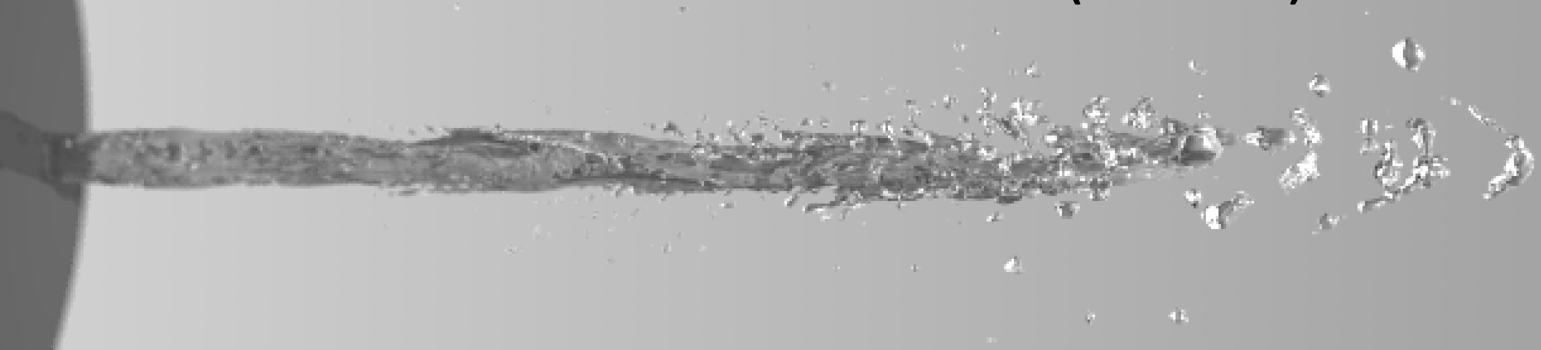
Spray A: internal and external flow

Marco Arienti (Sandia)



10/02/2014

Approaches

Institution/Code	ANL Converge	UMass HRMFoam	CMT ESA	IFP C3D	Sandia
Liquid fuel	n-dodecane	n-dodecane	n-dodecane	n-dodecane	n-dodecane
Equation of State	Incomp.	Const. compressibility (input error!), perfect gas	Non-linear function of p,T, perfect gas	Stiffened gas EOS, ideal gas	Non-linear function of p,T, perfect gas
Cavitation Enabled?	Yes	No for A, Yes for B	No	Yes	No
Cavitation Model	Homogenous Relaxation	Homogenous Relaxation	--	GERM	-
Inclusion of turbulent viscous energy generation?	N	N	Y	Y	N
Turbulence	RANS k-epsilon	LES one-eq. eddy	RANS SST k-ω	LES Smagorinksy	None
Spatial Discretization	2nd order	2nd / 1st order	1st order	2nd order	Cell-integrated semi-Lagrangian

Computational Domain

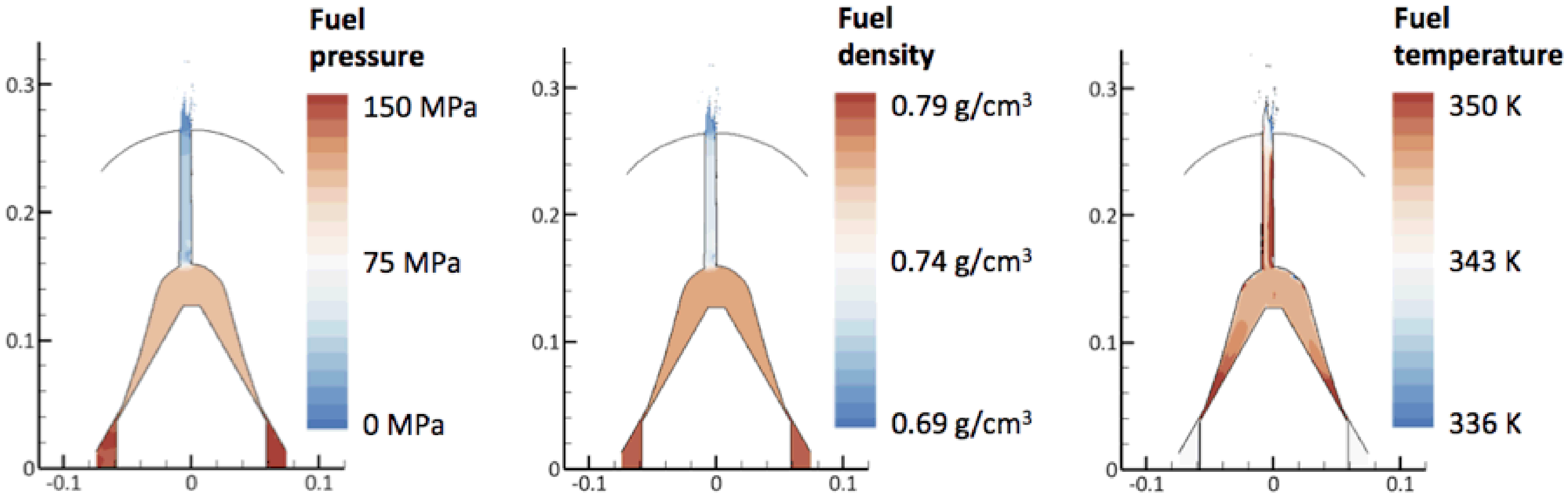
Institution/Code	ANL Converge	UMass HRMFoam	CMT ESA	IFP C3D	Sandia
Dimensionality	3	3	2	3	3
Cell Type	Hex cut cell	Hex, polyhedral	Quad, polyhedral	Hex	Embedded boundary
Cell count (total interior and exterior)	2.5M early, 0.8M main	2.8M	64K	1M	74M
Needle motion?	Yes	No	No	Yes (lift, no wobble)	Yes
Geometry	CNRS yearly, Same as last year for main	Same as last year	Last year(2D)	CNRS scan	Based on description

Boundary Conditions

Institution/Code	ANL Converge	UMass HRMFoam	CMT ESA	IFP C3D	Sandia CLSVOF
Time Accurate ROI Profile?	Yes	Yes	Yes	Yes	Yes
Inlet	Time varying total pressure	Time varying velocity	Time varying static pressure	Time varying static pressure	Fixed static pressure (150 MPa)
Wall BCs	L.O.W.	Slip	No-slip	Slip	No-slip
Needle motion?	Yes	No	No	Yes (lift, no wobble)	Yes

