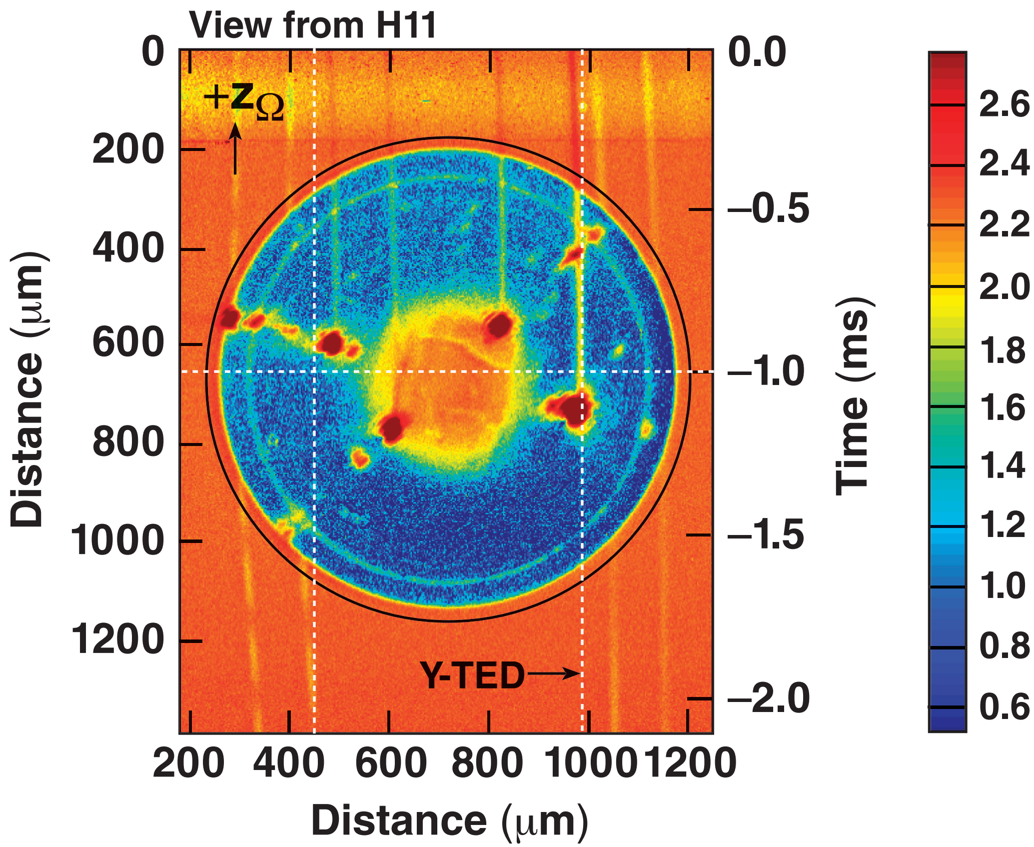
Direct-Drive Implosions Using Cryogenic D_2 Fuel



T. C. Sangster
OMEGA Experiments Group Leader
University of Rochester
Laboratory for Laser Energetics

35th Annual Anomalous
Absorption Conference
Farjardo, Puerto Rico
27 June–1 July 2005

Summary

Direct drive is a robust alternative for ignition on the National Ignition Facility

- The baseline symmetric direct-drive cryogenic D_2 campaign has demonstrated target performance consistent with 1-D and 2-D hydrocode predictions.

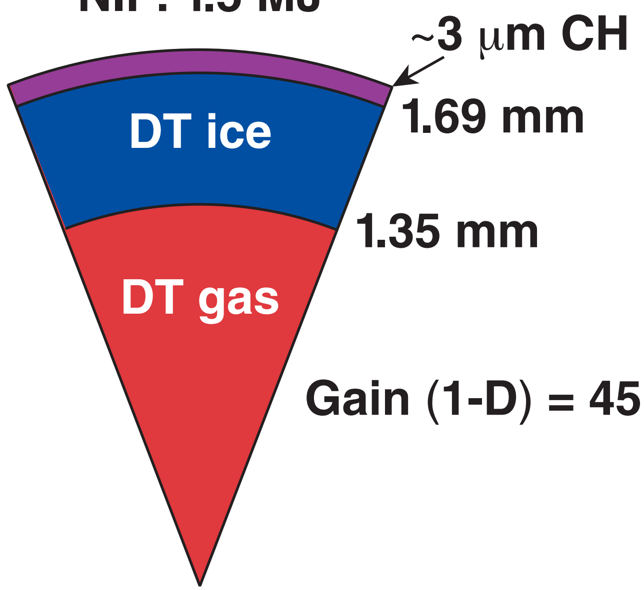
- Laser and cryogenic target uniformity are approaching the requirements for scaled ignition validation.

- DT cryogenic implosions will be performed before the end of FY05.

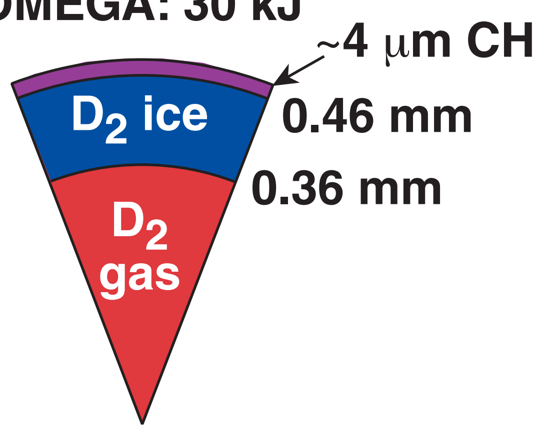
- OMEGA EP will be completed by the end of FY07.

OMEGA cryogenic targets are energy scaled from the NIF symmetric direct-drive point design

