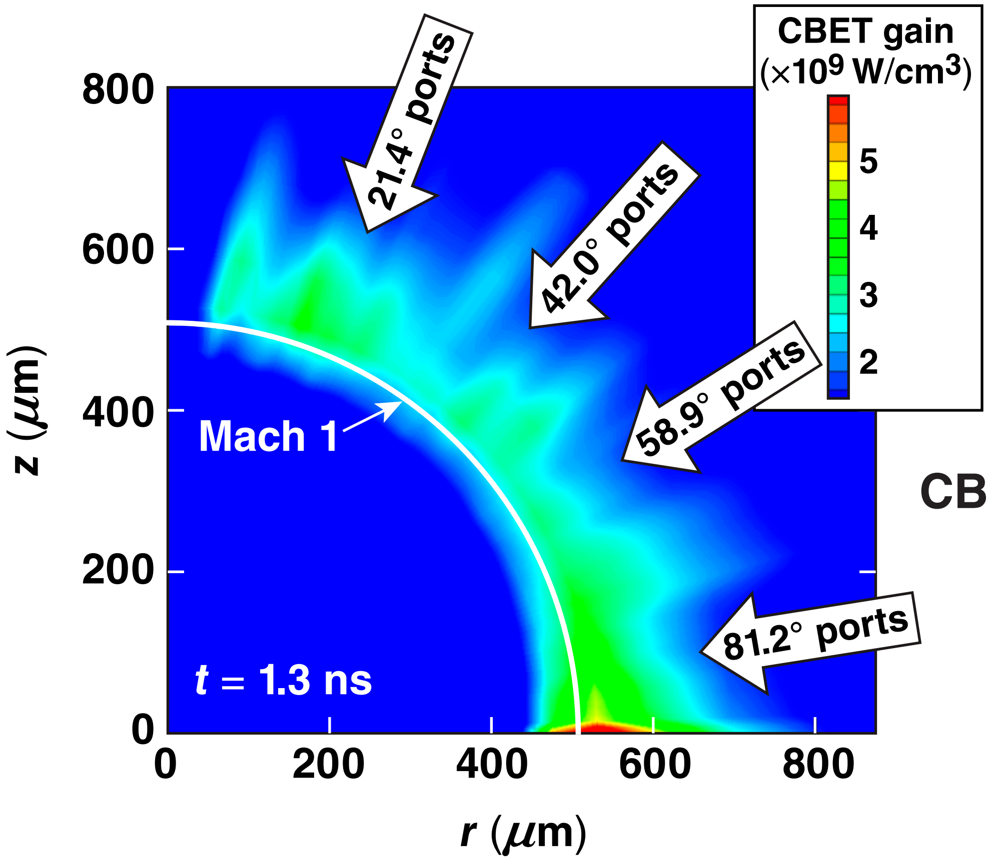
Two-Dimensional Analysis of Crossed-Beam Energy Transfer (CBET) in Direct-Drive ICF Implosions



$$\mathrm{CBET_{gain}} = E_0\left(e^{\frac{x}{L_{\mathrm{CBET}}}} - 1\right)\frac{1}{\mathrm{Vol} \times dt}$$

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Summary

Crossed-beam energy transfer (CBET) manifests itself as increased scatter in rings surrounding the beam axes

- The CBET effect increases scattered light through stimulated Brillouin scattering (SBS) of outgoing rays that remove energy from incoming high-energy rays
- The CBET effect improves agreement of hydrocodes with experiment
- The 2-D hydrodynamics code *DRACO* requires a domain decomposition reconfiguration of the 3-D ray trace to handle the CBET modeling
- Integrated CBET modeling in *DRACO* simulations illustrate the 3-D nature of scattered-light gain

Collaborators

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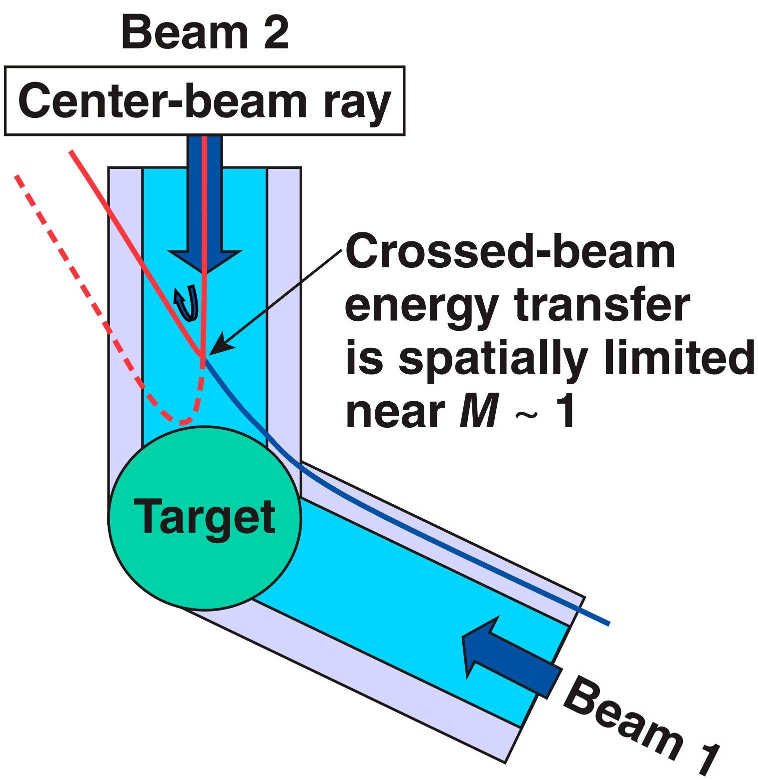
CBET involves electromagnetic (EM)-seeded, low-gain SBS sidescattering



