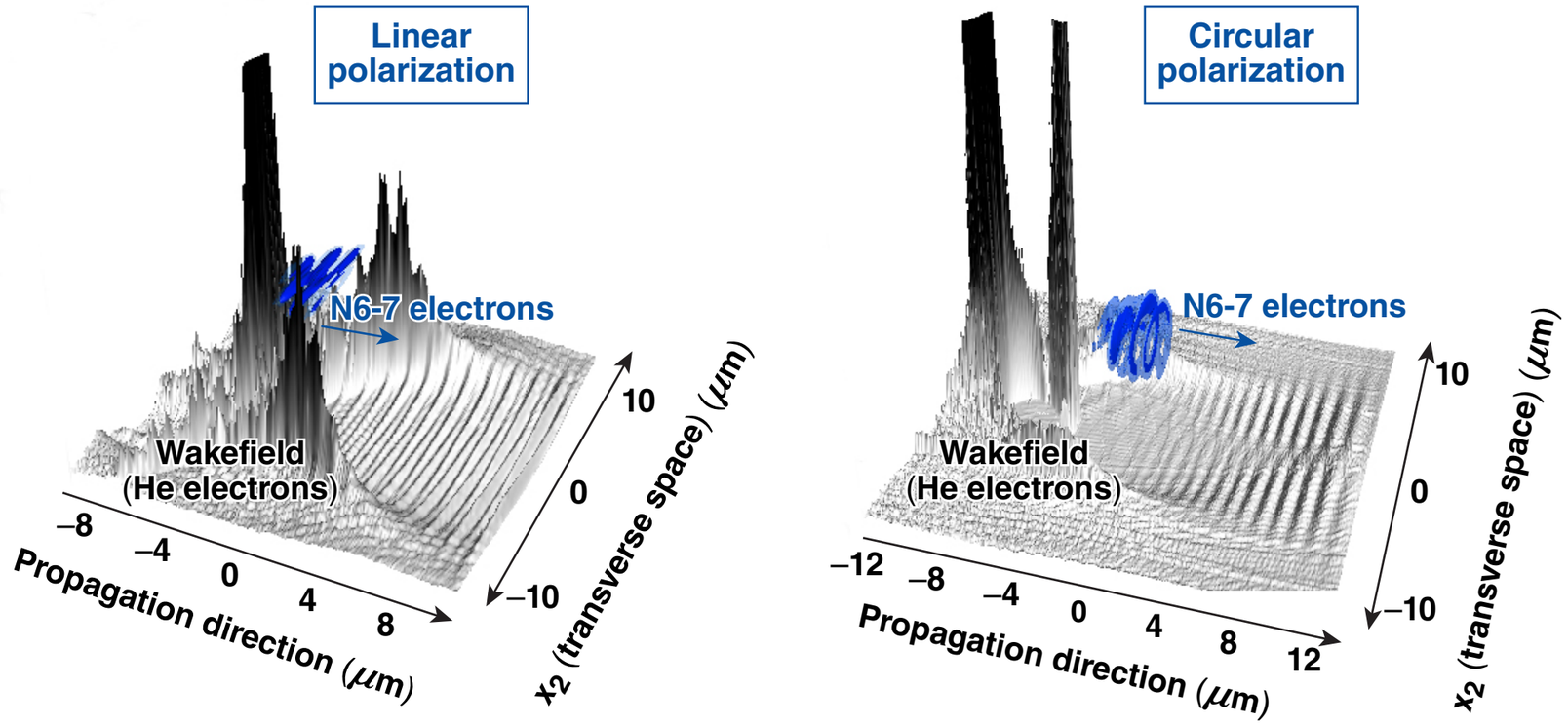
Direct Laser Acceleration in Wakefield Accelerators Driven with Circularly Polarized Lasers



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Summary

When laser wakefield accelerators (LWFA's) are driven with circularly polarized lasers, direct laser acceleration can contribute to the energy gain of the highest-energy electrons

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- Three dimensional particle-in-cell simulations investigating the energy-gain dynamics show electrons gain energy through direct laser acceleration (DLA) from both transverse components of the laser electric field
- This presence of DLA leads to increased oscillation radii that can enhance betatron x-ray emission

