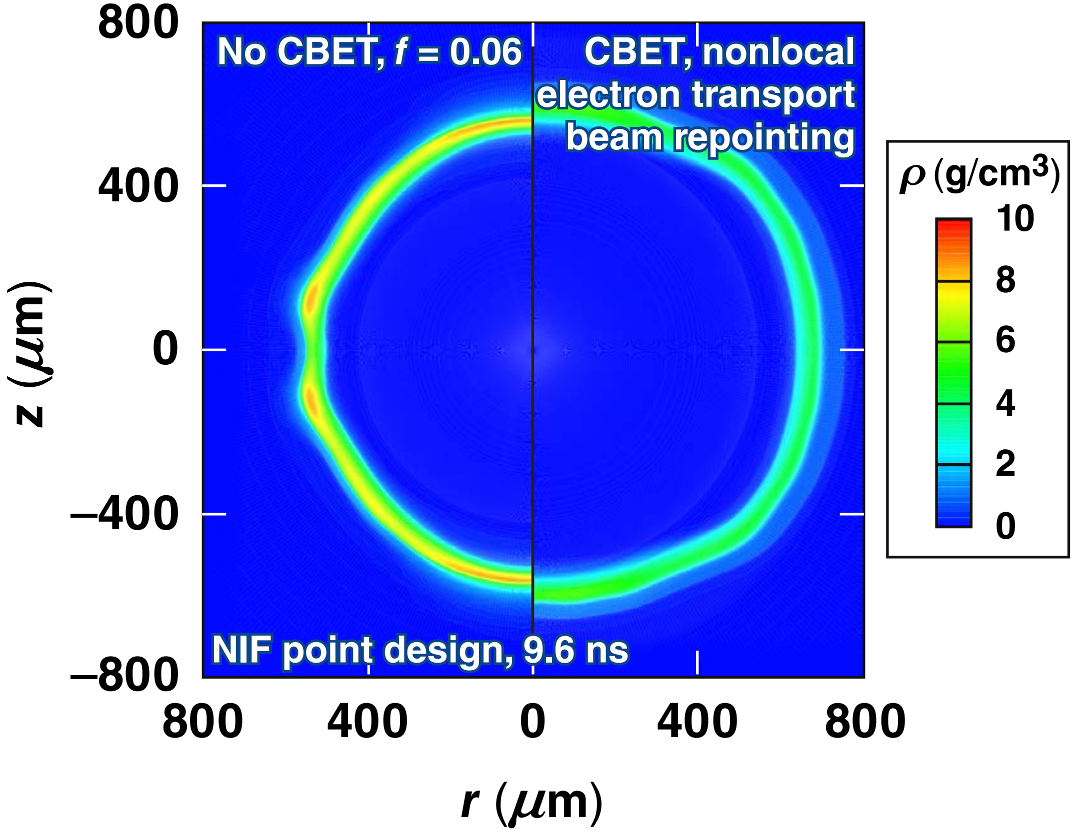
Optimization of the NIF Polar-Drive–Ignition Point Design



T. J. B. Collins
University of Rochester
Laboratory for Laser Energetics

55th Annual Meeting of the American Physical Society Division of Plasma Physics
Denver, CO
11–15 November 2013

Summary

Nonlocal electron transport improves the drive near the equator, helping offset the loss in drive caused by cross-beam energy transfer (CBET)

UR LLE

- In addition, several mitigation methods are being explored
  - drive coupling is increased by 12% when the wavelengths for the northern and southern beams are detuned by ±6Å in the UV
  - drive coupling is increased by 6% when the laser spot is modified to reduce rays prone to CBET
  - increasing the overall power by 10% raises the absorbed laser energy by 5%
- Even without the increase in drive resulting from nonlocal electron transport, these mitigation methods restore a majority of the drive lost to CBET

