Purification of argon

A Facility for Materials selection ..

Randoms

.

My hands-on experience is limited to liquid Argon aimed at Neutrino Detectors..

Newish to issues to do with low-background physics searches

Aware of only some of the issues with argon.

Basic measurements have been done in the context of specific experiments – not necessarily collected in a common literature. (Noble Gas Detectors (2006) Aprile, Bolotnikov,Bolozdynya, Doke – fine collection - could be updated?)

Time scale includes addressing Issues to be faced by LBNE and G-2 & 3 Dark Matter Searches

Why Noble Elements?

Material available in tons, is a bright scintillator and allows free electrons to live unattached for (milli)seconds, can be liquefied by liquid nitrogen – a gift of nature. This gift can be corrupted (or modified) by relatively small amounts of contaminants.

Contaminants affect different physics and different styles of detectors – differently

Neutrino – Dark Matter / Single Phase – Dual Phase

Internal contaminations that affect **physics** (source of triggers and/or background)

Impurities that affect **production** of light and/or free charge .. (could be helpful, but in any case they need to be controlled)

Impurities that affect **transmission** of light and/or charge .. (ditto)

Can always cut to the chase and see how detector performs .. If it doesn't ..

Identification and measurement of `impurities' critical for any understanding ..

Techniques include:

Low radioactivity setup to measure ^{39}Ar in argon (1 in 10^{17}) – Princeton

Cavity Ring Down for H_2O in Ar (1 in 10^9) in and more - Tiger Optics, Black Hills State

RGA + Cold Trap to remove major component for O_2, CH_4 (1 in 10^{10}), N_2 (1 in 10^9), Kr (1 in 10^{12})

Direct Measurement of electron drift-lifetime:

ICARUS gridded ionization chamber

Purification (Argon):

Issues :

Oxygen – electron drift-lifetime - ppb x lifetime (microseconds) ~ 300 *
- light output falls factor of 2 at 1 ppm
- absorption?

Nitrogen – light output falls factor of 2 at 10 ppm
minimal effect on electron drift-lifetime
absorption?

H_2O - electron drift-lifetime – ppb x lifetime (microseconds) ~ 30 (guess)
- light output?
- absorption?

Impurities which affect output affect slow component > fast component, and therefore distort pulse shape (discrimination)

* => 10^{12} collisions per second .. cps is basis for capture and production effects

Purification in liquid phase or in gas phase:

In liquid: H_2O typically removed by Zeolites, Oxygen by active copper, Nitrogen?

In gas: heated Zirconium (or Calcium) (SAES has a monopoly?) ..

Liquid advantage – process large mass, reagent relatively cheap ..

