Wetted Foam Liquid Fuel ICF Experiments

Can wetted foam liquid fuel ICF experiments be useful for exploring the transition from "hydro-like" to "kinetic-like" behaviors at the time of shock convergence?

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The hot spot formation processes in DT ice layer and DT liquid layer ICF capsules are quite different.

The baseline DT ice layer ICF ignition capsule design requires a hot spot convergence ratio > 30 with a hot spot that is dynamically formed from DT mass originally residing in a very thin layer at the inner DT ice surface.

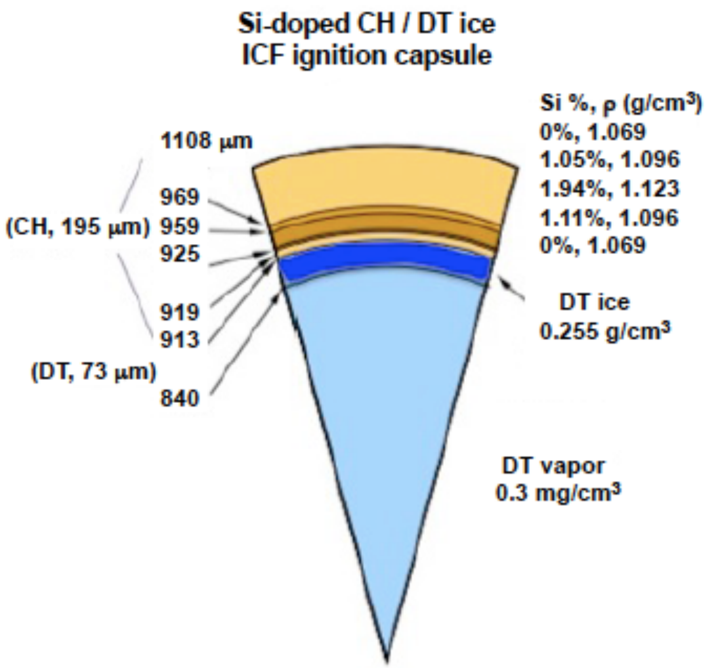
DT liquid layer capsules can have the hot spot formed from mass originating within a spherical volume of DT vapor and can have significant flexibility in hot spot convergence ratio (CR) and in the range of 12 to 25 via the adjustment of the initial cryogenic capsule temperature and, hence, DT (or DD) vapor density.

Simulations indicate that backing off on hot spot CR is an excellent way to reduce capsule instability growth and to improve robustness to low-mode x-ray flux asymmetries.

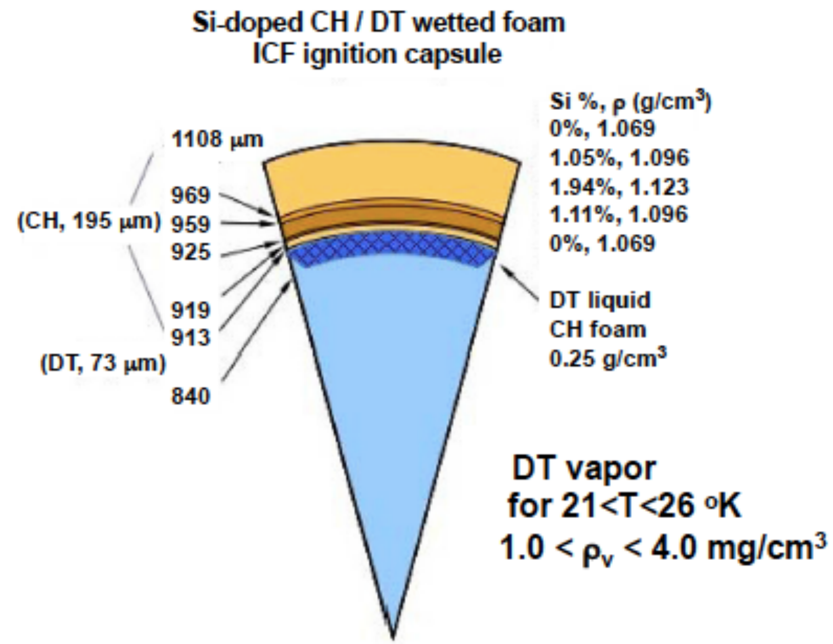
There are a number of additional motivations for developing a wetted foam liquid fuel layer platform, including potential hot spot diagnostic applications .

A detailed comparison of the performance of DT liquid layer and DT ice layer capsules can be found in R. E. Olson and R. J. Leeper, "Alternative Hot Spot Formation Techniques Using Liquid DT Layer ICF Capsules", Phys. Plasmas 20, 092705 (2013).

A liquid DT layer (wetted into CH foam) allows for a higher vapor density compared to a DT ice layer. This provides flexibility in hot spot CR.



