The Liquid Argon Purity Demonstrator

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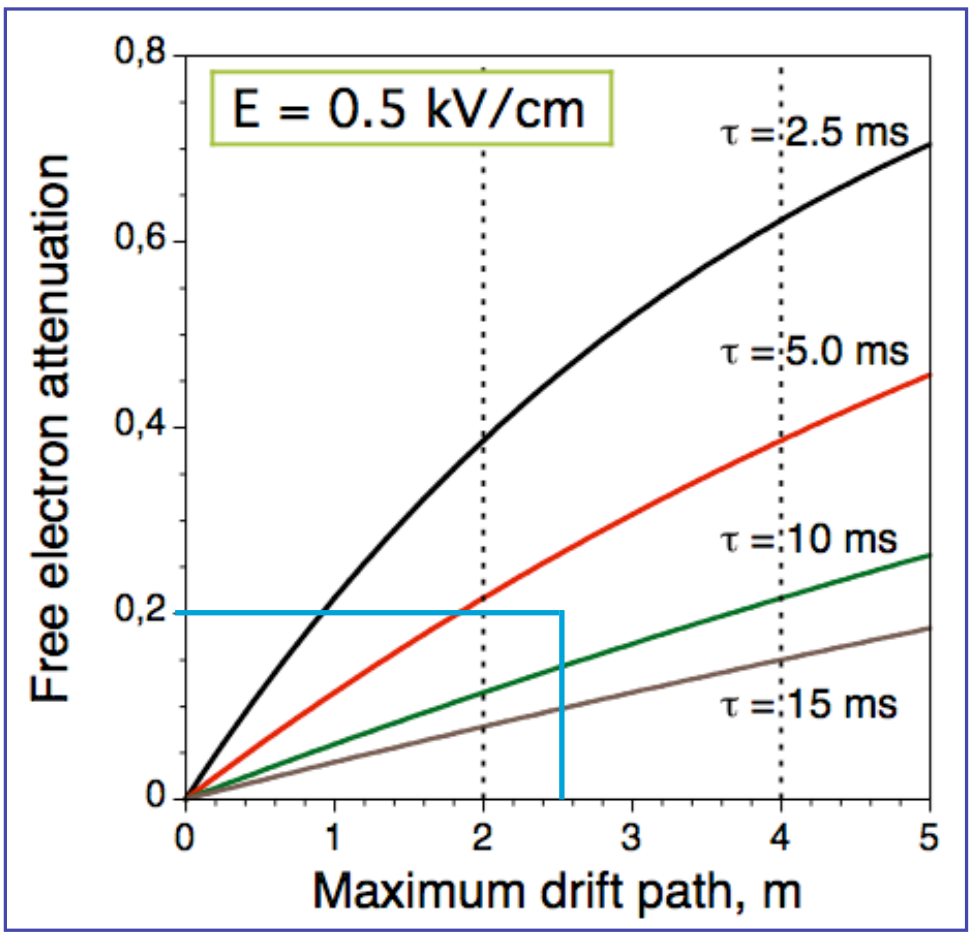
June, 2011

Why LAPD?

- Currently operating systems such as test stands at FNAL and ArgoNeuT use evacuation as the first step to achieve high purity
- Building large vessels that can be evacuated is expensive - scales the cost by at least a factor of 2 for small vessels, more for large vessels
- Want an alternative to evacuation for large vessels - LAPD is test stand at FNAL to study possibility of filling without evacuation
- Makes use of previous FNAL experience in design of system

LAPD Goals

- Primary goal is to show that required electron lifetimes for a 2.5m drift can be achieved without evacuation in an empty vessel - Phase I
- Will also monitor temperature gradients, concentrations of water, O_2, and N_2 during all stages of project where appropriate
- Phase II will place materials that would be used in a TPC into the volume and show that the lifetime can still be achieved



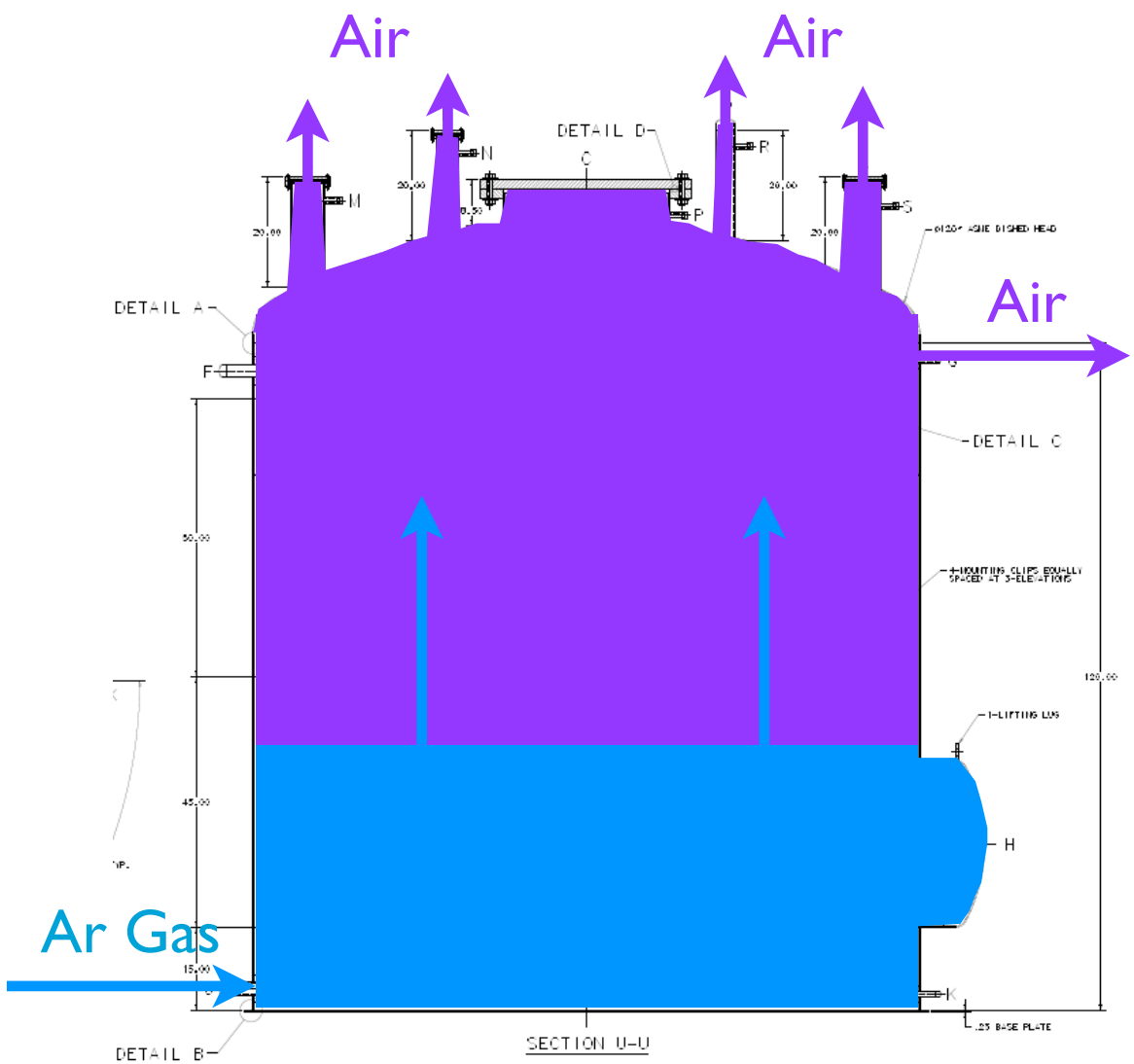
From C. Montanari, June 2007

Vessel Details

- Vessel holds ~30 t of LAr
- 3 m diameter and 3 m from base to top
- 0.48 cm thick stainless steel walls
- Insulation is 27.3 cm thick and allows heat leak of 45 W/m^2
- Heaters placed on outside walls of vessel to help boil off water during the purge

Phase I - Purification without Evacuation

- Basic idea is to use an argon piston for initial purification, followed by a few more volume exchanges
- Cycle a few volumes of clean, warm Ar gas through the volume to push out ambient air and dry out surfaces
- Then recirculate the gas through filter system to achieve < 50 ppm contamination



