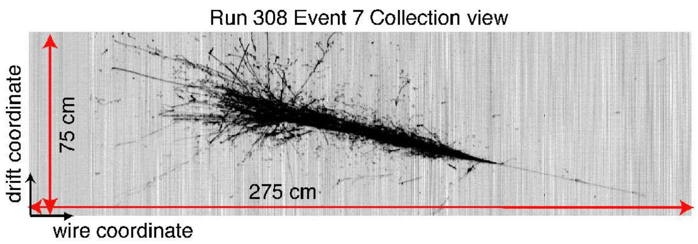
B.T.Fleming
P5 at SLAC
February 21, 2008

Liquid Argon Detectors

Liquid Argon TPC detectors



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)
•Proton decay searches: sensitive to $p \rightarrow \nu\, k$
•Supernova

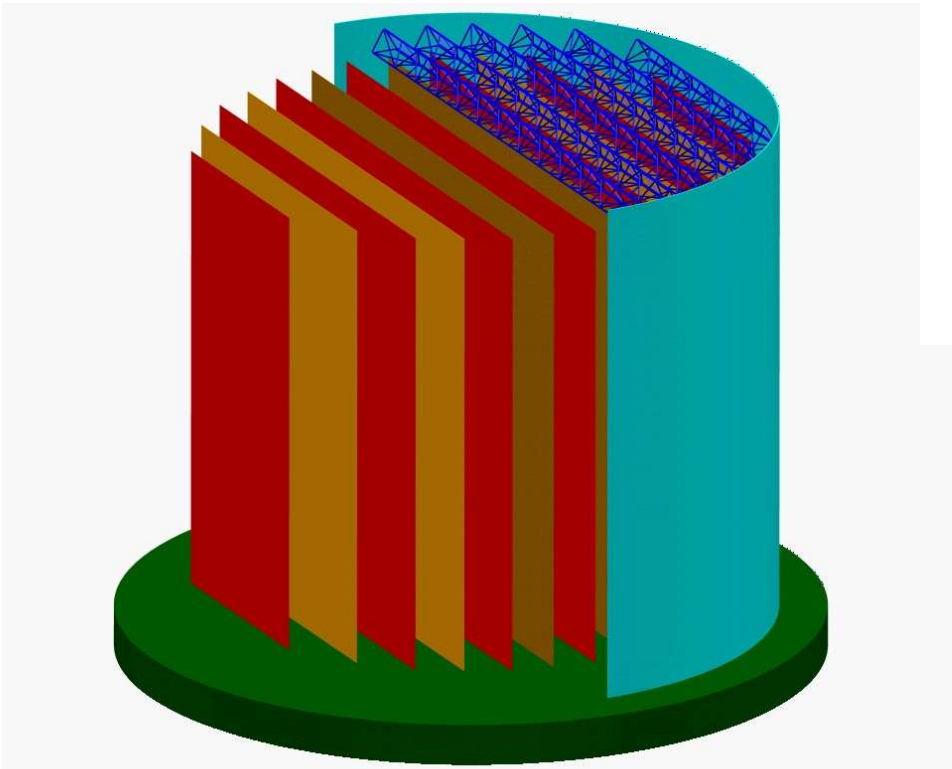
These are great detectors!

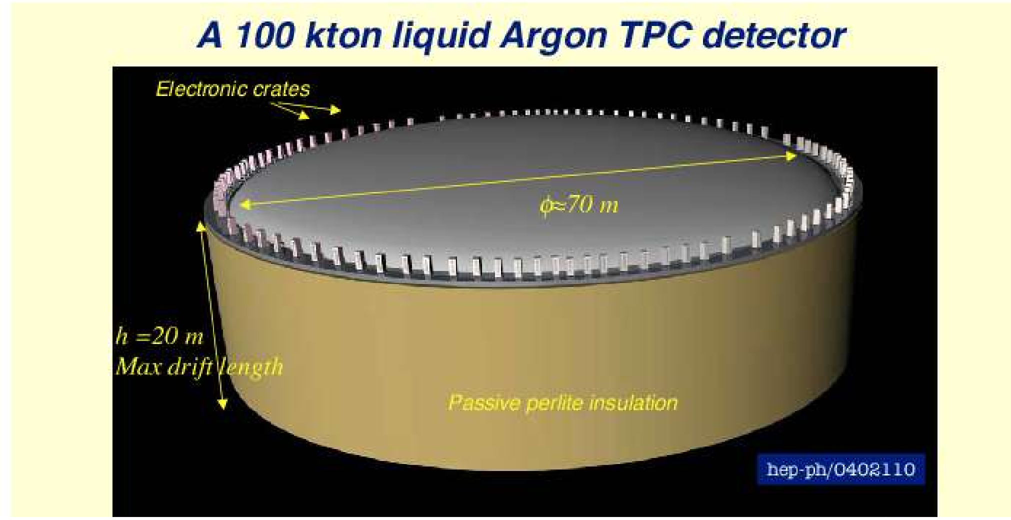
Are they technically feasible on massive scales?

We need to pursue an aggressive R&D program
to address this in a timely way....

Possible designs for massive detectors:

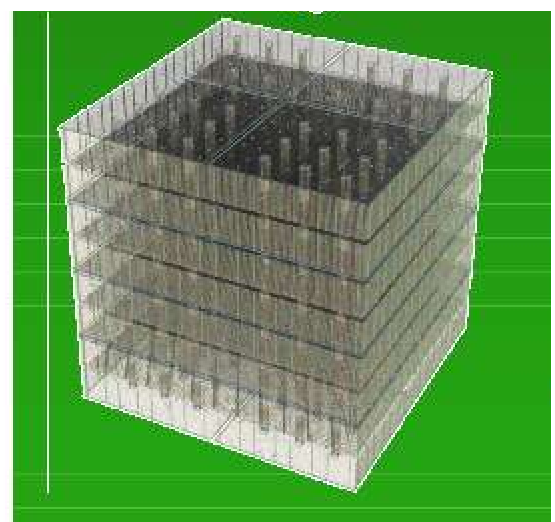
LArTPC: Modularized drift regions in one large (10-50kton) tank (un-evacuated)