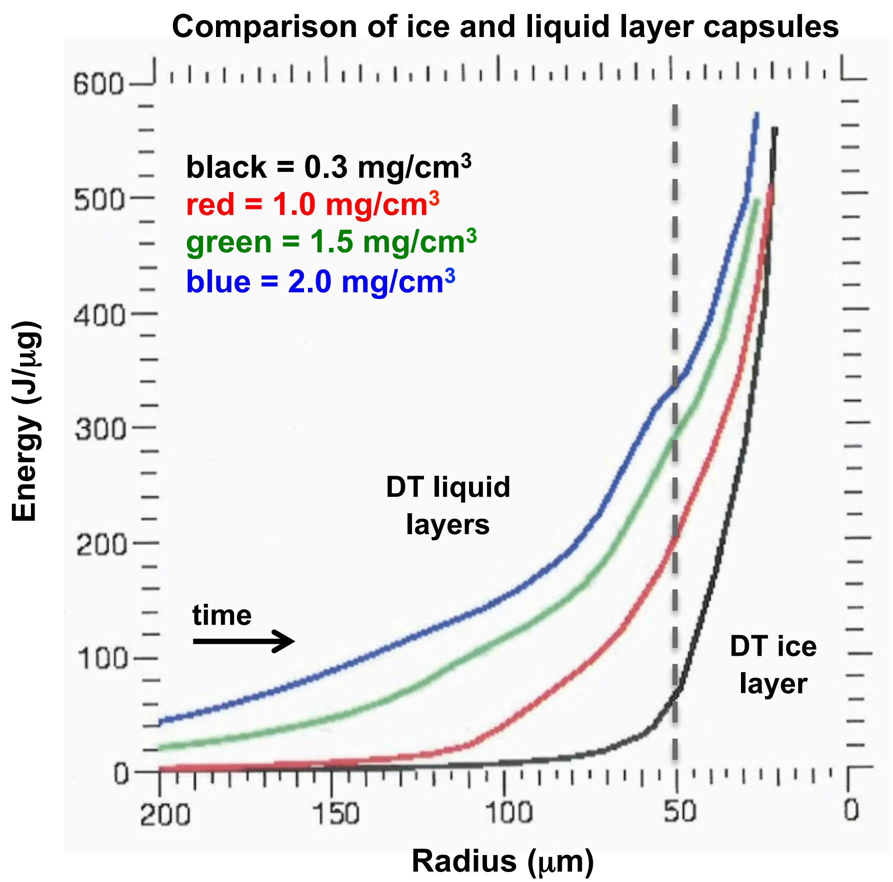
hot spot CR = 34
S. W. Haan et al., Phys. Plasmas <u>18</u> 051001 (2011)



hot spot CR depends upon vapor density (14 < CR < 25)
R. E. Olson and R. J. Leeper, Phys. Plasmas <u>20</u> 092705 (2013)

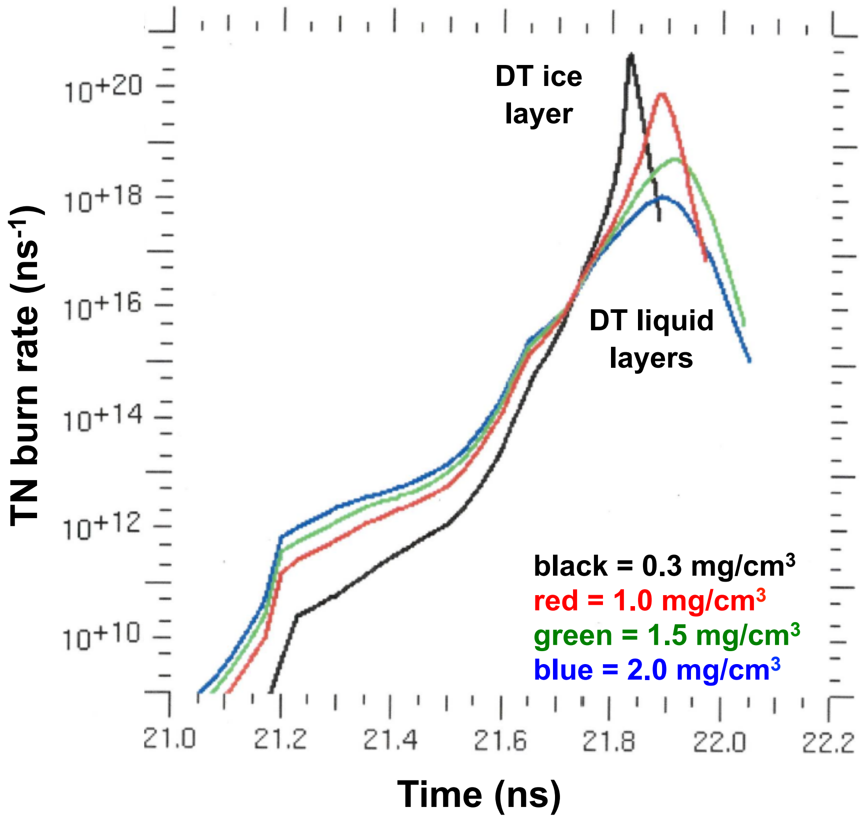
As the capsule implodes, the hot spot specific energy is gained at a larger radius in liquid DT layer capsules.

Variations on the Si-doped CH NIC ignition capsule:

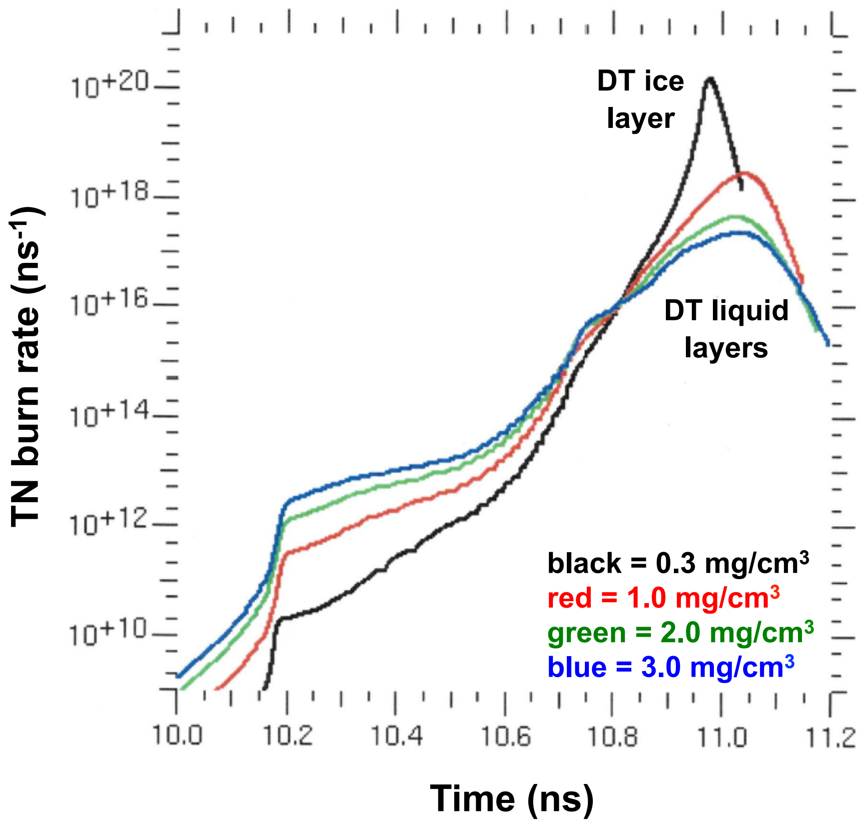


Shock flash TN burn rate is higher and compression burn rate is lower with liquid layers as compared to ice layers.

variations on the Si-doped CH NIC ignition capsule



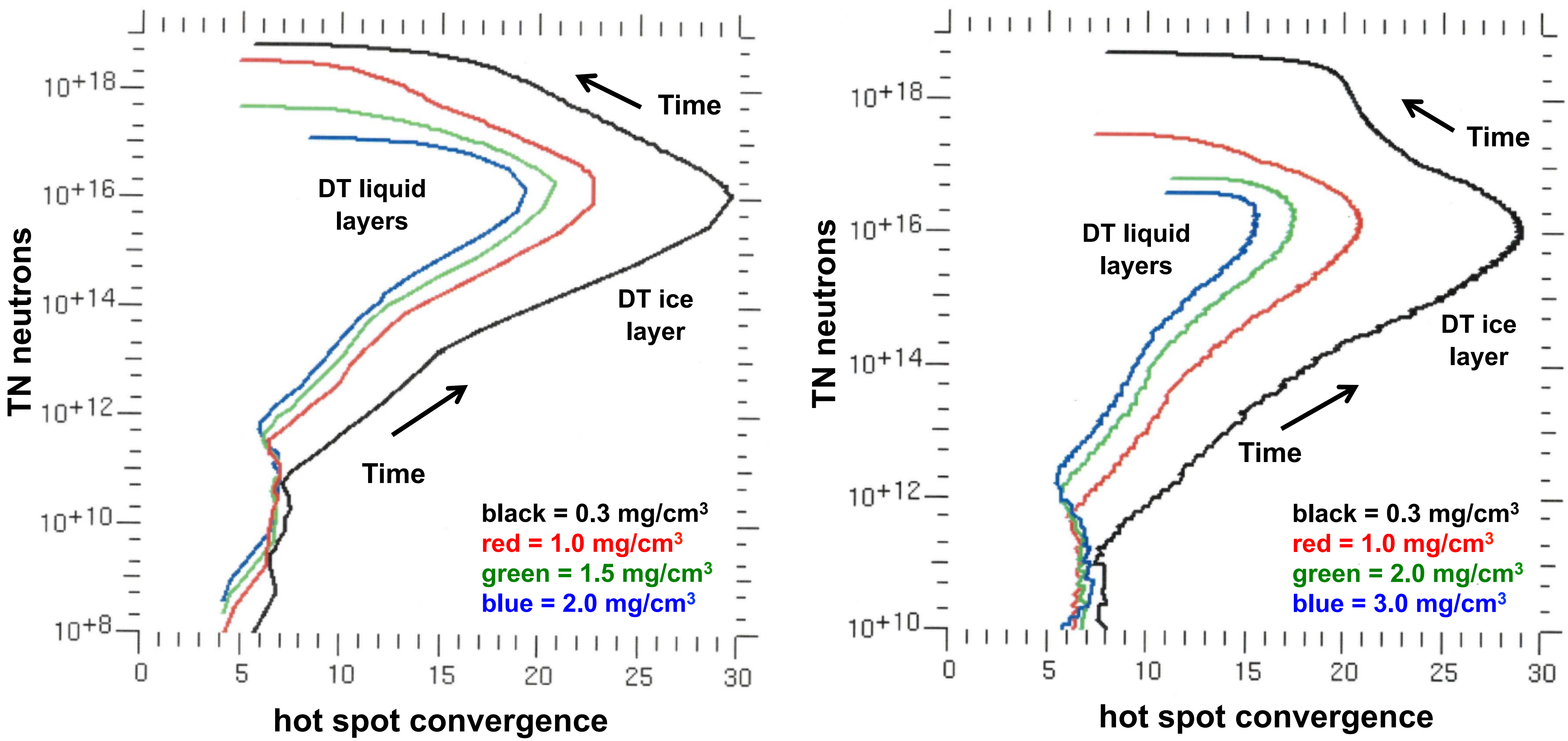
variations on the full-scale wetted foam HDC capsule



