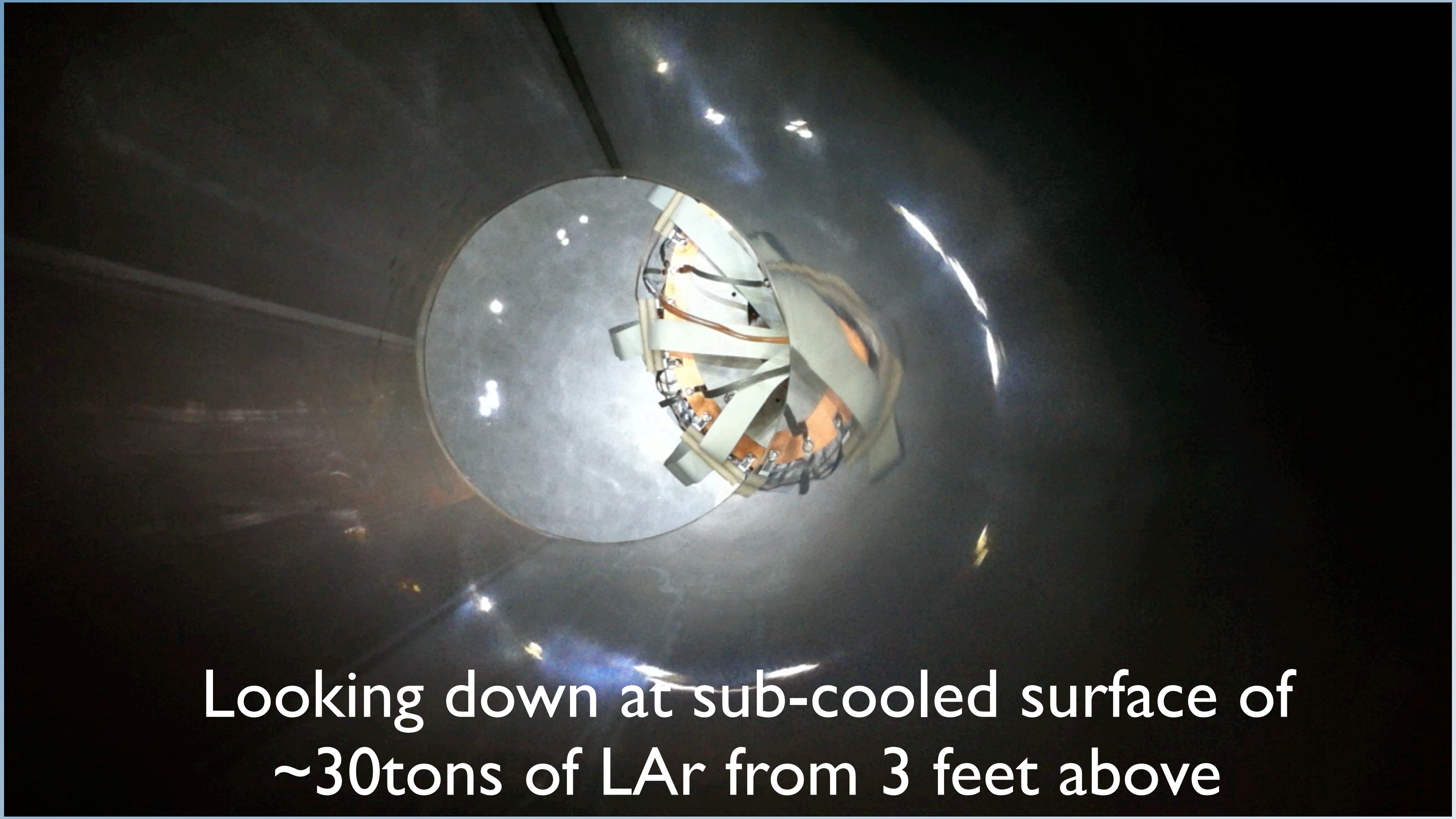
Liquid Argon Detector Development



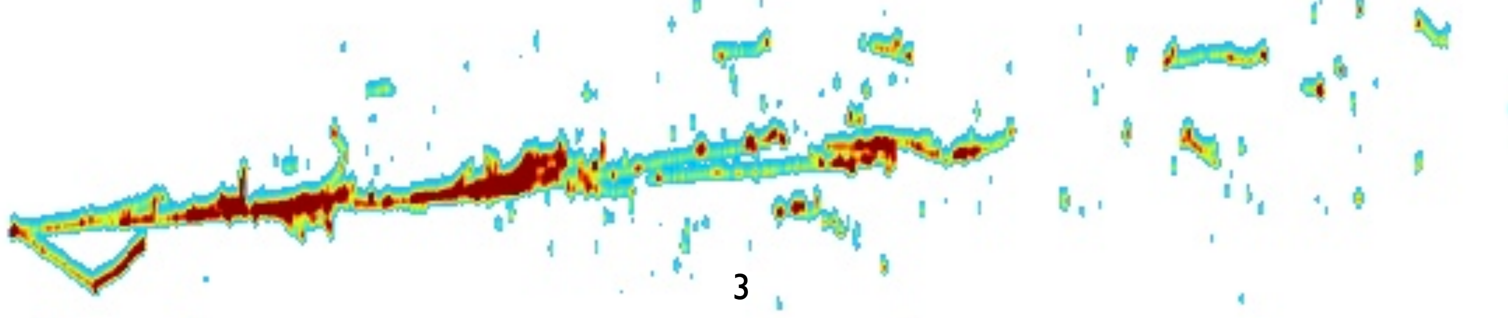
Brian Rebel
June 6, 2013

Outline

- Coordinating LArTPC R&D with the community
- Fermilab development of LArTPCs
    - Purification and Cryogenics (MTS, LAPD, MicroBooNE, LBNE, LArIAT)
    - Electronics,DAQ, and Triggering (Long-Bo, MicroBooNE, LBNE, LArIAT)
    - Photon Detection (Tall-Bo, MicroBooNE, LBNE, SCENE)
    - TPC and High Voltage (Long-Bo, MicroBooNE)
    - Calibration and Test Beams (LArIAT, MicroBooNE)
    - Software (LArSoft)

LArTPC Community Coordination

- Coordinating Panel for Advanced Detectors (CPAD) empowered by DPF to facilitate advanced detector development in US
- LArTPC Detector Group of CPAD convened by Brian Rebel (FNAL), Craig Thorn (BNL) and Jon Urheim (Indiana U)
- We have identified several areas of effort related to making LArTPC detectors a standard technology
- Goal is to provide a clear picture of what work is happening and what questions still need to be answered
- LArTPC group will convene annually to update the community and learn about new ideas



Topical Areas for LArTPC Detectors

- Physics: needs of the planned experiments will drive the requirements in these areas. Interfacing with representatives from the Intensity Frontier and Cosmic Frontier to quantify those needs
- Cryogenics (Cavanna [INFN/Yale])
- Purification (Pordes [FNAL])
- TPC and High Voltage (Marchionni [FNAL], Lang [UT Austin])
- Electronics,DAQ, and Triggering (Thorn [BNL], Bromberg [MSU])
- Photon Detection (Mufson [Indiana], Katori [MIT])
- Calibration and Test Beams (Raaf [FNAL], Mauger [LANL])
- Software (Junk [FNAL], Soderberg [Syracuse])

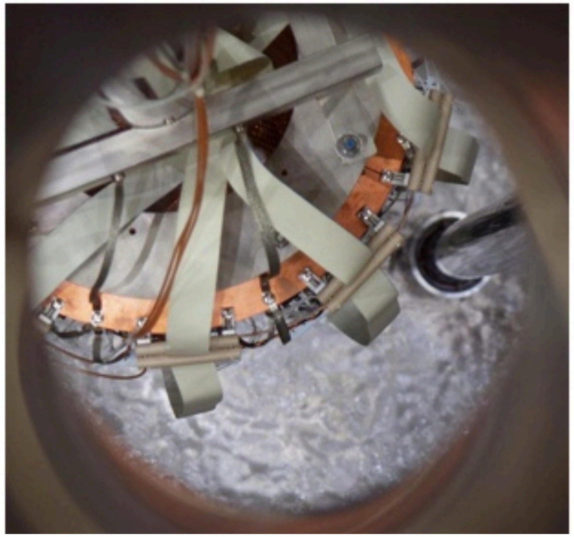
LArTPC (Liquid Argon Time Projection Chamber Detector) R&D Workshop

20-21 March 2013 *Fermi National Accelerator Laboratory*

US/Central timezone

- **Overview**
- Agenda
- Registration
  - Modify my registration
- Registrants List

Contact: Cynthia M. Sazama



Liquid Argon Time Projection Chamber Research and Development in the United States

C. Bromberg,[1] F. Cavanna,[2] T. Junk,[2] T. Katori,[3] K. Lang,[4] A. Marcionni,[2] S. Mufson,[5] S. Pordes,[2] J. Raaf,[2] B. Rebel,[2] M. Soderberg,[6] C. Thorn,[7] and J. Urheim[5]

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[4]*University of Texas at Austin, USA*
[5]*Indiana University, Bloomington, IN 47405, USA*
[6]*Syracuse University, NY, USA*
[7]*Brookhave National Laboratory, , USA*

(Dated: May 14, 2013)

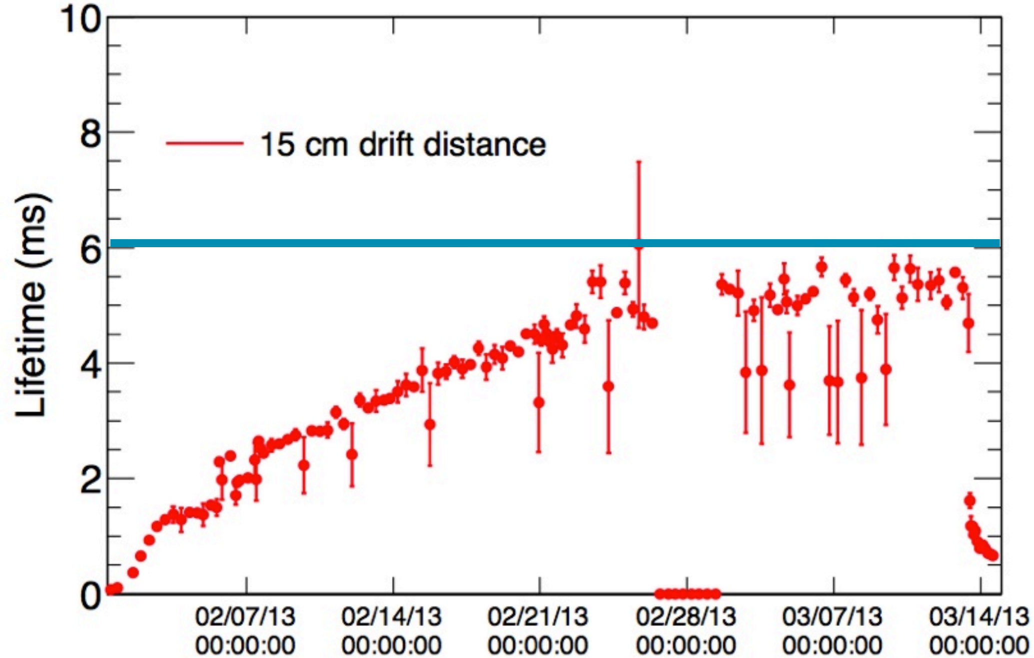
A workshop was held at Fermilab on March 20-21, 2013 to discuss the development of liquid argon time projection chambers (LArTPC) in the United States. The workshop was organized under the auspices of the Coordinating Panel for Advanced Detectors, a body that was initiated by the American Physical Society Division of Particles and Fields. All presentations at the workshop were made in plenary sessions organized into seven topical categories: *i*) Argon Purity, *ii*) Cryogenics, *iii*) TPC and High Voltage, *iv*) Electronics, Data Acquisition and Triggering, *v*) Scintillation Light Detection, *vi*) Calibration and Test Beams, and *vii*) Software. This document summarizes the current efforts in each of these topical categories. It also highlights areas in LArTPC research and development that are common between neutrino experiments and dark matter experiments.

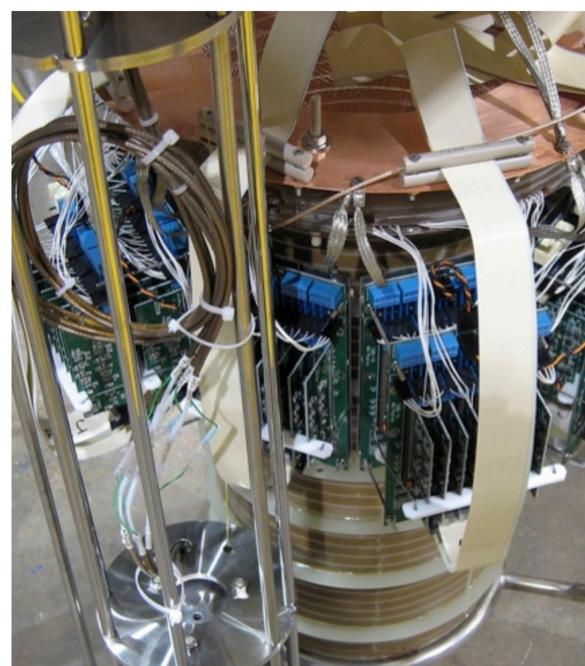
- Fermilab is the facilitator of knowledge transfer, allows community to take informed action
- We are organizing workshops for efficient knowledge transfer
- Workshops allow community to identify primary development goals
- Documentation of the workshops is vital for efficient development of multi-kiloton scale detectors
- Recently hosted LIDINE on light collection, planning workshop on HV for this fall

https://indico.fnal.gov/conferenceDisplay.py?ovw=True&confId=6395

Purity

- MTS continues to operate and provide service measurements to community
- Water and oxygen are the key electronegative impurities
- No sources of oxygen after initial clean-up, water sticks on surfaces for ever
- Major result: LAPD second run has achieved >5 ms electron lifetimes in presence of 2 m TPC
- First tracks observed in 2 m long TPC
- LAPD will cease running this FY to allow resources to be used in other parts of the program





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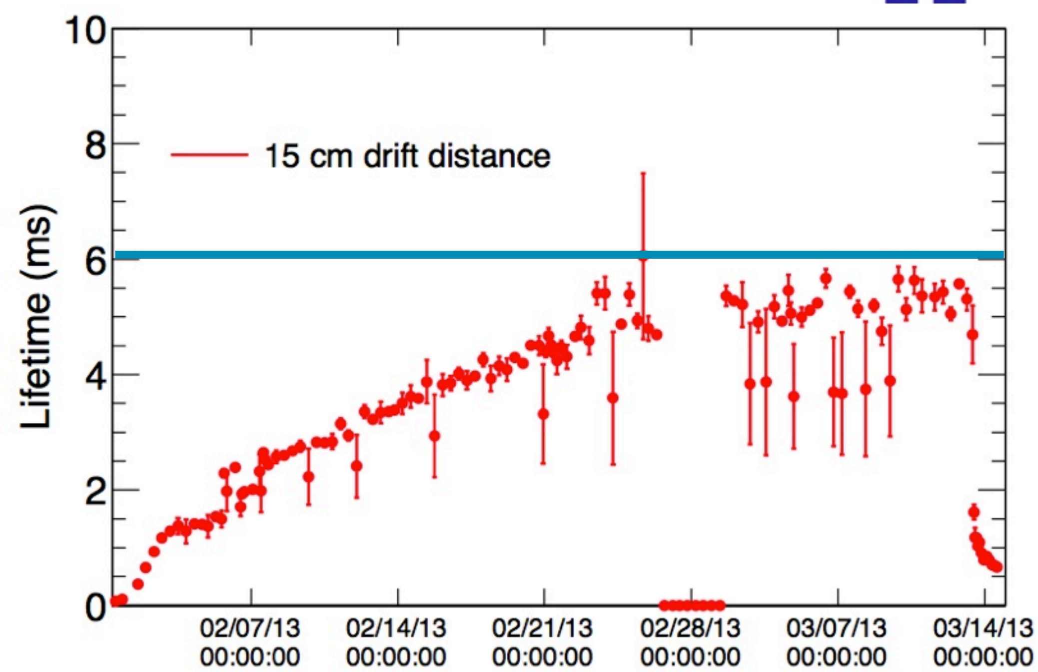
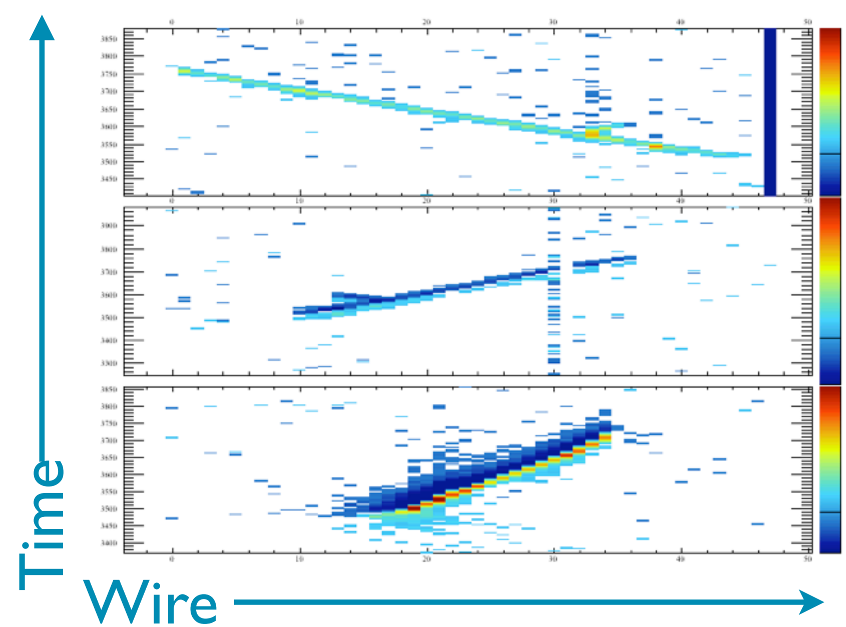
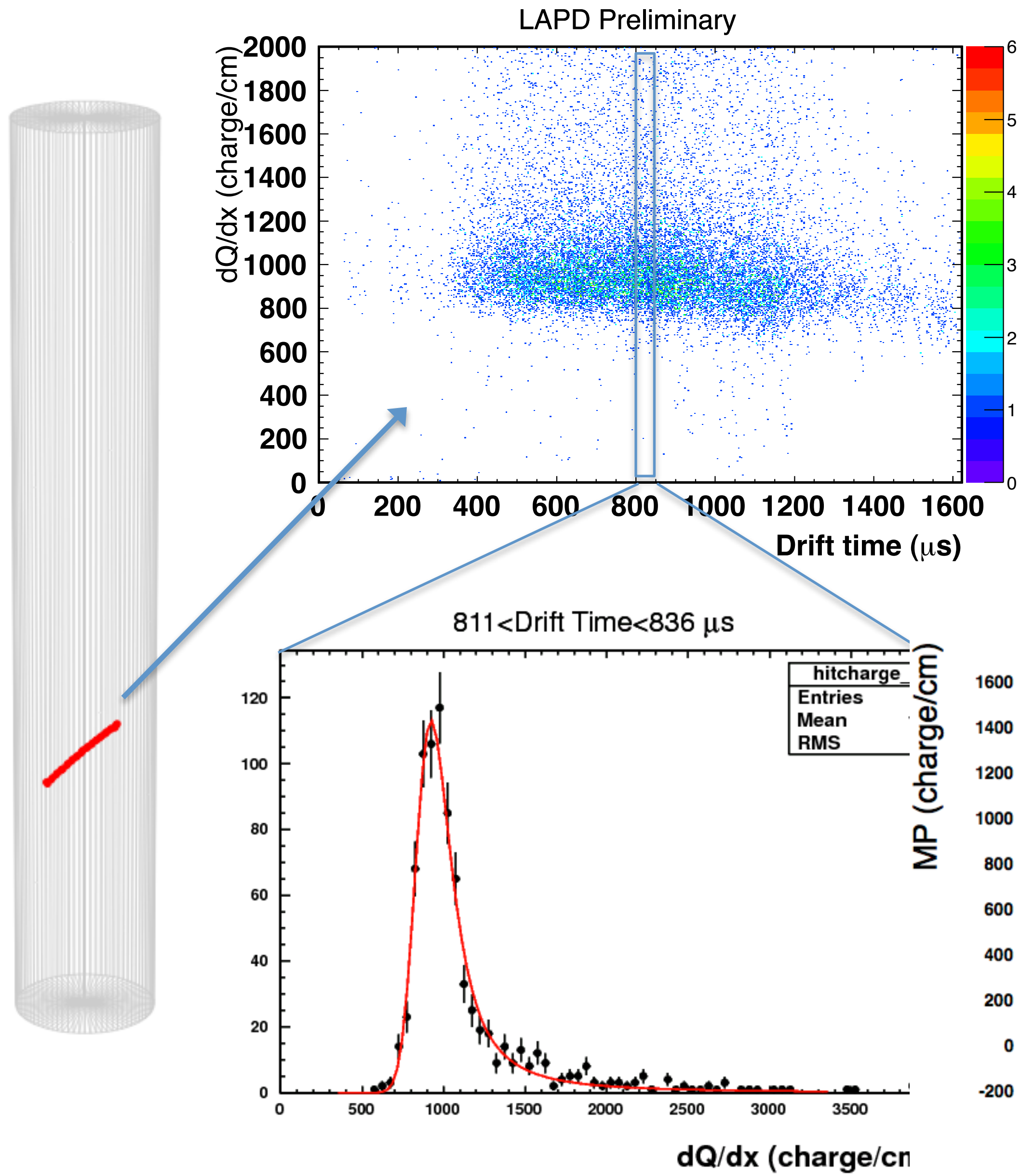
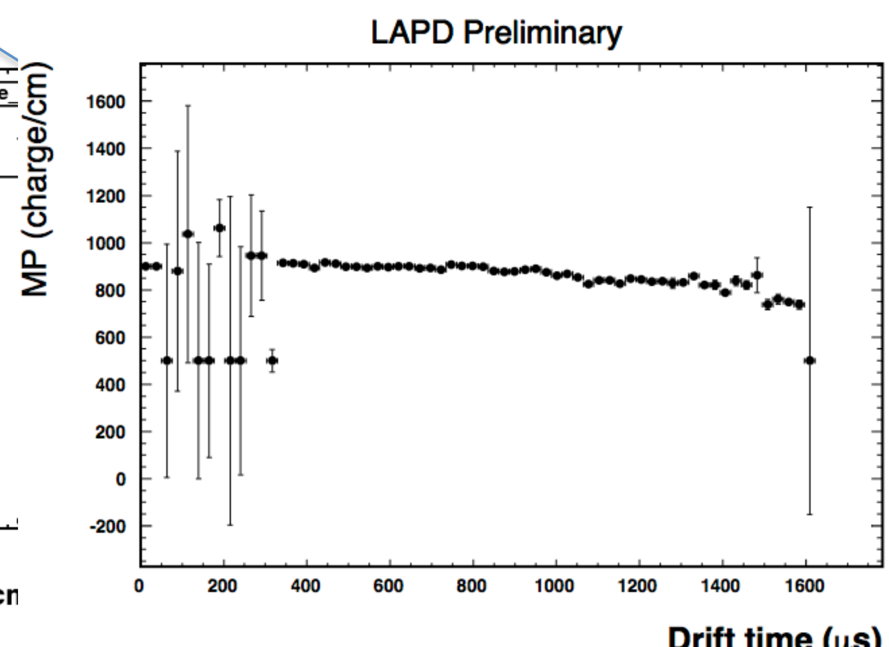




