FACET-II | Facility for Advanced Accelerator Experimental Tests

# Results of the differential pumping system test in experimental area

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May 3, 2022

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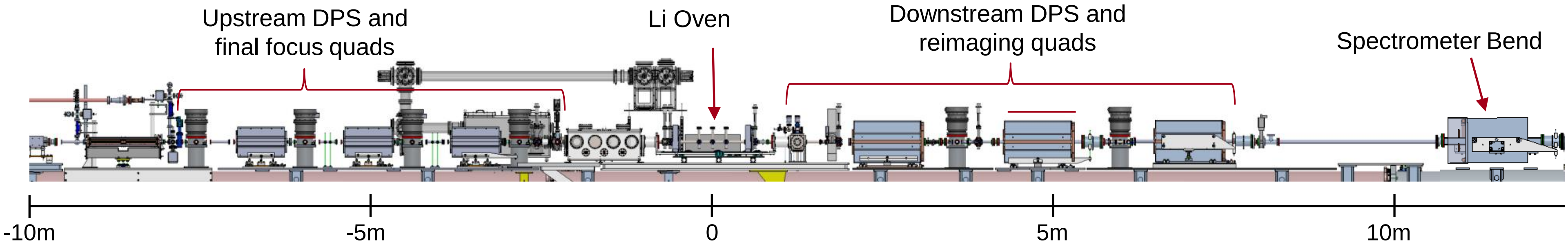
# Experimental Area Differential Pumping System




Requirements for E300 (from *FACET-II Differential Pumping System ESD*)

i. **Gas Load:** Up to 5 Torr He gas at IP, steady state

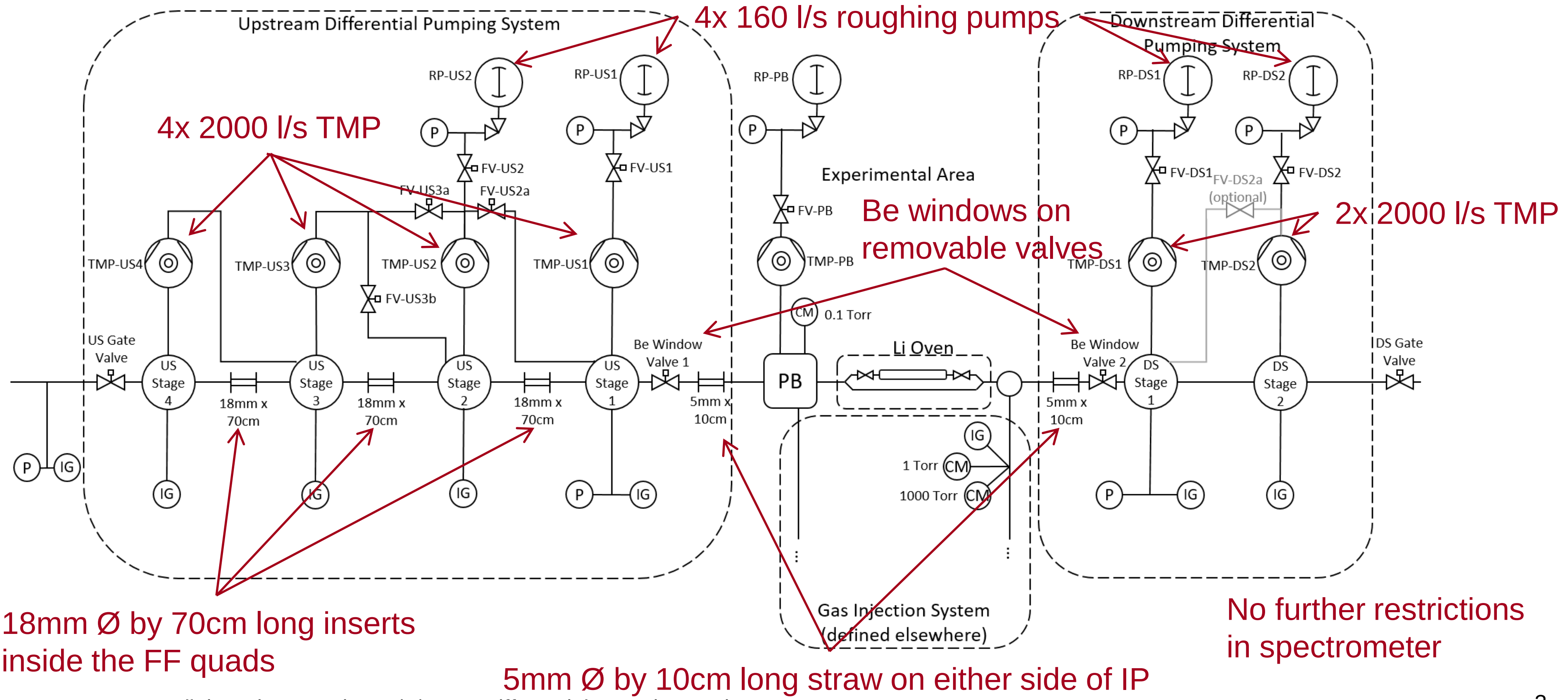
ii. **Upstream pressure:** P~1e-9 Torr at location of the XTCAV

