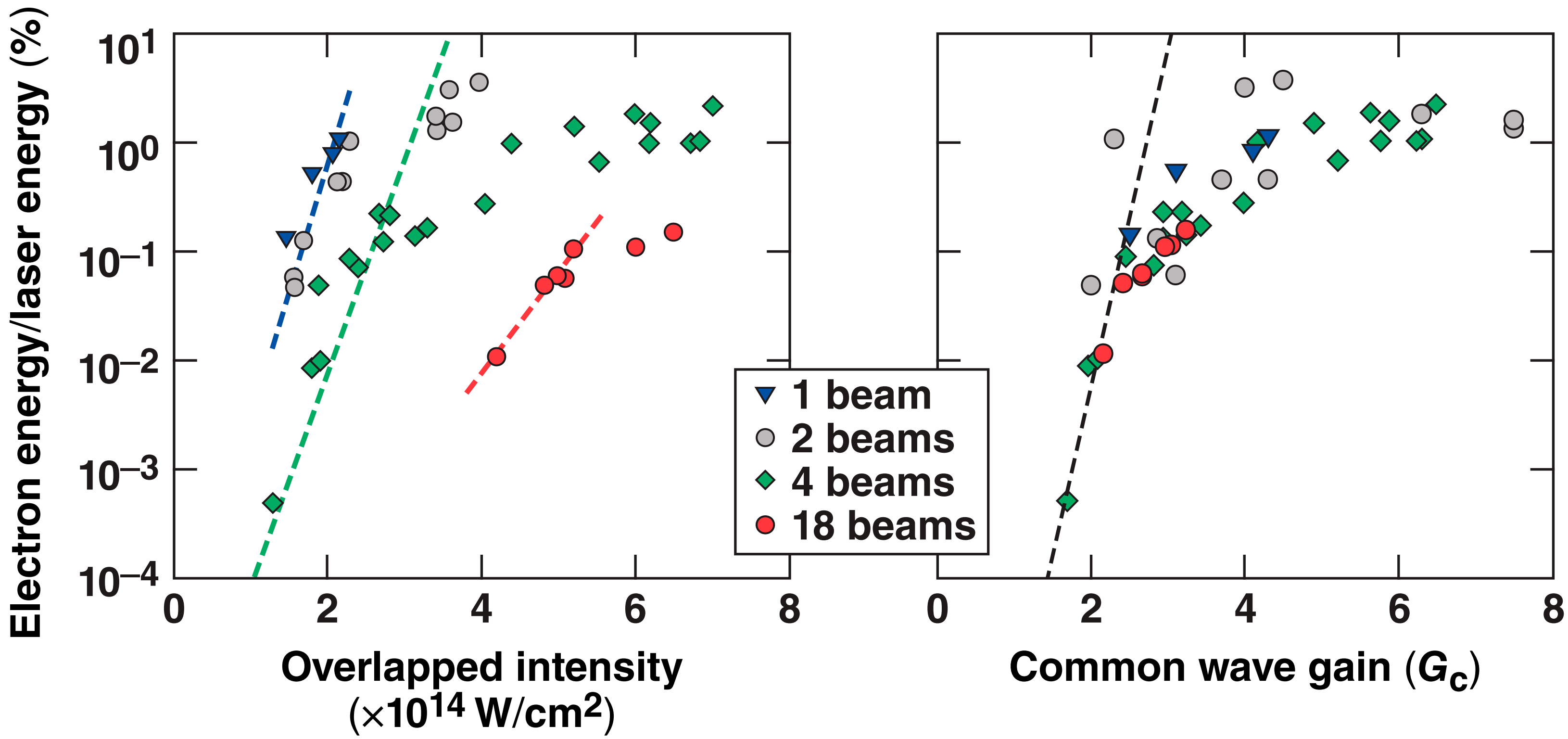
Experimental Validation of the Two-Plasmon-Decay (TPD) Common-Wave Process



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Summary

A common-wave, two-plasmon-decay (TPD) theory is consistent with the TPD growth observed in OMEGA and OMEGA EP experiments

- OMEGA EP experiments shows that for two beams the TPD is proportional to the overlapped intensity, but not for four beams*
- Linear theory shows that a resonant common wave can be driven by multiple beams in the region bisecting the beams. In this region, the gain is proportional to the overlapped intensity times a geometric factor*
- Reducing the number of symmetric beams that overlap at $n_c/4$ will reduce the common-wave gain

*D. T. Michel *et al*., "Experimental Validation of the Two-Plasmon-Decay Common-Wave Process," submitted to Physical Review Letters.

