Cryogenics and Plan for Instrumentation

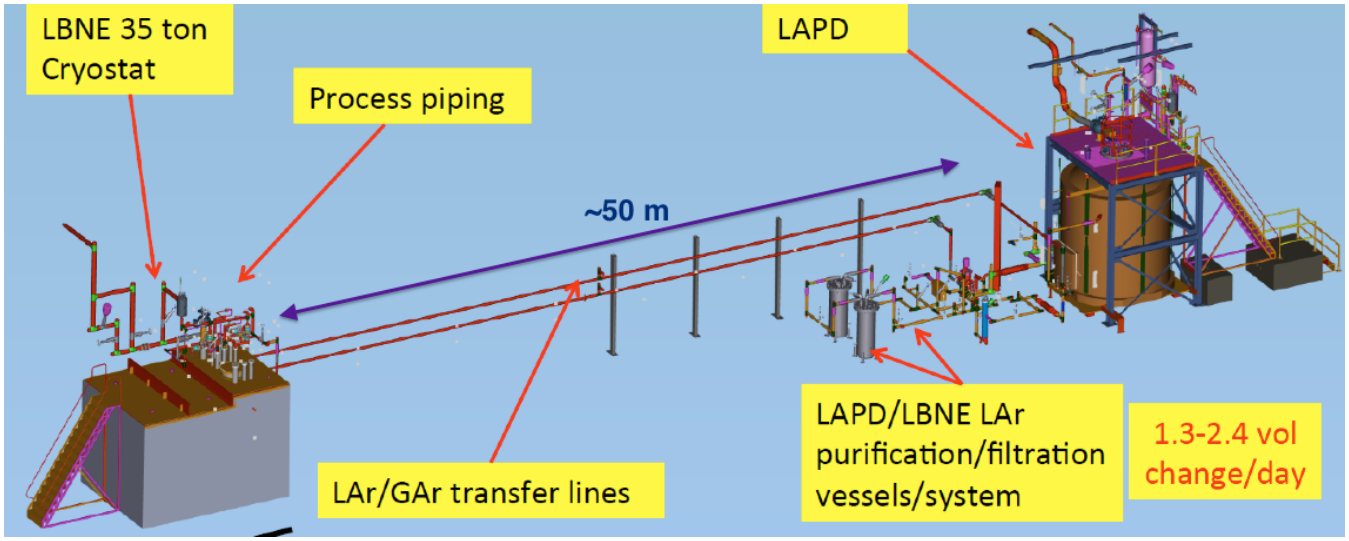
Alan A. Hahn
FNAL

Outline

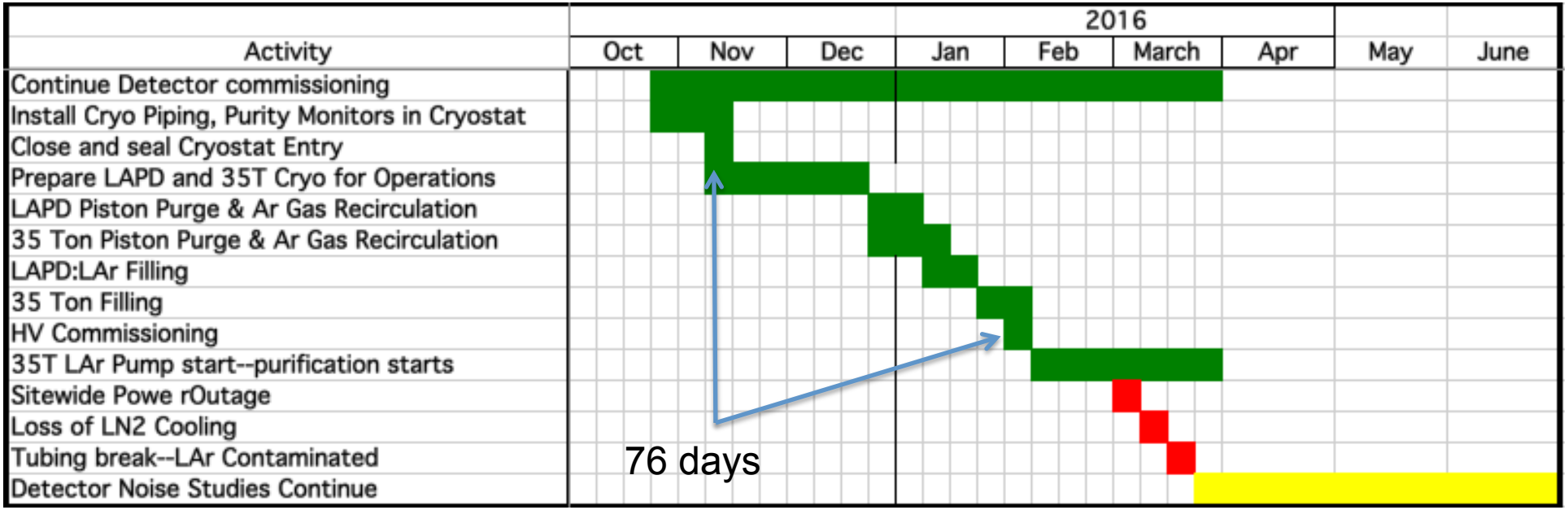
- Intro to PC4
- Cryo Schedule/Timeline
  - Filling
  - Running
  - Emptying
- Cryo Instrumentation
  - Purity Monitors
  - “Precision” Temperature Measurement
  - Gas Analyzers
  - “Standard” Cryo Devices