- Also: adiabatic boundary conditions at the injector's walls
- Gas phase at rest: 2 MPa / 303 K (no evaporation model)

Pressure, density and temperature distribution of the liquid phase at SOI t = 0.339 ms

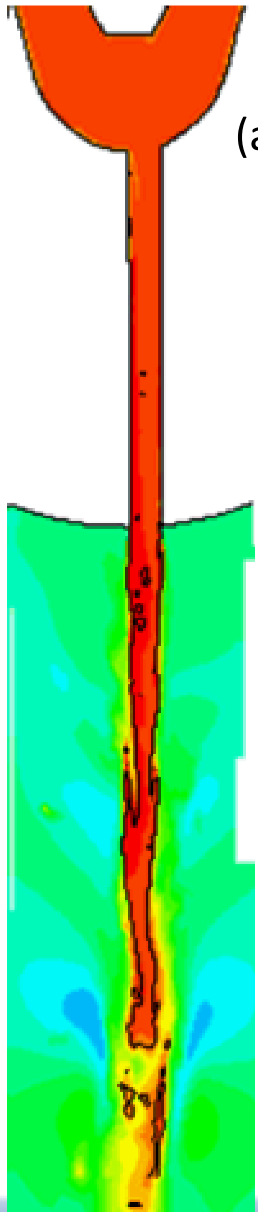


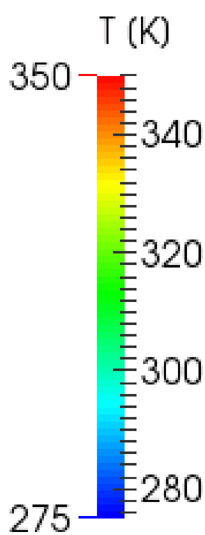
- Start of Ignition (SOI) from half-filled sac
- Adiabatic expansion of the liquid near the exit
- Limited range of density and temperature variation

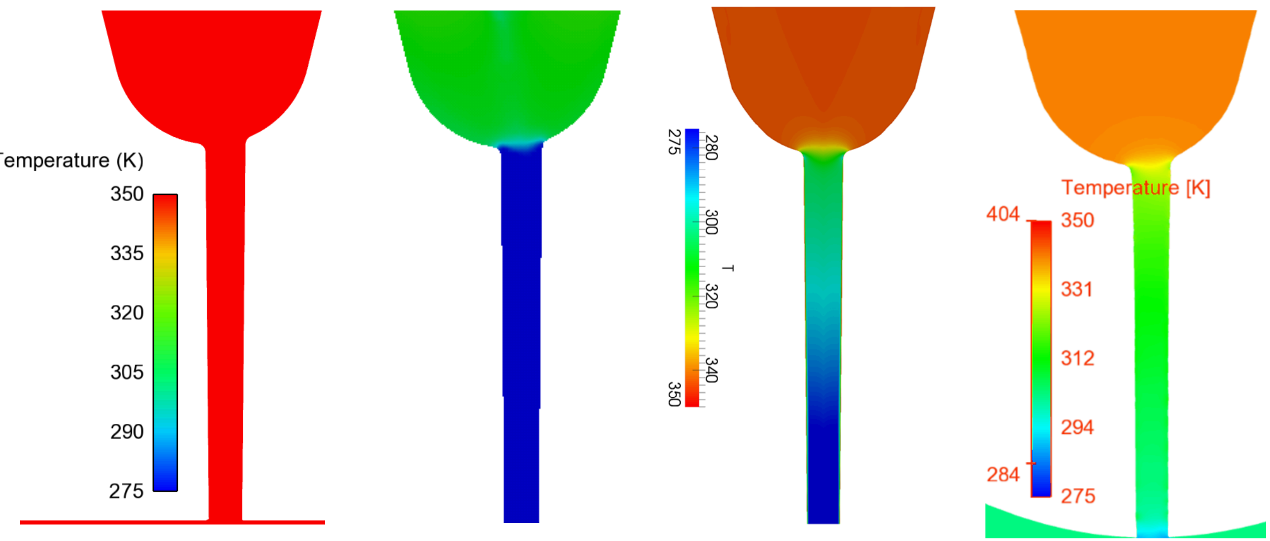
Temperature, transverse (x-y) view

Sandia

(at 5 μs ASOI)







ANL UMass CMT IFPEN

(at 0.75 ms ASOI)

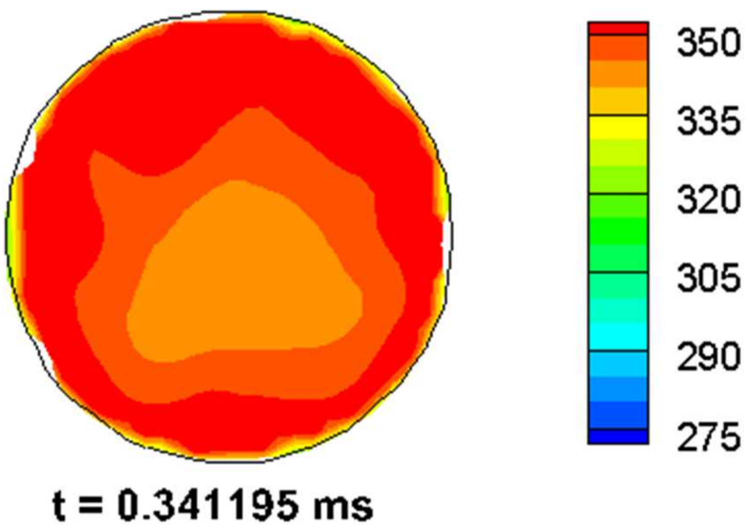
- Note: the current simulation does not have a heat transfer model between liquid and gas phase

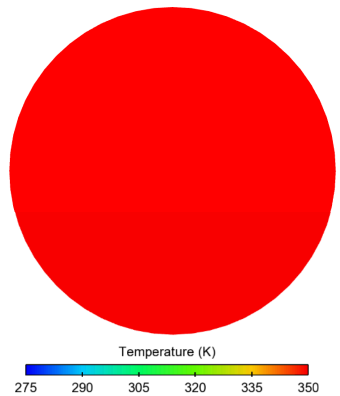
Temperature distribution at the orifice exit

