Liquid Argon Purity Demonstrator (LAPD) at Fermilab

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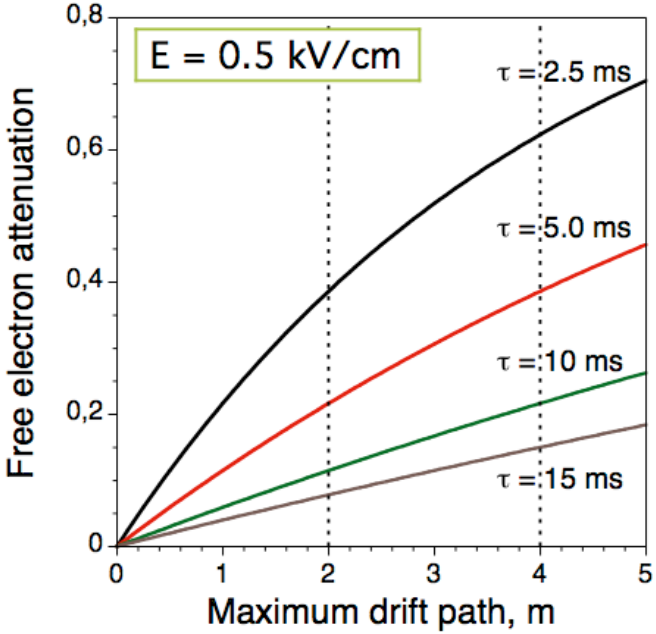
Why Do We Need an LAPD?

- Current LAr systems must evacuate as the first step to achieve high enough purity for time projection chambers (TPCs).
- Contaminants are electronegative impurities such as oxygen and water.
- Prior evacuation is not feasible for very large vessels.
- LAPD was built to explore the possibility of filling with LAr without evacuation.

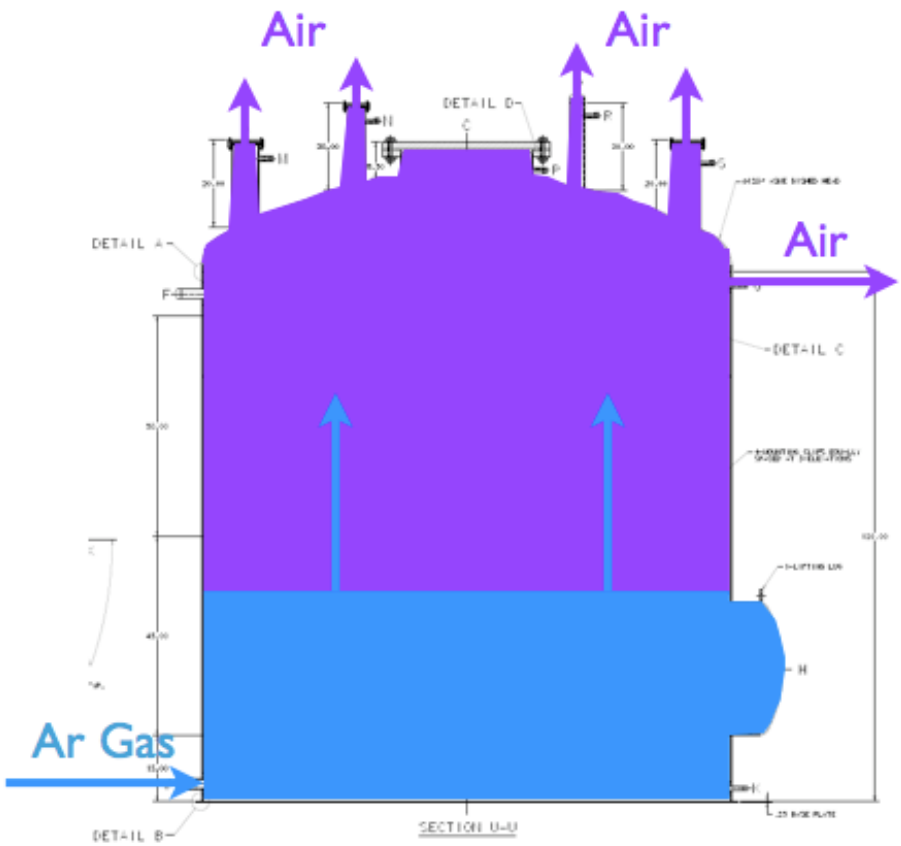
Goals

- Show that the necessary electron lifetime for drift distances of at least 2.5 m can be achieved
  - 3 ms is equivalent to100 ppt of O_2 contamination
  - Requirement for 3.7 m LBNE drift is 1.5 ms
- Measure temperature gradients and concentrations of water, O_2 and N_2 in the tank.
- A second phase will place TPC materials into the volume and attempt to show that the lifetime can be achieved.