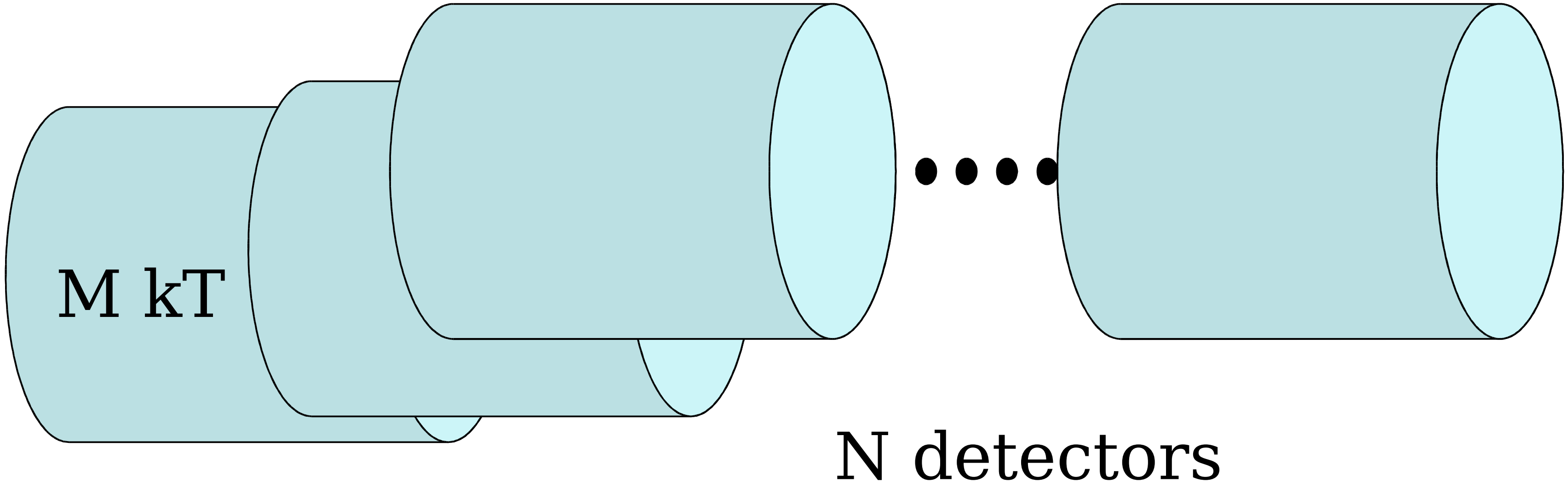


GLACIER: Combination of charge and light collection, single large drift area

LAANDD: single module cubic evacuated vessel



Modularized Option



$M \times N = 100$

$100 > M > 5$

$1 < N < 20$

Optimize M & N against cost, schedule, technical feasibility, and safety

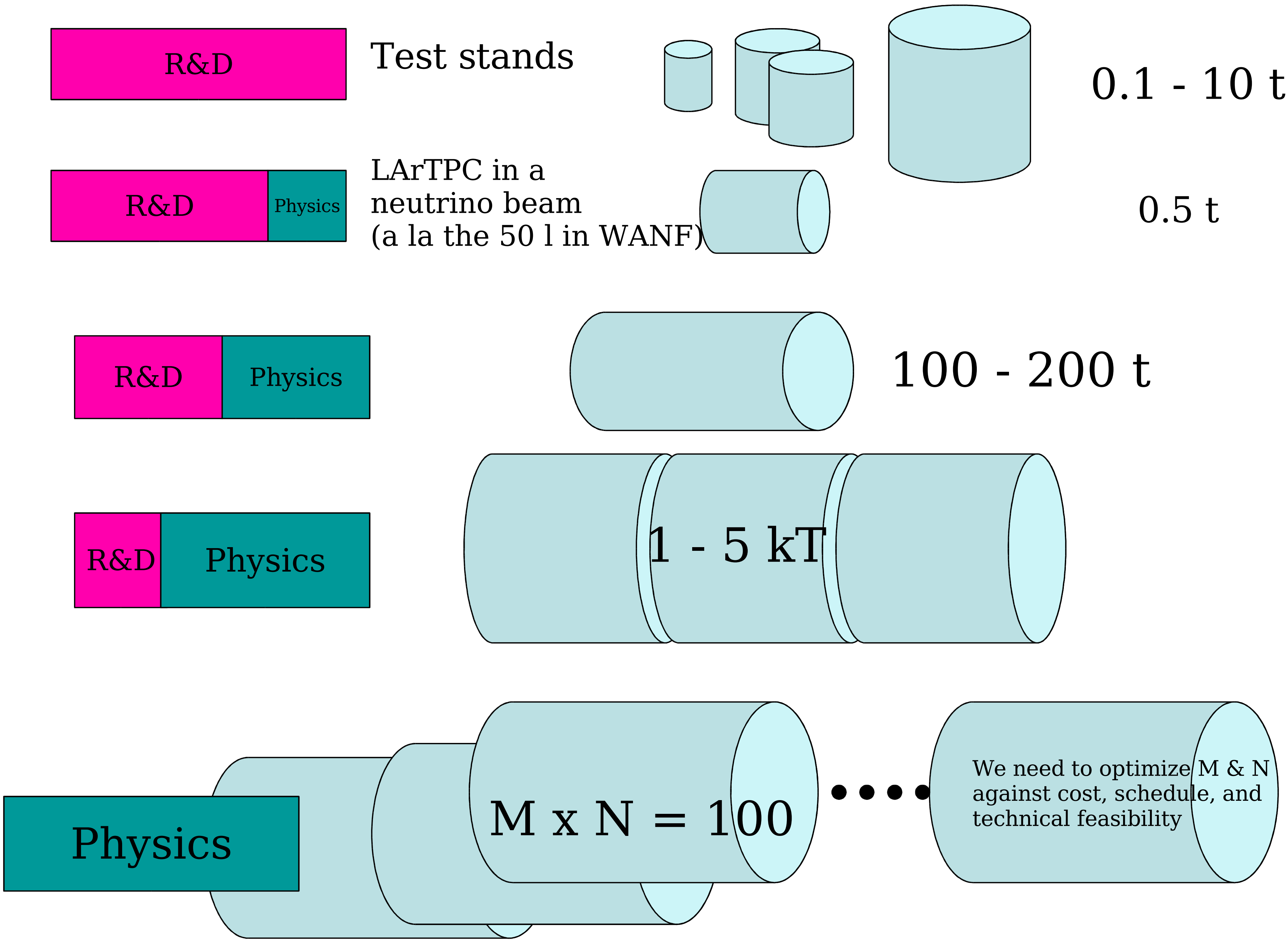
R&D for massive detectors:

- 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

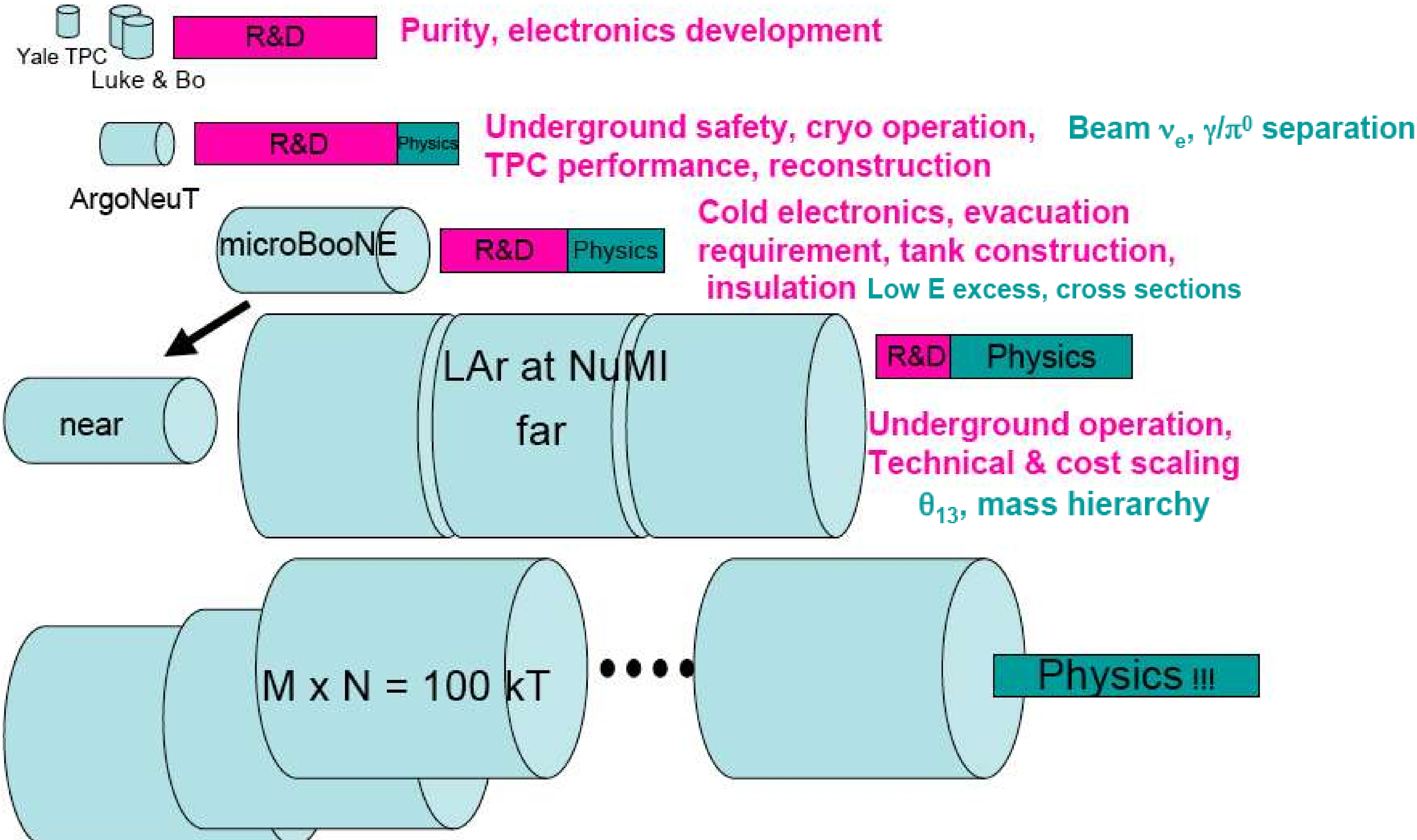
Need a staged program for LArTPC detectors

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

Evolution of a Liquid Argon Physics Program

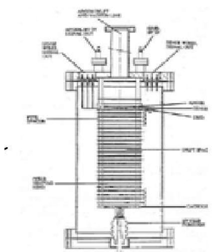


Evolution of the Liquid Argon Physics Program in the US



Similar evolution in European program

Test Stands →

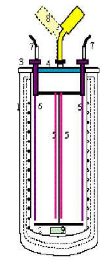


24 cm drift wires chamber

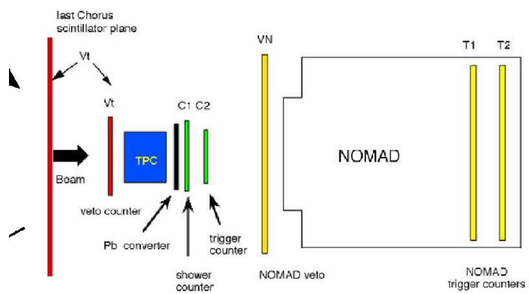
1987: First LAr TPC. Proof of principle. Measurements of TPC performances.