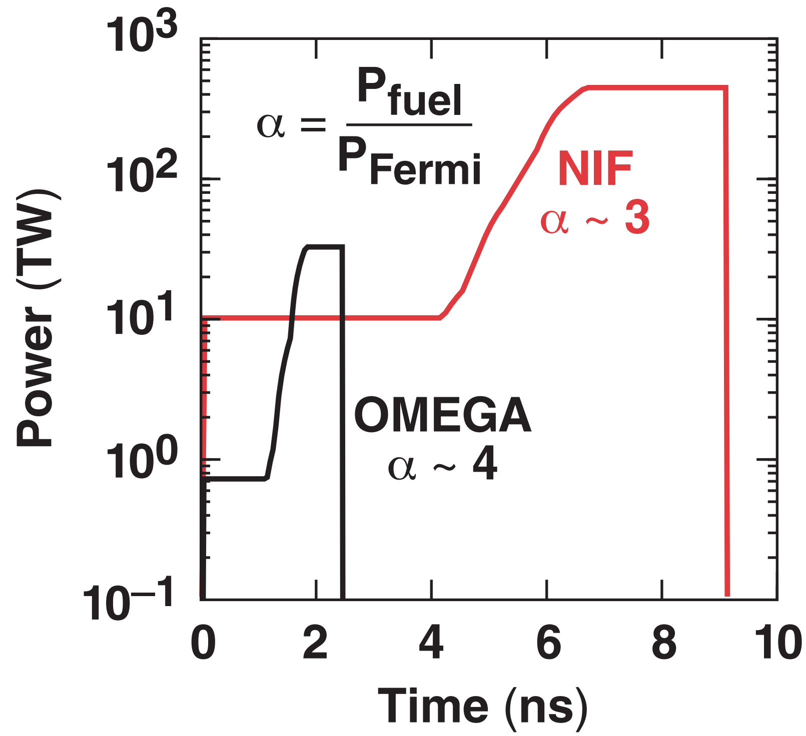
NIF: 1.5 MJ



OMEGA: 30 kJ



Energy ~ radius^3;
power ~ radius^2;
time ~ radius



E11251g

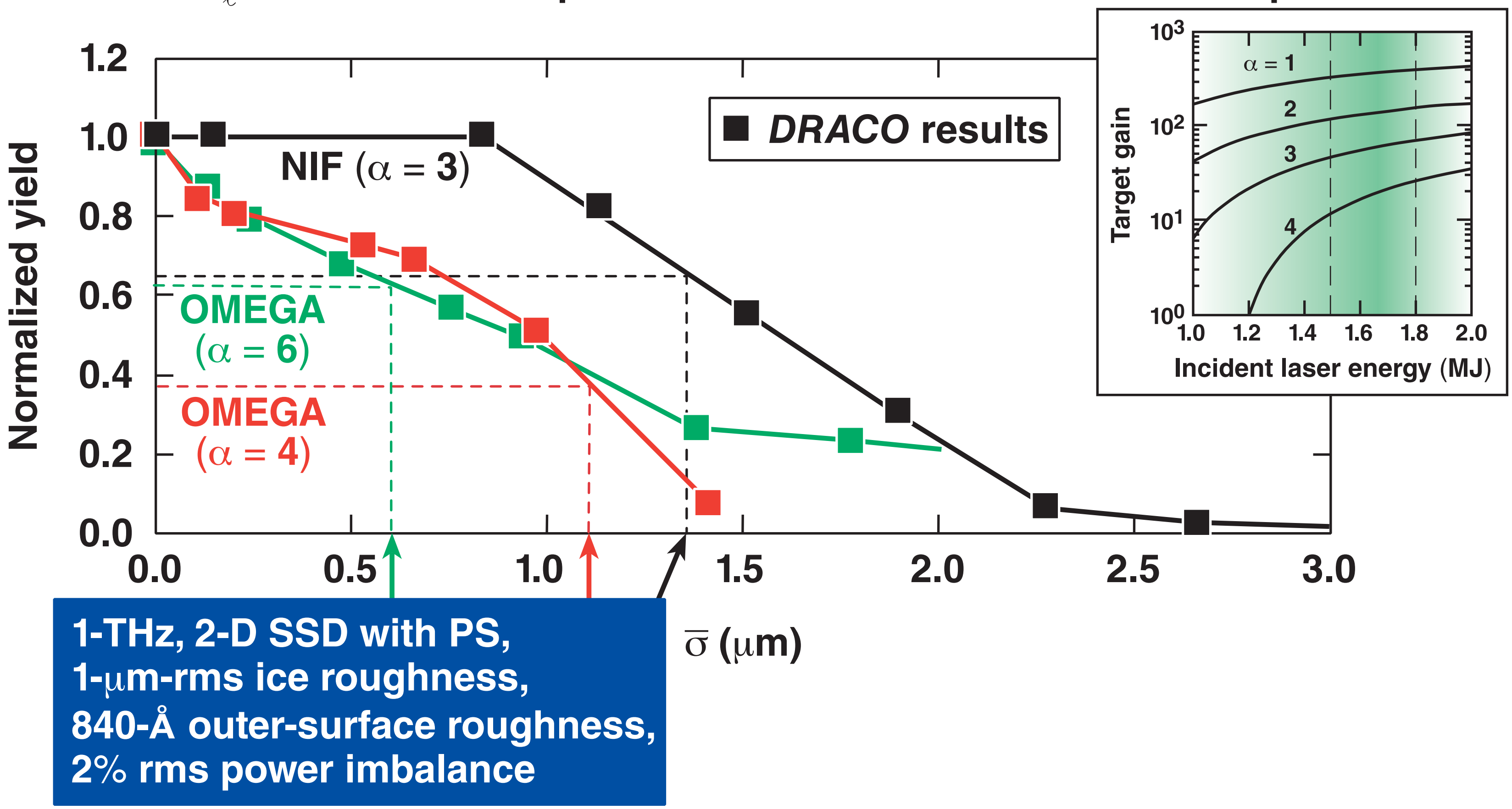
A stability analysis* defines the ignition-scaling performance window for low adiabat implosions

UR LLE

- The NIF gain and OMEGA yield can be related by

$$\bar{\sigma}^2 = 0.06\,\sigma^2_{\ell<10} + \sigma^2_{\ell\geq 10},$$

where the σ_ℓ's are the rms amplitudes at the end of the acceleration phase*.

