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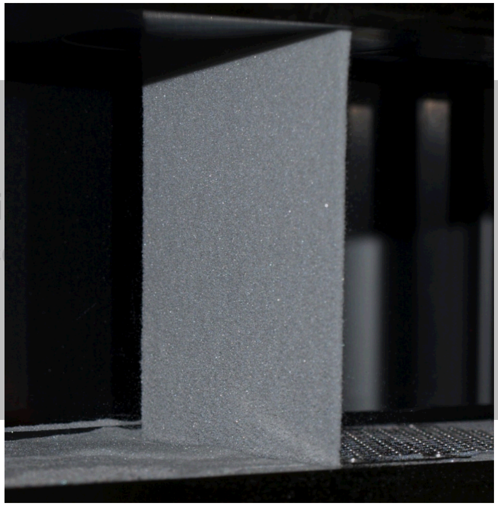
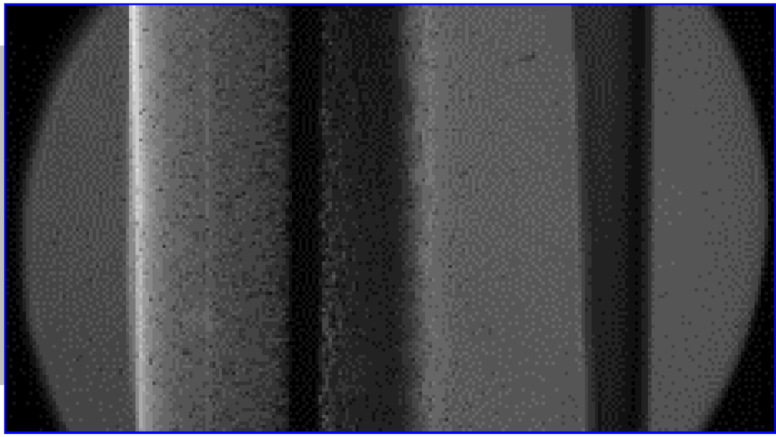
SAND2015-5623C

Towards Time-Resolved Particle Image Velocimetry Measurements during Shock-Particle Curtain Interactions





Justin L. Wagner, Steven J. Beresh, Edward P. DeMauro, Brian O. Pruett, Paul A. Farias

19th Biennial Conference of the APS Topical Group on Shock Compression of Condensed Matter

June 16th, 2015

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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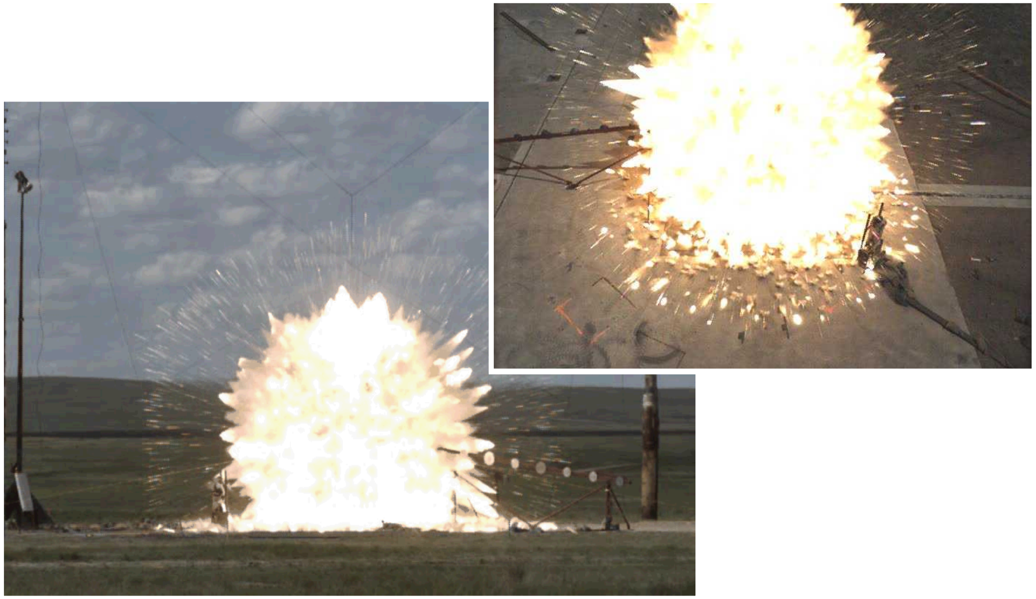
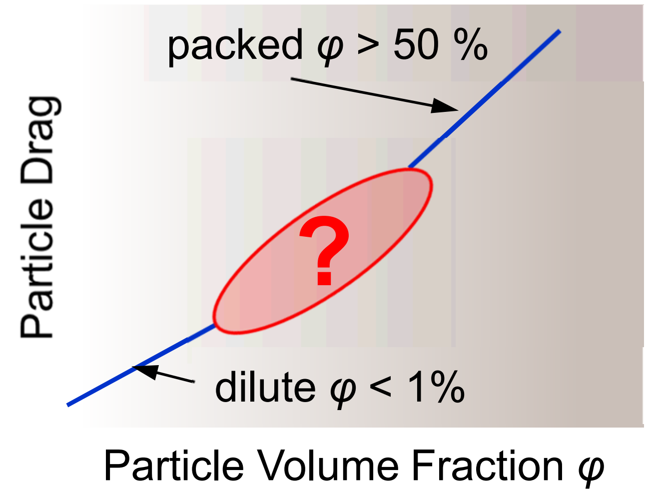
Motivation





Explosive Particle Dispersal

- Dynamics of densely packed particles influence explosive processes [1, 2]

Particle Dynamics

- Dynamics governed by volume fraction φ [2]
- Very little data in "dense" regime ($1\% < \varphi < 50\%$)

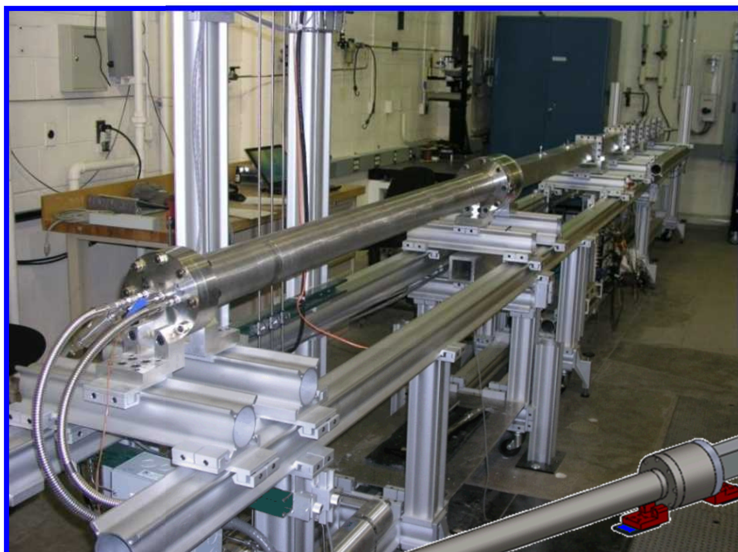
[1]Frost et al, *Physics of Fluids*, **24**, 2012

