Fuel-Assembly Experiments with Gas-Filled, Cone-In-Shell, Fast-Ignitor Targets on OMEGA

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C. Stoeckl
University of Rochester
Laboratory for Laser Energetics

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Collaborators

T. R. Boehly, J. A. Delettrez, D. R. Harding, V. Yu. Glebov, J. E. Miller, T. C. Sangster, V. A. Smalyuk, and W. Theobald

University of Rochester
Laboratory for Laser Energetics

R. B. Stephens

General Atomics
San Diego, CA

S. P. Hatchett

Lawrence Livermore National Laboratory
Livermore, CA

J. A. Frenje, C. K. Li, R. D. Petrasso, and F. H. Séguin

Plasma Science and Fusion Center
Massachusetts Institute of Technology

S. Fujioka, H. Shiraga, and K. A. Tanaka

ILE, Osaka University
Osaka, Japan

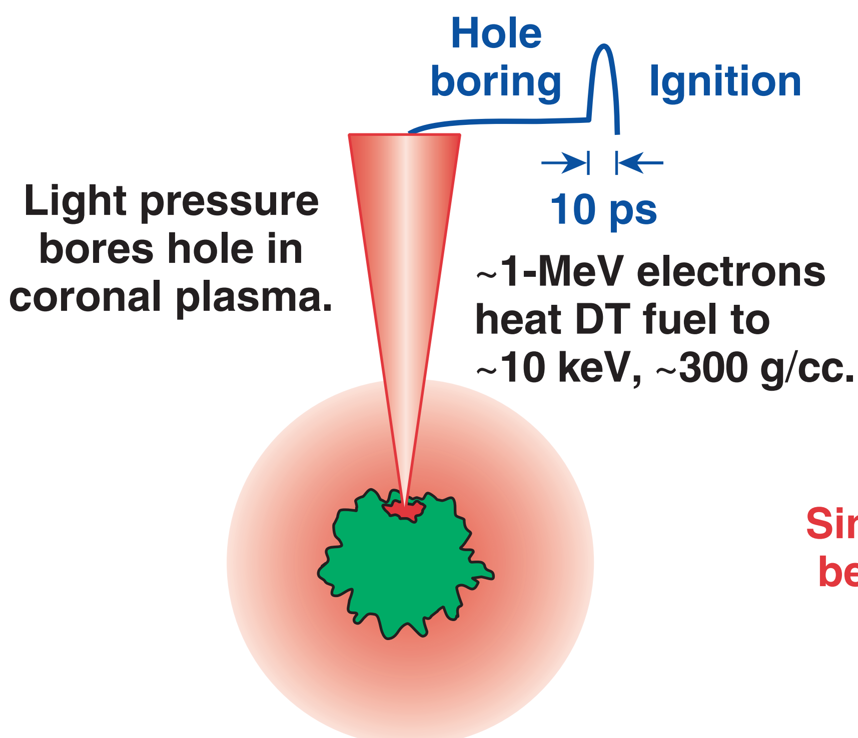
Summary

Fuel-assembly experiments with cone-in-shell targets show encouraging scalability to ignition

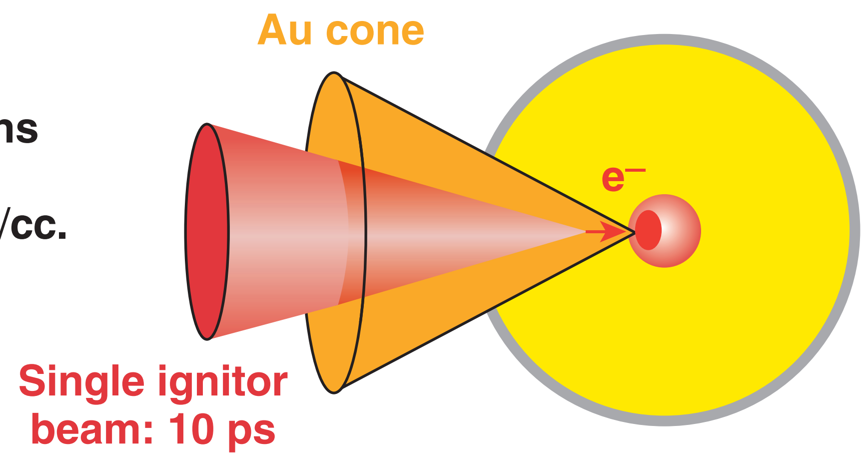
- Experiments were performed with gas-tight, cone-in-shell, fast-ignitor targets in laser direct-drive geometry.
- An areal density of 60 to 70 mg/cm^2, more than 2/3 of that expected from equivalent fully spherical targets, was observed with 21 kJ of laser energy.
- No mixing between the gold cone and the dense core was observed with 70° cones, both in the self-emission and backlit images.
- Filling the interior of the cone, where the ultrafast laser has to propagate, starts after peak compression.
- Experiments with cryogenic targets are the next logical step before integrated, fast-ignitor experiments on OMEGA with the upcoming OMEGA EP laser beginning in FY08.

The two viable fast-ignition concepts share fundamental issues: hot-electron production and transport to the core

Channeling Concept



Cone-Focused Concept



E11710d

Gas-tight targets were developed to be able to use nuclear diagnostics for areal-density measurements

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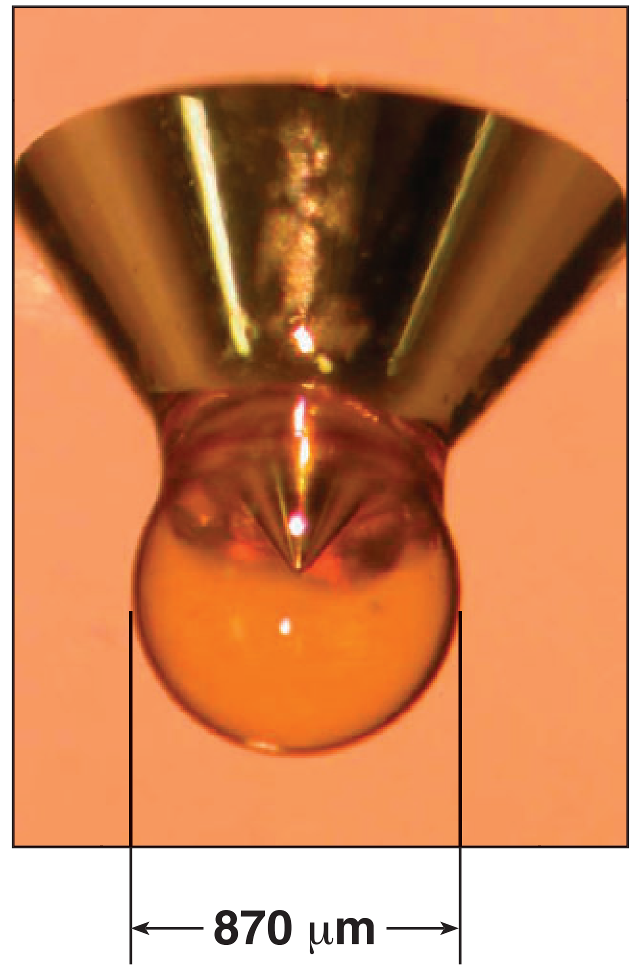
GENERAL ATOMICS

