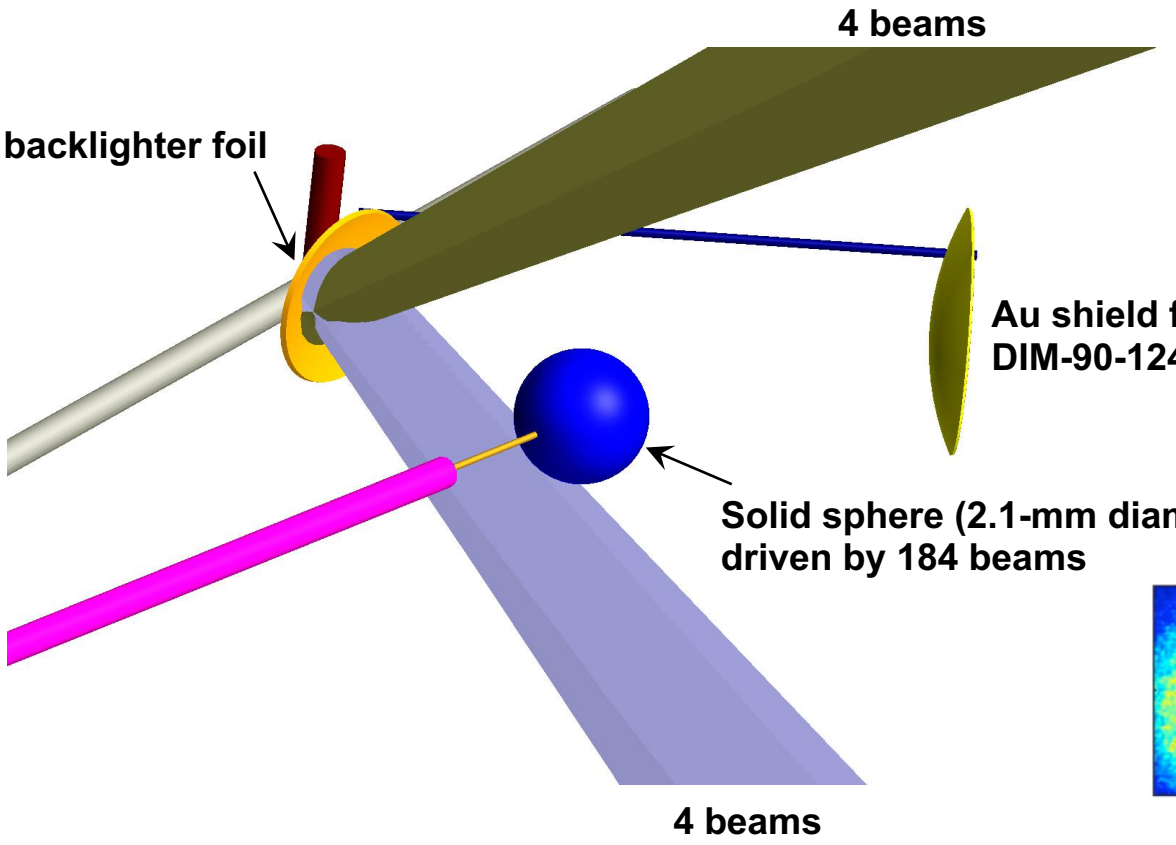
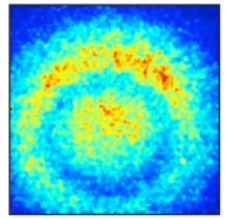
Laser-Direct-Drive Energy-Coupling Experiments Using Spherical Solid-Plastic Targets at the National Ignition Facility (NIF)





Time-resolved x-ray radiograph of spherical shock wave

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Laboratory for Laser Energetics

62nd Annual Meeting of the APS
Division of Plasma Physics
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Summary

Energy-coupling experiments relevant to laser-direct-drive (LDD) ignition-target designs* are being conducted at the National Ignition Facility (NIF) using a spherical, solid-plastic target

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- Solid spheres offer the advantage of quantifying energy coupling without the challenges from hydrodynamic instabilities of thin-shell implosions or kinetic effects in exploding pushers
- NIF polar-direct-drive (PDD) implosions were irradiated with 0.5 MJ of laser energy and a peak intensity of 8×10^{14} W/cm^2
- 2-D *DRACO* simulations using CBET** and nonlocal heat-transport models* predict accurately the energy coupling diagnosed with shock-trajectory measurements

Future experiments on OMEGA with scaled solid spheres are planned to test the scaling arguments of PDD implosions from OMEGA to the NIF.

