



---

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

---

# **35 Ton Run 2**

## **Operation and Experiences**

Fritz Schwartz

October 26, 2016

# Outline

---

- Background information
  - Overview of system and key components
- Operating modes of 35T
  - Piston Purge
  - Cooldown & Filling
- Issues seen during operation
  - Liquid Pump Seizure
  - Power outage
  - Loss of LN2 cooling to condensers
  - Vapor pump failure leading to gross contamination of liquid argon
- Future plans for 35T system

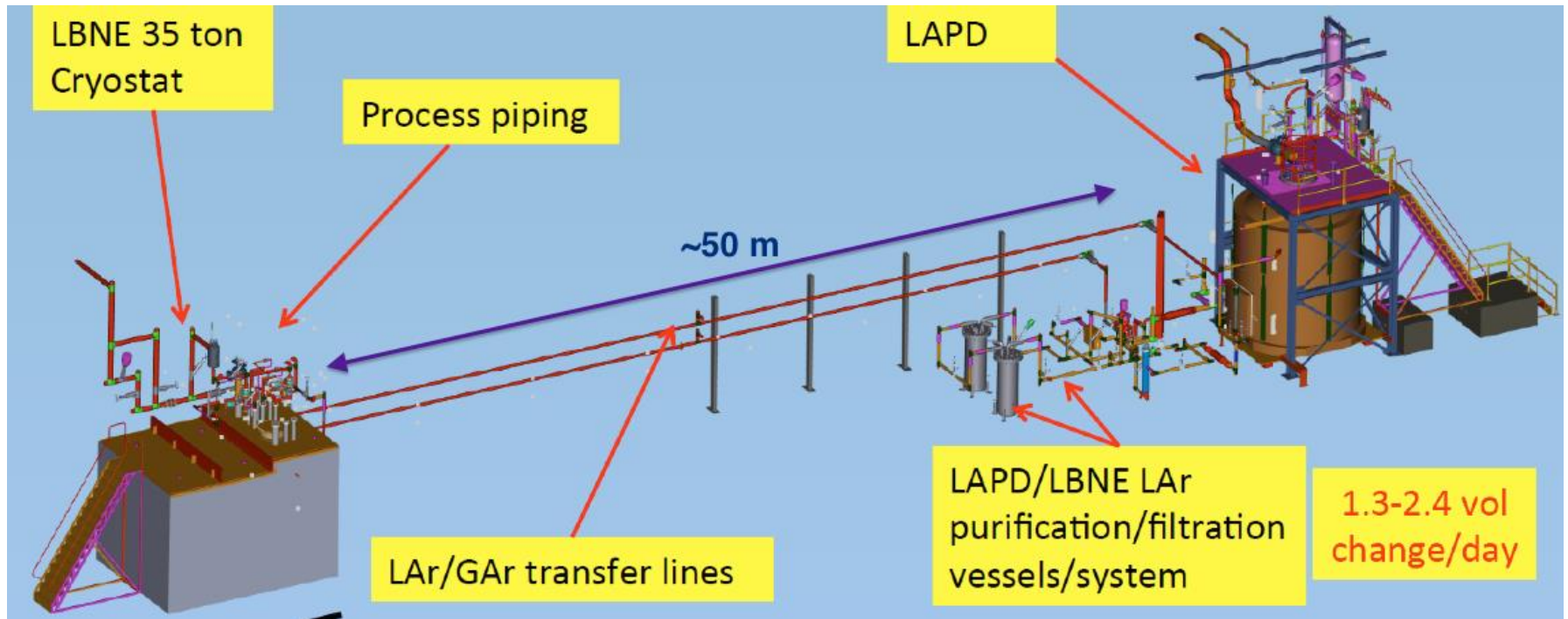
# Background Information

---

- Prototype Cryostat at Fermilab to show the suitability of the membrane technology for LAr detectors
- Constructed in 2012 in a decommissioned proton beam line, adjacent to the existing Liquid Argon Purity Demonstrator (LAPD)
- Reuse the existing purification and instrumentation infrastructure of LAPD
- Run 1 of 35T was a successful demonstration of techniques of piston purge, cooldown and purification in the membrane cryostat of rectangular shape and warm top plate without TPC (detector)
- Run 2 was initiated in 2015 to test operations of the newly installed TPC
- Filtration stopped on March 19, 2016 after warm pump failed resulting in intake of atmospheric air and contaminating 35T LAr inventory

