B.T.Fleming
PAC presentation
November 3rd, 2008

ArgoNeuT and MicroBooNE

- ArgoNeuT Status
- MicroBooNE Status
- Impact on the broader program

Will have updated collaboration
list here to point out
new institutions
new collaborators
will list grad students in red?

R&D | Physics

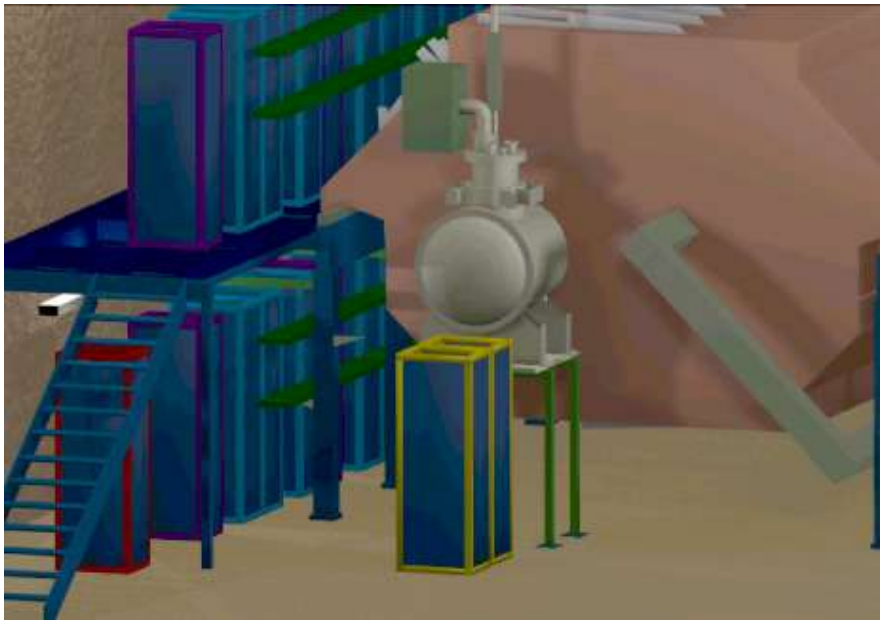
ArgoNeuT (2008)

Joint NSF/DOE project

0.3 ton active volume

0.5 x 0.5 x 1.0 m^3 TPC; 500 channels

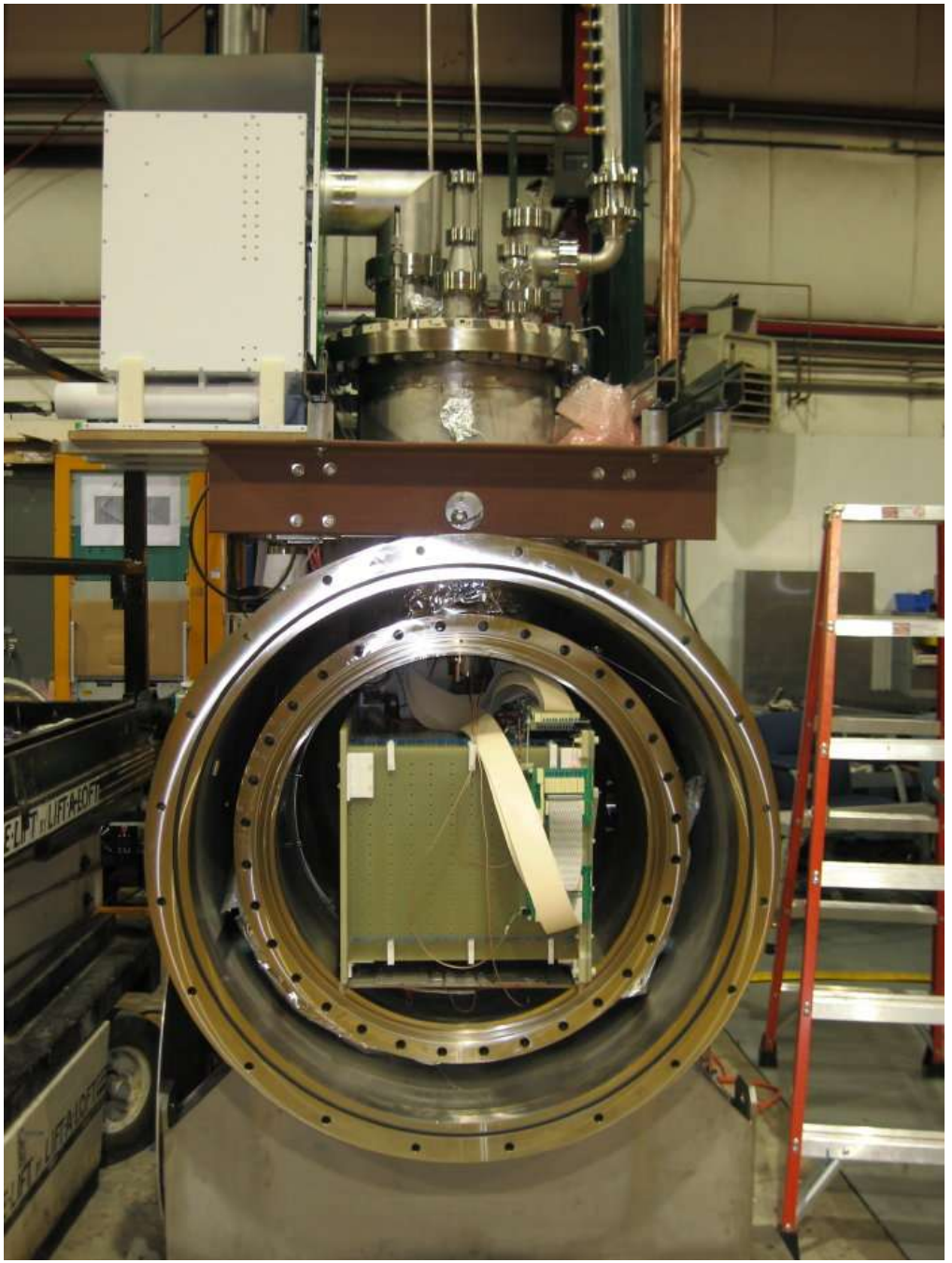
- See neutrino interactions (~150 evts/day)
- Long term running conditions
- Underground issues

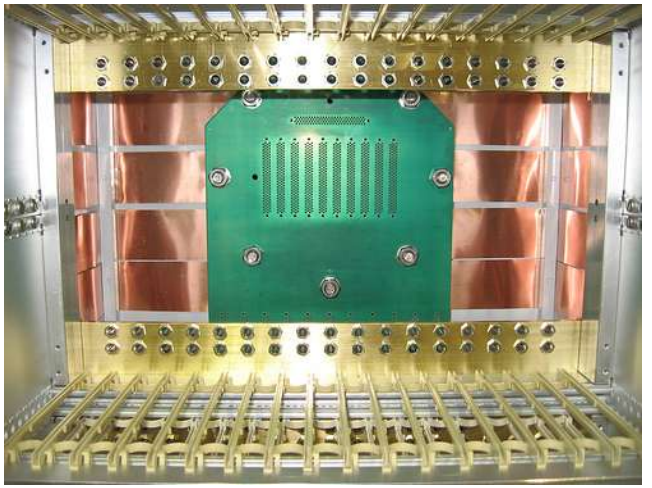


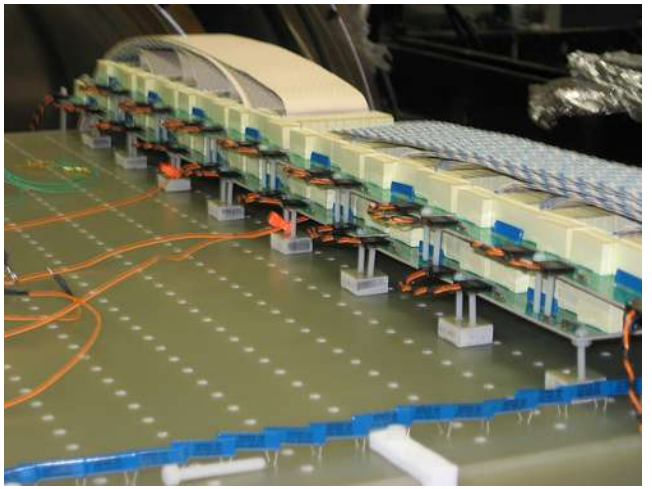
Located in NuMI near hall using MINOS near detector as a muon catcher

