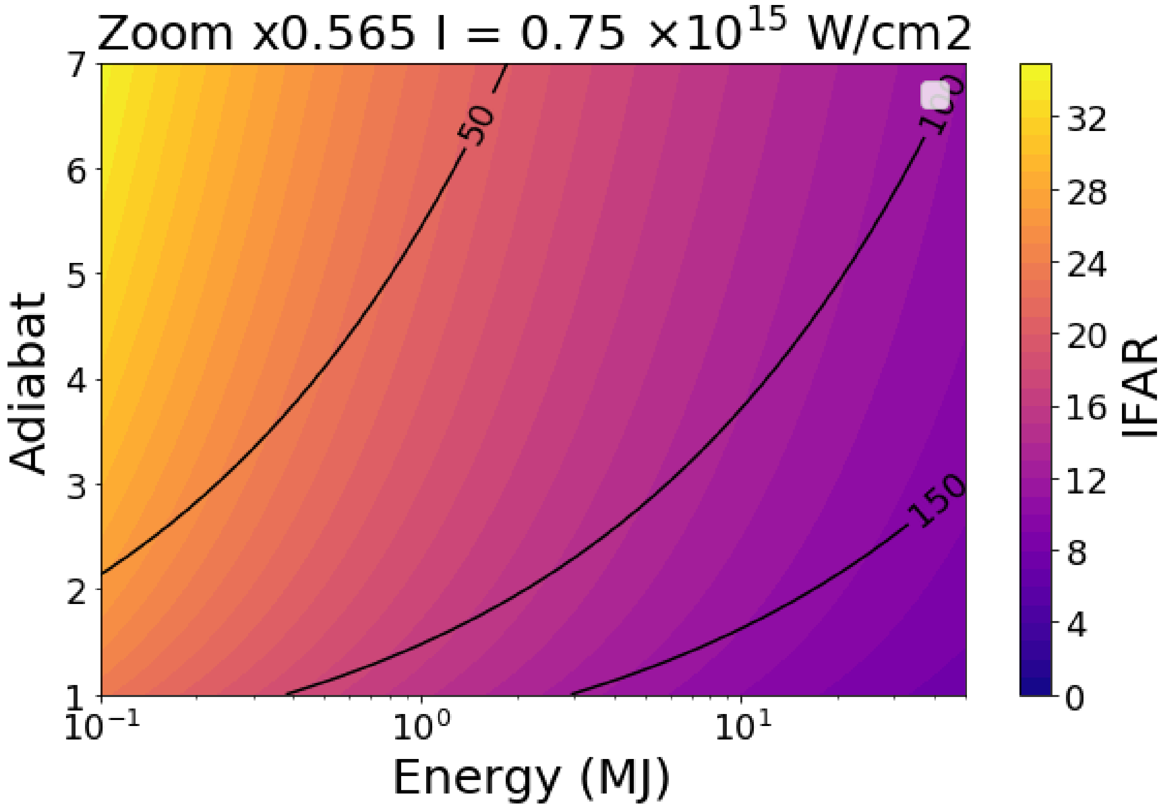
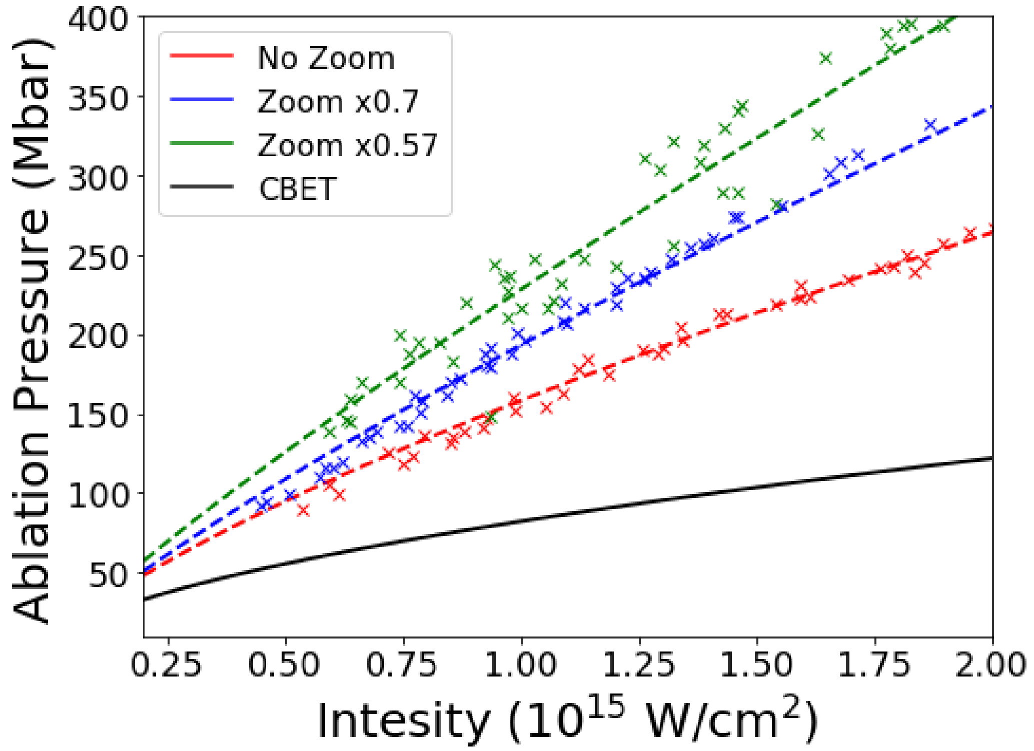
Inertial Fusion Energy Target Designs to Capitalize on Next-Generation Laser Technologies