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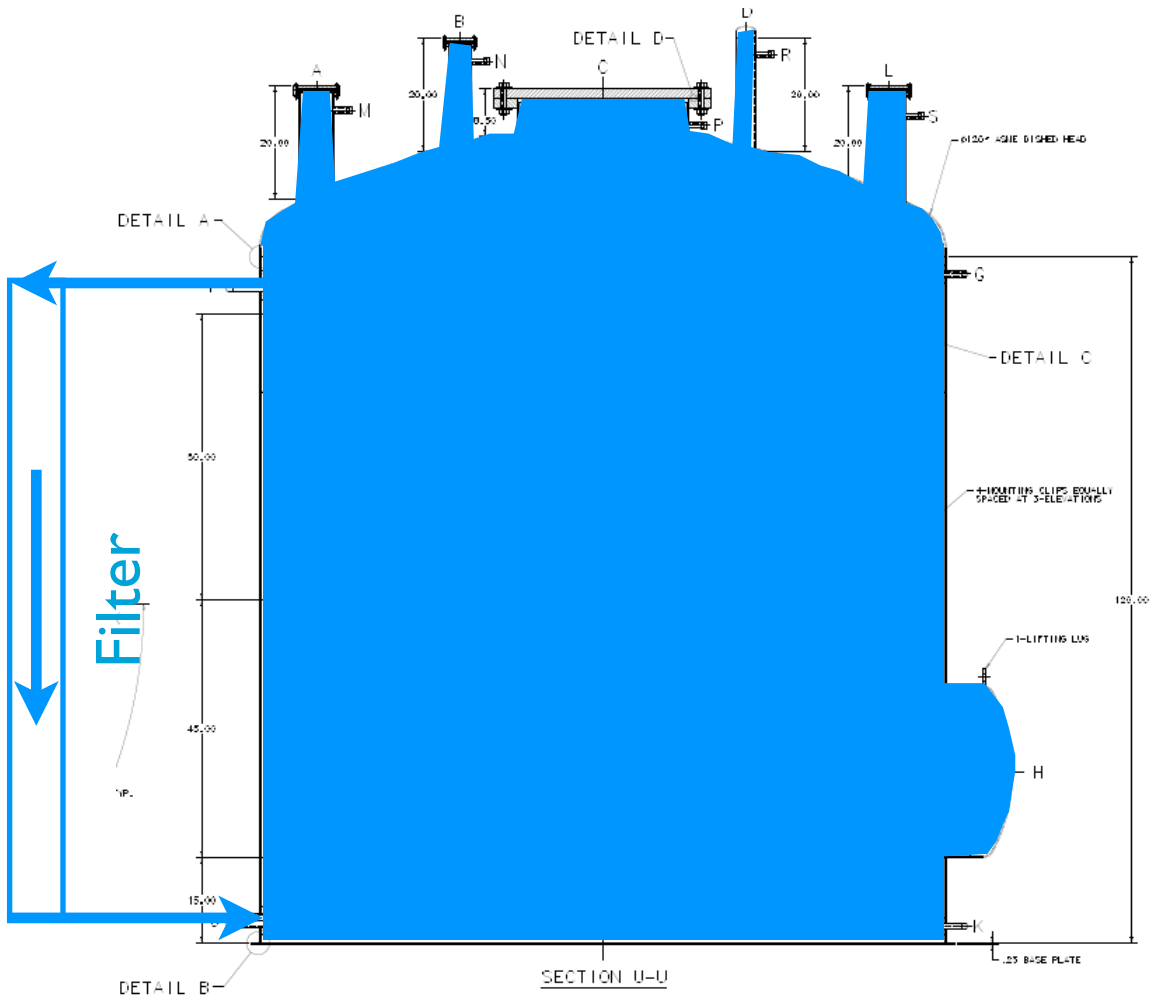
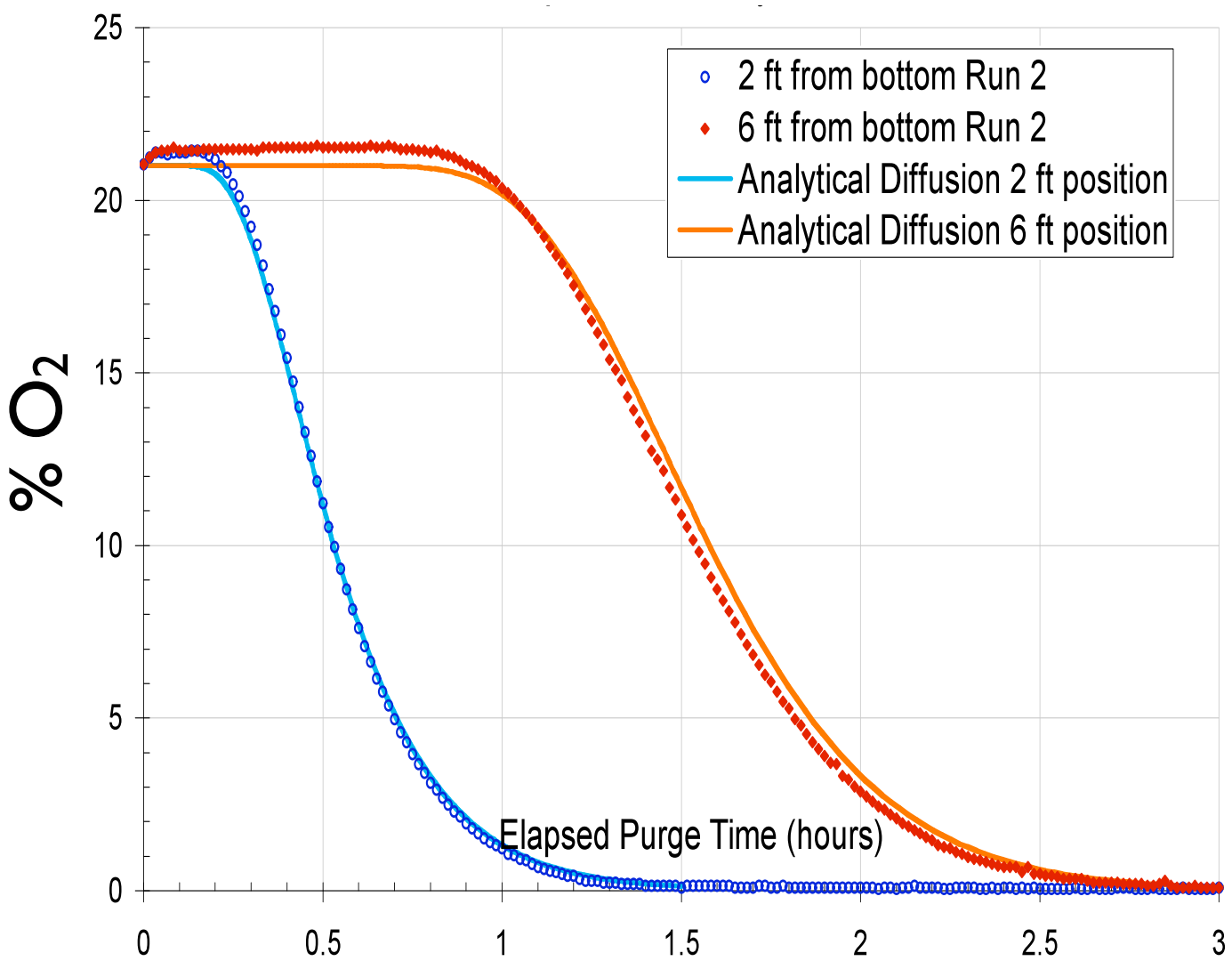
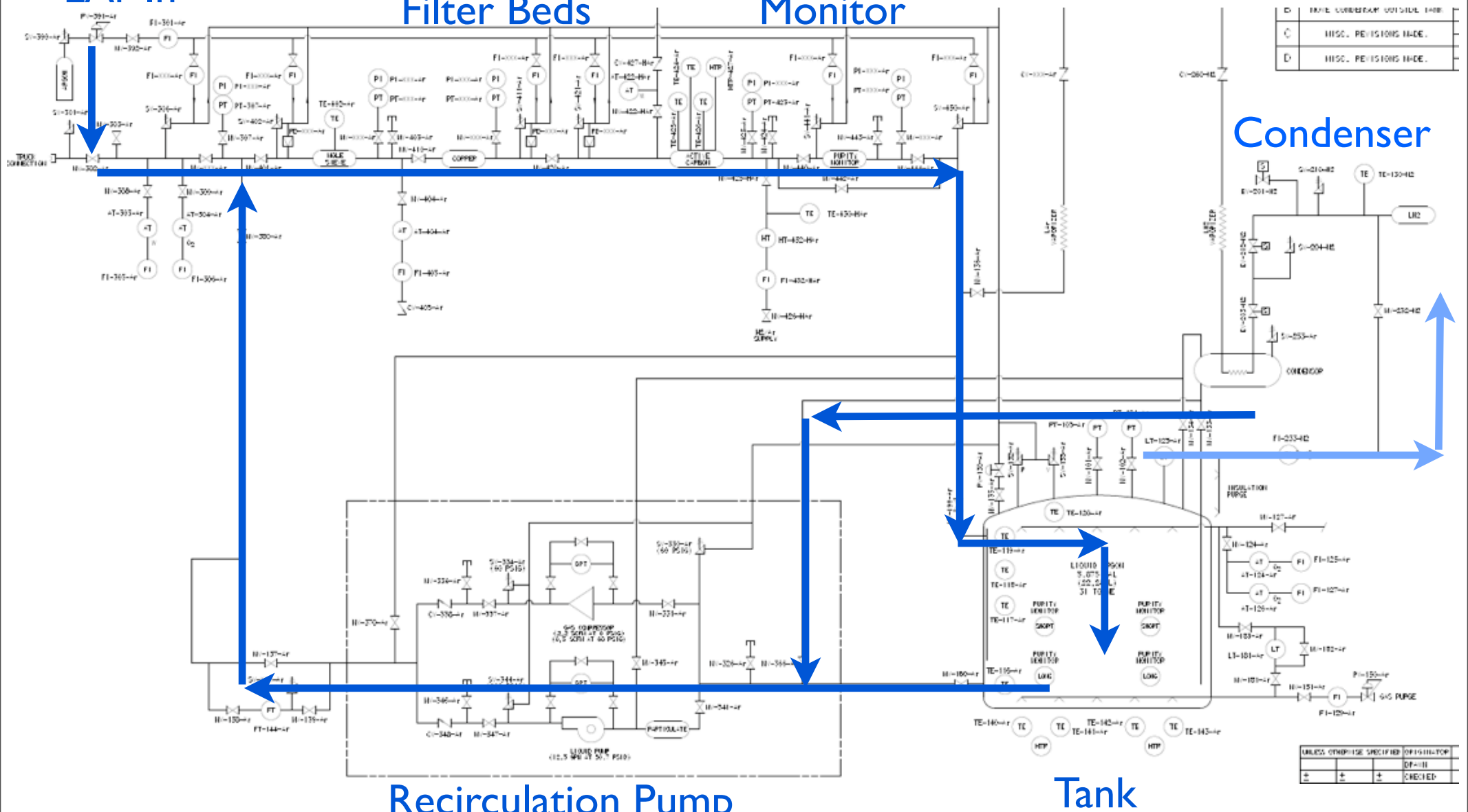


Number of Gas Volume Exchanges



- Study at FNAL shows it takes 2.6 volume exchanges to reduce contaminants to 100 ppm (no recirculation)

System Flow


LAr In
Filter Beds
Inline Purity Monitor
Condenser
Recirculation Pump
Tank

System Flow

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LAr In

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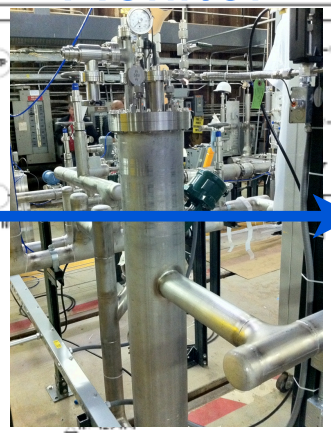


Condenser

Recirculation Pump

Tank

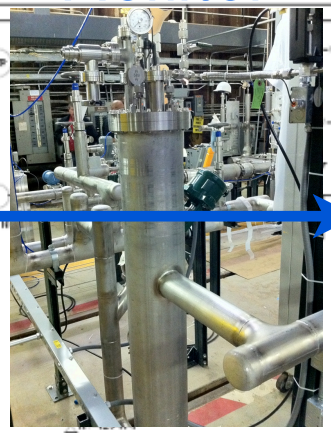
System Flow

LAr In

Filter Beds

Inline Purity Monitor

Condenser



Recirculation Pump

Tank

System Flow

LAr In

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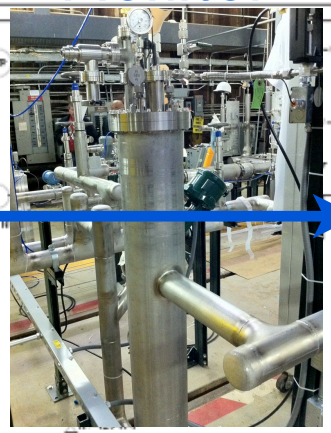
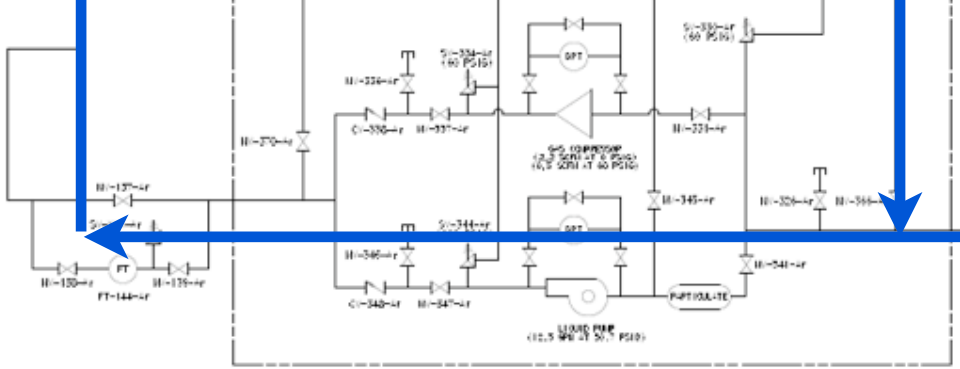
Inline Purity Monitor