Collaborators

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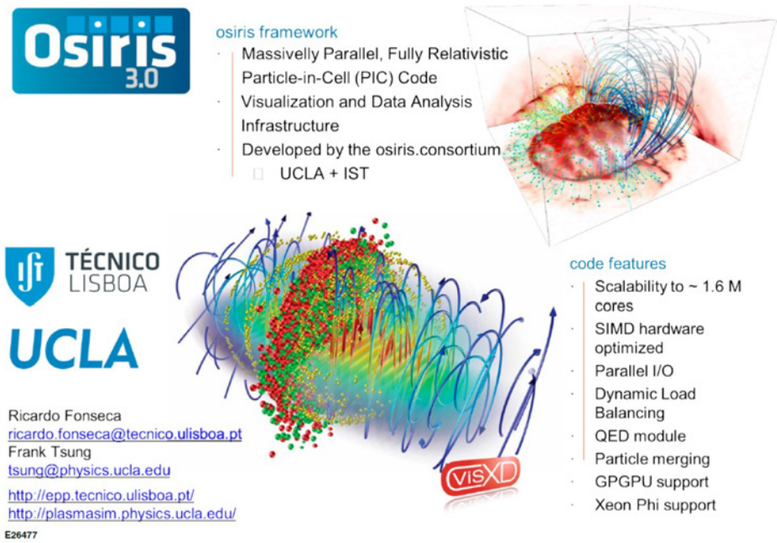
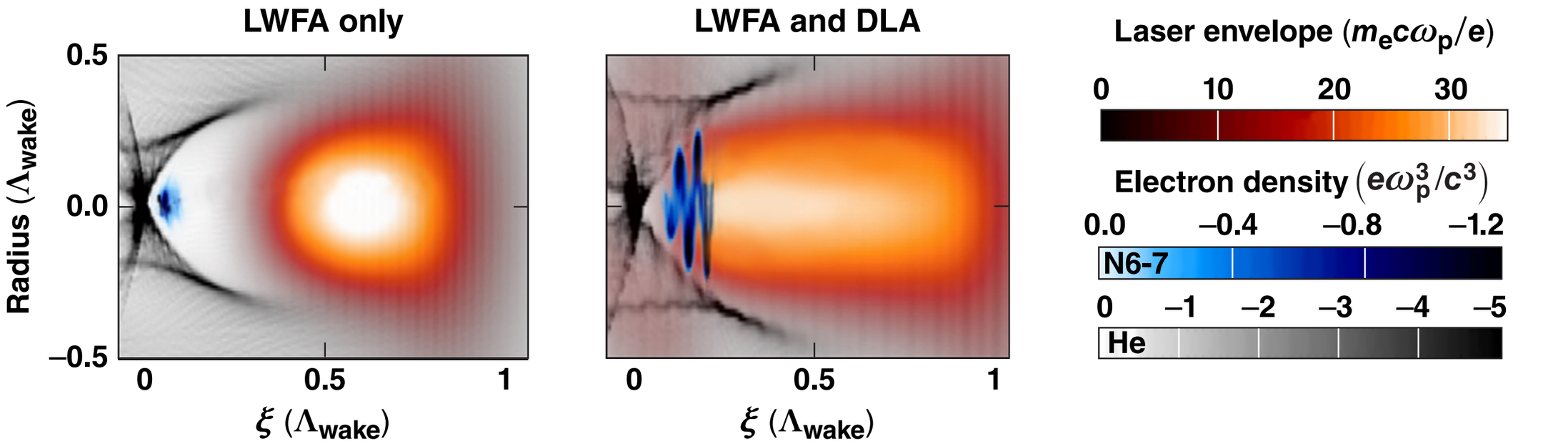