Collaborators

A. V. Maximov, R. W. Short, J. F. Myatt, W. Seka, J. A. Delettrez, R. Follett,
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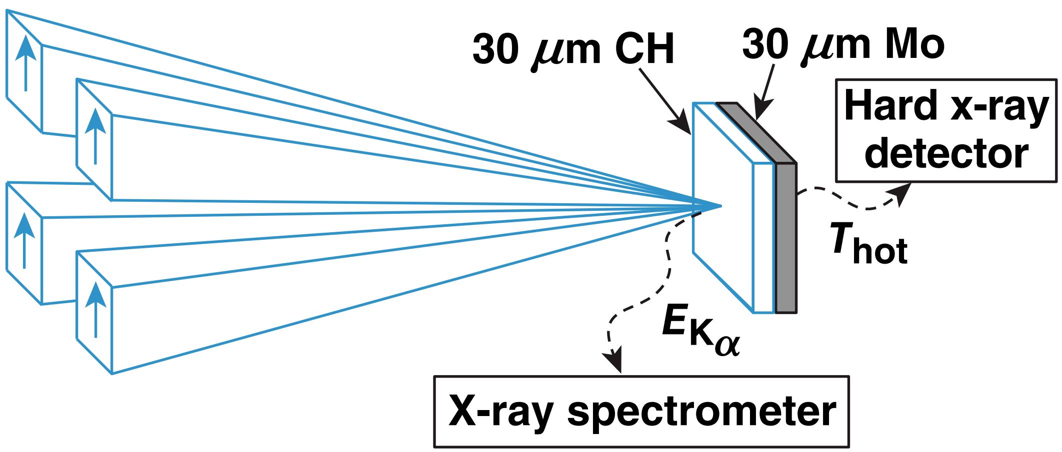
OMEGA EP provides a planar-target platform to study two-plasmon decay near ignition coronal-plasma conditions



$L_n/T_e \sim 170\ \mu$m/keV

Monte Carlo simulations

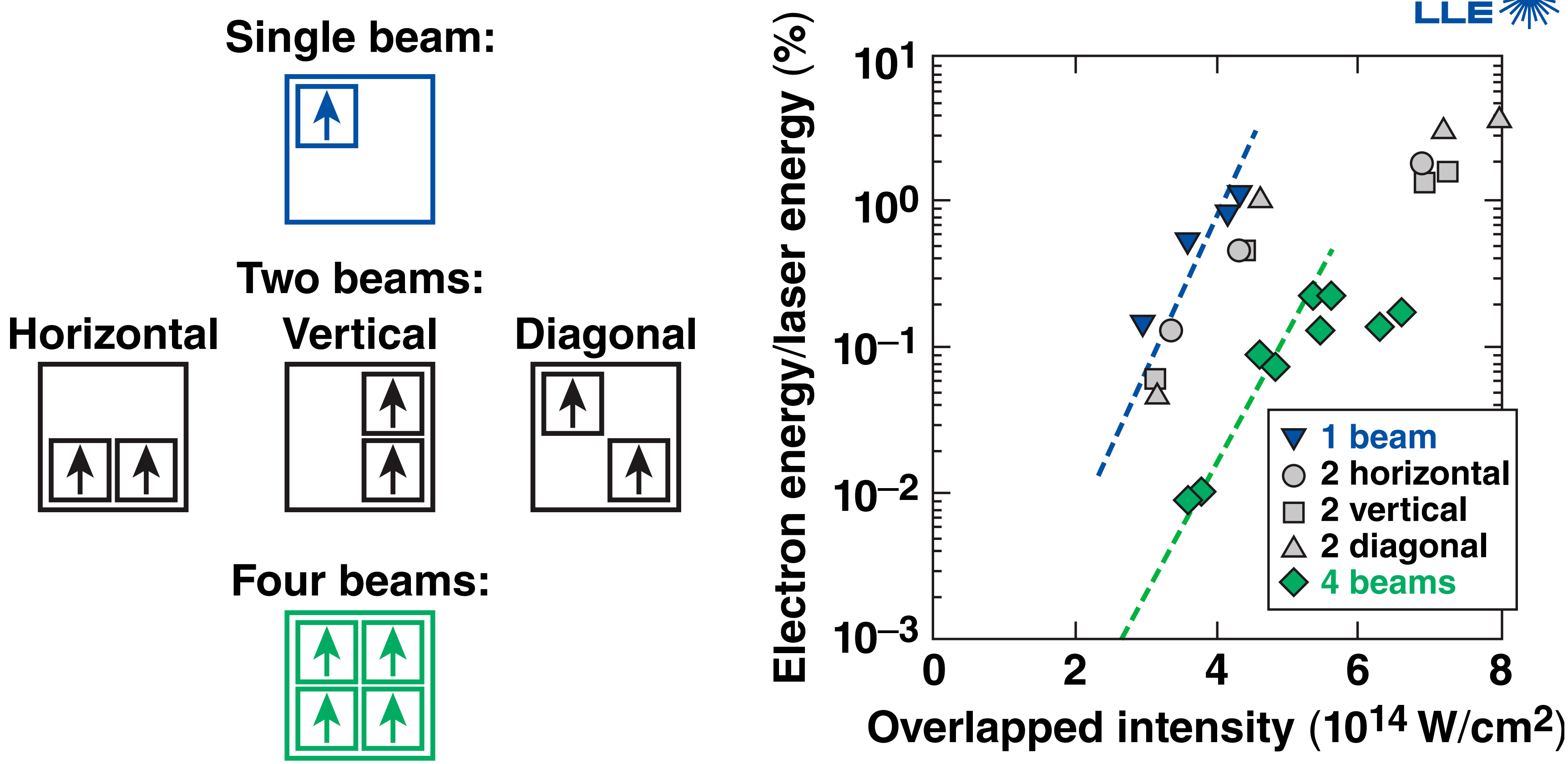
$$E_e \sim 138 \frac{E_{K\alpha}}{\sqrt{T_{hot}}}$$

This target platform accounts for all electrons generated by TPD; the energy coupled to the direct-drive shell will be reduced.

