Liquid and Vapor velocity measurements in Spray G

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5th Engine Combustion Network Workshop

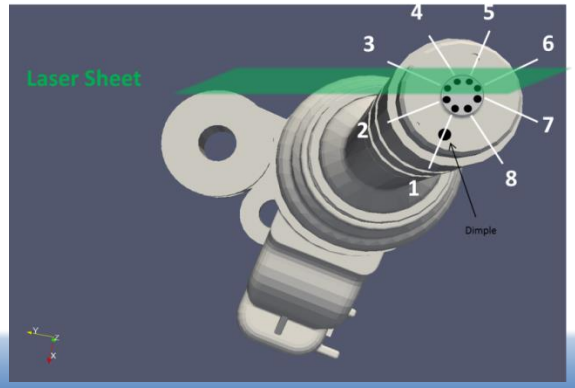
Presentation Outline

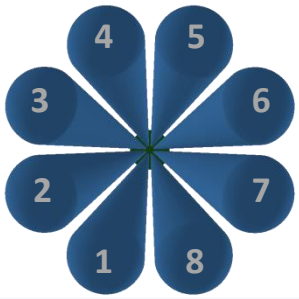
- Experimental Setups
- Time evolution of the vapor velocity between neighboring plumes
- All different measurements indicate plume redirection towards the centerline
- Measured Vapor and Liquid velocity
- Droplets size changes as a function of time ASI and location
- Effect of temperature on droplets and gas velocity

Experimental Setups

Unique high-speed velocity diagnostic (SNL)

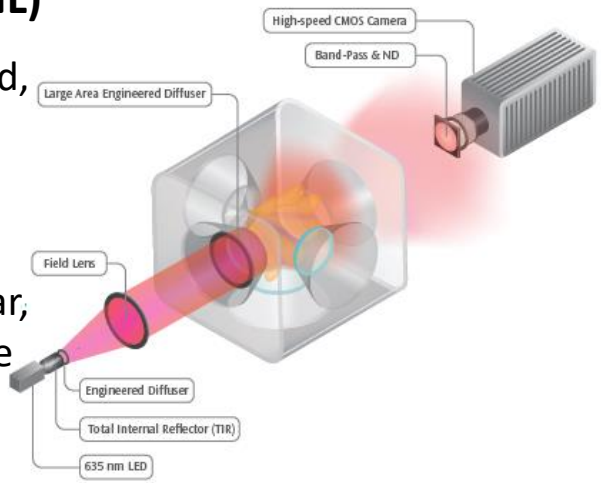
- Custom pulse-burst laser
  - 100 kHz pulse pairs
  - with 15 mJ/pulse at 532 nm
- Applied PIV
  - 1μm zirconia particles seeded in ambient gas
  - Signal collected by 200 kHz imaging
  - Liquid-phase avoided by probing between plumes and moving downstream
  - Intensive image processing (preparing images, removing mist)
    and cross-correlation (sliding SOC)
  - Planar Velocity field





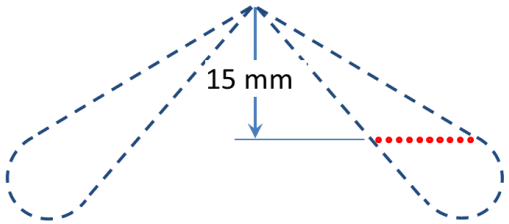
High-speed DBI (SNL)

- 3.5W LED was used, emitting at 635nm
- driven at 100kHz, with 500ns pulses
- Line of sight, planar, light-transmittance measurement, indicating liquid phase

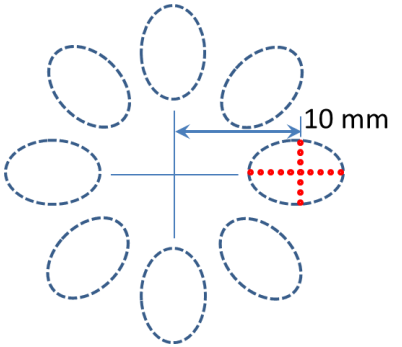


Phase Doppler Interferometry (GM)

- Droplet Velocity, Direction and Size measured on these points:



Radial scan

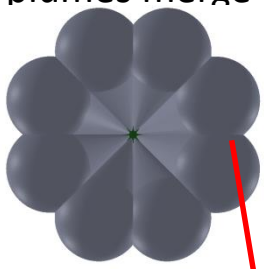


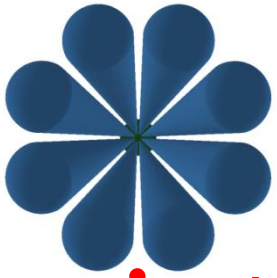
Transverse scan

Time evolution of vapor velocity between neighboring plumes

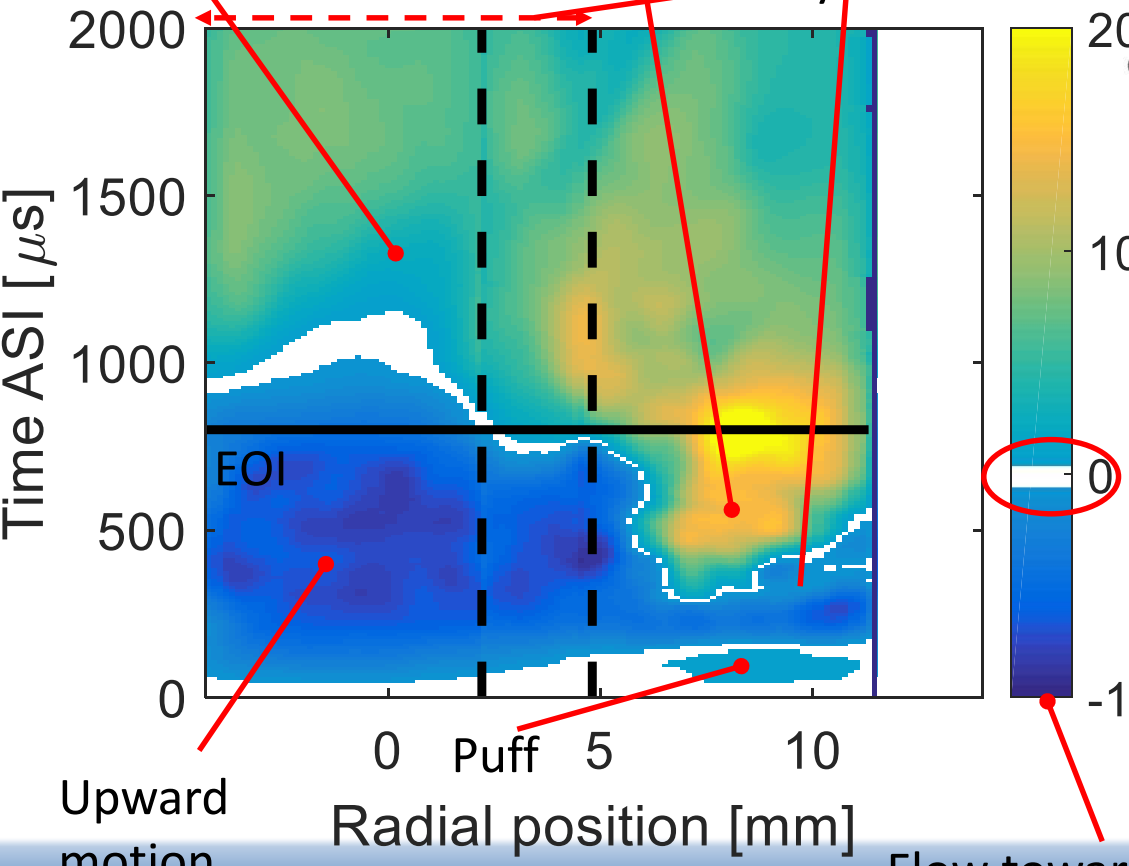
All plumes merge at center

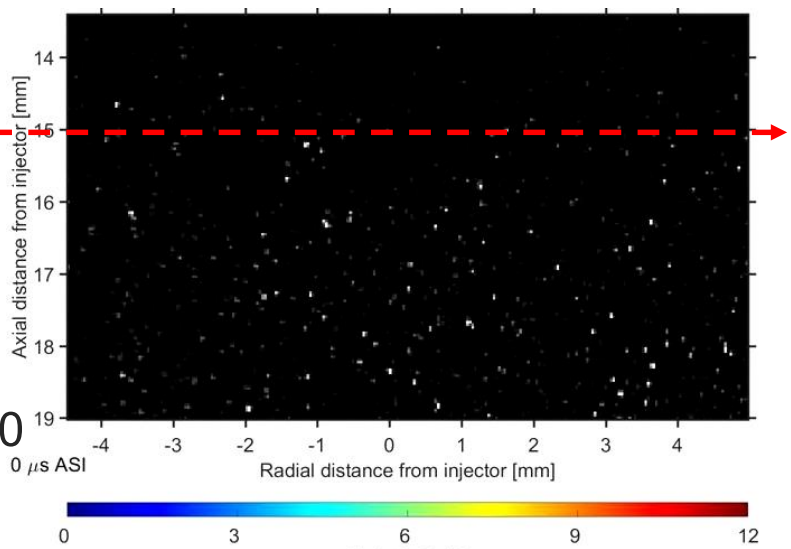
Neighboring-plumes merge



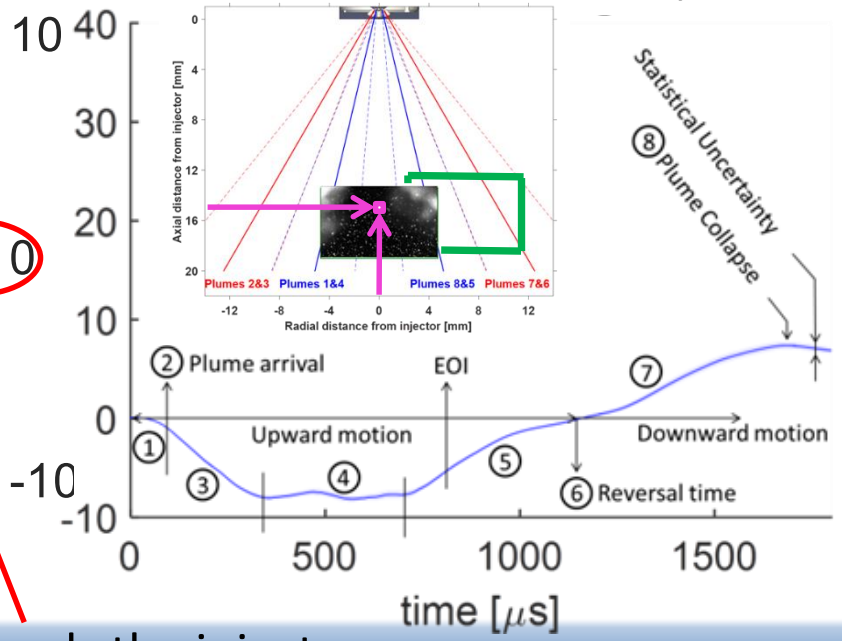


15-mm axial velocity





15-mm axial velocity



Upward motion

Flow towards the injector

Different measurements indicate plume redirection to centerline

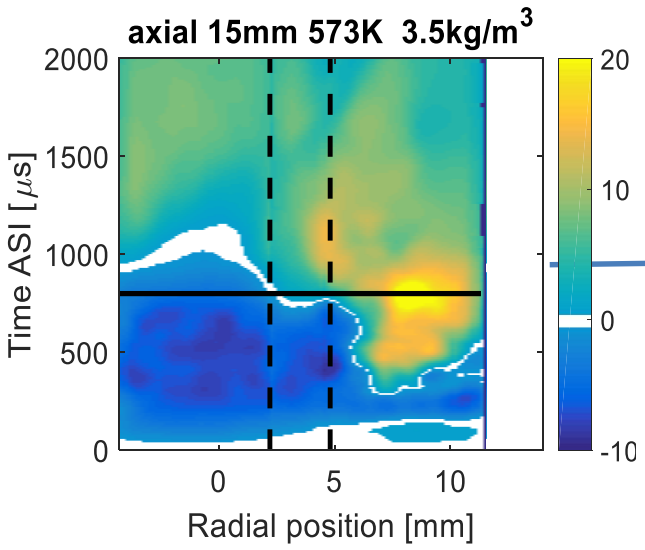
Different measurements of

vapor and liquid velocity and liquid concertation

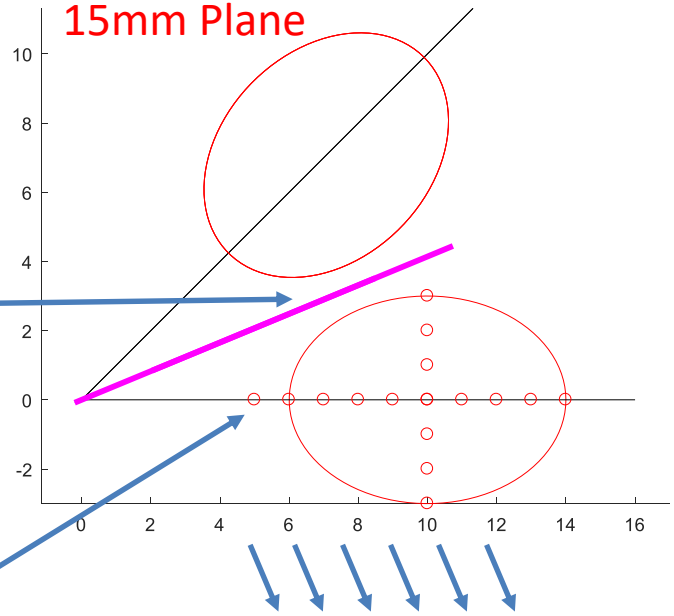
All indicate movement of the plume direction towards the centerline as a function of time ASI

(please visit us at ILASS on effects of injection duration on spray collapse)