Collaborators

J. A. Marozas, J. A. Delettrez, P. W. McKenty,
K. S. Anderson, A. Shvydky, and F. J. Marshall

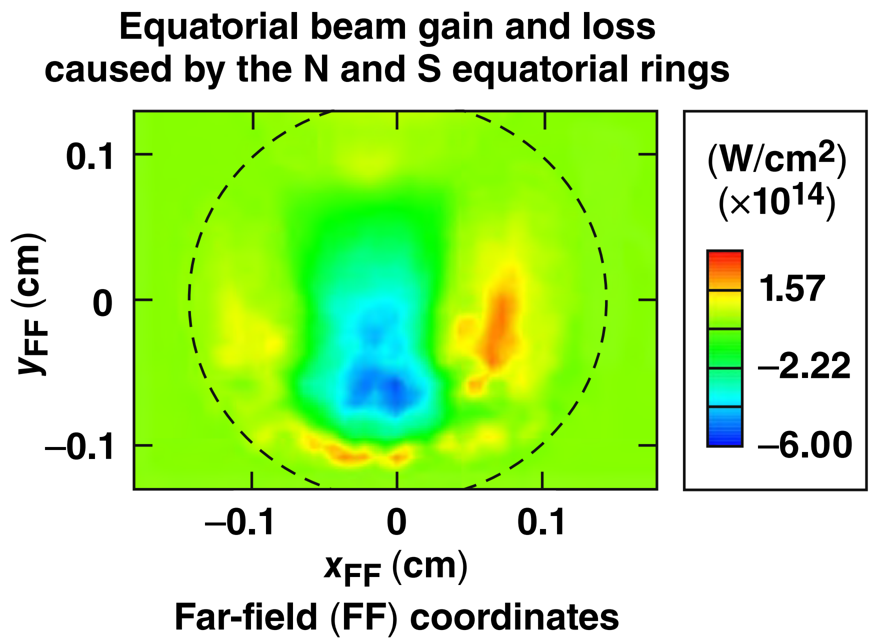
University of Rochester
Laboratory for Laser Energetics

D. Cao, J. Chenhall, A. Prochaska, and G. Moses

University of Wisconsin

The greatest CBET* energy transfer occurs near the equator in polar-drive (PD) simulations

- The energy exchange is primarily between the equatorial beams in the northern and southern hemispheres
- The energy gain occurs near the edge of the beam and energy loss near the center of the beam

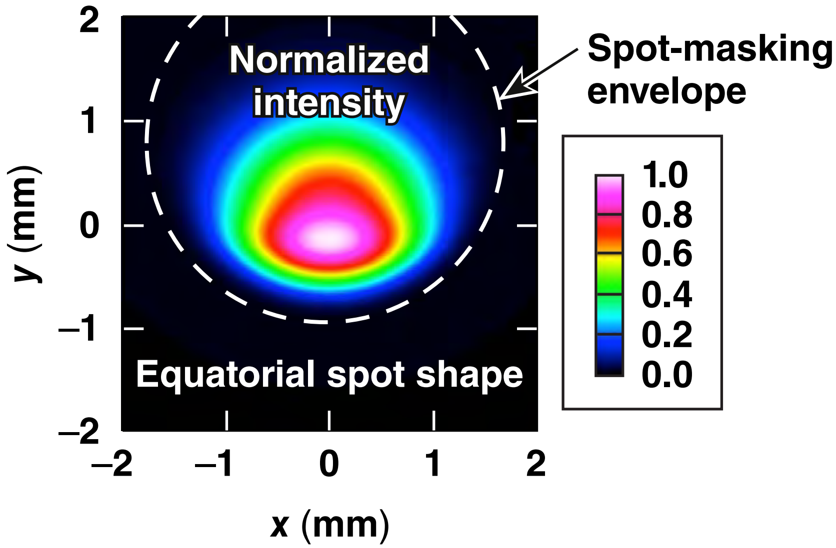


*C. J. Randall, J. R. Albritton, and J. J. Thompson, Phys. Fluids 24, 1474 (1981); J. Marozas *et al*., CO7.00004, this conference.