Detector fully assembled and commissioned above ground in August

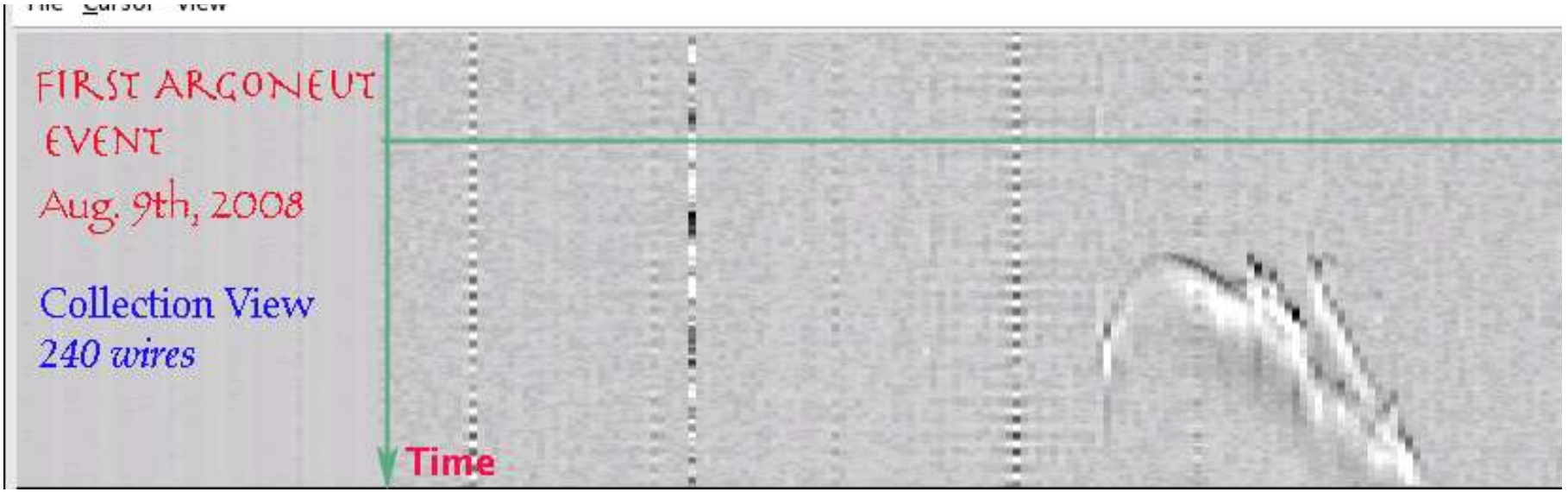
Inner detector and Readout

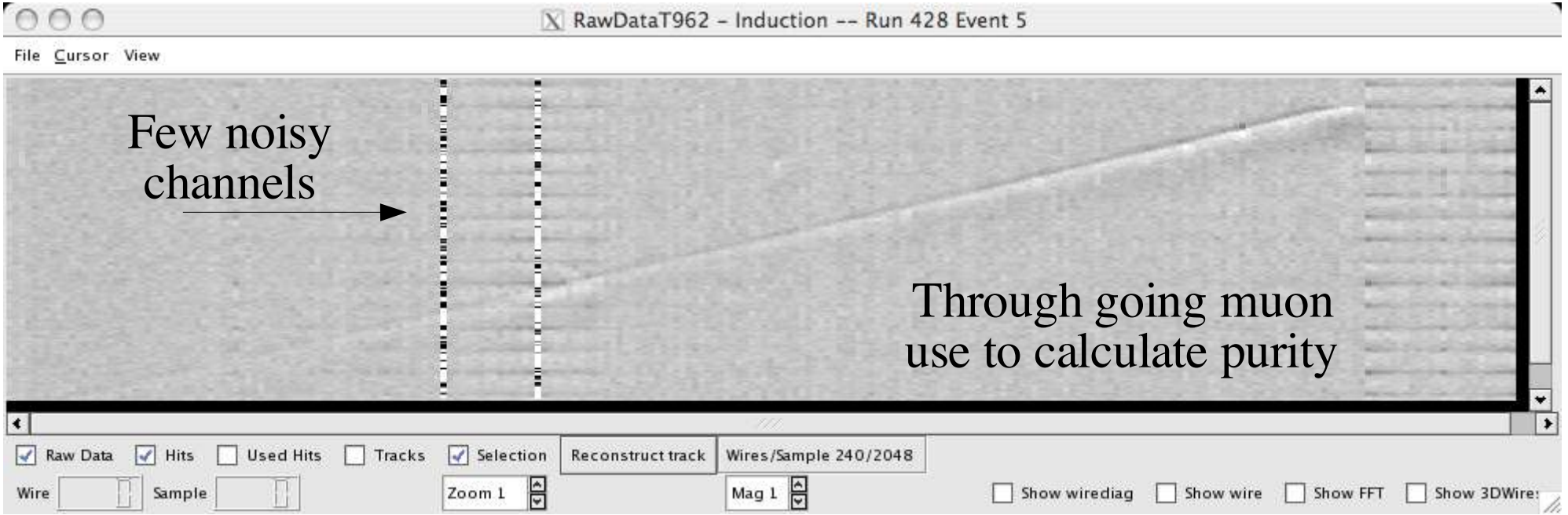




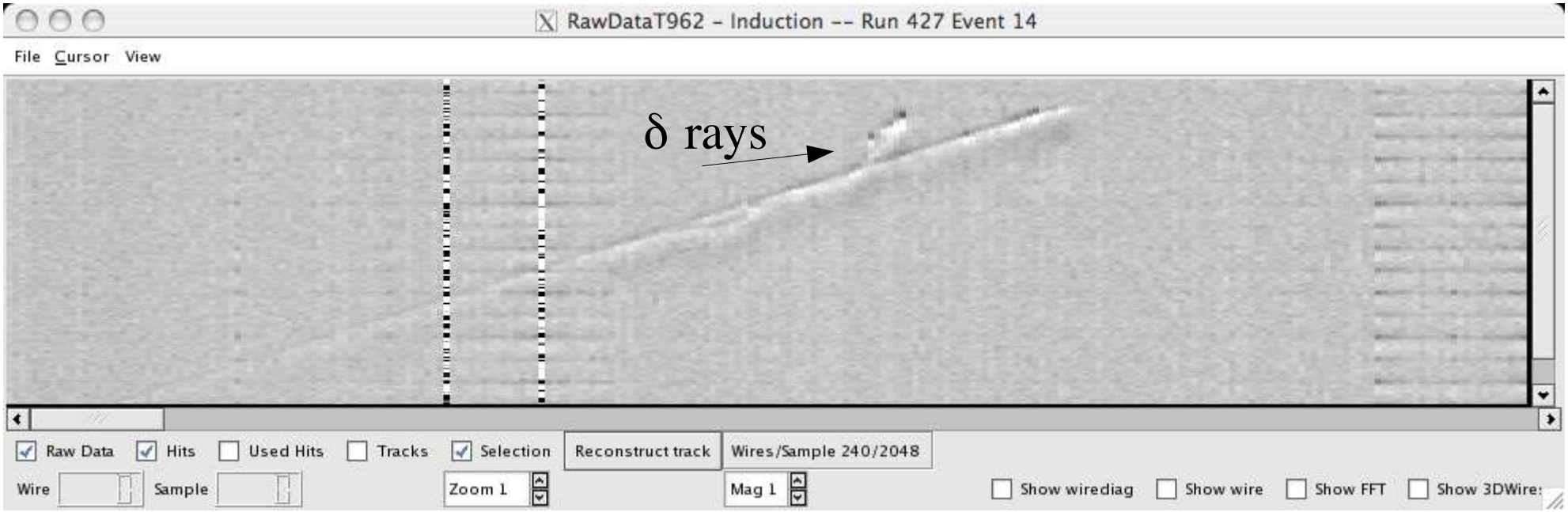


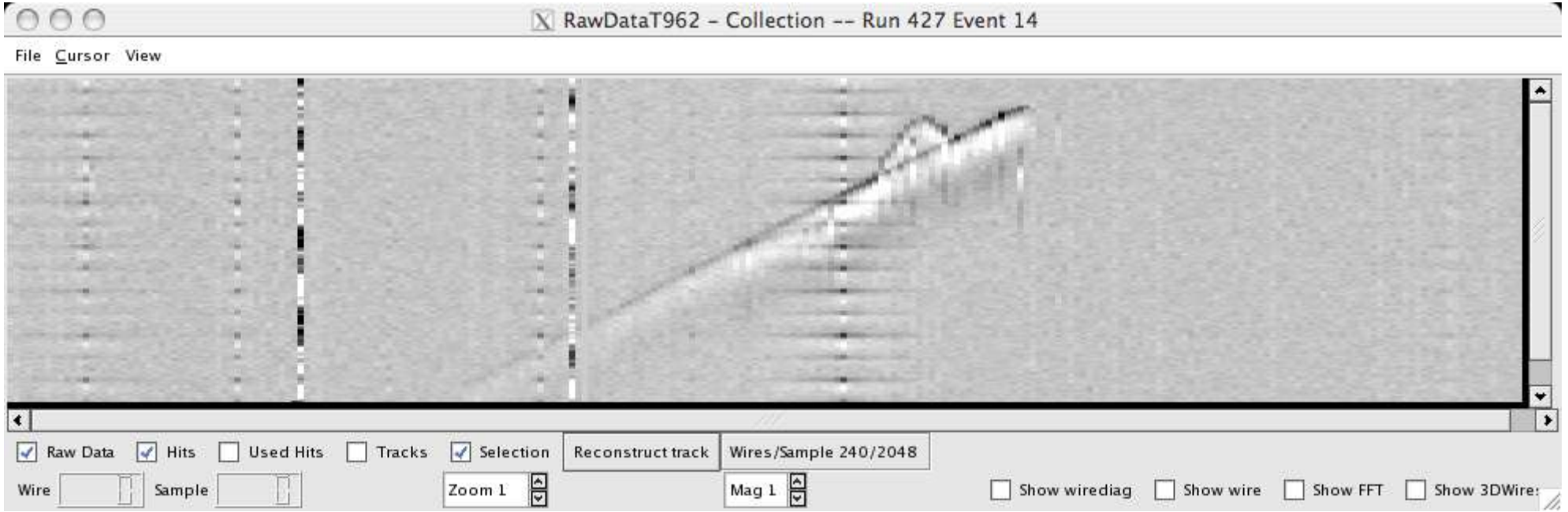
ArgoNeuT fill with LAr for first time on August 4th. First cosmic tracks seen on August 9th!



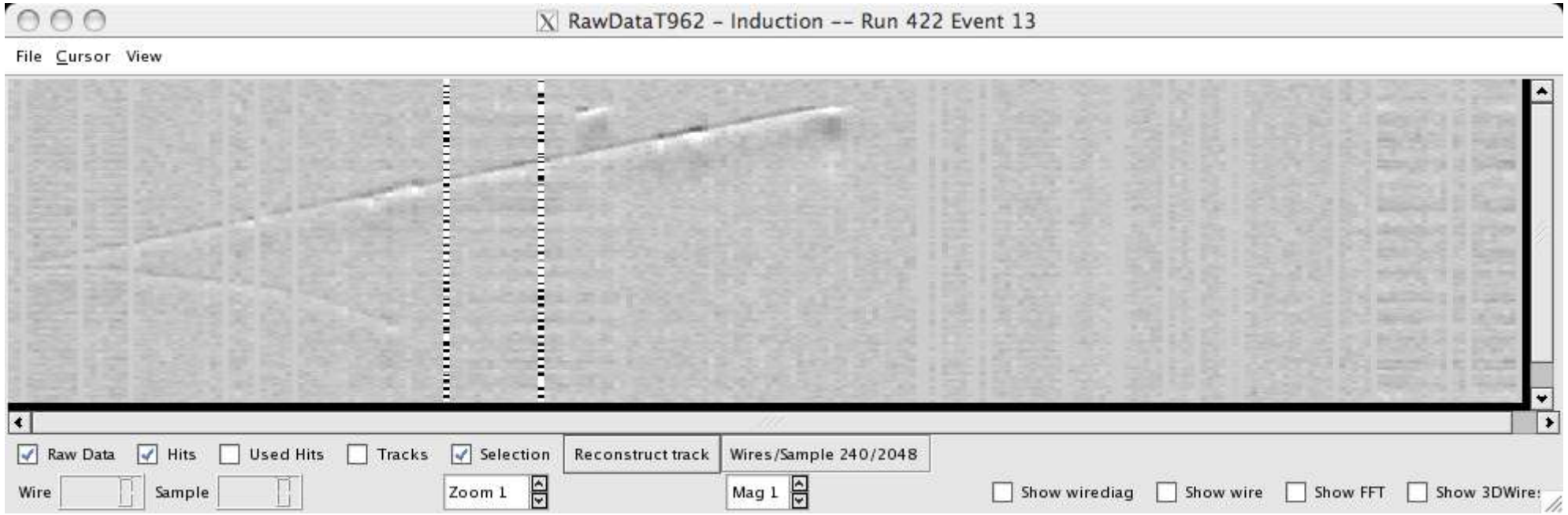


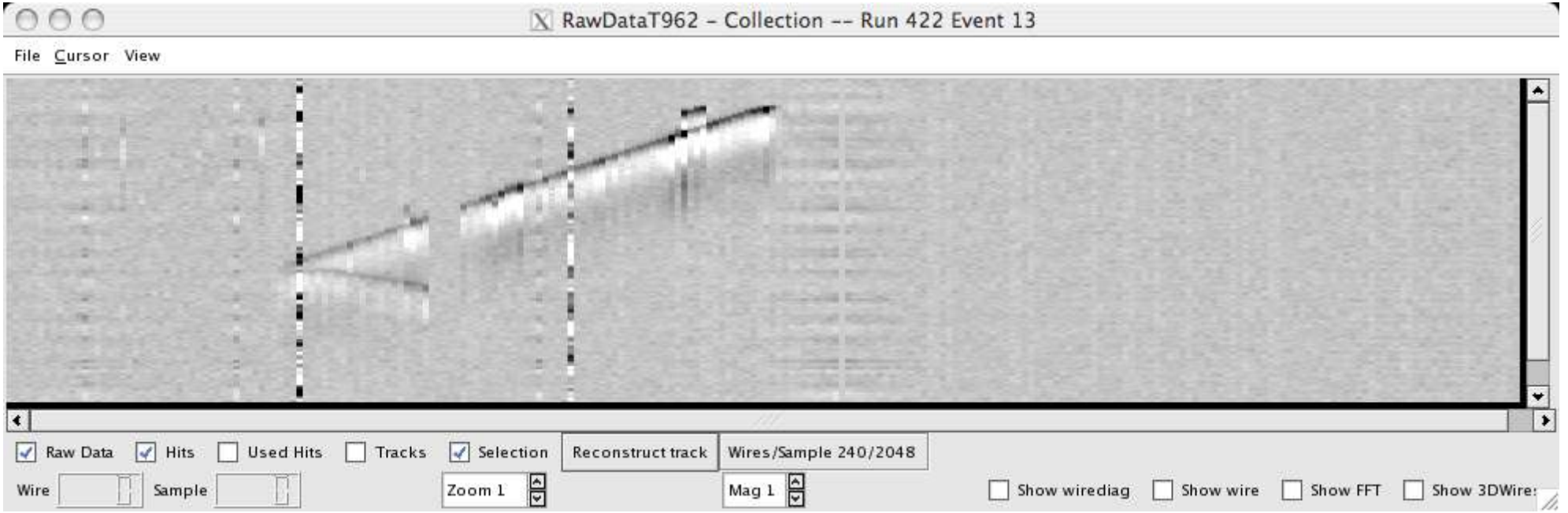
Another muon – in Induction and Collection planes





Candidate neutrino interaction in Induction and Collection planes



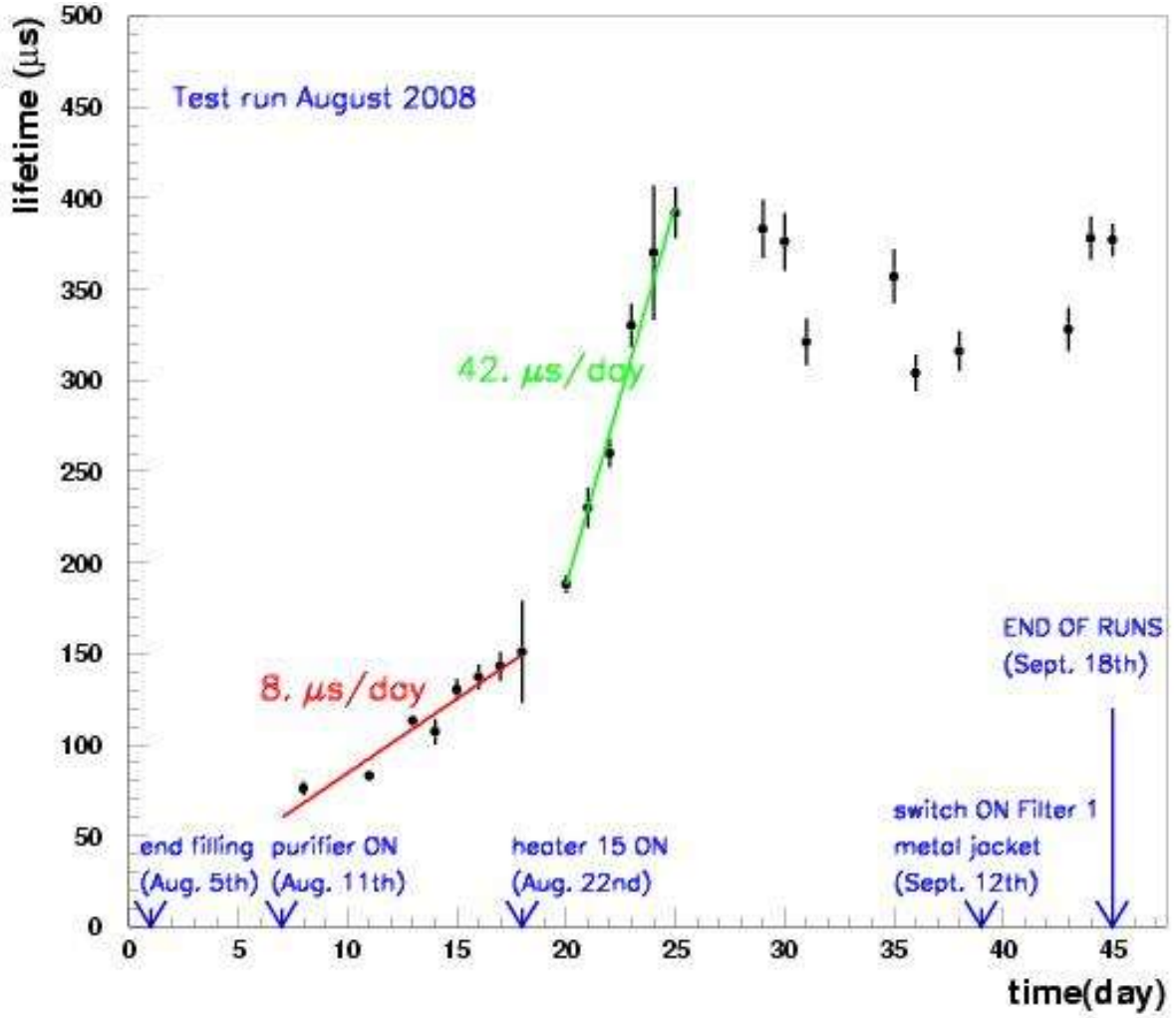


Lessons learned:

- This is not "black majic"!
- That said: Purity is good enough for ArgoNeuT, but details in the fill procedure and purification/cryogenic system are important!

