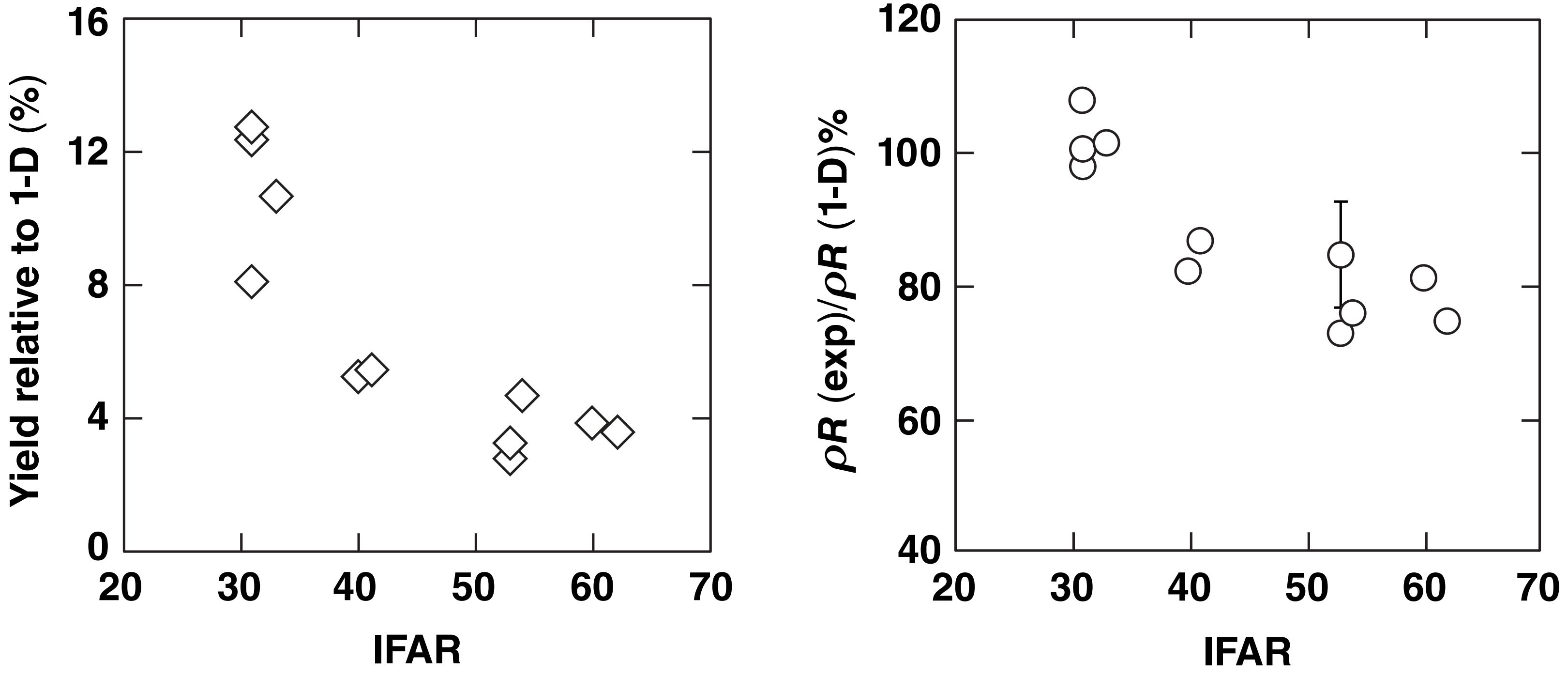
The Effect of Nonuniformity on Direct-Drive Plastic-Shell Implosions on the OMEGA Laser

Triple-Picket Warm CH Implosions



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Summary

Near 1-D areal densities are obtained for in-flight aspect ratio ~31 in warm-CH implosions

- In-flight aspect ratio (IFAR)[1], the ratio of shell radius to thickness, is an important parameter characterizing nonuniformity growth and the minimum energy required for ignition
- IFAR is varied in triple-picket, warm-plastic implosions by changing picket energies and timings with the goal of identifying the maximum allowed IFAR for direct drive
- Target performance degrades with increasing IFAR
  - neutron yield decreases by a factor of ~2.5 when IFAR is increased to 31 from 60
  - the fraction of areal density recovered in the experiment also decreases significantly when IFAR is increased

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[1] J. D. Lindl, *Inertial Confinement Fusion*, (Springer-Verlag, New York 1998).

