PRad-II Gas Target Status

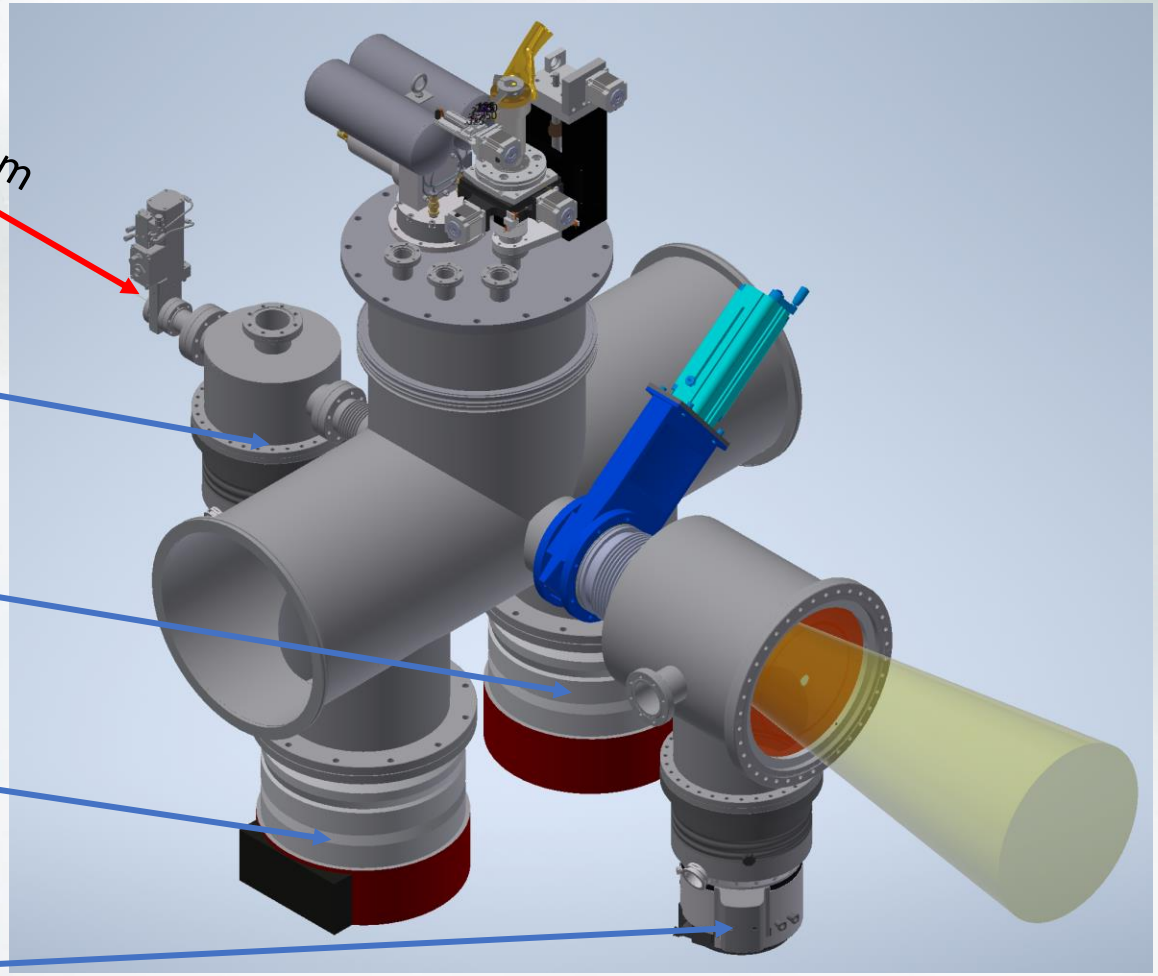
Xiangdong Wei

Jefferson Lab

PRad-II/X-17 collaboration Meeting

09/12/2025

Target Designs



Upstream Pump
1450 l/s

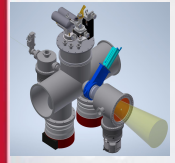
Beam-Left Pump
2700 l/s for H_2

Beam-Right Pump
2700 l/s for H_2

Downstream Pump
1450 l/s

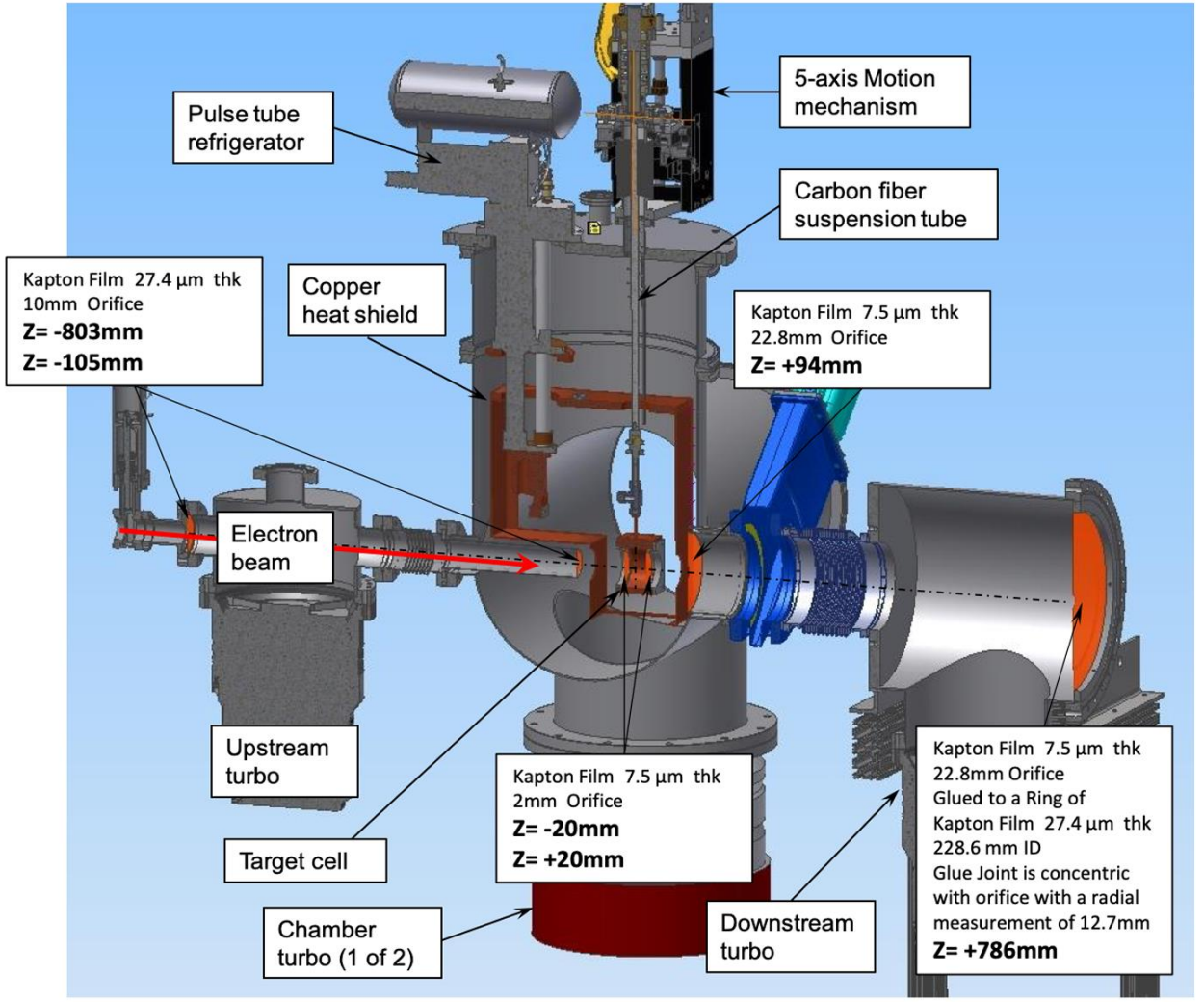
5 Turbo pumps around the target:

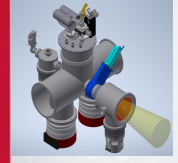
Both 2700 l/s turbo pumps are backed by a 1900l/s turbo pump and then fed into a multi-stage roots pump.



