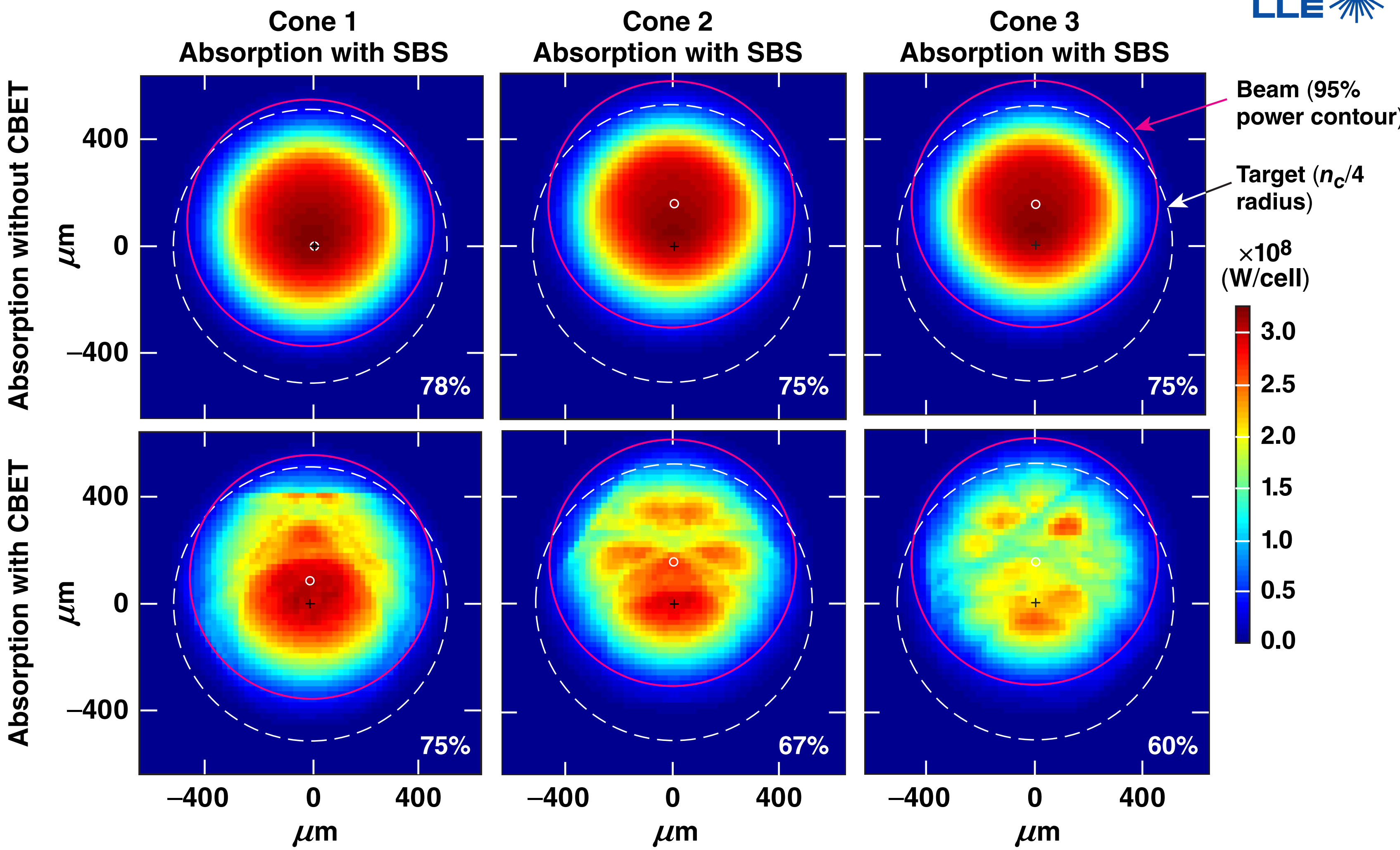
Cross-Beam Energy Transfer in Polar-Drive Implosions



D. H. Edgell
University of Rochester
Laboratory for Laser Energetics

41st Annual Anomalous Absorption Conference
San Diego, CA
19–24 June 2011

Summary

Cross-beam energy transfer (CBET) predictions show significant absorption profile modifications in Polar Drive (PD)

- EM-seeded SBS transfers energy between direct-drive laser beams that cross in the coronal plasma
  - preventing energy from reaching the high absorption region
- CBET can reduce the laser absorption in symmetric implosions and must be included for simulations to match experiments
- CBET has been calculated for a nonsymmetric polar-drive configuration (predictions indicate ~10% reduction in absorption for OMEGA PD)
- CBET must be included in PD implosion modeling and its mitigation through phase plate design will be studied

Collaborators

I. V. Igumenshchev
W. Seka
J. F. Myatt
V. N. Goncharov
R. S. Craxton
J. A. Delettrez
A. V. Maximov
R. W. Short
P. W. McKenty
D. H. Froula

EM-seeded SBS cross-beam energy transfer causes some laser energy to "bypass" the high-absorption zone