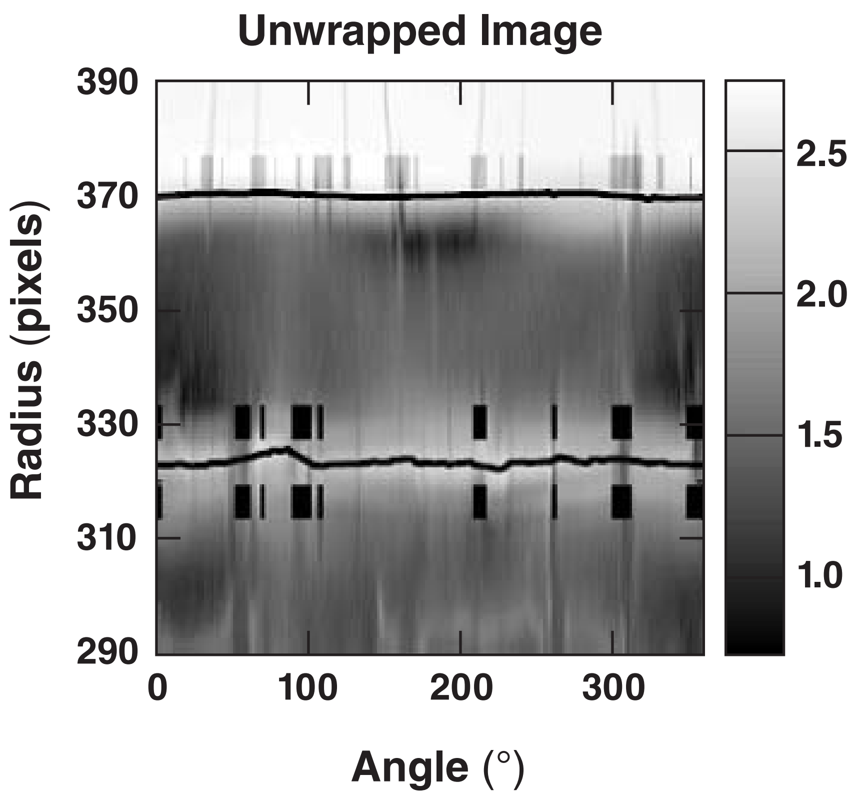


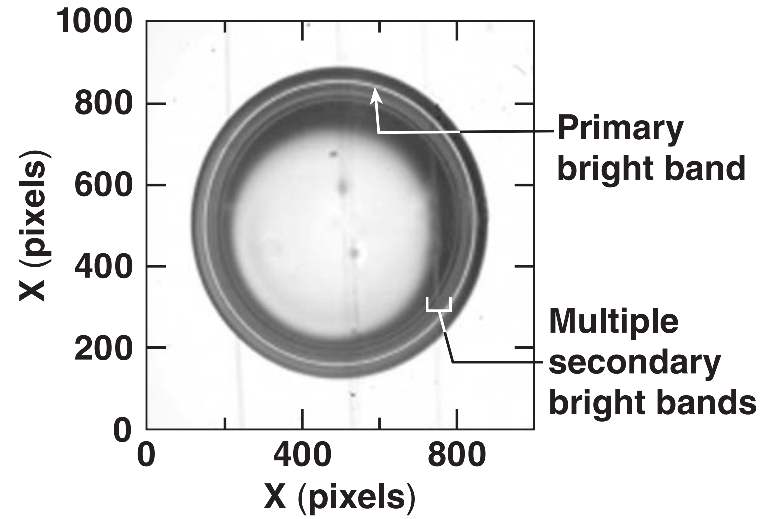
E12008I

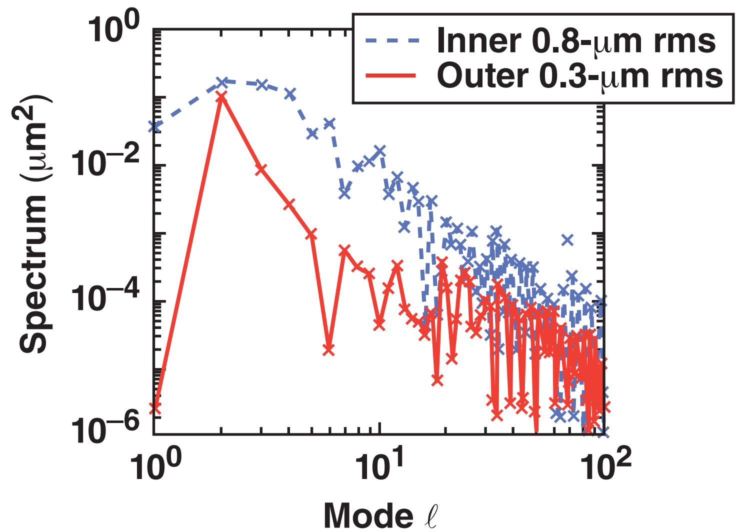
*P. W. McKenty *et al.*, Phys. Plasma 8, 2315 (2001).

The best layer to date is 1.2-μm rms (all modes) with the best regions below 1.0-μm rms

- 24 shadowgraphic views of “x” and “y”

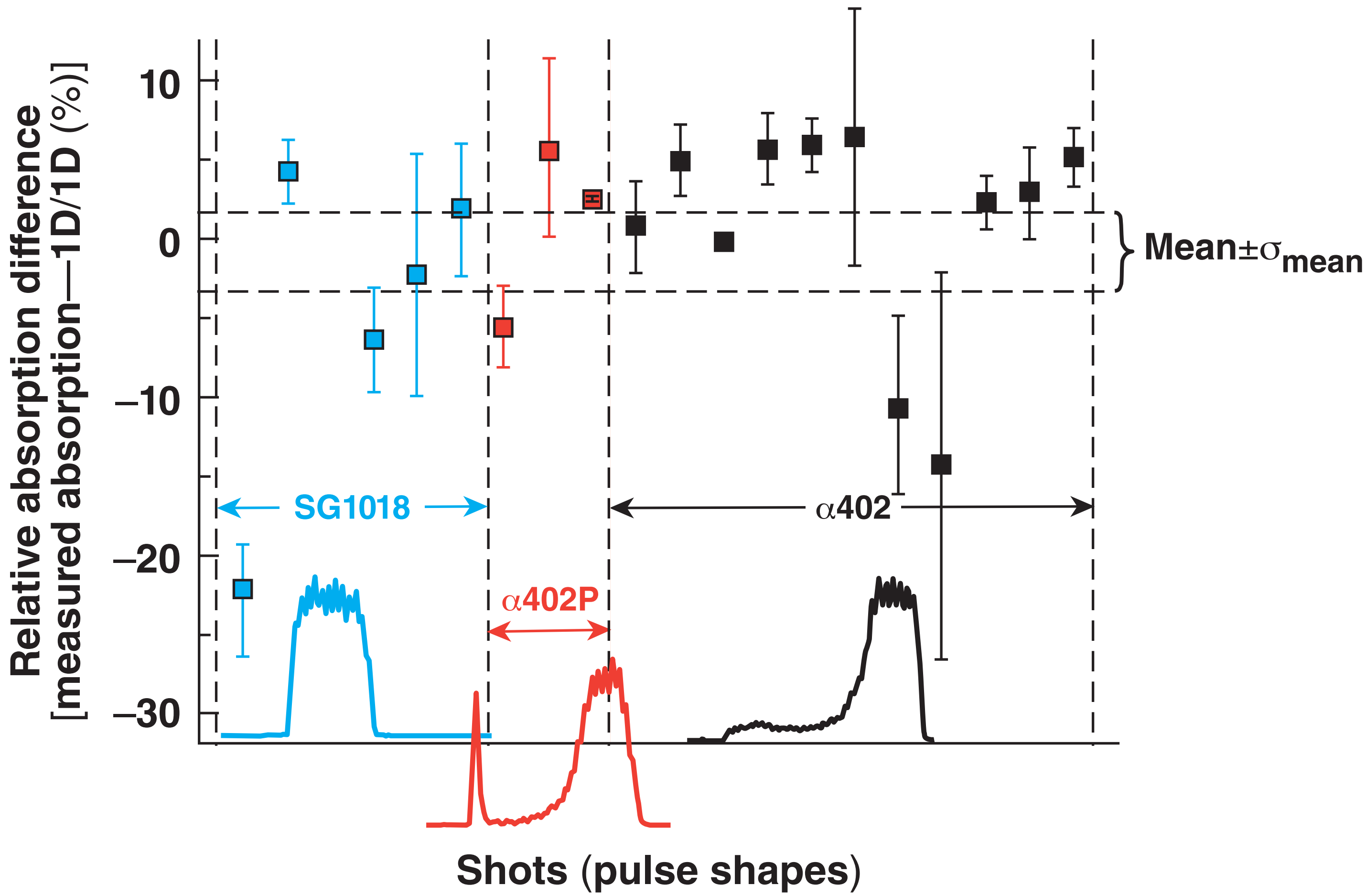






T1905e

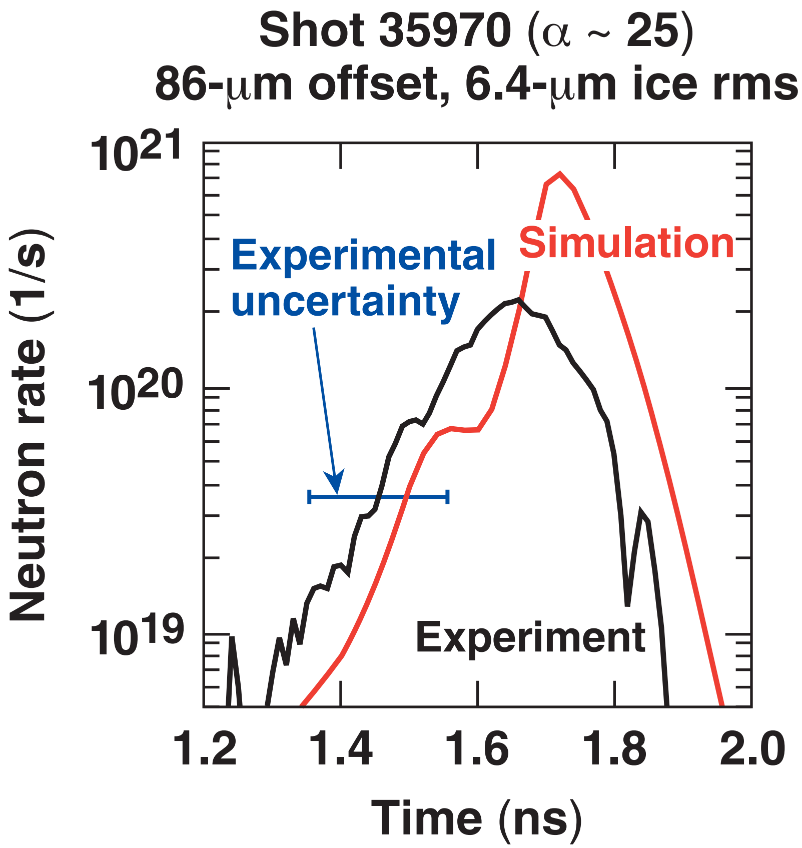
Absorption measurements for cryogenic D_2 shots agree with 1-D hydrodynamic simulations for all pulse shapes



