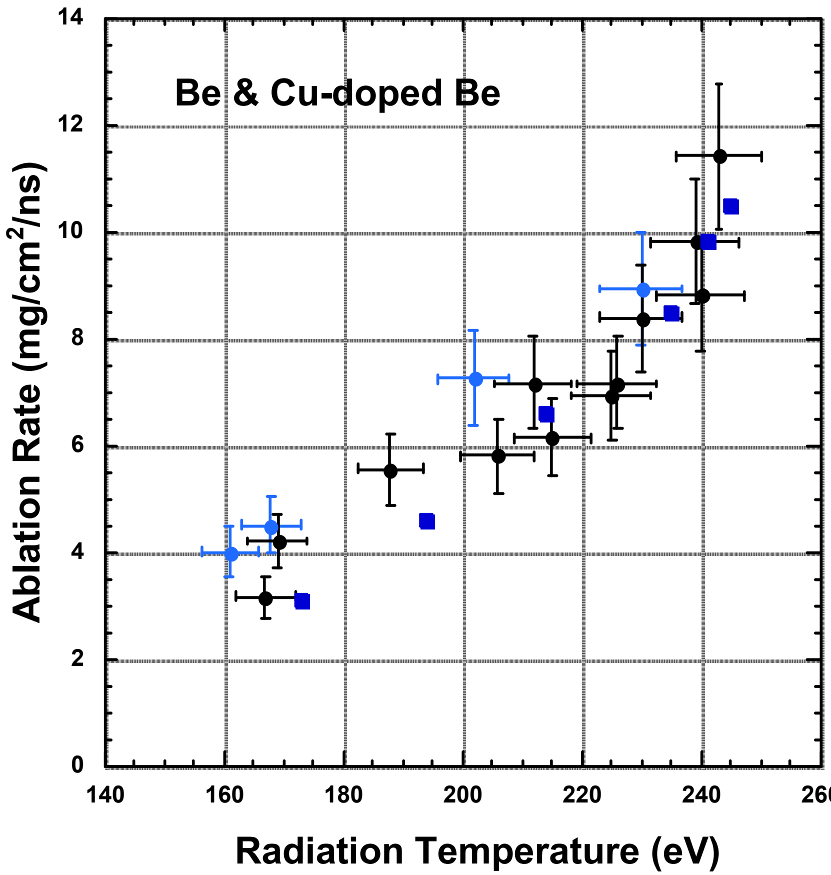
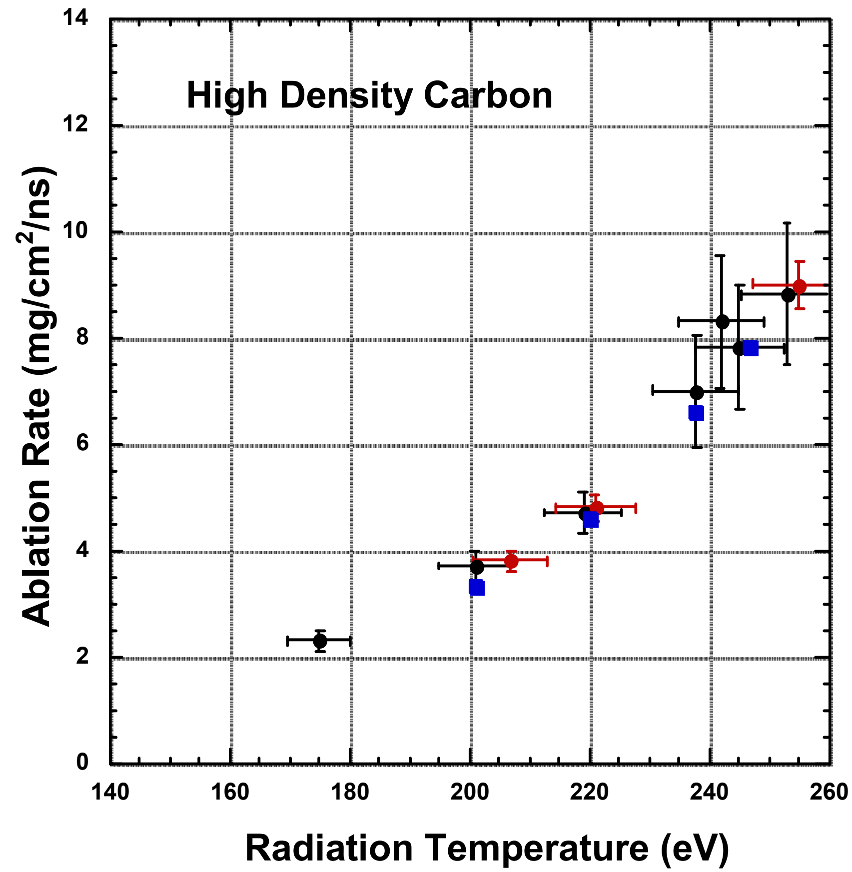
SAND2007-5659C

Ablation Rate Measurements for ICF Capsule Materials

Presented at IFSA07; Kobe, Japan; September 10-14, 2007





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Ablation Rate Measurements for ICF Capsule Materials

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Brian Spears, Steve Haan, Damien Hicks, Nino Landen

