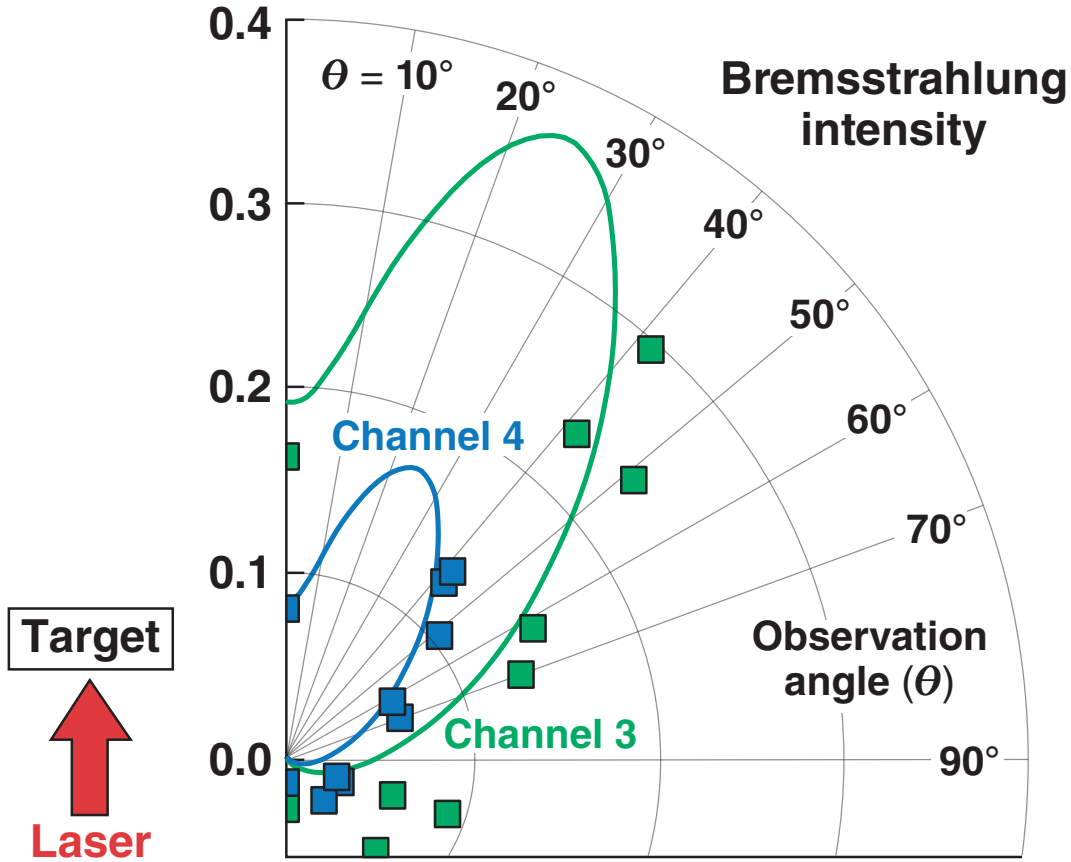
Two-Plasmon Decay Hot-Electron Distributions from Anisotropic Thick-Target Bremsstrahlung Measurements



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Summary

Measurements of bremsstrahlung from thick planar targets show a dramatic anisotropy in emission

- The direction of fast electrons must be also anisotropic.
- The electron source is assumed to be the two-plasmon decay instability (TPD).
- Directionality of TPD electrons is important for the calculation of fuel preheat*.
- The bremsstrahlung spectral distribution is well modeled with a hot-electron temperature of 120±20 keV.
- Bremsstrahlung is consistent with collimated electrons, characterized by $\Theta = 10^{\circ} \pm 5^{\circ}$ (half angle).
- Cooperative multi-beam TPD is implicated.

TC8353

*J. A. Delettrez (TO5.00002).