E21298

*D. H. Froula *et al*., Phys. Rev. Lett. 108 165003 (2012).

Experiments on OMEGA EP show that the fraction of hot electrons does not always depend on the overlapped intensity*



A significant reduction of the hot-electron energy is observed when four beams are used with the same overlapped intensity.

*D. T. Michel *et al.*, "Experimental Validation of the Two-Plasmon-Decay Common-Wave Process," submitted to Physical Review Letters.

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These results are explained by a common-wave process, where multiple beams share a common plasma wave*, **

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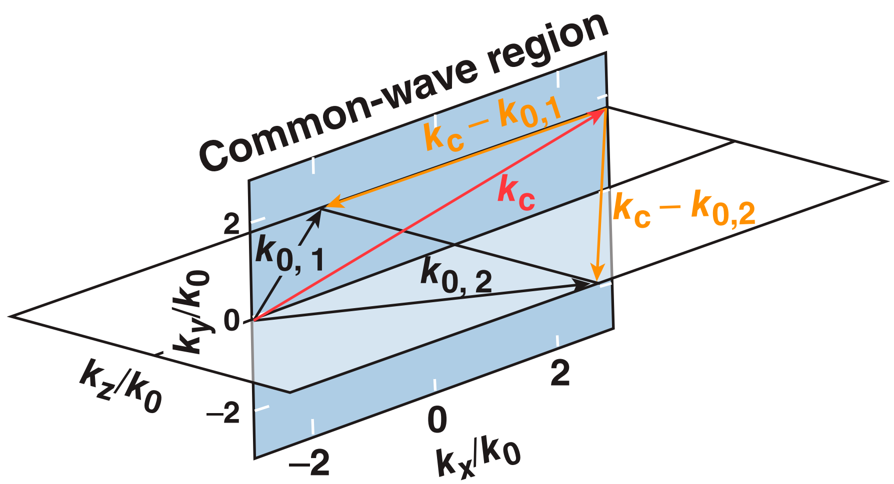
- The dispersion relation of each daughter $(\omega_c - \omega_0, k_c - k_{0,i})$ beam must be satisfied:

$$(\omega_c - \omega_0)^2 = \omega_{pe}^2 + 3\left(\vec{k}_c - \vec{k}_{0,i}\right)^2 v_{th,e}^2$$

Term which must be conserved

- Therefore, the common-wave volume is defined by:

$$\left|\vec{k}_c - \vec{k}_{0,i}\right| = \text{constant}$$



The resonant common-wave process occurs in the region bisecting the beams.

* R. W. Short and J. F. Myatt, Bull. Am. Phys. Soc. 56, 329 (2011).
** D. T. Michel *et al*., "Experimental Validation of the Two-Plasmon-Decay Common-Wave Process," submitted to Physical Review Letters.

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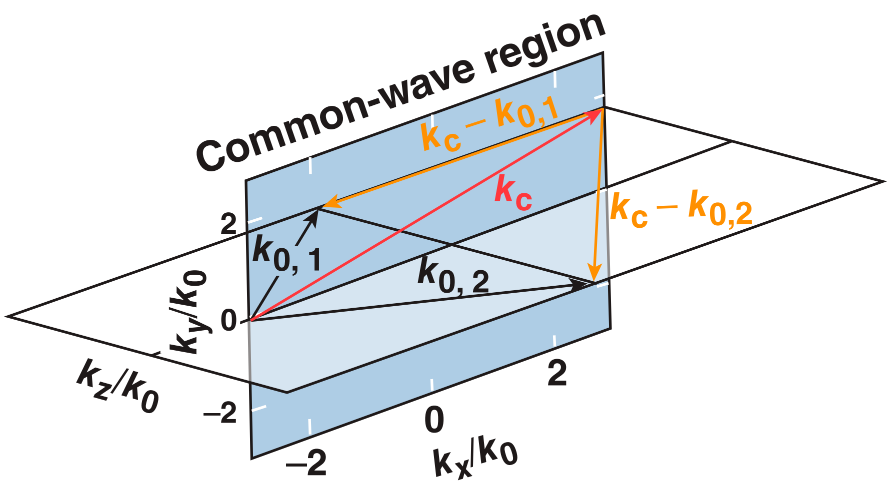
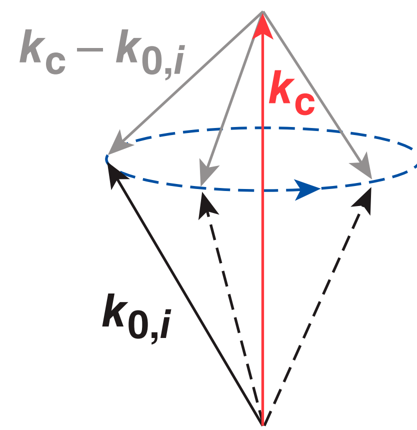
The resonant common-wave region for two beams forms a plane and for more beams becomes a line*

Two-beam common-wave region



Multiple-beam common-wave region



Symmetry is necessary for more than three beams

The resonant common-wave gain is calculated in the common-wave region.

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*D. T. Michel *et al.*, "Experimental Validation of the Two-Plasmon-Decay Common-Wave Process," submitted to Physical Review Letters.

