Indirect Drive Fast Ignition Target Designs for the National Ignition Facility

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NIF will provide a platform for a Fast Ignition (FI) demonstration experiment in the next few years

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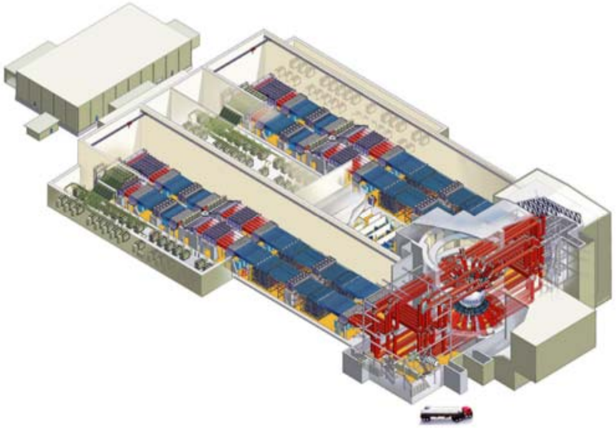
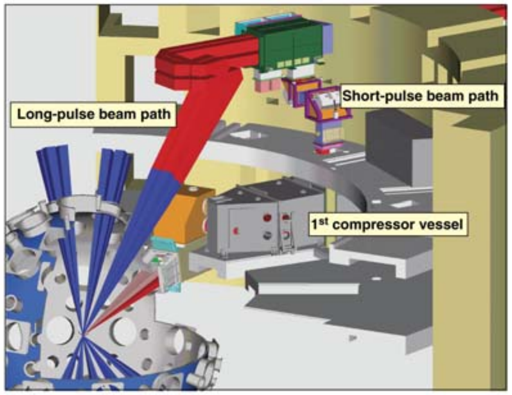
The NIF laser is nearly complete

- Indirect drive hot spot ignition campaign will begin in 2010



Advanced Radiography Capability (ARC) Petawatt will be ready by 2011

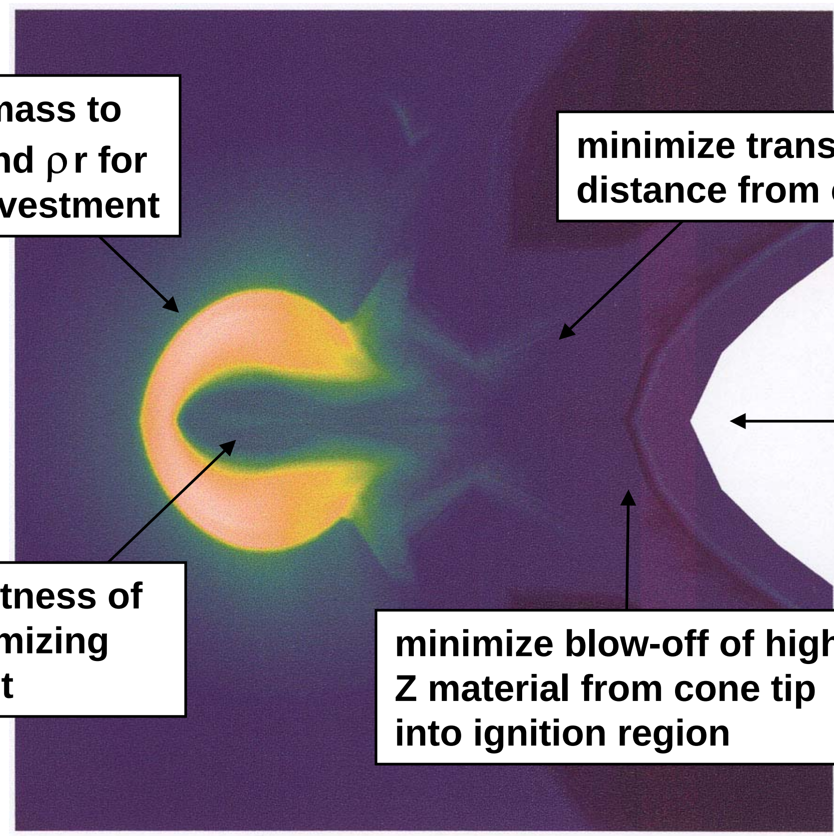
- 10 kJ in 20 ps and a 140 μm spot
- Enable radiography of imploded fuel assembly



A non-cryogenic FI coupling campaign is planned at ignition scale for 2011 - 2012