UR LLE — **Omega Operations Team**

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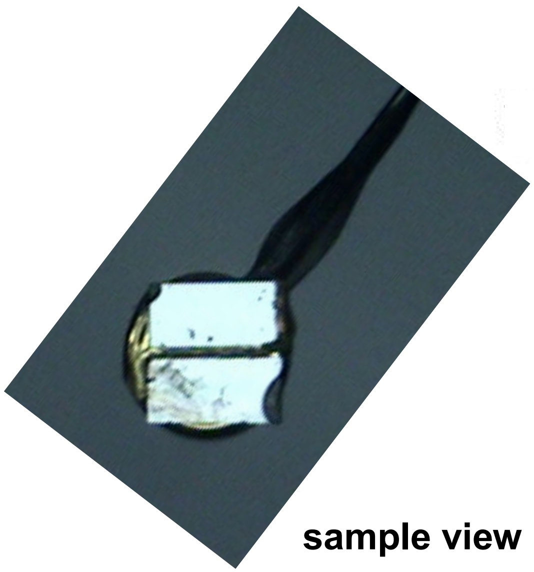
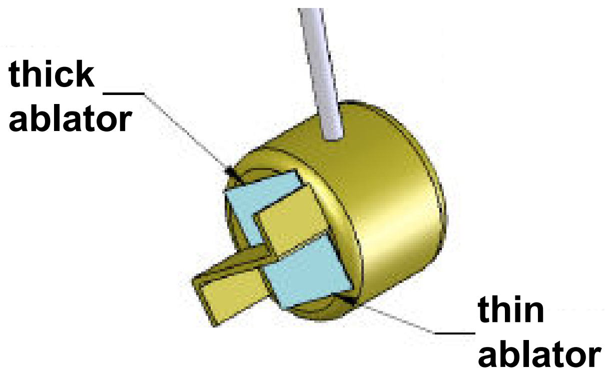
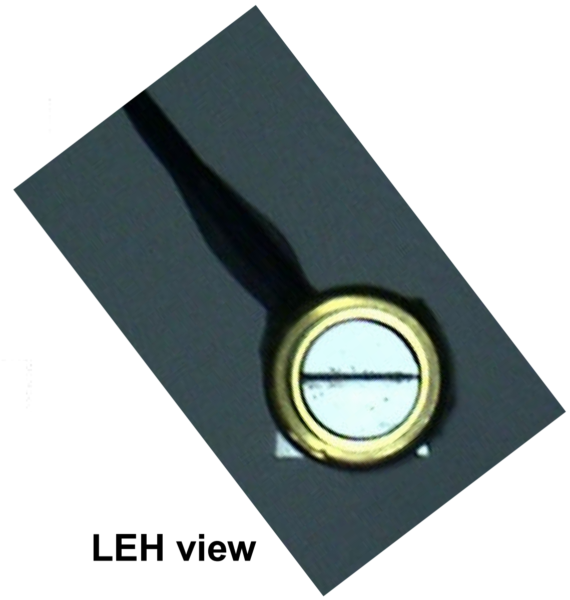
The ablation rate measurements were made using halfraums heated by the Omega laser.

Three scales of halfraum targets were used in the AR measurements.
Scale 3/4 halfraums are 1.250mm dia. x 0.950mm length, 0.80mm LEH.
Scale 5/8 halfraums are 1.050mm dia. x 0.800mm length, 0.80mm LEH.
Scale 1 halfraums are 1.650 mm dia. x 1.250 mm length, 1.20 mm LEH.
The multiple sample targets had a ~ 0.5 mm long shield.



sample view

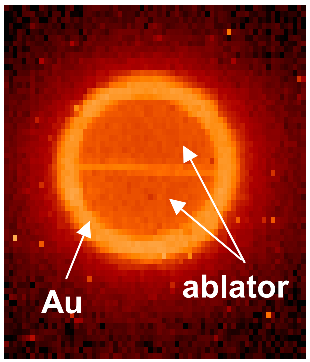




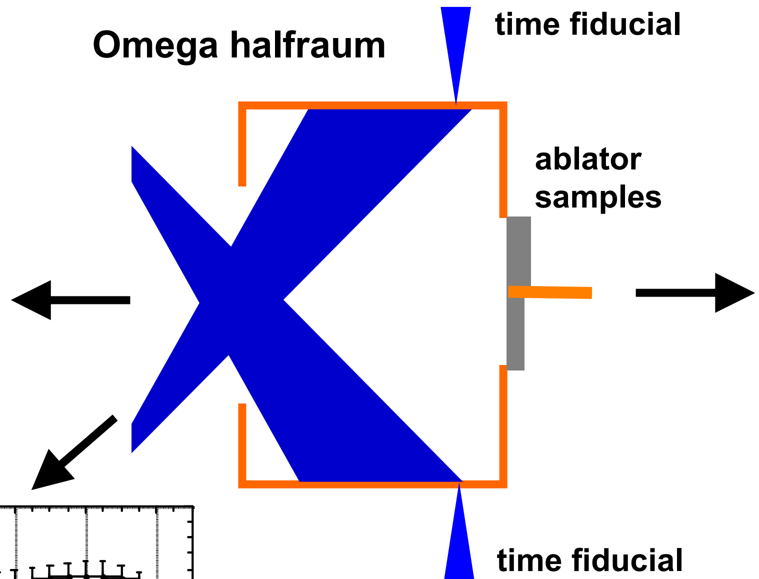
LEH view

The primary diagnostics for the ablation rate measurements are the SXI, XRFC, and Dante.

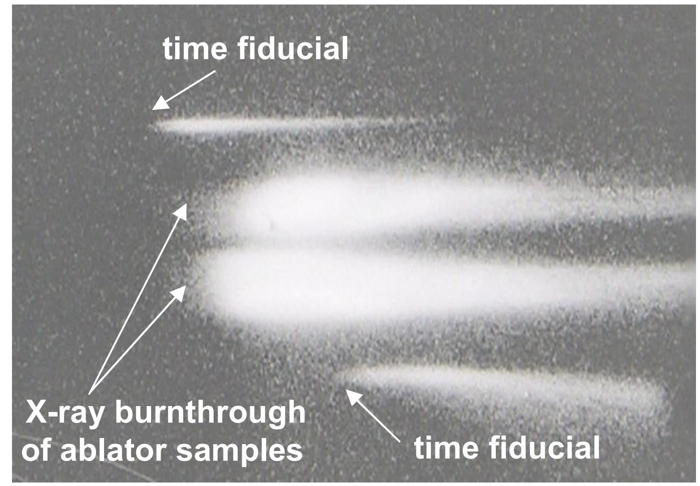
X-Ray Framing Camera (XRFC)