35-ton Prototype and LAPD
Located in PC4, former Fixed Target Proton Beamline

- 35-ton Cryostat uses
  - the LAPD Filters
  - Gas Analyzers
  - Instrumentation
- LAr can be shifted back & forth between LAPD & 35-ton
  - However there is a "tax"
    - ~10% from LAPD->35 Ton
    - ~30% from 35T -> LAPD
    - Function of pump head of two cryostats



35T Phase 2 cryo timeline

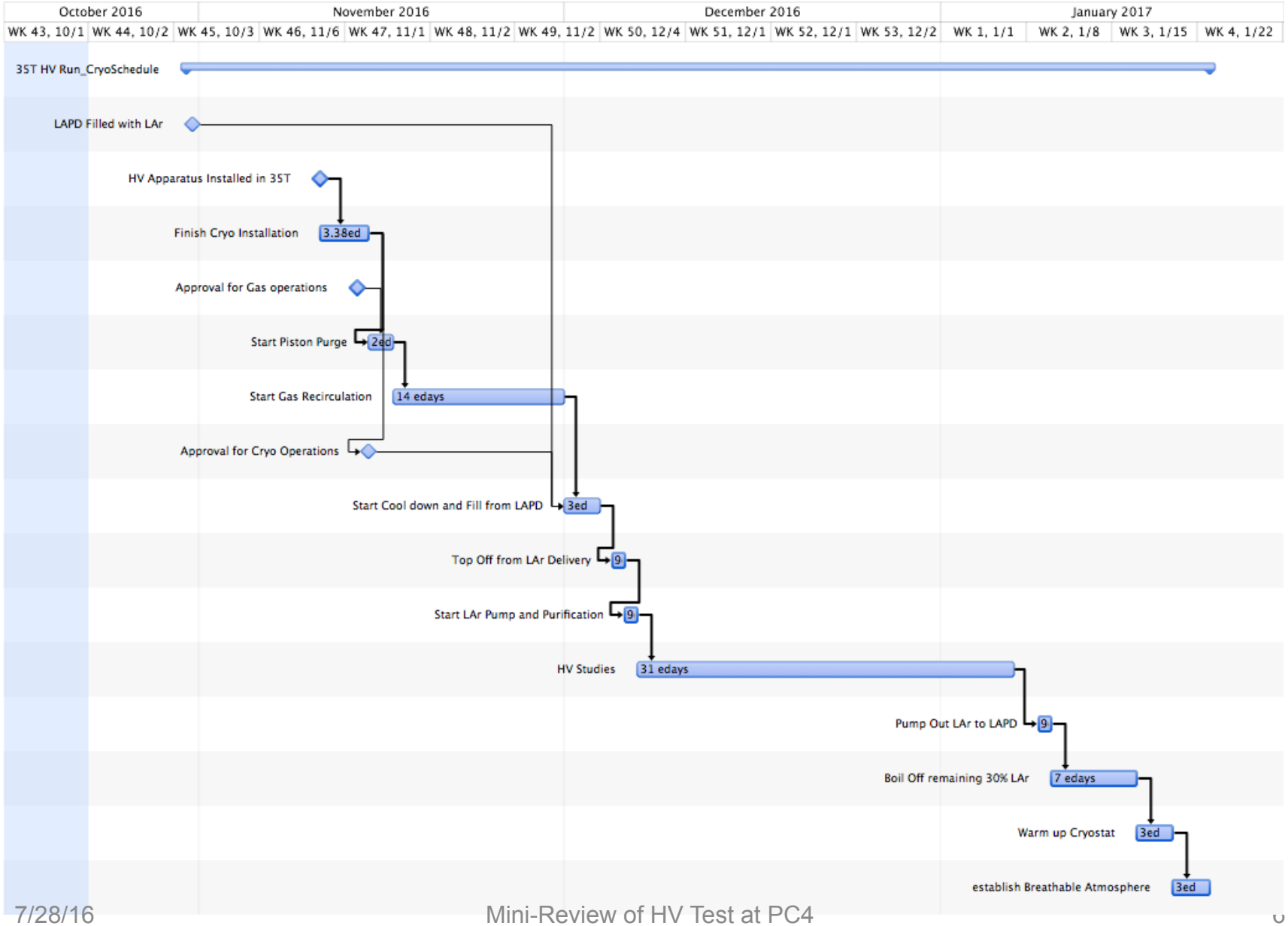


Want to minimize the time between installation of apparatus and HV Commissioning

35T Cryo Timeline

- 35T Phase 2
  - From Detector Installation Finish to Running– 76 days
  - “Running” = start of HV Commissioning
  - At least one reason is that LAPD Commissioning started after the the Detector Installation and not before.
- This time want LAPD filled and ready at time of Apparatus installation
  - Want Gas operation permit of 35 Ton (for purging and recirculation also on hand at/near time of installation.