Procedure: Argon piston purge

- Start with tank full of ambient air.
- Argon gas is pumped in from the bottom ("argon piston").
- Cycle a few volumes of clean argon gas.
- Recirculate the gas through the filter system until contamination level remains constant.
- Flow rate of about 3 hours per volume change.

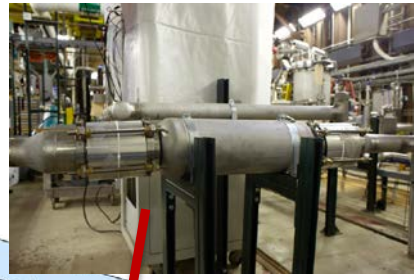


Tank size: 30 ton LAr
(25,000 liters)

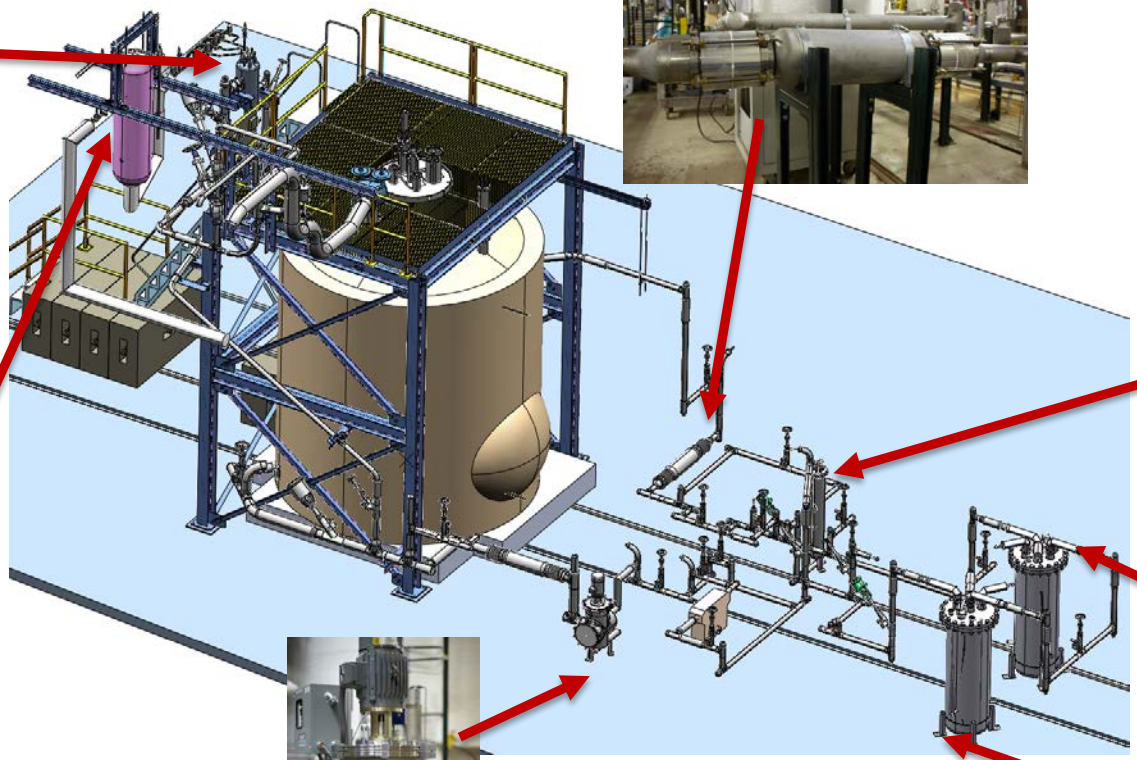