# Cryogenic System Overview

- System as installed in PC4 facility



# Key System Components

---

- Cryostats
- Liquid Argon Pumps
- Condensers
- Filtration
- Purity Monitoring

# Cryostats





# Liquid Argon Pumps

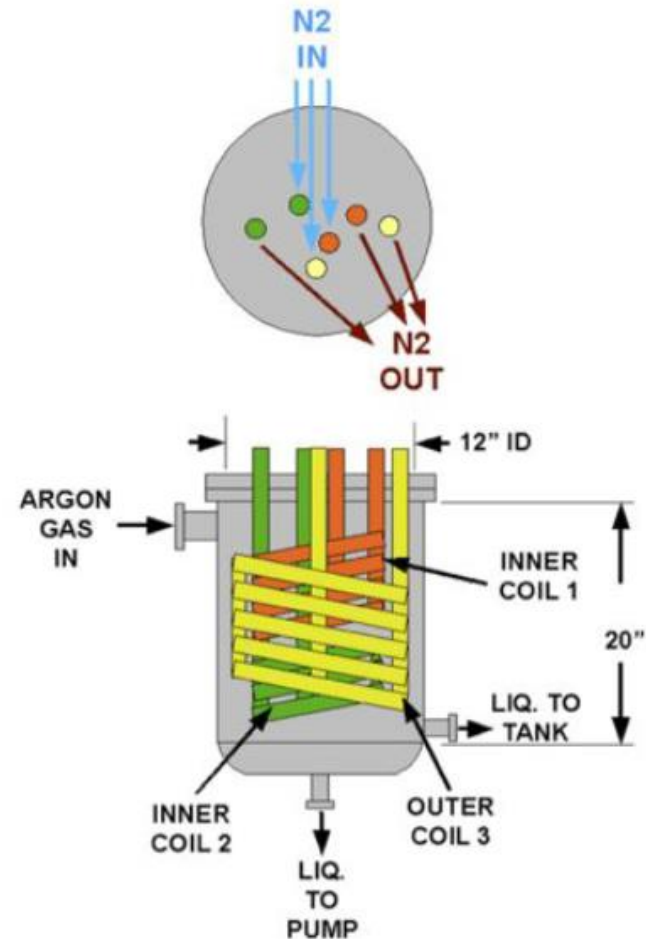
---

- ACD submersible AC32 pumps



# Condenser Design

- Coiled tubing circulating liquid nitrogen
- Seamless tubing with connections outside vessel to decrease possibility of leak into cryostat argon
- Control valves regulate the flow to each coil depending upon heat load





# Filtration

---

- Water filter
  - ~80 liters 4A porous sphere molecular sieve
  - Regenerated using heated argon gas, followed by evacuation
  - Upstream of oxygen filter because oxygen filter also removes water
- Oxygen filter
  - ~80 liters of copper catalyst
  - A thin layer of copper on a high surface area alumina substrate
  - Regenerated using a heated mixture of hydrogen/argon gas which removes oxygen from the copper to form water, followed by evacuation
  - Capacity at LAr temperature is approximately 0.5g O<sub>2</sub> per kg of filter material
- Particulates
  - Sintered metal filters, large surface areas
  - Used to protect other equipment from debris

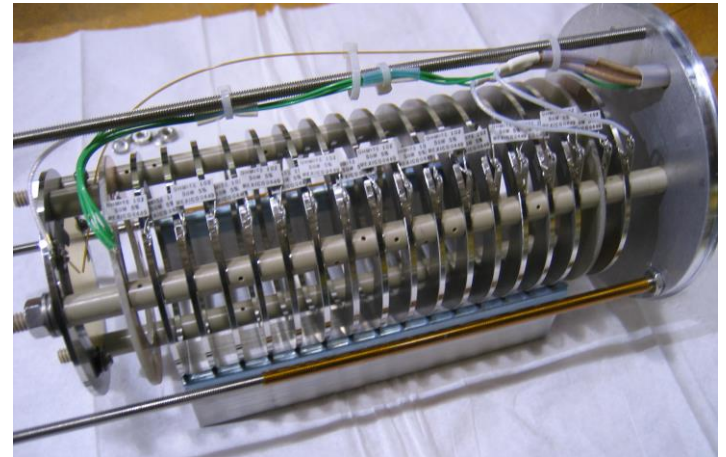
# Water & Oxygen Filter Design



# Purity Monitoring

---

- Commercial/Laboratory Gas Analyzers
  - Nitrogen
  - Oxygen (3 with multiple ranges)
  - Water (Rough dew point and higher precision)
- Purity Monitor
  - Creates an electron drift using xenon flash lamp and photo cathode
  - In-line and cryostat installations