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Mitigating LPI losses and boosting ablation pressure permits high-gain Central Hotspot ignition (CHS) target designs at IFE-relevant energies

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- **When combined with zooming this allows for the design of CHS targets of gain and energies relevant to IFE**
- **Simple scaling laws were determined from 1D rad-hydro simulations using LILAC allowing to find target specifications for any gain/energy**

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Collaborators

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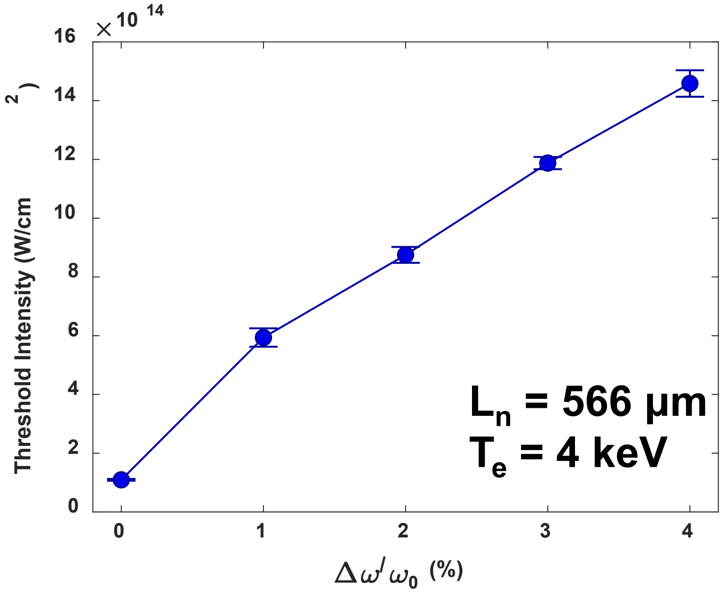
Next-Generation laser technology will use bandwidth to reduce LPI and allow for zooming

- **Current drawback of LDD‡ is the reduced ablation pressure due to LPI †**
- **Bandwidth raises the thresholds for LPI**
- **Reducing LPI will bring ablation pressure to allow for high-gain IFE designs**
- **Zooming will also enhance ablation pressure**



