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Particle simulation of plasma polarization and correlation effects in the transport of alpha particles

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Abstract: Fusion reactions of thermonuclear fuel can produce energetic alpha particles. In the process of transport in tokamak core, alpha particles can transmit their energy to plasma by colliding with deuterons, tritons and other ways, as the most effective method to realize the self-heating[1]. So far, in most of the investigations of alpha particle transport in combustion plasmas, the researchers usually focused their attention on the Coulomb collision and alpha particle channel effect[2,3]. However, polarization of the background plasma and the correlation effects between alpha particles are seldom considered.

In this work, a two-dimensional particle-in-cell (PIC) simulation model is proposed to investigate time evolution and energy deposition for an alpha ion cluster injected into magnetized plasmas. As one can see in Fig. 1, when the ion cluster penetrates further into the plasma, due to the Coulomb repulsions between the ions, the density of the ion cluster decreases and the distance between the ions increase gradually. More importantly, as a perturbation of the target plasma, the charged particles can produce a polarization electric field and lose their energy under the action of the electric field as shown in Fig. 2.

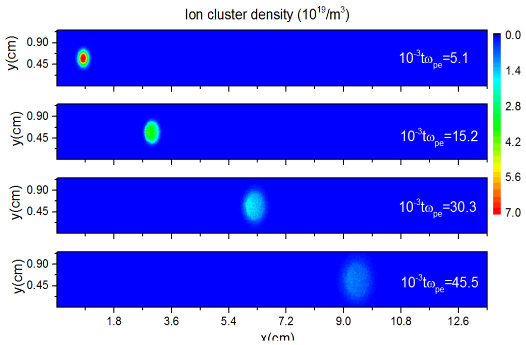

Fig. 1 Time evolution of the cluster which is injected from the left boundary at $10^{-3}t\omega_{pe} =$ 5.1,15.2,30.3 and 45.5 respectively.

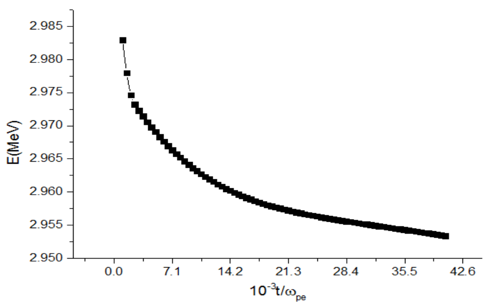

Fig. 2 Time evolution of the average energy of alpha particles.

In our investigation we further find that the valid stopping power decreases a lot as the alpha particles disperse during penetration. The correlation effect between alpha particles has a significant effect on the transport of the cluster, especially for its energy and density distribution. Moreover, the shielding of the induced electric field may in turn hinder the particles losing their energy. However, when a uniform magnetic field is added, the polarization of electrons would be restrained due to the Lorenz force. Consequently, the magnetic field can greatly enhance the energy deposition of alpha particles. As it is shown in Fig. 3, relatively stronger magnetic fields correspond to larger stopping power.

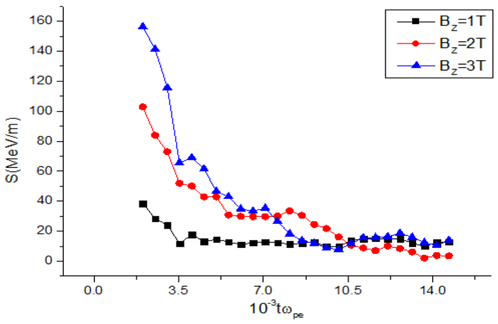

Fig. 3 Average stopping power of alpha particles for different magnetic field value which direction is perpendicular to the direction of motion .

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