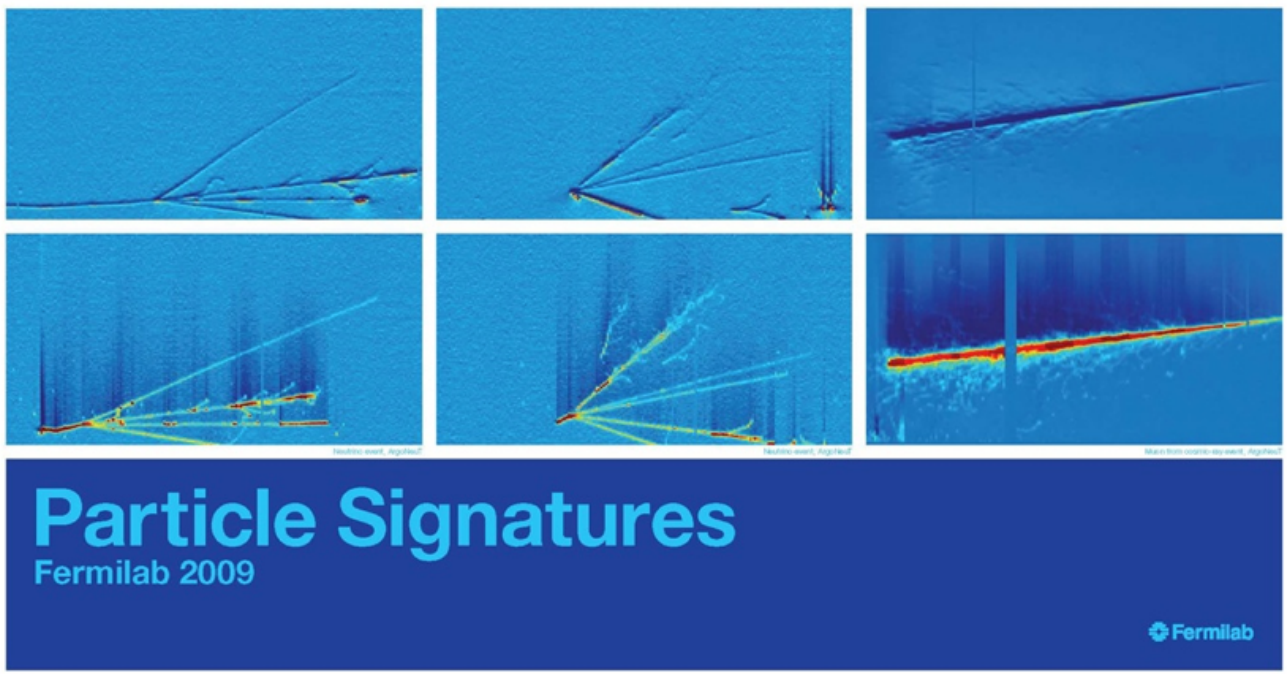
Bonnie Fleming
Intensity Frontier Workshop
November 30-December 2, 2011

US Plans towards a Large Liquid Argon Detector for LBNE



LArTPCs are ideal detectors for electron neutrino appearance and host a broad program of physics beyond this

- High efficiency for signal events
- Excellent background rejection
- Capability to use CC inclusive sample

Wide band beam approach works best with LArTPCs

- Additional physics augment this program: Proton decay, Supernova searches

Conceptual Design for LArTPCs for underground physics is based on extensive **Engineering Development** program

Experience designing, building, operating, and analyzing neutrino data from these detectors most recently from ICARUS and ArgoNeuT

Led to well advanced Conceptual Design for LAr40

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Current LBNE LAr Inputs

From LAr case study

channel	range	value chosen for LBNE sensitivities
ν_e CC efficiency	80-95%	80%
ν_μ NC π^0 surviving fraction	0.2-0.5%	1%
ν_μ CC mis-identification rate	0-0.3%	1%
other channels	0%	0%
electron energy resolution	$3\%/\sqrt{E(GeV)}$	$15\%/\sqrt{E(GeV)}$
muon energy resolution	$10-20\%/\sqrt{E(GeV)}$	$20\%/\sqrt{E(GeV)}$ (for E_ν)

Table 4–3: Estimated or measured range of efficiencies, backgrounds, and resolutions from the studies described above (middle column) and the value chosen for the LBNE neutrino oscillation sensitivity calculations described in Section 5.2 (last column).

Jen Raaf

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Information from several sources:

	Average ν energy	# events	ν_e efficiency
Tufts Hand Scan (2006)	1.5-4.5 GeV (E_{vis}) NuMI ME off-axis beam	450	81%
FNAL Hand Scan (2009)	NuMI ME off-axis beam E_ν < 3.5 GeV	4997	95.5%
T2K 2km proposal (2005)	250 MeV, 500 MeV, 2 GeV	1000 CC ν_e 1000 NC π^0	90%

Note: 2km analysis was more sophisticated, using dE/dx information, PID, and event topology with a neural net folded in with hand scan results.

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ν_μ CC mis-i		
other chann		
electron ene		)
muon energ		or E_ν)

New hand scan using standard LBNE LAr tools
LArSoft simulation and reconstruction
Underway now

First results confirm assumptions used here

Informatio

					ν_μ CC mis-ID fraction
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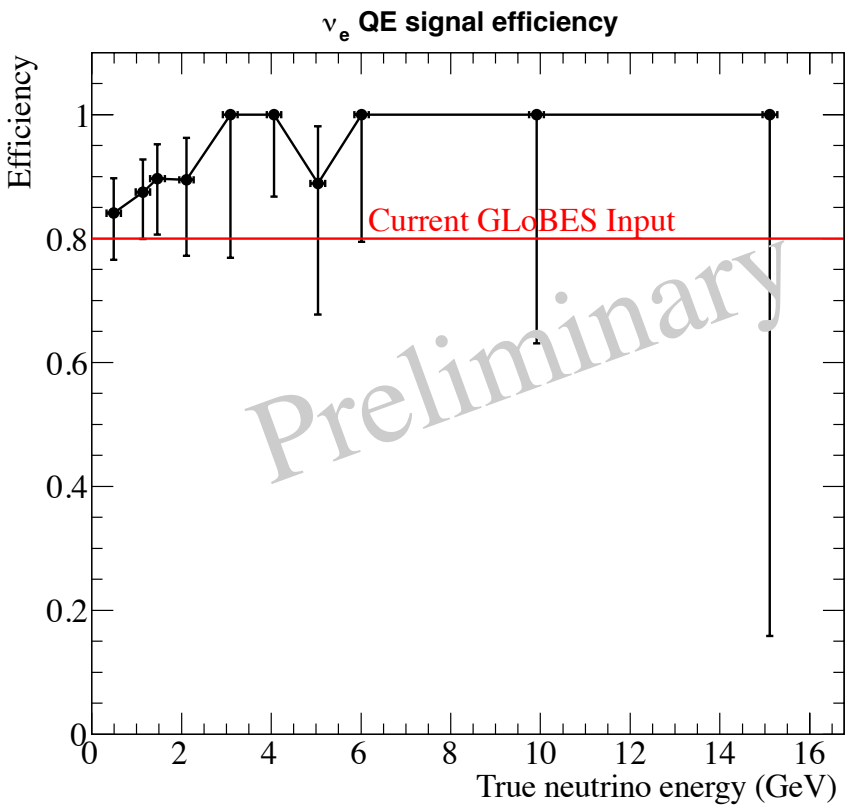
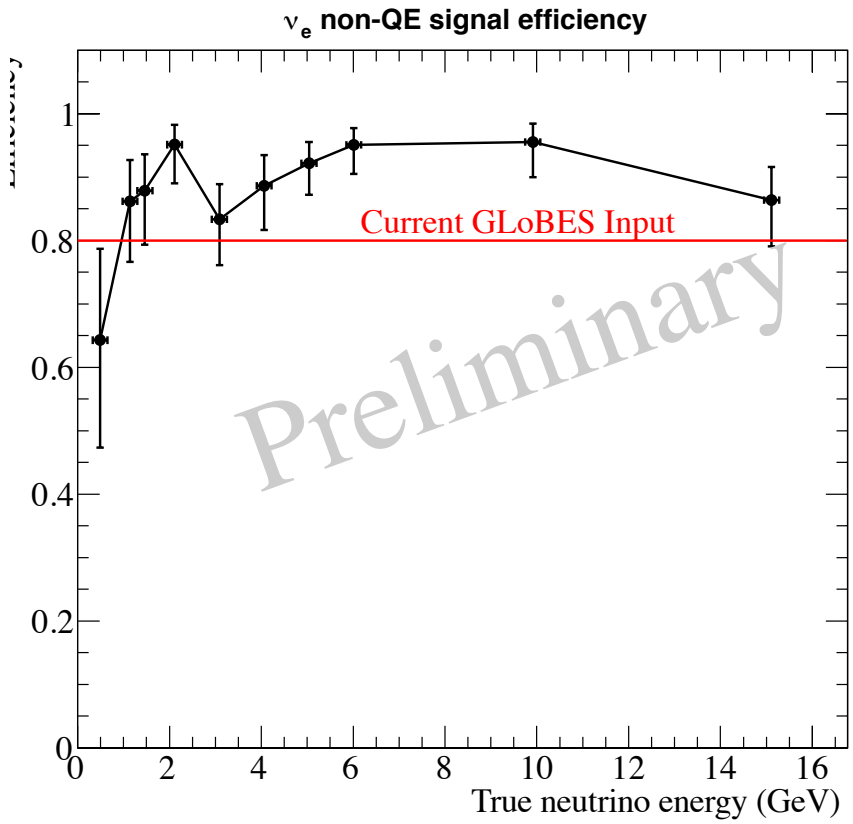
Jen Raaf

For example: Preliminary results of efficiency vs energy from simulated LArTPC events in an LArTPC using LArSoft tools

