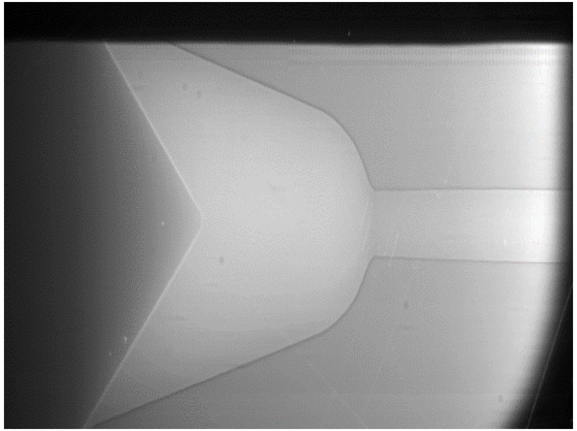
SEPTEMBER 10, 2018

ECN6: TOPICS 1 & 2 DIESEL INTERNAL AND NEAR NOZZLE FLOW



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ECN 6 Workshop, Valencia, Spain

2) INTERNAL NOZZLE EFFECTS

Contributors

- Sandia: Julien Manin, Lyle Picket
- Perugia: Michele Battistoni
- UMass: Peetak Mitra, Declan Gwynne, Eli Baldwin, David Schmidt
- Sandia: Joonsik Hwang, Marco Arienti
- RWTH: Mathis Bode, Marco Davidovic, Heinz Pitsch

ENGINE COMBUSTION NETWORK

MODEL DESCRIPTION

Institution/Group	**Approach**	**CFD code**	**Compressibility and EOS**	**Turbulence model**
RWTH Aachen Bode, Davidovic, Pitsch	LES/DNS	CIAO	Compressible code with HEM with (SG/PR EOS)	Dynamic Smagorinsky (Lag. Averaging)
UMass Mitra, Gwynne, Baldwin, Schmidt	RANS Homogenous Relaxation Model	HRMFoam	Compressible Refprop (NIST database)	$\kappa-\omega$
Perugia Battistoni	Diffuse interface (mixture)	CONVERGE	barotropic liquid + RK gas	LES Dynamic Structure
Sandia Hwang, Arienti	RANS	CONVERGE	Standard compressible formulation based on extended barotropic	RNG k-e

ENGINE COMBUSTION NETWORK

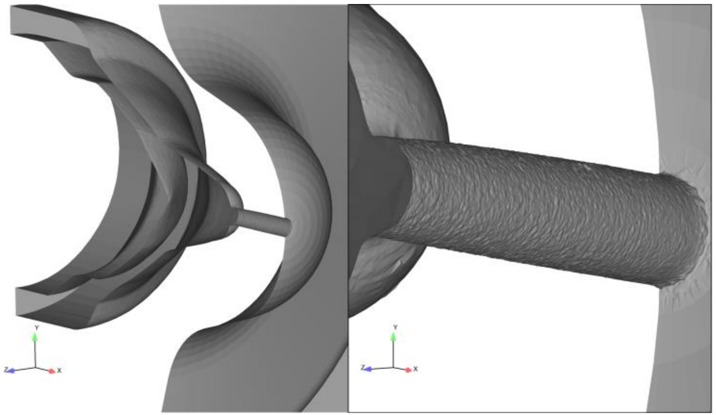
MODEL DESCRIPTION

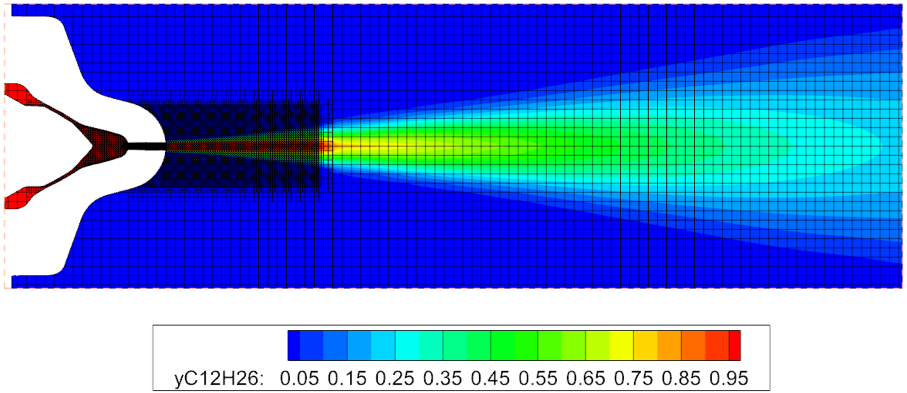
Institution/Group	Nozzle surface	min-max mesh resolution	Needle motion	Dimensionality
RWTH Aachen Bode, Davidovic, Pitsch	C #37 – high resolution STL D #134 – high resolution STL	1.0 μm – 10 μm	Measured	3D
UMass Mitra, Gwynne, Baldwin, Schmidt	Wireframe	1.1 μm – 25 μm (Pacman mesh motion Library)	Fixed	3D
Perugia Battistoni	C #37 – high resolution STL D #134 – high resolution STL	2.5 μm – 40 μm (with AMR)	Fixed – high lift	3D
Sandia Hwang, Arienti	C #37 – high resolution STL	7.81μm - 250μm (With embedded mesh refinement and AMR)	Fixed – high lift	3D

