MICROBOONE CRYOGENICS: INSTALLATION AND COMMISSIONING

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Fermilab

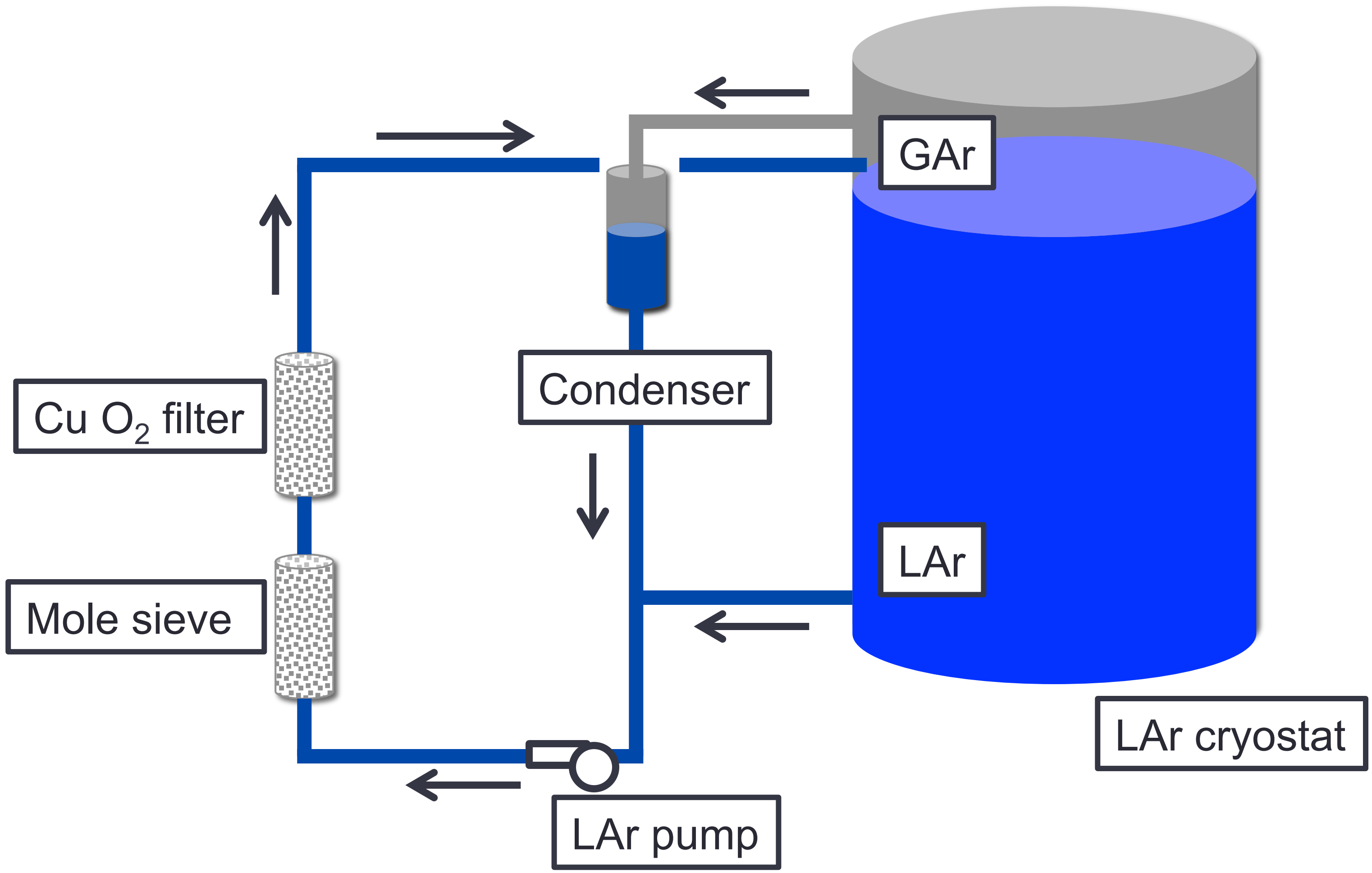
Outline

- Requirements for MicroBooNE
- Basic operation of a LAr cryogenics system
- The commissioning and operation of MicroBooNE Phase I
  - —A stripped down version of the full purification system
- The remaining construction needed for Phase II
  - —The full MicroBooNE cryogenics system needed for operation of the detector

System Requirements

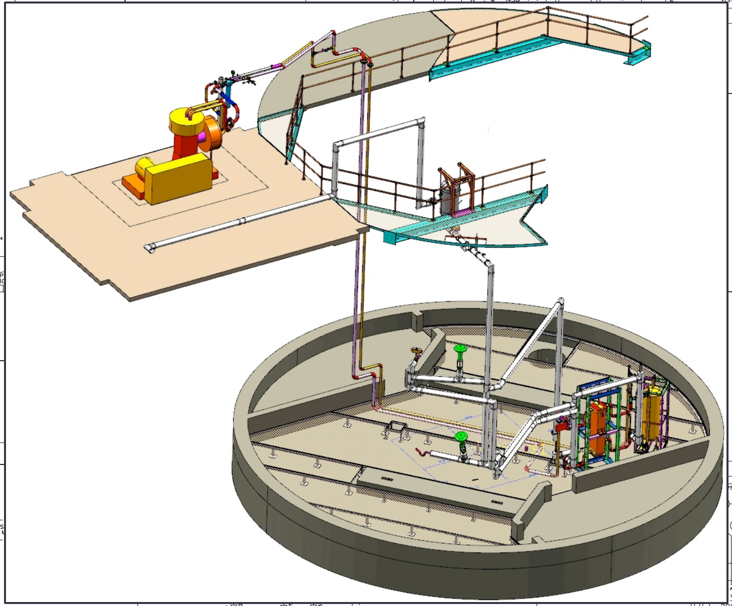
- Liquid argon (LAr) kept at 88K
- Prevent heat leaks which produce convective flow in the cryostat and ice build up outside
- Need LN_2 for cooling and obviously LAr, places requirements on infrastructure
- Need low concentrations of electronegative contaminants (e.g. O_2 and H_2O)
- For MicroBooNE, our specs are < 100 ppt O_2 (electron lifetime requirement drives this) and < 2 ppm N_2 (contaminant for scintillation light)

