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X-Ray Ablation Rates of ICF Capsule Materials

Presented at APS-DPP, Orlando, FL

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UR LLE — **Omega Operations Team**

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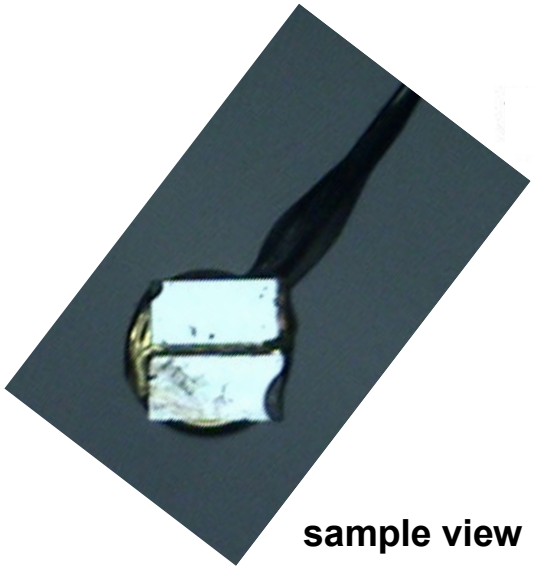
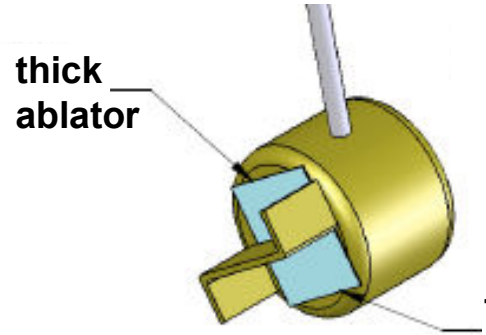
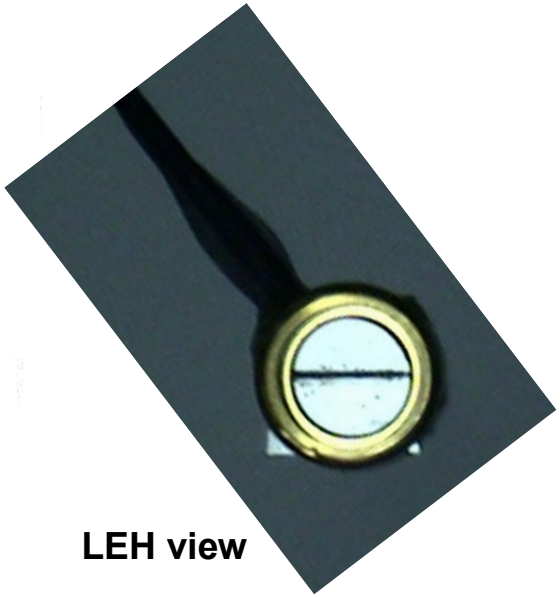
The ablation rate measurements were made using halfraums heated by the Omega laser.

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

Variations in laser power, pulse shape, and hohlraum size are used to provide peak radiation temperatures in the range of 160-260 eV.

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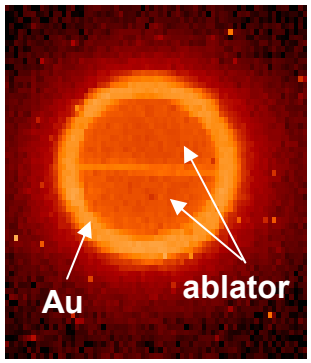
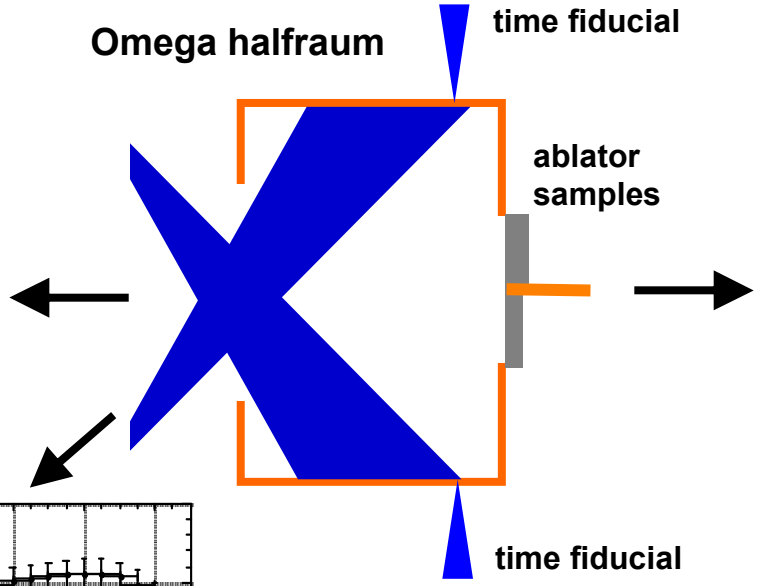
The primary diagnostics for the ablation rate measurements are the SXI, XRFC, and Dante.

