B.T.Fleming
for the MicroBooNE
collaboration
March 27, 2008

MicroBooNE:
Update on Proposal P974

Presentation to the Fermilab PAC, Spring 2008

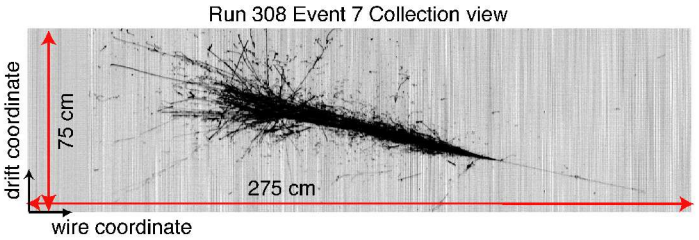
MicroBooNE Status:

Proposal Addendum submitted,
motivated by:

- advances in our own studies
- evolution of broader program
- guidance from PAC and directorate

- MicroBooNE in the broader program
- Status of MicroBooNE's physics case
- Expanded R&D program: MicroBooNE and beyond
- MicroBooNE baseline design update
- Updated cost and schedule

Liquid Argon TPC detectors for neutrino oscillation physics



Unique Detectors
⇒ precision measurements in neutrino physics
⇒ appear scalable to large volumes

- Neutrino oscillation physics: 3-4 times more sensitive than WC detectors.

(Differentiate π°s vs e's using topology and dE/dx)

ν_e appearance is difficult! Yet to be done with no complications.....

- Proton decay searches: sensitive to $p \rightarrow \nu k$
- Supernova

These are great detectors!

Are they technically feasible on massive scales?

Phased R&D program, come into focus over Project X workshop series, is necessary to get to large detectors....

R&D for massive detectors:

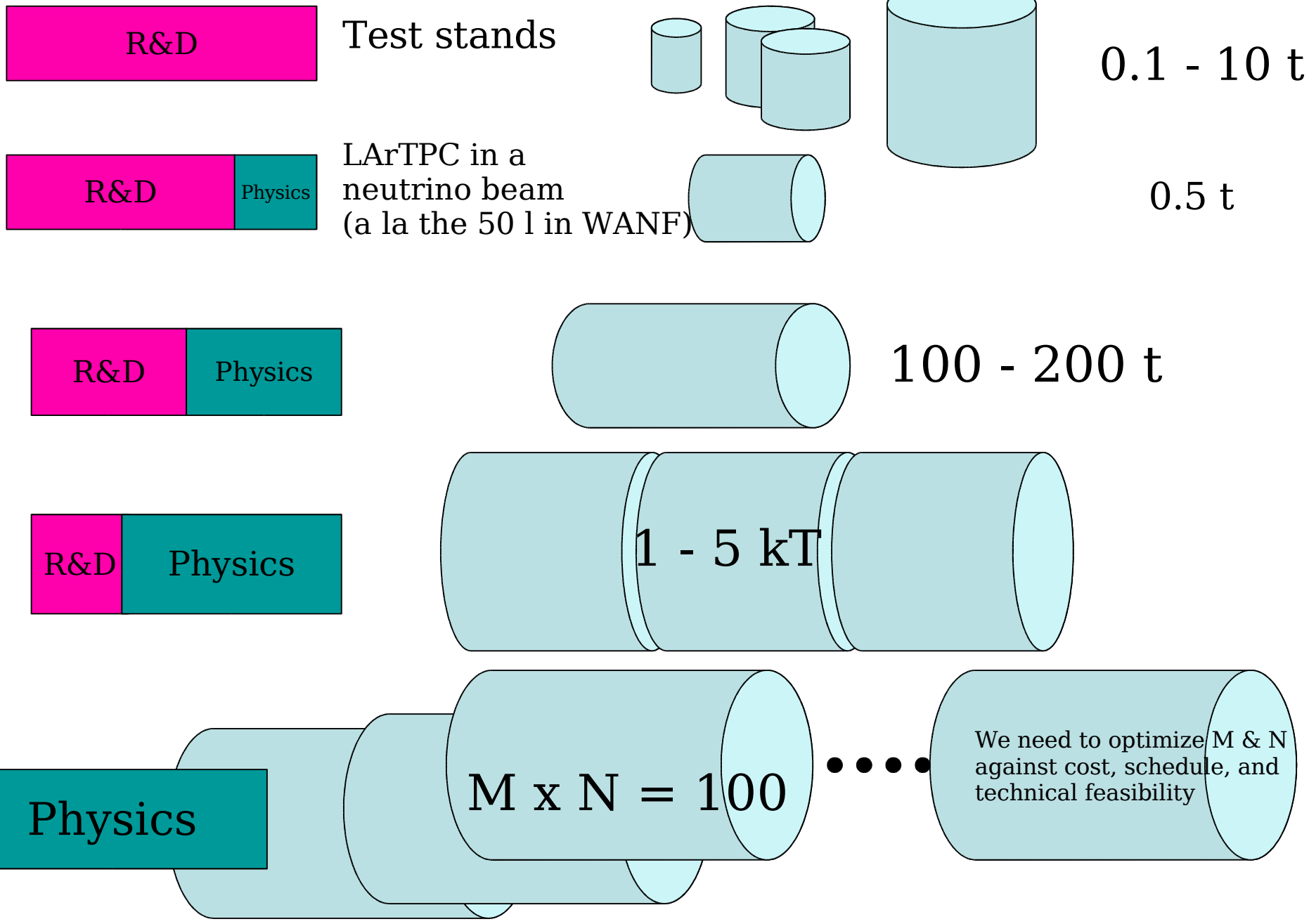
- Low Noise Electronics and signal multiplexing
- Light detection for Triggering
- Purification Issues: large, industrial vessels
- Physics Development: Interactions on argon, simulation, reconstruction, data reduction
- TPC design: Wire plane structure
- Vessel Design: materials, insulation, feedthroughs
- Vessel location: Surface, near surface, underground

Need a staged program for LArTPC detectors

- address R&D questions at the relevant scale
- Move from R&D to physics goals
- Appropriate steps in size, time, and cost

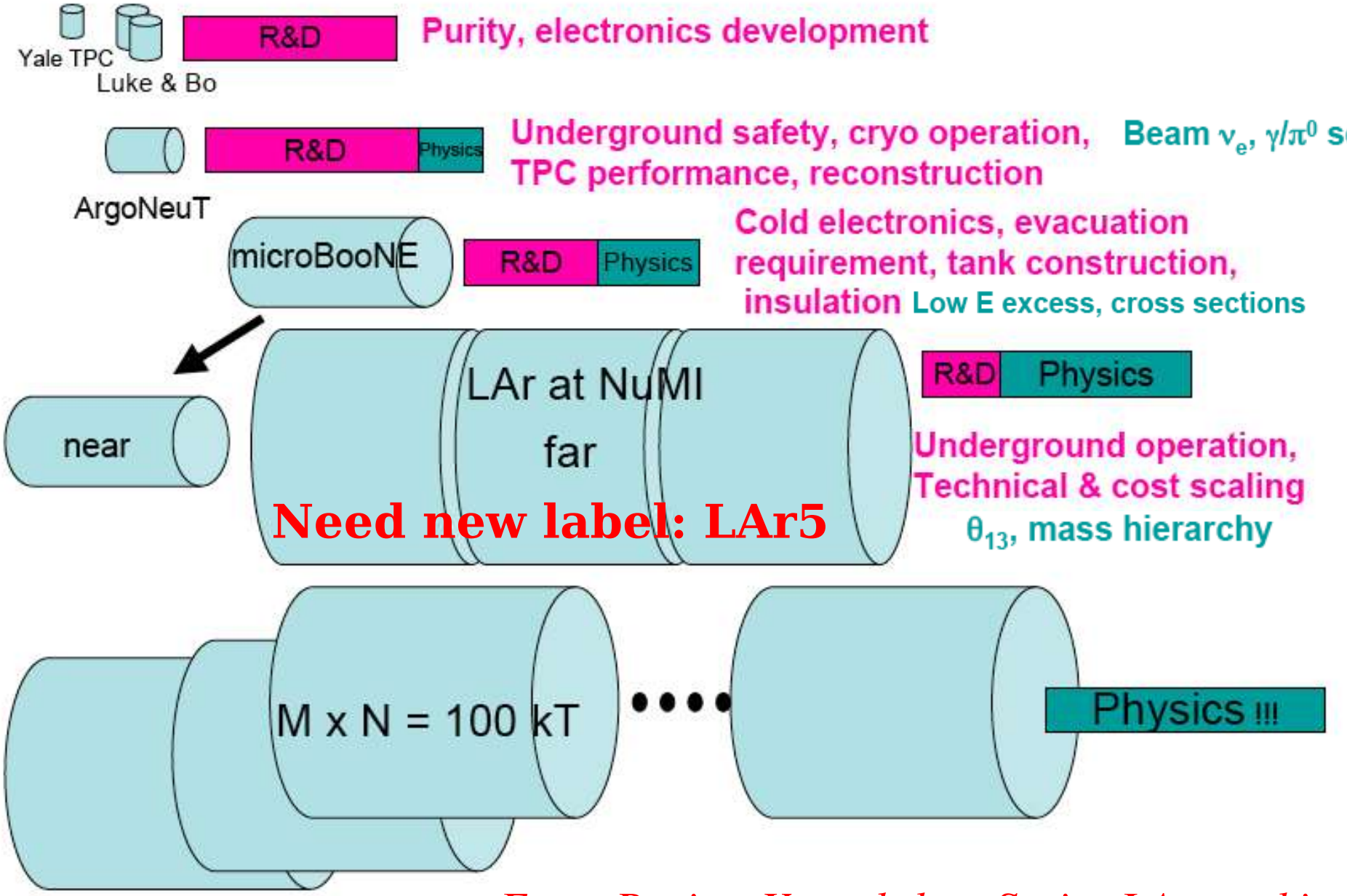
From Project X workshop Series LAr working group

Evolution of a Liquid Argon Physics Program



From Project X workshop Series LAr working group

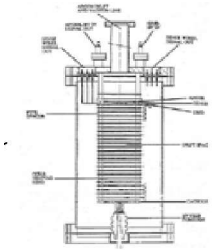
Evolution of the Liquid Argon Physics Program in the US



From Project X workshop Series LAr working group

Similar evolution in European program

Test Stands →

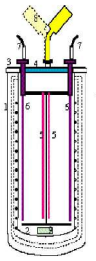


24 cm drift wires chamber

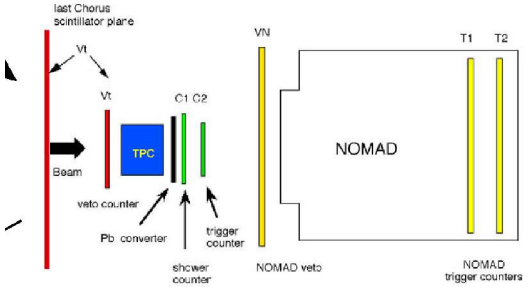
1987: First LAr TPC. Proof of principle. Measurements of TPC performances.