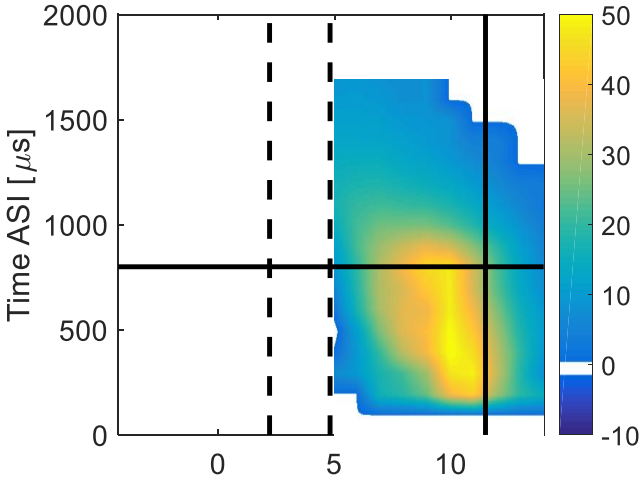
PIV- Vapor Velocity



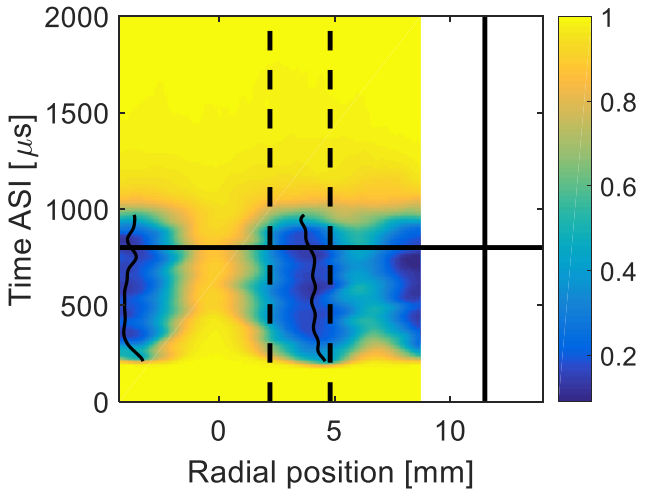
15mm Plane



PDI- Liquid Axial Velocity



DBI – Liquid Transmittance

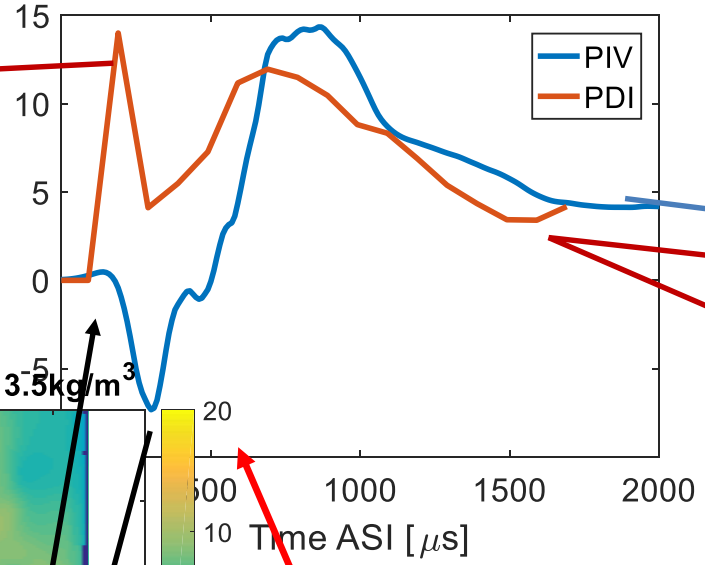


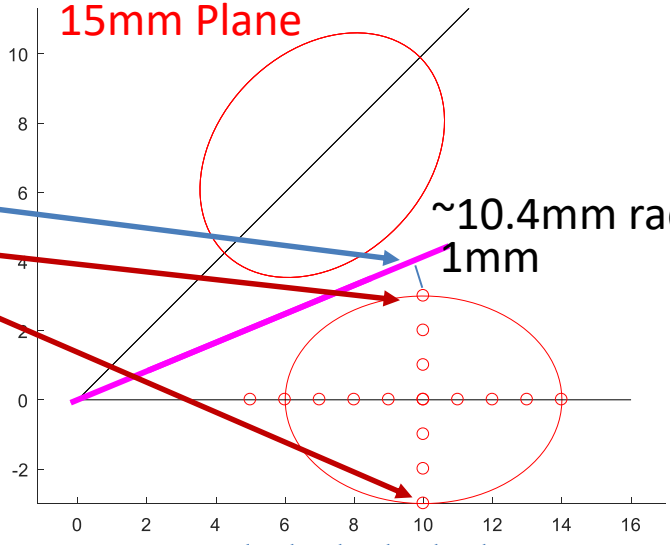
Plumes move to center

Droplet and Liquid velocity Different

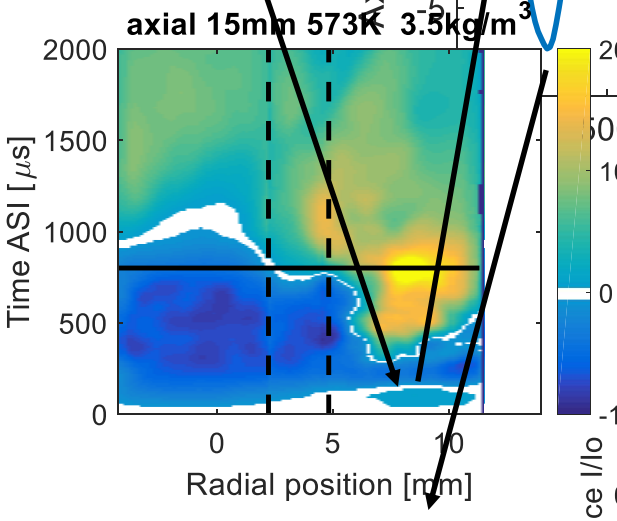
Spray head
Fast Droplets

Remember the
PIV vapor puff?

