MICROBOONE

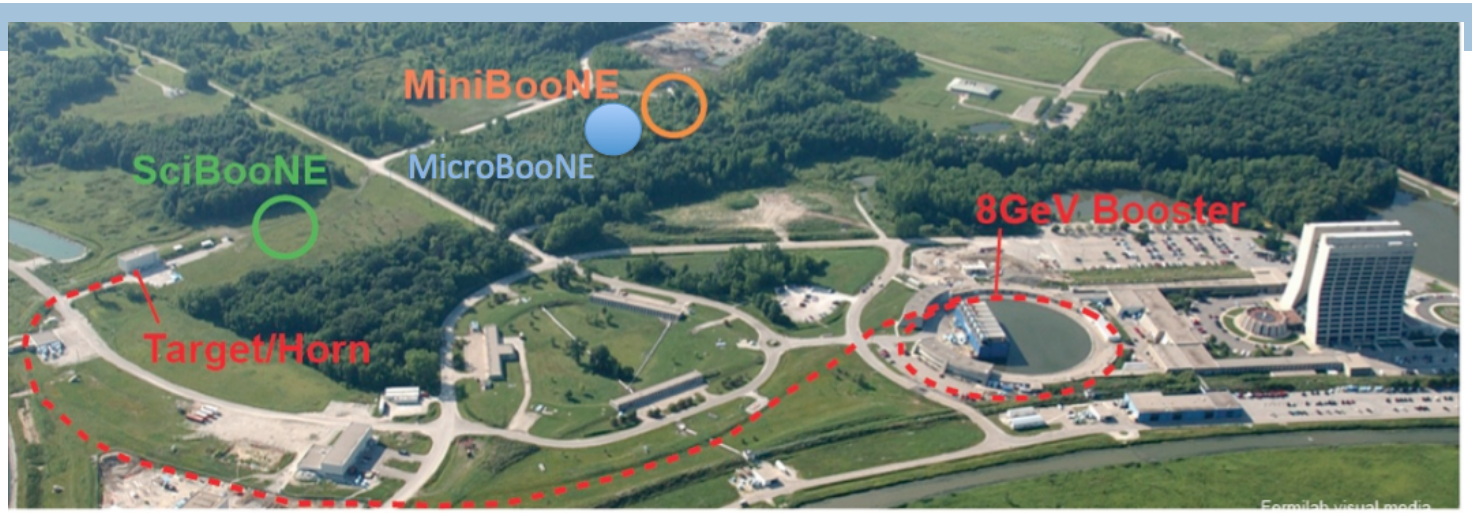
Sam Zeller
Fermilab

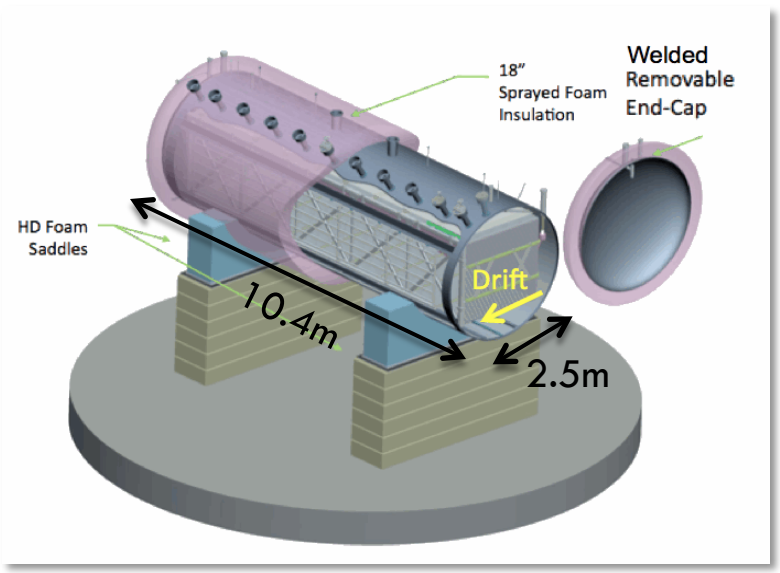
PAC

June 5, 2013

- current situation and progress being made on MicroBooNE

MicroBooNE





- 170 ton LAr TPC
  - *same beam & location as MiniBooNE*
  - *new detector technology*
- goals:
  - *MiniBooNE excess events*
  - σ_ν *measurements in argon*
  - *R&D for future LAr TPCs*

MicroBooNE Collaboration

- 109 collaborators from 19 institutions, 23 postdocs, 13 grad students

Brookhaven: H. Chen, S. Duffin, J. Farrell, F. Lanni, Y. Li, D. Lissauer, G. Mahler, D. Makowiecki, J. Mead, V. Radeka, S. Rescia, A. Ruga, J. Sondericker, C. Thorn, K-C. Wu, B. Yu

University of Chicago: D. Schmitz

University of Cincinnati: R. Grosso, J. St. John, R. Johnson, B. Littlejohn

Columbia University: N. Bishop, D. Caratelli, L. Camilleri, C. Chi, J. Dickinson, D. Kaleko, G. Karagiorgi, B. Seligman, M. Shaevitz, B. Sippach, K. Tatem, K. Terao, B. Willis

Fermilab: R. Acciarri, B. Baller, D. Bogert, B. Carls, M. Cooke, H. Greenlee, C. James, H. Jostlein, M. Kirby, S. Lockwitz, B. Lundberg, A. Marchionni, S. Pordes, J. Raaf, G. Rameika, B. Rebel, R. Schmitt, S. Wolbers, T. Yang, G.P. Zeller*

Kansas State University: T. Bolton, S. Farooq, S. Gollapinni, G. Horton-Smith, D. McKee

Los Alamos: G. Garvey, J. Gonzales, W. Ketchum, B. Louis, G. Mills, Z. Pavlovic, R. Van de Water

MIT: W. Barletta, L. Bugel, G. Collin, J. Conrad, C. Ignarra, B. Jones, T. Katori, M. Toups

Michigan State University: C. Bromberg, D. Edmunds

New Mexico State University: T. Miceli, V. Papavassiliou, S. Pate, K. Woodruff

Otterbein University: N. Tagg

Princeton University: R. Klemmer, M. Komor, K. McDonald, W. Sands

Saint Mary's University of Minnesota: P. Nienaber

Syracuse University: J. Asaadi, M. Soderberg

University of Texas at Austin: S. Cao, J. Huang, K. Lang, R. Mehdiyev

University of Bern, Switzerland: A. Ereditato, I. Kreslo, C. Rudolf von Rohr, T. Strauss, M. Weber

INFN, Italy: F. Cavanna, O. Palamara *(currently at Yale)*

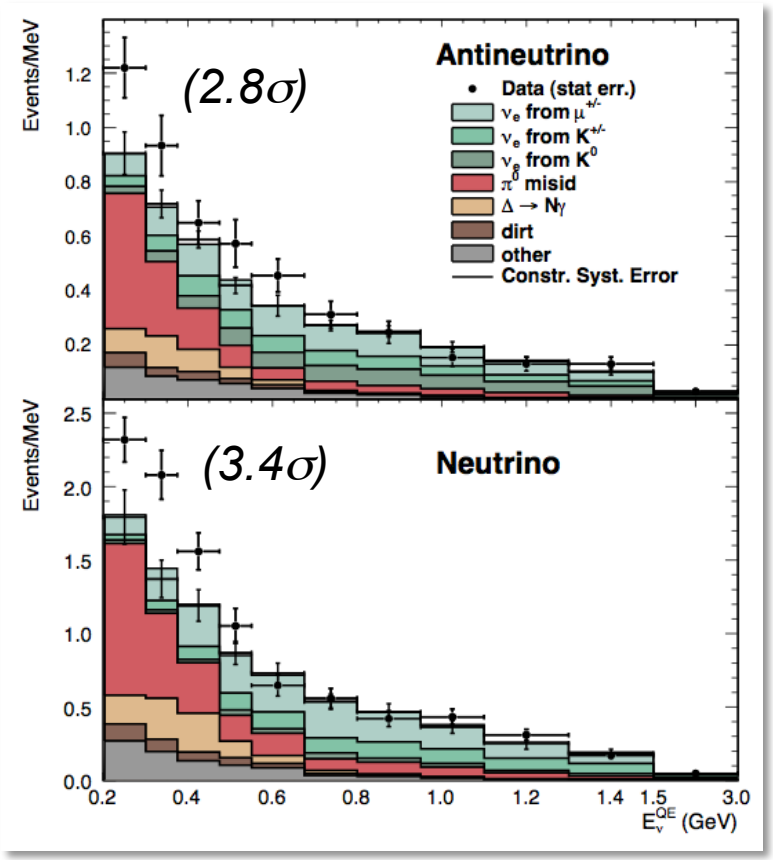
Virginia Tech: M. Jen, L. Kalousis, C. Mariani

Yale University: C. Adams, E. Church, B. Fleming*, R. Guenette, K. Partyka, A. Szelc

* spokespeople

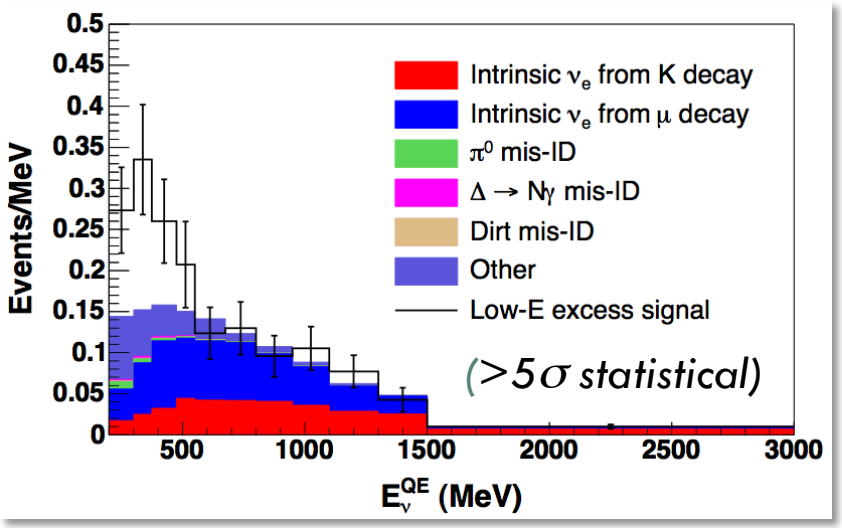
Motivation = MiniBooNE Excess

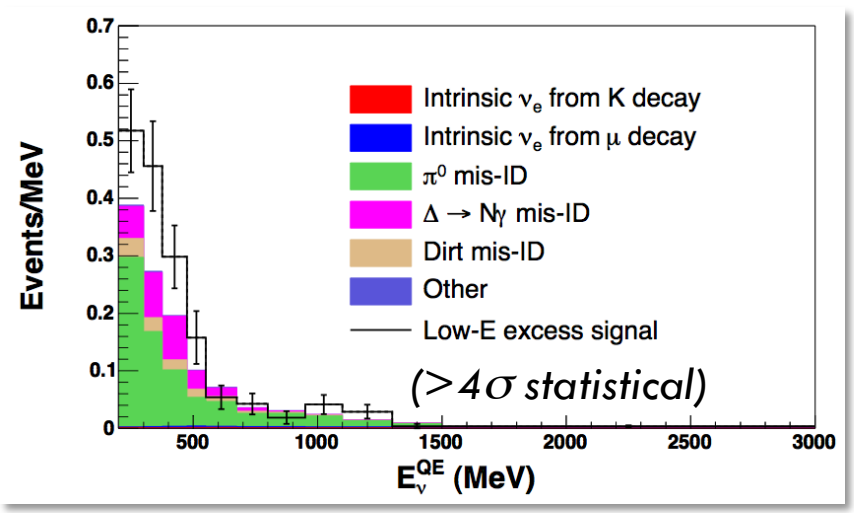
- MiniBooNE has published ν_e and $\overline{\nu}_e$ results with the entire data set
  (Aguilar-Arevalo et al., Phys. Rev, Lett. 110, 161801 (2013))