Condenser

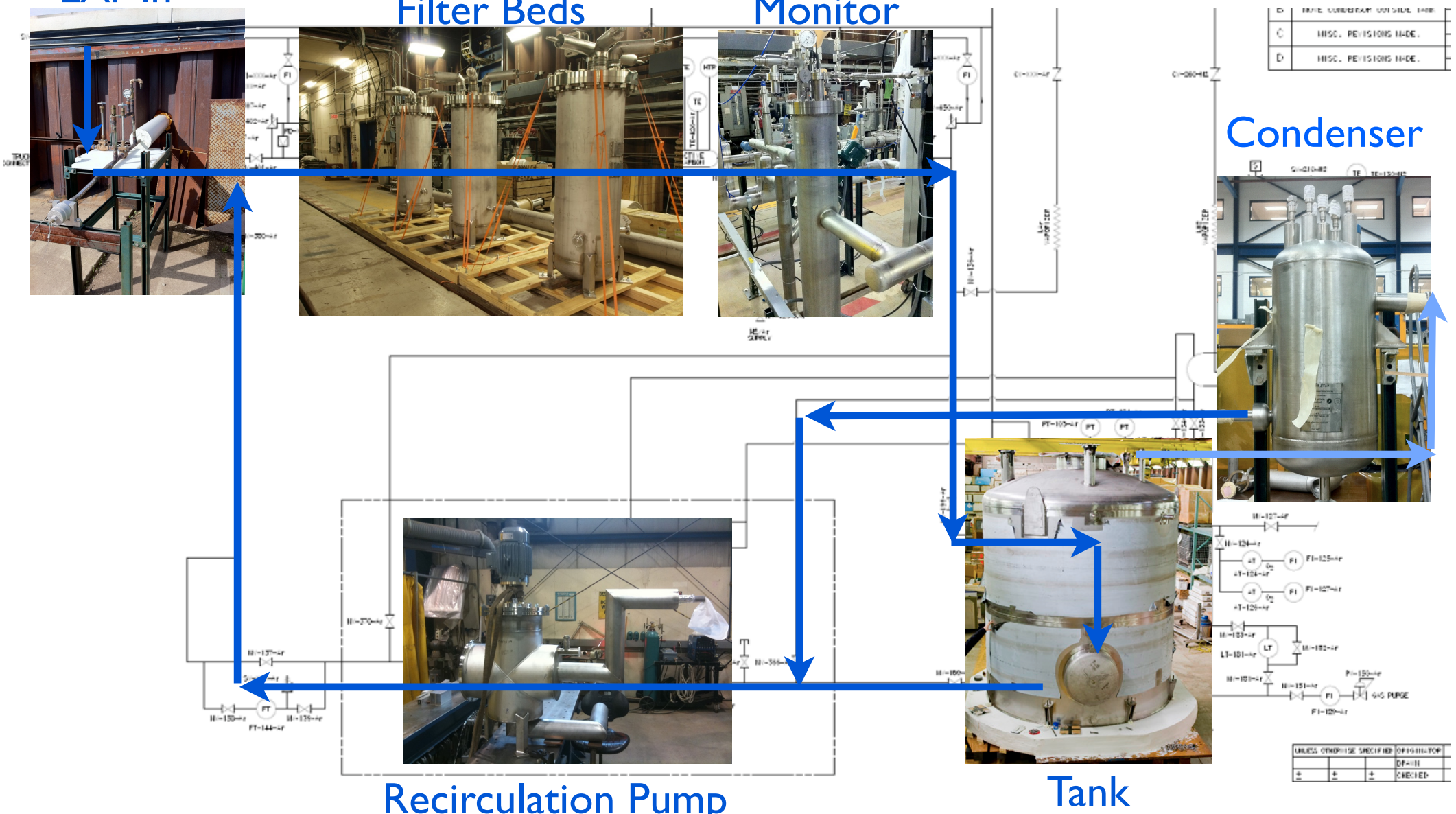




Recirculation Pump

Tank

System Flow


LAr In
Filter Beds
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Condenser
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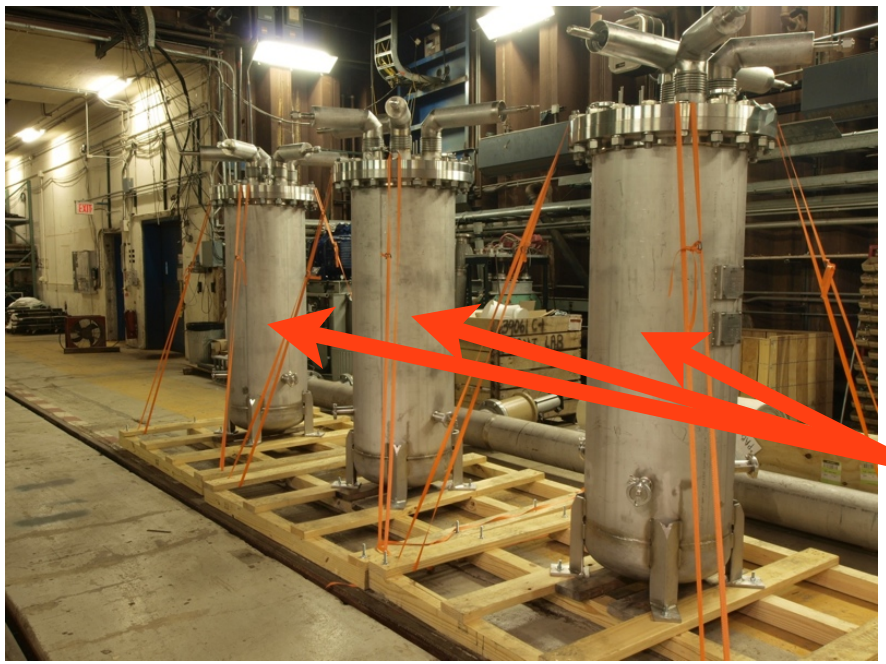
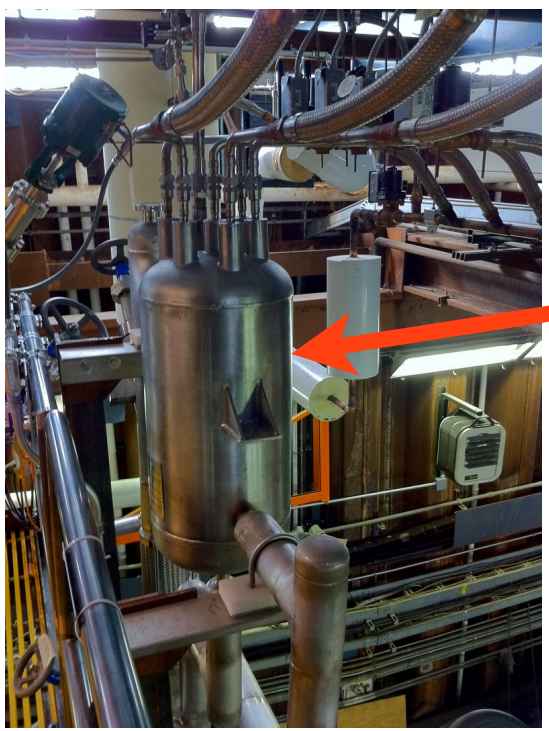
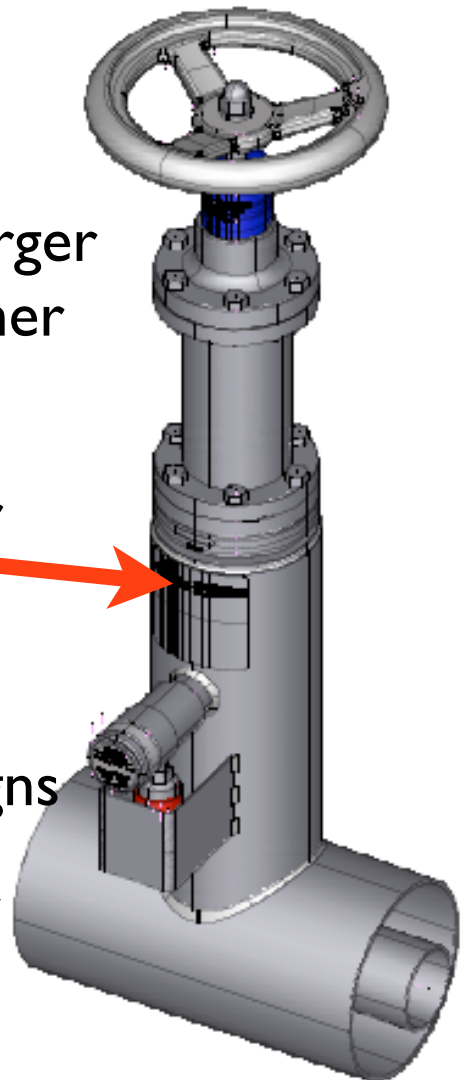
Tank

