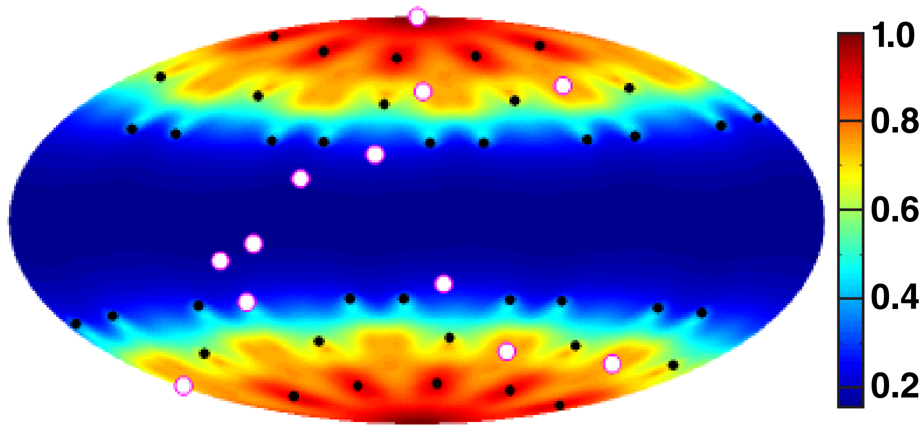
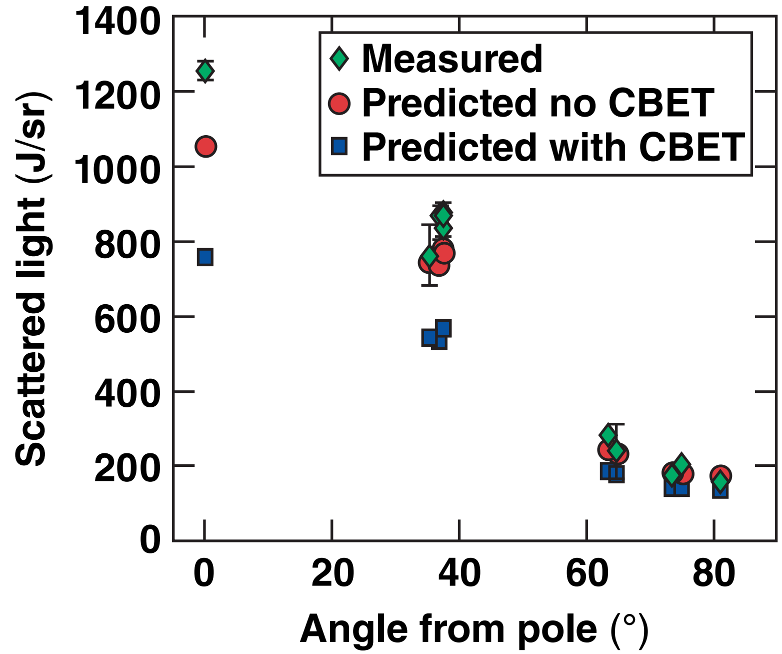
Mitigation of Cross-Beam Energy Transfer in Polar-Drive Implosions

Predicted scattered light normalized distribution at wall



Measured and predicted energy collected by calorimeters



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Summary

Modeling suggests that cross-beam energy transfer (CBET) is significant during polar-drive (PD) implosions, but mitigation strategies exist

- Modeling predicts that CBET will reduce absorption of the laser energy by ~10% during PD on OMEGA
  - this level is similar to that in symmetric 60-beam implosions
- CBET will affect the drive symmetry
  - the equatorial ring is affected more than the other rings
- CBET mitigation strategies for PD implosions include
  - wavelength shifting the beam rings can be used to control or balance the absorption in the rings
  - two-stage "zooming" by using a smaller spot size during the main pulse might eliminate most CBET

Collaborators

P. B. Radha, R. S. Craxton, J. A. Delettrez, D. H. Froula,
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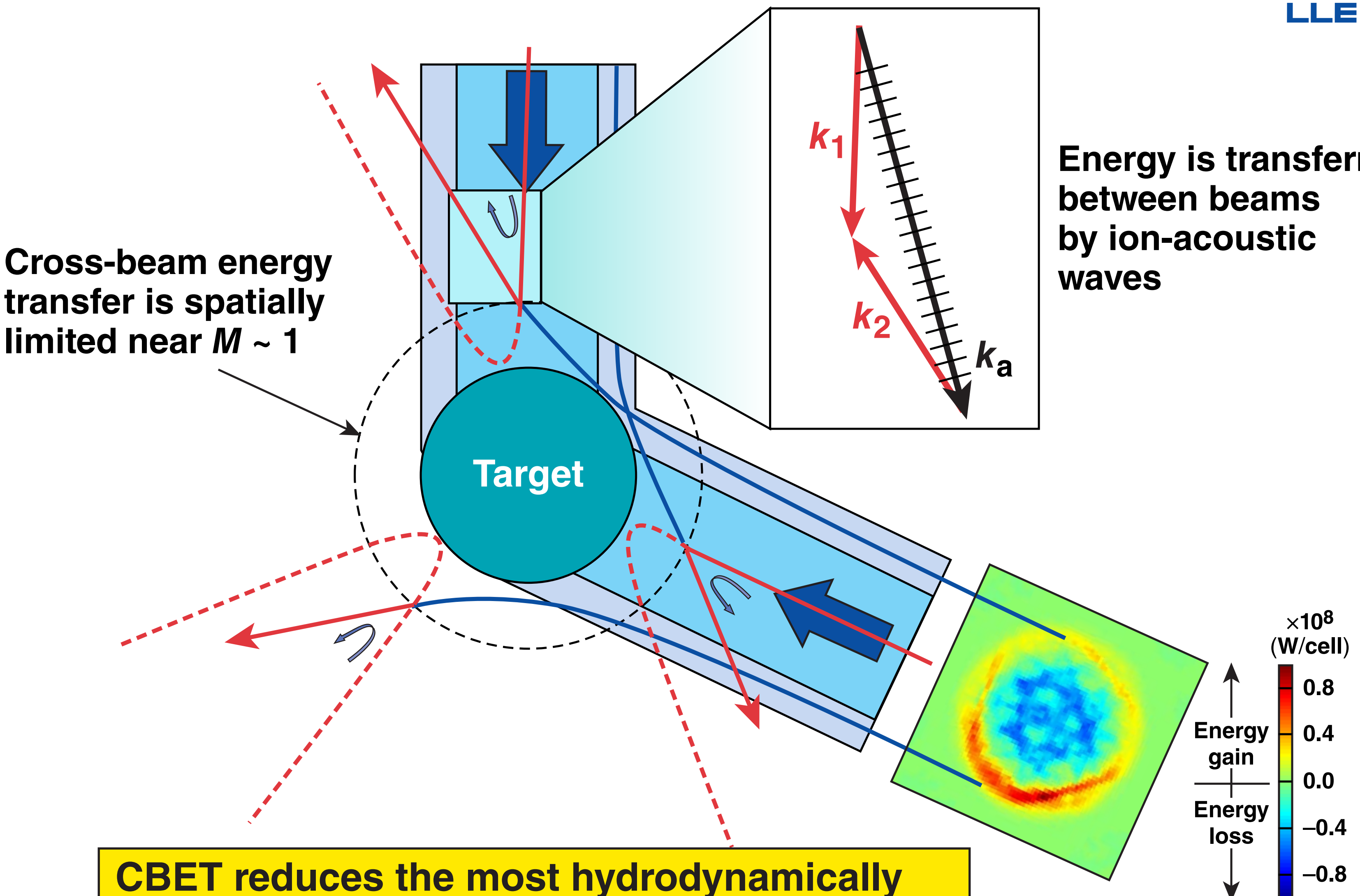
Electromagnetically-seeded SBS cross-beam power transfer* results in laser energy "bypassing" the high absorption zone