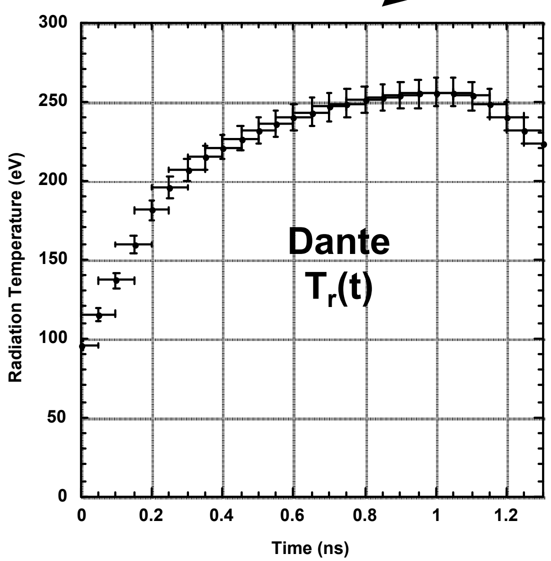


Omega halfraum



Streaked X-Ray Imager (SXI)

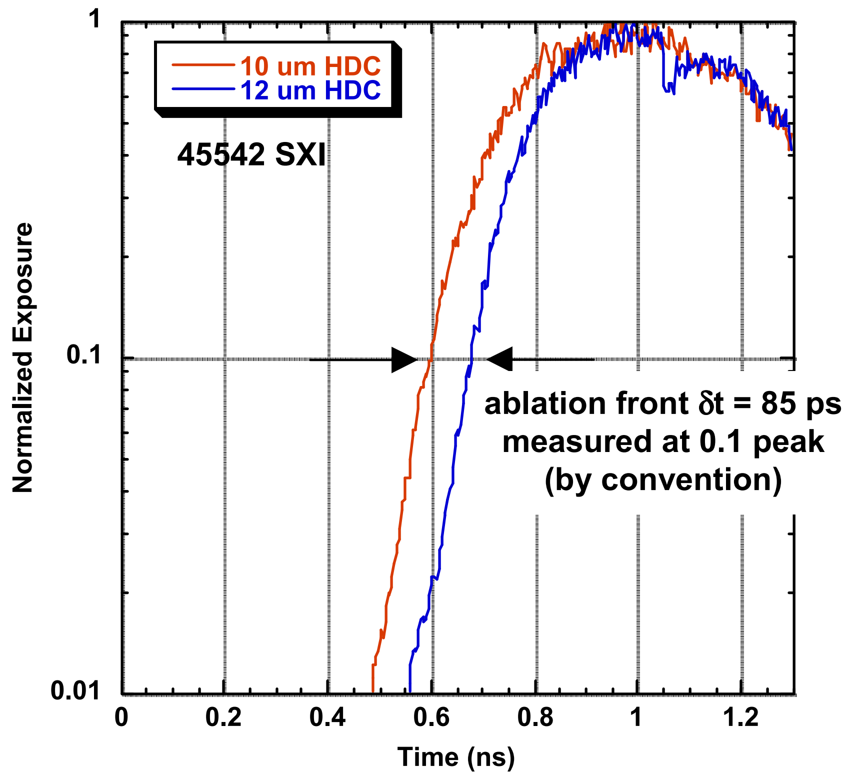


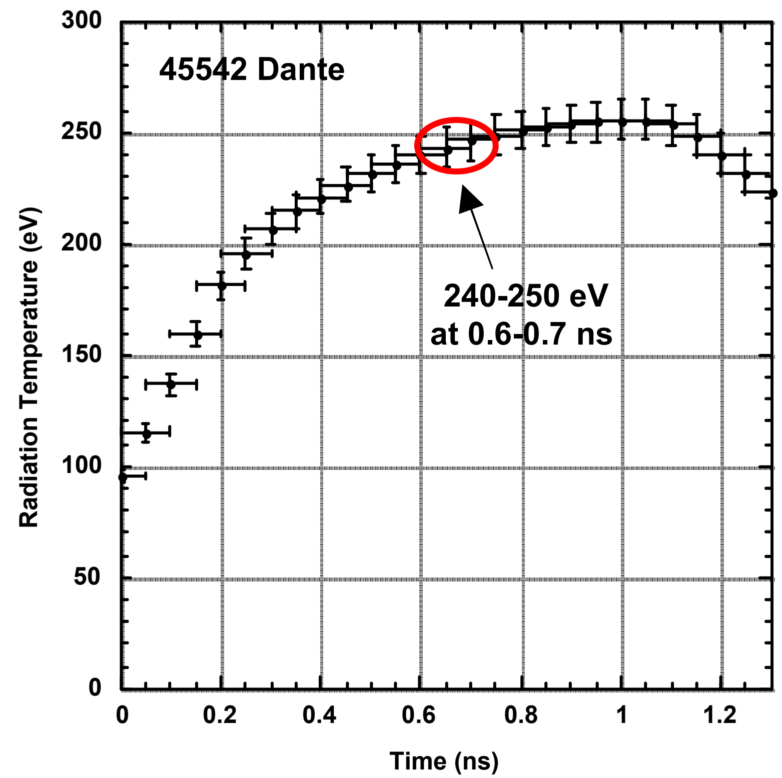


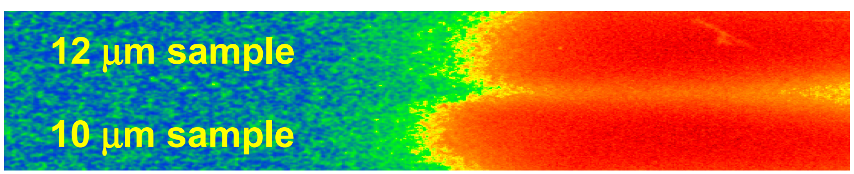
The Streaked X-Ray Imager (SXI) includes an imaging slit + X-Ray filter + transmission grating + offset slit + X-Ray Streak Camera.

The SXI measures burnthrough time for each ablator sample thickness. The Dante provides a time-resolved hohlraum radiation temperature. The XRFC provides an X-Ray re-emission flux relative to the re-emission of the Au wall (and, hence, an estimate of the absorbed X-ray flux).

The SXI and Dante measurements are used to determine ablation rate and Tr.