Collaborators

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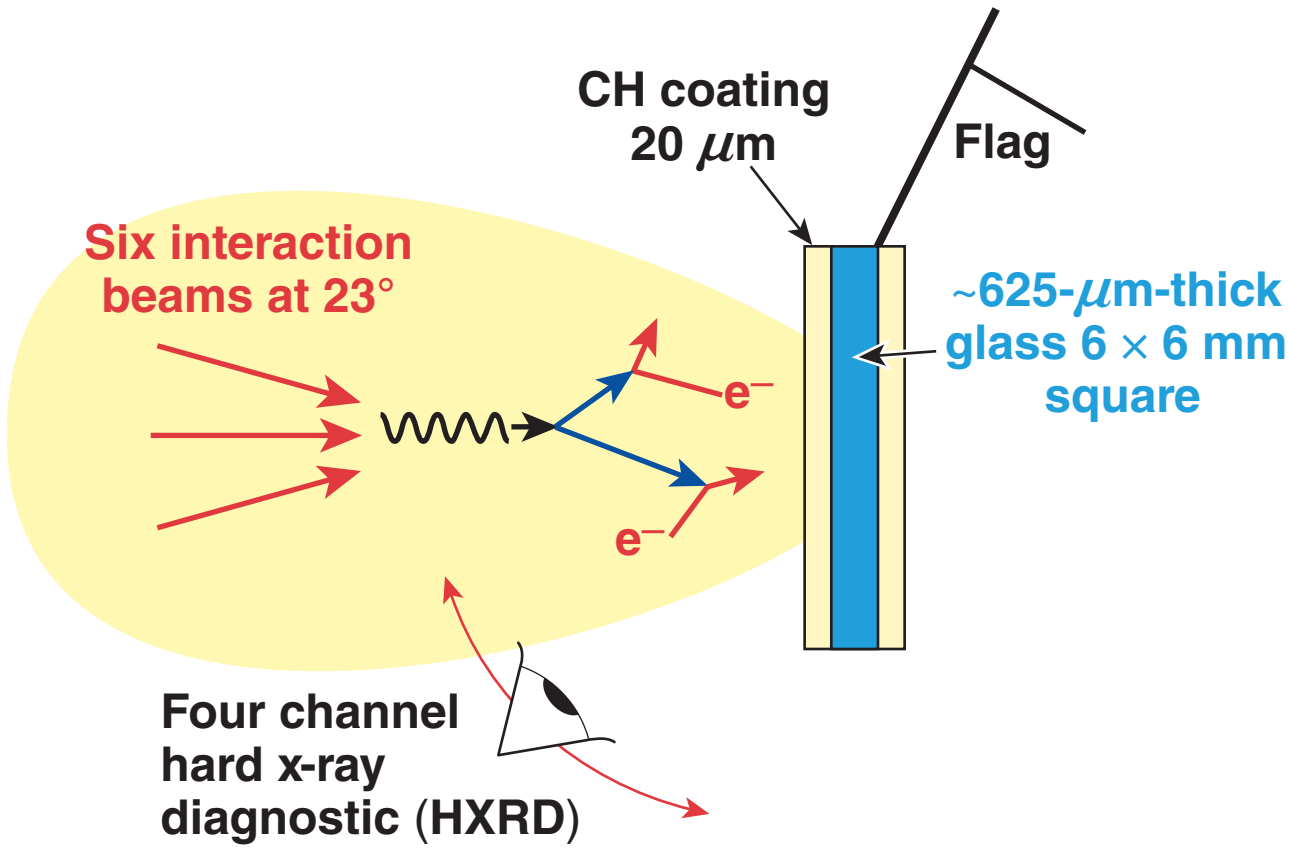
The experiments used six OMEGA interaction beams incident on a planar glass target



- Six symmetrically arranged interaction beams
- The angular dependence of the x-ray emission was diagnosed with a time-resolved, four-channel hard x-ray detector (HXRD).*

