CAS 2017
Vacuum simulations

INDIVIDUAL WORK – TUTORIAL GROUP #1

15 JUNE 2017 – GLUMSLOV - SWEDEN

Outline

Problem description

Molflow in a nutshell

Geometrical model

Results

- Sticking factor & outgassing rate
- Saturation time - analytical versus Monte Carlo approaches
- Transmission probability and pressure ratio as a function of sticking probability

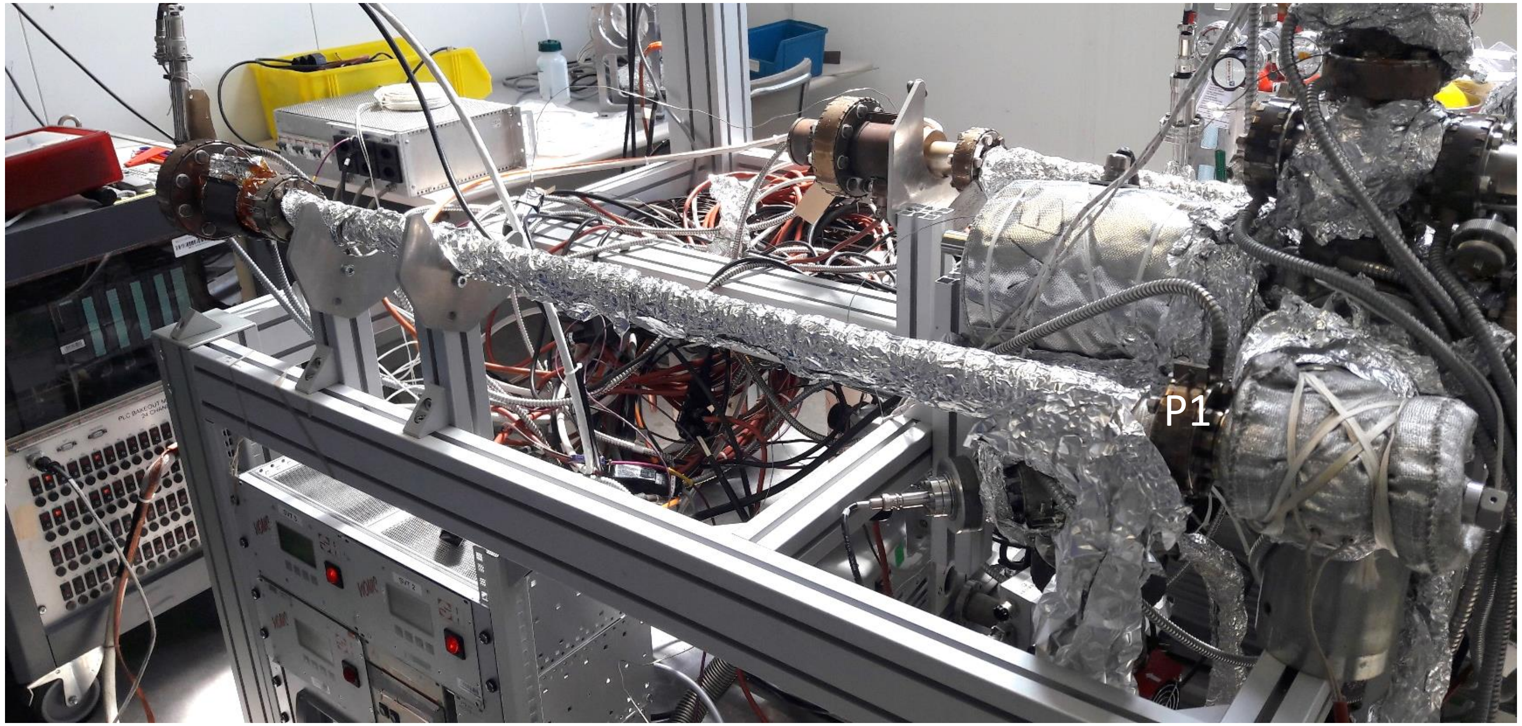
Reference paper

Conclusions

Problem description

We have a NEG coated vacuum pipe connected to a vacuum system and two pressure gauges reading.
A gas injection is performed and at steady state, the pressures measured in gauges 1 and 2 are:

- $P_1 = 1 \cdot 10^{-6}\ mbar$
- $P_2 = 2.5 \cdot 10^{-9}\ mbar$



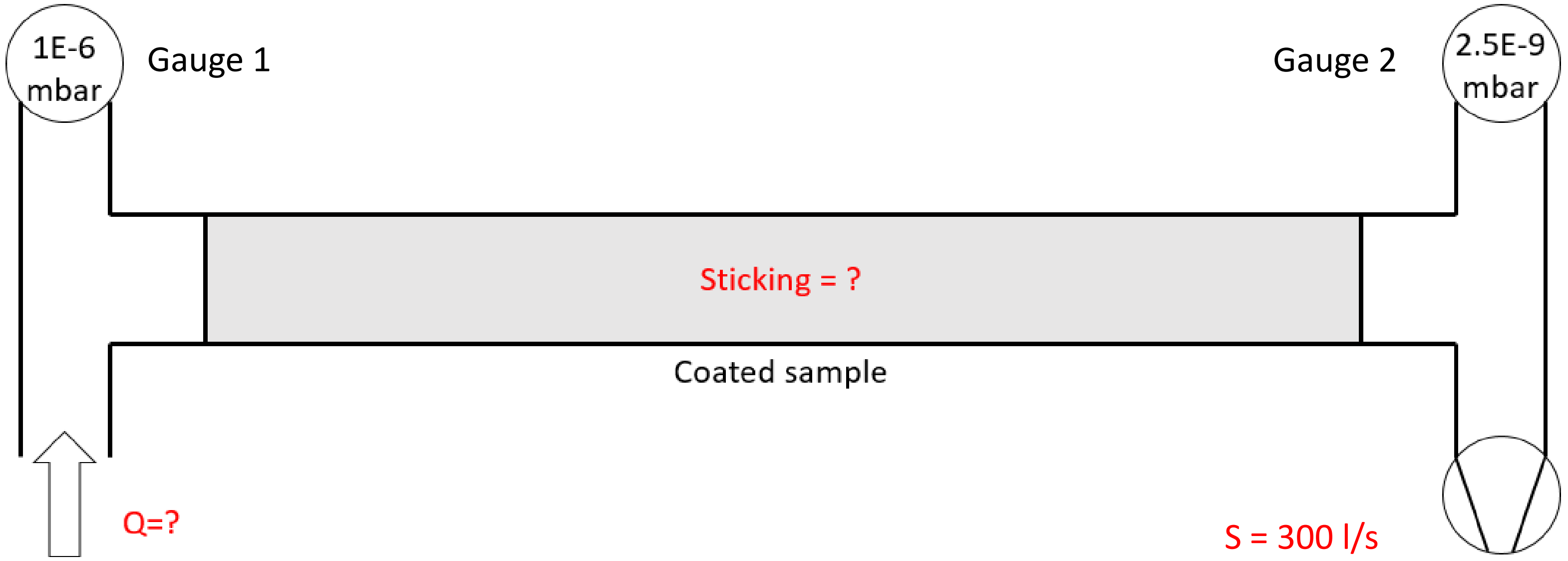
What is the sticking factor of the NEG?