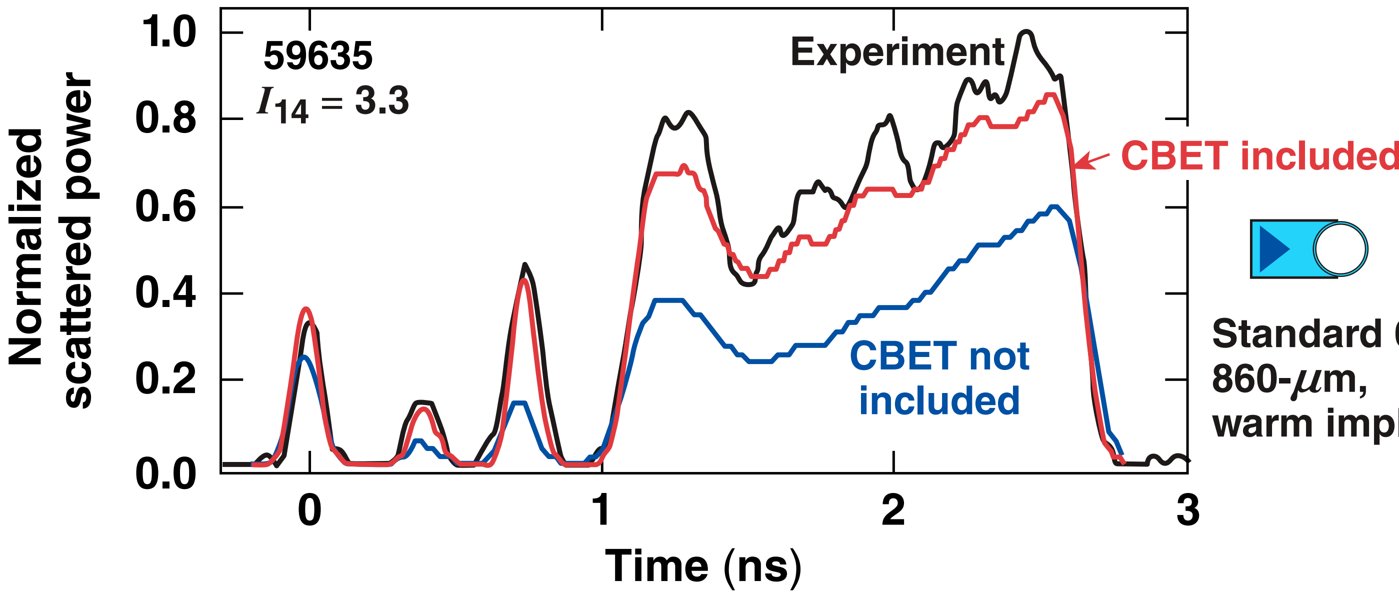
- EM seed is provided by outer parts of beams
- Inner parts of beams transfer some of their energy to outgoing parts of other beams

- **This process reduces hydrodynamic drive efficiency**
- **Reducing the beam size can reduce cross-beam energy transfer**

E19905d

I. V. Igumenshchev, YI3.00001
I. V. Igumenshchev *et al.*, Phys. Plasmas 17, 122708 (2010).

CBET is required to match the measured scattered light from standard OMEGA direct-drive implosions