* J. A. Marozas, JT02.00001, this conference (invited).
** CBET: cross-beam energy transfer
K. Anderson *et al.*, TO08.00009, this conference.

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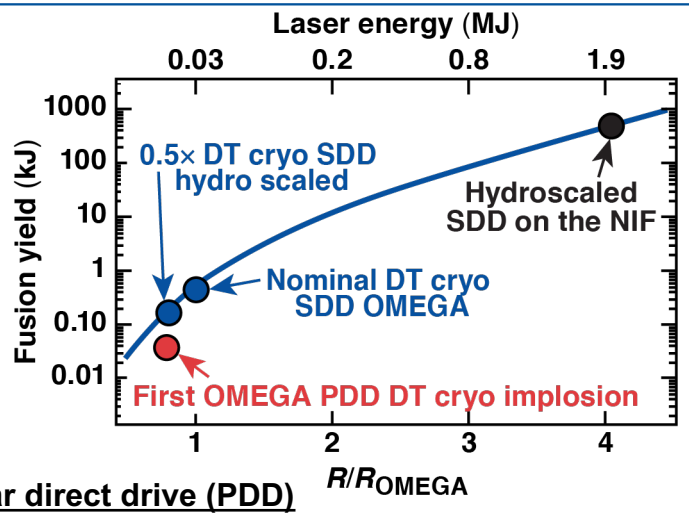
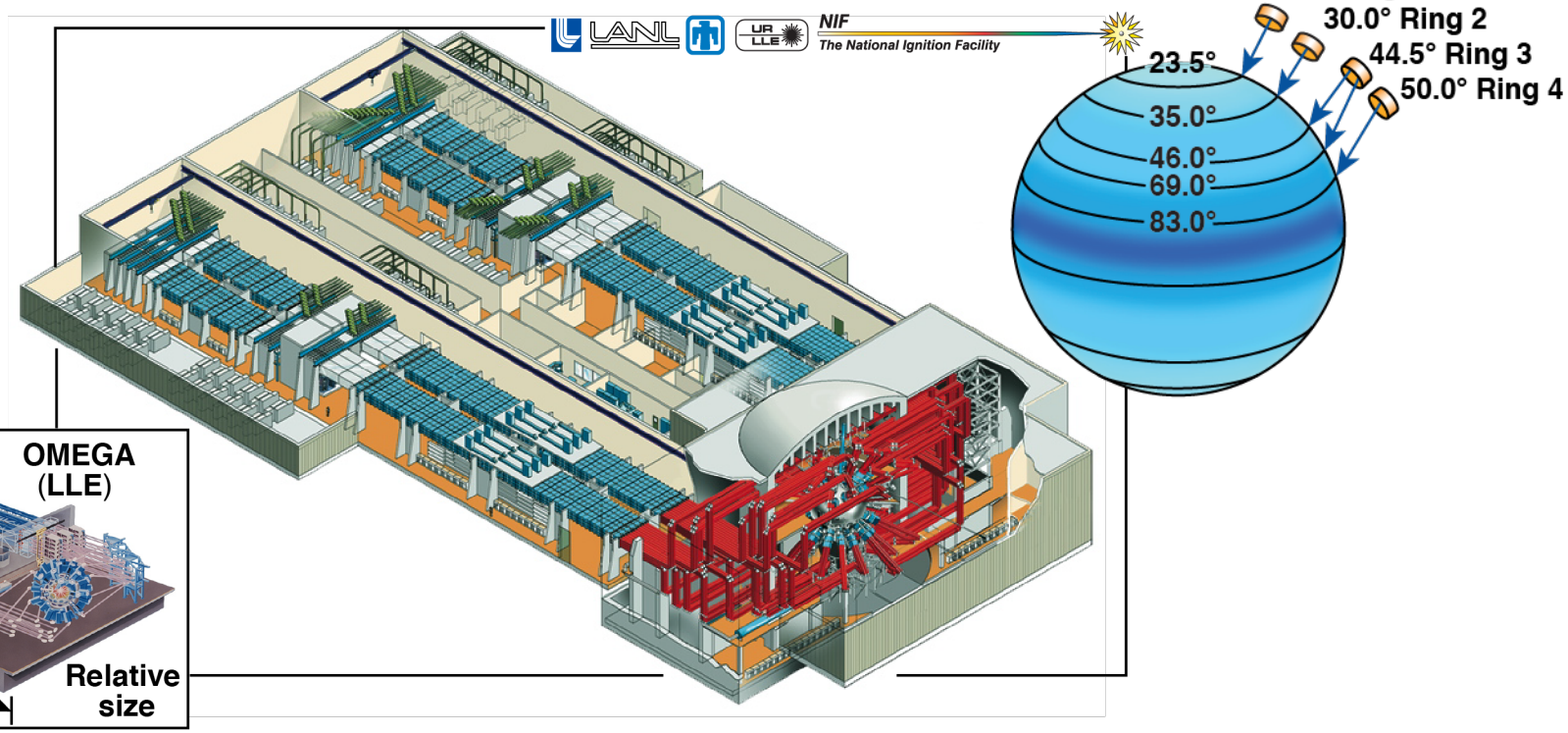
Motivation