What is the flow rate of the inlet gas?

Problem description

What do we know:

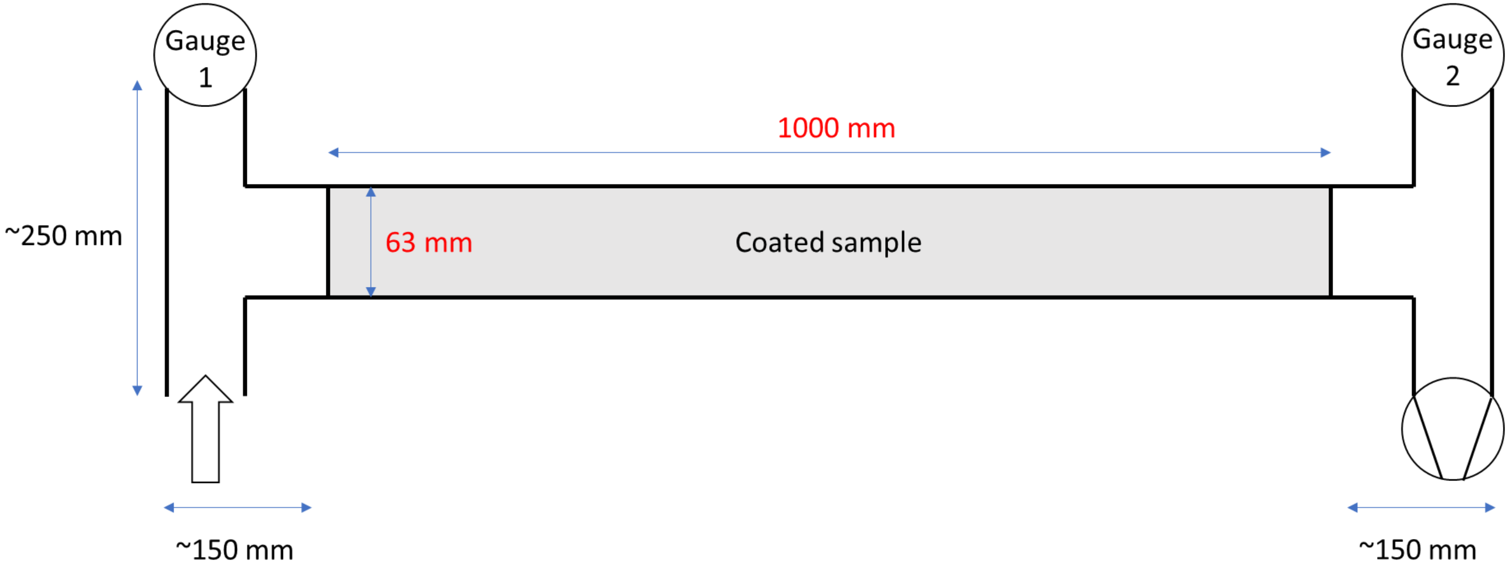
- Pipe geometry
- Pumping speed of the pump
- Pressure on gauges



Problem description

Principle:

- Mass flow flowing through a coated chamber
- Some molecules sticking to the coating
- Some molecules pumped

