Effects of pulse shape and plasma density on laser propagation in laser-driven wakefield accelerators

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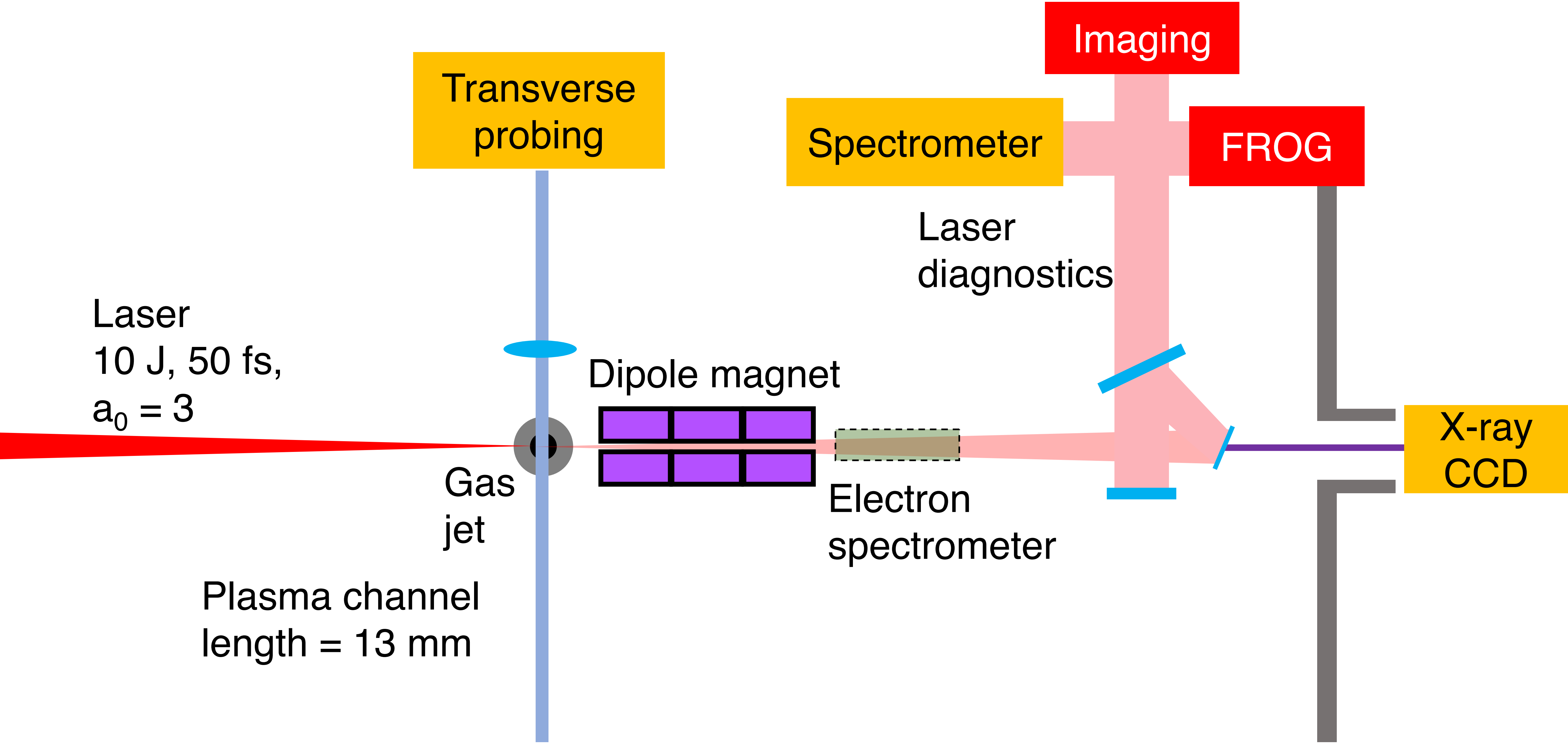
