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Title:	Burn Front and Reflected Shock Wave Visualization in an Inertially Confined Detonation of High Explosive
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Burn Front and Reflected Shock Wave Visualization in an Inertially Confined Detonation of High Explosive

Guillermo Terrones, Michael W. Burkett, and Christopher Morris

Abstract

Proton radiography was used to investigate the spatiotemporal evolution of the burn front and associated reflected shocks on a PBX-9502 charge confined between an outer cylindrical steel liner and an inner elliptical tin liner. The charge was initiated with a line wave generator at 30 degrees from the major axis of the ellipse. This configuration provides a large region where the high explosive (HE) is not within the line of sight of the detonation line and thus offers a suitable experimental platform to test various burn models and EOS formulations. In addition, the off axis initiation allows for the burn fronts to travel around the charge through different confining paths. Simulations were performed to assess the accuracy of several HE burn methodologies. Experimental data from initiation through HE shock collision will be presented and simulation comparison results will be discussed.

Burn Front and Reflected Shock Wave Visualization in an Inertially Confined Detonation of High Explosive

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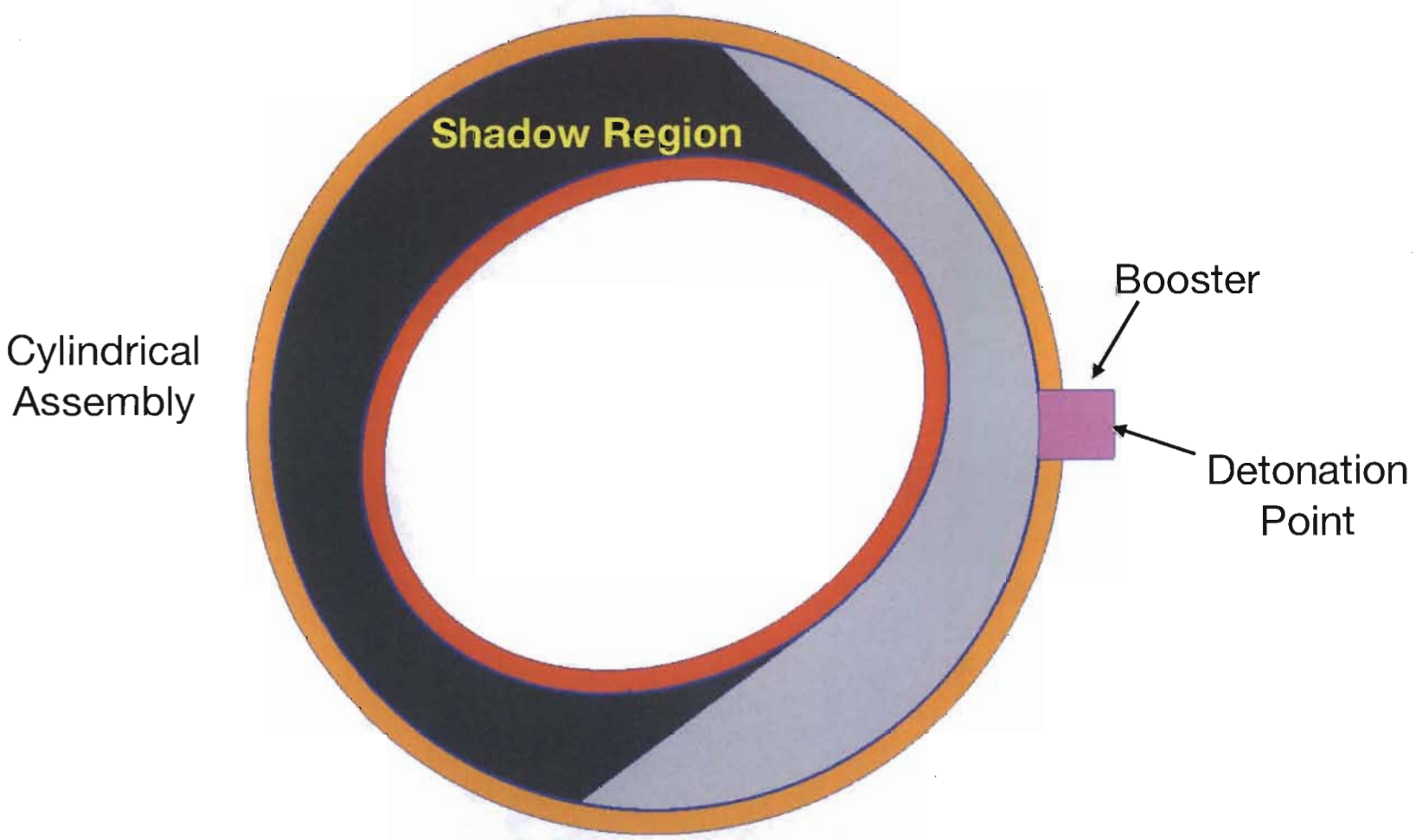
- J. D. Zumbro

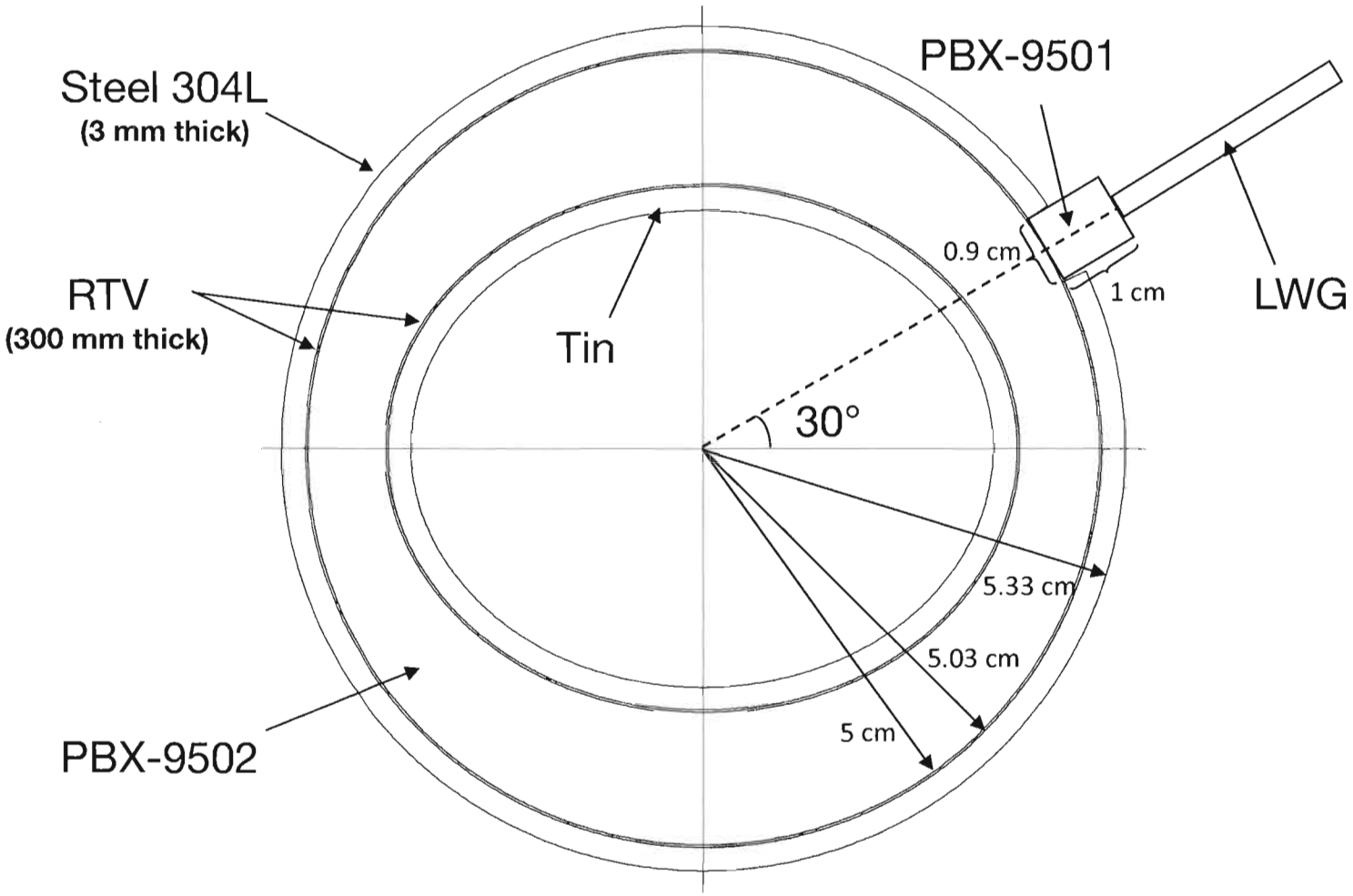
Objective

- Use pRad data to determine the accuracy of current burn models for the computation of the burn front and associated reflected shocks beyond the shadow region in an insensitive high explosive.