UR LLE

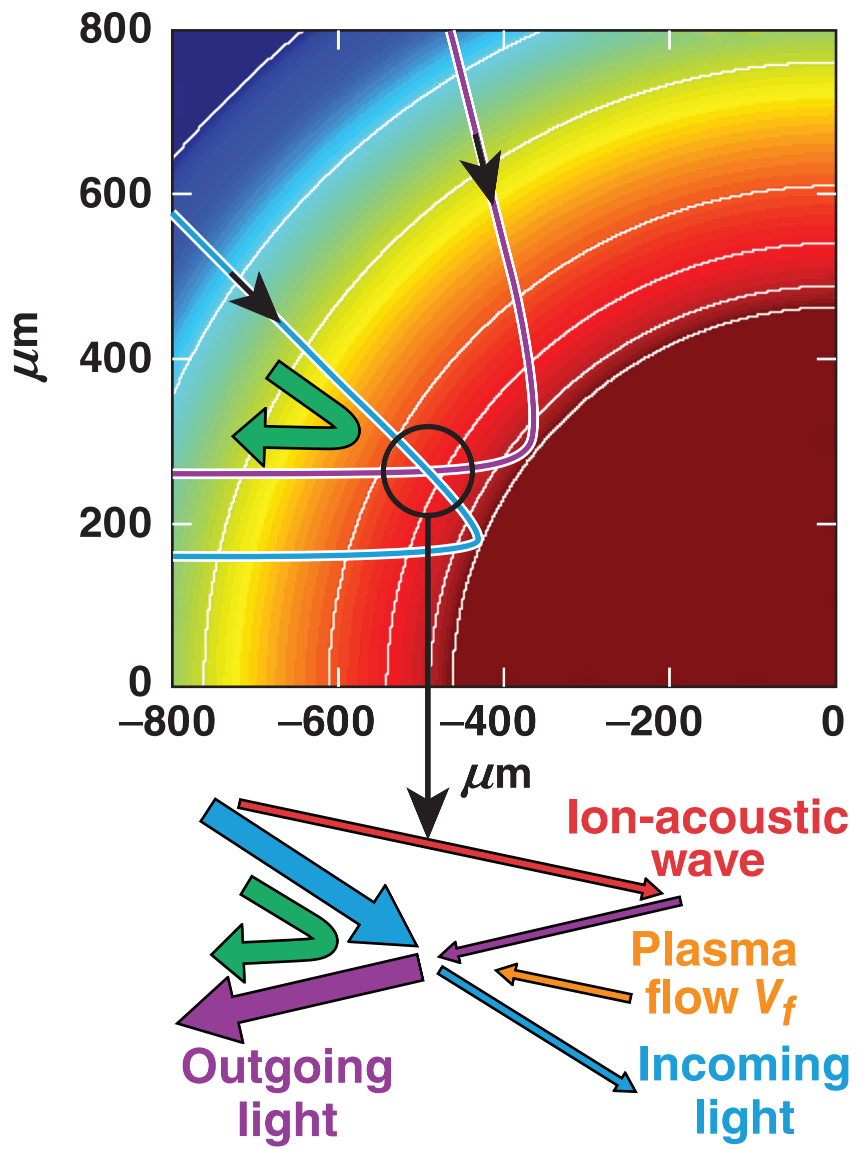
- Ion-acoustic wave (IAW) transfers energy from a "pump" EM wave (light entering plasma) to a "seed" EM wave (light leaving plasma)

$$\omega_{pump} = \omega_{seed} + \omega_{IAW}$$

$$\vec{k}_{pump} = \vec{k}_{seed} + \vec{k}_{IAW}$$

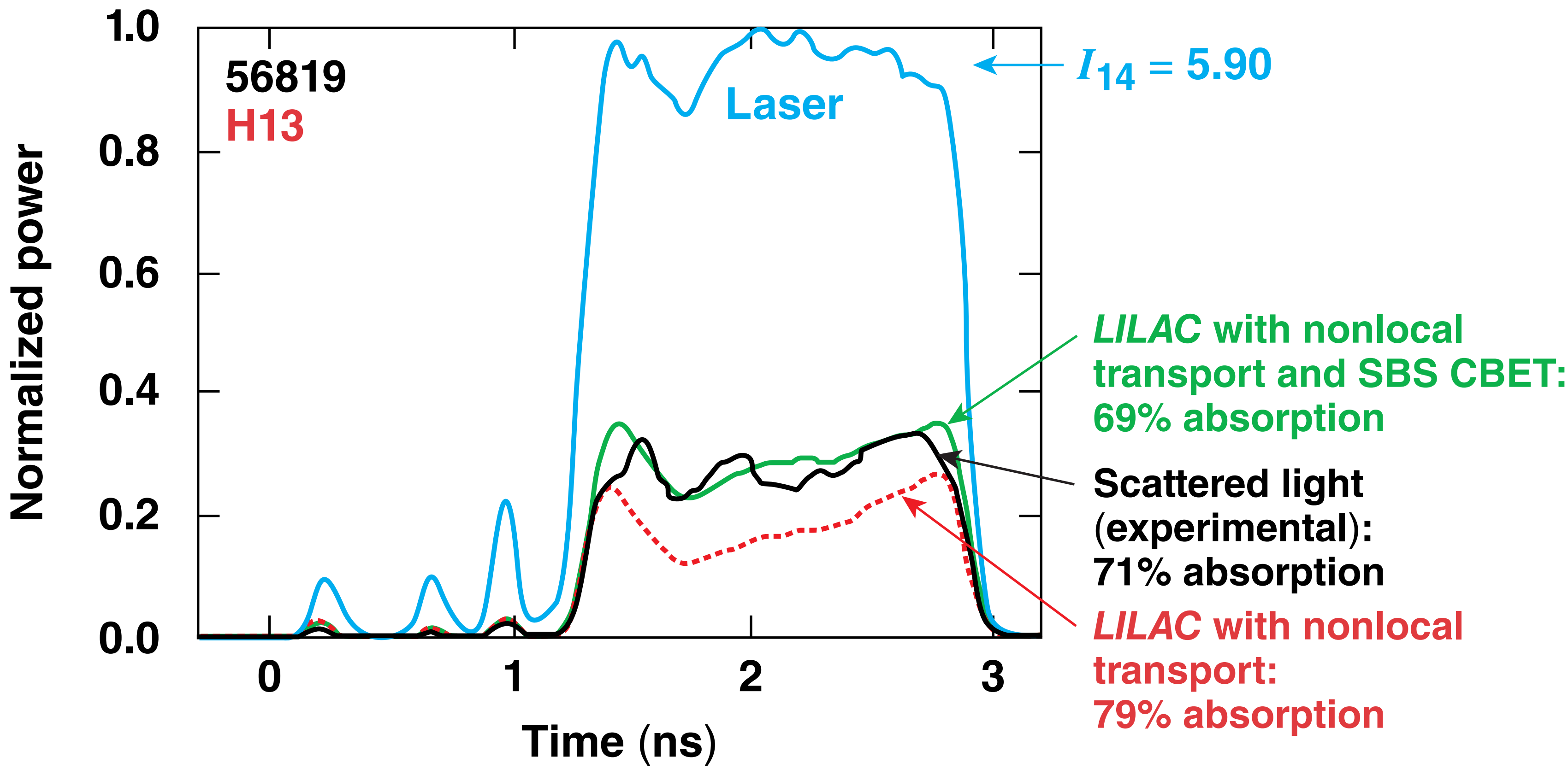
$$0 = \pm c_s \left| k_{IAW} \right| + \vec{v}_f \cdot \vec{k}_{IAW} - \omega_{IAW}$$