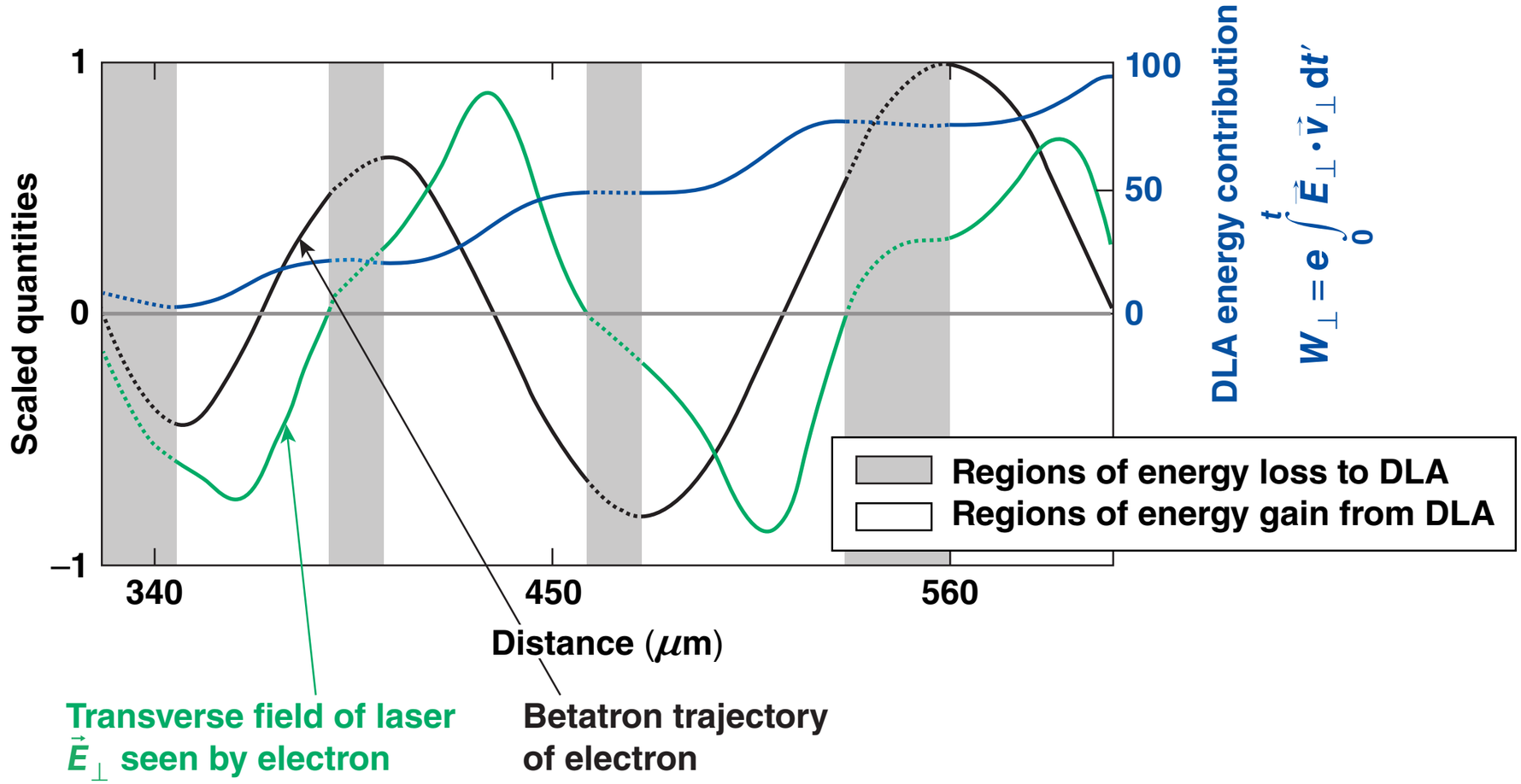
Significant overlap between the laser and the trapped electrons in a LWFA cavity can lead to energy gain from both the LWFA and DLA mechanisms*



*J. L. Shaw *et al.*, Plasma Phys. Control. Fusion 56, 084006 (2014);