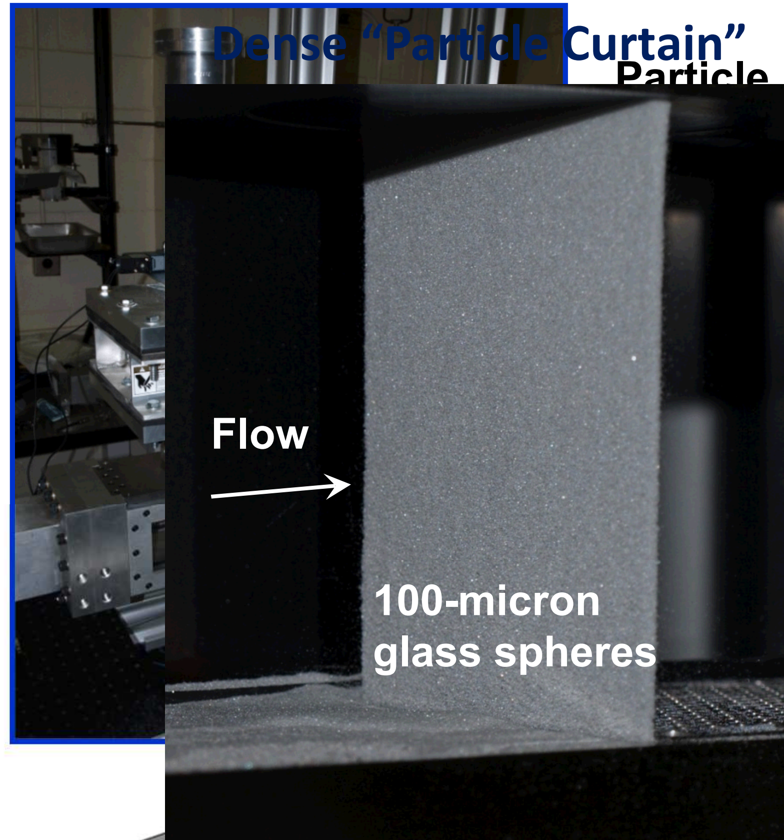
[2]Zhang, Frost, Thibault, *Shock Waves*, **10**, 2001

Particle Curtain Experiments in MST

A unique shock tube facility [1]

- MST allows study of shock-particle interactions in dense gas-solid flows.
- Shock Mach #s up to about 2, driven section at atmosphere



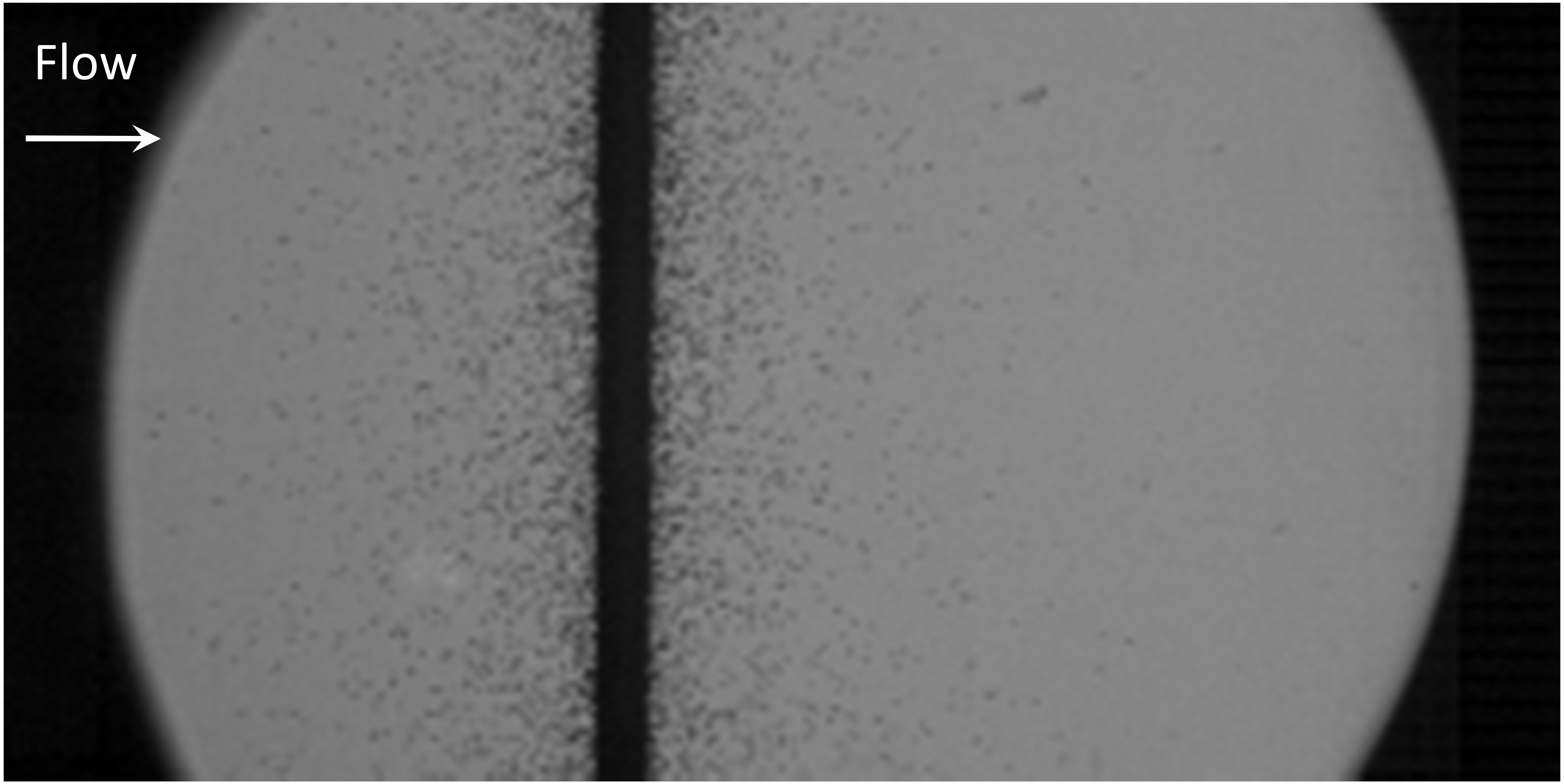


Particle volume fraction ≈ 20%

[1]Wagner, Beresh, Kearney, Pruett, Castaneda, Trott, Baer, *Experiments in Fluids*, 2012

High-speed Schlieren

Interaction at shock Mach number = 1.67



[1]Wagner, Beresh, Kearney, Pruett, Castaneda, Trott, Baer, *Experiments in Fluids*, 2012

Pressures (Mach 2.02 Interaction)