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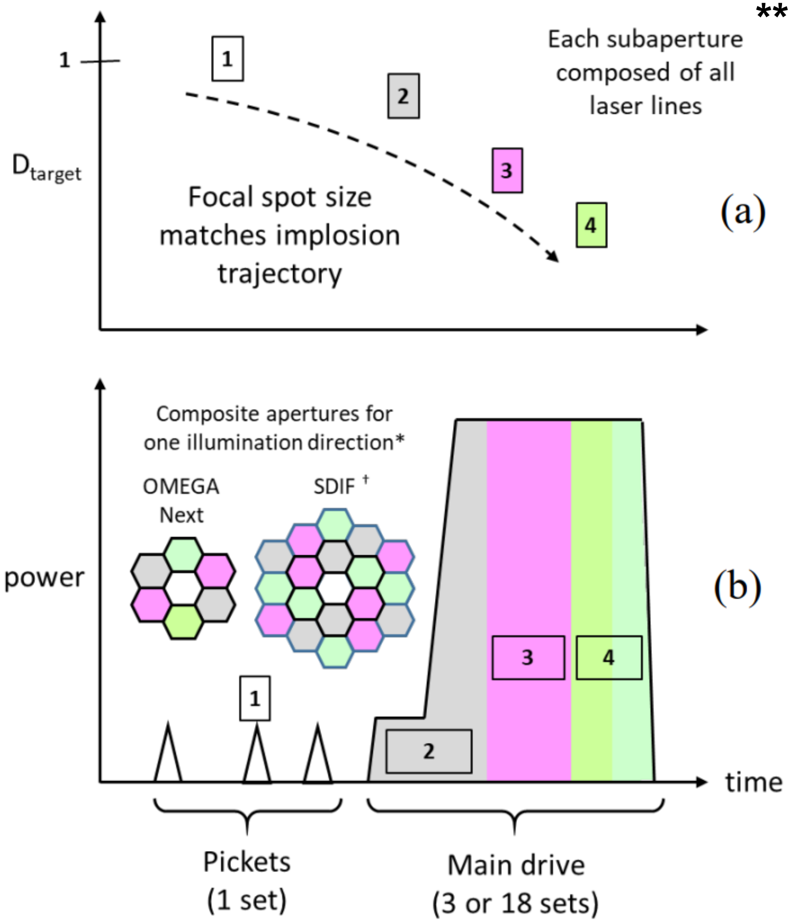


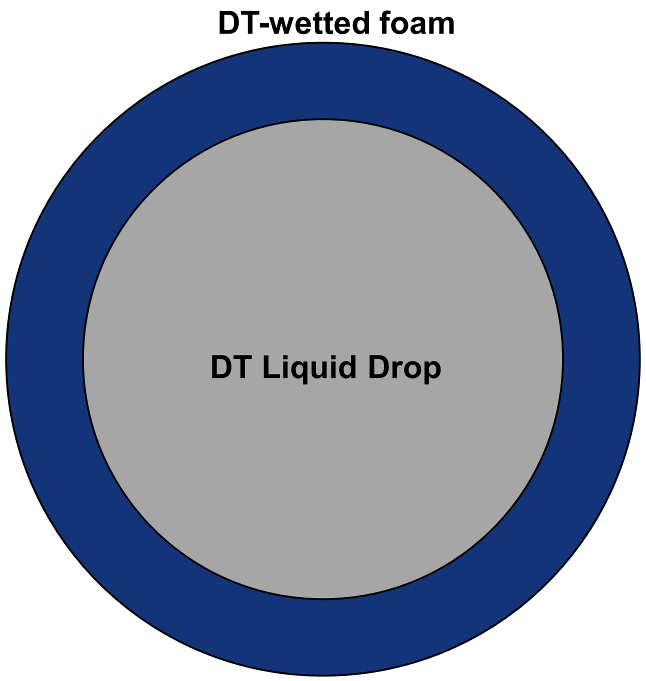
‡ LDD – Laser Direct-Drive
*Figure from RK. Follet
** Figures from J. Zuegel
† LPI: Laser-plasma Instability

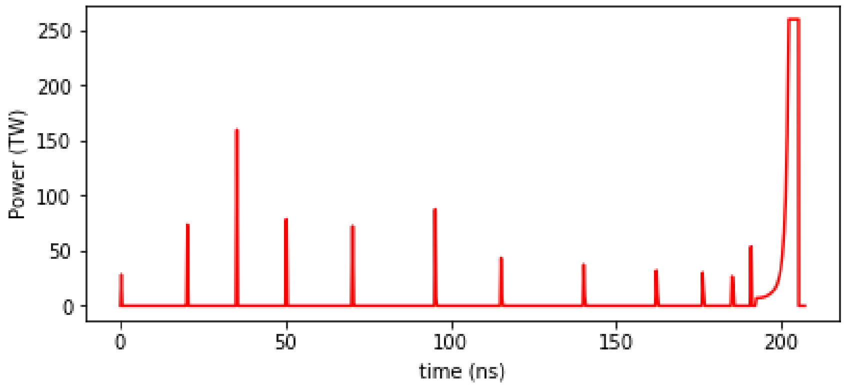
D. Eimerl et. al., J Fusion Energ (2014) 33:476–488

