The EGG
(Exchange Gas Guard)

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Aaron Galper and Brian Lantz

LVK meeting, Lake Geneva 2020

Outline

- Motivation and previous results
- The idea
  - How can we trap the Exchange Gas?
  - The EGG Prototype
- Results
  - Pictures!
  - Okay, but did the bag work?
- Conclusions

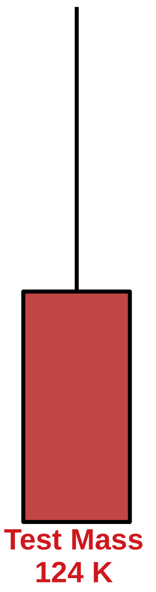
Outline

- Motivation and previous results

On Cryogenic GW Detectors

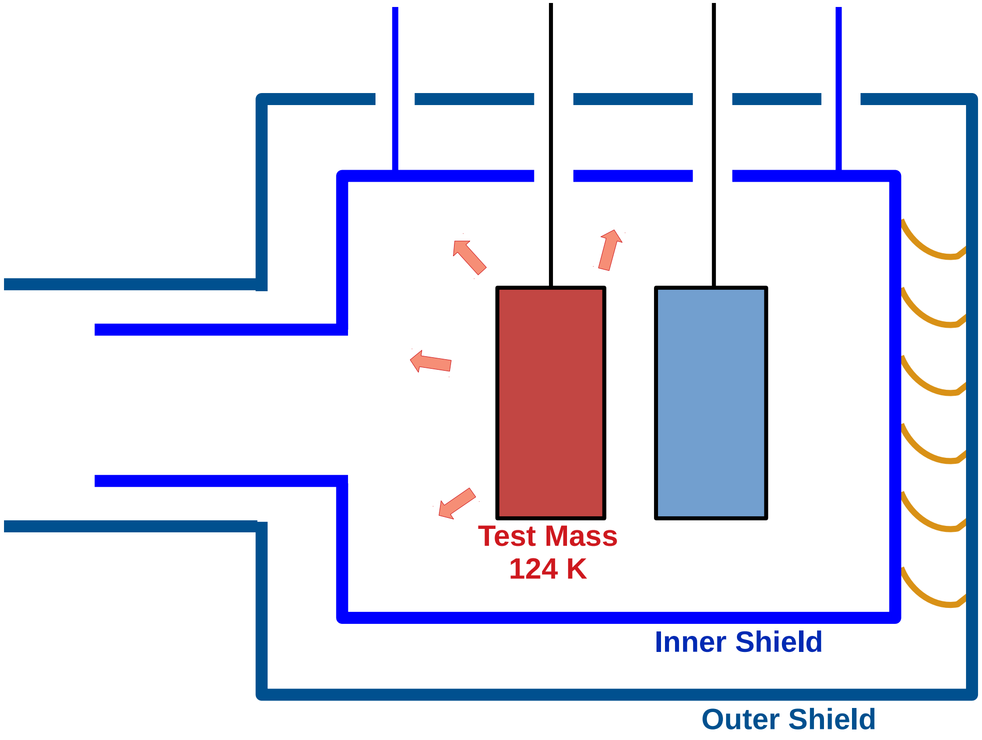
✔ **124 K Silicon Test Mass**

(Reduces Thermal Noise)



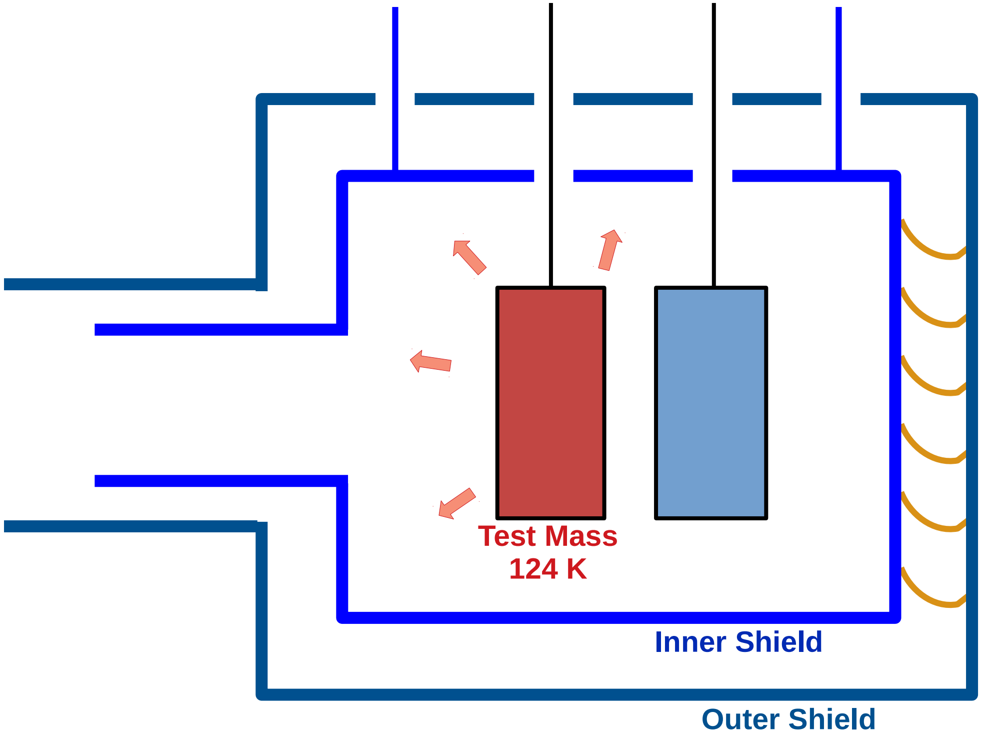
On Cryogenic GW Detectors

- ✔ **124 K Silicon Test Mass**
- ✔ **Steady state radiative cooling**



On Cryogenic GW Detectors

- ✔ **124 K Silicon Test Mass**
- ✔ **Steady state radiative cooling**
- ✗ **Slow Initial Cooldown**



Why Faster Cooldown?

- **The ice problem**
  - Water condensing in the optic surfaces can compromise the sensitivity of the interferometer.
    [see Hasegawa (2019) or Steinlechner (2019)]
  - It might take ~2 weeks for the water vapor in the vacuum chamber to be low enough for safe cryo operations.
    [see, T1900786]

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- **Faster iteration time:**
  - Numerical estimates set the initial cooldown time between 3 days and a week.
  - Reducing this time to 1-2 days can save a lot of time when at the start of any run.

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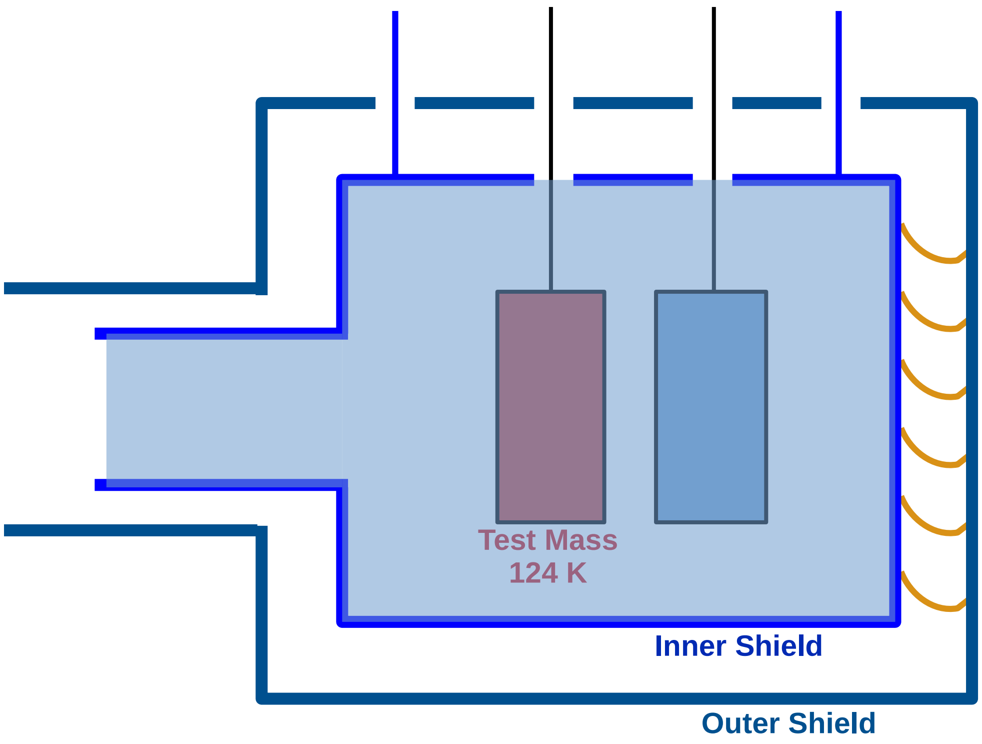
- **Prototype facilities**
  - Any test facilities for cryo GW observatories would greatly benefit from the fast iteration time.

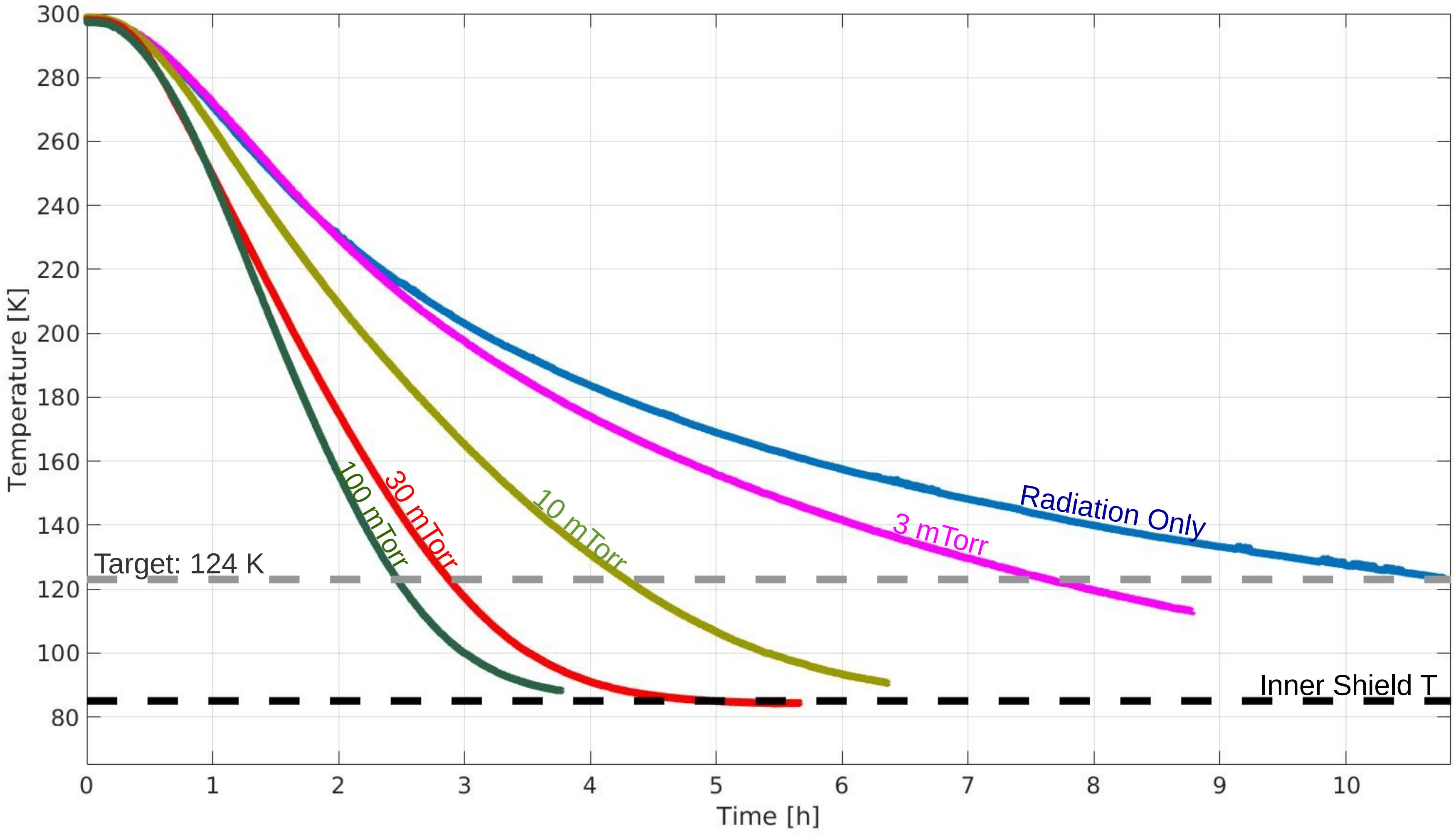
On Cryogenic GW Detectors

- ✔ **124 K Silicon Test Mass**
- ✔ **Steady state radiative cooling**
- ✔ **Exchange Gas Initial Cooldown***