Collaborators

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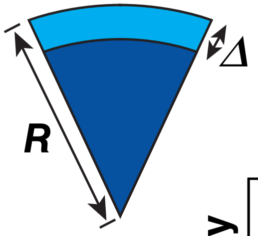
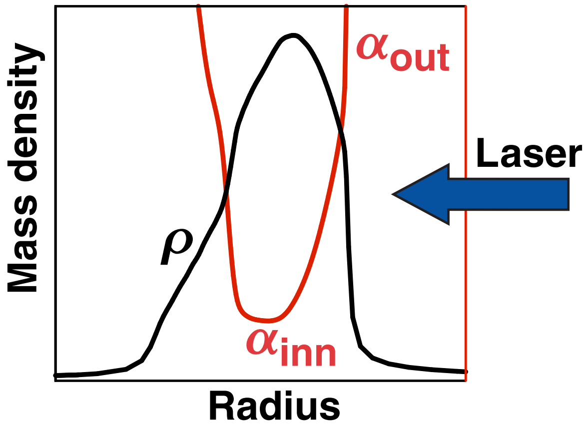
IFAR is an important parameter characterizing target performance for hot-spot ignition

$$\text{IFAR} = \frac{R}{\Delta} = \frac{60\left(V_{\text{imp}} \big/ 3 \times 10^{7}\,\text{cm/s}\right)^{2}}{\langle \alpha \rangle^{0.6}\, I_{15}^{0.27}}$$





- IFAR is defined at 1/3rd distance traveled (~100 μm) during acceleration

- The minimum energy for ignition

$$E_{\text{min}}\,(\text{kJ}) = 1.3 \times 10^{7} \left(\frac{\alpha_{\text{inn}}}{\langle \alpha \rangle}\right)^{1.8} \frac{1}{(\text{IFAR})^{3}\, I_{15}^{1.3}} \quad {}^{*}$$

- Shell stability is determined by IFAR

$$N_{\text{e}}\,(k\Delta = 1) = \gamma\left(k\Delta = 1\right)\, t \approx \sqrt{\text{IFAR}}\left[1 - \frac{0.09\,\alpha_{\text{out}}^{0.3}}{I_{15}^{0.2}}\left(\frac{\alpha_{\text{out}}}{\langle \alpha \rangle}\right)^{0.3}\right] \quad {}^{**}$$