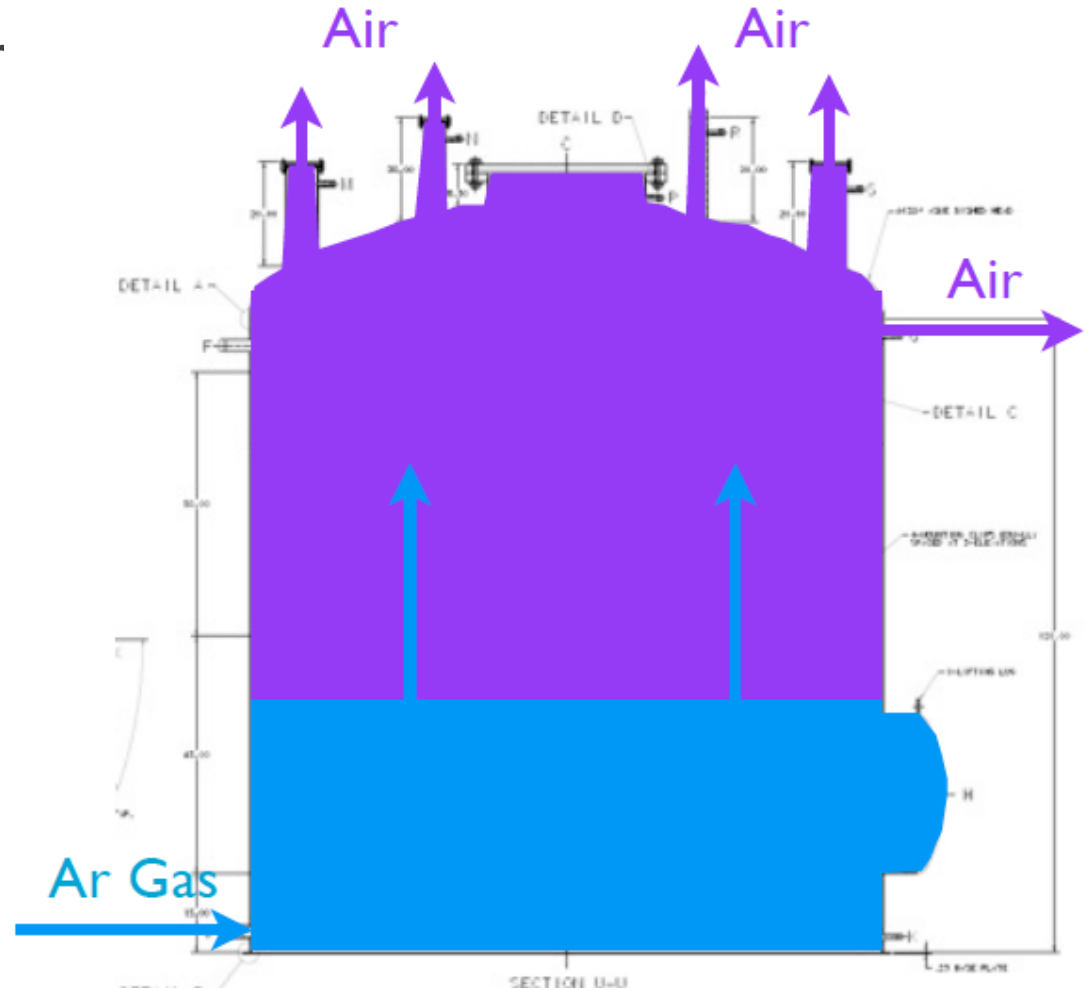
# Outline

---

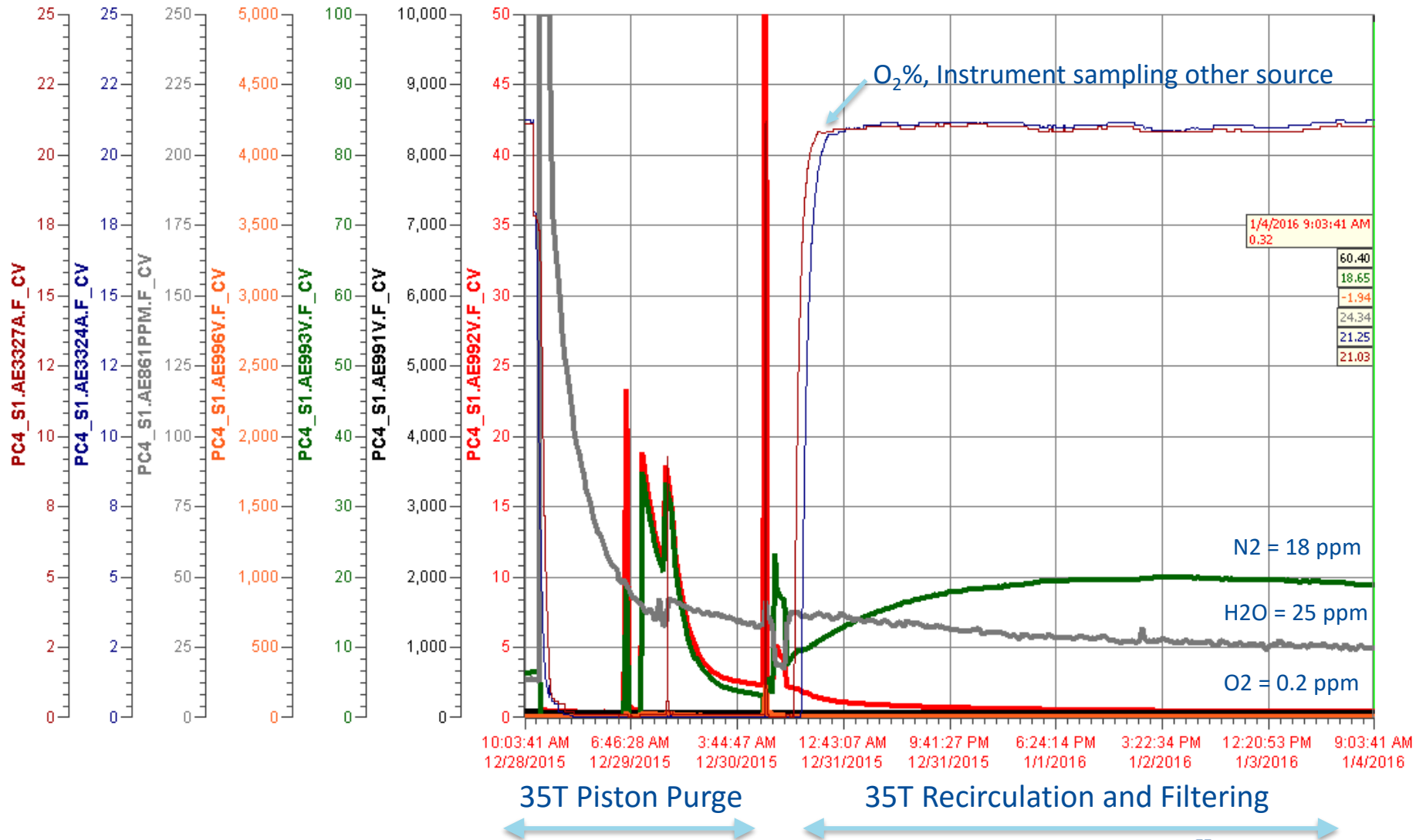
- Background information
  - Overview of system and key components
- Operating modes of 35T
  - Piston Purge
  - Cooldown & Filling
- Issues seen during operation
  - Liquid Pump Seizure
  - Power outage
  - Loss of LN2 cooling to condensers
  - Vapor pump failure leading to gross contamination of liquid argon
- Future plans for 35T system

# 35T Piston Purge & Recirculation

- Using higher density of argon to push out other gases from bottom to top
- Vertical velocity of 1.2 meters per hour determined best to reduce mixing