Operation of Purification

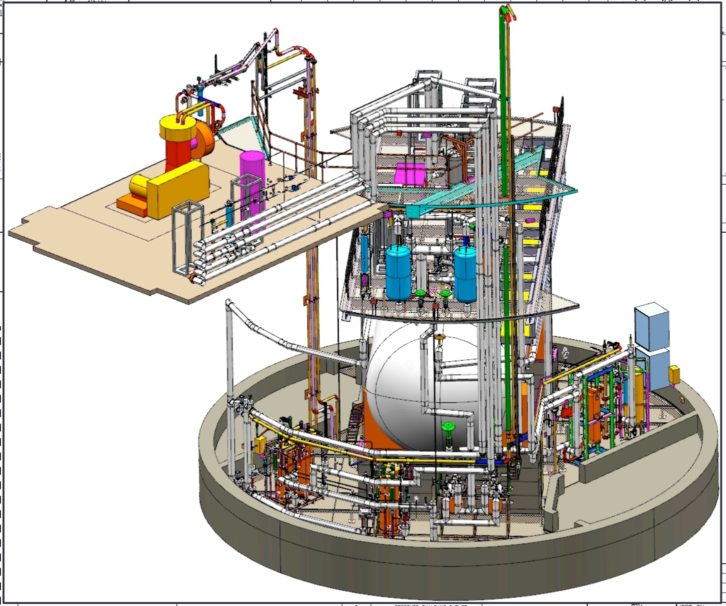


MicroBooNE Cryogenics

Complex, but can be divided into two primary systems, cool-down and purification



Cool-down system



Purification system

MicroBooNE Cryogenics

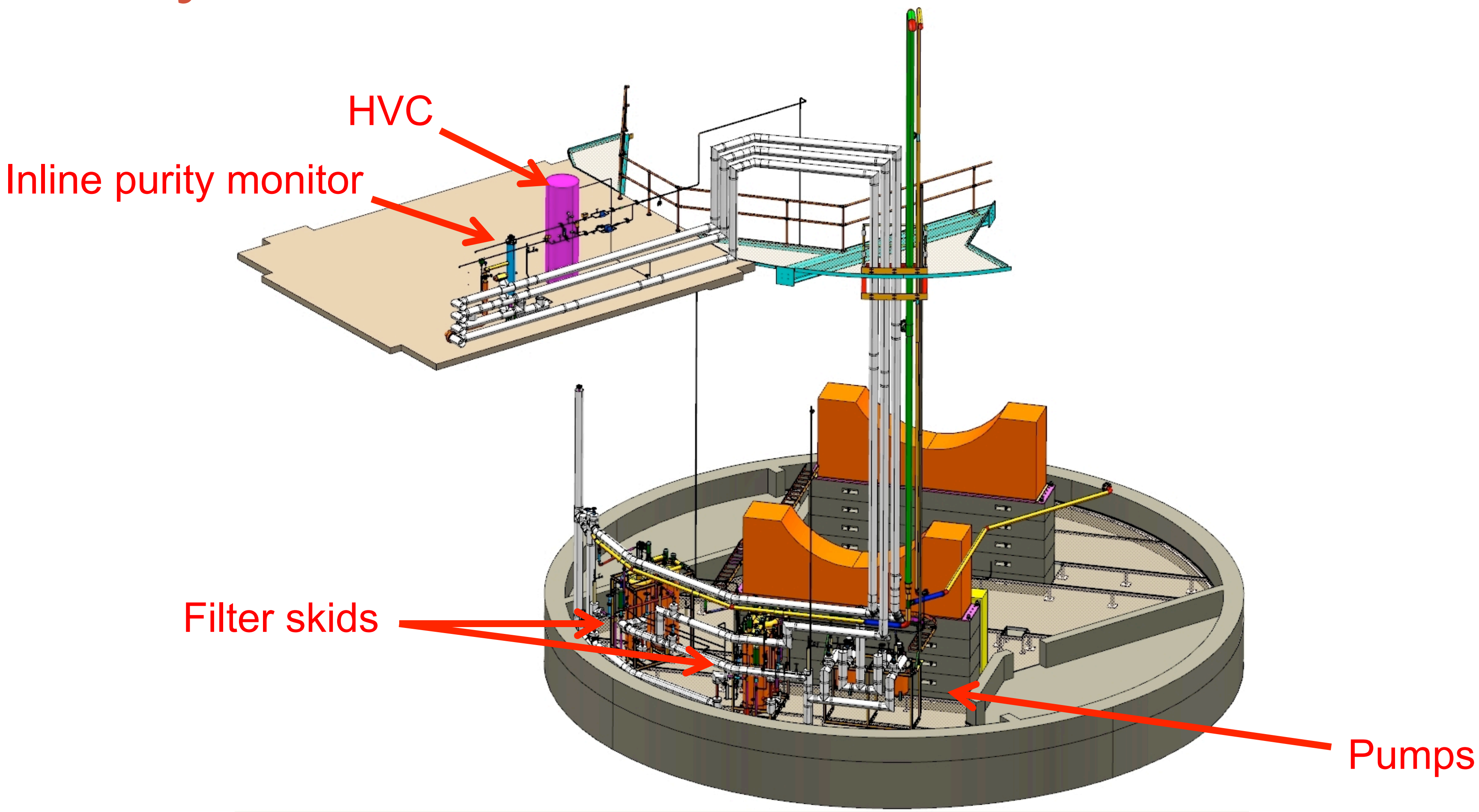
- MicroBooNE cryogenics system based heavily on LAPD (see talk by Michelle Stancari)
- Few differences, such as using insulated piping instead of vacuum jacketed
- Carries out similar procedure of purge, gas recirculation, and liquid filling