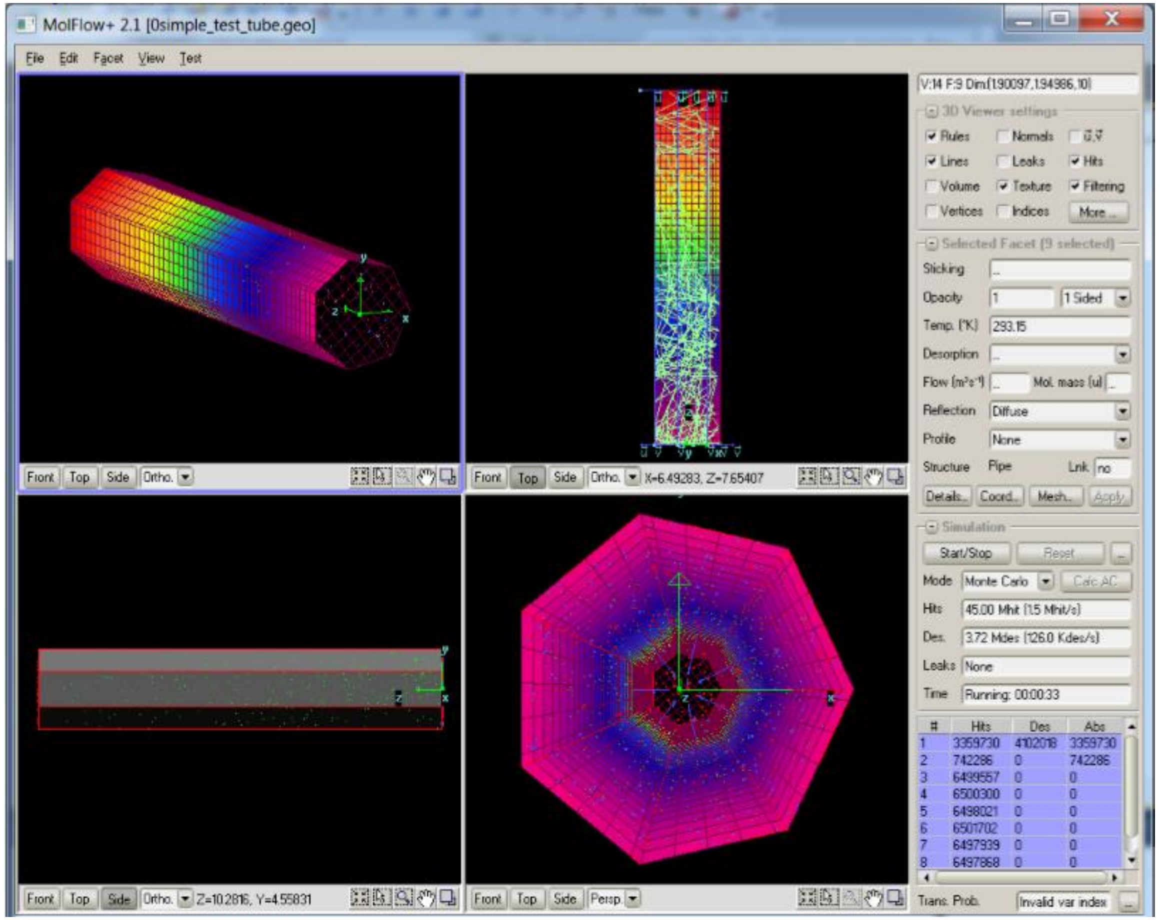


Molflow in a nutshell

MolFlow+ is a software developed at CERN in 1990 based on Monte Carlo method

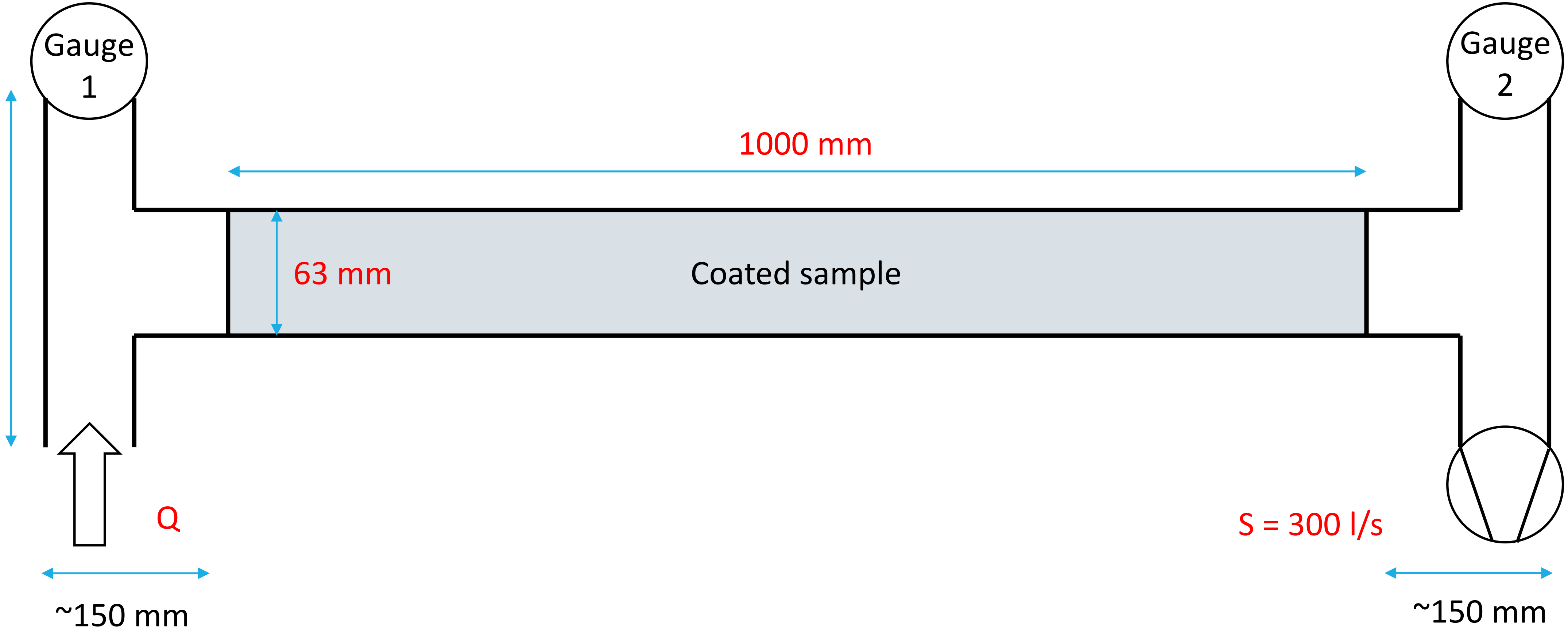
The software allows to:

- Draw a vacuum system
- Calculate pressure profiles for complex geometries in molecular flow regime
- In our case, evaluate the sticking probability α of NEG coating