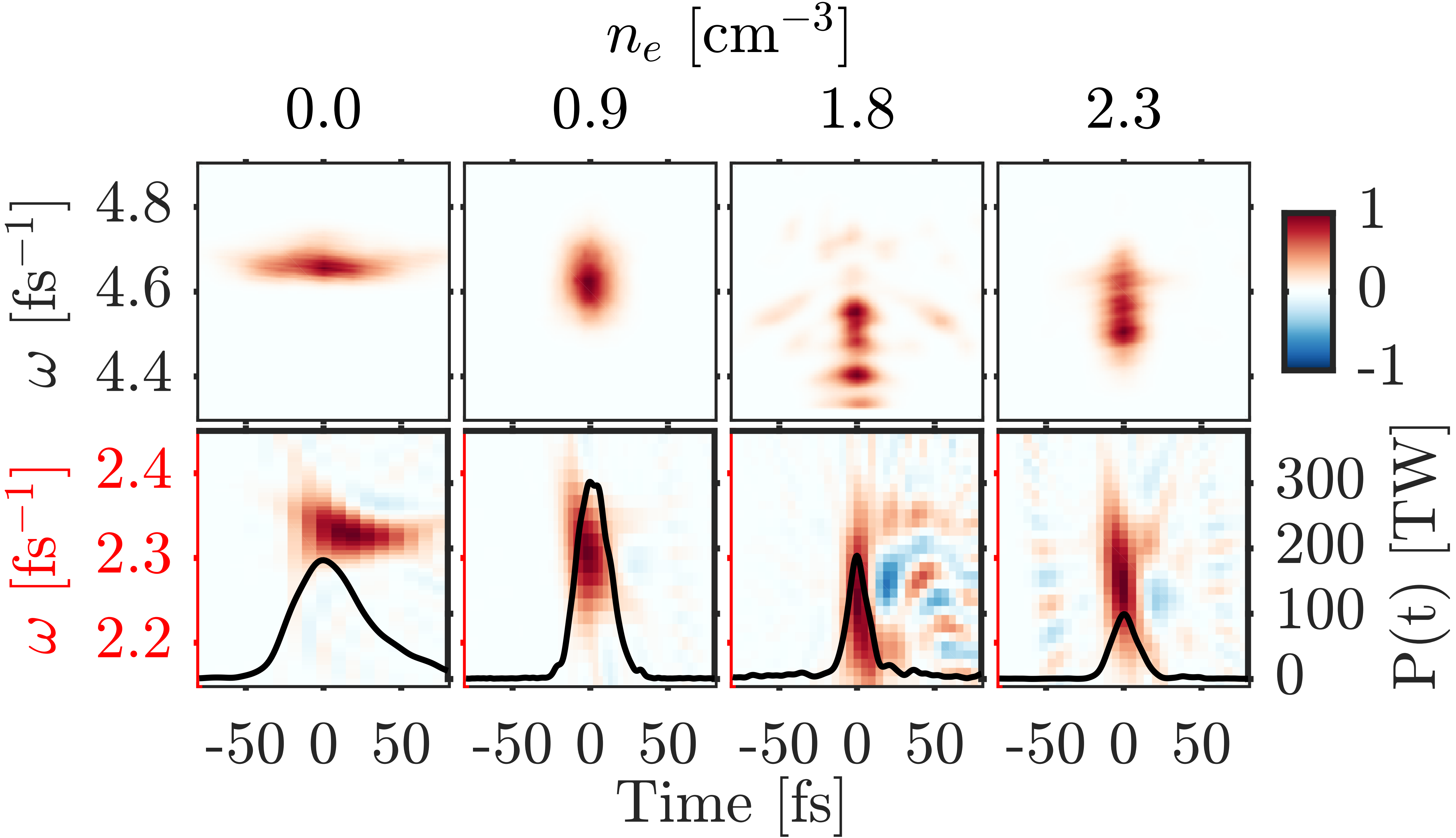
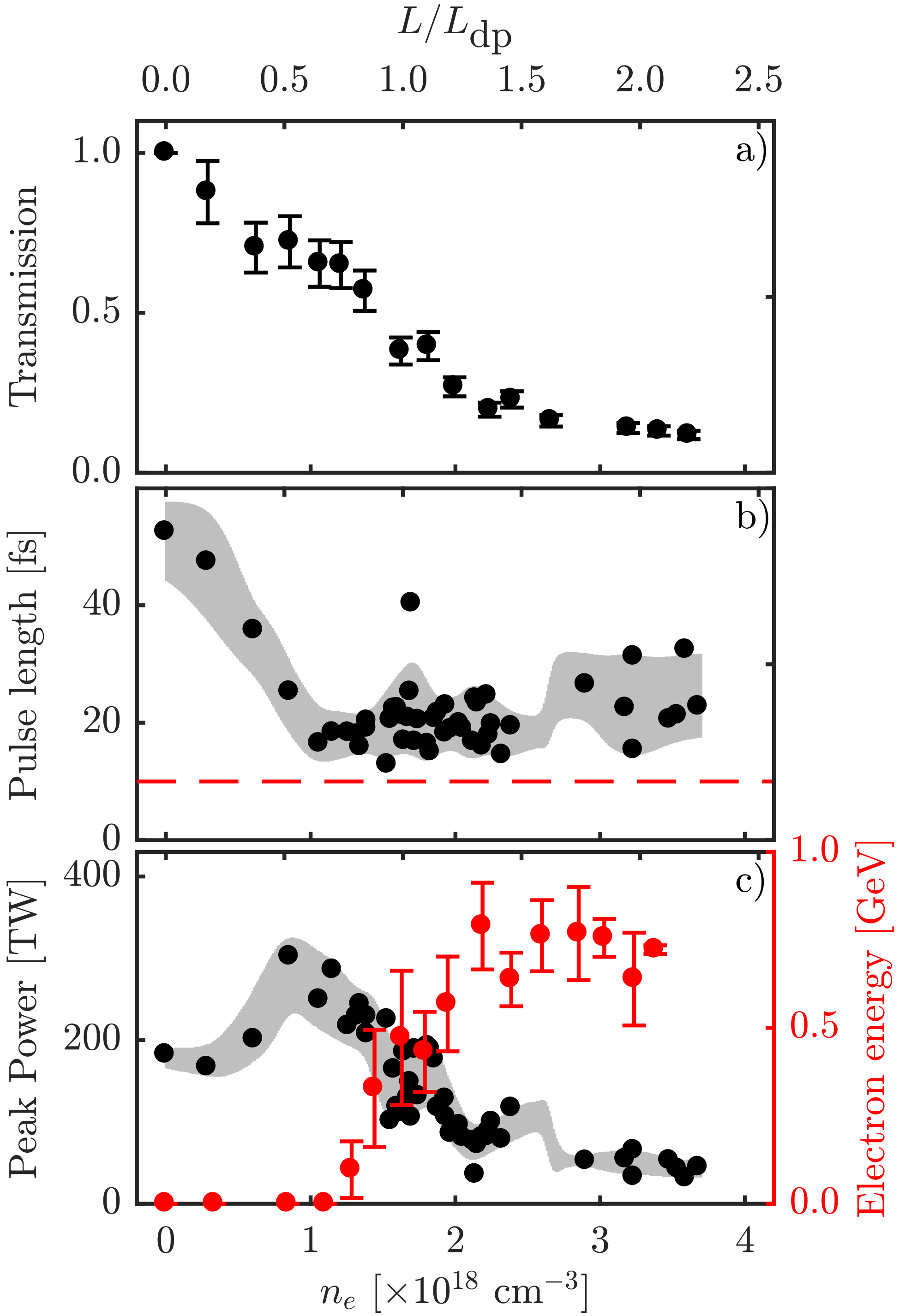