— MicroBooNE cryostat has a 150” diameter and is 40 ft long and 6/17” thick
— Will be insulated with spray on Polyurethane (16”) for a heat leak of ~11 W/m^2
— Will hold 170 t of LAr, fiducial volume of 60 t

MicroBooNE Phase I

- To gain experience and speed up commissioning of the full system, we operated a stripped down version of the cryogenics system
- Elements included the pump, filters, gas analyzers, and purity monitor
- The original scope of the run plan was changed to incorporate the high-voltage cryostat (HVC) in order to test breakdown in liquid argon (see talk tomorrow by Sarah Lockwitz)

Phase I is a stripped down version of the full system



The interior components of the system are shown here

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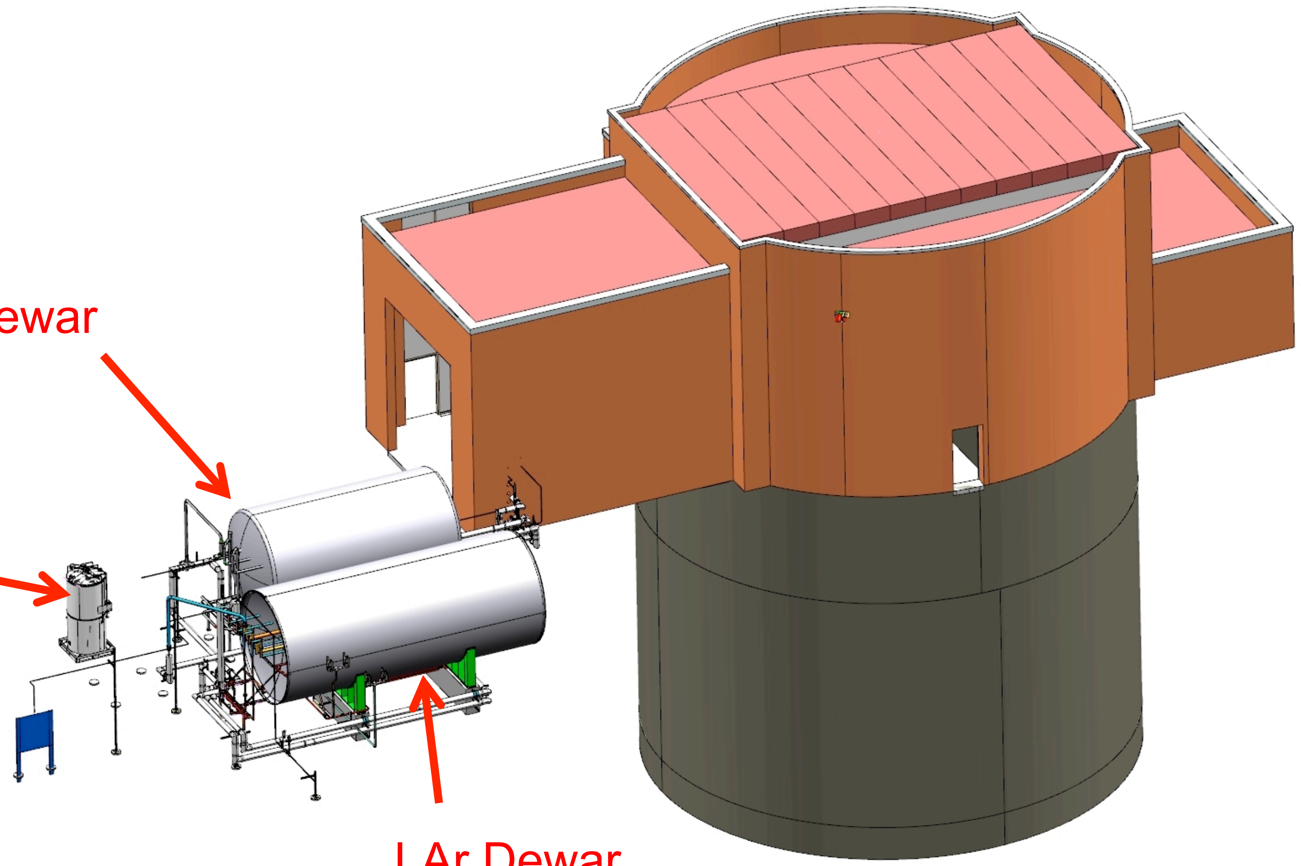
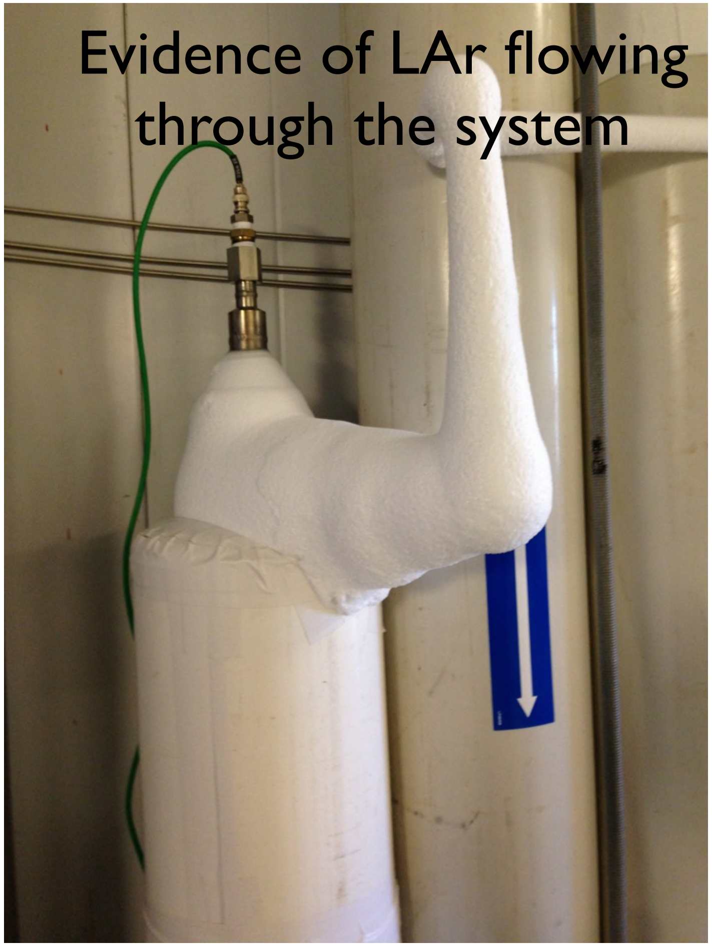