- 870-μm OD shell
- 24-μm wall
- ~10 atm D_2 or D^3He fill
- 70° and 35° angle gold cones
- Backlighting
  - 35 beams, 12 kJ, 1 ns on target
  - 15 beams, 6 kJ, 1 ns on backlighter
- Areal-density measurements
  - 55 beams, 22 kJ, 1 ns on target
- Cone-filling experiment
  - 48 or 54 beam, 18 to 21 kJ, 1 ns



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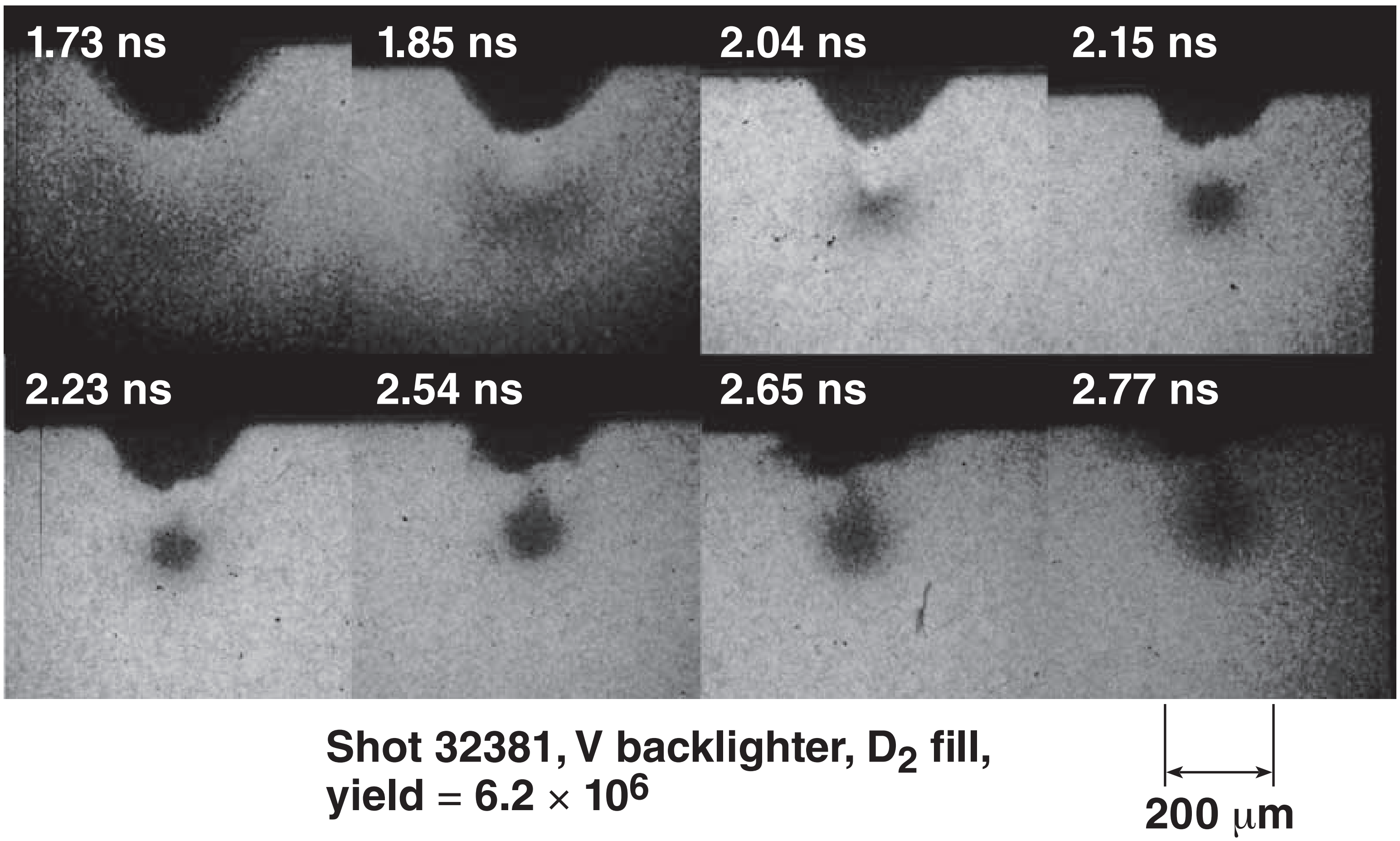
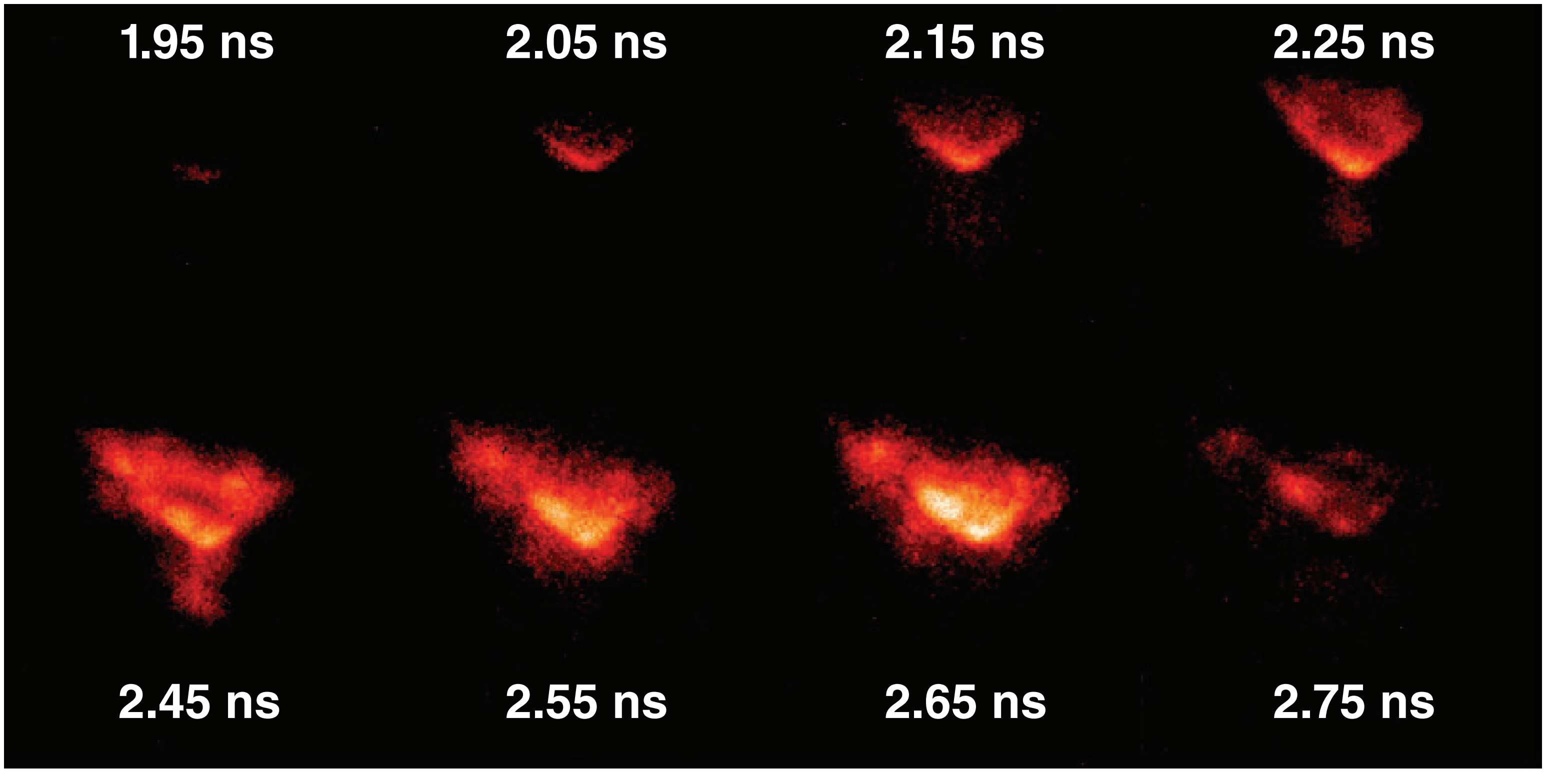
The backlit framing camera images show the core assembly and cone reaction in great detail