Modification of the equatorial spot shape helps reduce the loss of drive caused by CBET

UR LLE

- All laser spots are enveloped by a high-order super-Gaussian centered on the target to reduce the loss of energy over the target horizon
- Reducing the spot radius reduces the effects of CBET*
- The spot mask can be modified by specifically targeting the portion of the spot subject to the greatest loss
- Modifying the equatorial spot mask raises the absorption fraction by 6% in simulations with flux-limited thermal transport

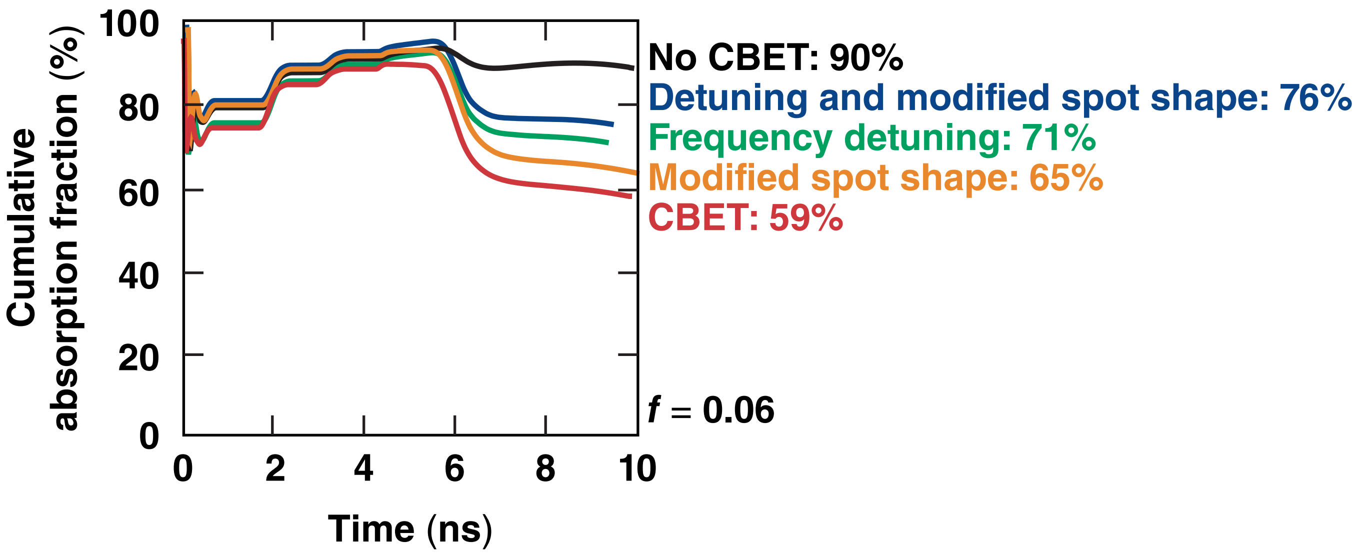


*D. H. Froula *et al*., Phys. Rev. Lett. 108, 125003 (2012);
I. V. Igumenshchev *et al*., Phys. Plasmas 19, 056314 (2012).

TC11014

Detuning the northern and southern laser frequencies helps recover drive diminished by CBET

- Stimulated Brillouin scattering has a resonance condition for the transfer of energy between rays by means of an intermediary ion-acoustic wave
- The resonance condition depends on the wavelength difference $\Delta\omega$ between the beams; increasing $\Delta\omega$ reduces or eliminates the portion of the beam that satisfies this condition
- Detuning the wavelengths for the equatorial beams in the northern and southern hemispheres by ±6 Å in the UV increases laser coupling by 12%

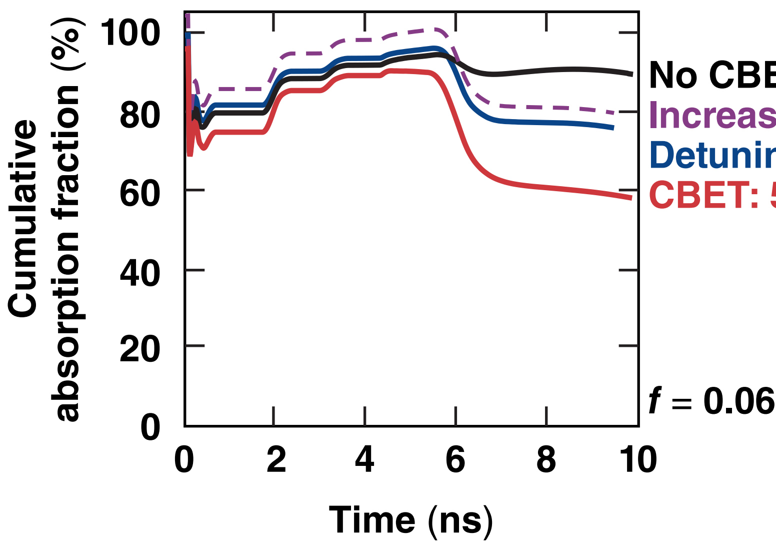


Mitigating CBET by frequency detuning and spot-shape modification recovers over half of the drive energy lost to CBET.