The exterior components of the system are shown here

We accomplished several milestones during Phase I commissioning

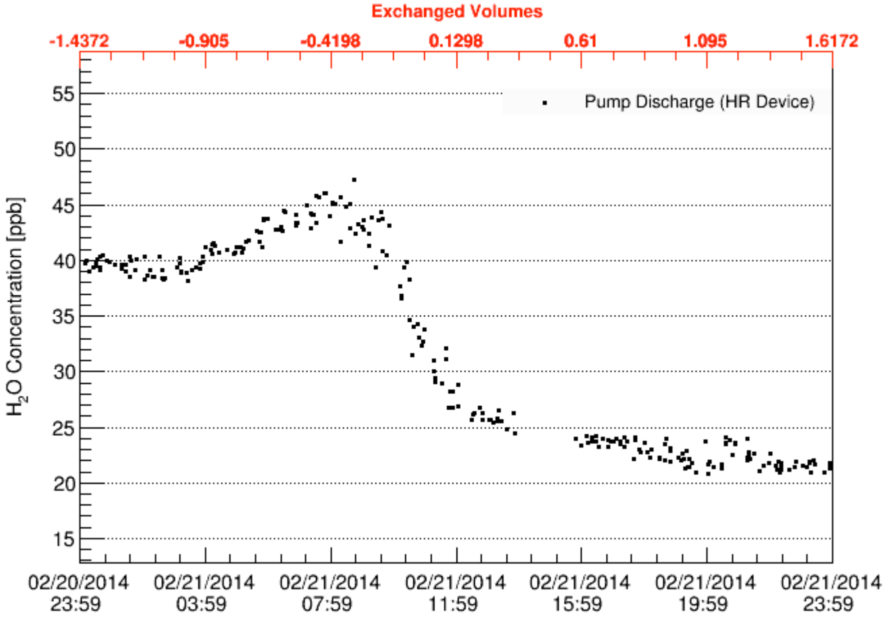


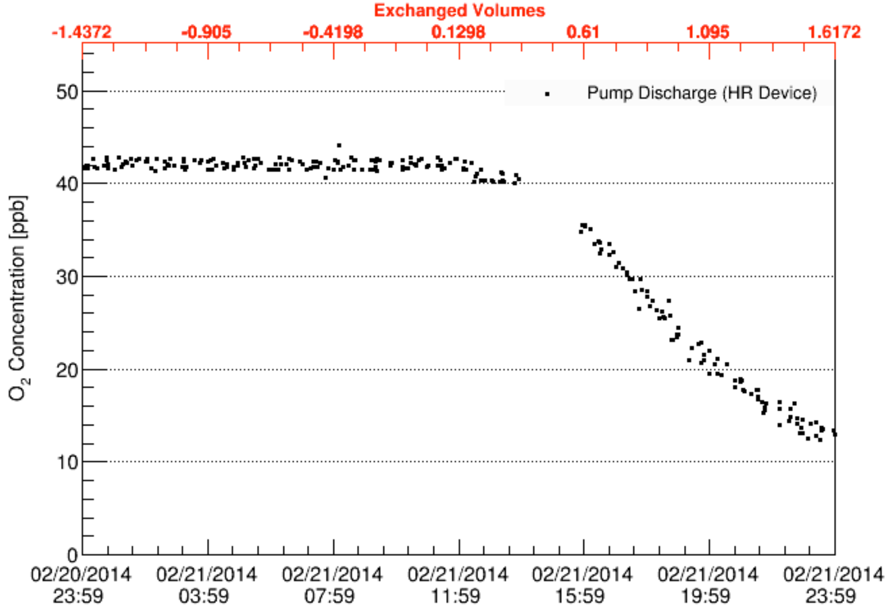
- Filters regenerated
  - Performed using a mixture of argon and hydrogen gas
- Pump flow established February 18
- Filter flow established
  - Started February 19, going full speed on February 21
- Flow into HVC was achieved on February 26

MicroBooNE employs gas analyzers to monitor purity

- Capability to measure at several points in the system
- Two oxygen sensors, one at range of 0-500 ppm, another at 0-20 ppm with lower limit of 75 ppt
- Water sensor covering 0-20 ppm with lower limit of 2 ppb
- Nitrogen analyzer 0-10 ppm