* more info: G1900526

1 kg Silicon Mass results:
(see G1900526)



- *Additionally, we can model the heat transfer rates within 5% accuracy by using the Sherman-Lees formula for heat conduction in gases.*

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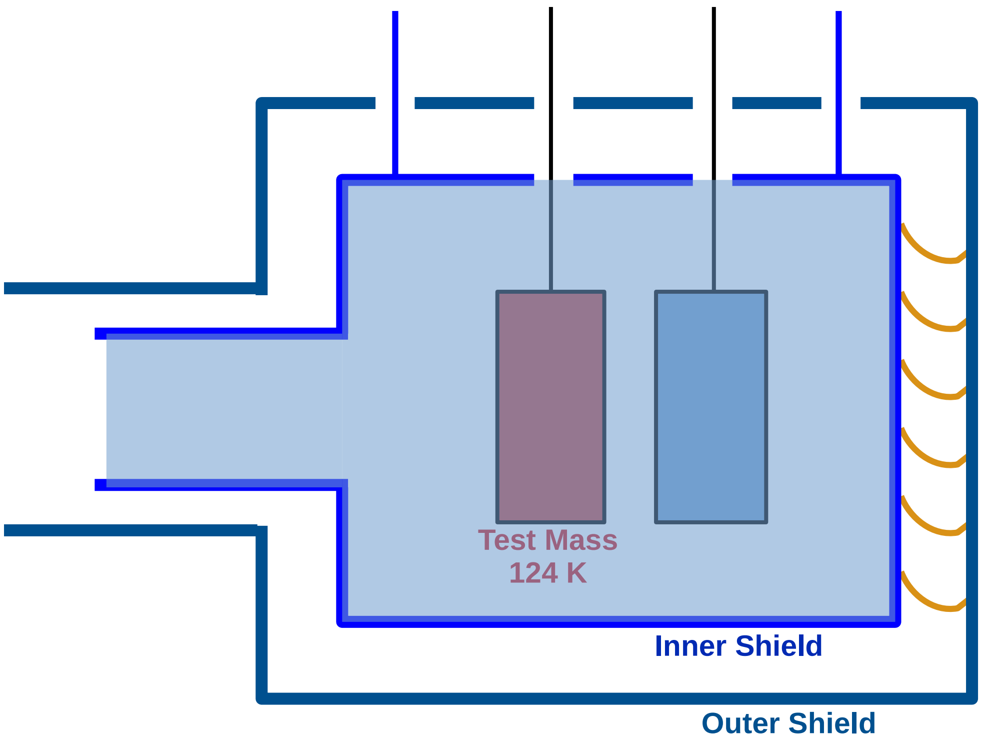

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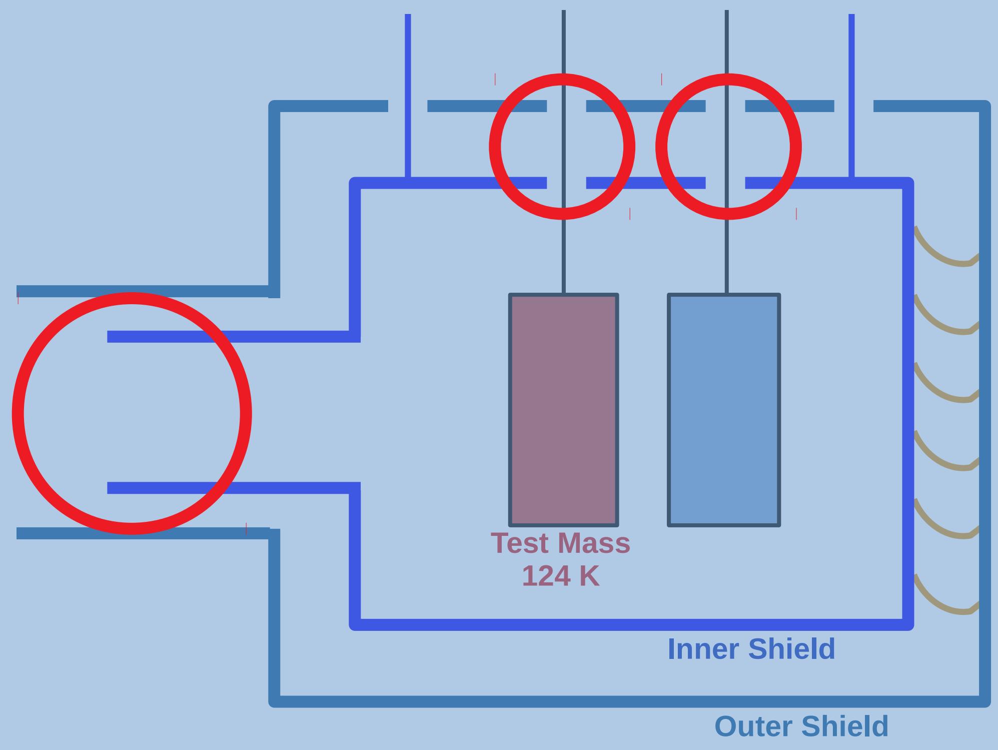
On Cryogenic GW Detectors

- ✔ **124 K Silicon Test Mass**
- ✔ **Steady state radiative cooling**
- ✔ **Exchange Gas Initial Cooldown**
- ✗ **Gas Leaks!**



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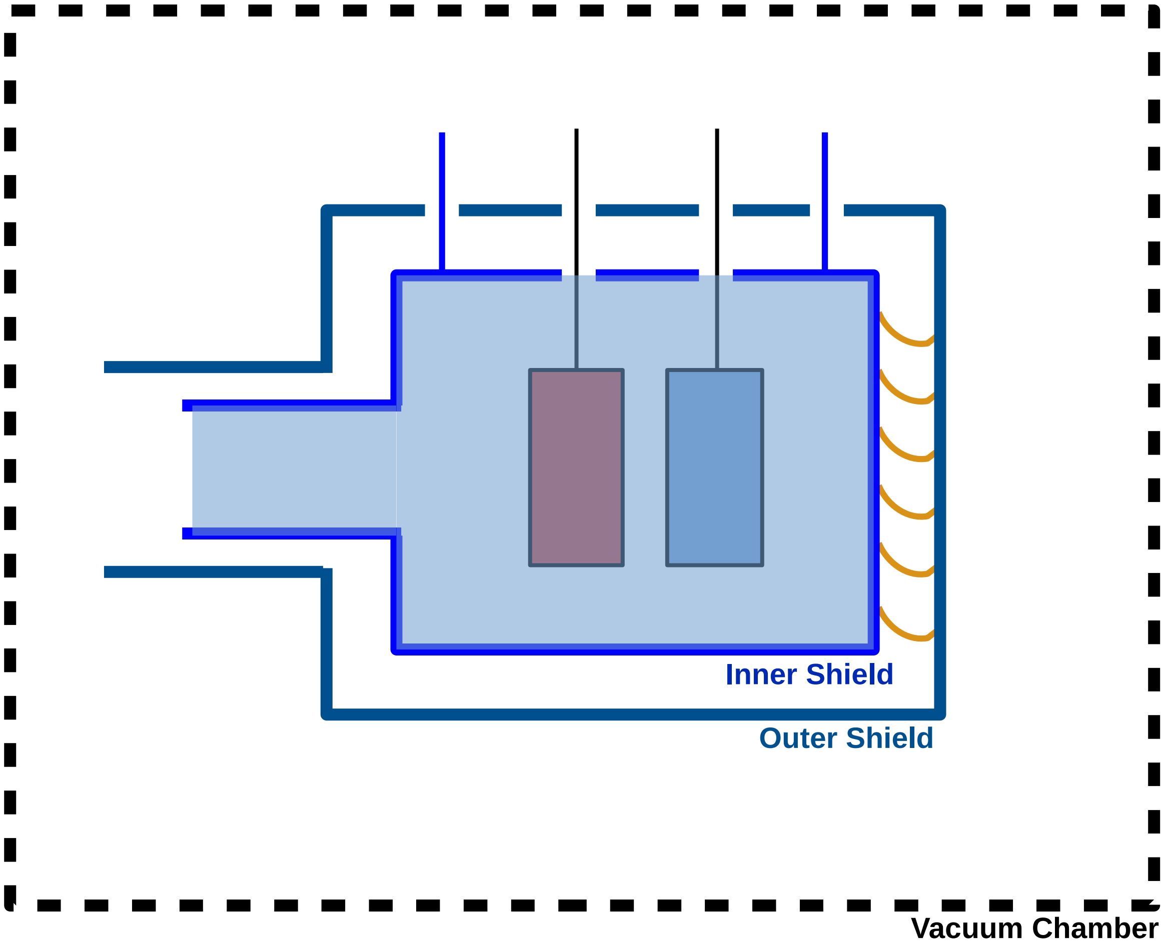
  - The EGG Prototype

Trapping the Exchange Gas

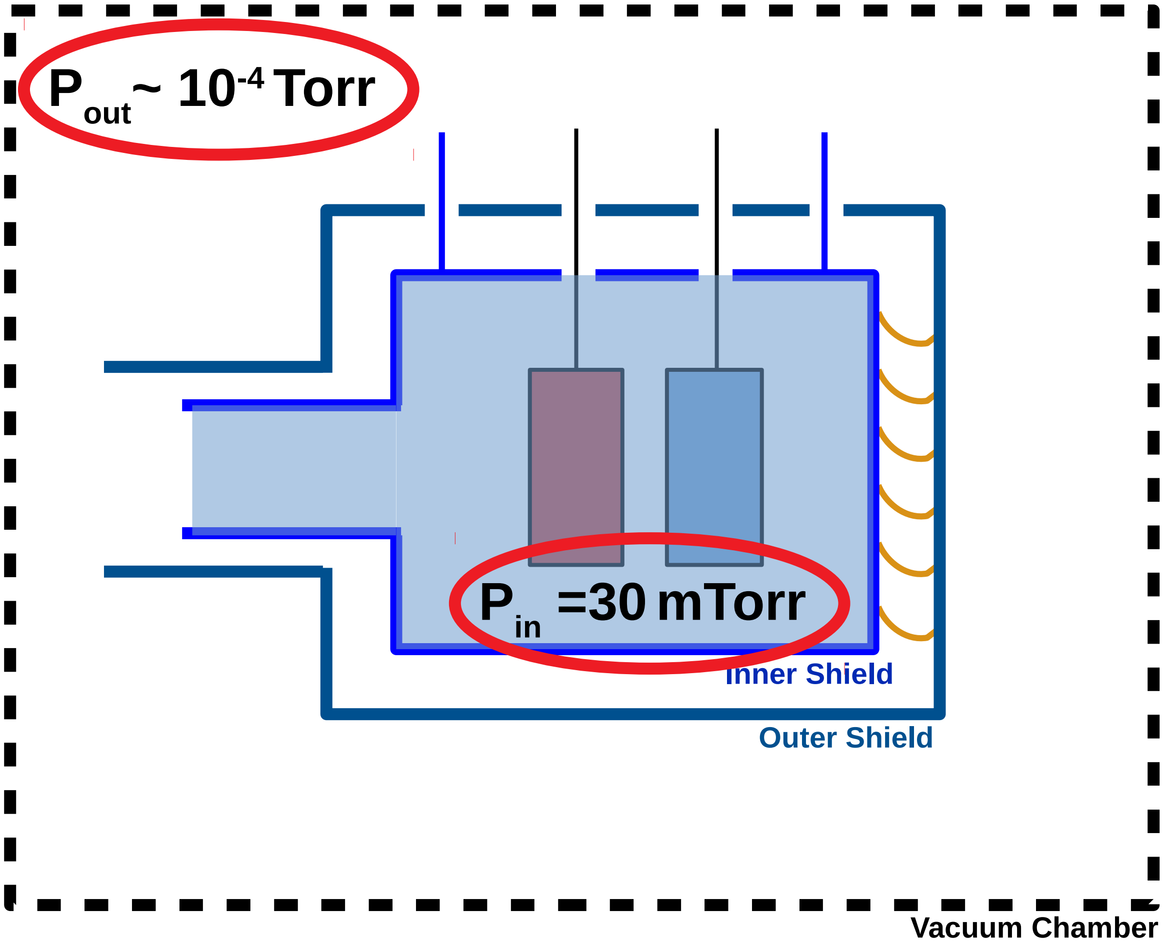
Requirements:



Trapping the Exchange Gas

Requirements:

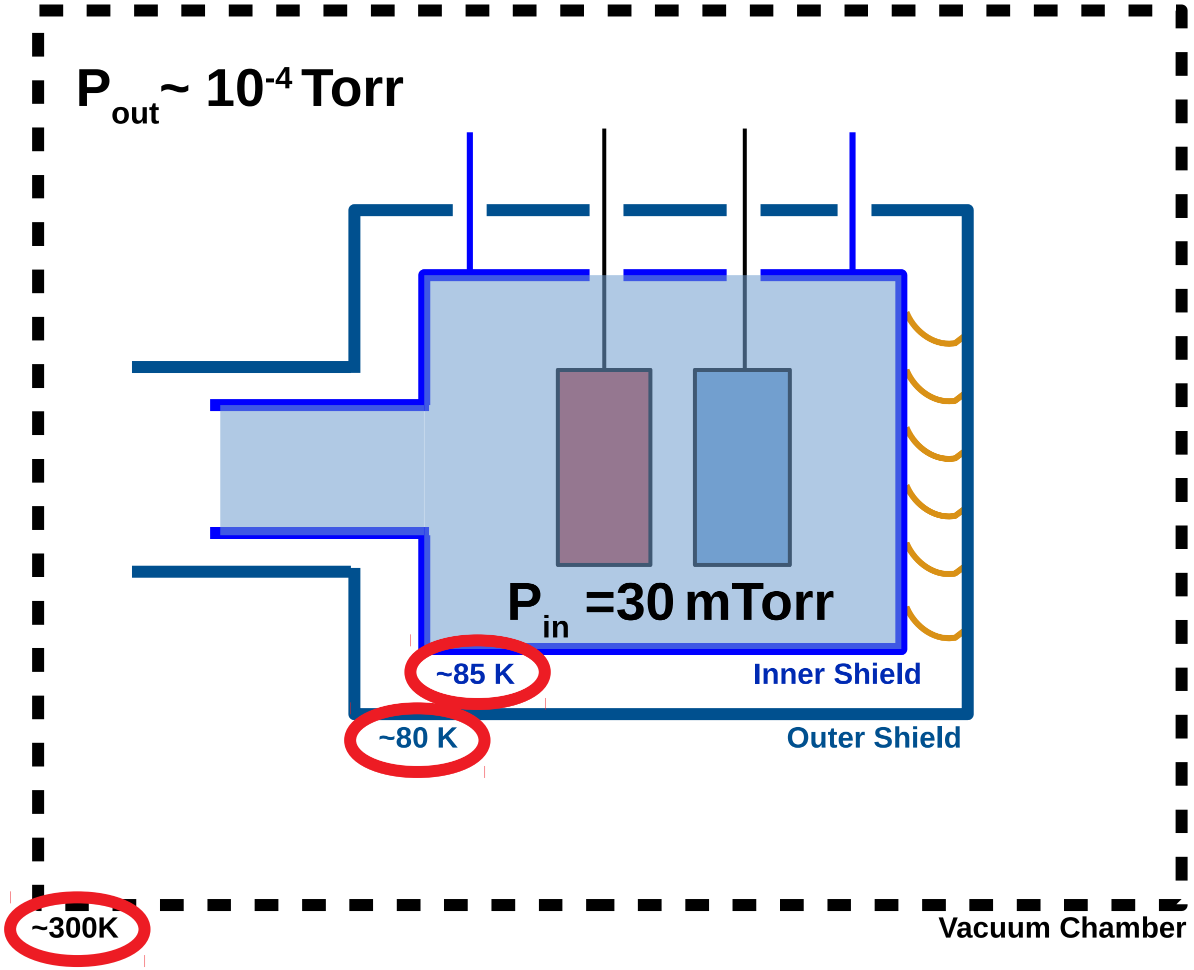
- Pressure Differential.



Trapping the Exchange Gas

Requirements:

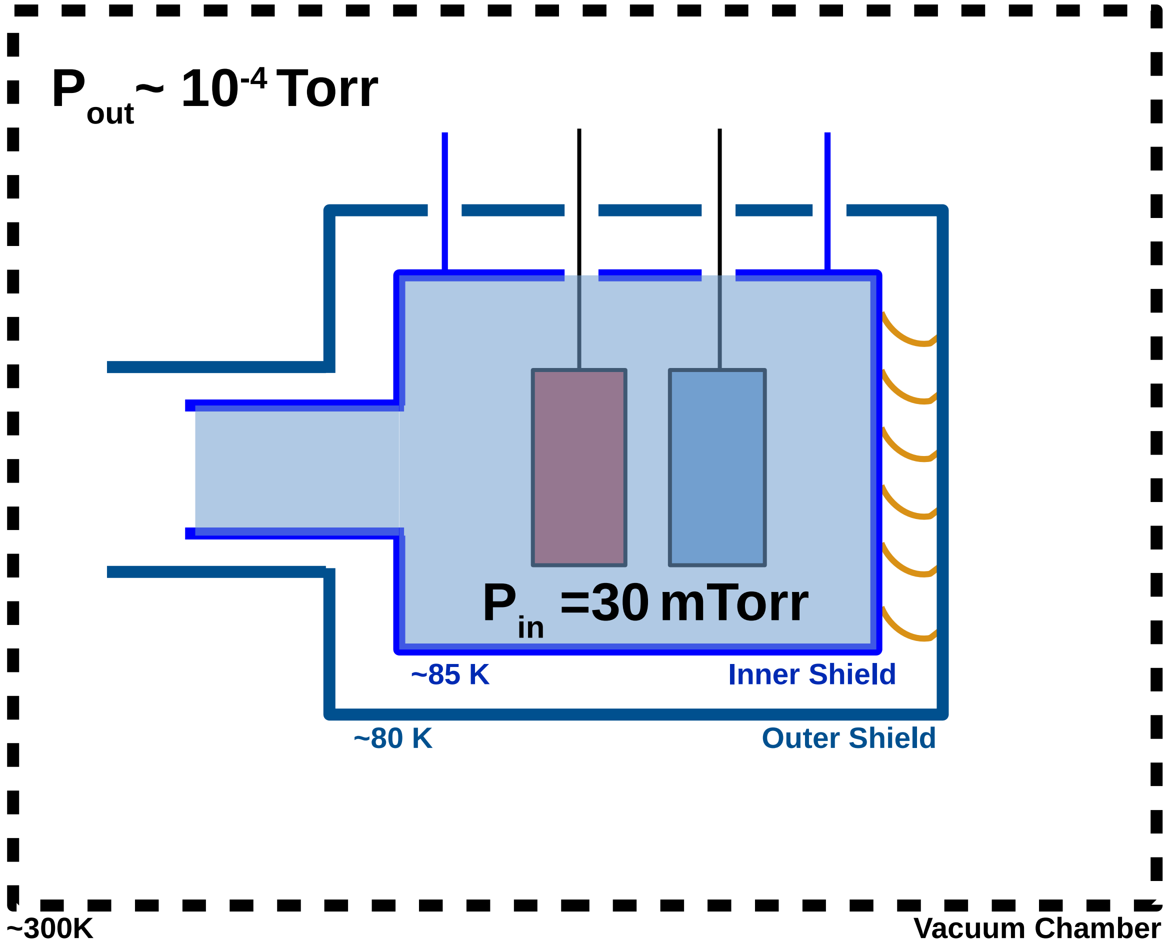
- Pressure Differential.
- Temperature Differential



Trapping the Exchange Gas

Requirements:

- Pressure Differential.
- Temperature Differential
- Reproducible/Consistent
- Vacuum Compatible