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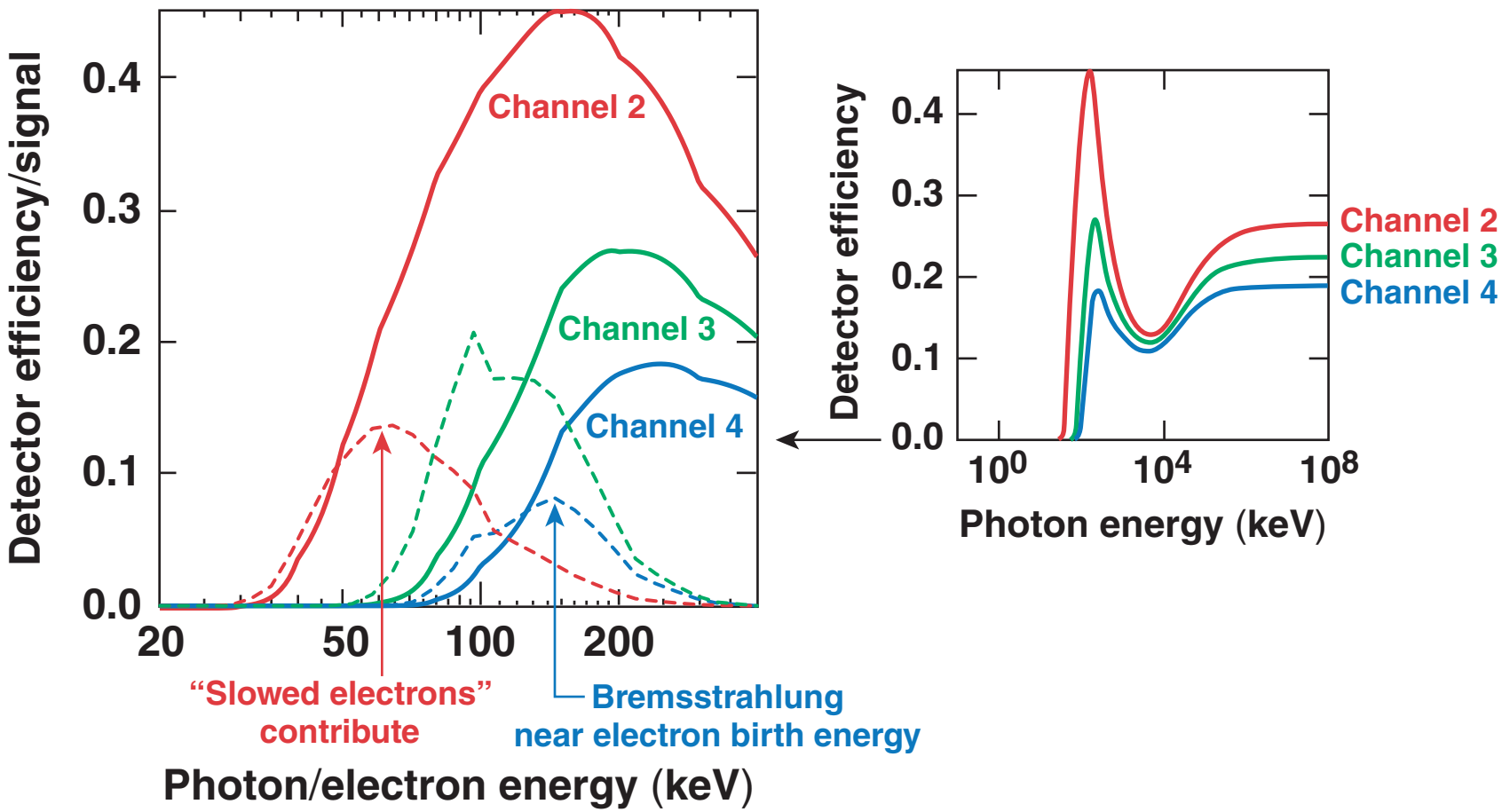
*C. Stoeckl *et al*., Rev. Sci. Instrum. 72, 1197 (2001).

