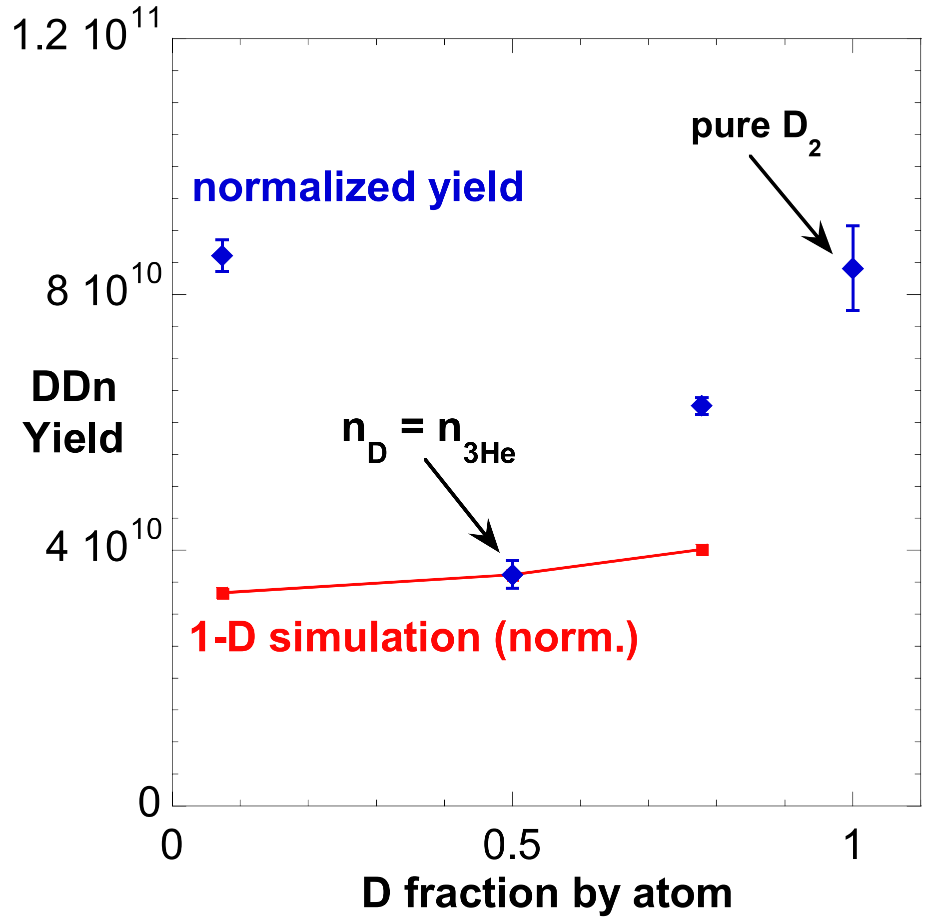
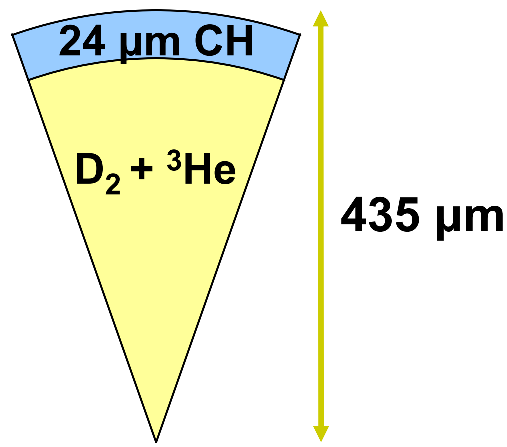
# Testing Hydrodynamic Equivalence of Implosions with different $D_2$ + $^3He$ mixtures

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# Contributors

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# Summary

- An investigation of hydrodynamic equivalence was carried out using implosions with different mixtures of $D_2$ and $^3He$

- The experimental yield scaling was found to deviate from that expected assuming hydrodynamic equivalence

- A similar deviation was seen over a wide range of conditions, including:

    - Simultaneously for D-D and D-$^3$He nuclear reactions
    - Implosions with different shell thicknesses
    - Implosions with different fill pressures
    - For shock burn and compression burn

- This deviation is not explained by measurements of ion temperature and initial fill composition

# Hydrodynamically equivalent fuels have the same mass density and total particle density

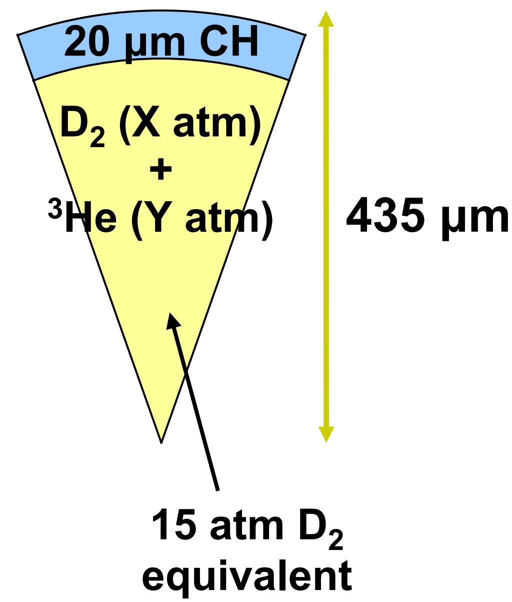
Fill pressures for different fill compositions are chosen such that on full ionization the following are equivalent:

- ρ
- $(n_i+n_e)$
- EOS

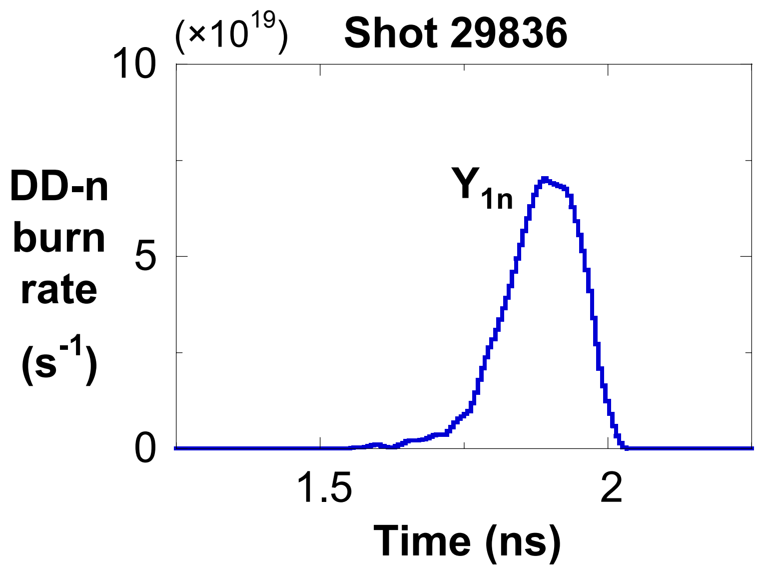
For $D_2(X)^3He(Y)$ filled capsules, hydro-equivalence to a $D_2(15)$ capsule requires:

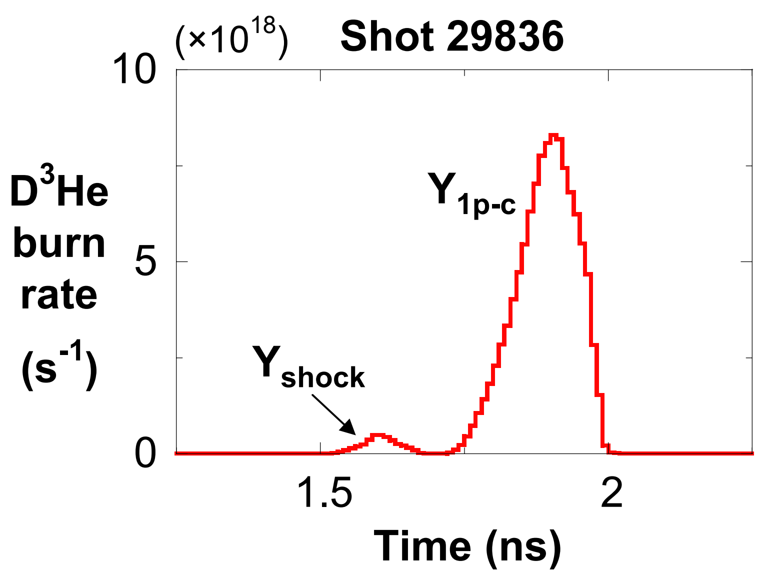
$$\frac{X}{15atm}+\frac{Y}{20atm}=1$$

OMEGA target
23 kJ, 1 ns
square pulse

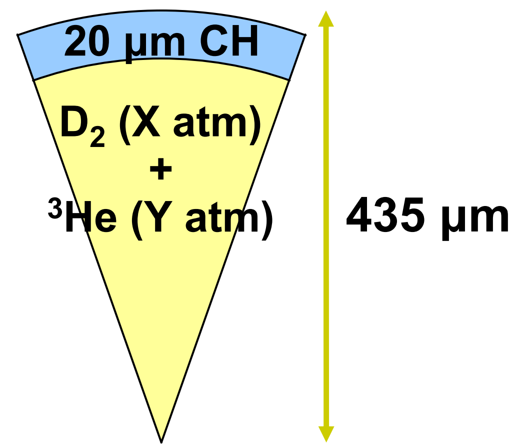


# Yields from two nuclear reactions can be used to diagnose OMEGA implosions




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



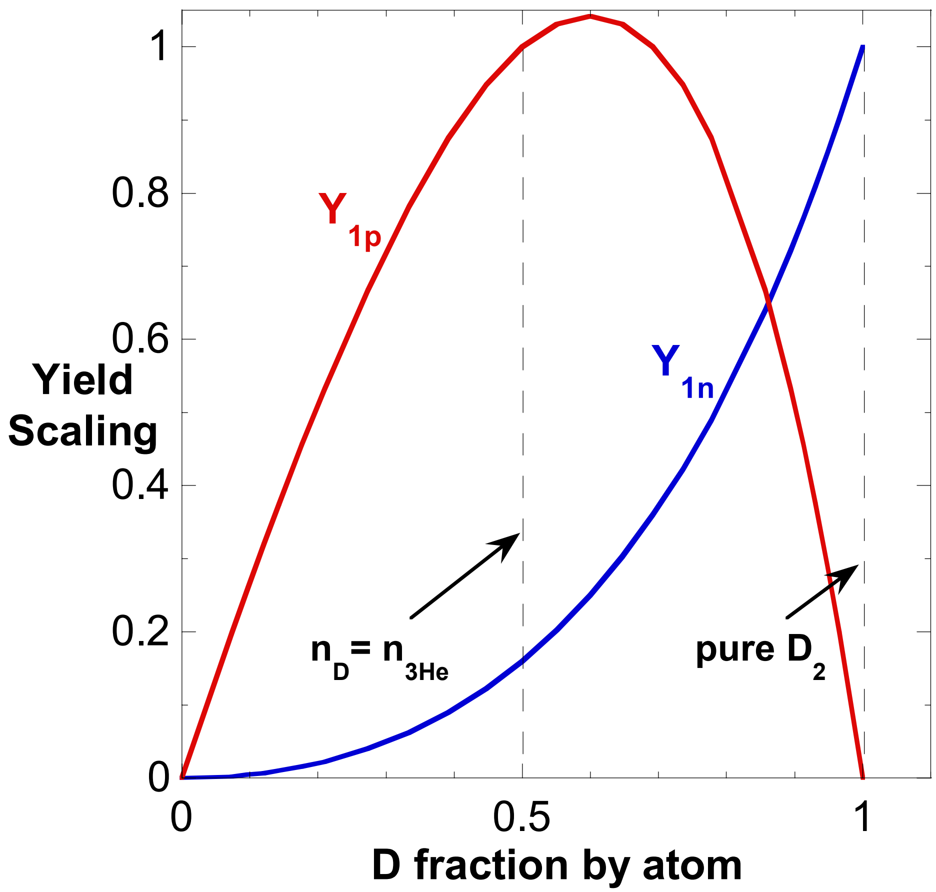

$D + {}^3He \Rightarrow {}^4He(3.6) + p(14.7\ MeV)$

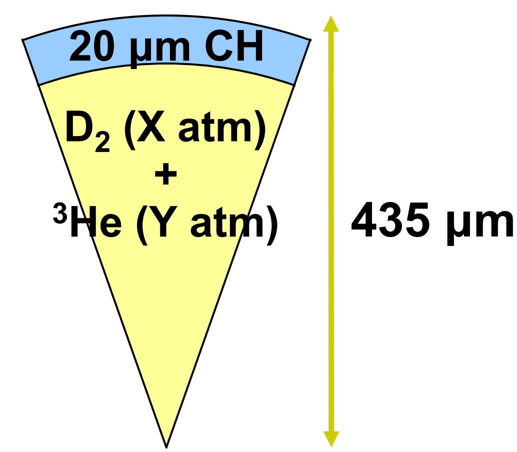
# DD-n and D³He reaction yields scale differently with fuel composition

**Anticipated yield scaling:**

$Y_{1n} \propto X^2$

$Y_{1p} \propto X\ Y$



# All yields will be normalized according to the scaling anticipated by the composition

**Anticipated yield scaling:**

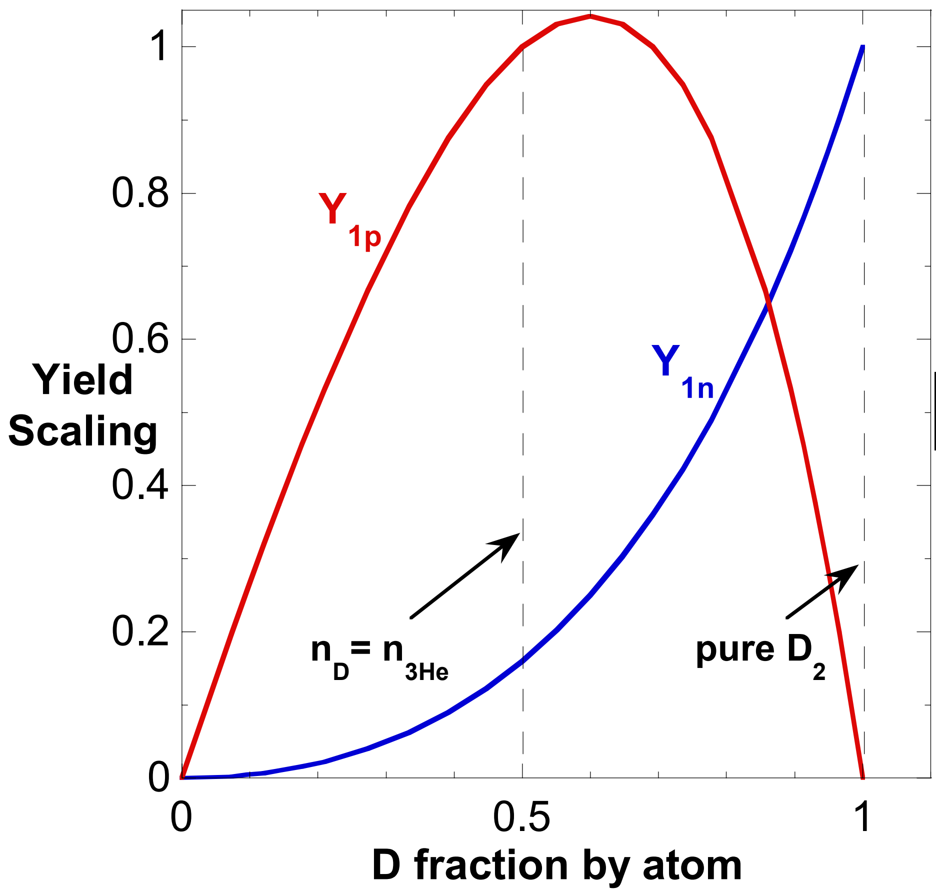
$Y_{1n} \propto X^2$

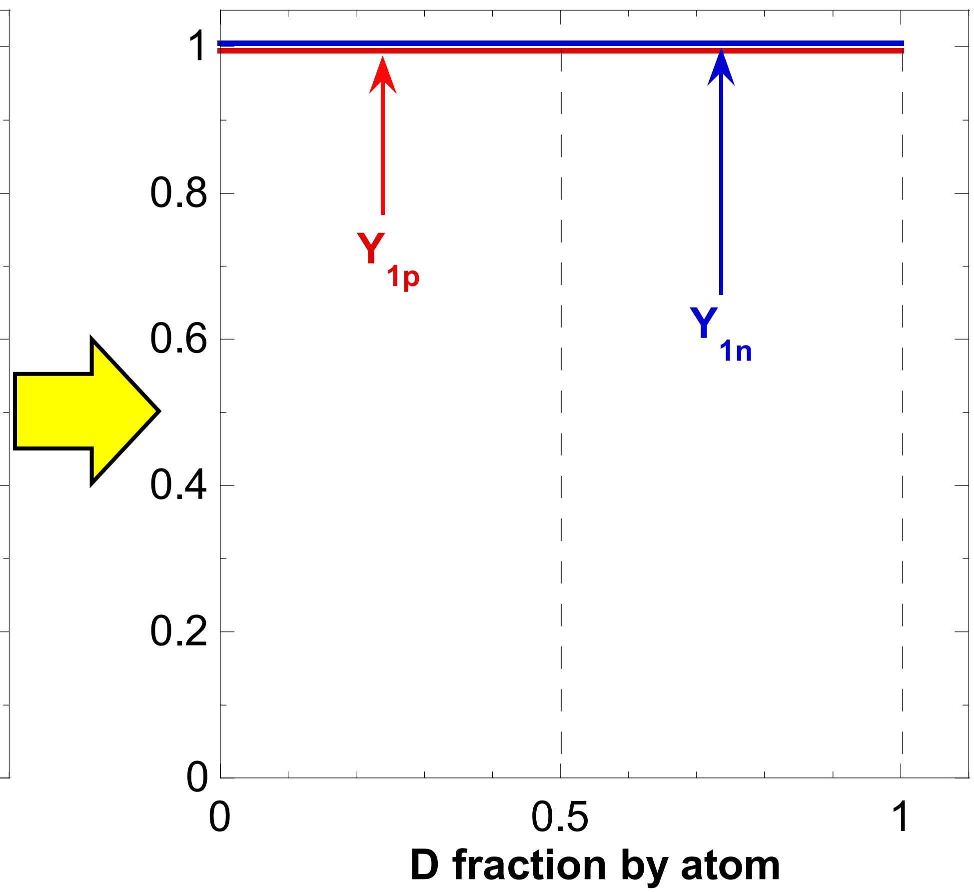
$Y_{1p} \propto X\, Y$

**Normalized yield scaling:**

$Y_{1n\text{-norm}} = Y_{1n}(X_0/X)^2$

$Y_{1p\text{-norm}} = Y_{1p}(X_0Y_0)/(XY)$

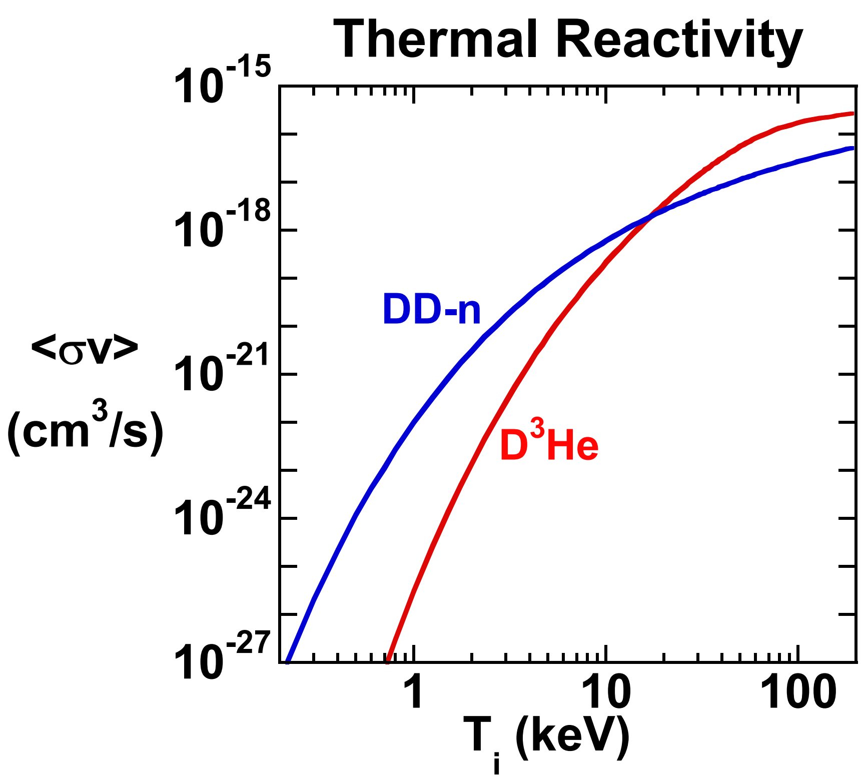


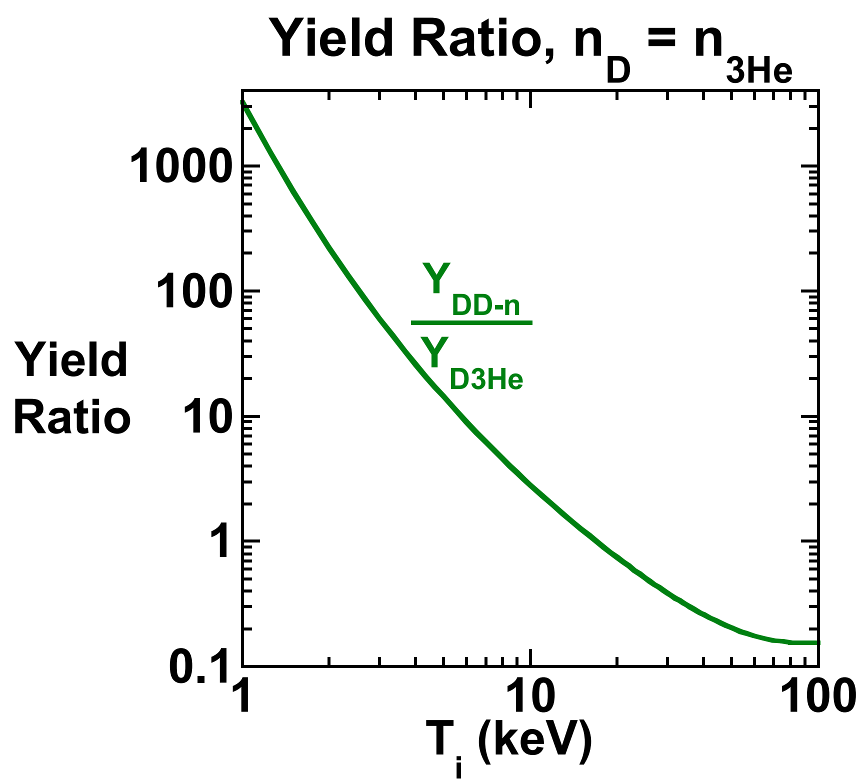



# The ratio of yields can be used to estimate a burn-averaged ion temperature

$D + {}^3He \rightarrow {}^4He\ (3.6) + p\ (14.7\ MeV)$

$D + D \rightarrow {}^3He\ (0.8) + n\ (2.45\ MeV)$

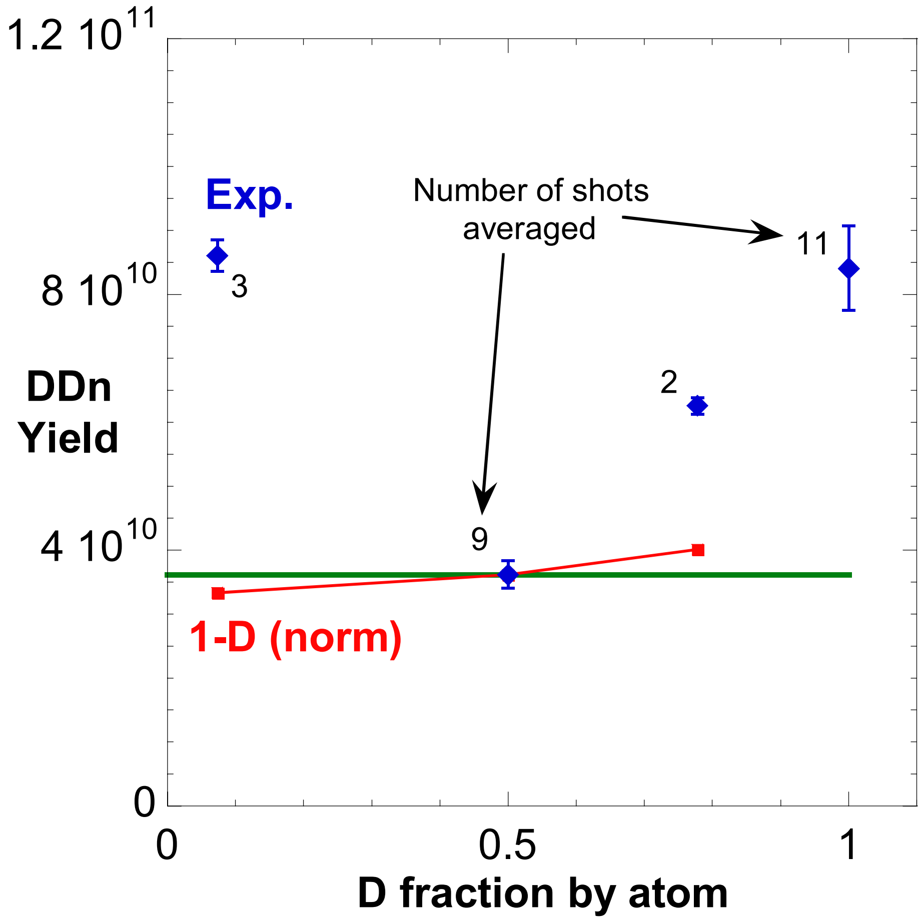


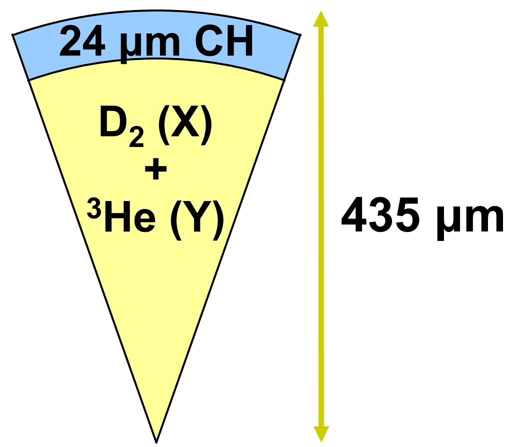



# DD-n experimental yield does not scale as expected based on hydro-equivalence

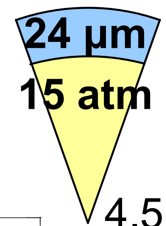
## DD-n Yield (norm)

$Y_{1n\text{-}norm} = Y_{1n}\,(15\ atm/X)^2$



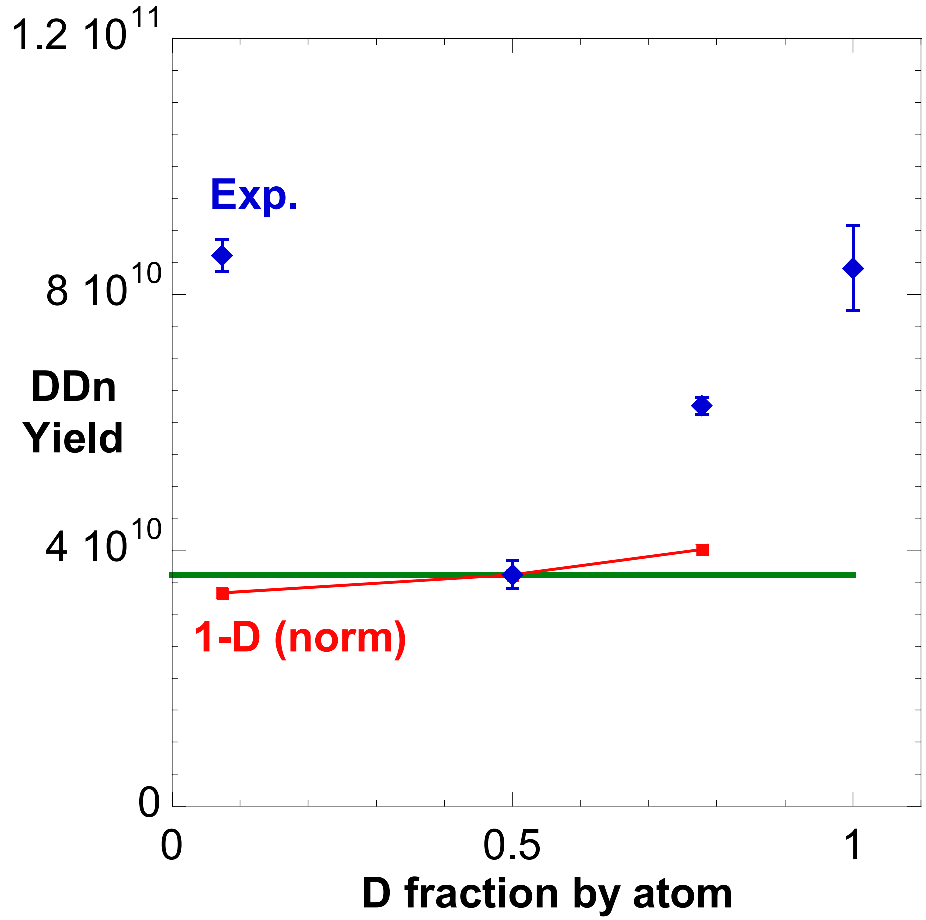



# $D^3He$ compression yield also deviates from hydro-equivalent scaling



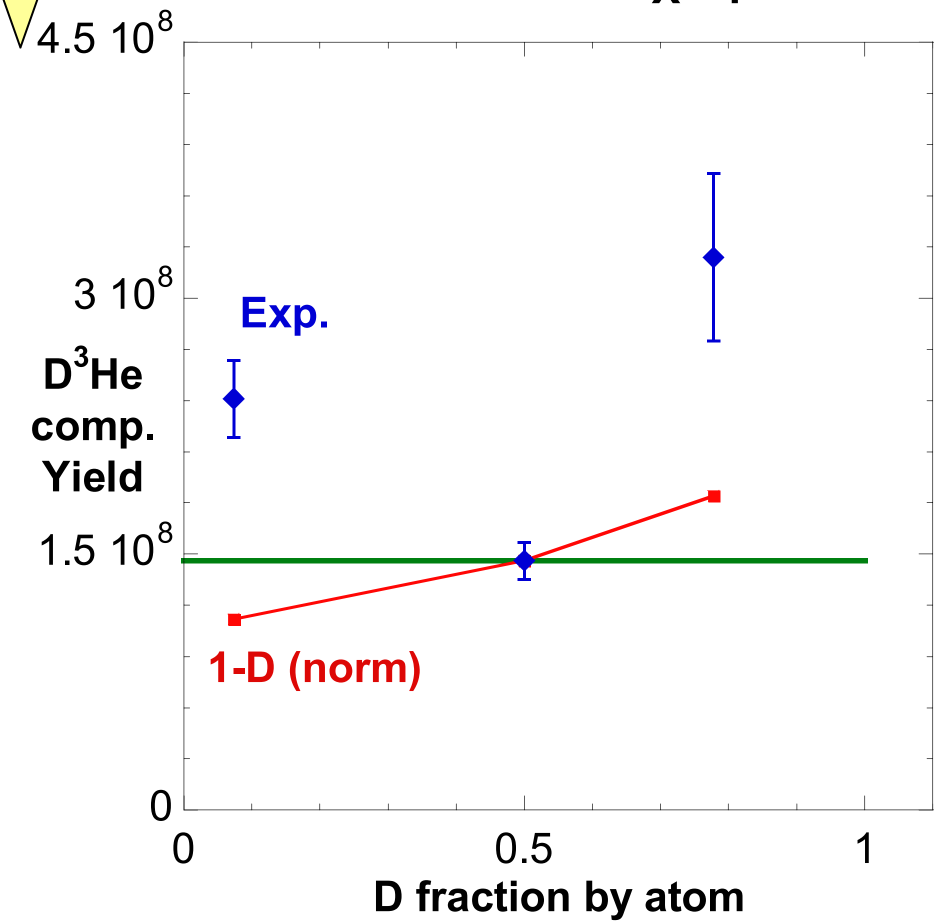

## DD-n Yield (norm)

$$Y_{1n\text{-}norm} = Y_{1n}\,(15\ \text{atm}/X)^2$$

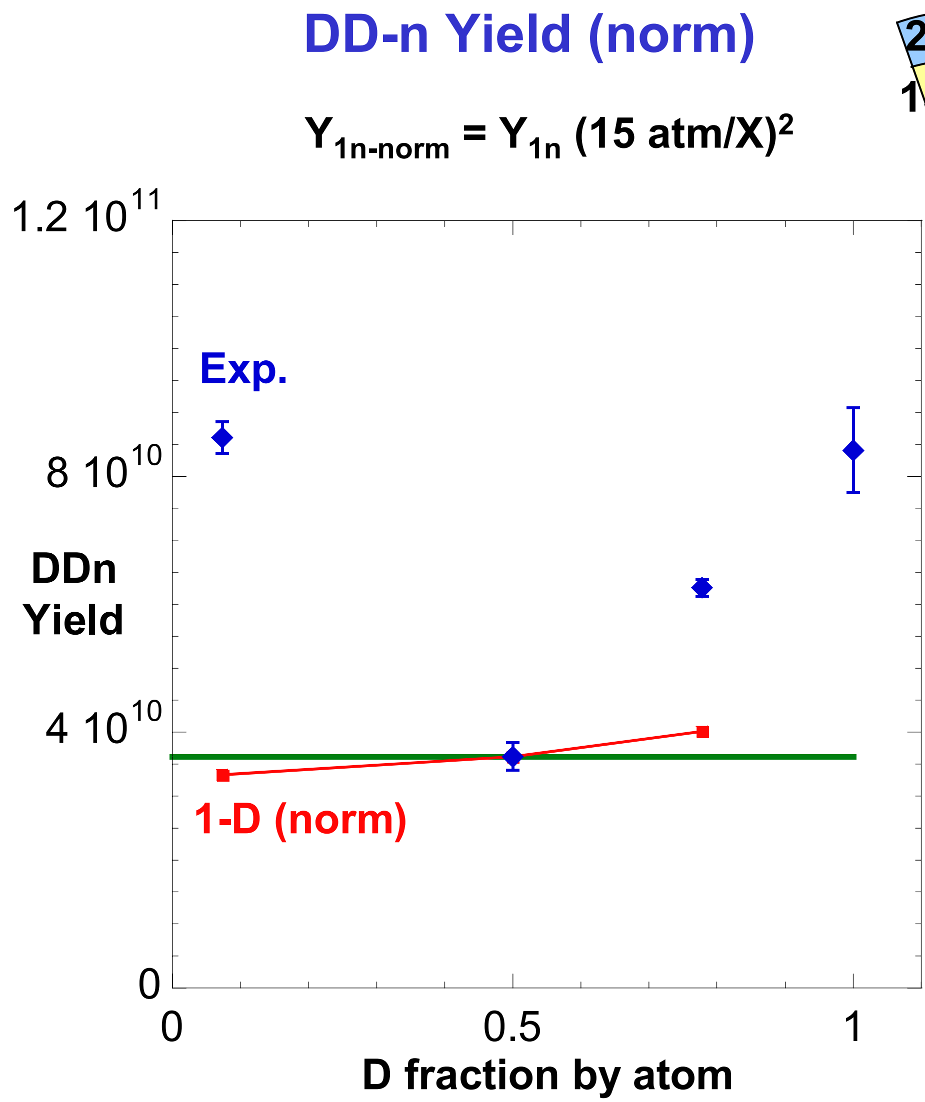


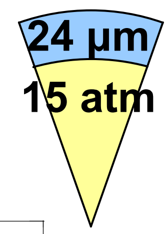

## $D^3He$-p Yield (norm)

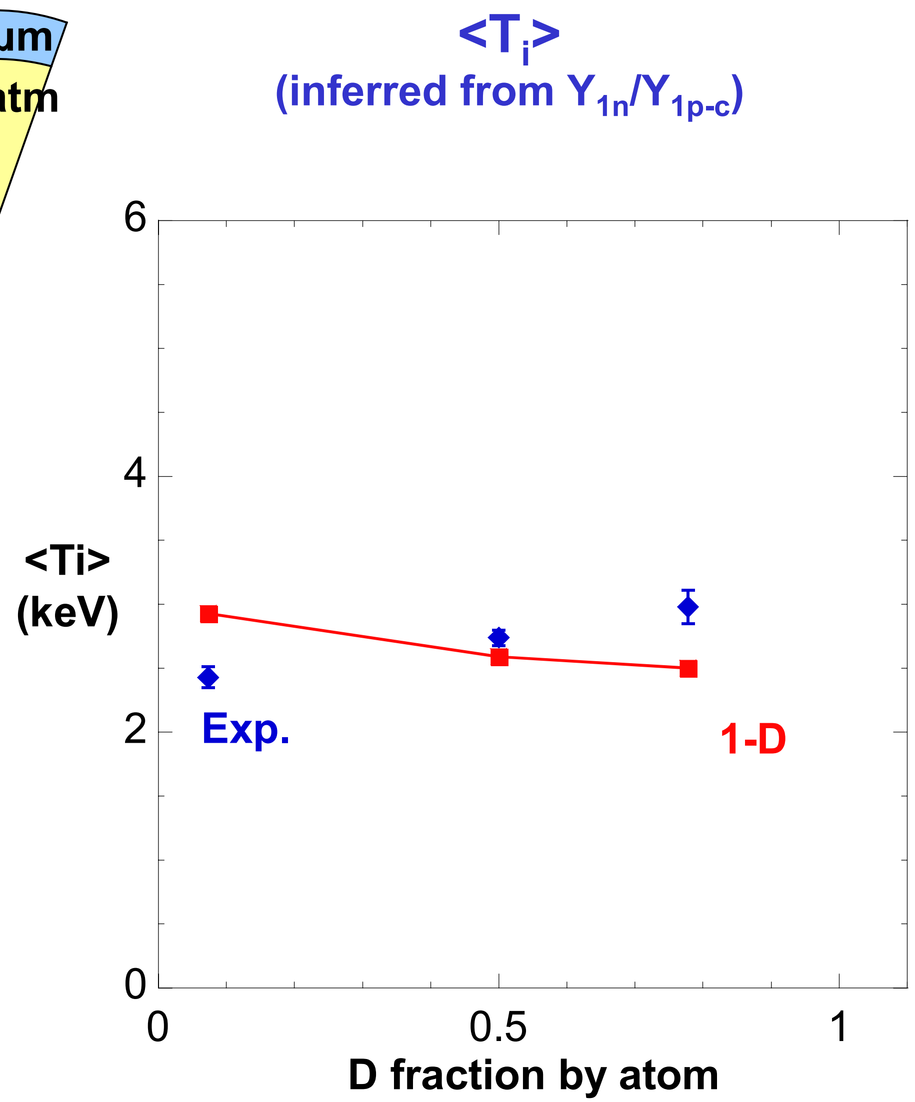
$$Y_{1p\text{-}norm} = Y_{1p\text{-}c}\,\frac{6\ \text{atm} * 12\ \text{atm}}{X * Y}$$



# Yield scaling deviation is not explained by ion temperature measurements



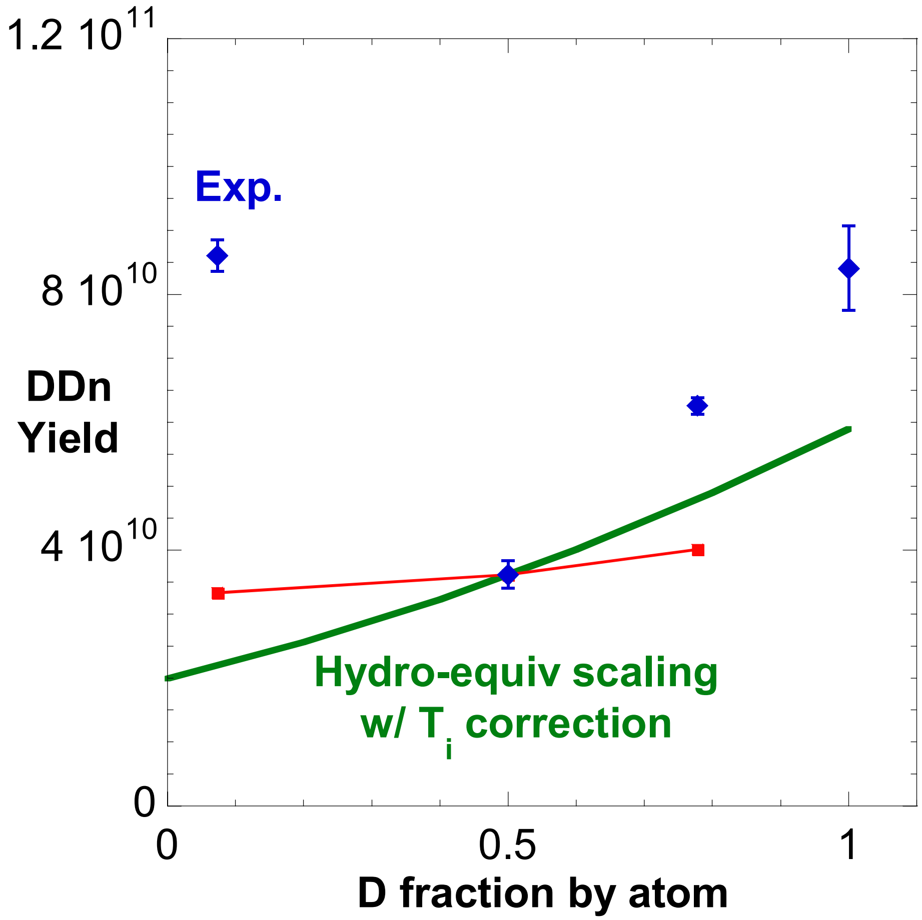



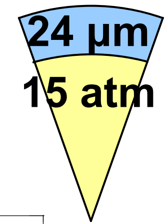



# Yield scaling deviation is not explained by ion temperature measurements

## DD-n Yield (norm)

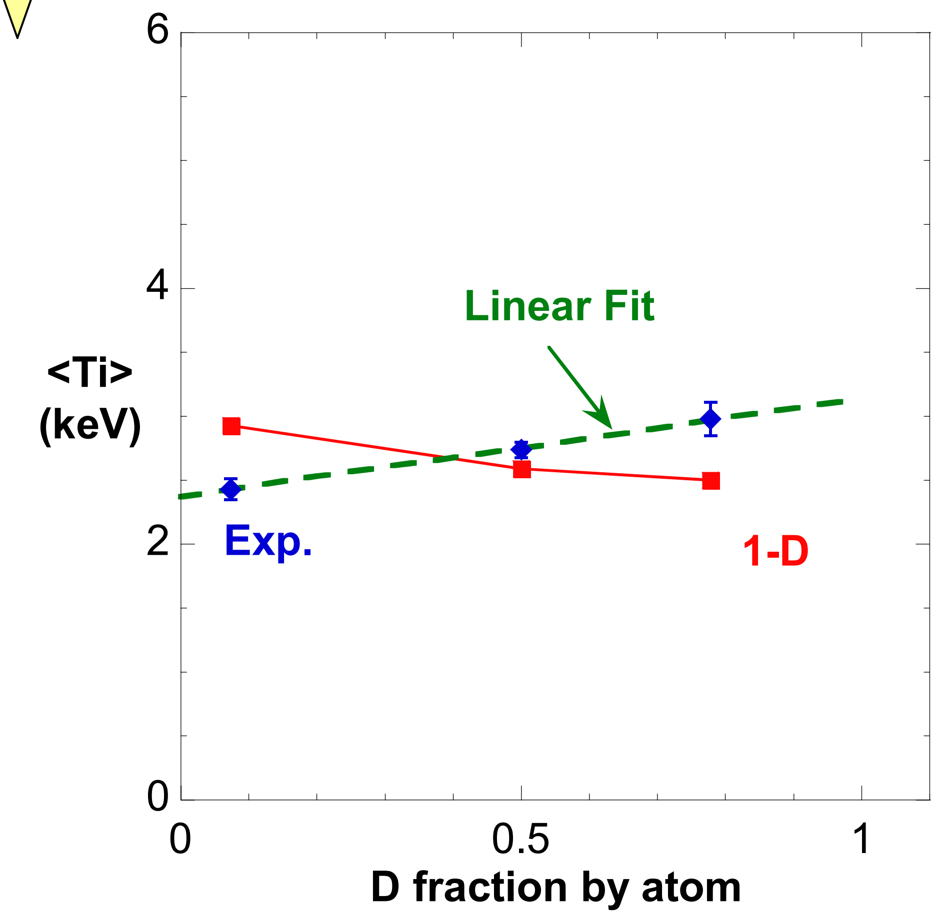
$Y_{1n\text{-}norm} = Y_{1n}\,(15\ \text{atm}/X)^2$