Shot 32381, V backlighter, D_2 fill, yield = 6.2×10^6

E12558

The framing camera images in self-emission show the cone lighting up first



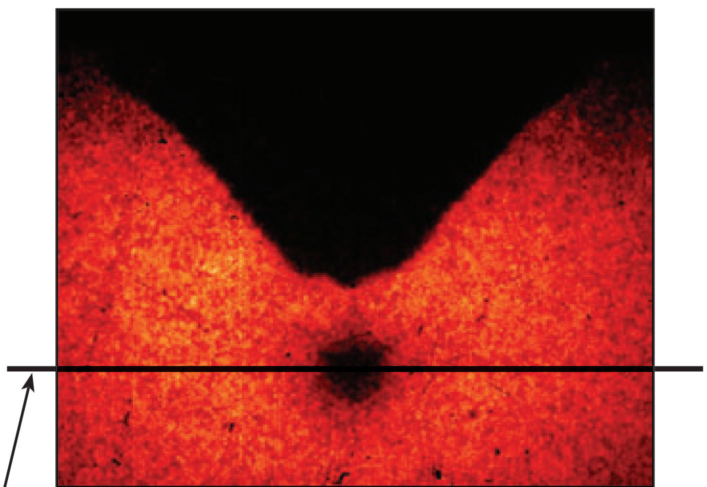
Shot 32387, D_2 fill, yield = 1.7×10^7,
logarithmic intensity scale

200 μm

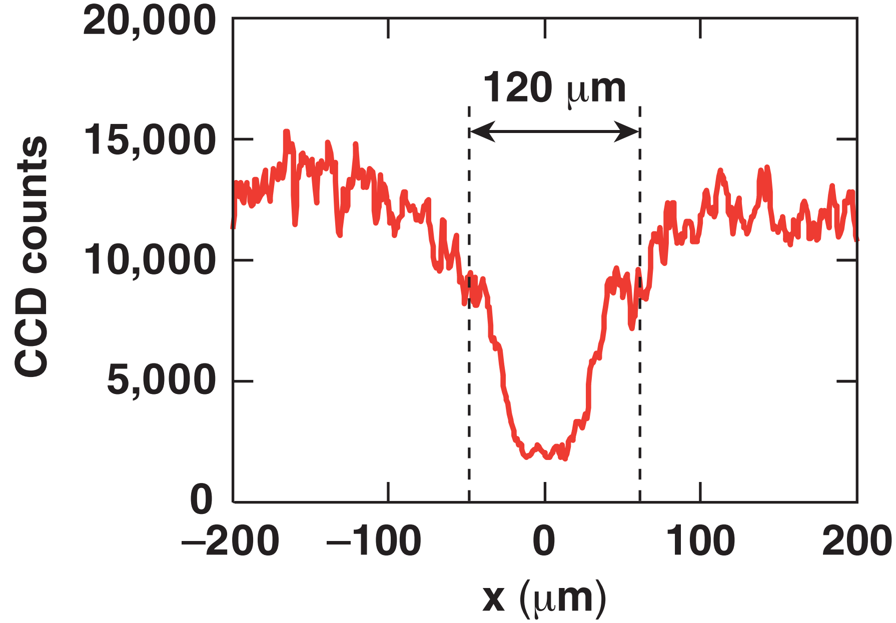
E12559

The size of the dense core as seen in the backlit images can be used to infer the areal density

Backlit image



Lineout



Areal density: $\rho R = CR^2 \times \rho R_0 \times \eta_{abl} \cong 60\pm10\ \text{mg/cm}^2$