# 35T Piston Purge & Recirculation





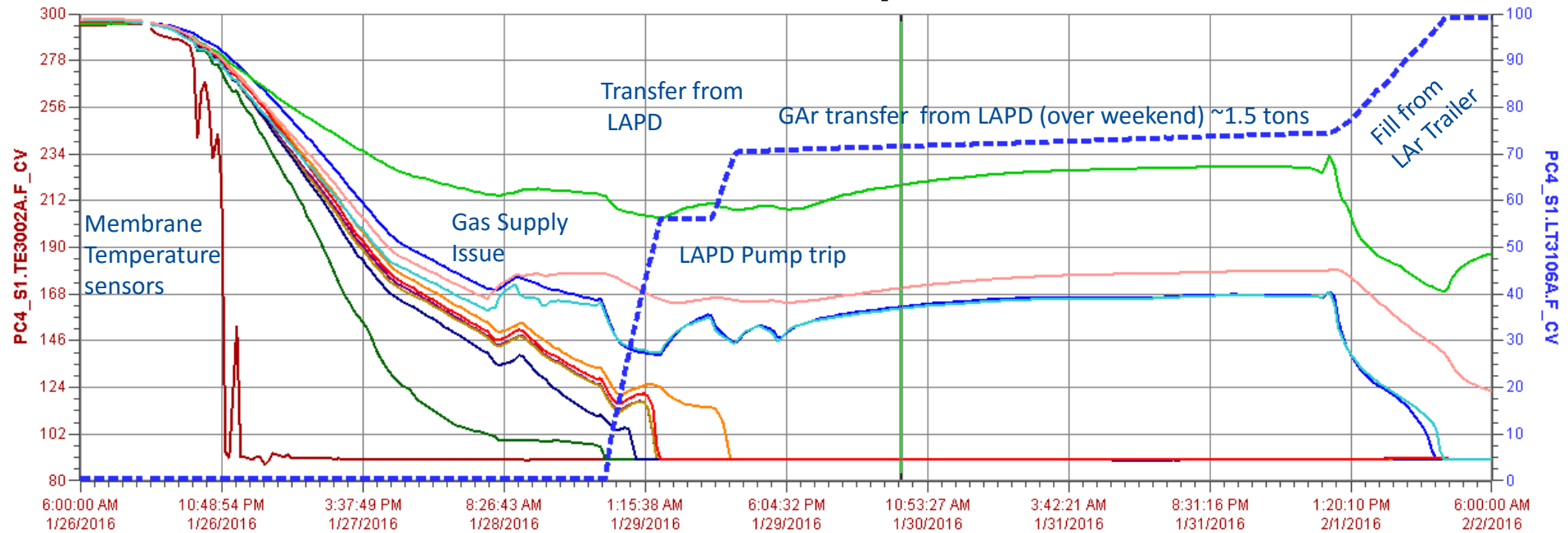
# Cooldown Sprayers

- Mix liquid and gas argon
- Additional nozzles provide necessary momentum to circulate flow around volume of cryostat
- Design rate of 10K/hr supplied by cryostat manufacturer



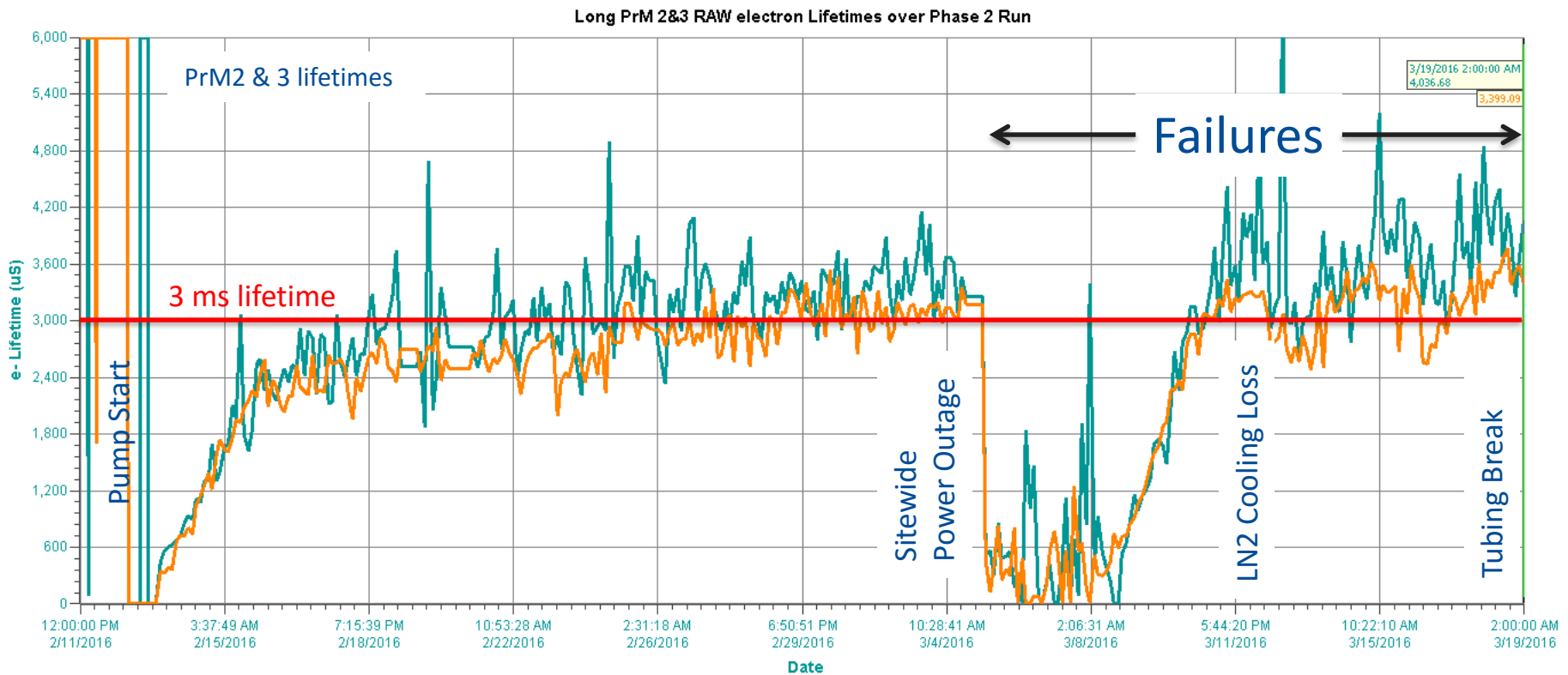
# Cooldown and Fill of 35T

Membrane RTDs and LAr Level during Cooldown&Fill



# Results of Run 2

- Several issues occurred during this run – did provide valuable lessons for future systems