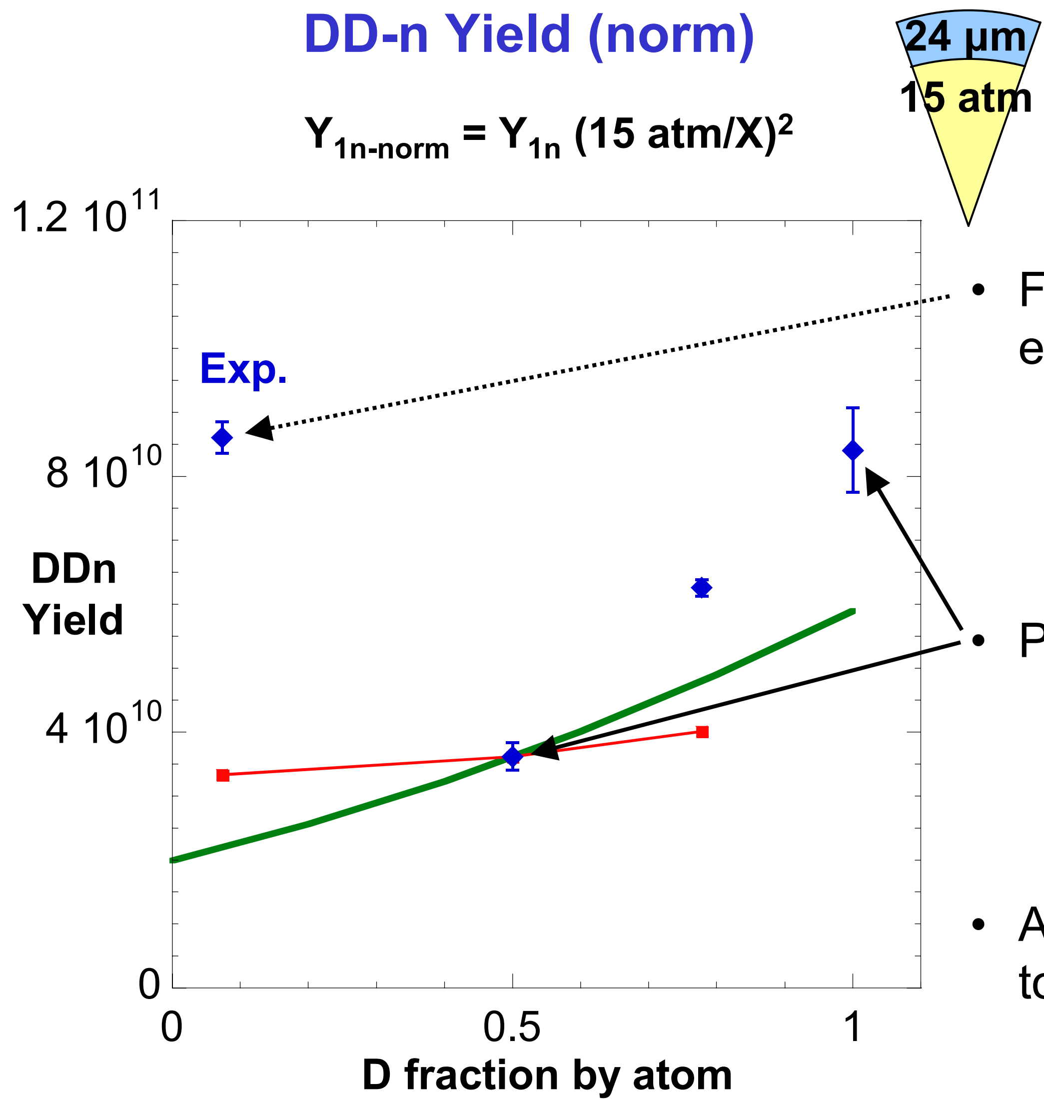




## $\langle T_i \rangle$

(inferred from $Y_{1n}/Y_{1p\text{-}c}$)

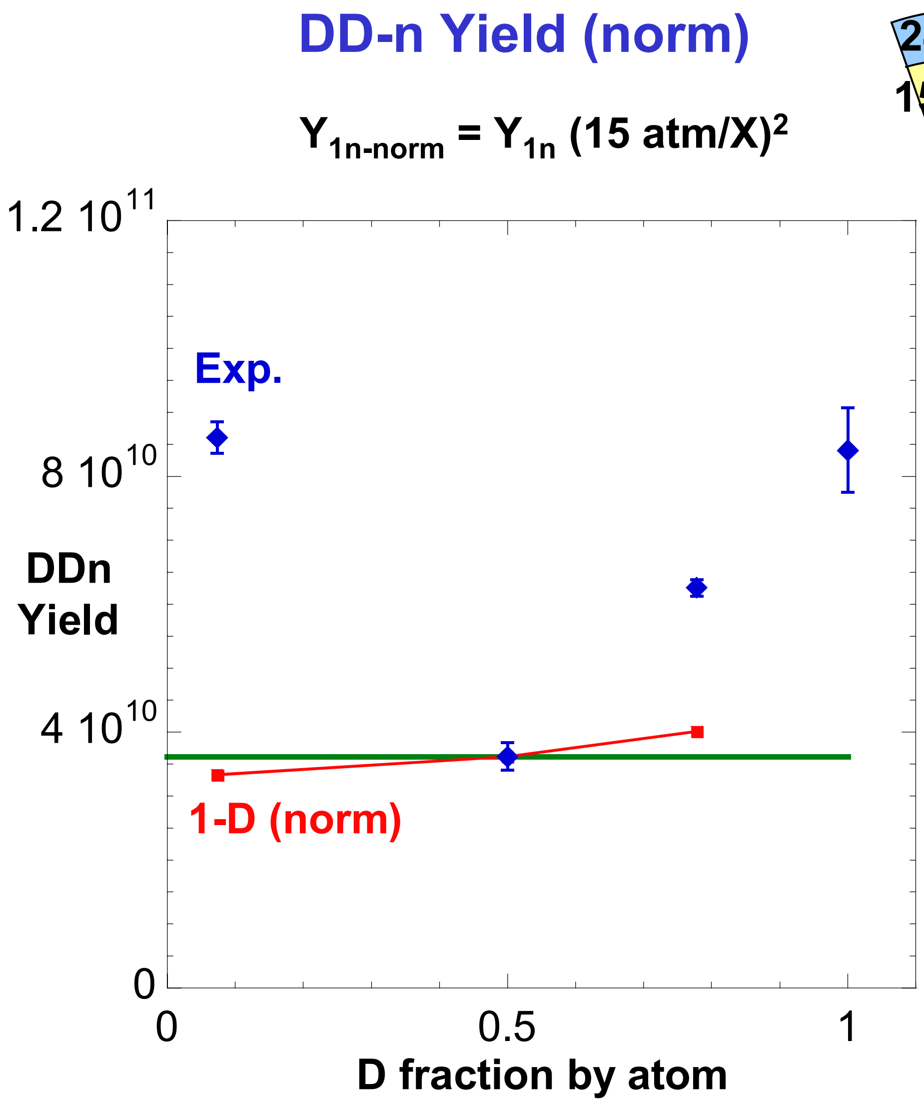


# Yield scaling deviation is not explained by a fill composition error

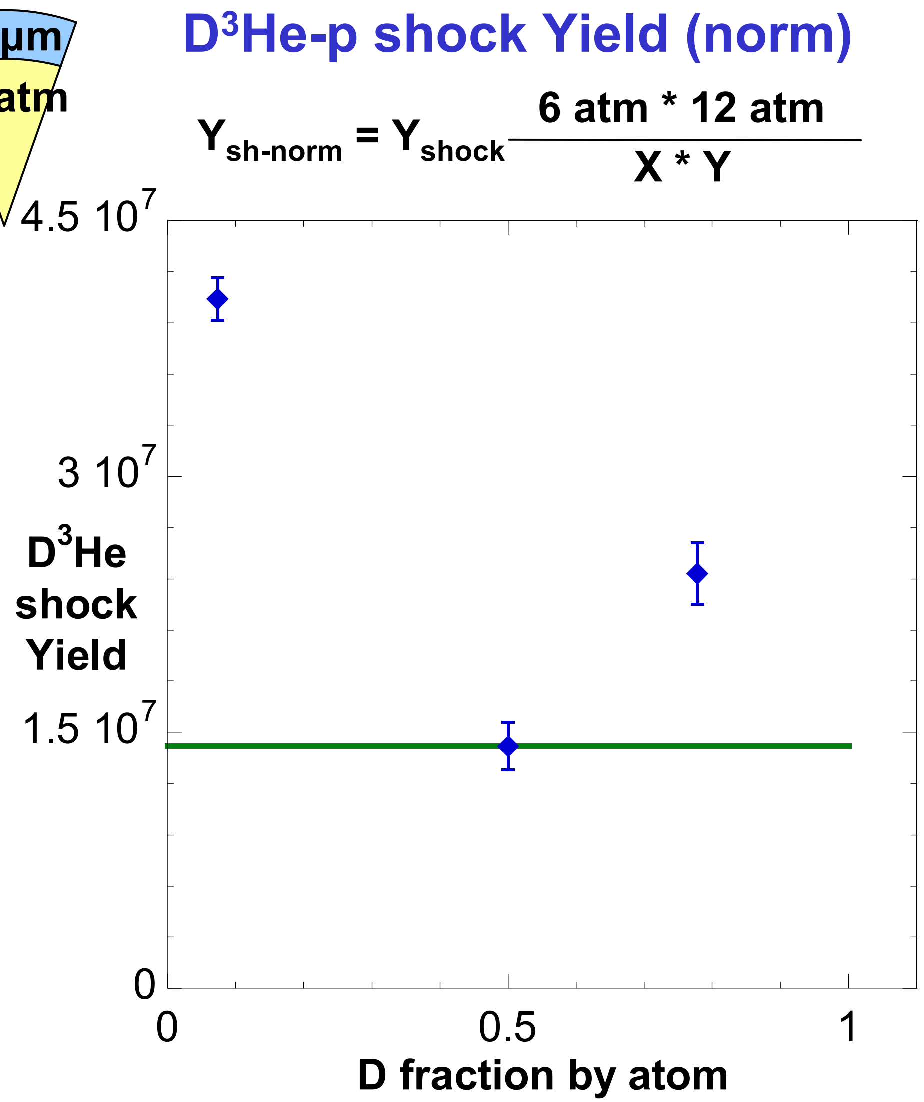



- Fill composition error ≈ 1-2% -- but fill error must be 50% to follow trend
- Premixed: composition error ~$10^{-4}$
- A different composition error is needed to explain $Y_{1n}$ and $Y_{1p}$ data