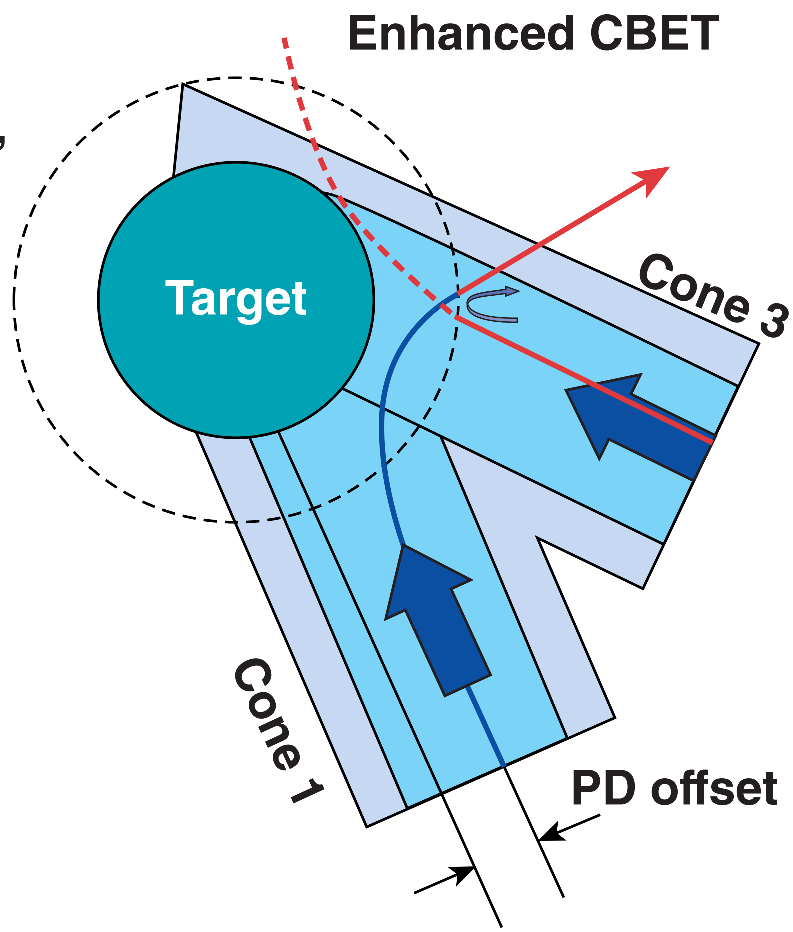
CBET reduces the most hydrodynamically efficient portion on the incident laser beams.

E19971c

*I. V. Igumenshchev, Phys. Plasmas 17, 122708 (2010).

Direct-drive experiments at the NIF require the nonsymmetric PD geometry

- In PD, the cylindrically symmetric NIF beams uniformly implode a spherical target by optimizing the beam pointing, power, and profile
- Beams must be repointed toward the equator
- The center of the beam profile
  - refracts more
  - penetrates into the coronal plasma less
  - is absorbed less
- This results in more energy from one beam crossing other beams

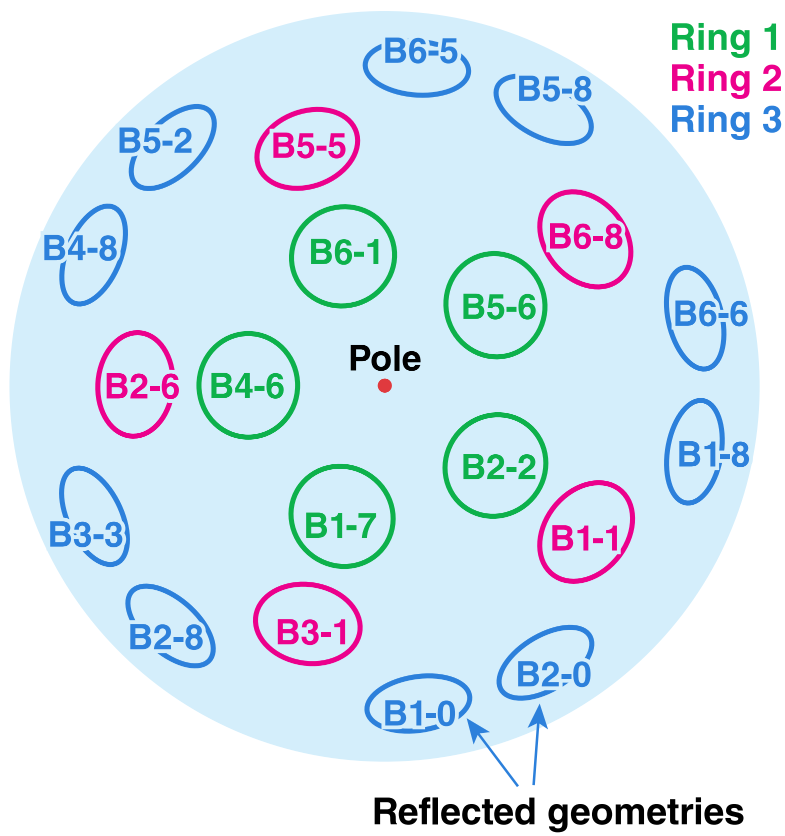


PD is being studied on OMEGA.

E21272

CBET has been examined using our scattered-light simulation code for a 3-D PD geometry on OMEGA

- Plasma parameters taken from 2-D *DRACO* hydrocode calculations
- Ray tracing used to calculate the paths and Doppler shifts of many beamlets for each PD beam
- A parallel MATLAB code is used to calculate all the beam crossings at each point along a beamlet path
- All the beams in a OMEGA PD ring have identical beam geometries (or reflections of the same geometry)
  - CBET only needs to be calculated for one beam in each beam geometry



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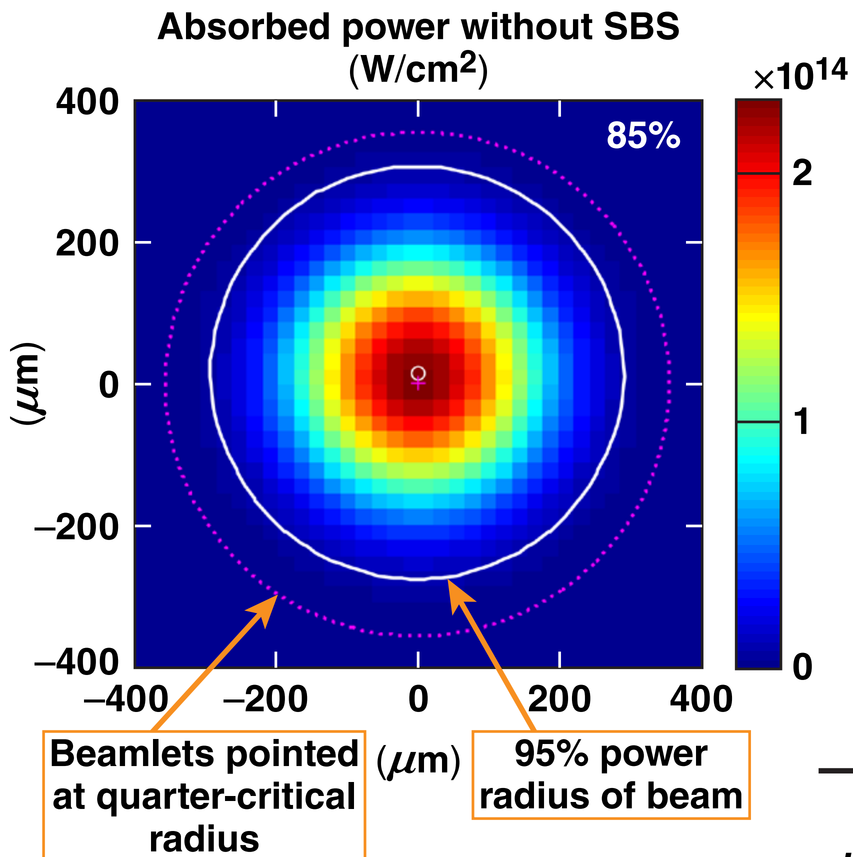
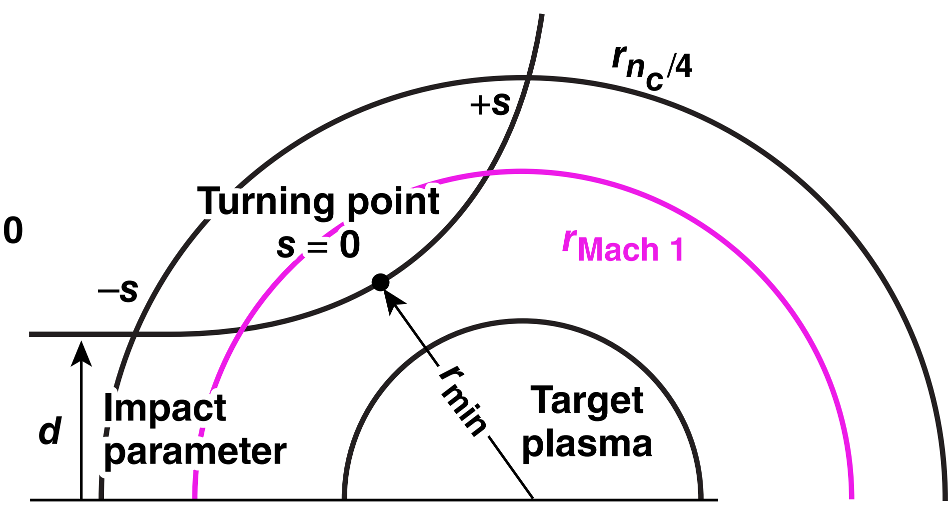
To display 3-D calculations we integrate along the beamlet paths to form a 2-D image