Imaging
Transverse probing
Spectrometer
FROG
Laser diagnostics
Laser
10 J, 50 fs,
$a_0 = 3$
Dipole magnet
X-ray CCD
Gas jet
Electron spectrometer
Plasma channel length = 13 mm



n_e [cm^{-3}]
0.0
0.9
1.8
2.3
ω [fs^{-1}]
4.8
4.6
4.4
1
0
-1
ω [fs^{-1}]
2.4
2.3
2.2
300
200
100
0
P(t) [TW]
-50 0 50
-50 0 50
-50 0 50
-50 0 50
Time [fs]



$$L_{\mathrm{dp}} \approx \frac{\omega_0}{\omega_p}^2 \sigma_t c$$

Depletion length

$$L_{\mathrm{d}} \approx \frac{\omega_0}{\omega_p}^2 \lambda_p$$

Dephasing length

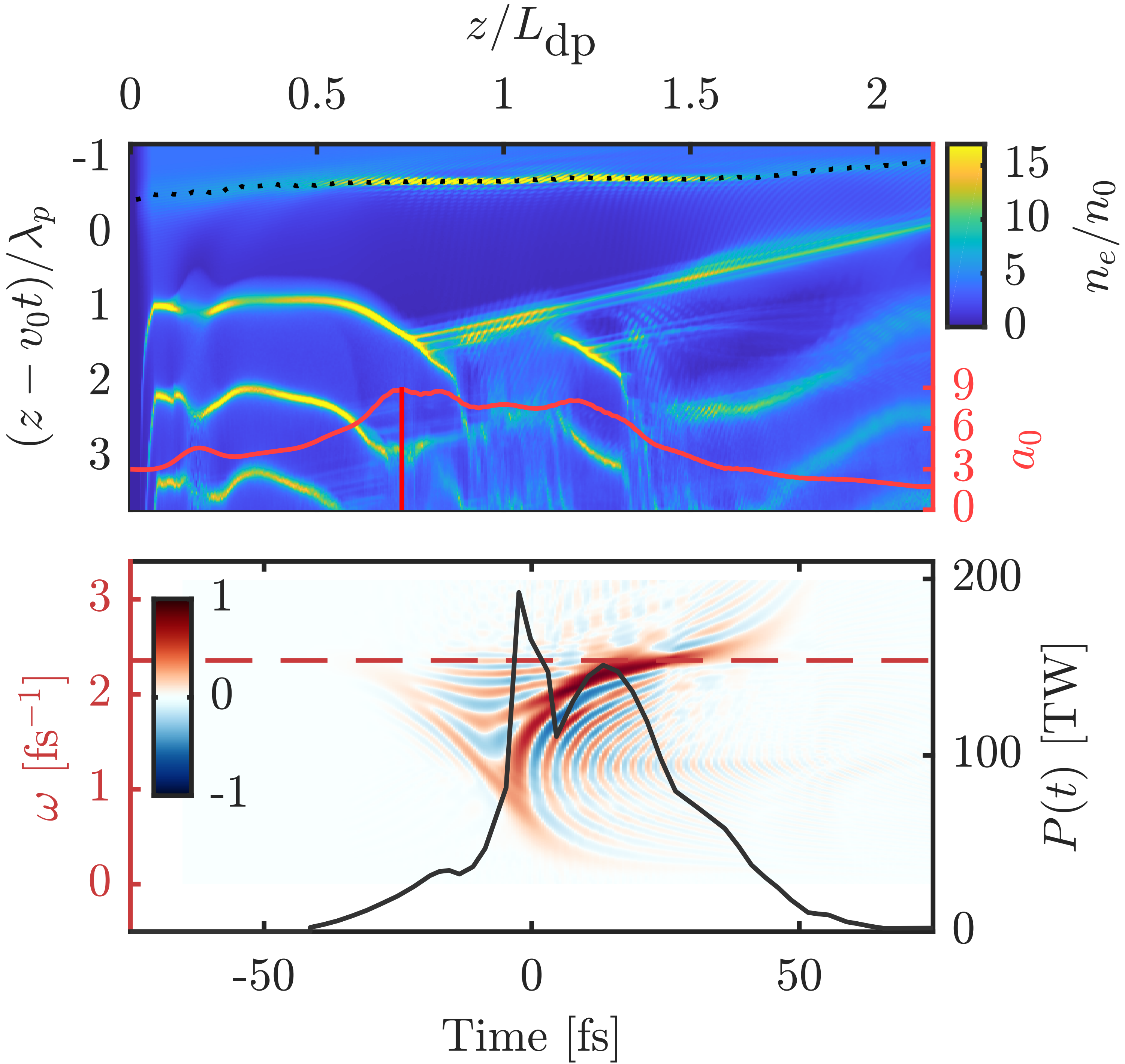
Decker, C. D. et al. *Physics of Plasmas*, *3*(5) (1996).

Lu, W., et al. Physical Review STAB 10(6), 1–12 (2007).

