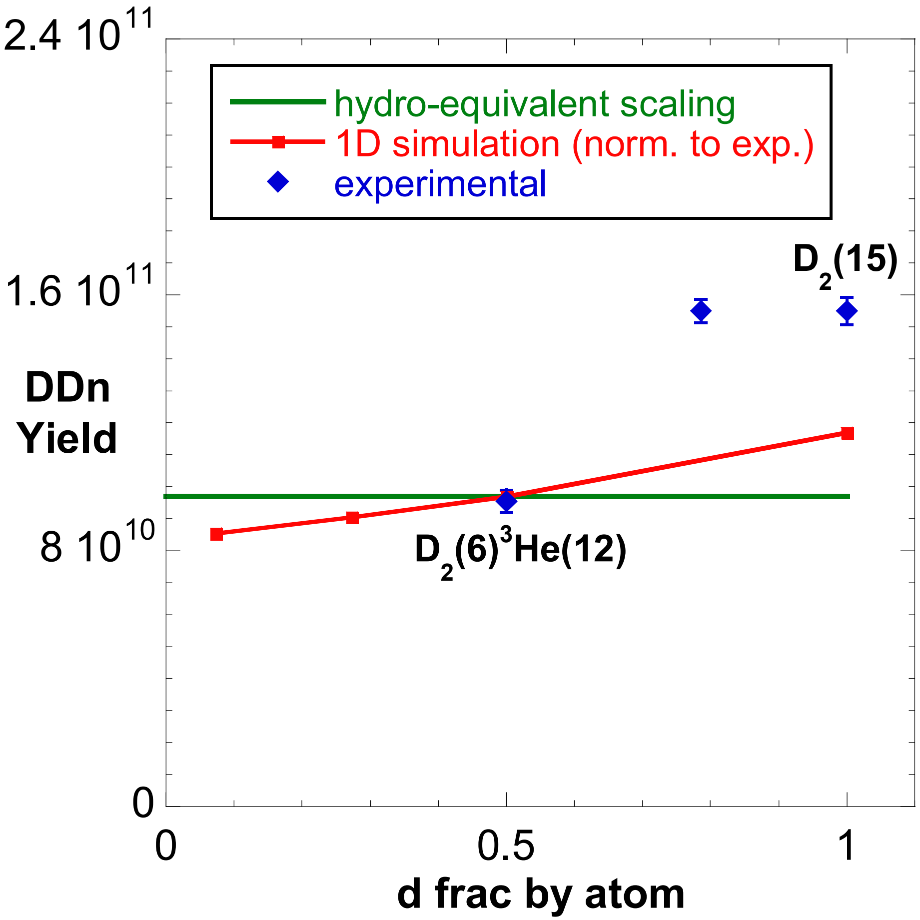
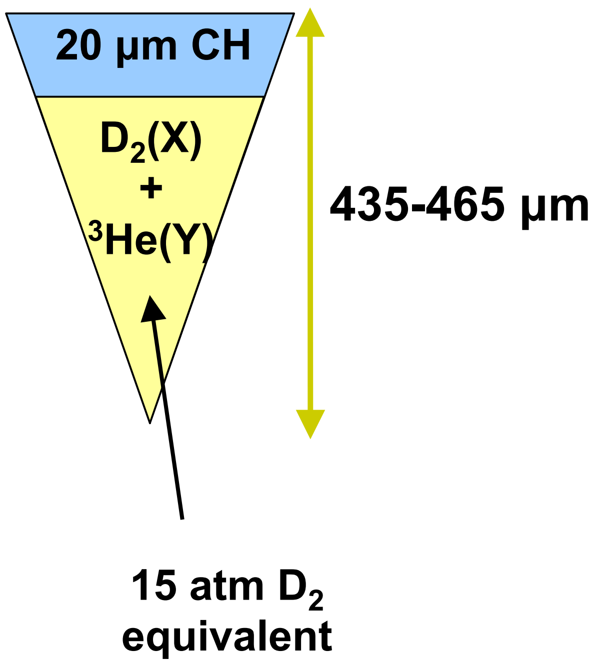
Testing Hydrodynamic Equivalence of D_2 and ^3He mixtures





Contributors

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Summary

- "Surrogate" fuels with advantageous nuclear properties (such as D_2 or D^3He for DT) are often used to study implosion dynamics
- Interpretation of surrogate implosions typically assumes that fuels can be interchanged with minimal impact on implosion hydrodynamics
- An investigation of hydrodynamic equivalence using different fill compositions was carried out using a mixture of D_2 and ^3He
- The experimental yield scaling was found to deviate from that expected assuming hydrodynamic equivalence

Hydrodynamically equivalent fills have the same total number of particles (e + i) on full ionization

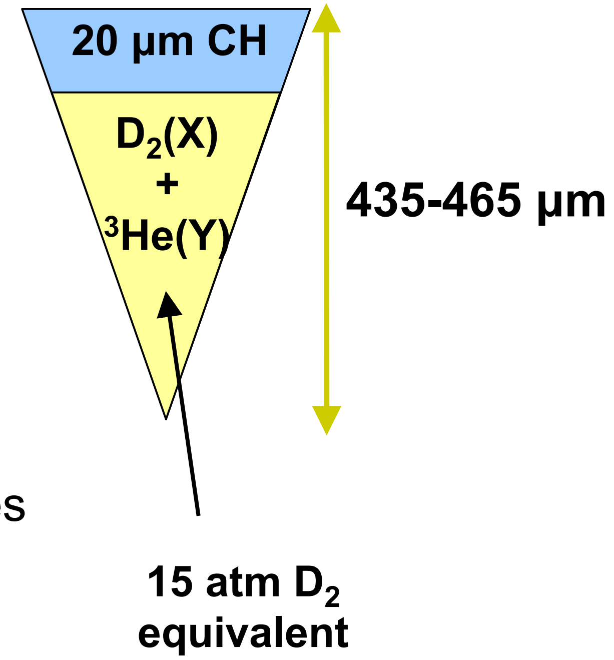
Fill pressures for different fill compositions are chosen such that there are the same total number of particles (e + i) when the gas is completely ionized.

