleko
Bill Seligman
Mike Shaevitz
Bill Sippach
Kathleen Tatum
Kazuhiro Terao
Bill Willis

Fermilab
Roberto Acciarri
Bruce Baller
Dixon Bogert
Ben Carls
Michael Cooke
Herb Greenlee
Cat James
Eric James
Hans Jostlein
Mike Kirby
Sarah Lockwitz
Byron Lundberg
Alberto Marchionni
Stephen Pordes
Jennifer Raaf
Gina Rameika
Brian Rebel
Rich Schmitt
Steve Wolbers
Tingjun Yang
Sam Zeller (*)

Kansas State University
Tim Bolton
Saima Farooq
Sowjanya Gollapinni
Glenn Horton-Smith
David McKee

Los Alamos National Laboratory
Gerry Garvey
Jackie Gonzales
Wes Ketchum
Bill Louis
Geoff Mills
Zarko Pavlovic
Richard Van de Water

Massachusetts Institute of Technology
William Barletta
Len Bugel
Gabriel Collin
Janet Conrad
Christina Ignarra
Ben Jones
Teppei Katori
Matt Toups

Michigan State University
Carl Bromberg
Dan Edmunds

New Mexico State University
Alistair McLean
Tia Miceli
Vassili Papavassiliou
Stephen Pate
Katherine Woodruff

Otterbein University
Nathaniel Tagg

Princeton University
Kirk McDonald
Bill Sands

Saint Mary's University of Minnesota
Paul Nienaber

SLAC
Mark Convery
Matt Graham
David Muller

Syracuse University
Jonathan Asaadi
Mitch Soderberg

University of Texas at Austin
Son Cao
Junting Huang
Karol Lang
Rashid Mehdiyev

Laboratory for High Energy Physics, University of Bern, Switzerland
Antonio Ereditato
Igor Kreslo
Michele Weber
Christoph Rudolf von Rohr
Thomas Strauss

Istituto Nazionale di Fisica Nucleare, Italy
Flavio Cavanna
Ornella Palamara

Virginia Tech
Mindy Jen
Leonidas Kalousis
Camillo Mariani

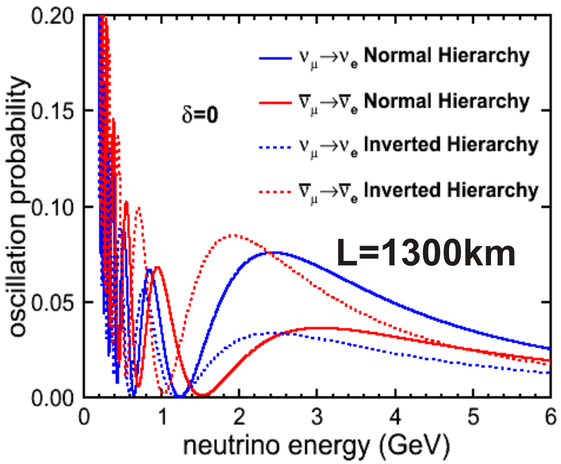
Yale University
Corey Adams
Christina Brasco
Eric Church
Bonnie T. Fleming (*)
Ellen Klein
Ornella Palamara
Flavio Cavanna
Roxanne Guenette
Kinga Partyka
Andrzej Szelc