3 ton prototype

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

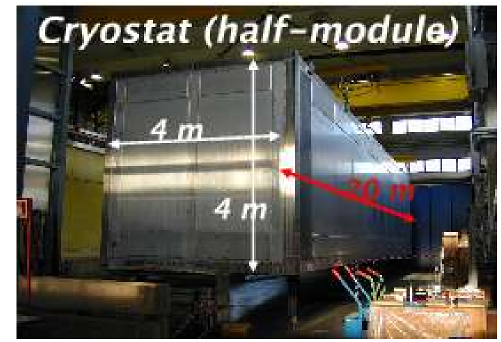


Seeing neutrino Interactions →



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.

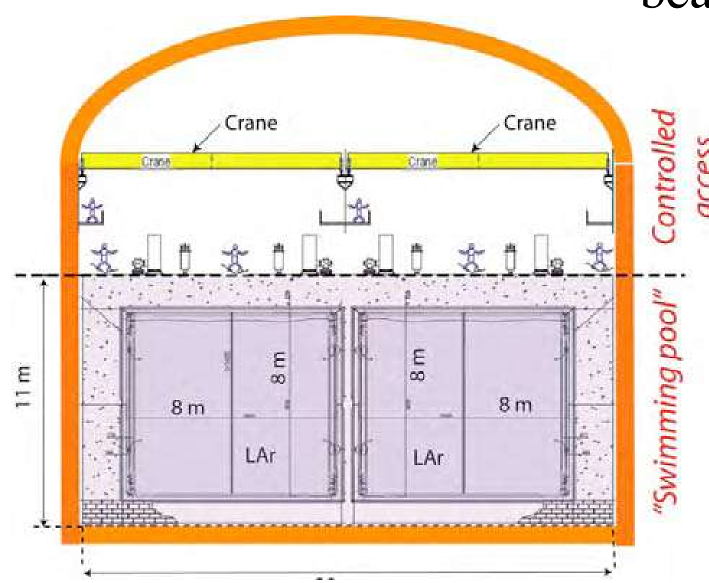


T600: data in '08
~2000 evts/yr, 17 GeV CNGS beam

Towards massive detectors →

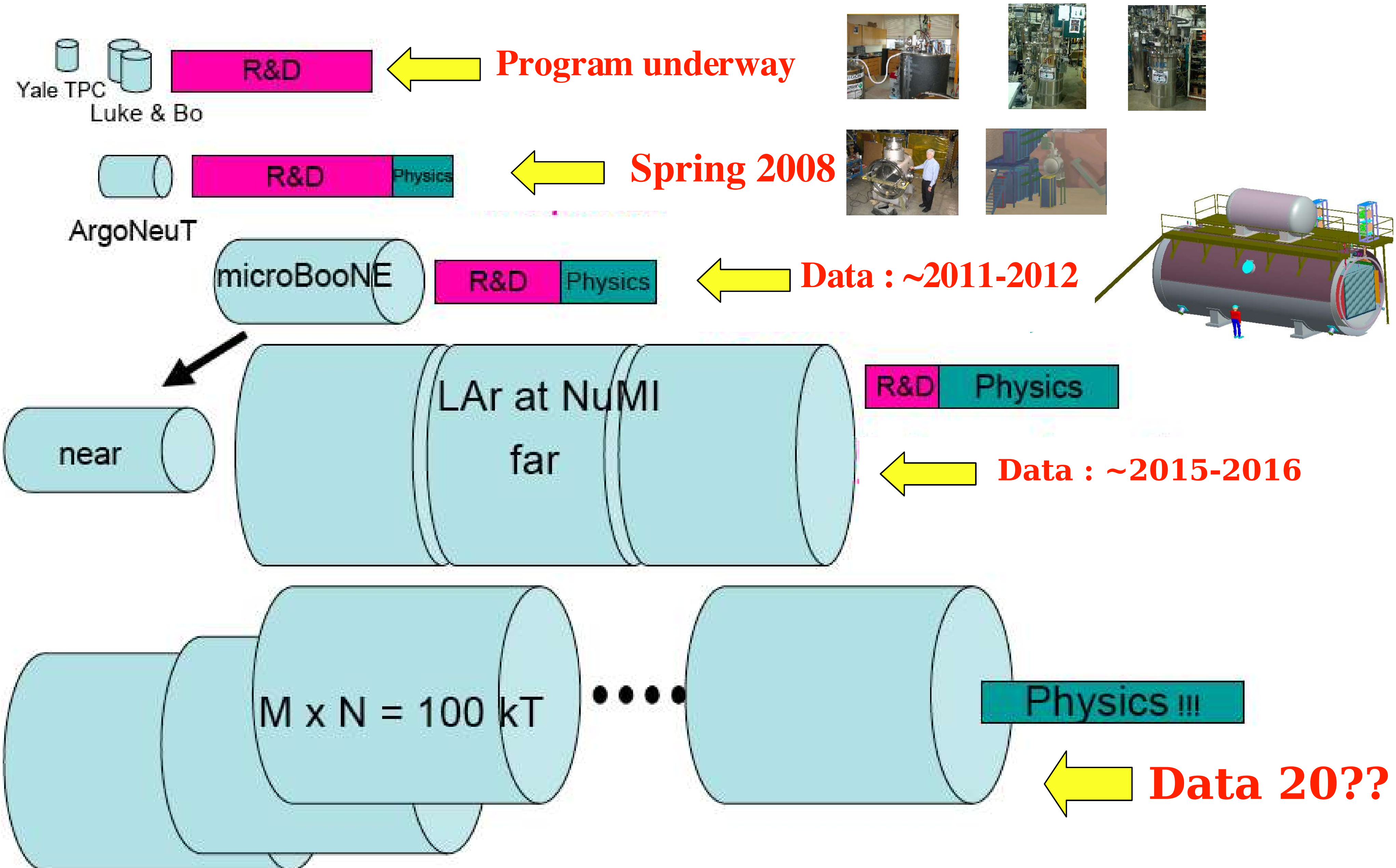
SLICE:
slice of MODULAr

- 600 ton LArTPC
- low energy ν interactions
- prototype for MODULAr



MODULAr:
5kton modules

Evolution of the Liquid Argon Physics Program



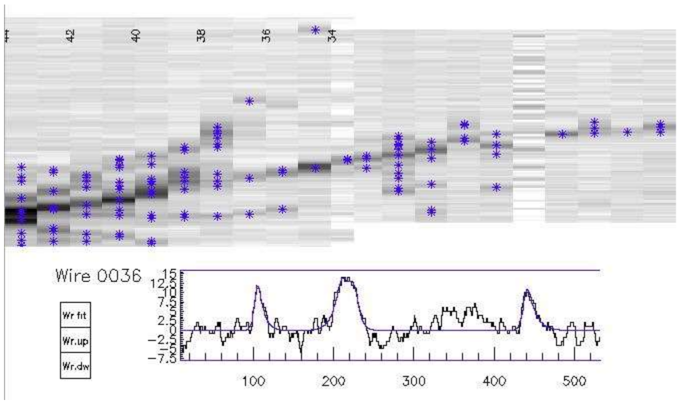
R&D

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



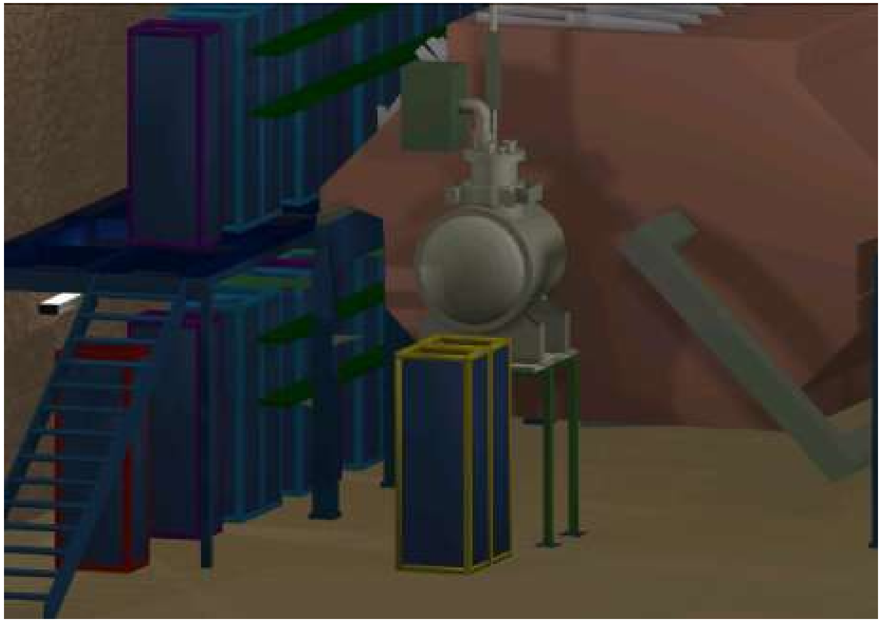
Materials Test Stand
Electronics Test Stand