The signal in the hardest x-ray channel comes from hot electrons whose direction of propagation is largely unmodified by collisions in the glass converter



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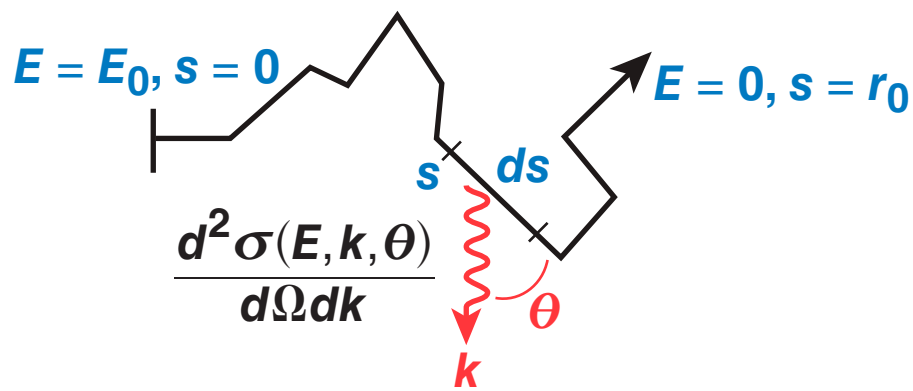
*C. Stoeckl *et al.*, Rev. Sci. Instrum. 72, 1197 (2001).

Predicted bremsstrahlung angular distributions are based on partial-wave calculations† in a relativistic self-consistent potential

- This is the thick-target bremsstrahlung problem.
- The bremsstrahlung distribution is constructed with the following assumptions:
  - straight line trajectories; lose energy according to *csda* stopping power*
  - exponentially distributed in energy, characterized by T_{hot}
  - uniformly distributed in half angle Θ



†H. K. Tseng *et al.*, Phys. Rev. A 19, 187 (1979).
*H. O. Wyckoff, ICRU Report, 37, International Commission on Radiation Units and Measurements, Inc., Bethesda, MD (1984).

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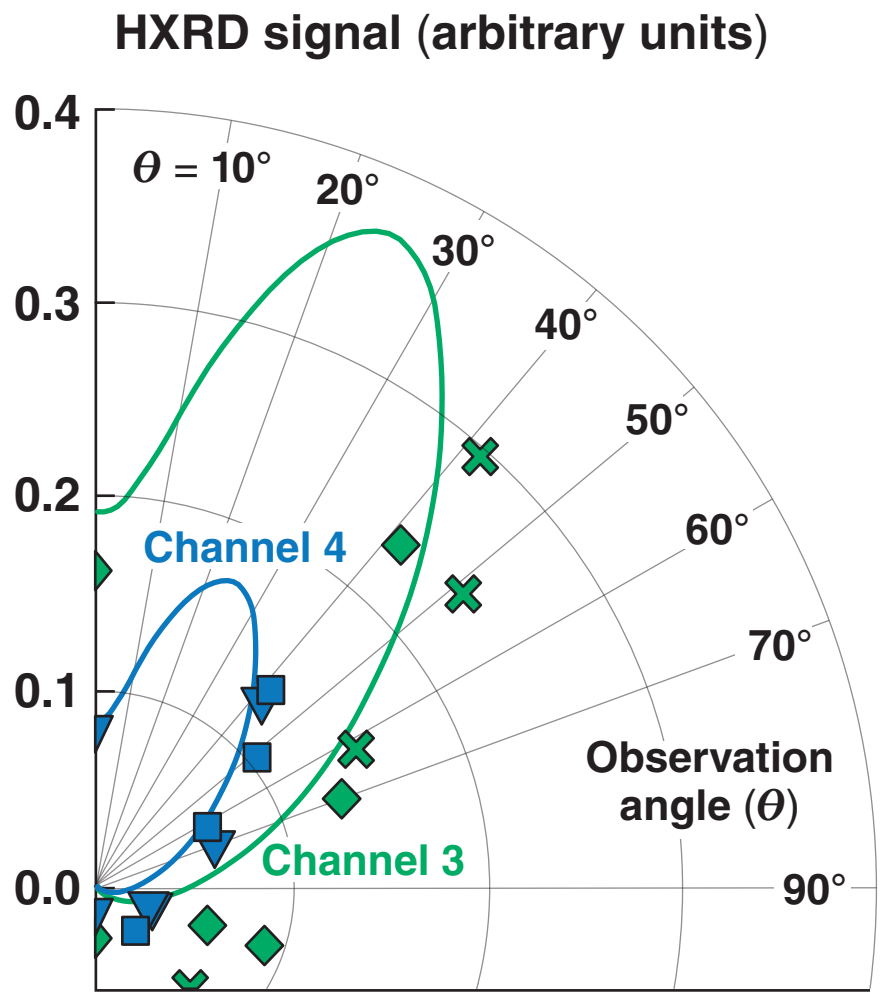
Reasonable agreement with the observed bremsstrahlung angular distribution is achieved with a narrow beam of hot electrons, $\Theta = 10° \pm 5°$