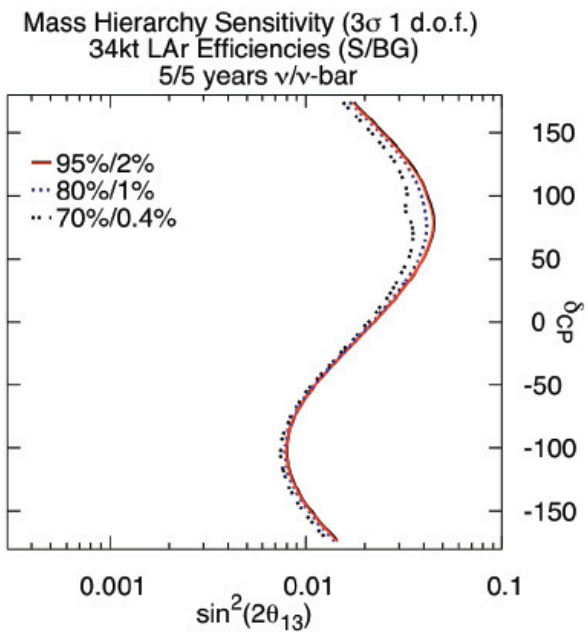


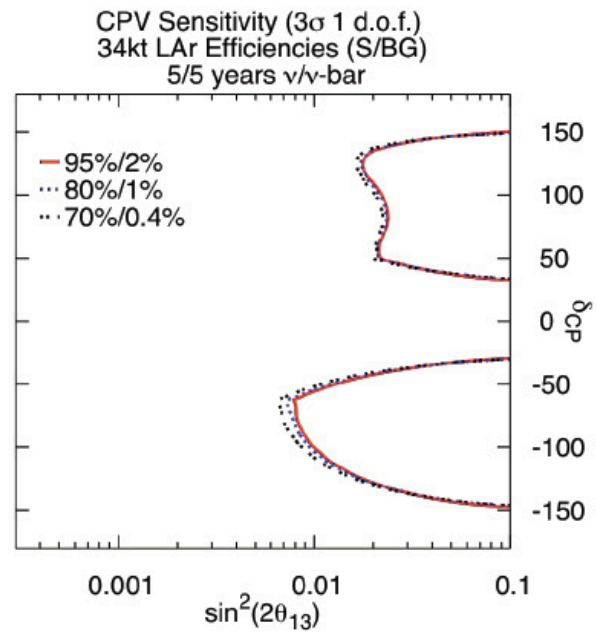


Oscillation Sensitivity

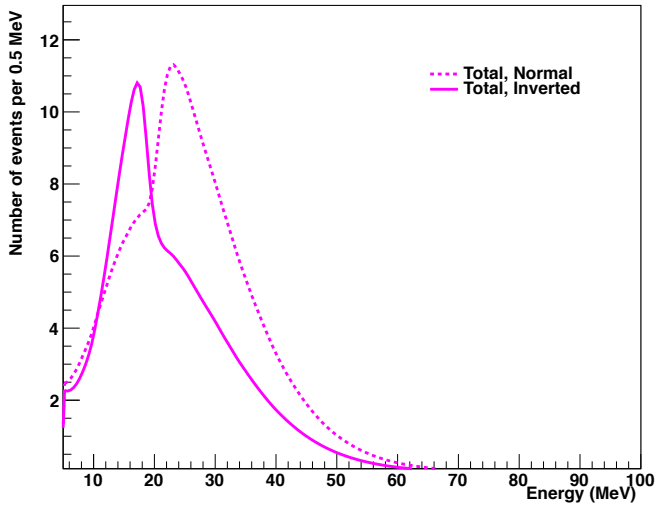
Development of fully automated simulation and reconstruction has been significant in the last couple of years but is still evolving

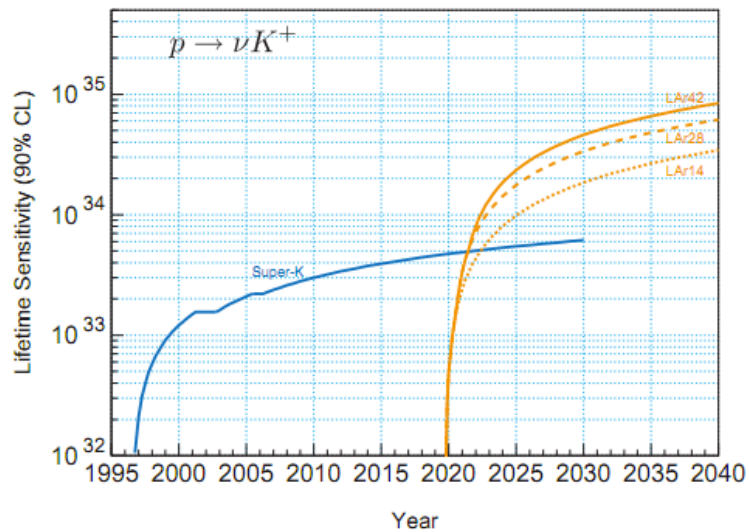
Conservative estimates of detector performance have been used to determine sensitivity to oscillation physics





SuperNova Sensitivity and Proton Decay



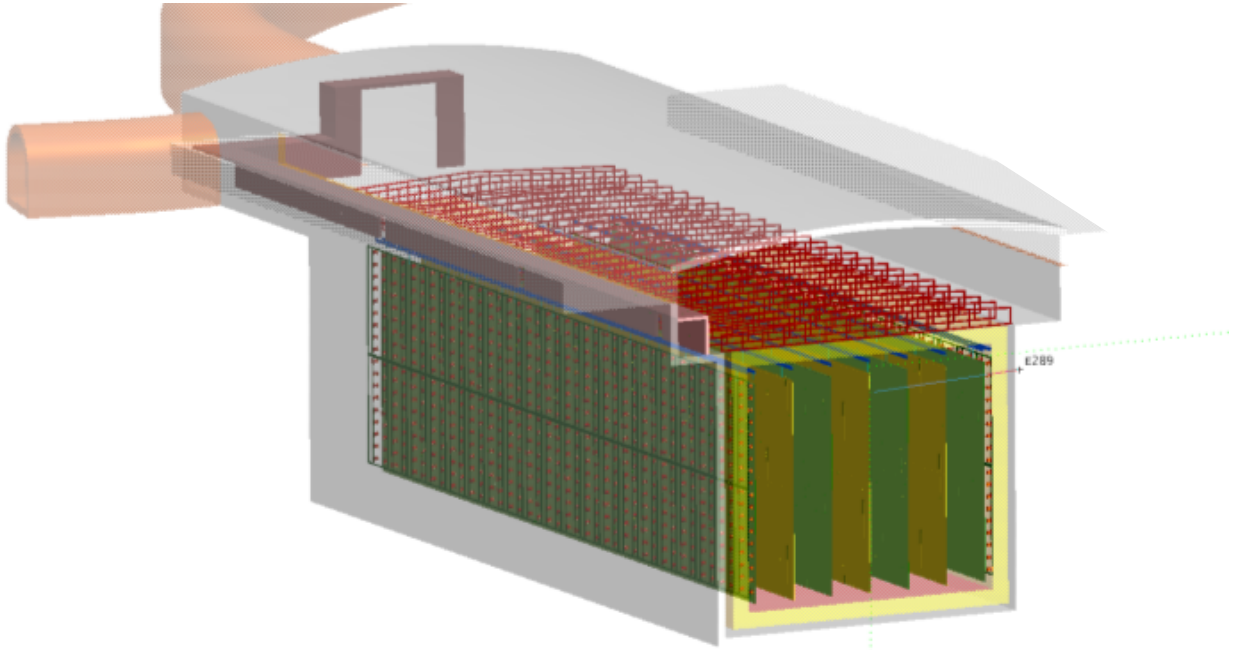


LArTPCs are electron neutrino filter

Unique signature tags hierarchy, for example, for one particular time slice

LArTPC efficient in detecting proton decay in νK mode (and others)
Many other modes to explore!

Technical Design



Well advanced design for underground or near surface operation

While this technology is challenging….

Detector design is beyond R&D with experience designing, fabricating, and operating detectors – **Development program** towards LAr40 underway

Integrated Development Activities

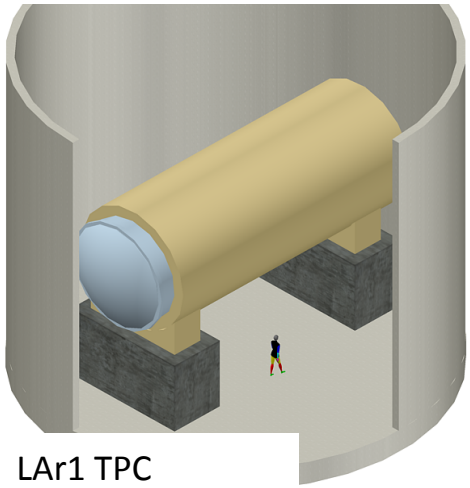
Jon Urheim

ArgoNeuT

FNAL Test Stands

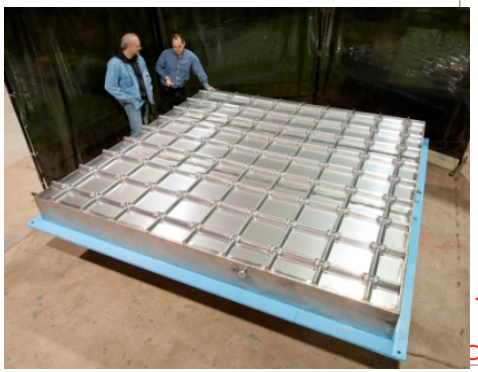
LAr Purity Demonstrator

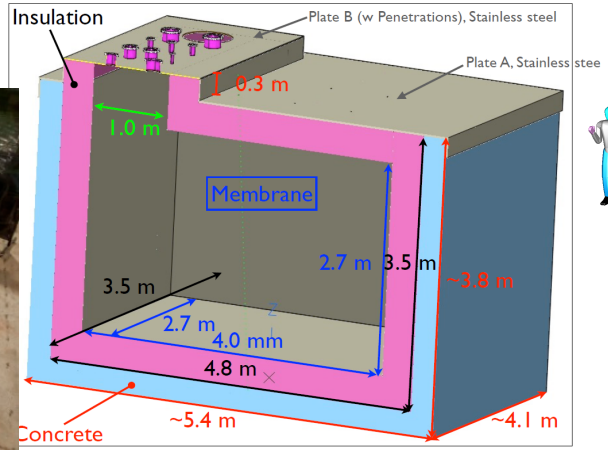
MicroBooNE (2013)