Because the EM-seed amplitude is of the same order as the pump, very small gains of only a few percent can significantly reduce the absorbed energy.



E17994a

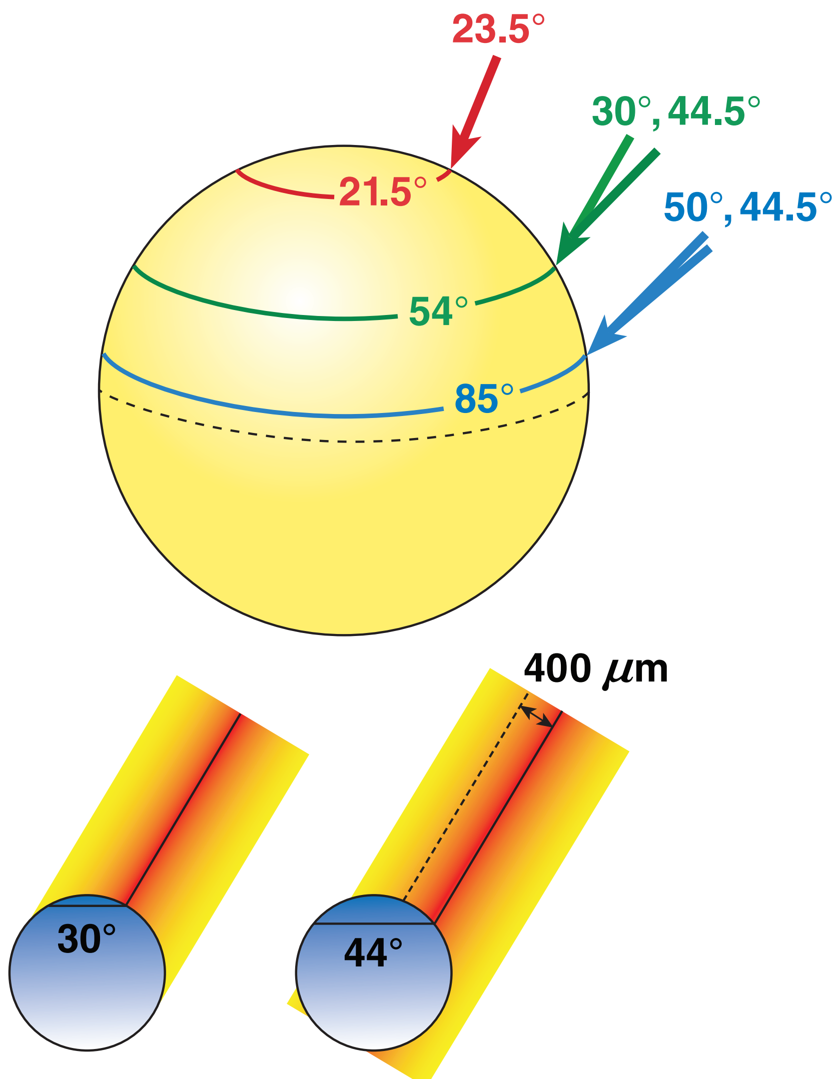
Accurate simulations of direct-drive implosions on OMEGA require CBET in the hydrocode*



*W. Seka, "Reducing the Cross-Beam Energy Transfer in Direct-Drive Implosions Through Laser-Irradiation Control," this conference.

E19899

Direct-drive experiments on the NIF require the nonsymmetric polar-drive geometry