Physical Layout

LAr condenser

particulate filter



in-line purity monitor



LN2 phase separator

Cu (oxygen) filter

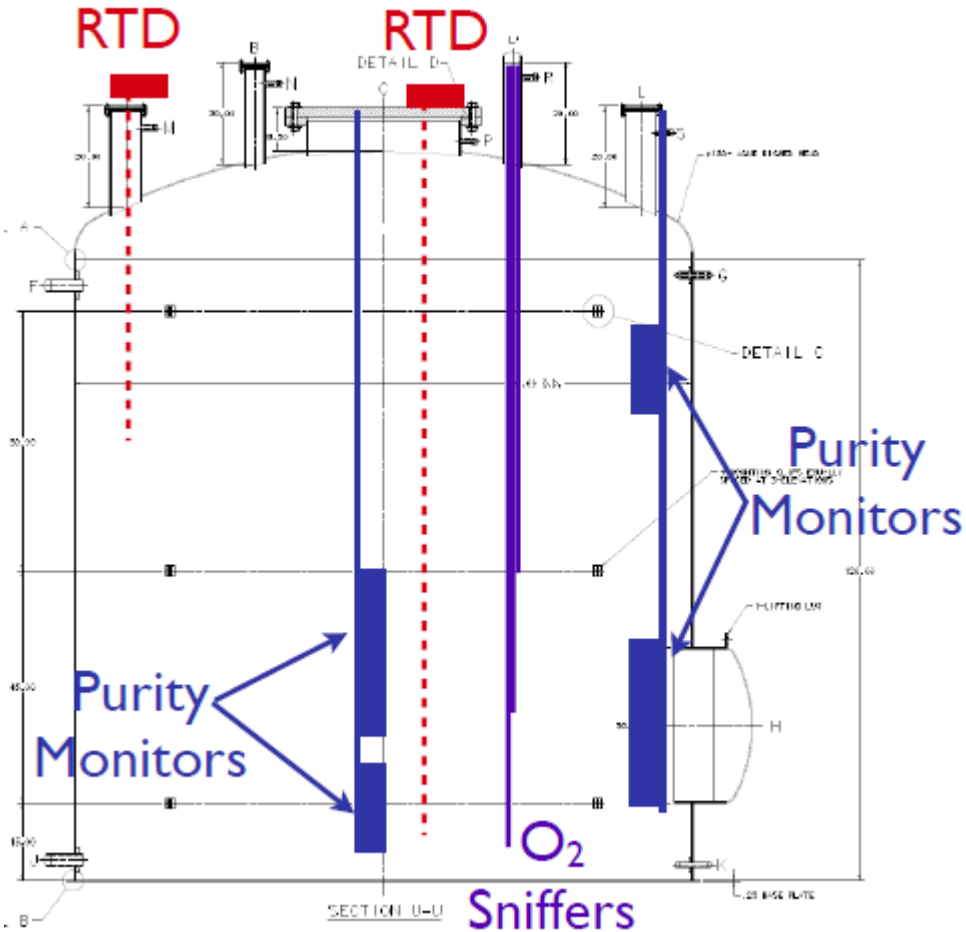
pump

Zeolite (H_2O) filter

Physical Layout II

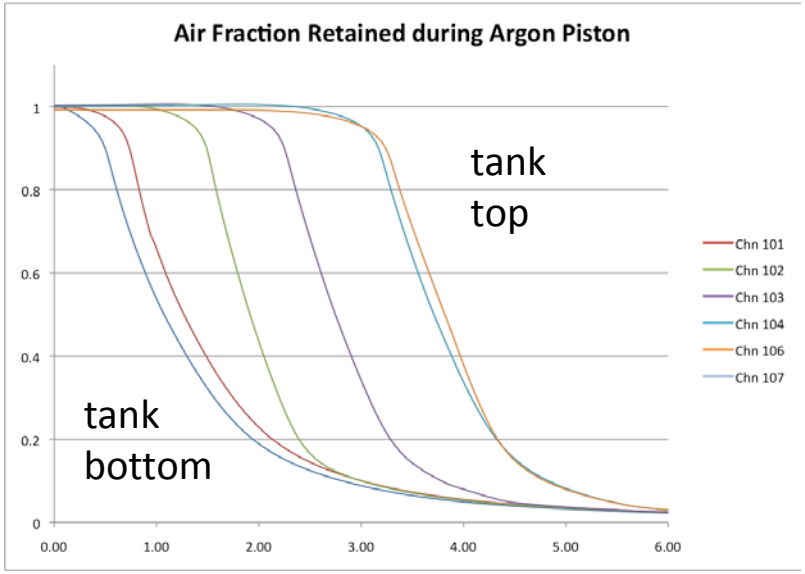
Instrumentation

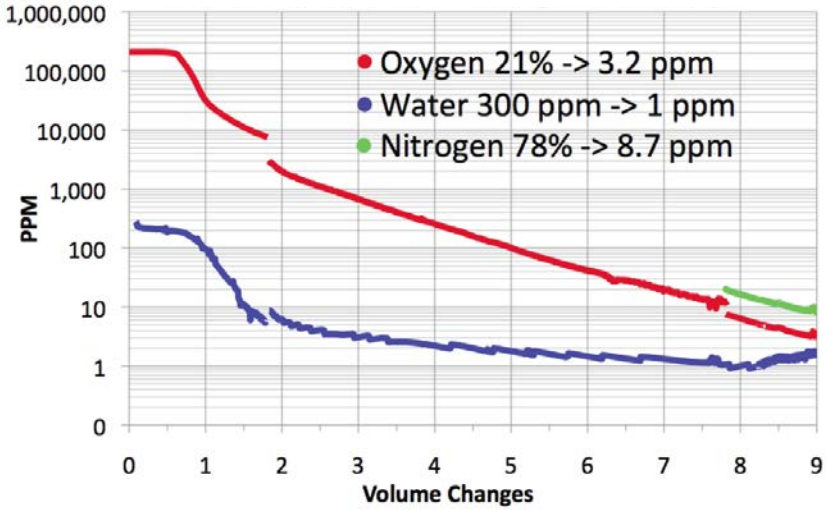
- 4 purity monitors - 2x 20 cm long, 2x 58 cm long
- 2 resistive thermal device (RTD) translators, each with 3 RTDs