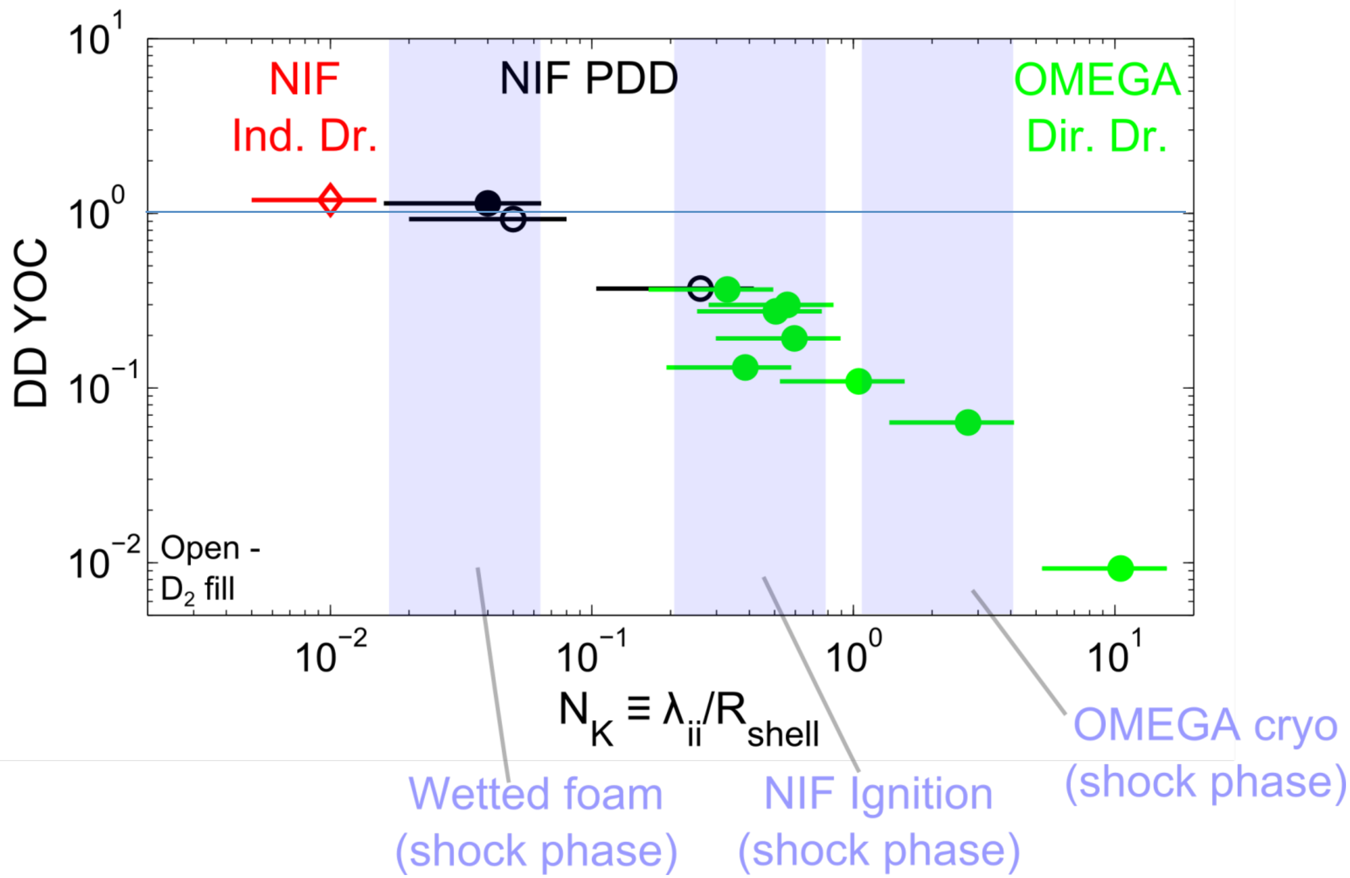
Significant TN burn occurs with less convergence with liquid layers as compared to ice layers.

variations on the Si-doped CH NIC ignition capsule

variations on the full-scale wetted foam HDC capsule



Shock convergence phase of the wetted foam design is in a much more "hydrodynamic-like" regime than other ignition-relevant implosions

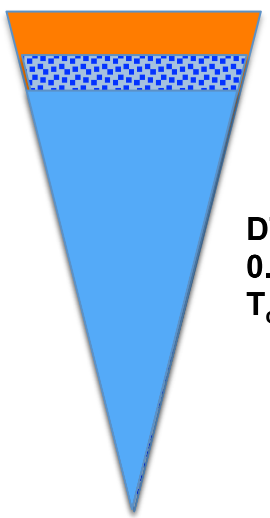


Hydrocodes matched measured yields in exploding pusher implosions at Knudsen numbers (N_K) comparable to the wetted foam design, suggesting kinetic effects may be minimal

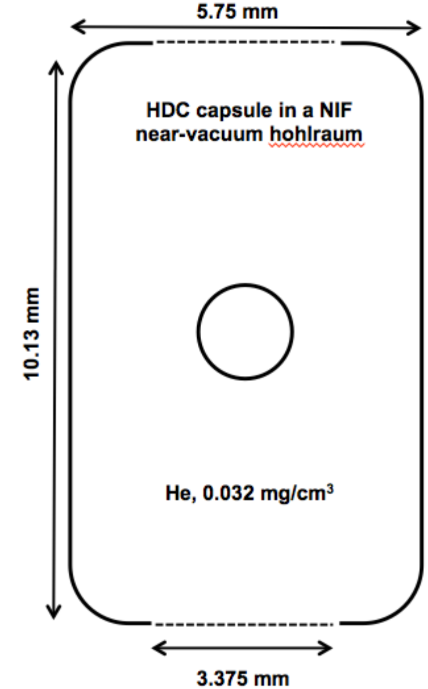
We are developing a new NIF experimental platform that employs wetted foam liquid fuel layer ICF capsules.

The liquid layer platform builds upon some recent innovations.