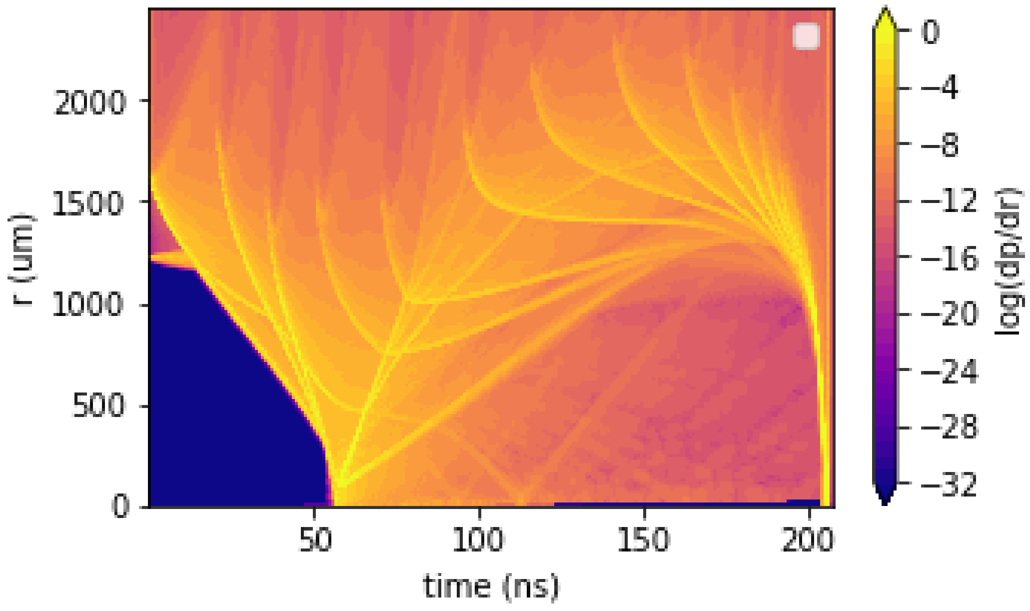
IFE targets are DT-wetted foams which are suitable candidates for mass-production at high rep-rate and low cost

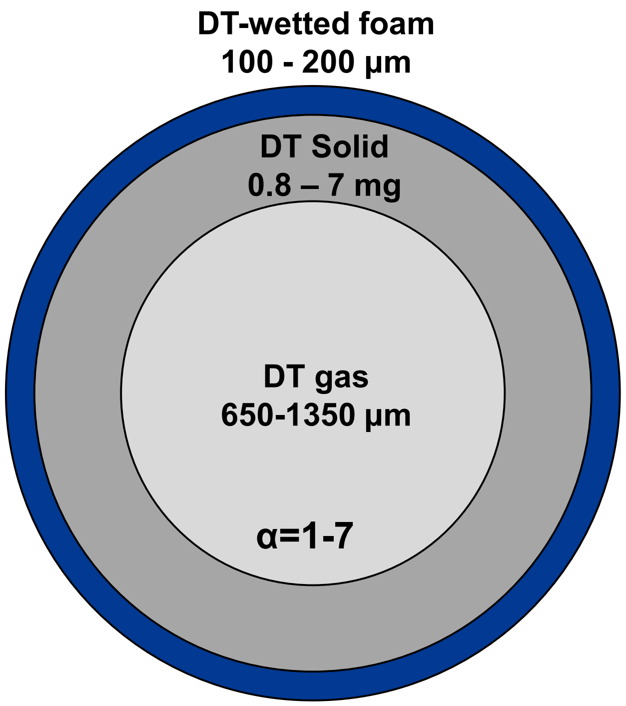
UR LLE

Dynamic Shell Target









The most significant way to increase gain is to maximize the ablation pressure for a given intensity

Goal: $\text{Gain} = f(E_L, \alpha, p_a)$

Zoom x0.57: $p_a = 228\, I_{15}^{0.86}$ Mbar

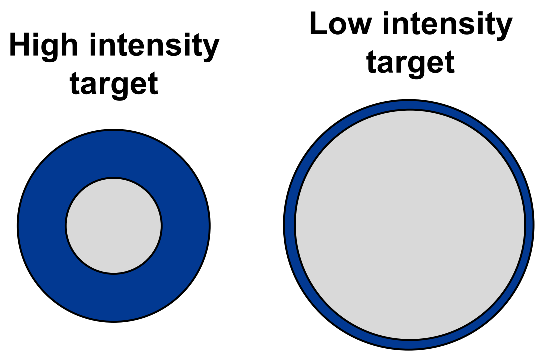
$$\text{Gain} = \frac{f_b M_{DT} \varepsilon_{DT}}{E_L}$$