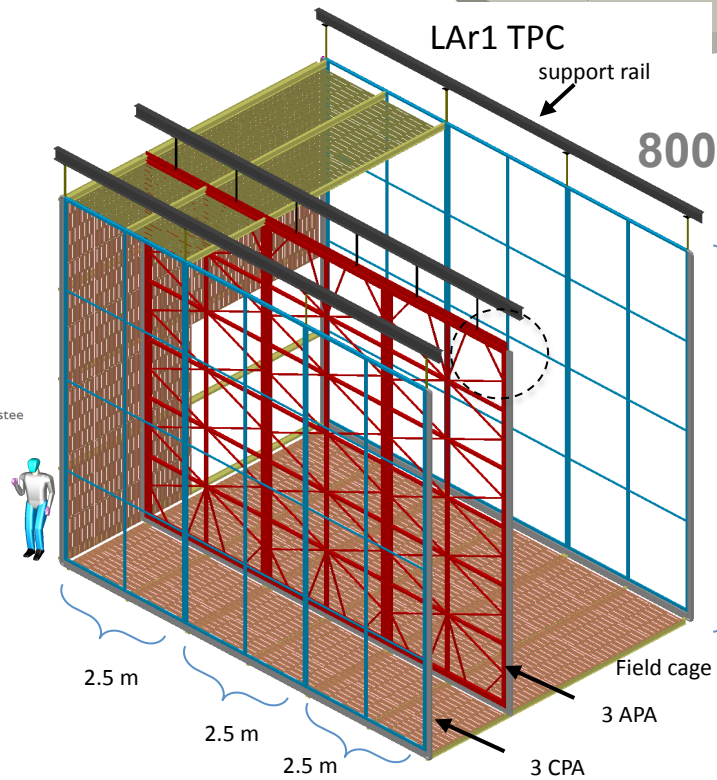
35t Membrane Cryostat (2012)

Membrane Wall





800t TPC (2014)



LAr Purity Demonstrator

- LAPD has now run its liquid through the filters and continues to take data
- Now measuring lifetimes > 5 ms after 8 volume exchanges, and still rising (1.4 ms is needed for the LBNE drift)
- Next goal: Maintain 5ms purity for several weeks

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- Additional physics augment this program: Proton decay, Supernova searches

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Led to well advanced Conceptual Design for LAr40

- LArTPC for ν-Experiments:

- ICARUS 50 lt: 1997-98 @ WANF (CERN) - [small LAr-TPC]
  Status: *run completed*
  (data analysis published in 2005- Icarus-Mi U. Collab)

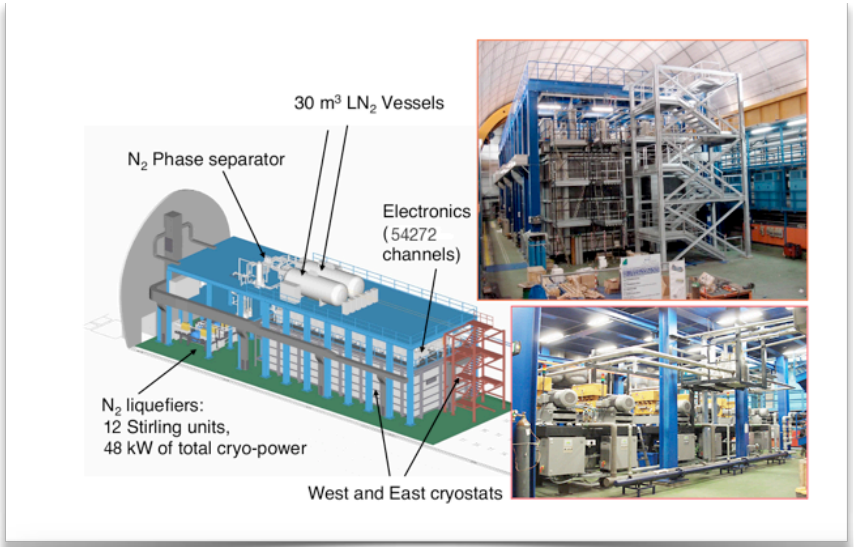
- ICARUS T600: ≥ 2010 @ CNGS (LNGS) - [first large LAr-TPC]
  Design Study &Tech. Proposal 1995-96
  Detector construction 1997-2001
  Test on surface (T300 unit): May-Aug 2001
  Transportation to LNGS: Nov.'04-Jan'05
  Status: *running*

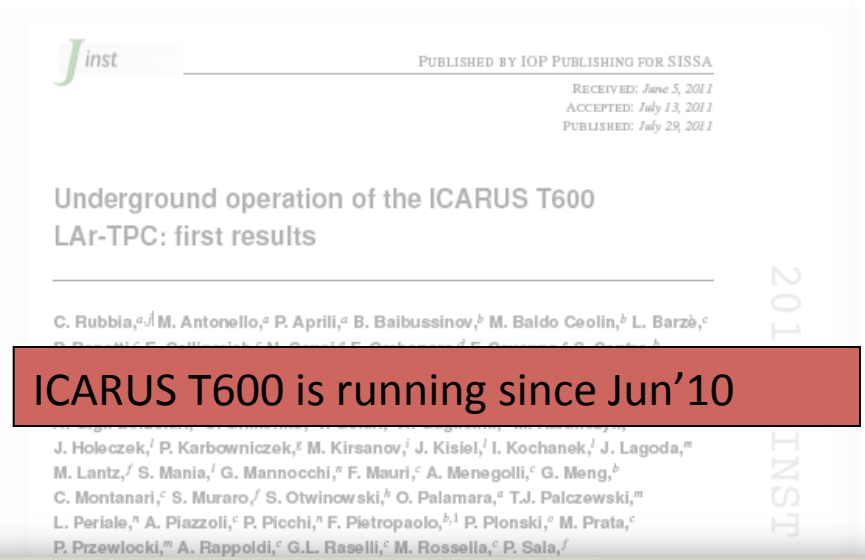
- ArgoNeuT: 2009-10 @ NuMI-LE (FNAL) - [small LAr-TPC]
  Status: *run completed*
  (publications from data analysis in progress)

F. Cavanna from SciCap Review

- ICARUS - T600

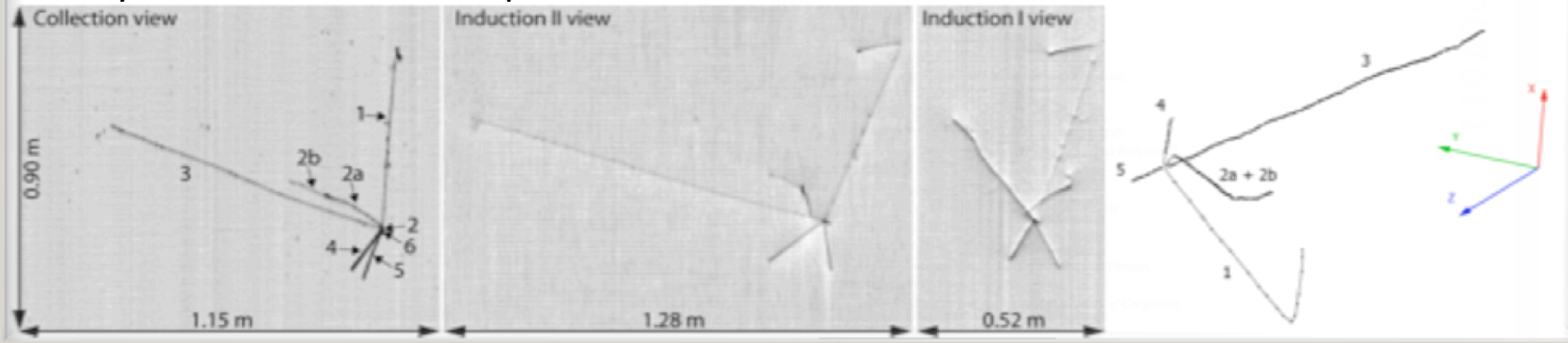
The First large LArTPC built and operated underground