Electron lifetime vs time during commissioning run.

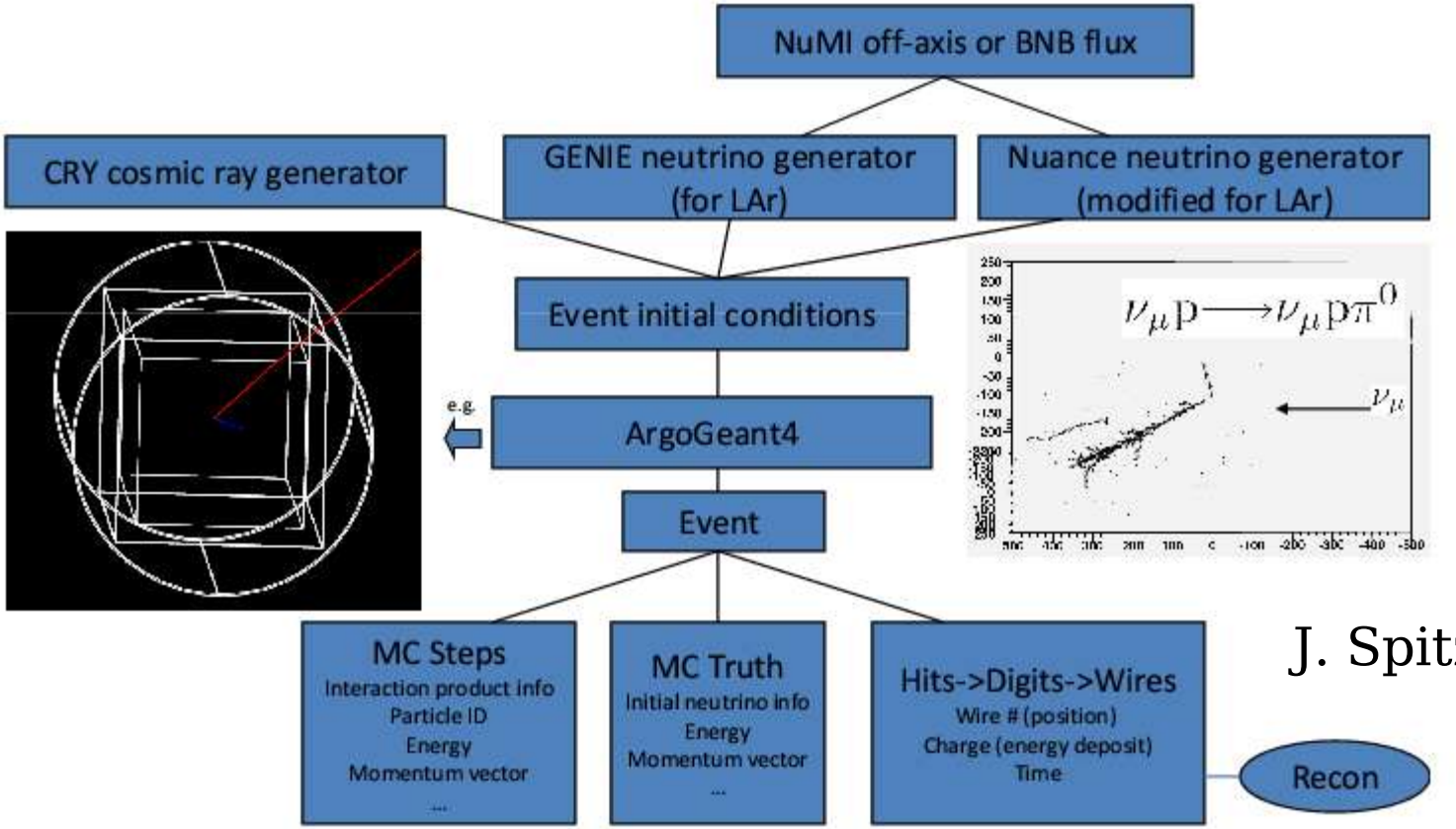
Late August/Early Sept., purity remains constant/decreases: Heat load changes or exhausted filter are possible causes



- Optimizing other systems before going underground: routing of readout cables, filter insulation, heat load balance, purity monitor fiber....

Simulation/Reconstruction effort

The Monte Carlo tree



J. Spitz

Overall framework for Simulation and Reconstruction packages in development.

Combined Analysis tools effort for ArgoNeuT/MicroBoone

B.T.Fleming
PAC presentation
November 3rd, 2008

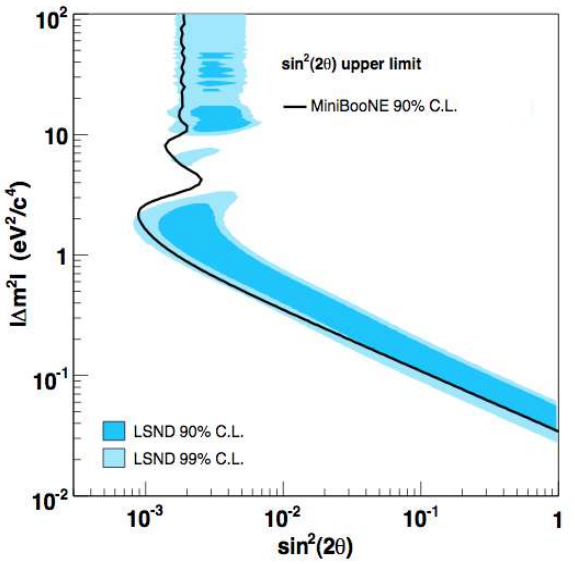
ArgoNeuT and MicroBooNE

- ArgoNeuT Status
- MicroBooNE Status
- Impact on the broader program

- Physics Motivation update
- Detector design work
- Review process

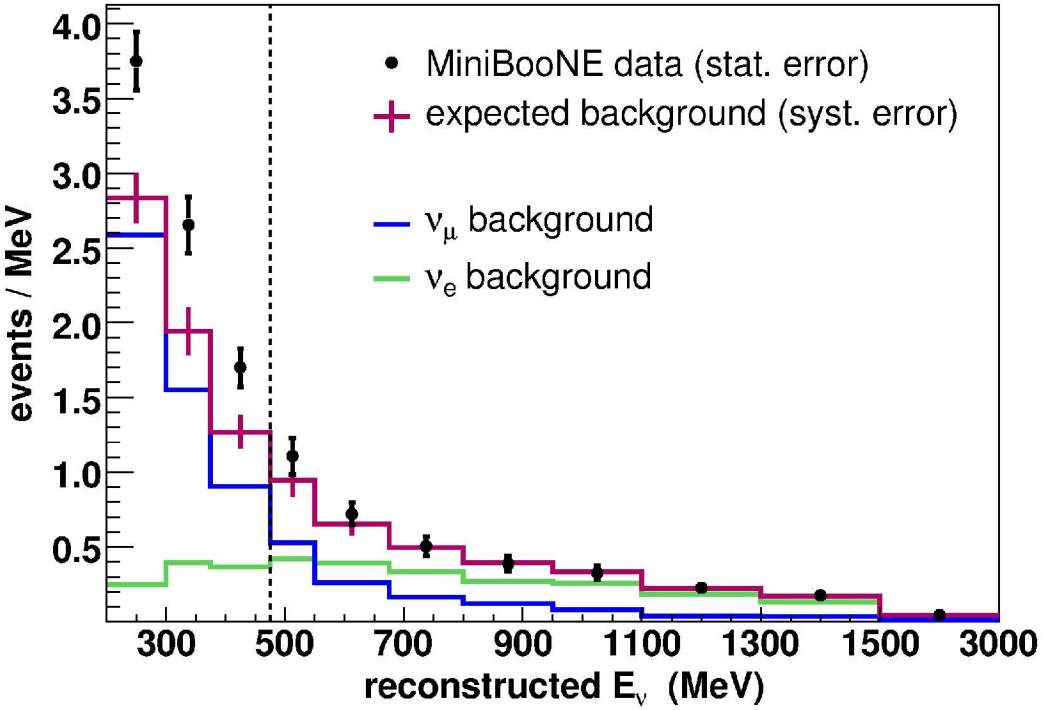
MiniBooNE Results, 2007

Data consistent with background in $475 < E_\nu^{QE} < 3000$ MeV analysis region



Incompatible with the LSND experiment at 98% CL.

Excess below this not well understood



reconstructed neutrino energy bin (MeV)	200-300	300-475
total bkgnd	284±25	274±21
ν_e intrinsic	26	67
ν_μ induced	258	207
NC π^0	115	76
NC $\Delta \rightarrow N\gamma$	20	51
Dirt	99	50
other	24	30
data	375±19	369±19
	2.5σ	3.7σ

MiniBooNE spent ~1 year to understand the low energy region and continues to see a >3 sigma excess.....

- Basic checks that events looked electromagnetic, were distributed evenly in time and space
- In depth analysis of backgrounds, uncertainties, and cuts

Some effects added to excess, some removed excess...

- Improved treatment of π flux errors
- Improved π^0/radiative Δ analysis
- Additional hadronic processes in cross section model
- Additional cuts to remove dirt events
- New data (0.83E20 pot in neutrino mode during SciBooNE run)

Final Results

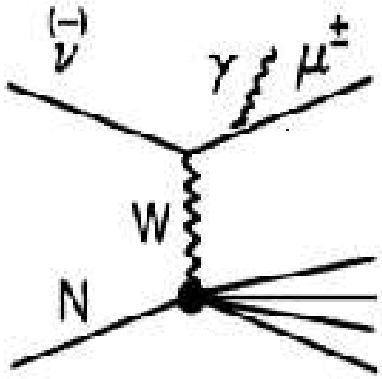
reconstructed neutrino energy bin (MeV)	200-300	300-475
total bkgnd	186.8±26.0	228.3±24.5
ν_e intrinsic	18.8	61.7
ν_μ induced	168	166.6
NC π^0	103.5	77.8
NC $\Delta \rightarrow N\gamma$	19.5	47.5
Dirt	11.5	12.3
other	33.5	29
data	232	312
	1.7 σ	3.4 σ

Excess persists!

There is a range of possible explanations….

Commonplace

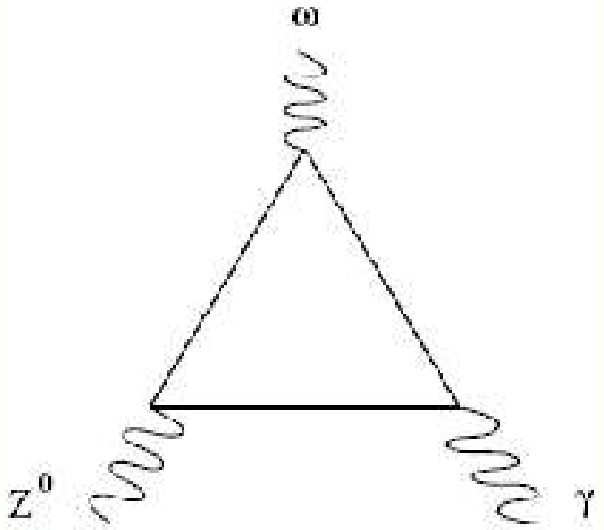
- Muon bremsstrahlung
  (Bodek, 0709.4004)



- Easy to study in MB with much larger stats from events with a Michel tag
- Proved negligible with MB data in 0710.3897

SM, but odd

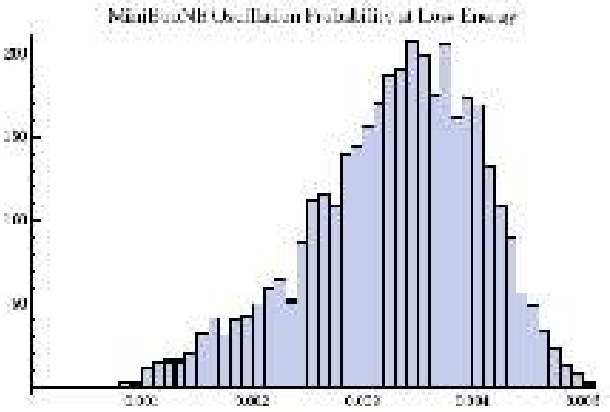
- Anomaly-mediated γ
  (Harvey, Hill, Hill, 0708.1281)



- Still under study, nuc. effects neglected, δg_{ω}
- Has to contribute…how much?