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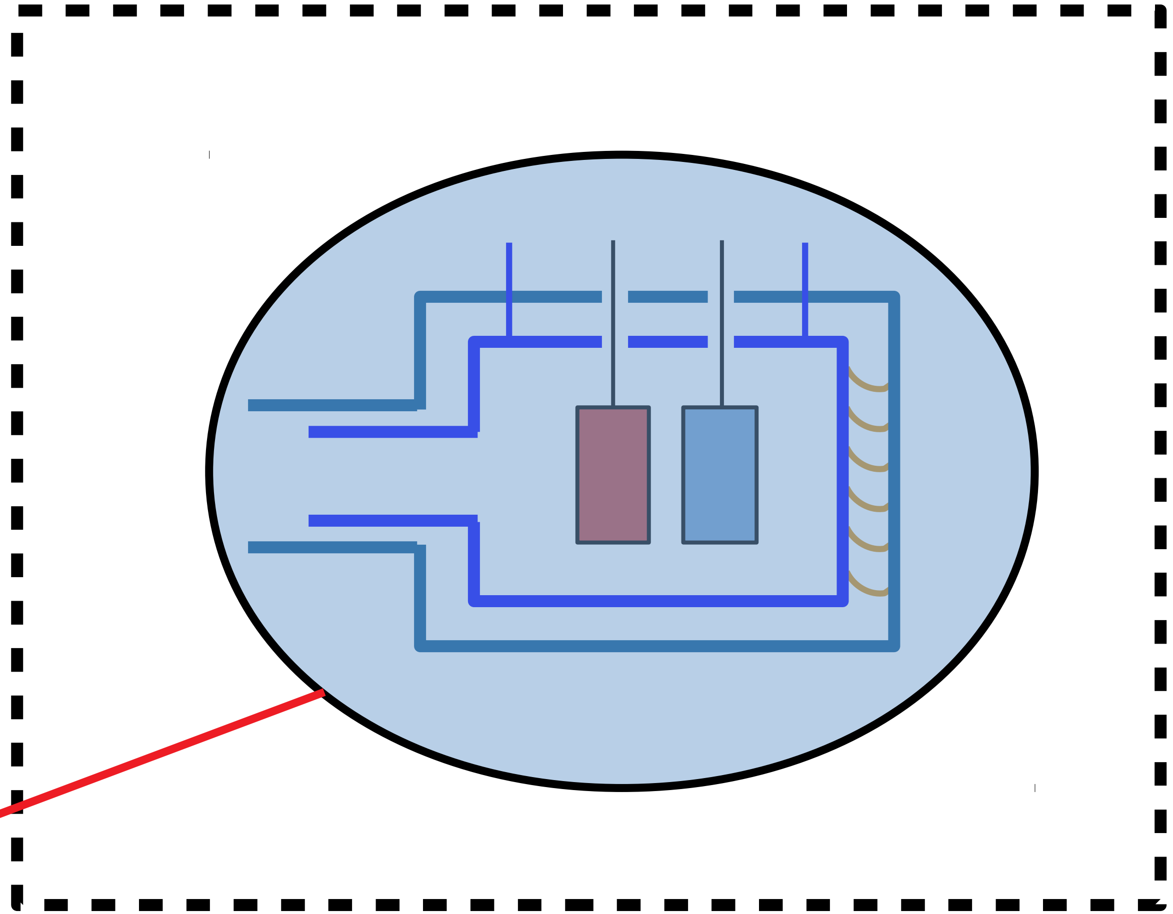
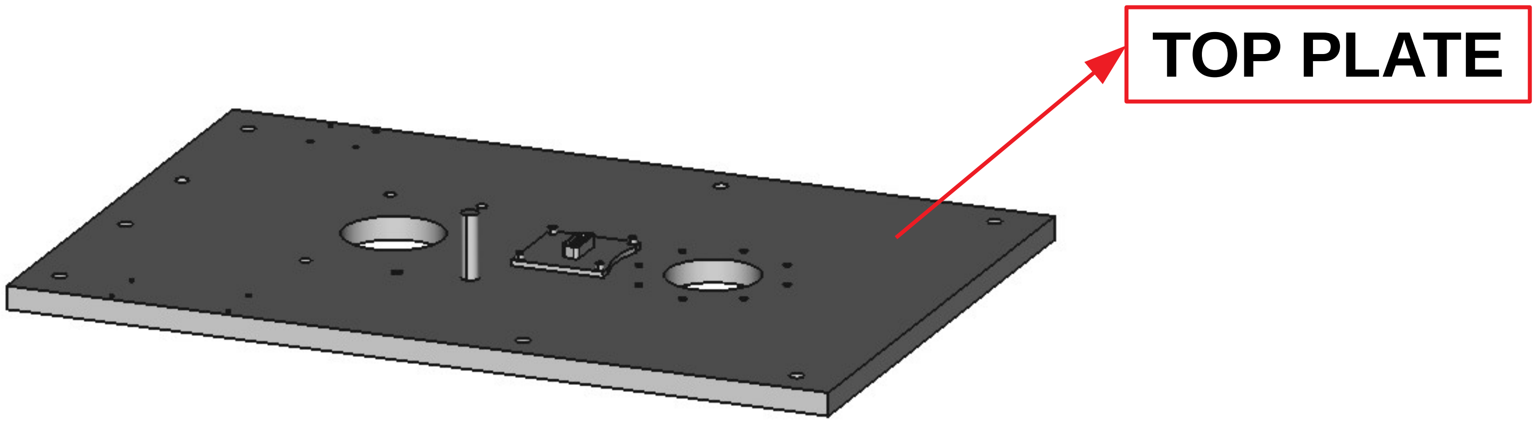


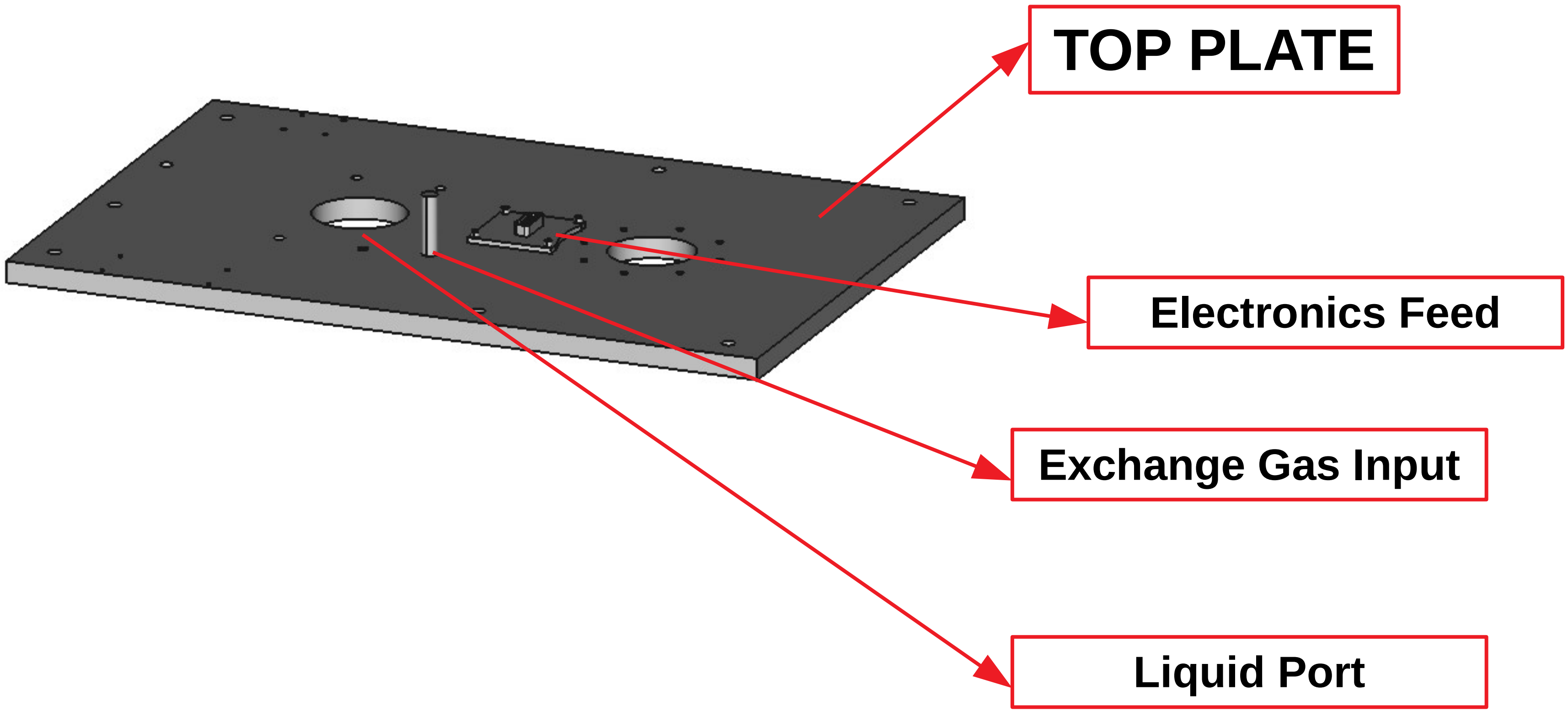
Exchange Gas Guard (EGG)