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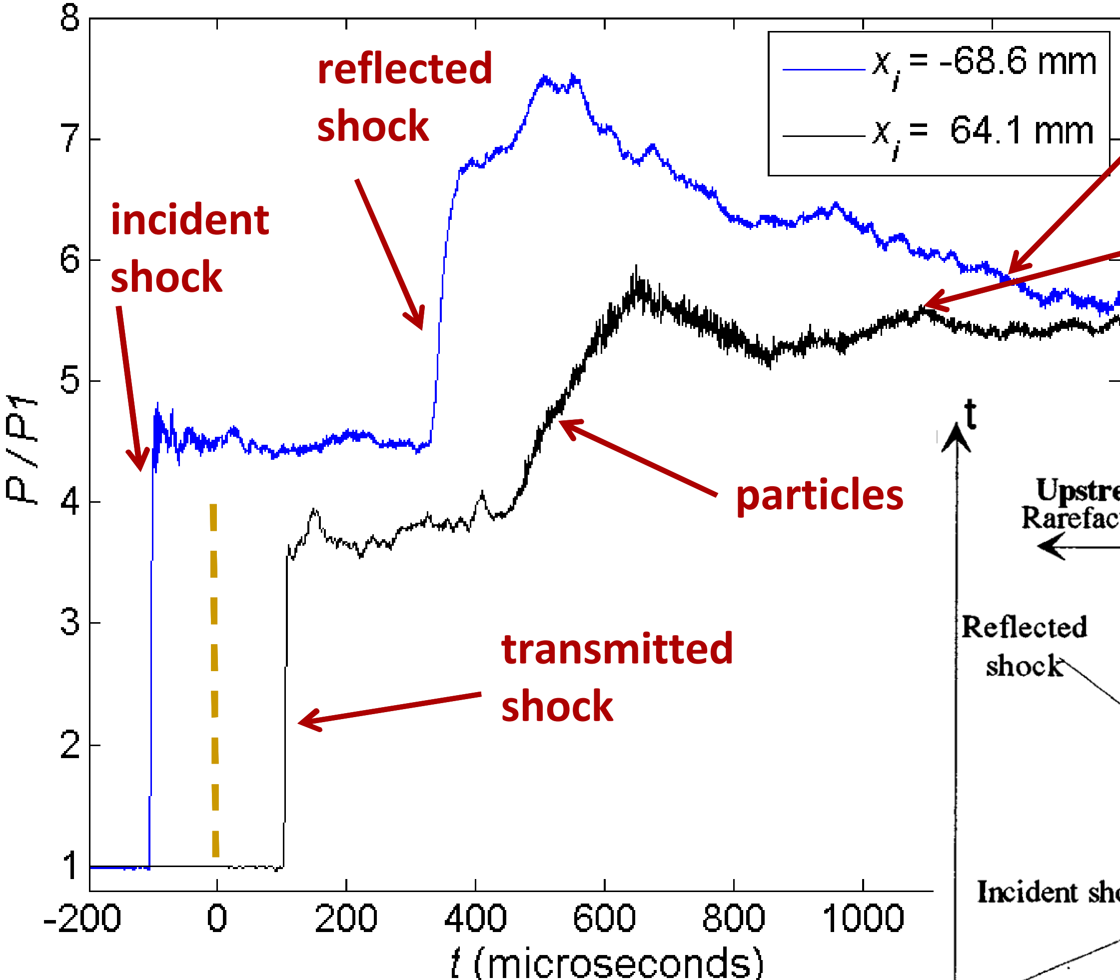
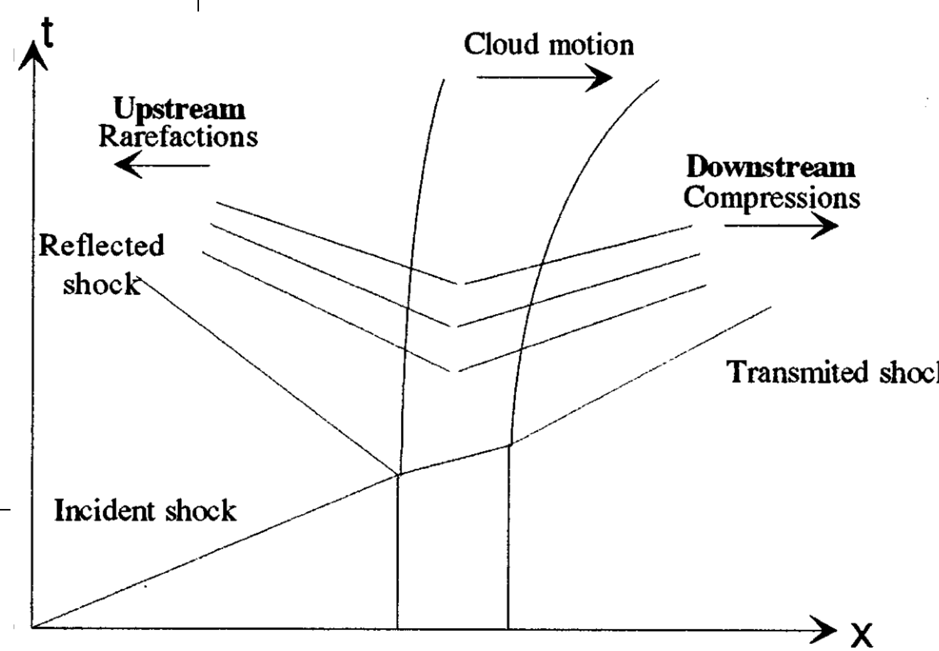


x-t diagram (Rogue et al)

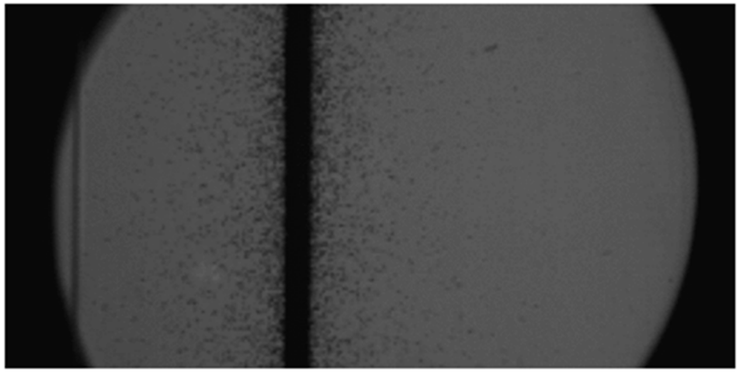


Rogue et al, *Shock Waves*, **8**, 1998

[1]Wagner, Beresh, Kearney, Pruett, Castaneda, Trott, Baer, *Experiments in Fluids*, 2012

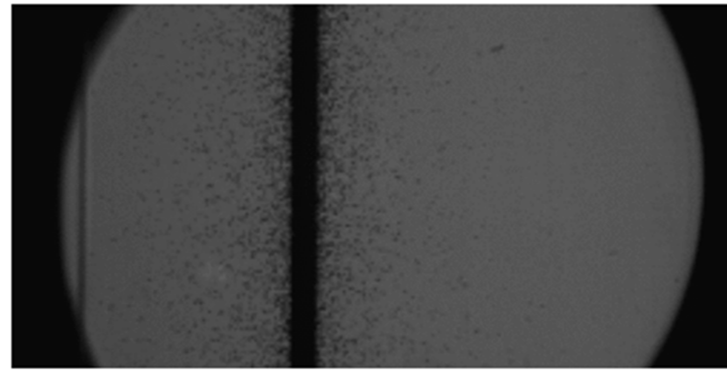
Comparison to Modeling (*Balachandar et al.*)

Standard Drag Model [1]



Particle trajectories substantially under predicted by Re # model

New Drag Model [1]