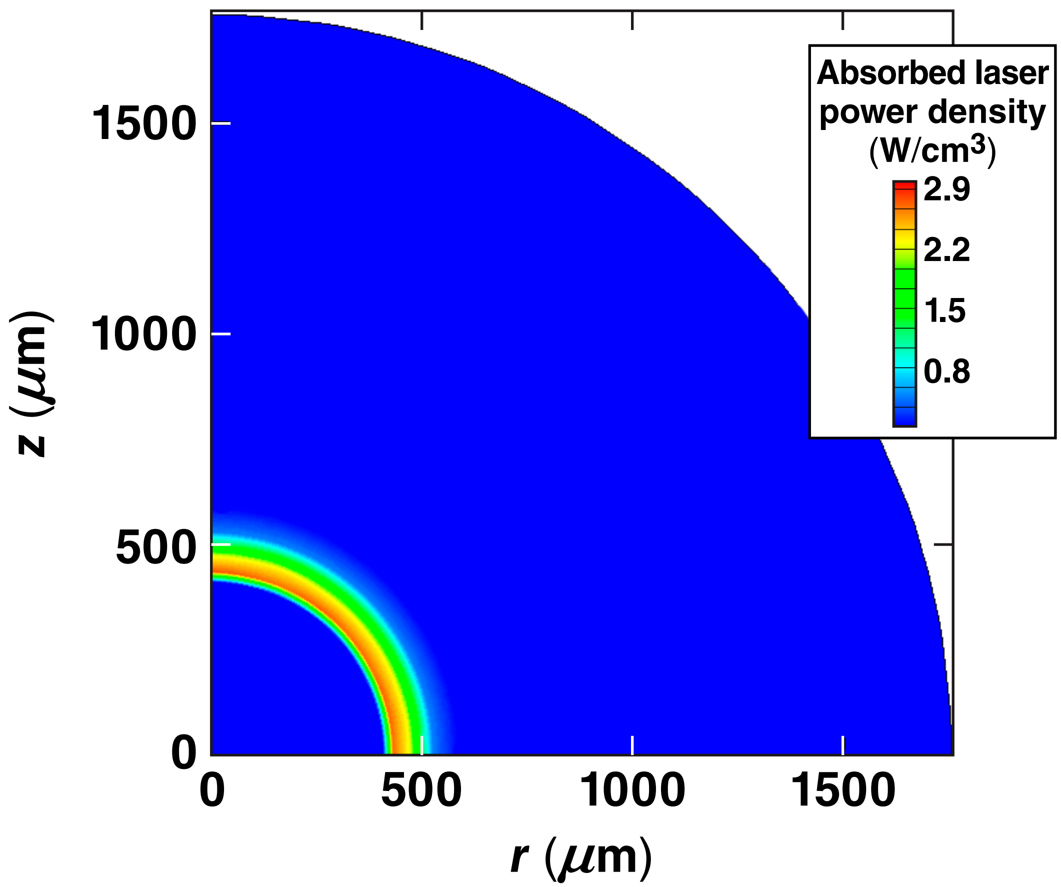


Standard 60-beam, 860-μm, warm implosion

- The model is implemented in *LILAC* (1-D hydrocode) that calculates the beam-to-beam resonant coupling of laser light through the ion-acoustic waves
- The CBET model agrees well with measured bang time