# Outline

---

- Background information
  - Overview of system and key components
- Operating modes of 35T
  - Piston Purge
  - Cooldown & Filling
- Issues seen during operation
  - Liquid Pump Seizure
  - Power outage
  - Loss of LN2 cooling to condensers
  - Vapor pump failure leading to gross contamination of liquid argon
- Future plans for 35T system

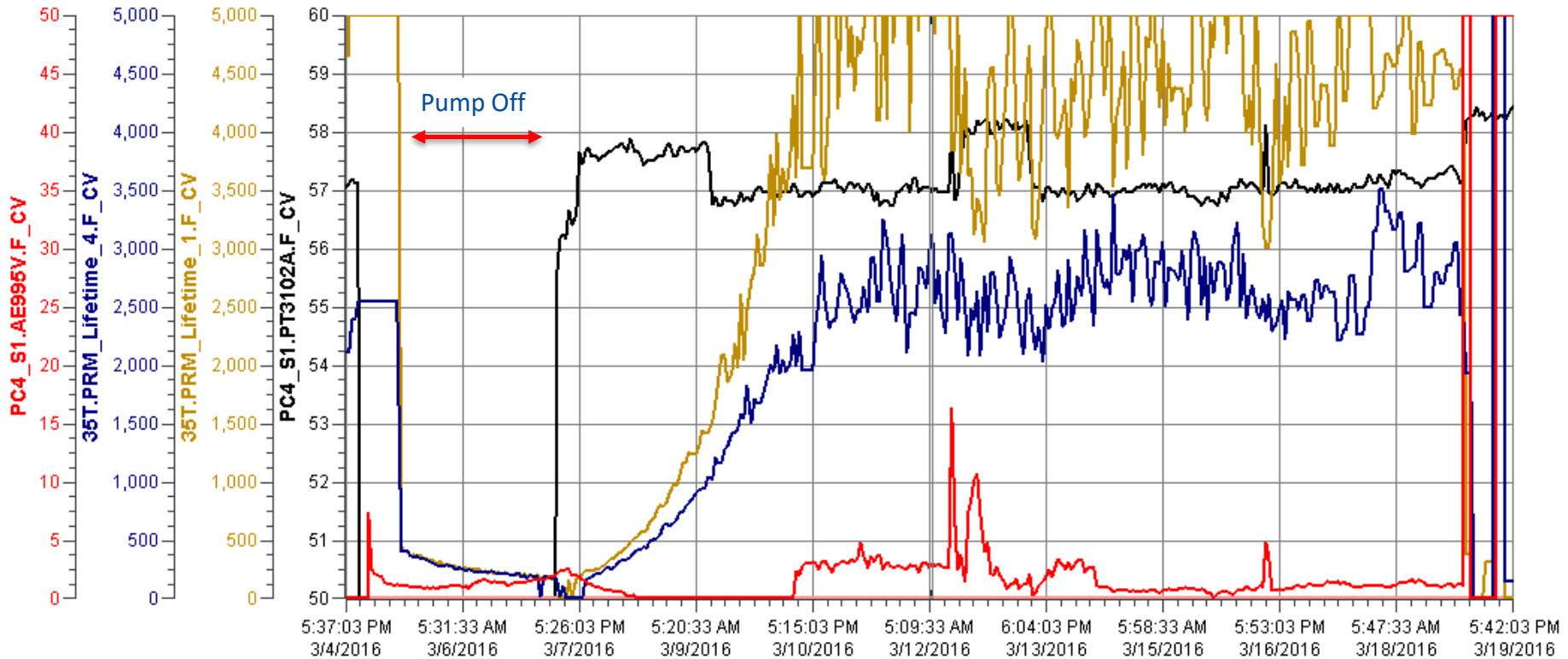
# Liquid Pump Seizure

---

- With 35T cryostat completely filled, the submersible pumps were seized up and blowing fuses
- Pumps were rebuilt after Run 1, suspected that they were not tested prior to trying to operate them now
- Controls group bypassed fast acting fuses with disconnect fuses and installed simple ON/OFF switch to bump motor several times (momentarily ON, 1 minute OFF)
- The pump finally broke free after 12 repetitions
- Restored original wiring once pumps were freed

