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Title: Investigation of Surface Phenomena in Shocked Tin in Converging Geometry

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Investigation of Surface Phenomena in Shocked Tin in Converging Geometry

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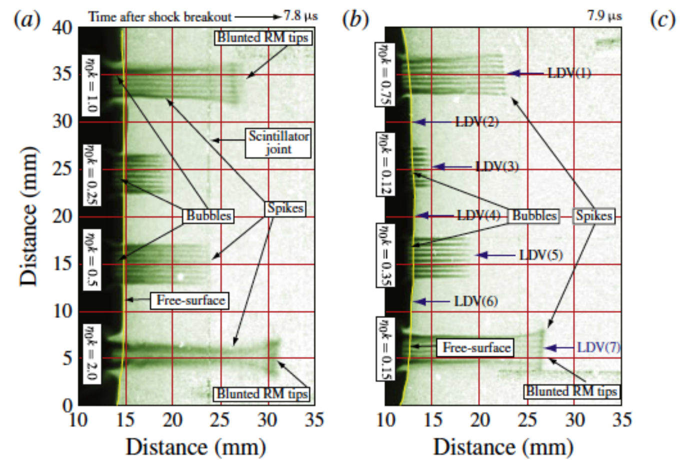
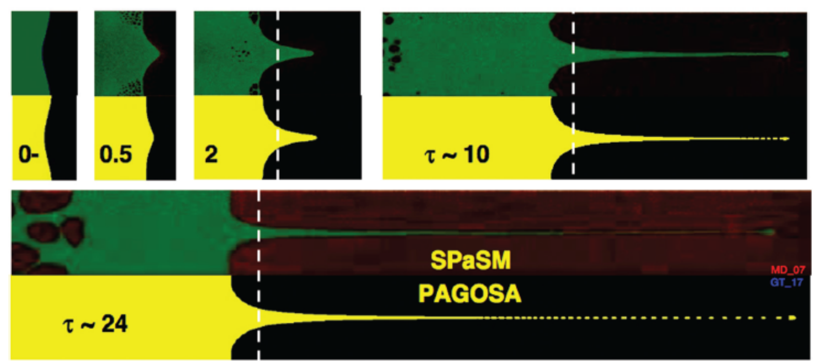
6 April 2016

Great Interest in RMI as Source of Ejecta from Metal Shells

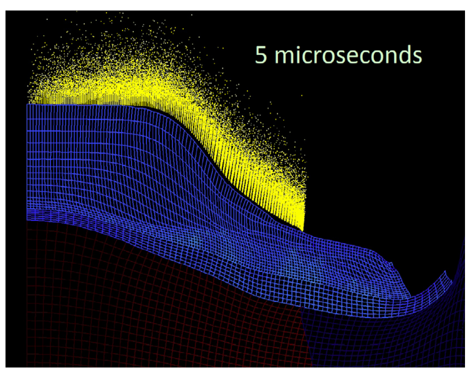
- Previous experiments have explored wavelength*amplitude (kA) variation but have small range of drive pressures and are in planer geometry.
- Simulations, both MD and hydro, have explored RMI in planer geometry.
- Ejecta source model from RMI is an area of active algorithm and code development in ASCI-IC Lagrangian Applications Project.



W. T. Buttler et al., J. Fluid Mech. 2012



G. Dimonte et al., J. App. Phys. 2013

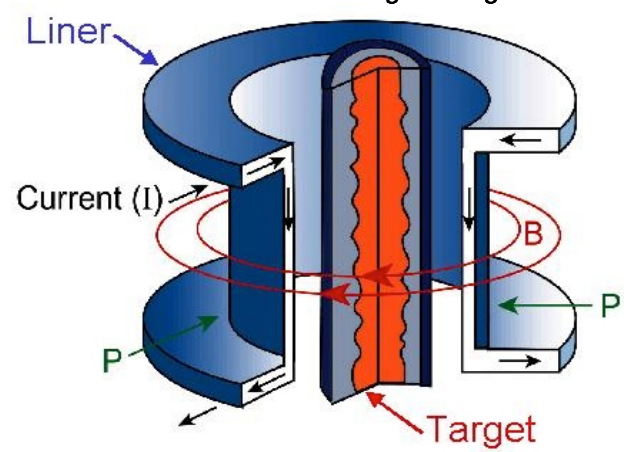


J. Fung et al., Computers and Fluids 2013

PHELIX Offers Precise, Reproducible Variable Driver for Hydro and Material Physics Diagnoses with Proton Radiography