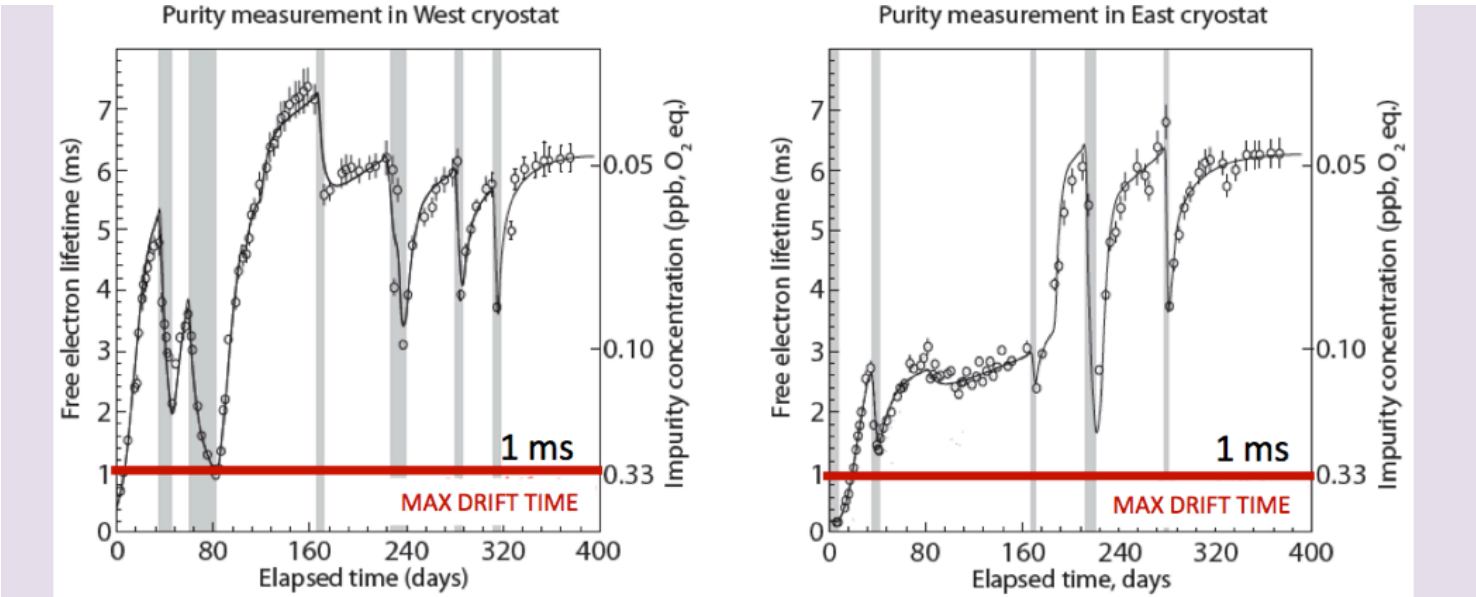
ICARUS T600 is running since Jun'10

Fully reconstructed atmospheric ν-event



Physics results (CNGS ν-beam and atm. ν) are expected soon

- ICARUS - T600: 1 kton x yr demonstration of LAr purity at 6-7 ms level

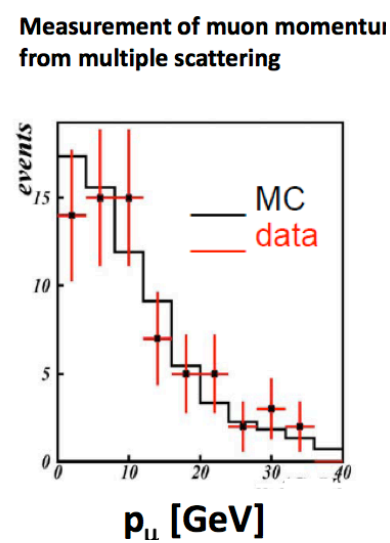


- Electronegative impurities (mainly O_2, H_2O) can attenuate e^- signal: high purity is crucial!

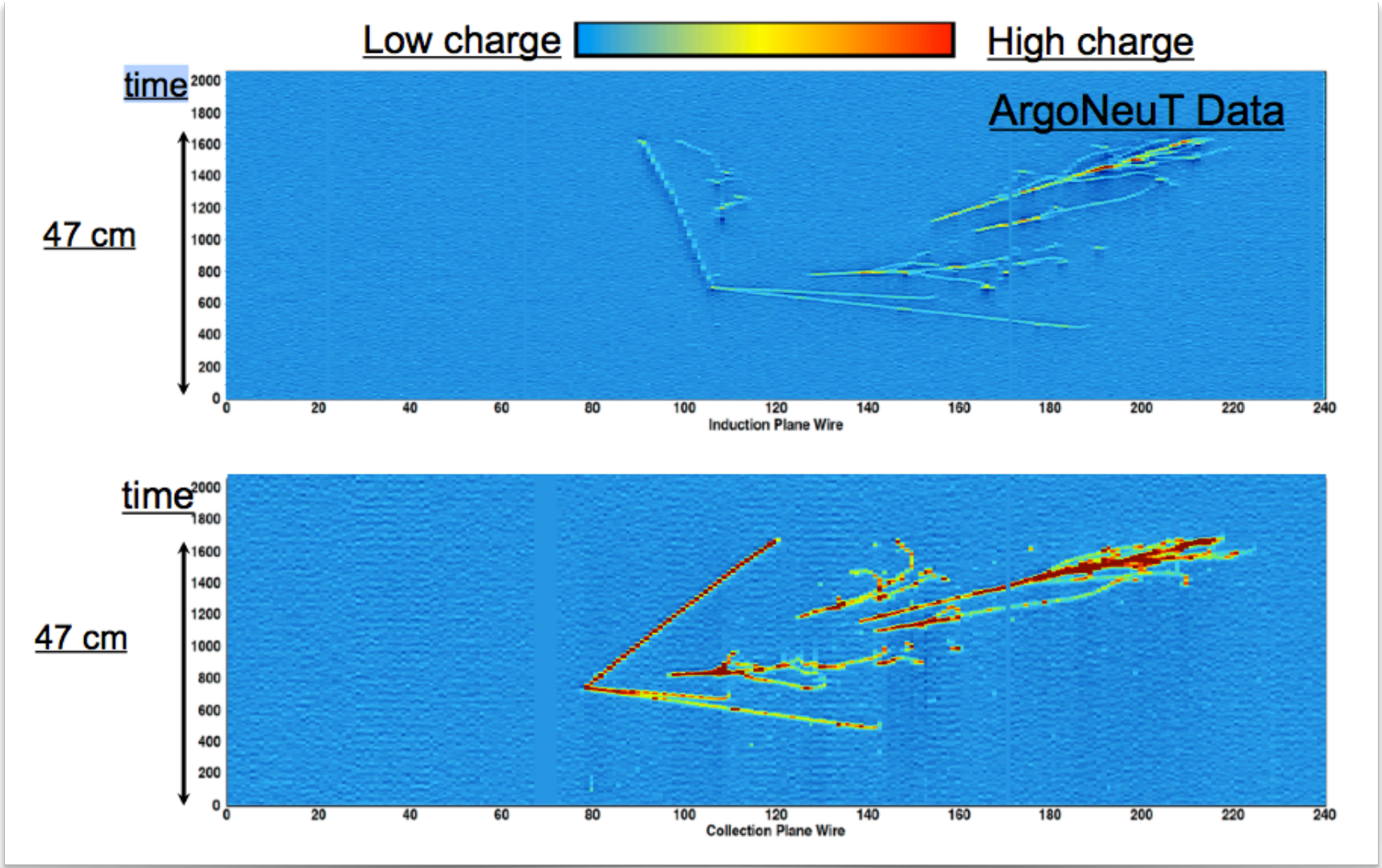
Icarus talk @ NuFact'11

Achieved and maintained good purity

Reconstructing events



ArgoNeuT: Argon Neutrino Test



unprecedented neutrino event image quality

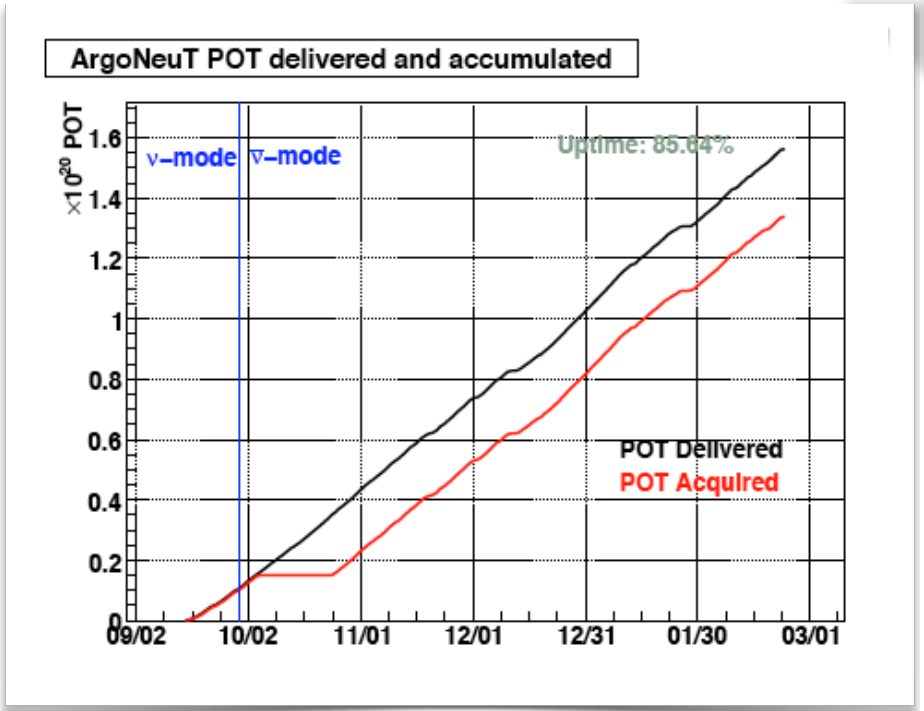
ArgoNeuT

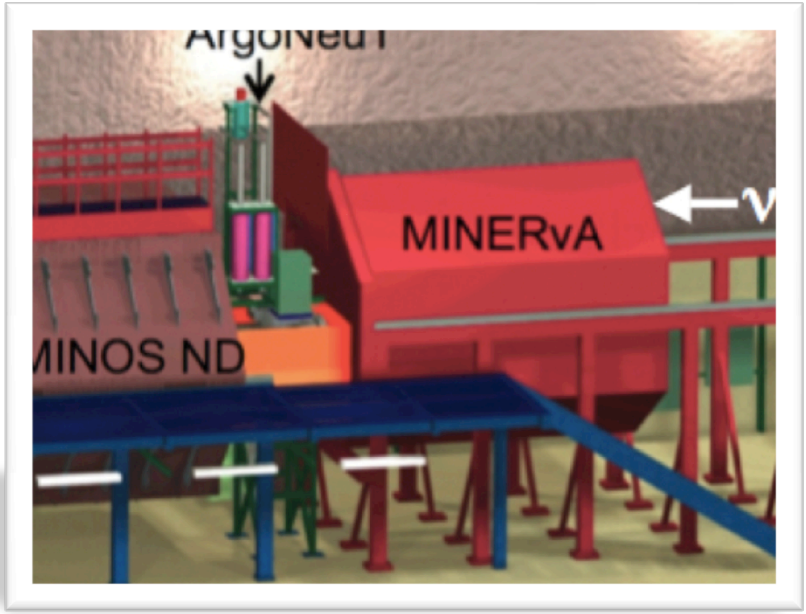
BACKED BY MINOS ND (MAGNETIZED CALORIMETER)