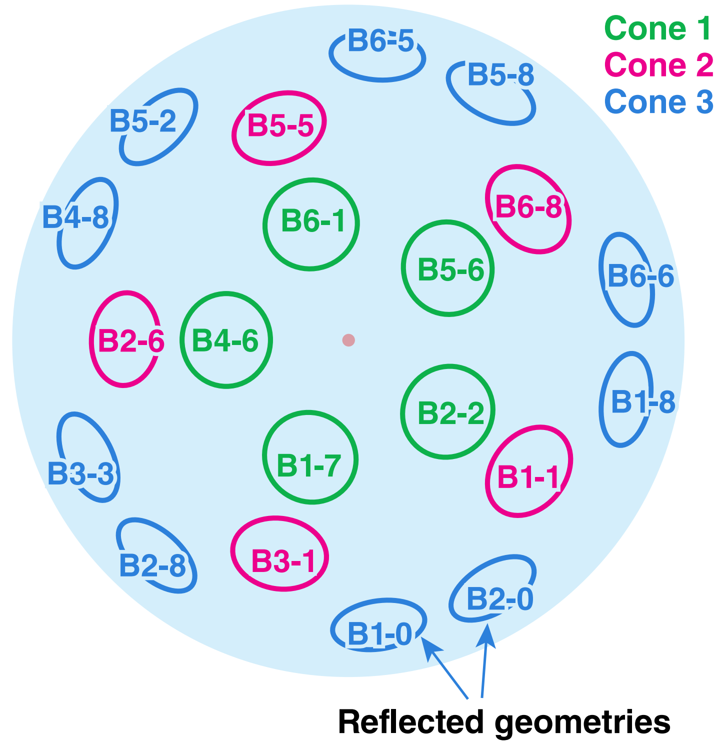


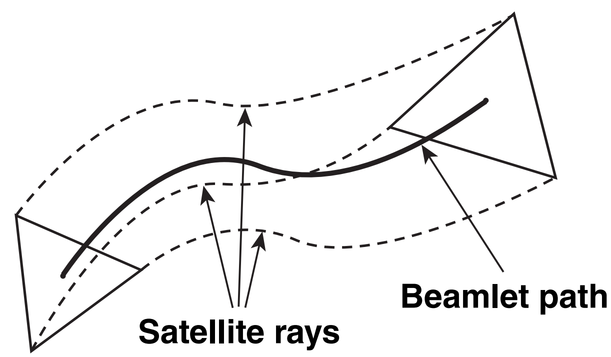
- Quasi symmetric intensity on target is achieved through a combination of spot shape, pulse shape, and beam-pointing control.
- Repointing beams from the x-ray-drive pointing leads to higher angles of incidence at the equator relative to the pole.
- The effects of CBET on beam intensity and uniformity with repointed PD beams is now modeled.

TC6468c

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

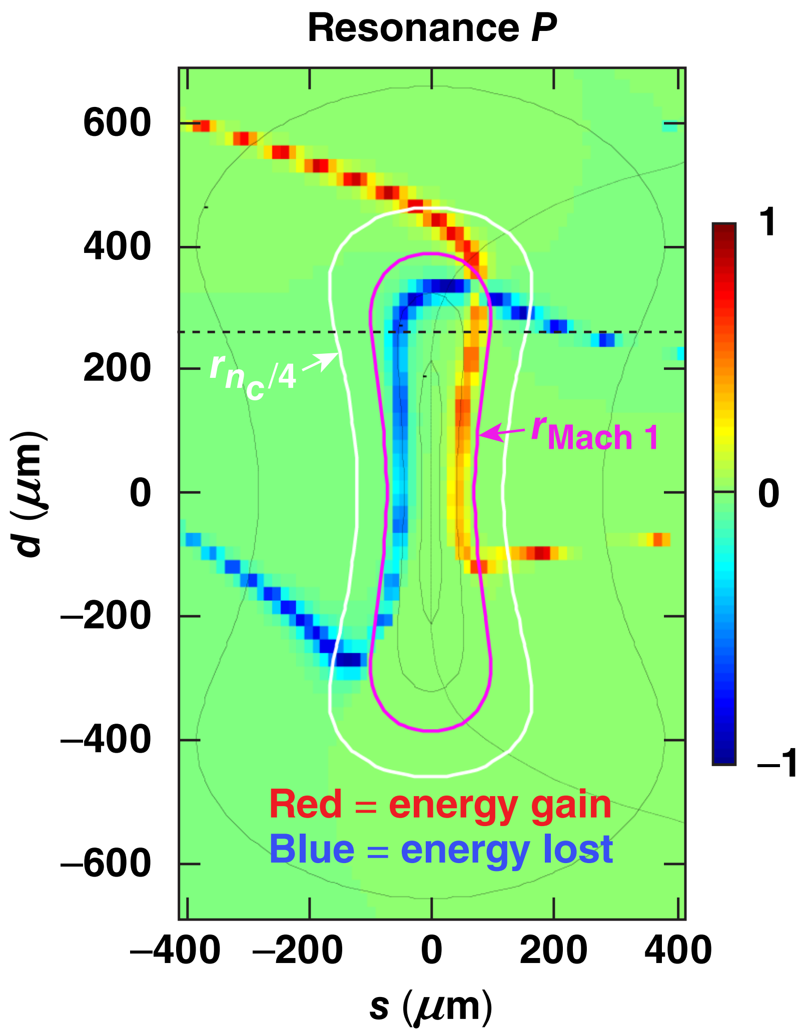
- OMEGA PD symmetry exploited to simplify calculations
- Ray tracing used to calculate the paths and Doppler shifts of many beamlets on a square grid covering the target for each PD cone angle
- All the beam crossings and CBET are calculated at each point along a beamlet path
  - no feedback into hydrocode
- Power transfer for many different beam profiles and pointings do not require new raytrace or CBET calculations
- The change in intensity for each beamlet due to the spreading area is calculated from the divergence of closely spaced satellite rays near the beamlet center

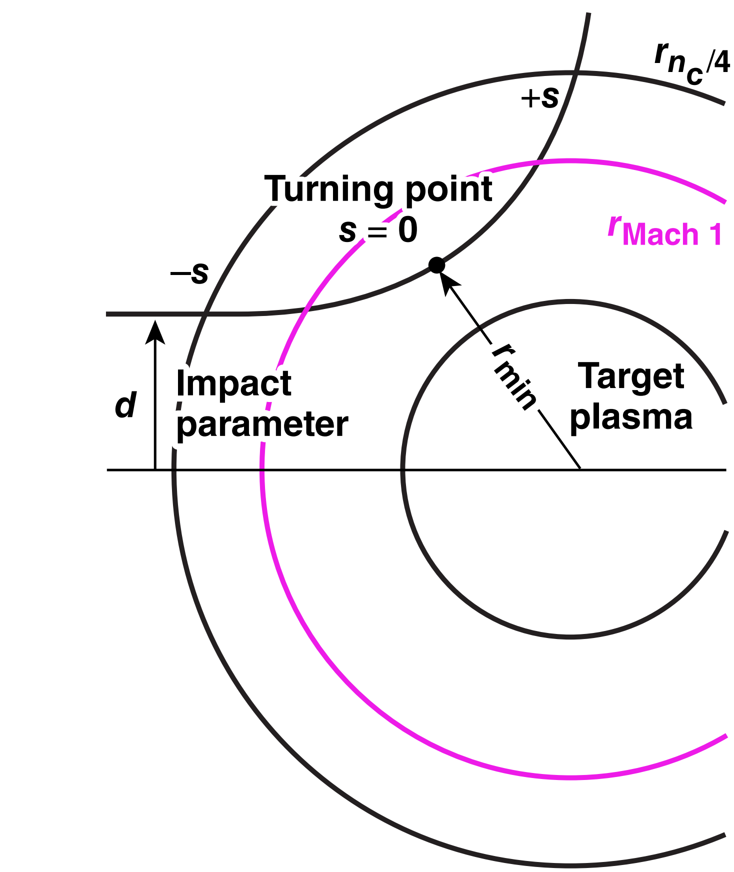




E19900

Resonance function* (P) is a measure of how close the conditions are to resonance for SBS cross-beam transfer