- Drive is continuously variable ($1 < I_{peak} < 5$ MA, dt ~ 10 us) and highly reproducible.
- $P \sim (I/R)^2$ allows scaling to smaller diameters at lower energies (300 kJ stored).
- Current multiplying transformer technology enables portable platform.
- Converging geometry with diagnostic access.
- $0.5 < V_{liner} < 3$ km/s for shocked and quasi-isentropic target configurations.
- pRad gives the highest imaging data rate per experiment of a pulsed-power hydro facility.
- Other Target Configurations
  - Linear flyer (rail-gun) configuration is possible (v ~ 1 km/s with a 30 g flyer).
  - Sandia ICE strip-line configuration (r ~ 1-10 mm) could yield P_{mag} ~ 4-40 GPa.

Z-Pinch Liner-on-Target Configuration



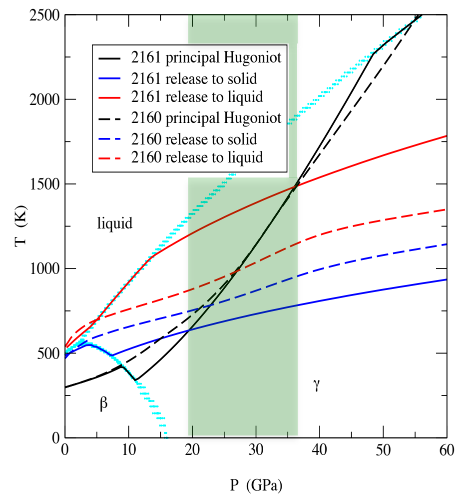
PHELIX at Area-C

Crenulation-1 Target Designed to Image RMI Growth/Saturation

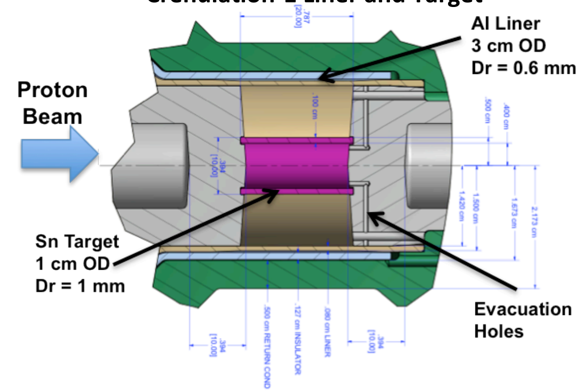
- Single-mode - kA = 0.1, 0.2, 0.3
- Convergence and shell thickness also have dimensionless scaling $k^*R_0 \sim 24$, $k^*dr \sim 6$
- 1 < Mach < 3
- Atwood = -1

Series of PHELIX Driven Experiments Spans the Release state Tin (e.g. Solid, Mixed, Liquid) with kA variations

