

Ion Acceleration

Advanced Plasma Physics

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Ion Acceleration Mechanisms

- proton acceleration due to the ambipolar fields arising in the free expansion of the strongly heated electrons at the front and the rear of the target;
- proton acceleration in a collisionless, electrostatic shock formed at the front of the target;

Sheath Acceleration

- The laser interacts with the target producing hot electrons, that penetrate through the target. The electric field induced, ionizes the atoms at the rear and front surface and accelerates the ions.

$$E_{sheath} \approx \frac{k_B T_{hot}}{e \lambda_D} \quad , \quad \lambda_D = \sqrt{\frac{k_B T_{hot}}{4\pi e^2 n_{hot}}} \quad v_{sheathions}(t) \approx \frac{Ze E_{sheath} t}{m_i}$$

Electrostatic Shock formation

- The ponderomotive force of the laser launches an electrostatic, laminar shock from the front surface of the target, and the structure propagates almost undisturbed across the target.
- The shock can pick up ions and reflect them to velocities $\approx 2v_{shock}$.

$$\frac{v_{shock}}{c} \approx \frac{v_{piston}}{c} = \sqrt{\frac{(1 + \eta)I}{n_i m_i c^3}}$$

$$\frac{c_s}{c} = \sqrt{\frac{k_B T_{hot}}{m_i c^2}} = \sqrt{\frac{0.8 a_0 m_e}{m_i}}$$

$$M = \frac{v_{shock}}{c_s} \approx \sqrt{\frac{(1 + \eta)}{0.4} \frac{n_c}{n_i} a_0}$$

Dominant Acceleration Mechanism

Acceleration in the shock becomes the dominant acceleration mechanism when:

$$2v_{shock} \gtrsim v_{sheathions} \qquad L_{target} \lesssim \frac{4v_{shock}^2 m_i \lambda_D}{Z e k_B T_{hot}} = \frac{4M^2 \lambda_D}{Z}$$

Simulation time step and grid step

$$\frac{N_{particles}}{\lambda_D} \gtrsim 50$$

$$\Delta x \gtrsim c\Delta t$$

$$\Delta x \lesssim \lambda_D$$

$$\Delta t \lesssim \frac{0.2}{\omega_{max}}$$

$$\Delta x \lesssim \frac{c}{\omega_p}$$

Simulation 1D - Parameters

Same as fig1 from article:

$$\Delta t = 0.03/\omega_0$$

$$\Delta x = 0.032c/\omega_0$$

$$Sizeofbox = 800c/\omega_0$$

$$ParticlesperCell = 32 + 32$$

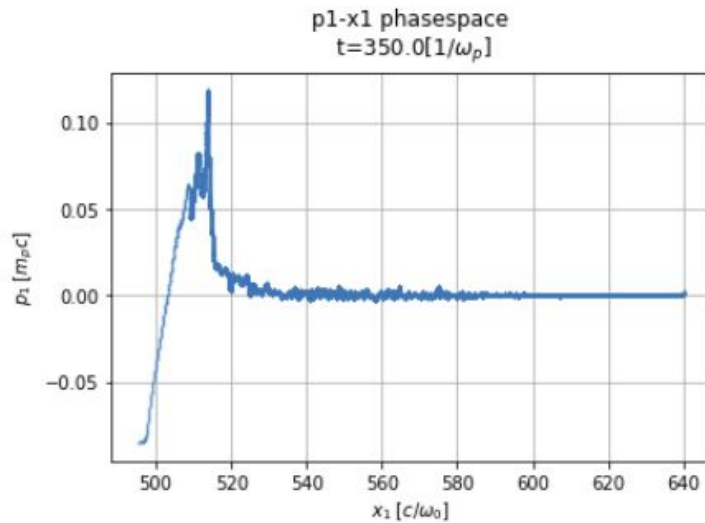
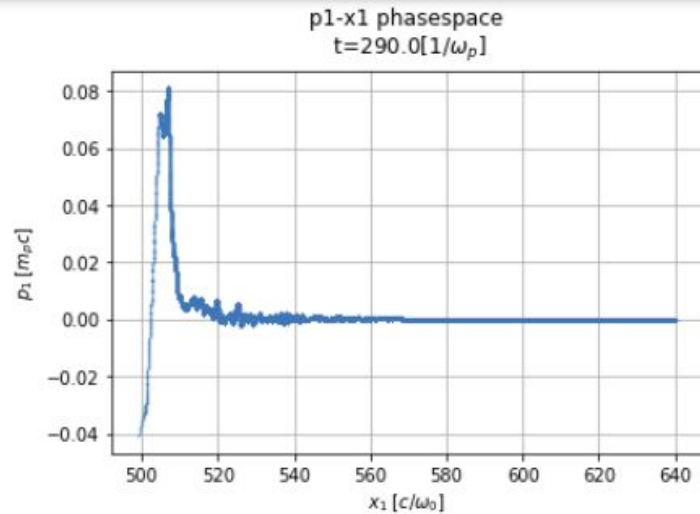
$$a_0 = 16$$