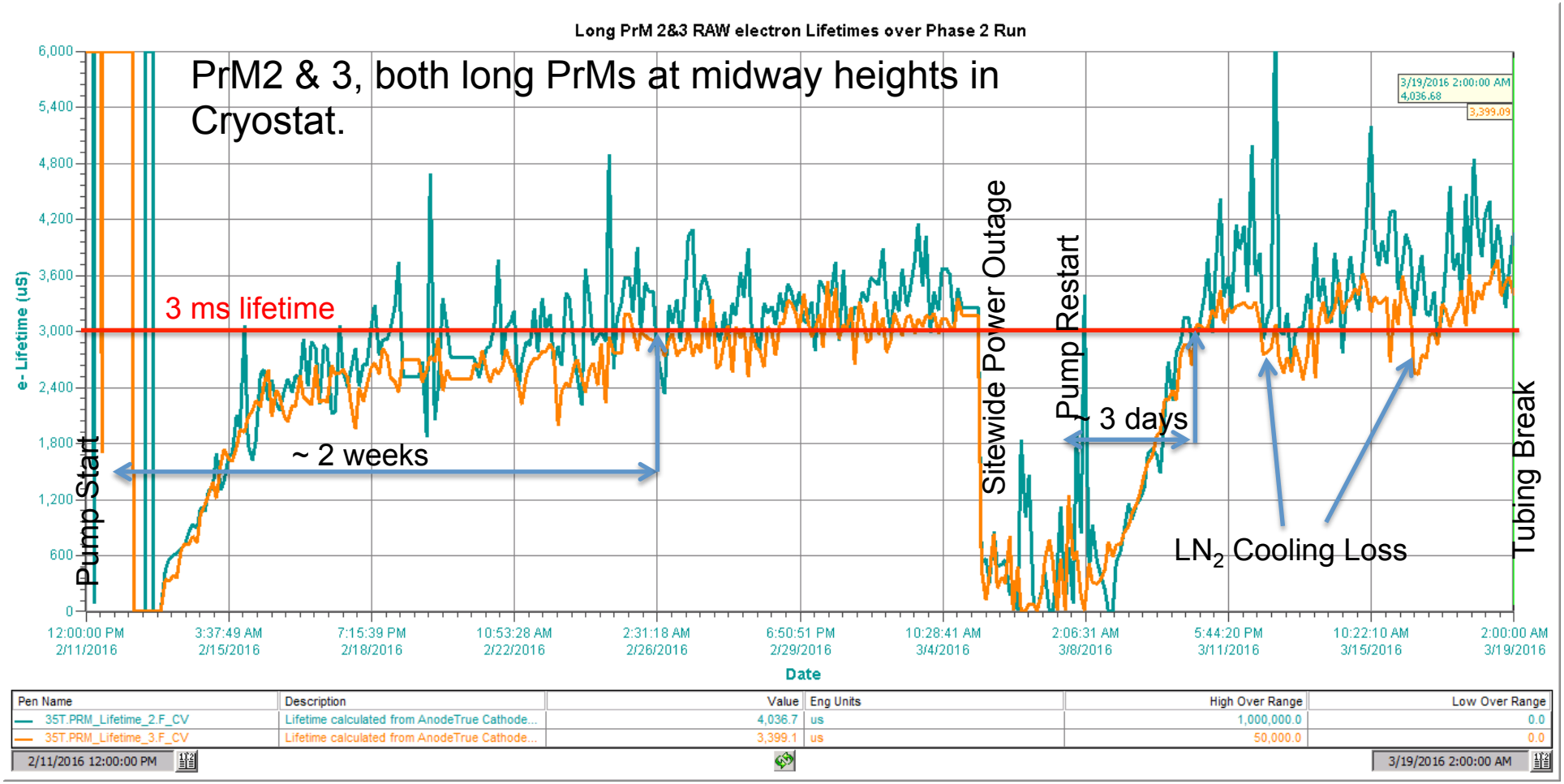
Stage 1 Cryo Run Timeline



Length of HV Run Period

- Assume HV Commissioning starts as soon as Cryostat is filled and pump is recirculating LAr to filters.
- It takes ~2 weeks to get to a e^- lifetime of ~2-3 ms.
  - See next slide.
- Assume one week at Design Field & 2-3 ms e^- lifetime (impurities ~100 ppt) demonstrates "Holding" HV.
- Adding extra week (or so) for contingency or higher HV fields gives ~1 month.
- Length of Stage 1 run is limited by desire to get Stage 2 run finished in a "timely" manner

e^- Lifetime over Phase 2 Run



35T Emptying Timeline

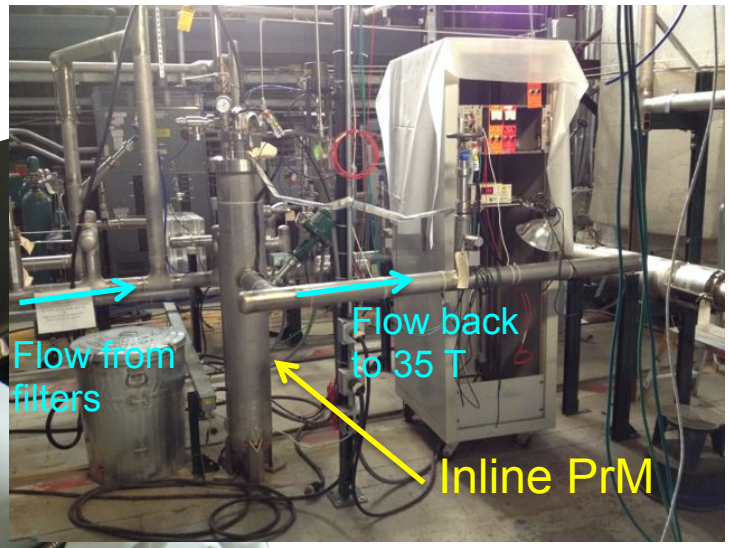
- Reduction in time due to
  - No need to vaporize LAr as in last run– pump directly to LAPD
  - Plan to add electric heaters (6 kW) to boil off remaining LAr
    - ~2-3x faster than bubbling N_2 as done before
  - Combine warmup (after LAr gone) with dry air purge
    - Need Cryo temps in 200 K range first.