CBET resonance:

$$0 = \pm c_s \left| k_{IAW} \right| + \vec{v}_f \cdot \vec{k}_{IAW} - \omega_{IAW}$$

For one set of beamlets from one beam crossing one other beam.

E17999a

*C. J. Randall, J. R. Albritton, and J. J. Thomson, Phys. Fluids 24, 1474 (1981).

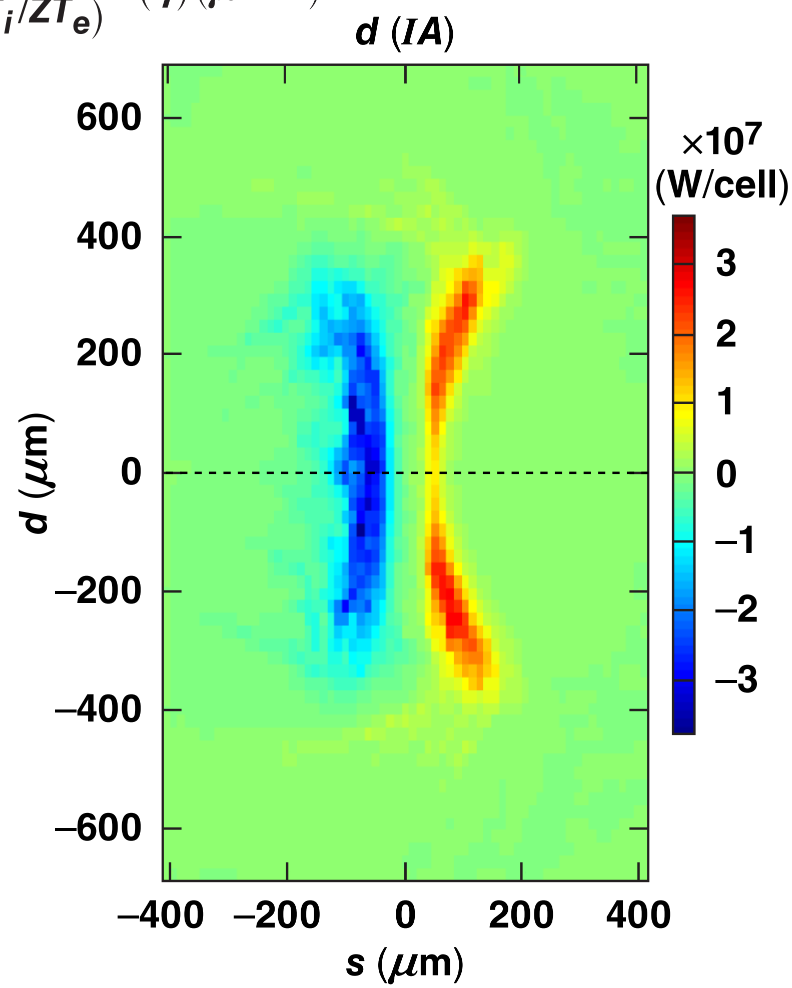
Iterative calculations find the energy lost/gained along each beamlet for a beam

- **The strength of the transfer is estimated using the spatial gain length* L_{SBS} for crossing planar waves**

$$L_{SBS}^{-1} = 2.8 \times 10^{-2} \frac{1}{v_i \lambda_{0,\mu m}} \frac{n_e/n_c}{\sqrt{1-n_e/n_c}} \frac{I_{14}\lambda_{0,\mu m}^2}{T_{e,keV}(1+3T_i/ZT_e)} P(\eta)\left(\mu m^{-1}\right)$$

- **The rate of change in intensity due to cross-beam transfer and absorption can be integrated along each path to determine the intensity**

$$d(IA) = -IA\left(\frac{1}{L_{Abs}} + \sum_{\text{all beams}} \frac{1}{L_{SBS}} P\right) ds$$