$$CR = \frac{D_{init}}{D_{final}} = \frac{820\ \mu\text{m}}{120\ \mu\text{m}}$$

Convergence ratio

$\rho R_0 = 2.4\ \text{mg/cm}^2$

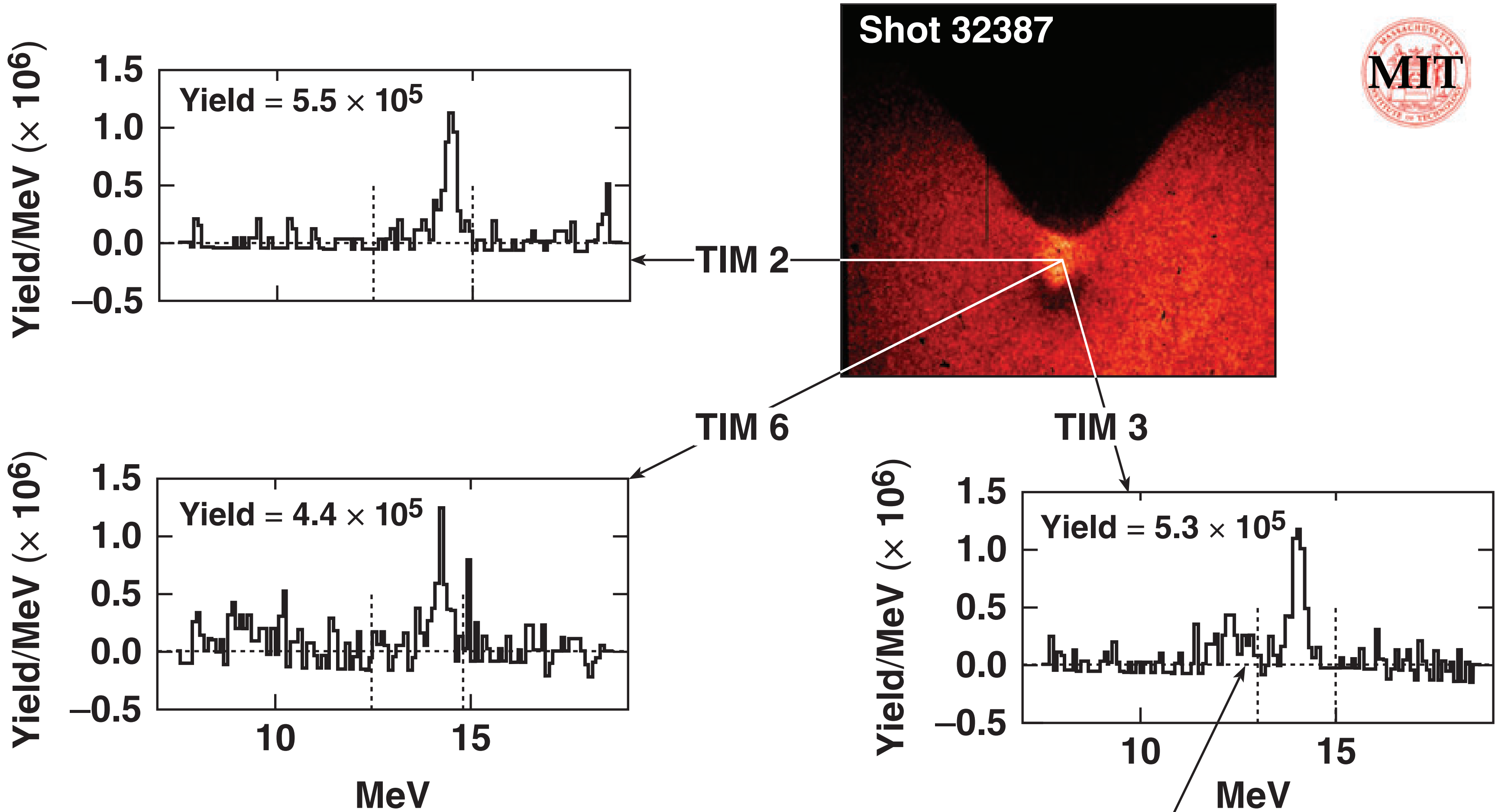
Initial areal density

$\eta_{abl} = 0.5$

Ablation fraction

E12680

A total areal density of ~60 mg/cm^2 can be inferred from the primary D^{3}He proton spectrum



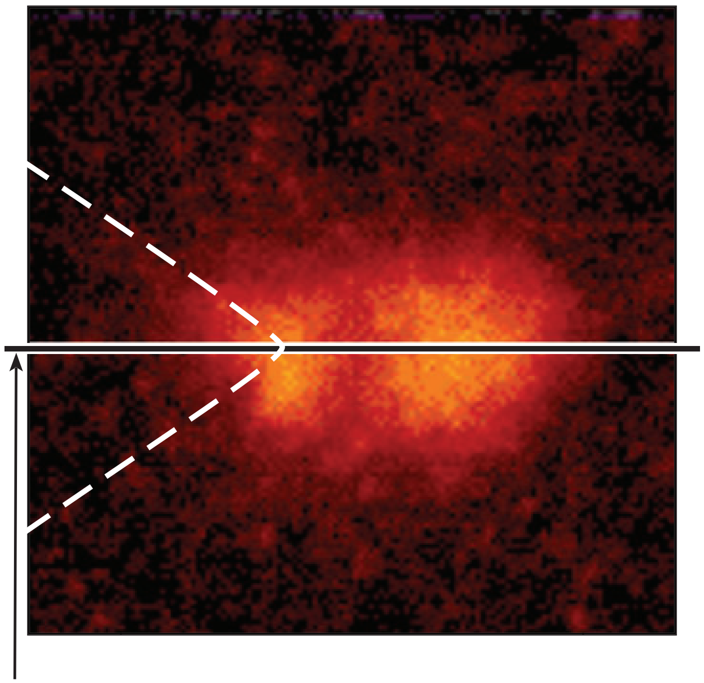
Downshift:
~2 MeV ≅ 60±10 mg/cm^2

Shot 32425, D^{3}He fill, yield = 8.5 × 10^7

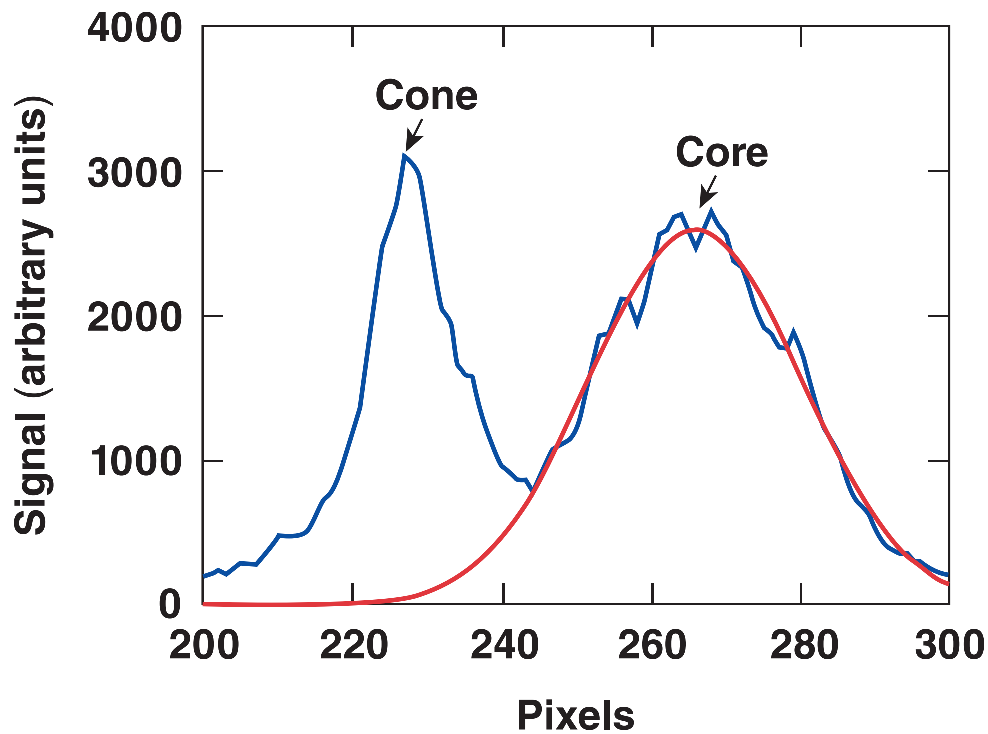
E12686

A lineout through the center of the self-emission image shows a perfectly symmetric core