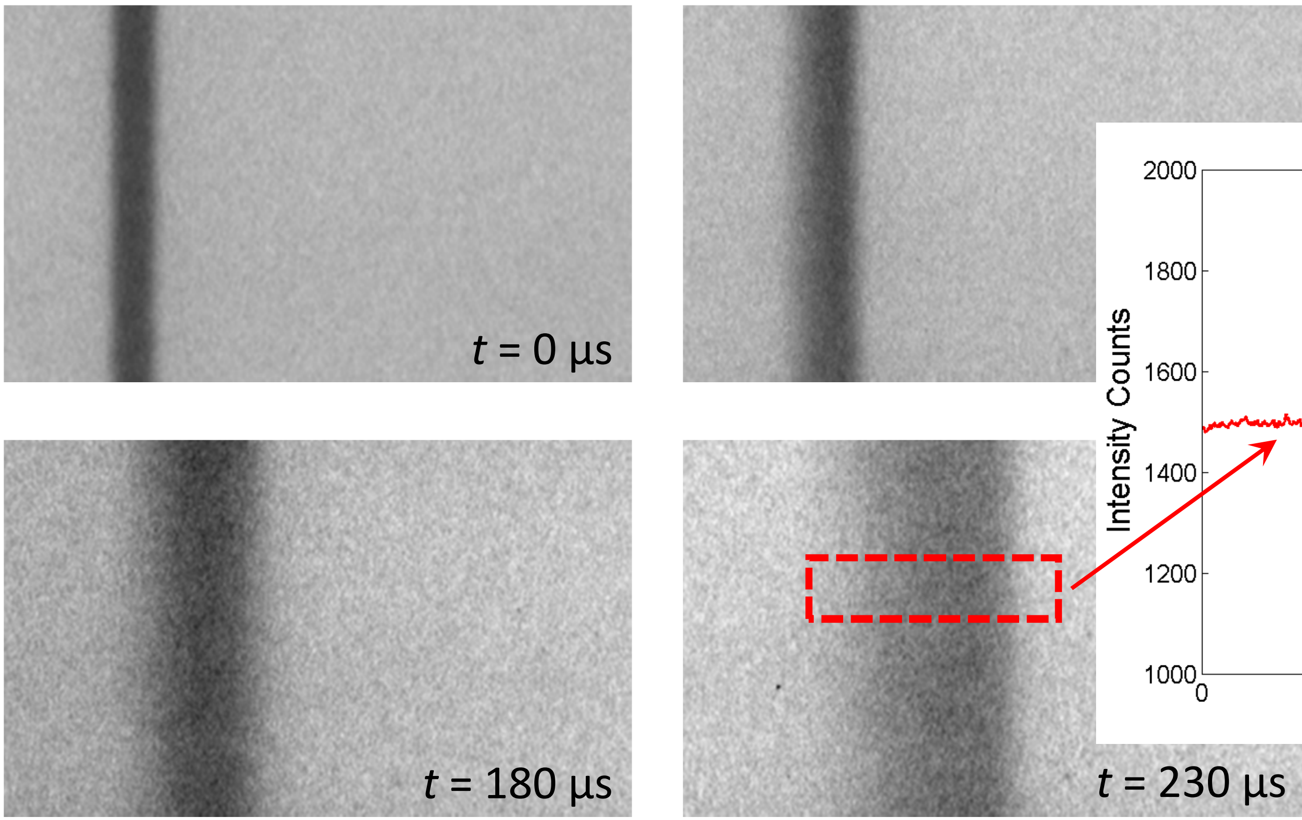
Results including dense volume fraction effects much improved

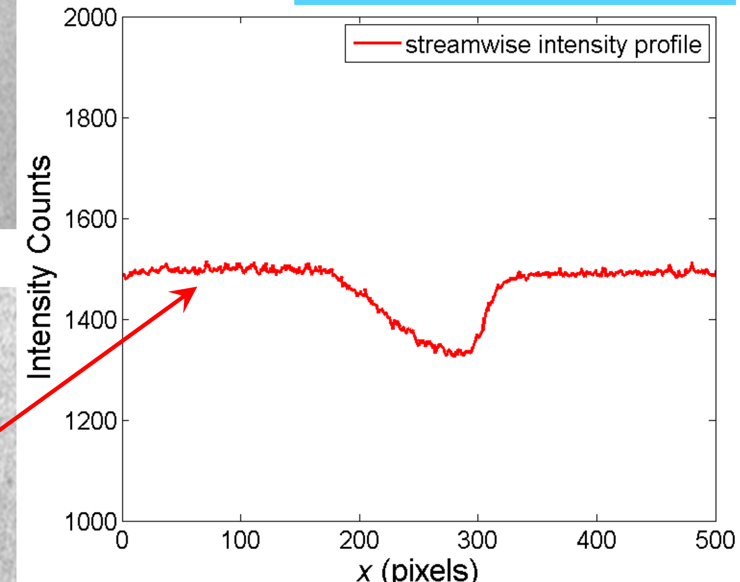
[1]Ling, Wagner, Beresh, Kearney, Balachandar, *Physics of Fluids*, 24, 2012

Interaction Radiographs

0-230 µs

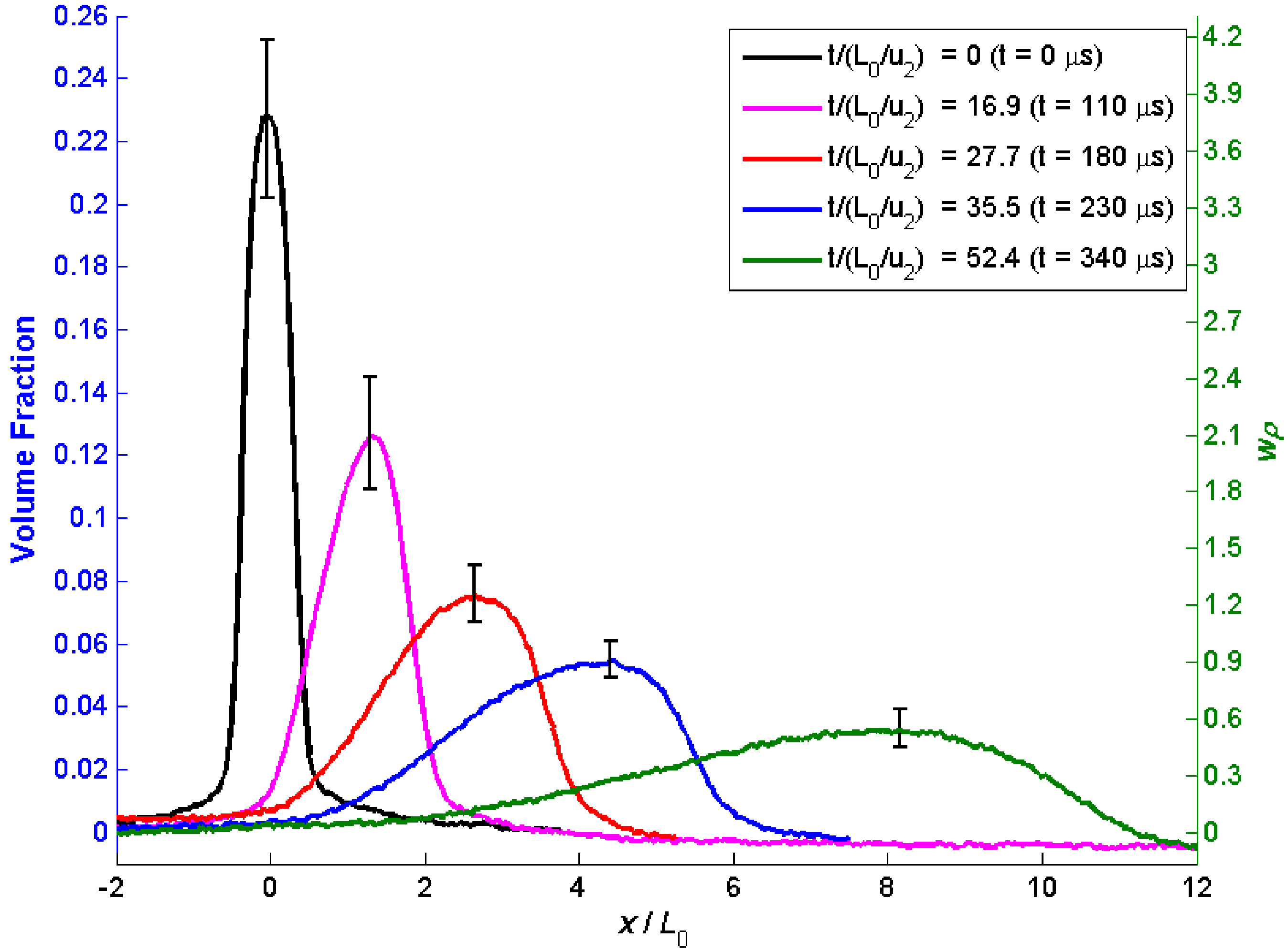
Apply Beer's law to back out volume fraction profiles





$$\varphi = \frac{w}{w_0} = \frac{\ln \frac{I}{I_0}}{-A w_0 \rho}$$

Volume Fraction Profiles



Curtain spreads in asymmetric fashion with the downstream-side exhibiting steeper gradients

[1]Wagner, Kearney, Beresh, DeMauro, Pruett, *under review in Experiments in Fluids*, also AIAA 2012-1054 .