- O_2 sniffers at various heights for use in purge phase



O_2 Monitoring During Purge

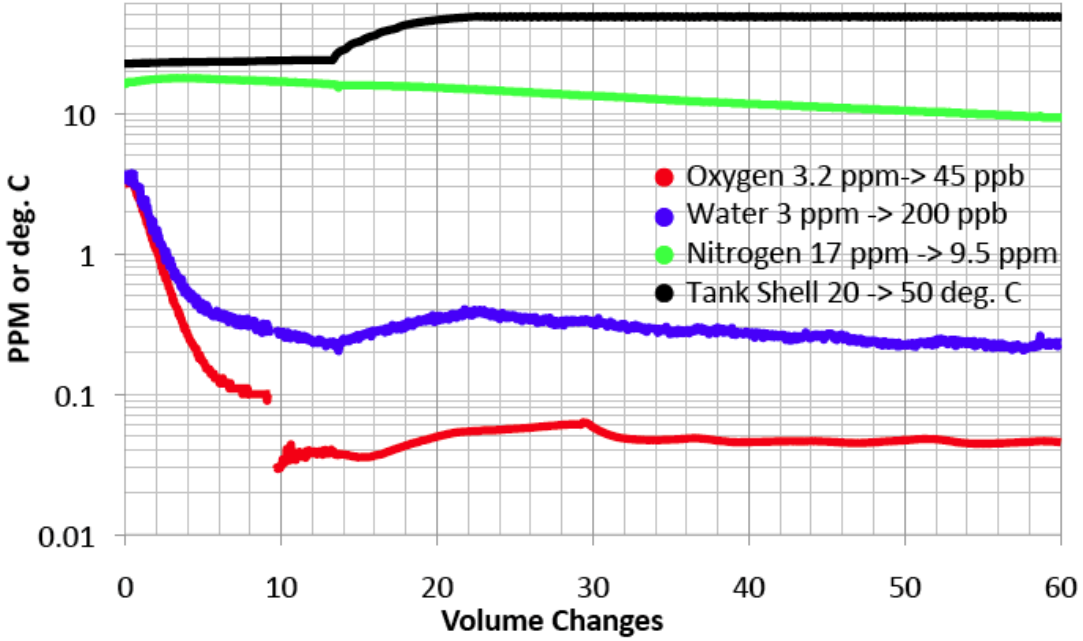
- Measures oxygen contamination of the gas at various depths during the purge.
- Top plot shows the content relative to the pre-purge state of the tank
- 1800 ppm of O_2 in tank after 2 volume exchanges (6 hours).
- 9.1 volume exchanges total before the purge was stopped.