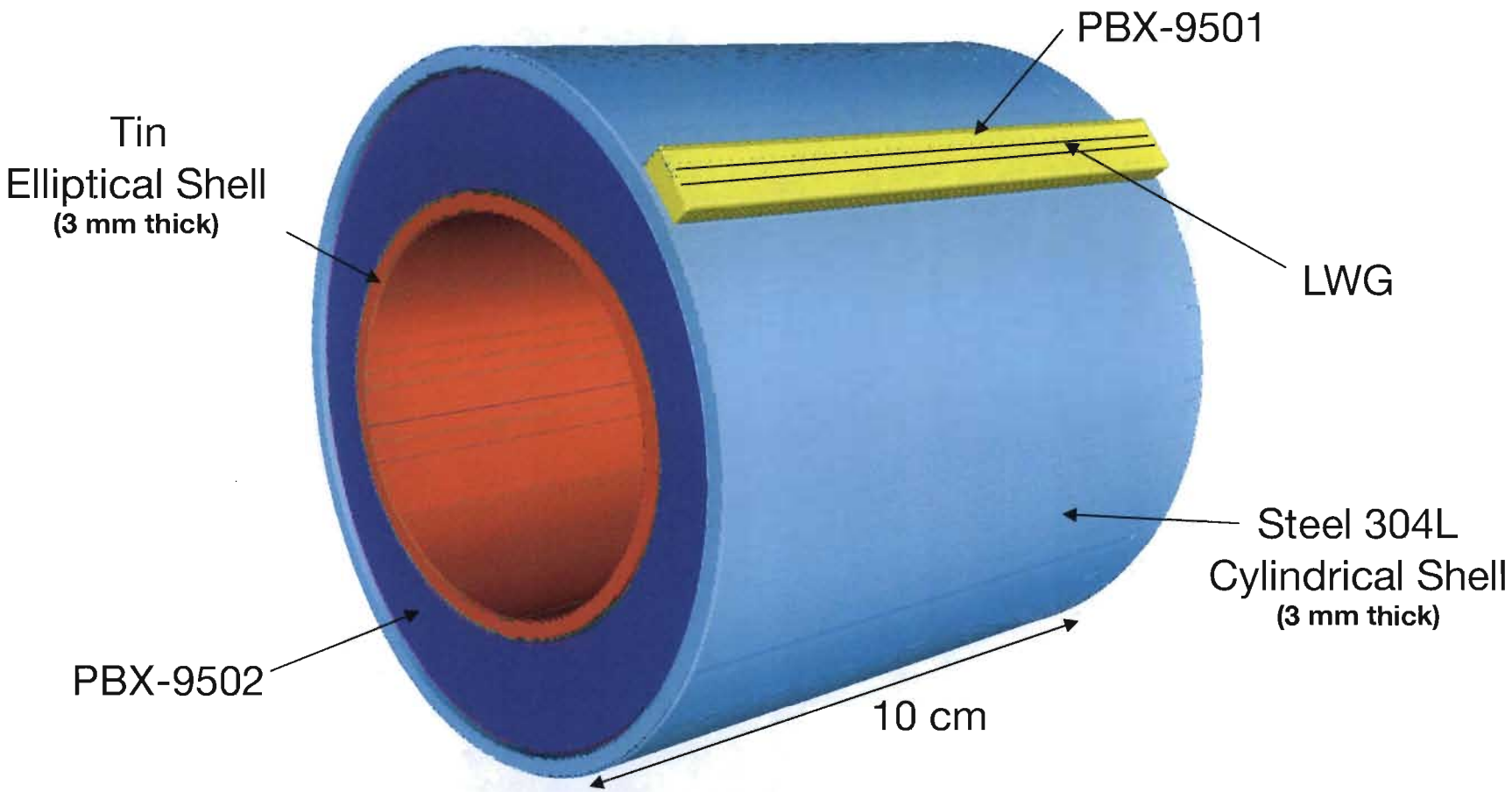
Conceptual Design



Cylinder Cross Section

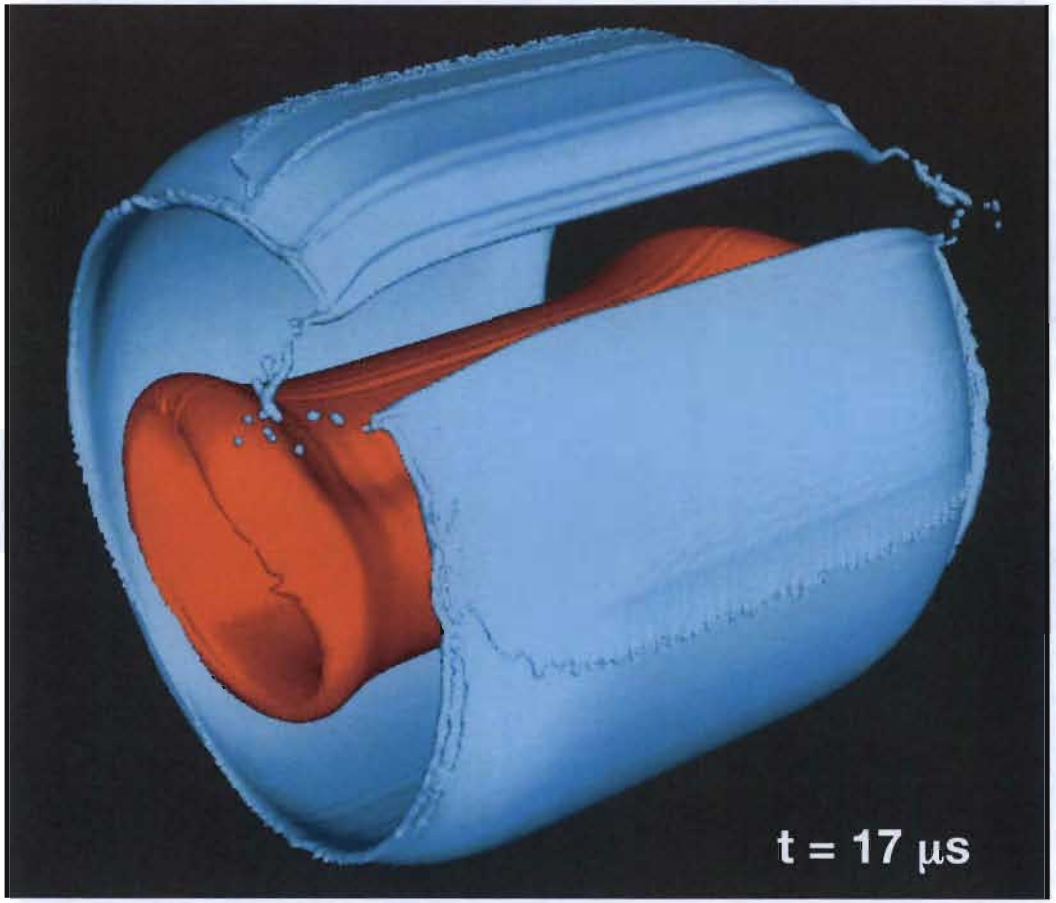


3D Model

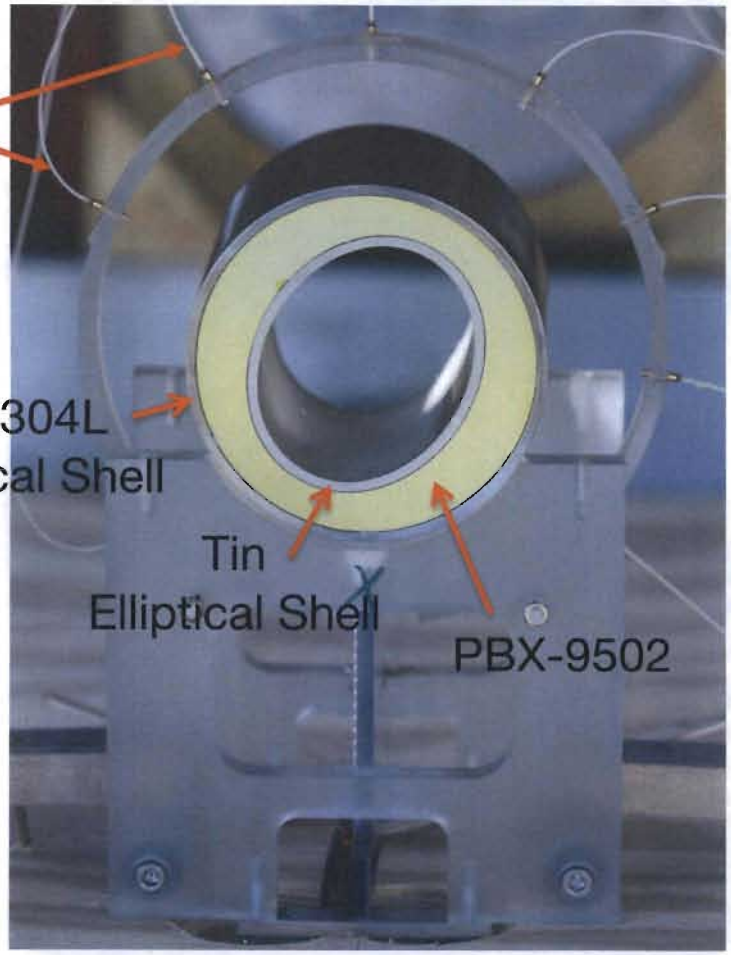

PBX-9501
Tin
Elliptical Shell
(3 mm thick)
LWG
Steel 304L
Cylindrical Shell
(3 mm thick)
PBX-9502
10 cm