Logarithmic intensity scale

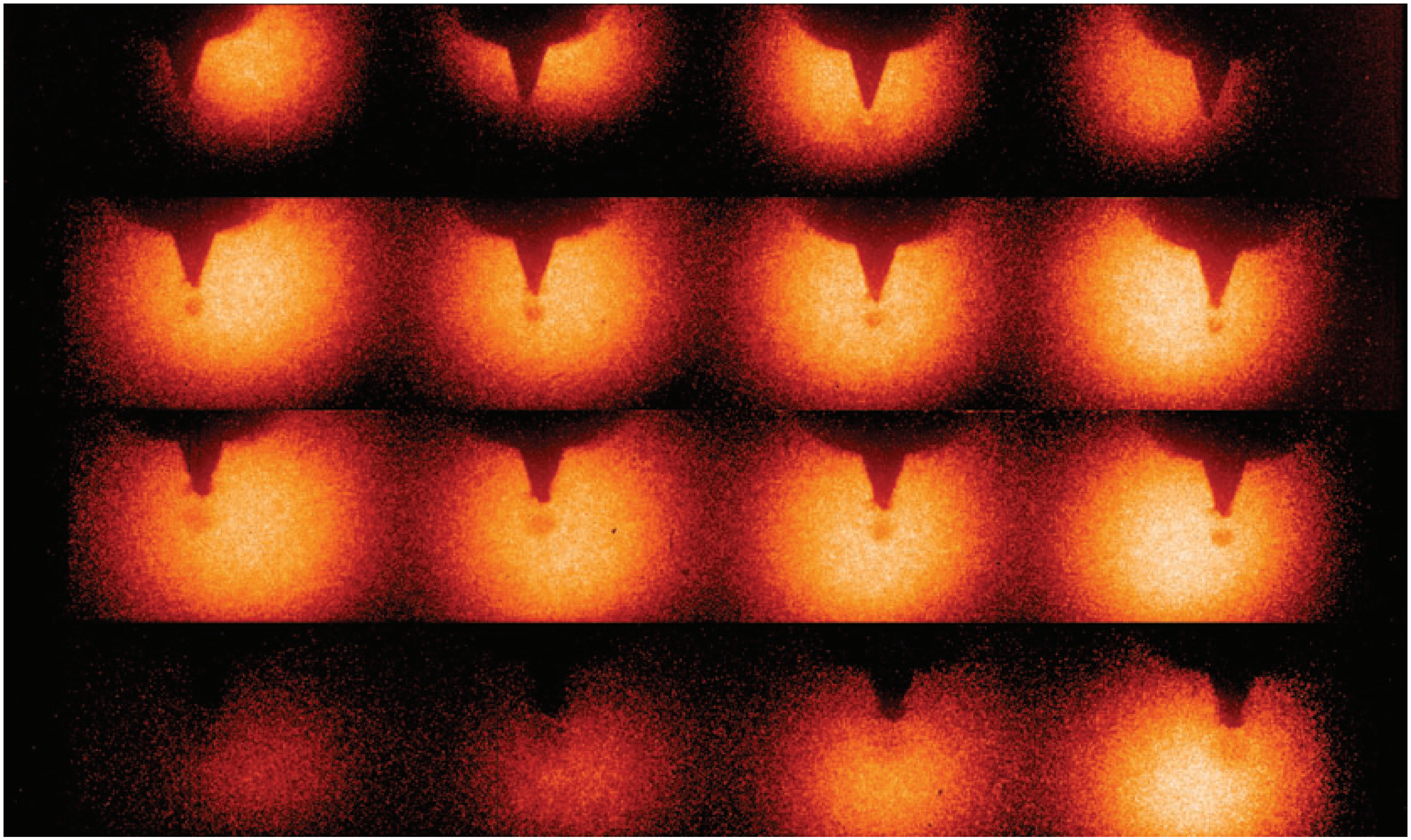


Lineout



- A rough estimate shows that a 0.01% mass density gold contamination would be visible in the lineout.

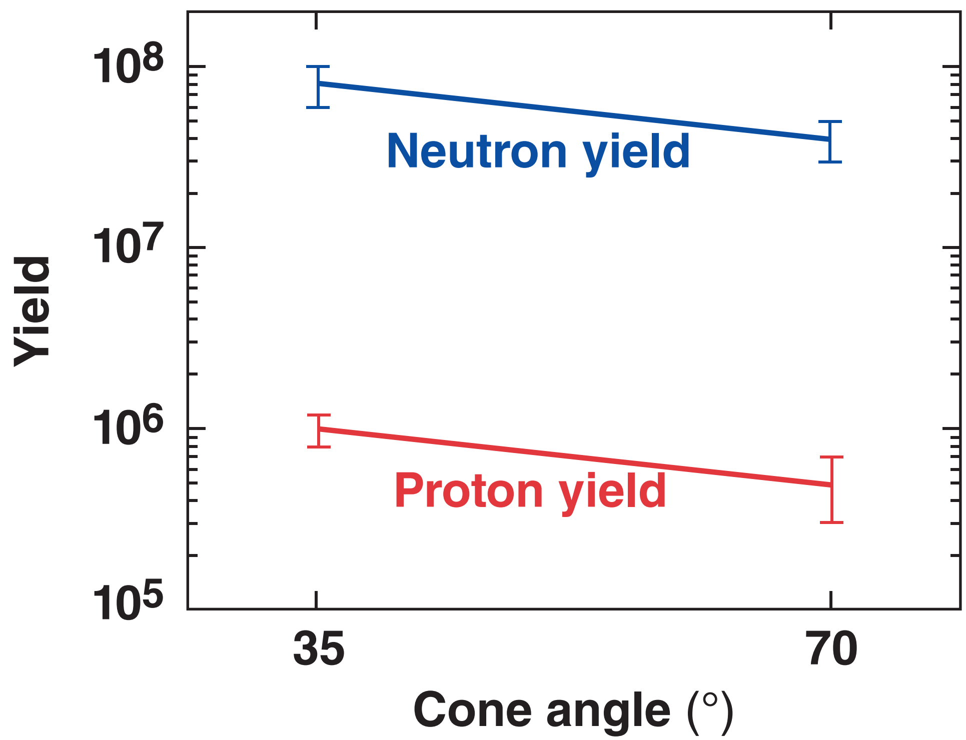
The hydrodynamic evolution of the 35° cones shown in the backlit images is very similar to the 70° cones



Shot 37212, Fe backlighter, no fill

E13817

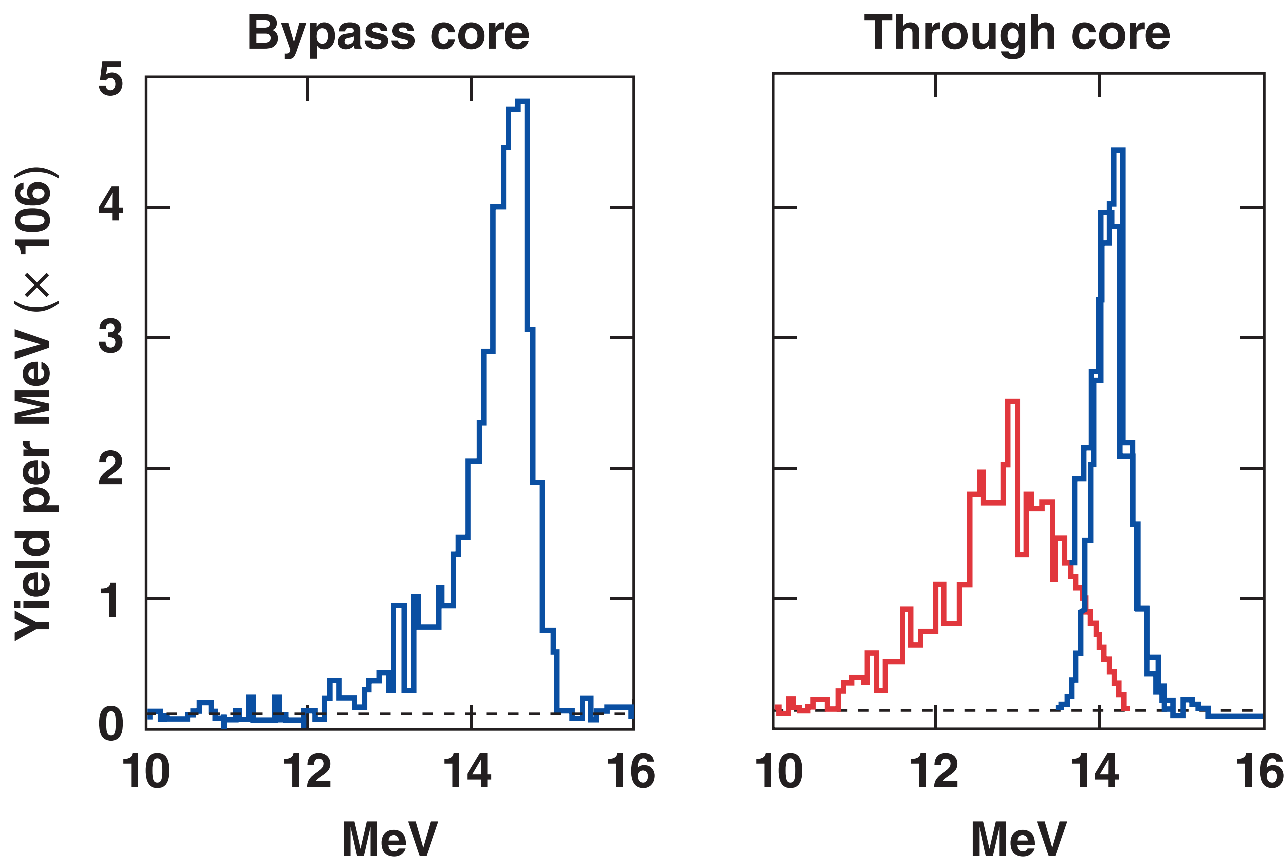
Both the neutron and proton yields are a factor of 2 higher in the 35° cone targets than in the 70° cones



