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Investigation of inward particle flux formation on the PKU Plasma Test (PPT) device

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The up-gradient particle transport (inward particle transport) is conducive to transport barrier formation and confinement improvement. It is associated with the formation of a peaked density profile, which contributes to improve the fusion rate and the realization of steady-state discharge [1]. Experimental results demonstrate that shear flow influences the production of inward particle flux, but the formation mechanism of inward particle transport is still not studied thoroughly in the experiment. During the fusion process, plasma burning is concentrated in the plasma core region. The existing feeding technologies include pellet injection, molecular beam injection, cluster jet injection and fueling by CT injection [2-5]. The fuel injection location is generally at the plasma edge and the fuel particles, limited by the depth of injection, cannot enter the core to replenish the consumption of fusion reaction. Therefore, the investigation of inward particle transport mechanism is also helpful to solve the challenge of plasma fueling. More deep studies are needed for a thorough understanding of inward particle transport.

Recently, inward particle flux and outward particle flux are observed simultaneously in the PKU Plasma Test (PPT) device, a linear plasma device. And the inward particle flux is induced by streamer structure shown in Figure1. Based on the theoretical and experimental analysis, the nonlinear interaction of streamers is the critical factor of inward particle flux formation in the region without the boundary effect. As shown in Figure 2, in the r = 23-30 mm, i.e., the blue box region, the nonlinear interaction term induces an inward particle flux. The particle flux induced by the nonlinear term in the blue box region is almost equal to the experimentally measured particle flux induced by this mode. Therefore, the nonlinear interaction of streamer modes is the kinetic mechanism of inward particle flux formation when the density perturbation reaches saturation without the influence of boundary effects.

When the nonlinear interaction of streamers is dominating, the particle orbit is quasi-periodic and the inward particle flux forms for the decrease of entropy. The particle orbit is chaotic when the nonlinear interaction between streamers and DWs is predominant and then the particle flux is down-gradient for the increase of entropy. These results provide a new perspective for the investigation of inward particle transport mechanism.

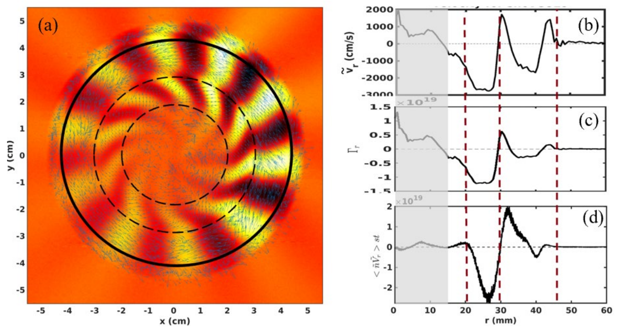

Figure 1. (a) Frequency averaged velocity fields obtained streamer structure by 2D TDE analysis. (b) The fluctuation of radial velocity calculated by camera data. (c) The particle flux driven by streamers calculated by camera and probe data. (d) The particle flux calculated by and probe data.

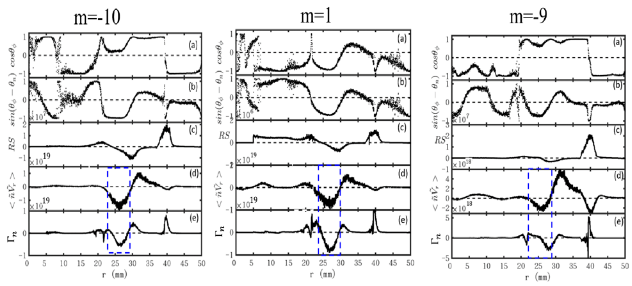

Figure 2: (a) The cosine of floating potential. (b)The cross-phase between potential and density. (c) Reynold stress. (d) Particle flux measured. (e) Particle flux induced by the nonlinear interaction with the other two modes.

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