Wrocław University
of Science and Technology

de Laval Micro-nozzle

comparison with simple geometry nozzle

CFD simulations in 2D

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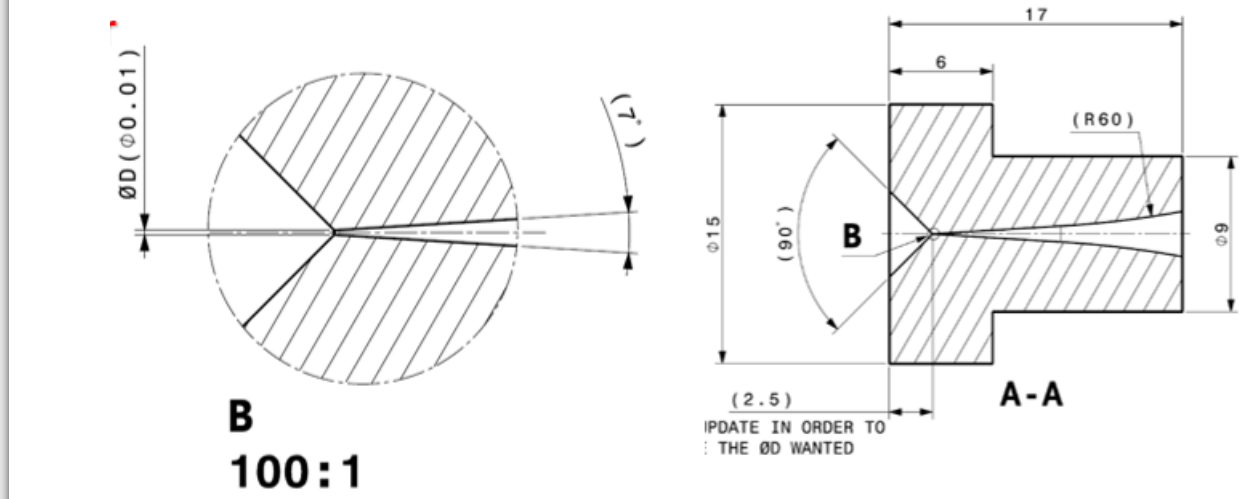
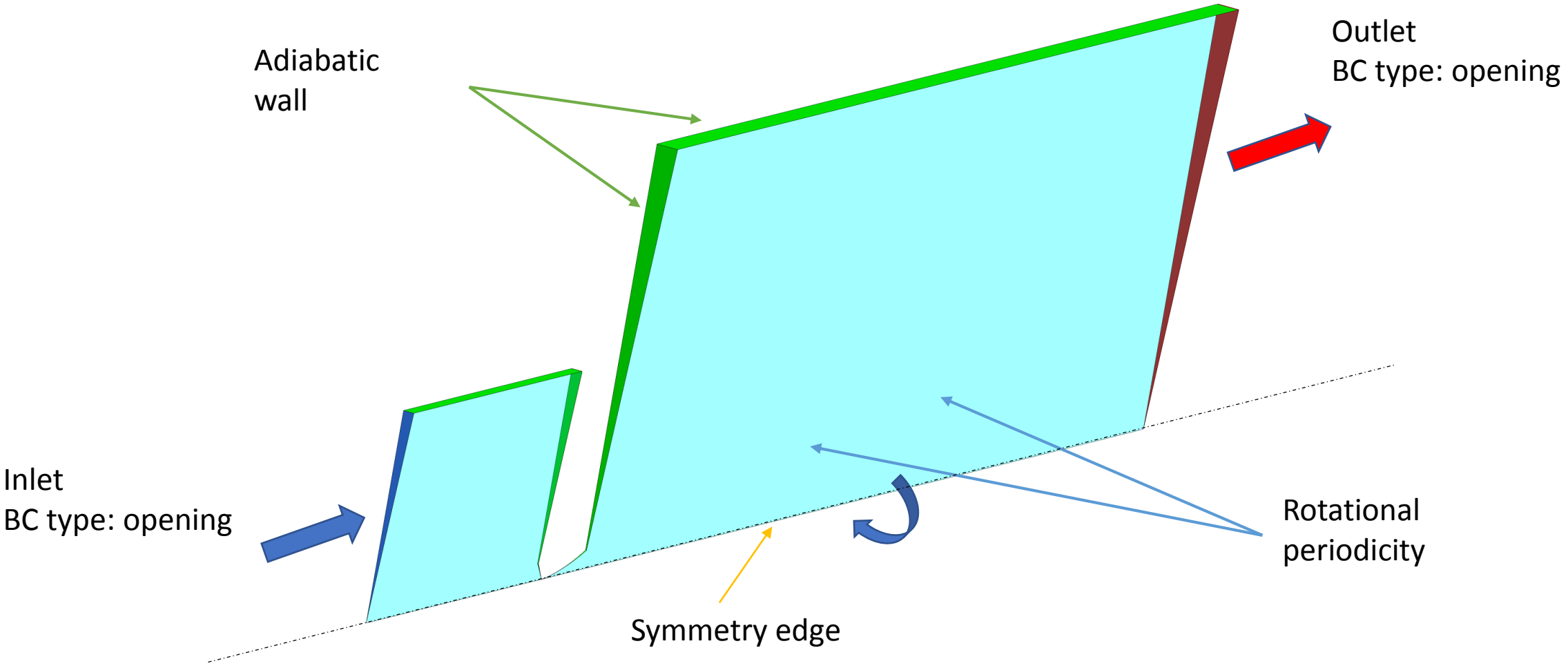
Specification

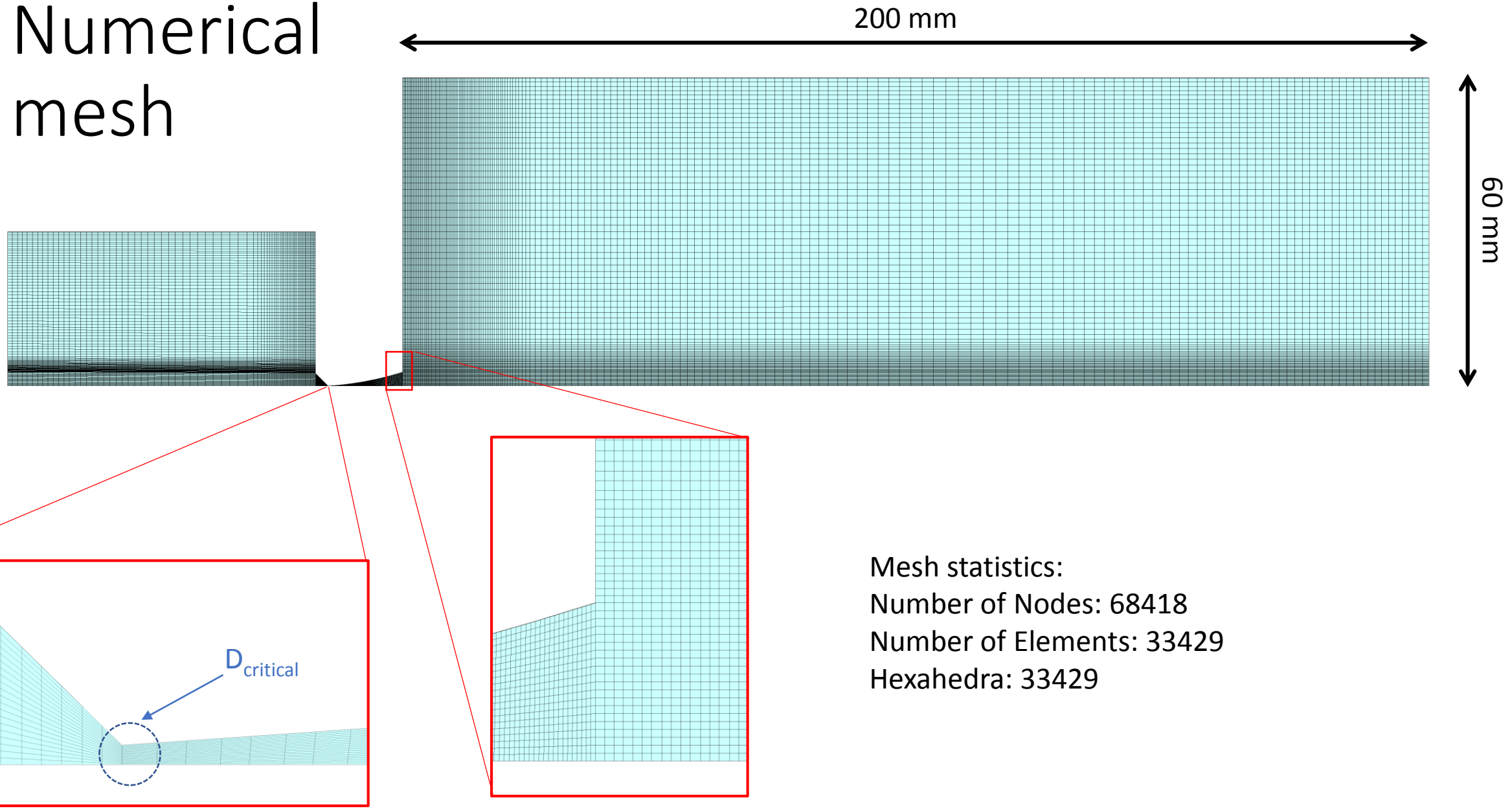
- Dimensions for de Laval nozzle was taken from the file delivered from the CERN machine shop
- In the present research has been shown the comparison between a „de Laval” nozzle and simple geometry nozzle (previos calculations given by Paolo)
- Simulations were performed for nitrogen



Numerical Domain: 2D simulation



Numerical mesh



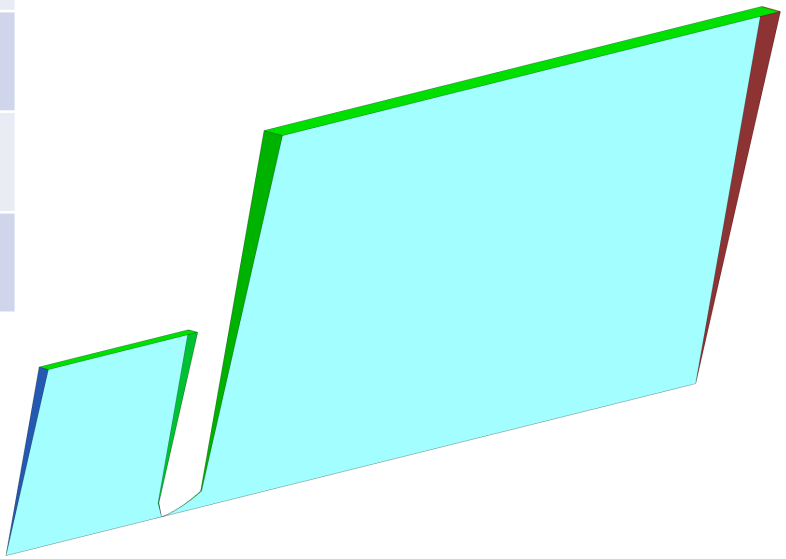
Mesh statistics:
Number of Nodes: 68418
Number of Elements: 33429
Hexahedra: 33429

Detailed view on mesh close to neuralgic part of the domain

Boundary conditions

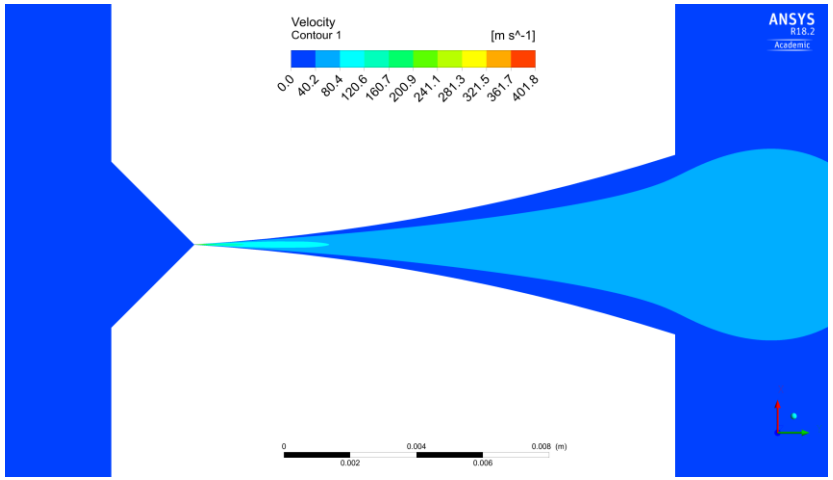
Case no.	Inlet		Outlet	
	Pressure*	Temperature	Pressure*	Temperature
$D_{critical}$ = 10 microns				
1	1 bar	20°C	0 Pa	20°C
2	3 bar	20°C	0 Pa	20°C
3	10 bar	20°C	0 Pa	20°C
$D_{critical}$ = 30 microns				
4	10 bar	20°C	0 Pa	20°C