Back Up Slides

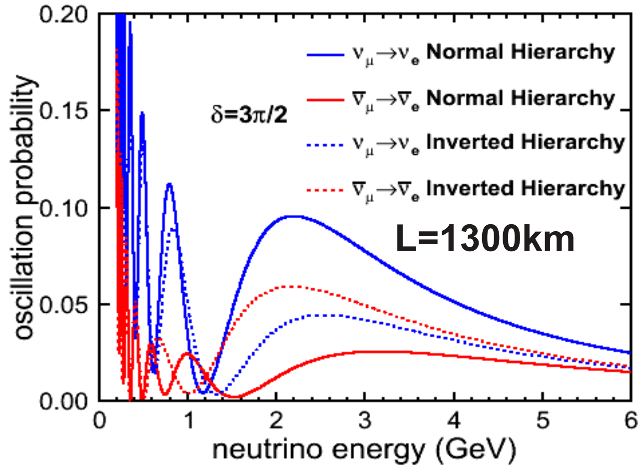
Physics with LArTPCs

The LArTPC is becoming the go-to technology in neutrino physics

No CP violation

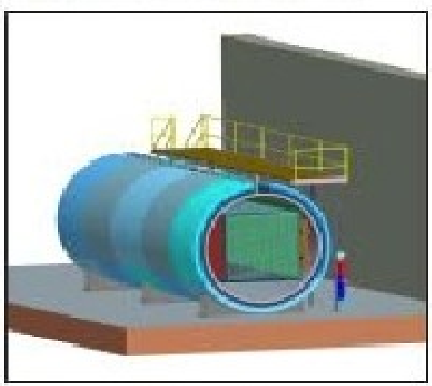


Maximal CP violation

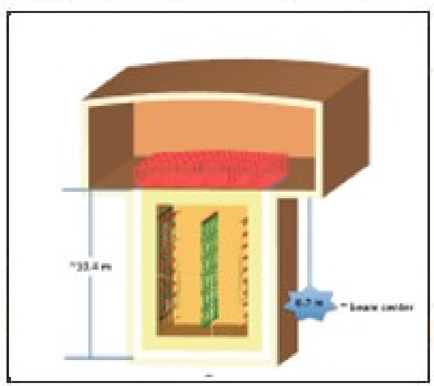


The physics effects we want to measure are becoming more and more subtle. Need to keep errors as small as possible. Increasing statistics is hard! So let's try systematic errors.

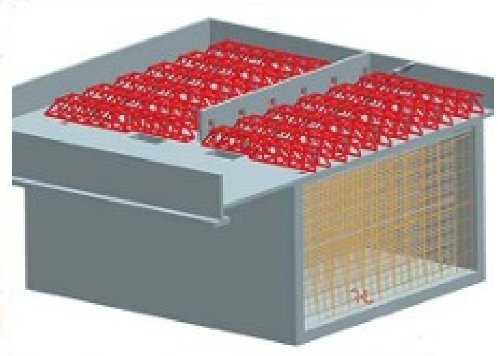
MicroBooNE



LAr1



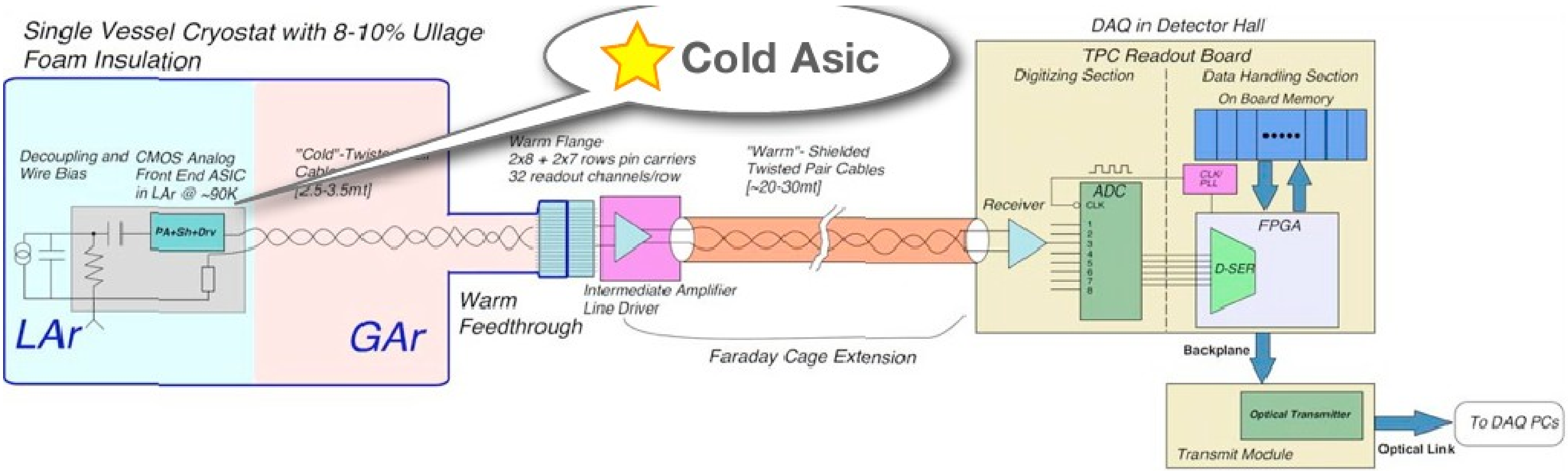
LBNE



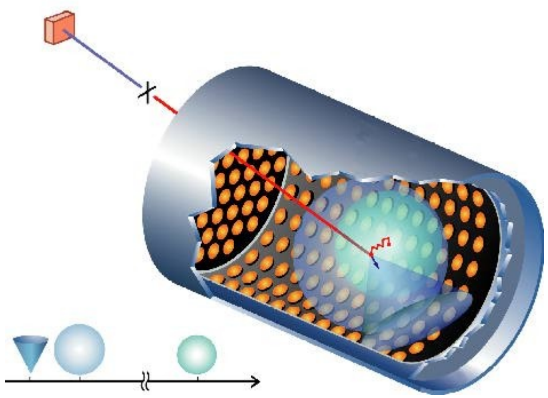
+Several other projects throughout the world