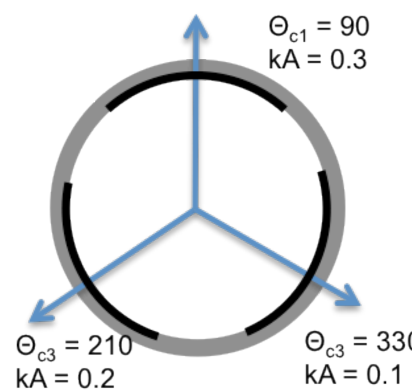
LANL SESAME for Tin

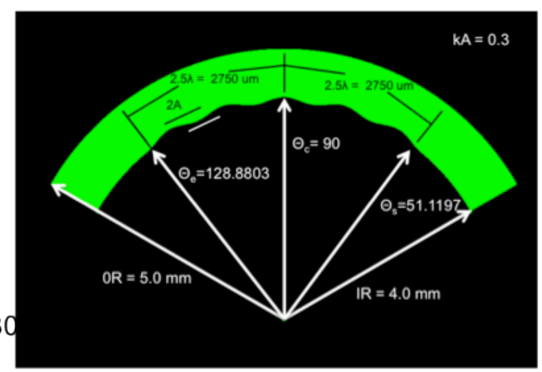


Crenulation-1 Liner and Target



Single-Mode Layout Details

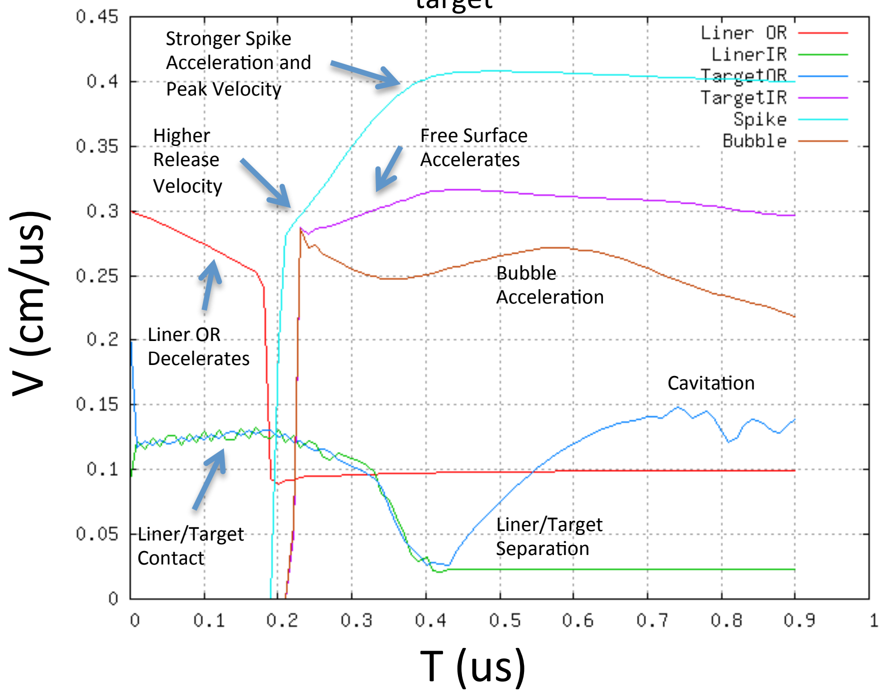




Calculations Show Expected Convergent Geometry Effects (Melt-on-Release)

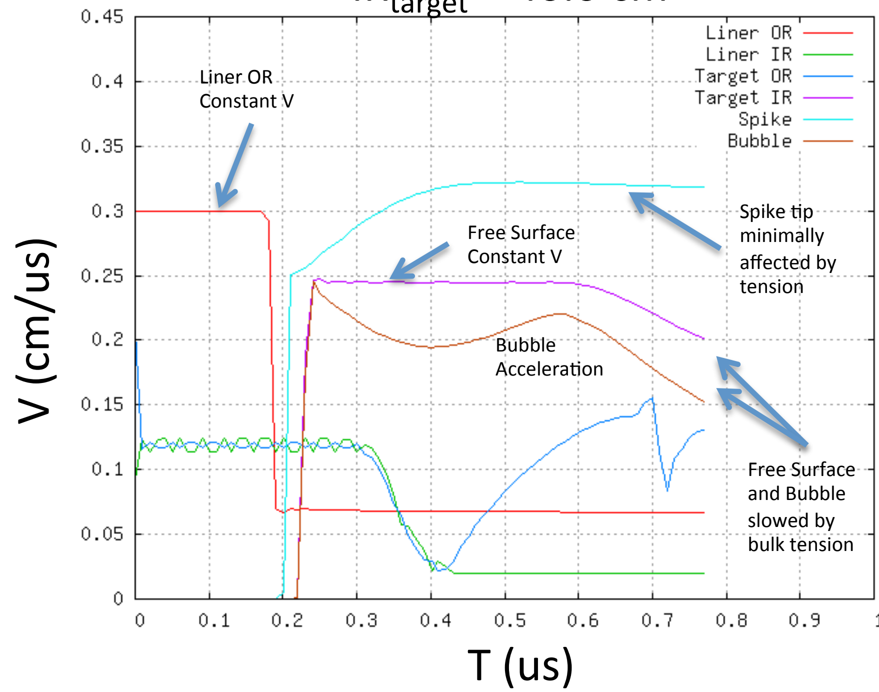
Strong Curvature

IR_{target} = 0.4 cm



Planer

IR_{target} = 40.0 cm



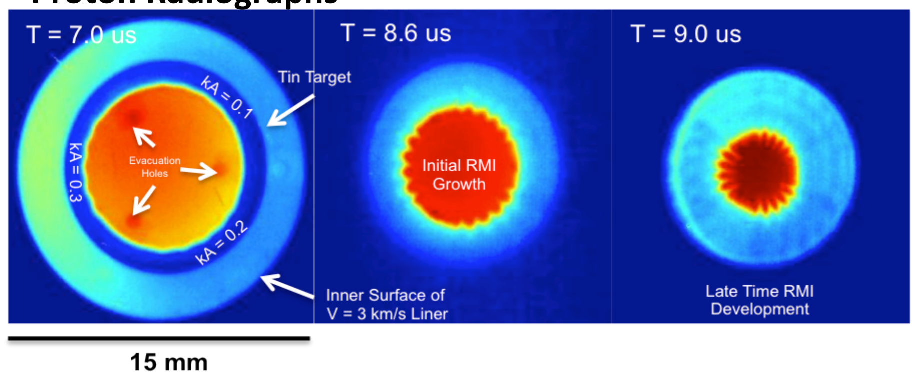
kA=0.3, V_{liner} = 0.3 cm/us
Thickness Liner = 0.143 cm - Aluminum
Thickness Target = 0.100 cm – Tin
Wavelength = 0.1100 cm
Atwood = -1
Mach ~ 3