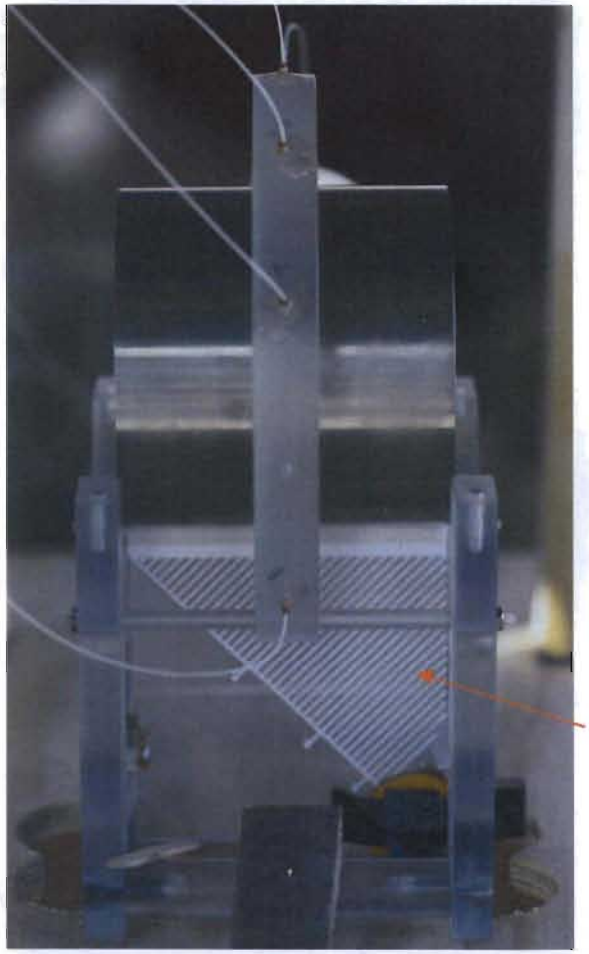
No Field of View Obstructions

All HE
Has burned

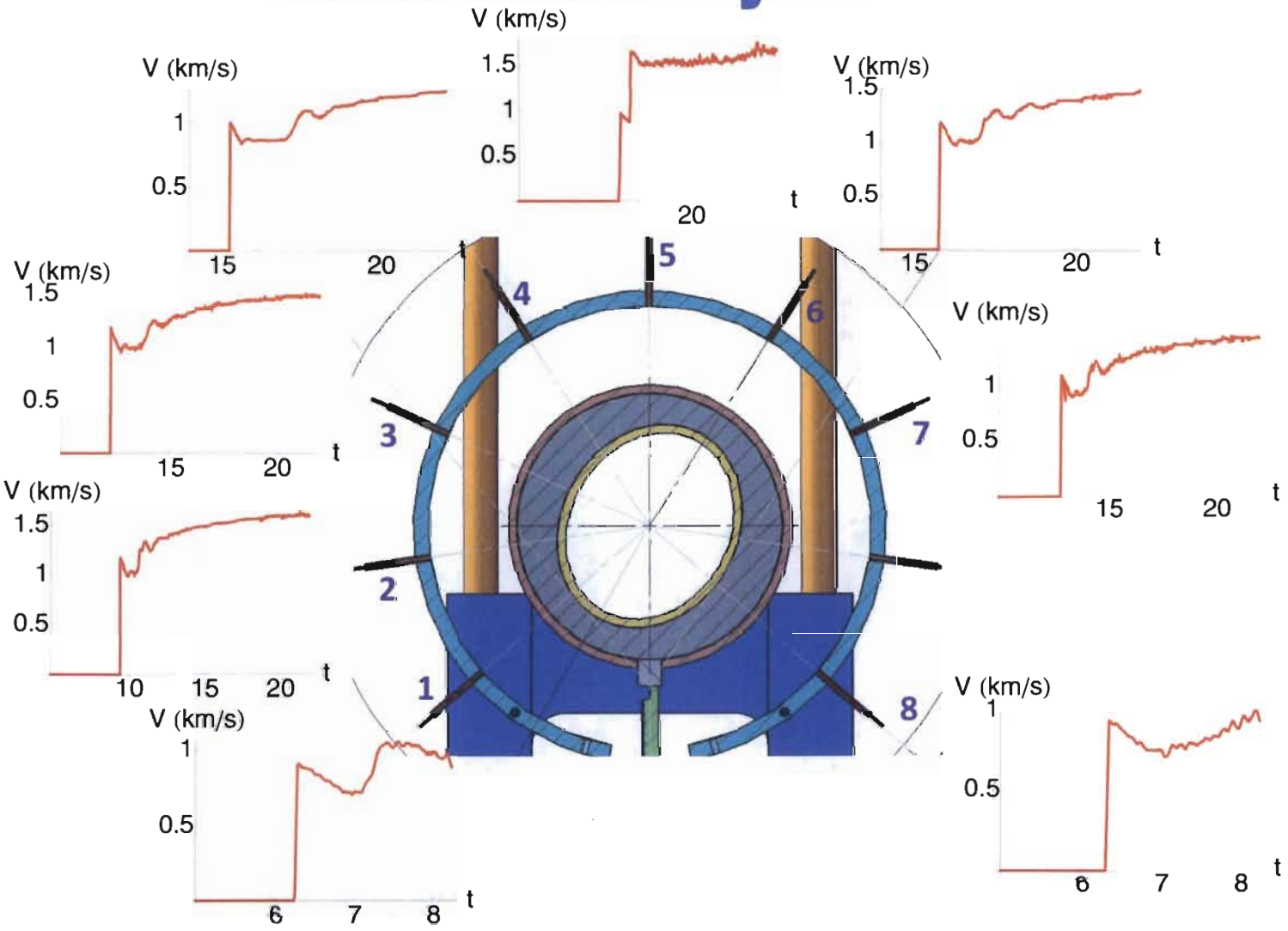


Field Assembly

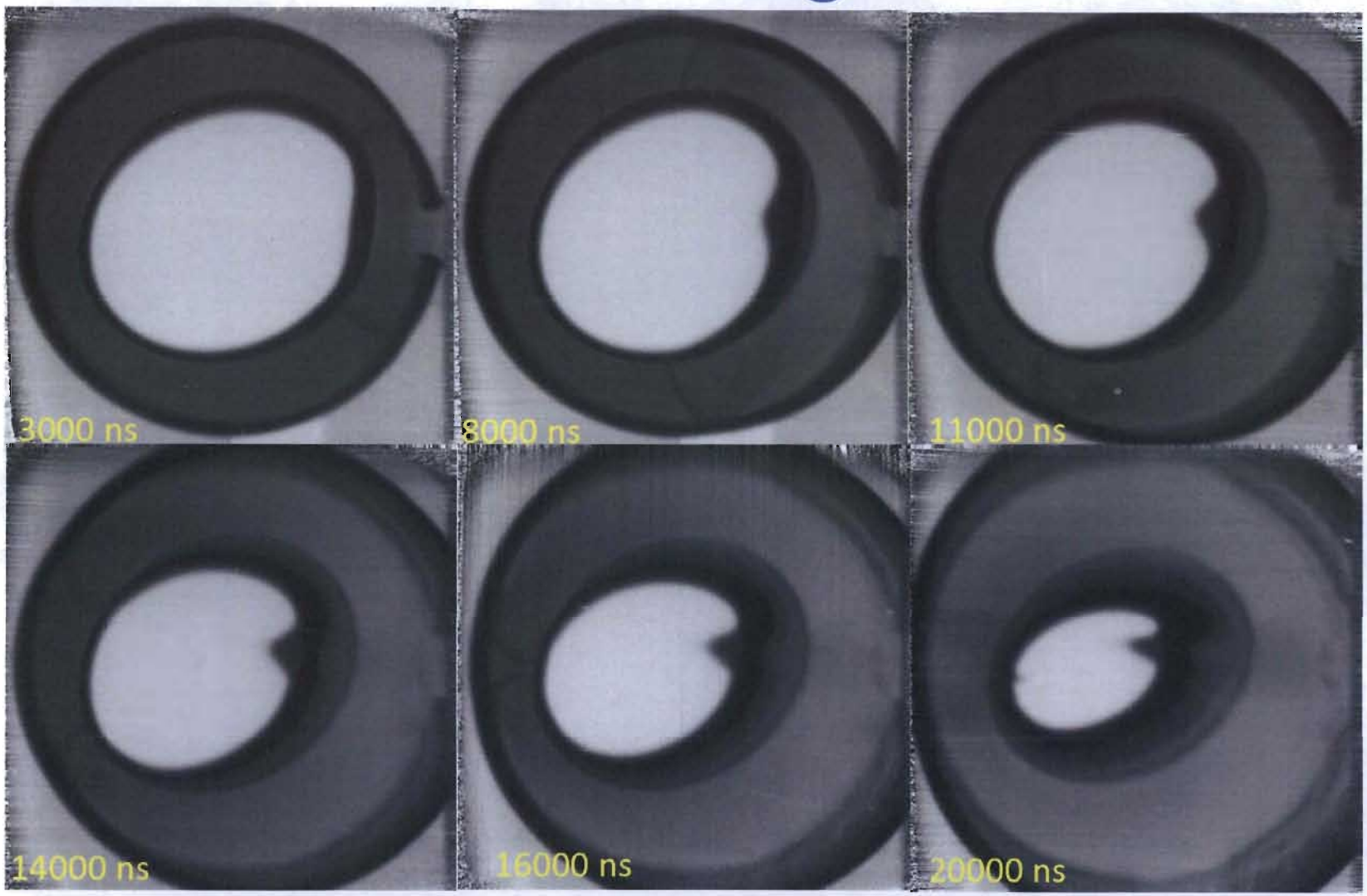




Velocimetry Data

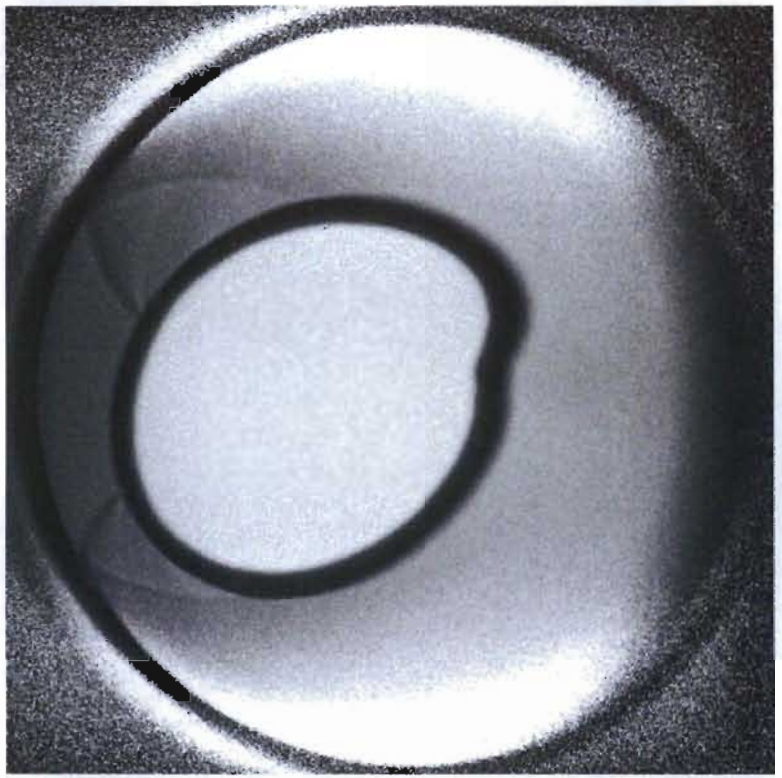


P-Rad Images



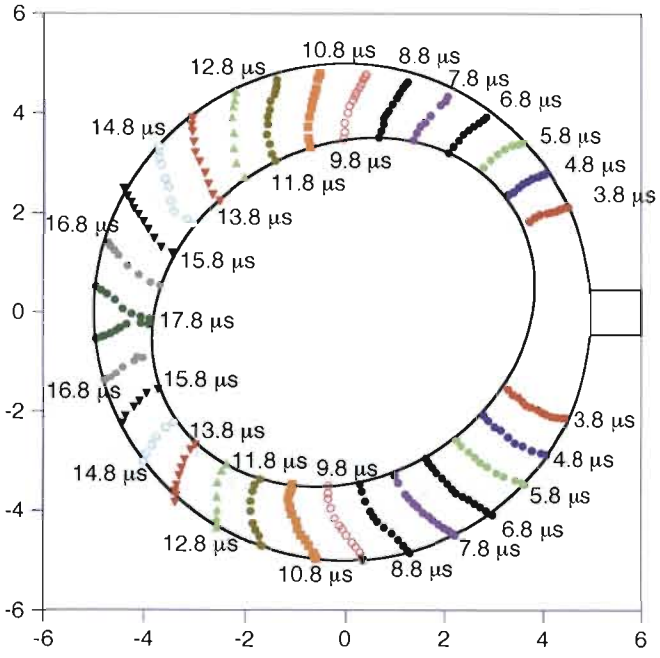
Synthetic P-Rad

pRad Image at 14.8 μs

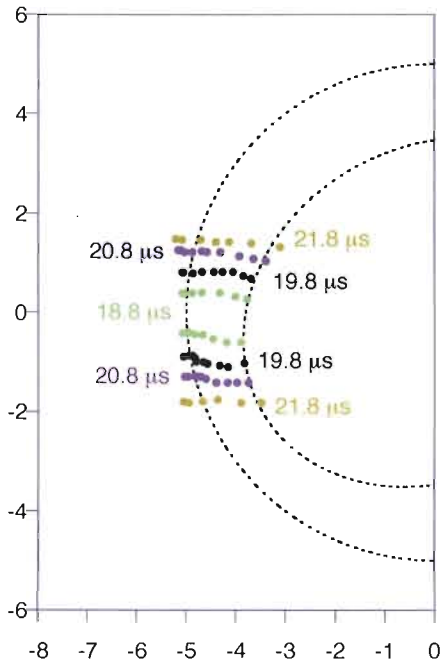


Synthetic pRad Image at 15 μs computed with MCNP by John Zumbro

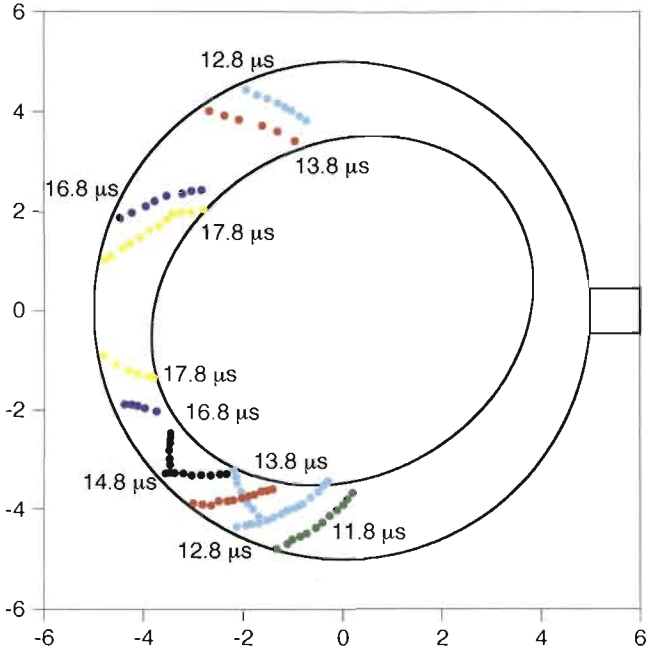
Digitized pRad Shock Data



Burn Fronts

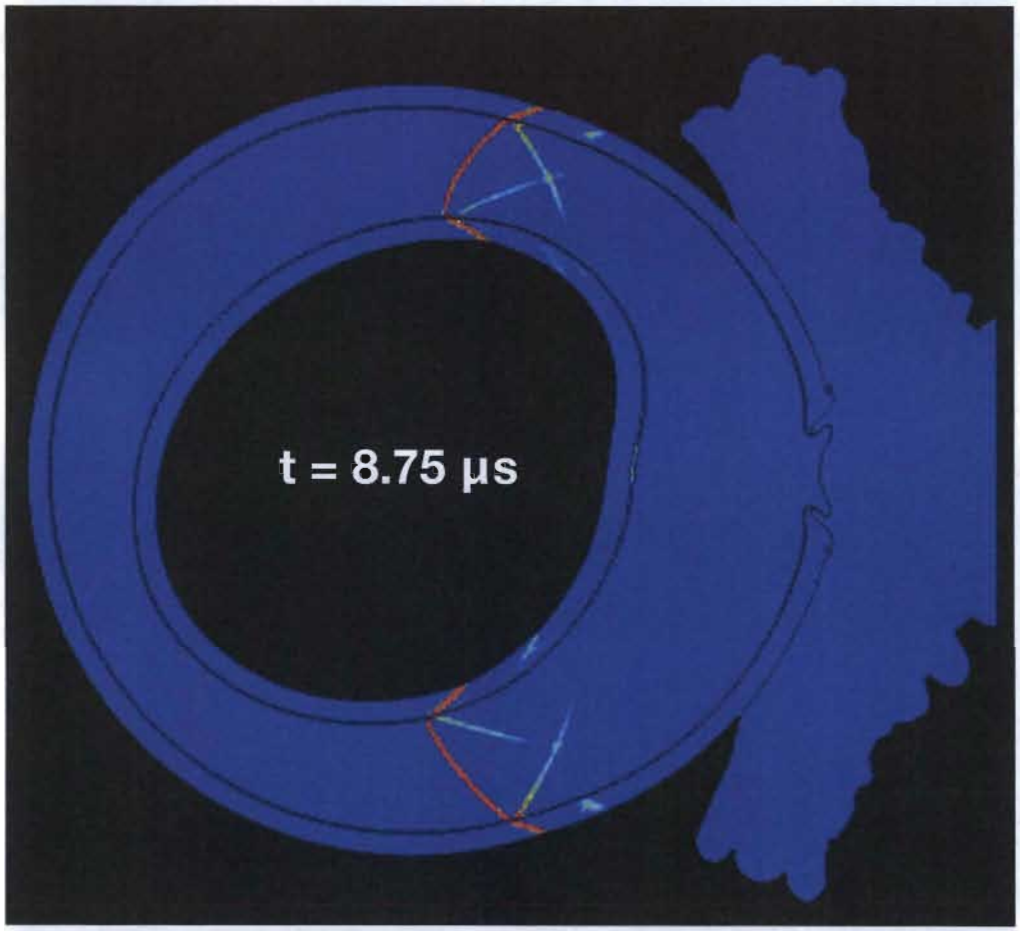


