

# PIP2IT HEBT Final Design Review

## Vacuum design

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Final Design Review for the PIP-II Injector Test  
High Energy Beam Transport

13 February 2019

In partnership with:

India/DAE

Italy/INFN

UK/STFC

France/CEA/Irfu, CNRS/IN2P3

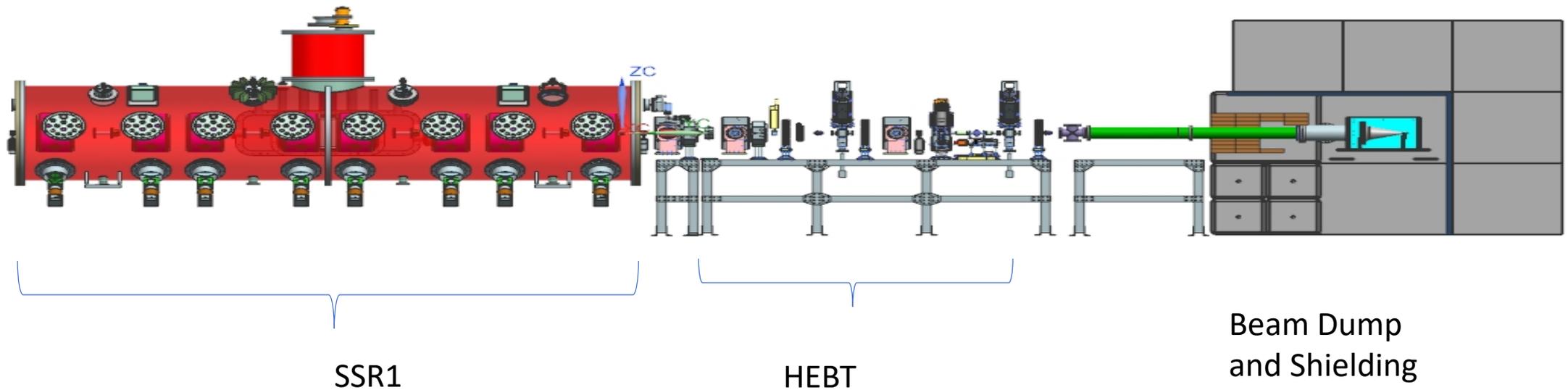
# Outline

- Introduction
- Configuration
  - Ion Pumps
  - NEG
  - Cold Trap
  - Turbo Pump
- MolFlow+ Simulation
  - Criterion for Optimization
  - Pressure Profile of residual gas (Hydrogen)
- Vacuum Protection Test Results
  - Failure at Upstream of Differential Pumping Insert (DPI)
  - Failure at Downstream of DPI, (*applied for HEBT*)

# HEBT VACUUM

(Introduction)

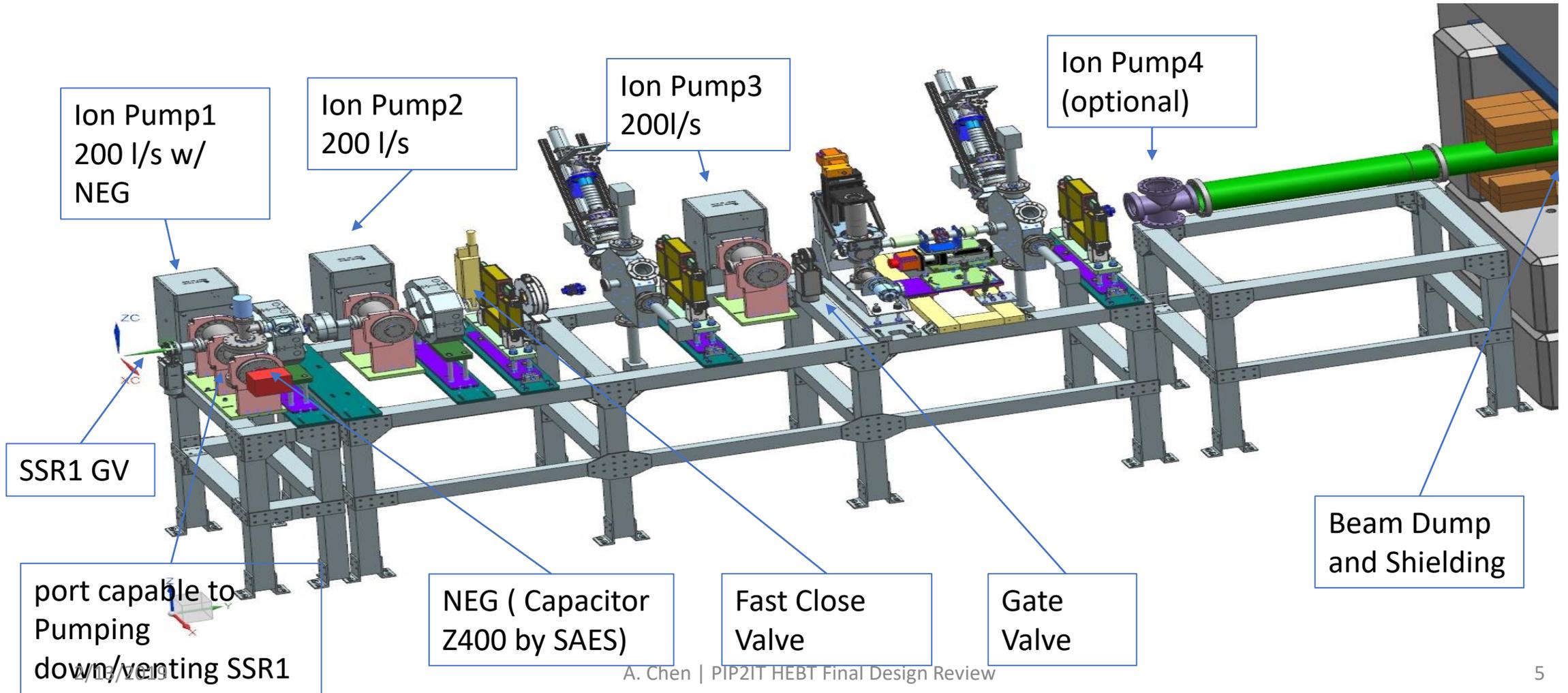
- Low Particulate Vacuum
- $1E-9$  torr at the entry of CM
- Protect CM from vacuum failure