J. L. Shaw *et al.*, AIP Conf. Proc. 1777, 040014 (2016);
J. L. Shaw *et al.*, Plasma Phys. Control. Fusion 58, 034008 (2016);
J. L. Shaw *et al.*, Phys. Rev. Lett. 118, 064801 (2017).

E26801

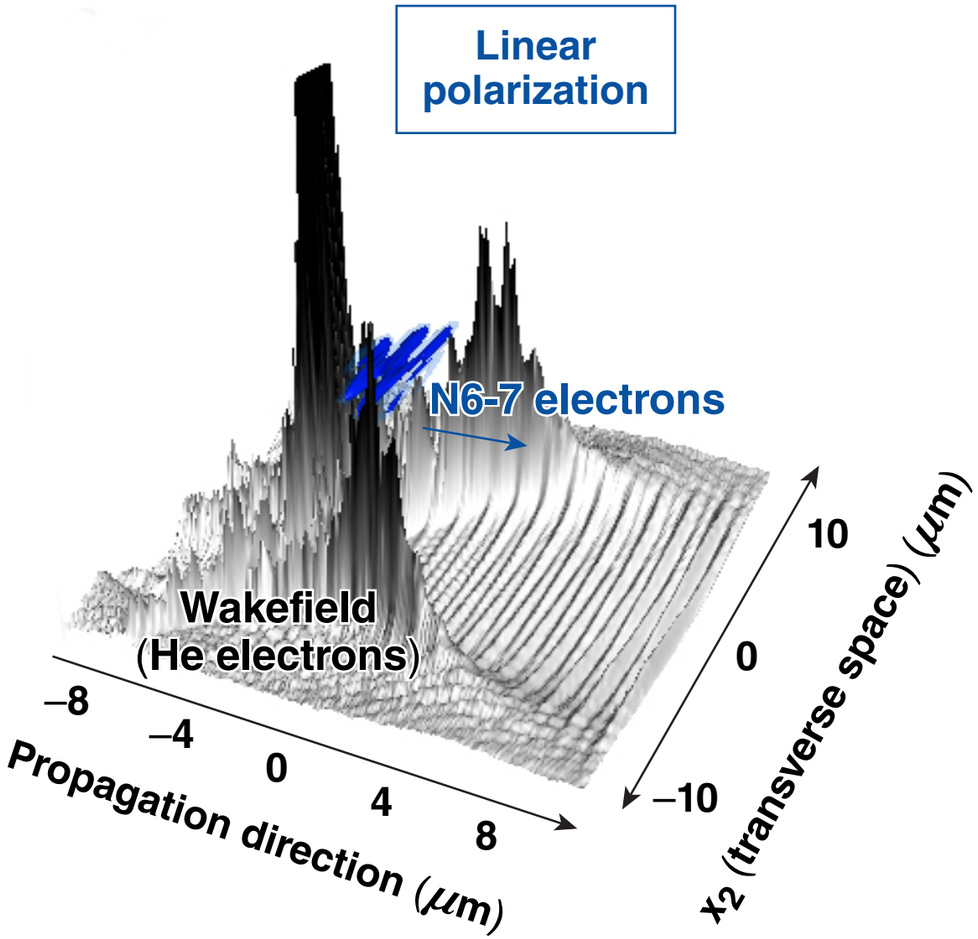
Quasi-resonant DLA can lead to sizeable energy gain*,**