The resonant common-wave gain is consistent with the 1-, 2-, and 4-beam OMEGA EP results*

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$$G_c = 17 \times 10^{-2} f_g \frac{I_{\Sigma,q}^{sym} L_n}{T_e}$$

$I_{\Sigma,q}^{sym}$ is the overlapped intensity of symmetric beams at quarter critical

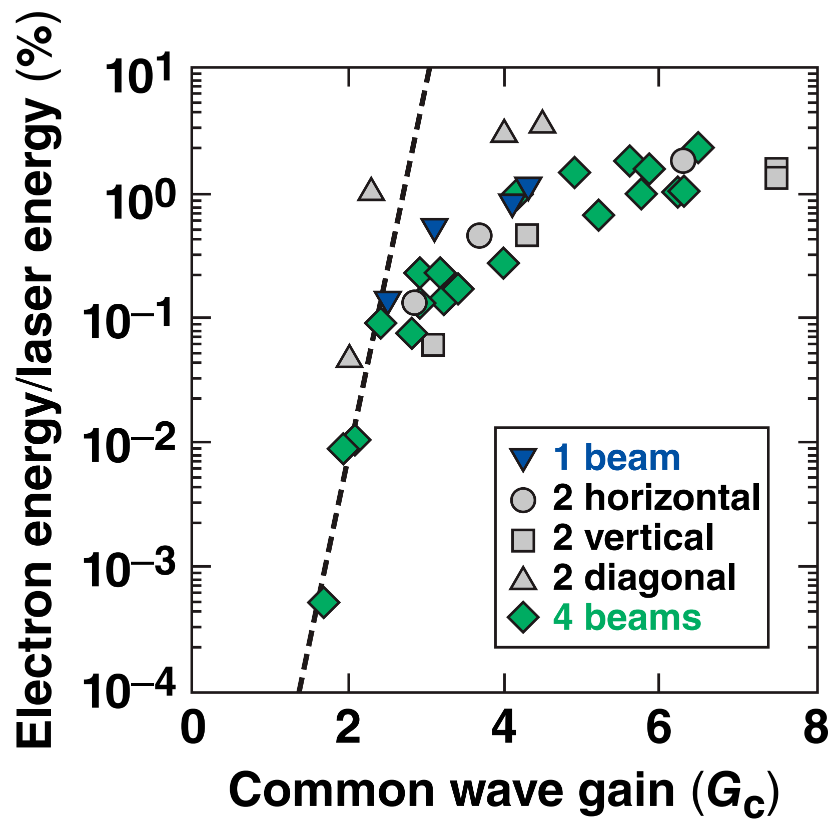
$$f_g = \max\left[\left(\frac{k_c^2 - \left(\vec{k}_c - \vec{k}_{0,1}\right)^2}{k_{0,1}\left|\vec{k}_c - \vec{k}_{0,1}\right|}\right)^2 \sum_i \cos^2(\alpha_i)\beta_i\right]$$

Fraction of intensity in the beam:

$$\beta_i = \frac{I_i}{I_{\Sigma,q}^{sym}}$$

Fraction of intensity in the beam:

$$\alpha_i = \text{angle}\left(\vec{e}_i, \vec{k}_c\right)$$

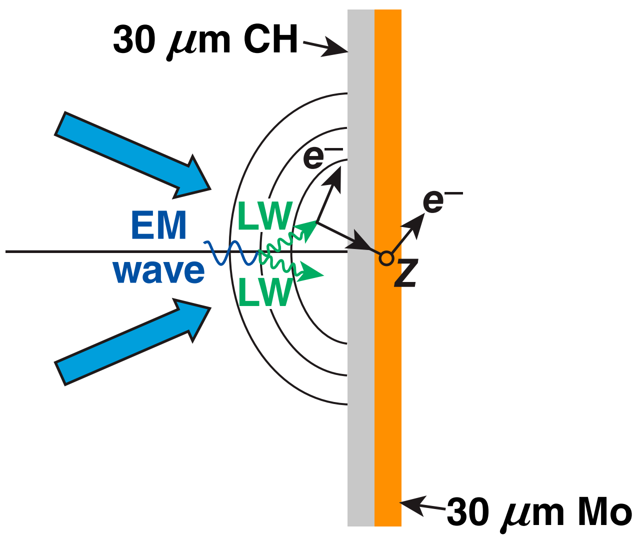


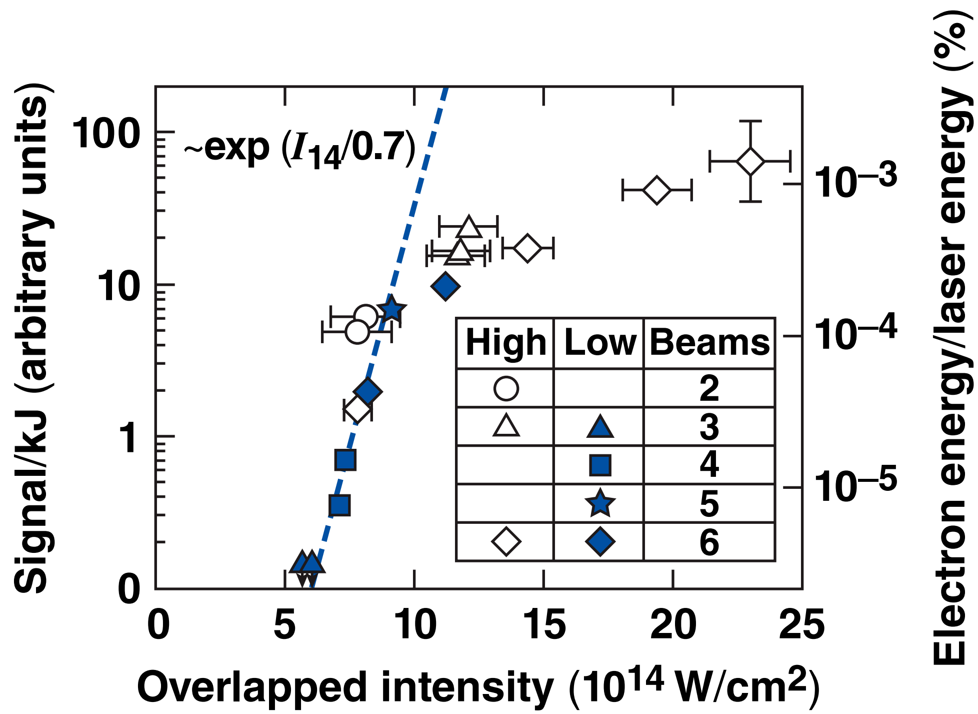
The geometric factor explains the observed differences in the two-beam and four-beam results.

*D. T. Michel et al., "Experimental Validation of the Two-Plasmon-Decay Common-Wave Process," submitted to Physical Review Letters.

This common-wave model is consistent with 2003 results, where TPD scaled with overlapped intensity*

OMEGA planar
Six beams interact in a preformed plasma





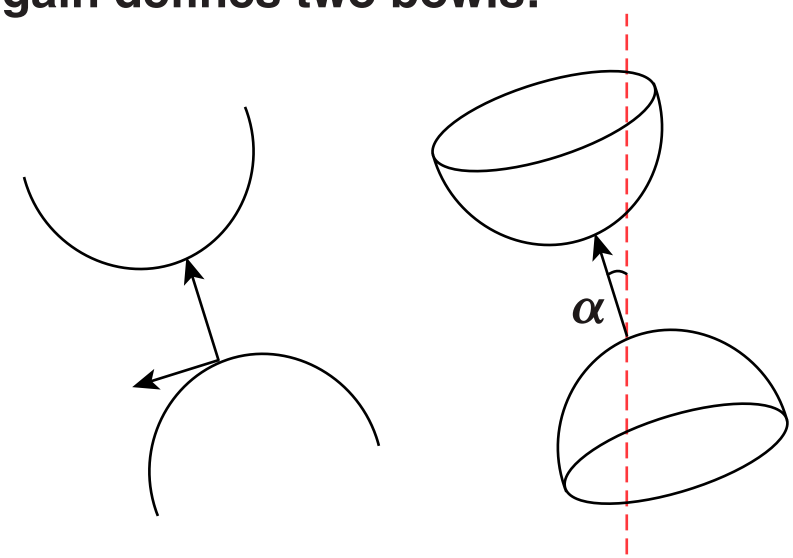
The TPD was shown to scale with overlapped intensity when using 2, 3, 4, 5, and 6 beams with polarization smoothing (PS).

E21304

*C.Stoeckl *et al*., Phys. Rev. Lett. 90, 235002 (2003).

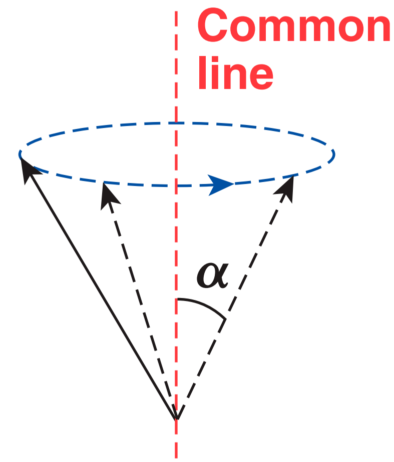
When using PS, the gain is proportional to half of the overlapped intensity

For beams with PS, the maximum gain defines two bowls:



The maximum gain with PS is proportional to half the overlapped intensity

From symmetry, the gain on the line is given by:



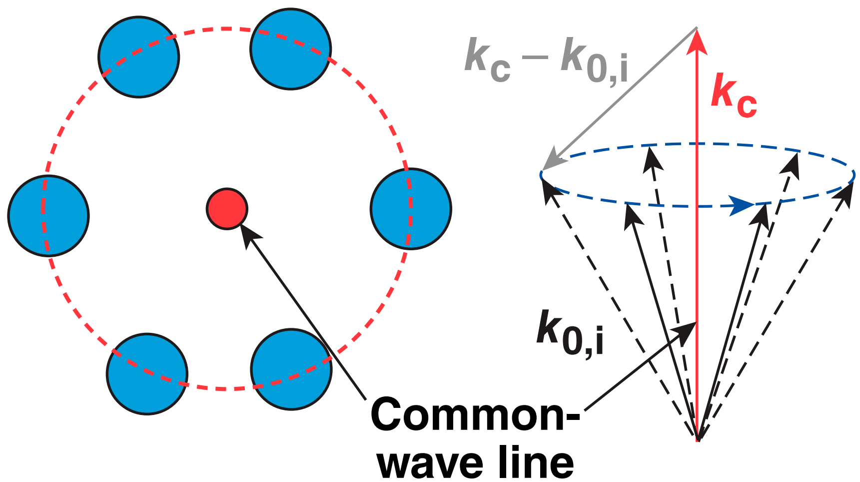
$$G_c = G_1 + G_2 + \ldots = n_{beam} G_1 \propto 0.5 \times I_{\Sigma,q}$$

The geometric factor when using PS is reduced to 0.5 (1, 2, *n*... beams).