MODEL DESCRIPTION

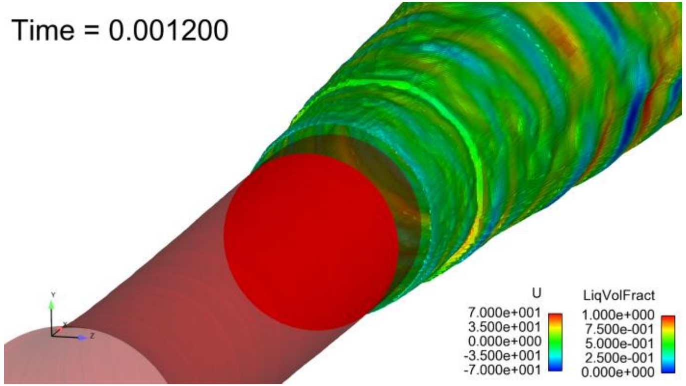
Institution/Group	Cell type	Cell count	Spatial discretization	Temporal discretization
RWTH Aachen Bode, Davidovic, Pitsch	Cartesian structured	80M	Hybrid 2nd order	2nd order RK
UMass Mitra, Gwynne, Baldwin, Schmidt	Polyhedra	2.1M	2nd order	1St order Euler
Perugia Battistoni	hex	50M	1) 2nd order CD for all (with flux limiter), except for turbulence,	1st order Euler Dt ~ 1.0 ns
Sandia Hwang, Arienti	Brick	1M	First-order upwind for momentum with blending factor 1.0. Rhie-Chow and strictly conservative.	Transient solver

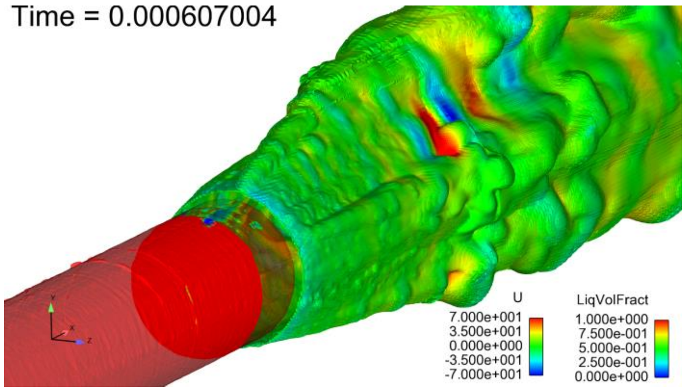
MESHES





RECALL: ECN5 – SPRAY D (BATTISTONI)