Integral along beamlet paths of the absorbed laser energy $\sum_{s} dE_{abs}$

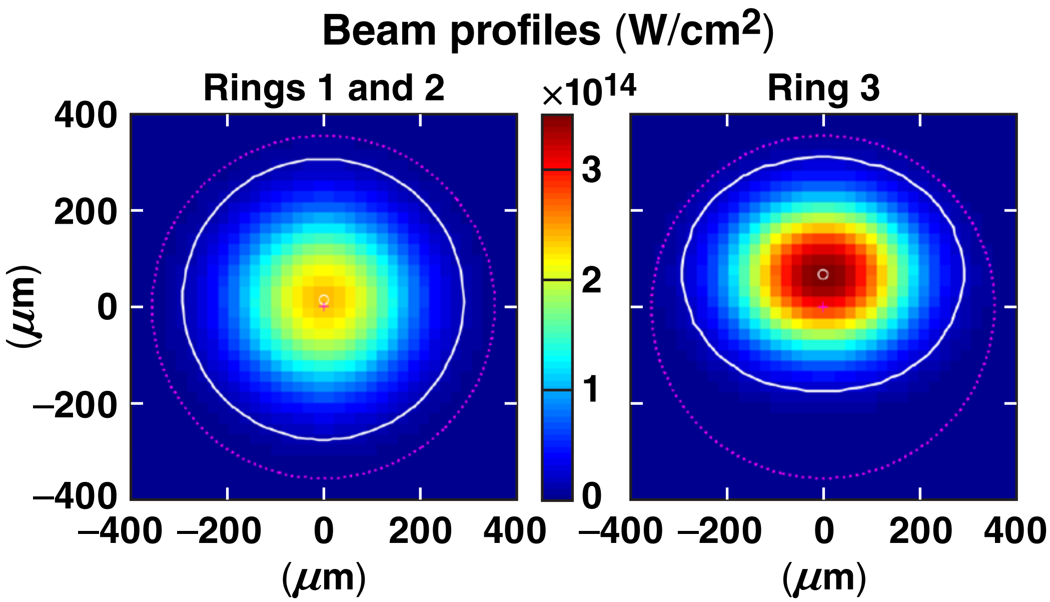


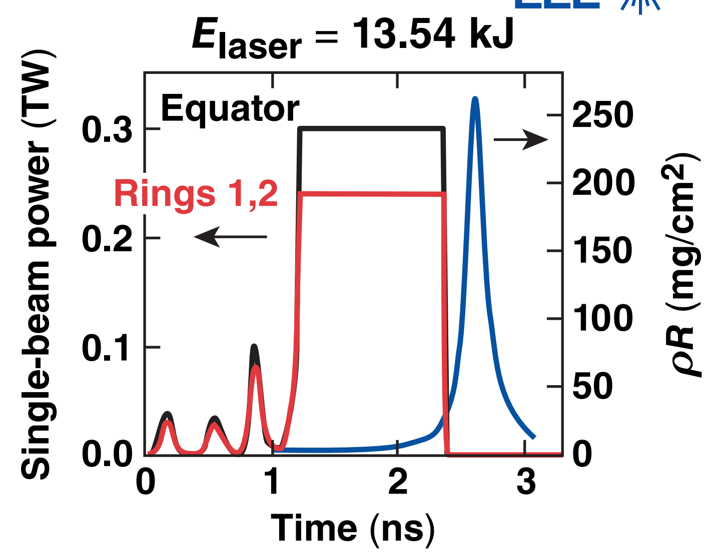
- Each pixel in the 2-D image represents a beamlet
  - rays were launched on this square grid
- Energy absorbed and/or cross-beam transferred integrated along each beamlet path *s*



E21273

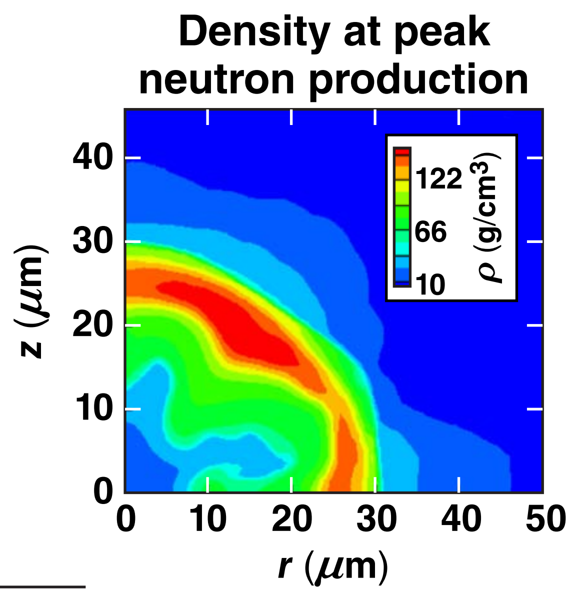
CBET is studied using the recently designed DPP's for optimized PD on OMEGA*