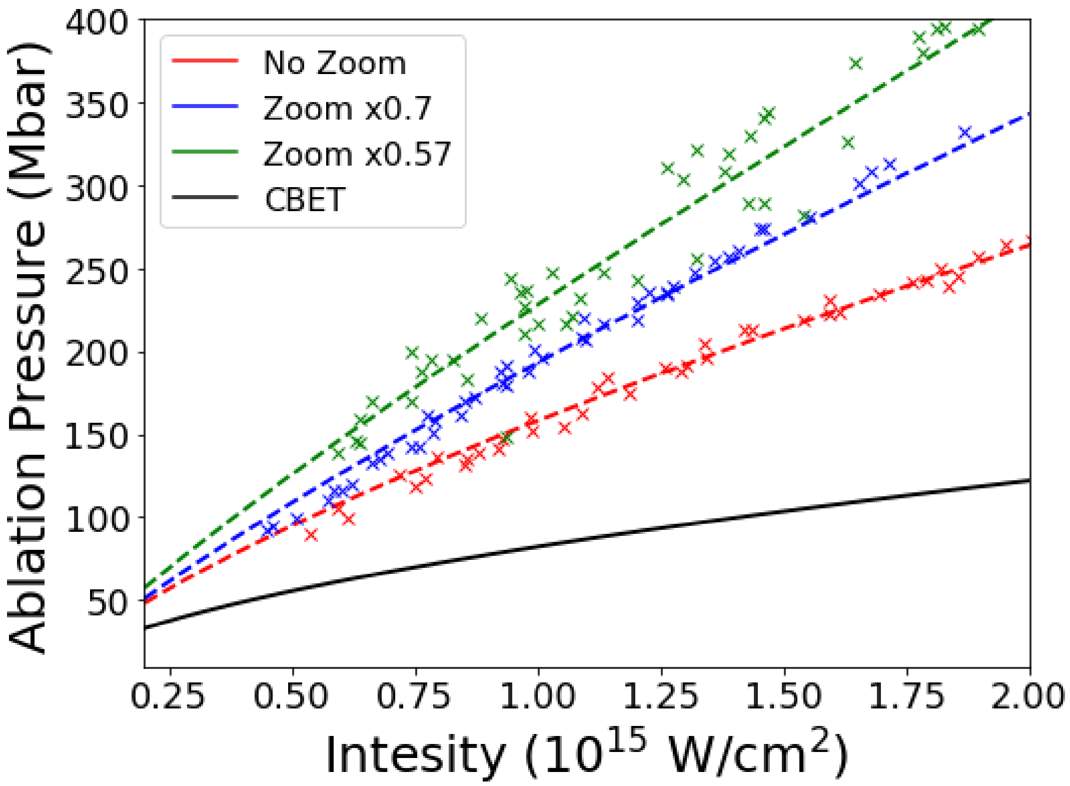
Simple physics arguments, $F = ma$ →

$$\text{Gain} = C\, f_b \frac{p_a}{v_{\text{imp}} I}$$

f_b - burn fraction
M_{DT} - assembled mass
ε_{DT} - DT energy density
E_L - laser energy

C - constant
p_a - ablation pressure
v_{imp} - implosion velocity
I - incident intensity