# Power Outage

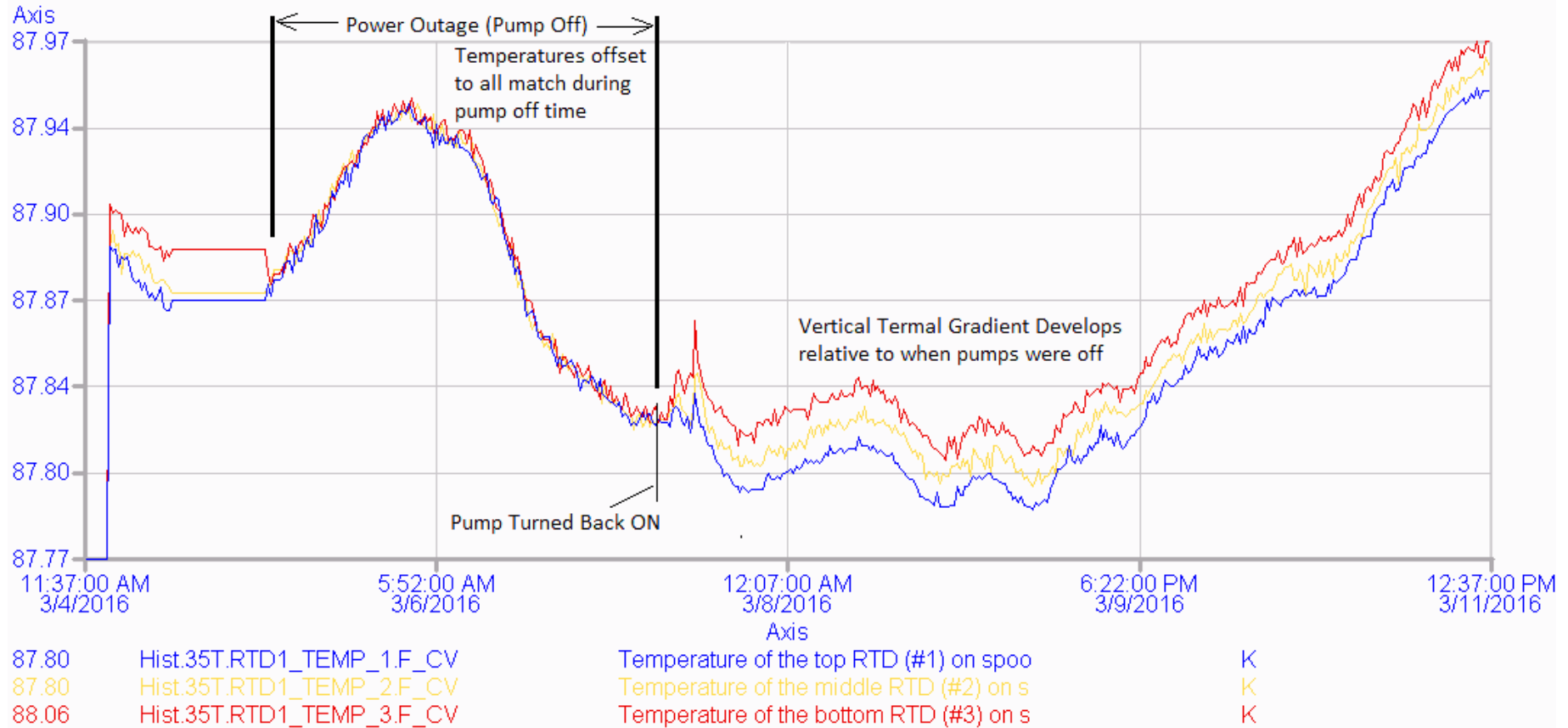
- The power outage provided an opportunity to identify purity gradients within the liquid