CH foam-lined HDC capsules



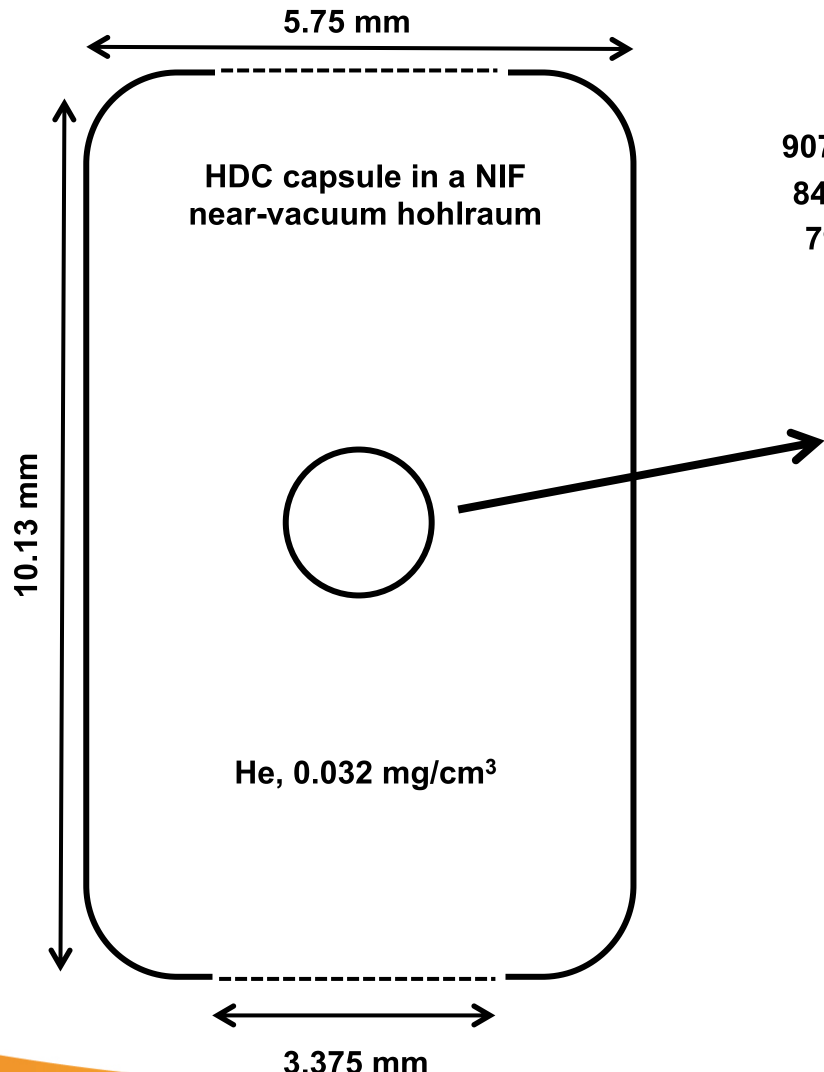
Near-Vacuum Hohlraums



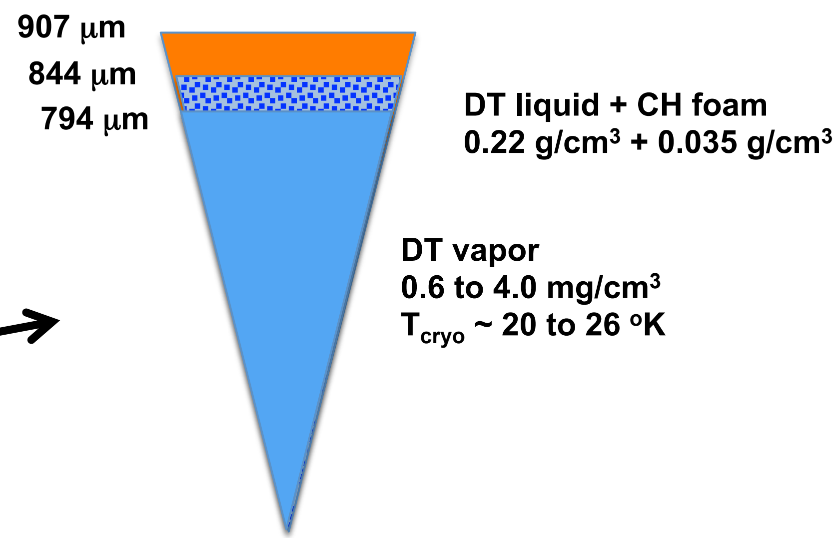
J. Biener *et al.*, "A new approach to foam-lined indirect-drive NIF ignition targets," *Nucl. Fusion* 52, 062001 (2012).

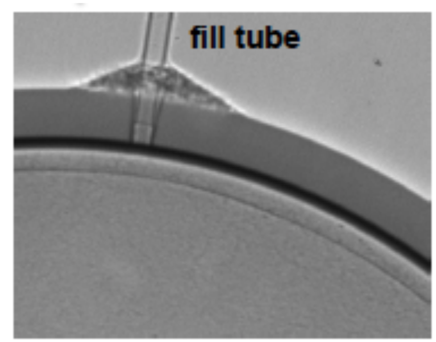
L. Berzak Hopkins *et al.*, "Near-vacuum hohlraums for driving fusion implosions with HDC ablators", *Phys. Plasmas* 22, 056318 (2015).

Initial experiments will use sub-scale HDC capsules with liquid D2 or DT layers fielded in a NIF "575 near vacuum hohlraum" (575 NVH).