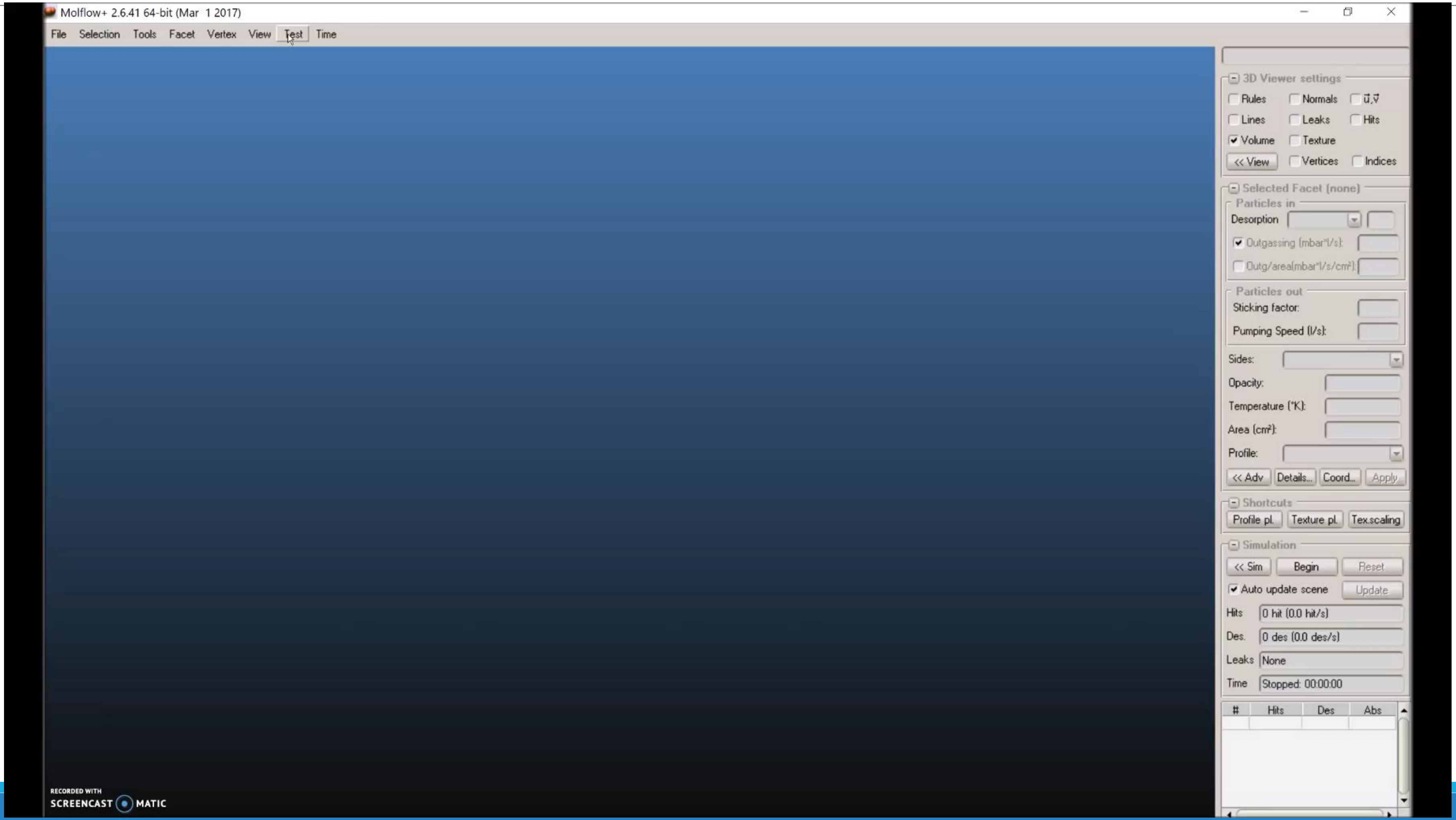


All the results can be visualized in a user friendly way and shown in a real time

Building the geometry



Building the geometry



Question 1: sticking probability and injection rate

Work out pressure ratio of two gauges

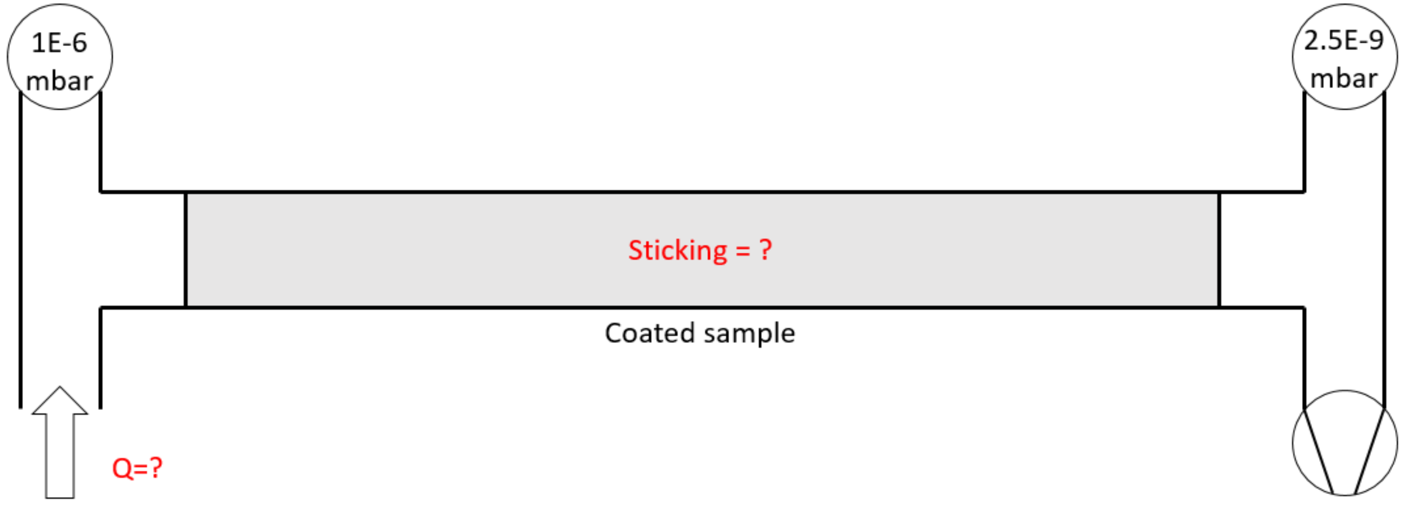
$$P_{ratio} = \frac{P_2}{P_1} = 2.5 * 10^{-3}$$