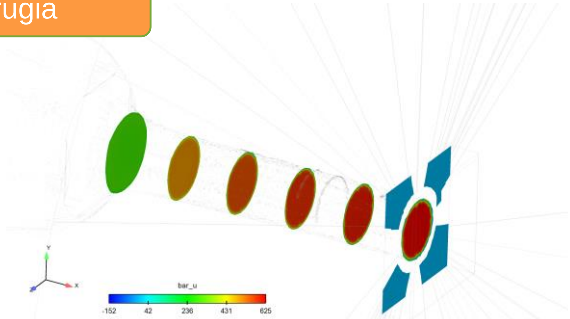


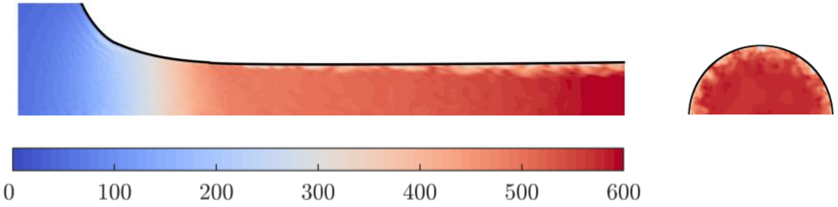


- Effects of geometry on Spray D studied

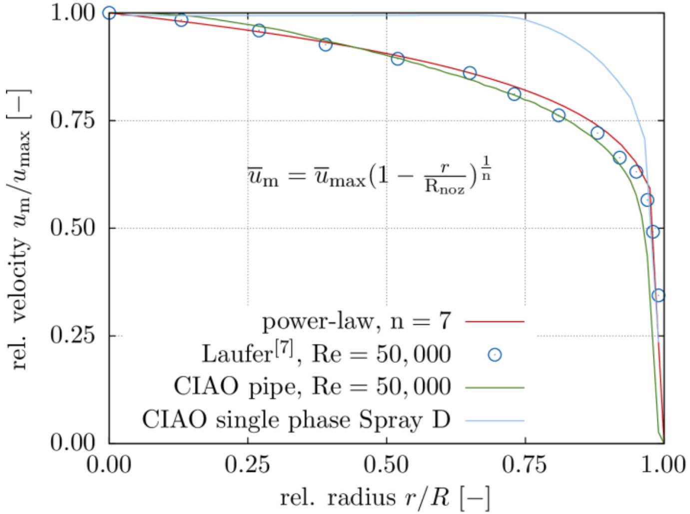
SPRAY D - VELOCITIES

Perugia



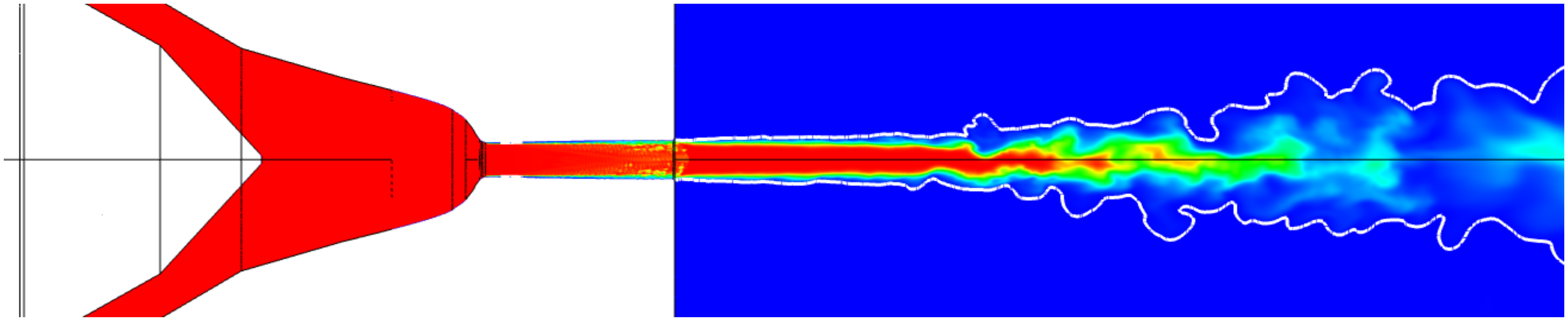


RWTH



- Different LES yield different turbulence

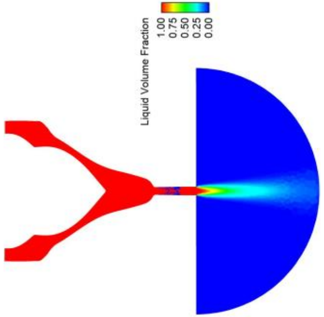
RECALL: ECN4 – SPRAY C (BATTISTONI)



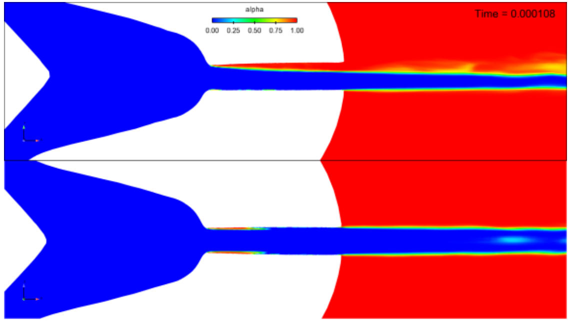
- Wireframe symmetric geometry
- Symmetric vapor volume fraction