CH target
Outer diameter = 300 μm
Shell = 27 μm
YOC = 55%

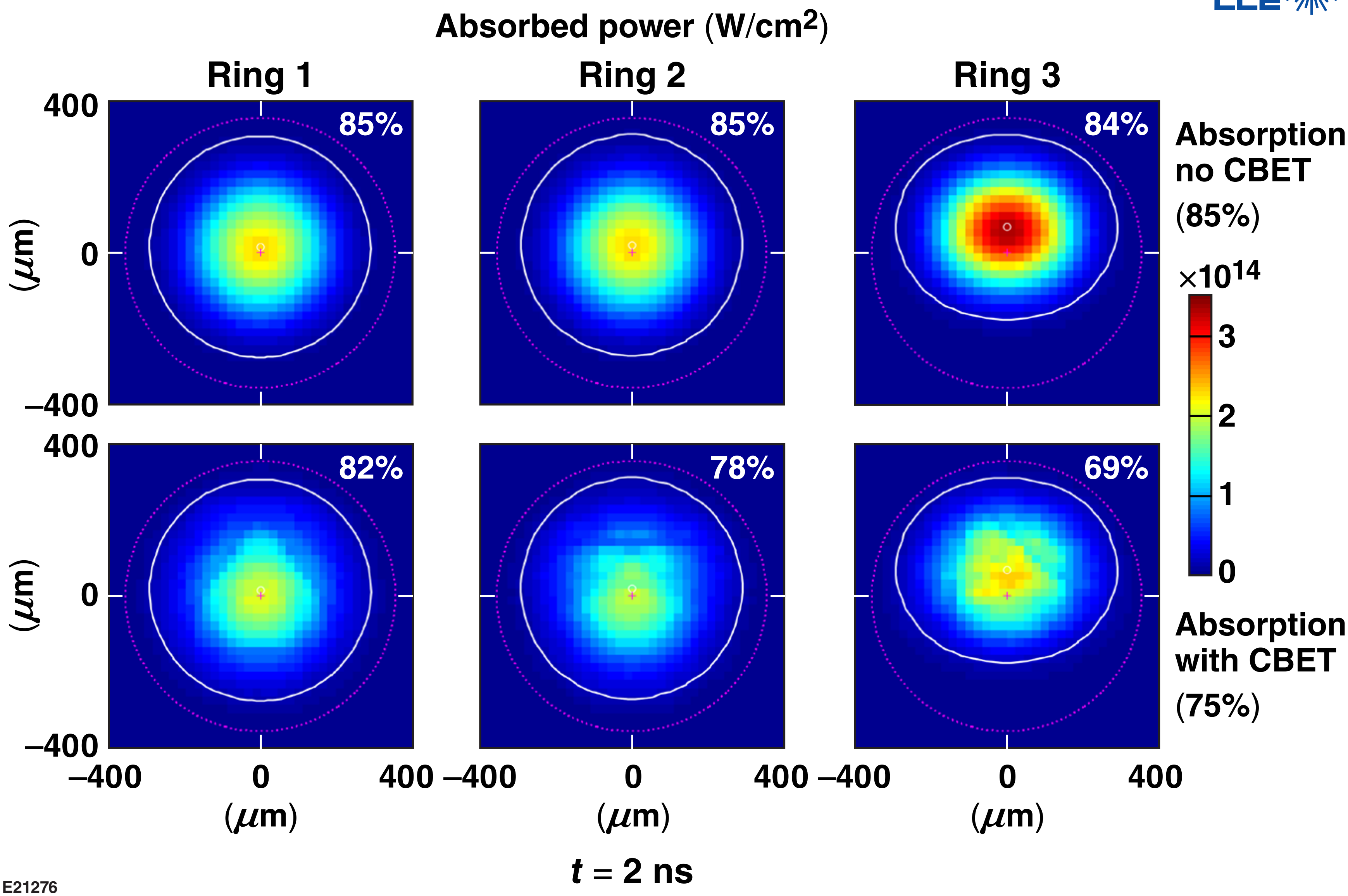
DRACO
simulation



E21274

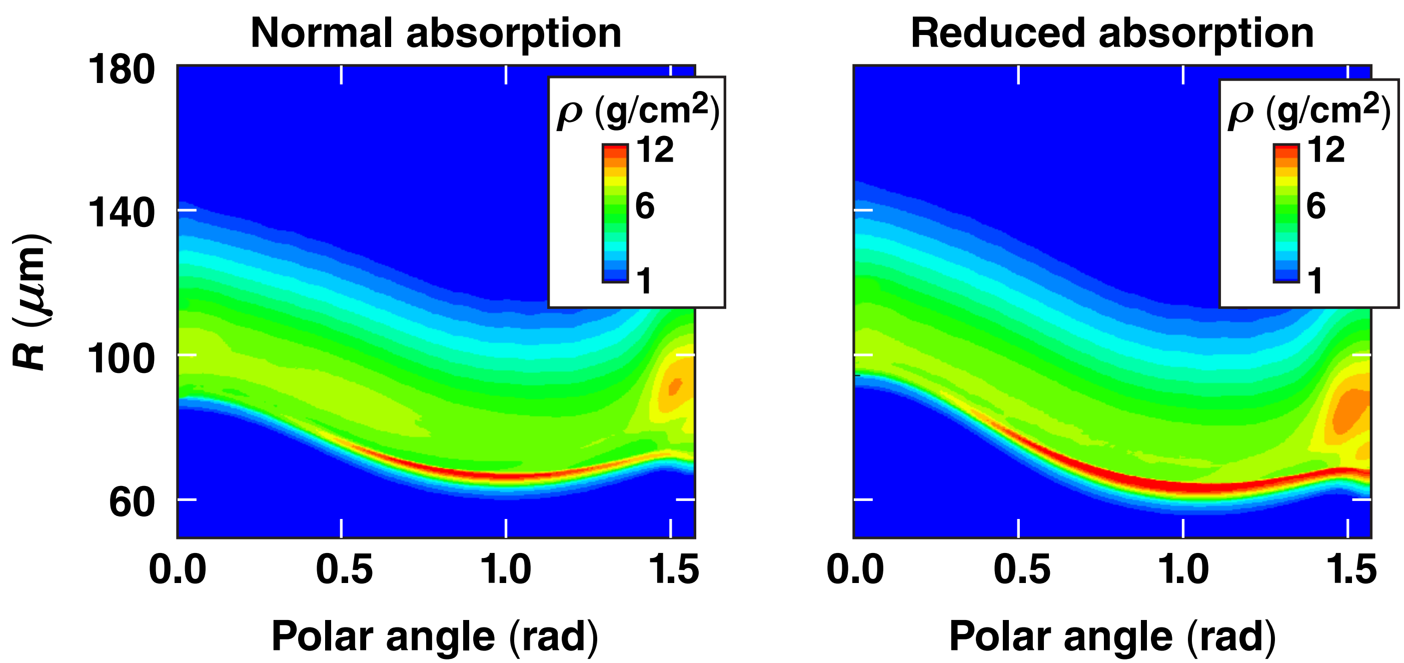
*P. B. Radha, submitted to Physics of Plasmas

The equatorial third ring suffers the most CBET, but the 10% reduction in total absorption is similar to 60-beam case