Bubble velocity doesn't follow 1/τ (τ ~ 0.7 us) asymptotic theory. Shows finite shell thickness and converging effects.

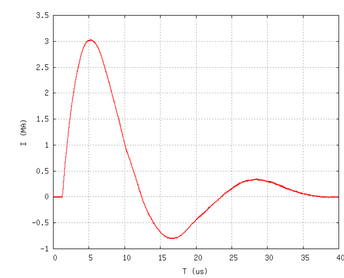
Cren-1 Shocked to Melt on Release and Data Agrees Well with Calculations

- Single-mode peak-to-valley shows linear growth
- Converging Geometry
  - Higher shock pressure
  - Higher spike velocity
- Finite target thickness
  - Pull-back of Free Surface and Bubble
  - Cavitation

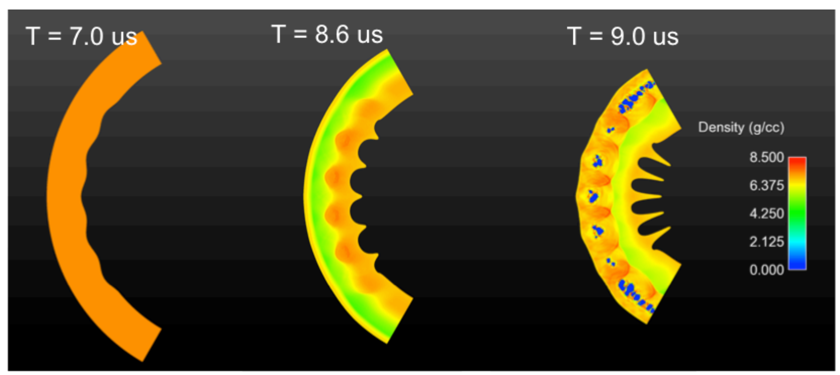
Proton Radiographs

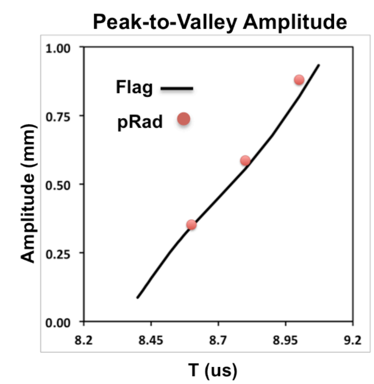


Measured Current



FLAG Calculation



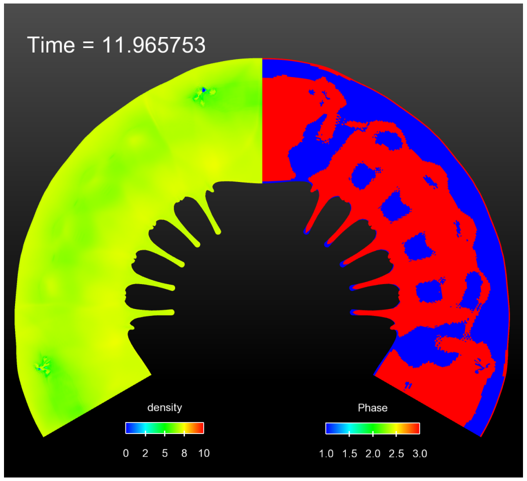


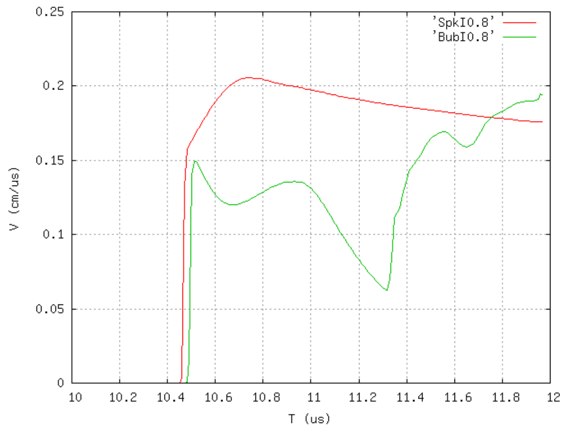
Next Crenulation Experiments will Examine Single Mode RMI Growth/Saturation in Mixed and Solid State

- Scale the Measured Current (I = 0.9X – 0.5X) as input to Simulations
- ASC Multi-phase EOS and Phase aware Strength Predict
  - Saturation due to refreeze for mixed state release
  - Growth/Decay for solid phase release.