* - absolute pressure



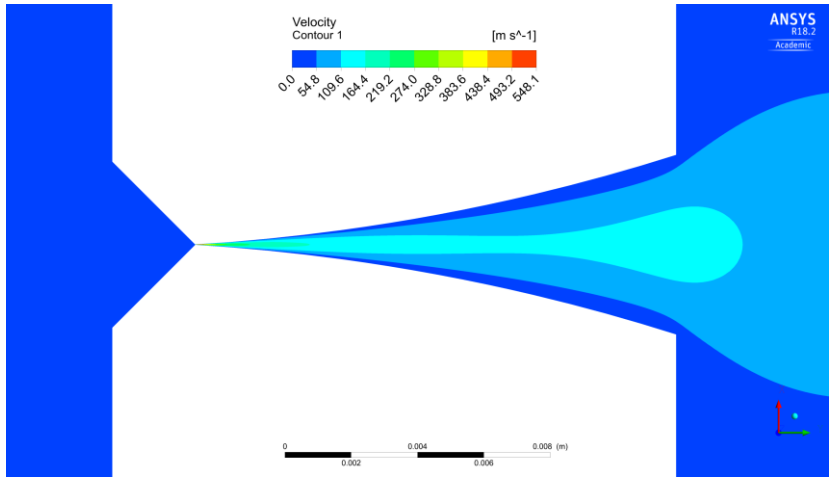
Case no.1

$p_{_INLET}$ = 1 bar



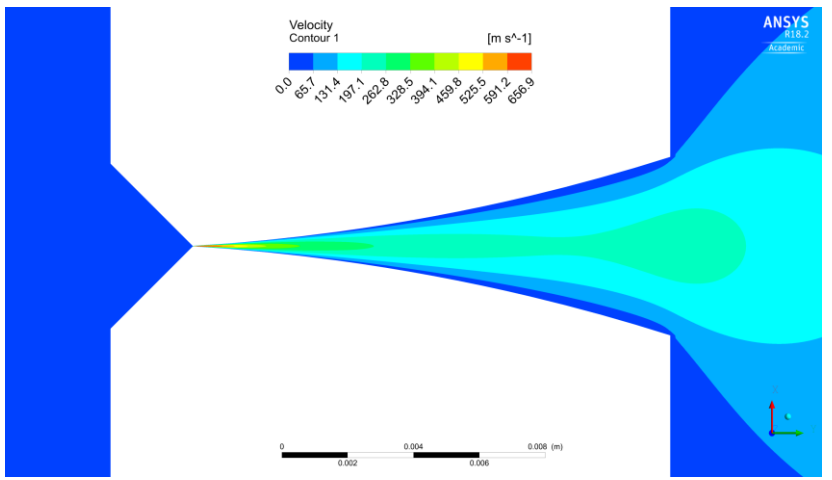
Case no.2

$p_{_INLET}$ = 3 bar



Case no.3

$p_{_INLET}$ = 10 bar

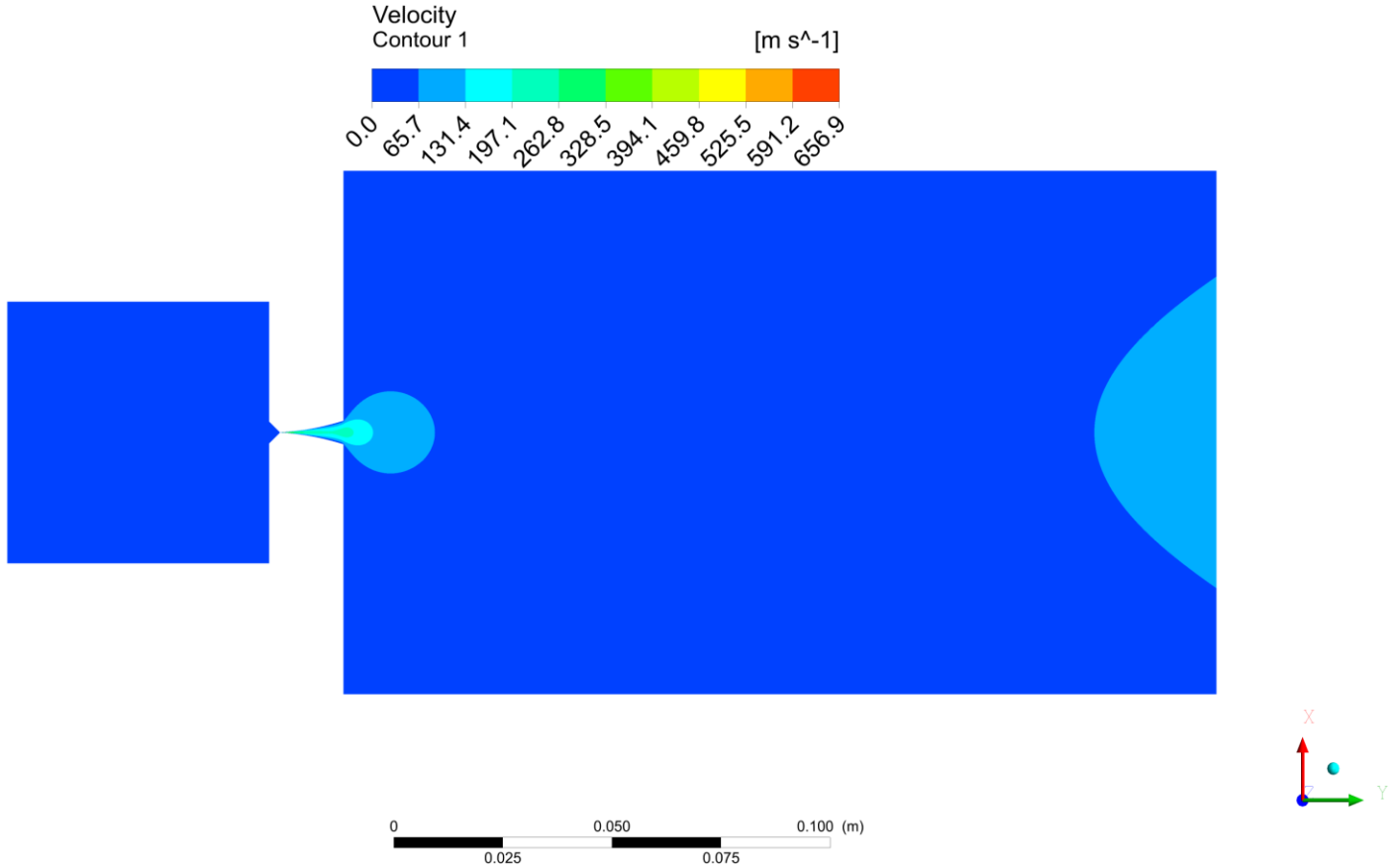


Velocity profile

$D_{critical}$ = 10 microns

Case no.3

$p_{_INLET}$ = 10 bar



Velocity profile

$D_{critical}$ = 10 microns

Case no.1

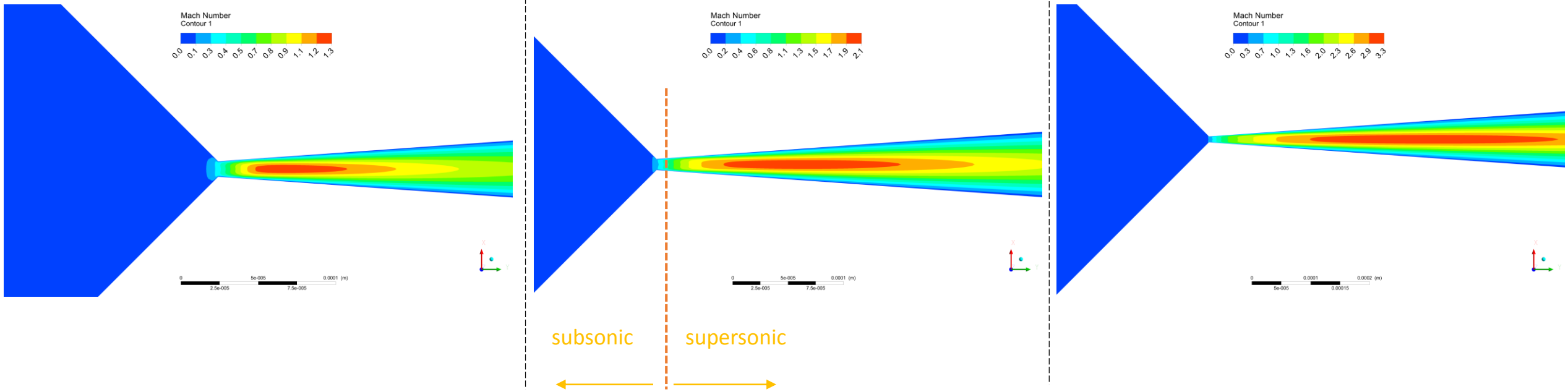
$p_{_INLET}$ = 1 bar

Case no.2

$p_{_INLET}$ = 3 bar

Case no.3

$p_{_INLET}$ = 10 bar



Mach number close to critical cross-section

$D_{critical}$ = 10 microns

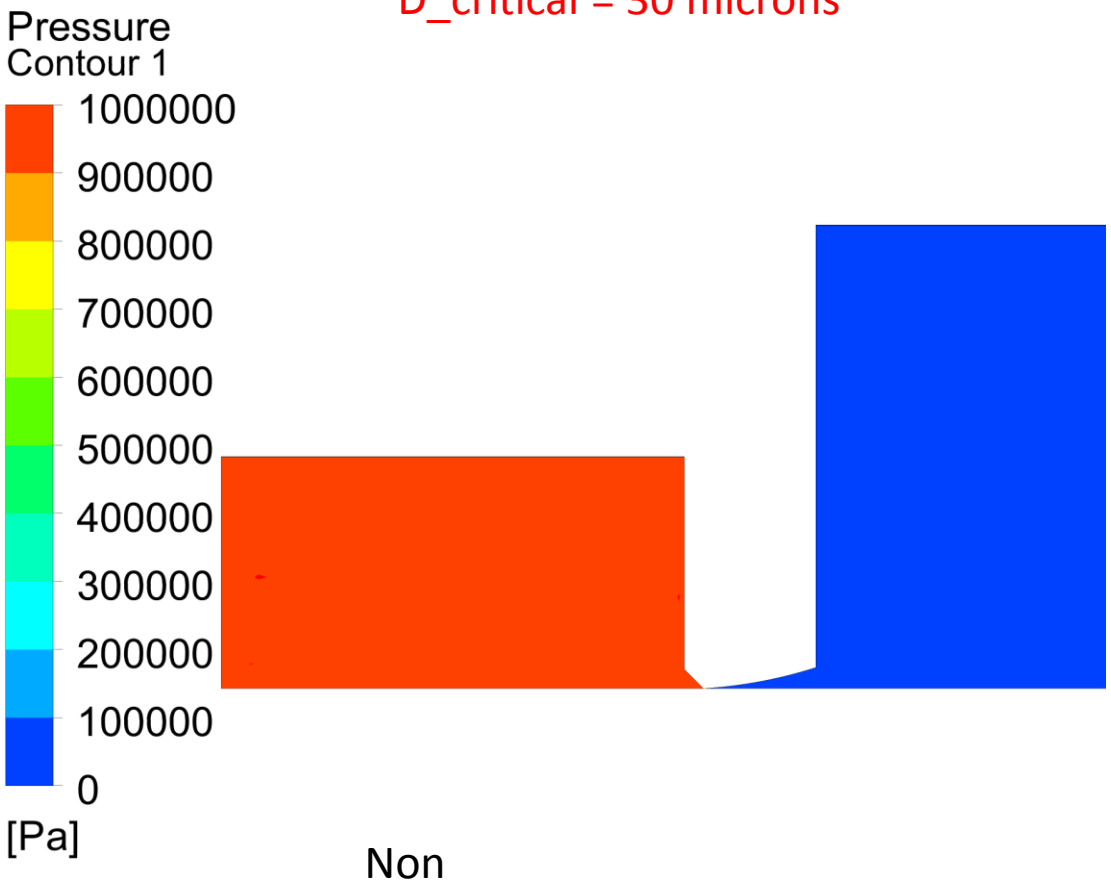
Comparison with the simple geometry nozzle

- For the comparison reson the critical diameter of the de Laval nozzle was increased from 10 microns to 30 microns. The same value of the critical diameter (30 microns) is presented in the simple geometry nozzle.
- Test was performed with similar boundary conditions.

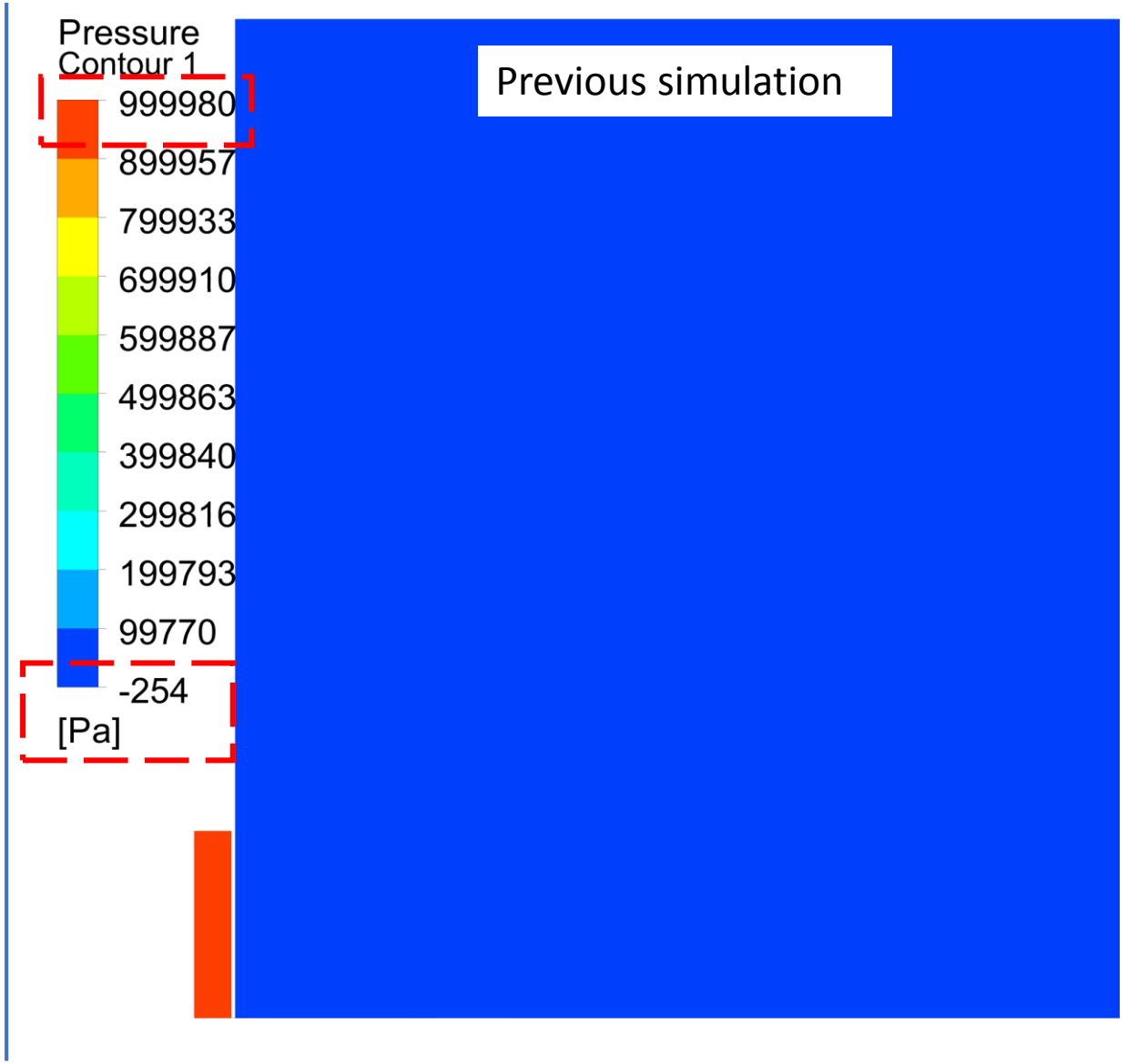
Simulations comparison: global pressure

Present simulation

D_critical = 30 microns



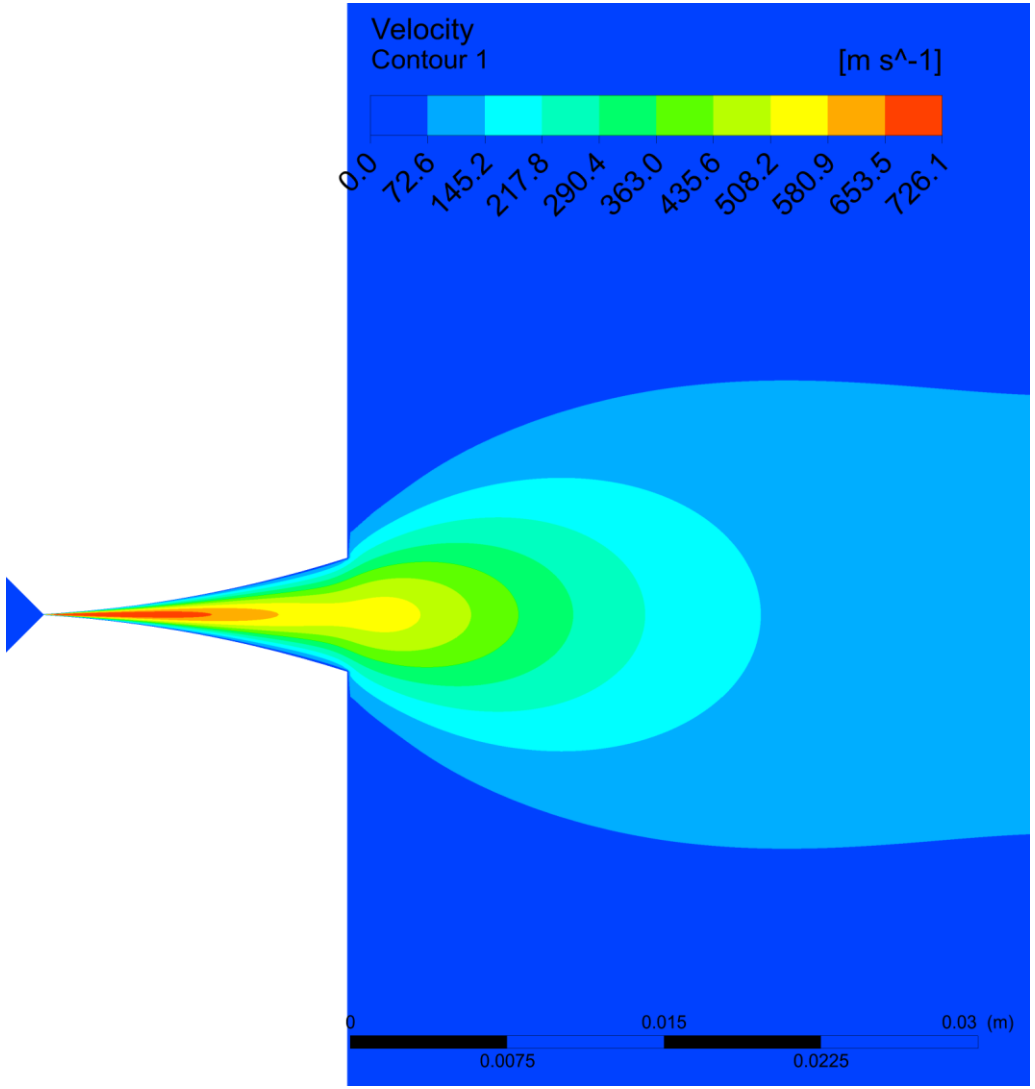
Non



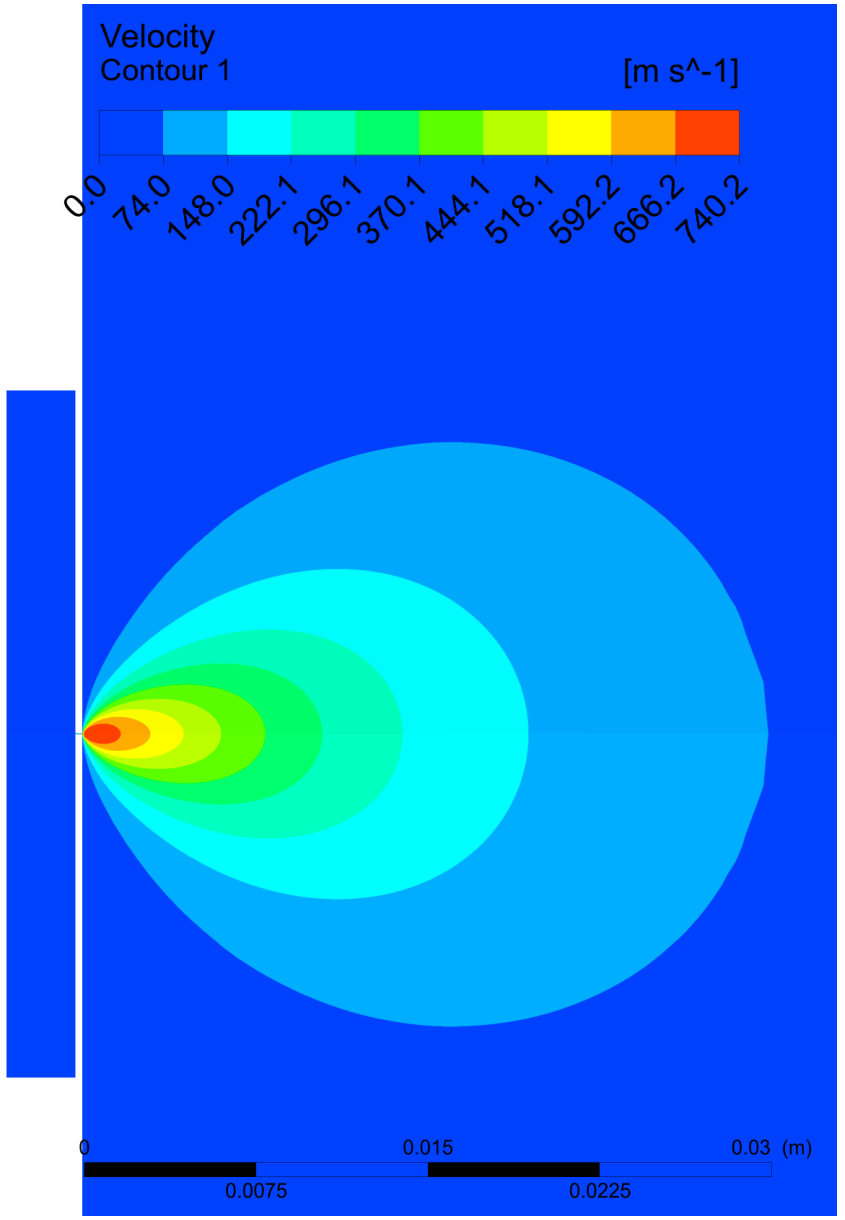
Velocity Profile

De Laval

Side view



Simple Geometry



Conclusions

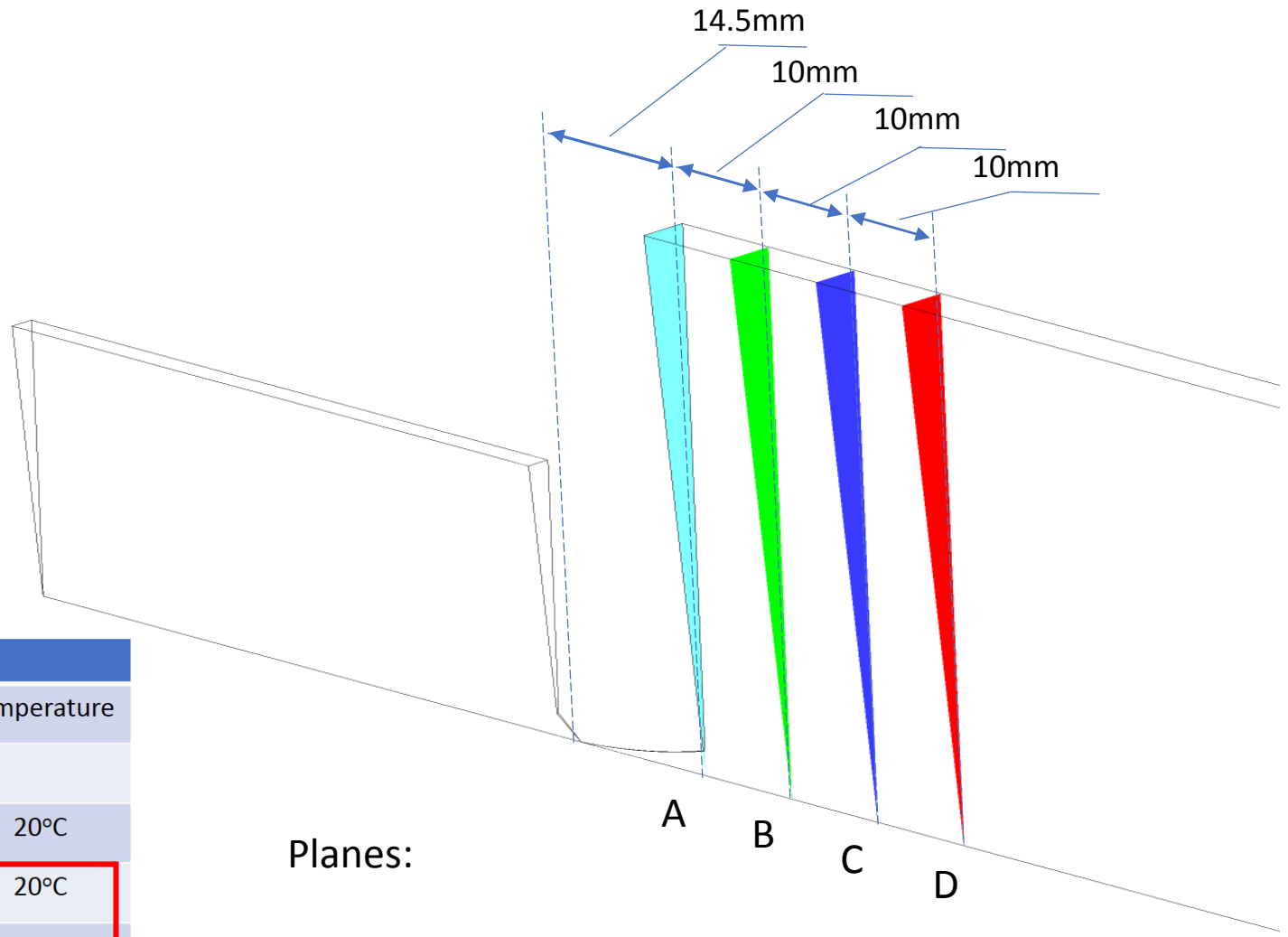
- The numerical simulation for the proposed de Laval nozzle with 10 microns critical diameter has been performed with high convergence level (under RMS factor 10^{-6})
- De Laval construction of the nozzle provides better concentration of the beam and higher density in further distance from the nozzle outlet
- Between planes C and D could be an optimal place for the placement of the 1st skimmer

Complementary post-processing

Profile planes position - de Laval nozzle

De Laval

nozzle throat 10 µm



Planes:

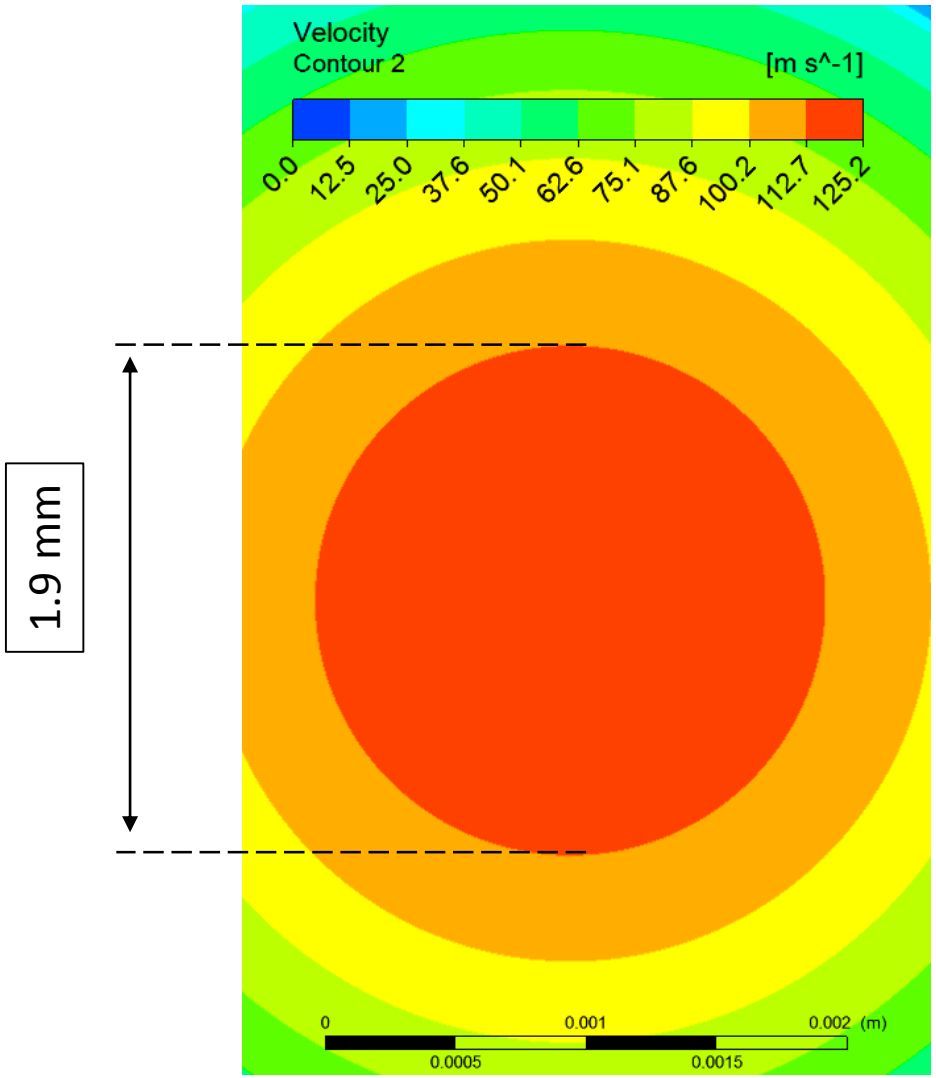
Comparison between those two cases

Case no.	Inlet		Outlet	
	Pressure*	Temperature	Pressure*	Temperature
	$D_{critical}$ = 10 microns			
1	1 bar	20°C	0 Pa	20°C
2	3 bar	20°C	0 Pa	20°C
3	10 bar	20°C	0 Pa	20°C
	$D_{critical}$ = 30 microns			
4	10 bar	20°C	0 Pa	20°C