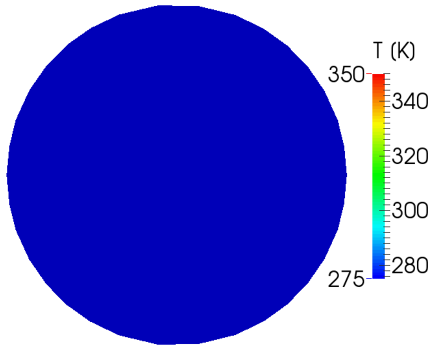
ANL

UMass

Sandi
a

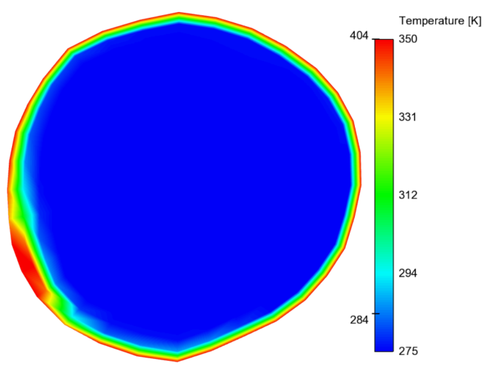


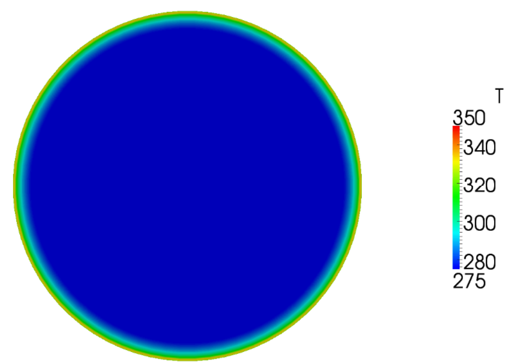




IFPEN

CMT



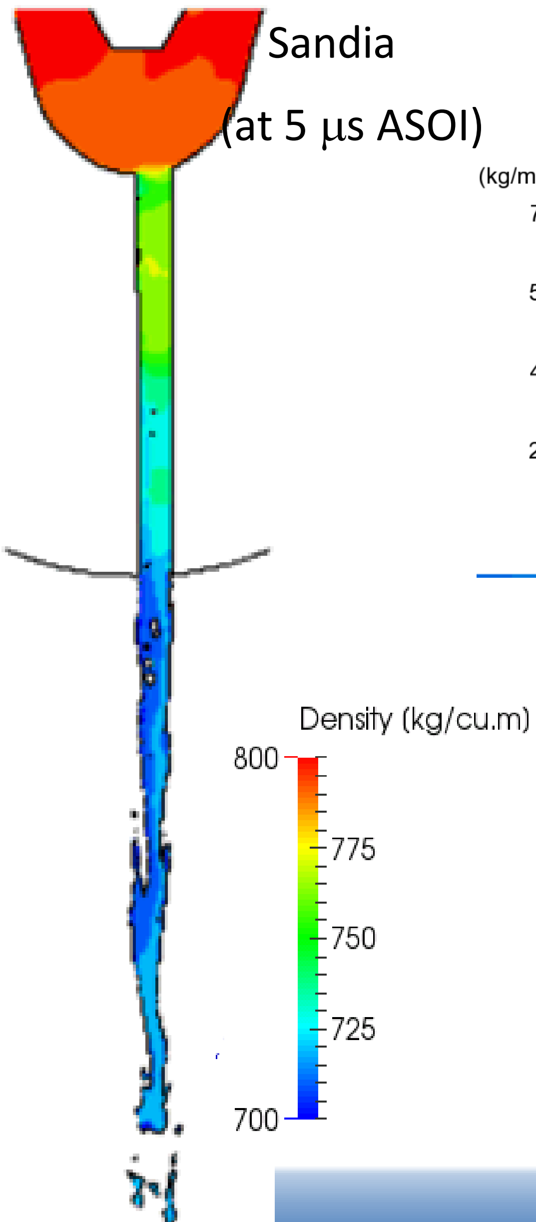


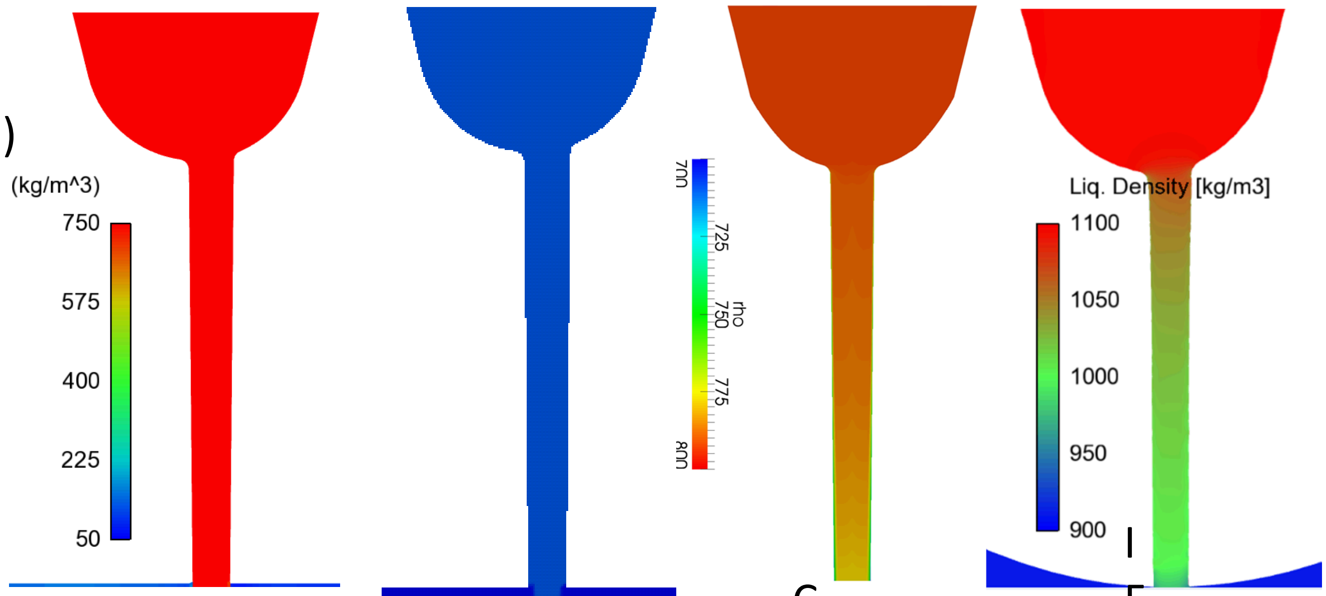
- Cross-section taken immediately before orifice exit

Density, transverse (x-y) view

Sandia

(at 5 μs ASOI)