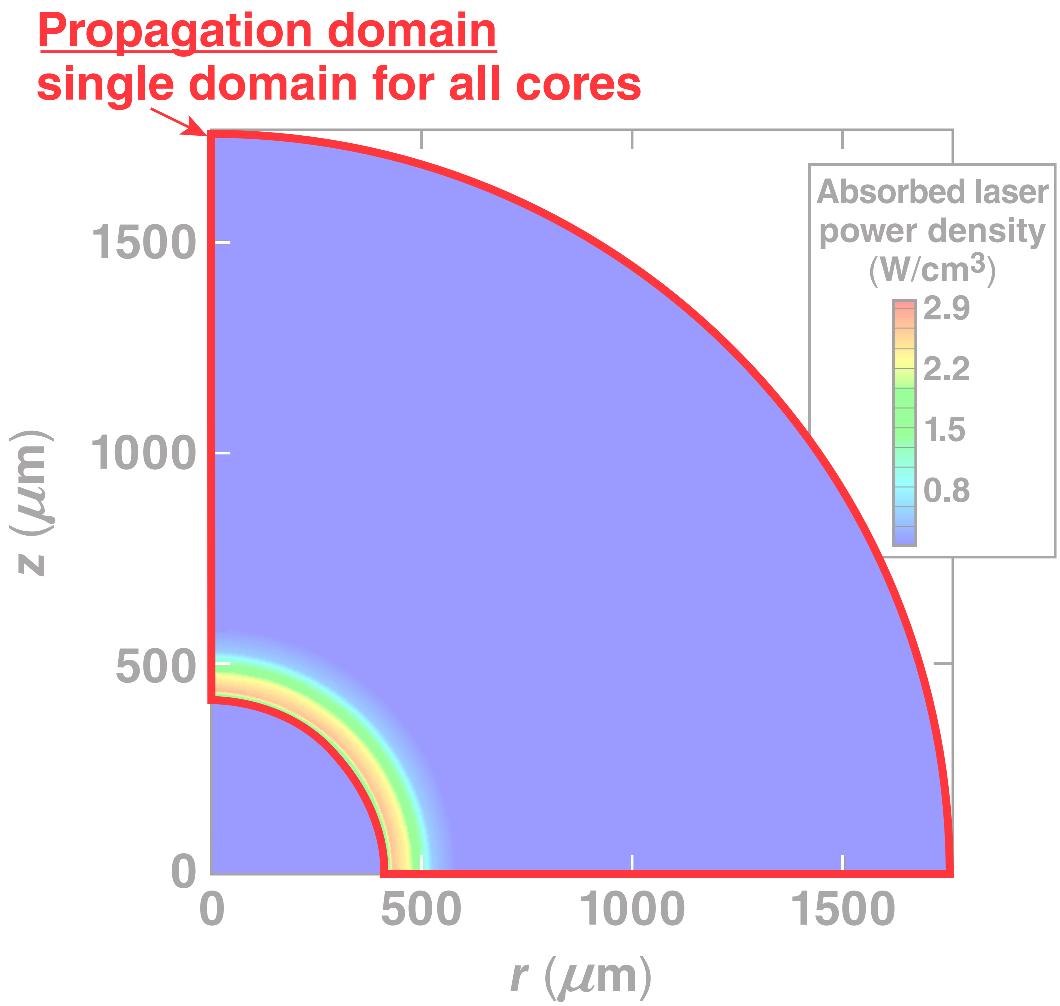
E19973d

The CBET effect is modeled by accumulating the angular spectrum representation (ASR) resulting from all laser ports



- A 3-D ASR (2 relative directions plus frequency shift) is gathered in each cell that supports propagation
- Propagation region: $150 \times 350 = 52.5$ kcells
- 3-D ASR: 20^3 bins → 64 kB per cell

The memory requirement for the 3-D ASR prohibits implementation of CBET in a single domain

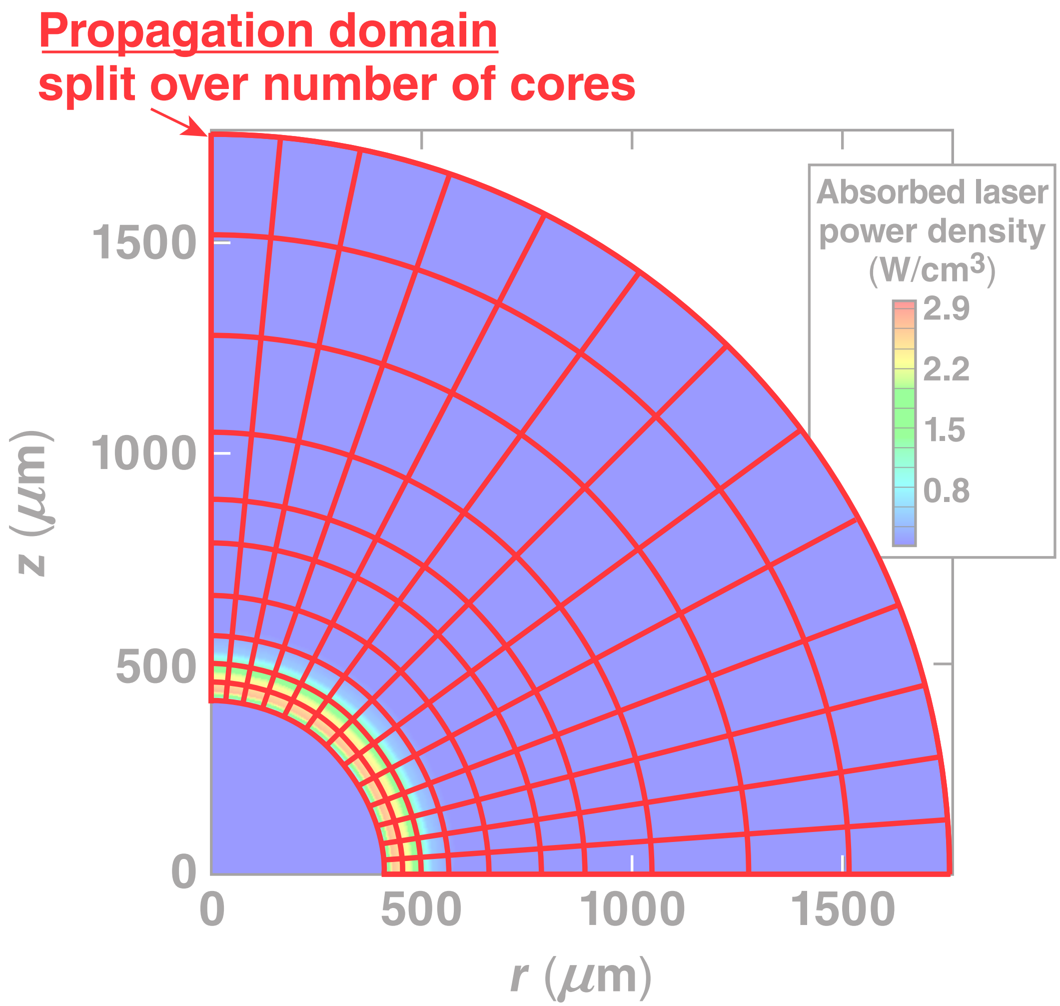


- Propagation region: $150 \times 350 = 52.5$ kcells
- 3-D ASR: 20^3 bins → 64 kB per cell
- Memory for 3-D ASR: 3.36 GB per core
  - single domain *DRACO* raytrace

Modeling the CBET effect will require a domain decomposed raytrace.

