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

MicroBooNE:
Update on Proposal P974

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St. Marys: P. Nienaber
UTAustin: S. Kopp, K. Lang
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Presentation to the Fermilab PAC, Spring 2008

MicroBooNE Status:

Proposal Addendum submitted,
updates motivated by:

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

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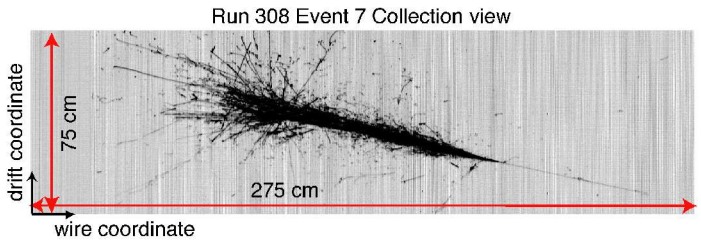
- MicroBooNE in the broader program
- Status of MicroBooNE's physics case
- Expanded R&D program: MicroBooNE and beyond
- MicroBooNE baseline design update
- Updated cost and schedule

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! Need powerful LAr detectors.....
- 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:

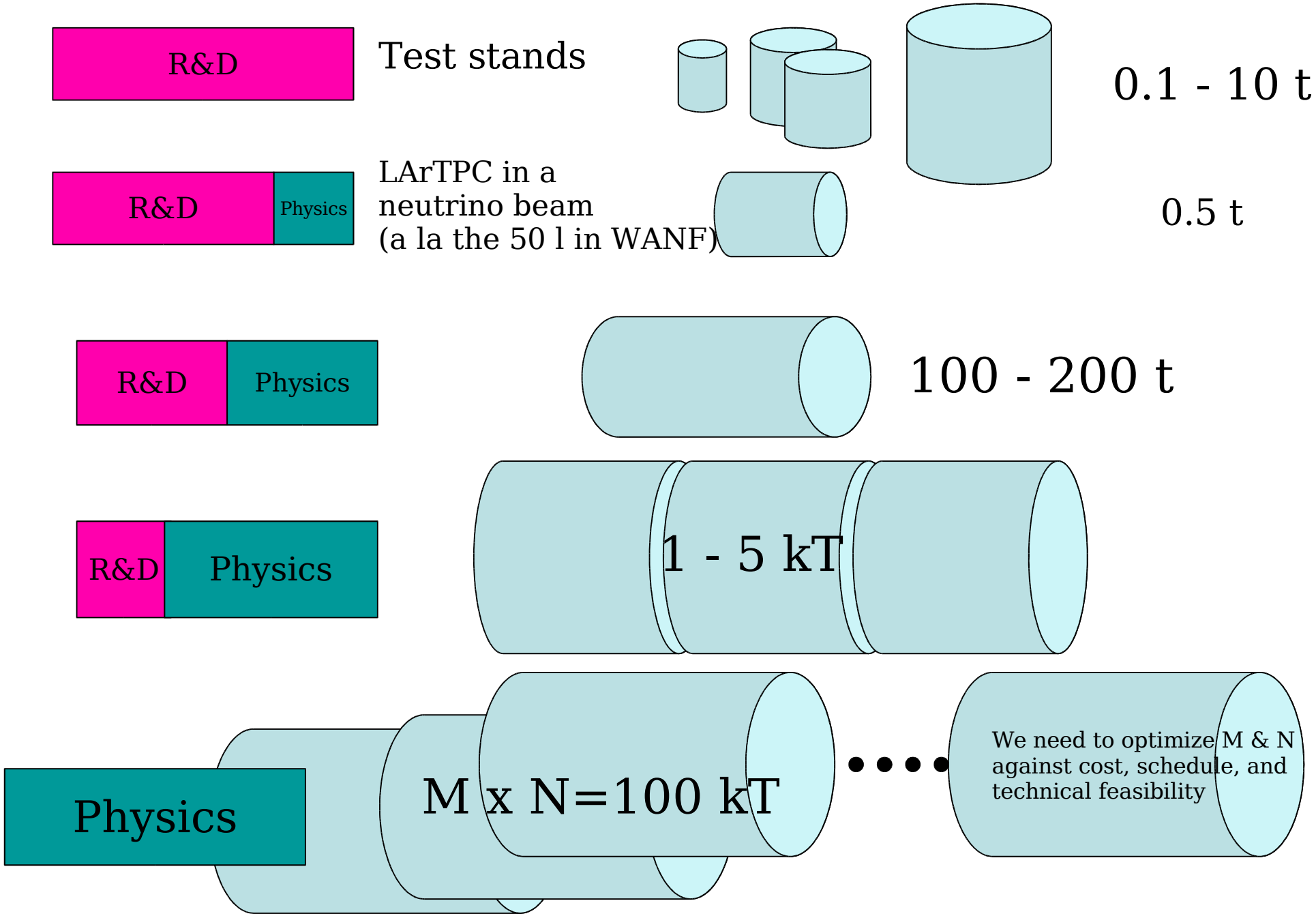
- Low Noise Electronics and signal multiplexing
- Light detection for T_0 determination
- Purification Issues: large, industrial vessels
- Physics Development: Measure interactions on argon: analysis tools, hardware strengths and shortcomings
- TPC design: Wire plane structure
- Vessel Design: materials, 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

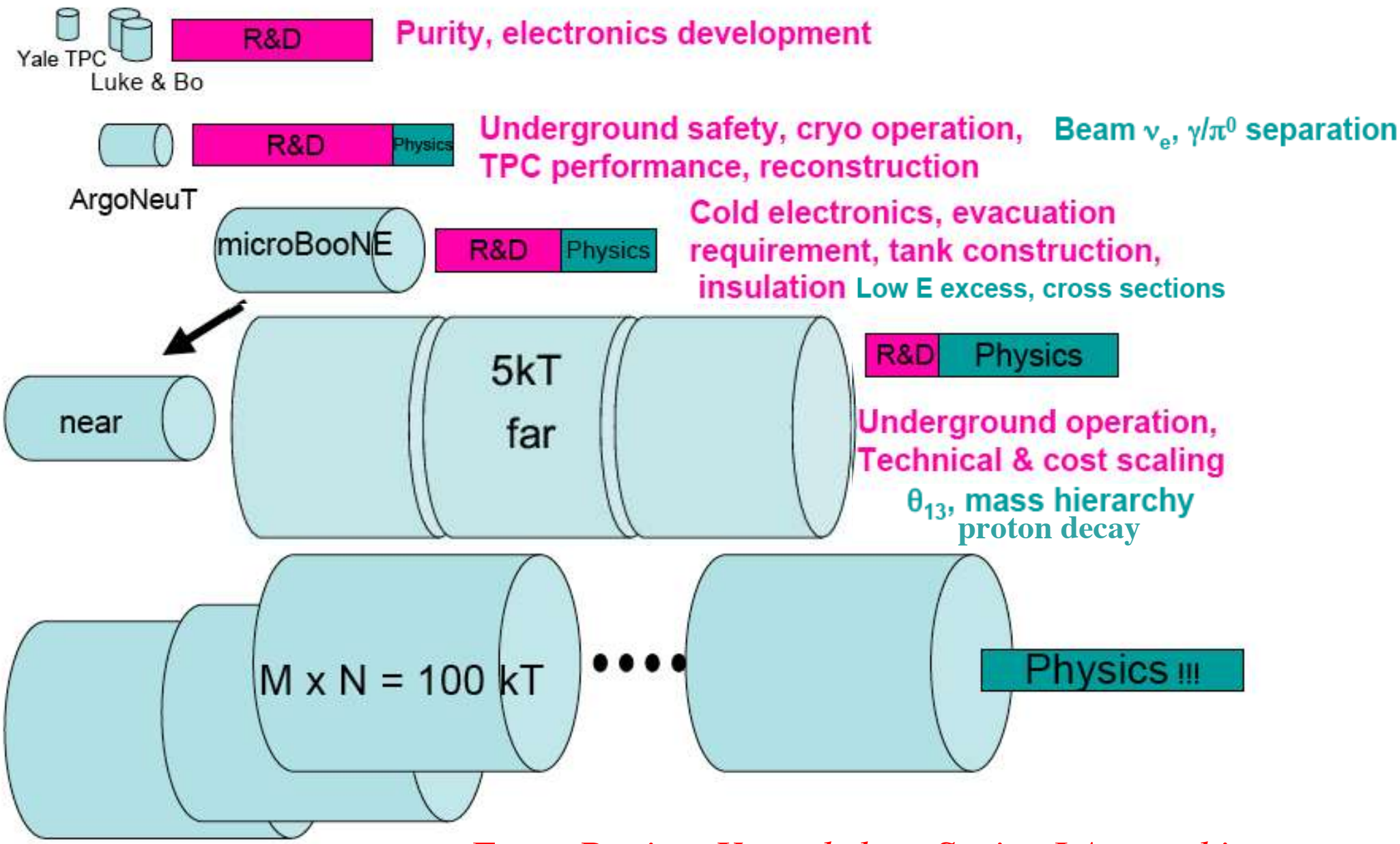
From Project X workshop Series LAr working group

Evolution of a Liquid Argon Physics Program



From Project X workshop Series LAr working group

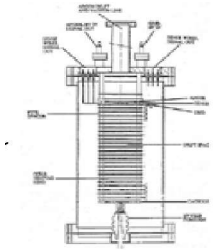
Evolution of the Liquid Argon Physics Program in the US



From Project X workshop Series LAr working group

Similar evolution in European program

Test Stands →

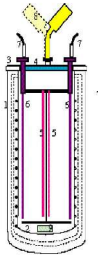


24 cm drift wires chamber

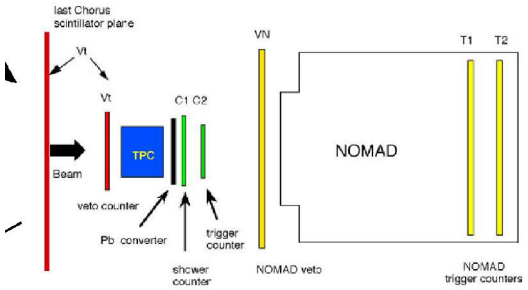
1987: First LAr TPC. Proof of principle. Measurements of TPC performances.

3 ton prototype

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

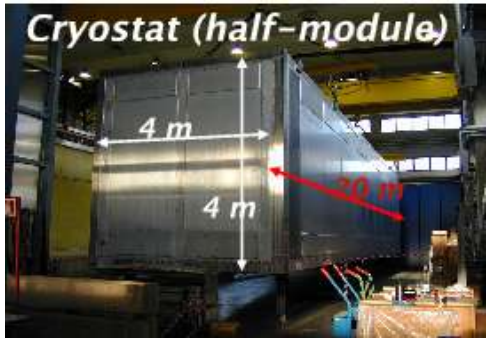


Seeing neutrino Interactions →



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.