System Design and Fabrication



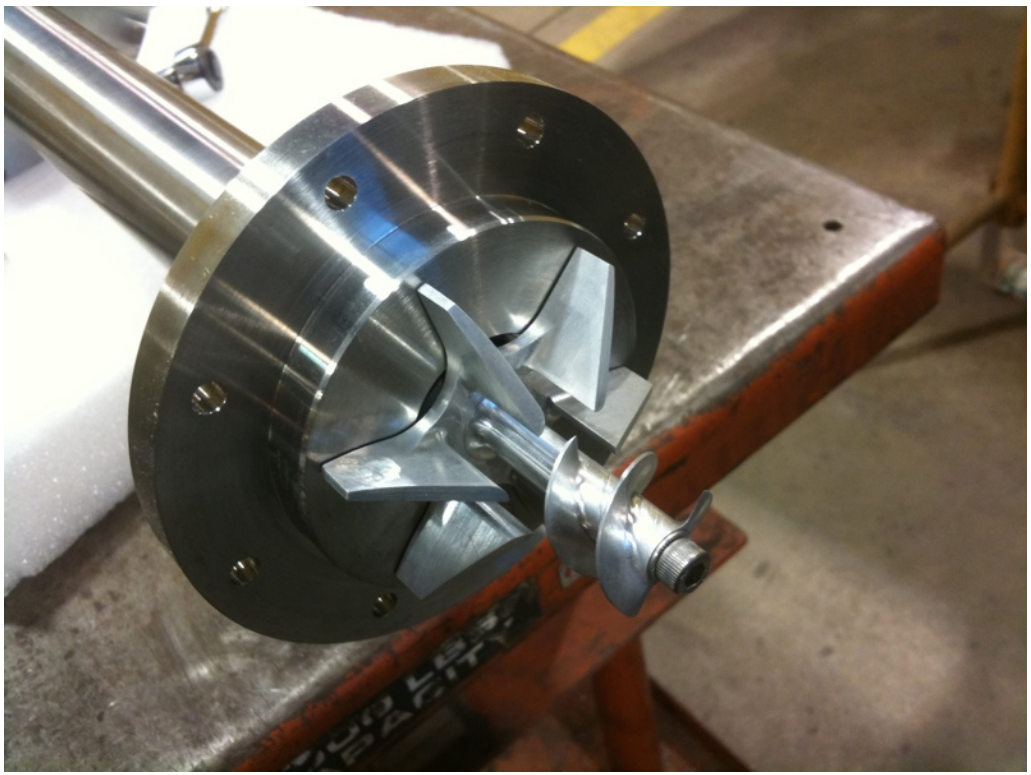


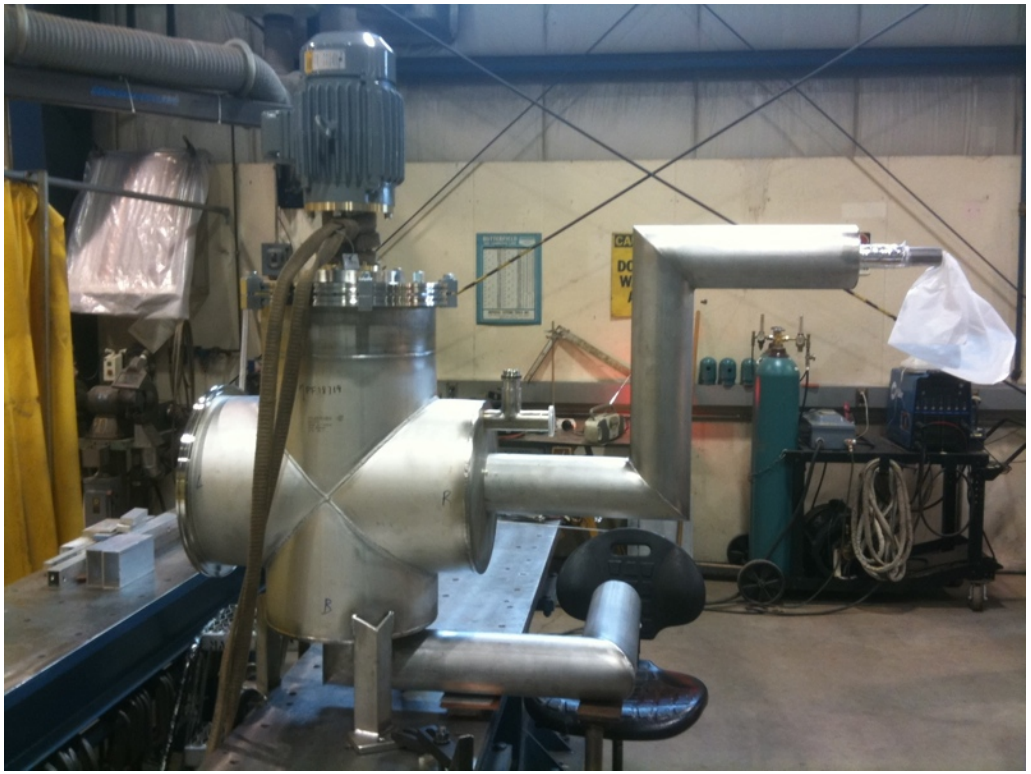
- Several new components designed for larger scale of LAPD compared to previous test stands and ArgoNeuT
- Filters sized to handle larger volume compared to other test stands
- Bellows sealed valves for high purity operation
- Condenser and phase separator also new designs
- Various monitors mostly identified from previous experience



Eden Cryogenics

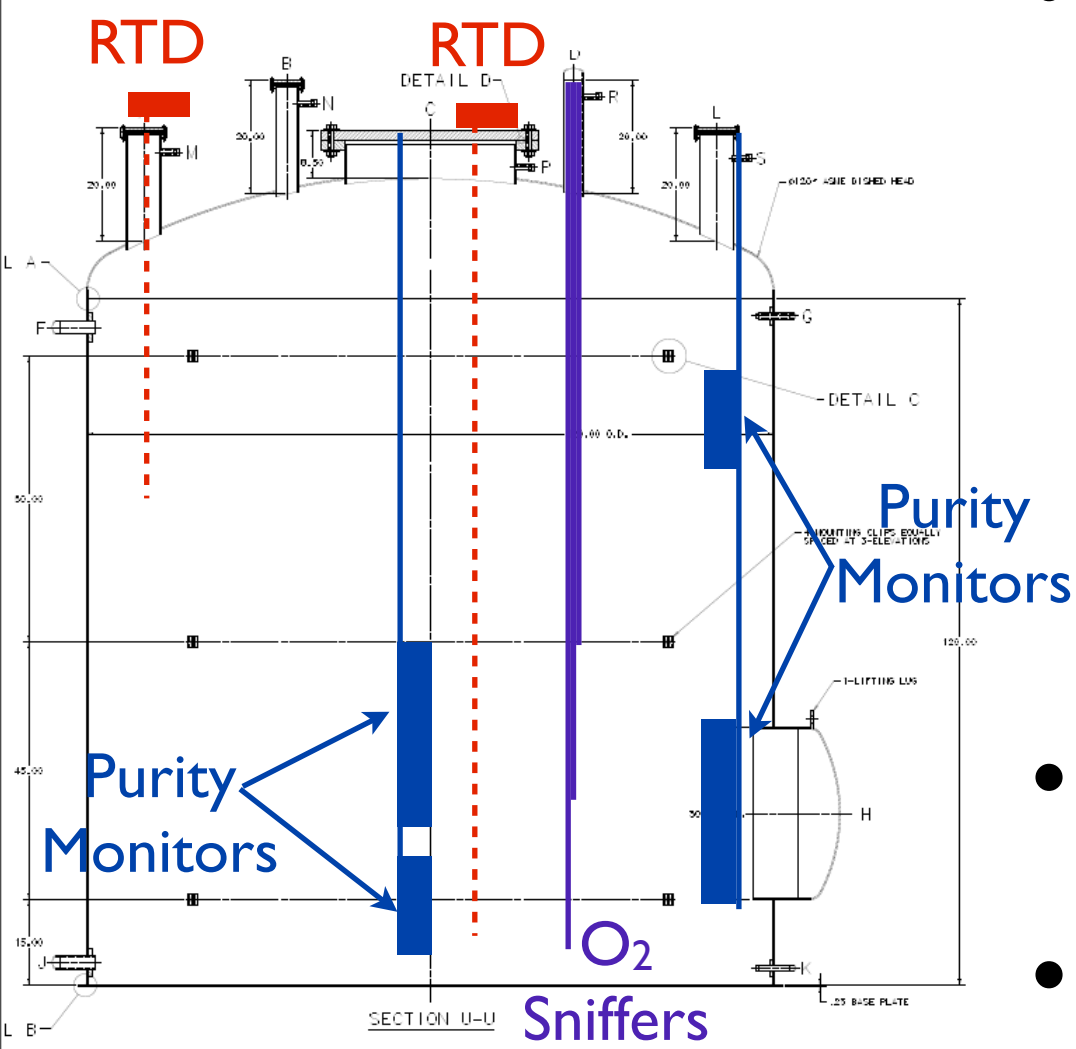
Pump





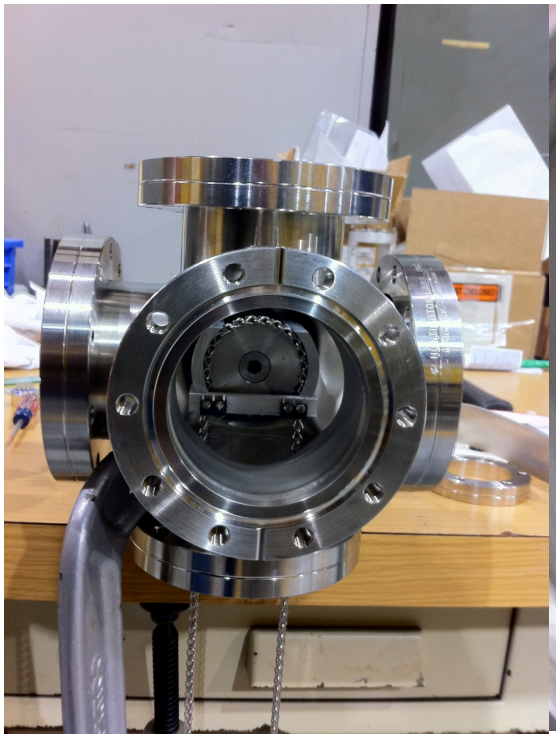
- Variable speed pump with magnetically coupled drive shaft to maintain high purity of the system
- Nominal flow rate is 46 liter/min or 1 volume exchange every 8 hours. Rate can be adjusted.
- Will vary the flow to study rates necessary to obtain and maintain desired purity levels

