EX24705

運動論的レーザープラズマ相互作用で発生する非熱的高速電子特性の解析

Analysis of non-thermal electron characteristics generated by kinetic laser-plasma interactions

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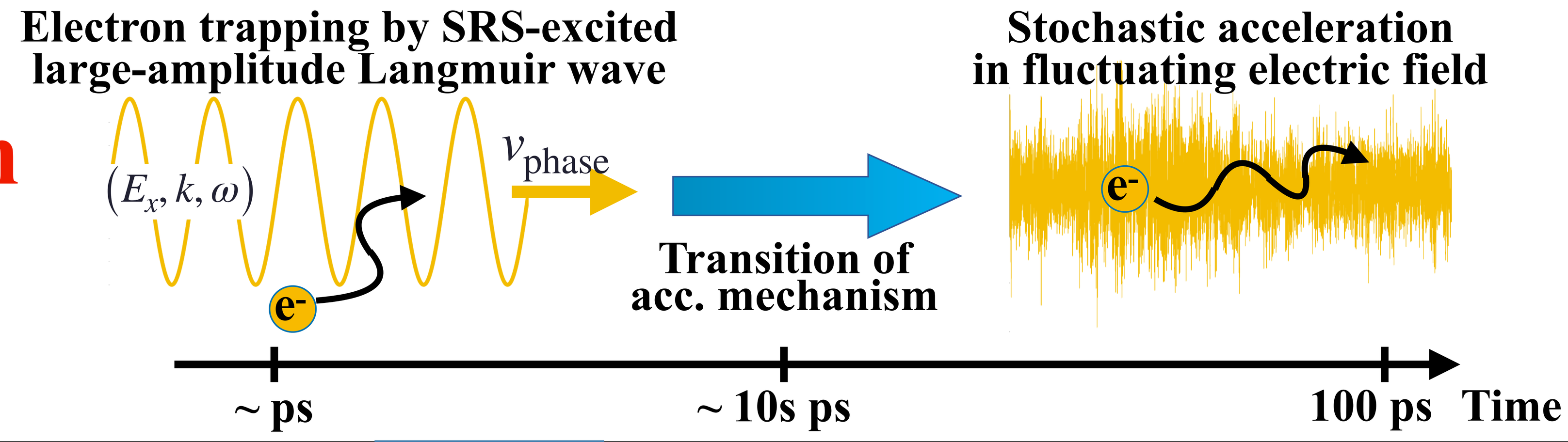
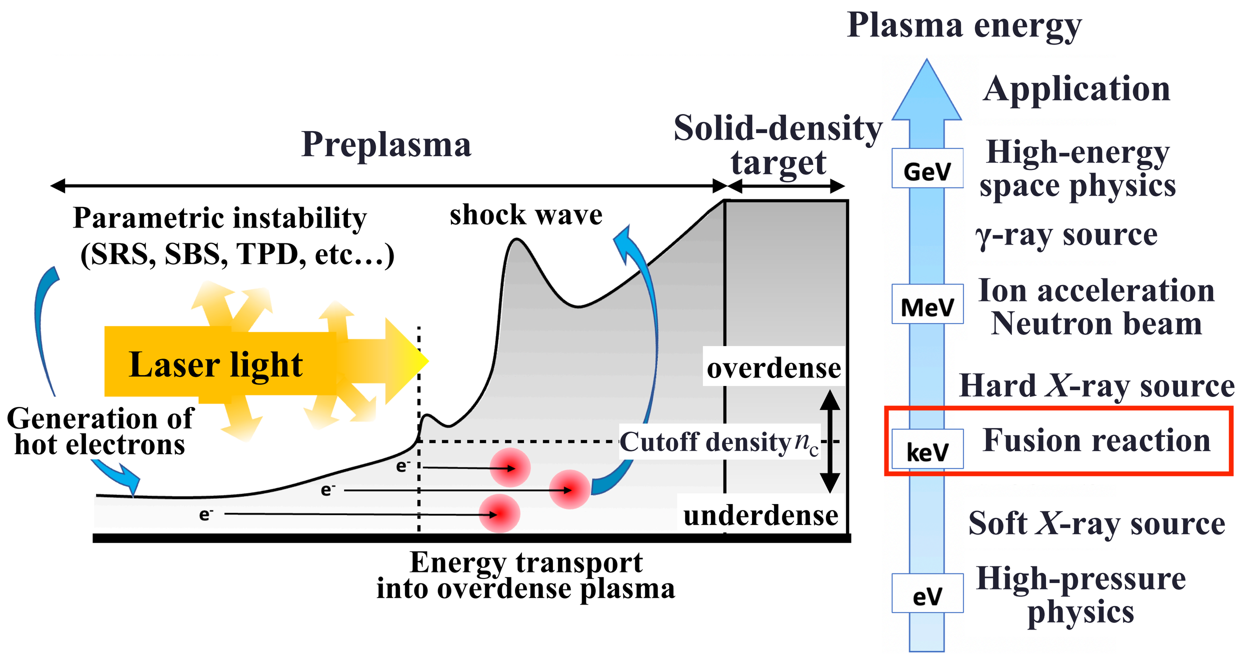
Take-home message:

In long-time interaction, mechanism of SRS-driven electron acceleration shifts from electron trapping by plasma waves to stochastic acceleration.



Buckground

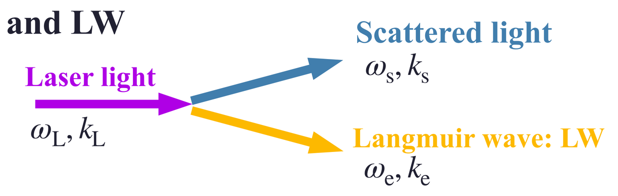
PIs play important role for energy transfer in sub-relativistic ($10^{14\text{-}16}$ W/cm²) regime.



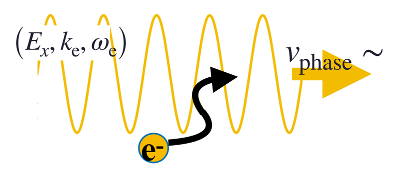
HEs play important roles:
Shock enhancement in shock ignition
Target preheating by prepulse of relativistic-intensity lasers

SRS excites density perturbations and LALWs.
LALWs trap and accelerate electrons around phase velocities.

SRS (stimulated Raman scattering)
Three-wave resonance process
Decay of laser light to scattered light and LW
Frequency matching: $\omega_0 = \omega_1 + \omega_2$
wavenumber matching: $k_0 = k_1 + k_2$



Excitation of Large-amplitude Langmuir wave (LALW)



Electron trapping and acceleration by LALW

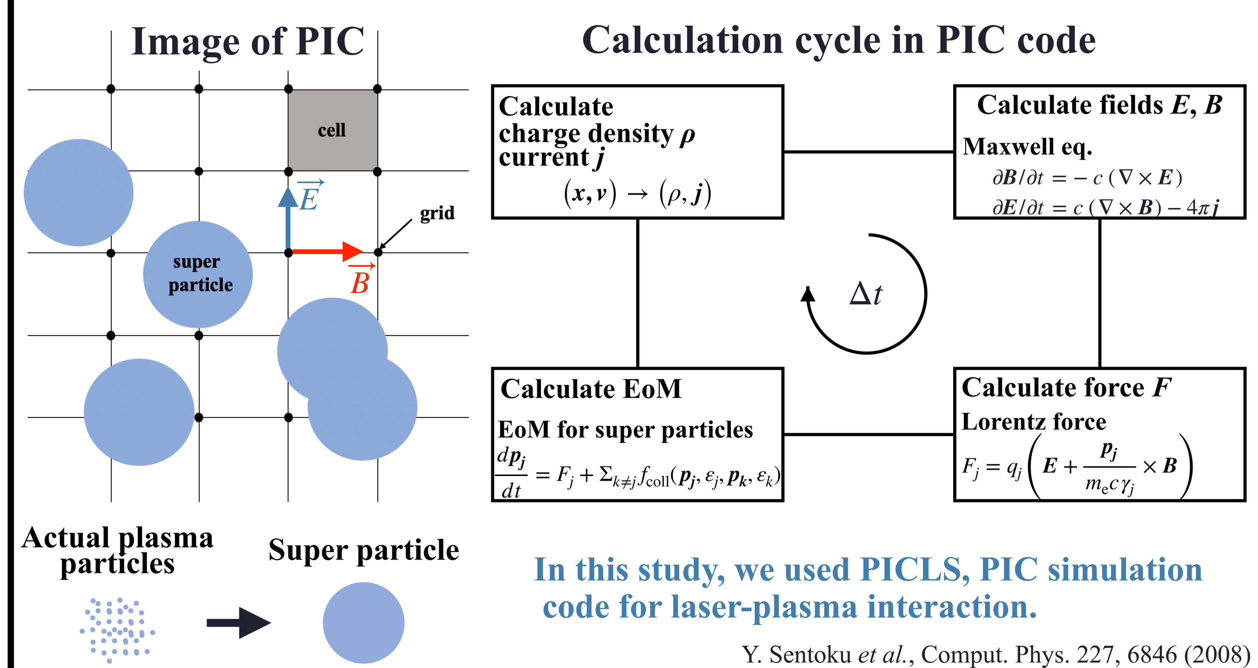
Typical energy of HEs by SRS is ~ 10s keV.
Suprathermal HEs (Fast electrons: FE) > 100 keV are observed in exp.