Pulse front etching model:

$$v_{\mathrm{etch}} = c\frac{{\omega_p}^2}{{\omega_0}^2}$$

$$v_0 = v_g - v_{\mathrm{etch}}$$



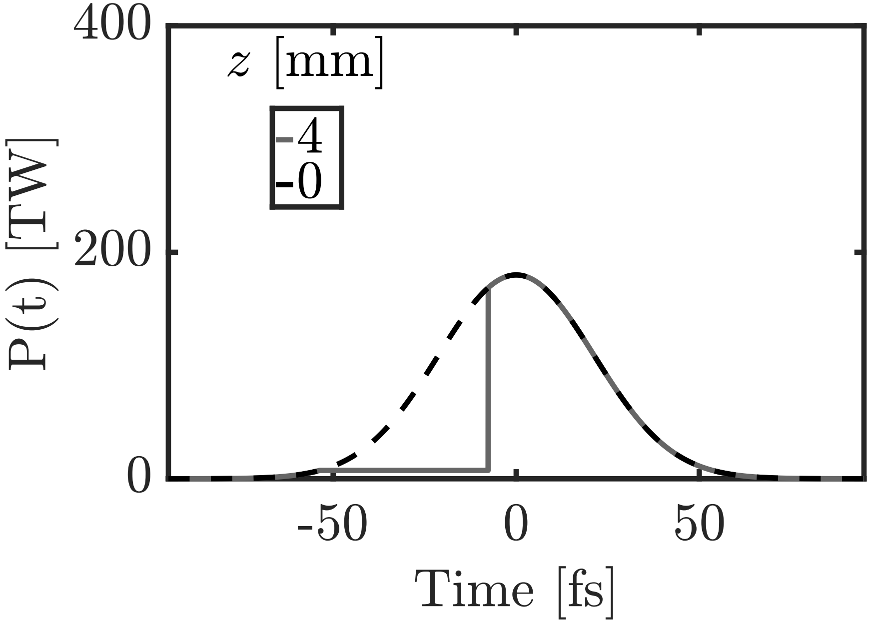
Lower limit on redshifted photons that drift back faster than the etching velocity:

$$v_g(1) = v_g(0) - v_{\mathrm{etch}}$$

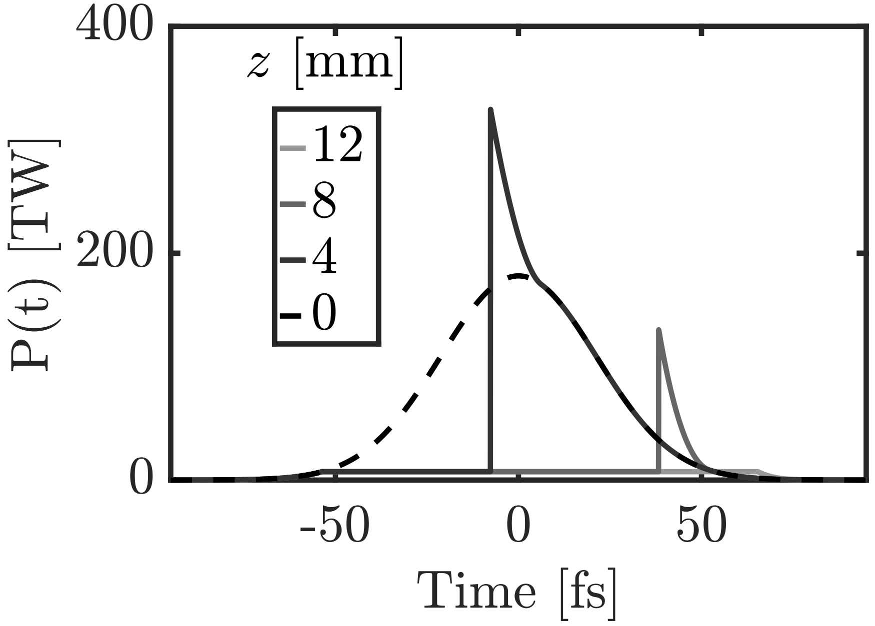
$$c\sqrt{1-\frac{{\omega_p}^2}{{\omega_1}^2}} = c\sqrt{1-\frac{{\omega_p}^2}{{\omega_0}^2}} - \frac{{\omega_p}^2}{{\omega_0}^2}$$

