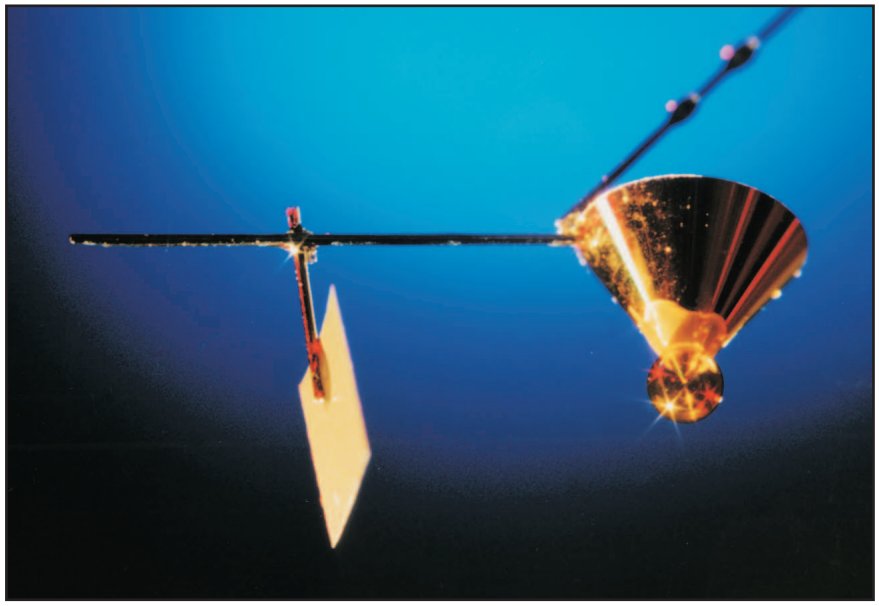
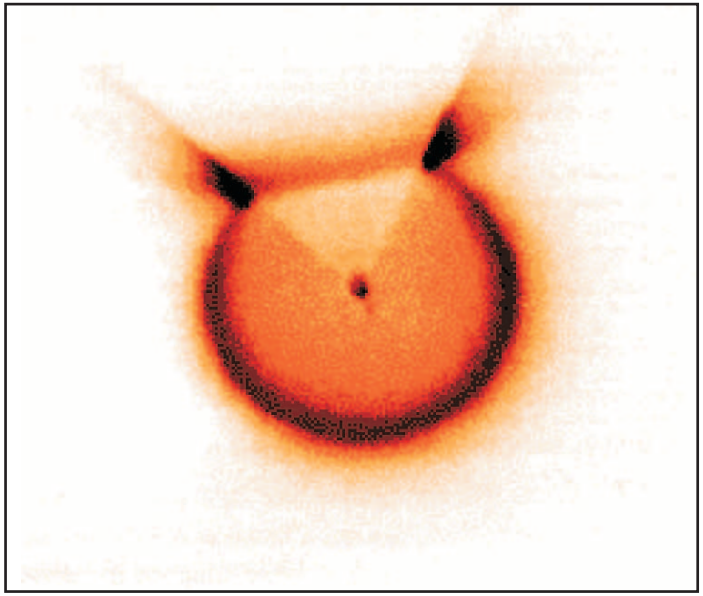
Fast-Ignitor Research at the Laboratory for Laser Energetics

UR LLE





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Collaborators

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Summary

LLE is studying the direct-drive fast-ignition concept experimentally and theoretically

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- LLE performs direct-drive (DD) cryogenic implosions that may lead to areal densities of ~350 mg/cm^2.
- LLE (with GA, ILE, LLNL) is beginning to study fuel assembly for fast-ignition (FI) targets:
  - Initial DD cone target implosions (empty)
  - Development of DD cone target with gas fill for diagnostics
  - Design of non-cone, high-areal-density implosions (cryo fuel)
- LLE has proposed to add high-energy petawatt capability for integrated FI experiments: OMEGA EP.

Implosions

A multi-year science and engineering effort (with GA) was required to produce a reliable and precise cryogenic target experimental capability