Beyond the SM

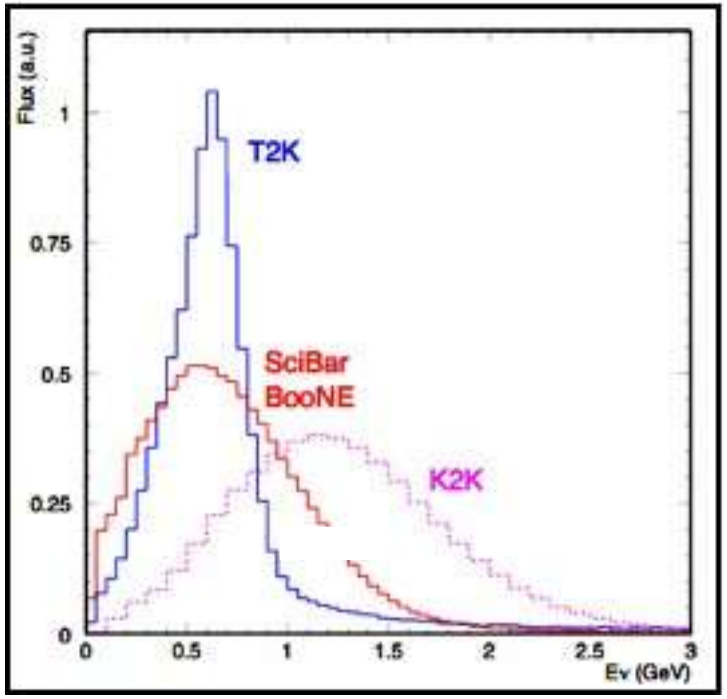
- New gauge boson
  (Nelson, Walsh,0711.1363)



- Can accommodate LSND and MiniBooNE
- Firm prediction for anti-neutrinos

Distinguishing electrons from gammas is key to interpreting the signal

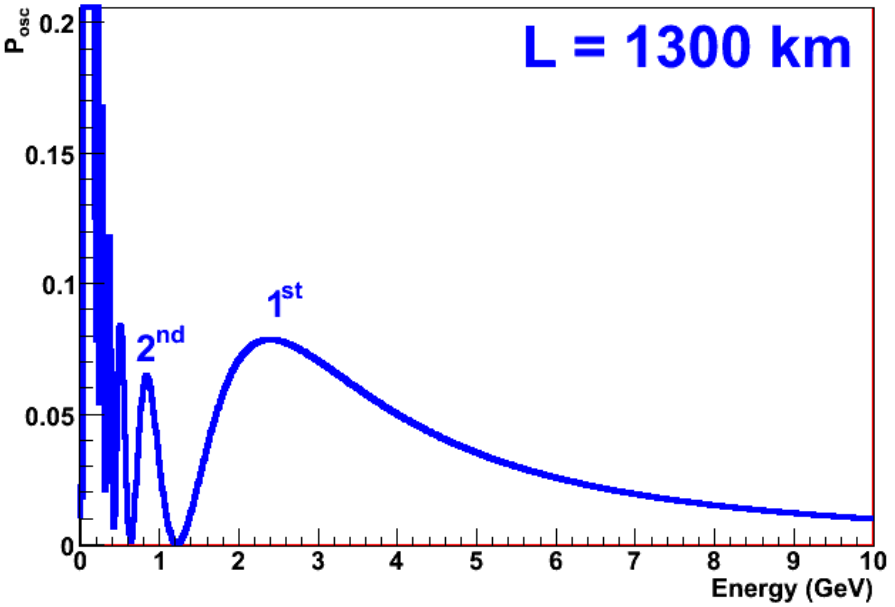
Regardless of interpretation, excess must be understood for next generation ν_e appearance measurements.



T2K experiment:

- Similar energy spectrum
- Cerenkov detection technique
- <1% oscillation probability
- excess would be a background of ~100 events at >100 MeV

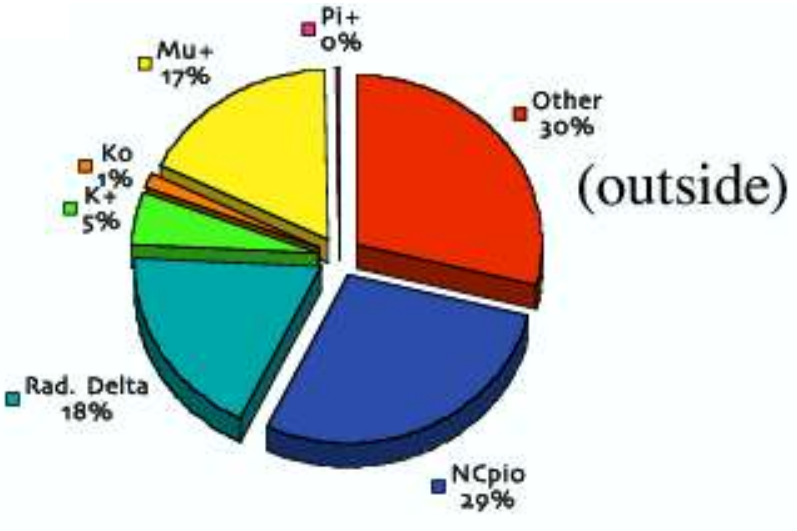
DUSEL Long Baseline Program:
Low energy excess in region of 2^{nd} oscillation maxima



MicroBooNE's LArTPC detection technique extremely powerful

- e/γ separation capability removes ν_μ induced single γ backgrounds
- electron neutrino efficiency: ~x2 better than MiniBooNE
- sensitivity at low energies (down to tens of MeV compared to 200 MeV on MiniBooNE)

MiniBooNE low E backgrounds



Translates to 5σ sensitivity if excess is ν_es

3σ if excess is γs

in MicroBooNE's 70 ton fiducial volume

Low energy neutrino interactions:

Sizable samples contained interactions and rare interactions to make unique measurements

- CCQE sample: ~15k contained events is enough to study kinematics and extract MA

- ~500 neutrino interactions in which a K+ is produced with an energy and decay signature similar to Ks from proton decay
- Study of coherent pion production
- Search for anomalous photon production
- Measure photo-nuclear interactions
- ~170 intrinsic electron neutrino interactions

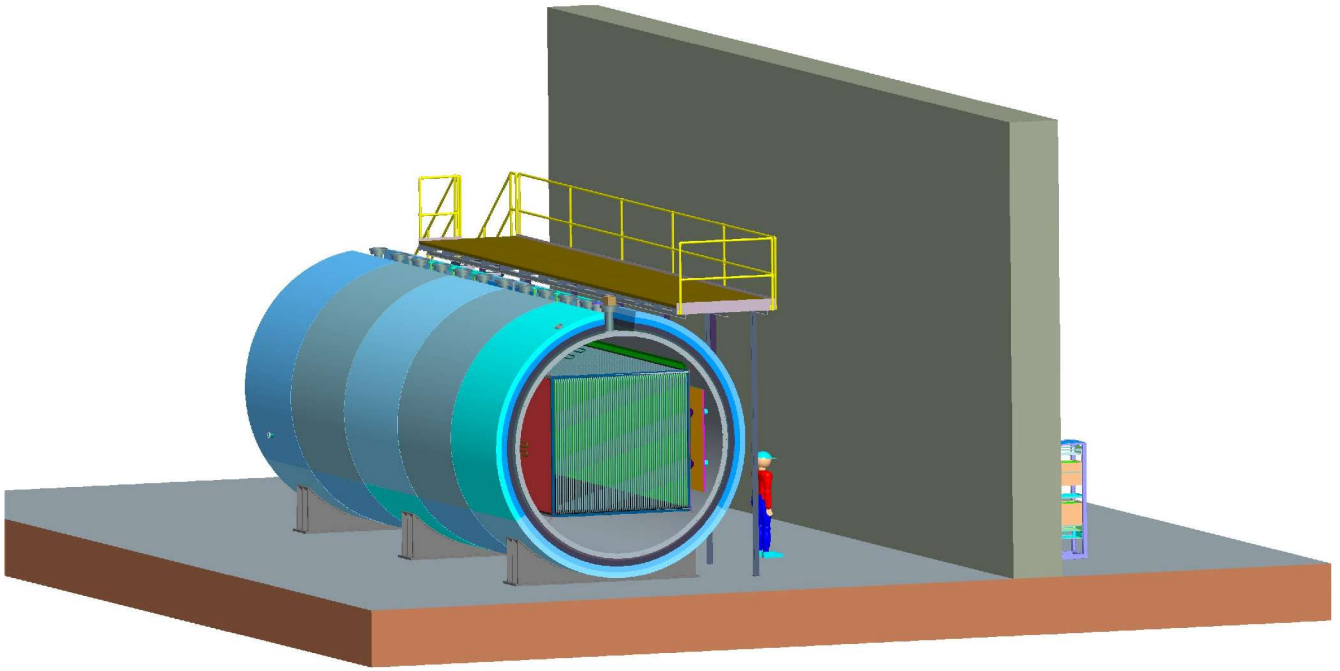
- Measurement of Ncpi0 and Delta decays at low energies

MicroBooNE design parameters:

Physics case and R&D program are driving the MicroBooNE design:

- Detector size
- TPC and PMT design
- Dynamic range and data readout
- Cryostat and Cryogenics

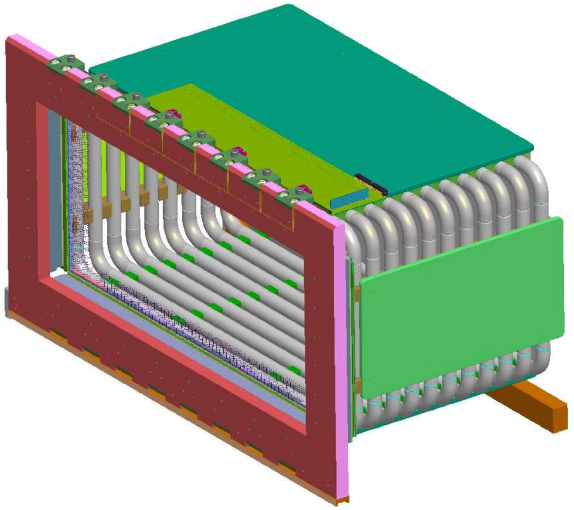
Setting these design parameters and proceeding with design work towards CD-1 in February



Detector size

- As big as possible to use MicroBooNE to learn about the next steps
- As big as possible while remaining a reasonable cost and reasonable size to construct in industry and ship to FNAL.
- The right size to be sensitive to the low energy excess and to have sizable samples for low energy cross section measurements

Active Detectors design:



Wire termination movie goes here

Mechanical prototype (in design) to understand details of:

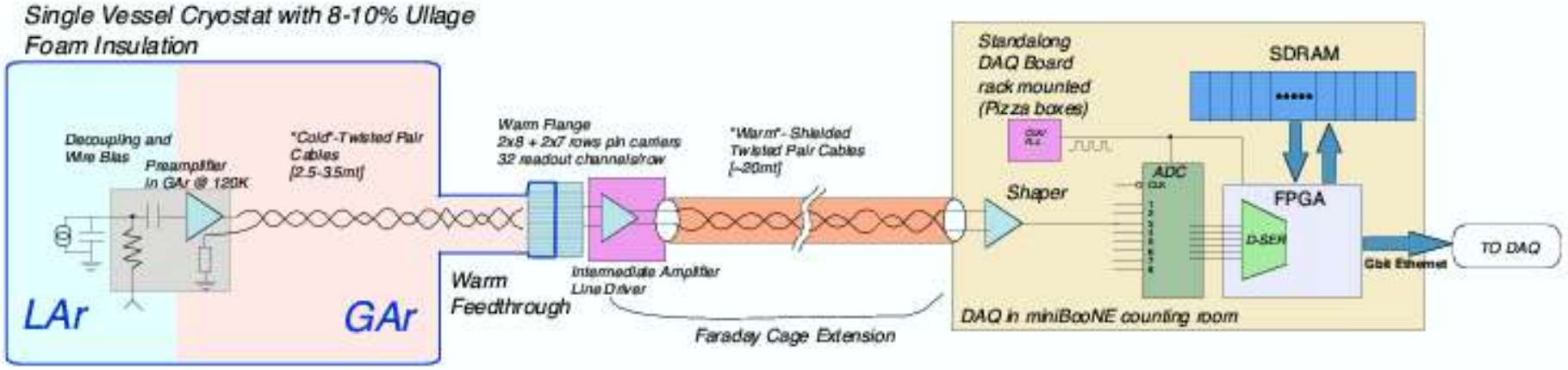
- Wire carrier assembly and attachment
- Wire choice and stringing and tensioning process
- Field cage and resistor chain design
- Quality Assurance checks

Other issues to be addressed:

- Wire chamber frame and field cage piece size (issues related to installation for MicroBooNE and beyond)
- Wire sag of long wires over time

TPC construction and wire assembly to be done at Yale
PMT assembly and testing to be done through MIT → NSF MRI