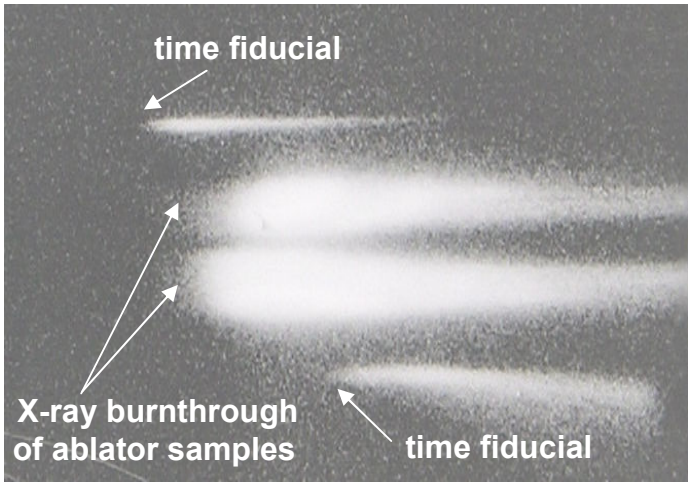
X-Ray Framing Camera (XRFC)



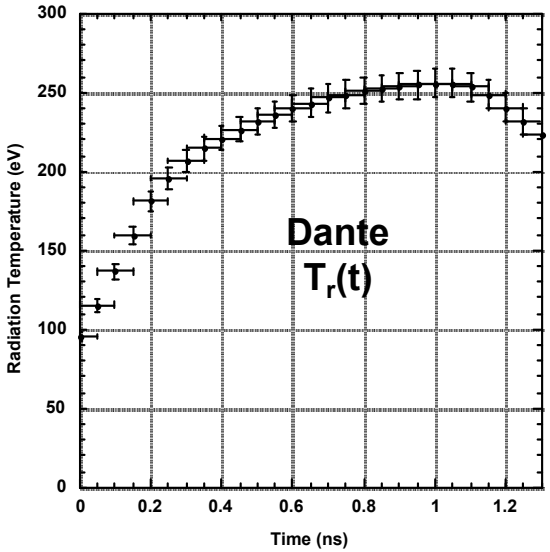
Omega halfraum



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).