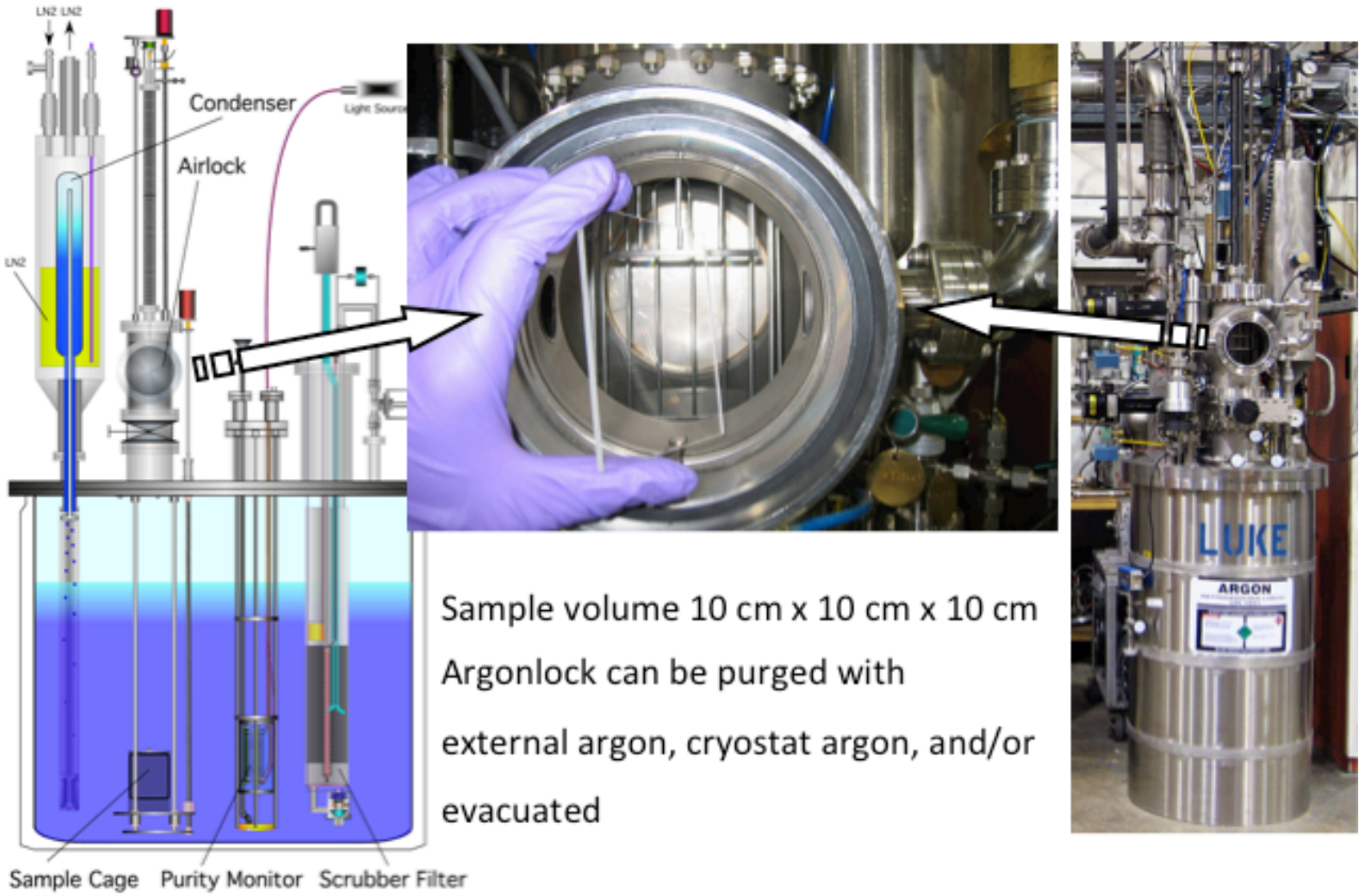
Liquid problems – reagents are radioactive and may get carried into output stream,
do not remove Nitrogen (very obviously)

Gas advantage – cleans up (almost) everything, clean

Gas problems – expensive per unit mass, limited throughput, put heat into system

Materials Selection: avoid contamination by detector materials ..

MTS at Fermilab allows insertion of materials into clean argon and measurement of their effect on electron drift-lifetime.



Sample volume 10 cm x 10 cm x 10 cm

Argonlock can be purged with external argon, cryostat argon, and/or evacuated

For argon, no material we have tested affects the lifetime when material is in the liquid.
Outgassing of water from materials in the ullage is the (only) major concern
Cryogenic design in large LArTPCs maintains an upwards flow of gas to counteract diffusion.
Outgassing strong function of temperature & material.

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
Bostik	didn't pass submerging in the liquid argon					992
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

Improvements:

Measurement Capabilities:

For water, at least, would like factor 100 more sensitivity (10 ppt)

Would like simpler technique for ^{39}Ar measurement

Would like range of gases for Cavity Ring Down

Would like more efficient cathodes for ICARUS style lifetime monitor

Purification Techniques:

Would like high-throughput Nitrogen removal; would like `clean' reagents in liquid

Materials Measurement (for argon)

Would like to perform in gas at elevated (e.g., room) temperature since materials in liquid have no effect

Randoms

Pumps are an issue – cleanliness for Dark Matter, cost and cleanliness for Neutrinos

Solid argon may have some advantages - once pure.