Target Parameters

- **Target cell**: 75 mm x 75 mm x 40 mm,
- **Thin end walls**: 63mm dia. by 7.5µm thick polyimide foils,
- **"Windowless"** ---Beam enter and exits via 2 mm holes on the center of Kapton foils,
- **Target Material**: High-purity hydrogen gas (>99.99%),
- **Target Length**: 40 mm,
- **Target Pressure**: 0.63 mBar,
- **Target Temperature**: Regulated at 20K,
- **Vacuum Vessel Pressure**: 6.8 x 10^{-4} mBar.

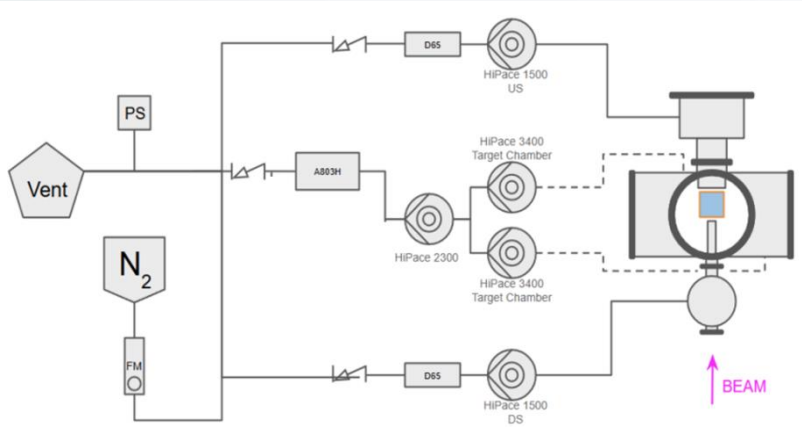




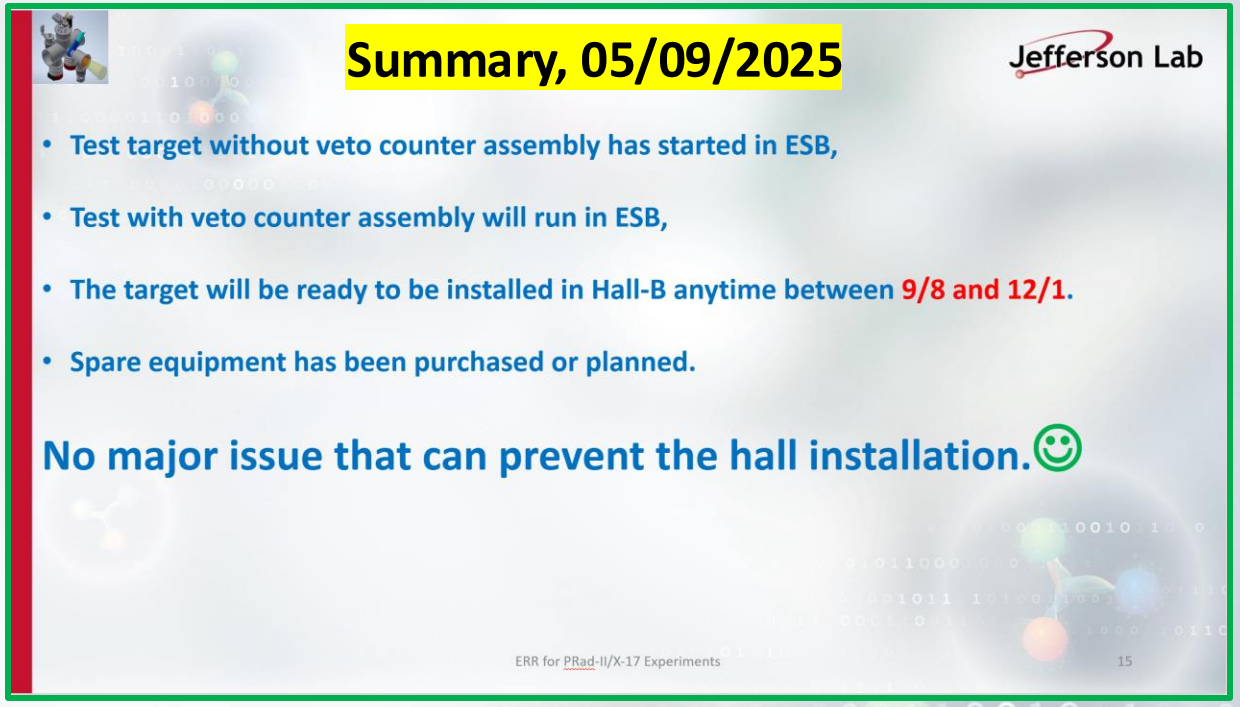
Summary Reported at ERR

- During ERR, we reported that the LabView control program started to communicate with the target and the refrigerator functioned well.

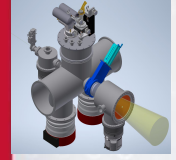
- Therefore, as we continue to tune the LabView program and learn the operation, the target commissioning run was gradually started.



Pumping scheme for initial test at ESB
(to compare test results at EEL in 2015)



Committee Comment:
Use 99.99999 % Pure H2 (99.9999 % is marginally acceptable).



Performing Test with a "known" Scheme

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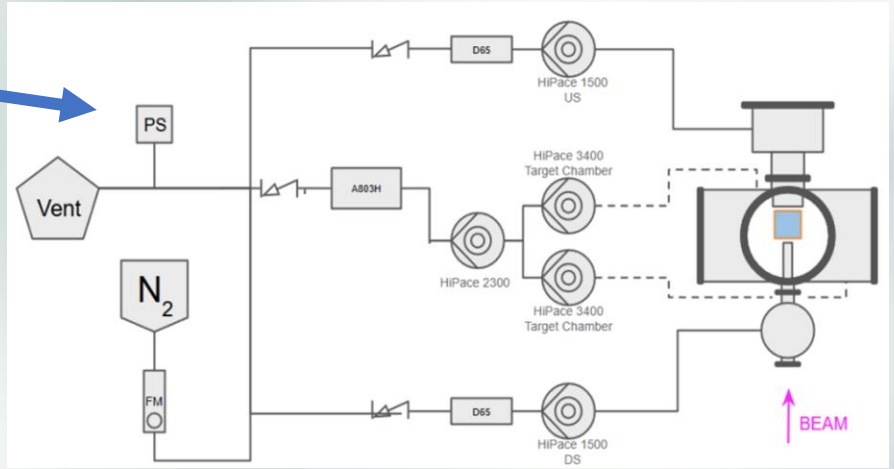
All tests were performed with this pumping scheme, until July, when we realized that no matter how we conducted the runs, we couldn't repeat the performance for a few sets of test obtained at EEL bldg. in 2016.