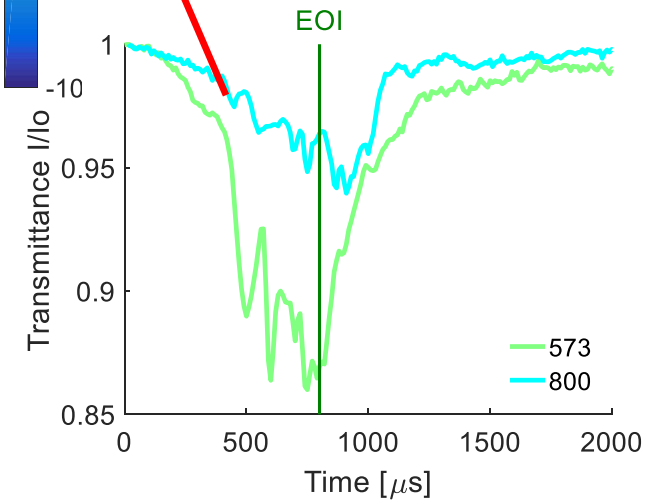




~10.4mm radially
1mm

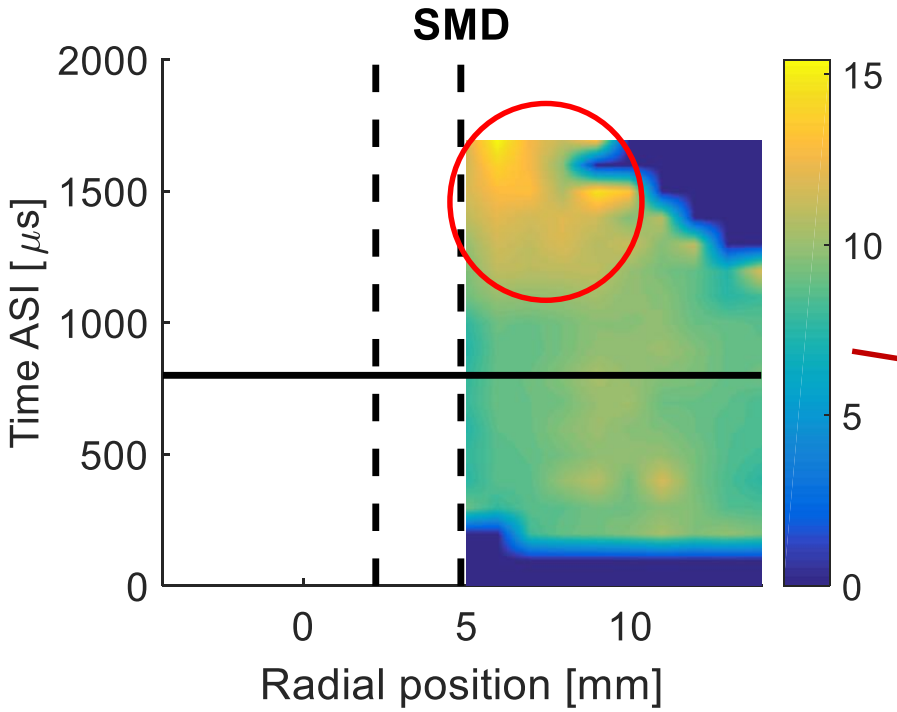


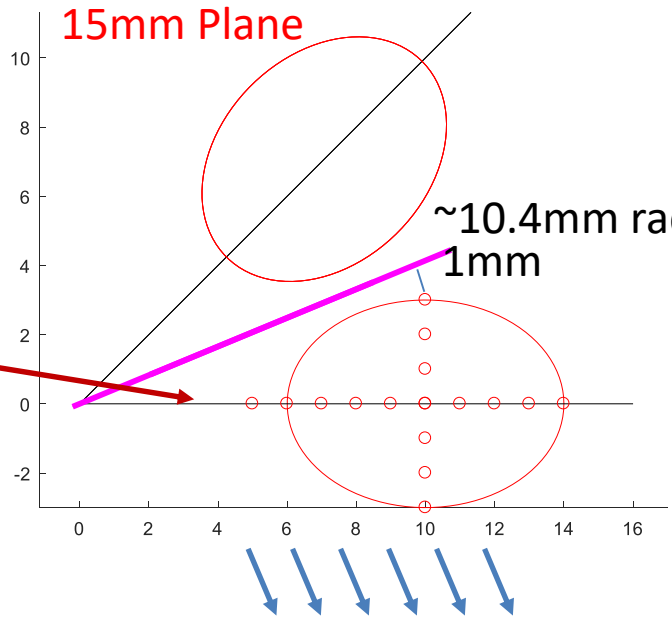
After 600us similar. Droplets



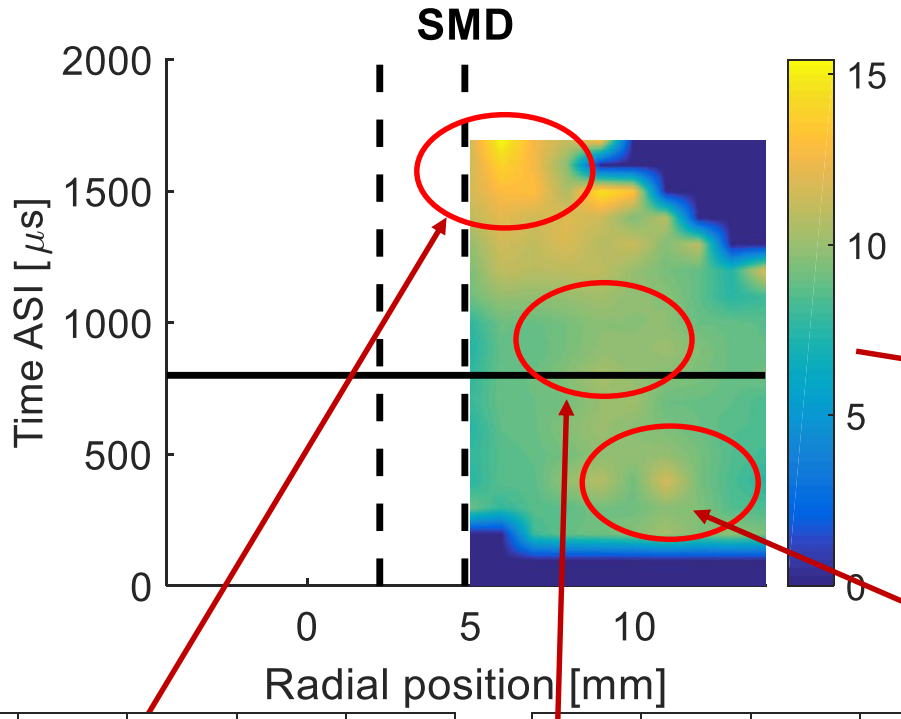
But the air entrainment of the plumes creates a vapor recirculation between neighboring plumes.
Where is the liquid?

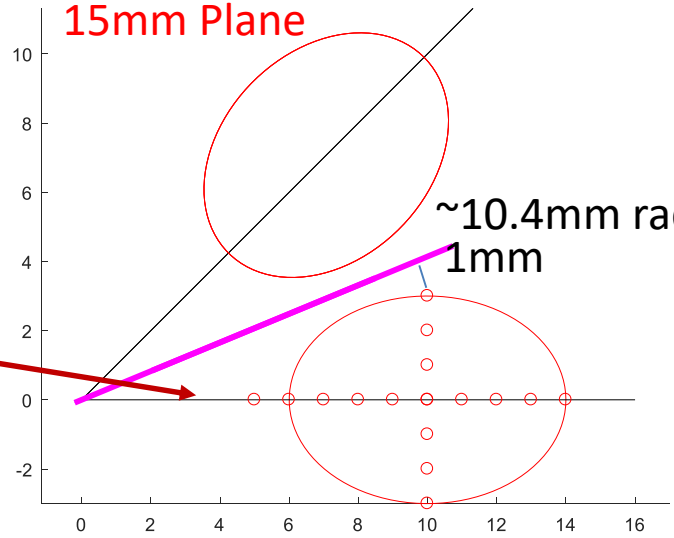
Droplets are larger at the Spray head and collapse