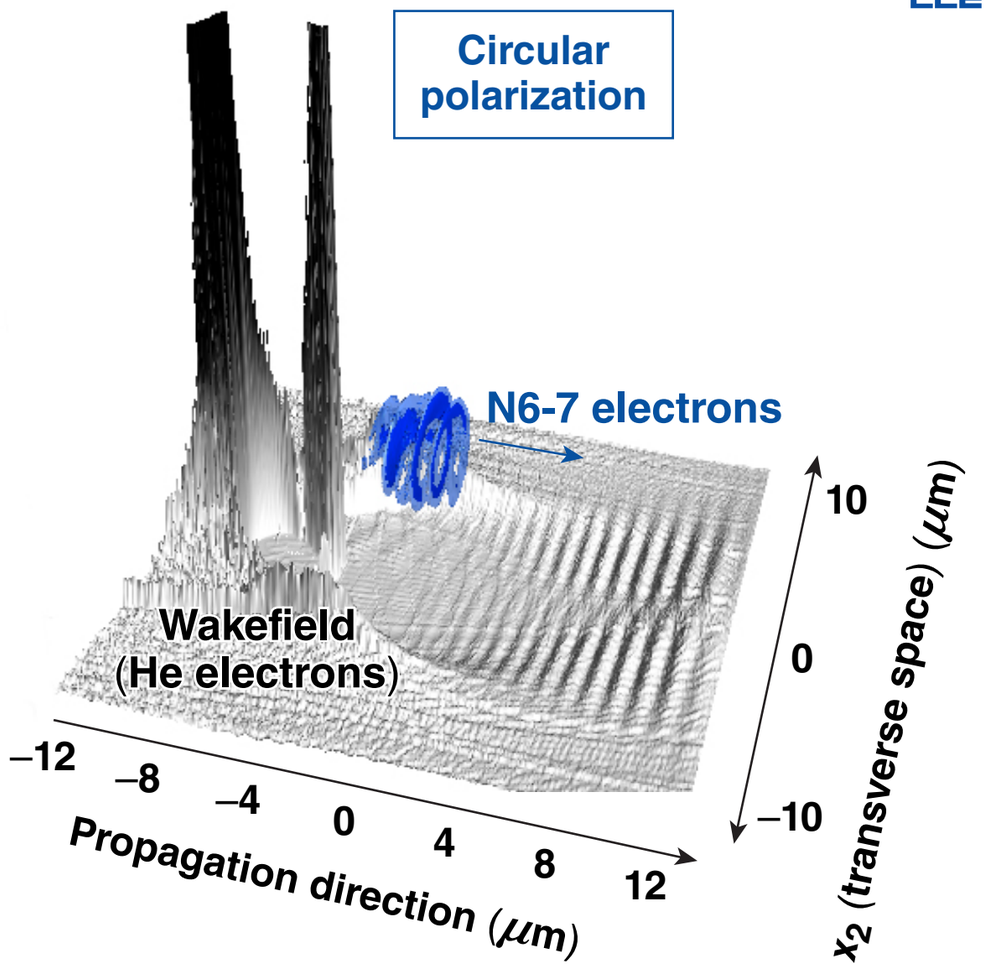


*J. L. Shaw *et al.*, Phys. Rev. Lett. 118, 064801 (2017).
**J. L. Shaw, Ph.D. thesis, University of California, Los Angeles, 2016.