9 MONTHS ACTIVE (6 MONTHS PHYSICS RUN) ON NuMI BEAM LINE AT FNAL.

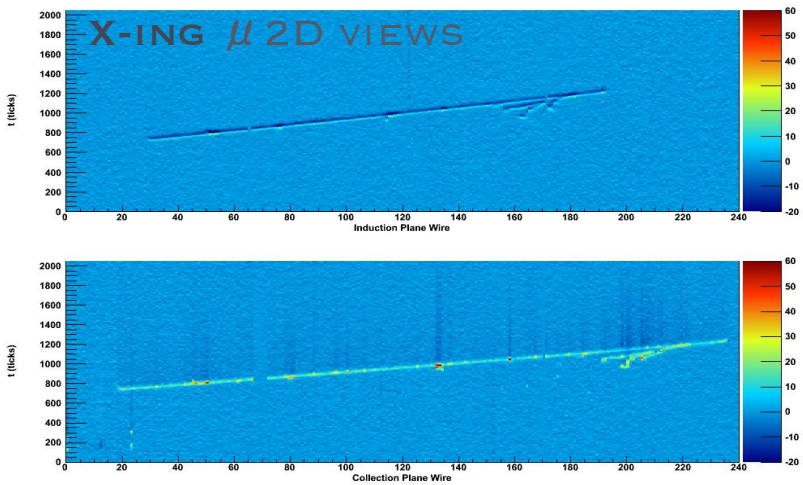
RUN OPERATIONS STABLE AND PRACTICALLY SHIFT-FREE

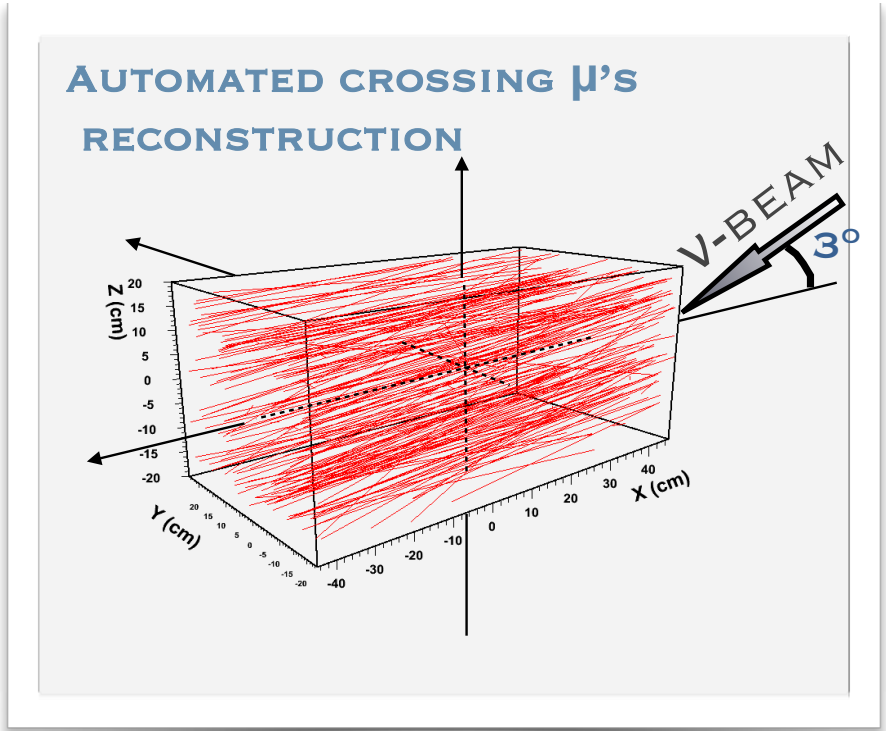
Uptime of 96% not including 2 week downtime for off-the-shelf cryocooler failure

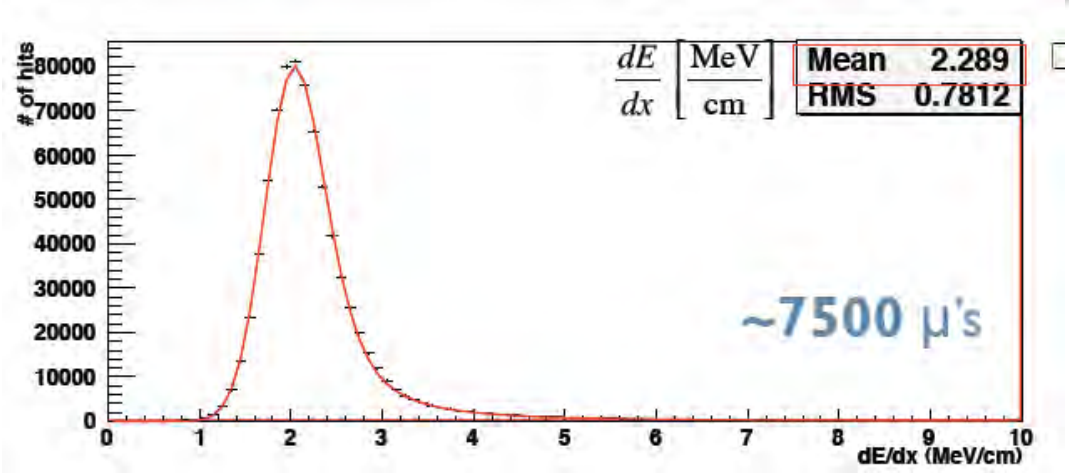


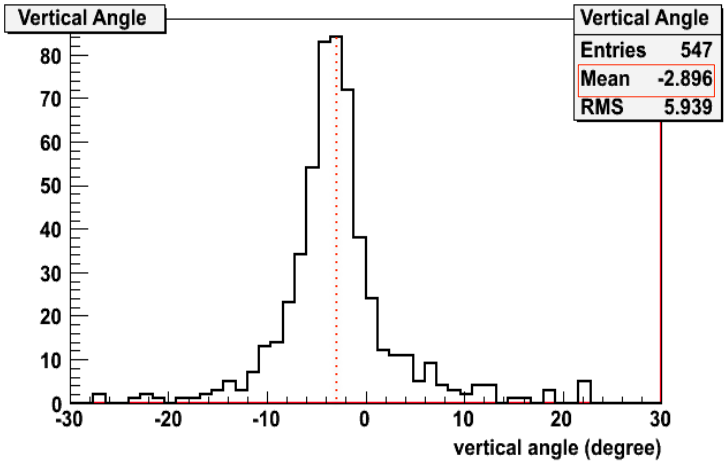


ArgoNeuT


X-ING μ 2D VIEWS
t (ticks)
Induction Plane Wire
Collection Plane Wire

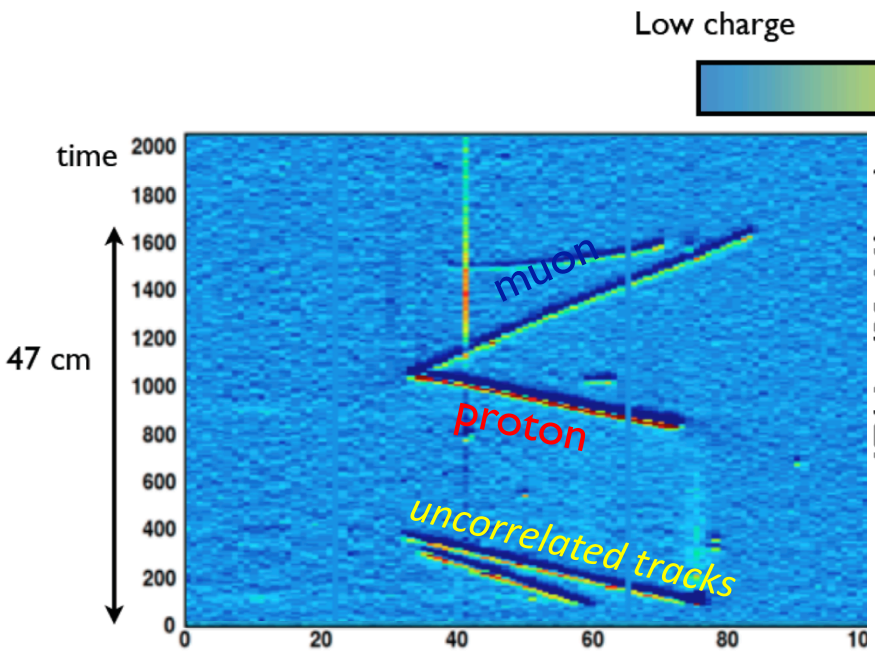

AUTOMATED CROSSING μ'S RECONSTRUCTION
V-BEAM
3°
Z (cm)
Y (cm)
X (cm)


dE/dx [MeV/cm]
Mean 2.289
RMS 0.7812
~7500 μ's
# of hits
dE/dx (MeV/cm)

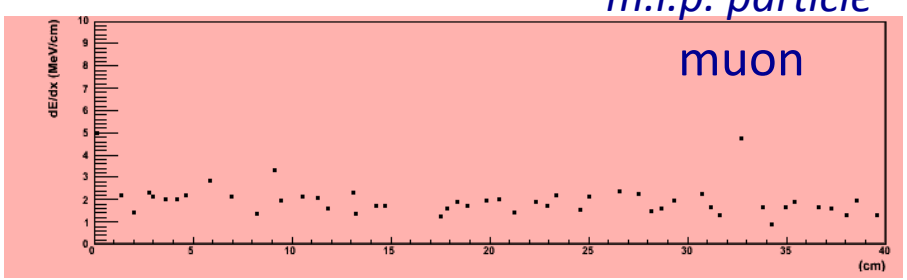

Vertical Angle
Entries 547
Mean -2.896
RMS 5.939
vertical angle (degree)