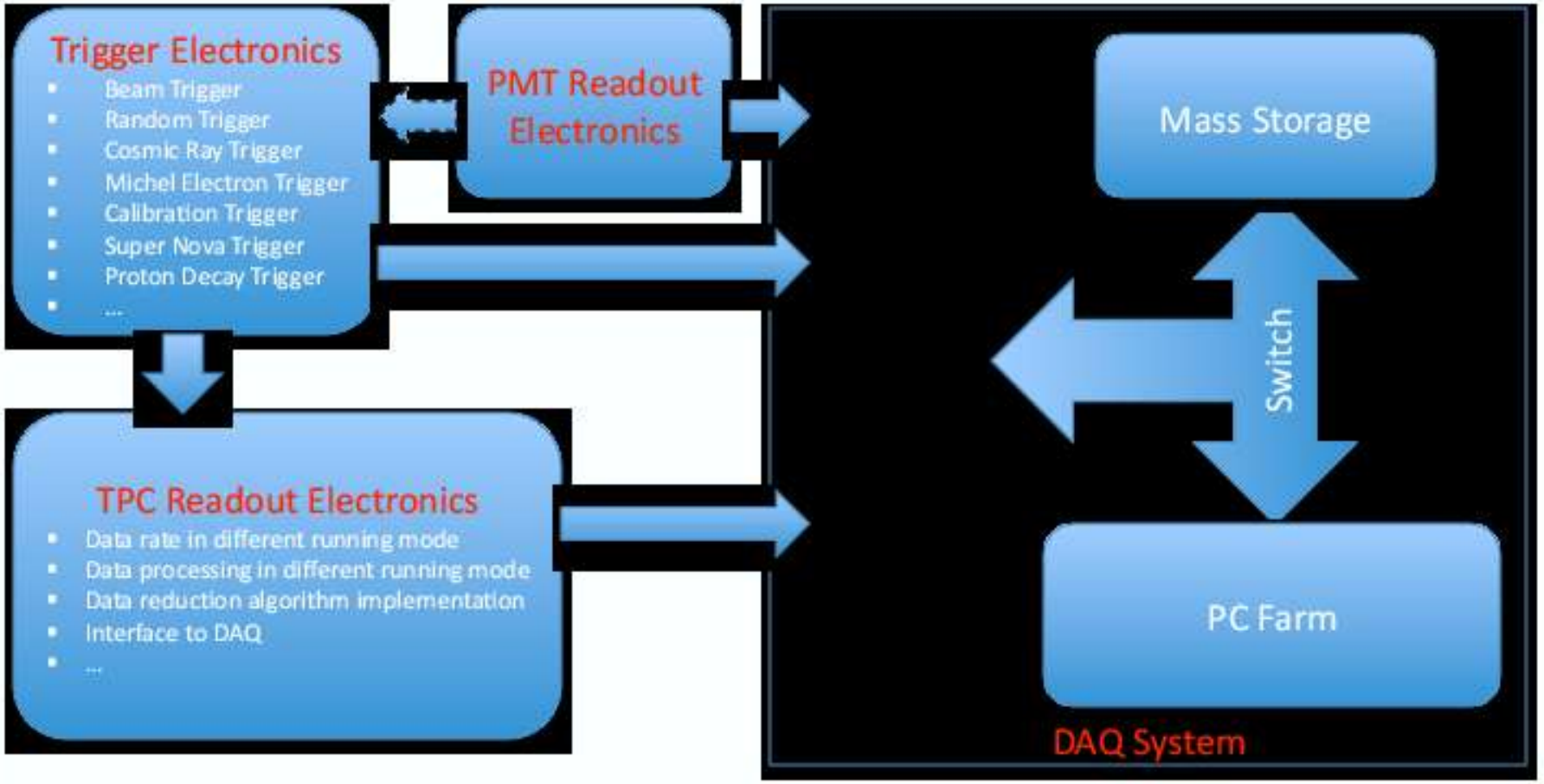
TPC Readout Scheme



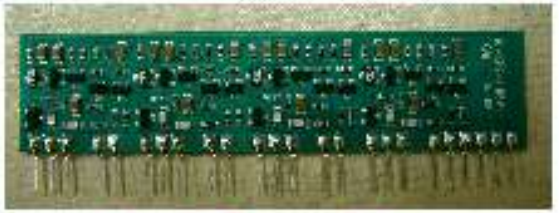
- Cold Electronics
  - Preamplifier — Prototype
  - Cold Motherboard — Prototype
  - Cold Cable
- On-Detector Electronic
  - Intermediate Amplifier — Prototype
  - Warm Cable
- Readout Electronics
  - TPC Readout Board
    - Analog Part — Layout
    - Digital Part — Prototype
  - Calibration Board
  - Transmission to DAQ
    - Gigabit Ethernet
- DAQ
  - Event Builder
  - DAQ Software

Parameters driving design:
Dynamic range needed for physics goals
Data readout rate for MicroBooNE and beyond

Layout of MicroBooNE Readout System

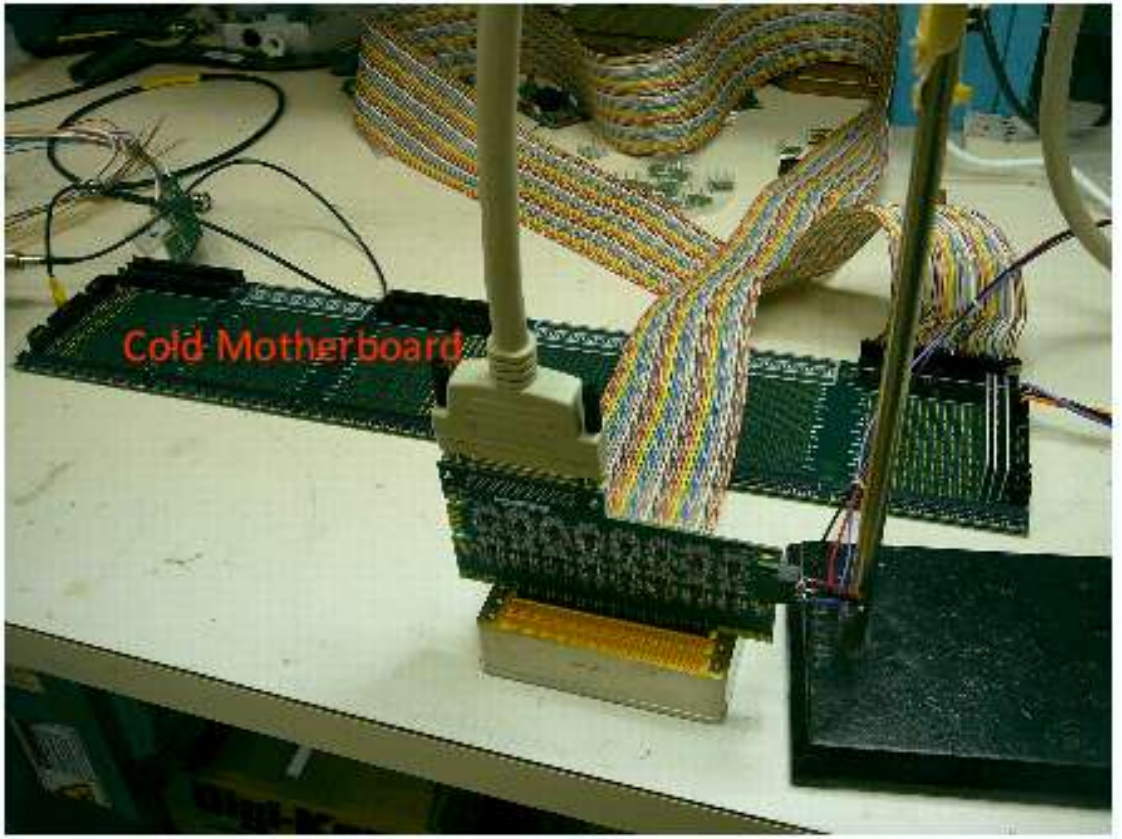


Prototype of Cold Electronics and On-Detector Electronics

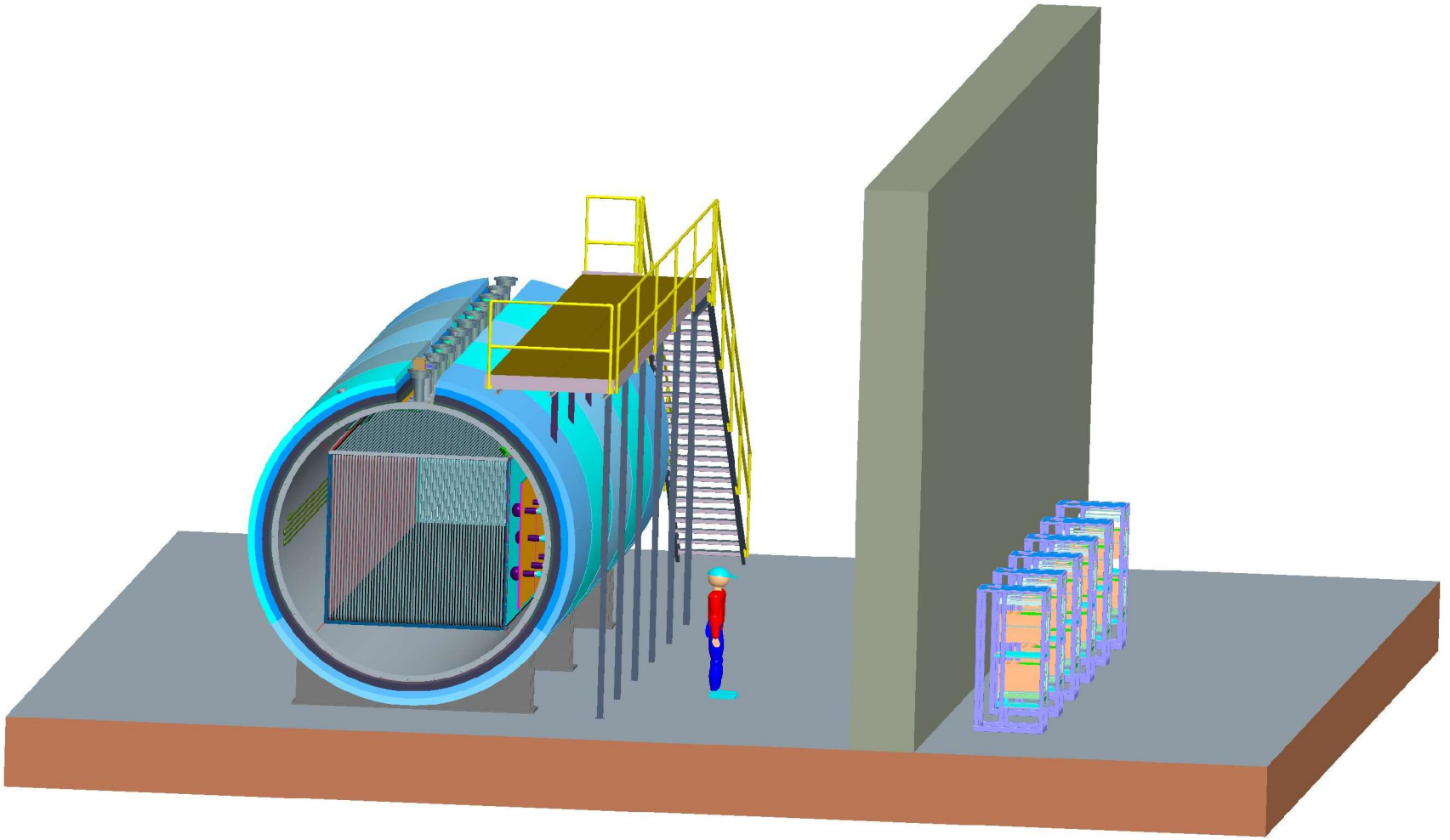


Quad Preamplifier

Intermediate Amplifier



Front End Readout Electronics Test Setup



Cryostat/Cryogenics/Purification design work continues.

Cryogenics engineering resources are tight
Trying to augment cryogenics team with cryogenics engineers outside FNAL/BNL

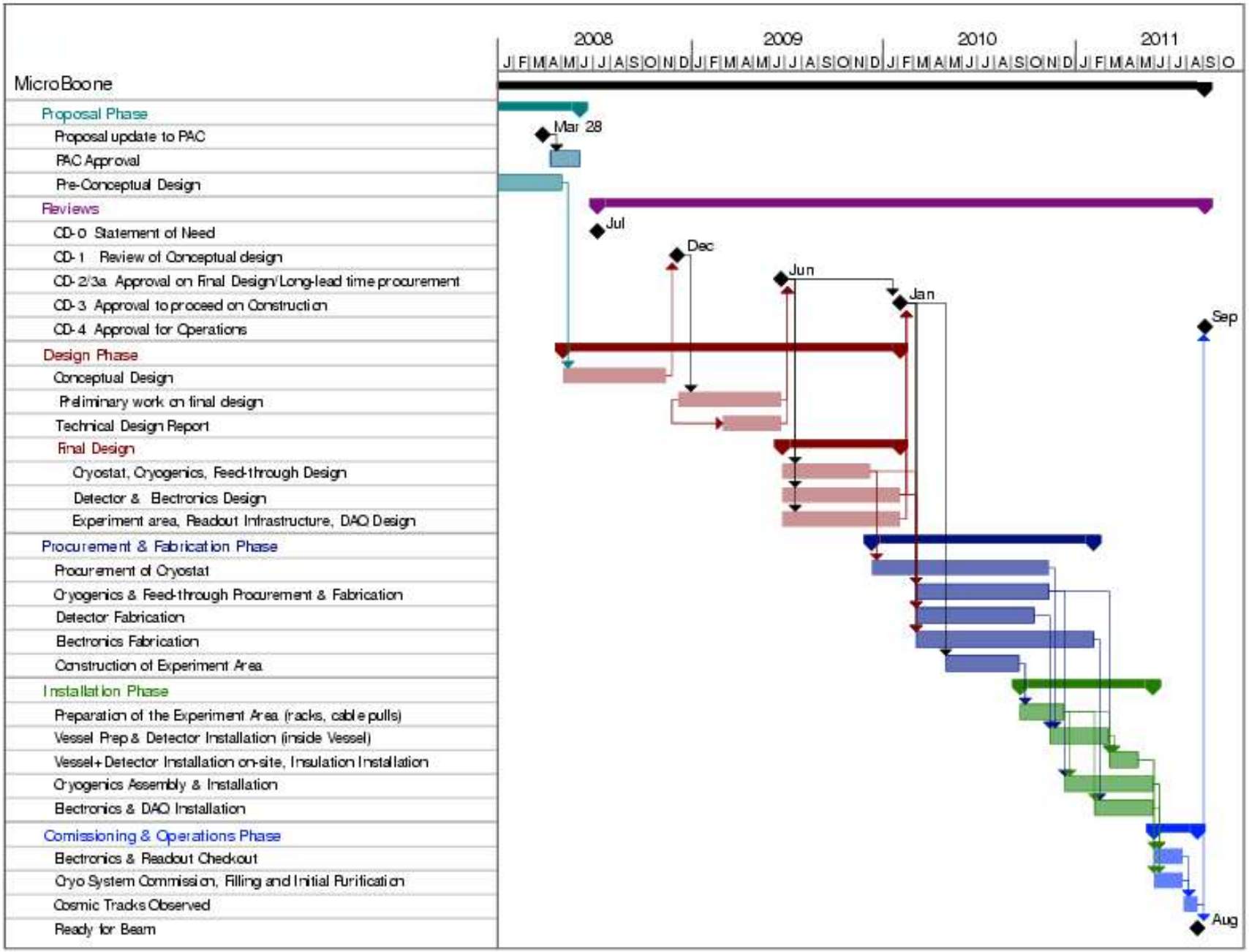
Collaboration re-structuring to move through this design period

Project Manager: Cat James

Working Groups	Conveners	CAMs
Active Detectors	Bo Yu, Teppei Katori	Bonnie Fleming
Electronics	Hucheng Chen	HuCheng Chen
DAQ		
Cryostat/Cryogenics and Purification	Stephen Pordes Dave Schmitz	Brian Rebel
Beam	Sacha Kopp	Sacha Kopp
Building and Infrastructure	Cat James	Cat James
Analysis Tools	Mike Shaevitz Brian Rebel	
Physics Analysis	Janet Conrad Mitch Soderberg	

Formation of Institutional Board and bylaws
Formation of Technical Board to advise on design

Working on design and materials needed for CD-1 in February


2008
2009
2010
2011
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O
MicroBoone
Proposal Phase
Proposal update to PAC
PAC Approval
Pre-Conceptual Design
Reviews
CD-0 Statement of Need
CD-1 Review of Conceptual design
CD-2/3a Approval on Final Design/Long-lead time procurement
CD-3 Approval to proceed on Construction
CD-4 Approval for Operations
Design Phase
Conceptual Design
Preliminary work on final design
Technical Design Report
Final Design
Cryostat, Cryogenics, Feed-through Design
Detector & Electronics Design
Experiment area, Readout Infrastructure, DAQ Design
Procurement & Fabrication Phase
Procurement of Cryostat
Cryogenics & Feed-through Procurement & Fabrication
Detector Fabrication
Electronics Fabrication
Construction of Experiment Area
Installation Phase
Preparation of the Experiment Area (racks, cable pulls)
Vessel Prep & Detector Installation (inside Vessel)
Vessel+Detector Installation on-site, Insulation Installation
Cryogenics Assembly & Installation
Electronics & DAQ Installation
Comissioning & Operations Phase
Electronics & Readout Checkout
Cryo System Commission, Filling and Initial Purification
Cosmic Tracks Observed
Ready for Beam
Mar 28
Jul
Dec
Jun
Jan
Sep
Aug

Concurrently working on
MicroBooNE Phase 2 R&D towards next step:

- Purity Program: MicroBooNE purge test: 6 week program to precede physics run
- Cold Electronics development: 4 year program to develop electronics and signal multiplexing to run in LAr
- Optimize detector design for MicroBooNE and beyond: constructability, cost scaling, value engineering

The LBL program to DUSEL is moving quickly – Exciting time!