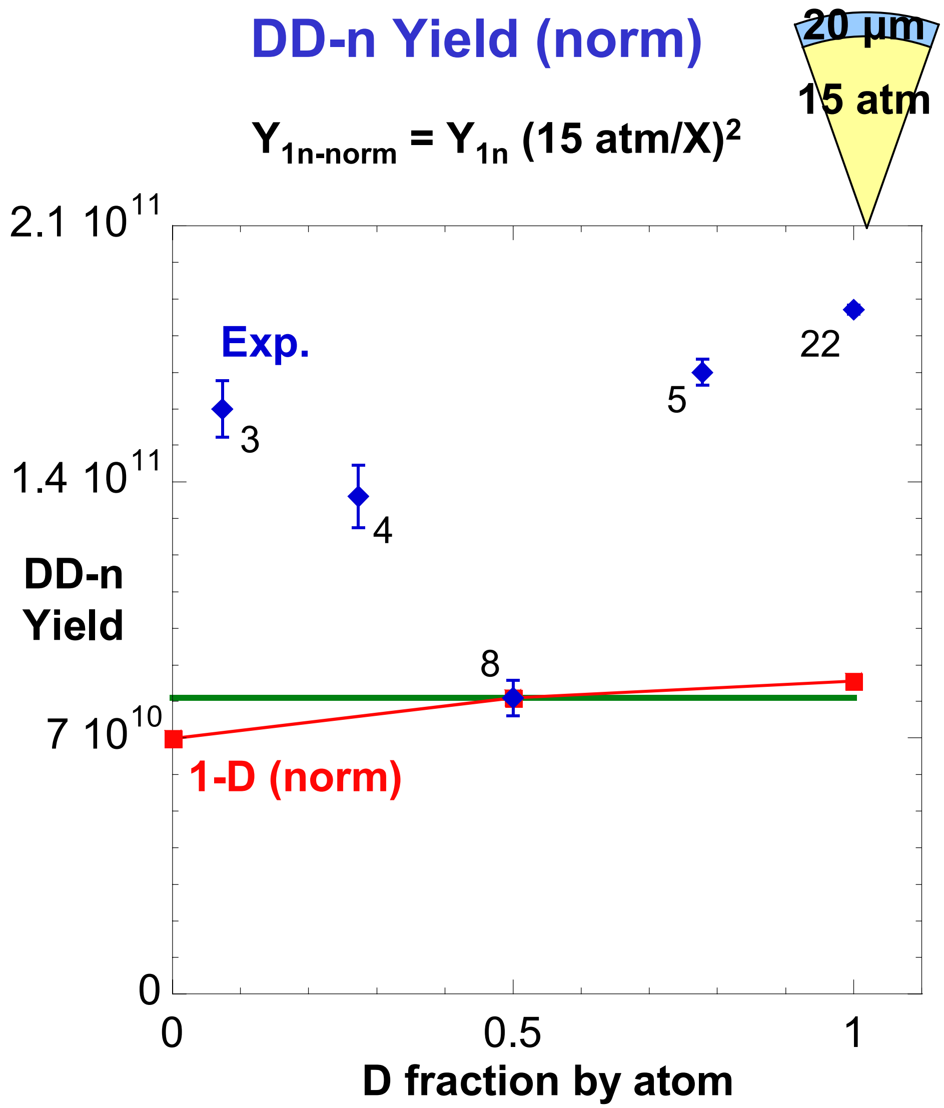
# Yield scaling deviation is seen for shock burn and compression burn

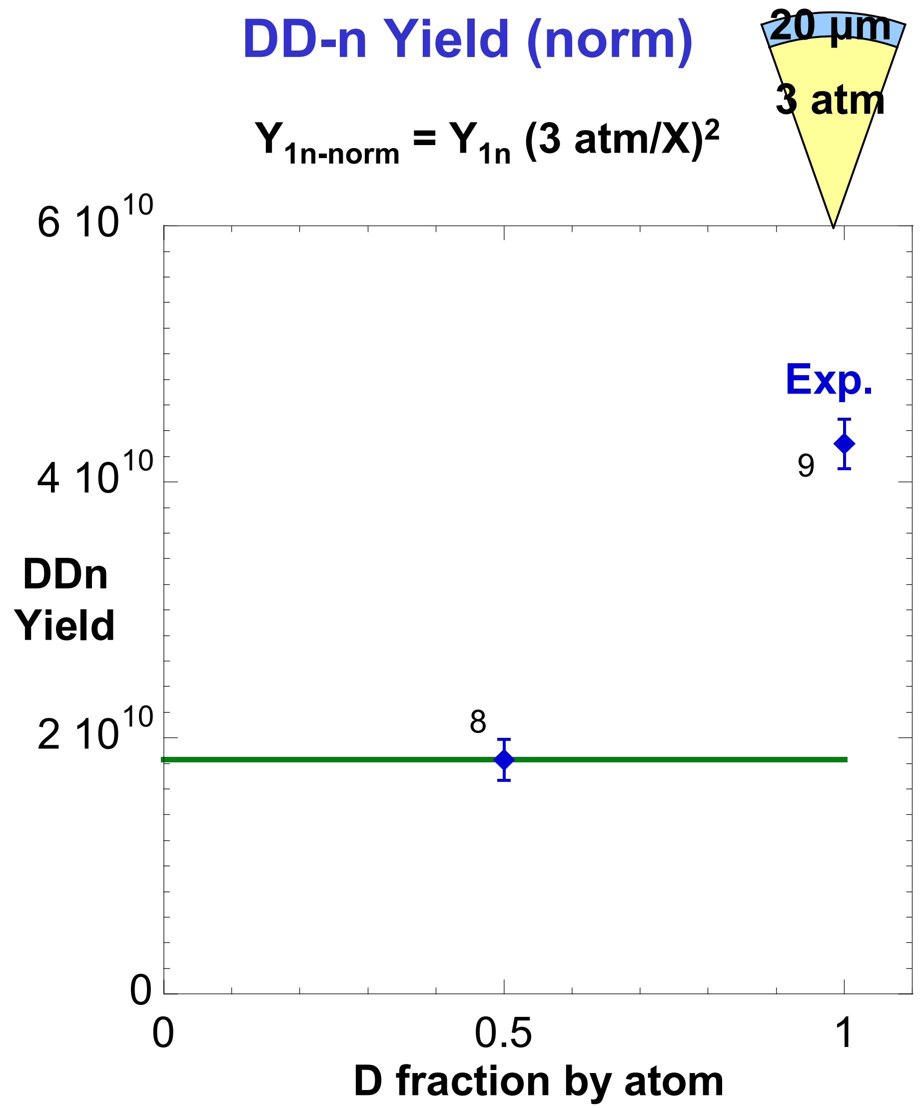






# Yield scaling deviation is also seen for thinner shells and for lower pressures



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