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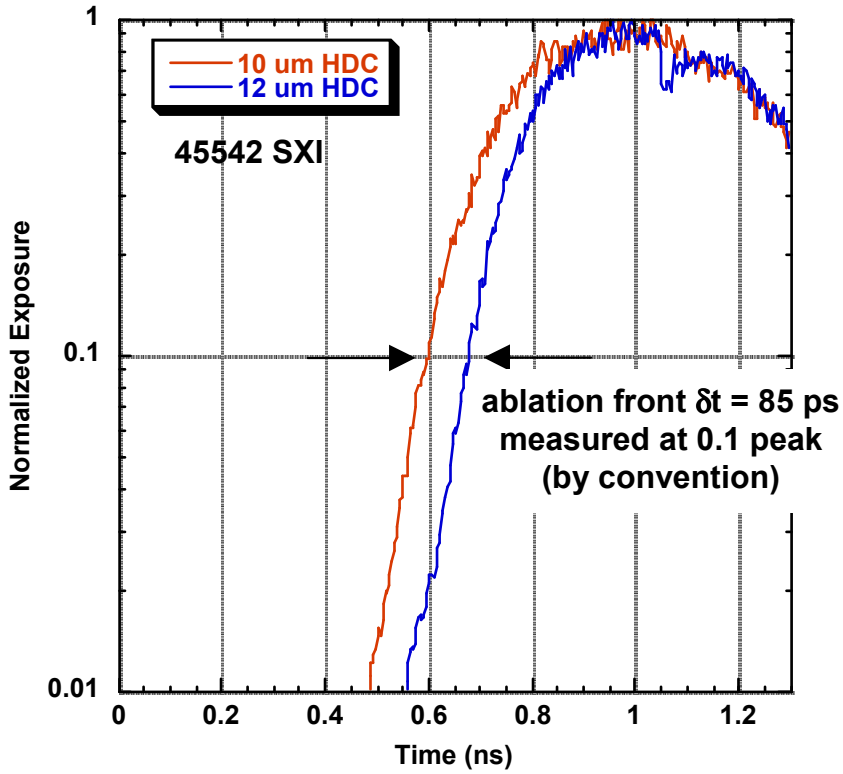
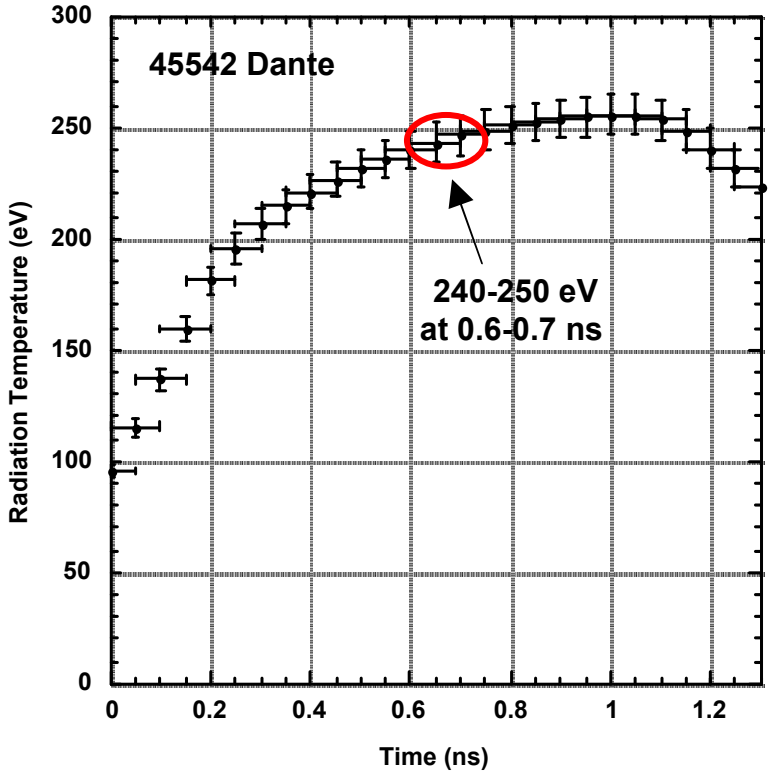
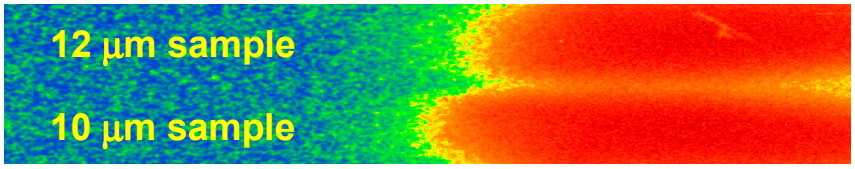
The SXI and Dante measurements are used to determine ablation rate and Tr.







