High-gain laser direct-drive target designs

presented by

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on behalf of:
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Outline

Summary of current hi-gain designs

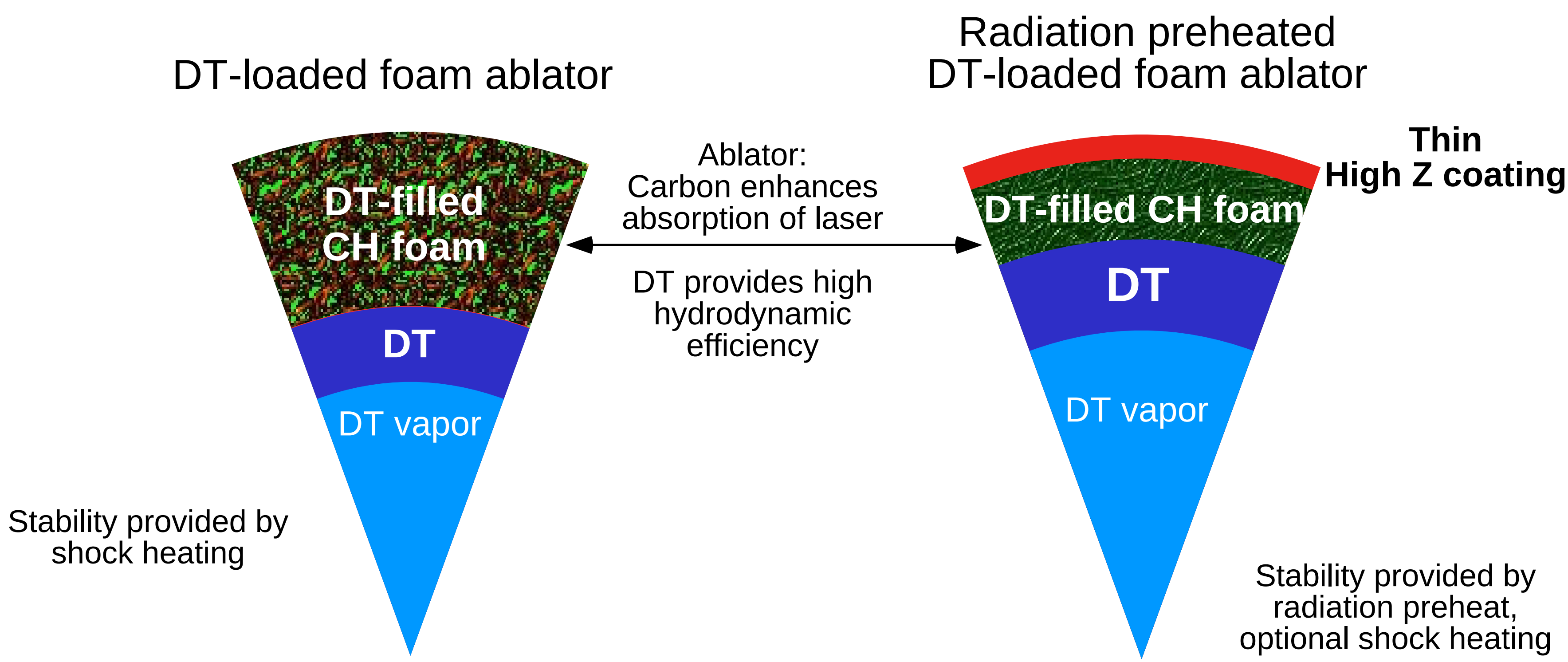
Constraints as we view them

Current open questions

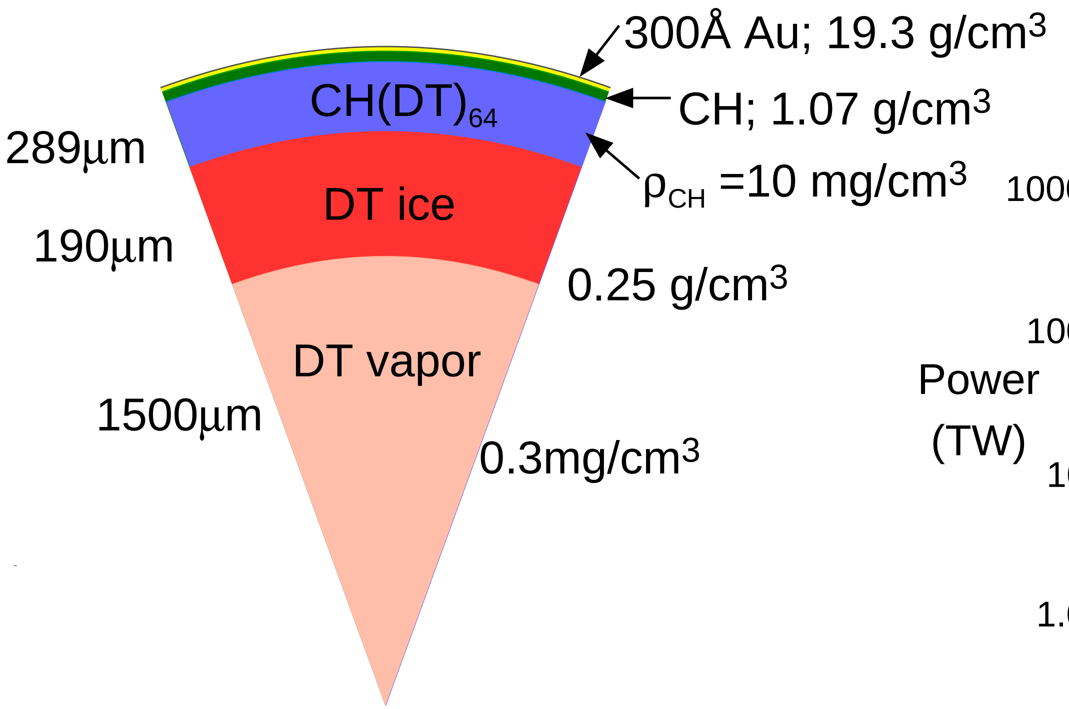
Two types of pellets are currently being investigated

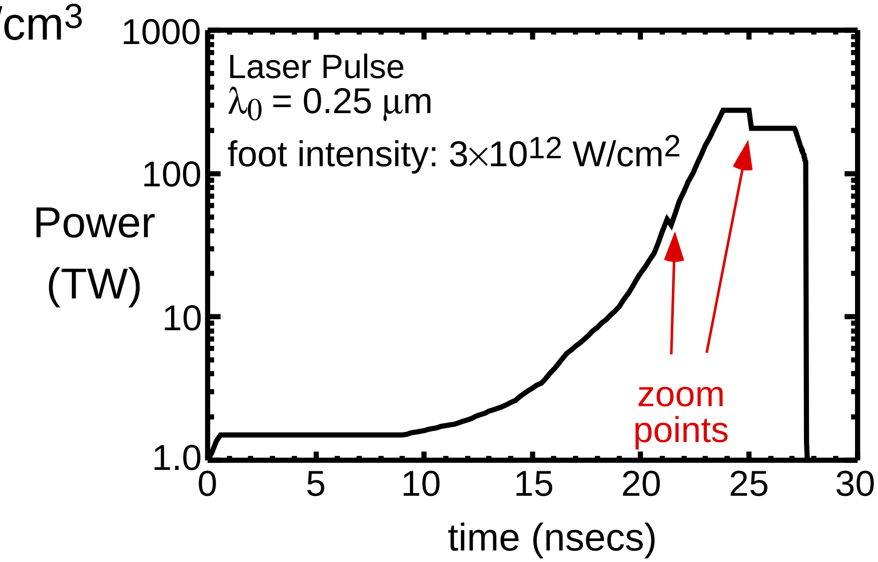
Goals for ICF target design:

- preferentially preheat the ablator to decrease RT instability
- keep inner fuel cold for ignition, allowing higher gain



High gain radiation preheated target is designed for KrF with 'zooming'





Laser Energy: (with zooming)	1.3MJ
1D Yield:	160 MJ
Gain:	124
e-folds$_{max}$	7.3
e-folds$_{net}$	5.5

(crude) Debris Summary:

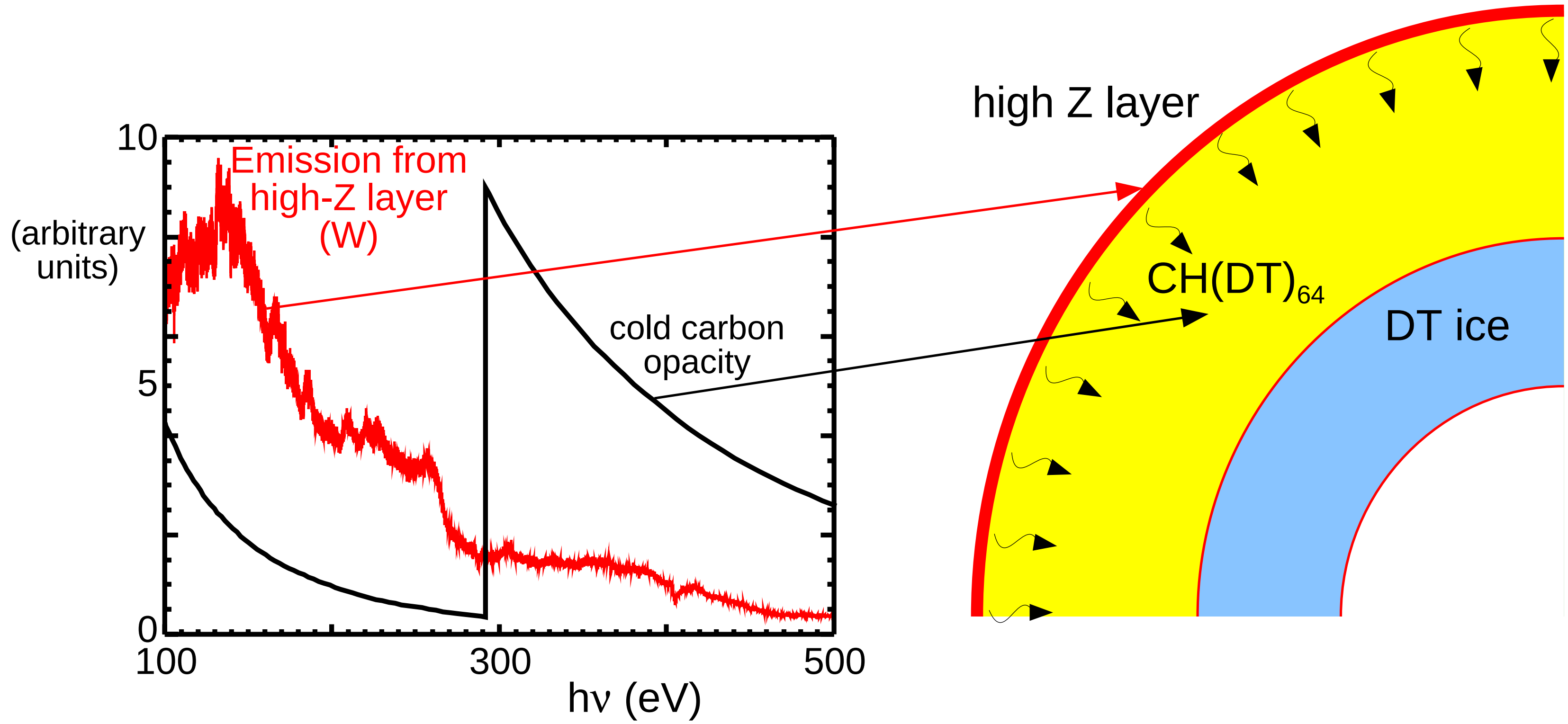
Neutrons		128.83 MJ
X-rays		3.82 MJ
Total Ion Kinetic Energy		22.89 MJ
-- by specie:		
D	8.16 MJ	
T	12.23 MJ	
H	0.14 MJ	
C	1.69 MJ	
Au	0.67 MJ	
Total Ion Thermal Energy		0.04 MJ