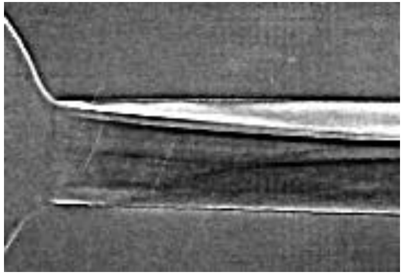
SPRAY C – SIMULATION RESULTS

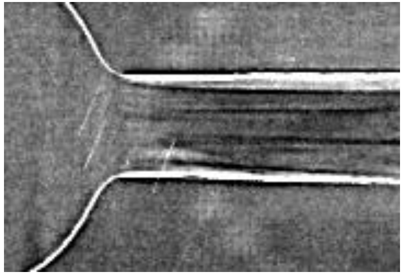
UMass

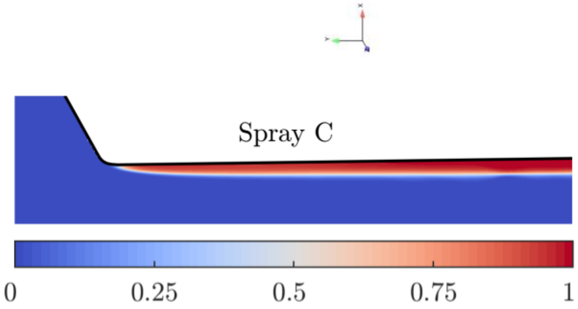


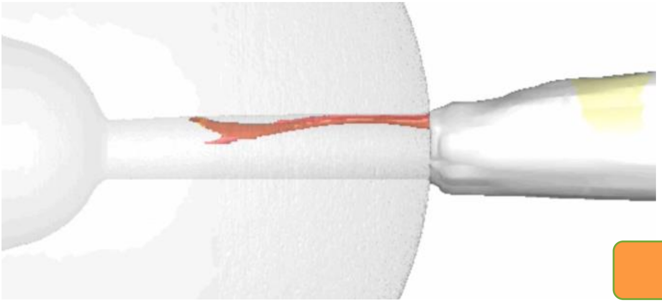
Perugia







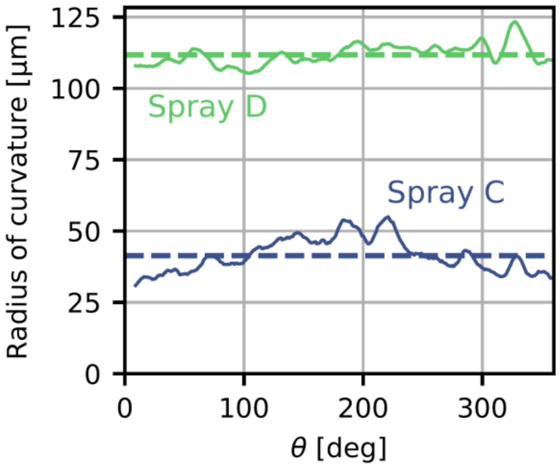


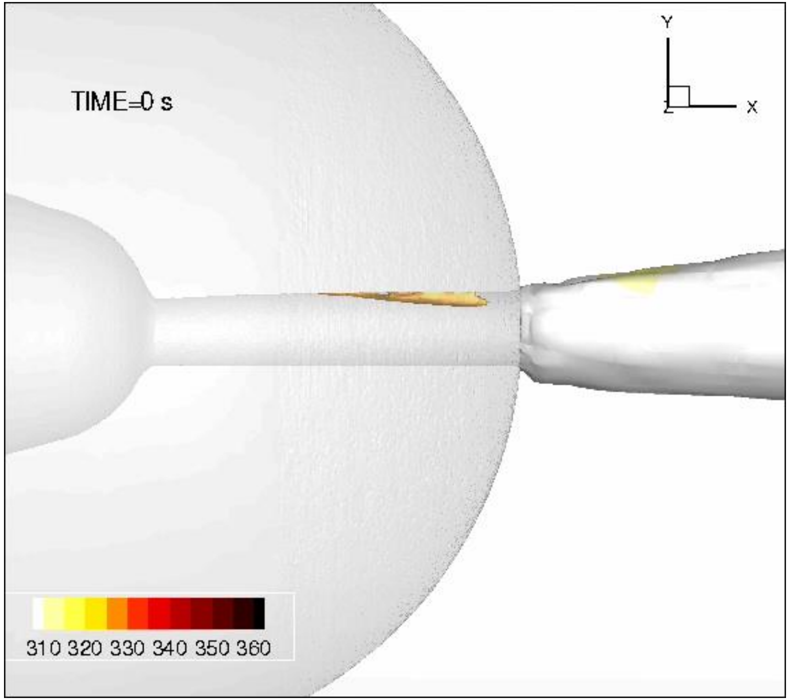


Sandia

RWTH

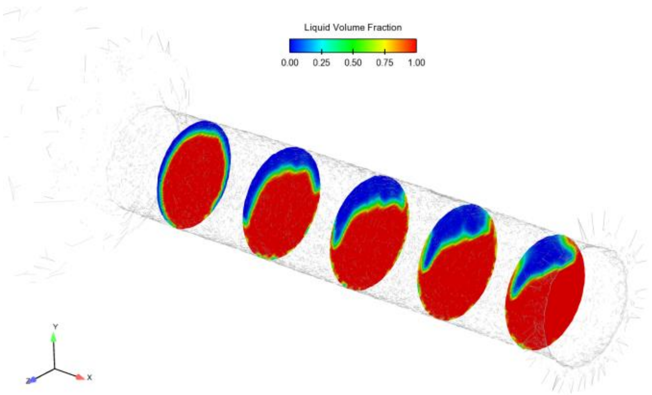
EVOLUTION OF VAPOR

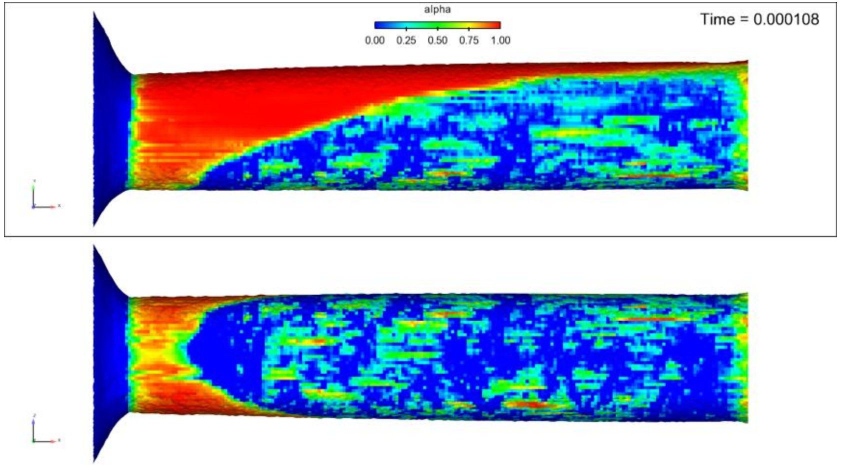




Sandia

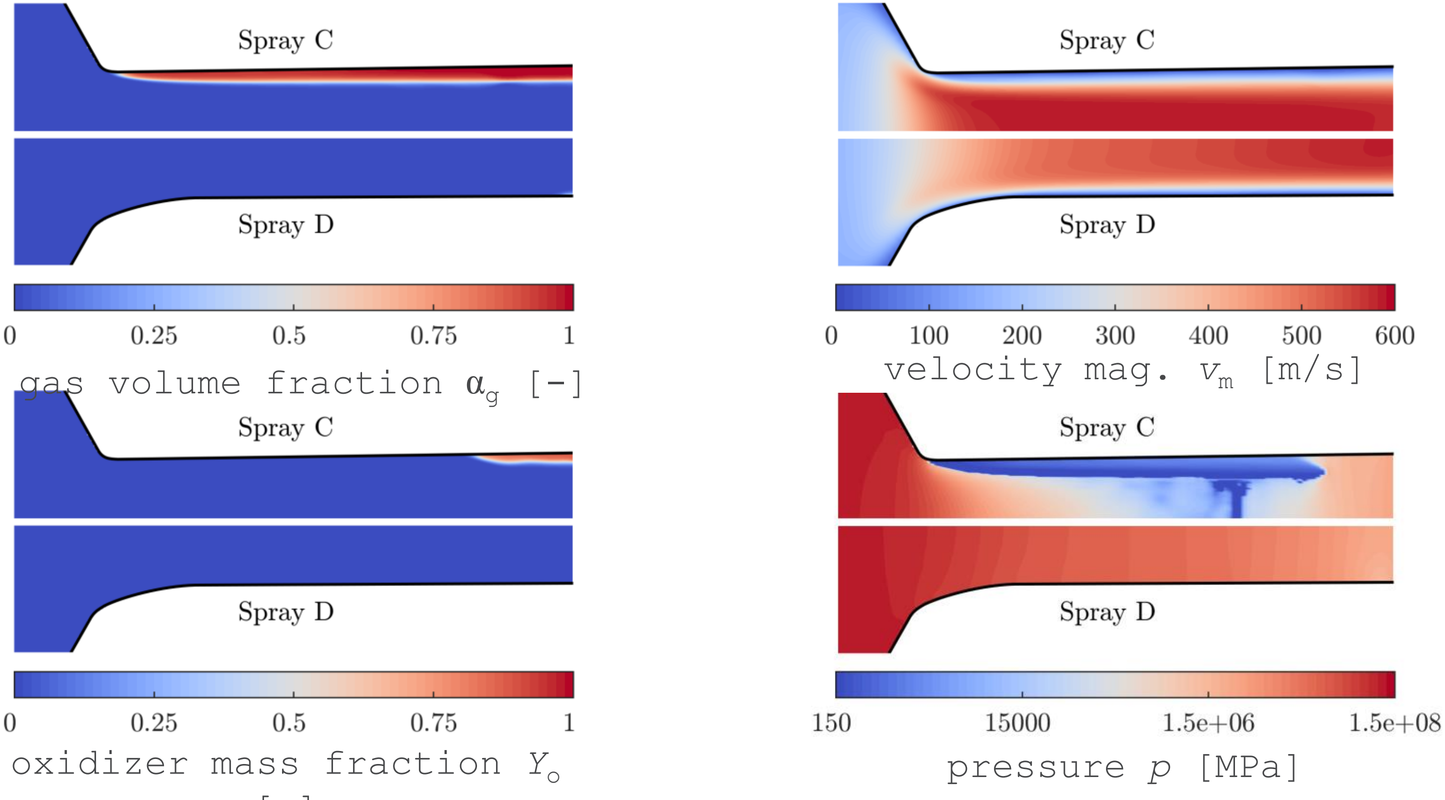
LOCATION OF VAPOR FRACTION



