Wrocław University of Science and Technology

HP side CFD simulations

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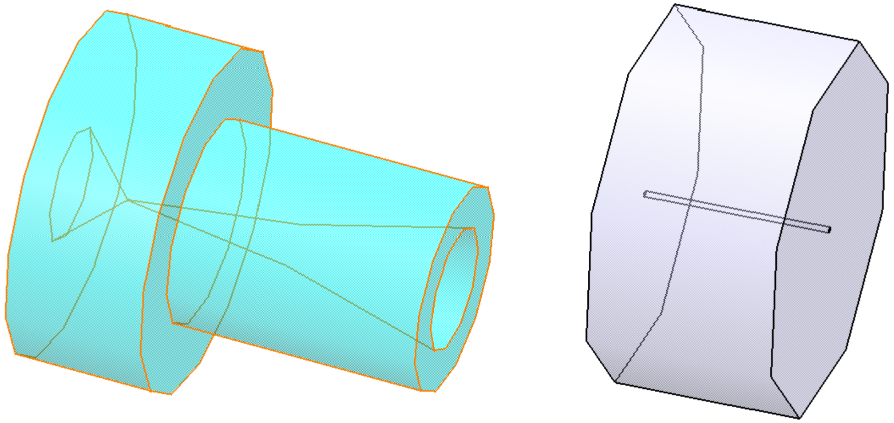
BGC Collaboration Meeting

Hotel Krone, Hirschberg

2018-03-19

Agenda

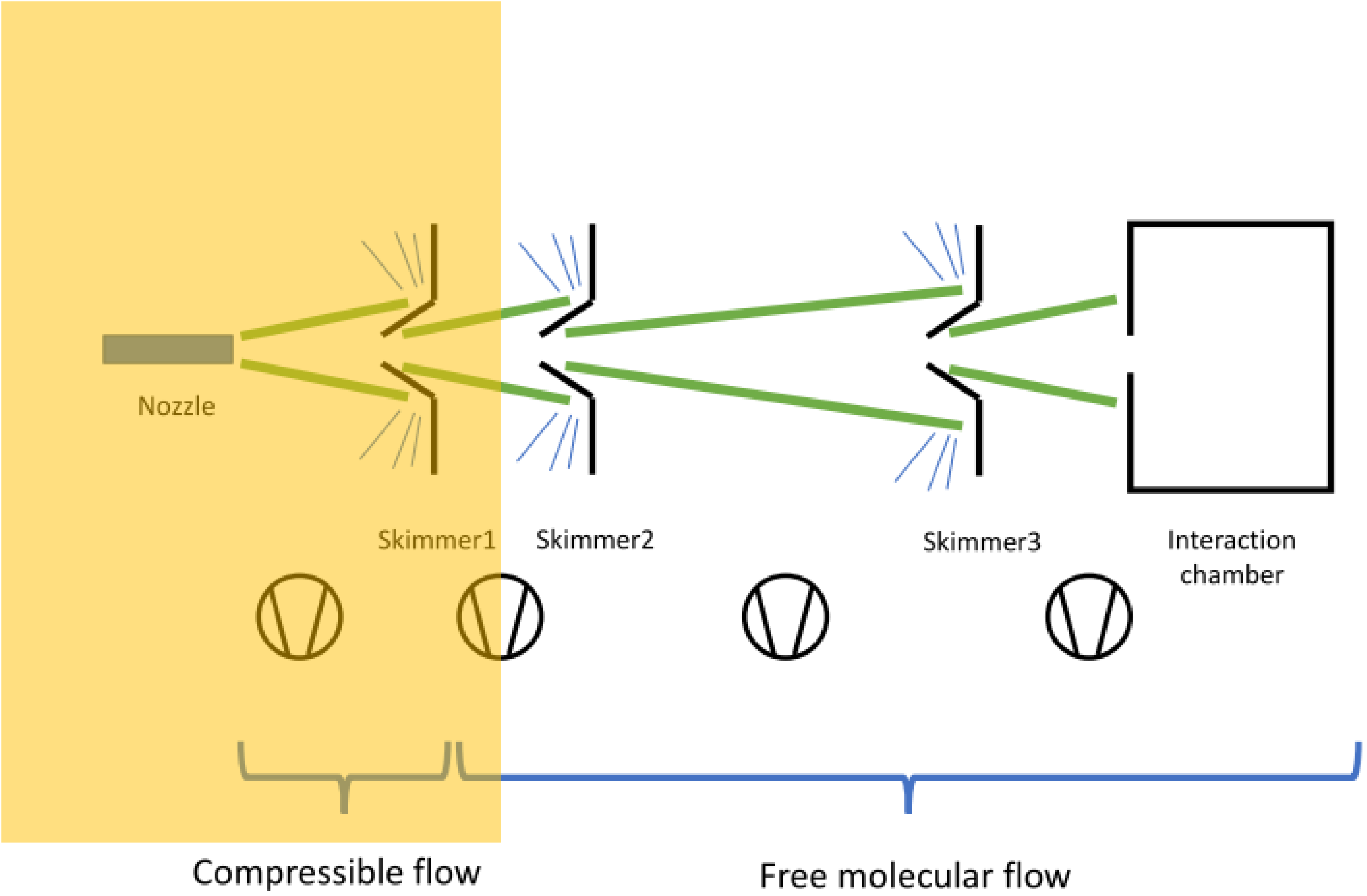
- Work done so far – a brief summary
- What we have learned from the CFD simulaitons
  - Nozzle parameters dependences
  - Gas temperature after expansion
  - Impact of the first skimmer
- Nozzle optimization
- Further development of the simulaitons



Abbrevaitions used in the presentation:

- Simple Geometry nozzle -> SG
- de Laval nozzle -> DL

Gas jet formation



Work done so far in CFD

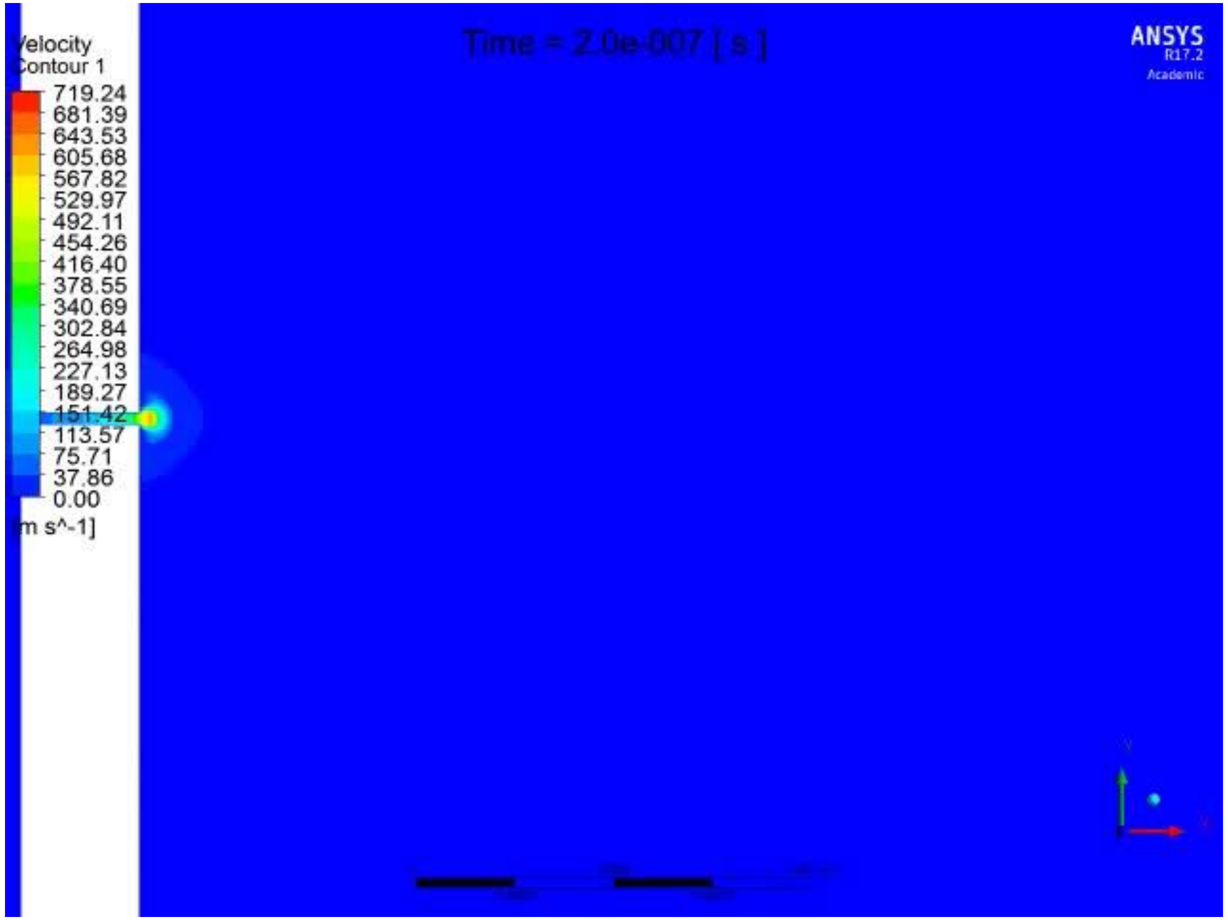
- Formation of the gas jet for SG in time *– without the skimmer*
- Comparison between SG and DL *– without the skimmer*
- Simulations with the 1^{st} skimmer for SG and DL
- Comparison between different boundary conditions for DL