iii. **Upstream apertures:** Adhere to nominal beam stay clear requirements. Upstream apertures must be located upstream on the holed mirror in the picnic basket

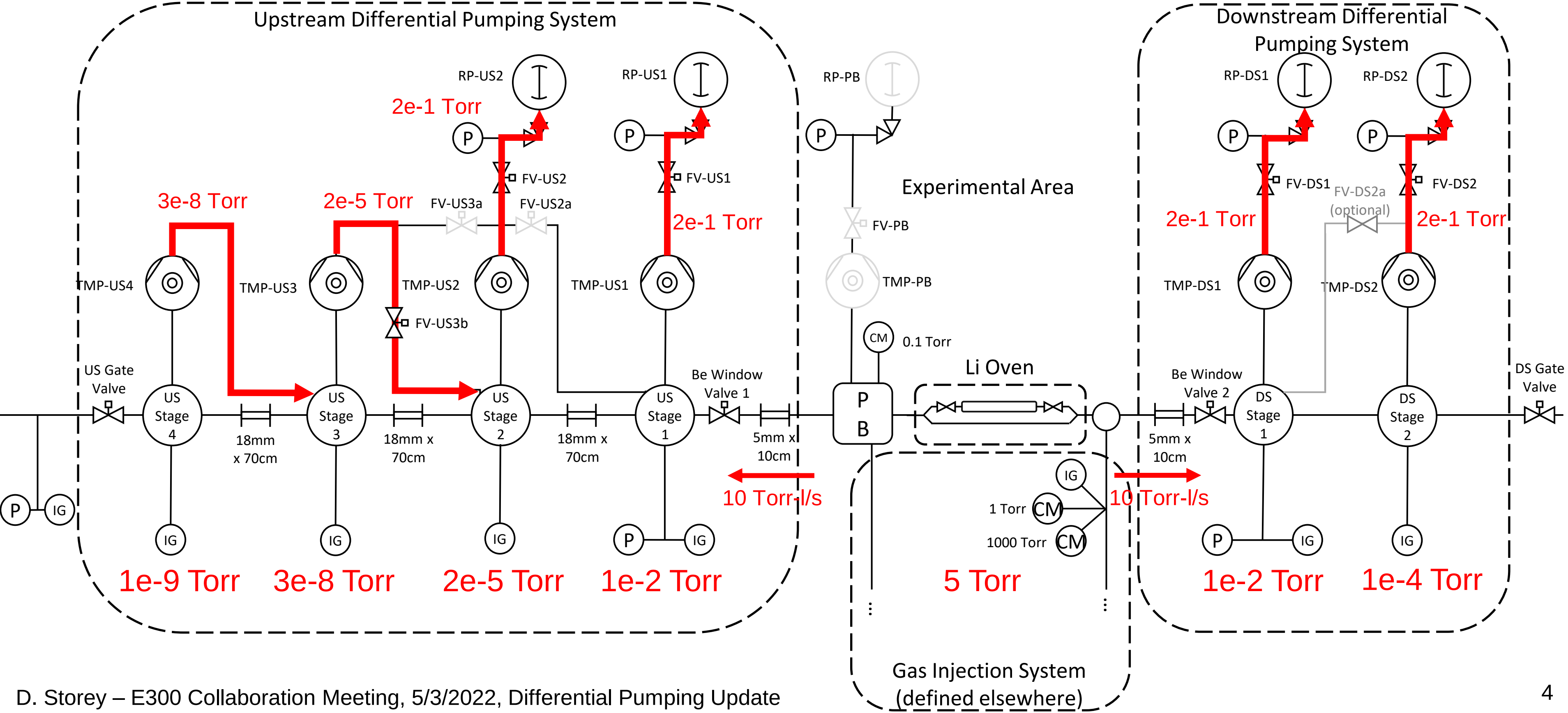
iv. **Downstream pressure:** P<1e-1 Torr with 2 meters of the exit of the plasma oven