- observe an excess of low energy events in both running modes
- source of the excess is unknown (MicroBooNE!)
  - γ (background)
  - e^- (signal)
- both outcomes are interesting

MicroBooNE



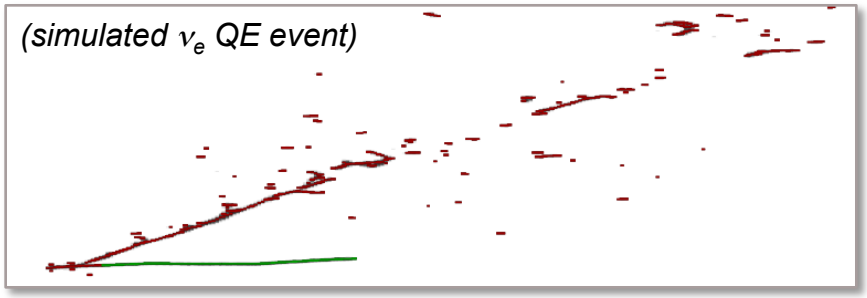


(projections for 6.6×10^{20} POT)

- unlike MiniBooNE, MicroBooNE can distinguish e^-'s from γ's

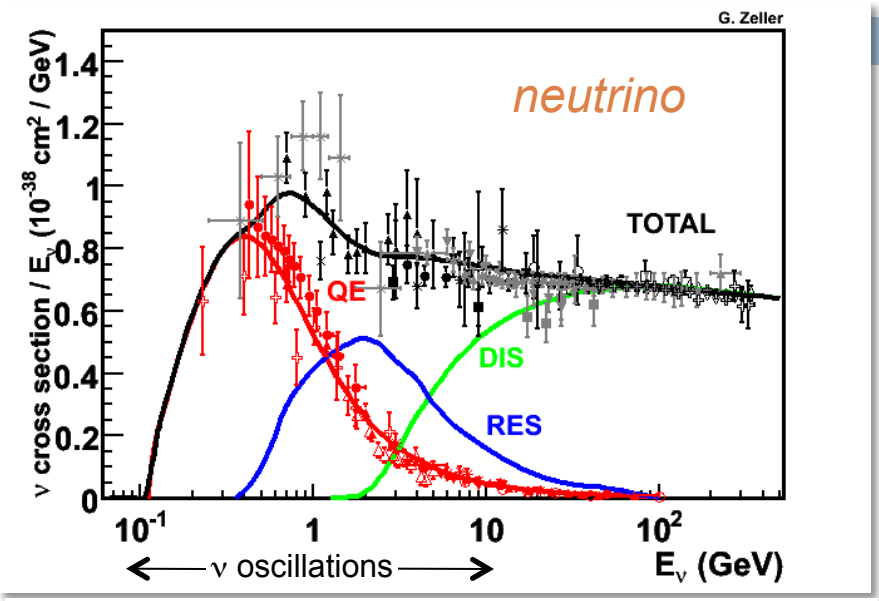
if assume an <u>electron signal</u> and have analyzed for an e^-

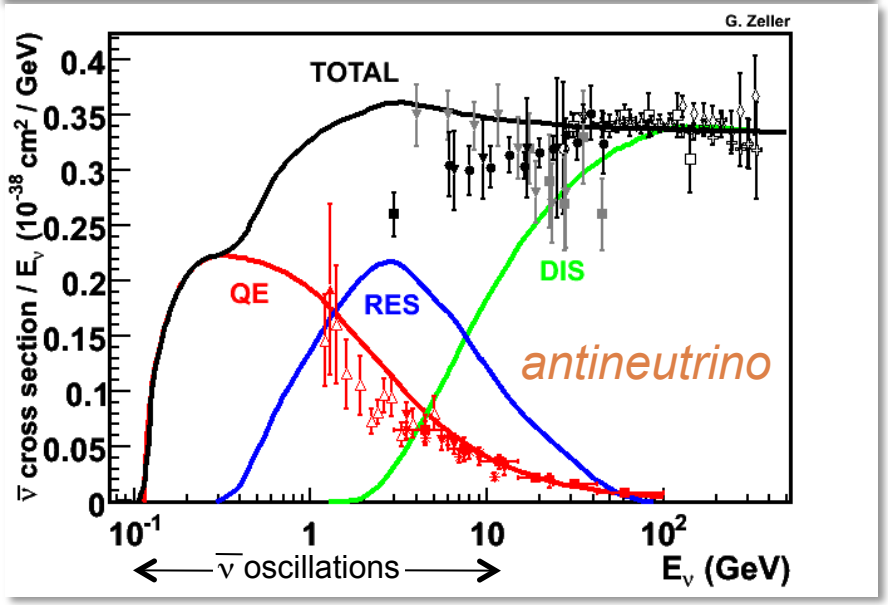
if assume a <u>photon background</u> and have analyzed for a γ



B. Carls (FNAL)

Neutrino Cross Sections

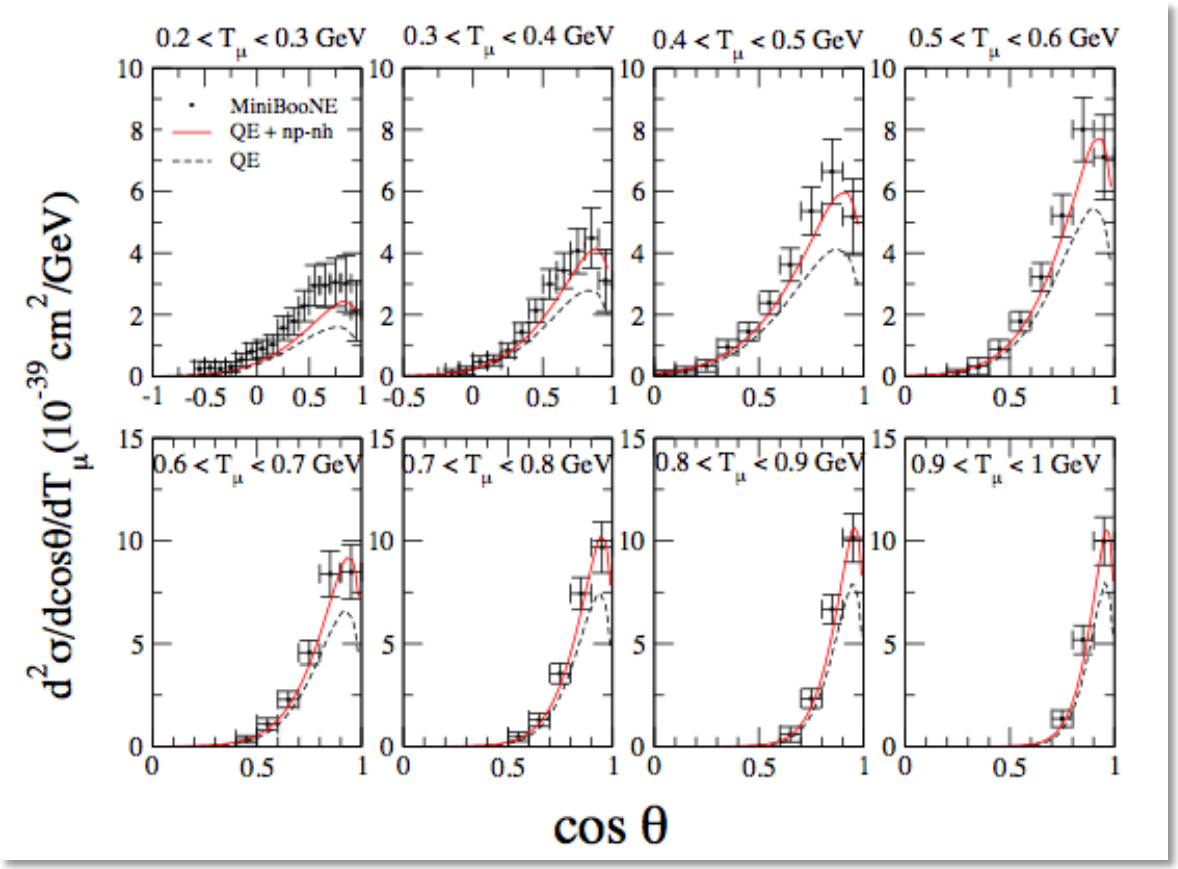




- this topic has received a lot of attention recently
- ν cross sections historically not well-known in the energy range we care about
  - *crucial for ν oscillations*
- new data is telling us that nuclear effects are far more complex than we thought
  - *has forced a dramatic shift in our thinking in last couple years (ex., MB σ_ν program >650 citations)*

MiniBooNE QE Data

(one ex: Martini/Ericson, arXiv:1303.7199 [nucl-th])



- new data suggest that more complex nuclear processes are taking place and as a result, we may be missing a large source of events

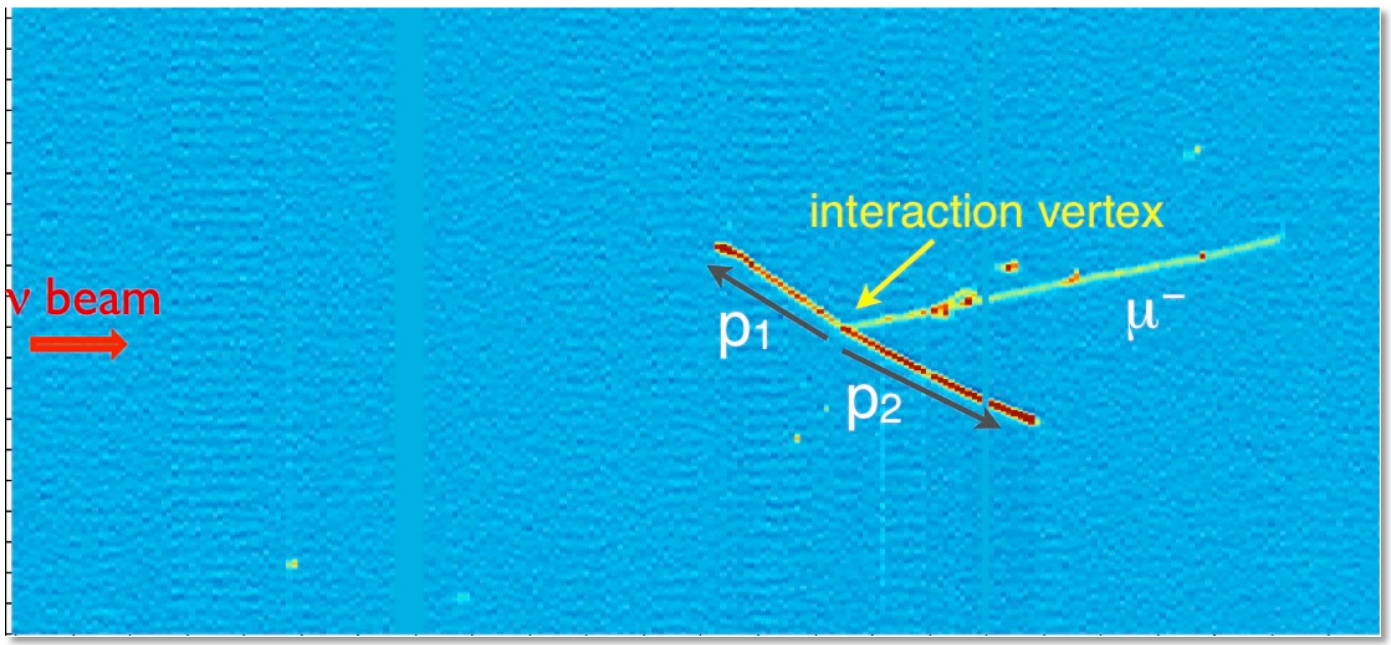
$$\nu_\mu \begin{pmatrix} n \\ p \end{pmatrix} \rightarrow \mu^- \; p \; p$$