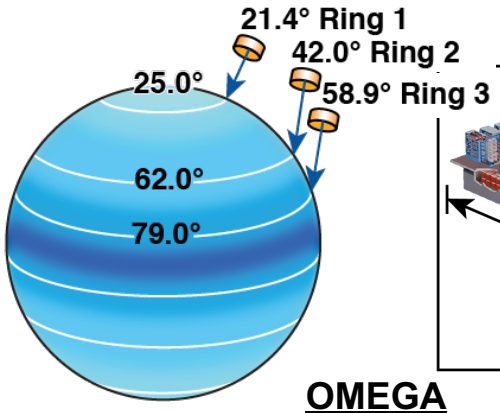
The overarching goal is to test the scaling arguments of PDD implosions from the 20-kJ OMEGA (configured for PDD) to the 2.1-MJ NIF*

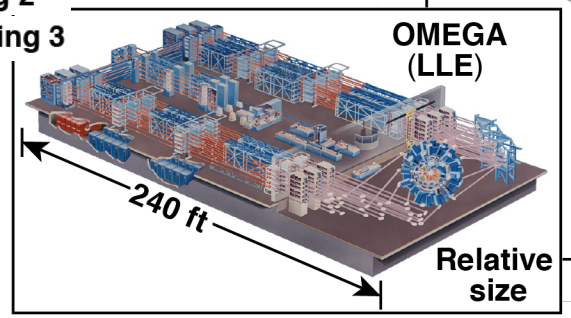


NIF
192 beams, 351 nm, 2.1 MJ



Polar direct drive (PDD)





OMEGA
60 beams, 351 nm, 30 kJ (20 kJ for PDD)

Cross-beam energy transfer (CBET) and electron thermal conduction affect energy coupling in LDD*.

* NNSA 2020 Red Team Review, Laboratory for Laser Energetics, University of Rochester, Rochester, NY (28 May 2020).

Previous Experiment

Energy coupling was investigated for NIF PDD implosions using shell trajectory measurements inferred from coronal plasma emission and x-ray radiography*

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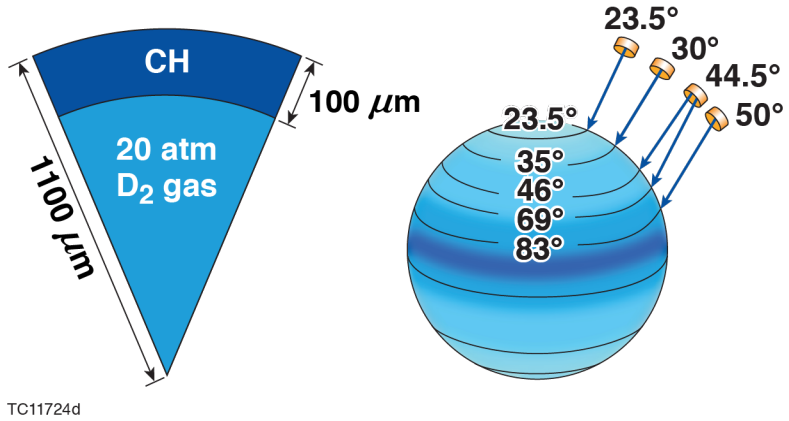
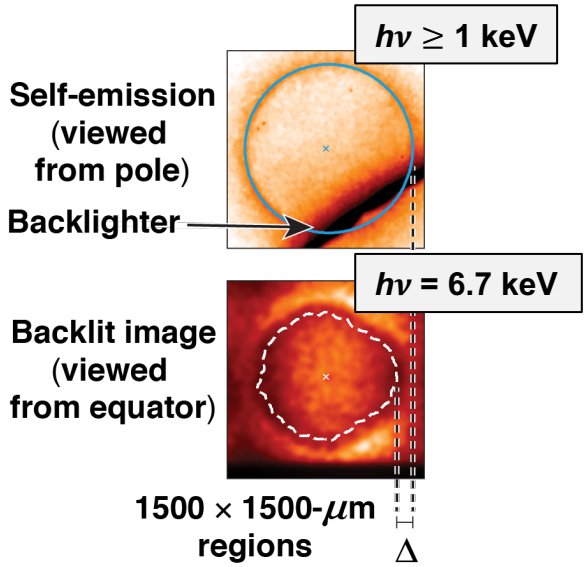
NIF PDD implosion
(0.65 MJ, 1.2 x 10^{15} W/cm^2)