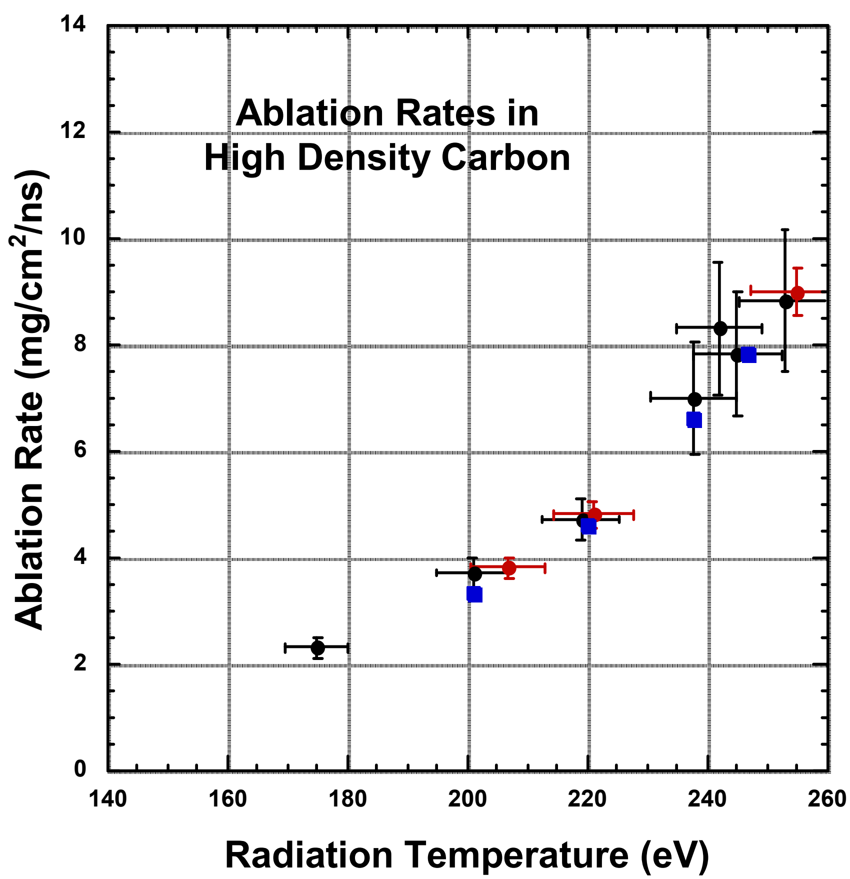




AR = (3510 mg/cm^3) (.0002 cm) / .085 ns

AR = 8.3 mg/cm^2/ ns at ~ 245 +/- 5 eV

For each experiment, an ablation rate was determined along with a burnthrough radiation temperature.



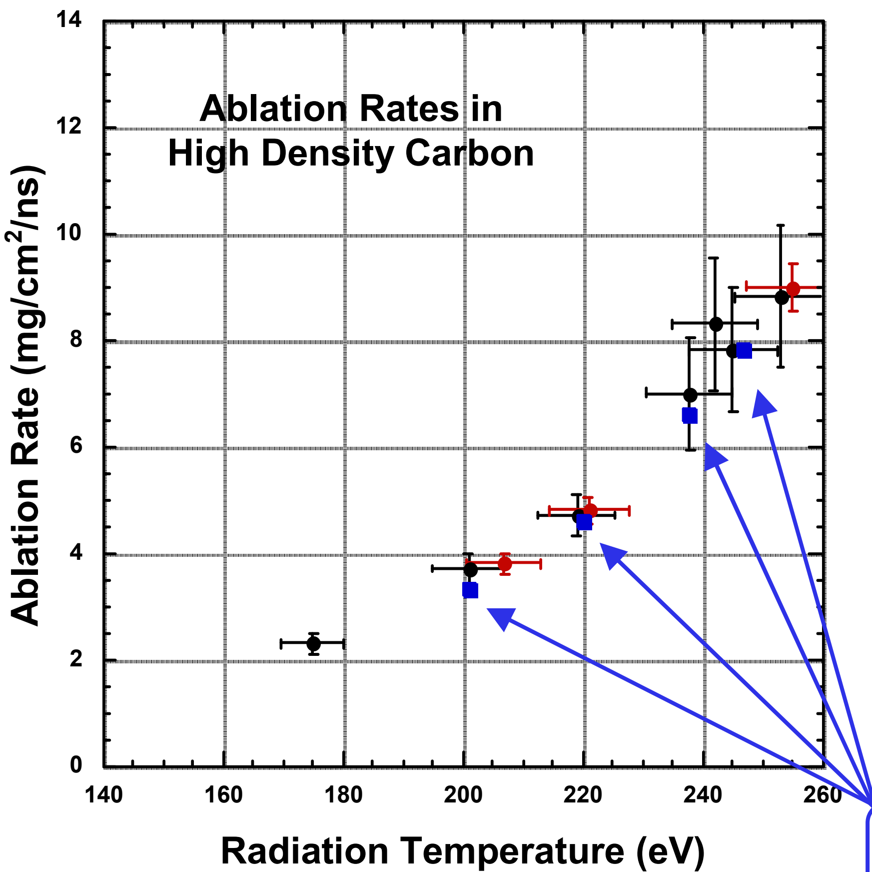
The most accurate measurements were made for HDC.

Thicknesses of all HDC samples were measured to < 1%. The best samples are +/- 0.2% and worst are +/- 0.6%. The uncertainty across the step is usually +/- 1.0-1.5%. The HDC density is 3.51 g/cm^3 +/- 0.2%. The SXI offset slit width is 150 μm. The sweep is about 60 ps/mm. Thus, the random uncertainty in the image is about 9 ps. We digitize at 1 ps/px, and smooth the lineouts over 9 pixels. At 260 eV, this represents an ablation rate uncertainty of about +/- 5%. At 200 eV, this represents an ablation rate uncertainty of about +/- 2%.

The variation in hohlraum temperature during the burnthrough Δt is usually well within the absolute uncertainty in the Dante measurement, which is about +/- 3.5% in Tr.

Not all measurements were made with this level of precision, but these "best" case numbers serve to illustrate the constraints on accuracy.