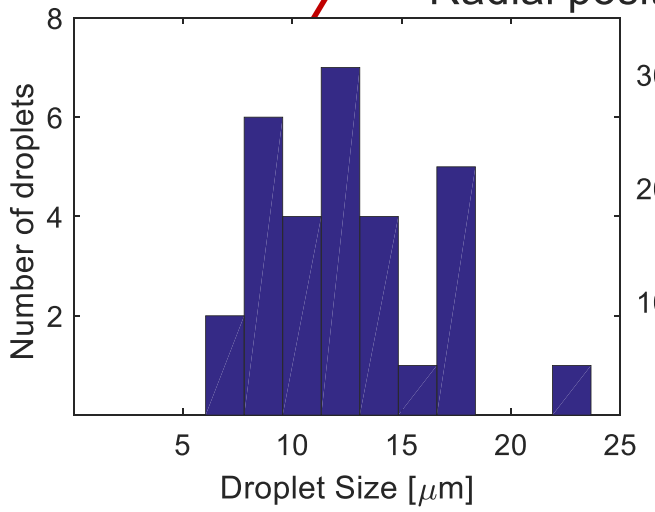


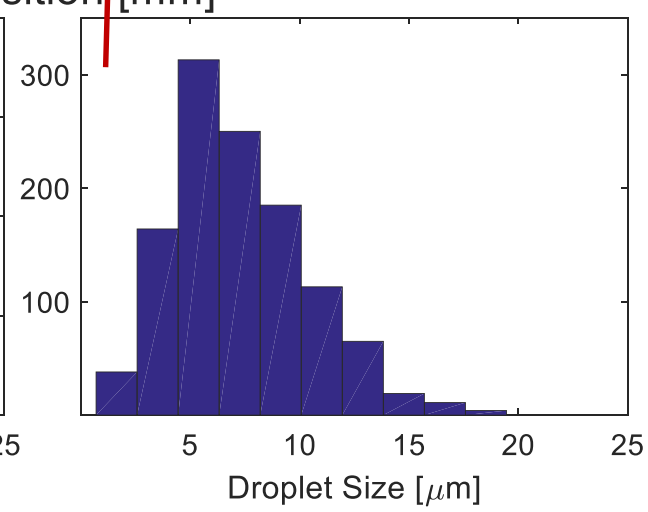


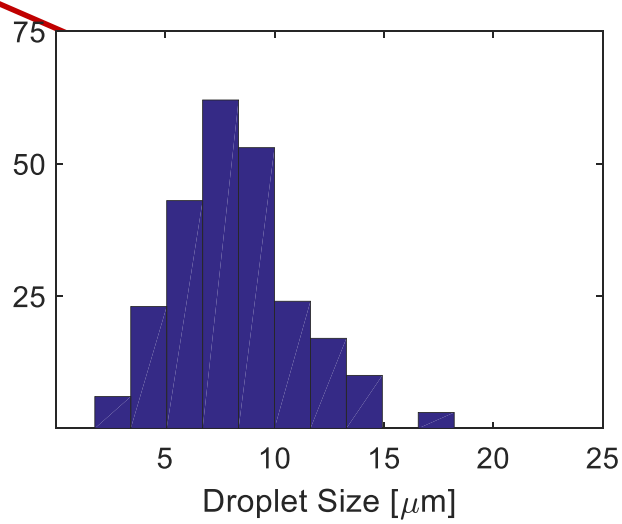
Droplets are larger at the Spray head and Collapse











Increased temperature makes droplets smaller but V higher

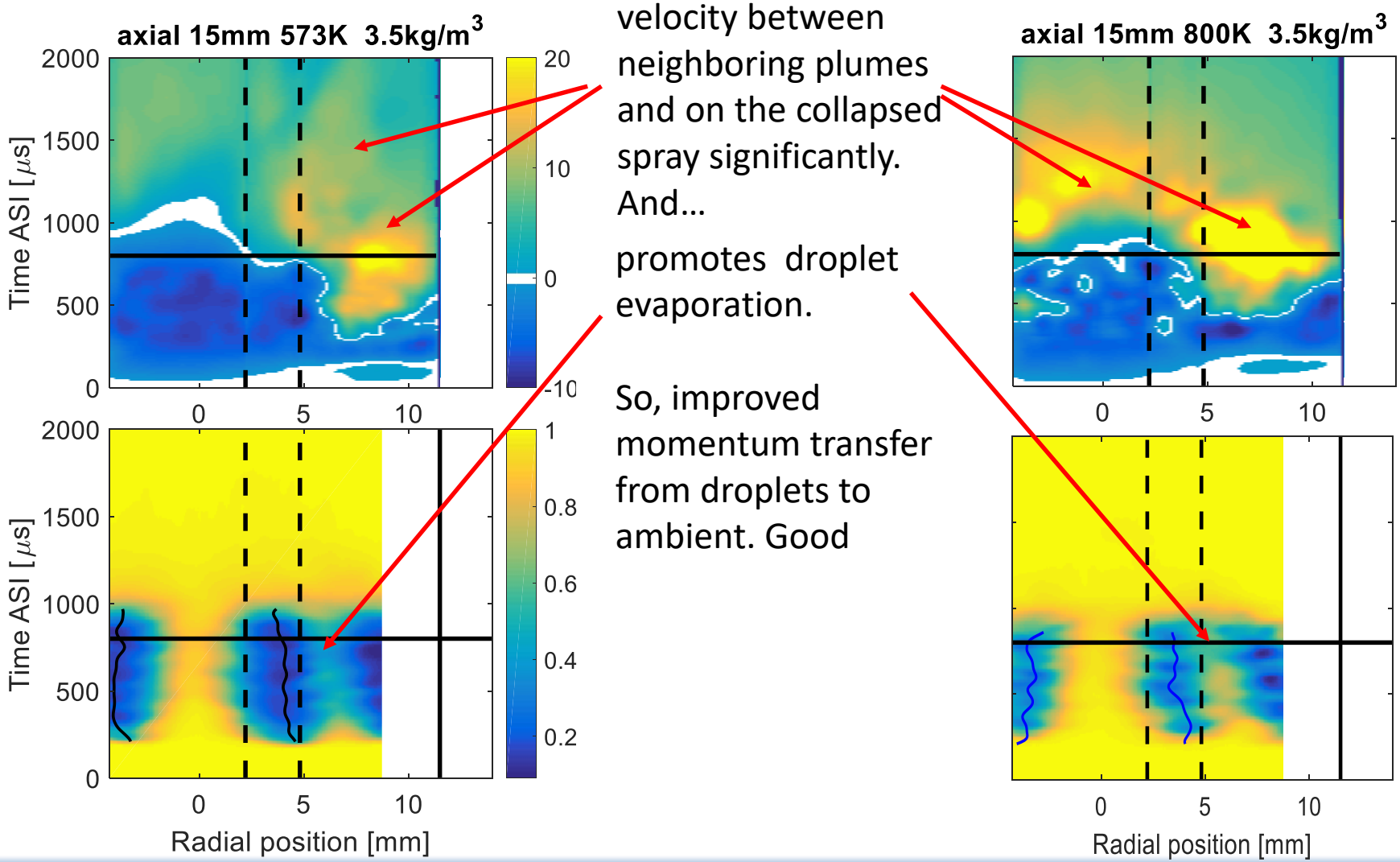
573K

800K

High temperature increases the gas velocity between neighboring plumes and on the collapsed spray significantly. And…

promotes droplet evaporation.

So, improved momentum transfer from droplets to ambient. Good



Conclusions

In Summary

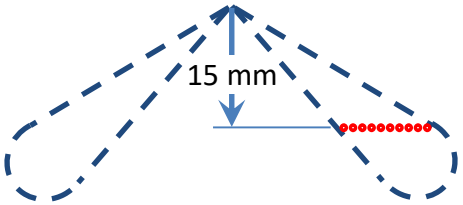
- The time evolution of the Liquid and Vapor velocity in Spray G were quantified.
- Different measurements indicate redirection of the plumes to the centerline (Do the LES and RANS models capture this trend? Please come to my SAE presentation on Wednesday) Thank you Sibendu Som, Kaushik Saha (ANL) and Tommaso Luccini, Gianluca D'Errico (PoliMi)
- the droplets are larger at the Spray head and the collapsed spray.
- Increased temperature makes droplets smaller but Velocity higher. Some videos shared on: https://ecn.sandia.gov/pub-links/ps001/

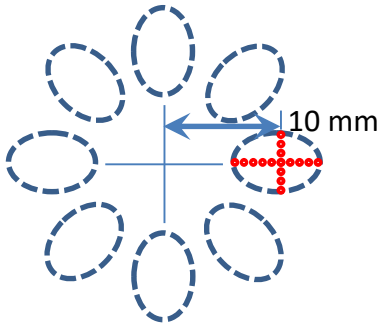
(Do the models capture this? Please stay for Lyle's presentation right now)