<u>Some statistics:</u>

- Solved over 79 different simulations, from which approx. 80% were used as an initial value for single case: One case consist of 3 to 5 initial value simulations
- Time for single simulation ~ 6h
- Processor core used: from 8 to 16 per one simulation
- RMS error target 10^{-7}

Forming of a jet – first $1 \cdot 10^{-5}$ s

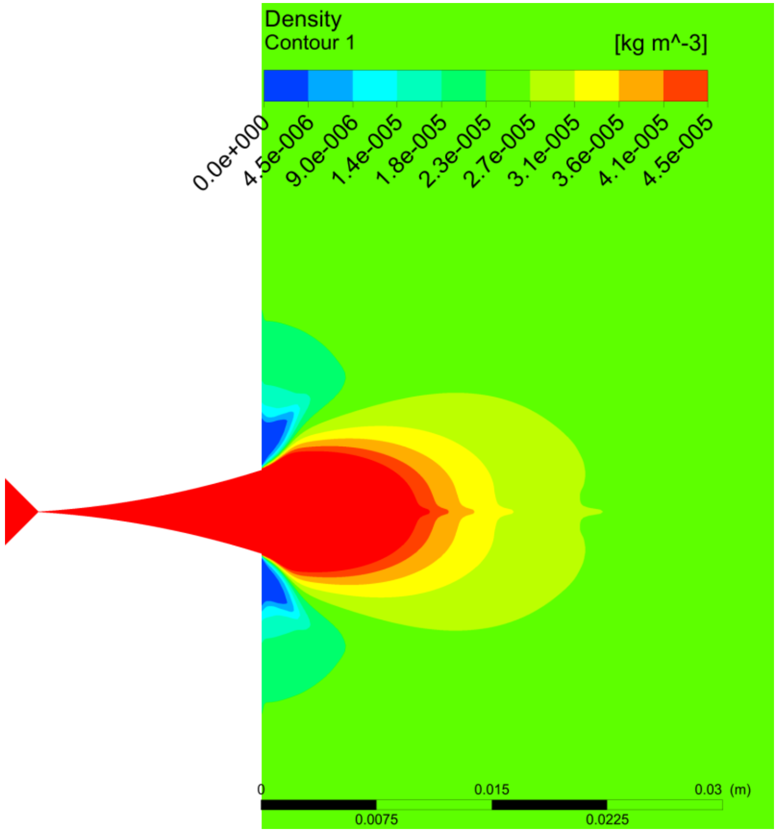
Jet formation into high vaccum needs less than 1e-5 s to fully developed a stable stream



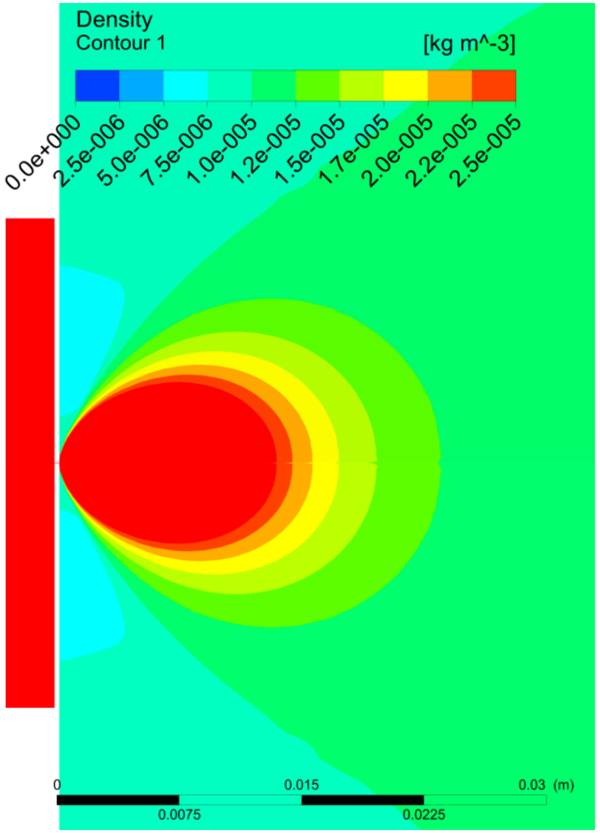
Density Profile – comparison of the nozzle design