Measuring Attenuation with Long Bo



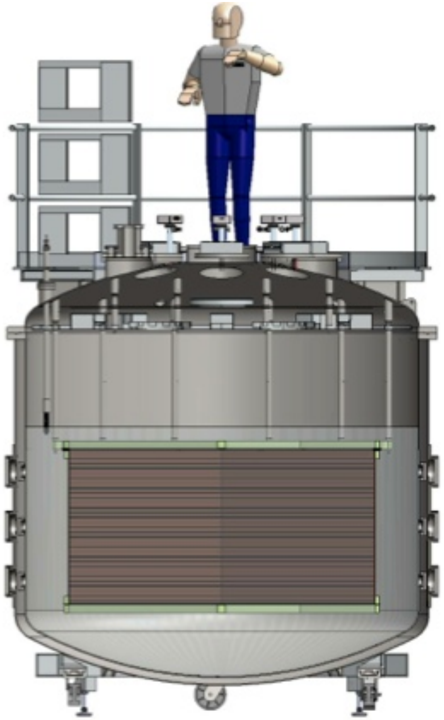
- Select single muon events in range 50 < θ < 70 and remove δ
- Use dQ/dx of muon hits as a function of drift time to measure attenuation
- Less than 20% attenuation over 1 m



Cryogenics

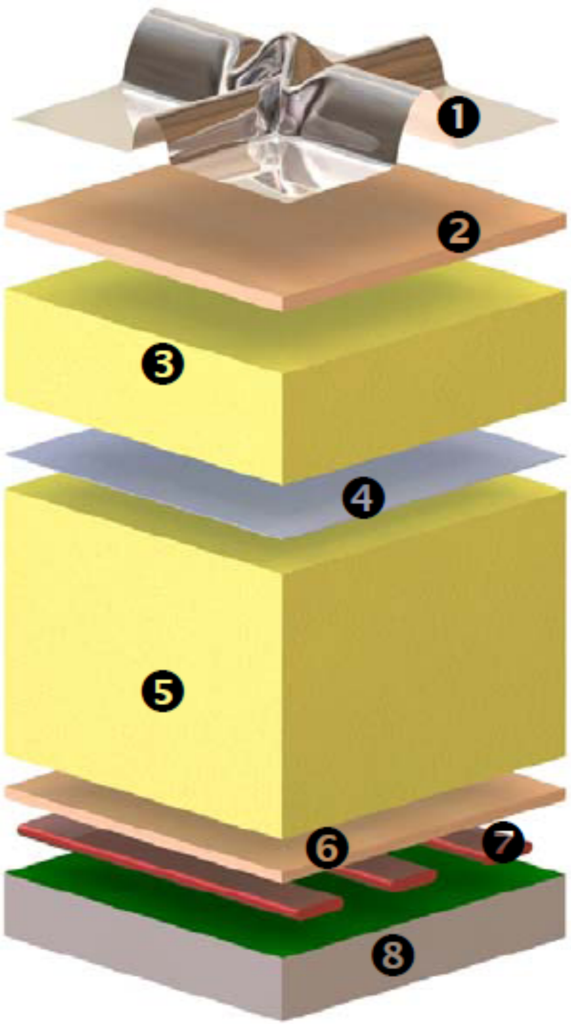
- LAPD was first large scale cryogenic system
- Informed design for MicroBooNE, LBNE, LArIAT, and CAPTAIN
- Several designs shared from LAPD and MicroBooNE with others
- MicroBooNE showed cool down scheme could be a place to realize cost savings
- LBNE has found less expensive alternatives, but those are yet to be tested
- ODH analysis is a key place for standardization across projects
- Dedicated safety panel for LArTPC projects

LArIAT



CAPTAIN

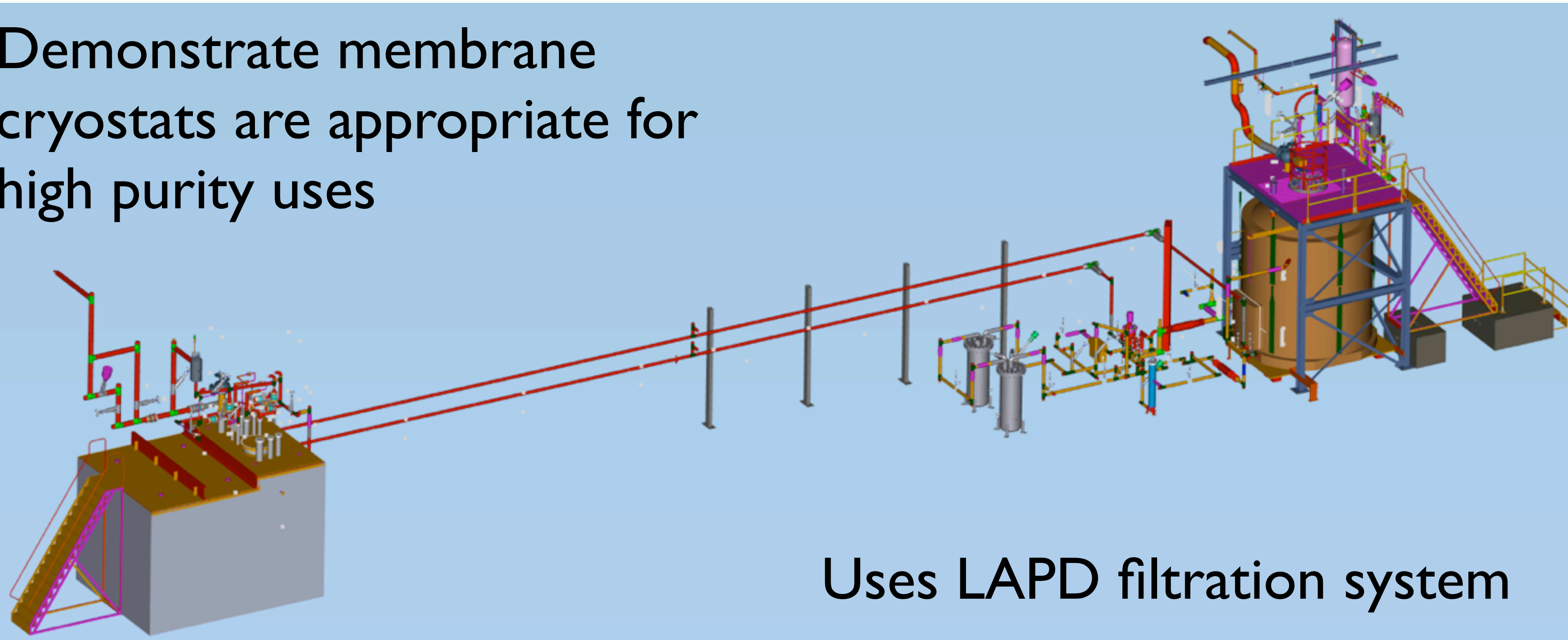
Membrane Cryostat for LBNE



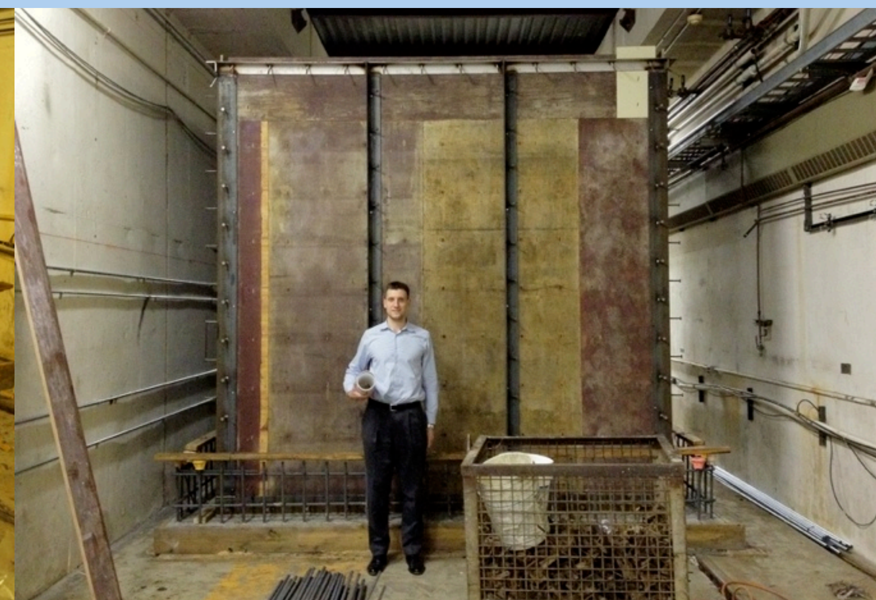
1. Stainless steel primary membrane
2. Plywood board
3. Reinforced polyurethane foam
4. Secondary barrier
5. Reinforced polyurethane foam
6. Plywood board
7. Bearing mastic
8. Concrete covered with moisture barrier

35 Ton Membrane Cryostat Prototype

Demonstrate membrane cryostats are appropriate for high purity uses



Uses LAPD filtration system



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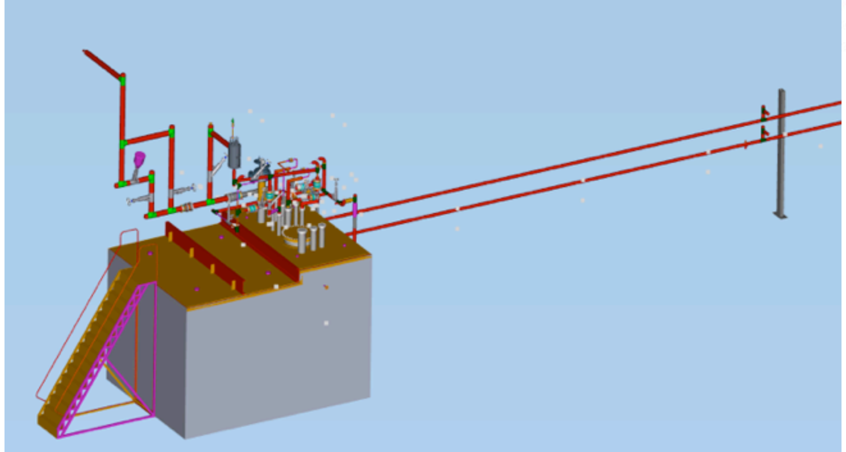
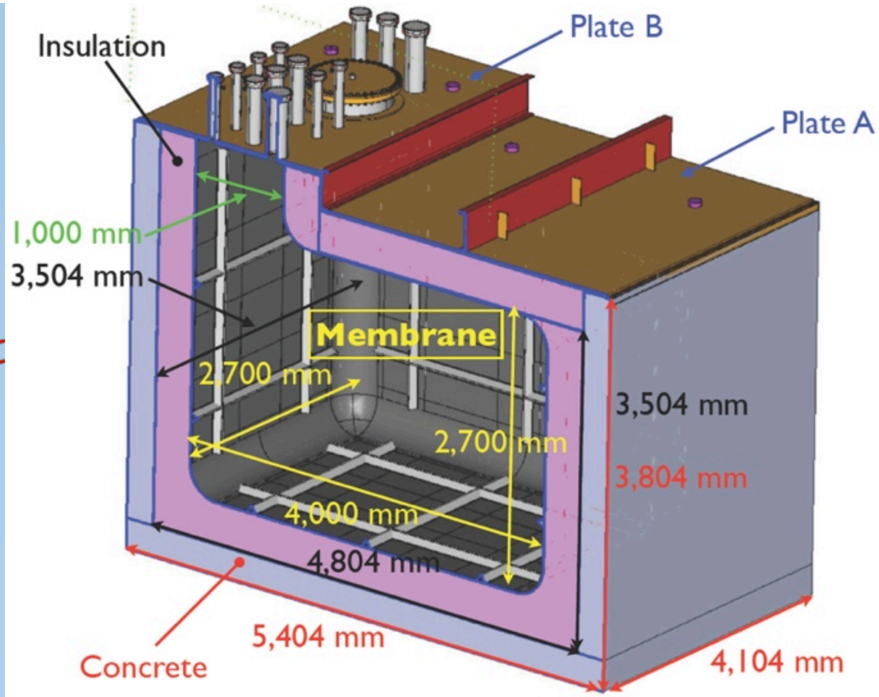
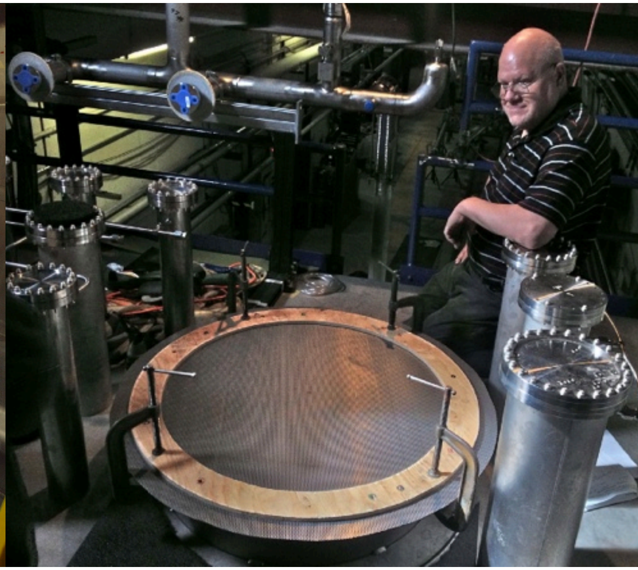




35 Ton Membrane Cryostat Prototype

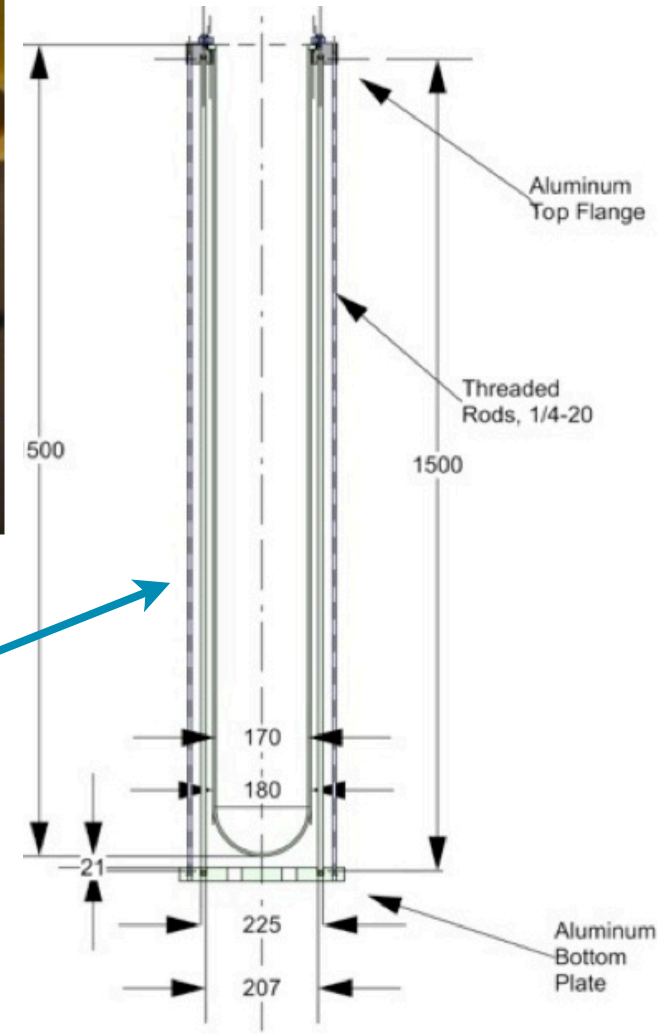


- Cryostat is now complete
- Connecting process piping to the LAPD filtration system
- First run will test use of in liquid pumps

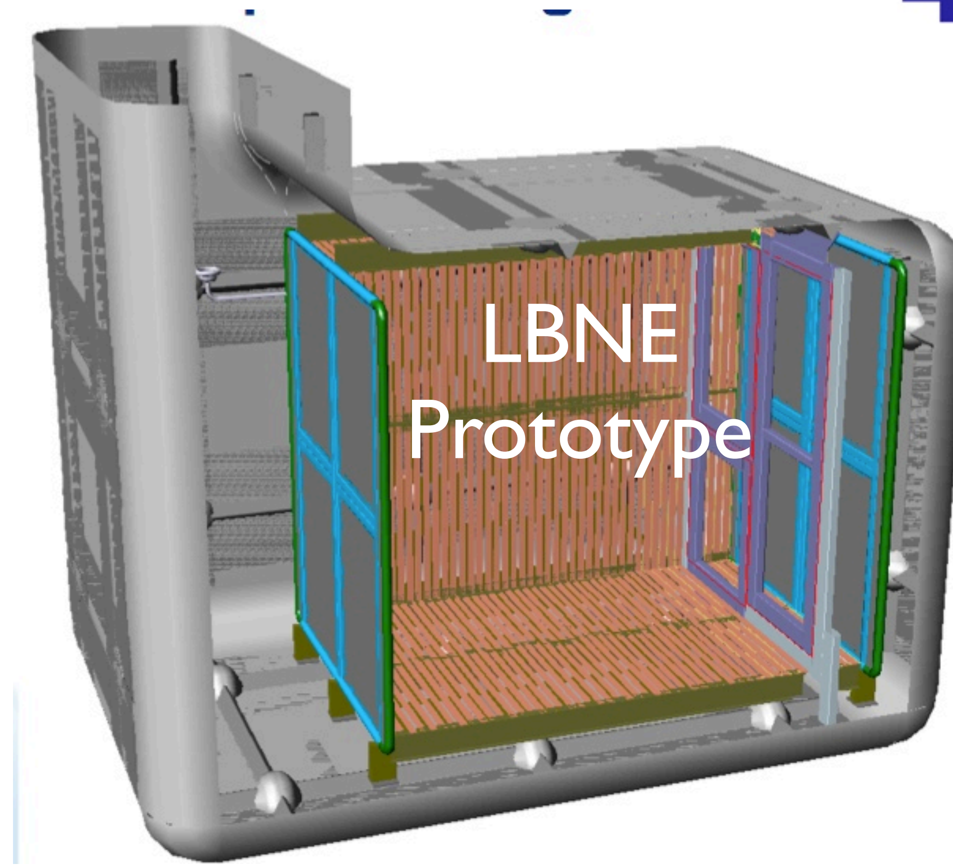
Parameter	Value
LAr Temperature	89K ± 1K
Operating Gas Pressure	70 mBar (~ 1 psig)
Vacuum	No Vacuum, we will SLOWLY purge it with GAr (See LAPD)
Design Pressure	207 mBar (~ 3 psig)
Leak tightness	10^{-6} mBar*l/sec (with NH_3 leak check, ASTM standard)
Heat Leak	< 13 W/m^2 (~11.5 W/m^2)
Design Code	Applicable parts of JGA Recommended Practice for LNG In ground storage tanks FESHM 5031.5