Velocity Profile

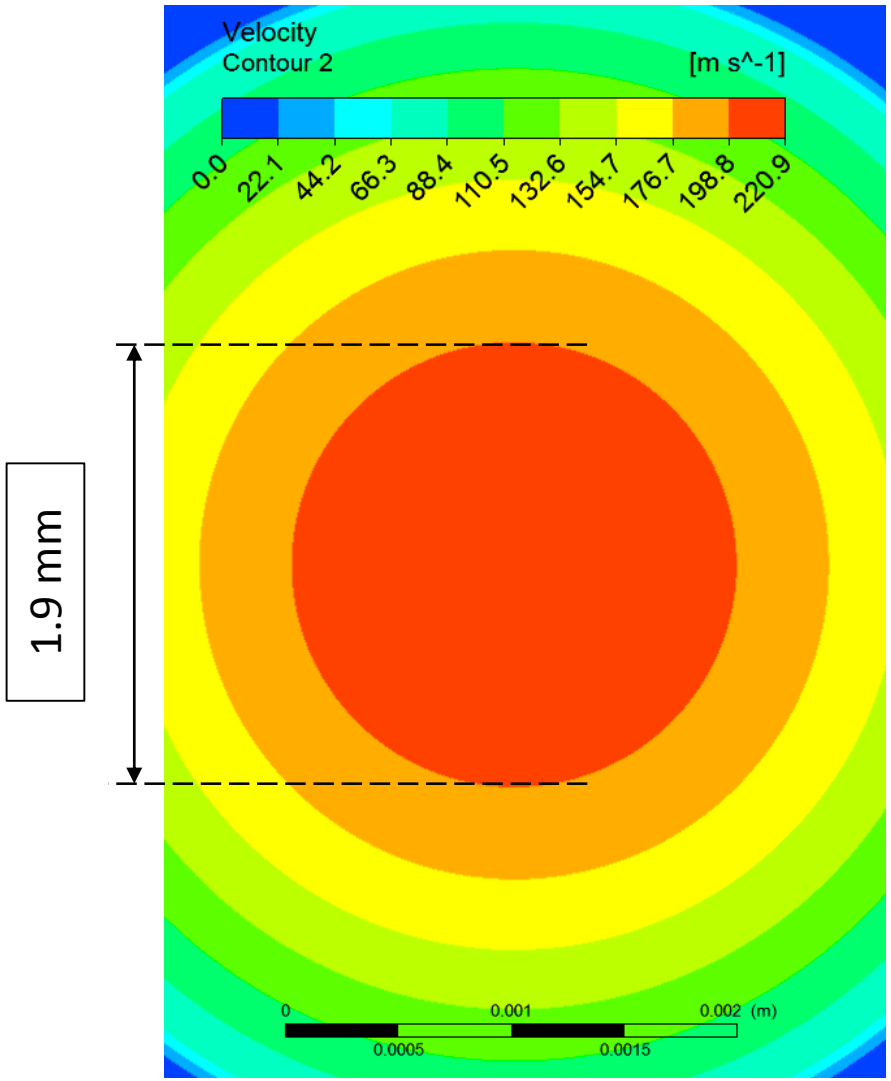
Plane A

p_{INLET} = 3 bar



nozzle throat 10 µm

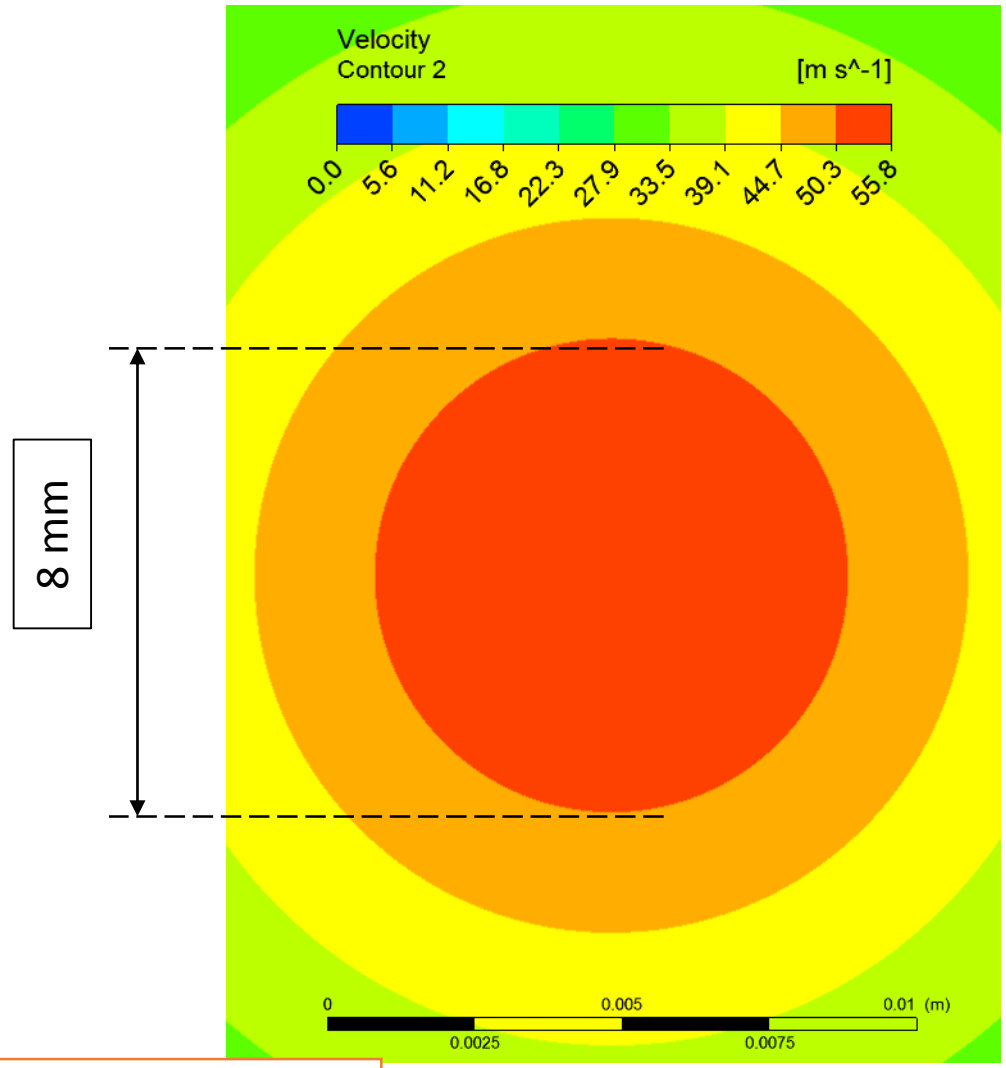
p_{INLET} = 10 bar



Velocity Profile

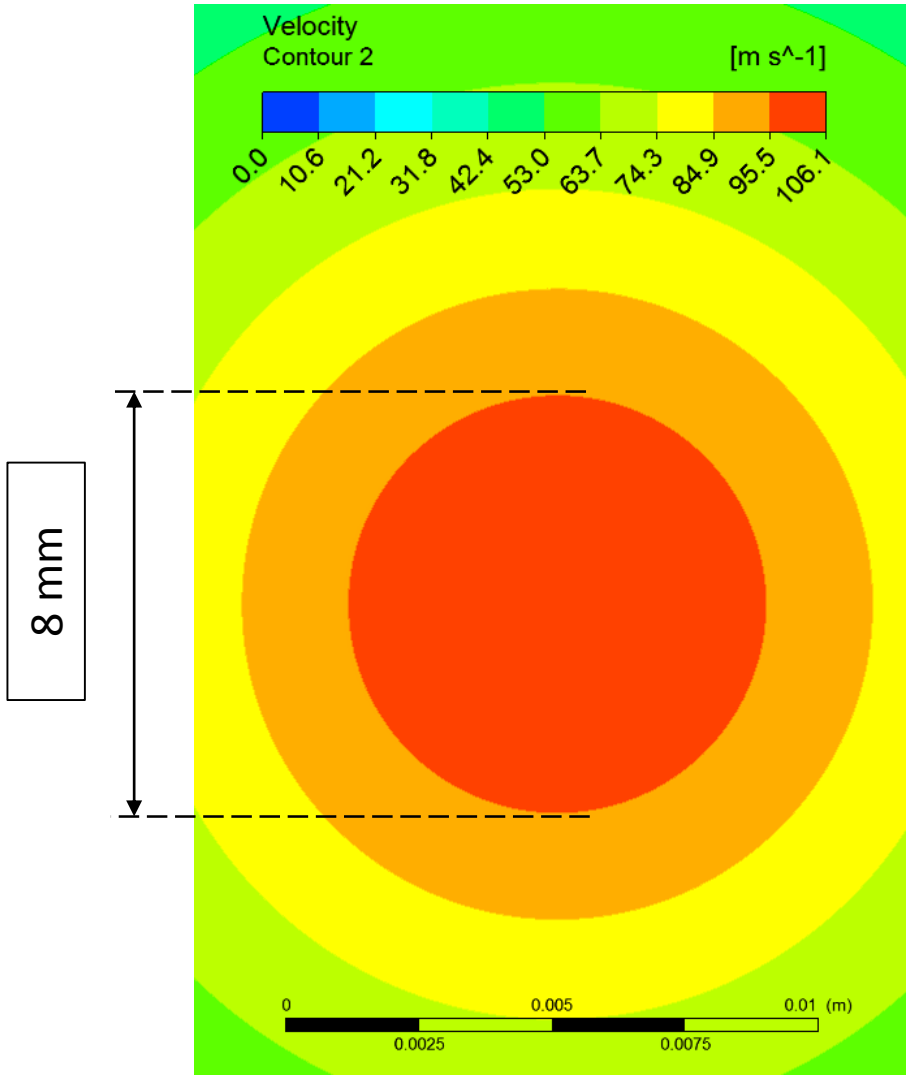
Plane B

$p_{_INLET}$ = 3 bar



nozzle throat 10 µm

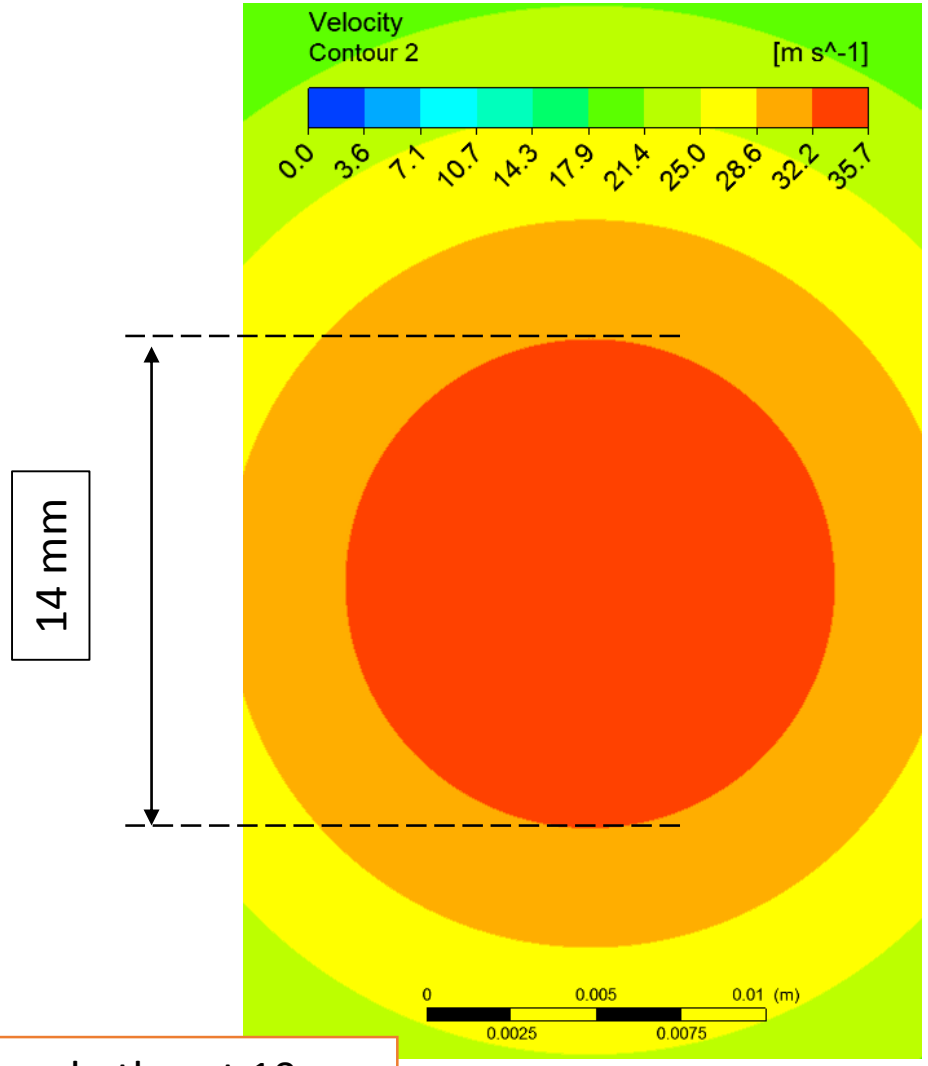
$p_{_INLET}$ = 10 bar



Velocity Profile

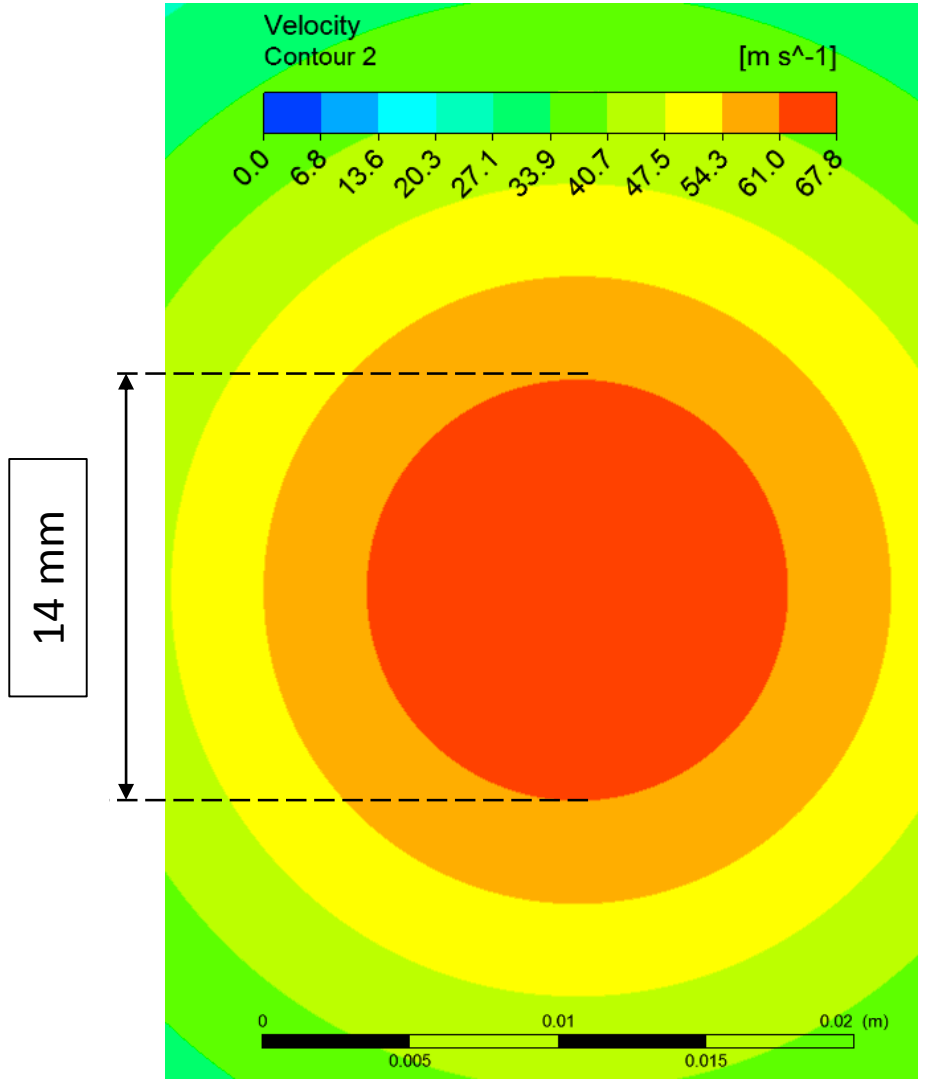
Plane C

p_{INLET} = 3 bar



nozzle throat 10 µm

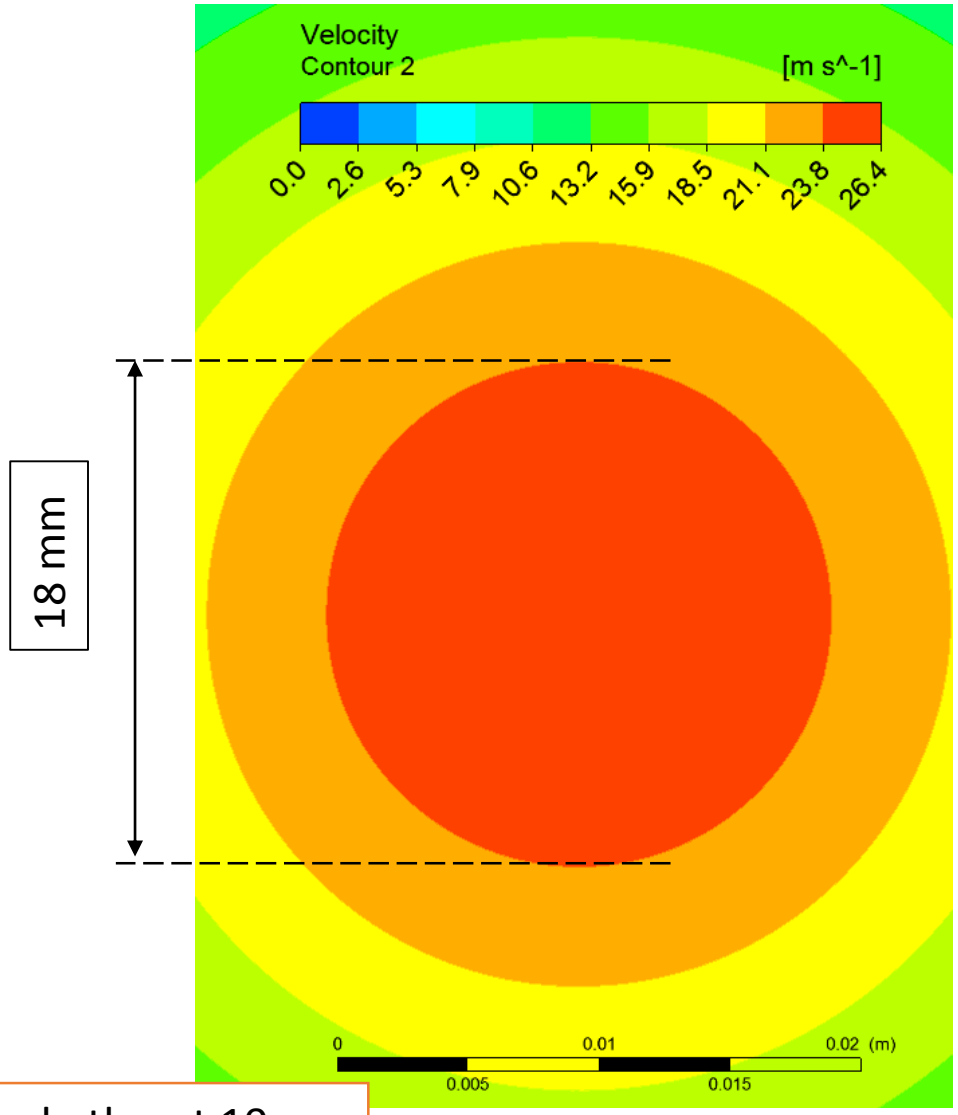
p_{INLET} = 10 bar



Velocity Profile

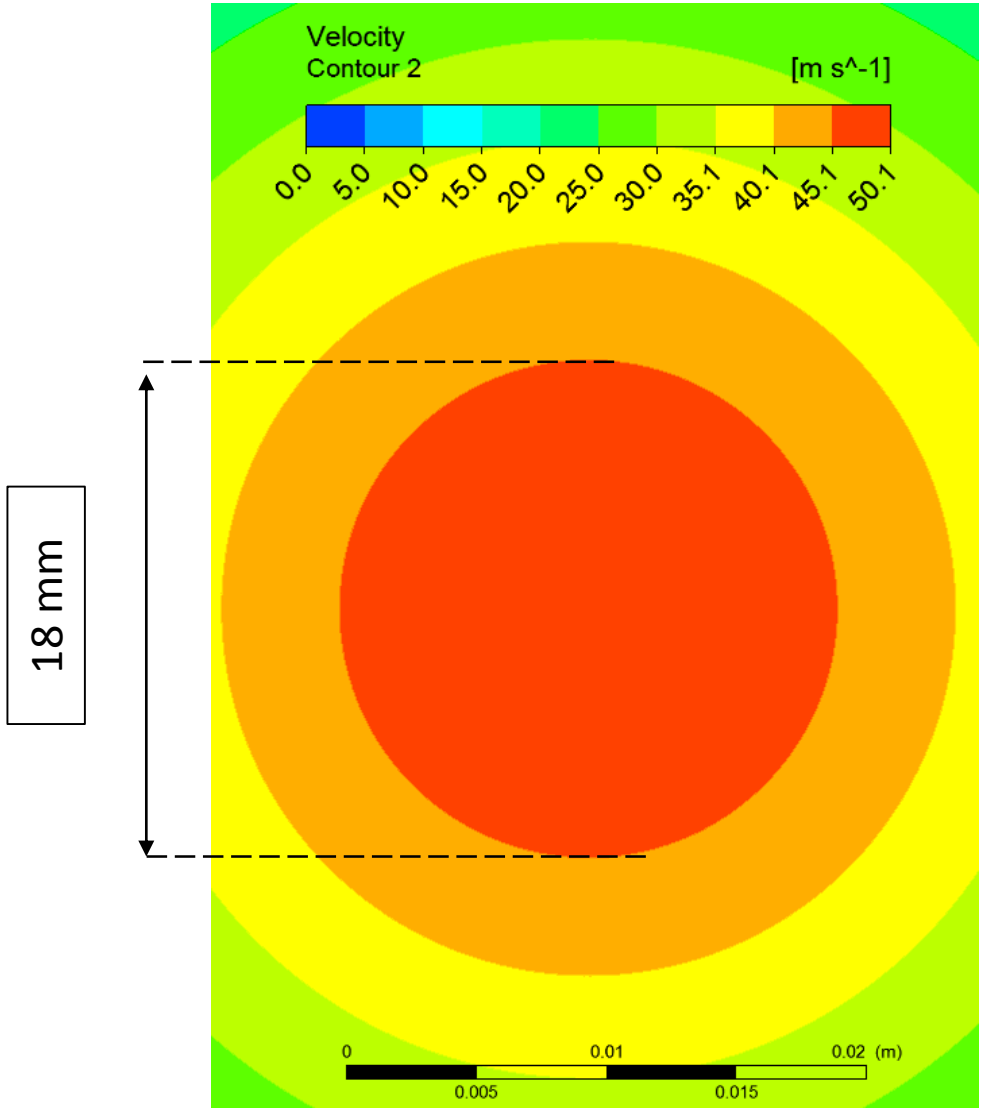
Plane D