AR = (3510 mg/cm^3) (.0002 cm) / .085 ns
AR = 8.3 mg/cm^2/ ns at ~ 245 +/- 5 eV

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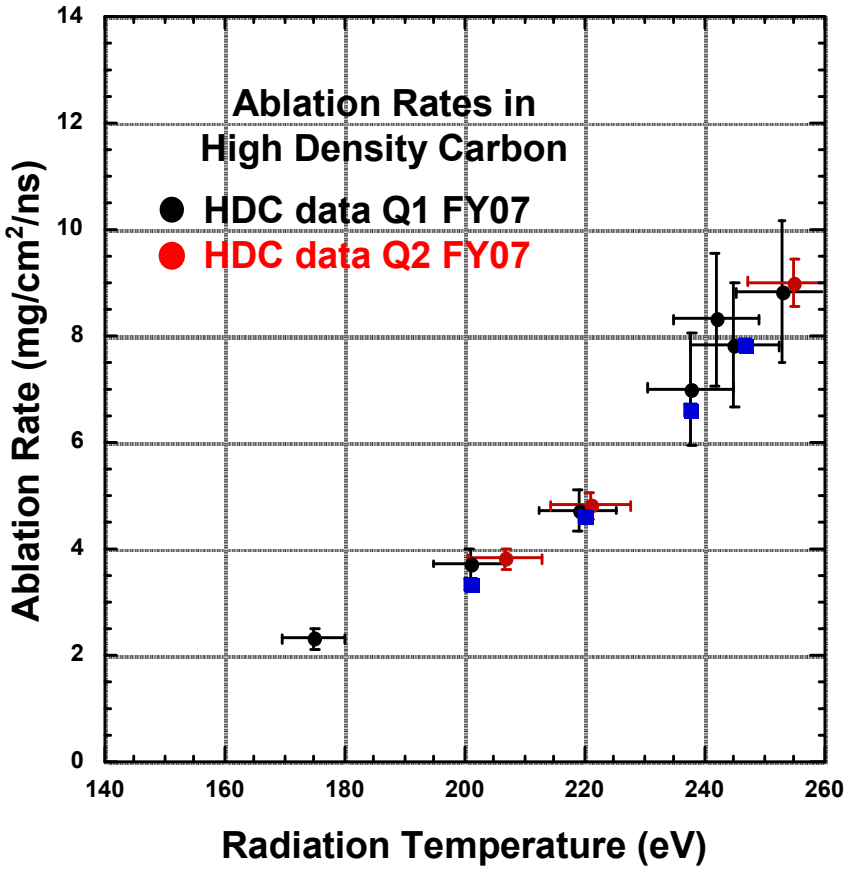
For each experiment, an ablation rate was determined along with a burnthrough radiation temperature.