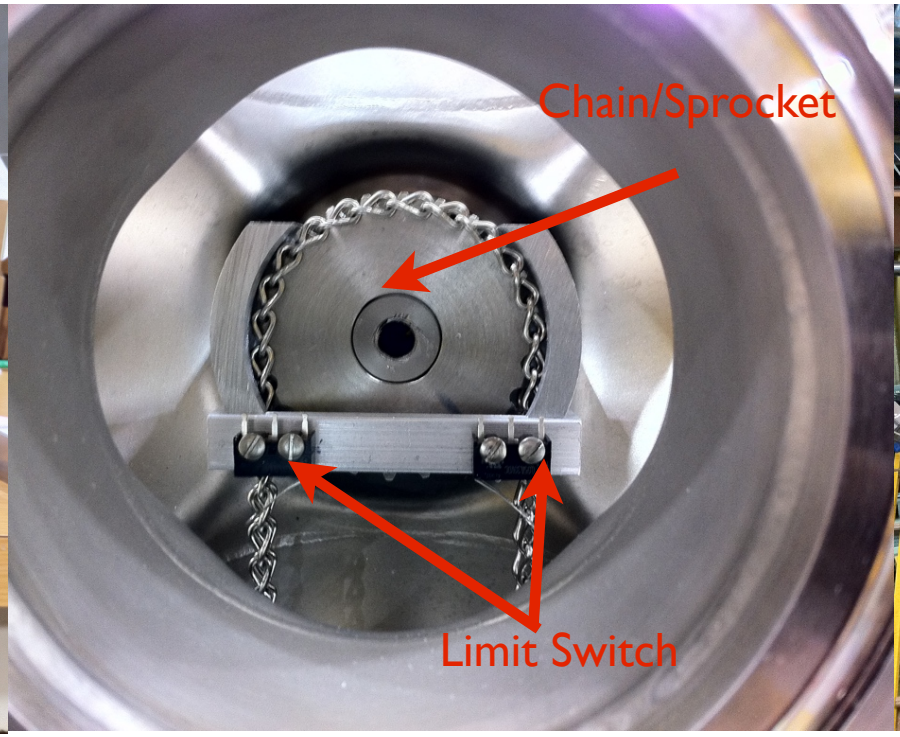
Instrumentation



- Main instrumentation inside tank:
  - 4 purity monitors - 2x 20 cm long, 2x 58 cm long
  - 2 resistance temperature detector (RTD) translators, each with 3 RTDs
  - O_2 sniffers at various heights for use in purge phase
- Purity monitors will be inserted in pairs, 1 long and 1 short
- 1 purity monitor and 1 RTD translator deployed in center of tank, 1 each at a radius

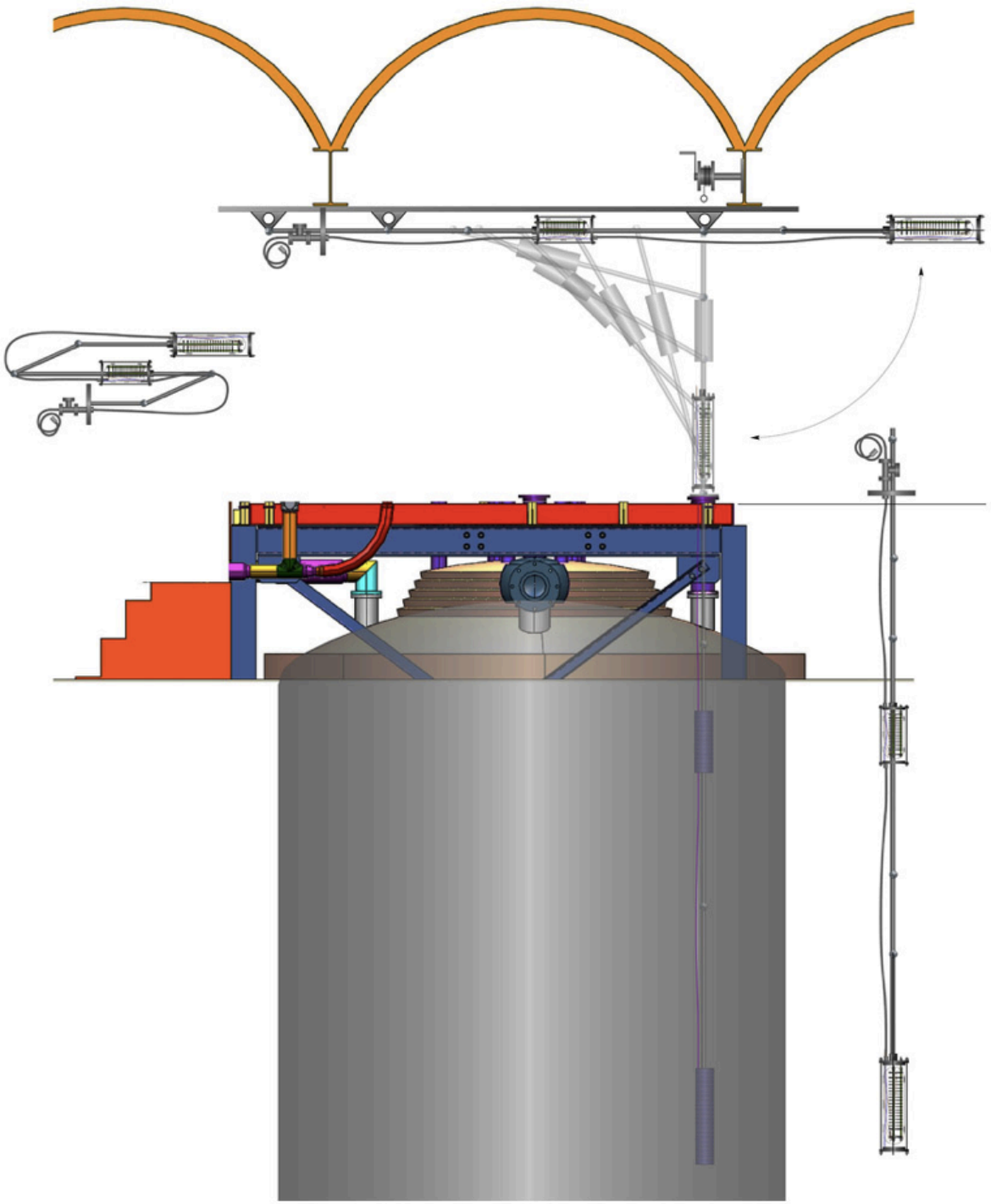
RTD Translator





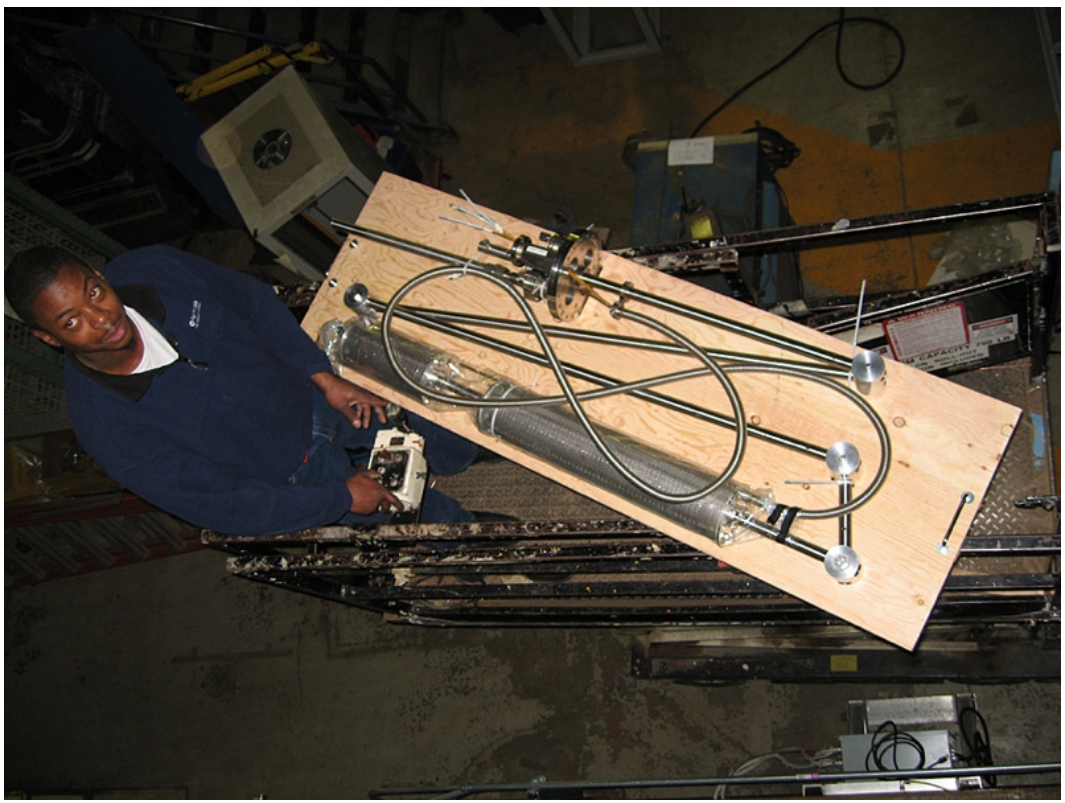
- 3 RTDs are mounted on a circuit board
- Circuit board translates vertically through the tank with stops at predefined locations to take temperature measurements
- Looking for the temperature gradient in the tank, absolute calibration is not important, but devices are good to within 0.1 K
- Chain driven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

Purity Monitor Inserter

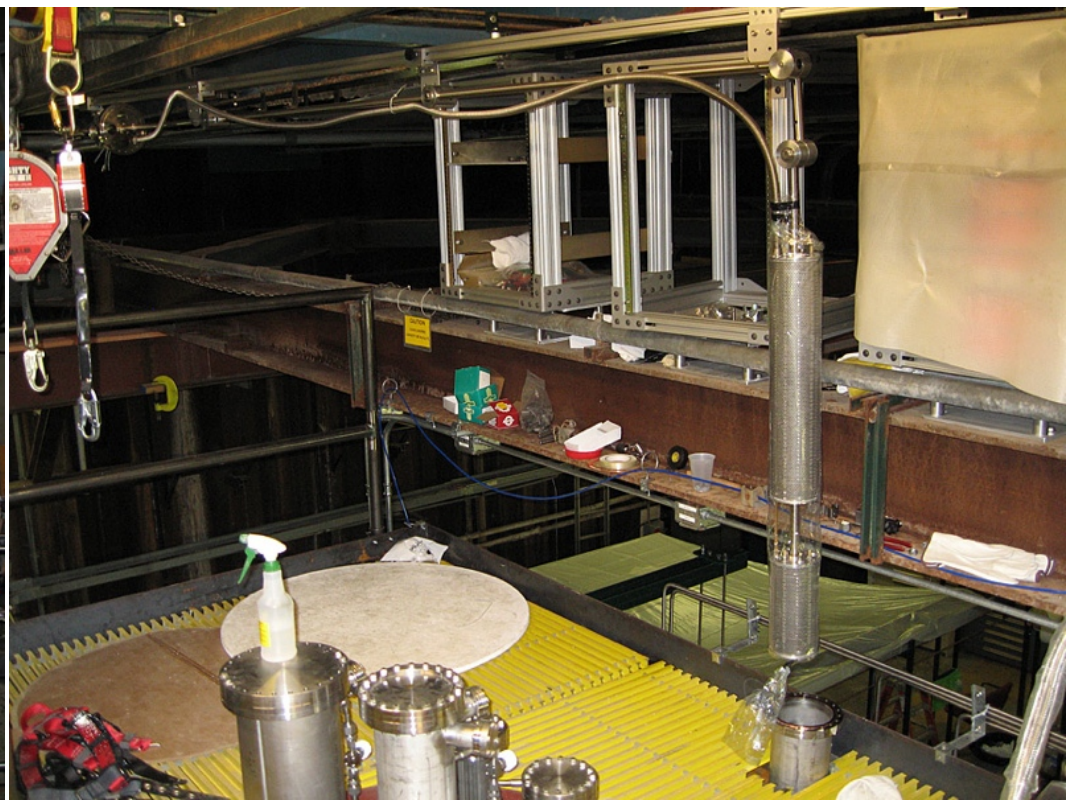


- Purity monitor insertion devices designed to allow gradual installation into the tank
- Both devices are fabricated and a test insertion was successful
- Purity monitors are located at different positions for each device