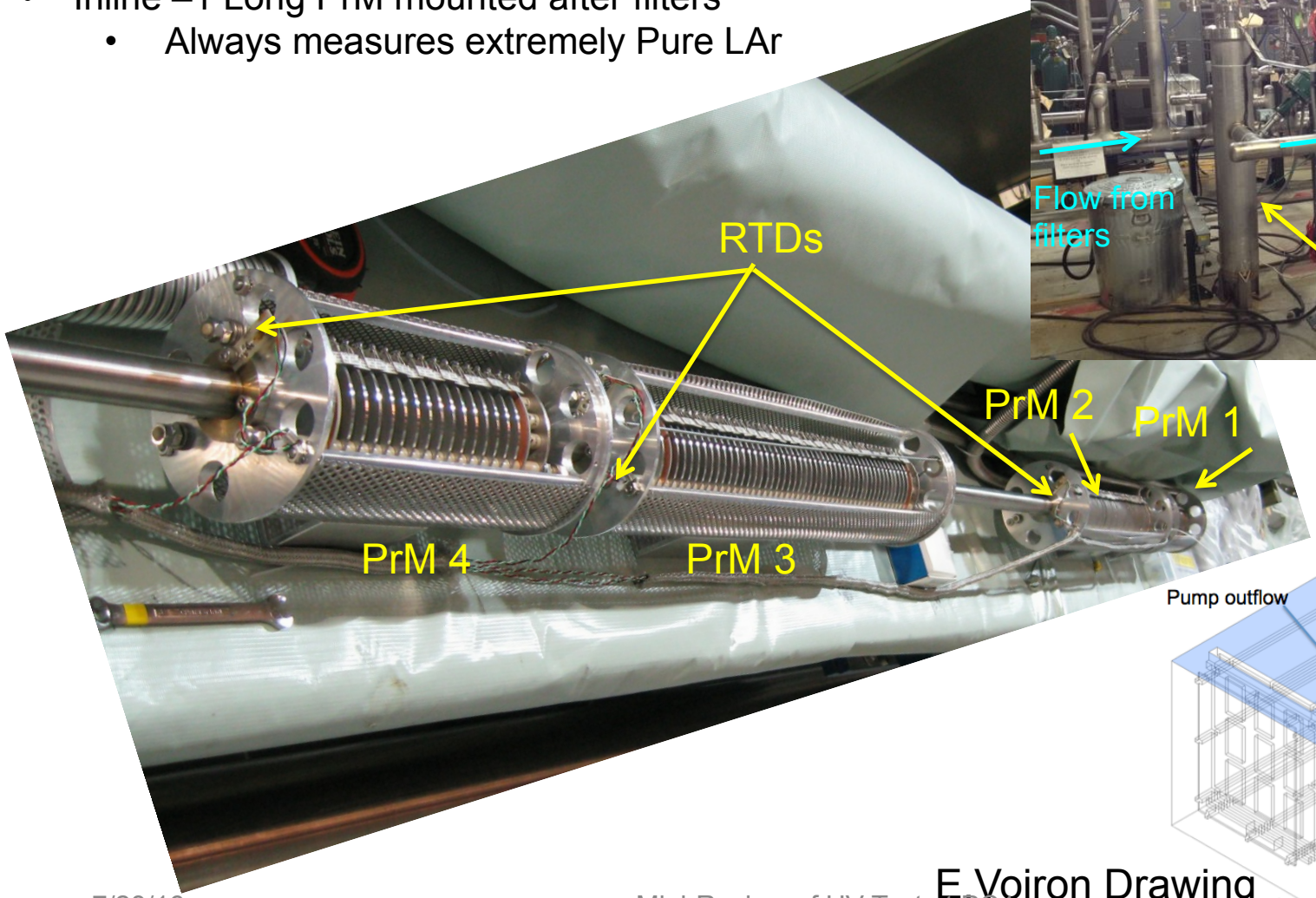
				Last Run	
				Phase 2 actual days	HV Stage 1 proposed days
8923	5/2/16	Starting Pump in Bypass mode to empty cryostat---this is 1 gal/min in order to vaporize the LAr			
8933	5/5/16	Level dropping 17.4"/day	LAr Pumping	4	1
8935	5/6/16	LAr Pump tripped off due to low discharge pressure interlock (~32" Lar ~2000-2500 gallons LAr.)			
8937	5/6/16	Purge Insulationspace with N2 so N2 Bubbling doesn't lower Cryo temp and liquify Gar in insulation space	N2 Purge insulation		
8945	5/10/16	Turn off LN2 cooling in LAPD		4	2
8946	5/11/16	Start bubbling N2 into 35T piston purge piping to remove remaining Lar.			
8947	5/11/16	RTD 1 response to N2 Bubbling	N2 Bubbling	13	7
8954	5/13/16	2.5"/day drop in LAr/N2 mixture			
8960	5/24/16	All floor membrane RTDs are in GAr.			
8961	5/25/16	12.5 SCFM N2 flow continues in Cryostat			
8963	5/25/16	Membrane RTDs at 220K	N2 Warmup		
8967	5/27/16	Membrane RTDs at 0C		6	6
8970	5/31/16	Interior of Cryostat at 70F (297K)			
8972	5/31/16	Change Gas flow to breathable air	Breathable		
8977	6/6/16	O2= 18.7% (no elog entry for when O2=21%		3	0
8981	6/9/16	Xfer lies between LAPD filtration and 35T are loto'd to enable entry.			
			total time	38	16