- ARC upgraded to 9 kJ in 5 ps and 40 μm
- Accommodate NIF indirect drive configuration
- Develop hydro. equivalent CD targets which meet the requirements for electron coupling demonstration

Indirect drive Fast Ignition targets have specific hydrodynamic requirements



The NIF FI implosion goal is ρ ~ 300 g/cm^3 and ρr ~ 2 g/cm^2 using 0.6 MJ of compression laser energy

Outline

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Introduction

- Indirect drive FI target requirements

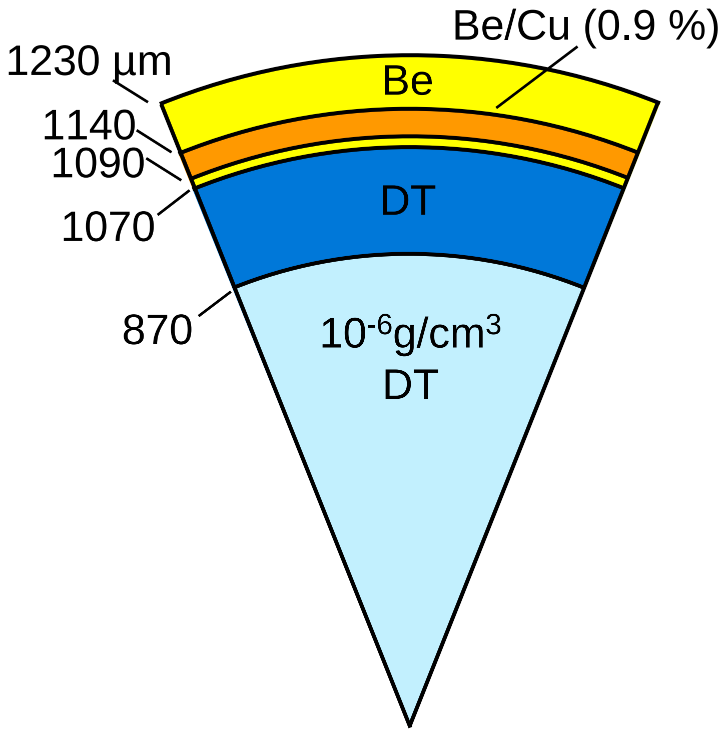
Detailed capsule designs

- Single-shock and multi-shock 1-D designs
- Sensitivity studies to pulse-shaping errors
- 2-D simulations of capsule-cone interaction
- Assessing and controlling cone tip blow-off

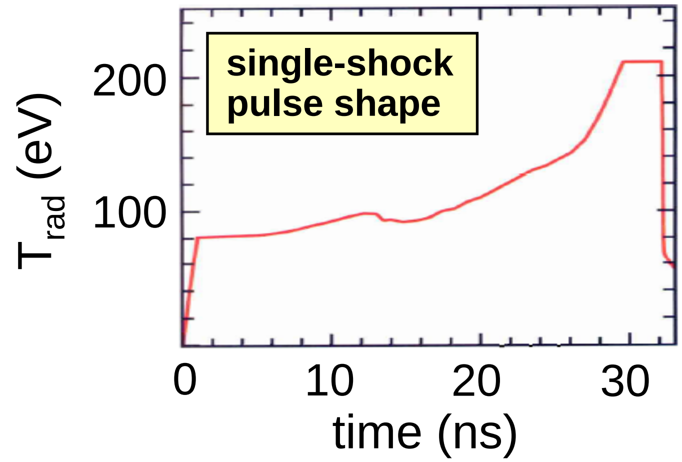
Hohlraum design

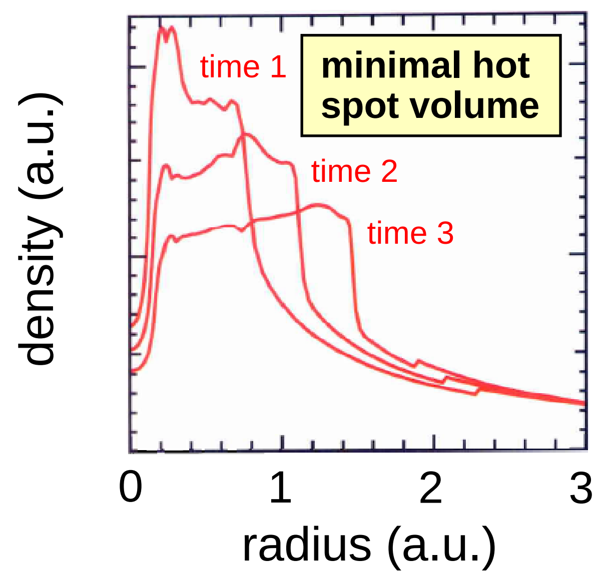
- Energetics and symmetry

A quasi-self-similar, single-shock design was developed to minimize the hot spot in 1-D



$$m_{\text{fuel}} = 0.6 \text{ mg}$$
$$(\rho r)_{\text{fuel}} = 2.1 \text{ g/cm}^2$$