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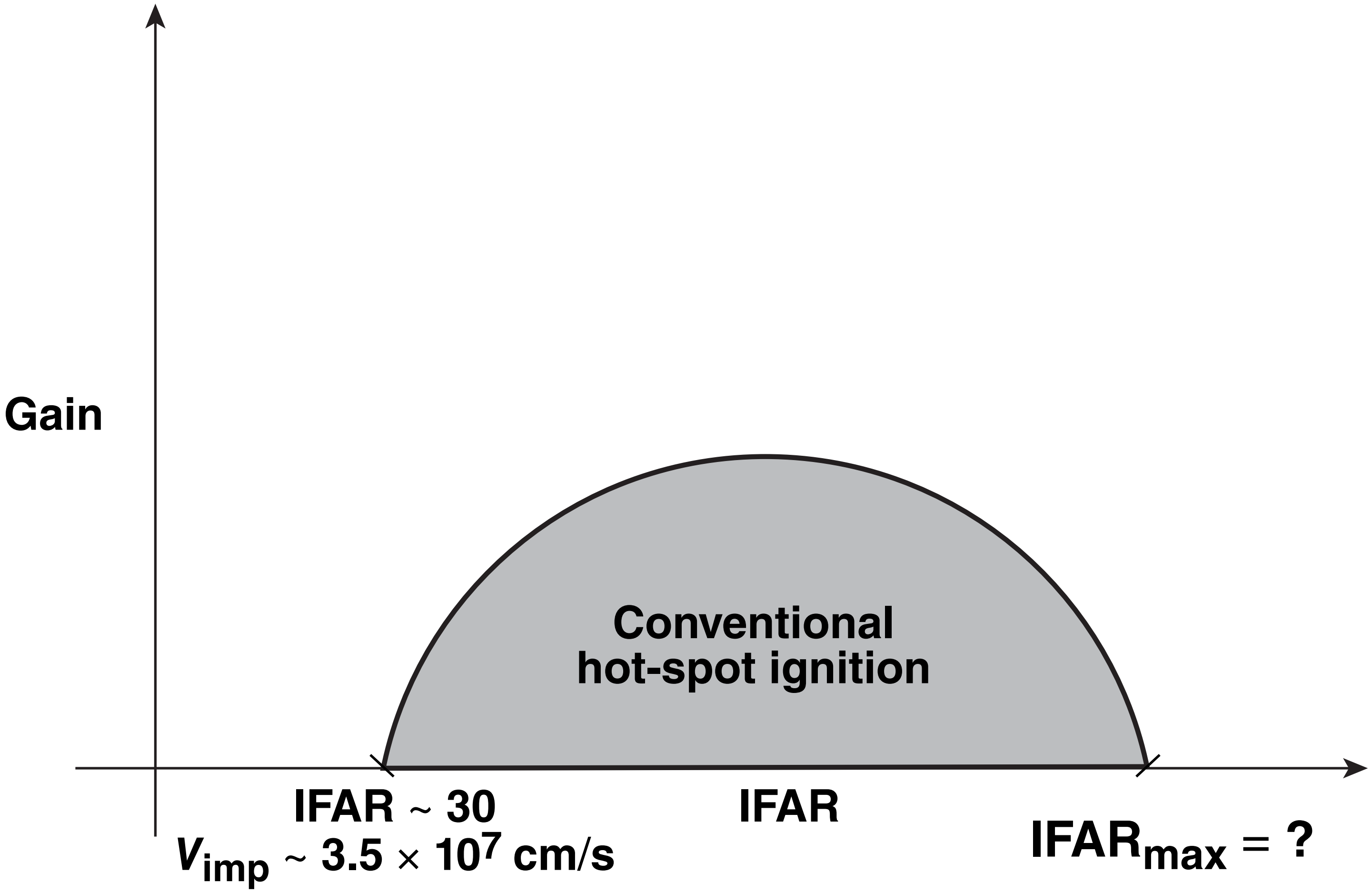
[*] M. C. Hermann *et al.*, Nucl. Fusion 41, 99 (2001).