nozzle throat 30 μm

De Laval



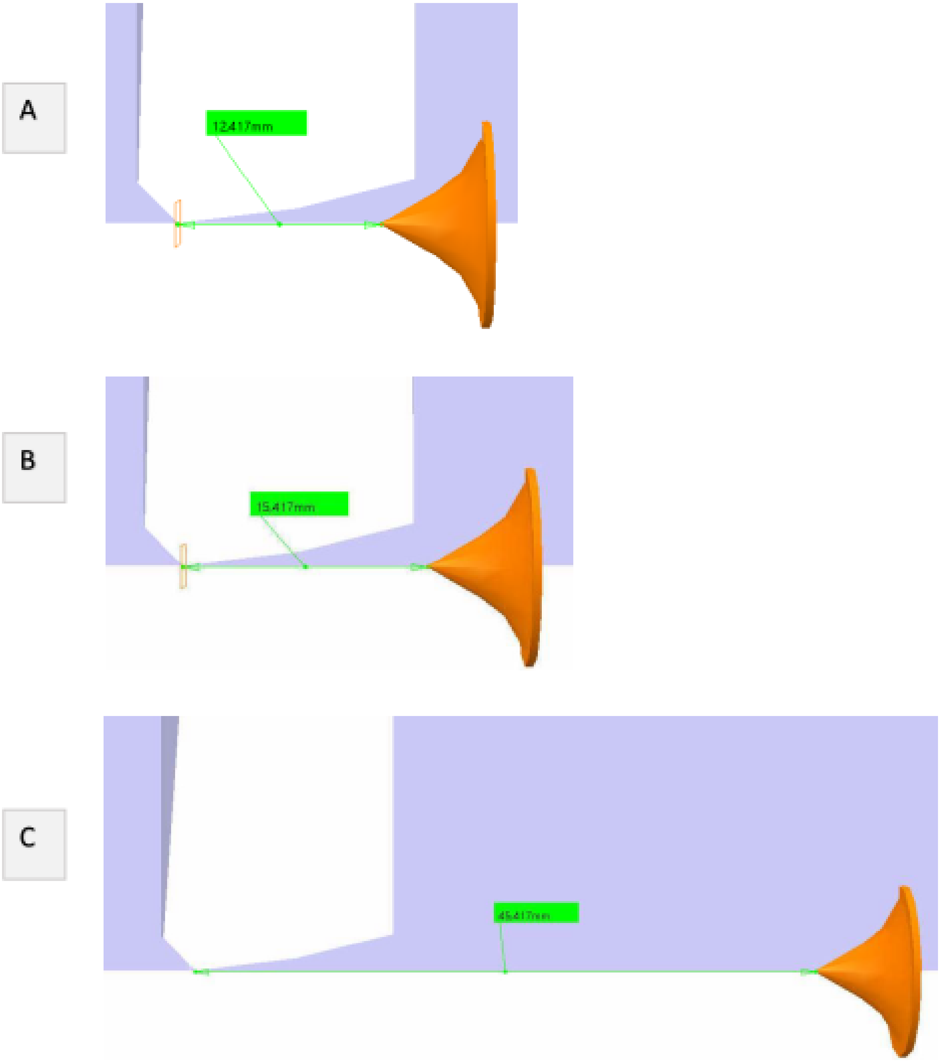
Simple Geometry

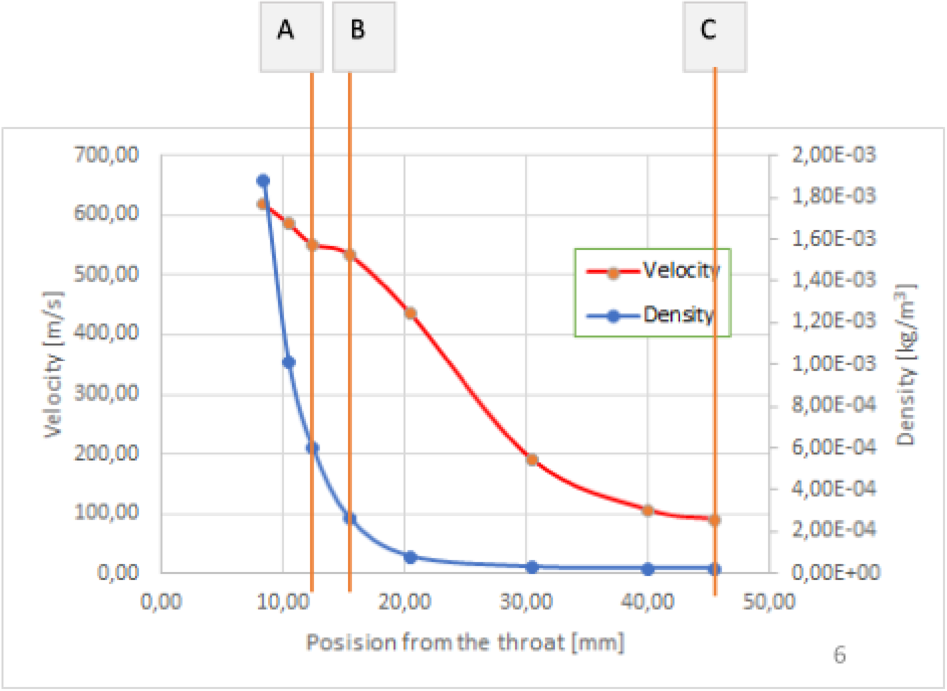


Taking into consideration the same boundary conditions, the de Laval (convergent-divergent) nozzle shows higher density profile, which is around 2 times higher in comparison to simple geometry nozzle.