ANL

Mass

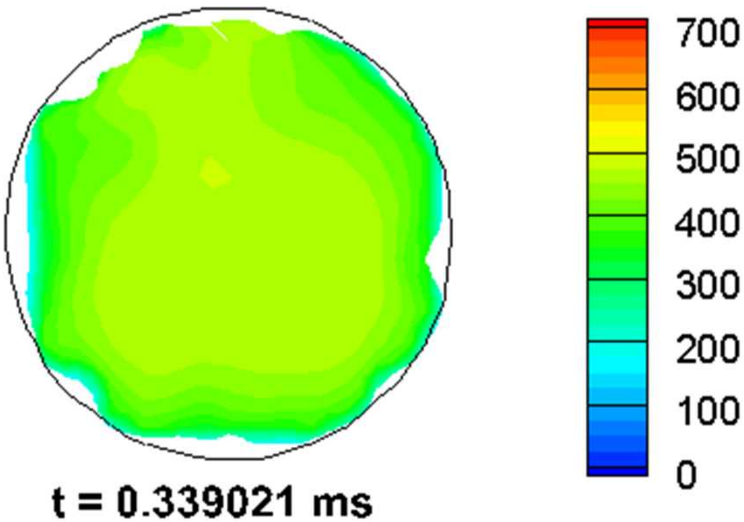
CMT

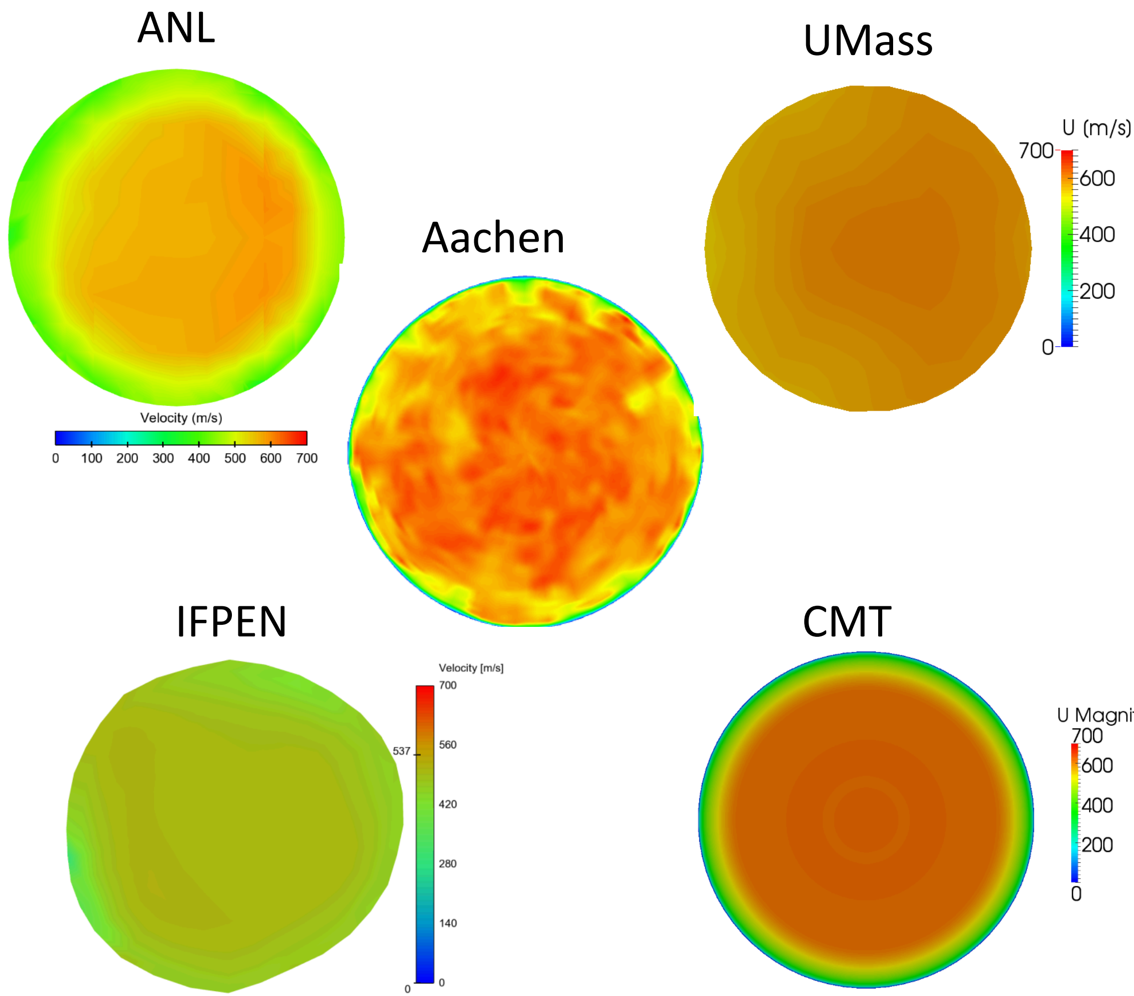
IFPEN

(at 0.75 ms ASOI)

- Note: Only the liquid phase is shown here (in the simulation there are two distinct density fields)