The EGG

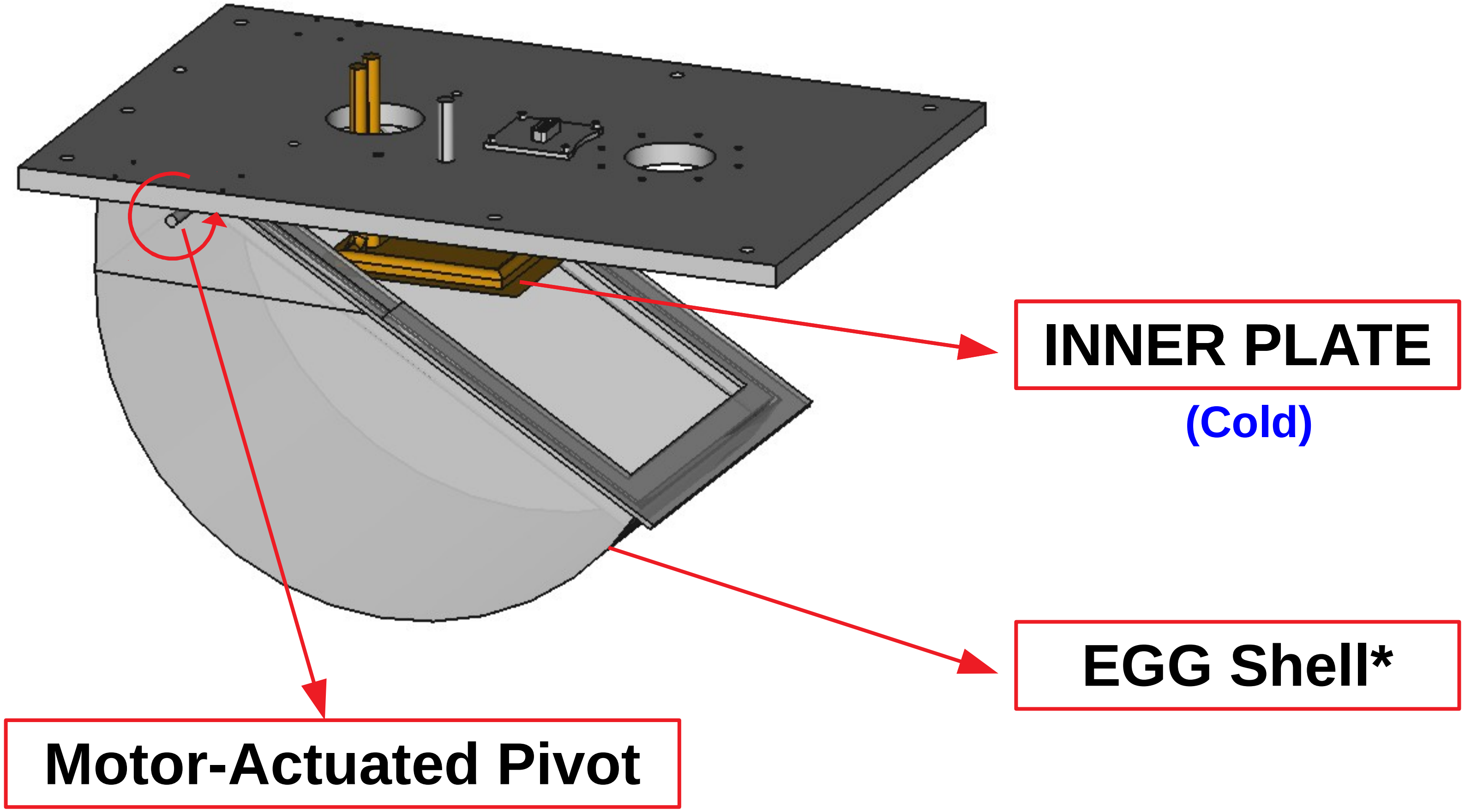
The EGG



The EGG

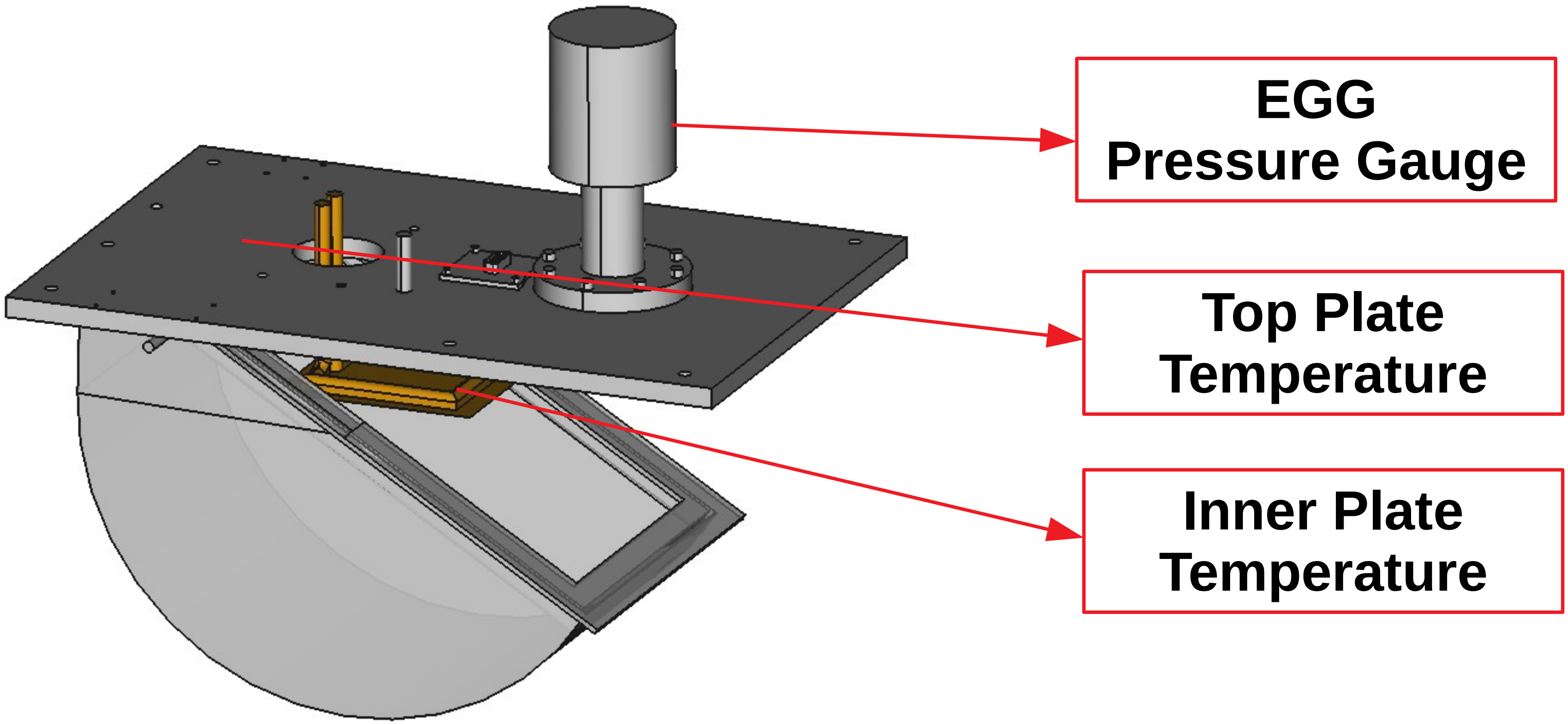


The EGG



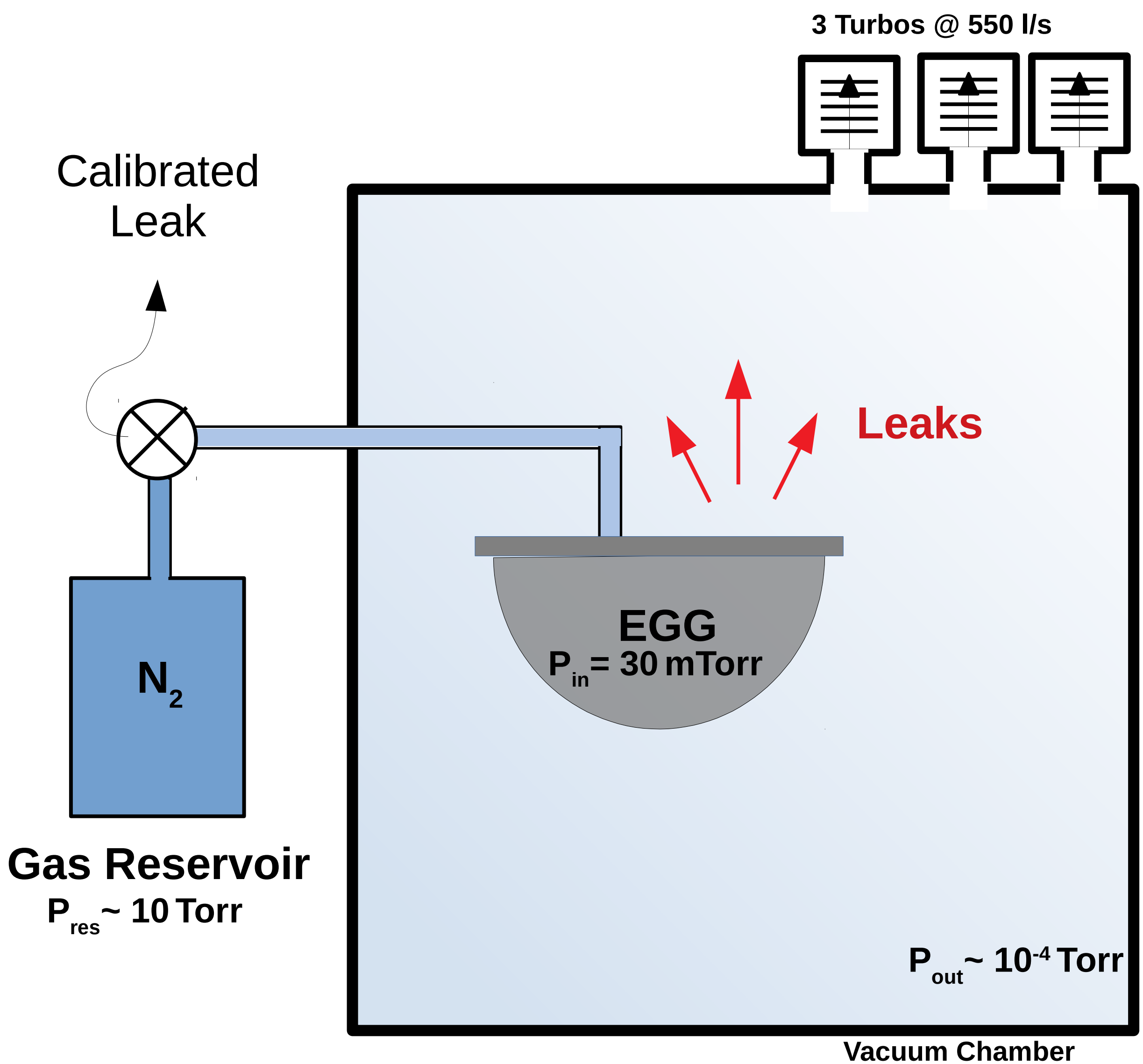
* Made with a thin film of PTFE. The EGG Shell’s consistency is that of a bag

The EGG



* We also monitored the Vacuum Chamber's Pressure and the Temperature of the optics Table underneath the EGG.

Experimental Setup



Experimental Questions

- Can the prototype EGG hold the pressure differential?
- Can it sustain the temperature difference?
- Can it be operated reproducibly under vacuum?

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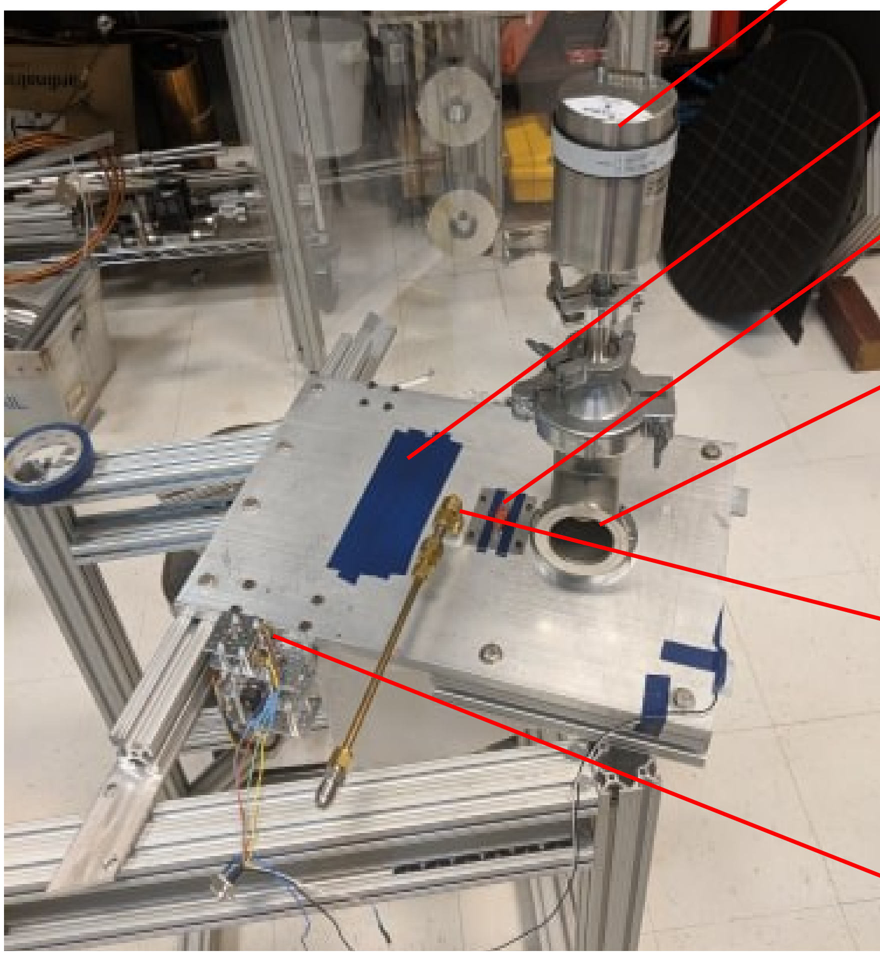
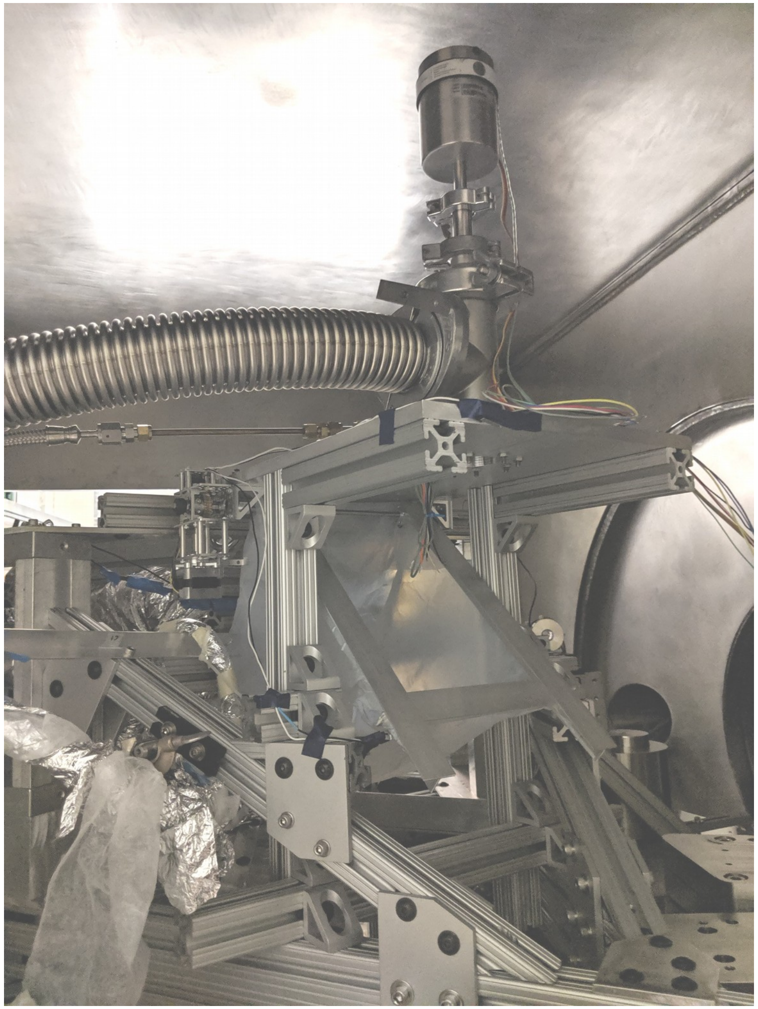
Results