Thank you for your attention

Spray G – Velocity and drop size observations

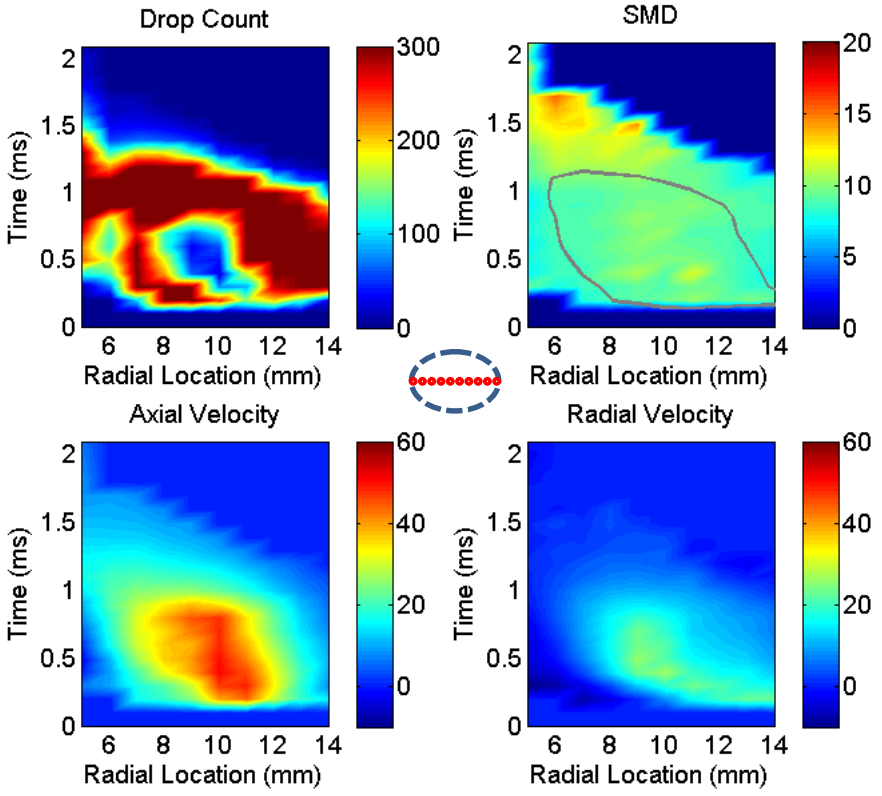
Scott Parrish, GM
ECN3



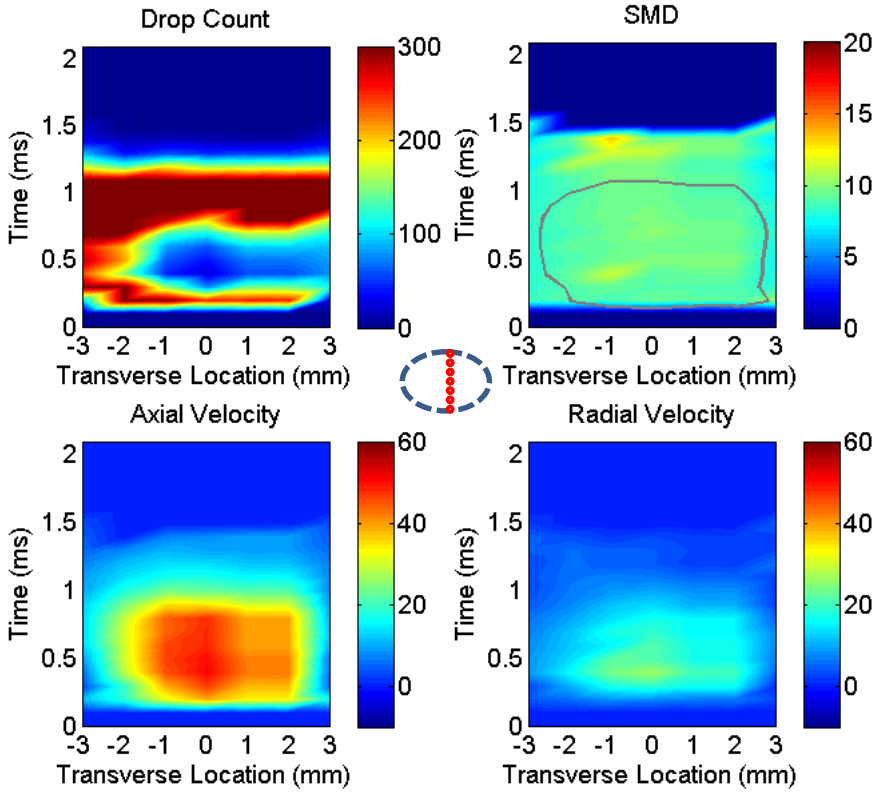


for injector #16,
plume #1:
Substantial dataset with
~ 10,000 injections

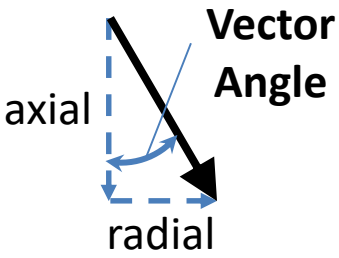
Radial Scan

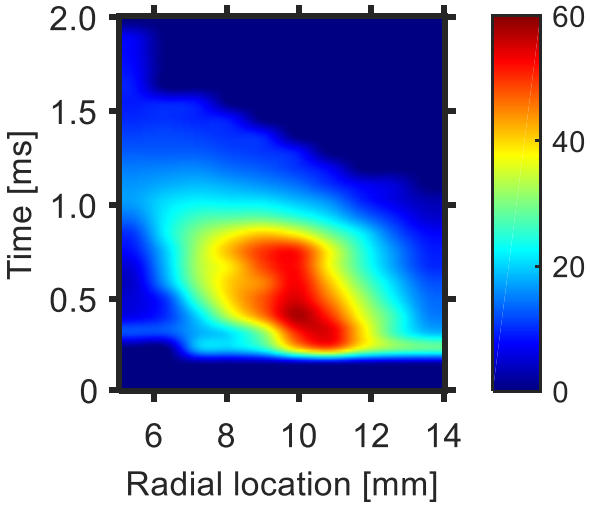


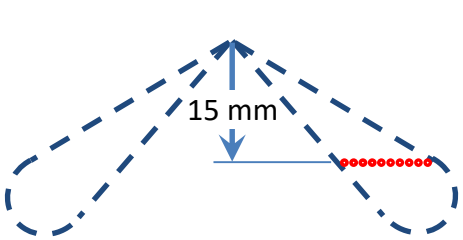
Transverse Scan

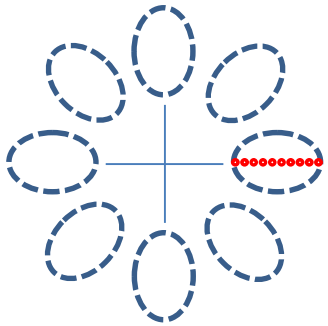


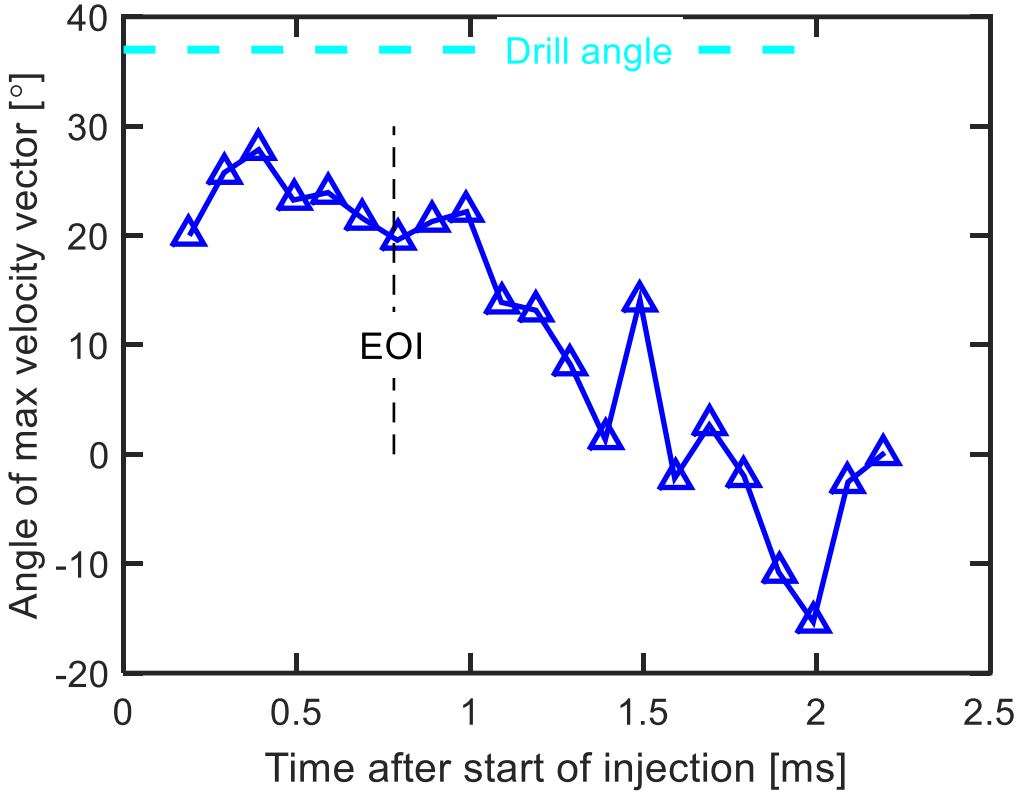
Plume inclination angle decreases with time