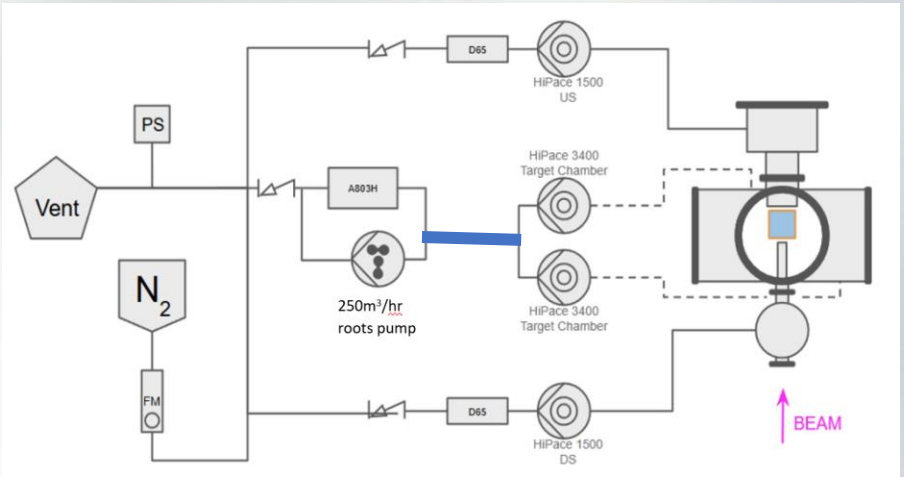
For the first few weeks, although all pumps were behaved correctly, we still got cold block everyday. After exhausting the gas purity concerns, target group helped us found an internal leak (due to rust/acid/mechanical motion) on a gas panel pressure gauge. We bypassed it and ordered a new one (long lead time, but we have it now) and continue the test.

The 2nd pumping scheme, based on stretched memory, was tested.

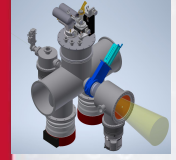
The system was running continuously for weeks with different conditions, and we collected a lot of data, but none of them matched the original test at EEL.



Initial test pumping scheme at ESB



2nd test pumping scheme at ESB



Testing PRad-II Target

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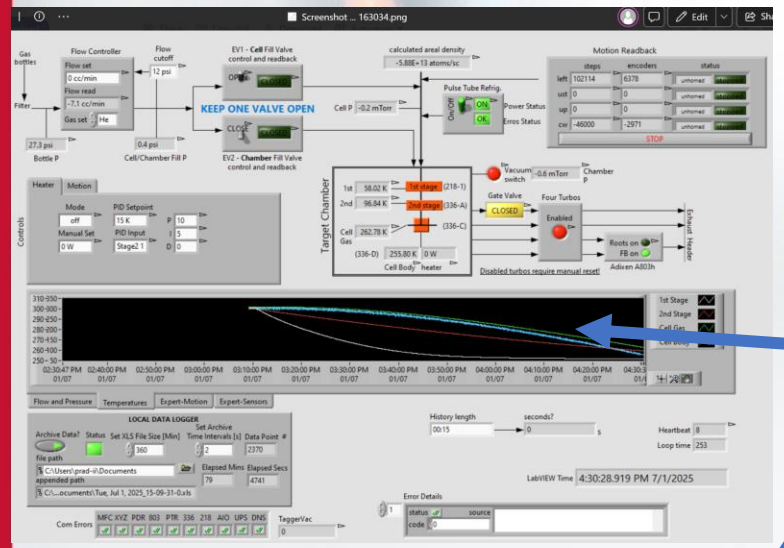
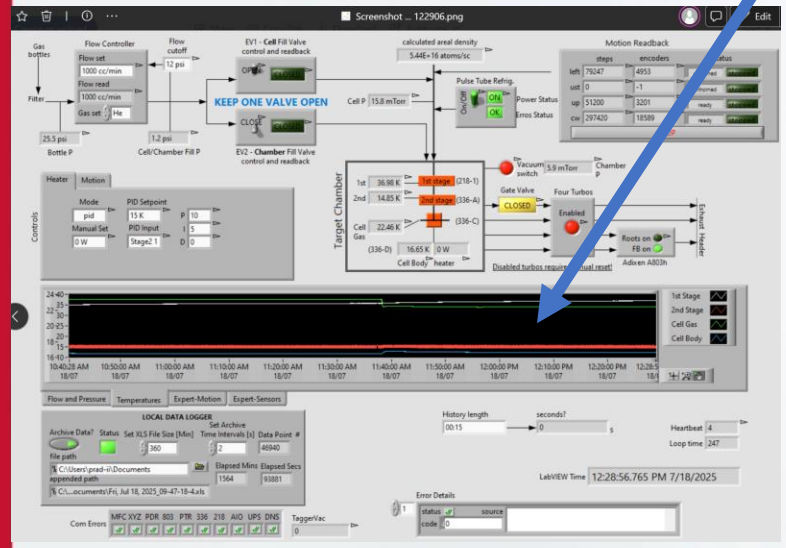
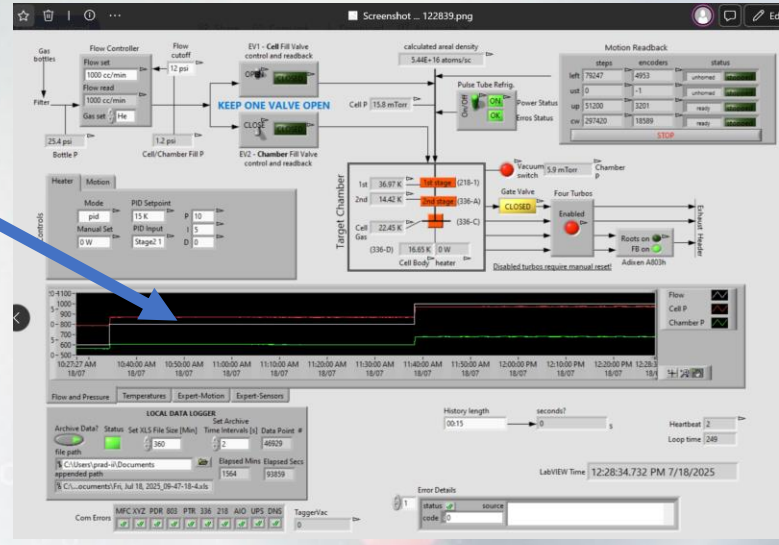


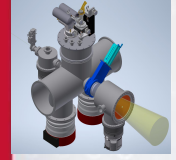
The screenshots of the LabView control program with temperature chart are shown on the left, while with pressure and flow charts are on the right.

The target was cooling down quickly (upper left) and temperature was stable as gas flow changed (lower left).

The large temperature noise (upper right) was fixed by fine tuning the LabView control program (lower right).







Test Results and Findings

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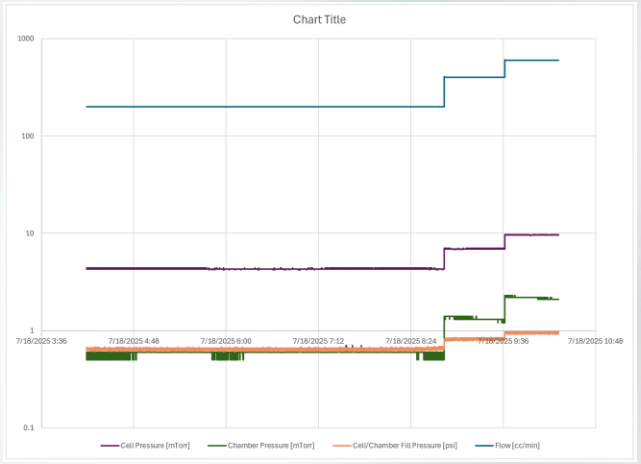
Some results of test runs at different conditions are plotted here.