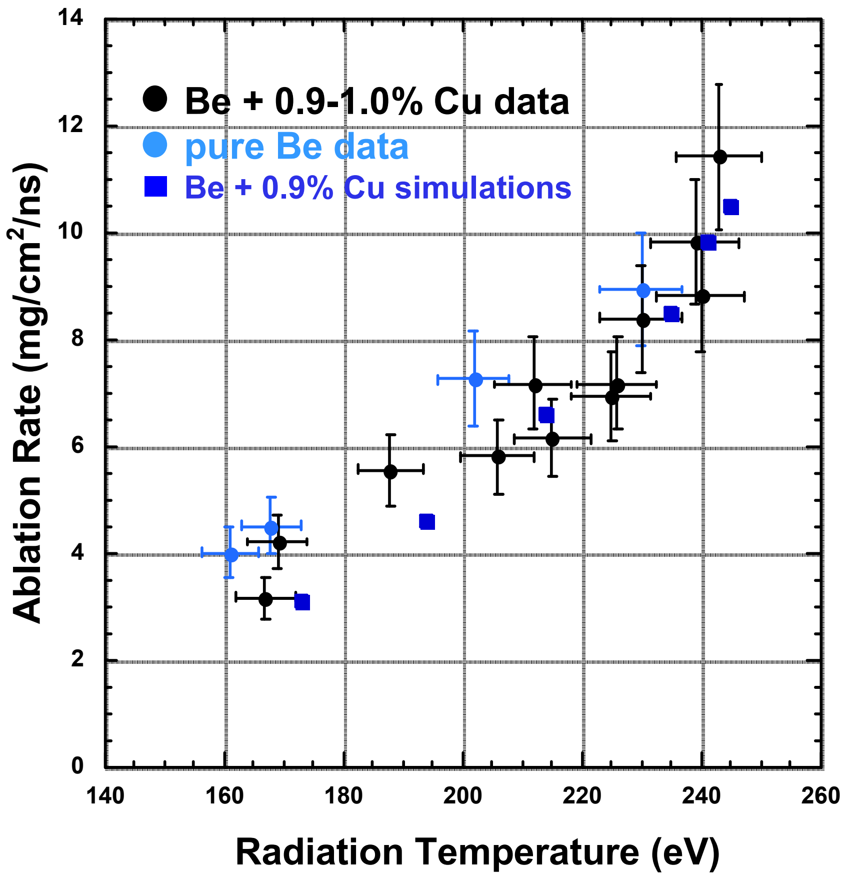
Post-shot computational simulations were done for some of the Omega halfraum experiments.

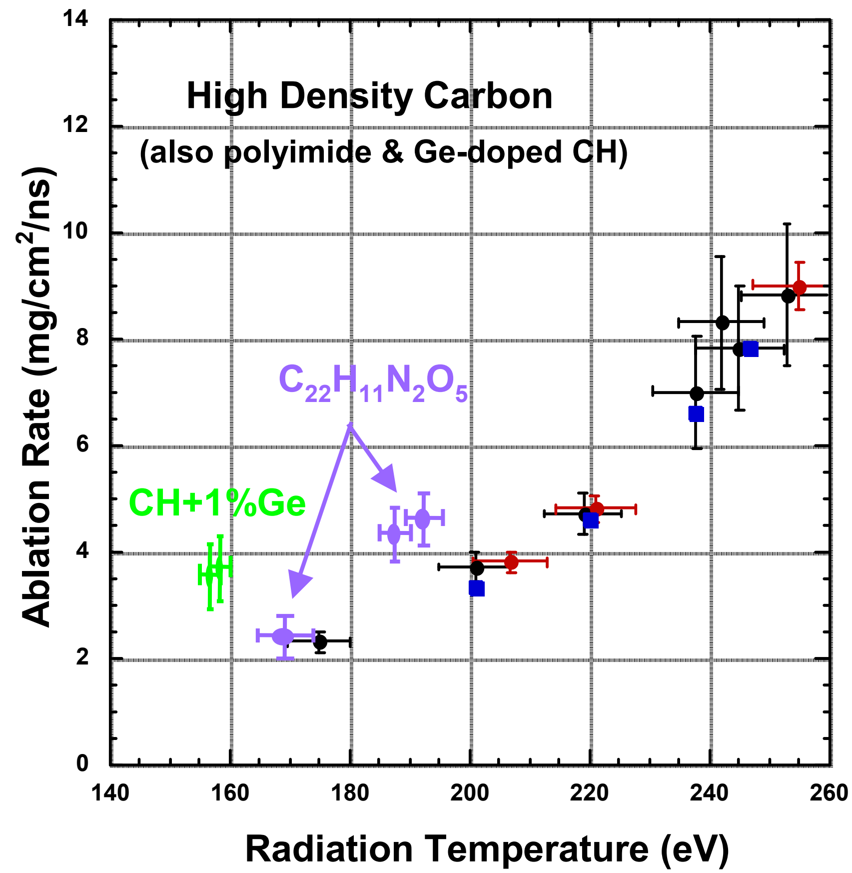


__Computational simulation procedure__:

1) Set up 3D VISRAD simulations of the laser-halfraum-Dante system for each scale-size Omega experiment.
2) For each scale-size, develop a table of X-ray flux at Dante compared to X-ray flux at the ablator sample. (similar to Cohen, Landen, MacFarlane, *Phys. Plasmas*, 12 122703 (2005).
3) For each Omega experiment, convert the measured Dante X-ray drive flux (Ch 1-9) into an input flux at the ablator sample.
4) For each Omega experiment, set up two Lasnex calculations – one for each sample thickness. *Use calculational techniques and physics packages that are as close as possible to the ones used in the LLNL ignition capsule design.*
5) For each Omega experiment, post-process the two Lasnex calculations to provide simulated SXI intensity-time lineouts.
6) For each Omega experiment, determine an ablation rate from the two simulated SXI lineouts using the same procedure that was used with the experimental data.
7) The simulated ablation rates can be plotted vs. Dante Tr (blue squares) and directly compared with the measured ablation rates.