Colombant et al., Phys Plasmas ***7****, 2046 (2000).*

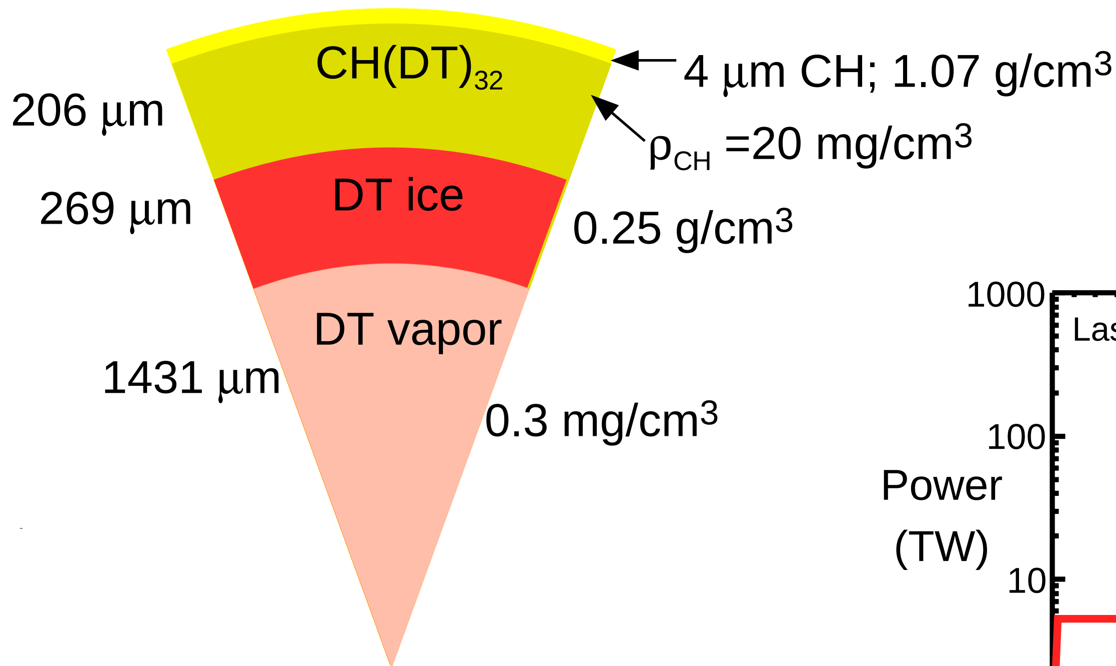
Radiation preheat target details

The thin layer of high-Z on the pellet produces soft xrays (~100's eV) at early times during the pulse, then ablates away. These x-rays are "designed" to penetrate deeply into the ablator (but not into the fuel), by judicious doping of the ablator (mostly the carbon in the foam)