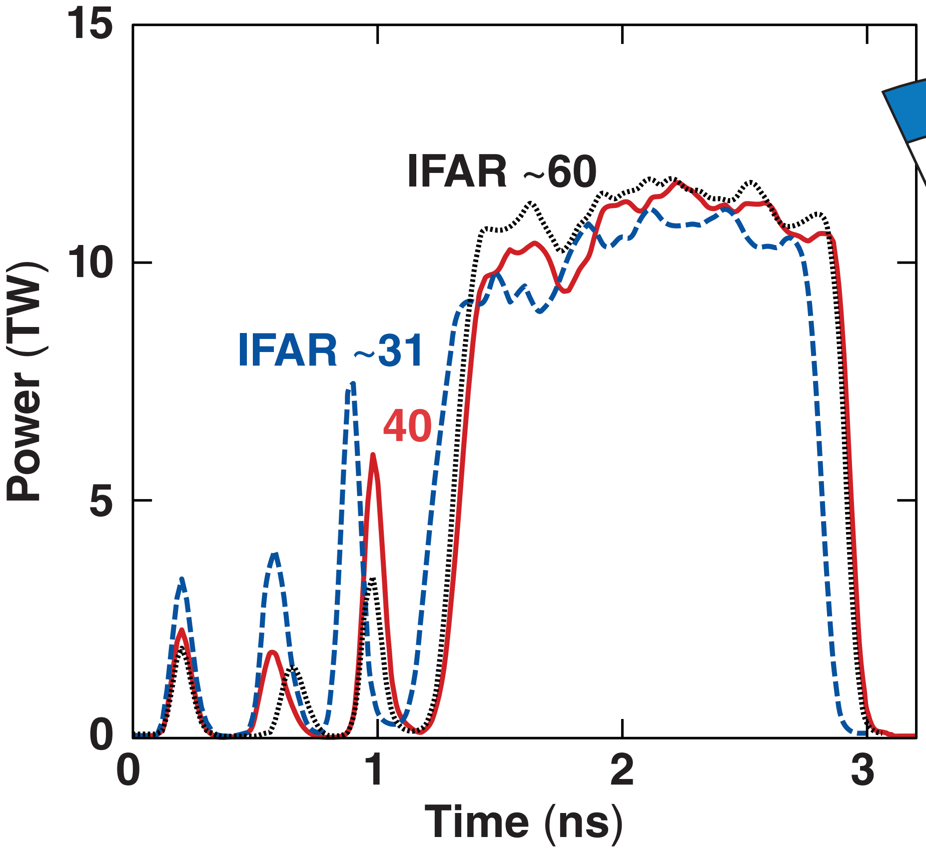
[**] C. D. Zhou and R. Betti, Phys. Plasmas 14, 072703 (2007).

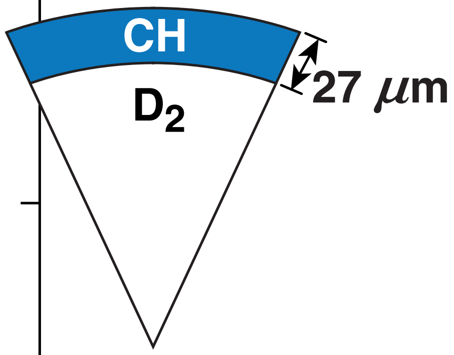
IFAR is an important parameter characterizing target performance for hot-spot ignition



IFAR is varied in warm-plastic-shell implosions by varying picket energies and timings in triple-picket laser pulse shapes

- OMEGA cryogenic implosions irradiated with triple pickets have shown near 1-D $\rho R \sim 300\ \mathrm{mg/cm^2}$ with IFAR ~ 30 and $V_{\mathrm{imp}} = 3.0 \times 10^7$ cm/s.*