TC11015

A 10% increase in the overall power produces a 5% increase in the absorbed power

- An increase of equatorial power P_{Eq} by 20% corresponds to a 10% increase overall from 1.5 MJ to 1.65 MJ, and 10.4-kJ energy per equatorial beam
- Despite the extra CBET losses, there is still an overall increase in absorbed power, improving both coupling and uniformity



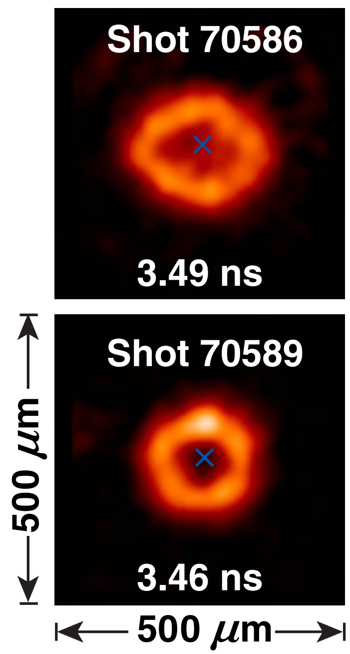
An absorption fraction of 80% is expected when spot-shape modification and frequency detuning are combined with increased equatorial power.

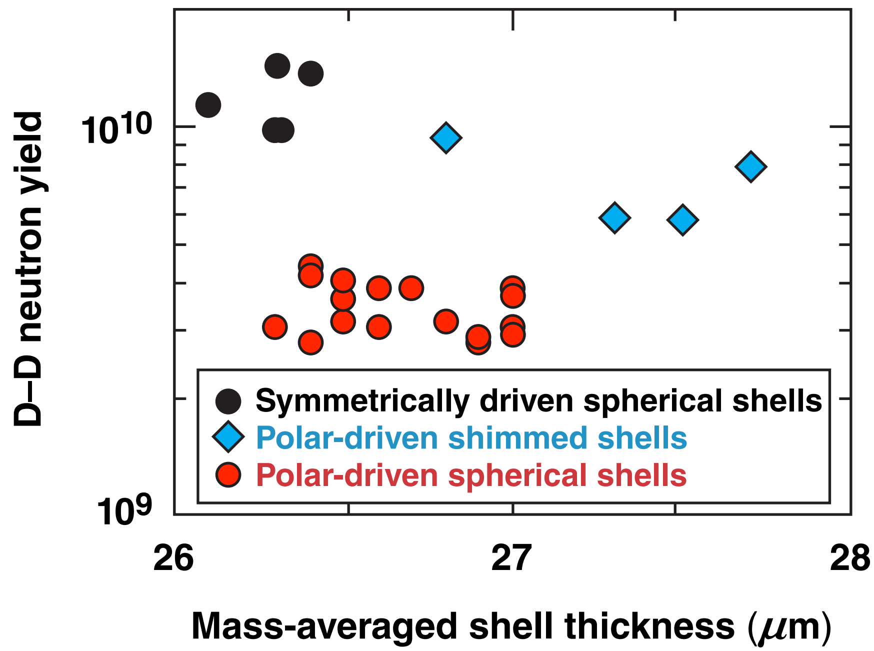
The best symmetry in PD implosions on OMEGA has been achieved with shimmed shells*

- Shimmed shells have an imposed P_1 ice-layer mode, reducing the equatorial mass
- OMEGA yields from PD shimmed targets exceeded those of similar spherical targets by more than a factor of 2