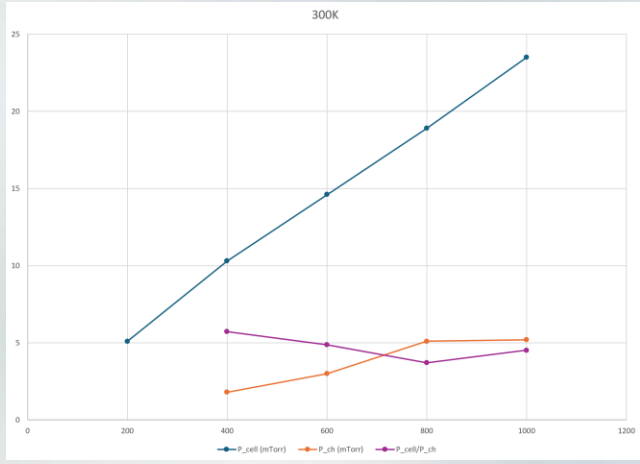
The test results shown all turbo pumps were functioning as expected, low power consumption at full speed with small helium flows; and the chamber pressure was low as expected.

The cell pressure were too low, ~ 2 orders of magnitude less than the data in published target paper. Those results indicated that the gas leaked out through hole(s) much bigger than 2mm.

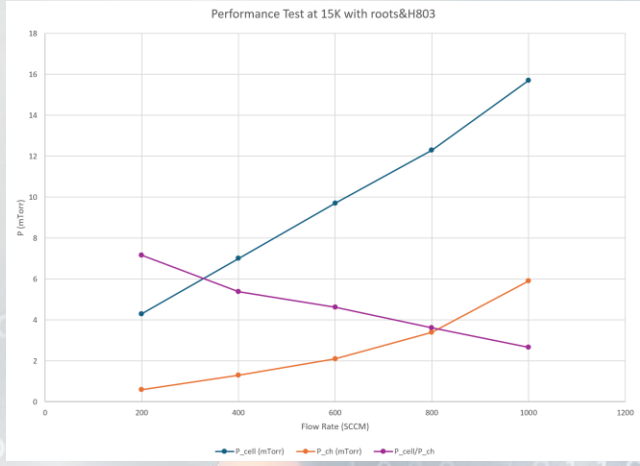
P_cell, P_ch, P_fill and Flow Rate at ~50K

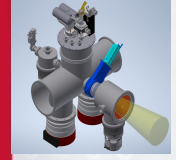


P_cell, P_ch and P_cell/P_ch at 300K



P_cell, P_ch and P_cell/P_ch at 15K





Cell Inspection, Issues and Solutions

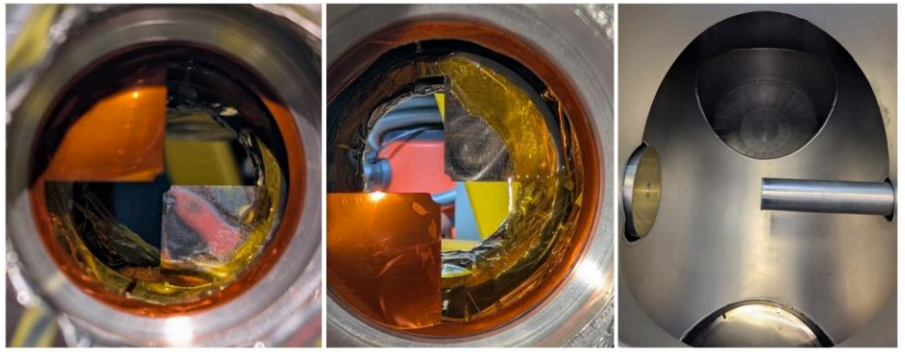
James, Phillip and Tsuneo inspected the target cell and solid target foils.

- Both target cell windows were found teared.
- Carbon foil was also damaged. The cause of it cannot be explained with fast or slow evacuation of target, since both sides of carbon foil were at the same vacuum space. Therefore, no pressure differential cross the carbon foil could be generated with pumping. The damage might be caused by physical touching (impossible because it's inside the thermal shield box) or deterioration due to time, moisture or radiation damage.
- New windows were installed. This time the 2mm holes were cut with laser.
- Carbon and Al foils were ordered, and will be installed after helium and H2 tests in Hall-B.

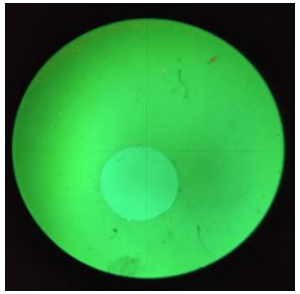
20250808

Thursday, August 7th 2025, the PRad Target was pulled from the target vacuum chamber by Denny and the Hall B Technicians. Once removed it was apparent the cell membranes were not intact. From the tear propagation pattern of the polyimide membrane and the remains of the optical alignment quadrants, it appears to me that the target cell imploded from a negative pressure differential. The re-entrant window membranes appear to be intact and no remnants of the kapton window films were found inside the target chamber. This limited damage to only the cell windows would be consistent with a rapid evacuation of the target cell when the chamber is at atmosphere as opposed to a rapid loss of vacuum of the chamber and cell.

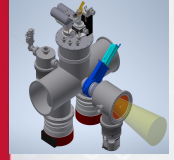
The cell has experienced 3000 sccm (max flow for the Mass Flow Meter) flow rates in the past without any damage. Although if the chamber is at ATM and the bypass valve on the gas panel is left open when the Gas Panel Roughing Pump is turned on, the only flow limiting components are the small gas feed tube and the pumping speed of the Gas Panel Roughing Pump. This flow rate is much greater than 3000 sccm. It is my opinion that the window membranes were destroyed early in the testing since no significant pressure differential has been observed to date.



Left to right: View of target cell from downstream, from upstream, and inside of target chamber w/ re-entrant windows. (08/07/2025)



Inspection Report



Re-Installation after Fixing Windows

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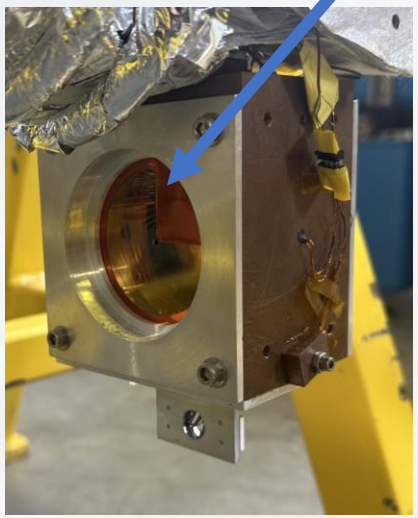
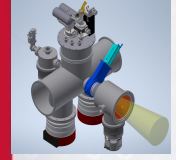
Target stand was modified (see picture on the right) while waiting for fixing the broken windows.
Target Group made a pair of new windows and mounted them on target cell. After several surveys, the target is back in the chamber and installed on the Modified Stand.





Pumping Schemes for ESB and Hall-B

Jefferson Lab

In early Aug., Target Group issued a Criteria for testing PRad-II target, based on testing PRad-I target in EEL and Hall-B in 2016. This document will serve as the standard for us to compare the test results for ESB and Hall-B. The pumping schemes and results for helium and H_2 tests are clearly listed.

PRad II: Criteria for Demonstrating a Successful Helium Test

James Brock 20250717

The minimum requirements needed to declare a successful helium test of the PRad II Target should reproduce previous results from the first experimental test runs in 2015/2016. The problem is that each test leading up to, and bleeding into, the PRad Hall B installation had small incremental configuration changes that improved the performance margins. The most drastic change was the pumping configuration which occurred after the installation. The "backup" turbo pump and a Roots blower carts were added in parallel at this time. The assumption that helium, being inherently safer, would be an adequate substitution for hydrogen was a mistake that was not fully accounted for. Although both are light gases, the pumping curves and compression ratios are vastly different depending on the sealing mechanism of the vacuum pump(s) used. To further confuse things, during testing the cell orifice was changed from 4 mm to 2 mm and the re-entrant, exit orifice diameters and positions also were changed making sorting through old notes and data more difficult.