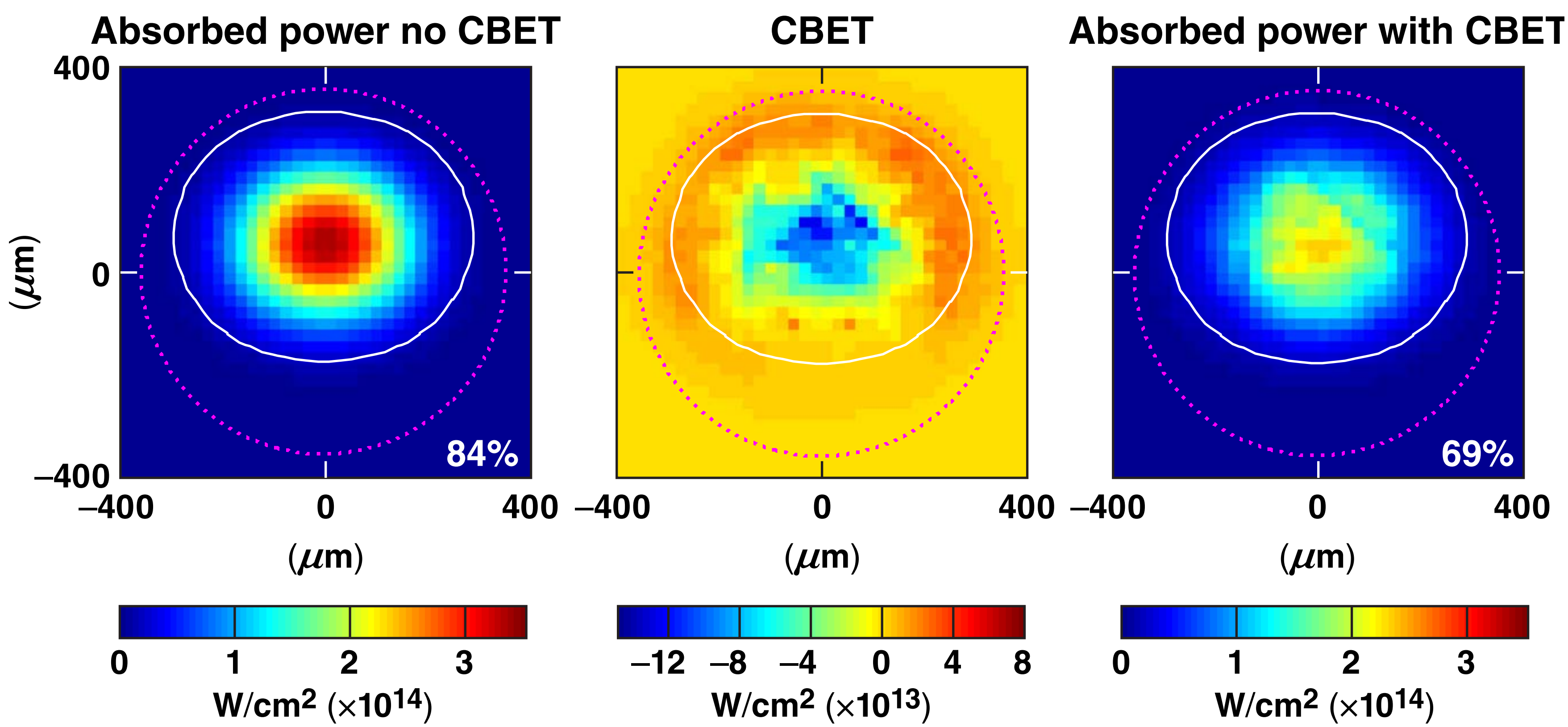
This level of CBET is consistent with observations during previous PD implosions on OMEGA

- The bang times in previous OMEGA PD experiments are later than predicted by a ~180-ps delay, similar to those seen in symmetric 60-beam implosions
  - similar reduction in drive (absorbed energy)
- Modeling shows that changes in absorption at this magnitude would *not* cause any noticeable nonuniformity in the measured implosion shape
  - at convergence = 7 where previous measurements were taken



E21277

CBET reduces and adds structure to the laser absorption in PD

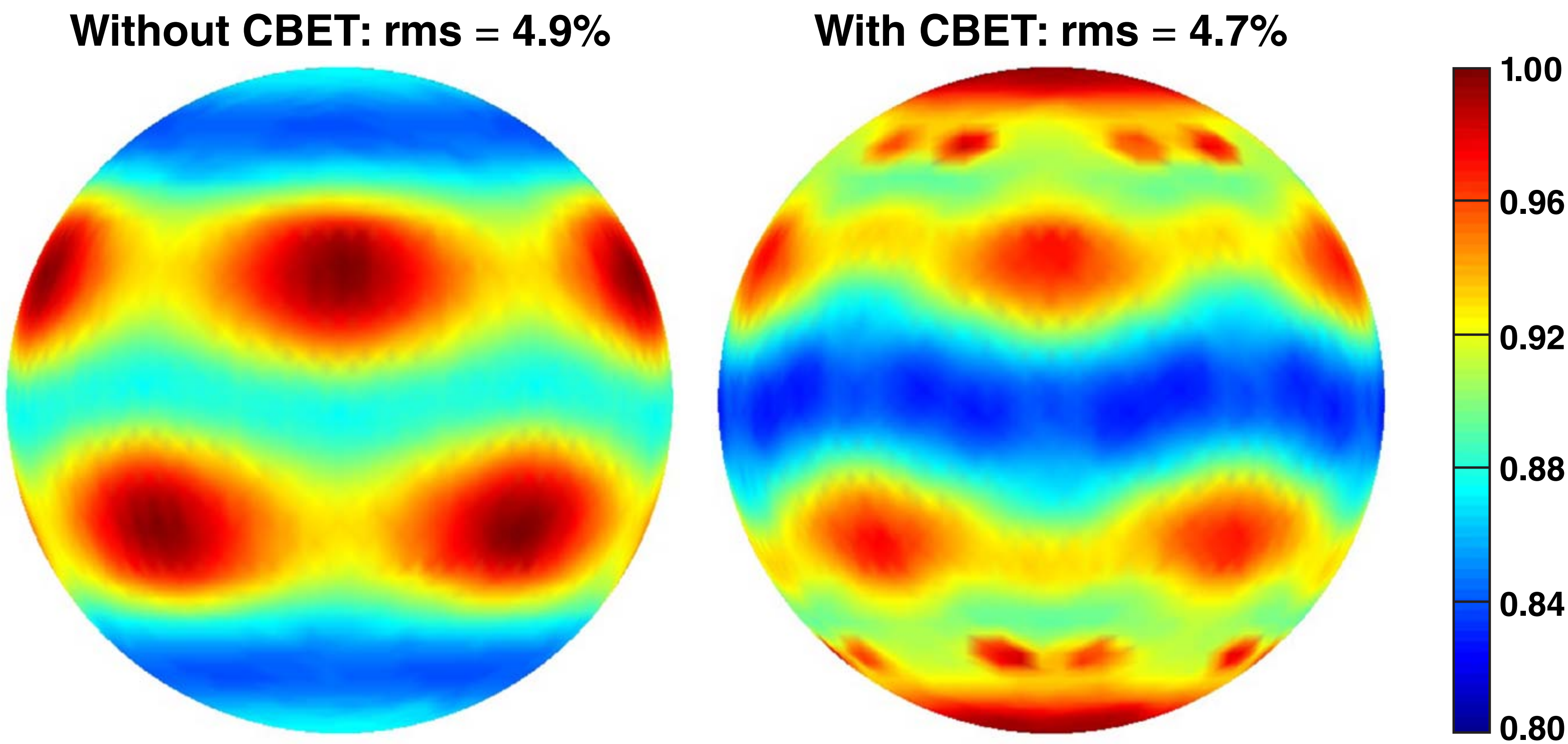


Ring 3
t = 2 ns

- **Similar to a symmetric implosion, CBET takes energy out of the center of the beam profile and moves it into the edges**

