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P1.1027 Optimal conditions for alpha channelling in burning plasmas

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Alpha channelling is a mechanism to transfer the power associated with the fusion-generated alpha particles to the thermal ions through the interaction with an externally excited Ion Bernstein Wave (IBW) that absorbs the alpha particle energy associated with the perpendicular motion. The extraction of energy is associated with a radial diffusion towards the plasma edge. However, such extraction cannot be accomplished by the IBW alone, unless unrealistically high values for the injected IBW toroidal number are considered. Thus, alpha channelling schemes have included a second, low-frequency Alfvén wave to facilitate the extraction of the alphas that have already transferred most of their energy to the IBW. In this paper, the optimal conditions for alpha channelling are investigated for burning plasmas. In [1] the alpha particle distribution function has been determined by solving the Fokker-Planck equation in slab geometry. The model includes the effects of classical slowing down on the electron population and diffusion in the constant of motion space due to the interaction with the IBW. The low frequency wave is modeled via a boundary condition of outward particle flux Q at the boundary in phase space where the high-frequency wave induced diffusion vanishes. This approach has been generalized to arbitrary magnetic equilibria to quantify the amount of power transferred to the IBW and the energy spectrum of the alpha particles crossing the magnetic separatrix. The resulting flux depends on the toroidal IBW wave number and it can be made compatible with the condition of limited losses of high-energy particles under very general conditions. The possibility of alpha channelling relies on the excitation of IBW that are absorbed by the thermal ions and have negligible damping on the electrons. In order to determine the optimal excitation conditions, the propagation of IBW between the mode conversion layer and the resonance has been analytically studied using a generalization of the approach proposed in [2]. The ray trajectories and the wave amplitude have been determined including the effect of alpha channelling that acts as a volumetric source term in the wave amplitude equation. A comparison with the ray propagation obtained by the RAYIBW code has been performed. Using this solution it has been possible to determine the condition of maximum transfer from the IBW to the thermal ions. In parallel, the dynamics of the Alfvénic wave has been investigated in the frame of hybrid MHD-particle simulations performed by the XHMGC code. Alpha particles are described by yielding as initial (equilibrium) distribution function the analytic solution of the Fokker-Planck equation mentioned above. The distribution function is then let to evolve, according to the Vlasov equation, with the electromagnetic fields produced by the plasma response. The value of the flux at the boundary of the region where the quasilinear term is dominant are evaluated. When such a value matches the value used to obtain the analytic form of the equilibrium distribution function, the solution can be considered self-consistent.

[1] F. Cianfrani and F. Romanelli Nucl. Fusion 58 076013 (2018)
[2] A. Cardinali and F. Romanelli Phys. of Fluids B4 504 (1992).

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