Target Physics Issues

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With lots of help from
A. Schmitt, J. Gardner, S. Bodner, D. Colombant, and a host of others

Outline

A primer on high gain target design

Higher target gains (~ 100) can be achieved with:

- **Zooming the laser**
- **Using as smooth a laser as possible**
- **Tailoring the adiabat**

A trio of target designs

2-D stability analysis has been performed on Pure DT and CH foam/DT adiabat

- **Looks pretty good**

Highest gains to date are 127 with gold + CH Foam/DT adiabat

- **But 2-D stability has not been done**

Expect to have integrated target designs within a year

There is a wide spectrum of targets to choose from, and ARIES team should evaluate these in terms of the entire reactor

Fast Ignitor is at the developmental stage.

- **May be appropriate for evaluation by ARIES-IFE in a years time**

High Gain target designs try to keep the adiabat of the fuel as low as possible consistent with the control Rayleigh Taylor Growth

$$A\,(t) = A_o\, e^{g t}$$

$$g = [kg/(1+kL)]^{1/2} - 3kv_a$$

where v_a = mass ablation velocity = (dm/dt)/r_{max}

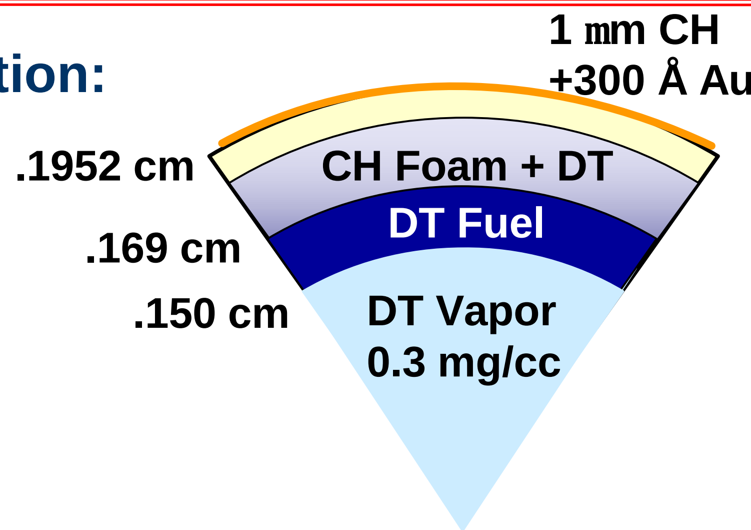
Preheating the target (e.g raising the adiabat) reduces the density,
……. which increases the ablation velocity
…….which lowers the growth rate
……so the target is stable

BUT….

The lower density results in lower gain

The NRL "Tailored Adiabat" concept is designed to --preheat the ablator, to mitigate RT growth, --but keep the fuel cold (dense), to maximize gain

One **way to do this is with radiation:**



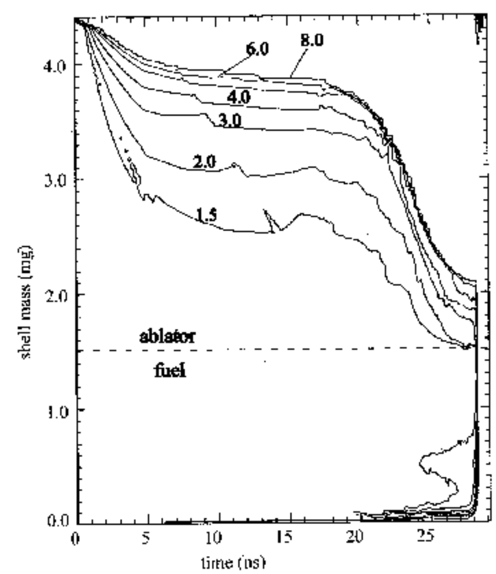
1. Foot of laser heats gold to~ 70 eV

2. Produces broadband radiation just below K-edge in carbon foam

3. X-rays heat up Foam + DT (ablator)

4. Radiation does not get to pure DT so fuel stays cold

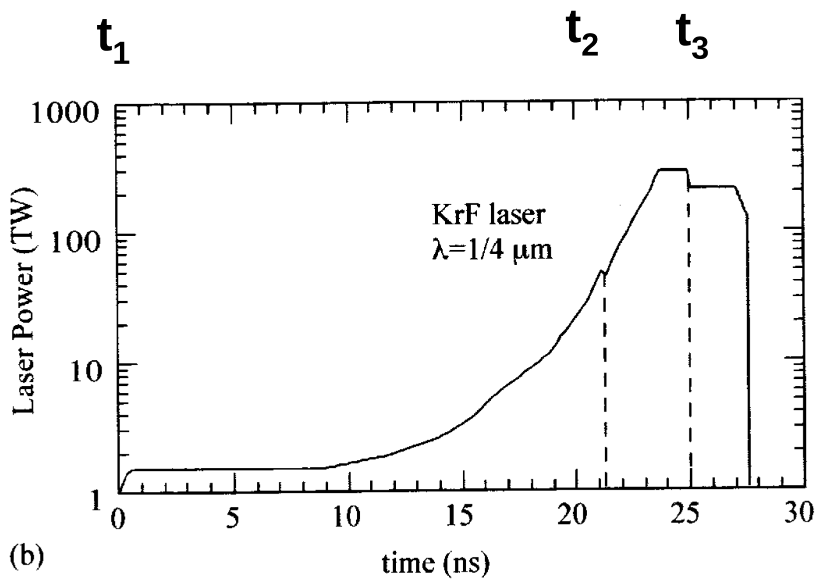
5. Gold expands from target stops radiating after ~ 10 nsec