TC11724d

Measured gated x-ray images
(dx = 30 μm, dt = 100 ps)



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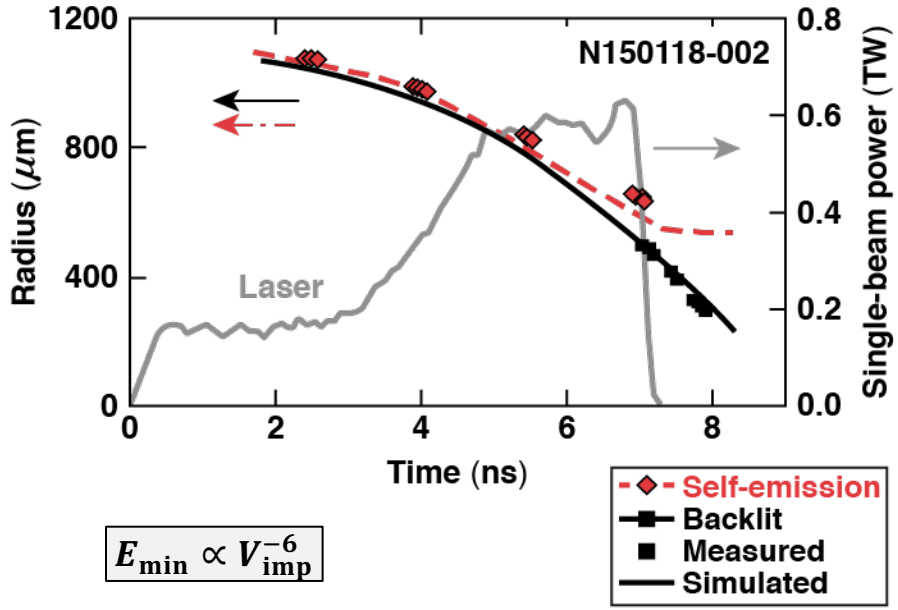
Shell trajectory