High Voltage Feed Throughs

- MicroBooNE and LBNE designs follow “traditional” method
- Stainless steel inner and outer conductors, separated by PE
- MicroBooNE prototype operating in Long Bo, achieved 70 kV goal is 125 kV
- HV in LAr not fully understood - where does breakdown occur, mechanism for the breakdown
- Borosilicate cryostat obtained to allow visual monitoring of the system to look for arching
- Increasing HV effort to understand these issues



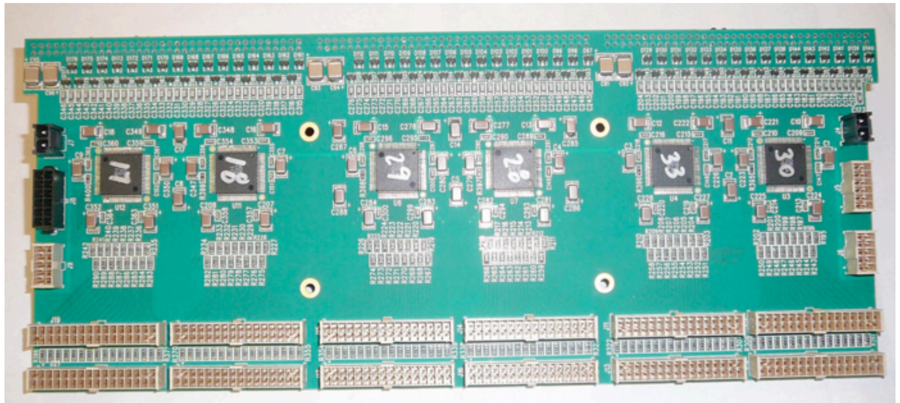
TPC Development

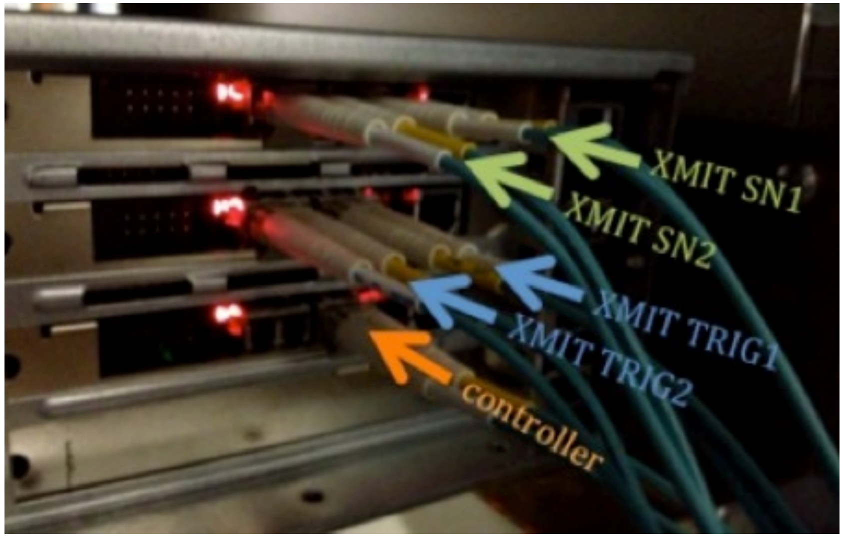


- MicroBooNE wire plane assembly is finished!
- Learned a lot about assembly and tolerances for cathode flatness, etc
- LBNE prototype will have miniature APAs with wrapped wires
- Prototype APA design nearly complete, construction next FY

Electronics, DAQ, and Triggering

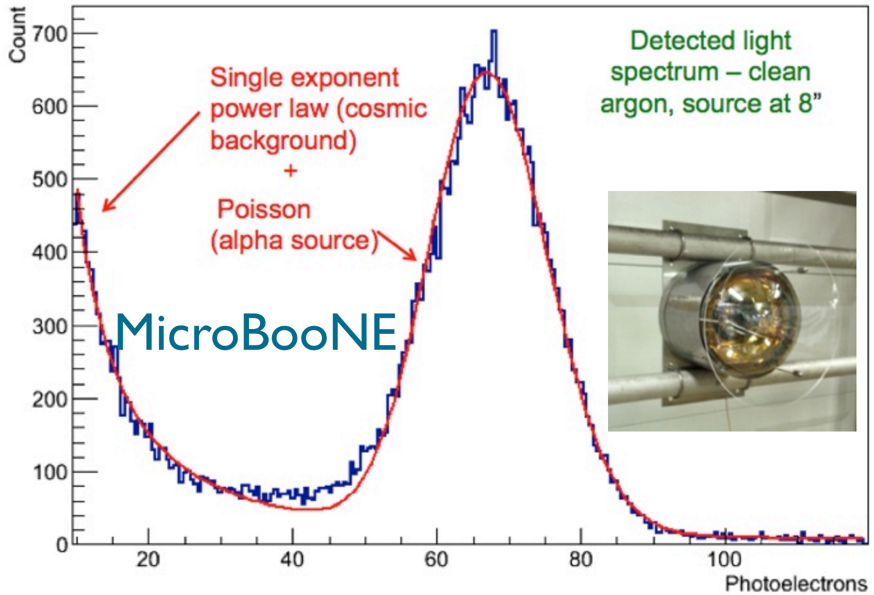
- Two approaches to cold electronics in the US - MSU off the shelf and BNL custom built
- Converging as MSU incorporated MicroBooNE ASIC into LongBo test
- DAQ and triggering development handled by experiments
- MicroBooNE DAQ has to handle 7 TB/day for SN data, test stand in place
- MicroBooNE and LArIAT provide great test of operating on the surface
- Vital experience because cold components in large detectors are inaccessible for repair

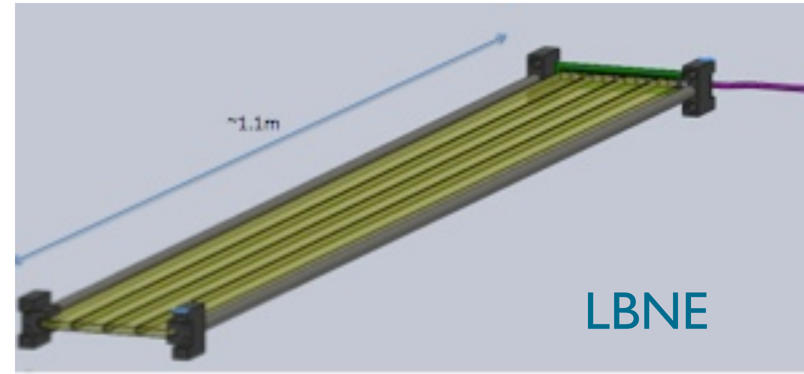




MicroBooNE DAQ Rack

Photon Detection

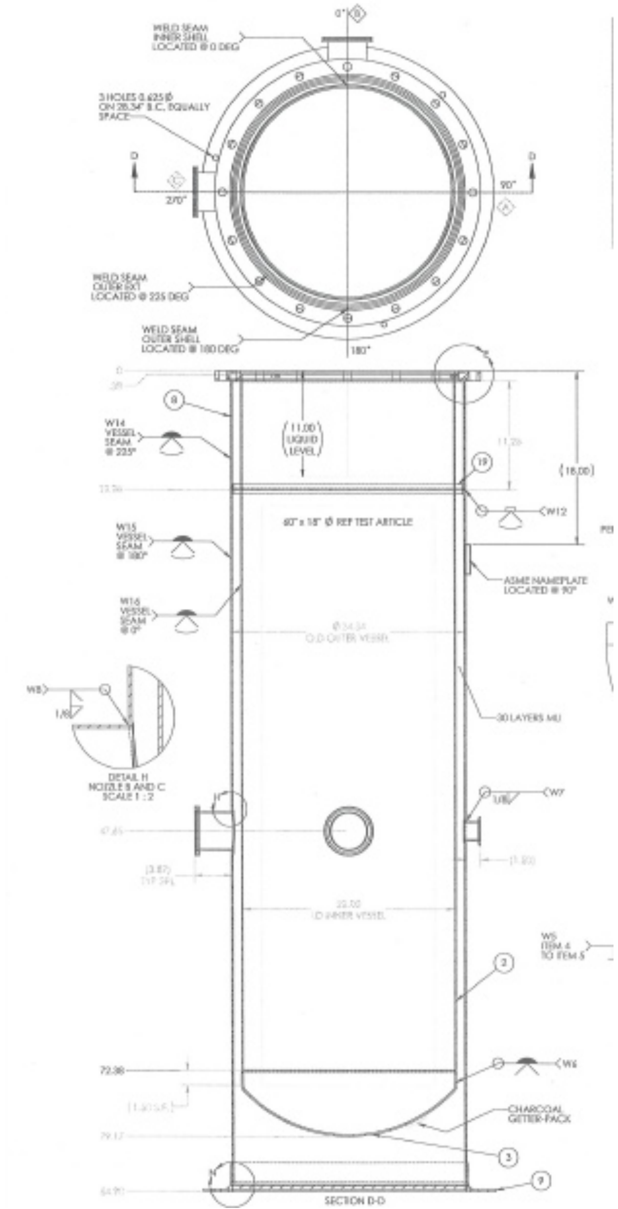




- Several groups interested in this problem, representing LArIAT, MicroBooNE, and LBNE
- MicroBooNE uses PMTs with TPB coated plates to shift scintillation light to the appropriate wavelength
- Test stand to understand PMT performance in use at PAB, already detecting light from alpha sources
- MIT group used PAB facility to measure absorption by nitrogen
- LBNE has different space requirements so looking at slimmer options

Photon Detection

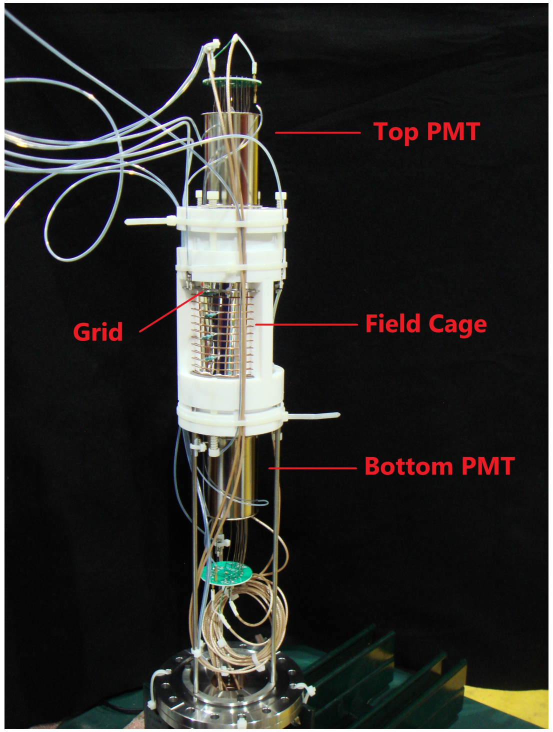
- Fermilab providing facilities to test these photon detection options
- MIT group currently using "Bo" cryostat to test PMTs
- PAB system provides cryostat as well as purified LAr and devices to monitor contaminants (N_2)
- Will incorporate Nevis readout electronics later this year
- New "Tall Bo" cryostat ordered from vendor to provide testing location for LBNE scintillator paddle + SiPM design
- "Tall Bo" ready to run in September

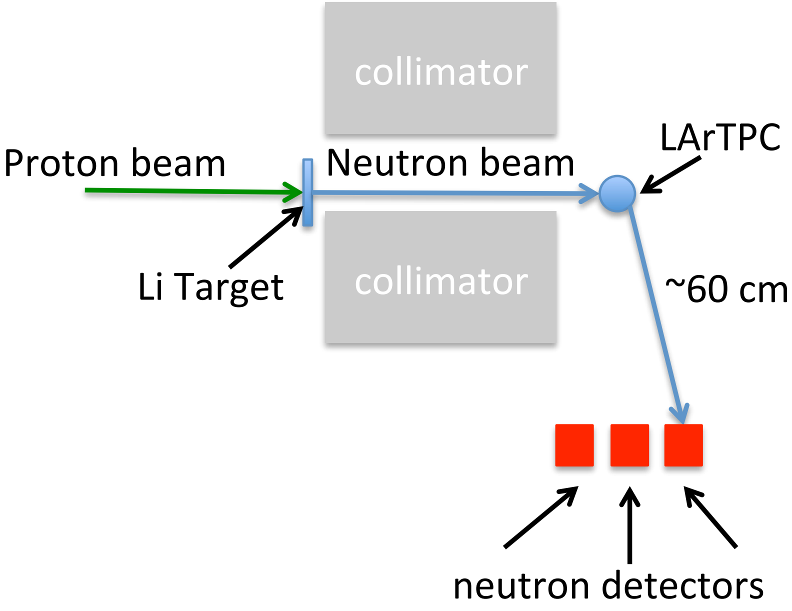


Tall Bo

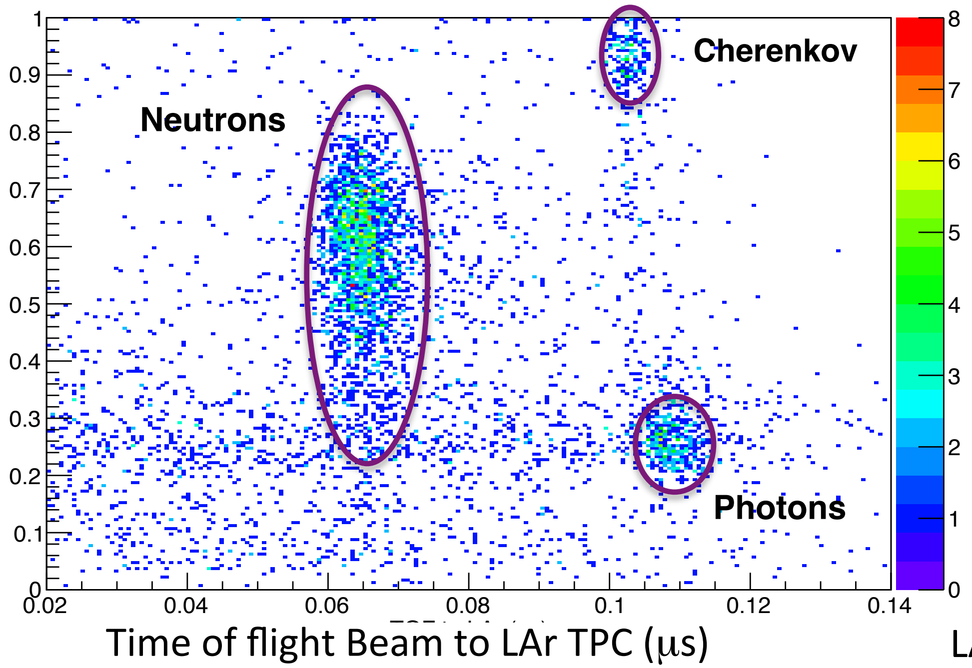
Photon Detection for Dark Matter

- SCENE (Scintillation Efficiency of Noble Elements) Fermilab, Naples, Notre Dame, Princeton, Temple, UMass
- Measure S1 and S2 for nuclear recoils in argon and xenon as function of energy transfer and TPC field strength
- No good measurements below 20 keV recoil energy
- Using known, variable energy pulsed neutron beam at Notre Dame
- Small LArTPC and neutron detectors select scatters of interest
- Nice, clean, recoil signal

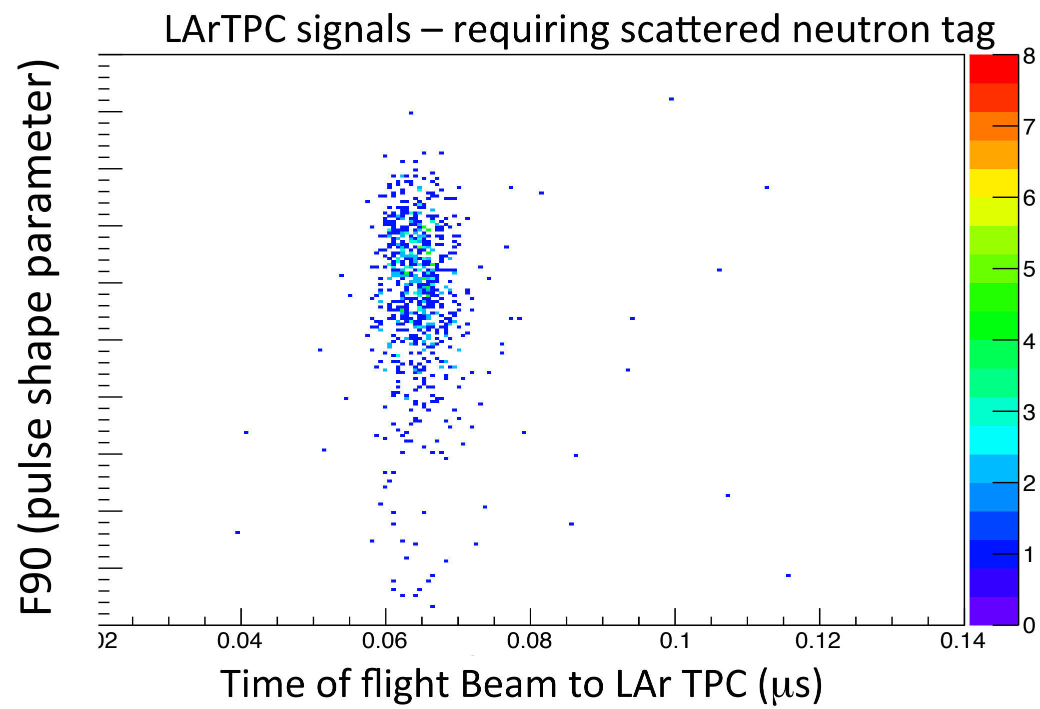




Photon Detection for Dark Matter



Pulsed beam allows identification of different sources
(Cerenkov is photon into glass of PMT)



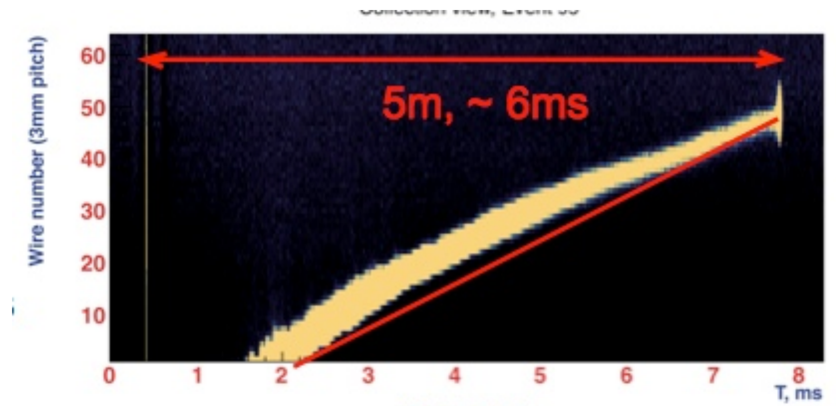
Clean (very) neutron signal

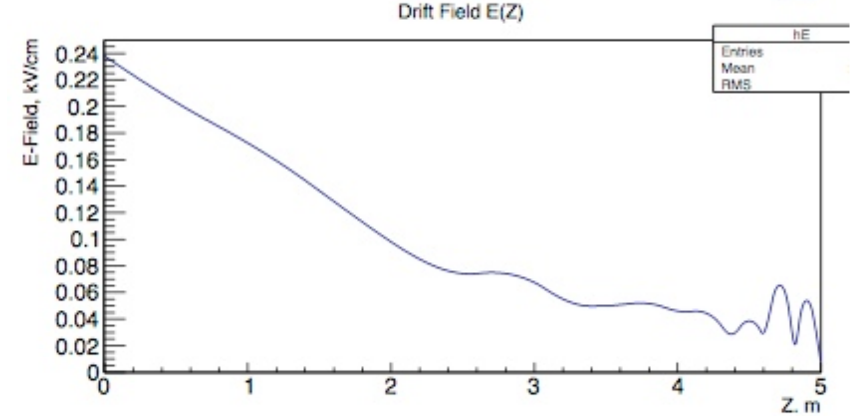
[F90 = signal in 90ns/signal in 7 μs]