Purification without Evacuation

Liquid Argon Purity Demonstration

All existing LArTPC detectors have been evacuated before filling. Probably not practical for kiloton detectors

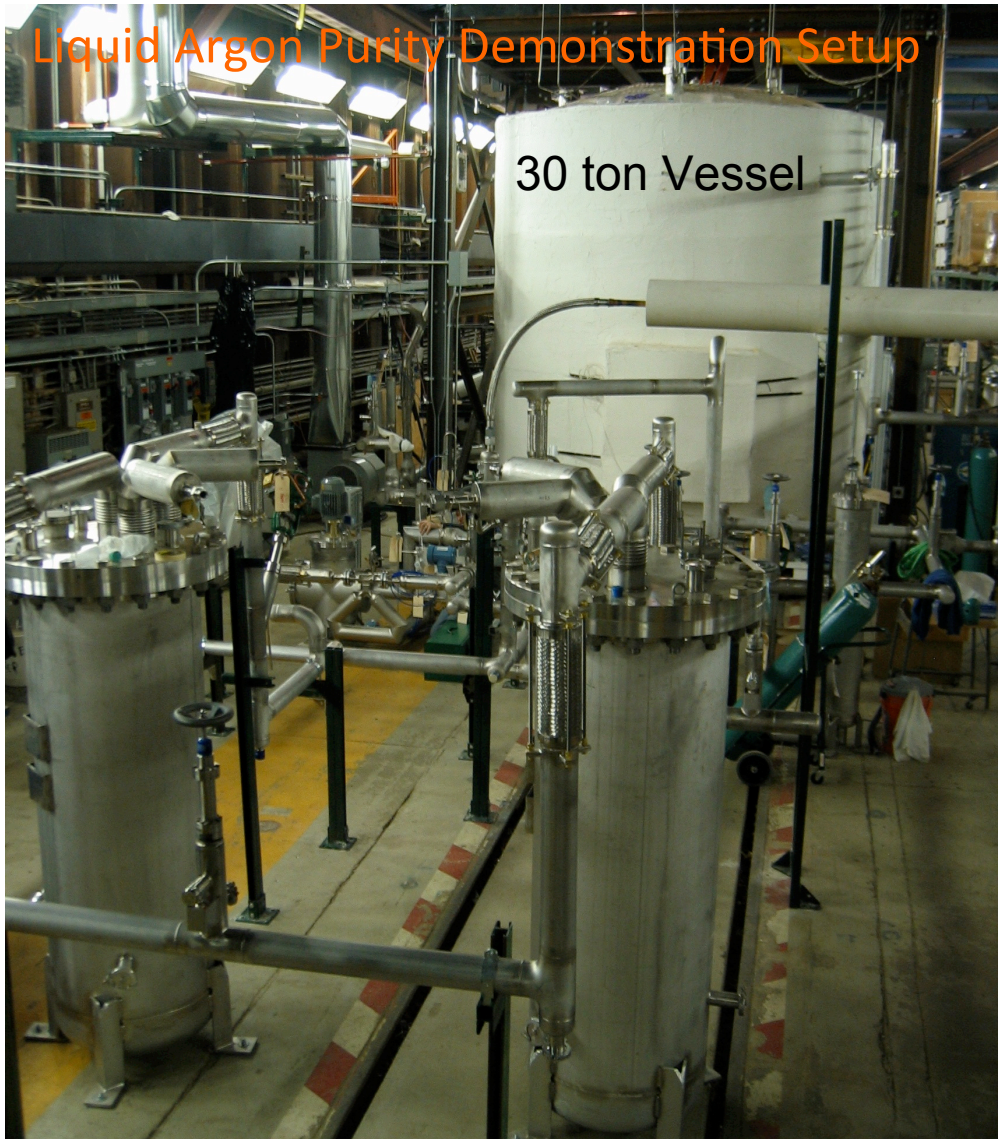
Goal: Demonstrate good life-time **in an industrial vessel without evacuation**.

First multi-ton purification system designed and built at Fermilab.