- similar effects have been observed in e-nucleus scattering *(Carlson et al., PRD 65, 024002 (2002))*

- important to get this right *(need more data!)* & into our simulations *(re: E_ν, ν vs. $\bar{\nu}$)*

ArgoNeuT

- there are already some interesting results coming out of ArgoNeuT
  ("hammer events"; see Fermilab Today article this Friday)
- CC neutrino interactions with two energetic back-to-back protons



(O. Palamara, ArgoNeuT data from 175L LAr TPC in LE NuMI beam)

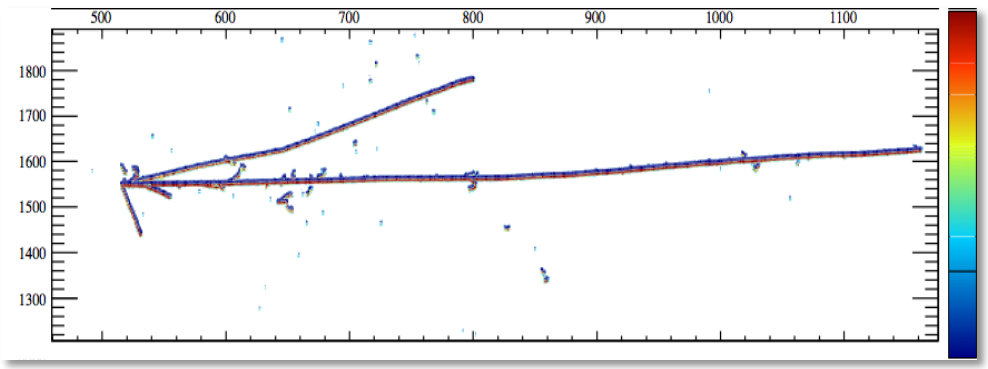
$$\nu_\mu \begin{pmatrix} n \\ p \end{pmatrix} \rightarrow \mu^- \; p \; p$$

are we seeing direct evidence for short-range correlations in neutrinos?

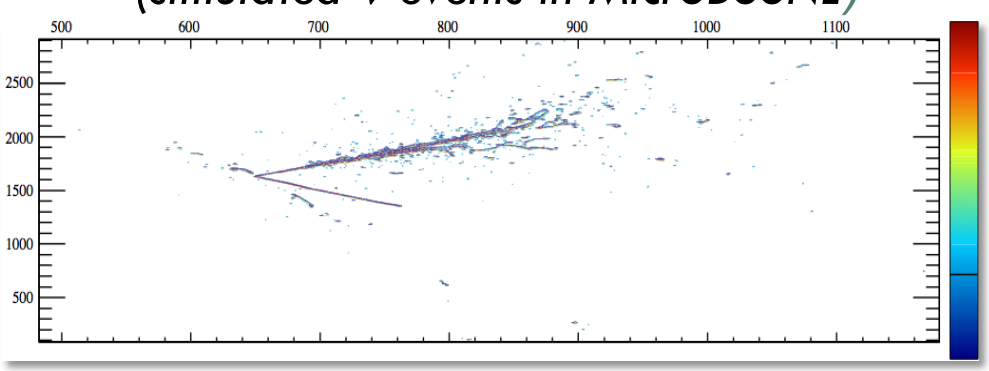
not sure

MicroBooNE Cross Sections

- will more precisely examine final states produced in ν interactions by exploiting LAr TPC capabilities and building off of what we've learned in both MiniBooNE & ArgoNeuT



(simulated ν events in MicroBooNE)



	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 will make first σ_ν measurements in argon at low neutrino energies (~1 GeV)
- these analyses will benefit from well-known Booster neutrino flux

Aguilar-Arevalo et al., PRD 79, 072002 (2009)

R&D

- MicroBooNE detector is not a pure prototype for LBNE; however, it incorporates several major advances over the (larger, 1st generation) ICARUS detector, which are important "proofs of principle" for next generation large detectors:

  - *non-evacuated cryostat*
  - *cold (in liquid) electronics*
  - *2.5 meter drift*

- additionally, MicroBooNE will collect a large data set of ν events which will be used to develop fully automated event <u>reconstruction</u>

- being near the surface, MicroBooNE will also measure non-beam backgrounds which are relevant to determining the reach of add'l physics which can or cannot be done with a <u>surface detector</u>

Collaboration Organization

Spokespeople
B. Fleming, G. Zeller

Project Manager
G. Rameika

Physics Analysis
J. Conrad, M. Soderberg

- **Oscillations** — *G. Karagiorgi, R. Guenette*
- **Cross Sections** — *F. Cavanna, T. Katori*
- **Calibration** — *T. Strauss*
- **Beam** — *Z. Pavlovic*
- **R&D** — *J. Asaadi, A. Szelc*
  - **Cosmic Rays** – L. Kalousis, S. Lockwitz
  - **Veto Studies** - T. Miceli
  - **Bo Vertical Slice Test** – M. Toups

Analysis Tools
E. Church, H. Greenlee

- **Reconstruction** — *W. Ketchum, T. Yang*
- **Simulation** — *M. Toups, B. Seligman*
- **MC Management** — *B. Carls*
- **Data Management** — *J. Asaadi, Z. Pavlovic*
- **Database Tools** — *J. St. John, A. Szelc*
- **Software Tools** — *S. Gollapinni, H. Greenlee*
- **Event Display** — *T. Miceli, N. Tagg*

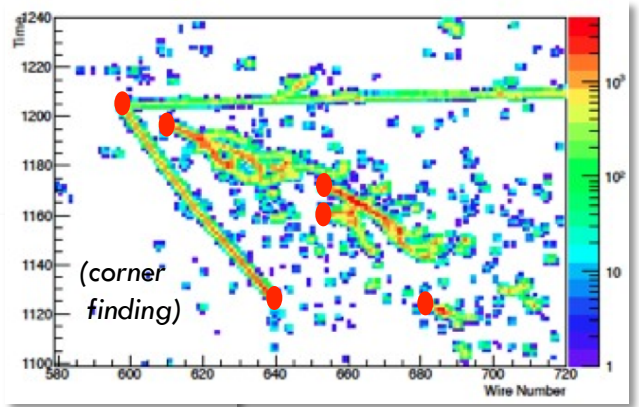
Operations
TBD

- **Commissioning** — *TBD*
- **Run Coordinator** — *TBD*
- **Online** — *C. Mariani*

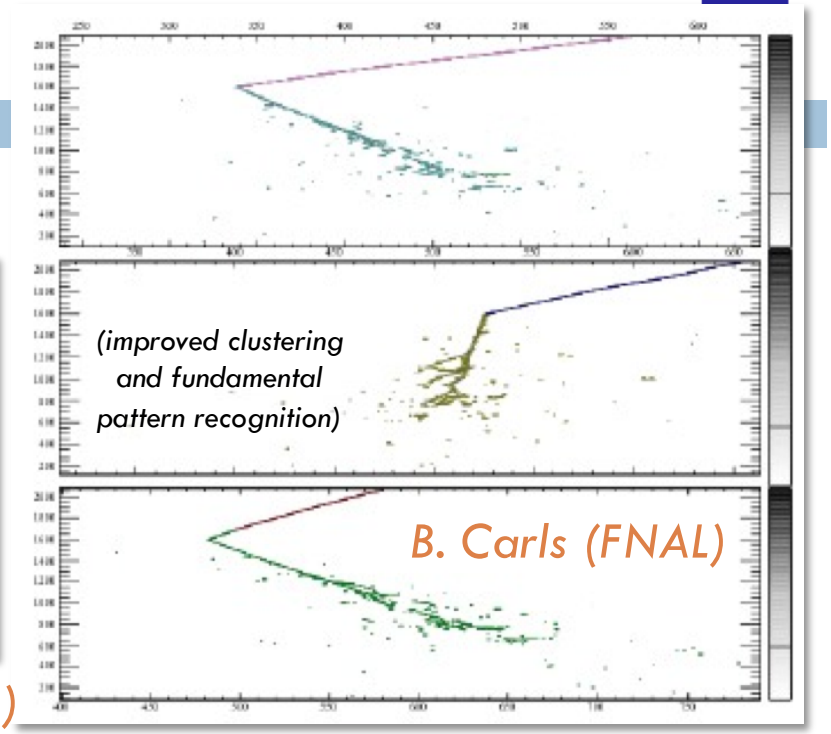
- physics groups are fully active & have been meeting regularly
- plus, grad student presentations through-out this summer

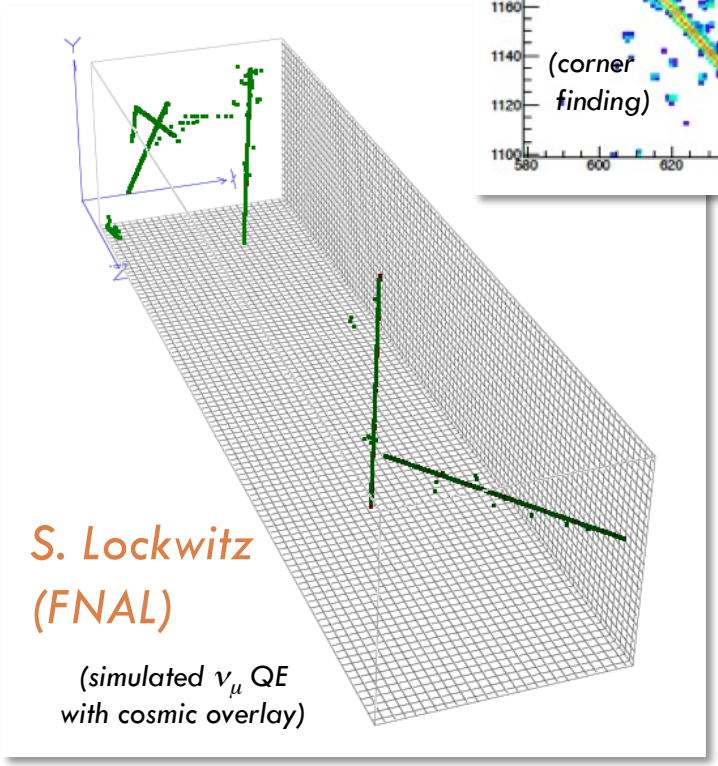
Reconstruction

- preparing for another large Monte Carlo production



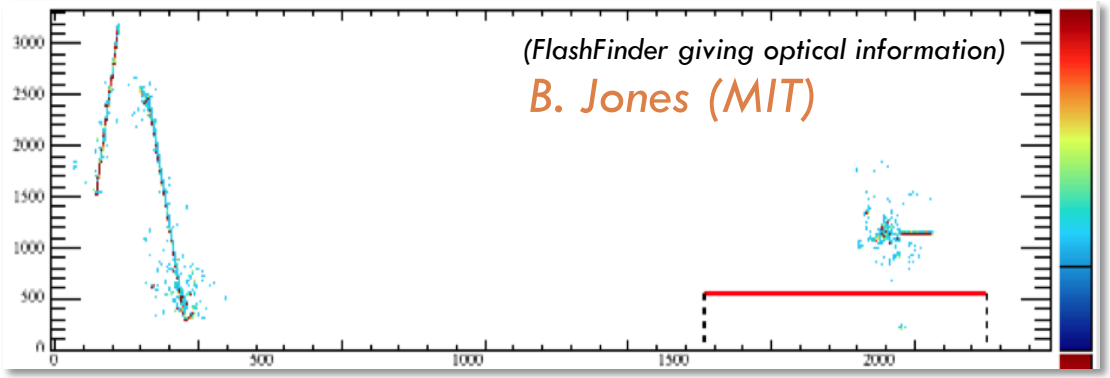
W. Ketchum (LANL)