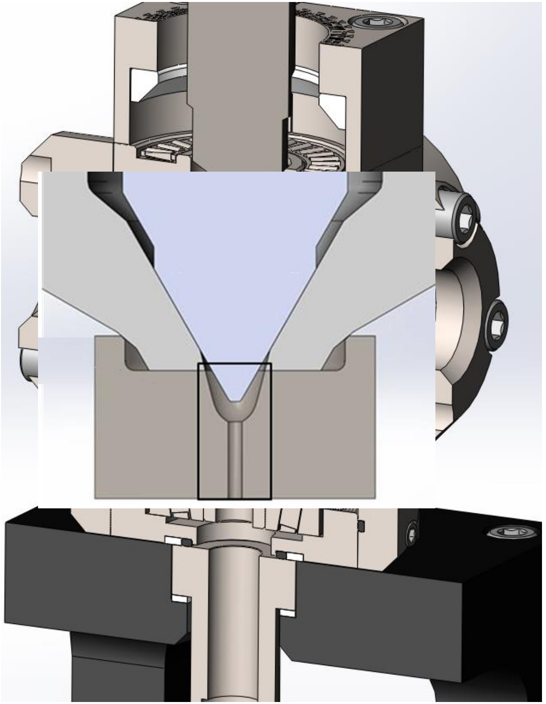


Perugia

GAS INSIDE THE NOZZLE



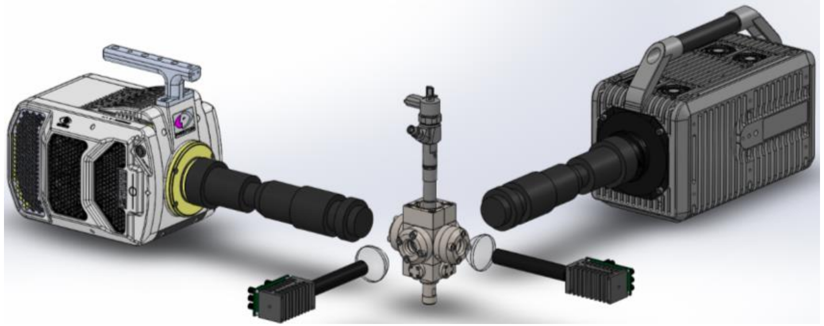
ACRYLIC NOZZLE



- Custom chamber for optical flow characterization in transparent nozzles
  - Continuous flow
  - Vacuum and high-pressure (6 MPa) capabilities
- Real-size transparent nozzles made of cast acrylic
  - Mechanical properties superior to quartz
  - Refractive index close to fuel (n-dodecane)
  - Geometrical match for ECN Spray D (190 mm)
  - Cylindrical nozzle measures 175 mm

EXPERIMENTAL SETUP