$p_{_INLET}$ = 3 bar



nozzle throat 10 µm

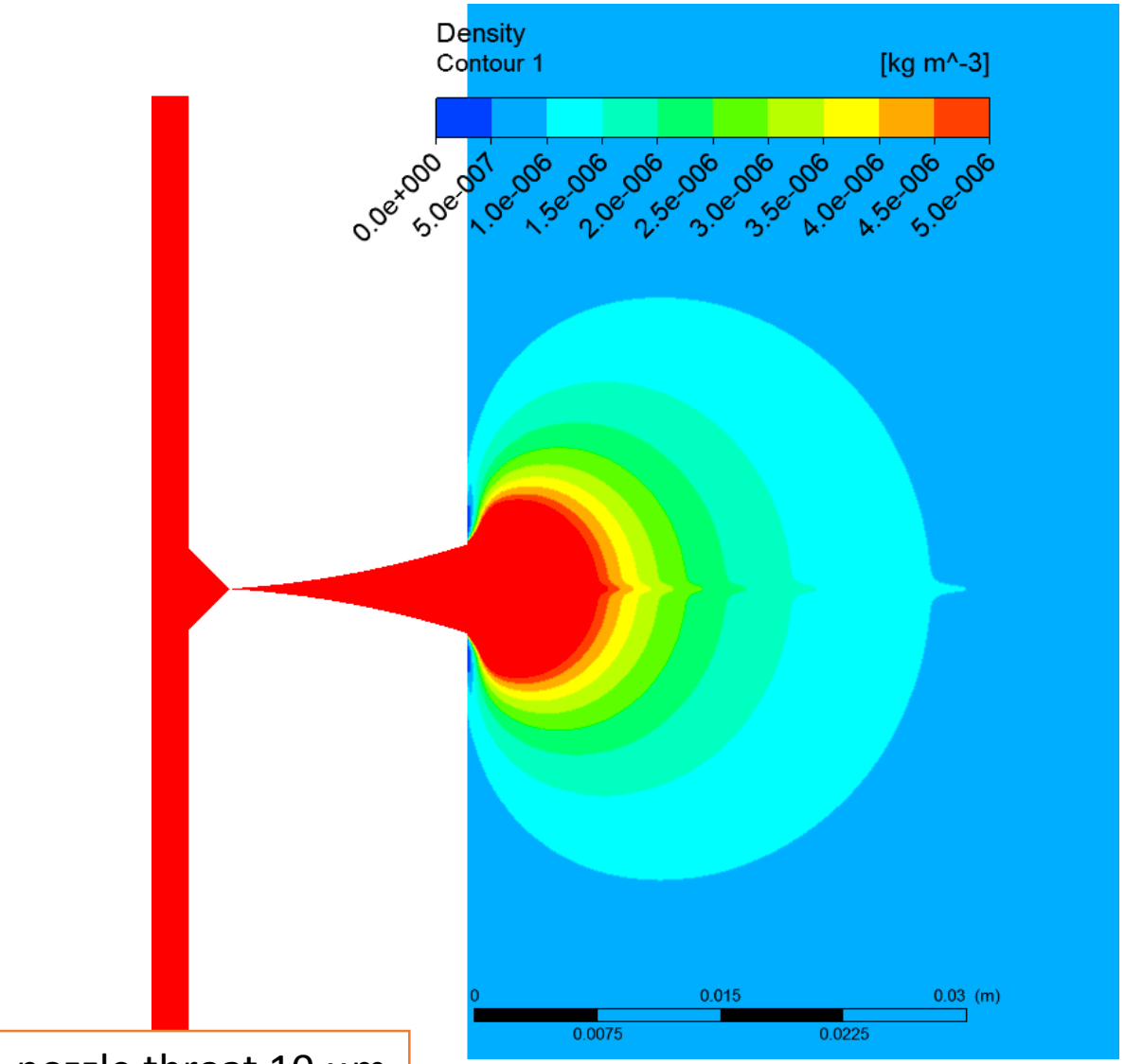
$p_{_INLET}$ = 10 bar



Density Profile

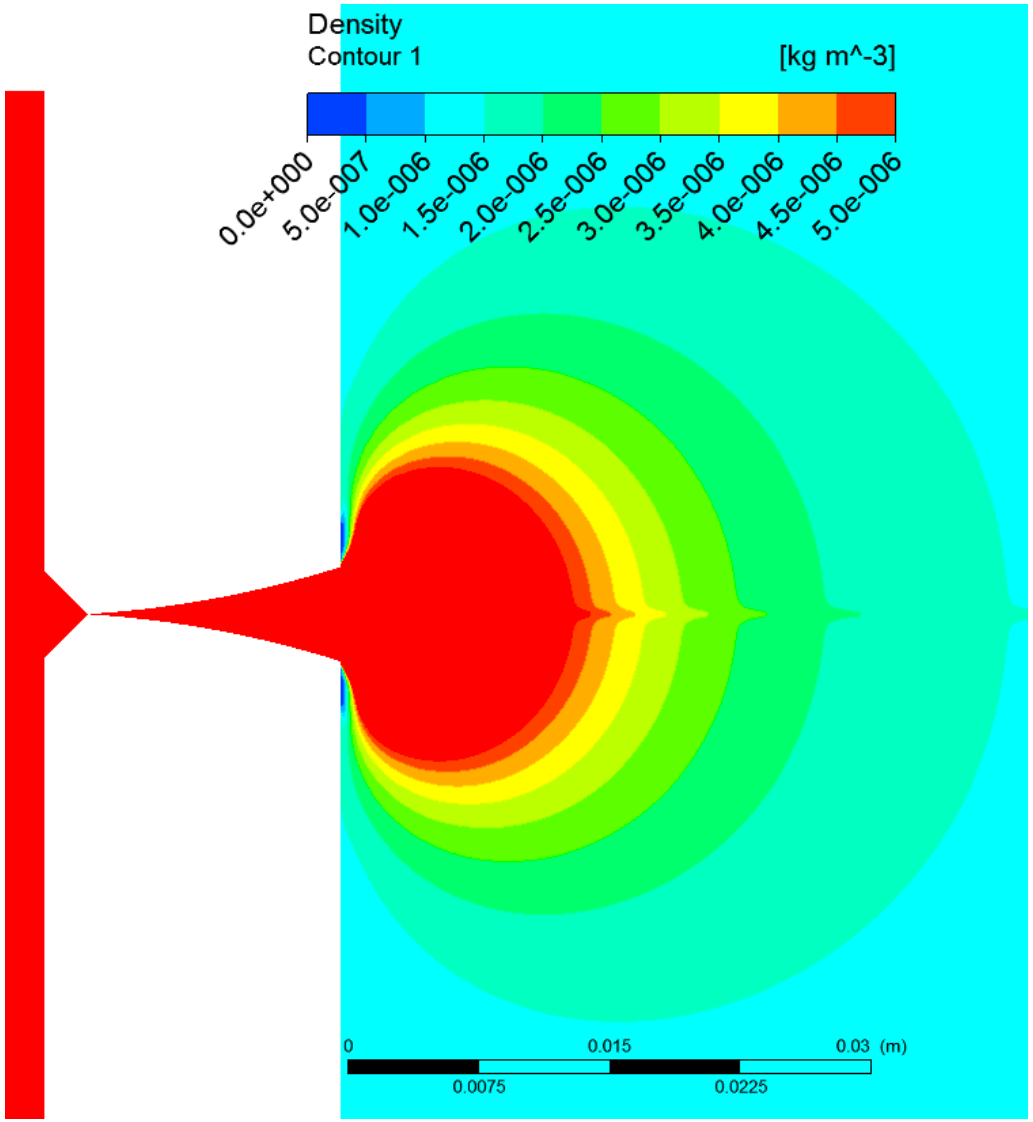
Side view

$p_{_INLET}$ = 3 bar



nozzle throat 10 µm

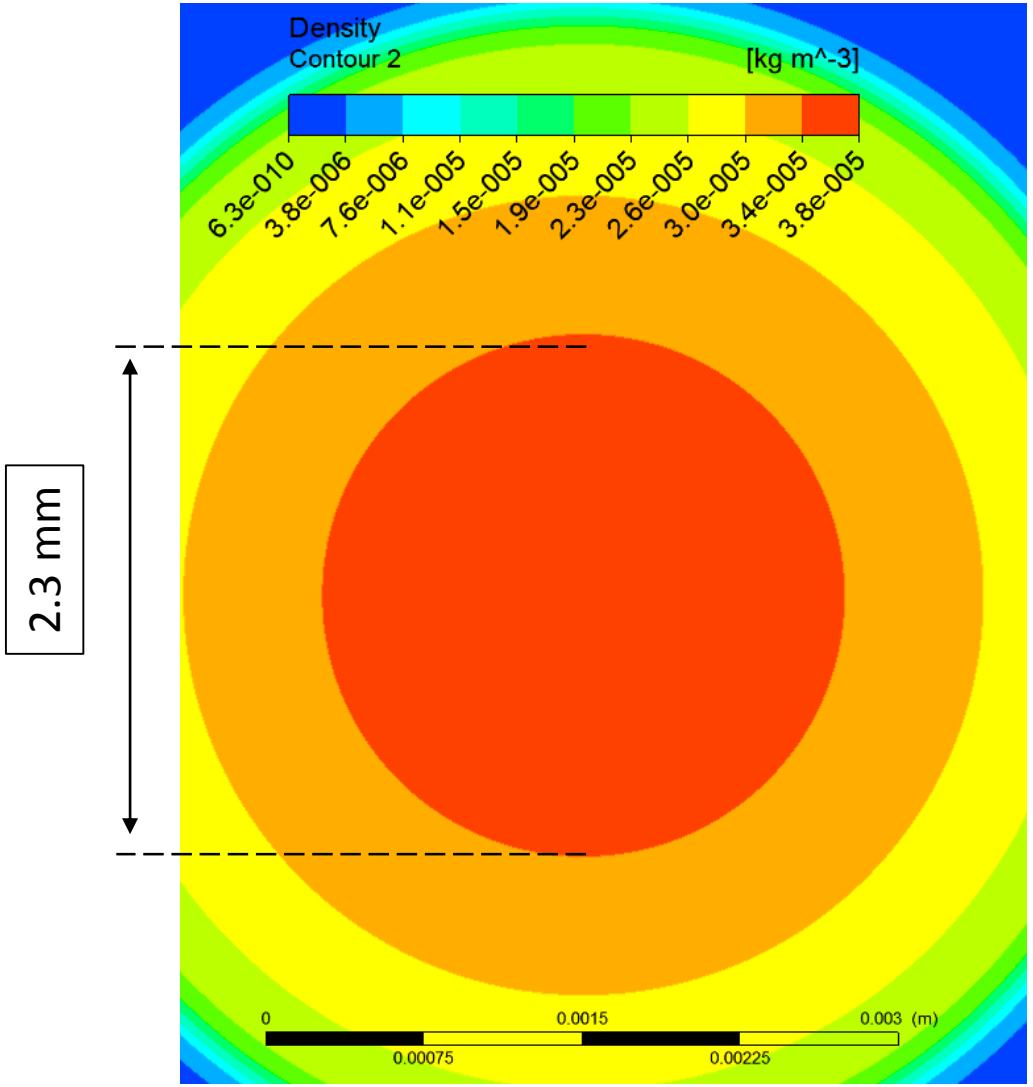
$p_{_INLET}$ = 10 bar



Density Profile

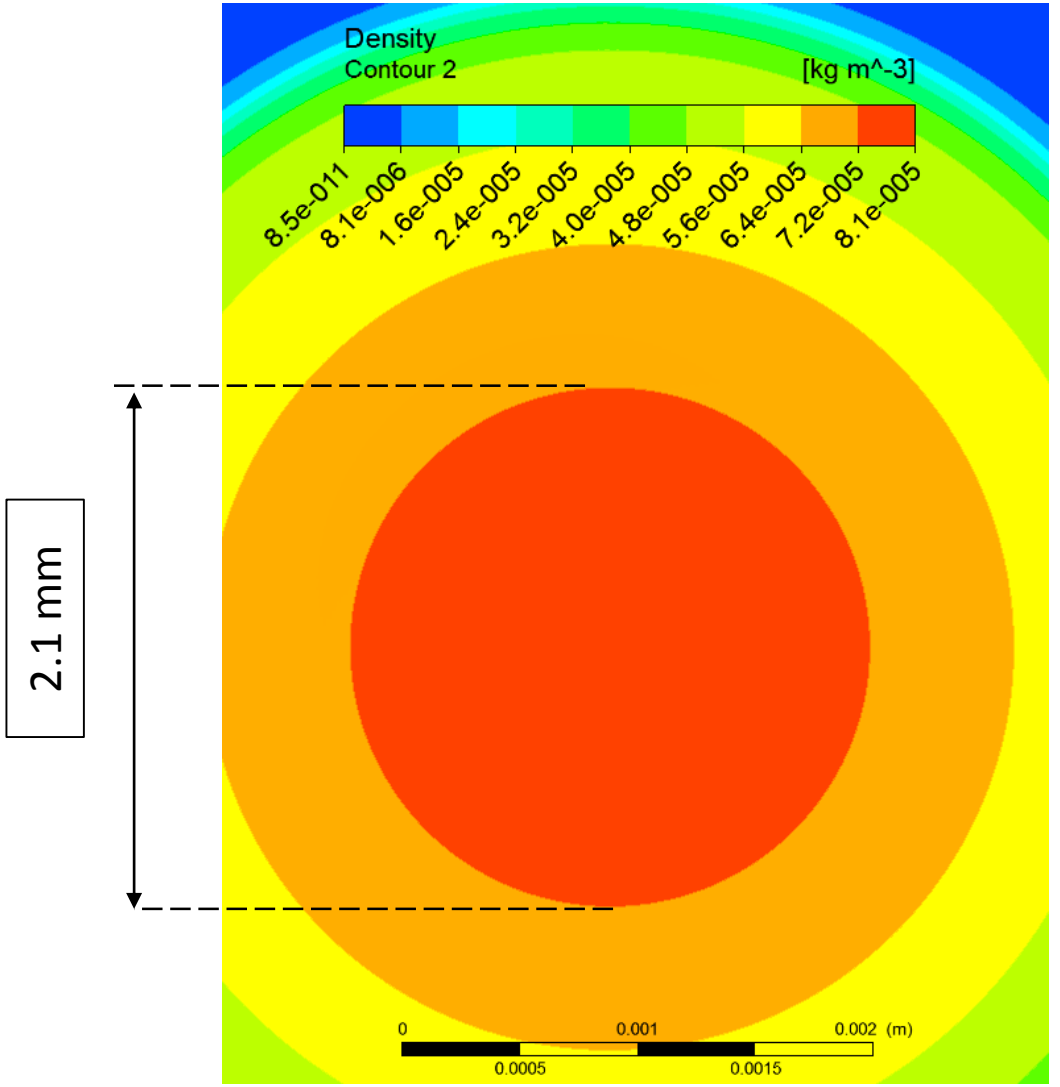
Plane A

$p_{_INLET}$ = 3 bar



nozzle throat 10 µm

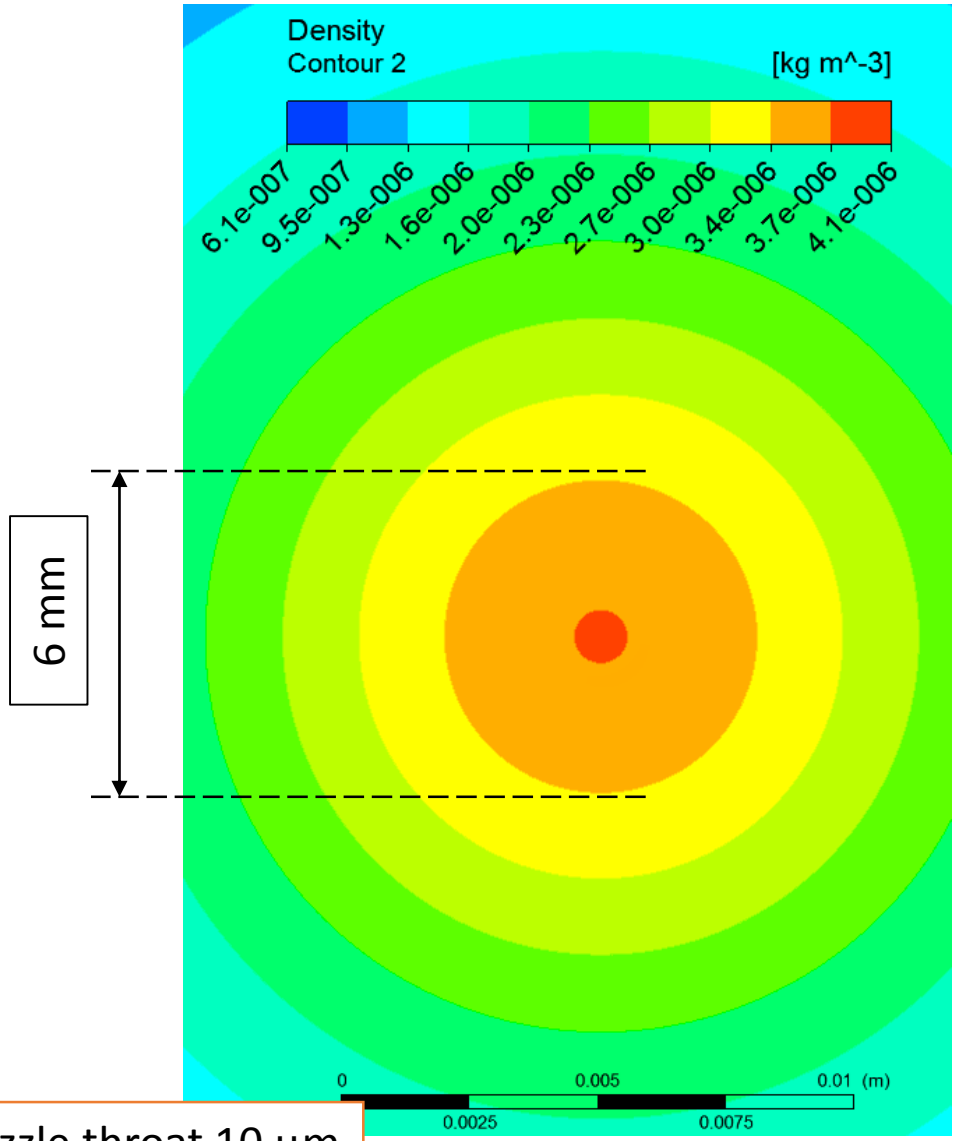
$p_{_INLET}$ = 10 bar



Density Profile

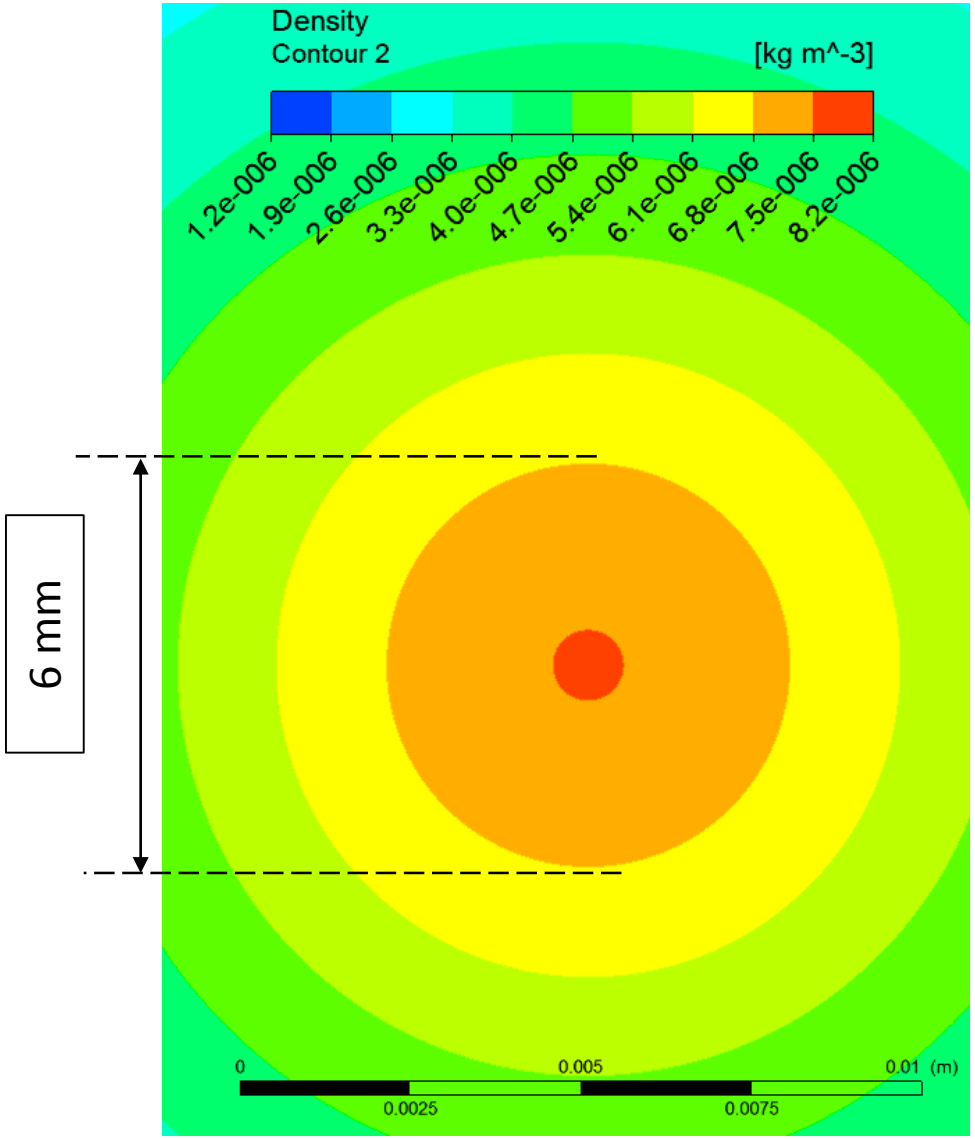
Plane B

$p_{_INLET}$ = 3 bar



nozzle throat 10 µm