HE Reflected Shocks

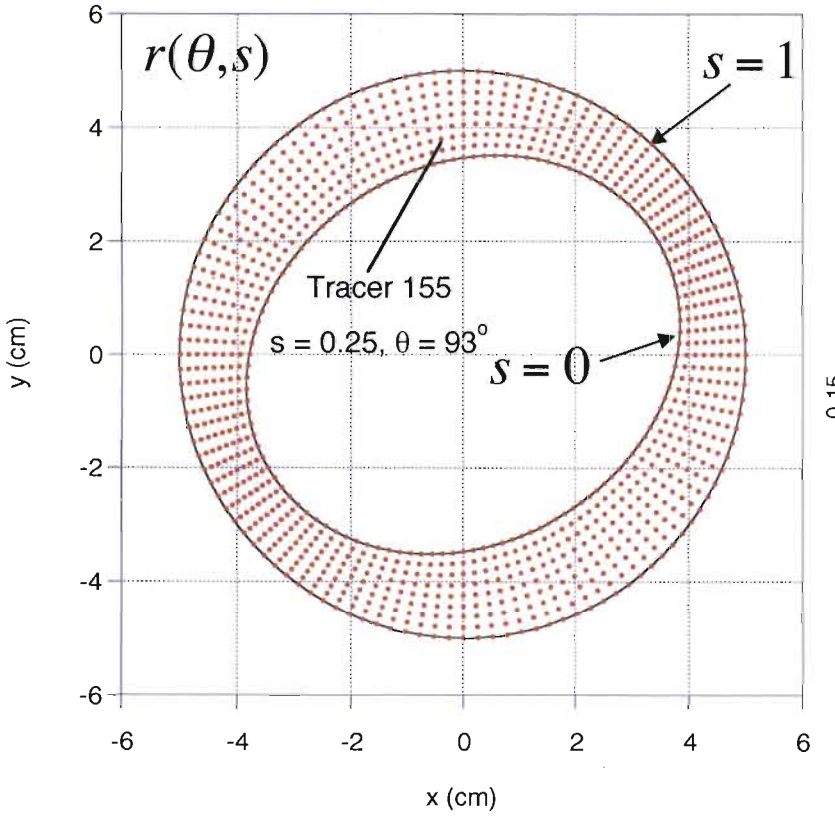


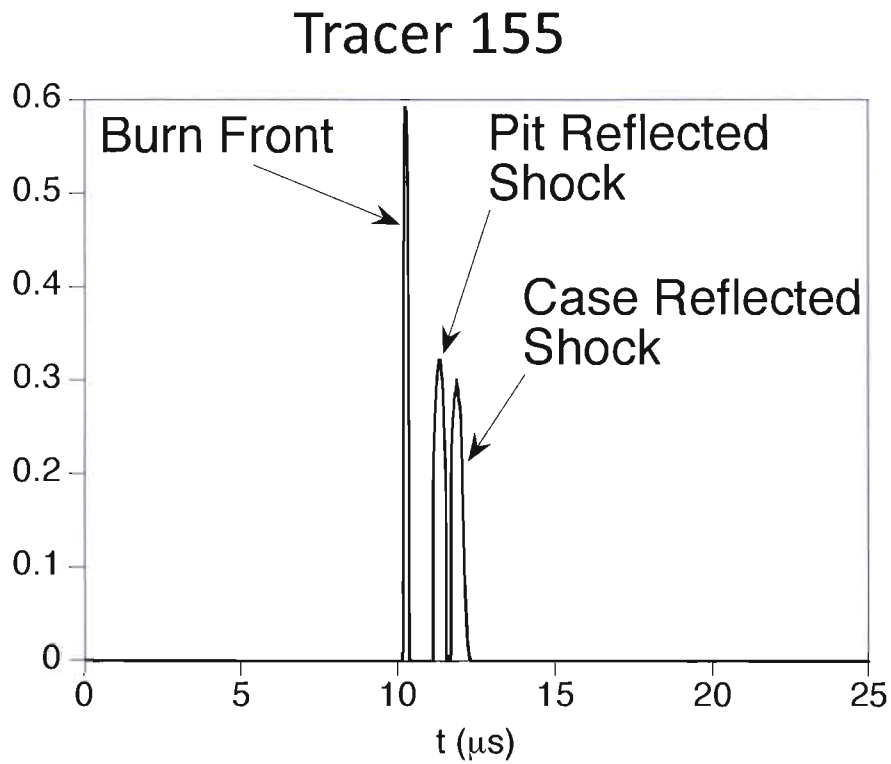
Reflected Shocks

Artificial Viscosity (Q) Map



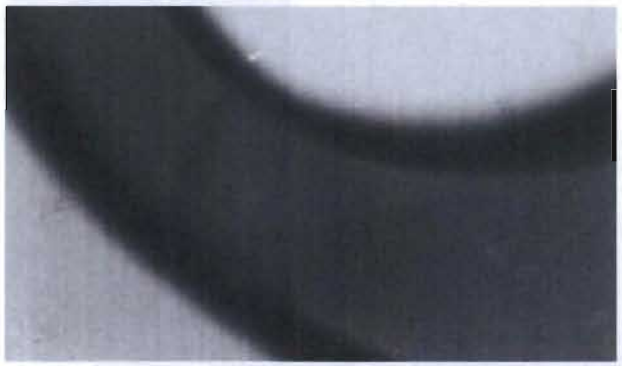
Shock Fronts from Processing Q

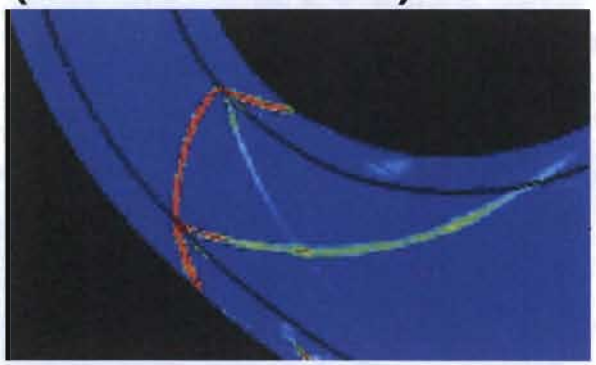




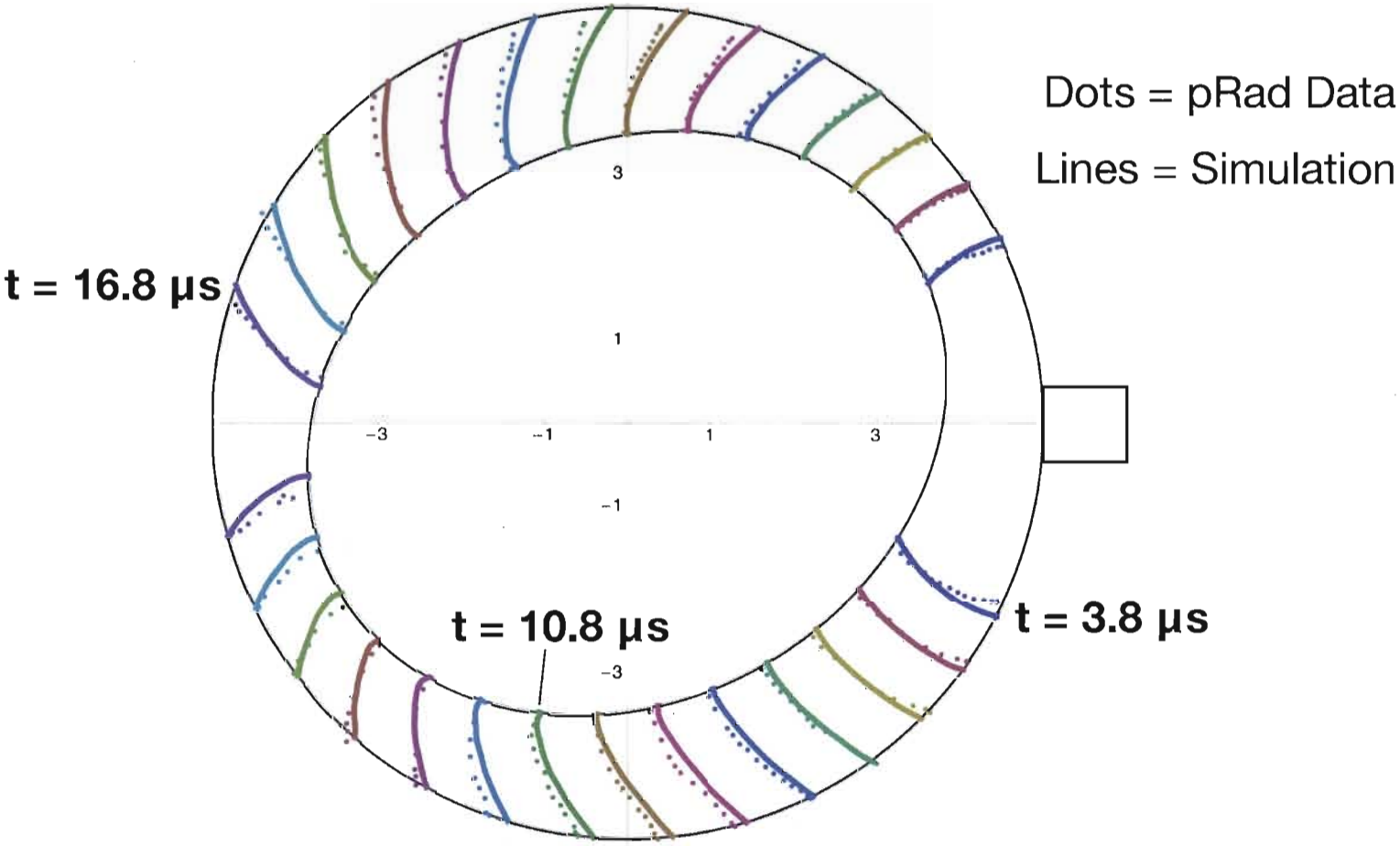
Quantitative Comparisons

- Metric: The time $\Delta\tau$ (in shakes) it would have taken the computed front to reach the experimental one ($\Delta\tau > 0 \Rightarrow$ data leads).
- Calculate the average for every point on the isochrone $\langle \Delta t \rangle$ (in shakes).