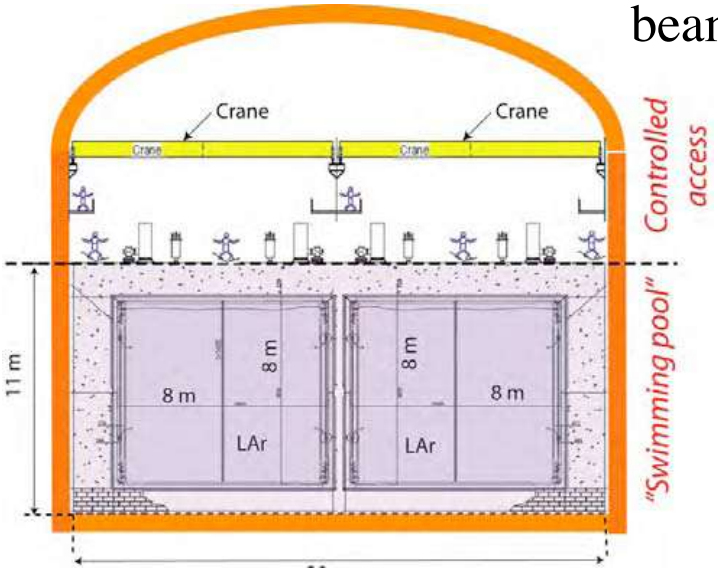


T600: data in '08
~2000 evts/yr, 17 GeV CNGS beam

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

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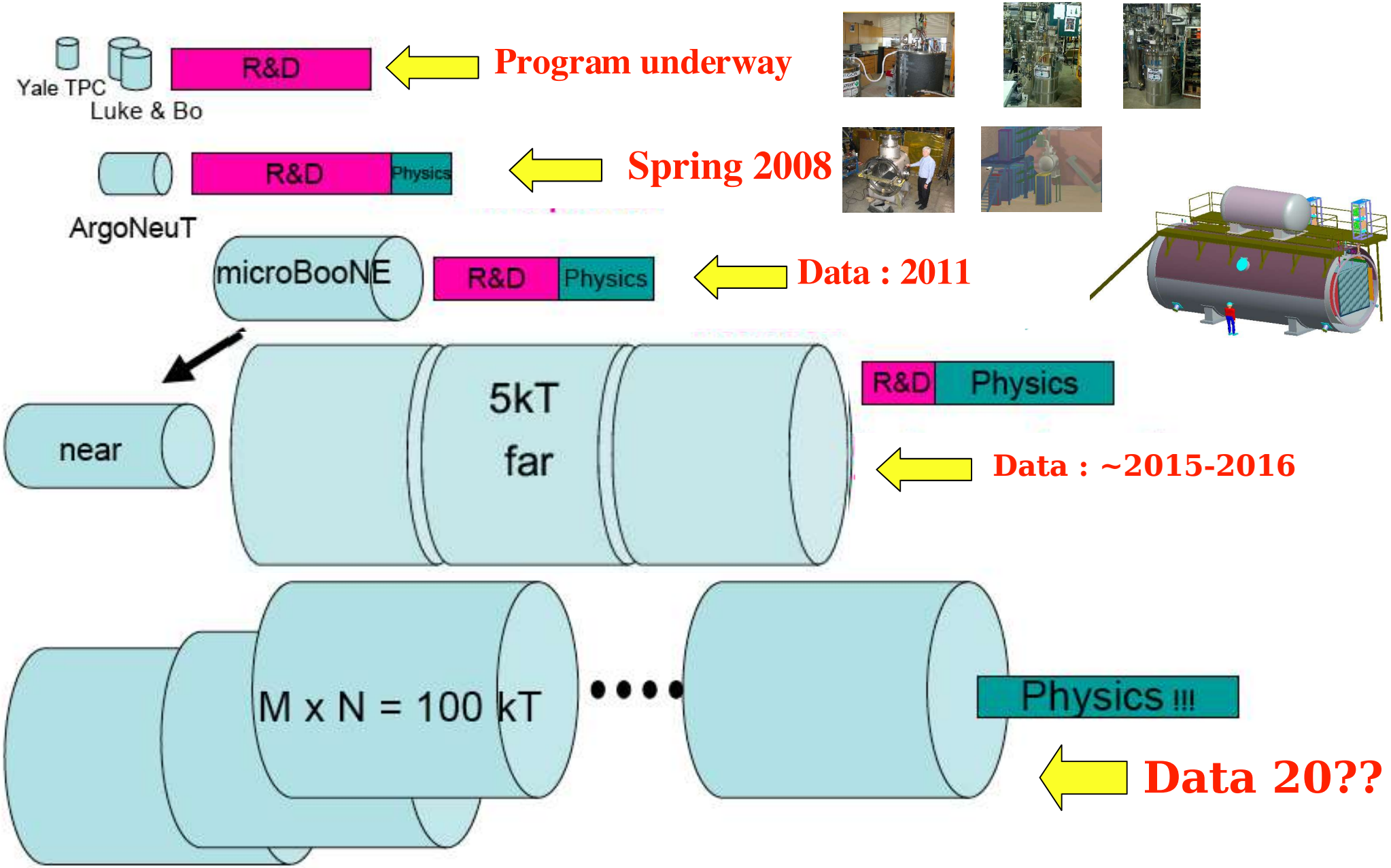


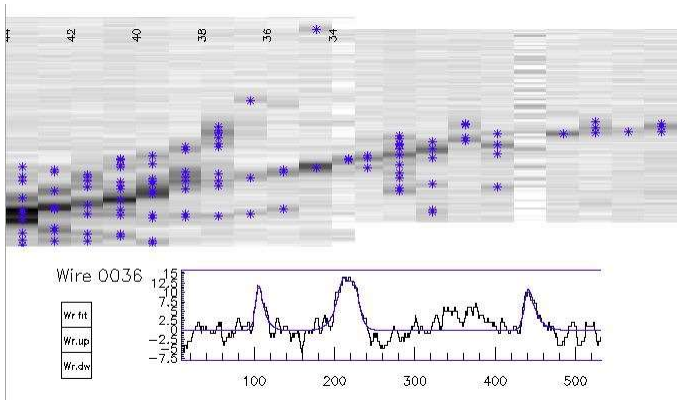
R&D

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

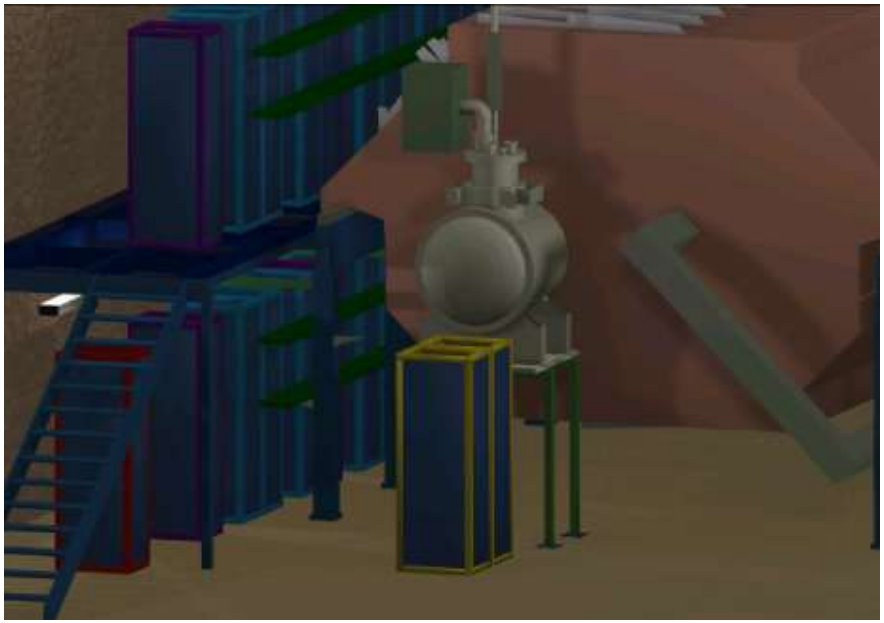
Materials Test Stand
Electronics Test Stand
at Fermilab

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

M. Soderberg, Yale

Joint NSF/DOE project

R&D | Physics

MicroBooNE: Full scale experiment

Compelling and timely physics case
R&D for next generation LArTPCs

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

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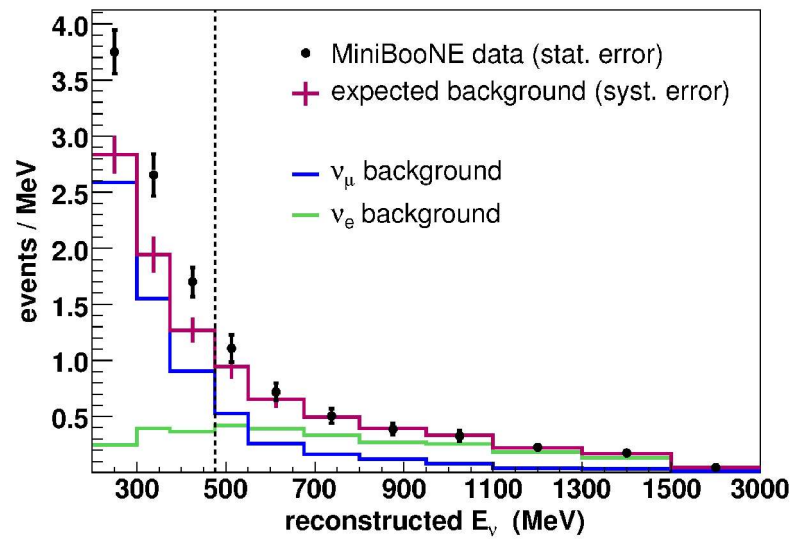
MiniBooNE Low Energy Excess

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....