Need to move quickly on MicroBooNE to be ready for this!

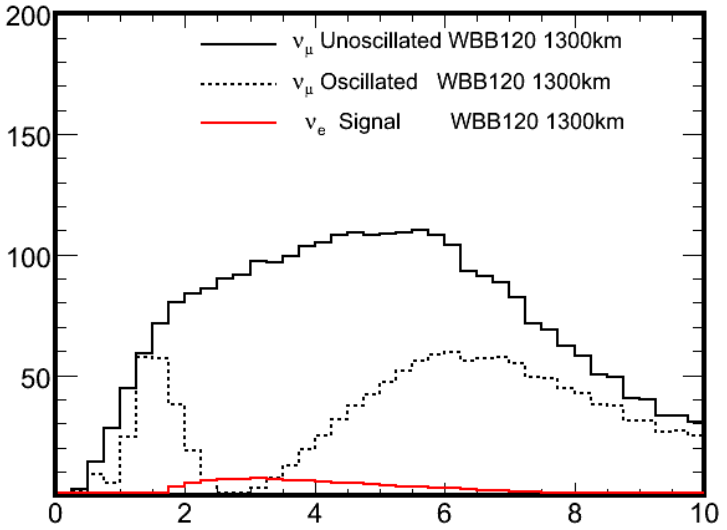
MicroBooNE
has both a physics impact on broader program
and an R&D impact on broader program

B.T.Fleming
PAC presentation
November 3rd, 2008

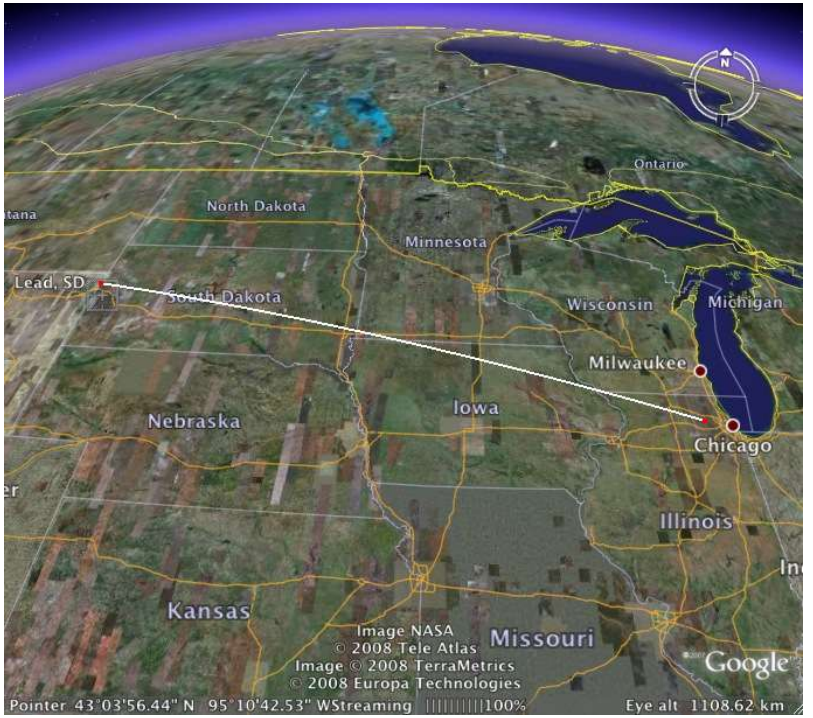
ArgoNeuT and MicroBooNE

- ArgoNeuT Status
- MicroBooNE Status
- Impact on the broader program

Long baseline neutrino program: Intense neutrino beam from Fermilab to DUSEL



Look for CP Violation in the neutrino sector



L = 1300 km (more matter effect in the oscillations)

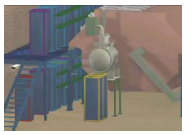
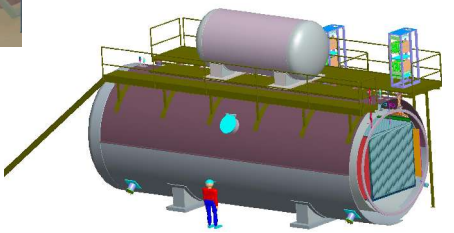
Oscillation maximum at higher energies

Broad band beam can cover 1st and 2nd maximum

Evolution of the Liquid Argon Physics Program





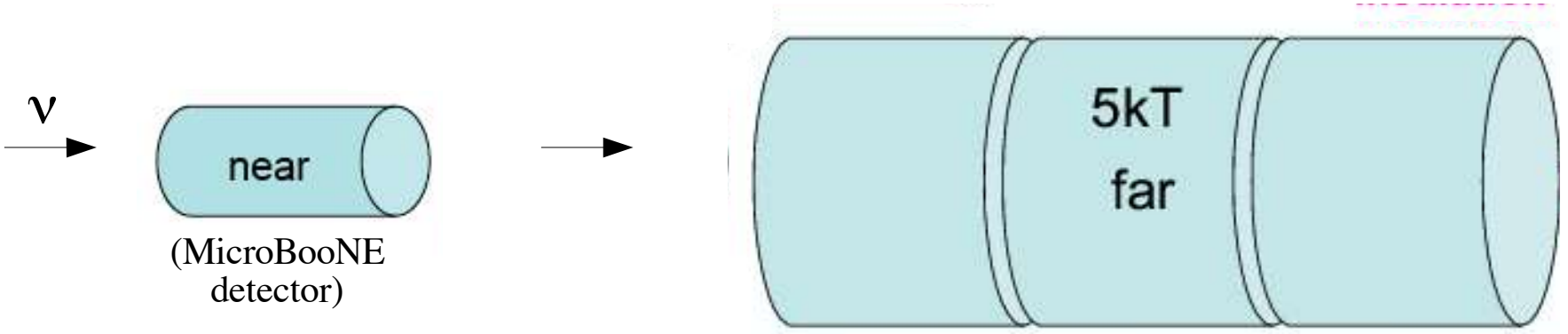
Yale TPC
Luke & Bo
R&D
Program underway

ArgoNeuT
R&D
Physics
Spring 2008

microBooNE
R&D
Physics
Data : 2011

near
5kT
far
R&D
Physics
Data : ~2015-2016?

M x N = 100 kT
Physics !!!
Data 20??



DUSEL Baseline detector plan: 5+(25) ktons

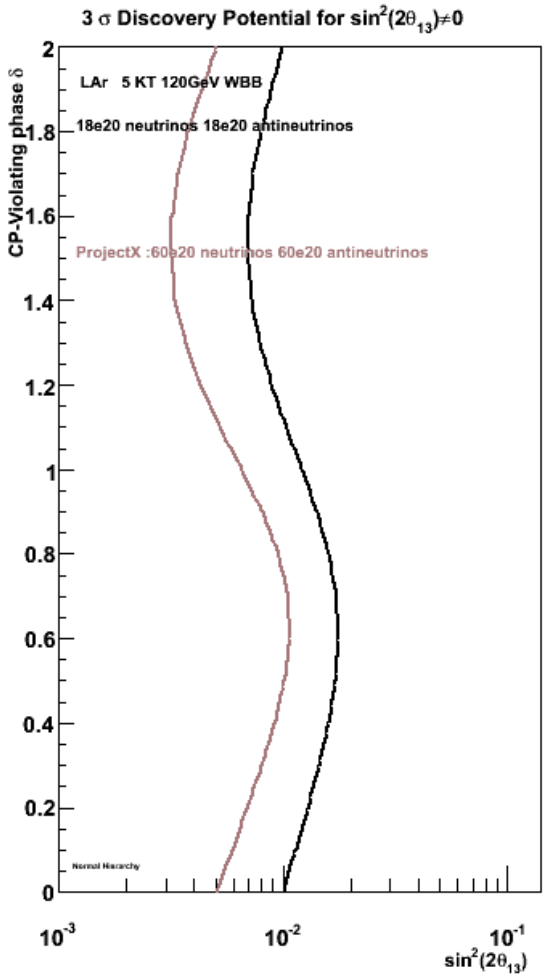
First step is 5 kton
•good step in scale, cost, and physics

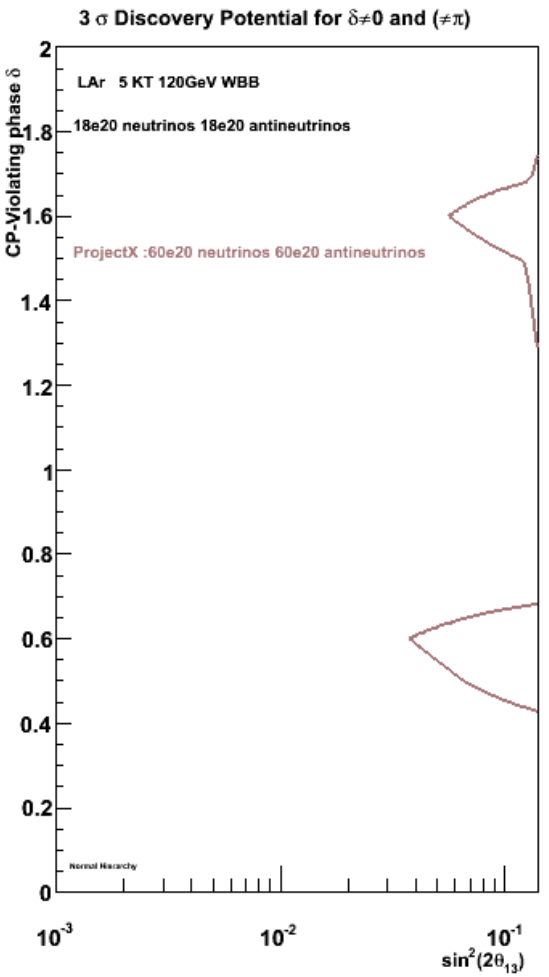
Next step is ~25ktons although design would be driven by what we learn in the next few steps: (ie: can we live without evacuatable vessels..)

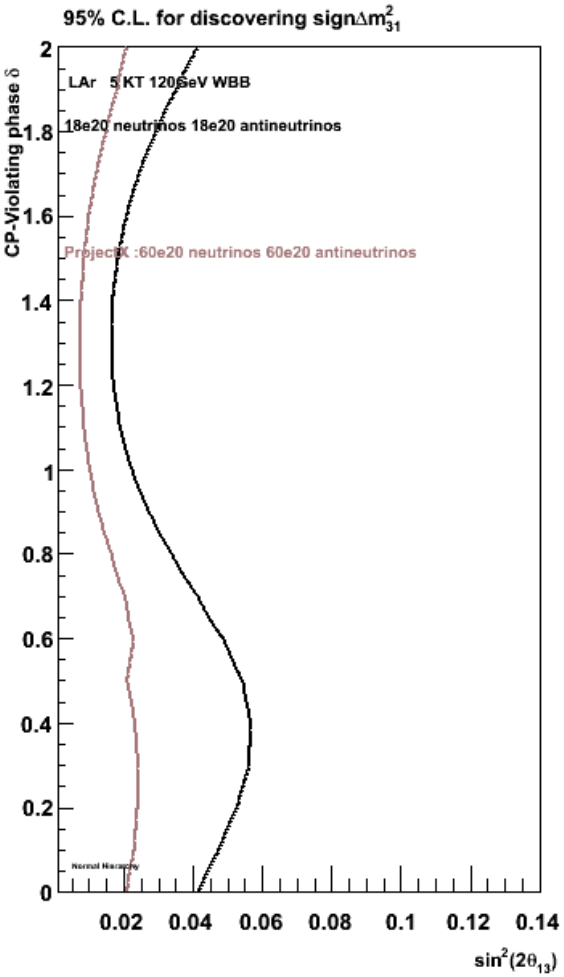
Steps beyond this in ~30kton modules: Significant physics gain as you add more modules