For $D_2(X)^3He(Y)$ filled capsules, hydro-equivalence to a $D_2(15)$ capsule requires:

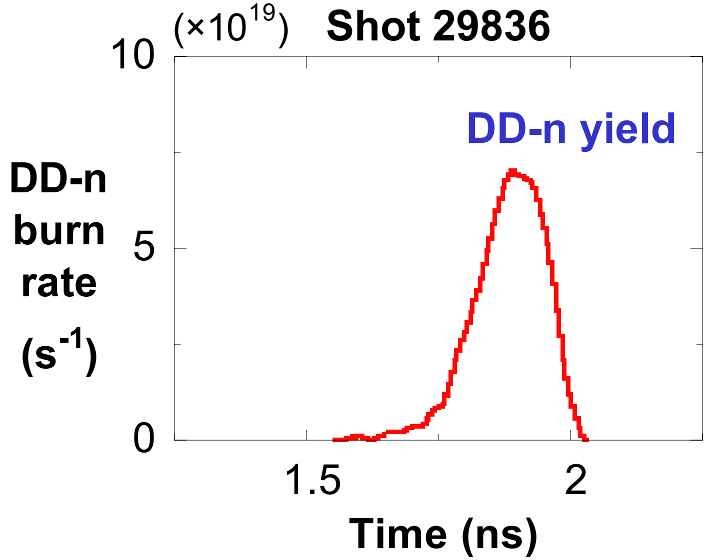
$$\frac{X}{15atm}+\frac{Y}{20atm}=1$$

➔ The mass density is the same for all such mixtures

Driven with a 23 kJ, 1 ns square pulse

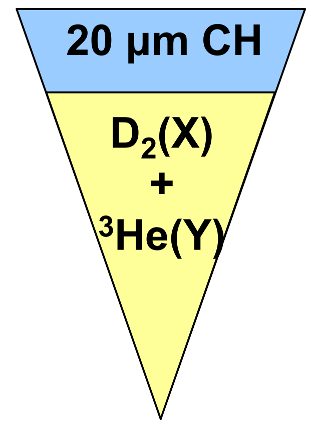


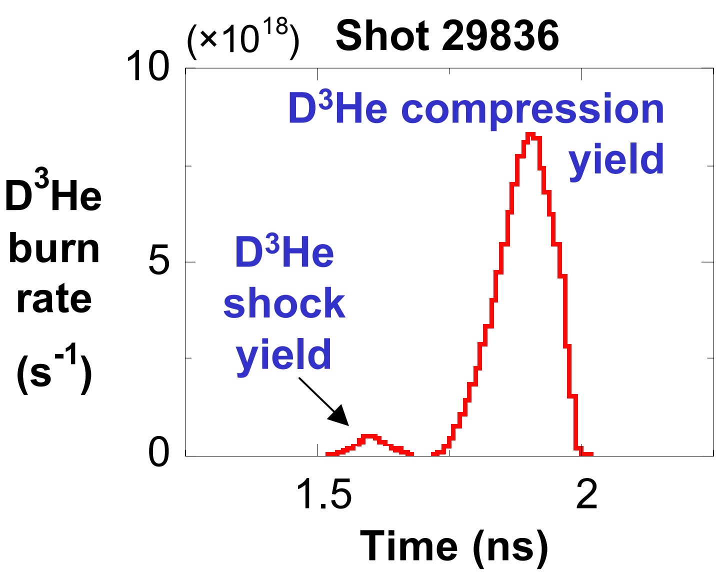
Yields from two nuclear reactions are used to diagnose such implosions



$$D + D \Rightarrow {}^3He(0.8) + n(2.5\ MeV)$$

$$\mathbf{Y_{DDn} \propto X^2}$$





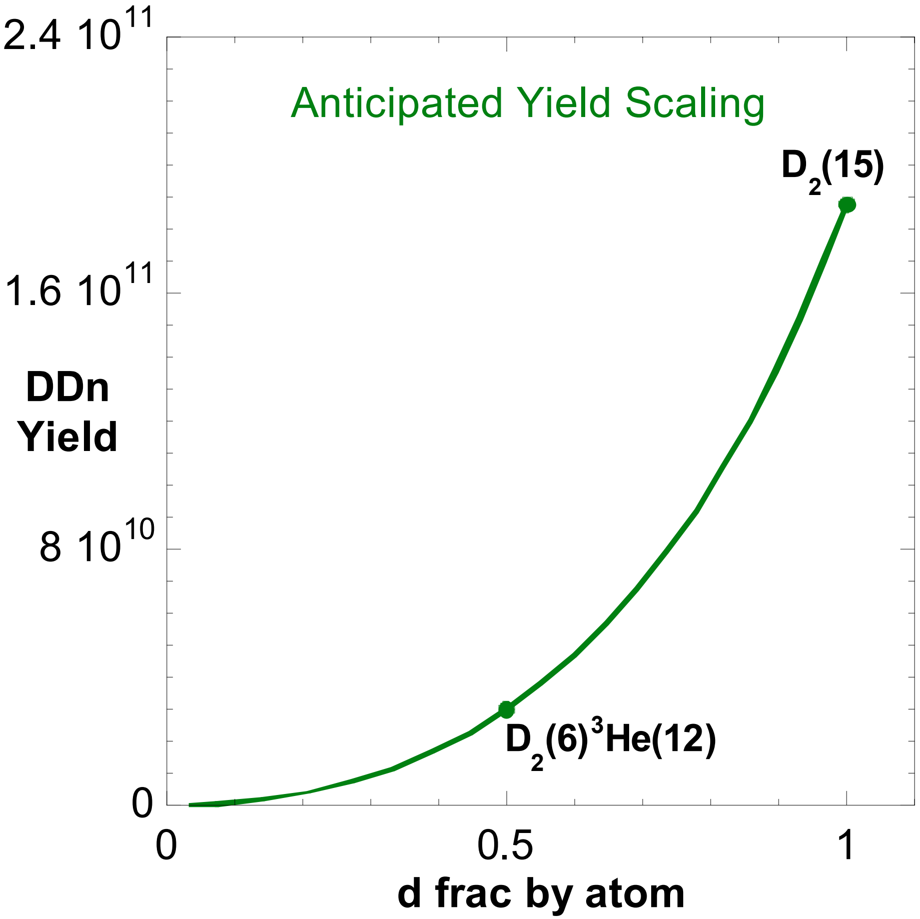
$$D + {}^3He \Rightarrow \alpha(3.6) + p(14.7\ MeV)$$