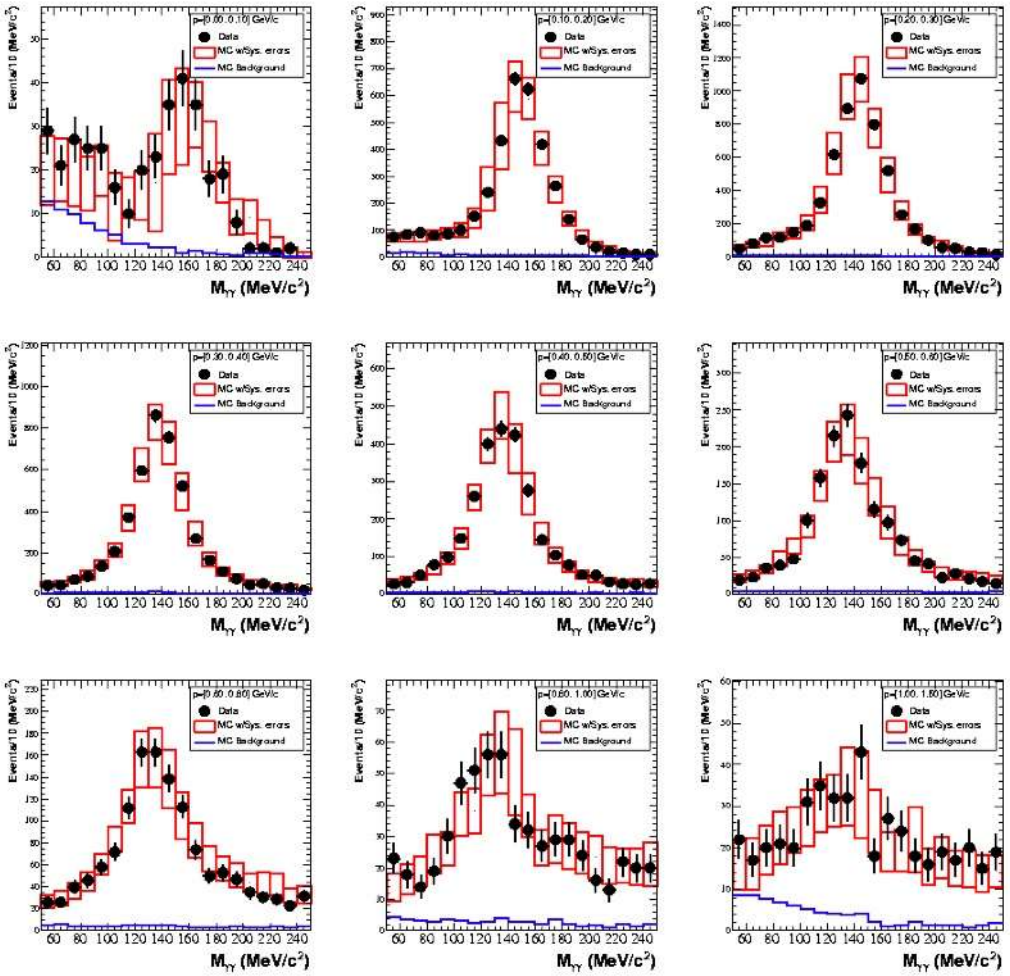
NCπ° and radiative $\Delta \rightarrow N\gamma$ constrained by identified NCπ° events (paper submitted to PLB, March '08)

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

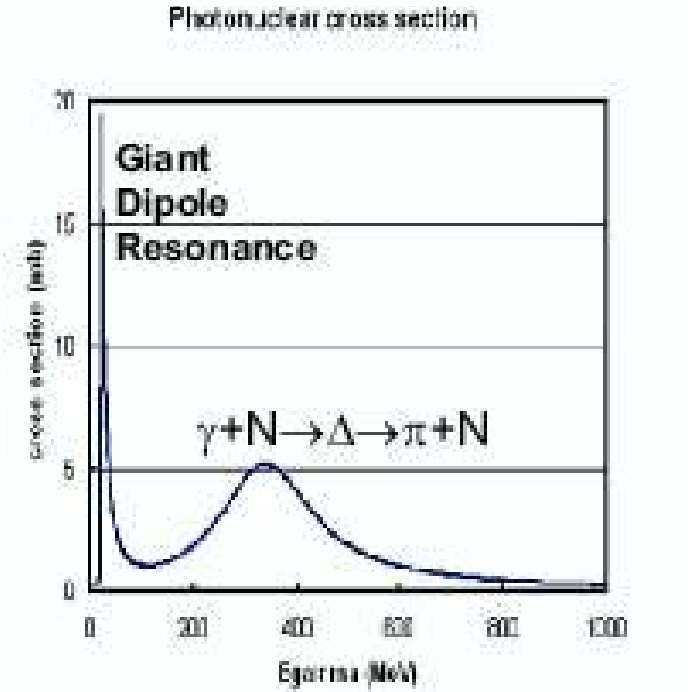
Error due to absolute rate of events, not flux or cross section errors -> robust!

Coherent rate determined from angular distributions



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

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



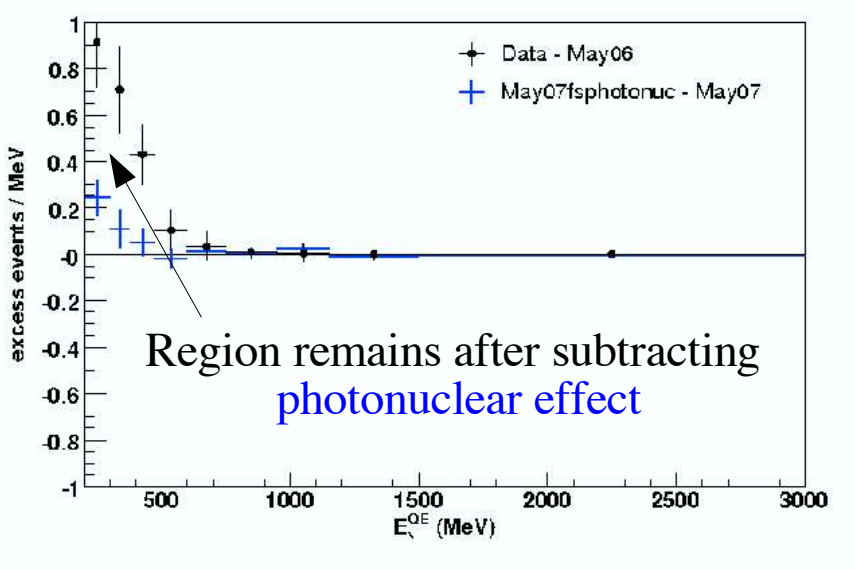
One gamma lost due to interactions with nuclei

interaction often results in other particles produced – final state interactions

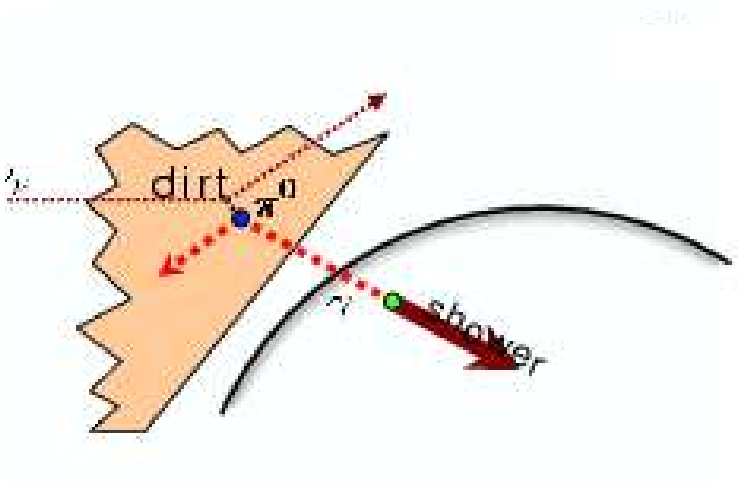
Cannot be constrained by MiniBooNE data:

Most conservative error on rate assessed to determine background

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

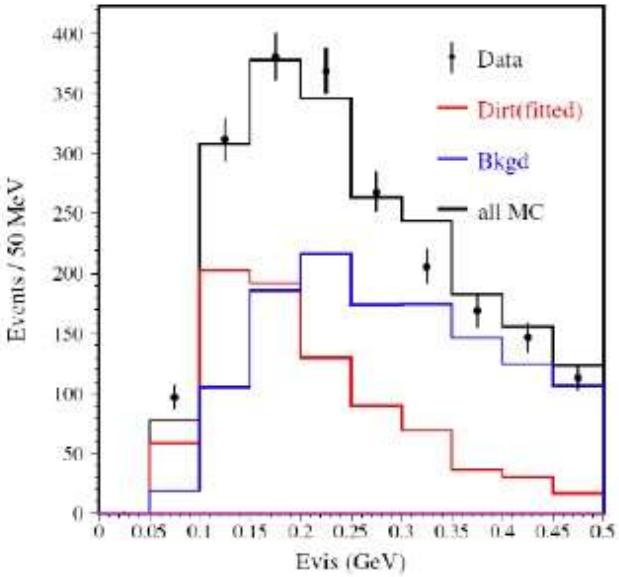


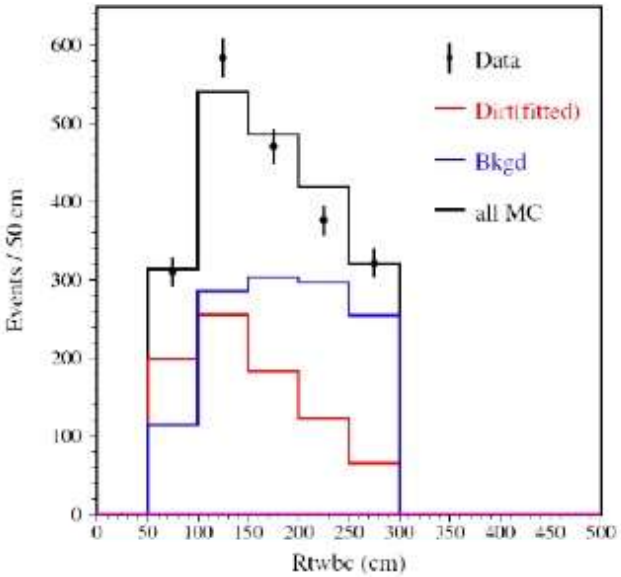
“Dirt” backgrounds

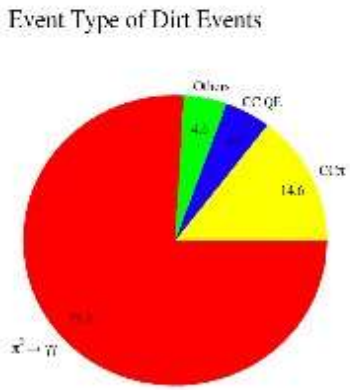


Beam neutrino interactions in dirt around detector can produce single gamma events in detector