The sensitivity of this design to pulse shaping errors is being assessed

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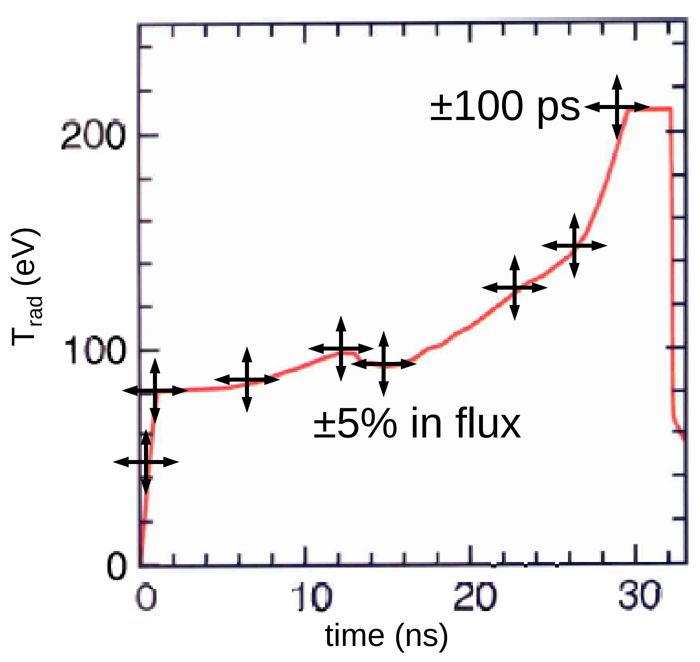
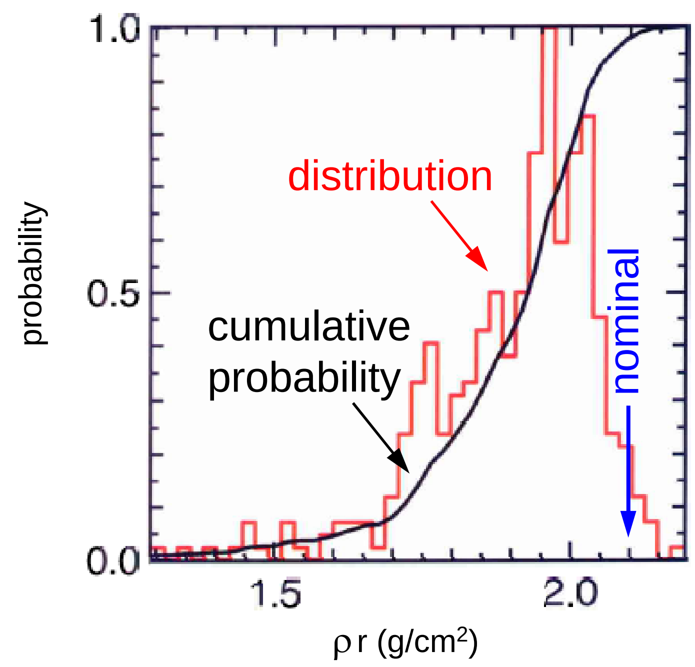
Applied random drive variations



Distribution of ρr from 400 samples



Further assessments of the design's robustness to other sources of error (EOS uncertainty, opacity uncertainties, etc.) are planned