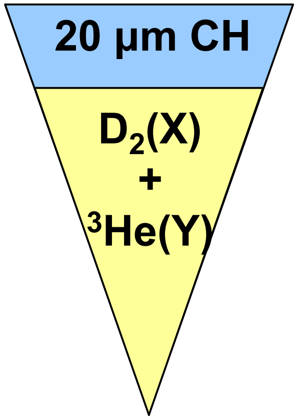
$$\mathbf{Y_{D3He} \propto X \times Y}$$

For hydrodynamically-equivalent implosions, DD-n yield scales as the square of D_2 fill pressure

DD-n Yield

$Y_{DDn} \propto X^2$

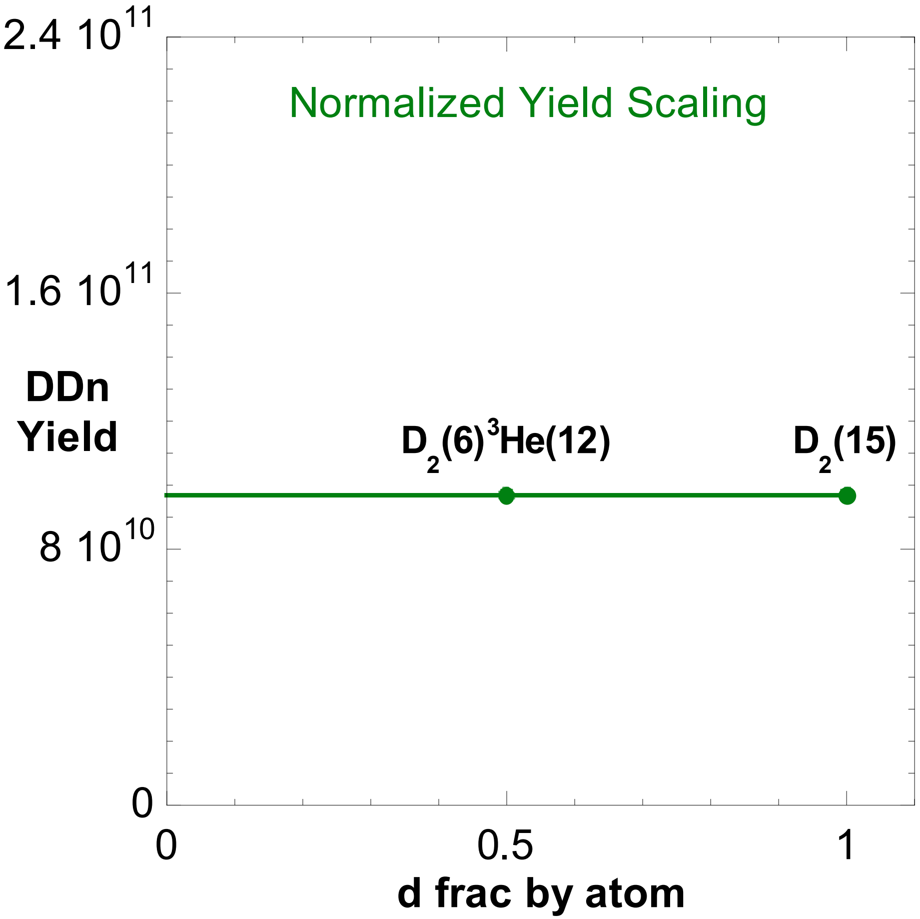


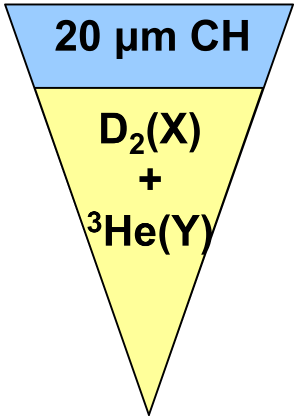


Yields have been normalized to the fill composition

DD-n Yield (norm)