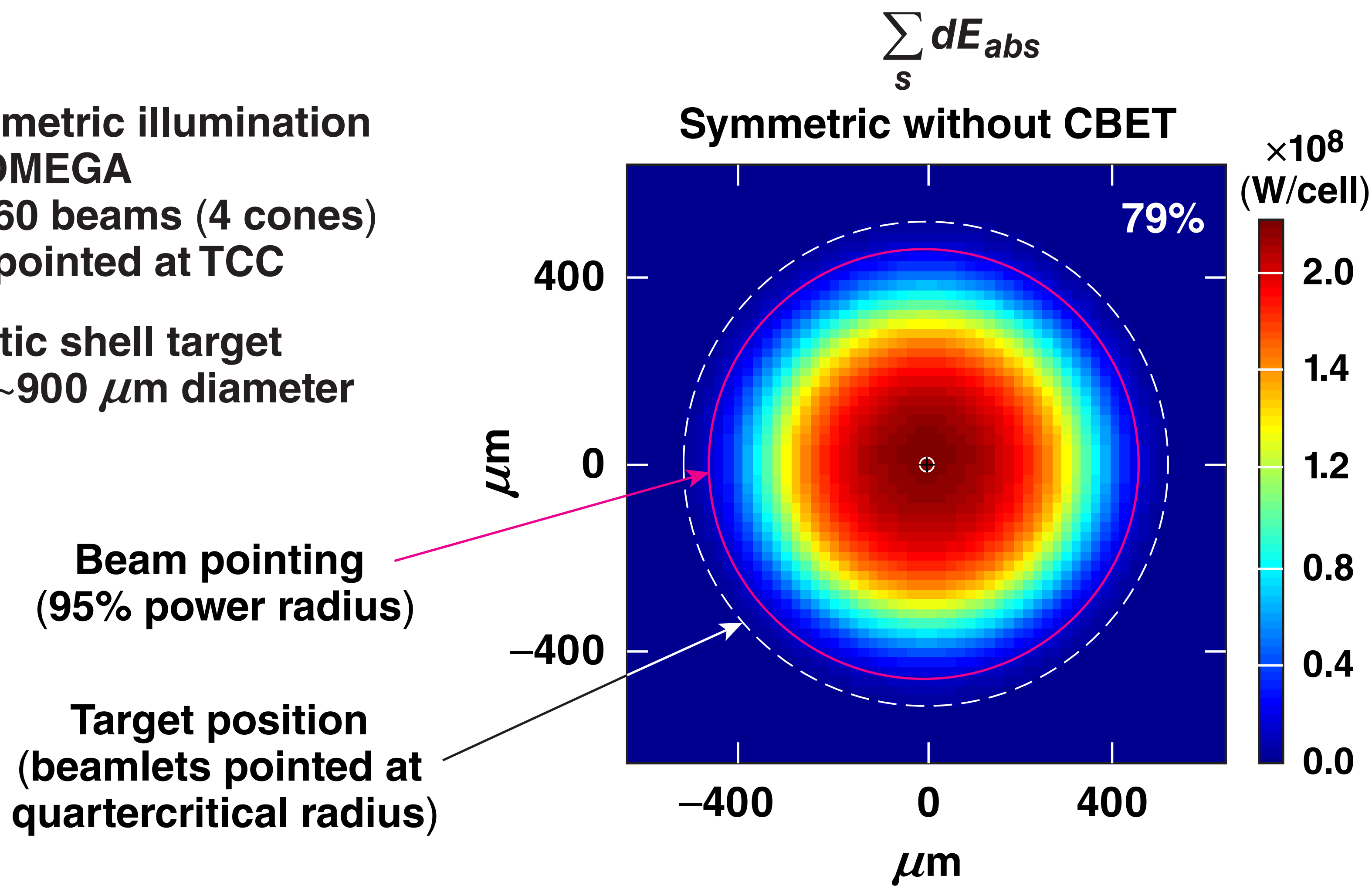


*J. F. Myatt *et al.*, Phys. Plasmas 11, 3394 (2004).

E17997b

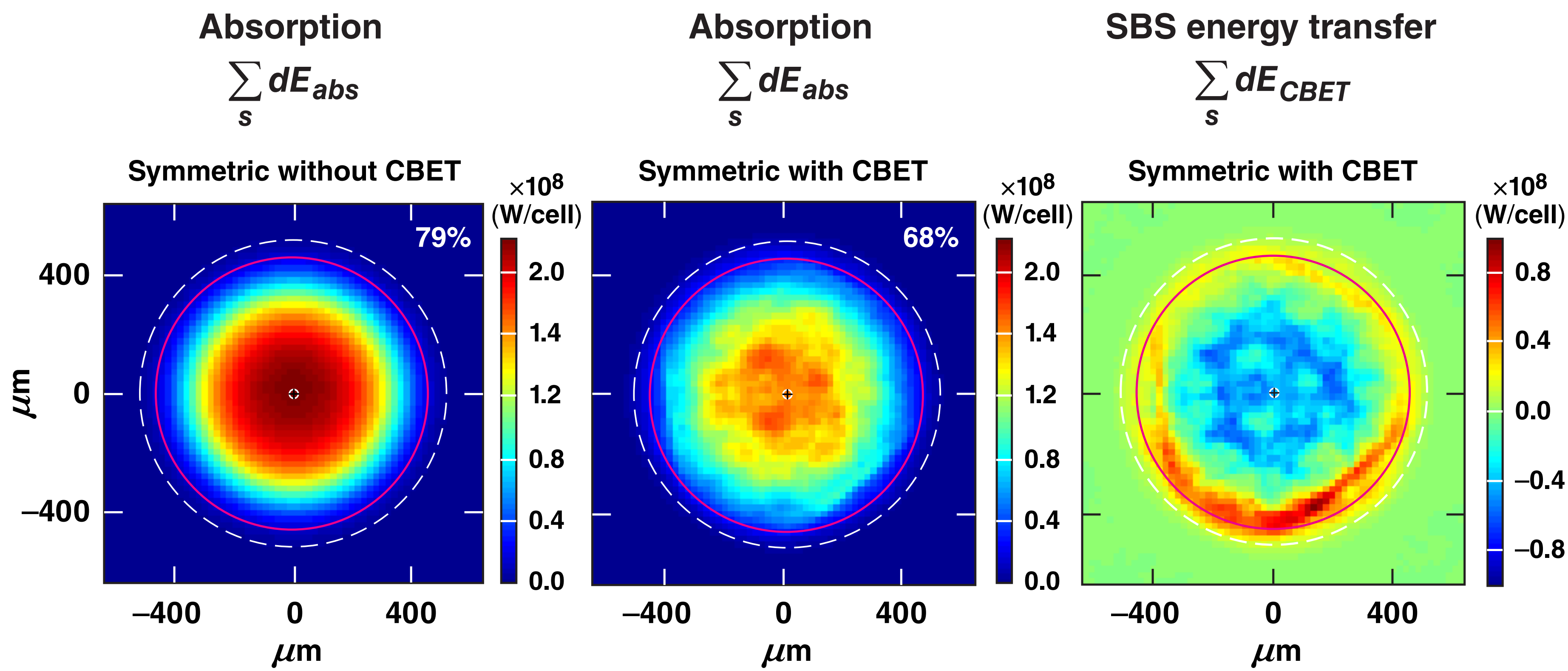
The integral of absorbed energy along the beamlet path shows no fine structure with symmetric illumination and without CBET