at Fermilab

R&D | Physics

ArgoNeuT (Spring 2008)

0.3 ton active volume

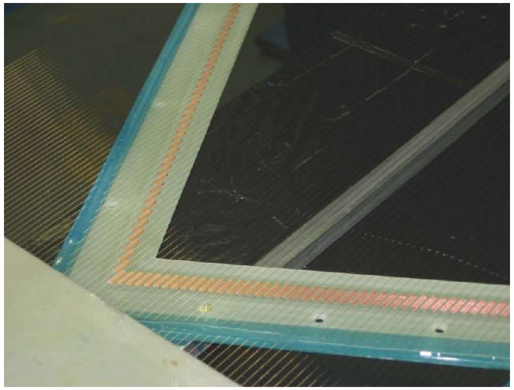
0.5 x 0.5 x 1.0 m^3 TPC; 500 channels



- 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

Wire chamber plane



Joint NSF/DOE project

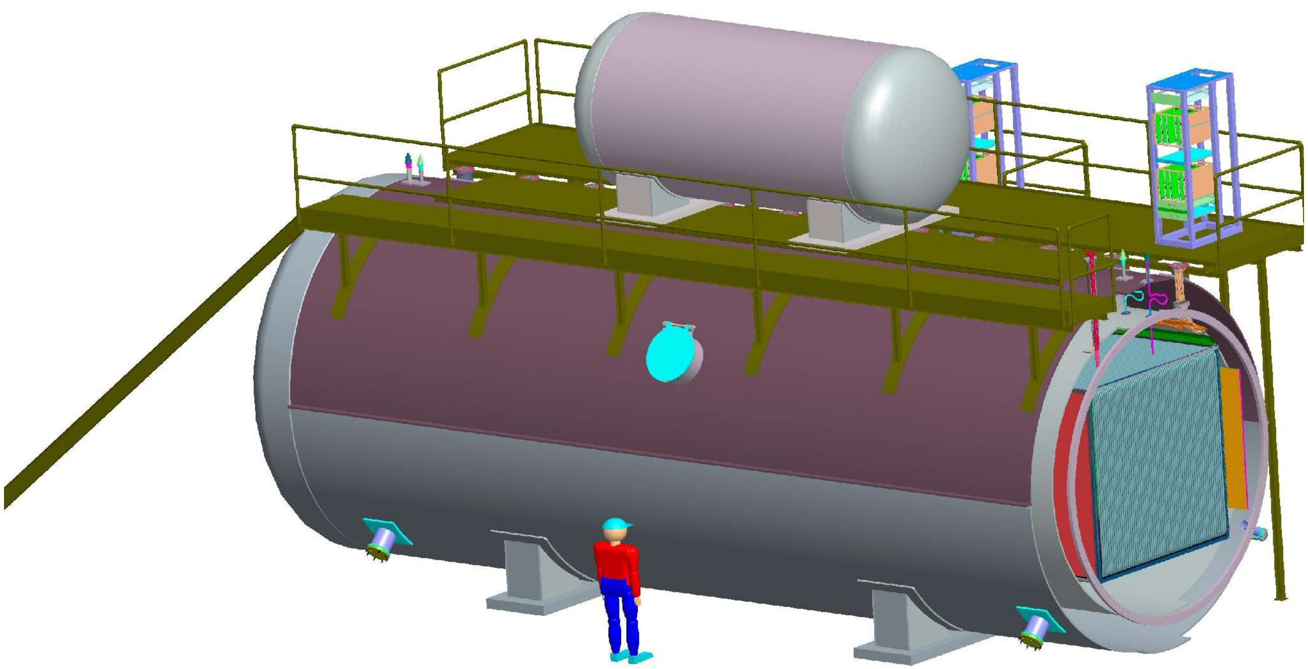
R&D | Physics

MicroBooNE: Full scale experiment physics results with a LArTPC detector

- Purity in a non-evacuated vessel
- Full systems test of low noise electronics
- Light Detection: data reduction, triggering
- Physics Development
  - See fully contained n interactions
  - Simulation, reconstruction, analysis
  - Study surface running issues (cosmics)
- TPC and Vessel Design
- Value engineering