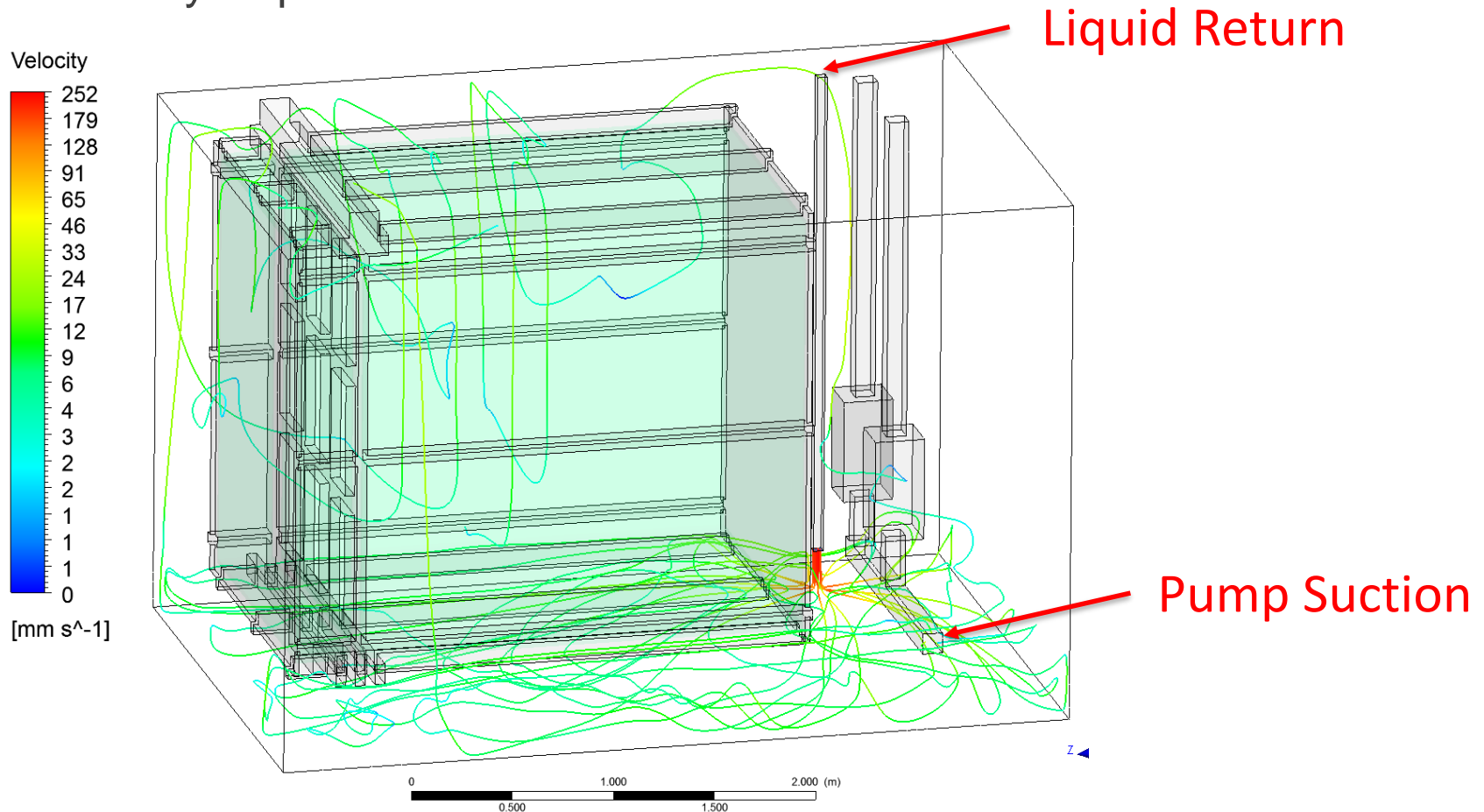
# Power Outage

- Small thermal gradients were also noticed



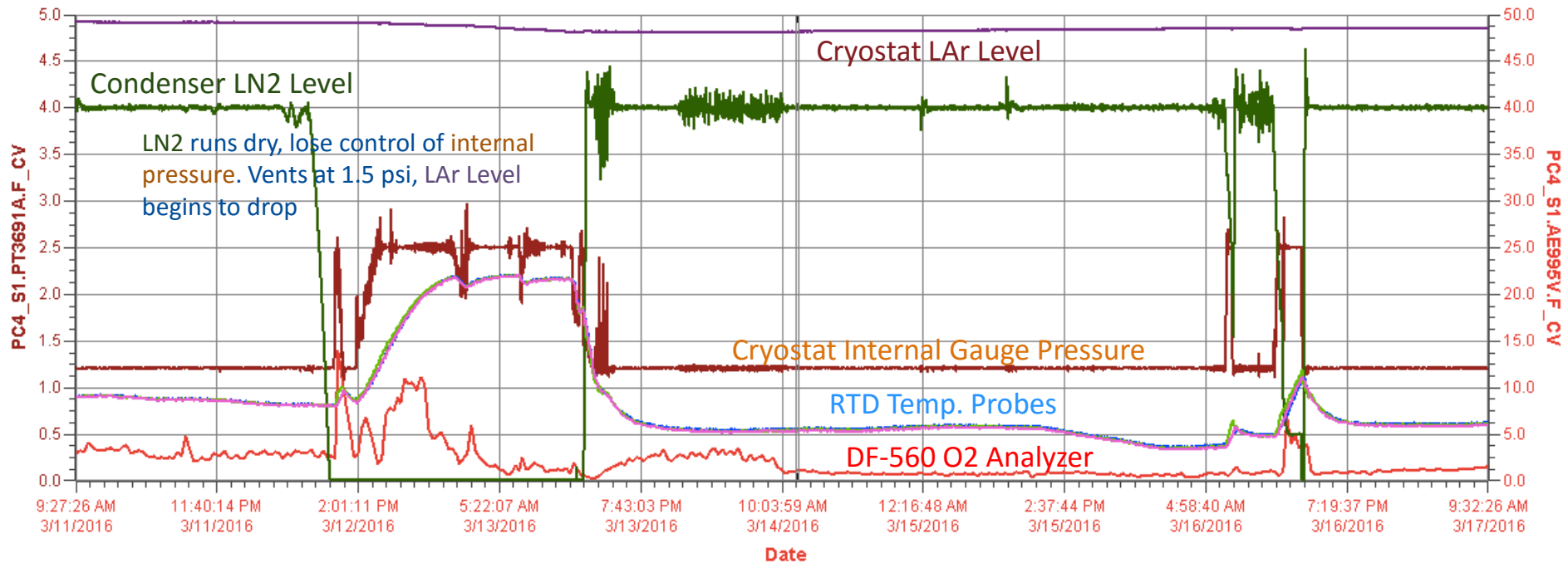
# CFD Analysis (Erik Voirin)

- Suspected that the liquid return was the primary cause
- CFD analysis performed to confirm



# Loss of LN2 Cooling

- Loose valve plug on LN2 supply line



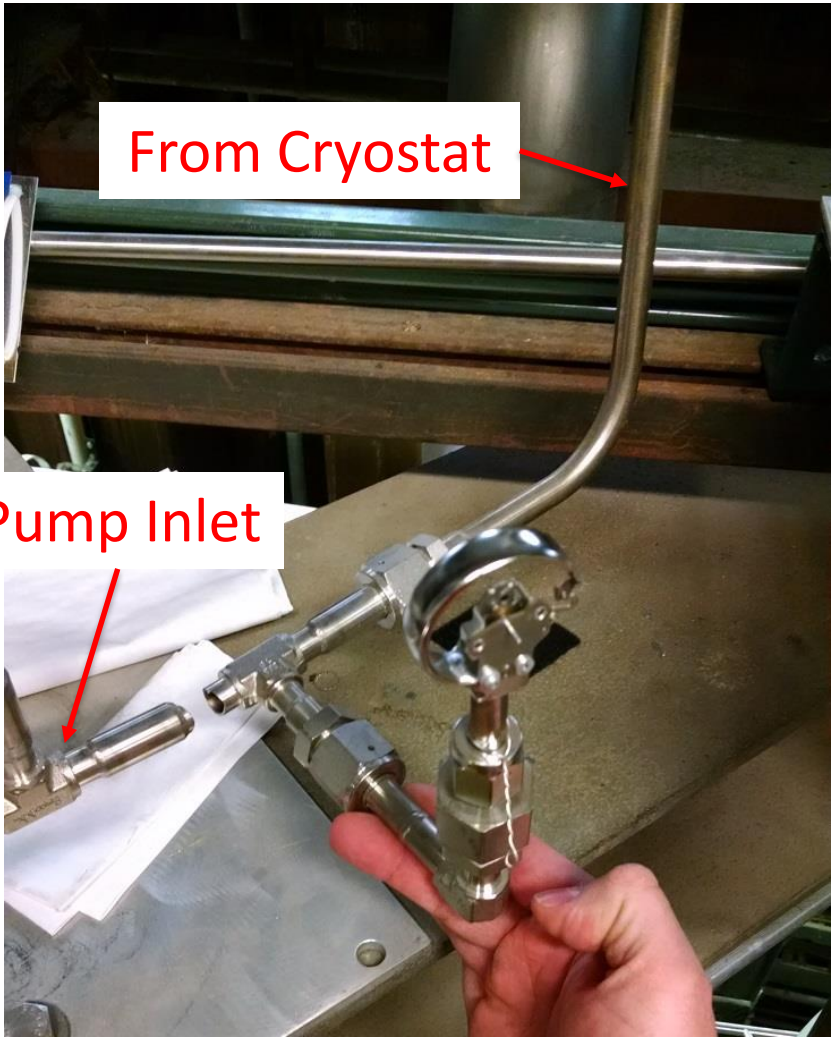
Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
PC4_S1.AE995V.F_CV	Analyzer Delta F NanoTrace O2 (F_CV)	0.904	PPB	13.860	0.148
PC4_S1.PT3691A.F_CV		1.2	PSID	3.0	1.1
PC4_S1.LT3161N.F_CV	LBNE tank liquid level (F_CV)	0.80	%	0.93	0.00
35T.RTD1_TEMP_1.F_CV		87.77	K	88.60	87.67
PC4_S1.LT3106A.F_CV	LBNE tank liquid level (F_CV)	96.32	%	98.43	96.15
35T.RTD1_TEMP_3.F_CV		88.02	K	88.85	87.91
35T.RTD1_TEMP_2.F_CV		87.76	K	88.60	87.66