X-ray radiographs near peak compression

Triple-picket pulse;
CH shell, 10-atm D_2 fill;
Final CR~19





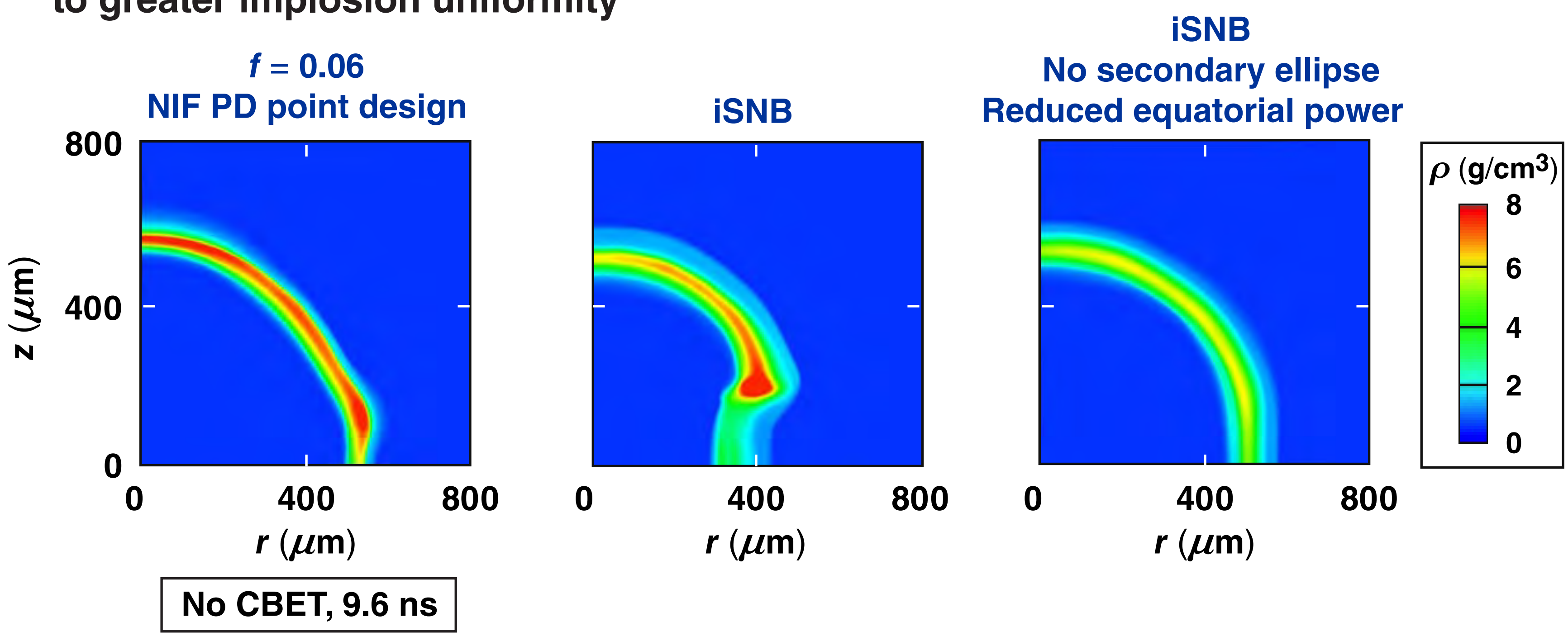
- The NIF PD-ignition design currently incorporates a 12-μm amplitude shim
- Increasing this amplitude will help offset reduced equatorial drive

TC11017

*F. J. Marshall *et al*., UO4.00006, this conference.

Nonuniformity caused by nonlocal heat transport can be controlled using pulse- and spot-shape modifications