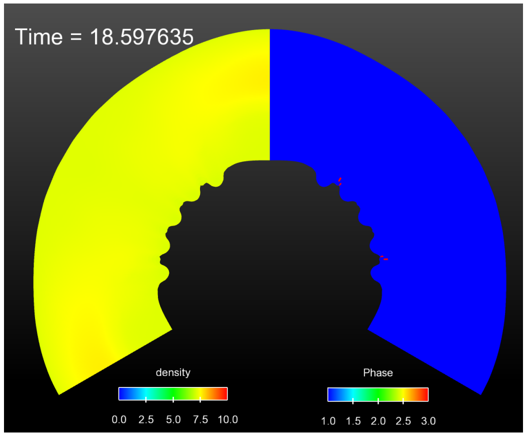
Scale Factor	Liner Velocity (km/s)	V_shock in Tin (km/s)	P_shock in Tin (Gpa)
1	2.9	1	38
0.9	2.1	0.9	29
0.8	1.5	0.8	20
0.7	1.3	0.65	14
0.6	1	0.4	9.5
0.5	0.74	0.3	7.3

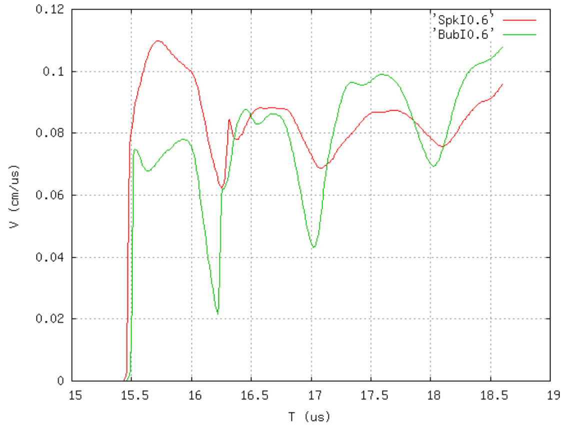
Mixed Phase Release (I= 0.8X)





Solid Phase Release (I= 0.6X)





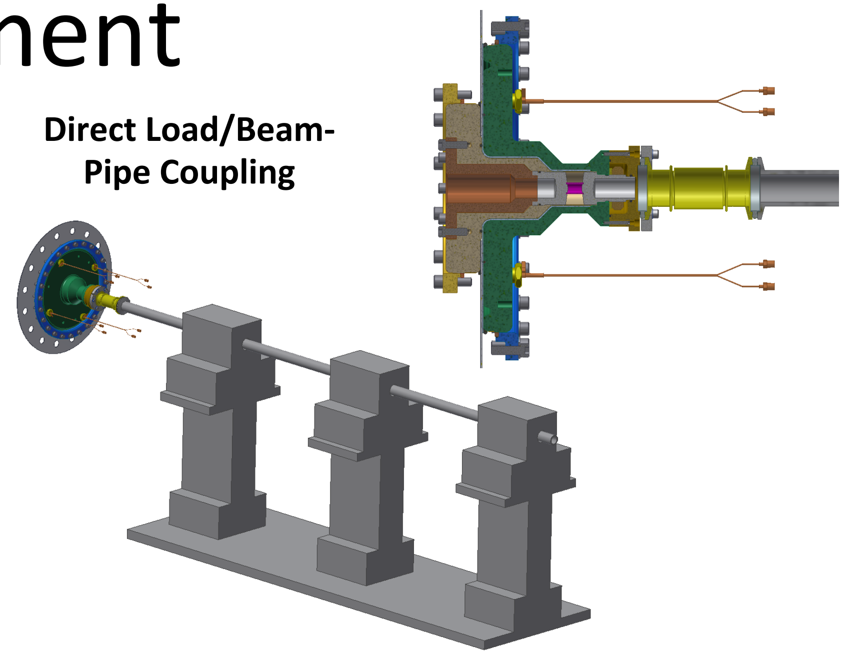
Propose 2 Experiments in 1 Week of Prad Time