A model for gain can developed by fitting implosion parameters to scaling laws

Goal: $\text{Gain} = f(E_L, \alpha, p_a)$

$$\text{Gain} = C\, f_b \frac{p_a}{v_{\text{imp}} I}$$

Fit to LILAC

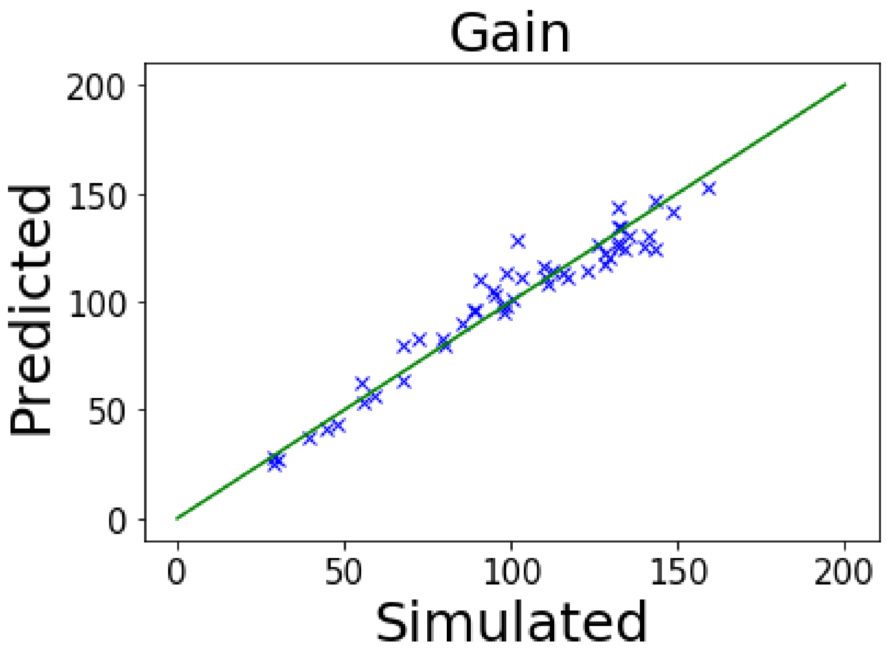
$$\text{Gain} = f_b\, 458\, p_a^{-0.39} v^{-1.75}$$

$f_b = f(\rho R) = f(E_L, \alpha)$

Maximum pressure gives most stable target, limited by LPI

Use ignition criteria to find relation to E_L and α

- **We now take the suggested previous**
- **By using a series of physics arguments we can relate the gain to E_L, α and p_a**
- **Full details of this model is being prepared for publication**



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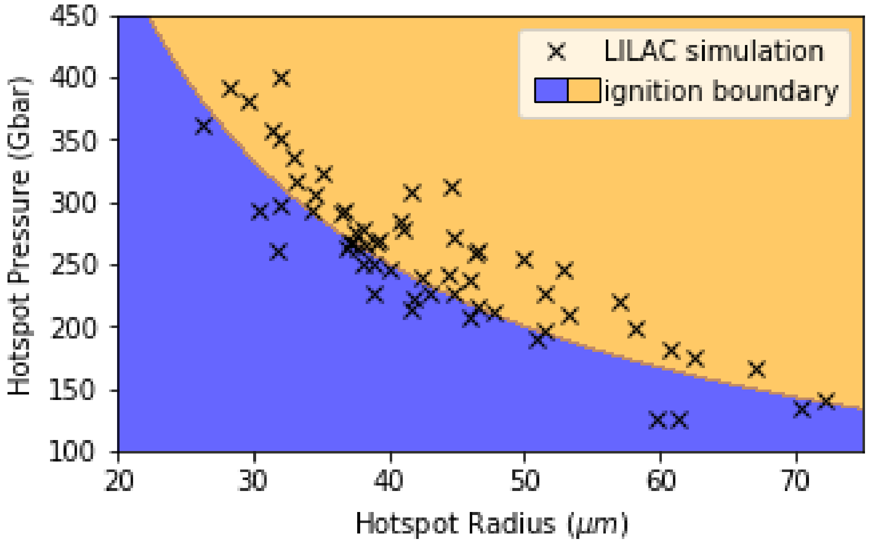
A minimum implosion velocity is imposed on the model by considering a simple ignition criterion