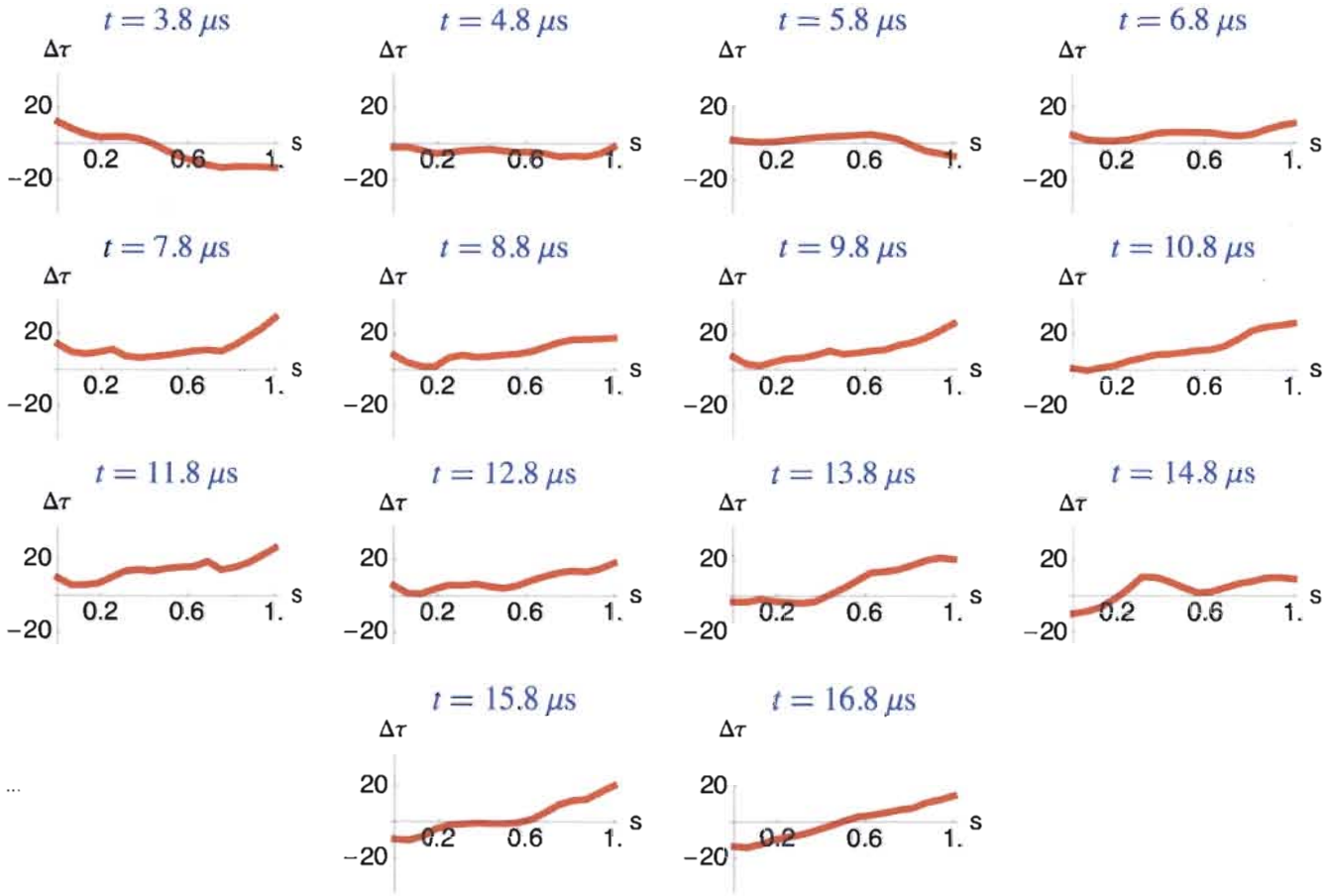




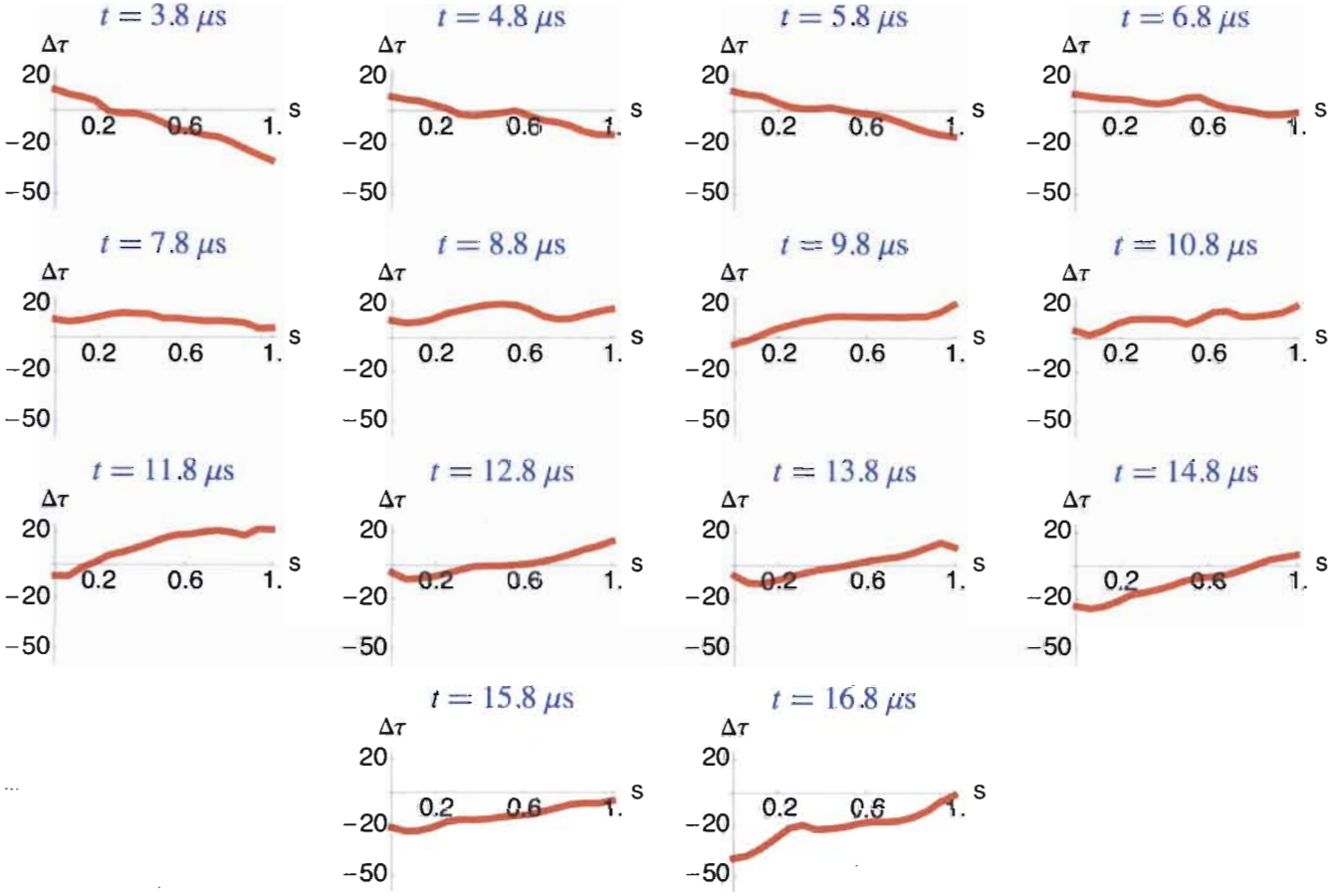
Shadow Fraction = 0.95



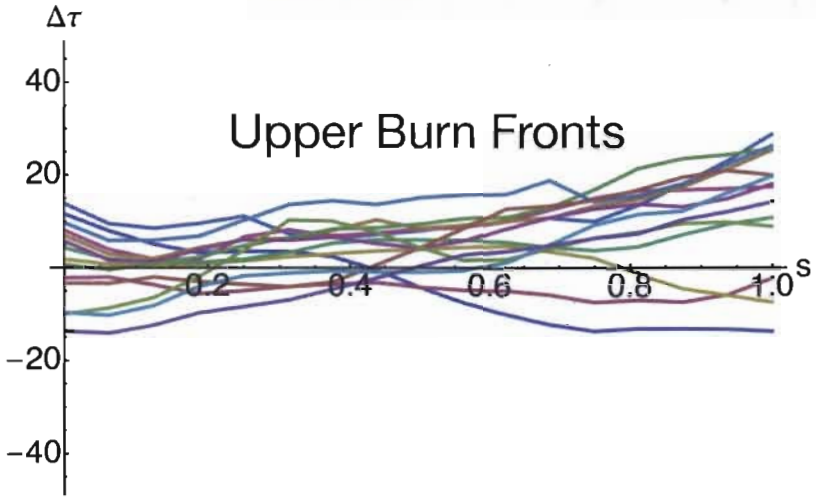
0.95 Shadow Fraction (Upper Fronts)