Apply sticking probability to obtain the same pressure ratio in Molflow

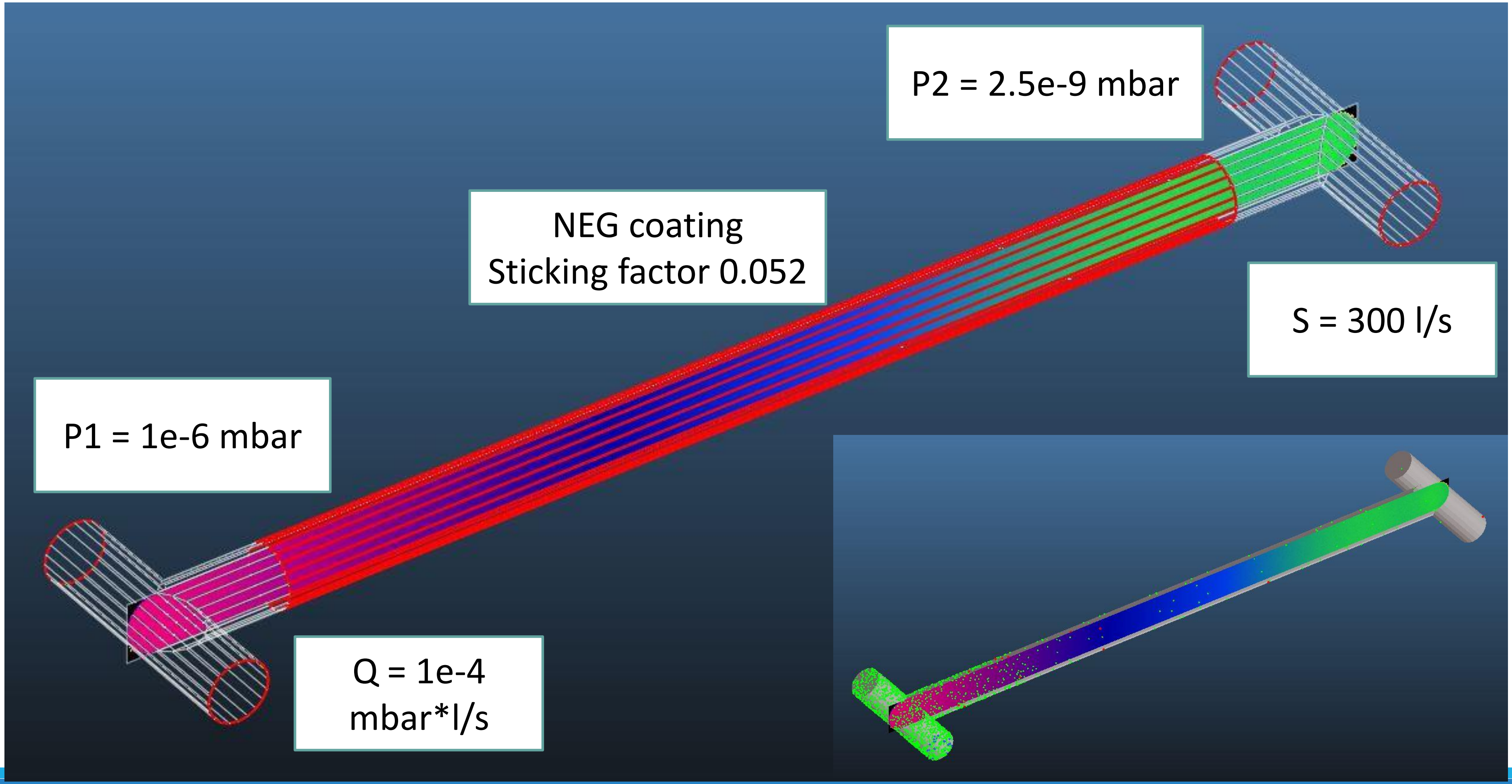
– 0.052

Set the gas injection rate in the simulation to get the same pressures as given above

– 0.0001 mbar*l/s



The complete system



Question 2

NEG coating is an effective pump, but it can't pump gas forever: eventually it saturates. Its pumping ability drops quickly when the pumped gas forms one monolayer on the surface – corresponding to about 1E15 pumped molecules/cm^2

In our setup, how much gas is that?

How much time does it take until our setup saturates?

Question 2: time for complete saturation - analytical way

How much time does it take until our setup saturates?