$$Y_{norm} = Y_{DDn}\,(15\ \text{atm}/X)^2$$





Experimental yields deviate from the expected "hydro-equivalent" yield scaling

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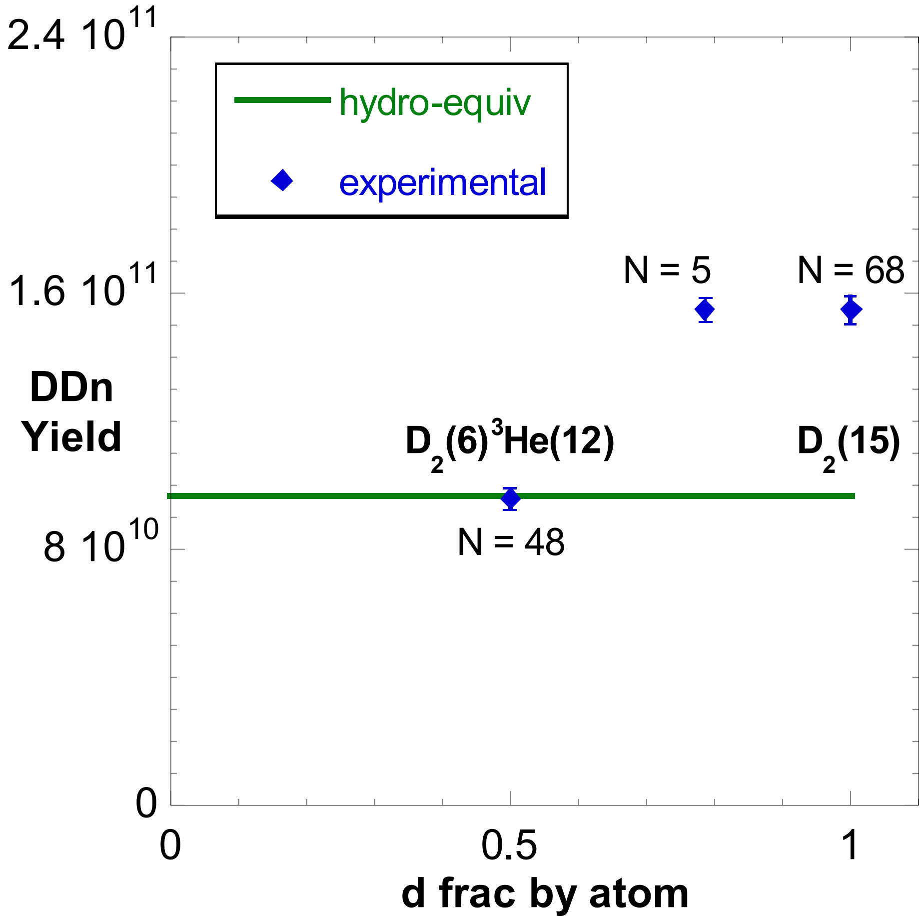
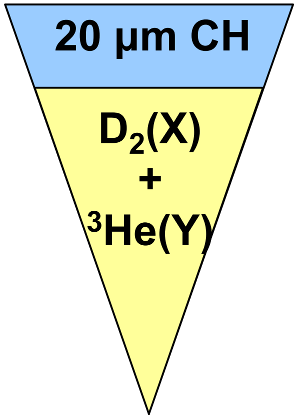
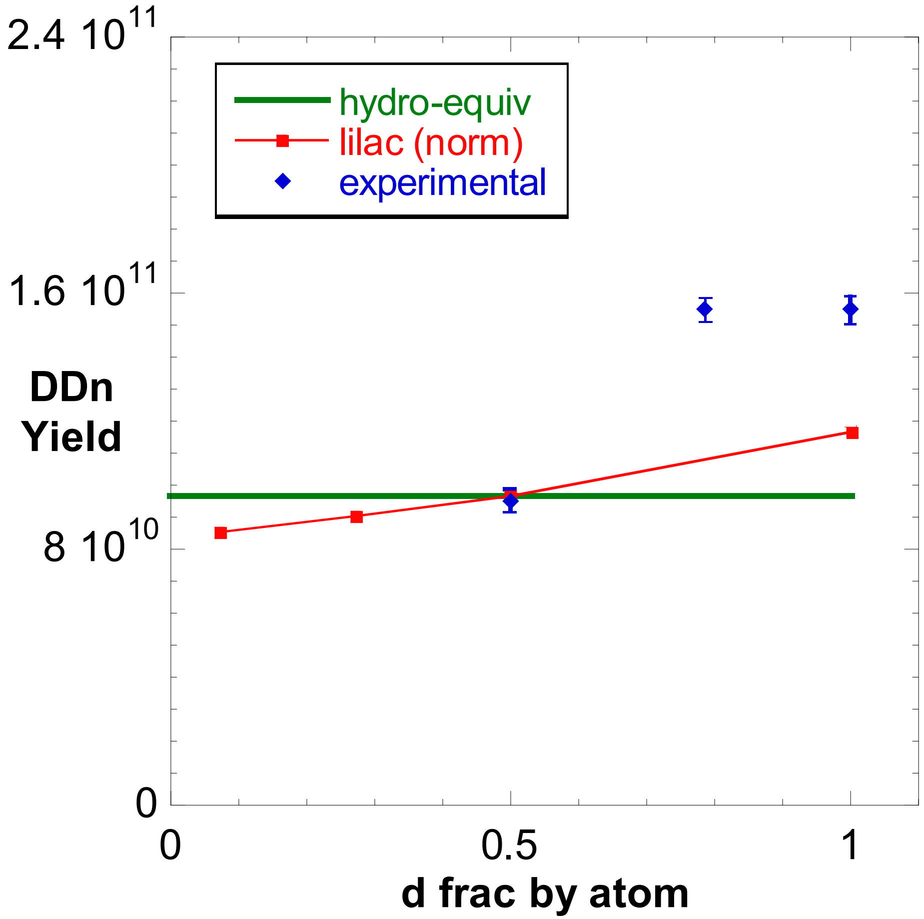


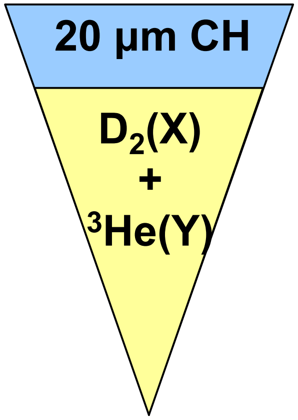


1D simulations also deviate from the expected "hydro-equivalent" yield scaling

DD-n Yield (norm)