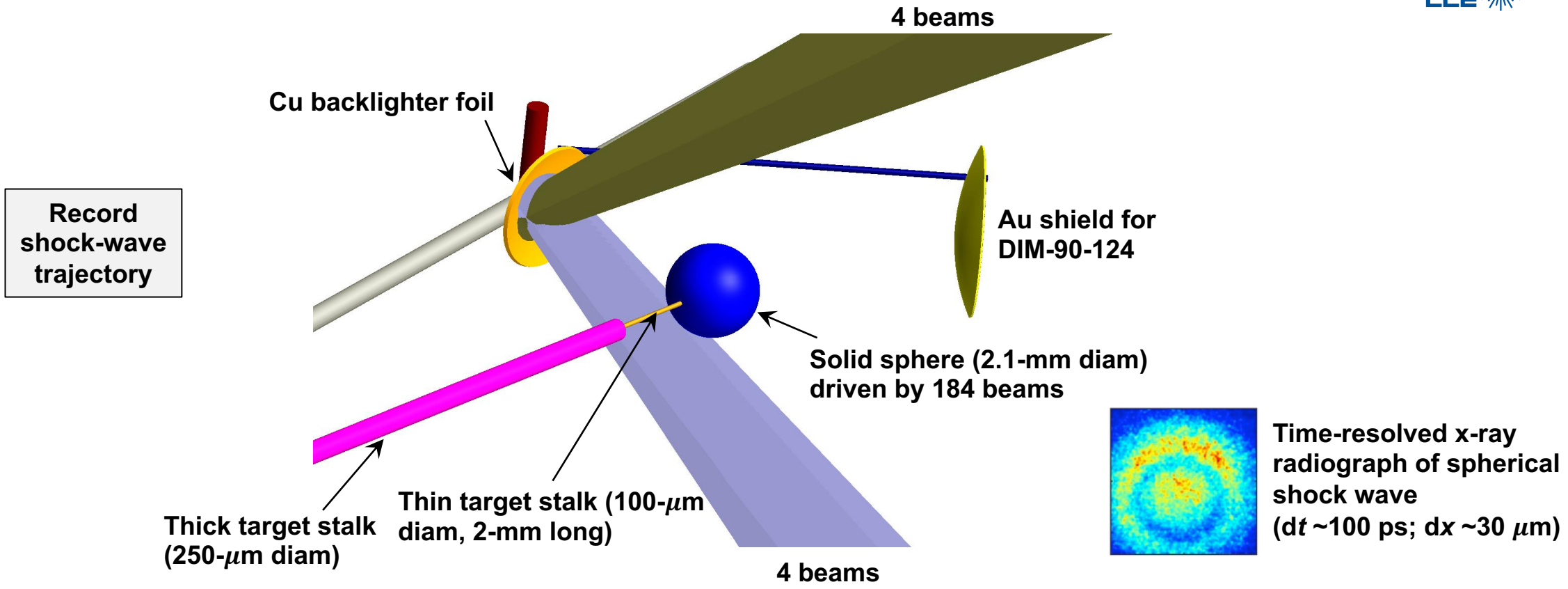
$E_{\min} \propto V_{\text{imp}}^{-6}$

TC12730b

Backlit image: Indicates match in modeled and measured V_{imp} within 1%*
Self emission: Indicates a 9% overprediction of V_{imp} attributed to laser imprint and subsequent Rayleigh–Taylor growth*

* P. B. Radha *et al.*, Phys. Plasmas 23, 056305 (2016).
$E_{\min}$: minimum fuel energy required for ignition
V_{imp}: implosion velocity

Energy-coupling experiments relevant to LDD ignition-target designs are being conducted on the NIF using a spherical, solid-plastic target



Solid spheres offer the advantage of quantifying energy coupling without the challenges from hydrodynamic instabilities of thin-shell implosions or kinetic effects in exploding pushers.