TC9858

Domain decomposition reduces the memory requirement by the number of cores used, allowing even higher 3-D ASR resolution

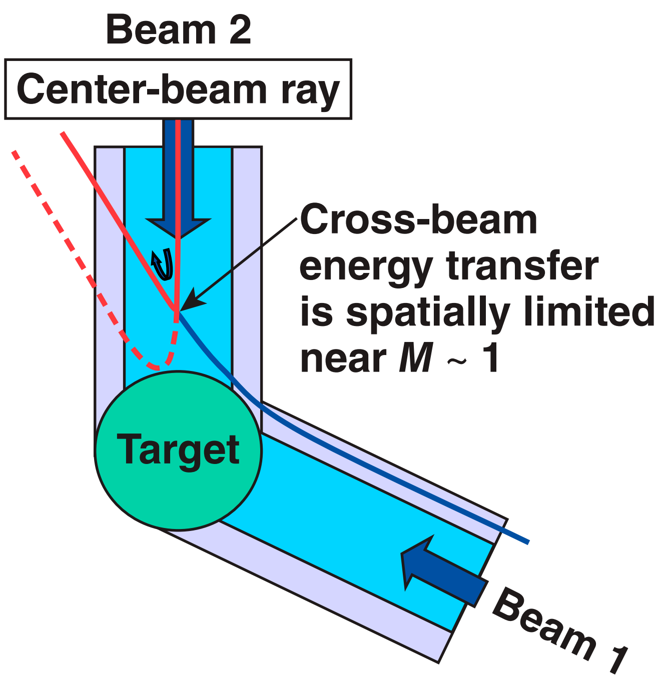


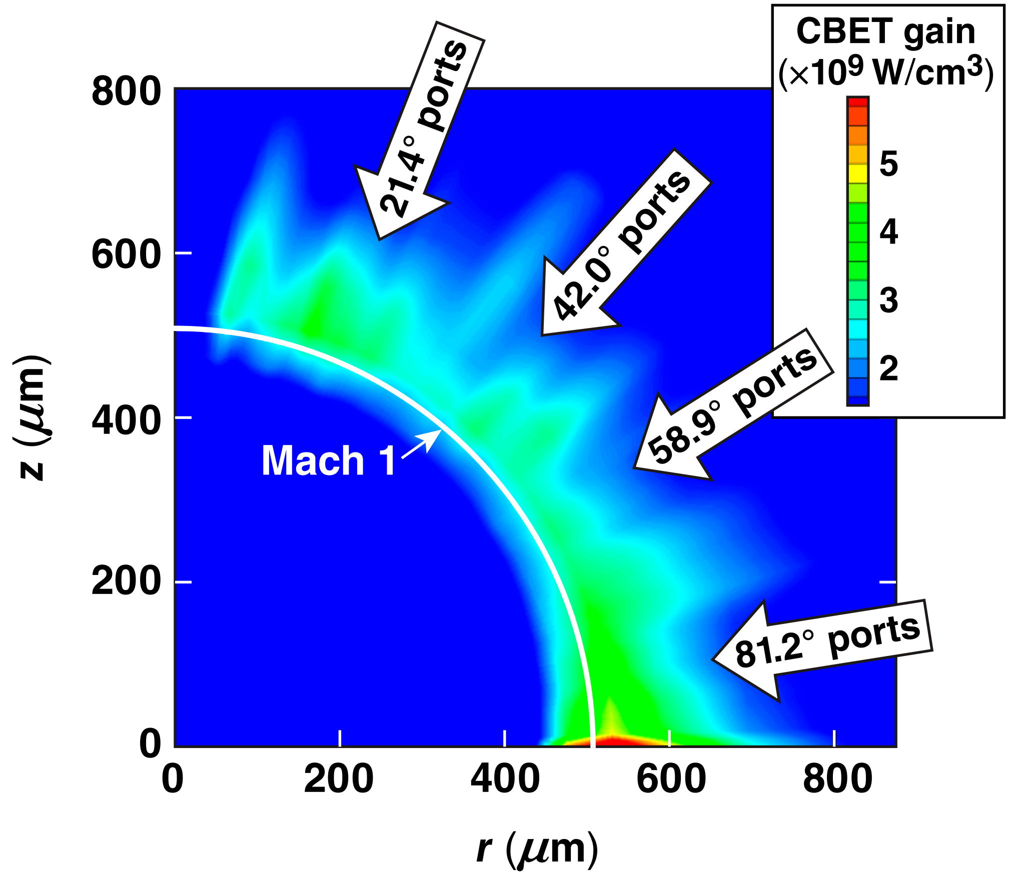
- **Propagation region: $150 \times 350 = 52.5$ kcells**
- **3-D ASR: 20^3 bins → 64 kB per cell**
- **Memory for 3-D ASR: 3.36 GB per core**
  - **single domain *DRACO* raytrace**
- **Memory for 3-D ASR: 26.3 MB per core**
  - **domain decomposed *DRACO* 3-D raytrace on 128 cores**