Influence of the distance to the throat cross-section

Free parameters, high pressure part

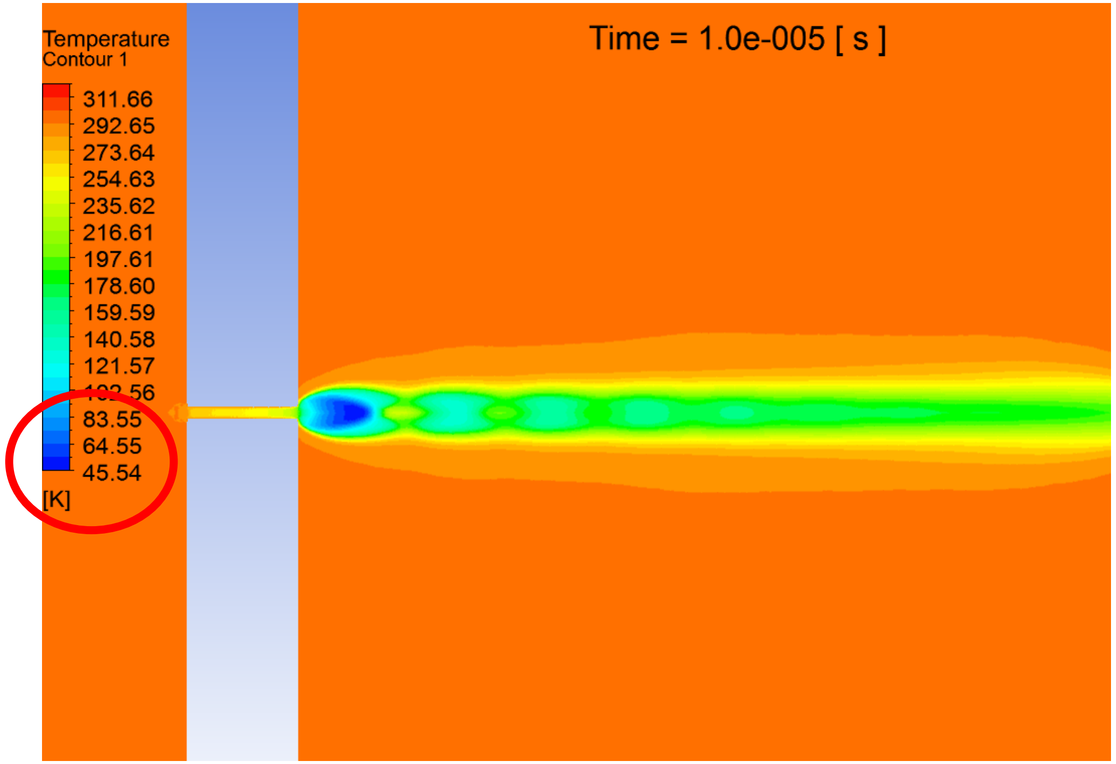


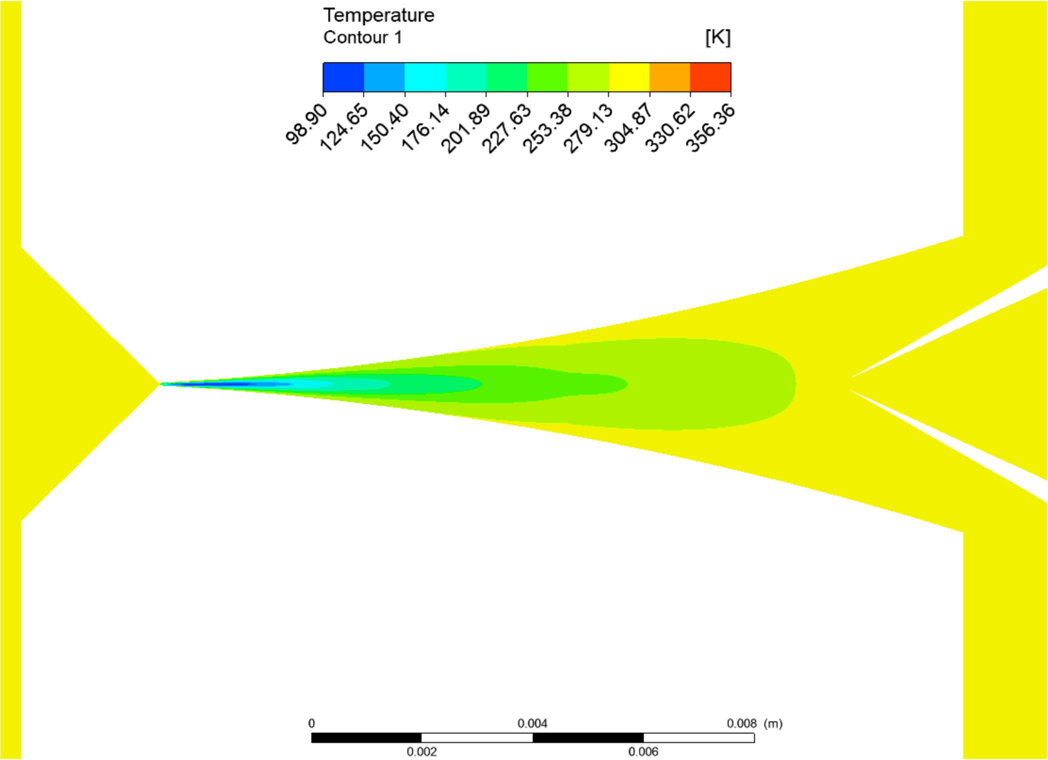


Gas temperature after expansion

SG
Tin = 20^{o}C
Pin = 10 bar
Pout = 1.0 mbar

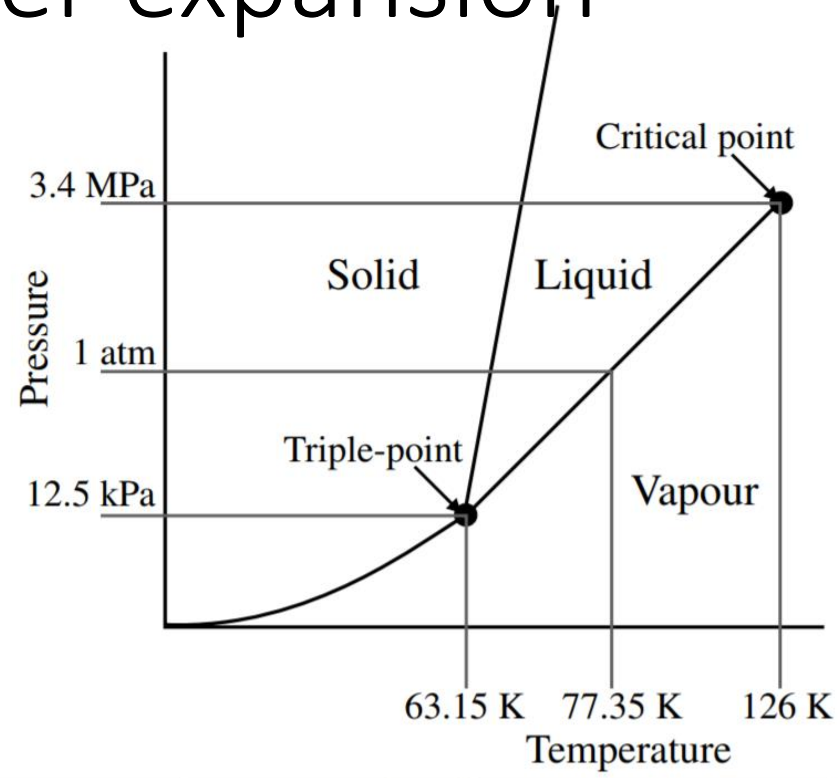
DL
Tin = 20^{o}C
Pin = 3 bar
Pout = 0 Pa





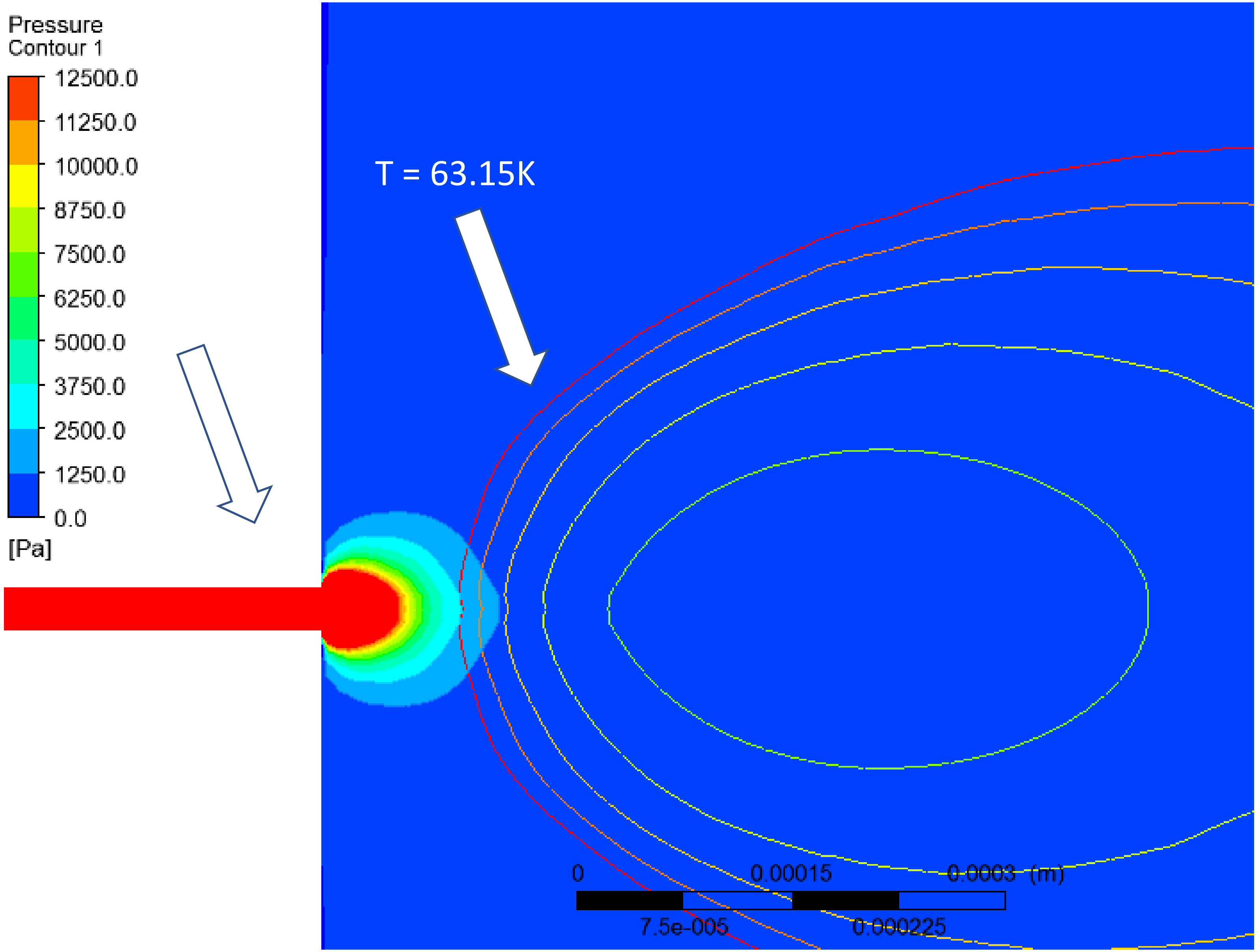
Gas temperature and pressure after expansion

- After expansion of a gas is possible to reach the cryogenic temperature of the medium
- It could be dangerous in order to:
  - reach a liquid or sold state at the end of expansion
  - simulation results obtained for a single phase medium will be wrong



	T_{liquid} @ 1bar	T @ triple-point	p @ triple-point
Nitrogen	77.35 K	63.15 K	12.50 kPa
Argon	87.30 K	83.81 K	68.89 kPa
Neon	27.10 K	24.56 K	43.37 kPa