S. Lockwitz (FNAL)

(simulated ν_μ QE with cosmic overlay)



- Rick Snider: LArSoft project leader (SCD)
- Rob Roser: several meetings with our PDs

MicroBooNE Status

- less than a year ago …

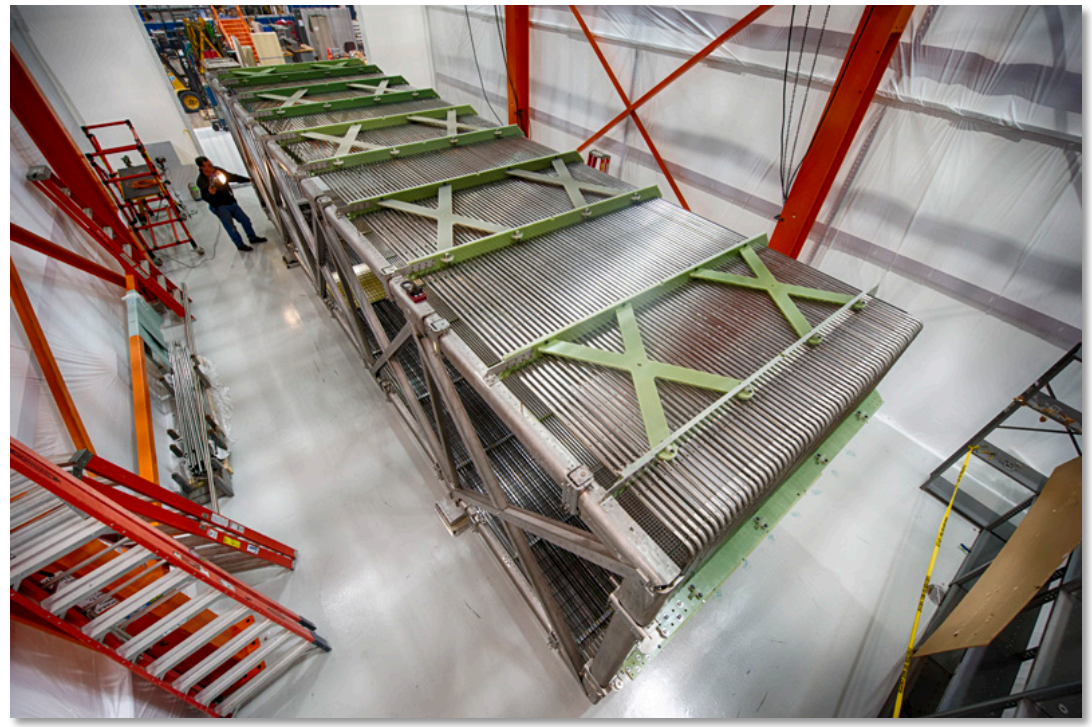
empty clean room tent at DAB →

← LArTF was just artist's rendering

MicroBooNE Status

- now we have …

a detector →



← and a really nice place to put it in the Booster neutrino beam

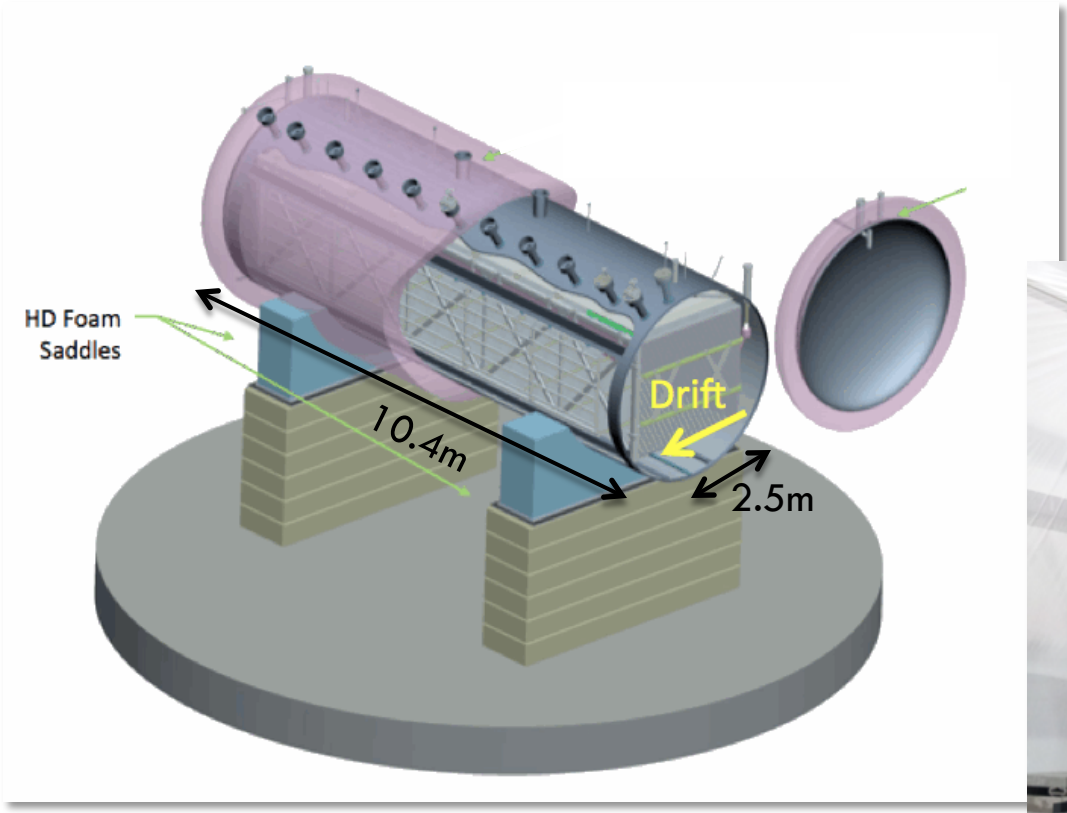
Project & Collaboration Closely Work Together

- TPC part cleaning last summer …

- we are gearing up for another busy summer

MicroBooNE Detector

- 170 ton (total volume) LAr TPC (size of a school bus)



- TPC frame:

MicroBooNE Detector

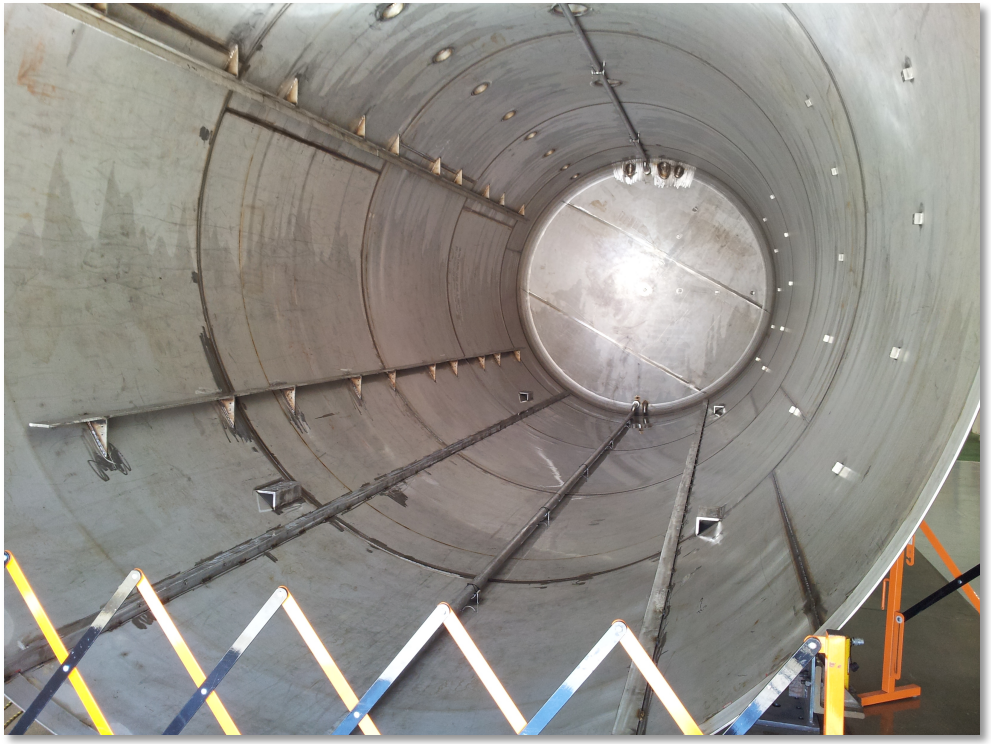
- 170 ton (total volume) LAr TPC (size of a school bus)

- cryostat arrived in March 2013

- TPC frame:

MicroBooNE Detector

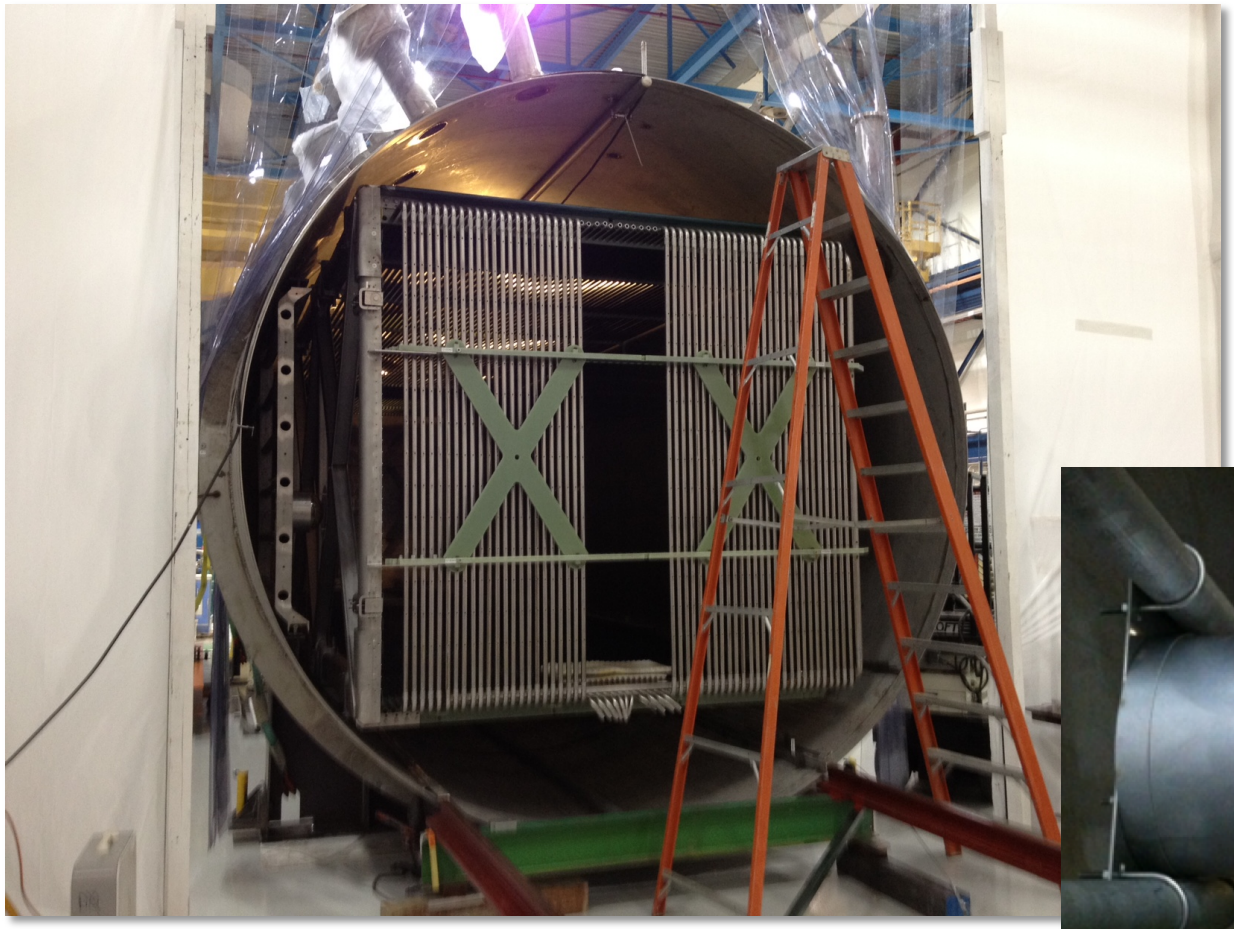
- 170 ton (total volume) LAr TPC (size of a school bus)