C. Rousseaux *et al.*, Phys. Plasmas 4, 2589 (1992).
E. L. Dewald *et al.*, Rev. Sci. Instrum. 81, 10D398 (2010).

Method

Particle-in-cell simulation

Set spatial grids and charged particles (super particle).
Calculate motion of charged super particle from their eq. of motion.
Calculate evolutions of electromagnetic field on grids from Maxwell eq.

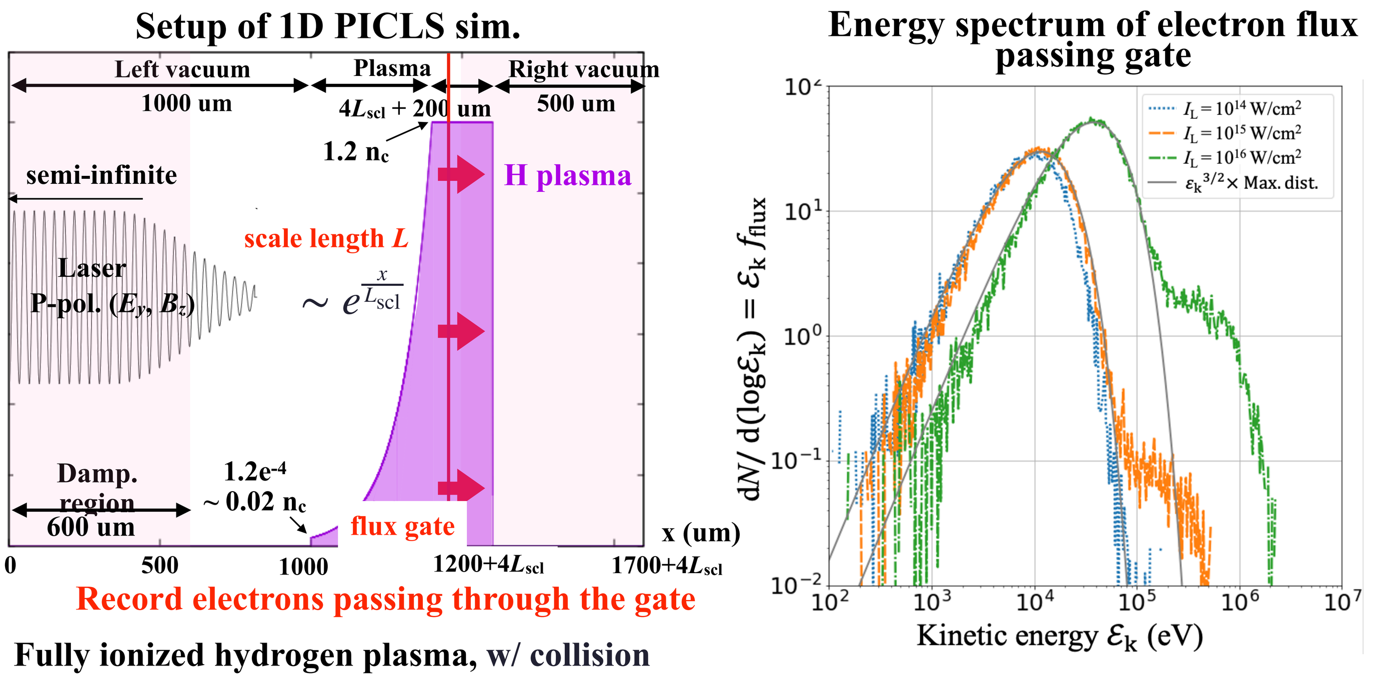


In this study, we used PICLS, PIC simulation code for laser-plasma interaction.

Y. Sentoku *et al.*, Comput. Phys. 227, 6846 (2008)

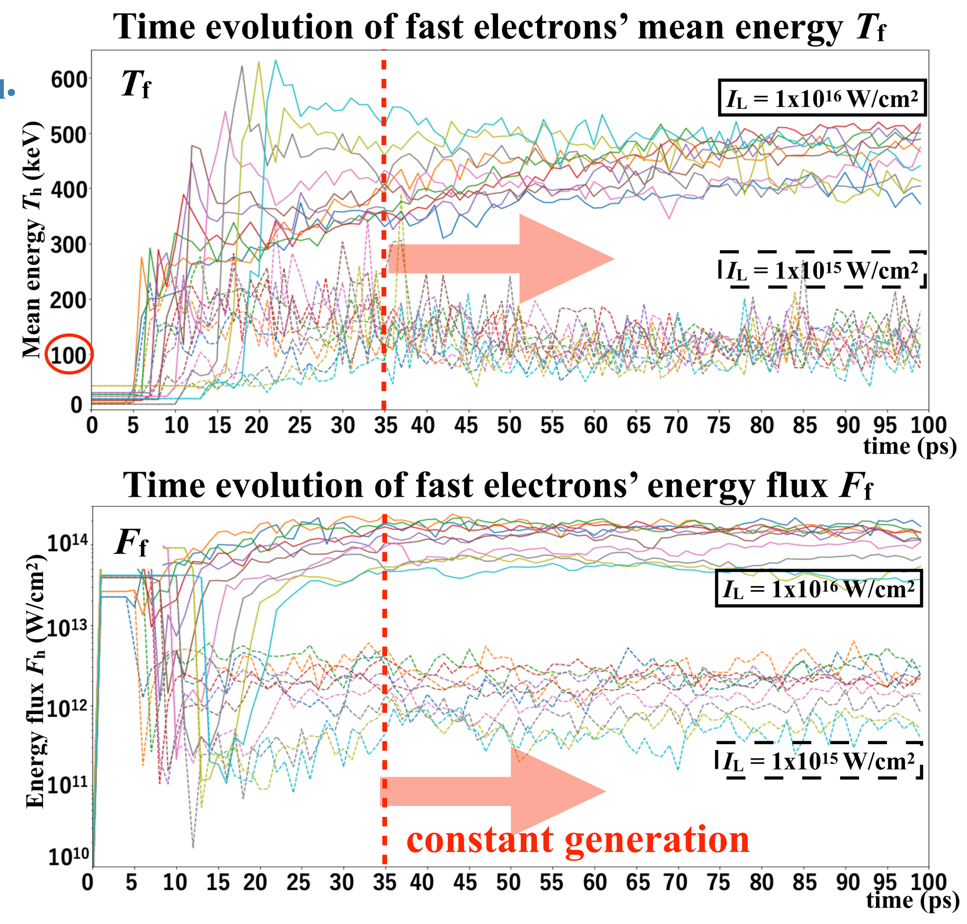
Result

We performed 1D PIC simulations to investigate dependences of hot electrons on laser intensity I_L and plasma density scale length L_{scl}.

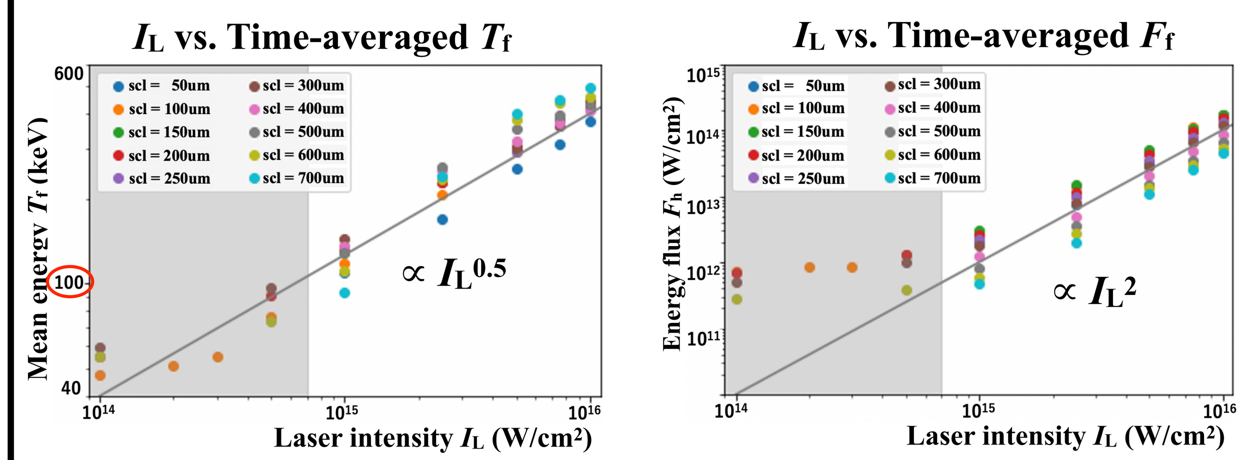


Record electrons passing through the gate

Fully ionized hydrogen plasma, w/ collision
I_L = 1×10^{15} ~ 1×10^{16} W/cm², λ_L = 1 um, L_{scl} = 50 ~ 800 um, Init. T_i = 1 keV, T_e = 5 ke
dx = 0.05 um, dt = 0.17 fs, N_x = 4x10⁴ ~ 10⁵ grid, N_t = 6x10⁵ time step, up to 100 ps (3x10⁴ T_L)
70 particles/cell, ~ 500-2000 node-hour



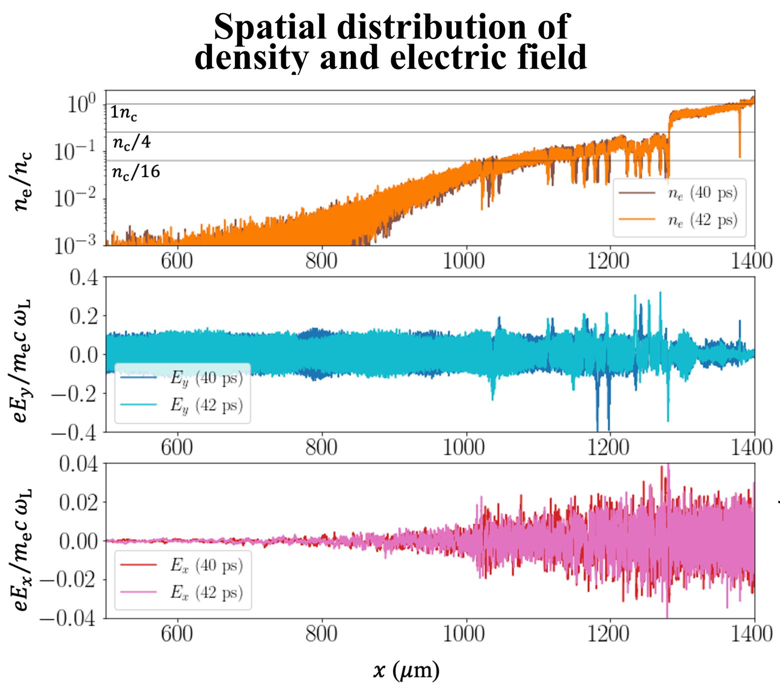
After 35ps, mean energy T_f and energy flux F_f become constant and their magnitudes strongly depend on laser intensity I_L.

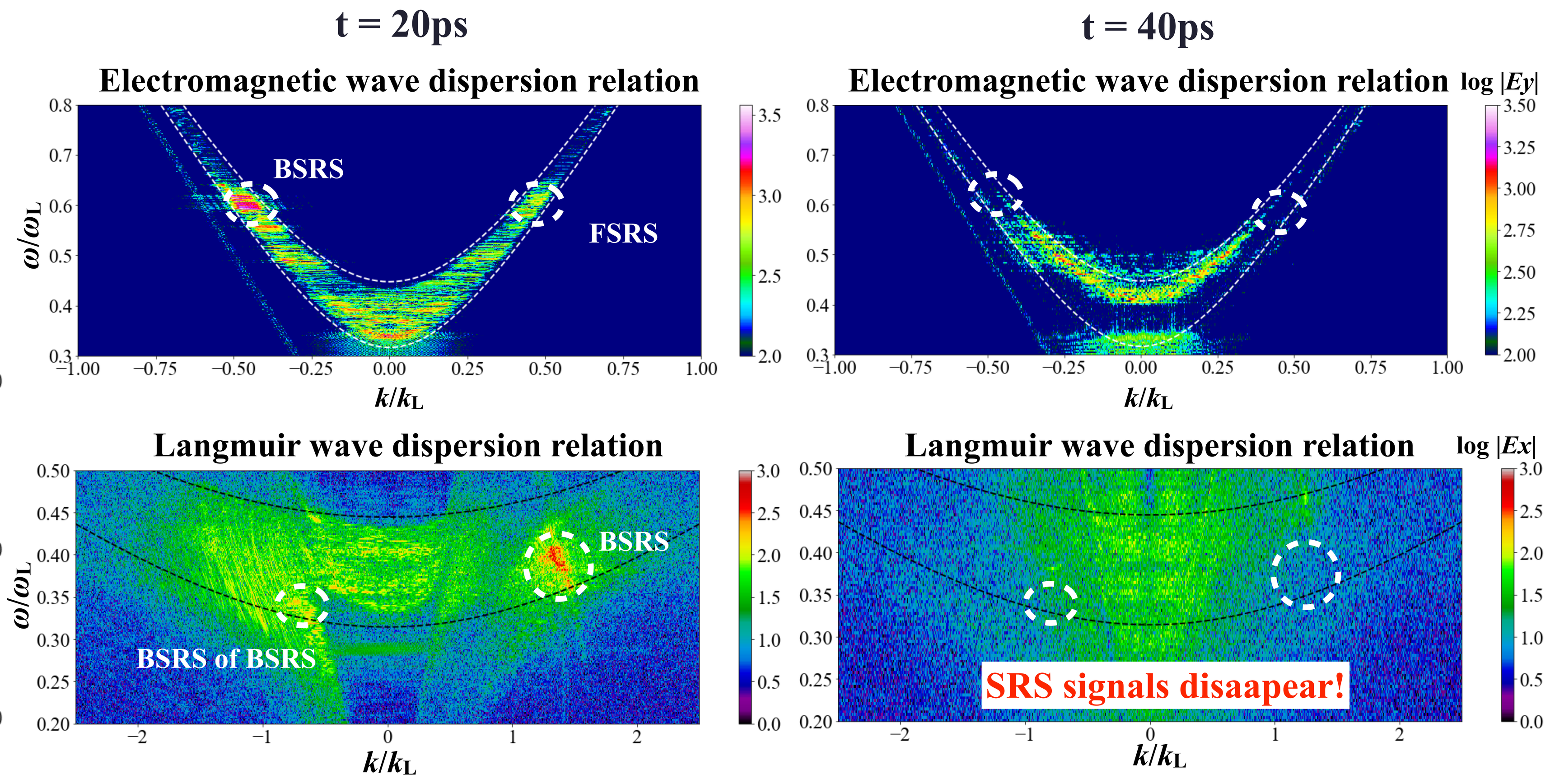


What mechanism constantly accelerate fast electrons >100 keV ?

Analysis: Mode

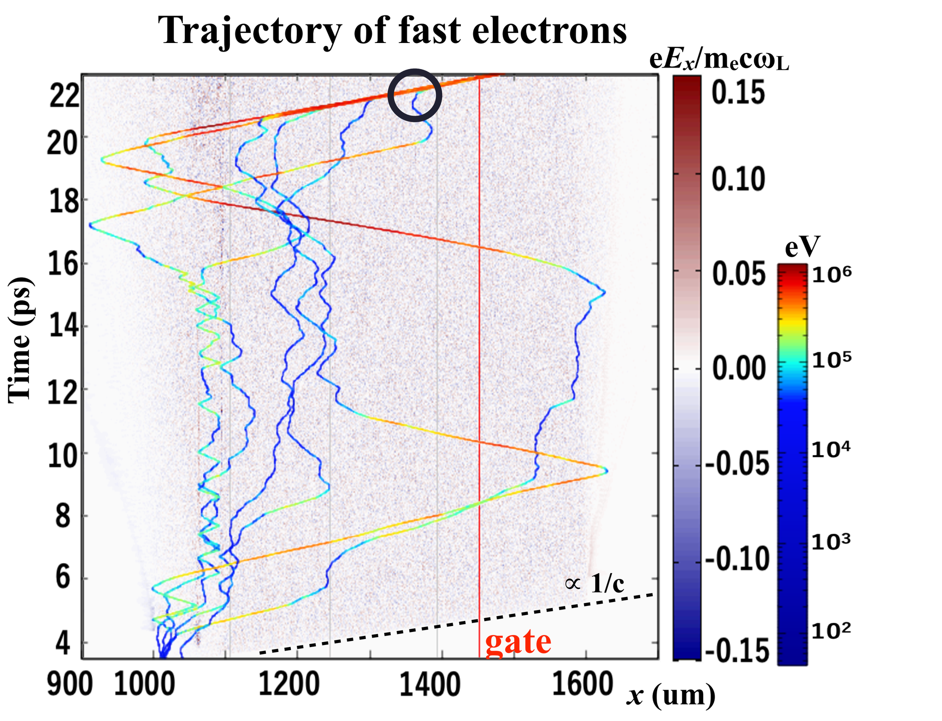
We performed Fourier analysis of electric field to investigate growth of SRS.



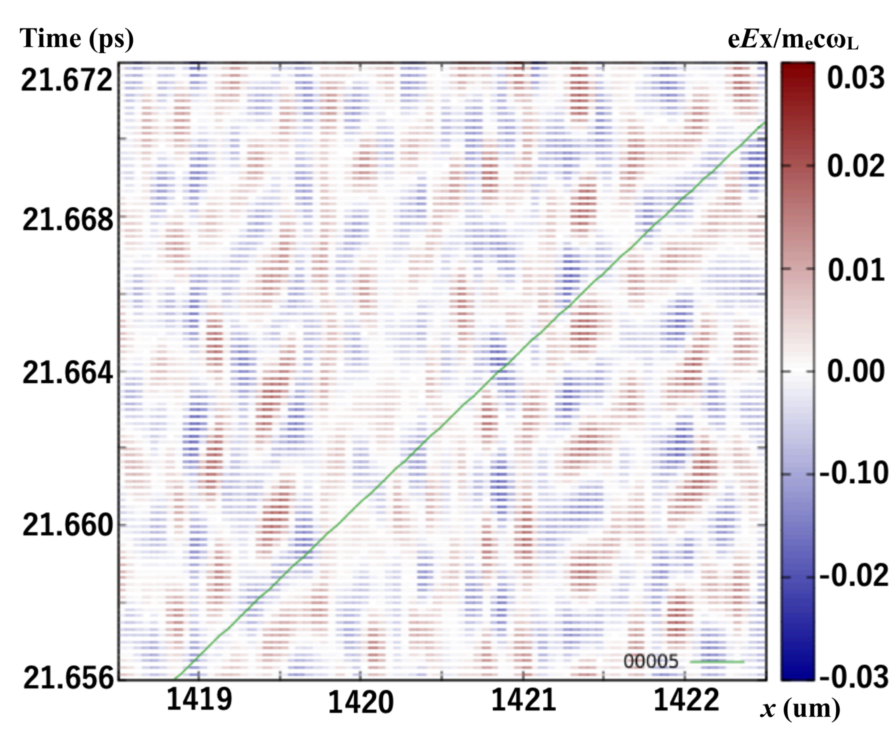


→ Electron-trapping by LALWs cannot occur after 35 ps.
Other acceleration mechanisms are required!

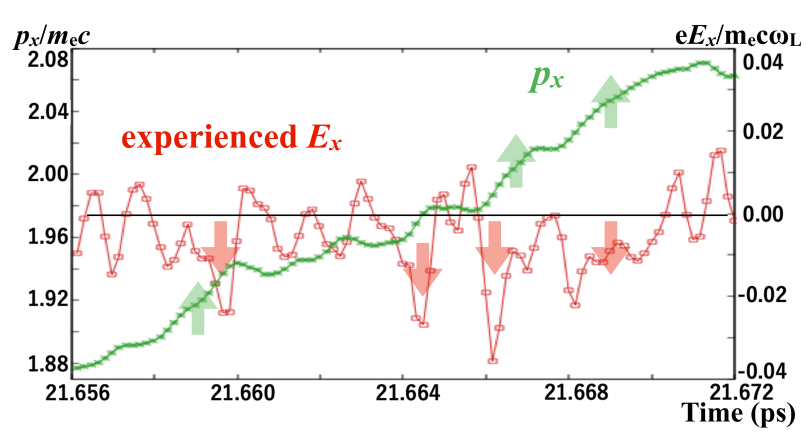
To clarify acc. process, we tracked trajectories of FEs.



Analysis: Trajectory

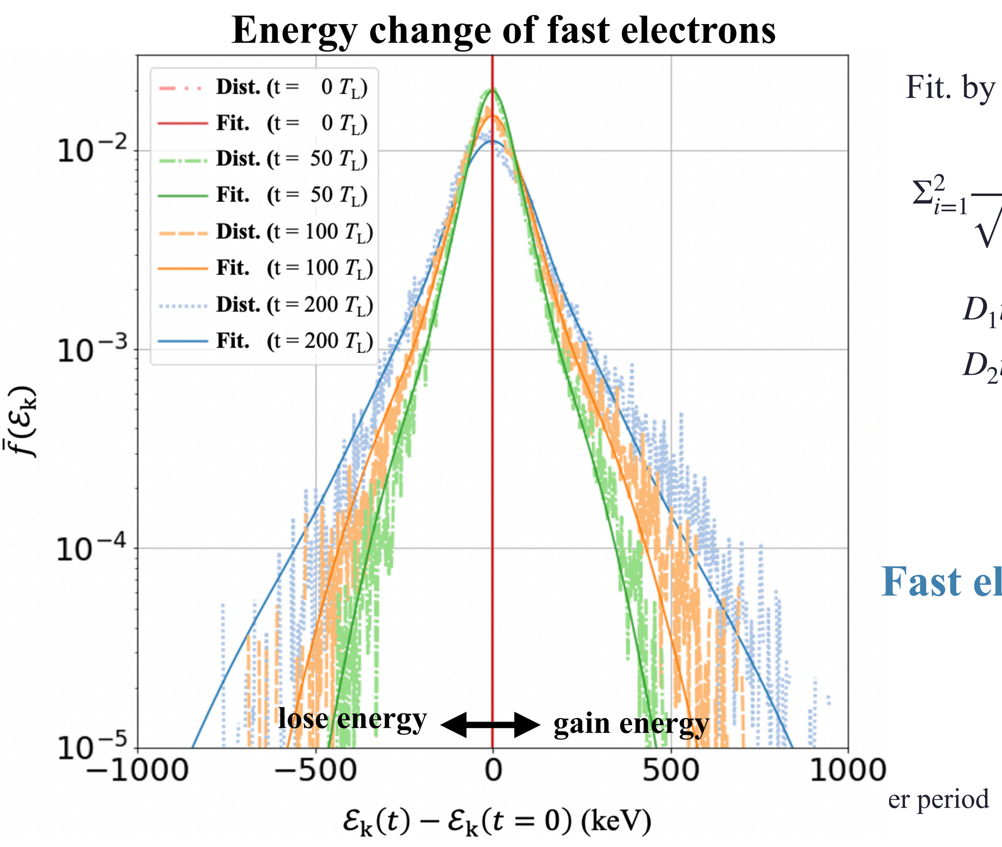


I_L = 1x10¹⁶ W/cm², L_{scl} = 100 um, w/o collision



E_x-field is not advective, fluctuating.
Fast electrons gain energy when they go through large negative field.

We investigated collective behavior: energy changes of 60,000 FEs during 200 T_L.



Fit. by Diffusion eq.

$$\Sigma_{i=1}^{2} \frac{f_i}{\sqrt{4\pi D_i t}} \exp\left[\frac{-(\varepsilon_k(t) - \varepsilon_k(0))^2}{4D_i t}\right]$$

$D_1 t \simeq 1.6 \times 10^3$
$D_2 t \simeq 10^4$

Fast electrons diffusively change their kinetic energy.

After 35ps, stochastic acceleration process generates fast electrons.