$Y_{norm} = Y_{DDn} (15\ atm/X)^2$

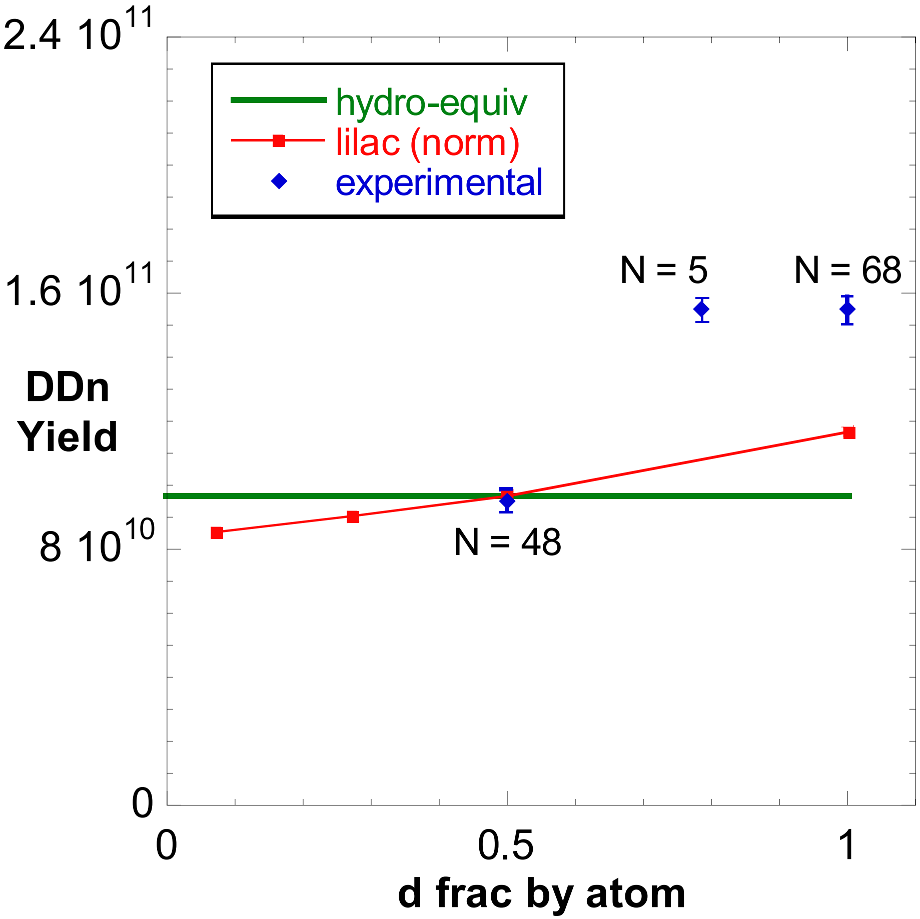




Experimental D^3He yields also deviate from the expected "hydro-equivalent" yield scaling

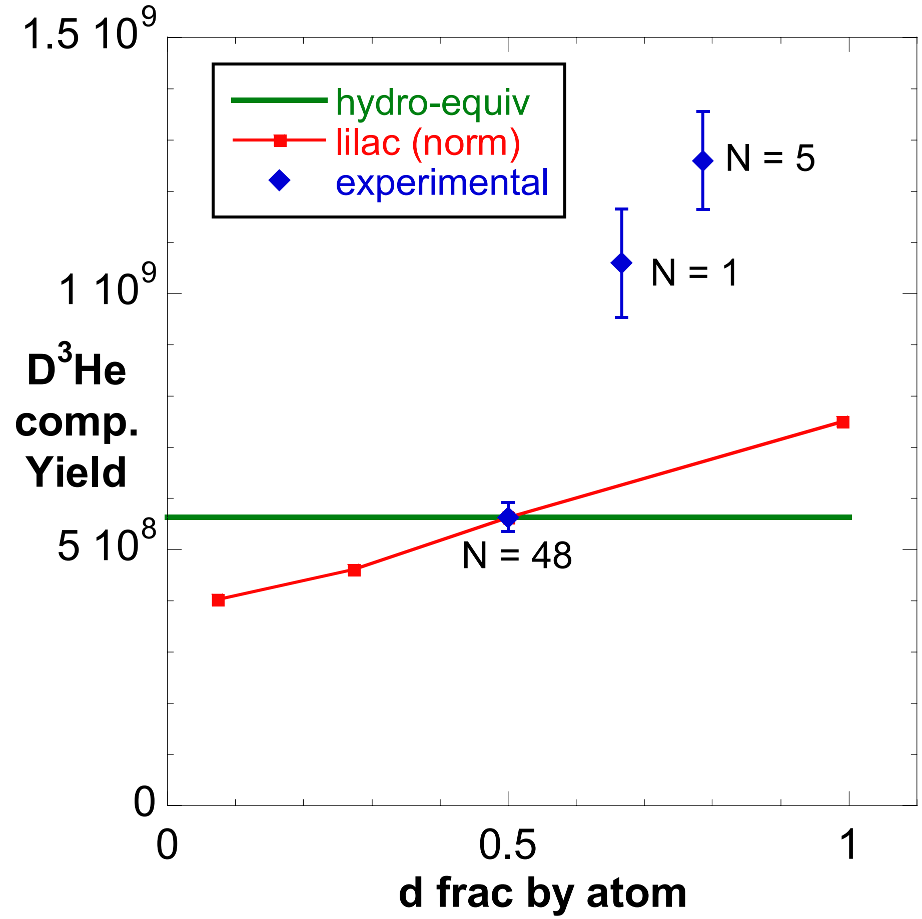
DD-n Yield (norm)

$$Y_{norm} = Y_{DDn}\,(15\ \text{atm}/X)^2$$



D^3He-p Yield (norm)

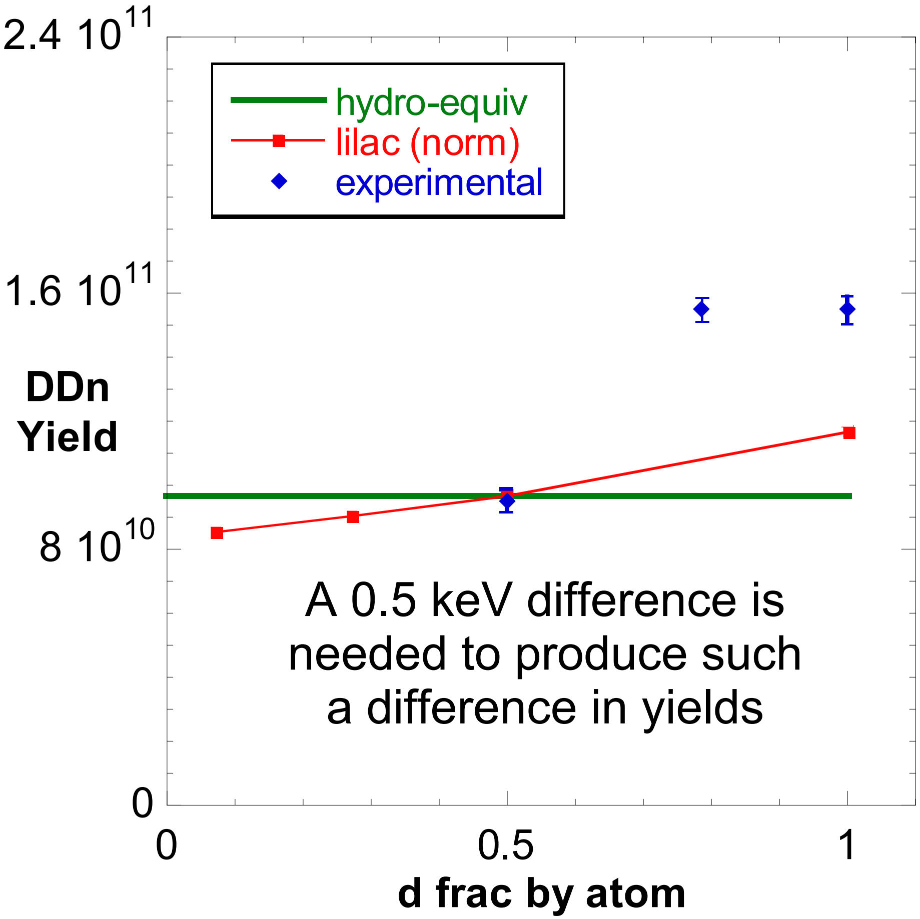
$$Y_{norm} = Y_{d3he}\,\frac{6\ \text{atm} * 12\ \text{atm}}{X * Y}$$