# Configuration

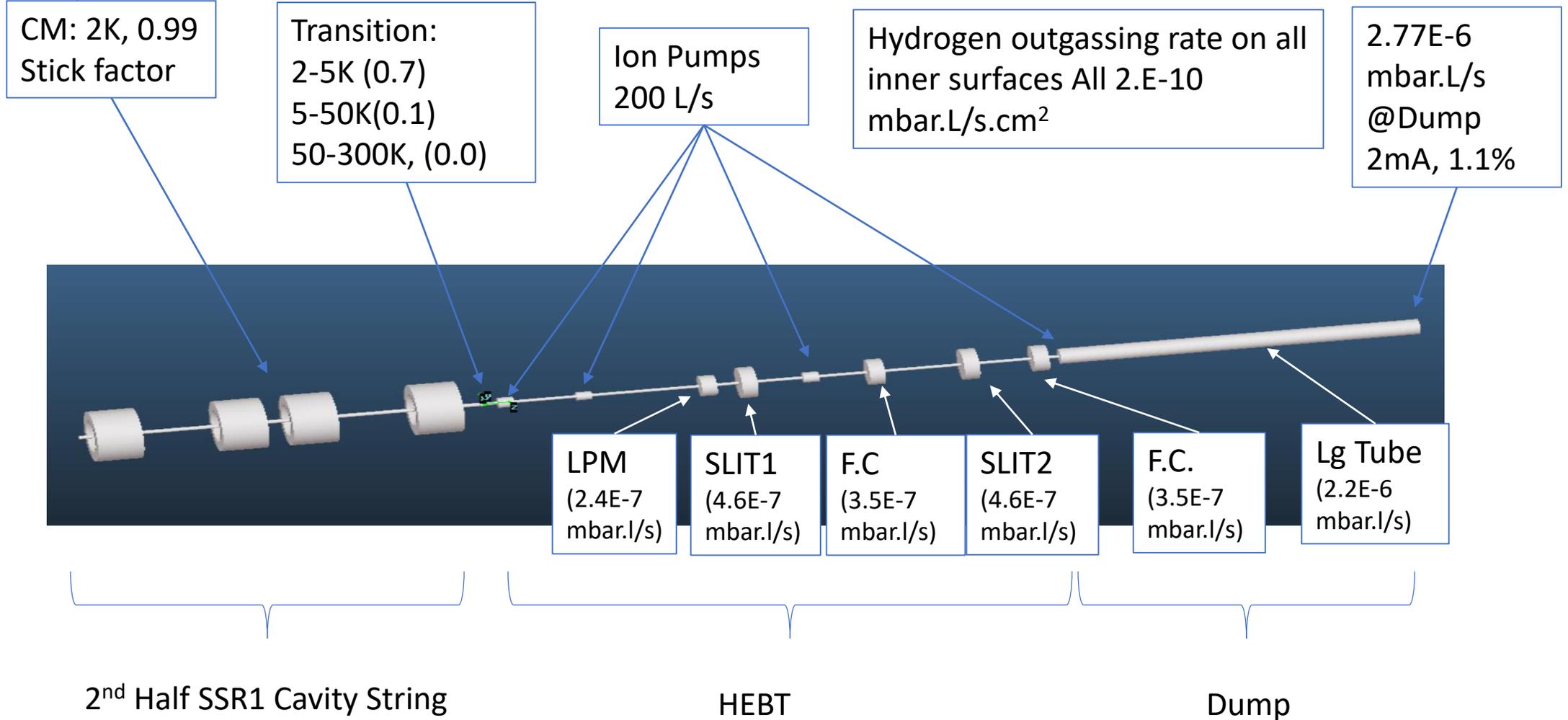
- Ion Pumps: to achieve UHV, HV for reliable operation, (4 vs 3)
- NEG: in order to enhance hydrogen pumping at entrance of CM
- Cold Trap: not chosen for cost/benefit reason
- Turbo Pump: only for initial pumping down SSR1,
- HEBT vacuum will be initially evacuated by slow pumping cart at downstream port
- Venting will be done through slow pumping cart from upstream port near SSR1
- One gate valve is used for segmentation

# HEBT VACUUM Configuration (to SSR1 and Beam Dump)



# SSR1-HEBT VACUUM Simulation

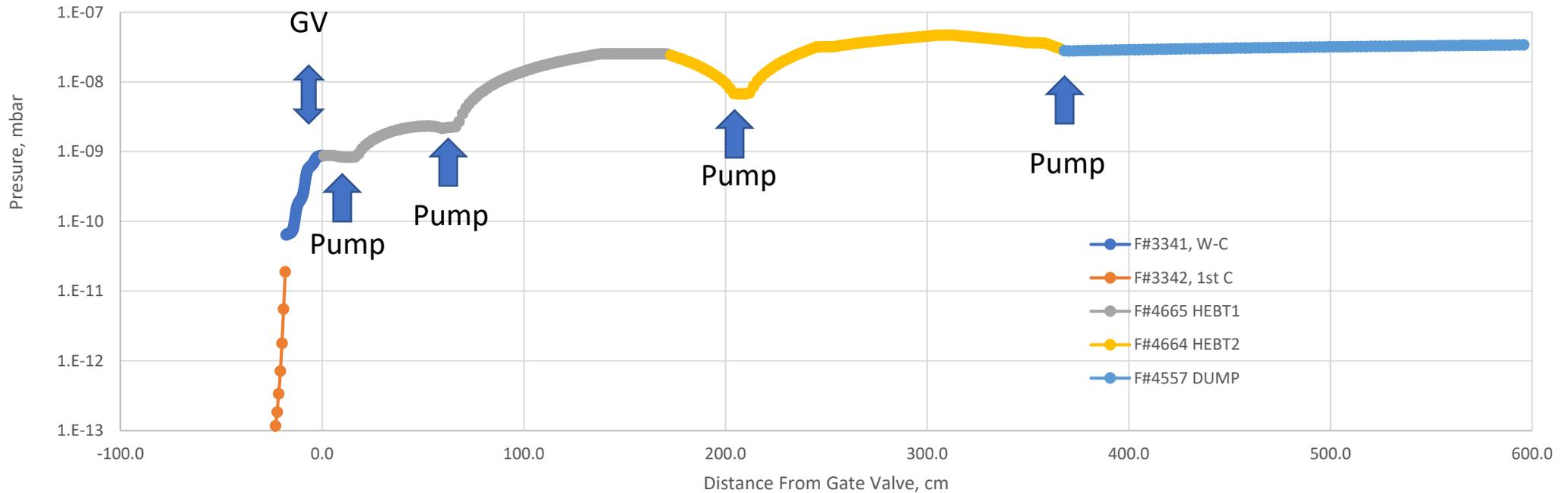
(Simplified Model in MolFlow+)