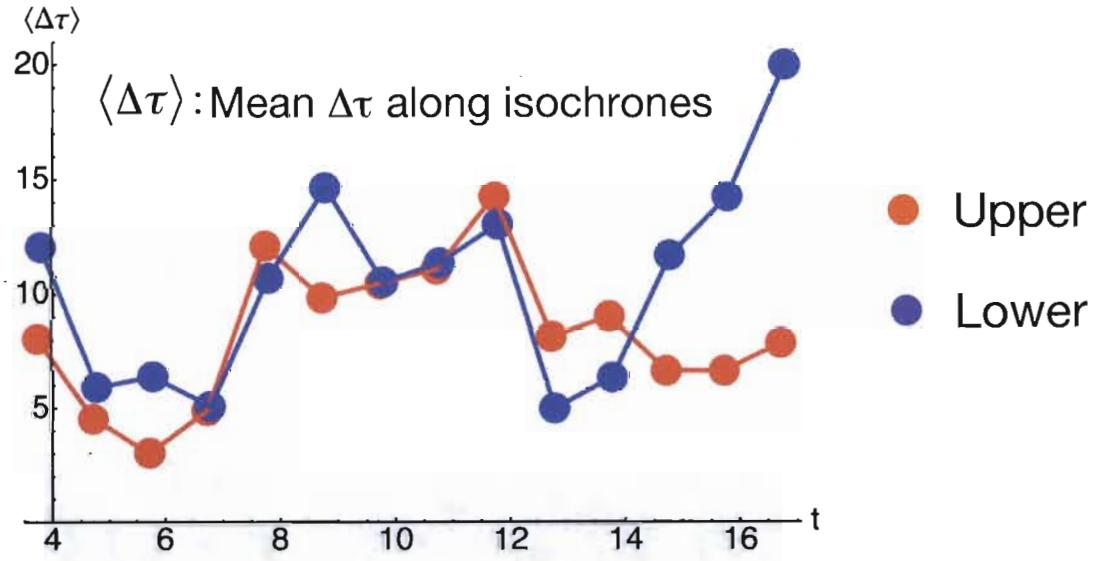


0.95 Shadow Fraction (Lower Fronts)

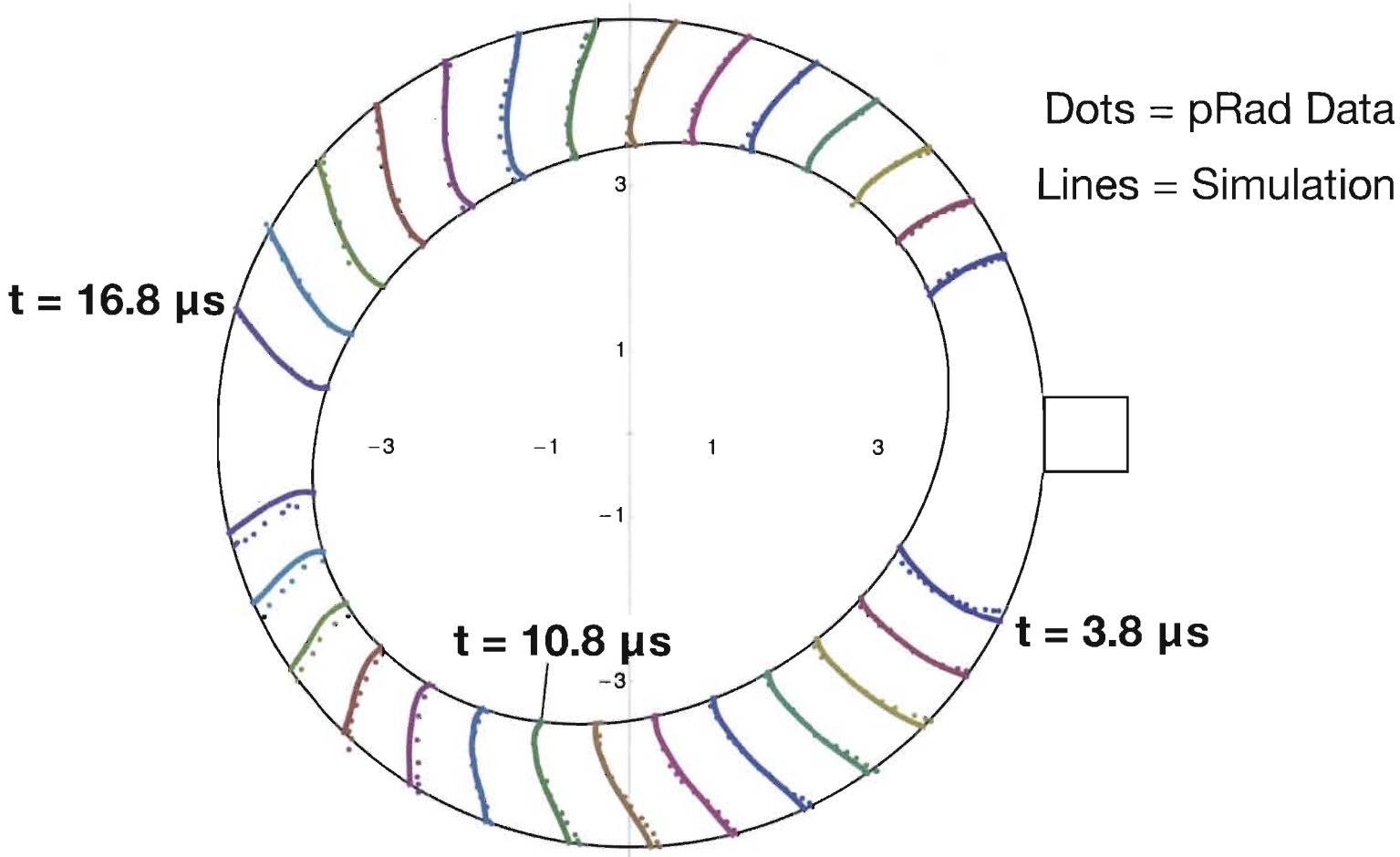


Shadow Fraction = 0.95

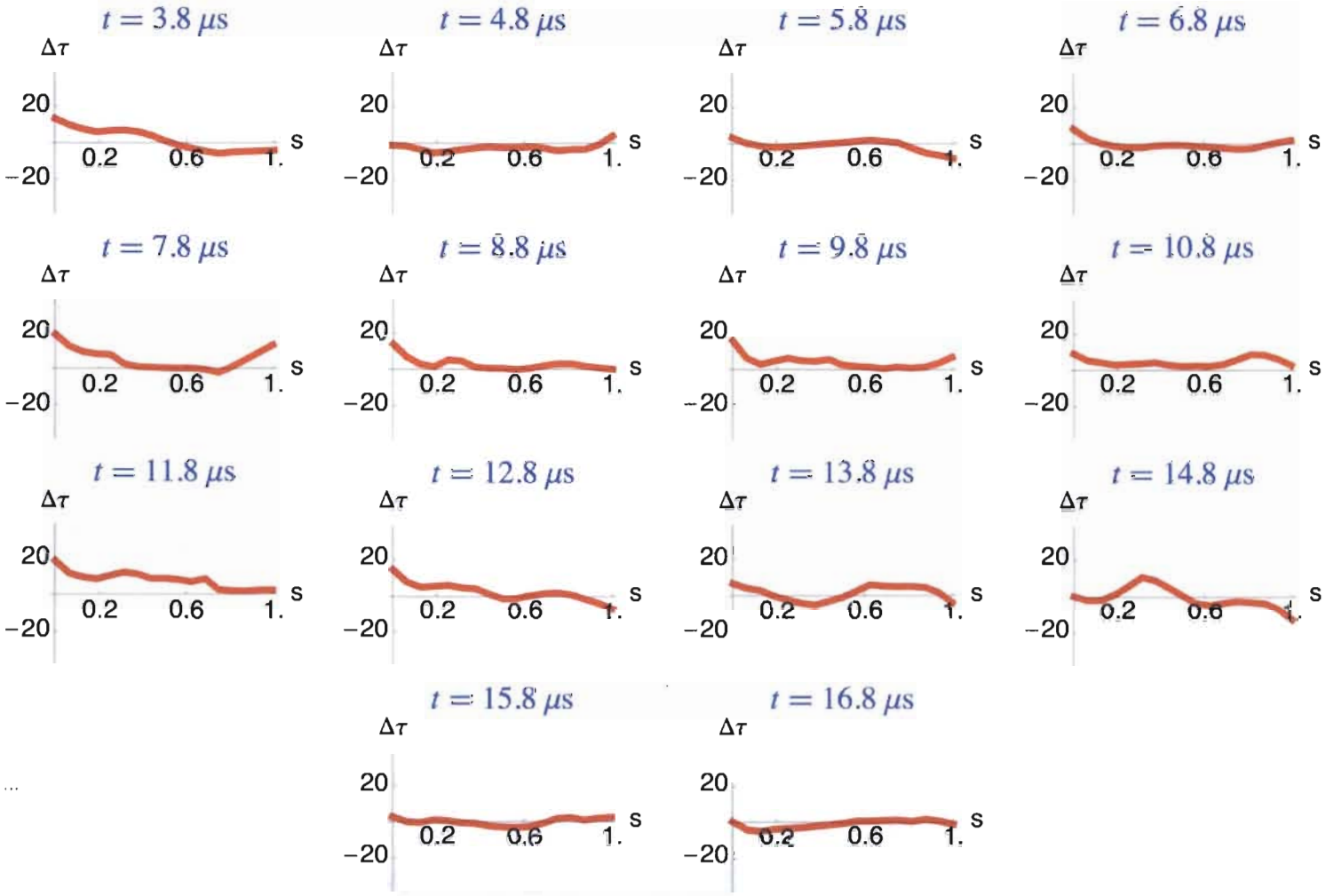




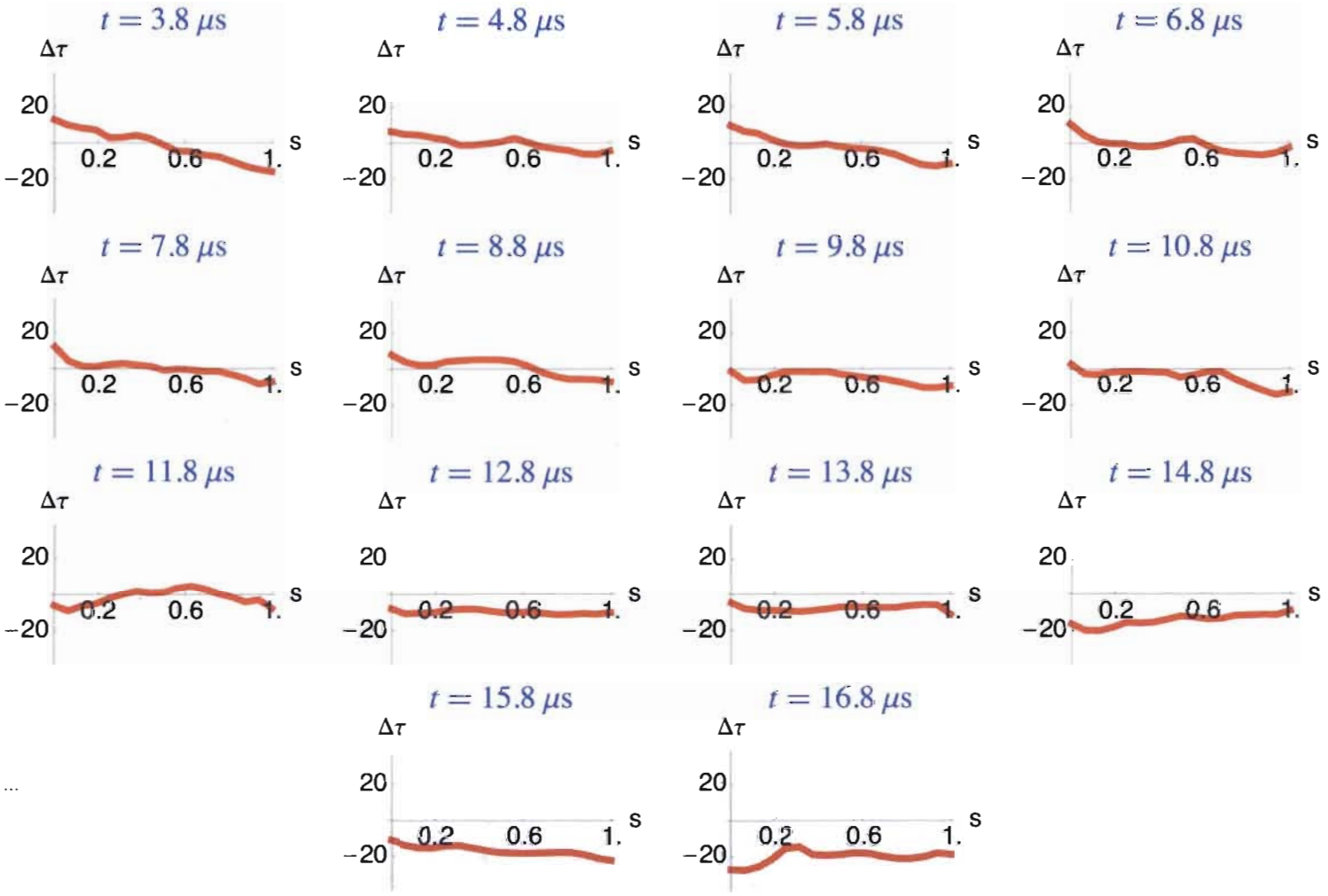
DSD


Dots = pRad Data
Lines = Simulation
t = 16.8 µs
t = 10.8 µs
t = 3.8 µs
3
1
−1
−3
−3
−1
1
3

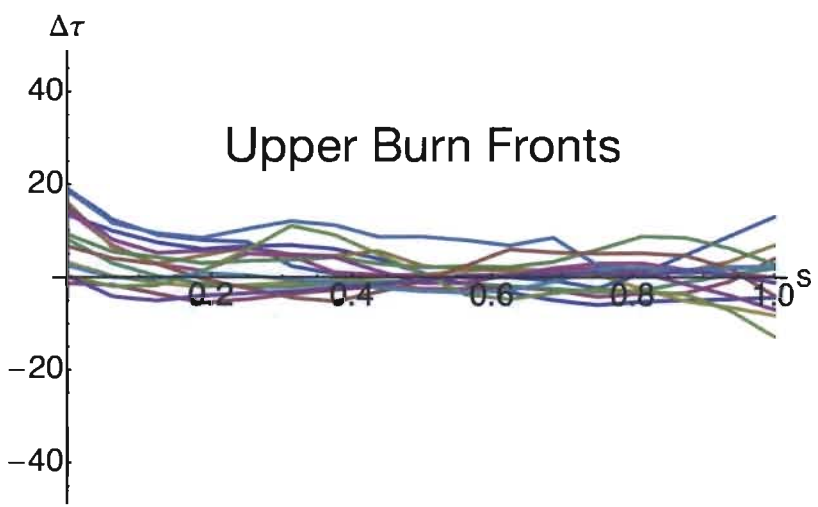
DSD (Upper Fronts)

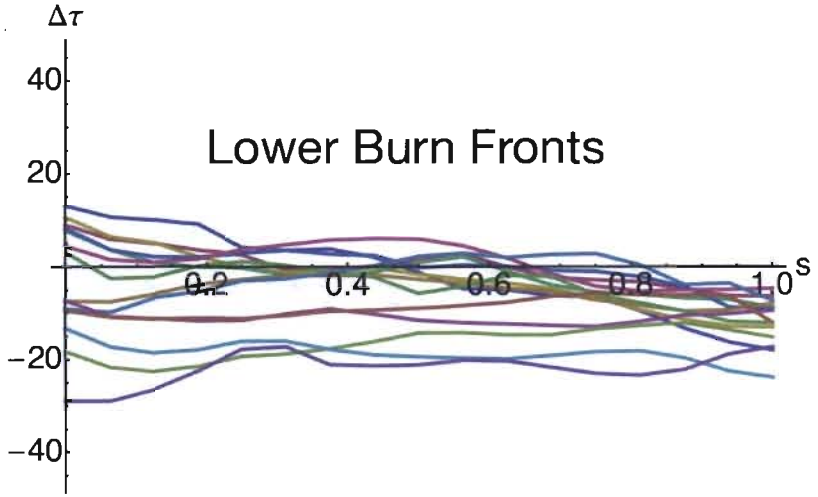


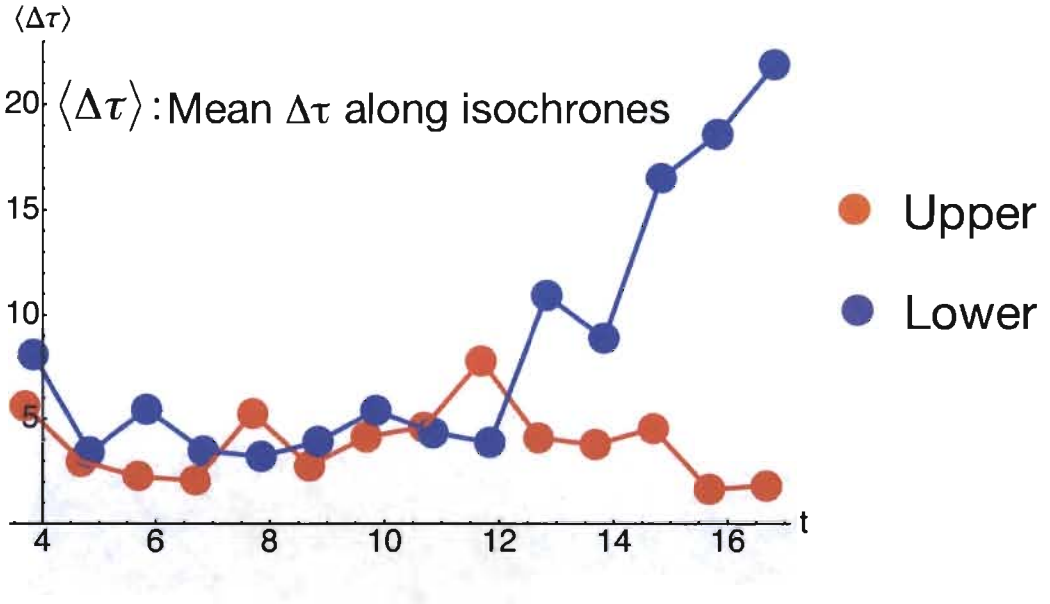
DSD (Lower Fronts)