$$n_e = 10n_c$$

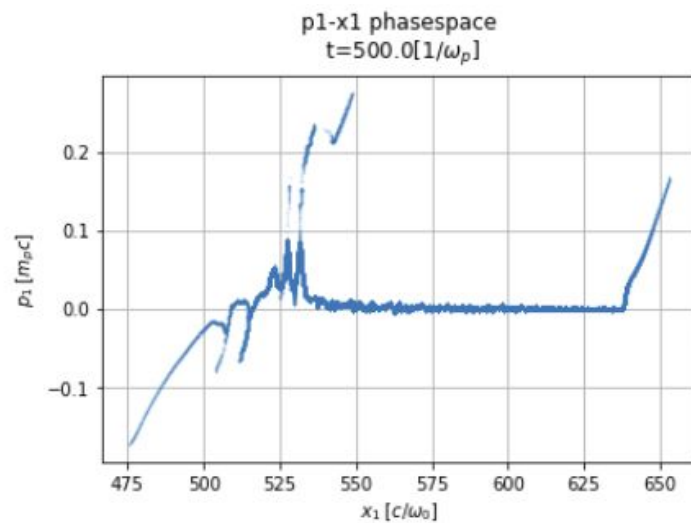
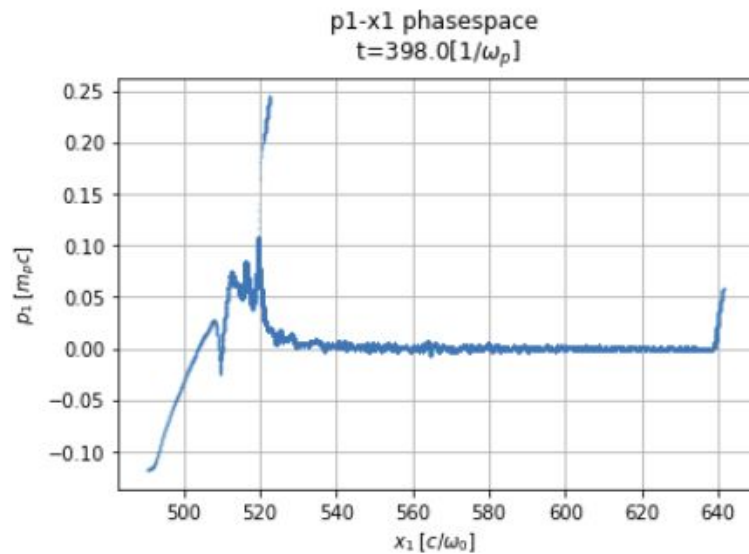
$$\omega_p = \sqrt{10}\omega_0$$