ArgoNeuT

CC-QE EVENT $\nu_\mu + \mathrm{n} \rightarrow \mu^- + \mathrm{p}$

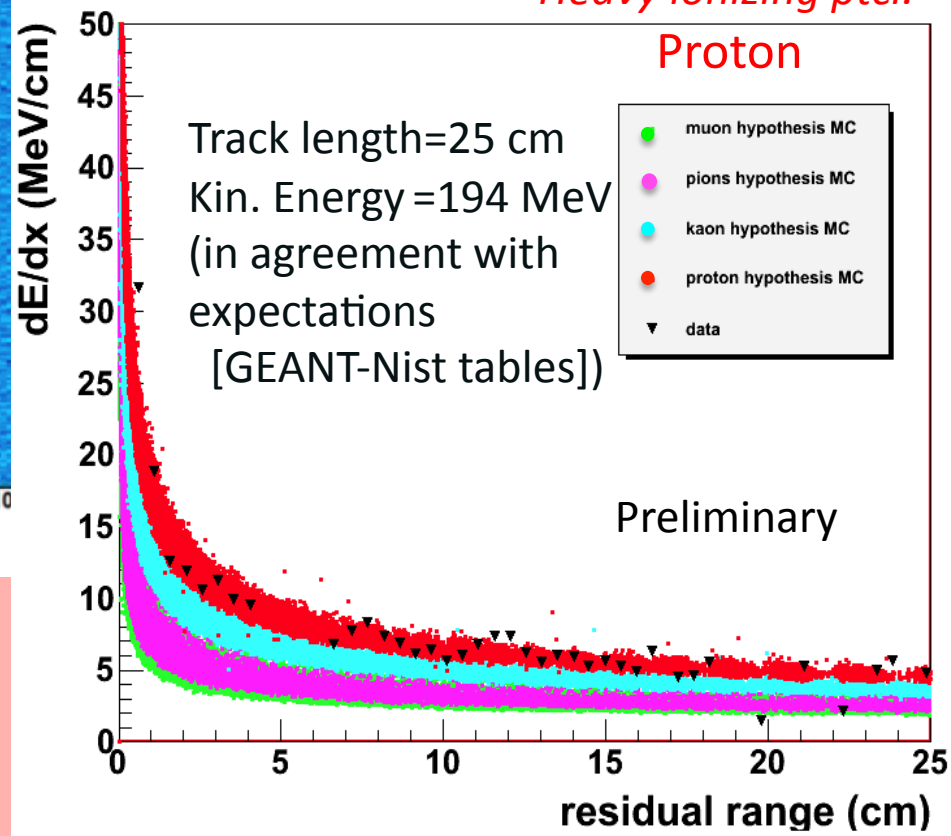


m.i.p. particle



dE/dx along the track ~ 2 MeV/cm

Heavy ionizing ptcl.



ArgoNeuT

ν_μ CC-Inclusive Cross Sections

arXiv:1111.0103v1 [hep-ex] 1 Nov 2011

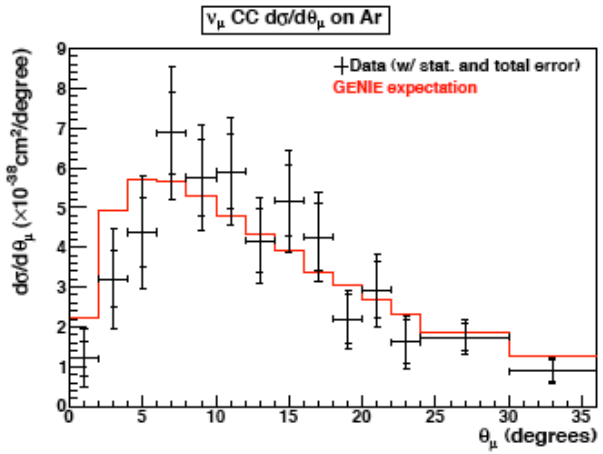


FIG. 2: The ν_μ CC differential cross section (per argon nucleus) in muon angle.

First Measurements of Inclusive Muon Neutrino Charged Current Differential Cross Sections on Argon

C. Anderson,[1] M. Antonello,[2] B. Baller,[3] T. Bolton,[4] C. Bromberg,[5] F. Cavanna,[6] E. [illegible],[1] [illegible] Edmunds,[5] A. Ereditato,[7] S. Farooq,[4] B. Fleming,[1] H. Greenlee,[3] R. Guenette,[1] S. Haug,[7] G. Horton-Smith,[4] C. James,[3] E. Klein,[1] K. Lang,[8] P. Laurens,[5] S. Linden,[1] D. McKee,[4] R. Mehdiyev,[8] B. Page,[5] [illegible] Palamara,[2] K. Partyka,[1] A. Patch,[1] G. Rameika,[3] B. Rebel,[3] B. Rossi,[7] M. Soderberg,[3,9] J. Spitz,[1] A.M. Szelc,[1] M. [illegible]ber,[7] T. Yang,[3] and G. Zeller[3]

(The ArgoNeuT Collaboration)

[1] *Yale University, New Haven, CT 06520*
[2] *INFN - Laboratori Nazionali del Gran Sasso, Assergi, Italy*
[3] *Fermi National Accelerator Laboratory, Batavia, IL 60510*
[4] *Kansas State University, Manhattan, KS 66506*
[5] *Michigan State University, East Lansing, MI 48824*
[6] *Universita dell'Aquila e INFN, L'Aquila, Italy*
[7] *University of Bern, Bern, Switzerland*
[8] *The University of Texas at Austin, Austin, TX 78712*
[9] *Syracuse University, Syracuse, NY 13244*

SUBMITTED TO PRL

Josh Spitz

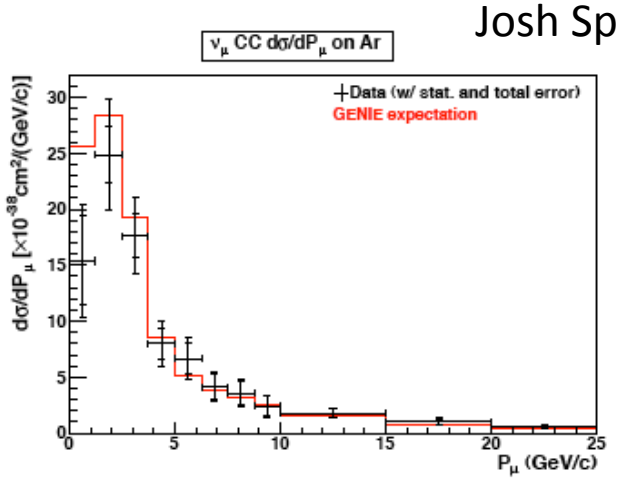


FIG. 3: The ν_μ CC differential cross section (per argon nucleus) in muon momentum.

ArgoNeuT has performed the first ν_μ CC differential cross section measurements for scattering on argon. The results are consistent with the GENIE predictions from $0° < \theta_\mu < 36°$ and $0 < P_\mu < 25$ GeV/c. The results elucidate the behavior of the outgoing muon in ν_μ CC interactions, information useful for tuning neutrino event generators, reducing the systematics associated with a long baseline neutrino oscillation experiment's near-far comparison, and informing the theory of the neutrino-nucleus interaction in general. In addition to importance in understanding neutrino scattering and relevance for neutrino oscillation, these measurements represent a significant step forward for LArTPC technology as they are among the first with such a device.

A number of other cross section analysis underway now!

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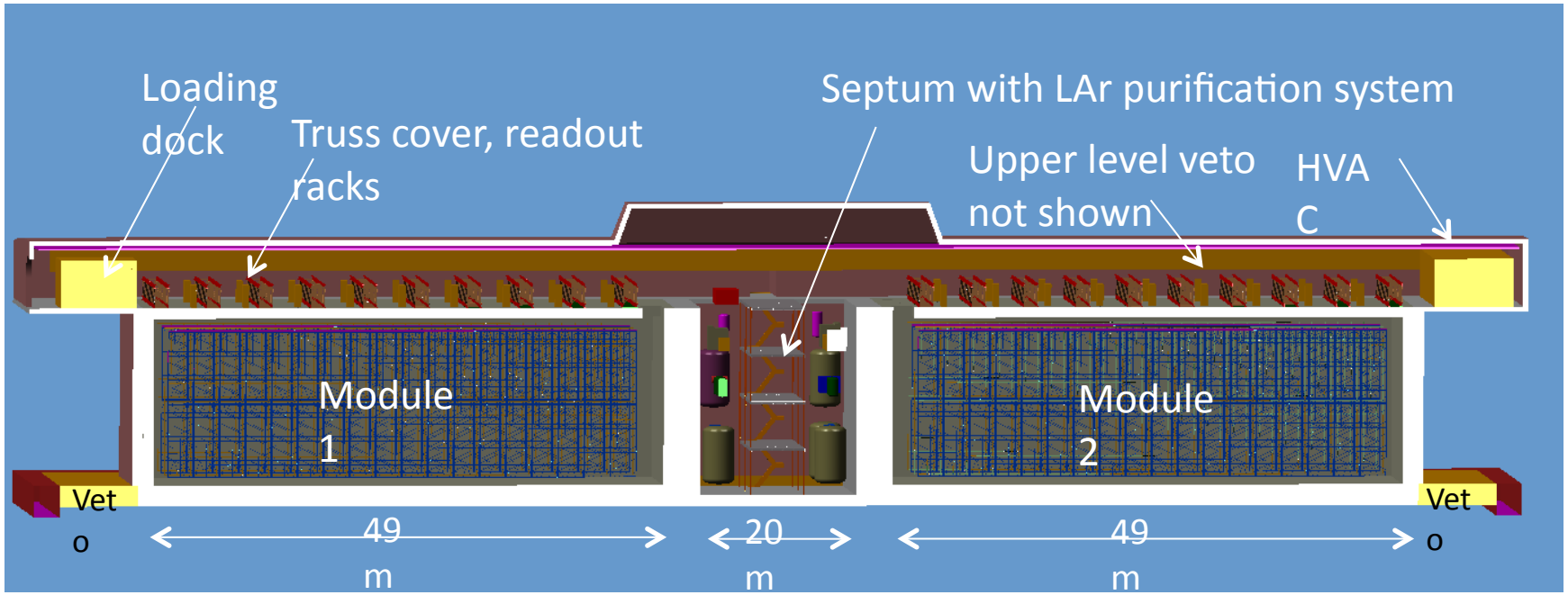
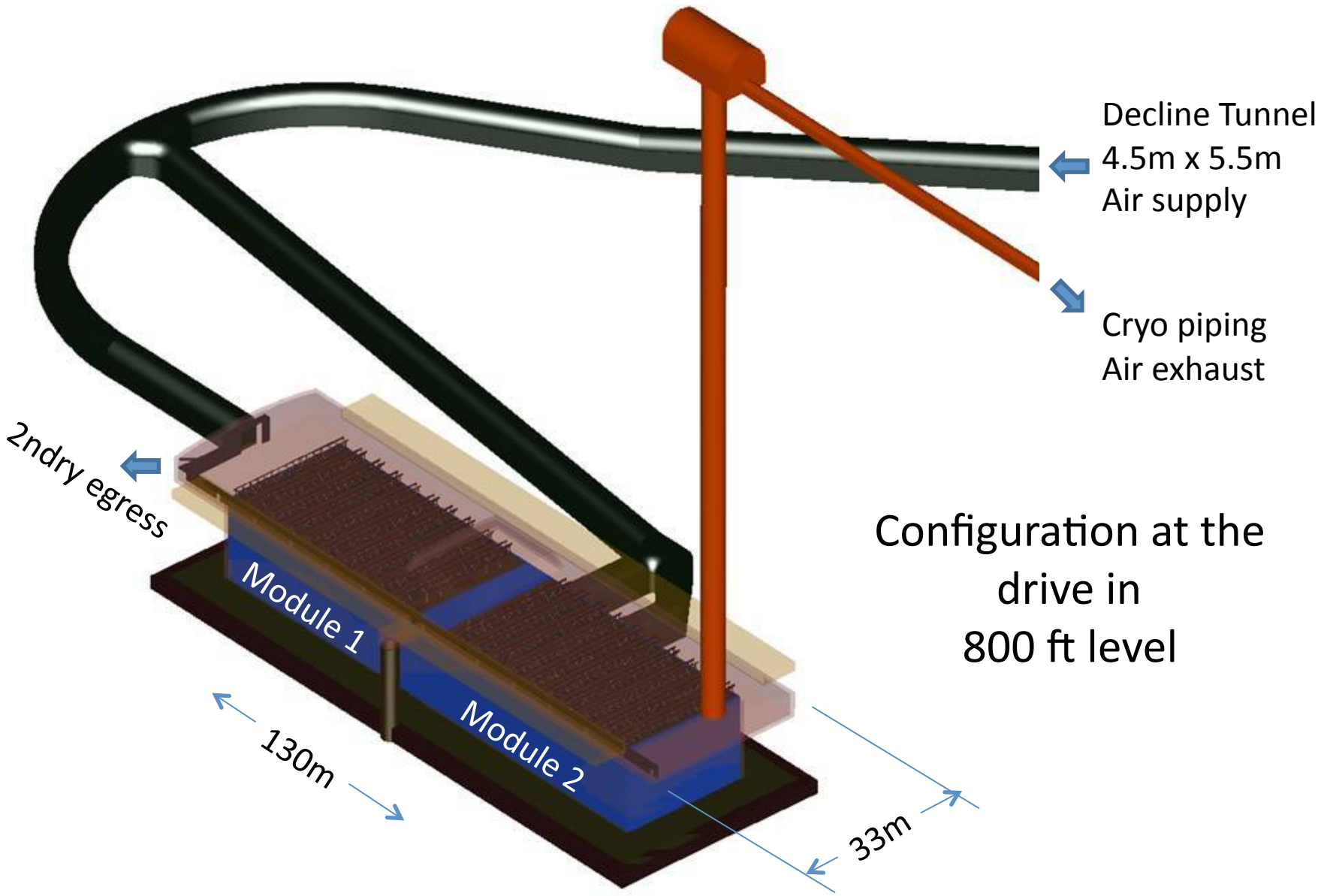
→ Led to well advanced Conceptual Design for LAr40