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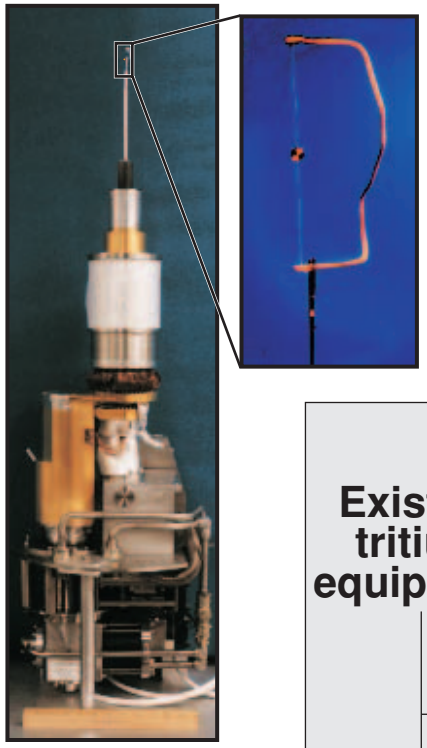
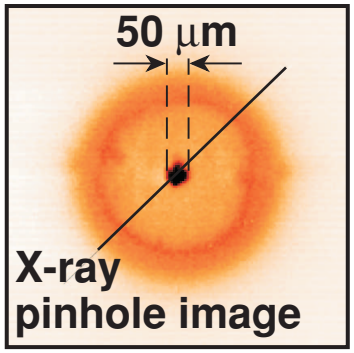
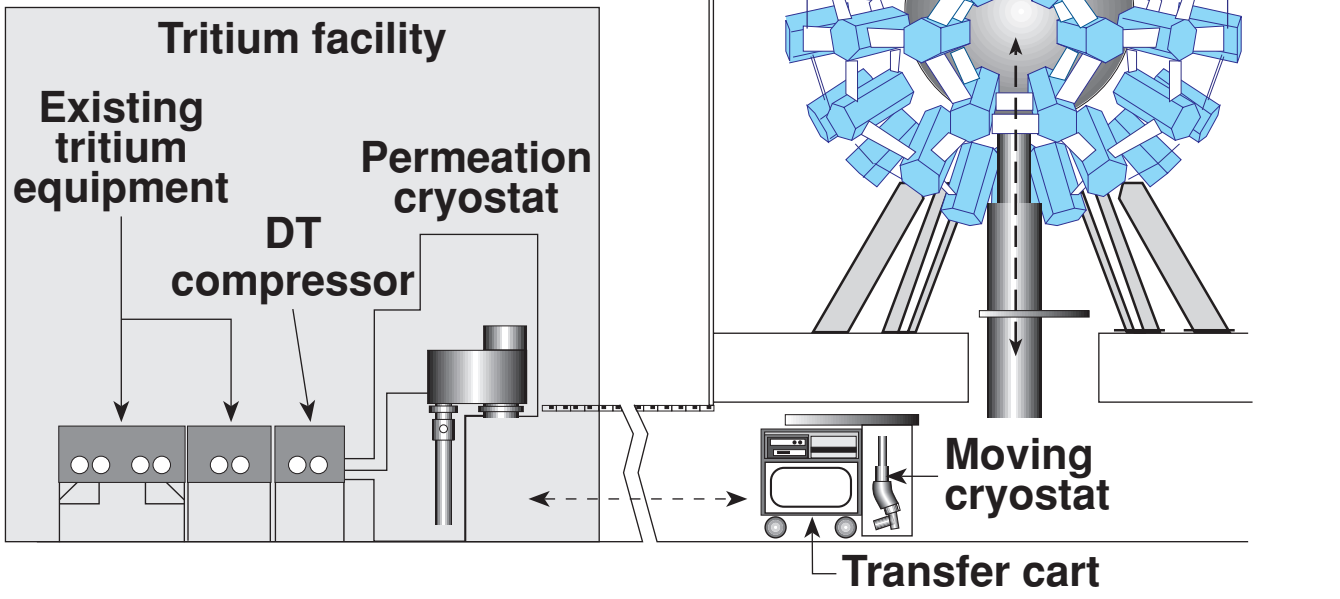
Target positioning and mounting



Target shot





E11002c