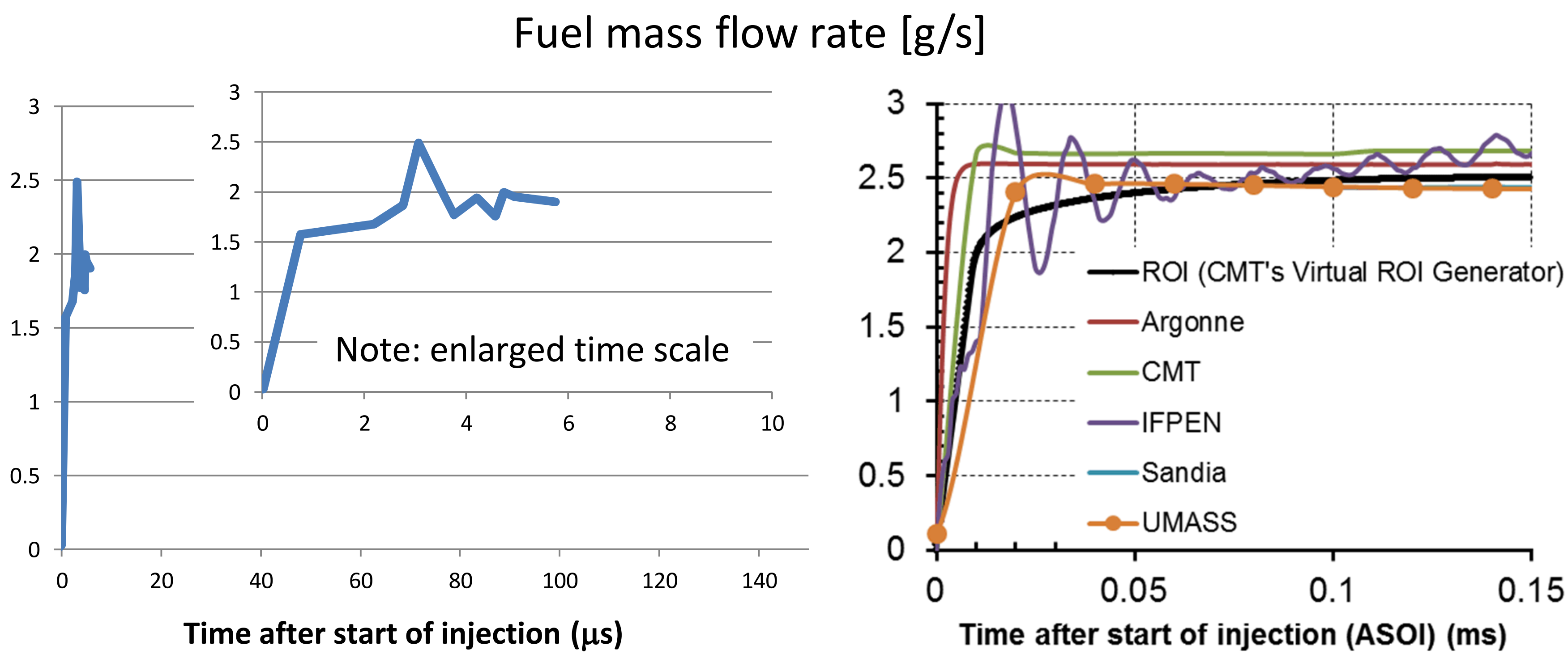
Velocity distribution at the orifice exit





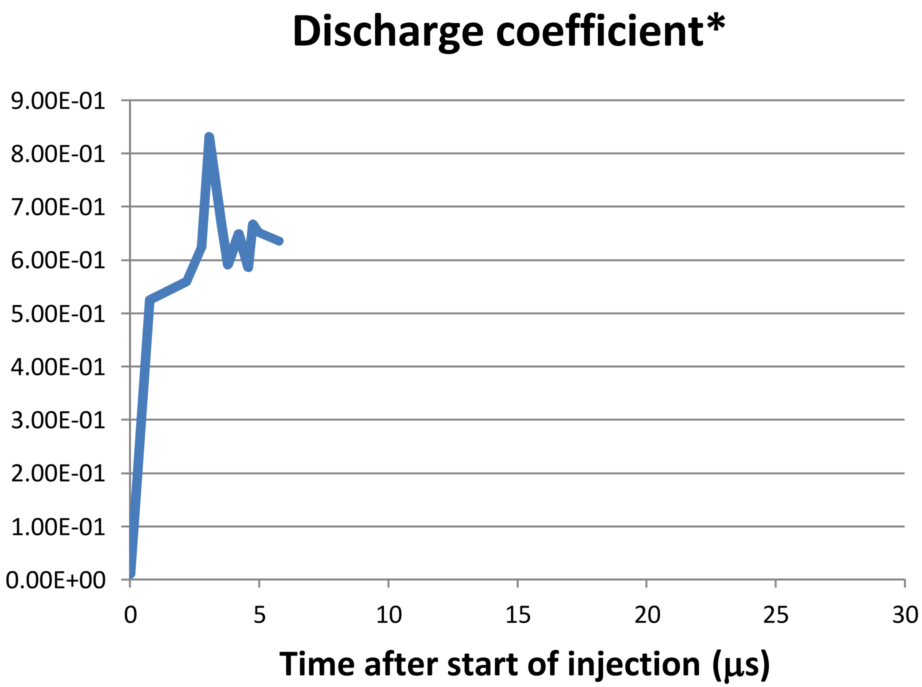
- Re = 31,500
- Evidence of gas inclusion near the orifice exit

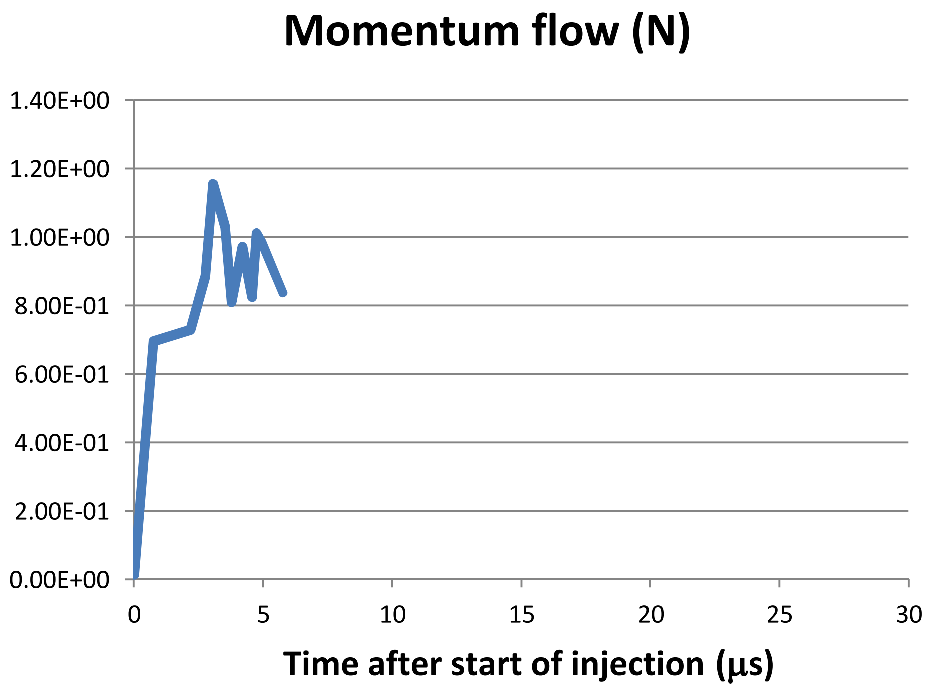
Mass flow rate – opening transient



- Rapid increase in fuel flow, followed by oscillatory behavior (at higher frequency than the needle's motion)