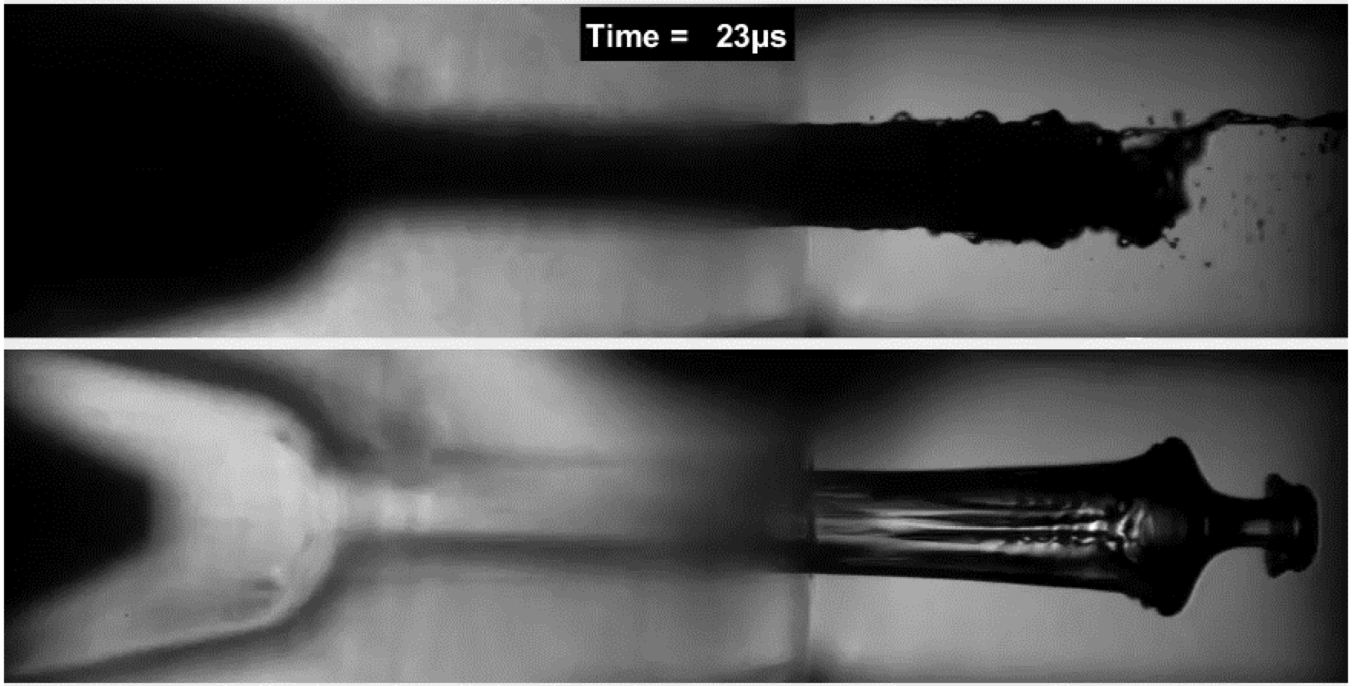
- Synchronized and spectrally-separated stereo-microscopy setup allowing stereo/3-D visualization of needle motion and flow processes
- Primary system (Phantom):
  - 8X magnification (3.5 mm/pix)
  - 120 – 380kHz acquisition rates
- Secondary system (Photron):
  - 3X magnification (7 mm/pix)
  - 270kHz acquisition rate
- Illumination via Sandia-developed ultrafast high-power LED pulsers
  - Custom single and multi-die LED emitters
  - 30 ns pulse duration to freeze flow motions