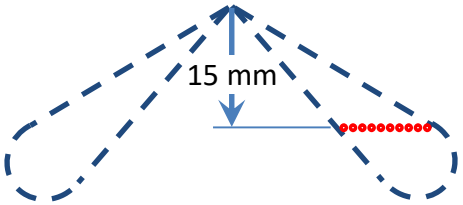


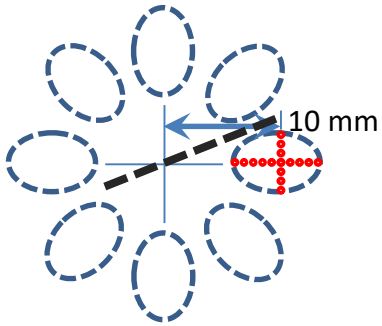




Gas- and liquid-phase velocities

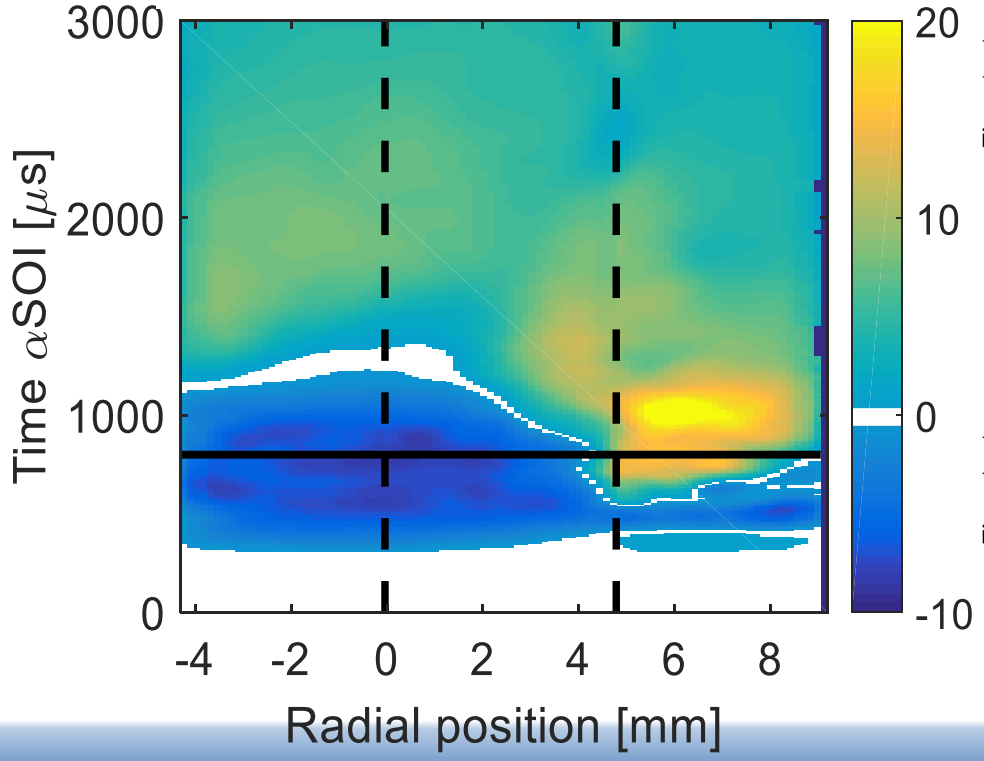
Scott Parrish, GM
ECN3



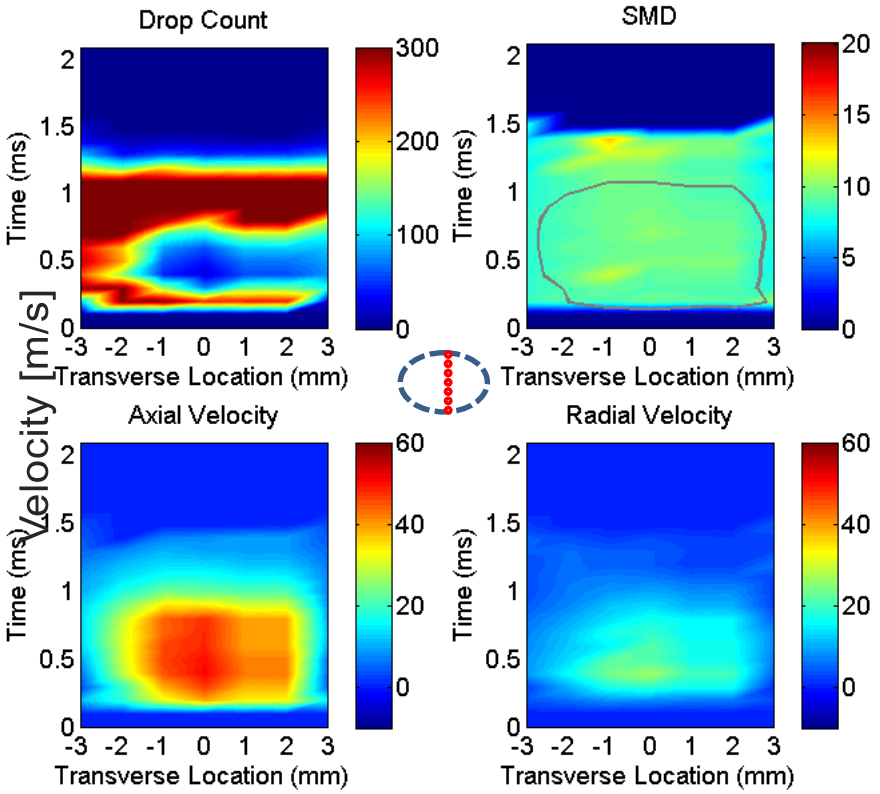


for injector #16,
plume #1:
Substantial dataset with
~ 10,000 injections

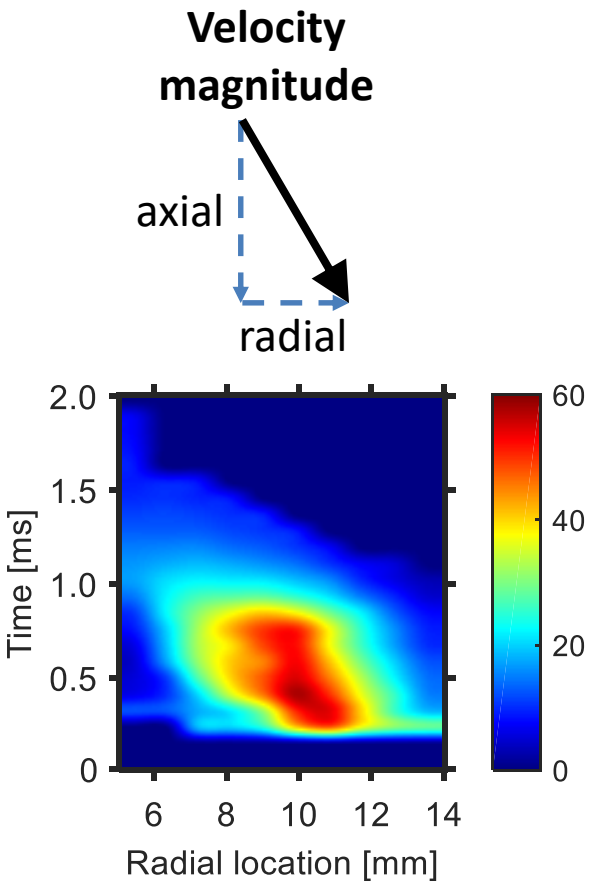
Z = 15 mm PIV (gas-phase)
axial velocity

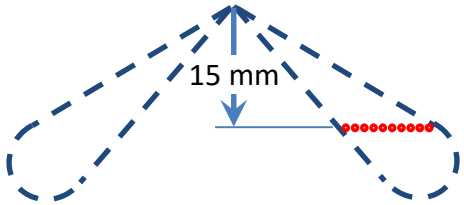


Transverse Scan

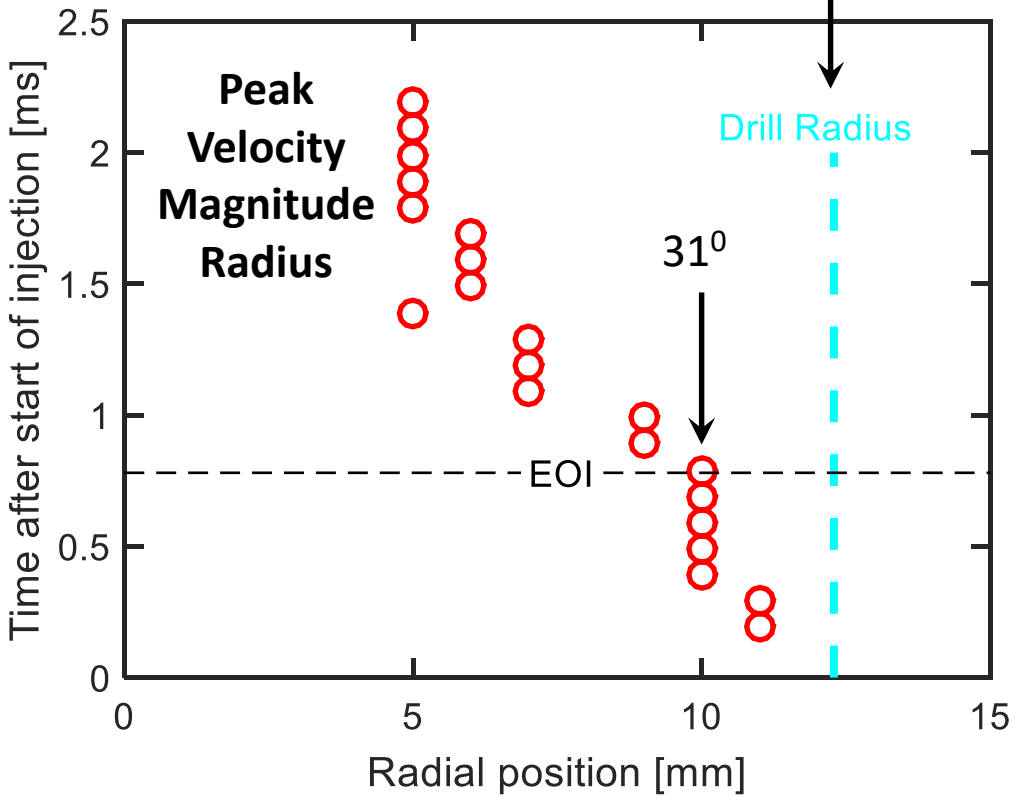