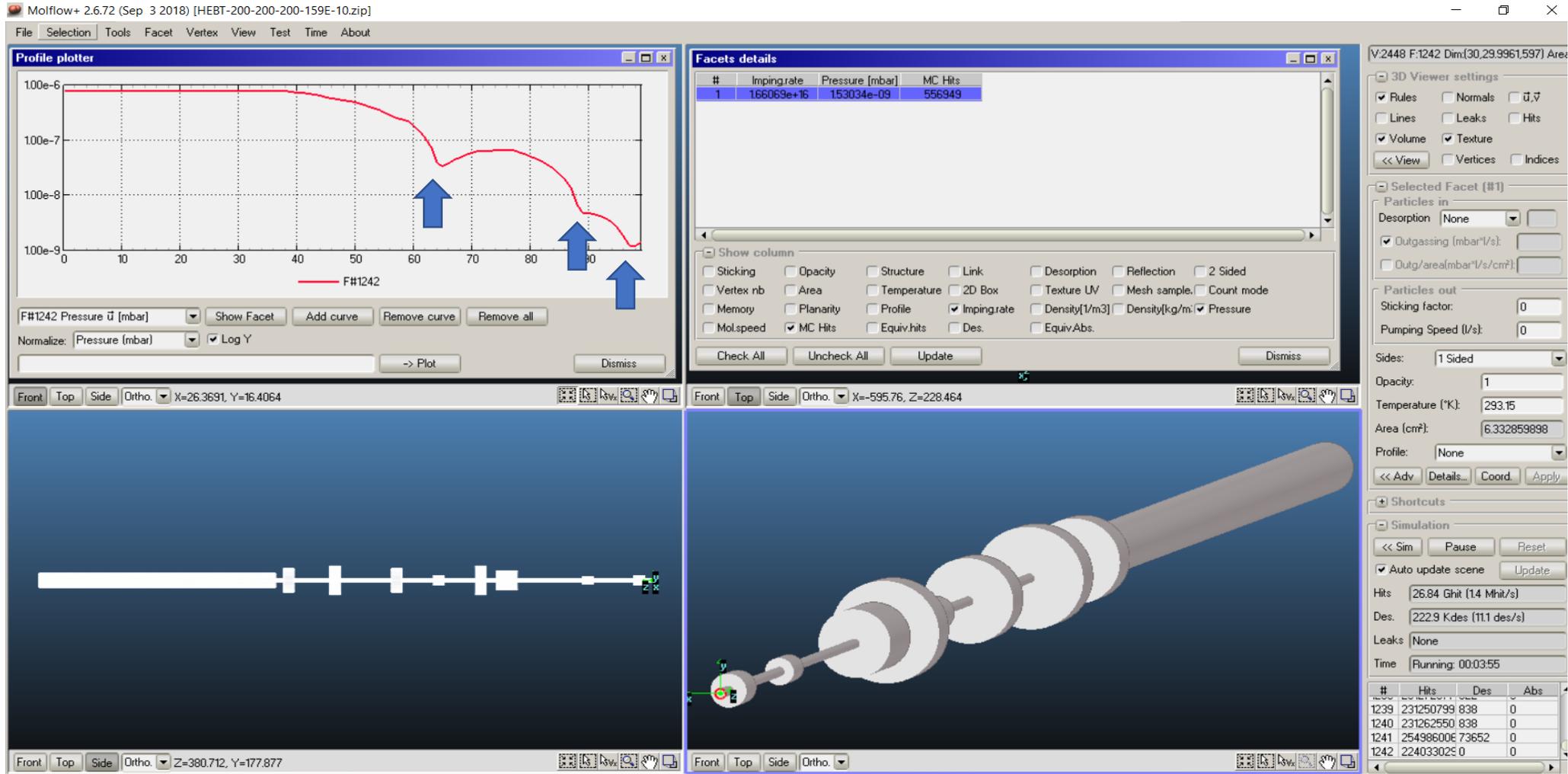
# SSR1-HEBT VACUUM Simulation

(Pressure Profile, Hydrogen)

HEBT H2 Pressure Profile Along Beam Line



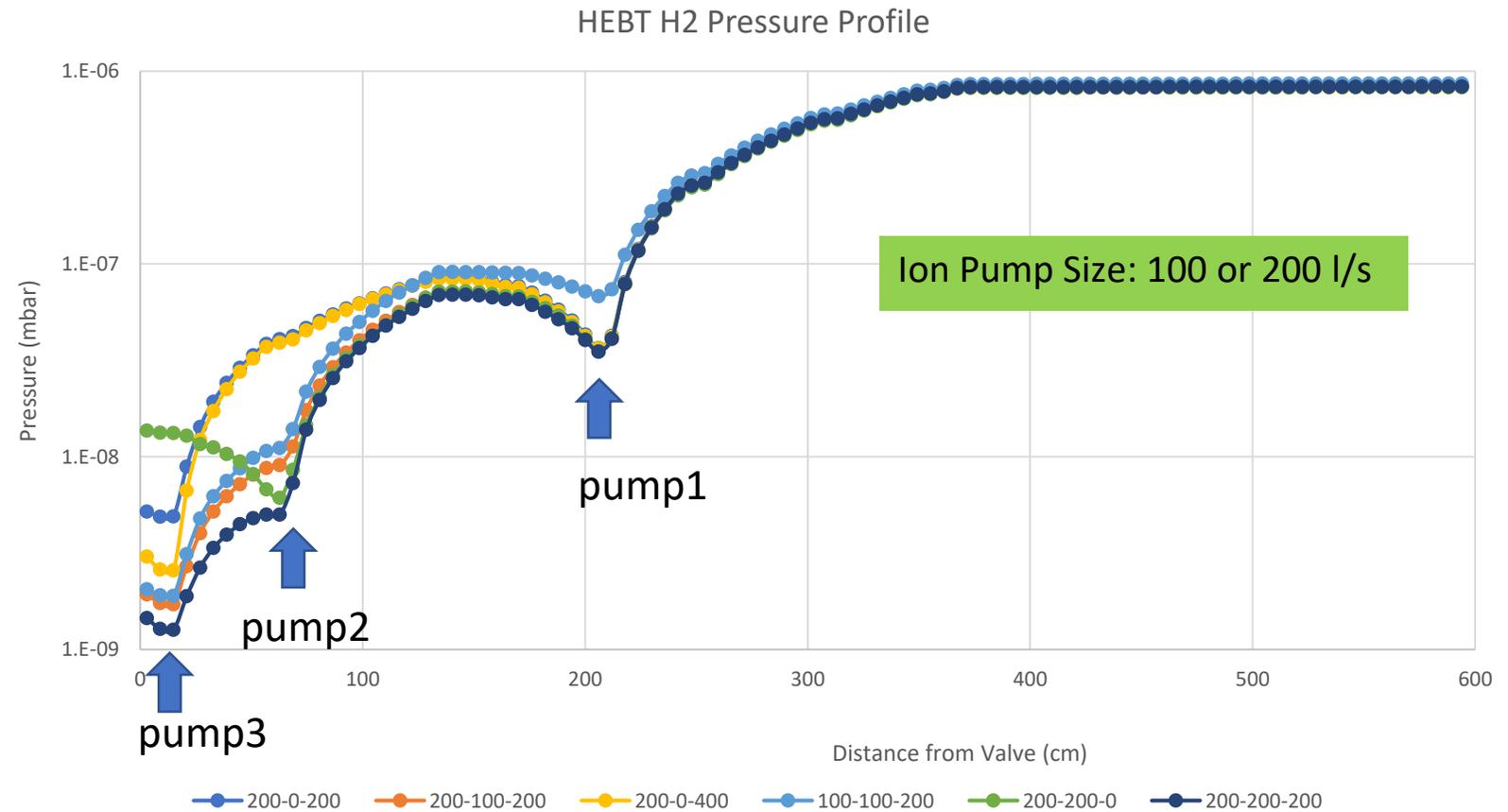
# HEBT VACUUM (Warm Section) (MolFlow Simulation: intermedium results)