Background can be reduced significantly with “RtoWall” cuts – *work in progress*







Backgrounds have been reviewed and studied extensively

-constrained to data for resonant and dirt events

-conservative errors assumed where not constrained by data

Photonuclear effect considered since published result

-reduces excess but excess still significant

Optimized cuts on low energy backgrounds

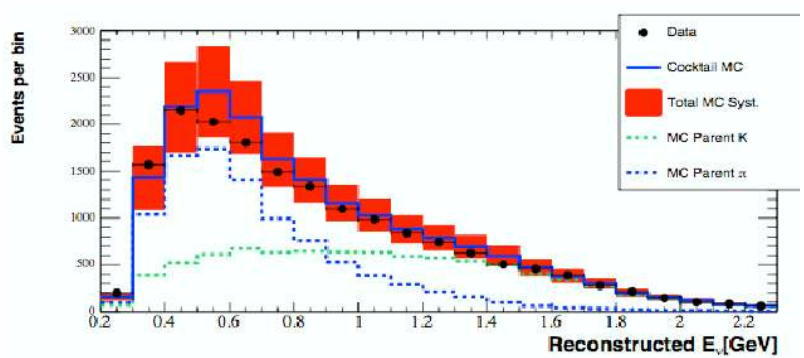
-work in progress

Comprehensive review to be presented at Neutrino '08

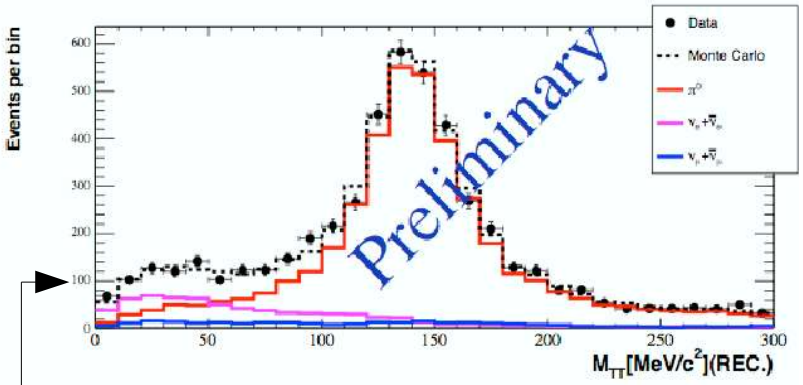
New results from NuMI events in MiniBooNE detector

(FNAL wine and cheese, Z. Djurcic, 12/2007)

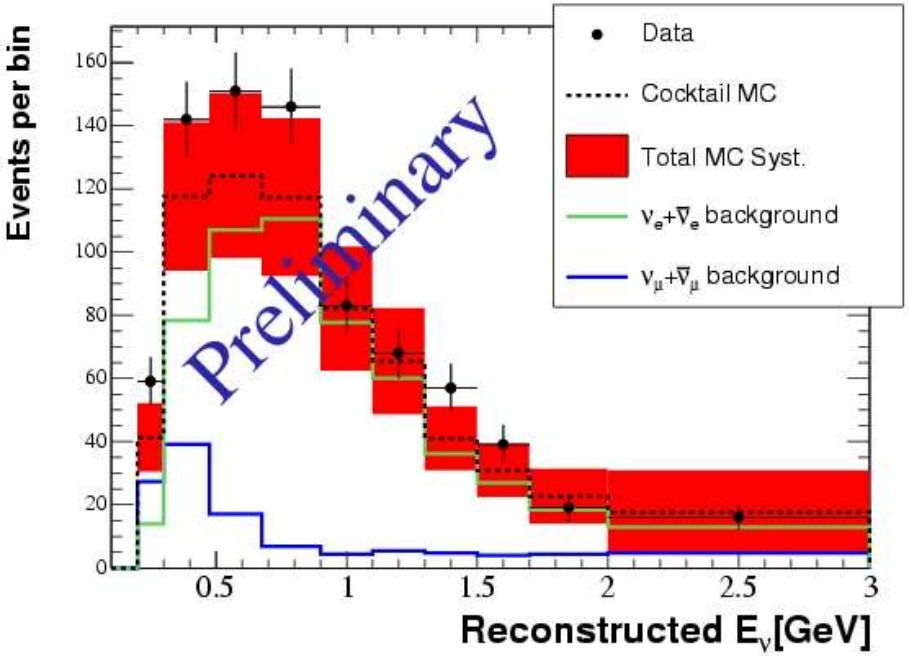
Absolute Data/MC comparisons:



CCQE events well modeled.



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



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

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

Impact on Broader program:

Interpretations of excess:

as ν_es:

Beyond-the-Standard model:

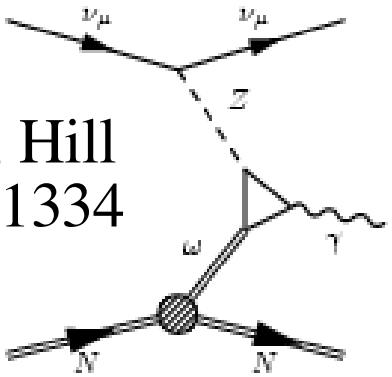
- hep-ph/0705.0107v1
- hep-ph/0706.1462
- hep-ph/0710.28985
- hep-ph/0702049
- hep-ph/0504096
- hep-ph/0707.4953
- hep-ph/0606154
- hep-ph/0602237
- hep-ph/0707.2285
- hep-ph/0711.1363

Recent work...

as γs:

Standard Model process:

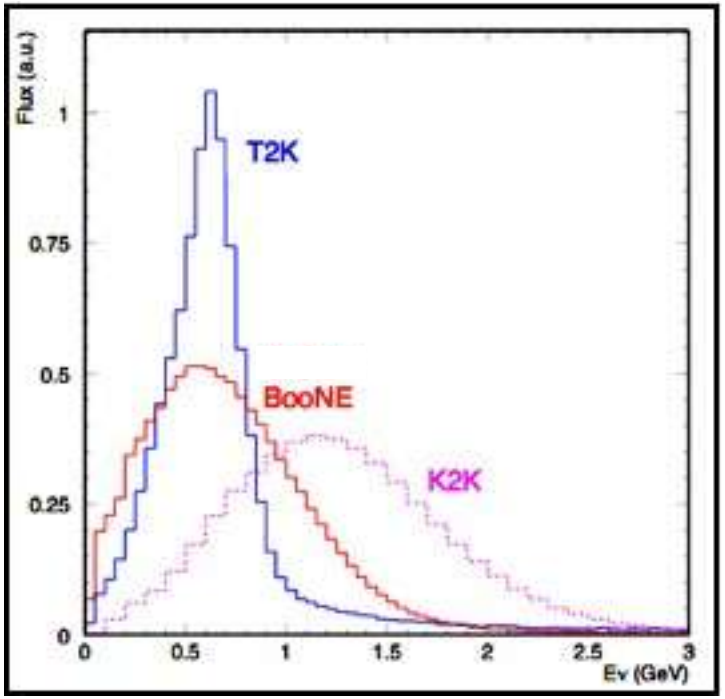
Harvey, Hill, Hill
hep-ph/0708.1334



- Uncertainty in normalization
  $\rightarrow$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.



For example,
T2K experiment:

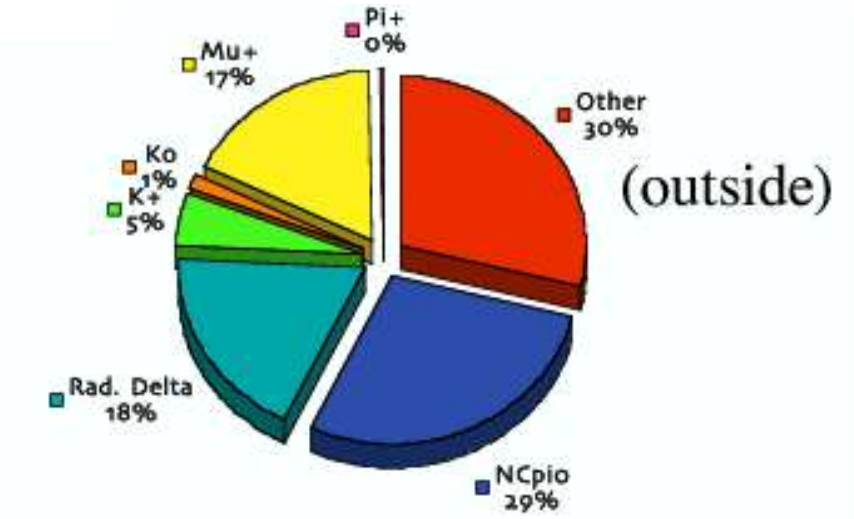
- Similar energy spectrum
- Cerenkov detection technique
- <1% oscillation probability
- excess would be a background of ~100 events at >100 MeV

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

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 9σ sensitivity if excess is ν_es

3.4σ if excess is γs

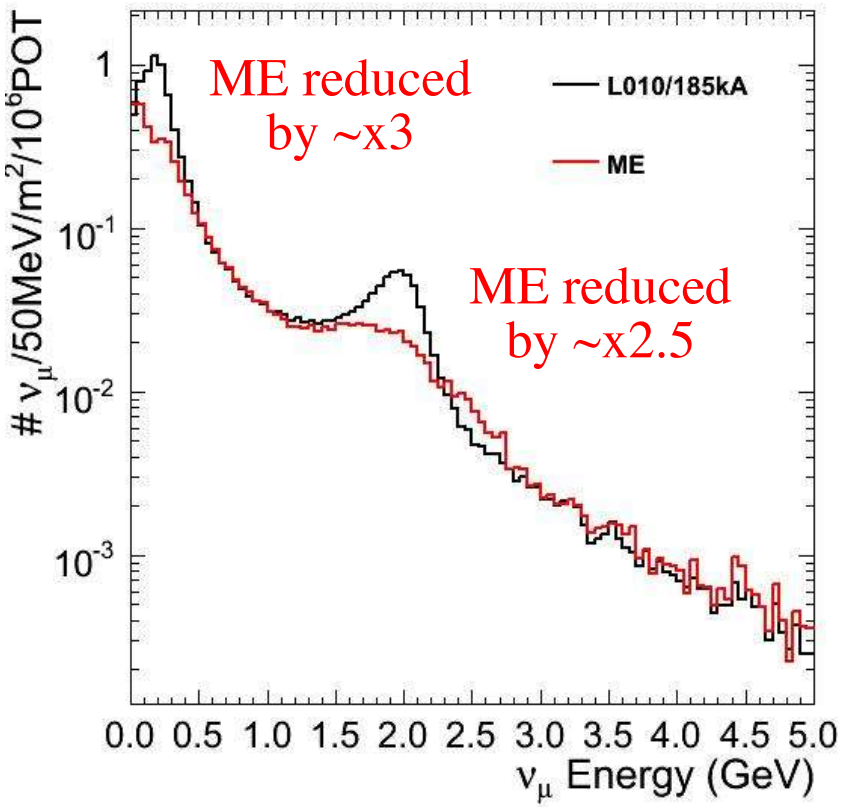
Inability to identify excess as ν_es or γs illustrates the need for the best detectors for ν_e appearance physics