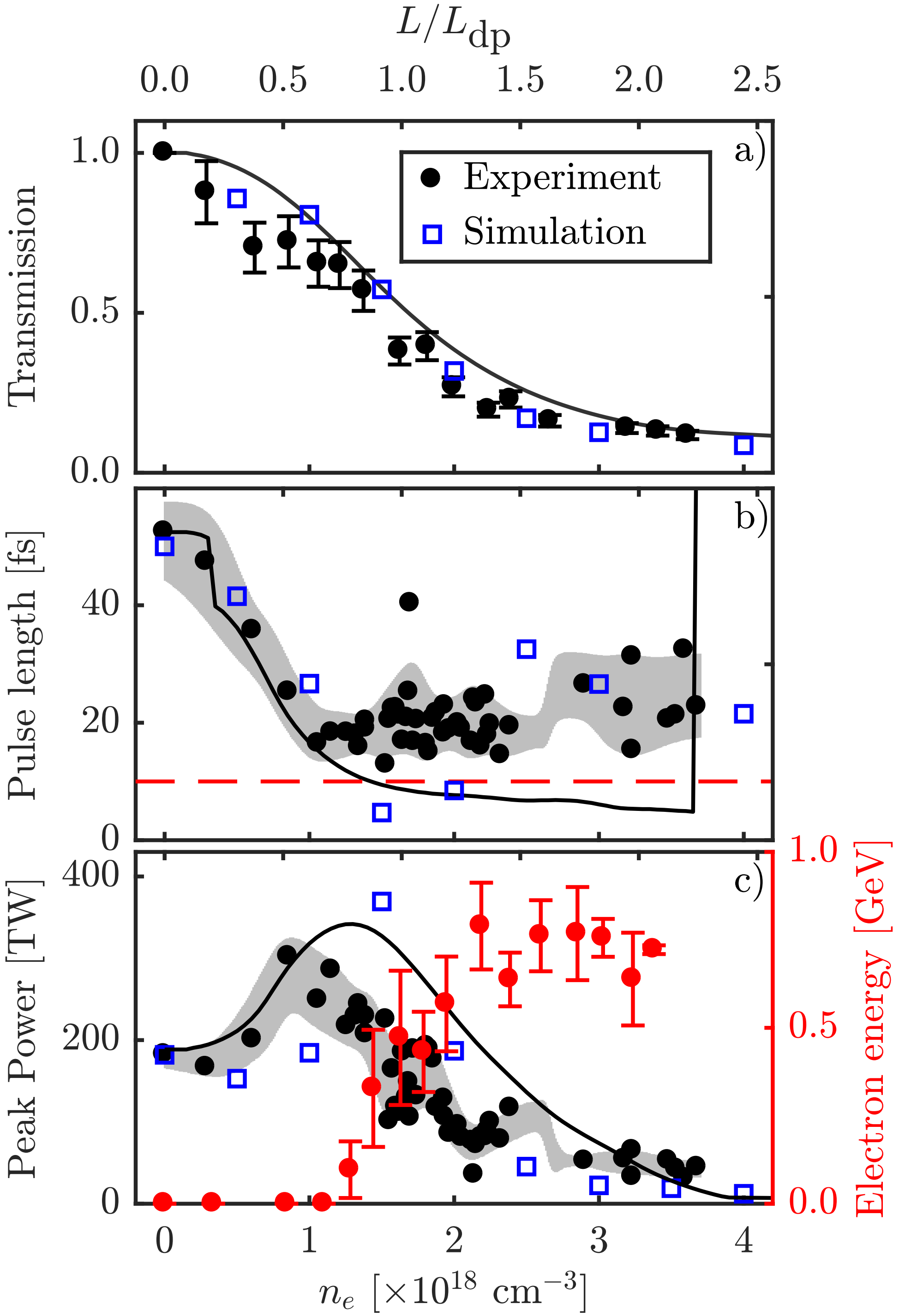
$$\omega_1 = \frac{\omega_0}{\sqrt{3}}$$

Pulse front etching model



New model with group velocity dispersion





For a gaussian pulse:

$$L_{\mathrm{evol}} \approx \sigma_t c \left(\frac{2}{3} \frac{{\omega_0}^2}{{\omega_p}^2} \right) \sqrt{\frac{1}{2} \ln \left(\frac{P_0}{P_c} \right)}$$

$$L_{\mathrm{dp}} \approx 2 L_{\mathrm{evol}}$$

Acknowledgements

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