3 ton prototype

1991-1995: First demonstration of the LAr TPC on large masses. Measurement of the TPC performances. TMG doping.

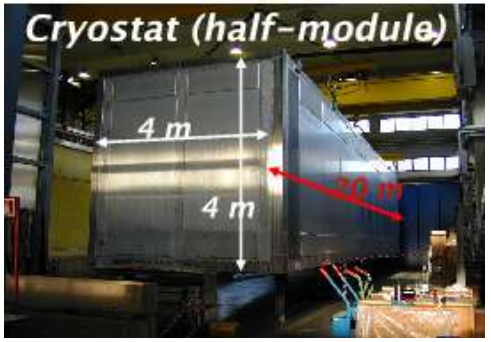


Seeing neutrino Interactions →



50 litres prototype
1.4 m drift chamber

1997-1999: Neutrino beam events measurements. Readout electronics optimization. MLPB development and study. 1.4 m drift test.

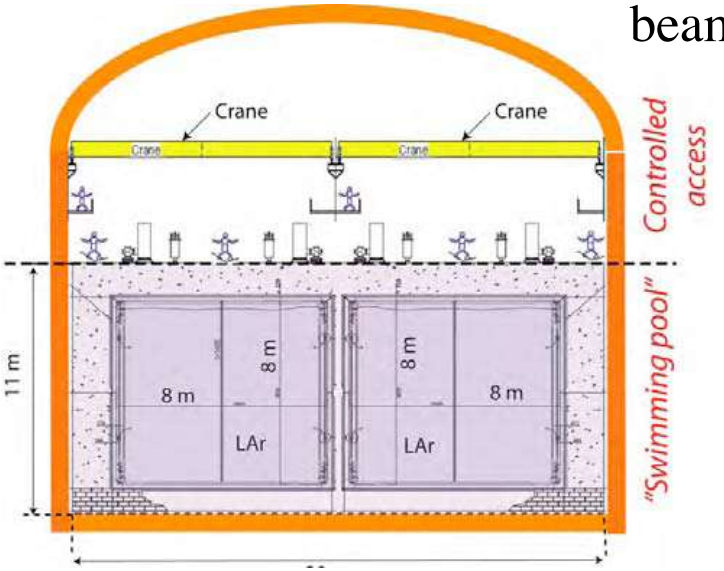


T600: data in '08
~2000 evts/yr, 17 GeV CNGS beam

Towards massive detectors →

SLICE:
slice of MODULAr
- 600 ton LArTPC
- low energy ν interactions
- prototype for MODULAr

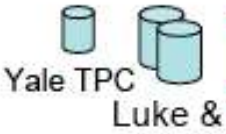
similar program to MicroBooNE



MODULAr:
5kton modules

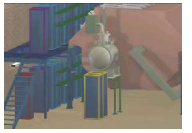
From Project X workshop Series LAr working group

Evolution of the Liquid Argon Physics Program

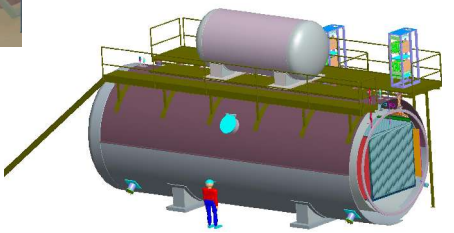


R&D ⟵ **Program underway**

ArgoNeuT — R&D | Physics ⟵ **Spring 2008**



microBooNE — R&D | Physics ⟵ **Data : 2011**



near

LAr at NuMI
far

R&D | Physics ⟵ **Data : ~2015-2016**

Need new label: LAr5

M x N = 100 kT • • • • Physics !!! ⟵ **Data 20??**

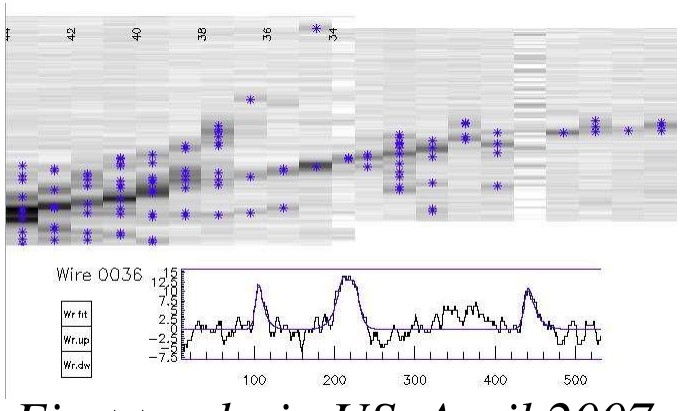
R&D

Test stands

-developing electronics components
-developing filtering techniques
    -Testing materials in Argon
    -Gaseous argon purge for purification
-developing Light Collection techniques
-technology transfer

Good as “bench top” tests, but
there are scale limitations....

TPC at Yale



First tracks in US, April 2007

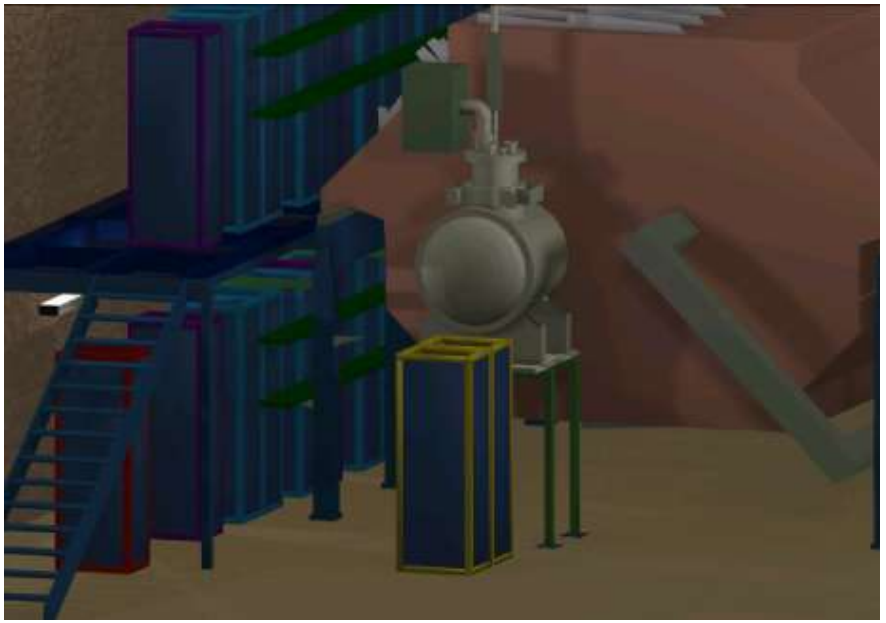
Materials Test Stand
Electronics Test Stand
at Fermilab

R&D | Physics

ArgoNeuT (Spring 2008)

0.3 ton active volume

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



- See neutrino interactions (~150 evts/day)
  - Physics Development: Simulation, reconstruction, Verification of efficiencies and purities
- Long term running conditions
- Underground issues

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

Joint NSF/DOE project

R&D | Physics

MicroBooNE: Full scale experiment

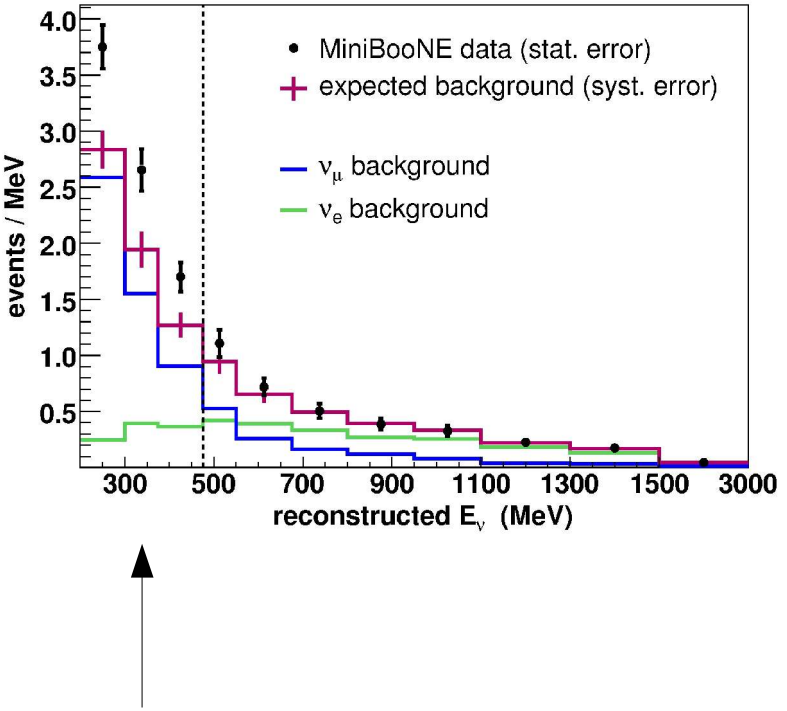
- physics results with a LArTPC detector
- R&D for next generation LArTPCs

Physics case:

- MiniBooNE low energy excess
  - Clarification of backgrounds from MiniBooNE
  - Results from NuMI
  - Impact on broader program
- Neutrino cross sections
  - Measurements using BNB and NuMI beams
- "Physics R&D" for future detectors
  - Cross sections for oscillation physics
  - Measurements for proton decay studies
  - Development of simulation, reconstruction, and analysis tools.

MiniBooNE Low Energy Excess

E_ν^{QE} [MeV]	200-300	300-475	475-1250
total background	284±25	274±21	358±35
ν_e intrinsic	26	67	229
ν_μ induced ("Mis-ID")	258	207	129
NC π^0	115	76	62
NC Δ rad	20	51	20
Dirt	99	50	17
other	24	30	30
Data	375±19	369±19	380±19
Data-background	91±31	95±28	22±40



MiniBooNE has done substantial work on verifying backgrounds at low Energy

Continued work on optimizing level of backgrounds....