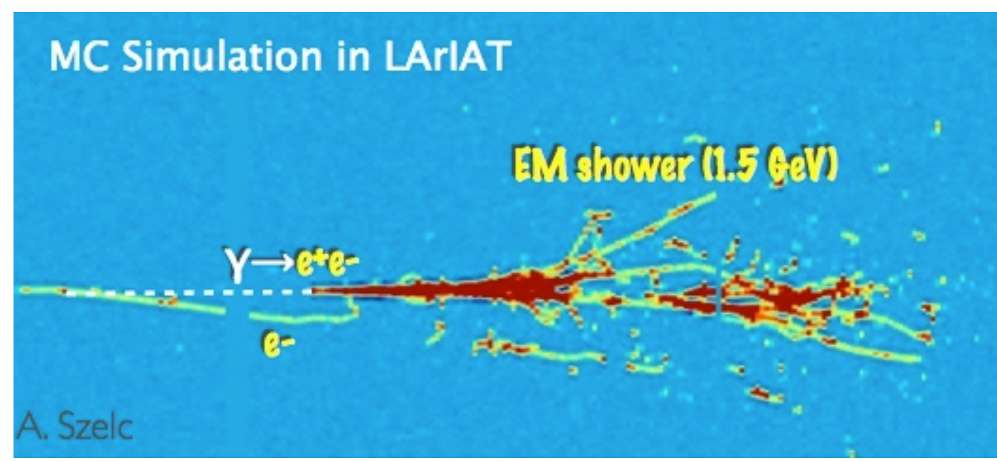
Test Beam and Calibration

- Bern group has demonstrated the utility of a VUV laser for lifetime and field calibration, implementing for MicroBooNE

- Several test beam experiments around the world
  - ArgoNeuT: published two papers last year- detector description and analysis of neutrino induced muons
  - LArIAT: calibration and R&D in a charged particle beam at FNAL
  - CAPTAIN: Neutrons, low energy neutrinos, possibly NuMI
  - T32: charged particle beam, high K fraction at JPARC

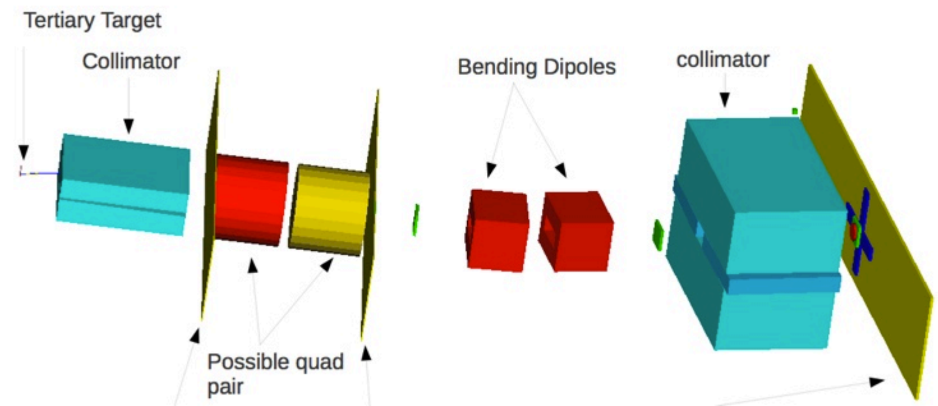


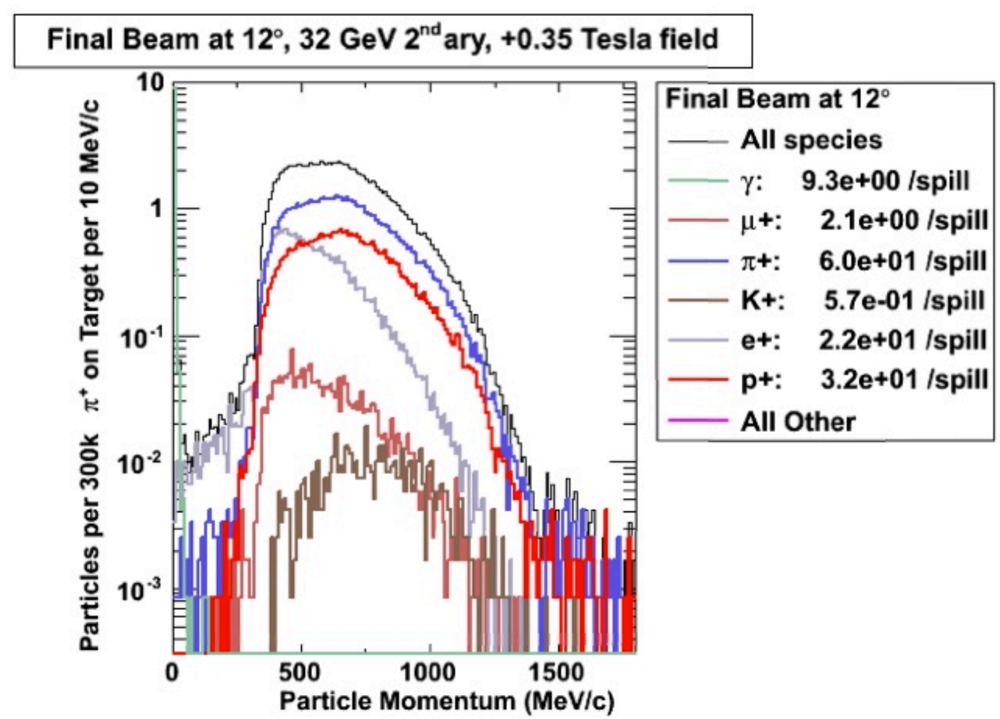




LArIAT: T-1034

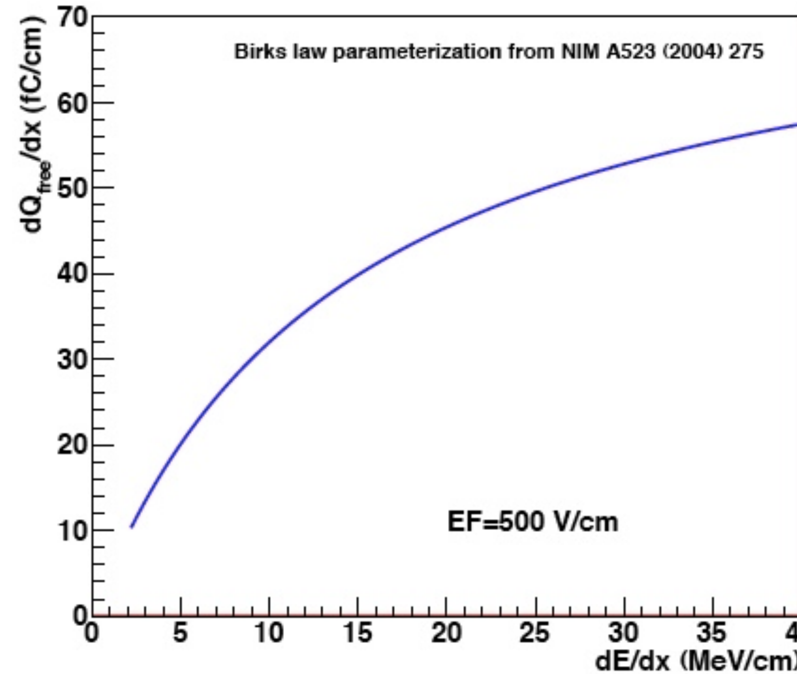
- 2 phases: upgraded ArgoNeuT cryostat followed by much larger cryostat and TPC
- Fermilab R&D Advisory Group consulted at early stages for guidance
- Much progress in last year
  - ArgoNeuT cryostat modified
  - Purchased cryogenic pump
  - Beam line design maturing
  - Recycling counters from CDF
  - DAQ work underway to improve rates
  - Cryogenic system for both phases being built by vendor



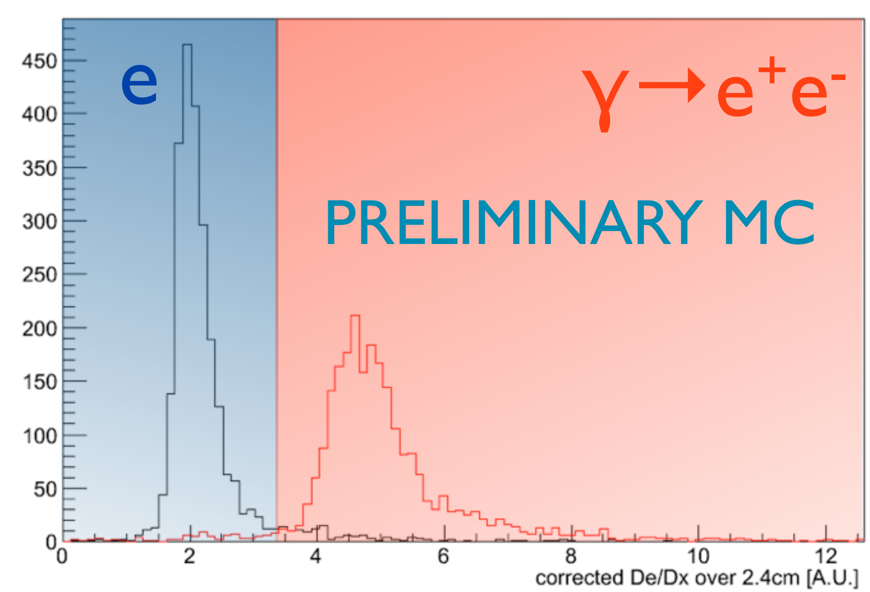


LArIAT Phase 1: Upgraded ArgoNeuT

- ArgoNeuT cryostat upgraded
  - PMTs to detect scintillation light
  - Cold window to minimize amount of steel between the beam and LAr
  - Ports to allow liquid filtration
- Study charge to energy conversion with single track topologies
- Operate in multiple field strengths
- Study initial ionization in EM showers to understand e/γ separation
- Optimize particle ID methods for a broad range of particles and momenta

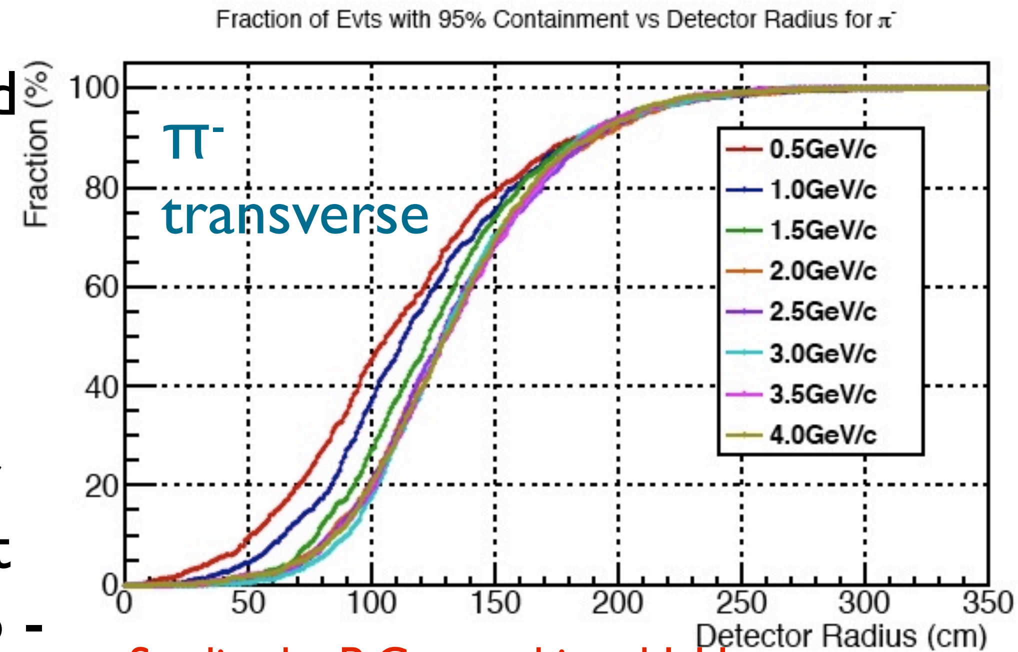


Corrected De/Dx first 2.4 cm preliminary

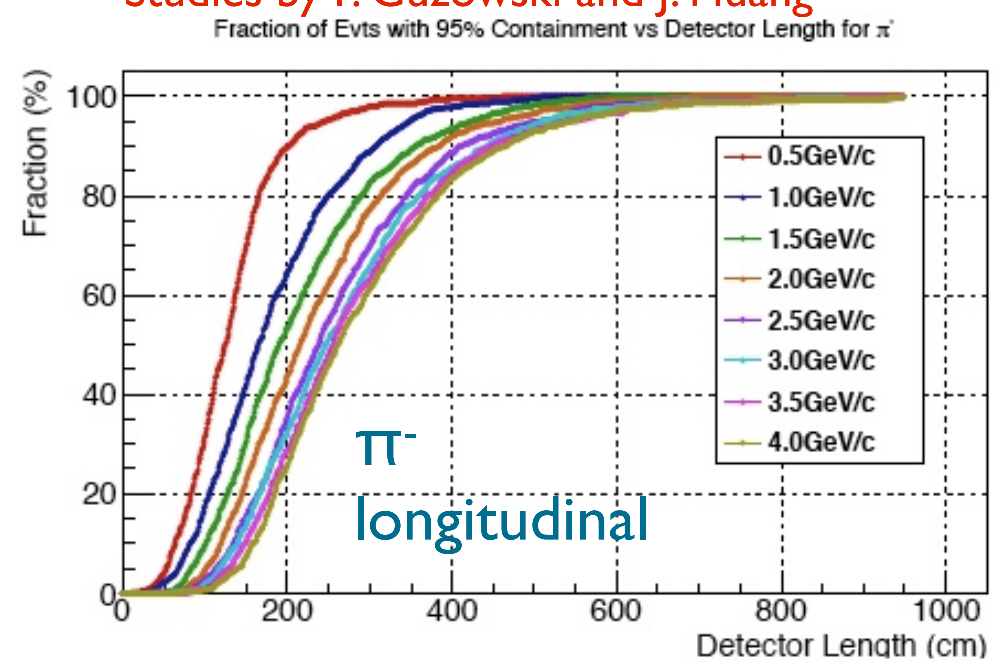


LArIAT Phase 2: TPC Size

- Muons lose 2.2 MeV/cm, hadronic interaction length in LAr is 80 cm, and radiation length is 14 cm
- Hadron containment determines the scale of the detector
- MC studies show that ~2 m diameter will contain 95% of total energy for at least 20% of the interactions from 0.5 - 4 GeV pions
- Length should be ≥3 m for similar containment in that direction
- Costs and hall size combined with containment indicates TPC be on the scale of 2m x 2m x 3m
- Make cryostat longer for upgrades



Studies by P. Guzowski and J. Huang



The Facility

Phase 1 Filter

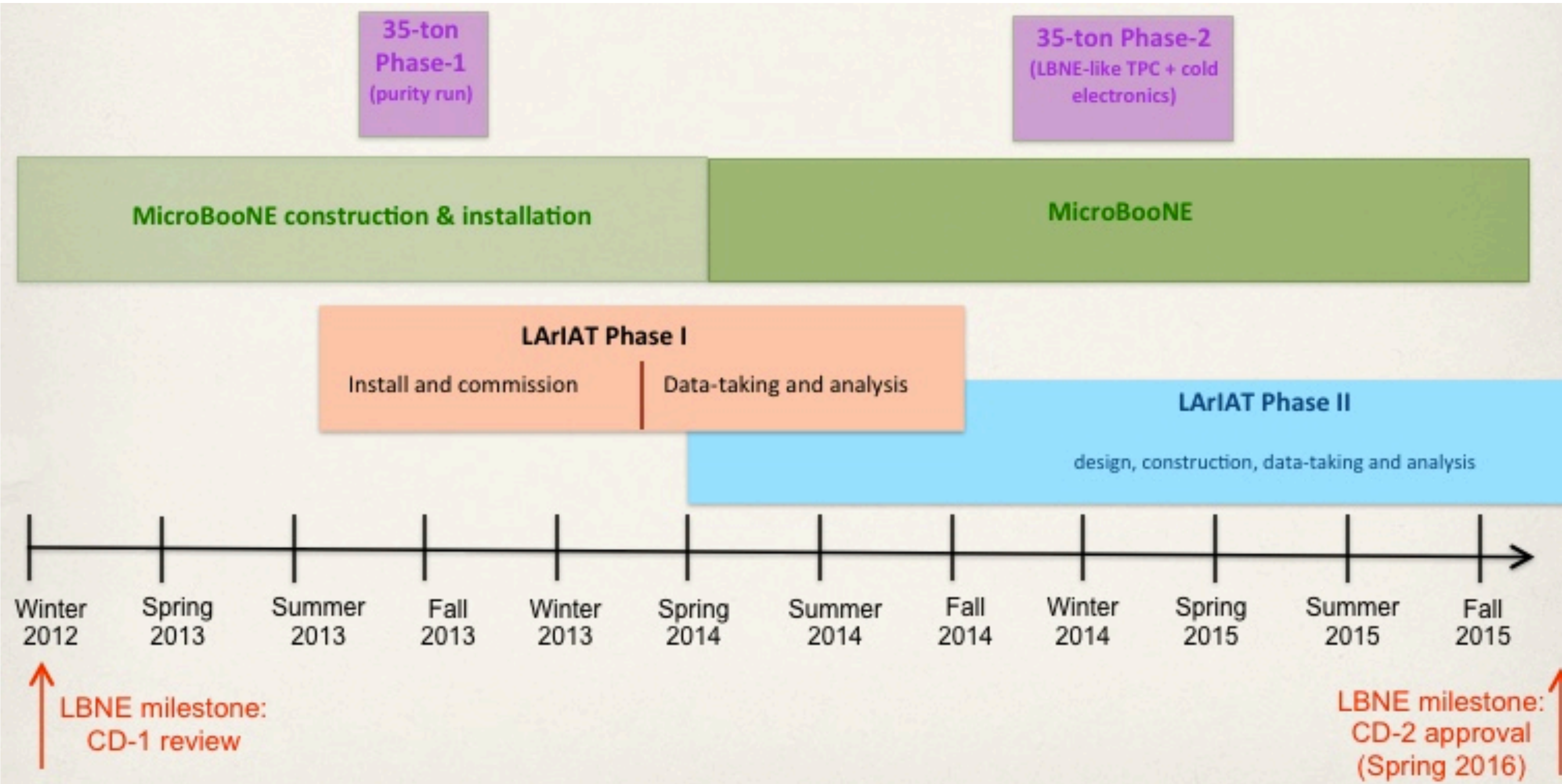
LAr Pump

- Fermilab providing the facilities, other groups provide the active detectors
- Beam line design is underway, first beam sent to MC7 since MIPP
- Filtration and pumping system will be appropriately sized to the volume of LAr for both phases: pump and initial filters on hand
- Phase 2 cryostat will allow convenient access to inside of vessel
- Imagine exchanging electronics, light collection systems, TPCs, etc during several year program

LArIAT Physics Program

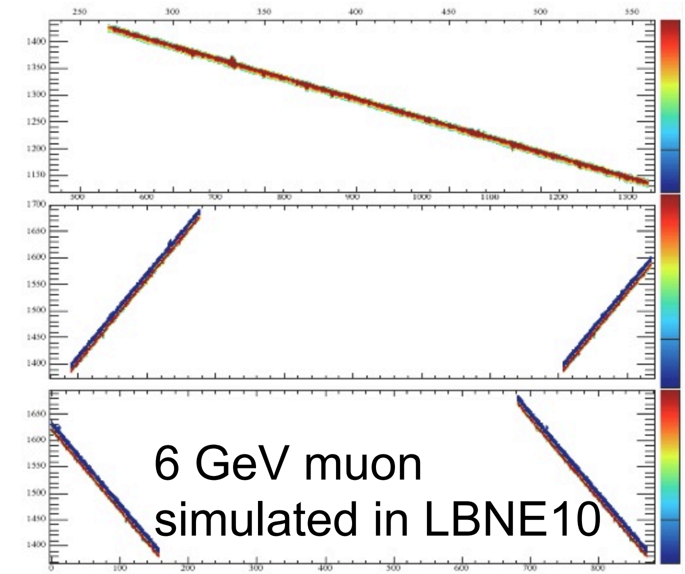
- Measurements to be made include
  - EM shower energy resolution (Phase 1, Phase 2)
  - Hadronic shower energy resolution, visible vs invisible energy (Phase 2)
  - Directionality of through going particles using delta rays (Phase 2)
  - Particle identification (Phase 1 and Phase 2)
  - dE/dx for several particle species (Phase 1 and Phase 2)
  - Light collection efficiency (Phase 1 and Phase 2)
  - Surface operation in a high cosmic ray rate environment (Phase 2)
  - Studies of proton decay backgrounds (Phase 2)
  - Diffusion studies over long drift distances (Phase 2 and beyond)