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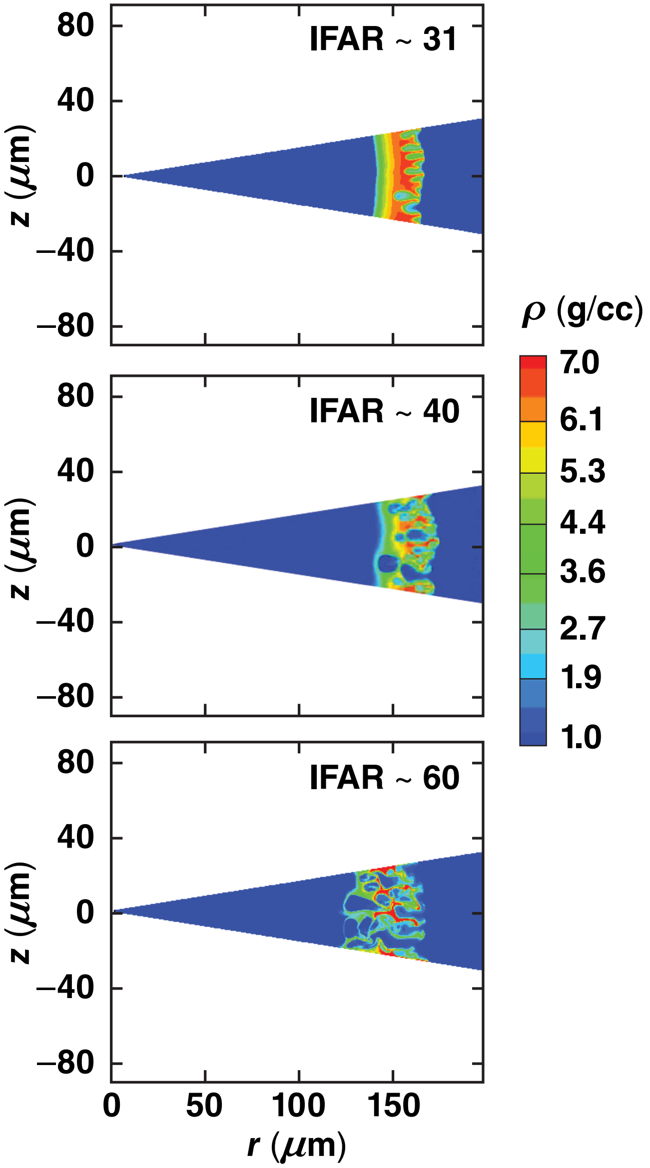
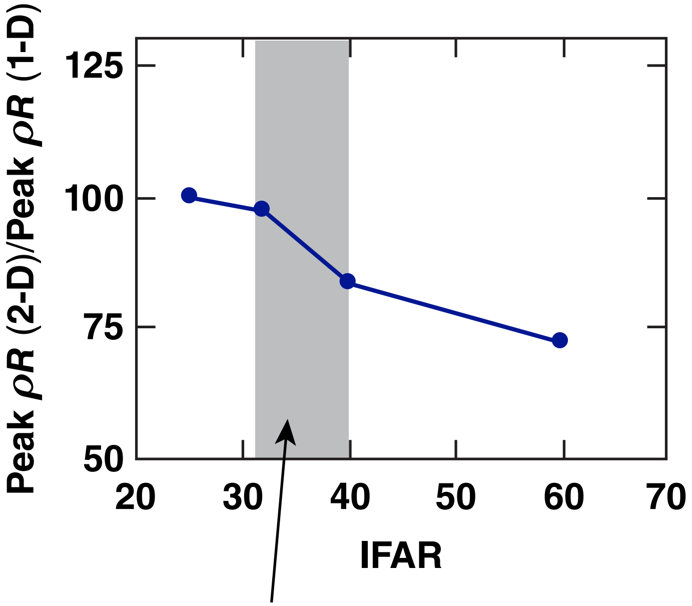
*V. N. Goncharov *et al.*, Phys. Rev. Lett. 104, 165001 (2010).

Two-dimensional *DRACO* simulations indicate the degradation of areal density for IFAR between 30 and 40



DRACO simulation
Nonuniformity seeds: laser imprint
Density contours at end of acceleration