- cryostat arrived in March 2013

- TPC frame:

Test Fit

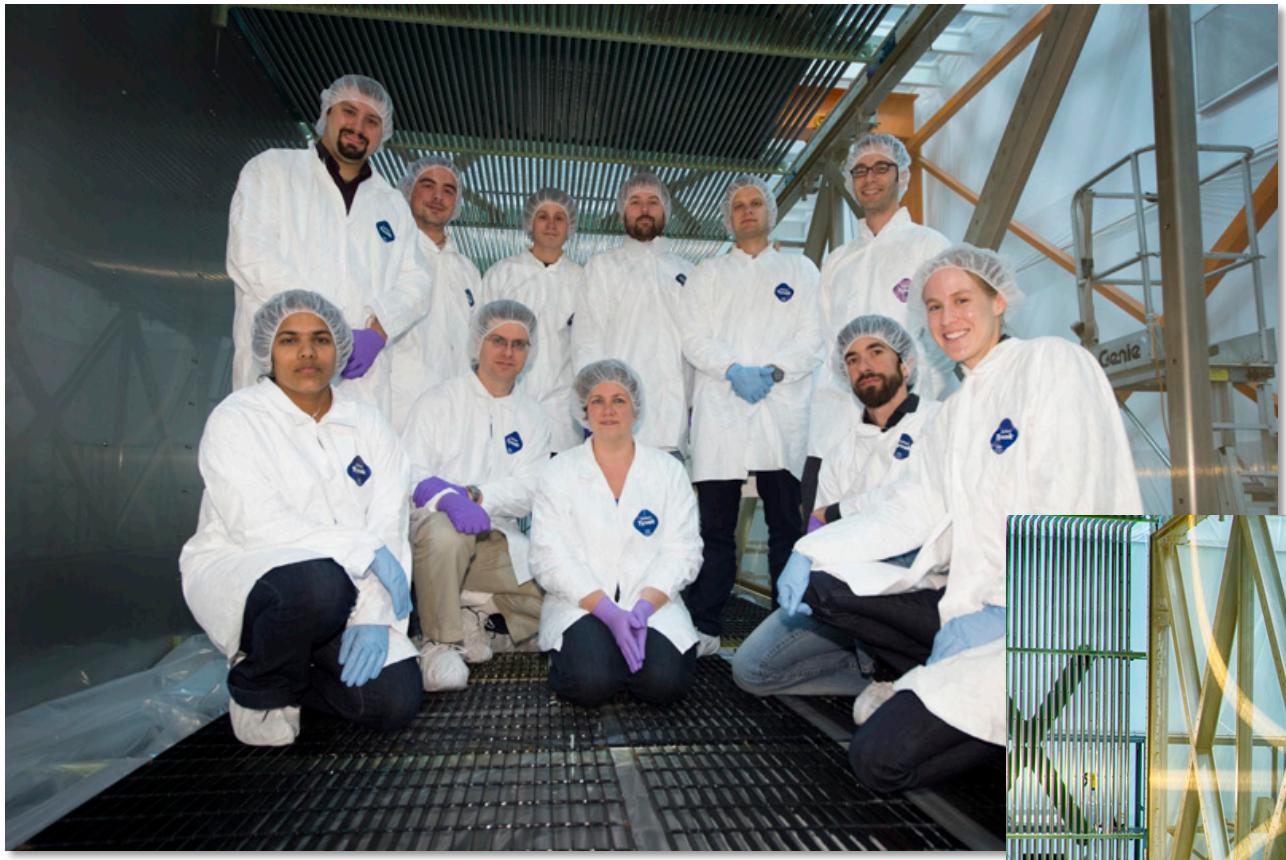


- test fit of the TPC and PMT rack in the cryostat

  (TPC with mock wires installed)

April 2013

TPC is Complete



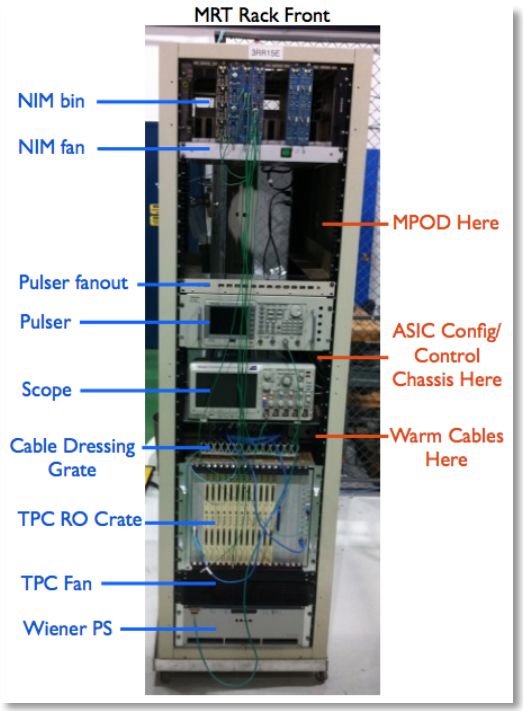
- all 8,256 wires have been installed and tensioned (3mm wire spacing)

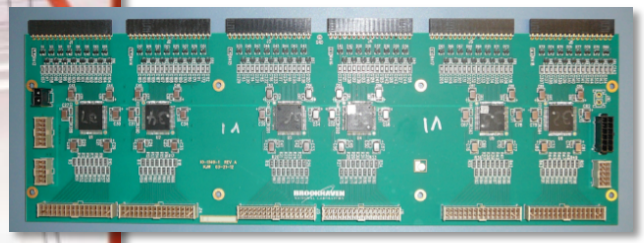
May 2013

wire stringing team: R. Grosso (Cincinnati), R. Acciarri (FNAL), C. Rudolf von Rohr (Bern), A. Szelc (Yale), T. Strauss (Bern), J. St. John (Cincinnati), S. Gollapinni (KSU), D. McKee (KSU), J. Raaf (FNAL), J. Asaadi (Syracuse), S. Lockwitz (FNAL)

Cold Electronics

- front-end (cold) electronics arrive at FNAL this week from BNL
- will be installed in TPC and tested





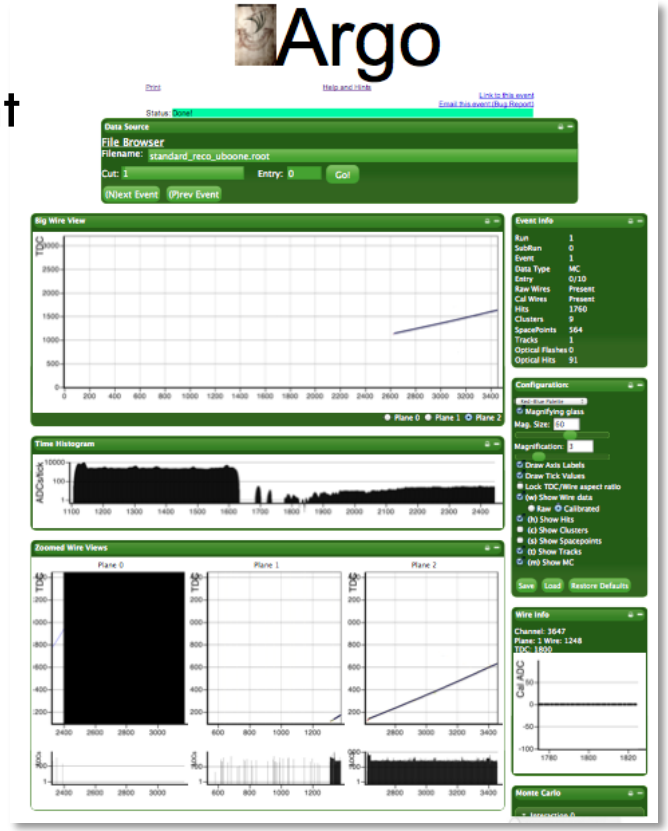
MRT team: B. Littlejohn (Cincinnati), L. Bagby (FNAL), J. St. John (Cincinnati), H. Chen (BNL) plus with help from BNL team!

June 2013

DAQ/Readout/Online

- DAQ test stand at DAB:

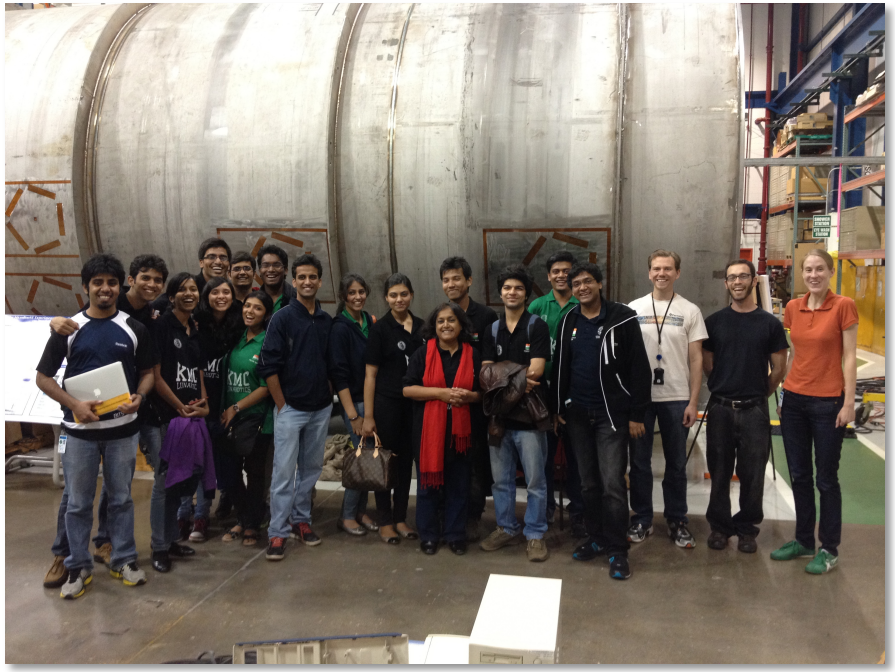
- new event viewer (N. Tagg):



B. Baller (FNAL), E. Church (Yale), K. Biery (FNAL), L. Camilleri (Columbia), S. Gollapinni (KSU), G. Horton-Smith (KSU), D. Kalecko (Columbia), G. Karagiorgi (Columbia), W. Ketchum (LANL), L. Kalousis (VT), G. Lukhanin (FNAL), C. Mariani (VT), R. Mehdiyev (UT Austin), Z. Pavlovic (LANL), R. Rechenmacher (FNAL),M. Shaevitz (Columbia), A. Szelc (Yale), N. Tagg (Otterbein), K. Terao (Columbia)