SG
Tin = 20°C
Pin = 10 bar
Pout = 1.0 mbar
Steady-state simulation

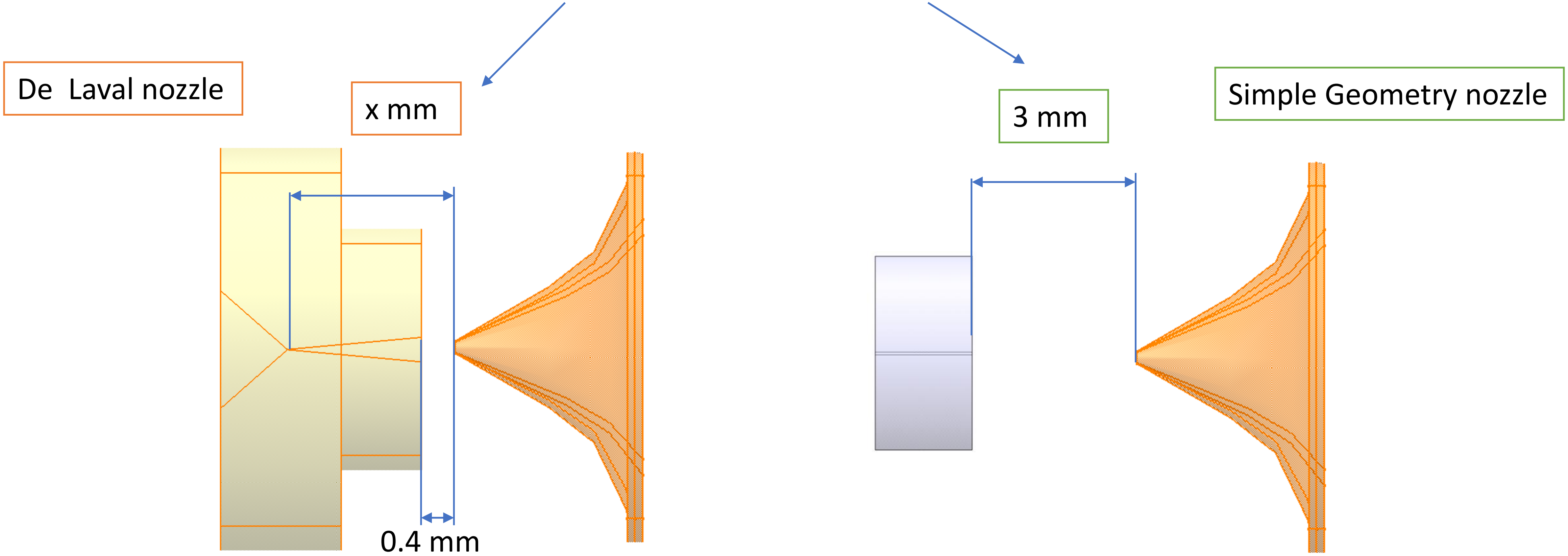


Nozzle optimization
Comparison criteria

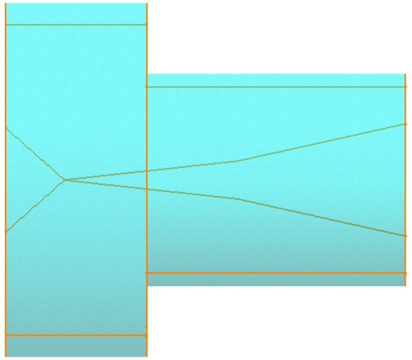
Gas: Nitrogen

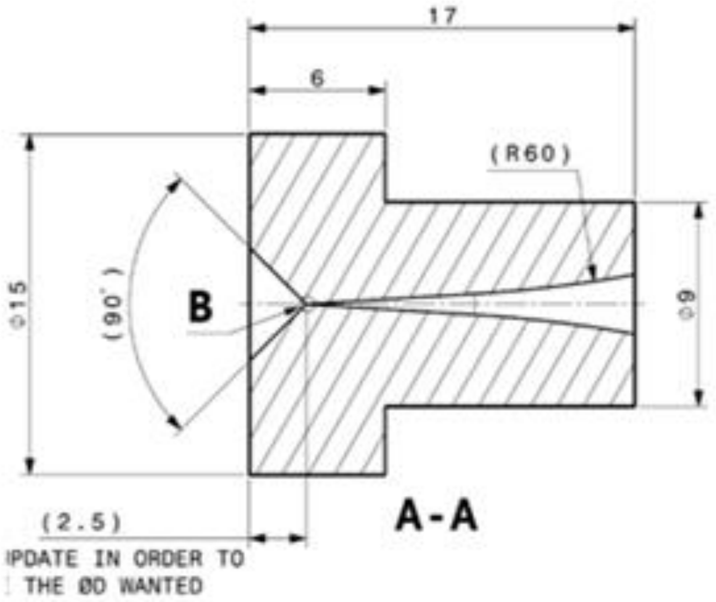
Nozzle throat 30µm

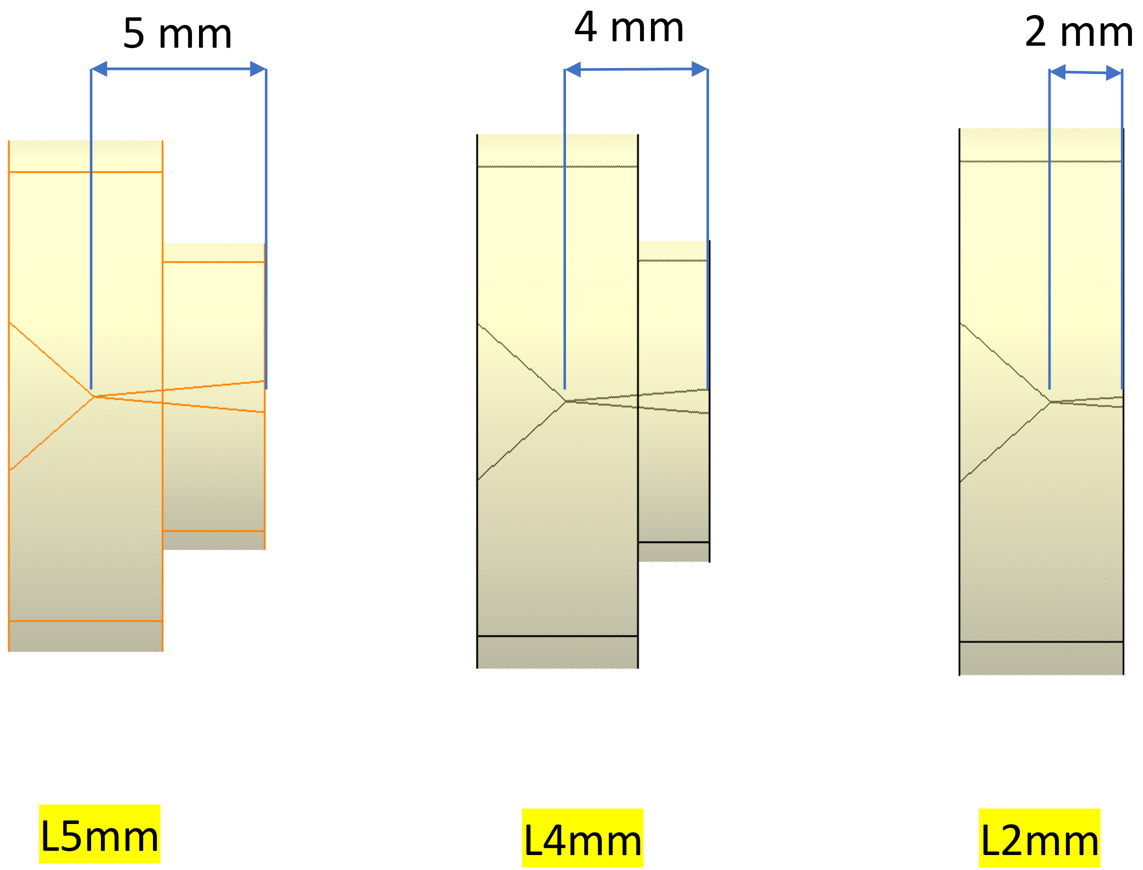
- For the comparison of the both nozzle constructions was chosen the distance between critical nozzle diameter and 1st skimmer inlet