- Targets are filled with 6 atm of D^3He and imploded using 21 kJ in 55 beams and a 1-ns-sq pulse.
- 1-D calculated yields for a symmetric implosion:
  $Y_n = 1 \times 10^{10}$ $Y_p = 3 \times 10^8$

E13819

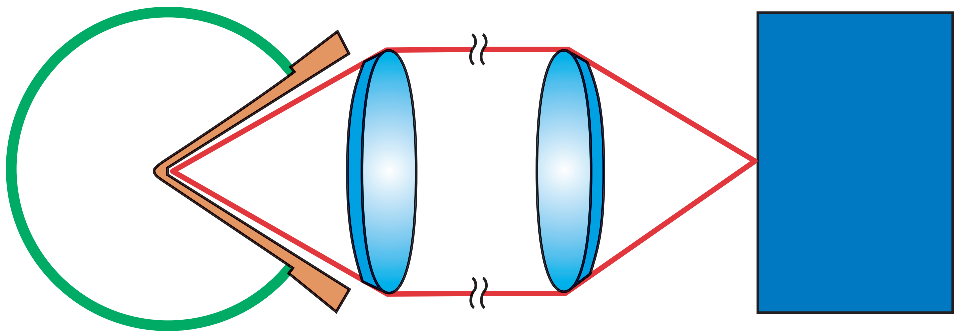
An areal density of ~70 mg/cm^2 at compression was inferred from the proton spectra of the 35° cones

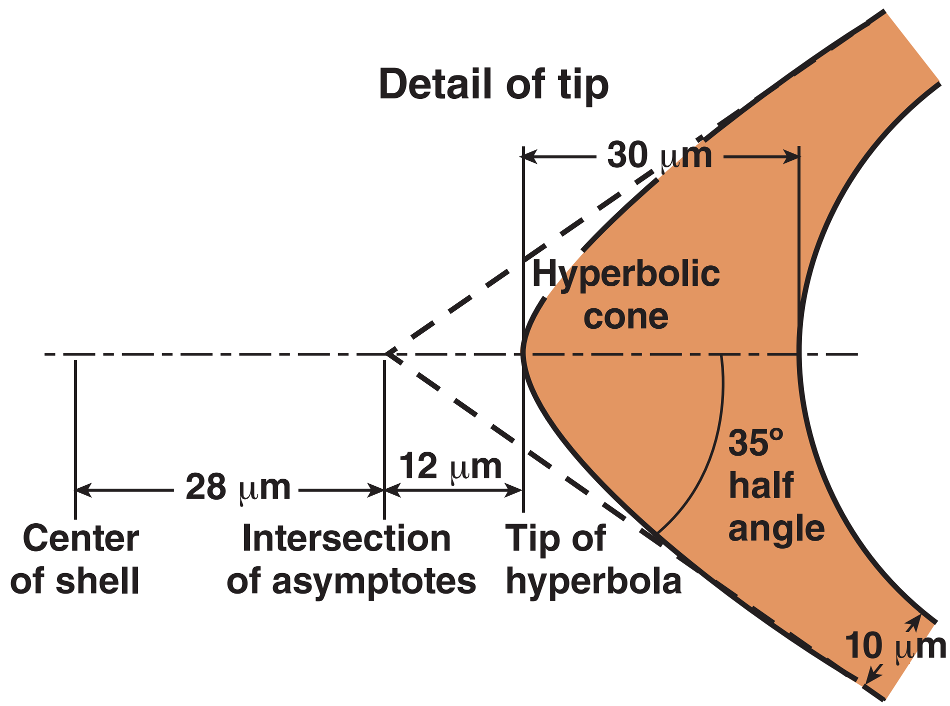


- Targets are filled with 6 atm of D^3He and imploded using 21 kJ in 55 beams and a 1-ns-sq pulse.
- Data from three consecutive shots with 35° cone targets were integrated.

E13820

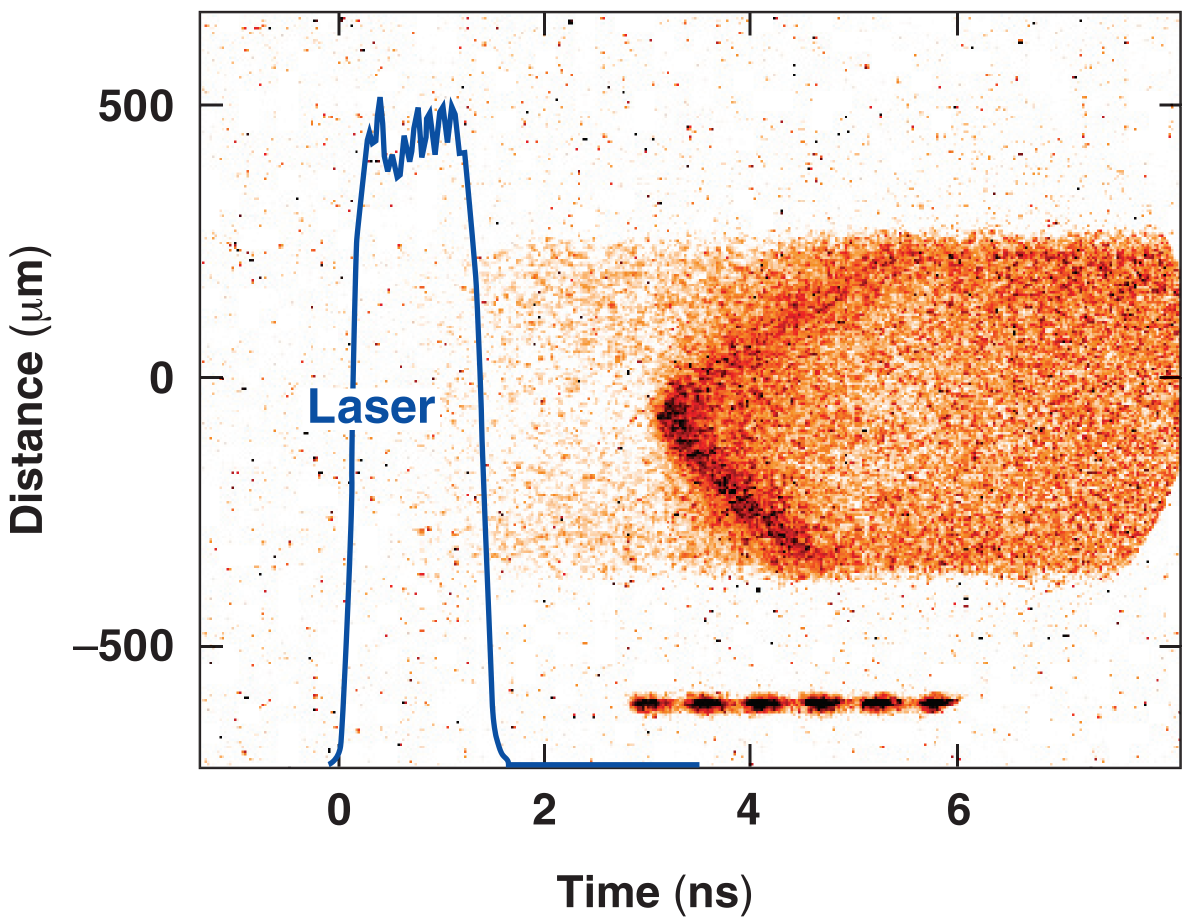
Streaked optical pyrometry (SOP) is used to observe the cone filling with plasma