We Are a Popular Tour Destination

DOE/NSF tour – October 22, 2012

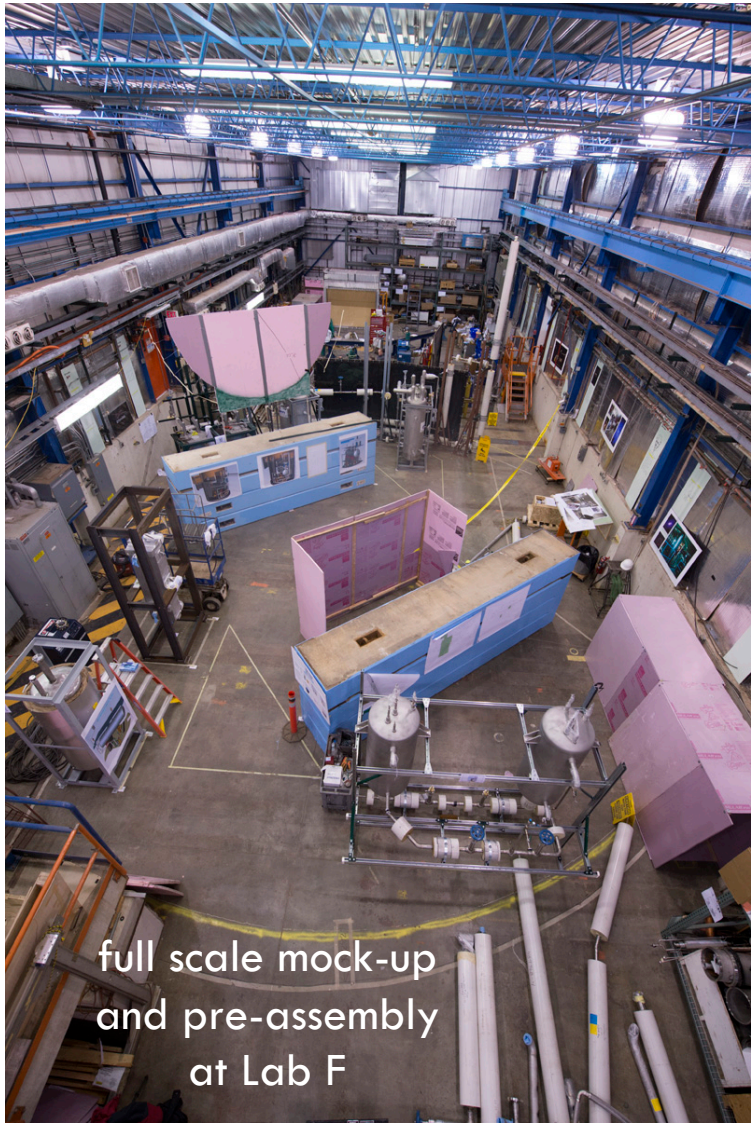


Delhi University students – May 29, 2013

CD SOS team – April 22, 2012

Cryogenics System

- pipes pre-assembled at lab F which will help minimize assembly time in LArTF
- this will be first subsystem installed in LArTF



J. Kilmer (FNAL), B. Rebel (FNAL),
B. Carls (FNAL), M. Cooke (FNAL),
D. Markley (FNAL), B. Sanders (FNAL),
J. Tillman (FNAL), M. Zuckerbrot (FNAL)
+ crew at lab F

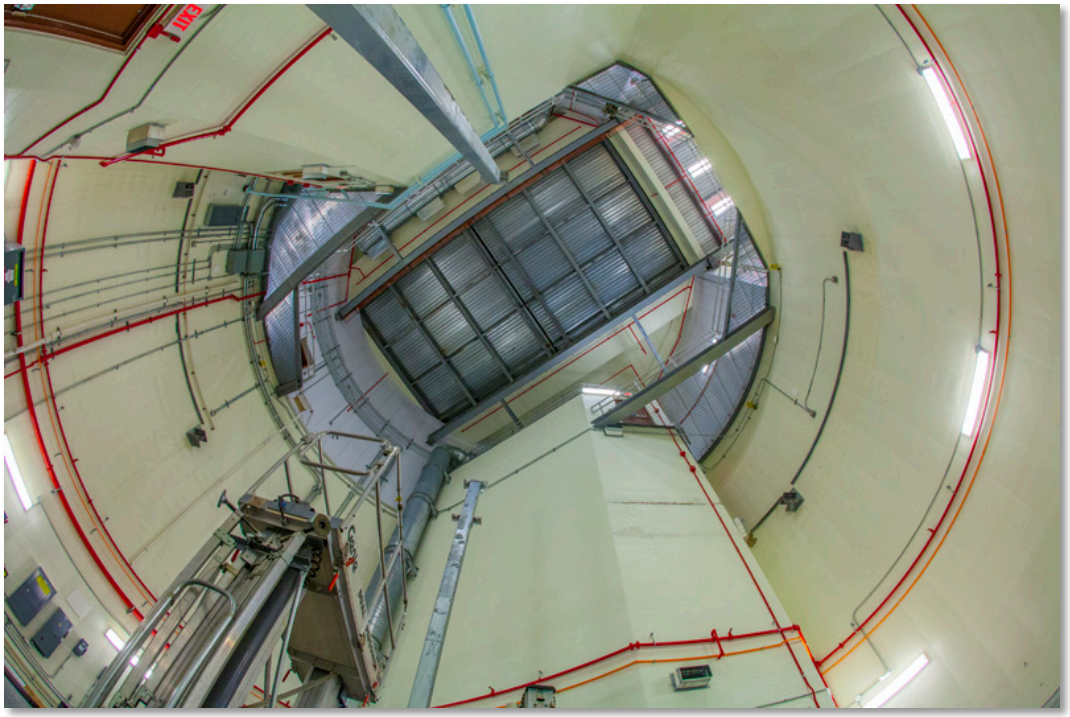
LArTF

- received beneficial occupancy on May 16, 2013
- MicroBooNE will be the first tenant