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.

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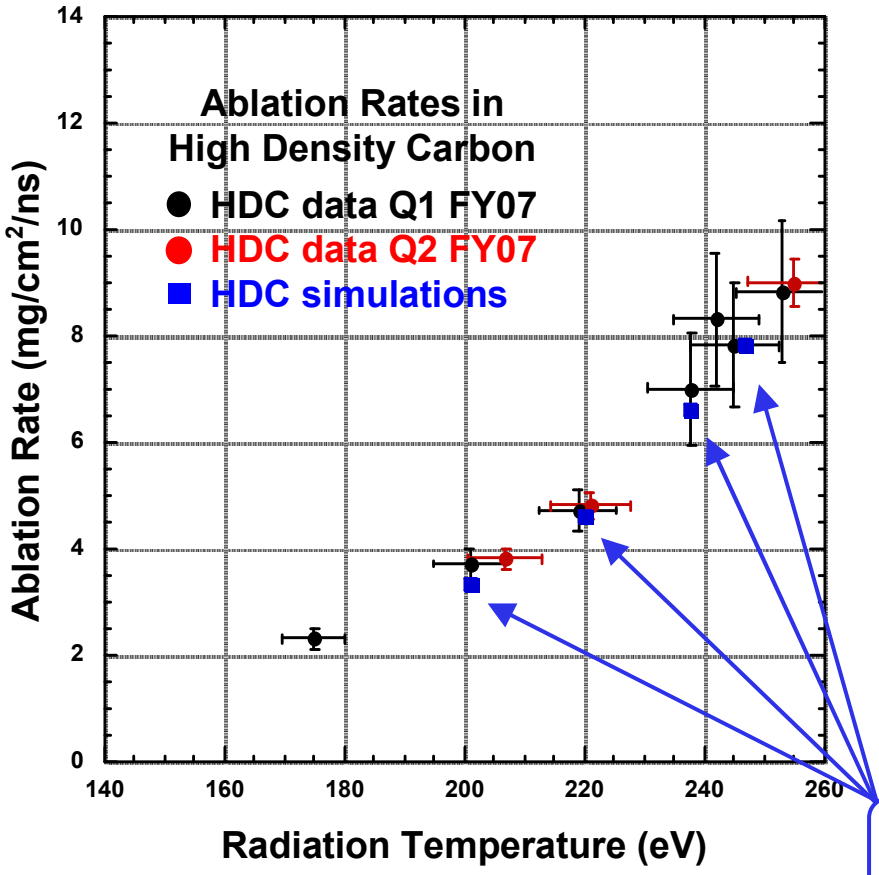
Post-shot computational simulations were done for some of the Omega halfraum experiments.