Modification of the nozzle shape – divergent part of the nozzle



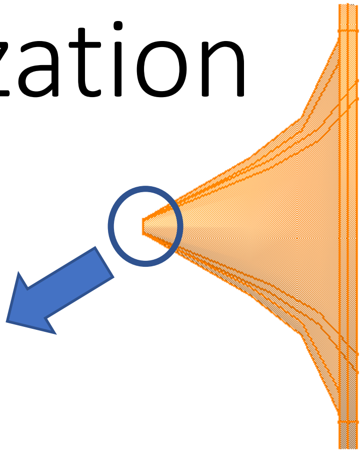


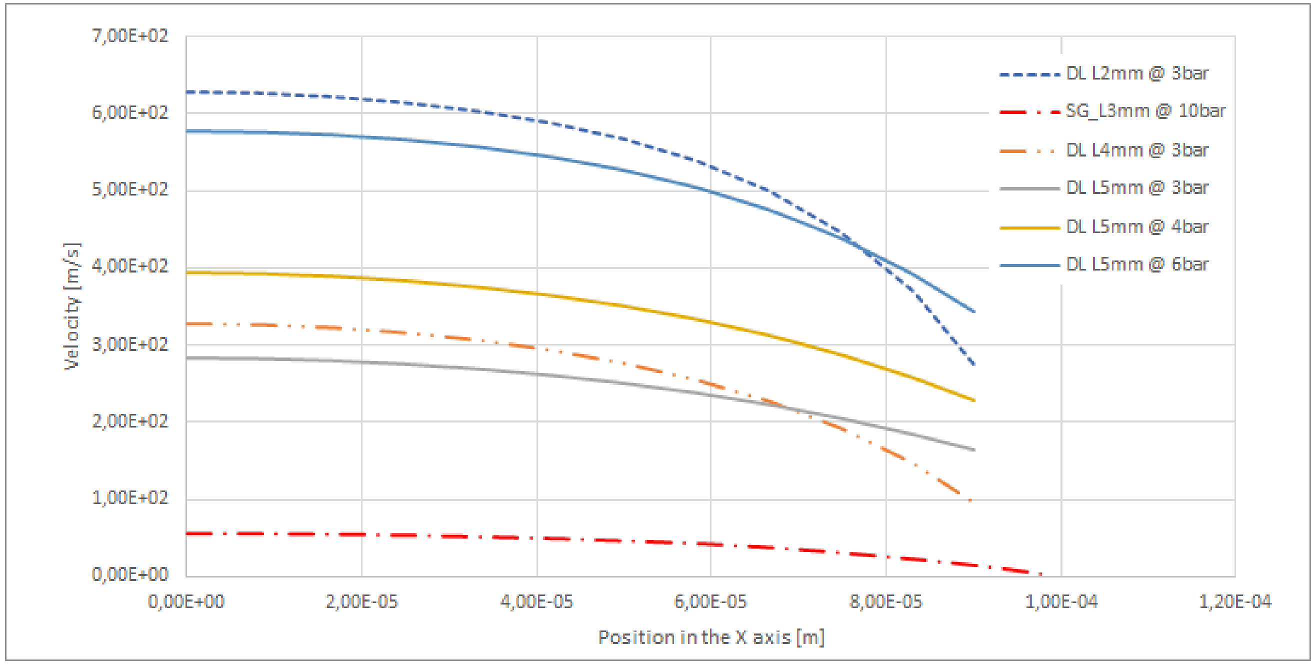


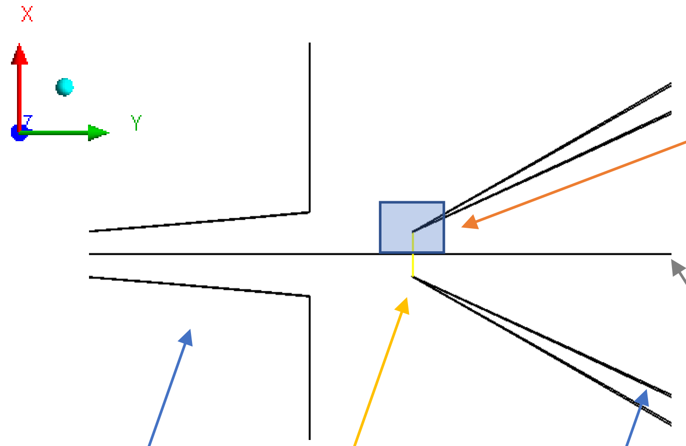
Nozzle optimization

Gas: Nitrogen

Nozzle throat 30µm







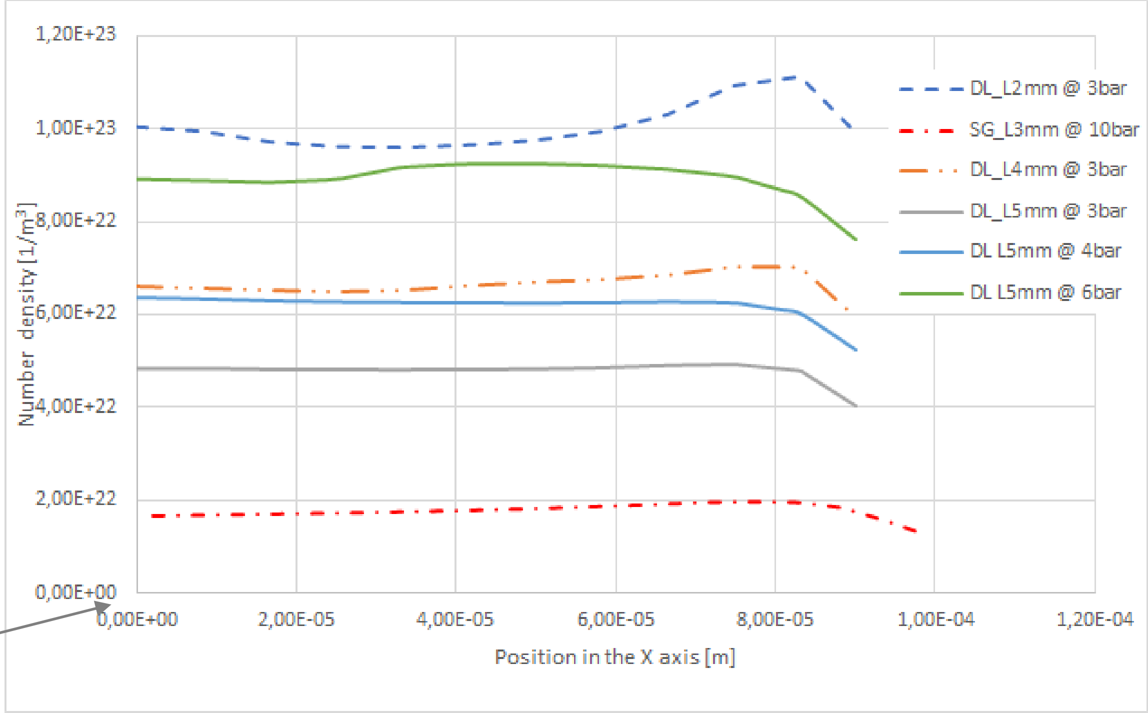
Only half of the domain is considered

The data line

nozzle

skimmer

Symmetry axis

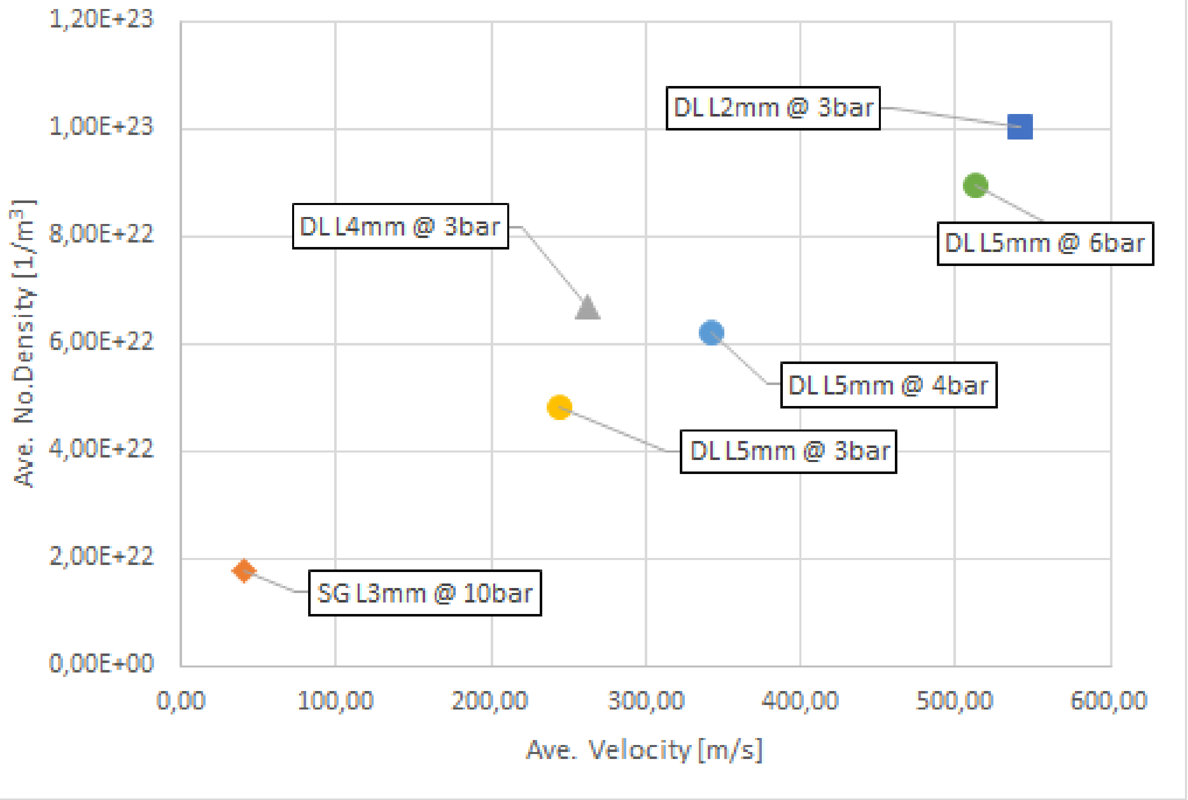


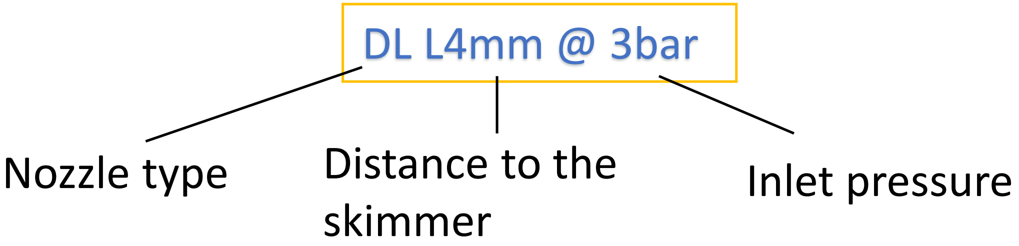
Nozzle optimization

Gas: Nitrogen

Nozzle throat 30µm

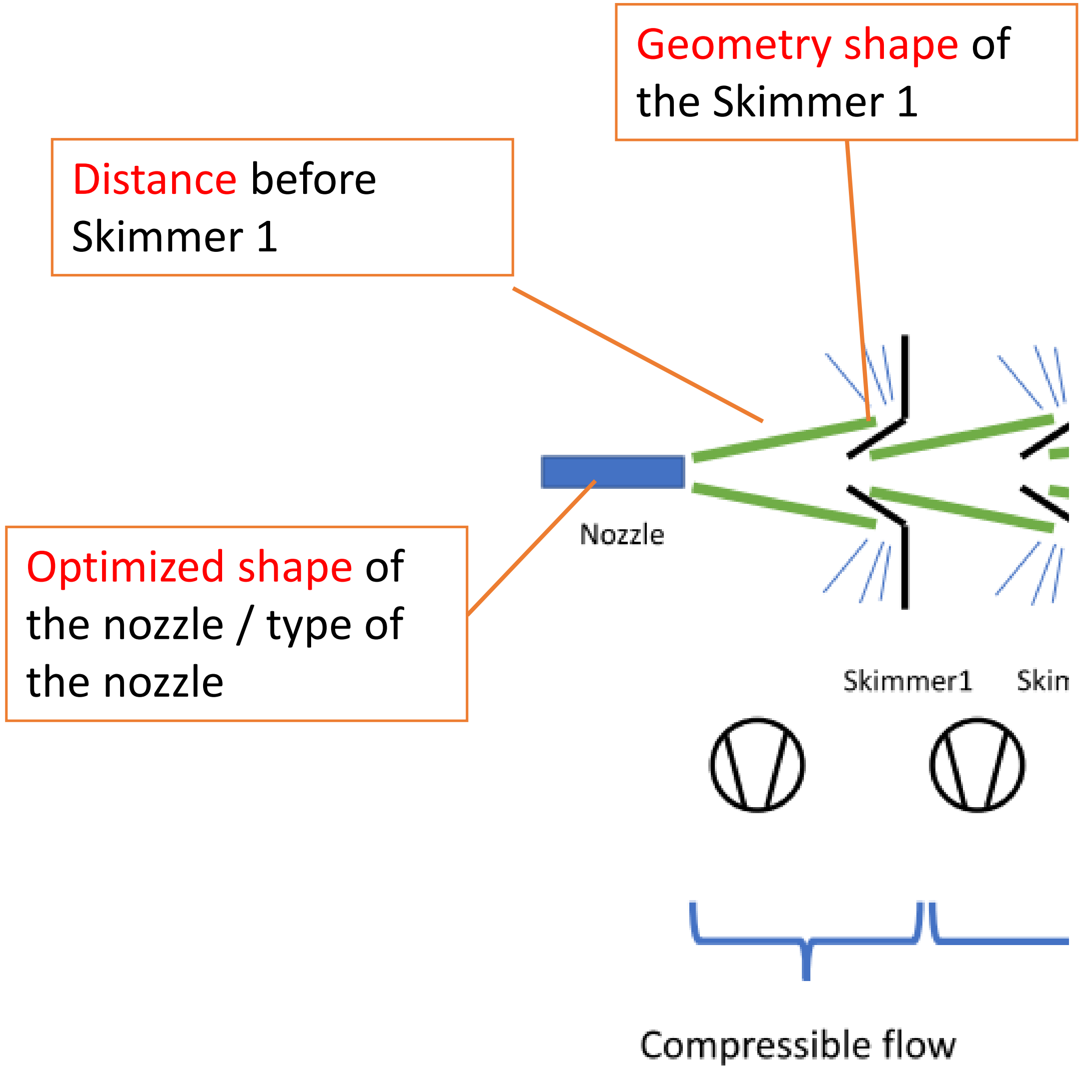
- By extending the numerical simulation procedure it is possible to obtain an optimal solution for given requirements
- To perform the next step of the simulation, the boundary conditions need to be set up (minimal/maximal density level at skimmer inlet or velocity value)





Next steps

- Influence of the Skimmer wall thickness on overall nozzle performance.
- Shape modification in order to increase the density of the gas at the Skimmer inlet.
- Simulations for different gas mediums (Argon, Neon…)
- Optimization of major dimensions in order to get high speed, uniform, dense gas jet at the Skimmer together with reduction of mass stream at the nozzle outlet
- Reduction of the mass stream to meet the requirements of the project -> pulsating gas stream formation ?