v. **Downstream Apertures:** Adhere to nominal beam stay clear requirements. Downstream apertures must be located downstream of the holed mirror in the 8” cube. Apertures should not reduce the acceptance angle of the diagnostics beyond that defined by the spectrometer magnets.

# DPS Vacuum Schematic



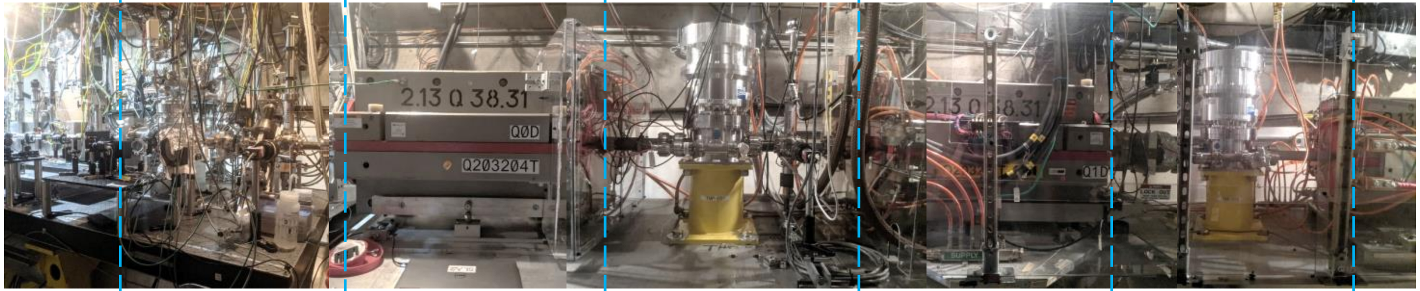
# DPS Vacuum Schematic – State 1: Li Oven



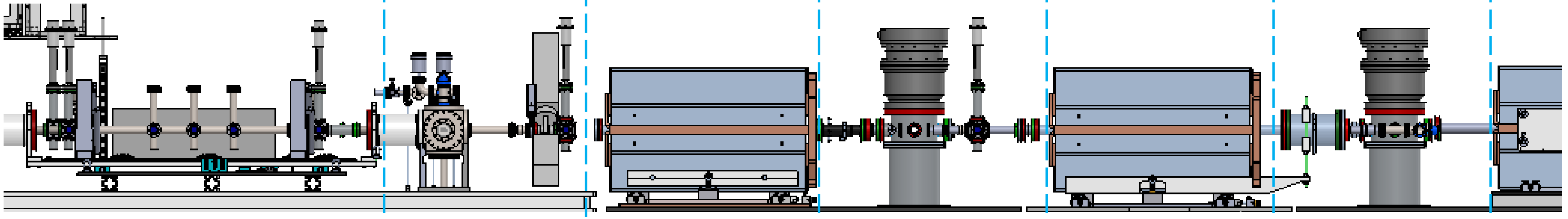
# Overview of the downstream DPS installation