E21305a

When PS is used, the geometric factor is reduced to $f_g = 0.5$ (1, 2, *n*… beams)

The symmetry between the beams allows for the same common-wave region for the 3, 4, 5, and 6 beam conditions



When PS is used, the geometrical factor is reduced to 0.5:

$$G_c = 8.5 \times 10^{-2} \frac{I_{\Sigma,q} L_n}{T_e}$$

When using beams with PS, the TPD threshold is proportional to the overlapped intensity, consistent with 2003 experiments.

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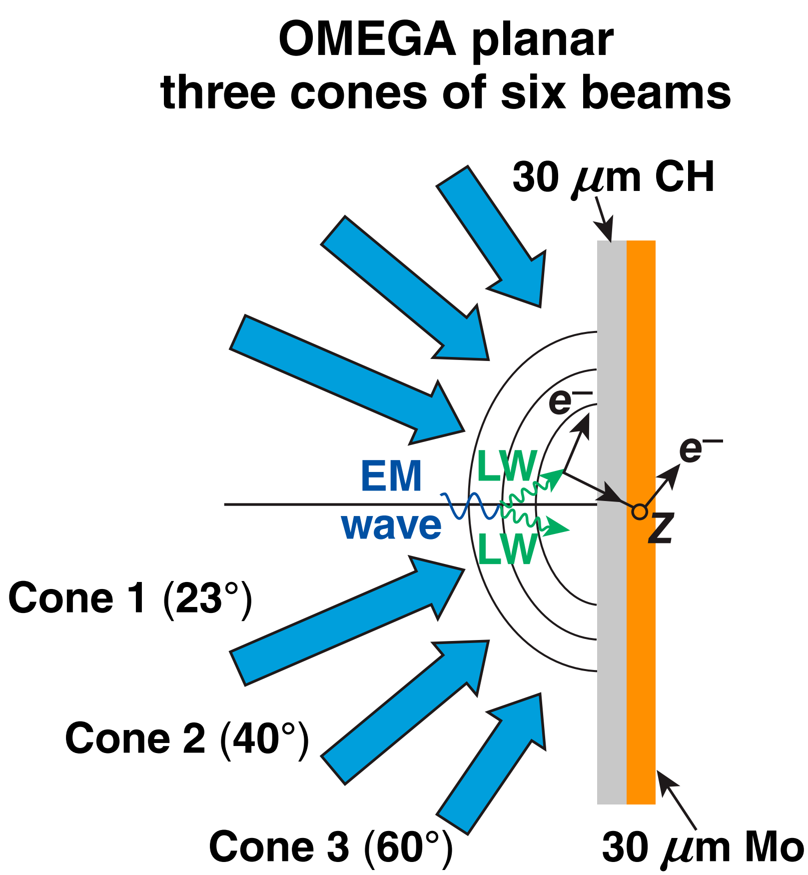
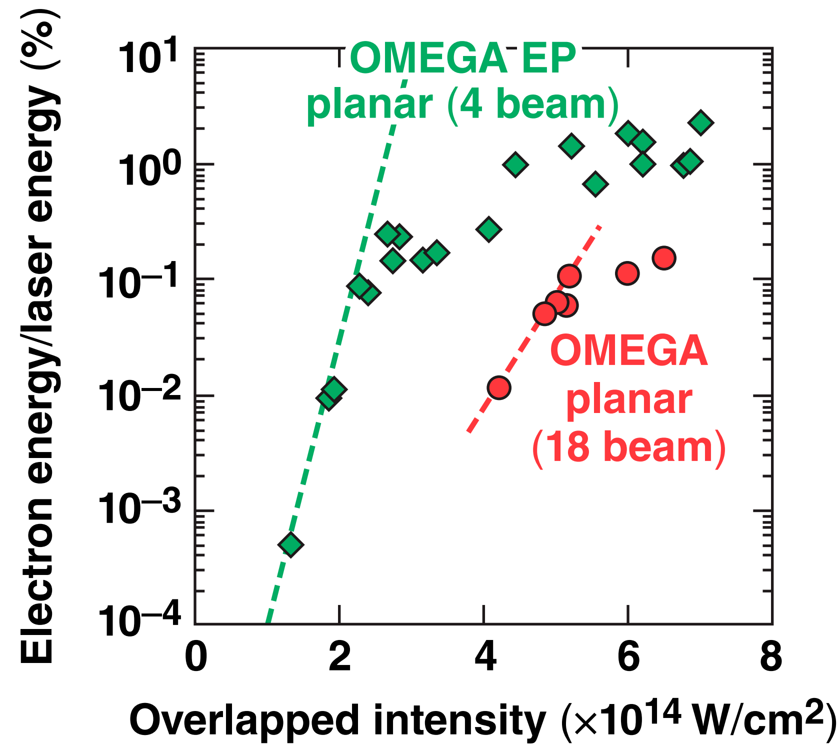
For 18 beams, a further decrease of the TPD growth with the overlapped intensity is observed





The TPD threshold is increased by a factor of ~3.