- Parameters of the model are T_{hot} and Θ only.
- There is good agreement at angles $\theta < 70°$ for $\Theta = 10° \pm 5°$ and $T_{hot} = 120 \pm 20$ keV.
- Agreement cannot be obtained if electrons are assumed to be more isotropic.
- Isotropic electrons in forward half-space are excluded



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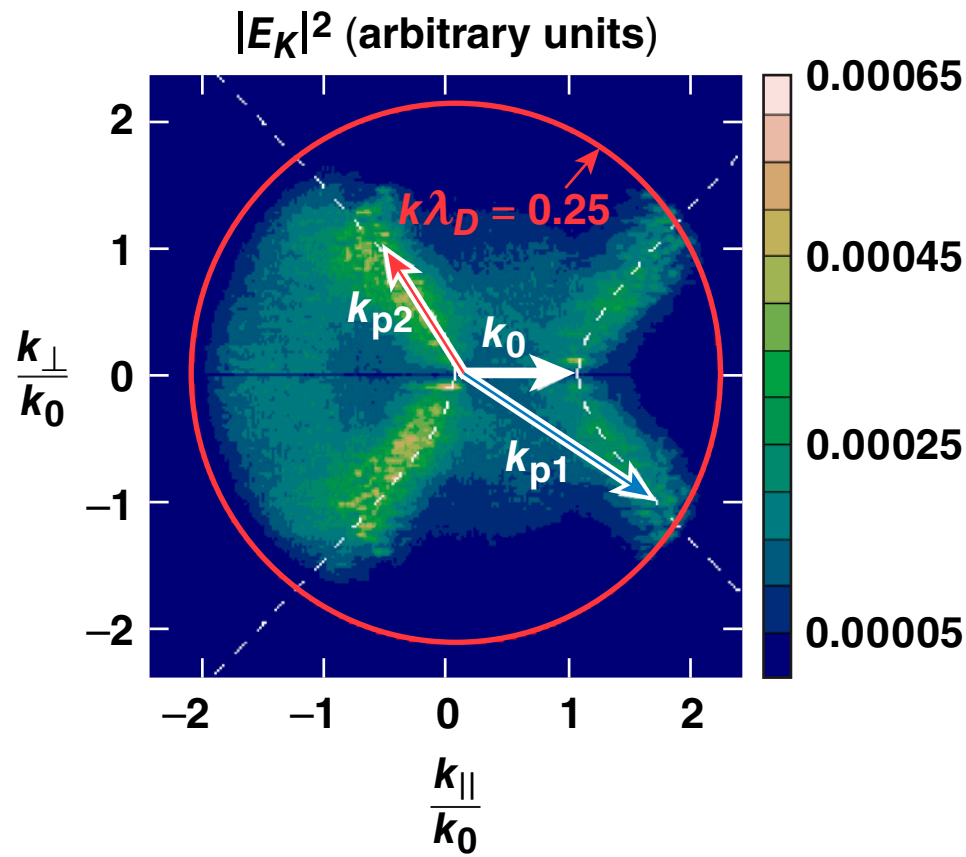
Hot electrons would not be expected to be generated in such a narrow angle based on the predictions of the linear TPD theory for a single beam