**Beamline installation:**

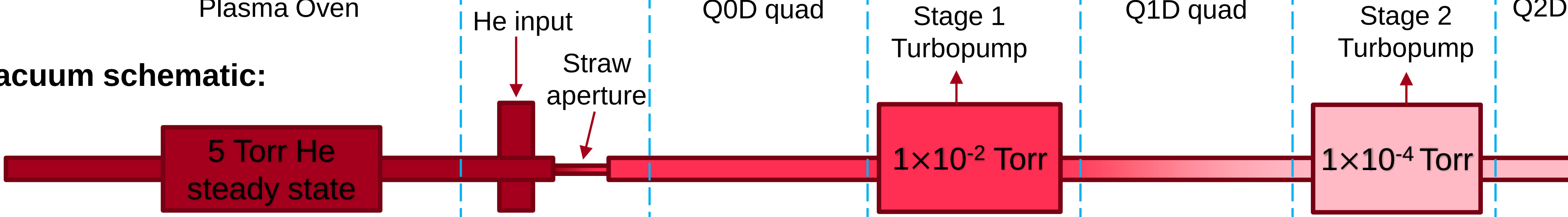
- Installation of downstream DPS system in Jan 2022
- First test with “straw aperture” on 4/7/2022
- Upstream-DPS ready to install




**Simplified sketch:**

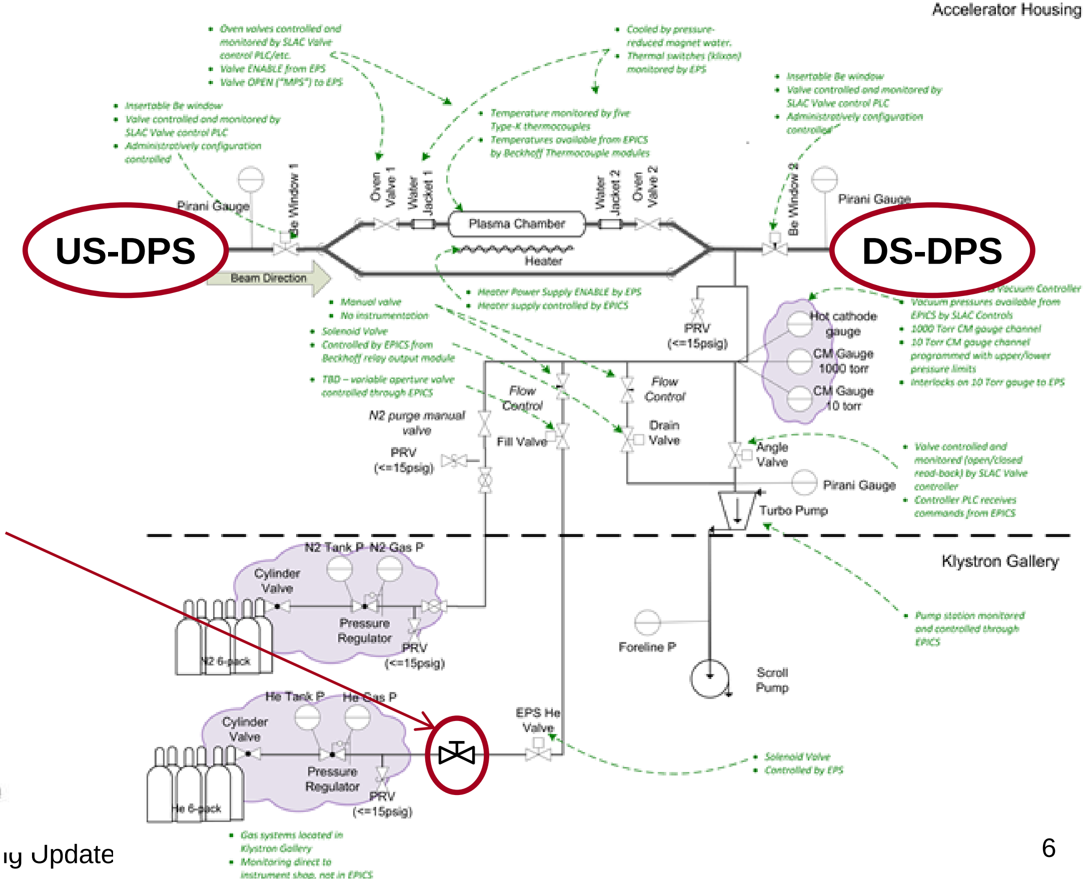



**Vacuum schematic:**



# Changes to gas delivery system

- Manual flow valve added to helium gas fill line
- No further changes made to gas delivery at this time
- Changes are compatible with Li oven operation with static fill