Purity Monitor Inserter Test

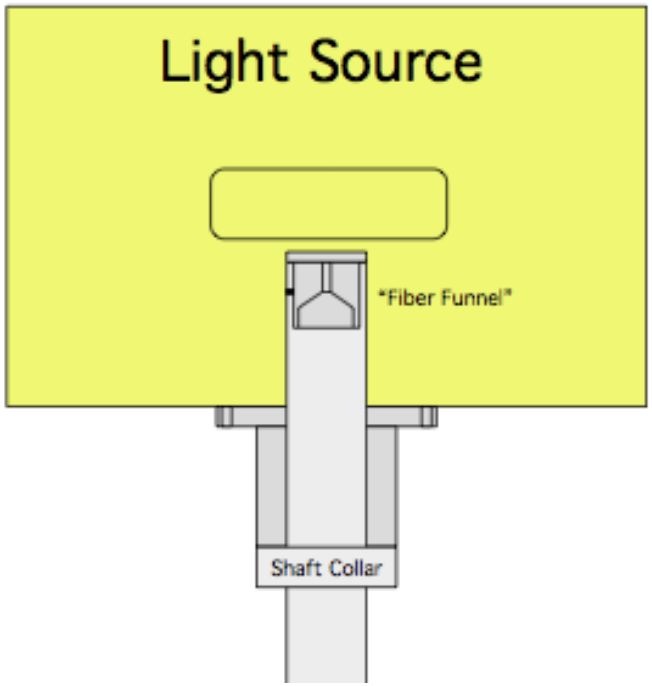


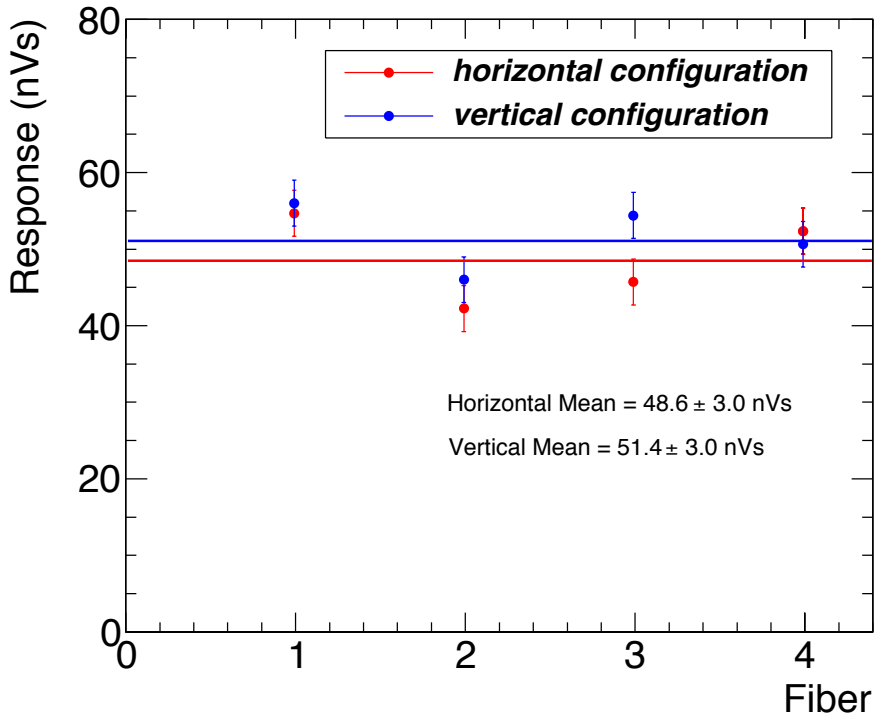
Transport of device accomplished by affixing it to a piece of plywood



Inserting into radial flange

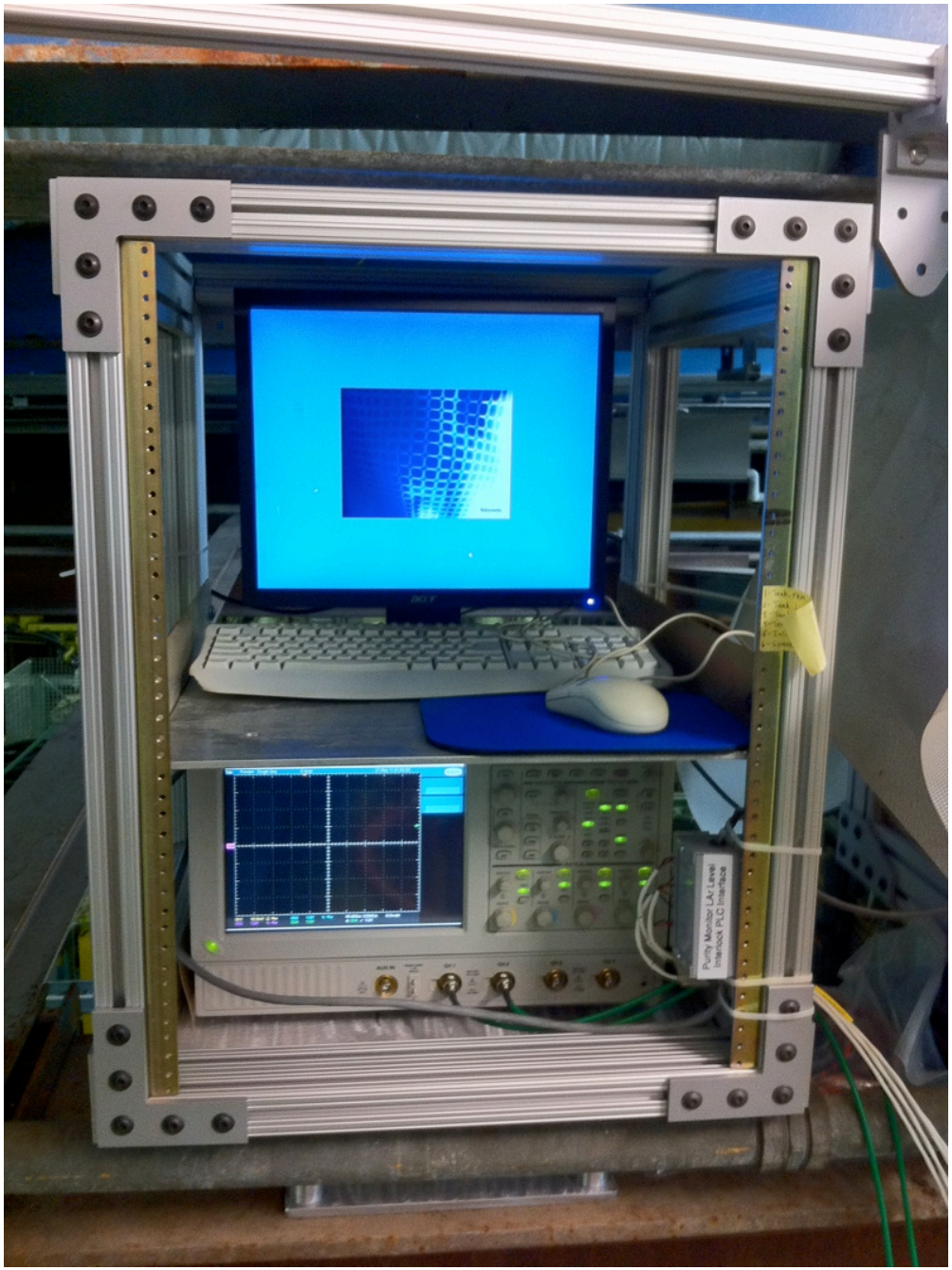
Fiber Tests For Purity Monitors





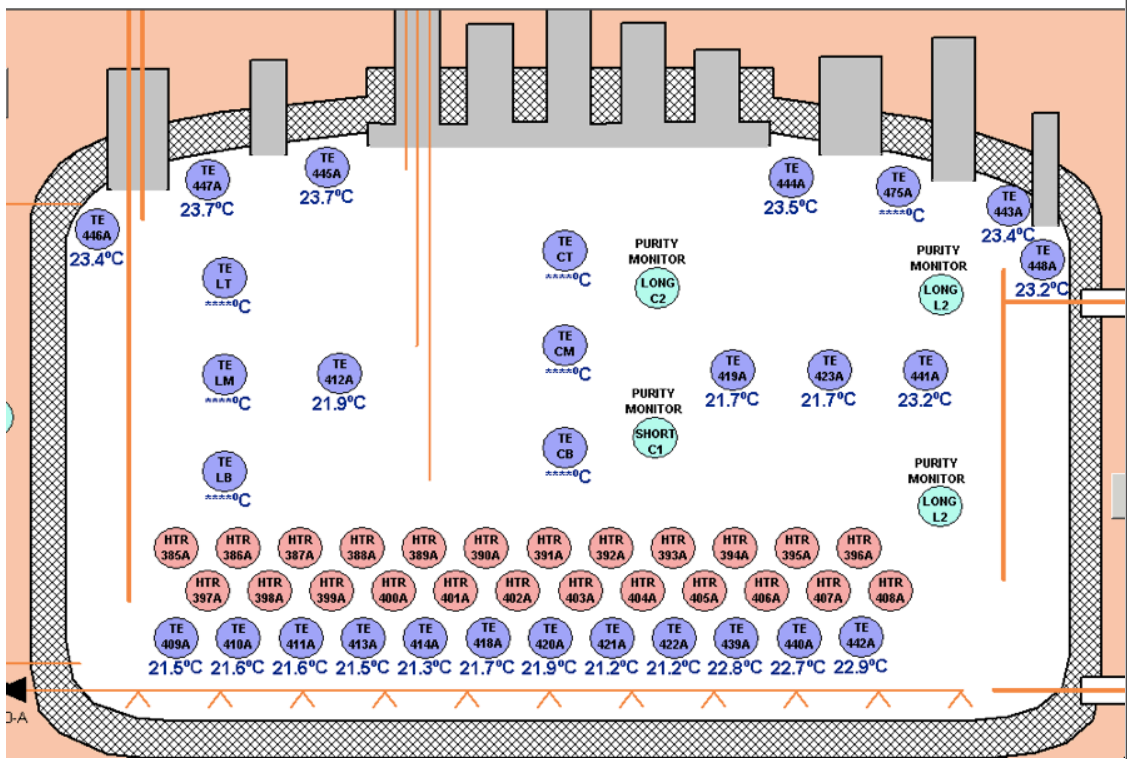
- Because fibers are placed into single location at light source, we wanted to understand how light transmission would be affected by fiber position in the funnel
- Looked for light transmission differences between fibers
- Fiber output is distributed reasonably about the mean in different orientations of the lamp