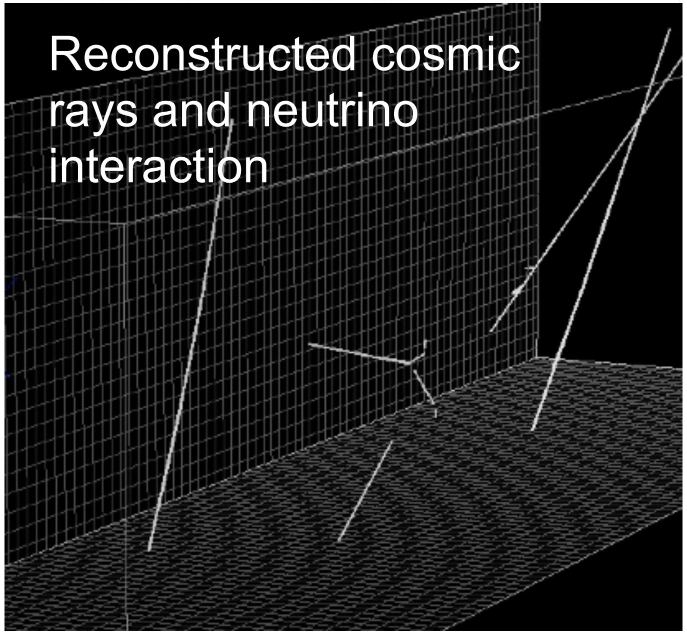
LArIAT Timeline



LArSoft

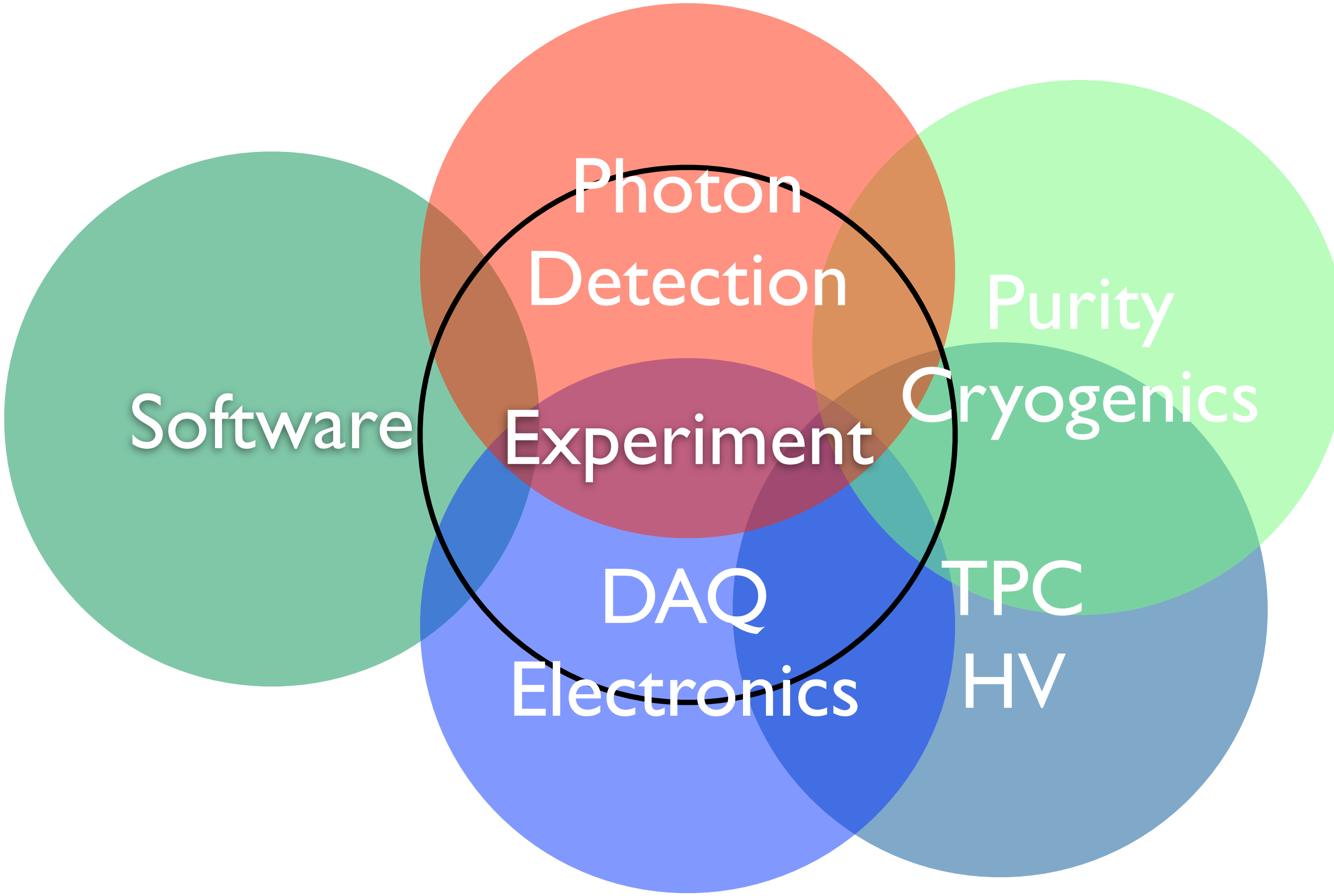
- LArSoft is a simulation, reconstruction and analysis framework for any LArTPC
- Goal is to have a fully automated simulation and reconstruction for any LArTPC
- LArSoft leverages the efforts of a variety of experiments into a single product
- Lots of effort - between 125 and 250 commits to code each month over last year
- LBNE and MicroBooNE becoming primary contributing experiments
- Now managed by Fermilab Scientific Computing - major step forward in the project





LArSoft Documentation at https://cdcvs.fnal.gov/redmine/projects/larsoftsvn/wiki

Bringing it all Together



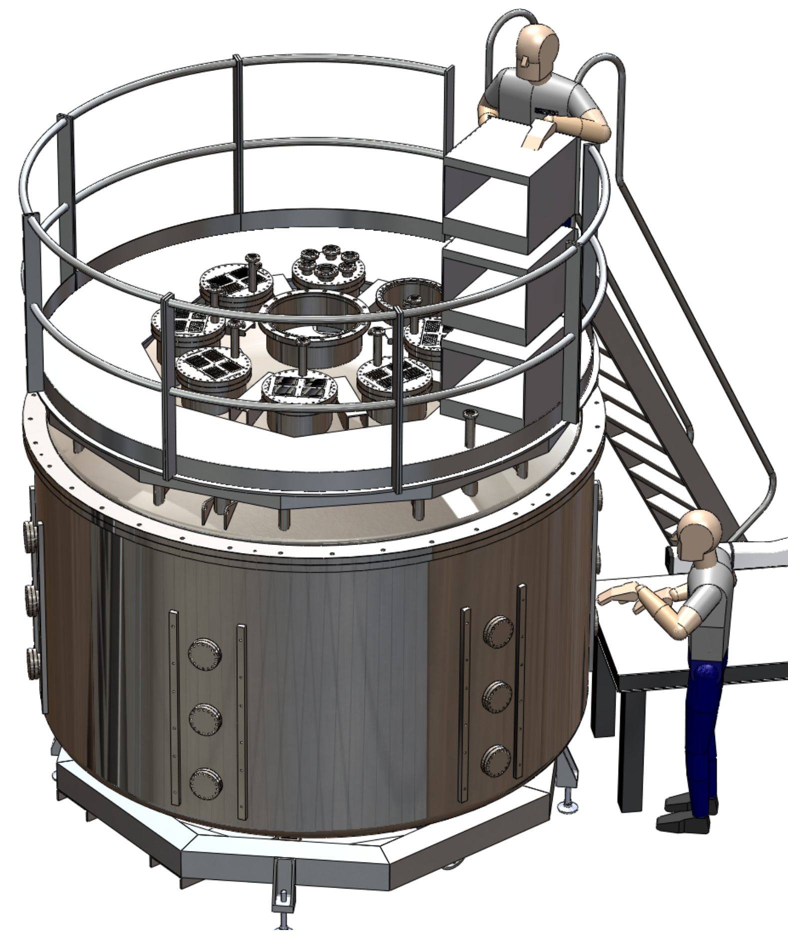
- The Fermilab LArTPC R&D is very successful - built on experience abroad and developed into a world class program
- Each area of development informs multiple other areas; new efforts emerging and older efforts being phased out
- Experiments, large scale or test beam, sit at the center of the process

Summary

- Fermilab has dedicated program to make multi-kiloton scale LArTPCs
  - Detector R&D Advisory Group continues to facilitate the program
  - LAPD has shown that electron lifetimes of > 5 ms can be achieved without evacuation and in the presence of a TPC, will stop running in FY13
  - Priorities going forward are high voltage, light collection and test beam
- Fermilab is actively coordinating community efforts in LArTPC development
  - Organization of workshops to make community aware of important issues and where to place new effort
  - Provides resources and facilities for testing new ideas
- The program is world class and is providing key steps on the way to
  - Large neutrino detectors for LBNE and beyond
  - Dark matter experiments

LArIAT and CAPTAIN

- CAPTAIN is an LANL LDRD funded program
- Measurements are complementary to LArIAT
  - Empirical muon capture signals
  - Spallation backgrounds, low energy particle identification, optical photons vs. ionization
  - spallation studies using LANL neutron beam
  - running in neutrino beam at ORNL (SN neutrino energies), possibly FNAL (NuMI medium energy tune)
- LArIAT will provide calibrations for neutrino beam running, CAPTAIN will provide information for astrophysical neutrinos



CAPTAIN

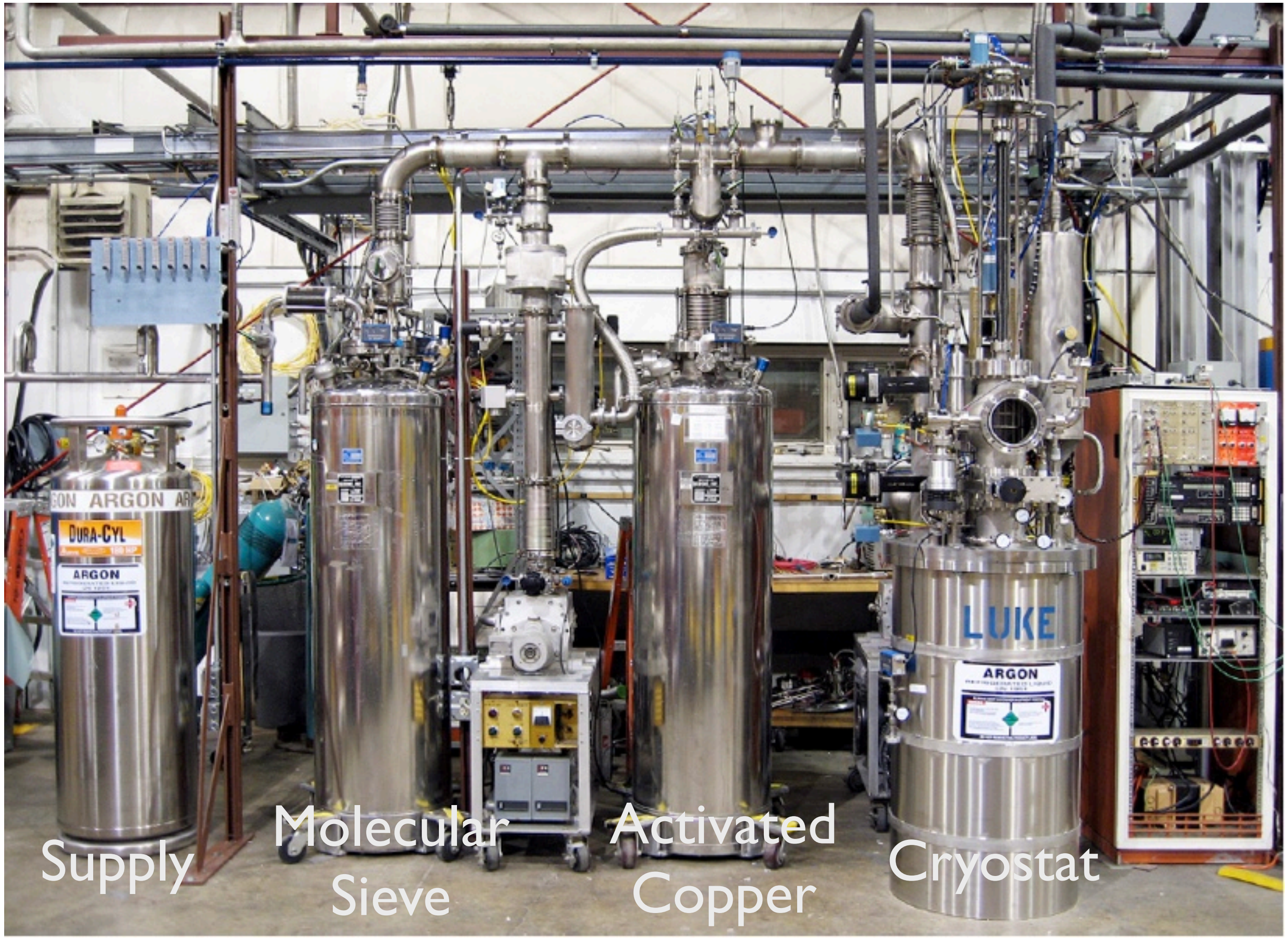
Community Coordination

- **Formation and function**
  - The CPAD would be initiated under the auspices of the DPF Executive Committee
  - The CPAD would not be managed by any national laboratory, the DPF or the funding agencies. (i.e. self-organized)
  - However, the CPAD would inform the laboratories, the DPF Executive Committee (or designated individuals), the funding agencies and the community at large of its work on a regular basis.
- **Membership of CPAD:**
  - One representative from each of the five HEP national laboratories (ANL, BNL, FNAL, LBNL and SLAC); appointed by the labs
  - At least an equal number of representatives from the university community; appointed by DPF
  - Observers from outside the U.S.; appointed by DPF

Fermilab Program for Understanding Purity

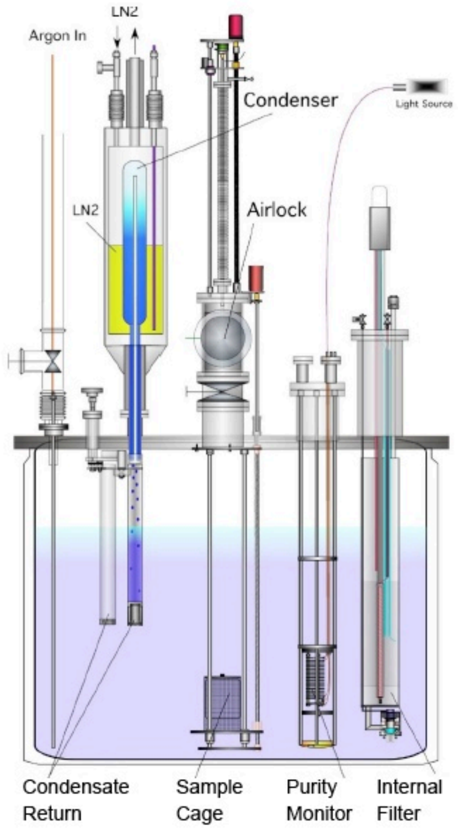
- The mantra is to learn and keep learning from existing systems, like ICARUS
- In addition, we want to develop experience with filters, cryogenics, pumps and electronics
- Use home grown test stands to get the experience and push the development
- Test stands allow us to judge suitability of materials to use in a LArTPC (MTS), and understand how to achieve large drift lifetime without evacuation

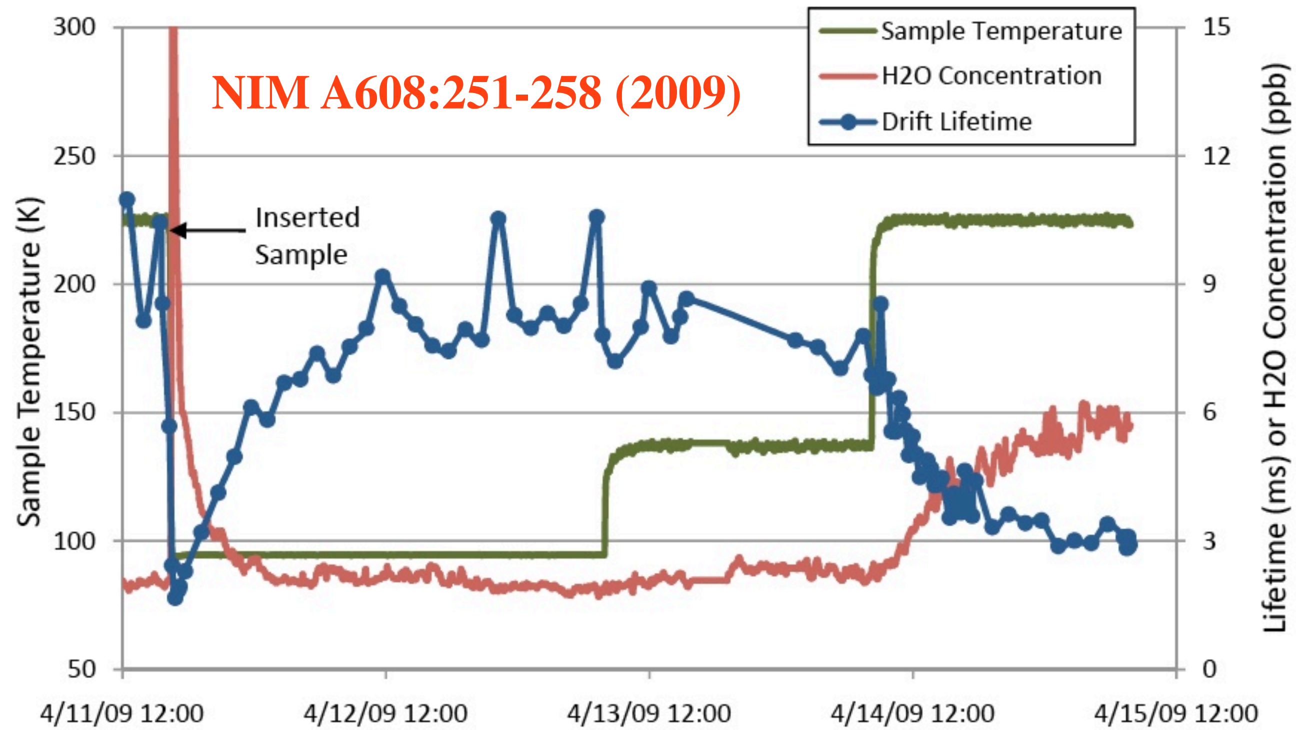
Materials Test Stand (MTS)



- Goals are to develop purification techniques and qualify materials that are intended for use in LArTPCs
- Commercial LAr passes through molecular sieve to remove water then activated copper to remove oxygen