E26475d

Full 3-D PIC* simulations are required to fully investigate electron energy gain dynamics when a circularly polarized laser pulse overlaps trapped electrons

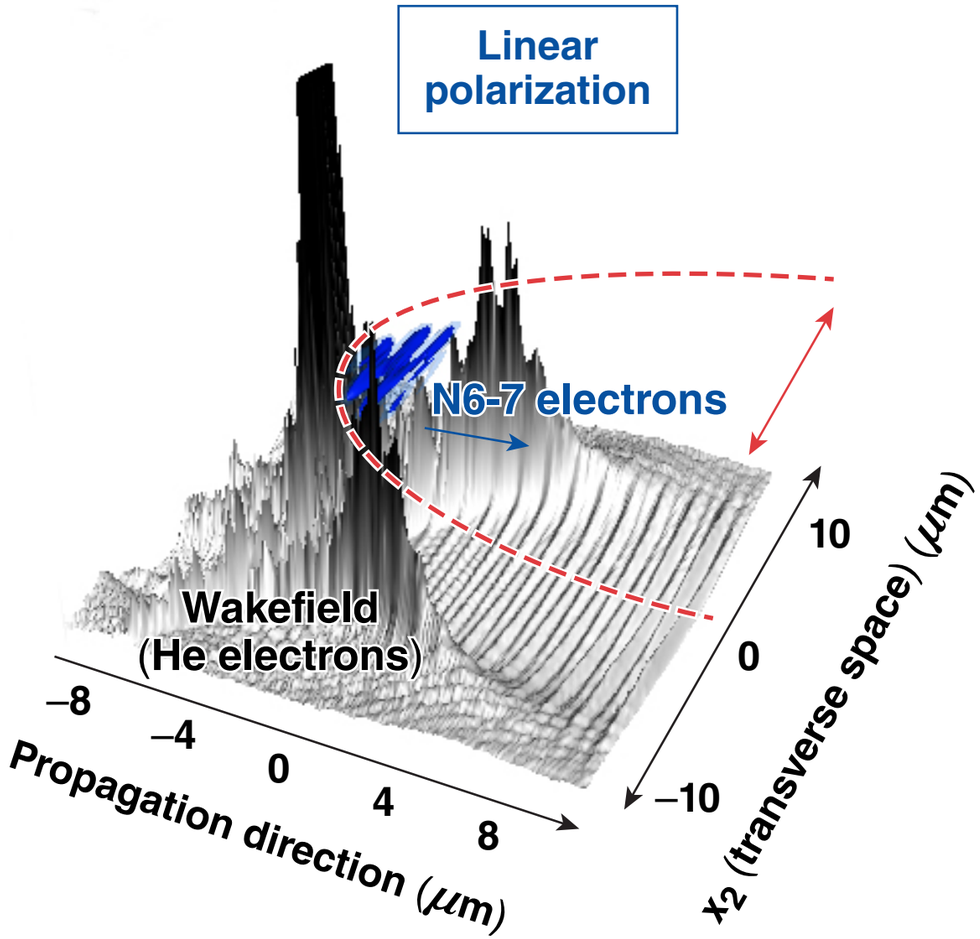


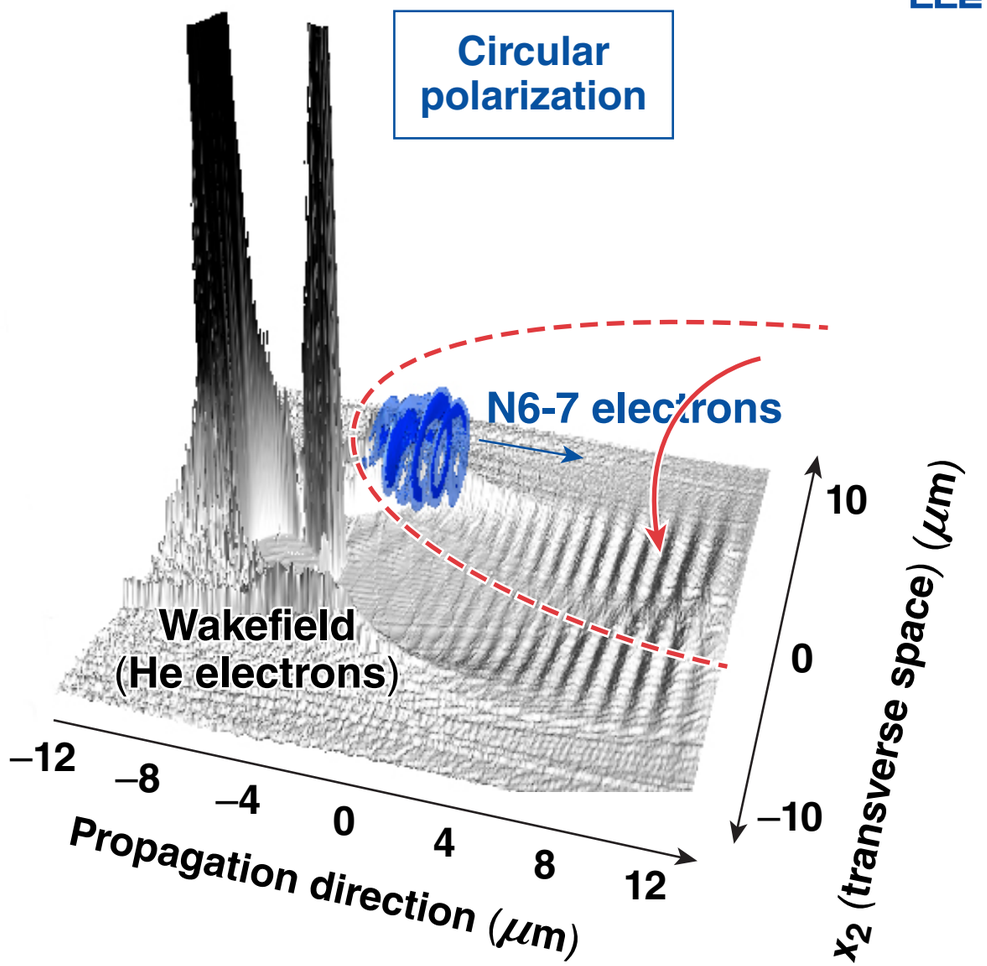


E26802

*PIC: particle in cell

Full 3-D PIC* simulations are required to fully investigate electron energy gain dynamics when a circularly polarized laser pulse overlaps trapped electrons