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 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 NIF ignition capsule designs.***
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.

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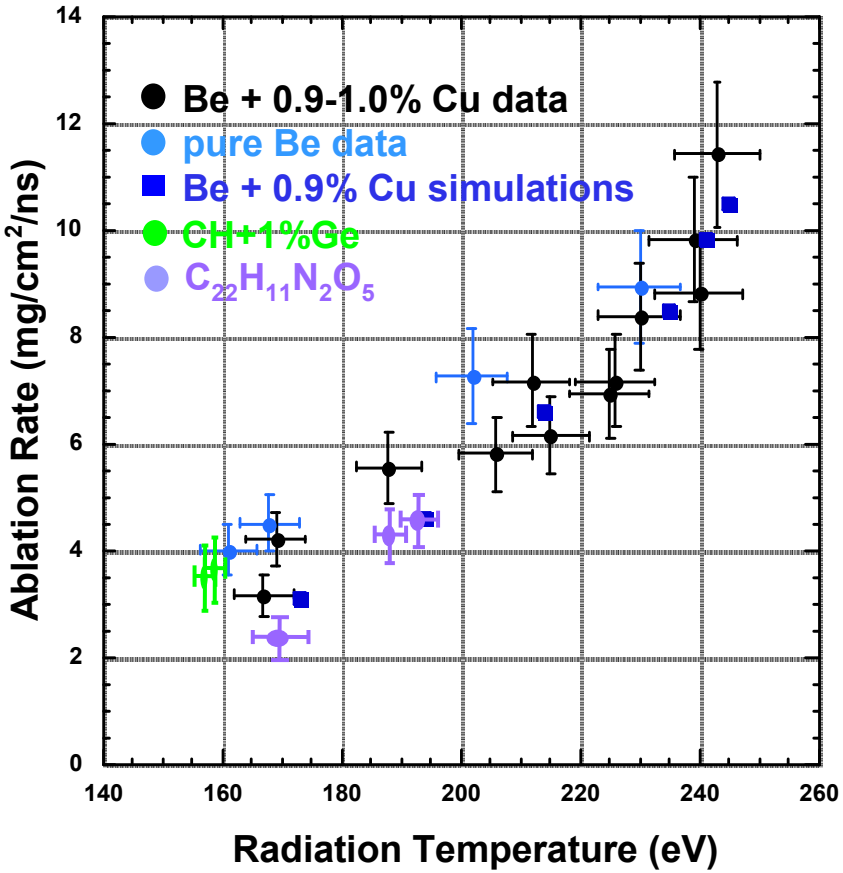
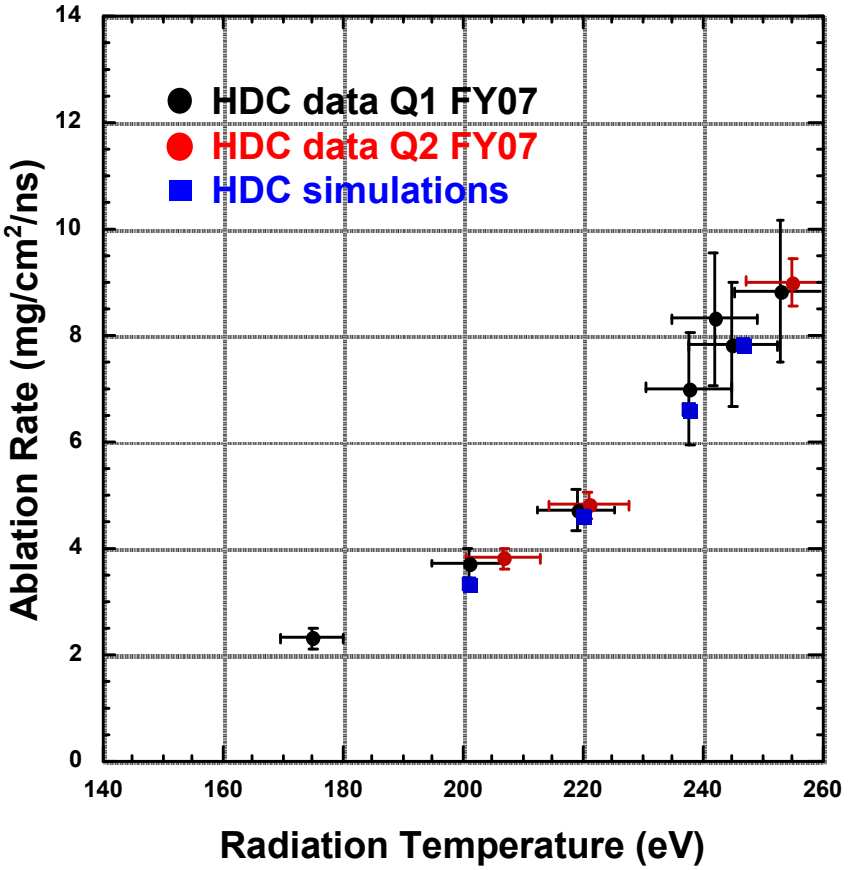
For Tr < 230 eV, the HDC ablation rates are significantly lower than the Be, Cu-doped Be, and CH ablation rates.