OMEGA can assemble ~ 1 kJ of fast-ignition-relevant cryogenic fuel at high density

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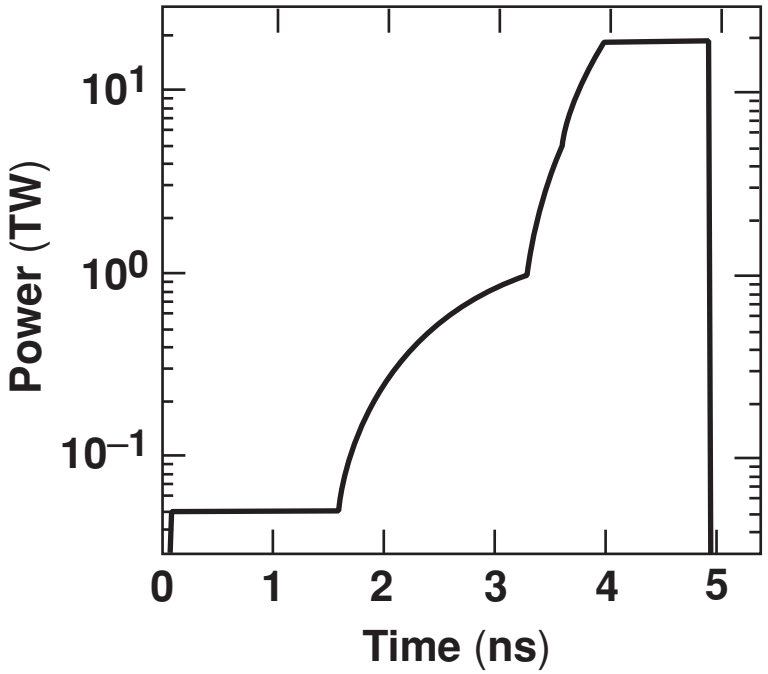
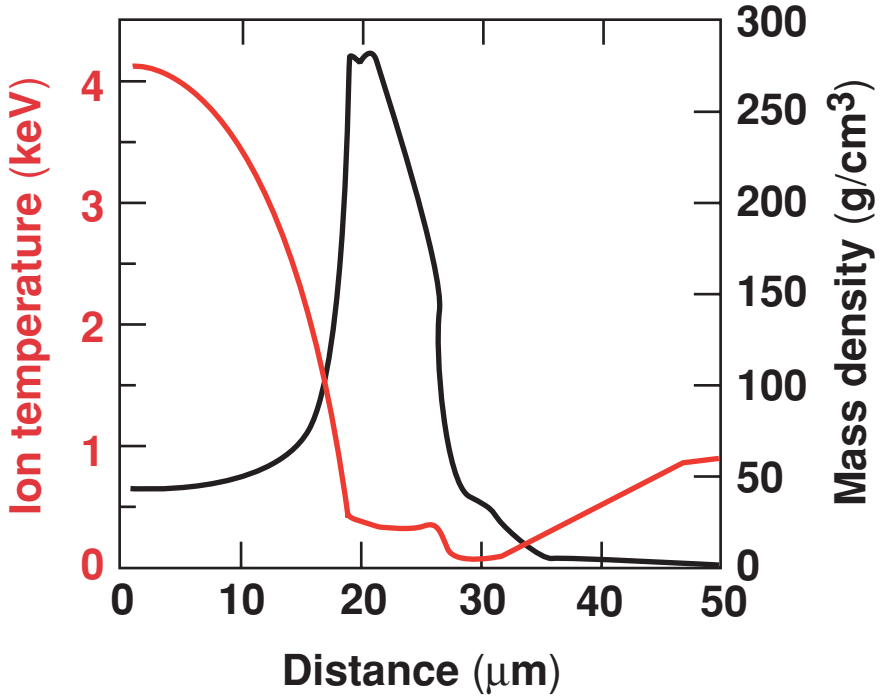
Pulse for the fast-ignitor cryo D_2 target