- Maximum growth occurs on a hyperbola
- Two pairs: blue plasmon propagates up the gradient, red down the gradient

$$\left[k_x(x), k_y(x)\right] = \left\{1/2\, k_0 \pm k_{De}\left[\Omega(x)/6\,\omega_{p0}\right]^{1/2} \pm \left[k_{De}\Omega(x)/6\omega_{p0} - k_0^2\right]^{1/2}\right\},$$

$$\Omega(x) \equiv \omega_0 - 2\omega_{pe}(x)$$

2-D simulation with plane wave normal to density gradient



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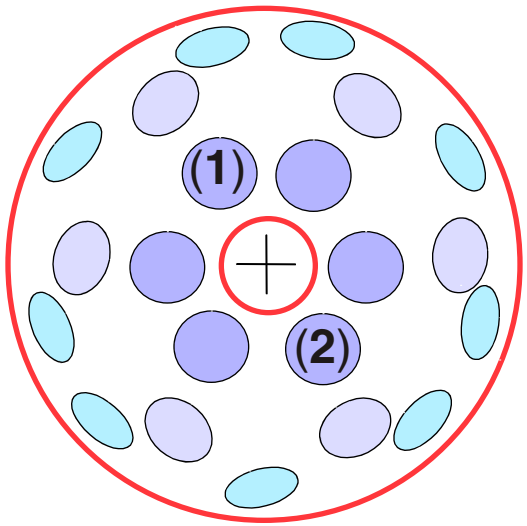
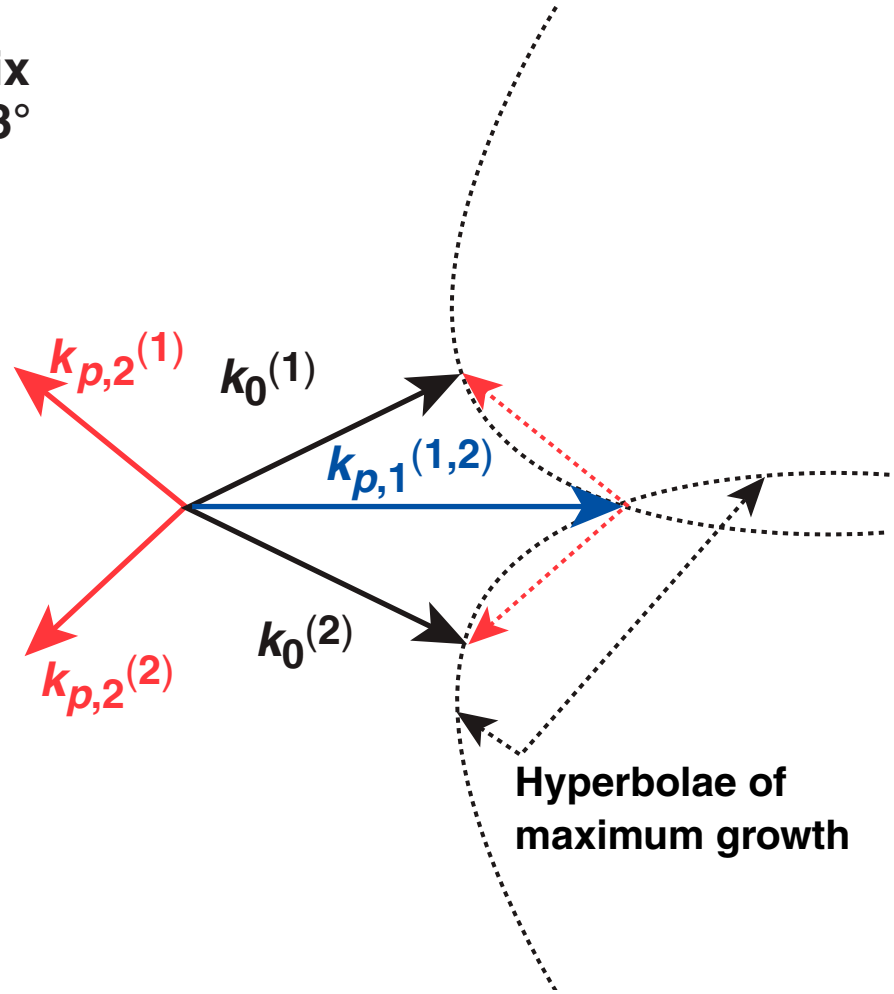
It is suggested that hot electrons are forward directed in the experiments due to the presence of a cooperative mode of TPD