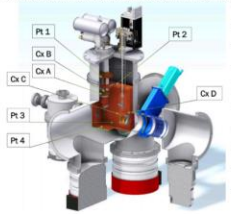
I would set the threshold parameters for a successful He Test as follows:

- ☐ Pulse Tube 2nd Stage Temperature **~ 15 K, but must be > 14 K**
- ☐ Minimum Chamber Pressure **< 0.001 mtorr (the lower the better)**
- ☐ P_{Cell}, T_{Gas} , and Cell to Chamber P_{Ratio} **> 0.47 torr, ~ 19.4 K, and > 304 (higher is better at T,P) @ rh = 600 sccm**

12/15/2015 Helium Test

NOTE: Cell orifice diameters have been reduced from 4 mm to 2 mm from previous tests.

This data was after the Heat Shield modification, the reentrant upstream orifice was placed closer to the target. The conical reentrant window downstream reduces the effective length of the main chamber from ~20 inches down to ~7.5. The MLI on the Heat shield and internal gas supply line is ~20 layers and ~ 11 layers on the target cell. The temperatures measured by CX and readout on LS336, Cell and Chamber pressure is measured by capacitance manometers and PDR2000, Upstream and Downstream pressures measured by MKS CC. Yaw φ cell adjustment is in place along with x, y, z.



	Location	Serial #	Bead Color
Cx A	Stage 2 P.T.	x88429	WHT
Cx B	Stage 2 P.T.	x104515	BLU
Cx C	Cell A	x88426	BLK
Cx D	Cell B	x104517	YEL
Pt 1	Stage 1 P.T.	Pt501	WHT
Pt 2	Heat Shield Top	Pt501	BLU
Pt 3	Heat Shield Side	Pt501	GRN
Pt 4	Heat Shield Bottom	Pt501	ORN

Current as of 05/11/2016-JDB

Flow [sccm], Temp [K], P_{Cell} , $P_{Chamber}$ [Torr], Up, Dn Pressure [Torr]

Gas	Time	Flow	CxA	CxB	CxC	CxD	Cell	Chamber	Up	Dn	Ratio Cell:Chamber
He	09:59	1000	9	28	15.8	10.7	0.745	2.73e-3	2.2e-5	1.3e-4	272.89
He	10:08	1200	9	28	15.1	10.8	0.876	3.39e-3	3.1e-5	1.8e-4	258.41
He	10:12	1400	9	28.5	14.6	10.9	1.001	4.05e-3	4.1e-5	2.4e-4	247.16
He	10:17	1600	9	28.5	14.5	11.1	1.140	4.70e-3	5.5e-5	3.4e-4	242.55
He	10:29	1800	9	29	14.4	11.2	1.280	5.43e-3	7.3e-5	5.3e-4	235.73
He	10:31	2000	9	30	14.2	11.4	1.400	6.16e-3	9.5e-5	7.5e-4	227.27
He	10:33	2200	9	30	14.1	11.5	1.550	6.97e-3	1.1e-4	1.2e-3	222.38
He	10:35	2400	9	30	14.1	11.7	1.700	7.84e-3	1.4e-4	1.7e-3	216.84
He	10:39	2600	9	30	14.2	11.8	1.840	8.74e-3	1.9e-4	2.7e-3	210.53
He	10:42	2800	9.5	30	14.2	12.0	1.98	9.91e-3	2.3e-4	3.8e-3	199.80
He	10:46	3000	9.5	30.5	14.3	12.2	over	1.12e-2	2.7e-4	5.5e-3	-
He	10:52	800	8.5	27.5	16.8	10.6	0.606	2.15e-3	1.7e-5	8.6e-5	281.86
He	10:55	600	8.5	27.0	17.3	10.3	0.470	1.53e-3	1.2e-5	5.9e-5	307.19
He	10:57	400	8	26	20.3	9.9	0.348	0.94e-3	7.6e-6	3.7e-5	370.21
He	11.00	200	7.5	24	25.8	9.1	0.189	0.38e-3	4.1e-6	1.9e-5	497.37

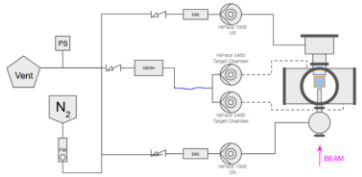
Heater Temp PID set to 15K. P=30, I=10, D=0.Temperature oscillates around 15 ±0.5
Flow [sccm], Temp [K], Pressure [Torr]

Gas	time	Flow	CxA	CxB	CxC	CxD	Cell	Chamber	Up	Dn	Ratio Cell:Chamber
He	14:37	1000	15	40	21.1	16.7	0.862	2.7e-3	2.1e-5	1.2e-4	319.26
He	14:48	1200	15	40	20.7	16.7	1.023	3.36e-3	2.7e-5	1.7e-4	304.46
He	14:56	1400	15	40	20.4	16.7	1.183	4.05e-3	3.6e-5	2.2e-4	292.10
He	15:00	1600	15	40	20.0	16.8	1.332	4.75e-3	4.8e-5	3.1e-4	280.42
He	15:03	1800	15	40	19.8	16.8	1.498	5.51e-3	6.0e-5	4.5e-4	271.87
He	15:14	2000	15	40	19.5	16.9	1.660	6.33e-3	7.5e-5	6.3e-4	262.24
He	15:18	2200	15	40	19.4	17.0	1.987	8.16e-3	1.2e-4	1.5e-3	243.50
He	15:22	2400	15	40	19.3	17.1	over	9.25e-3	1.4e-4	2.1e-3	-

These data points recorded with a cell temperature of 15K are included for reference only. The flow rates above are not sustainable with the desired pressure distribution needed for the experiment.

05/12/2016 First Hydrogen and Helium Test in Hall B

At this time the pumping configuration has the Pfeiffer 3600's backed by the A803H directly. **(NOTE: The intermediate HiPace 2300 was NOT installed at the time the following data was recorded.)**



Hydrogen Gas Test 05/16/2025 (1st discovery of the pumping issue)

Ev1 Valve opened (flowing through cell)

Gas	Time	Flow	CxA	CxB	CxC	CxD	Cell	Chamber	Up	Dn	Ratio Cell:Chamber
H_2	18:23	400	-	33	-	-	0.348	2.60e-2	-	-	13.38

Ev2 valve opened (flowing directly into chamber)

H_2		400	-	~33*	-	-	2.97e-2	2.67e-2	-	-	1.11

Prior to the following data the gate valves up stream and down stream were closed off to eliminate the vacuum load from the beam line and the scattering chamber.

Ev2 valve opened (flowing directly into chamber)

H_2		400	-	~33*	-	-	0.136	.250**	-	-	0.54

* Convectron enhanced pirani

Ev1 Valve opened (flowing through cell)

H_2		400	-	~33*	-	-	0.376	.210**	-	-	1.79

* Not properly documented, maximum value shown
** Convectron enhanced pirani

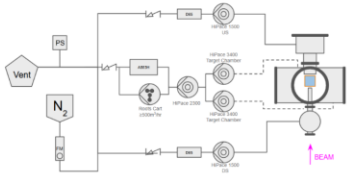
The difference in compression ratio of H_2 vs He for the turbo and multistage Roots backing (A803H) pumps was seen for the first time. The target gas was switched from H_2 to He to reproduce results from the EEL Test.

Helium Gas Test 05/12/2016

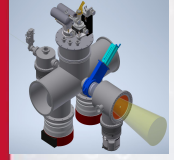
He		200	-	~33*	-	-	0.266	6.4e-4	-	-	415.63
He		300	-	~33*	-	-	0.378	9.8e-4	-	-	385.71
He		400	-	~33*	-	-	0.500	1.3e-3	-	-	384.62
He		600	-	~33*	-	-	0.690	2.03e-3	-	-	339.90
He		1000	-	~33*	-	-	1.096	3.5e-3	-	-	313.14

The Pfeiffer Hipace 2300 was added on May 17 and the Roots blower cart parallel to the A803H was added May 19th, 2016.