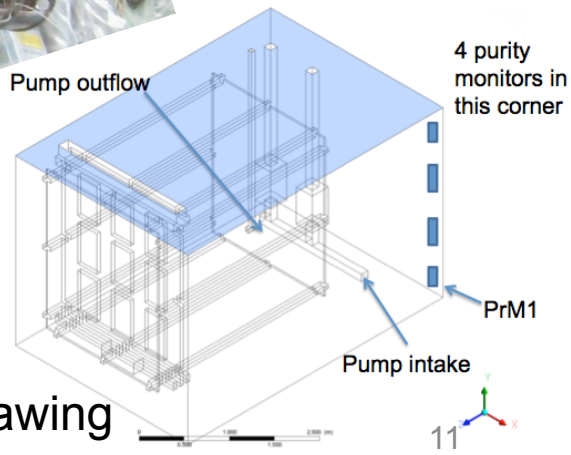
Cryo Instrumentation

Purity Monitors

- Cryostat: String of 4 PrMs, Short-Long—Long-Short
- Inline –1 Long PrM mounted after filters
  - Always measures extremely Pure LAr



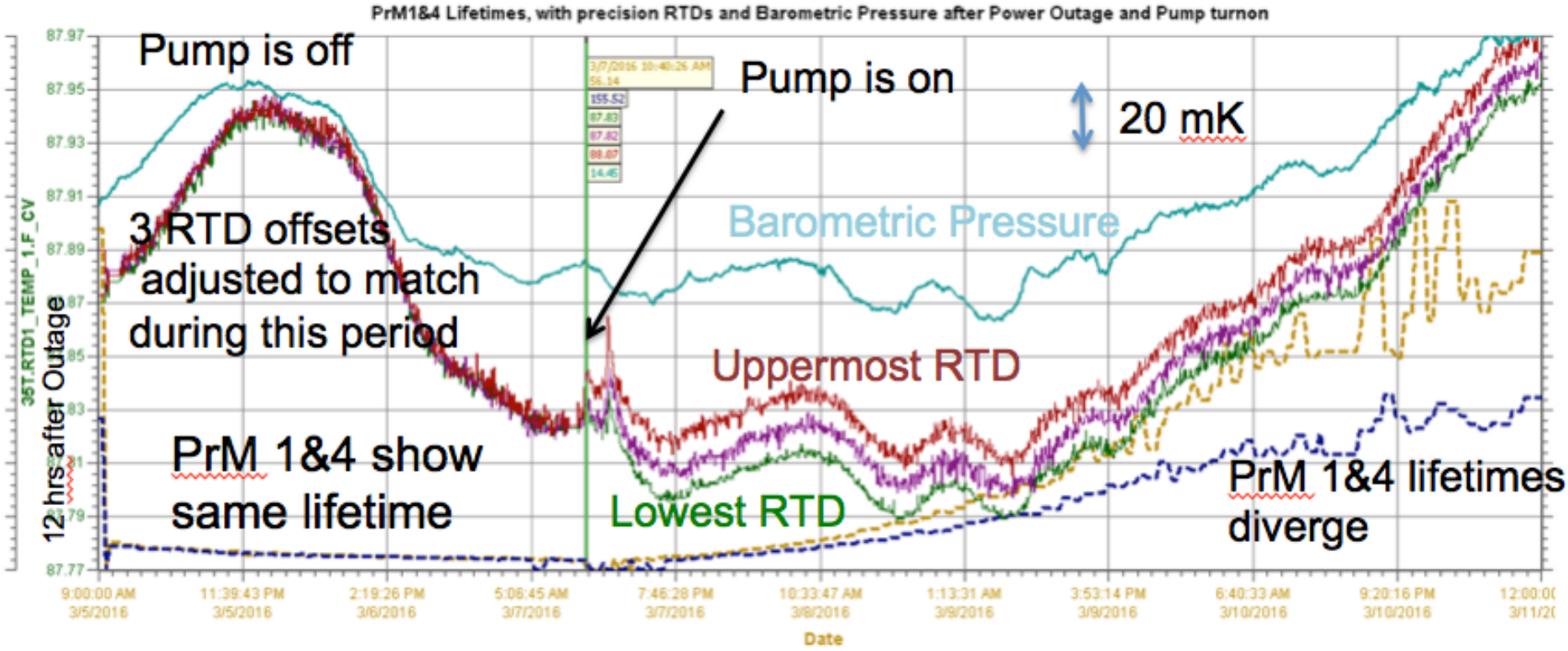




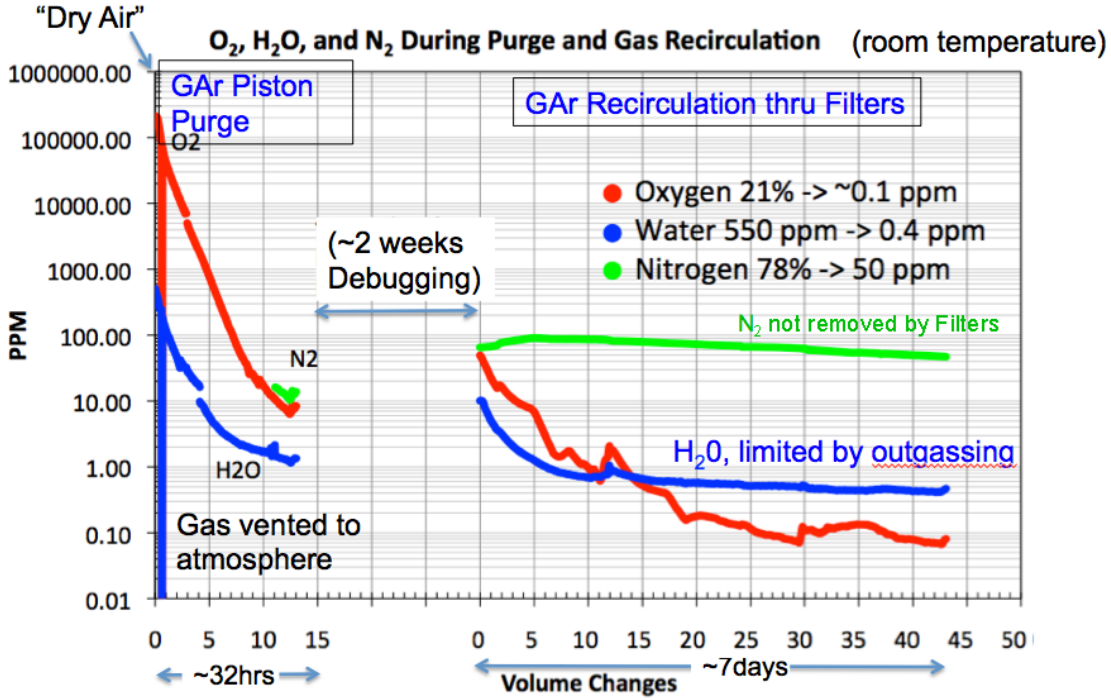
E Voiron Drawing

Precision Temperature Measurement

- RTD Readout—Lakeshore 218
  - Have achieved ~ 2 mK rms resolution (statistical) on 35T Phase 2 RTD readout.
  - These are the RTDs shown in previous slide.