Inside LArTF

Inside LArTF

- view from the lower level



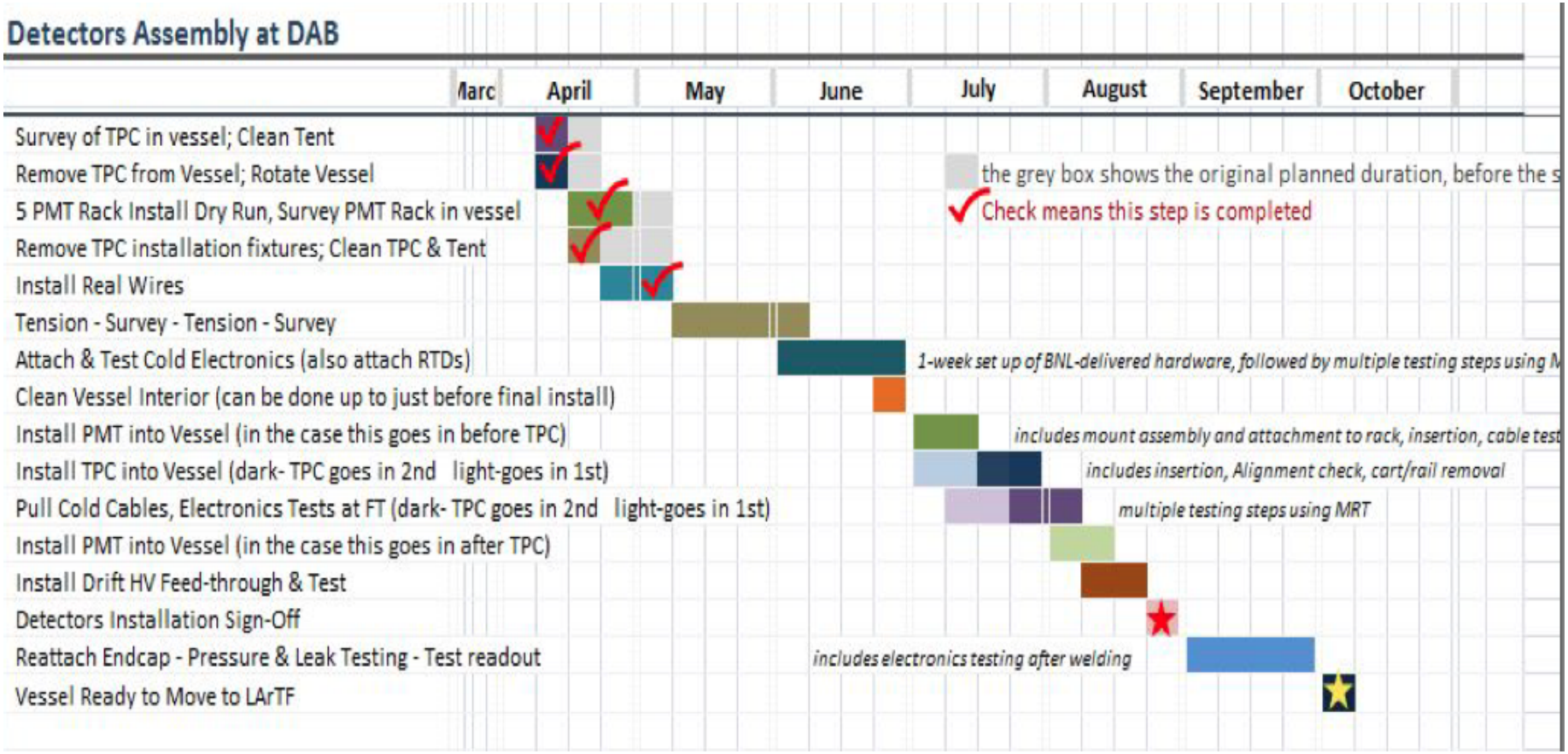
Activities at LArTF

cryo-piping being installed outside

computer room

Current Schedule

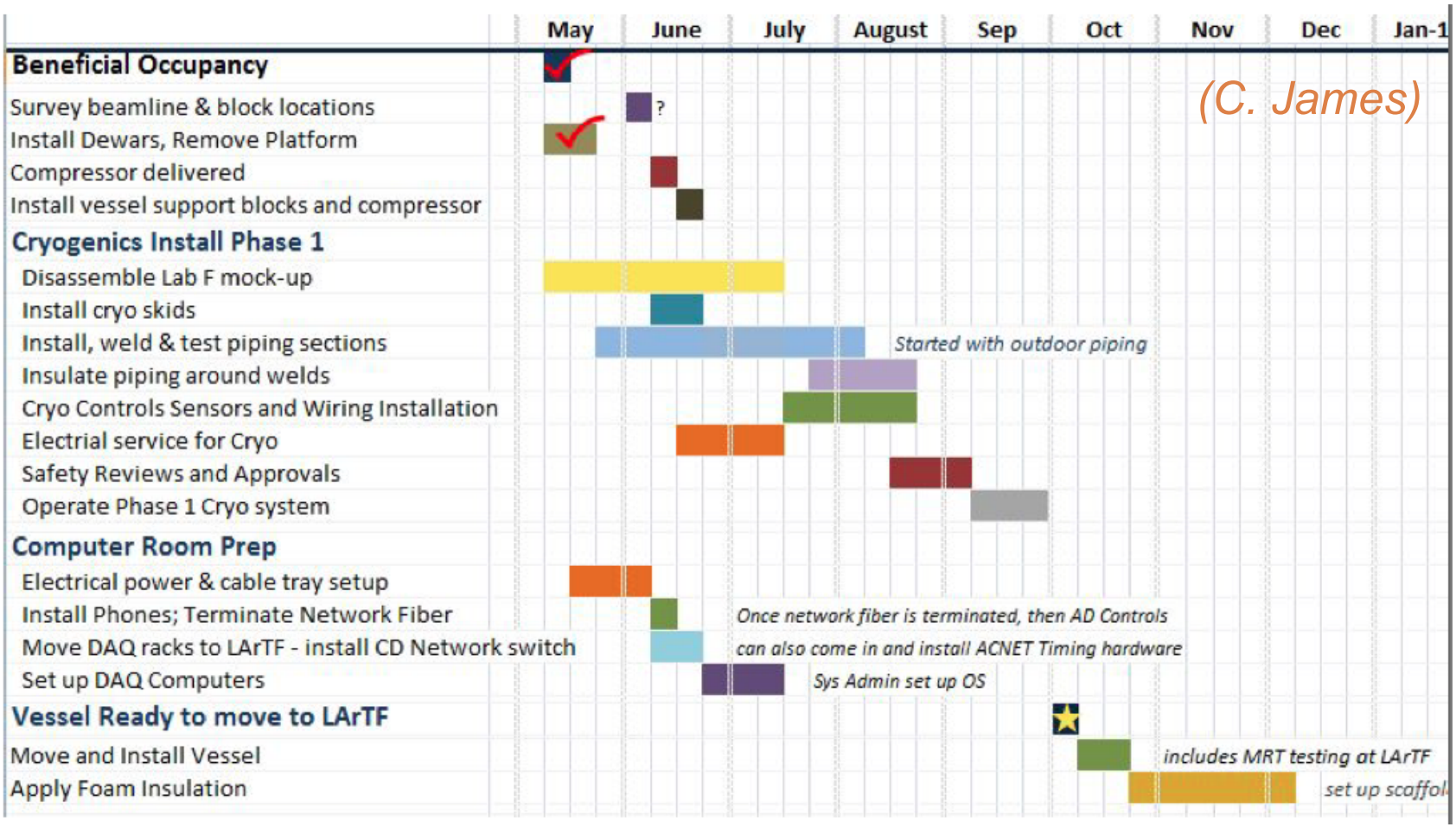
- vessel should be ready to be moved over to LArTF in October



(C. James)

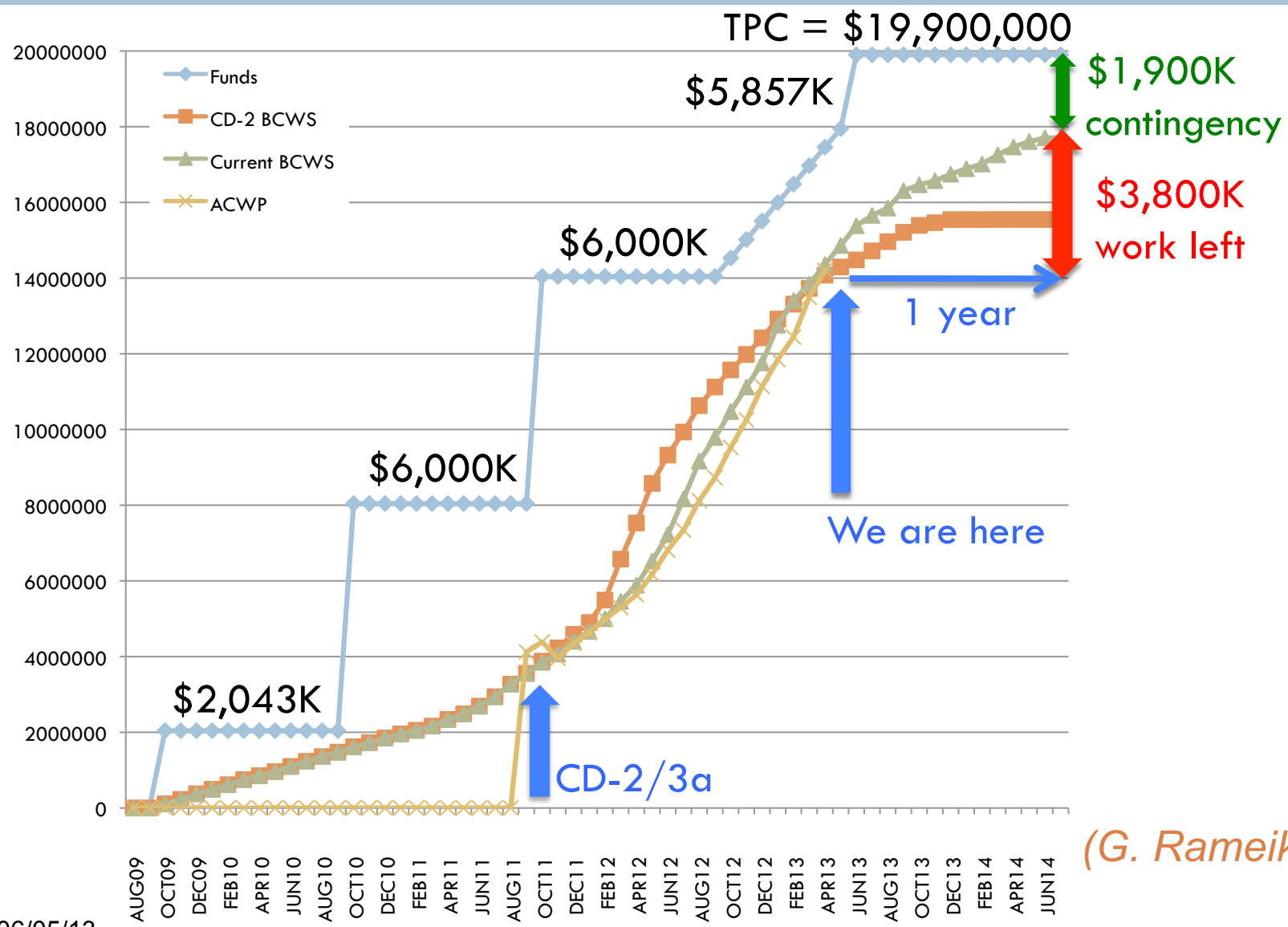
Current Schedule

- installation/insulation of detector in LArTF before end of calendar year



- then, purge, gas recirc, cool down, fill, liquid recirc … commissioning

MicroBooNE Project Funding and Budget



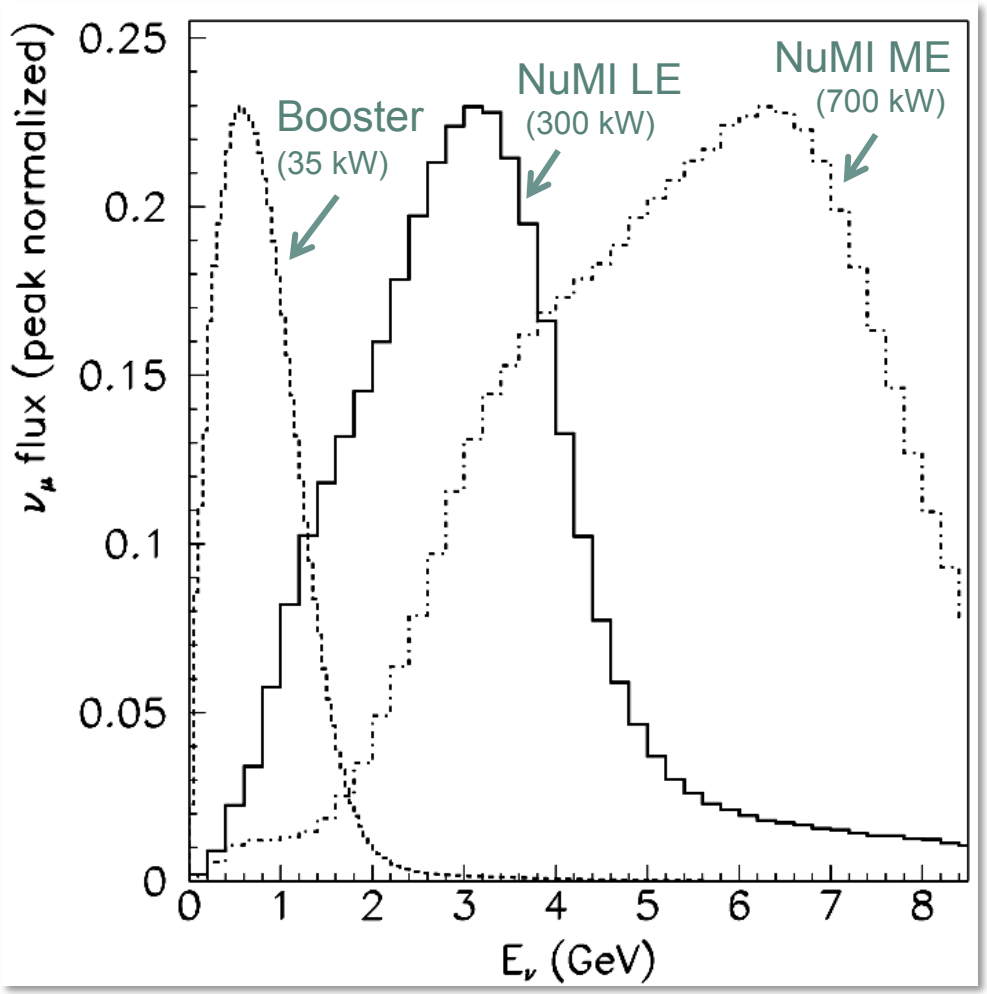
(G. Rameika)

Conclusions

- MicroBooNE is in our last year of construction
- the project and collaboration have been working very closely to build the experiment
- we are extremely fortunate to have a lot of students and postdocs who are fully participating in (and leading) detector construction and preparing for our first data with this new device
- we have made excellent progress and we are eager to start commissioning the detector
- we will be ready for Booster neutrino beam at about this time next year (our request = 2×10^{20} POT/yr)

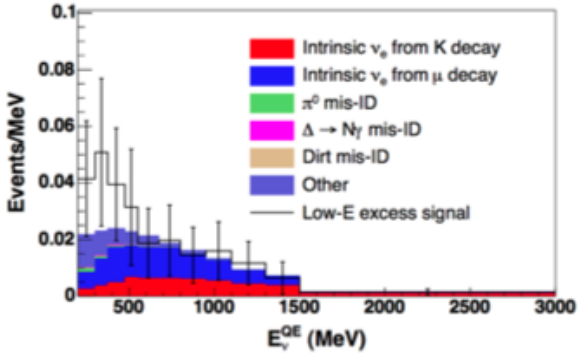
Backups

Flux Comparison

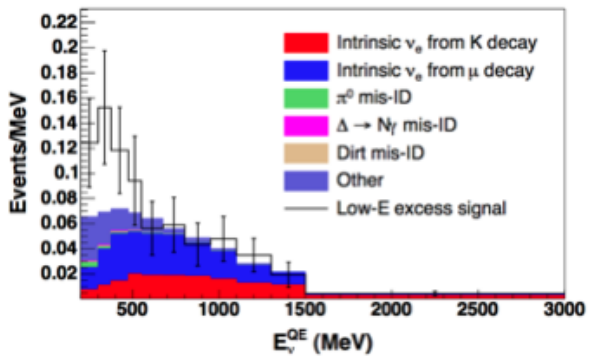


(relative comparison, not neutrino cross section weighted)