The clean-up was monitored with gas analyzers





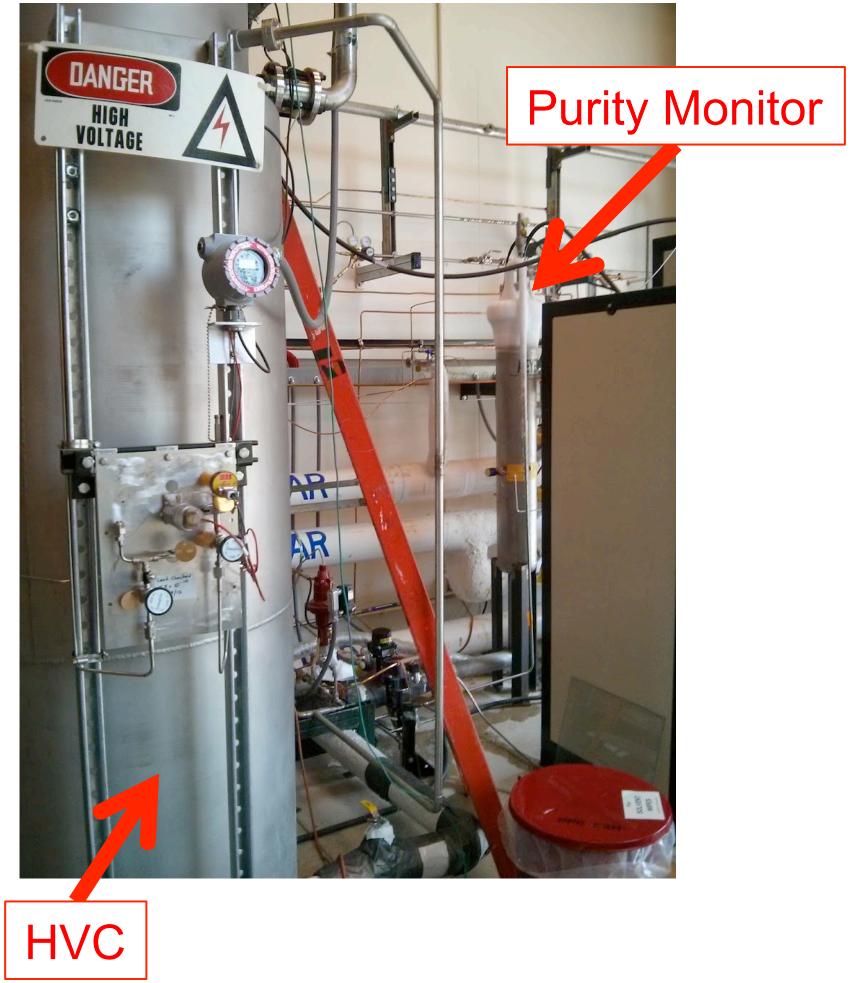
- These plots show water and oxygen concentrations as flow was established through the filters

Filter regeneration

- We have the capability to regenerate the filter material
- Use heated mixture of 2.5% hydrogen/97.5% argon gas
- Internal RTDs prevent overheating
- If needed we can vacuum out the filter material

The HVC and purity monitor

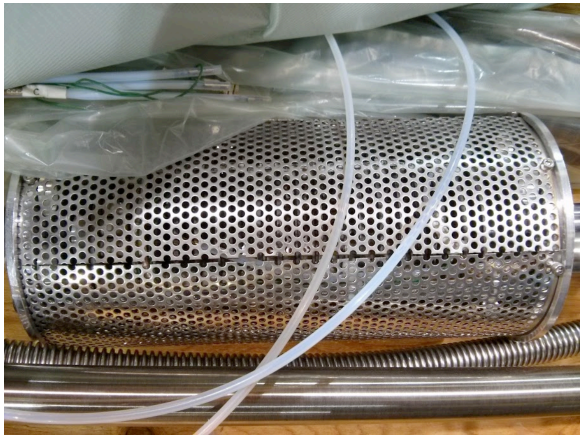
- The goals of the HVC included measuring breakdown at varying LAr purity levels
- The HVC sat behind the filters in the system
- Following the HVC sat the purity monitor, allowed measurements of HVC content

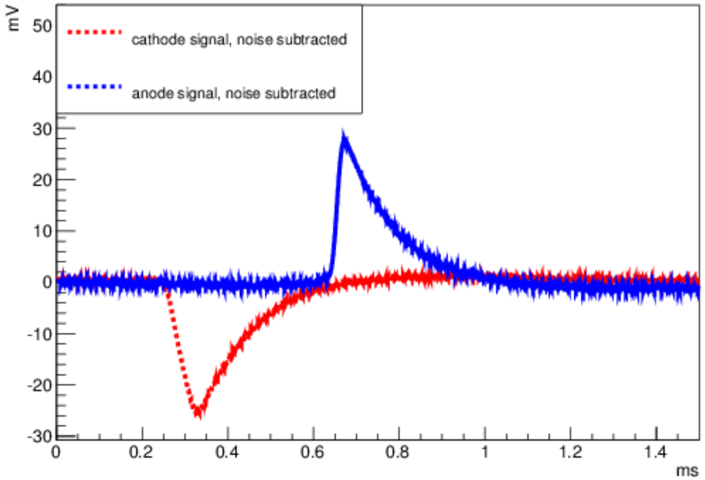


Measuring purity

- Use purity monitors, consisting of a field cage, photocathode and anode
- A quartz fiber optic cable carries UV light from a flash lamp to a gold photocathode
- Measure electron signal loss from cathode to anode to find lifetime:

$$Q_{anode} = Q_{cathode} \times \exp(-t_{drift} / \tau)$$





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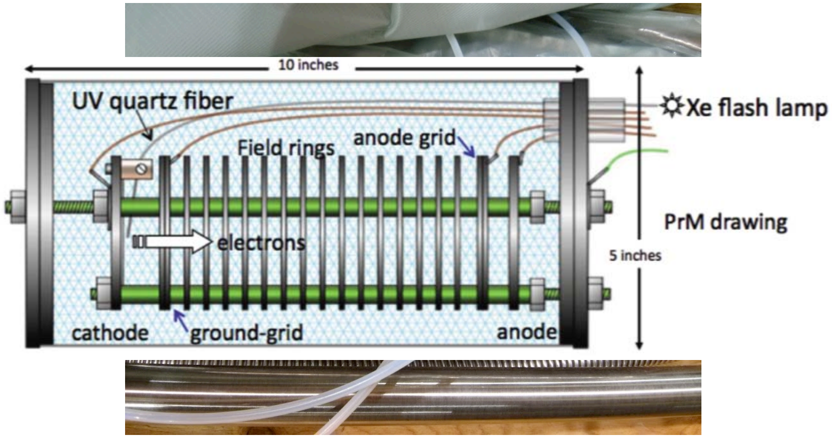
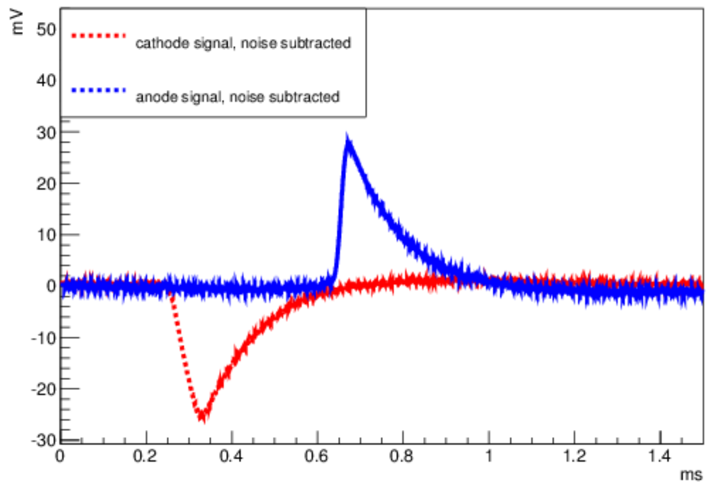
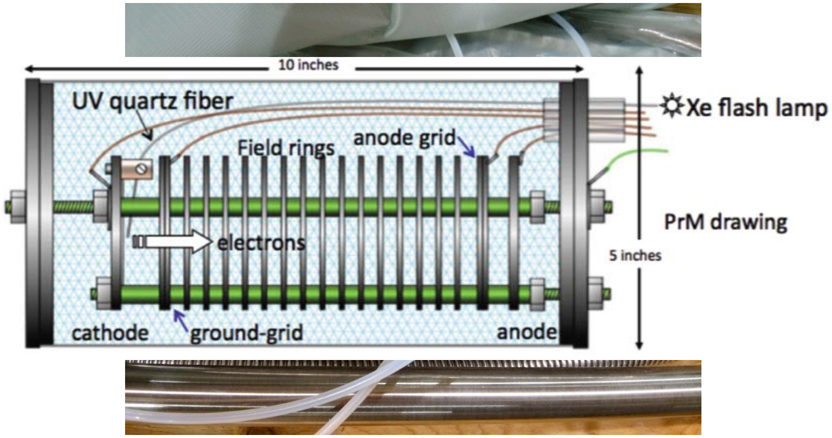
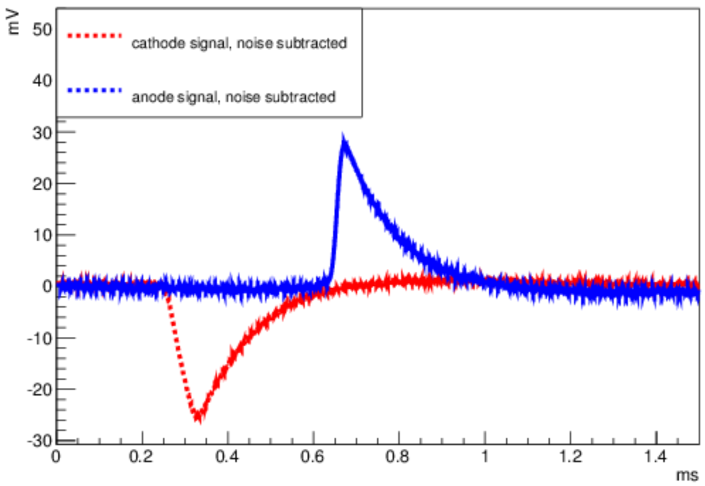




We have achieved on-spec purity

- We have measured a lifetime of 3.5 ms (< 100 ppt)
- This a lower bound on the lifetime as systematic uncertainties have the effect on increasing it
- Details on the measurement and hardware appears here: arXiv:1403.7236 [physics.ins-det]