Primary Results from the MTS





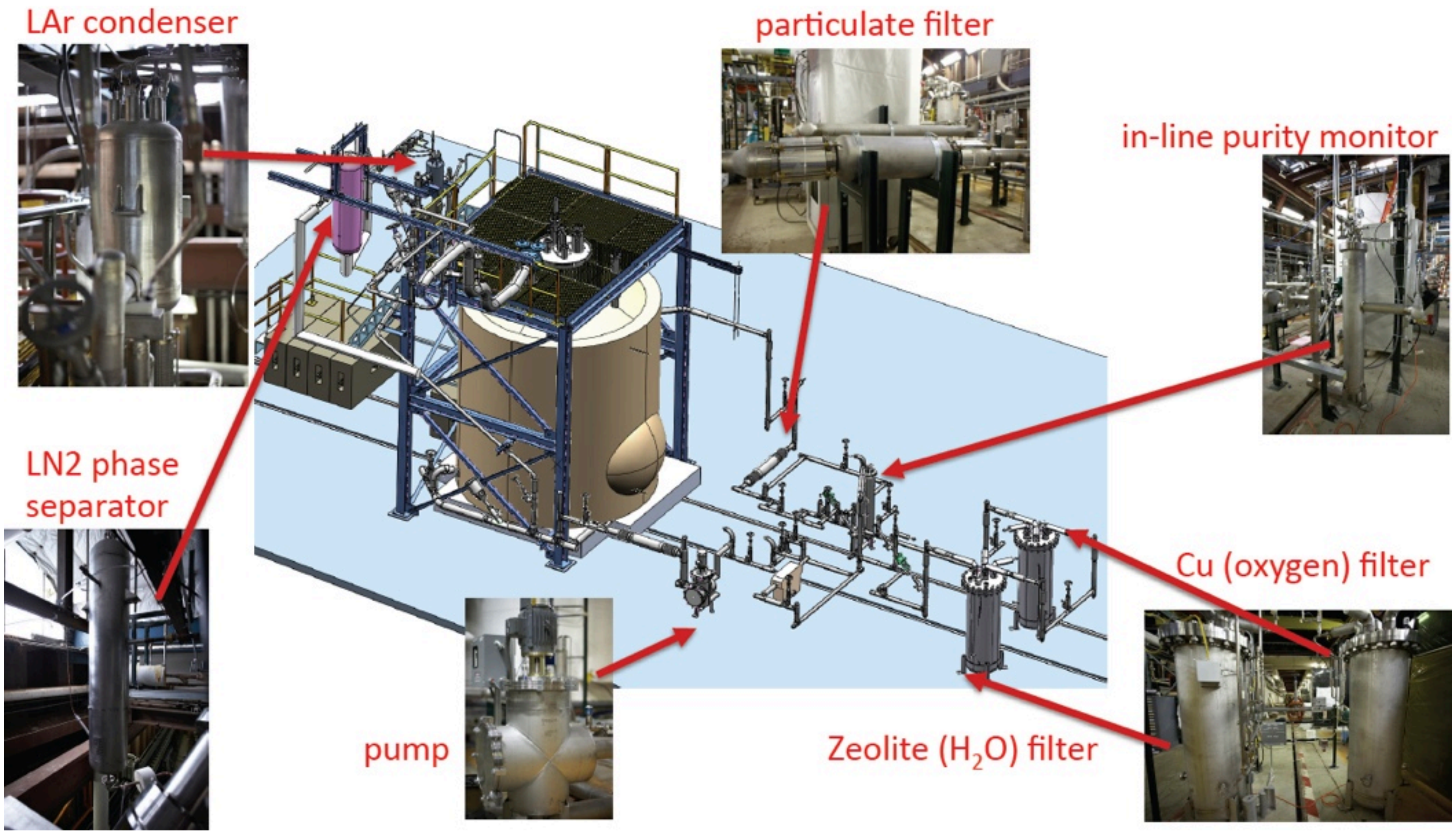
- Direct relation between electron lifetime and water concentration
- Water concentration in vapor space influenced by materials in vapor space
- No change in electron lifetime when materials are in liquid
- Condensed LAr should not be returned directly to the bulk liquid

Data from Various Materials

Material	Date test started	Preparation	Tests	Water [ppb]	Lifetime [ms]	LogBook #
Cleaning Solution	6/29/09	evac. 24 h	vapor/liquid	4	5	946
Vespel	7/9/09	evac. overnite	liquid/vapor	5-7	2-5, 4-6	960
MasterBond glue	7/16/09	purged 18 h	vapor/liquid	1.6	1.3- 2.9	974
LEDs	7/31/09	purged 38 h	vapor	3.5	5	993
Carbon filter material	8/12/09	evac. 24 h	liquid/vapor	2	4-9	1000
962 FeedTru Board V2	10/12/09	evac. 24 h	vapor/warm	85	1-5	1062
Teflon cable	1/9/10	purged 28 h	warm/liquid/vapor	8-20	2-5	1175
3M "Hans" connectors	1/29/10	purged 46 h	warm/liquid/vapor	5-12	3	1198
962 capacitors	3/2/10	evac. 24 h	warm/liquid/vapor	6-14	3-6	1228
962 polyolefin cable	4/12/10	evac. 16 days	warm	25-60	2	1237
Rigaku feedthrough	4/20/10	purged 7.5 h	warm	15	3	1250
Rogers board (Teppei)	4/23/10	purged 26 h	warm/liquid/vapor	40	2, 6-10	1254
Arlon Board (Teppei)	5/14/10	evac. 0.5 h, pur.2 days	warm/vapor	300, 80	1.3, 3.5	1263
Polyethylene tubing	5/24/10	evac. 6 h, pur. 66 h	warm	300-500	1	1278
Teflon tubing	5/27/10	evac. 1 h, pur.17 h	warm	9-13	4-5	1283
Jonghee board	5/28/10	evac. 6 h, pur. 1.5 h	warm/vapor	100,28	1.2, 5-8	1285
Jonghee connectors	6/4/10	evac. 3.5 h, pur. 16 h	warm/vapor	50	2-3	1290
PVC cable	6/14/10	evac. 29 h, pur.1 h	warm	120	1-2	1296
Teppei TPB samples	8/3/10	purged 26 h	warm	600-1600	0.7	1342
Teppei TPB samples	9/4/10	purged 37 h	liquid /vapor	15, 300	6	
PrM feed tru (baked)	10/5/10	purged 25 h	warm/vapor	35, 20	3, 2	1396
Copper foil on mylar film	10/14/10	purged 26 h	warm/liquid/vapor	15, 10, 9	3, 8, 7	1409
Teppei SHV connector	10/25/10	purged 25 h	warm/vapor/liquid	35, 11, 0	2, 6, 6	1415
FR4	11/16/10	purged 25 h	warm/liquid/vapor	180, 20, 65	1.5, 6, 2.5	1429
Gaskets	3/11/11	purged 24 h	warm/liquid/vapor	8, 10	2.5, 8 , 7	1521
LBNE AP-219 Color. Developer	4/13/11	purged 25 h	warm/vapor	65, 15	4, >6	1722
LBNE RPUF Foam	4/22/11	evac. 26 h, pur.1 h.	warm	800	0.2	1729
LAPD LEDs	5/12/11	purged 49 h	vapor	0.6 ppb	10	1769

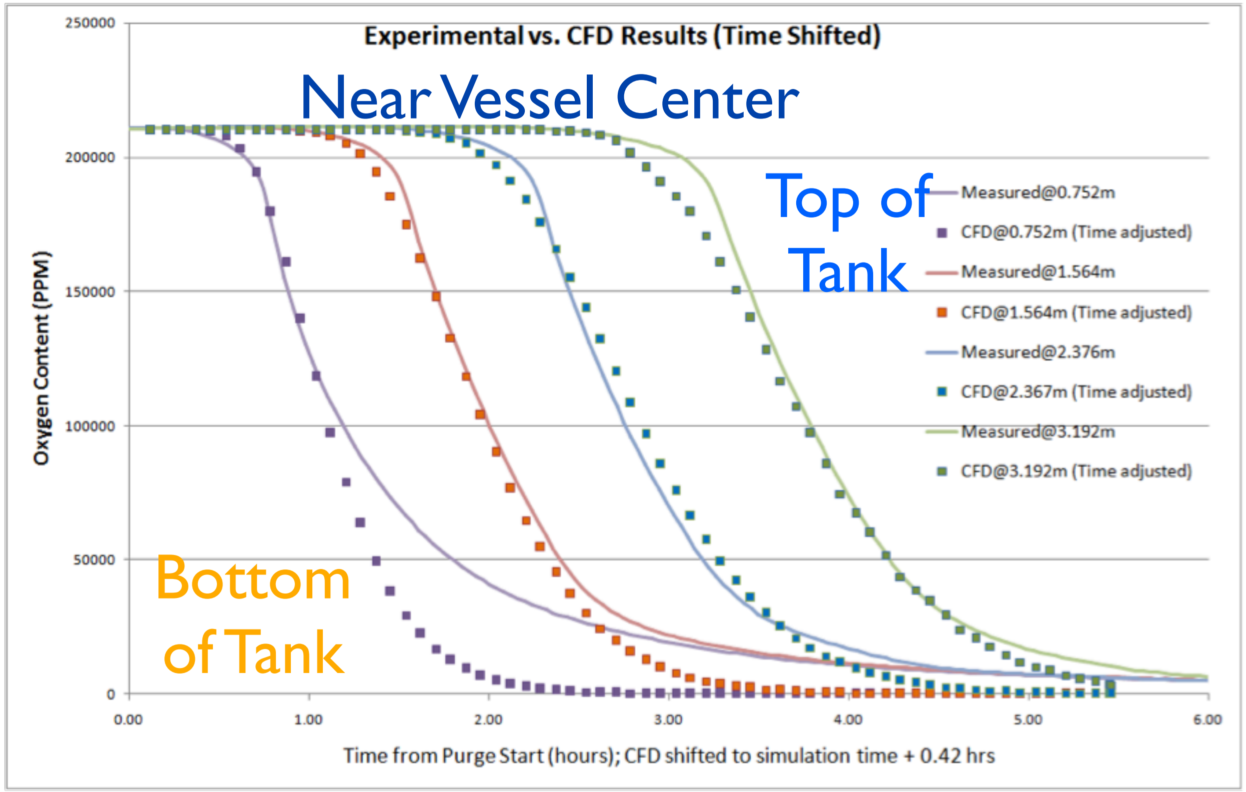
- Significant correlation with data in water-content database at outgassing.nasa.gov
- FR4 is fine to use in the liquid, don’t place it in warm gas
- Teflon tubing is far superior to polyethylene tubing

Liquid Argon Purity Demonstrator



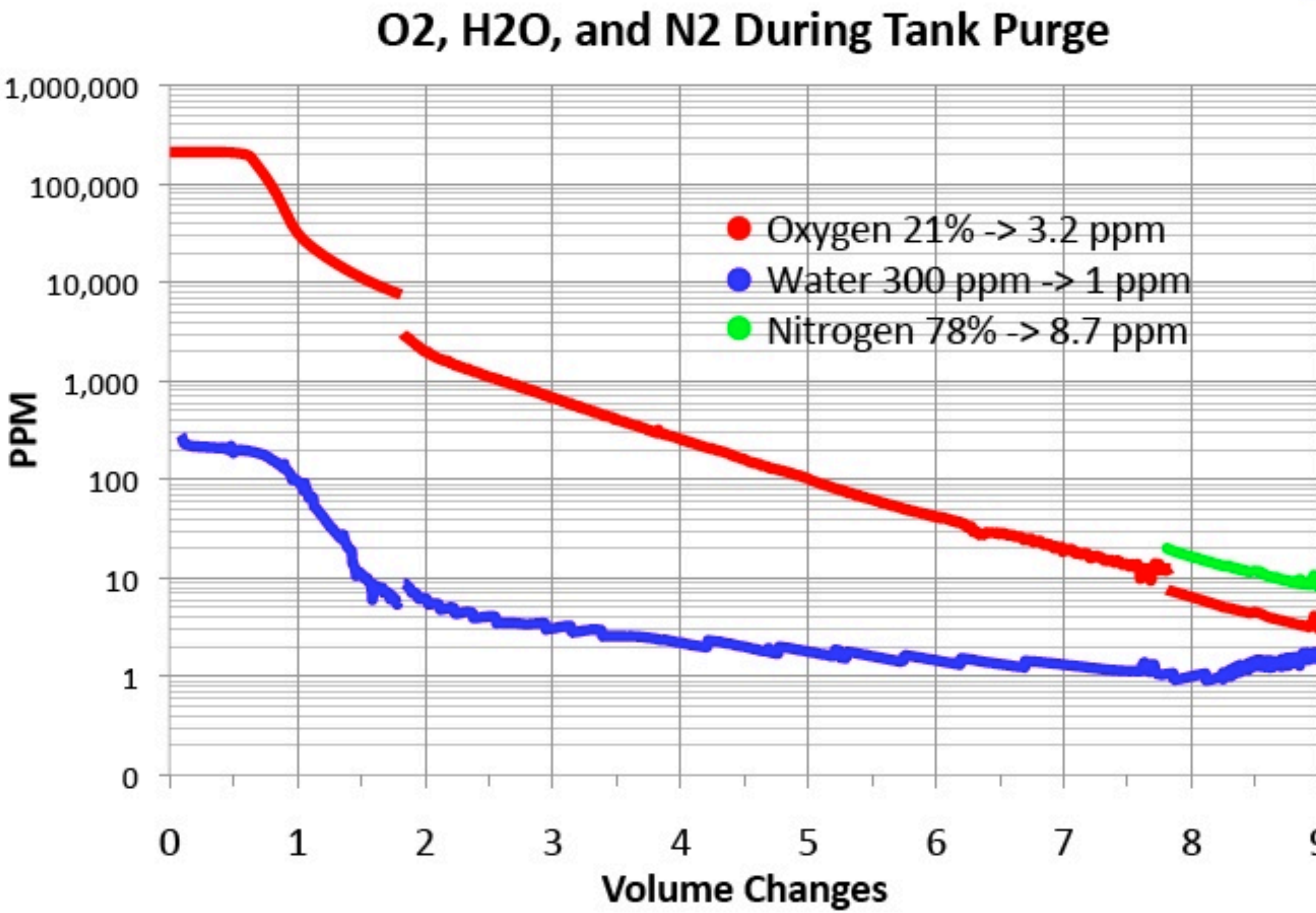
- Primary goal: show required electron lifetimes can be achieved without evacuation in an empty vessel using gaseous argon purge, followed by gaseous argon filtration, followed by liquid argon fill and filtration

Gaseous Argon Purge

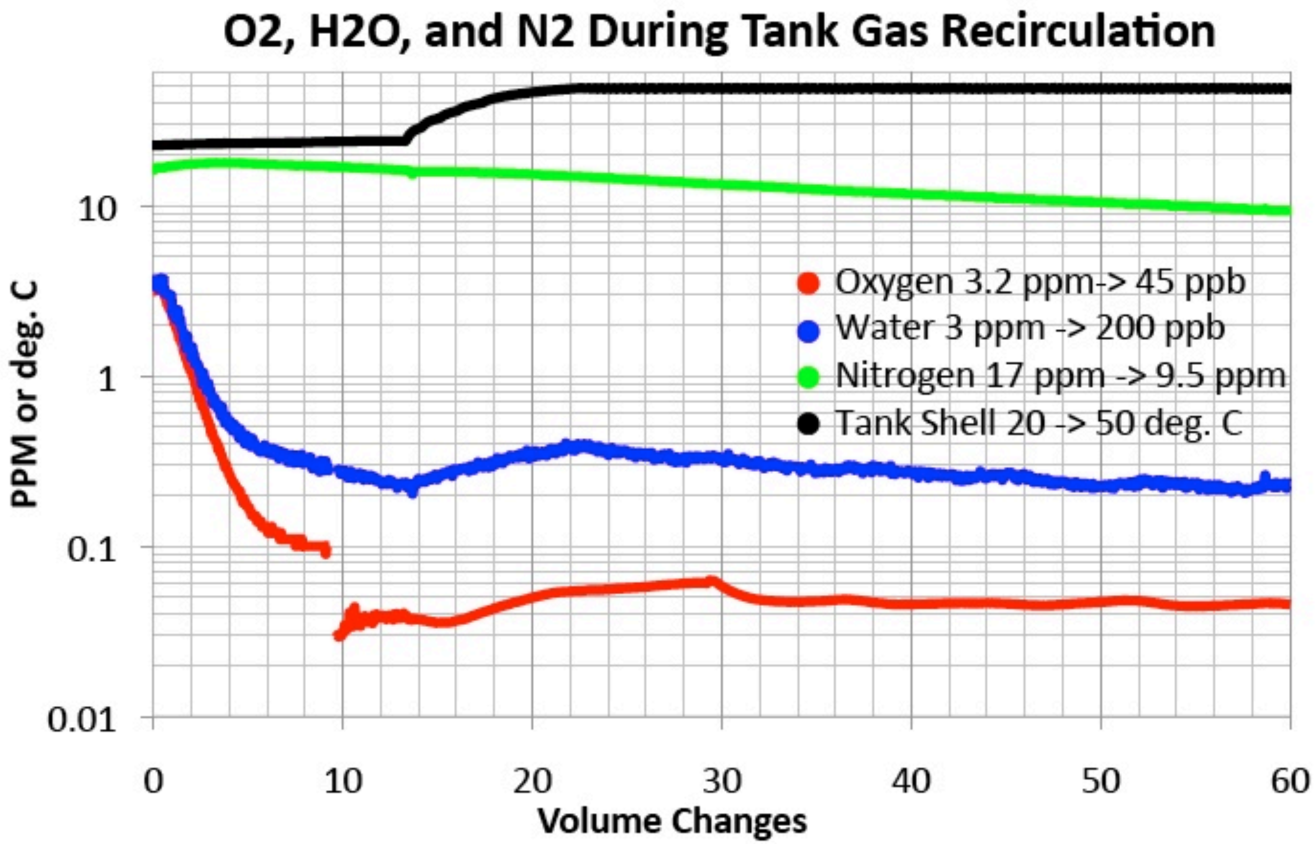


- Set of sniffer tubes monitored the oxygen content of the gas inside the vessel at various depths throughout the purge
- Plot shows the content relative to the pre-purge state of the tank in solid lines
- Clear front of argon gas moving through the vessel
- Comparison to calculations (points) shows good agreement, aside from some discrepancy in time that is likely due to 3D flow and mixing as argon gas is forced into the bottom of the tank

Gaseous Argon Purge



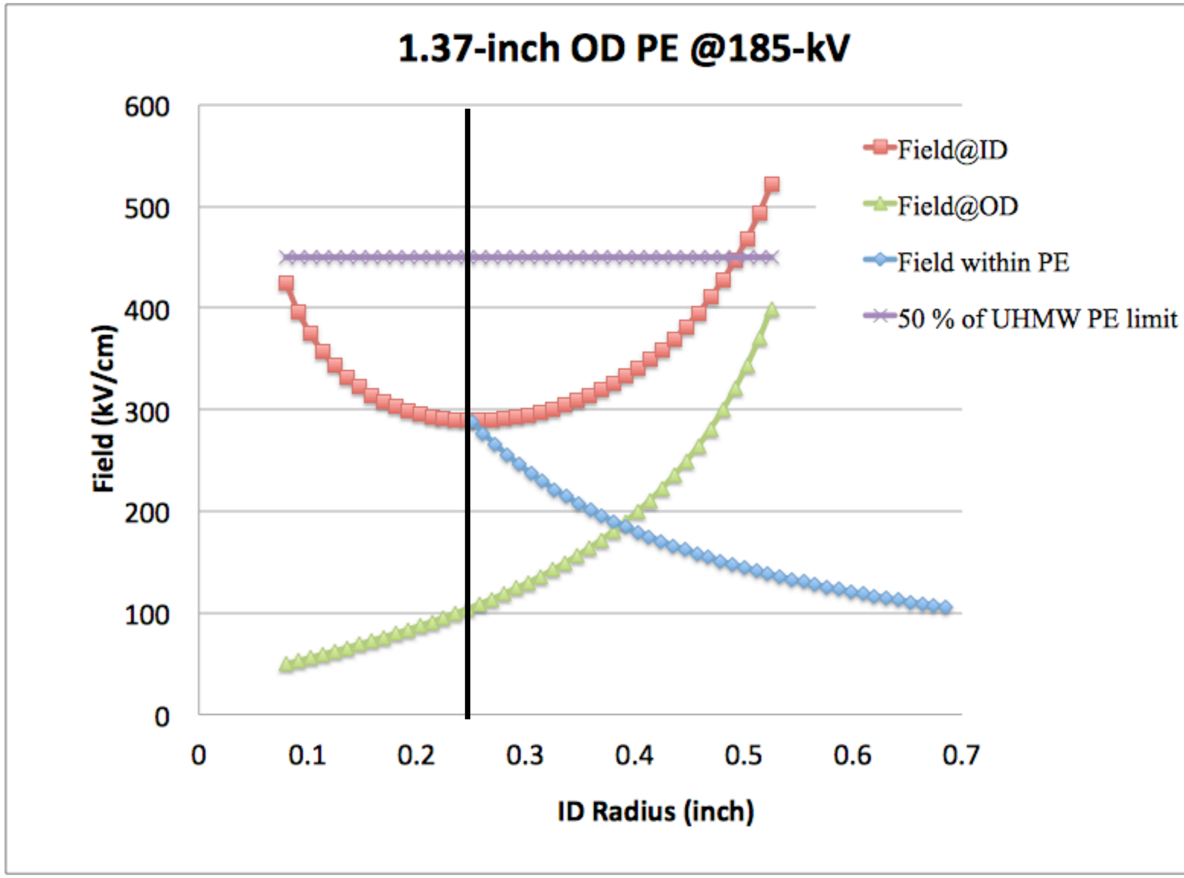
Gaseous Argon Recirculation



- The purge was very successful and brought the vapor in the tank to a contamination level that was below the specifications for the delivered liquid
- Both O_2 and H_2O contamination were well below 1 ppm after 3 volume exchanges
- Maintained sub-ppm levels in the gas for over 20 days
- Heating the tank shell allowed more contamination to be “baked” out

Geometry Design Considerations

- At a given outer diameter, (OD) there is an optimum inner diameter (ID) to minimize field strength on the ID surface
- Optimal ID for a 1.37 inch OD is 0.5 inch
- Blue points show field within the polyethylene (PE)
- Purple line shows 50% of dielectric strength for ultra-high molecular weight PE
- Tip geometry, TPC design and connection details also important to determining limiting HV for feedthrough



H. Wang, A. Teymourian (UCLA)

Filtering

- Ripples from the HV power supply will induce charge pick up by the readout electronics
- Electronics and TPC geometry will determine requirements on allowed level of ripple
- Plot shows voltage ripple for different load resistors, 0.001% peak to peak ripple
- MicroBooNE design 0.03% ripple

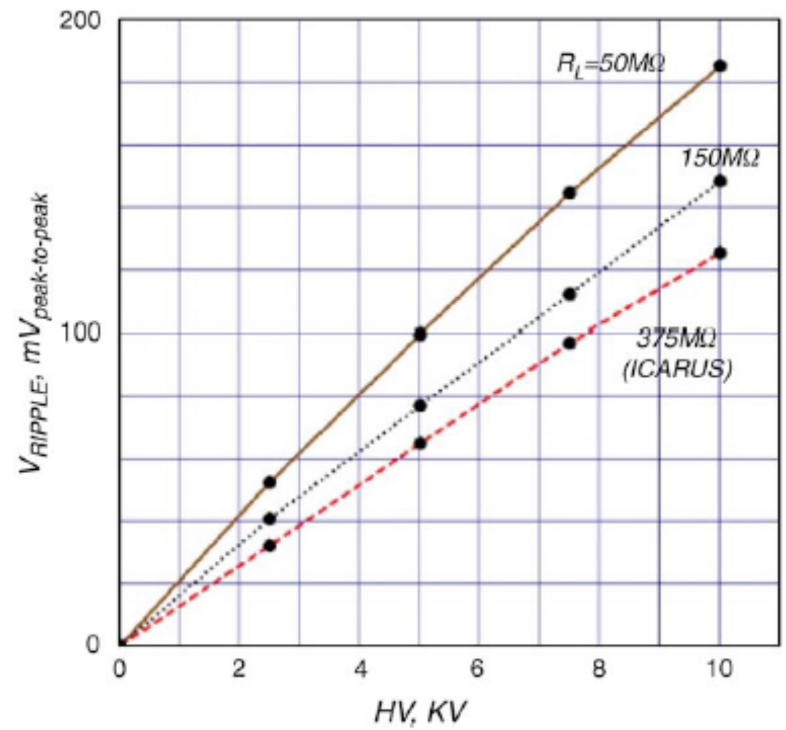


Fig. 41. Dependence of the voltage ripple (peak-to-peak) on the HV for different load resistors. (a) Solid line: $R_L = 50$ MΩ; (b) dotted line: $R_L = 150$ MΩ; (c) dashed line: $R_L = 375$ MΩ (T600 working conditions).