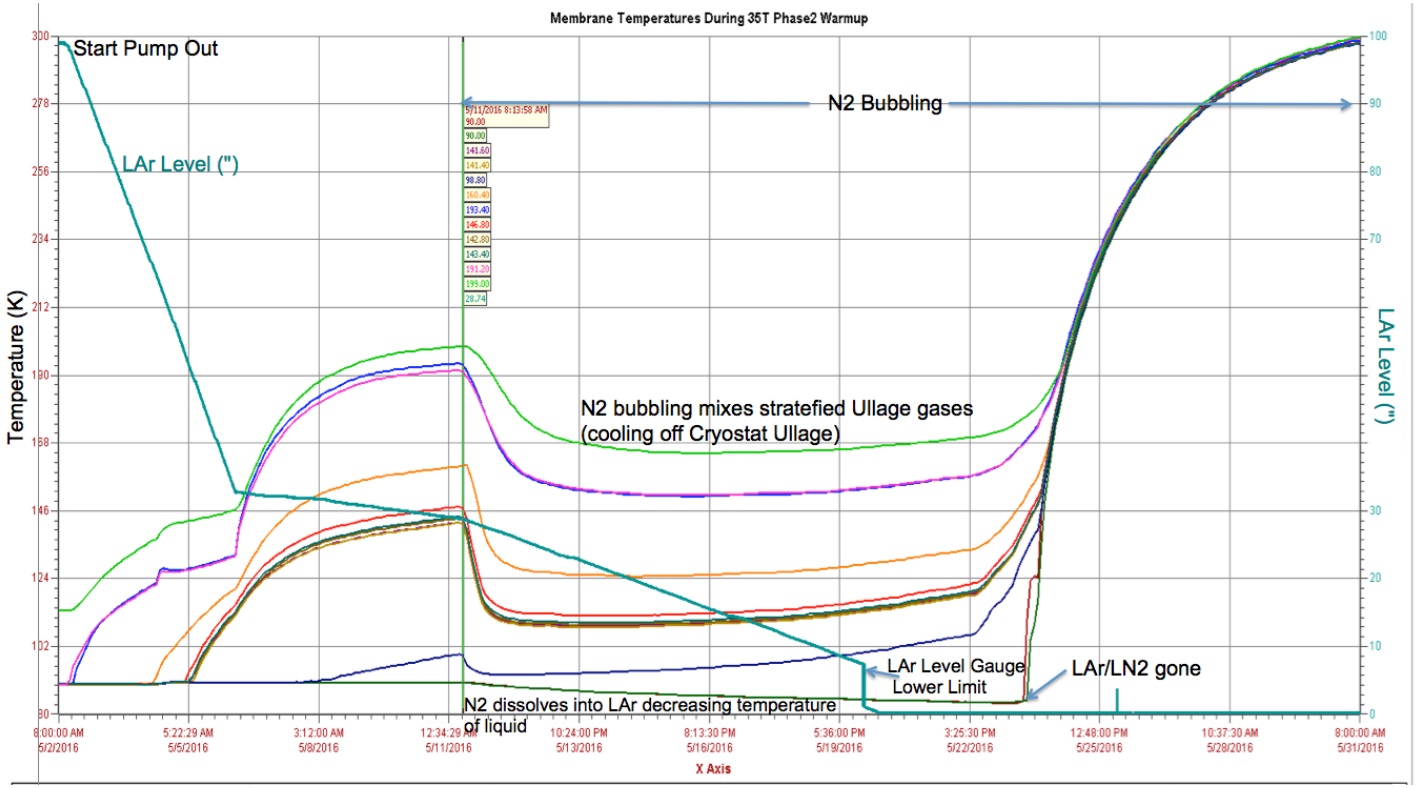
Gas Analyzers



- Can "sniff" liquid or gas regions of cryostat
  - O_2, N_2, H_2O units, with sensitivities from % to sub-ppb levels
  - Useful for both debugging during initial phase of gas purging and during the run to help identify contamination

More Cryo Instrumentation

- RTDs, Pressure Transducers, LAr Level Indicators…
- Monitored and archived by the Cryo Controls System

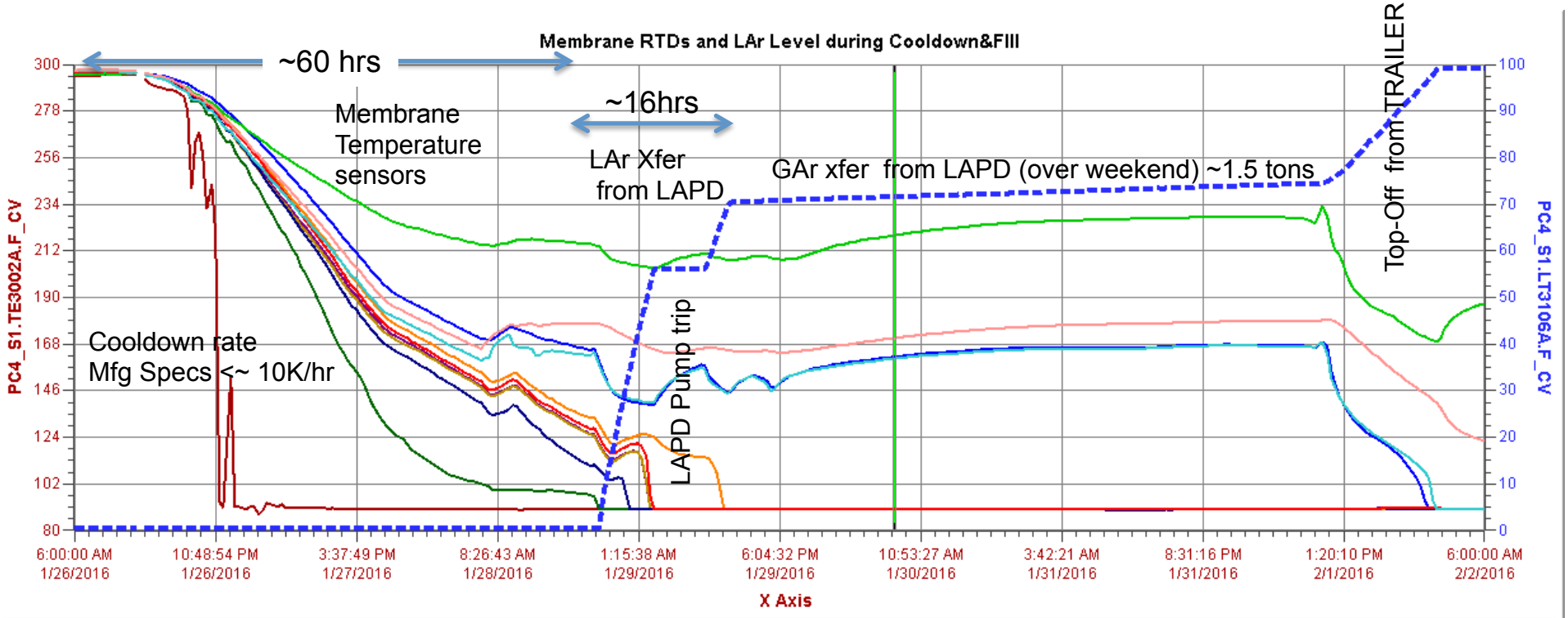


Other Cryo Motivation for this Run

- 35T Phase 2 (and perhaps Phase 1) showed that the Purity in Cryostat was vertically stratified.
  - See slides 12 and 18
  - Erik Voiron theorizes this is due to the filtered highly pure LAr that is returned to the Cryostat is slightly cooler than the bulk LAr.
    - Seems to be backed up by PrM mounted RTDs (slide 12)
  - LAr is being introduced at bottom of Cryostat and tends to stay there since it is cooler
  - The pump intake is also at the bottom.
    - We are filtering the LAr that is already pretty pure.
- We plan to alter the return point to be near the surface layer of the Cryostat
  - See if this avoids the previous stratification by better mixing the return LAr into the bulk LAr.
  - Plan to place a “Precision” RTD near the return manifold to sample the temperature.
  - As a side, with better mixing we might improve the overall purity of LAr.
- See Erik’s DuneDocDB1156 for more info