Multi-shock NIF-scale designs are also being studied

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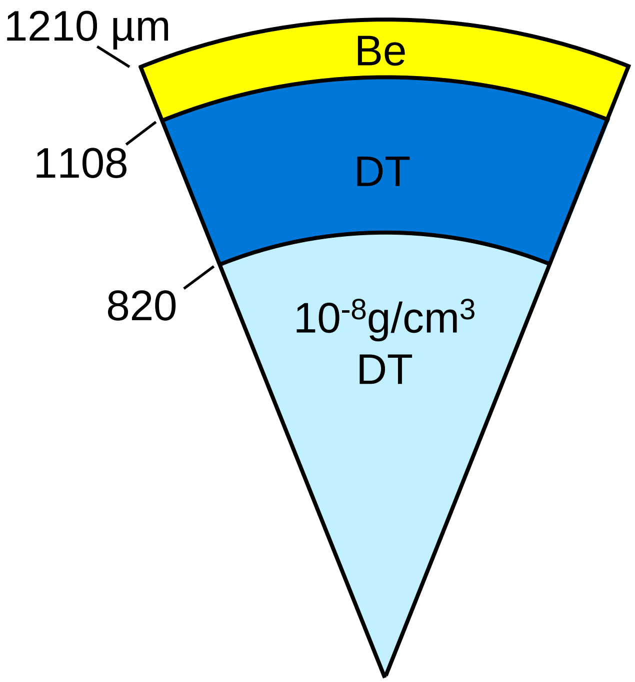
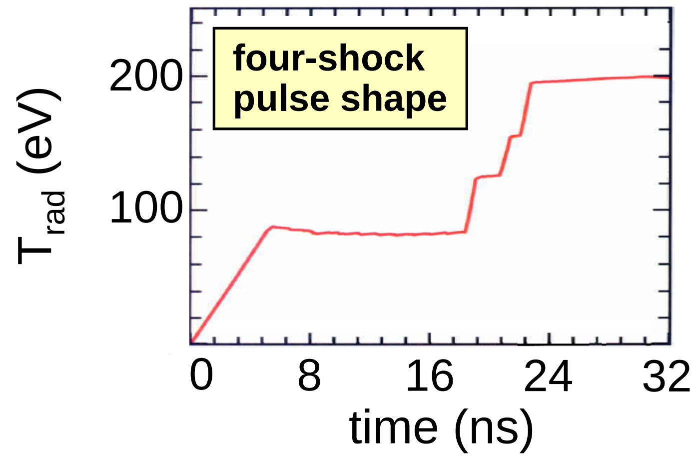
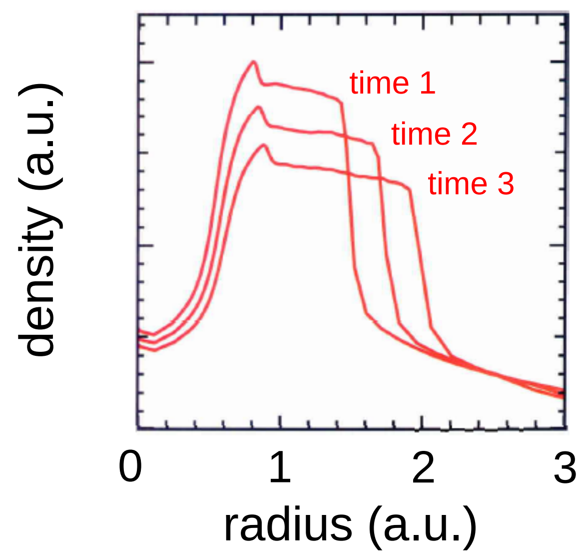