→ the strength of the LAr detection technique

Cross sections measurements:

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

Expect ~100K events from BNB (6E20 POT)
~60K events from LE, 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

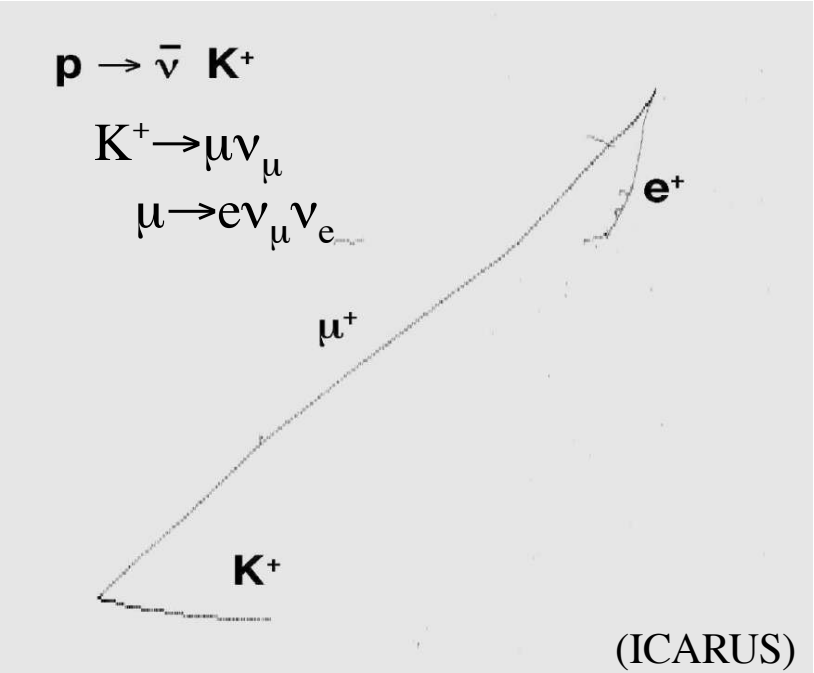
While LE mode is preferred, ME mode is acceptable

Physics R&D: Studies for proton decay sensitivities

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

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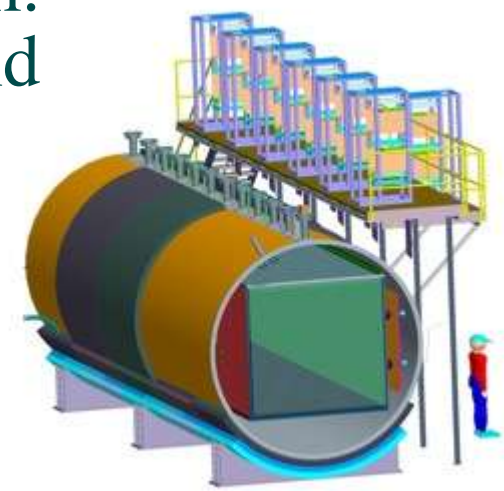
R&D | Physics

Expanded R&D Program: MicroBooNE and beyond



Two overlapping phases

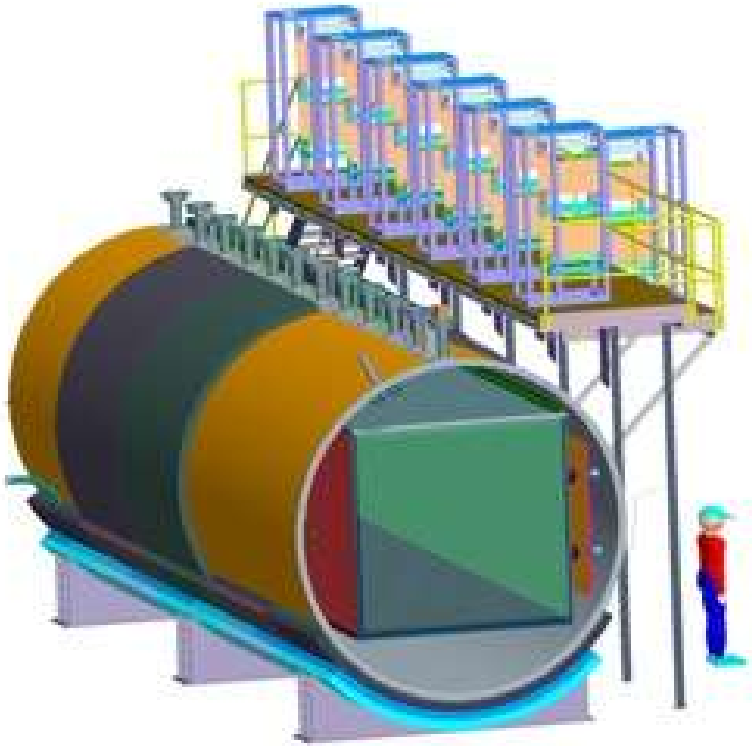
- Phase 1, already underway: design questions specific to MicroBooNE: changes reflected in MicroBooNE Baseline design update, for example, cryostat
- Phase 2: longer term R&D questions relevant for the next stage in LArTPC program. Beginning work on these issues
  - Achieving and maintaining Argon purity 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

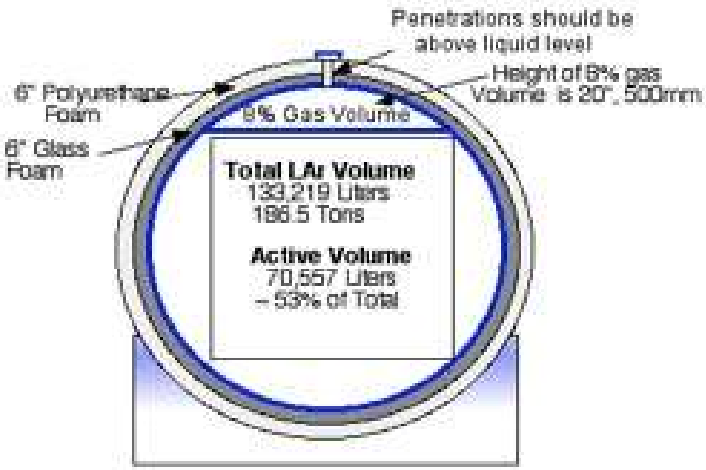
Staging allows for successful combination of R&D and physics goals

Phase 1: Cryostat and Cryogenics design

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

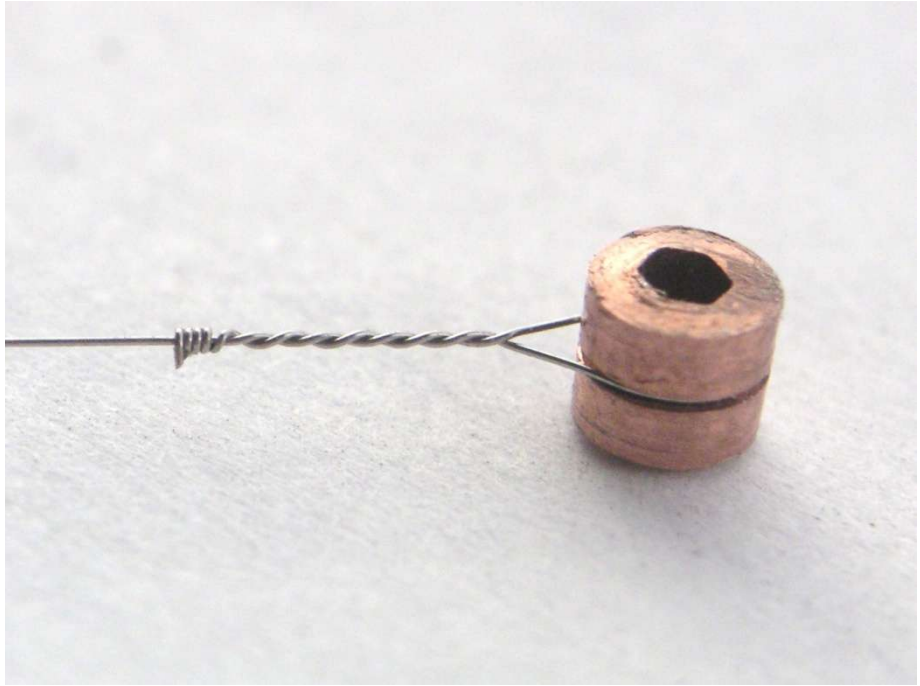




Cross section of cryostat

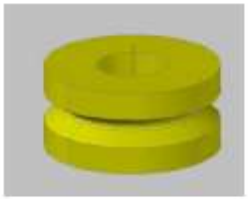
8% Gas volume at top of tank

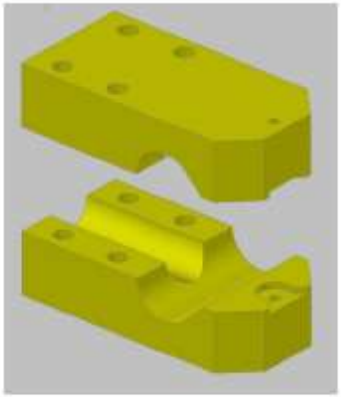
- No need for expansion/storage vessel
- JFET hybrid pre-amps at 120K in GAr

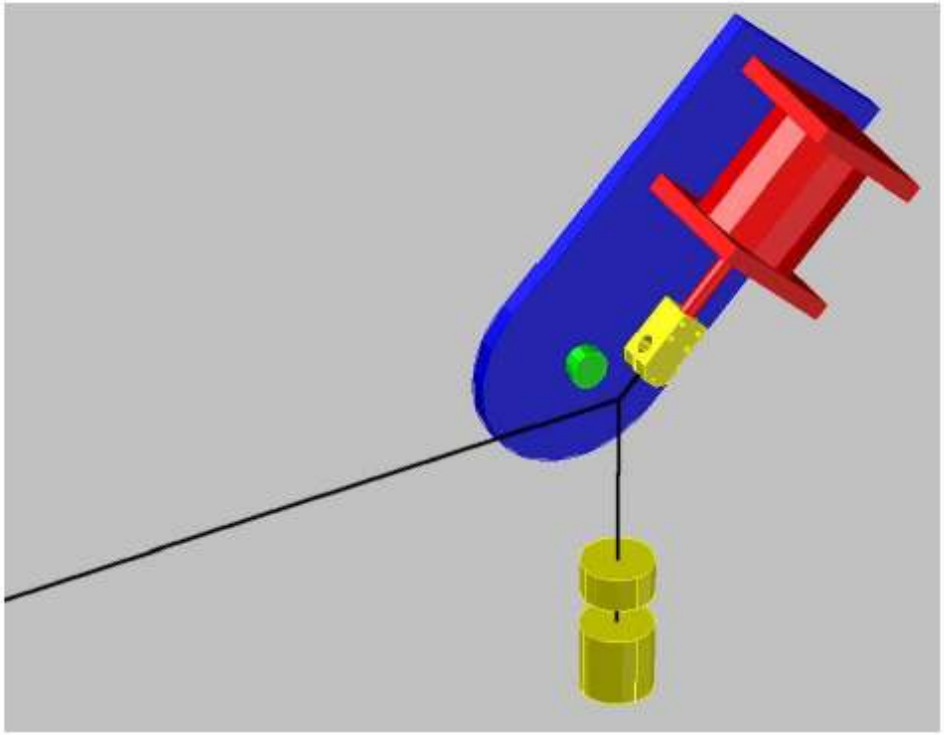


Phase 1:
Wire termination and wire properties:

Technique for termination:
- Robust: keeps tension
- Scalable



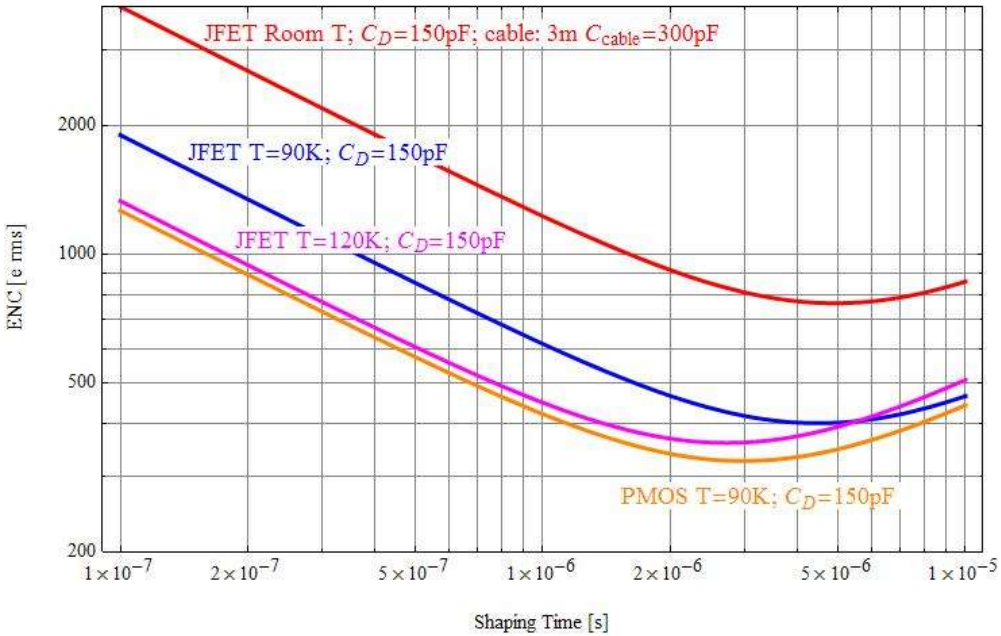


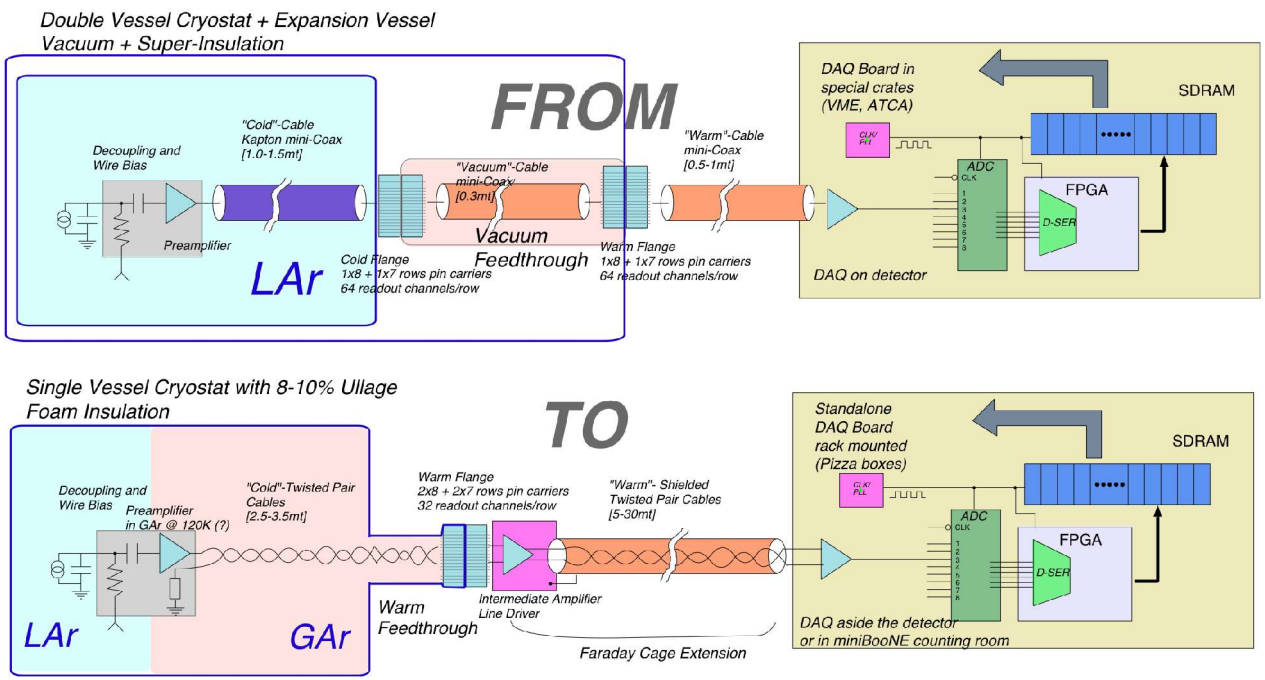


Concept for winding machine

Phase 1: Readout electronics design

JFET in GAr ullage:
- low noise at 1-2 μs shaping
- Study S/N levels expected in next generation LArTPCs

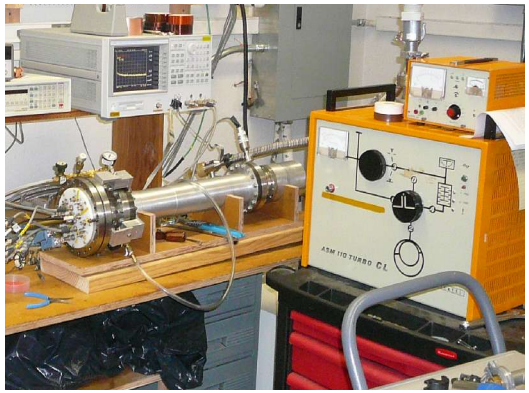


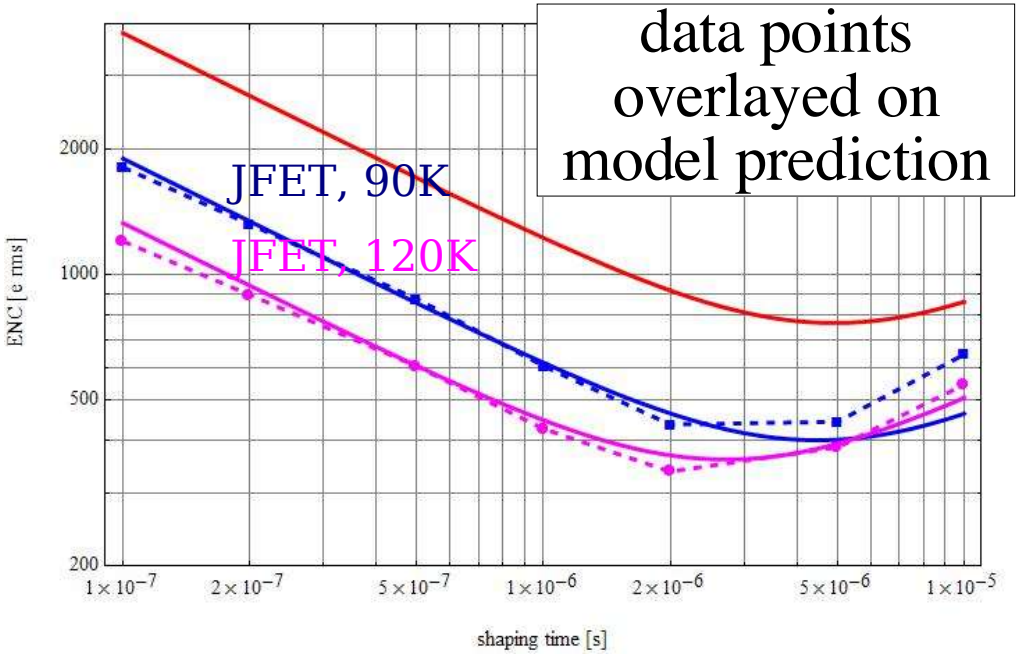


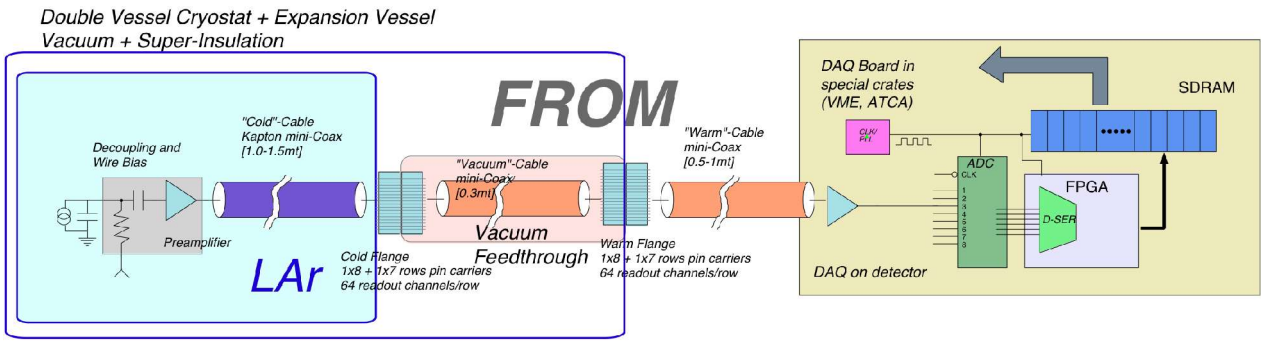
- move to twisted pair cables (less costly)
- Intermediate line driver allows for flexibility in location of DAQ crates