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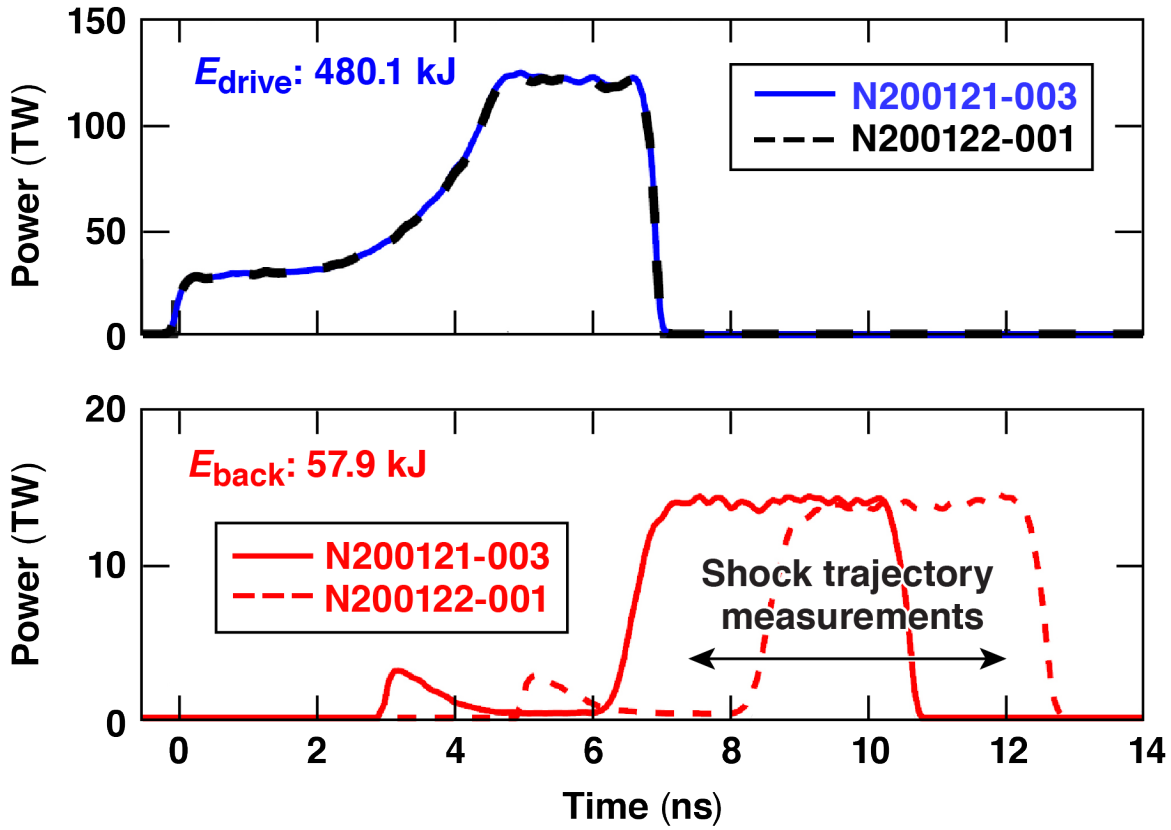
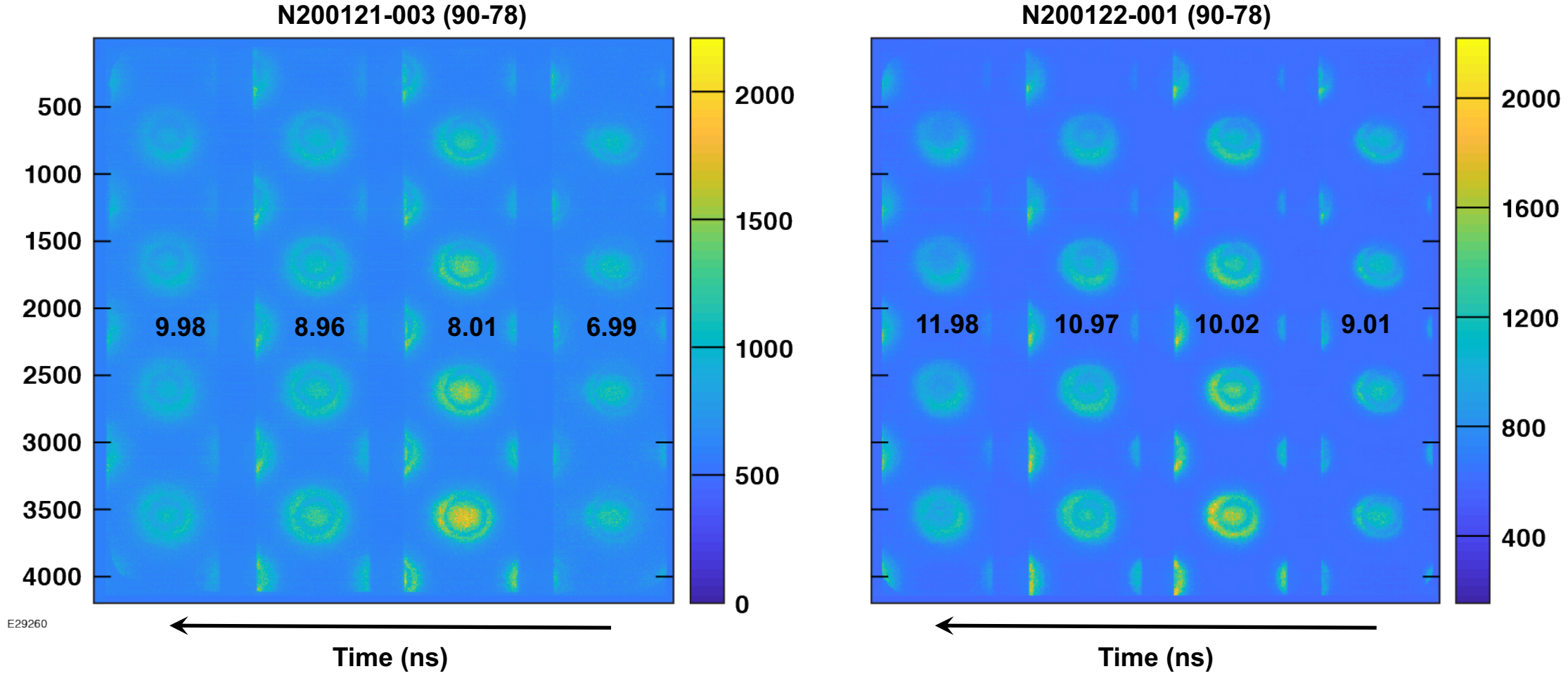
One hundred eighty-four NIF laser beams having total energy of 0.5 MJ irradiated the target in a PDD geometry with a peak intensity of 8×10^{14} W/cm^2