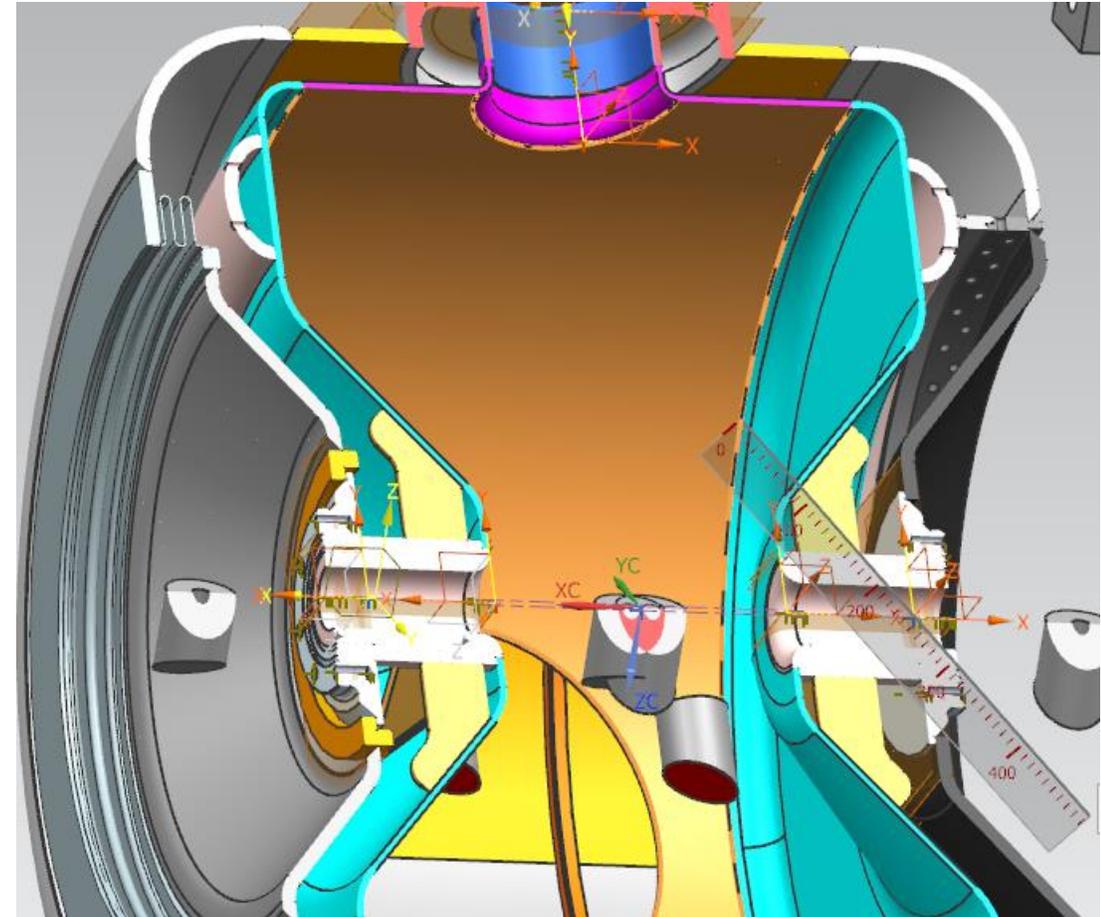
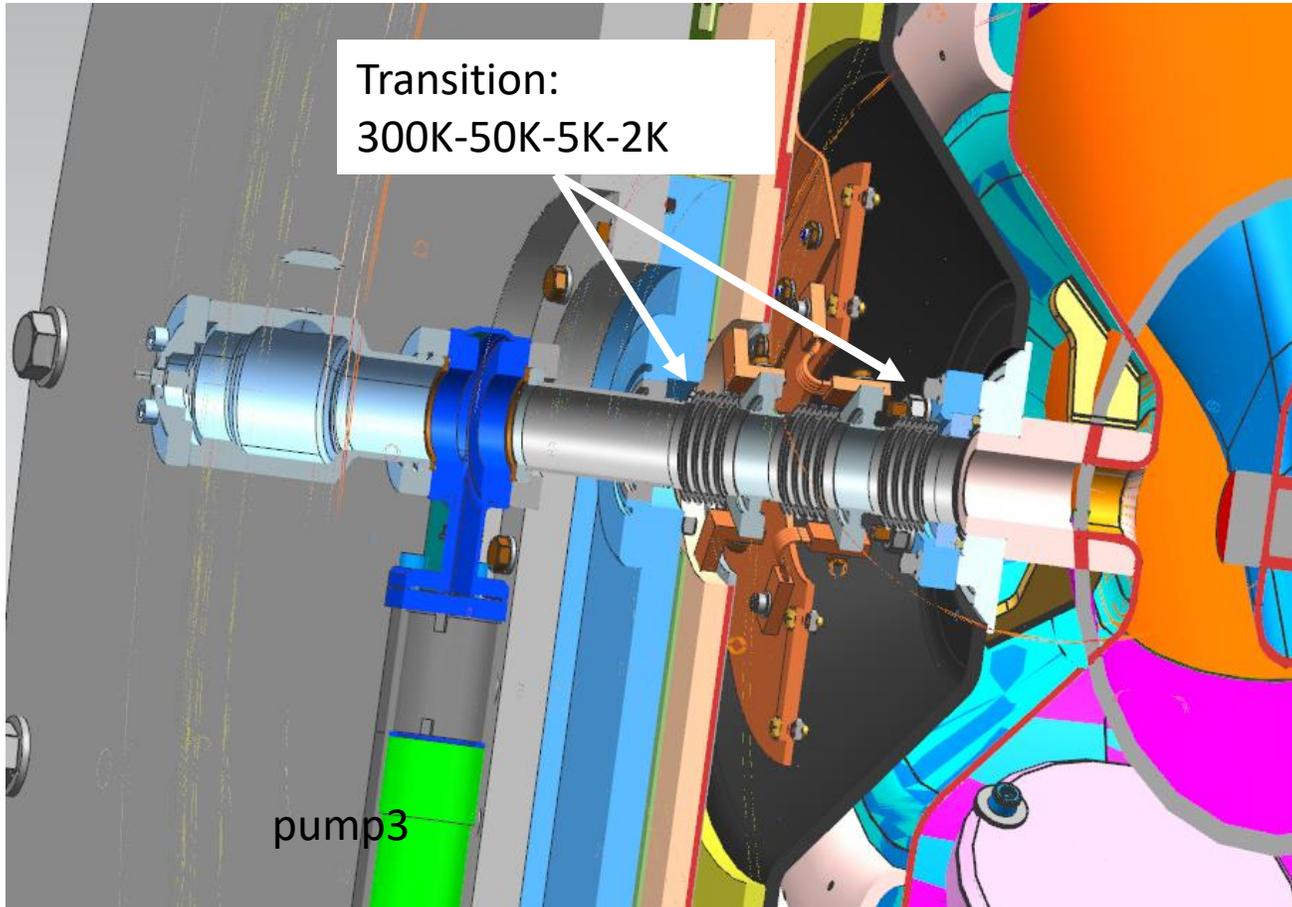
# HEBT VACUUM (Warm Section)

(MolFlow Simulation)

- Goal: to achieve 1E-9 Torr at the entrance of CM
- Studied: the pump size and its locations



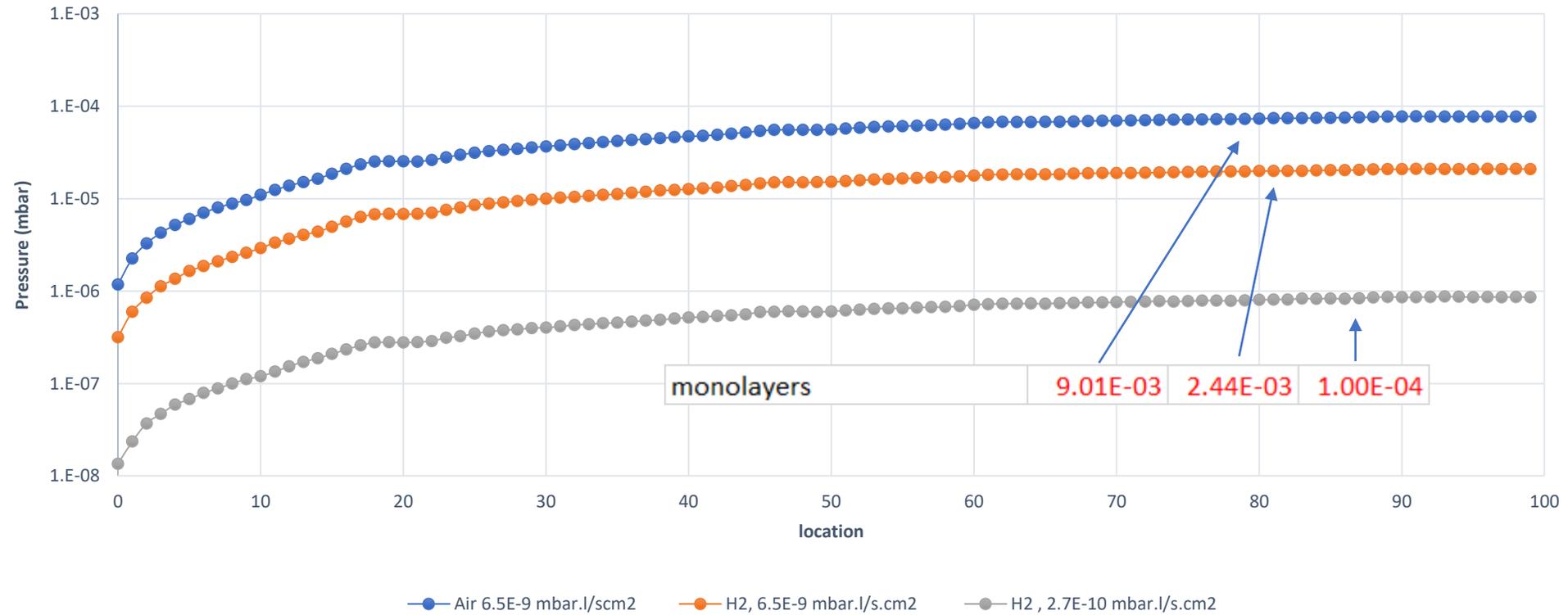
# SSR1 (MolFlow Simulation)