Simulations with burn-off

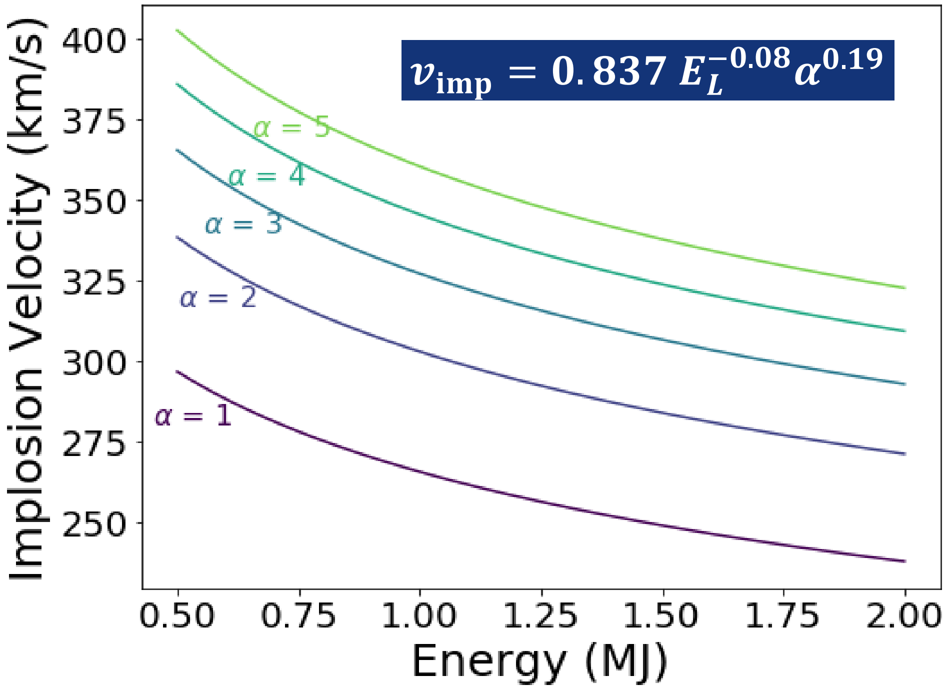
$$\rho R \times T_i > 0.3\ \mathrm{gcm}^{-2} \times 4.5\ \mathrm{keV}$$

$$P_{hs} \times R_{hs} > 1\ \mathrm{Gbar} \times \mathrm{cm}$$ *



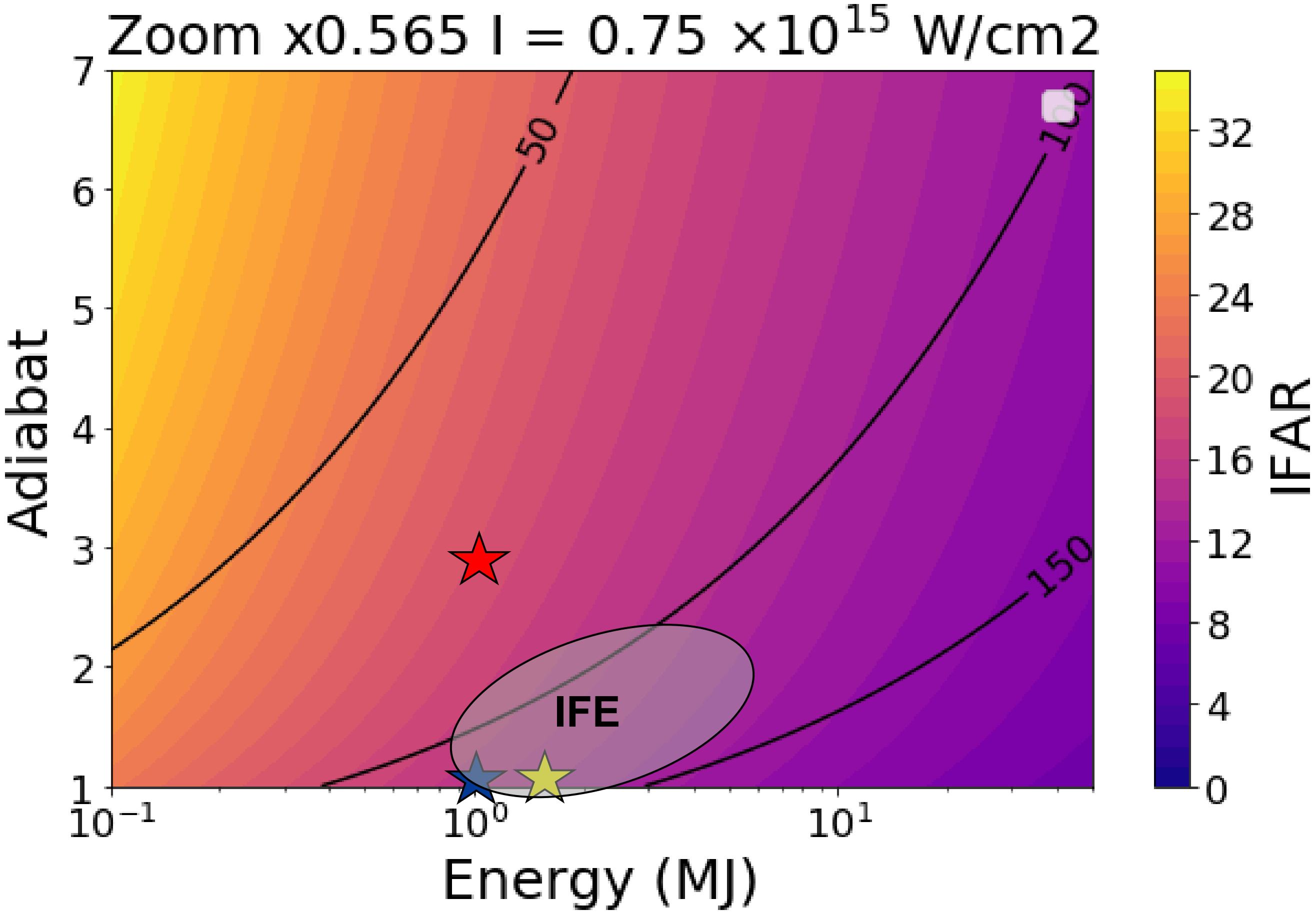
$$P_{hs} = f(v_{\mathrm{imp}}, p_a, E_L, \alpha)$$
$$R_{hs} = f(v_{\mathrm{imp}}, p_a, ,)$$