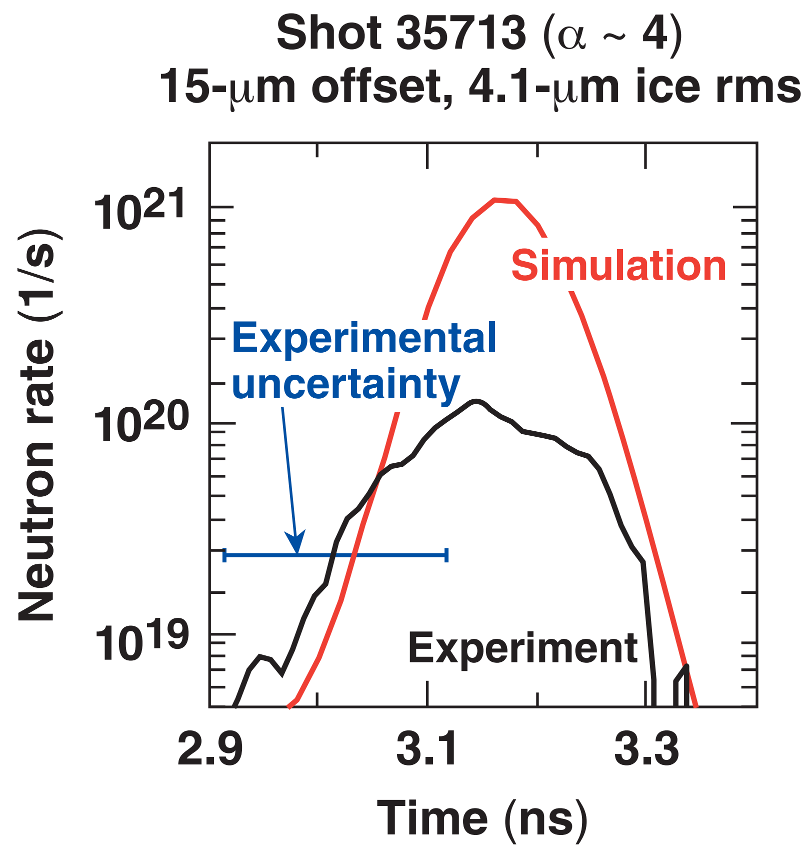
The average difference between 1-D predictions and absorption measurements is –1±2%.

E13392

The reaction history and bang time are close to the 1-D predictions for cryogenic D_2 implosions



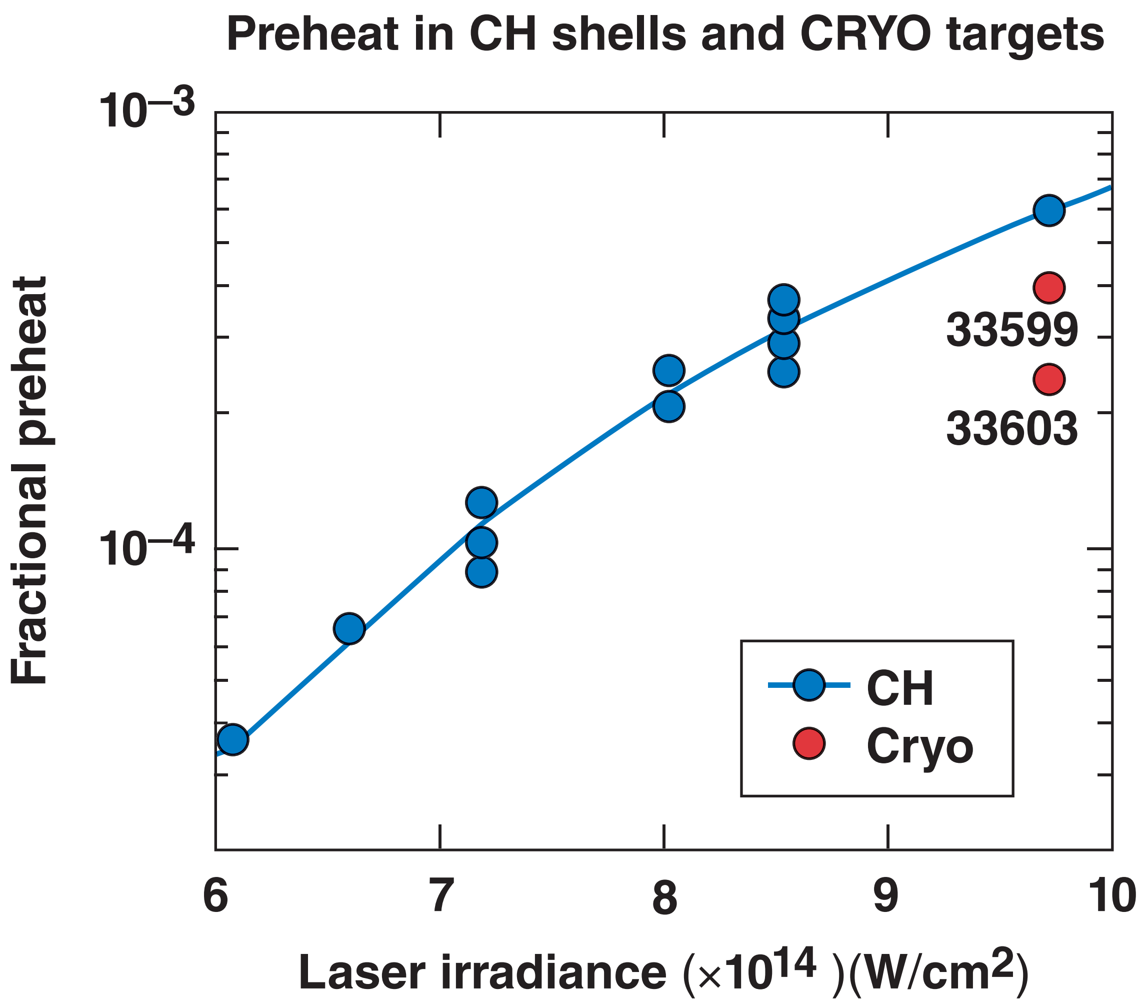
f_{abs} { Exp.: 0.55±0.02; 1-D: 0.57



f_{abs} { Exp.: 0.57±0.01; 1-D: 0.55

E13394a

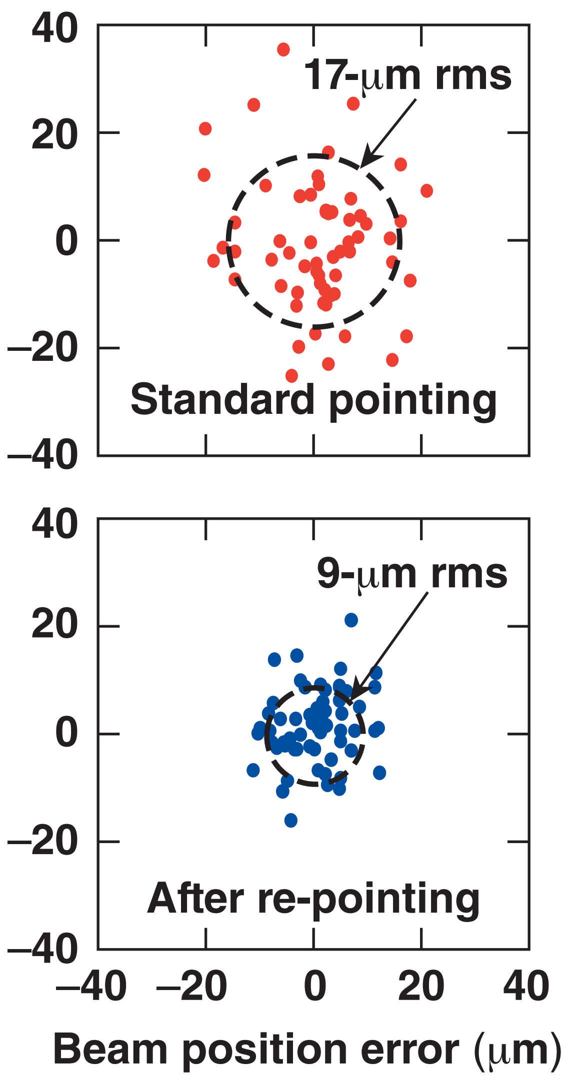
Preheat estimates for cryogenic targets are well below the threshold of concern (0.1%)