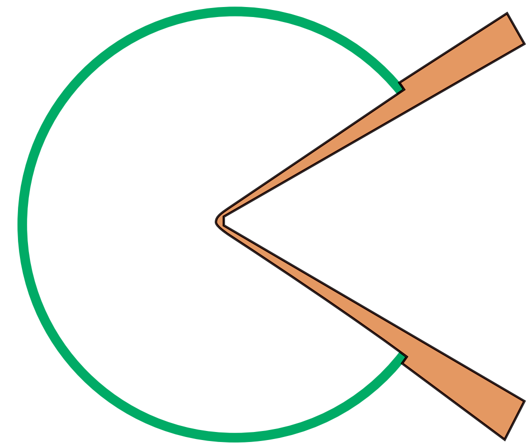




E13821

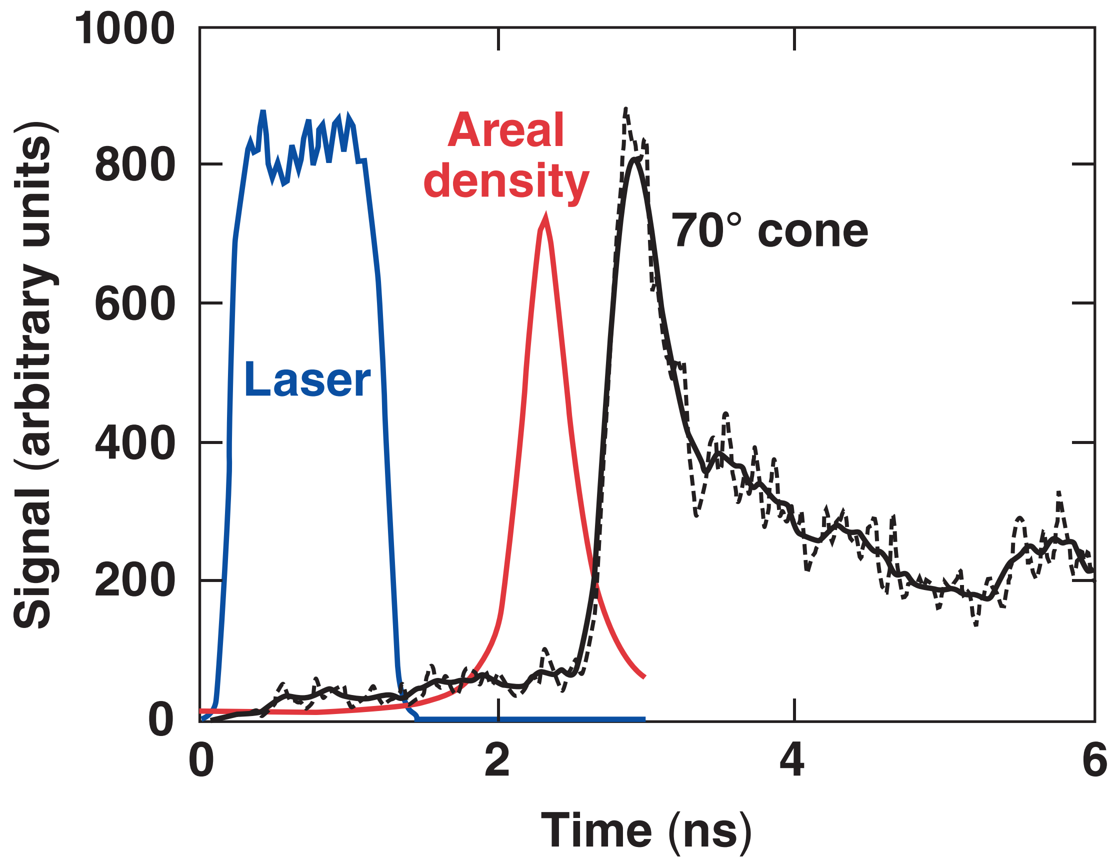
The 70° cone shows a clean shock-breakout signal at the tip of the cone





E13823

The emission inside the 70° cone starts after the time of peak compression (~2.2 ns)



- Lineouts through the tip of the cone in the center of the SOP streak
- Areal density from 1-D hydrocode simulations
- Shock temperature ~10 eV

E13825

Experiments with cryogenic targets are the next step before integrated fast-ignitor experiments