$$\lambda_D \approx 1.13c/\omega_0$$

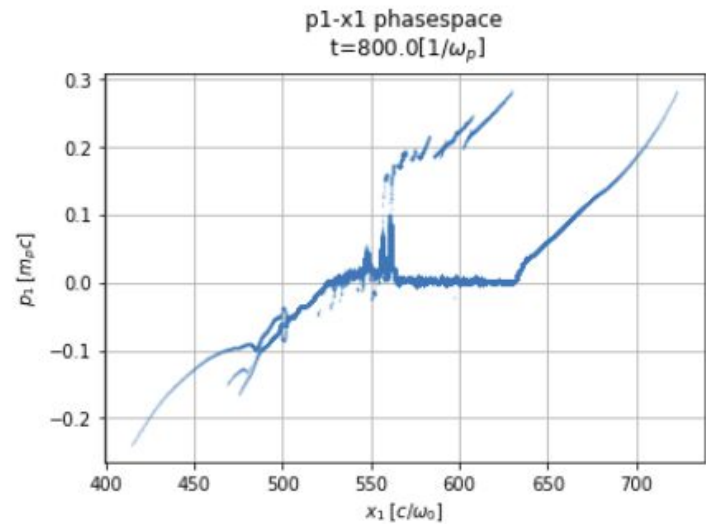
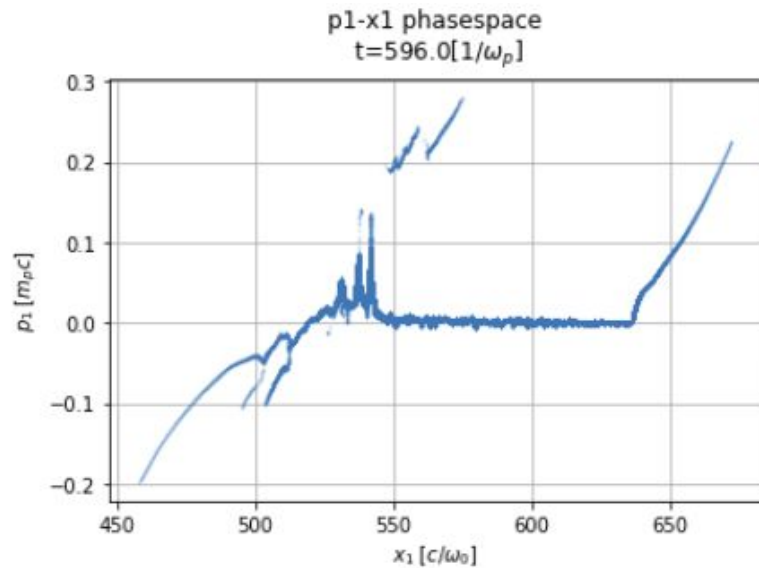
Simulation 1D



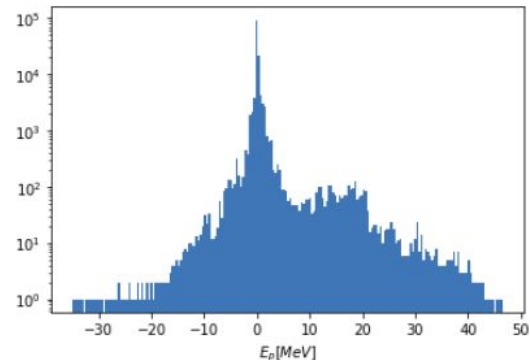
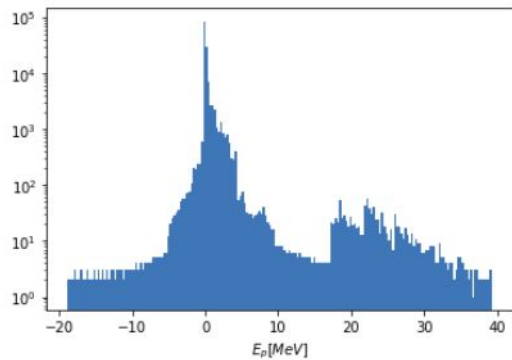
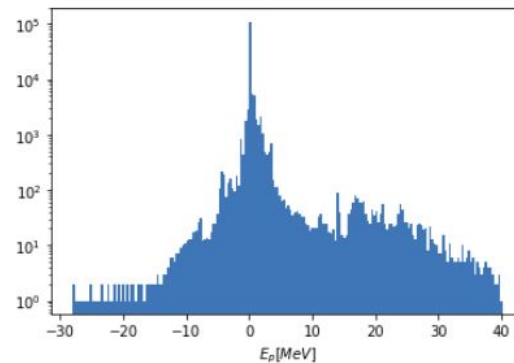
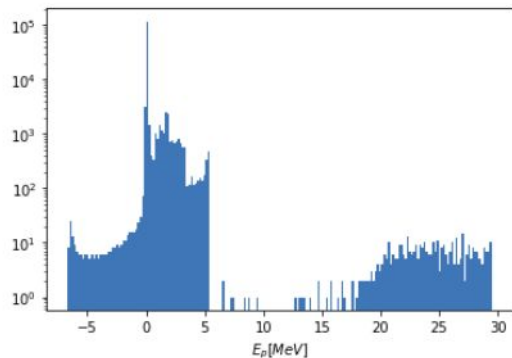
Simulation 1D