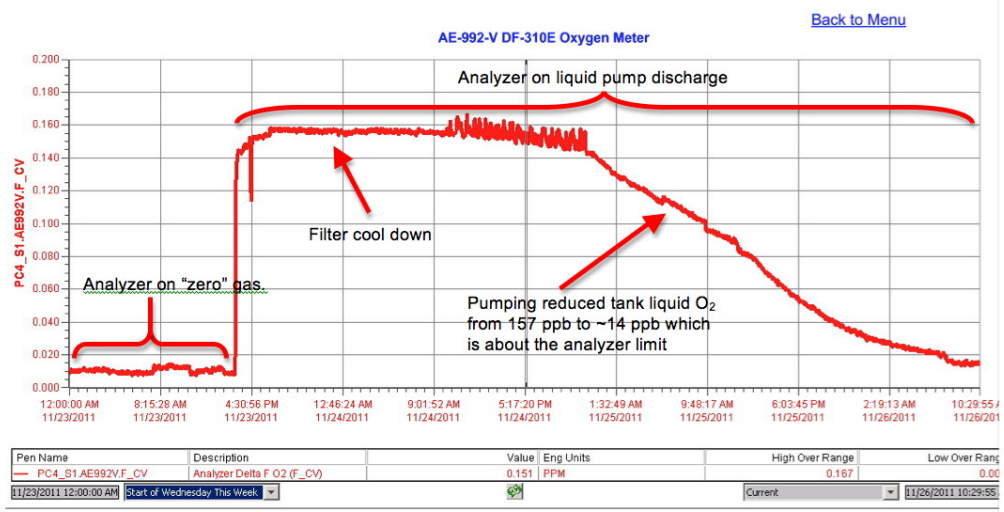
Argon Gas Recirculation

- Purge was successful and brought the tank vapor contamination level below the specifications for the delivered liquid.
- O_2 and H_20 contamination were well below 1 ppm after 3 volume exchange.
- Maintained sub-ppm levels in the gas for over 20 days



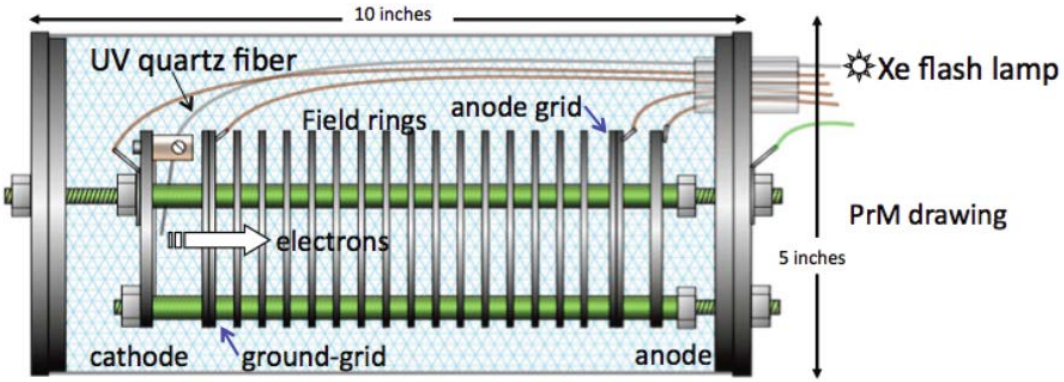
Liquid Argon Fill

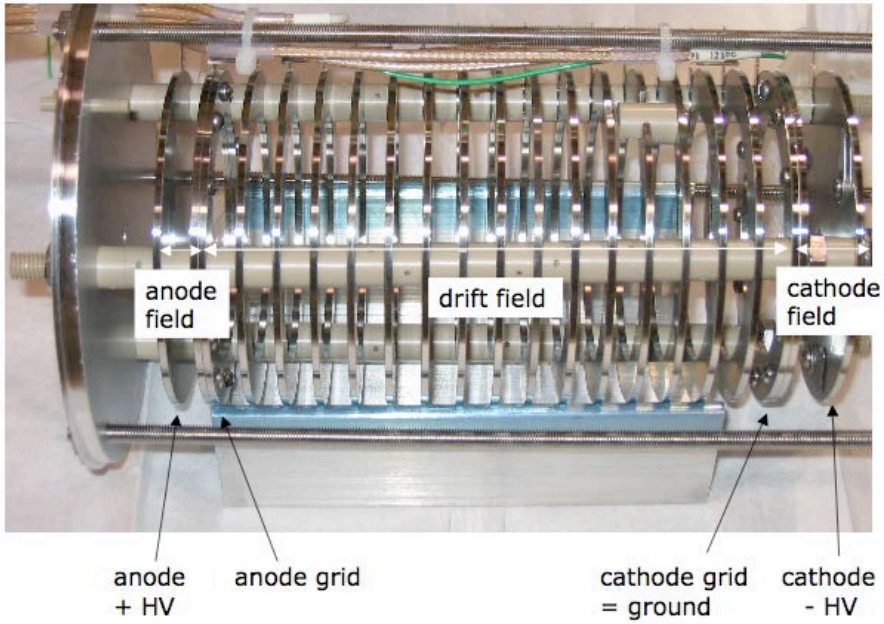
- Tank filled with 0.22 ppm O_2, 0.33 ppm N_2 LAr.
- Tank filled to 35% capacity
  - liquid is at the 4 ft level (out of 10ft)
  - this is a more stringent test since the upper portions of the tank shell are warm and actively outgassing H_2O
- Liquid pump moves argon through filters at 5.5hrs/vol exchange.