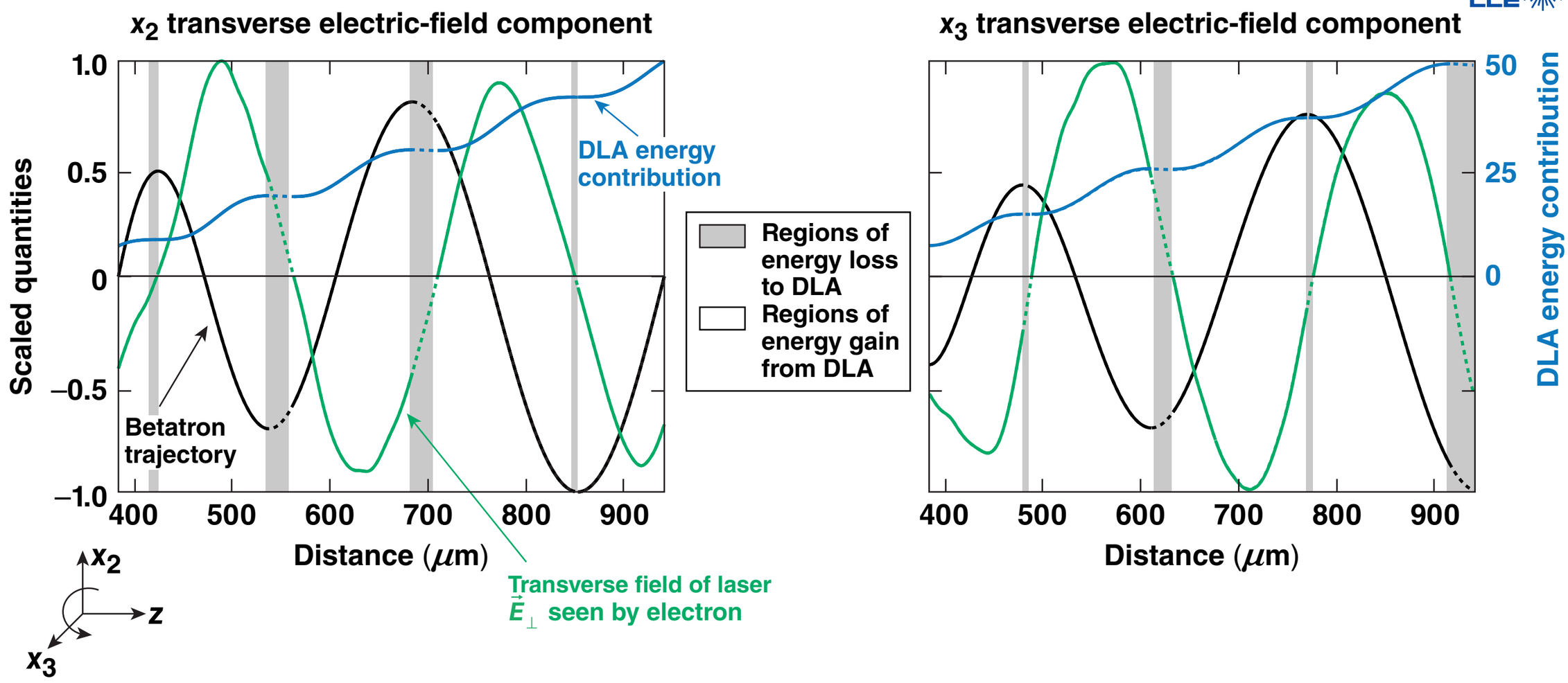




E26850

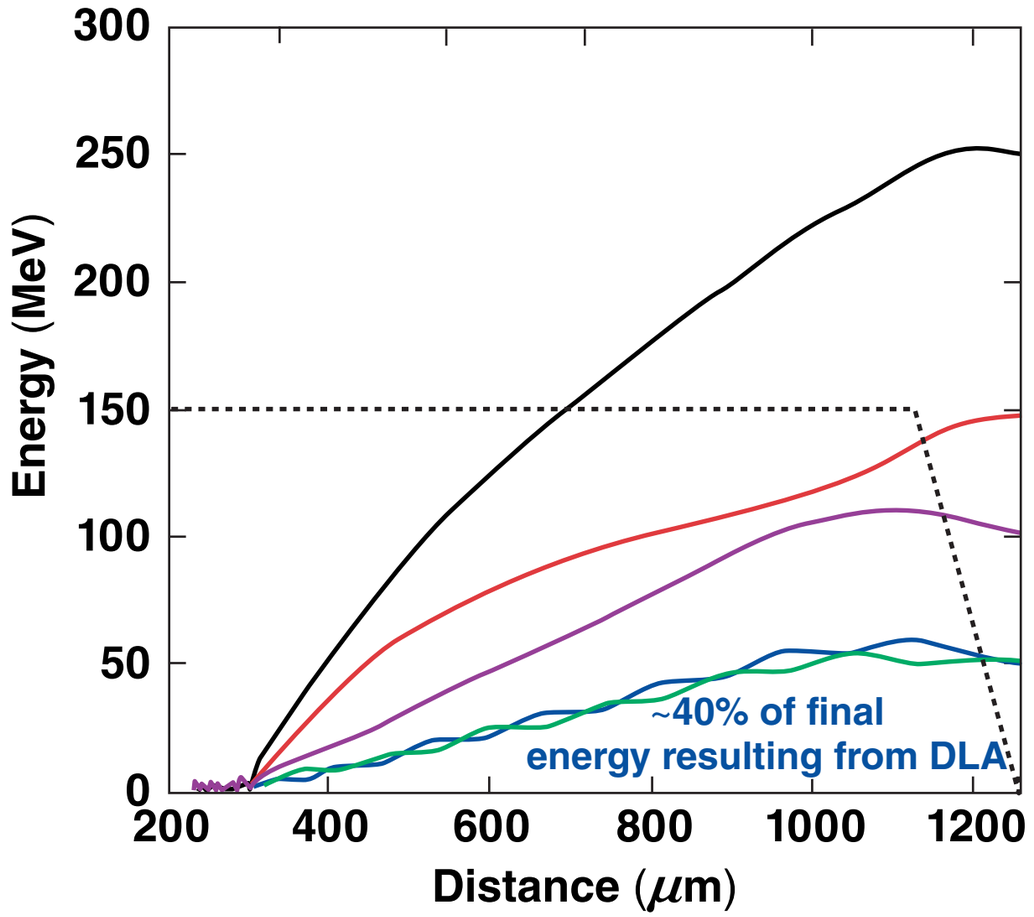
*PIC: particle in cell

Electrons gain energy from each transverse field component of the circularly polarized drive laser



E26803

Combined effects of both transverse laser field components lead to continuous energy gain



Total energy

LWFA contribution: $W_{\parallel} = e \int_0^t \vec{E}_{\parallel} \cdot \vec{v}_{\parallel} \, dt'$