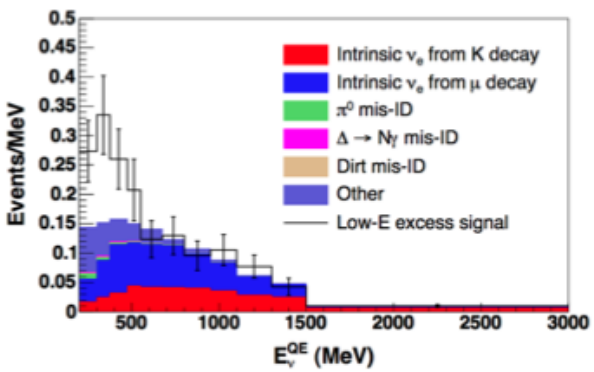
Evolution in Time



$1x10^{20}$ POT
e-like: 2.2σ
γ-like: 1.6σ



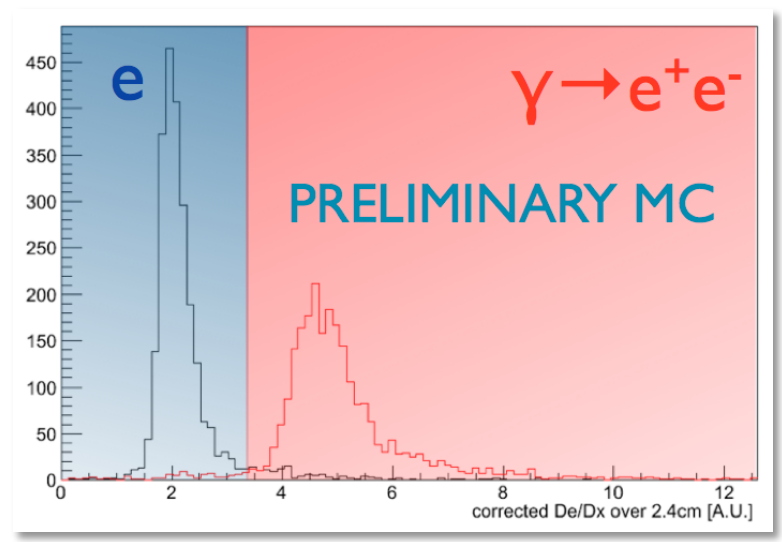
$3x10^{20}$ POT
e-like: 3.8σ
γ-like: 2.8σ



$6.6x10^{20}$ POT
e-like: 5.7σ
γ-like: 4.2σ

- evolution of expected low energy excess observation over time

(200-475 MeV, statistical errors only)



A. Szelc (Yale)

What Does This All Mean?

- something as simple as QE scattering is not so simple
  - nuclear effects can significantly increase the cross section
  - idea that could be missing ~40% of σ in our simulations is a big deal

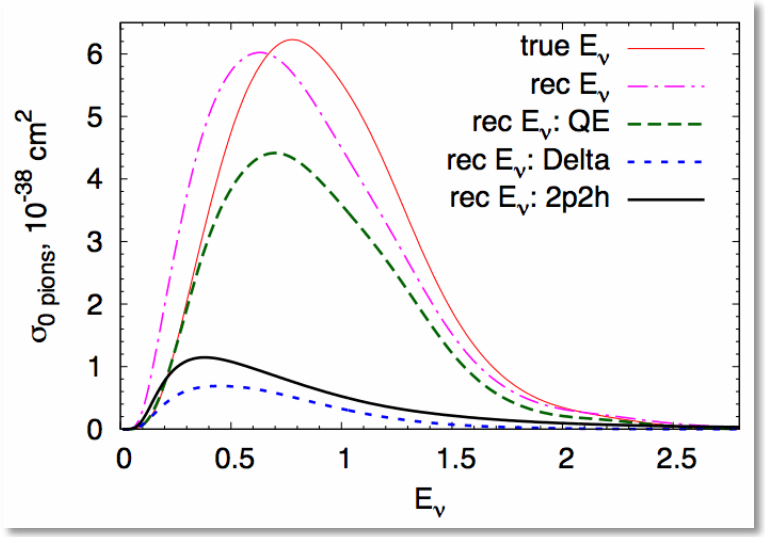
- good news: expect larger event yields
- bad news: need to understand the underlying physics

(1) impacts E_ν determination

ex: Mosel/Lalakulich 1204.2269, Martini *et al.* 1202.4745, Lalakulich *et al.* 1203.2935, Leitner/Mosel PRC81, 064614 (2010)

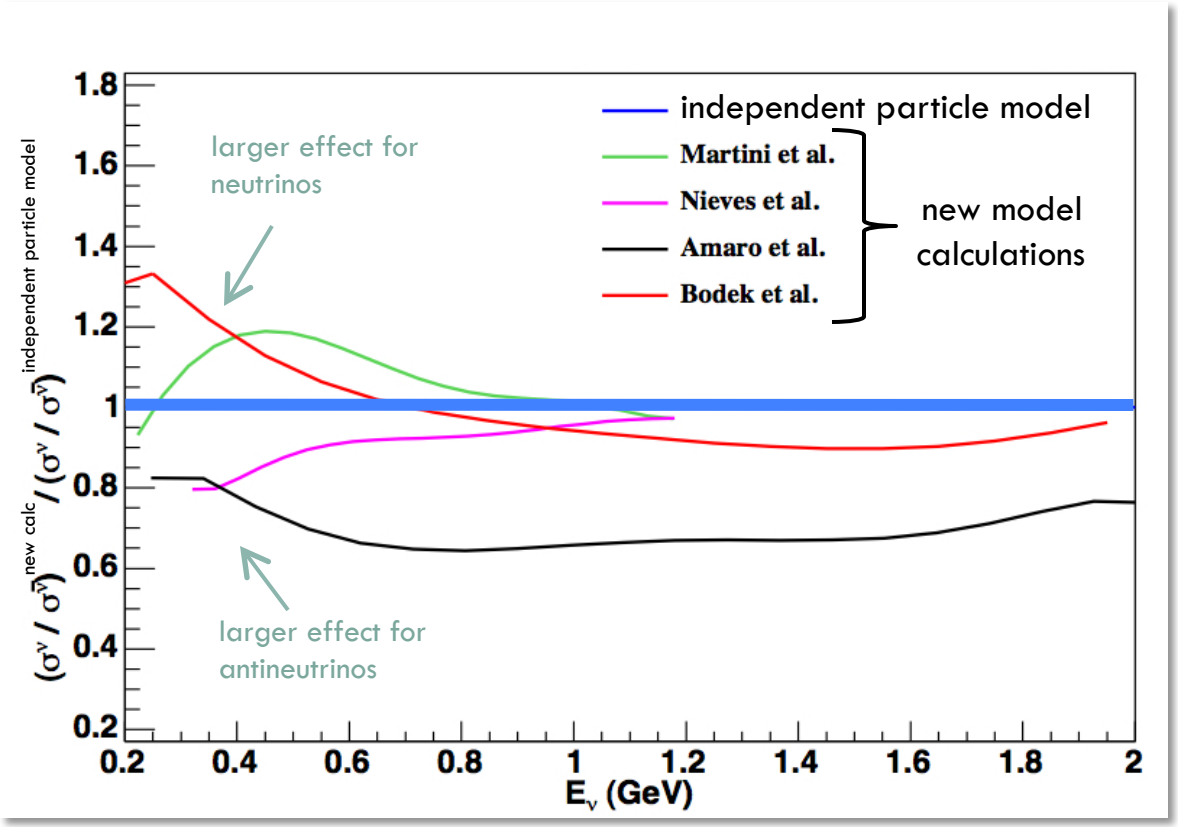
(2) effects will be different for ν vs. $\overline{\nu}$

(at worse, could produce a spurious $\not{CP}$ effect)



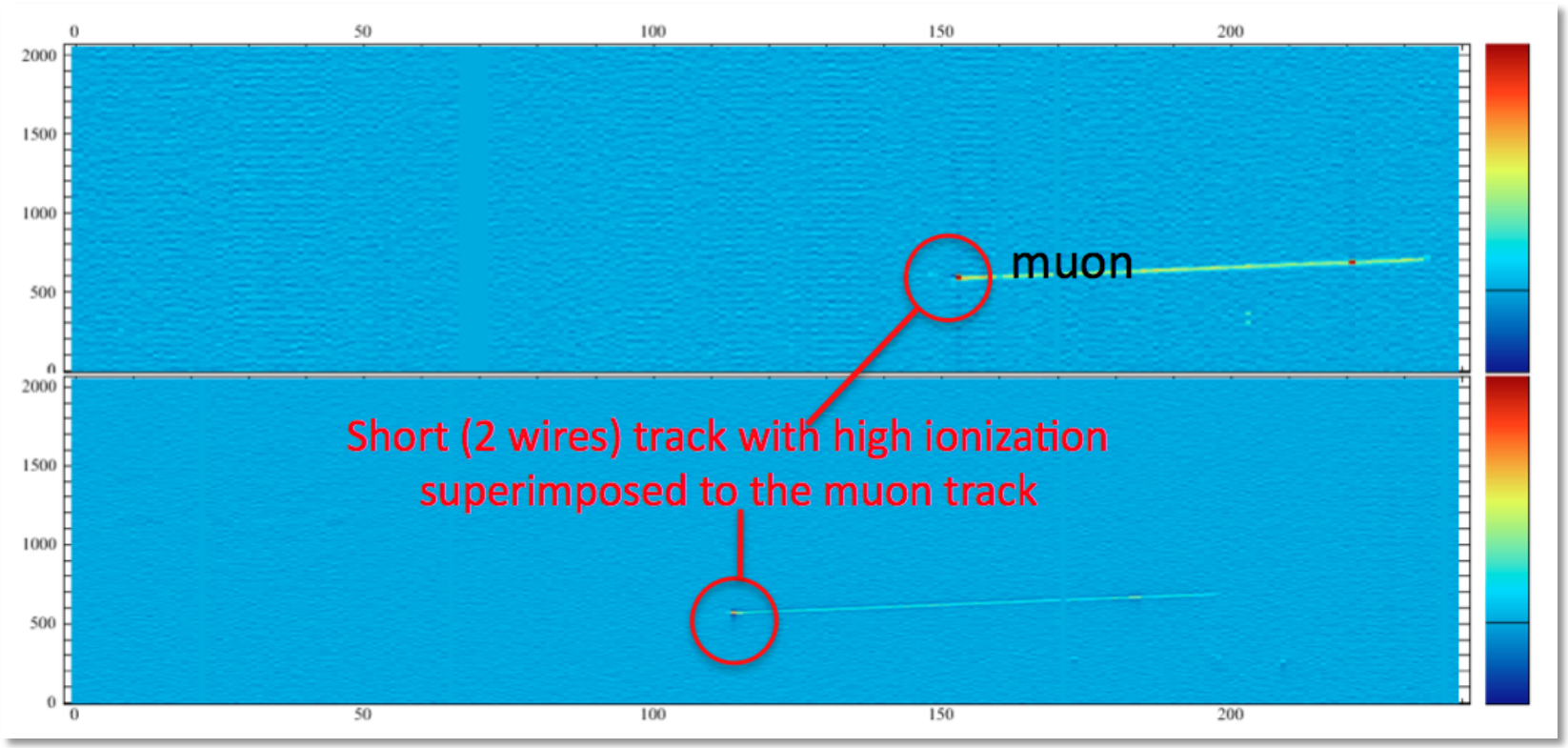
Lalakulich, Gallmeister, Mosel, 1203.2935

Neutrino/Antineutrino Ratio



(J. Grange)

- models give different predictions for $\nu/\bar{\nu}$
- the situation is unclear and will need to get resolved
- large θ_{13} means $\nu/\bar{\nu}$ CP asymmetry we're trying to detect is small so will need a detailed understanding of these $\nu,\bar{\nu}$ differences!

Very Low Energy Proton Threshold

- example of a data event in ArgoNeuT with a 22 MeV KE proton overlaid on top of a muon track