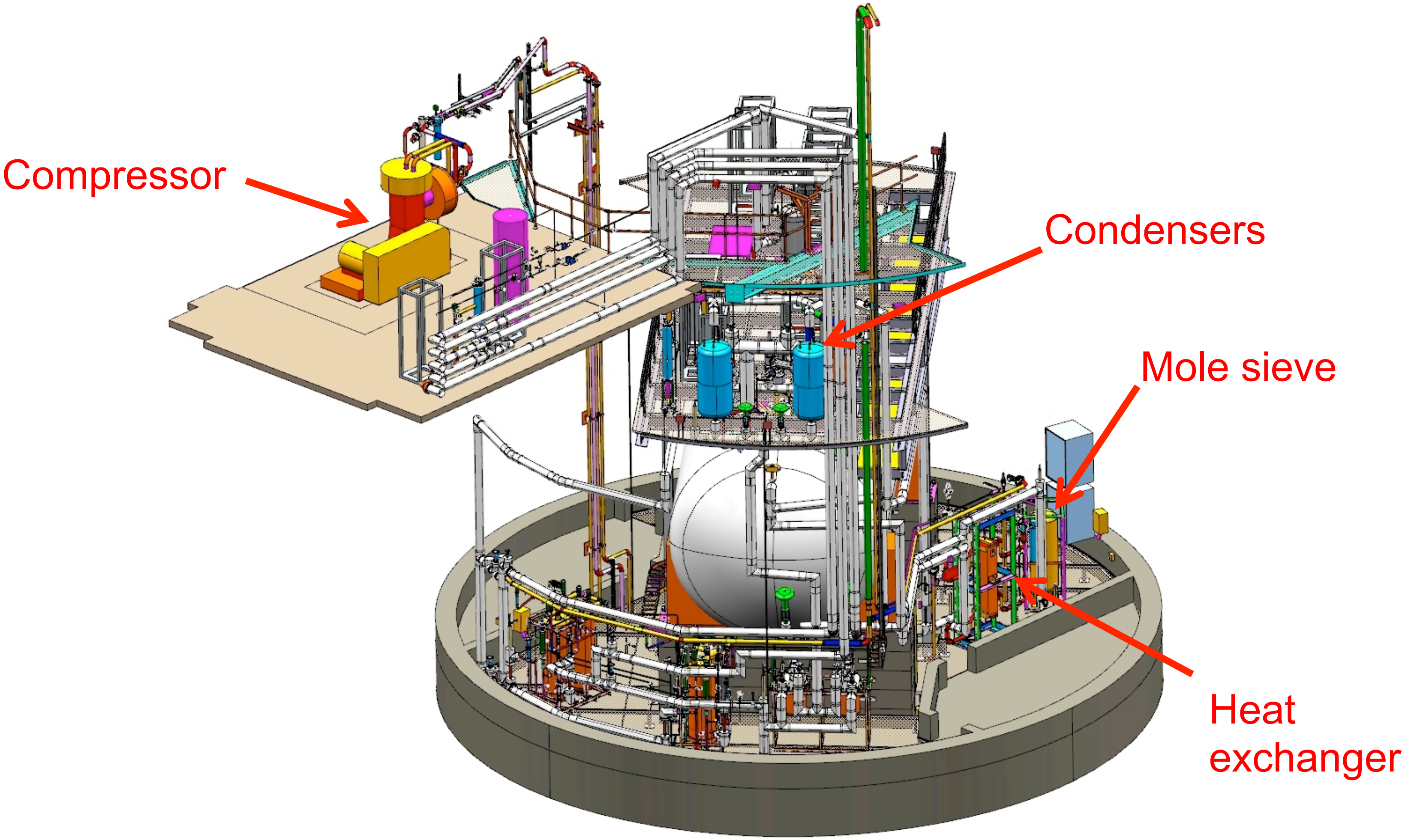




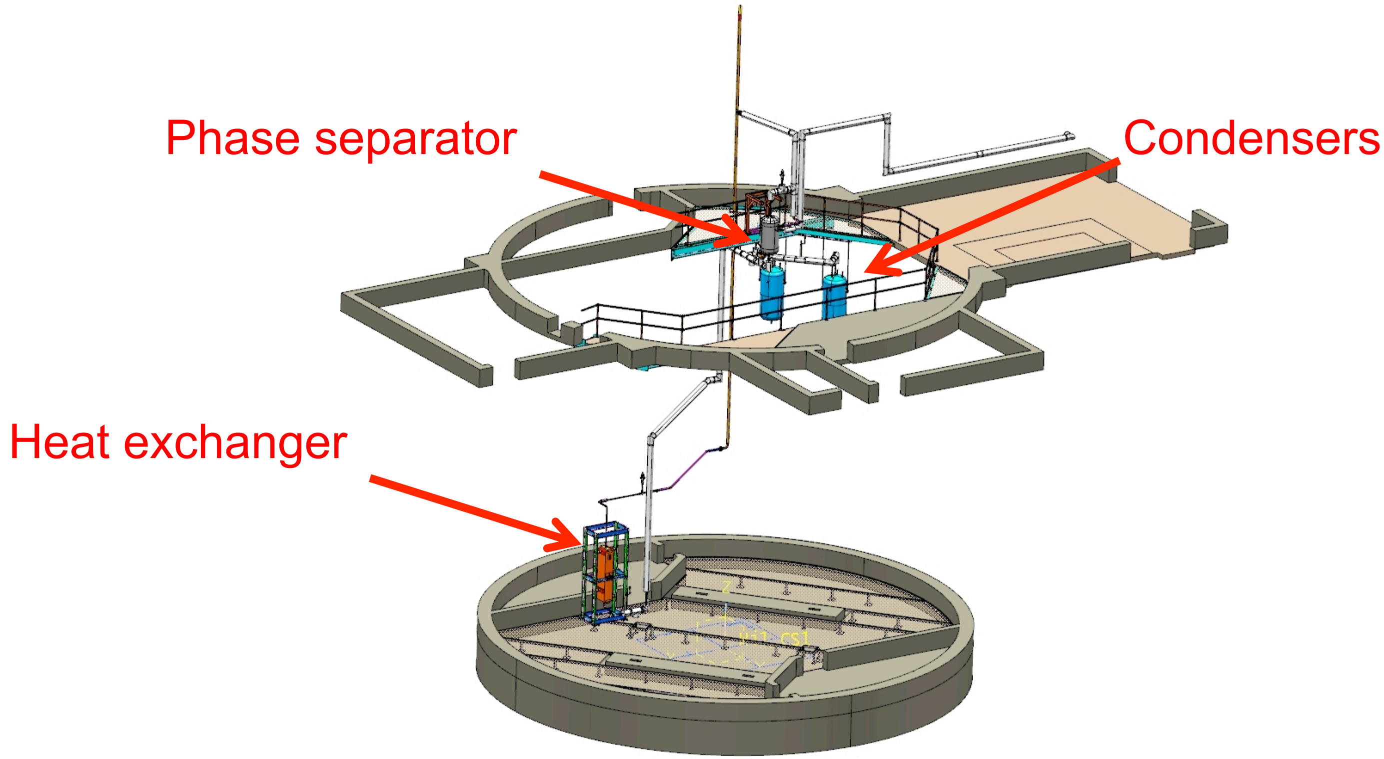
Wrapping up Phase I

- Phase I operations ceased on June 2
- Upon completion, the Phase I system began being reconfigured to allow the MicroBooNE cryostat to be moved into the building
- Phase I was a great success, we owe a lot of thanks to a lot of people, especially Mike Zuckerbrot and Bryan Johnson

Phase II full installation

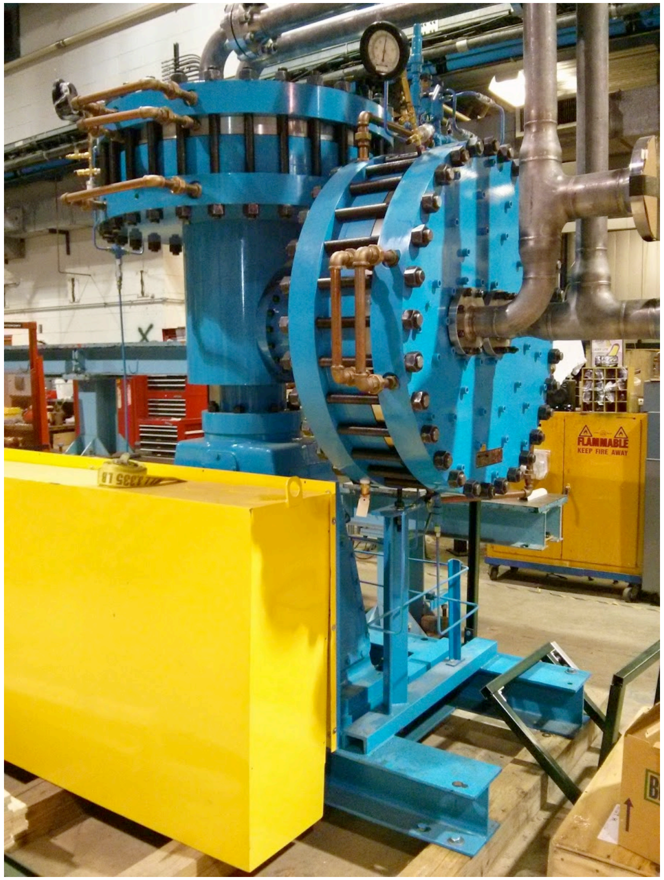


Phase II nitrogen system



- We will be using about 60 gallons of liquid nitrogen per hour
- Used in the condensers and heat exchanger

Big elements remain for the Phase II installation



Cool-Down Compressor

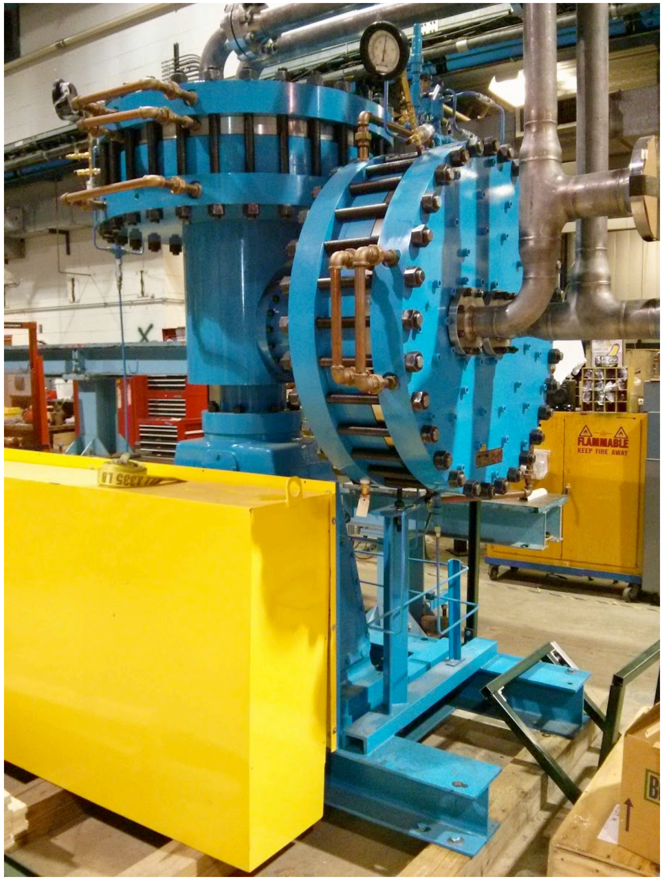
Condensers

Big elements remain for the Phase II installation

Condensers

- The condensers here have been foamed up
- One spare, the other active
- Uses liquid nitrogen as coolant
- Similar design to LAPD
- Delivers 9 kW of cooling capacity

Big elements remain for the Phase II installation



Cool-Down Compressor

- Powers the cool-down circuit (gradually cools the cryostat down to limit mechanical stress at the beginning of running)
- The cool-down circuit will hopefully only need to be used once

We owe a lot of thanks to many people!

Rob Acciarri, John Bell, John Cornele, Ben Carls, Roberto Davila, Bill Gatfield, Tim Griffin, Walter Jaskierny, Bryan Johnson, Jim Kilmer, Dan Knight, Bob Kubinski, Andy Lathrop, Sarah Lockwitz, Ryan Mahoney, Dan Markley, Tim Martin, John Najdzion, Brian Rebel, Bob Sanders, Mike Sarychev, Anne Schukraft, Mark Shoun, Kourosh Taheri, Justin Tillman, John Voirin and Mike Zuckerbrot

Summary

- Phase I was a success, we accomplished our goals of operating the cryogenics system without the MicroBooNE cryogenics system in place
- The system performed well in delivering liquid argon at varying levels of purity to the HVC
- Phase II construction will be in full swing soon, waiting on the cryostat to be foamed

Back-up

Filter details

- Molecular sieve based on 208604-5KG Type 4A material (Sigma-Aldrich)
- Oxygen filter uses CU-0226 S 14 × 28 (Research Catalysts, Inc.)

Purity monitor systematics

- We assume the acceptance of electrons hitting the anode is 100%, this is likely lower, electrons that traversed the entire purity monitor length will not be counted, this makes Q_A smaller
- The possibility exists that electrons could be absorbed by the cathode grid, thus the value of Q_C is an upper limit
- There is additionally an uncertainty of the RC time constant, this will also drive up the value of Q_A/Q_C