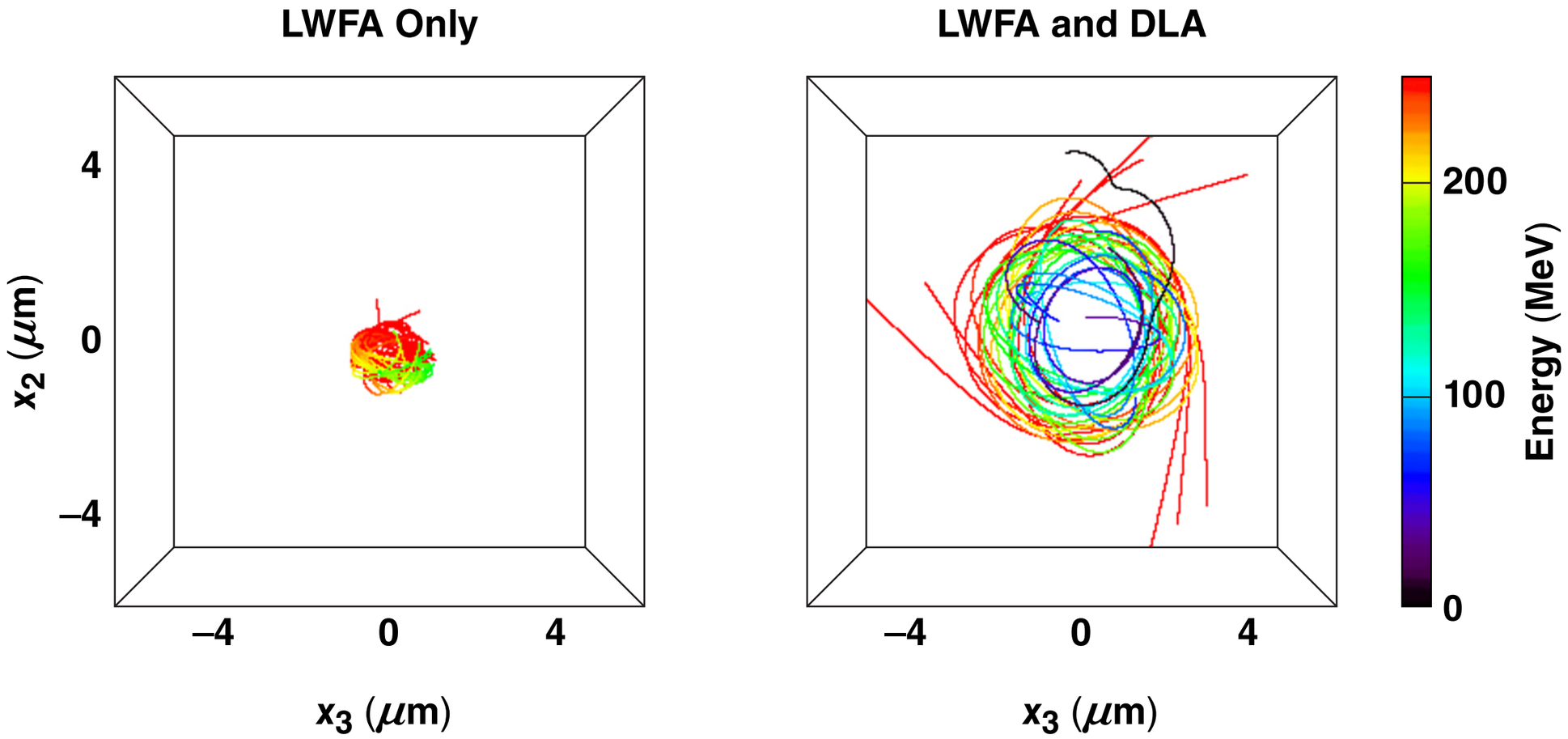
x_2 DLA contribution: $W_{\perp} = e \int_0^t \vec{E}_2 \cdot \vec{v}_{\perp} \, dt'$

x_3 DLA contribution: $W_{\perp} = e \int_0^t \vec{E}_3 \cdot v_{\perp} \, dt'$

Total DLA = x_2 + x_3 contributions

E26804

The presence of DLA increases the betatron oscillation radius



E26805

Summary/Conclusions

When LWFA's are driven with circularly polarized lasers, DLA can contribute to the energy gain of the highest-energy electrons

- Three-dimensional PIC simulations investigating the energy-gain dynamics show electrons gain energy through DLA from both transverse components of the laser electric field
- This presence of DLA leads to increased oscillation radii that can enhance betatron x-ray emission

DLA resonance condition

- Resonance occurs when the Doppler-shifted laser frequency witnessed by the electrons is approximately the betatron frequency of the electrons
- Resonance condition:* $N\omega_\beta = \left(1 - \frac{v_\parallel}{v_\phi}\right)\omega_0$
  - N = harmonic of the betatron frequency (integer)
  - $\omega_\beta = \omega_p / (2\gamma)^{1/2}$ = betatron frequency of electron
  - $v_\parallel$ = longitudinal velocity of electron
  - v_ϕ = phase velocity of laser
  - ω_0 = laser frequency

*A. Pukhov, Z. M. Sheng, and J. Meyer-ter-Vehn, Phys. Plasmas 6, 2847 (1999).