Gas Phase Velocity Data with PIV

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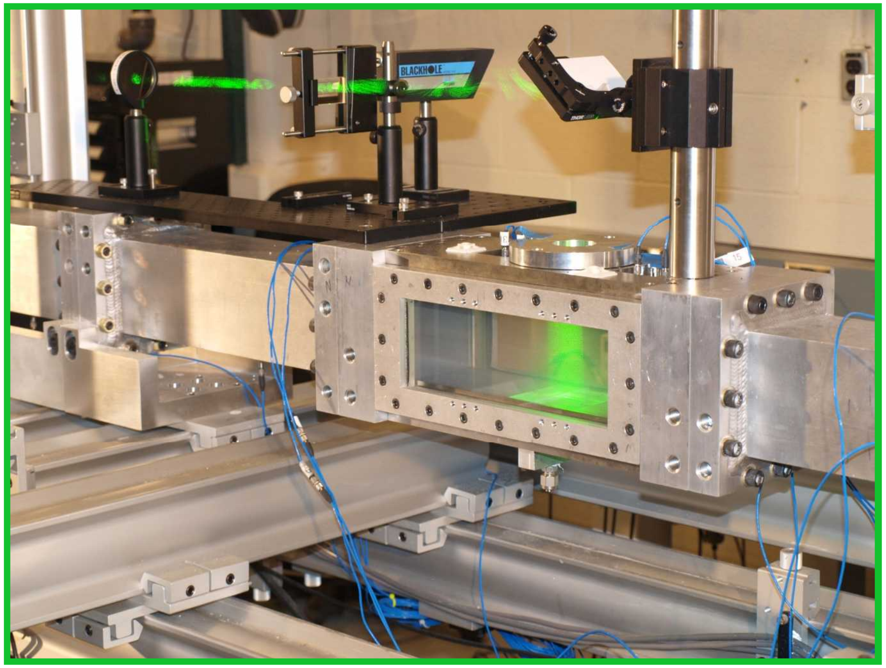
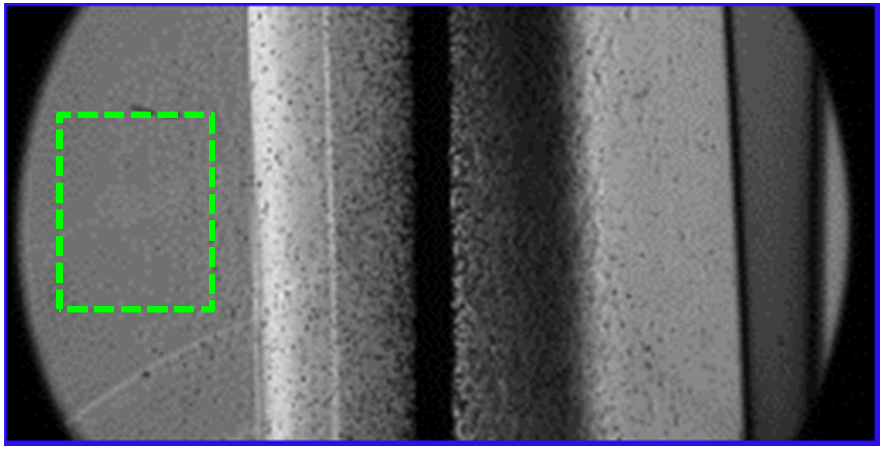
PIV Setup



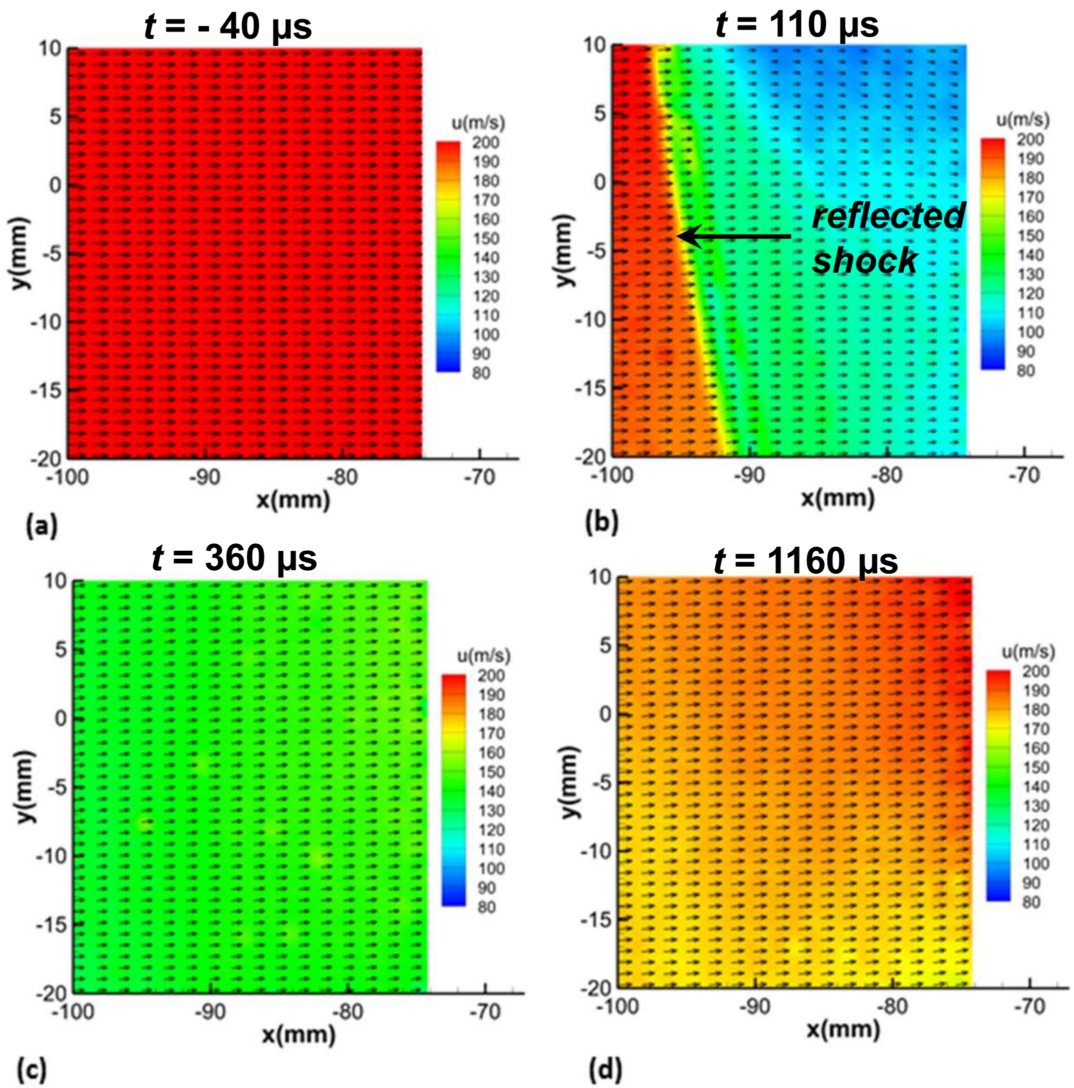
We seed the gas with micron-size particles to measure gas velocity.