HDC sub-scale capsule with liquid DT wetted CH foam



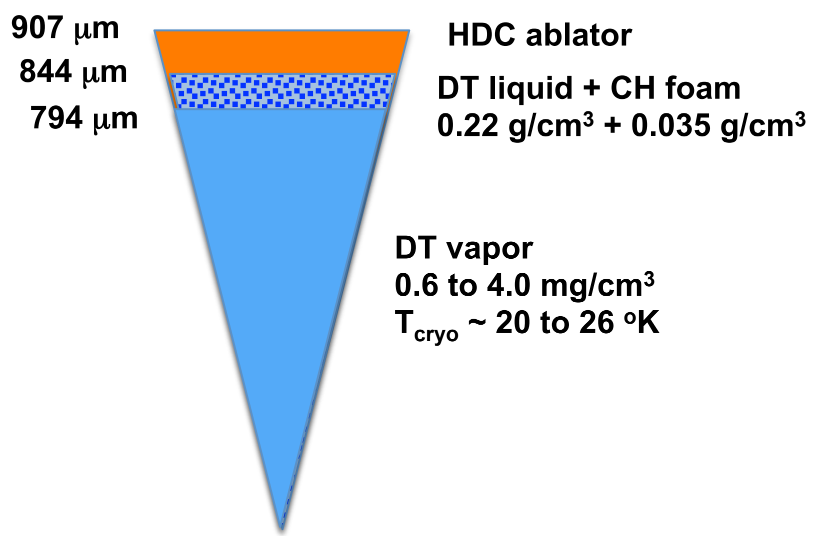


HDC ablator

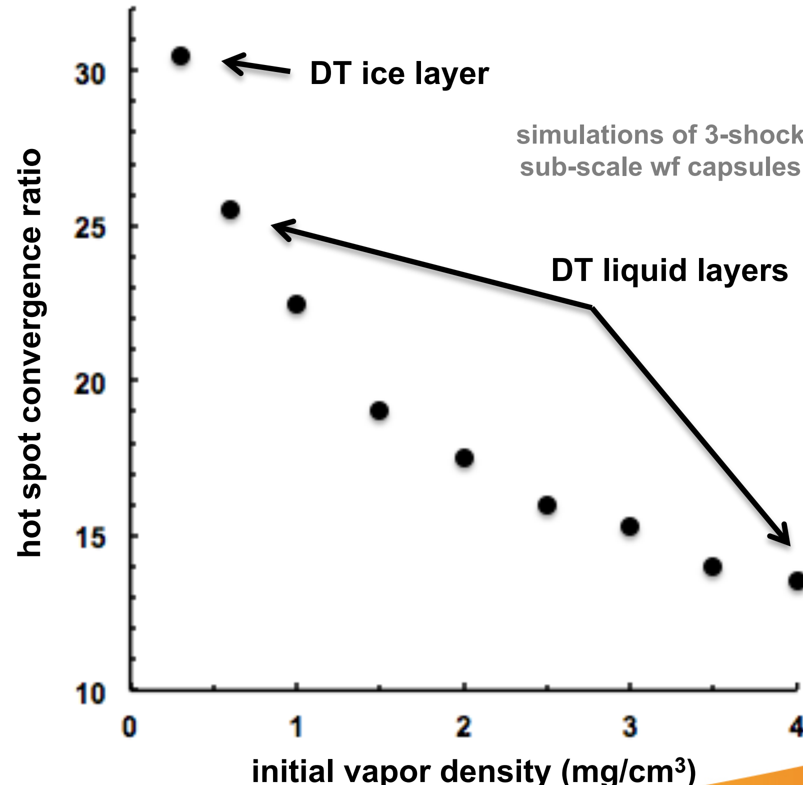
Liquid D2 layer

We will use DT liquid layer capsules in a NIF sub-scale campaign to explore the relationship between convergence ratio and robustness of hot spot formation.

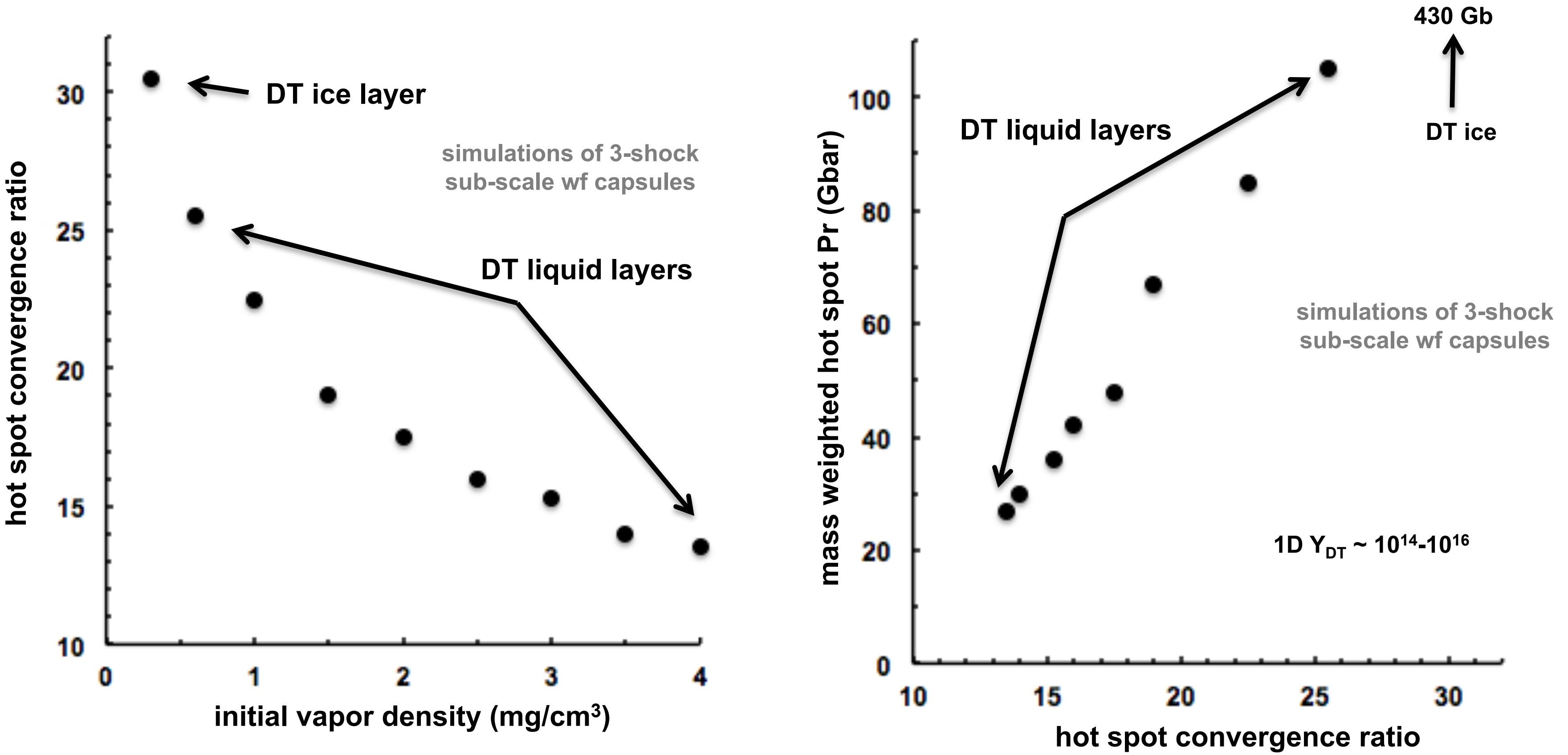
HDC sub-scale capsule with liquid DT wetted CH foam