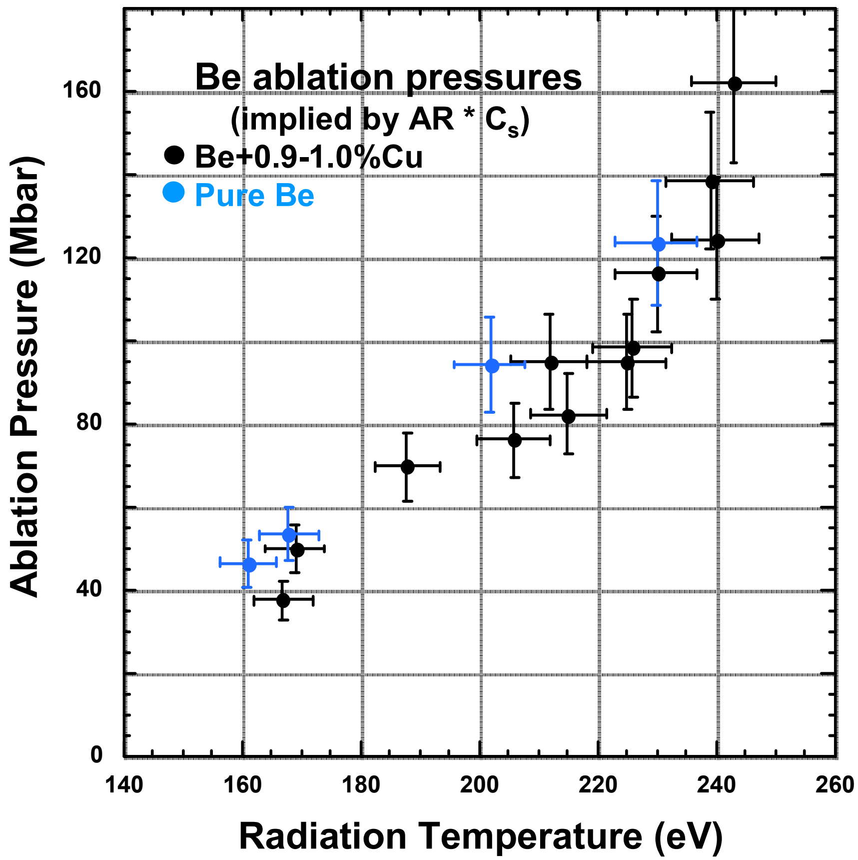
Ablation rate measurements were also made for Be, Cu-doped Be, Ge-doped CH, and polyimide.

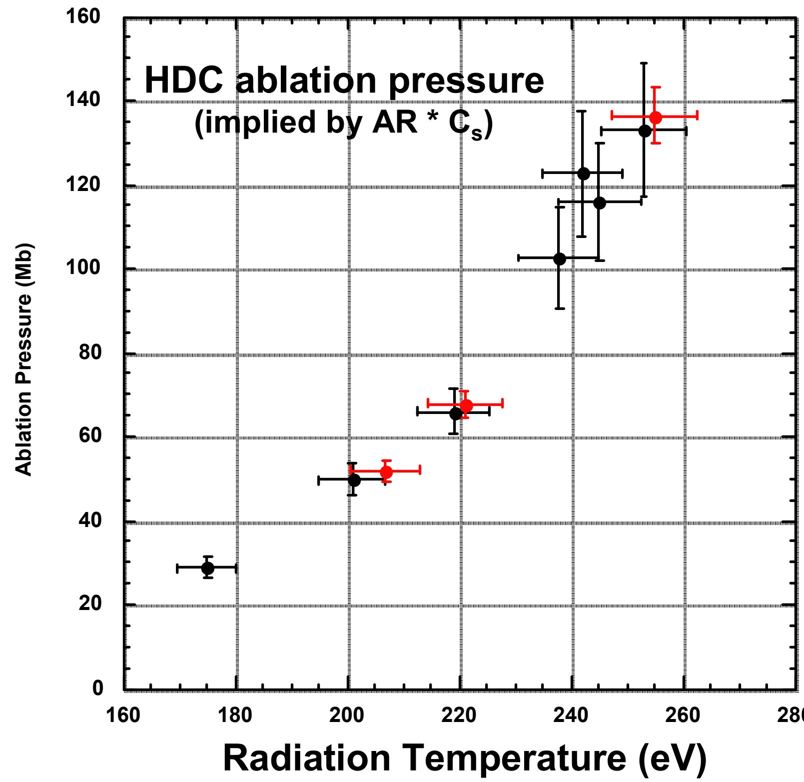




The implied ablation pressures are in the range of 40-160 Mbar for Be and 20-140 Mbar for HDC.

*(assuming full ionization in Be and C and that Pr = AR * C_s)*



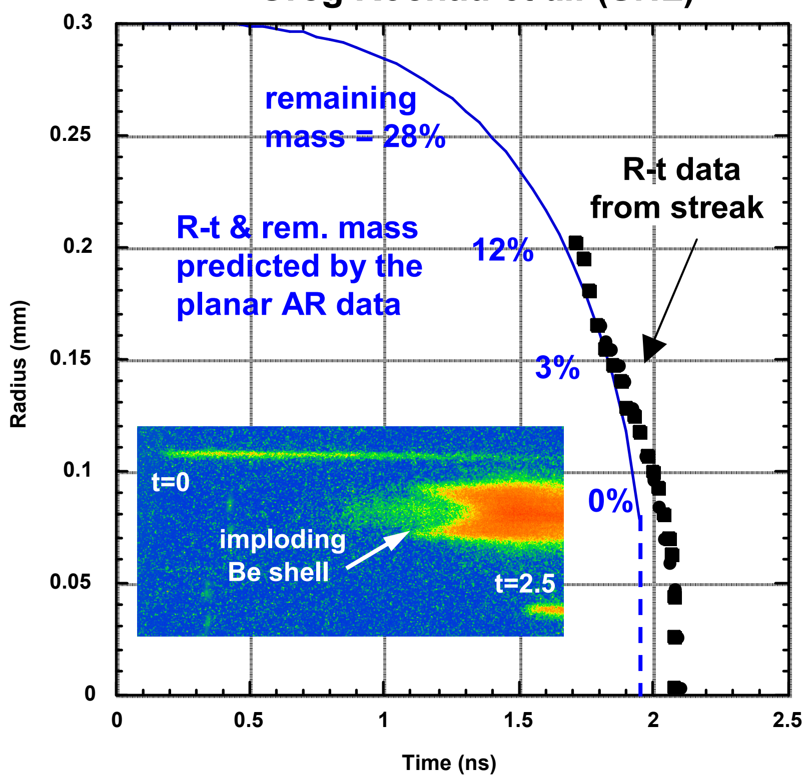


An iterative rocket model (Newton's Law) can be used to relate the planar ablation rate data to converging geometries.