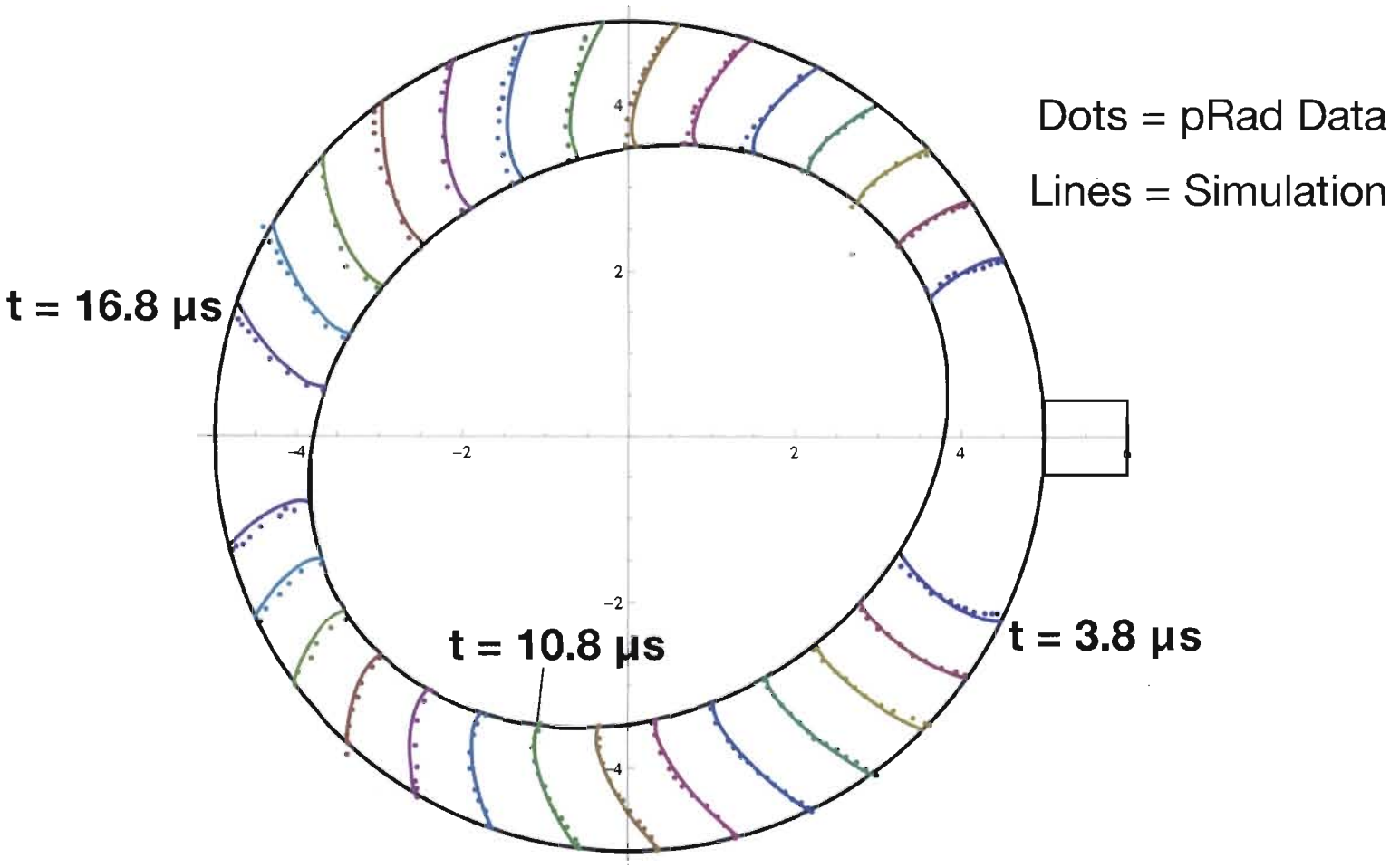
DSD


Δτ
40
20
−20
−40
Upper Burn Fronts
0.2
0.4
0.6
0.8
1.0
s

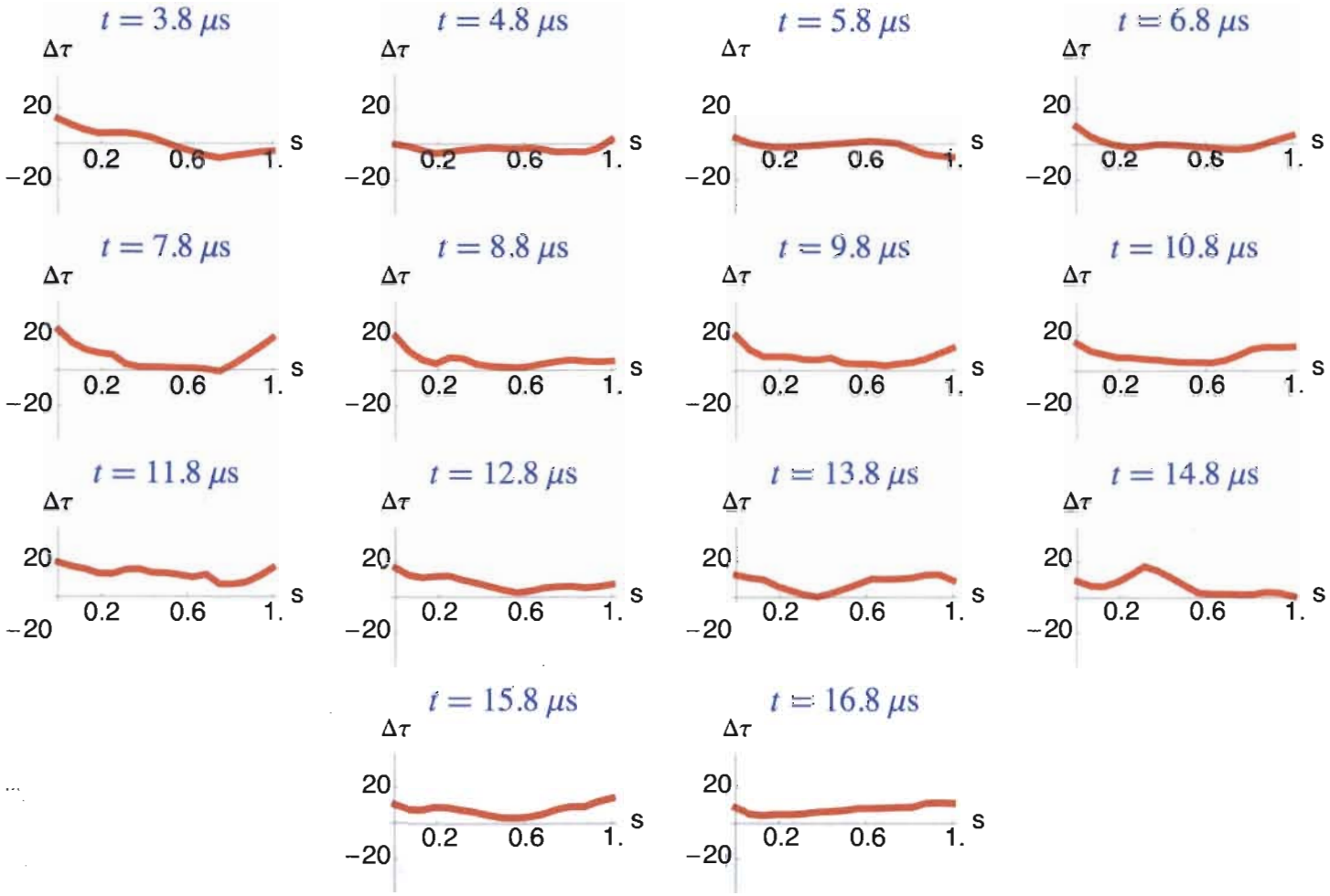

Δτ
40
20
−20
−40
Lower Burn Fronts
0.2
0.4
0.6
0.8
1.0
s


⟨Δτ⟩
⟨Δτ⟩ : Mean Δτ along isochrones
20
15
10
5
4
6
8
10
12
14
16
t
Upper
Lower

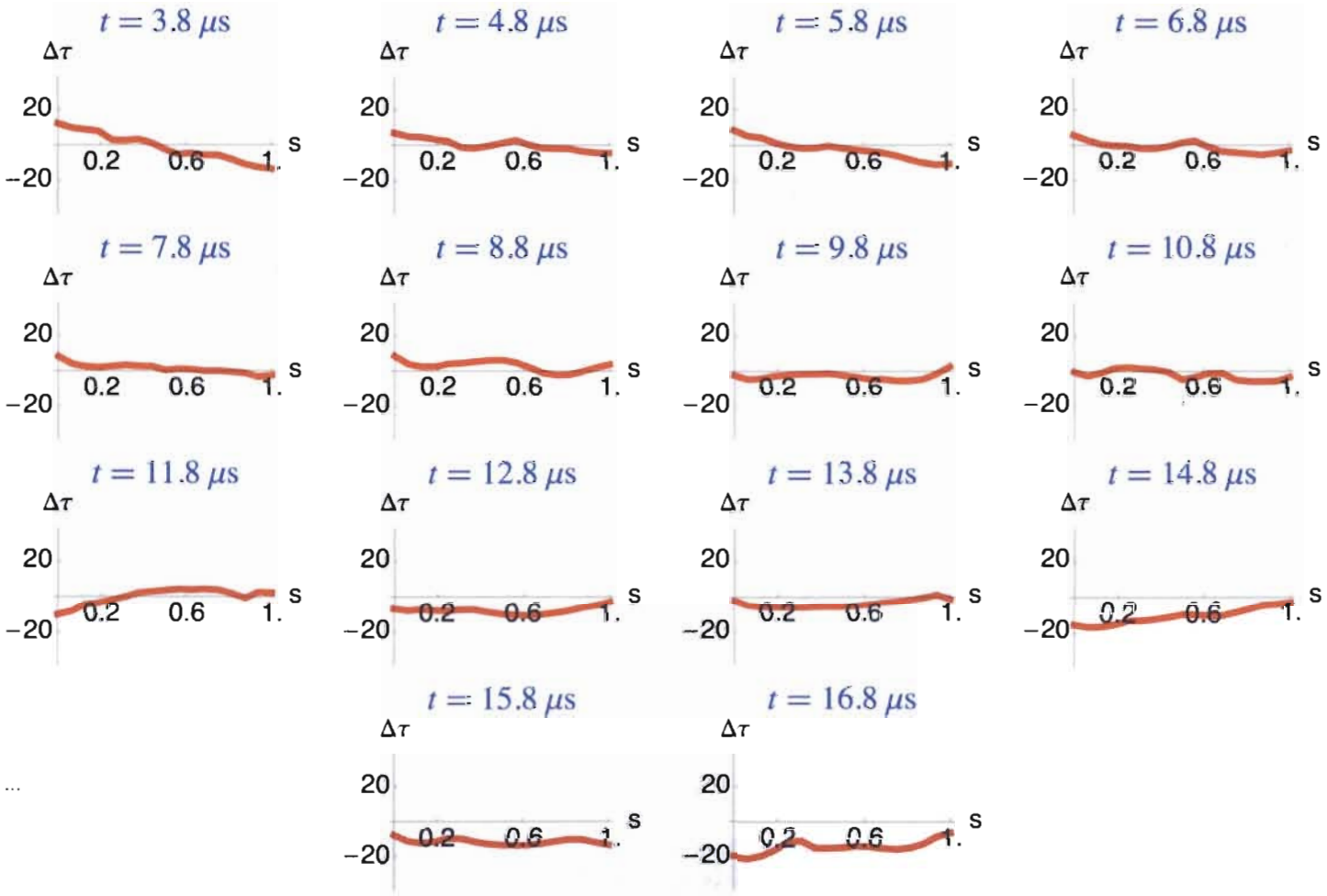
Forest Fire


Dots = pRad Data
Lines = Simulation
t = 16.8 µs
t = 10.8 µs
t = 3.8 µs
4
2
−2
−4
−4
−2
2
4