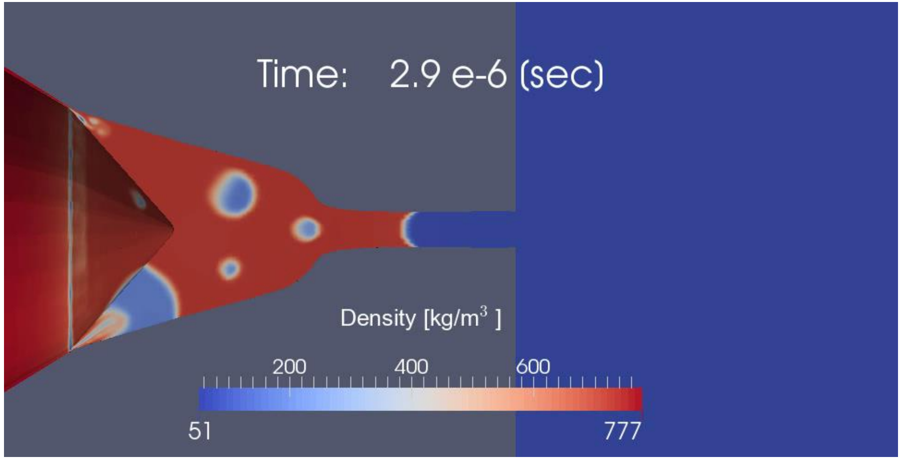
EFFECT OF INTERNAL GAS - EXPERIMENTS

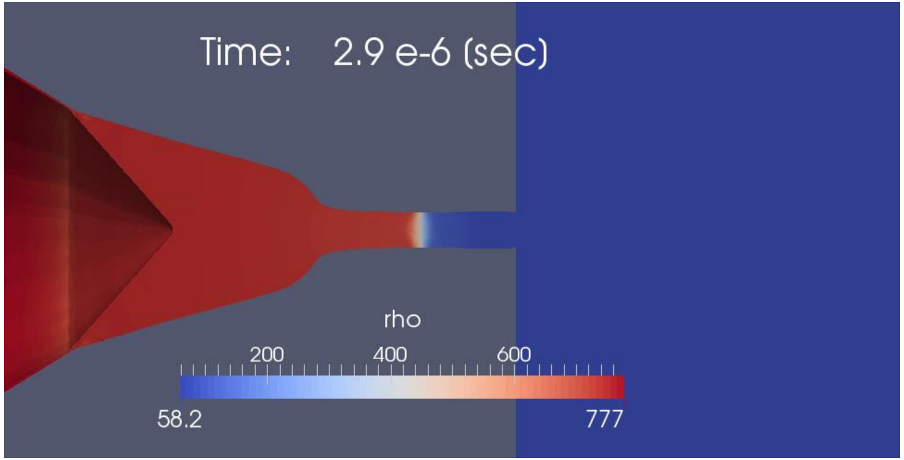
Nozzle full of gas
25 MPa – 1 atm.

Nozzle full of liquid
50 MPa – 1 atm.