The Final Target Configuration for PRad I Experiment



The diagram above is the FINAL pumping configuration used in the PRad 1 experiment. None of the data in this document used this final configuration shown here.



PRad-II Target Team

Jefferson Lab

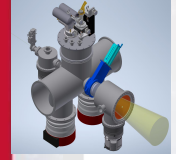
Now (*09/12/2025*)

- **JLAB:** **Phillip Dobrenz (30%), Tsuneo Kageya (20%), Xiangdong Wei (40%),** Pablo Rojas (DSG, as needed), (Target Group).
- **UMass:** **Andrew Schick (<50%).**
- **Duke:** **Yining Liu is onboard, Yi Yu will start in 3 weeks.**

Then (*03/03/2025*)

- **JLAB:** **Phillip Dobrenz, Tsuneo Kageya, Xiangdong Wei, Donald Williams,** Pablo Rojas (DSG, as needed), (Target Group).
- **UMass:** **Andrew Schick.**
- **MSU:** **Bhesha Devkota.**

Our team is ready to run the final test at ESB, after re-installating the target.



Updated Schedule

Jefferson Lab

TIMELINE

Today

Jan '25 | Feb '25 | Mar '25 | Apr '25 | May '25 | Jun '25 | Jul '25 | Aug '25 | Sep '25 | Oct '25 | Nov '25 | Dec '25 | Jan '26 | Feb '26 | Mar '26 | Apr '26 | May '26 | Jun '26 | Jul '26

Testi
Wed

Prad-II Run
Fri 2/20/26 - Mon 6/1/26

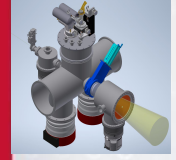
X-17 Run
Sat 6/6/26 - Mon 7/27/26

Finish
Tue 7/28/26

FY26 Experimental Run Ends

GANTT CHART

	Task Name	Duration	Start	Finish
35	Testing indivdiual components	11.13 days	Thu 2/6/25	Fri 2/21/25
36	**Long lead parts arrival**	**14.13 days**	**Fri 4/4/25**	**Thu 4/24/25**
44	Testing interlocks	1 day	Thu 4/24/25	Fri 4/25/25
45	Running altogether	5 days	Fri 4/25/25	Fri 5/2/25
46	ERR	2 days	Thu 5/8/25	Fri 5/9/25
47	Measuring vessel pressures	34.29 days	Fri 5/2/25	Fri 6/20/25
48	Testing with add'l roots pump	15 days	Mon 7/7/25	Fri 7/25/25
49	Modifying target stand for VetoCounter	3 wks	Wed 8/6/25	Tue 8/26/25
50	Fixing Broken Windows	3 wks	Wed 8/6/25	Tue 8/26/25
51	Survey	2 days	Fri 9/5/25	Mon 9/8/25
52	Install new windows	1 day	Tue 9/9/25	Tue 9/9/25
53	Survey	1 day	Wed 9/10/25	Wed 9/10/25
54	Reinstallation	6 days	Tue 9/9/25	Tue 9/16/25
55	Testing after window fix	15 days	Wed 9/17/25	Tue 10/7/25
56	Add viewport on large flange	1 day	Wed 10/8/25	Wed 10/8/25
57	Modifying Pipes	2 wks	Wed 9/3/25	Tue 9/16/25
58	**Testing with Veto Counter**	**23 days**	**Wed 9/24/25**	**Fri 10/24/25**
59	Veto counter delivery	1 day	Wed 9/24/25	Wed 9/24/25
60	Installing veto counter assembly	1 wk	Wed 10/8/25	Tue 10/14/25
61	Connecting vacuum hoses	2 days	Wed 10/15/25	Thu 10/16/25
62	Pumping target vessel	1 day	Fri 10/17/25	Fri 10/17/25
63	Testing motion	0.25 days	Mon 10/20/25	Mon 10/20/25
64	Leak Check	2 days	Mon 10/20/25	Tue 10/21/25
65	Check the minimum pressure	3 days	Wed 10/22/25	Fri 10/24/25
66	Test Processes COMPLETE	0 days	Fri 10/24/25	Fri 10/24/25
67	**Closing at ESB**	**1 day**	**Mon 10/27/25**	**Mon 10/27/25**
68	Close Project at ESB	1 day	Mon 10/27/25	Mon 10/27/25
69	**Hall Installation**	**33 days**	**Tue 10/28/25**	**Thu 12/11/25**
70	Preparing to move	2 days	Tue 10/28/25	Wed 10/29/25
71	Preparing operation manual	1 day	Tue 10/28/25	Tue 10/28/25
72	Preparing ePas	2 days	Wed 10/29/25	Thu 10/30/25
73	Moving to Hall-B	1 day	Tue 11/18/25	Tue 11/18/25
74	Installing on the beamline	4 days	Wed 11/19/25	Mon 11/24/25
75	Installing Al and C foil targets	1 day	Tue 11/25/25	Tue 11/25/25
76	Testing at room Temp	5 days	Wed 11/26/25	Tue 12/2/25
77	Testing with H2 performance	7 days	Wed 12/3/25	Thu 12/11/25
78	**PRad-II & X-17 Runs**	**117 days**	**Mon 2/16/26**	**Mon 7/27/26**
79	alignment	1 day	Mon 2/16/26	Mon 2/16/26
80	Cooling down & Verifying Target	2 days	Tue 2/17/26	Wed 2/18/26
81	Project COMPLETE	0 days	Wed 2/18/26	Wed 2/18/26
82	Prad-II Run	71.1 days	Fri 2/20/26	Mon 6/1/26
83	X-17 Installation	4 days	Mon 6/1/26	Fri 6/5/26
84	X-17 Run	37 days	Sat 6/6/26	Mon 7/27/26
85	**FY26 Experimental Run Ends**	0 days	Tue 7/28/26	Tue 7/28/26