Want gas velocities during interactions



Our first data set was obtained upstream of the curtain using a standard 10-Hz system.

Interaction Data Upstream of Curtain

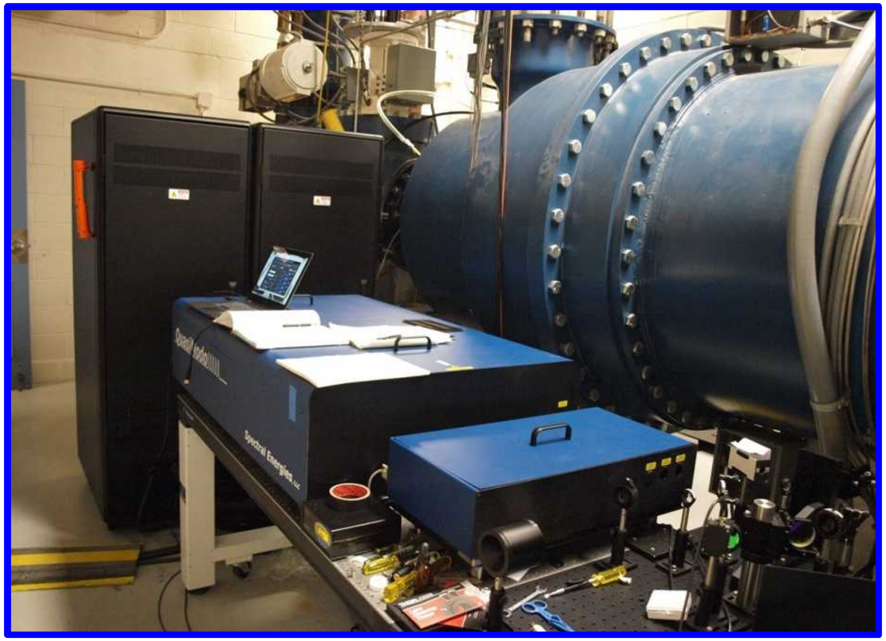


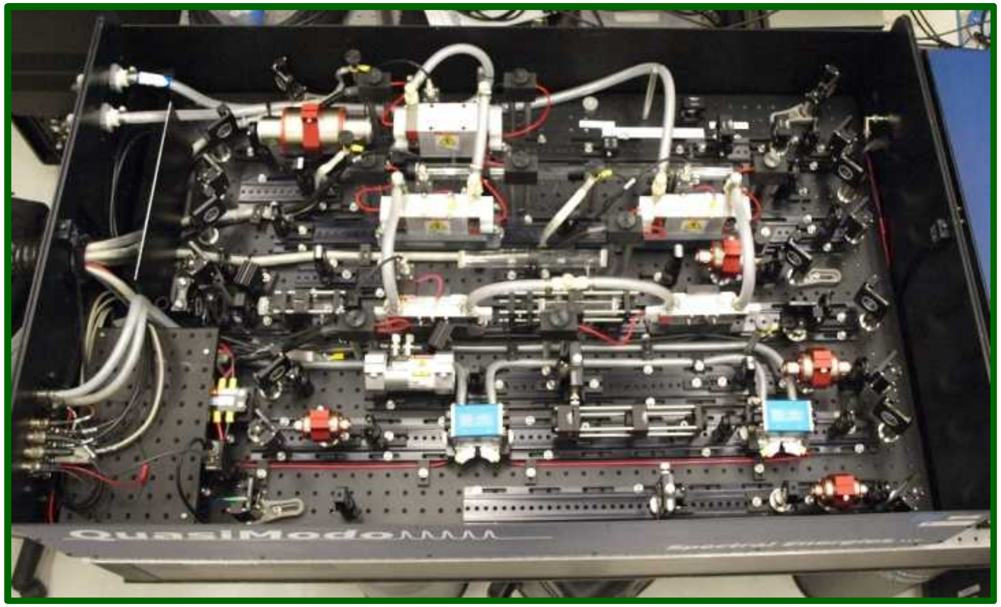
Form a pseudo-sequence from shots at various delays

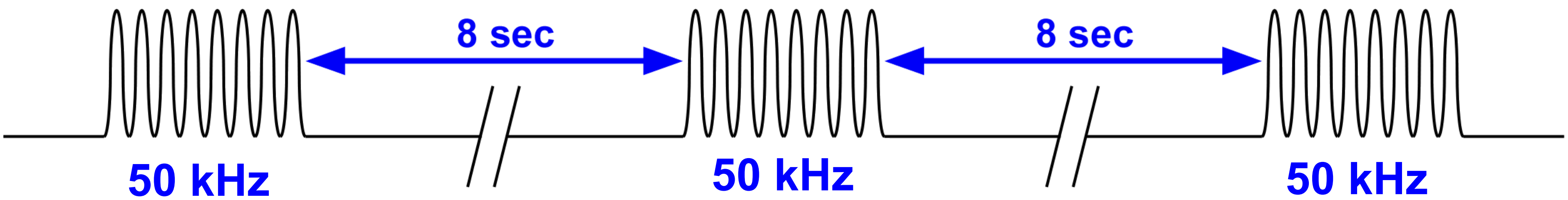
See flow induced by the incident shock, the reflected shock, and later time flow acceleration

10-Hz data provide proof-of-concept, though, inefficient and difficult to discern dynamics…