$$m_{\mathrm{fuel}} = 0.8\ \mathrm{mg}$$

$$(\rho r)_{\mathrm{fuel}} = 2.2\ \mathrm{g/cm}^2$$





larger hot spot

Cone-focused FI implosions are inherently 2-D and involve complex hydrodynamics

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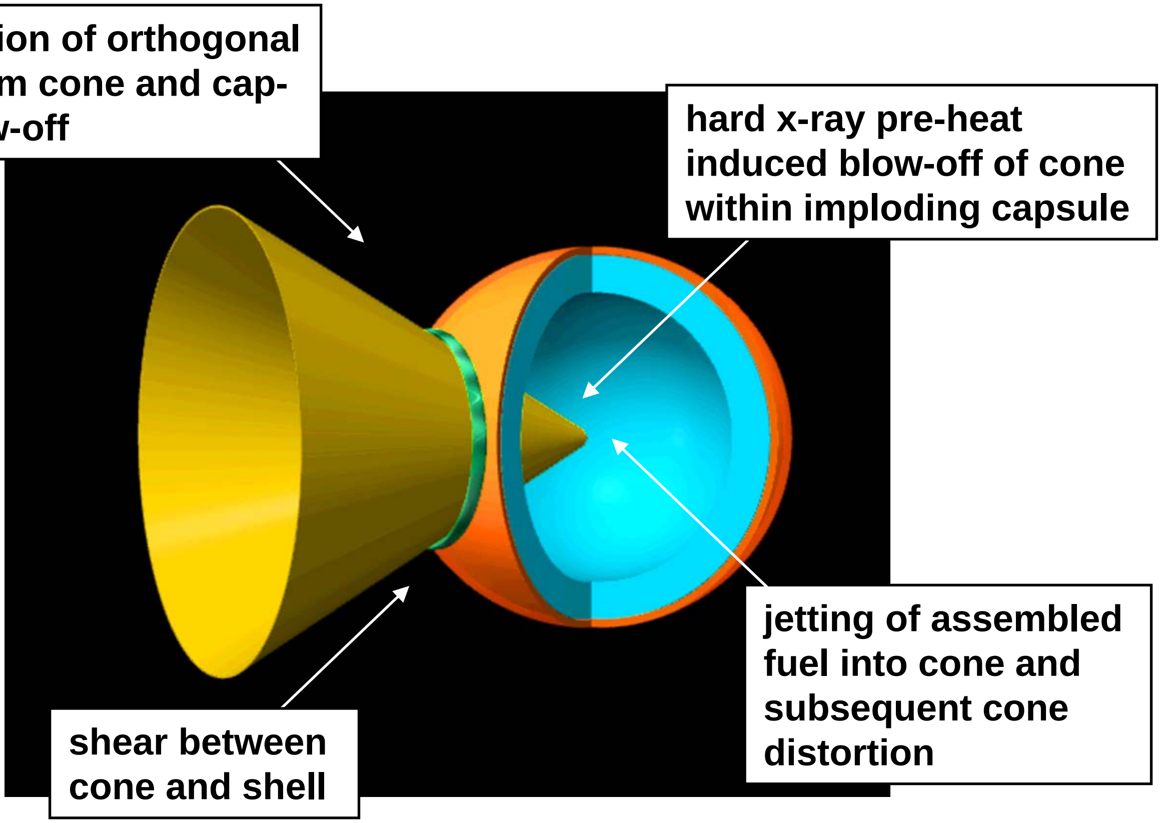

FI targets afford a large design space of parameters (cone thickness, angle, off-set, etc.) which must be scanned for an optimal design

In 2-D the single-shock design achieves an acceptably compact fuel mass if there is sufficient cone stand-off

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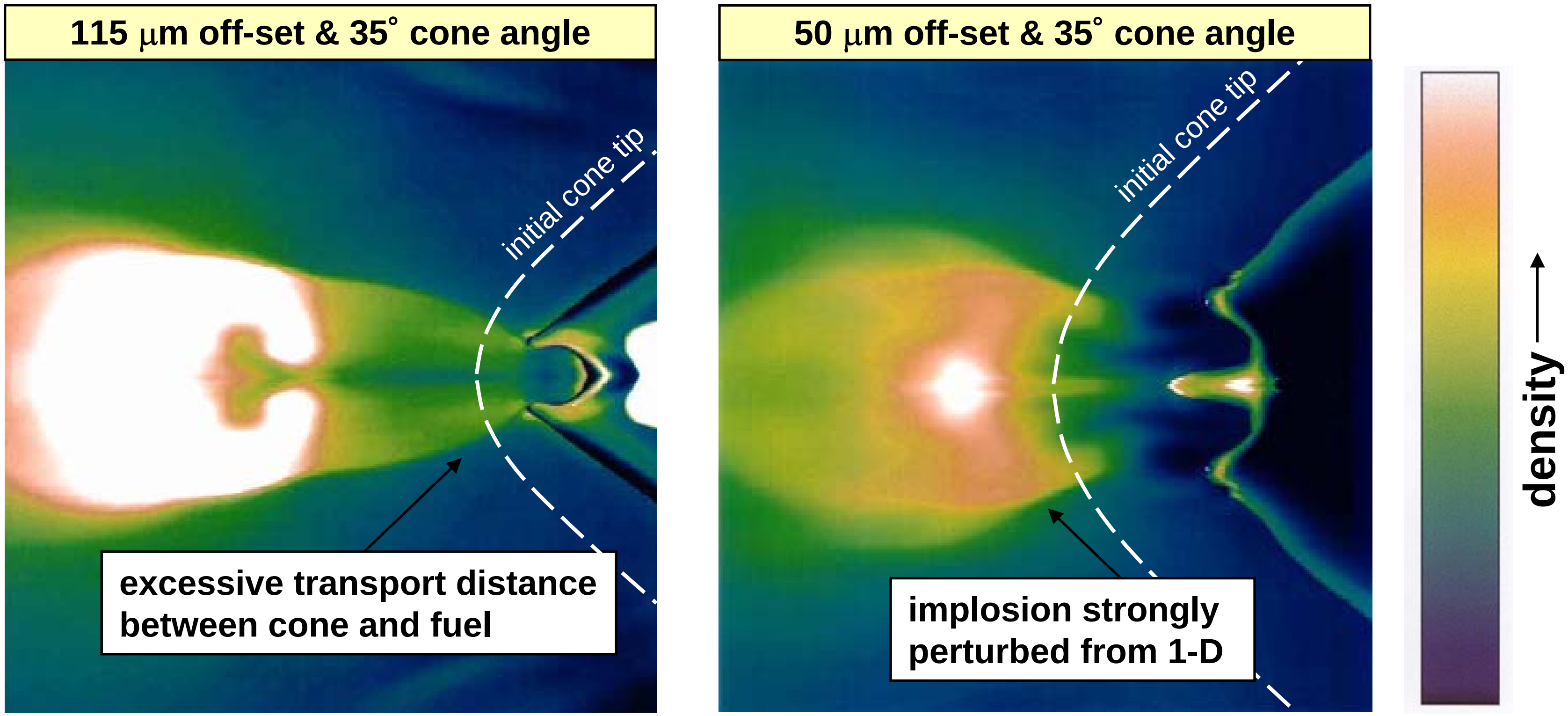