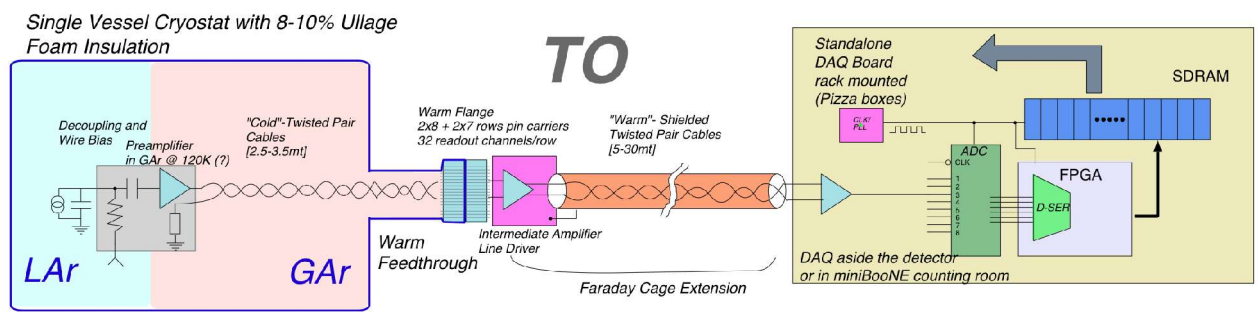
Phase 1: Readout electronics design

Bench tests of JFET hybrid at Brookhaven: room temp, 90K, 120K



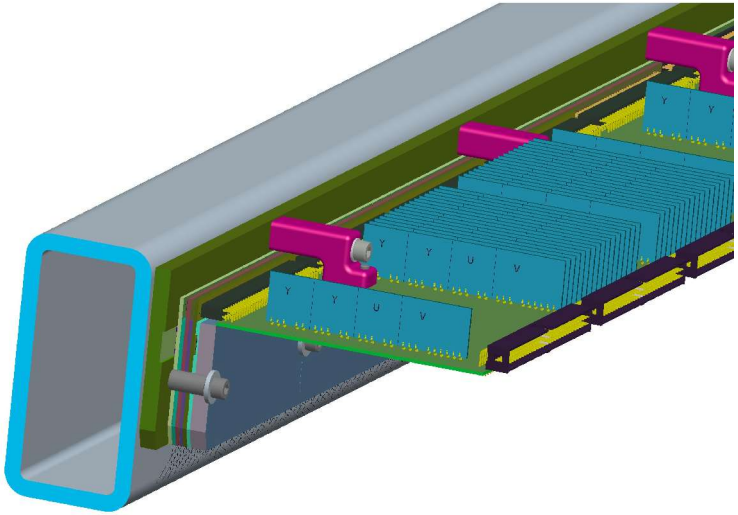


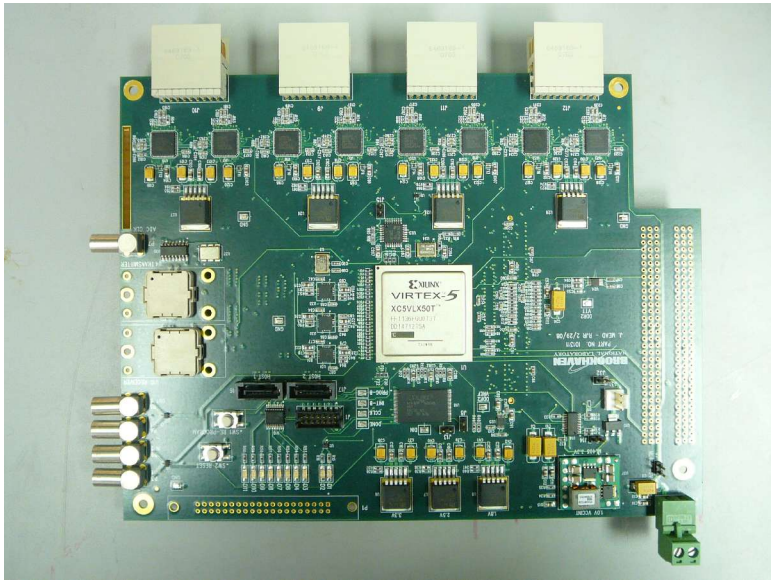




- move to twisted pair cables (less costly)
- Intermediate line driver allows for flexibility in location of DAQ crates

Phase 1: Wire Holder and DAQ



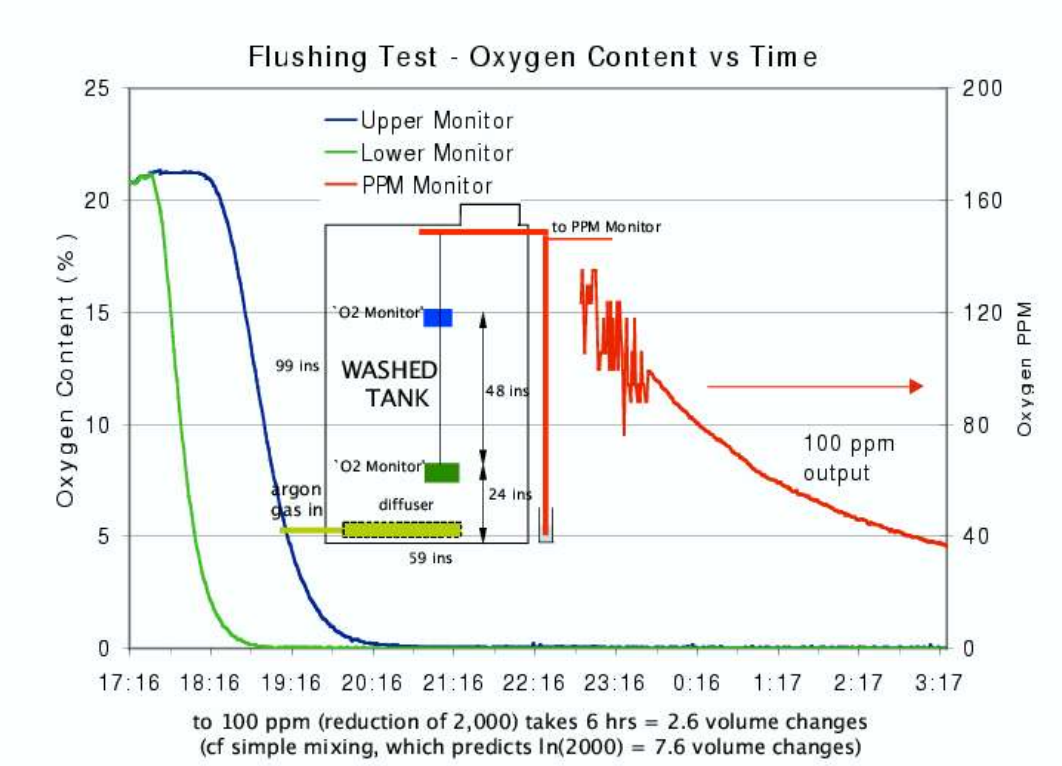


Further development on wire holder,
JFET hybrid, motherboards, and
DAQ boards

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

Phase 2: Purity program

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



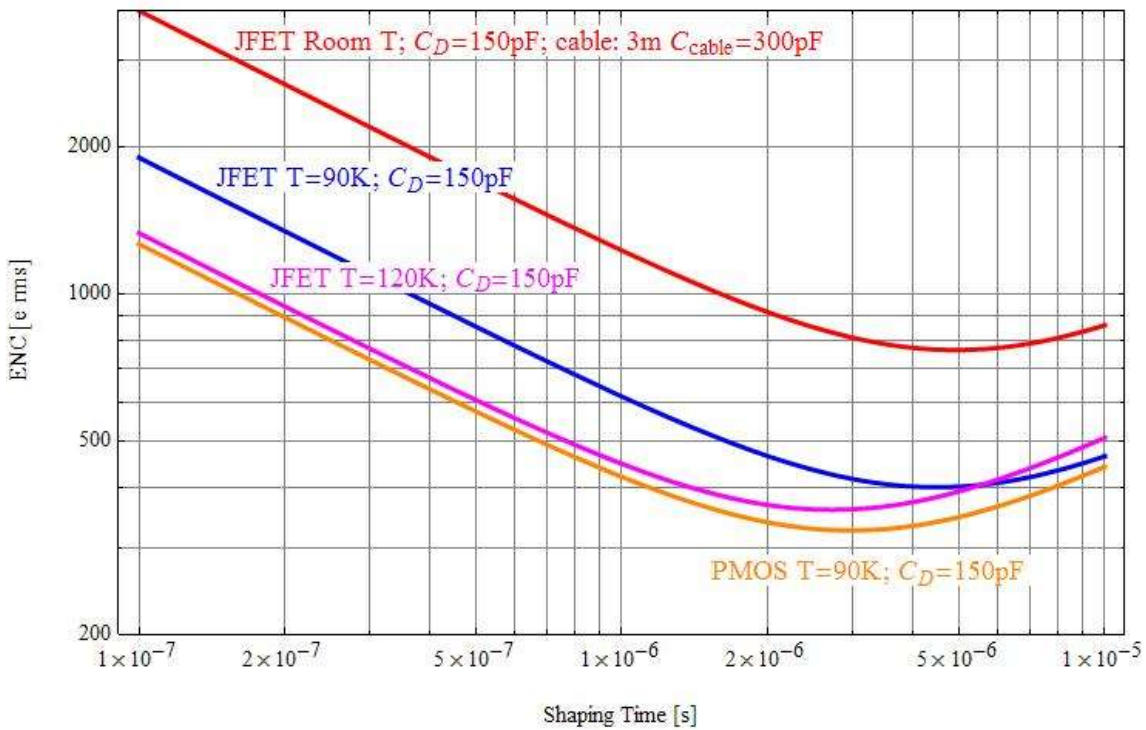
First tests at FNAL are promising.