- Experiments
  - I ~ 0.8X – shock to mixed state
  - I ~ 0.6X – shock to solid state
- Loads
  - 1 “on-the-shelf”
  - 1 would need to be fabricated
- Would benefit from X7 magnifier
  - Working on PHELIX/magnifier interface
- Scheduling PHELIX after a maintenance week simplifies operations

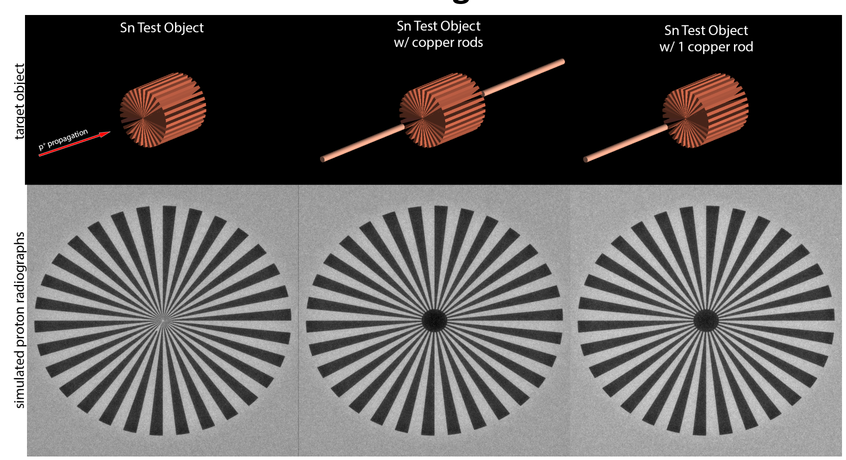
Extras

Upgrade of Damage Mitigation and Confinement

- Video feed from inside PHELIX box
- Direct coupling of load to beam pipes
  - Flexible bellows needed for alignment.
  - Eliminates
    - Upstream/downstream air gaps
    - 25 mil Kapton windows
  - Glass/Al windows 10 m upstream/ downstream
- 1 mm axial rod inside the tin cylinder
  - Inhibit jet formation
  - Calculations show it doesn’t affect image quality