Collaboration forming to drive effort on 5kton

Physics reach of 5ktons







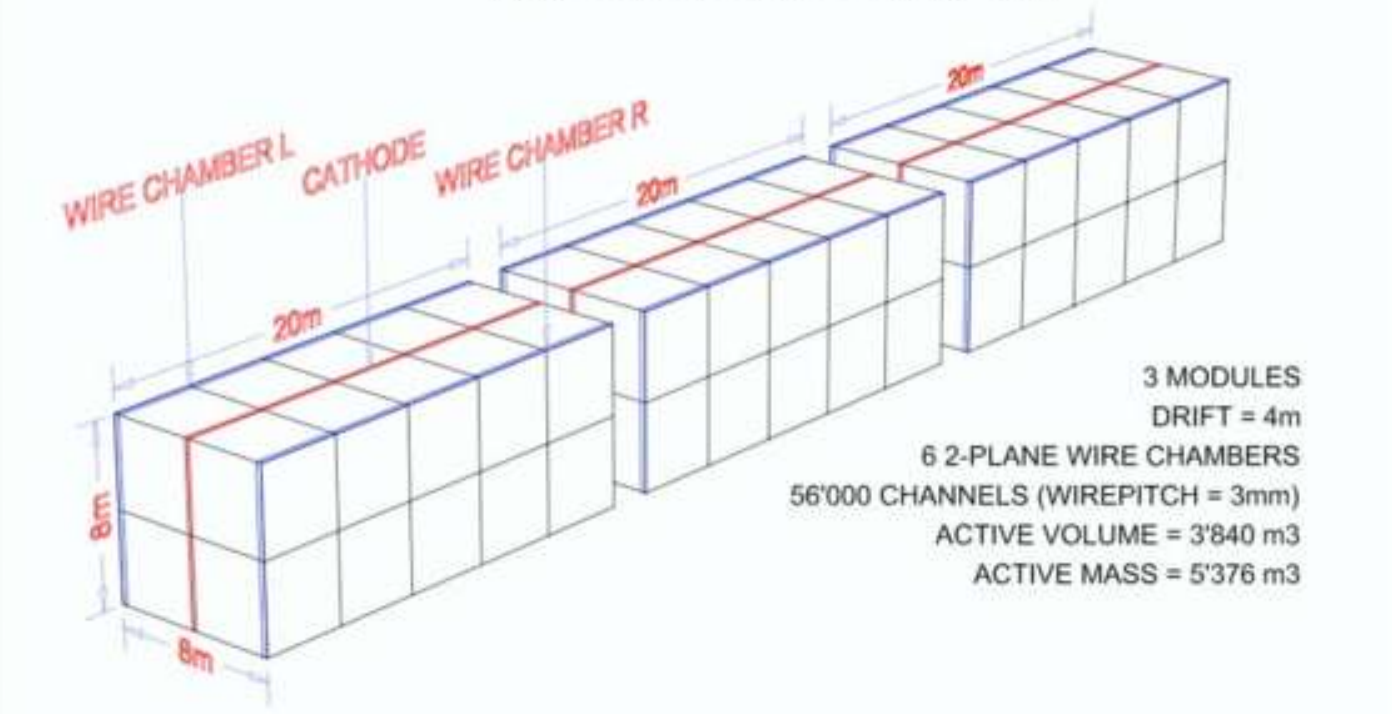
N. Saoulidou

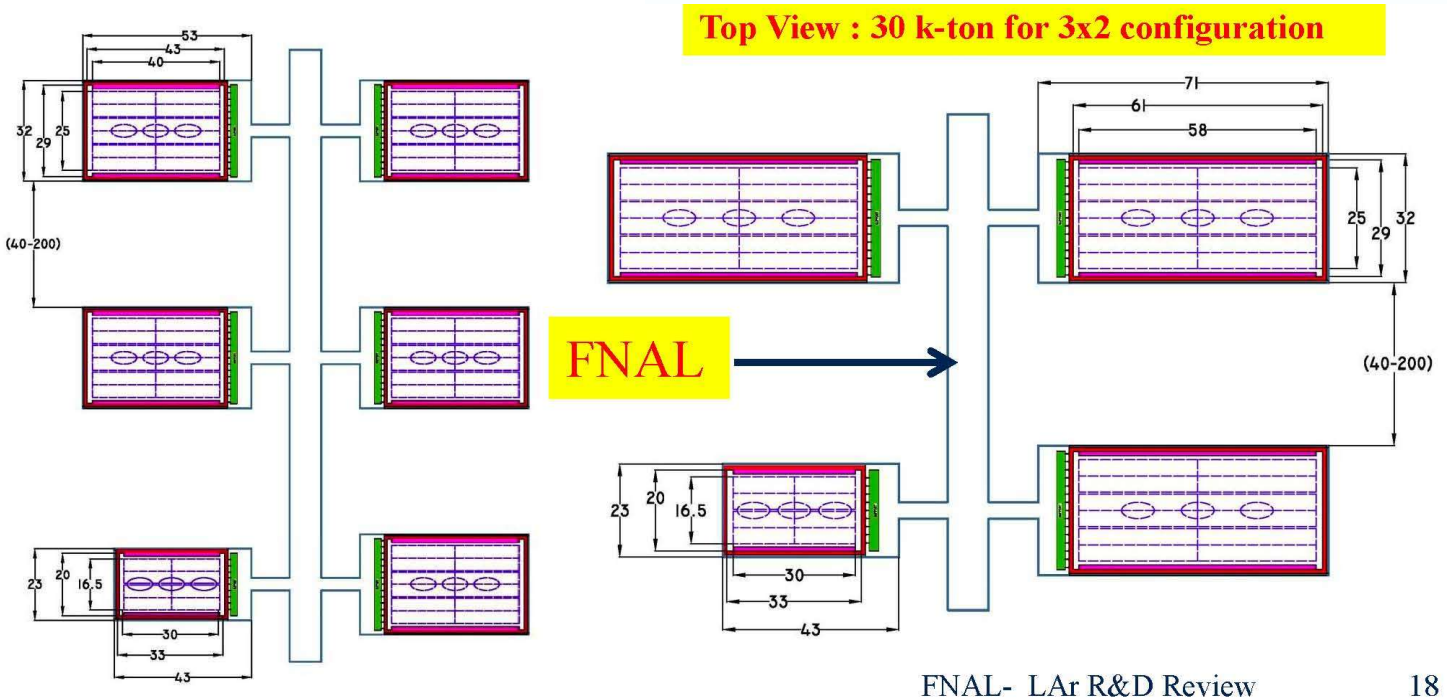
$p \rightarrow K^{+}\nu$

WC efficiency = 0.14
BG = 1.2 evts/100 kty
Nobs = Nbg

LAr efficiency = 0.98
BG = 0.1 evts/100 kty
Nobs = Nbg

5kton LAAND Modular Concept (D. Cline, F. Sergiampietri)





Microboone like concept: modularized detectors

5kton + larger modules in various possible configurations..

General underground siting issues:

LAr loss: 0_2 content, reduction of temperature

Mitigation:

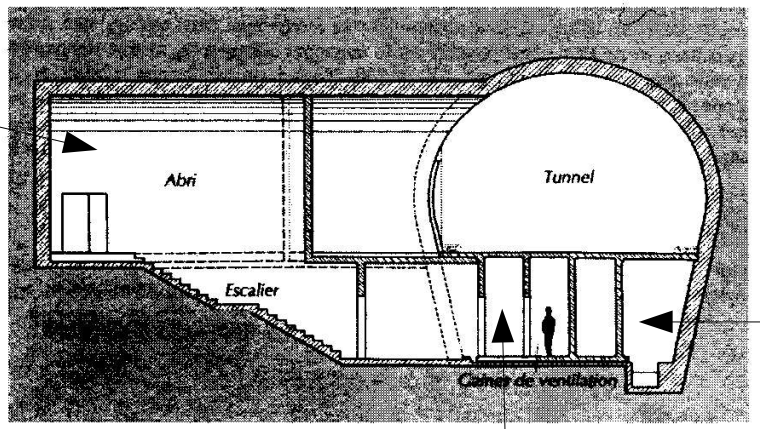
- Design: Use best cryo-techniques to minimize leaks
- Egress/Shelter: In cavern and from cavern

Experience from LNGS industry on bulk transport and storage

Mont-Blanc Safety upgrade

Refuge Shelter with fresh air

Ventilation ducts



Smoke extraction

- Ventilation: Dedicated exhaust shaft
- Freeze/thaw damage: placement and insulation

Summary:

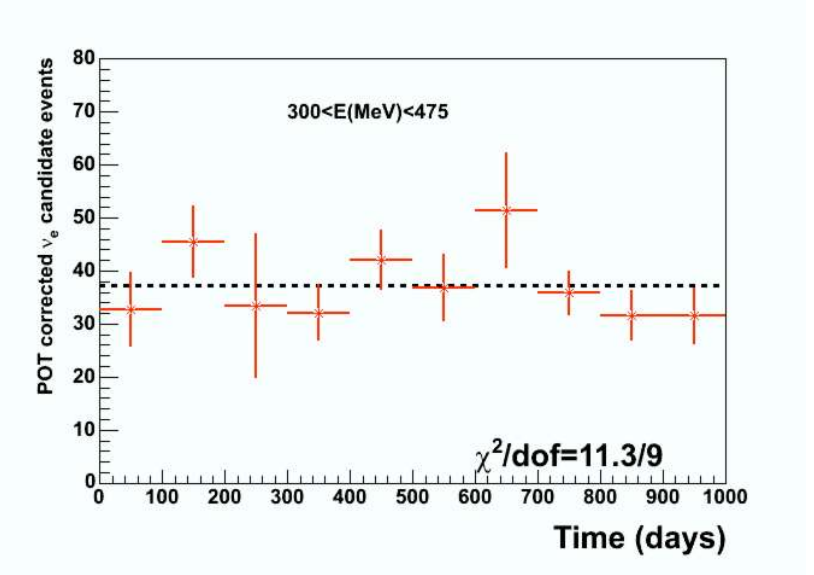
- MicroBooNE moving into design and review stage
- On track for CD-1 in February
- Cryogenics resources are tight

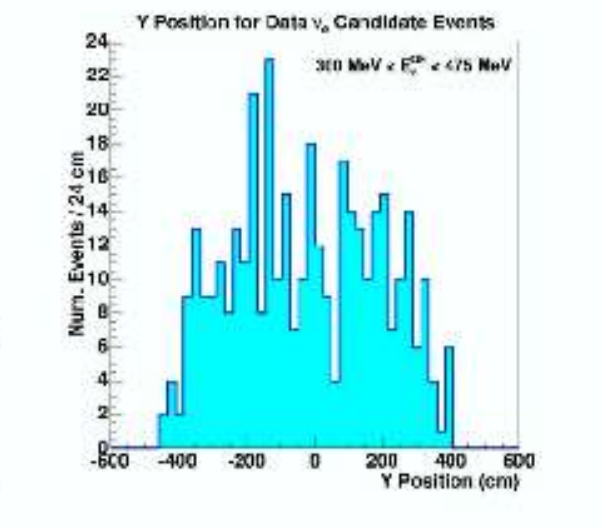
Success in timescales for DUSEL depend on an aggressive MicroBooNE Schedule!

Backup Slides

Basic checks:

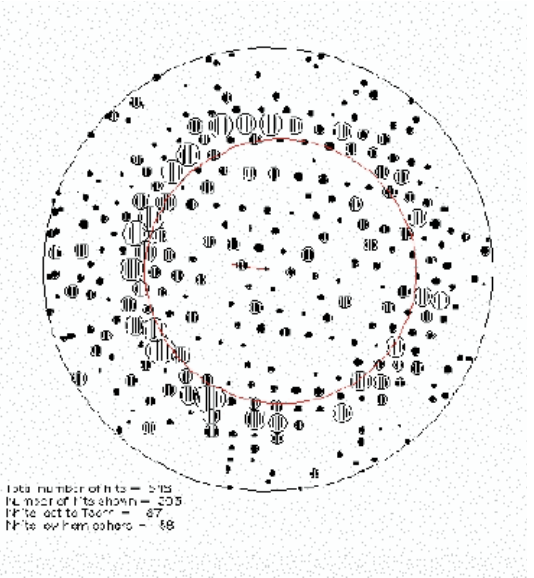
Are events distributed evenly in time?





Are they distributed evenly in space?

Do the events look ring-like?



Check backgrounds and error estimates.....

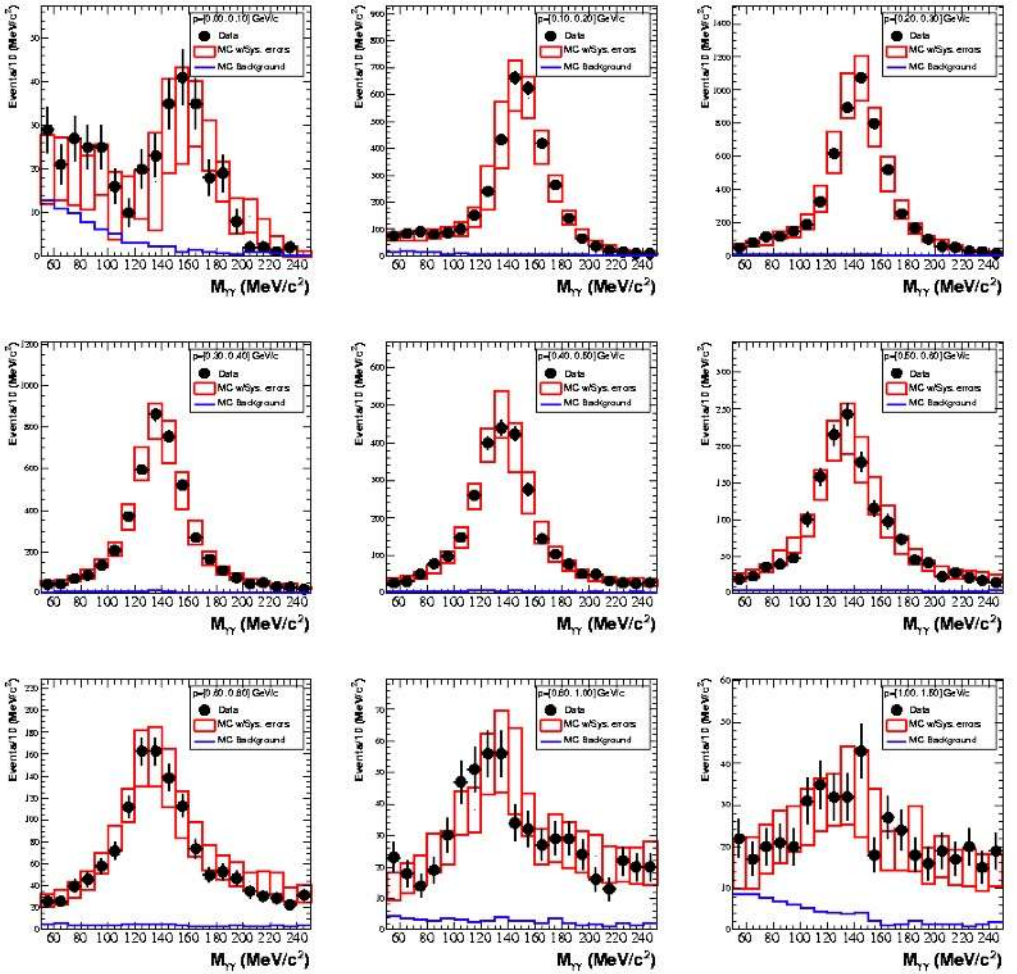
NCπ° and radiative $\Delta \rightarrow N\gamma$ constrained by identified NCπ° events (paper submitted to PLB, March '08)

Mis-IDs are back-to-back decays with one "weak" gamma. Mis-ID rate is driven by kinematics of π° decay – known to $<(1 \pm 0.1)\%$

MC tuned to match rate measurements in momentum bins

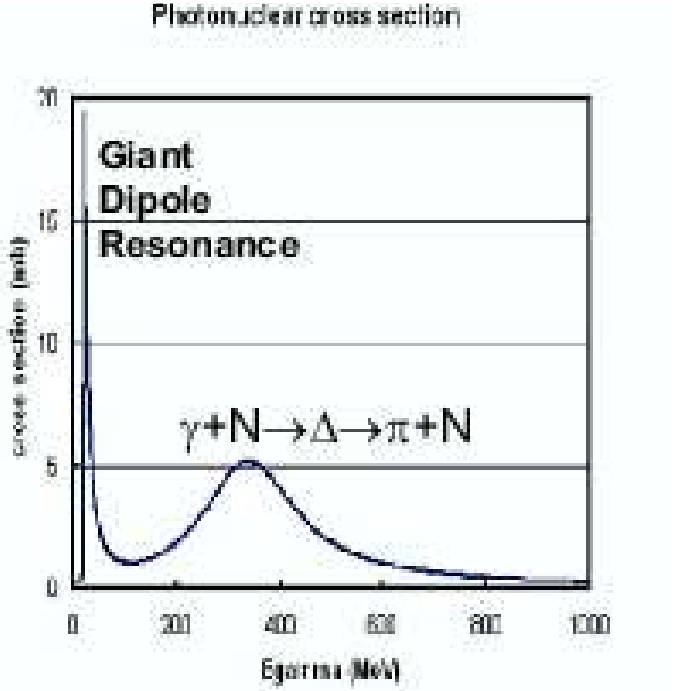
Error due to absolute rate of events, not flux or cross section errors -> robust!

Coherent rate determined from angular distributions



Rate of delta-radiative decays constrained by resonant production measurements for NCπ°s.

Photonuclear interactions of π°:



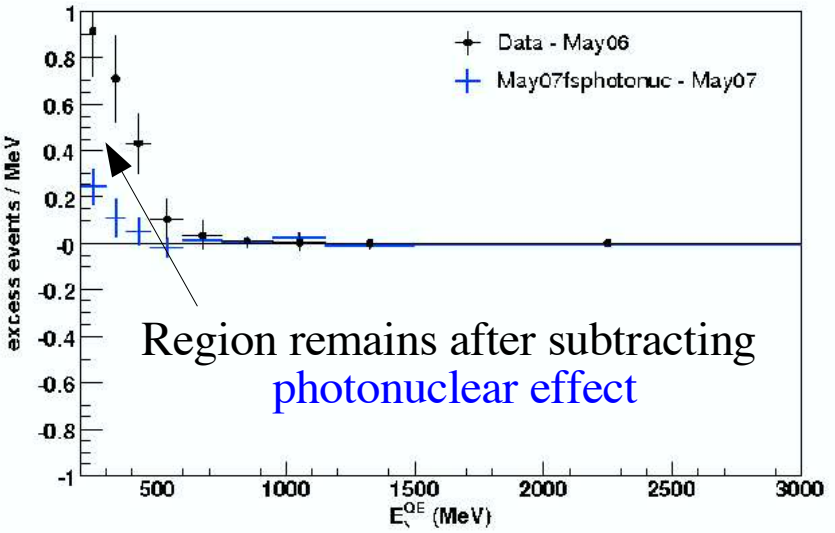
One gamma lost due to interactions with nuclei

interaction often results in other particles produced – final state interactions

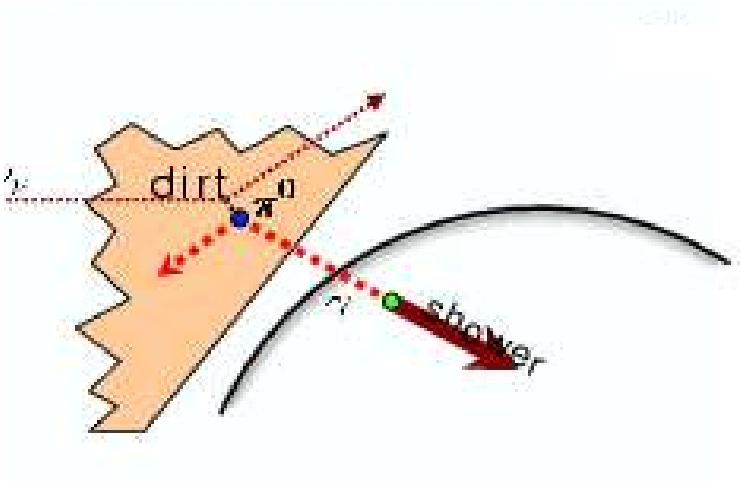
Cannot be constrained by MiniBooNE data:

Most conservative error on rate assessed to determine background

Reduces excess by
~13% at 300-475 MeV
~27% at 200-300 MeV



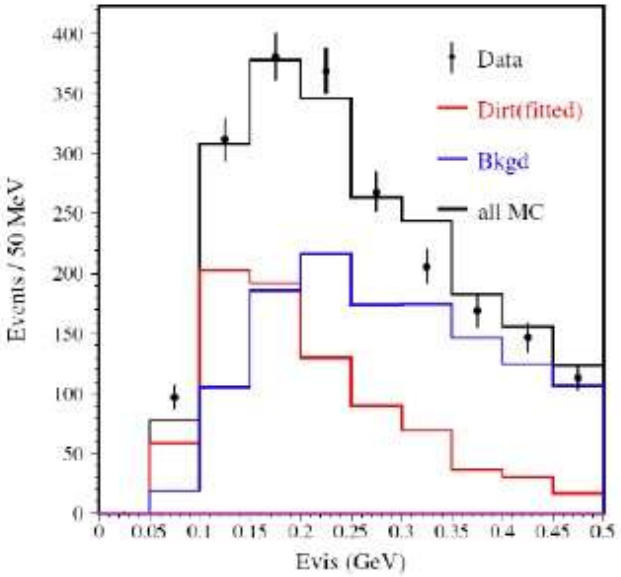
“Dirt” backgrounds

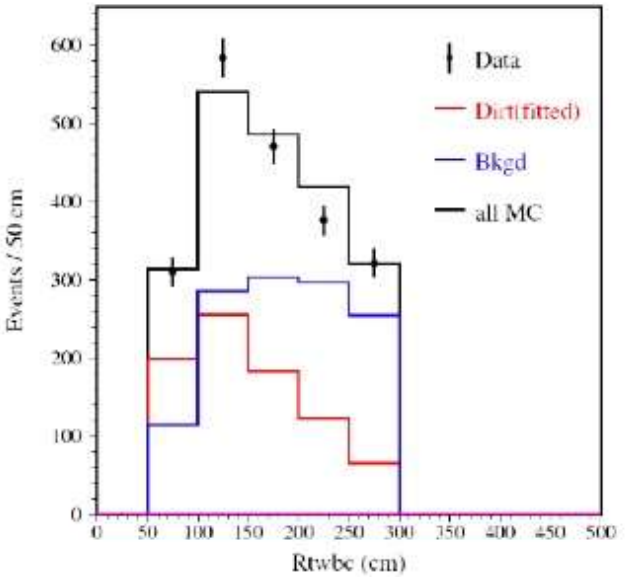


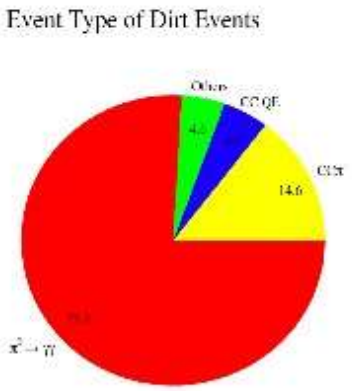
Beam neutrino interactions in dirt around detector can produce single gamma events in detector

Background can be reduced significantly with radial energy cut

Removes ~85% of the background at low energy





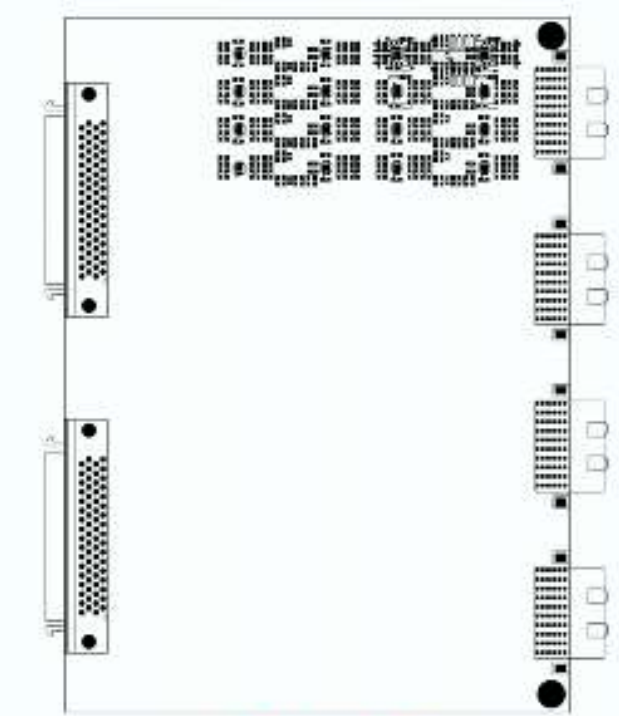


Different Exposures

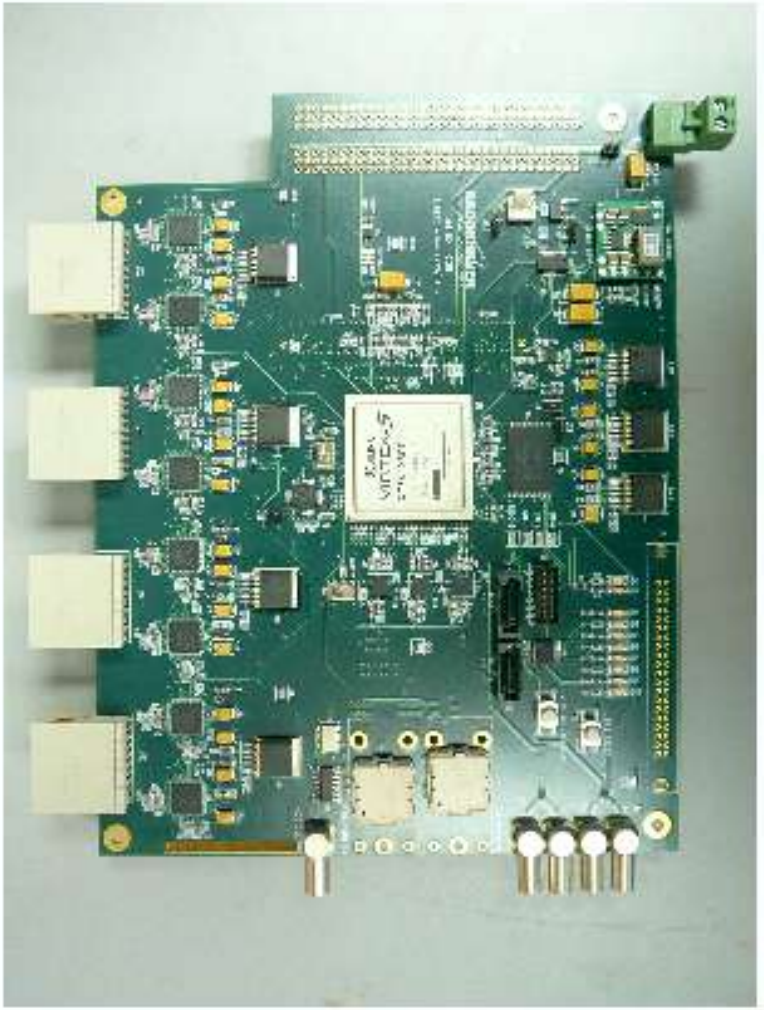
		$\sin^2 2\theta_{13} \neq 0$ 3σ, all δ_{cp}	sign(Δm^2_{31}) 3σ, all δ_{cp}	CPV 3σ, 50% δ_{cp}
Water Cherenkov	300kt, 1.2MW	0.008	0.018	0.030
	300kt, 2.4MW	0.006	0.012	0.015
	600kt, 2.4MW	0.004	0.010	0.008
Liquid Argon	50kt, 1.2MW	0.007	0.014	0.018
	50kt, 2.4MW	0.005	0.011	0.010
	100kt, 2.4MW	0.003	0.008	0.003

Need ~6x smaller LAr to obtain similar sensitivities to WCh
Small NC bkg contamination will affect LAr, in particular CPV

Prototype of TPC Readout Board



Analog Part



Digital Part