IFAR range where ρR degradation begins

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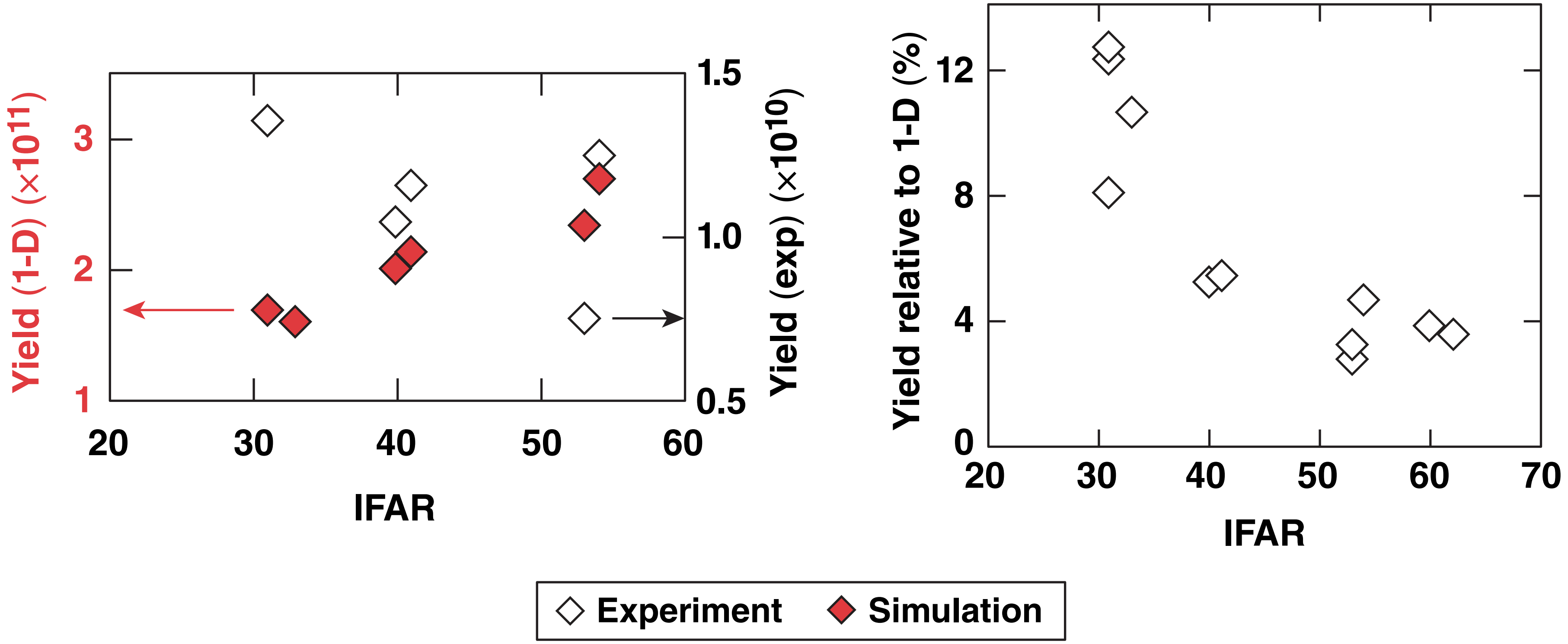