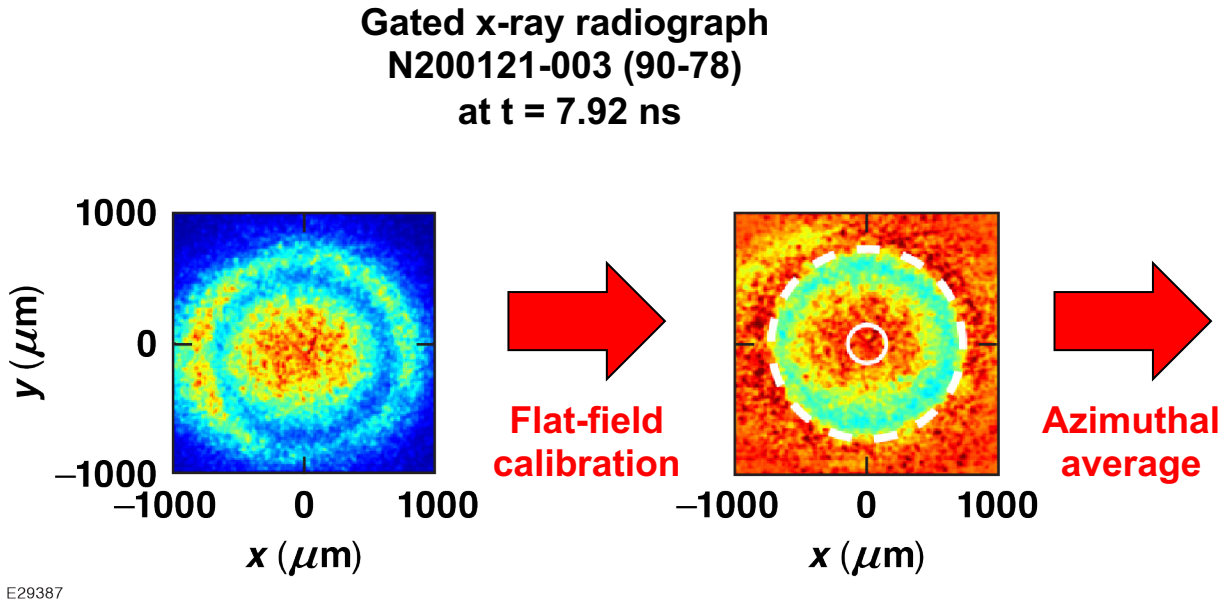


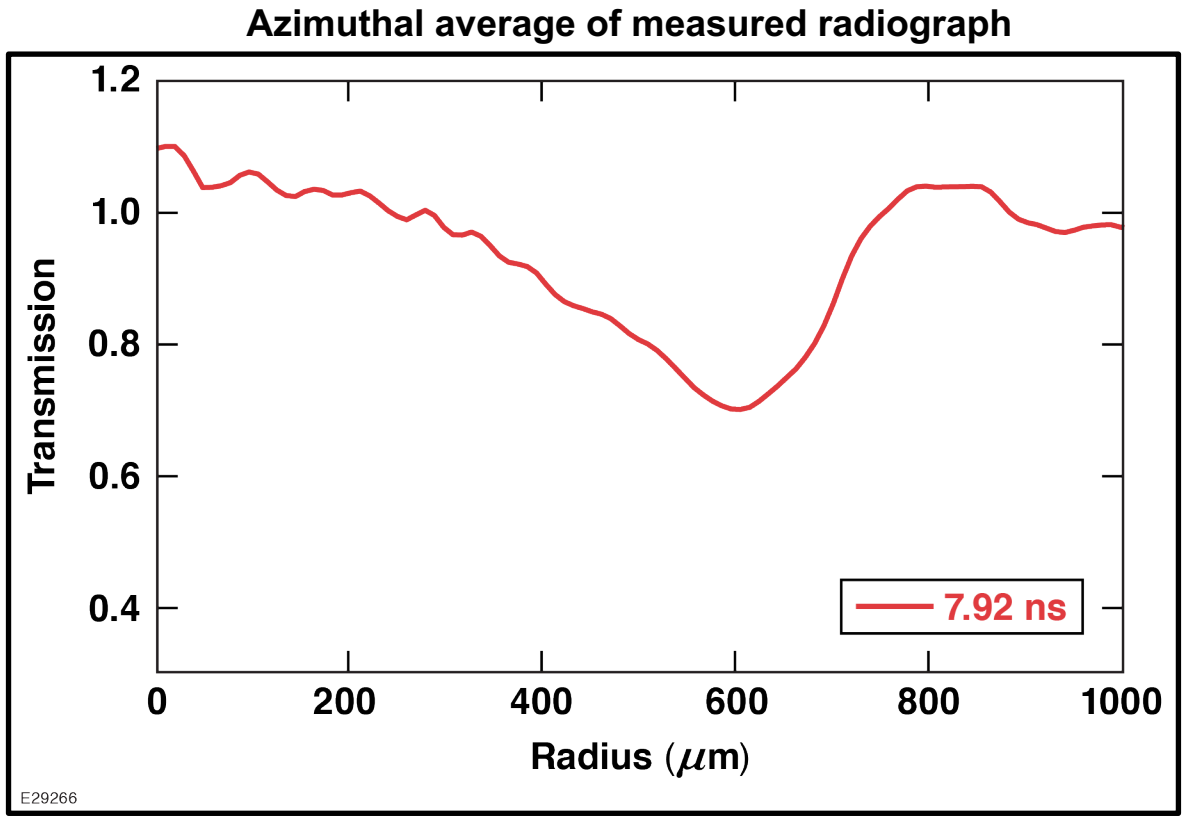
Shock-trajectory measurements are recorded after the main drive turns off.