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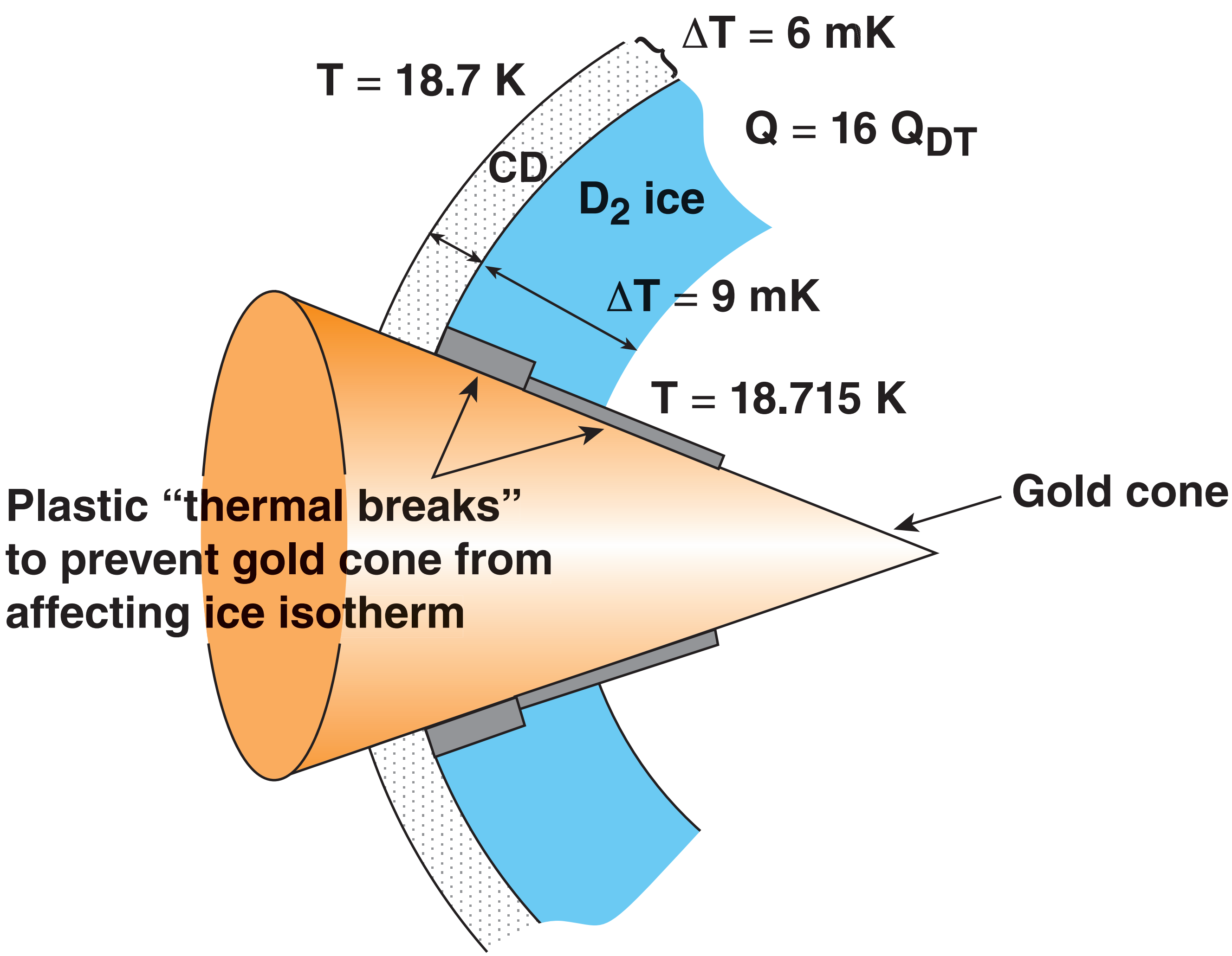
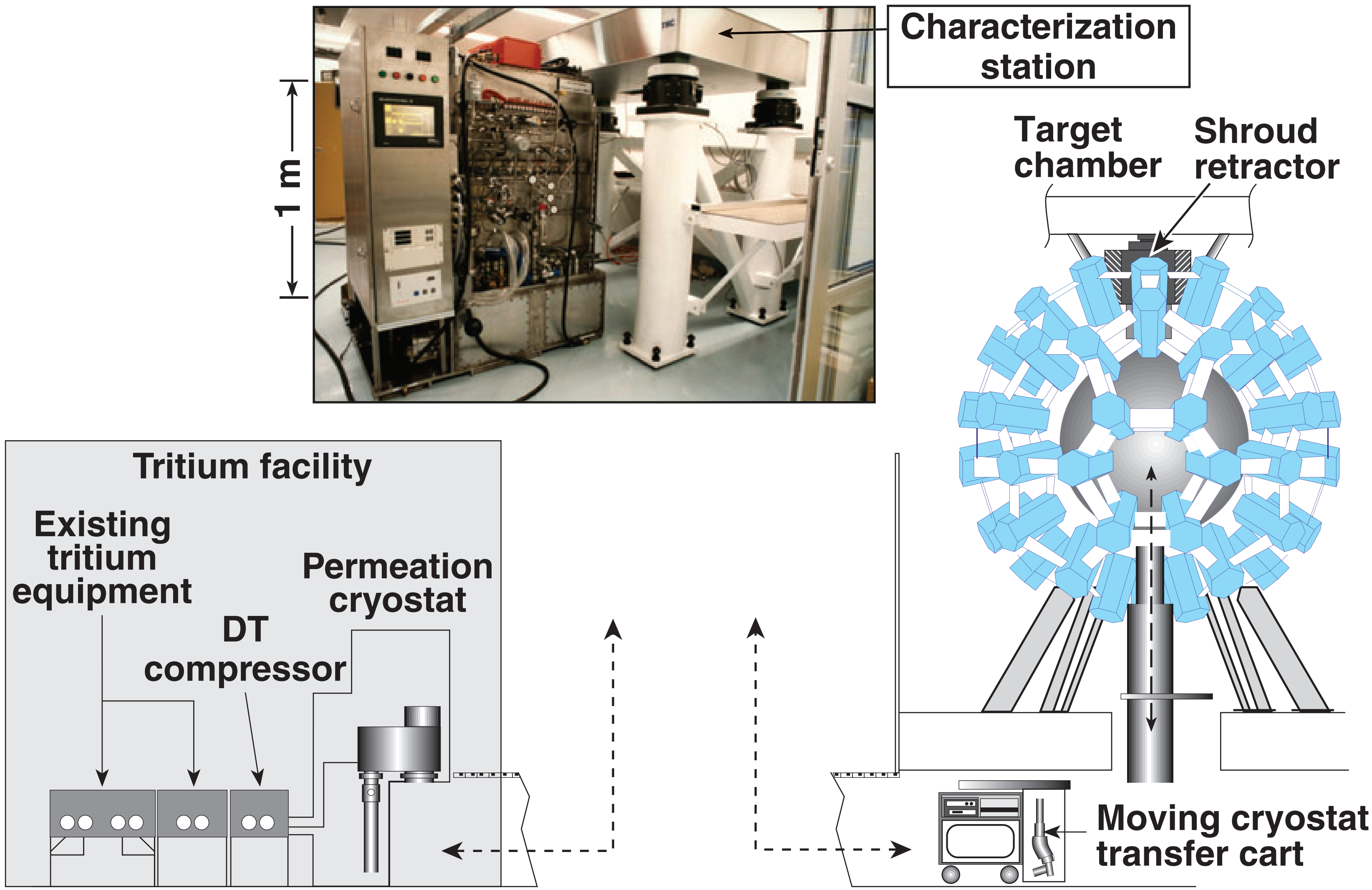
- Cryogenic DT targets will be required for fast ignition.
- The mixing of cone and core material will be reduced in cryogenic targets because of the lower emission of the hydrogenic ablator.
- Filling the interior of the cone will be delayed due to the lower pressure of the DT compared to a equivalent CH target.
- LLE already has the infrastructure for experiments with cryogenic DT fast-ignitor targets.
- Upon completion at the end of FY07, the new short-pulse laser OMEGA EP will provide up to 2.6 kJ in 10 ps for integrated fast-ignitor experiments.

Uniform ice thickness within a cryogenic “cone” target will require careful control of target design



E11717b

LLE has the infrastructure to field cryogenic DT-filled fast ignitor targets



Summary/Conclusions

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An OMEGA EP Use Plan is under development

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- 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 on the mailing list, contact

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