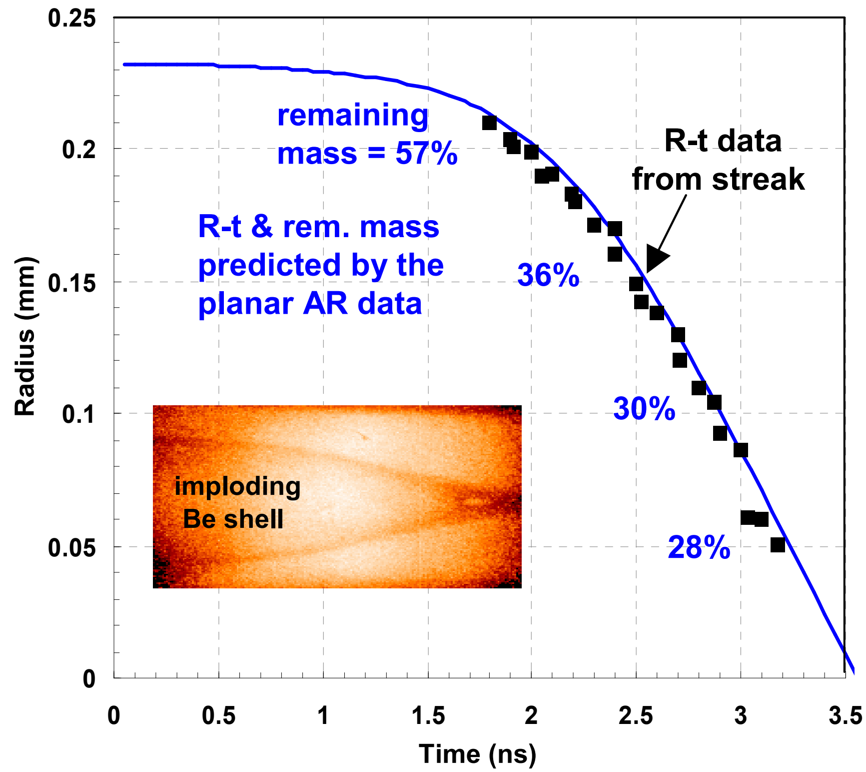
1. The original shell radius, thickness, and density are known.
2. Dante provides the radiation temperature at each time step.
3. A fit to the ablation rate (AR) data provides a calculation of mass removed at each time step.
4. The shell radius, mass and Pr = AR * C_s combine to provide the inward acceleration and, hence, a new velocity at each time step.
5. The next time step uses the new shell radius, mass, velocity, and Dante radiation temperature.
6. This iterative rocket model (IRM) produces an R-t plot and an estimate of remaining mass as a function of time or radius.
7. The AR data loses relevence if T_r is falling or $V > C_s$ The IRM can be modified to use the XRFC absorbed flux estimate. The IRM is invalid when stagnation or compression pressure exceeds ablation pressure.

An IRM has been used to compare the planar Be AR data with converging Be shell implosion experiments.

Pinhole streaked imaging of ablation front self-emission of converging Be hemi-shell
Greg Rochau *et al.* (SNL)



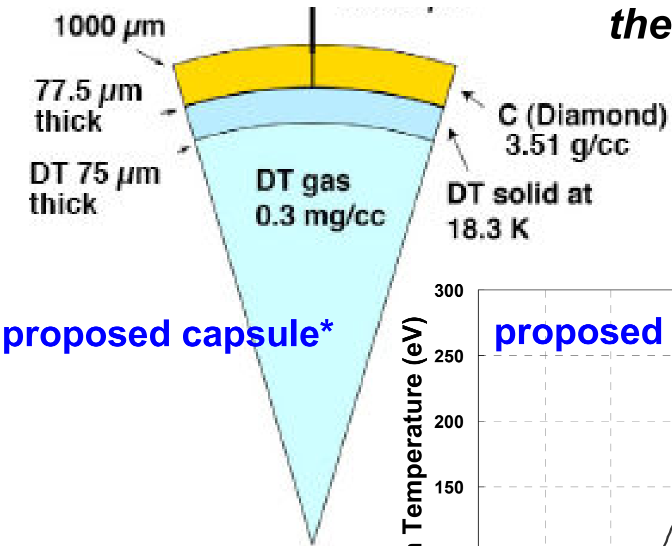
Cross-slit streaked high energy radiography of converging Be shell
Damien Hicks *et al.* (LLNL)