Purity Monitoring: Electron Drift Distance

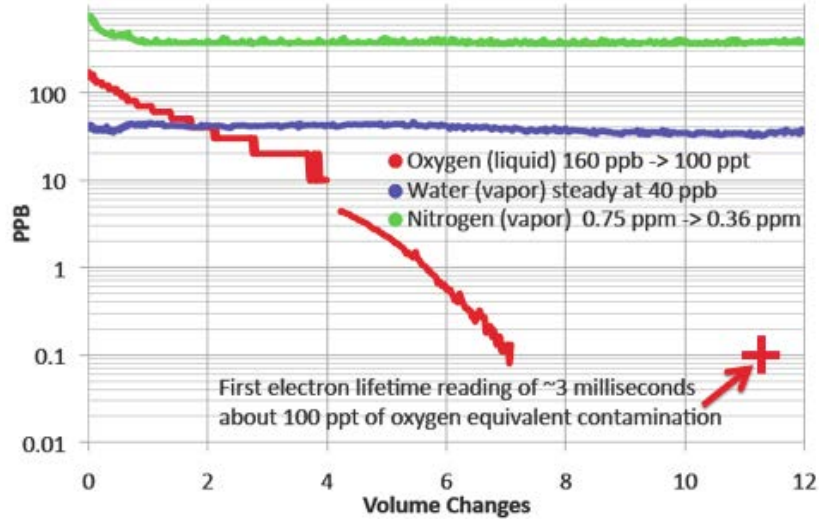
- Purity monitor based on the ICARUS design and the same as used by the Materials Test Station (MTS) at Fermilab:
- Operated with same electric field as expected in the detector - 500 V/cm

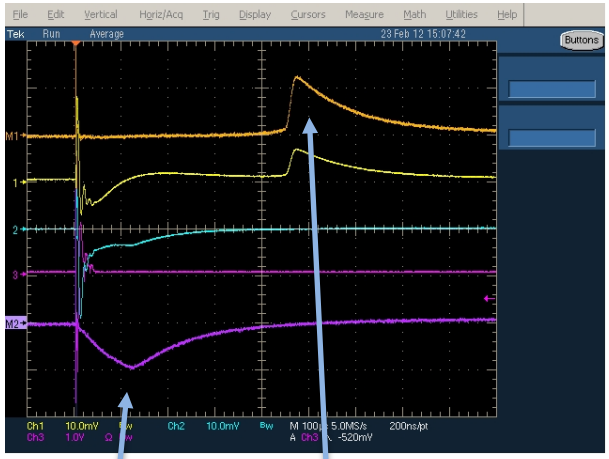




Purity Monitoring: Electron Drift Distance

- First electron lifetime measurements made after 11 volume exchanges.
- Electron lifetimes were determined to be at least 3 ms, LBNE needs 1.5 ms.