Peak ρR ~ 350 mg/cm^2
Target conditions at peak density for fast-ignitor cryo D_2 target



Expect burn-averaged ρR_{fuel} to approach 150 mg/cm^2 in FY03 and > 300 mg/cm^2 in the next 2 to 3 years.

E12031

A 1-kJ, 1-MeV electron beam raises the ion temperature in the high-density fuel shell to ~10 keV

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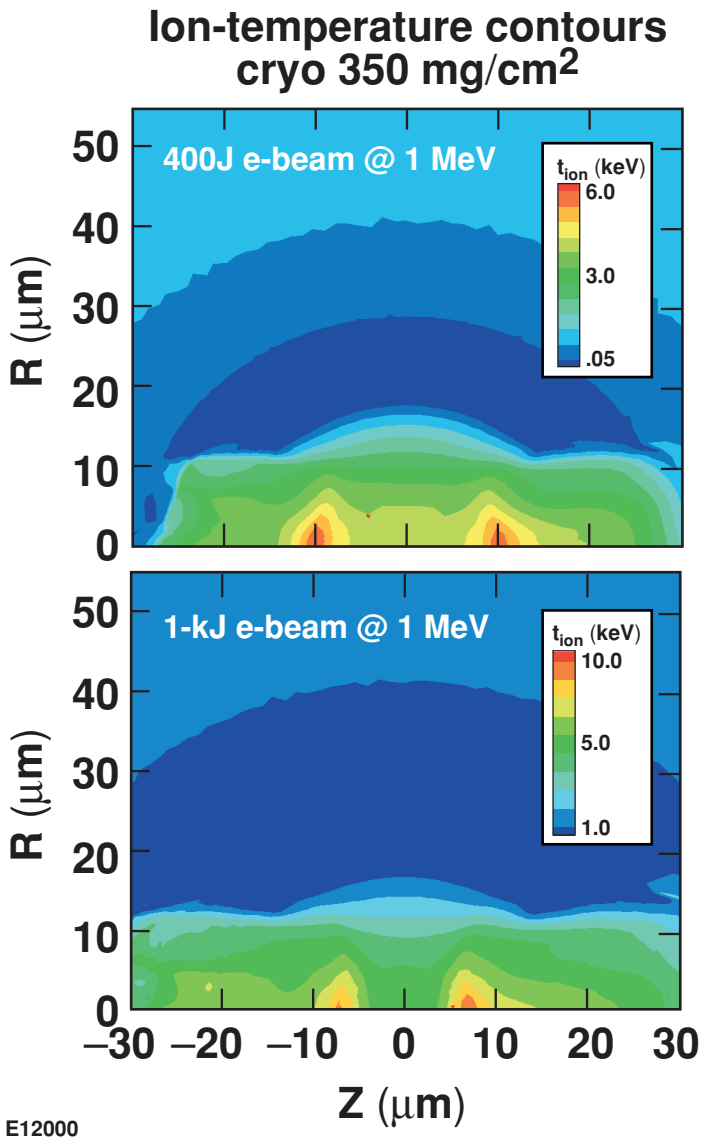
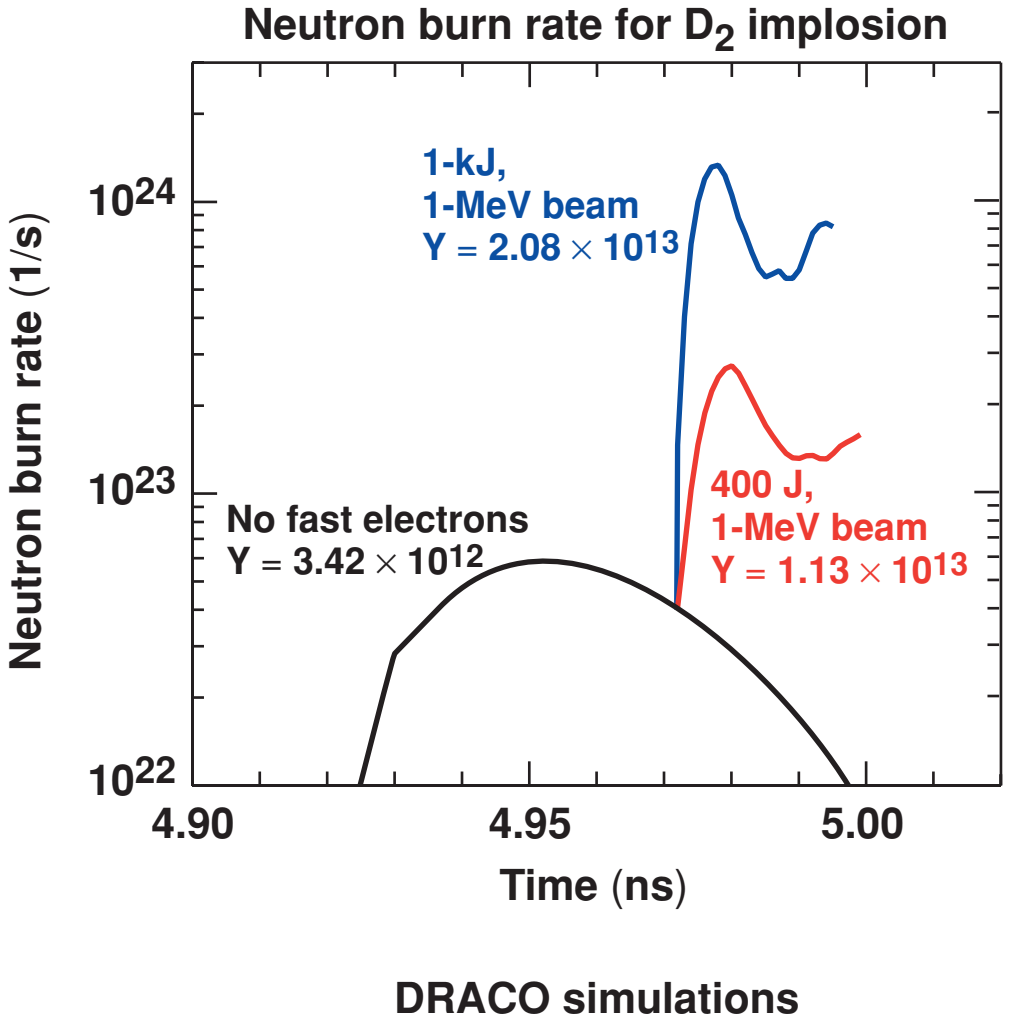