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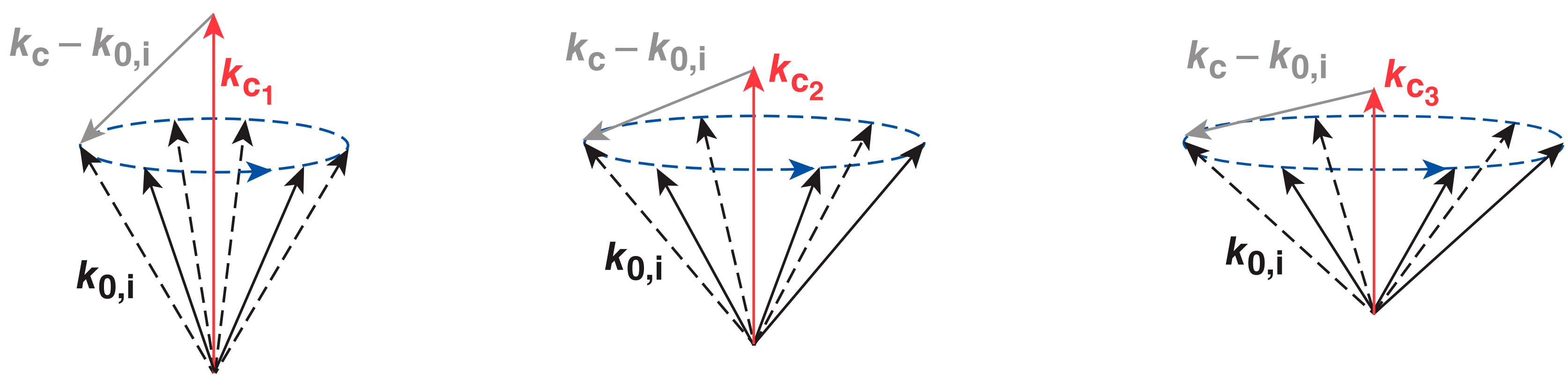
The effective intensity driving the common plasma wave is given only by cone 1

- **Each common wave requires:**

$$\left| \vec{k}_c - \vec{k}_{0,i} \right| = \text{constant}$$

- **This is not satisfied between different cones on OMEGA:**

Cone 1: **Cone 2:** **Cone 3:**



The reduction in intensity (I_q^{sym}) explains the observed factor of three difference in the thresholds.

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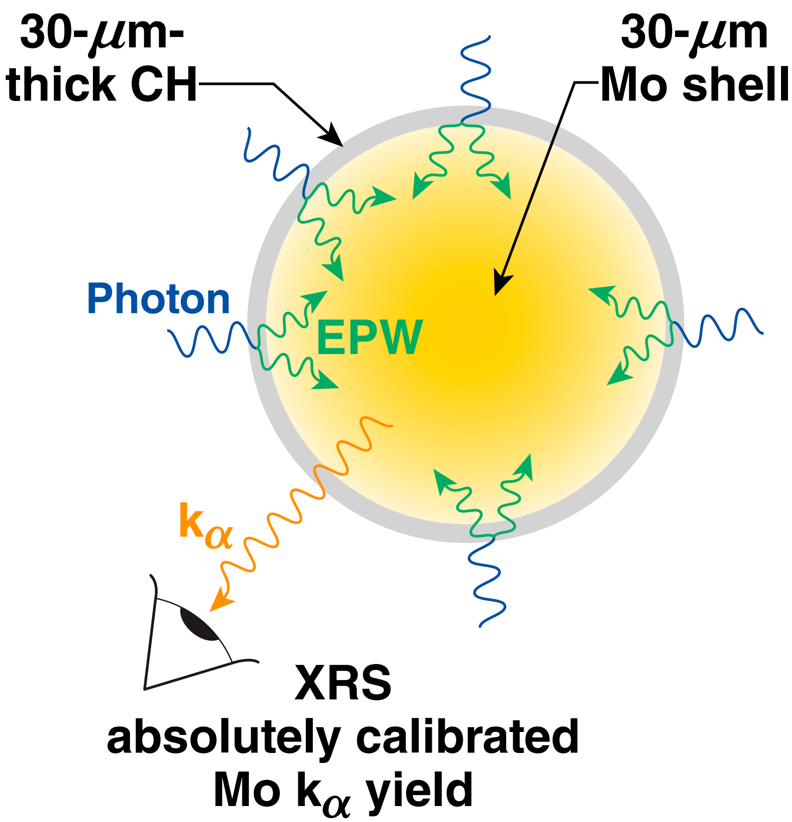
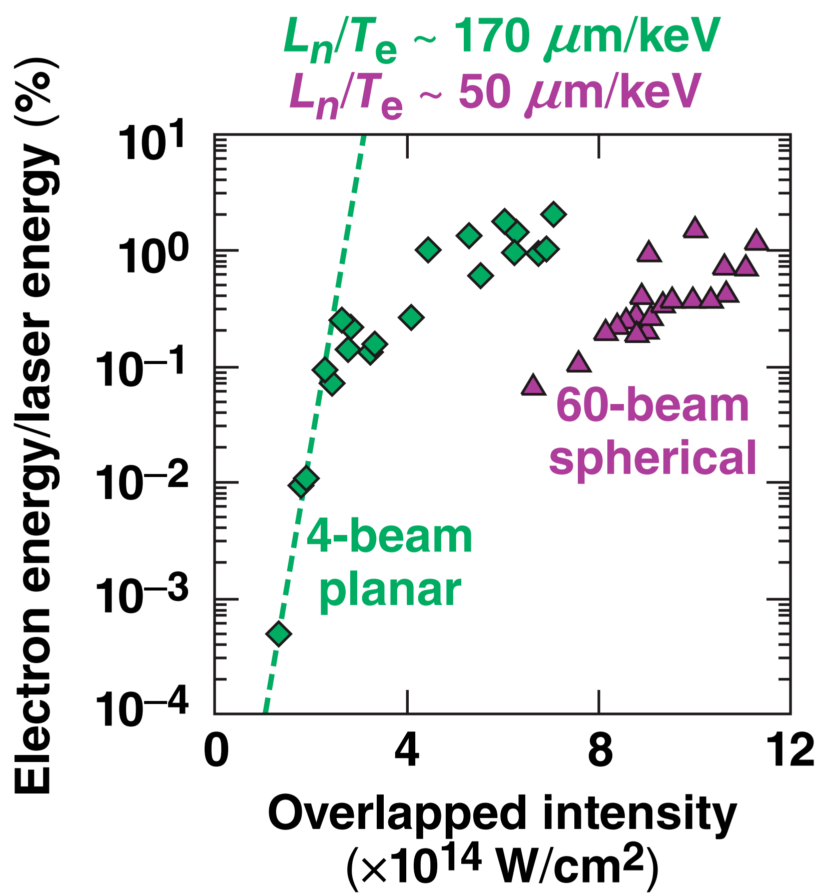
The hot-electron fraction is further reduced in spherical geometry for a given overlapped intensity