E21278

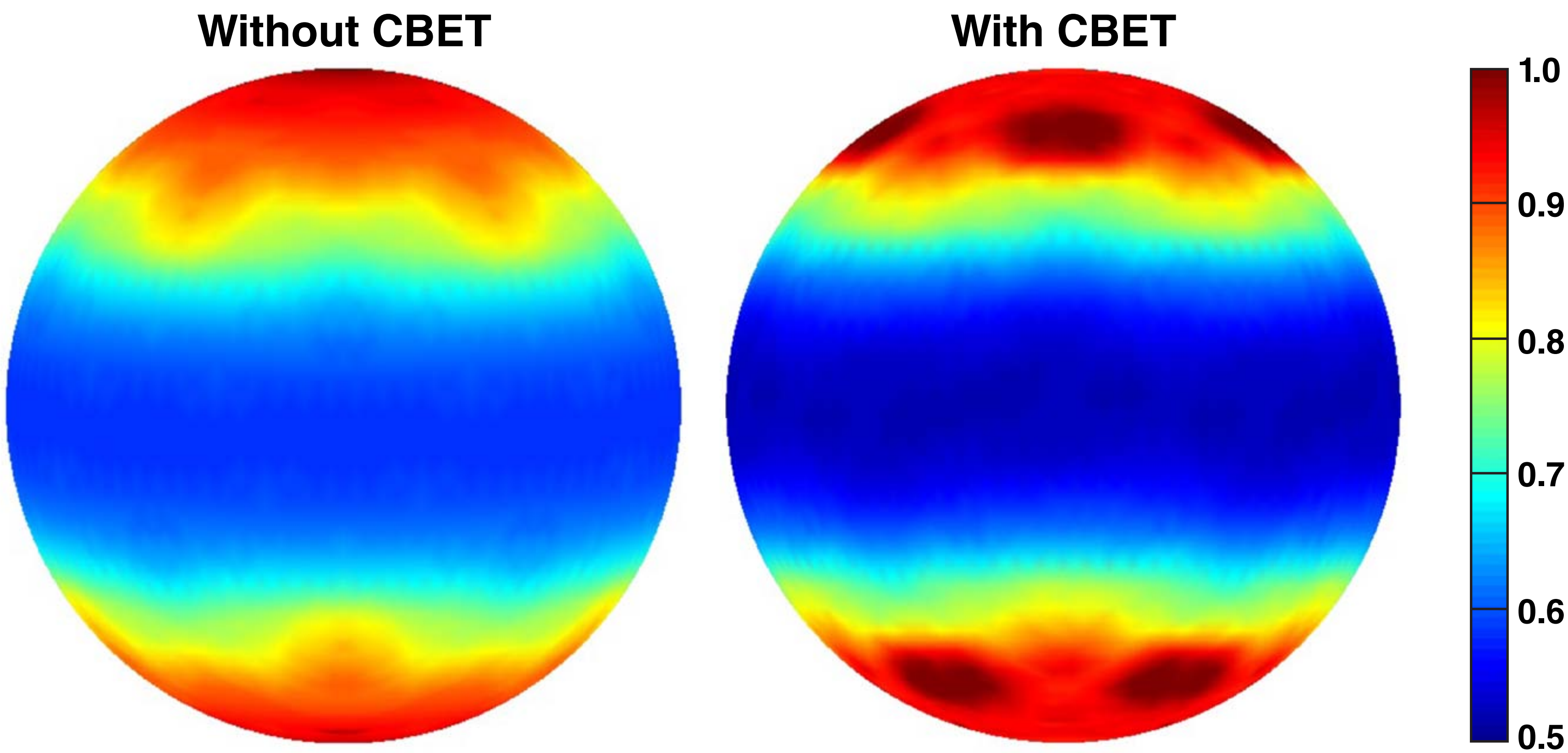
CBET alters the pattern of the energy absorbed by the target, but the rms changes little



- Relative variation in time-integrated energy absorbed inside the quarter-critical density surface predicted for the DPP's optimized for polar drive on OMEGA

E21279

CBET changes the pattern of light scattered from the implosion

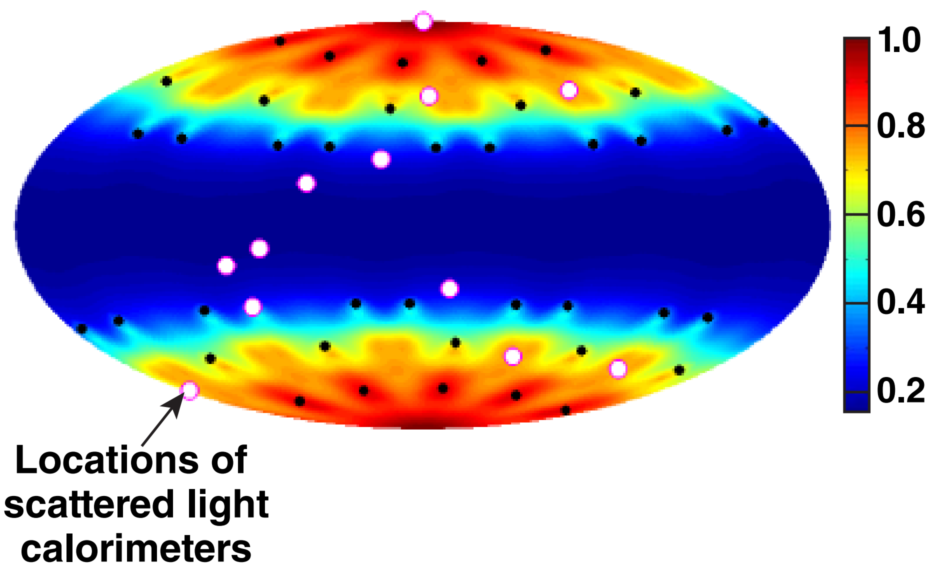


- Relative variation in time-integrated scattered light at the target chamber wall predicted for the DPP's optimized for polar drive on OMEGA

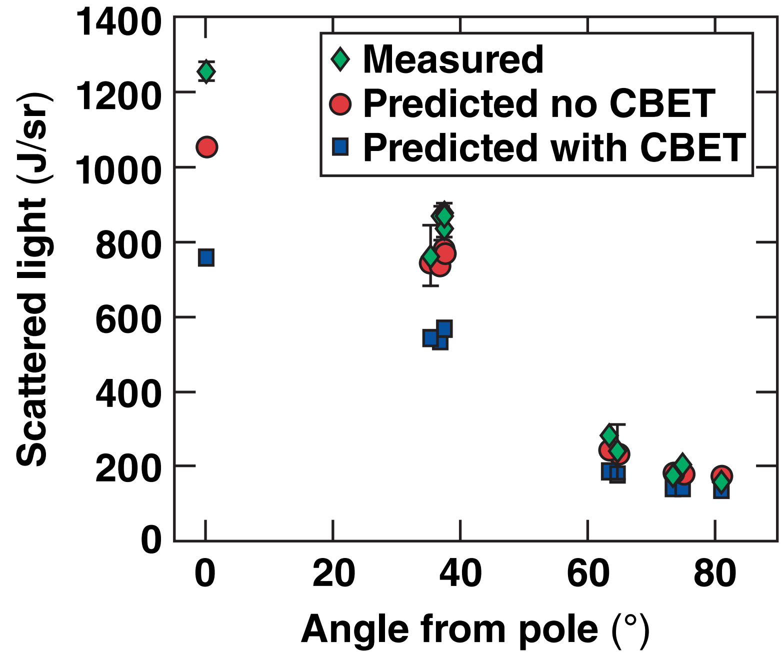
E21280

Scattered-light measurements of PD implosions using the existing DPP's support the CBET predictions

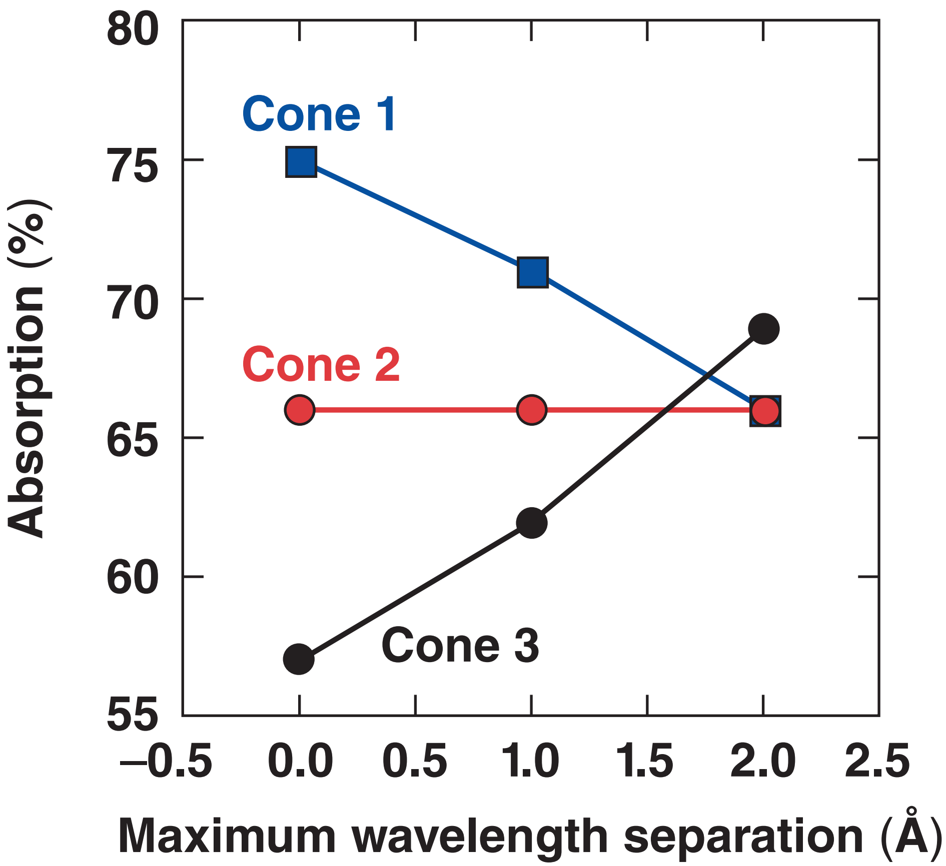
Predicted scattered light normalized distribution at wall