TC9876

The CBET gain peaks on either side of the beam-port centers and near Mach 1

- The CBET effect in *DRACO* increases the scattered light

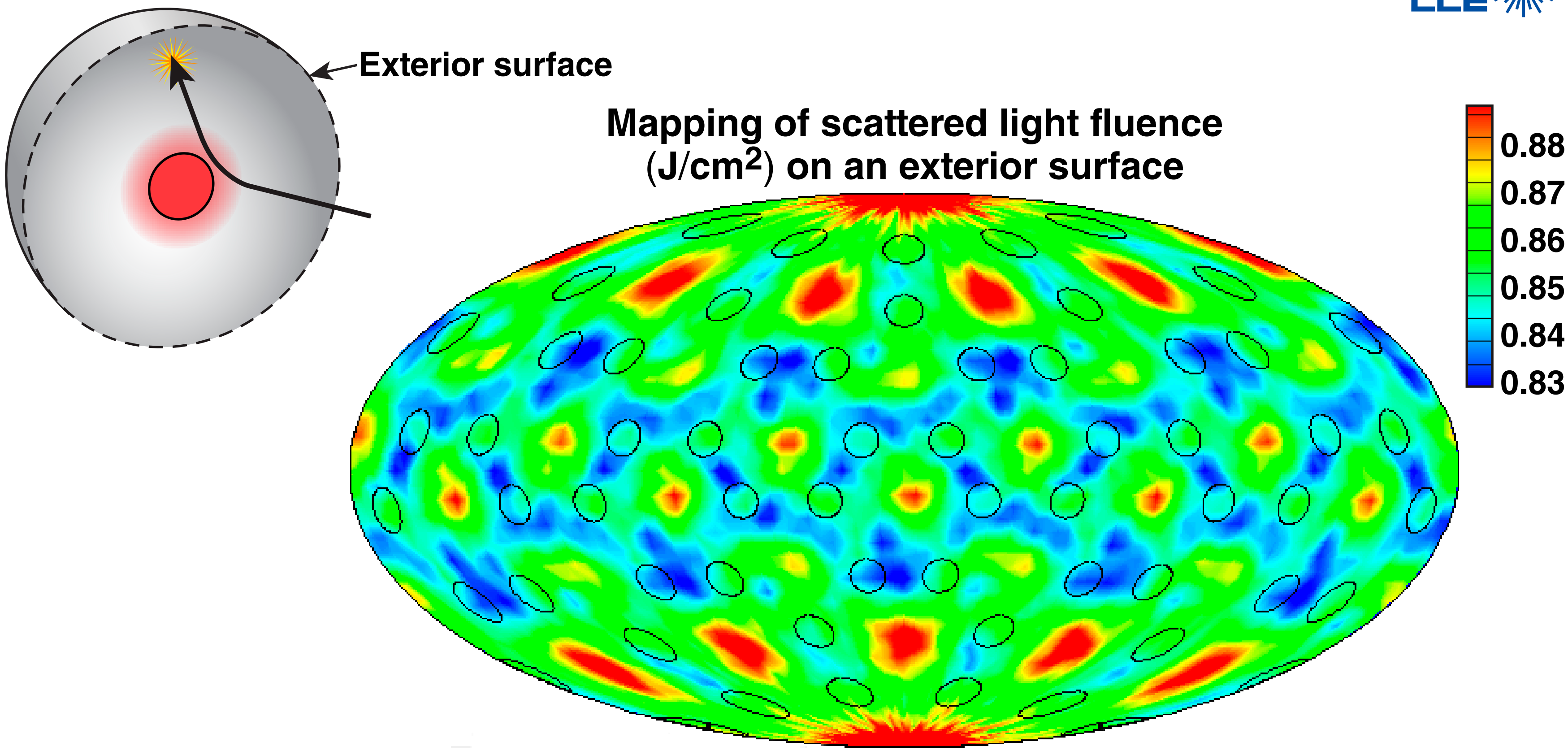




$$\mathrm{CBET}_{\mathrm{gain}} = E_0\left(e^{\frac{x}{L_{\mathrm{CBET}}}} - 1\right)\frac{1}{\mathrm{Vol} \times dt}$$