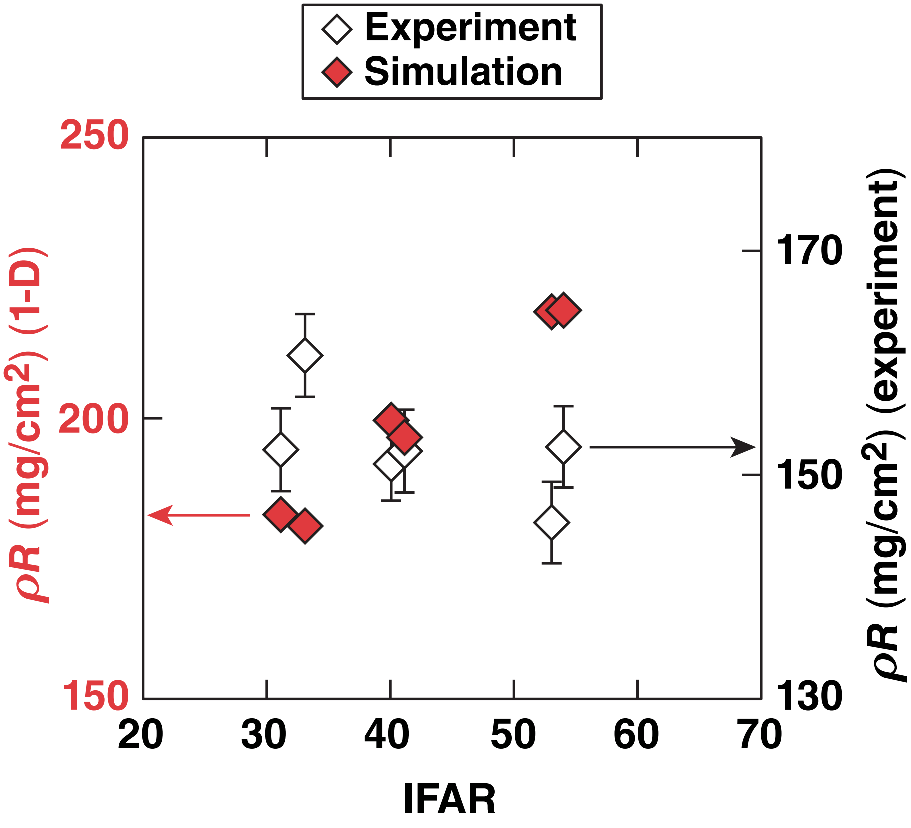
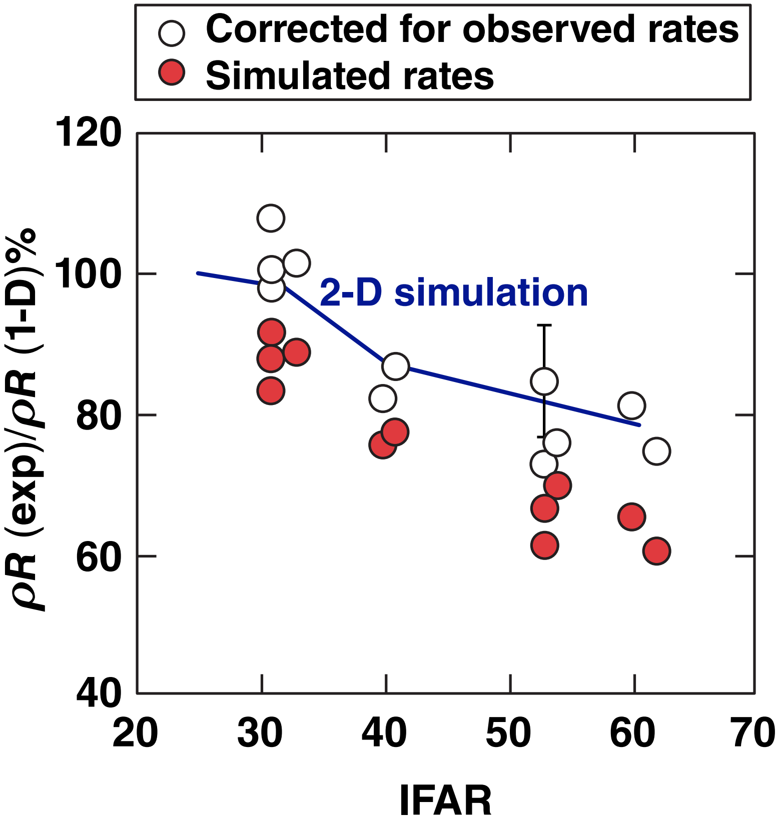
Measured neutron yield degrades significantly with increasing IFAR