- Low energy neutrino interactions
  - Resolve MiniBooNE low energy excess
  - Measure neutrino cross sections
  - Measure kinematics for PD signals

Collect:
- BNB: 100K n events
- NuMI: 60K n events

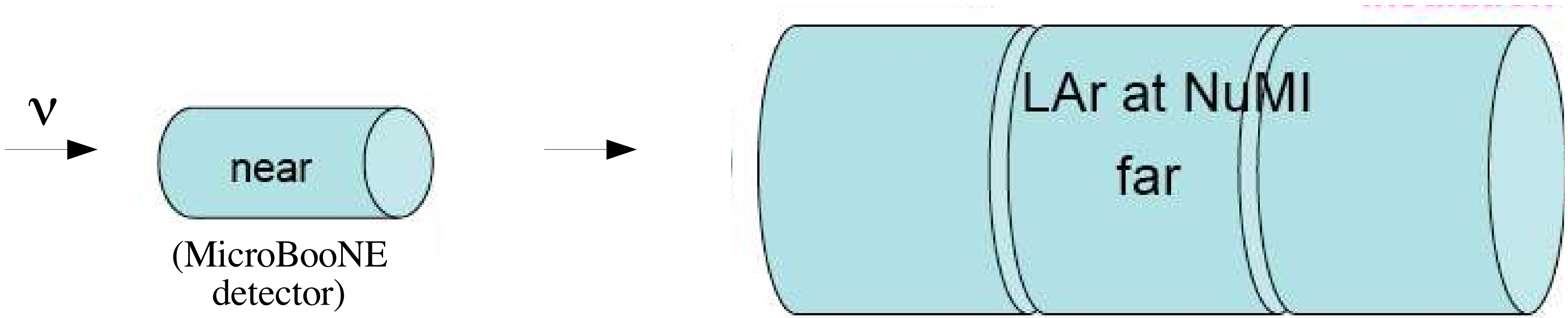


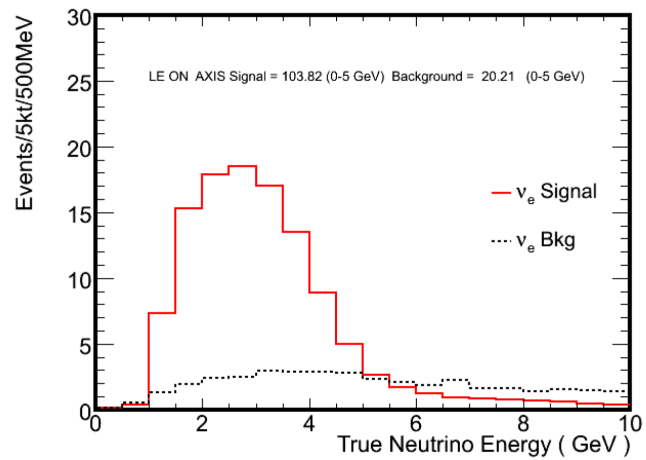
Cost: <16 M
(6M materials)
(35% cont;
25% G&A)

Schedule:
Construction: 2009
Data taking: 2011

R&D | Physics

LAr5: 5kton LarTPC

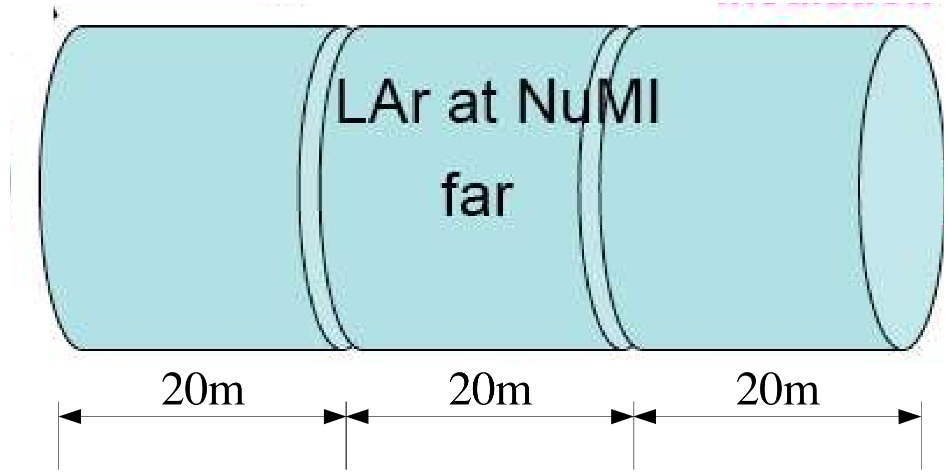


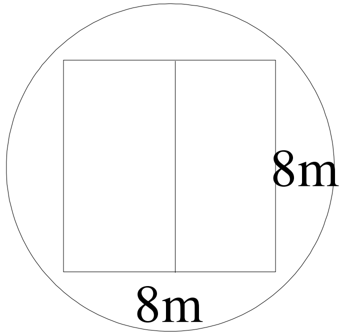


On-axis ν beam

Concept developed for operation Soudan (2000 ft)
Ideas for DUSEL at 300ft and/or 4850 ft

Lar5:
5kton LarTPC
Design





2-4 m
drift regions

R&D:

- Issues related to underground siting
- Value engineering
- Cost reduction from scaling

Features of Modularization:

- Stageability: Cost and Schedule
- Cavern geometry
  - Aligned along beam direction
  - Shape amenable to mining techniques
- Safety (LAr single volume loss)

General underground siting issues:

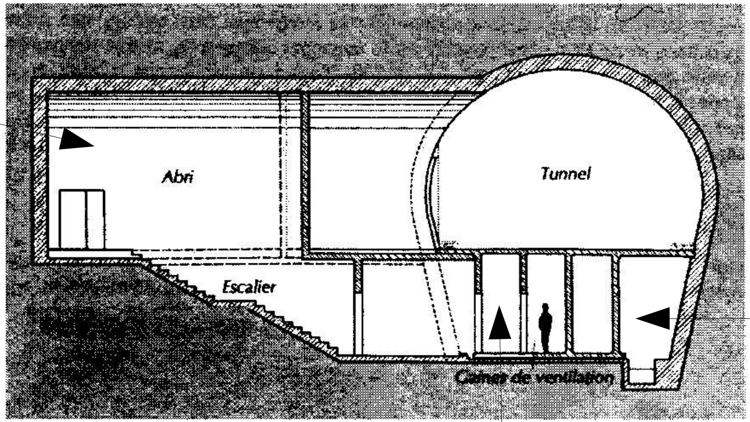
LAr loss: 0_2 content, reduction of temperature

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

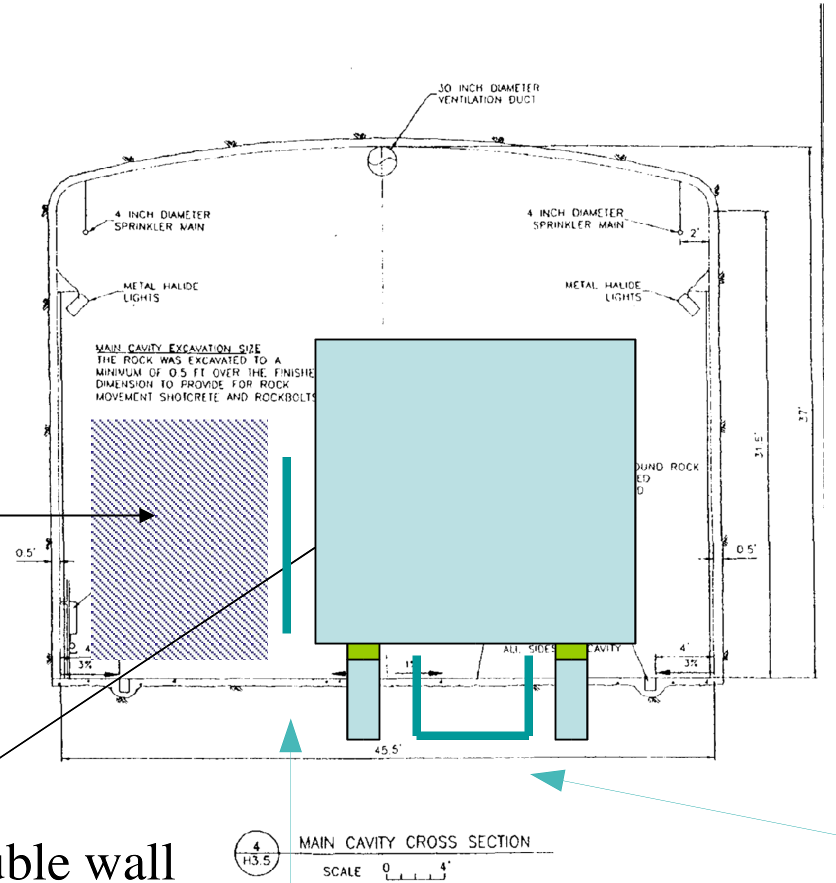
Ventilation ducts

Smoke extraction

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

LAr5 at Soudan:

MINOS cavern cross section



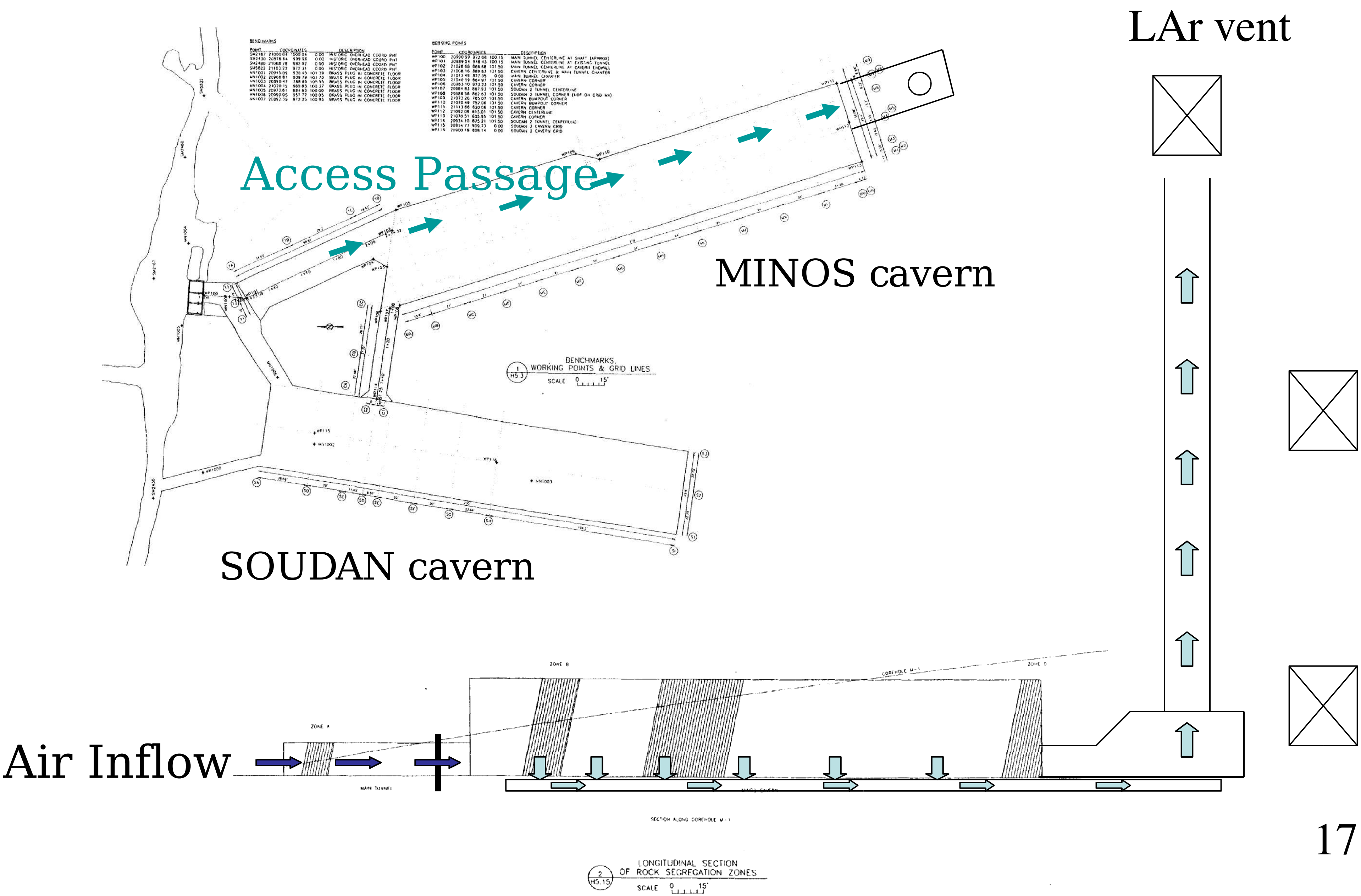
Access Passage
For Construction
and Egress