DT liquid layer ICF capsules can provide flexibility in hot spot convergence ratio via the adjustment of the initial vapor density.



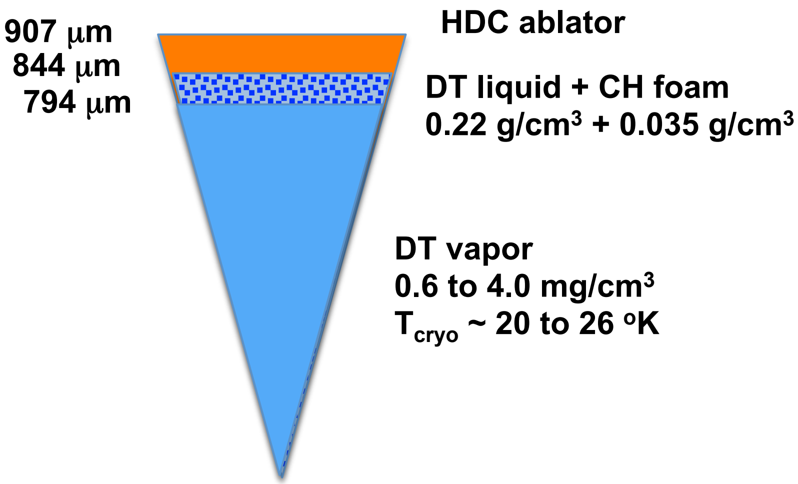
An initial goal will be to measure hot spot size, neutron yield, T_{ion}, and burn width to infer hot spot pressure for liquid layer implosions.



Our hypothesis is that hot spot formation will be robust and 1D-like for a relatively low convergence ratio hot spot in which hot spot is created largely from the vapor, but will deviate from 1D-like behavior as vapor pressure is reduced and hot spot convergence ratio is increased.

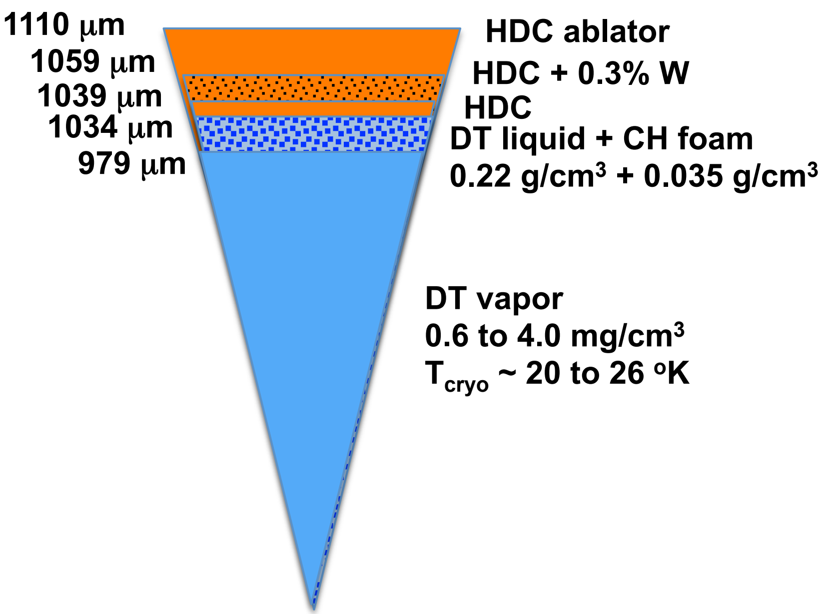
When we discover a CR threshold with 1D-like behavior, we will advance from sub-scale to full-scale NIF experiments.

HDC sub-scale capsule with liquid DT wetted CH foam



575 NVH, 300 TW, 900 kJ, 285 eV

Full-scale HDC capsule with liquid DT wetted CH foam



672 NVH, 420 TW, 1.7 MJ, 300 eV

1D performance will depend upon initial vapor density and resulting hot spot CR.