Technical Design for LAr40



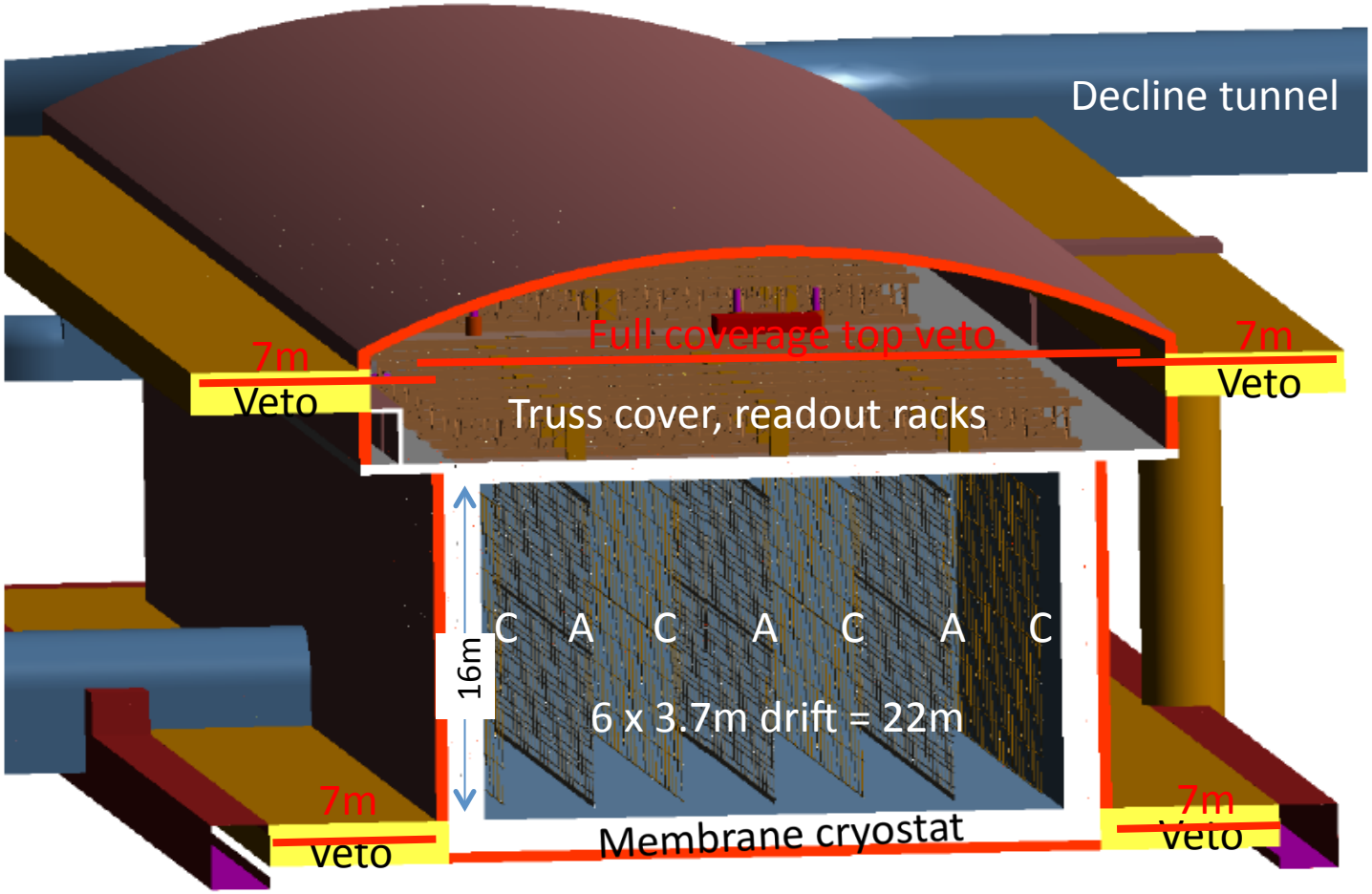
Well advanced design for underground or near surface operation
Development program towards LAr40 underway

2-20 kton modules – One could consider phased approach and/or smaller modules (scalable design)

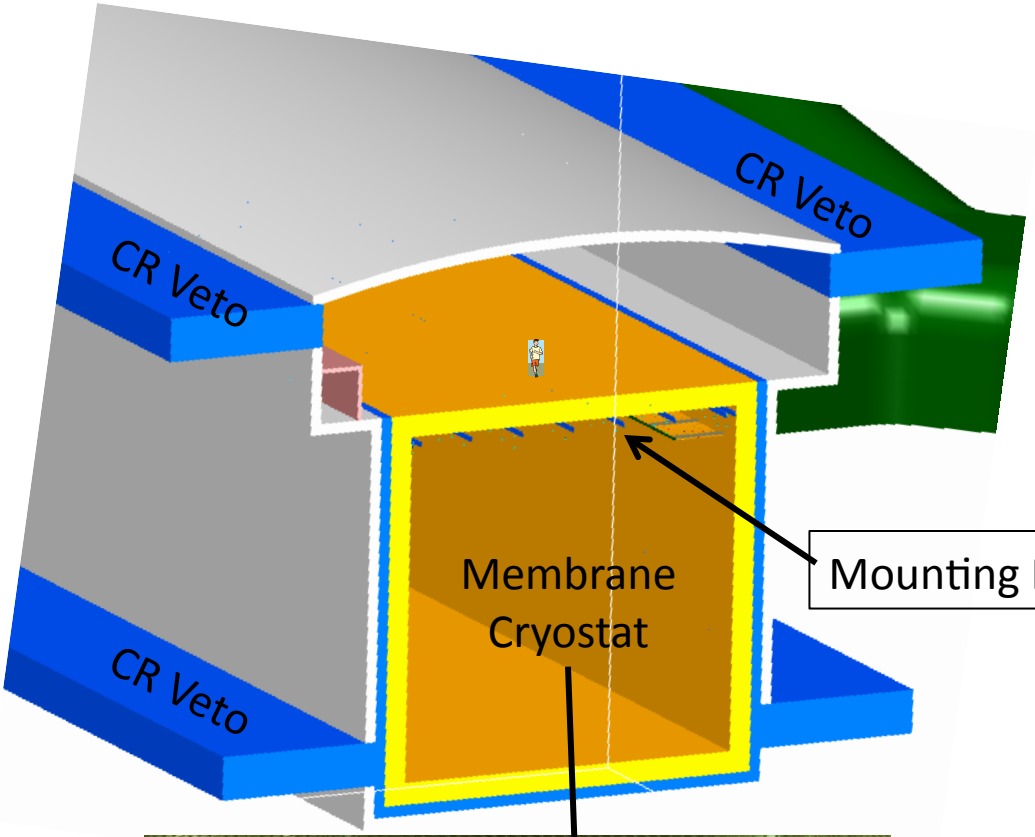


Configuration at the drive in 800 ft level

Cross sectional view of one module



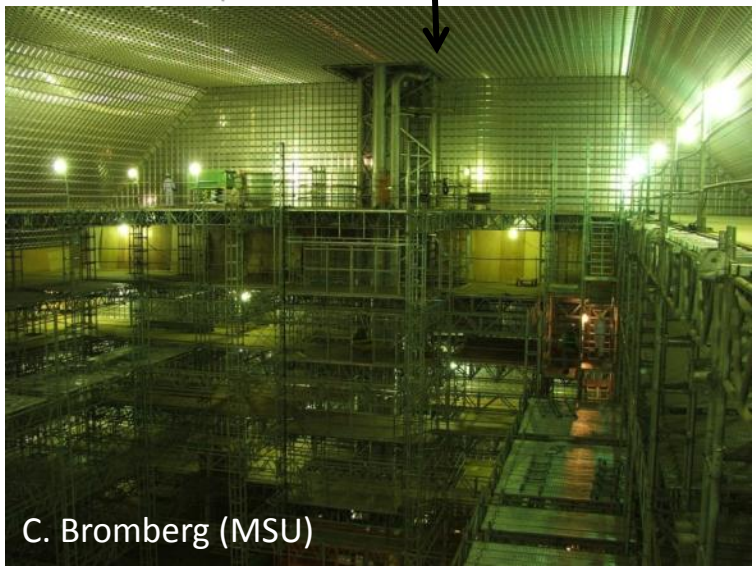
A total of 218 Cathode and Anode "ladders" separated by 3.7m drift
Hung from the roof with electronics and veto above (and on the side)