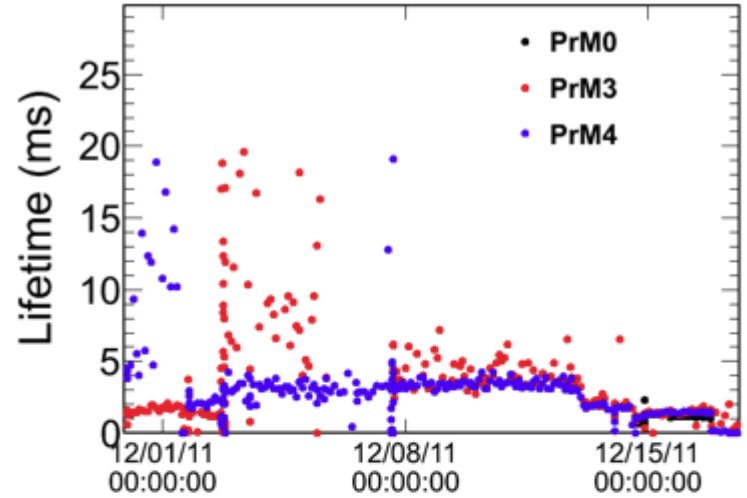


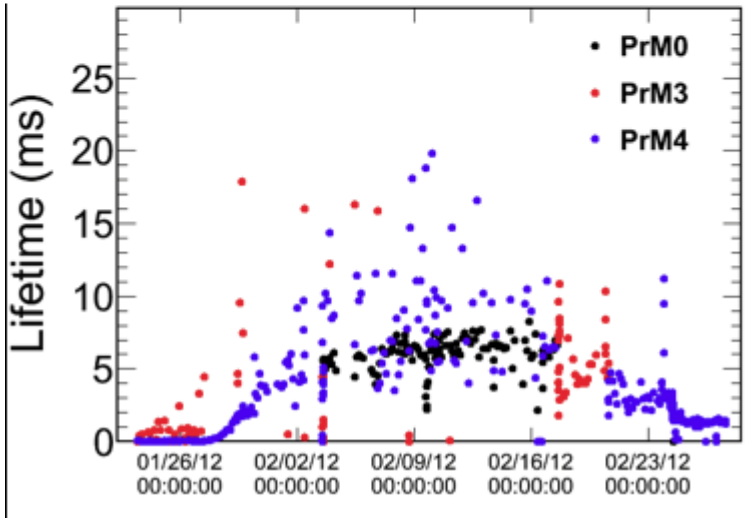
$$Q_{anode}/Q_{cathode} = e^{-t_{drift}/\tau}$$

G. Carugno et al., NIM A292 (1990) and ICARUS-TM/02-14

Electron Lifetime Stability

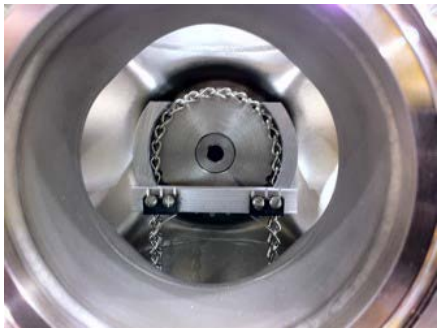
- Lifetime was stable at 3 ms or better until 12/15/2011 indicating filter saturation
- Filters were regenerated around 1/3/2012 and running resumed
- Lifetimes went up to 5 ms
- Filters started showing signs of saturation again but a power outage on 2/27/2012 stopped the run prematurely.
- When power was returned, the liquid was at about the 2 ft level.