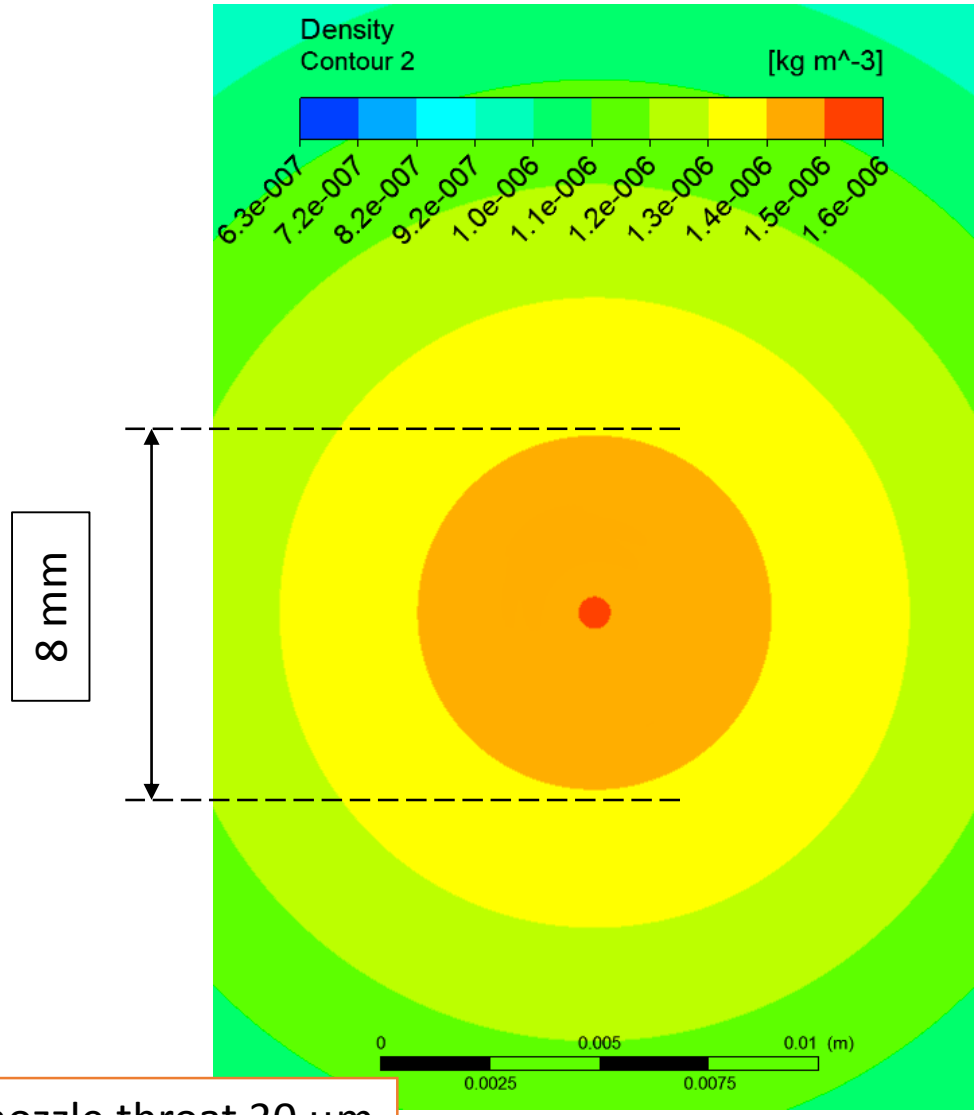
$p_{_INLET}$ = 10 bar



Density Profile

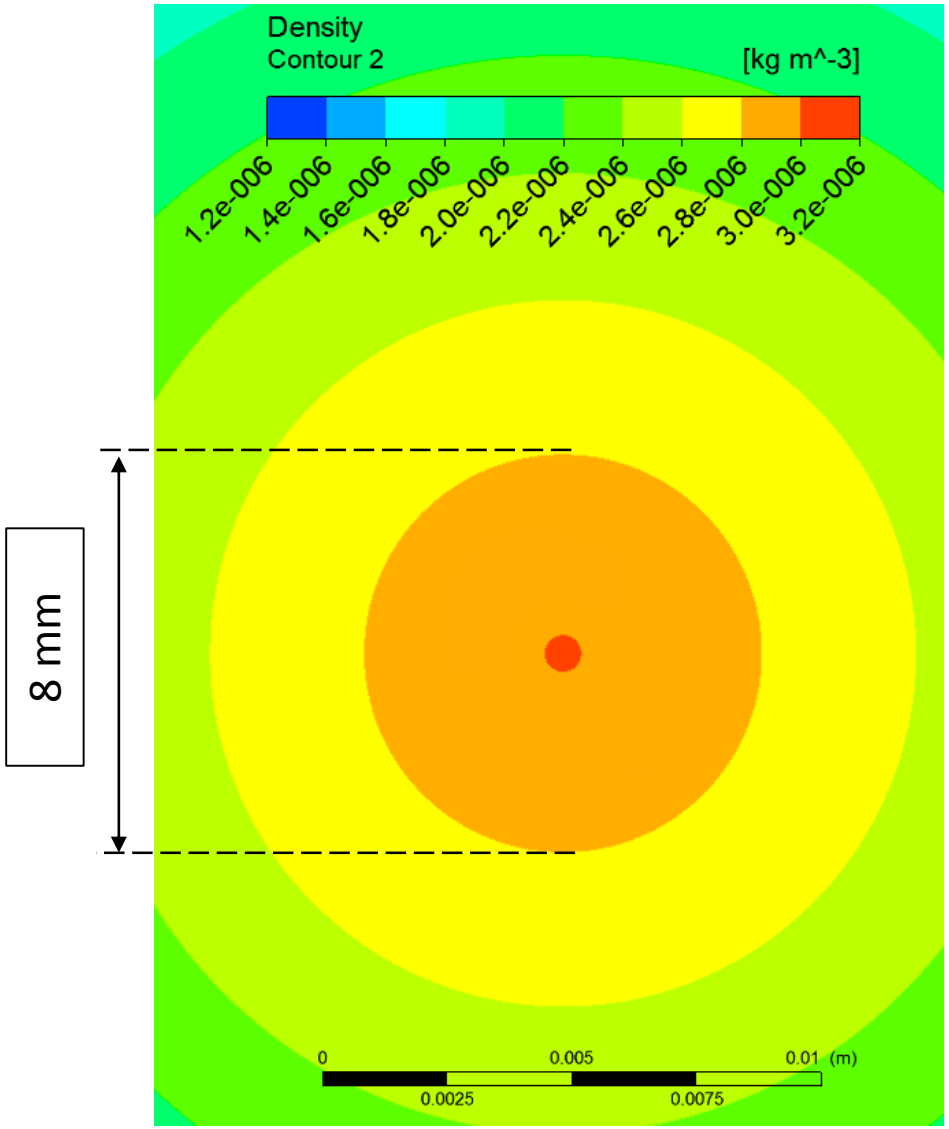
Plane C

$p_{_INLET}$ = 3 bar



nozzle throat 30 µm

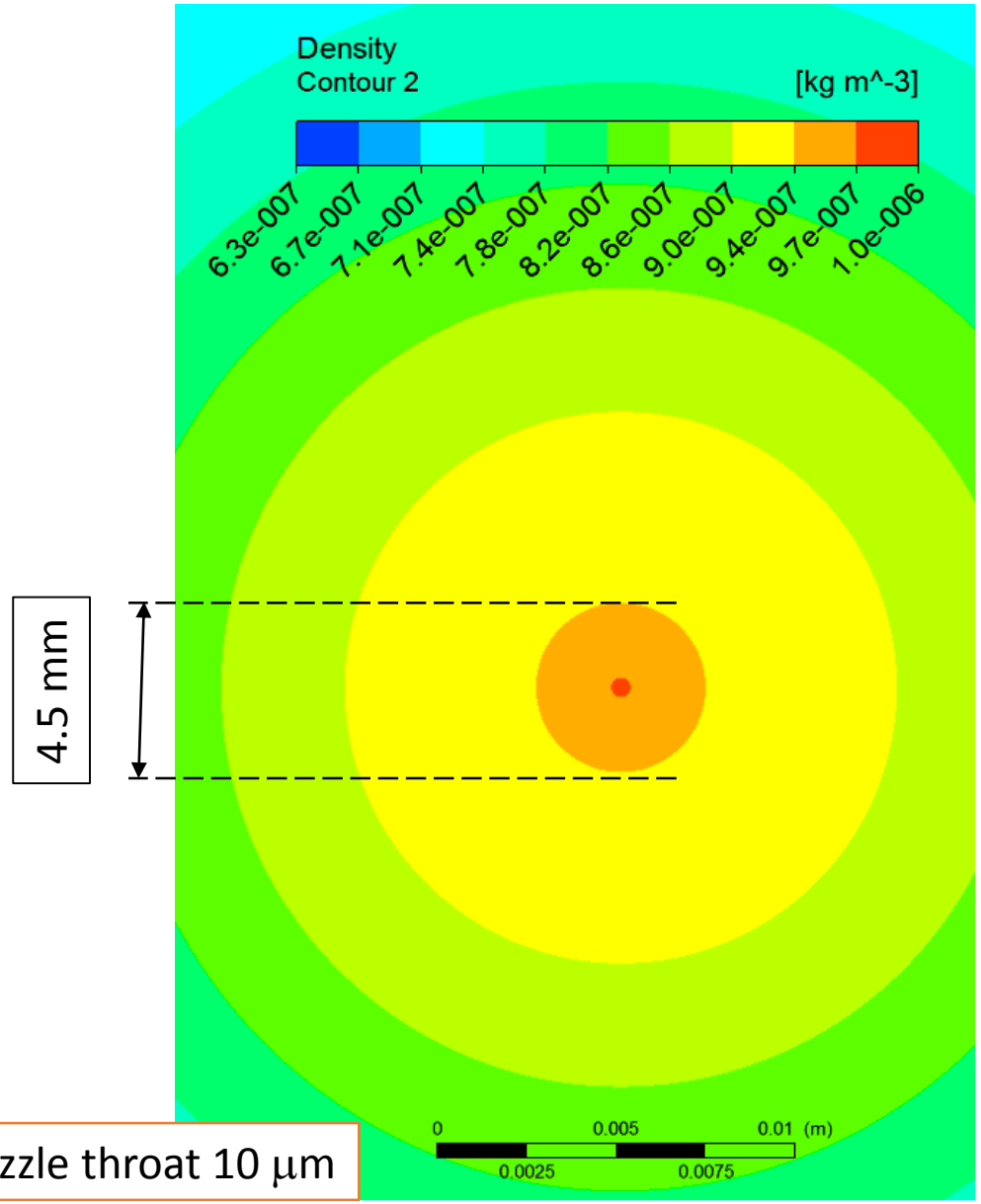
$p_{_INLET}$ = 10 bar



Density Profile

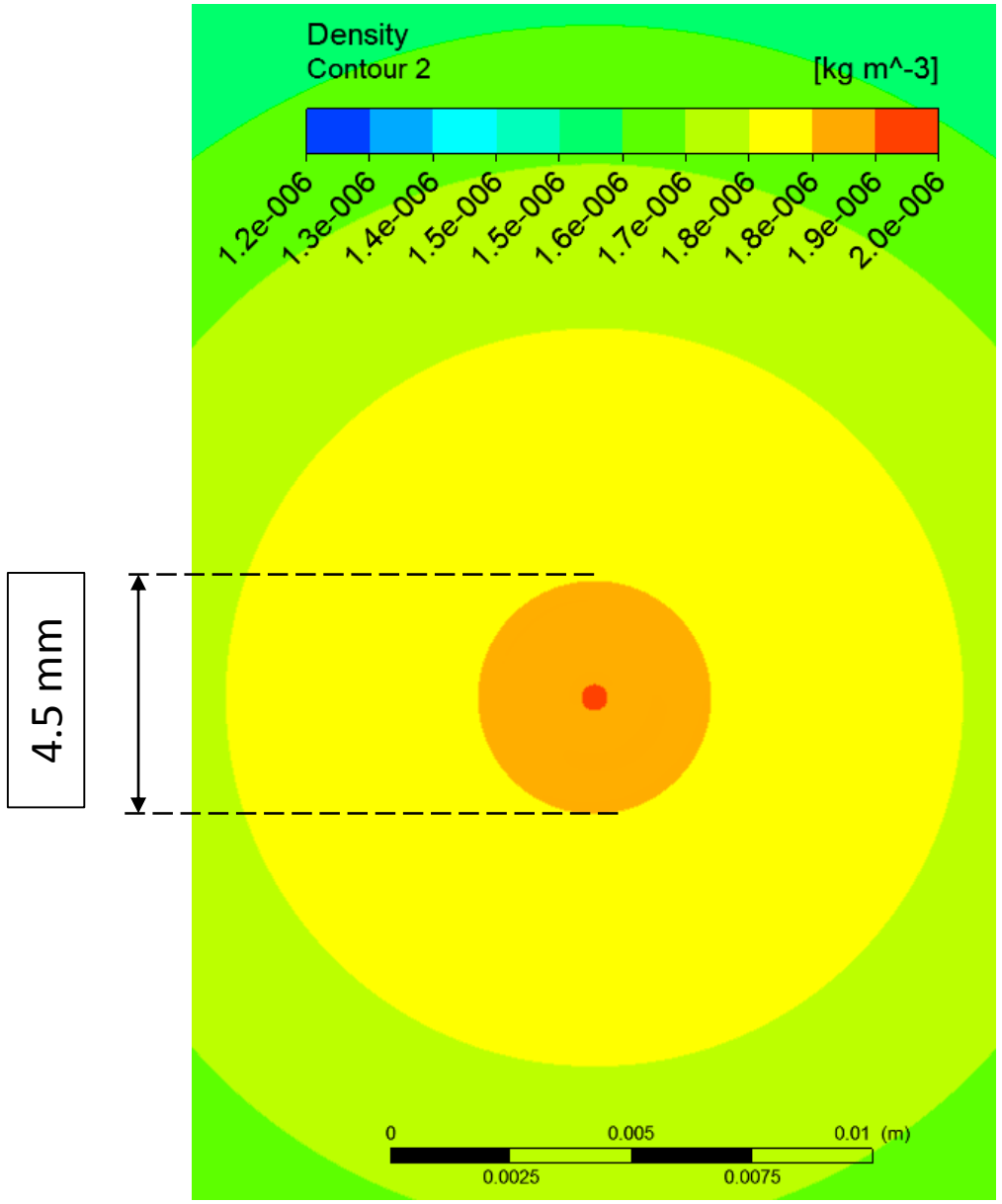
Plane D

p_{INLET} = 3 bar



nozzle throat 10 µm

p_{INLET} = 10 bar

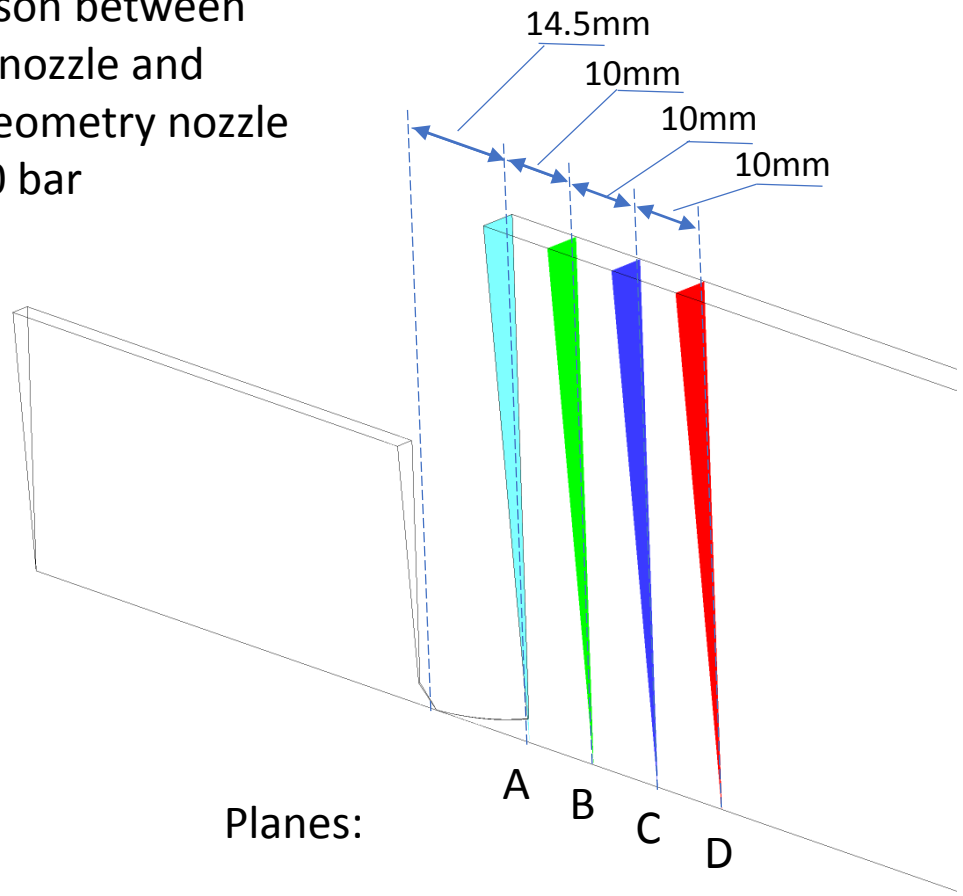


Profile planes position

De Laval

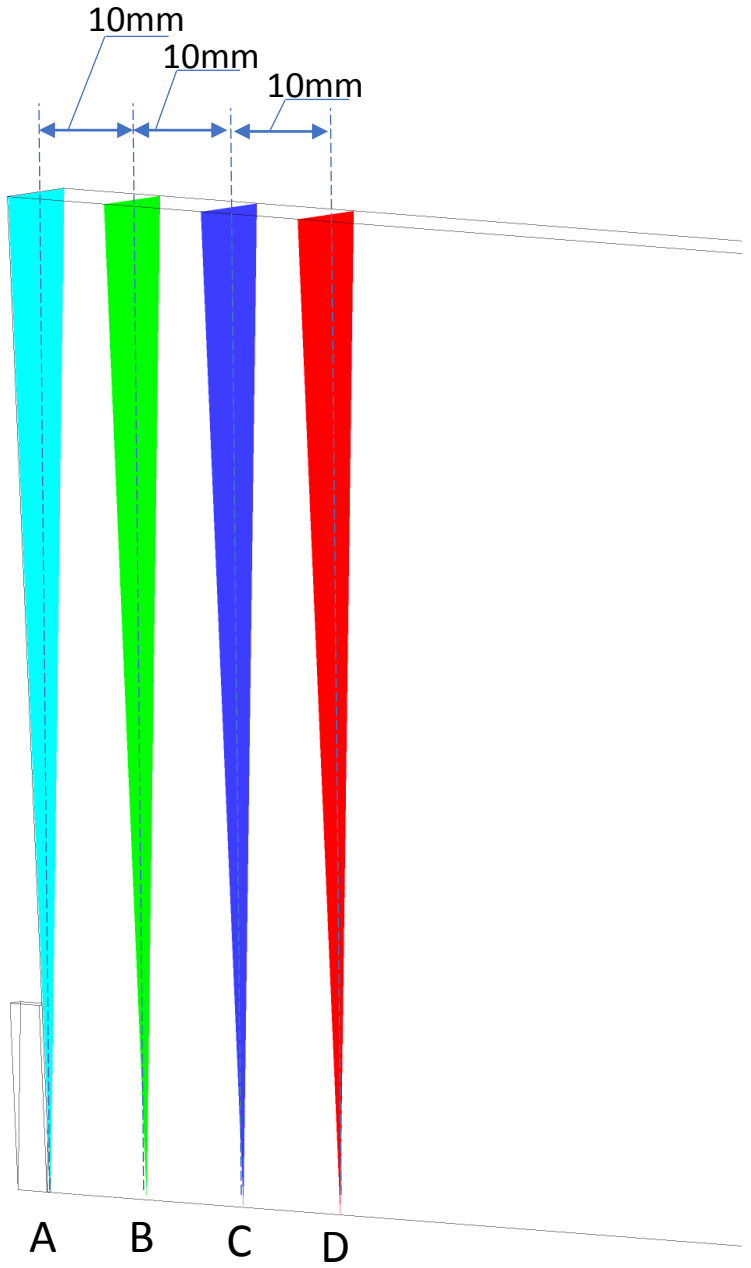
nozzle throat 30 μm

Comparison between
de Laval nozzle and
simple geometry nozzle
p_{inlet} = 10 bar



Planes:

Simple Geometry

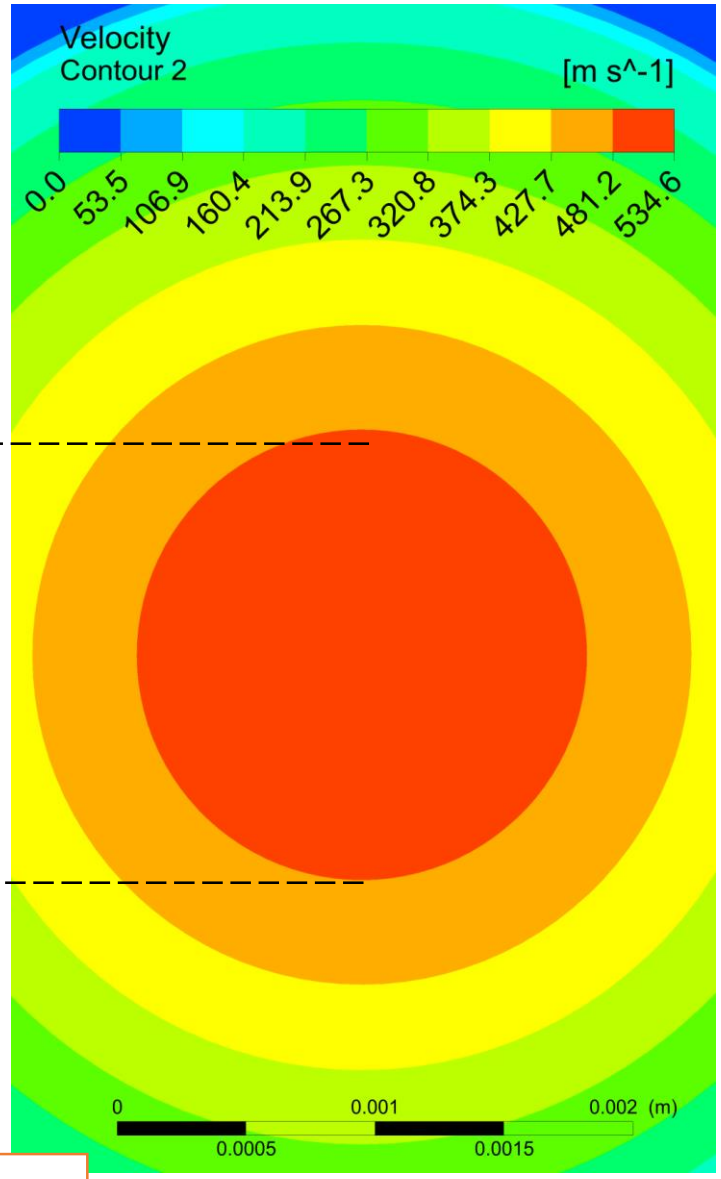


Velocity Profile

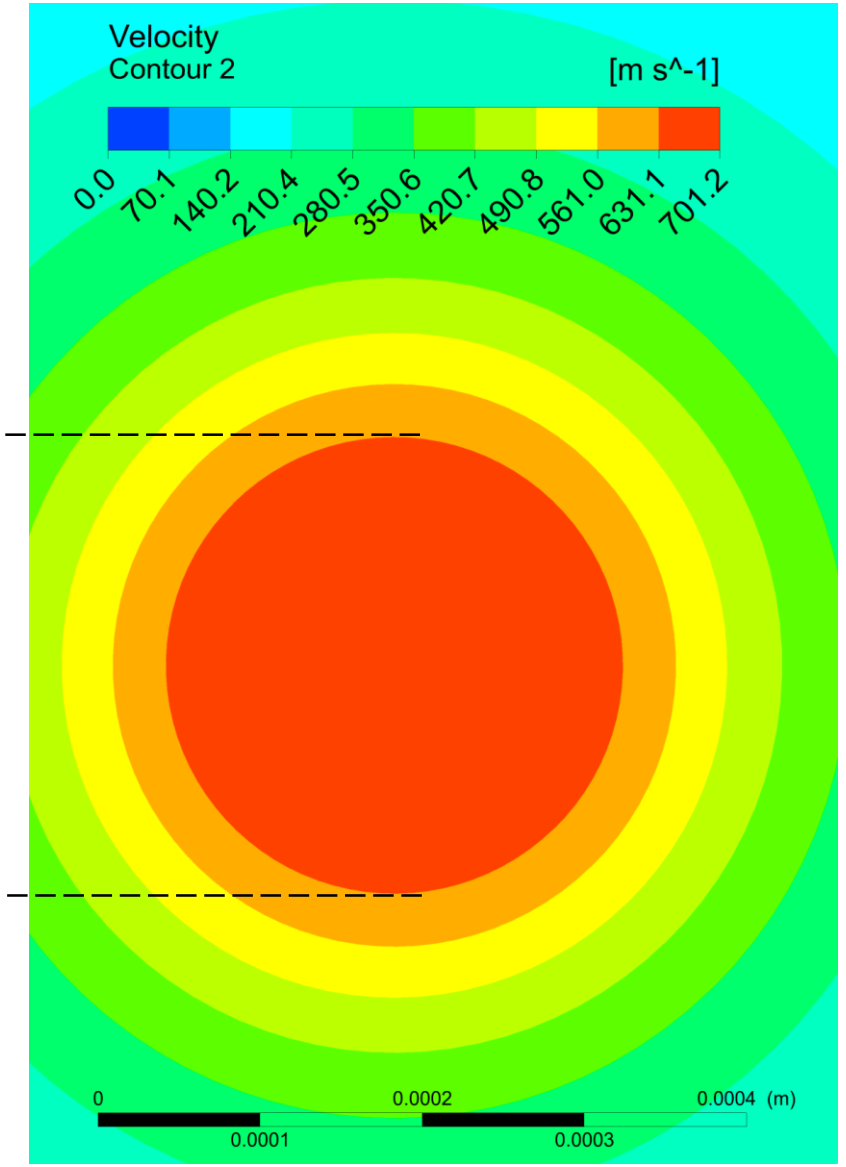
De Laval

Simple Geometry

Plane A



1.7 mm



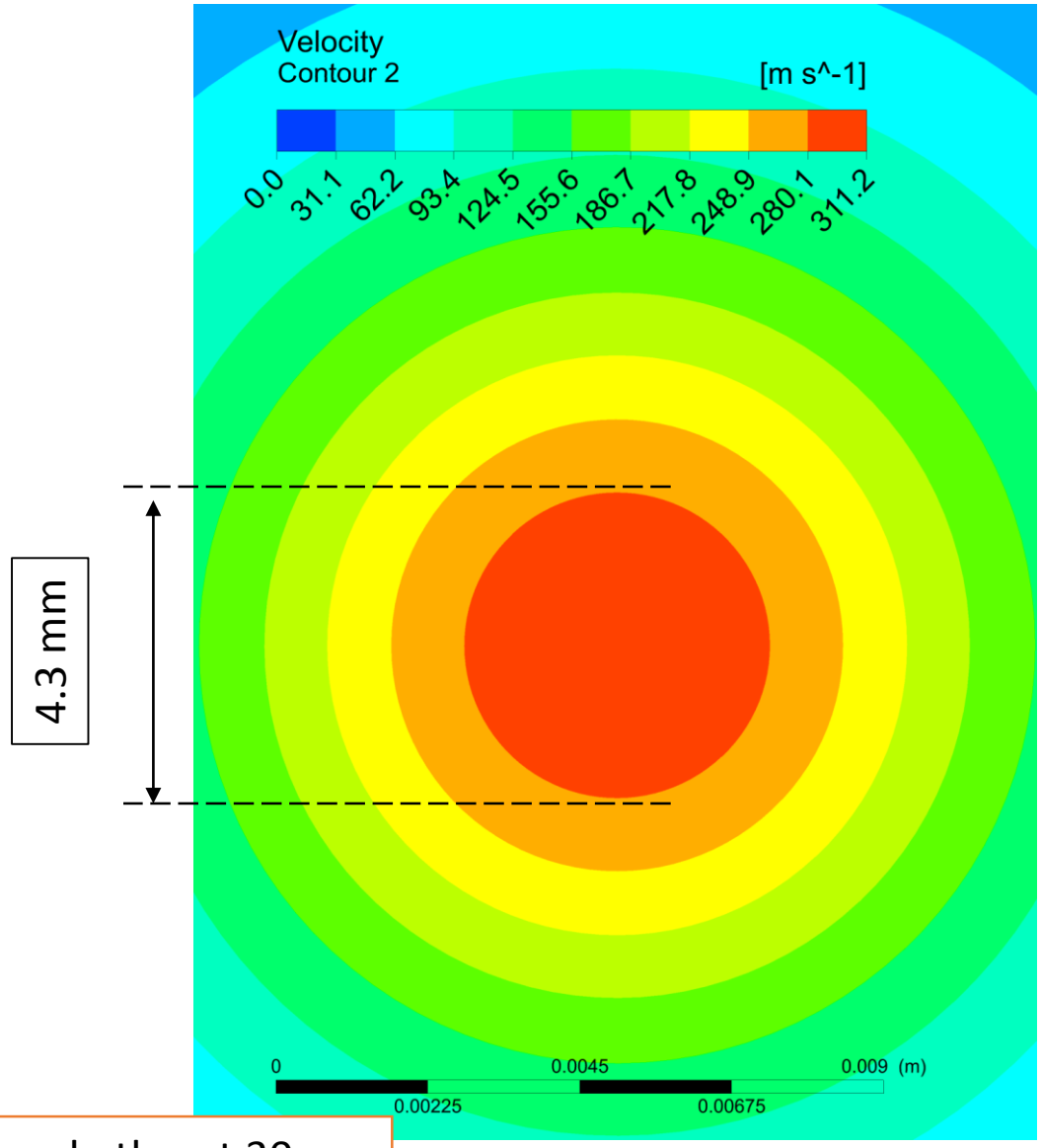
0.29 mm

nozzle throat 30 μm

Velocity Profile

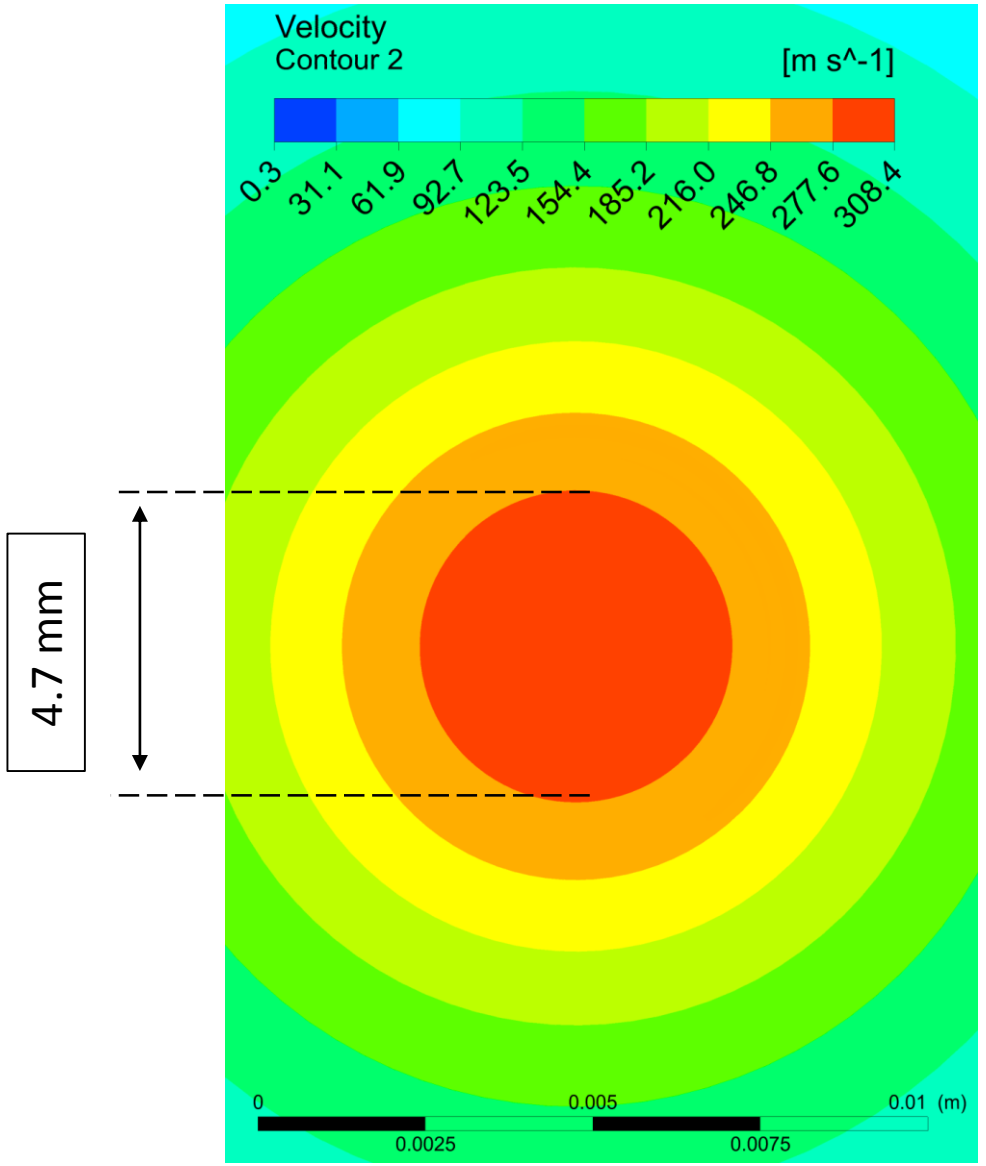
De Laval

Plane B



nozzle throat 30 µm

Simple Geometry

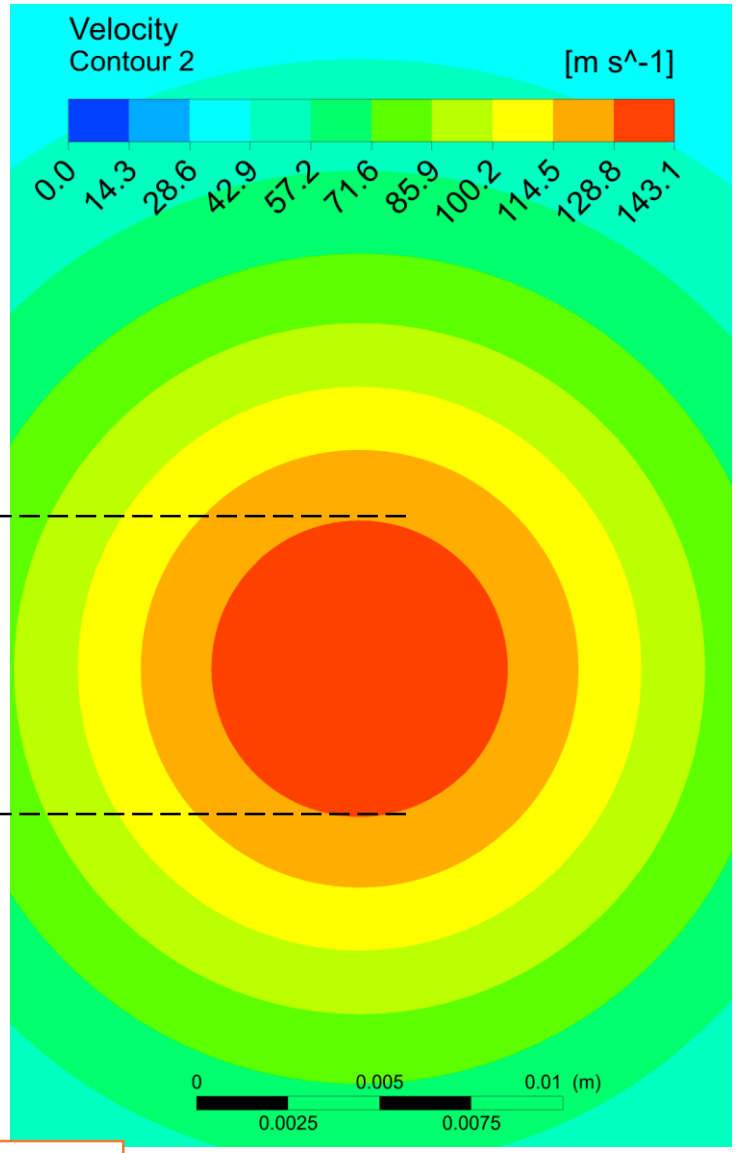


Velocity Profile

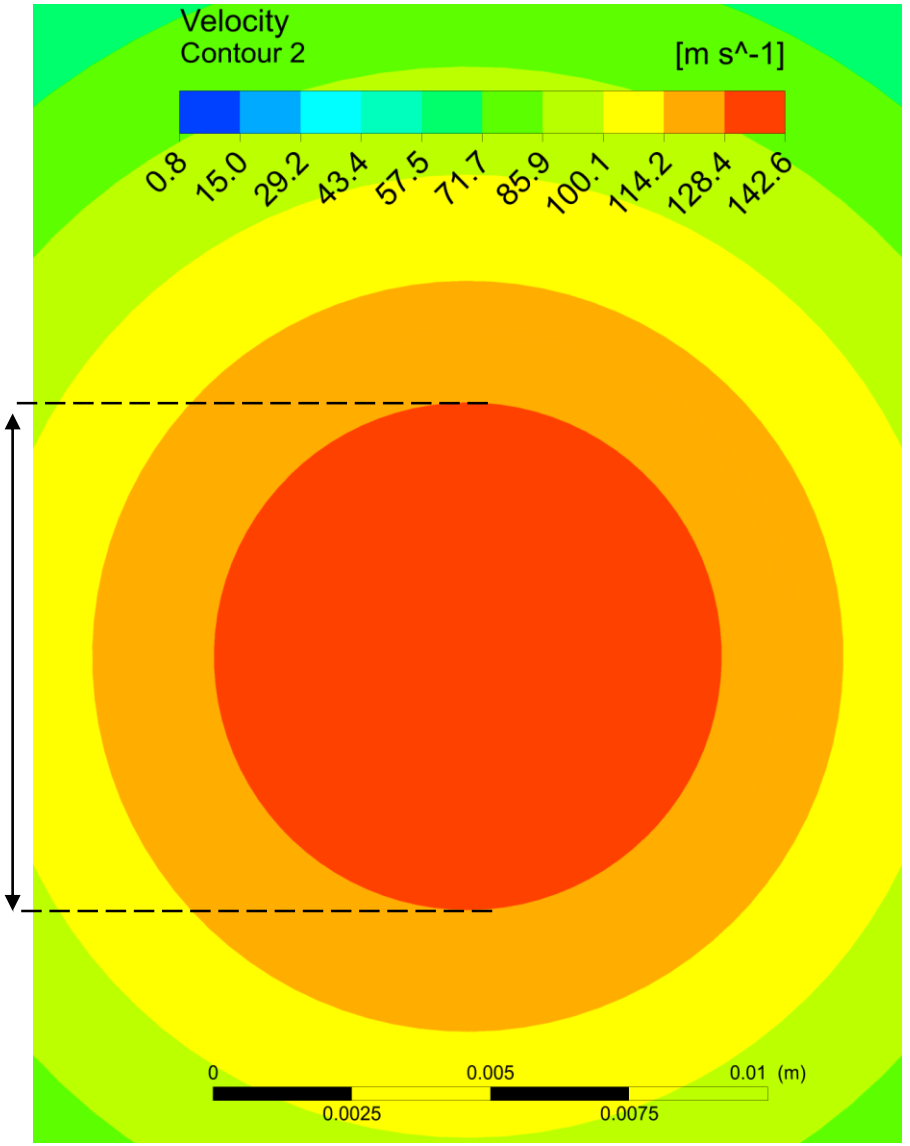
De Laval

Simple Geometry

Plane C



7.6 mm