$$v_{\mathrm{imp}} = f(E_L, \alpha, p_a)$$



* Phys. Plasmas 21, 056315 (2004)

These scaling laws can now be used to predict the target properties of a design for any given gain and laser energy



E_L = 1.0 MJ
Gain = 132
α = 1.1
IFAR = 13
v_{imp} = 251 km/s

E_L = 1.0 MJ
Gain = 55
α = 2.8
IFAR = 22
v_{imp} = 389 km/s

E_L = 1.3 MJ
Gain = 140
α = 1.1
IFAR = 13
v_{imp} = 247 km/s

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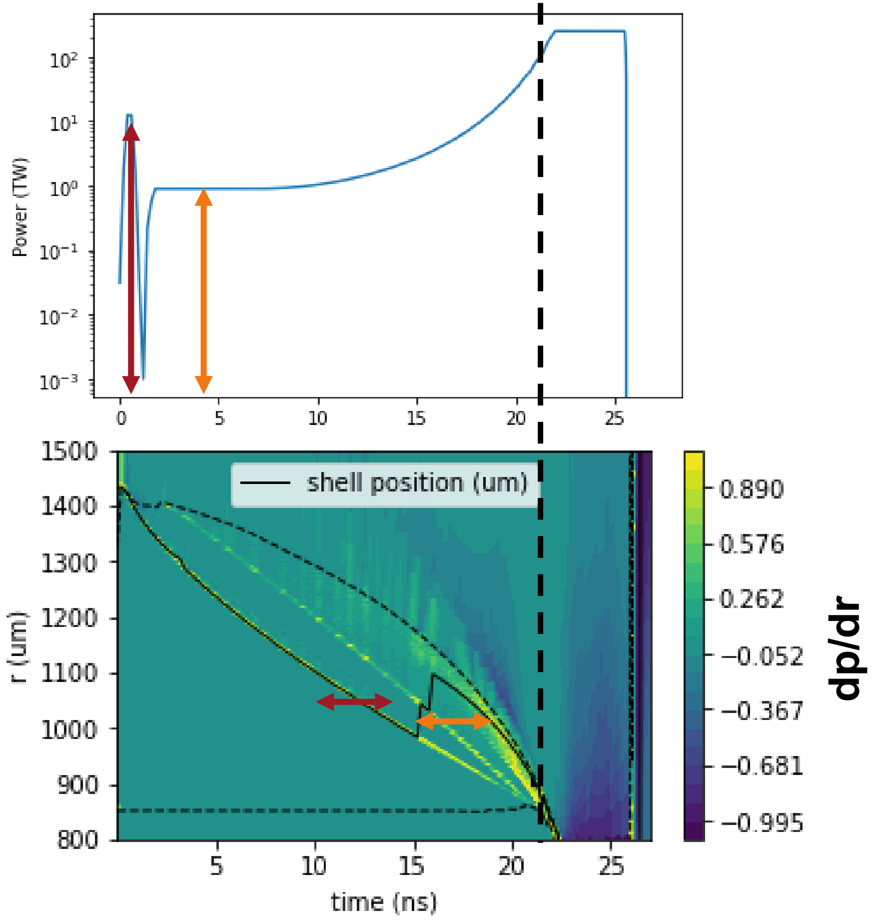
Additional Slides

IFE targets are designed using a picket to set fuel adiabat and a Kidder-like rise

The picket and foot set the fuel adiabat and the breakout time



The peak ends at maximum v_{imp} and ablator burn-through