$p_1 = 1*10^{-6}$ mbar

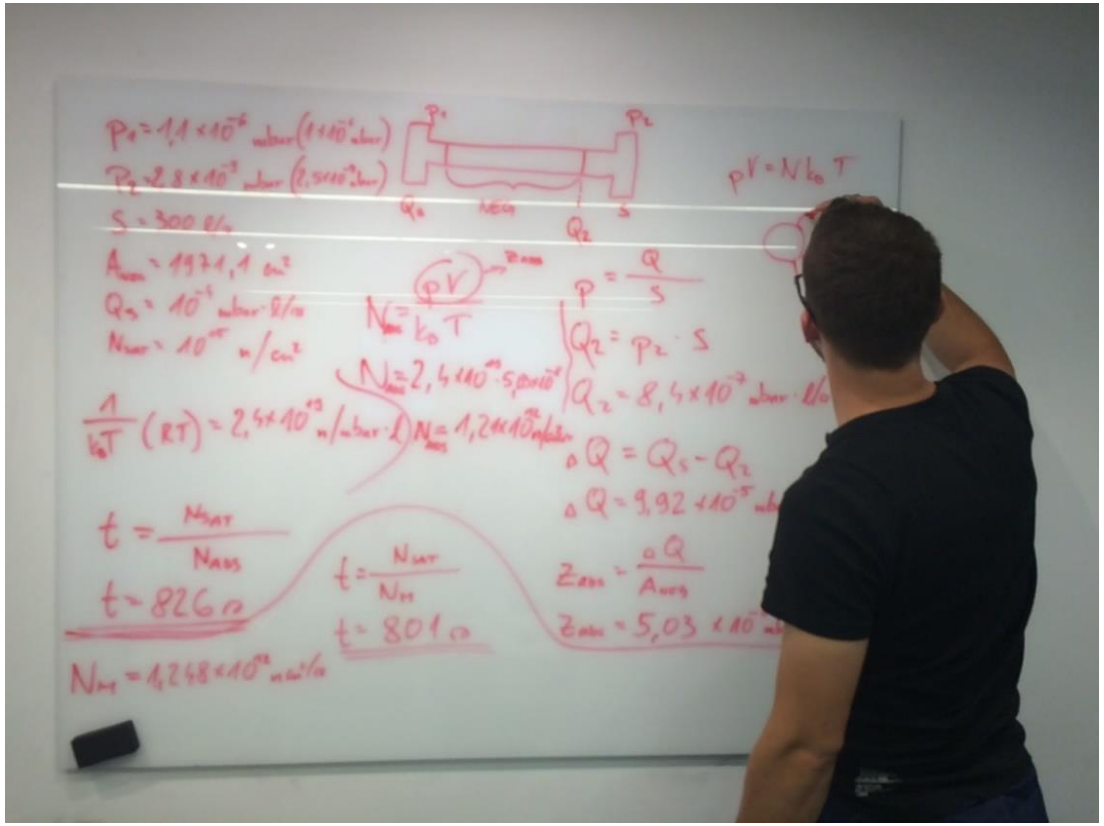
$p_2 = 2.5*10^{-7}$ mbar

$S = 300 l/s$

$A_{neg} = 1971.1 cm^2$

$Q_s = 10^{-4}$ mbar*l/s

$N_{sat} = 10^{15}$ molecules/cm^2



Question 2: time for complete saturation - analytical way

As first we calculate the gas load Q_2 after the NEG chamber:

$$p_2 = \frac{Q_2}{S}$$

$$Q_2 = p_2 * S = 8.4 * 10^{-7} \frac{mbar * l}{s}$$

To get the gas load absorbed by NEG coating we just subtract it from the total inlet gas:

$$\Delta Q = Qs - Q_2 = 9.92 * 10^{-5} \frac{mbar * l}{s}$$

By dividing with the total surface area of NEG chamber we get the absorption rate of coating:

$$z_{abs} = \frac{\Delta Q}{A_{neg}} = 5.03 * 10^{-8} \frac{mbar * l}{cm^2 * s}$$

Question 2: time for complete saturation - analytical way

With the ideal gas equation we get number of molecules absorbed by NEG surface area in a second:

$$p * V = N * k_b * T$$

$$N_{abs} = \frac{p * V}{k_b * T} = \frac{z_{abs}}{k_b * T} = 1.21 * 10^{12} \frac{molecules}{cm^2 * s}$$

With division of number of absorbed molecules with total number of molecules needed to saturate the film we gate the time before pumping speed of NEG drops to zero:

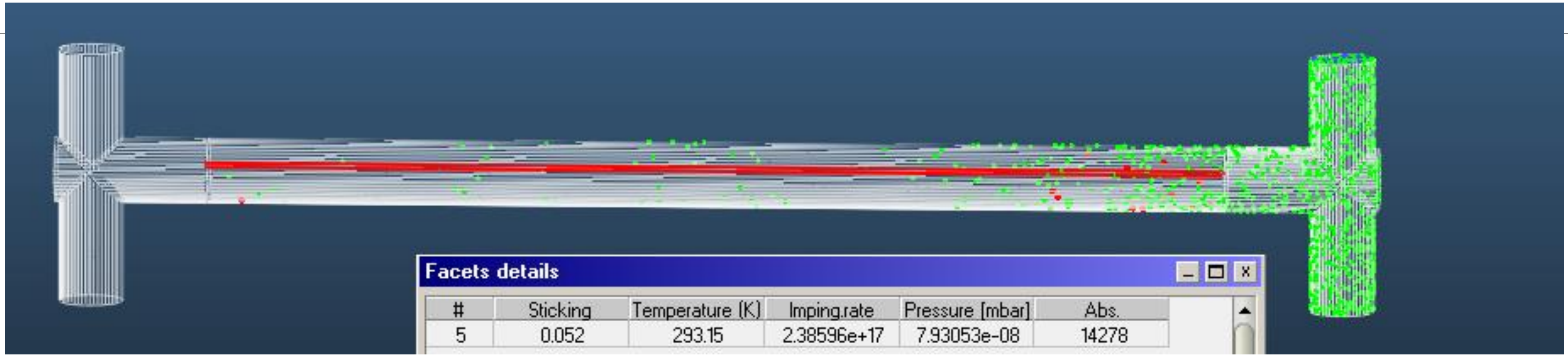
$$t_a = \frac{N_{sat}}{N_{abs}} = 826s$$

In our setup, how much gas is that?

$$N = N_{sat} * A_{NEG} = 1.97 * 10^{18}\text{molecules}$$

13.77 min

Question 2- time for complete saturation in Molflow



Engineering way: Using Molflow+ to solve the problem

1) Select a facet of the NEG area and read impingement rate : 2.4 x10^{17} molecules*m^{-2}*s^{-1} = 2.4 x10^{13} molecules*cm^{-2}*s^{-1}

2) The impingement rate times the sticking factor of the NEG of 0.05 gives us the number of absorbed particles per area N_{abs} = 1.2x10^{12} molecules*cm^{-2}*s^{-1}