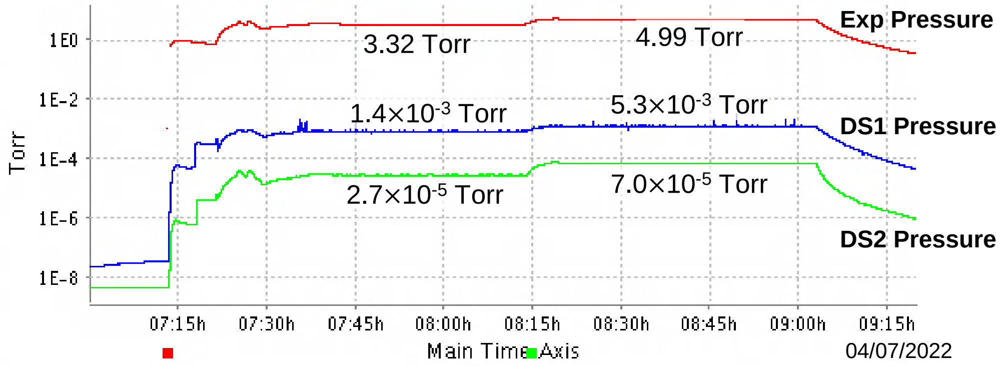



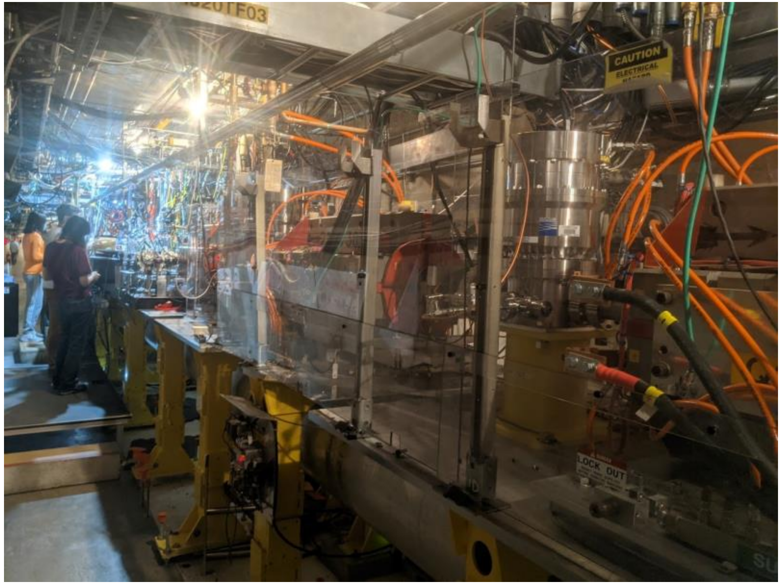
# Initial test results from the downstream DPS

- Beamline apertures installed:
  - 5mm Ø x 10 cm straw before Q0D (removed after test)
  - no additional aperture required on stage 2

- Pressure drop along the beamline meets requirement.
- Experimental area pressure stable to <0.5% over duration of test.
- Pump temperatures remain well within operating limits.

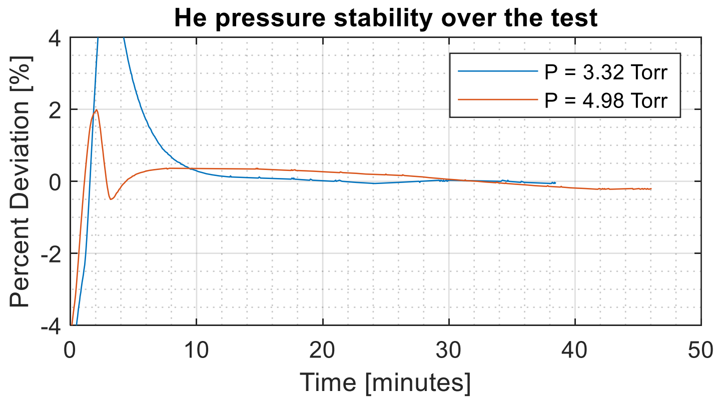
**DS-DPS test with 5mm Ø x 10cm long straw**



# Pressure stability and gas usage

- Two gas pressures tested for about 40 minutes each
- Slow drift of ~0.5% over 40 minutes
  - Need to understand if this is gauge drift, drift in gas delivery rate, and if it settles to a fixed value over time
  - What is the requirement on buffer gas pressure stability?