3/11/2016 9:27:26 AM

3/17/2016 9:32:26 AM

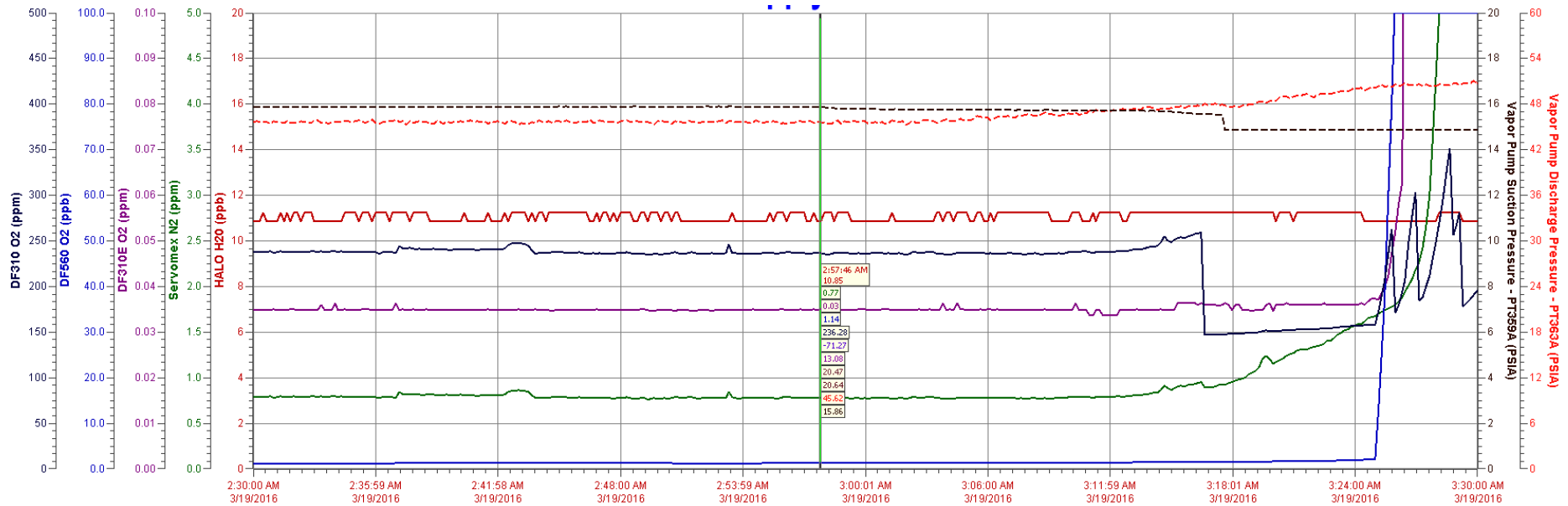


# Vapor Pump Failure



# Vapor Pump Failure

- Gas analyzers sampling from ullage space
- Filters saturate, see response from analyzers within 20 minutes
- Complete loss within 30 minutes...ending the run



# Recommendations to Reduce Major Contamination

---

- A panel was formed to investigate the failure of the pump
- Conclusion was that design was done to acceptable codes and standards, also considering the short expected runtime
- Panel suggested that analyzers be installed at locations where contamination can be caught prior to entering cryostat
- Location is likely to be at liquid return line to cryostat where nitrogen (or oxygen) analyzer can be utilized
- Upon detection of impurities, controls need to isolate cryostats – total shutdown mode



# Outline

---

- Background information
  - Overview of system and key components
- Operating modes of 35T
  - Piston Purge
  - Cooldown & Filling
- Issues seen during operation
  - Liquid Pump Seizure
  - Power outage
  - Loss of LN2 cooling to condensers
  - Vapor pump failure leading to gross contamination of liquid argon
- Future plans for 35T system

## Future Plans of 35T

---

- Two runs planned for 2016-2017, with preparation work being performed now
  - High voltage test of ProtoDUNE style field cage assembly
  - Beam plug test to investigate effects of reducing amount of liquid argon between detector and cryostat wall
- Modifications to liquid argon return line in 35T cryostat
  - Investigate effects on the purity gradient issue
- Addition of heating elements in 35T cryostat to increase boil-off between runs, also useful for boil-off of pooling liquid during the spray cooling phase

---

# Questions?