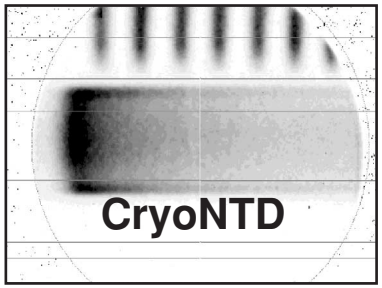




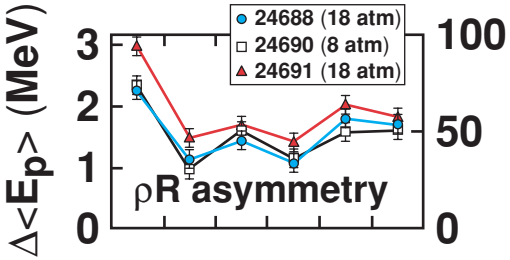
DRACO simulations

E12000

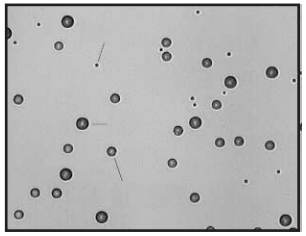
Integrated cryogenic DD FI experiments would validate/compare both channeling and cone concepts on a single facility



Neutronics

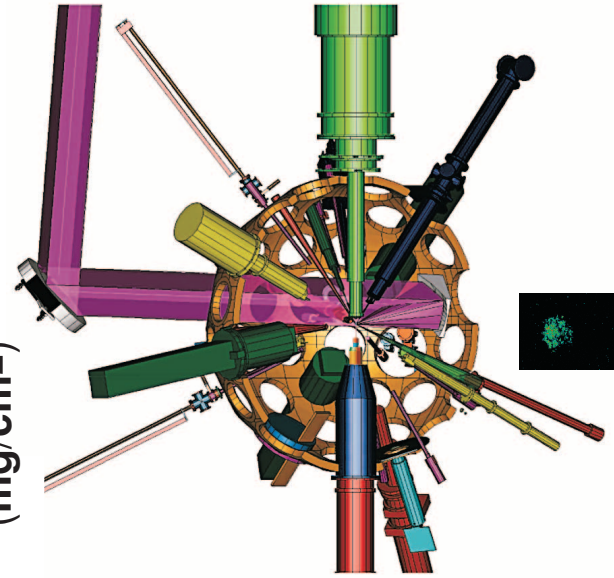


Charged-particle spectroscopy

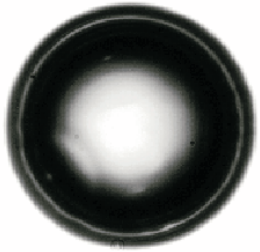


CR-39 track data

Petawatt beam
(EP upgrade proposal)