Solution: Pulse-Burst PIV

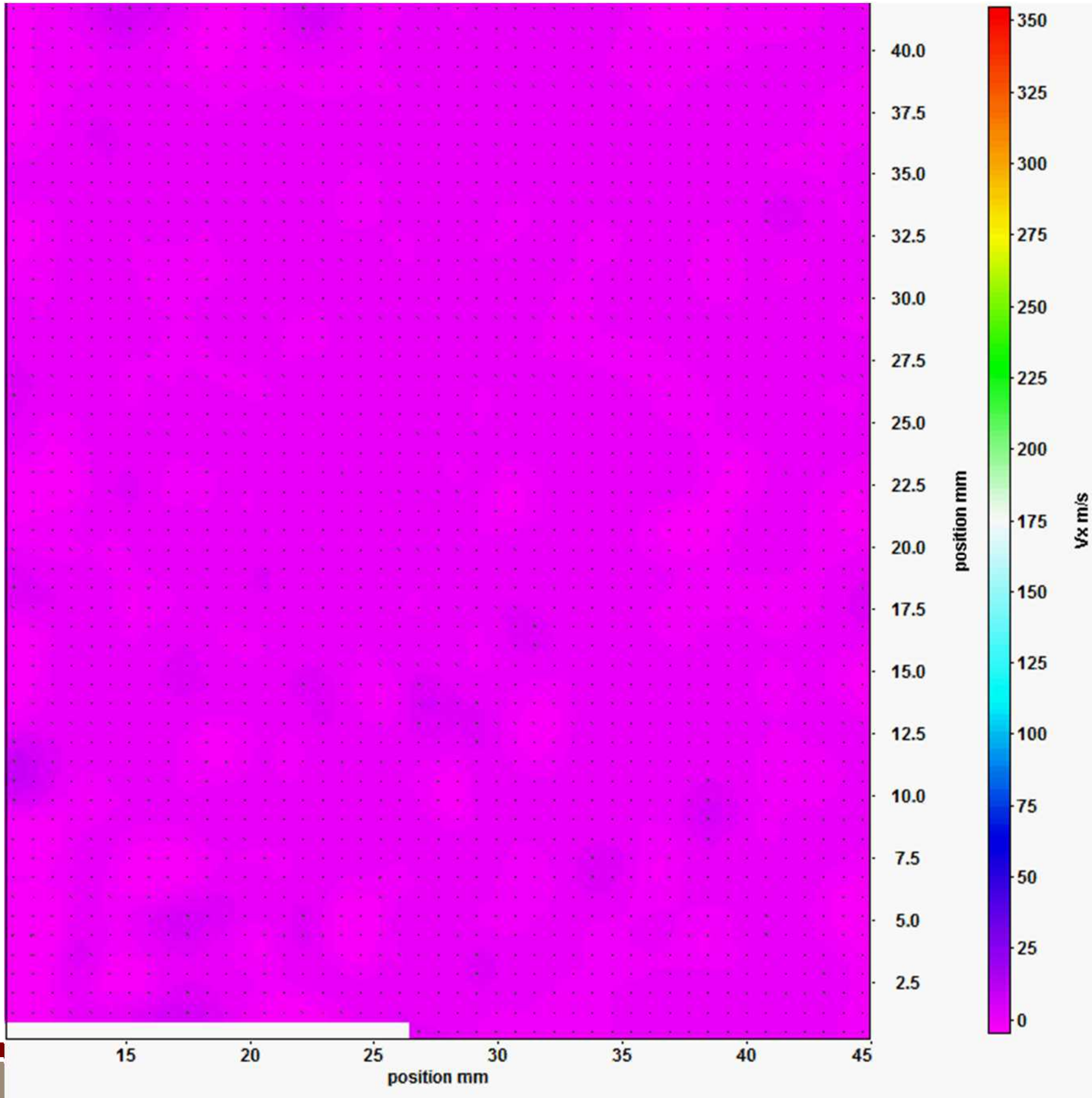






Bursts of high repetition rate pulses last up to 10.2 ms, *plenty long in a shock tube flow.*

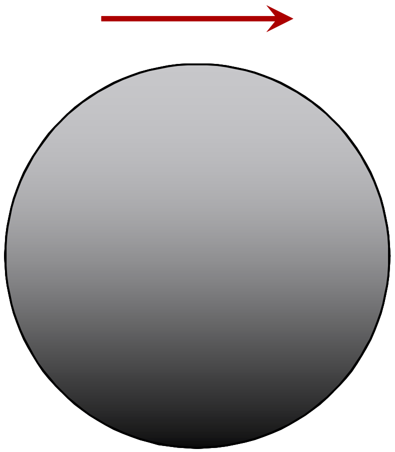
Core-Flow and BL Growth (M_s = 2)

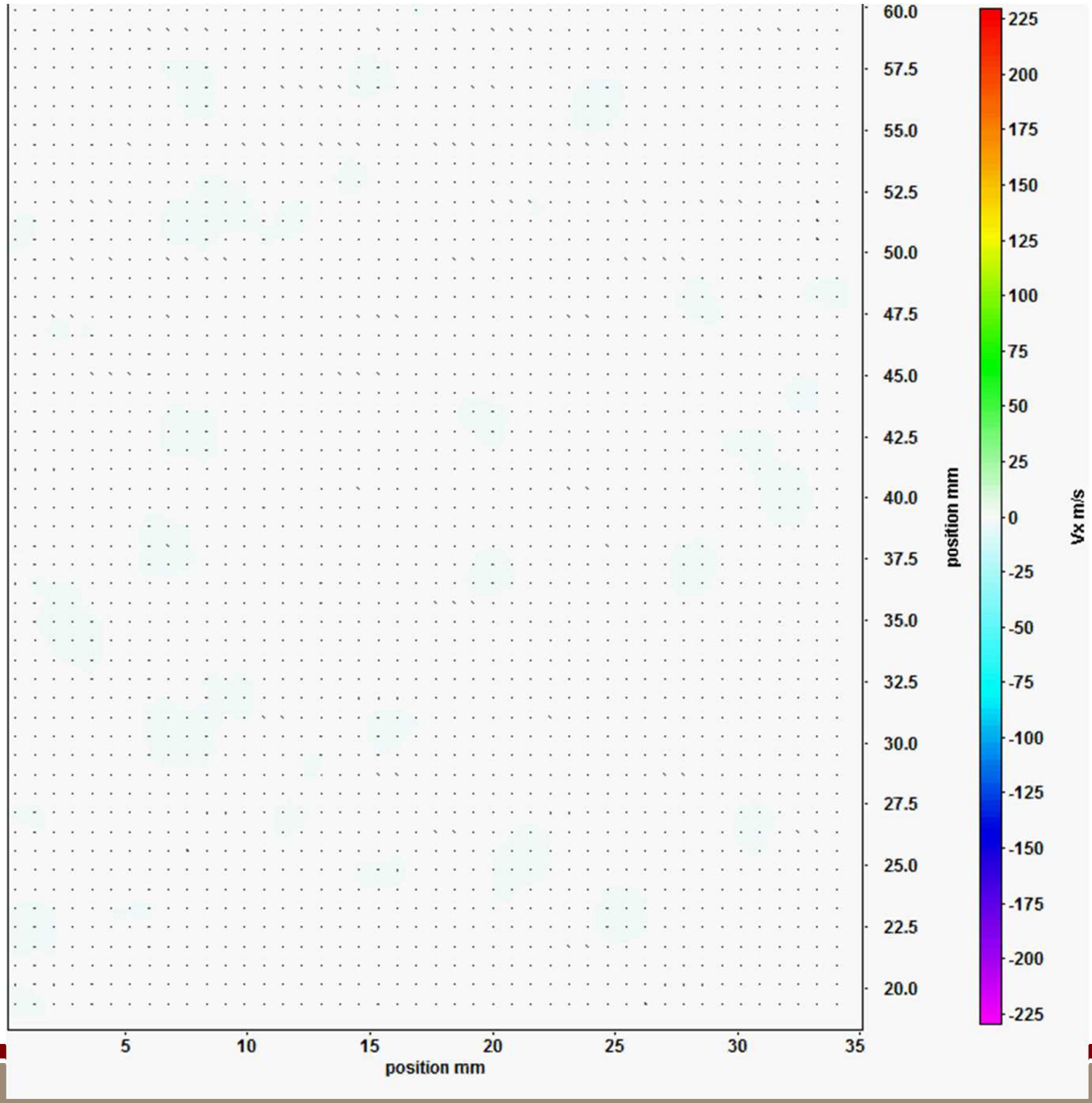


First Results in Shock Tube

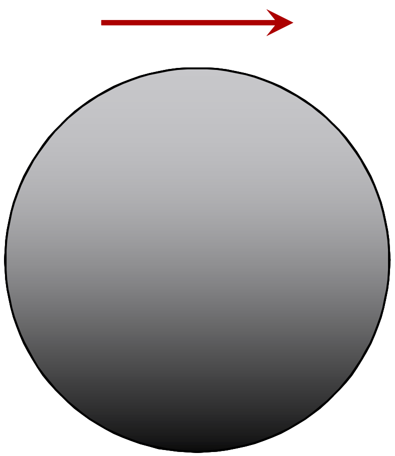
- Instead of one vector field per shot, we get one every 20 microseconds to produce movies
- Empty data capture the lower vertical half of the shock tube quantifying the incident shock, boundary layer growth, core flow velocity, and the reflected shock.