3) We know that NEG coating is saturated at N_{sat} =10^{15} molecules*cm^{-2}

4) The full saturation is reached at t=N_{sat}/N_{Abs}

t=10^{15} molecules*cm^{-2}/2.4 x10^{13} molecules*cm^{-2}*s^{-1}= 833 s

13.88 min

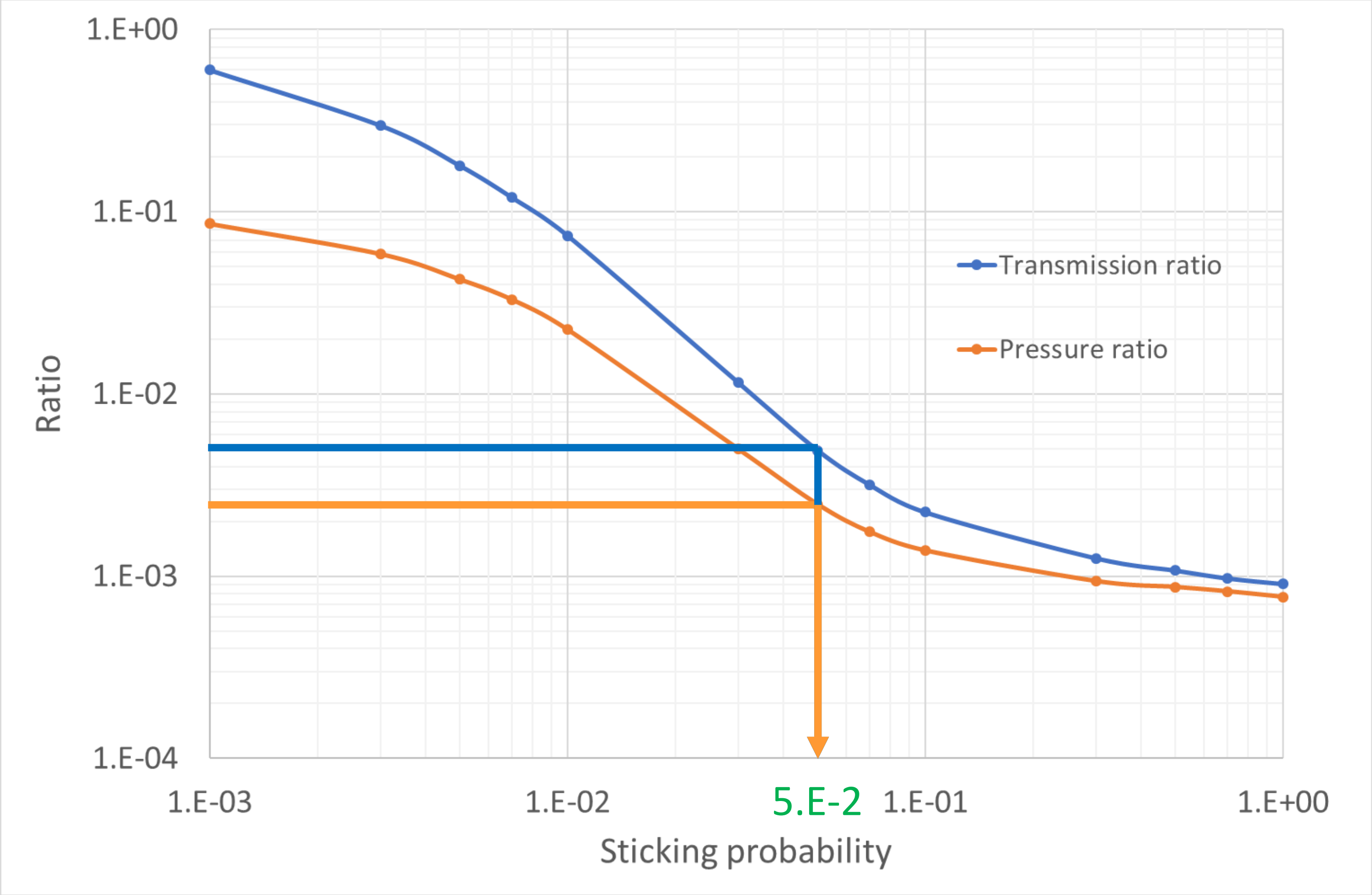
Question 3

What was the transmission ratio of the gas for the pressure ratio given in the task?

By changing the simulation parameters, make a “transmission ratio as a function of the sample’s sticking factor” plot given that:

- X axis: different sticking factor values (around 5-7 different values)
- Y axis: gas transmission ratio