Be and HDC ablators approximately follow the expected T_r^3 AR scaling.





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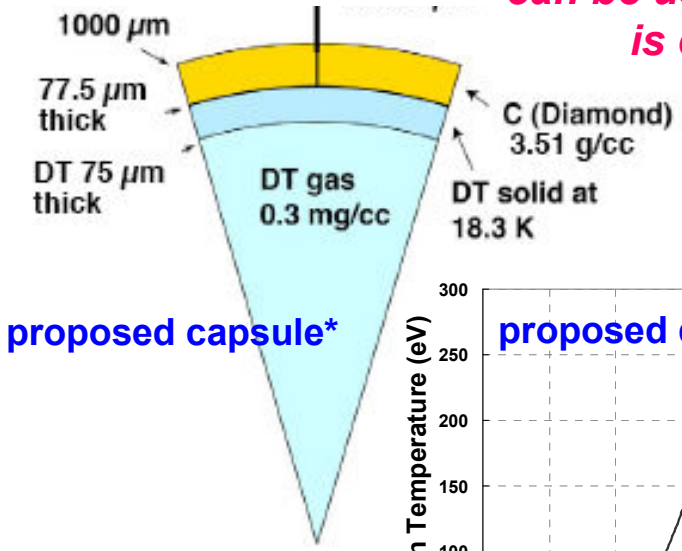
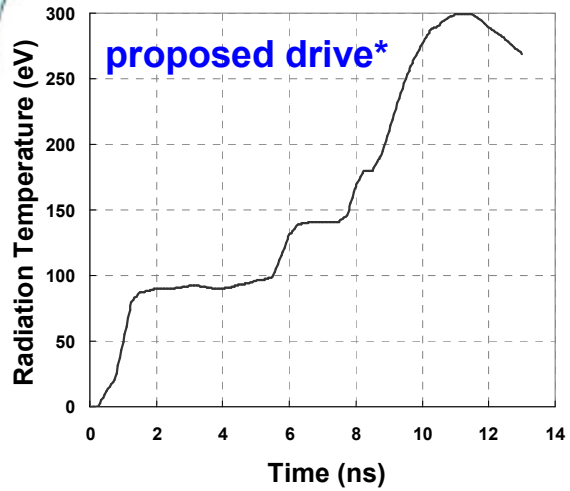
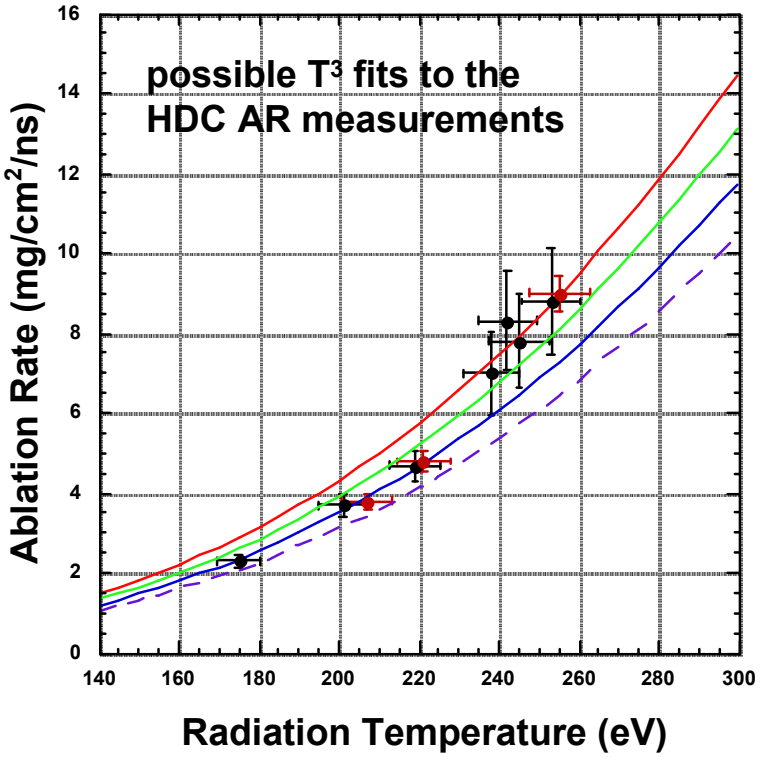
At last year's APS-DPP meeting, LLNL proposed a HDC ignition capsule design.

An iterative spherical rocket model $4\pi R^2 AR(T)\, v_e(T) = M\, dv_R/dt$ can be used to check on whether the proposed capsule design is consistent with the ablation rate measurements.



proposed capsule*





*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).