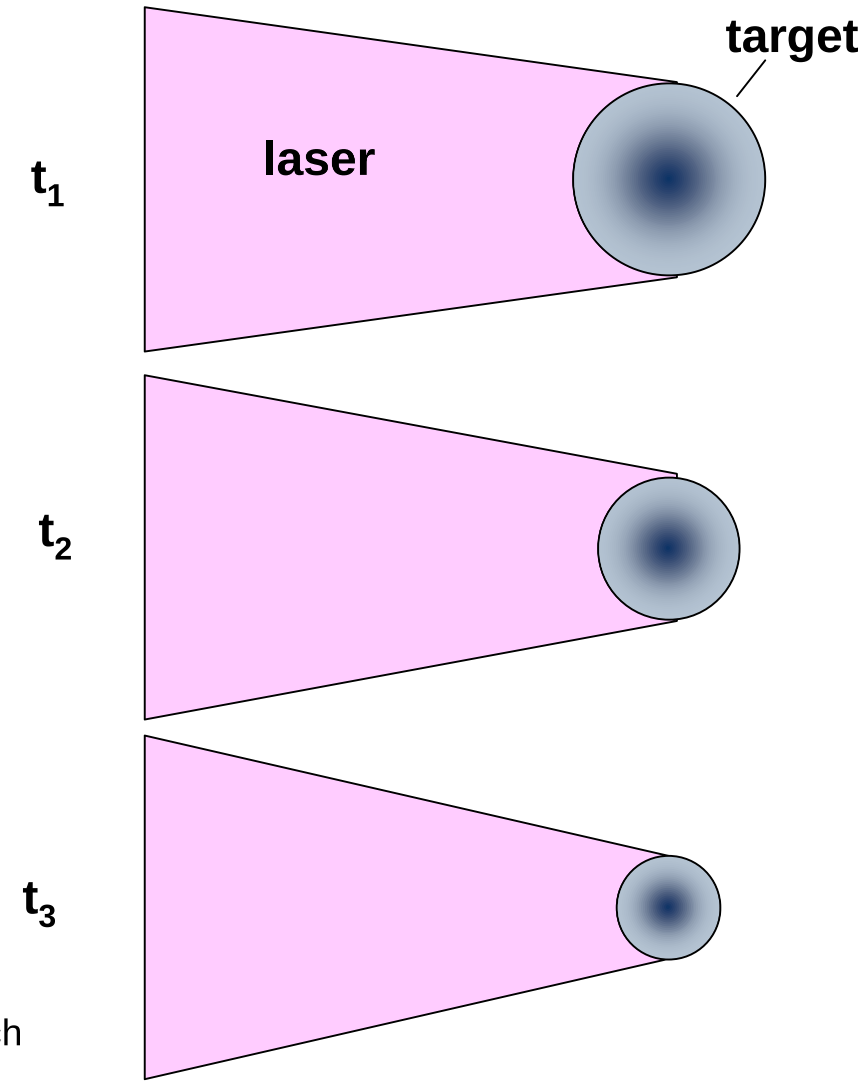


Ref: High Gain direct drive target design for laser fusion
S.E. Bodner, D.G. Colombant, A.J. Schmitt & M. Klapisch
Physics of Plasmas, **7**, 2298 (2000)

Gains can be boosted substantially (~ 70%) by "Zooming" the laser beams

Decrease the laser focal spot to follow the compressing target





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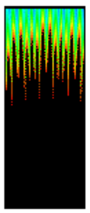
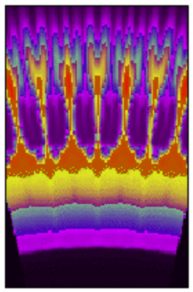
A wide array of target designs have been simulated with a wide range of surface finish and laser imprint pellet perturbations

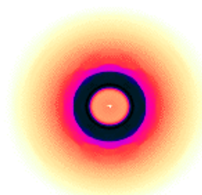
Short wavelengths saturate but lead to mix on outer surface
l ≥ 512