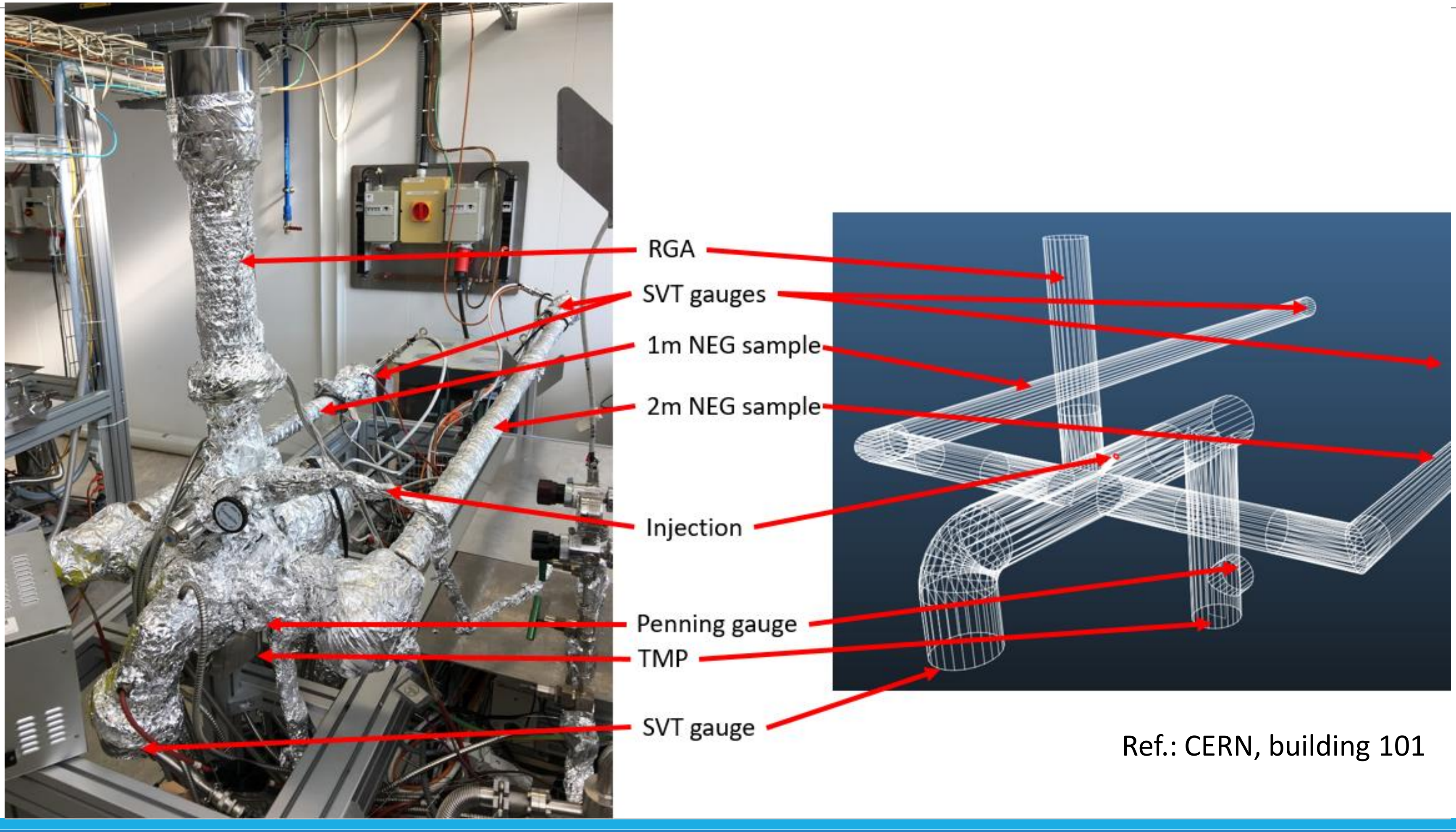
Question 3: trans. probability and pressure ratio as a function of α



$$T_{ratio} = \frac{N_{abs}}{N_{inj}} = 5 * 10^{-3}$$

$$P_{ratio} = \frac{P_2}{P_1} = 2.5 * 10^{-3}$$

Real life applications



Ref.: CERN, building 101

Reference paper

The CERN Accelerator School

CERN

PERGAMON

Vacuum 60 (2001) 67–72

VACUUM

SURFACE ENGINEERING, SURFACE INSTRUMENTATION & VACUUM TECHNOLOGY

www.elsevier.nl/locate/vacuum

Synchrotron radiation-induced desorption from a NEG-coated vacuum chamber

P. Chiggiato[a,*], R. Kersevan[b,1]

[a]*CERN, Organisation for Nuclear Research, EST Division SM Group, CH-1211 Geneva 23, Switzerland*

[b]*ESRF, European Synchrotron Radiation Facility, BP 220, F-38043 Grenoble, France*

Abstract

When the whole inner surface of a vacuum chamber is coated with a non-evaporable getter film, very low static and dynamic pressures are expected after activation. In an accelerator environment this could result in a longer beam lifetime, in a lower risk of pressure bumps, and in a lower level of bremsstrahlung radiation due to the beam–gas interactions. To substantiate these favourable characteristics a Ti–Zr–V coated stainless-steel chamber has been tested on a dedicated beamline at the ESRF. It is shown that a large reduction of the synchrotron radiation-induced desorption occurs after activation.

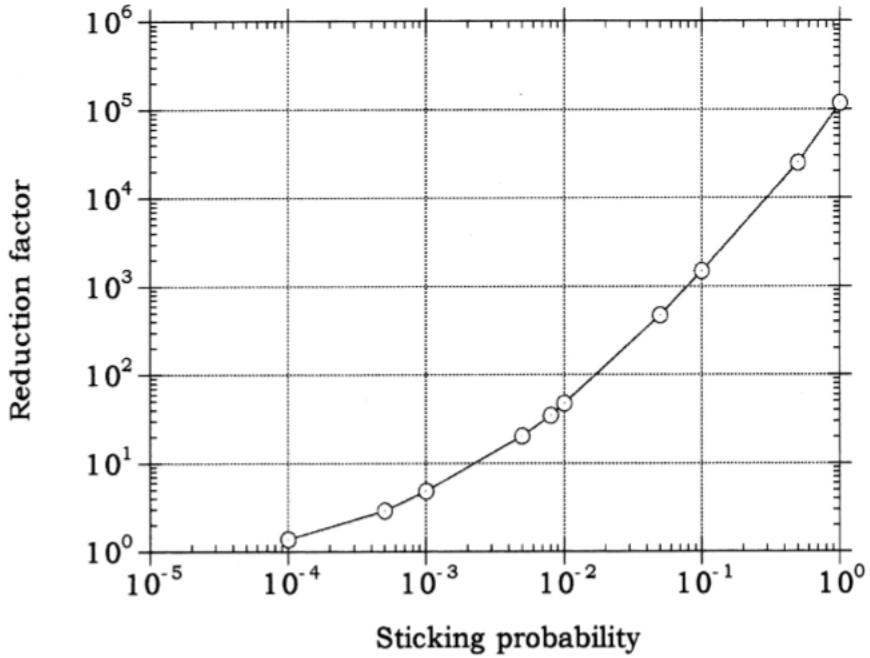


Fig. 3. Pressure reduction factor as a function of the coating sticking probability obtained by Monte-Carlo simulation assuming a constant gas load before and after activation.

Conclusions

Tutorial based on a real world application

The same problem was addressed analytically and numerically

With the basic knowledge of vacuum technology, Molflow becomes a very powerful tool

Final conclusion
Hard work & Ice cream

The CERN Accelerator School

CERN