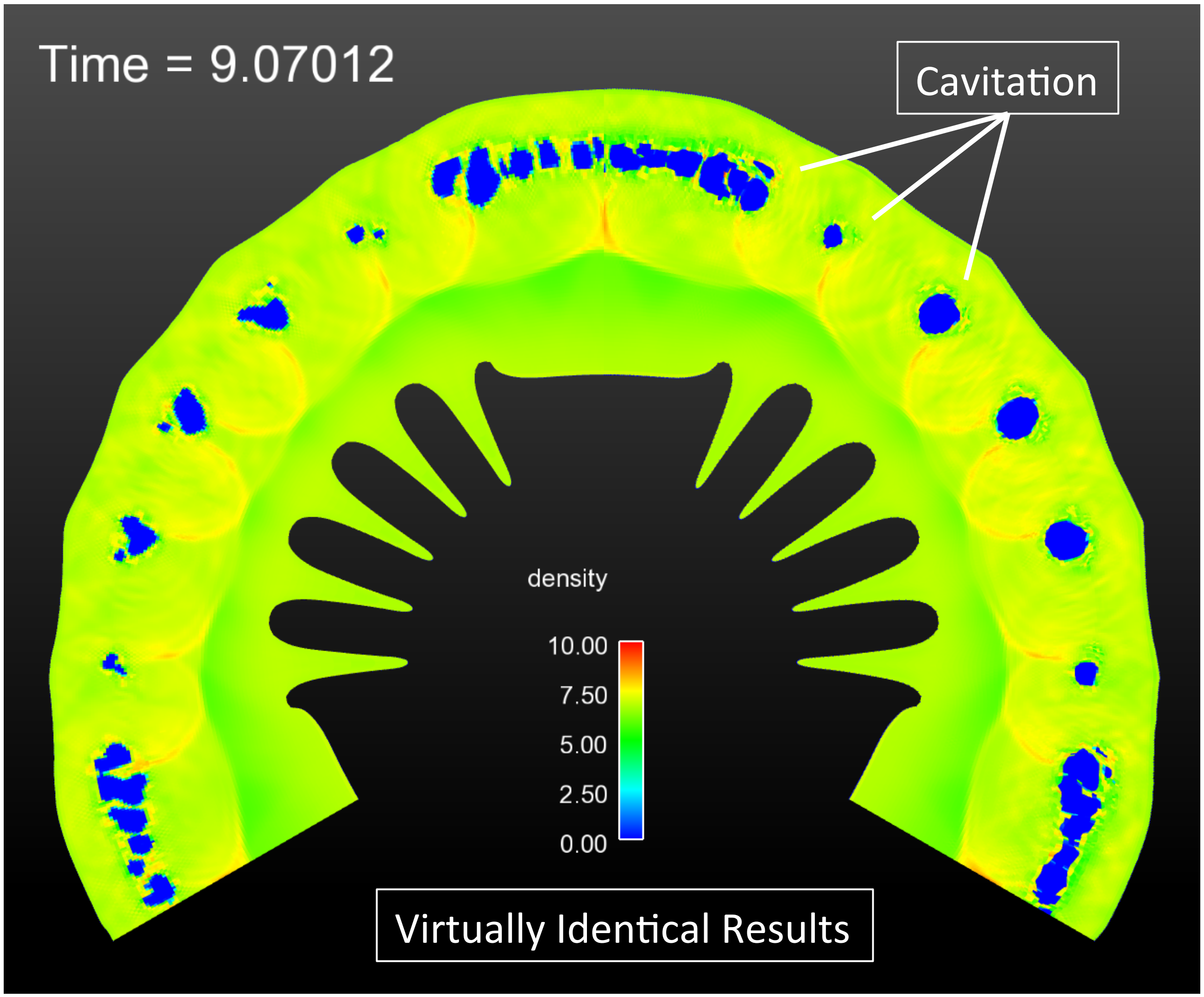


Simulated Proton Images with Axial Rods



Multi Phase Strength Model of Tin with ASC- Flag (Sanity Check)