ICARUS

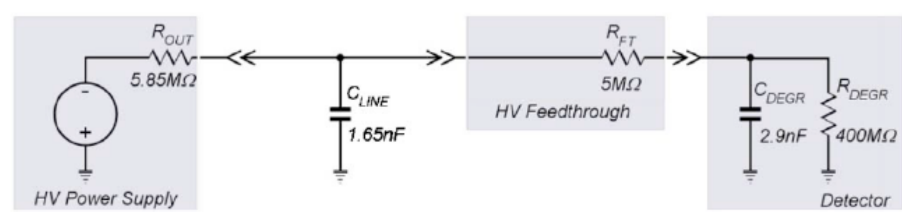
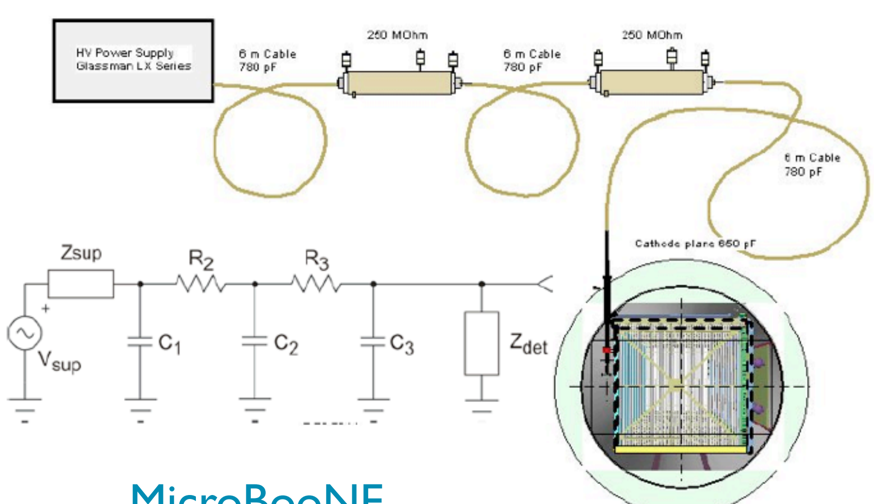


Fig. 42. Electric scheme of the external ripple rejection filter.

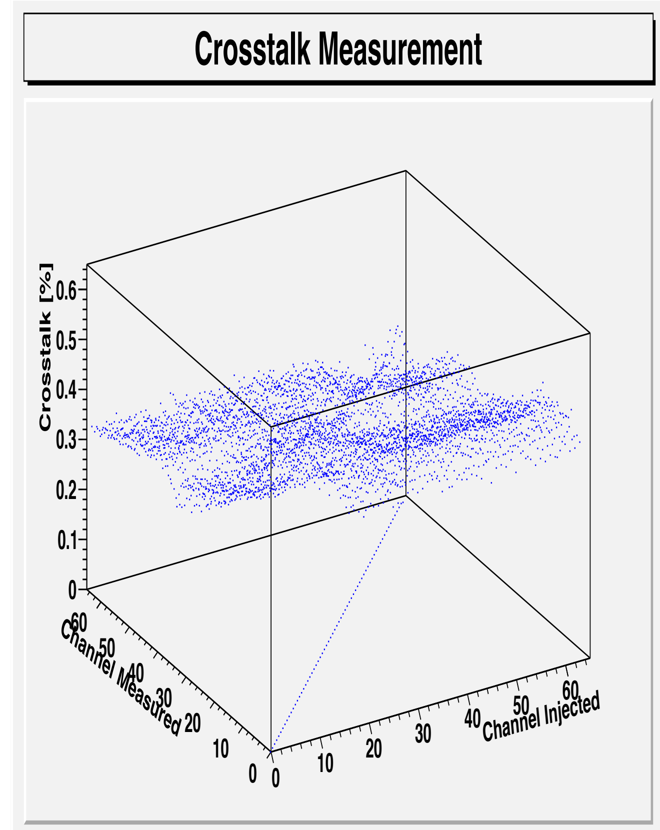


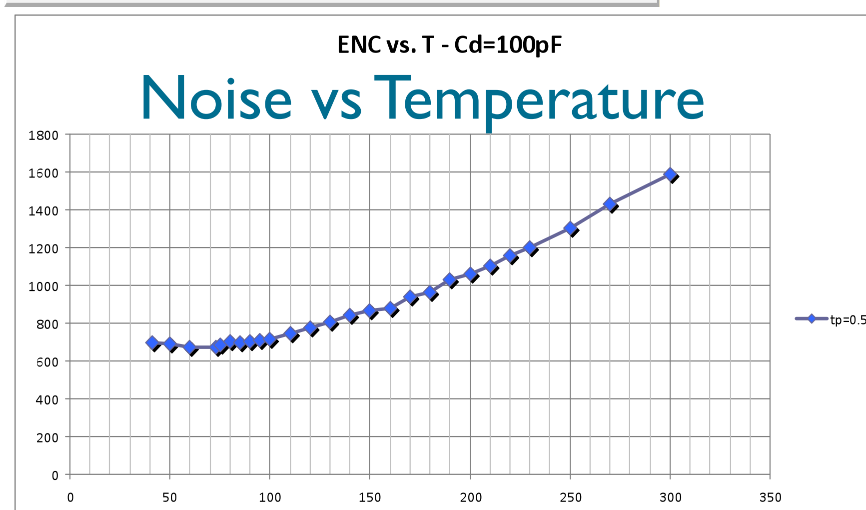
MicroBooNE

Figure 6. The circuit for the HV power supply and filter with the field cage as a load.

μBooNE/LBNE: Cold Electronics

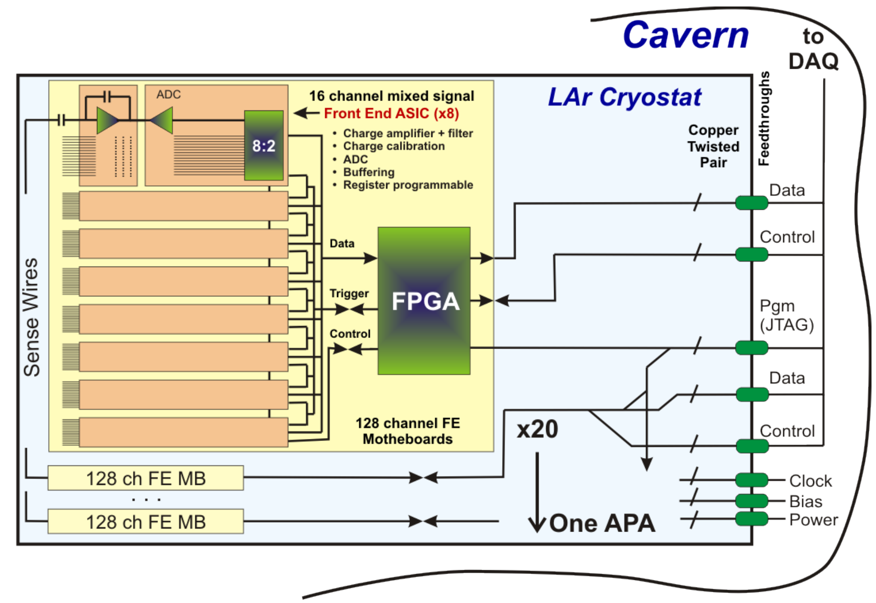
- A primary goal of μBooNE is to understand running cold electronics in a LArTPC
- Electronics are being designed primarily by BNL, will be used in LBNE too
- Tests show
  - Noise at 87k is half that at 300k
  - crosstalk is < 0.3%, gain variations are 7%
- Stress tests also performed show no problems after many immersions in LN_2
- ATLAS and NA48 calorimeters show very low failure rate over many years, designed for > 30 year lifetime

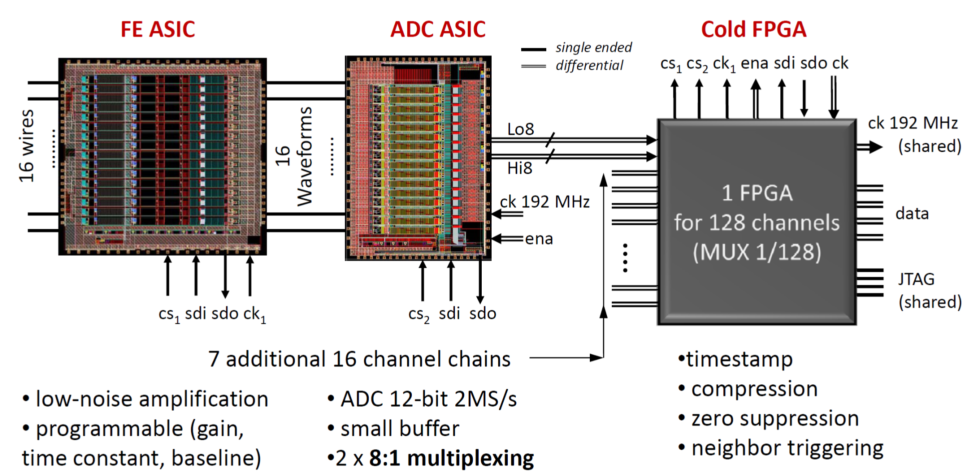




Cold Electronics

- Placing front end chips directly in the LAr minimizes capacitance and noise
- On chip digitization converts analog to digital inside the cryostat
- Multiplex signals to high speed serial link - reduces number of cables and minimizes out-gassing. This approach is important to scaling to large detectors
- Cold FPGA houses flexible algorithms for data processing and reduction
- Can use industry standard serial link to connect directly to back end system, minimizes conventional DAQ hardware





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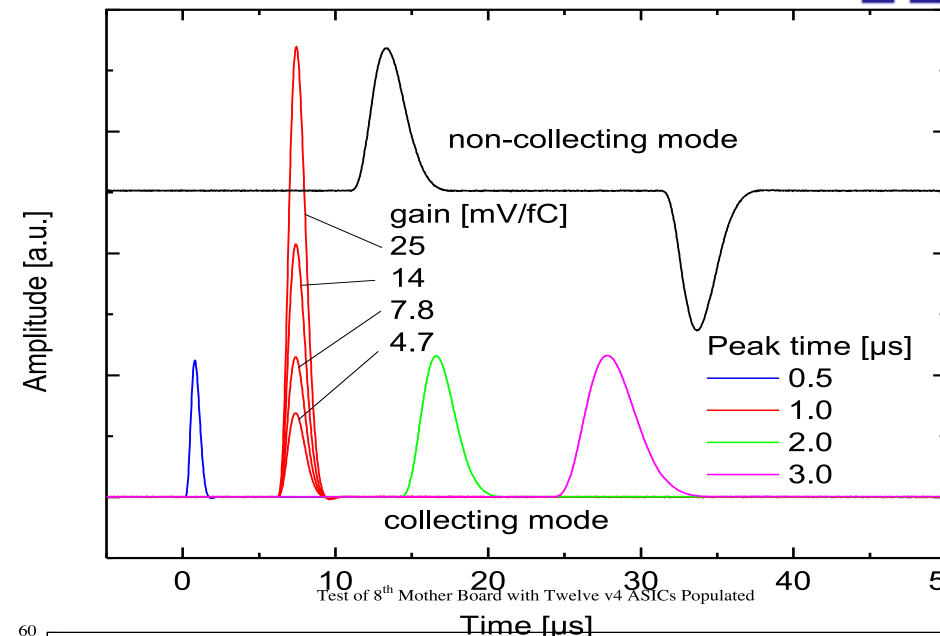
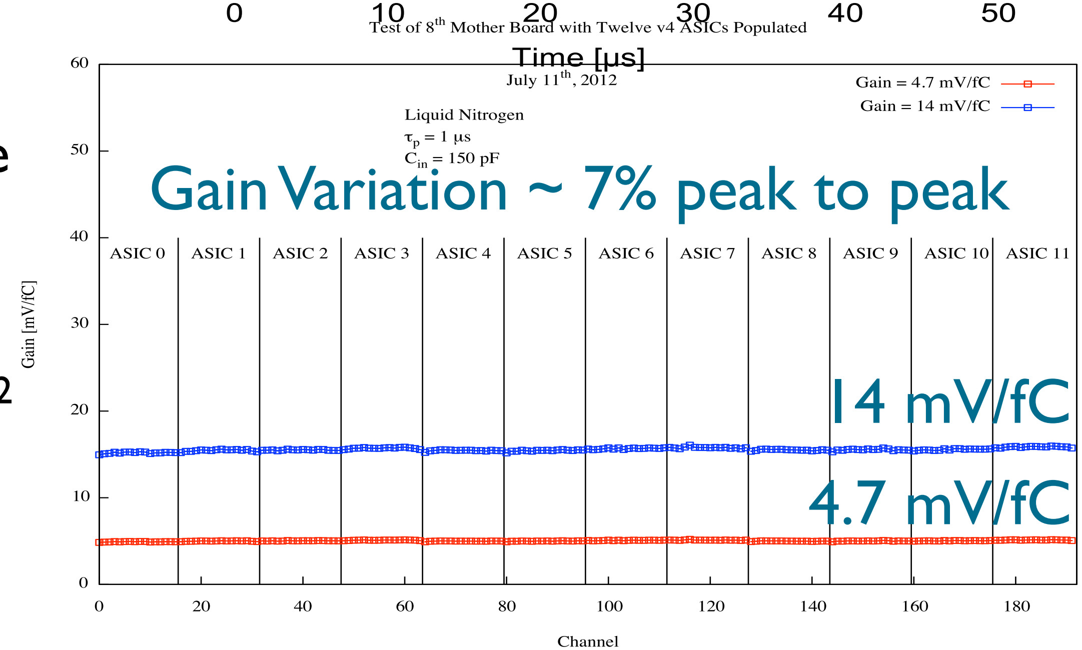




Light Guides

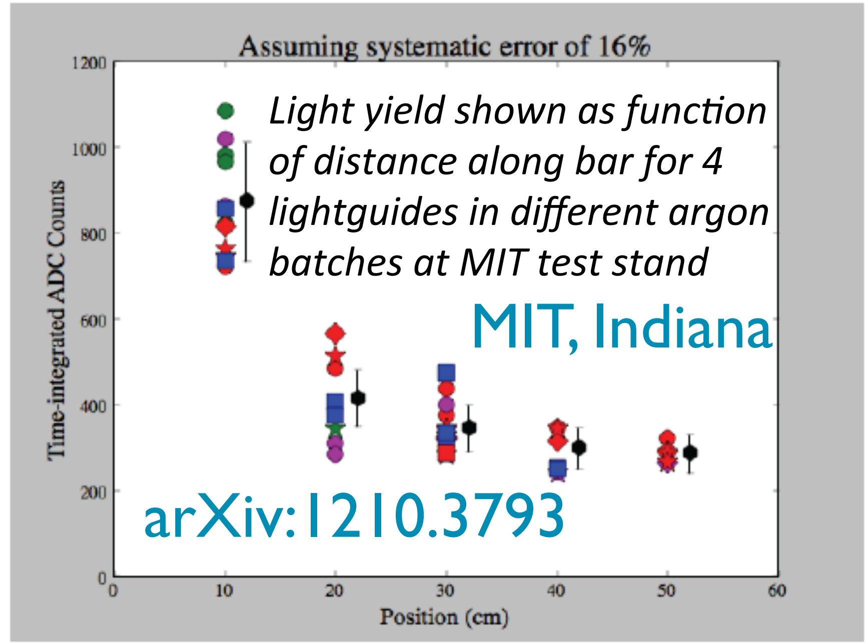
- Options for light collection include placing TBP coated plates in front of PMTs, coated bars as light guides to SiPMs, or wavelength shifting fibers connected to SiPMs

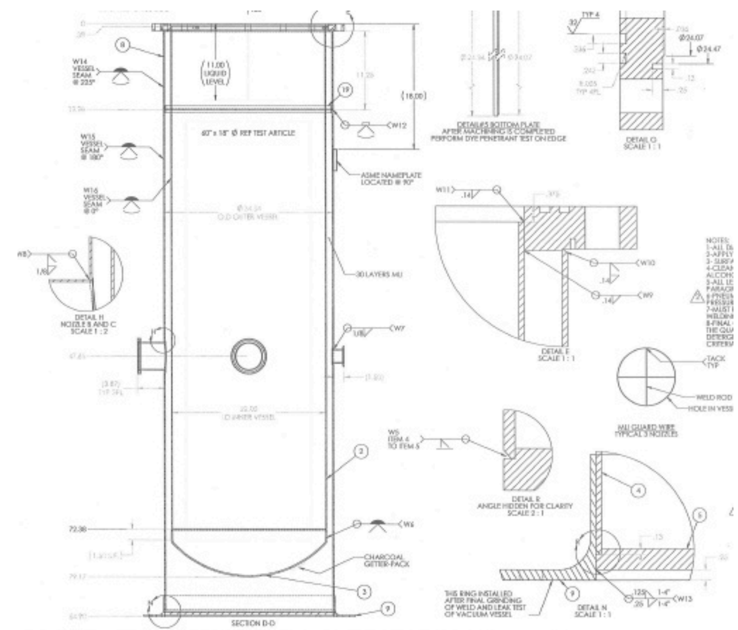
- TPB degrades when exposed to UV light, as does Bis-MSB

- New cryostat for testing various light collection techniques - 22 inch diameter and 60 inch height with argon delivery and filtration

- First customer will be Indiana University to test paddle system for LBNE

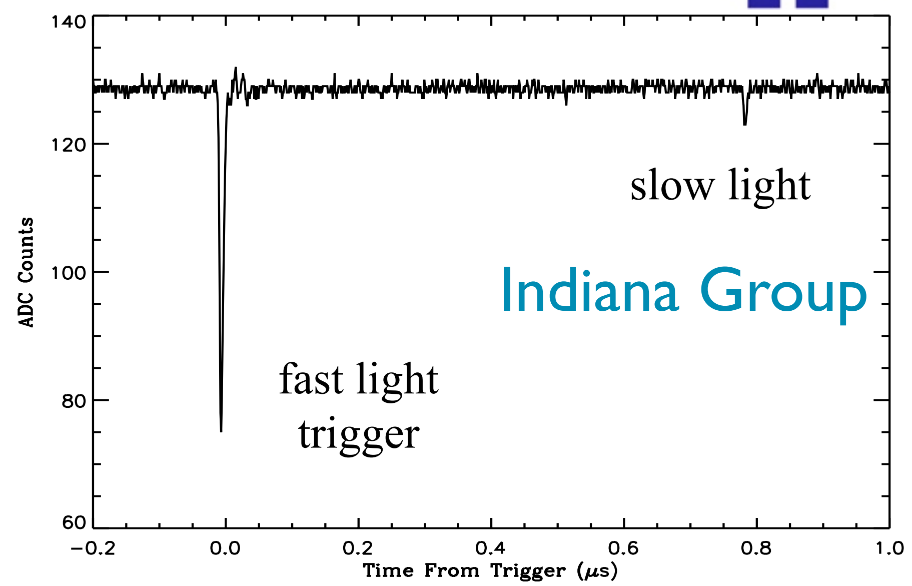
- Can be used to test other techniques like LAPPDs