Gas usage:

- 8 Torr l/s per side → 16 Torr l/s total
- One 300 $ft^3$ He bottle contains $6.5\times10^6$ Torr l
- Approximately 4.5 days/bottle

# Radiation related issues

Turbopumps have been operating in the tunnel without issue for ~3 months

- Turbo controllers are located in gallery

Roughing pumps have been tripping off ~1/week

- Trips are highly correlated with high radiation measured by experimental area radiation monitors
- Controllers are on the pumps, pumps located below the beamline

Studying mitigation options:

- Move the roughing pumps out of the tunnel
  - Testing conductance limitations for a ~40ft foreline
- Move the pumps upstream of the IP
  - Once nominal radiation levels are more controlled this could be an option
- Add local shielding to pumps

# Next steps + Discussion

- Sort out roughing pump operational issues
- Installation of the US-DPS pumps and guages
- Installation of aperture restrictions inside the final focus quads
- Design and installation of 5mm x 10cm straws and upstream Be window
- Test of the full system with the XTCAV

**Discussion questions:**

- What are the requirements for pressure stability for Li oven operation?
- How will the oven behave in the various failure modes, i.e. sudden loss of a pumping stage
- What other requirements exist for first test with oven

- What will it take to convince ourselves that we are ready for a test of the full system with the Li oven?

# Extra slides

# Differential Pumping Requirements

Differential Pumping System (DPS) will:

- Isolate the IP experimental area beamline from the upstream UHV conditions for the TCAV and linac
- Limit emittance growth from beam-gas scattering
- Maintain beam stay clear requirements whenever possible
- Must fit into the available space between quadrupoles

Four modes of operation will serve most of the experimental programs:

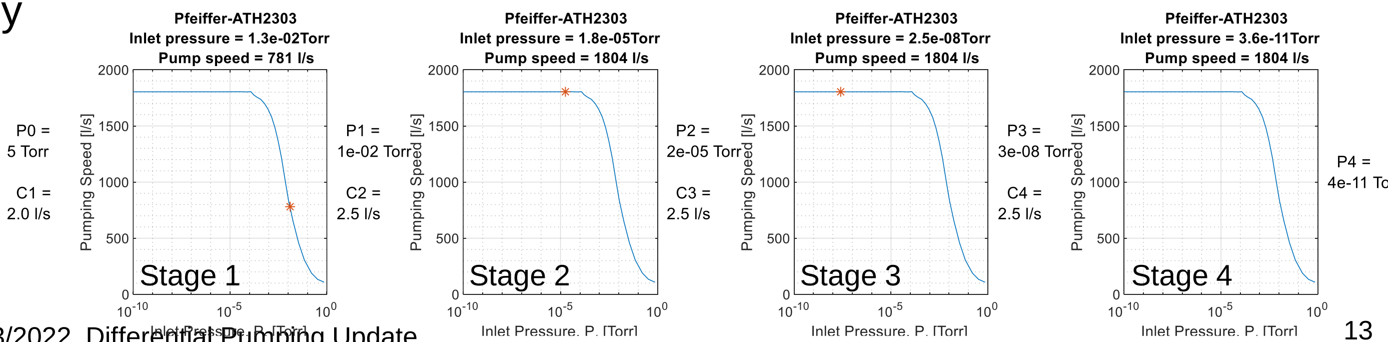
| Requirements | State 0: High vacuum | State 1: Li Oven operation | State 2: $H_2$ gas plasma | State 3: Gas jets in the PB |
|---|---|---|---|---|
| Gas load | none | $\leq$ 5 Torr He | $\leq$ 5 Torr $H_2$ | $\leq 10^{-4}$ Torr $H_2$ |
| US pressure | $P \sim 10^{-9}$ Torr at XTCAV | $P \sim 10^{-9}$ Torr at XTCAV | $P \sim 10^{-9}$ Torr at XTCAV | $P \sim 10^{-9}$ Torr at XTCAV |
| US Apertures | Nominal Beam Stay Clear (BSC) | Nominal BSC. US apertures located US of holed mirror | Nominal BSC. US apertures located US of holed mirror | Nominal BSC. US apertures located US of holed mirror |
| DS pressure | $P < 100$ mTorr in spectrometer | $P < 100$ mTorr within < 2 m of plasma exit | $P < 100$ mTorr within < 2 m of plasma exit | $P < 1$ mTorr in spectrometer |
| DS Apertures | Nominal BSC. Cannot reduce gamma aperture | Nominal BSC. DS aperture located DS of holed mirror. Cannot reduce gamma aperture | Nominal BSC. DS aperture located DS of holed mirror. Cannot reduce gamma aperture | Nominal BSC. DS aperture may located DS of PB. Cannot reduce gamma aperture |