The trajectory was recorded over two NIF shots using a pinhole imager on an x-ray framing camera with ~100-ps temporal and ~30-μm spatial resolution



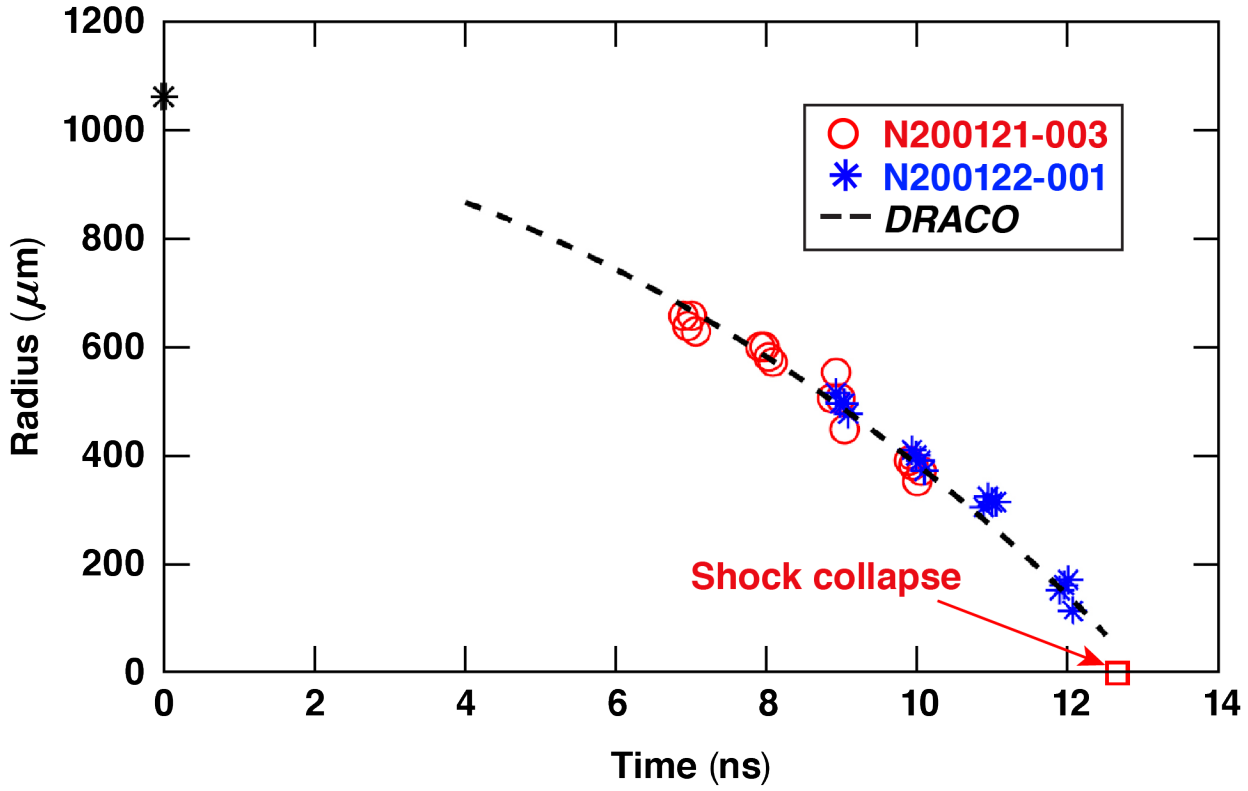
The peak attenuation in the measured azimuthally-averaged x-ray radiograph was used to track the shock trajectory





The radius of peak attenuation is recorded for each of the gated x-ray radiographs.

2-D *DRACO* simulations using CBET and nonlocal heat-transport models* predict accurately the energy coupling diagnosed with shock-trajectory measurements



X-ray radiographs including the instrument response function are calculated with 2-D *DRACO* / Spect3D, azimuthally averaged, and compared with the measurements.**

* J. A. Marozas, JT02.00001, this conference (invited).
** J. J. MacFarlane *et al.*, High Energy Density Phys. 3, 181 (2007).

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