- Symmetric illumination on OMEGA
  - 60 beams (4 cones)
  - pointed at TCC
- Plastic shell target
  - ~900 μm diameter



E19902

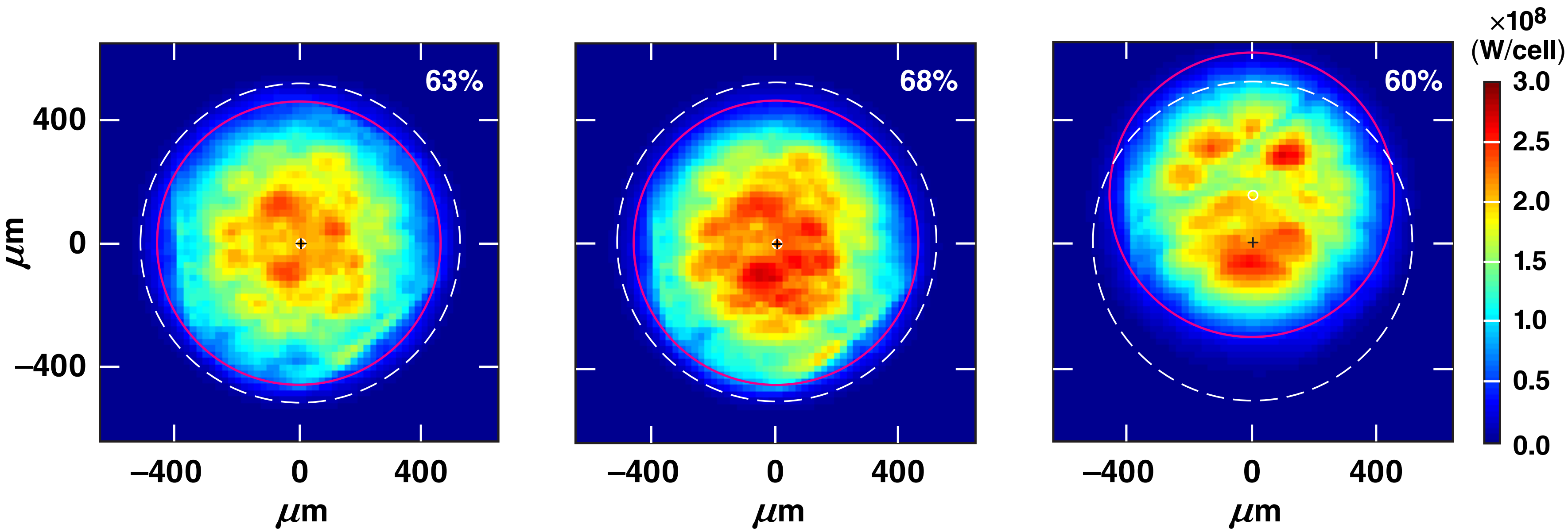
Including CBET with symmetric illumination transfers energy from inner beam and reduces the absorption



E19903

PD affects the absorption primarily through the beam pointing offset

Absorbed energy $\sum_s dE_{abs}$



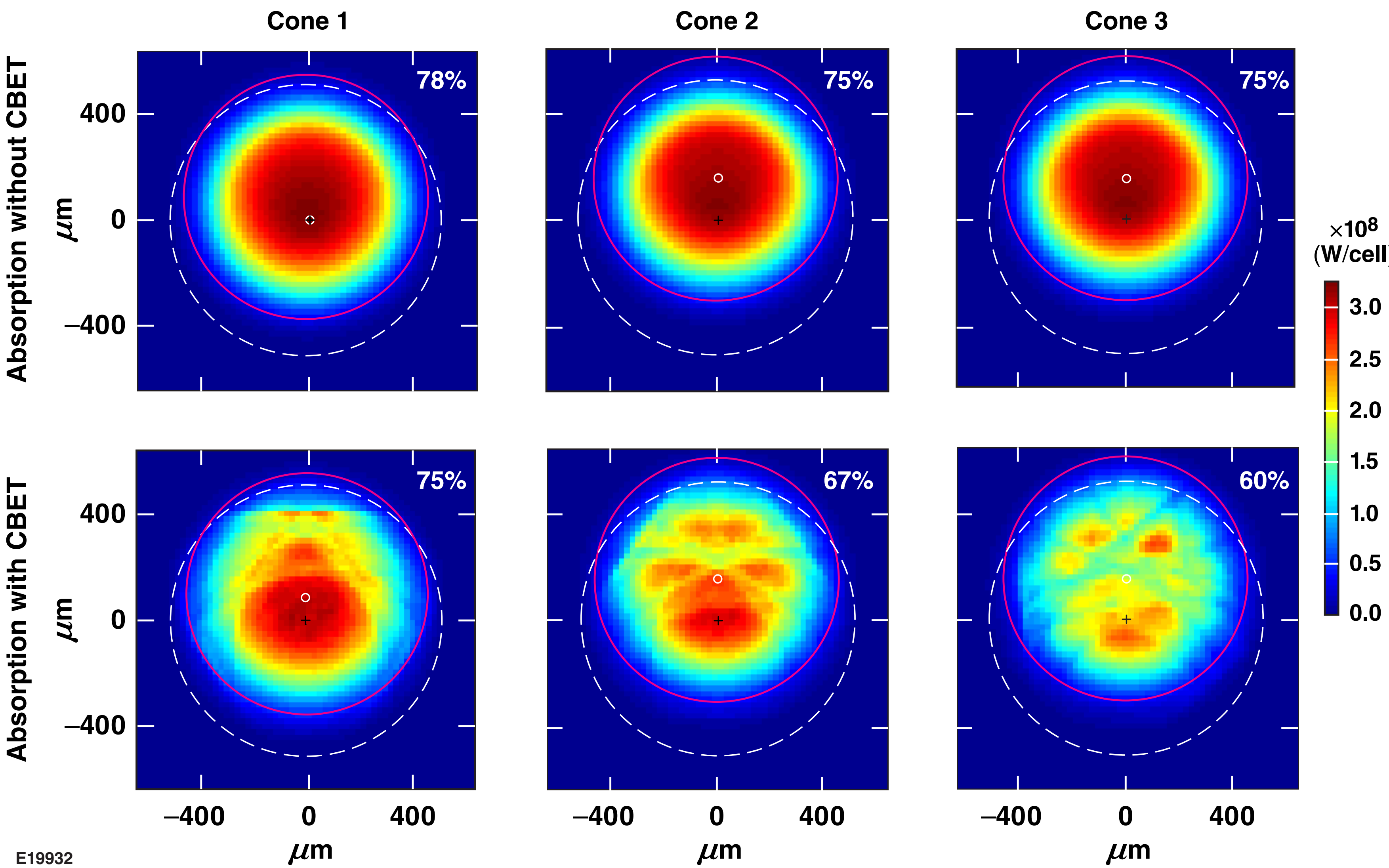
Symmetric illumination
4 cones
No offsets