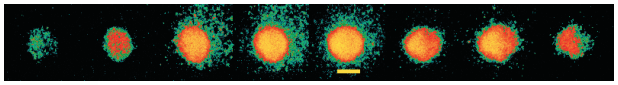


Direct-drive DT cryo capsules and slide cone targets

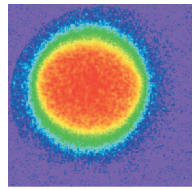


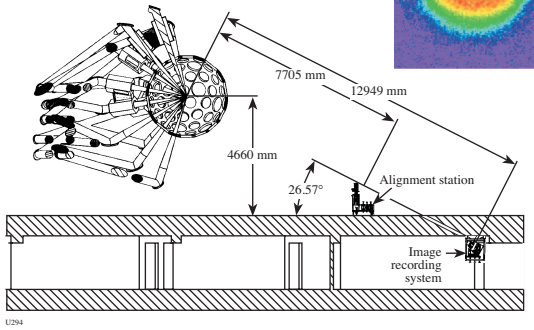
- Dedicated program
- High throughput
- Proven diagnostics
- Proven cryogenics

X-ray imaging



Neutron imaging





E11738

LLE is beginning to implode direct-drive cone targets on OMEGA

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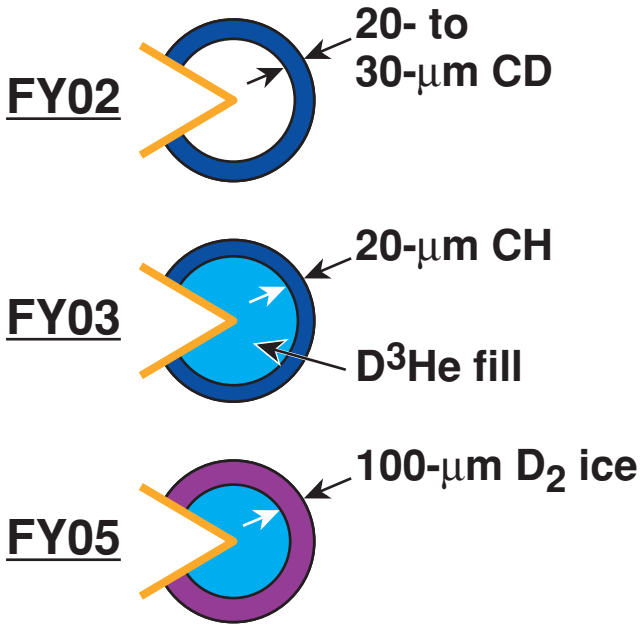
- Cone target implosions have shown encouraging performance.*
- LLE will commence imploding cone targets in the near future:
  - Initially, empty shells with gold cones will be used.
  - Improved target fabrication techniques will allow gas-filled cone targets to be imploded.
  - In the future, cryogenic cone targets will be studied and may be imploded.



*Kodoma *et al.*, Nature 412, 798 (2001); R. Stephens, private communication.

Fuel assembly experiments with cone-focused targets have begun on OMEGA

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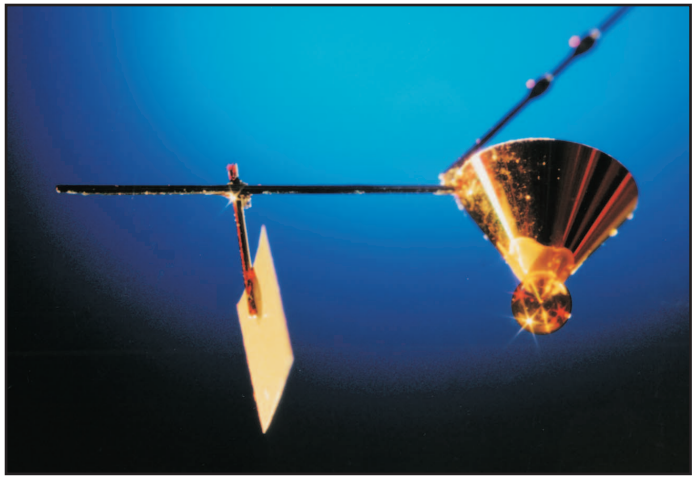
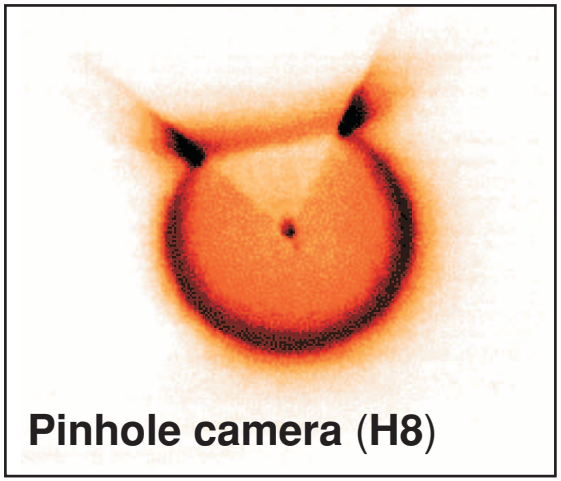
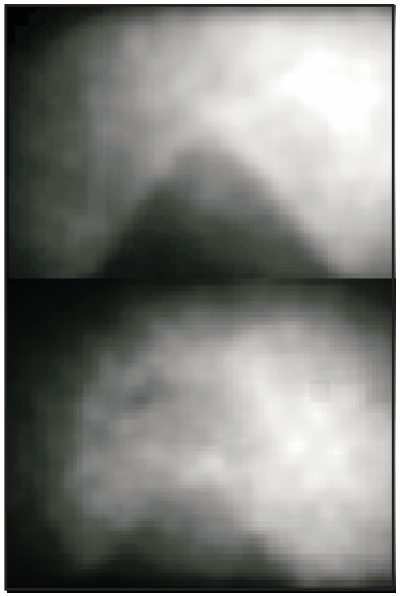
Direct-drive cone targets shot on OMEGA in FY02 (LLNL, GA)