PRad-I Pumping Configuration in Hall-B

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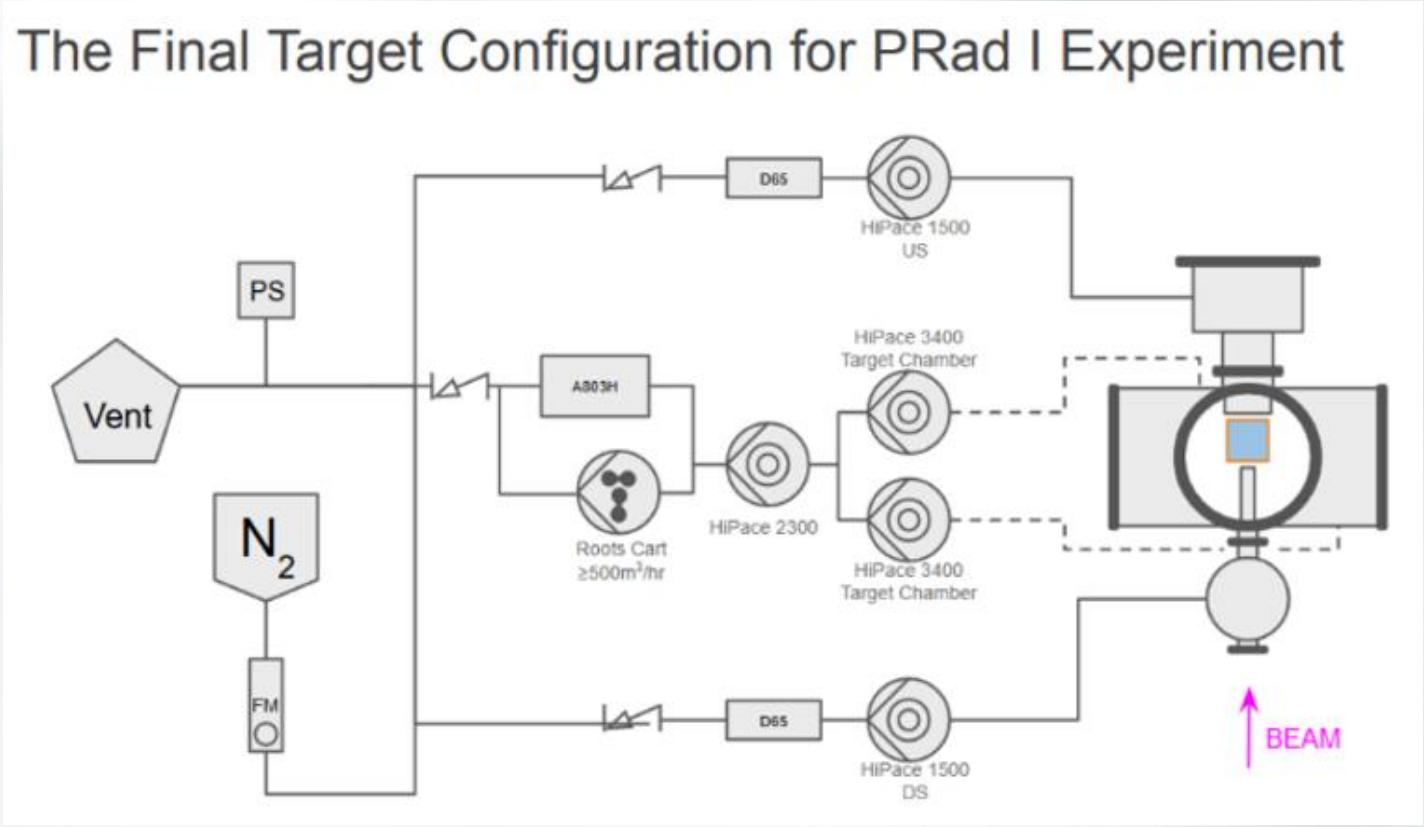
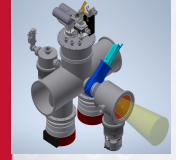
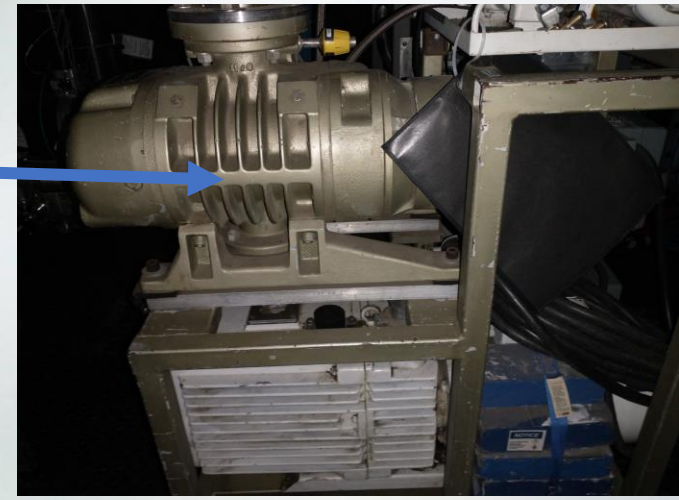


"Standard Pumping configuration" used for PRad-I run in 2016.
Target Group located a 500 m^3/hr roots pump station which will be used for PRad-II run.

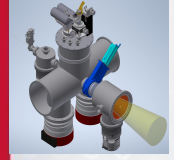


Spare Components

Target Group located a 500 m^3/hr roots pump station which will be available for us to use after the current run.
Denny found an old 500 m^3/hr roots pump station stored in Hall-B (see in the upper picture on the right), which we can use either in parallel or as a spare (need to be tested first).



The backup turbo pump, ***HiPace2800-IT*** purchased by Duke University, has arrived and will be tested before Hall-B installation.



“Storing” Backup Turbo Pump

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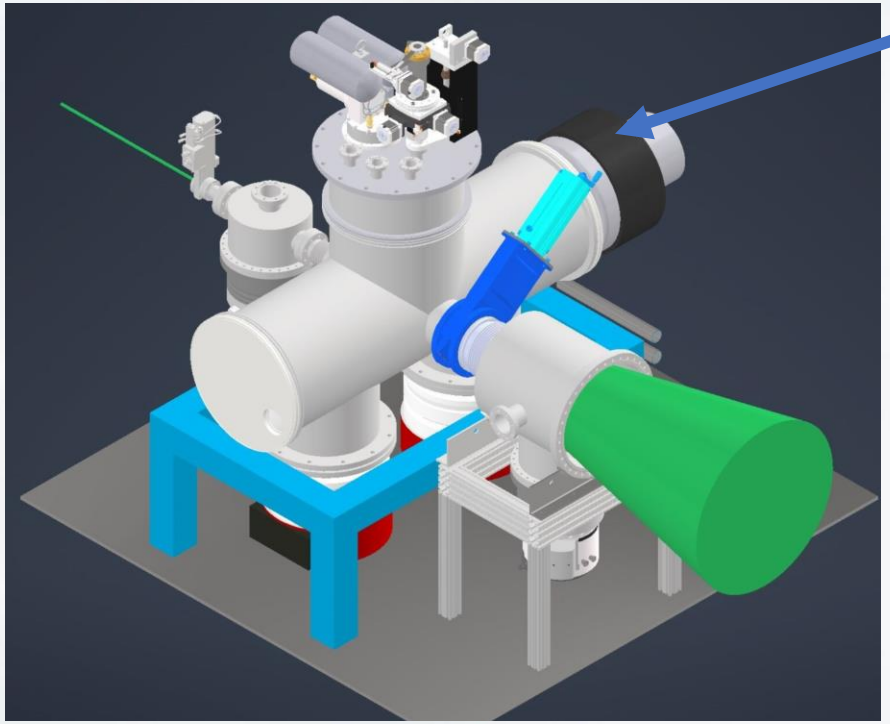
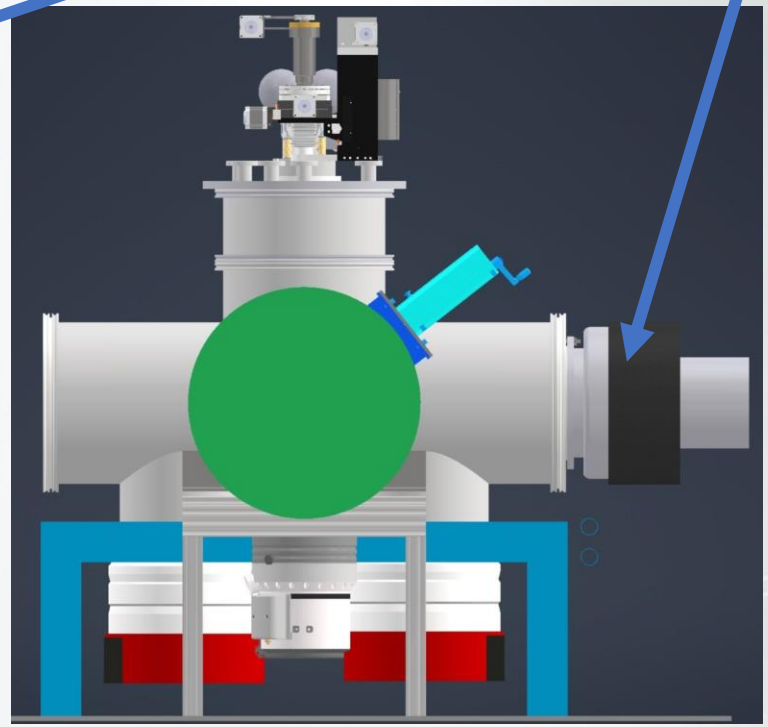
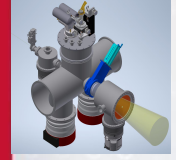
3-turbo configuration alone
=> ~1/3 chamber pressure reduction

HiPace2800-IT "stored" on the target chamber with a modified flange.