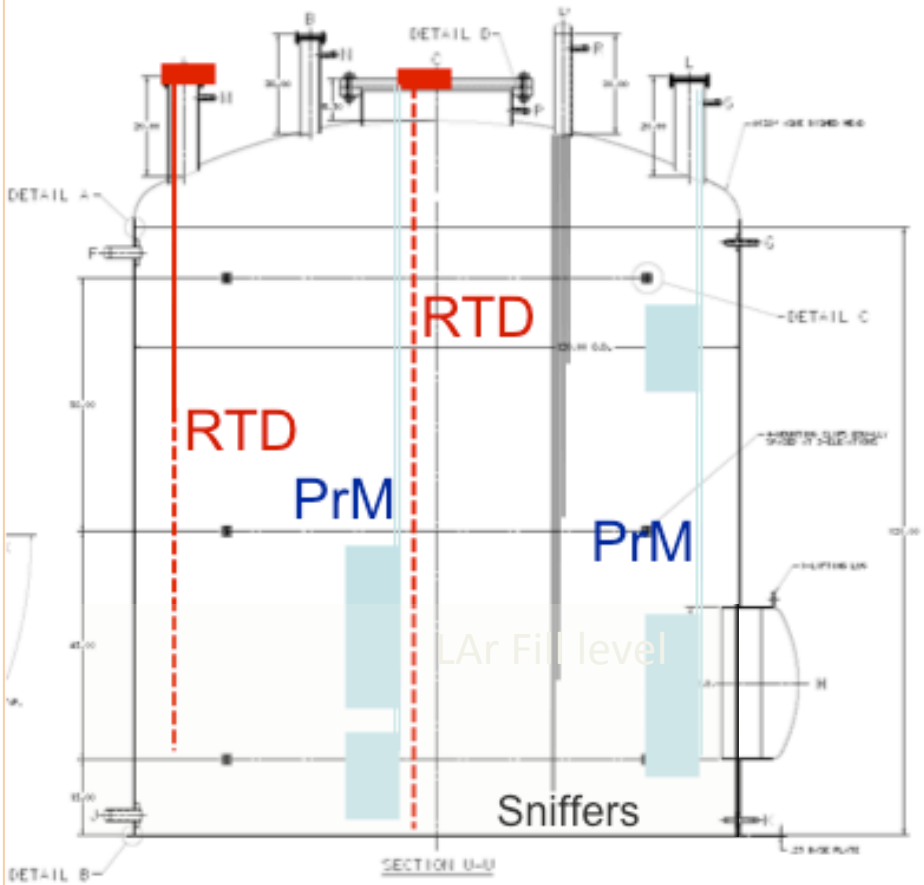
Commissioning started in October 2011

Stage 1 – bare tank & Instrumentation

- Sniffers for evolution of gas purge
- Analyzers – for O_2, N_2, and H_2O levels
- RTDs – for temperature (gradients)
- Purity Monitors - for drift-lifetime



Instrumentation for LAPD:



Analytic Equipment

Oxygen meters (0.4 ppb sensitivity)

H20 meters (0.5 ppb sensitivity)

N2 meter (20 ppb sensitivity)

can sample multiple points

In the Tank

2 sets of 2 PrM (20 cm / 60 cm)