Discharge coefficient and momentum flow

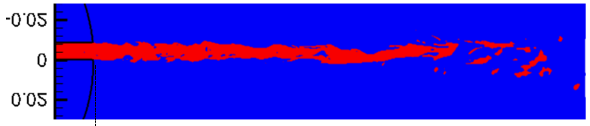




*The discharge coefficient is calculated based on density at 0.1 MPa, 343 K conditions and for a pressure jump of 248 MPa

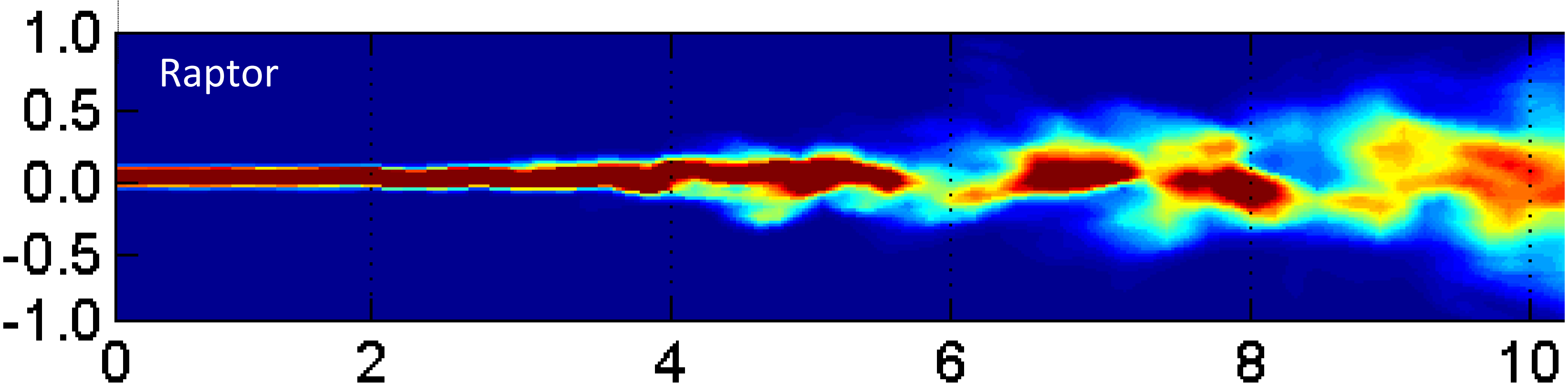
Jet development

Zero level set value at 0.006 ms ASOI

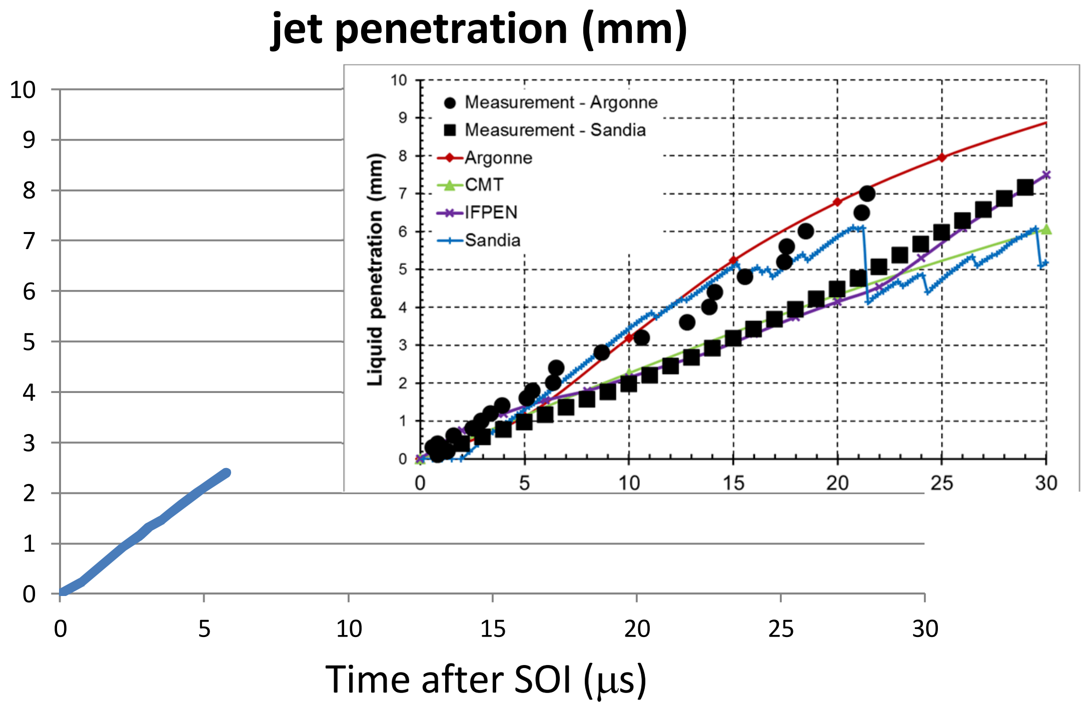


Current simulation

Projected mass density at 0.1 ms ASOI



Jet development



- Jet penetration (length of contiguous liquid) seems to follow Argonne's experiment more closely