Purity Monitor DAQ



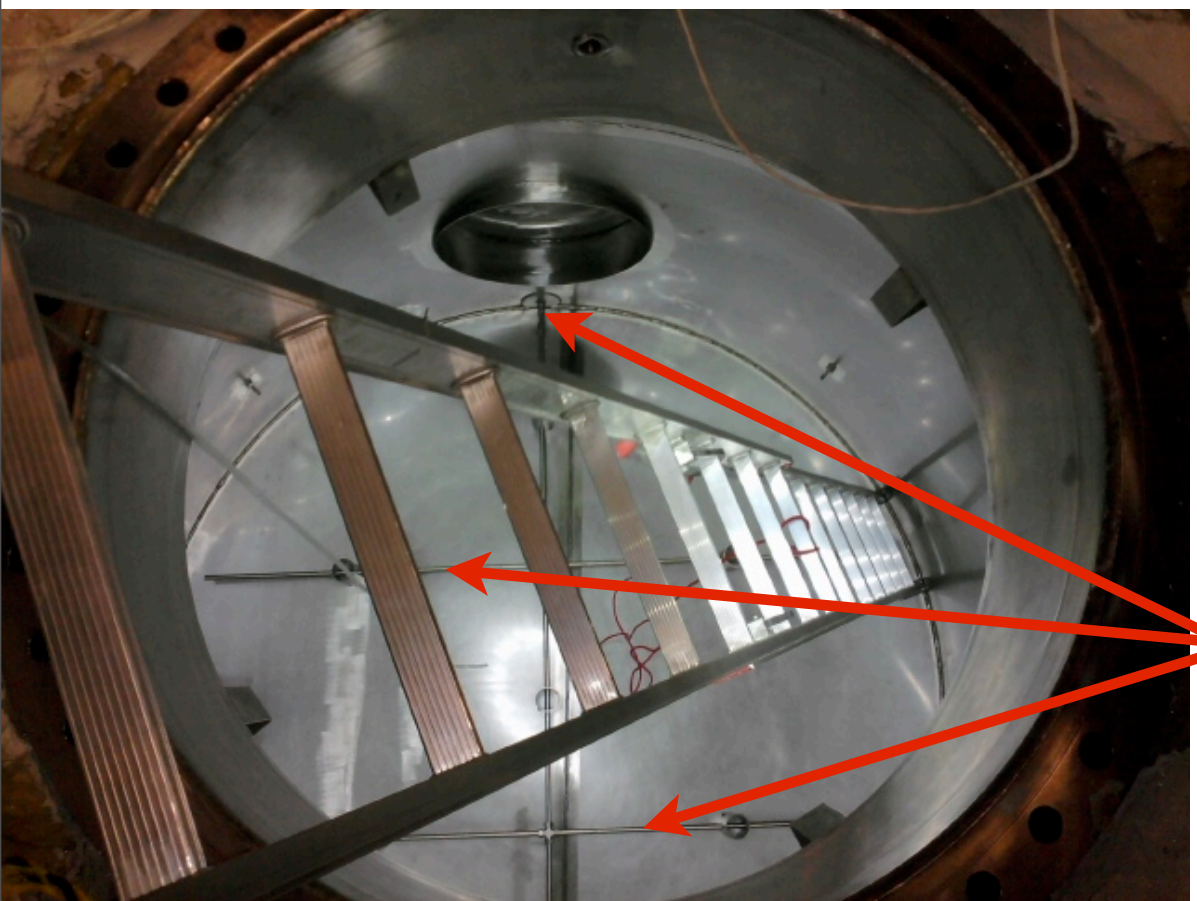
- DAQ system is based on system used by the materials test stand
- Oscilloscope triggers on light from the xenon flash lamp used to create photoelectrons in purity monitors
- Developed an analog multiplexer to run all 5 purity monitors from the same scope
- Electronics used to run the purity monitors have been extensively tested before deployment

Instrumentation Check-out



- There are approximately 120 sensors and instruments in the system that are controlled by the PLC
- All have been checked out and are ready to go
- PLC program is up and running and waiting to take data

Cleaning the Vessel



- Vessel was cleaned using a HEPA filter vacuum followed by wiping down the surfaces
- Tyvek suits and shoe covers were used for final entry into the tank
- Can see the gas purge piping behind/below the latter