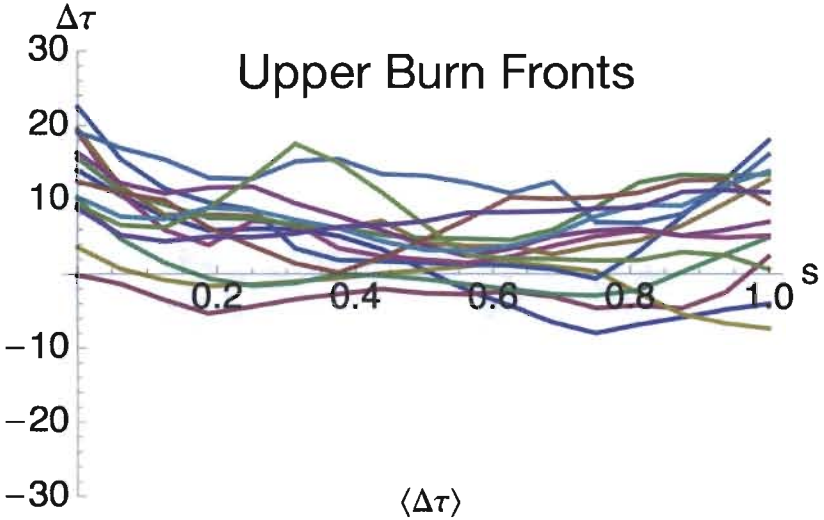
Forest Fire (Upper Fronts)

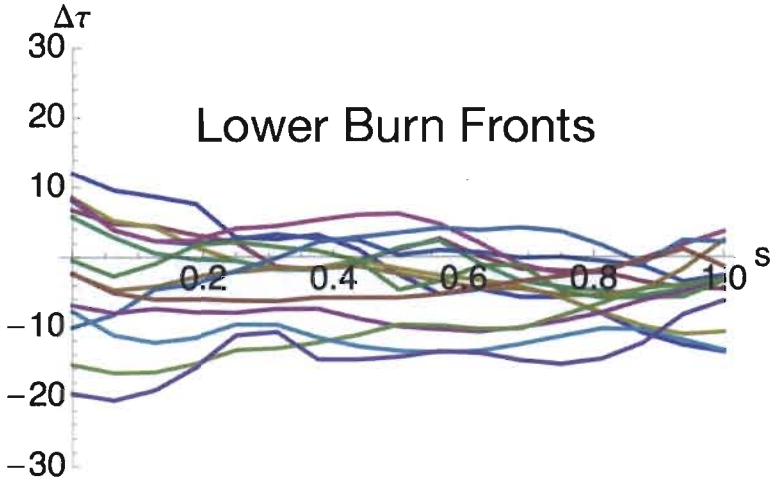


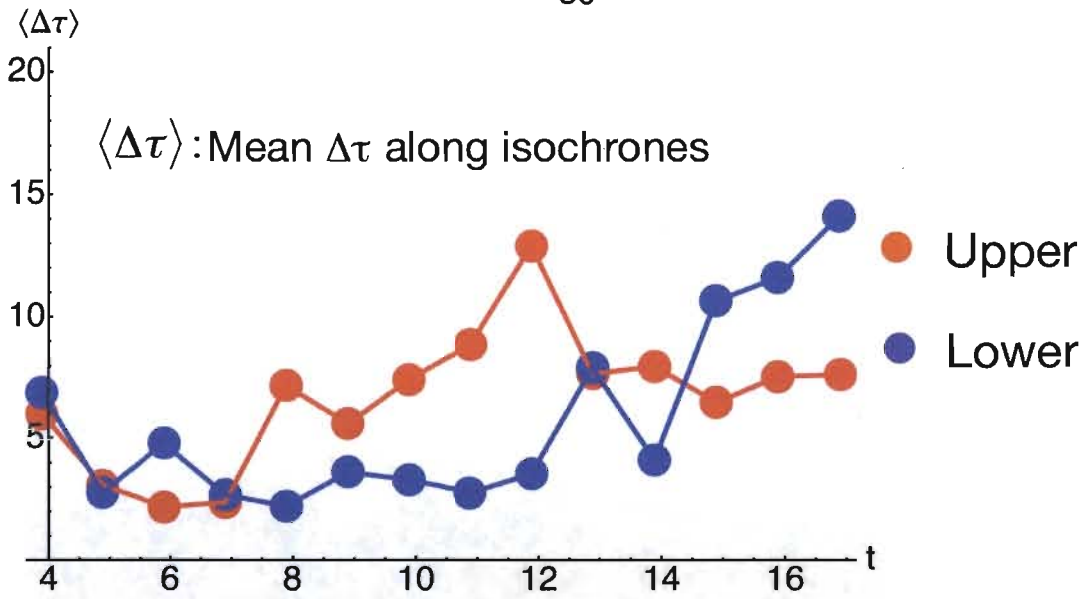
Forest Fire (Lower Fronts)



Forest Fire


Δτ
30
20
10
−10
−20
−30
Upper Burn Fronts
0.2
0.4
0.6
0.8
1.0
s

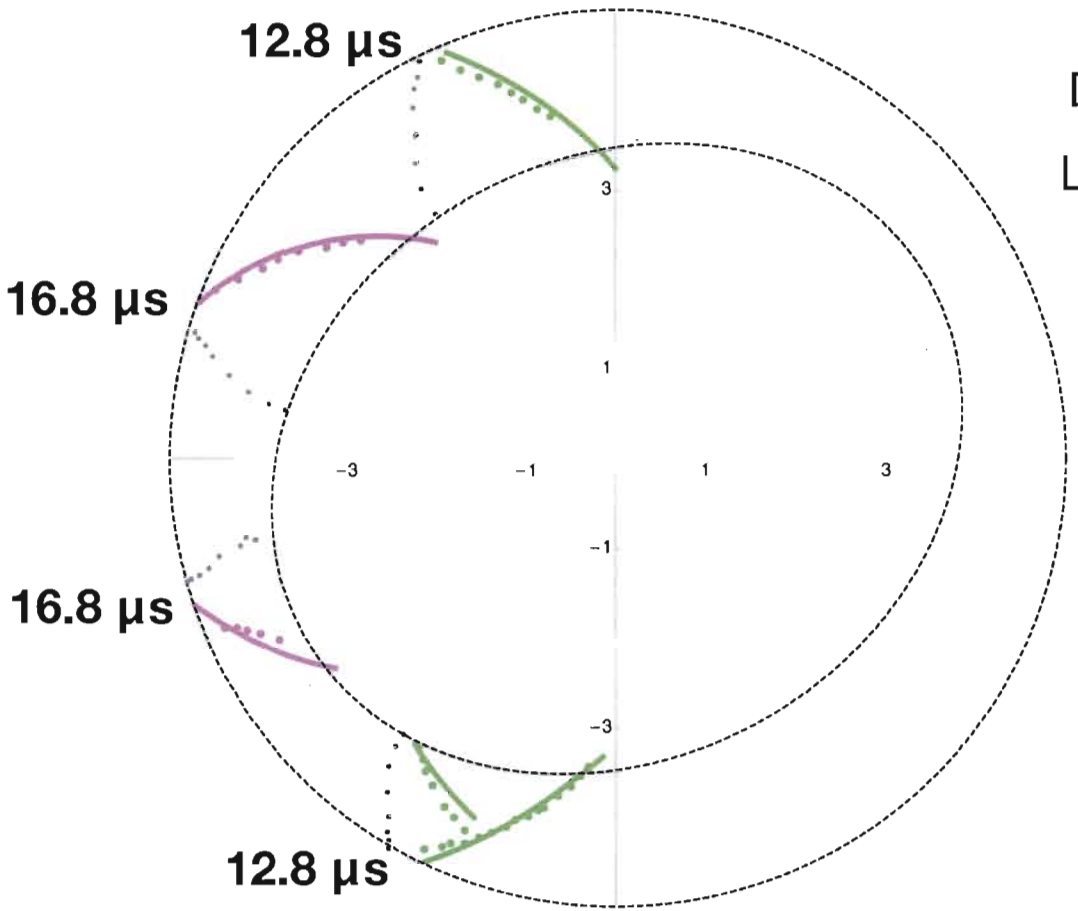

Δτ
30
20
10
−10
−20
−30
Lower Burn Fronts
0.2
0.4
0.6
0.8
1.0
s


⟨Δτ⟩
20
15
10
5
⟨Δτ⟩ : Mean Δτ along isochrones
Upper
Lower
4
6
8
10
12
14
16
t

Sapatiotemporal Global Averages in Shakes

- No Shadow Fraction
  - Up 21.6
  - Down 26.1
- Shadow Fraction 0.95
  - Up 8.4
  - Down 10.6
- Two Regions No Shadow Fraction
  - Up 6.3
  - Down 9.6
- DSD
  - Up 3.8
  - Down 8.4
- Forest Fire
  - Up 6.6
  - Down 5.7

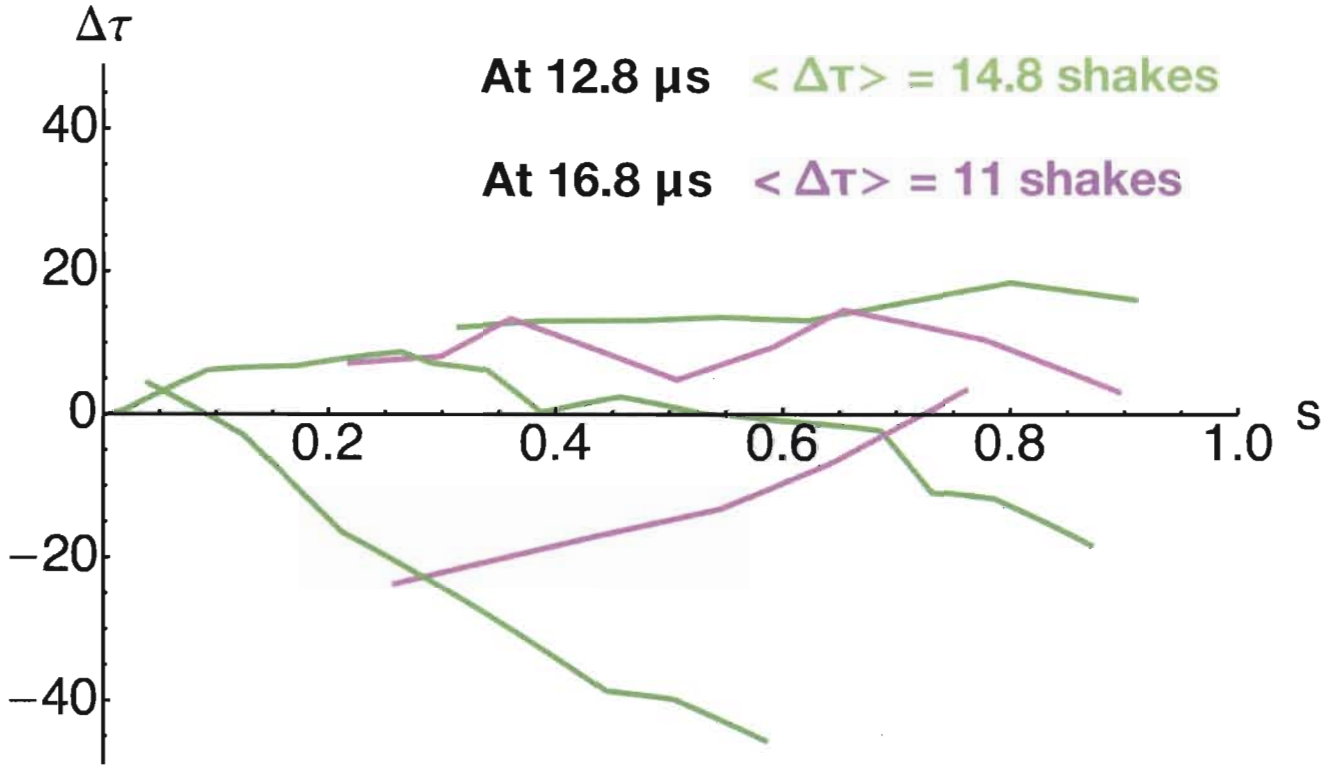
Reflected Shocks



Dots = pRad Data

Lines = Simulation

Reflected Shocks



Concluding Remarks

- The Forest Fire reactive burn model and DSD have provided the best agreement with the data. However, FF is mesh dependent and in this problem it required a mesh resolution of 150 μm.
- Two more burn algorithms (CJ Volume and Dynamic Burn) will be compared with data.
- While the agreement with reflected shocks loci is acceptable, on average is twice as large as that for the burn fronts.