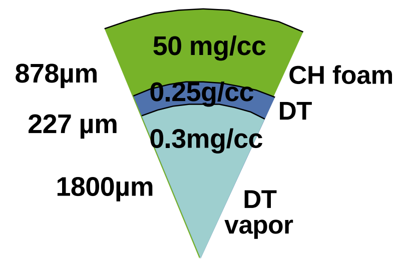


Moderate wavelengths distort target and can lead to shell breakup
16≤ l ≤ 512

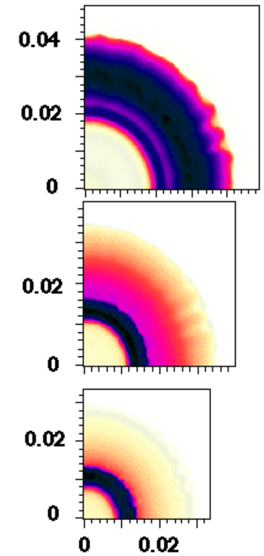


Long wavelengths can distort target and lead to core mix
l ≤ 16



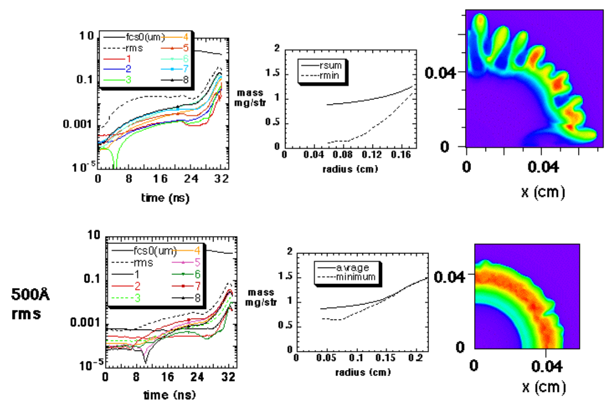


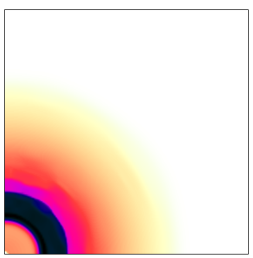
foam coated pellet design



final stages of pellet implosion near shell collapse. the core has converged by a factor of > 25

Comparison of outer surface roughness shows surface finish must be less than 500Å rms

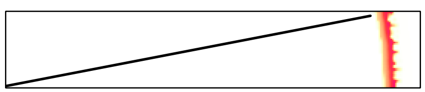




Low modes: *2 = l = 32*

Geometry: ***r, q***

Resolution: 300 *x 512*



Moderate modes: *32 = l = 512*

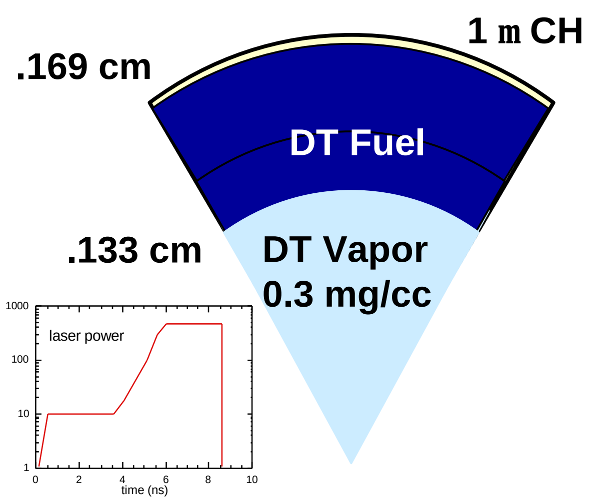
NRL FAST code pellet design results

A trio of Laser Direct Drive Target Designs

NIF BASELINE

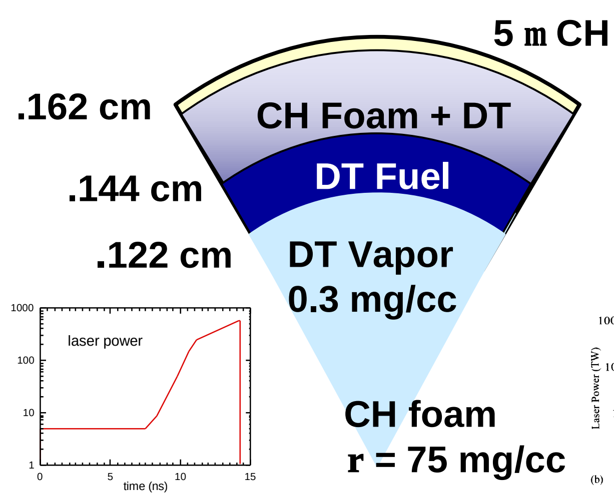
PURE DT

(shock heated)