Even with a substantial stand-off of the cone tip from the capsule center a damaging axial jet is directed into the cone tip

Narrowing the cone angle diminishes the perturbation to the fuel assembly but causes the cone to collapse

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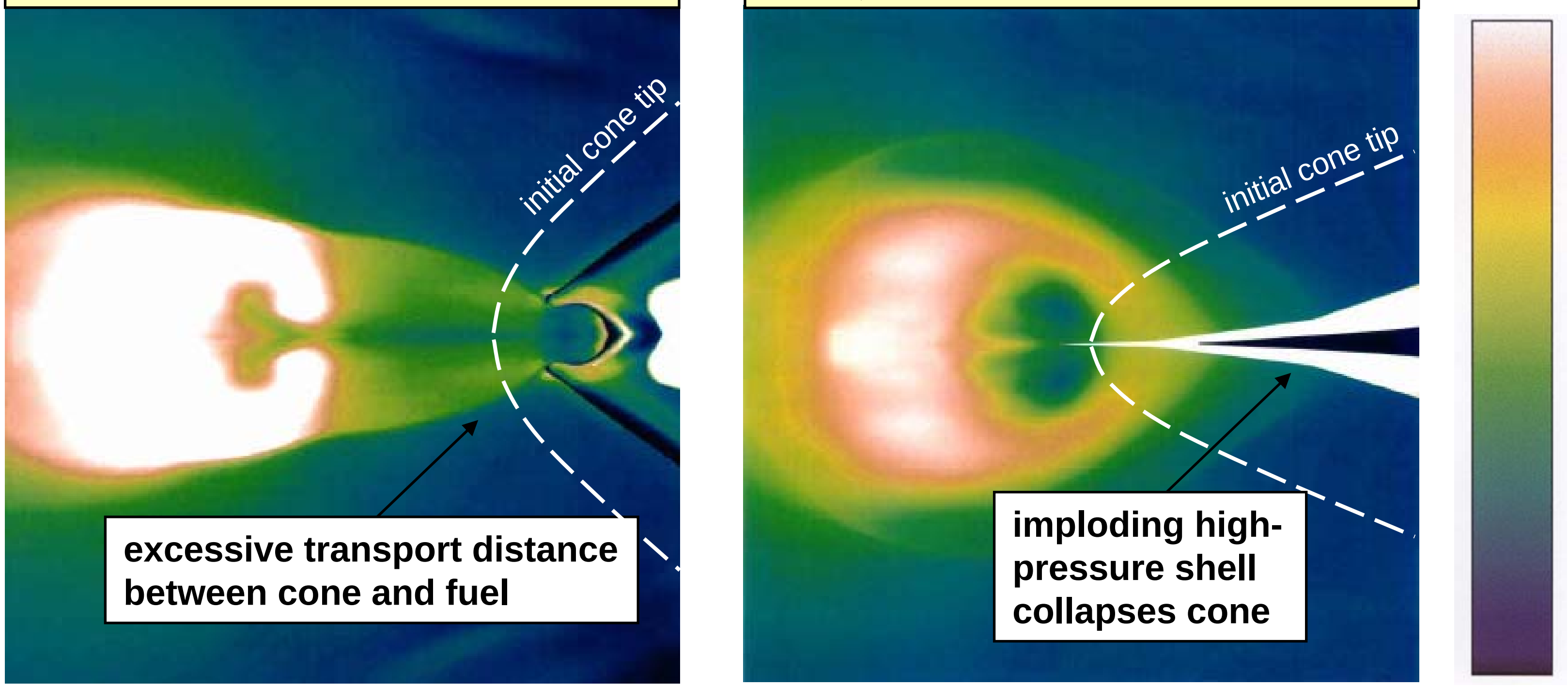
115 μm off-set & 35° cone angle | **50 μm off-set & 22.5° cone angle**