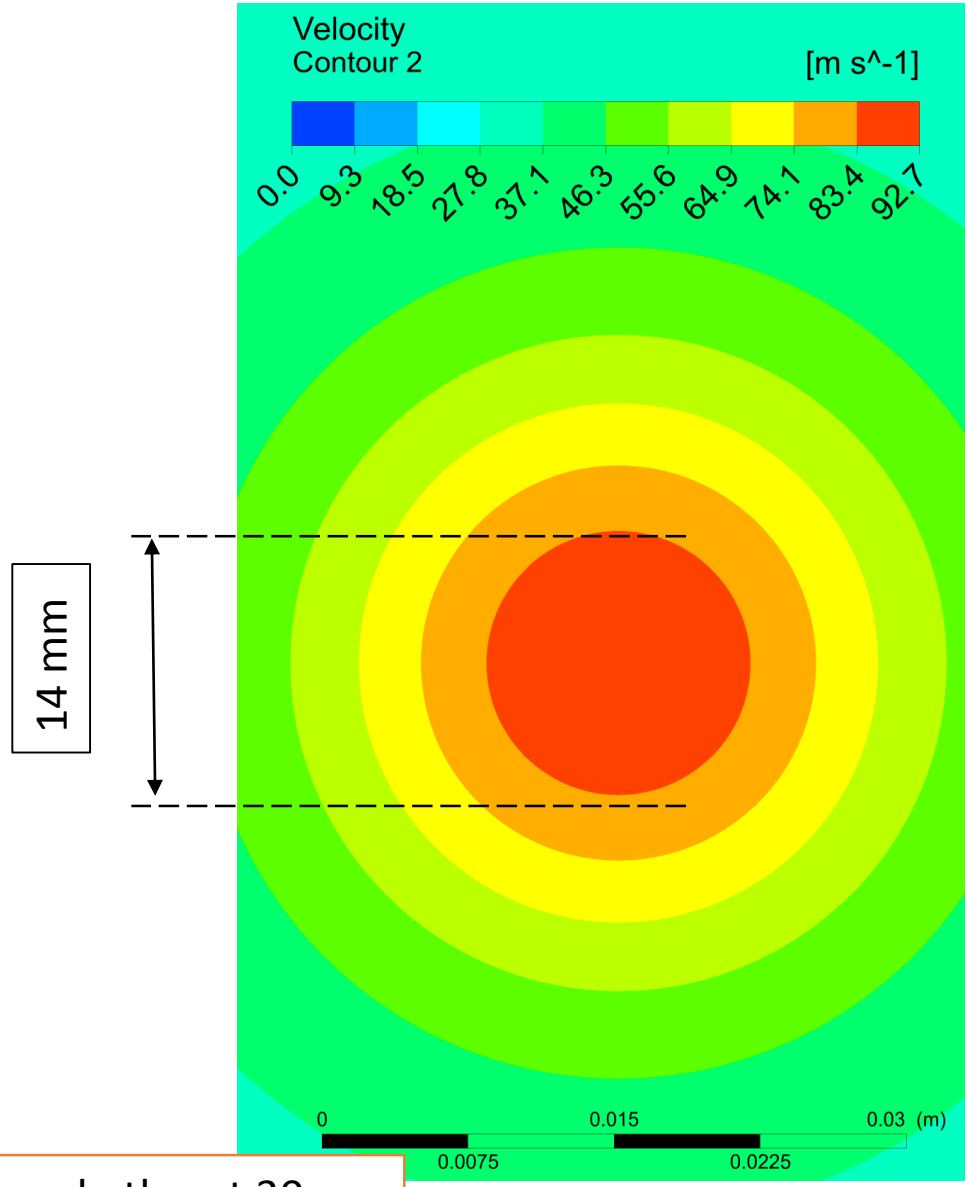
9 mm

nozzle throat 30 µm

Velocity Profile

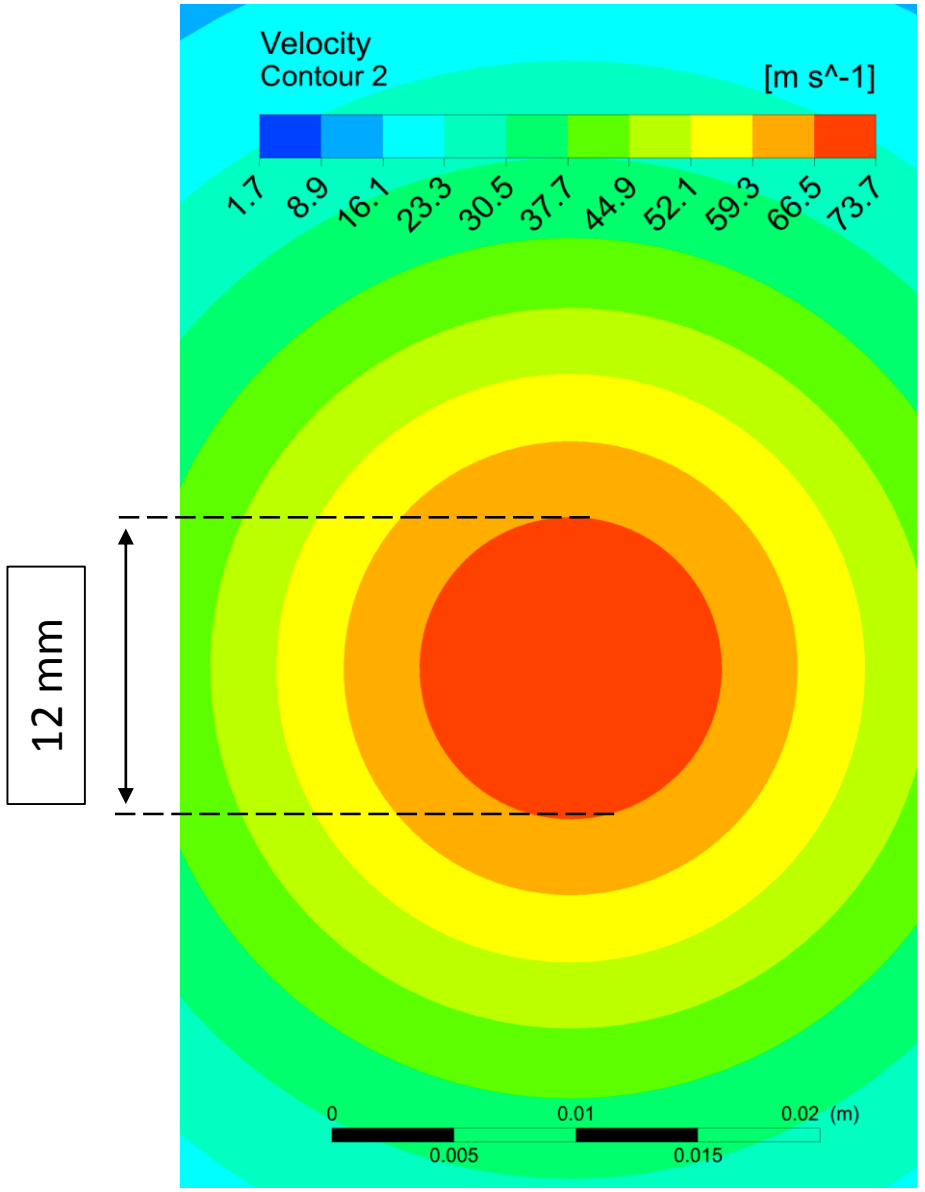
Plane D

De Laval



nozzle throat 30 µm

Simple Geometry

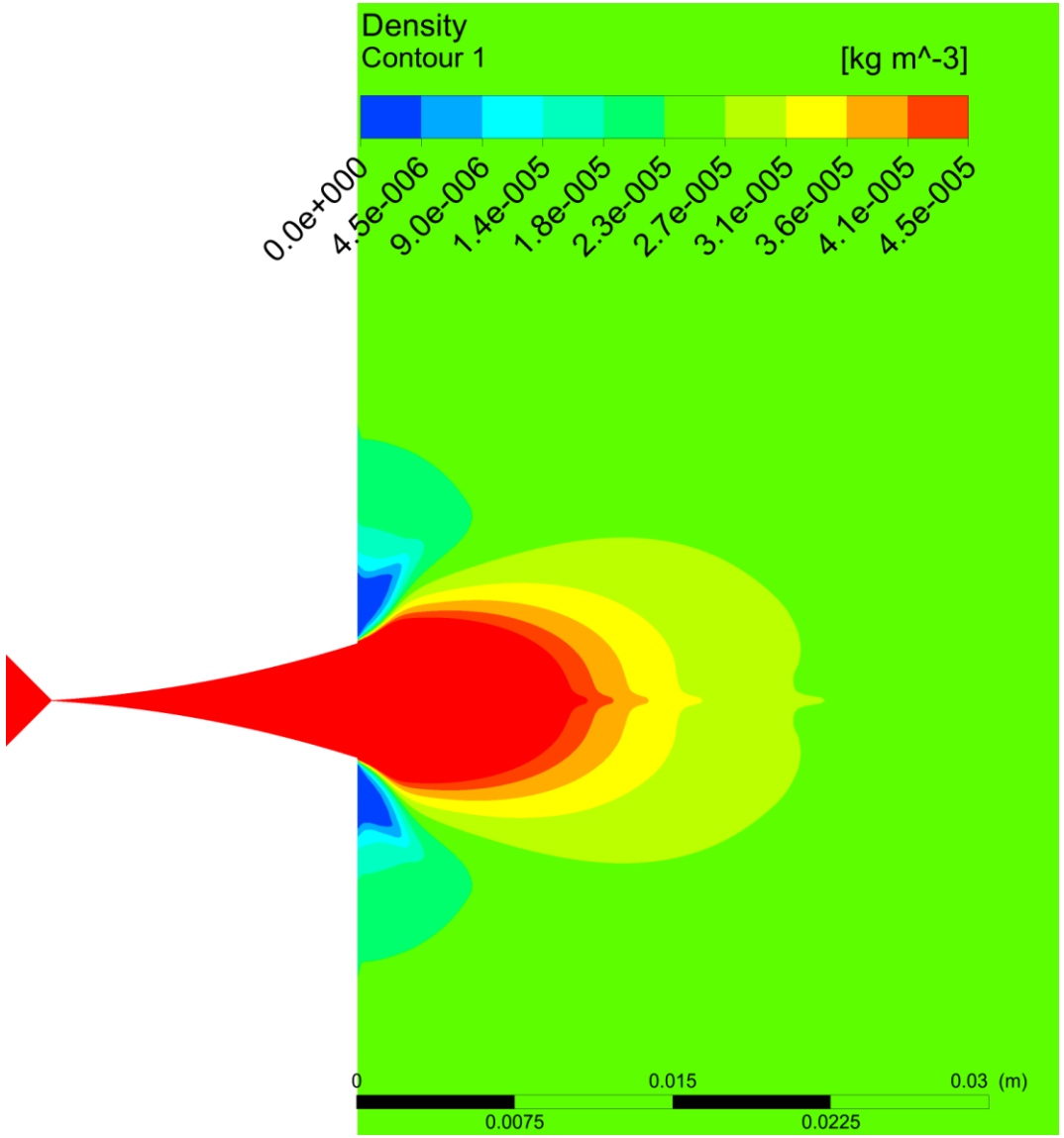


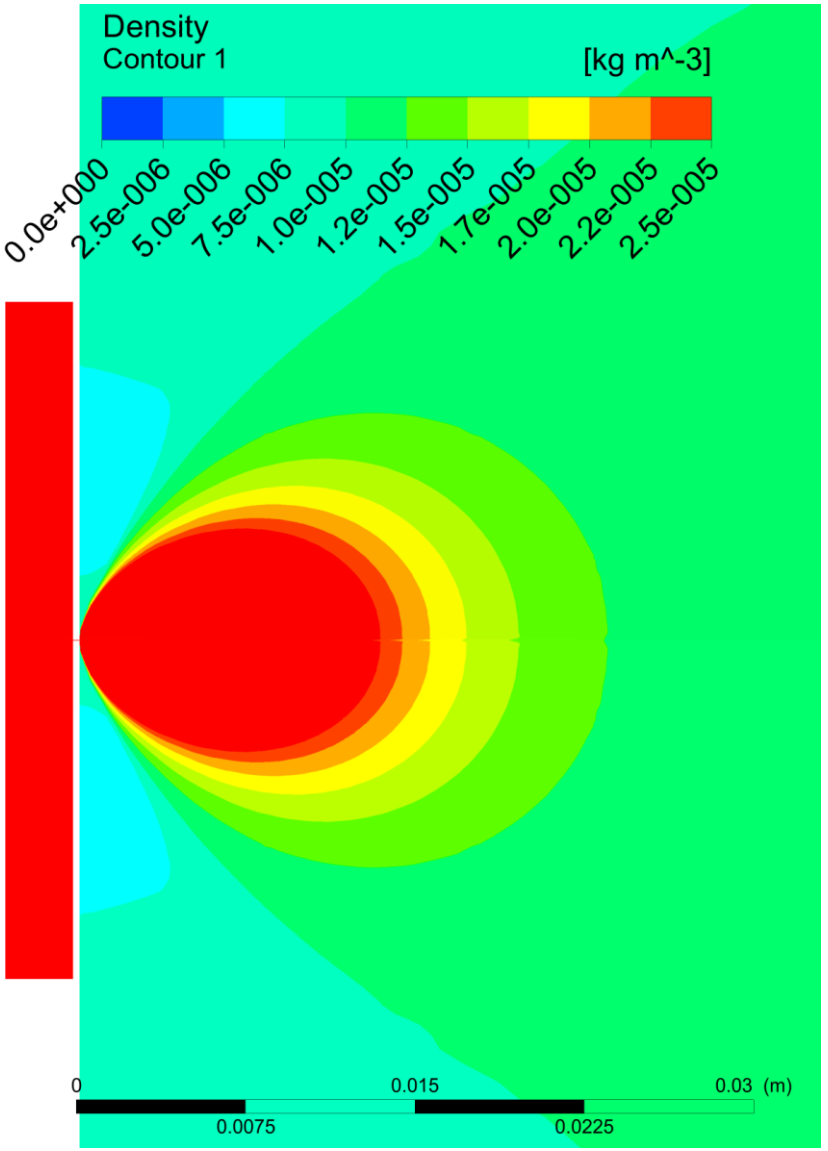
Density Profile

De Laval

Simple Geometry

Side view



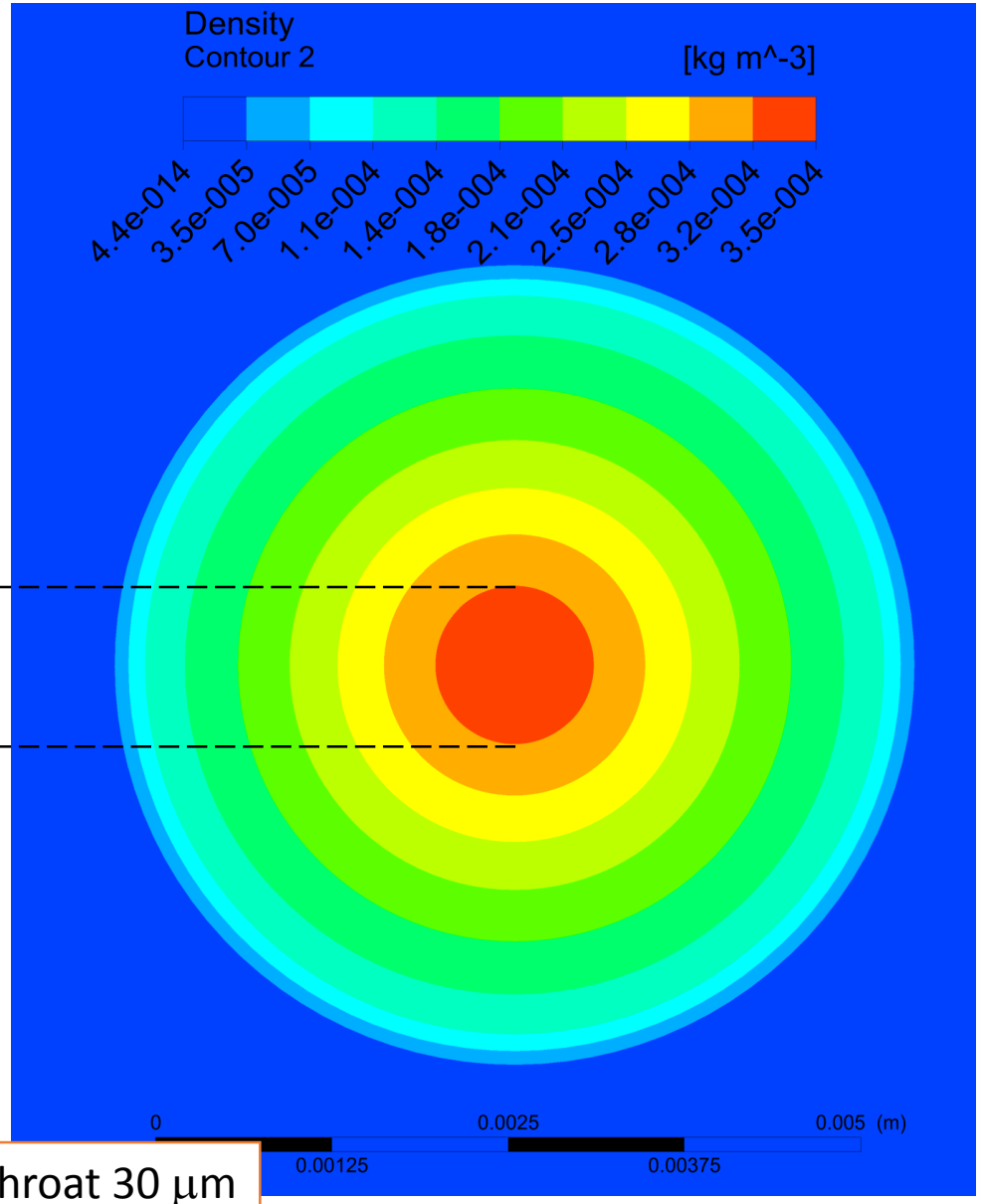


nozzle throat 30 µm

Density Profile

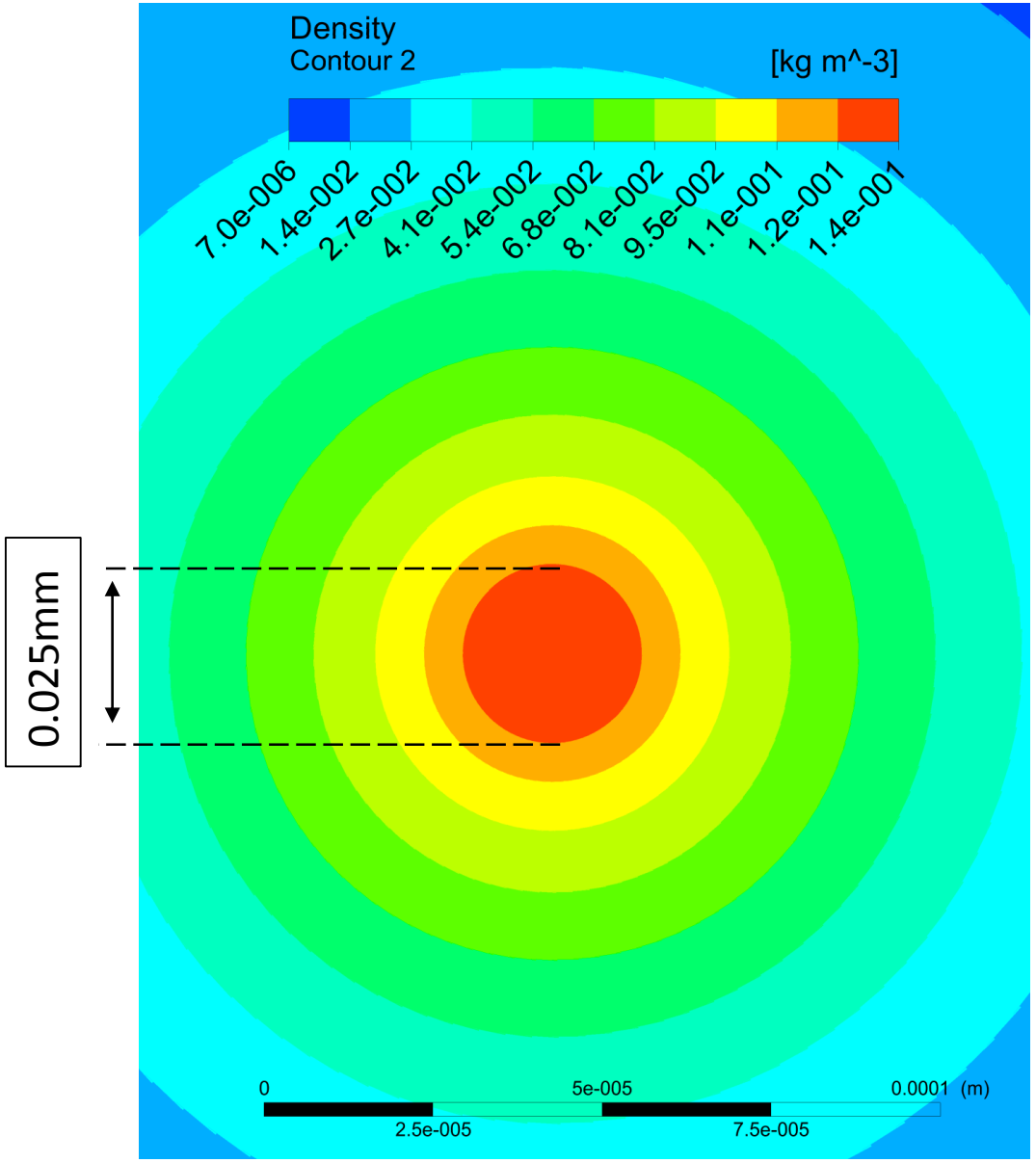
Plane A

De Laval



nozzle throat 30 μm