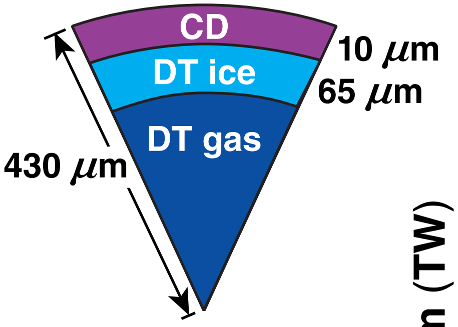


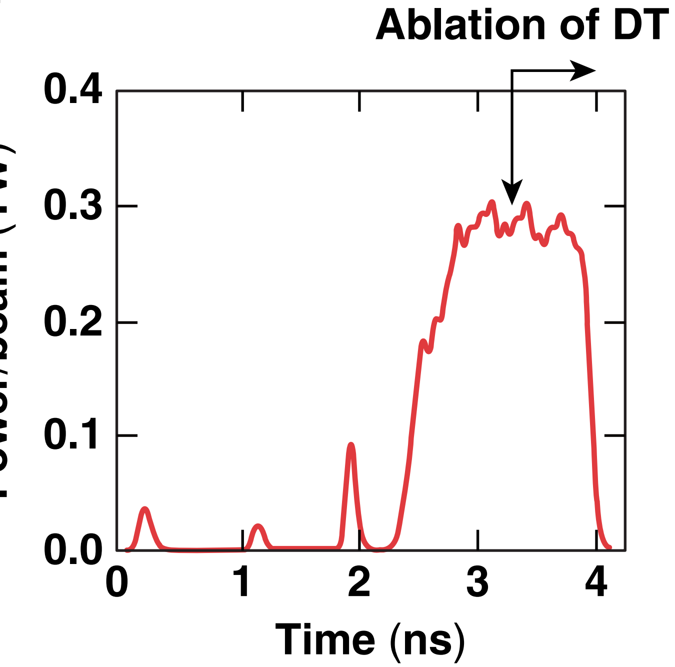
The fraction of areal density recovered experimentally decreases with increasing IFAR

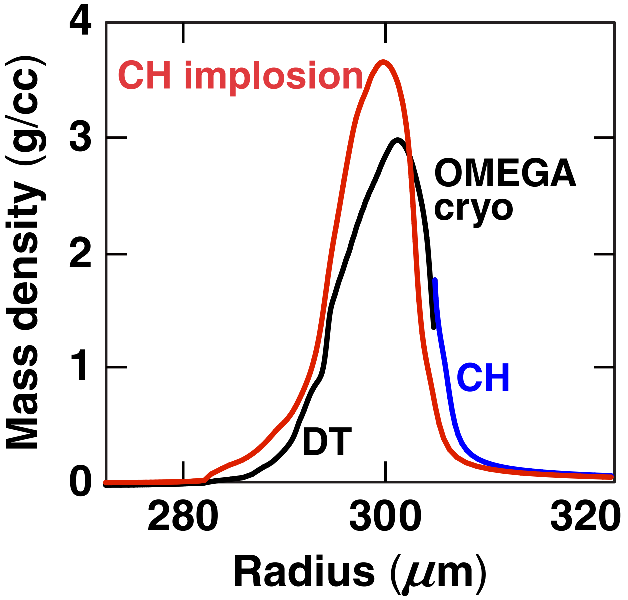




Cryogenic implosions can tolerate a higher IFAR because of the presence of DT at the ablation surface







$$N_e(k\Delta=1)=\gamma(k\Delta=1)\;t\approx\sqrt{\mathrm{IFAR}}\left[1-\underbrace{\frac{0.09\,\alpha_{\mathrm{out}}^{0.3}}{I_{15}^{0.2}}\left(\frac{\alpha_{\mathrm{out}}}{\langle\alpha\rangle}\right)^{0.3}}_{\text{Ablative stabilization}}\right]$$

$$\frac{\alpha_{\mathrm{out}}(\mathrm{DT})}{\alpha_{\mathrm{out}}(\mathrm{CH})}\sim 1.6$$

$$\mathrm{IFAR(DT)}\sim 1.25\times\mathrm{IFAR(CH)}$$

Summary/Conclusions

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