Commercial LNG Tank "double wall
metal storage tank"
thermal insulation/vibration isolation..
Future blasting, etc.

Collection trench..
Channel liquid gas towards
Vent Shaft

Containment barrier..
Give people more
Time to leave

LAr5 at Soudan: Underground siting and safety egress/venting



Lar5 at Soudan: Cost and Schedule

Detector: 30-60M
Underground costs: 15M
(vent. Shaft 6M)

Total: <100M

Preliminary so contingency added!

Based on conservative ranges of costs

Task	per unit estimate
Liquid Argon procurement & delivery	\$1 Million per kiloton
Cryogenic Tank fabrication	\$3.75 M + 0.4M/kiloton
Cryogenic Tank Roof customizing	$\$4500/m^2$
Purification and Cryo System fabrication	\$4M
TPC and Cathode System	\$50K/panel
Electronics, Data Acquisition and Slow Control	\$200K + \$50/channel
Cables in and out of cryostat	\$50/channel
Photmultiplier Tubes and Readout	\$7.5K/pmt
Detector Installation and Integration	\$200K/month
Engineering and Engineering Support	\$150K per person-year

LOI for LAr5

R&D program:
- -electronics design
- -un-evacuated vessel tests
- -underground siting issues

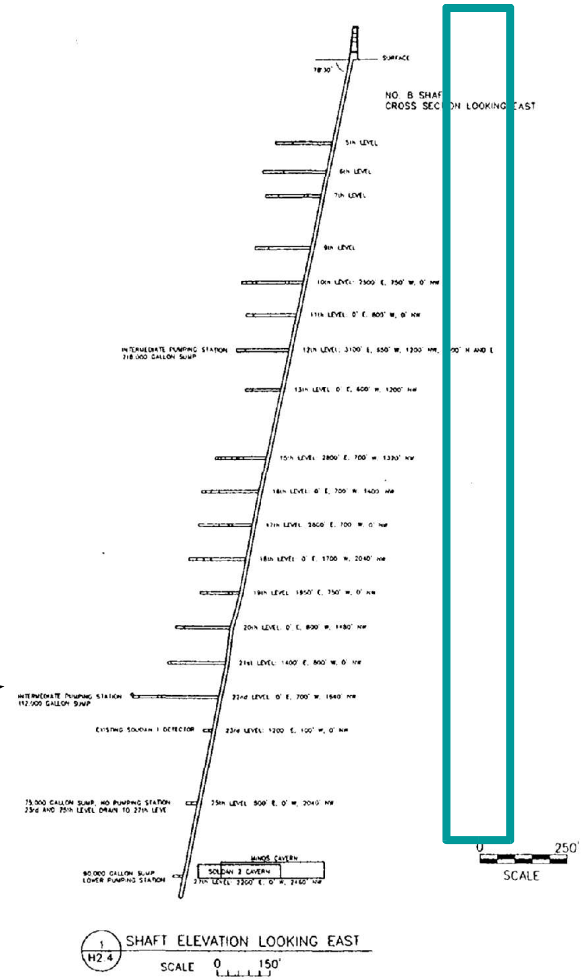
Learn from test stands and MicroBooNE

Experiment turn on ~2015, provided push on R&D

LAr at Homestake

- 300 foot overburden drive in location
  - likely much easier in terms of safety
  - space for modularized massive total volumes
  - compromise proton decay physics (effective mass reduced to ~ ½ total mass)

- 4850 ft location
  - Davis cavern will hold only ~1kton LAr
  - dedicated ventilation shaft needed
  - effective mass for proton decay physics: near total mass



Soudan $\Leftrightarrow$ Homestake

- Underground siting issues
  - Both are hard rock mines
  - Airflow, rock temp are a little different
  - Concepts for underground siting shared
  - Soudan has existing large cavern

  } Focus of this talk

- Beam delivery schedule

- Upgradeability for the future

- Physics Potential *(work in progress)*

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
Univversity 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

Summary:
LArTPCs are great detectors with unique capabilities
for ν_e appearance physics

To address technical feasibility on appropriate timescales...

Need to pursue an aggressive R&D program
in a timely way

↓

stageable program of R&D and physics
~20M over the next 3-4 years...
investment for long term neutrino program!