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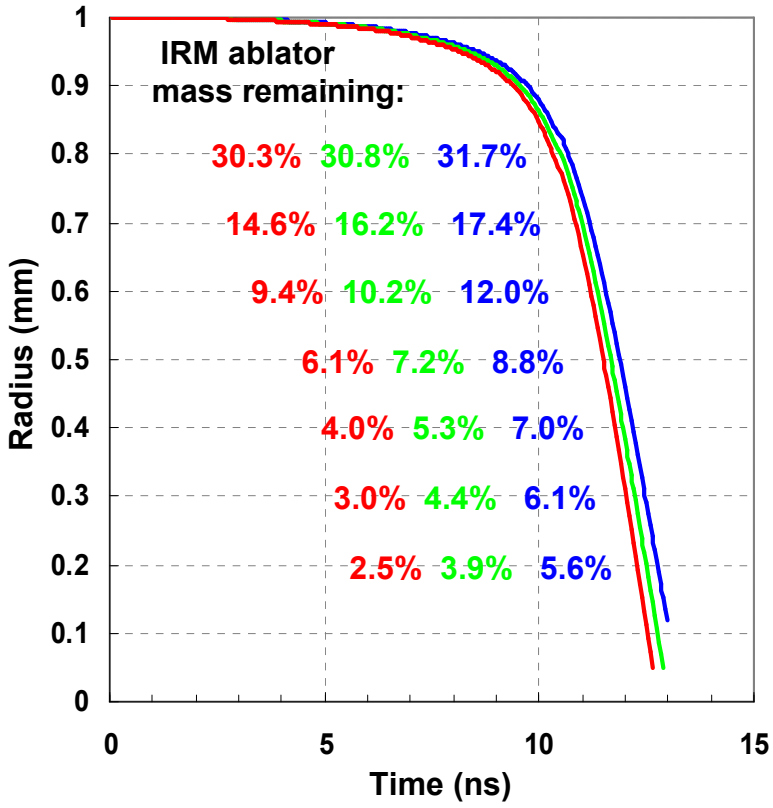
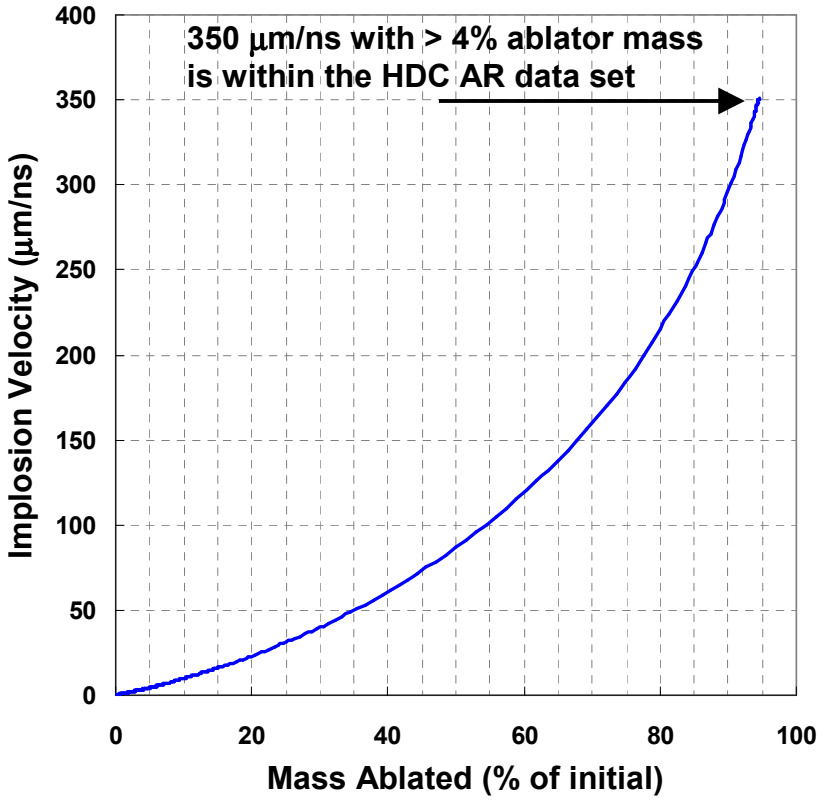
The ablation rate data can be used to produce an R-t plot and an estimate of remaining mass as a function of R, t, or v.

The HDC capsule design is near the lower fit to the AR data.
(The Be ignition capsule designs have a similar trend)





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Ablation rates have been measured for proposed NIF ignition capsule materials.

Ablation Rates have been measured for HDC Be, and Cu-doped Be over the range of 160-260 eV. The ablation rates scale approximately as T_r^3.

Computational simulations of the ablation rate experiments provide results within the uncertainties of the measurements. These simulations use the same code and physics models as the ignition capsule design codes.

Measurements of capsule implosion trajectories (Omega experiments) have been used to confirm the basic validity of relating the planar ablation rate data to convergent experiments via an iterative spherical rocket model.

Proposed NIF capsule designs have been checked for consistency with the ablation rate data set using an iterative spherical rocket model. According to this technique, the designs are "conservative" and could use slightly more ablator mass or possibly a reduced time at peak drive.

Direct measurements of the implosion trajectory of full-scale ignition capsules will be done at NIF. Final adjustments to ignition capsule ablator thickness will be based on those results.