# Differential Pumping Performance – Upstream DPS

- Performance estimated by matching the rate of flow though tubes to TMP pumping speed
- Assumed 2000 l/s TMP pumping speed curve
- Pressure at final stage expected to be limited by outgassing rate
- Performance of State 1 first stage confirmed by bench tests

| State | Exp. Condition | Stage 1: Eff. TMP speed / Pressure | Stage 2: Eff. TMP speed / Pressure | Stage 3: Eff. TMP speed / Pressure | Stage 4: Eff. TMP speed / Pressure | Stage 1 flow rate |
|---|---|---|---|---|---|---|
| 0 | ~1e-9 Torr | ~1800l/s<br>1e-9 Torr | n/a | n/a | n/a | minimal |
| 1 | 5 Torr He | ~780<br>1e-2 Torr | ~1800 l/s<br>2e-5 Torr | ~1800 l/s<br>3e-8 Torr | ~1800 l/s<br>~1e-9 Torr | 10 Torr l/s |
| 2 | 5 Torr $H_2$ | ~300<br>7e-2 Torr | ~1800 l/s<br>2e-4 Torr | ~1800 l/s<br>3e-7 Torr | ~1800 l/s<br>~1e-9 Torr | 23 Torr l/s |
| 3 | 1e-4 Torr $H_2$ | ~1100<br>5e-8 Torr | ~1800 l/s<br>~1e-9 Torr | n/a | n/a | minimal |

**State 1 - US Differential Pumping Calculated Performance**



# Differential Pumping Performance – Downstream DPS

- Downstream DPS easily meets requirements in 2 stages
- The downstream aperture may be removed completely in State 3 to increase the gamma and electron angular acceptance
- Flowrate through stage 1 on both sides defines the gas consumption of the system:
    - 20 Torr-l/s He = ~ 4 days use
    - 46 Torr-l/s $H_2$ = ~ 4 hours use

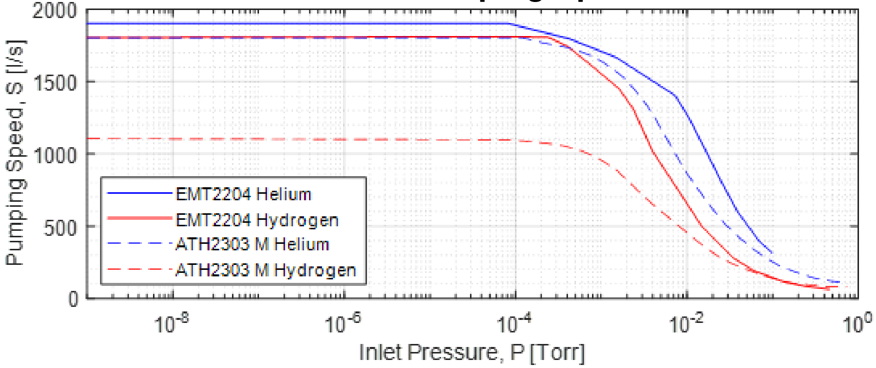
| State | Exp. Condition | Stage 1: Eff. TMP speed / Pressure | Stage 2: Eff. TMP speed / Pressure | Stage 1 flow rate |
|---|---|---|---|---|
| 0 | ~1e-9 Torr | ~2000l/s<br>1e-2 Torr | n/a | minimal |
| 1 | 5 Torr He | ~780<br>1e-2 Torr | ~2000 l/s<br>1e-4 Torr | 10 Torr l/s |
| 2 | 5 Torr $H_2$ | ~300<br>7e-2 Torr | ~1800 l/s<br>1e-3 Torr | 23 Torr l/s |
| 3 | 1e-4 Torr $H_2$ | Aperture removed<br>~1100<br>1e-6 Torr | n/a | minimal |