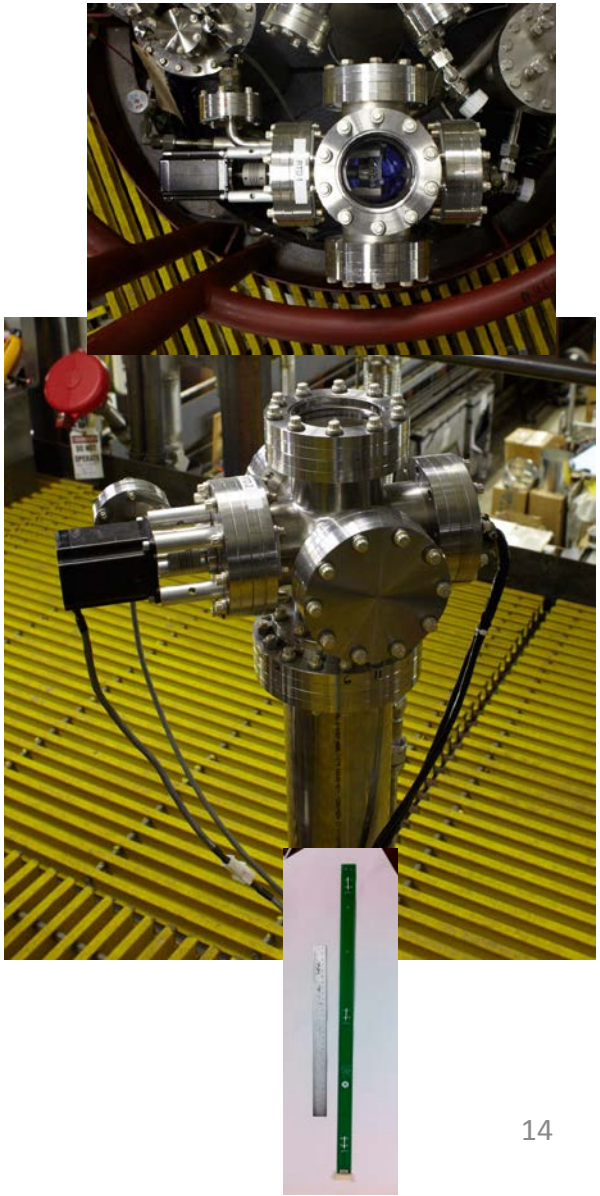




Temperature Monitoring: Translating RTD

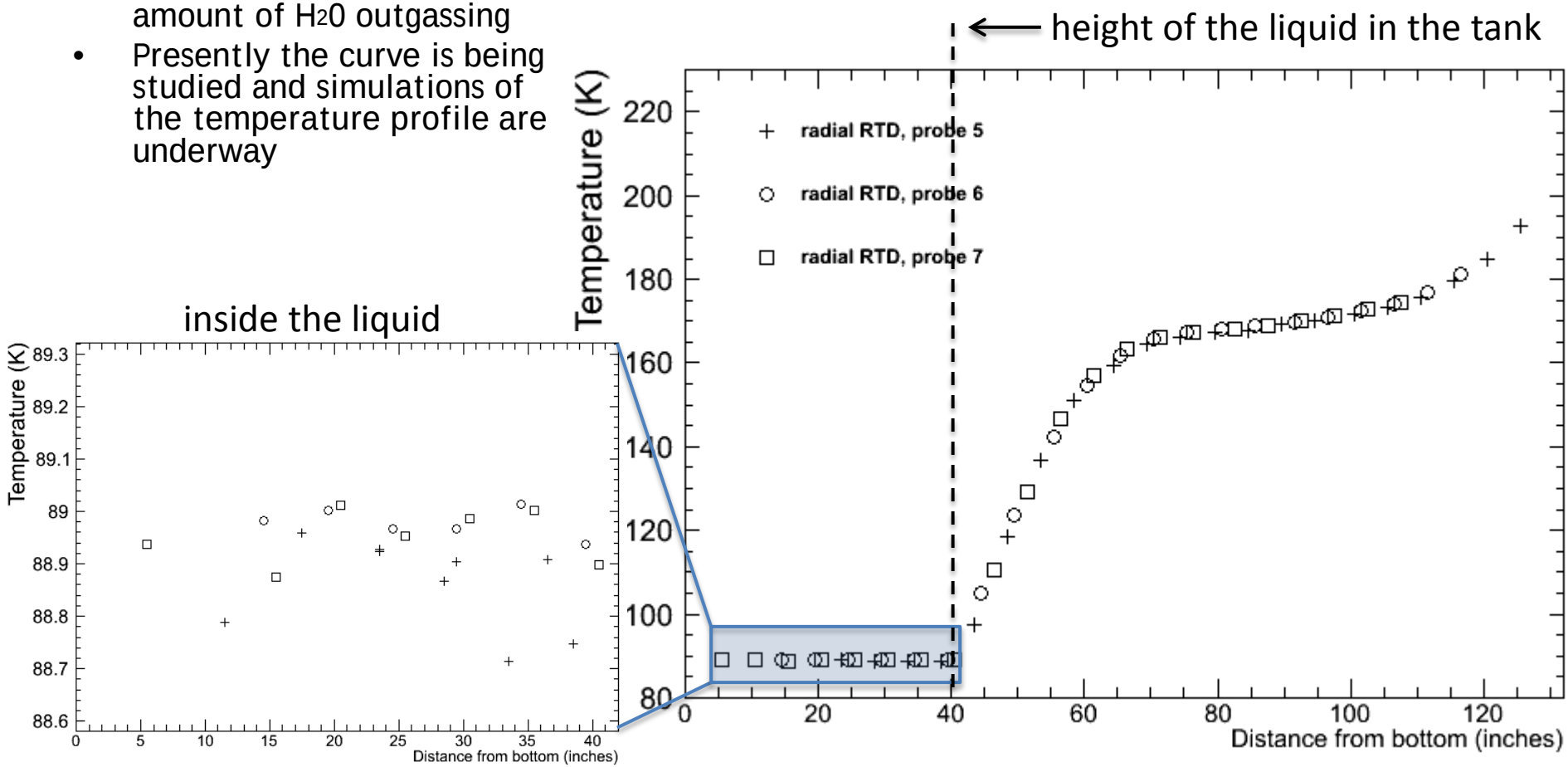
- Three RTDs (resistive thermal devices) are mounted on a circuit board
- Circuit board translates vertically through the tank with stops at predefined locations to take temperature measurements
- Looking for the temperature gradient in the tank, absolute calibration is not important, but devices are good to within 0.1 K
- Chain driven device, includes mechanical stops to prevent failures from power outages





Temperature Monitoring: Translating RTD

- Understanding the temperature above the liquid is very important since it determines the amount of H_2O outgassing
- Presently the curve is being studied and simulations of the temperature profile are underway



Conclusions

- LAPD has demonstrated that it is possible to obtain a better than 3 ms electron lifetime in a large, non-evacuated vessel.
- Future work:
  - commence a second run with a full tank which will fully submerge all 4 purity monitors
  - installation of a small TPC