Need test with large, fully instrumented vessel
->MicroBooNE

<u>MicroBooNE Purge test: 6 week program to precede physics run</u>

- 10 volume changes of GAr to reduce O_2 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

Phase 2: Readout Electronics R&D



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

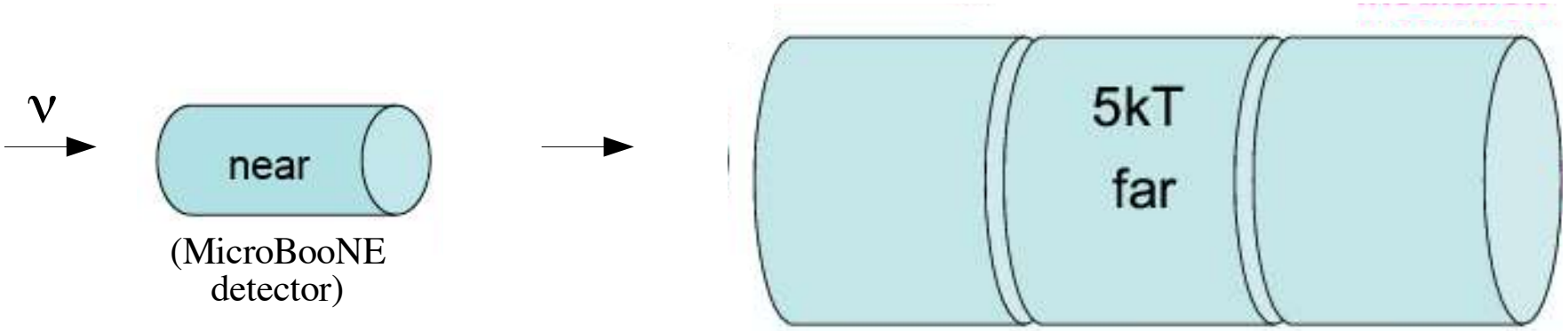
Combine what is learned with JFET hybrids in GAr in MicroBooNE (very similar S/N to CMOS) with development of CMOS technology in LAr

- Develop Readout architecture → multiplexing at cryogenic temperatures to handle ~million channels of very large detectors

4 year R&D program for both CMOS technology and multiplexing

Phase 2: General detector design

(TPC cage geometry, resistor chains and holders, wire chambers and connections, PMT array, purification system, ...)



Optimize detector design for MicroBooNE and beyond:

- constructibility
- cost scaling
- value engineering

MicroBooNE Status:

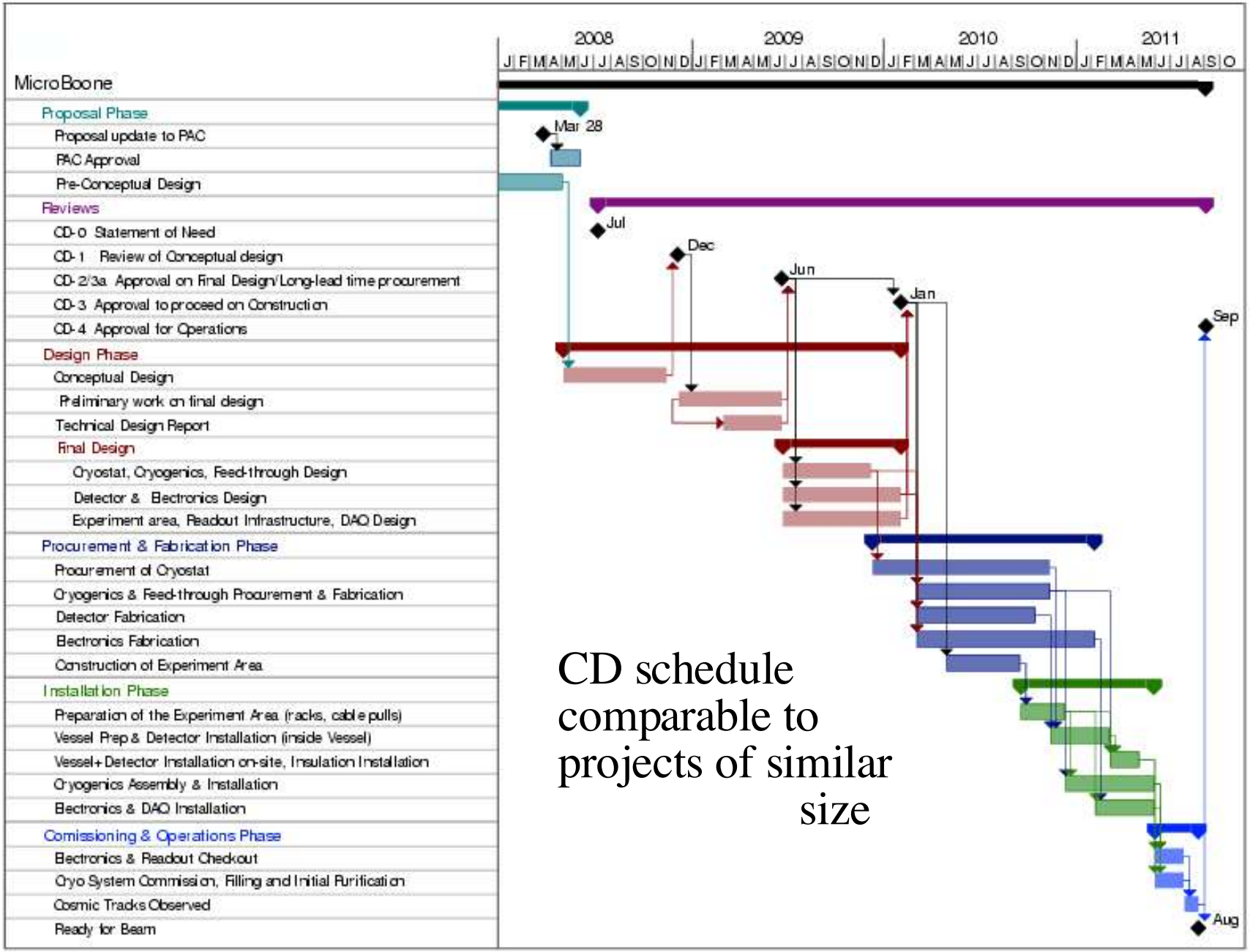
Proposal Addendum submitted,
motivated by:

- 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

Developed MicroBooNE's implementation plan including CD schedule



Data taking in mid-2011

MicroBooNE Costs Rollup	Total Cost Estimate	Labor Cost Estimate	Materials Cost Estimate
	$19,210,980.00	$8,283,000.00	$10,927,980.00
Contingency 50% of summed estimates	$6,403,660.00	$2,761,000.00	$3,642,660.00
		Labor Costs are the average FNAL PPD annual rates with OPTO/Vac/Fringe/Indirect applied. Material Costs include 18% MSA.	
Sum of Estimates listed below	$12,807,320.00	$5,522,000.00	$7,285,320.00
Detector Facility	$501,500.00	$0.00	$501,500.00
Cryostat, Cryogenics, and Feed-throughs	$5,066,160.00	$1,571,000.00	$3,495,160.00
Detector - TPC and Photodetector	$1,738,400.00	$995,000.00	$743,400.00
Electronics, Readout, Power Supplies, DAQ	$3,790,260.00	$1,481,000.00	$2,309,260.00
Installation, Integration, and Commissioning	$1,711,000.00	$1,475,000.00	$236,000.00

Developed MicroBooNE Costs:

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

Labor costs developed from bottoms-up FTE estimates

Overhead and G&A assessed on labor appropriate for FNAL/BNL

18% overhead on Materials

50% contingency applied

- 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

The MicroBooNE program combines

R&D	Physics

- 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 next step in LArTPC program

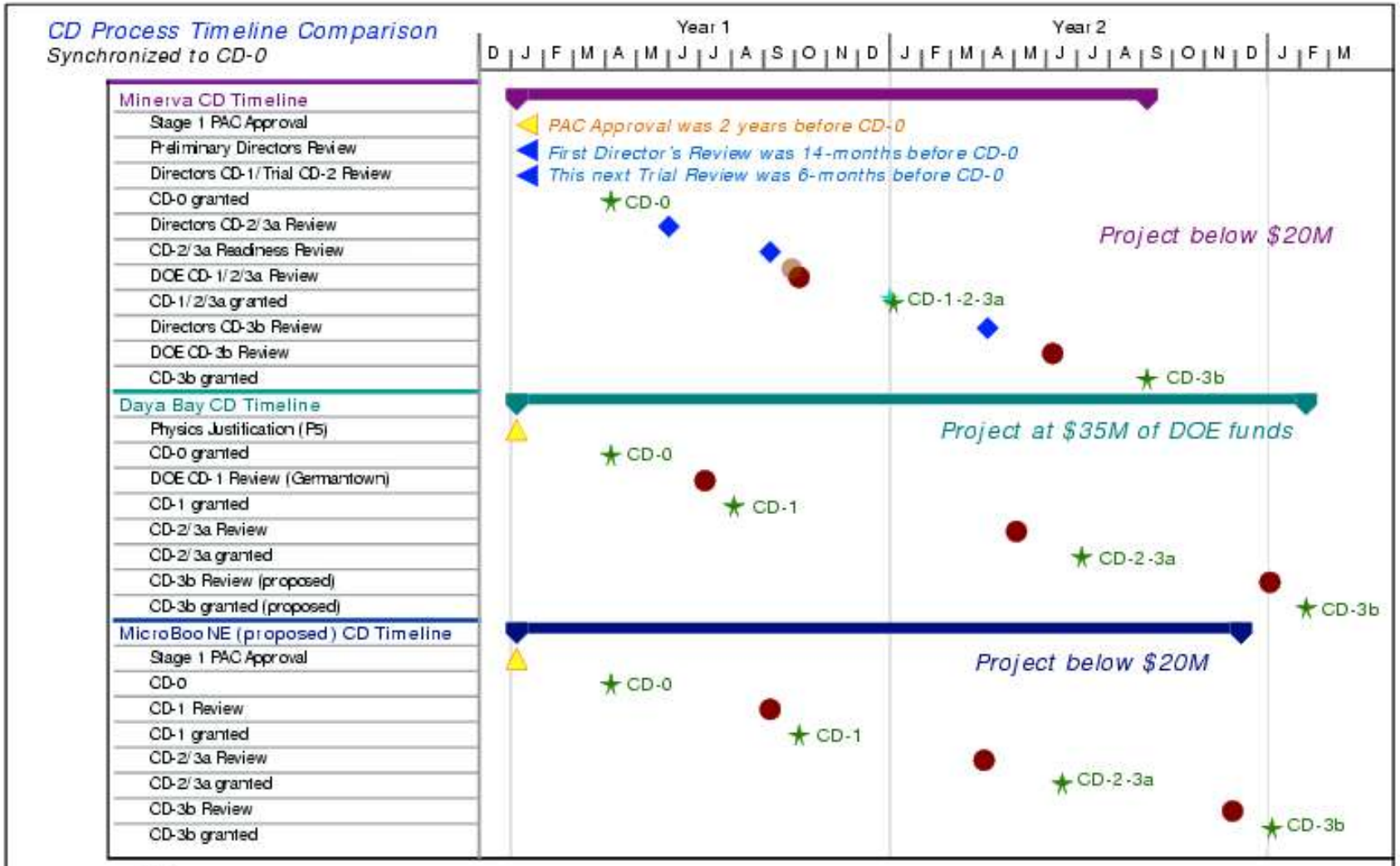
Combination of hardware R&D, strong physics case, and timely results that make MicroBooNE the optimal next step in R&D towards massive LArTPCs

We ask the PAC to endorse the physics case and the technicological program for MicroBooNE by recommending Stage 1 approval.

Presentation to the Fermilab PAC, Spring 2008

Backup slides

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.