SES 2061
SG Strength
for each phase*



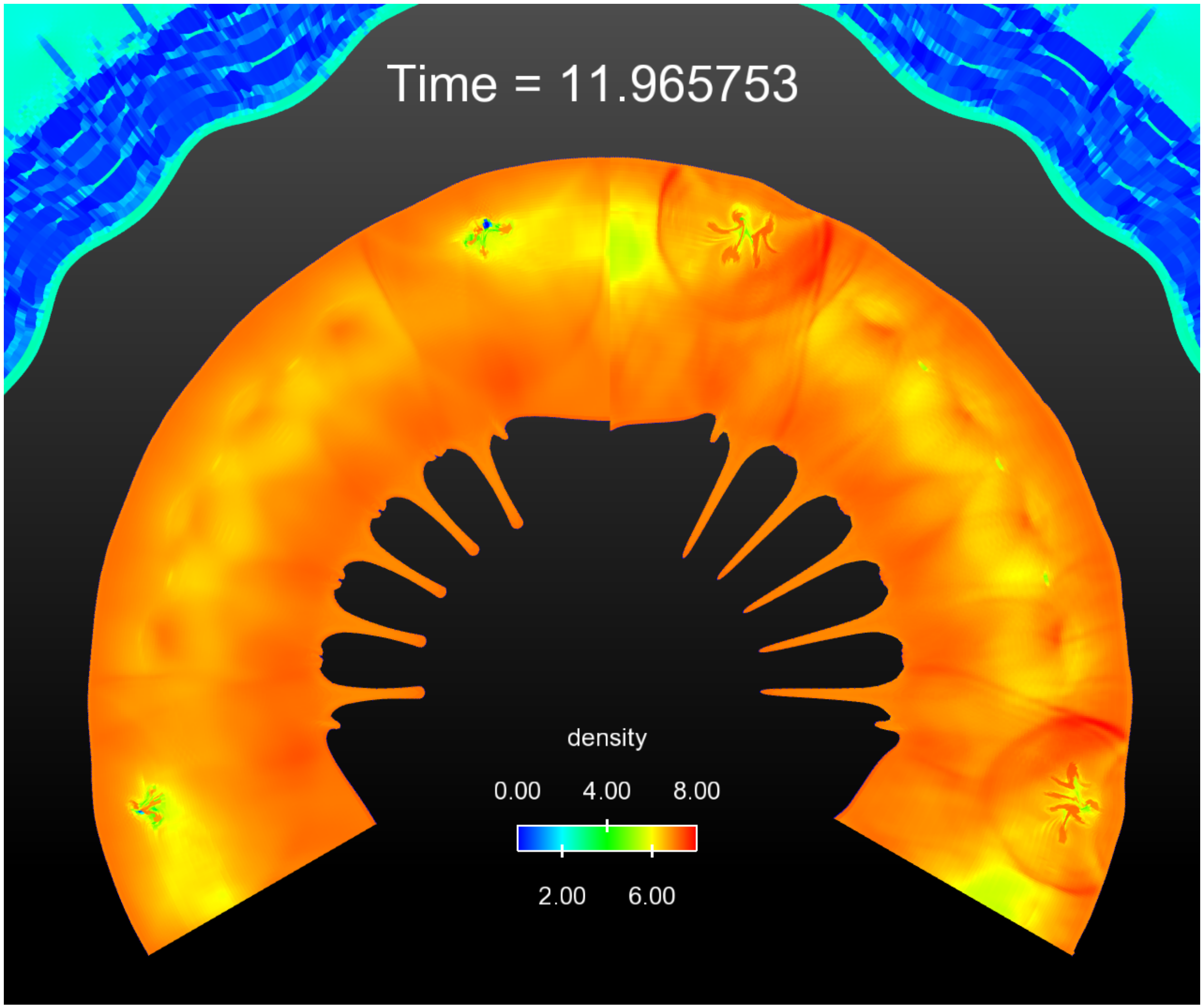
SES 2061
SG Strength

*T. Canfield and T. Carney

PHELIX Cren-1 (Pure Melt-on-Release)

Sn Target, kA =0.3, I = 0.8X

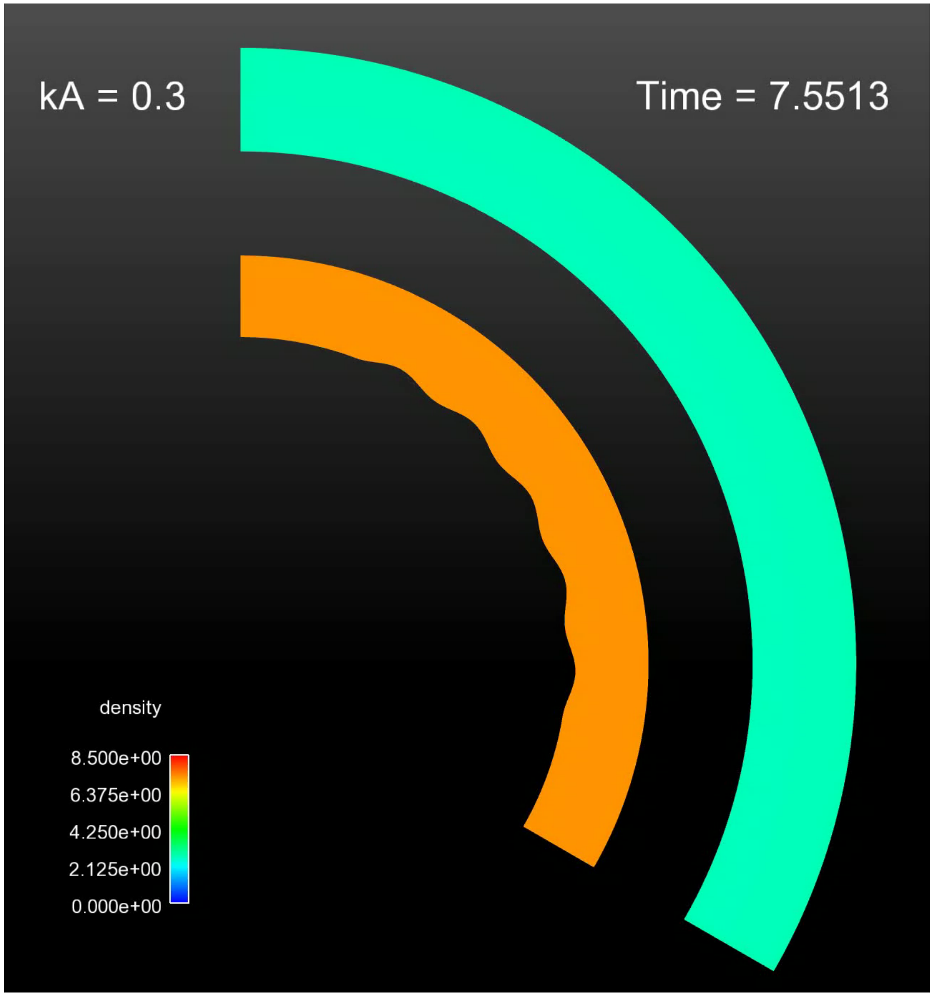
SESAME 2161
Phase Aware
Strength



SESAME 2161
Single Strength
Model

~6 mm

Movies: Cren-1 (I = 1.0X)



Movies: Cren-2-3 (I = 0.8X, 0.6X)