B. Yaakobi *et al.*, "Measurement of Preheat Due to Fast Electrons in Laser Implosions of Cryogenic Deutrium Targets," to be published in Physics of Plasmas.

E13627

Low-ℓ-mode drive nonuniformities due to OMEGA beams have been significantly reduced



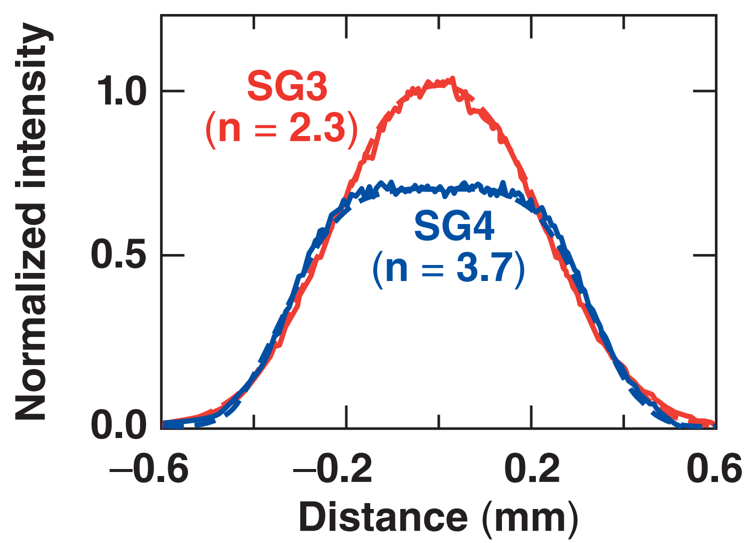
- New DPP's, better overlap, and beam re-pointing have minimized low-ℓ-mode ($\ell < 6$) contributions.

$$\sigma^2_{tot} = \sigma^2_{size} + \sigma^2_{pntg} + \sigma^2_{balance}$$

$$SG3 = (1.5)^2 + (2.2)^2 + (1.3)^2,\ \sigma_{tot} = 3.0\%$$

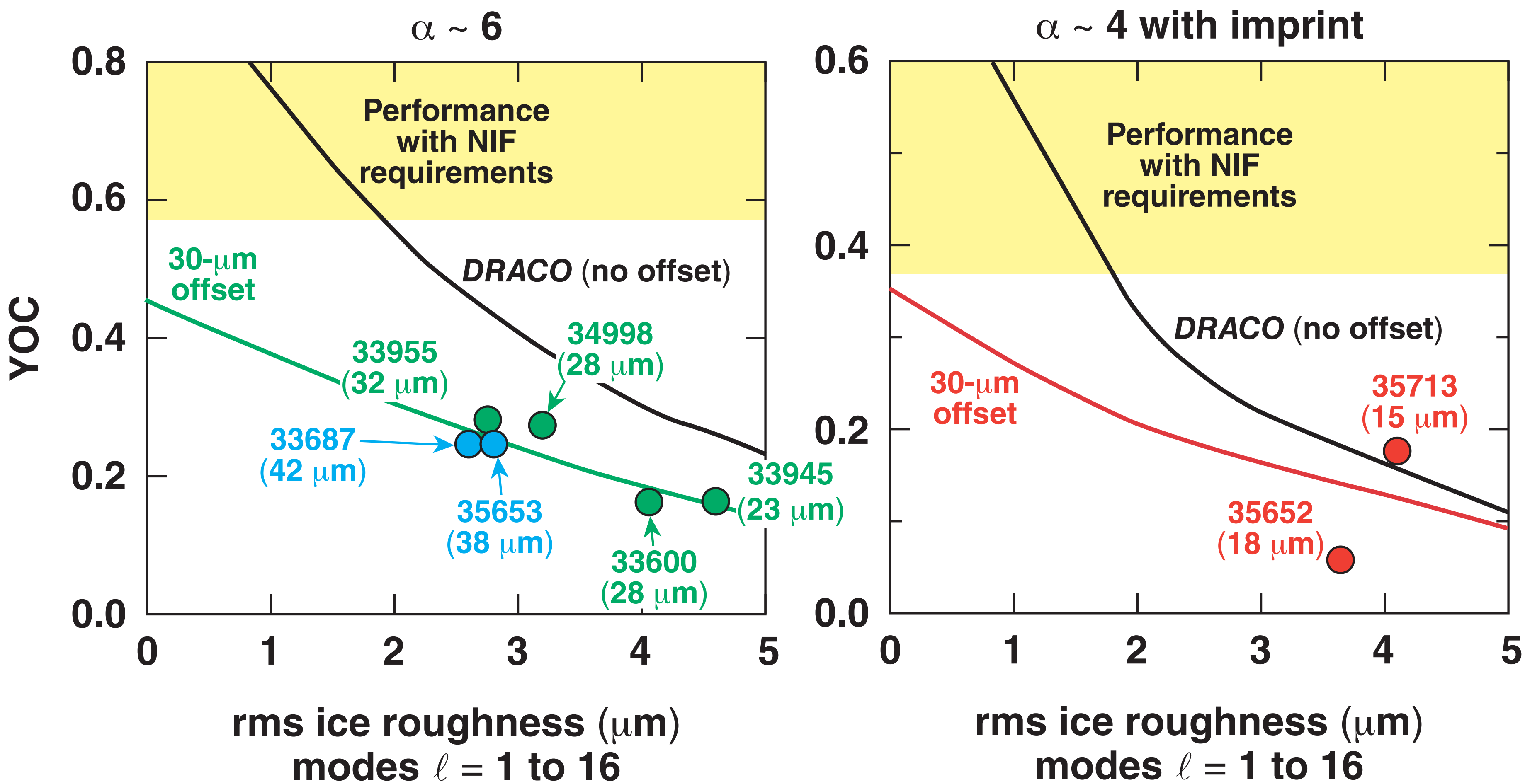
$$SG4 = (0.6)^2 + (0.7)^2 + (0.6)^2,\ \sigma_{tot} = 1.1\%$$

ETP's on OMEGA



E13393

Hydrodynamic simulations are consistent with implosion data over a wide range of ice roughness and target offset