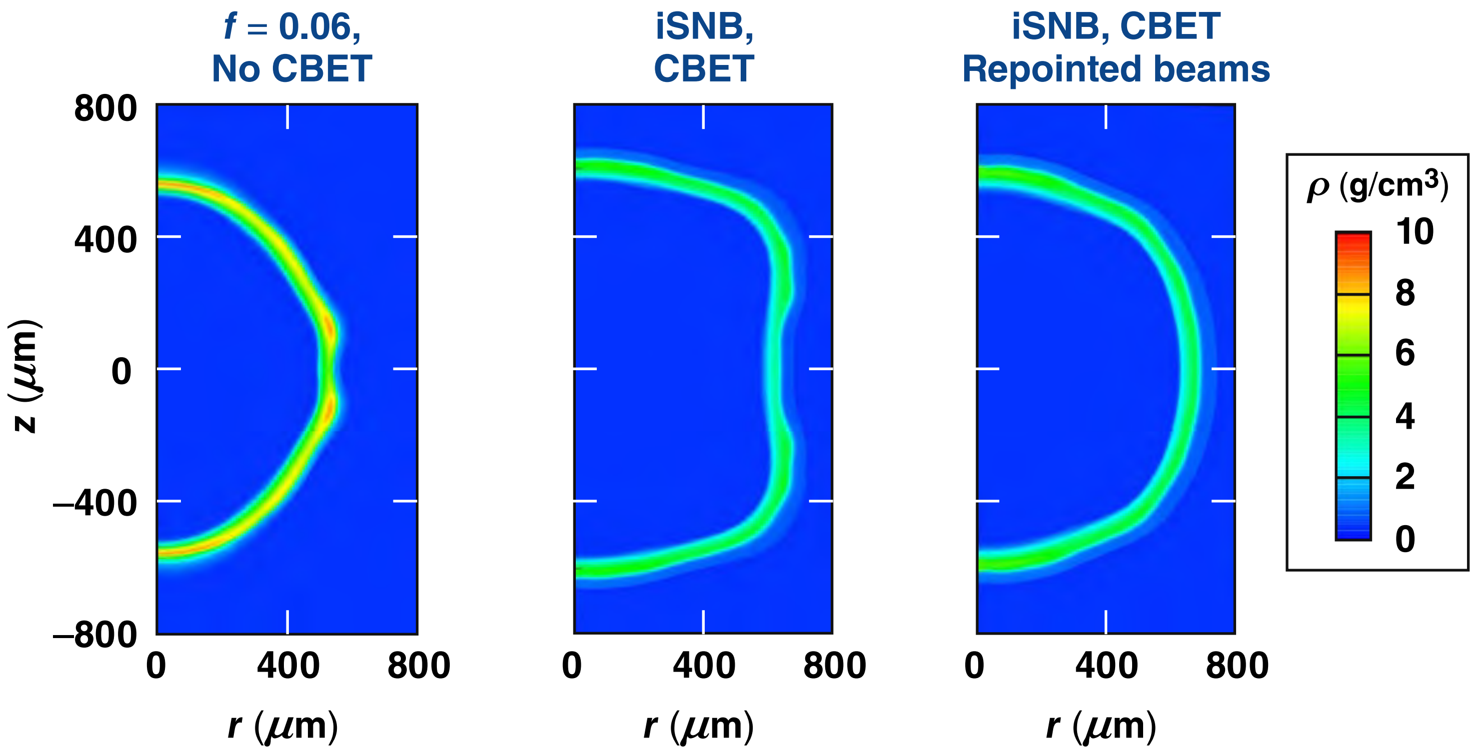
- In PD, energy is concentrated near the equator using beam repointing, specialized equatorial spot shapes, and ring-dependent pulse shapes
- These increase the equatorial thermal gradients, leading to a greater nonlocal heat flux, as simulated using the implicit Schurtz–Nicolaï–Busquet (iSNB)* model
- By reducing the equatorial power, the nonlocal heat flux is reduced, leading to greater implosion uniformity



*G. P. Schurtz, Ph. D. Nicolaï, and M. Busquet, Phys. Plasmas 7, 4238 (2000);
D. Cao *et al.*, TP8.00081, this conference; J. A. Delettrez *et al.*, UO4.00007, this conference.

Increased drive from nonlocal heat transport partially compensates for the decrease in equatorial drive

- Repointing the equatorial beams 5° away from the equator further improves implosion uniformity and reduces the overall obliquity of the rays, increasing laser coupling
- The increased laser absorption resulting from beam repointing and nonlocal electron transport increases the implosion velocity by 6%



TC11019

Summary/Conclusions

Nonlocal electron transport improves the drive near the equator, helping offset the loss in drive caused by cross-beam energy transfer (CBET)

UR LLE

- In addition, several mitigation methods are being explored
  - drive coupling is increased by 12% when the wavelengths for the northern and southern beams are detuned by ±6Å in the UV
  - drive coupling is increased by 6% when the laser spot is modified to reduce rays prone to CBET
  - increasing the overall power by 10% raises the absorbed laser energy by 5%
- Even without the increase in drive resulting from nonlocal electron transport, these mitigation methods restore a majority of the drive lost to CBET