Collapsing of the cone for small angles remains a design challenge — is there an optimal intermediate cone angle?

Cone tip blow-off occurs in this design despite substantial dopant in the ablator

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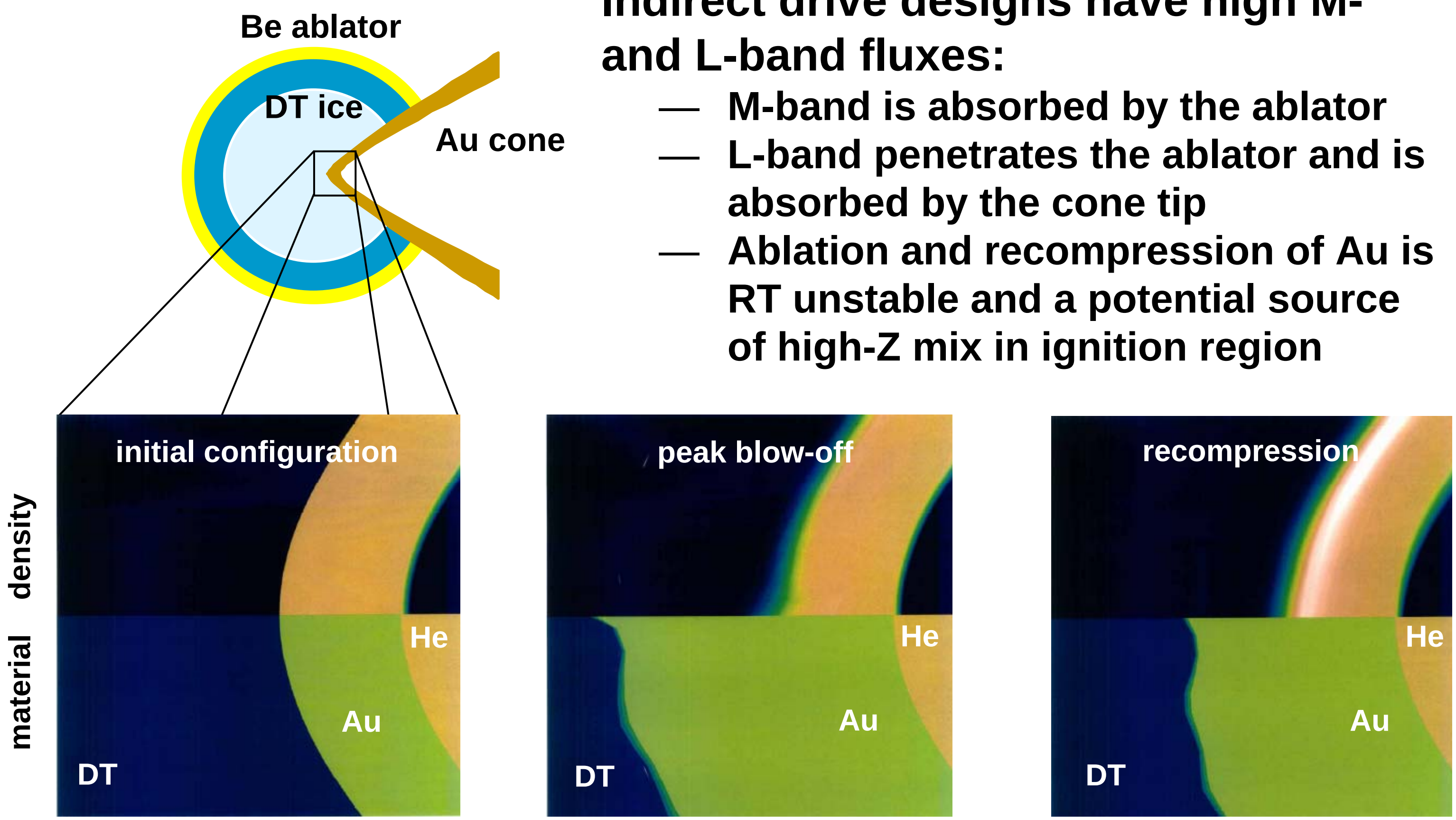
Indirect drive designs have high M- and L-band fluxes:

- M-band is absorbed by the ablator
- L-band penetrates the ablator and is absorbed by the cone tip
- Ablation and recompression of Au is RT unstable and a potential source of high-Z mix in ignition region



Tamping of the cone tip with beryllium will be necessary to control the gold blow-off and lining the hohlraum may reduce the L-band source

Hohlraum simulations to assess energetics and symmetry are beginning

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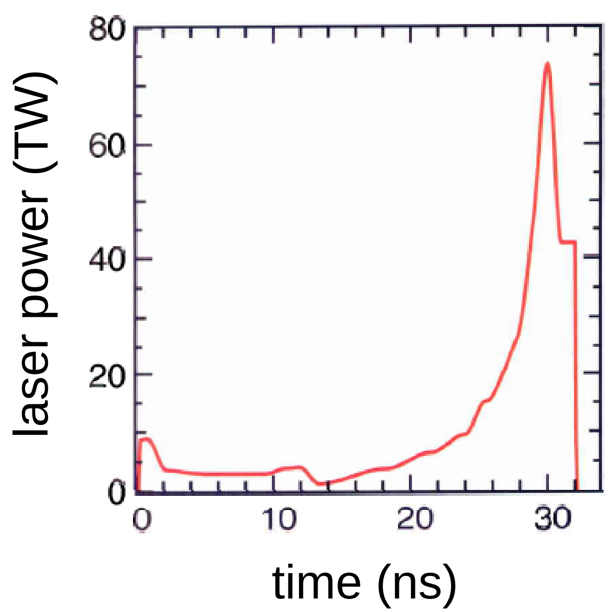
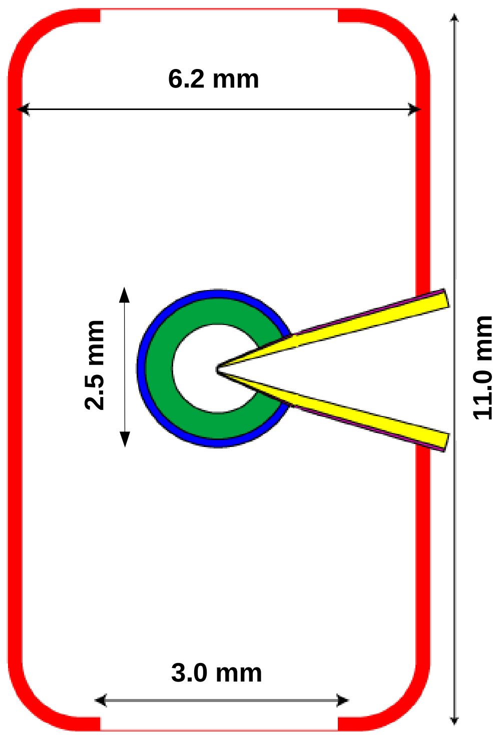
Simulations so far are run in 2-D without the cone:

- **Peak power: 70 TW**
- **Contrast ratio: 35-to-1**
- **Laser energy (3ω): 650 kJ**
- **Pulse length: 32 ns**





hohlraum geometry with cone is inherently 3-D

FI demonstration on NIF continues to pose many hydro. design challenges

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1-D capsule hydrodynamics

- — Continue optimization of designs for maximum ρr, minimum hot spot size, and minimum total energy
- — Continue sensitivity studies of designs to pulse shaping uncertainties, EOS uncertainties, etc.
- — Develop CD non-cryo surrogates and pulse tuning strategy

2-D capsule hydrodynamics

- — Develop strategy to preserve the cone from jetting or collapse before ignition time — without excessive stand-off or tip thickness
- — Mitigate cone tip blow-off with increased ablator doping, low-Z tamping of the cone, or hohlraum lining

Hohlraum design

- — Assess energetics and symmetry of various capsule designs
- — Assess 3-D impact of cone in hohlraum

FI demonstration on NIF would provide a platform for HEDLP experimental science and a gateway to high gain IFE