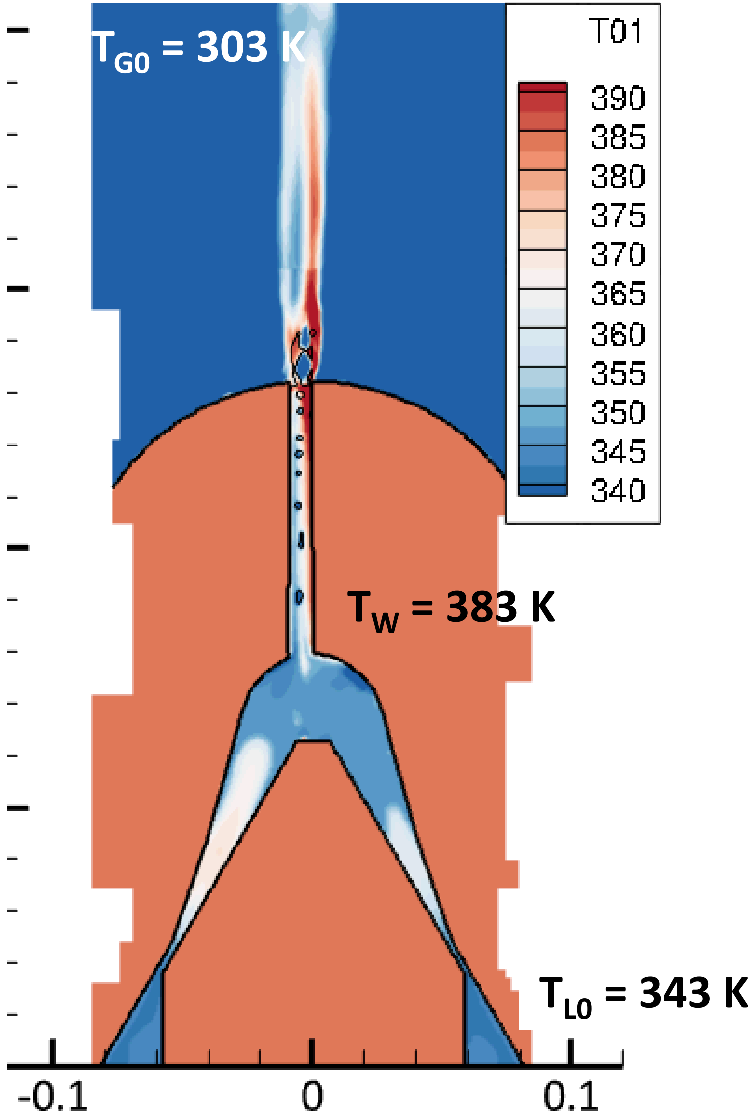
Path forward

- The current adiabatic simulation will continue to 30 μs from SOI to collect data on primary atomization

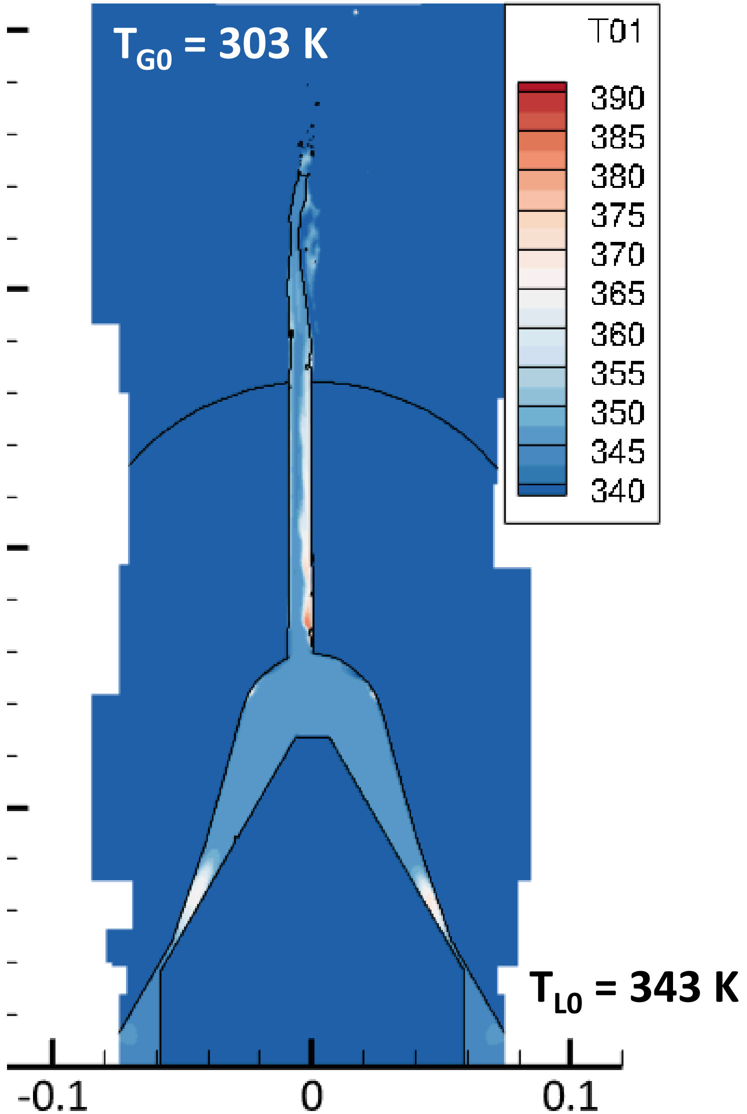
  - With more than 80M cells (3μm resolution) and with the current resources, a 2μs advancement per week is expected (at best)