LAPD Construction

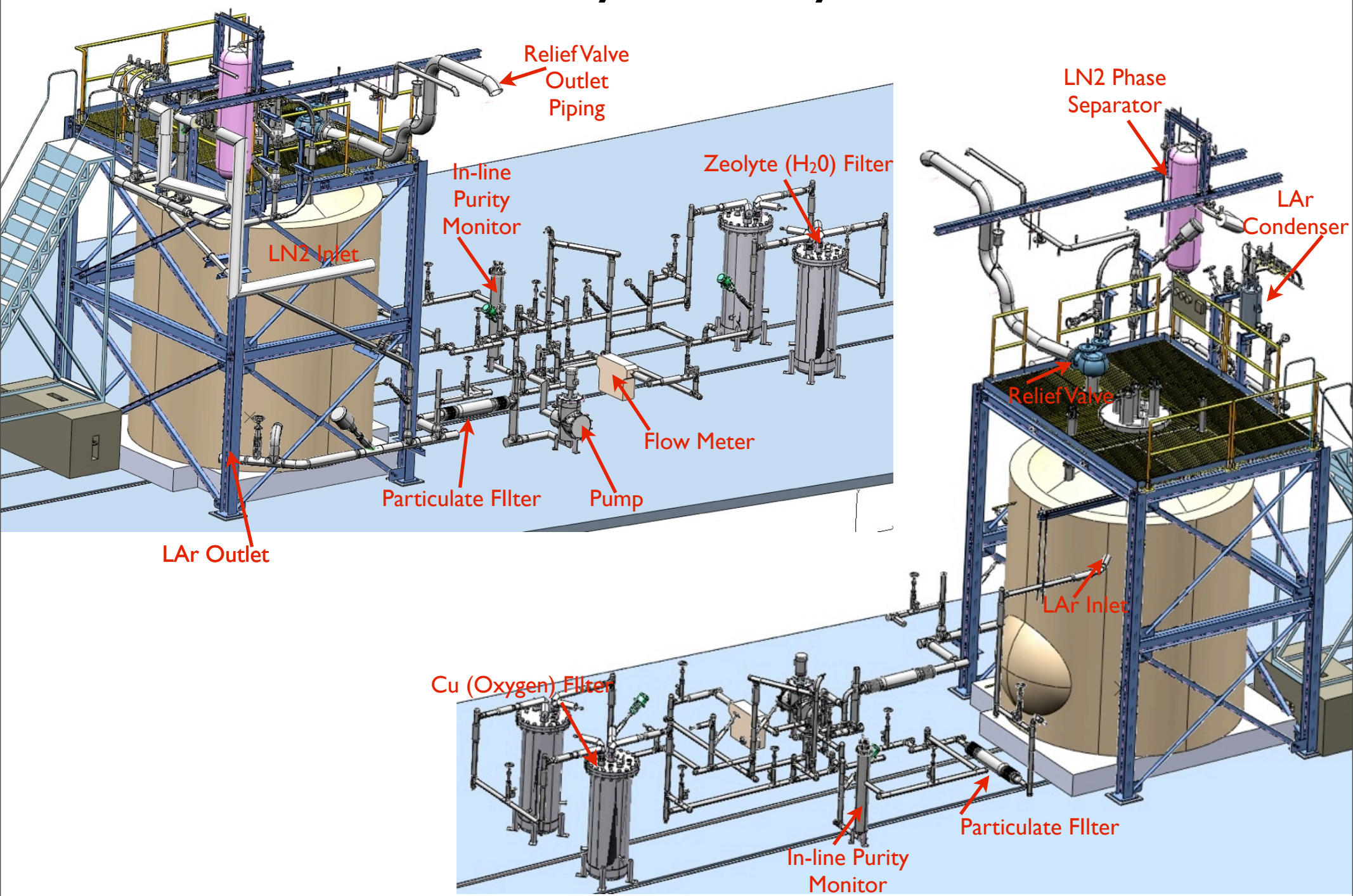
View from the platform

LAPD Construction

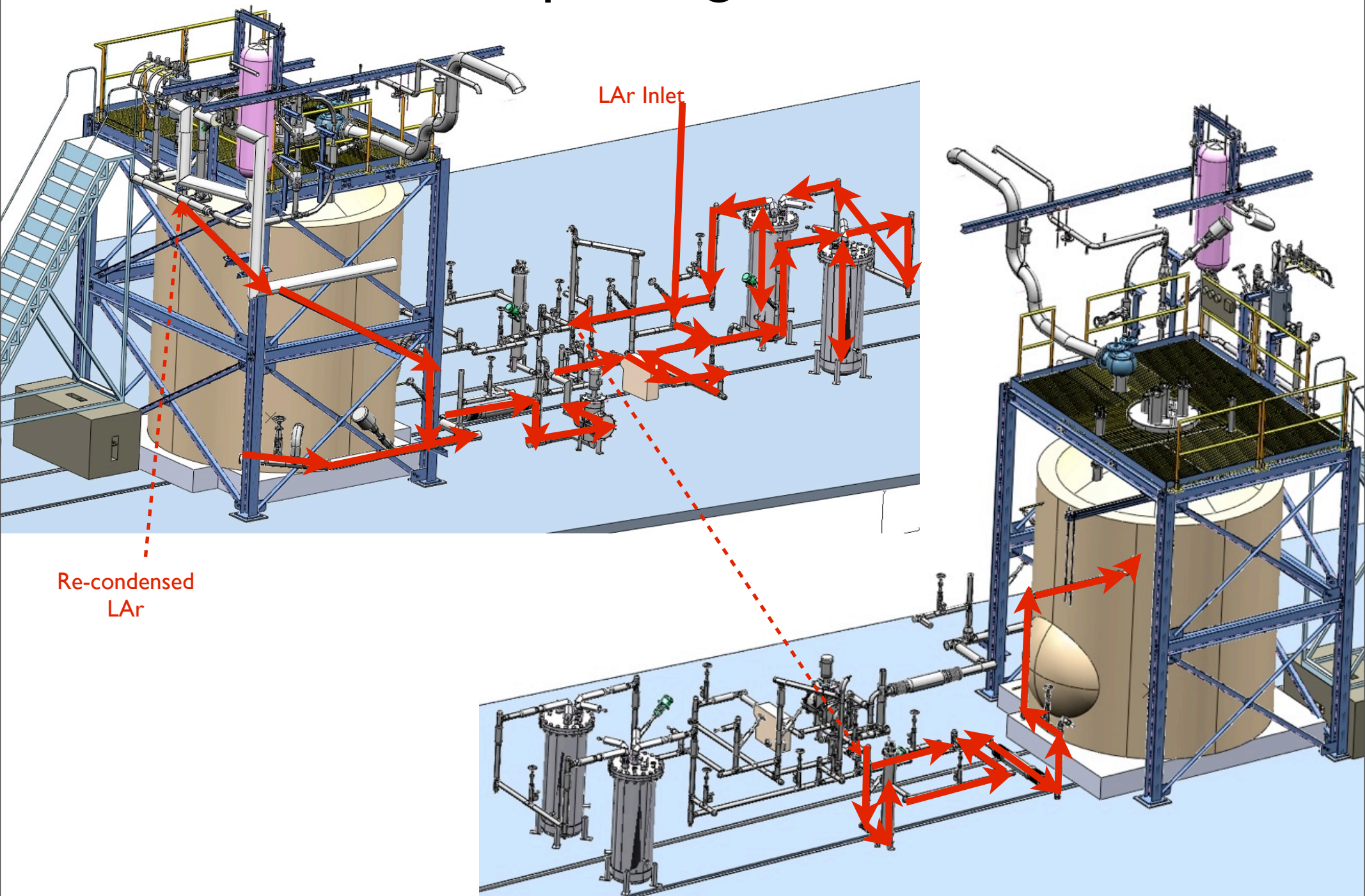
View towards the tank

View from the tank base

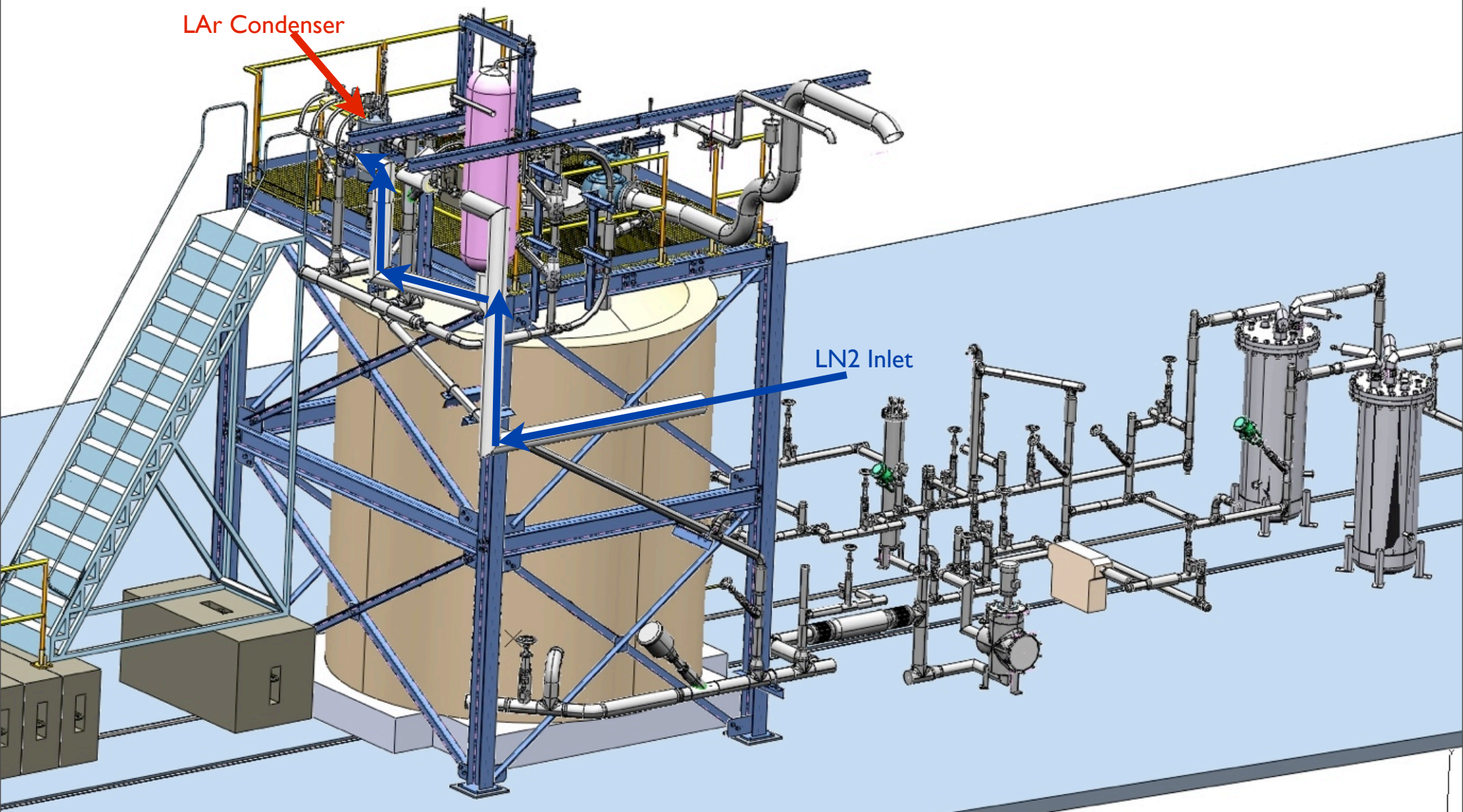
3D System Layout



Liquid Argon Flow



Liquid Nitrogen System



Run Plan

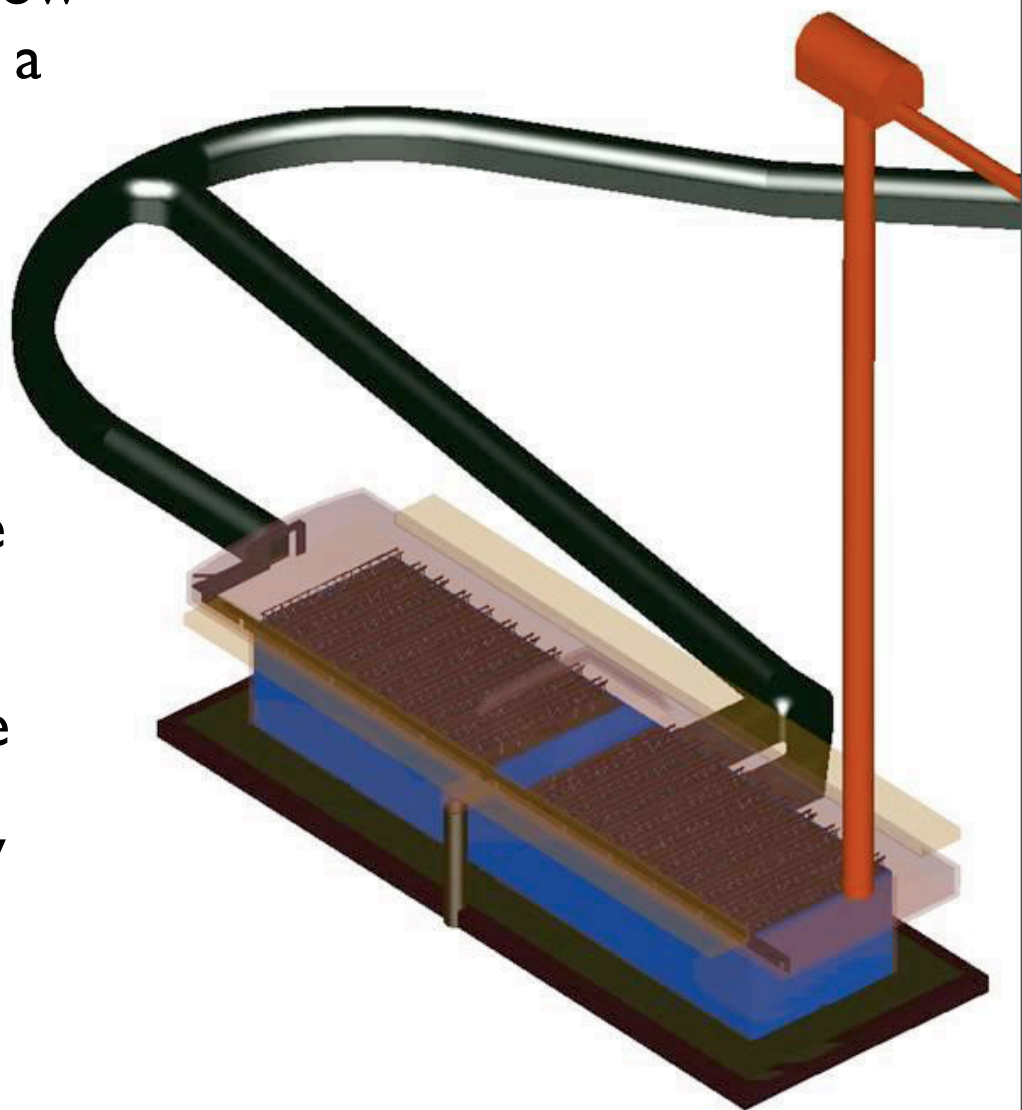
- 4 parts to the Phase 1 Run
- Part 1: Gaseous argon purge
  - Vaporize 11 liters/hour to provide the gas for the purge
  - Measure O_2 with sniffers every 2 minutes
  - Measure temperature every 15 minutes with RTD translators
  - Also monitor the water concentration
  - End when O_2 concentration is 260 ppm
- Part II: Gaseous argon recirculation
  - 1 volume exchange each 2.6 hours
  - Continue until O_2 concentration is 50 ppm

Run Plan

- Part III: Liquid argon filling
  - Initially only fill to half the capacity
  - More stringent test than completely filling the vessel
- Part IV: Liquid argon recirculation
  - Measure temperature distributions in the liquid and gas to look for evidence of convective mixing
  - Measure electron lifetime in the tank and after the filtration

Scalability Studies

- One goal of LAPD is to understand how to scale the cryogenics system up for a multi-kiloton scale detector
- In addition to already mentioned measurements, will do studies of
  - Number of LAr volume exchanges needed to reach necessary lifetime for 2.5m drift
  - Rate necessary to maintain lifetime
  - Filter capacity as a function of flow rate
  - Ability to recover from intentional contamination



Outlook

- Installation completed
- Currently waiting on sign off from the cryogenic safety committee
- 2-3 weeks of commissioning work to complete, progressing in parallel with review by the safety committee
- Will start the purge as soon as safety approval is received
- A planned phase 2 upgrade is to put a camera in the vessel to look for boiling at any desired location