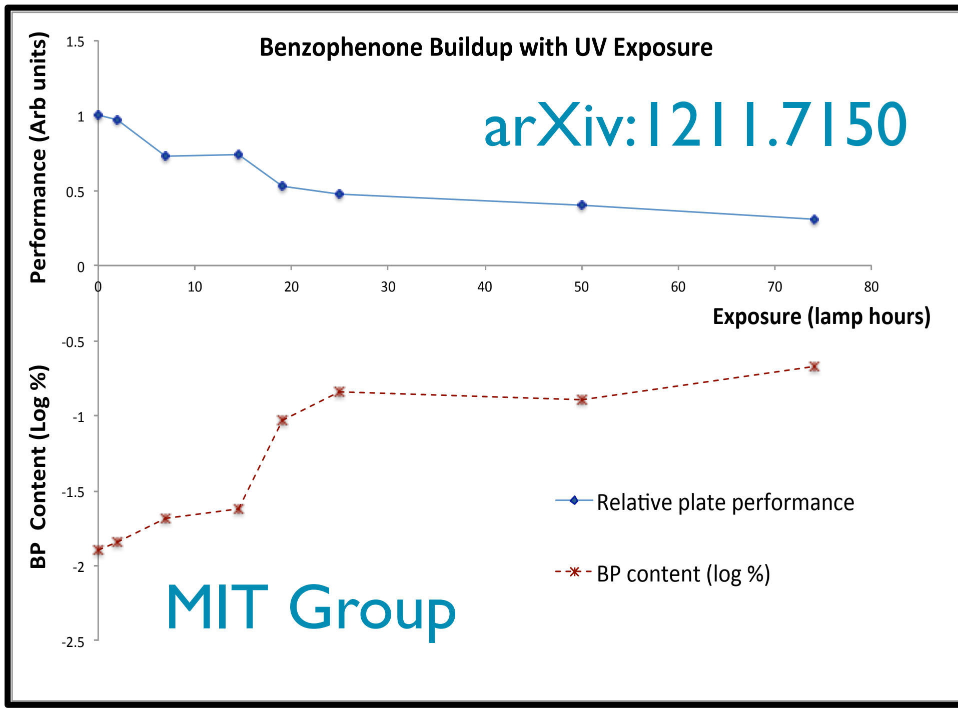


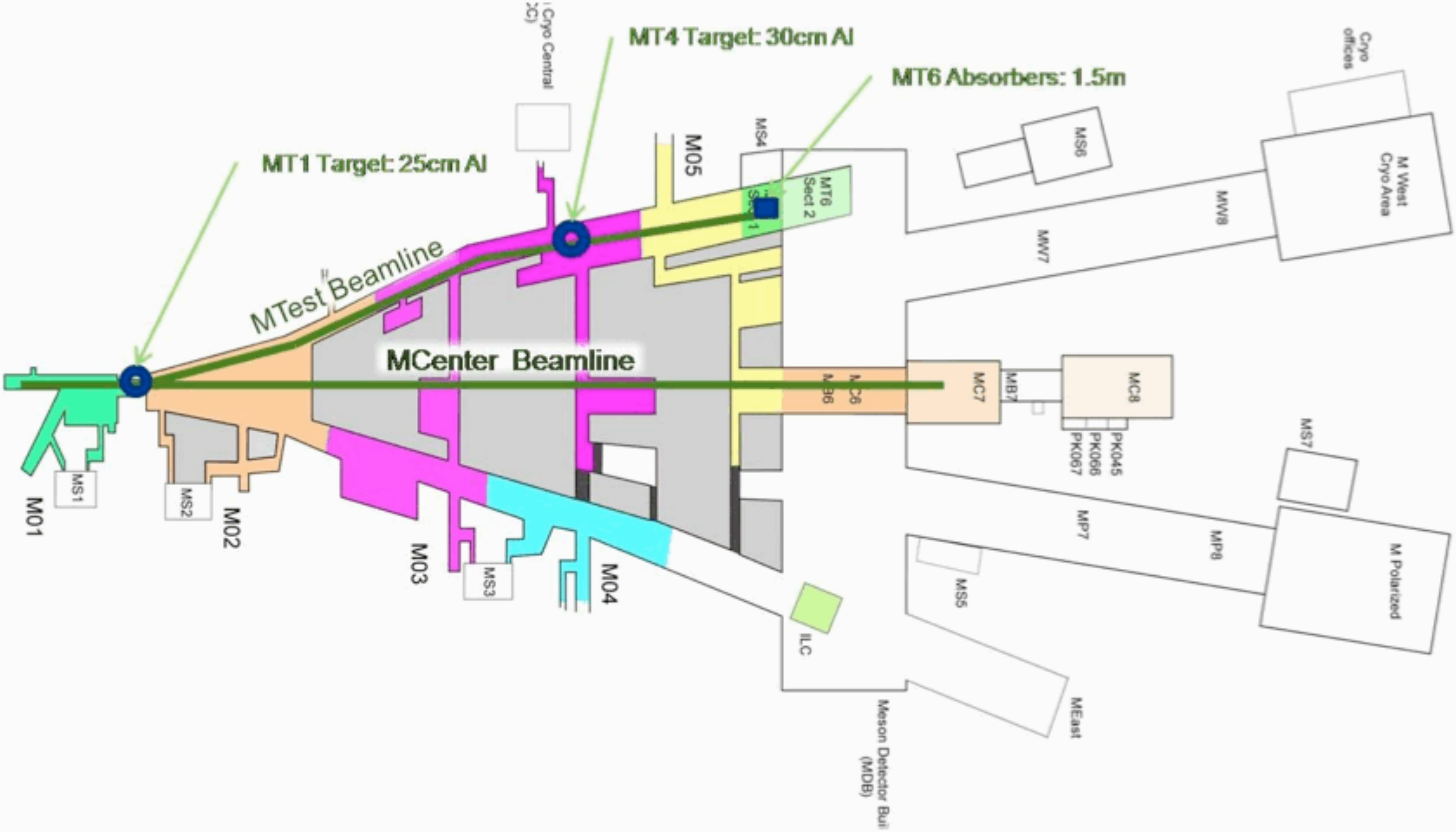


Wavelength Shifting

- The emitted light (128 nm) has to be shifted to a wavelength where light detectors have high quantum efficiency
- Tetraphenyl Butadiene (TPB) shifts the light to the blue (430 nm)
- TPB degrades when exposed to UV light - indicated by rising concentration of benzophenone
- Handling TPB requires care to ensure it still works when installed





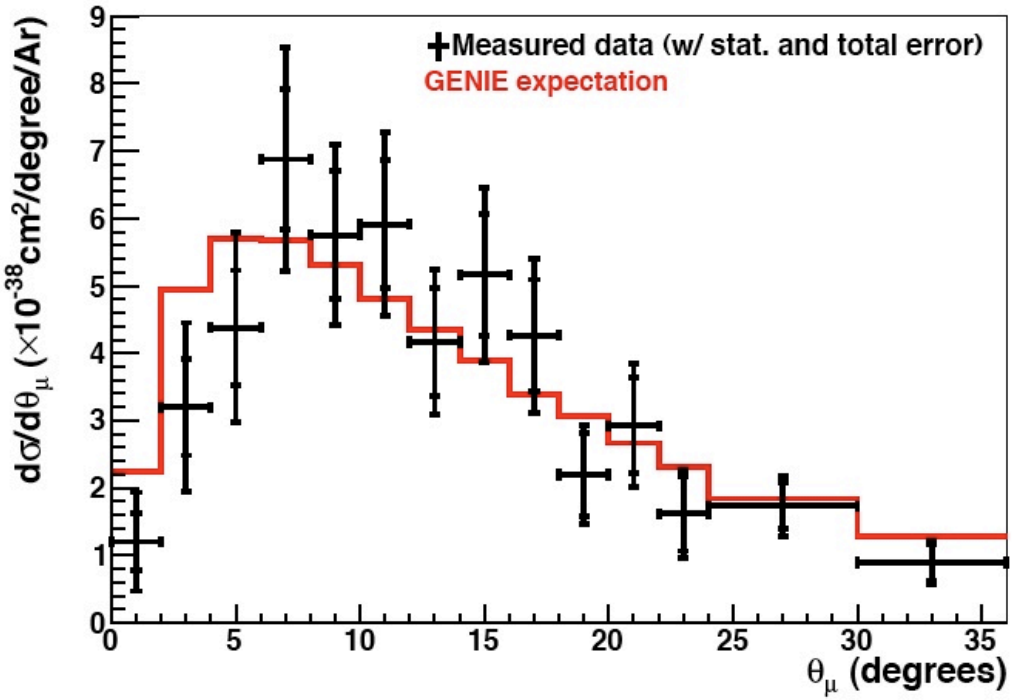

MT1 Target: 25cm Al
MT4 Target: 30cm Al
MT6 Absorbers: 1.5m
MTest Beamline
MCenter Beamline
M01
M02
M03
M04
M05
MS1
MS2
MS3
MS4
MS5
MS6
MS7
MT6 Sect 2
MC7
MC8
MB7
PK045
PK066
PK067
MW7
MW8
MP7
MP8
M West Cryo Area
M Polarized
MEast
ILC
Meson Detector Bui (MDB)
Cryo offices
Cryo Central

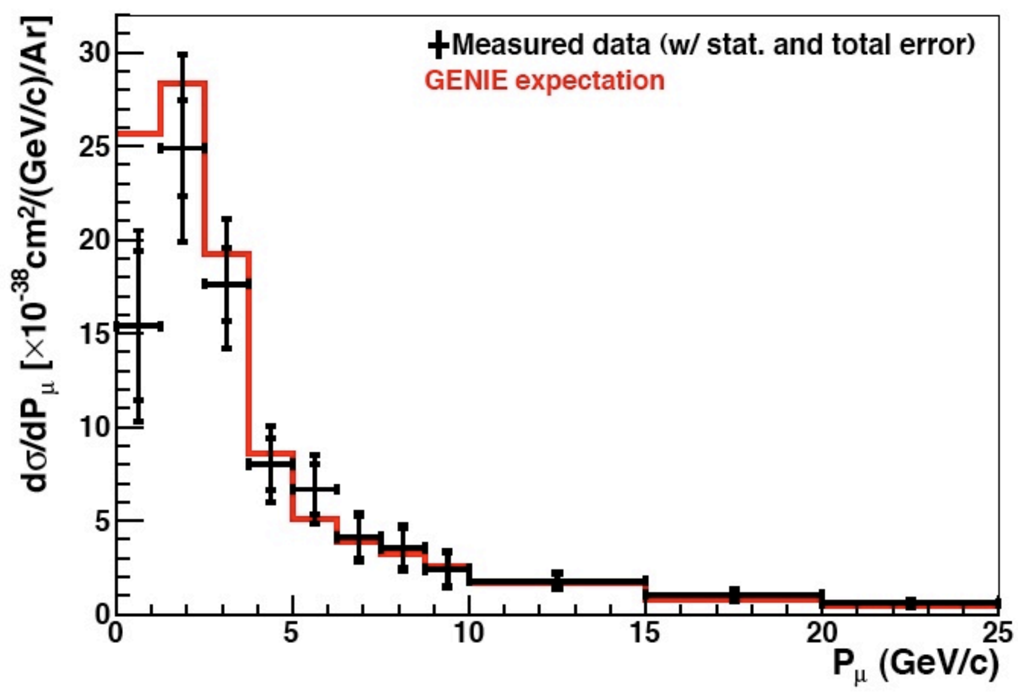
ArgoNeuT

- First LArTPC in a low energy neutrino beam - mostly R&D, but with some Physics thrown in
- Cryostat went into the MINOS hall in December 2008
- Filled with LAr May 8, 2009
- Ran through February, 2010

Cryostat Volume	500 Liters
TPC Volume	175 Liters
# Electronic Channels	480
Wire Pitch	4 mm
Electronics Style (Temperature)	JFET (293 K)
Max. Drift Length (Time)	0.5m (330μs)
Light Collection	None

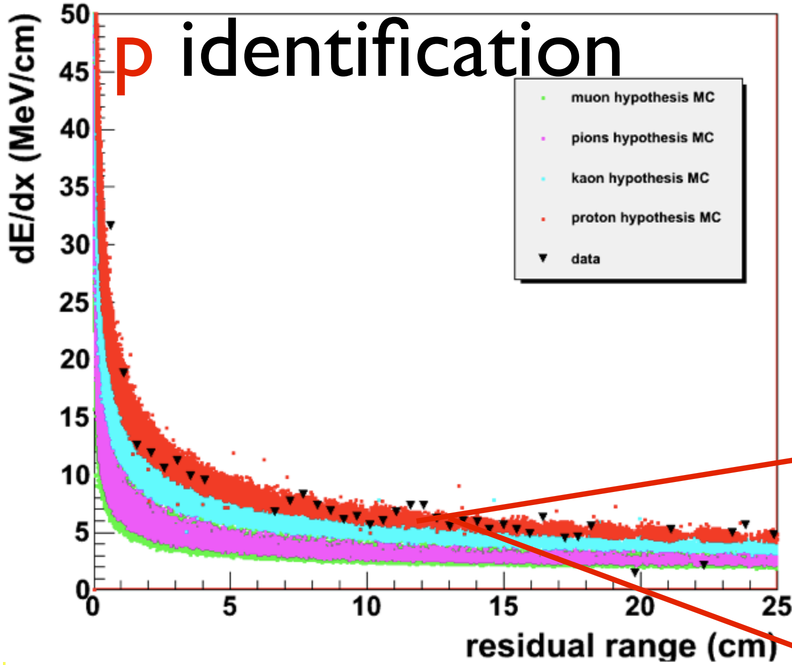
First Cross Section Measurements on Ar

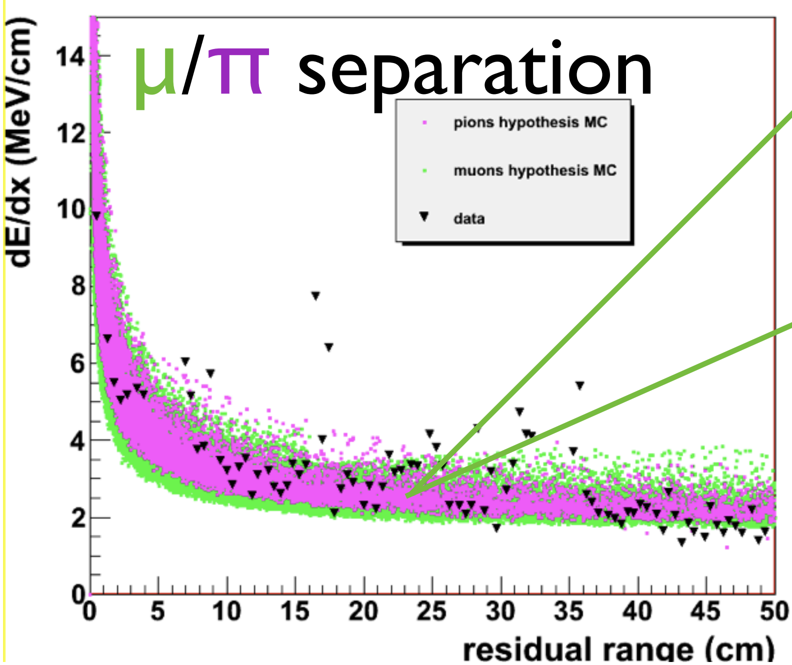


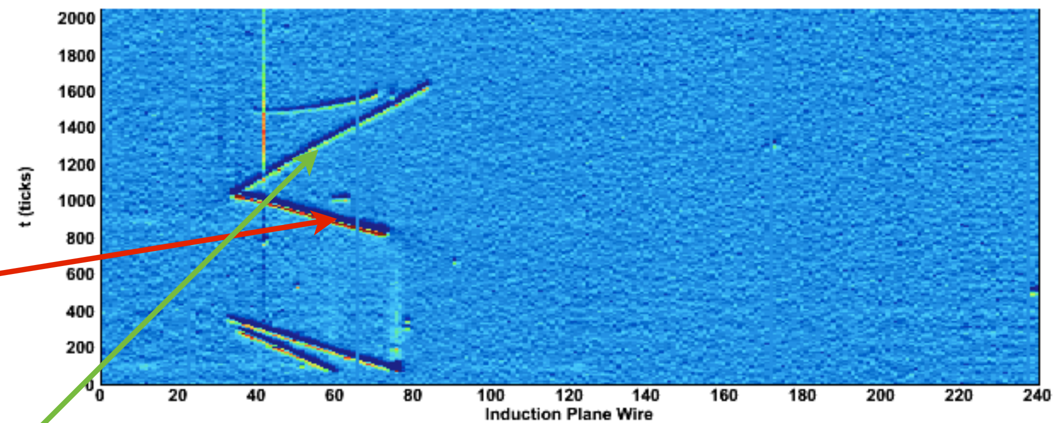


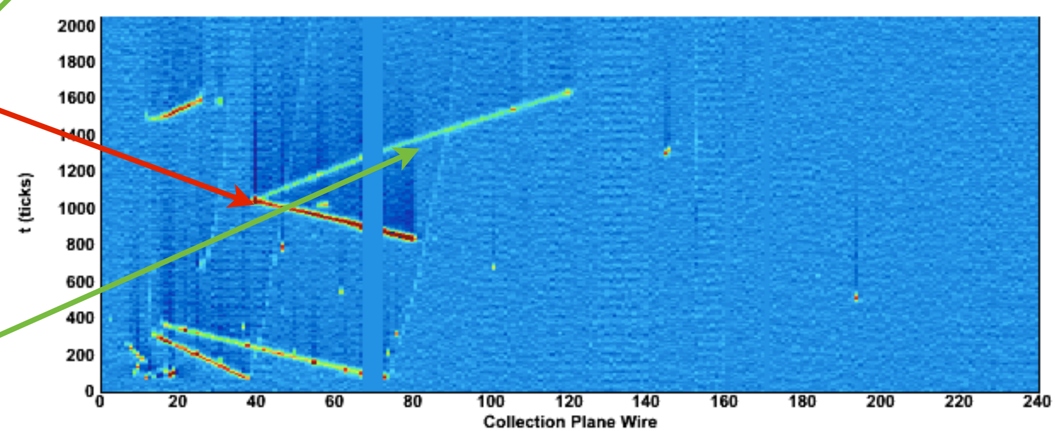
- Differential cross section measurements are the industry standard
- Measurements agree well with prediction from GENIE Monte Carlo generator
- $\sigma/E_\nu = (7.3 \pm 1.2) \times 10^{-39} \frac{\text{cm}^2}{\text{GeV}} \quad \langle E_\nu \rangle = 4.3\ \text{GeV}$

ArgoNeuT Particle Identification









- μ/π separation difficult based on dE/dx alone, need to use event topology as well
- Protons id'ed as heavily ionizing particles

LArIAT Participants

17 Institutions
40+ physicists

Community Coordination

Coordinating Panel for Advanced Detectors (CPAD)

- Advisor & Community input: A coordinating panel will elevate & champion instrumentation, community voice, representative of the community ensure complete coordinated balanced program, promote cooperation across community, decadal perspective, advocate with congress and industry & other disciplines, can be used by DOE as a source of advice (when asked to do so)
- *The primary recommendation of the Taskforce report is that a standing Coordinating Panel for Detector R&D the Coordinating Panel for Advanced Detectors (CPAD) be formed, under the auspices of the DPF Executive Committee*
- Recommendations
  1. A standing body – CPAD - should be formed to promote and stimulate the national instrumentation detector R&D program.
  2. The CPAD should be largely self-organized and consist of representatives from the national HEP labs and the university community to form a representative panel of outstanding capability in detector and instrumentation R&D.
  3. The primary role of CPAD should be to promote and assist in generic detector R&D

Ian Shipsey, Joint CPAD and Instrumentation Frontier Meeting, January 2013

Community Coordination

- Role of Panel (see longer list in Task Force Report)
  - "...promote national detector R&D and stimulate new ideas in instrumentation development.
  - Improved coordination among the national HEP laboratories and university groups engaged in detector R&D........"
  - ".... help facilitate utilization of targeted resources at the national laboratories...."
- <u>Not role of Panel</u>
  - Acting as a Program Advisory Committee ....
  - Acting as a standing review body for proposals .... or for peer review of proposals;
  - Providing a "roadmap" for the national detector R&D program. (But would be aware of roadmap for field)