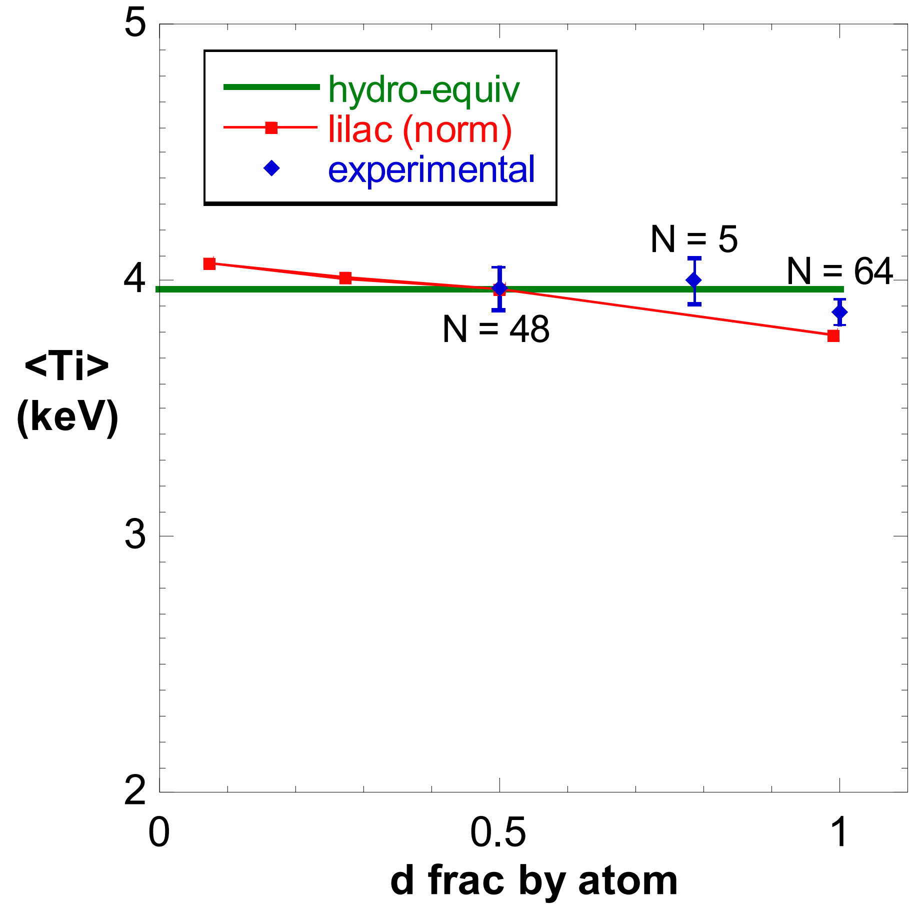
These yield trends are not due to differences in DD-n burn-averaged ion temperature

DD-n Yield (norm)

$Y_{norm} = Y_{DDn}\,(15\ \text{atm}/X)^2$



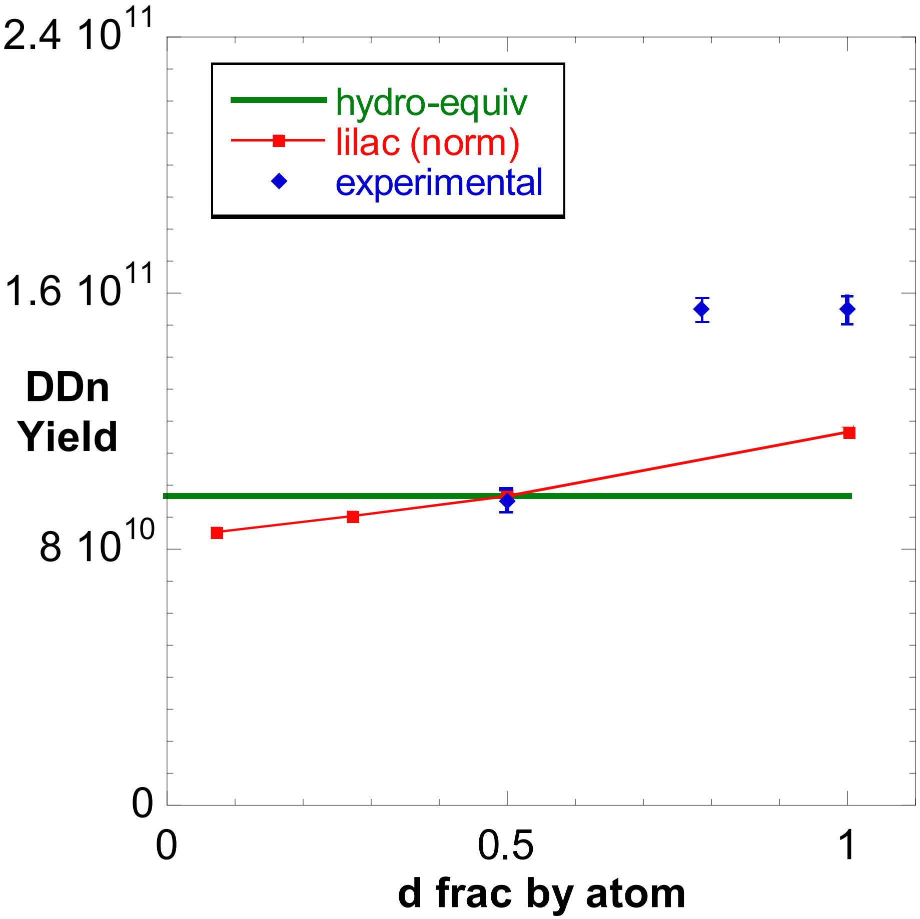
$\langle T_i \rangle$ (averaged over DD-n burn)