Measured and predicted energy collected by calorimeters



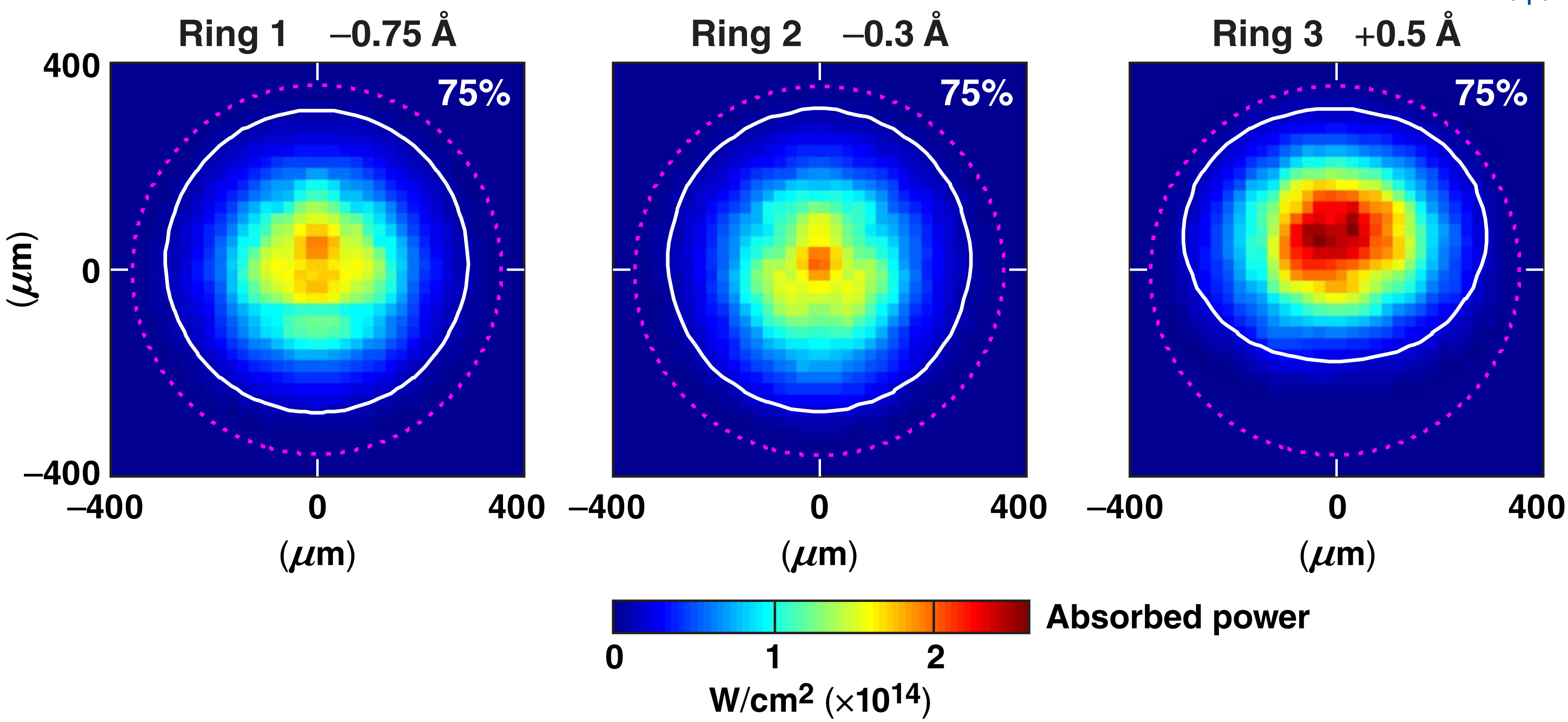
Calculations indicate that shifting the wavelength between cones could significantly alter the energy exchange



- The ring structure of PD allows similar beams to be wavelength shifted as a group
- Wavelength shifting (by only a couple of Å) can balance the rings or funnel power to the equatorial ring

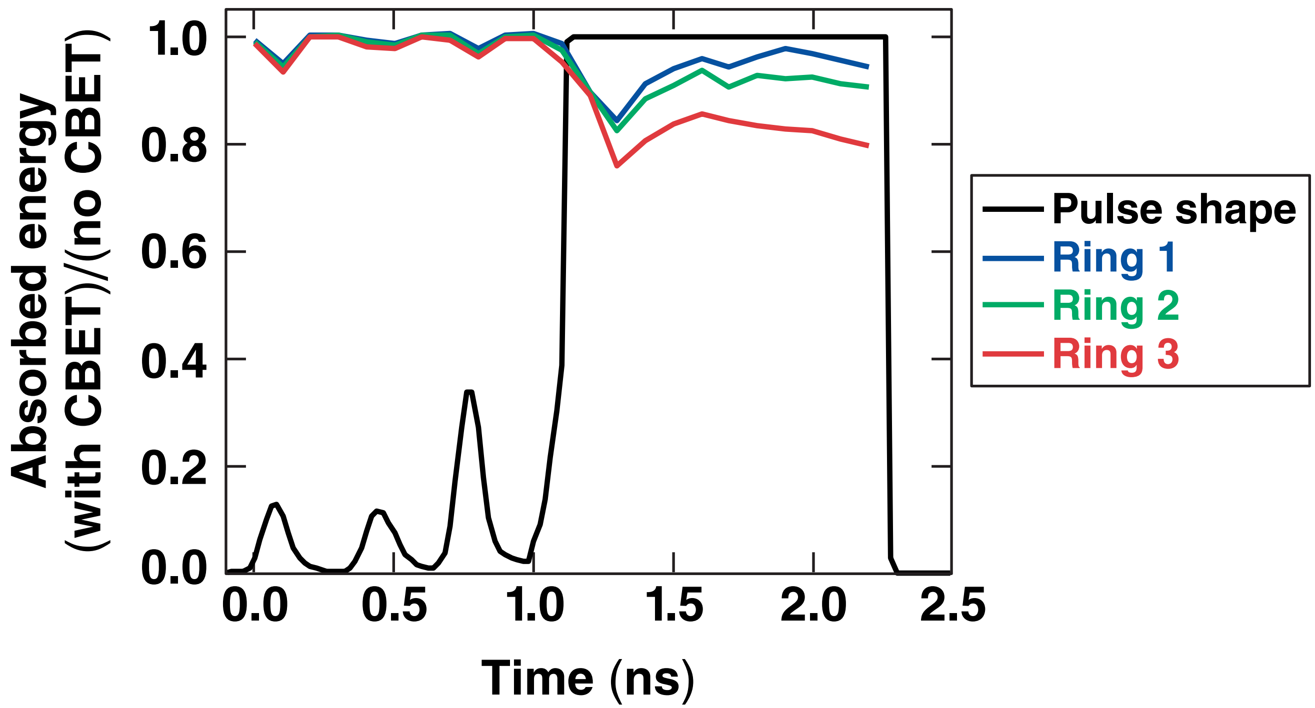
E21282

Wavelength shifting the rings corrects the ring imbalance caused by CBET



- Total absorption still lowered and beam-profile asymmetries caused by CBET must still be considered
- Wavelength shifting is not currently possible on OMEGA, but is available on the NIF
  - should be able to show some oblate/prolate shape control by wavelength shifting rings on the NIF