Concluions

- Numerical simulations for HP side show that higher densities and velocities at the first skimmer inlet are possible to obtain by convergent-divergent, de Laval nozzle
- Optimization of the high pressure side could be performed in various options in case of using DL
- Parameters at a nozzle have to be controlled in order to avoid liquefaction or solidification of the jet medium

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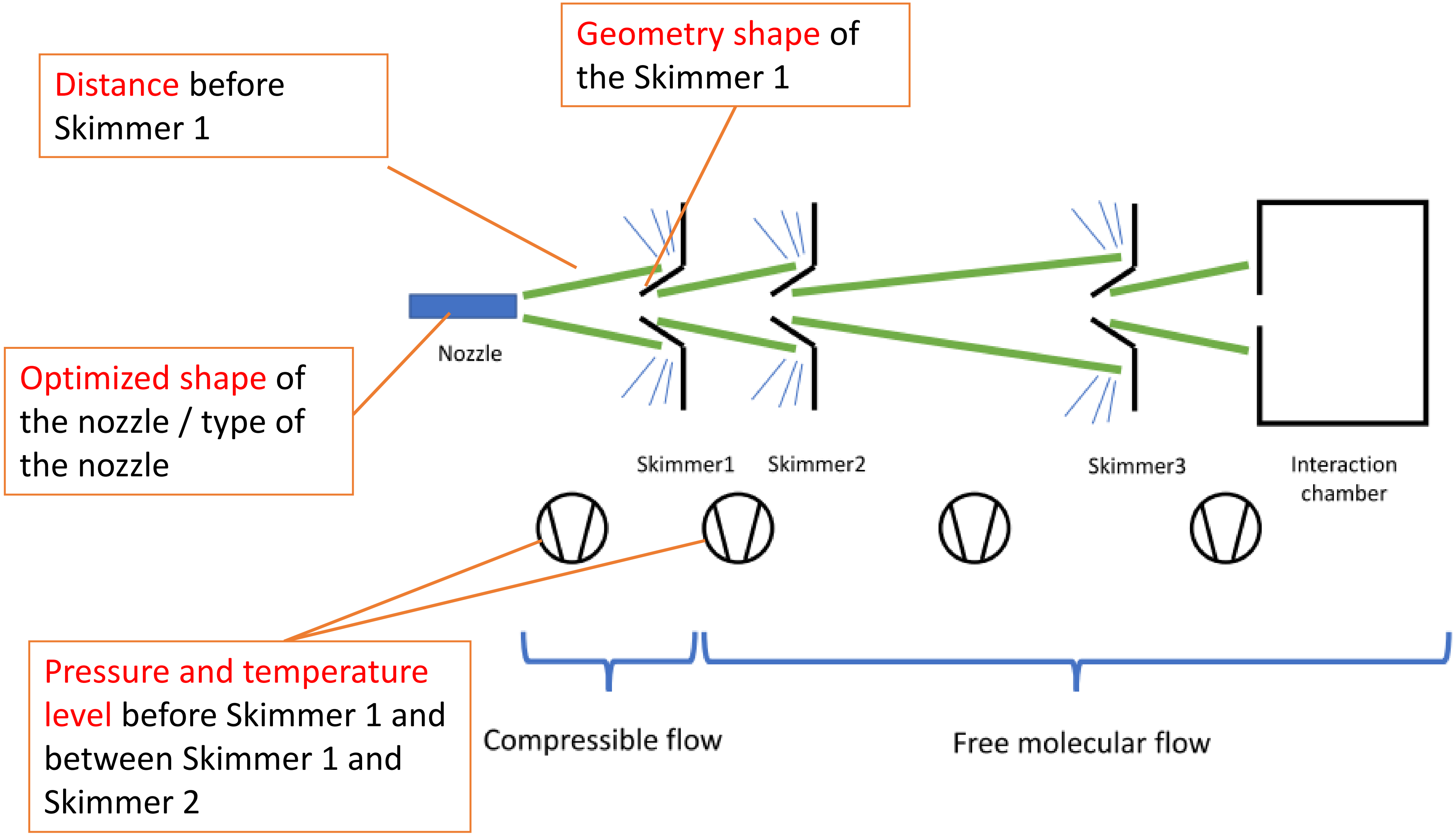
Thank you for your attention

Still to consider in HP side …



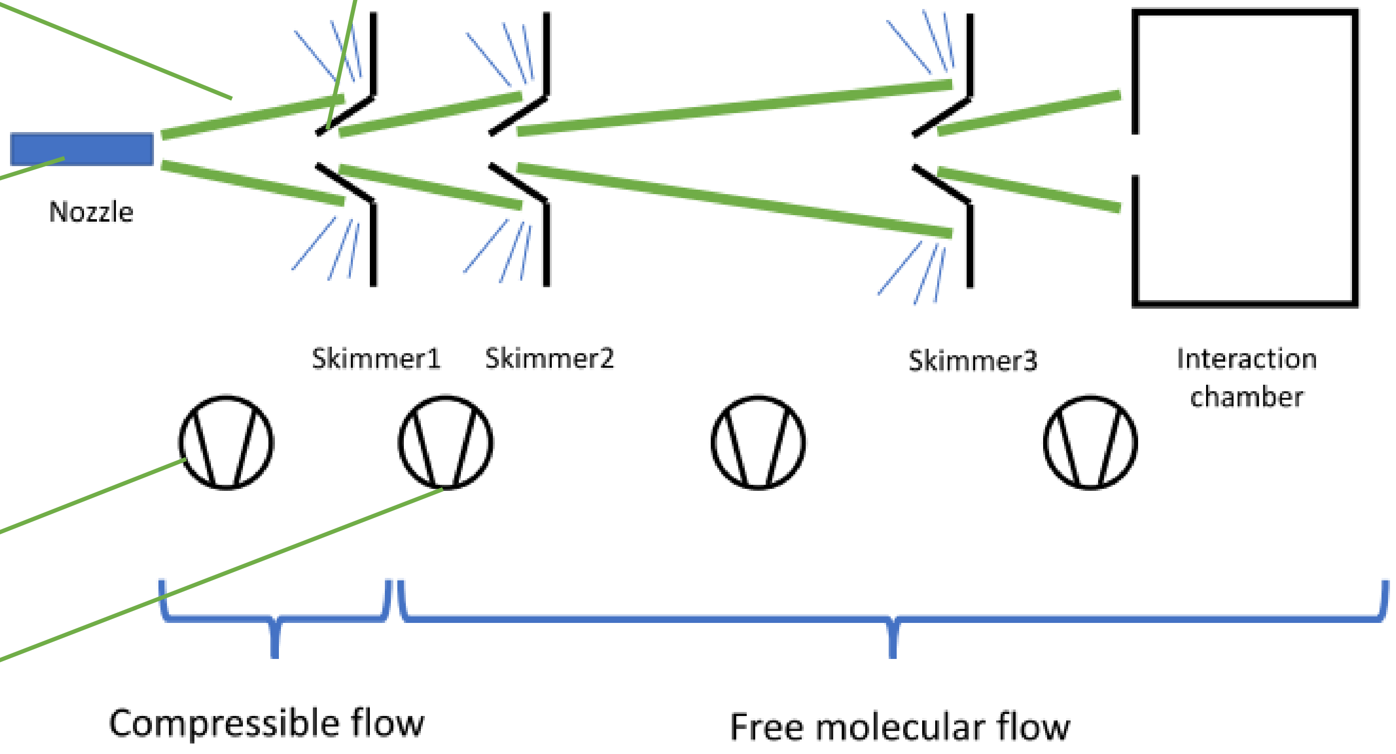
Bounadry conditions

Gas: Nitrogen

Zero thickness
Skimmer inlet

Distance:
position A
(prev. Slide)

DeLaval nozzle 30μm throat; 3 bar Inlet pressure



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Pressure 1 Pa (absolute)
Temperature 20°C

Pressure 0 Pa (absolute)
Temperature 20°C

T-s diagram for nitrogen