Adding a Metal Bellows Pump

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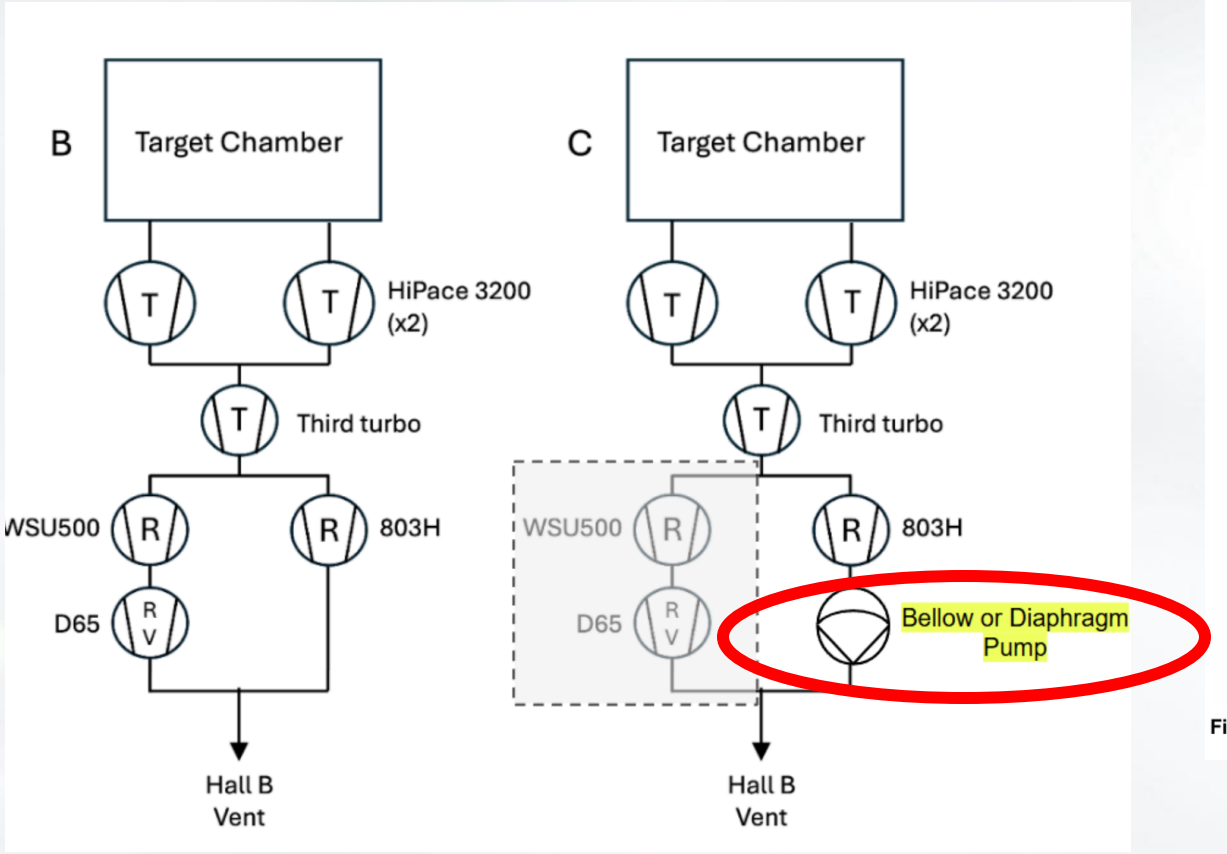
According to James Brock's suggestion yesterday, based on his latest test, a **Matel Bellows Pump** (available from target group) can be added behind A803H multi-stage pump to improve the pumping speed ratio.



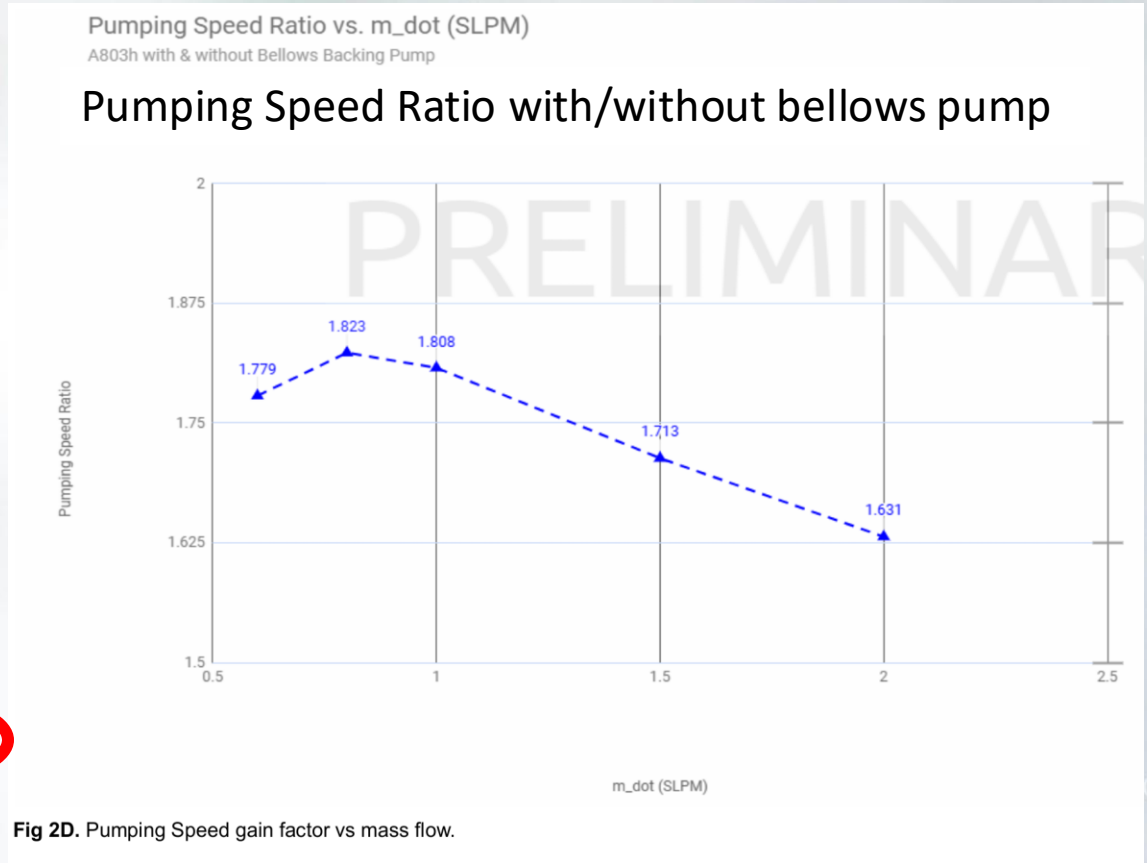
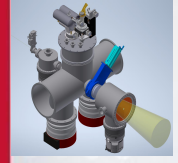


Fig 2D. Pumping Speed gain factor vs mass flow.



Summary

- The target performs well except low cell pressure.
  - New windows were installed.
  - Target cryostat is installed on Modified Stand.
- Performance test with 2015 EEL settings will start next week.
- The target can be moved to Hall-B as soon as 10/24/2025.
- Available options (combinable) to improve the chamber vacuum & target reliability.