TC9759

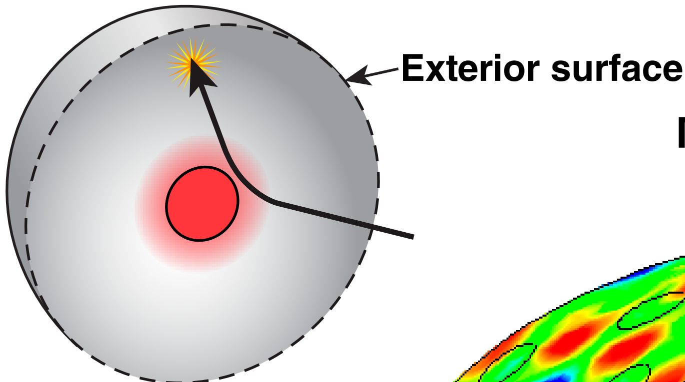
The time-integrated scattered light collected from a simulation without CBET peaks at the centers of all the pent's and hex's

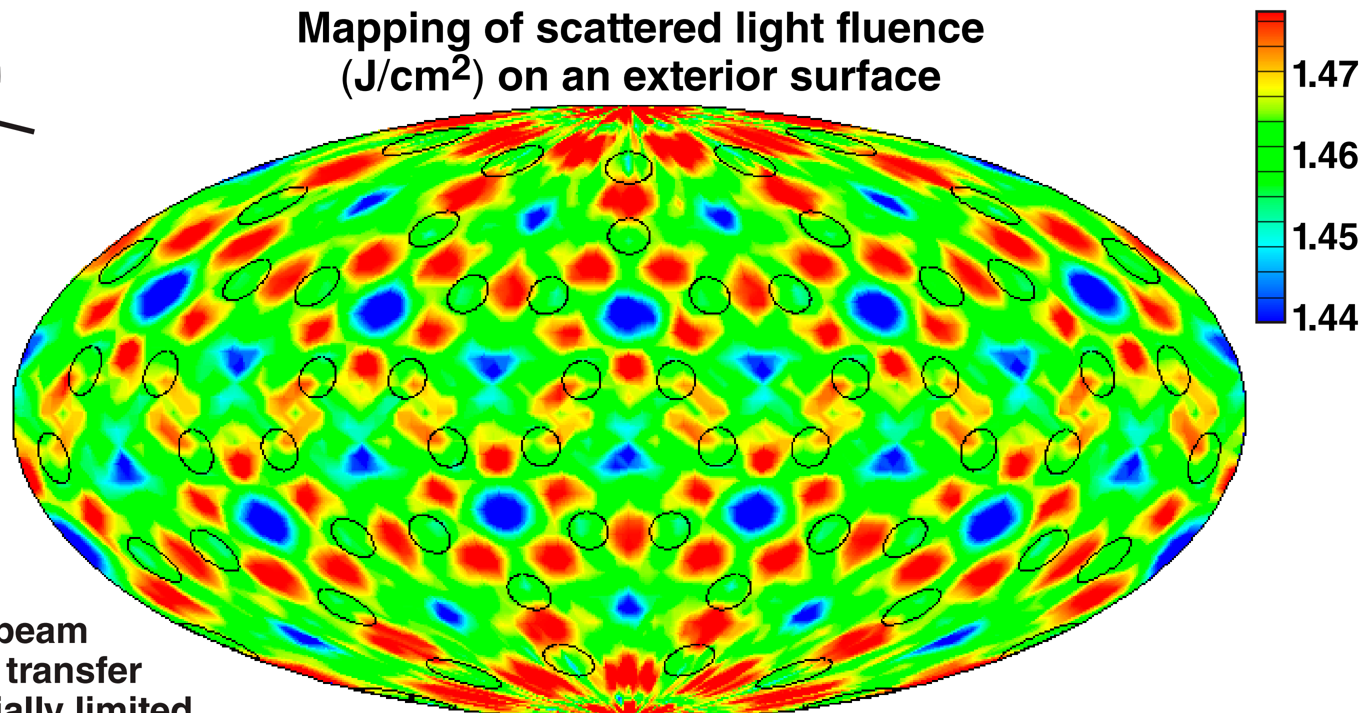


Without CBET, σ_{rms} = 2.6% at 1.3 ns, S59635

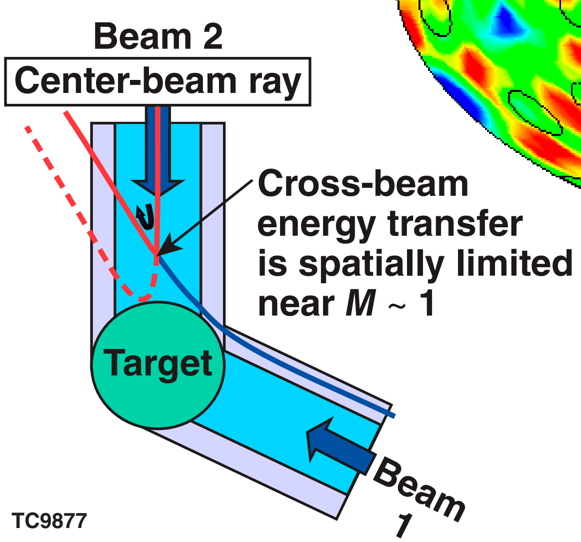
TC9854

The time-integrated scattered light collected from a simulation with CBET produces peaks between adjacent ports as a result of the rings of scattered light from each port