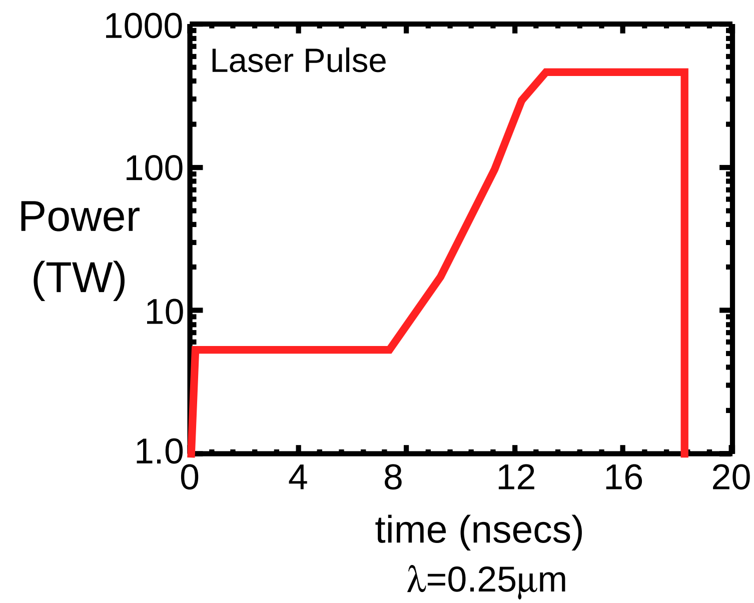
Some additional heating of the ablator occurs from foam self emission during the main drive



Target based on previous design for KrF laser and zooming



Laser Energy:	1.6 MJ
1D Gain:	111
$V_{implosion}$ ($\times 10^7$ cm/s)	3.6
ρR_{max} (g/cm^2)	2.19
e-folds$_{max}$	6.1
e-folds$_{net}$	3.2



<absorption>= 93 %

Constraints

Pellet ablator materials:

DT is desirable for high hydrodynamic efficiency
Foams increase laser absorption without much adverse effect on efficiency, + tune ablator opacity
Thin overcoats provide (limited) radiation preheat

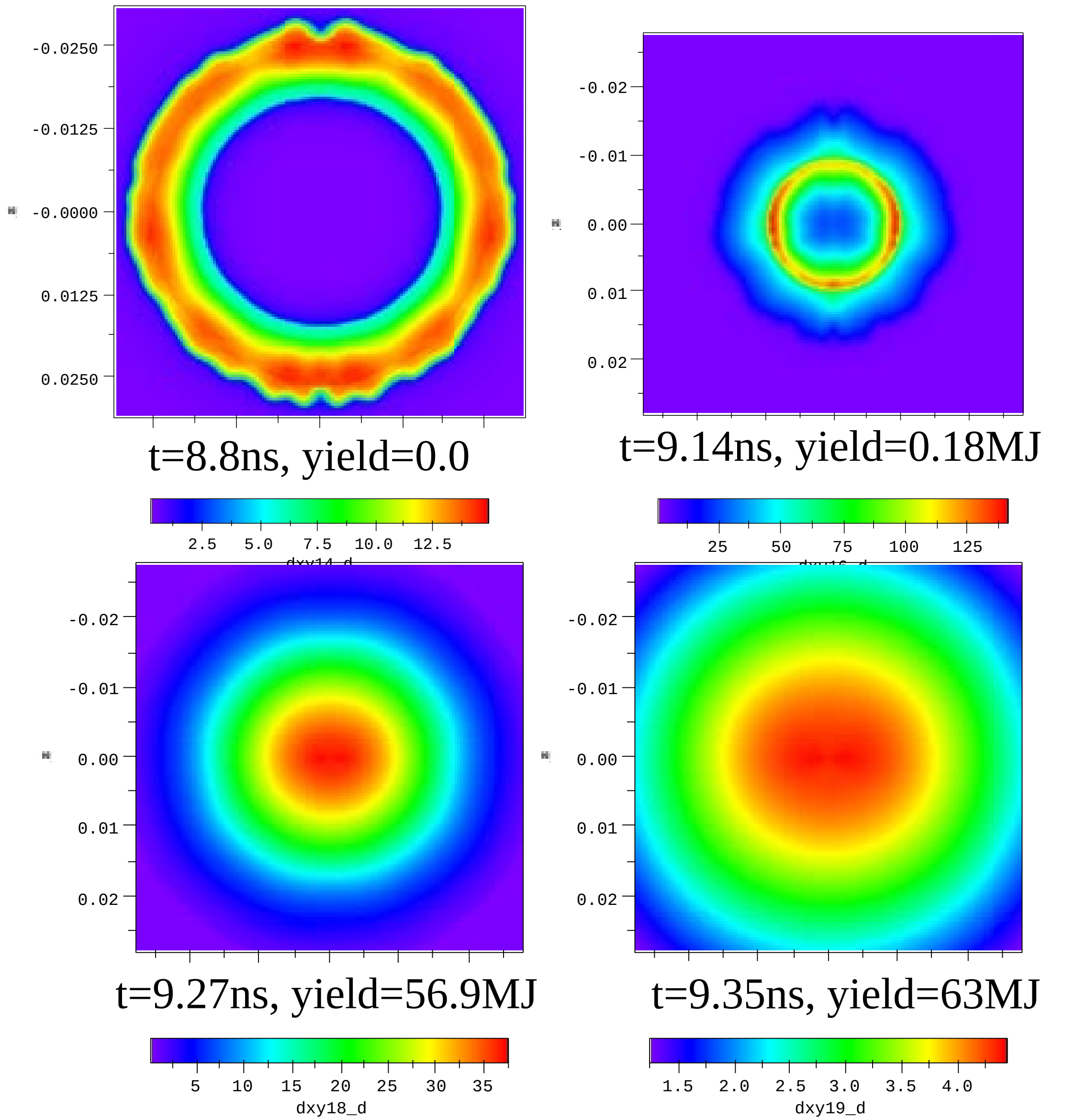
Symmetry:

- high ℓ-mode asymmetry:
  - due to (single) beam structure, pellet fabrication
  - determines Rayleigh-Taylor seeding
  - to be controlled by ablative stabilization

- low ℓ-mode asymmetry:
  - energy/power balance between beams
  - aiming accuracy & pellet placement

- How much reduction in pellet gain/yield?
  - currently undergoing evaluation

Integrated calculations of stability and nonuniformity effects on gain are beginning to be done: here's an example.



All DT pellet
1.6MJ (NIF) laser
1% nonuniformity
in modes ℓ=2-32

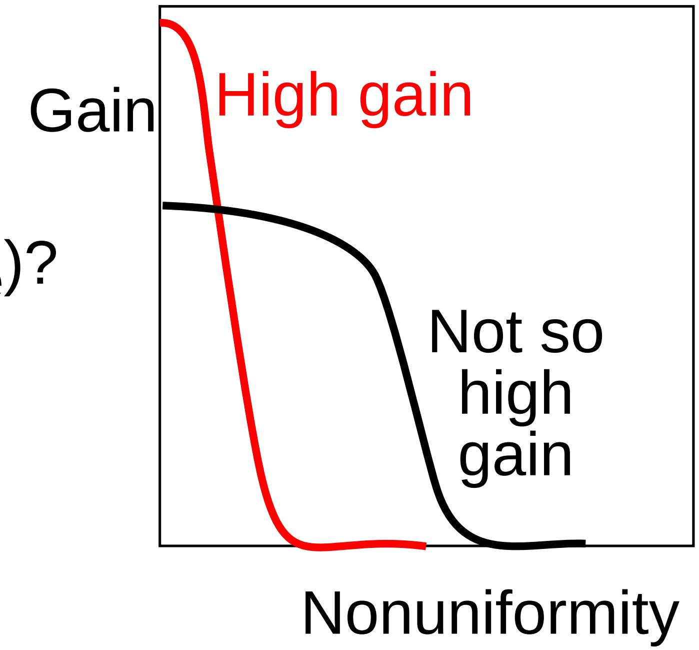
Total yield: 63MJ
1D 'clean' yield: 64MJ