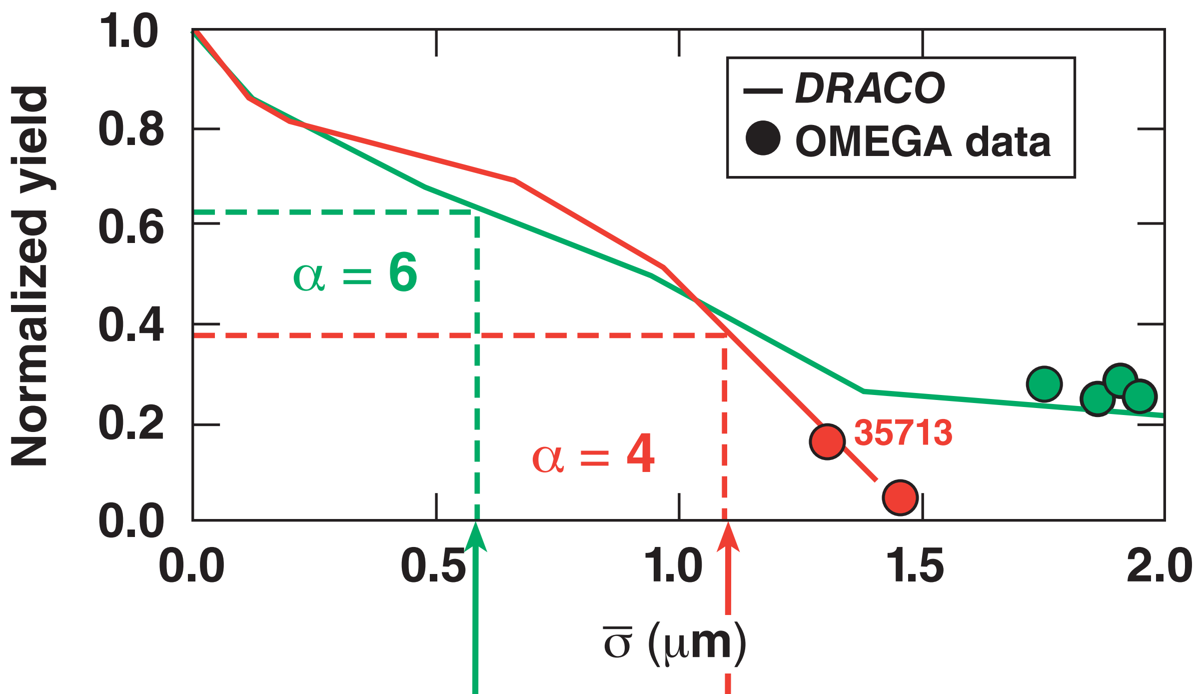


Average error of offset = 10 μm

E13085e

Scaled ignition performance on OMEGA is approaching the predicted equivalence of high gain on the NIF

UR LLE



1-THz, 2-D SSD with PS,
1-μm-rms ice roughness,
840-Å outer-surface roughness,
2% rms power imbalance

Target offset and ice quality presently limit access to low $\overline{\sigma}$ for $\alpha = 4$ campaign

E13398

The near term cryogenic shot plan will be focused on high $\langle \rho R \rangle_n$ and validating adiabat shaping

- The working physics plan is geared toward direct-drive ignition on the NIF and includes
    1. adiabat shaping validation with pickets
    2. high $\langle \rho R \rangle_n$
    3. ignition-scale ρR/DT implosions
    4. adiabat shaping validation with Rx drive pulses
    5. advanced cryogenic target designs including
        - fill tubes (NIF CTHS baseline)
        - wetted foams
        - saturn targets (best prospect for PDD on the NIF)
        - cone in shell (FI)

These objectives will be met with ~1-μm rms ice and TCC offsets of ~10 μm (or less).

E13624a

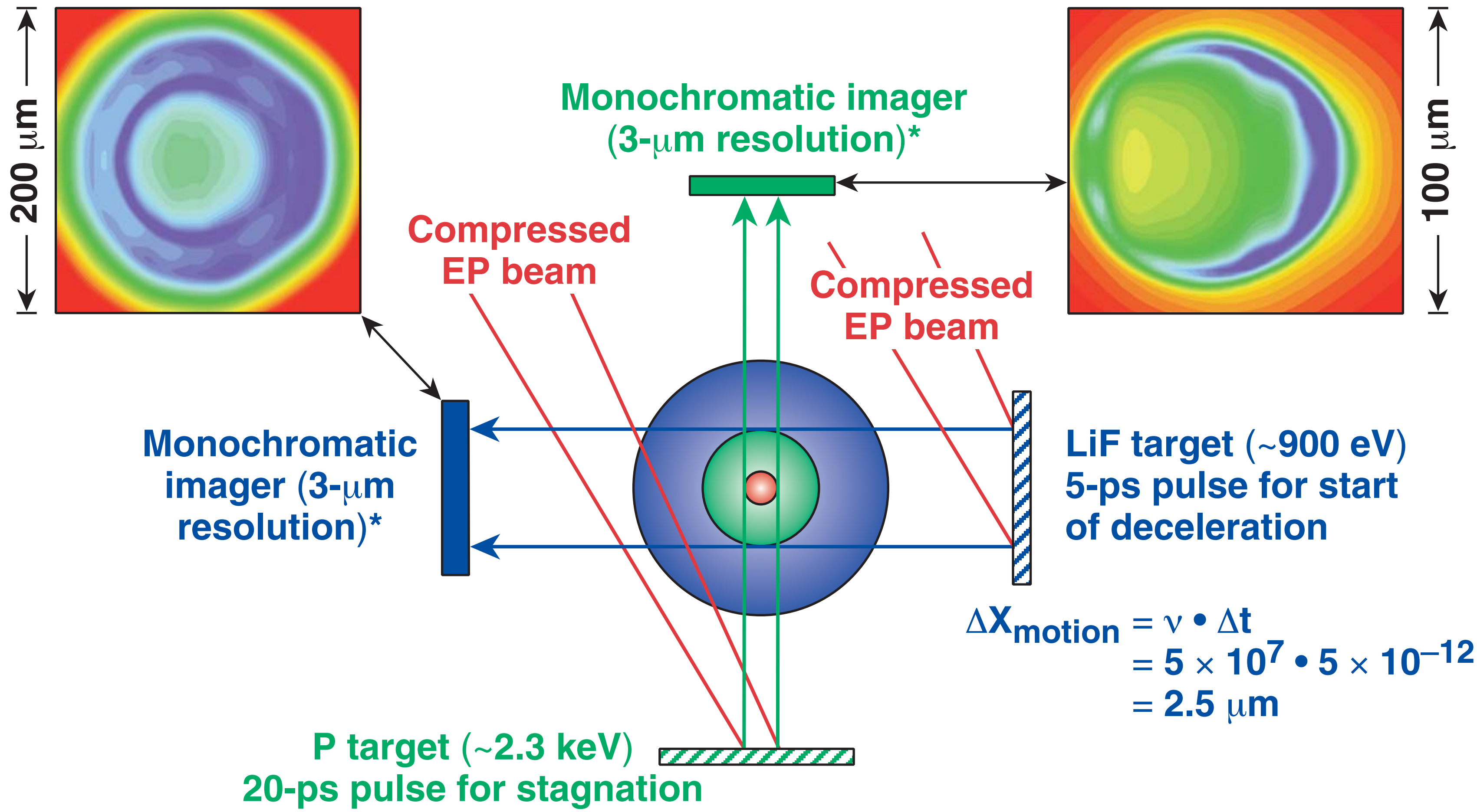
Tritium will be introduced gradually, following a readiness review in June

UR LLE

- A second FTS will be complete in July for concurrent D_2 cryogenic target production.
- One MCTC will be dedicated to DT operations.
  - At most, one DT implosion per shot day (up to 24/year).
- Potential tritium contamination of the characterization station may limit the throughput for D_2 implosions.
- The initial tritium fraction will be 0.1% and be raised incrementally ($\times$10) to reach 50:50 DT by fall 2005.
  - Layering studies can begin with 10% tritium.
- A dedicated cryogenic target test stand is being designed for advanced target development.
  - maintain production target throughput

The nonuniformity of the inner ice layer at the end of the accelerating phase will be directly inferred using the OMEGA EP HEPW laser system

UR LLE



TC5944g

*F. J. Marshall et al., Rev. Sci. Inst. 68, 735 (1997).