- A second case with isothermal walls (at 383 K) is being explored

New case: isothermal walls



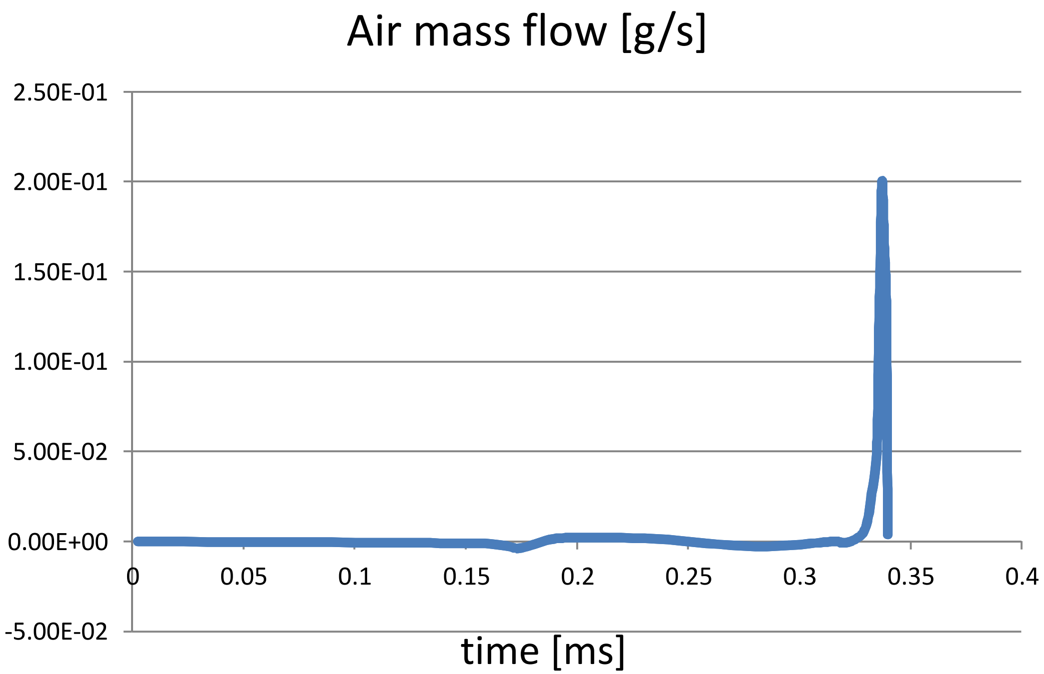
Baseline: Adiabatic walls



Back-up

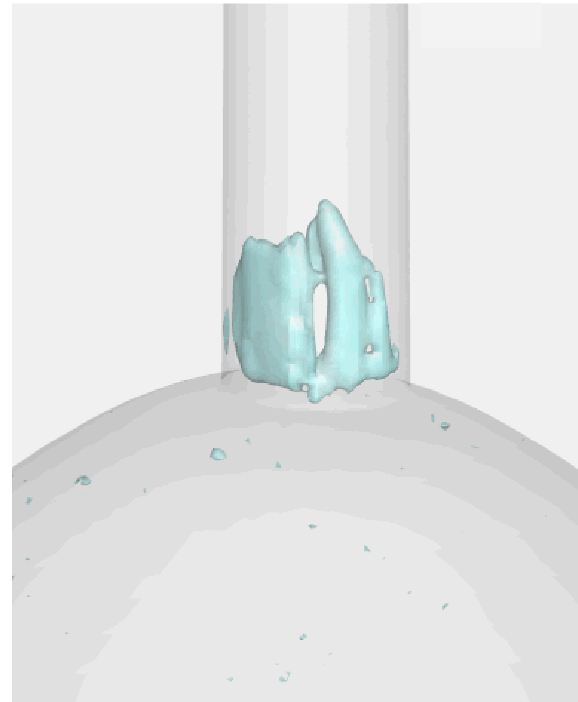
Mass flow – opening transient

time [ms]	mass flow – AIR [g/s]	mass flow – FUEL [g/s]
0.00255753	2.40E-06	0
0.1587736	-1.23E-03	0
0.1732709	-3.82E-03	0
0.187601	1.08E-03	0
0.19837	2.05E-03	0
0.235546	1.42E-03	0
0.280205	-2.83E-03	0
0.315518687	9.29E-07	0
0.317500687	-6.54E-06	0
0.319629	-8.46E-04	0
0.324989	1.12E-03	0
0.329654	7.11E-03	0
0.3326556	2.71E-02	0
0.334792	4.90E-02	0
0.3361497	1.41E-01	0
0.33717	2.00E-01	0
0.33806	1.69E-01	0
0.339021	1.34E-01	1.37E-01
0.3397494	3.73E-03	1.442248



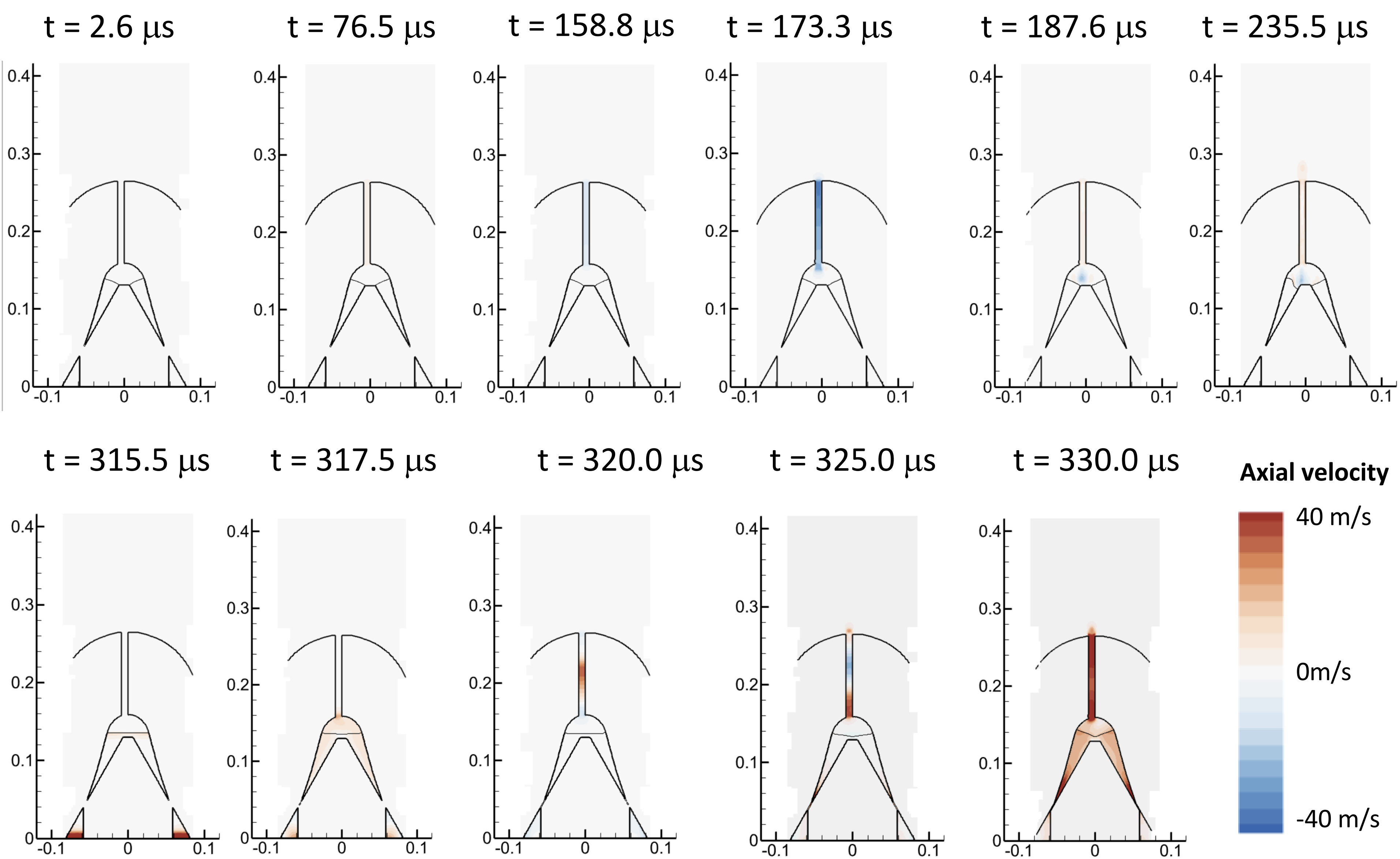
- The flows are calculated by integration of the axial flux over a cross-section of the orifice located just before the exit

Trapped gas at t = 390.7 μs



- Estimated gas volume ~ 3 10^{-7} cm^3 = 0.0015 V_{sac}
- The average density of the gas inside the bubble is ~ 0.2 g/cm^3
- The estimated residual gas mass is therefore 6 10^{-8} g

Axial velocity – early opening transient



Axial velocity – opening transient