Equatorial cone removed
3 cones
No offsets

Polar Drive
3 cones
Offset beams

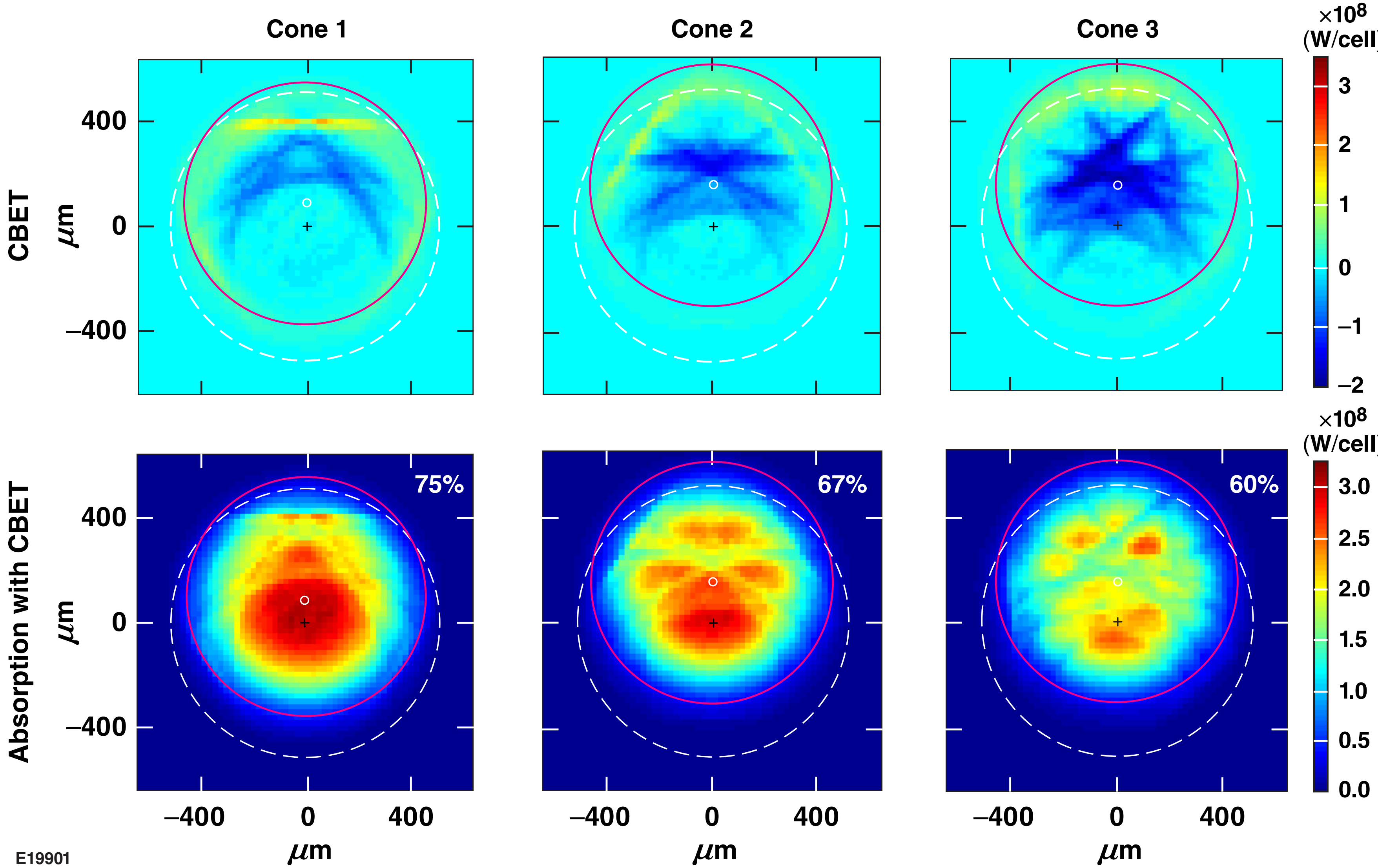
E19931

CBET has a measured effect on the cones closer to the equator



E19932

CBET has a measured effect on the cones closer to the equator



E19901

Summary/Conclusions

Cross-beam energy transfer (CBET) predictions show significant absorption profile modifications in Polar Drive (PD)

- EM-seeded SBS transfers energy between direct-drive laser beams that cross in the coronal plasma
  - preventing energy from reaching the high absorption region
- CBET can reduce the laser absorption in symmetric implosions and must be included for simulations to match experiments
- CBET has been calculated for a nonsymmetric polar-drive configuration (predictions indicate ~10% reduction in absorption for OMEGA PD)
- CBET must be included in PD implosion modeling and its mitigation through phase plate design will be studied