OMEGA EP will be operational in FY07 (two beams) and ready for target physics in FY08

UR LLE

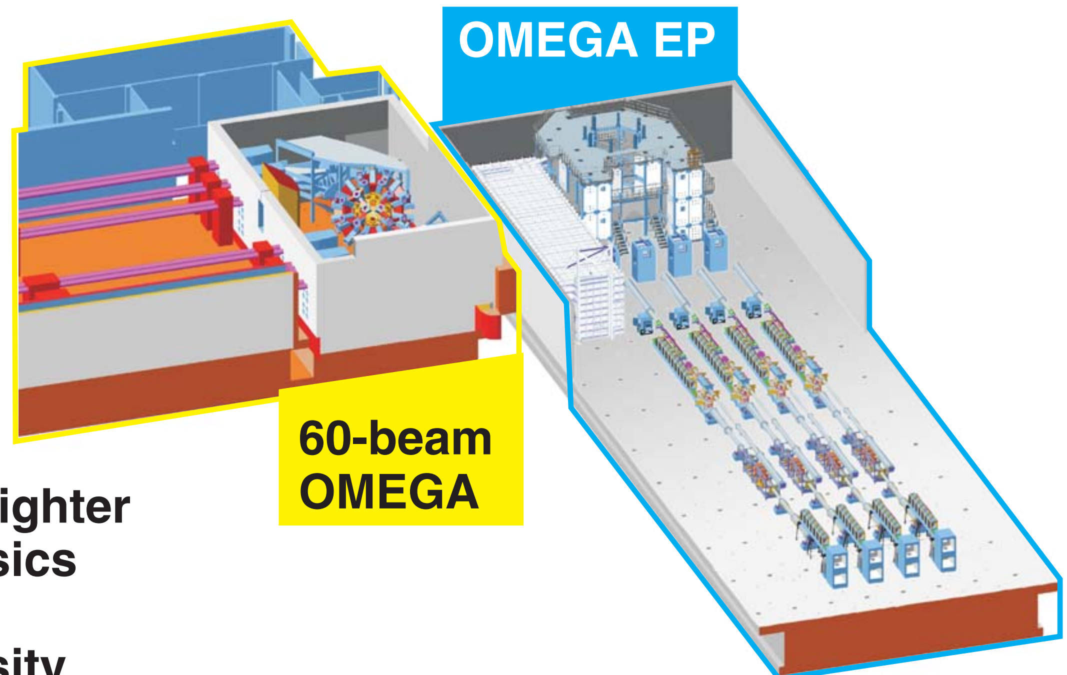
- There are four primary missions.

  1. Extend ICF research capabilities with high-energy and high brightness backlighting

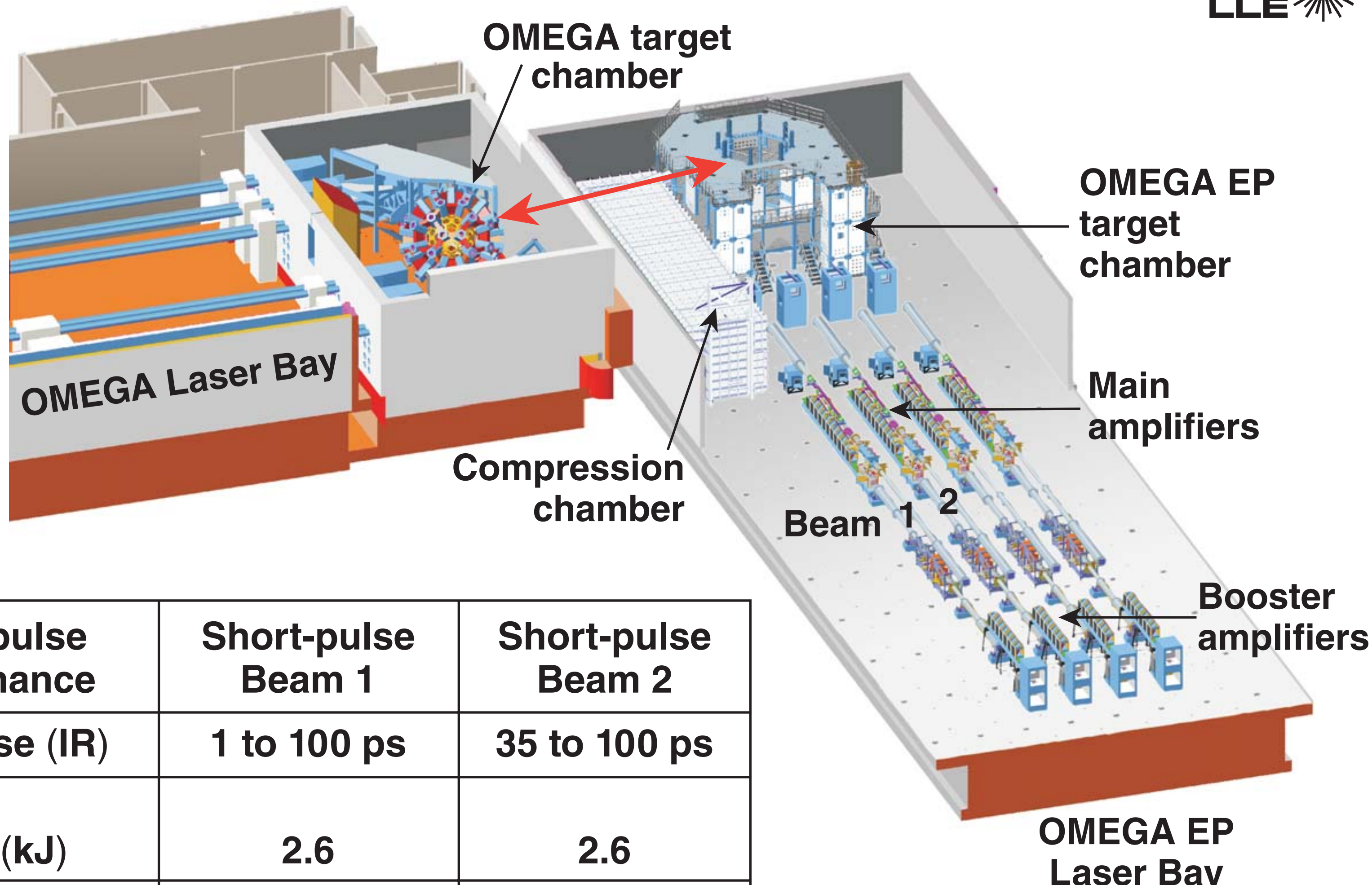
  2. Perform integrated fast-ignition (FI) experiments