Xtra slides

Phase 2: 35T Cooldown and Filling



Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
PC4_S1.TE3004A.F_CV	LAPD tank (base) (F_CV)	89.40	C	295.60	89.20
PC4_S1.TE3005A.F_CV	LAPD tank (midpoint (F_CV)	89.20	C	295.40	89.20
PC4_S1.TE3006A.F_CV	LAPD tank (base) (F_CV)	89.20	C	295.40	89.00
PC4_S1.TE3007A.F_CV	LAPD tank (base) (F_CV)	89.20	C	295.40	89.20
PC4_S1.TE3008A.F_CV	LAPD tank (base) (F_CV)	161.48	C	295.60	89.40
PC4_S1.TE3009A.F_CV	LAPD tank (midpoint) (F_CV)	89.40	C	295.40	89.20
PC4_S1.TE3014A.F_CV	LAPD tank (midpoint) (F_CV)	219.15	C	295.40	168.60
PC4_S1.TE3016A.F_CV	LAPD tank (top - L) (F_CV)	160.68	C	296.80	89.20
PC4_S1.TE3017A.F_CV	LAPD tank (top - E) (F_CV)	170.35	C	297.20	122.00
PC4_S1.LT3106A.F_CV	LBNE tank liquid level (F_CV)	71.530	%	99.062	0.084

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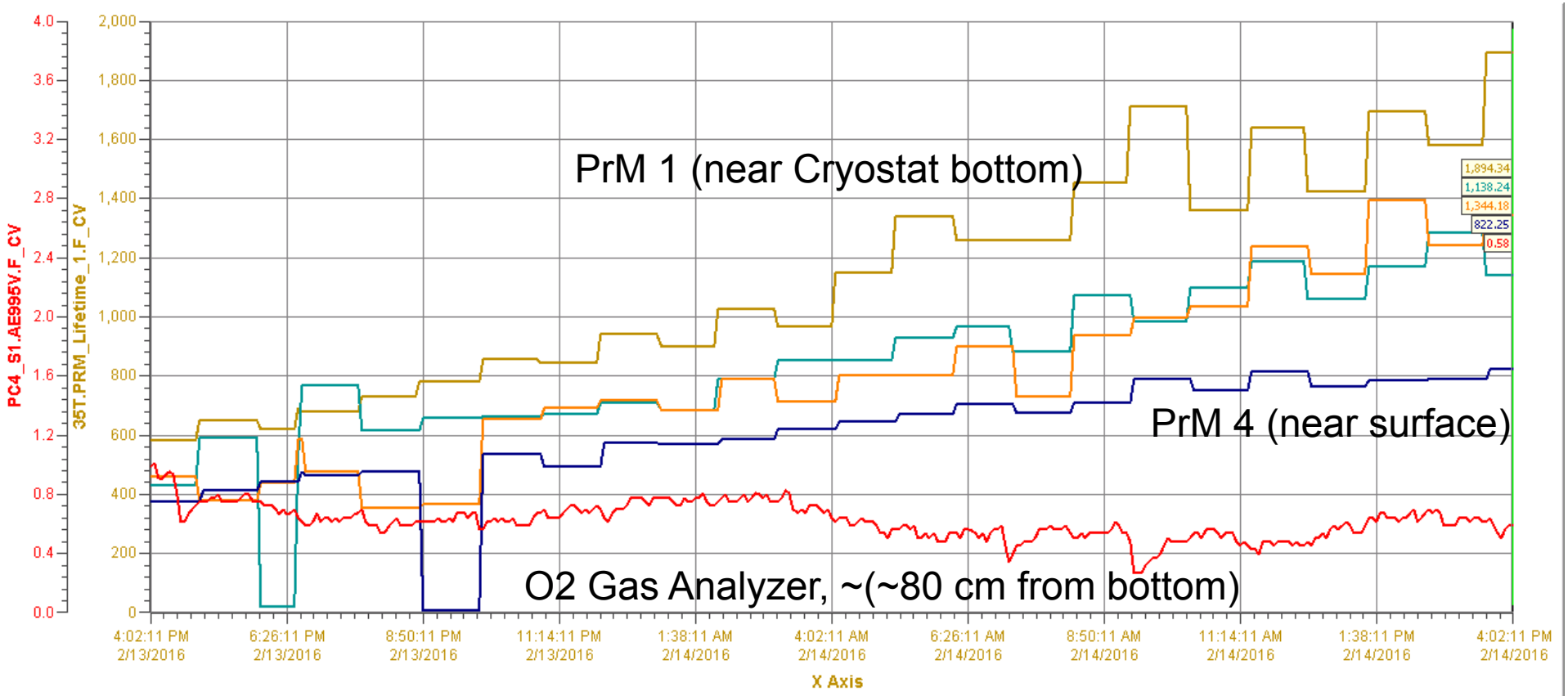
Immediately Notice Purity Stratification after pump start and purification



Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
35T.PRM_Lifetime_1.F_CV	Lifetime calculated from AnodeTrue Cat...	1,894.3	us	1,894.3	578.2
35T.PRM_Lifetime_2.F_CV	Lifetime calculated from AnodeTrue Cat...	1,138.2	us	1,281.4	15.0
35T.PRM_Lifetime_3.F_CV	Lifetime calculated from AnodeTrue Cat...	1,344.2	us	1,393.3	352.6
35T.PRM_Lifetime_4.F_CV	Lifetime calculated from AnodeTrue Cat...	822.2	us	822.2	1.6
PC4_S1.AE995V.F_CV	Analyzer Delta F NanoTrace O2 (F_CV)	0.582	PPB	1.005	0.257

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