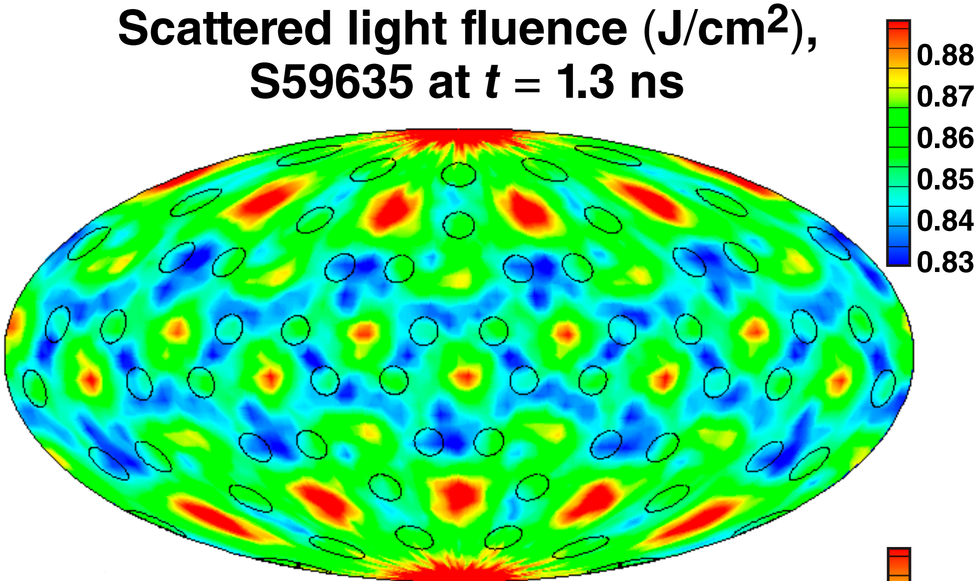
With CBET, σ_{rms} = 1.1% at 1.3 ns, S59635



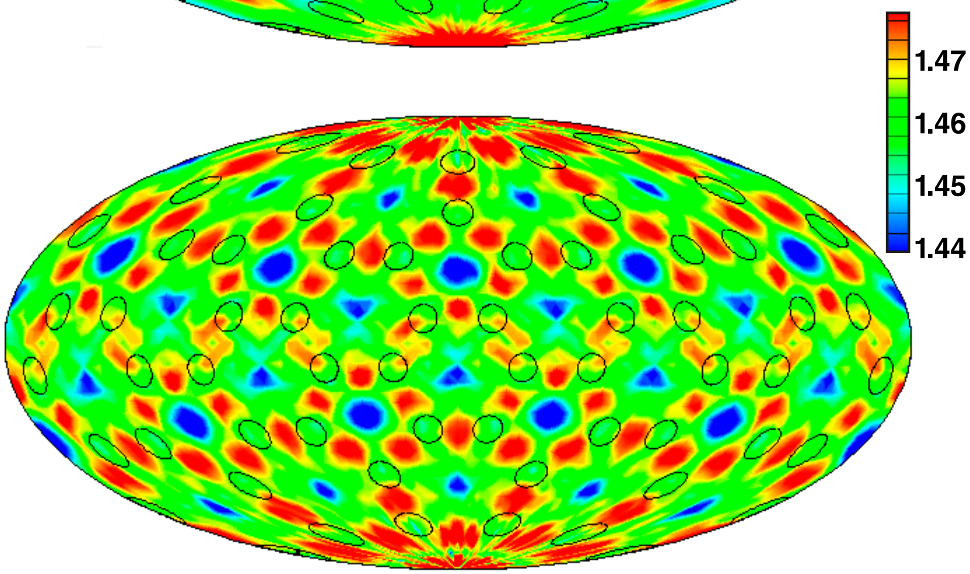
TC9877

The modal structure changes dramatically when CBET modifies the scattered light

Scattered light fluence (J/cm^2), S59635 at t = 1.3 ns



- **Without CBET the scattered light peaks at the centers of the hex's and pent's**
  - **σ_{rms} = 2.6%**



- **With CBET the scattered light peaks between adjacent ports**
  - **σ_{rms} = 1.1%**
  - **increased scatter results in a smoother distribution**
  - **scattered energy increases by ~1.8×**

TC9878

Summary/Conclusions

Crossed-beam energy transfer (CBET) manifests itself as increased scatter in rings surrounding the beam axes

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