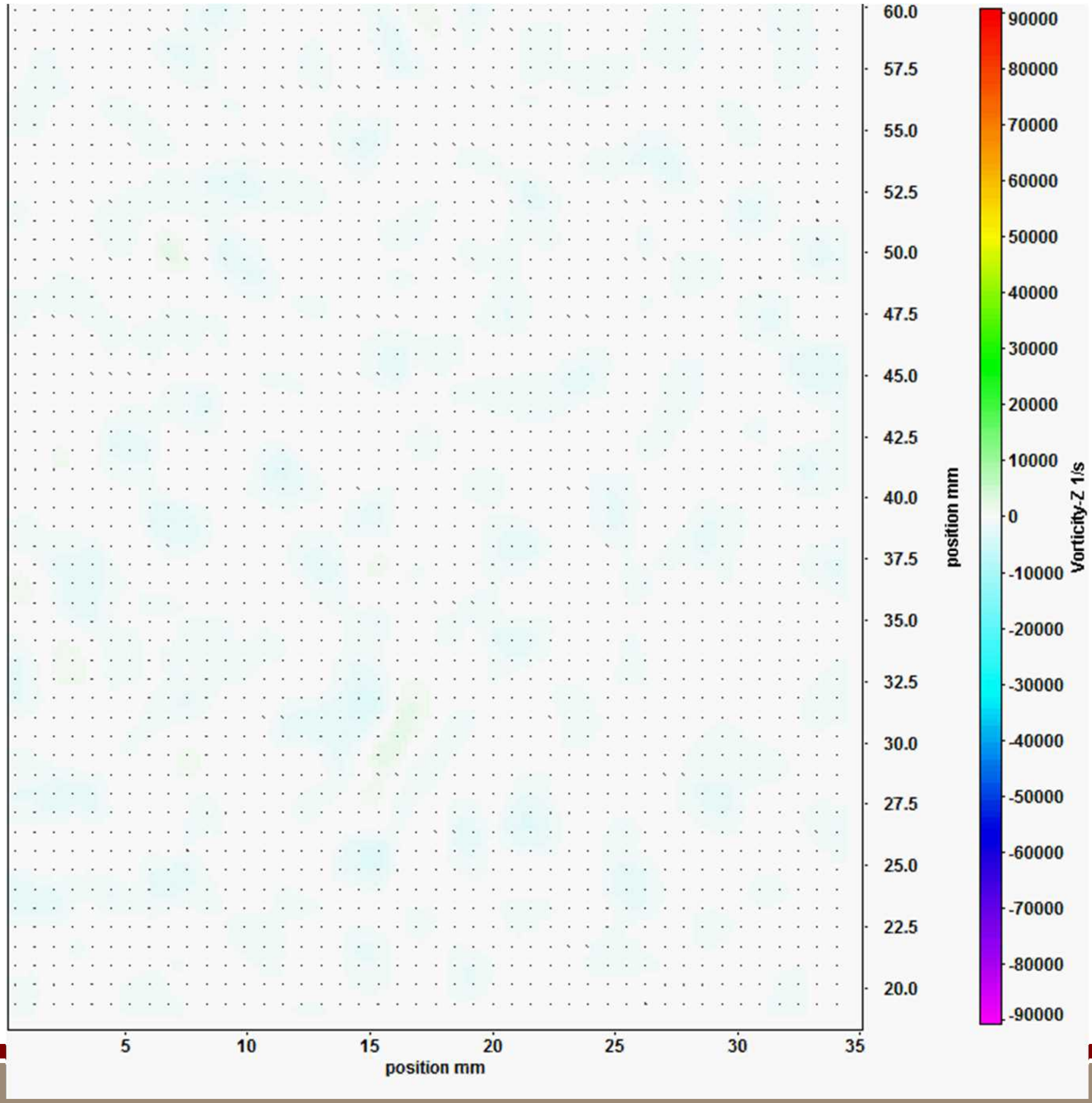
Transient Wake (M_s = 2, u)





Transient Wake (M_s = 2, vorticity)





Upcoming Work

1) Pulse-Burst PIV during Shock-Particle Curtain Interactions

Data will help quantify:

1. **Interphase momentum transfer**
2. **Interaction unsteadiness**
3. **Particle-induced turbulence downstream of curtain…**

Questions?

Backup Slides (Quantify Transients)

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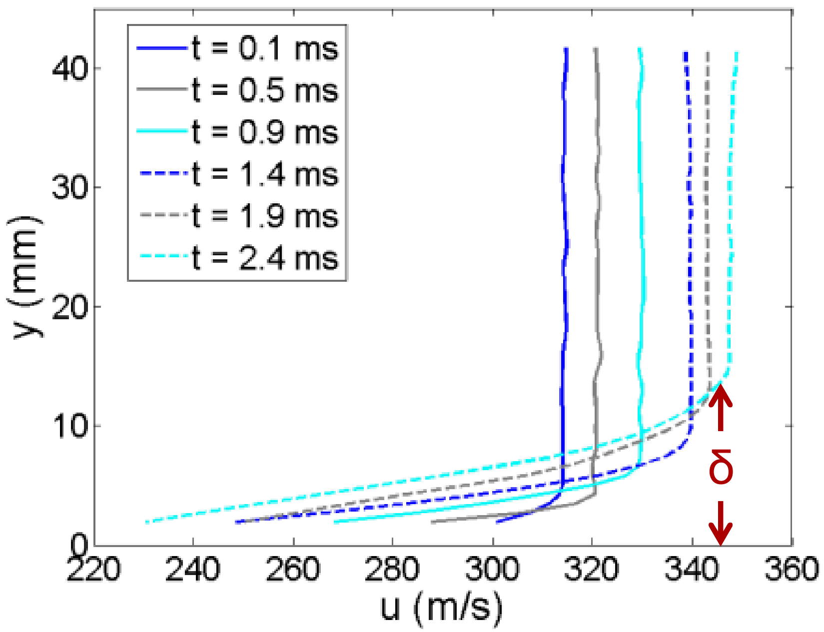
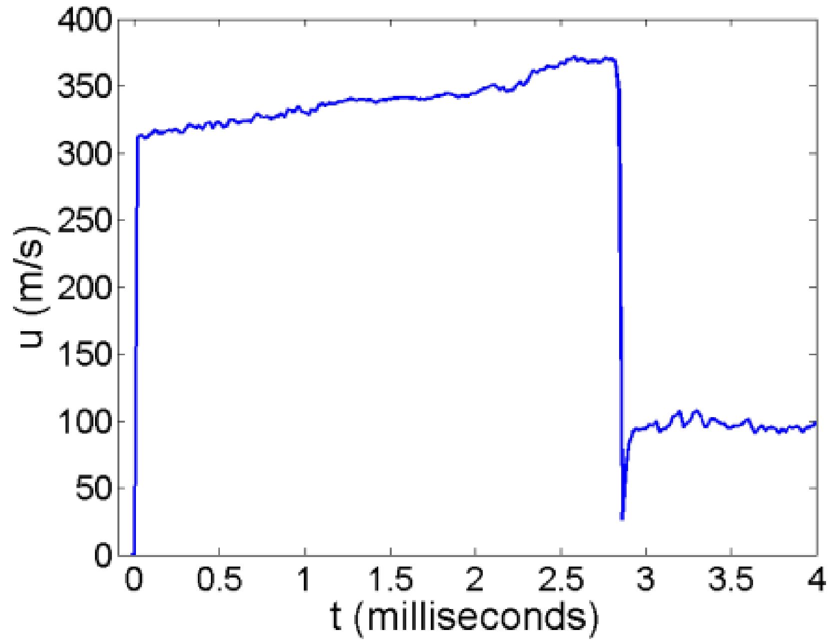
Boundary Layer Growth



Core-Flow Velocity



Boundary layer growth leads to a core flow acceleration of about 20% over the test time.