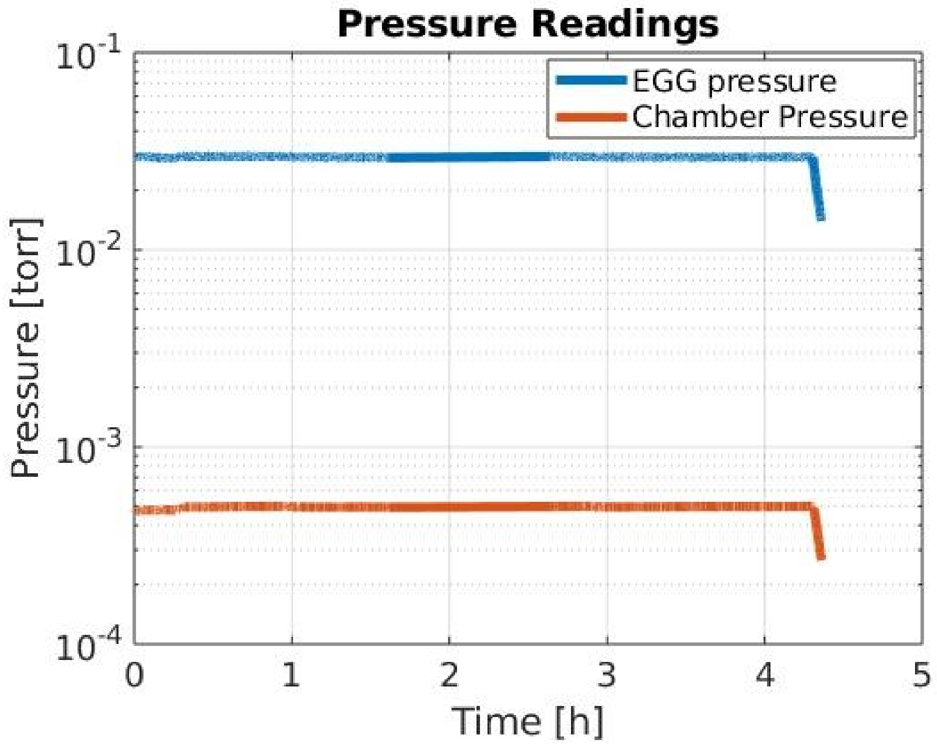


- Pressure Gauge
- LN port (Blanked)
- 15 pin Electronic feed
- Gas Output
- Gas input
- Stepper Motor Structure

Results



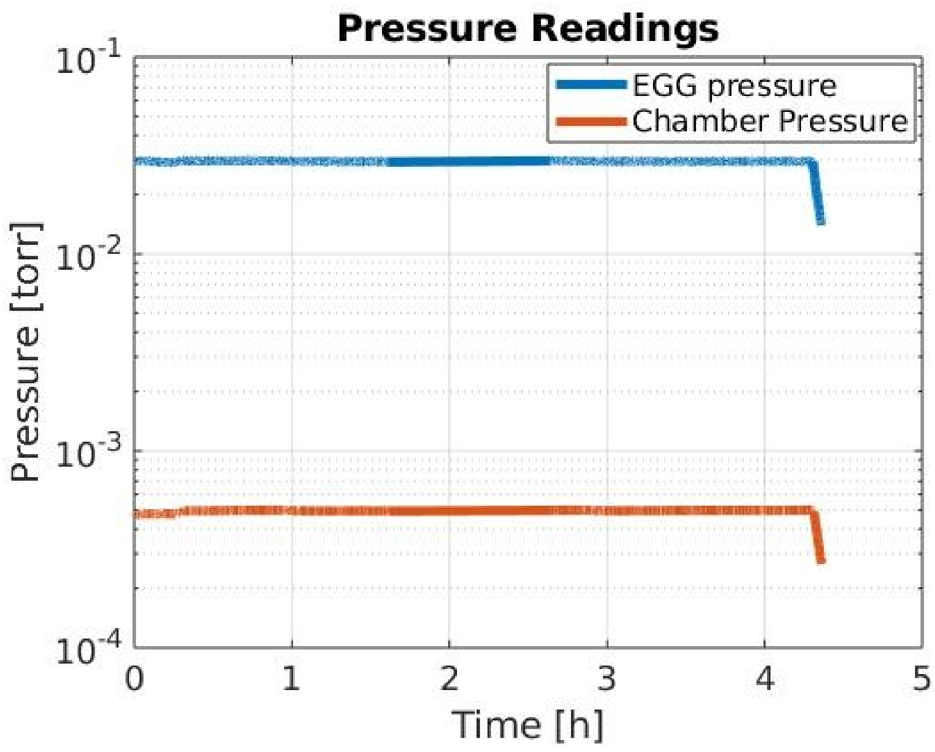
Results:
Nominal Operation

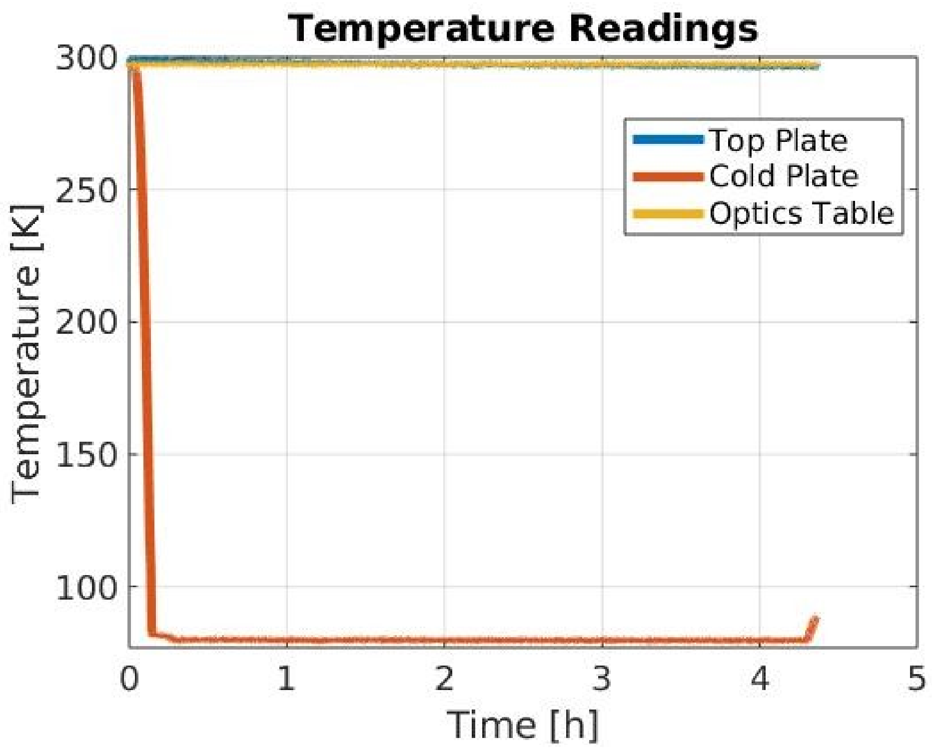


P_{egg}= 30 mTorr

P_{cham}= 5x10^{-4} Torr

Results:
Nominal Operation





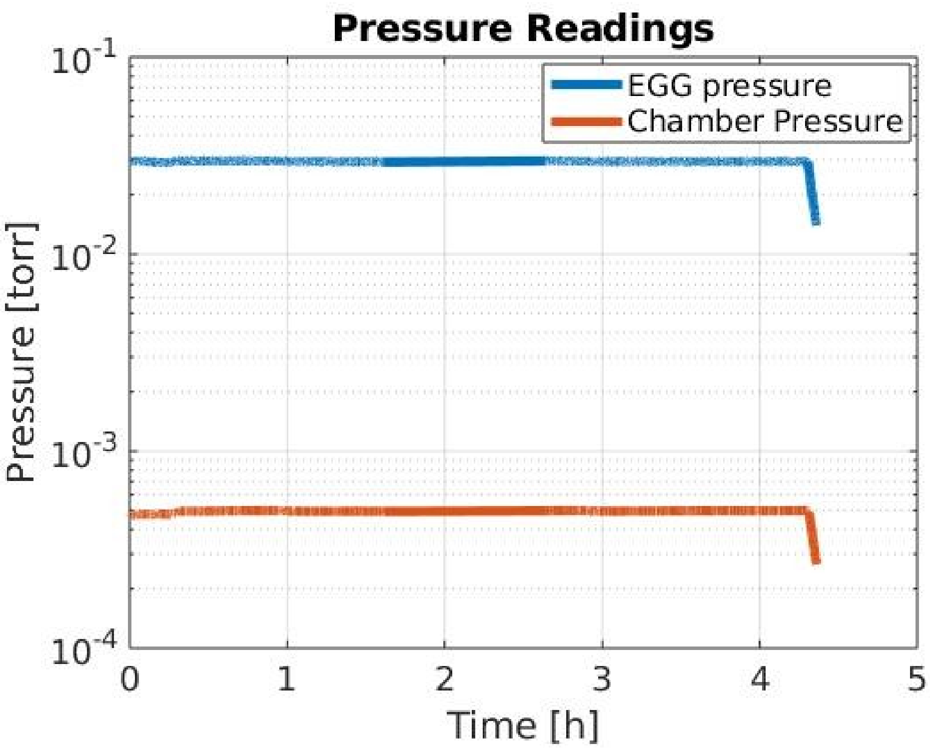
P_{egg} = 30 mTorr

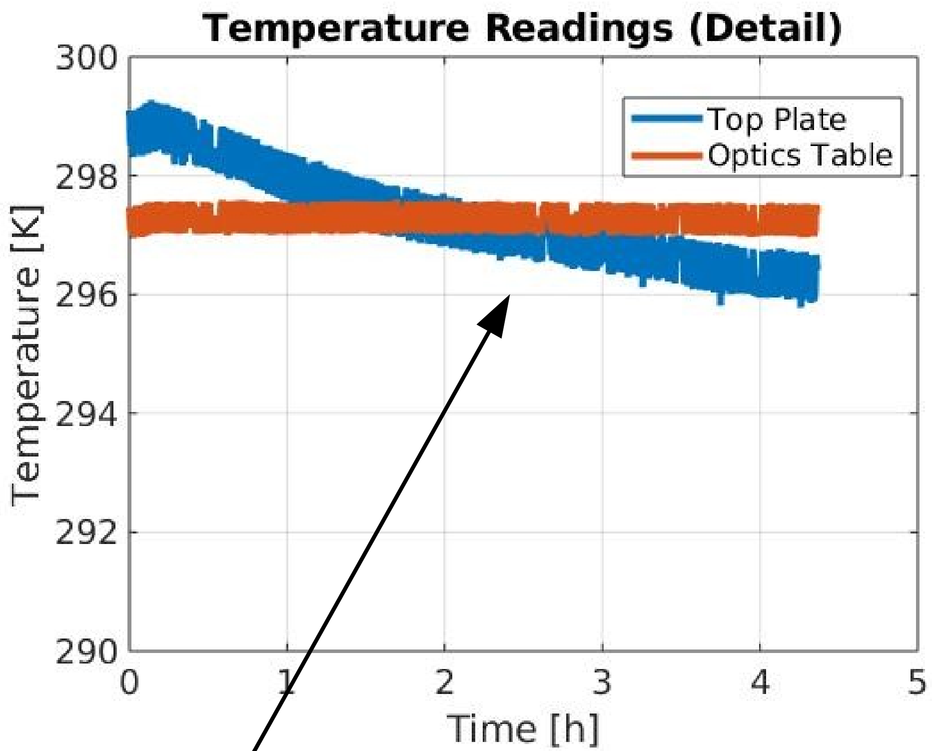
P_{cham} = 5x10^{-4} Torr

T_{inn} = 80 K

T_{opt} = 297 K

Results: Nominal Operation





ΔT_{Top}=3K

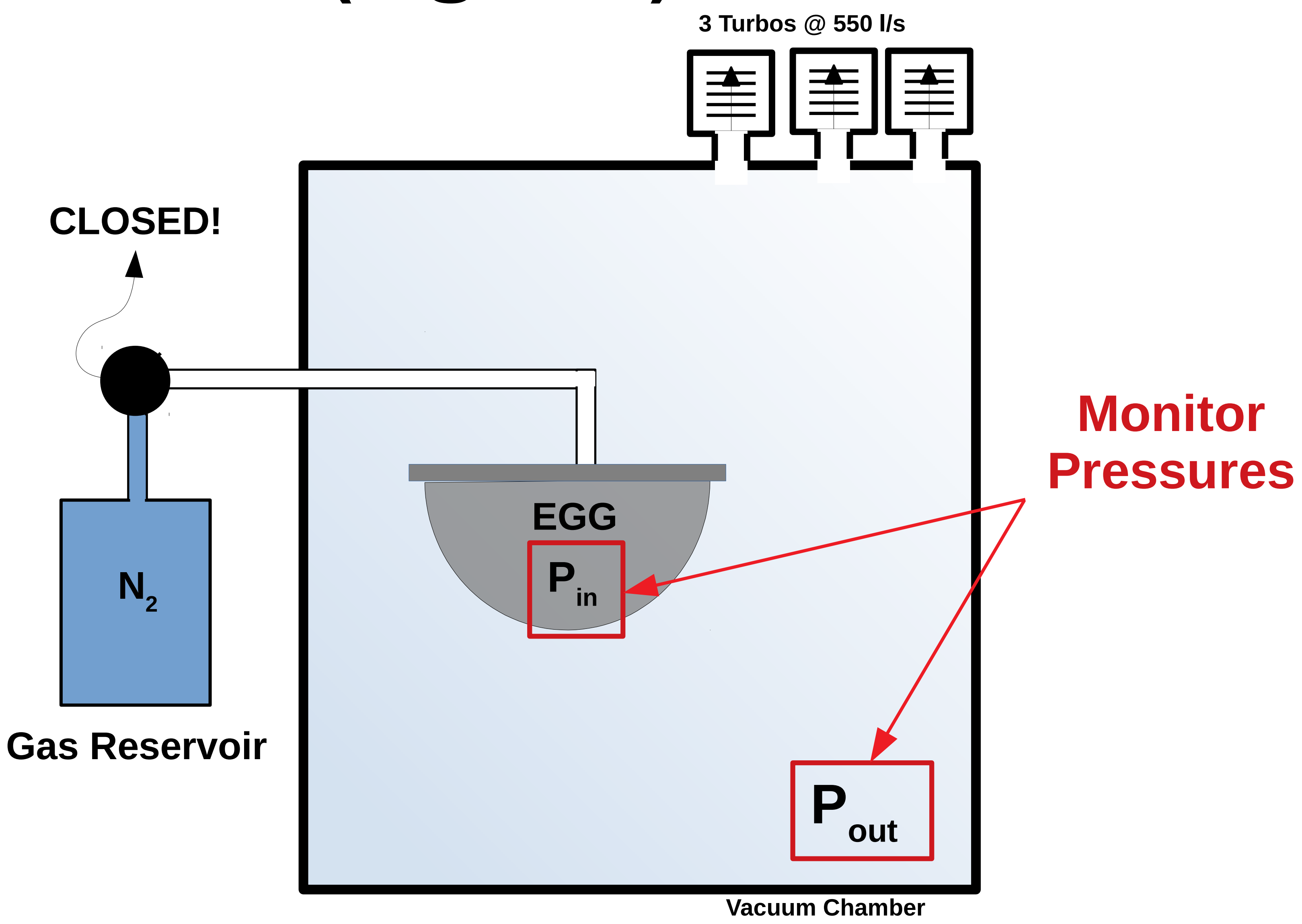
P_{egg}= 30 mTorr

P_{cham}= 5x10^{-4} Torr

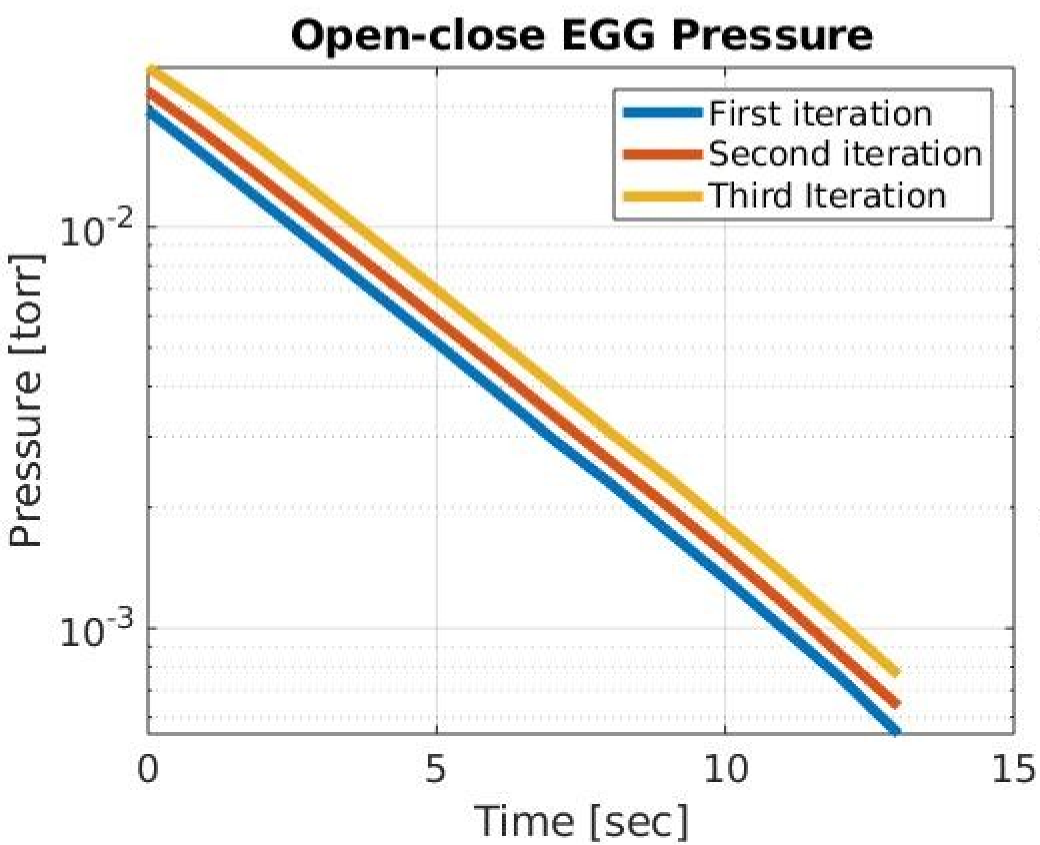
T_{inn}= 80 K

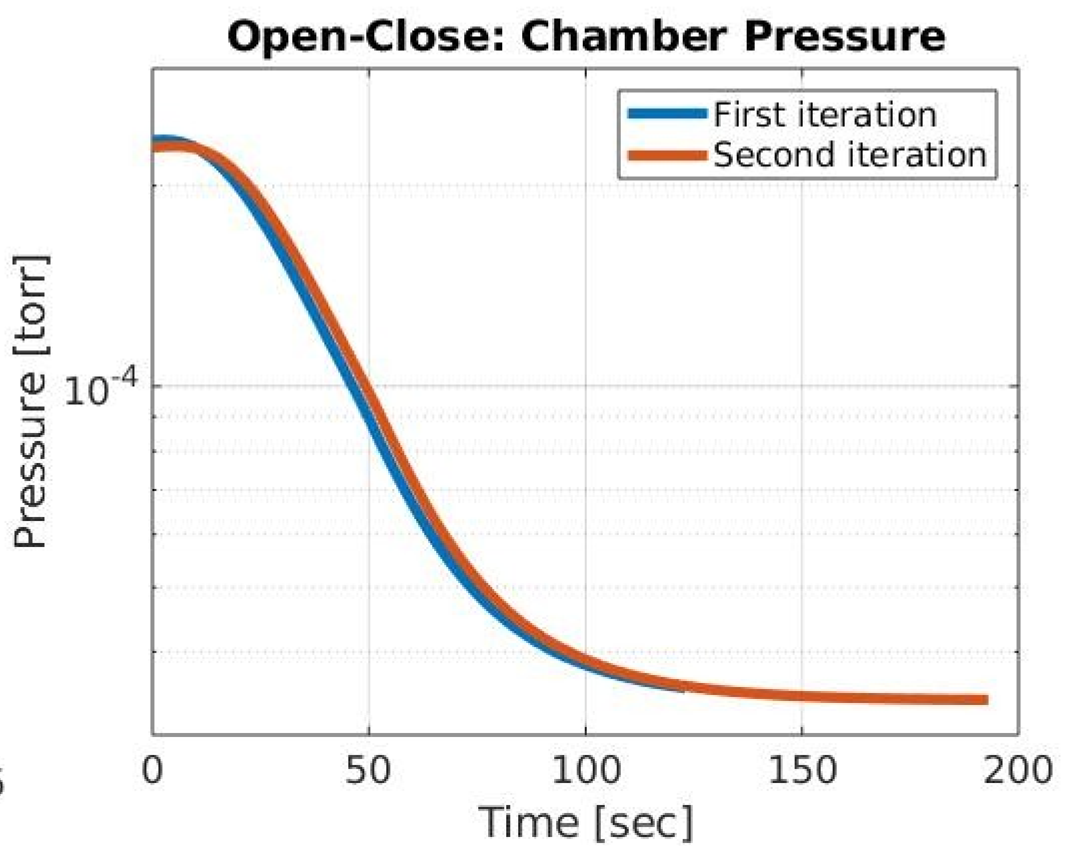
T_{opt}= 297 K

Experimental Setup (Again!)



Results





- The Vacuum Chamber returns to its base pressure in under 2 minutes

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Conclusions

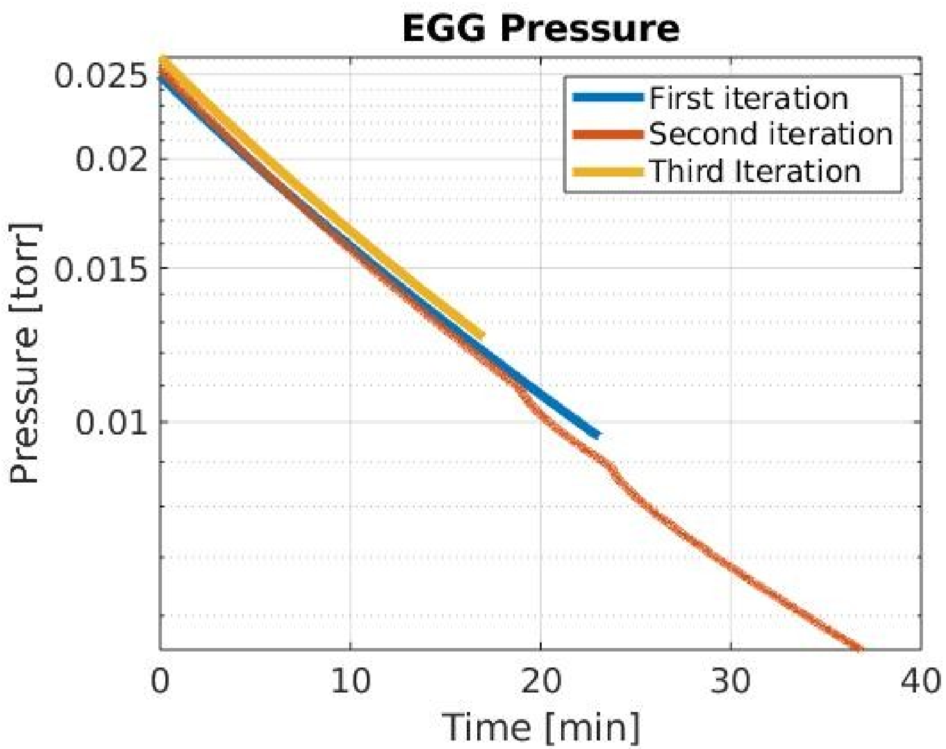
- We prototyped a simple design (the EGG) to keep the pressure differential required for the exchange gas to be viable.
- The design, while simple, can support a Liquid nitrogen temperature object inside of it.
- The materials and pieces are either vacuum compatible or can be made with ease.