- Experimentally on OMEGA, six beams are incident each at 23° from the target normal.
- The axis of symmetry coincides with the target normal





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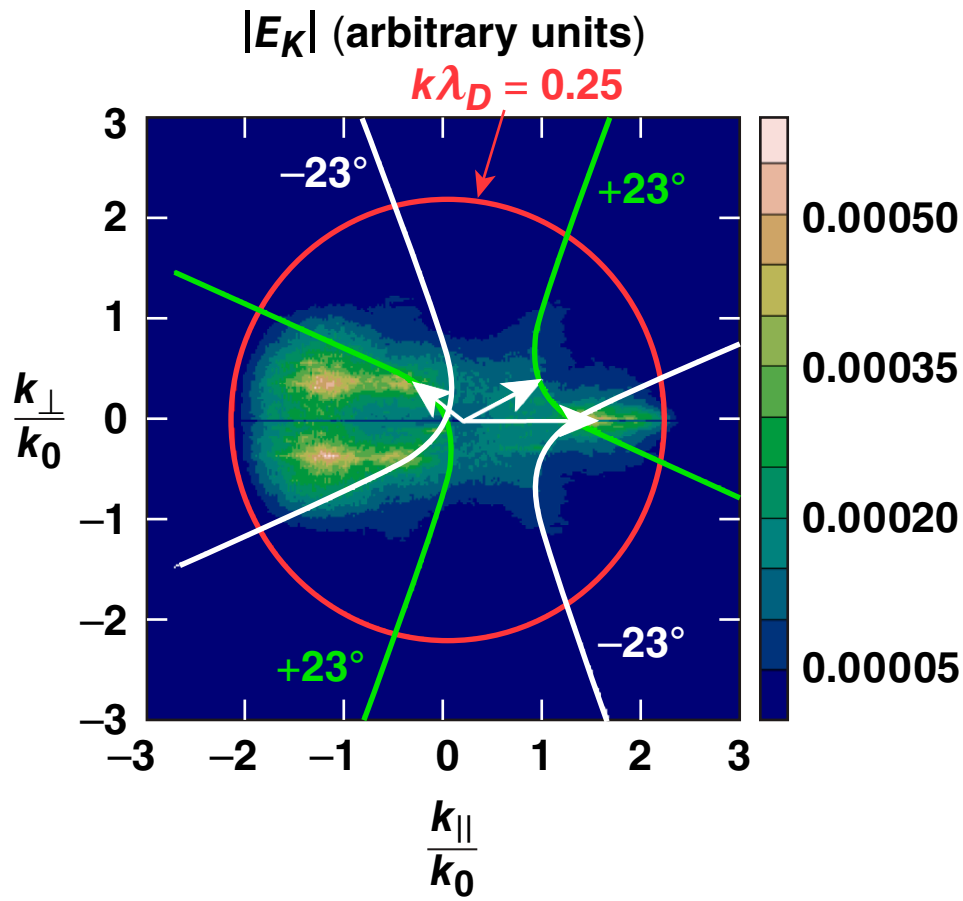
Recent two-dimensional extended Zakharov modeling[1,2] of TPD lends support to this hypothesis

- Plasma-wave k-vectors are contained within an angle of θ = 15°.
- Electron acceleration is not currently modeled.
- The next step will be to use a hot electron distribution taken from the numerical calculation.



[1]D. F. DuBois, D. A. Russel, and H. A. Rose, Phys. Rev. Lett. 74, 3983 (1995).
[2]D. A. Russell and D. F. DuBois, Phys. Rev. Lett. 86, 428 (2001).

TC8356

Summary/Conclusions

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