  3. Develop advanced backlighter techniques for HED physics

  4. Conduct ultrahigh-intensity laser–matter interaction research



The two short pulse beams can be delivered to both target chambers

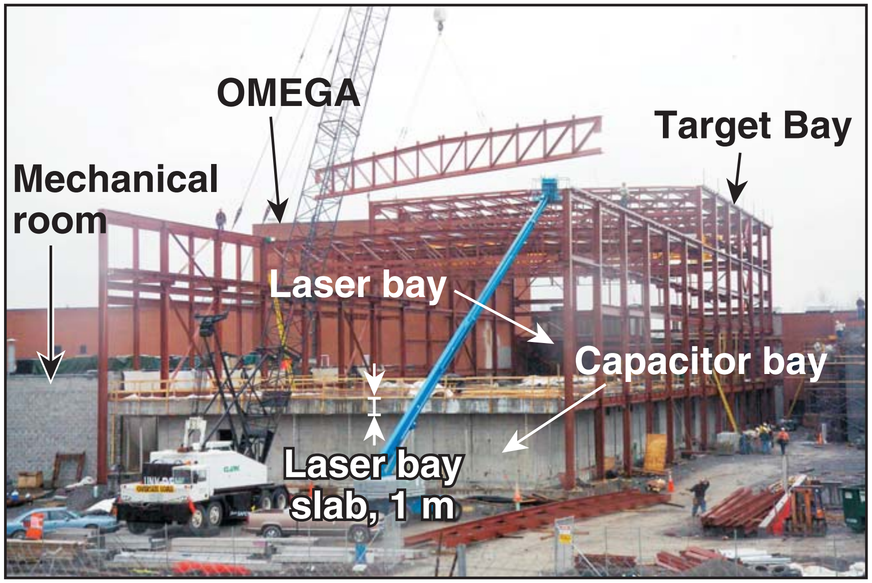


Short-pulse performance	Short-pulse Beam 1	Short-pulse Beam 2
Short pulse (IR)	1 to 100 ps	35 to 100 ps
IR energy on-target (kJ)	2.6	2.6
Intensity (W/cm^2)	6×10^{20}	$\sim 4 \times 10^{18}$
Focusing (diam)	> 80% in 20 μm	> 80% in 40 μm

G5546t

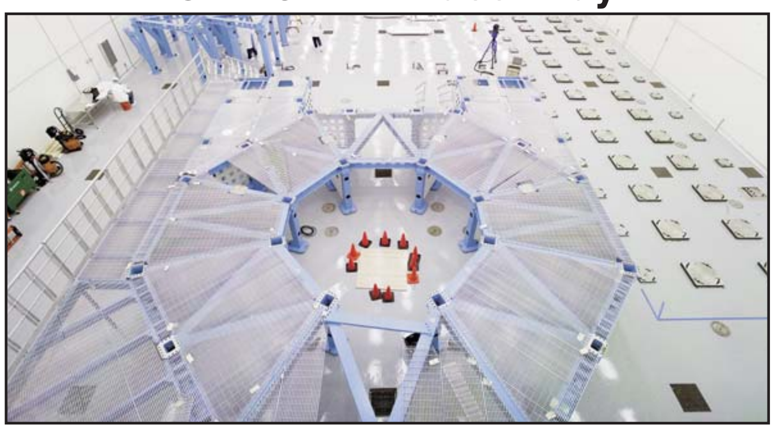
The OMEGA EP building was completed in February 2005

April 2004



January 2005

OMEGA EP Laser Bay



The source laser was installed in April 2005.

E13574c

An OMEGA EP Use Plan is under development

- The OMEGA EP Use Plan will
  - define the expected operating parameters and availability,
  - the avenues for non-LLE users to obtain access, and
  - initial experimental campaigns.
- The Use Plan will be completed in Spring 2006.
  - An informational and informal discussion meeting will be held at the 2005 APS/DPP meeting.
  - A workshop will be held at UR/LLE in December 2005/ January 2006
    - to allow potential users to propose experiments and discuss access availability and
    - to consider capabilities required to carry out the experiments.
- If you wish to be informed of, or participate, in this planning activity and be included in the mailing list, contact

David D. Meyerhofer
Laboratory for Laser Energetics
ddm@lle.rochester.edu

E13897

Summary/Conclusions

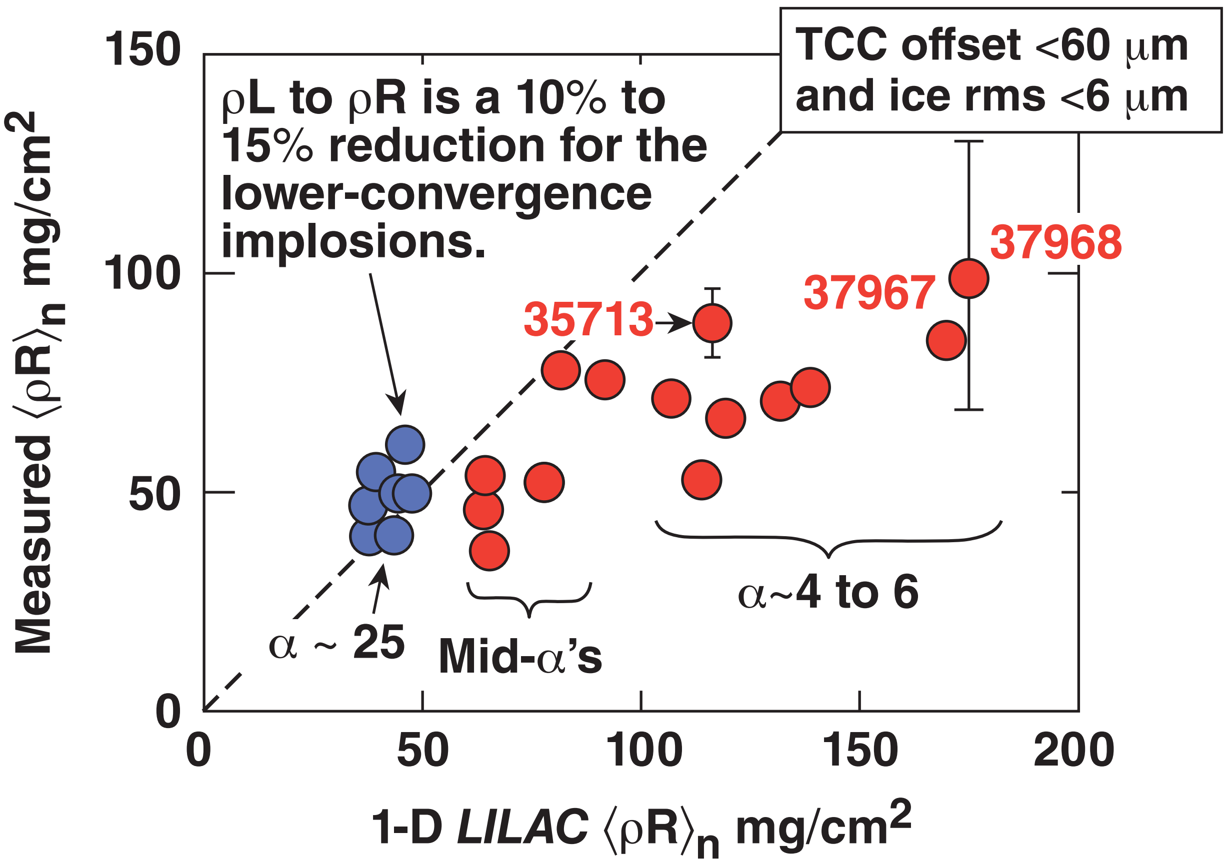
Direct drive is a robust alternative for ignition on the National Ignition Facility

UR LLE

- The baseline symmetric direct-drive cryogenic D_2 campaign has demonstrated target performance consistent with 1-D and 2-D hydrocode predictions.
- Laser and cryogenic target uniformity are approaching the requirements for scaled ignition validation.
- DT cryogenic implosions will be performed before the end of FY05.
- OMEGA EP will be completed by the end of FY07.

The measured $\langle\rho R\rangle_n$ is close to 1-D for all but the lowest-adiabat implosions

UR LLE



Ice roughness and target offset appear to limit the measured $\langle\rho R\rangle_n$ for higher-convergence implosions.

E13492a

F. Marshall *et al.*, "Direct-Drive Cryogenic Implosions on OMEGA," to be published in Physics of Plasmas.