The observed yield trends could be due to higher convergence for D-rich fill

DD-n Yield (norm)

$Y_{norm} = Y_{DDn} (15 \text{ atm}/X)^2$



A simple density calculation to explain yield trends:

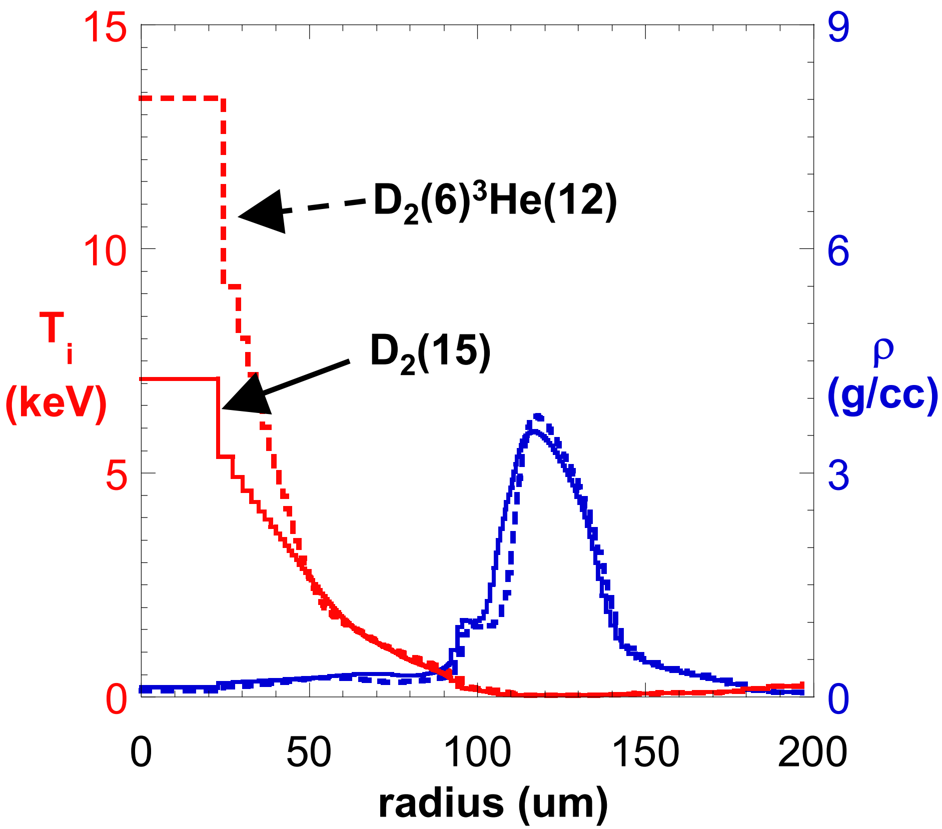
$$\rho_{D2} = 1.25\ \rho_{D3He}$$

…implies a higher convergence for pure D_2 fills over 1 to 1 D^3He fills:

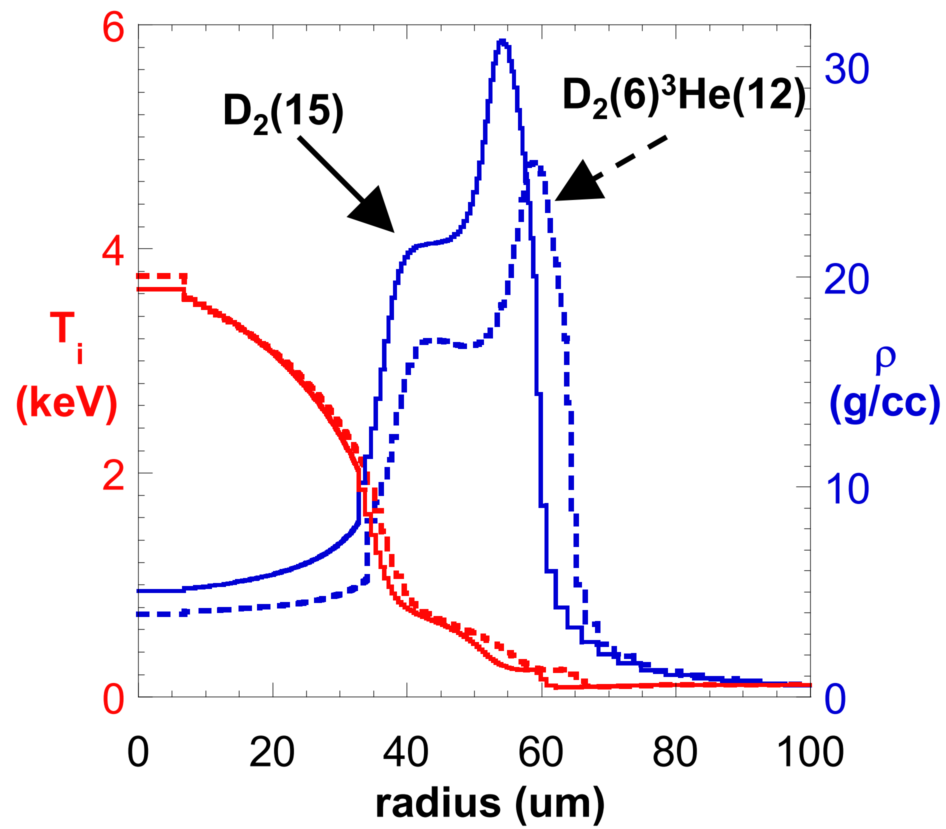
$$C_{r,D2} = 1.08\ C_{r,D3He}$$

1D simulations suggest that shock "preheating" leads to lower convergence for lower D_2 fraction