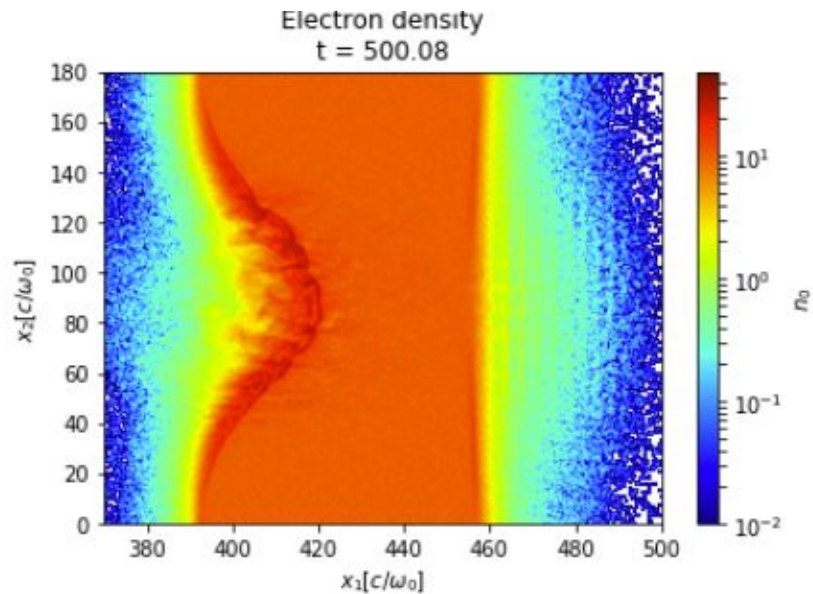
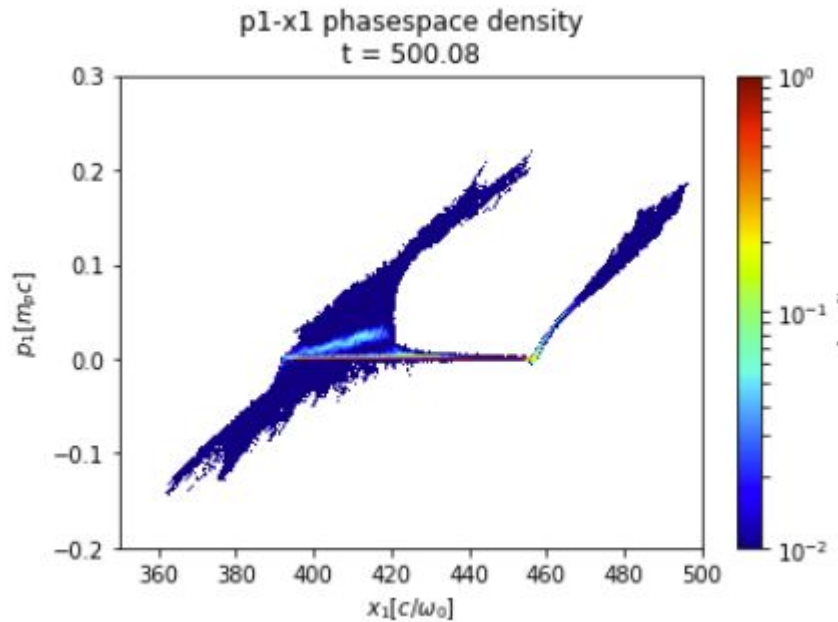
Simulation 1D



Simulation 1D



Simulation 2D



Simulation 2D