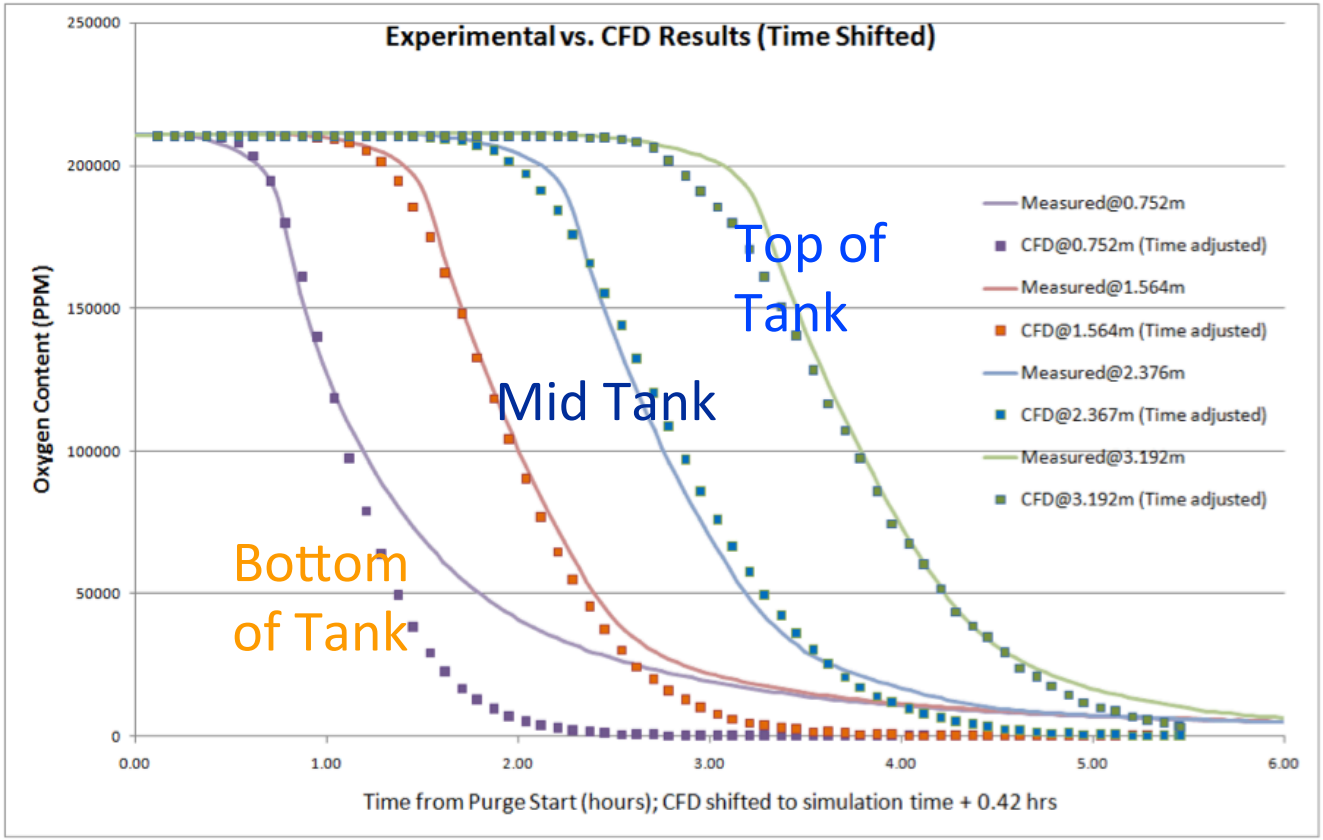
2 sets of 3 translating RTDs

Sniffer set to measure purge evolution

Inline

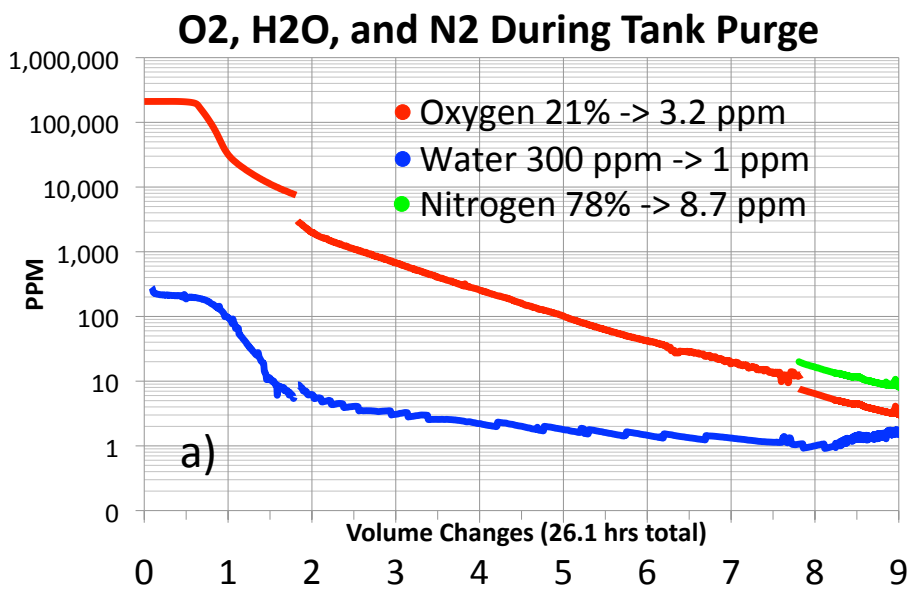
Purity Monitor

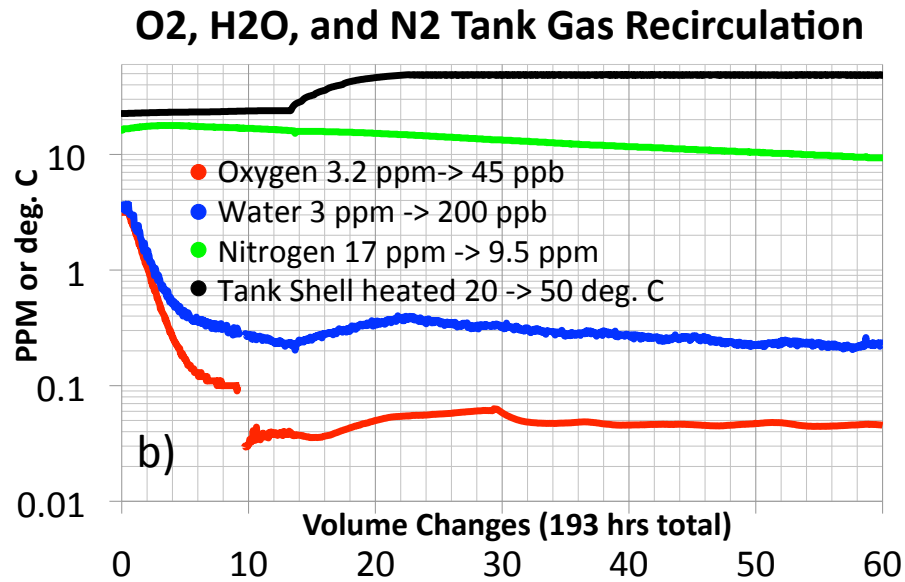
LAPD Gaseous Argon Purge

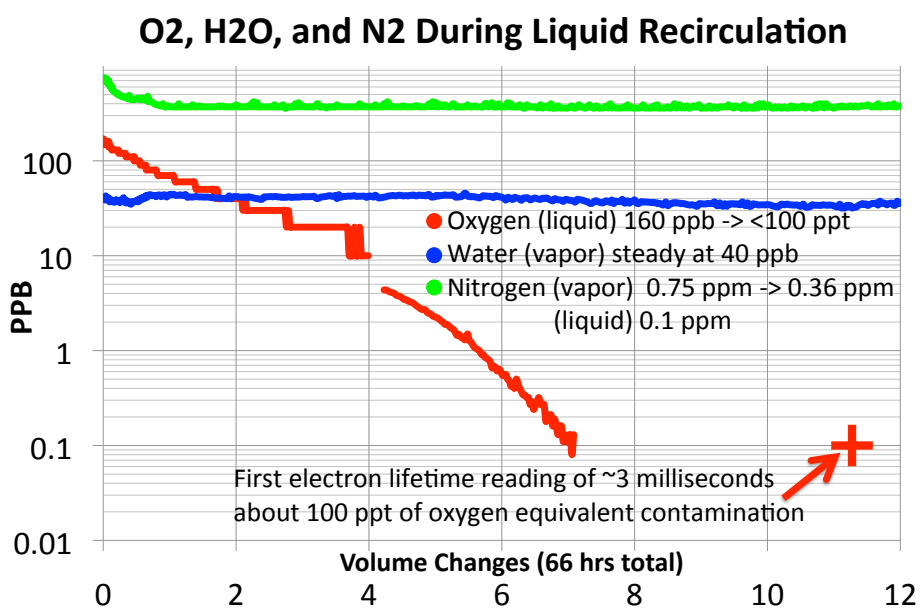


- Set of sniffer tubes at various depths monitored the oxygen content of the gas inside the vessel throughout the purge
- Lines are measurements, dots are simulation - no free parameters
- Comparison to calculation is reasonable – some issue about mixing near the bottom