CBET occurs primarily during the drive portion of the pulse so two-stage spot-size "zooming" may mitigate it in PD*

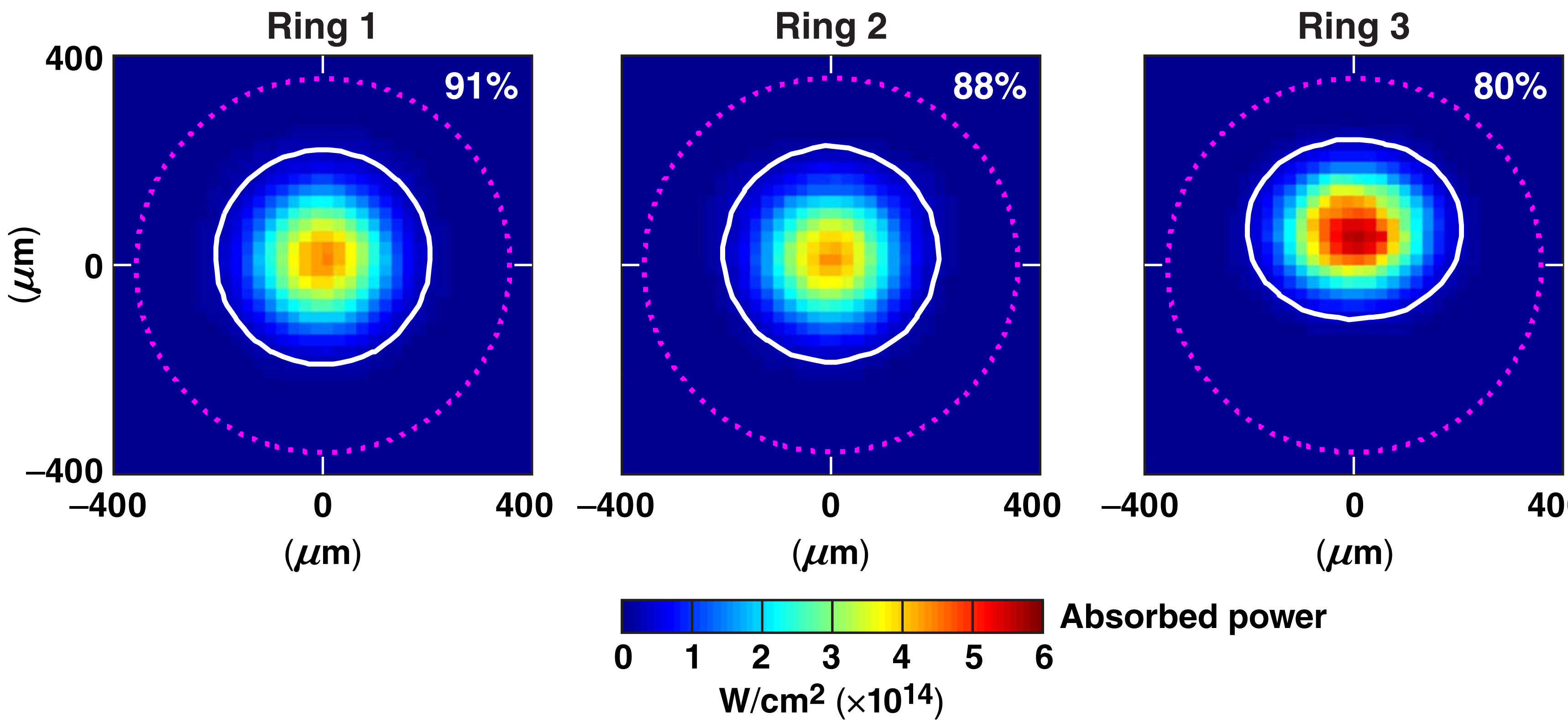


- Two-stage zooming
  - larger laser spot sizes (roughly equal to target diameter) during pickets reduces the nonuniformities imposed on a target when it is vulnerable to them
  - smaller laser spot sizes during drive reduce CBET when it is most detrimental to the implosion

E21284

*previous talk by D. H. Froula

Two-stage "zooming" using a smaller spot size for the main drive than for pickets may alleviate CBET in PD



$R_b/R_t = 0.7$

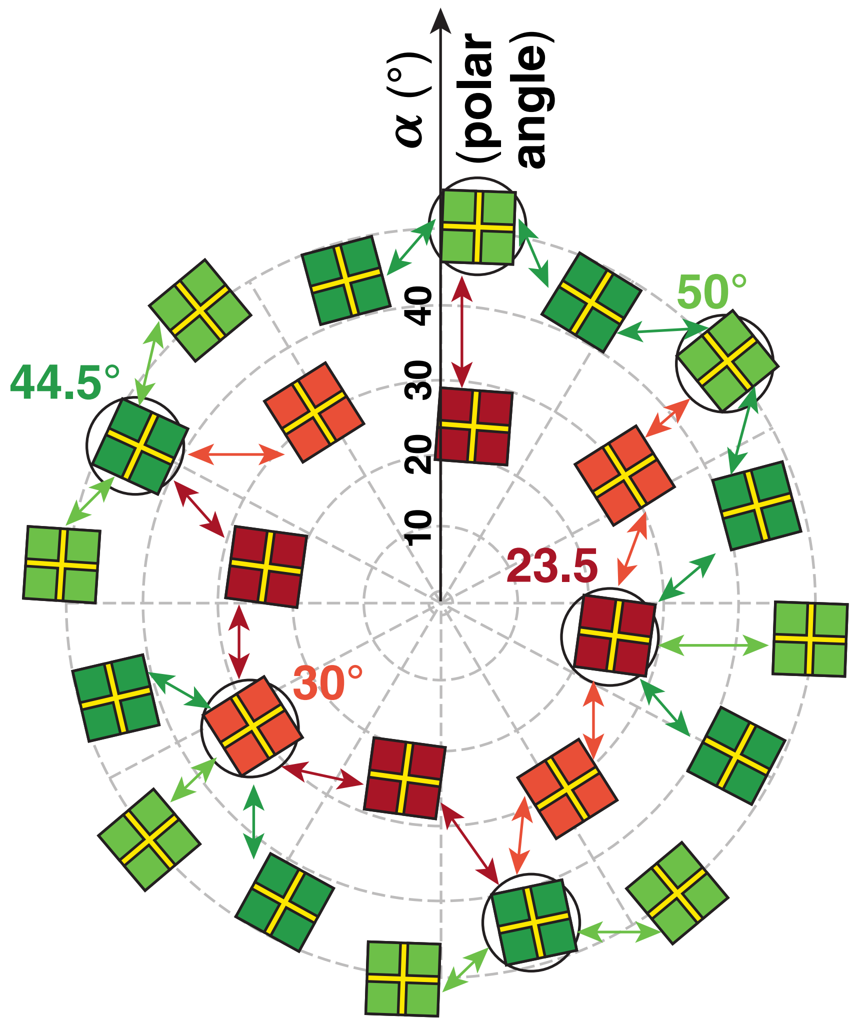
Absorption with CBET (85%)

at $t = 2$ ns

Could be an effective mitigation strategy for PD on OMEGA.

E21285

CBET modeling needs to be applied to NIF PD conditions



- NIF has more beams and more complicated geometry than OMEGA
- There are still symmetries that can be exploited to reduce the number at different beam geometries that need to be modeled
- Can a quad be treated as one beam?
  - if not, then many separate rings

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