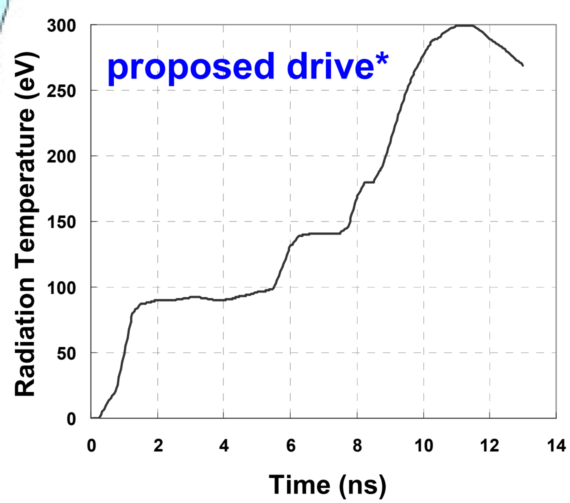


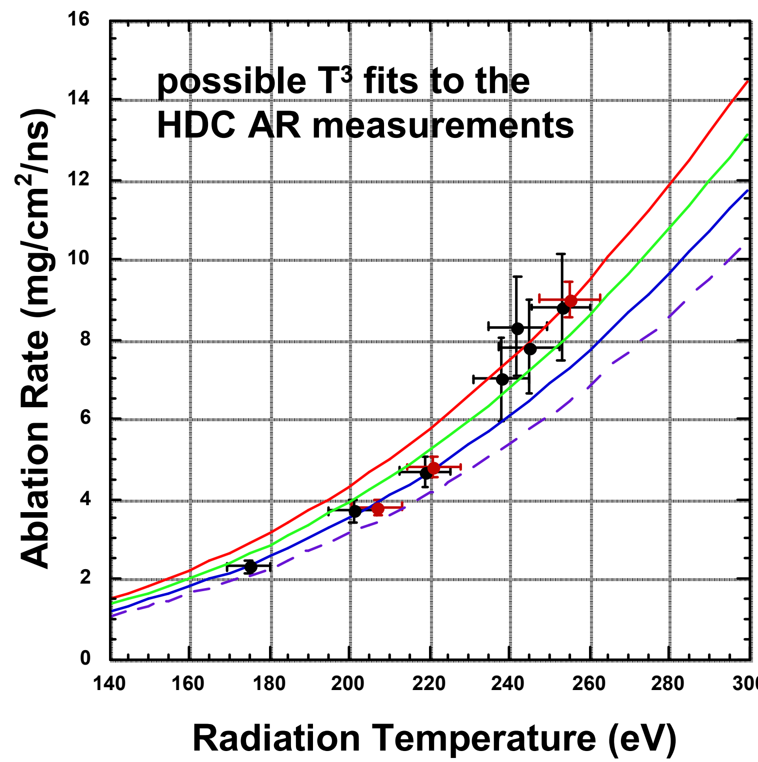
Capsule dimensions, Dante data, and Be AR vs T_r data fit were used as inputs to the IRM.

Proposed ignition capsule designs can be checked for consistency with the ablation rate data.

The capsule dimensions, proposed drive, and fits to the HDC AR data can be used as inputs to the IRM.



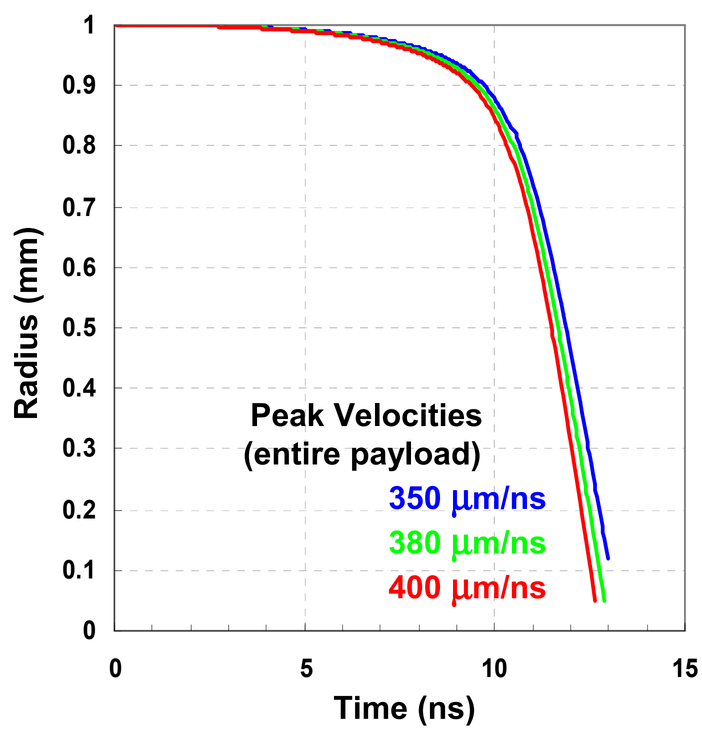


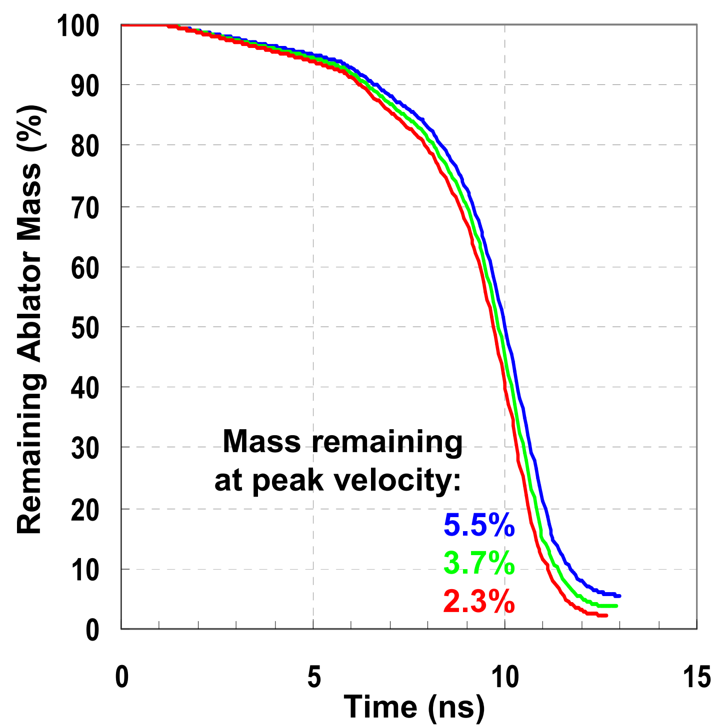


*D. Ho, S. Haan, M. Hermann, J. Salmonson, "Ignition Capsule with High Density Carbon Ablator for NIF," *Bull. Am. Phys. Soc.* 51, no. 7, p. 213 (2006).

The proposed capsule design is within a few percent of the fits to the AR data, perhaps the shell is a bit too thin.

The proposed capsule dimensions, proposed drive, and the high, medium, low fits to the HDC AR data were used as inputs to the IRM.





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The ablation rate measurements add to our confidence in the validity of proposed NIF ignition capsules.

The detailed computational simulations of the ablation rate measurement experiments provide results within the uncertainties of the measurements. These simulations use the same radiation hydrodynamics code and the same opacity and eos models as the ignition capsule design codes.

Direct measurements of capsule implosion trajectories have been used to confirm the basic validity of relating the planar ablation rate data to convergent experiments via a simple iterative rocket model (IRM).

Proposed NIF capsule designs employing Cu-doped Be and HDC ablators have been compared to the mass-remaining predictions of the ablation rate data set using an IRM. The designs seem a bit too thin, but are within a few percent of the data fits – probably well within the uncertainties of this technique.

Direct measurements (as described in Brian Spears' presentation) of the implosion trajectory of a full-scale ignition capsule will be done at NIF. Final adjustments to ablator thickness will be based on those results.