Liquid velocity analysis confirms that plume center moves towards injector axis during/after injection



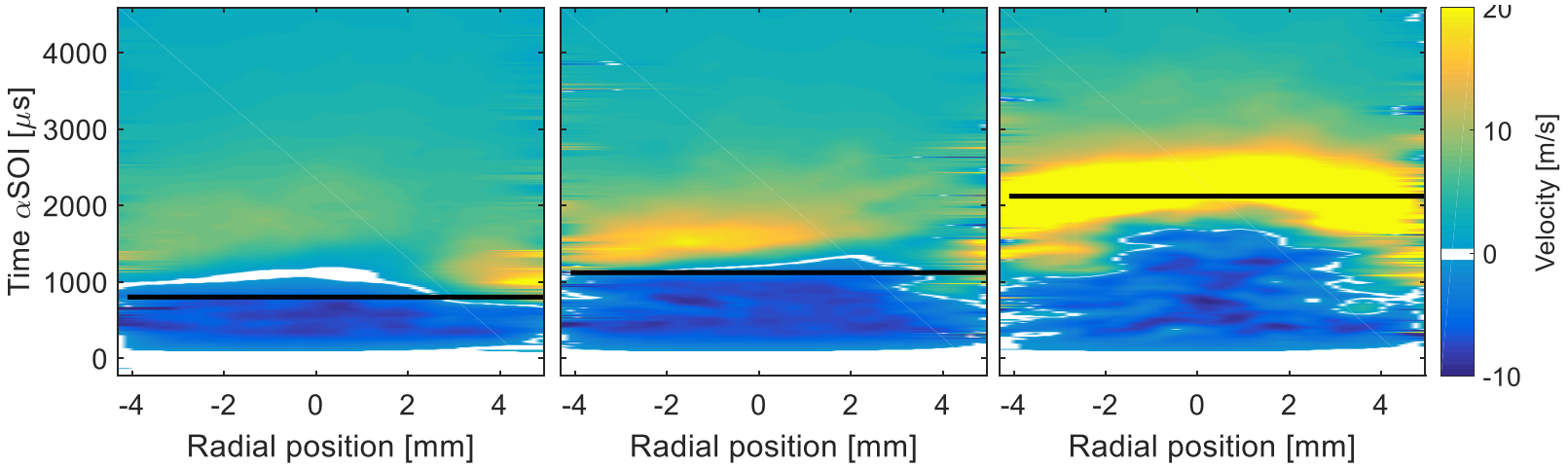


radius at 15 mm for 37^0 drill angle



Injection duration affects spray collapse

Spray G (573 K)



- Operating at 573 K (with iso-octane), Sandia observes complete collapse for longer injection duration
- Operating at 298 K (with surrogate fuel), Argonne does not

Plume centroid at z = 10 mm, Argonne (ECN4)