Pinhole camera (H8)

Raw framing camera images: Top shows early in time, bottom near stagnation.



Note that near stagnation, the tip of the Au cone has started to disappear.

E11959a

A new high-energy petawatt capability at OMEGA next to the existing 60-beam facility will allow integrated FI experiments

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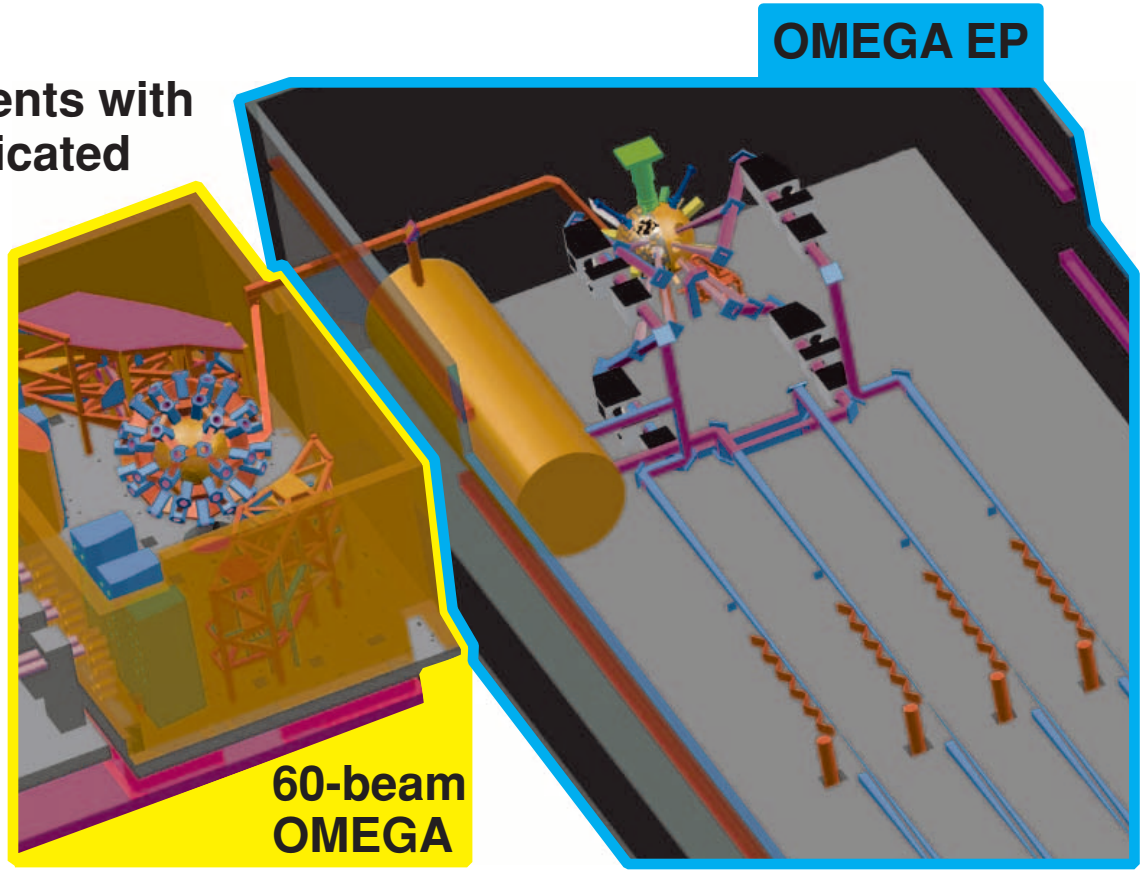
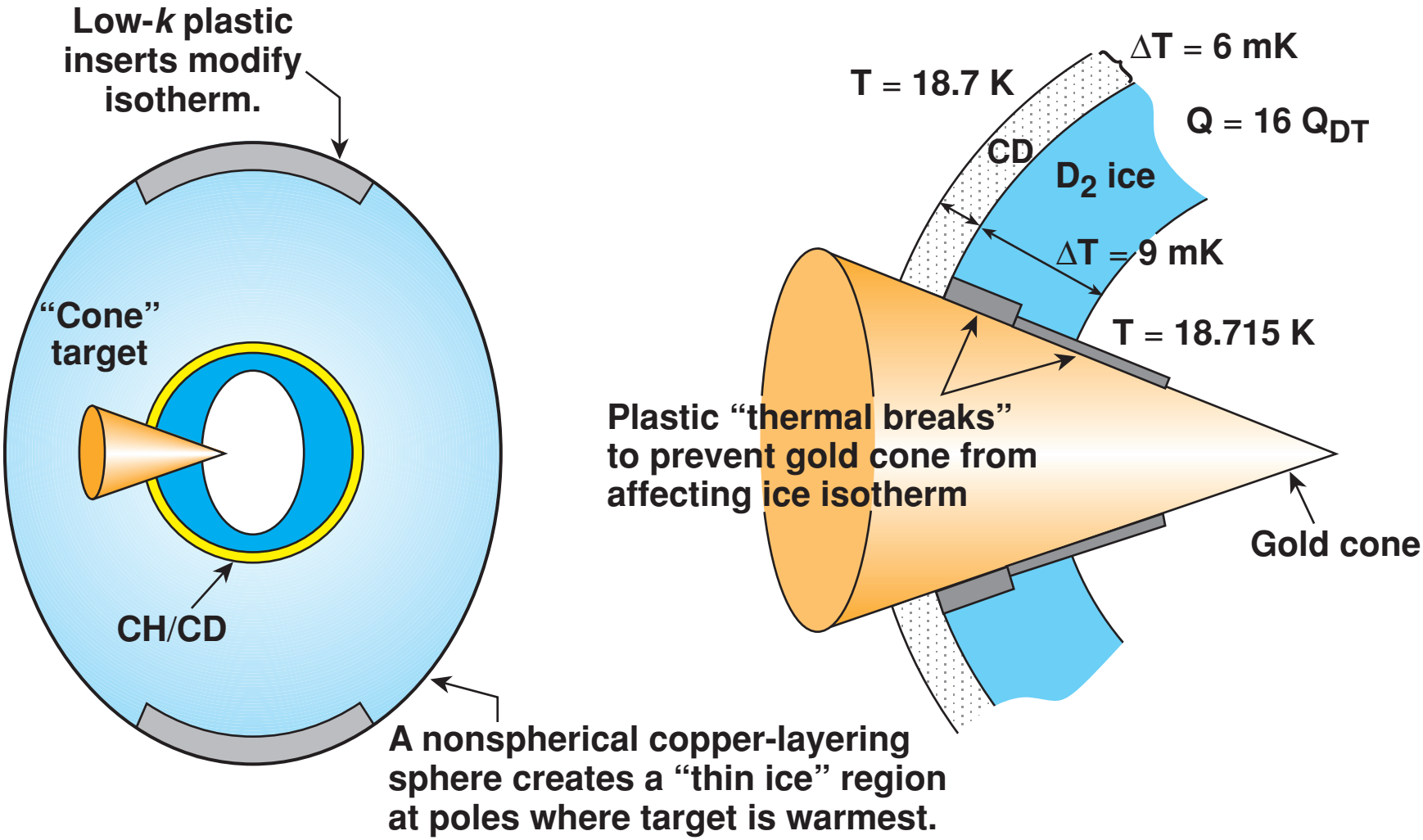
- Two short-pulse, 2 ~ 3-PW, 2.6-kJ beams
- Up to four long-pulse (10-ns) UV beams with ~6.5 kJ each
- NIF-like staging
- Integrated experiments with OMEGA or in a dedicated target chamber
- < 2-h shot cycle



I1268f

By tailoring the DT-ice distribution it should be possible to optimize the fuel assembly for direct-drive FI on the NIF



Modify thermal environment to create low-ℓ-mode variation.

E11945

Integrated direct-drive FI experiments could be carried out on the NIF in indirect-drive configuration