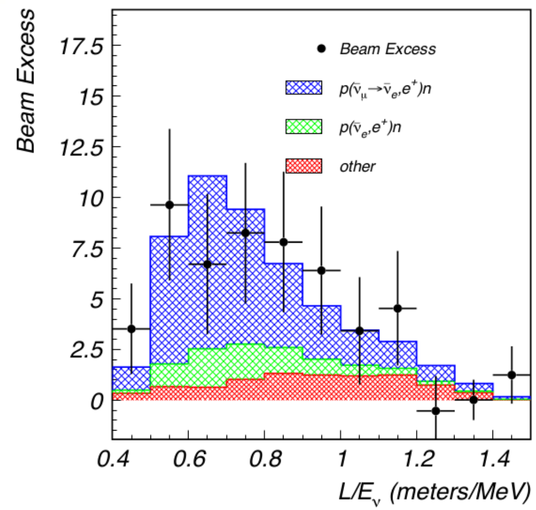
MiniBooNE excess	Sterile neutrino(s)	CP violation, Mass Hierarchy

Cold Electronics

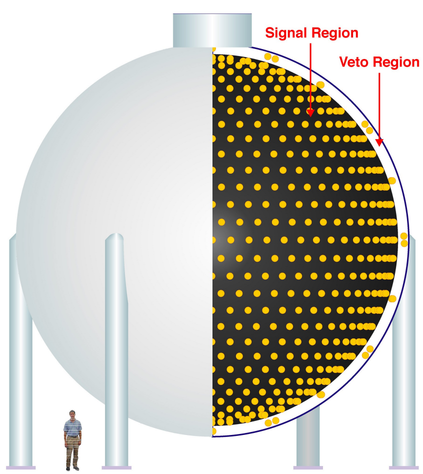


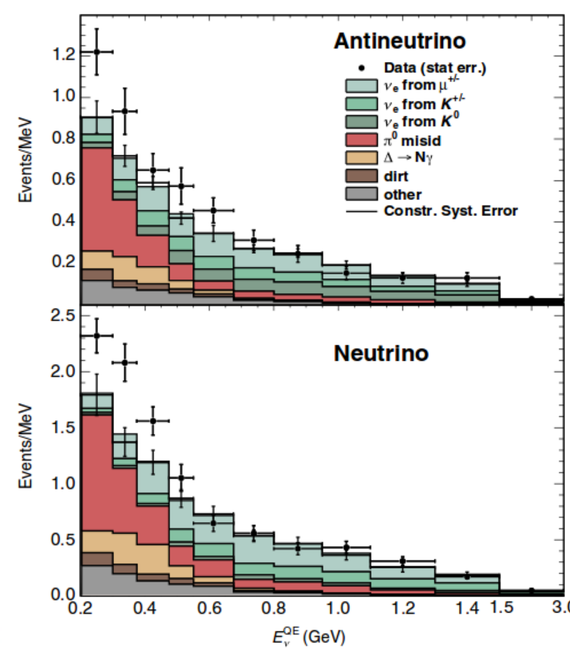
LSND and MiniBooNE



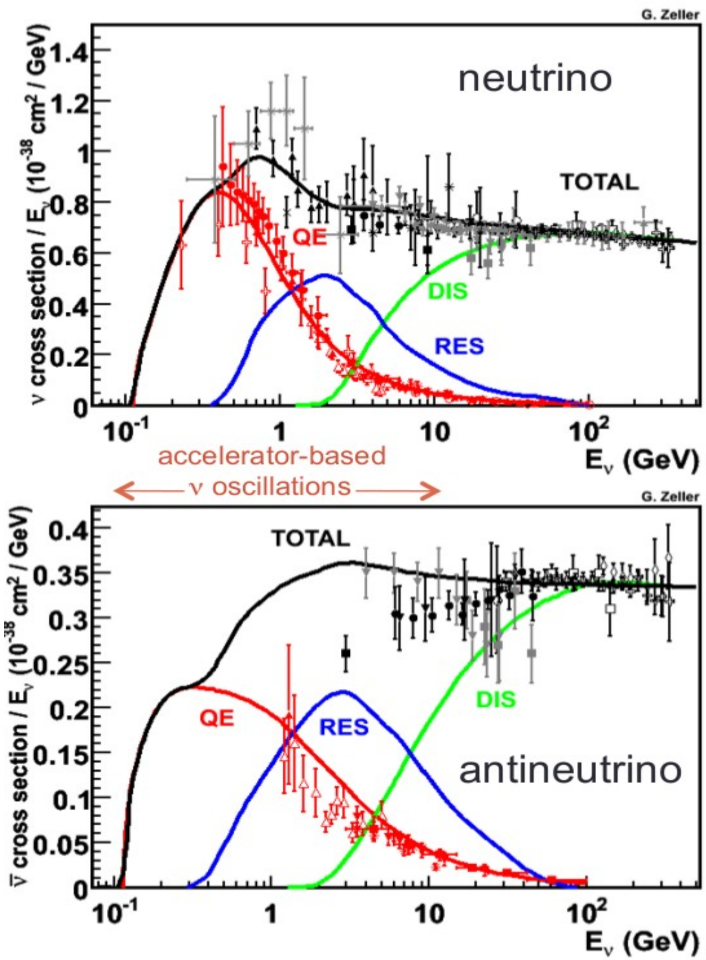


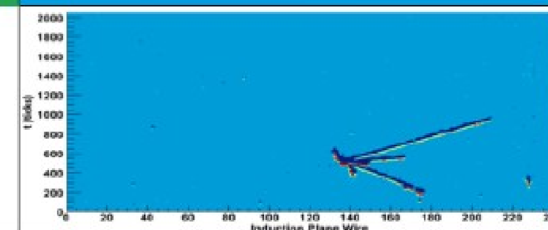
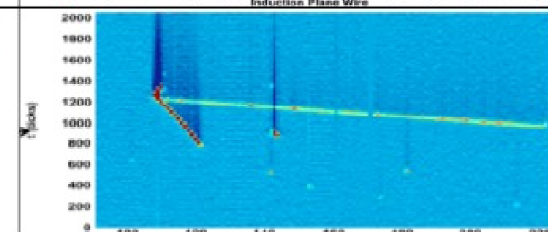
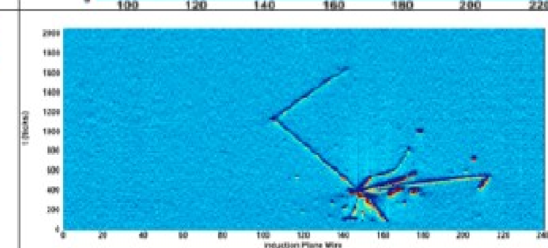
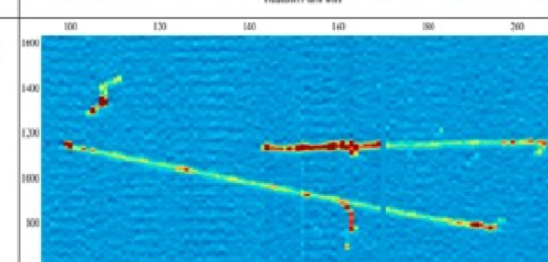
MiniBooNE Detector





Cross-Section Physics



CC processes	Example of Topologies from ArgoNeuT data
$\nu_\mu + Ar \rightarrow 1\mu + X$ (ν_μ-CC inclusive Cross Section)	
$\nu_\mu + Ar \rightarrow 1\mu + 0\,\pi + (n_p\, p + n_n\, n)$ [n_p, n_n = 0, or 1, or 2] (ν_μ-"0-pion" CC Cross Section)	
$\nu_\mu + Ar \rightarrow 1\mu + 1\,\pi^{\pm} + (n_p\, p + n_n\, n)$ [n_p, n_n = 0, or 1, or 2] (ν_μ-"1-$\pi^{\pm}$" CC Cross Section)	
$\nu_\mu + Ar \rightarrow 1\mu + 1\,\pi^{0} + (n_p\, p + n_n\, n)$ [n_p, n_n = 0, or 1, or 2] (ν_μ-"1-π^{0}" CC Cross Section)	

MicroBooNE sensitivities