Open questions

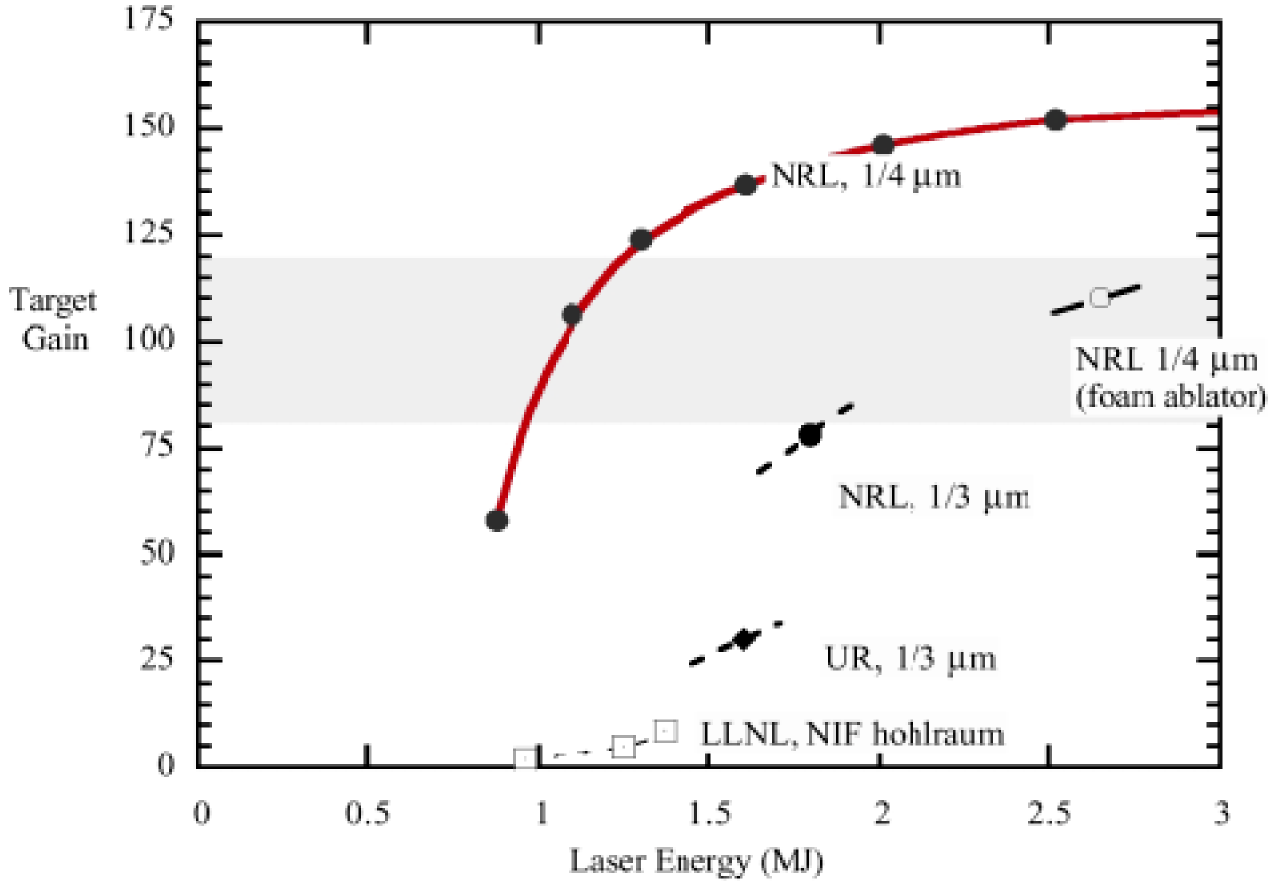
Gain/stability tradeoff is current area of research
Inherent nonuniformities:
- single beam uniformity (high ℓ mode asymmetry)
- beam overlap, aiming, beam energy and power balance, pellet movement and alignment (low ℓ mode asymmetry)
- do high-Z coverings help or hurt?

Plan B: more driver energy?

Physics impacts from:
- laser parametric instabilities ($2\ \omega_{pe}$)?
- nonthermal electron transport?



Target gain versus laser energy for various target designs



The gray region indicates the minimum gain required for a power plant.

Bodner et al., IAEA Madrid meeting, June 2000.