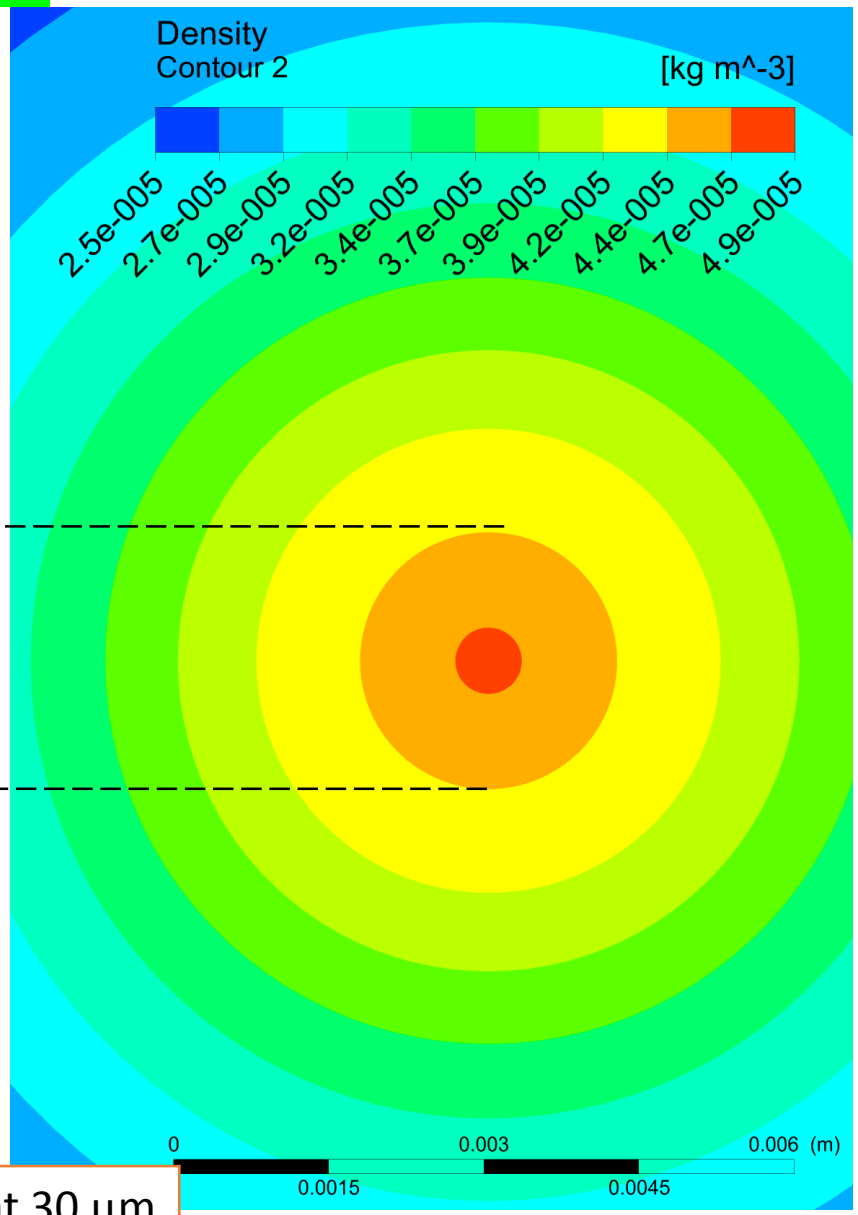
Simple Geometry



Density Profile

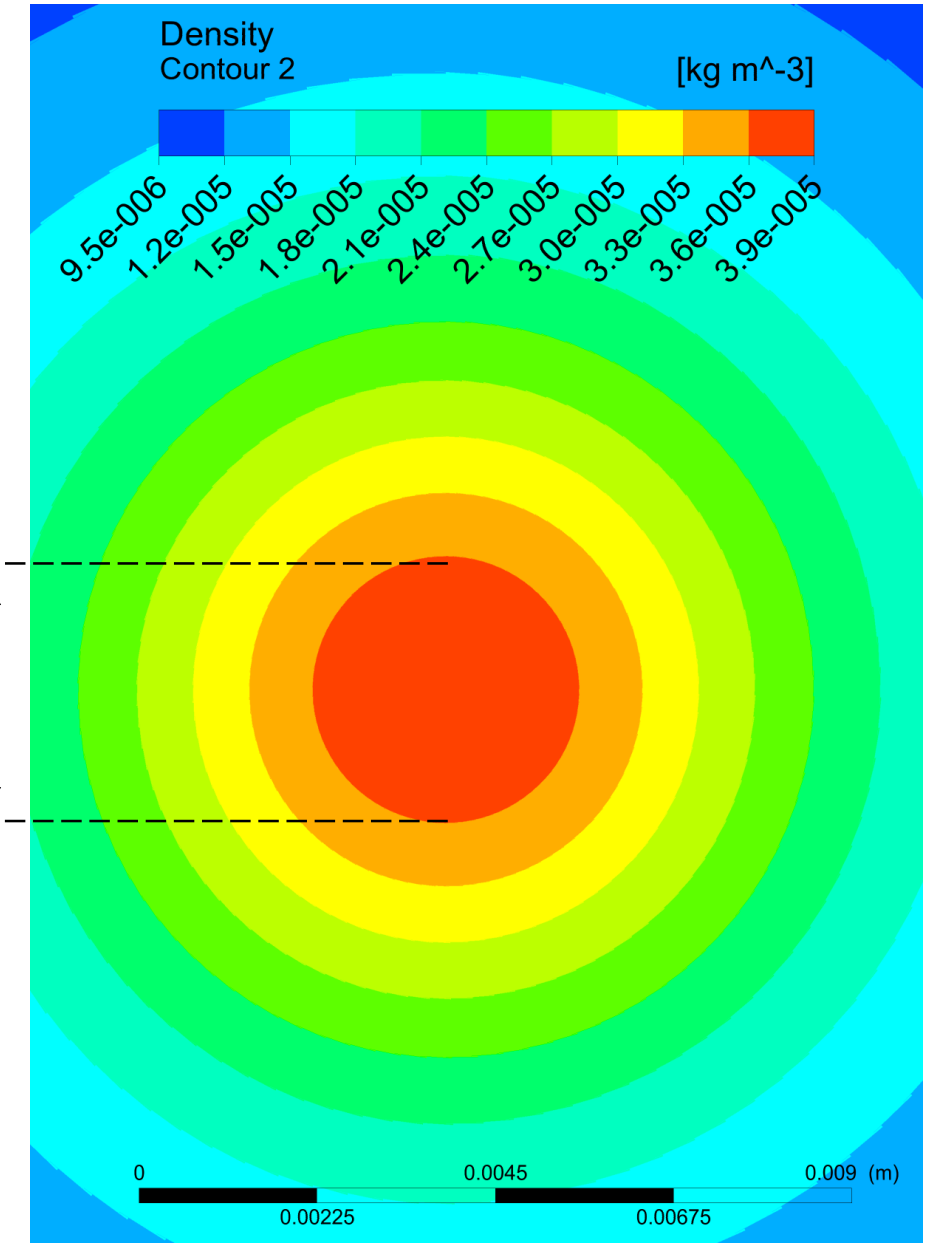
De Laval

Plane B



nozzle throat 30 µm

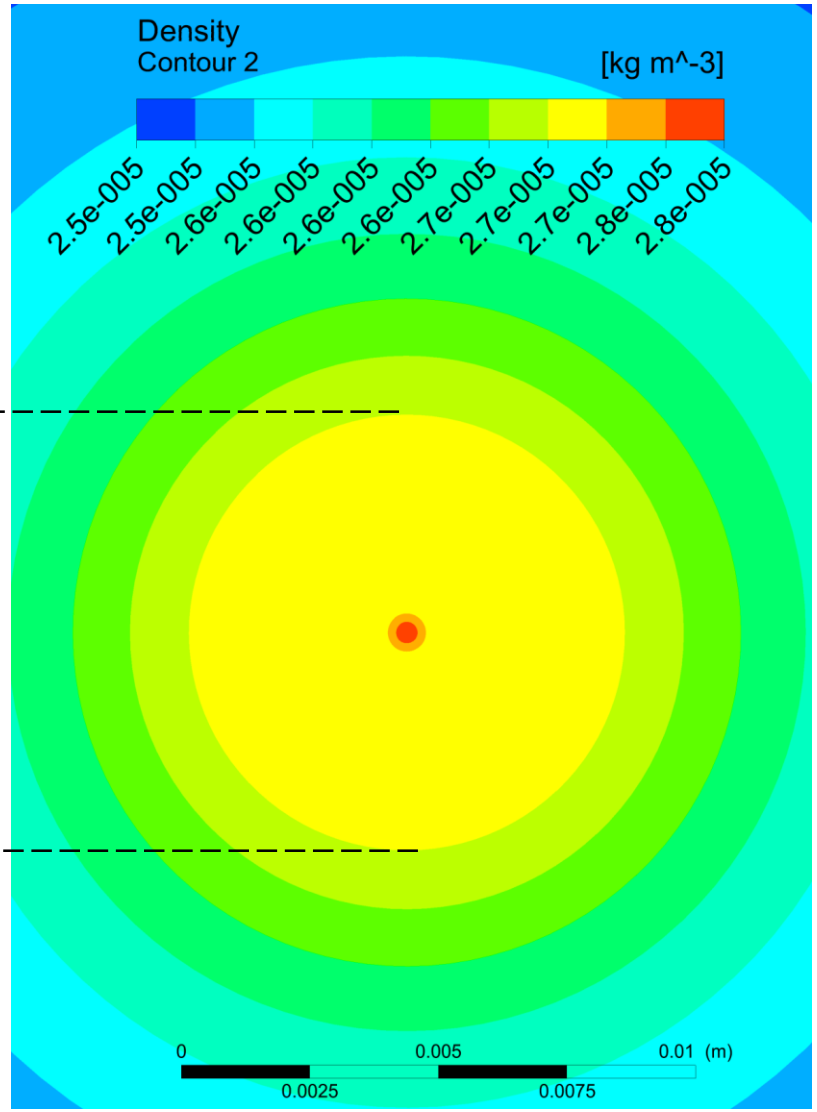
Simple Geometry



Density Profile

De Laval

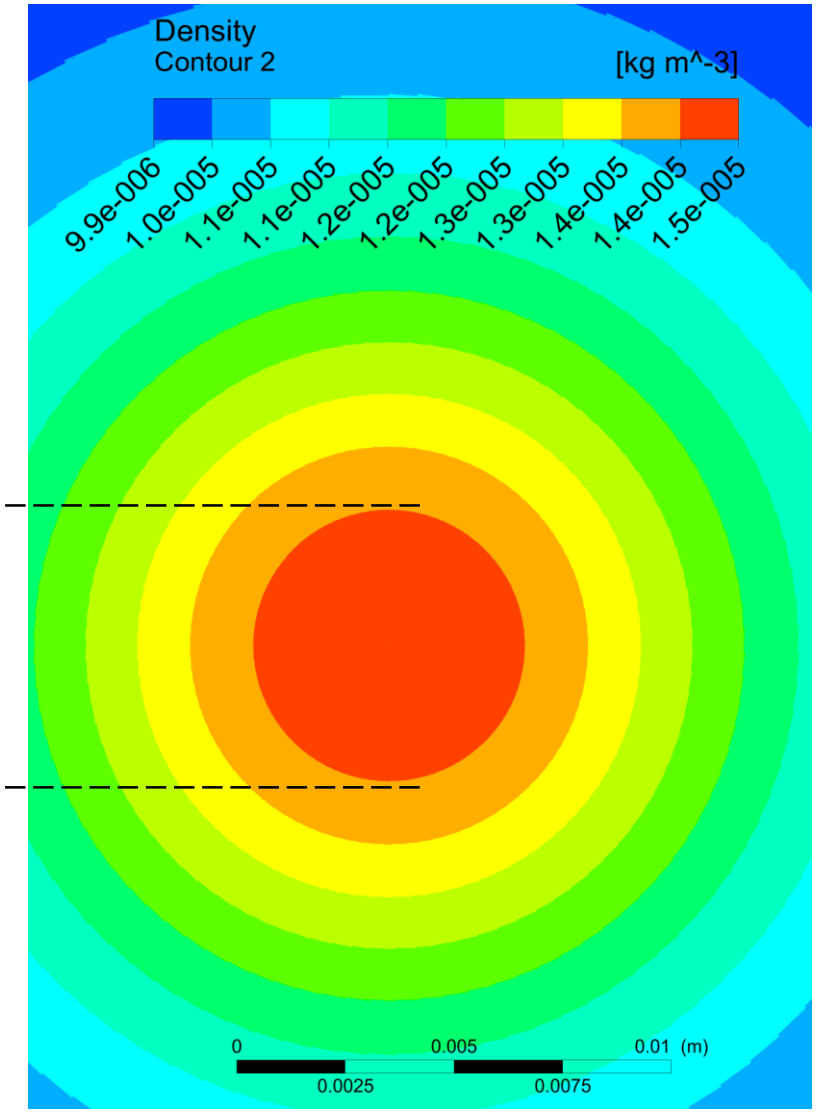
Plane C



8 mm

nozzle throat 30 µm

Simple Geometry

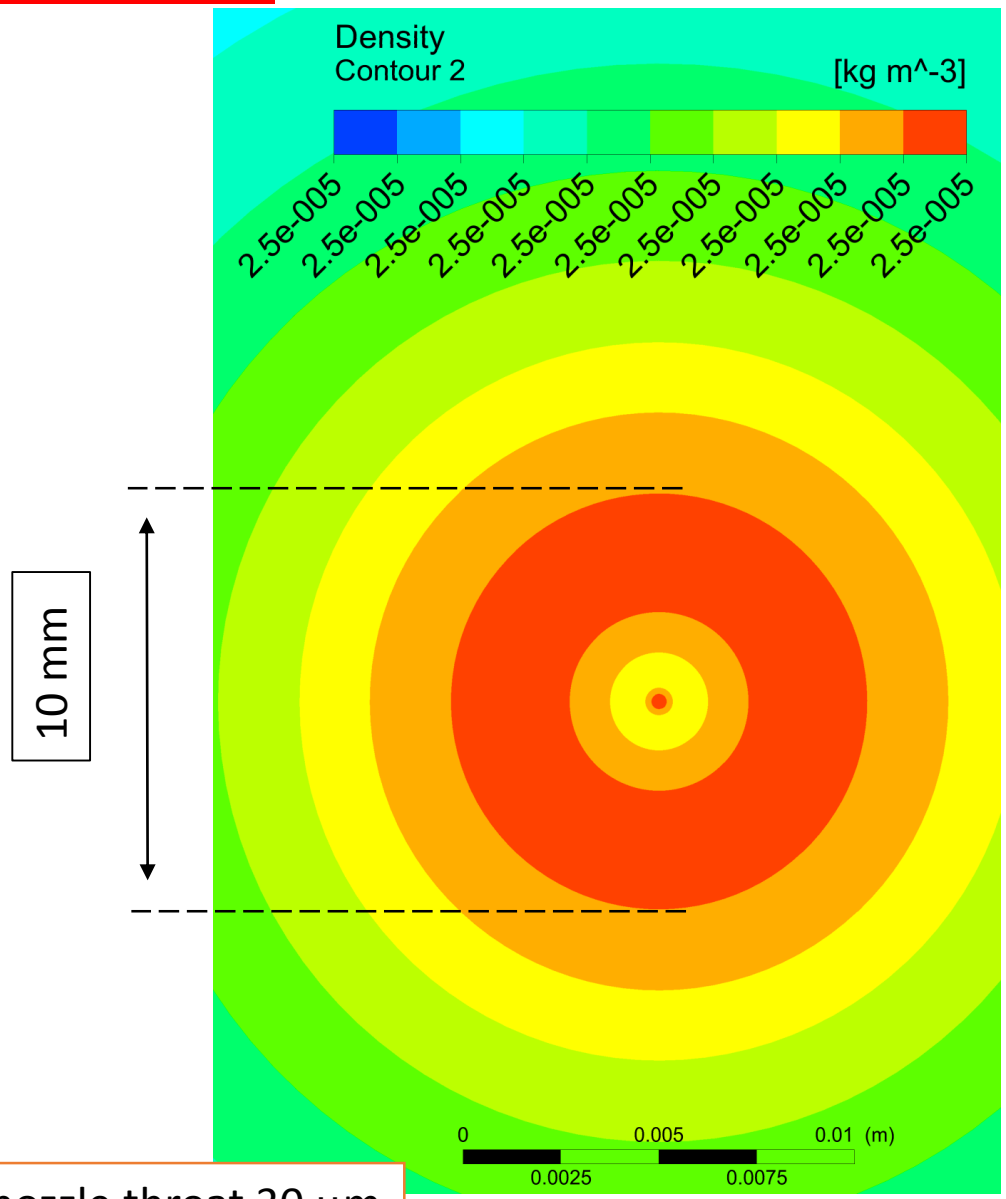


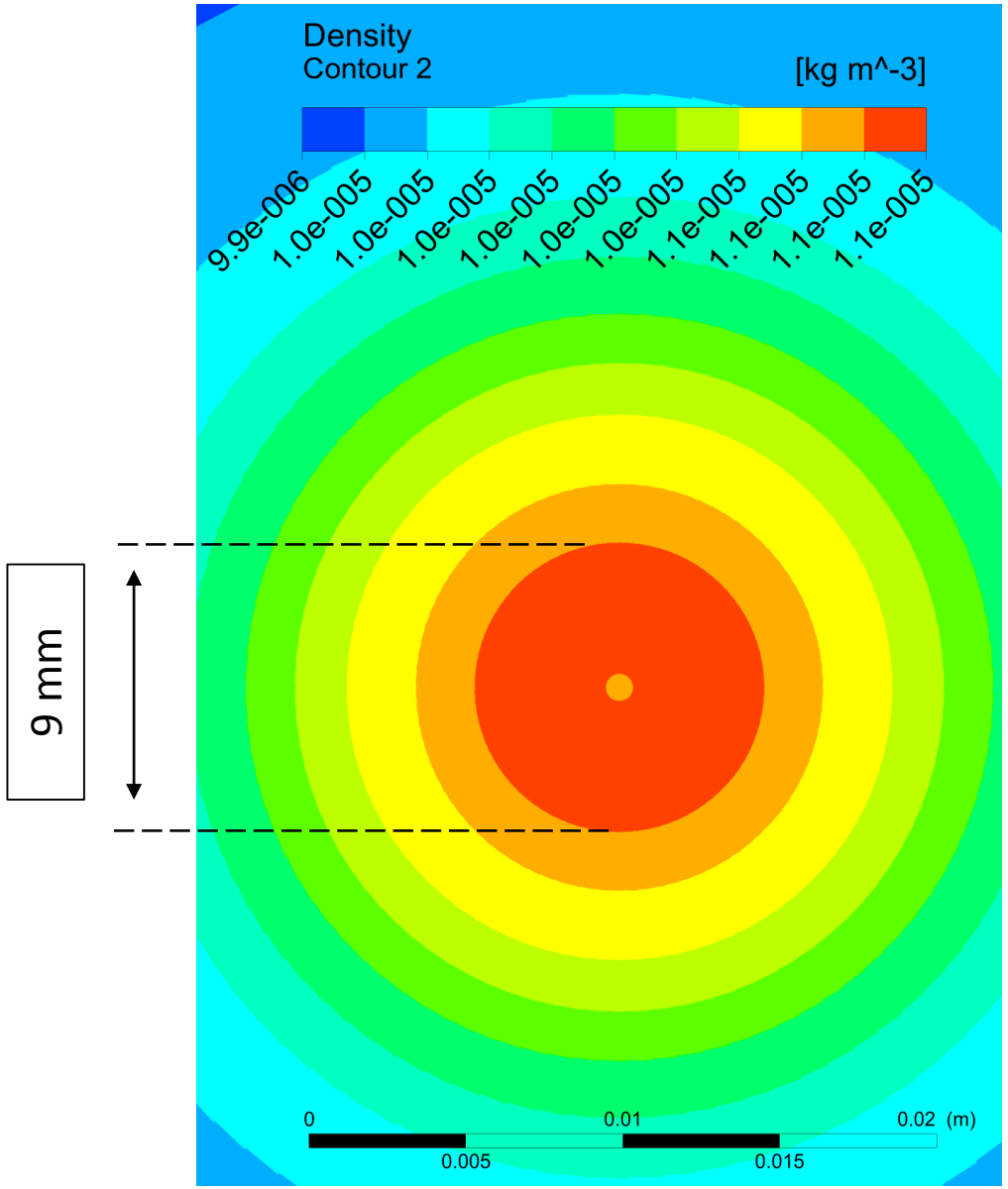
6 mm

Density Profile

De Laval

Plane D



nozzle throat 30 µm

Simple Geometry