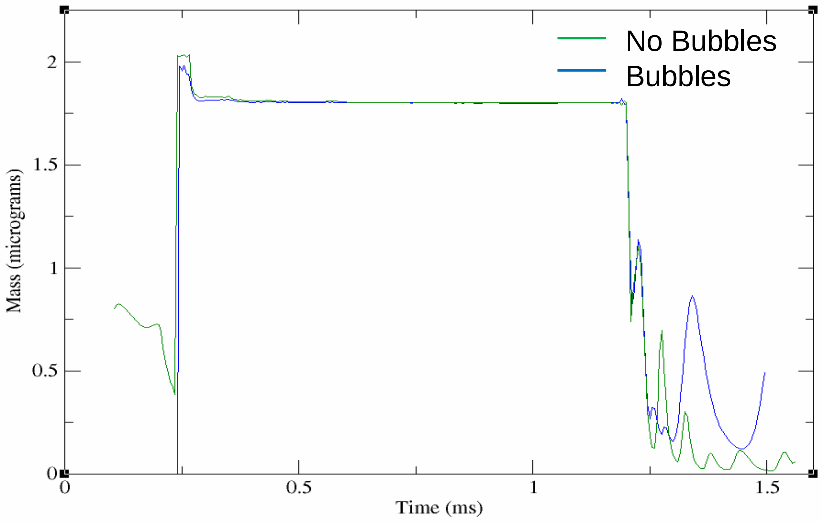
EFFEFCT OF INTERNAL GAS - SIMULATIONS





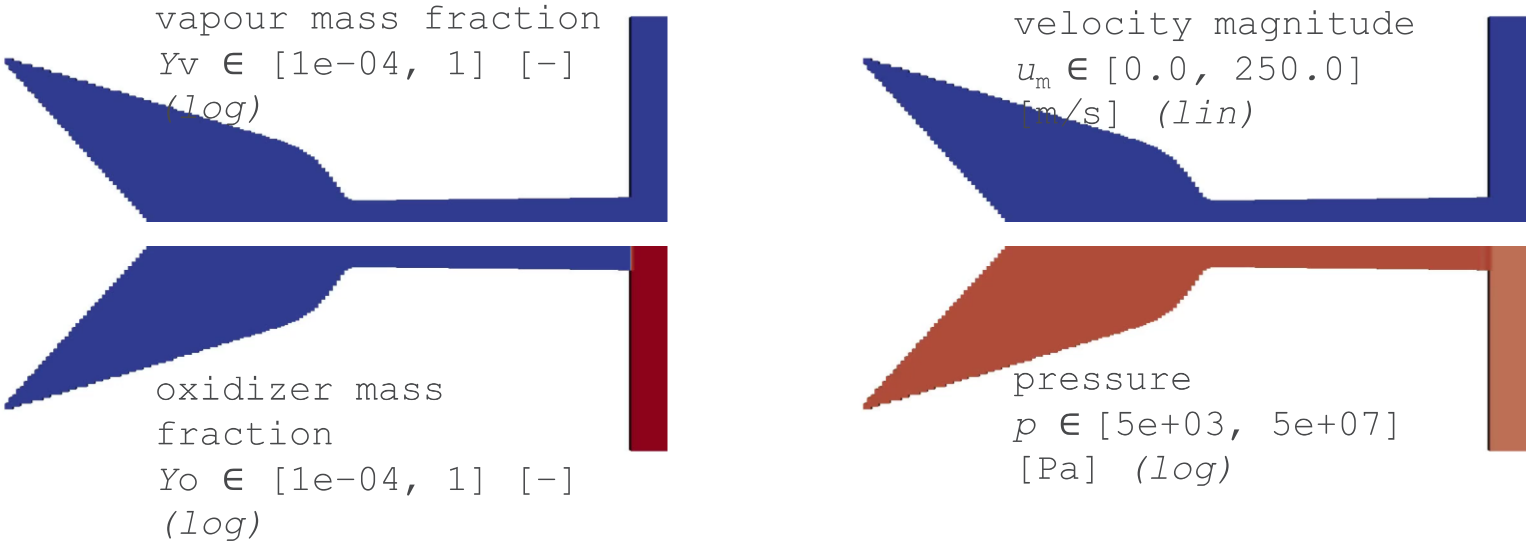
- Gas in sac compresses as the sac pressurizes
- Injection is slightly delayed by the gas in the sac (7.1 vs. 5.6 mus)
- The injection of gas bubbles results in spray breakup

EFFECTS OF INTERNATL GAS - SIMULATIONS



- Cases with Bubble tend to start with low mass flows because the bubble takes time to eject.
- However their residual fuel mass during dwell is higher thus causing potential emission problems.

EFFEFCT OF INTERNAL GAS - SIMULATIONS



- Changes in the early surface formation of ~10%

SUMMARY

- Many effects are captured correctly by simulations
- Basic experimental data such as turbulence information would be nice
- Shot to shot variations of internal flow should be considered
- How predictive is predictive enough should be discussed