LAPD purge and recirculation measurements







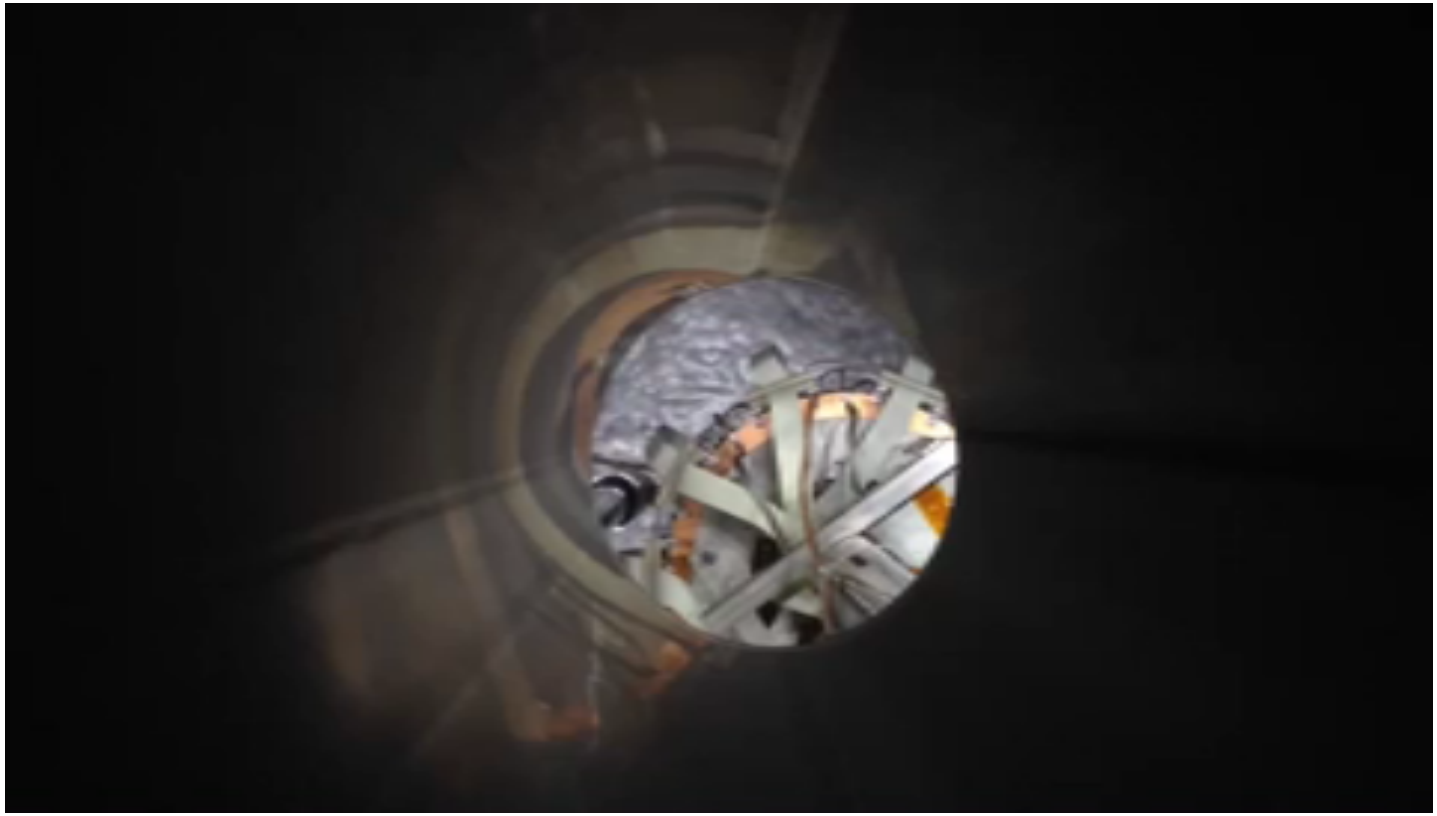
Concentrations of O_2, N_2 & during

a) purge,
b) gas recirculation through filters, and
c) liquid recirculation.

Note: **constant level of H_20** (in vapor)* and **the removal of N_2** (which affects light production at 1 ppm level)

*H_20 in liquid below measurable levels

Filling LAPD yesterday (Thursday) night



Looking from top into tank – seeing cables at top of TPC