Lilac - Peak Shock Burn



Lilac - Peak Compression Burn



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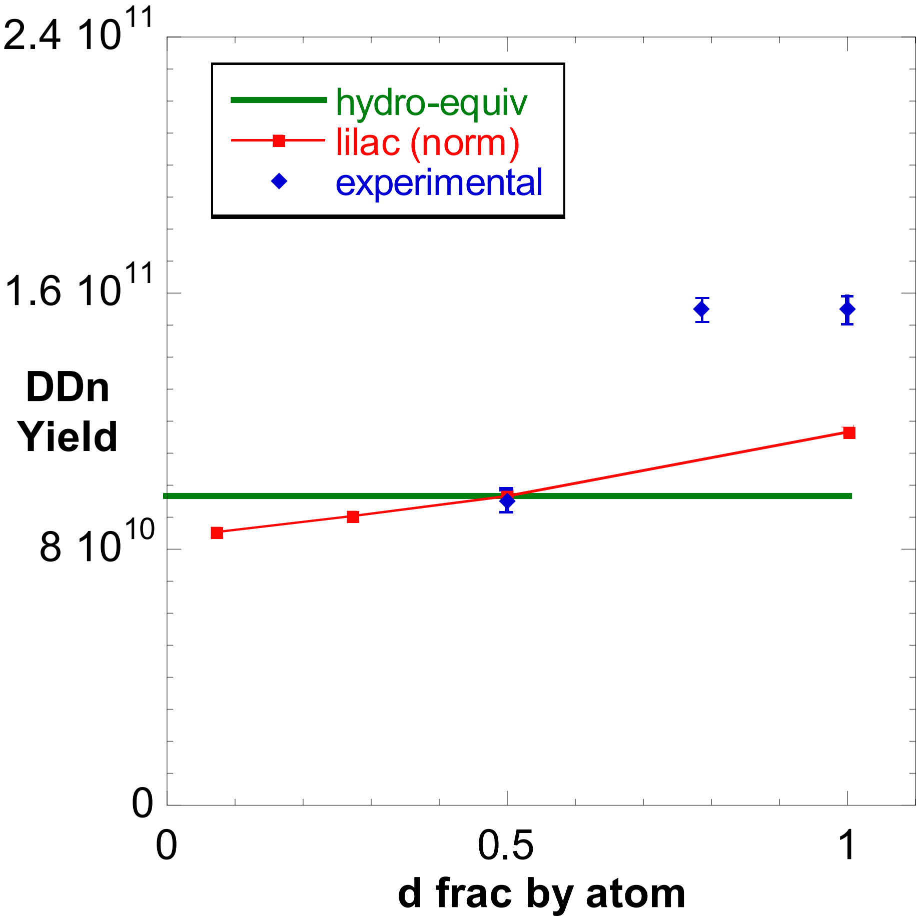

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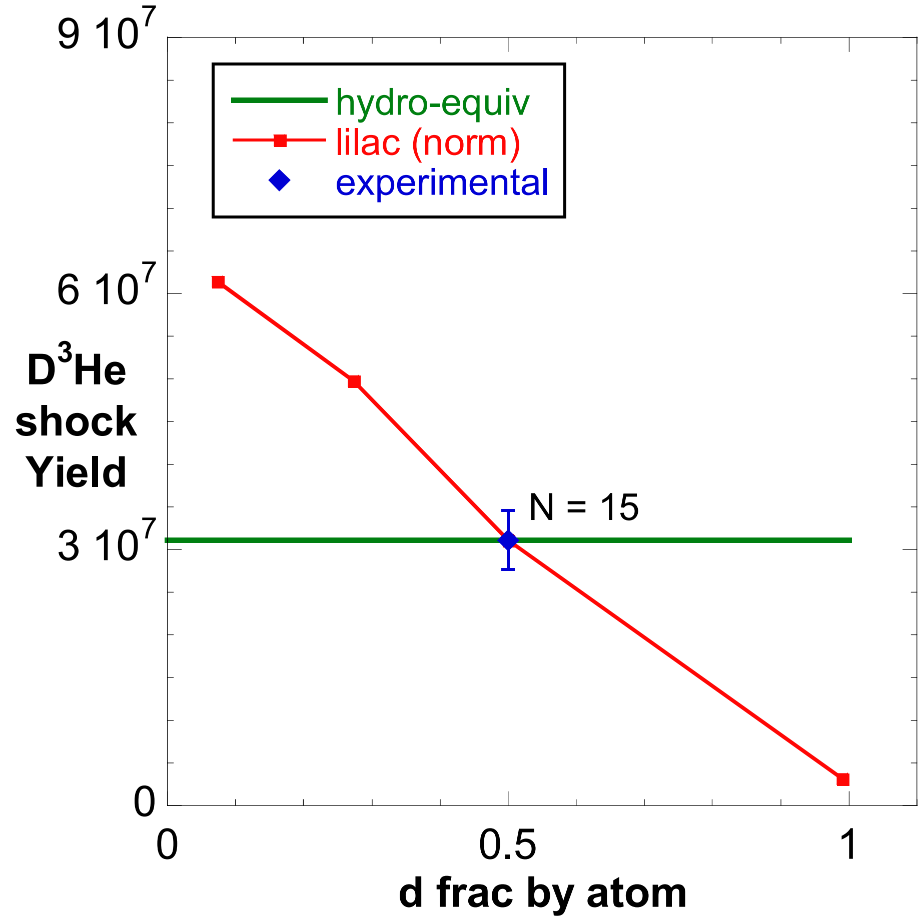

Nuclear measurements are a sensitive probe of hydrodynamic equivalence

- An investigation of hydrodynamic equivalence using different fill compositions was carried out using a mixture of D_2 and ^3He
- Observed trends of DD-n and D^3He yields differed significantly from those anticipated based on hydrodynamic-equivalence and on 1-D simulations
- The yield trends are not caused by a trend in ion temperature
- An 8% difference in the convergence ratio is sufficient to explain the experimental yield scaling