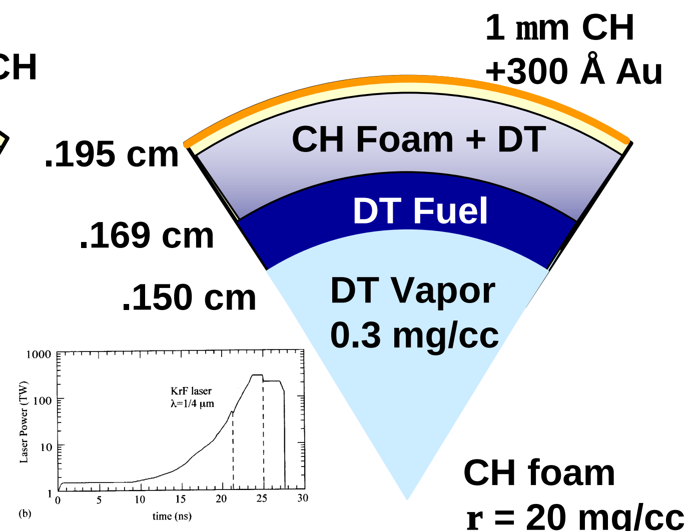


ADVANCED DESIGNS

CH FOAM /DT+ DT



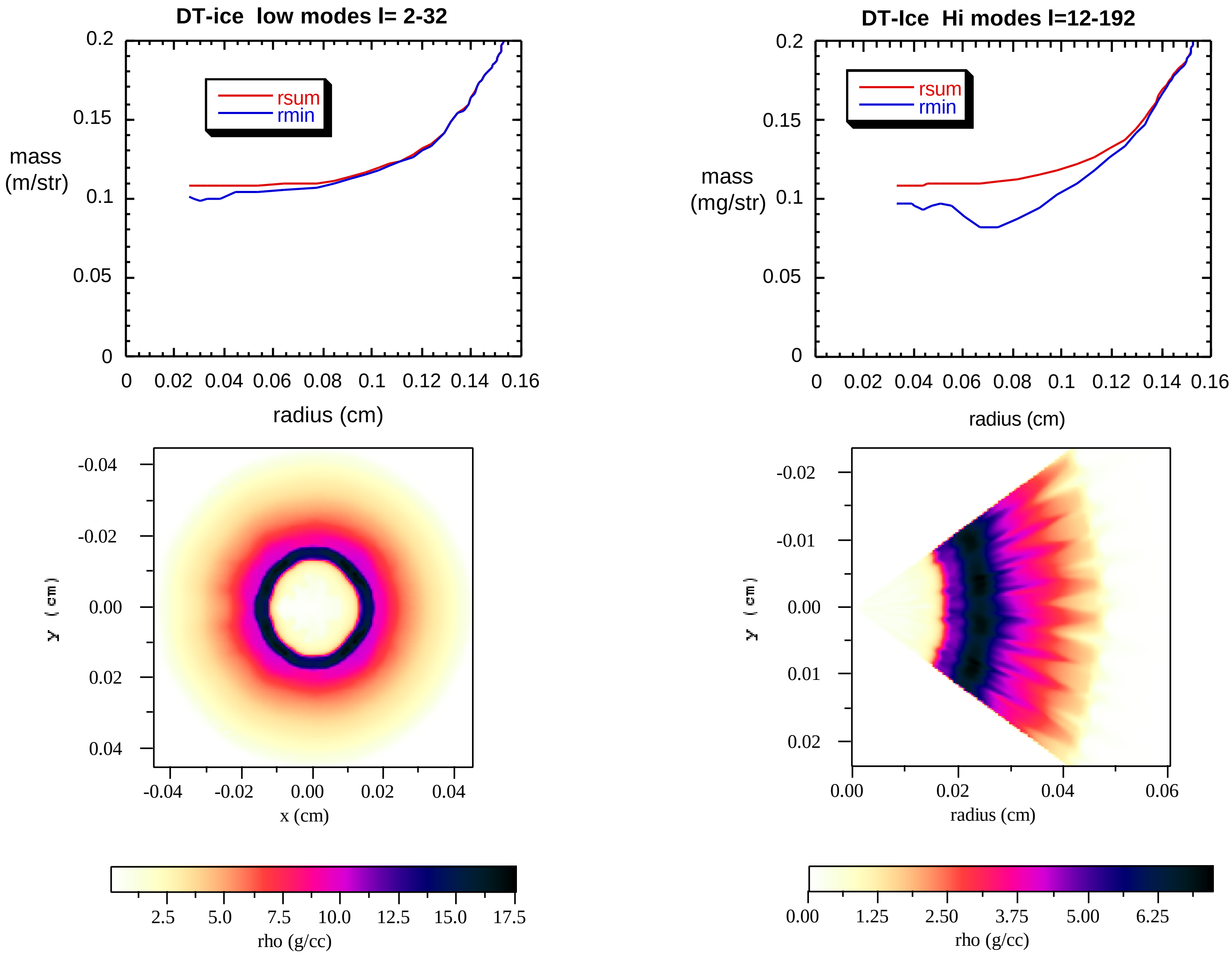
GOLD+ CH FOAM / DT + DT



	NIF Baseline	Advanced	Advanced	Advanced
Laser Type	Glass	Glass	KrF	KrF (ISI)
Laser Energy	1.6 MJ	1.6 MJ	1.6 MJ	1.3 MJ
1-D Gain	23	62	108	127
Zooming	No	No	Yes	Yes
rR_{max}	1.2	1.86	2.11	1.8
e-folds_{max}	4.7	4.8	6.1	8
Ref:	C. Verdon UR	NRL	NRL	NRL

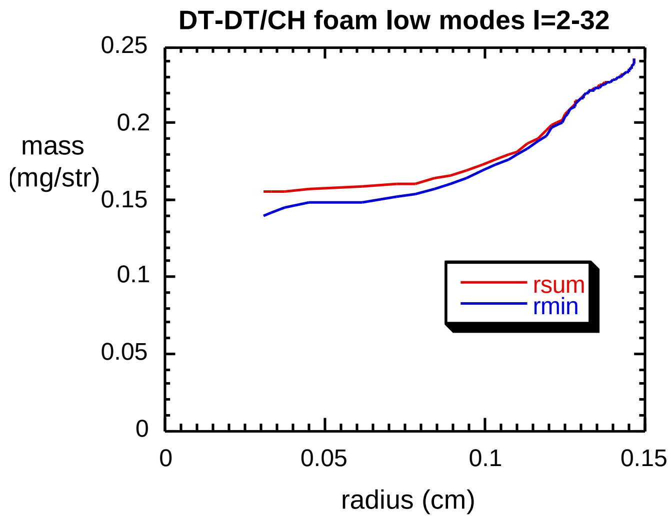
For NIF baseline, see S.V. Weber et al. Phys Plasmas **4**, 1978 (1997), also S. E. Bodner, et al, Phys Plasmas **5**, 1901 (1998)