# Choice of pumps

Turbopumps:

- 2000 l/s class TMP that can withstand ~krad radiation dose/week
- Remote controller unit and >20m cable
- Low vibration → magnetic levitation bearing
- Low maintenance

- Choices:
  - ✓ Ebara EMT 2204
  - \- Pfeiffer ATH 2303M
    - H2 pump speed is low




Backing pumps:

- Large flow rate required
- Dry, low maintenance
- N2 purge gas to increase light gas pumping speed

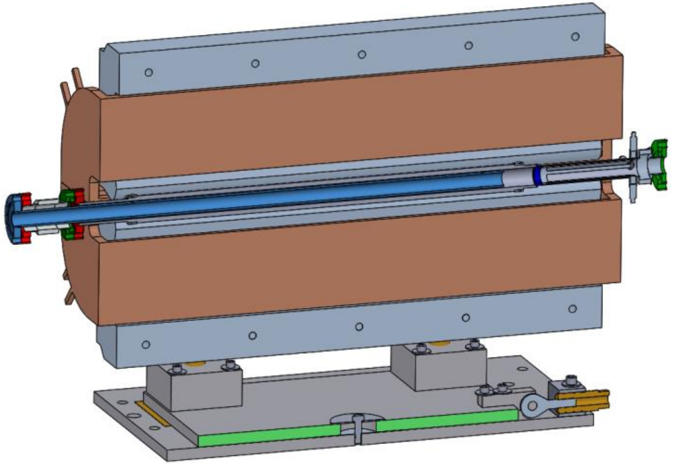
- Choices:
  - ✓ Ebara EV-S100P
  - \- Pfeiffer ACP40
  - \- Leybold Ecodry 65 Plus

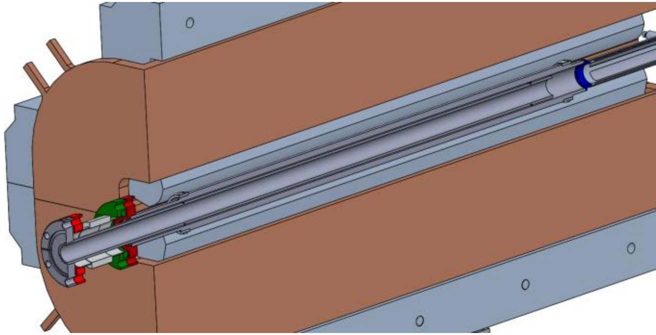
Ebara EMT 2204:

Pfeiffer ATH 2303M:

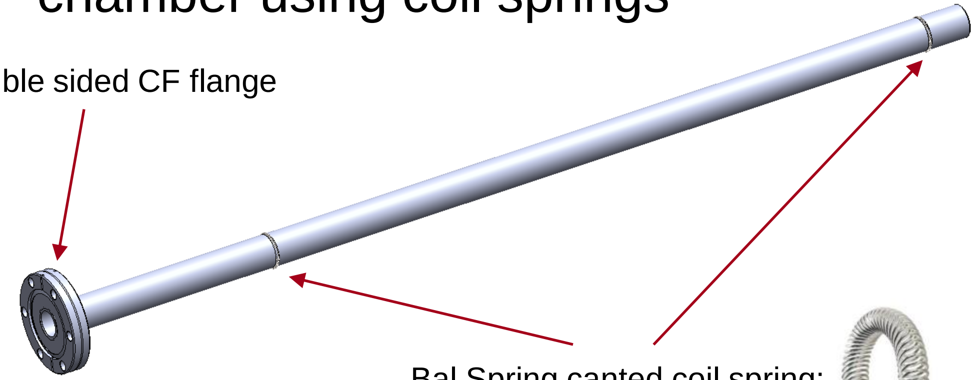
# Aperture limiting inserts

- 18mm x 70cm aperture insert
- Designed to be removable, replaceable
- Fabricated from SS tube
- Self-centering within the quad magnet chamber using coil springs





Double sided CF flange



Bal Spring canted coil spring: