Systematic Measurement of the Pumping Capabilities of Cryogenic Surfaces

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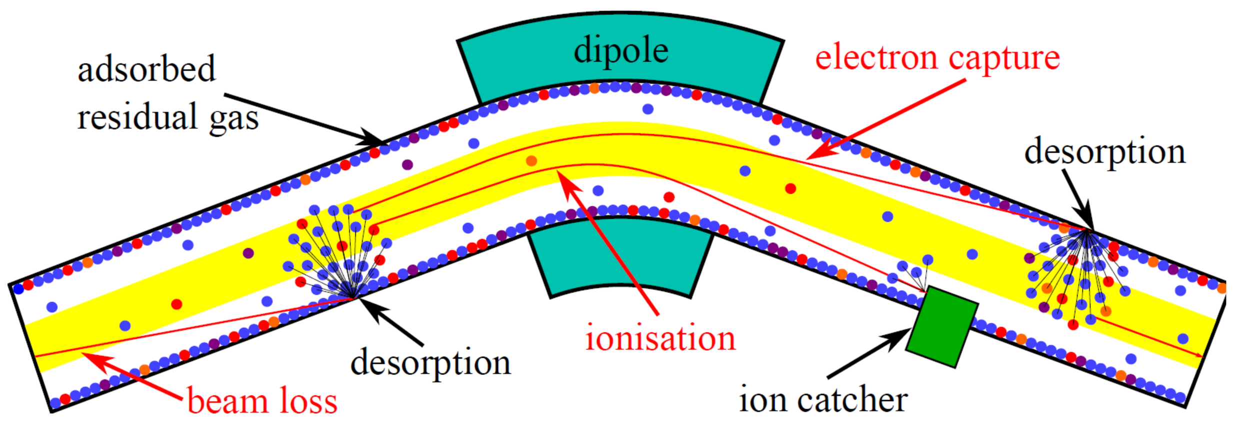
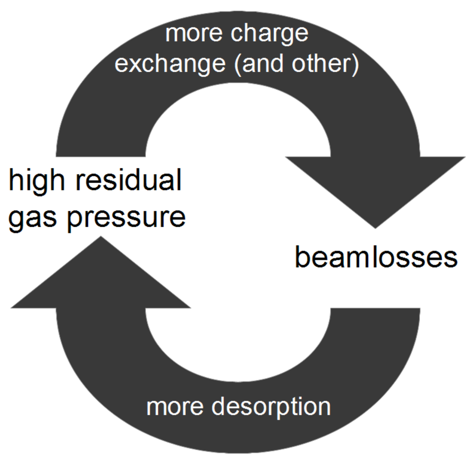
Dynamic Vacuum in Circular Accelerators





- Residual gas causes beam loss, mostly by charge exchange.
- Lost ions trigger impact stimulated desorption from the walls.
- Use of ion catchers reduces desorption yield by two orders of magnitude.
- Dynamic vacuum effects are a limiting factor for the intensity in SIS18.
- StrahlSim [3]: Self consistent simulation of beam - vacuum interactions needs Improved data basis for cryogenic surface pumps.

Break this self-amplifying circle:
- Avoid beam losses in the ring [1]
- Reduce desorption with ion catchers [2]
- Improve the vacuum conditions, for example with cryogenic surfaces

Measurement Concept

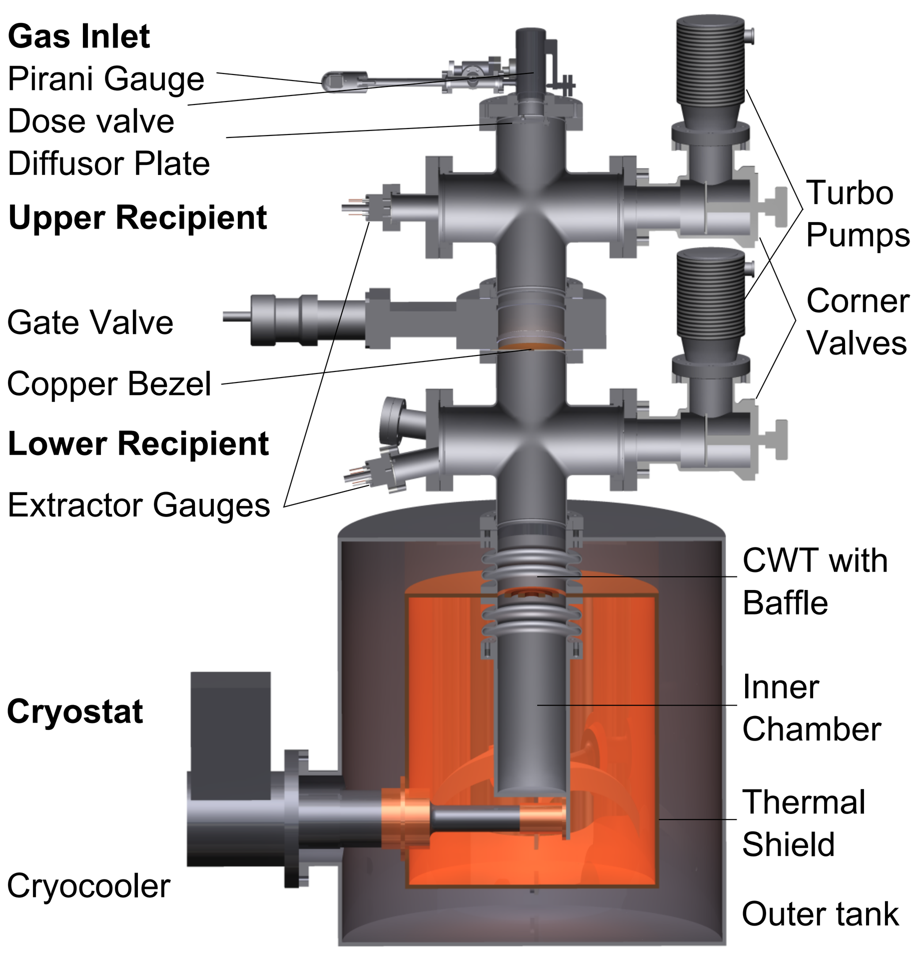
Two parameters [3] have to be measured in dependance of temperature and surface coverage:
- Sticking Probability: Probability, that a residual gas particle impinging on a surface is bound
- Mean Sojourn Time: Average time span a particle stays bound to a (cryogenic) surface

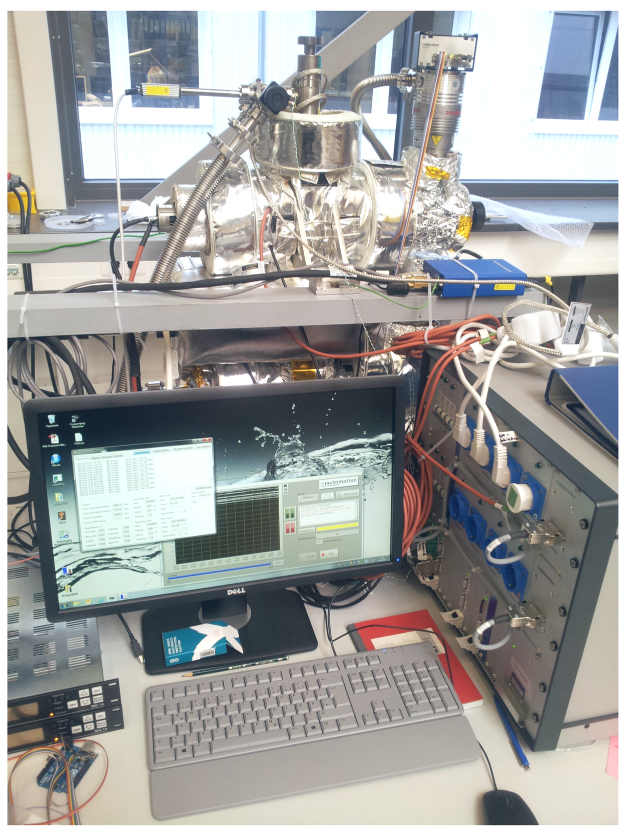
$$S=\frac{1}{4}\sigma\bar{v}A \qquad N_{ads}=S\frac{p}{k_b T} \qquad N_{des}=\frac{N_{bound}}{\tau}$$

→ Measure volume pumping speed S to acquire Sticking Probability σ ! This is possible with a Pneurop like setup consisting of two recipients connected over a well defined conductance.

- Equilibrium state: Adsorption rate equals desorption rate
- This equilibrium pressure plotted over different surface coverages N_{bound} / A is called isotherm [6].
- If S is already known, the mean sojourn time τ can be calculated.
- The number of bound particles can be deducted from the amount of gas pumped since the last cool down.

Phase 1: Controlled gas inlet to measure S and keep track of surface coverage
Phase 2: Measurement of the equilibrium pressure in the closed system
Keep doing this while surface coverage is rising.

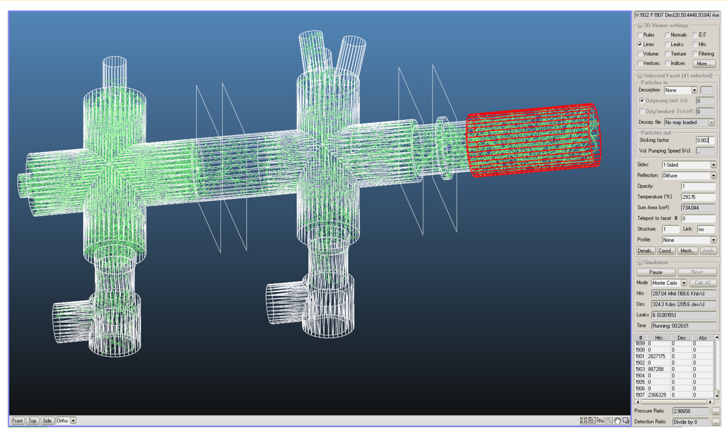




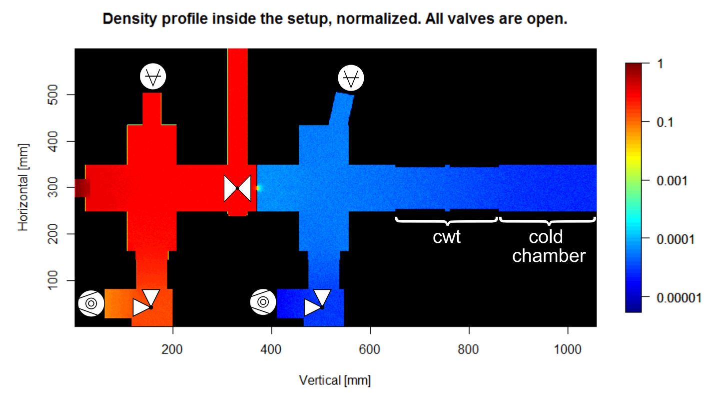
Concepts for Data Inversion

- **We want:** Pumping speed and outgassing of the cold surfaces.
- **We have:** Geometry and surface temperatures of the setup, gas densities at two points in the warm part.

Idea: Use MolFlow+ [5]. Assign desorption to the location of the gas inlet, and variable sticking values to the cold surface (red) to match the measured density ratio.



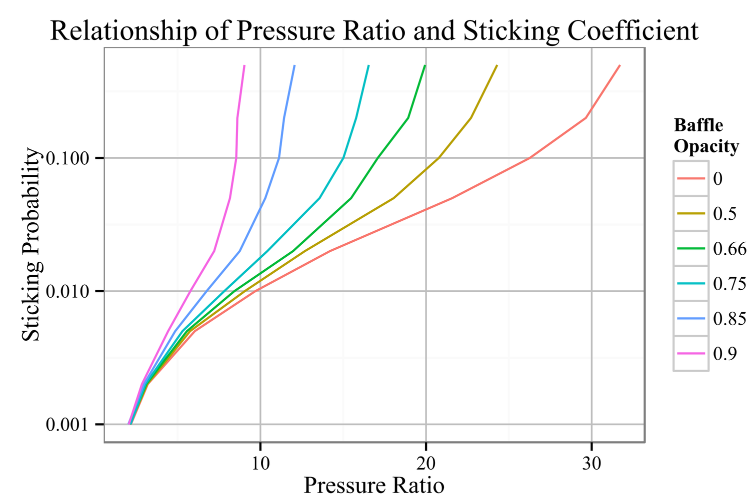
Alternative: Use the concept of multiple connected vacuum elements to calculate missing vacuum properties. This is only a good representation if there are truly isobaric areas like the two warm crosses. Continuous transitions, like inside the cwt, are not covered.

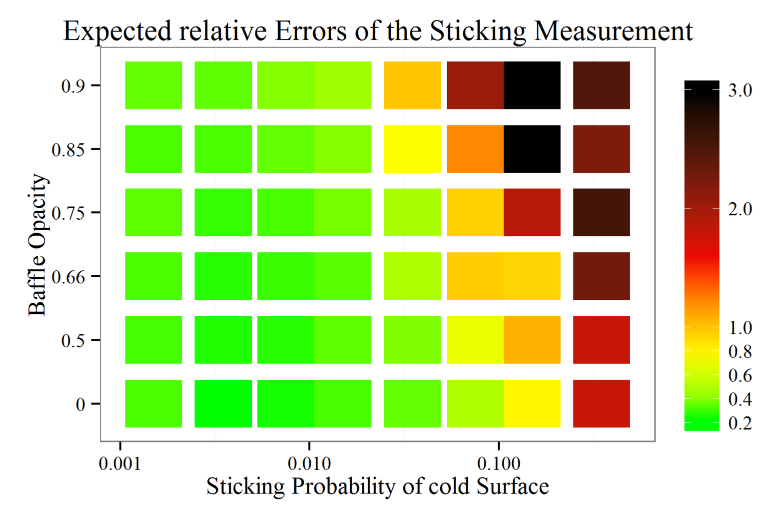


Recent results from MolFlow+ calculations:
- The corner valves have a transmission of 0.165. This means the pumps should have only 16.5% of their nominal pumping speed (77 l/s for N_2). The measured effective pumping speed was 10.2 ± 1.2 l/s.
- With an equal outgassing of all surfaces, the density ratio between the two crosses is 1.31 with the gate valve open (1.35 when closed). Measurements showed ratios of 1.24 ± 0.13.

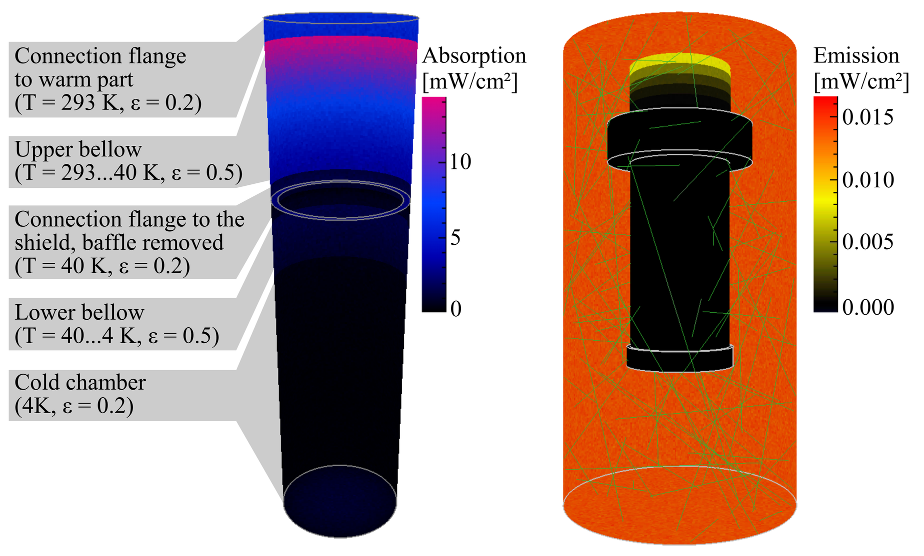
Development of the Cryostat

- Cryostat is currently being constructed externally.
- Tailored around an existing cryocooler with a cooling power of 1 W at 4 K
- Challenge: Heat loads must stay below this cooling capacity to reach ultimate temperatures.
- Thermal shield and Superisolation protects against heat radiation from the outside, conductance is under control by using a cold warm transition (cwt) with bellows and GFK fittings.
- But: Heat radiation from the warm diagnostics part through the cwt is an issue.
- A baffle can stop that, but this also lowers vacuum conductance and thereby measurement accuracy.
  → Compromise has to be found for maximum vacuum conductance while not exceeding cooling power





Top: Sticking Probabilities have been linked to possible pressure ratios as described in the box "Data Inversion". The slope of those curves is decisive for the error propagation. This leads to the second picture, which shows how opening or even removing the baffle increases the accuracy.

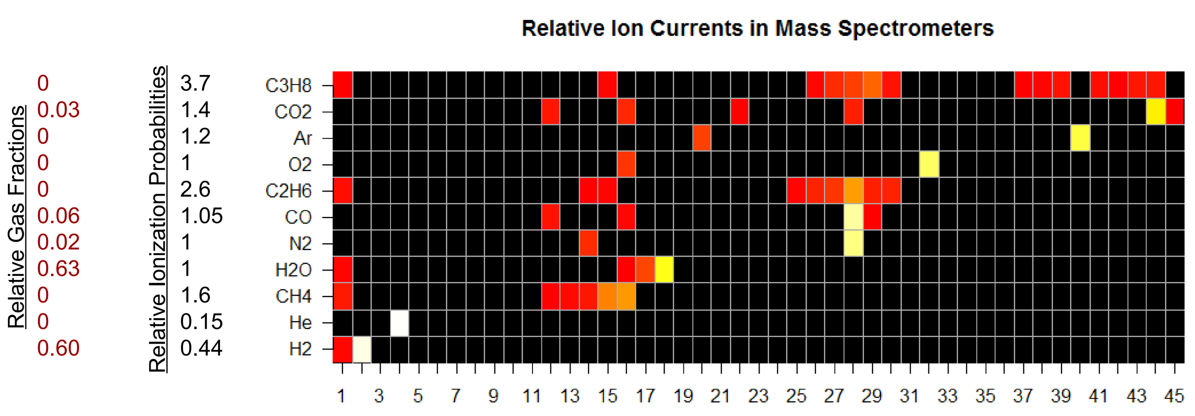


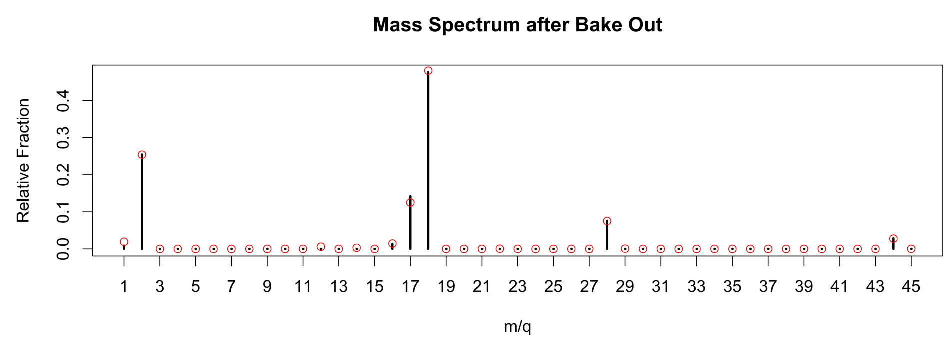
Bottom: Thermal radiation was simulated with McCryoT. The picture shows the geometries used and some results. Summation over all surfaces belonging to the inner chamber yields the (radiation) heat load on the second stage of the cryocooler.

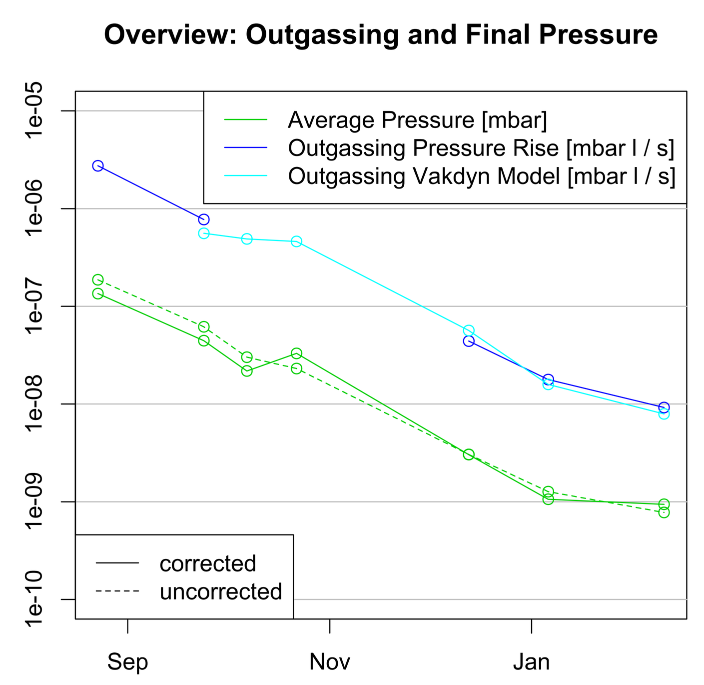
Warm Measurements within the existing Part

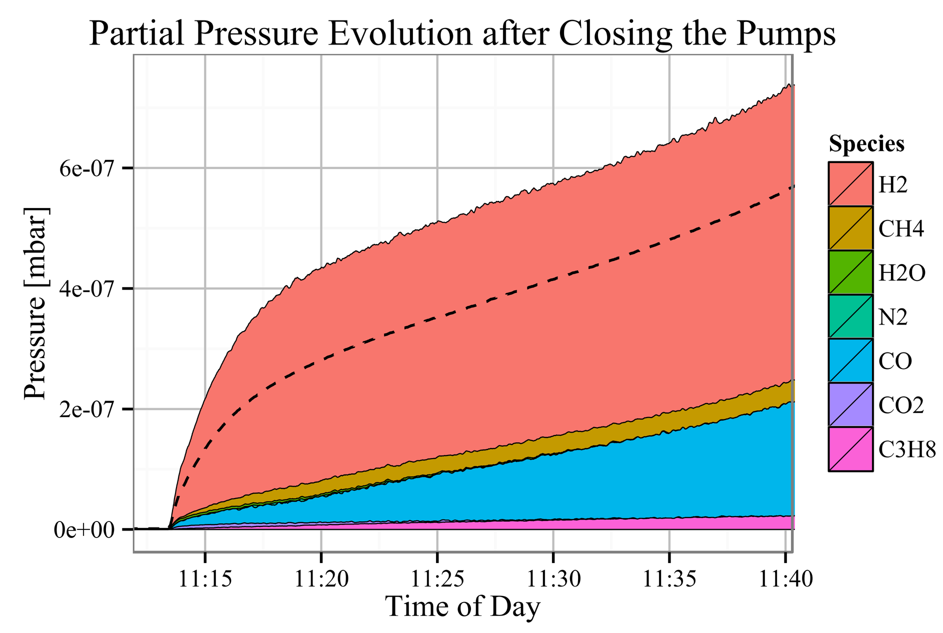
Residual gas composition needed for:
- Correction of displayed pressure values
- Partial pressures

Analysis of the measured mass spectra
- Each residual gas species creates a footprint in the mass spectrum (black bars), according to the color table shown below (individual for each RGA). Some mass peaks can originate from different gas species.
- A non zero least square fit (red dots) is performed to find the most probable gas composition.

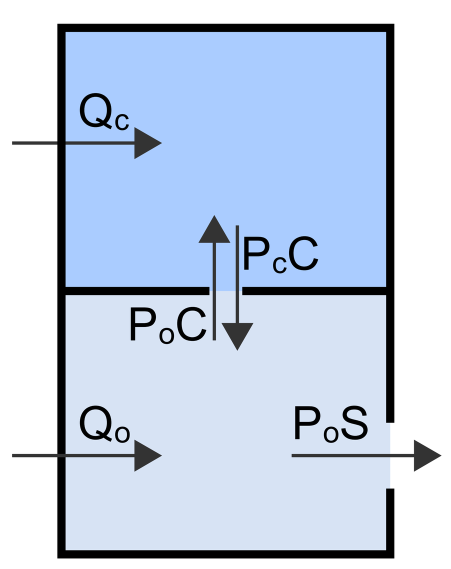


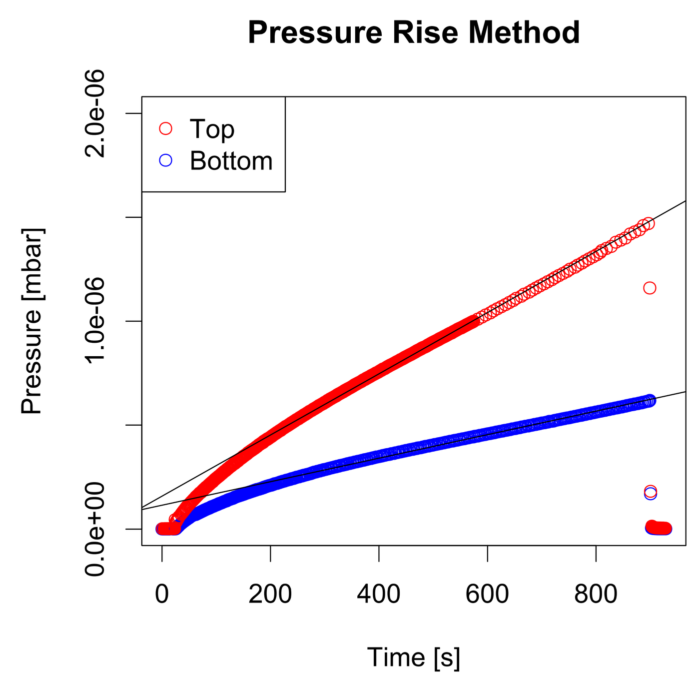






Measurement of the integral outgassing rate





Via vacuum element model:
Close one corner valve, so S = 0 for this chamber (top chamber in the figure).
Then solve: $Q_c = P_c C - P_o C$
Do the same for the other chamber

Via pressure rise:
- Close the corner valves to the pumps.
- Take the slope of the resulting pressure rise in mbar / s and multiply by the volumes of the chambers in l.
- Voila: The outgassing rate in mbar l / s

References:
[1] Y. El Hayek, Dissertation (2013)
[2] L. Bozyk, Dissertation (2012)
[3] P. Puppel, Dissertation (2012)
[4] V. Ziemann, Vacuum 81, p. 866-870 (2007)
[5] R. Kersevan, J. Vac. Sci. Technol. A 27, 1017 (2009)
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