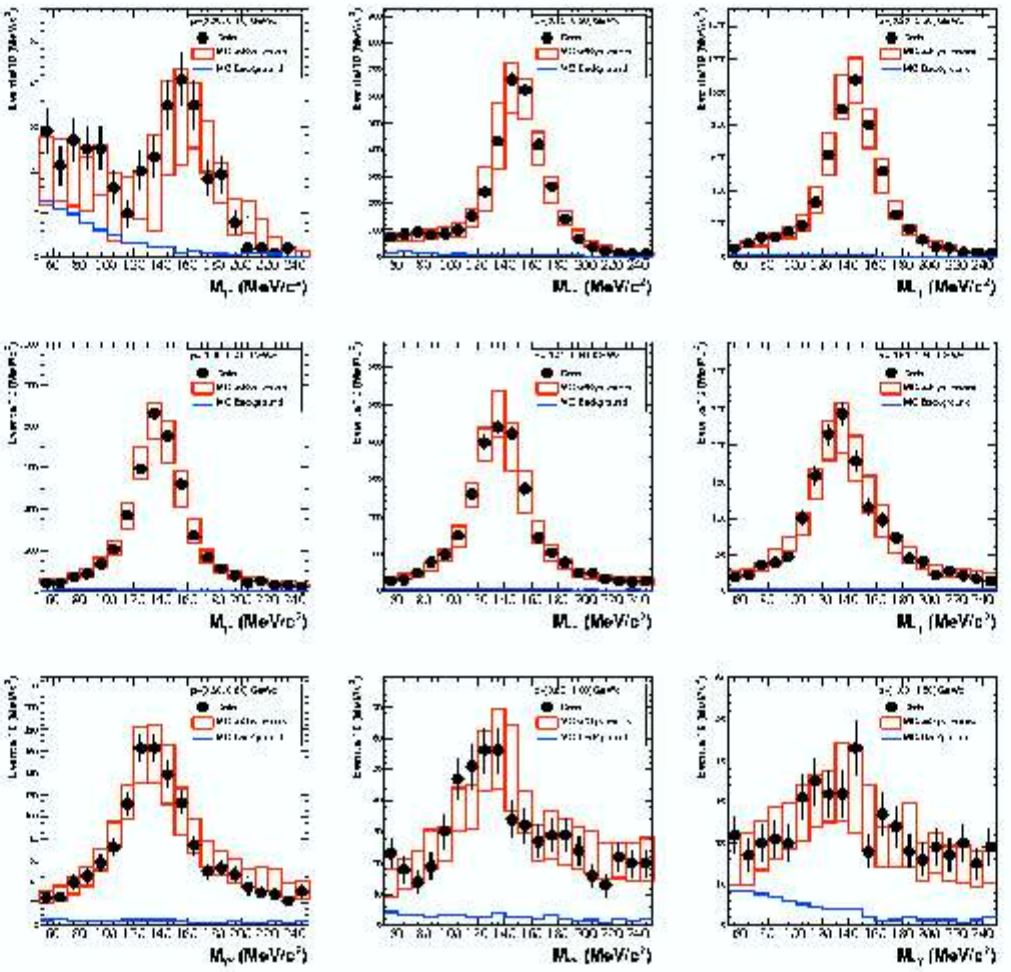
NCπ° and radiative $\Delta \rightarrow N\gamma$ constrained by identified NCπ° events (paper submitted to PRL, March '08)

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

MC tuned to match rate measurements in momentum bins

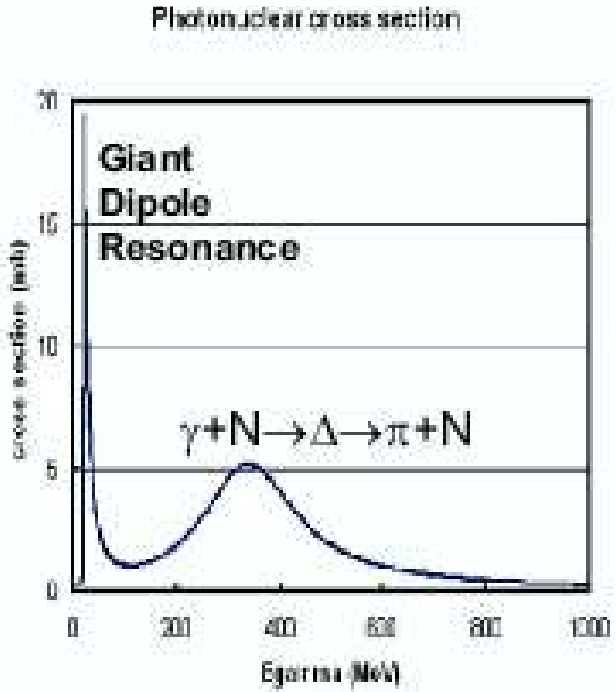
Error due to absolute rate of events, not flux or cross section errors -> robust!

Coherent rate determined from angular distributions



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

Photonuclear interactions of π°: (not included in published result)



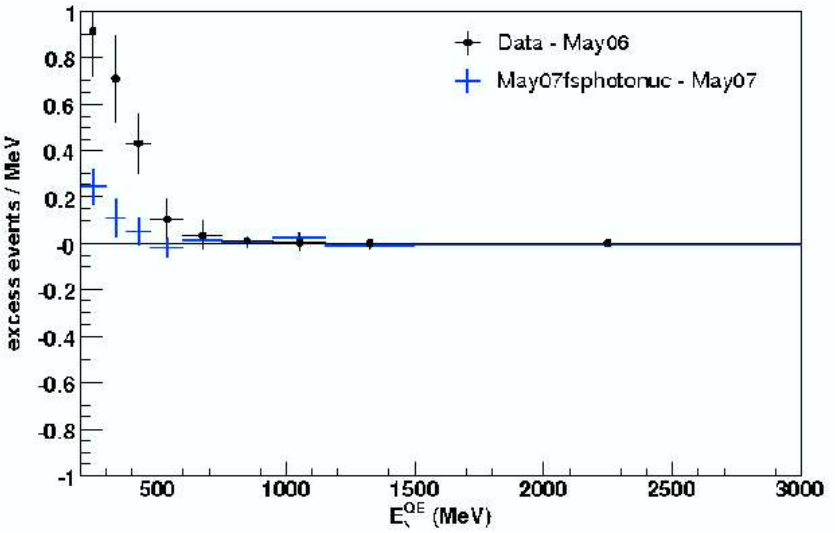
One gamma lost due to interactions with nuclei

interaction often results in other particles produced – final state interactions

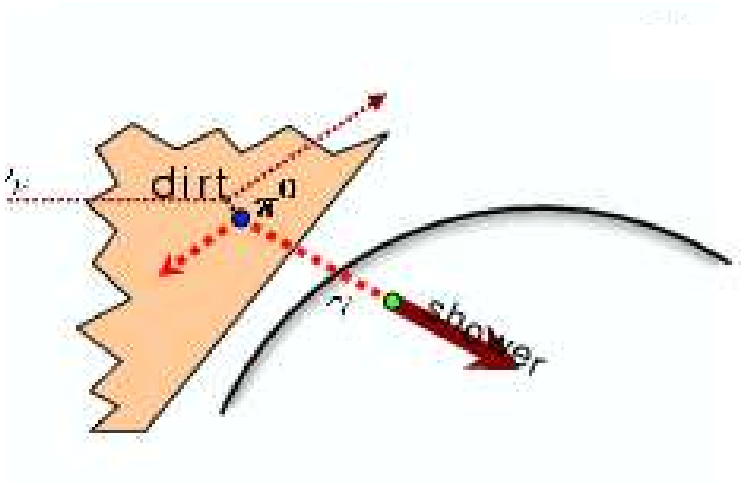
Cannot be constrained by MiniBooNE data:

Most conservative error on rate assesed to determine background

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

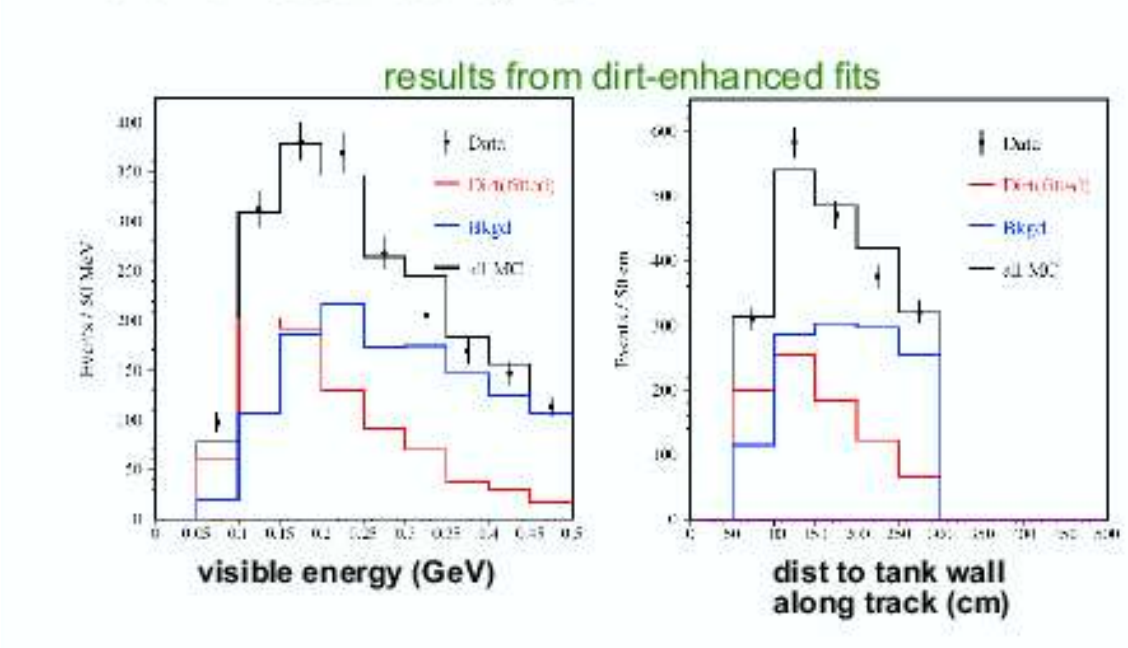


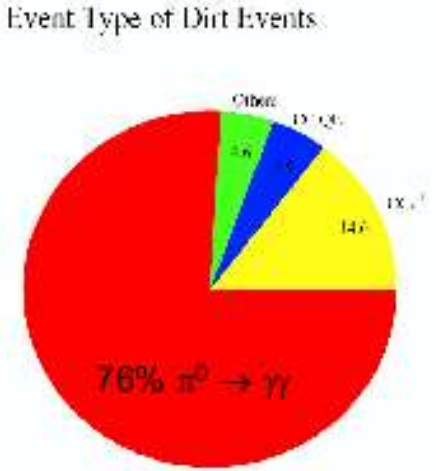
“Dirt” backgrounds



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

Background can be reduced significantly with energy and distance to wall cuts – *work in progress*





Backgrounds have been reviewed and studied extensively
-constrained to data for resonant and dirt events
-conservative errors assumed where not possible

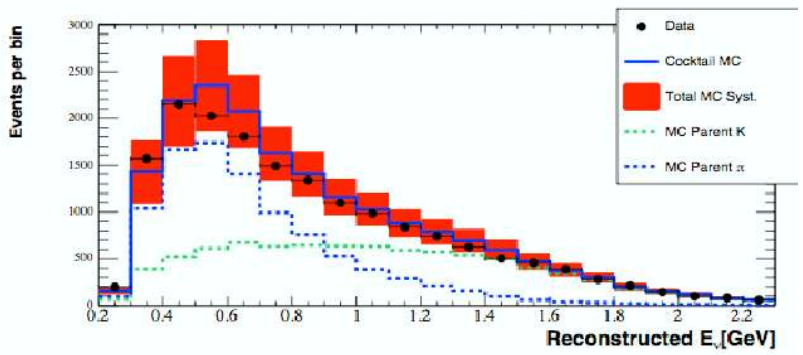
Photonuclear effect considered since published result
-reduces excess but excess still significant

(List of other things considered and ruled out)
(not sure how much of this I can show)

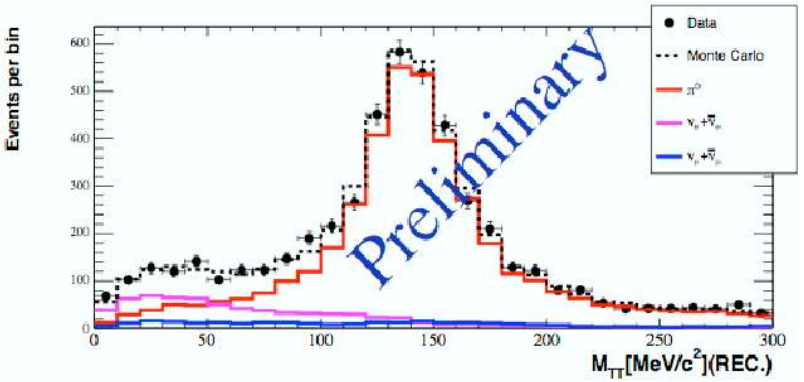
Comprehensive review to be presented at Neutrino '08

New results from NuMI events in MiniBooNE detector

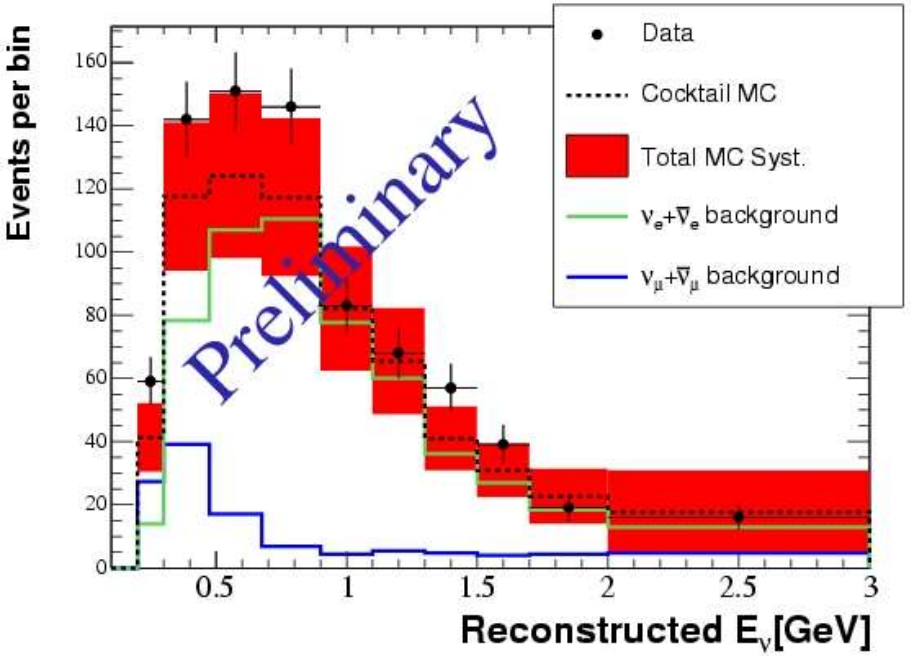
Absolute Data/MC comparisons:



CCQE events well modeled.



Enhanced Ncπ° sample. Good agreement at low invariant mass where intrinsic ν_es dominate....



E_ν^{QE} distributio for ν_e candidates:
Slight excess (1.4σ) but large systematic errors

Future analysis -> use ν_μs to constrain ν_es
reduce systematic errors substatially...

Impact on Broader program:

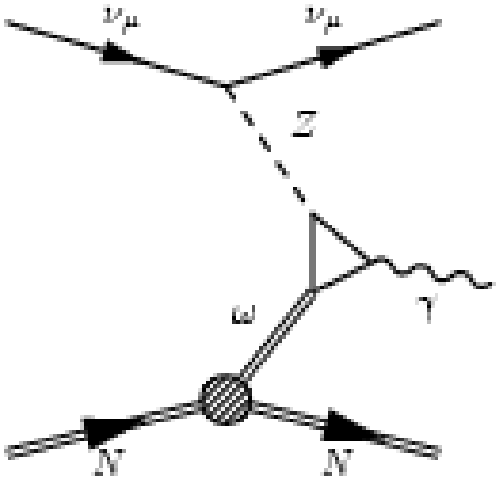
Interpretations of excess:

Beyond-the-Standard model:

- hep-ph/0705.0107v1
- hep-ph/0706.1462
- hep-ph/0710.28985
- hep-ph/0702049
- hep-ph/0504096
- hep-ph/0707.4953
- hep-ph/0606154
- hep-ph/0602237
- hep-ph/0707.2285
- hep-ph/0711.1363

Recent work...

Standard Model process:

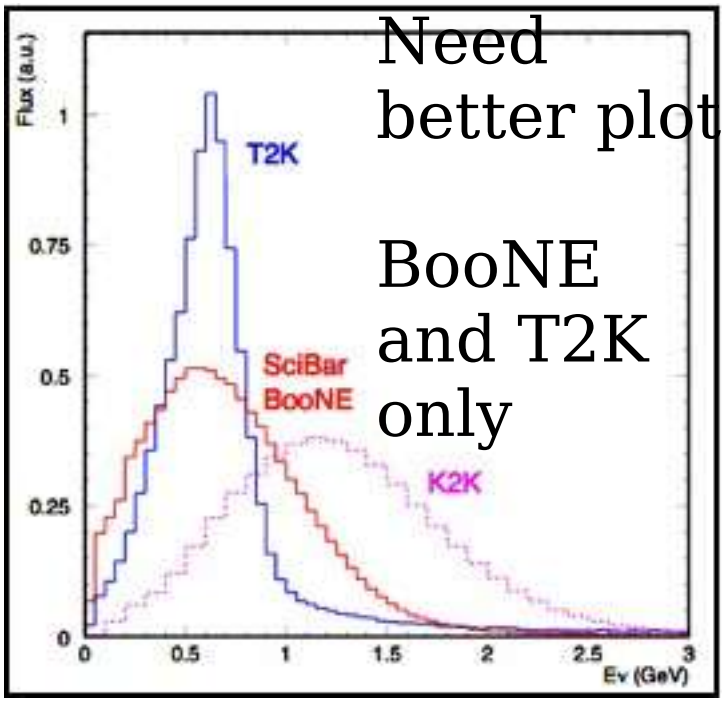


Harvey, Hill, Hill
hep-ph/0708.1334

- Uncertainty in noramlization -> 1-100% of excess
- difficulty explaining angular distribution of excess

Impact on Broader program cont:

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



Need better plot

BooNE and T2K only

For example,
T2K experiment:

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

Detectors on BNB (SciBooNE) and T2K beamlines (ND280) unable to resolve excess

Key improvements in MicroBooNE are:

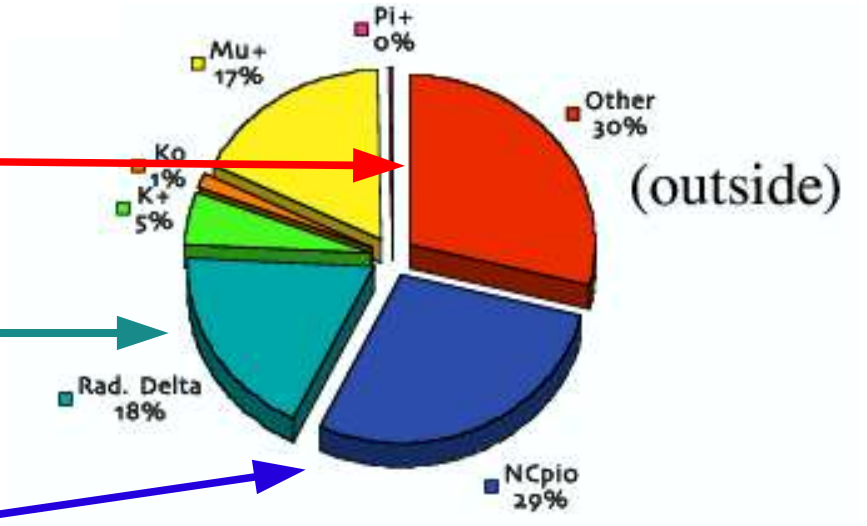
- e/γ separation capability removes ν_μ induced single γ backgrounds

Dirt: Primarily NCpi0 interactions where only one γ enters detector

Radiative Delta: Δ-> Nγ

NCpi0: Asymmetric decays where only one γ is visible

$$\nu + N \rightarrow \nu + N + \gamma + X$$



background fractions below 475 MeV

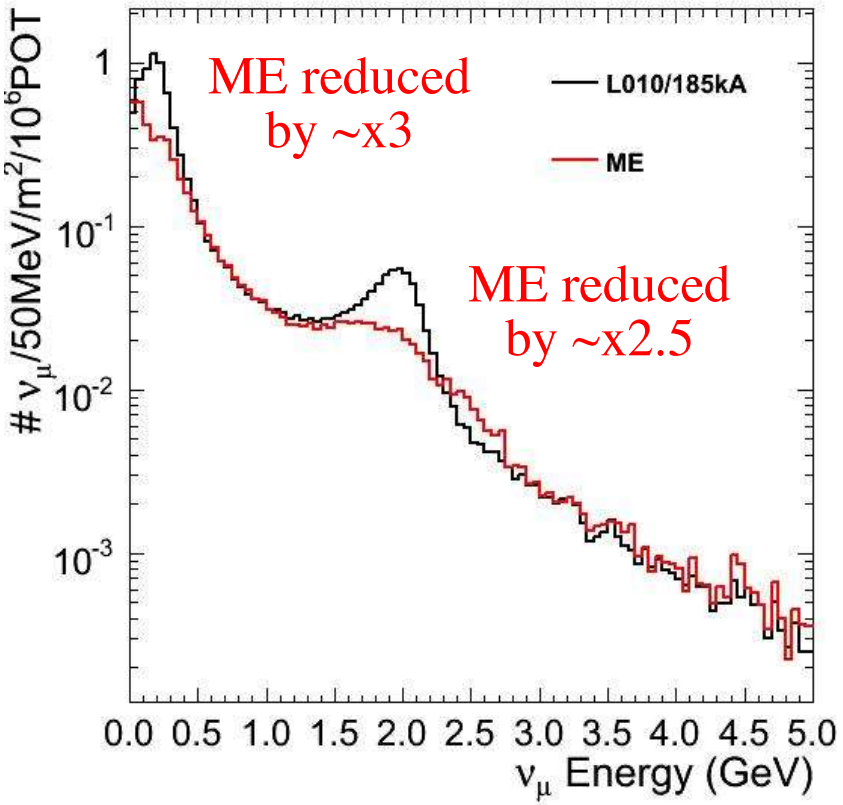
- electron neutrino efficiency: ~x2 better than MiniBooNE
- sensitivity at low energies (down to tens of MeV compared to 200 MeV on MiniBooNE

Translates to 9σ sensitivity if excess is ν_es, 3.4σ if γs

Cross sections measurements:

- relevant for future oscillation experiments
- Interesting in their own right

Expect ~100K events from BNB (6E20 POT)
~60K events from ME, off-axis, NuMI beam (8E20 POT)



Differences in energy spectra between LE and ME beam tunes:

Reduction in ME mode compensated by increase in POT on target expected in NovA era.

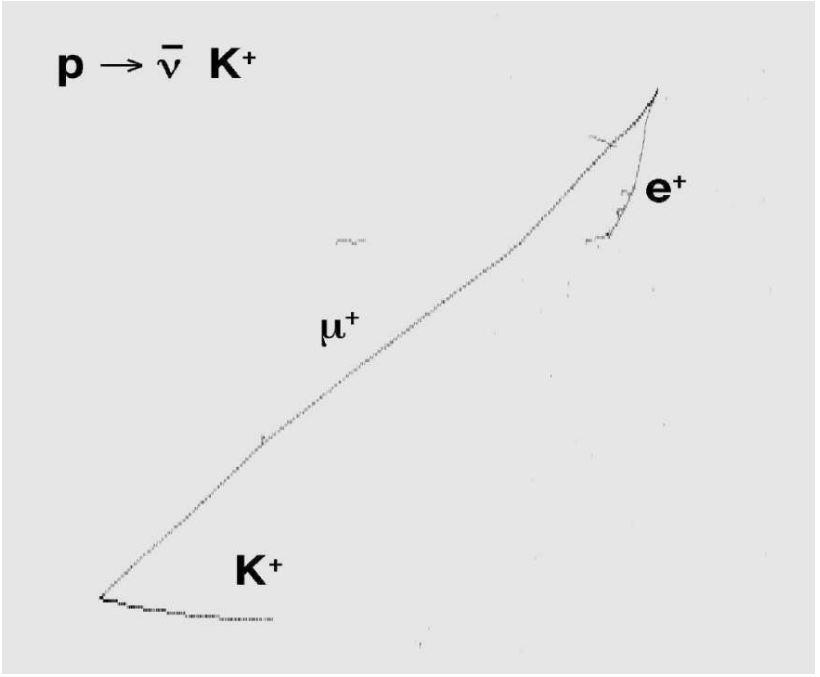
30% additional run time needed in ME mode

While LE mode is preferred, ME mode is acceptable

Physics R&D: Studies for proton decay sensitivitites

Massive underground detectors
are rich in physics reach beyond oscillations

Opportunities to
- Extend reach in proton decay sensitivity
  - Water Cerenkov detectors most sensitive to $p \rightarrow e\pi^{\circ}$
    (47% efficient for WC and LAr, governed by pion absorption)
  - Lar detectors most sensitive to $p \rightarrow \nu k$
    (17% efficient for WC compared to estimated 97% for LAr)



Simulated K^+ event in LAr

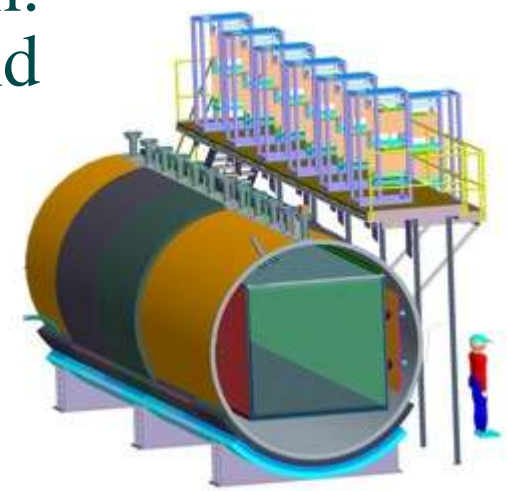
~500 kaons expected from BNB

Understand signal and backgrounds
(like K2K -> SuperK: hep-ex/0801.0182)
using beam neutrino interactions

dE/dx measurements study kaon "signal"
ID and background rejection

R&D | Physics

Expanded R&D Program: MicroBooNE and beyond



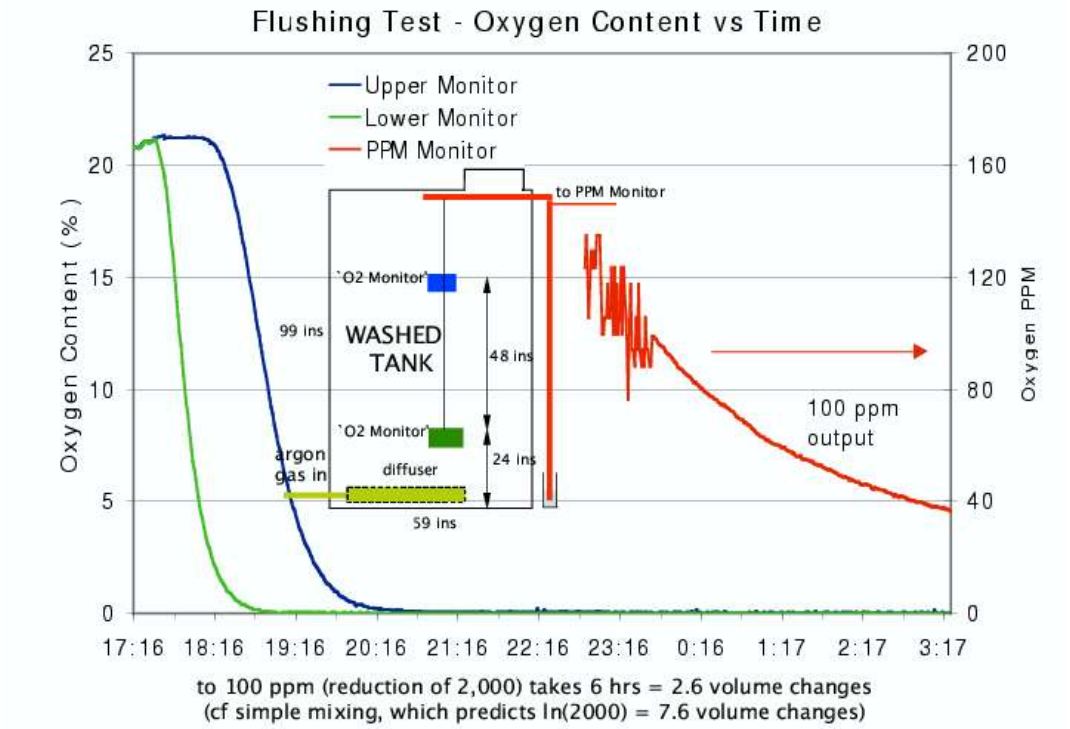
- Two overlapping phases
  - Phase 1, already underway: design questions specific to MicroBooNE: changes reflected in MicroBooNE Baseline design update, for example, cryostat
  - Phase 2: longer term R&D questions relevant for the next stage: LAr5. Beginning work on these issues

- Achieving and maintaining Argon purity using an un-evacuated cryostat
- Developing cold, low-noise electronics suited for geometry and running conditions of very large LArTPCs
- Implementing general detector design appropriate for the next phase in the LArTPC program

Staging allows for successful combination of R&D and physics goals

Purity program

- prohibitive to evacuate massive vessels
- GAr flush to "clean" vessels



First tests at FNAL are promising.

Need test with large, fully instrumented vessel

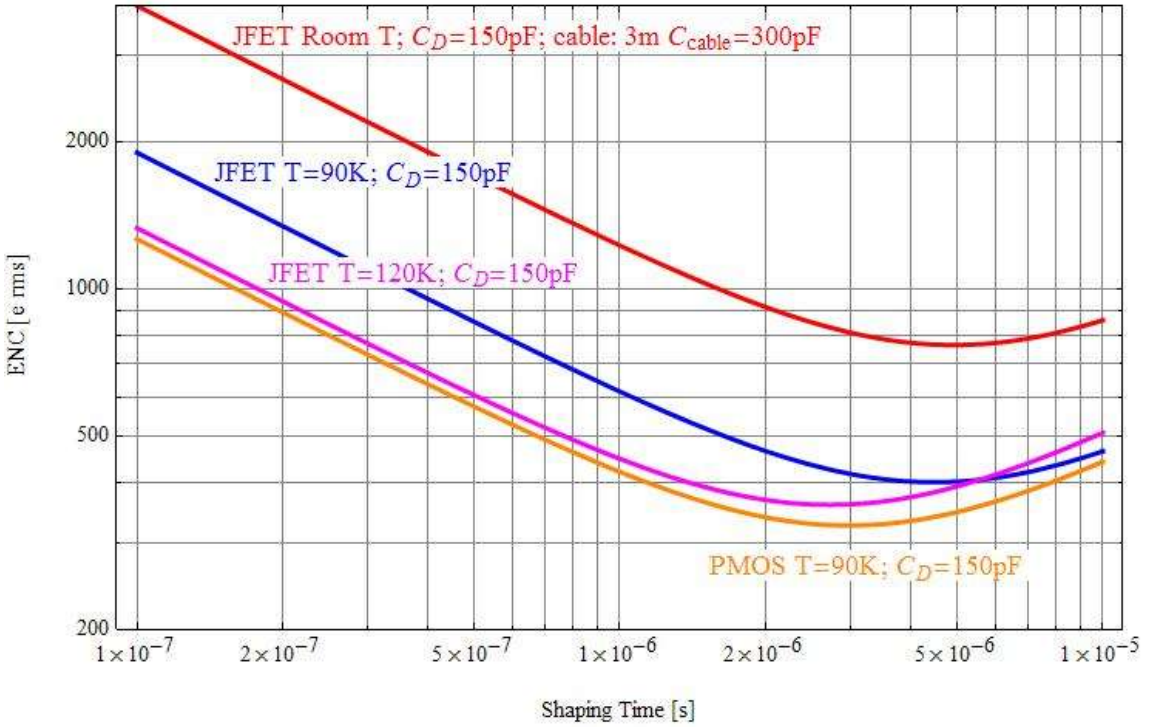
->MicroBooNE

MicroBooNE Purge test: 6 week program to preceed physics run

- 10 volume changes of GAr to reduce O2 concentrations to 10 ppm
- Recirculate filtered gas or introduce small amount of LAr as getter and continue purification for ~1 month
- Introduce filtered LAr and test for purity

Readout Electronics

•Massive detectors -> require ~million channels.
Readout architecture -> multiplexing at cryogenic temperatures
3-4 year R&D program



•To maximize S/N and have flexibility in detector geometry

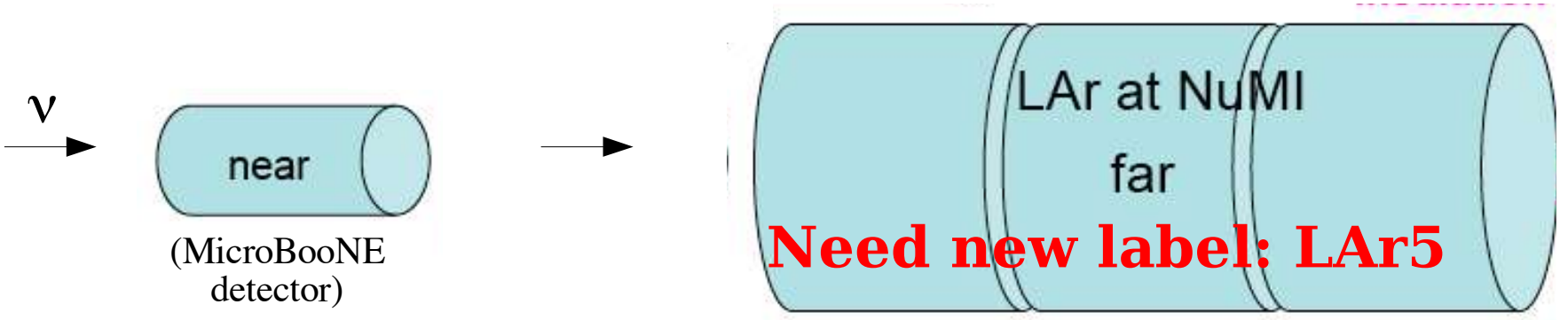
Readout ASIC must operate in LAr

-> 2 year R&D program to develop CMOS ASICS operating in LAr

Combine what is learned with JFET hybrids in GAr in MicroBooNE (very similar S/N to CMOS ASICs) and development of CMOS technology (MicroBooNE Phase2 R&D)

⟶ key piece in design for future detectors

General detector design similar to concept for Lar5 and beyond:
(TPC cage geometry, resistor chains and holders, wire chambers and connections, PMT array, cryostat and cryogenics, purification system, ...)



Optimize detector design for MicroBooNE and LAr5:

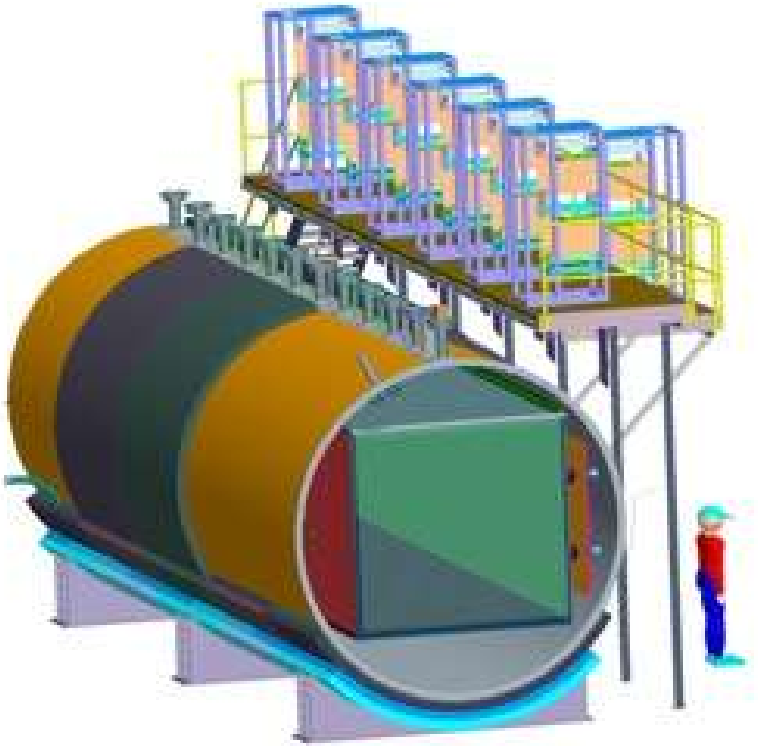
- constructability
- cost scaling
- value engineering

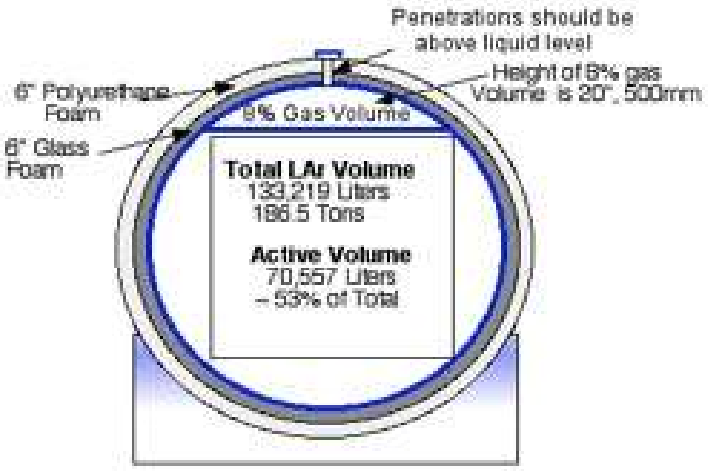
This philosophy has driven changes in Baseline design:

- Cryostat
- Wire termination and field cage design
- Readout electronics

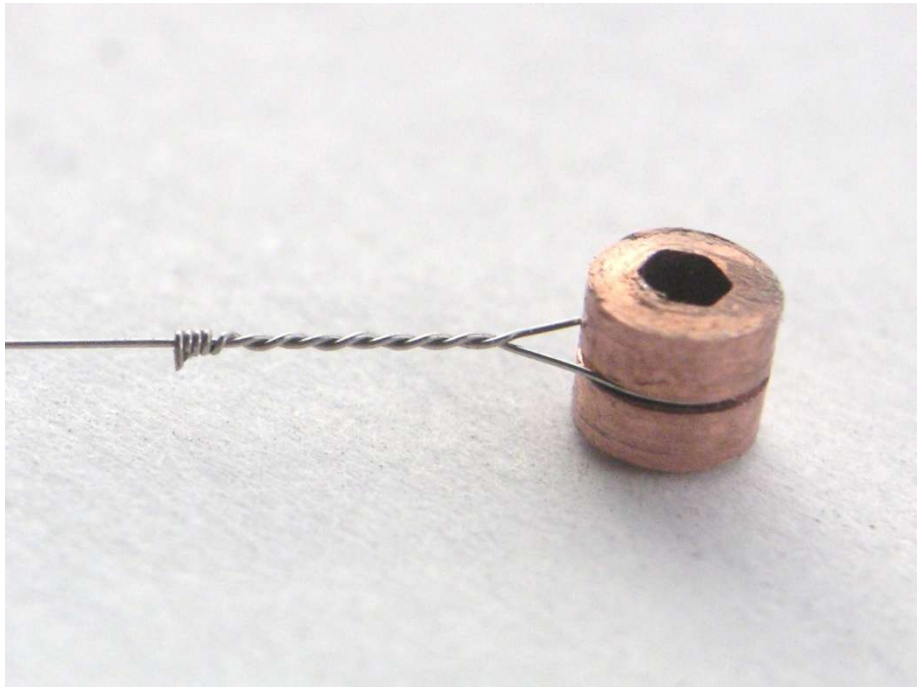
Cryostat:
Moved to mechanically insulated (foam) single vessel

- Similar to large vessel concepts
- Advantages in supporting fully loaded vessel
- Less costly construction
- Advantages in cold-to-warm transition for readout electronics



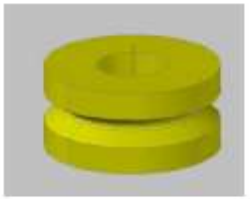


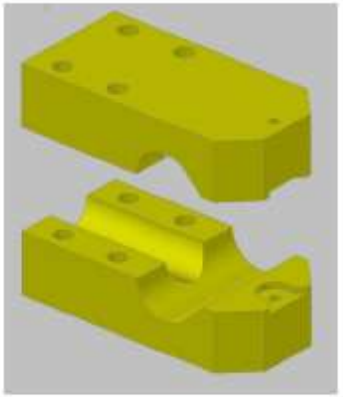
8% Gas volume at top of tank
- JFET hybrid pre-amps at 120K in Gar
- No need for expansion/storage vessel

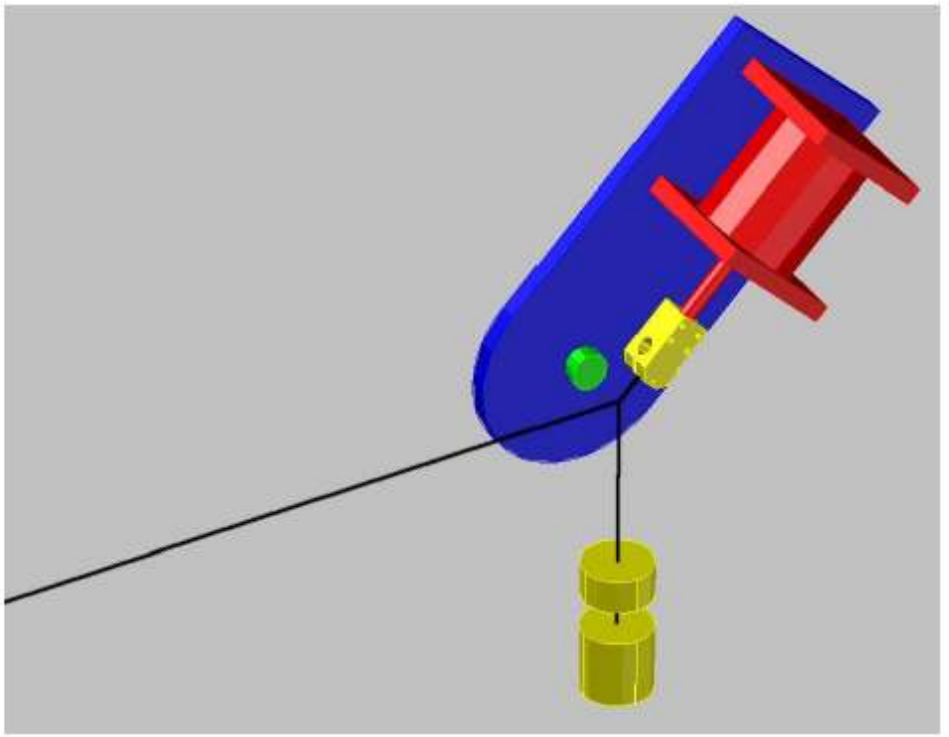


Wire termination and wire properties:

Technique for termination:
- Robust: keeps tension
- Scalable

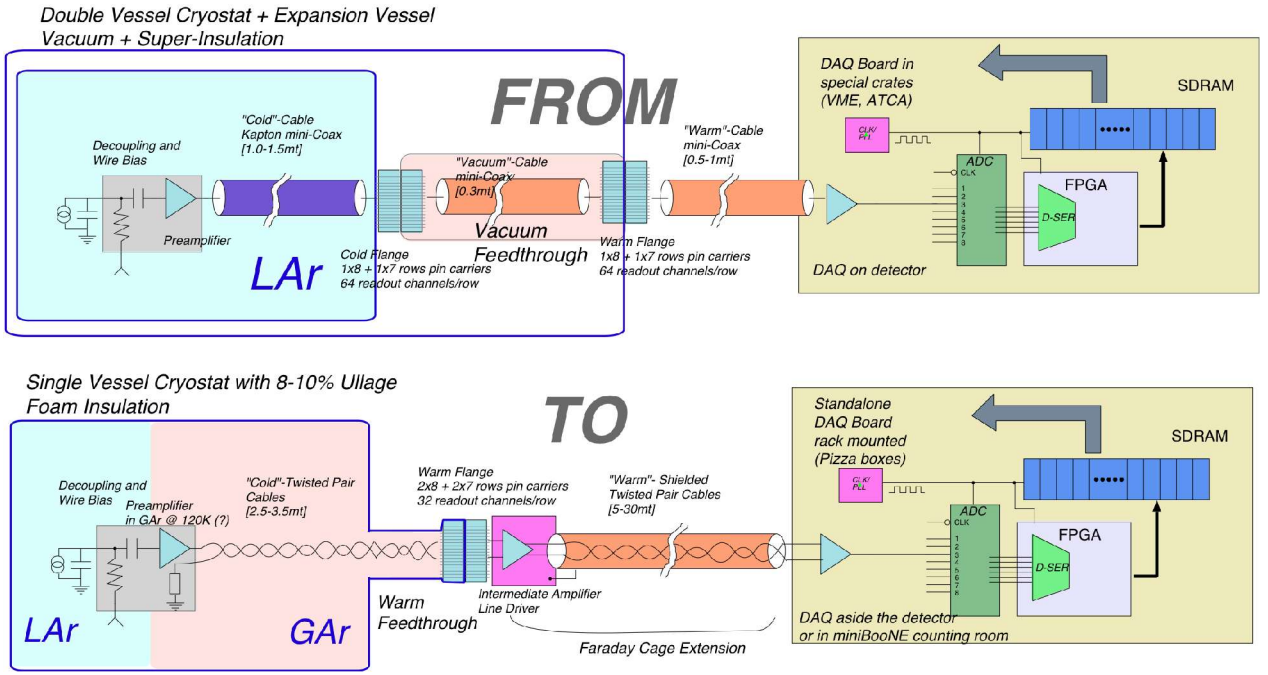




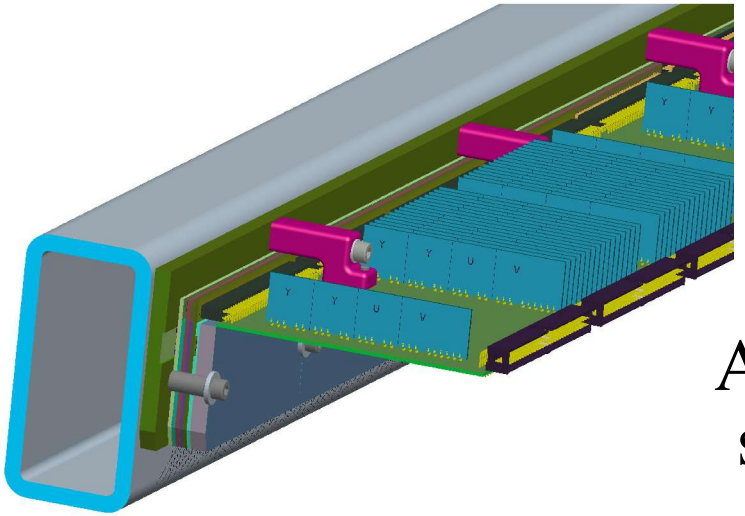


Concept for winding machine

Re-arranged readout electroncis:



- Reduces number of connectors necessary
- move to twisted pair cables (less costly)
- Intermediate line driver allows for flexibility in location of DAQ crates



Further development on wire holder, pre-amp hybrid, motherboards, and DAQ boards

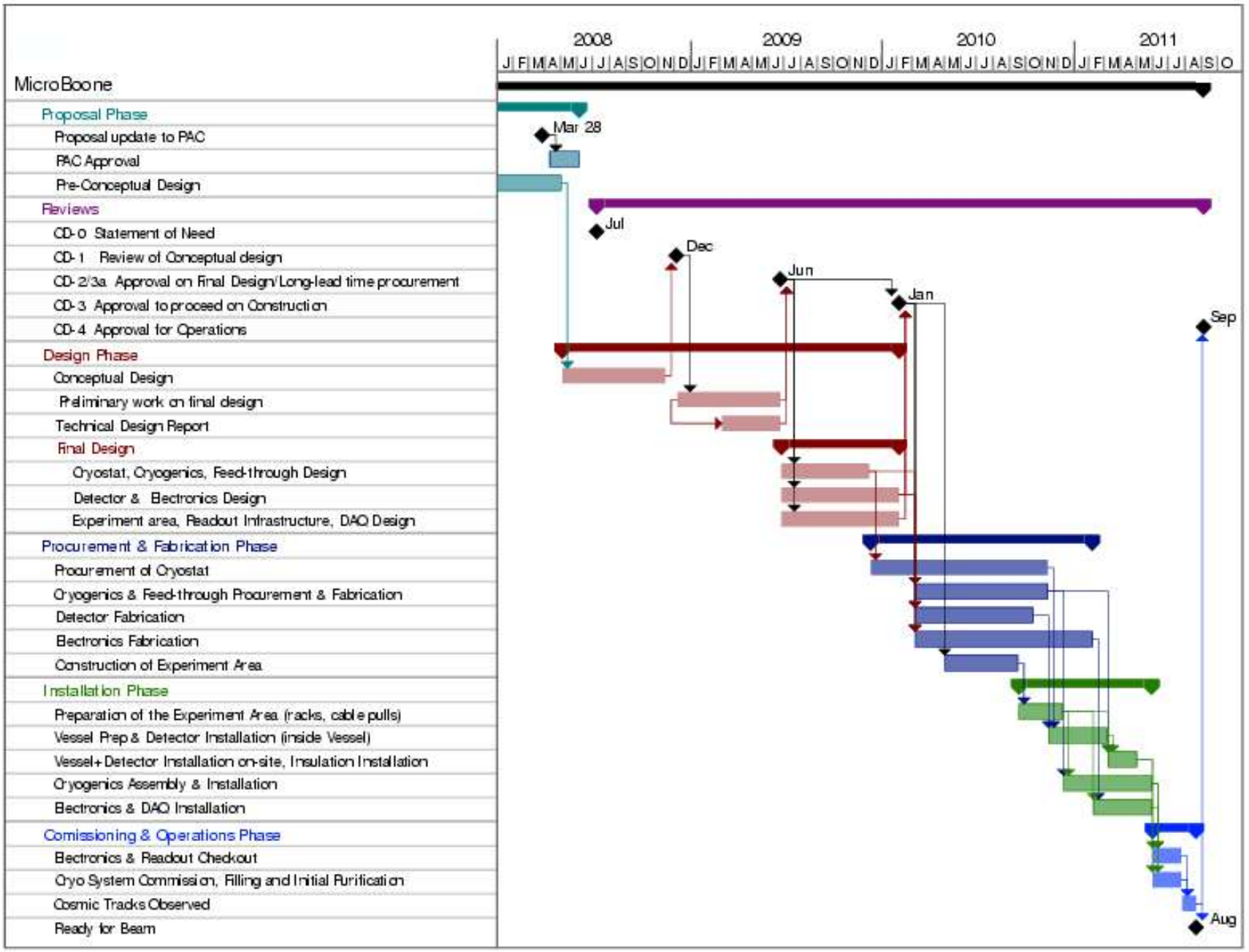
Advanced designs at this rather early stage allow for aggressive schedule beyond this

The MicroBooNE R&D program:

Running detector and physics analysis of real data provides best way to understand detector strengths and shortcomings

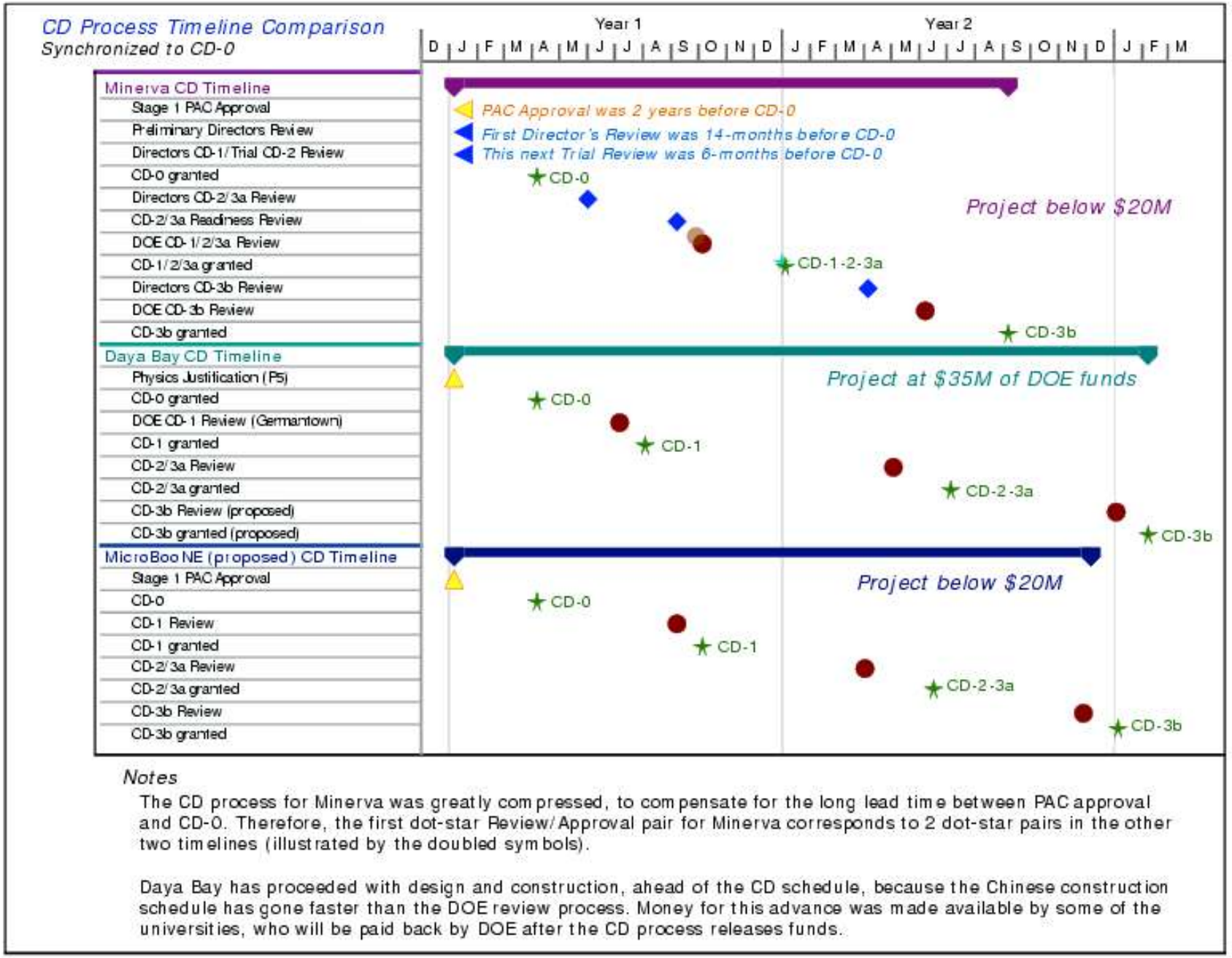
Combination of hardware R&D, strong physics case, and timely results that make the MicroBooNE program a comprehensive test for LAr5 and beyond

Developed MicroBooNE's implementation plan including CD schedule



Data taking in mid-2011

Review schedule like those for similar size experiments...



Notes

The CD process for Minerva was greatly compressed, to compensate for the long lead time between PAC approval and CD-0. Therefore, the first dot-star Review/Approval pair for Minerva corresponds to 2 dot-star pairs in the other two timelines (illustrated by the doubled symbols).

Daya Bay has proceeded with design and construction, ahead of the CD schedule, because the Chinese construction schedule has gone faster than the DOE review process. Money for this advance was made available by some of the universities, who will be paid back by DOE after the CD process releases funds.

	Total Cost Estimate	Labor Cost Estimate	Materials Cost Estimate
MicroBooNE costs	$15,718,500.00	$6,780,000.00	$8,938,500.00
Contingency 50% of summed estimates	$5,239,500.00	$2,260,000.00	$2,979,500.00
Sum of Estimates listed below	$10,479,000.00	$4,520,000.00	$5,959,000.00
Facility and Infrastructure	$425,000.00	$0.00	$425,000.00
Cryostat, Cryogenics, and Feed-throughs	$4,457,000.00	$1,695,000.00	$2,762,000.00
Detector - TPC and Photodetector	$1,1[illegible]0.00	$[illegible]0.00	$630,000.00
Electronics, Readout, and Power Supplies	$2,807,000.00	$1,135,000.00	$1,672,000.00
DAQ & Monitoring	$310,000.00	$110,000.00	$200,000.00
Installation, Integration, and Commissioning	$1,370,000.00	$1,100,000.00	$270,000.00

Final numbers coming from Cat

Developed MicroBooNE Costs:

Materials cost same as in proposal: ~6M in materials

Labor costs now included

Contingecy/Overhead assesed: 50% contingency

xx% overhead and G&A on labor

16% overhead on Materials > 800k

- Possible funding from non-DOE sources (NSF MRI submitted, university funds, etc) not taken into account
- Phase 2 R&D in MicroBooNE program not included in Experimental costs

LAr Collaborators: growing effort....

Test Stands: Brookhaven, Fermilab, Michigan State, Yale

ArgoNeuT

Fermilab: B. Baller, G. Rameika, C. James, R. Schmitt, B. Sanders
Gran Sasso: O. Palamara, F. Arneodo, M. Antonello
L'Aquila: F. Cavanna
Michigan State: C. Bromberg, D. Edmunds
Padova: F. Pietro-Paolo
UTAustin: S. Kopp, K. Lang
Yale: C. Anderson, B. T. Fleming, S. Linden, M. Soderberg, J. Spitz

MicroBooNE

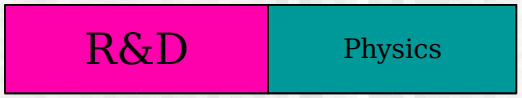
Brookhaven: H. Chen, J. Farrell, F. Lanni, D. Lissauer, D. Makowiec, J. Mead, V. Radeka, S. Rescia, J. Sondericker, B. Yu
Columbia: L. Bugel, J.M. Conrad, V. Nguyen, M. Shaevitz, W. Willis
Fermilab: C. James, S. Pordes, G. Rameika
Michigan State: C. Bromberg, D. Edmunds
St. Marys: P. Nienaber
UTAustin: S. Kopp, K. Lang
Yale: C. Anderson, B. T. Fleming, S. Linden, M. Soderberg, J. Spitz

LAr5

Fermilab: B. Baller, D. Finley, D. Jensen, H. Jostlein, C. Laughton, B. Lundberg, R. Plunkett, S. Pordes, R. Rameika, N. Saoulidou, R. Schmitt
Indiana University: M. Messier
Michigan State: C. Bromberg, D. Edmunds
University of Minnesota: K. Heller, M. Marshak, E. Peterson
UT Austin: S. Kopp, K. Lang
Tufts University: H. Gallagher, W.A.Mann, J. Schneps
Yale University: B.T.Fleming

Brings together expertise in neutrino physics, LAr detetcors and LArTPCs

The MicroBooNE program combines



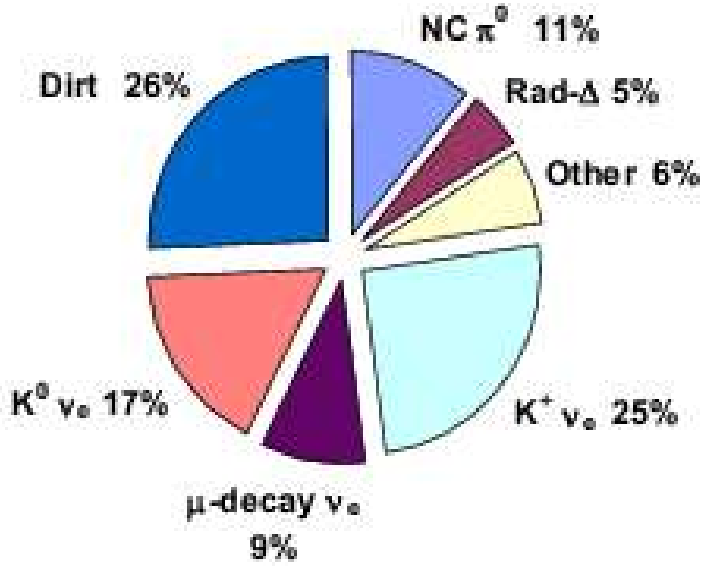
- Compelling physics case
  - Resolve MiniBooNE low energy excess
  - Measure neutrino processes on Argon
- R&D towards next generation detectors
  - Phase1: towards MicroBooNE design
  - Phase2: for LAr5 and beyond

Shall we request approval here?

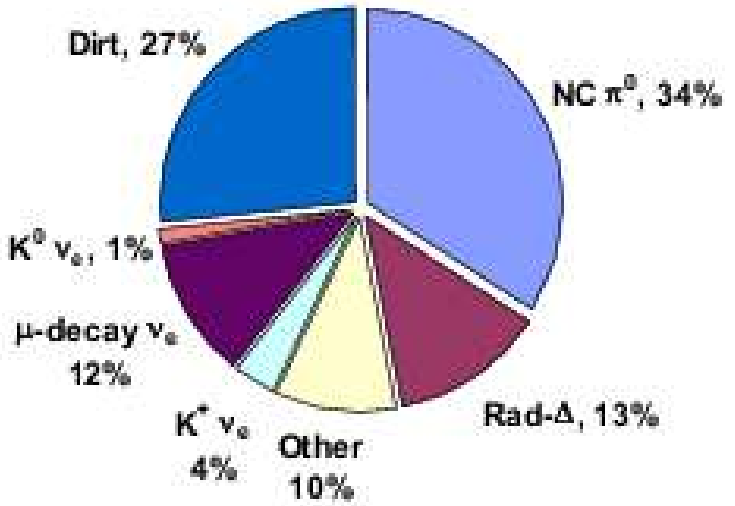
Backup slides

ν_e Backgrounds – NuMI vs MiniBooNE events

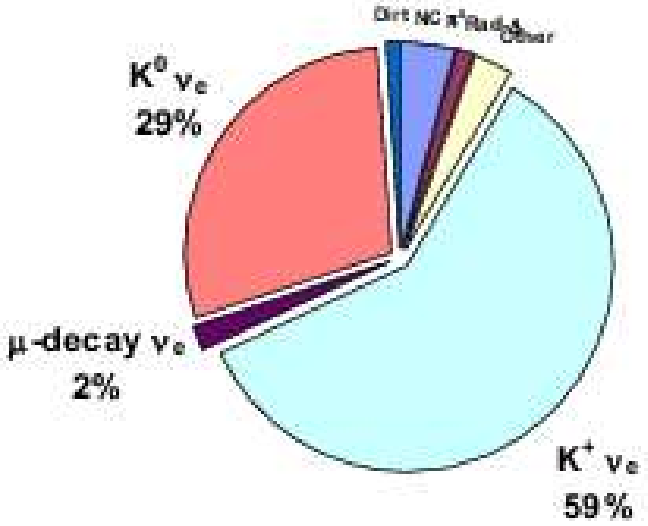
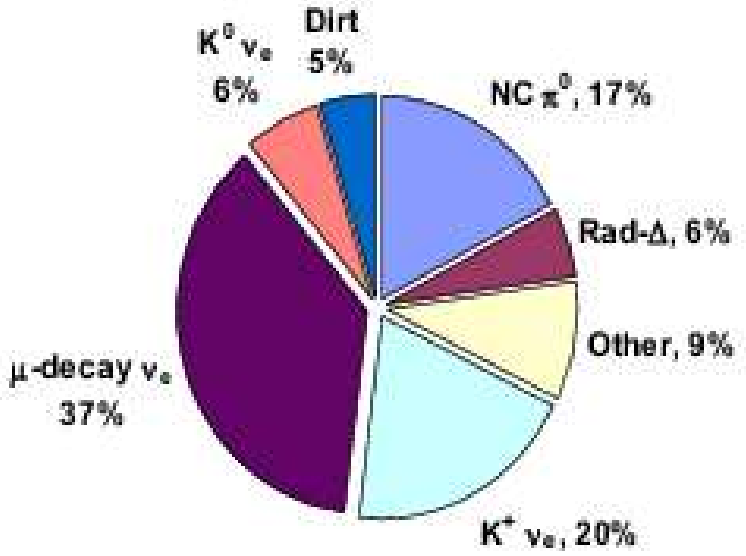
NuMI Background Events (200 - 475 MeV)



MiniBooNE Background Events (200 - 475 MeV)



NuMI Background Events (> 475 MeV)



MiniBooNE Background Events (>475 MeV)