# SSR1

(Pumping Down with 160 l/s)

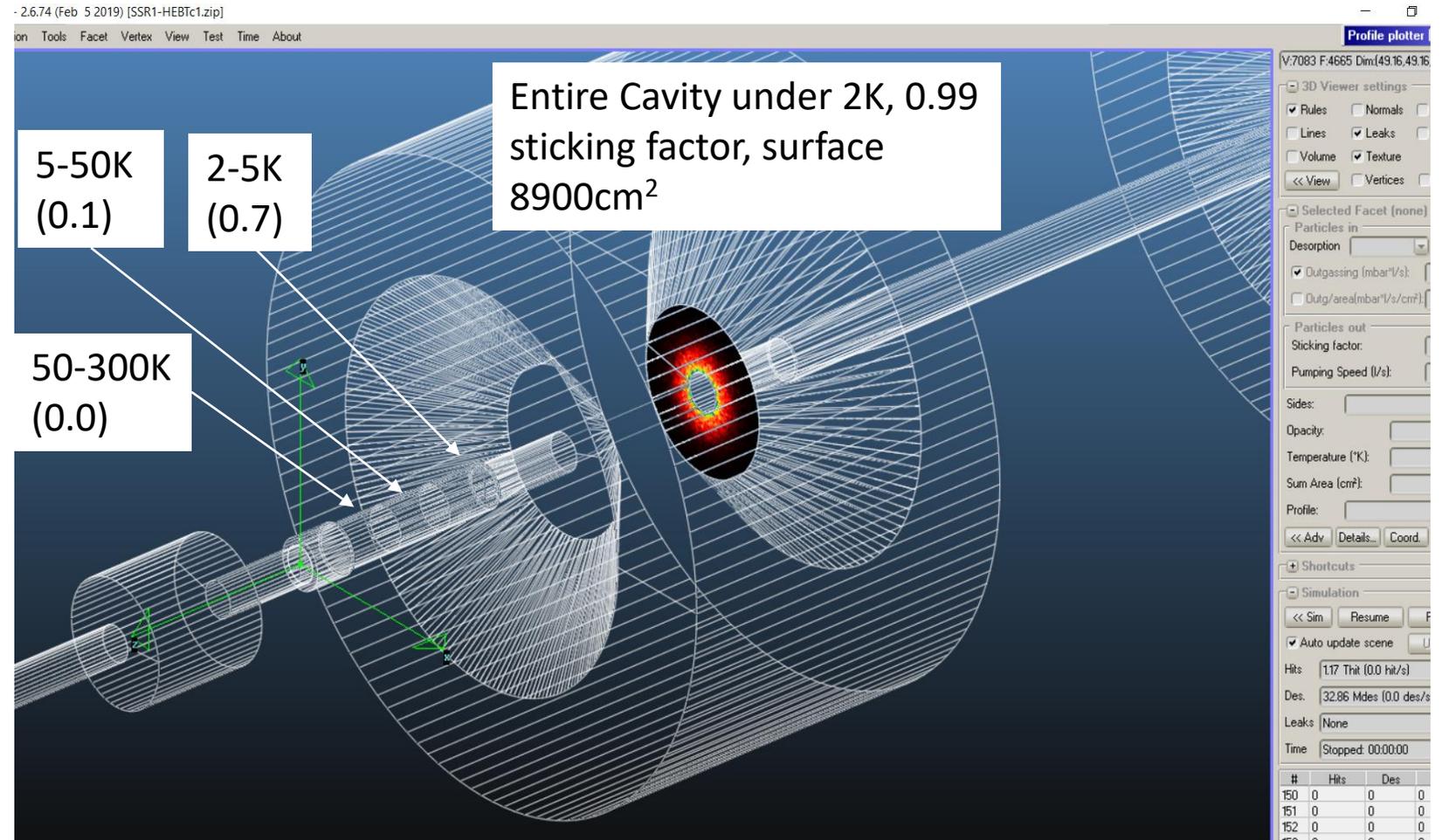
## SSR1 Pumping Down



# SSR1-HEBT VACUUM Simulation

## (Hydrogen Condensation on 1<sup>st</sup> Cavity surface)

- The sticking factors of hydrogen for the three transit region 2-5K, 5-50K, 50-300K are 0, 0.1, 0.7
- Entire cavity was under 2K, sticking factor 0.99 was assigned
- Most significant hydrogen flux arrived on the face of down stream wall
- **It takes 1.5 week to buildup one monolayer on the face**, however, on 1<sup>st</sup> cavity, H<sub>2</sub> will diffuse on the other surfaces due to beam induced desorption



# SSR1-HEBT VACUUM Simulation

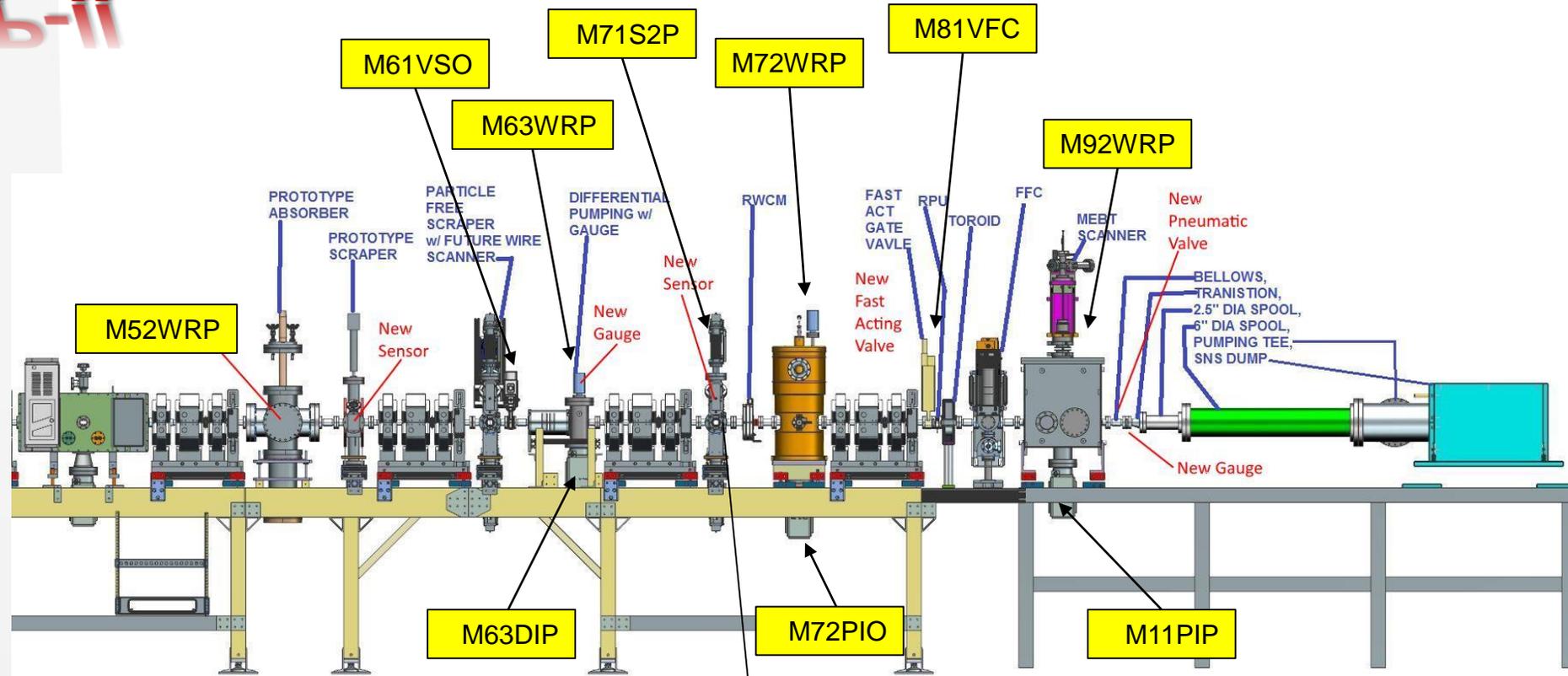
(Hydrogen Condensation on Cavity surface)

	Facet #	Sticking	Opacity	structure	area (cm <sup>2</sup> )	Temp (K)	Imping. rate (s <sup>-1</sup> m <sup>-2</sup> )	Pressure (mbar)	Monolayer time, year	even dist. Entire cavity
Cavity4	67	0.99	1	5	125.085	2	2.72E+10	1.89E-15	1.32E+01	6.10E+02
	777	0.99	1	5	125.085	2	1.46E+10	8.55E-17	2.45E+01	
Cavity3	875	0.99	1	4	125.085	2	6.23E+10	4.29E-15	5.75E+00	3.50E+02
	1585	0.99	1	4	125.085	2	1.06E+10	6.06E-17	3.39E+01	
Cavity2	1683	0.99	1	3	125.085	2	1.44E+11	9.89E-15	2.50E+00	1.70E+02
	2393	0.99	1	3	125.085	2	6.19E+09	3.61E-17	5.79E+01	
Cavity1	2491	0.99	1	2	125.085	2	1.17E+13	3.43E-13	3.07E-02	2.18E+00
	3200	0.99	1	2	125.085	2	2.67E+10	1.46E-16	1.34E+01	

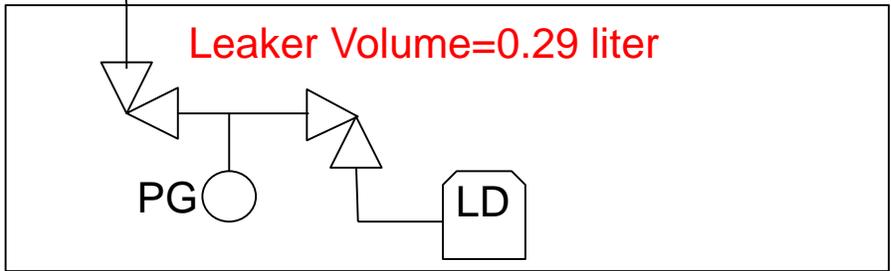
# Protection to CM from Vacuum Failure

- Low particulate Vacuum practice in handling & installation
  - HEBT vacuum will be initially evacuated by slow pumping cart at downstream port
  - Venting will be done through slow pumping cart from upstream port near SSR1
  - One gate valve is used for segmentation
- Fast close valve installed to minimize the vacuum failure impact on CM
  - Test was done at MEHT,
  - Gas flux into CM is sufficiently low

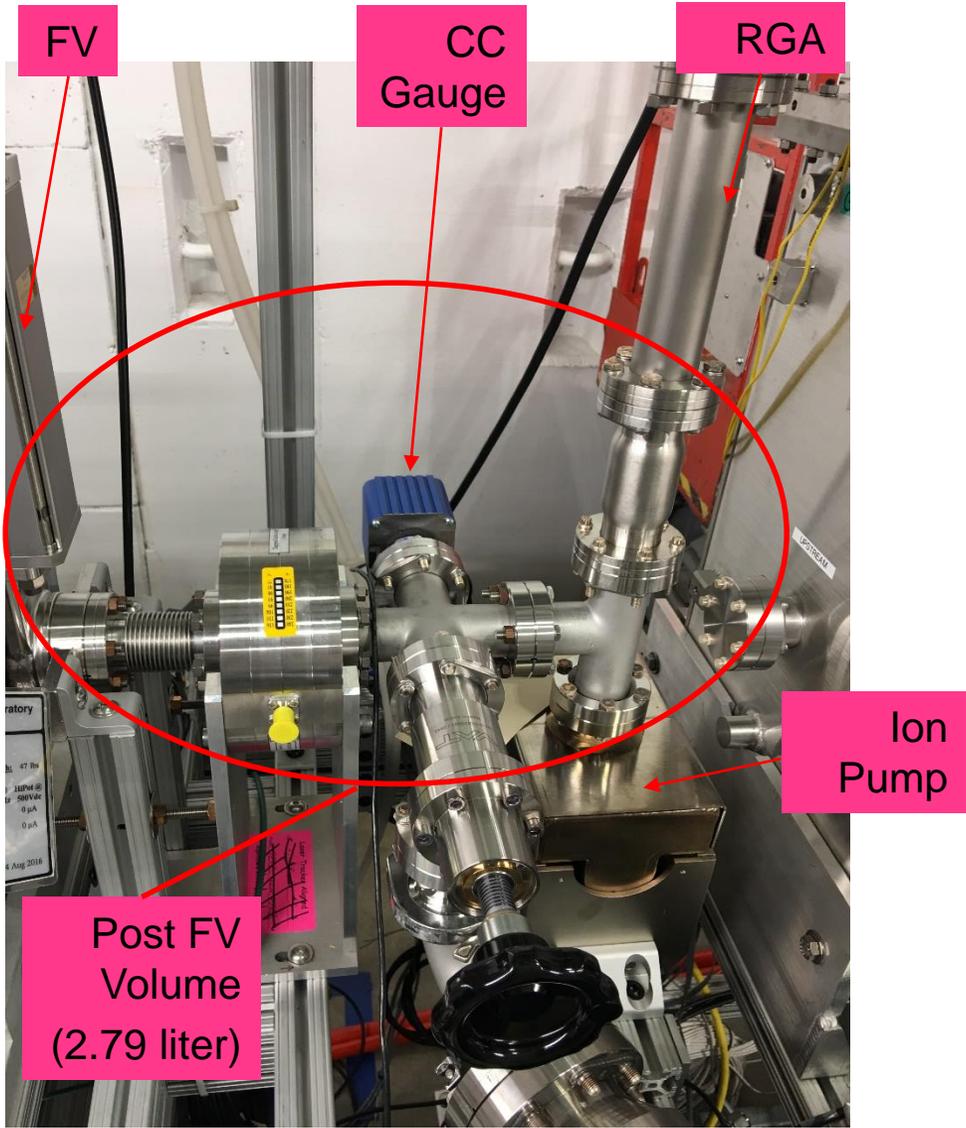
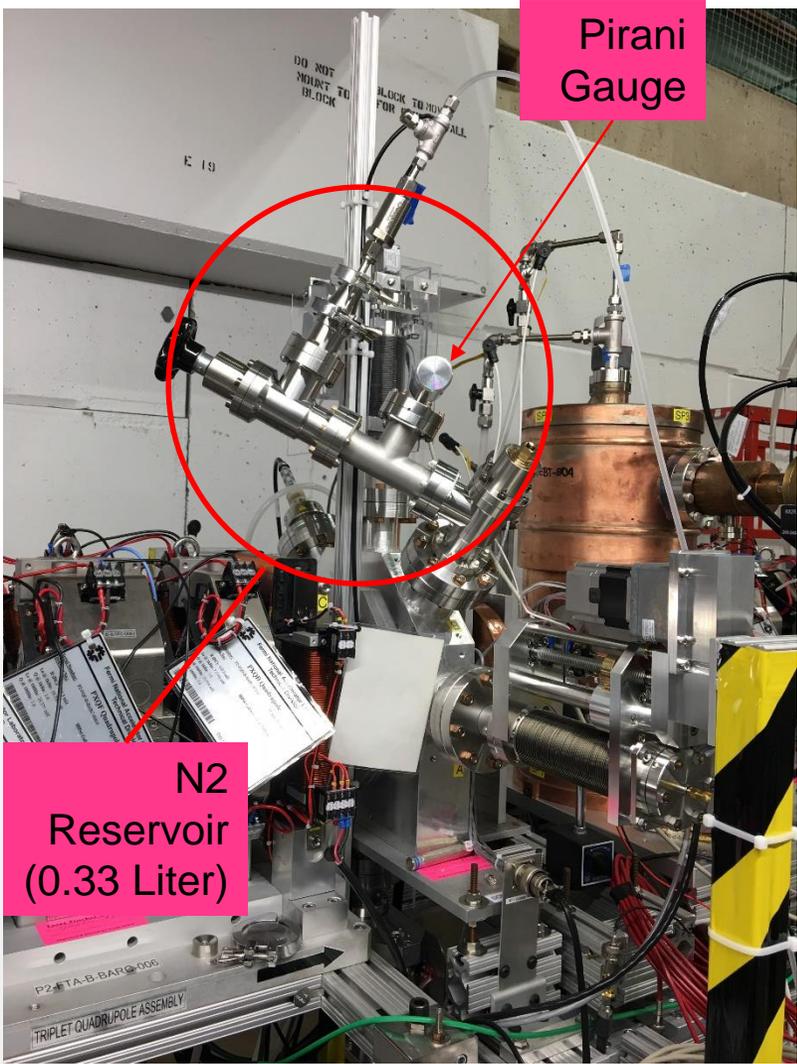
# 1<sup>st</sup> Test on MEBT DPI-FV



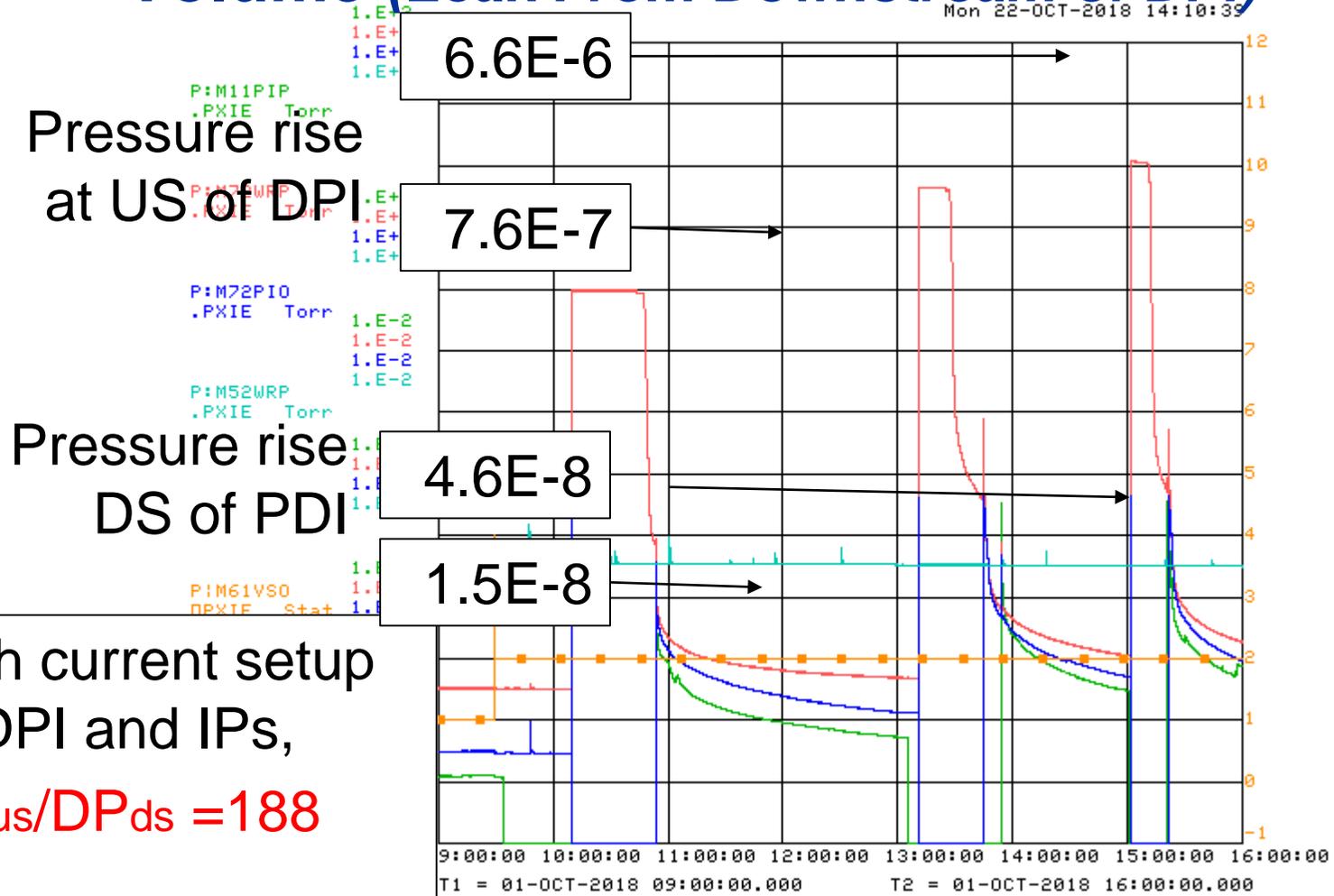
1. V1=36.5 liters(M61VSO-FV)
2. V2=95.1 liters(POST FV)
3. Permeation rate from Scanner O-Ring is about 6E-7 torr.l/s



# Setup of 2<sup>nd</sup> Test

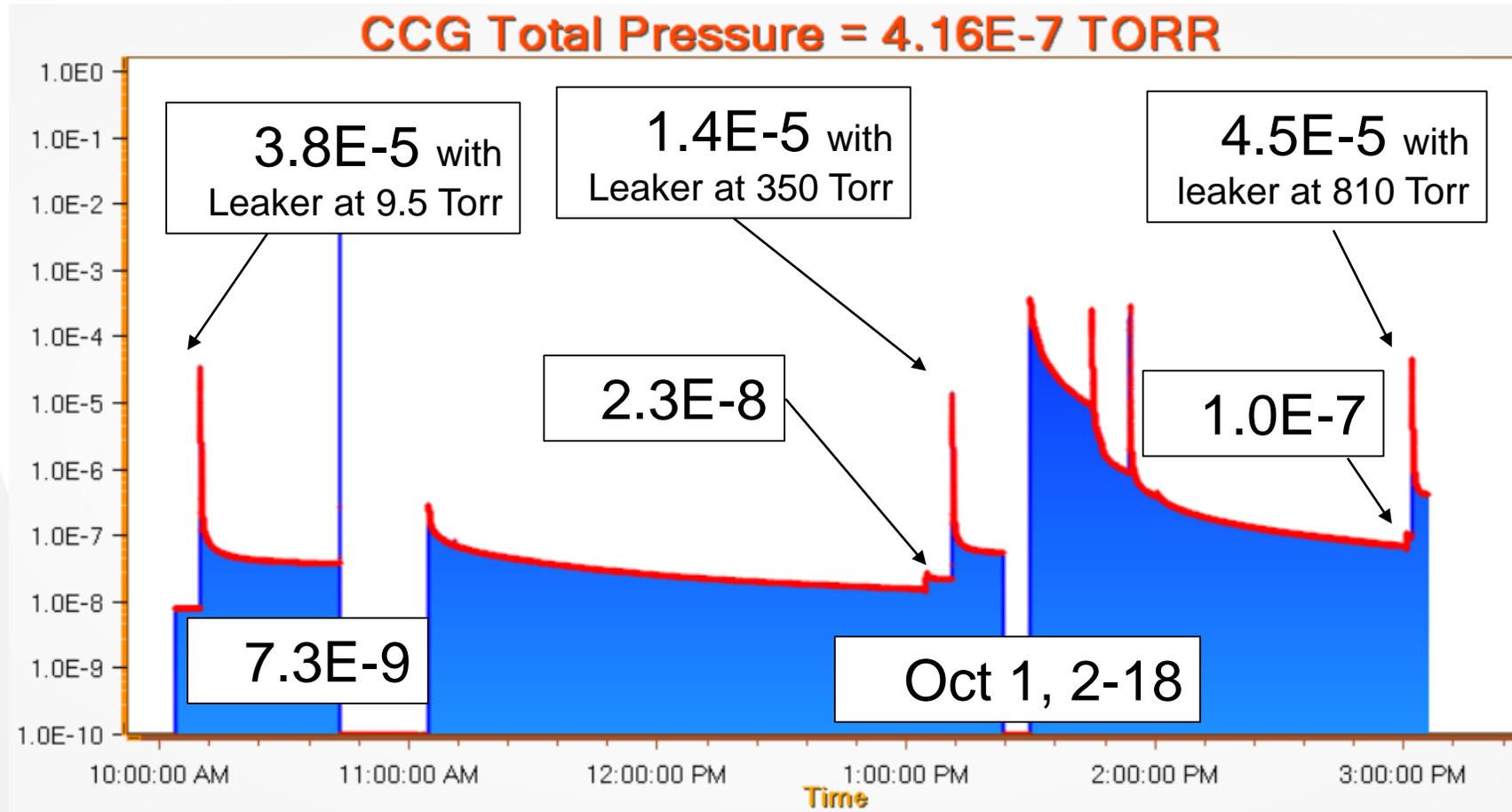


## 2<sup>nd</sup> Test With Smaller and Tighter Volume (Leak From Downstream of DPI)



With current setup of DPI and IPs,  
 $DP_{us}/DP_{ds} = 188$

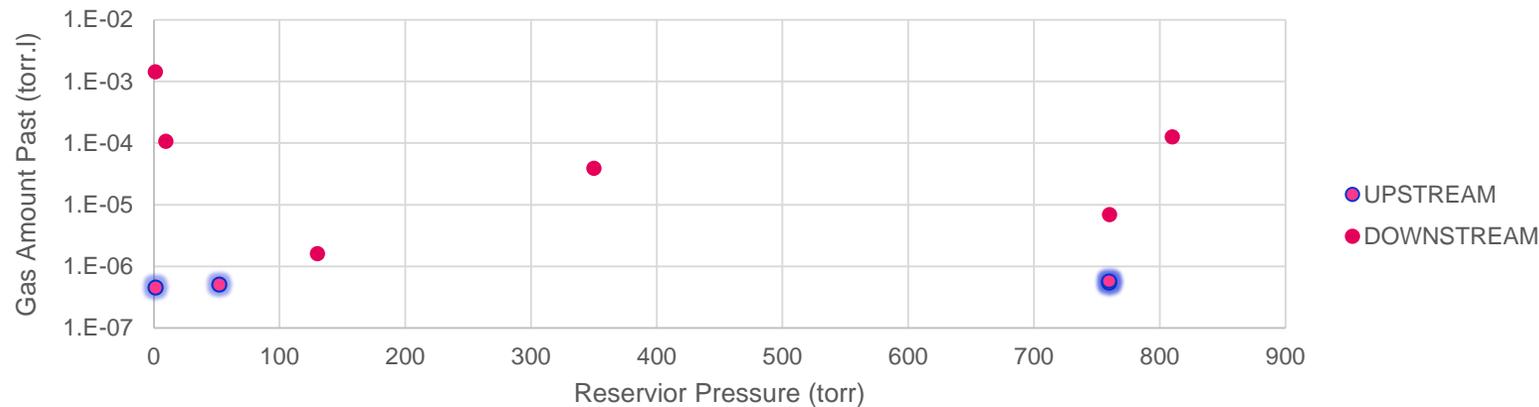
## 2<sup>nd</sup> Test With Smaller and Tighter Volume (Leak From Downstream of DPI)



# Summary of Results for Vacuum Protection

	Leaker	P0	P1	dP	Gas Amount	monolayer coverage	Leaker Location
	torr	torr	torr	torr	torr.liter	cm2	
23-Aug	1.7	6.2E-09	1.7E-07	1.6E-07	4.6E-07	1.3E-02	US DPI
	52	7.5E-09	1.9E-07	1.8E-07	5.1E-07	1.5E-02	
24-Aug	760	7.9E-09	2.0E-07	1.9E-07	5.4E-07	1.6E-02	
	760	2.3E-08	2.3E-07	2.1E-07	5.8E-07	1.7E-02	
1-Oct	9.5	7.3E-09	3.8E-05	3.8E-05	1.1E-04	3.1E+00	DS DPI
	350	2.1E-08	1.4E-05	1.4E-05	3.9E-05	1.1E+00	
	810	1.0E-07	4.5E-05	4.5E-05	1.3E-04	3.6E+00	
8-Oct	1.2	6.1E-09	5.1E-04	5.1E-04	1.4E-03	4.1E+01	
9-Oct	130	6.0E-09	5.8E-07	5.7E-07	1.6E-06	4.6E-02	
	760	3.0E-08	2.5E-06	2.5E-06	6.9E-06	2.0E-01	

Gas Past Fast Valve in Vacuum Failures



# Summary

- Configure can satisfy the vacuum requirement
- MolFlow simulation was done, and residual gas (Hydrogen) pressure profile along beamline was established,
- However the hydrogen condensation on the cavity at ends may be a concern if no sufficient desorption induced by beam or electrical power.
- Fast valve to minimize gas flux into CM during vacuum failure
- One gate valve to isolate the UHV region near CM from HV region near dump
- All installation, pumping down, venting up follow practice of low particulate vacuum

# DPI (differential pumping insert)