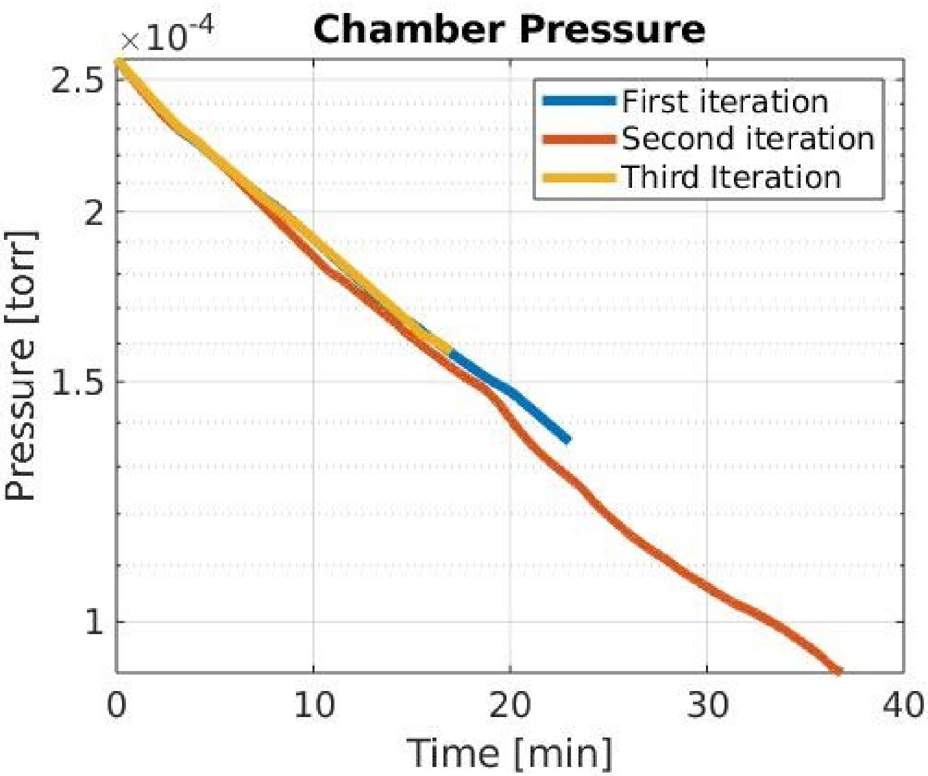
Next Steps:

- Consolidate the Exchange Gas Information in a document
- [Tentative] Test EGG with a radiatively cooled 'test mass'.
- Investigate other cryo technologies of interest (neon cooling, thermosiphons, etc)

THANK YOU!

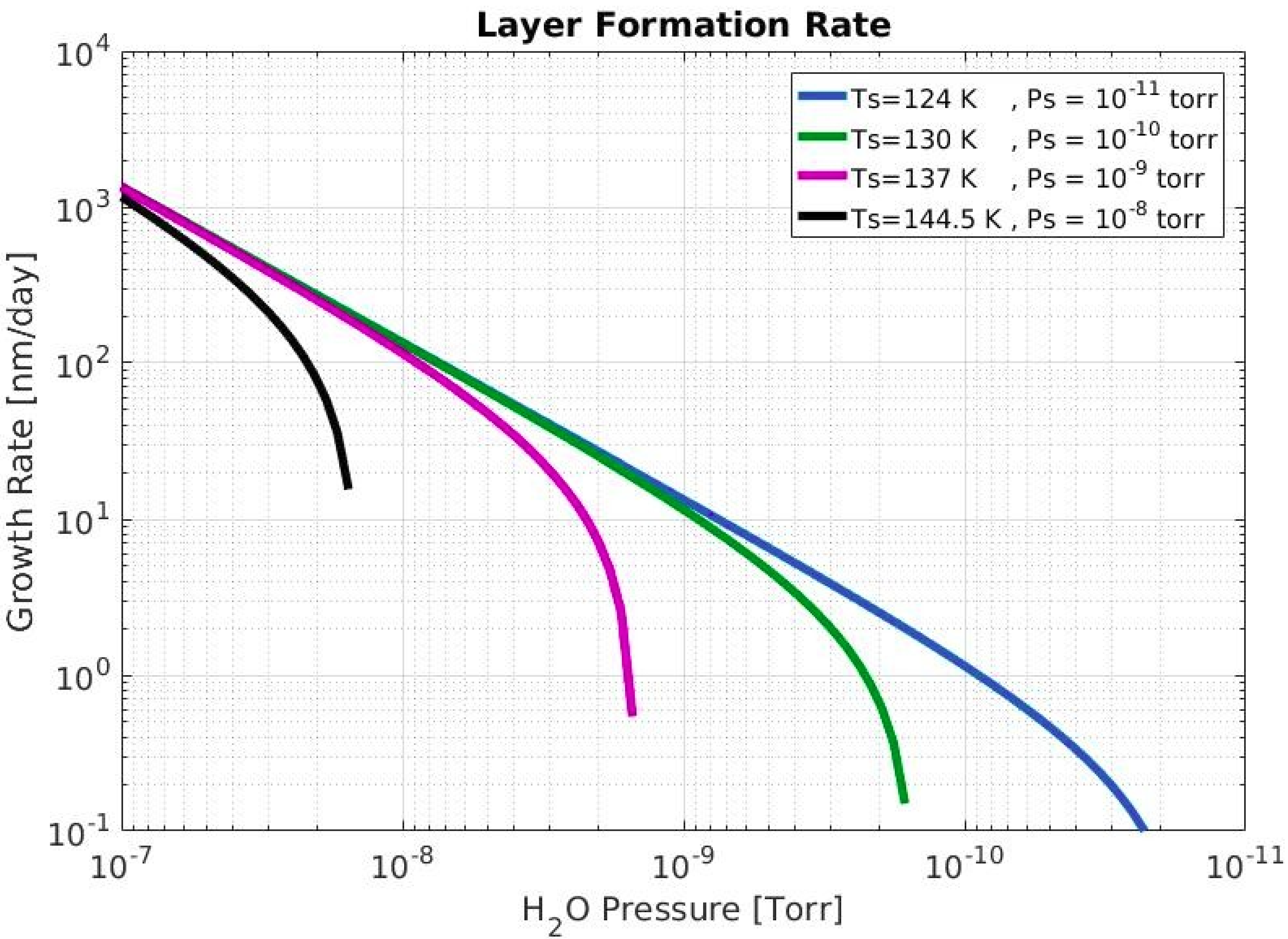
Results





The relaxation time is **τ** ~ 30 min.

The Ice Problem



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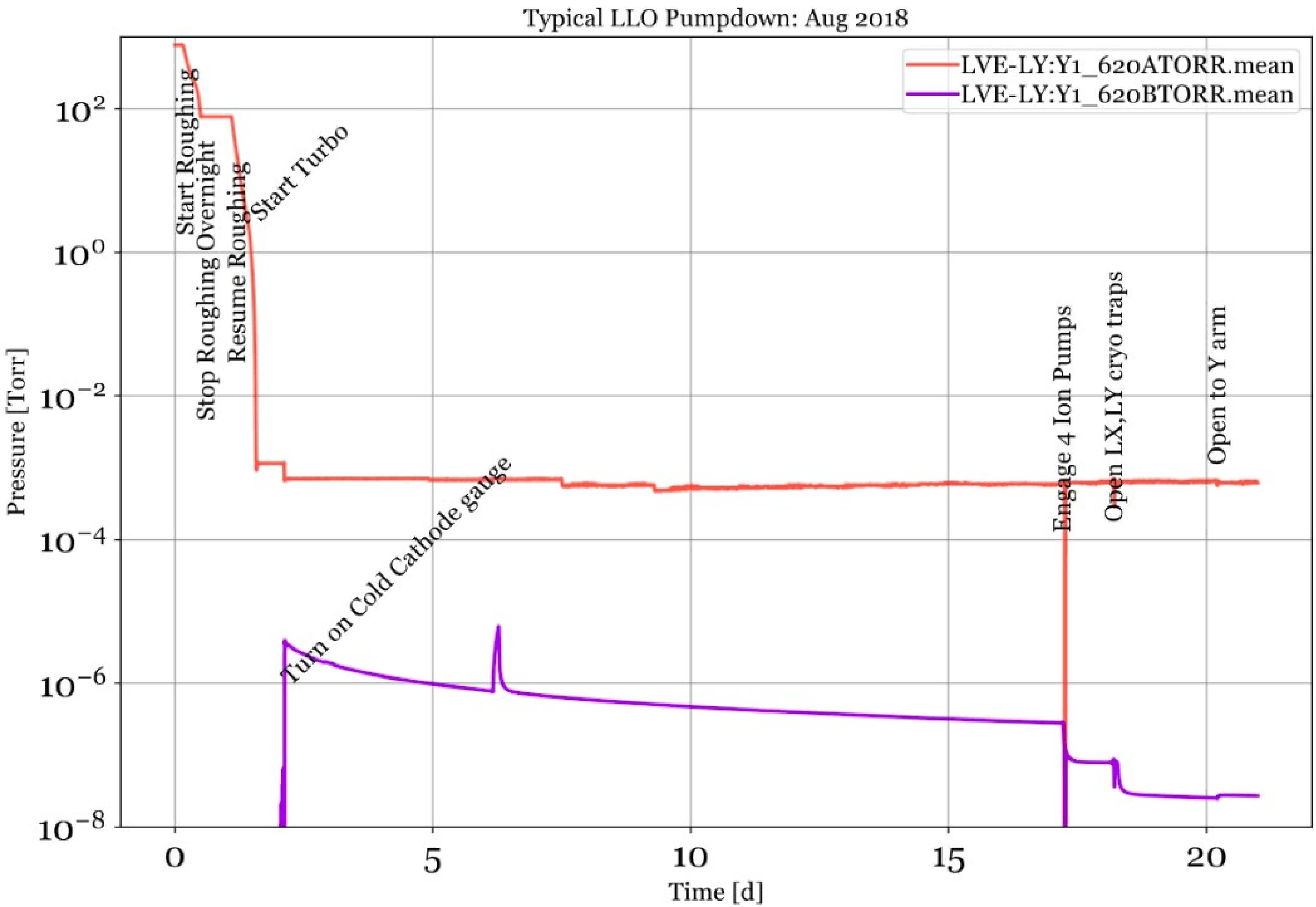
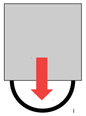
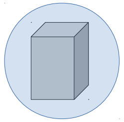


Source: T1400226

Gas Trap Comparison

		Easy to Test	Cryo Compatible	Easy to Integrate	Reproducible
	**Shield Door**				
	**Over Bag**				
	**Iris Valve**				

GREAT	OKAY	CHALLENGING	IMPOSSIBLE

Gas Trap Comparison

	Easy to Test	Cryo Compatible	Easy to Integrate	Reproducible
~~Shield Door~~	[yellow]	[red]	[green]	[yellow]
Over Bag	[green]	[green]	[red]	[green]
~~Iris Valve~~	[yellow]	[red]	[green]	[red]

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EXCHANGE GAS GUARD (EGG)