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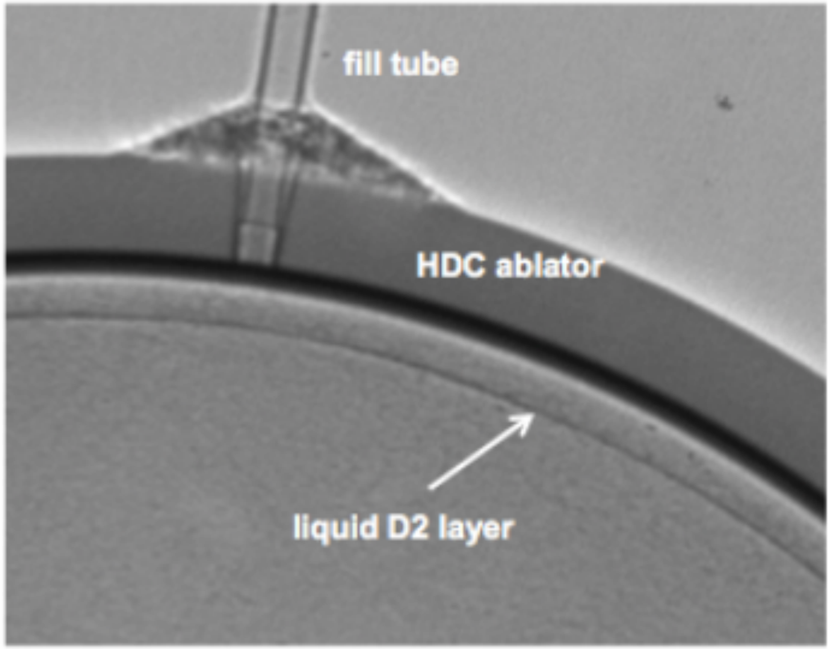
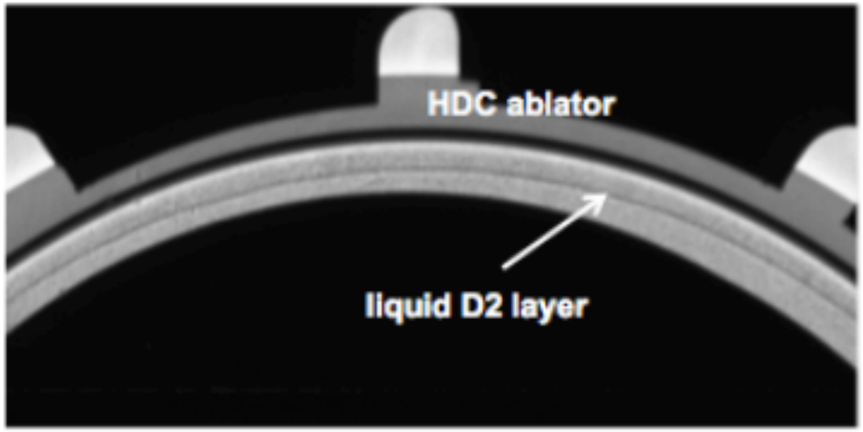
An HDC capsule with a CH foam layer was assembled into a Au 575NVH, was wetted with liquid D2, and was successfully shot in NIF experiment N160320-002.

LEH view



equatorial view (looking through the starburst)



The first wetted foam implosion was successfully shot on NIF using a liquid D2 layer, with CR ~ 14.

The first liquid DT layer experiment is scheduled for April 21, also with CR ~ 14.

A demonstration of changing convergence via vapor density is scheduled for June 26.

We will use DT liquid layer HDC capsule implosions to explore the relationship between convergence ratio and robustness of hot spot formation.

- **We will use sub-scale HDC capsules with wetted CH foam layers to implode capsules with vapor densities in the range of 0.6 to 4.0 mg/cm^3 and predicted hot spot CR's in the range of 12 to 25.**
- **The HDC sub-scale capsules with liquid DT layers will be fielded in NIF "575 near vacuum hohlraums" (575 NVH).**
- **Our hypothesis is that hot spot formation will be robust and 1D-like for a relatively low convergence ratio hot spot in which hot spot is created largely from the vapor, but will deviate from 1D-like behavior as vapor pressure is reduced and hot spot convergence ratio is increased.**
- **A goal of the sub-scale experiments is to measure hot spot size, neutron yield, T_{ion}, and burn width to infer hot spot pressure for liquid layer implosions and determine a CR limit at which burn truncation occurs due to 3D effects.**
- **The wetted foam liquid fuel layer platform would then be used for hot spot diagnostic applications to understand and repair departures from 1D-like behavior as CR is gradually increased.**

Can wetted foam liquid fuel ICF experiments be useful for exploring the transition from "hydro-like" to "kinetic-like" behaviors at the time of shock convergence?

- **Rosenberg and Petrasso have pointed out that the shock convergence phase of the wetted foam design can be in a much more "hydrodynamic-like" regime than other ignition-relevant implosions.**

- **As the capsule implodes, the hot spot specific energy is gained at a larger radius in liquid DT layer capsules as compared to DT ice layer capsules.**

- **Shock flash TN burn rate is higher and compression burn rate is lower with liquid layers as compared to ice layers.**

- **Significant TN burn occurs with less convergence with liquid layers as compared to ice layers.**

- **Regardless of the Knudsen number at shock convergence, the vast majority of TN yield occurs during the compression phase, when the Knudsen number is low. Is it possible that inaccurately-modeled conditions at shock flash in the DT ice layer design can ultimately have a harmful impact at compression?**