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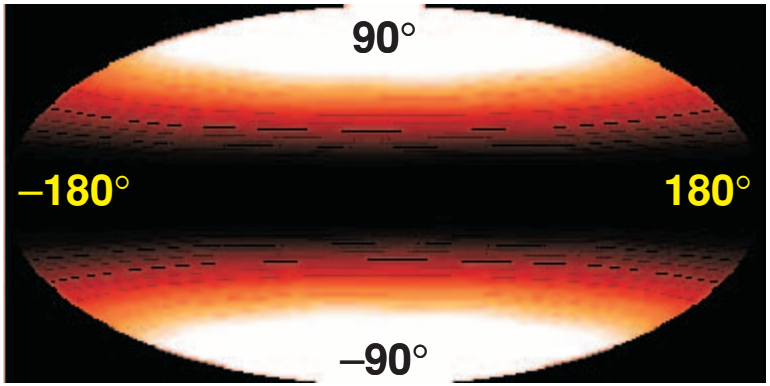
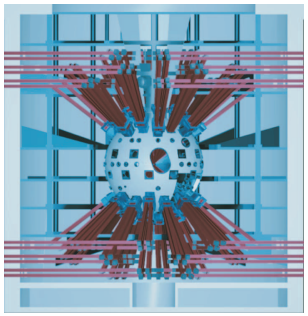
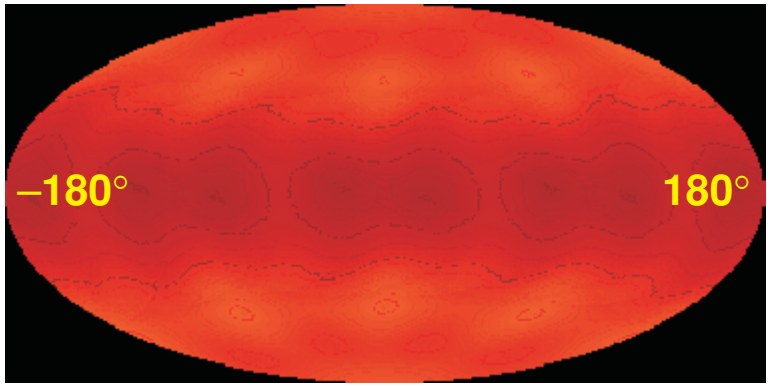
Aitoff projection of intensity on a capsule



σ_{rms} = 48%
peak-to-valley = 157%

NIF direct-drive distribution using 24 (×4) beams in indirect-drive illumination





σ_{rms} = 6%
peak-to-valley = 22%

NIF direct-drive intensity distribution with 24 (×4) beams repointed to a pattern similar to OMEGA 24

The penalty from asymmetric illumination may be mitigated by the clever use of phase plate design, beam pointing, pulse shaping, and ice layer/capsule shimming.

E11720

An integrated test on OMEGA EP will demonstrate the physics of direct-drive fast ignition

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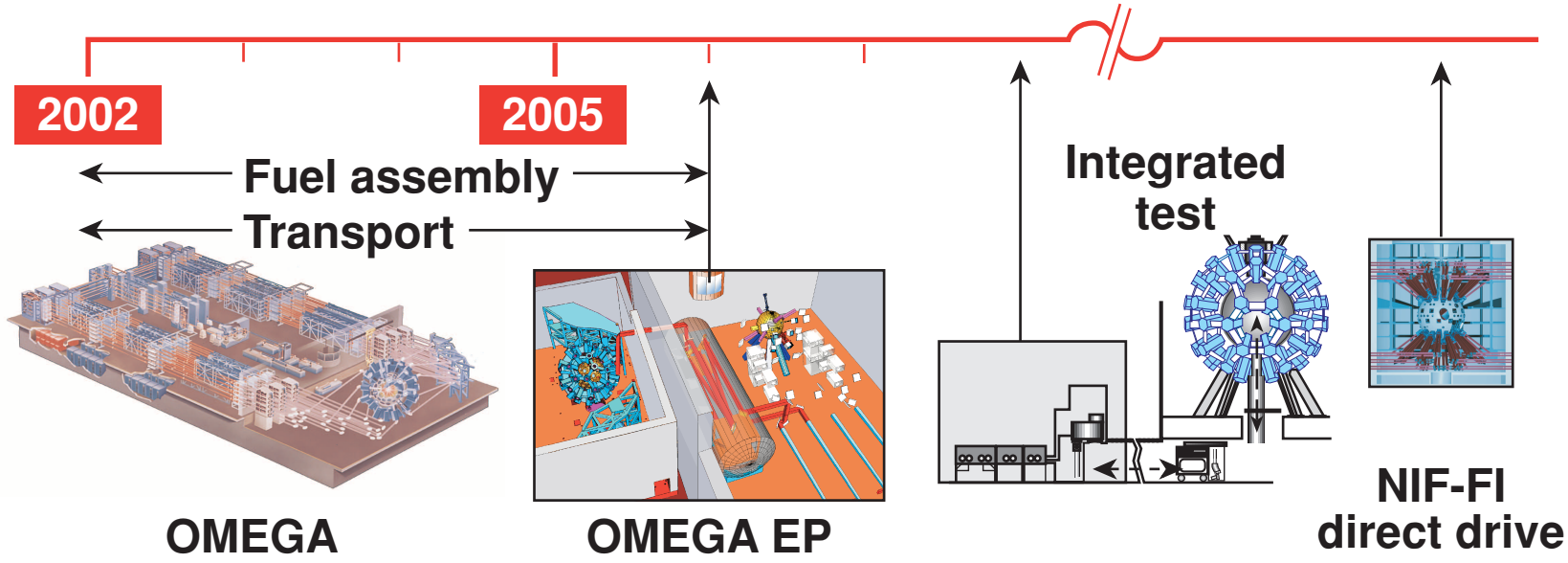
$$\text{Driver energy} = \frac{1}{\eta_c \eta_{hydro}} \frac{4\pi(\rho r)^3}{3\rho^2} \varepsilon_f$$

$$E_{FI} > 140 \eta_c \left[\frac{100}{\rho}\right]^{1.8} \text{kJ}$$



Modifications to the NIF for fast ignition by direct drive will be modest.

E11672

Summary/Conclusions

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