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Residual Zonal Flows for non-Maxwellian Equilibrium Distribution Function

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Residual zonal flow level R_{ZF} [1] is one of the key relevant quantities which determine turbulence and transport of tokamak plasmas [2]. While there have been various theoretical extensions of the original work in Ref. [1] including the isotopic dependence [3], most previous works have assumed Maxwellian equilibrium distribution function F_0 with rare exceptions, for instance Refs [4,5]. Neoclassical polarization shielding determines the long term behavior of zonal flows and it can be derived in the context of modern gyrokinetic [6] and bounce-kinetic theories [7]. This approach not only elucidates the underlying physics of residual zonal flows, is but also applicable to an arbitrary F_0. Using this method, we show that the long wavelength, high aspect ratio result, $R_{ZF} = \frac{1}{1+1.63q^2/\sqrt{\epsilon}}$ derived for a Maxwellian F_0 in Ref. [1] remains valid for any F_0 which is isotropic in velocity space. In addition, it is found that presence of high energy ions such as fusion product α-particles described by slowing-down F_0 can enhance R_{ZF} considerably in the intermediate wavelength regime $k_r\rho_{Ti} \sim 0.1$ [4]. This presentation will cover the physics behind the neoclassical polarization shielding and long term asymptotic behavior of zonal flows and the effects of the fusion product α-particles on these.

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