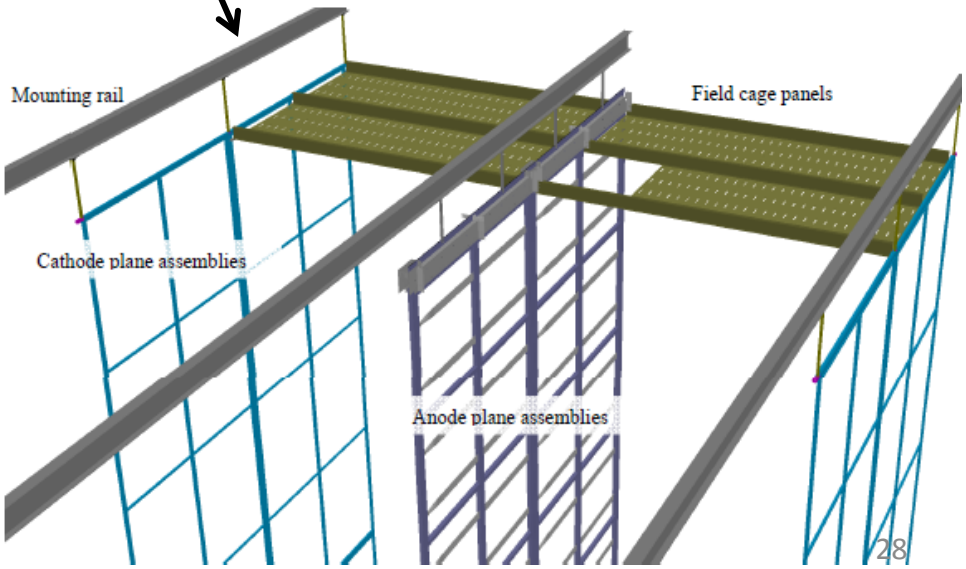


Cryostat is a "membrane" mounted against cavern walls. Membrane cryostats in use in boats carrying LNG

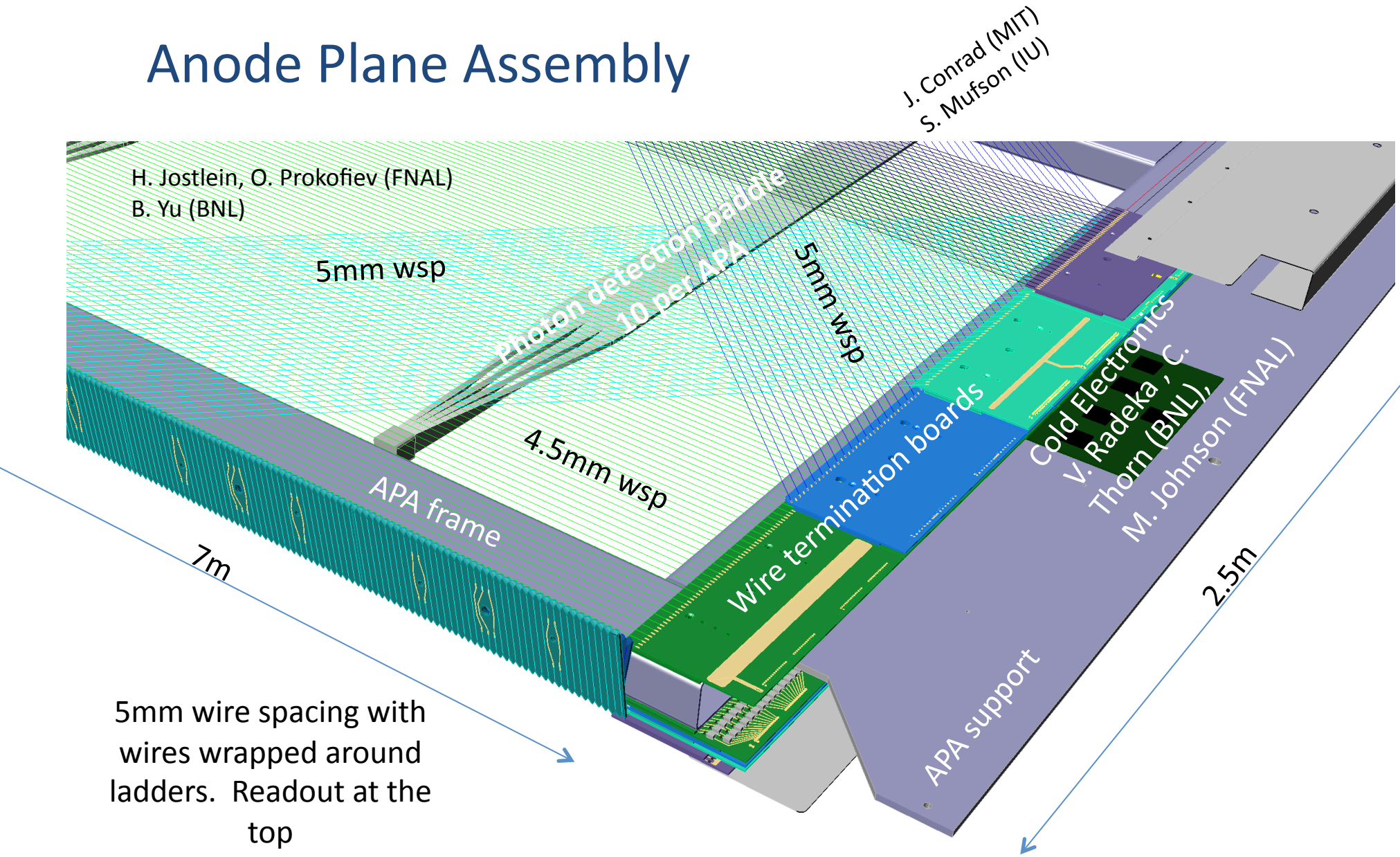
Prototype membrane cryostats for LBNE in development at Fermilab

Wire chambers are hung from the top via trusses.





Anode Plane Assembly

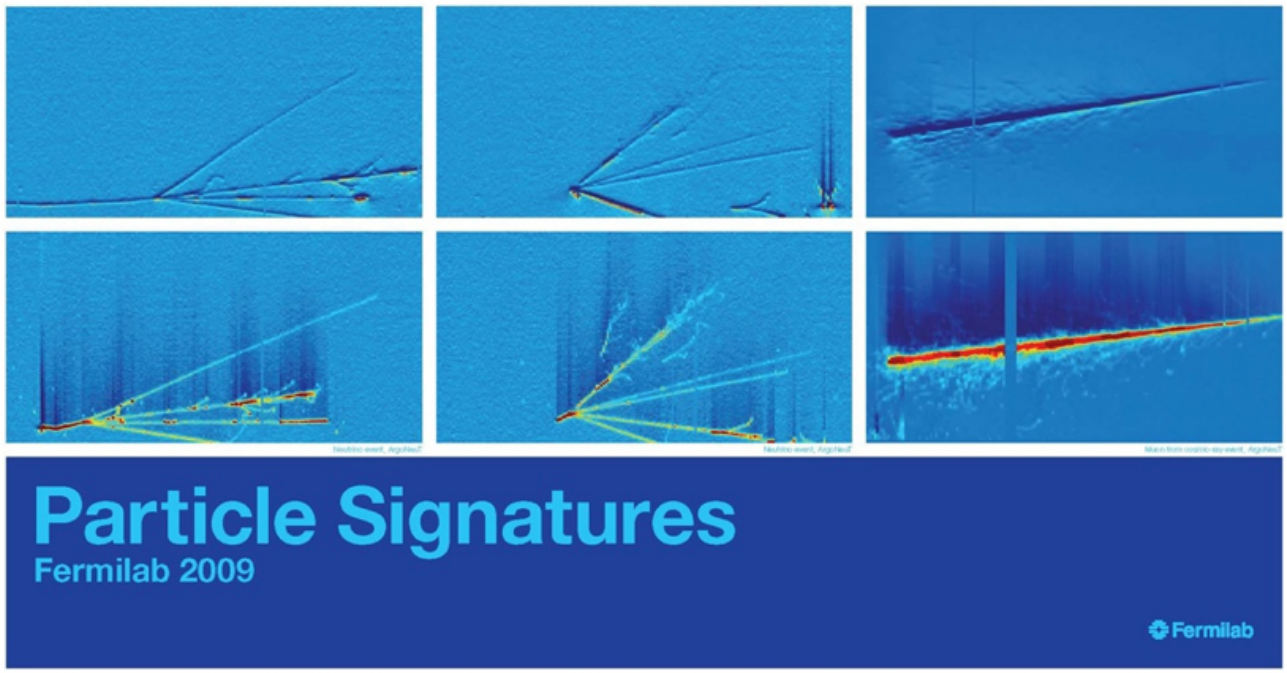


5mm wire spacing with wires wrapped around ladders. Readout at the top

Light collection via photon detector paddles in between wire chamber planes

LArTPCs are ideal detectors for electron neutrino appearance and host a broad program of physics beyond this

(New detector technologies are often transformative! Who knows what we may find!)



Significant progress in the US Integrated development program in last year.
Engineering development needed to realize LAr40 (D but not R&D)