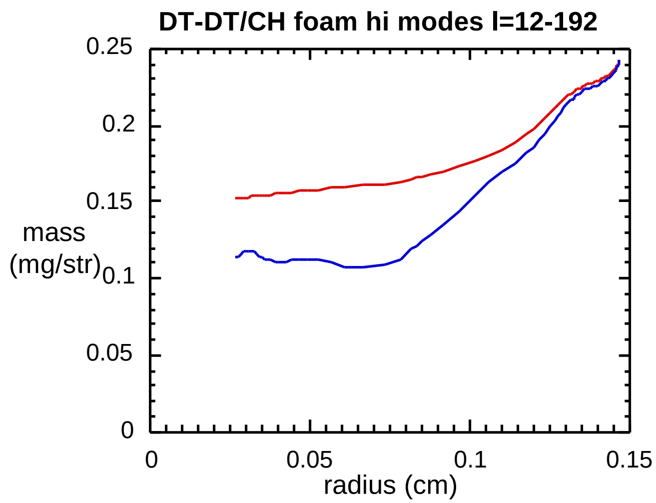
Stability of pure DT target (NIF baseline)

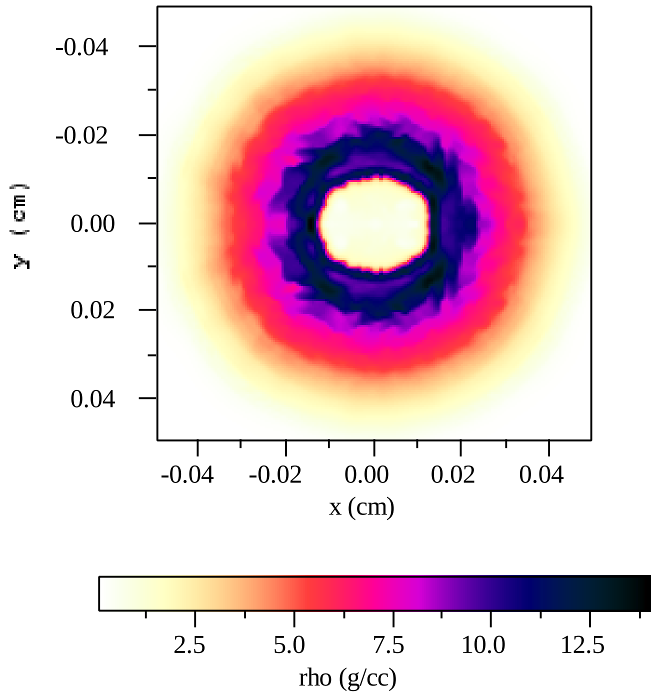


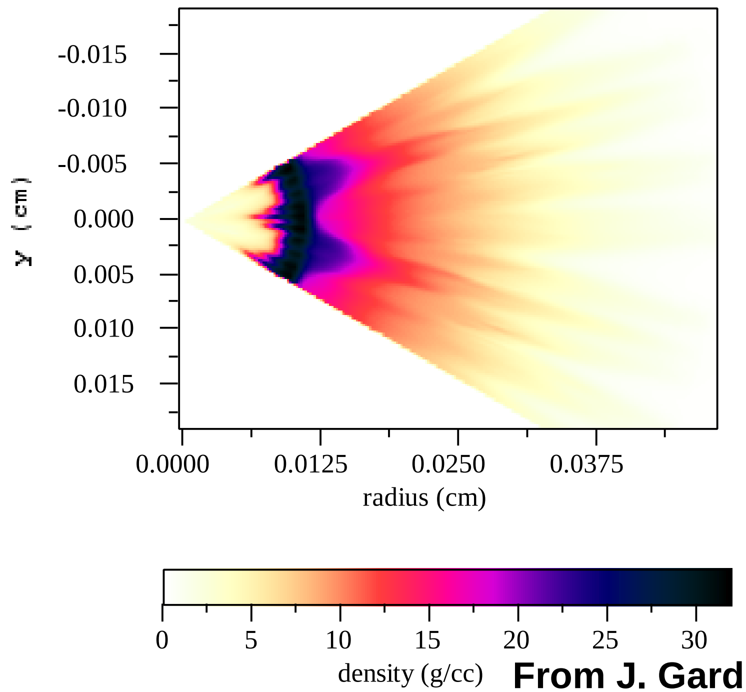
From J. Gardner, NRL

Stability of CH Foam/DT + DT, target (advanced, NIF)









From J. Gardner, NRL

Gold--friend or foe?