The reduction of L_n/T_e (50 μm/keV) explains the reduction of TPD for spherical targets.

E21309

The multiple-beam convective gain accounts for the differences in hydrodynamics, laser-beam geometry, and PS

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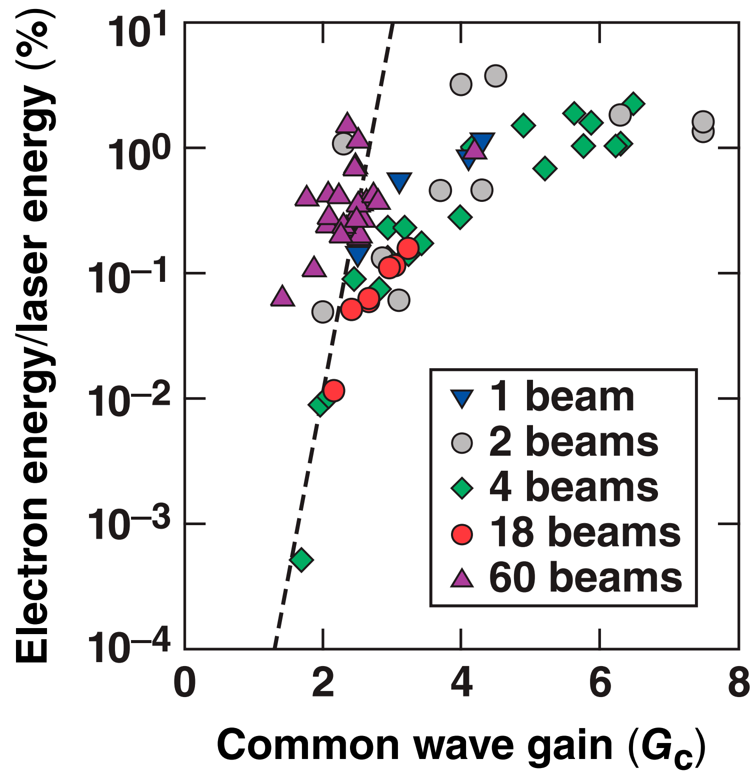
$$G_c = 17 \times 10^{-2} f_g \frac{I_{\Sigma,q}^{sym} L_n}{T_e}$$

Configuration	Geometry	f_g	n(sym)	$L_{n,q}/T_{e,q}$
1 beam	1 cone	1.0	1	175
2 beams	1 cone	1.0	2	175
4 beams	1 cone	0.5	4	175
18 beams (PS)	3 cone	0.5	6	135
60 beams (PS)	Spherical	0.5	6	50



For each configuration, the TPD growth scales with the common wave gain G_c.

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This theory points to mitigation strategies

$$G_{max} = f_g\left(\frac{I_{\Sigma,q}^{sym} L_n}{47 \times T_e}\right)$$

(a) Breaking the beam symmetry will reduce the number of beams that can contribute to the common-wave gain $\left(I_{\Sigma,q}^{sym}\right)$

(b) Polarization management could reduce the geometric factor

(c) Changing the ablator material could

- reduce the scale length and increase the electron temperature (L_n/T_e)
- modify the TPD saturation level*

(d) Increasing the number of beams reduces the single-beam intensity

E21308

*J. Myatt, this conference, Tuesday

Summary/Conclusions

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