The GOOD

- **Highest 1 D gains**
- **Imprint reduction**
- **High albedo makes injection easier (protection from hot wall)**
- **Probably easier to track in chamber**

The BAD

- **Stability (2 and 3D) analysis challenging**
- **Undesirable material in chamber**
- **Filling with DT takes longer**

The UGLY

- **IR layering (smooth DT ice surface) impossible (for uniform layer of gold)**
- **RF layering of target also impossible (for uniform layer of gold)**

This is a “cross discipline” issue

The ARIES study should look at the entire spectrum of target designs. It should evaluate them not just for gain, but for how they fit into the integrated reactor scenario

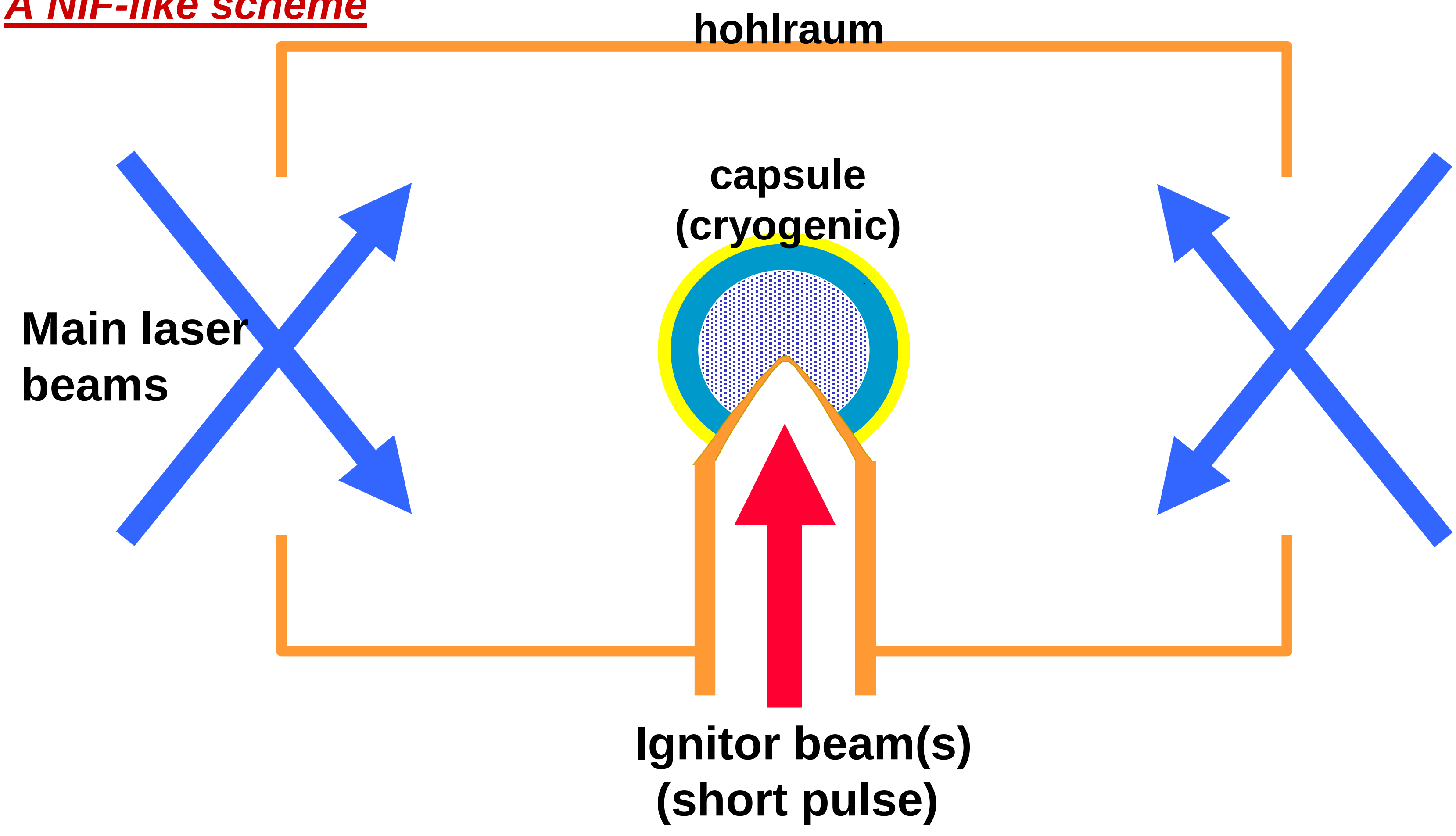
Fabrication (including filling & storage)
Injection (including acceleration)
Debris (x-rays, ionic, and crud)
Gain
Driver Requirements

Fast Ignitor (courtesy J.Lindl, LLNL)

Indirect drive scheme:

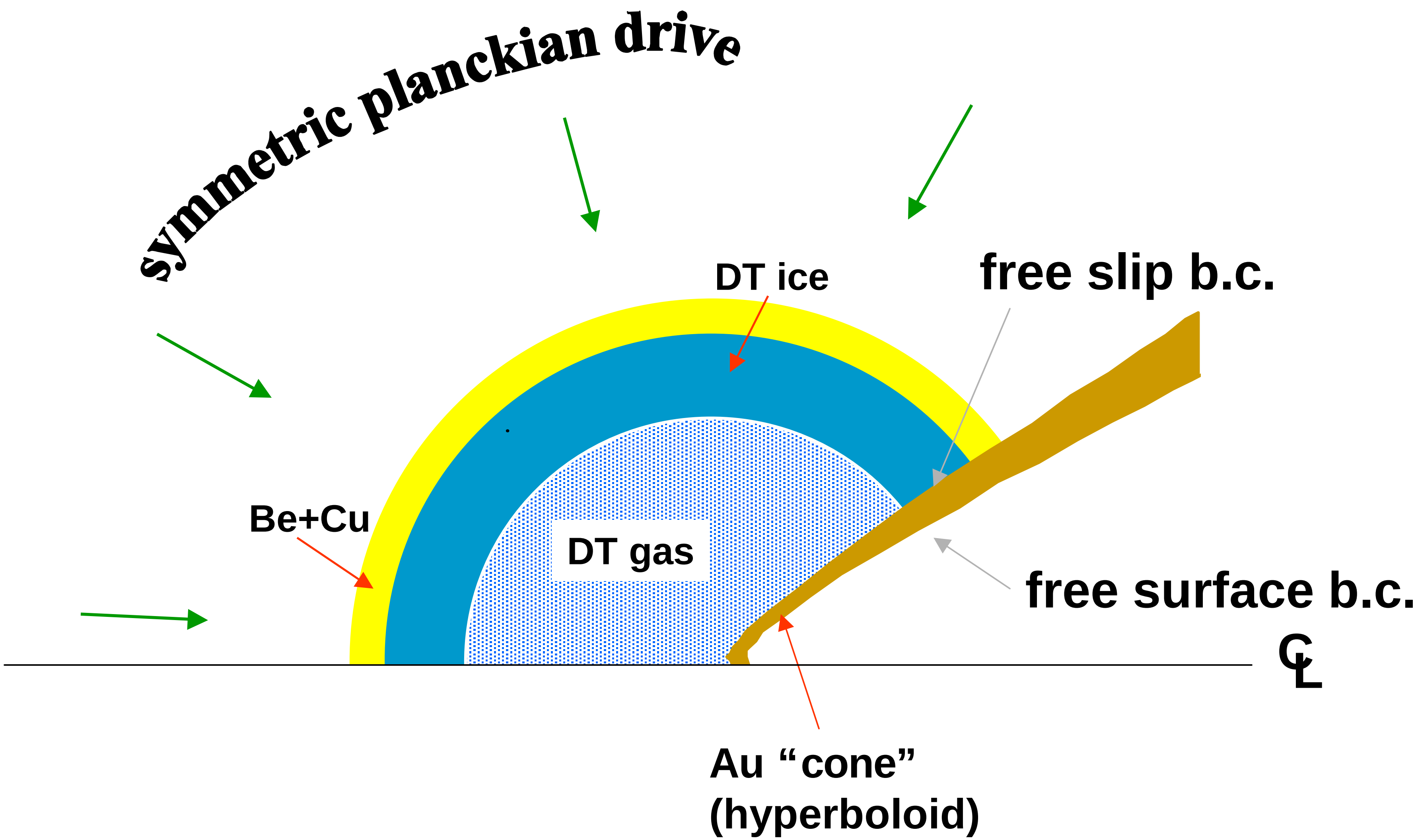
A re-entrant tube and cone provide access for ignitor beam to the imploded, compressed core:

A NIF-like scheme

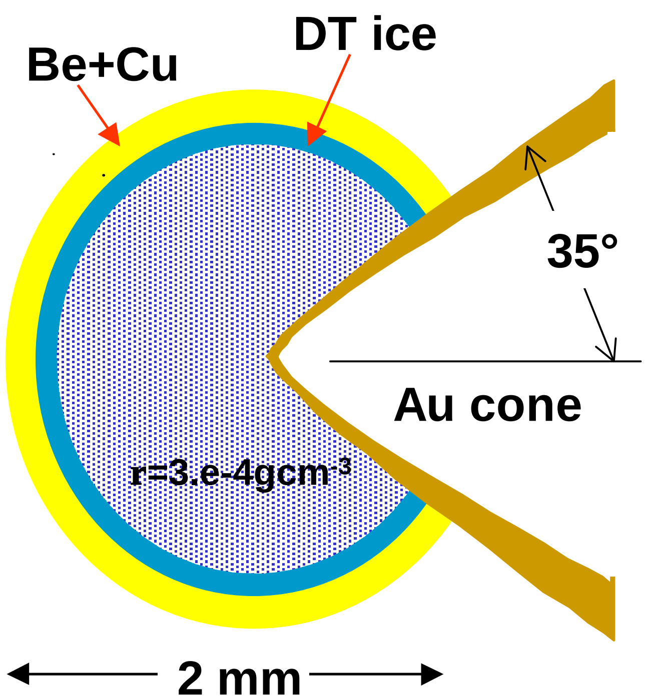


Calculation scheme:

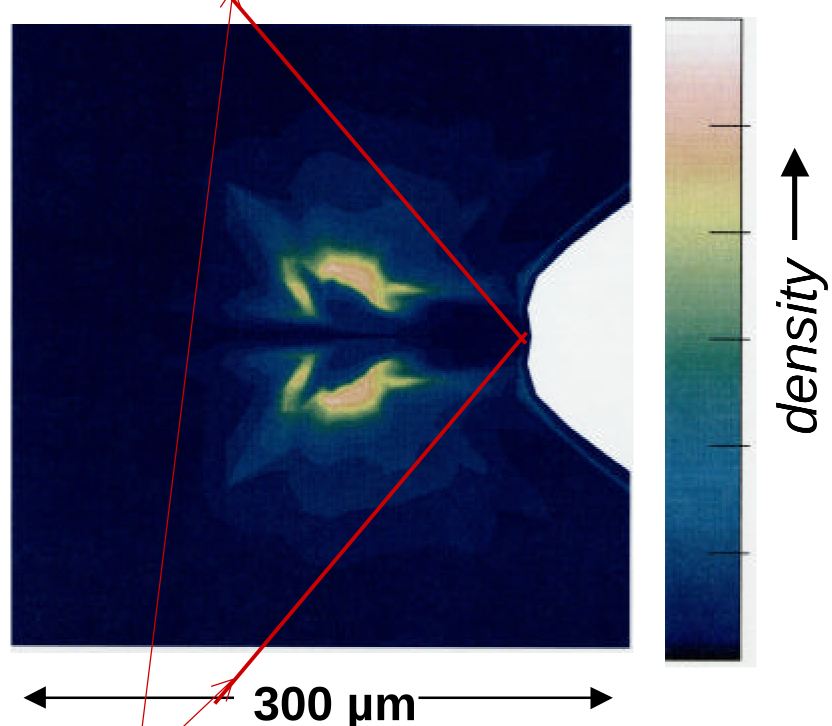
2-D hemispheric, lagrangian, radiation-driven implosion.



Indirectly driven, cone-focussed, "standard" NIF ignition capsule can be imploded to $\langle rR \rangle_{DT}$=1.33 g cm^{-2}. (in 1-D: rR_{DT}=1.5)



Imploded config. — peak $\langle rR \rangle_{DT}$



$T_{R,max}$=270 eV

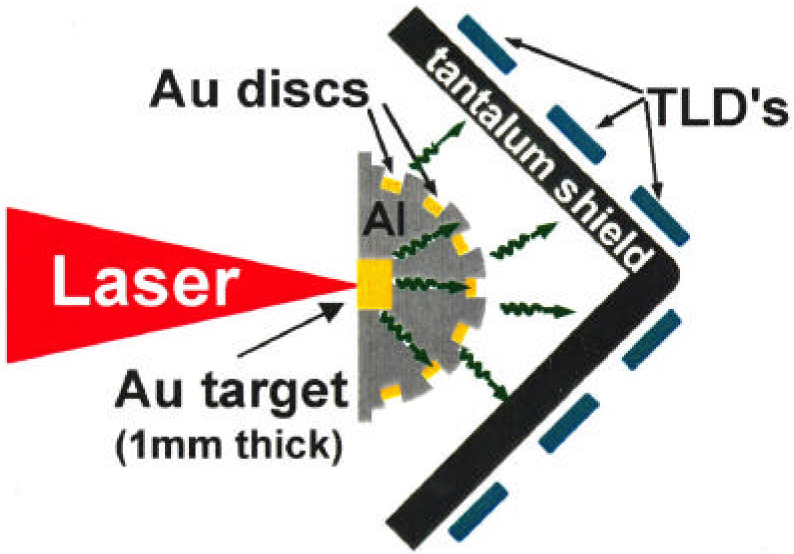
(ign. cap. has $T_{R,max}$=300 eV)

100° e^- spray seen in bremsstrahlung data

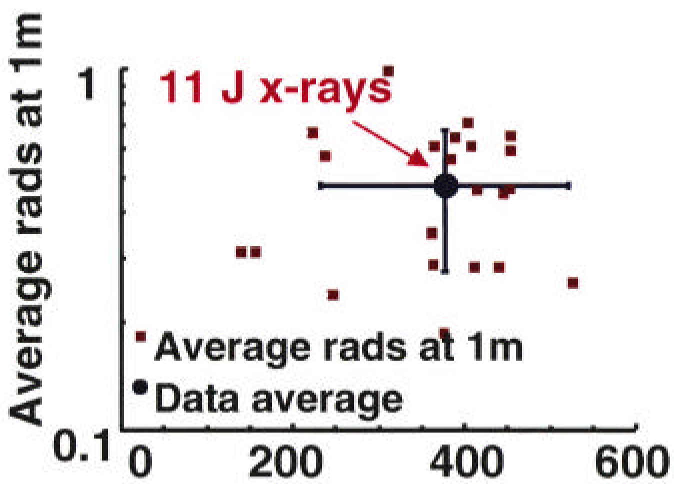
Monte-Carlo modeling of bremsstrahlung production suggests average conversion efficiency of <u>40%</u> to *50%*

NIF
The National Ignition Facility

Measure x-rays to infer fast electron number and spectrum.



Hemisphere average x-ray yield



Laser energy [J]

(0.5 ps pulse)

Summary

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